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The Standards for Soil Erosion and Sediment Control In New Jersey

7th Edition, January 2014

Cover: Restoration of 800 feet of the Ramapo River bank after damage by Hurricane Irene in August 2011. Restoration by the Boro of Oakland, Bergen County NJ Spring 2013 (completed). Technical and funding assistance from the USDA Natural Resources Conservation Service. Erosion Control oversight by the Bergen County Soil Conservation District.

STANDARDS

FOR

SOIL EROSION AND SEDIMENT CONTROL IN NEW JERSEY

Adopted
December 2013

Vegetative and Engineering Standards, chapters 1 - 32 inclusive are promulgated as "Standards" pursuant to the Soil Erosion and Sediment Control Act of 1975 as amended (N.J.S.A. 4:24-39 et seq.) and New Jersey Administrative Code (N.J.A.C. 2:90-1.1 et seq.).

By the

NEW JERSEY STATE SOIL CONSERVATION COMMITTEE

Douglas H. Fisher, Chairman, Secretary, New Jersey Department of Agriculture

Robert Martin, Commissioner, New Jersey Department of Environmental Protection

Dr. Robert M. Goodman, Exec. Dean, School of Environmental and Biological Sciences, Rutgers University

Dr. Larry Katz, Director, Rutgers Cooperative Extension, Cook College

Carrie Mosley, State Conservationist, USDA Natural Resources Conservation Service

Raymond Cywinski, Supervisor, Bergen County Soil Conservation District

Priscilla Hayes, Supervisor, Mercer County Soil Conservation District

Barbara Rosko, Supervisor, Sussex County Soil Conservation District

Anthony DiLodovico, Supervisor, Ocean County Soil Conservation District

Charles Buscaglia, Supervisor, Freehold Soil Conservation District

Joseph Lomax, Supervisor, Cape-Atlantic Conservation District

John Kocubinski, Governor's Appointee

Frank Minch, Executive Secretary, State Soil Conservation Committee

FOREWORD AND ACKNOWLEDGMENTS

2014 marks the 38th year of service to New Jersey by the Soil Erosion and Sediment Control Program administered by the Department of Agriculture and the New Jersey Soil Conservation Districts. Since the inception of the idea to apply conservation practices to urban development in 1976, New Jersey has significantly evolved in its approach to erosion control. From simple hay bales for filtering runoff, to advanced computer simulations which model watershed runoff, New Jersey's erosion control practices have taken advantage of developing technologies. Periodically the Department, and Soil Conservation Districts update the "*Standards for Soil Erosion and Sediment Control* " to reflect the ongoing emergence of science and technology.

The *Standards* are a blend of agronomic science and state of the art engineering practices, embodied in 32 individual design chapters and detailed appendices that enable developers to successfully design erosion control practices for construction sites. Soil loss prevention is addressed both during as well as after construction to safeguard New Jersey's natural resources.

Since 1976, more than 920,000 acres of land have been protected from erosion by the application of construction site best management practices to control erosion. This equates to more than 28 million tons of soil that have been prevented from entering the state's waterways. Erosion protection allows for the continuation of recreational opportunities, aids in flood prevention efforts and minimizes the need for water treatment.

The seventh edition of the *Standards* has been revised to include additional guidance for assessing downstream stability, rip rap design, the use of infiltration and additional options for vegetation used in the Pinelands National Reserve. Future revisions are planned to enhance the quality of soil used in establishing vegetation for stabilization of development sites.

The New Jersey Department of Agriculture acknowledges its long-time partners - the United States Department of Agriculture – Natural Resources Conservation Service, the state's 15 Soil Conservation Districts, Rutgers University and the New Jersey Department of Environmental Protection for their assistance in developing these *Standards*. Additionally, the Department appreciates the valued expertise of the New Jersey Pinelands Commission, the New Jersey Department of Transportation and the many representatives of the New Jersey Builders Association and Professional Consulting Engineers who assisted in this project. These partnerships have achieved great success in the minimization of damage due to excessive stormwater runoff and related soil loss from construction sites while at the same time promoting concepts of good stewardship of the state's resources to all of New Jersey's residents.

Douglas H. Fisher
Secretary, New Jersey Department of Agriculture
January 2014

COMMITTEE FOR REVIEW AND DEVELOPMENT OF

STANDARDS FOR SOIL EROSION
AND
SEDIMENT CONTROL

January 2014

Mr. William Brash
District Director
Mercer County Soil Conservation District

Mr. Anthony DiLodivico
President
Tony D Environmental Permitting, LLC

Mr. Steven Jacobus
Watershed Team Leader
Division of Watershed Management N.J. Department of Environmental Protection

Mr. David Lamm, P.E.
State Conservation Engineer
Natural Resources Conservation Service
U.S. Department of Agriculture

Mr. John Showler, P.E.,
State Erosion Control Engineer
State Soil Conservation Committee
N.J. Department of Agriculture

Mr. Angelo Caruso
District Manager
Bergen County Soil Conservation District

Mr. David Earl, ASLA
Section Chief
Office of Landscape Architecture
NJ Department of Transportation

Mr. Paul Schiariti, P.E.
NPS Coordinator
Mercer County Soil Conservation District

Mr. Anthony Castillo, P.E.
Principal
SESI Consulting Engineers, Inc.

Mr. Wayne Birchler, P.E.
Former District Engineer
Gloucester County Soil Conservation District

Mr. Ken Marsh, P.E.
Supervisor (retired)
Somerset-Union Soil Conservation District

Mr. David Kreck, P.E.
Senior Managing Engineer
Rodriguez Consulting, LLC

Mr. Richard Eigenbrood
Natural Resource Conservationist (retired)
Gloucester County Soil Conservation District

Ms. Stephanie Murphy, PhD.
Soil Scientist
Rutgers University

Mr. Ernest Thurlow, PhD.
Manager (retired)
Somerset-Union Soil Conservation District

Mr. Don Kinesik
President
Pinelands Nursery

Mr. David Friedman
Manager (retired)
Ocean County Soil Conservation District

Ms. Amy Karpati, PhD
Director for Conservation Science
Pinelands Preservation Alliance

Ms. Valarie Hrable, P.E.
Manager, Hydrology & Hydraulics
Greenman &Pedesen, Inc.

Mr. Robert McCarthy, P.E.
Principle
DW Smith, Inc.

Mr. Brian McClendon
Section Chief
Stormwater Permitting NJDEP

Mr. Ron Bannister
Environmental Specialist
Groundwater NJDEP

Mr. Fred Bowers, PhD
Section Chief (retired)
Groundwater NJDEP

Mr. Barry Chalofsky
Bureau Chief (retired)
Stormwater Permitting, NJDEP

Ms. Robyn Jeney
Regulatory Programs Specialist
New Jersey Pinelands Commission

Developing a Successful Plan to Control Soil Erosion on Construction Sites

"He who fails to plan, plans to fail…." is an oft-quoted proverb. Its original author is unknown, but it is frequently attributed to such famous individuals as Benjamin Franklin, Abraham Lincoln and Winston Churchill. Regardless of who coined the phrase, failure to plan (properly) is never more evident than in a poorly thought out erosion and sediment control plan. Once a slope has eroded, or an infiltration basin has failed, it is too late to 'plan'. It is only time to react and correct. And usually, it costs more to do something twice, than to do it right the first time.

Though not an exhaustive list, the following represent many of the primary design considerations and constraints in preparing an effective erosion control plan. Effective erosion control should be integrated into planning for stormwater management, and not done as an after-thought. A properly developed plan should address the following aspects of site construction when designing for erosion control:

General Considerations-

1. Design report included and submitted to the district
2. Table of Contents for the design report denoting location of erosion control designs
3. Plan drawn at proper scale (usually not less than 1:50)
4. Erosion Control Plan sheets labeled, signed and sealed by a NJ Licensed Engineer or Architect
5. Pre and post construction contours clearly labeled and depicted
6. Limits of disturbance clearly delineated and corresponding to area of disturbance on the application form
7. Temporary controls such as sediment barriers, inlet filters graphically depicted on plan sheets
8. Details for erosion control applications clearly shown on a 'detail sheet'; dimensions correspond to deign report
9. District notes, vegetative stabilization specifications and other notes shown on the detail page
10. Soil delineations shown on the erosion control plan sheets
11. Other natural features, such as streams, wetlands and buffers delineated on plan sheets
12. Permanent structures graphically depicted on plan sheets (piping, basins, rip rap outlets, swales, basins etc)
13. Offsite improvements (sewer, water, storm drainage, electrical utilities) shown and included in area calculations
14. Proposed staging and stockpile areas depicted (on and off site).

Construction Disturbance Considerations-

1. Phasing of disturbed areas (minimizing open soil areas)
2. Sequence of construction specific to the site (avoid generic sequencing)
3. Stormwater management on a construction site
    a. Temporary sediment basins with design support and appropriate details
    b. Diversions & swales
    c. Grading
    d. Filtering via pumped discharge
    e. Dewatering excavations and points of discharge
4. Temporary stabilization with vegetation, mulch, man-made materials etc.
5. Location of temporary controls such as inlet filters, sediment barriers, construction entrances
6. Soil movement – cuts, fills, removal, stockpiles and importation shown on plans
7. Minimization of soil compaction – restrict vehicle travel, avoid working wet soils, restore if needed

Hydrologic Design Considerations-

1. Correct application of hydrologic analysis both onsite and within the local drainage area
    a. Correct unit hydrograph (i.e., Delmarva for coastal plain areas)
    b. Pre and post drainage area maps with Tc flow paths and POI's identified
    c. Realistic sheet flow length in time of concentration (in all cases, not to exceed 100')
    d. Correct pre and post development runoff coefficients
    e. Influence of geology (esp. limestone prone areas)
    f. Submission of electronic modeling files to the district
    g. Submission of Hydrologic Summary forms for each basin
2. Assessment of pre and post development flows for the 2, 10 and 25 (rip rap) year storm events

3. Determination of soil types and their associated limitations (i.e., depth to ground water, slope stability) using the Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm)
4. Final points of discharge from the site and stability at those locations
5. Discharging to agricultural fields (generally not permitted due to stability concerns)
6. Infiltration and failure analysis for stability
7. Impact of discharge beyond the limits of the project (off site stability)
8. Stability of slopes – both from overland flow as well as impacts due to infiltration saturation
9. Proper use of permanent vegetative cover – species selection, irrigation, soil quality, maintenance
10. Use of turf reinforcement matting on steep slopes or channel lining
11. Rock rip rap sizing, gradation and availability; alternate use of gabions or reinforced concrete
12. Grass water way designs using vegetative retardance (D & E) factors, soil conditions, velocity, proper vegetation and reinforcement mating

Requirements of Other Agencies-

1. NJ Department of Environmental Protection-
   a. Stormwater Rules
   b. Wetlands
   c. Highlands
   d. Stream Encroachment
2. Residential Site Improvement Standards
3. NJ Department of Transportation
4. NJ Pinelands Commission
5. County and municipal construction codes

When preparing an erosion control plan, one resource which should not be overlooked is New Jersey's 15 Soil Conservation Districts. With a broad spectrum of expertise in the areas of erosion and sediment control, agronomy, horticulture and stormwater management, District staff are available to assist designers with development of reliable and effective strategies for controlling erosion from construction sites. A list of New Jersey Soil Conservation District contact information is found in Appendix E of the Standards.

Procedure for the evaluation of new erosion control technologies, products and services for compliance with the Standards for Soil Erosion and Sediment Control in New Jersey

In order to address opportunities to utilize new and innovative technologies, products and services (TPS) for sediment and erosion control, the New Jersey Department of Agriculture, State Soil Conservation Committee (SSCC) has adopted the following evaluation process which is intended to provide compliance with the Standards.

The Standards include, where appropriate and necessary, design and performance specifications so that any TPS which meets these specifications would be acceptable for use on construction sites in New Jersey for compliance with the Act without the need for extensive (and expensive) laboratory testing. A new TPS which differs from design or performance standards, or which attempts to define a non-standardized practice must be field tested in New Jersey prior to acceptance.[1]

Field performance will be monitored by Soil Conservation District personnel as well as the NJDA State Erosion Control Engineer (as needed). The process for TPS field evaluation is as follows:

1. The vendor will provide a written request for evaluation to the State Engineer and the local Soil Conservation District where the product is to be evaluated. The request must include a physical/chemical description of the product, design limitations (if any), what function the product is intended to perform, and which Standard it is to be used in compliance for. Laboratory or other supplier-derived test data may also be submitted if desired.

2. The State Engineer will review the request and consult with the respective district or districts to verify that the TPS being proposed is appropriate for the intended application and site location. Alternative locations may be suggested if the proposed location is not deemed adequate for a complete evaluation. Written permission and agreement for allowing the evaluation must be secured from the site owner and is the responsibility of the vendor, with a copy provided to the district and State Engineer.[2] The State Engineer can provide written confirmation to the site owner that for testing and evaluation purposes, the owner is assisting the State in its evaluation of a new product and will not be liable for a lack of erosion control compliance with their certified plan due to product failure as long as the product is properly installed and is provided with the appropriate routine maintenance, as would be the case for the use of any erosion control product.

3. The State Engineer will advise the SSCC and other districts of the request for testing at the next SSCC meeting.

4. Once a proper location is secured, the vendor will oversee and provide training (if necessary) for proper installation of the product to ensure an adequate evaluation is performed. During the evaluation, District staff and/or the State Engineer will monitor and observe the performance of the TPS and maintain observations in project record notes as part of routine inspections. The TPS must be properly installed and in good working order during a test event to be considered as a viable test. Unintentional damage or improper installation and subsequent failure will not count as a viable test. The State Engineer may consult with other experts, as needed, to ensure comprehensive evaluation. The vendor will be notified if any product failure or damage occurs so that corrective action may be taken, if appropriate, to restore proper functioning of the TPS.

5. TPS's which are intended to secure against erosion by resisting the forces of water and/or wind will be evaluated for 3 discrete events, each of which must meet the minimum event criteria (such as minimum precipitation depth, flow rate, velocity, etc.) prescribed by the vendor or as stipulated in the applicable Standard. For TPS's intending to promote or enhance vegetative stabilization an evaluation period of two consecutive growing seasons will be observed to determine product performance.

6. The State Engineer will review notes, photos, etc. and present findings and conclusions to the SSCC with recommendations. These recommendations may be:

   (1) the TPS is acceptable for use anywhere in NJ;

   (2) the TPS is acceptable for use only in particular locations in NJ

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1 Not every Standard is based on design and/or performance criteria. Certain Standards require computation or specific materials in their application for compliance.

2 Neither the Soil Conservation District nor the State Engineer may compel a project owner to allow the use of a new product for testing on his or her site. Assistance is strictly voluntary on the part of the owner.

(3) the TPS is acceptable for use only for particular site and/or weather conditions

(4) the TPS is not acceptable for use in NJ.

The SSCC may, at is pleasure and discretion, accept, accept with modifications or reject the recommendations.

7. A TPS that is found to be acceptable for use in NJ (with or without conditions) will be identified in a TPS Bulletin (PSB) to be maintained and published by NJDA-SSCC. Conditions or limitations of the TPS will be identified in the bulletin, which will be published on the Department's website and will be available for public download. The vendor will be provided a copy of the findings and conclusions along with a copy of a TPS Bulletin, if one is issued.

8. Once a TPS Bulletin is issued, no further written approval or requests for use will be required for inclusion on soil erosion and sediment control plans or as an equivalent substitute to controls that are already shown on a plan. All manufacturer installation details, maintenance requirements and limitations must be included on the plan adjacent to the installation details.

Compliance with the Standards is required by N.J.S.A. 4:24-39 et seq. for all construction sites in New Jersey which meet the definition of a soil disturbance 'project' as defined in the Act. As a result, the specific inclusion of proprietary, manufactured products, product names, technologies or services is prohibited in that this may constitute the endorsement of one product over another by the State. Generic products which have historically been used for controlling erosion and are considered to be in the public domain may be generically referenced in the Standards without the use of trade-marked ™ names.

State Soil Conservation Committee

Standards For Soil Erosion and Sediment Control in New Jersey

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Appendices

STANDARD FOR CHANNEL STABILIZATION

Definition

Stabilizing a channel, either natural or artificial, in which water flows with a free surface.

Purpose

Open channels are constructed or stabilized to be non-erodible and provide adequate capacity for the conveyance of flood water, drainage, other water management purposes or any combination thereof.

Conditions Where Practice Applies

This standard applies to the construction and stabilization of open channels for storm water conveyance and flood control and to the restoration of existing streams or ditches regardless of drainage area. It does not apply to diversions or grassed waterways.

Water Quality Enhancement

This standard seeks to produce a water conveyance channel which is characterized by natural features as much as possible while still incorporating engineered stability. This includes protection of existing vegetation and channel meander, rapid establishment of new stabilizing vegetation and design of new "natural" channel structures such as pools, riffles etc. Including these features helps promote low suspended solids, high dissolved oxygen levels and healthy macro invertebrate populations all of which are indicators of good water quality.

Design Criteria – Storm water conveyance and flood control channels

Planning

The alignment and design of channels shall involve giving careful consideration to the preservation of valuable fish and wildlife habitat. Trees of significant value for wildlife food or shelter shall be preserved whenever possible.

Where channel construction will adversely affect a significant fish or wildlife habitat, mitigation measures should be included in the plan. Mitigation measures may include pools, riffles, flats, cascades or other similar provisions.

As many trees as possible are to be left after considering the requirements for construction, operation and maintenance. See Standard for Tree Protection During Construction.

Realignment

The realignment of channels shall be kept to an absolute minimum.

Channel Capacity

The capacity for open channels shall be determined by the designer and/or the appropriate regulatory authority.

Capacity (peak discharge) shall be determined by the following methods:

1. Rational Method - for peak discharge of uniform drainage areas as outlined in Technical Manual for Stream Encroachment, Trenton, N.J., Bureau of Flood Plain Management,

2. USDA NRCS hydrologic procedures including WinTR55 and WinTR20.

3. U.S. Army Corps of Engineers HEC HMS

4. Other methods which produce similar results to the models listed above.

Hydraulic Requirements

Manning's formula shall be used to determine the velocities in the channels.

The "n" values for use in this formula shall be estimated using currently accepted guides along with knowledge and experience regarding the conditions.

Acceptable guides can be found in Appendix A11, Refs. 6, 7, and Appendix A8.

Every reach shall be individually designed unless all reaches are designed on the worst cases for velocity and capacity (lowest allowable velocity, steepest slope).

Channel Side Slopes

Channel side slopes in earth shall be 2:1 or flatter unless the design, using the procedures in Appendix A8, shows that a steeper side slope is stable. Channel side slopes of materials other than earth shall be designed stable.

Channel Stability (General)

All channel construction, improvement and modification shall be in accord with a design which results in a stable channel.

Characteristics of a stable channel are:

1. It neither aggrades nor degrades beyond tolerable limits.

2. The channel banks do not erode to the extent that the channel cross section is changed appreciably.

3. Excessive sediment bars do not develop.

4. Excessive erosion does not occur around culverts and bridges or elsewhere.

5. Gullies do not form or enlarge due to the entry of uncontrolled surface flow to the channel.

The determination of channel stability considers bankfull flow. Bankfull flow is defined as the flow in the channel which creates a water surface that is at or near normal ground elevation for a significant length of a channel reach. Excessive channel depth created by cut through high ground, such as might result from realignment of the channel, should not be considered in determinations of bankfull flow.

Channel Stability (drainage area of one square mile or less)

1. Permanent Channel

   Channels in this category shall be considered stable if the actual velocity is less than the allowable velocities shown in Table 11-1. The actual velocity is defined as the velocity developed during the lesser of the following events:

a. Bankfull discharge

b. 10-year frequency, storm, peak

2. Temporary (90 days or less) Bypass Channel

   Channels in this category shall be considered stable if the actual velocity is less than the allowable velocities shown in Table 11-1. The actual velocity is defined as the velocity developed during the 2-year frequency peak discharge.

3. As a stable design, the channel shall meet the following allowable velocity criteria and shall not be designed above 90% of critical flow (Froude number = 0.90).

Table 11-1
Allowable velocity for various soil textures

SOIL TEXTURE	ALLOWABLE VELOCITY ft./sec.
Sand	1.8
Sandy loam	2.5
Silt loam, loam	3.0
Sandy clay loam	3.5
Clay loam	4.0
Clay, fine gravel, graded loam to gravel	5.0
Cobbles	5.5
Shale (non weathered shale)	6.0

Linear crossing of existing channels by pipelines and similar devices do not require a stability analysis of the channel provided the final cross sectional area of the stream remains the same.

Channel Stability (drainage area greater than one square mile)

Channels must be stable under conditions existing immediately after construction (as-built condition) and under conditions existing during effective design life (aged condition). Channel stability shall be determined for discharges under these conditions as follows:

1. As-built condition - Bankfull flow, design discharge, or 10-year frequency flow, whichever is smallest, but not less than 50% of design discharge.

2. Aged condition - Bankfull flow or design discharge, whichever is larger, except that it is not necessary to check stability for discharges greater than the 100-year frequency.

Stability checks are not required if the actual velocity is 1.8 fps or less.

Linear crossing of existing channels by pipelines and similar devices do not require a stability analysis of the channel provided the final cross sectional area of the stream remains the same.

Where vegetation can be rapidly established by natural or artificial means, the allowable as-built velocity (regardless of type stability analysis) in the newly constructed channel may be increased by a maximum of 20%. The 20%

adjustment does not apply to the allowable velocity for aged condition. This increase is justified only if:

1. The soil and site in which the channel is to be constructed are suitable for rapid establishment and support of erosion-controlling vegetation,

2. Species of erosion-controlling vegetation adapted to the area and proven methods of establishment are known, and

3. The channel design includes detailed plans for establishing vegetation on the channel side slopes.

For newly constructed channels in fine-grained soils and sands, the "n" values shall be determined according to specifications in Appendix A8 and shall not exceed 0.025. The "n" value for channels to be modified by clearing and de-snagging only shall be determined by reaches according to the expected channel condition upon completion of the work.

The above stability checks will be made using either tractive stress or allowable velocity procedures given in Appendix A8. The choice of method will depend upon the grain size and cohesiveness of the soil being checked. The following will be used as a guide in choosing the method:

A. Tractive Stress - see Appendix A8

   1. Coarse grained soils

   2. Fine grained noncohesive soils (PI <10)

B. Allowable Velocity - see Appendix A8

   1. Coarse grained soils (tractive stress procedure recommended)

   2. Fine grained cohesive soils (PI >10)

   3. Fine grained noncohesive soils (PI <10) (tractive stress procedure recommended)

Stability checks should be made for each significant soil horizon present. Soil sampling and testing is required to determine the grain size distribution and plasticity index of each material to be checked.

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<u>Channel Linings and Structural Measures</u>

Where channel velocities exceed allowable velocities, the channel must be stabilized.

Channels may be stabilized by using one or more of the following methods:

1. <u>Rock Riprap Lining</u> shall be designed using the procedures given in Standard for Riprap, p. 23-1.

2. <u>Concrete Lining</u> shall be designed according to currently accepted guides for structural and hydraulic adequacy. They must be designed to carry the required discharge and to withstand the loading imposed by site conditions. Concrete lining shall be reinforced where required.

3. <u>Grade Stabilization Structures</u> can be used where excessive grades exist. The structures provide for one or more drops along the channel profile to reduce the channel slope. See Standard for Grade Stabilization

Structures.

The structures must be designed hydraulically to adequately carry the channel discharge and structurally to withstand loadings imposed by the site conditions. They may be constructed of concrete, rock, masonry, steel, gabions, aluminum or treated timber. Appendix A11, Chapter 6, Ref. #8, provides procedures for use in the design of these structures.

Energy Dissipaters are employed to force a hydraulic jump and its associated turbulence to occur at a location where suitable protection can be provided against bank scour and channel erosion. Construction of energy dissipaters are normally at the base of chutes or drop structures and are usually an integral part of the design of the structure. Sills, baffles, floor blocks or other obstructions to channel flow may serve as energy dissipaters. Appendix A11, Chapter 15, Ref. #6, provides design considerations for energy dissipation with the hydraulic jump.

4. Consideration may be given to the utilization of Soil Bioengineering techniques for channel stabilization. These techniques are not to be used when a structural design is required for safety, etc. See Standard for Soil Bioengineering for additional design guidance.

Design Criteria – Stream Restoration

Designs for stream restoration try to mimic natural conditions present in stable reaches proximate to the area to be treated. The extent of structural treatments beyond toe protection will be evaluated on a case by case basis. Generally, vegetative or bioengineering treatments (Soil Bioengineering) shall be used to stabilize low risk areas (agricultural, wooded, or other natural settings where there is little threat to adjacent structures or improvements. In high risk areas where there is significant threat of damage to physical improvements (homes, buildings, utilities, roadways, etc.) or to important cultural or environmental features, structural protection will be more appropriate.

A site assessment shall be performed to determine if the causes of instability are local (e.g. poor soils, high water table in banks, alignment, obstructions deflecting flows into bank, etc.) or systemic in nature (e.g. aggradation due to increased sediment from the watershed, increased runoff due to urban development in the watershed, degradation due to channel modifications, etc.). The assessment need only be of the extent and detail necessary to provide a basis for design of the treatments and reasonable confidence that the treatments will perform adequately for the design life of the measure.

In low risk areas treatments shall be evaluated under bankfull or ten-year return period (10 percent probability) flow conditions, whichever is less. High risk areas may require evaluations under less frequent flow events (up to a 100 year return period) depending on the value of the protected area. More frequent storm events should also be evaluated where these result in higher flow velocities.

Changes in channel alignment shall not be made without an assessment of both upstream and downstream fluvial geomorphology that evaluates the affects of the proposed alignment. The current and future discharge-sediment regime shall be based on an assessment of the watershed above the proposed channel alignment.

Bank protection treatment shall not be installed in channel systems undergoing rapid and extensive changes in bottom grade and/or alignment unless the treatments are designed to control or accommodate the changes. Bank treatment shall be constructed to a depth at or below the anticipated lowest depth of streambed scour.

Toe erosion shall be stabilized by treatments that redirect the stream flow away from the toe or by structural treatments that armor the toe. Additional design guidance is found in the National Engineering Handbook Part 654, Stream Restoration Design. Where toe protection alone is inadequate to stabilize the bank, the upper bank shall be shaped to a stable slope and vegetated, or shall be stabilized with structural or soil-bioengineering treatments. Measures to redirect flow shall not reduce the flood carrying capacity of the stream nor cause adverse erosion or sedimentation elsewhere in the stream system. All treatments shall be stable under design flow conditions.

Where flooding is a concern, the effects of protective treatments shall not increase flow levels above those that existed prior to installation. When vegetative treatments are planned, flow levels shall be evaluated under mature growth conditions.

Installation Requirements

1. All trees, brush, stumps, and other objectionable materials that would interfere with the construction or proper functioning of the channel shall be removed.

2. Where possible, trees will be left standing, brush and stumps will not be removed and channels will be excavated from one side, leaving vegetation on the opposite side.

3. Construction plans will specifically detail the location and handling of spoils.

4. Seeding, fertilizing and mulching shall conform to the Standard for Permanent Vegetative Cover for Soil Stabilization.

5. Vegetation shall be established on all disturbed areas immediately after construction, weather permitting. If weather conditions are such as to cause a delay in the establishment of vegetation the area shall be mulched in accordance with the Standard for Stabilization with Mulch Only.

STANDARD
FOR
CONDUIT OUTLET PROTECTION

Definition

Conduit Outlet Protection consists of an erosion resistant section between a conduit outlet and a stable downstream channel.

Purpose

To provide a stable area at the outlet of a conduit in which the exit velocity from the conduit is reduced to a velocity consistent with a stable condition in the downstream channel.

Conditions Where Practice Applies

This practice applies to all conduit outlets. Conduit outlet protection is not needed if the design flow is not constricted by the conduit in the waterway or stream (top width in culvert equals normal flow top width in stream). Under this condition, transition areas such as at bridge or culvert abutments shall be armored up and downstream in accordance with the riprap standard. This includes areas in the immediate vicinity of the culvert which may be disturbed in order to facilitate the culvert installation.

Water Quality Enhancement

The use of this standard will protect the area immediately downstream of a conduit outlet from localized erosion in the form of scour, which is a common source of sediment in lakes and streams.

Design Criteria

Determination of Needs

The need for conduit outlet protection shall be determined by comparing the allowable velocity for the soil onto which the conduit is discharging to the velocity in the conduit. The allowable velocity for the soil shall be that given in Table 12-1, pg. 12-2. The velocity in the conduit shall be that which occurs during passage of the conduit design storm or the 25-year frequency storm, whichever is greater. When the velocity in the conduit exceeds the allowable velocity for the soil, conduit outlet protection will be used.

TABLE 12-1 ALLOWABLE VELOCITIES FOR VARIOUS SOILS

SOIL TEXTURE	ALLOWABLE VELOCITY (ft./sec.)
Sand	1.8
Sandy loam	2.5
Silt loam (also high lime clay), loam	3.0
Sandy clay loam	3.5
Clay loam	4.0
Clay, fine gravel, graded loam to gravel	5.0
Cobbles	5.5
Shale (non-weathered)	6.0

A. Horizontal Riprap Apron (fig. 12-1, 12-2)

Apron Dimensions – unconfined outlet

1. The length and width of the apron shall be determined from the formulas:

TW < ½ D_o $$La = 1.8\left(\frac{q}{Do^{0.5}}\right) + 7Do \qquad Wa = 3Wo + La$$

TW ≥ ½ D_o $$La = 3\left(\frac{q}{Do^{0.5}}\right) \qquad Wa = 3Wo + 0.4La$$

where $q = \frac{Q}{Wo}$

Where D_o is the maximum inside culvert height in feet, W_o is the maximum inside culvert width in feet, q is the unit discharge, = Q/W_o in cfs per foot for the conduit design storm or the 25 year storm, whichever is greater and L_a is the length of the apron determined from the formula and W_o is the culvert width.

The width of the apron at the culvert outlet shall be at least 3 times the culvert width.

2. Where there is a well-defined channel downstream of the apron, the bottom width of the apron shall be at least equal to the bottom width of the channel; and the structural lining shall extend at least one foot above the tailwater elevation but no lower than two-thirds of the vertical conduit dimension above the conduit invert.

3. The side slopes shall be 2:1 or flatter.

4. The bottom grade shall be 0.0% (level).

5. There shall be no over fall at the end of the apron or at the end of the culvert.

B. Riprap

1. The median stone diameter, D_{50}, in feet, shall be determined from the formula:

For Horizontal Apron: $$d_{50} = \frac{0.02}{Tw} q^{1.33} \quad \text{where} \quad q = \frac{Q}{Wo}$$

For areas where Tw cannot be computed, use Tw = 0.2 D_o

Where q and D_o are as defined under apron dimensions and T_W is tailwater depth above the invert of culvert in feet.

<u>Preformed Scour Hole</u>

Performed scour holes may be utilized, as depicted in Figure 12-3 where conditions dictate the impractical use of flat aprons. The median stone diameter, D_{50}, in feet, shall be determined from the following formulas:

where Y = ½ D_o $$d_{50} = \frac{0.0125}{Tw} q^{1.33}$$

where Y = D_o $$d_{50} = \frac{0.0082}{Tw} q^{1.33}$$

Y = depth of scour hole below culvert invert and $q = \frac{Q}{Wo}$

The use of scour holes shall comply with county or local ordinances which would restrict the use of such devices due to possible problems with mosquito breeding.

Conduit Outlet Protection Design for Discharge into Detention Basins

Design of the median stone size for pipes discharging into a basin shall be based on one of the following methods:

1. Q shall be the 25 year storm discharge and Tw shall equal the 2 year storm elevation in the basin.

2. Analyze the hydraulic characteristics of the basin for the design storm to determine the combination of conduit discharge and tailwater that results in the largest required D_{50} stone size.

<u>Downstream Protection</u>

The conduit discharge shall not cause erosion in the downstream channel or aggravate conditions in the downstream channel. The designer shall furnish calculations to show that the conditions downstream will not be degraded as a result of the proposed construction (See Standard for Off-Site Stability, pg. 21-1)

Riprap Requirements

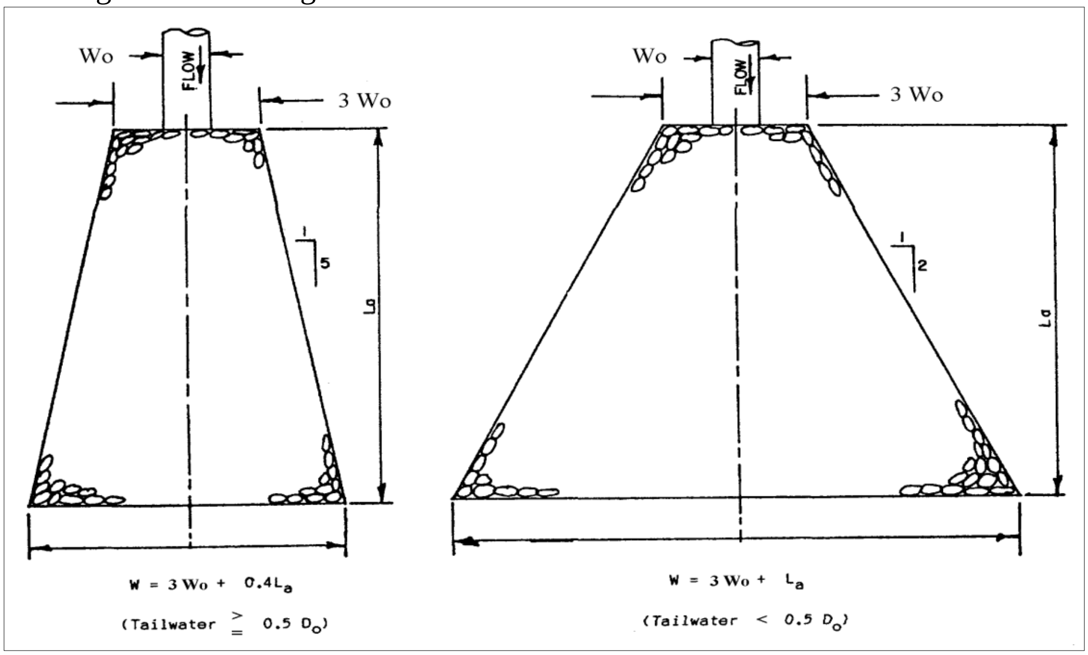
1. Fifty percent by weight of the riprap mixture shall be smaller than the median size stone designated as D_{50}. The largest stone size in the mixture shall be 1.5 times the D_{50} size. The riprap shall be reasonably well graded.

2. The thickness of riprap lining, filter and quality shall meet the requirements in the Riprap Standard pg. 22-2 & 22-3.

3. Properly designed concrete paving may be substituted for riprap.

4. Plastic-coated wire mesh stone-filled baskets or mattresses or concrete revetment blocks may be substituted for riprap if the D_{50} size calculated above is less than or equal to the thickness of the wire mesh structures or concrete revetment blocks. Design life of the wire mesh structures is estimated to be ten (10) years (minimum). Wire mesh baskets shall be filled with 4" to 7" angular shaped rock. For wire mesh "mattress" structures 3" to 4" stone may be used provided the mesh opening is small enough to contain the stone. Smaller stone will provide more stone "layers" in the mattress where larger stone would not sufficiently fill the structure's void space.

Figure 12-1 Configuration of Conduit Outlet Protection

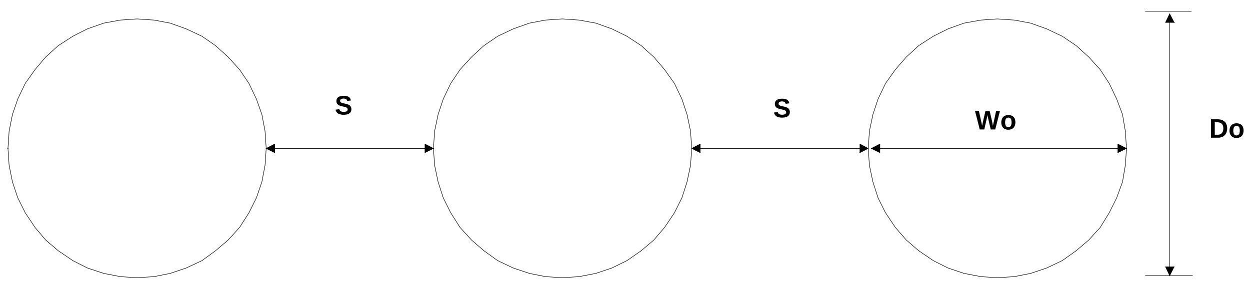


Installation Requirements

1. No bends or curves at the intersection of the conduit and apron or scour hole will be permitted.
2. There shall be no over fall from the end of the apron to the receiving channel.

