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A TECHNICAL MANUAL

FOR EROSION AND SEDIMENT CONTROL

IN URBAN AREAS OF DEVELOPING COUNTRIES

OFFICE OF HOUSING
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

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INTRODUCTION

THE PROBLEM

Uncontrolled storm runoff poses major constraints to the successful completion and long-term maintenance of many economic projects in developing countries, particularly those located in tropical climatic zones. The need for improved stormwater management has become especially critical in urban areas which are experiencing rapid population growth and urbanization of surrounding lands. The process of land conversion from agricultural or low density residential to a high density land use pattern is resulting in major changes to surface and underground hydrologic conditions.

In areas undergoing these land use changes, the quantity of total rainfall that was being returned to groundwater reserves for gradual release throughout the year to surface streams, rivers and other water bodies is being dramatically reduced. A corresponding increase in storm runoff, which has not been recycled by means of groundwater recharged or transpiration processes, is occurring. With the removal and loss in the amount of existing vegetative cover, compaction of surface soils, and an increase in the amount of impervious land surfaces (building lot coverage, streets, etc.), storm runoff coefficients are being changed from .15-.25 (forest/agricultrual uses) to .70-.90 (mixed urban uses) of the amount of rainfall.

PURPOSE AND SCOPE OF THE MANUAL

The primary purpose of this manual is to provide practical guidelines and technical materials to assist AID and host country officials and their technical support personnel engaged in land development projects to prevent the occurrence of uncontrolled strom runoff from building sites. The focus of an effective management program to reduce or eliminate the potential destructive effects of stormwater runnoff requires that special attention be focused on the control of erosion and sedimentation. For those who have only a general knowledge of conventional erosion and sedimentation control measures, the manual will assist in preparing the reader with the technical rationale and practical guidelines for formulating and implementing effective control programs by discussing the following topics:

- SECTION I. INTEGRATION OF EROSION AND SEDIMENTATION CONTROL CONSIDERATIONS IN SITE ANALYSIS AND PROJECT DESIGN ACTIVITIES

  Provides the basic procedural methods and guidelines of how to integrate effectively the need and sensitivity of erosion and sedimentation control into the planning, design and construction phases of a development project.

- SECTION II. PROJECT MANAGEMENT DECISIONS AND FIELD CONSTRUCTION PRACTICES FOR EFFECTIVE CONTROL OF EROSION AND SEDIMENTATION

  Identifies and describes what critical management decisions and construction field practices must be implemented if an erosion and sedimentation program is to become effective.

- Section III. CRITICAL PROBLEMS, CONTROL STRATEGIES, AND ALTERNATIVE CONTROL PRACTICES

  Presents five (5) typical problem situations commonly found in the field and outlines a series of alternative control strategies and specific control practices that could be used to correct these problems.

- SECTION IV. DESIGN CONSIDERATIONS IN DETERMINING HOW TO CONTROL SURFACE RUNOFF

  Summarizes the basic design factors that should be taken into consideration in planning the utilization of a prospective development site with respect to how stormwater should be best managed given physical conditions both on-site and off-site.

- SECTION V. DESIGN, CONSTRUCTION AND MAINTENANCE CONSIDERATIONS FOR SELECTED CONTROL MEASURES

  Presents the required technical guidelines for site planners, engineers and construction personnel to insure the proper use, design, construction and maintenance of the most commonly used erosion and sediment control devices.

SECTION I

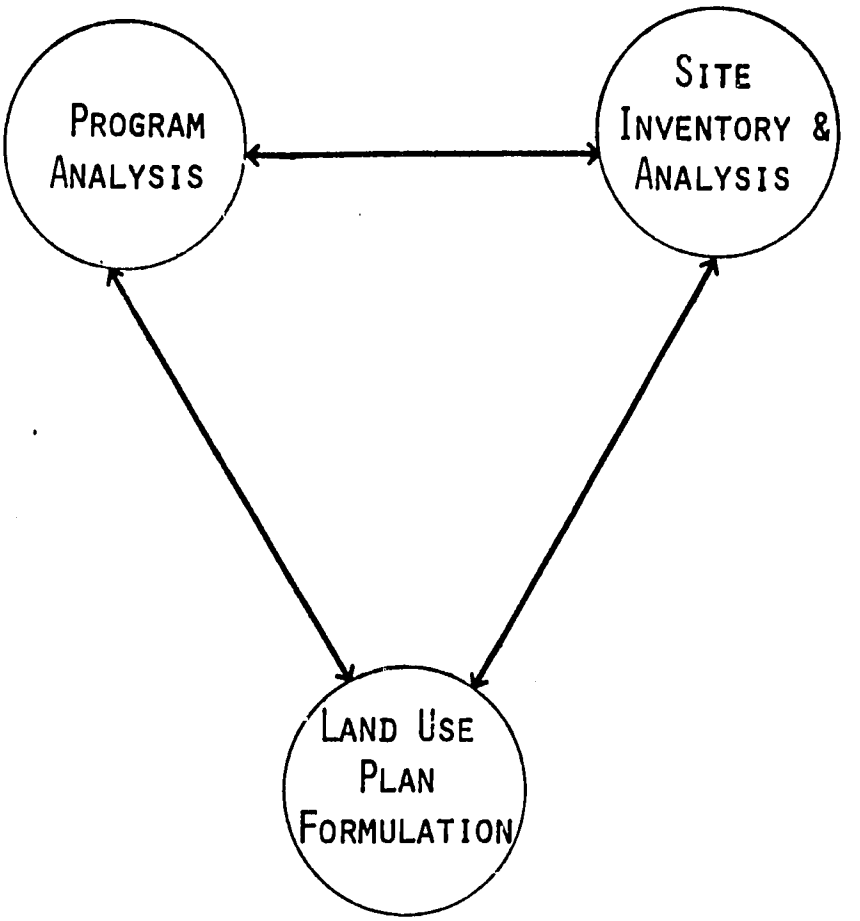
INTEGRATION OF EROSION AND SEDIMENT CONTROL CONSIDERATIONS IN SITE ANALYSIS AND PROJECT DESIGN

RECOGNITION OF NATURAL PROCESSES AS DESIGN DETERMINANTS

The best method of erosion and sediment control is preventing or minimizing its occurrence through careful site planning. Good planning attempts to balance the natural constraints and opportunities of a site so that the development plan meets the criteria of environmental, technical and economic soundness. In the past, many natural processes such as landslides, flooding, earthquakes, erosion, sedimentation, etc., were viewed as development obstacles to be overcome by engineering and by building drainage channels, retaining walls, changing land forms by excessive grading and other similar solutions. In retrospect, many of these solutions have succeeded in resolving the problems, but only temporarily and at high costs. Increasingly, the evaluation of development projects shows eventually that natural processes wear out these attempts to modify the forces of nature.

In particular, the forces of storm runoff and the ensuing processes of erosion and sedimentation should be recognized as special design constraints in the tropics. The combination of factors of tropical rainfall intensity and duration plus the gravity pull of running water downhill and the high erodibility of soil can set in motion one of the most destructive chains of events on the surface of the earth. The consequences of uncontrolled storm runoff may adversely impact natural life support systems as well as man-made improvements. To avoid or minimize the extent and severity of these problems, the collection and analysis of data on existing site conditions should be done as an integral part in the evolution of a land use plan as shown in Figure 1. This component of the planning process may be carried out either before or after the formulation of a specific development program.

When site analyses are conducted following establishment of minimum land use and development requirements such as: (1) geographic location, (2) physical area, (3) accessibility to jobs, services, etc., and (4) lot development and construction cost ceilings, the analysis process may involve a comparative evaluation of alternative sites to determine which best meets the physical, social and economic objectives of the development program. Frequently, the situation exists where a tract of land has been already purchased without the benefits of technical analysis inputs. Under these circumstances, development objectives and design solutions should remain somewhat flexible in terms of land use allocation development densities and cost ceilings in order to await the determination of the presence or absence of serious physical limitations to a site's optimum use.



ANALYTICAL COMPONENTS IN THE PREPARATION OF A DEVELOPMENT PLAN

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It is preferable to implement the site analysis investigations prior to rather than after land purchase. Implementation of a forced development solution on a particular site should be avoided. Such solutions often create other short- and long-term problems which need not otherwise occur. A forced solution may raise the estimated construction and/or maintenance costs of a project, thereby compromising program objectives as well as the financial viability of the project. In addition, it may well destroy the natural site features that were partially responsible for the selection of the project location. (See Figure 2.)

Advanced planning for the effective management of storm runoff on construction sites involves three (3) basic steps. Each of these activities should be carried out sequentially and is designed to help the site planner/engineer prepare appropriate erosion and sediment control plans which best fit the proposed development and the physical site conditions. A control plan to handle erosion and sediment should be planned concurrently with the project's other plan components, particularly storm drainage system and land use. The lack of integrated planning of these components may result in loss or impairment of development work as well as other downstream land uses. The proposed time sequence and technical analyses for integrating erosion and sediment control as an integral part of the site planning process are identified and described below:

STEP 1. PRELIMINARY SITE INVESTIGATION AND ANALYSIS

A. Data Collection

Preventing or minimizing the impacts of a water and soil conservation problem requires an adequate informational base upon which informed decisions can be made. Thus, it is advisable prior to the purchase of a tract of land to collect and analyze carefully certain physical data which have a direct bearing on its development feasibility/limitations and potential economic value. Critical data to be collected and mapped (Figure 3) for erosion and sediment control purposes should include:

1. Property Boundary and Topography Data

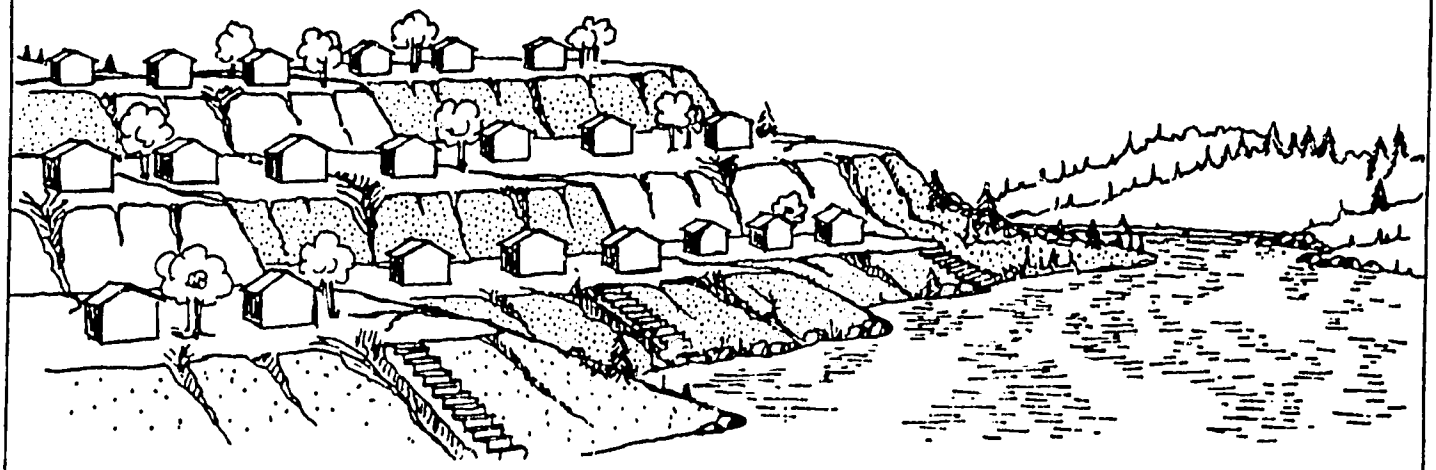
Both boundary and topographic maps of the site should be prepared to delineate physical limits of ownership and contour elevations at no less than two-meter intervals. Topographic mapping of the project site should overlap the property line at least 20-30 meters to show existing conditions and potential influences of adjacent properties.

2. Soil and Geology Data

Major soil types of the site should be identified and delineated on the topographic map. In addition, a description of urban use soil limitations should be obtained. Specific characteristics for which

Recognition of Natural Design Determinants

Disregard of Physical Limitations



ALTERNATIVE APPROACHES TO SITE DEVELOPMENT

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information should be collected or developed from field survey techniques where published data may not exist include:

- permeability of surface and subsurface
- erodibility
- subsurface drainage
- slippage potential
- flood potential
- acidity and alkalinity properties
- depth of surface soils.

Supplementing general soil classification data, geologic information should be collected to enable an assessment of underlying parent materials. Knowledge of a site's geologic structure and its interrelationship to soil, hydrology and vegetation conditions is important. In particular, data on the following subjects should be obtained where possible:

- permeability of subsurface strata
- ground water recharge areas (aquifers)
- slope stability - slippage/landslides.

Where published data is not available, site investigations of geologic features should be conducted. Site geology can be readily determined where it has been exposed in areas of road cuts, landslides, erosion, etc.

3. Hydrology and Drainage Data

The existing location and general condition of watercourses, bodies of water, and drainage swales should be noted on the topographic map. In addition, the physical limits and natural drainage flow patterns ought to be shown for both major and minor watersheds. Statistical and descriptive information on precipitation conditions should complement this physiographic data. Climate-related data to be collected include:

- mean annual rainfall
- monthly distribution and frequency
- rainfall intensity and duration
- design storm - 2, 10, 25, 50, and 100-year frequency.

4. Vegetation

Existing vegetative patterns, densities of ground cover and types of representative species should be identified and noted on the topographic map. Similarly, areas which have been denuded or show evidence of soil exposure should be field checked and delineated on the topographic base map.

B. *Data Analysis*

Following completion of the site investigations to inventory existing physical conditions, supplemented by the collection of published or unpublished information from other sources, an analysis of the data information should be made to determine what important development conclusions can be drawn from it. Specific outputs to be derived from the data analysis are identified in italics below. It is critical to examine the interrelationships of these physical components to assess the site's vulnerability to erosion and sedimentation. Figure 4 provides a graphic example of what a site analysis map might show.

1. *Indicate where soils, topography, and vegetation combine to create critically erodible areas.*

2. *Indicate how the site relates to surrounding streams, drainageways, or other bodies of water. Assess the vulnerability to erosion and sediment damage of these drainageways and surface waters and all off-site areas.*

3. *Indicate where stormwater runoff crosses the site boundaries. Indicate the potential options for disposing of stormwater runoff by including potential locations of sediment control structures.*

4. *Indicate how areas disturbed by construction might be protected from increasing surface stormwater runoff.*

1. Topography

The analysis of the site's topographic contours ought to be directed at the identification of specific areas which may be subject to serious erosion and soil loss. Two basic characteristics should be examined -- slope steepness and slope length. The erodibility potential is much greater where slopes are longer and steeper. The classification of slope gradients into four general ranges of soil erodibility has been found to be meaningful in identifying potential problem areas:

0 - 5% -low erosion hazard
5 -10% -moderate erosion hazard
10 -15% -slightly hugh erosion hazard
15% or more-high erosion hazard.

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The potential for greater erodibility within each of these slope gradient ranges exists due to the factor of slope length. Therefore, site planners should be particularly cautious in the analysis of areas with long uninterrupted slopes. As a rule of thumb, the erosion hazard will become critical when slope lengths exceed the following limits:

0 - 5%	-300 feet
5 -10%	-150 feet
10 -15%	-100 feet
15% or more	- 75 feet.

2. Soils and Geology

The most important soil consideration from the viewpoint of erosion and sediment control is the potential erodibility of each soil type. An analysis of the site's soil map should be carried out, and those areas with a high probability of erosion should be delineated on a separate map of development problems and opportunities. Other soil considerations to be taken into account may include surface and subsurface soil permeability, shrink-swell potential, slippage tendencies, and acidity/alkalinity characteristics.

Geologic factors to be weighed should include identification of aquifers, areas with high ground-water percolation or impermeability, slope stability and deposits of stone or rock materials for construction of mechanical control measures.

3. Hydrology and Drainage

The topographic map should be analyzed and the natural drainage divides for all major and minor watersheds delineated on it. In addition, the location and condition of existing waterways, swales, drainage ditches, and underground water sources should be noted. Since off-site drainage courses from adjacent properties may adversely affect a site, they should be evaluated, and appropriate notes added to the site analysis map. Furthermore, estimates of existing and future storm runoff rates and flood levels in the principal streams and bodies of water should be determined.

4. Vegetation

The condition of the site's vegetative ground cover is one of the most important factors that will control the extent and severity of its erosion and sedimentation problems. Soils located in areas of steep or long, gradual slopes are vulnerable if ground cover does not exist or is removed during construction. Therefore, the interrelationships between topography, soils, drainage and plant communities must be examined jointly in the analysis process of delineating potential critical problem areas.

STEP 2. SITE PLAN DEVELOPMENT AND ITS EVALUATION

Based upon inputs from Step 1, the site designer/engineer should have a clear understanding of the natural processes, physical constraints and opportunities that must be carefully reflected in the preparation of the site plan. It is recommended that a list of specific site planning guidelines be developed for each site as a preliminary step to the preparation of alternative conceptual land use plans.

A. Site Planning Guidelines

1. Fit Development to Terrain

The development of an area should be tailored to the existing site conditions. This will avoid unnecessary land disturbance, minimizing the erosion hazards and excessive high construction costs.

2. Confine Construction Activities to the Least Critical Areas

Any land disturbance in the critically erodible areas will necessitate the installation of more costly control measures.

3. Cluster Buildings Together

This minimizes the amount of disturbed area, concentrates utility lines and connections in one area, and provides more natural open space. The cluster concept not only reduces the amount of erodible area, but it beautifies the development, and generally lowers development costs.

4. Minimize Impervious Areas

Keep paved areas such as parking lots and roads to a minimum. This goes hand in hand with cluster developments in eliminating the need for duplicating parking areas, access roads, etc. The more land that is kept in vegetative cover, the more water will infiltrate, thus minimizing runoff and erosion.

B. Preliminary and Final Site Plan Development

The preparation of the conceptual development should proceed on the basis of the site planning guidelines and with input from various technical specialists. Areas of development and their designated land uses should be fitted compatibly to the site and surrounding landscape. Streets, parking areas, lots and building layouts can minimize or promote soil erosion and sedimentation. Therefore, the designer(s) should carefully weigh the consequences of the physical plan and seek to exploit the strengths and avoid or minimize conflicts with the limitations of the site.

In problem areas where slopes and soils pose potential erosion problems and control costs may be high, alternative land uses or physical layouts that are compatible with the site's capabilities should be evaluated. Under these particular circumstances, the cluster concept of design offers special advantages while minimizing construction costs. In areas of sloping terrain, houses are clustered around cul-de-sacs located in more level areas, and the steeper, more erodible land is left undisturbed.

C. Evaluation of the Site Plan

Prior to the preparation of the final site plan, a review of the physical design layout should be made to insure its physical, social, economic and environmental soundness. The parameters set forth under site planning guidelines should be the basis of the evaluation. In addition, specific stormwater management considerations to be examined might include:

1. consistency of the physical layout with existing natural drainage patterns and soil/slope limitations;

2. allocation of space to accommodate the expected future volume of stormwater on site;

3. provisions for handling off-site drainage coming into the project site; and

4. protective measures to reduce potential flooding or drainage impacts on adjacent properties and downstream areas.

STEP 3. PLAN FOR EROSION AND SEDIMENT CONTROL

When the site plan has been completed, an effective erosion and sediment control program needs to be prepared to avoid or minimize problems of surface runoff from disturbed areas. It is recommended that the control program be formulated in concert with the preparation of the grading and storm drainage plans. The following basic procedure may be used to assist in preparing the plan:

A. Drainage Areas and Direction of Surface Water Flows Mapped

Using the site's topographic mapping, a determination must be made of the major drainage divides and the sub-watersheds within the project area. This data will indicate the relative size of the drainage areas, direction of surface flows, and will permit calculations to be made of estimated current and future runoff volumes and velocities.

B. Limits of Clearing and Grading Delineated

The location of the land uses shown on the site plan should be used to define the physical limits of clearing and grading. With the

surface runoff data developed previously, it will be possible to assess how both disturbed and undisturbed areas may be affected. Special attention should be directed on those areas previously identified as potential problem areas due to steep or long, moderately steep gradients, soil erodibility, impermeability, etc.

C. *Alternative Control Strategies Evaluated and Specific Erosion and Sediment Control Practices Selected*

When specific problem areas have been identified, based on site inspections and analyses of physical mapping data, any one, or a combination of alternative stormwater management strategies should be evaluated to handle each particular problem. The following strategies should be considered:

- reduction of runoff
- interception of runoff
- diversion of runoff
- detention of runoff
- controlled handling and disposal of concentrated runoff flow.

Once a particular control strategy has been determined as the one most appropriate for each problem area, then selection of the specific control practices needs to be completed. Erosion and sediment control practices can be divided into three (3) broad categories:

- vegetative controls
- structural controls
- management practices.

Sections II, III, IV, and V of the manual discuss in detail the planning, design and implementation aspects of these different types of controls. Each category of control is briefly described below:

VEGETATIVE CONTROLS - These types of control measures provide temporary protection of disturbed areas during construction as well as a permanent defense against long-term problems after construction has been completed. These measures consist of mulches, fibrous materials and temporary/permanent cover crops. They are used to prevent or reduce the impact of raindrops and overland flow of runoff. These control measures are some of the least expensive and most effective.

STRUCTURAL CONTROLS - Where vegetative controls do not provide adequate protection against erosion and sediment damages, other control measures will be needed. Structural measures are designed and built generally to intercept surface runoff and convey it to a suitable area for safe disposal. In the process of interception and disposal of storm runoff, the volume and velocity of surface waters must be controlled below the critical erodibility point. In addition, runoff laden with sediment must be intercepted and the soil particles removed before entering the storm drainage system.

Structural measures may include land grading practices, diversion devices, grade stabilization measures, sediment control devices, storm drain protective measures, and storm detention measures. These types of controls require proper design and construction. They are generally more expensive and less efficient than vegetative controls.

MANAGEMENT CONTROLS - Equally as important as the vegetative and structural control practices are management practices involving the physical development phasing, timing of clearing, grading and construction operations in relationship to wet and dry seasons, and the actual construction practices carried out in the course of the project's implementation. These considerations are discussed in further detail in Section II of the Manual.

D. Preparation of the Erosion and Sediment Control Plan

The final step consists of the preparation of the actual physical control plan and a concise narrative report. These documents should consolidate all the pertinent data analysis undertaken in III A, III B, and III C, and the required control actions to mitigate any identified potential problem areas. The erosion and sediment control plan should be prepared on the topographic map and may consist of various maps or drawings to support the findings of the written report.

The following is a checklist of the basic informational requirements which should be included in the narrative and on the site plan:

1. Narrative Report

- Brief description of the overall development project;
- anticipated phasing of construction and staging of clearing and grading operations;
- general location and description of the areas on the site which pose potentially serious erosion and sediment problems;
- brief description of the overall stormwater management strategy and control program;
- details of the inspection and maintenance program including the proposed schedule of inspections, method and frequency of cleanouts, disposal of waste material and specifications of temporary and permanent stabilization measures; and
- design considerations and calculations for all mechanical control measures.

2. Site Plan (See sample control plan, Figure 5.)

- Vicinity map showing relationship to surrounding watersheds, streams, highways, etc.;
- changes to existing topographic contours;
- location of proposed site improvements;
- limits of clearing and grading;
- approximate limits of flooding given full development of watershed;
- identification of existing and potential critical problem areas; and
- location and type of proposed control measures;

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SECTION II

PROJECT MANAGEMENT DECISIONS AND FIELD CONSTRUCTION PRACTICES FOR EFFECTIVE CONTROL OF EROSION AND SEDIMENTATION

The effectiveness of an erosion and sediment control program will depend substantially on the managerial and technical soundness of the actions taken by the project's decision-makers and construction implementers. The following are critical areas to be given special attention to insure that the control plan becomes a workable tool in preventing costly damages caused by uncontrolled runoff.

A. PLANNING AND SCHEDULING OF CONSTRUCTION OPERATIONS

The planning and scheduling of construction operations are significant factors in controlling erosion and sedimentation problems. Because construction schedules are subject to change, it is recommended that specific control activities should be initiated by the progress of certain construction activities, such as clearing and grading as opposed to fixed calendar dates. The scheduling of land clearance and grading operations should reflect special consideration of probable weather conditions and the physical limitations of the project site.

Prior to, or in conjunction with, initial site clearing and earth moving, it should be required that erosion and sediment control measures be installed. When construction activities are carried out by contractors, they should be made responsible for repairing any damage to erosion control measures that have been built.

B. ON-SITE PLAN REVIEW

To insure a thorough understanding of the importance of managing storm runoff, the specific purpose of recommended control measures, and their construction specifications, an on-site plan review should be conducted by the professionals responsible for preparing the control plan for the benefit of the construction supervisor(s), inspectors, and contractors. By doing this, the site preparation, construction activities, and erosion/sediment control efforts should be carried out in a more coordinated manner. Dates and responsibilities should be clarified regarding construction of the controls, frequency of inspections, maintenance requirements, and disposal of clean-out debris and sediment.

C. FIELD CONSTRUCTION PRACTICES

The best defense against erosion and sedimentation problems is the careful execution of the project throughout its construction phase. When land has been disturbed, it is at this point that the site is most vulnerable to erosion and sediment damages. Therefore, acceptable methods of conservation, construction and maintenance are particularly critical. The following are some field construction practices that should be carefully adhered to:

1. Limits of clearing and grading are to be marked to insure conservation of adjacent areas.

2. No disturbed area is to be left unprotected for more than 15-30 days during the rainy season.

3. All protective erosion and siltation control measures are to be in place prior to or at the time of initial clearing and grading operations.

4. Infrastructure easements are to be compacted and mulched and seeded to prevent damage or displacement.

5. Temporary interception, diversion and silt trapping devices are to be compacted, mulched and seeded to maximize their efficiency and durability.

6. Any stockpiled topsoil which will not be used in the course of the construction season are to be seeded with temporary vegetation and protected with a ditch and/or silt trap; and

7. During construction, all storm and sanitary inlets are to be protected by silt traps.

SECTION III

CRITICAL PROBLEMS, CONTROL STRATEGIES, AND ALTERNATIVE CONTROL PRACTICES

This section of the manual identifies and examines five (5) serious problem areas where the destructive impacts of erosion and sedimentation most frequently occur on construction sites. By reviewing the probable location and causes of the problems and discussing how each might be approached in terms of weighing alternative control strategies and selecting specific control measures, it is hoped that professional errors in handling these situations will be minimized and adverse construction impacts reduced in severity. However, no attempt is made here to identify the best strategy and control measures for each type of problem situation. Simply, there is no universal solution that always works best.

In the process of preparing an erosion and sediment control plan, a thorough analysis of the specific conditions of each site is required to determine how much control is needed, what control strategy should be used, and which control measures will function effectively given site-specific factors.

In addition, Section III is designed to accomplish the following specific objectives:

- Identify the most critical areas where major erosion and sedimentation problems are likely to be found and where preventive actions are required;

- Expand the knowledge of site planners and engineers beyond simply an understanding of traditional structural control measures to include consideration of alternative control strategies and control practices; and

- Show where and how these control strategies and control practices might be used in practical situations.

PROBLEM #1: STEEP OR LONG, GRADUAL SLOPES

Definition of the Problem: Development on hillsides poses potentially significant problems when little attention is given to underlying geology, drainage patterns and surface soil conditions. During construction, removal of protective vegetative cover of the fragile soil base makes these sensitive areas vulnerable to the impacts of rain droplets and the force of surface runoff. In addition, if the geologic structure of the hillside is unstable, the process of erosion and sediment transport may cause part of the hillside to fail, resulting in landslides, slumps, mudflows or similar mass movement.

Discussion of Problem: Severe erosion of hillside slopes is usually caused by the concentration of stormwater running overland from the top of cut or fill slopes. The downward gravity pull of runoff causes a shearing or cutting effect of the soil base material. As slope steepness increases, a corresponding rise in the velocity of the surface runoff occurs. A doubling of the runoff velocity causes its erosion power to be four (4) times greater. Equally important to note is the cumulative build-up and erosive effects that can occur from runoff flowing over long, unbroken slopes of medium gradient (4°-10°). In summary, the rate of erosion is directly affected by slope steepness, length and shape as well as soil permeability, vegetative cover, density, and precipitation variables.

CONSIDERATION OF ALTERNATIVE CONTROL STRATEGIES	SELECTION OF ALTERNATIVE CONTROL PRACTICES
1. DETENTION OF STORM RUNOFF	• Diversion dikes • Vegetative buffers • Sediment traps • Sediment basins and ponds • Underground storage - French trench - Percolation catchments - Gravel surface parking lots - Drain tiles
2. INTERCEPTION AND DIVERSION OF RUNOFF	• Straw bale barriers • Interceptor dikes • Perimeter dikes • Diversion dikes • Level spreader • Waterways and outlets - Swales - Ditches - Channels • Reverse benches and terraces
3. MODIFICATION OF LAND FORM	• Benches • Terraces • Ditches • Diversion dikes • Manipulation of slope shape (concave)
4. CONTROL RUNOFF FLOWS OVER STEEP SLOPES AND DISPOSAL OF CONCENTRATED FLOWS	• Mechanical compaction of fill slopes • Re-establishment of temporary and permane vegetative cover • Level spreader • Chutes/downdrains • Straight drop spillways • Box inlet drop spillway • Drop box culvert • Paved waterways/outlets • Riprap in waterway lining • Use of energy dissipators at point of discharge
5. LAND CONSERVATION AND PROTECTION	• Limit area of clearing and grading • Cluster development to minimize the amount of disturbed area • Conservation of hillside buffer strips • Retention of natural vegetation along watercourses • Confine planned development to compatible areas • Control of development densities based on slope sensitivity
6. SOIL PREPARATION FOR INCREASING RAINFALL FILTRATION AND PERCOLATION	• Scarification or roughening • Furrowing • Tracking
7. RE-ESTABLISHMENT OF VEGETATIVE COVER FOR SOIL STABILIZATION	• Mulching - Straw - Grasses - Wood chips • Use of protective matting • Seeding - Temporary - Permanent • Sprigging • Grass sodding • Reforestation

BEST AVAILABLE DOCUMENT

PROBLEM #2: STREET AND ADJACENT DITCH DRAINAGE

[illegible]: One of the principal areas of concentrated break-up of pavement surfaces, washout of shoulders, undercutting of pavement surfaces, and loss of complete sections of roadways or structures. In addition, where the problem of erosion is prevalent, sedimentation is a corollary concern to be addressed in terms of its financial implications. Not only must the loss of soil and road base material be replaced, but clogged drainage structures must be cleaned out. Prevention of erosion and sedimentation in this area will protect the initial investment, reduce maintenance costs and minimize safety hazards for motorists and pedestrians.

[illegible]: Critical factors affecting the frequency and severity of erosion and sediment problems on street and roadside drainage areas are:

(1) Steepness of slopes adjacent to drainage ditches;

(2) Roundedness of edge on roadside shoulders;

(3) Relative cleanness and compaction of stone material for construction of temporary/permanent road base, shoulder and ditch sections;

(4) Provision of diversion devices to prevent overland flow occurring on steep slopes adjacent to roadside ditches;

(5) Adequacy of design of roadside ditches in terms of shape and size to handle runoff volumes and use of appropriate linings to control runoff velocities;

(6) Use and location of storm drainage structures to control concentrated flows and their discharge into nearby waterways; and

(7) Protective measures to re-establish vegetative cover on all disturbed areas.

CONSIDERATION OF ALTERNATIVE CONTROL STRATEGIES	SELECTION OF ALTERNATIVE CONTROL PRACTICES
ADJACENT SLOPES	
1. DIVERSION OF STORM RUNOFF FROM CUT AND FILL SLOPES ADJACENT TO STREET	• Diversion dikes at top and/or bottom of slopes • Reverse benches • Reverse terraces
2. CONTROL OF STORM RUNOFF OVER STEEP SLOPES AND DISSIPATION OF ENERGY	• Chutes/downdrains • Pipe slope drains • Waterways with protective linings • Level spreader • Sodding of slopes • Seeding, mulching or use of protective coverings (jute, burlap, etc.) • Energy dissipators - Riprap - Cemented concrete blocks - Drop spillways
3. PROPER GRADING OR FILLING OF ADJACENT STREET SLOPES	• Grading slopes preferably 3:1 or 4:1 where terrain is flat or gently rolling • Grading slopes to no less than 2:1 in fill conditions or where terrain is steep • Mechanical compaction of fill slopes
DRAINAGE DITCHES	
4. PROPER DESIGN AND CONSTRUCTION OF DITCH SECTIONS	• Slopes of ditches cut from 4:1 to 2:1 with rounded edges at their intersections • Sufficient volume capacity in bottom of ditch to prevent overflows
5. PROTECTION OF DITCHES WITH SUITABLE LINING	• Grass lining - Sodding - Seeding • Paved lining - Asphalt - Concrete - Stone/riprap
6. DESIGN OF DITCHES TO HANDLE RUNOFF VOLUME AND VELOCITY	• Grass ditches (minimum 0.5% slope) • Velocity checks in ditch - Staked straw bales or riprap check dams - Drop box inlets • Alternate use of paved and grassed ditches to reflect erodibility factors of soils and slopes
STREET SHOULDERS	
7. PROPER DESIGN AND CONSTRUCTION OF SHOULDER WITH APPROPRIATE COMPACTED MATERIAL	• Use of relatively clean and compacted stone material in shoulder section particularly during and after final construction • Sufficient slope to facilitate drainage of shoulder and prevent ponding • Stone base material compacted flush to street pavement
STREET PAVEMENT	
8. INTERCEPTION AND DIVERSION OF STORM RUNOFF DURING CONSTRUCTION AND AFTER COMPLETION	• Use of interception dikes on gradual and steep slopes during construction period • Gravel filters to prevent sediment transport • Grassed or paved ditches and waterways to divert waters away from str[illegible]

PROBLEM #3: WATERWAYS AND STREAMS

Definition of the Problem: The concentration of storm runoff in natural or man-made swales, channels and other types of watercourses may pose critical erosion and sediment transport problems on construction sites. The conversion of tracts of land from a relatively low density use (agricultrural or sparse residential settlement) to a medium or high coverage use (residential, commercial, or industrial) significantly influences the hydrology of the area's watersheds. The increase in the percent of land surface coverage due to changes in land uses or concentration of development could readily alter a watershed's storm runoff coefficient from .15 to .90. The increase in runoff volumes and flow velocities requires that special measures be employed in areas where these runoff flows are concentrated.

Causes of the Problem: Frequently, natural drainage courses do not have sufficient capacity to handle the increased volume of runoff as rapid urbanization occurs. As a result, several critical problems are likely to occur in or near waterways and streams. These problems and associated causes are outlined below:

(1) Flooding or high water flows will cause stream bank erosion and build-up of sediment in the channel course;

(2) Tributary streams with higher than normal runoff velocities will be subject to possible stream bank and channel erosion.

(3) Uncontrolled discharges of tributary streams into larger receiving streams will be subject to increased stream channel or bottom erosion;

(4) Higher loading rates of sediment will occur in downstream areas, thus increasing the risks of flooding in these areas; and

(5) Rapid rate of runoff discharged from the land into watercourses diminishes the quantity of water available for recharge into groundwater resources as well as its uptake by vegetation root systems. The reduction in the quantity of water recharging ground resources directly causes major fluctuations in surface stream flows -- high peak flows in the rainy season and low flows (drought conditions) in the dry season.

CONSIDERATION OF ALTERNATIVE CONTROL STRATEGIES	SELECTION OF ALTERNATIVE CONTROL PRACTICES
I. LAND CONSERVATION AND PROTECTION OF ENVIRONMENTALLY SENSITIVE AREAS	• Limit area of clearing and grading • Cluster development to minimize the amount of disturbed area • Confine development to the extent possibl to areas of medium-high impermeability and retain areas of high permeability in open space or low density for recharging ground-water resources • Conservation of hillside buffer strips • Retention of natural vegetative buffers along watercourses
2. INTERCEPTION AND DIVERSION OF RUNOFF	• Perimeter dikes • Straw bale barriers • Interceptor dikes • Diversion dikes • Waterways and outlets - Swales - Ditches - Channels • Reverse benches and terraces
3. SEDIMENT CONTROL	• Interceptor dikes with gravel outlet structures • Sediment traps • Sediment basins • Check dams
4. DETENTION OF STORM RUNOFF	• Diversion dikes • Sediment traps • Sediment basins and ponds • Underground storage - French trench - Percolation catchments - Gravel surface parking lots - Drain tiles
5. CONTROL VELOCITY OF DISCHARGED RUNOFF	• Lining of ditches - Pavement - Riprap • Stilling basins • Check dams • Level spreaders • Gabion or riprap lining of stream banks
6. SOIL PREPARATION FOR INCREASING RAINFALL, INFILTRATION AND PERCOLATION	• Scarification or roughening • Furrowing • Tracking
7. RE-ESTABLISHMENT OF VEGETATIVE COVER FOR SOIL STABILIZATION	• Mulching - Straw - Grasses - Wood chips • Use of protective matting • Seeding - Temporary - Permanent • Sprigging • Grass sodding • Reforestation

PROBLEM #4: SITE AND LOT GRADING

Definition of the Problem: The necessity for land grading on a project site is required to the extent that the proposed development design deviates from the site's natural topographic conditions. A well-designed project is one that utilizes a site's existing topography to the best advantage with minimal alterations. One of the principal reasons for reshaping a site's topography is to insure adequate drainage so that storm runoff will flow away from occupied areas and be conveyed through and off the site by means of natural and man-made drainage systems. When land grading is carried out without properly prepared grading and storm drainage plans, the effects of uncontrolled or mismanaged storm runoff can have disastrous and costly impacts during construction and following completion of the project.

Contributory Factors: The following improper grading practices are major contributory factors in causing the severity and duration of erosion and sedimentation problems to be increased significantly on construction sites:

(1) In areas of hilly or steep terrain, insufficient land area is provided for stepping-down lots with proper slopes of 2:1 or 3:1 ratios unless reinforced retaining walls are constructed;

(2) Diversion dikes, drainage ditches and swales are not provided or are improperly located to adequately divert or intercept overland flows at the top or bottom of slopes and between lots, thus allowing runoff to concentrate and travel at high erosive velocities across built-up areas of the site;

(3) Where elevations along the front or rear property lines of a lot are considerably higher or lower than the other, positive drainage away from or around the structure is often not provided, thus causing ponding or negative drainage towards the structure on the lot; and

(4) When elevations between streets and house floors are not properly set before grading operations commence, drainage conflicts frequently occur. When floor elevations are lower than street grades, excessive runoff from the streets will cause erosion and ponding problems on the lots. If lot elevations are considerably higher than the street, this may result in creating steep slopes which are erosion-prone and contribute to sediment clogging storm drainage improvements.

CONSIDERATION OF ALTERNATIVE CONTROL STRATEGIES	SELECTION OF ALTERNATIVE CONTROL PRACTICE
1. INTERCEPTION AND DIVERSION OF RUNOFF	• Diversion dikes or waterways in the middle of long, gradual slopes • Diversion ditches, swales or yard inlet to prevent ponding or accumulated overland flow of runoff between lots • Diversion dikes at the top of steep slopes
2. DETENTION OF STORM RUNOFF ON-SITE AND WITHIN LOTS	• Sediment traps • Sediment basins and ponds • Underground storage - French trenches - Percolation catchments or soakaway pits - Gravel surface parking lots - Drainage tiles • Use of street crossing of drainage-ways for permanent storage
3. RE-ESTABLISHMENT OF VEGETATIVE COVER FOR SOIL STABILIZATION	• Mulching - Straw - Grasses - Wood chips • Use of protective mattings • Temporary and permanent seeding • Sprigging • Grass sodding • Reforestation
4. IMPROVED LAND GRADING	• Schedule grading operations to occur during periods of the year when storm (rainfall) frequencies and intensities are least likely to cause serious erosion and sediment problems. • Stage land grading operations to coincide with areas planned for immediate construction. • Limit grading to areas of workable size so as to limit the duration of exposure for disturbed and unprotected areas to erosion hazards. • Install erosion and sediment control devices and storm sewers during the initial stage of rough grading. • Where feasible, cut-and-fill slopes shall not be steeper than 2:1. • Where feasible, benches or diversions shall be provided on slopes steeper than 3:1 when vertical height exceeds 15 feet. • Provisions must be made to conduct concentrated runoff safely to storm drains or to stabilized watercourses to insure that surface runoff will not damage slopes or other graded areas. • Subsurface drainage must be provided where necessary to intercept seepage that would adversely affect slope stability or create excessively wet site conditions. • Slopes should not be created so close to property lines as to endanger adjoining properties without adequately protecting such properties against erosion, slippage, settlement, subsidence, or other related damages. • Avoid intrusion into natural watercourses or flood channels for purposes of clearing and grading or disposal of debris, excess fill material, etc., in order to avoid reducing the capacity of streams and floodways. • Stabilize all temporary construction roads, streets and parking areas after rough grading with a base of coarse, crushed store and provide adequate drainage ditches. • In areas delineated for clearing and grading, special measures should be taken to stockpile and later re-use top soils for revegetation purposes. Stockpiled material which is not used within a construction season should be seeded for temporary vegetation and sediment traps or barriers constructe at appropriate locations to prevent damages from sediment-laden runoff from these areas.

PROBLEM 5: INFRASTRUCTURE

Definition of the Problem: Storm runoff damage to infrastructural improvements (storm sewers, sanitary sewers and water lines) on development sites is a common problem not only throughout the construction period of a project, but also years after its completion. When a tract of land is developed and the amount of impervious surfaces increases, the quantity of runoff and the velocity at which it travels can be dramatically higher. These waters will follow an overland course of least resistance in response to the pull of gravity. Because infrastructural improvements are generally located to maximize gravity flow, the easements in which these facilities are constructed frequently become natural corridors which concentrated runoff flows follow unless preventative measures are taken.

Three of the principal problems involving uncontrolled runoff and its destructive impacts on infrastructure improvements are: (1) the severe soil loss and sediment transport that occurs in disturbed and unprotected utility and infrastructure easements; (2) physical displacement and damage to installed water, sewer and sanitary lines and their support structures when exposed by erosive runoff; and (3) the physical deterioration or wearing down of storm runoff conveyance improvements (paved ditches and closed storm sewers) due to high runoff velocities, low design standards and/or construction material specifications.

Contributory Factors: The occurrence of these types of problems can be both costly and result in the delay of project completion. Therefore, project designers and engineers should be cognizant of the main causes of these problems so that steps may be taken at appropriate project stages to avoid or to minimize the severity of their impacts. Critical factors having a direct bearing on the causes of these problems are presented below:

(1) Soil Loss and Sediment Transport

- Excessive clearing and grading for utility/infrastructure easements;
- Soils within disturbed construction easements are not adequately compacted nor protected against erosion immediately following work completion; and
- Lack of or improper construction and maintenance of erosion and sediment control measures.

(2) Physical Displacement and Damage

- Shallow trenches for the burial of water, sewer and storm drainage expose infrastructural improvements to high damage risks from the erosive force of runoff as well as downward pressure exerted from traffic passing overhead;
- Improper selection of bedding material and less than minimum thickness or depth both under and along the sides of the pipe causes sagging and eventual vertical or horizontal dislocation; and
- Insufficient compaction of backfill material along the sides and top of pipes provides opportunities for runoff to follow the excavated trench and to scour out the protective cover of earth and stone materials.

(3) Physical Deterioration

- Use of standard ditch cross-sections regardless of the size of contributing drainage areas and projected runoff volumes results in overbank flows, erosion of ditch side slopes and undercutting of support bedding material;
- High runoff velocities in piped or open paved ditch sections of storm drainage systems may cause excessive wear within a short period unless suitable construction specifications for the manufacture of the storm sewers are carefully defined and adhered to;
- Storm debris, if allowed to enter into a piped storm sewer system, may cause blockage and possible separation at the pipe joints due to the build-up of high pressure;
- Lack of adequate attention to the potential problem of friction inside storm sewer pipes, particularly in areas of steep slopes (15-20%) may cause accelerated wear of the pipe and possible separation at the joints if runoff velocities are excessively high; and
- Unless surface runoff is intercepted or properly diverted away from pipe culvert endwalls or headwalls, these support structures may be undercut and ultimately cause their failure.

CONSIDERATION OF ALTERNATIVE CONTROL STRATEGIES	SELECTION OF ALTERNATIVE CONTROL PRACTICES
1. LAND CONSERVATION AND PROTECTION	• Limit area of clearing and grading. • Temporary erosion and sediment controls are to be installed prior to or concurrent with grading and trench excavation activities. • The length of trench to be opened during the rainy season should be limited to the average amount of pipe laying and trench compaction work normally completed on a daily basis. • Excess material from excavation activities should be mounded on top of the trench and compacted to divert runoff away from this area. • Disturbed areas are to be reseeded after backfilling has been completed and before the start of the rainy season.
2. INTERCEPTION AND DIVERSION OF RUNOFF	• Straw bale barrier • Interceptor dikes • Perimeter dikes • Diversion dikes • Level spreaders
3. RE-ESTABLISHMENT OF VEGETATIVE COVER FOR SOIL STABILIZATION	• Seeding - Temporary - Permanent • Sprigging • Use of protective mattings • Mulching - Straw - Thatch - Wood chips
4. PROPER SELECTION OF BEDDING MATERIAL AND IMPROVED DESIGN CONSTRUCTION PRACTICES	• Minimum depth of cover for sanitary sewers and water - 1 meter. • Minimum depth of cover for storm sewers - 2½ meters unless reinforced pipe is used - 1 meter. • Minimum depth of utilities where traffic passes overhead - 2½ meters. • Granular bedding material should have a minimum thickness of ¼ the outside pipe diameter (4" minimum) and extend half-way up the sides of the pipe. The material should be free of large stones and debris. • Overlay the granular bedding and the pipe with minimum depth of 12" of carefully compacted fill material. • Minimum depth of clean backfill soil should be 12" overlaying the granular bedding and pipe. Soil should be placed in the trench and carefully compacted in 6-8" layers by mechanical or hand tampers. • Endwalls and headwalls should be constructed on firm foundations to prevent settlement or tipping. Footing should be placed well below the streambed to prevent undermining. Consideration should be given to design wings on these structures to provide added support and to prevent erosion from undercutting. Concentrated surface runoff should be diverted or intercepted and piped away from these structures to avoid failure.

SECTION IV

DESIGN CONSIDERATIONS IN DETERMINING HOW TO CONTROL SURFACE RUNOFF

Design of a cost-effective and technically sound stormwater management/erosion and siltation control program for development projects requires careful consideration of a number of basic factors. There is a wide range of technical analysis techniques available to guide the site planner/engineer in calculating the design of such critical factors as runoff volumes, flow velocities, discharge rates, etc. The selection of technique should be guided by the size and complexity of the site and watershed under consideration, the degree of public safety and user convenience desired, pollution control requirements, and cost constraints. Irrespective of the analysis techniques chosen to address these specific technical design considerations, the following fundamental issues should be addressed and determinations made in the course of the planning and design process: (1) determination of risks; (2) design options; and (3) analysis of costs. Each of these issues is discussed in detail below.

A. DETERMINATION OF RISKS

It is important that the degree of risk involving human life and safety, physical loss or damage to property and improvements, and financial cost questions be analyzed in all construction projects. Determining the level of risk requires consideration of the probability of a damage-producing storm or flood that may occur during the project's construction period or following its completion. Without such an analysis, whether cursory or detailed in nature, there is no quantifiable basis for evaluating if too much or too little erosion and sediment control has been built into the project.

Determing the level of risk requires consideration of numerous variables including:

(1) DESIGN STORM

The statistical probability that a major raw storm (50,100,200 years, etc.) exceeding the selected "design" storm standard, may occur once in a period of time equal to some multiple of the realistically projected construction period and for the life span of the project.

(2) UNIQUE SITE AND REGIONAL CONDITIONS

Each site must be analyzed separately to evaluate its own peculiar set of natural characteristics (climate, soils, topography, vegetation, etc.), development constraints, and occupancy potentials. These variables and their interrelationships may differ greatly between sites in a given community or regions within a country.

Therefore, a reasonable and cost-effective control program on one site may be inappropriate and excessive in terms of the types and amount of control devices required on another site.

(3) LIFE AND PROPERTY LOSS OR DAMAGE

The frequency and severity of minor and major storm damages require assessment in terms of the potential on-site and off-site risks they may pose to the loss or injury of property and/or human life. Special attention should be given to estimate the increment of change in runoff volumes, velocities, and sediment loading rates in minor and major waterways and to evaluate their implications on personal safety and human well-being.

Within a project site high rates of surface runoff and sediment movement can result in: (1) loss of fill material needed for use in the construction of roads, bridges and the grading of lots; and (2) physical damage to completed or partially constructed infrastructure facilities as well as to the residential structures themselves. To communities located downstream, the effects of uncontrolled runoff may be more serious and long term. Sharp fluctuations in surface water flows will mean increased flood hazards and probable high risks of the loss of lives and damage to property, particularly to residents living in low-lying areas.

(4) EVIRONMENTAL POLLUTION

High sediment loading rates affecting bodies of water in environmentally sensitive aquatic communities such as nursery beds can have disastrous effects on both fresh and saltwater fishery production. The level of acceptable deterioration in water quality due to runoff pollutants from disturbed raw land or urban land uses must be evaluated on a site-to-site basis. Preliminary site investigations of project sites should identify all tributary streams and main bodies of water into which they discharge and determine what, if any, important or unique biological communities may be threatened by runoff pollutants such as sediment, nutrients (nitrogen and phosphorus) and toxic substances, including pesticides and heavy metals (lead, zinc manganese, cadmium), etc.

Acceptable loading rates of urban runoff pollutants will vary, depending on the site's location, climatic conditions and the character of existing and planned land uses within the project's watershed.

B. DESIGN OPTIONS

The design of the stormwater management/erosion and sedimentation control programs will be greatly influenced by the basic decision of the extent to which a site's increased urban runoff is to be detained or stored on-site, or piped through a conveyance system and discharged off-site. The extent to which either or both of these two methods of handling stormwater are used may significantly affect development costs, site design and the potential for off-site stream erosion, flooding and environmental degradation of water-related resources.

(1) OFF-SITE DISCHANGE OF STORM RUNOFF

Traditional methods of solving site drainage problems have relied extensively upon expensive structural measures (piping) to maximize a site's potential development yield and to minimize on-site inconveniences to residents during major storm events. In practice, this approach to handling storm runoff has meant that it is usually directed into an open, paved ditch or underground pipe, conveyed to the edge of a site and discharged into the nearest stream channel. The cumulative effects of this approach have been a major cause of increased frequency of downstream flooding, reduction of ground-water resources for municipal water supplies, and a requirement for massive engineering works in lower sections of watersheds in order to prevent the occurrence of flood damage.

(2) ON-SITE DETENTION OR STORAGE OF STORM RUNOFF

This approach to stormwater management is based on the concept of detaining or storing runoff on-site to the maximum extent feasible, given each site's particular natural features and engineering capabilities. Using control measures such as temporary diversion dikes, swales, sediment basins or permanent holding ponds, etc., excess storm runoff is stored and released slowly, in effect simulating the natural hydrologic process.

The benefits derived from stormwater detention and storage include: (1) reduction in peak runoff rated; (2) lessening the possibility of downstream flooding, stream erosion and sedimentation; (3) enabling the full or partial development of a watershed where limited channel capacity may be considered a growth constraint; and (4) aid in the recharging of ground-water resources critical to domestic water supplies and maintaining more uniform flow levels of streams and rivers throughout the year.

As important as detention and storage is, it should not be viewed as a cure-all for storm drainage design. It is likely that in many instances the storage capacity required to assure both maximum safety and convenience will not be economically feasible, even through it may be highly desirable. Therefore, a balance needs to be established between the inherent liabilities and benefits that each method of stormwater management presents. The site planner/engineer must evaluate how much runoff control is needed and the most cost-effective and environmentally sound methods to achieve it. Underlying this analysis process must be a recognition of the responsibilities and obligations to balance private development interests and protection of public safety and well-being.

C. ANALYSIS OF COSTS

In reaching a determination of acceptable levels of risks and the feasibility and suitability of alternative storm runoff control methods to meet defined risk thresholds, the costs of a control program must be evaluated. The economic analysis should assess the estimated cost of alternative levels of protection for each major design option. This

comparison should consider: (1) initial capital costs; (2) expected cleaning, repair and maintenance costs; (3) replacement costs; and (4) socio-economic costs to the community.

If the cost of required protection exceeds the anticipated damage or potential loss estimates of no protection, the basis of the storm water management plan should be reexamined and a more cost-effective solution prepared.

SECTION V
DESIGN, CONSTRUCTION AND MAINTENANCE GUIDELINES FOR SELECTED CONTROL MEASURES

A. Interception and Diversion Practices

1. Interceptor Dike
2. Diversion Dike
3. Diversion
4. Perimeter Dike
5. Straw Bale or Hay Barrier
6. Waterway or Outlet

B. Grade Stabilization Structure

1. Straight Drop Spillway and Drop Box Culvert
2. Chute or Flume
3. Down Drainage Structure
4. Pipe Slope Drain

C. Land Grading and Soil Loosening Practice

1. General Land Grading
2. Terraces and Benches
3. Soil Loosening

D. Sediment Control Practice

1. Construction Entrance
2. Sediment Trap
3. Check Dam
4. Sediment Basin
5. Gravel Outlet Structure

E. Storm Drain Outlet Protection

1. Level Spreader
2. Rip-Rap
3. Paved Apron and/or Riprap

F. Soil Stabilization Practices

1. Vegetative Controls
2. Non-Vegetative Controls

A. INTERCEPTION AND DIVERSION PRACTICES

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Diversion Dike 36

Diversion 39

Perimeter Dike 44

Straw Bale or Hay Barrier 48

Waterway or Outlet 51

INTERCEPTOR DIKE

DESCRIPTION

This is a temporary ridge of compacted soil, or preferably gravel, constructed across disturbed rights-of-way and similar sloping areas (Figure 6).

FUNCTION

To shorten the length of exposed slopes, thereby reducing the potential for erosion by intercepting storm runoff and diverting it to stabilized outlets.

APPLICATION

It is constructed across disturbed rights-of-way, such as temporary or permanent streets or roadways until they are stabilized. For use in drainage areas of 2.0 hectares or less. Larger drainage areas require that a diversion be designed.

DESIGN CRITERIA

A design criterion is not required.

Top Width:
0.60 m. minimum.

Height:
0.50 m. minimum, unless otherwise noted on plans. The height is measured from the upslope toe to the top of the dike.

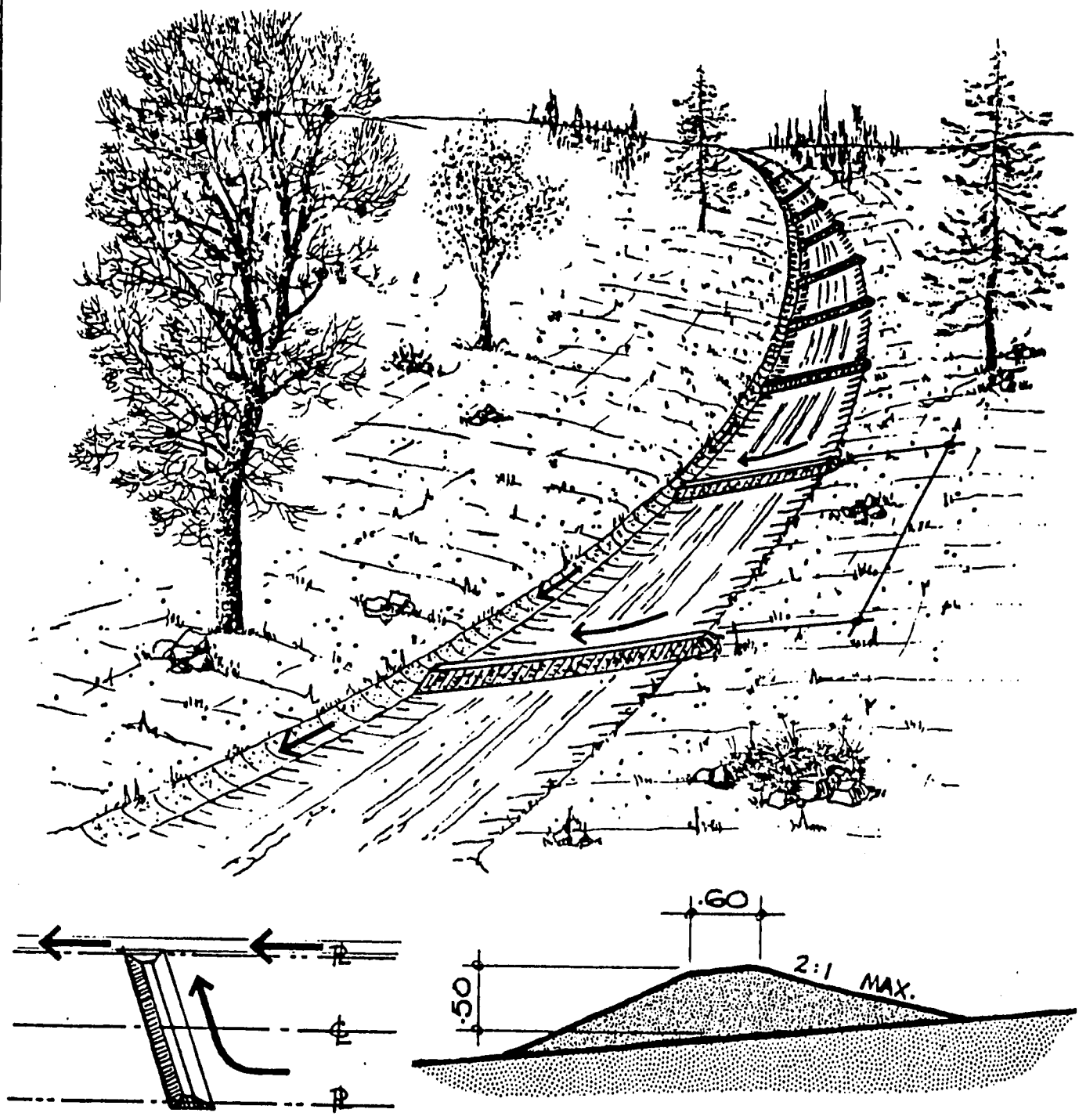
Side Slopes:
2:1 or flatter. Flat enough to allow construction traffic to cross if required.

Grade:
1.0% to 1.5%.

Spacing:

Distance between dikes	45 m.	60 m.	90 m.
Maximum slope gradient where used	>10%	5-10%	<5%

Outlet:
Diverted runoff must discharge into stabilized outlets. Interceptor dikes must have outlets that control the velocity of concentrated flows such as ditch linings, stone outlets, check dams, etc. The on-site conditions should dictate the location of the interceptor dikes and the type of outlets to be used.



INTERCEPTOR DIKE

6

CONSTRUCTION SPECIFICATIONS

- Preferably, all dikes should be machine-compacted. (Use small bulldozer.)
- All dikes must have a positive grade to an outlet.
- Top width may be wider and side slopes may be flatter, if desired.
- Location of dikes should be adjusted in the field as needed to utilize a stabilized outlet.
- Diverted runoff must outlet directly onto an undisturbed or stabilized area by means of a level spreader or a grade stabilization structure.
- Periodic inspection and required maintenance must be provided promptly.

MAINTENANCE CONSIDERATIONS

- Periodic inspections.
- Watching for high intensity storms.
- Reshape of the dike and its compaction.
- Cleaning and regrading.
- Vegetation of the ditch.
- Watch for height of water.

DIVERSION DIKE

DESCRIPTION

A temporary diversion dike (Figure 7) is a compacted earthen ridge, placed above cut or fill slopes. Its life expectancy is approximately one year.

FUNCTION

To intercept storm runoff from small areas at the top or toe of slopes and to divert it away from disturbed slopes to a stabilized outlet.

APPLICATION

Located above newly constructed fill or cut slopes until more permanent drainage features are installed or the slope is stabilized with vegetation. Once stabilization is accomplished, the dike can be removed.

DESIGN CRITERIA

A formal design is not required. However, the following general criteria should be used as a guide:

Drainage Area:
Less than 2 hectares. If the drainage area is larger, consider use of either diversion or waterways.

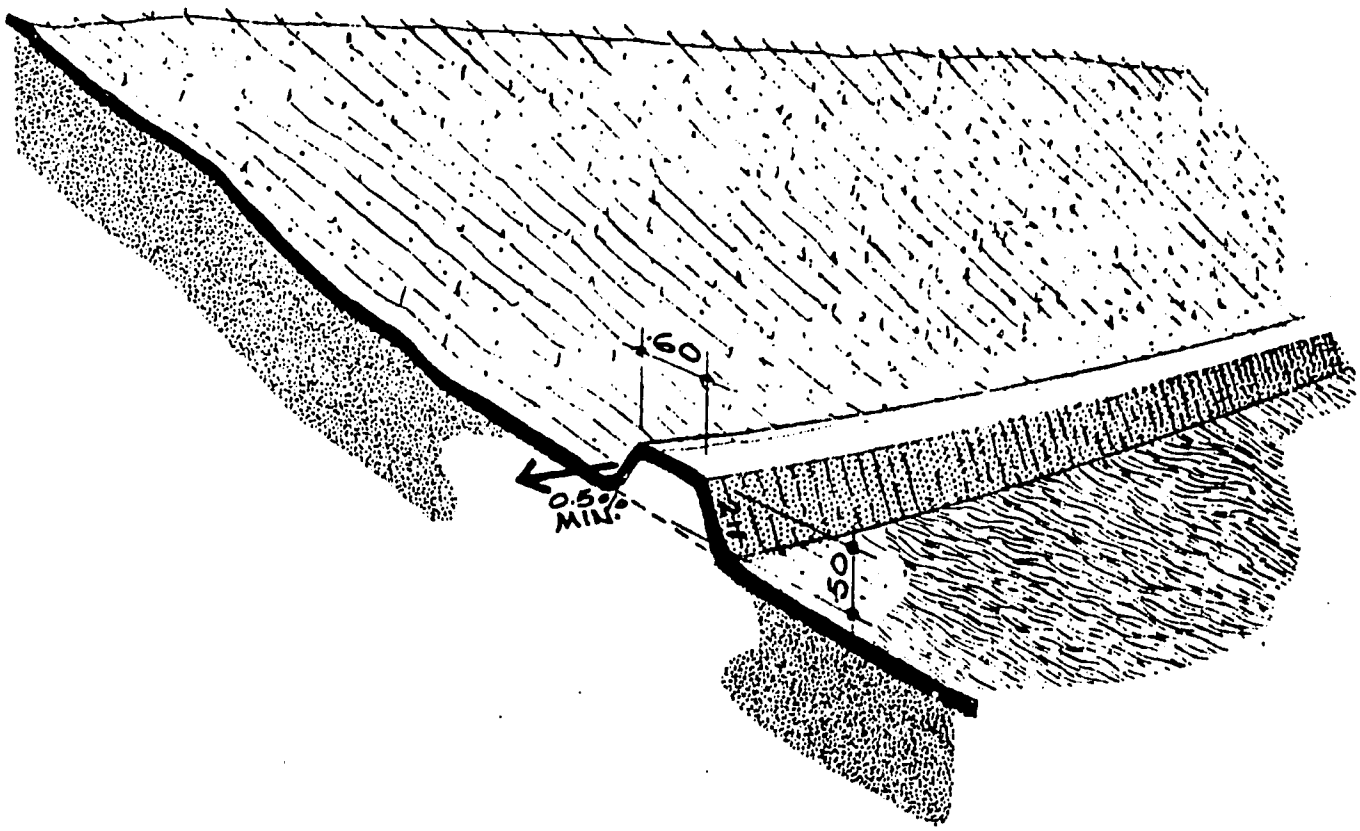
Top Width:
0.60 m. minimum.

Height:
0.50 m. minimum height measured from the existing grade of the upslope toe to the top of the dike (compacted fill).

Side Slopes:
2:1 or flatter.

Grade:
Dependent upon topography, but must have positive drainage to the outlet; where slope of channel (flow area) behind the dike is less than 2%, stabilization is not required; where the slope is between 2% and 5%, stabilization may be required, depending on the characteristics of the site; when the slope is 5% or greater, stabilization is required.

Outlet:
If diverted runoff must discharge onto an undisturbed stabilized area, then a level spreader or a grade stabilization structure should be used to control runoff velocity.



DIVERSION DIKE

7

CONSTRUCTION CONSIDERATIONS

- Preferably, dikes should be machine-compacted (better with the use of small bul'dozer).
- All dikes must have positive grade to an outlet, not less than 1%.
- Diverted runoff must discharge directly onto an undisturbed stabilized area using either a level spreader or a grade stabilization structure.
- Periodic inspection and required maintenance must be provided.
- Dikes must be placed far enough away from disturbed area to permit the use of equipment for regrading or cleaning (3 m. minimum).
- Diversion dikes must be seeded and mulched immediately after construction.

MAINTENANCE CONSIDERATIONS:

- High intensity storms may cause severe damage.
- Periodic inspections are critical, particularly following major storms.
- Where storm damage occurs, reshaping and compaction are required.
- Cleaning of the channel of debris and sediment will prolong the life of dikes.
- Establishment of vegetation on dikes will avoid or reduce storm drainage.

DIVERSION

DESCRIPTION

Diversion (Figure 8) is a temporary or permanent earthen drainageway constructed by excavating a shallow ridge along a hillside and building a dike along the downhill edge of the ditch with the excavated soil. It is a combination of a ditch and dike.

FUNCTION

While diversions can be used in place of temporary structures, such as diversion dikes and swales, they are primarily used to provide more permanent runoff control on long slopes subject to heavy flow concentrations. The contributing area draining into a diversion structure could be as large as 40 hectares. Their failure hazard is low.

APPLICATION

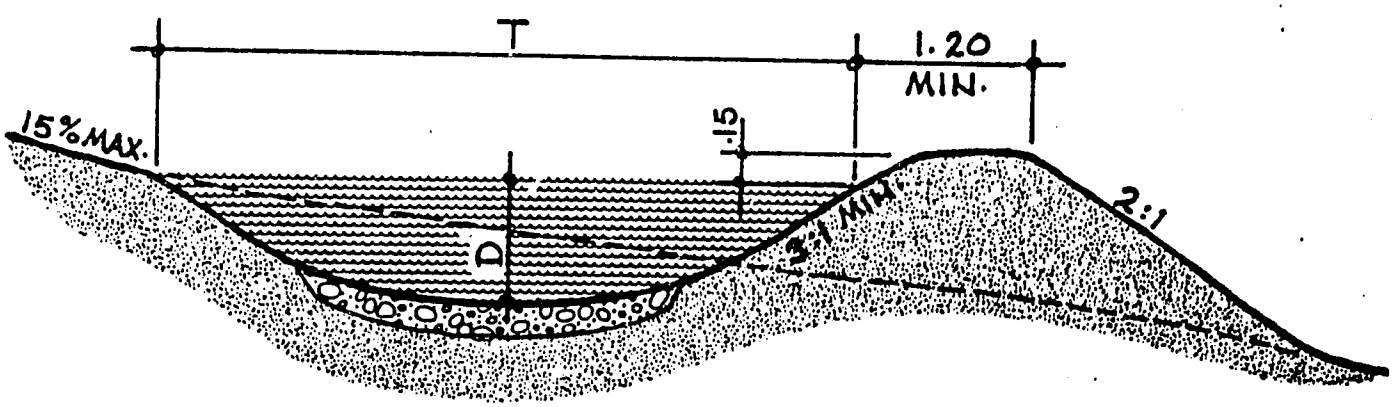
The diversions can be used where:

- Rapid overland flow has the potential for damaging property, causing erosion, contributing to stream pollution, flooding, or interfering with or preventing the establishment of vegetation on lower slope areas;
- There is possibility of damaging cut or fill slopes or steeply sloping terrain;
- The length of slope needs to be reduced so that soil loss will be minimized;
- Where active gullies or other erodible areas exist, diversions are only applicable below stabilized or protected areas.

Avoid establishment on slopes greater than 15%. Diversions should be used with caution on soils subject to slippage. Diversions must have stable outlets. In addition, diversions require side slopes and channel bottoms be stabilized and maintained throughout their planned life. Permanent diversions are not applicable below high sediment-producing areas, unless land treatment practices or structural measures, designed to prevent the transport of sediment into the channels, are installed with or before the diversions.

DESIGN CRITERIA

Drainage Area:
40 hectares.



DIVERSION

8

Capacity:

Peak runoff values used in determining the capacity requirements should be based in the rational method (Q=CIA), or by another accepted method. In all cases, the design storm frequency should be chosen to provide protection which is compatible with the hazard or damage that would occur if the diversion should overtop, but in no case should the design be for less than a ten-year frequency. Channel dimensions may be determined by using the appropriate retardance factor, such as indicated in Appendix D, or by Manning's formula, using a suitable "n" value.

Velocities:

Table 1. Permissible Design Velocities For Diversions with Bare Channels.

Soil Texture	Permissible Design Velocity (ft./sec.)
sand, silt, sandy loam, and silty loam	1.5
silty clay loam, sandy clay loam	2.0
clay	2.5

Source: New Castle County, Delaware. Specifications Guide For Sediment & Erosion Control, June 1977.

Permissible design velocities for diversions with vegetated channels should be in accordance with the standards for grassed waterways or outlets.

Cross Section:

The channel may be parabolic, triangular, or trapezoidal and should be designed to have stable side slopes. In determining the cross section of temporary diversions, consideration should be given to soil type and frequency and type of equipment that is anticipated to be crossing the diverison. In no case should side slopes be steeper than 2:1. The ridge should have a minimum width of 1.20 m. at the design water elevation. Also, a minimum of 0.10 m. free board and reasonable settlement factor should be provided.

Grade:

Channel grade for diversions may be uniform or variable. The permissible velocity for the soil type and vegetative cover will determine maximum grade. Level diversions with blocked ends may be used, provided pipes of sufficient size and spacing are placed in the embankment to drain the channel following cessation of runoff.

Outlets:

Diversions are to have adequate outlets which will convey runoff without causing erosion. The following types of outlets are acceptable:

- Natural or constructed vegetated outlets capable of safely carrying the design discharge. The outlet should be established and well vegetated prior to construction of the diversion;
- Properly designed and constructed grade stabilization structures or storm sewers;
- Natural or constructed open channels which are stable and have adequate capacity and depth; and
- A stable area having a good sod cover or a woodland area with a deep erosion-resistant litter. When one of these two types of outlets is used, the outlet end of the diversion channel should be flared in a manner to spread the water over a wide area at a shallow depth.

CONSTRUCTION SPECIFICATIONS

- All trees, brush, stumps, and other obstructions should be removed and disposed of so as not to intefere with the proper functioning of diversion flows.
- The diversion should be excavated or shaped according to the line, grade, and cross section to meet established design criteria.
- Repaired areas should be compacted to prevent unequal settlement that may cause eventual damage to the diversion.
- All earth removed and not needed in construction should be spread or disposed of so that it will not interfere with the functioning of the diversion.
- Stabilization.

  --Vegetative Protection
  - Follow country-specific standards and specifications for disturbed area stabilization in terms of time of seeding, sprigging or sodding, liming and fertilizing, and site and seedbed preparation.
  - Mulching should be a requirement for all seeded or sprigged channels and should be performed according to standards and specifications for disturbed area stabilization (with mulching only).
  - Temporary protection during establishment should be provided when conditions permit the use of temporary diversions or other means to dispose of water.

--Mechanical-Vegetative Protection

- Stone center diversions should be constructed as shown in waterways or outlets (Figure 11) and should be stabilized with riprap according to the standards and specifications for riprap.

--Mechanical Protection

- Paving shall be performed according to country-specific construction standards and specifications.

MAINTENANCE CONSIDERATIONS

- Constant inspection of the channel or dike stability.
- Establishment of vegetation in the diversion channel and on the dike.
- Removal of sediment deposits in the channel.
- Use of small and appropriate maintenance equipment (small grader, small tractor, trailer, etc.).
- Annual care of vegetation--scheduled yearly mowing and cleaning program.

PERIMETER DIKE

DESCRIPTION

This is a temporary ridge of soil, machine-compacted, constructed along the perimeter of a disturbed area and with a life expectancy of no more than one year (Figure 9).

FUNCTION

To divert the storm runoff away from undisturbed areas and discharge it to an on-site sediment trap device or stabilized area.

APPLICATION

Usually located at the perimeter of a site or denuded area to contain and divert sediment-laden storm runoff from entering areas where sheet or concentrated flows cause serious erosion and sedimentation problems. Since it is a temporary control device, the dike is left in place until the site is permanently stabilized.

DESIGN CRITERIA

There are no design criteria for this type of device, but there are some standards that can be followed:

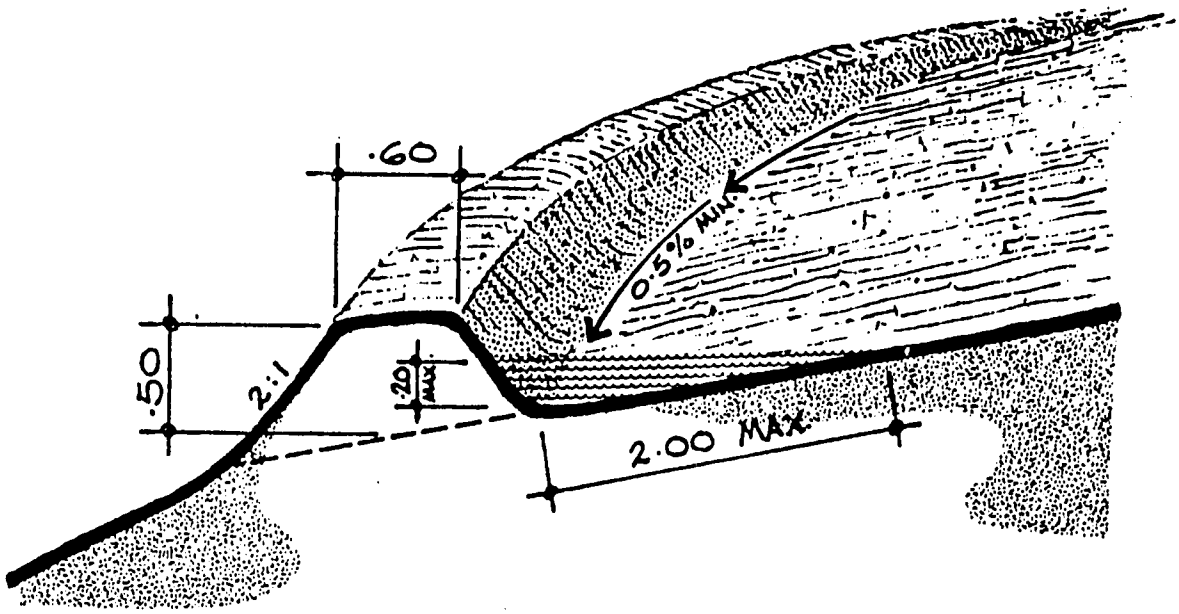
Drainage Area:
Not to exceed 2.0 hectares.

Top Width:
Not less than 0.60 m.

Height:
Not less than 0.50 m. after compaction, unless otherwise noted on the plans. This height is measured from the natural ground at the upslope toe to the crown of the dike.

Side Slope:
2:1 or flatter.

Grade:
The minimum gradient of the dike must be 0.05% in order to maintain positive drainage to the outlet. When the slope behind the dike is more than 2.0%, channel stabilization may be required such as gravel, vegetation, or plastic mat. On steep slopes, the location of the perimeter dike across the slope can be used to control runoff velocities by reducing the size of the collection area. The water surface in the channel behind the dike should not be more than .20 m. deep.



PERIMETER DIKE

9

Capacity:
Should not exceed 4.0 cfs.

Velocity:
Should not exceed 1.0 m./sec.

Outlet:
Sediment-laden runoff must be discharged directly into a sediment-trapping facility, such as a sediment basin, sediment trap, gravel outlet, or to a disposal area prepared to receive this otherwise unwanted material.

This dike is generally used as an elongated sediment dam with a trap device or outlet pipe provided, and with enough height to guarantee a certain level of detention of ponding.

CONSTRUCTION SPECIFICATIONS

- All perimeter dikes must be machine-compacted (light equipment).
- All perimeter dikes must have positive grade drainage to a sediment-trapping facility.
- Periodic inspections and required maintenance must be provided.
- Dikes must be placed far enough away from disturbed areas (30 m. minimum) to permit machine regrading and clean-out.
- Perimeter dikes must be seeded and mulched immediately following construction.
- Provide a stake (wooden, iron, etc.) with a mark dented on it showing the maximum depth of the dike at ponding area.

MAINTENANCE CONSIDERATIONS

- Perimeter dikes should be inspected frequently and maintenance rendered when needed.
- Repairs have to be carried out immediately when damage is noticed.
- Careful compaction is required on top of the dike by light equipment (DC-4 tractor).
- Eliminate sizeable stones from fill material, especially in areas where ponding conditions may occur.
- Always check for positive drainage, low velocities, etc., to guarantee the efficiency of the device.
- A fixed stake should be left in the berm so as to ensure the correct height of the dike when it has to be repaired.

- Keep perimeter dikes away from wooded areas or hanging branches te ensure proper maintenance.

STRAW BALE OR HAY BARRIER

DESCRIPTION

Straw bale or hay barriers (Figure 10) are temporary diversion berms constructed of baled straw or hay. These are placed at the toe of a slope to intercept and detain sediment by retaining and filtering surface runoff.

FUNCTION

To intercept and detain small amounts of sediment from unprotected areas of 0.20 hectares or less.

APPLICATION

Located at the top of slopes, in front of storm drain inlets, across swales and ditches, along property lines and in other temporary situations. Uses include areas where:

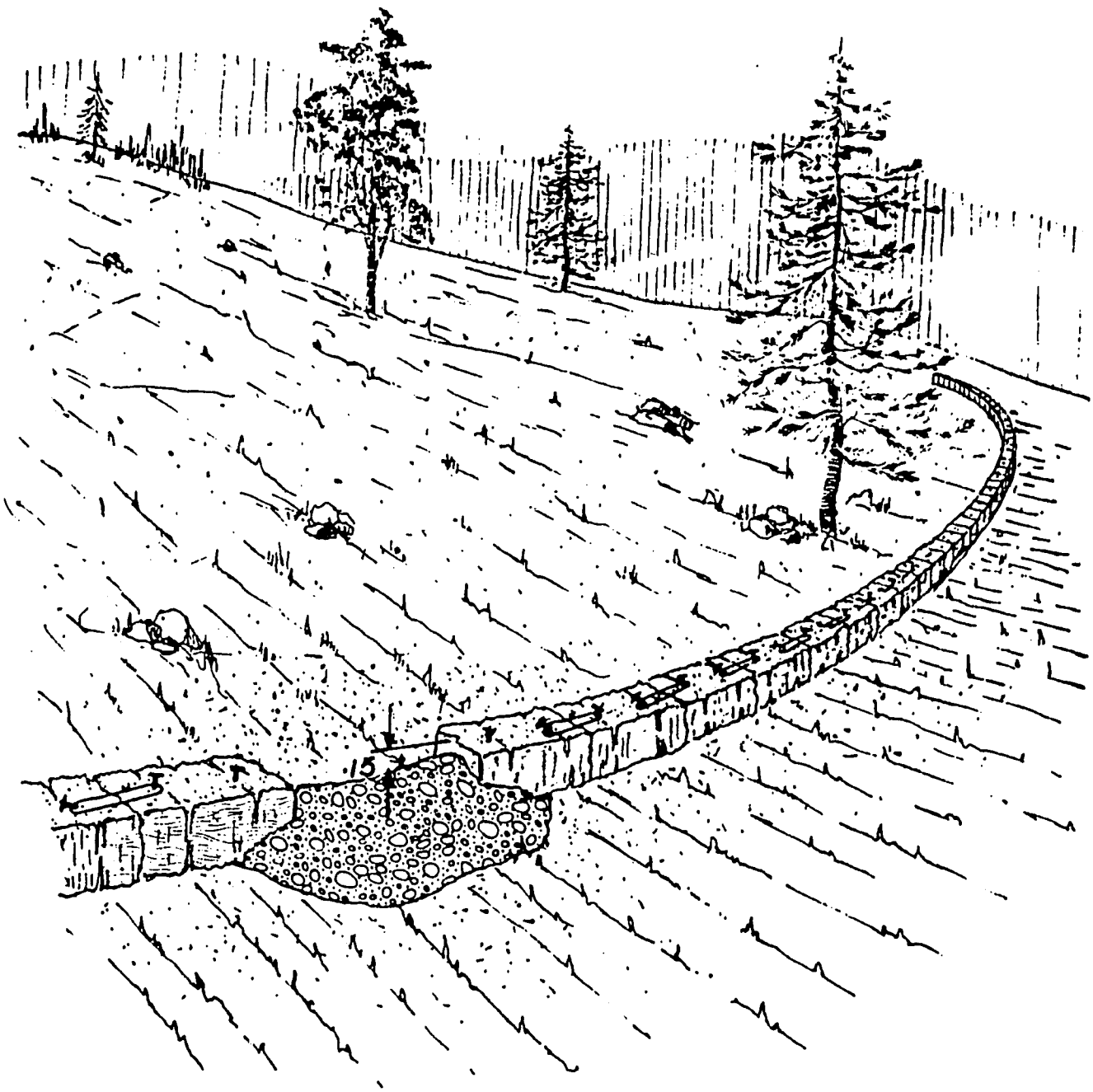
- Contributing area is approximately .20 hectares or less;
- No concentration of water in the channel above the barrier;
- Sheet or rill erosion would normally occur;
- Length of slope above the barrier is less than 30 m.;
- Straw bales may be combined with gravel outlets to filter and remove sediment;
- Not to be used on high sediment-producing areas, above "high risk" areas where water concentrates or where there is a possibility of washout.