Figure 12-2 Guidance for Multiple Culvert Outlets

All Culverts Same Diameter
Discharging Same Q



For $S < \frac{1}{4} W_o$ Size Riprap & Length for 1 pipe.
Width shall accommodate all culverts

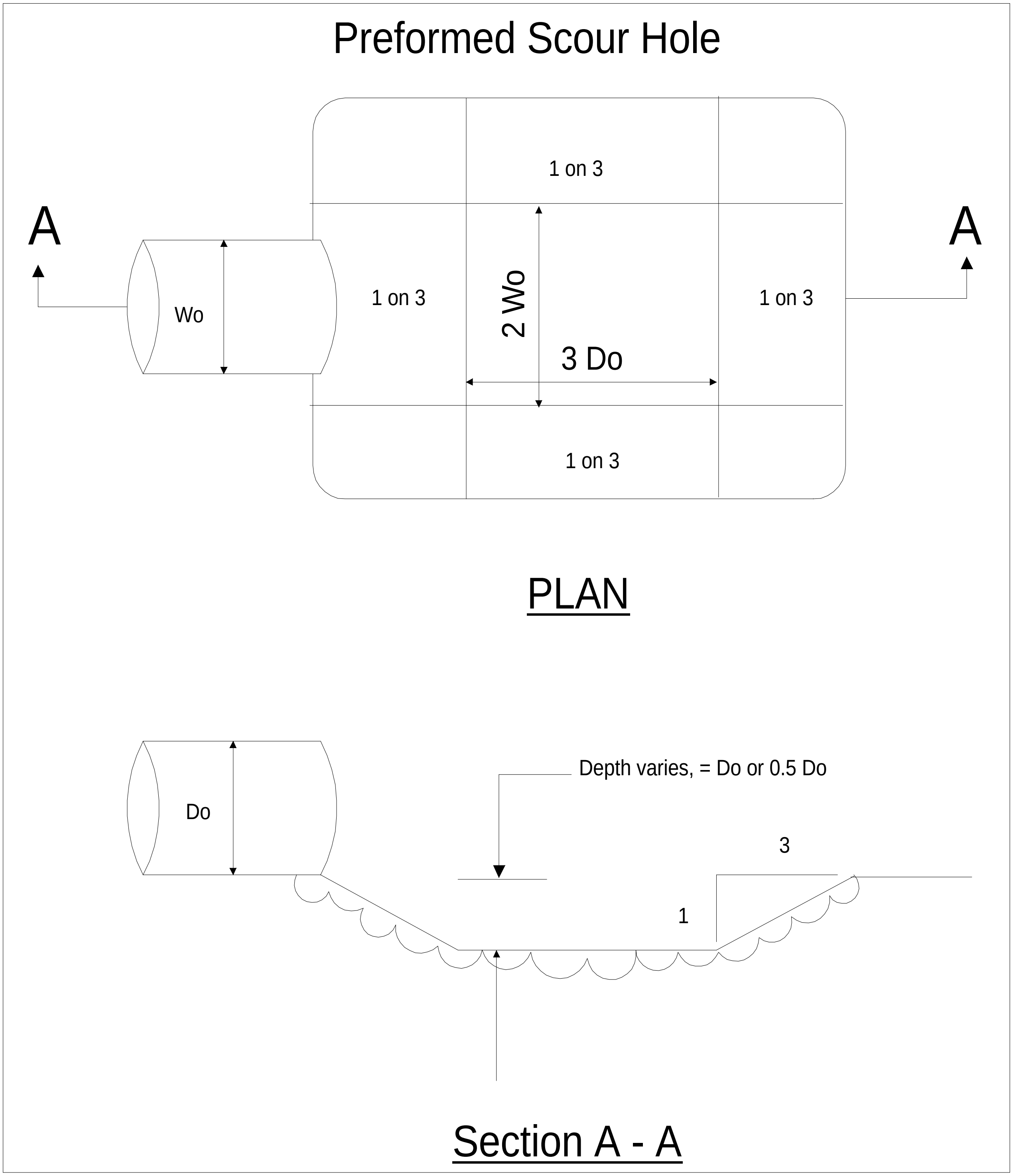
For $S \geq \frac{1}{4} W_o$ Size Riprap & Length for 1 pipe and
increase values by 25 %

For culverts of varying diameters or discharge check riprap size and apron length for each. Use the largest values. Increase length and riprap values by 25% if spacing is greater than ¼ W_o. Width shall accommodate all culverts.

References

Fletcher, B. P. and Grace, J. S. Jr., Practical Guidance For Estimating And Controlling Erosion at Culvert Outlets, 1972, Corps of Engineers Research Report H-72-5, Waterways Experimentation Station, Vicksburg, Mississippi

Figure 12-3 Configuration of Preformed Scour Hole



STANDARD
FOR
DETENTION STRUCTURES
FOR CONTROL OF DOWNSTREAM EROSION

Definition

A structure providing for temporary storage of stormwater runoff and its controlled release.

Structures created by construction of dams or barriers are referred to as "Embankment Structures" and those constructed by excavation as "Excavated Structures." Structures resulting from both excavation and embankment construction are classified as "Embankment Structures" where the depth of water impounded against the embankment at the emergency spillway elevation is 3 feet or more. Other forms of detention are also addressed in this standard such as rooftop and parking lot storage and underground detention systems.

Scope

This standard covers the installation of all detention, and infiltration / retention structures (those which retain a permanent pool of water below the design storm storage volume elevation).

Purpose

Detention structures are an available option to reduce erosion damages downstream by controlling the release from flows of predetermined frequencies. They may also permit the use of more economical channel improvements or stabilizing structures in the channel downstream and reduce environmental hazards and pollution.

Conditions Where Practice Applies

This practice applies if there is a potential for increased downstream erosion due to construction at development sites or from other land use changes or if local ordinances require storm detention structures. In general the practice applies to reducing the post development peak flows to 50% and 75% of predevelopment peak flows for the 2 and 10 year storms, respectively. The increased downstream erosion may be caused by increased runoff volume and/or increased peak discharge. If the detention structure is also intended to comply with the provisions of the Stormwater Management Act of 1981 or any revisions thereto, regulations promulgated by DEP pursuant to that Act shall apply. Additional design criteria required by the NJ Pinelands Commission may also apply.

.

Special consideration shall be given to the use of infiltration for peak flow modifications as follows:

Point of Discharge Stability Analysis

When infiltration practices are proposed, an alternate analysis (failure analysis) must be provided which ignores infiltration (no dead storage volume available, no static or dynamic infiltration loss rates in the routing calculations, etc) and demonstrates that no erosion will occur at the point of discharge if infiltration fails to function. Flow rates based solely upon basin inlet and outlet hydraulics must be used in comparison to Table 21-1 to document a stable outlet.

Downstream (off-site) Stability Analysis.

Infiltration may be used to meet peak flow reduction requirements (outlined above) for the purposes of documenting stability of the downstream receiving channel, provided that the complete loss of infiltration function does not result in an increase in peak flow values above the predevelopment levels.

Water Quality Enhancement

The use of a detention structure to control stormwater runoff may have several beneficial effects on water quality. First and foremost, control of small event storms will help prevent downstream erosion. Larger storms are managed to mitigate against flooding. By virtue of their ability to store runoff for a prolonged period, other effects such as deposition of suspended solids (including floatable trash and loose vegetation) and biochemical degradation of fertilizers, pesticides and biosolids is also possible. Detention structure design and application should be predicated upon a watershed analysis (model) whenever possible to achieve the maximum benefit to stormwater management.

Design Criteria

Structural aspects of detention structures shall be as stipulated by applicable State requirements and are not regulated in this or other Standards. In the absence of such criteria Appendix A-10, Structural Guidelines for Detention Structures may be used. In Karst regions of the State, sufficient surface and subsurface investigations shall be conducted in order to identify the presence or absence of limestone within the reservoir and embankment area. Locations where sinkholes or solution channels are present or locations which have the potential for formation of these features, should be avoided. If alternate locations are not available, sealing or lining of the reservoir area may be required to prevent excessive seepage. See requirements under **Investigation, Design and Remedial Measures for Areas Underlain by Cavernous Limestone**, Appendix A10-19.

In addition it must be shown for the peak outflow as determined by the Modified Rational Method, USDA-NRCS Technical Release 55, Technical Release 20 , USACOE - HEC HMS or other methods which produce similar results to these models, that there will be no soil erosion and sedimentation problems offsite. A detailed hydraulic analysis of the detention structure shall be submitted which will include an off site stability analysis pursuant to the Standard for Off-Site Stability, pg. 21-1. A completed Hydrologic Summary Form (Appendix A-2) shall be submitted to the district for each detention structure proposed.

Design Storms

The peak discharge from the 2-year and 10-year frequency storm shall be analyzed. Frequency, duration and distribution shall be as defined in the USDA-NRCS Technical Release 55.

Design storm and volume may be determined by the Modified Rational Method on drainage structures up to 20 acres as described in Special Report 43 by the American Public Works Association, Practices in Detention of Urban Stormwater. This method is not recommended for analysis of sites with sensitive off-site areas. If there is an overall storm water management plan for the watershed that considers erosion, downstream peak flow increases that are compatible with the overall plan may be allowed. Note - more restrictive stormwater management regulations may be required by other state or local agencies.

Outlets for Conduits

Protection against scour at the discharge end of the spillway shall be provided in accordance with the Standard for Conduit Outlet Protection or by suitable hydraulic structures proven effective by properly documented research.

Outlets discharging into structures shall also be designed in accordance with the Standard for Conduit Outlet Protection.

Vegetation

The dam, emergency spillway, spoil, borrow areas and other disturbed areas above the crest of the principal spillway shall be vegetated in accordance with the Standard for Permanent Vegetative Cover for Soil Stabilization. All cut or fill slopes should be flat enough to accommodate the proposed operation and maintenance equipment.

Safety

Detention structures attract children and can be very dangerous. Local, county or state regulations regarding health and safety must be adhered to.

This portion of the Standard is for guidance only.

Ownership

Ownership and responsibility for operation and maintenance of the detention structure must be determined during design and shown on the plans and on the completed "Hydraulic and Hydrologic Data Base Summary Form" (Appendix A2). To be effective over a long period of time the structure must be properly maintained.

This portion of the Standard is for guidance only.

Operation and Maintenance - General

A detailed schedule of operation and maintenance should be prepared for use by the owner or others responsible for the structure to insure that the structure functions properly. This schedule should provide requirements for at least annual inspection, operation, and maintenance of individual components, including outlets. It should be prepared during design and should specify who is responsible for maintenance. Additional requirements of other state and local agencies may apply.

Underground Facilities

Underground detention facilities shall be designed to prevent failure due to internal or external pressures including hydrostatic uplift pressure and imposed surface loads such as vehicles operated on or adjacent to the detention facility. Criteria for structural design are outside the scope of this standard. Structural design criteria must be based on sound and accepted engineering practices.

In acid or sulfidic soils, materials shall be non-reactive with the soil or measures shall be taken to protect the facility from the soil. Provisions shall be made to prevent debris from entering the facility. Debris collectors shall be placed so that the need for maintenance can be readily detected and cleaning operations easily performed. The bottom of the facility shall be on a slight grade to insure complete drainage. Access must be provided to the facility to permit removal of sediment and other debris.

Soil Conservation Districts are responsible for the enforcement of operation and maintenance of stormwater management facilities during construction for the control of erosion and sedimentation only. Once a Final Certificate of Compliance has been issued by the district proper operation and maintenance becomes the responsibility of the entity designated on the plans and schedule.

STANDARD FOR DEWATERING

Definition

The removal and discharge of sediment-laden water from an excavated area, construction site or sediment basin.

Purpose

To properly remove suspended sediments and water from excavated areas through filtration and/or settlement prior to discharging water to a receiving water course or body.

Conditions Where Practice Applies

During construction excavated facilities need to be dewatered to facilitate or complete the construction process. The water pumped out of the excavated areas contain sediments that must be removed prior to discharging to receiving bodies of water. This standard does not address the removal of ground water through well points etc.
This standard describes the following practices for the removal of sediment laden waters from excavation areas: removable pumping stations, sump pits, portable sedimentation tanks and silt control bags.

Water Quality Enhancement

Water discharged from excavated areas on construction sites may be a significant contributor of sediment to surface waters during construction. Water must be removed and disposed of in order for construction to move forward. Typically, water is pumped or containment berms are breached and sediment laden waters are permitted to flow uncontrolled into surface waters such as streams or lakes. By employing practices described in this standard, the majority of sediment suspended in waters may easily be removed prior to leaving the site. Filters and materials described herein are readily available and are easy to install and maintain.

Design Criteria

1. Removable Pumping Stations are used when long durations of pumping are required. The number of removable stations and their locations shall be shown on the plans and shall conform to detail 14-1. Water pumped from the station shall be discharged into a sediment basin or suitable filter area.

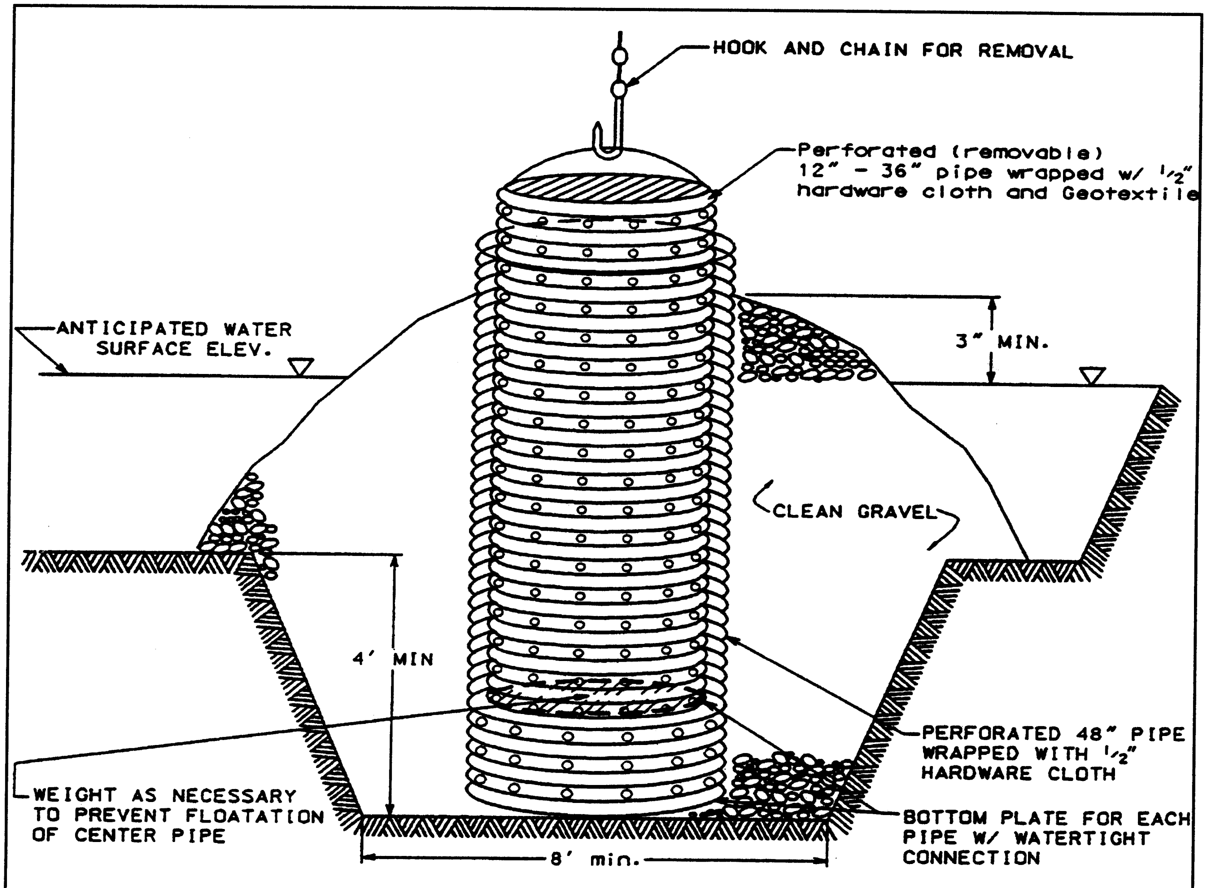
Construction Specifications

A. The suction hose from the pump shall be placed inside the inner pipe to begin dewatering. The discharge hose shall be placed in a stabilized area downslope of unstabilized areas to prevent erosion.

B. Maintenance- The inner pipe can easily be removed to facilitate changing the geotextile when it clogs. Maintenance must be performed when the pump runs dry and backed up water remains.

C. See Detail 14-1 for additional specifications.

Detail 14-1 Removable Pumping Station



ELEVATION (CUT AWAY)

Construction Specifications

1. The outer pipe should be 48" dia. or shall, in any case, be at least 4" greater in diameter than the center pipe. The outer pipe shall be wrapped with 1/2" hardware cloth to prevent backfill material from entering the perforations.

2. After installing the outer pipe, backfill around outer pipe with 2" aggregate or clean gravel.

3. The inside stand pipe (center pipe) should be constructed by perforating a corrugated or PVC pipe between 12" and 36" in diameter. The perforations shall be 1/2" X 6" slits or 1" diameter holes 6" on center. The center pipe shall be wrapped with 1/2" hardware cloth first, then wrapped again with Geotextile Class E.

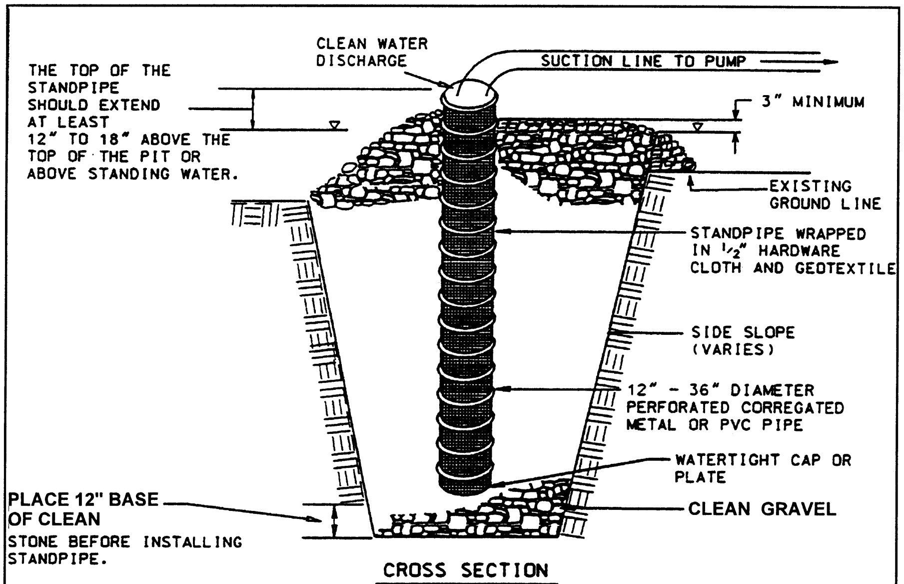
4. The center pipe should extend 12" to 18" above the anticipated water surface elevation or riser crest elevation when dewatering a basin.

Source: USDA NRCS 1994

2. <u>Sump Pits</u> are temporary pits which are used to remove excess water while minimizing sedimentation. The number of sump pits and their locations shall be included on the plans. Pits may be relocated to optimize use but discharge location changes must be coordinated with the local conservation district. The design must conform to the general criteria outlined on detail 14-2.

   A perforated vertical standpipe is wrapped with 2" hardware cloth and geotextile fabric then placed in the center of an excavated pit which is then backfilled with filter material consisting of anything from clean gravel (minimal fines) to ASTM C 33 stone (1 2" maximum diameter). Water is then pumped from the center of the standpipe to a suitable discharge area such as into a sediment basin or suitable filter.

Detail 14-2: Sump Pit



Construction Specifications

1. Pit dimensions are variable, with the minimum diameter being 2 times the standpipe diameter.

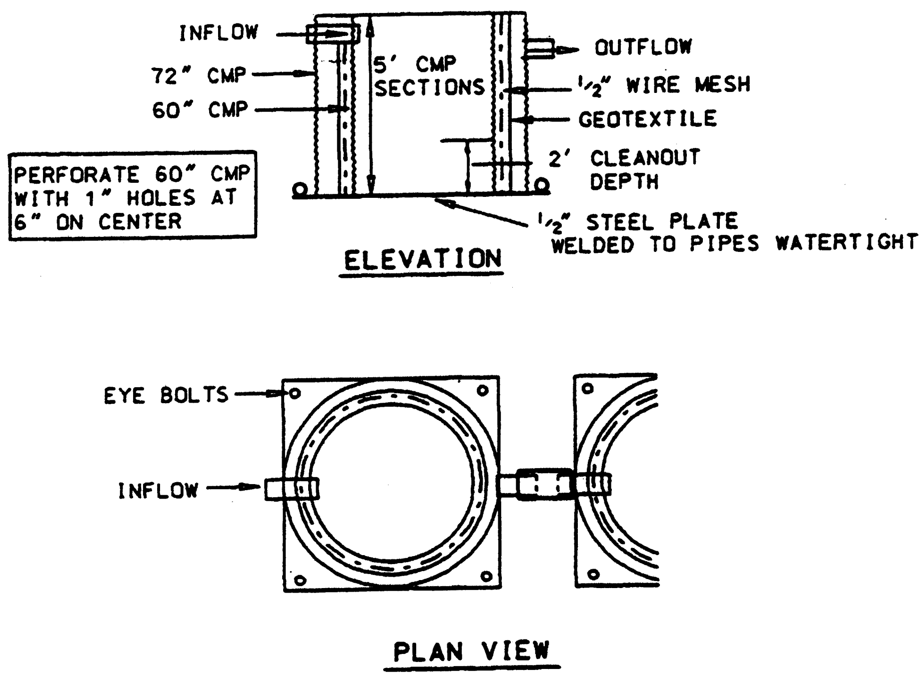
2. The standpipe should be constructed by perforating a 12" to 24" diameter corrugated or PVC pipe. Then wrapping with ½" hardware cloth and Geotextile fabric. The perforations shall be ½" x 6" slits or 1" diameter holes.

3. A base of filter material consisting of clean gravel or ASTM C 33 stone should be placed in the pit to a depth of 12". After installing the standpipe, the pit surrounding the standpipe should then be backfilled with the same filter material.

4. The standpipe should extend 12" to 18" above the lip of the pit or the riser crest elevation (basin dewatering only) and the filter material should extend 3" minimum above the anticipated standing water elevation.

Source: USDA NRCS 1994

Detail 14-3 Portable Sediment Tank



Construction Specifications

1. The following formula should be used in determining the storage volume of the sediment tank: 1 cubic foot of storage for each gallon per minute of pump discharge capacity.

2. An example of a typical sediment tank is shown above. Other container designs can be used if the storage volume is adequate and approval is obtained from the local conservation district

3. Tanks may be connected in series.

Source: USDA NRCS 1994

3. Sediment Tank / Silt Control Bags are containers through which sediment laden water is pumped to trap and retain the sediment. A sediment tank or a silt control bag is to be used on sites were excavations are deep, and space is limited and where direct discharge of sediment laden water to stream and storm drainage systems is to be avoided.

Construction Specifications

A. Location. Containers (tanks or bags) shall be located for ease of clean-out and disposal of the trapped sediment and to minimize interference with construction activities and pedestrian traffic. Bags shall not be place directly into receiving waters.

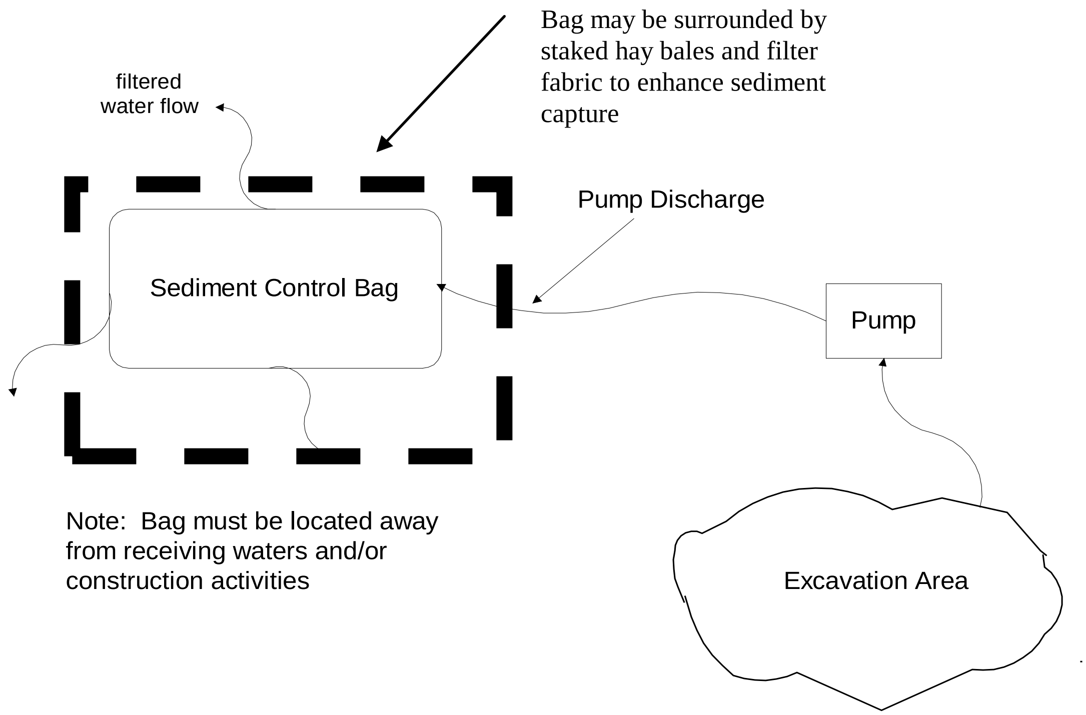
B. Tank size. The following formula should be used in determining the storage volume of the tank: 1 cubic foot of storage for each gallon per minute of pump discharge capacity. Typical tank configuration is shown on Detail 14-3. Tanks may be connected in series to increase effectiveness.

C. Tanks consist of two concentric circular pipes (CMP), attached to a watertight baseplate. The inner CMP is perforated with 1" holes on 6" centers and is wrapped with geotextile and hardware cloth. Pumped water is discharged into the inner CMP where it flows through the geotextile into the space between the two CMP=s. A discharge line is attached to the outer CMP and draws filtered water from the annulus between the two concentric CMP=s. The discharge line may be connected to another tank where it drains to the inner CMP of the second tank. This series connection may be continued indefinitely.

D. Sediment Control Bags must be located away from receiving waters and disposed of according to manufacturer's instructions. See Detail 14-4. Bags may be combined with temporary filters (item 4, following) for enhanced filtration.

4. Temporary filters for small impoundments For small quantities of ponded water such as may be found in shallow excavations (small trenches, manhole installations etc.) a sediment filter may be constructed using combinations of hay bales, small clean stone and filter fabric. This method is limited to small quantities of trapped surface water (pumping of well points is excluded from this standard) and where sediments are not highly colloidal in nature.

Detail 14-4 Sediment Control Bag for Dewatering



Bags must be disposed of according to manufacturer's instructions. Bags may not be reused.

STANDARD
FOR
DIVERSIONS

Definition

A channel with a supporting ridge on the lower side constructed across the slope.

Scope

This standard covers the installation of diversions with drainage areas up to 100 acres.

Temporary

Diversions installed as an interim measure to protect or facilitate some phase of construction. They usually have a life expectancy of one year or less. The failure hazard is low.

Permanent

Diversions installed as an integral part of an overall water management and disposal system and to remain for protection of property.

Purpose

The purpose of this practice is to divert water from areas where it is in excess to sites where it can be used or disposed of safely.

Conditions Where Practice Applies

This practice applies to sites where runoff is damaging: (1) low lying areas, (2) cut or fill slopes or steeply sloping land, (3) critical sediment source areas in construction sites, (4) buildings, residences, streets and (5) active gullies or other erodible areas.

Permanent diversions are not applicable below high sediment producing areas unless land treatment practices or structural measures, designed to prevent damaging accumulations of sediment in the channels are installed with or before the diversions.

Water Quality Enhancement

The primary benefit to water quality is through the prevention of erosion of lands with large drainage areas or steep slopes. Diversions control and direct stormwater runoff to stable locations, thus preventing the development of erosive forces which result not only in soil loss, but the transportation of associated soil nutrients, fertilizers, pesticides etc. into surface and possibly ground water resources.

Design Criteria

Capacity and Freeboard

Peak discharge values shall be determined by the following:

1. Rational Method - for peak discharge of uniform drainage areas as outlined in Technical Manual for Land Use Regulation Program, Bureau of Inland and Coastal Regulations Stream Encroachment Permits, Trenton, N.J.

September 1997 or subsequent editions.

2. USDA-NRCS Win TR-55 or Win TR-20.

3. U.S. Army Corps of Engineers HEC HMS

4. Other methods which produce similar results to the models listed above.

The minimum size shall be that required to confine the peak runoff from the design storm plus required freeboard. The design storm and freeboard shall comply with the following table:

Table 15-1 Temporary and Permanent Diversion Sizing

Diversion Type	Typical Area of protection	Design Storm Frequency	Freeboard Required (ft)
Temporary	Construction Areas (structures, roads, pipelines, etc.)	2 years	0.0
	Building Sites	5 years	0.0
Permanent	Agricultural Land	25 years	0.3 ft.
	Urban Land Areas, Play Fields, Recreation Areas, Agricultural Buildings, etc.	25 years	0.3 ft
	Homes, schools, industrial buildings, etc.	50 years	0.5 ft

General Notes

1. Diverted runoff shall outlet onto an undisturbed stable area or onto an area that has been stabilized.
2. Periodic inspection and required maintenance must be provided.

Velocity

The maximum permissible velocity for design flow will be determined by the most erodible soil texture exposed and the type of vegetation expected and maintained in the channel. As a stable design, the diversion shall meet the following permissible velocity criteria and shall not be designed above 90% of critical flow (Froude number = 0.90). The following table will be used in selecting maximum permissible velocities:

Table 15-2 Maximum Permissible Velocity by Soil Type

SOIL TEXTURE	Maximum Permissible Velocity (ft./sec.) (velocities based on flow of clear water.)		
	Channel Vegetation		
	Non-Veg.*	Veg.**	Sod***
Sand	1.8	2.0	3.0
Silt loam, sandy loam, loamy sand, loam, and muck	2.0	2.0	3.0
Silty clay loam, sandy clay loam	2.0	2.5	4.0
Clay, clay loam, sandy clay, silty clay	2.5	3.0	5.0

* Temporary Diversions

** Vegetated Channels - The minimum capacity and maximum velocity shall be determined by using the appropriate retardance factors listed below. See Appendix A6 for example and charts for use in design. Maximum allowable velocities for channels stabilized by seeding may be increased according to the type of Flexible Channel Liner used as shown in the Standard for Grassed Waterways . These velocities may be added to the allowable velocities shown above, except for sands.

Agricultural Handbook No. 667, Stability Design of Grass-Lined Open Channels, may also be used to design grass lined diversions based on tractive stress.

*** On well to excessively drained soils, the use of most cool season sod types will not survive without continued irrigation. Placement of sod in such areas must be approved by the District.

Permanent Cover and Erosion Protection

A permanent vegetative cover shall be established on all diversions in accordance with the Standard for Permanent Vegetative Cover for Soil Stabilization, or Standard for Permanent Stabilization with Sod. Where the season and other conditions may not be suitable for growing permanent erosion resistant cover, erosion protection will be provided in accordance with the Standard for Temporary Vegetative Cover for Soil Stabilization, or Standard for Stabilization with Mulch Only.

Diversions that are not designed to have a permanent vegetative cover shall be designed for bare channel velocities and with flat side slopes to prevent channel and side slope erosion. Diversions that are designed to have a permanent vegetative cover shall be seeded from the toe of the back slope to the upstream side of the designed channel width plus any required filter strip. Other areas disturbed by diversion construction shall also be seeded.

Vegetative Retardance Factors

Minimum Capacity - “D”

Maximum Allowable Velocity - “E”

Tables to select channel dimensions are available in Chapters 7 and 9, Ref. #1, appendix A-11

Bare Channels - The minimum capacity and maximum velocity shall be determined by using Manning's formula with an "n" value of 0.025.

Cross Section

The shape of the channel cross section shall be such that the diversion can be properly maintained with modern equipment. The channel may be parabolic, vee-shaped or trapezoidal.

The side slopes for permanent diversions shall not be steeper than 3:1 for maintenance purposes and preferably 4:1. Where frequent crossings are expected, slopes should be flatter. The back slope of the ridge is not to be steeper than 3:1 and preferably 4:1. The ridge shall include a settlement factor equal to 5 percent of the height. **The minimum top width of the diversion ridge after settlement is to be 4.0 feet at the design water elevation.**

In determining the cross section for temporary diversions, consideration should be given to soil type, frequency of operation and type of equipment that is anticipated to be crossing the diversion. In no case shall slopes be steeper than 1.5:1.

The top of the constructed ridge shall not be lower at any point than the design elevation plus the specified overfill for settlement.

Profile(s) and cross-section(s) of all channel diversions shall be submitted on the Soil Erosion and Sedimentation Control Plan.

Location

Diversion location shall be determined by outlet conditions, topography, land use, soil type and length of slope. Consideration must be given to the effects caused by changing natural water courses and putting additional flow into a water course.

Spacing on Slopes

To prevent surface runoff on slopes from exceeding the maximum sheet flow threshold distance (100 feet as defined by USDA-NRCS TR-55), spacing between multiple diversions on slopes will be **no greater than 33 vertical feet or 100 horizontal feet**. Diversions utilized on landfill slopes shall incorporate a drainage network of diversions running parallel to the slope to control runoff from very large or steep landfill caps. All diversions shall outlet into a properly designed chute which shall safely convey runoff to a stable location or other stormwater control structure. Care must be taken to prevent subsurface percolation and flow beneath the chute.

Grade

Diversion channel grade may be uniform or variable. Uniform grades are normally better. The allowable velocity for soil type and vegetative cover will determine maximum grade. Diversions with blocked ends may be used provided adequate pipe outlets are installed. If grade is to vary then each section must be individually designed.

Protection Against Sedimentation

When the movement of sediment into the diversion channel is a significant problem:

1. Land treatment or structural measures shall be installed to stabilize the source of sediment or trap the sediment.

2. If it is not possible to stabilize or trap the sediment, a filter strip of close growing grass shall be maintained above the diversion channel. The filter strip width measured from the center of the channel shall be at least

one-half the channel top width plus 15 feet.

Outlet

Each diversion must have an adequate, stable outlet. The outlet may be: a grassed, stone centered or lined waterway; a vegetated or paved area; a grade stabilization structure; a storm sewer; a stable watercourse; a tile outlet; or open channel.

The outlet in all cases, must be stable and convey water to a disposal point where damage will not result. Constructed vegetative outlets must be established prior to diversion construction.

Temporary Stone Outlet Structure

A temporary stone outlet structure (Fig. 15-1 & 2) for a diversion may be used only where the contributing watershed is less than five acres. **The minimum length, in feet, of the crest of the stone outlet structure shall be equal to six times the number of acres of the contributing drainage area**. The crest of the stone outlet structure shall be level and at least six inches lower than the lowest elevation of the top of the diversion. The stone shall be crushed stone and be 4" to 8" in diameter except for a one-foot thick blanket of 2" diameter stone on the upstream face.

The temporary stone outlet structure shall be located so as to discharge onto an already stabilized area or into a stable watercourse. The stone structure shall be embedded into the soil a minimum of four inches.

Installation Requirements

All trees, brush, stumps or other objectionable material shall be removed so they will not interfere with construction or proper functioning of the diversion. All ditches or gullies which must be crossed, will be filled and compacted prior to, or as part of the construction. Fence rows and other obstructions that will interfere with construction or the successful operation of the diversion are to be removed.

Vegetation is to be removed and the base for the ridge thoroughly disked before placement of fill.