DESIGN CRITERIA

No design is required. The following general criteria will be used as guidelines:

Drainage Area:
0.2 hectares or less.

Top Width:
0.6 m.. minimum.



STRAW BALE OR HAY BARRIER

10

Height:

0.5 m., minimum. With diagonal reinforcement, .90 m.

Placement:

When more than one row, place two bales at bottom in .10 m. trench and place behind a wire fence, 12 or 14 gauge, well secured with diagonal bracings or stakes, if necessary.

Grade:

No more than 2%.

Outlet:

Discharge to a diversion, gravel outlet, or sediment trap.

CONSTRUCTION SPECIFICATIONS

- Barriers should be placed parallel to contours.
- Bales should be placed in a row with ends tightly abutting the adjacent bales.
- Each bale should be embedded in the soil a minimum of .10 m.
- To avoid piping where runoff flows between bales, straw bales must be placed in shallow trenches with their ends tightly abutting.
- Bales should be securely anchored in place by two stakes. They should be driven to a depth of .45 m.
- Inspection should be frequent and repair or replacement should be made promptly as needed.
- Bales should be removed when they have served their usefulness so as not to block or impede storm flow or drainage.

MAINTENANCE CONSIDERATIONS

- Inspect after each storm for clean out.
- Correct alignment of bales.
- Check filtration capabilities.
- If little filtration is occurring, eliminate two bales and replace them with a stone filter outlet.
- Leave 1.5 m. space between the bales and the toe of the fill for maintenance and clean-out.
- When more than three vertical bales are used, watch the supporting bracing and staking, especially after the filtering life of the bale is ended.

WATERWAY OR OUTLET

DESCRIPTION

A waterway or outlet (Figure 11) is a natural or constructed watercourse shaped and/or graded and stabilized as needed for the safe disposal of storm runoff. The channel in waterways is normally wide and shallow and conveys the runoff over sloping terrain.

FUNCTION

The purpose of these structures is to dispose safely of concentrated runoff flows without causing damage by erosion or flooding.

APPLICATION

Waterways are used where added capacity and/or stabilization is required to control high concentrations of runoff. They may be used alone or in combination with other practices: outlets for diversions and terraces; as outlets for subsurface and surface drainage systems on sloping land; to dispose of water collected by road ditches or discharged through culverts; to rehabilitate natural swales carrying concentrations of runoffs.

DESIGN CRITERIA

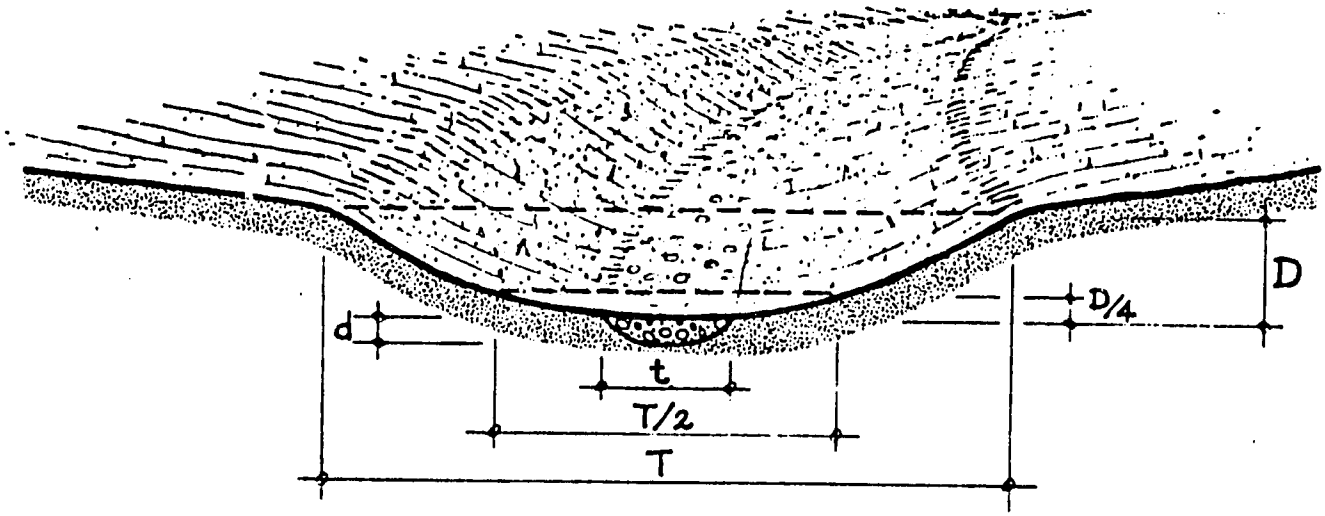
The following design criteria must be followed:

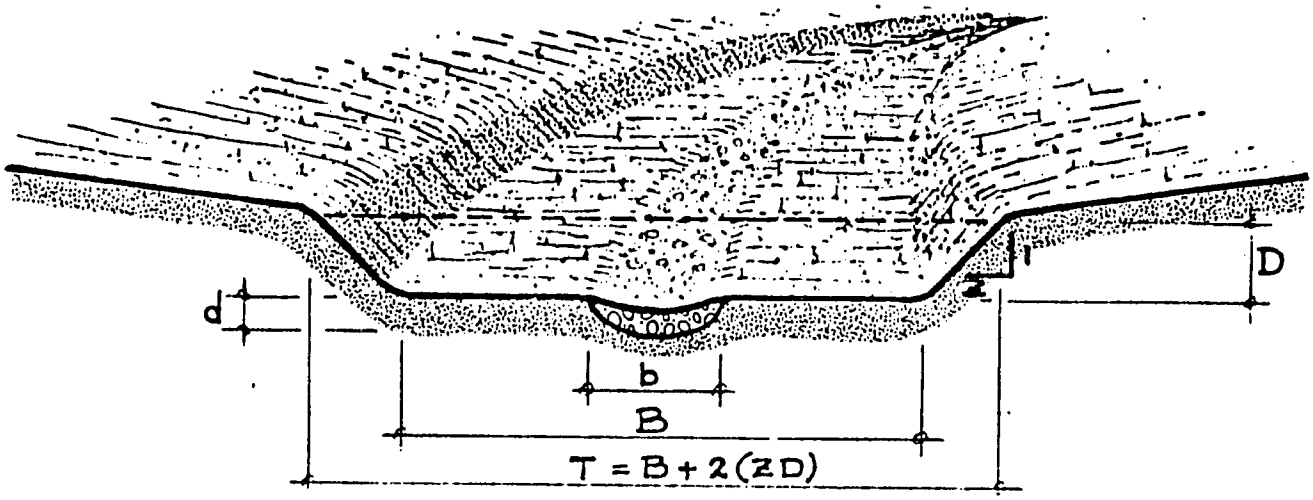
Drainage Area:

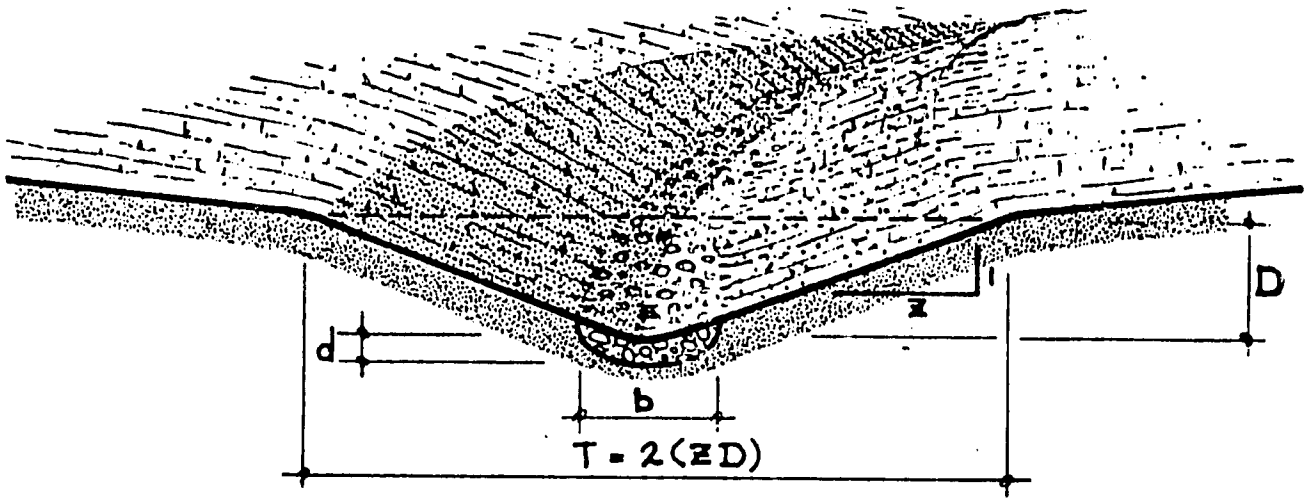
A maximum of 20 hectares is recommended.

Capacity:

The minimum capacity should be that required to confine the peak rate of runoff from a storm of ten-year frequency. Peak runoff values should be computed by the method of the rational formula or other commonly known methods. Where there is a base flow, it should be handled by a stone center, subsurface drain or other suitable means since constant wetness may retard or prevent growth of vegetative cover. The cross-sectional area of the stone center or subsurface drain should be determined by using a flow rate of 0.1 cfs/acre.







WATERWAY OR OUTLET

11

Velocity:

The permissible velocities of flow for the conditions of stabilization stated below should be as follows:

Table 2. Design Velocities for Varied Grass Conditions in Waterways.

Quality of Vegetative Cover	Range of Channel Gradient (%)	Permissible Velocity (ft./sec.)
good grasses	0-5	5-6
	5-10	4-5
	over 10	3-4
medium grasses	0-5	4-5
	5-10	3-4
	over 10	2.5-3
poor grasses	0-5	2.5 maximum
mechanical-vegetative (Stone Center)	all	as determined by the stone site from riprap specifications
mechanical paved	all	any

Cross Section:

The designed water surface elevation of a waterway receiving water from diversion or other tributary channels should be equal to or less than the design water surface elevation in the diversion or other tributary channels at their junctions when both are flowing at their design hydraulic gradient. The cross section for a trapezoidal or triangular channel should be designed based on the Manning formula. A free board of 0.3 d must be provided. For the design of trapezoidal, triangular or parabolic channels with grass or stone centers, see Figure 11.

The top width of parabolic waterways should not exceed 9 m., and the bottom width of a trapezoidal waterway should not exceed 3.6 m., unless multiple or divided waterways, stone centers, or other means are provided to control meandering of low flows.

Outlets:

Each waterway should have a stable outlet. The outlet may be another waterway, a stabilized channel, or a grade stabilization structure. In all cases, the outlet must discharge in such a manner as not to cause erosion. Outlets should be constructed and stabilized prior to the operation of the waterway. In many cases it is better to reduce its capacity by dividing the runoff between two or more smaller outlets.

CONSTRUCTION SPECIFICATIONS

- All trees, brush, stumps, and other obstructions should be removed and disposed of, so as not to block or reduce the flow capacity of the waterway.

- The waterway or outlet should be excavated or shaped to line, grade and cross section as required to meet the criteria specified herein, free of bank projections or other irregularities which will impede normal flow.

- Filled areas should be compacted as needed to prevent uneven settlement that would cause damage in the completed waterway.

- All earth removed and not needed in construction should be spread or disposed of so that it will not interfere with the functioning of the waterway.

- Stabilization.

  --Vegetative Protection

  - Country-specific vegetative standards should be followed for time of seeding, sprigging or sodding, liming and fertilizing and site and seedbed preparation.

  - Mulching should be a requirement for all seeded or sprigged channels and should be performed according to standards and specifications for disturbed area stabilization (with mulching only). This type of protection will take a maximum of 3.5 ft./sec. velocities.

  - Temporary protection during establishment of grass cover should be provided when conditions permit, through temporary diversions or other means to dispose of water.

  --Mechanical-Vegetative Protection

  - Stone centers should be constructed as shown in Figure 11.

  - Waterways should be stabilized with riprap according to standards and specifications for riprap. This type of protection will take velocities above 3.5 ft./sec. to 6.5 ft./sec.

  - Mechanical protection. Paving should be performed according to local standards and specifications. This type of protection will take velocities above 6.5 ft./sec.

MAINTENANCE CONSIDERATIONS

- Continuous inspections.
- Maintain vegetative cover by mowing, spraying, fertilizing and performing other maintenance work as needed (cleaning, re-seeding, reshaping the channel, etc.).
- No vehicular traffic should be permitted in the waterway.
- Livestock shall be excluded during rainy season.
- Periodic watering of newly seeded channels should be provided if seeding occurs during the dry season. Preferably, seeding should be done at the beginning of or just before the start of the rainy season.

B. GRADE STABILIZATION STRUCTURES

Straight Drop Spillway and Drop Box Culvert 57

Chute or Flume 61

Down Drainage Structure 66

Pipe Slope Drain 69

STRAIGHT DROP SPILLWAY AND DROP BOX CULVERT

DESCRIPTION

These devices are used to dissipate the energy of flowing water so that waterway grades and velocities may be held within non-erosive limits. The devices may consist of straight drop spillways, drop box culverts (Figures 12 and 13) or similar disposal structures.

FUNCTION

Structures are used to reduce or prevent excessive erosion by reduction of velocities in the watercourse or by providing channel linings or structures that can withstand the higher velocities.

APPLICATION

These measures apply to sites where:

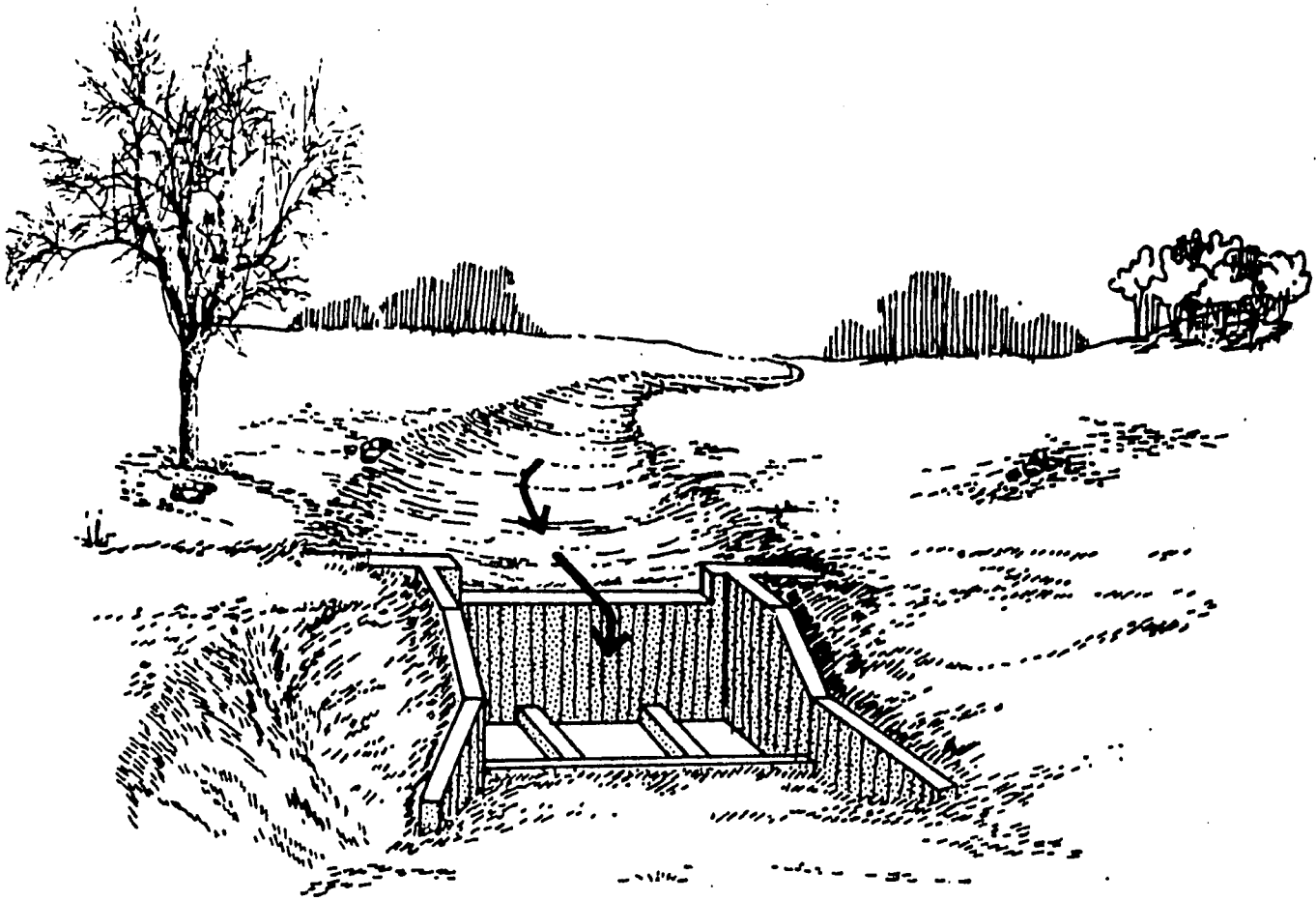
- the capabilities of earth and vegetative measures are exceeded in the safe handling of water at permissible velocities;
- water is to be conveyed from one level to a lower level;
- excessive grades are encountered;
- it is necessary to stabilize headcutting of water courses; and
- a change in the direction of water flow is desired.

DESIGN CRITERIA

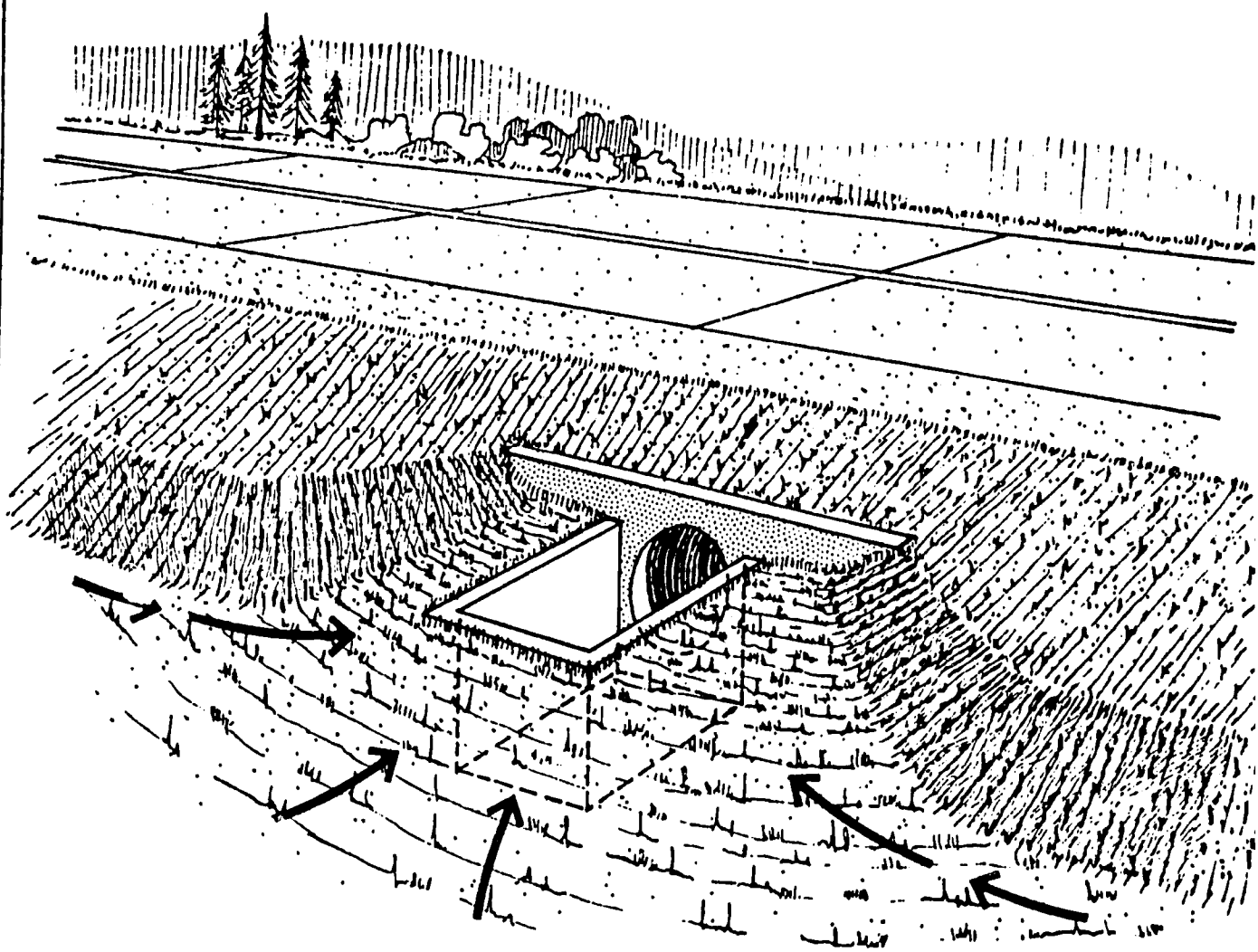
These measures should generally be planned and installed along with or as part of other measures in an overall water disposal system. Formal design is usually required. Sufficient surveys of soils, subsurface, geology, and hydrologic and hydraulic information should be obtained to design properly the structure.

When designing structures, consideration should be given to:

- Determining a realistic service life.
- Assessing the danger of structural failure during construction, when in service, and at the end of the design period.
- Reducing any hazard presented by structures when the service life is exceeded.



STRAIGHT DROP SPILLWAY



DROP BOX CULVERT

- Hydraulic capacity should be based on the latest hydrologic data for the area involved. Future impervious areas such as building roofs and paved areas should be estimated. Spillway capacity should be adequate to pass, without damage to the structure, the design outflow. The design storm should be commensurate with the purpose of the structure and the probable damages associated with failure of the structure.

- Structures should be constructed of materials that remain serviceable throughout their life unless easily replaced and not critical to structural safety. The danger of failure should be considered during their service life and afterward.

- Adequate protection should be provided to prevent erosion and scour of the structures, especially at outlets.

- Construction drawings should show topography, elevations, lines and grades of existing and final watercourses, survey data, soils, and subsurface information. Specifications and maintenance requirements should be part of the plans.

- Construction scheduling should be an integral part of the plans. It should establish a sequence of construction operations including the installation of temporary measures that will facilitate the control of erosion and sediment.

CHUTE OR FLUME

DESCRIPTION

A temporary or permanent channel (Figures 14 and 15) constructed of bituminous concrete, Portland Cement concrete, or comparable non-erodible material used to channel surface runoff from the top to the bottom of a slope

FUNCTION

To convey concentrated runoff safely down slopes without causing erosion.

APPLICATION

Where concentrated flow of surface runoff over slopes would otherwise cause excessive erosion. To serve as spillway for flood prevention, water conservation and sediment collecting structures.

DESIGN CRITERIA

The assistance of an engineer is always required.

Size:

The chutes or flumes are divided into groups of two sizes as follows:

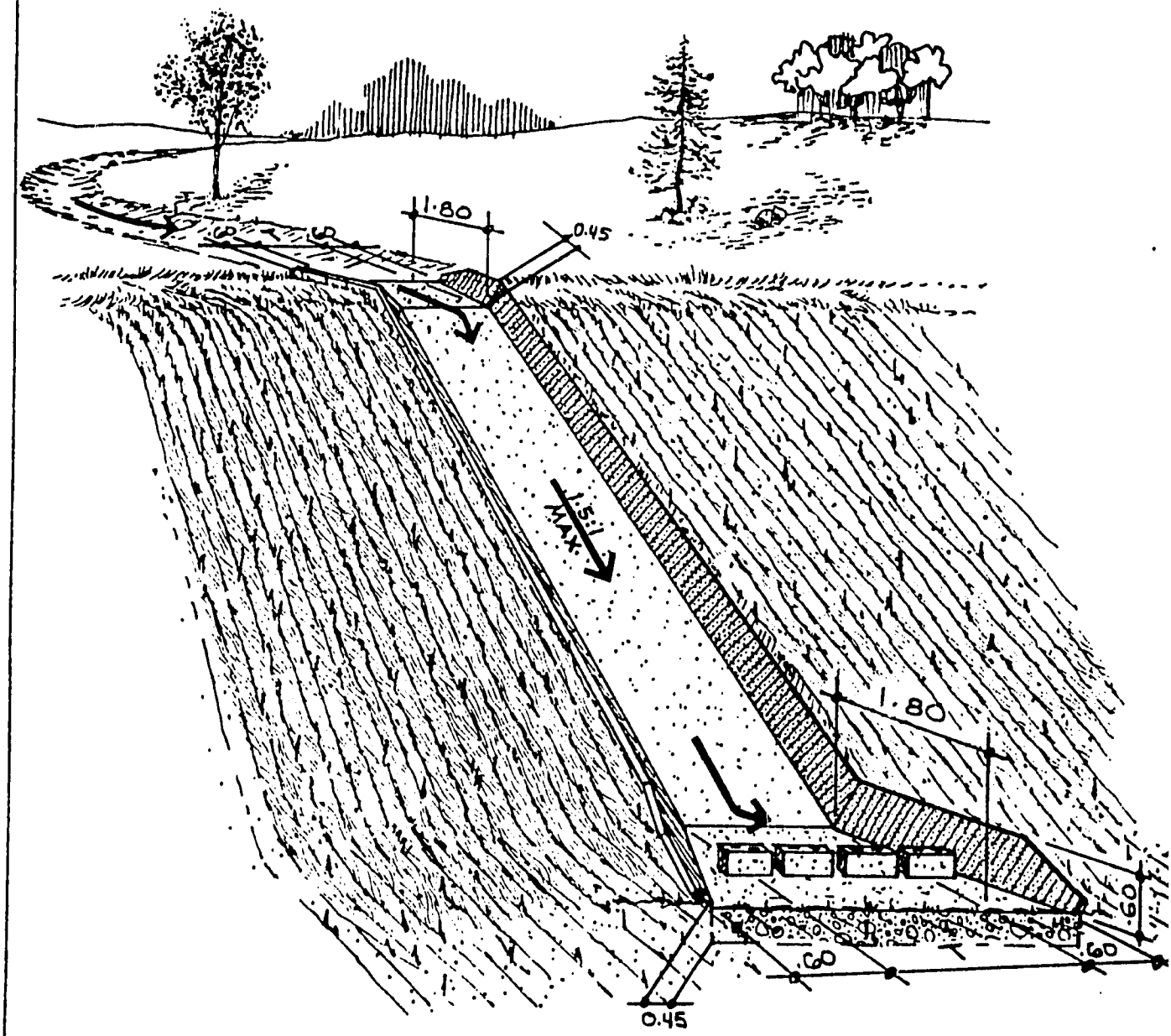
Size Group A

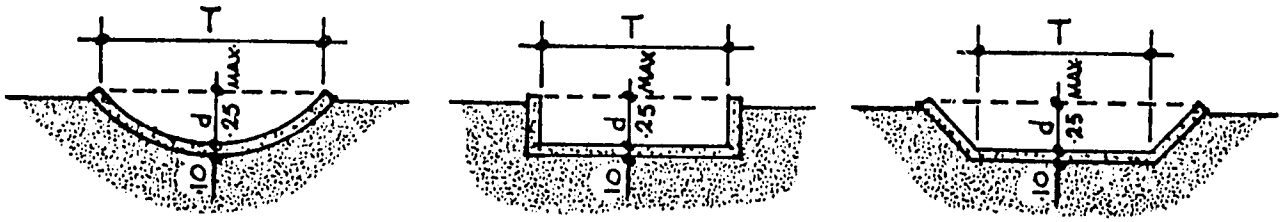
- The height of the dike at the entrance (H) equals 0.45 m.
- The depth of flow down the chute (d) equals 0.20 m.
- The length of the inlet and outlet sections equal 1.50 m.

Size Group B

- The height of the dike at the entrance (H) equals .60 m.
- The depth of flow down the chute (d) equals .25 m.
- The length of the inlet and outlet sections 1.80 m.

Each size group has various bottom widths and allowable drainage areas as shown on the following table:





PAVED CONCRETE CHUTE OR FLUME

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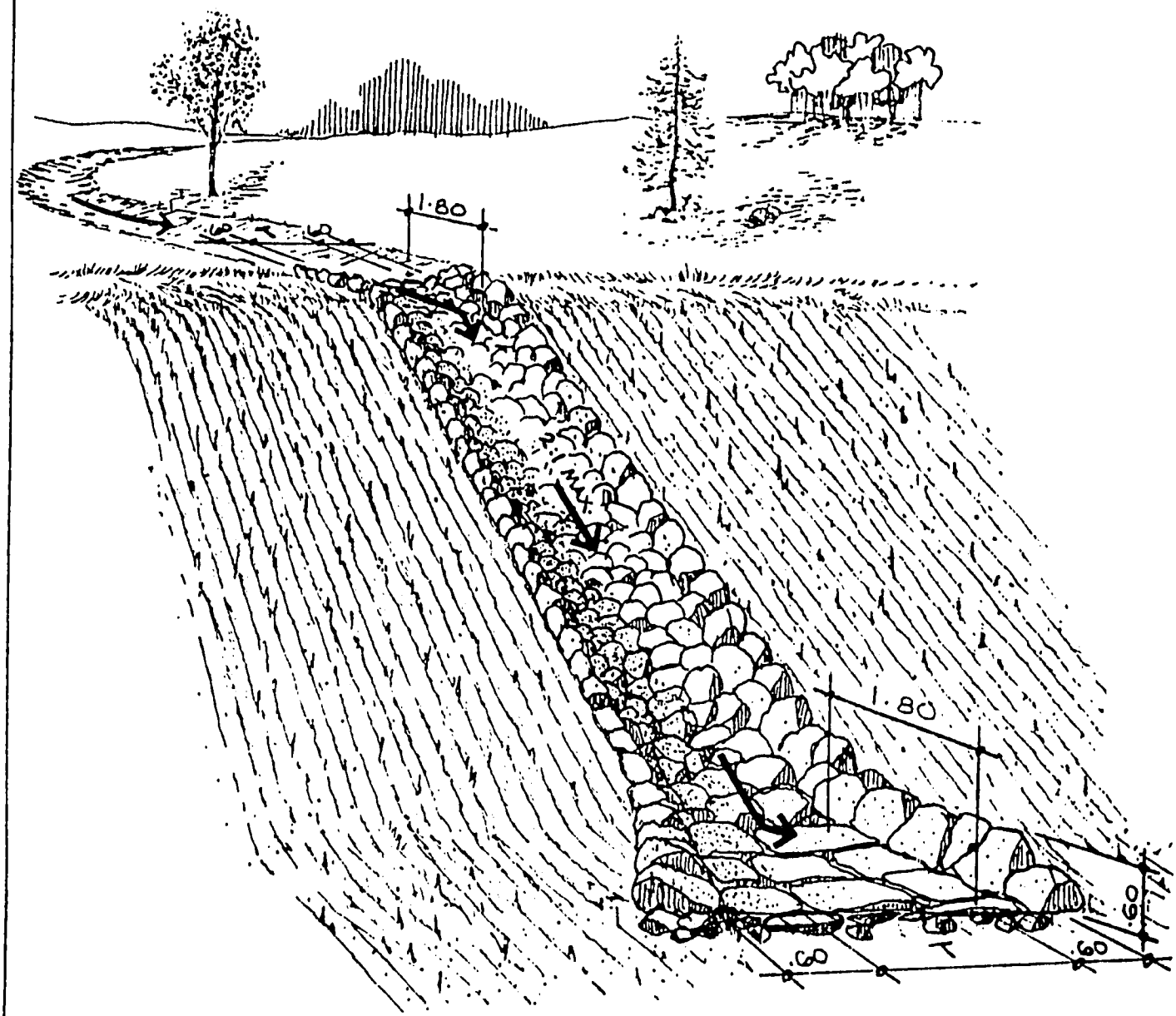

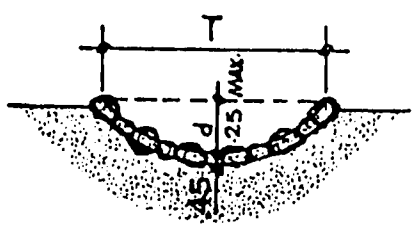

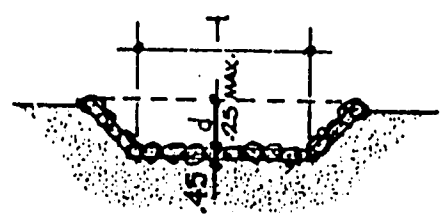

STONE LINED CHUTE OR FLUME

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Table 3. Design Criteria for Deteriming Bottom Widths of Chutes or Flumes *

Size 1/	Bottom Width, (T) (m)	Maximum Drainage Area (hectares)	Size 1/	Bottom Width, (T) (m.)	Maximum Drainage Area (hectares)
A-2	.60	2.00	B-4	1.20	5.70
A-4	1.20	3.25	B-6	1.80	8.00
A-6	1.80	4.50	B-8	2.45	10.00
A-8	2.45	5.70	B-10	3.00	12.50
A-10	3.00	7.30	B-12	3.70	14.60

1/ The size is designated with a letter and a number, such as A-6, which means a chute or flume in Size Group A with a 1.80 m. bottom width.

If a minimum of 75% of the drainage area will have a good grass or woodland cover throughout the life of the structure, the drainage areas listed above may be increased by 50%. If a minimum of 75% of the drainage area will have a good mulch cover throughout the life of the structure, the drainage areas listed above may be increased by 25%.

CONSTRUCTION SPECIFICATIONS

- The structure should be placed on undisturbed soil or on well-compacted fill.
- The cut or fill slope should not be steeper than 1.5 horizontal to 1 vertical (1.5:1) and should not be flatter than 20:1.
- The top of the earth dikes should not be lower at any point than the top of the lining at the entrance of the structure.
- The lining at the entrance to the structure should extend to the top of the earth dikes on either side.
- The lining should be placed beginning at the lower end and proceeding up the slope to the upper end. The lining should be well compacted and free of voids. The lining surface should be reasonably smooth.
- The entrance floor at the upper end of the structure should have a slope toward the outlet of 2.0 to 4.0%.
- The cutoff walls (footers) at the entrance and at the end of the discharge aprons should be continuous with the lining (0.45 m.).
- An energy dissipator should be designed for the bottom of the chute to prevent erosion at the outlet.

* Source: Fairfax County, Virginia. Public Facilities Manual, Volume III, 1977

MAINTENANCE CONSIDERATIONS

- Periodic inspections are required due to potential damage of high flow velocities and the transportation of debris into the channels. This structure has a tendency to be damaged.
- Check for high intensity storm rainfall.
- Repairs have to be done immediately following any damage. If they have to be done during the rainy season, divert runoff to another temporary outlet prior to start of the required work.
- Compaction has to be done properly.
- Check the diversion berms leading to the chute for stability.
- There is considerable danger of undermining by rodents. In poorly drained locations seepage may weaken the foundation. It must be placed on compacted fill or undisturbed soil in an abutment.

DOWN DRAINAGE STRUCTURE

DESCRIPTION

A flexible conduit of heavy duty fabric or other material (Figure 16).

FUNCTION

To conduct temporarily storm runoff safely from one elevation to another without causing erosion of slope until permanent slope stabilization occurs.

APPLICATION

Flexible down drains are used on slopes where concentrated storm runoff will cause erosion damages. These structures are removed once the permanent water disposal system is installed.

DESIGN CRITERIA

Formal design is generally not required.

Drainage Area:
Less than 2 hectares.

Placement:
On undisturbed soil or well-compacted fill.

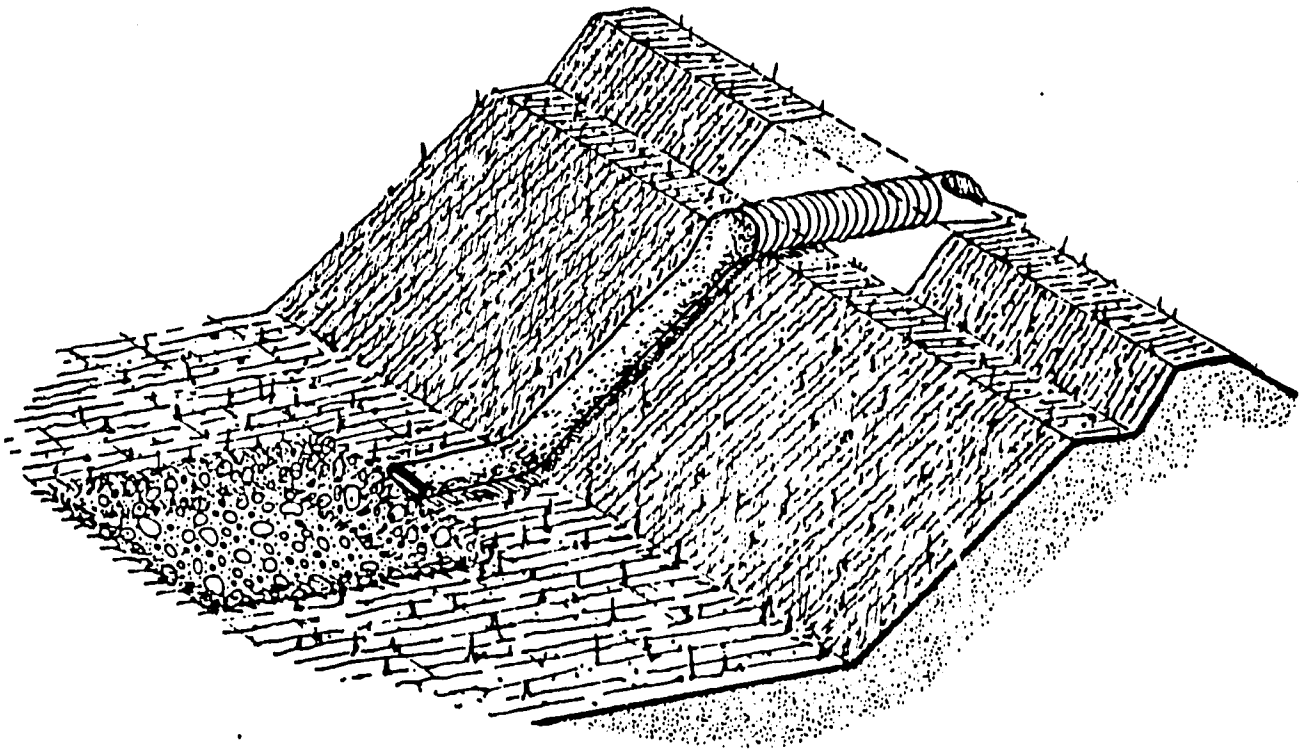
Diameter:
Sufficient capacity required to convey maximum runoff expected during the life of the drain. See Table 4 below for pipe/tubing size for down drainage structures.