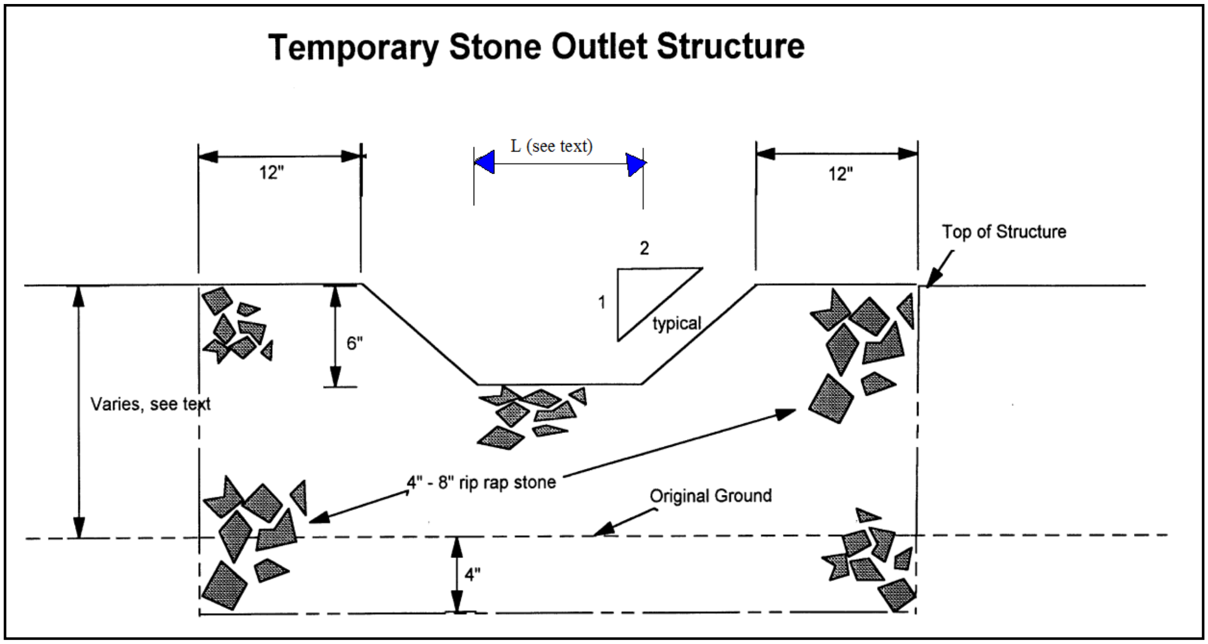
The minimum constructed cross-section is to meet the design requirements.

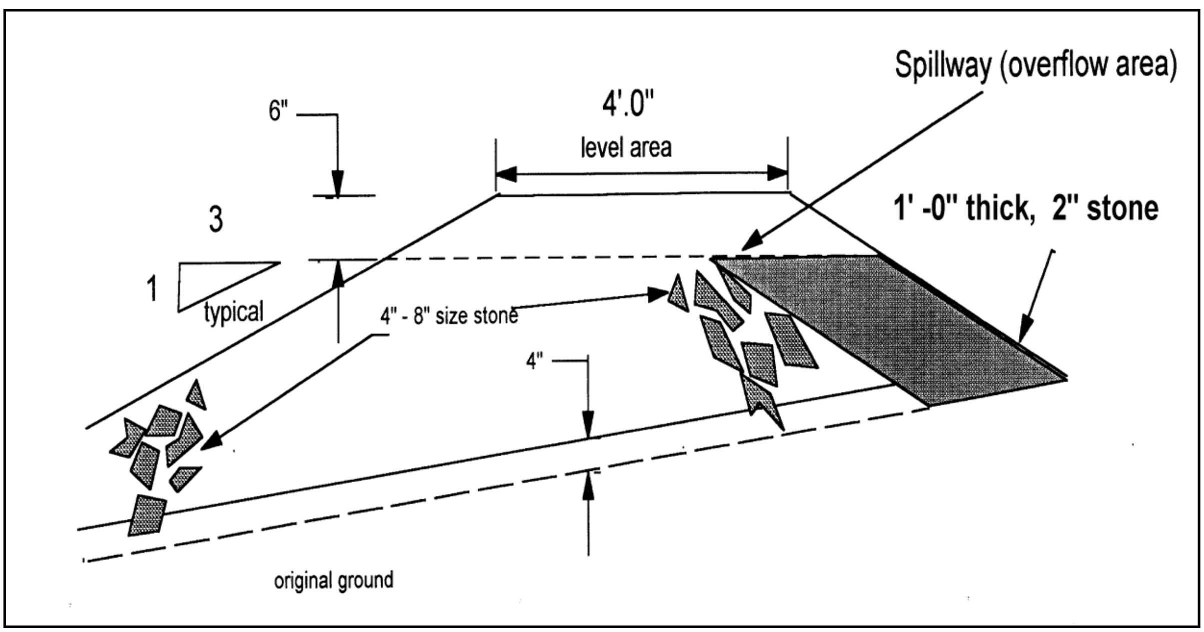
The top of the constructed ridge is not to be lower than the design elevation plus the specified amount for settlement. Fertilizing, seeding and mulching shall conform to the requirements in the Standard for Permanent Vegetative Cover for Soil Stabilization.

If there is no sediment protection provided on temporary diversions it should be anticipated that periodic cleanout may be required.

Construction operations shall be carried out in such a manner that erosion and air and water pollution will be minimized. State and local laws shall be complied with.

Figures 15-1 & 15-2: Outlet Structure Cross Section and Profile





Roadbed Diversions.

Where the diversion will be temporarily used to direct water off a graded right of way onto stable areas (Figure 15-3), and the only area draining toward the diversion is the roadbed itself, the following spacing and size may be used instead of preparing individual designs for each diversion.

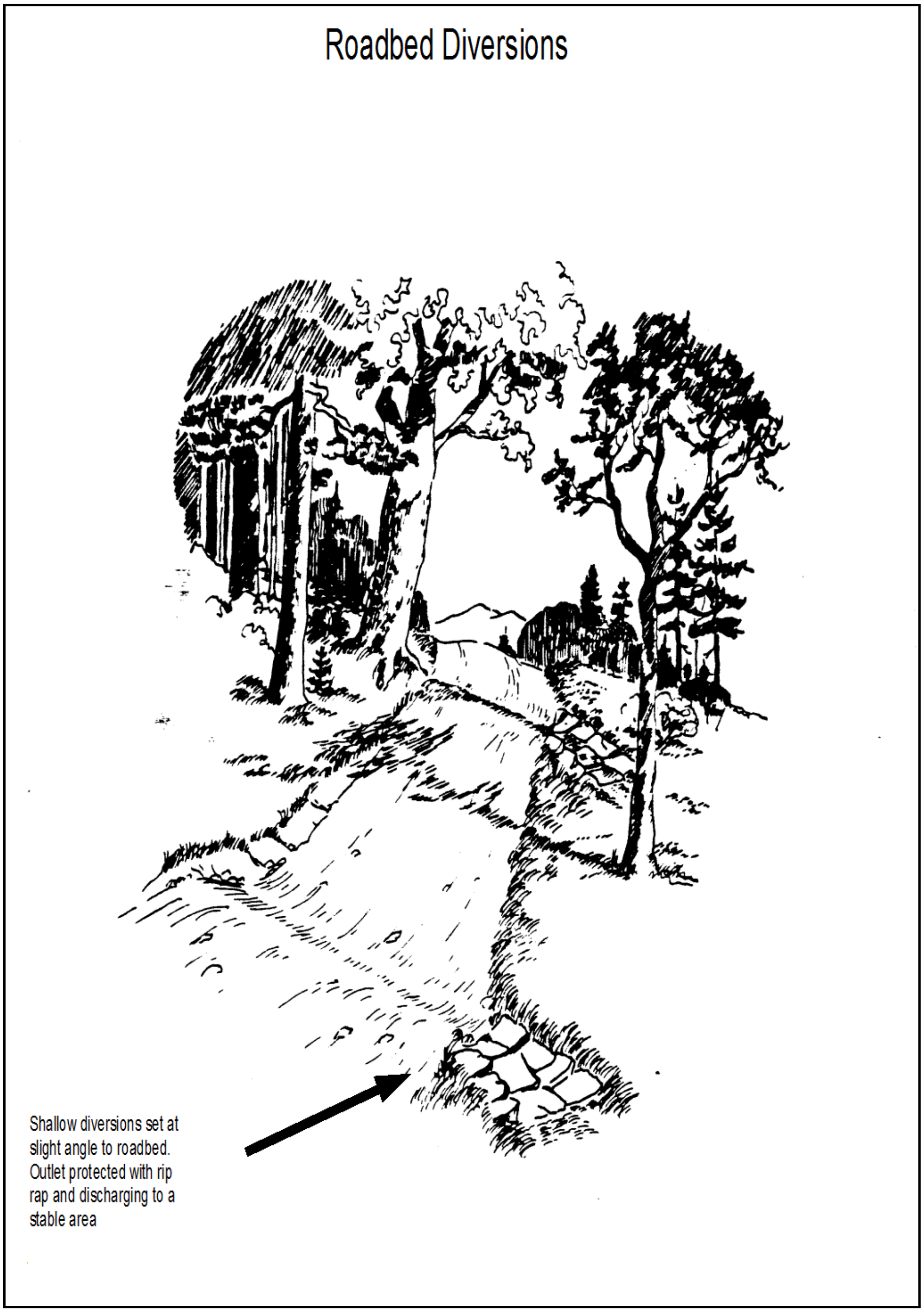
Table 15-3 Roadbed Diversion Spacing by Slope

Road Grade (percent)	Approximate Distance Between Diversions (ft)	Road Grade (percent)	Approximate Distance Between Diversions (ft)
1	400	15	60
2	245	20	50
5	125	25	40
10	80	30	35

Design Criteria:

- parabolic section
- 2 cfs or less flow rate
- 1% slope (grade) on diversion
- Top width: 12 feet
- Depth: 0.6 feet (0.5’ depth + 0.1’ settlement), no freeboard

Figure 15-3: General layout of roadbed diversions



STANDARD
FOR
DUST CONTROL

Definition

The control of dust on construction sites and roads.

Purpose

To prevent blowing and movement of dust from exposed soil surfaces, reduced on-site and off-site damage and health hazards and improve traffic safety.

Condition Where Practice Applies

This practice is applicable to areas subject to dust blowing and movement where on-site and off-site damage is likely without treatment. Consult with local municipal ordinances on any restrictions.

Water Quality Enhancement

Sediments deposited as "dust" are often fine colloidal material which is extremely difficult to remove from water once it becomes suspended Use of this standard will help to control the generation of dust from construction sites and subsequent blowing and deposition into local surface water resources.

Planning Criteria

The following methods should be considered for controlling dust:

Mulches - See Standard of Stabilization with Mulches Only, pg. 5-1

Vegetative Cover - See Standard for: Temporary Vegetative Cover, pg. 7-1, Permanent Vegetative Cover for Soil Stabilization pg. 4-1 and Permanent Stabilization with Sod, pg. 6-1

Spray-On Adhesives - On mineral soils (not effective on muck soils). Keep traffic off these areas.

Table 16-1 Dust Control Materials

MATERIAL	WATER DILUTION	TYPE OF NOZZLE	APPLY GALLONS/ACRE
Anionic asphalt emulsion	7:1	Coarse Spray	1200
Latex emulsion	12.5:1	Fine Spray	235
Resin in water	4:1	Fine Spray	300
Polyacrylamide (PAM) - spray on Polyacrylamide (PAM) - dry spread	Apply according to manufacturer's instructions. May also be used as an additive to sediment basins to flocculate and precipitate suspended colloids. See Sediment Basin standard, p. 26-1		
Acidulated Soy Bean Soap Stick	None	Coarse Spray	1200

Tillage - To roughen surface and bring clods to the surface. This is a temporary emergency measure which should be used before soil blowing starts. Begin plowing on windward side of site. Chisel-type plows spaced about 12 inches apart and spring-toothed harrows are examples of equipment which may produce the desired effect.

Sprinkling - Site is sprinkled until the surface is wet.

Barriers - Solid board fences, snow fences, burlap fences, crate walls, bales of hay and similar material can be used to control air currents and soil blowing.

Calcium Chloride - Shall be in the form of loose, dry granules or flakes fine enough to feed through commonly used spreaders at a rate that will keep surface moist but not cause pollution or plant damage. If used on steeper slopes, then use other practices to prevent washing into streams or accumulation around plants.

Stone - Cover surface with crushed stone or coarse gravel.

STANDARD FOR GRADE STABILIZATION STRUCTURES

Definition

A structure (drop, chute, etc) to control the grade and head cutting in natural or artificial channels.

Scope

This standard applies to all types of grade stabilization structures. It also applies to structures installed to lower the water from a surface drain or a waterway to a deeper channel to control erosion, head cutting or channel grade. It does not apply to structures designed to control the rate of flow or to regulate the water level in channels.

Purpose

To stabilize the grade and control erosion in natural or artificial channels, to prevent the formation or advance of gullies and to reduce environmental and pollution hazards.

Conditions Where Practice Applies

This standard applies to areas where the concentration and flow velocity of water requires structures to stabilize the grade or to control gully erosion in channels. Special attention shall be given to maintaining or improving habitat for fish and wildlife and to maintaining or improving the natural stream flow characteristics, where applicable.

Water Quality Enhancement

Use of this standard will help prevent and control degradation of the interior surfaces of waterways both in man-made and natural channels which in turn will reduce the amount of sediment carried by the channel to receiving waterways.

Design Criteria

Structures

The structure must be designed so that it is stable after installation. The crest of the inlet must be set at an elevation that stabilizes the upstream channel. The outlet must be set at an elevation level that results in a stable structure. Structures must not create unstable conditions upstream or downstream.

Structure Embankments

Embankments used with structures must meet the following requirements:

Foundation - The area on which an embankment is to be placed shall consist of material that has sufficient bearing strength to support the embankment without excessive consolidation.

Top width - The minimum top width shall be as follows:

Embankment Height and Top Widths

TOTAL HEIGHT OF EMBANKMENT (feet)	TOP WIDTH (feet)
up to 20	10
20 - 24	12

Side slopes - The combined upstream and downstream side slopes of the settled embankment shall not be less than five horizontal to one vertical, with neither slope steeper than 2:1. Slopes must be designed to be stable in all cases, even if flatter side slopes are required.

Freeboard - The minimum elevation of the top of the settled embankment shall be 1.0 feet above the maximum water surface upstream during the total capacity design storm.

Settlement - The design height of the embankment shall be increased by the amount needed to insure that after all settlement has taken place, the height of the embankment will equal or exceed the design height. This increase shall not be less than 5%, except where detailed soil testing and laboratory analysis shows a lesser amount is adequate.

Length - If natural ground elevation is used for an emergency spillway, the constructed top elevation of the embankment shall extend at least 40 feet in both sides of the structure.

<u>Structure Spillways</u>

Chute and drop spillways shall be designed according to the principles set forth in the Engineering Field handbook for Conservation Practices, The National Engineering Handbook and other applicable USDA-NRCS publications and reports.

Entrances to chutes and drop spillways will be protected against the force of flowing water at the interface between the structure's entrance walls and the earthen embankment. Acceptable methods include rip rap and keying of the entrance walls into the embankment. Channels must **not** enter these structures at an angle where energy will be dissipated in a bend.

The minimum capacity shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 17-1 or 17-2, as applicable, less any reduction because of detention storage.

Full flow structures are structures where the structure spillway plus an emergency spillway, if used, carry all the flow from the watershed. Typical full flow structures are drop spillways and rock chutes.

Island structures are structures where flows larger than the structure spillway design flow spread out, and the larger flows are not significantly carried by the structure spillway. Typical island structures are pipe drop and hooded inlets.

TABLE 17-1 MINIMUM CAPACITY OF FULL-FLOW STRUCTURES

		MINIMUM DESIGN STORM		
DRAINAGE AREA (acre)	VERTICAL DROP (feet)	STRUCTURE SPILLWAY CAPACITY FREQUENCY (year)	TOTAL CAPACITY FREQUENCY (year)	MINIMUM DURATION (hour)
250 or less	5 or less	5	10	24
500 or less	10 or less	10	25	24
all other	all other	25	100	24

TABLE 17-2 MINIMUM CAPACITY OF ISLAND STRUCTURES

		MINIMUM DESIGN STORM		
DRAINAGE AREA (acre)	VERTICAL DROP (feet)	STRUCTURE SPILLWAY CAPACITY FREQUENCY (year)	TOTAL CAPACITY FREQUENCY (year)	MINIMUM DURATION (hour)
250 or less	5 or less	1	10	24
500 or less	10 or less	1	25	24
all other		1 year or channel design capacity, whichever is higher	50	24

Total Capacity Design Storm

All structures shall have the capacity to pass the peak flow expected from the minimum design storm for total capacity in Tables 17-1 and 17-2, as applicable, less any reduction because of detention storage. This may be accomplished by using a structure spillway or a combination of structure spillway and emergency spillway. There shall not be damage to or erosion of the structure spillway or emergency spillway during passage of the total capacity design storm. Water flowing through an emergency spillway during the total capacity design storm must re-enter the channel without erosion.

Emergency spillways may use natural ground or be constructed. Minimum design flow depth for natural ground emergency spillways is 0.3 feet.

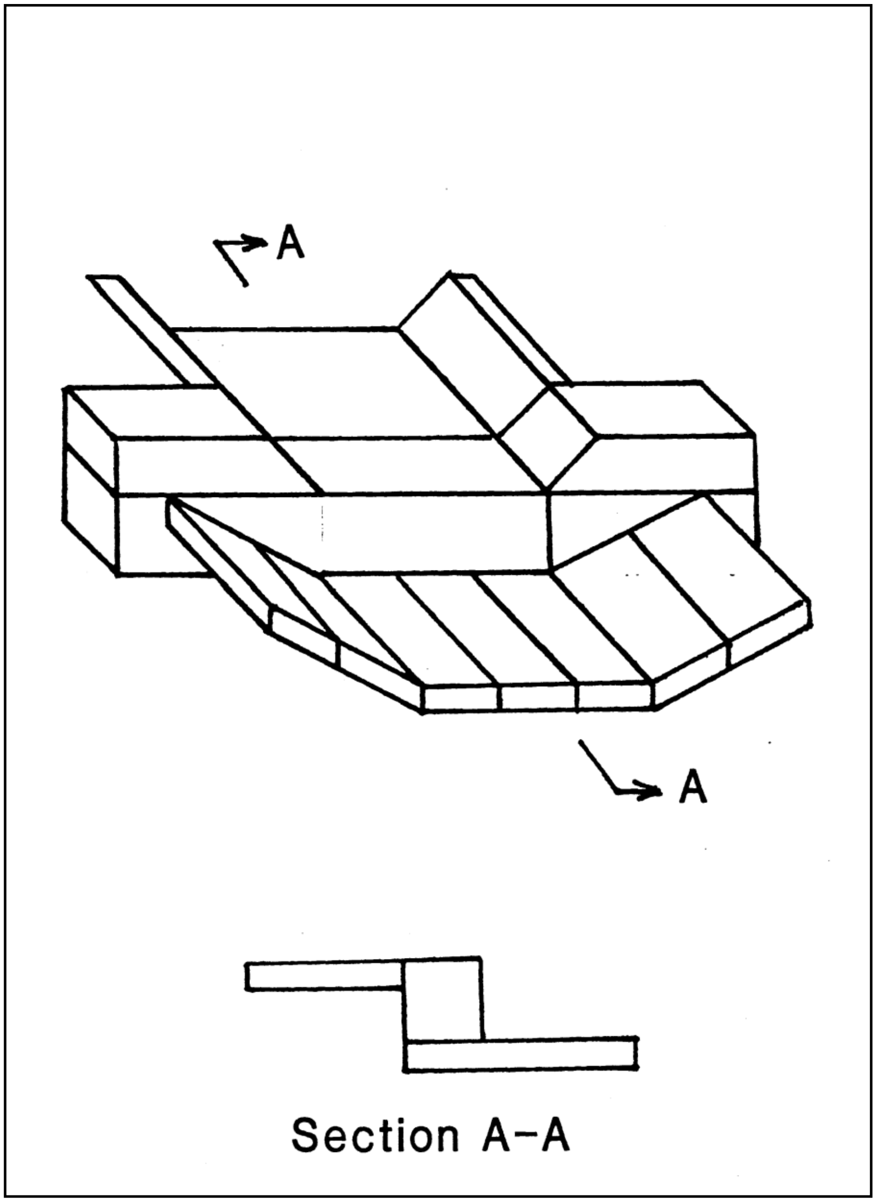
Toe Wall Drop Structures

Toe wall drop structures may be used if the vertical drop is 4 feet or less, flows are intermittent and downstream grades are stable.

Road Culvert Box Inlets

The minimum capacity of drop boxes to culverts shall be as specified in Tables 17-1 or 17-2, as applicable or as required by the responsible road authority, whichever is greater.

Figure 17-1 : Schematic of Drop Grade Structure
(Source: USDA- NRCS)



STANDARD
FOR
GRASSED WATERWAYS

Definition

A natural or constructed watercourse shaped or graded in earth materials and stabilized with suitable vegetation for the safe conveyance of runoff water.

Purpose

To provide for the conveyance of excess surface water without damage by erosion or flooding.

Conditions Where Practice Applies

This practice applies to sites with drainage areas less than 200 acres where concentrated runoff requires vegetative protection or stone center lining to control erosion. Slope of waterway must be less than 10%. Some of the other practices that may be required with this practice are: (1) grade control structures, (2) subsurface drainage to permit the growth of suitable vegetation and to eliminate wet spots, (3) a section stabilized with stone or other material within the waterway or (4) buried storm drain to handle frequently occurring storm runoff, base flow or snowmelt. This practice is not appropriate when maintenance of the grass lining cannot or will not be performed.

Water Quality Enhancement

Use of this standard will provide protection of the waterway lining from the erosive forces of flowing water. Additionally, stormwater runoff quality may be enhanced through adsorption and infiltration (absorption) of minor suspended solids and associated pollutants, such as excess fertilizers and pesticides, hydrocarbons and through bacterial degradation of biosolids. Minor groundwater recharge may also be provided. The total effect on water quality is limited by higher flow velocities and concentrated flows in the waterway. Swales should not be depended upon to provide the sole means of improving runoff water quality. They should be used in conjunction with other erosion control practices listed in these standards, whenever possible.

Design Criteria

Capacity

Peak discharge values shall be determined by the following:

1. Rational Method - for peak discharge of uniform drainage areas as outlined in Technical Manual for Land Use Regulation Program, Bureau of Inland and Coastal Regulations Stream Encroachment Permits, Trenton, N.J. September 1997 or subsequent editions.

2. USDA-NRCS Win TR- 55 or Win TR-20.

3. U.S. Army Corps of Engineers HEC HMS

4. Other methods which produce similar results to the models listed above.

Minimum capacity and maximum velocity shall be based on the 10 year frequency storm, unless a larger storm event is to be conveyed for reasons of safety, compatibility with other stormwater management measures etc.

Velocity

The maximum allowable velocity for design flow will be determined by the most erodible soil texture exposed and the type of vegetation expected and maintained in the channel. As a stable design the waterway shall meet the following allowable velocity criteria and shall not be designed within 10% of critical flow (Froude number = 0.90). .

Table 18-1 Maximum Allowable Velocities by Soil Texture

SOIL TEXTURE	Maximum Allowable Velocity (fps)	
	Seeded Vegetation**	Sod***
Sand	2.0	3.0
Silt loam, sandy loam, loamy sand, loam, muck	2.0	3.0
Silty clay loam, sandy clay loam	2.5	4.0
Clay, clay loam, sandy clay, silty clay	3.0	5.0

Maximum Allowable Velocities are based on flow of clear water.

** Maximum allowable velocities for channels stabilized by seeding may be increased according to the type of Flexible Channel Liner used as shown in the following table. These velocities may be added to the allowable velocities shown above, except for sands.

***On well to excessively drained soils, most cool season sod types will not survive without continued irrigation. Placement of sod in such areas must be approved by the District.

Table 18-2 Classification of Flexible Channel Liners by Texas DOT

"Class 2" Flexible Channel Liner Designation [1]	Allowable Shear Stress[2] (psf)	Incremental increase in velocity (fps)
Type "E"	0 to 2	1.0
Type "F"	0 to 4	1.5
Type "G"	0 to 6	2.0
Type "H"	0 to 8	3.0
Type "I"	0 to 10	4.0
Type "J"	0 to 12	5.0

[1] Designations defined by Texas Department of Transportation Hydraulics and Erosion Control Laboratory Field Performance Testing of Selected Erosion Control Products (as amended or most current) Evaluation Cycle

[2] Typically refers to maximum stress with a fully vegetated matting

There shall be no increase in allowable velocity beyond that indicated for sod if the design life of the flexible channel liner is less than the planned service life of the grassed waterway.

Vegetative Retardance Factors and Manning's "n" Value

The minimum capacity and maximum velocity shall be determined by using the appropriate vegetative retardance factors listed below. Appendix A2 contains examples and charts for use in design. Agricultural Handbook No. 667, Stability Design of Grass-Lined Open Channels, may also be used to design grass waterways based on tractive stress.

Vegetative Retardance Factors

Minimum for Capacity - “D”

Maximum for Allowable Velocity - “E”

Tables to select channel dimensions are available in Appendix A11, Ref. #1, Chapter 7.

Dimensions

The dimensions of the waterway will be based on: (1) the minimum required for capacity, the channel slope, the maximum permissible velocity, the vegetation, the soil; (2) ease of crossing and maintenance; and (3) site conditions such as water table, depth to rock or possible sinkholes.

The minimum top width of a waterway will be 10 feet. The maximum design top width shall not exceed 50 feet.

The minimum design flow depth shall be sufficient to completely submerge the vegetative lining during the design flow (consideration may be given to expected mature height undergoing deflection during flow or an artificially maintained height) such that uniform flow characteristics are achieved. Design flow depths which are less than the lining height may tend to produce meandering and erosion in the waterway bottom and will not be accepted.

The cross section may be parabolic, vee-shaped, or trapezoidal. Cross-section(s) and profile(s) of all grassed waterways shall be submitted on the Soil Erosion and Sedimentation Control Plan.

Drainage

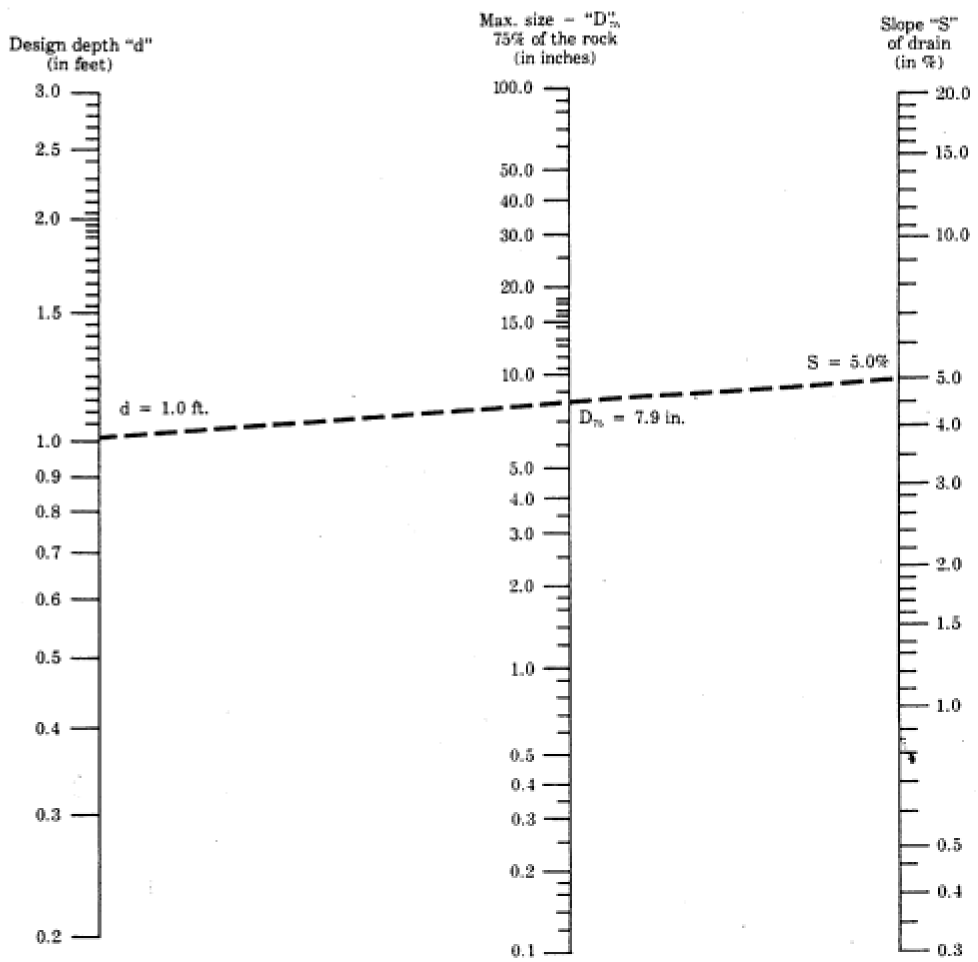
In areas with low flow, high water table or seepage problems, underdrains, stone centers or other subsurface drainage methods are to be provided. A minimum drainage coefficient of ½ inch in 24 hours is to be used for underdrain design. An open joint storm drain may be used to serve the same purpose and also handle frequently occurring storm runoff, base flow or snowmelt. The storm drain shall be designed to handle base flow, snowmelt or the runoff from at least a one-year frequency storm, whichever is greater.

Design of Stone Center lining for wet or low flow conditions:

Where a stone lining is needed due to seepage, low flow, high water table, etc.,stone size shall be based on the maximum design flow (10 year storm event minimum) to be conveyed and shall be installed to a depth equal to the design flow depth for a 1 year, 24 hour storm. The stone shall be **EMBEDDED FLUSH** with the waterway surface.

The following nomograph may be used to determine the D_{75} stone size for the center lining:

Nomograph to Compute Stone Size for Grass Waterway Center Lining



Example: "d" = 1.0 foot "S" = 5%
Place straight edge at "d" value in Design Depth column and at "S" value in "Slope" column. Read rock size in middle column, 7.9 inches; round to 8 inches.

For Design:
25% of the rock by volume should be in sizes of 8 inches or slightly larger. The remaining 75% or less should be of well-graded material, smaller than 8 inches, including sufficient sands and gravels to fill the voids between the larger rock.

*U.S. GOVERNMENT PRINTING OFFICE: 1986 – 621 – 073:00048

Outlet

The outlet must handle the design flow without flood damage. The outlet must be stable for the 10-year storm.

Vegetation - Permanent Cover

A permanent vegetative cover shall be established on all grassed waterways in accordance with the Standard for Permanent Vegetative Cover for Soil Stabilization or Standard for Permanent Stabilization with Sod. Where the season and other conditions may not be suitable for growing permanent erosion resistant cover, erosion protection will be provided in accordance with the Standard for Temporary Vegetative Cover for Soil Stabilization or by the use of a Class 2 Flexible Channel Liner as described above. The seeding will extend to at least the design top width.

Installation Requirements

Construction

Trees, brush, stumps and other material in objectionable amounts are to be cleared and disposed of so as not to interfere with construction or proper functioning of the waterway.

Fills are to be compacted as needed to prevent unequal settlement that will cause damage in the completed waterway. Where deep cuts are made into the subsoil, consideration shall be given to adding organic soil amendments or topsoil.

Vegetative Lining

Waterways or outlets shall be protected against erosion by vegetative means as soon after construction as practical and before diversions or other channels are discharged into them. Consideration should be given to the use of a flexible channel liner or sodding channels to provide erosion protection as soon after construction as possible.

Seeding, fertilizing, mulching and sodding shall be in accordance with the applicable Standards.

Maintenance

Routine maintenance of the vegetative lining, including mowing, liming and fertilizing must be performed to ensure that the waterway continues to perform as designed (see the Standard for Maintaining Vegetation). If maintenance cannot be or is not planned to be performed an alternate means of waterway stabilization or means of runoff conveyance should be considered.

STANDARD
FOR
LAND GRADING

Definition

Reshaping the ground surface by grading to planned elevations which are determined by topographic survey and layout.

Purpose

The practice is for one or more of the following: Provide more suitable sites for land development; improve surface drainage and control erosion.

Conditions Where Practice Applies

This practice is applicable where grading to planned elevations is practical and it is determined that grading is needed. Grading that involves the disturbance of vegetation over large areas shall be avoided. It may be necessary to provide for temporary stabilization of large areas.

Water Quality Enhancement

Proper grading of disturbed sites will protect against soil loss from erosion, enhance establishment of permanent vegetative cover and help to properly manage stormwater runoff all of which will reduce off site discharge of pollutants.

Planning Criteria

The grading plan and installation shall be based upon adequate topographic surveys and investigations. The plan is to show the location, slope, cut, fill and finish elevation of the surfaces to be graded. The plan should also include auxiliary practices for safe disposal of runoff water, slope stabilization, erosion control and drainage. Facilities such as waterways, ditches, diversions, grade stabilization structures, retaining walls and subsurface drains should be included where necessary.

Erosion control measures shall be designed and installed in accordance with the applicable standard contained herein.

The development and establishment of the plan shall include the following:

1. The cut face of earth excavations and fills shall be no steeper than the safe angle of repose for the materials encountered and flat enough for proper maintenance.

2. The permanently exposed faces of earth cuts and fills shall be vegetated or otherwise protected from erosion.

3. Provisions shall be made to safely conduct surface water to storm drains or suitable water courses and to prevent surface runoff from damaging cut faces and fill slopes.

4. Subsurface drainage is to be provided in areas having a high water table, to intercept seepage that would adversely affect slope stability, building foundations or create undesirable wetness. See Standard for Subsurface Drainage, pg. 32-1.
5. Adjoining property shall be protected from excavation and filling operations.

6. Fill shall not be placed adjacent to the bank of a stream or channel, unless provisions are made to protect the

hydraulic, biological, aesthetic and other environmental functions of the stream.

Installation Requirements

Timber, logs, brush, rubbish, rocks, stumps and vegetative matter which will interfere with the grading operation or affect the planned stability or fill areas shall be removed and disposed of according to the plan.

Topsoil is to be stripped and stockpiled in amounts necessary to complete finish grading of all exposed areas requiring topsoil. See Standard for Topsoiling, pg. 8-1.

Fill material is to be free of brush, rubbish, timber, logs, vegetative matter and stumps in amounts that will be detrimental to constructing stable fills.

All fills shall be compacted sufficiently for their intended purpose and as required to reduce slipping, erosion or excessive saturation.

All disturbed areas shall be left with a neat and finished appearance and shall be protected from erosion. See Standards for Permanent Vegetative Cover for Soil Stabilization, pg. 4-1.

Trees to be retained shall be protected if necessary in accordance with the Standard for Tree Protection During Construction, pg. 9-1.

Soil compaction resulting from land grading activities can impact the infiltration rate of the soil. Restoration of compacted soils through deep tillage (6" to 12") and the addition of organic matter may be required in planned pervious areas to enhance the infiltration rate of the disturbed soil. **This practice is permissible only where there is no danger to underground utilities (cables, irrigation systems, etc.)**

STANDARD
FOR
LINED WATERWAY

Definition

A watercourse with an erosion resistant lining of concrete, stone or other permanent material. The lined section extends up the side slopes to design flow depth. The earth above the permanent lining shall be vegetated or otherwise protected.

Scope

This standard applies to waterways with linings of non-reinforced, cast-in place concrete; flagstone mortared in place; rock riprap or similar permanent linings. This standard does not apply to grassed waterways with stone centers. The maximum capacity of the lined waterway flowing at design flow depth shall not exceed 100 cfs.

Purpose

Waterways are lined to provide for safe disposal or runoff without damage by erosion or flooding in situations where grassed waterways would be inadequate.

Conditions Where Practice Applies

This practice applies where the following conditions exist:

1. The water velocity is such that lining is required to control erosion in the waterway.

2. Wetness, prolonged base flow or seepage would prohibit establishment of erosion-resistant vegetation.

3. The location is such that damage from use by people, vehicles or animals precludes use of vegetated waterways.

4. High value property or adjacent facilities warrant the extra cost to contain design runoff in a limited space.

5. Soils are highly erodible, highly acidic or other soil or climatic conditions precludes using vegetation.

6. On slopes greater than 10% the Standard for Slope Protection Structures shall apply.

Water Quality Enhancement

This standard is intended to protect larger capacity waterways from the extreme forces of erosion resulting from concentrated, high volume - high velocity flows. The primary benefit will be the prevention of soil loss from the channel lining surface. Subsequently, areas downstream will be protected from the deleterious effects of sediment deposition and conveyance of soil nutrients into local surface and groundwater systems.

Design Criteria

Capacity

Capacity shall be computed using Manning's formula or water surface profile models such as HEC RAS with a coefficient of roughness "n" as follows:

Table 20-1 Manning's "n" Values for Various Channel Lining Materials

LINING	"n" VALUE
Concrete	
Trowel finish	0.012 - 0.014
Float finish	0.013 - 0.017
Gunite	0.016 - 0.022
Cable or articulated block	Specified by manufacturer
Flagstone	0.020 - 0.025
Wire Mesh Stone filled baskets	0.025
Riprap	see the Standard for Riprap

Peak discharge values shall be determined by the following:

1. Rational Method - for peak discharge of uniform drainage areas as outlined in Technical Manual for Land Use Regulation Program, Bureau of Inland and Coastal Regulations Stream Encroachment Permits, Trenton, N.J. September 1997 or subsequent editions.

2. USDA-NRCS Win TR-55 or Win TR-20.

3. U.S. Army Corps of Engineers HEC HMS.

4. Other methods which produce similar results to the models listed above.

Minimum capacity and velocity shall be based on the 10 year frequency storm unless a larger storm event is to be conveyed for reasons of safety, compatibility with other stormwater management measures, etc.

Velocity

Maximum design velocity shall be as shown below. Except for short transition sections, slopes in the range of 0.9 to 1.10 of the critical slope must be avoided.

Table 20-2 Flow Depths and Velocities for Lined Waterway Design

DESIGN FLOW DEPTH	MAXIMUM VELOCITY
0.0 - 0.5' 0.5 - 1.0' > 1.0'	25 FPS 15 FPS 10 FPS

Lined waterways with velocities exceeding critical shall discharge into an energy dissipater to reduce velocity to less than critical.

Cross-Section

The cross-section shall be triangular, parabolic or trapezoidal. Monolithic concrete may be rectangular.

Freeboard

The minimum freeboard for lined waterways shall be 0.25 feet above design flow depth in areas where erosion resistant vegetation cannot be grown adjacent to the lined side slopes. No freeboard is required where good vegetation can be grown and is maintained.

Side slope

Steepest permissible side slopes, horizontal to vertical will be as follows:

Table 20-3 Side Slopes for Corresponding Lining Materials

LINING	STEEPEST PERMISSIBLE SIDE SLOPE
Non-Reinforced Concrete- Hand-placed, formed concrete Height of lining 1.5 feet or less	vertical
Hand-placed, screeded concrete or mortared in-place flagstone- Height of lining less than 2 feet Height of lining more than 2 feet	 1 to 1 2 to 1
Reinforced slip form concrete- Height of lining less than 3 feet	 1 to 1
Rock riprap	2 to 1

Lining Thickness

Minimum lining thickness shall be as follows:

Concrete

Poured in place, reinforced - 4.0 inches
Interlocking concrete blocks - per manufacturer's instructions
Cabled concrete - per manufacturer's instructions (non-corroding cable shall be used)

Rock riprap - as per Standard for Riprap

Flagstone - 4 inches including mortar bed

Related Structures

Side inlets, drop structures and energy dissipaters shall meet the hydraulic and structural requirements for the site.

Filters or bedding

For non-reinforced concrete flagstone linings, installation shall be made only on low shrink-swell soils that are well drained or where subgrade drainage facilities are installed.

Filters or bedding to prevent piping, prevent erosion, reduce uplift pressure and collect water will be used and will be designed in accordance with "National Cooperative Highway Research Program Report 108 - Tentative Design Procedures for Riprap-Lined Channels," USDA-NRCS procedures or other generally accepted methods. Weep holes and drains will be provided as needed.

Concrete or Mortar

Concrete or mortar shall meet New Jersey Department of Transportation Standard Specifications, Ref. #10, Appendix A11.

Rock Riprap or Flagstone

Stone used for riprap or flagstone shall be dense and hard enough to withstand exposure to air, water, freezing and thawing. Flagstone shall be flat for ease of placement.

STANDARD FOR OFF-SITE STABILITY

Definition

A condition below and beyond the immediate limits of the site or property where the soil and related natural resources are subject to damage directly or indirectly by the discharge of stormwater runoff.

Purpose

To protect and maintain the stability and integrity of natural resources on downstream or off-site property due to changes in the rate and volume of stormwater runoff associated with construction activity and of land development.

Conditions Where Practices Applies

For purposes of analysis two areas of concern shall be addressed: (1) at the point of discharge and (2) downstream of the discharge point (which may require a watershed-based analysis).

Technical criteria for demonstrating off-site stability include consideration of proximity to a defined waterway, site topography (slope), soil texture, vegetative cover and other factors. Where the potential for erosive forces from stormwater runoff exceeds the threshold of acceptability as defined below, the plan shall provide for the construction of a stabilized channel, installation of a conduit to a stable condition or other types of hydraulic improvements to the channel. Additional design criteria or restrictions from the New Jersey Department of Environmental Protection or the New Jersey Pinelands Commission may also apply.

Water Quality Enhancement

Stormwater runoff is that portion of precipitation that returns to water bodies over the surface of the ground. The amount of stormwater runoff in a given area is a function of several factors including but not limited to: the amount and intensity of precipitation, soil texture, vegetative cover and slope. Unless properly managed stormwater runoff can adversely affect the environment through increased flood damages, increased erosion and sedimentation, increased waterway surges, destruction of vegetation, impaired water quality and increased turbidity. By addressing these factors in combination with one another this standard provides guidance for the design of off-site stormwater discharge which will result in minimized environmental impact and the long term protection of downstream water quality.

Design Criteria

This Standard involves two areas of analysis: (1) at the point(s) of stormsewer discharge and (2) beyond the site boundaries, typically a receiving channel or waterway. Stability documentation for each area is outlined in detail below. Generally the analyses involve the manipulation of peak rates of discharge for the 2 and 10 year, 24 hour storm events such that peak flow rate values and velocities are below established thresholds. Discharges shall be located in areas with low gradient topography and covered in perennial erosion resistant vegetation as noted in table 21-1 below.

Special consideration shall be given to the use of infiltration for peak flow modifications as follows:

Point of Discharge Stability Analysis

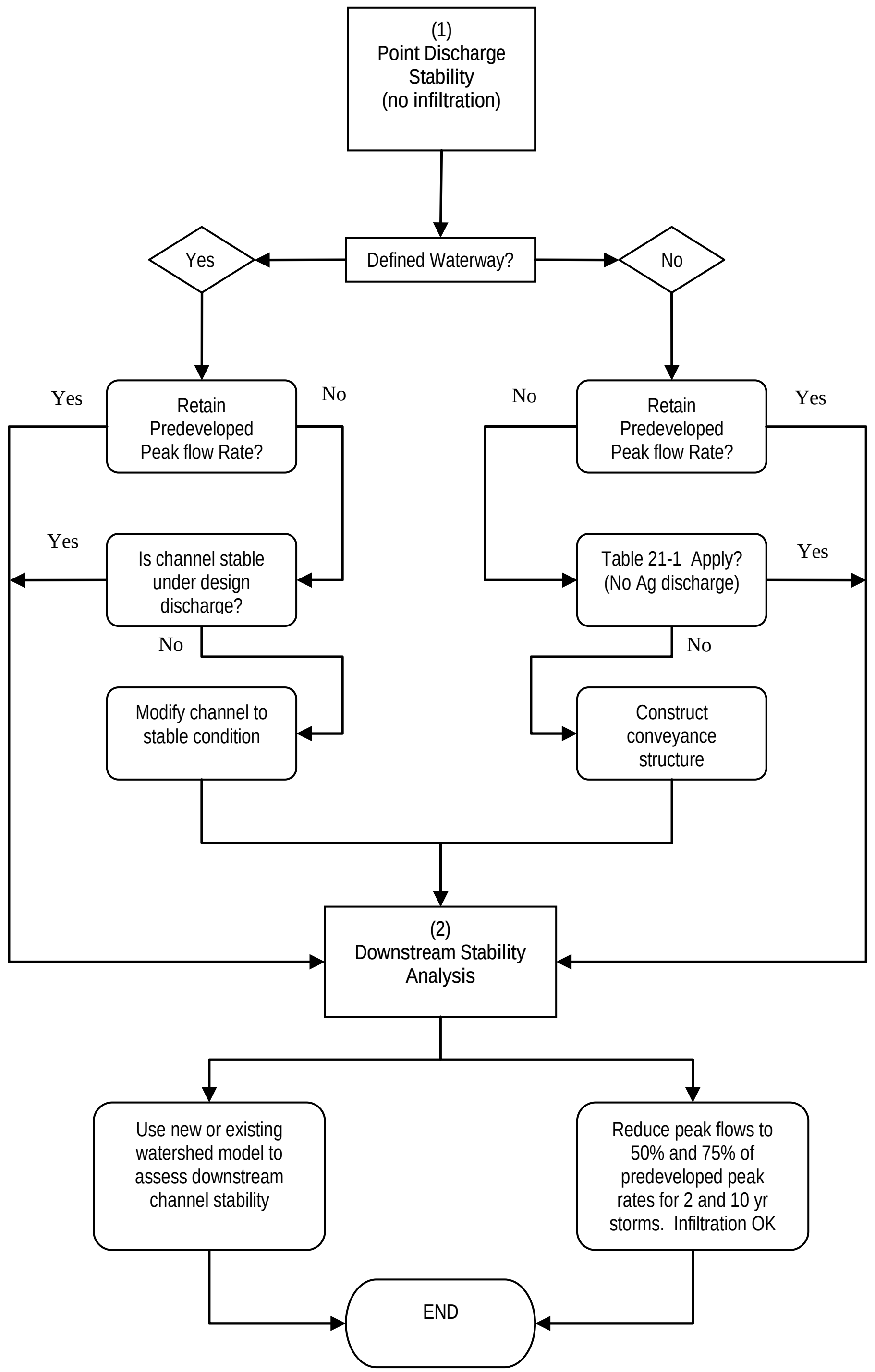
When infiltration practices are proposed, an alternate analysis (failure analysis) must be provided which ignores infiltration (no dead storage volume available, no static or dynamic infiltration loss rates in the routing calculations, etc) and demonstrates that no erosion will occur at the point of discharge if infiltration fails to function. Flow rates based solely upon basin inlet and outlet hydraulics must be used in comparison to Table 21-1 (below) to document a stable outlet.

Downstream (off-site) Stability Analysis.

Infiltration may be used to meet peak flow reduction requirements (outlined below) for the purposes of documenting stability of the downstream receiving channel, provided that the complete loss of infiltration function does not result in an increase in peak flow values above the predevelopment levels.

A generalized procedure for assessing point and offsite stability is depicted in figure 21-1:

Figure 21–1
Point Discharge and Downstream Stability Analysis Procedure



Point of Discharge - Methods for Achieving Stability

1. **No well-defined waterway below the point of discharge**:

Stability cannot be achieved by the allowable velocity method since there can be no determination where the runoff will concentrate. A land-form not previously subjected to concentrated water flow will become unstable.

Stability can be achieved by one of the following alternatives:

a. Retain pre-existing runoff characteristics. Do not increase the amount and rate of runoff for the development and **do not concentrate flows**.

b. Where there is no well defined channel, no sandy condition, no trees or brush to substantially concentrate the flows and it can be reasonably assumed that the flow will disperse over a broad area. The combinations of slopes and soils in table 21-1 and the following criteria are considered stable for flows of 10cfs or less for a 25 year, 24hr design storm.

Table 21-1 Non-Erosive Velocities for Point Discharges

Maximum Stable Slope for Point Discharges for Various Soils	
Soil Type	**Perennial, Natural Vegetation**
	Maximum Slope (%)
Sands	1.8
Sandy loam	2.0
Silt loam, loam	2.5
Sandy clay loam	3.5
Clay loam	5.0
Graded loam to gravel	8.0

Stability Criteria (in conjunction with table 21-1)

i. The maximum discharge rate shall be 10 cfs or less for the twenty-five (25) year storm.

ii. Multiple outlets may be utilized to reduce individual outlet flow rates to levels below the thresholds noted above. Outlets should be spaced no closer than 50 ft horizontally to avoid re-mixing of flows

iii. Flow over the outlet area shall be less than 0.5 cfs/ft. Designers shall not design excessive widths which will cause flows to concentrate.

iv. Conduit outlet protection shall be provided in accordance with that Standard and may include: flat aprons, preformed scour holes, impact basins, stilling wells, plunge pools, etc. **Level spreaders are not an acceptable design**.

v. Topography shows broad uniform outlet area where flows will not concentrate.

vi. Discharge locations shall contain perennial, erosion resistant vegetation

vii. Peak discharge velocities (in the last pipe section) do not exceed 2 fps.

viii. The maximum length of slope below the outlet(s) is 100 feet

c. Construct conveyance structure (pipe or channel)

i. Pipe to a stable condition. When constructing a pipe through wetlands, an impervious trench shall be required. The pipe trench shall be compacted and filled with impervious material instead of the classic stone filled trench. The Conduit Outlet Protection Standard shall be adhered to.

ii. Construct a channel pursuant to the Standards for:
- Channel Stabilization
- Grassed Waterways
- Lined Waterways
- Rip Rap
- Soil Bioengineering

Discharge to Agricultural Lands

Conditions represented in table 21-1 (and following) presume the presence of perennial, natural vegetation and in-situ, undisturbed soil conditions. Agricultural lands which are routinely disturbed due to cultivation and harvesting practices do not conform to the presumptions of this model and are therefore not suitable locations for point discharge. Generally, discharges to actively cultivated agricultural lands will require the construction of a conveyance structure across fields and land owner permission to discharge stormwater. Verification of landowner permission along with all appropriate engineering designs must be submitted to the soil conservation district to be considered for plan certification

Note: Some form of detention may be required in conjunction with the use of a constructed pipe or channel depending on the final discharge location. Consideration shall be given to the effects of an extended time of peak discharge duration as compared to the instantaneous peak discharge when detention is not used. Extended peak runoff may saturate the soil, destroy existing vegetation and loosen the soil to an eroding condition. If detention is required, the Standard for Detention Structures shall be addressed.

2. Well-defined waterway[1] below the point of discharge:

a. Retain pre-developed runoff characteristics. Do not increase the rate of runoff from development.

b. Analyze the waterway or channel for stability under the planned rate of discharge using the Standard for Grassed Waterways or Standard for Channel Stabilization, as appropriate. Peak flows from the 2 and 10 year storms shall be analyzed.

[1] "Waterway" shall be construed to mean an actual channel, gulley or topographic landform which has a discernable cross section.

c. Modify the waterway or channel to a stable design condition.

Downstream of the Point of Discharge (Off-Site Stability Analysis)

In addition to ensuring erosion does not occur at the point of discharge, areas downstream and beyond the immediate area of site development may be damaged due to erosive forces resulting from extended duration of hydrograph peak flows. An unintended consequence of the practice of detaining and slowly releasing stormwater is the ability for peak flows to be sustained for longer periods of time, offering an opportunity for upstream discharges to coincide with project site discharges. The resulting combined discharge may be equal to or even exceed that of the pre-development condition.

To limit the potential for such an occurrence the designer may choose either of two approaches for **downstream stability** protection:

1. Examine hydraulic characteristics of the receiving stream channel considering upstream discharge in combination with site discharge to assess channel stability. The scope and scale of the analysis shall be appropriate to the scale of the project and the post development peak discharge rate and volume. Of particular concern are hydraulic control points, (culverts , bridges, etc.), bends in streams and sudden changes in channel cross sections downstream of the discharge point. The following may be utilized to assess stability:

    a. Utilize an existing watershed or regional stormwater management plan to verify the proposed discharge will not cause erosion downstream of the discharge point. The model should reflect the current conditions in the watershed.

    b Perform a new watershed analysis. Modeling multiple watersheds, routing stormwater structures and modeling water surface profiles shall be done, as necessary, to determine pre and post development velocities in channels and through structures.

    Analysis of the receiving channel shall include a comparison of pre and post condition velocities in the channel and overbank (if applicable) areas for the 2 and 10 year storm events. Cross sections and a scaled map of the section stations shall be included in the hydraulic analysis of the channel.

    In the event the analysis determines that the post development runoff must be controlled prior to discharge, some form of detention will be required. Refer to the Standard for Detention Structures for design requirements.

2. In lieu of performing a comprehensive watershed analysis, design a detention facility that reduces peak flows to the following levels. <u>Infiltration may be used to meet these criteria</u>:

    2 year storm – 50% of the predevelopment peak
    10 year storm – 75% of the predevelopment peak

    Reductions in peak flows are to be compared to **predeveloped** drainage area points of discharge in the event that drainage is re-directed in the post developed condition. **Reductions are only required of the developed or modified portions of the project site.**

<u>Plan Requirements for Documenting Stability</u>

In addition to a complete hydraulic and hydrologic analysis described above, drawings must be submitted with the erosion control plan which show the predeveloped drainage condition for the proposed point of discharge along with the time of concentration flow path.

STANDARD FOR RIPRAP

Definition

A layer of loose rock, aggregate, bagged concrete, gabions, or concrete revetment blocks placed over an erodible soil surface.

Purpose

The purpose of riprap is to protect the soil surface from the erosive forces of water.

Conditions Where Practice Applies

This practice applies to soil-water interfaces where the soil conditions, water turbulence and velocity, expected vegetative cover, and groundwater conditions are such that the soil may erode under the design flow conditions. Riprap may be used, as appropriate, at such places as channel banks and/or bottoms, roadside ditches, drop structures and shorelines of open freshwater bodies. Riprap may also be used in conjunction with Soil Bioengineering Techniques which are found in that standard (pg. 26-1). This Standard applies to slopes less than ten percent.

Water Quality Enhancement

Both stream channel and shoreline environments will benefit from the protection against erosion caused by flowing water and wave action. Protection of banks and shores not only prevents soil loss directly into surface waters, but also protects vegetation in these areas which contribute other water quality and wildlife benefits. .

Design Criteria - Open Channel Flow Conditions

Design Storm

The riprap shall be designed to be stable when the channel is flowing at the design discharge or the 25-year frequency storm discharge, whichever is greater.

Capacity shall be determined by the following methods:

1. Rational Method - for peak discharge of uniform drainage areas as outlined in Technical Manual for Land Use Regulation Program, Bureau of Inland and Coastal Regulations Stream Encroachment Permits, Trenton, N.J. September 1997 or subsequent editions

2. USDA-NRCS hydrologic procedures such as WinTR55 or WinTR20.

3. U.S. Army Corps of Engineers HEC HMS

4. Other methods which produce similar results to the models listed above.

Riprap Design

Storm water conveyance or flood control channels

Riprap shall be sized using the design procedures in this Standard or the "National Cooperative Highway Research Program Report No. 108, Tentative Design Procedure for Riprap-Lined Channels." These procedures are for determining a design stone size, such that the stone is stable under the design flow conditions. The design stone size is the d_{50} stone diameter.

Erosive forces of flowing water are greater in bends than in straight channels. If the riprap size (d_{50}) computed for bends is less than 10% greater than the riprap size (d_{50}) for straight channels, then the riprap size for straight channels shall be considered adequate for bends. Otherwise, the larger riprap size shall be used in the bend. The riprap size to be used in a bend shall extend upstream from the point of curvature and downstream from the point of tangency a distance equal to five times the channel bottom width, and shall extend across the bottom and up both sides of the channel.

Riprap for banks shall extend up the banks to the level of the design storm or the top of bank, whichever is lower.

In channels where no riprap or paving is required in the bottom, but is required on the banks, the toe of the bank riprap shall extend below the channel bottom a distance at least 8 times the maximum stone size, but in no case more than 3 feet unless analysis of scour potential demonstrates the need for deeper installation. The only exemption to this would be if there is a non-erodible hard, rock bottom.

Stream stabilization- Soil Bioengineering

For determining $d_{50,}$ riprap may be sized using the procedures in this Standard or procedures contained in Chapter 16 of the NRCS Engineering Field Handbook including the Isbash Curve or Lane's Method. For stream stabilization, the use of riprap is generally limited to critically erosive locations such as the base of the channel side slopes up to the elevation of the one year flow event. Riprap is designed to be used in combination with vegetation as a part of a bioengineering solution (see Standard for Soil Bioengineering). Riprap may be placed on slopes steeper than 2 horizontal to 1 vertical following the procedures in this Standard (Curve 22-6). Large, over-sized stone having a minimum d_{50} of 18 inches, or two times the required d_{50}, whichever is greater, may be stacked to a slope no steeper than 0.5 horizontal to 1 vertical where site conditions are acceptable. Stability of the stream bank and bed material along with the flow conditions in the stream shall be evaluated in determining site acceptability.

Riprap Gradation

The riprap shall be composed of a well-graded mixture such that 50% of the mixture by weight shall be larger than the d_{50} size as determined from the design procedure. A well-graded mixture as used herein is defined as a mixture composed primarily of the larger stone sizes, but with a sufficient mixture of other sizes to fill the progressively-smaller voids between the stones. The diameter of the largest stone size in such a mixture shall be 1.5 times the d_{50} size. The d_{75} should be 1.25 times the d_{50} and the d_{15} should be 0.5 times the d_{50} size.

The designer, after determining the riprap size that will be stable under the flow condition, shall consider that size to be a minimum size and then, based on riprap gradations actually available in the area, select the size or sizes that equal or exceed the minimum size. The possibility of vandalism shall be considered by the designer in selecting a riprap size.

Thickness of Riprap Lining

Construction techniques, discharge, size of channel, sizes and graduation of riprap, etc., should be taken into consideration when determining the thickness of riprap lining. The thickness of riprap lining shall meet at least one of the following two criteria:

1. A thickness of at least three times the d_{50} size if a filter layer is not used.

2. A thickness of at least two times the d_{50} size if a filter layer is used.

The minimum thickness shall be 6 inches.

Filter

Leaching is the process by which the finer base materials beneath the riprap are picked up and carried away by the turbulence that penetrates the interstices of the riprap. Leaching is reduced to a negligible rate by using a properly designed filter under the riprap, or by making the riprap layer thick enough and with fine enough interstices to keep erosion currents away from underlying soil.

A filter is required unless the riprap lining has a thickness of at least 3 times the d_{50} size of the riprap. On steep slopes, highly erodible soils, loose sand, or with high water velocities, a filter should be used or riprap thickness increased beyond the minimums.

A filter can be of two general forms. One is a geotextile manufactured for that express purpose. Another is a properly graded layer of sand, gravel, or stone.

A sand, gravel, or stone filter shall meet the following criteria:

$$\frac{d_{15}\text{ Riprap}}{d_{85}\text{ Filter}} < 5 < \frac{d_{15}\text{ Riprap}}{d_{15}\text{ Filter}} < 40$$

$$\frac{d_{50}\text{ Riprap}}{d_{50}\text{ Filter}} < 40$$

Where d_{15}, d_{50}, and d_{85} are the diameters of riprap and filter material of which 15, 50, and 85% are finer by weight. The base material may be used as the filter if it meets the above criteria. The minimum sand gravel or stone filter thickness shall be 6 inches or 3 times the d_{50} size of the filter, whichever is greater.

Geotextile fabric[1] shall meet the following criteria:

A. For filter fabric adjacent to granular materials containing 50% or less by weight of fines (Minus No. 200 material):

For Woven Fabric:

1. $$\frac{\text{85\% size of material (mm)}}{\text{AOS[2] (mm)}} \geq 1$$

   and AOS no smaller than the opening in the U.S. Standard Sieve No. 100

2. For non-woven fabric: AOS no larger than the opening in the U.S. Standard Sieve No. 40.

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[1] Geotextile fabric shall meet the U.S. Army Corps of Engineers Guide Specifications, CW02215-86, for strength. Riprap that is 12" and larger shall not be dumped directly onto synthetic filter cloth unless the manufacturer recommends such use for the cloth. Otherwise, a 4-inch minimum thickness blanket of gravel shall be placed over the filter cloth. Where seepage forces exist or where hydrostatic pressures may be developed in the base soil, the permeability of the geotextile shall be 10 times the permeability of the base soil.

[2] Apparent Opening Size is defined as the number of the U.S. Standard sieve having openings closest in size to the geotextile openings.

B. For geotextile fabric adjacent to all other soils:

For woven fabric:

1. AOS no larger than the opening in the U.S. Standard Sieve No. 70, and AOS no smaller than the opening in the U.S. Standard Sieve No. 100.

2. For non-woven fabric: AOS no larger than the opening in the U.S. Standard Sieve No. 40.

Quality

Stone for riprap shall consist of field stone or quarry stone of approximately rectangular shape. The stone shall be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering. The specific gravity of the individual stones shall be at least 2.5.

Rubble concrete may be used provided it has a density of at least 150 pounds per cubic foot, and otherwise meets the requirements of this Standard.

Bagged Concrete

Bagged concrete is made up of bags filled with concrete and placed next to each other. The consistency of the concrete shall be as stiff as satisfactory discharge from the mixer and the process of bagging will permit. The bags shall be filled three-quarters full with concrete and shall be laid in close contact, with staggered joints and tied ends turned in.

Bagged concrete may be used when all the following conditions are met:

1. The design storm, riprap size and location, and filter criteria for riprap are met.

2. The weight of the filled bags is at least equal to the weight of the maximum stone size required for rock riprap.

3. Settlement or lateral movement of foundation soils is not anticipated.

4. Ice conditions are not severe.

5. A filter is used.

6. Slopes somewhat steeper than 2 to 1 may be permitted under special circumstances.

Wire-mesh stone filled structures

Baskets formed of plastic-coated wire mesh and filled with cobbles or coarse gravel (a thinner version of gabions is known as a “mattress”) may be used when all the following conditions are met:

1. The design storm shall be the same as that required for riprap. Riprap size and location, filter, and quality criteria shall be as outlined below.

2. The design water velocity does not exceed that given in table 22-1:

Table 22-1 Gabion Dimensions

GABION THICKNESS (ft.)	MAXIMUM VELOCITY (ft./sec.)
1/2	6
3/4	11
1	14

3. The Manning's "n" value used for gabions shall be 0.025.

4. The wire mesh structures are not exposed to abrasion from sand or gravel transported by moving water.

5. Plastic coated wire shall be used.

6. All wire mesh structures placed against the bottom of a channel shall be underlain by geotextile or a gravel filter designed according to the limits outlined in Table 22-1.

7. The rock used to fill basket structures shall be 4" to 7" angular, block-shaped rock. For wire mesh “mattress” structures, 3" to 4" stone may be used provided the mesh opening is small enough to contain the stone. Smaller stone will provide more stone “layers” in the mattress where larger stone would not sufficiently fill the structure’s void space

Table 22-2 Maximum Gabion Slope by Soil Texture

Soil Texture	Erosive Velocity, VE (fps)	Maximum Allowable Bottom Slope (ft./ft.) using geotextile Fabrics*
Sandy Loam	2.5	0.029
Silt Loam	3.0	0.041
Sandy Clay Loam	3.5	0.056
Clay Loam	4.0	0.074
Clay, fine gravel, graded loam to gravel	5.0	0.115
Cobbles	5.5	0.139

*For bottom slopes steeper than those shown, a properly designed gravel filter shall be placed under the gabions.

Sand, gravel, or stone filters placed under wire mesh basket structures shall meet the filter requirements shown on page 22-3.

Concrete Revetment Blocks

Concrete revetment blocks are precast interlocking or cabled concrete grids designed for soil stabilization.

Concrete revetment blocks may be used when all the following conditions are met:

1. The design storm shall be the same as that required for riprap.

2. The water velocity does not exceed 9 feet per second.

3. The Manning's "n" value used for concrete revetment blocks shall be 0.026, unless otherwise recommended by manufacturer's literature.

4. A filter is used in accordance with manufacturer's recommendations.

5. Cabled-concrete shall use non-degrading, non-corroding cable.

Recommended Design Procedure for Riprap-Lined Channels

This design of riprap-lined channels is from the "National Cooperative Highway Research Program Report No. 108, Tentative Design Procedure for Riprap-Lined Channels." It is based on the tractive stress method, and covers the design of riprap in two basic channel shapes: trapezoidal and triangular.

NOTE: This procedure is for uniform flow at normal depth in channels and is not to be used for design of riprap energy dissipation devices immediately downstream from such high velocity devices as pipes and culverts. See the Standard for Conduit Outlet Protection, p. 12-1.

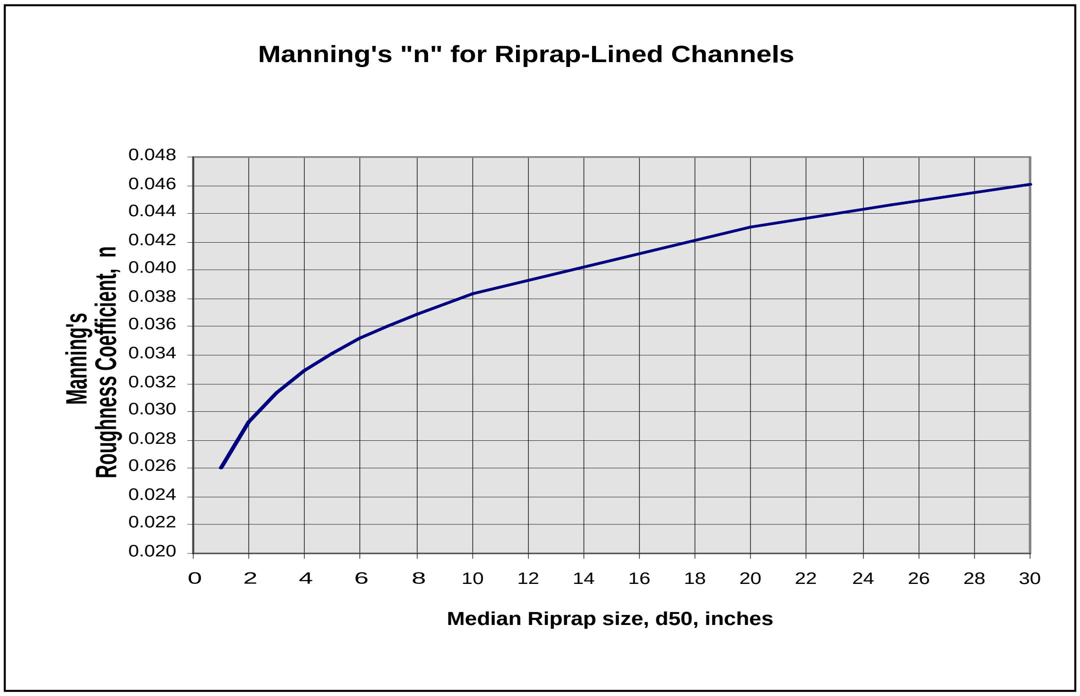
The method in Report No. 108 (design procedure beginning on p. 18) gives a simple and direct solution to the design of trapezoidal channels, including channel carrying capacity, channel geometry, and the riprap lining.

This procedure is based on the assumption that the channel is already designed and the remaining problem is to determine the riprap size that would be stable in the channel. The designer would first determine the channel dimensions by the use of Manning's equation. The "n" value for use in Manning's equation is obtained by estimating a riprap size and then determining the corresponding "n" value for the rip rapped channel from:

$$n = 0.0395(d_{50})^{0.167}$$

where d_{50} is in feet, or by using Curve 22-1 where d_{50} is in inches.

Curve 22-1



When the channel dimensions are known, the riprap can be designed (or an already completed design may be checked) as follows:

Trapezoidal Channels

1. Calculate the b/d ratio and enter Curve 22-2 to find the P/R ratio.

2. Enter Curve 22-3A with S_b, Q, and P/R to find median riprap diameter, d_{50}, for straight channels.

3. Enter Curve 22-1 to find the actual "n" value corresponding to the d_{50} from step 2. If the estimated and actual "n" values do not reasonably agree, another trail must be made.

4. For channels with bends, calculate the ratio Bs/Ro, where Bs is the channel surface width and Ro is the radius of the bend. Enter Curve 22-4 and find the bend factor, F_B. Multiply the d_{50} for straight channels by the bend factor to determine riprap size to be used in bends. If the d_{50} for the bend is less than 1.1 times the d_{50} for the straight channel, then the size for straight channel may be used in the bend; otherwise, the larger stone size calculated for the bend shall be used. The riprap shall extend across the full channel section and shall extend upstream and downstream from the ends of the curve a distance equal to five times the bottom width.

5. Enter Curve 22-5 to determine maximum stable side slope of riprap surface. In Curve 22-5, the side slope is established so that the riprap on the side slope is as stable as that on the bottom. If for any reason it is

desirable to make the side slopes steeper than what is given by Curve 22-5, the size of the riprap can be increased and the side slopes made steeper by using the following procedures:

a. Compute d_{50} and maximum stable side slope as above.

b. Enter Curve 22-6 with the computed side slope to determine K for that side slope.

c. Enter Curve 22-6 with the desired side slope to determine K'.

d. Compute riprap size for desired slope by the formula:

$$d50' = d50\ K/K'$$

6. Maximum side slopes, 2:1.

Triangular Channels

1. Enter Curve 22-3B with S_b, Q, and Z and find the median riprap diameter, d_{50}, for straight channels.

2. Enter Curve 22-1 to find the actual "n" value. If the estimated and actual "n" values are not in reasonable agreement, another trial must be made.

3. For channels with bends, see step 4 under Trapezoidal channels.

Example:

Given:

Trapezoidal channel

Q = 100 cfs.
S = 0.01 ft./ft.
Side slopes = 2.5:1.
Mean bend radius, Ro = 25'.

n = 0.033 (estimated, and used to design the channel to find that b = 6' and d = 1.8').
Type of rock available is crushed stone.

Solution:

Straight channel reach

b/d = 6/1.8 = 3.33.

from Curve 22-2, P/R = 13.0.

from Curve 22-3A, d_{50} = 3.4"

from Curve 22-1, n (actual) = 0.032, which is reasonably close to the estimated n of 0.033

Use 5" as maximum riprap size and 8" as riprap layer thickness with a filter.

Channel bend

Bs = b + 2zd = 6 + (2)(2.5)(1.8) = 15'

Bs/Ro = 15/25 - 0.60.

from Curve 22-4, F_B = 1.33

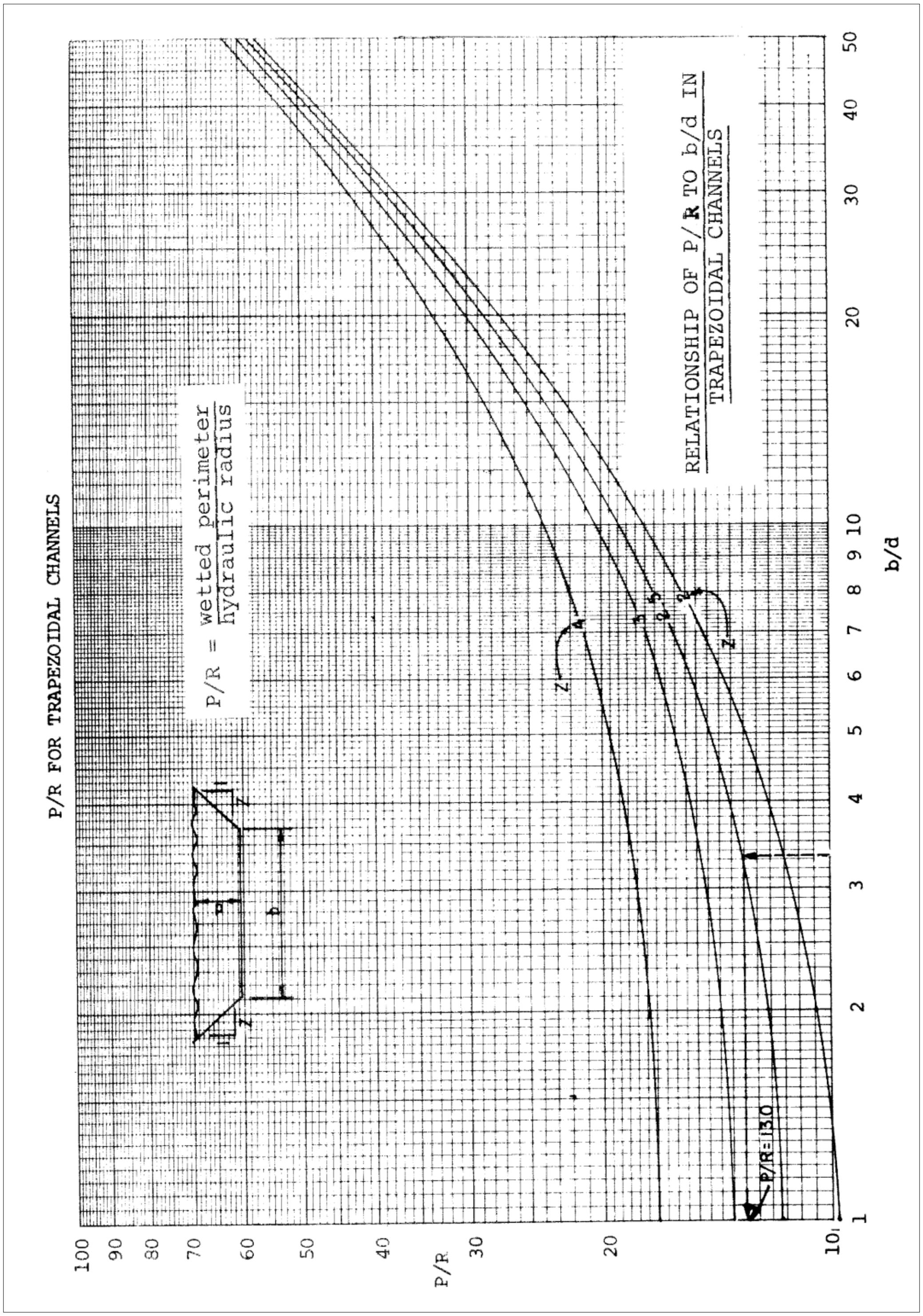
F_B = 1.33 > 1.1, therefore, the bend factor must be used.