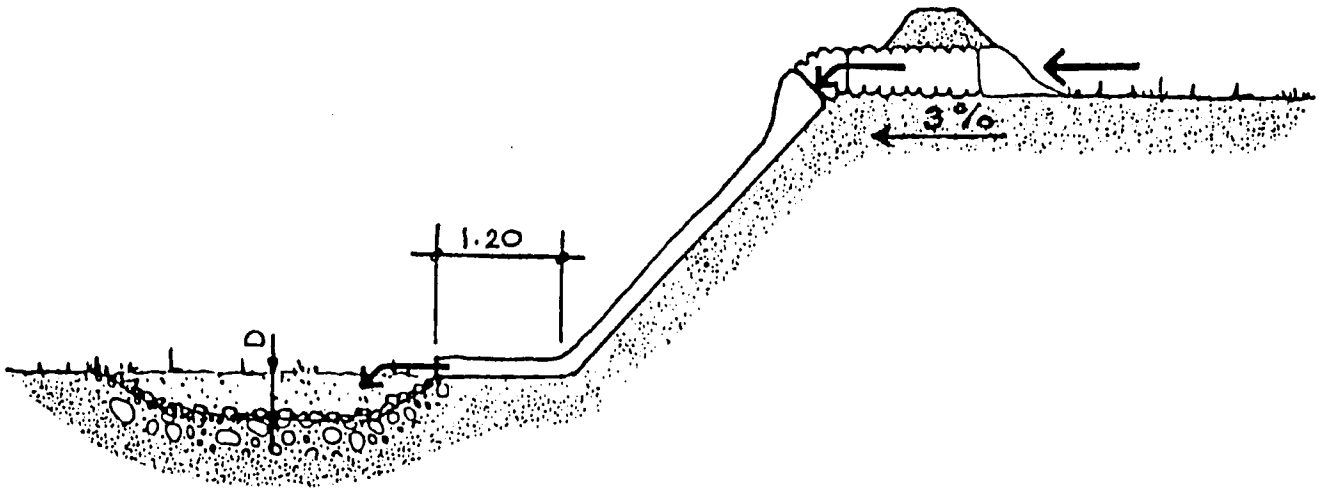
Table 4. Sizing of Pipe/Tubing for Down Drainage Structures

Maximum Drainage Area (hectares)	Pipe/tubing diameter, D (inches)
.2	12
.6	18
1.0	21
1.4	24
2.0	30

Source: U.S. Environmental Protection Agency. Erosion and Sediment Control, Volume II, October 1976.

End Sections:
Standard metal. Entrance section should slope toward outlet at rate of at least ½" per foot. Selected soil should be placed and thoroughly compacted around entrance section to insure against piping failure along end section and extension collar.





FLEXIBLE DOWN DRAINAGE STRUCTURE

16

Extension Collars:
.30-m.-long, corrugated metal pipe. Avoid use of Helical pipe.

Securing Straps:
Fabric, metal, etc., secure in at least one corrugation of extension collar.

Anchors:
Metal "T" pins anchored in soil through grommets attached to flexible down drain, 6 m. centers.

Outlet:
To stabilized area where erosion will not be a problem.

MAINTENANCE CONSIDERATIONS

- Inlet section should be inspected often for indications of piping along metal sections.
- Anchors should be re-secured as necessary.
- Avoid placement of any material on collapsed down drain.
- Inspect for clogging or damage after each storm.

PIPE SLOPE DRAIN

DESCRIPTION

A pipe slope drain (Figure 17) consists of a rigid pipe together with a prefabricated end section, and it is temporarily placed to extend from the top to the bottom of the slope.

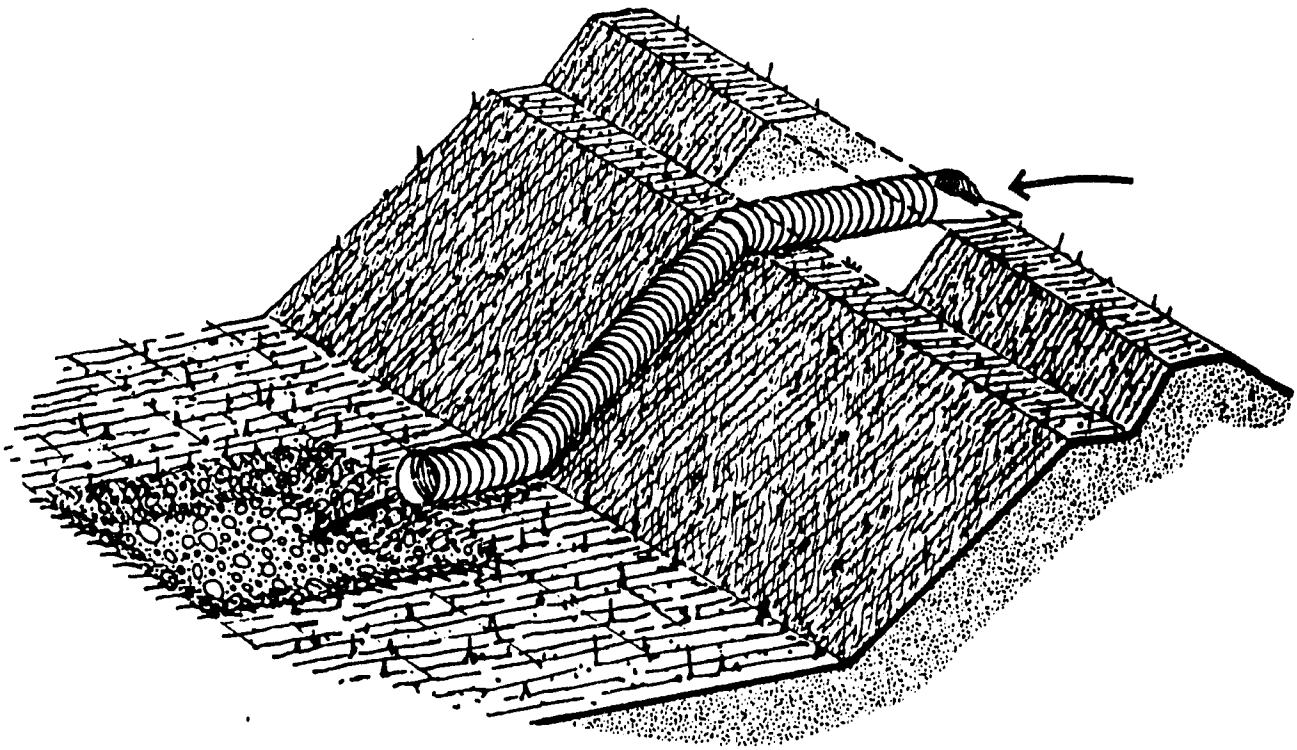
FUNCTION, APPLICAT ON AND DESIGN CRITERIA

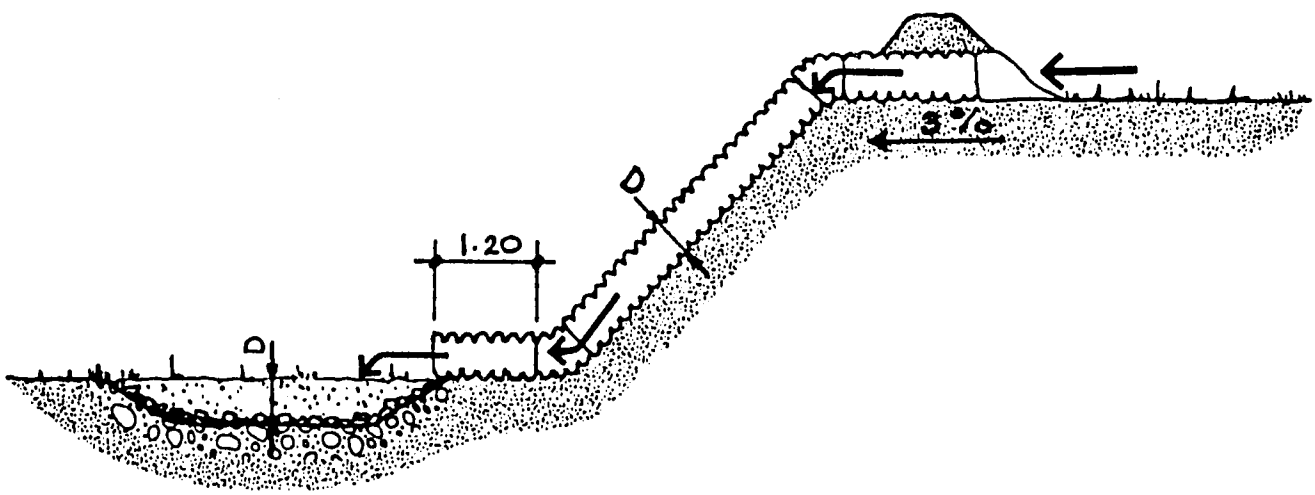
Same as those mentioned for down drainage structures.

Pipe slope drain should discharge into a sediment trapping device, a stilling basin, or a stabilized watercourse.

CONSTRUCTION SPECIFICATIONS

- The inlet pipe should have a slope of 3% or steeper.
- The top of the earth dike over the inlet pipe and those dikes carrying water to the pipe should be at least .30 m. higher at all points than the top of the inlet pipe.
- The pipe should be corrugated metal pipe with watertight connecting bands.
- A riprap apron should be provided at the outlet. This should consist of 6-inch-diameter stone placed as shown in Figure 17.
- The soil around and under the inlet pipe and entrance sections should be hand tamped in 10 cm. lifts to the top of the earth dike.
- Follow-up inspection and any needed maintenance should be performed after each storm.





RIGID PIPE SLOPE DRAIN

17

C. LAND GRADING PRACTICES

General Land Grading 72

Terraces and Benches 75

Soil Loosening 78

GENERAL LAND GRADING

DESCRIPTION

Reshaping the ground surface by grading to plan as determined by engineering survey and layout. For example, grading of roadside ditches (Figure 18) or terraces and benches (Figure 19).

FUNCTION

The soil surface can be graded and shaped to accomplish the following purposes:

- provide sites more suitable for buildings, facilities, and other land uses;
- improve surface drainage;
- reduce and detain runoff; and
- control erosion and sedimentation processes.

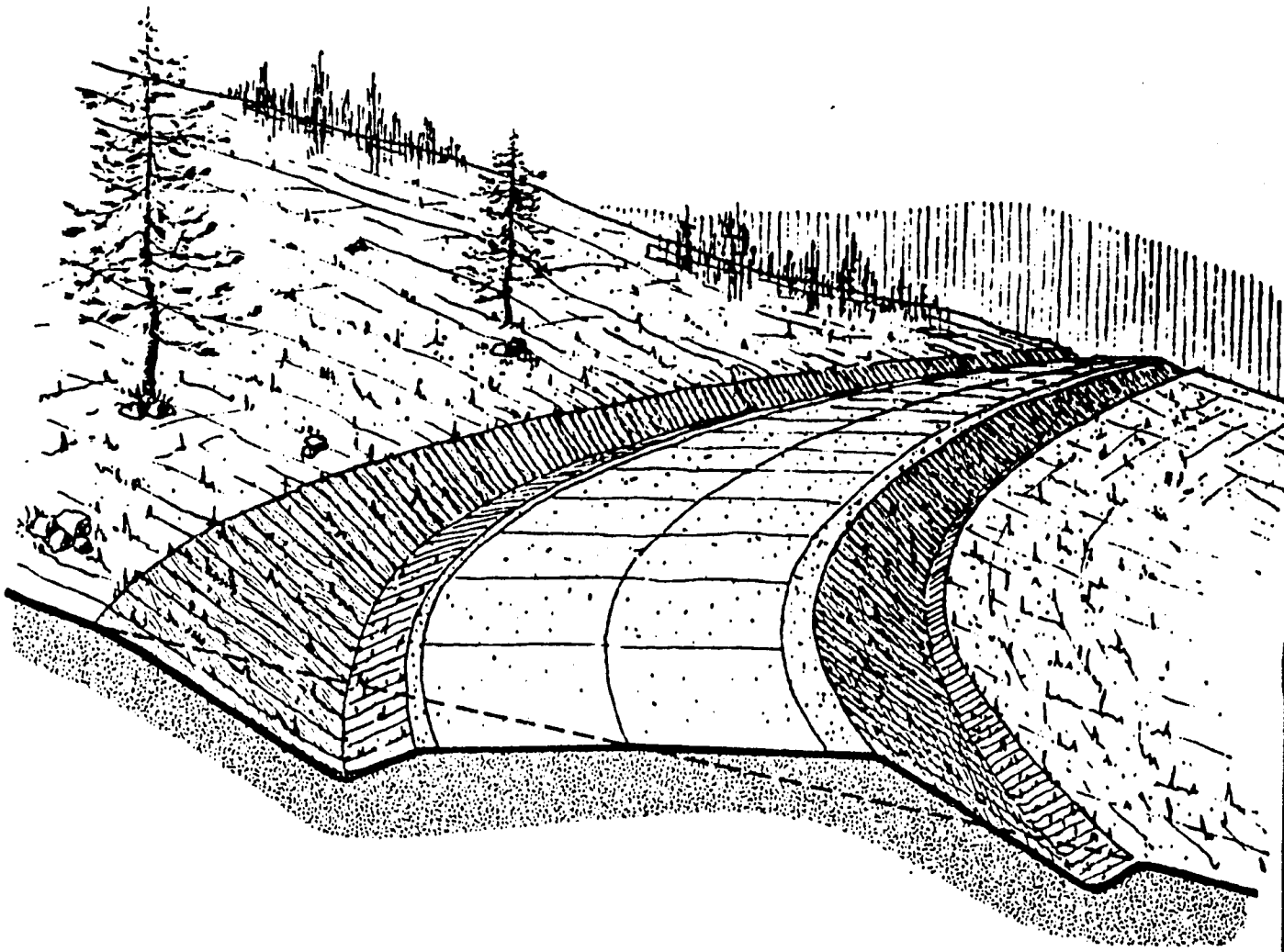
APPLICATION

This practice is applicable where grading to planned elevations is practical for the purposes enumerated above. Cutting slope gradient should be based on the erodibility of the surface soil as well as stability against landslides.

DESIGN CRITERIA

The following requirements should be incorporated into the grading plan:

- The grading plan should be based upon adequate surveys and investigations.
- The plan should show the locations, slopes, cuts, fills, and finish elevations of the surfaces to be graded together with auxiliary practices for erosion contorl, slope stabilization, safe disposal of runoff water, and drainage facilities such as waterways, lined ditches, diversions, grade stabilization structures, and surface and subsurface drains.
- Where feasibile, cut and fill slopes should not be steeper than 2:1.
- Where feasible, benches or diversions should be provided on slopes steeper than 3:1 when vertical height of slope exceeds 4.5 m.



GRADING OF ROADSIDE DITCH

- Provisions should be made to conduct surface runoff safely to storm drains or to stable watercourses to insure that surface runoff will not damage slopes or other grades areas.

- Subsurface drainage should be provided where necessary to intercept seepage that would adversely affect slope stability or create excessively wet site conditions.

- Steep slopes should not be created so close to property lines as to endanger adjoining properties or structures without adequate protection against erosion, slippage, settlement, subsidence, or other related damages.

- Fills must be made of approved clean material from cut areas, borrow pits, or other acceptable sources. Fill should be placed in lifts not to exceed 30 cm. and compacted at density specified on the grading plan.

TERRACES AND BENCHES

DESCRIPTION

A graded, relatively flat section of varying width constructed by cut or fill along a contour, having a vertical drop to the slope below and a horizontal slope to the rear (Figure 19).

FUNCTION

Commonly used as means to reduce the overall slope angle, thus reducing the risks of slope instability or costly re-enforcement measures, to catch debris and prevent damage to property at lower elevations, and to avoid the concentration of runoff at the toe of the slope.

APPLICATION

The use of terraces is appropriate to terrain that is typified as moderately to steeply sloping (20% or greater) and intended to enable use of these areas for a variety of purposes. Benching is a grading practice designed to stabilize steep slopes against landslides and to prevent severe soil erosion. Thus, benches are protective devices used to insure the safety of activities occurring at lower elevations and are not built upon.

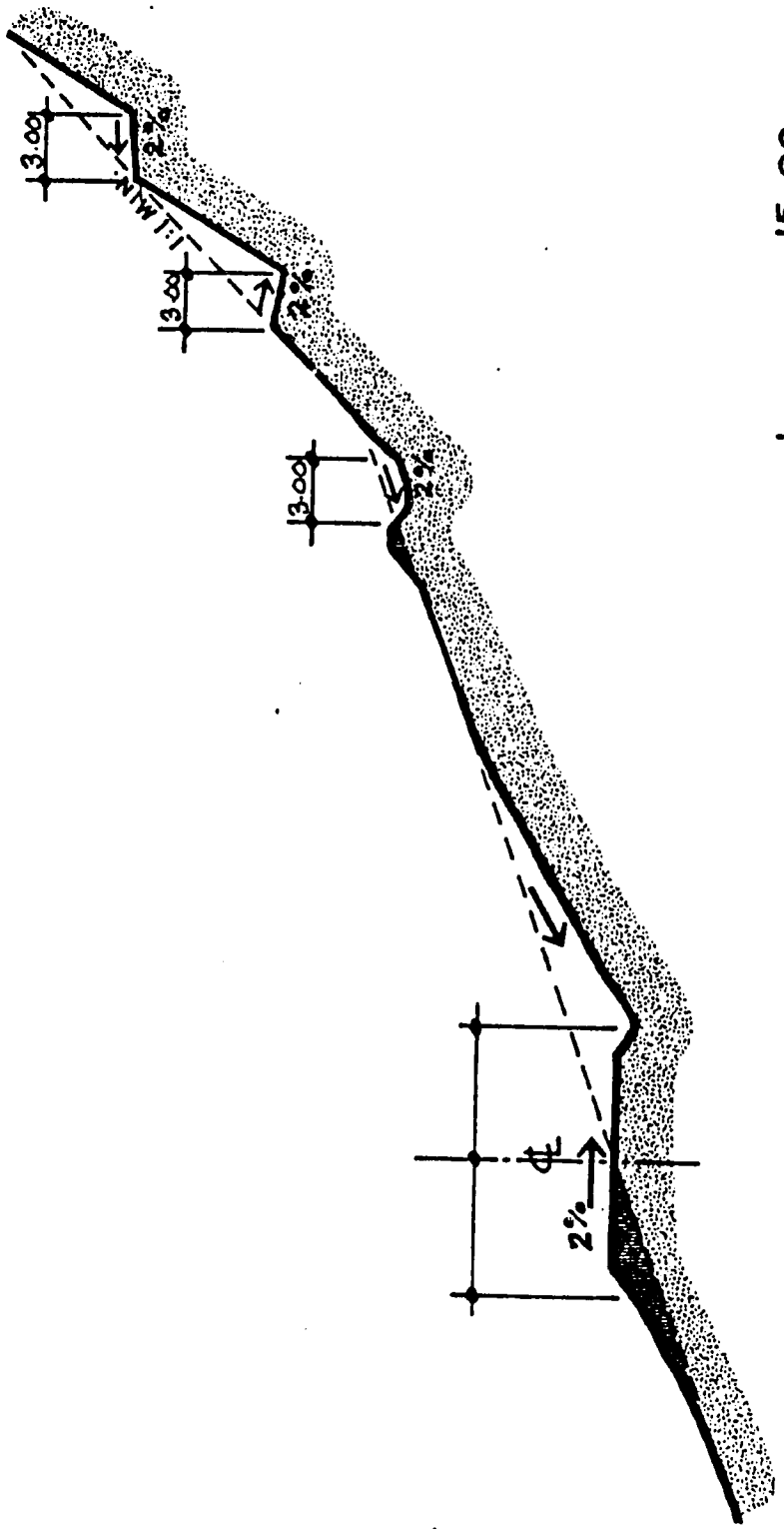
DESIGN CRITERIA

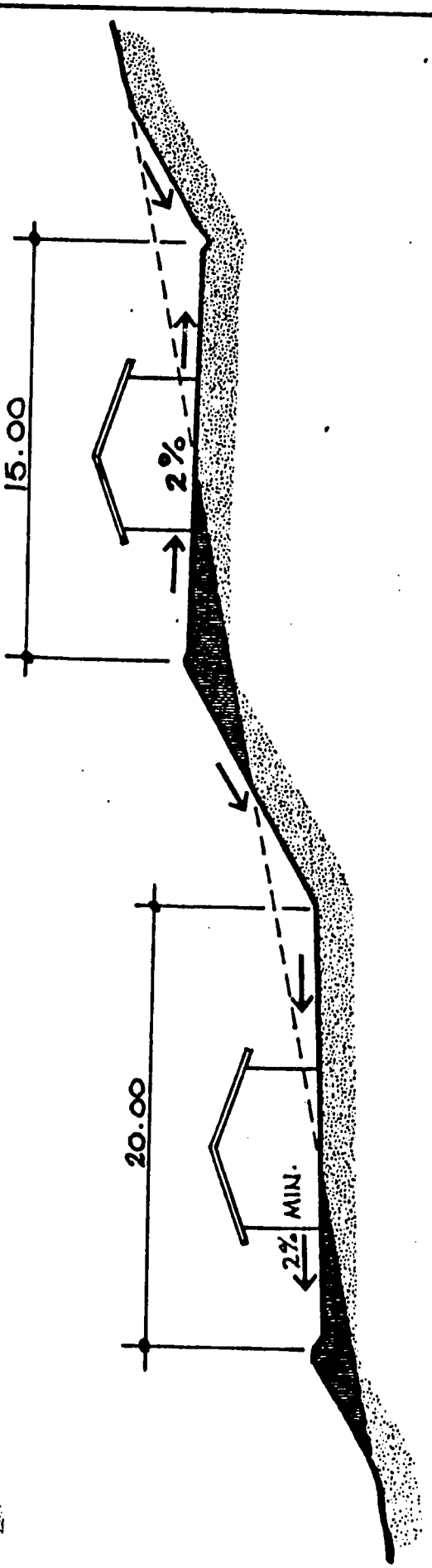
- Terraces should be graded with a minimum width of 15 meters in cases where runoff is intercepted and diverted at the toe of the slope. Where positive drainage flow is desired to the front of the slope, then the terrace width should be 20 meters. The minimum width of benches should be 3 meters.

- Minimum 3:1 slopes should be maintained between terraces.

- The gradient of terraces and benches along contours of a hill should be carefully controlled to provide for adequate flow (minimum 1-2%) without causing the drainage channel or diverison dike to be scoured or washed out.

- Negative or positive drainage from lots should be achieved by maintaining a minimum slope of 2%. The area occupied by any structure should be built up to cause runoff to be diverted around the building rather than flowing into it.





GRADING TERRACES AND BENCHES

- Whether terraces or benches are graded for the collection of runoff to the front or rear of a lot, a ditch or channel should be provided for the collection and disposal of stormwater. Diversion dikes or berms are critical in cases where positive drainage toward the front slope is desired in order to protect against sheet or rill erosion on the slope.

- Temporary and permanent vegetative cover should be established and maintained on the bottom and side slopes of all terraces to avoid short- and long-term erosion problems.

SOIL LOOSENING

DESCRIPTION

Turning up and/or roughening the soil surface by a variety of mechanical or manual means (Figure 20).

FUNCTION

Proper lossening or roughening of the soil surface is designed to accomplish the following:

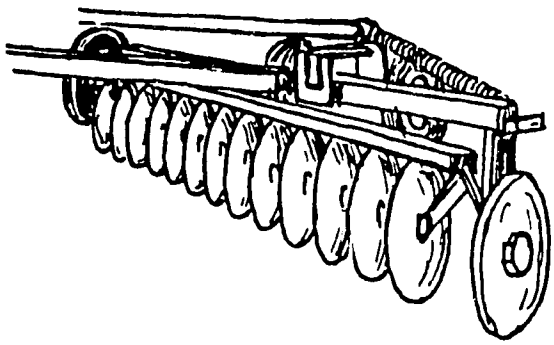
- reduce the amount of surface runoff and its speed of movement;
- enhance on-site retention and detention of runoff;
- increase groundwater recharge and extend time period of off-site discharge; and
- encourage rapid and sustained plant growth in areas designated for revegetation and those preserved as open space.

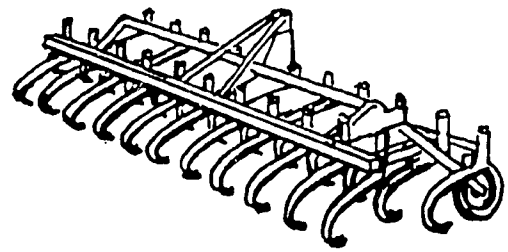
APPLICATION

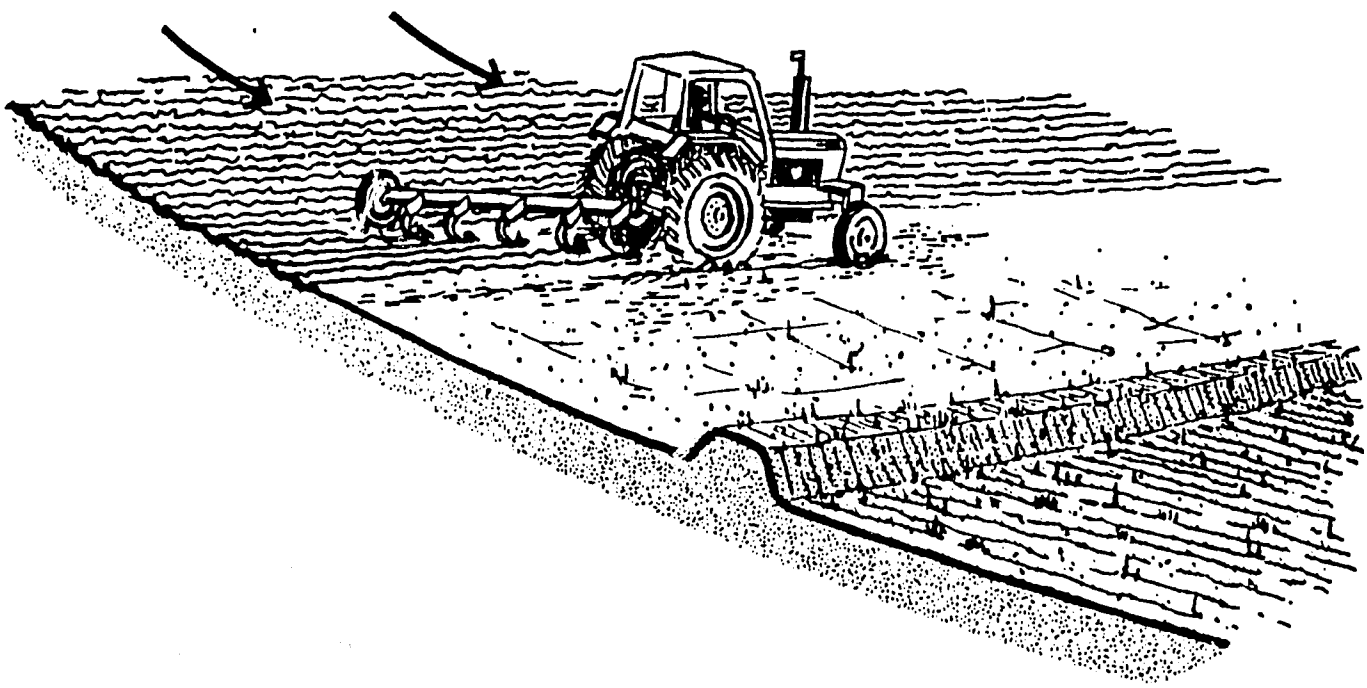
All disturbed areas resulting from clearing, grubbing and grading operations accompanying land development activities. Particularly applicable to areas of moderate to steep sloping terrain (8% or greater) which may pose risks of sheet or rill erosion and/or high rate of sediment loading. In addition, it is a critical preparatory step in revegetation programs to prepare the soil for seeds, sprigs or plugs. Prompt establishment of vegetative cover is important in all cases since rain droplets will cause compaction of loose soils within a short period.

METHODS (See Figure 20.)

- Scarification or Plowing.
  Use of plows, discs or rakes parallel to a slope's contours.
- Tracking.
  Running a cleated tractor or bulldozer up steep slopes parallel to the contour.
- Furrowing or Small Dikes.
  Use of a single-blade plow parallel to the contour.







SOIL LOOSENING TECHNIQUES

D. SEDIMENT CONTROL PRACTICES

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Sediment Traps 84

Check Dam 92

Sediment Basins 96

Temporary Gravel Outlet Structure 106

CONSTRUCTION ENTRANCE

DESCRIPTION

A construction entrance (Figure 21) is a stabilization measure to control erosion caused by the movement of construction-related vehicles at either ingress and egress points or at watercourse crossings. It is built of a serge stone pad and designed to serve one or two traffic lanes which are moving from the site to a public right-of-way, street, or roadway.

FUNCTION

To reduce or eliminate the transport of mud from the construction area onto public rights-of-way by motor vehicles or by storm runoff.

APPLICATION

This control practice is used at appropriate points of construction ingress and egress.

DESIGN CRITERIA

A formal design is not required. The following general criteria should be used:

Drainage Area:
No more than 1 hectare of contributing area.

Location:
Entrance should be located so as to prevent sediment from leaving the site.

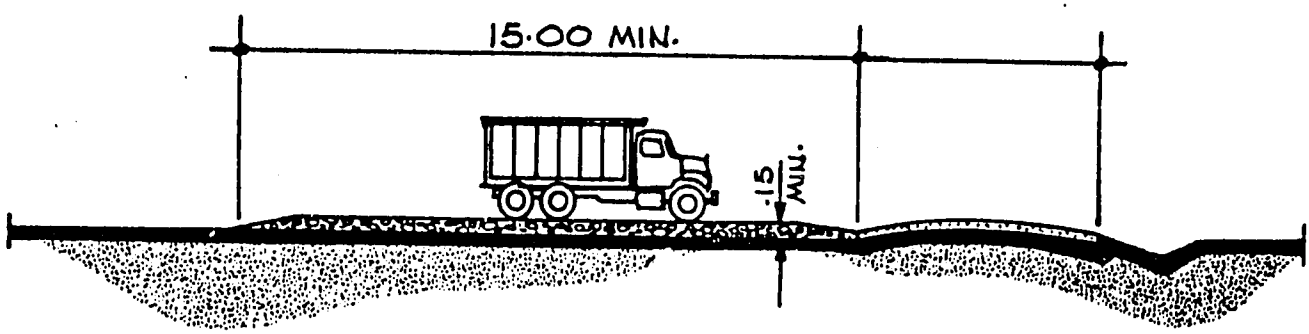
Pad Width:
Depending upon the number of traffic lanes: 3.5 m. minimum width for one lane and 7.0 m. minimum for two lanes.

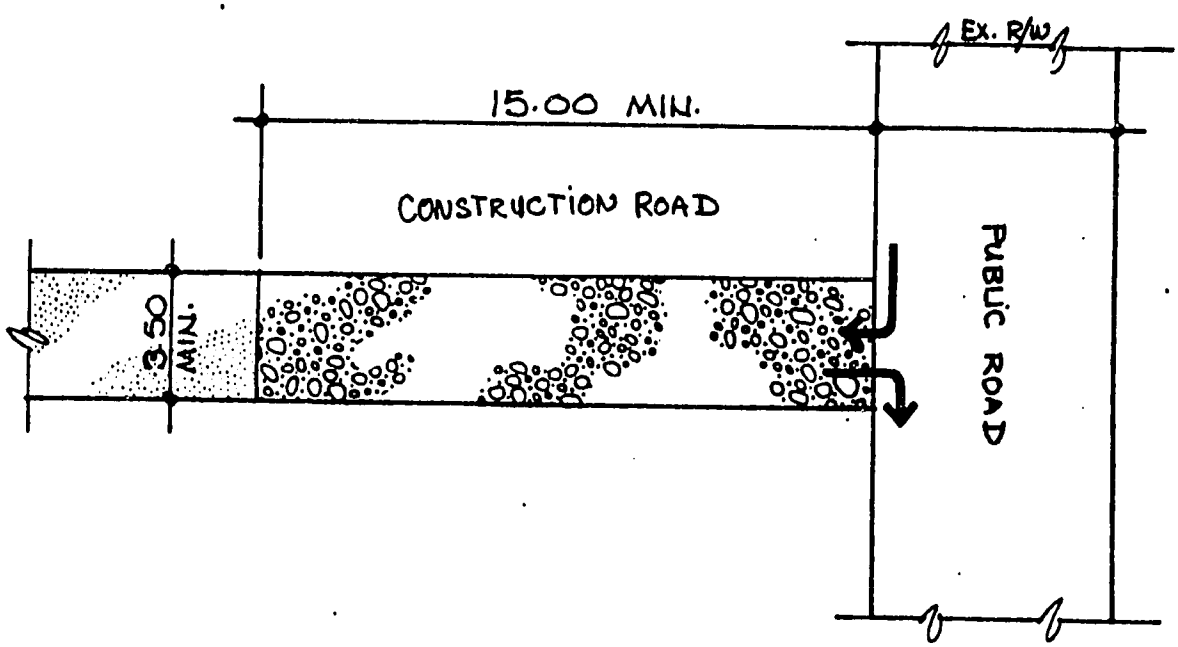
Pad Length:
15.0 m minimum.

Pad Thickness:
It should not be less than .15 m minimum.

End Slopes:
1:10 to avoid traffic detention.

Grade:
Should have positive drainage to an outlet and follow the street grade.





CONSTRUCTION ENTRANCE

Washing:

Wheels must be cleaned to remove mud prior to entering onto public rights-of-way. When washing is required, it should be done in an area stabilized with crushed stone which drains into a sediment trap or sediment basin or truck wash rack pit.

MAINTENANCE CONSIDERATIONS

Entrance should be maintained in a condition which will prevent tracking or flow of mud onto public rights-of-way. This may require periodic top dressing, with 2-inch stone, as conditions demand, and repair and/or clean out of any structure used to trap sediment. All materials spilled, dropped, washed or tracked from vehicles or site onto public streets, roadways or into storm drains should be removed immediately to prevent safety hazards and dust nuisance.

SEDIMENT TRAPS

DESCRIPTION

Sediment traps (Figures 22 to 25) are small temporary basins formed by excavation or creation of barriers to intercept sediment-laden runoff and to trap and retain the sediment. In so doing, drainageways, ditches and storm drainage-sanitary facilities below the traps are protected from sediment damage.

FUNCTION

To prevent sediment from leaving the site, or from entering natural or constructed drainageways or storm drainage systems, prior to permanent stabilization of disturbed areas.

APPLICATION

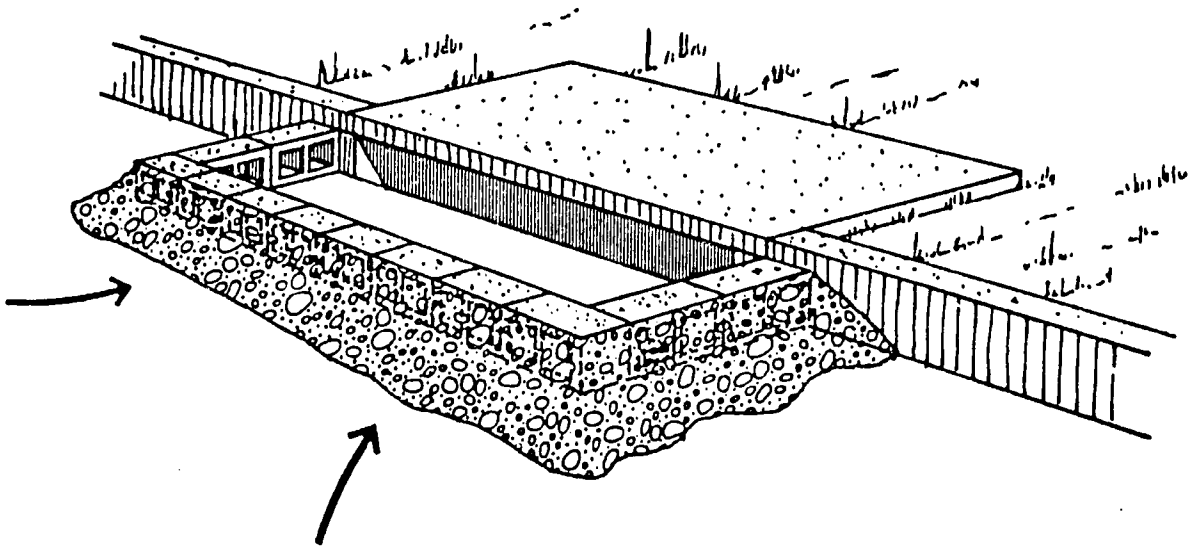
Where construction schedules or other considerations preclude erosion control treatment on sediment-producing areas not exceeding 2 hectares in size. Traps are usually excavated or installed at or around storm drain inlets, drainageways, swales, or at other points of discharge of sediment-laden storm runoff.

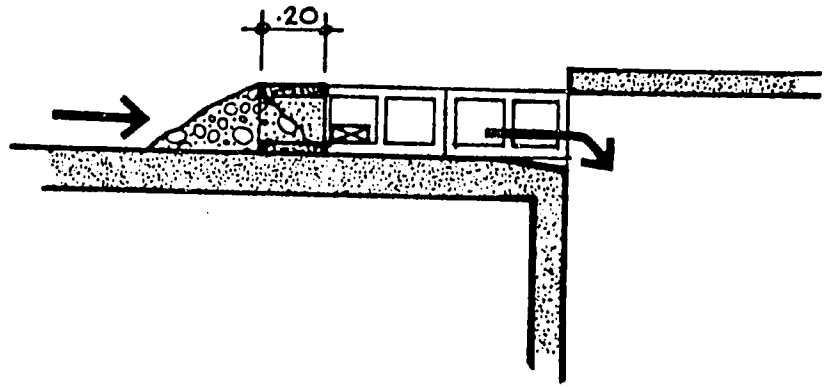
DESIGN CRITERIA

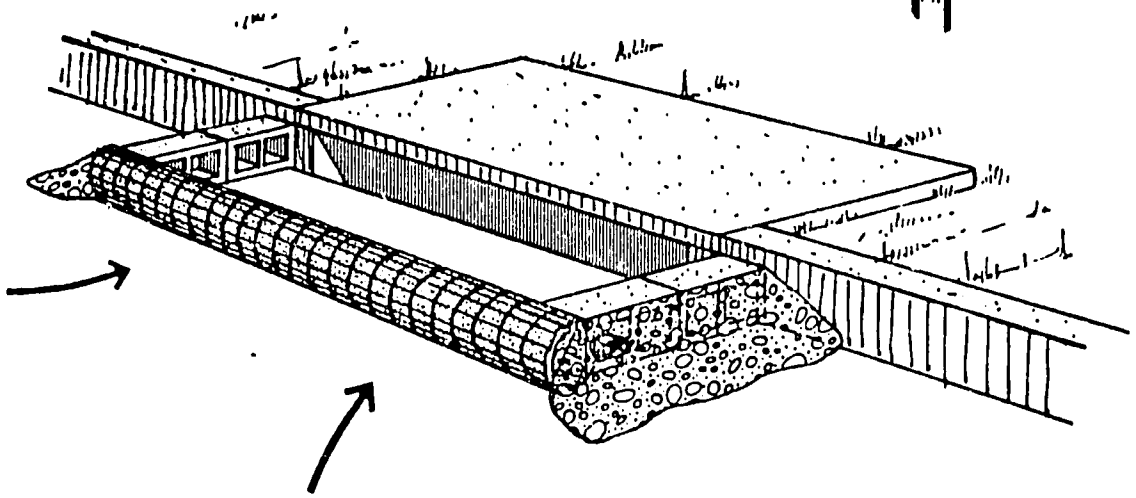
There are three basic types of small-scale sediment traps: (1) inlet filter barriers; (2) earth detention structures; and (3) stone embankment filters. Their specific uses and design guidelines are summarized below:

- Inlet Filter Barriers (Figures 22 and 23)
  This type of temporary sediment trap may be constructed of crushed stone, mini-gabion, gravel and concrete blocks, or straw bales to prevent sediment from entering storm drain and sanitary systems. In the case of using the concrete blocks or the mini-gabion type controls shown in Figure 22, it is recommended that a board be placed behind the front row of blocks or mini-gabion to prevent them from being pushed into the inlet openings.