Riprap size in bend, d_{50} = 3.4 x 1.33 = 4.52"

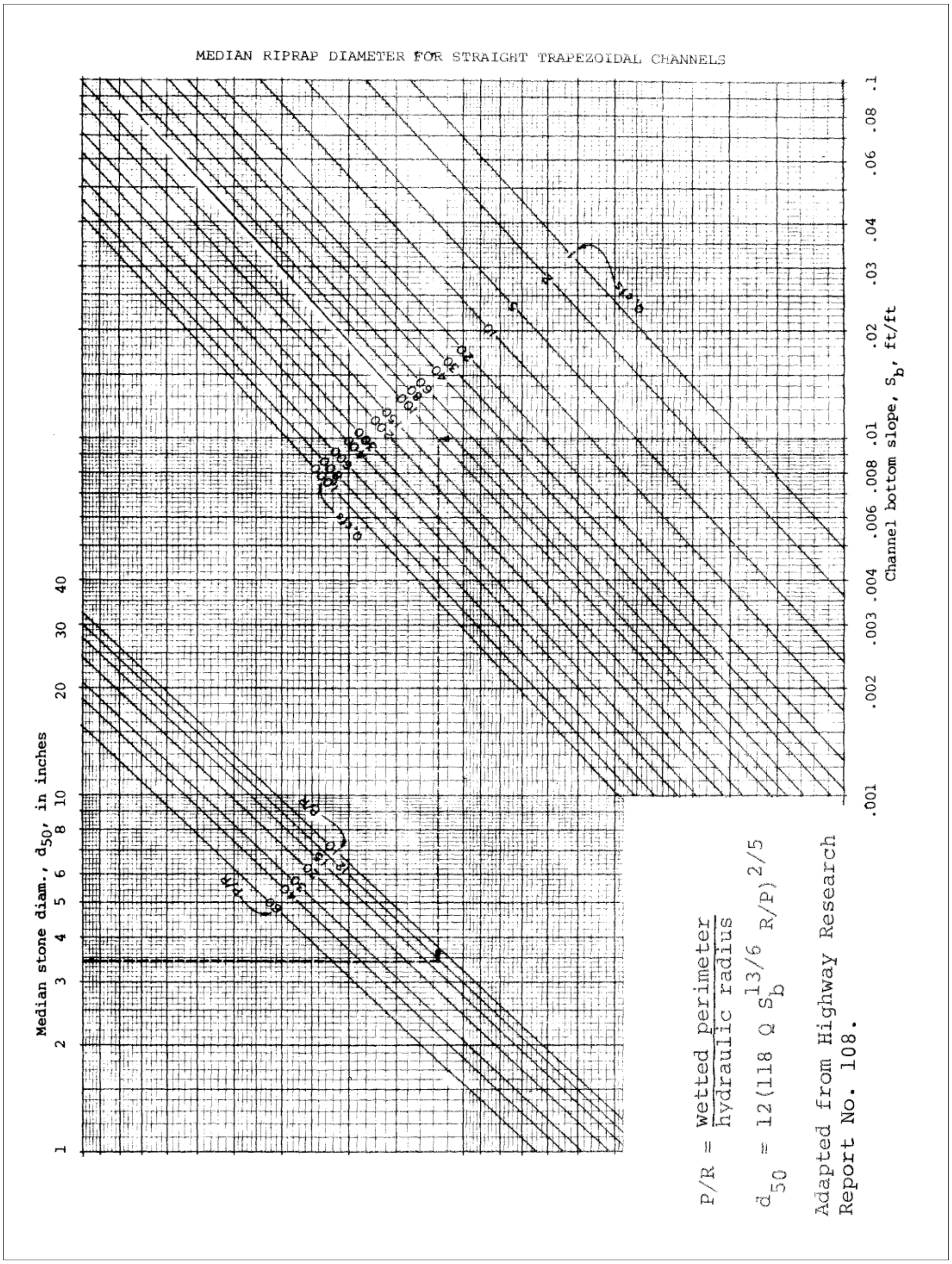
The heavier riprap for the bend shall extend upstream and downstream from the ends of the bend a distance of (5)(6) = 30 feet.

From Curve 22-5, it can be found that the riprap for d50 = 3.4" and 4.52" will both be stable on a 2.5:1 side slope.

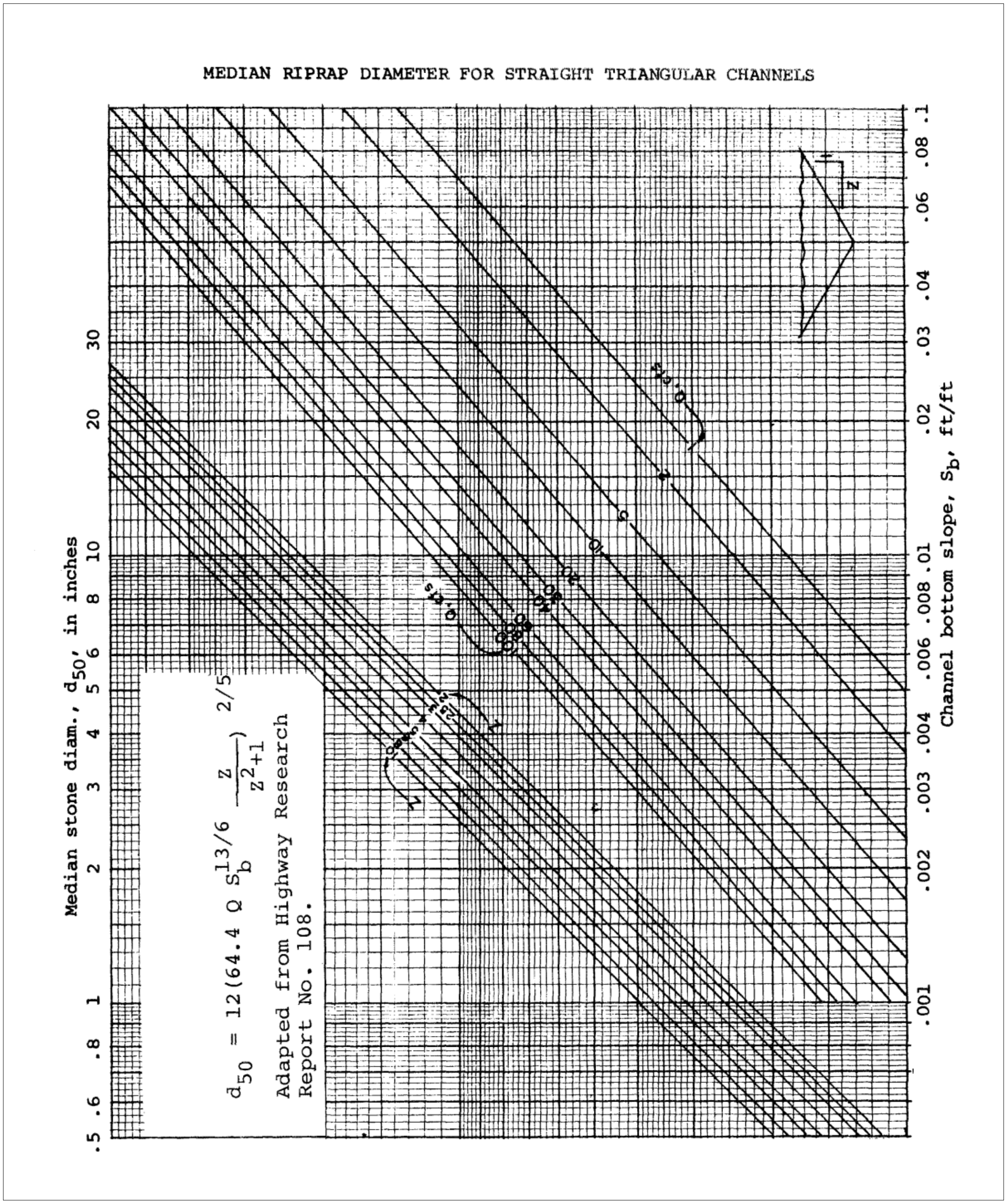
Curve 22-2


P/R FOR TRAPEZOIDAL CHANNELS
P/R = wetted perimeter / hydraulic radius
RELATIONSHIP OF P/R TO b/d IN TRAPEZOIDAL CHANNELS
P/R=13.0
P/R
b/d
Z
4
3
2
1.5

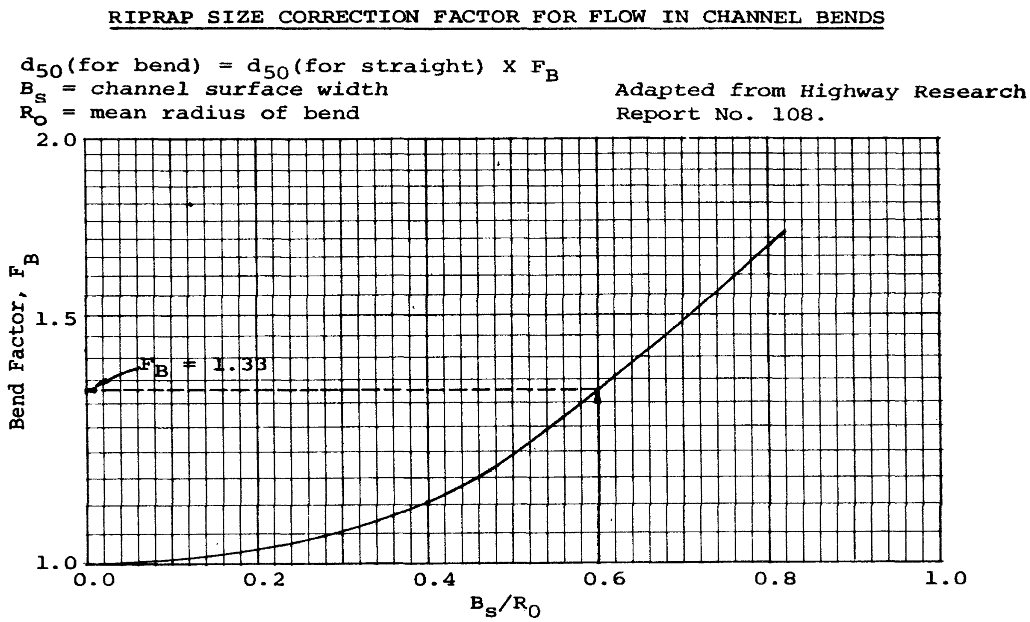
Curve 22-3A


MEDIAN RIPRAP DIAMETER FOR STRAIGHT TRAPEZOIDAL CHANNELS
Median stone diam., d50, in inches
Channel bottom slope, Sb, ft/ft
P/R = wetted perimeter / hydraulic radius
d50 = 12(118 Q Sb^13/6 R/P)^2/5
Adapted from Highway Research Report No. 108.

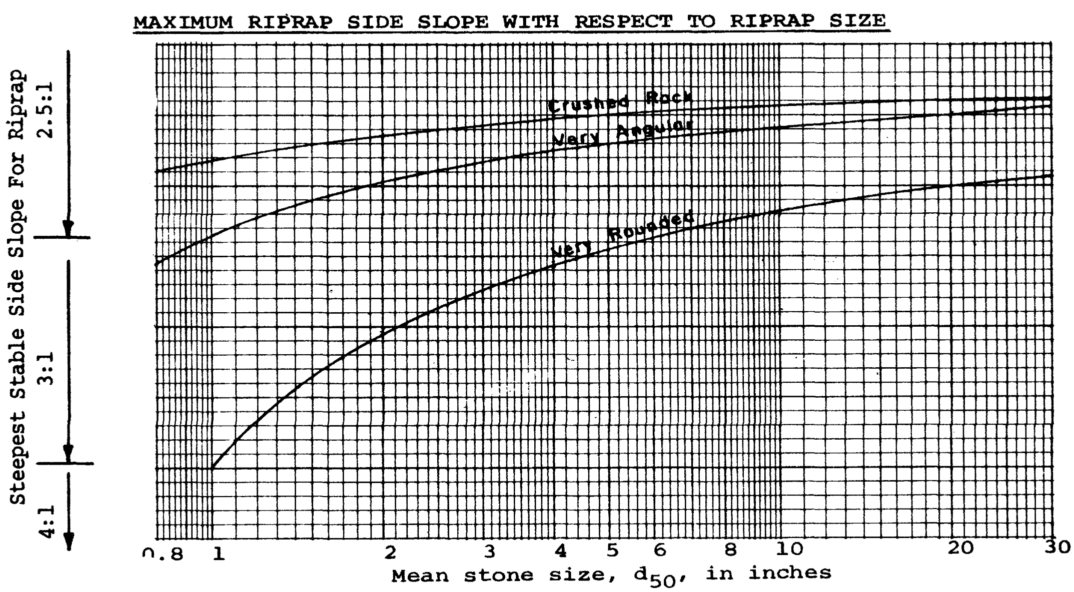
Curve 22-3B


MEDIAN RIPRAP DIAMETER FOR STRAIGHT TRIANGULAR CHANNELS
Median stone diam., d_{50}, in inches
Channel bottom slope, S_b, ft/ft
$d_{50} = 12(64.4\ Q\ S_b^{13/6}\ \frac{Z}{Z^2+1})^{2/5}$
Adapted from Highway Research Report No. 108.
Q, cfs

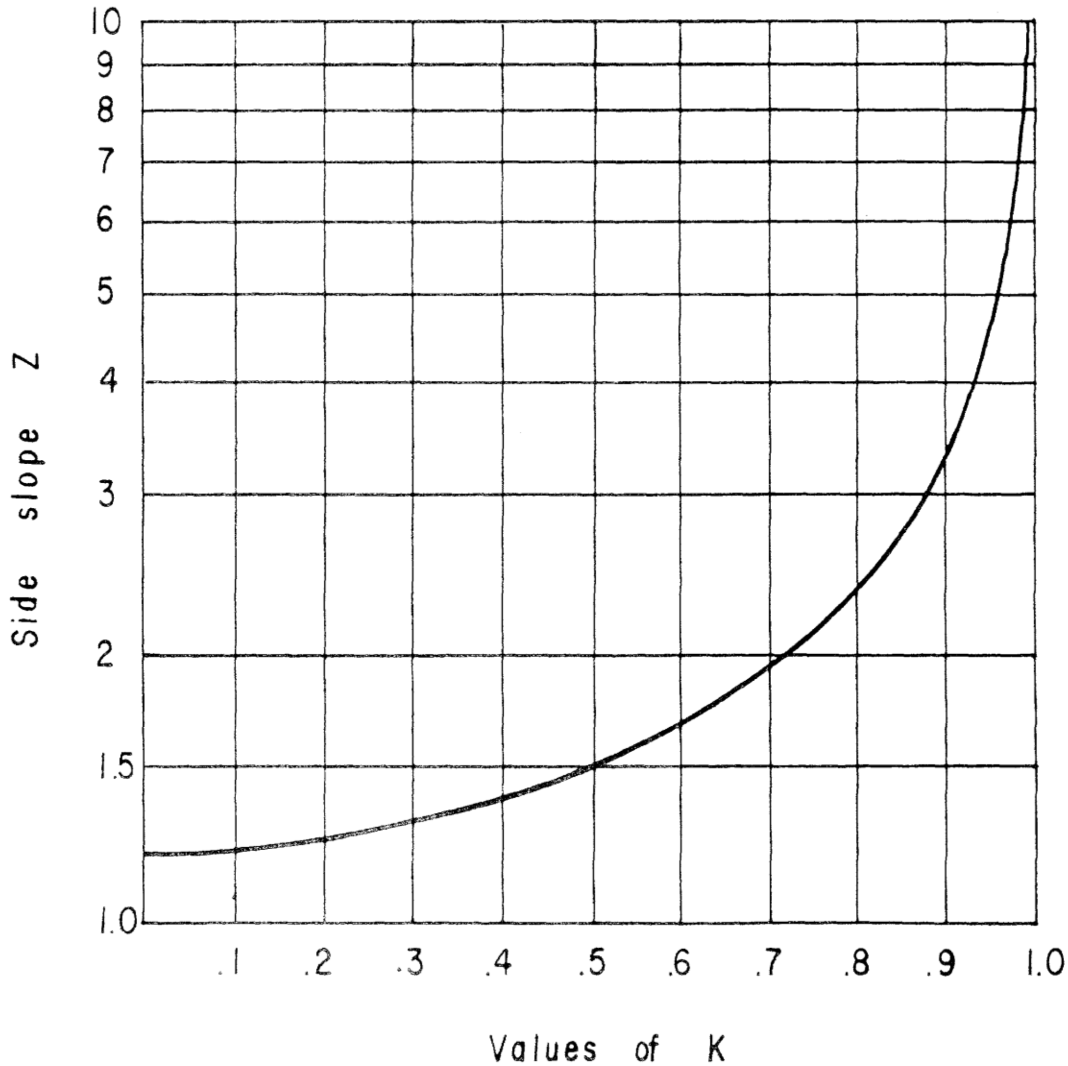
Curve 22-4



Curve 22-5



Curve 22-6



Riprap Shoreline Protection

Conditions where practice applies

This design procedure applies to riprap protection of shorelines surrounding open bodies of water, such as lakes, bays, estuaries etc. against the erosive action of surface waves. It is not intended as a design procedure for the protection of embankments of open channels. Refer to the beginning of this standard for open channel riprap design.

Design Procedure

1. Find wind speed from Figures 22-1 or 22-2 (figures are based on the 10 or 25 year return period). In general, use a 25 year return period unless a higher risk of failure is acceptable.

2. Find wave height from Table 22-3, 22-4, 22-5 or 22-6. Fetch length is the distance across open water in the prevailing wind direction.

3. Find rock weight (in lbs) from Tables 22-7, 22-8 and 22-9.

4. Find rock size (d_{50}) from Curve 22-7 Note: curve is calibrated for rock with a specific gravity of 2.6, or a unit weight of 165 lbs/ ft^3. Table 22-9, Correction for unit weight, will correct for rock with a different unit weight.

Riprap is to be installed according to limits established for depth, filter material and slope as outlined earlier in this standard.

Example:

Given:

25 year storm event, fetch length of 1 mile, depth of 5 feet, installation slope of 1:3, and stone unit weight = 160 lbs/ft^3, find:

1. From figure 22-2, wind speed for Central New Jersey for the 25 year design storm is 75 mph.

2. From Table 22-3, wave height is 2.0 feet for a fetch length of 1.0 mile and average depth of 5.0 feet.

3. From Table 22-7, the estimated required weight of stone based on wave height is 50 lbs. (per piece).

4. From Table 22-8, the correction factor for a slope of 1:3 is 0.7.

5. From Table 22-9, the correction factor for stone unit weight of 160 lbs/ft^3 is 1.1.

6. The required stone weight is: 50 x 0.7 x 1.1 = 38.5 lbs. (per piece).

7. From Curve 22-7, the d_{50} stone size for 38.5 lbs is 9.3 inches, say 9 inches.

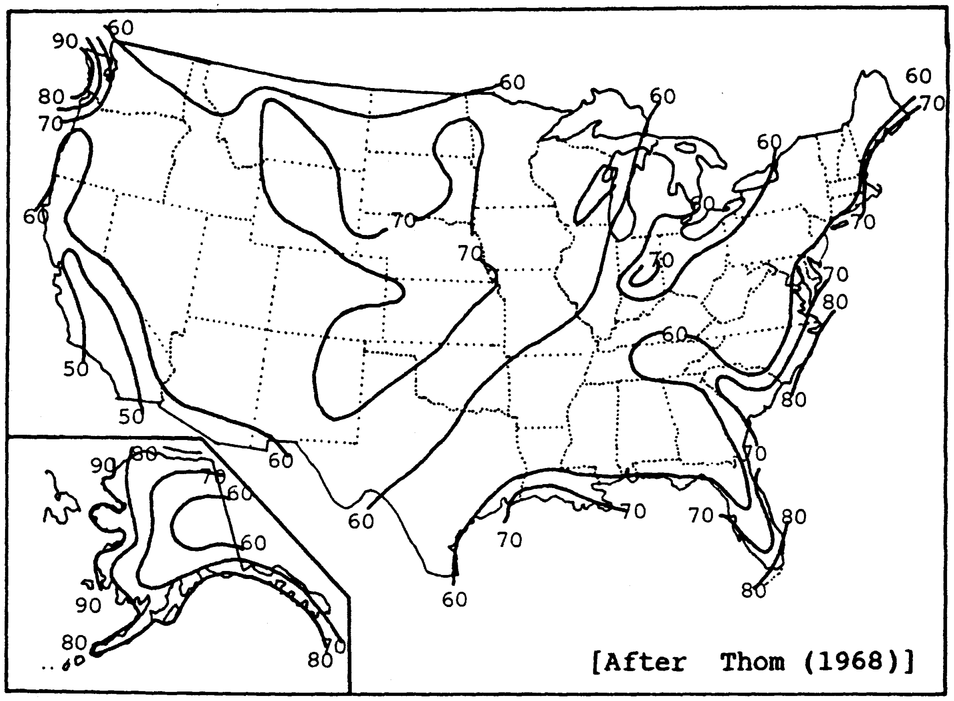


Figure 22-1 Fastest-Mile Wind Speeds: 10-year Return Period

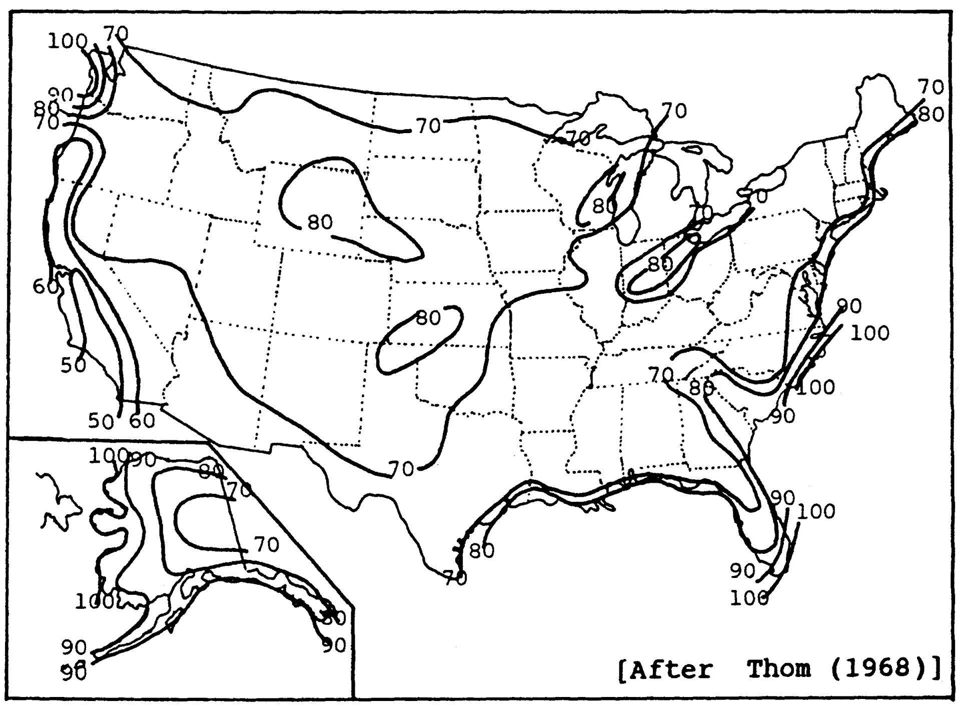


Figure 22-2 Fastest-Mile Wind Speeds: 25-year Return Period

Table 22-3

WIND-GENERATED WAVE HEIGHTS AND (PERIODS)
FETCH LENGTHS WITH AVERAGE DEPTHS = 5 FEET

Wind Speed	Fetch Length (miles)														
(mph)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0	10.0
10	0.5 (1.0)	0.5 (1.0)	0.5 (1.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)
20	0.5 (1.0)	0.5 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)
30	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.5 (2.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)
40	1.0 (2.0	1.5 (2.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)
50	1.5 (2.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)
55	1.5 (2.0)	1.5 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)
60	1.5 (2.0	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)
65	1.5 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)
70	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)
75	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)	2.0 (4.0)
80	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (4.0)	2.5 (4.0)	2.5 (4.0)	2.5 (4.0)	2.5 (4.0)	2.5 (4.0)	2.5 (4.0)	2.5 (4.0)	2.5 (4.0)	2.5 (4.0)

Table 22-4

WIND-GENERATED WAVE HEIGHTS AND (PERIODS)
FETCH LENGTHS WITH AVERAGE DEPTHS = 10 FEET

Wind Speed	Fetch Length (miles)														
(mph)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0	10.0
10	0.5 (1.0)	0.5 (1.0)	0.5 (1.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)
20	0.5 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.5 (2.0)	1.5 (2.0)	1.5 (2.0)	1.5 (2.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)
30	1.0 (2.0)	1.5 (2.0)	1.5 (2.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)
40	1.5 (2.0)	1.5 (2.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (4.0)	2.5 (4.0)	2.5 (4.0)
50	1.5 (2.0)	2.0 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)
55	2.0 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)
60	2.0 (3.0)	2.5 (3.0)	2.5 (3.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)
65	2.0 (3.0)	2.5 (3.0)	3.0 (3.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)
70	2.5 (3.0)	3.0 (3.0)	3.0 (3.0)	3.0 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)
75	2.5 (3.0)	3.0 (3.0)	3.0 (3.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)
80	2.5 (3.0)	3.0 (3.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (5.0)	4.0 (5.0)	4.0 (5.0)	4.0 (5.0)	4.0 (5.0)	4.0 (5.0)	4.0 (5.0)

Table 22-5

WIND-GENERATED WAVE HEIGHTS AND (PERIODS)
FETCH LENGTHS WITH AVERAGE DEPTHS = 15 FEET

Wind Speed (mph)	Fetch Length (miles) 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0	10.0
10	0.5 (1.0)	0.5 (1.0)	0.5 (1.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)
20	0.5 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.5 (2.0)	1.5 (2.0)	1.5 (2.0)	1.5 (2.0)	1.5 (2.0)	1.5 (2.0)	1.5 (3.0)	1.5 (3.0)	2.0 (3.0)	2.0 (3.0)
30	1.0 (2.0)	1.5 (2.0)	1.5 (2.0)	1.5 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)
40	1.5 (2.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	3.0 (3.0)	3.0 (3.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)
50	2.0 (2.0)	2.0 (3.0)	2.5 (3.0)	2.5 (4.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	4.0 (4.0)
55	2.0 (3.0)	2.5 (3.0)	3.0 (3.0)	3.0 (4.0)	3.0 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)
60	2.0 (3.0)	2.5 (3.0)	3.0 (3.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (5.0)	4.5 (5.0)
65	2.5 (3.0)	3.0 (3.0)	3.5 (3.0)	3.5 (4.0)	3.5 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (5.0)	4.5 (5.0)
70	2.5 (3.0)	3.0 (3.0)	3.5 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (5.0)	4.5 (5.0)	4.5 (5.0)	4.5 (5.0)	4.5 (5.0)
75	2.5 (3.0)	3.5 (3.0)	3.5 (4.0)	4.0 (4.0)	4.0 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (5.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)
80	3.0 (3.0)	3.5 (4.0)	4.0 (4.0)	4.0 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (5.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)

Table 8

WIND-GENERATED WAVE HEIGHTS AND (PERIODS)
FETCH LENGTHS WITH AVERAGE DEPTHS = 20 FEET

Wind Speed (mph)	Fetch Length (miles) 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0	10.0
10	0.5 (1.0)	0.5 (1.0)	0.5 (1.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	0.5 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)
20	0.5 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.0 (2.0)	1.5 (2.0)	1.5 (2.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	1.5 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)
30	1.0 (2.0)	1.5 (2.0)	1.5 (3.0)	1.5 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.0 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	3.0 (3.0)	3.0 (4.0)	3.0 (4.0)
40	1.5 (2.0)	2.0 (3.0)	2.0 (3.0)	2.5 (3.0)	2.5 (3.0)	2.5 (3.0)	3.0 (3.0)	3.0 (4.0)	3.0 (4.0)	3.0 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)
50	2.0 (3.0)	2.5 (3.0)	2.5 (3.0)	3.0 (4.0)	3.0 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	3.5 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.5 (4.0)	4.5 (4.0)
55	2.0 (3.0)	2.5 (3.0)	3.0 (3.0)	3.0 (4.0)	3.5 (4.0)	3.5 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (5.0)	4.5 (5.0)	4.5 (5.0)
60	2.0 (3.0)	3.0 (3.0)	3.0 (4.0)	3.5 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.0 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (5.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)
65	2.5 (3.0)	3.0 (3.0)	3.5 (4.0)	4.0 (4.0)	4.0 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (4.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)	5.5 (5.0)
70	2.5 (3.0)	3.5 (4.0)	4.0 (4.0)	4.0 (4.0)	4.5 (4.0)	4.5 (4.0)	4.5 (4.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)	5.5 (5.0)	5.5 (5.0)	5.5 (5.0)	5.5 (5.0)
75	3.0 (3.0)	3.5 (4.0)	4.0 (4.0)	4.5 (4.0)	4.5 (4.0)	5.0 (4.0)	5.0 (5.0)	5.0 (5.0)	5.0 (5.0)	5.5 (5.0)	5.5 (5.0)	5.5 (5.0)	5.5 (5.0)	6.0 (5.0)	6.0 (5.0)
80	3.0 (3.0)	4.0 (4.0)	4.5 (4.0)	4.5 (4.0)	5.0 (4.0)	5.0 (5.0)	5.5 (5.0)	5.5 (5.0)	5.5 (5.0)	5.5 (5.0)	5.5 (5.0)	6.0 (5.0)	6.0 (5.0)	6.0 (5.0)	6.0 (5.0)

TABLE 22-7
ESTIMATED WEIGHT OF ARMOR STONE

WAVE HEIGHT H (ft)	ESTIMATED WEIGHT W (lb)
0.5	1
1.0	10
1.5	20
2.0	50
2.5	100
3.0	160
3.5	260
4.0	390
4.5	550
5.0	750
5.5	1000
6.0	1300
6.5	1650
7.0	2100

TABLE 22-8
CORRECTION FOR SLOPE

SLOPE (ft/ft)	CORRECTION FACTOR K_1
1:2	1.0
1:2½	0.8
1:3	0.7
1:3½	0.6
1:4	0.5
1:4½	0.4
1:5	0.4
1:5½	0.4
1:6	0.3

TABLE 22-9
CORRECTION FOR UNIT WEIGHT

UNIT WEIGHT w_r (lb/ft^3)	CORRECTION FACTOR K_2
120	4.3
130	2.8
135	2.4
140	2.0
145	1.7
150	1.5
155	1.3
160	1.1
165	1.0
170	0.9
175	0.8
180	0.7
185	0.6
190	0.6

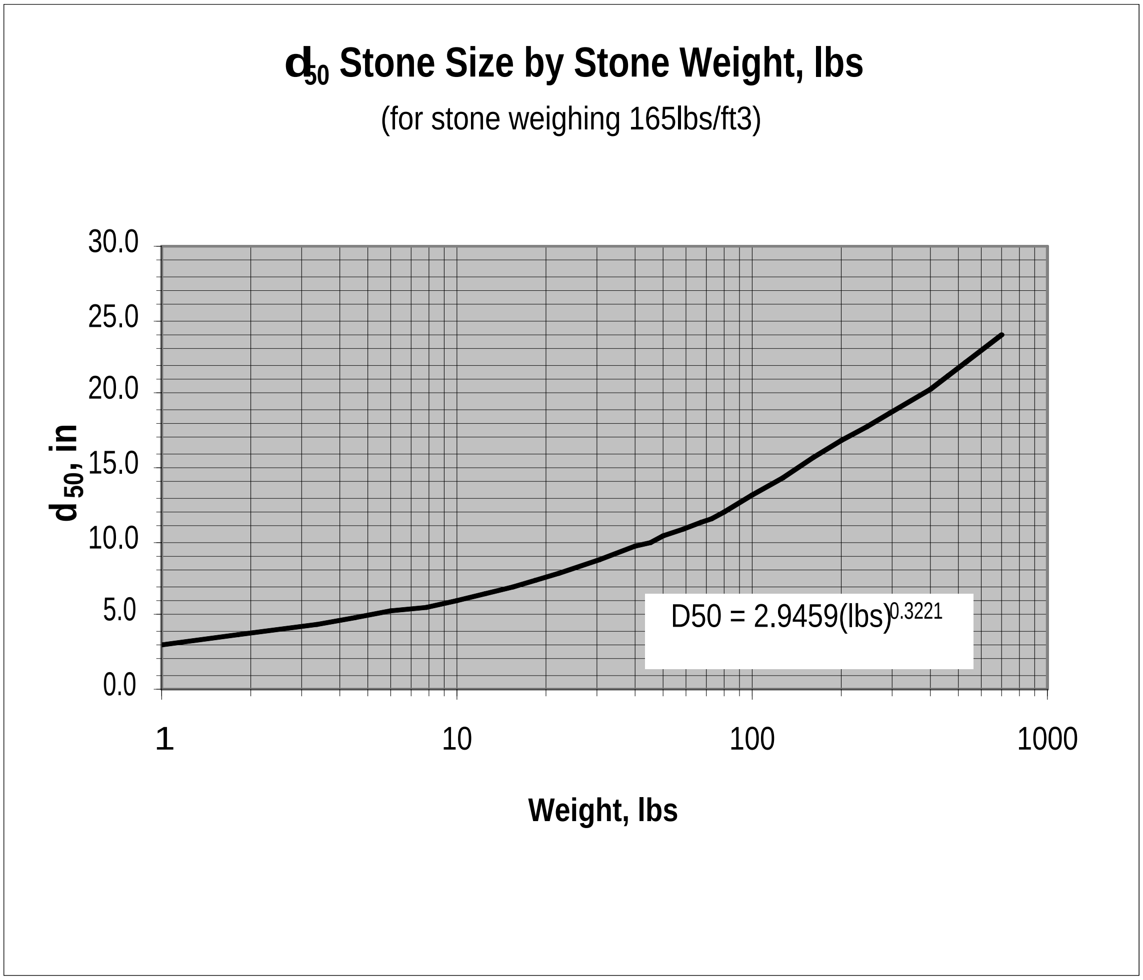
EXAMPLE

GIVEN: The wave height (H) is 3.0 feet and the structure slope is 1 on 3 (1 Vertical on 3 Horizontal) and one cubic foot of rock weighs 155 lbs (w_r)

FIND: The required weight of armor stone (W) from the tables (Dashed Line)

W = 160 lbs x 0.7 x 1.3 = 145 lbs

Curve 22-7


d50 Stone Size by Stone Weight, lbs
(for stone weighing 165lbs/ft3)
d50, in
30.0
25.0
20.0
15.0
10.0
5.0
0.0
D50 = 2.9459(lbs)0.3221
1
10
100
1000
Weight, lbs

STANDARD FOR SEDIMENT BARRIERS

Definition

A temporary barrier installed across or at the toe of a slope.

Purpose

The purpose of a sediment barrier is to intercept and detain small amounts of sediment from unprotected areas of limited extent.

Conditions Where Practice Applies

The sediment barrier is used where:

1. No other practice is feasible,

2. There is no concentration of water in a channel or other drainage way above the barrier, and

3. Erosion would occur in the form of sheet and rill erosion.

Design Criteria

A. All types of sediment barriers:

    1. Contributing drainage area is less than 1 acre and the length of slope above the barrier is less than 150 feet.

    2. The slope of the contributing drainage area for at least 30 feet adjacent to the barrier shall not exceed 5%.

    3. The barrier shall be constructed so water cannot bypass the barrier around the ends.

    4. Inspection shall be frequent and repair or replacement shall be made promptly as needed.

    5. The barrier shall be removed when the contributing drainage area has been stabilized so as not to block or impede storm flow or drainage.

B. Requirements for bale barrier (e.g., straw, hay, or other acceptable vegetative material):

    1. All bales shall be securely tied and staked on the contour (Fig. 23-1).

    2. Bales shall be placed in a row with ends tightly abutting the adjacent bales.

    3. Each bale shall be embedded in the soil a minimum of 4 inches.

    4. Bales shall be securely anchored in place by two stakes or re-bars driven through each bale. The first stake in each bale shall be driven toward previously laid bale to force bales together.

C. Requirements for silt fence:

1. Fence posts shall be spaced 8 feet center-to-center or closer. They shall extend at least 2 feet into the ground and extend at least 2 feet above ground (Fig. 23-2). Posts shall be constructed of hardwood with a minimum diameter thickness of 1 ½ inches.

2. **"Super" silt fence** - A metal fence with 6 inch or smaller mesh openings and at least 2 feet high may be utilized, fastened to the fence posts, to provide reinforcement and support to the geotextile fabric. Posts may be spaced less than 8 feet on center and may be constructed of heavier wood or metal as needed to withstand heavier sediment loading. This practice is appropriate where space for other practices is limited and heavy sediment loading is expected. "Super" silt fence is not to be used in place of properly designed diversions (pg. 15-1) which may be needed to control surface runoff rates and velocities.

3. A geotextile fabric, recommended for such use by the manufacturer, shall be buried at least 6 inches deep in the ground. The fabric shall extend at least 2 feet above the ground. The fabric must be securely fastened to the posts using a system consisting of metal fasteners (nails or staples) and a high strength reinforcement material (nylon webbing, grommets, washers etc.) placed between the fastener and the geotextile fabric. The fastening system shall resist tearing away from the post. The fabric shall incorporate a drawstring in the top portion of the fence for added strength.

D. Requirements for stone barrier:

1. The stone shall be piled to a natural angle of repose with a height of at least 2 feet.

2. The stone shall meet ASTM C-33 size No. 2 (2.5 to 1.5) or 3 (2 to 1 inch).

<u>Maintenance</u>

1. Sediment shall be removed from the upstream face of the barrier when it has reached a depth of ½ the barrier height.

2. Repair or replace barrier (fabric, posts, bales etc.) when damaged.

3. Barriers shall be inspected daily for signs of deterioration and sediment removal.

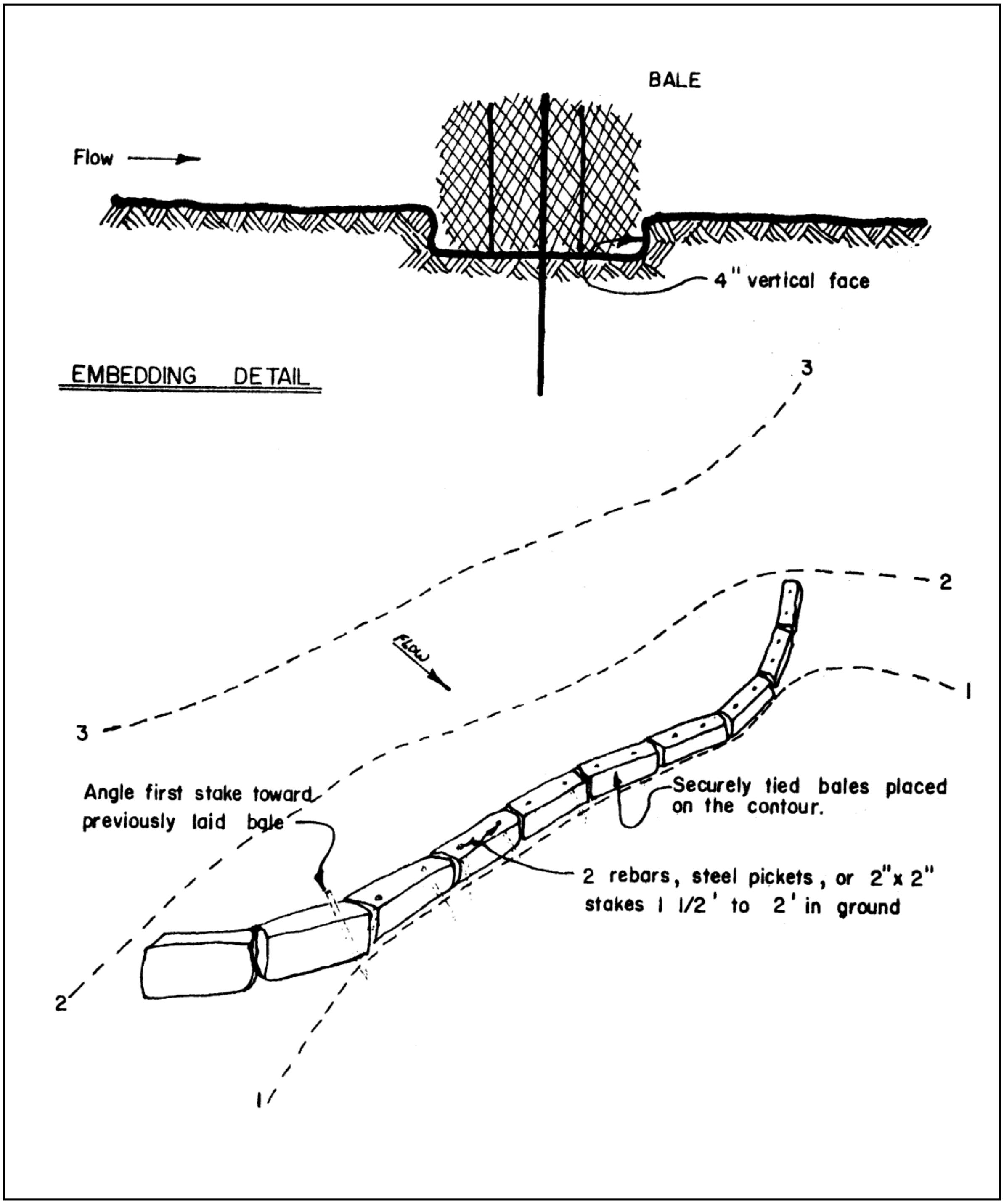
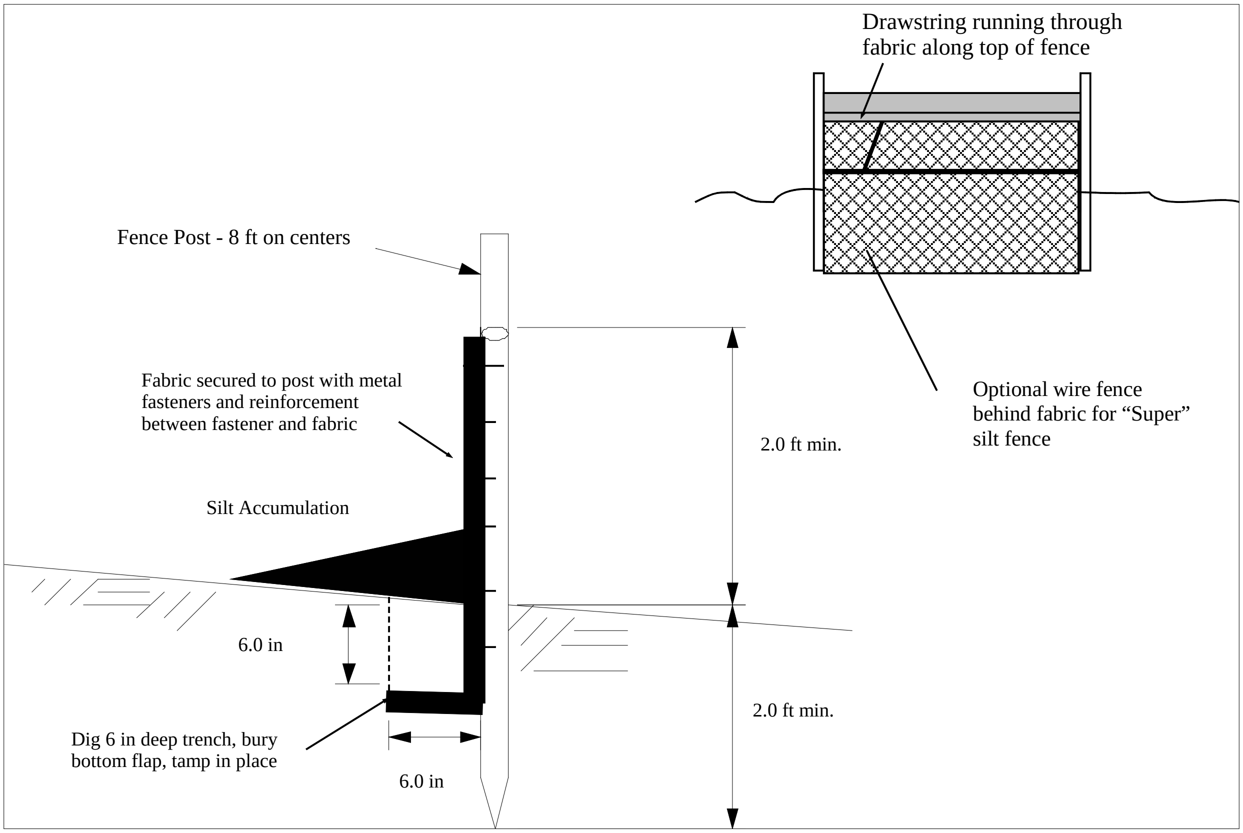


Figure 23-1: Placement and Anchoring Detail Bale Sediment Barriers

Figure 23-2: Silt Fence construction and installation detail



**STANDARD
FOR
SEDIMENT BASIN**

Definition

A barrier, dam, excavated pit, or dugout constructed across a waterway or at other suitable locations to intercept and retain sediment.

Basins created by construction of dams or barriers are referred to as "Embankment Sediment Basins" and those constructed by excavation as "Excavated Sediment Basins." Basins resulting from both excavation and embankment construction are classified as "Embankment Sediment Basins" where the depth of water impounded against the embankment at the emergency spillway elevation is 3 feet or more.

Scope

The standard covers the installation of sediment basins on sites where:

1. Failure of the sediment basin should not, within reasonable expectations, result in loss of life.

2. Failure of the sediment basin would not result in damage to homes, commercial or industrial buildings, main highways, or railroads; or interrupt the use or service of public utilities.

3. The drainage area is 320 acres or less.

4. The effective height of the dam is 20 feet or less. The effective height of the dam is defined as the difference in elevation in feet between the emergency spillway crest and the lowest point in the cross section taken along the centerline of the dam. If there is no emergency spillway, the top of the dam becomes the upper limit.

Sediment basins that are not within the above scope shall be designed to meet the criteria in "Earth Dams and Reservoirs, Technical Release 60" (TR60) by the USDA-NRCS.

For dams which raise the water elevation five (5) feet or greater in height as defined in NJAC 7:20, the rules and regulations established by the New Jersey Department of Environmental Protection, Division of Engineering and Construction, Dam Safety, shall apply for all structural criteria. Flood Hazard Area Regulations NJAC 7:13-1.1 et. seq. may also apply.

Purpose

To preserve the capacity of reservoirs, ditches, canals, diversions, storm sewers, waterways, and streams; to prevent undesirable deposition on bottom-lands and developed areas; to trap sediment originating from critically eroding areas and construction sites; and to reduce or abate pollution by providing basins for deposition and storage of silt, sand, gravel, and stone.

Conditions Where Practice Applies

This practice applies where physical conditions, land ownership, or construction operations preclude the treatment of the sediment source by the installation or erosion control measures to keep soil and other material in place, or a sediment basin offers the most practical solution to the problem. The effectiveness of sediment removal is greatly reduced when soils are highly colloidal in nature. Additional source controls (stabilization) or flocculants must be utilized to reduce the delivery of fines to the sediment basin.

Water Quality Enhancement

During the construction process, large areas of bare soil are frequently exposed to erosion due to stormwater runoff. Suspended soils can contribute significantly to degraded water quality, both from downstream deposition as well as acting as a carrier for other pollutants which may adsorb onto soil particles. The use of a properly designed sediment basin, in combination with other erosion control standards can significantly reduce both volumetric and pollution transport problems associated with soil erosion from construction sites.

Design Criteria

Structural aspects of detention basins shall be as stipulated by applicable state, county or municipal requirements. In the absence of such criteria, Appendix A-10, "Structural Guidelines for Detention Basins", may be used. In addition, it must be shown for the peak outflow of a 10 year, 24 hour storm event (over and above basin design storage) as determined by Win TR-55, Win TR-20 , USACOE HEC HMS or other comparable methods, that there will be no soil erosion and sedimentation problems offsite. A detailed hydraulic analysis of the basin shall be submitted.

1. Sediment Basin Location:

The basin shall be designed to accommodate the individual storm runoff and sediment accumulation from the basin's total drainage area.

The basin should be located as much as possible:

a. To intercept only runoff from disturbed areas.
b. To minimize disturbance from its own construction.
c. To obtain maximum storage benefit from the terrain.
d. For ease of cleanout of the trapped sediment.
e. To minimize interference with other construction activities and construction of utilities.

2. Shape and Depth:

The length, width, and depth are measured at the principal spillway crest elevation. The basin configuration shall be such that the effective flow length is equal to at least two times the effective flow width. This basin shape may be attained by selecting the basin site, by excavating the basin to the required shape or by the installation of one or more baffles.

The minimum width shall be:

$$W = 10 \times (Q_5)^{1/2}$$

where: W = the width in ft.
Q_5 = peak discharge from a 5 year frequency storm in cfs.

The average depth shall be at least 4 feet.

When downstream damage may be severe, the minimum width should be:

$$W = 10 \times (Q_{25})^{1/2}$$

where: W = width in feet
Q_{25} = peak discharge from a 25 year frequency storm in cfs.

The average depth shall be at least 4 feet.

See Appendix A-10 for Structural Guidelines for basins.

3. Outlet for Conduits

Protection against scour at the discharge end of the spillway shall be provided in accordance with the Standard for Conduit Outlet Protection, pg. 12-1, or by suitable hydraulic structures proven effective by properly documented research.

4. Vegetation

The dam, emergency spillway, spill and borrow areas, and other disturbed areas above crest of the principal spillway shall be stabilized in accordance with the standards for temporary (pg. 7-1) or permanent (pg. 4-1) vegetative cover, whichever is applicable.

Sediment Basin Sizing

A. Sediment Basin Volume

The volume in the sediment basin below the crest elevation of the emergency spillway shall be the larger of:

1. The volume necessary to obtain 70% trap efficiency at the start of the basin's useful life, or

2. The volume necessary to provide sediment storage capacity and provide for temporary stormwater runoff storage from a 2-year frequency, 24-hour duration, Type III storm.

Flood routing to determine the required temporary floodwater storage for a 2-year frequency, 24-hour duration, Type III storm shall be done using the approximate methods in the USDA-NRCS "Engineering Field Manual," the approximate methods in the USDA-NRCS "Urban Hydrology for Small Watersheds" (Win TR55), Win TR-20, or other generally accepted methods of flood routing.

The Modified Rational Method on a drainage basin up to 20 acres, as described in Special Report 43 by the American Public Works Association, Practices in Detention of Urban Stormwater, is also applicable.

1. Trap Efficiency

Trap efficiency is the amount, in percent, of the sediment delivered to the sediment basin that will remain in the basin. The sediment basin shall have adequate volume below the crest of the emergency spillway to have an actual trap efficiency of at least 70% at the start of its useful life using Curve 26-1 and with:

C = total capacity of the sediment basin up to the crest elevation of the emergency spillway in acre feet.

I = average annual surface runoff from Figure 26-1 converted to units of acre feet.

For a normally dry sediment basin, the actual trap efficiency is reduced 10% where the incoming sediment is predominately silt, clay, or fine grained. Therefore, enter Curve 26-1 with 80% trap efficiency to achieve 70% actual trap efficiency. For a normally dry sediment basin, the actual trap efficiency is reduced 5% where the incoming sediment is sand or coarse grained. Therefore, enter Curve 26-1 with 75% trap efficiency to achieve 70% actual trap efficiency.

2. Sediment Storage Capacity plus 2 Year Storm Runoff Volume

The sediment storage capacity of a sediment basin shall equal the volume of sediment expected to be trapped at the site during the planned useful life of the sediment basin. Where it is determined that periodic removal of sediment is practicable, the sediment storage capacity may be proportionately reduced. Planned periodic removal of sediment shall not be more frequent than once a year. The capacity shall be determined by one of the following methods:

Provide sediment storage based on the following formula and figures:

$V = (DA)(A)(DR)(TE)(1/\gamma_s)$ (2,000 lbs./tons)(1/43560 sq. ft./Ac.)

where:

V = the volume of sediment trapped in Ac. ft./yr.
DA = the total drainage area in acres.
A = the average annual erosion in tons per acre per year using the values below for the listed land use

Average Annual Erosion by Land Use Type

LAND USE	AVERAGE ANNUAL EROSION
Wooded areas	0.2 ton/ac/yr
Developed urban areas, grassed areas, pastures, hay fields, abandoned fields with good cover	1.0 ton/ac/yr
Clean tilled cropland (corn, soybeans, etc.)	10 ton/ac/yr
Construction areas	50 ton/ac/yr

DR = the delivery ratio determined from Curve 26-2
TE = the trap efficiency as determined above.
γ = the estimated sediment density in the sediment basin in lbs/cu. ft. (See Table 26-1).
γs = the submerged density in a wet sediment pool.
γa = the aerated density in a normally dry sediment pool.

TABLE 24-1 Soil Densities by Soil Type

SOIL TEXTURE	γs Submerged (lbs./cu.ft.)	γs Aerated (lbs./cu.ft.)
Clay	40-60	60-80
Silt	55-75	75-85
Clay-silt mixtures (equal parts)	40-65	65-85
Sand-silt mixtures (equal parts)	75-95	95-100
Clay-silt-sand mixtures (equal parts)	50-80	80-100
Sand	85-100	85-100
Gravel	85-125	85-125
Poorly sorted sand and gravel	95-130	95-130

The NRCS Type III 2 year Storm Runoff Volume draining to the Sediment Basin shall be added to the Sediment Storage Capacity to arrive at the total storage volume for the Sediment Basin under this criteria.

B. Sediment Basin Outlets:

1. Dewatering Hole:

If the sediment basin is de-watered by using a hole in the riser:

a. The elevation of the hole shall be the elevation that results in 50% actual trap efficiency in the basin. The value for C used to determine the 50% actual trap efficiency is the capacity of the basin between the bottom of the basin and the invert of the dewatering hole. The riser shall be completely watertight except for the inlet at the top and one hole 4 inches or less in diameter to de-water the basin.

b. The sediment shall be removed from the basin when the sediment reaches the elevation of the bottom of the hole.

c. A ‘skimmer” or “floating riser” may be utilized to draw down cleaner water from the water surface. The flexible connection to the outlet control structure must be water tight. Provision must be made to prevent the skimmer from resting on the basin floor when the pool has been completely drained. See Appendix A-7 for general details.

If the Sediment Basin has a permanent pool:

a. De-watering the Sediment Basin - Sediment basins with a permanent pool of water trap sediment more effectively than basins that are normally dry and usually create less of a mosquito problem and safety hazard. Therefore, a sediment basin with a permanent pool is usually a better design than a normal dry sediment basin.

If a normally dry or partially dry sediment basin is planned, the basin shall be de-watered by methods depicted above and in appendix A7.

If the sediment basin is de-watered by using a subsurface drain, it shall be in accordance with the Subsurface Drain Standard, pg. 32-1 and appendix A-7.

A flocculent such as “PAM” (Polyacrylamide) may be added to the basin in accordance with manufacturer’s instructions to remove fine suspended colloidal material prior to dewatering. All dewatering discharges must be to a stabilized location. A source of free cationic ions (such as Ca 2+) may be required at a rate of 50- 60 gm Ca2+ /kg PAM to encourage bonding between colloids and PAM. Materials such as lime, CaCl, gypsum or flyash may be used to provide the cation component. The flocculent shall not cause adverse environmental conditions to develop in the area receiving the basin discharge.

Flocculent may be added through the use of 'logs' or similar devices impregnated with PAM to dose inflow water prior to entrance to the sediment basin. Such devices shall be placed to allow complete passage of the design storm and shall not obstruct flow through storm sewer systems.

2. Principal Spillway Crest Elevation – Top of Temporary Sediment Riser:

The principal spillway crest elevation shall be the lower of:

a. one (1) foot below the emergency spillway crest elevation or,

b. the elevation that provides (between the crest of the principal spillway and the crest of the emergency spillway), the required temporary floodwater storage for a 2-year frequency, 24-hour duration, Type III storm.

3. Emergency Spillways for Excavated and Embankment Sediment Basins:

Emergency spillways are provided to convey large floods safely past sediment basins.

An emergency spillway must be provided for each sediment basin, unless the principal spillway is large enough to pass the routed emergency spillway design storm and the trash that comes to it without overtopping the dam. A closed conduit principal spillway having a conduit with a cross-sectional area of 3 square feet or more, an inlet which will not clog, and an elbow designed to facilitate the passage of trash is the minimum size and design that may be utilized without an emergency spillway.

a. Excavated Sediment Basins - Excavated sediment basins may utilize the natural ground or the fill for the emergency spillway if the downstream slope is 5 to 1 or flatter, has existing vegetation, or is immediately protected by sodding, rock riprap, asphalt lining, concrete lining, or other equally effective protection. The spillway shall meet the capacity requirement for embankment sediment basins.

b. Embankment Sediment Basins - Embankment sediment basins shall meet the following requirements:

Capacity - The minimum capacity of the emergency spillway shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 26-2 less any reduction creditable to conduit discharge and detention storage.

When discharge of the principal spillway is considered in calculating outflow through the emergency spillway, the crest elevation of the inlet shall be such that full flow will be generated in the conduit before there is discharge through the emergency spillway. The emergency spillway shall safely pass the peak flow or the storm runoff shall be routed through the reservoir. If routed, the routing shall start with the water surface at the elevation of the crest of the principal spillway. The flood routing may be done using the approximate methods in the USDA-NRCS Engineering Field Manual; the USDA-NRCS TR-55 or TR-20; the modified rational method up to 20 acres, as described in Special Report 43 by the American Public Works Association, Practices in Detention of Urban Stormwater; or other accepted methods of emergency spillway flood routing.

Table 24-2 Minimum Design Storm

DRAINAGE AREA (acres)	FREQUENCY (years)	MINIMUM DURATION* (hours)
less than 20	10	24
21 - 49	25	24
over 49	100	24

*For use by USDA-NRCS methods only.

Disposal

The sediment basin plans shall indicate the method(s) of disposing of the sediment removed from the basin. The sediment shall be placed in such a manner that it will not erode from the site. The sediment shall not be deposited downstream from the basin, in or adjacent to a stream or floodplain or in wetlands.

The plans shall also show the method of removal of the sediment basin after the drainage area is stabilized, and shall include the stabilizing of the sediment basin site. Water lying over the trapped sediment shall be removed from the basin by pumping, cutting the top of the riser, or other appropriate method prior to removing or breaching the embankment. Sediment shall not be allowed to flush into the stream or drainage way.

Sediment shall be removed from the basin for maintenance purposes when the sediment level reaches the 50 % Trap Efficiency elevation. The elevation shall be identified either by the invert elevation of the 50 % Trap Efficiency dewatering hole (if one is used) or by a marker which shall be visible from the basin edge.

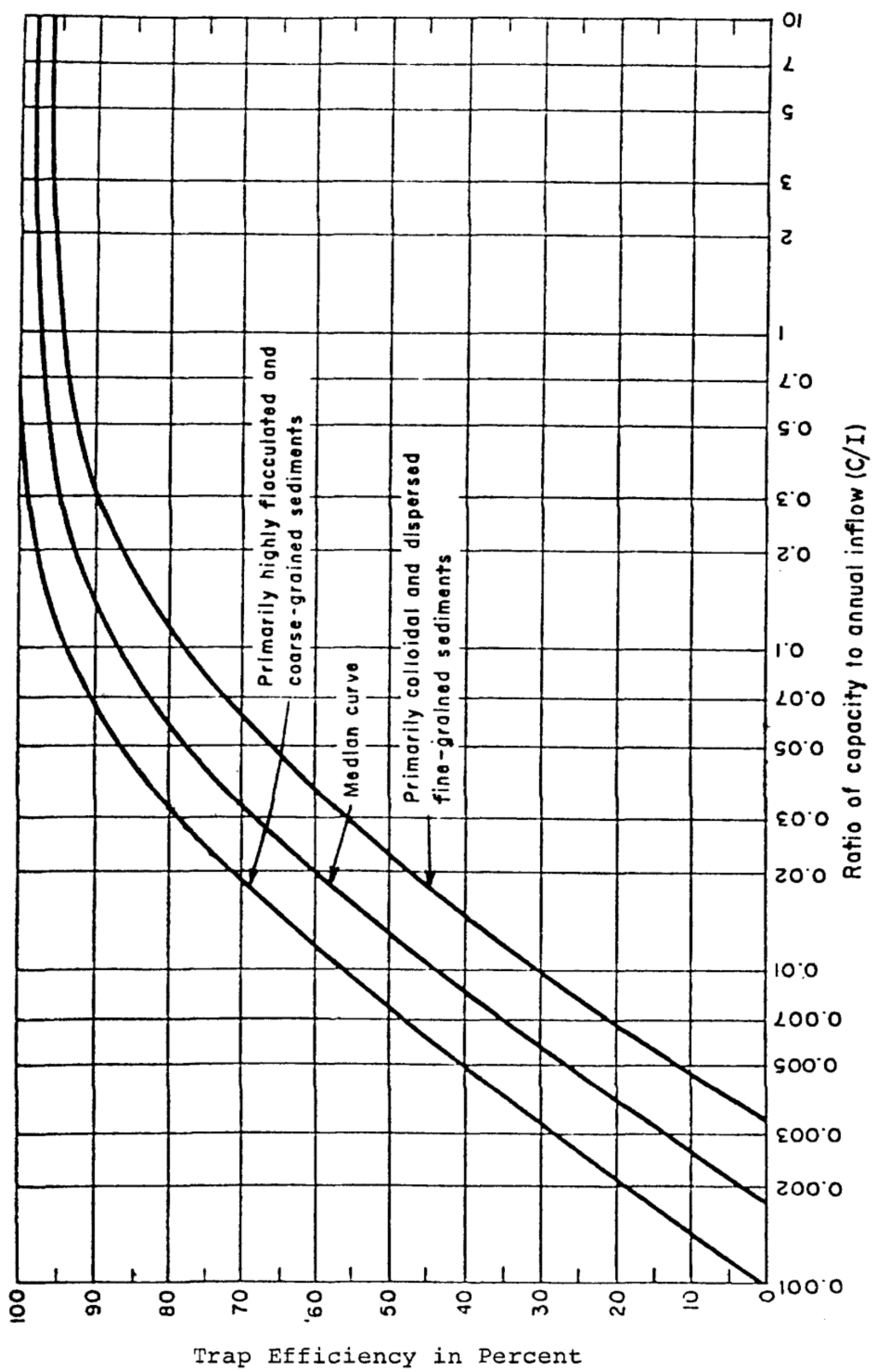
Safety - This portion of the Standard is for guidance only.

Sediment basins attract children and can be very dangerous. Local County or State ordinances and regulations regarding health and safety must be adhered to.

Maintenance

The plans shall indicate who is responsible for operation and maintenance during the life of the sediment basin.

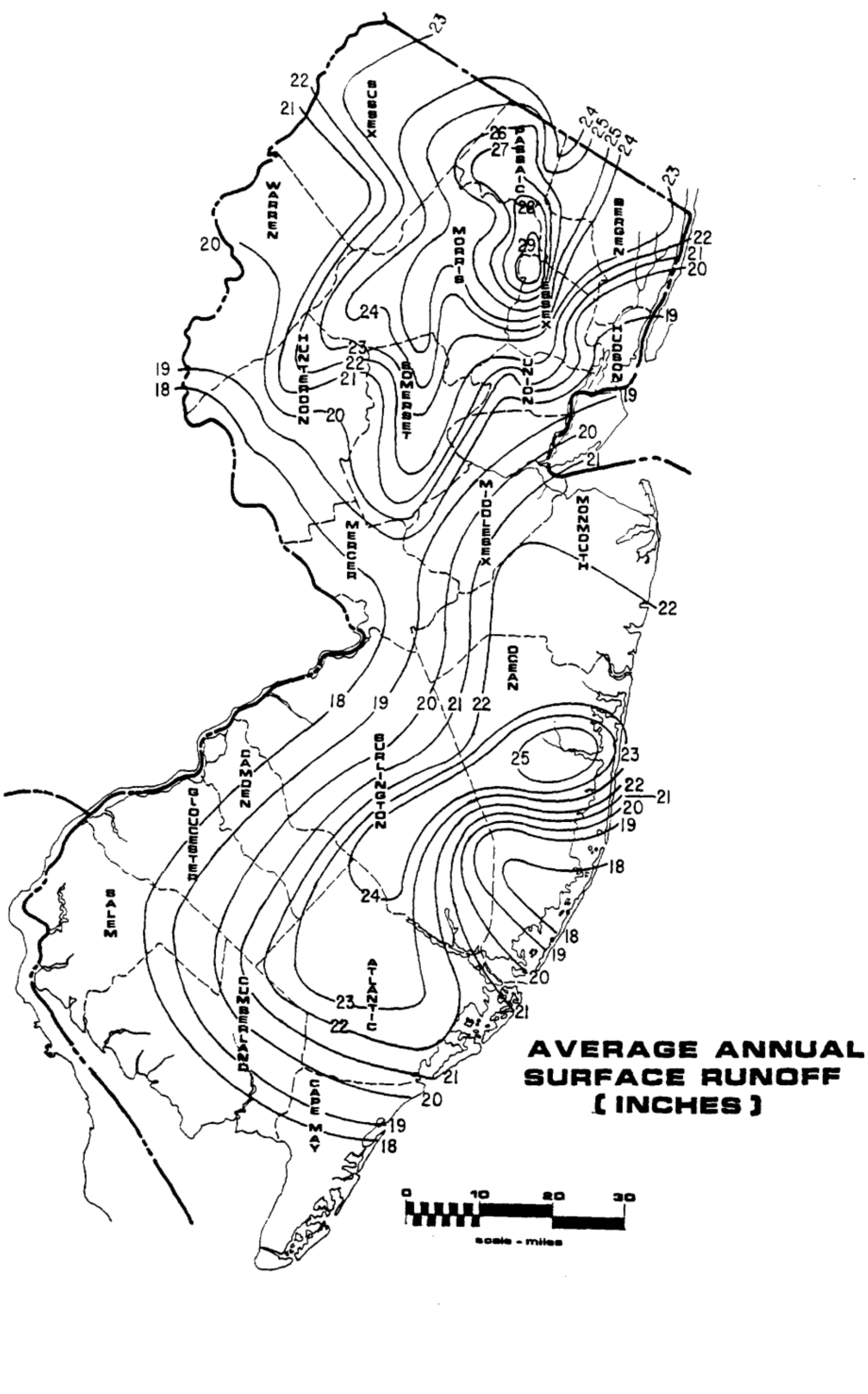
CURVE 24-1



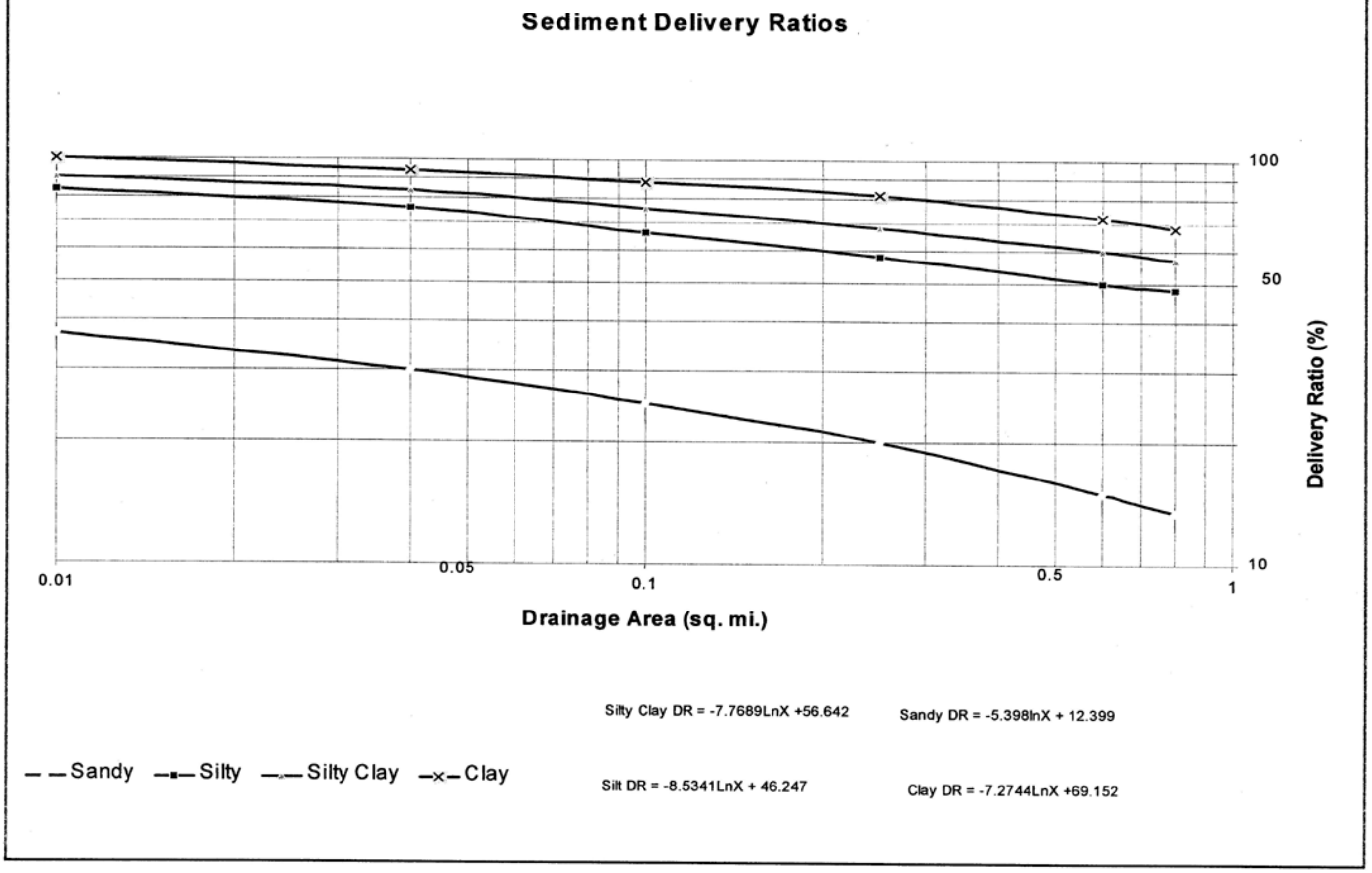
TRAP EFFICIENCY OF RESERVOIRS

Reference: Brune, Gunnar M., "Trap Efficiency of Reservoirs", Trans. AGU, Vol. 34, No.3, pp 407-418, June 1953.