- Earthen Traps (Figure 24)
  These are small earthen depressions created by excavation and/or embankments not exceeding generally 1.5 meters in height. The drainage area for this type of trap should be less than 2 hectares. Embankments should have a minimim width of .80 m. at the

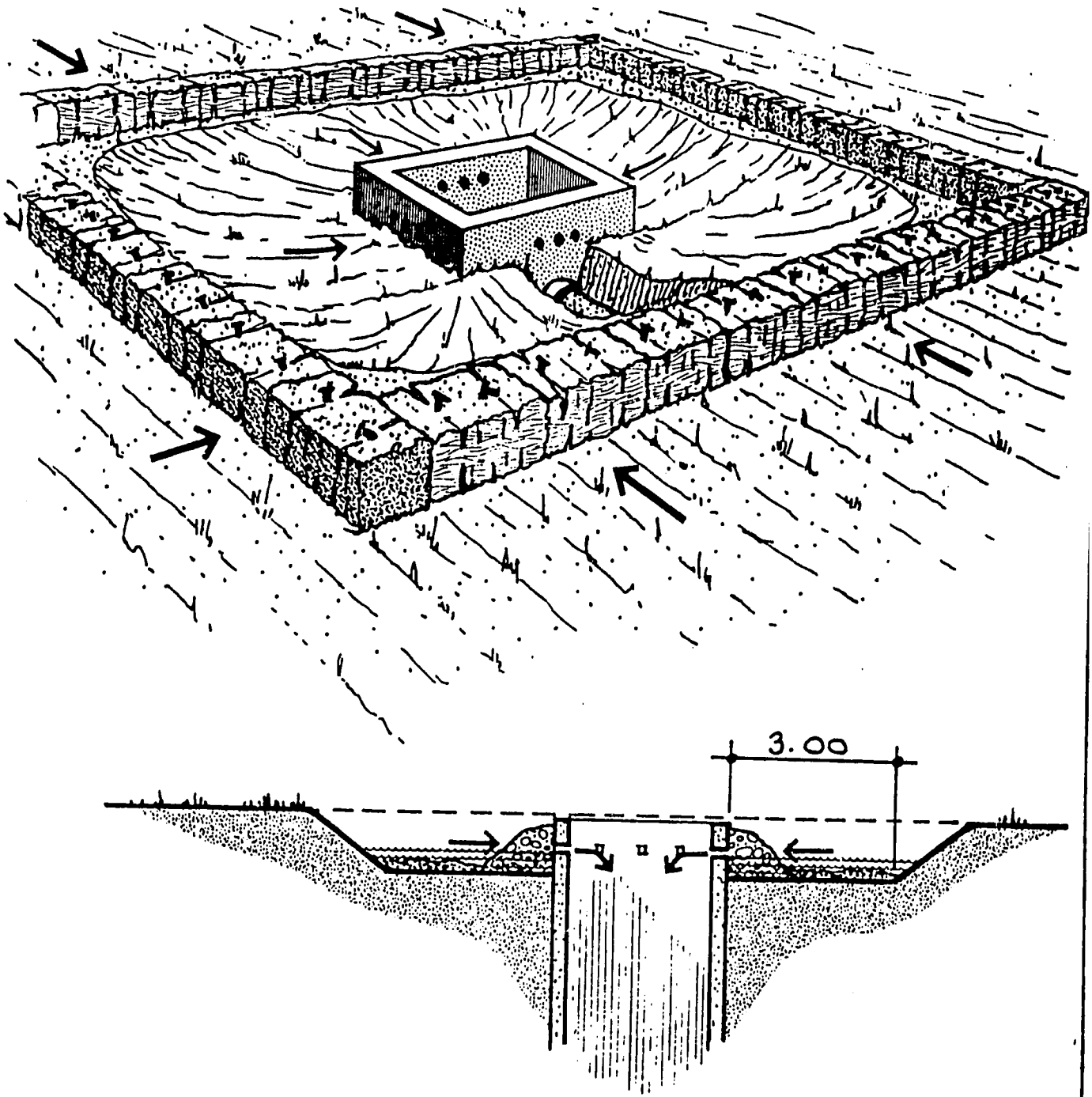






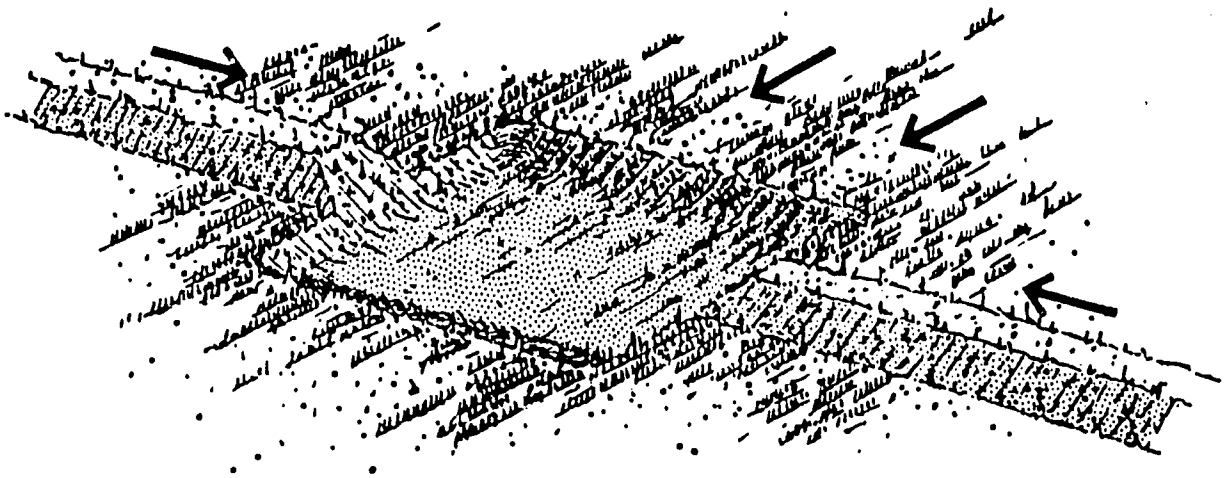
CURB INLET SEDIMENT TRAPS

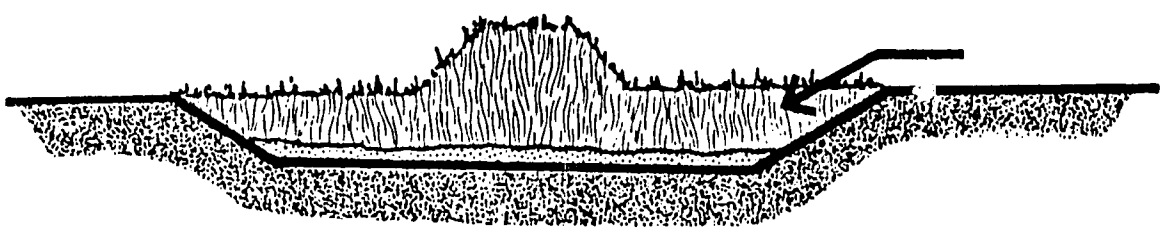
22



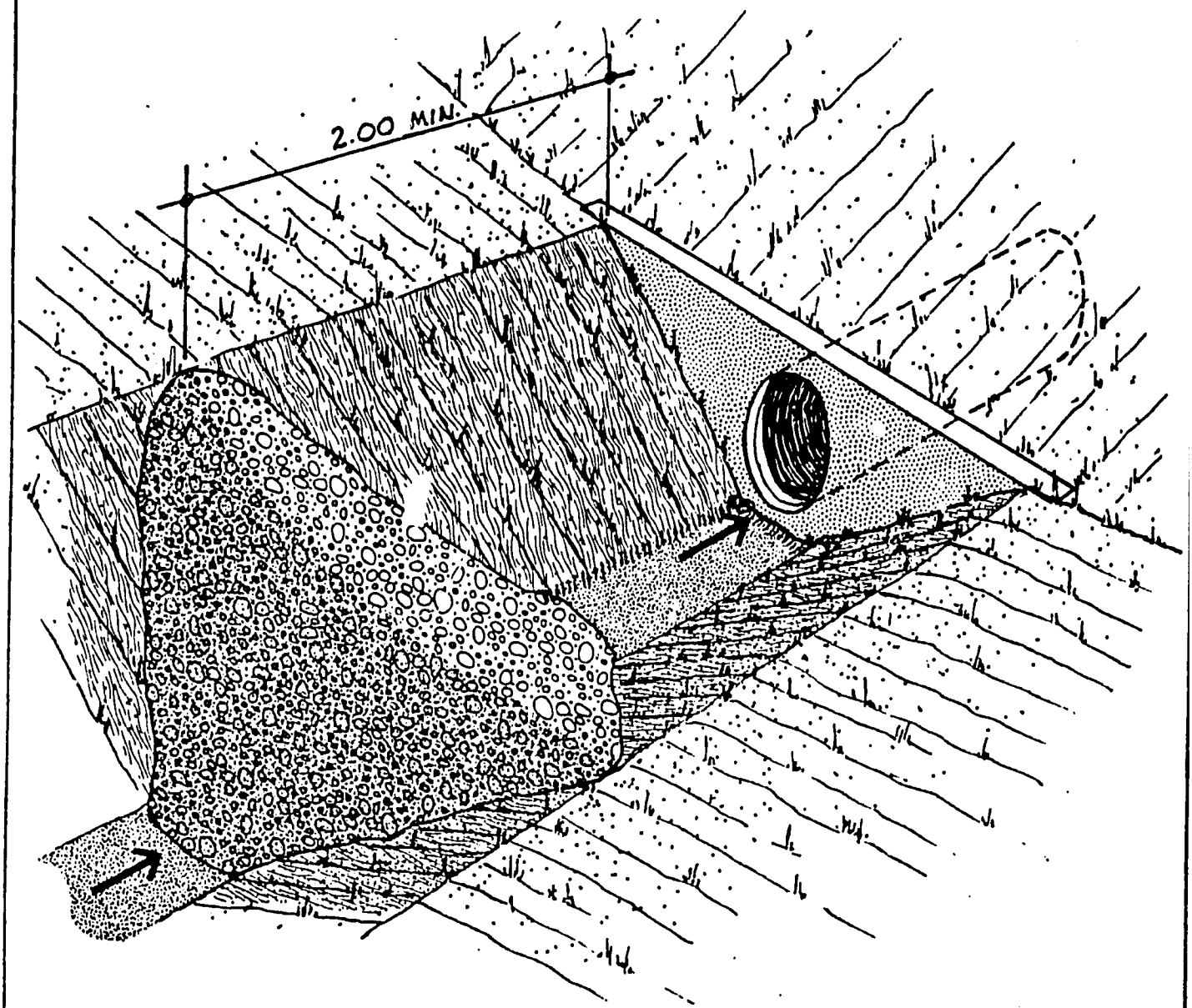
STORM INLET OR SANITARY MANHOLE SEDIMENT TRAP

23





EARTH OUTLET SEDIMENT TRAP



STONE FILTER SEDIMENT TRAP

top and side slopes of 2:1 or flatter. The slope of the bottom should not be less than 0.5%.

The volume of storage required depends on the amount and intensity of rainfall and on estimated sediment loading rates. However, this trap should provide about 21 cubic yards of storage per hectare of drainage area to obtain a trap efficiency of 70%.

- Stone Filter Traps (Figure 25)

  This type of trap is usually used in storm drainage ditches to prevent silting or clogging of the installed storm drainage culverts and drop structures until these improvements are completed. Futher design details are outlined under check dams and riprap controls.

There are three different types of earthen sediment trap outlets:

1. Earth Outlet. The outlet width should be equal to 4.5 times the number of hectares draining to the trap. If an embankment is used, the outlet crest should be at least .30 m. below the top of the embankment. The outlet should be free of any restriction to flow.

2. Pipe Outlet (Figure 28). The outlet for the trap is through a perforated riser and a pipe through the embankment. The outlet pipe and riser should be made of corrugated metal. The riser diameter should be of the same or larger diameter than the pipe. The top of the embankment should be at least 0.45 m. above the crest of the riser. At least the top two-thirds of the riser should be perforated with ½" diameter holes spaced 8" vertically and 10" to 12" horizontally. All pipe connections should be watertight. This type of outlet is commonly used with sediment basins, and are discussed in further detail under sediment basins.

Select pipe diameter from Table 5 below:

Table 5. Diameter of Pipe Outlets for Sediment Traps

Maximum Drainage Area (hectares)	Minimum Pipe Diameter (inches)
0.4	12
0.8	18
1.2	21
1.6	24
2.0	30

Source: U.S. Environmental Protection Agency. Erosion and Sediment Control, Volume II, October 1976.

3. Stone Outlet (Figure 29). A stone outlet sediment trap consists of a basin formed by an embankment or a combination of an embankment and an excavation. The outlet for the trap is over a level stone section. The stone outlet for a sediment trap differs from that for a stone outlet structure because of the intentional ponding of water behnind the stone. To provide for a storage area, a relatively impervious core (e.g., timber, concrete block or straw

bales) is placed in the stone. The core should be covered by 0.15 m. of stone. Outlet selection is based on construction costs. The type and size of the traps are dependent on the type of structure which has to be protected.

CONSTRUCTION SPECIFICATIONS

Earth Outlet Sediment Traps

- Area under embankment should be cleared, grubbed and stripped of any vegetation and root mat. The pool area should be cleared.
- The fill material for the embankment should be free of roots or other woody vegetation as well as oversized stones, rocks, organic material, or other objectionable material. The embankment should be compacted by traversing it with equipment while it is being constructed.
- The structure should be inspected after each rain, and repairs made as needed.
- Construction operations should be carried out in such a manner that erosion and water pollution are minimized.
- The structure should be removed and area stabilized when the drainage area has been properly stabilized.
- All cut and fill slopes should be 2:1 or flatter.
- Outlet crest elevation should be at least .30 m. below the top of the embankment.

Pipe Outlet Sediment Traps

In addition to the above:

- All pipe connections should be watertight.
- At least the top two-thirds of the riser should be perforated with ½-inch-diameter holes spaced 8 inches vertically and 10-12 inches horizontally.
- Fill material around the pipe spillway should be hand-compacted in 10-centimeter layers. A minimum of .60 meter of hand-compacted backfill should be placed over the pipe spillway before crossing it with construction equipment.

Stone Outlet Sediment Traps

- The crushed stone or gravel used in the outlet should be sized based on expected flow velocities. (See Riprap for sizing details.)

MAINTENANCE CONSIDERATIONS

- Frequent inspections and clean-outs are required.
- Special inspections should be made after each high intensity storm.
- If earth outlets are used, it should be stabilized with vegetation.
- Traps should be cleaned when accumulated sediments equal about one-half of trap storage capacity, or 70% efficiency.

CHECK DAM

DESCRIPTION

A check dam (Figure 26) is a temporary or permanent structure used to stabilize the grade or to control excessive cutting in natural or artificial channels. Check dams are used to reduce or prevent erosion by reduction of high velocities in watercourses or by providing partially-lined channel sections or structures that can withstand high flow velocities.

FUNCTION

Check dams are used in reducing erosion in roadside ditches or other small waterways and to trap sediment-laden runoff both during and following construction.

APPLICATION

Check dams are applied where the capability of earth and/or vegetative measures are exceeded in the safe handling of water at permissible velocities, where excessive grade or overall conditions occur, or where water is to be lowered from one elevation to another.

DESIGN CRITERIA

Drainage Area:

1.0 hectare maximum. Check dams should be constructed so that flowing water is kept in the center of the channel (dam lower in center) and does not bypass the structure by eroding the bank or roadside ditch. Use Manning formula for computing the discharge "Q".

Minimum Capacity:

Minimum capacity should be that required to pass the peak flow from a ten-year frequency storm without causing damage to the ditch or dike.

Height:

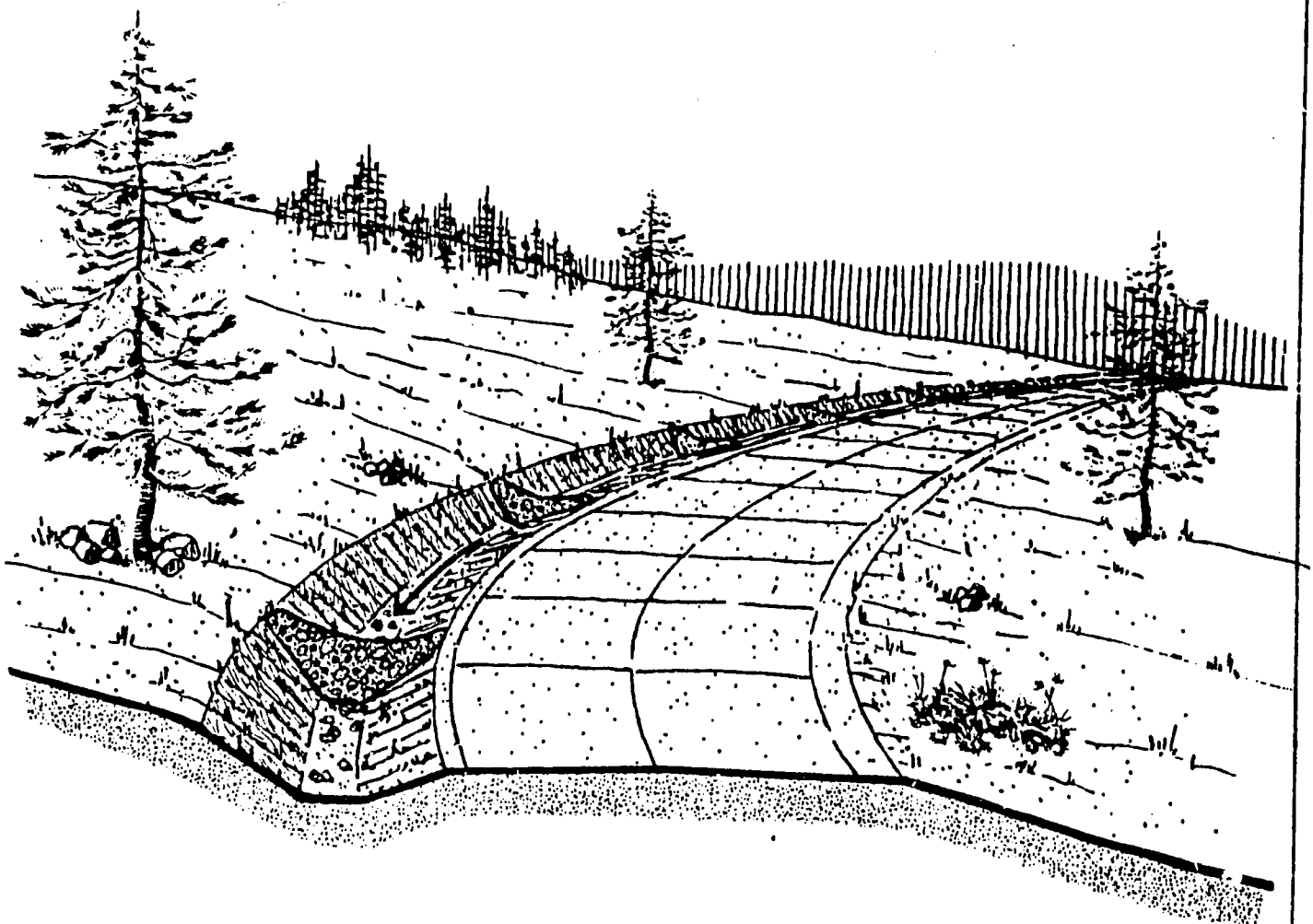
Top elevation of each dam should be above the toe elevation of the next dam uphill. Check dam material must be able to stand high runoff flows and velocities without movement.

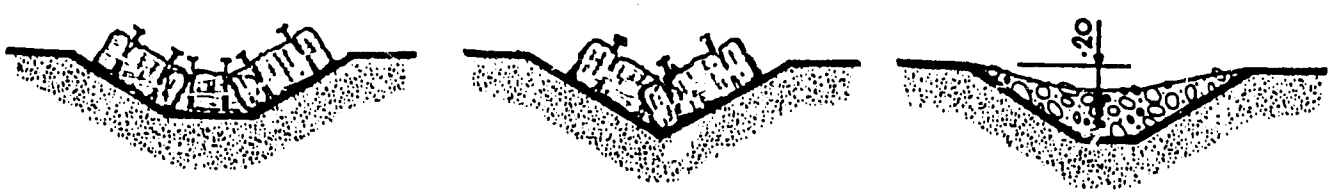
Side Slopes:

2:1 or flatter.

Top Width:

0.60 m. minimum.





CHECK DAM

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Grade:
Normally a check dam is placed at grades where the runoff velocities exceed 1.0 mps in roadside ditches or other watercourses

Space Separation:
Minimum separation between check dams should be approximately 10 m.

Outlet:
A storm sewer inlet, ditch or other watercourse.

CONSTRUCTION SPECIFICATIONS

- Concrete rock, broken blocks or bricks, straw bales or gabions, wood, brush, etc., may be used in the construction of check dams.
- The structure should be located in a reasonably straight channel section, and particular attention must be given to the potential for overbank flows and their effects on adjacent existing natural and man-made features.
- Gradient and soil conditions and aesthetic considerations are important factors in construction material selection.
- Design channel grade above and below the structure should be analyzed to determine if erosion or sediment deposition will be a problem.
- Special attention should be given to providing adequate width to the check dams and a slightly lower center to insure that runoff will pass over the top of the dam and not bypass it by scouring around the sides.

MAINTENANCE CONSIDERATIONS

- Check dams should be inspected after each heavy storm.
- When damage occurs from high velocity flows, the check dams should be carefully repaired and reshaped.
- When silt reaches an elevation half of the height of the dam, it should be cleaned out and the channel reshaped.
- Displaced material form the check dam should be immediately replaced.
- The ability of the check dam to perform as a filter device must be frequently checked. At the same time, its ability to work as a detention device should not be forgotten, depending upon the requirements present at the time of design.

- Silt material obtained from cleaning the channel should be disposed of either on the upper side of the channel or removed to another area where erosion and siltation problems can be avoided. Consideration should be given to recessing sediment material for topsoil or soil conditioning in conjunction with revegetation efforts.

SEDIMENT BASINS

DESCRIPTION

A sediment basin (Figures 27 and 28) can be built by constructing a barrier, daming across a waterway, excavating a basin, or a combination of these measures. It usually consists of a dam, an outlet, and an emergency earthen spillway. The size of the structure is determined by its location, size of drianage area, soil type, and rainfall conditions.

FUNCTION

They act as the last major defense against off-site sediment release and are used to detain on-site runoff and to trap sediment from disturbed areas. Furthermore, they are intended to protect properties and drainageways below the basin from damage by excessive sedimentation and debris. While storm runoff is temporarily stored, and the bulk of the sediment, which is transported by overland flow, drops out and is retained in the basin as the water is gradually released.

APPLICATION

This type of control is used in critical areas where physical site conditions, construction schedules or other restrictions may preclude the installation of common erosion control devices to reduce erosion and sedimentation. However, these structures should be used in combination with other practices and should remain in effect until sediment-producing areas are permanently stabilized.

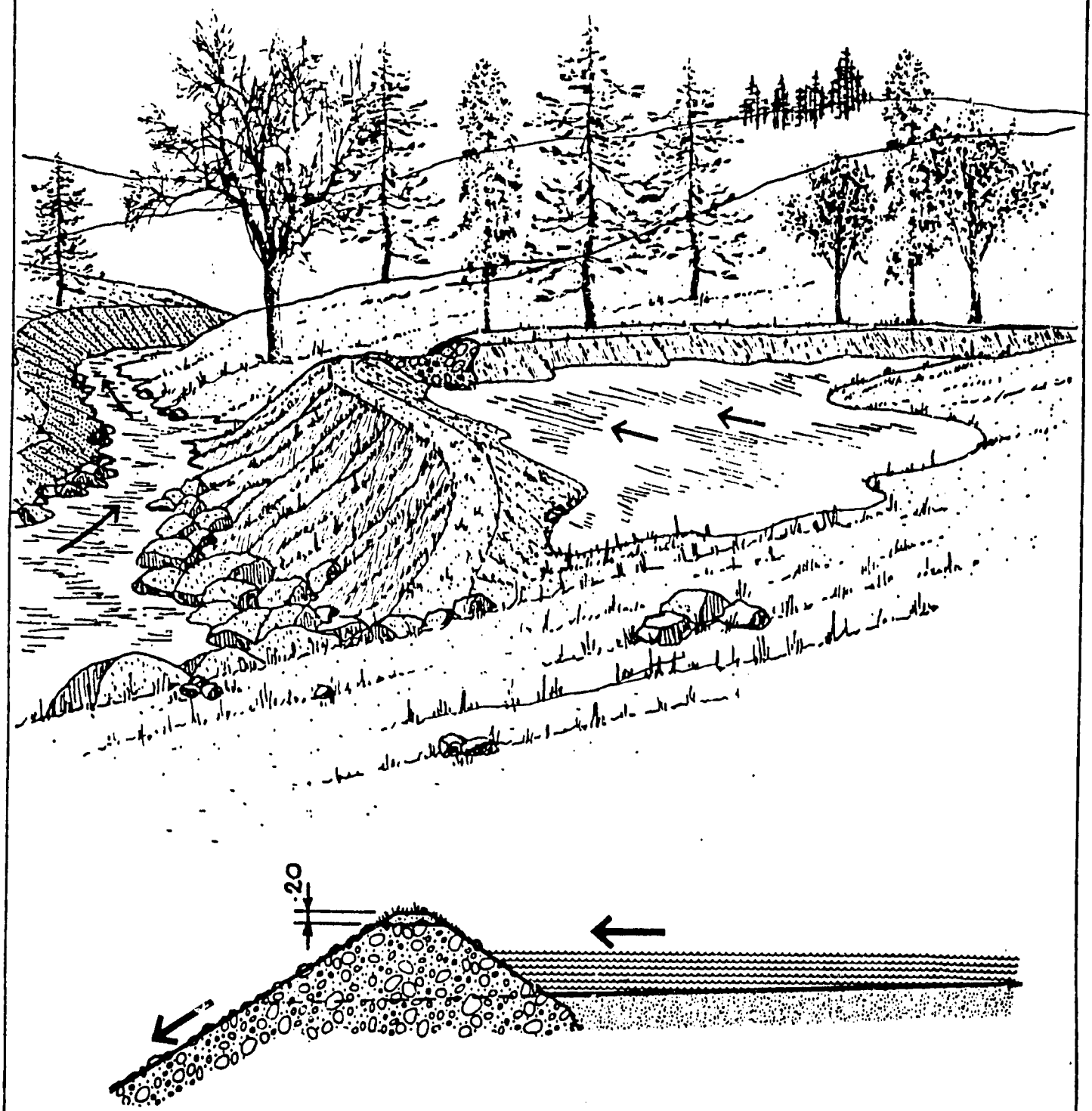
TYPES

For purposes of this manual, sediment basins are classified into broad categoris, temporary and permanent basins.

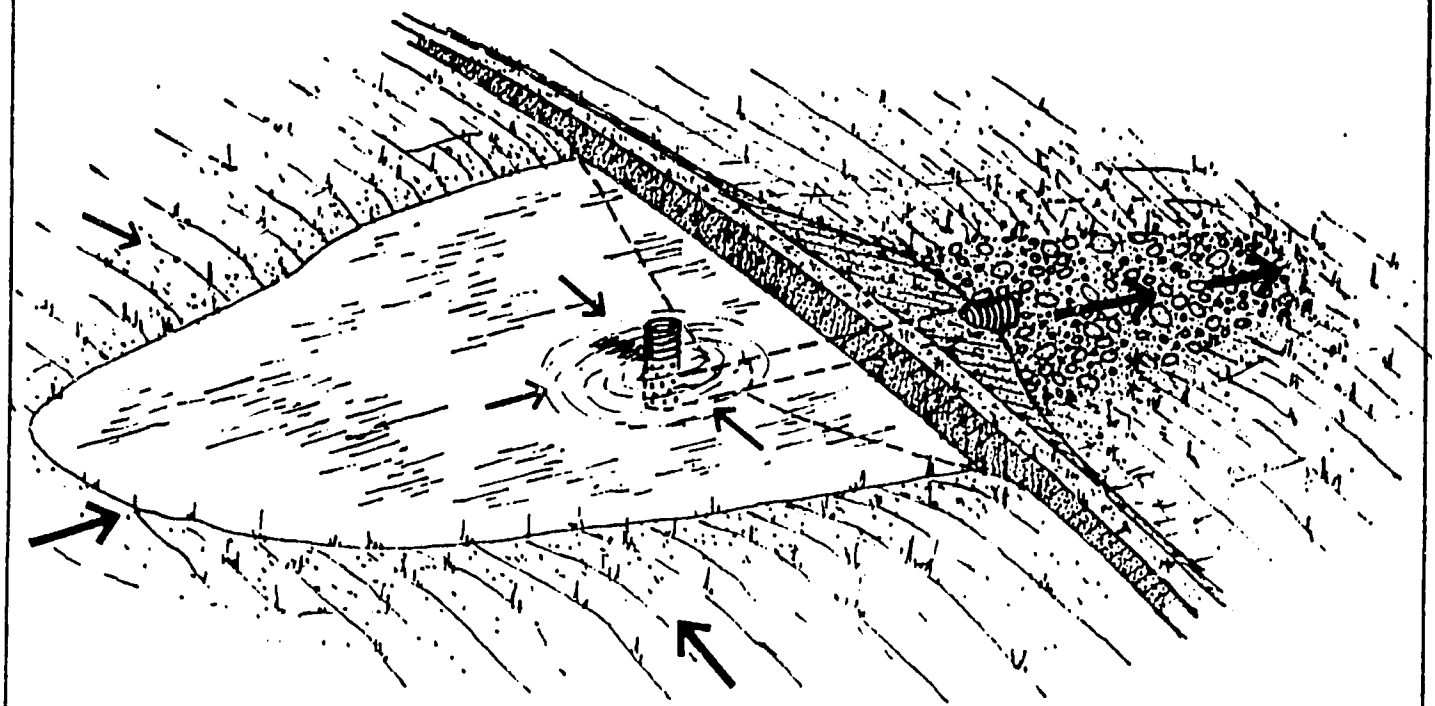
1. Temporary Basins (To Be Removed Within 18 Months)

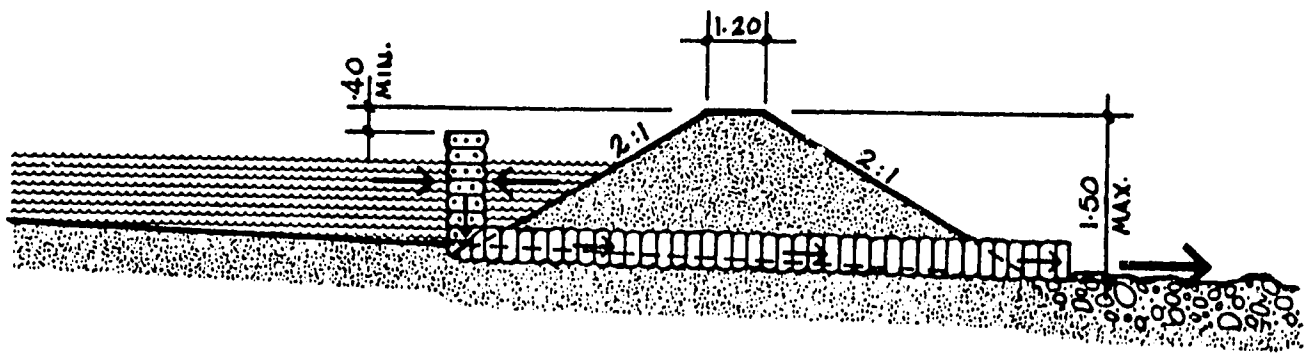
Temporary sediment basins should conform to the design criteria for #1 and #2 (see Table 6). Installation of temporary sediment basins is applicable on sites where:

- Failure of the structure would not result in loss of life or interruption of use or service of public utilities; and
- Drainage area does not exceed 60 hectares.
  (Note: This practice may be used on larger drainage areas if designed on an individual basis by a qualified engineer.)



SEDIMENT BASIN TRAP





SEDIMENT BASIN WITH SUBSURFACE PIPE OUTLET

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2. Permanent Basins (To Function More Than 18 Months)

Permanent sediment basins should conform to the design criteria appropriate for permanent structures as reflected in types #3 and #4. The stroage capacity of permanent sediment basins should equal or exceed the capacity requirements of temporary basins. This is because sediment basins can be designed to accomplish the objectives of trapping silt and acting as a detention or storage structure.

DESIGN CRITERIA

Location:

Locate the basins to provide maximum volume capacity for trapping sediment behind the structure as well as for greatest ease of clean-out.

Classification:

Table 6. Design Criteria for Sediment Basins

TYPE	MAX. DRAINAGE AREA.(HECTARES)	MAX HEIGHT 1/ OF DAM (METERS)	ENBANKMENT SIDE SLOPE	EMERGENCY SPILLWAY REQ'D	DESIGN STORM FREQUENCY
#1 rge Stone Outlet	To 8.0	1.5	2:1 or Flatter	None 2/	10yrs.
#2 op Pipe Outlet	To 60.0	3.0	2:1 or Flatter	Yes	10yrs.
#3 op Pipe Outlet	To 80.0	4.5 3/	2:2½ or Flatter	Yes	25 to 50 yr
#4 op Pipe Outlet	Over 30.0	6.0 or higher 3/	3:1 or Flatter	Yes	50 + yrs.

1/ Height is measured from the low point of original ground along the center line of dam.

2/ Where sites conditions make it impractical for construction of emergency spillways or where downstream hazards for causing physical damage do not exist.

3/ To be designed by a qualified engineer.

Storage:

The capacity of the sediment basin, as measured to the elevation of the crest of the emergency spillway, or the principal spillway if there is no emergency, should be at least 67 cubic yards per acre of drainage area (0.5 watershed inches).

Sediment basins should be cleaned out when the storage capacity as described above is reduced by sedimentation to 27 cubic yards per acre of drainage area (0.2 watershed inches). In no case should the sediment level be permitted to build up higher than one foot below the principal spillway crest. The elevation corresponding to this level should be determined and will be stated in the design data as a distance below the top of the riser. See: Appendix A-1 for criteria, Appendix A-2 to A-5 for procedure and A-5 and A-6 for examples on sediment trap cleanout.

Spillway Design: (See Appendix B-2 and B-4.)

Runoff will be computed by the method of rational formula. Q=CIA, or by other acceptable methods. Runoff computations should be based upon the soil cover conditions expected to prevail in the contributing drainage area during the anticipated effective life of the structure. The combined capacities of the principal and emergency spillways should be sufficient to pass the peak rate of runoff from a ten-year frequency storm.

Principal Spillway:

A spillway consisting of a vertical pipe or box type riser joined (watertight connection) to a pipe (barrel) which will extend through the embankment and outlet beyond the downstream toe of the fill. The riser will be perforated to provide for a gradual draw down after each storm event. The minimum capacity of the principal spillway will be sufficient to discharge 5 inches of runoff from the drainage area in 24 hours (0.21 cfs per acre of drainage area) when the water surface is at the emergency spillway crest elevation. For those basins with no emergency spillway, the principal spillway should have the capacity to handle the ten-year frequency peak flow. The minimum size of the barrel will be 8 inches in diameter. See Appendix B-4 and B-5 for principal spillway sizes and capacities.

- Crest Elevation (See Appendix A-2).
  When used in combination with emergency spillways, the crest elevation of the riser should be one foot below the elevation of the control section of the emergency spillway. If no emergency spillway is provided, the crest elevation of the riser should be a minimum of three feet below the crest elevation of the embankment.

- Perforated Riser (See Appendix A-3).
  The sediment basin pool should be drained by using a perforated riser or by some other approved means. The riser should be perforated with ½-inch diameter holes spaced 8 inches vertically and 10-12 inches horizontally. Additional drainage of the sediment to facilitate periodic clean-out may be accomplished by installation of a drain in the bottom of the basin as shown in Appendix A-3.

- Anti-Vortex Device and Trash Rack (See Appendix A-2).
  An anti-vortex device and trash rack should be securely installed on top of the riser. An approved anti-vortex device is a rigid vertical plate firmly attached to the pipe and oriented normally to the center line of dam. The plate dimensions should be: length = diameter of the riser plus 12 inches; height = diameter of the barrel. Another approved device is the concentric cover trash rack which also functions as an anti-vortex device. See Appendix B-7 and B-8.

- Base.
  The bottom of the riser should be located at the low point in the basin to insure complete drainage. The riser should have a base attached with a watertight connection and should have sufficient weight to prevent flotation of the riser.

Two approved bases are: (1) a concrete base 18" thick with the riser imbedded 6" in the base; (2) a ¼" minimum thickness steel plate with continuous weld all around the base of the riser to form a watertight connection. The plate should have two feet of stone, gravel, or tamped earth placed on it to prevent flotation. In either case, each side of the square base shall be twice the riser diameter.

- Anti-Seep Collars (See Appendix A-2)
  Anti-seep collars should be installed around the pipe conduit within the normal saturation zone to increase the seepage length at least 10% when any of the following conditions exist: (1) the settled height of dam exceeds 4.5 meters, (2) the embankment material has a low silt-clay content and the pipe diameter is 10 inches or greater, and (3) the conduit is of corrugated metal pipe larger than 12" in diameter.

  The anti-seep collar and its connection to the pipe should be watertight. The maximum spacing should be approximately 14 times the minimum projection of the collar measured perpendicular to the pipe.

- Outlet Protection.
  Protection against scouring at the discharge end of the pipe spillway should be provided. Measures may include stilling basin, riprap, revetment, excavated plunge pools, or other approved methods.

Emergency Spillways:

Emergency spillways should not be constructed on fill. The emergency spillway cross section should be trapezoidal with a minimum bottom width of 8 feet.

- Capacity.
  The minimum capacity of the emergency spillway should be that required to pass the peak rate of runoff from the ten-year frequency storm, less any reduction due to flow in the pipe spillway. Emergency spillway dimensions may be determined by using the method outlined in Appendix B-9 and B-10.

- Velocities. The maximum allowable velocity of flow in the exit channel should be 6 feet per second for vegetated channels. For channels with erosion protection other than vegetation, velocities should be within the allowable safe range for the type of protection used.

- Erosion Protection.
  Erosion protection should be provided for by vegetation as prescribed in this manula or by other suitable means such as riprap. Asphalt and concrete, etc., are recommendable in special cases.

- Freeboard.
  Freeboard is the difference between the design flow elevation in the emergency spillway and the top of the settled embankment. If there is no emergency spillway, it is the difference between the elevation required to pass the design flow through the pipe and the top of the settled embankment. The minimum freeboard should be one foot.

Embankment Cross Section:

Table 7. Design Calculation For Embankment Width

Type	Embankment Height	Embankment Width
# 1	4/5 x (0.75 - 1.5 m.)	= 0.60 - 1.2 m.
# 2	4/5 x (1.5 - 3.0 m.)	= 1.2 - 2.4 m.
# 3	2/3 x (3.0 - 4.5 m.)	= 2.4 - 3.0 m.
# 4	3/5 x (4.5 - 6.0 m. or higher)	= 3.0 - 3.6 m. or more

Provision for Lowering Runoff into Basin:

Points of entrance of surface runoff into excavated sediment basins should be protected to prevent development of an erosion problem. Diversion or interceptor dikes should be installed as necessary to insure direction of runoff to protect points of entry. Points of entrance should be located so as to insure maximum travel of entering runoff to point of exit from the basin.

Safety:

Sediment basins are attractive to children and can be very dangerous. Therefore, they should be fenced and posted or otherwise made inaccessible to persons or animals unless this is deemed unnecessary due to the remoteness of the site or other circumstances.

CONSTRUCTION SPECIFICATIONS

- Areas under the embankment and any structural works should be cleared, grubbed, and stripped of topsoil to remove trees, vegetation, roots, or other objectionable material. In order to facilitate clean-out and restoration, the pool area (measured at the top of the pipe spillway) should be cleared of all brush and trees.

- A cut-off trench should be excavated along the dam centerline on earth fill embankments. The minimum depth should be 2 feet. The cut-off trench should extend up both abutments to the riser crest elevation. The minimum bottom width should be 4 feet, but wide enough to permit operation of compaction equipment. The side slopes should be no steeper than 1:1. Compaction requirements should be the same as those for embankment. The trench should be drained during the backfilling-compacting operations.

- The fill material should be taken from approved borrow areas. Areas on which fill is to be placed should be scarified prior to placement of fill. The fill material should contain sufficient moisture so that it can be formed by hand into a ball without crumbling. If water can be squeezed out of the ball, it is too wet for proper compaction. Fill material will be placed in 6- to 8-inch continuous layers over the entire length of the fill. Compaction should be obtained by routing the hauling equipment over the fill so that the entire surface of the fill is traversed by at least one wheel or tread track of the equipment, or by using a compactor. The embankment should be constructed to an elevation 10% higher than the design height to allow for settlement if compaction is obtained with hauling equipment. If compactors are used for compaction, the overbuild may be reduced to not less than 5%.

- The riser should be securely attached to the barrel, and all connections should be watertight. The barrel and riser should be placed on a firm, smooth foundation. The fill material around the pipe spillway should be placed in 4-inch layers and compacted under the shoulders and around the pipe to at least the same density as the adjacent embankment. A minimum of 2 feet of hand compacted backfill should be placed over the pipe spillway before crossing it with construction equipment.

- The emergency spillway must not be installed in fill. Elevations, design width, entrance, and exit channel slopes are critical to the successful operation of the emergency spillway.

- Stabilize embankment and emergency spillway in accordance with the appropriate standards and specifications for grass or riprap spillways (See Appendix B-11 and riprap section).

- Construction operations should be carried out in such a manner that erosion and water pollution will be minimized.

- Appropriate measures such as fencing, sign and/or public information should be taken against the hazards of soft sediment and floodwater.