FIGURE 24-1


AVERAGE ANNUAL
SURFACE RUNOFF
(INCHES)
SUSSEX
PASSAIC
WARREN
MORRIS
BERGEN
ESSEX
HUDSON
HUNTERDON
SOMERSET
UNION
MIDDLESEX
MONMOUTH
MERCER
OCEAN
BURLINGTON
CAMDEN
GLOUCESTER
SALEM
ATLANTIC
CUMBERLAND
CAPE MAY
0 10 20 30
scale - miles

Curve 24-2


Sediment Delivery Ratios
100
50
10
Delivery Ratio (%)
0.01
0.05
0.1
0.5
1
Drainage Area (sq. mi.)
Silty Clay DR = -7.7689LnX +56.642
Sandy DR = -5.398lnX + 12.399
Silt DR = -8.5341LnX + 46.247
Clay DR = -7.2744LnX +69.152
Sandy
Silty
Silty Clay
Clay

STANDARD
FOR
SLOPE PROTECTION STRUCTURES

Definition

Structures to safely conduct surface runoff from the top of a slope to the bottom of the slope.

Purpose

The purpose of this practice is to convey storm runoff safely down existing slopes and cut and fill slopes to minimize erosion.

Conditions Where Practice Applies

Slope protection structures are to be used where concentrated water will cause excessive erosion on existing and/or recent cut and fill slopes. Temporary structures shall be left in place until adequate vegetation and the permanent drainage system have been installed. Permanent structures are part of the drainage system.

Water Quality Enhancement

The primary benefit to water quality is through the prevention of steep slope erosion, by providing a means to safely convey stormwater runoff down to a stable area or condition. Total suspended solids discharged from the site, both during and after construction will be reduced.

Design Criteria

Open Flumes

Flumes shall be adequately designed to convey runoff water concentrations safely down steep slopes based on a 10 year frequency storm, the rational method for uniform drainage area up to one-half of a square mile, or sized in accordance with the requirements of Tables 25-1 and 25-2.

Protection against scour at the discharge end of the open flume shall be provided in the form of an energy dissipater or other measures such as an SAF, rock riprap revetment, or plunge pool.

Recommended dimensions for flumes are defined as follows:

1. b - is the bottom width of the paved down slope section of a trapezoidal or rectangular flume. The minimum bottom widths and associated maximum drainage areas shall conform to Table 25-1.

2. T - is the top width of parabolic flumes. The minimum top widths and maximum drainage areas shall conform to Table 25-2.

3. H - is the height of the dike at the entrance to the structure and shall be a minimum of 2.5 feet.
4. d - is the depth of the paved down slope section and shall be a minimum of 10 inches for trapezoidal or rectangular flumes. The depths of parabolic flumes shall be as shown in Table 25-2.
5. L - is the length of the inlet and outlet paved sections and each shall be a minimum of 6 feet.

The above dimensions are illustrated in Figure 25-1.

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 in Tables 25-1 and 25-2 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 area listed in Tables 25-1 and 25-2 may be increased by 25%.

Flumes with dimensions and associated drainage areas other than those shown in this standard shall be designed on an individual job basis. Capacities shall be determined by acceptable hydrologic and hydraulic computations, as noted under Pipe Drops of this Standard.

TABLE 25-1

FLUMES WITH TRAPEZOIDAL AND RECTANGULAR SECTIONS

Bottom Widths And Drainage Area For Trapezoidal Flumes With Flow Depths Equal to 10 Inches	
Bottom Width (feet)	Drainage Area (acres)
2	7
4	10
6	13
8	16
10	19
12	24

Bottom Widths And Drainage Area For Rectangular Flumes With Flow Depths Equal to 10 Inches	
Bottom Width (feet)	Drainage Area (acres)
2	3
4	5
6	10
8	13
10	16
12	20

Dikes to be 2.5 feet in height above flume entrance.

TABLE 25-2
FLUMES WITH PARABOLIC SECTIONS

Depths Equal to 1 Foot	
Top Width (feet)	Drainage Area (acres)
4	3
6	4
8	5
10	6
12	7
14	8

Depths Equal to 1.5 Feet	
Top Width (feet)	Drainage Area (acres)
4	4
6	5
8	5
10	7
12	8
14	10
16	11

Dikes to be 2.5 feet in height above flume entrance

Riprap Lined Chutes

Stable rock sizes and flow depths for riprap-lined channels having gradients between 2 percent and 40 percent may be determined using the following detailed design process from **Design of Rock Chutes** by Robinson, Rice, and Kadavy.

For channel slopes between 2% and 10%:

$$D_{50} = [q\ (S)^{1.5}/4.75(10)^{-3}]^{1/1.89}$$

For channel slopes between 10% and 40%:

$$D_{50} = [q\ (S)^{0.58}/3.93(10)^{-2}]^{1/1.89}$$

$$z = [n(q\ )/1.486(S)^{0.50}]^{3/5}$$

where $n = 0.047(D_{50}S)^{0.147}$

D_{50} = Particle (stone) size for which 50% of the sample is finer, in.

S = Bed slope, ft./ft.

z = Flow depth, ft.

q = Unit discharge, ft^3/s/ft

(Total discharge÷Bottom width)

Except for short transition sections, flow in the range of 0.7 to 1.3 of the critical slope must be avoided unless the channel is straight. Velocities exceeding critical velocity shall be restricted to straight reaches. Maximum channel side slope shall not exceed 2:1 for this method.

Pipe Drops

The design capacity shall be as required to pass peak runoff from a 10-year frequency storm.

Peak discharge values shall be determined by the following:

1. Rational Method - for peak discharge of uniform drainage areas as outlined in Technical Manual for Land Use Regulation Program, Bureau of Inland and Coastal Regulations Stream Encroachment Permits, Trenton, N.J. September 1997 or subsequent editions

2. USDA-NRCS Win TR-55 or Win TR-20

3. U.S. Army Corps of Engineers HEC HMS

4. Other methods which produce similar results to the models listed above.

Pipe capacities may be determined from charts in Appendix 11, Chapter 6, Ref. (1), or other accepted sources.

A hood inlet type entrance should be used as shown in Figure 25-2. The pipe drop inlet shall be protected by riprap or concrete.

Outlet protection shall be provided by riprap or other means. Diversion dikes or deep curb cuts shall be used in conjunction with pipe drops. The dike height above the pipe inlet invert shall be adequate to contain a water elevation sufficient to cause full pipe flow plus an allowance of at least 0.5 feet for freeboard. A minimum water depth of 1.8 times the pipe diameter above pipe inlet invert is required to assure full pipe flow.

Installation Requirements

1. The structure shall be placed on undisturbed soil or well-compacted fill.

2. The cut or fill slope shall not be steeper than 1 vertical to 1.5 horizontal (1.5:1) and should not be flatter than 20:1.

3. Adequate vegetative protection per vegetation standards and drainage works shall be installed.

4. Open Flume

   a. The top of the earth dikes shall not be lower at any point than the top of the lining at the entrance of the structure.

   b. The lining should be placed beginning at the lower end and proceeding up the slope to the upper end. The lining shall be well compacted and free of voids.

   c. The entrance floor at the upper end of the structure shall have a slope toward the outlet of ¼ to ½ inch per foot.

5. Hood Inlet Pipe Drops

   a. The pipe shall be imbedded in the embankment to a depth that will insure stability.

   b. Protection measures of concrete or riprap shall be installed at the inlet and outlet as needed to protect against erosion.

   c. The pipe may be smooth or corrugated and shall be of the required strength and durability.

   d. Backfill shall be carefully placed in layers and tamped to insure adequate compaction.

6. Outlet Protection in accordance with the Conduit Outlet Protection Standard, pg. 12-1.

Unconcentrated surface runoff from paved surfaces

A permanent vegetative cover shall be established through seeding or pegged (anchored) sod on all slopes receiving unconcentrated runoff from paved surfaces. Seeded slopes shall utilize a non-biodegradeable turf reinforcement matting, installed in accordance with manufacturers instructions.

Slopes receiving unconcentrated surface flows shall not exceed those shown in the NJDEP Best Management Practices Manual, Chapter 9.10, Table 9.10-2 (reproduced below). An optional stone trench installed along the edge of pavement may be added to aid in the prevention of flow concentration. Maximum contributing drainage areas shall be as defined in Chapter 9.10 of the Manual.

For receiving **slopes that exceed** the thresholds designated in Table 9.10-2 of the BMP Manual, a properly designed slope protection structure must be provided in accordance with this Standard.

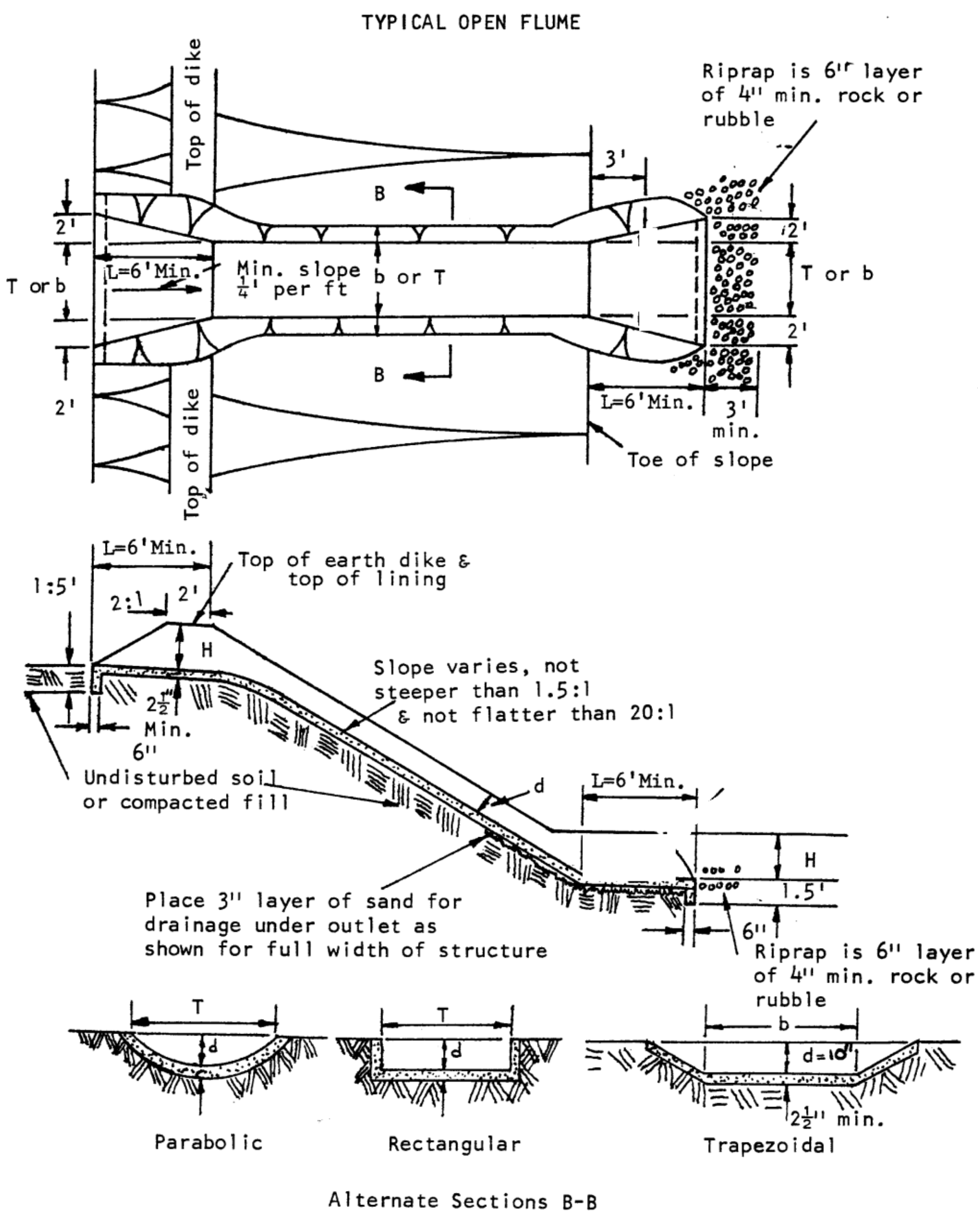
For receiving slopes with **contributing drainage areas that exceed** the thresholds defined in Chapter 9.10 of the BMP Manual, a properly designed slope protection structure must be provided in accordance with this Standard

If flows are to be directed and controlled via curb cuts, scuppers or other methods which will result in the concentration of flows., then a properly designed slope protection structure must be provided in accordance with this Standard.

Maximum slopes for unconcentrated flows from paved surfaces
(reproduced from NJDEP BMP Manual Table 9.10-2)

Soil type	Maximum Slope (percent)
Sand	7
Sandy Loam	8
Loam, Silt Loam	8
Sandy Clay Loam	8
Clay Loam, Silty Clay, Clay	8

Figure 25-1



Notes:

1. Lining shall be Portland Cement concrete, bituminous concrete or comparable material, reinforced where necessary.
2. Some type of energy dissipater, such as the one shown above, must be used to prevent erosion at the outlet.
3. The paved down slope section should have side slopes as required by construction methods.
4. The Standard for Conduit Outlet Protection 4.14 shall also apply.

FIGURE 25-2

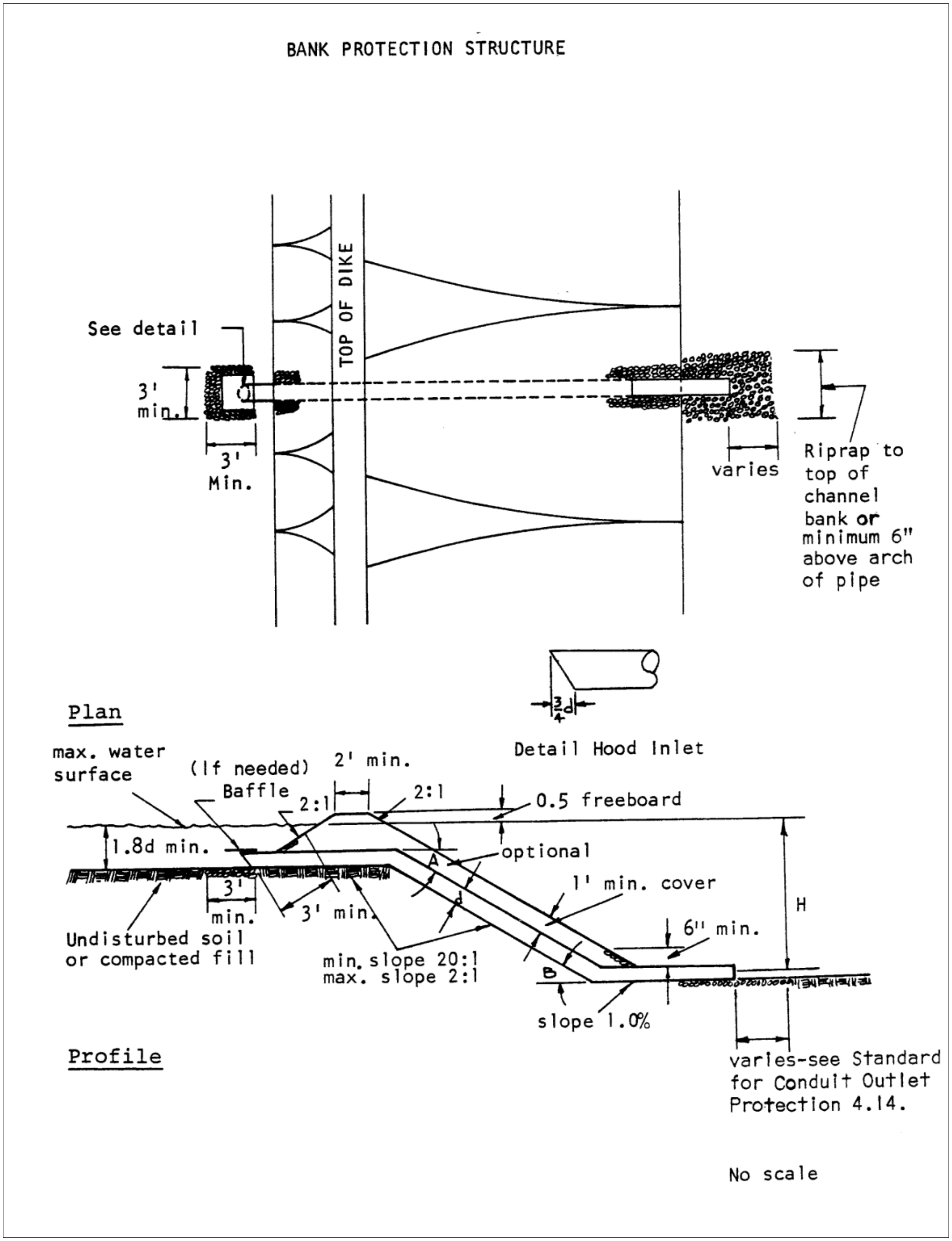
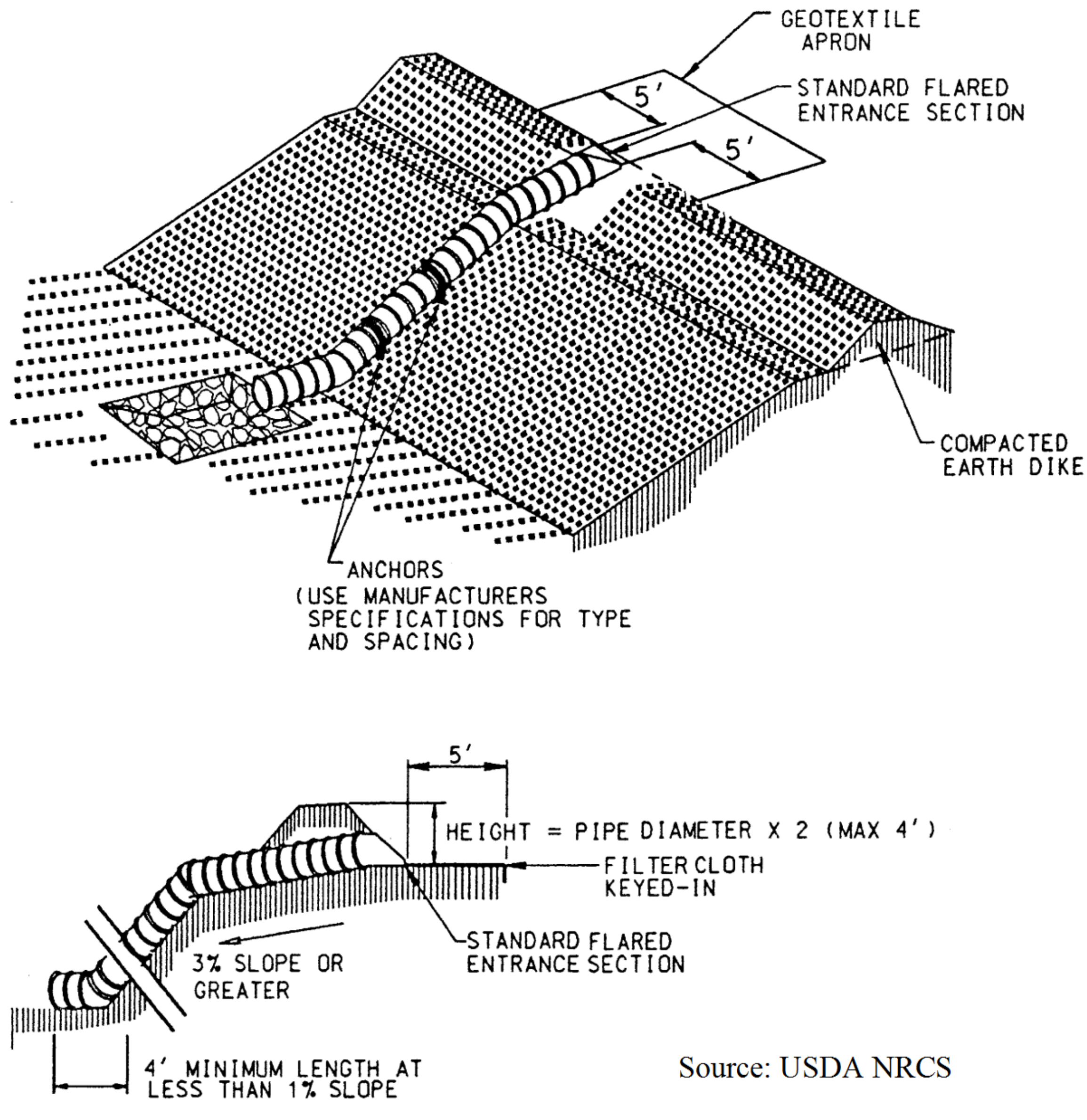

BANK PROTECTION STRUCTURE
TOP OF DIKE
See detail
3' min.
3' Min.
varies
Riprap to top of channel bank or minimum 6" above arch of pipe
Plan
$\frac{3}{4}$d
Detail Hood Inlet
max. water surface
(If needed) Baffle
2' min.
2:1
2:1
0.5 freeboard
1.8d min.
optional
A
1' min. cover
3' min.
3' min.
H
6" min.
Undisturbed soil or compacted fill
min. slope 20:1
max. slope 2:1
B
slope 1.0%
Profile
varies-see Standard for Conduit Outlet Protection 4.14.
No scale

Figure 25-3: Pipe Slope Drain



Source: USDA NRCS

STANDARD FOR SOIL BIOENGINEERING

Definition

The use of live, woody and herbaceous plants to repair slope failures and to increase slope stability. Living plant material may be used alone or in combination with structural components such as rock, wood, concrete, or geotextiles.

Purpose

To integrate structural and vegetative techniques to stabilize or protect banks of streams, lakes, shorelines, excavated channels and upland slopes; to prevent the loss of land or damage to facilities adjacent to the banks; to maintain the capacity of the channel; to reduce sediment loads causing downstream damages and/or pollution; and to protect and enhance water quality.

Conditions Where Practices Applies

Soil bioengineering techniques are generally appropriate for treatment of slopes, eroded stream banks, surface erosion, shallow mass wasting, cut and fill slope stabilization, earth embankment protection (other than dams), and small gully repair. **They are not to be considered when public safety is at risk** such as when substantial mechanical and or structural designs are required.

Descriptions of methods for installing individual Soil Bioengineering systems may be found in USDA Natural Resources Conservation Service Engineering Field Handbook (EFH), **Chapter 16** (Streambank and Shoreline Protection) and **Chapter 18** (Upland slope Protection).

Water Quality Enhancement

The use of vegetative techniques to stabilize stream banks, upland slopes and open shorelines provides long term erosion control as well as contributing to water quality through uptake of nutrients, moderation of water temperature and protection of dissolved oxygen content (in surface waters).

DESIGN CRITERIA

1. PLANNING

Flow Chart No. 26-1 (Soil Bioengineering Application Decision Chart) shall be used to determine if Soil Bioengineering Techniques alone are appropriate for correcting existing erosion problems or for preventing future erosion of shorelines, upland slopes or stream channels. Bioengineering techniques may be used singularly or in combination with one another or in combination with other erosion control techniques, such as rip rap bank protection.

The following conditions must be evaluated to help ensure a proper soil bioengineering design:

- Soil type and moisture availability
- Stream bed stability
- Slope stability
- Surface runoff (diversion may be necessary to ensure success - see Standard for Diversions, pg. 15-1)

- Availability of bioengineering materials
- Effects of mature vegetation on stream hydraulics, including up and downstream of the treatment area
- Time of year for installation (installation of all woody vegetation shall be performed during the dormant season only)
- Cause of the loss of existing vegetation (ice damage, livestock damage, fire invasive species etc.)

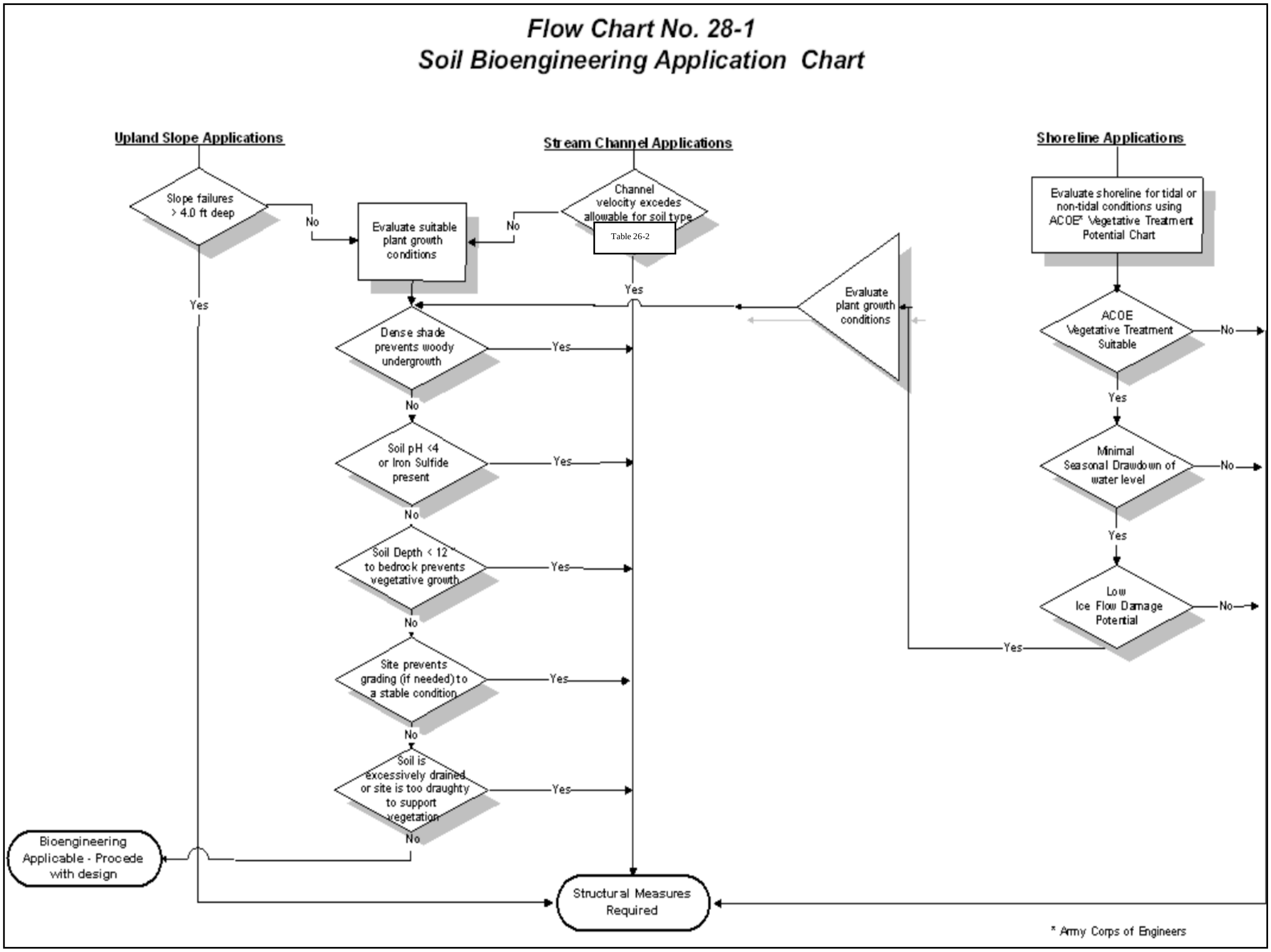
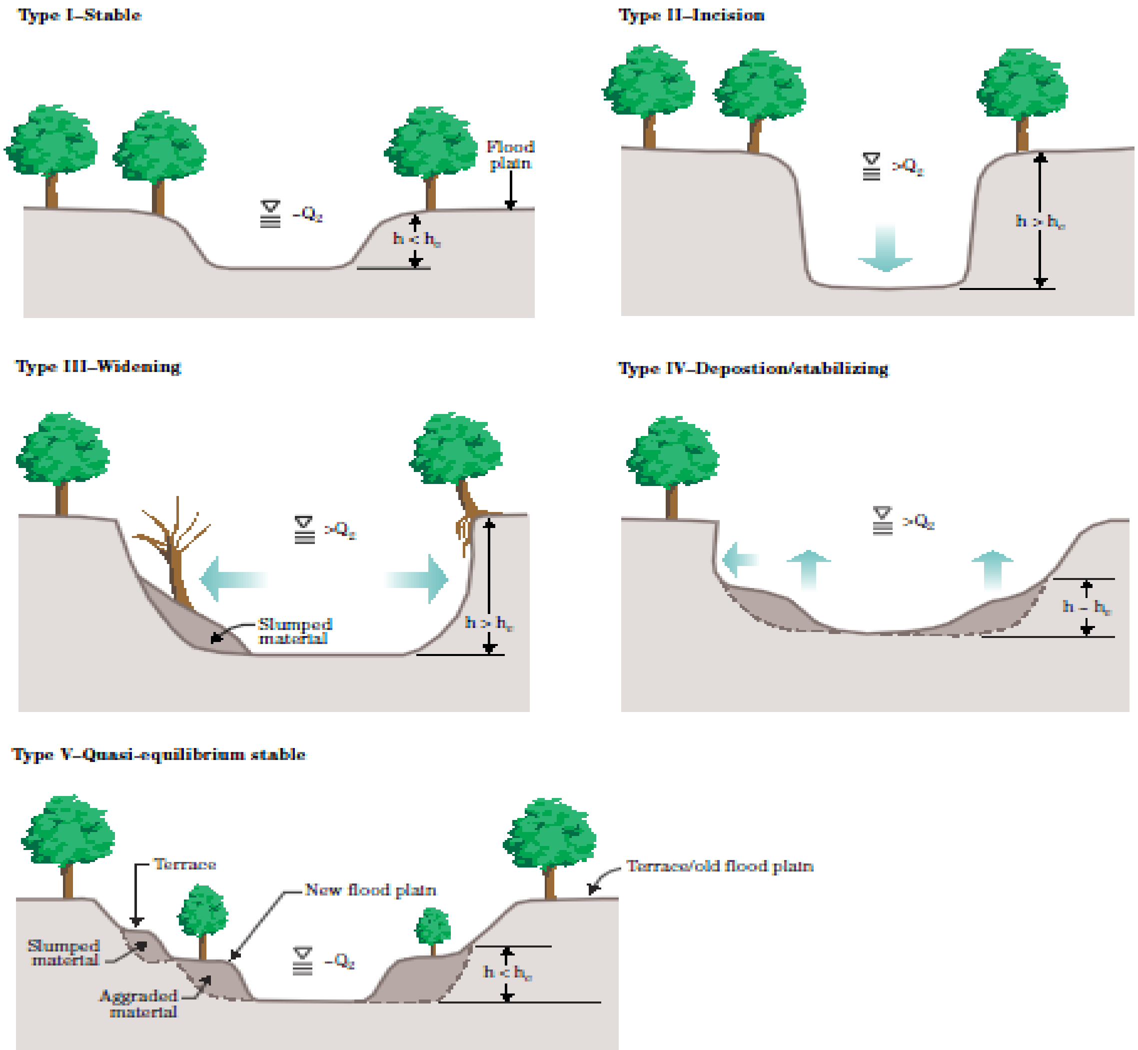


Figure 26-1 – Simplified Channel Evolution Model

Figure 3–4a Schumm, Harvey, and Watson (1981) schematic cross sections and longitudinal profile of an incised stream showing features of the five classes of the CEM



3–20 (210–VI–NEH, August 2007)

2. ENGINEERING

Grading

Steep, unstable slopes and deep undercuts in banks may require extensive grading to achieve a stable slope or will require structural measures, (such as crib walls, riprap, or wire-mesh baskets), or redirective measures within the channel (such as weirs or vanes) . For planting purposes only, the steepest acceptable slope is 1.5 horizontal to 1.0 vertical. Slope stability analysis or design shall be subject to municipal, county and state regulations. All newly graded banks shall be protected from overbank flow in accordance with the Standard for Diversions, pg. 15-1., Grade Stabilization, pg. 17-1 or Slope Protection, pg. 27-1 as appropriate.

Channel Realignment

The realignment of channels (change in location or cross-sectional geometry) shall be kept to an absolute minimum unless realignment is part of an overall stream restoration plan and is the subject of the soil erosion and sediment control plan.

Channel Capacity

Peak discharge and/or hydrographs for capacity shall be determined by the following methods:

1. Rational Method - for peak discharge of uniform drainage areas as outlined in Technical Manual for Land Use Regulation Program, Bureau of Inland and Coastal Regulations Stream Encroachment Permits, Trenton, N.J. September 1997 or subsequent editions

2. NRCS Win TR-55 or Win TR-20

3. U.S. Army Corps of Engineers HEC HMS

4. Other methods which produce similar results to the models listed above.

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Hydraulic Requirements

Manning's formula (where appropriate) or a water surface profile analysis shall be used to determine the velocities in the channels. Resistance (Manning's "n") values shall be estimated using Table 26-1. Site specific n values may be used if verified by USGS stream gage data or by a hydrologic and hydraulic analysis approved by the local district.

Design storm requirements for stability analysis shall be in accordance with the Standard for Channel Stabilization, pg. 11-1. Aged condition shall analyze capacity at vegetative maturity.

Table 26-1 - Estimating Manning's "n" for Soil Bioengineering practices

Bioengineering System	Manning's "n" values*	
	Installation condition (stability)	**Mature condition (capacity)**
Conventional vegetation (use of the retardance method is required for designing grass lining)	0.025	0.055
Live Staking Live Facines (wattling bundles) Branchpacking Brushmattress Live Cribwall (similar to wire-mesh baskets in hydraulic effects)	0.025	0.1
Joint Planting	see riprap standard	see riprap standard

* Does not consider channel alignment, obstructions etc. Based on non-gravel soils. See Appendix 8, supplement "A" for additional guidance for selecting "n" values

Maximum allowable velocities for bankfull and out of bank discharges (fig. 26-2) shall be based on allowable soil velocities found in Table 26-2. These velocities are based on the use of an acceptable erosion control matting in conjunction with the bioengineering system. Every reach shall be individually designed unless all reaches are designed for the worst cases for velocity and capacity (lowest allowable velocity, steepest slope). **Bioengineering designs must begin and end in a stable channel section**. Design procedures may be evaluated according to channel conditions represented in Table 26-3, below.

Table 26-2 - Maximum Allowable Velocities for Bioengineering

Soil Texture	Velocity (fps) with matting [1]
Sand	2
Silt loam, sandy loam, loamy sand, loam and muck	5
Silty clay loam, sandy clay loam	5.5
Clay, clay loam, sandy clay, silty clay	6

1. All Soil Bioengineering Application designs shall incorporate a an erosion control blanket or flexible channel liner over seeded areas and shall be integrated into the measure in accordance with USDA EFH Chapters 16 and/or 18. The flexible channel liner shall be selected based on the design requirements for the planned bioengineering application.