MAINTENANCE CONSIDERATIONS

- Repair all damages caused by soil erosion or construction equipment at or before end of each working day.
- Sediment should be removed from the basin and deposited in a suitable area when it reaches the specified distance below the top of the riser.
- Keep trash rack and anti-vortex device clear of debris (plastic, boards, logs, etc.).

FINAL DISPOSAL

Temporary sediment basins may be disposed of when the intended purpose has been accomplished, and the contributing drainage area has been properly stabilized. The embankment and resulting sediment deposits are to be leveled or otherwise disposed of in accordance with the sediment control plan.

TEMPORARY GRAVEL OUTLET STRUCTURE

DESCRIPTION

An auxiliary structure installed in conjunction with, and as a part of, a diversion, interceptor or perimeter dike, sediment trap/basin or other structrues designed to temporarily pond sediment-laden surface runoff. (Figure 29).

FUNCTION

To provide a means of slowing and filtering storm runoff which has collected behind a structure designed to retain runoff sediment.

APPLICATION

Any site where there is need to collect, detain, and dispose of sediment-laden storm runoff at a protected outlet.

DESIGN CRITERIA

Minimum Capacity:
The minimum capacity should be that required to pass the peak flood expected from a ten-year frequency storm without causing damage to the dike.

Minimum Length:
The minimum length in meters should not be less than four and a half times the number of hectares of contributing drainage area.

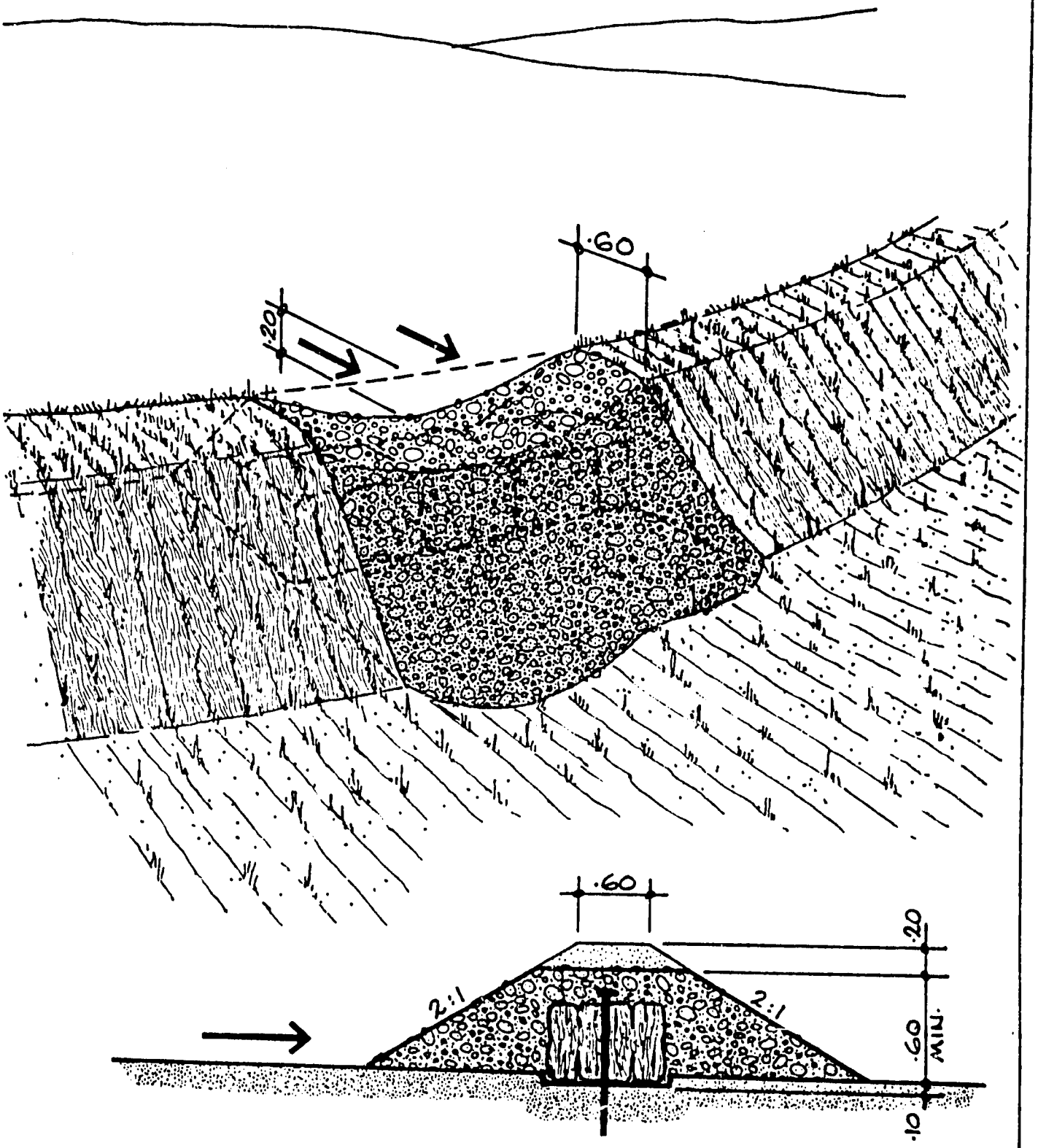
Drainage Area:
The drainage area should not be more than 2 hectares.

Height:
The height should not be less than 0.60 meters. The top elevation of the gravel outlet should not be less than .20 meters below the minimum elevation of the top of the dike. The gravel should consist of a mix of stone between 5 to 15 centimeters in diameter.

Side Slopes:
2:1 or flatter. A gravel outlet could be the largest available gabion stone.

Grade:
Must be positive to provide easy drainage - minimum 1.0%.

Outlet:
Gravel outlet should discharge onto a stabilized area or a stable watercourse.



SEDIMENT BASIN WITH GRAVEL OUTLET STRUCTURE

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CONSTRUCTION SPECIFICATIONS

- The bases and side slopes of the gravel should be placed so as to conform to the dike, ditch, or sediment basin configuration, except when gabions are used.
- The invert of the gravel outlet should be not less than .20 meters lower than the top of the adjoining earth dike.
- The gravel should extend to the top of the dike, leaving a parabolic shape in the middle to avoid water overtopping of the dikes.
- If bales are used as a core additional improvement, secure them exactly as shown in Figure 29 to avoid displacement when serge stone is placed.
- The outlet should be built prior to the construction of the gravel outlet.

MAINTENANCE CONSIDERATIONS

- Periodic inspections, preferable after each major storm.
- Watch for high intensity storm rainfalls.
- When damage occurs from high velocity flows, the outlet structures should be carefully repaired and reshaped to maintain its hydraulic characteristic
- To provide improved filtration, a straw bale core, staked and secured to the ground, should be placed in the center of the gravel outlet. In addition, this practice will lower construction costs by reducing the volume of serge stone required.
- To determine when cleaning is required, place a ribbon-marked stake at the low point of the basin or dike which represents the maximum height at 30% of trap efficiency. Appendix A-2 presents the trap efficiency calculations.
- When the maximum height of sediment is reached, clean the structure, replace the stone, and dispose of the silt in an appropriate area. Sometimes this material may be ideal for reestablishment of vegetation in denuded areas or construction of earthen dikes.
- Inspect the outlet.

E. STORM DRAIN OUTLET PROTECTION

Temporary or Permanent Level Spreader 110

Riprap 114

Paved Apron And/Or Riprap 116

TEMPORARY OR PERMANENT LEVEL SPREADER

DESCRIPTION

A level spreader (Figure 30) is an outlet built at zero grade across the slope whereby concentrated runoff may be discharged at non-erosive velocities onto undisturbed or stabilized areas.

FUNCTION

To convert a concentrated flow of storm runoff into sheet flow and to outlet it at reduced velocities onto areas stabilized by existing vegetation without causing erosion.

APPLICATION

It is used only in those situations where storm runoff is intercepted and diverted from graded areas, then released onto an undisturbed or stabilized area. Use of this control practice is restricted only where the spreader can be constructed on undisturbed soil and where the area directly below the level lip is stabilized by vegetative cover. The water must not be able to reconcentrate again below the point of discharge. Spreaders should not be used on highly erodible or expansive soils because their maintenance and repair will be a serious problem.

DESIGN CRITERIA

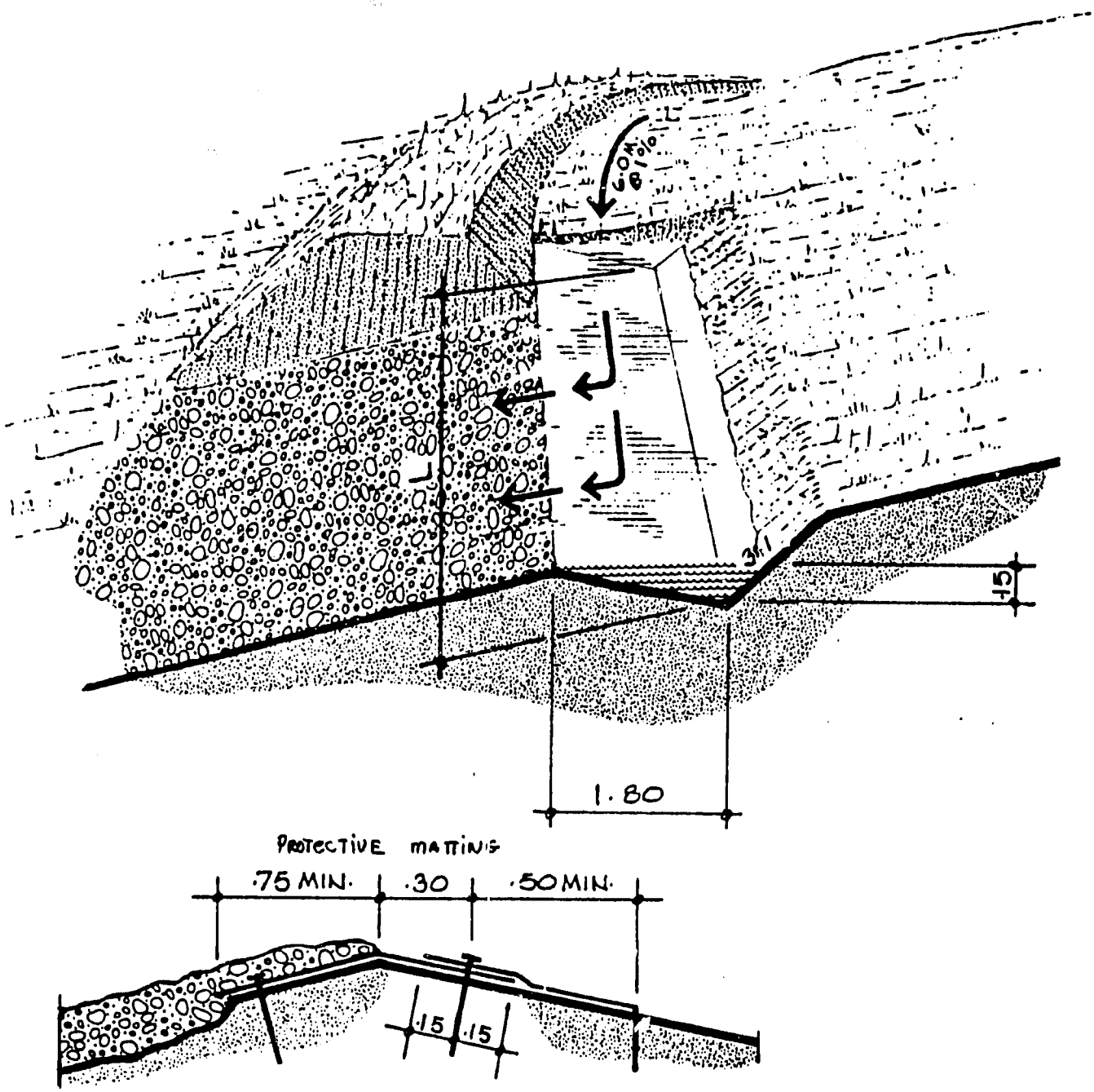
Drainage Area:

The area is determined by the capacity of the spreader. The capacity of the spreader is based upon the length of the level lip. See the table below for appropriate sizing details.

Table 8. Relationship of Capacity to Length of Level Spreader Lip

Designed Q (cfs)	Minimum Length ("L" in meters)
up to 10	4.5
10 to 20	6.0
20 to 30	8.0
30 to 40	11.0
40 to 50	13.5

Source: Fairfax County, Virginia. Public Facilities Manual, Volume III, 1977.



LEVEL SPREADER

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Width:

The width of the level spreader should not be in excess of 2 m.

Placement:

Measure from the edge of the lip to the center line of the channel. The entrance channel should not exceed 1% for at least 6 m. before entering the spreader.

Discharge:

The discharge is calculated based on the rational formula for a 10-year storm frequency.

Velocities:

The obtained velocity at the spreader lip should not exceed .90 m. per second (mps) unless a protective material is placed on top of it, in which case velocities should not exceed 2.0 mps.

Outlet:

The runoff must be discharged onto existing grade or stabilized outlet and the area below the spreader is vegetated or well stabilized.

For conditions different from these, the design has to be changed, and the use of a waterway or outlet is recommended.

CONSTRUCTION SPECIFICATIONS

- Level spreaders should be constructed under the direct supvervision of the engineer.
- Construct level lip on zero percent grade to insure uniform spreading of sediment-free runoff (converting channel flow to sheet flow).
- Entrance to spreader must be graded in a manner to insure that runoff enters directly onto a zero percent graded channel.
- Level spreaders should be constructed on undisturbed soil (not on fill).
- If required, a fiberglass (or similar) matting erosion stop should be placed vertically and at least .15 m. deep in a silt trench, .30 meters back of the level lip and parallel with the lip. This erosion stop should extend across the entire length of the level lip and should be trimmed after backfilling with tamped soil, so that the upper edge is flush with the soil surface.
- If required, the entire lip area should be protected by staking with two strips of jute or similar protective material (See Figure 30).

- The channel should not exceed 1% at least 6 m. before entering the spreader.

MAINTENANCE CONSIDERATIONS

- Regular inspections are required. Cleaning and repair are frequent, especially after heavy rainfails.
- Vegetative cover will almost always require watering and perhaps fertilizing until permanent cover is established.
- Maintenance and cleaning are of paramount importance for continued effectiveness.
- Repair of the level spreader lip should be carefully monitored.

RIPRAP

DESCRIPTION

A layer of loose rock or aggregate placed over an erodible soil surface.

FUNCTION

To protect the soil surface from the erosive forces of running water.

APPLICATION

Riprap is used where the soil conditions, water turbulence and velocity, expected vegetative cover, and groundwater conditions are such that the soil may erode under design flow conditions. Riprap may be used in such places as storm drain outlets, waterway channels, streambanks and bottoms, side ditches, and drop structures.

DESIGN CRITERIA

The design discharge should equal or exceed the maximum discharge from each reach of channel, and it should be based on maximum watershed development during the life of the structure.

Quality of Stone:
Stone for riprap should consist of field stone or rough, angular quarry stone of approximately rectangular shape. The stone should be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering, and it should be suitable in all other respects for the purpose intended.

Use in Drainage Ditches:
Factors to be weighed include an estimate of flow velocity, depth of channel and slope of the ditch flow line. Triangular ditches are not recommended due to the high risk of erosion at the bottom of the "V". A wide shallow channel with gentle side slopes (3:1 or greater) is preferred.

Table 9. Sizing of Riprap Stone for Drainage Ditches

FLOW VELOCITY (meters per second)	GRADED RIPRAP STONE (size in inches)		
	Max.	Avg.	Min.
1.5	3	1.5	1
2.0	6	3	2
3.0	12	6	3

Source: National Crushed Stone Association. Quarried Stone for Erosion and Sediment Control, June 1978.

Use in Pipe Outlet Protection:

The flow rate, culvert size and tailwater depth are important design considerations. Larger size riprap is required to handle storm drain flows which are discharged into a relatively level channel at the end of the pipe (non-scouring channel configuration). If a basin is prepared and lined with riprap (scour basin configuration), then it is capable of withstanding much higher velocity flows with smaller size riprap. Suggested size of riprap for either situation is indicated below:

Table 10. Sizing of Riprap for Outlet Basin Protection

FULL FLOW VELOCITY (Meters Per Second)		GRADED RIPRAP STONE (Size Centimeters)		
Scouring Basin	Non- Scouring Basin	Max.	Avg.	Min.
1.5	.5	6	3	2
2.5	1.0	12	6	3
3.0	1.5	18	9	5

Source: National Crushed Stone Association. Quarried Stone for Erosion and Sediment Control, June 1978.

CONSTRUCTION SPECIFICATIONS

- The subgrade for the riprap should be prepared to the required lines and grades. Any fill required in the subgrade should be compacted.

- The rock or gravel should conform to the specified grading limits when installed in the riprap.

- The stone for riprap may be placed by equipment. Both filter and riprap should each be constructed to the full course thickness in one operation and in such a manner to avoid displacement of the underlying materials. The stone for filter and riprap should be delivered and placed in a manner that will insure that the filter and riprap each will be reasonably homogeneous with the larger rocks uniformly distributed and firmly in contact one to another for purposes of filling the voids between the larger rocks. Hand placement may be required to the extent necessary to prevent damage to any nearby storm drainage structures.

PAVED APRON AND/OR RIPRAP

DESCRIPTION

Paved and/or riprap channel sections placed below storm drain outlets (Figure 31).

FUNCTION

To reduce the velocity of storm runoff before entering receiving streems or waterways.

APPLICATION

Used in conjuction with storm drain outlets, road culverts, paved channel outlets, etc,. which discharge surface runoff into existing streams, drainage courses or man-made waterways. Analysis and/or treatment of these flows extend from the end of the conduit, channel or structure to the point of entry into an existing stream or drainage course.

DESIGN CRITERIA

Length:
Minimum total length of riprap and/or paved section below outlet equals six times the diameter of the pipe or six times the depth of flow in the outlet channel.

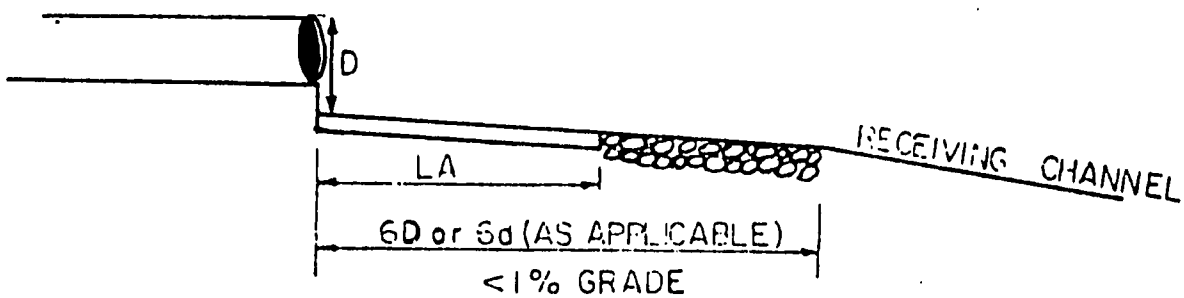
Grade:
Less than 1%.

Side Slopes:
2:1 or flatter.

Height of Sidewall:
The top of the sidewall should extend at least 30 centimeters maximum tailwater, but no lower than two-thirds of the vertical conduit dimension above the conduit invert.

Invert Elevation:
Equal to or lower than the lowest elevation on the cross-section immediately downstream from the end of the apron.

Riprap:
Riprap should be sized according to flow velocities. Where size of riprap is impractical, a concrete apron may be used with length determined according to the following table, and riprap the remainder of the length specified above.



PAVED APRON AND/OR RIPRAP

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Table 11. Calculation of Apron Length

OUTLET VELOCITY (fps)	Pipe Diameter in Inches (D)													
	15	18	21	24	27	30	33	36	42	48	54	60	66	72
	Length of Apron in Feet (LA)													
6	3	3	3	3	3	4	4	4	4	4	5	5	5	5
8	3	4	4	4	4	5	5	5	6	6	6	7	7	7
10	4	5	5	5	6	6	6	6	7	7	8	8	9	9
12	5	5	6	6	7	7	7	8	8	9	10	10	11	11
14	6	6	7	7	8	8	9	9	10	10	11	12	12	13
16	7	7	8	8	9	9	10	10	11	12	13	13	14	15
18	8	8	9	10	10	11	11	12	13	13	14	15	16	16
20	8	9	10	11	11	12	12	13	14	14	15	17	18	18
22	9	10	11	12	12	13	14	14	15	16	17	18	19	20
24	10	11	12	13	13	14	15	16	17	18	19	20	21	22
26	11	12	13	14	15	15	16	17	18	19	21	22	23	24
28	12	13	14	15	16	17	17	18	20	21	22	23	25	26
30	13	14	15	16	17	18	19	19	21	22	24	25	26	27

F. SOIL STABLIZATION PRACTICES

Vegetative Controls 120

Non-Vegetative Controls 123

VEGETATIVE CONTROLS

DESCRIPTION

Vegetative stabilization refers to the use of a wide variety of annual and perennial grasses and legumes which provide temporary or long-term protection of surface soils.

FUNCTION

The principal objective of vegatative soil stabilizers is to prevent soil erosion; to minimize the damages caused by runoff and sediment; and to enhance the physical appearance and aesthetic value of disturbed areas.

APPLICATION

In general, vegetative/non-vegetative and mechanical or structural control measures are used jointly in preventing or minimizing erosion and sedimentation problems. Therefore, considerable care and planning needs to be taken in the use of vegatative materials to determine whether temporary and/or long-term plant cover is required, what plant species are suitable to each region and site-specific problem area, and if the use of some temporary structural controls such as diversion dikes, straw bale barriers, waterways, etc. may be required to complement recommended vegetative control measures.

While vegetative cover is recognized as one of the most effective and least costly control strateges, its use must be guided by these plant growth factors:

- Slope gradient
- Depth of top soil
- Moisture content-drainage
- Soil structure and porosity
- Acidity (ph)
- Sun exposure and soil temperature
- Wind velocity
- Nutrient levels (nitrogen, phosphorus, magnesium and potassium)

These influencing factors in the selection of plant material should be considered as part of a systematic site analysis and soils testing program performed during the initial site investigation stage. In

general, the reestablishment of vegetation should be carried at the end of the tropical dry season and before commencement of the intensive rainfall period. Where seeds are to be used in establishing a protective cover of vegetation on denuded areas, a mixture is recommended so that quick germination and plant growth occur to provide early soil stabilization, followed by a more stable growth to fill in to meet desired long-term or permanent cover requirements.

ALTERNATIVE METHODS OF REESTABLISHING VEGETATION

- Seeding - The uniform spreading of grass and/or legume seeds on the soil surface may be accomplished by hand, cyclone seeder or hydro-seeder. With the exception of hydro seeding, the above-mentioned techniques require special soil preparation (loosening or roughening) for seed planting and provision of a mulch cover for protection against potential sun and rain damages. Table 12 below identifies a wide range of grass genera commonly used for erosion and sediment control purposes.

Table 12. Common Grasses Used For Revegetation Purposes

Region	Territory	Genera
East and Central Africa	Kenya	Cynodon, Pennisetum
	Uganda	Cynodon, Digitaria, Paspalum
	Tanganyika	Cynodon, Pennisetum
	Zanzibar	Stenotaphrum (also controls weeds)
	Somaliland	Any vegetation is regarded as helpful
	S. Rhodesia	Paspalum, Pennisetum
	N. Rodesia	Cynodon, Star, Swazi grasses
	Nyasaland	Paspalum
West Africa	N. Nigeria	Cynodon, Desmodium, Ipomoea
	E. Nigeria	Axonopus, Cymbopogon, Cynodon, Digitaria, Melinis
	Sierra Leone	Axonopus, Cymbopogon, Pueraria
West Indies	Barbados	Axonopus, Cynodon, Elusine, Euphorbia, Portulaca
	Br. Guana	Cyncdon
	Br. Honduras	Axonopus, Cynodon, Paspalum
	Jamaica	Bambusa, Vetiveria
	Antigua	Andropogon, Axonopus, Dicanthium
	Montserrat	Vetiveria, Sweet grass, Creeping grasses
	St. Kitts	Axonopus (wet sites), Cynodon (dry sites)
	Trinidad	Axonopus, Cynodon, Desmodium, Euphorbia, Mimosa, Sporobolus
	Dominica	Vetiveria
	Grenada	Andropogen, Axonopus, Cynodon, Cyperus, Panicum, Paspalum
	St. Vincent	Vetiveria, Panicum
Atlantic and Indian Ocean	Aden	None
	Bahamas	Cynodon, Sporobolus, Stylosanthes, Tribulus
	Bermuda	Stenotaphrum, Wedelia, Mesembryanthemum
	Mauritius	Cynodon, Stenotaphrum,* Ischaemum, Panicum †
Mediterranean	Cyprus	Most grasses and plants

Table continued

Region	Territory	Genera
Far East	Sinpapore	Axonopus, Digitaria, Ischaemum, Zoysia
	Sarawak	Axonopus, Chrysopogon, Ischaemum
	Hong Kong	Axonopus, Agrostis, Chrysopogon, Beuteloua, Cynodon
Western Pacific	Fiji	Decanthium, Ischaemum

* Low-and medium-rainfall areas
† High-rainfall areas

Source: Transportation Research Board of the National Academy of Sciences. Control of Erosion, 1979. Compendium 9.

- Sprigging- This method involves propagating by cuttings which are planted by spadding or cleating into the soil. Sqrigging is ideally suited to areas where labor costs are low or where severe steep slopes and high erodible soils require a quick solution. If sprigs are cleated in place, the resulting roughened soils increase groundwater recharge and reduce the amount of overland flow.

- Plugging - Refers to the use of sections of live grass and attached soil which have been manually or mechanically cut from established grass areas. This method of revegetation is more costly than seeding or sprigging, but is usually less expensive than sodding. Depending upon the climatic season when grass plugs are used, periodic watering may be required until the young plants establish sufficient root systems.

- Sodding - Strips of mature grass cover are used where immediate establishment of permanent vegetative cover is required. It may be applied in critical areas such as steep slopes, waterways or adjacent to building where splash protection is needed. Sod installation should occur within a period of 36 hours after being cut. Soil loosening is usually required prior to installation in order to facilitate root establishment. In addition, sodding requires fertilization, watering and some initial maintenance. In cases where it is used on steep slopes, waterways, or subject to moderately high runoff velocities, it should be staked or pegged to prevent it from slipping or being washed away.

NON-VEGETATIVE CONTROLS

DESCRIPTION

A variety of synthetic or natural processed materials used in temporary or permanent soil stabilization operations. These materials may include mulches or other stabilization materials such as jute or fiber glass nettings, plastic sheeting, burlap or crushed stone.

FUNCTION

To provide an additional series of flexible erosion and sediment control measures to complement either existing or planned structural or vegetative practices.

APPLICATION

Non-vegetative controls are used frequently to provided added erosion and sediment protection during the time when cover crops (grasses and legumes) are being established in areas where steep slopes or other physical limitations do not readily permit the use of mechanical measures or where grading operations are temporarily delayed and soil stabilization is required.

TYPES OF CONTROLS

1. Mulch:

A layer of shredded plant residue or inorganic material, applied to the soil surface after seeding to temporarily stabilize the soil and facilitate plant growth. Common types of mulches include:

- Straw, Hay or Grass

This is one of the best and least expensive temporary soil stabilizing materials available. It aids in conserving soil moisture, dissipating rain droplet energy, insulating against intense solar radiation and reducing erosion by sheet flow. It may be spread uniformly by hand or mechanically using a mulch blower. The rate of straw application will vary with local conditions, but is generally between 1000-1500 pounds acre(lbs.) or 70-90 lbs. per 1000 square feet. Where high wind or concentrated rainfall conditions prevail, it is advisable to anchor the straw. This may be accomplished by a crimper or form dis pulled along the slope contour, spraying asphalt or chemical tacks to bind the mulch together or using netting of jute, fiber glass or plastic where concentrated flows are expected to occur.

- Bagasse

  This is the unprocessed cane fibers from the sugar cane industry. When cut with a shredder or mulch machine, it is heavier but similar in size to straw mulch. Bagasse may be applied manually or mechanically at a rate of 1-2 tons per acre.

- Bark and Sawdust

  The outer skin or bark waste from sawmills serves as an excellent protective ground cover. It should be shredded or hogged to produce a uniform size for mulch purposes. Sawdust can be used as a soil conditioner or protective mulch cover however, it is subject washout on steep slopes. It should be applied 2-6 inches deep or a minimum of 300 cubic yards per acre.

- Wood or Brush Chips

  During clearing operations, the mulch formed from small branches trees and shrubs can be stored and later used for soil stabilization. Chips may be spread by hand or machine after soil and seeding preparations have taken place.

- Manure

  Animal wastes can serve both as a protective mulch and plant nutrient material. When applied at a rate of 8-10 tons per acre, or 370-460 lbs. per 1000 square feet, it has proven to be an effective erosion control on slopes of 10-12 percent. Where weed plants are not desirous, cow manure is recommended over the use of horse manure.

2. Netting, Matting and Sheeting

   A wide range of netting and matting materials can be used to supplement mulching, seeding, sodding, etc. type controls in critical areas of steep slopes or concentrated runoff flows. These porous coverings may be used with or without mulch and are made of jute, fiber glass, plastic or polypropylene monofilament yarn. They are designed to prevent the dislodgement of soil particles by runoff while permitting vegetation to grow up through them.

APPENDIX A

SEDIMENT BASIN DESIGN

Siltation Basin Clean-Out Criteria (for basins of 8 acres or less)

Clean-out @ 50% trap efficiency

Area Contributing to Basin (CA): _____ Ac. (Assume Average Basin Area A_1 (AC.) and Depth "d" feet)

Desired Silt Storage (DS): A x 0.5" x 1/12 = _____ Ac./Ft.

Actual Storage Available (AS): d x A_1 = _____ Ac./Ft.

Predicted Trap Efficiency:

Storage / Ac. In. = (AS) x 12 = (S) Ac./In.

Storage per Drainage Area Acre: $\frac{S}{A}$ = In./Ac.

Check Trap Efficiency - See Appendix A-6

To Determine Clean-Out Depth:

50% Trap Efficiency = 0.19 In./Ac. (Derived from Appendix A-6)

Storage in Ac./In. (S_1) = 0.19 x A = _____ Ac./In.

Storage in Ac./Ft. (S_2) = $\frac{S_1}{12}$ = _____ Ac./Ft. (Remains)

Volume Filled (S_3): As - S_2 = _____ Ac./Ft.

Area of Sediment Basin: (A_1) = _____ Ac./Ft.

Volume Filled: A_1 x d_1 = S_3

$d = \frac{S_3}{A_1} = d_1$ Ft. Clean-out when silt reaches depth of d_2 or when silt is ($d-d_2 = d_1$) below top of stone or pipe spillway.

APPENDIX A

SEDIMENT BASIN DESIGN PROCEDURE
FOR CLEAN-OUT

1. Determine Drainage Area - For Design "Q" (10 Yr. Storm)

2. Determine "Disturbed" Drainage Area - For sediment storage
(Note that 1/2" storage for
(entire drainage area is
(needed for 70% trap effic

3. Determine Desired Sediment Storage

   = 1/2" per Disturbed Acre. Convert to Acre Ft. or Acre In.

4. Determine Available Silt Storage in proposed basin.

   Capacity of basin to emergency spillway crest

5. Check Trap Efficiency

   Divide Acre - In. Storage by Total Drainage Area

   = Inches per drainage - area acre

   Check result against Curve on Appendix A-6 (Trap efficiency of 65-75% is desirable).

6. Determine Clean-Out Level

   Determine volume giving 50% trap efficiency - this is the remaining volume. Subtract remaining volume from the total available storage - this is the filled portion. Determine elevation at which this condition exists. Basin should be cleaned out when silt reaches this level (50% trap efficiency remaining). Relate this elevation to distance below riser crest.

7. Determine Size of Required Pipe Spillway. (Riser)

   Pipe spillway to pass 5" run-off from drainage area in 24 hours:

   (5" per Acre/24 hours. = .21 cfs per acre)

Req. Q_p = .21 x Drainage Area

Determine H_x = Water Surface El-Riser El.

Check Conduit and riser sizes to pass required Q_p using Charts p. 173, 174 and 176.

Both pipe and riser must pass Q_p. Normally use Riser with 1-1/2 x cross-section of conduit. Riser is perforated pipe.

8. Determine Size of Emergency Spillway.

Require Qes = Design Q - Q Pipe

Using Charts p. 17 and 17 determine combination of spillway bottom width, side slope, surface, and H_p which will produce required outflow. To increase Hp, either raise dam crest or lower emergency spillway and riser crests. Maintain 1' freeboard.

Show:
- b - bottom width
- z - side slope
- s - control slope, min. slope
- v - velocity
- x - control slope min. length

critical values

Check that velocity is acceptable for available soil and cover. If slope greater than S is used, check velocity: $V_e - V_e \left(\frac{se}{sc}\right)^{3/10}$ No V should exceed 6 feet per second.

9. Determine Need for and Spacing of Anti-Seep Collars.

Not required for CMP of 10" diam. or less.

a faulty conclusion - Seepage potential is a function of hydraulic head and soil media conditions, both unrelated to pipe diameter.

Spacing, with V (Vertical projection) of 2' standard:

Number: $\frac{L + 2nV}{L} = 1.1$ $\quad n - \frac{0.1\ L}{4} = .025L$

Space at distance no greater than 14V.

10. Check for Trash Rack

If $Q_p = \frac{Q10}{4}$, trash rack is required. Welded rods, to W.S. El. are acceptable.

11. Check for Anti-Vortex Device. (To insure head on pipe)

Use if riser diam. is 15" or greater

12. Drainage. Place the riser at the lowest point in the storage area, with the lower half in a cone of graded, crushed stone, preferably Virginia Department of Highways Specification 3 or 5. A six-inch perforated pipe with closed upper end, extending horizontally to the upstream limit of the cone, will assist in drying out the silt basin. This, in turn, will greatly facilitate clean-out.

Note that:

A dry basin has maximum storage space, and hence has better trap efficiency than one full of water.

A dry basin is much less of a safety hazard -- fencing may not be needed if occupied dwellings are not nearby.

TYPICAL NOTES - SEDIMENT BASINS

1. Construct temporary sediment basins prior to beginning or as the first step in rough grading operations.

2. The dam site shall be cleared and grubbed.

3. Embankment material is to be taken from approved borrow areas free from roots, woody vegetation and oversized stones. The material shall be placed in 9" layers (loose) and compacted by at least one tread of loaded spreading equipment (scraper) or 2 passes of a sheeps foot roller over the entire surface of each layer.

4. The reservoir area shall be cleared adn all trees cut off flush with the ground.

5. The top and sides of the embankment and emergency spillway shall be covered with topsoil and fertilized, seeded and mulched.

6. The emergency spillway shall be cut into undisturbed ground with 4 : 1 side slopes. The bottom width is to be as shown in the tabulation or as shown on the drawings. The approach slope is to be not less than 3%.

7. All bare earth surfaces shall be protected by seeding with oast, rye or other temporary cover, and with mulch, until a stand of semi-permanent vegetation is developed.

8. Excavate fill material from within the silt basin to increase the water and silt storage capacity.

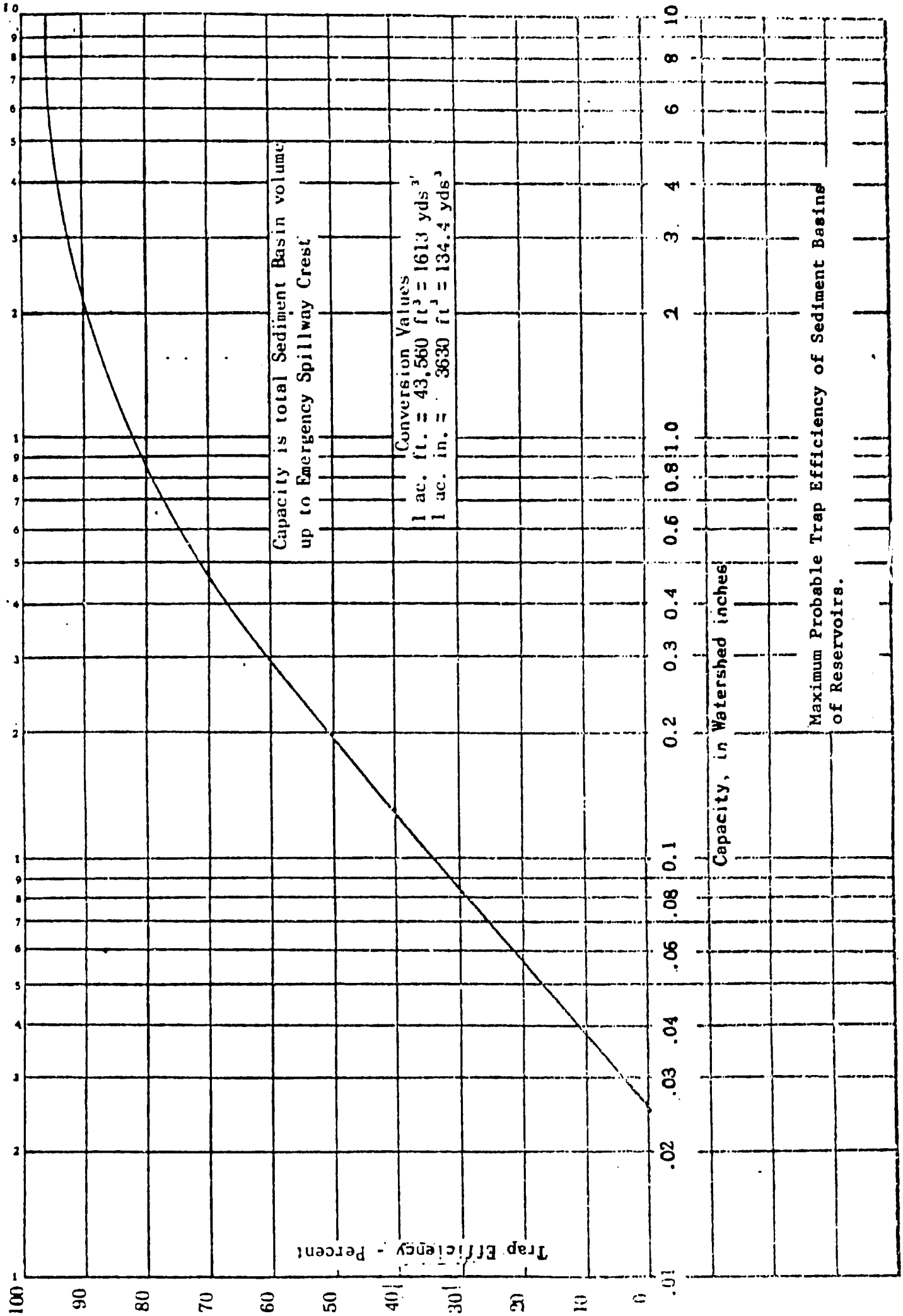
9. Temporary silt basins are to be maintained by the developer, and are to be cleaned out when silt reaches the elevation show below:

Basin "A"	1'-6" below riser top	(Mark with red paint
Basin "B"	6" below riser top	on riser)

10. If water tends to pond deeper than 18 inches for periods in excess of 24 hours, snow fencing or equivalent shall be erected around the minimum pool for child safety. (Applies when occupied houses are within one-half mile of the site.)

11. Temporary silt basins are to be removed and the sites restored to natural condition when the drainage area has been stabilized as approved by the inspector.

(These notes are "typical", but the minimum required)



Maximum Probable Trap Efficiency of Sediment Basins of Reservoirs.

Source: Fairfax County.

SAMPLE WORK SHEET #1

SEDIMENT BASIN CLEAN-OUT CRITERIA

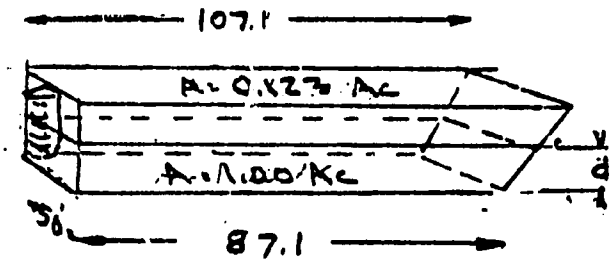
"Clean out at 50% Trap Efficiency ..."

I. Assume: Drainage Area = 10 Acres

Desired Sediment Storage = 10 x 0.5 x 1/12 = 0.417 Ac. Ft.

Assume: Storage Basin Shown:

Emer. Spillway Crest: 4.00'
Riser Crest: 3.00'
Basin Invert 0.00'



Actual Storage Available = $\frac{0.100 + 0.123}{2} \times 4 = 0.446$ Ac.Ft.

Predicted Trap Efficiency:

Storage in Acre-In = 0.446 x 12 = 5.35 Ac. In

Storage per Drainage Area Acre = $\frac{5.35}{10} = 0.535$ In.

From Appendix A-6: 0.535 In = 72% Trap Efficiency

To Determine Clean-Out Depth: Determine elevation at which remaining volume provides 50% trap efficiency.

Determine 50% Trap Efficiency Volume:

From Appendix A 6: 50% Trap Efficiency = 0.19 In. per drainage Area Acre

Storage in Acre-In = 0.19 x 10 = 1.9 Ac In

Storage in Acre-Ft = 1.9/12 = 0.158 Ac.Ft.

∴ Determine Elevation at which 0.158 Ac Ft REMAINS

Volume Filled = 0.446 − 0.158 = 0.288 Ac Ft.

Assume depth = d and Average area = 0.109 Ac

Volume Filled = 0.109 x d = 0.288

$d = \frac{0.288}{0.109} = 2.64$ Ft

Check: Remaining volume = $(4.00 - 2.64)\left(\frac{.118 + .123}{2}\right)$

= 1.36 x .120 = 0.163 Ac Ft.

Close: OK

THEREFORE: Clean out when sediment reaches depth of 2.64 Ft, or when sediment is 3.0 − 2.64 = 0.36 Ft below riser crest

MARK THIS ELEVATION ON RISER!

SAMPLE WORK SHEET #2

II. Assume: Drainage Area = 20 Acres

Desired sediment Storage = $\frac{20 \times 0.5}{12}$ = 0.834 Ac. Ft.

Assume no change in available storage = 0.446 Ac Ft.

Predicted Trap Efficiency:

Storage in Acre-In = 0.446 x 12 = 5.35 Ac In.

Storage per drainage area acre = $\frac{5.35}{20}$ = 0.268 In.

From Appendix A-6: 0.268 In = 58% Trap Efficiency

To determine clean-out depth: Determine elevation at which remaining volume provides 50% trap efficiency:

Determine 50% Trap Efficiency Volume:

From Appendix A 6, 50% Trap Efficiency requires 0.19 In/Acre

Required storage = 0.19 x 20 = 3.8 Acre-In

Storage in Ac Ft. = $\frac{3.8}{12}$ = 0.317 Ac. Ft.

Determine elevation at which 0.317 Ac Ft. Remains.

Volume Filled = 0.446 - 0.317 = 0.129 Ac Ft

Assume Ave Area = 0.104 Ac $\left(\frac{.100 + .108}{2}\right)$

Volume Filled = 0.129 = 0.104 d

$d = \frac{0.129}{0.104} = 1.24'$

Check: Remaining Volume = $(4.00 - 1.24)\left(\frac{.108 + .123}{2}\right)$

= 2.76 x .115

= 0.317 Ac Ft

Ok

Therefore: Clean out when sediment reaches depth of 1.24 Ft, or when sediment is 3.00 - 1.24 = 1.76 Ft below crest of riser

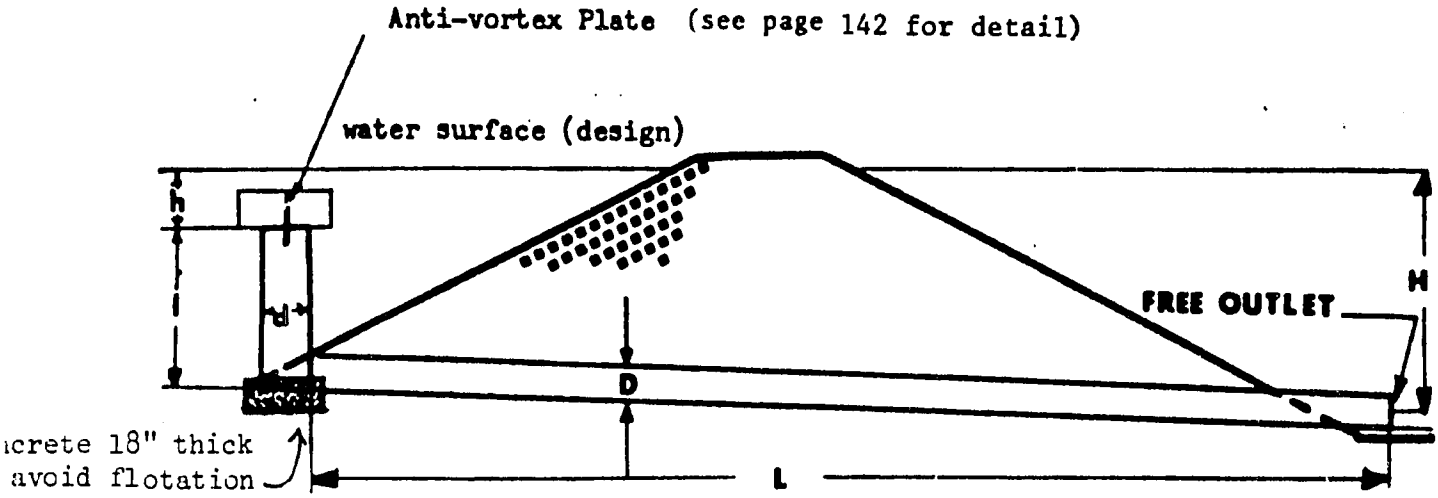
(More frequent clean out than for Case I)

Use a practical value — say nearest quarter of a foot.

APPENDIX B

PIPE SPILLWAY DESIGN

PIPE SPILLWAY DESIGN



H = Head operating pipe spillway (pipe flow) ft.
h = Head operating inlet riser (water flow) ft. h - 1' min.
L = Length of pipe in ft.
l = Length of operating inlet riser.
D - Diameter of pipe conduit
d = Diameter of pipe riser.

Spillway discharge capacities should be reduced 40% if no anti-vortex device is used.

To use charts:

See page B-4, or B-5 with H. (Coming from trap efficiency calculations). Read discharge under diameter of pipe conduit.

Enter chart, page B-6, with h. Read discharge under diameter of riser. Spillway discharge, Q = smaller of values obtained.

Example:

Given: D = 12" CMP
L = 60'
H = 9' to centerline of pipe - Free outlet
h = 1.5'
Find Q of spillway and size of riser
From inlet proportion table on page 138 for 12" pipe use 15" riser
Q pipe = 6.0 cfs x (correction factor) 1.07 = 6.4 cfs from page 140.

Q riser = 7.7 cfs from page 141 . < 6.4 cfs
Q ps - 6.4 cfs

TEMPORARY SEDIMENT BASIN DESIGN DATA SHEET

Computed by_____ Date_____

Checked by_____ Date_____

Project_____
Basin #_____ Location_____
Total Drainage Area_____ Acres. Total Disturbed Area_____ Acres.

SEDIMENT STORAGE DESIGN

1. Min. required storage = 0.5 inches x___ac. drainage x 1/12=_____ac.ft.
2. Approx. Vol. of basin = (0.4) (Surface ac.) (Max. depth in ft.)=_____ac.ft.
3. Excavate_____c.y. to obtain required capacity.
   Elevation corresponding to scheduled time of clean out_____
   Distance below top of riser_____

DESIGN DATA

Runoff

4. Q_T = CIA = _____x_____X_____=_____cfs (or other appropriate method)

Pipe Spillway (Q_{ps})

5. Min. pipe spillway capacity, Q_{ps} = 0.21 x_____D.A. Ac. = _____cfs
6. Barrel: Diam._____inches; Length_____ft.; Fall_____ft.
7. Riser: Diam._____inches; Length_____ft.
8. Actual Discharge (from APPENDIX B)
   H = _____ft. h = _____ft.
   Q_{ps} = _____cfs

Emergency Spillway Flow Q_{es}

9. $Q_{es} = Q_T - Q_{ps}$ = _____-_____=_____cfs

Emergency Spillway Design (from APPENDIX B)

10. Width_____ft. H_____ft.
    Entrance channel slope_____%
    Exit channel slope_____%

DESIGN ELEVATIONS

11. Riser Crest =_____ Design High Water =_____
    Em. Spwy. Crest =_____ Top of Dam =_____

TEMPORARY SEDIMENT BASIN DESIGN DATA SHEET INSTRUCTIONS FOR USE OF FORM

1. Minimum required trap efficiency requires storage of 0.5" of sediment from each acre of drainage. Values larger than 0.5% may be used for greater protection. Compute volume using entire drainage area although only part may be disturbed.

2. Approximate volume of basin is obtained using formula $V = 0.4\ A\ d$.[1/] Volume may be computed from contour information or other suitable methods.

3. If volume of basin is not adequate [illegible] required storage, excavate to obtain volume.
   Conversions: 1 ac. ft. = 43,56[illegible] cu. ft. = 1,613 c.y.

4. If rational method is used to compute run-off, obtain appropriate values for "I" and "C", depending upon water shed conditions during development.

5. Required discharge from pipe spillway equals 0.21 cfs/ac. times total drainage area. This is equivalent to a uniform run-off of 5 inches per 24 hours. The pipe may be designed to carry Q_T if site conditions preclude installation of an emergency spillway to protect the structure). Q_T - Total Discharge

6. Record appropriate sizes.

7. Determine value of "H" from field conditions; "H" is interval between design flow crest and centerline of outlet pipe. "h" is interval between design flow crest and riser crest. Use rating curves to obtain value for Q_{ps} actual. Q_{ps} = principal spillway discharge.

8. Compute Q_{es} by subtracting actual flow carried by the pipe spillway from the total inflow, Q_T. Q_{es} = Emergency spillway discharge.

9. Use appropriate tables to obtain values of H_p, bottom width, and actual Q_{es}. If no emergency spillway is to be used, so state, giving reason.

10. Fill in design elevations. Emergency spillway crest must be set no lower than value of "h" which causes pipe spillway to carry the minimum required Q. The elevation difference between spillways shall be not less than 1 foot. Design high water is the elevation of the emergency spillway crest plus the value of H_p, or, if thereis no emergency spillway, it is the elevation of the riser crest plus h required to handle the ten-year storm. Minimum top of dam elevation requires 1.0 feet of freeboard above design high water.

1/ Actually: $\frac{d}{3}(A - a - \sqrt{Aa})$

A = Area at surface
a = Area at bottom
d = Height of Basin

PIPE FLOW CHART (Full flow assumed)

For Corrugated Metal Pipe Inlet $K_e + K_b = 1.0$ and 70 feet of Corrugated Metal Pipe Conduit n = 0.025. Note correction factors for other pipe lengths.

Dia. / H	12"	15"	18"	21"	24"	30"	36"	42"
2	2.84	4.92	7.73	11.30	15.60	26.60	40.77	58.12
3	3.48	6.03	9.47	13.84	19.10	32.58	49.93	71.19
4	4.02	6.96	10.94	15.98	22.06	37.62	57.66	82.20
5	4.49	7.78	12.23	17.87	24.66	42.06	64.46	91.90
6	4.92	8.52	13.40	19.57	27.01	46.07	70.60	100.65
7	5.32	9.21	14.47	21.14	29.19	49.77	76.28	108.75
8	5.68	9.84	15.47	22.60	31.19	53.19	81.53	116.33
9	6.03	10.44	16.41	23.97	33.09	56.43	86.49	123.30
10	6.36	11.00	17.30	25.26	34.88	59.48	91.16	129.96
11	6.67	11.54	18.14	26.50	36.59	62.39	95.63	136.33
12	6.96	12.05	18.95	27.68	38.21	65.16	99.87	142.37
13	7.25	12.55	19.72	28.81	39.77	67.83	103.96	148.21
14	7.52	13.02	20.47	29.90	41.27	70.39	107.88	153.80
15	7.78	13.48	21.19	30.95	42.72	72.85	111.66	159.18
16	8.04	13.92	21.88	31.96	44.12	75.24	115.32	164.40
17	8.29	14.35	22.55	32.94	45.48	77.55	118.87	169.46
18	8.53	14.77	23.21	33.90	46.80	79.81	122.33	174.39
19	8.76	15.17	23.84	34.83	48.08	81.99	125.67	179.15
20	8.99	15.56	24.46	35.73	49.33	84.12	128.93	183.80
21	9.21	15.95	25.07	36.62	50.55	86.21	132.13	188.36
22	9.43	16.32	25.65	37.47	51.73	88.22	135.21	192.76
23	9.64	16.69	26.23	38.32	52.90	90.21	138.27	197.12
24	9.85	17.05	26.80	39.14	54.04	92.15	141.24	201.35
25	10.05	17.40	27.35	39.95	55.15	94.05	144.15	205.50
L	Correction Factors For Other Pipe Lengths							
40	1.23	1.22	1.20	1.19	1.16	1.14	1.13	1.11
50	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07
60	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.03
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	0.95	0.95	0.95	0.96	0.96	0.96	0.97	0.97
90	0.90	0.91	0.91	0.92	0.92	0.93	0.94	0.94
100	0.86	0.87	0.88	0.89	0.89	0.90	0.91	0.92

Pipe flow chart for corrugated metal pipe drop inlet spillway

PIPE FLOW CHART (Full Pipe flow assumed)

For R/C Drop Inlet, $K_e + K_b = 0.65$ with 70 feet of R/C conduit, n = .013. Note correction factors for other pipe lengths.

H \ Dia.	12"	15"	18"	21"	24"	30"	36"	42"
2	4.54	8.01	11.74	16.60	22.44	36.74	54.65	76.02
3	5.56	9.81	14.39	20.33	27.49	45.00	66.94	93.11
4	6.42	11.33	16.61	23.48	31.74	51.96	77.30	107.52
5	7.18	12.66	18.57	26.25	35.49	58.09	86.42	120.21
6	7.87	13.86	20.34	28.75	38.87	63.63	94.65	131.66
7	8.50	14.98	21.98	31.06	41.99	68.74	102.27	142.25
8	9.08	16.01	23.49	33.20	44.88	73.47	109.30	152.03
9	9.64	17.00	24.92	35.22	47.61	77.94	115.95	161.28
10	10.16	17.91	26.26	37.12	50.18	82.15	122.21	169.99
11	10.65	18.78	27.55	38.94	52.64	86.18	128.20	178.32
12	11.13	19.62	28.77	40.67	54.97	89.99	133.88	186.22
13	11.58	20.42	29.95	42.33	57.23	93.68	139.37	193.86
14	12.01	21.18	31.07	43.93	59.37	97.19	144.59	201.12
15	12.44	21.93	32.17	45.47	61.46	100.62	149.69	208.21
16	12.85	22.65	33.22	46.96	63.48	103.92	154.60	215.04
17	13.24	23.35	34.24	48.40	65.43	107.12	159.35	221.65
18	13.63	24.03	35.24	49.81	67.34	110.23	163.99	228.10
19	14.00	24.68	36.21	51.17	69.18	113.25	168.48	234.34
20	14.36	25.32	37.14	52.50	70.97	116.18	172.84	240.41
21	14.72	25.95	38.07	53.80	72.73	119.07	177.13	246.38
22	15.06	26.56	38.96	55.06	74.43	121.85	181.27	252.13
23	15.40	27.16	39.84	56.31	76.11	124.60	185.36	257.83
24	15.73	27.74	40.69	57.51	77.75	127.28	189.35	263.37
25	16.06	28.32	41.53	58.70	79.35	129.90	193.25	268.80
L	Correction Factors For Other Pipe Lengths							
40	1.15	1.13	1.11	1.09	1.08	1.06	1.06	1.05
50	1.09	1.08	1.07	1.06	1.05	1.04	1.04	1.03
60	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.02
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	0.96	0.96	0.97	0.97	0.98	0.98	0.98	0.99
90	0.93	0.94	0.94	0.95	0.95	0.96	0.97	0.97
100	0.90	0.91	0.92	0.93	0.93	0.95	0.95	0.96

Pipe flow chart for concrete pipe drop inlet spillway

PIPE FLOW CHART FOR SMALL SIZE PIPES

Discharge in C.F.S.

For 70 Feet of Welded Steel Pipe:

Head \ Dia	4"	6"	8"
4	0.42	1.19	2.42
6	0.51	1.45	2.95
8	0.60	1.69	3.42
10	0.66	1.89	3.82
12	0.73	2.06	4.19
14	0.79	2.23	4.52
16	0.84	2.38	4.83
18	0.89	2.53	5.13
20	0.94	2.66	5.40

Correction for Other Pipe Lengths

L	4"	6"	8"
40	1.20	1.19	1.17
50	1.12	1.11	1.10
60	1.06	1.05	1.05
70	1.00	1.00	1.00
80	.94	.95	.95
90	.91	.92	.93
100	.86	.87	.88

For 70 Feet of Corrugated Metal Pipe:

Head \ Dia	4"	6"	8"
4	NOT AVAILABLE	0.67	1.41
6		0.82	1.72
8		0.95	2.00
10		1.06	2.23
12		1.16	2.44
14		1.25	2.64
16		1.33	2.82
18		1.42	3.00
20		1.50	3.16

Correction for Other Pipe Lengths

L	4"	6"	8"
40	NOT AVAILABLE	1.26	1.25
50		1.16	1.15
60		1.08	1.07
70		1.00	1.00
80		0.94	0.94
90		0.89	0.90
100		0.84	0.85

From: Erosion and Sediment Control Technical Handbook,
James River Soil and Water Conservation District

CIRCULAR RISERS WITH SPLITTER WALL

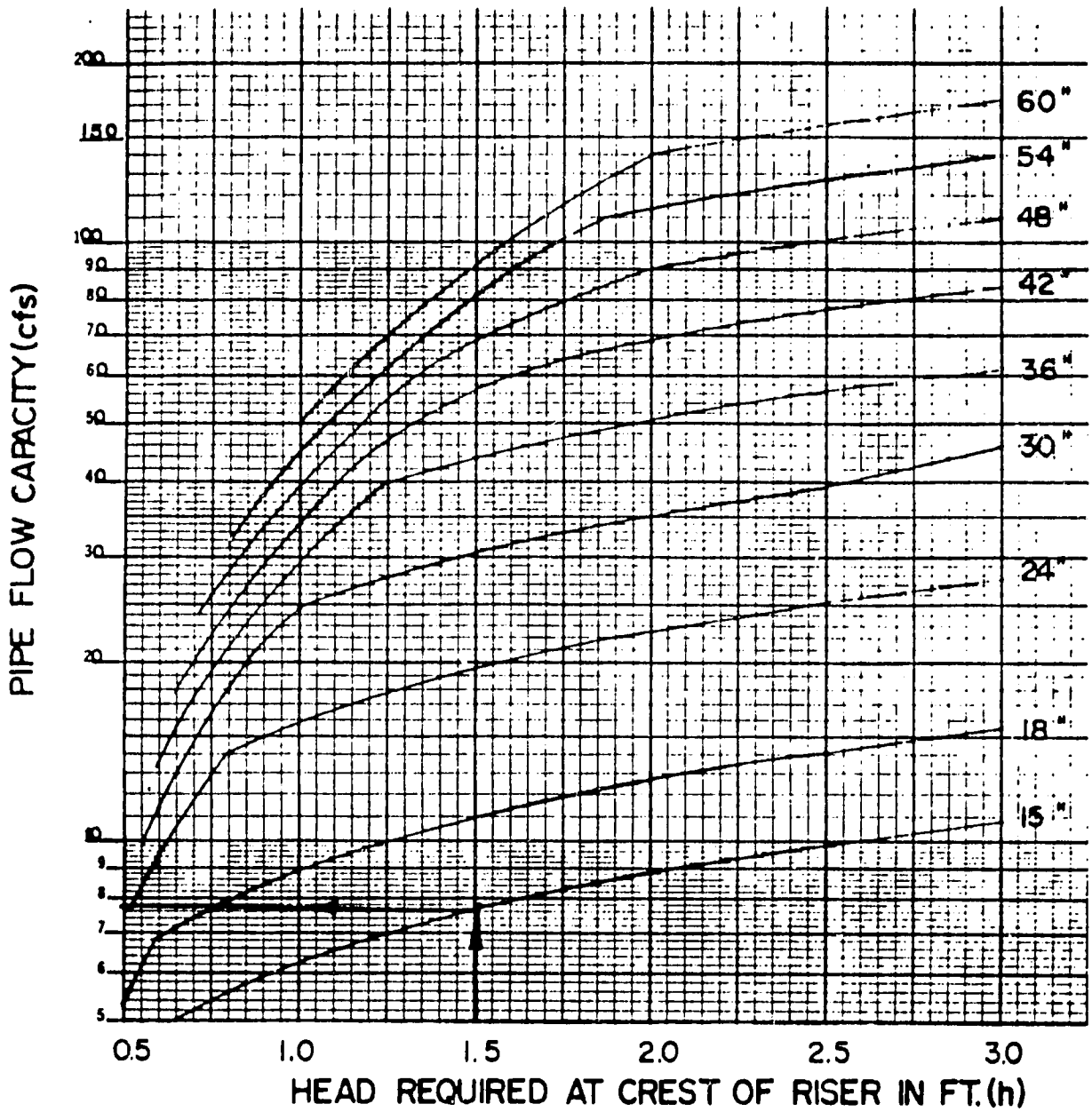
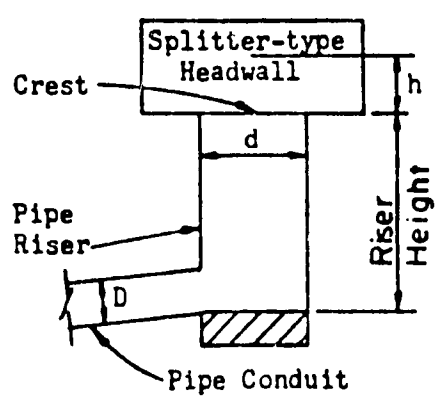
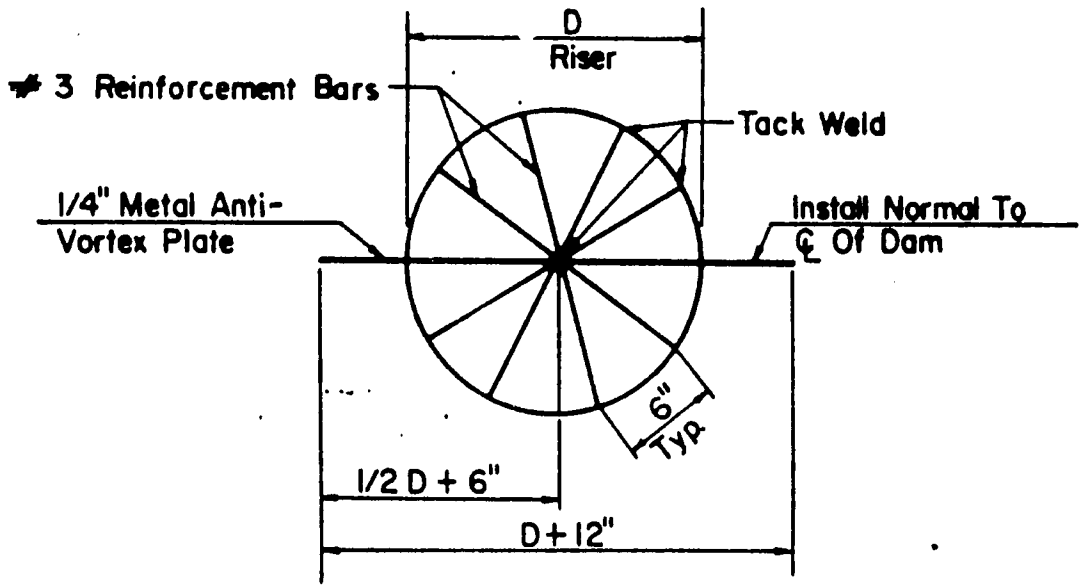


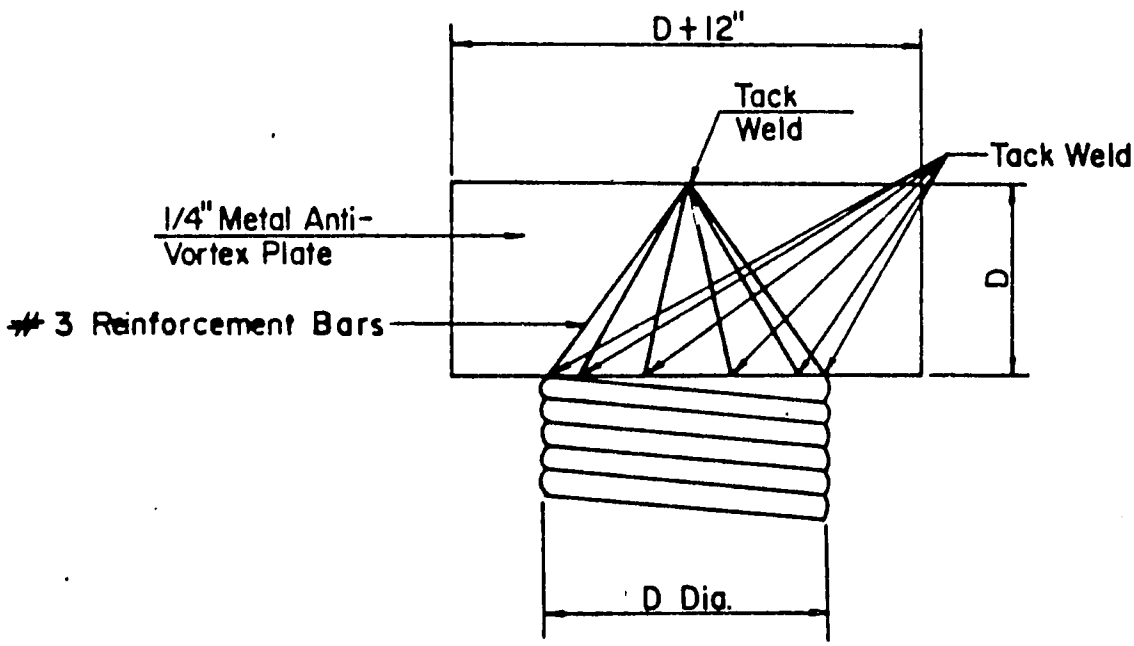
CHART FOR DETERMINING INLET PROPORTIONS

Suggested Inlet Proportions	
Pipe Conduit (D)-in.	Pipe Riser (d)-in.
8-12	15
15	18
18	21
21	24
24	30
30	36
36	48
42	54
48	60



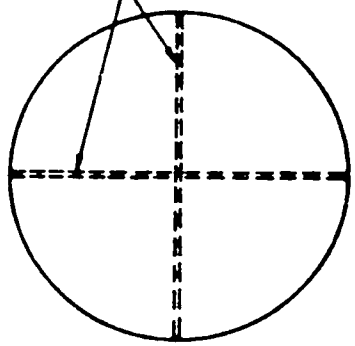


PLAN

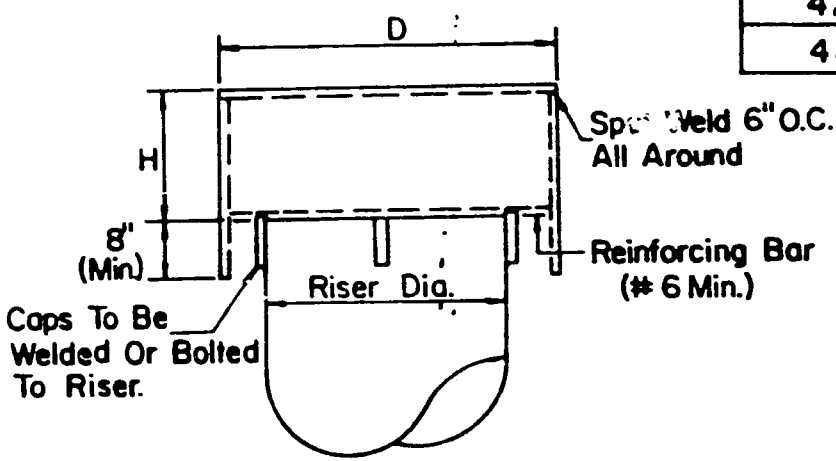


SECTION

DETAIL OF TRASH RACK AND ANTI-VORTEX DEVICE



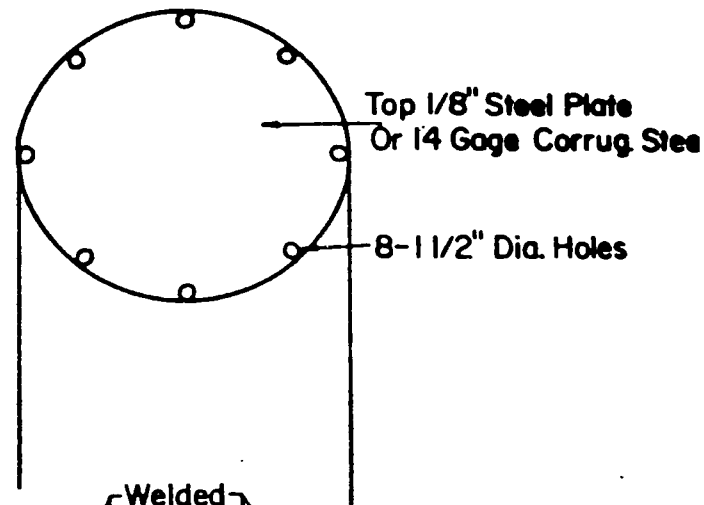
PLAN VIEW

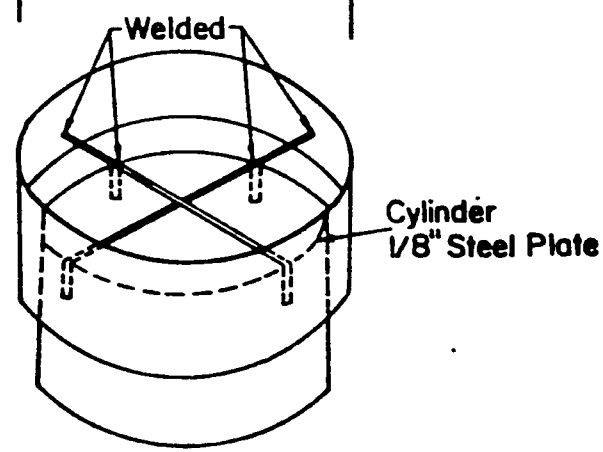


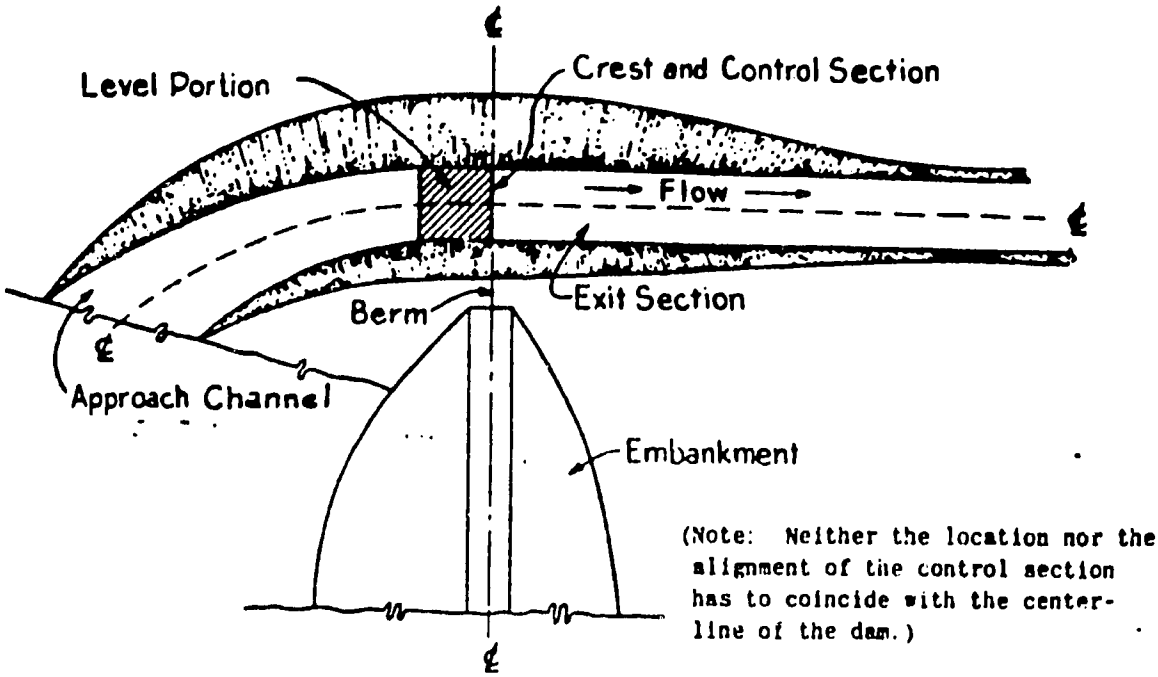
ELEVATION

DESIGN TABLE

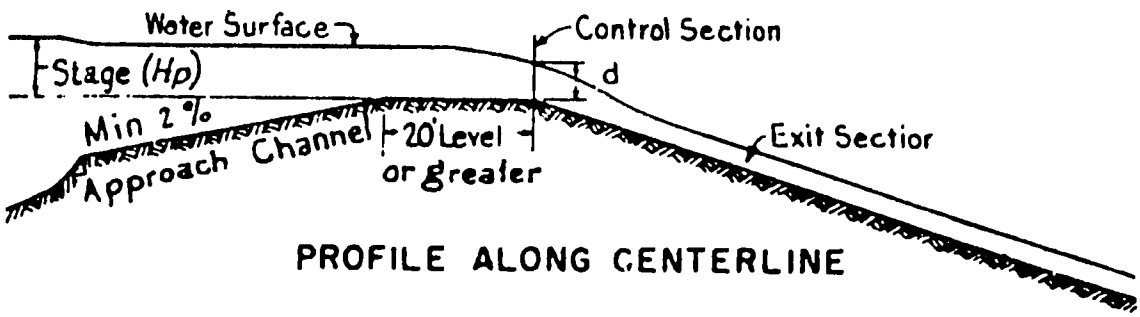
Riser Dia.	D Inch	H Inch
18	27	8
21	30	11
24	36	13
27	42	15
36	54	17
42	60	19
48	68	21



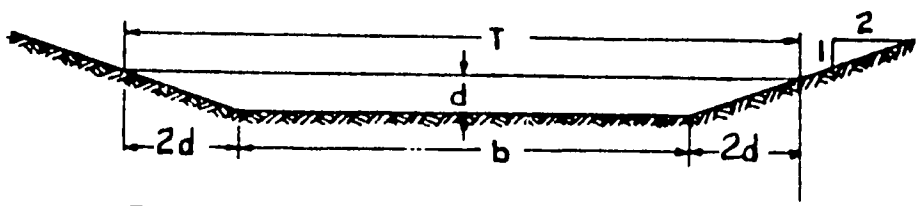




PLAN VIEW OF EXCAVATED EARTH SPILLWAY



PROFILE ALONG CENTERLINE



CROSS-SECTION AT CONTROL SECTION

Profile and cross section of excavated earth spillway.

EARTH SPILLWAY

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet Hp.
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.61
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q=87 c.f.s. Spillway Slope, Exit section (from profile)= 4%.

Find: Bottom Width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 feet. Use narrower bottom width, 24 feet, to minimize meandering. Stage in Reservoir will be 1.32 feet.

Note: Computations based on: Roughness coefficient, n=.040. Maximum velocity=5.50 ft. per sec.

DESIGN TABLE FOR VEGETATED SPILLWAYS

APPENDIX C

RUNOFF COEFFICIENTS FOR USE WITH RATIONAL FORMULA

RUN-OFF COEFFICIENTS FOR USE WITH RATIONAL FORMULA

RATIONAL FORMULA = Q = C.I.A. WHERE:

Q = Run-off generated in a water shed

C = Run-off coefficient (Above)

I = Intensity of rainfall per hour

A = Area of water shed in acres

VALUES OF "C"

TYPE	"C"
PAVED AREAS:	
Concrete or Bituminous	0.80 - 0.90
Gravel	0.45 - 0.60
MISCELLANEOUS:	
Parkland, Cemetaries	0.10 - 0.25
Schools	0.50 - 0.60
Roof Surfaces	0.90 - 1.00
Unimproved Areas	0.10 - 0.30
SOILS:	
Sandy to Silty Clay Earth - Greassed	0.20 - 0.60
Silty to Clay Gravel Earth	0.15 - 0.50
Loam	0.10 - 0.40
Sandy Soils	0.10 - 0.40
Turf Meadows	0.10 - 0.40
Cultivated Fields	0.20 - 0.40
Forested Areas	0.10 - 0.30

APPENDIX D

VALUES OF "n" IN MANNING FORMULA

VALUES OF "n" IN MANNING FORMULA

MANNING FORMULA:

$$Q = \frac{1.48}{n} \times A \times R^{2/3} \times 5\text{-}1/2$$

WHERE: Q = Discharge in cfs

N Manning coefficient (Above).

A = Area of designed channel section of sf.

R = Hydraulic Radous = $\frac{A}{P}$ (P = wetted Peri-meter)

S = Sradient Slope in ft/ft.

TYPE OF CHANNEL

Closed Conduits

Reinforced Concrete Pipe		0.013
Reincorced Concrete Elliptical Pipe		0.013
Corrugated Metal Pipe		
1 - 2-2/3" x 1/2" Corrugation (Riveted Pipe)		
a. Plain or fully coasted		0.024
b. Paved invert		
"/" Circumference paved	25%	50%
Depth of Flow; full	0.021	0.018
.8D	0.021	0.016
.6D	0.019	0.013
c. Corrugated mental arch pipe full coated with paved invert; Flowing full		0.019
Smooth Flow Pipe		0.013
Vitrified Clay Pipe		0.013

Open Channels; Lined

Asphalt	0.013 to 0.016
Brick	0.013 to 0.015
Concrete:	
Trowel Finish	0.013
Float Finish	0.015
Unfinished	0.017
Concrete, bottom float finished, with sides of:	
Dressed Stone	0.017
Random Stone	0.020
Cement Rubble masonry	0.025
Dry Rubble or riprap	0.030
Gravel Botton, sides of:	
Random stone	0.023
Riprap	0.033

VALUES OF "n" IN MANNING FORMULA

TYPE OF CHANNEL

Excavated or Dredged

Earth, straight and uniform	0.018 to 0.027
Earth, winding and sluggish	0.025 to 0.040
Channels, not maintained, weeds and brush uncut	0.080 to 0.100

Natural Stream

Streams:	
Clean stream, straight	0.030
Stream with pools, sluggish reaches, heavy underbrush	0.100
Flood Plains:	
Pasture, no brush	0.030
With some brush	0.050 to 0.100

APPENDIX E

PARABOLIC CHANNEL DESIGN

Parabolic Channel Design

Grade 0.25 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15																		
20																		
25	10	2.4																
30	11	2.3																
35	13	2.3																
40	15	2.3	10	2.7														
45	17	2.2	12	2.6														
50	19	2.2	13	2.6														
55	20	2.2	14	2.6														
60	22	2.2	15	2.5														
65	24	2.2	17	2.5														
70	26	2.2	18	2.5	13	3.1												
75	28	2.2	19	2.5	13	3.0												
80	29	2.2	20	2.5	14	3.0												
90	33	2.2	23	2.5	16	3.0												
100	38	2.2	25	2.5	18	3.0												
110	40	2.2	28	2.5	19	2.9												
120	44	2.2	30	2.5	21	2.9	15	3.6										
130	48	2.2	33	2.5	23	2.9	16	3.6										
140	51	2.2	35	2.5	25	2.9	18	3.5										
150	55	2.2	37	2.5	26	2.9	19	3.5										
160	58	2.2	40	2.5	28	2.9	20	3.5										
170	62	2.2	42	2.5	30	2.9	21	3.5	17	4.0								
180	66	2.2	45	2.5	31	2.9	22	3.5	18	4.0								

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 0.50 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	9	1.6																
20	11	1.6																
25	14	1.6	9	1.9														
30	17	1.6	11	1.9	8	2.2												
35	20	1.6	12	1.9	9	2.1												
40	22	1.6	14	1.8	11	2.1												
45	25	1.5	16	1.8	12	2.0												
50	28	1.5	18	1.8	13	2.0	10	2.4										
55	31	1.5	19	1.8	15	2.0	11	2.4										
60	33	1.5	21	1.8	16	2.0	11	2.4										
65	36	1.5	23	1.8	17	2.0	12	2.4										
70	39	1.5	24	1.8	18	2.0	13	2.3										
75	42	1.5	26	1.8	20	2.0	14	2.3	11	2.7								
80	44	1.5	28	1.8	21	2.0	15	2.3	12	2.7								
90	50	1.5	31	1.8	24	2.0	17	2.3	13	2.7								
100	55	1.5	35	1.8	26	2.0	19	2.3	15	2.6	12	3.0						
110	61	1.5	38	1.8	29	2.0	21	2.3	16	2.6	13	3.0						
120	66	1.5	42	1.8	31	2.0	22	2.3	18	2.6	14	2.9						
130	72	1.5	45	1.8	34	2.0	24	2.3	19	2.6	15	2.9						
140	77	1.5	48	1.8	36	2.0	26	2.3	20	2.6	16	2.9						
150	83	1.5	52	1.8	39	2.0	28	2.3	22	2.6	18	2.9	14	3.3				
160	88	1.5	55	1.8	41	2.0	30	2.3	23	2.6	19	2.9	15	3.3				
170	93	1.5	59	1.8	44	2.0	32	2.3	25	2.6	20	2.9	16	3.3				
180	99	1.5	62	1.8	47	2.0	33	2.3	26	2.6	21	2.9	17	3.3				

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 0.75 Percent

Q	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
cfs	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	12	1.3	7	1.6														
20	16	1.3	9	1.5														
25	19	1.3	11	1.5	8	1.7												
30	23	1.3	13	1.5	10	1.7	8	1.9										
35	27	1.3	15	1.5	11	1.7	9	1.9										
40	31	1.3	18	1.5	13	1.7	10	1.9										
45	35	1.3	20	1.5	14	1.7	11	1.8										
50	38	1.3	22	1.5	16	1.6	13	1.8	9	2.2								
55	42	1.3	24	1.5	18	1.6	14	1.8	10	2.1								
60	46	1.3	26	1.5	19	1.6	15	1.8	11	2.1								
65	50	1.3	28	1.5	21	1.6	16	1.8	12	2.1	10	2.4						
70	53	1.3	30	1.5	22	1.6	17	1.8	13	2.1	11	2.4						
75	57	1.3	33	1.5	24	1.6	19	1.8	14	2.1	11	2.3						
80	61	1.3	35	1.5	25	1.6	20	1.8	15	2.1	12	2.3						
90	68	1.3	39	1.5	28	1.6	22	1.8	16	2.1	13	2.3	11	2.6				
100	76	1.3	43	1.5	32	1.6	25	1.8	18	2.1	15	2.3	12	2.6				
110	83	1.3	48	1.5	35	1.6	27	1.8	20	2.0	16	2.3	13	2.6				
120	91	1.3	52	1.5	38	1.6	30	1.8	22	2.1	18	2.3	15	2.5	12	2.9		
130	98	1.3	56	1.5	41	1.6	32	1.8	23	2.1	19	2.2	16	2.5	13	2.8		
140	106	1.3	60	1.5	44	1.6	34	1.8	25	2.0	21	2.3	17	2.5	14	2.8		
150	113	1.3	65	1.5	47	1.6	37	1.8	27	2.0	22	2.2	18	2.5	15	2.8		
160	121	1.3	69	1.5	50	1.6	39	1.8	29	2.0	24	2.2	19	2.5	16	2.8	13	3.1
170	128	1.3	73	1.5	53	1.6	42	1.8	30	2.0	25	2.2	20	2.5	17	2.8	14	3.1
180	135	1.3	77	1.5	56	1.6	44	1.8	32	2.0	27	2.2	22	2.5	18	2.8	15	3.1

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 1.0 Percent

Q	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
cfs	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	13	1.1	8	1.3														
20	18	1.1	11	1.3	8	1.5												
25	22	1.1	14	1.3	9	1.5	8	1.6										
30	27	1.1	17	1.3	11	1.5	9	1.6										
35	31	1.1	19	1.3	13	1.5	11	1.6	8	1.8								
40	35	1.1	22	1.3	15	1.4	12	1.6	9	1.8								
45	40	1.1	25	1.3	17	1.5	13	1.6	10	1.8								
50	44	1.1	28	1.3	19	1.4	15	1.6	11	1.8	9	2.0						
55	48	1.1	30	1.3	20	1.4	16	1.5	12	1.8	10	2.0						
60	53	1.1	33	1.3	22	1.4	18	1.5	14	1.7	10	2.0						
65	57	1.1	36	1.3	24	1.4	19	1.5	15	1.7	11	2.0	9	2.2				
70	61	1.1	38	1.3	26	1.4	21	1.5	16	1.7	12	2.0	10	2.2				
75	66	1.1	41	1.3	28	1.4	22	1.5	17	1.7	13	2.0	11	2.2				
80	70	1.1	44	1.3	29	1.4	24	1.5	18	1.7	14	2.0	11	2.2				
90	79	1.1	49	1.3	33	1.4	27	1.5	20	1.7	15	1.9	13	2.2	11	2.4		
100	87	1.1	55	1.3	37	1.4	29	1.5	22	1.7	17	1.9	14	2.2	12	2.4		
110	96	1.1	60	1.3	40	1.4	32	1.5	24	1.7	19	1.9	15	2.1	13	2.4	11	2.6
120	104	1.1	65	1.3	44	1.4	35	1.5	27	1.7	20	1.9	17	2.1	14	2.4	12	2.6
130	113	1.1	71	1.3	47	1.4	38	1.5	29	1.7	22	1.9	18	2.1	15	2.4	13	2.6
140	121	1.1	76	1.3	51	1.4	41	1.5	31	1.7	24	1.9	20	2.1	16	2.3	14	2.6
150	130	1.1	81	1.3	55	1.4	44	1.5	33	1.7	25	1.9	21	2.1	17	2.4	15	2.6
160	138	1.1	87	1.3	58	1.4	47	1.5	35	1.7	27	1.9	22	2.1	19	2.3	16	2.5
170	147	1.1	92	1.3	62	1.4	50	1.5	38	1.7	29	1.9	24	2.1	20	2.3	17	2.5
180	155	1.1	97	1.3	65	1.4	53	1.5	40	1.7	30	1.9	25	2.1	21	2.3	18	2.5

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 1.25 Percent

Q	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
cfs	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	15	1.0	10	1.2	7	1.4												
20	20	1.0	13	1.1	9	1.3	7	1.5										
25	25	1.0	16	1.1	11	1.3	8	1.5	7	1.6								
30	31	1.0	19	1.1	13	1.3	10	1.4	8	1.6								
35	36	1.0	23	1.1	15	1.3	11	1.4	9	1.6	7	1.8						
40	41	1.0	26	1.1	17	1.3	13	1.4	11	1.6	8	1.8						
45	46	1.0	29	1.1	19	1.3	14	1.4	12	1.5	9	1.7						
50	50	1.0	32	1.1	21	1.3	16	1.4	13	1.5	10	1.7	8	2.0				
55	55	1.0	35	1.1	23	1.3	18	1.4	14	1.5	11	1.7	9	1.9				
60	60	1.0	38	1.1	26	1.3	19	1.4	16	1.5	12	1.7	10	1.9				
65	65	1.0	41	1.1	28	1.3	21	1.4	17	1.5	13	1.7	11	1.9	9	2.2		
70	70	1.0	45	1.1	30	1.3	22	1.4	18	1.5	14	1.7	11	1.9	9	2.2		
75	75	1.0	48	1.1	32	1.3	24	1.4	19	1.5	15	1.7	12	1.9	10	2.1		
80	80	1.0	51	1.1	34	1.3	25	1.4	21	1.5	16	1.7	13	1.9	11	2.1	9	2.3
90	90	1.0	57	1.1	38	1.3	29	1.4	23	1.5	18	1.7	15	1.9	12	2.1	10	2.3
100	100	1.0	63	1.1	42	1.3	32	1.4	26	1.5	20	1.7	16	1.9	13	2.1	11	2.3
110	109	1.0	70	1.1	46	1.3	35	1.4	28	1.5	22	1.7	18	1.9	14	2.1	12	2.2
120	119	1.0	76	1.1	51	1.3	38	1.4	31	1.5	24	1.7	19	1.8	16	2.1	14	2.2
130	129	1.0	82	1.1	55	1.3	41	1.4	33	1.5	26	1.7	21	1.8	17	2.1	15	2.2
140	139	1.0	88	1.1	59	1.3	44	1.4	36	1.5	28	1.7	23	1.8	18	2.1	16	2.2
150	148	1.0	94	1.1	63	1.3	47	1.4	38	1.5	30	1.7	24	1.8	19	2.0	17	2.2
160	158	1.0	101	1.1	67	1.3	50	1.4	41	1.5	32	1.7	26	1.8	21	2.1	18	2.2
170	168	1.0	107	1.1	71	1.3	54	1.4	43	1.5	34	1.7	27	1.8	22	2.1	19	2.2
180	177	1.0	113	1.1	75	1.3	57	1.4	46	1.5	36	1.7	29	1.8	23	2.1	20	2.2

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 1.50 Percent

Q	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
cfs	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	17	0.9	11	1.1	8	1.2												
20	23	0.9	15	1.0	10	1.2	7	1.4	6	1.5								
25	28	0.9	19	1.0	12	1.2	9	1.4	7	1.5								
30	34	0.9	22	1.0	15	1.2	10	1.3	8	1.5	7	1.6						
35	40	0.9	26	1.0	17	1.1	12	1.3	10	1.4	8	1.6						
40	45	0.9	30	1.0	20	1.2	14	1.3	11	1.4	9	1.6	7	1.8				
45	51	0.9	33	1.0	22	1.1	15	1.3	12	1.4	10	1.5	8	1.8				
50	56	0.9	37	1.0	25	1.1	17	1.3	14	1.4	11	1.5	9	1.8				
55	62	0.9	41	1.0	27	1.1	19	1.3	15	1.4	12	1.5	10	1.7	8	1.9		
60	67	0.9	44	1.0	30	1.1	20	1.3	16	1.4	14	1.5	11	1.7	9	1.9		
65	73	0.9	48	1.0	32	1.1	22	1.3	18	1.4	15	1.5	11	1.7	10	1.9		
70	78	0.9	51	1.0	34	1.1	24	1.3	19	1.4	16	1.5	12	1.7	10	1.9	9	2.1
75	83	0.9	55	1.0	37	1.1	25	1.3	21	1.4	17	1.5	13	1.7	11	1.9	9	2.1
80	89	0.9	59	1.0	39	1.1	27	1.3	22	1.4	18	1.5	14	1.7	12	1.9	10	2.1
90	100	0.9	66	1.0	44	1.1	30	1.3	25	1.4	20	1.5	16	1.7	13	1.9	11	2.0
100	111	0.9	73	1.0	49	1.1	33	1.3	27	1.4	22	1.5	17	1.7	15	1.9	12	2.0
110	121	0.9	80	1.0	54	1.1	37	1.3	30	1.4	25	1.5	19	1.7	16	1.8	14	2.0
120	132	0.9	87	1.0	58	1.1	40	1.3	33	1.4	27	1.5	21	1.7	18	1.9	15	2.0
130	143	0.9	95	1.0	63	1.1	43	1.3	35	1.4	29	1.5	22	1.7	19	1.8	16	2.0
140	154	0.9	102	1.0	68	1.1	47	1.3	38	1.4	31	1.5	24	1.7	20	1.8	17	2.0
150	164	0.9	109	1.0	73	1.1	50	1.3	41	1.4	33	1.5	26	1.7	22	1.8	18	2.0
160	175	0.9	116	1.0	78	1.1	53	1.3	43	1.4	36	1.5	27	1.7	23	1.8	20	2.0
170	186	0.9	123	1.0	82	1.1	57	1.3	46	1.4	38	1.5	29	1.7	25	1.8	21	2.0
180	196	0.9	130	1.0	87	1.1	60	1.3	49	1.4	40	1.5	31	1.7	26	1.8	22	2.0

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 1.75 Percent

Q	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
cfs	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	19	0.9	12	1.0	9	1.1	6	1.3										
20	25	0.9	16	1.0	11	1.1	8	1.3	7	1.3								
25	31	0.9	20	1.0	14	1.1	10	1.2	8	1.3	7	1.5						
30	37	0.9	24	1.0	17	1.1	12	1.2	10	1.3	8	1.4						
35	43	0.9	28	1.0	20	1.1	13	1.2	11	1.3	9	1.4	7	1.6				
40	49	0.9	32	1.0	22	1.1	15	1.2	13	1.3	10	1.4	8	1.6				
45	55	0.9	36	1.0	25	1.1	17	1.2	14	1.3	12	1.4	9	1.6	8	1.7		
50	61	0.9	40	1.0	28	1.1	19	1.2	16	1.3	13	1.4	10	1.5	8	1.7		
55	67	0.9	44	1.0	31	1.1	21	1.2	17	1.3	14	1.4	11	1.5	9	1.7	8	1.9
60	73	0.9	48	1.0	33	1.1	23	1.2	19	1.3	15	1.4	12	1.5	10	1.7	8	1.9
65	78	0.9	52	1.0	36	1.1	25	1.2	21	1.3	17	1.4	13	1.5	11	1.7	9	1.9
70	84	0.9	56	1.0	39	1.1	27	1.2	22	1.3	18	1.4	14	1.5	12	1.7	10	1.9
75	90	0.9	59	1.0	42	1.1	29	1.2	24	1.3	19	1.4	15	1.5	12	1.7	10	1.9
80	96	0.9	63	1.0	44	1.1	30	1.2	25	1.3	20	1.4	16	1.5	13	1.7	11	1.9
90	108	0.9	71	1.0	50	1.1	34	1.2	28	1.3	23	1.4	18	1.5	15	1.7	12	1.9
100	120	0.9	79	1.0	55	1.1	38	1.2	31	1.3	25	1.4	20	1.5	16	1.7	13	1.9
110	131	0.9	87	1.0	61	1.1	42	1.2	34	1.3	28	1.4	22	1.5	18	1.7	15	1.8
120	143	0.9	94	1.0	66	1.1	45	1.2	38	1.3	30	1.4	24	1.5	20	1.7	16	1.8
130	155	0.9	102	1.0	71	1.1	49	1.2	41	1.3	33	1.4	26	1.5	21	1.7	17	1.8
140	166	0.9	110	1.0	77	1.1	53	1.2	44	1.3	35	1.4	28	1.5	23	1.6	19	1.8
150	178	0.9	117	1.0	82	1.1	56	1.2	47	1.3	38	1.4	30	1.5	24	1.6	20	1.8
160	189	0.9	125	1.0	88	1.1	60	1.2	50	1.3	40	1.4	31	1.5	26	1.6	21	1.8
170	201	0.9	132	1.0	93	1.1	64	1.2	53	1.3	43	1.4	33	1.5	28	1.6	23	1.8
180	212	0.9	140	1.0	98	1.1	67	1.2	56	1.3	45	1.4	35	1.5	29	1.6	24	1.8

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 2.0 Percent

Q	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
cfs	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	21	0.8	13	0.9	9	1.0	7	1.2										
20	28	0.8	17	0.9	12	1.0	9	1.1	7	1.3	5	1.4						
25	35	0.8	21	0.9	15	1.0	11	1.1	8	1.3	7	1.4						
30	41	0.8	26	0.9	18	1.0	13	1.1	10	1.2	8	1.3	7	1.5				
35	48	0.8	30	0.9	22	1.0	15	1.1	11	1.2	9	1.3	8	1.5				
40	55	0.8	34	0.9	25	1.0	18	1.1	13	1.2	11	1.3	9	1.5	7	1.7		
45	62	0.8	38	0.9	28	1.0	20	1.1	14	1.2	12	1.3	10	1.4	8	1.6		
50	68	0.8	42	0.9	31	1.0	22	1.1	16	1.2	13	1.3	11	1.4	9	1.6	8	1.7
55	75	0.8	46	0.9	34	1.0	24	1.1	17	1.2	14	1.3	12	1.4	10	1.6	8	1.7
60	82	0.8	51	0.9	37	1.0	26	1.1	19	1.2	16	1.3	13	1.4	11	1.6	9	1.7
65	88	0.8	55	0.9	40	1.0	28	1.1	21	1.2	17	1.3	14	1.4	11	1.6	10	1.7
70	95	0.8	59	0.9	43	1.0	30	1.1	22	1.2	18	1.3	15	1.4	12	1.6	10	1.7
75	101	0.8	63	0.9	46	1.0	32	1.1	24	1.2	20	1.3	16	1.4	13	1.6	11	1.7
80	108	0.8	67	0.9	48	1.0	35	1.1	25	1.2	21	1.3	17	1.4	14	1.6	12	1.7
90	121	0.8	75	0.9	54	1.0	39	1.1	28	1.2	23	1.3	19	1.4	16	1.6	13	1.7
100	134	0.8	83	0.9	60	1.0	43	1.1	31	1.2	26	1.3	21	1.4	17	1.6	15	1.7
110	147	0.8	92	0.9	66	1.0	47	1.1	34	1.2	28	1.3	23	1.4	19	1.5	16	1.7
120	160	0.8	100	0.9	72	1.0	52	1.1	38	1.2	31	1.3	26	1.4	21	1.5	18	1.7
130	173	0.8	108	0.9	78	1.0	56	1.1	41	1.2	34	1.3	28	1.4	23	1.5	19	1.7
140	186	0.8	116	0.9	84	1.0	60	1.1	44	1.2	36	1.3	30	1.4	24	1.5	21	1.7
150	199	0.8	124	0.9	90	1.0	64	1.1	47	1.2	39	1.3	32	1.4	26	1.5	22	1.7
160	212	0.8	132	0.9	96	1.0	69	1.1	50	1.2	41	1.3	34	1.4	28	1.5	23	1.7
170	225	0.8	140	0.9	102	1.0	73	1.1	53	1.2	44	1.3	36	1.4	29	1.5	25	1.7
180	238	0.8	148	0.9	108	1.0	77	1.1	56	1.2	46	1.3	38	1.4	31	1.5	26	1.7

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 3.0 Percent

Q	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
cfs	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	24	0.7	16	0.8	11	0.8	9	0.9	7	1.0	5	1.2						
20	31	0.7	22	0.8	15	0.8	12	0.9	9	1.0	7	1.1	6	1.2				
25	39	0.7	27	0.8	19	0.8	15	0.9	11	1.0	8	1.1	7	1.2	6	1.3		
30	47	0.7	32	0.8	23	0.8	17	0.9	13	1.0	10	1.1	9	1.2	7	1.2	6	1.4
35	55	0.7	38	0.8	26	0.8	20	0.9	15	1.0	11	1.1	10	1.1	8	1.2	7	1.4
40	62	0.7	43	0.8	30	0.8	23	0.9	17	1.0	13	1.1	12	1.1	9	1.2	8	1.4
45	70	0.7	48	0.8	34	0.8	26	0.9	19	1.0	15	1.1	13	1.1	11	1.2	9	1.3
50	77	0.7	54	0.8	38	0.8	29	0.9	21	1.0	16	1.1	14	1.1	12	1.2	9	1.3
55	85	0.7	59	0.8	41	0.8	32	0.9	23	1.0	18	1.1	16	1.1	13	1.2	10	1.4
60	93	0.7	64	0.8	45	0.8	35	0.9	26	1.0	19	1.1	17	1.1	14	1.2	11	1.3
65	100	0.7	70	0.8	49	0.8	37	0.9	28	1.0	21	1.1	19	1.1	15	1.2	12	1.3
70	107	0.7	74	0.8	52	0.8	40	0.9	30	1.0	22	1.1	20	1.1	16	1.2	13	1.3
75	115	0.7	79	0.8	56	0.8	43	0.9	32	1.0	24	1.1	21	1.1	18	1.2	14	1.3
80	122	0.7	85	0.8	59	0.8	46	0.9	34	1.0	26	1.1	23	1.1	19	1.2	15	1.3
90	137	0.7	95	0.8	67	0.8	51	0.9	38	1.0	29	1.1	26	1.1	21	1.2	17	1.3
100	152	0.7	105	0.8	74	0.8	57	0.9	42	1.0	32	1.1	28	1.1	23	1.2	19	1.3
110	167	0.7	116	0.8	81	0.8	63	0.9	46	1.0	35	1.1	31	1.1	26	1.2	21	1.3
120	181	0.7	126	0.8	89	0.8	68	0.9	51	1.0	38	1.1	34	1.1	28	1.2	22	1.3
130	196	0.7	136	0.8	96	0.8	74	0.9	55	1.0	41	1.1	37	1.1	30	1.2	24	1.3
140	211	0.7	146	0.8	103	0.8	79	0.9	59	1.0	44	1.1	39	1.1	32	1.2	26	1.3
150	225	0.7	156	0.8	110	0.8	85	0.9	63	1.0	47	1.1	42	1.1	35	1.2	28	1.3
160	239	0.7	166	0.8	117	0.8	90	0.9	67	1.0	50	1.1	45	1.1	37	1.2	30	1.3
170	254	0.7	176	0.8	124	0.8	96	0.9	71	1.0	54	1.1	48	1.1	39	1.2	32	1.3
180	268	0.7	186	0.8	131	0.8	101	0.9	75	1.0	57	1.1	50	1.1	41	1.2	33	1.3

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 4.0 Percent

Q	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
cfs	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	28	0.6	20	0.7	14	0.7	10	0.8	8	0.9	6	0.9	5	1.1				
20	37	0.6	27	0.7	19	0.7	14	0.8	11	0.8	8	0.9	6	1.0	6	1.1		
25	46	0.6	33	0.7	23	0.7	17	0.8	13	0.8	11	0.9	8	1.0	7	1.1	6	1.2
30	55	0.6	40	0.7	28	0.7	20	0.8	16	0.8	13	0.9	10	1.0	8	1.1	7	1.2
35	64	0.6	46	0.7	32	0.7	24	0.8	18	0.8	15	0.9	11	1.0	10	1.1	8	1.2
40	73	0.6	52	0.7	37	0.7	27	0.8	21	0.8	17	0.9	13	1.0	11	1.0	9	1.1
45	82	0.6	59	0.7	41	0.7	30	0.8	23	0.8	19	0.9	14	1.0	12	1.1	10	1.1
50	91	0.6	65	0.7	46	0.7	34	0.8	26	0.8	21	0.9	16	1.0	14	1.1	11	1.1
55	100	0.6	72	0.7	50	0.7	37	0.8	29	0.8	23	0.9	17	1.0	15	1.0	12	1.1
60	109	0.6	78	0.7	55	0.7	40	0.8	31	0.8	25	0.9	19	1.0	16	1.0	13	1.1
65	117	0.6	84	0.7	59	0.7	44	0.8	34	0.8	27	0.9	20	1.0	18	1.1	14	1.1
70	126	0.6	90	0.7	63	0.7	47	0.8	36	0.8	29	0.9	22	1.0	19	1.0	15	1.1
75	135	0.6	97	0.7	68	0.7	50	0.8	39	0.8	31	0.9	24	1.0	20	1.0	17	1.1
80	143	0.6	103	0.7	72	0.7	53	0.8	41	0.8	33	0.9	25	1.0	21	1.0	18	1.1
90	161	0.6	115	0.7	81	0.7	60	0.8	46	0.8	37	0.9	28	1.0	24	1.0	20	1.1
100	178	0.6	128	0.7	90	0.7	66	0.8	51	0.8	41	0.9	31	1.0	27	1.0	22	1.1
110	195	0.6	140	0.7	99	0.7	73	0.8	56	0.8	45	0.9	34	1.0	29	1.0	24	1.1
120	213	0.6	153	0.7	107	0.7	79	0.8	61	0.8	49	0.9	37	1.0	32	1.0	26	1.1
130	230	0.6	165	0.7	116	0.7	86	0.8	66	0.8	53	0.9	40	1.0	35	1.0	28	1.1
140	247	0.6	177	0.7	125	0.7	92	0.8	71	0.8	57	0.9	43	1.0	37	1.0	31	1.1
150	264	0.6	189	0.7	133	0.7	99	0.8	76	0.8	61	0.9	47	1.0	40	1.0	33	1.1
160	280	0.6	201	0.7	142	0.7	105	0.8	81	0.8	65	0.9	50	1.0	42	1.0	35	1.1
170	297	0.6	213	0.7	150	0.7	112	0.8	86	0.8	69	0.9	53	1.0	45	1.0	37	1.1
180	314	0.6	225	0.7	159	0.7	118	0.8	91	0.8	73	0.9	56	1.0	48	1.0	39	1.1

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 5.0 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	29	0.6	21	0.6	15	0.7	12	0.7	9	0.8	7	0.8	6	0.9	5	1.0		
20	39	0.6	28	0.6	20	0.7	16	0.7	12	0.8	10	0.8	8	0.9	6	1.0	5	1.1
25	49	0.6	35	0.6	25	0.7	20	0.7	15	0.8	12	0.8	10	0.9	8	1.0	7	1.0
30	58	0.6	42	0.6	30	0.7	24	0.7	18	0.8	14	0.8	11	0.9	9	1.0	8	1.0
35	68	0.6	49	0.6	35	0.7	28	0.7	21	0.8	17	0.8	13	0.9	11	0.9	9	1.0
40	77	0.6	56	0.6	40	0.7	32	0.7	24	0.8	19	0.8	15	0.9	12	0.9	10	1.0
45	86	0.6	63	0.6	44	0.7	36	0.7	27	0.8	21	0.8	17	0.9	14	0.9	12	1.0
50	96	0.6	69	0.6	49	0.7	40	0.7	30	0.8	24	0.8	19	0.9	15	0.9	13	1.0
55	105	0.6	76	0.6	54	0.7	44	0.7	33	0.8	26	0.8	21	0.9	17	0.9	14	1.0
60	114	0.6	83	0.6	59	0.7	48	0.7	36	0.8	28	0.8	22	0.9	18	0.9	15	1.0
65	123	0.6	89	0.6	63	0.7	52	0.7	38	0.8	31	0.8	24	0.9	19	0.9	17	1.0
70	132	0.6	96	0.6	68	0.7	56	0.7	41	0.8	33	0.8	26	0.9	21	0.9	18	1.0
75	142	0.6	102	0.6	73	0.7	59	0.7	44	0.8	35	0.8	28	0.9	22	0.9	19	1.0
80	151	0.6	109	0.6	78	0.7	63	0.7	47	0.8	37	0.8	30	0.9	24	0.9	20	1.0
90	169	0.6	122	0.6	87	0.7	71	0.7	53	0.8	42	0.8	33	0.9	27	0.9	23	1.0
100	187	0.6	136	0.6	97	0.7	79	0.7	59	0.8	47	0.8	37	0.9	30	0.9	26	1.0
110	205	0.6	149	0.6	106	0.7	86	0.7	64	0.8	51	0.8	41	0.9	33	0.9	28	1.0
120	223	0.6	162	0.6	115	0.7	94	0.7	70	0.8	56	0.8	44	0.9	35	0.9	31	1.0
130	241	0.6	175	0.6	125	0.7	102	0.7	76	0.8	60	0.8	48	0.9	38	0.9	33	1.0
140	259	0.6	188	0.6	134	0.7	109	0.7	81	0.8	65	0.8	52	0.9	41	0.9	36	1.0
150	276	0.6	201	0.6	143	0.7	117	0.7	87	0.8	69	0.8	55	0.9	44	0.9	38	1.0
160	294	0.6	213	0.6	152	0.7	124	0.7	93	0.8	74	0.8	59	0.9	47	0.9	40	1.0
170	311	0.6	226	0.6	162	0.7	132	0.7	98	0.8	78	0.8	62	0.9	50	0.9	43	1.0
180	329	0.6	239	0.6	171	0.7	139	0.7	104	0.8	83	0.8	66	0.9	53	0.9	45	1.0

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 6.0 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	35	0.5	23	0.6	17	0.6	13	0.7	10	0.7	8	0.8	7	0.8	5	0.9	4	1.0
20	46	0.5	30	0.6	22	0.6	17	0.7	13	0.7	11	0.7	9	0.8	7	0.9	6	1.0
25	57	0.5	37	0.6	28	0.6	21	0.7	17	0.7	13	0.7	11	0.8	9	0.9	7	0.9
30	69	0.5	45	0.6	33	0.6	25	0.7	20	0.7	16	0.7	13	0.8	10	0.9	8	0.9
35	80	0.5	52	0.6	38	0.6	29	0.7	23	0.7	19	0.7	15	0.8	12	0.9	10	0.9
40	91	0.5	59	0.6	44	0.6	33	0.7	26	0.7	21	0.7	17	0.8	14	0.9	11	0.9
45	102	0.5	67	0.6	49	0.6	37	0.7	30	0.7	24	0.7	19	0.8	16	0.9	13	0.9
50	113	0.5	74	0.6	54	0.6	42	0.7	33	0.7	26	0.7	22	0.8	17	0.9	14	0.9
55	123	0.5	81	0.6	60	0.6	46	0.7	36	0.7	29	0.7	24	0.8	19	0.8	15	0.9
60	134	0.5	88	0.6	65	0.6	50	0.7	39	0.7	32	0.7	26	0.8	21	0.8	17	0.9
65	145	0.5	95	0.6	70	0.6	54	0.7	42	0.7	34	0.7	28	0.8	22	0.9	18	0.9
70	155	0.5	102	0.6	75	0.6	58	0.7	45	0.7	37	0.7	30	0.8	24	0.9	19	0.9
75	166	0.5	109	0.6	81	0.6	62	0.7	49	0.7	39	0.7	32	0.8	26	0.8	21	0.9
80	176	0.5	116	0.6	86	0.6	65	0.7	52	0.7	42	0.7	34	0.8	27	0.9	22	0.9
90	198	0.5	130	0.6	96	0.6	73	0.7	58	0.7	47	0.7	38	0.8	31	0.8	25	0.9
100	219	0.5	144	0.6	107	0.6	81	0.7	64	0.7	52	0.7	42	0.8	34	0.9	28	0.9
110	240	0.5	158	0.6	117	0.6	89	0.7	71	0.7	57	0.7	47	0.8	37	0.8	30	0.9
120	261	0.5	172	0.6	127	0.6	97	0.7	77	0.7	62	0.7	51	0.8	41	0.8	33	0.9
130	282	0.5	185	0.6	138	0.6	105	0.7	83	0.7	67	0.7	55	0.8	44	0.8	36	0.9
140	302	0.5	199	0.6	148	0.6	113	0.7	89	0.7	72	0.7	59	0.8	47	0.8	38	0.9
150	323	0.5	213	0.6	158	0.6	121	0.7	96	0.7	77	0.7	63	0.8	50	0.8	41	0.9
160	343	0.5	226	0.6	168	0.6	129	0.7	102	0.7	82	0.7	67	0.8	54	0.9	44	0.9
170	363	0.5	240	0.6	178	0.6	136	0.7	108	0.7	87	0.7	71	0.8	57	0.8	46	0.9
180	383	0.5	253	0.6	188	0.6	144	0.7	114	0.7	92	0.7	75	0.8	60	0.9	49	0.9

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 8.0 Percent

Q	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
cfs	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	37	0.5	27	0.5	19	0.5	15	0.6	12	0.6	9	0.7	8	0.7	6	0.7	5	0.8
20	49	0.5	35	0.5	25	0.5	20	0.6	16	0.6	13	0.7	10	0.7	9	0.7	7	0.8
25	61	0.5	44	0.5	31	0.5	25	0.6	19	0.6	16	0.7	13	0.7	11	0.7	9	0.8
30	73	0.5	53	0.5	37	0.5	30	0.6	23	0.6	19	0.7	16	0.7	13	0.7	11	0.8
35	85	0.5	61	0.5	43	0.5	35	0.6	27	0.6	22	0.6	18	0.7	15	0.7	12	0.8
40	97	0.5	70	0.5	49	0.5	40	0.6	31	0.6	25	0.6	21	0.7	17	0.7	14	0.8
45	109	0.5	78	0.5	55	0.5	45	0.6	35	0.6	28	0.6	23	0.7	19	0.7	16	0.8
50	120	0.5	87	0.5	61	0.5	50	0.6	38	0.6	31	0.7	26	0.7	21	0.7	17	0.8
55	132	0.5	95	0.5	67	0.5	55	0.6	42	0.6	34	0.7	28	0.7	23	0.7	19	0.8
60	143	0.5	103	0.5	73	0.5	60	0.6	46	0.6	37	0.7	31	0.7	25	0.7	21	0.8
65	155	0.5	111	0.5	79	0.5	65	0.6	50	0.6	40	0.7	33	0.7	27	0.7	23	0.8
70	166	0.5	120	0.5	85	0.5	69	0.6	53	0.6	43	0.6	36	0.7	29	0.7	24	0.8
75	177	0.5	128	0.5	91	0.5	74	0.6	57	0.6	46	0.7	38	0.7	31	0.7	26	0.8
80	188	0.5	136	0.5	96	0.5	79	0.6	61	0.6	49	0.6	41	0.7	33	0.7	28	0.8
90	211	0.5	152	0.5	108	0.6	88	0.6	68	0.6	55	0.7	46	0.7	37	0.7	31	0.8
100	234	0.5	168	0.5	120	0.6	98	0.6	75	0.6	61	0.7	51	0.7	41	0.7	34	0.8
110	256	0.5	185	0.5	131	0.6	108	0.6	83	0.6	67	0.7	57	0.7	46	0.7	38	0.8
120	278	0.5	201	0.5	143	0.6	117	0.6	90	0.6	73	0.7	61	0.7	50	0.7	41	0.8
130	300	0.5	217	0.5	154	0.6	126	0.6	97	0.6	78	0.7	65	0.7	54	0.7	44	0.8
140	322	0.5	233	0.5	166	0.6	136	0.6	104	0.6	84	0.7	70	0.7	58	0.7	48	0.8
150	344	0.5	248	0.5	177	0.6	145	0.6	112	0.6	90	0.7	75	0.7	62	0.7	51	0.8
160	366	0.5	264	0.5	188	0.6	154	0.6	119	0.6	96	0.7	80	0.7	66	0.7	54	0.8
170	387	0.5	280	0.5	199	0.6	164	0.6	126	0.6	102	0.7	85	0.7	70	0.7	58	0.8
180	408	0.5	295	0.5	210	0.6	173	0.6	133	0.6	107	0.7	90	0.7	74	0.7	61	0.8

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

Parabolic Channel Design

Grade 10.0 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	45	0.4	33	0.5	23	0.5	17	0.5	13	0.6	11	0.6	9	0.6	7	0.7	6	0.7
20	60	0.4	43	0.5	30	0.5	22	0.5	18	0.6	14	0.6	12	0.6	10	0.7	8	0.7
25	75	0.4	54	0.5	38	0.5	28	0.5	22	0.6	18	0.6	15	0.6	12	0.7	10	0.7
30	89	0.4	64	0.5	45	0.5	33	0.5	27	0.6	21	0.6	18	0.6	15	0.6	12	0.7
35	104	0.4	75	0.5	53	0.5	38	0.5	31	0.6	25	0.6	21	0.6	17	0.7	14	0.7
40	118	0.4	85	0.5	60	0.5	44	0.5	35	0.6	28	0.6	24	0.6	20	0.7	16	0.7
45	132	0.4	95	0.5	67	0.5	49	0.5	40	0.6	32	0.6	27	0.6	22	0.7	18	0.7
50	146	0.4	105	0.5	74	0.5	54	0.5	44	0.6	35	0.6	30	0.6	24	0.7	20	0.7
55	160	0.4	115	0.5	82	0.5	60	0.5	48	0.6	39	0.6	32	0.6	27	0.6	22	0.7
60	174	0.4	125	0.5	87	0.5	65	0.5	52	0.6	42	0.6	35	0.6	29	0.7	24	0.7
65	188	0.4	135	0.5	96	0.5	70	0.5	57	0.6	45	0.6	38	0.6	32	0.7	26	0.7
70	201	0.4	145	0.5	103	0.5	75	0.5	61	0.6	49	0.6	41	0.6	34	0.7	28	0.7
75	215	0.4	155	0.5	110	0.5	80	0.5	65	0.6	52	0.6	44	0.6	36	0.7	30	0.7
80	228	0.4	164	0.5	116	0.5	85	0.5	69	0.6	55	0.6	47	0.6	39	0.7	32	0.7
90	255	0.4	184	0.5	131	0.5	96	0.5	76	0.6	62	0.6	52	0.6	43	0.7	36	0.7
100	282	0.4	204	0.5	145	0.5	106	0.5	86	0.6	69	0.6	58	0.6	48	0.7	40	0.7
110	309	0.4	223	0.5	158	0.5	116	0.5	94	0.6	76	0.6	64	0.6	53	0.7	44	0.7
120	336	0.4	242	0.5	172	0.5	126	0.5	103	0.6	82	0.6	69	0.6	57	0.7	48	0.7
130	362	0.4	262	0.5	186	0.5	137	0.5	111	0.6	89	0.6	75	0.6	62	0.7	52	0.7
140	388	0.4	282	0.5	200	0.5	147	0.5	119	0.6	95	0.6	81	0.6	67	0.7	56	0.7
150	414	0.4	299	0.5	213	0.5	157	0.5	127	0.6	102	0.6	86	0.6	71	0.7	60	0.7
160	440	0.4	318	0.5	227	0.5	166	0.5	135	0.6	108	0.6	92	0.6	76	0.7	64	0.7
170	466	0.4	337	0.5	240	0.5	176	0.5	143	0.6	115	0.6	97	0.6	80	0.7	67	0.7
180	491	0.4	355	0.5	253	0.5	186	0.5	151	0.6	121	0.6	103	0.6	85	0.7	71	0.7

Q = Flow in Cubic Feet per Second V = Velocity in Feet per Second T = Top Width in Feet
D = Depth in Feet

TABLE 2

PARABOLIC STONE CENTER CHANNEL

Velocity, Top Width and Depth

	Grade 6 Percent		Grade 8 Percent		Grade 10 Percent		Grade 12 Percent		Grade 15 Percent	
V	8.0	10	8.0	10.0	8.0	10.0	8.0	10.0	8.0	10.0
D	1.3	1.6	1.1	1.3	1.0	1.2	0.9	1.1	0.8	0.9
Q					Top Widths					
20										
25					5		5		5	
30			5		6		6		6	4
35			6		7		7		7	5
40	6		7		8	5	8	5	8	6
45	7		8		9	6	9	6	10	7
50	7		9	6	10	7	10	6	11	7
55	8		9	6	11	7	11	7	12	8
60	9		10	7	12	8	12	8	13	9
65	9		11	7	12	9	13	8	14	9
70	10	7	12	8	13	9	14	9	16	11
75	11	7	13	9	14	10	15	10	17	11
80	12	8	14	9	15	10	16	10	18	12
90	13	9	15	10	17	12	18	11	19	13
100	14	10	17	11	19	13	20	13	21	15
110	16	11	19	13	21	14	22	14	24	16
120	17	11	21	14	23	16	24	15	26	18
130	19	12	22	15	25	17	26	17	29	20
140	20	13	24	16	27	18	29	18	31	21
150	22	14	26	17	29	20	31	19	33	23
160	23	15	27	18	31	21	33	21	36	24
170	25	16	29	19	33	22	35	22	38	26
180	26	17	31	20	34	23	37	24	40	28
190	27	18	32	22	36	25	39	25	43	29
200	29	19	34	23	38	26	42	26	45	31
220	32	21	38	25	42	29	44	28	47	33
240	35	23	41	27	46	31	48	31	52	38
260	38	25	44	30	50	34	53	33	57	39
280	40	27	48	32	54	36	57	36	62	42
300	43	29	51	34	57	39	61	39	67	45
							66	42	71	49

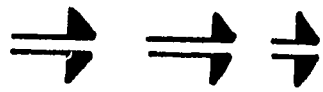
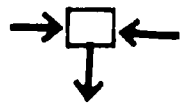
REFERENCE

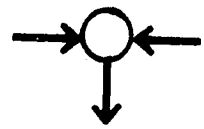
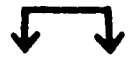
SCS - TP - 61

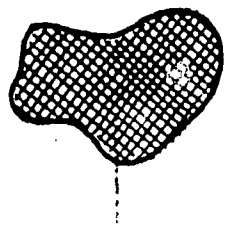
APPENDIX F

SYMBOLS FOR EROSION AND SEDIMENT CONTORL PRACTICES

SYMBOLS FOR EROSION AND SEDIMENT CONTROL PRACTICES

CONTROL PRACTICES	SYMBOL
Interceptor Dike	
Diversion Dike	
Diversion	
Perimeter Dike	
Straw Bale or Hay Barrier	
Waterway or Outlet	
Straight Drop Spillway	
Drop Box Culvert	
Down Drainage Structure	

CONTROL PRACTICES	SYMBOL
Pipe Slope Drain	
Terraces and Benches	
Construction Entrance	
Sediment Trap	
Check Dam	
Gravel Outlet Structure	
Level Spreader	
Riprap	
Paved Apron and/or Riprap	

CONTROL PRACTICES	SYMBOL
Jute Mesh, Plastic or Other	
Drainage Divide	
Minor Tributary or Swale	
Critical Erosion or Environmentally Sensitive Area	
Limits of Clearing and Grading	