Figure 26-2: Terminology in Channel Flow Descriptions

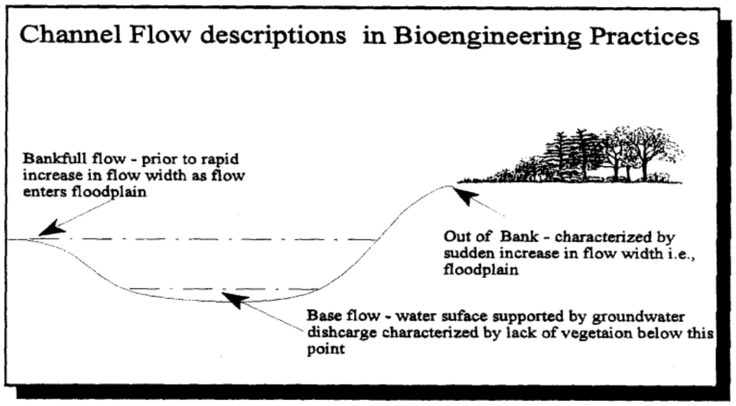
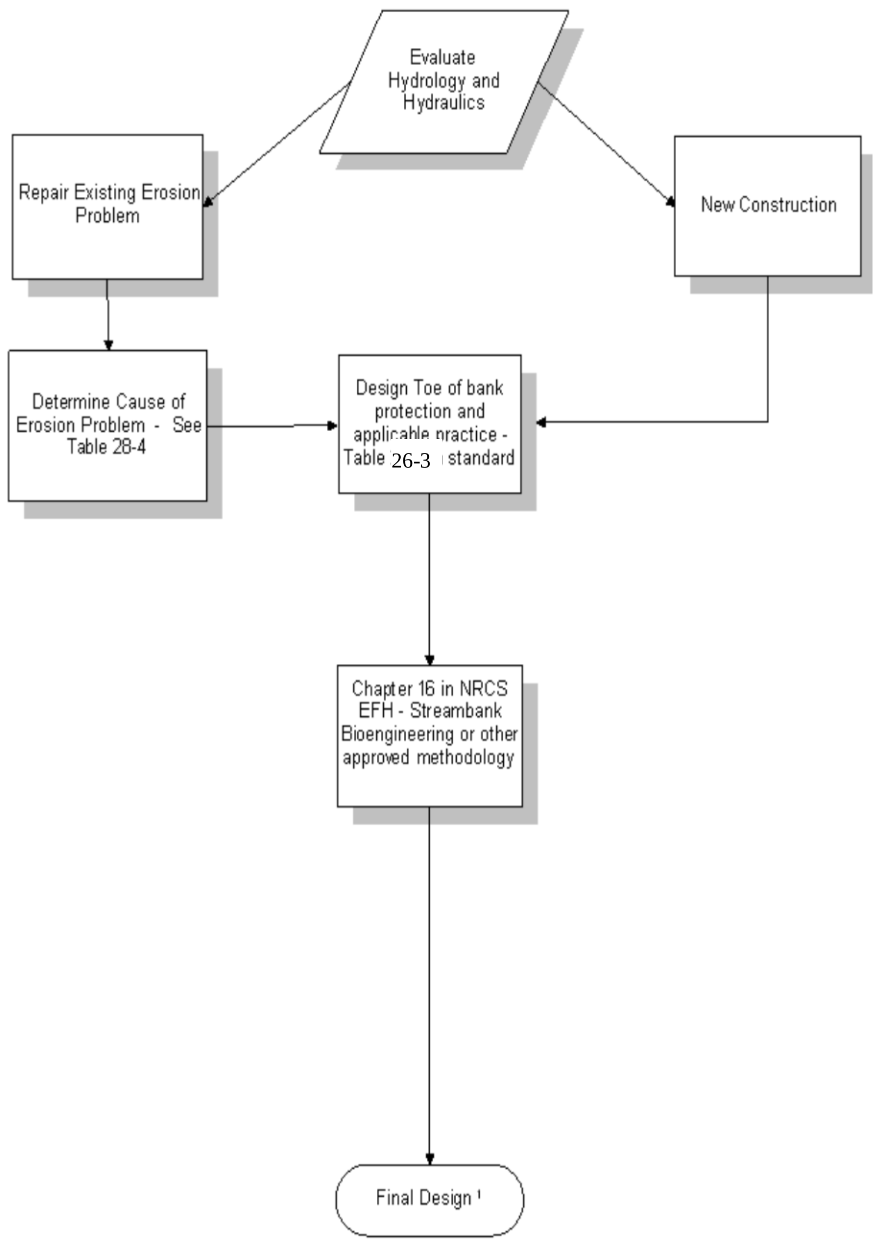


Table 26-3 – Design Approach based on Channel Boundary Conditions

Channel Boundary Condition	Design Consideration Approach
Significant sediment load and moveable channel boundaries	Alluvial channel design techniques
Boundary material smaller than sand size	Allowable Velocity
Boundary material larger than sand size	Allowable shear stress
Boundary material does not act as discrete particles	Tractive Power
No base flow in channel. Climate can support permanent vegetation	Grass lined (retardance) / tractive stress

Toe Protection at Base Flow Elevation - Toe protection is to be provided on all streambank stabilization projects. Methods of providing toe protection may consist of a fiber roll revetment (coir log) adequately anchored or a structural revetment such as rock rip rap. Fiber roll revetments have a design life of 5 years and are suitable for sites where there is a high probability that vegetation, once established, will be adequate for stabilizing the toe zone. In general, this will be in lower velocity channels where adjacent reaches indicate vegetation alone will be adequate. Riprap for toe protection shall be designed using the bankfull or design discharge velocity using procedures in the Standard for Riprap, pg. 22-1

Flow Chart No. 26-2
Soil Bioengineering In-Stream Design Chart



1 - Final design may need to include diversion of overland flows from slopes

Flow Chart No. 26-2 (Soil Bioengineering In-Stream Design Chart) shall be followed for stream channel designs.

Table 26-3 - Summary of Streambank /Upland Slope Bioengineering Protection Measures

System Type	**Zone of Application**[1] - Base Flow - Base to Top - Out of Bank	**Types of erosion problems for which the system is suitable**	**Comments and Restrictions**
Live stake	Base to Top Out of Bank	bank scour, overbank runoff	suitable for small, simple erosion problems when used in conjunction with other systems.
Live fascine	Base to Top, Out of Bank	general bank scour-, overbank runoff	useful for moderate to severe erosion-, should not be used on bank faces longer than 15 ft, after sloping.
Branchpacking	Base to Top, Out of Bank	local bank scour, gullies eroded by overbank runoff	restricted to repair of small sites(maximum depth = 4.0 ft.)
Vegetated Geogrid	All Zones	toe erosion, local bank scour	useful on steep slopes (up to 0.5H: IV) where space is limited/generally restricted to heights not exceeding 6 ft. overall
Live cribwall	All Zones	local bank scour, toe erosion (requires structural toe protection)	
Joint planting	Base to Top, Out of Bank	see riprap standard	see riprap standard
Brushmattress	Base to Top, Out of Bank	local and general bank scour; debris gouging	generally used on 3H: 1V graded slopes restricted to sites of 50 linear feet or less
Conventional vegetation	Base to Top, Out of Bank	general & local bank scour	See Table 26-2 for velocity restrictions
Tree revetment	Base to Top	general bank scour	Provides temporary protection, susceptible to damage by flooding debris and beavers
Riprap (incl. wire-mesh baskets)	All Zones	local & general bank scour, toe erosion	All headcutting and general bed degradation by erosion must have armored protection
Coir (coconut fiber) Logs	Base, Base to Top	toe erosion	Must be 2/3 submerged in water to be an effective rooting medium.

1. See Figure 26-1 for description of zones.

3. VEGETATION

Plant materials will be live, viable woody or herbaceous vegetation. The plant materials will be obtained from commercial sources or in the case of woody cuttings, may be harvested from native stands during the dormant period. (November-April).

Plant Adaptation Zones

Base Flow Zone (Toe Zone) - Too wet to grow vegetation or where side slopes meet channel bottom (intermittent streams). Select vegetation which develops an extensive root system and tolerates extended saturation. This includes Obligate and Facultative Wet herbaceous and woody plants.

Above Base flow to top of bank or 2 year storm elevation (Bank Zone) - Area between level of base flow and top of bank or 2 year storm elevation. Select vegetation which tolerates wetting and drying soils. This includes Facultative and some Facultative Wet grasses, forbs and shrubs.

Out of bank. (Terrace Zone**)** - Select vegetation which tolerates droughty conditions. This may include some Facultative and most Facultative Upland plants.

A. **Plant Material Specifications**

* Rooted seedlings - Plants shall be at least 12" long. The root system shall have approximately the mass equal to the top portion.

* Unrooted cuttings - Cuttings shall be 8"-12" in length and 1/4" - ½" in diameter.

* Live Stake - cuttings shall be 2.0' to 3.0' in length and ½" to 2.0" in diameter

* Live brush - Live brush will consist of the whole above ground portion of willow, redosier dogwood, or other hardwood species which root easily from cuttings. Plants shall be 4 to 8 feet in height and free of disease. When there is a shortage of live, dormant brush, up to 30% of nonrooting species may be mixed randomly with the rooting species. Brush will be cut by shears or saw, not by ax.

* Herbaceous plants - Grasses, sedges, and rushes shall be provided in multiple-culmed pots having a minimum of two stems per pot. Stems shall have a minimum length of 6".

B. Plant Selection - See Table 26-5 for specific species adaptations.

1. Herbaceous plant materials to be used in the coir fiber rolls shall consist of a mixture of the following:

Asclepias incarnate - Swamp milkweed
Acorns calamus/americanus - Sweet Flag
Calamagrostis spp. - Bluejoint reedgrass
Carex spp. - Sedges
Cinna arundinacea - Wood reedgrass
Distichlis spicata - Seashore saltqrass
Eupatorium purpureum - Joe-Pye weed
Glyceria spp. - Mannagrasses
Iris versicolor - Blueflag iris
Juncus spp. - Rushes
Lobelia cardinalis - Cardinal flower
Pontederia cordata - Pickerel Weed
Sagittaria latifolia - Duckpotato
Scirpus spp. - Bulrushes
Sparganium spp. - BurreedSpartina spp. - CordgrassesTypha spp. - cattails

2. Woody plants shall consist of bareroot plants or unrooted cuttings and stems (whips) of hardwood shrub species which root easily. The plant materials may come from nursery sources or existing local stands, or a combination of the two. Plant Materials suitable for use as rooted or unrooted cuttings include:

Cephalanthus accidentalis - buttonbush
Baccharis halimifolia - groundselbus
Cornus amomum - silky dogwood
Cornus serecia - redosier dogwood
Salix purpurea - "Streamcol purpleosier willow"
Salix cottetii -"Bankers" dwarf willow
Salix exigua - sandbar willow
Salix discolor - pussy willow
Sambucus canadensis - elderberry
Viburnum dentatum - southern arrowwood
Viburnum lentago - nannyberry
Viburnum prunifolium - blackhaw viburnum

c. Plant Materials suitable for use only as bareroot or containerized plants include:

Alnus rugosa - speckled alder
Alnus serrulata - smooth alder spp.
Amorpha fruitcosa - indigobush
Aronia arbutifolia - red chokecherry
Clethra alnifolia - sweet pepperbush
Cornus racemosa - gray dogwood
Ilex verticulata - winterberry holly
Lindera benzoin - spicebush
Physocarpus opulifolius - ninebark
Prunus pumila var. depressa - dwarf sand cherry
Rhododendron viscosum - swamp azalea
Rosa palustris - swamp rose
Spirea tomantosa - steeplebush

d. Supplemental Grass Mixtures

Grass species suitable for stabilizing disturbed areas that are somewhat poorly to poorly drained are:

SPECIES	COMMON NAME	REMARKS[1]
Agrostis alba	Redtop	SP,I,CG
Agrostis palustris	Creeping bentgrass	P,I,CG
Andropogon glomeratus	Lowland broom sedge	P,N,WG
Dicanthelium clandestinum	Deertongue	P,N,WG
Echinochloa cruagaiii	Japanese millet	A,T,WG
Elymus virginicus	Wild rye	P,N,CG
Lolium perenne[2]	Perennial ryegrass	SP,I,CG
Lotus corniculatus [3,4]	Birdsfoot trefoil	P,I,CL
Pani virgatum	Switchgrass	P,N,WG
Poa trivialis	Rough bluegrass	P,I,CG
Trifolum repens [4]	White/Ladino clover	SP,I,CL

1. P - perennial
   A - annual
   I - introduced
   N - native
   CG - Cool-season grass
   WG - warm season grass
   CL - Cool-season legume
   SP - Short-lived perennial

2. Perennial ryegrass may be substituted for redtop in all mixes except Mix # 7.

3. Birdsfoot trefoil is not well adapted to the coastal plain. Use only in northern and central Jersey.

4. Need specific legume inoculant.
   Note: Warm-season grass seeding rates are based on Pure Live Seed (PLS)

Suitable seeding mixtures and recommended seeding rates for various site conditions:

Seed Mix 1:
Cool-season mix suitable for shady sites.

*	Redtop	1/lbs./ac.
*	Hard fescue	40 lbs./ac.
*	Rough bluegrass	15 lbs./ac.

Seed Mix 2:
Warm-season mixture suitable for highly acid soils. Provides excellent wildlife value.

*	Blackwell switchgrass	15 lbs./ac. PLS
*	Tioga deertongue	10 lbs./ac. PLS
*	Japanese millet (nurse)	8 lbs./ac. PLS

Seed Mix 3:
All native mixture suitable for somewhat acid soils. Provides good to excellent wildlife value.

* Blackwell switchgrass and/or	10 lbs./ac.PLS
* Broomsedge	12 lb&./ac. PLS
* Tioga deertonque	5 lbs./ac. PLS
* Wild rye	5 lbs./ac.PLS

Use a nurse crop such as oats or rye.

Seed Mix 4:
Turfgrass mixture suitable for moist, shady areas.

* Rough bluegrass	25 lbs./ac.
* Perennial ryegrass	15 lbs./ac.
* Creeping bentgrass	10 lbs./ac.

Optional:

*White clover or	5 lbs./ac.
*Birdsfoot trefoil	8 lbs./ac.

Seed Mix 5:
Mixture for providing quick, semi-permanent cover in areas where natural succession is encouraged. Excellent wildlife value.

* Redtop	2 lbs./ac.
* Japanese millet	8 lbs./ac.
* White/Ladino clover	5 lbs./ac.

Seed Mix 6:
Shotgun mix (for those extremely complex sites)

*Tioga deertongue	15lbs./ac. PLS
*Redtop or	3lbs./ac.PLS
*Perennial ryegrass	5lb/./ac.PLS
*Wild rye	10lbs./ac.PLS
*Switchgrass	8lbs./ac. PLS
*Broomsedge	12lbs./ac. PLS

Wildflowers tolerant of wet conditions:

* Aqailega canadensis - Eastern Columbine
* Chrysanthemum leucanthemum - Ox-eye Daisy
* Hesperis 'matronalis - Dame's Rocket
* Lupinus perennis - Perennial Lupine
* Myostis sylvatica - Forget-Me-Not
* Rudbeckia hirta - (Golden Jubilee) Black-eyed Susan

Table 26-4: Types of Erosion And Causes of Erosion

Type of Erosion	**Causes**
Toe erosion and upper bank failure	Removal of unconsolidated or noncohesive lower materials, especially bank failure along outside bends. Widespread toe erosion may be associated with bed lowering.
General bed degradation (Bed scour over extended channelization, reaches)	Changes in stream gradient due to factors such as lowering of stream base level due to lake or tailwater fluctuations, stream or stream relocation. Increased stream discharge due to flow diversion or watershed changes such as urbanization.
Headcutting	In streams undergoing bed degradation, headcuts often develop at locations where more resistant materials outcrop in the stream channel. Headcuts may develop at a stream mouth when base level is lowered suddenly due to dredging, erosion or draining of a lake.
Middle and upper general bank scour	Increased discharge resulting from watershed changes; increased flow velocities caused by reduction in channel roughness or increased gradients; removal or loss of bank vegetation.
Local streambank scour	Scour of local lenses or deposits of unconsolidated material, erosion by secondary currents caused by flow obstructions and channel irregularities, loss of bank vegetation.
Local bed scour	Local bed scour may be caused by channel constrictions, flow obstructions such as debris dams or flow deflectors, or trapping of sediment in reservoirs or sediment traps. Some scour generally occurs below culverts.
Piping	Piping develops when fines are removed by water flowing laterally under the surface. Extensive pipe development requires 1) rapid infiltration, 2) steep hydraulic gradients, and 3) *zones of* concentrated flow. Piping may occur in stratified soils where vertical movement is restricted by sudden reduction in hydraulic conductivity between strata or where poorly compacted soil around buried pipes provides conduits for water movement.
Overbank runoff	Failure to provide adequate means of directing concentrated flows from overbank areas into the channel.

Table 26-5: Shrubs suitable for Soil Bioengineering Systems

Species	Habitat [1]	Bank Zone [2]	Root Form [3]	Shade [4] Tolerance	Flood [5] Tolerance	pH range [6]	Comments
Alnus serrulata **Smooth alder**	nontidal	toe	rooted	medium	regular	5.5-7.5	Nitrogen fixer weak wooded
Amorpha fruitcosa **False indigo**	tidal fresh moist woods	lower-mid	rooted	low	seasonal	6.0-8.5	Req. full sun Drought tolerant
Aronia arbutifolia **Red chokeberry**	nontidal	lower-mid	rooted	medium	irregular seasonal	5.1-6.5	Drought tolerant
Aronia melanocarpa **Black chokeberry**	nontidal	mid-upper	rooted	low	irregular seasonal	5.1-6.5	Drought tolerant
Baccharis halimifolia **Groundsel bush**	tidal tidal fresh	mid-upper	rooted, unrooted	high	seasonal	7.0-8.5	M/F separate plants
Cephalanthus occidentalis **Buttonbush**	nontidal tidal fresh	toe	rooted unrooted	high	permanent	6.1-8.5	Tolerates brief drought
Celthra alnifolia **Sweet pepperbush**	tidal nontidal	mid-upper	rooted	high	seasonal	4.5-6.5	
Cornus amomum **Silky dogwood**	streambankspond edges	lower-mid	rooted unrooted	medium	seasonal	5.5-8.5	Drought tolerant
Cornus racemosa **Gray dogwood**	streambanks pond edges	lower-mid	rooted unrooted	high	seasonal	5.5-8.5	Drought tolerant
Cornus serecia **Redosier dogwood**	streambanks pond edges	toe-mid	rooted unrooted	medium	seasonal	5.5-8.5	Drought tolerant
Ilex decidua **Possumhaw**	forested wetlands pond edges	lower-mid	rooted unrooted	high	irregular	4.0-6.0	M/F separate plants
Ilex glabra **Inkberry**	forested wetlands sandy woods	mid-upper	rooted	high	irregular inundation	4.5-6.0	M/F separate plants. Resists salt spray
Ilex verticulata **Winterberry holly**	tidal fresh forested wetland	lower-mid	rooted	high	seasonal	4.5-8.0	Drought tolerant
Itea virginica **Virginia sweetspire**	forested wetland streambanks	toe	rooted	high	regular	5.0-7.0	Tolerates some salt
Iva frutescens **Hightide bush**	tidal brackish	lower	rooted	low	regular	6.0-7.5	Tolerates 15ppt salt
Leucothe racemosa **Leucothe**	forested wetland moist woods	lower mid	rooted	high	regular	5.0-6.0	Tolerates some dry-down
Lindera benzoin **Spicebush**	seasonal wetlands floodplain	lower-mid	rooted	high	seasonal	4.5-6.5	Tolerates some drought

Table 26-5: Shrubs suitable for Soil Bioengineering Systems

Species	Habitat [1]	Bank Zone [2]	Root Form [3]	Shade [4] Tolerance	Flood [5] Tolerance	pH range [6]	Comments
Lyonia ligustrina **Maleberry**	open woods	lower-mid	rooted	low	seasonal	4.0-6.0	Acid tolerant
Magnolia virginiana **Sweetbay magnolia**	stream borders forested wetlands	lower-mid	rooted	high	irregular/ seasonal	4.0-6.5	Tolerates infreq. flooding by salt
Myrica cerifera **Wax myrtle**	tidal fresh brackish swales	mid-upper	rooted	high	regular	4.0-6.0	tolerates 10 ppt salt. N-fixing
Myrica pennsylvanica **Bayberry**	tidal fresh brackish nontidal	mid-upper	rooted	high	irregular-seasonal	5.0-6.5	Tolerates drought. N-fixer
Physocarpus opulifolius **Ninebark**	streamsides wood edges	low-mid	rooted	medium	seasonal		
Prunus pumila var. depressa **Dwarf sand cherry**	streamsides sandbars	mid-upper	rooted	low	irregular	6.5-8.5	Native to Del. River. Groundcover
Rhododendron viscosum **Swamp azalea**	forested wetlands	toe-low	rooted	medium	seasonal-regular	4.0-6.0	susceptible to disease
Rosa palustris **Swamp rose**	tidal fresh forested wetland streambank	toe-low	rooted	low	seasonal-regular		
Rhus typhina/glabra **Staghorn/Smooth sumac**	disturbed banks/dry sites	upper	rooted	low	irregular	6.1-7.0	tolerates some drought
Salix X cottetii **'Bankers' Dwarf willow**	streambank	toe-mid	unrooted rooted	medium	regular-permanent		introduced male hybrid. noninvasive
Salix discolor **Pussy willow**	streambank forested wetland	toe-mid	unrooted rooted	medium	regular-permanent	6.6-7.5	
Salix exigua **Sandbar willow**	streambank sandbars	toe	unrooted rooted	low	regular-permanent		
Salix purpurea **'Streamco' purpleosier** willow	streambank	toe-upper	unrooted rooted	medium	regular-permanent	6.0-7.0	introduced noninvasive shrub
Sambucus canadensis **Elderber**ry	tidal fresh nontidal wet meadow	low-mid	rooted-unrooted	high	irregular-seasonal	6.0-8.0	some salt tolerance tolerates drought
Spirea alba/tomentosa **Meadowsweet**	forested wetland	mid-upper	rooted	low	irregular	5.1-6.0	
Viburnum dentatum **Southern arrowwood**	tidal fresh nontidal forested wetland	mid-upper	rooted unrooted	medium	seasonal	5.1-7.0	tolerates drought

Table 26-5: Shrubs suitable for Soil Bioengineering Systems

Species	Habitat [1]	Bank Zone [2]	Root Form [3]	Shade [4] Tolerance	Flood [5] Tolerance	pH range [6]	Comments
Viburnum lentago **Nannyberry**	forested wetland	mid-upper	rooted unrooted	medium	seasonal		
Viburnum prunifolium **Blackhaw viburnum**	forested wetland	upper	rooted unrooted	medium	irregular	6.5-7.0	
Viburnum trilobum **Am. cranberrybush**	forested wetlands	lower-mid	rooted unrooted	low	irregular-seasonal	6.0-7.5	tolerates drought

Footnotes:

1. Habitat:
   Native habitat of the plant.
2. Bank zone:
   toe - elevation of baseflow
   lower to mid - from base to two year flood elevation
   upper - above two year elevation to flood plain
3. Root form:
   rooted - use bare-root plants
   unrooted - use dormant cuttings/brush
4. Shade Tolerance:
   low -requires full sun
   medium - tolerates partial shade and full sun
   high - tolerates full shade and full sun
5. Flood tolerance:
   permanent - tolerates inundation or saturation 76-100% of the growing season.
   regular - tolerates inundation or saturation 26-75% of growing season.
   seasonal - tolerates inundation or saturation 13-25% of the growing season.
   irregular - tolerates inundation or saturation 5-12% of the growing season.
6. pH range:
   Preferred range for successful plant establishment.

Table 26-6: Soil Bioengineering Vegetative Treatment Potential (VTP) for Ponds and Lake Shores

Shoreline Variables	**Directions For Use**: Enter the applicable VTP rating (bold number) in the last column. Add the total of the VTP ratings and compare with the Treatment Potential (TP) scale below					VTP
1. **Fetch**: Average distance in miles of open water measured perpendicular to the shore and 45 degrees either side of perpendicular to shore.	Less than 0.5 miles 8	0.5 to 1.4 miles 7	1.5 to 3.4 miles 4	3.5 to 4.9 miles 2	over 5.0 miles 0	
2. **General shape of shoreline** for distance of 200 yards on each side of planting site.	Coves 8	Irregular shoreline 3		Headland or straight shoreline 0		
3. **Shoreline orientation**: General geographic direction the shoreline faces.	Any less than ½ mile fetch 5	West to North 3	South to West 2	South to East 1	North to East 0	
4. **Boat traffic**: Proximity of site to recreational and commercial boat traffic.	None 5	1-10 per week withing ½ mile of shore 3	More than 10 per week within ½ mile of shore 2	1-10 per week within 100 yards of shore. 1	More than 10 per week within 100 yards of shore. 0	

_________________________ Cumulation of VTP for variables 1,2,3, and 4

Treatment Potential (TP) Scale : if TP is:

Between	And	Potential of site to be successfully stabilized with soil bioengineering
23	26	Excellent
20	22	Very Good
16	19	Good
13	15	Fair
below 13		Poor

Shoreline Stabilization

The Vegetative Treatment Potential (VTP) as shown in Table 26-6 shall be evaluated for all shoreline protection measures. Bioengineering treatments involving vegetation may only be considered where the Treatment Potential Scale indicates excellent to very good site conditions. Vegetative measures alone are not suited to sites where wave heights are greater than 1.5 feet and beach slopes are steeper than 12H to 1V. Fiber roll revetments or structural stabilization measures such as rock riprap, and off-shore wave dissipater berms shall be considered for use in combination with vegetation where site conditions are not suited to vegetation alone. Fiber roll revetments have a design life of 5 years and are suitable for sites where there is a high probability that vegetation, once established, will be adequate for stabilizing the shoreline. In general, this will be in lower energy situations where adjacent reaches indicate vegetation alone will be adequate. Riprap for shoreline stabilization shall be designed using procedures in the Standard for Riprap, pg. 22-1.

STANDARD FOR STABILIZED CONSTRUCTION ACCESS

Definition

A stabilized pad of clean crushed stone located at points where traffic will be accessing a construction site.

Purpose

The purpose of a stabilized construction access is to reduce the tracking or flowing of sediment onto paved roadways (or other impervious surfaces).

Conditions Where Practice Applies

A stabilized construction exit applies to points of construction ingress and egress where sediment may be tracked, or flow off, the construction site.

Water Quality Enhancement

In addition to minimizing sediments which can be tracked directly onto pavement during construction, oils, greases and diesel fuels which become mixed with sediment during construction may also migrate into the offsite drainage system where they may enter directly into a waterway. By preventing or minimizing the tracking of sediments onto paved areas, a significant reduction in construction related hydrocarbon pollution will also be controlled.

Design Criteria

Stone Size - Use ASTM C-33, size No. 2 (2 ½ to 1 ½ in) or 3 (2 to 1 in). Use clean crushed angular stone. Crushed concrete of similar size may be substituted but will require more frequent upgrading and maintenance.

Thickness - not less than six (6) inches.

Width - not less than full width of points of ingress or egress.

Length - 50 feet minimum where the soils are course grained (sands or gravels) or 100 feet minimum where soils are fine grained (clays or silts), except where the traveled length is less than 50 or 100 feet respectively. These lengths may be increased where field conditions dictate. Stormwater from up-slope areas shall be diverted away from the stabilized pad (see Standard for Diversions, pg. 15-1). Where diversion is not possible, the length of the stabilized pad shall be as shown in Table 27-1. Where the slope of the access road exceeds 5%, a stabilized base of Hot Mix Asphalt Base Course, Mix I-2 shall be installed. The type and thickness of the base course and use of a dense graded aggregate sub-base shall be as prescribed by local municipal ordinance or other governing authority.

At poorly drained locations, subsurface drainage gravel filter or geotextile shall be installed before installing the stabilized construction entrance.

Table 27-1: Lengths of Construction Exits on Sloping Roadbeds

Percent Slope of Roadway	**Length of Stone Required**	
	Coarse Grained Soils	**Fine Grained Soils**
0 to 2%	50 ft	100 ft
2 to 5%	100 ft	200 ft
>5%	Entire surface stabilized with Hot Mix Asphalt Base Course, Mix I-2[1]	

1. As prescribed by local ordinance or other governing authority.

Where a stabilized construction exit traverses between two buildings, it shall be stoned the entire length of the right-of-way. Mountable stone berms placed across the width of the exit may also be required at the transition point between paved and non-paved areas to trap sediments which are carried by stormwater flowing along the curbline.

Individual lot entrance and egress- After interior roadways are paved, individual lot ingress/egress points may require a stabilized construction entrance consisting of no. 3 stone (1" to 2") to prevent or minimize tracking of sediments. Width of the stone ingress/egress shall be equal to lot entrance width and shall be a minimum of ten feet in length.

Tire washing - If space is limited, vehicle tires may be washed with clean water before entering a paved area. A wash station must be located such that wash water will not flow onto paved roadways or into unprotected storm drainage systems.

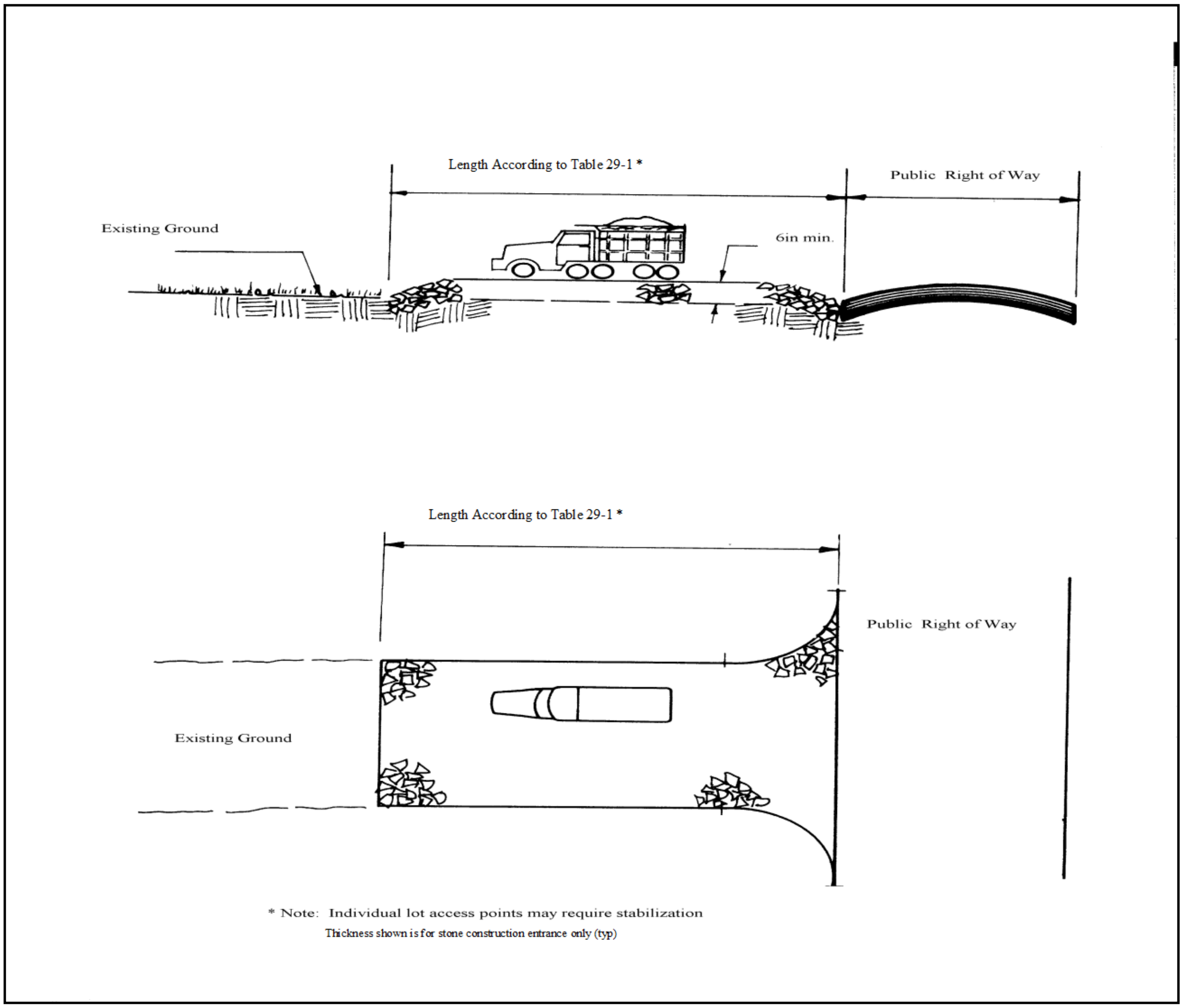
When the construction access exits onto a major roadway, a paved transition area may be installed between the major roadway and the stoned entrance to prevent loose stones from being transported out onto the roadway by heavy equipment entering or leaving the site.

Maintenance

The entrance shall be maintained in a condition which will prevent tracking or flowing of sediment onto roadways. This may require periodic top dressing with additional stone or additional length as conditions demand and repair and/or cleanout of any measures used to trap sediment. All sediment spilled, dropped, washed, or tracked onto roadways (public or private) or other impervious surfaces must be removed immediately.

Where accumulation of dust/sediment is inadequately cleaned or removed by conventional methods, a power broom or street sweeper will be required to clean paved or impervious surfaces. All other access points which are not stabilized shall be blocked off.

Figure 27-1: Stabilized Construction Access



STANDARD
FOR
STORM SEWER INLET PROTECTION

Definition

A temporary barrier and settling facility installed at a storm sewer inlet.

Purpose

The purpose of storm sewer inlet protection is to intercept and retain sediment, thus preventing the entrance of sediment into the storm sewer system.

Conditions Where Practice Applies

1. Contributing drainage area is 3 acres or less.

2. A storm sewer or the outlet channel of a storm sewer needs protection from sediment.

3. Traffic will not destroy or cause constant maintenance of the storm sewer inlet protection.

4. A traffic hazard will not be created.

5. A flooding problem will not be created.

Water Quality Enhancement

The primary benefit to water quality is the removal of sediment from stormwater runoff prior to entering the stormsewer system. As an added benefit, other floatable debris, such as vegetative matter and litter may also be filtered out of the runoff.

Design Criteria

The following applies to all methods of storm sewer inlet protection:

1. Must slow the storm water, provide the coarse sediment particles a chance to settle, and provide an area to retain the particles that have settled.

2. In all cases, inlet protection should not completely close off the inlet. Provision must be made to allow stormwater to overflow or bypass filter

3. The protection device will be designed to capture or filter runoff from the 1 year, 24 hour storm event and shall safely convey higher flows directly into the storm sewer system.

   Other methods that accomplish the purpose of storm sewer inlet protection may be used if approved by the Soil Conservation District.

Inspections shall be frequent. Maintenance, repair, and replacement shall be made promptly, as needed.
The barrier shall be removed when the area draining toward the inlet has been stabilized.

STANDARD
FOR
STREAM CROSSING

Definition

A structural span installed across a watercourse to provide a travel way for vehicles or pedestrians. Temporary structures will be in place for no more than one year and shall be removed prior to completion of construction.

Purpose

A stream crossing is designed to provide access across a watercourse while reducing sediment delivery into the stream, minimizing damages to the streambed or channel, and avoiding flood damages.

Condition Where Practice Applies

This standard applies to temporary and permanent stream crossings. The temporary stream crossing shall be used to cross streams with drainage areas less than one square mile. Structures which must handle flow from larger drainage areas should be designed as permanent structures using generally accepted engineering practice. Complex sites requiring bridge scour studies are beyond the scope of this standard.

Water Quality Enhancement

Flow restrictions caused by stream crossings can increase velocity through the structure causing stream bed erosion and scour. Reducing flow velocity or protecting the stream bed can minimize erosion and sediment production. Crossings can minimize or prevent oils, greases and diesel fuels which become mixed with sediment during construction and after or which could wash off vehicles, from entering the watercourse. In addition, temporary crossings help to minimizing sediments which can be tracked into the stream during construction.

I. Temporary Crossings

Planning

Temporary stream crossings are necessary to prevent construction vehicles from damaging streambanks and tracking sediment and other pollutants into the watercourse. These structures are, however, undesirable in that they represent a channel restriction which can increase flooding upstream or washout during periods of high flow. Therefore, the temporary nature of the structure is stressed. The structure should be planned to be in service for the shortest practical period of time and to be removed as soon as their function has been completed.

This standard pertains primarily to flow capacity and resistance to washout of the structure. From a safety and utility standpoint, the designer must also be sure that the span is capable of withstanding the expected loadings from heavy construction equipment.

The preferred method for temporarily crossing a stream is a bridge made of wood, metal or other material which can provide access across the stream. A bridge causes the least amount of disturbance to the stream bed and banks. They can also be quickly removed and reused. In addition, temporary bridges pose the least chance for interference with fish passage and migration. The other method of temporarily crossing a stream is a culvert crossing consisting of stone and a section(s) of pipe. Temporary culverts are used where the channel is too wide for normal bridge construction or the anticipated loading of construction vehicles may prove unsafe for single span bridges. There is some disturbance to the stream bed and banks during construction and removal of the temporary culvert crossing. The stone, along with the temporary culverts, can be salvaged and reused.

Design Criteria

1. **Temporary Bridge**

a. Structures may be designed in various configurations and out of various materials. However, the bridge must be able to withstand the anticipated loading of the construction traffic. An example of a typical bridge crossing is shown in figure 29-1.

b. Crossing Alignment - The temporary stream crossing shall be at right angles to the stream. Where approach conditions dictate, the crossing may vary 15 degrees from a line drawn perpendicular to the center line of the stream at the intended crossing location.

c. The centerline of the roadway approaches on both sides of the crossing shall coincide with the crossing alignment centerline for a minimum of 50 feet from each bank of the stream crossed. If physical right-of-way restraints preclude the 50 feet minimum, a shorter distance may be provided.

d. A water diversion such as a dike or swale shall be constructed (across the roadway on both roadway approaches) 50 feet (maximum) on either side of the stream crossing. This will prevent roadway surface runoff from directly entering the stream. The 50 feet is measured from the top of the stream bank. If the roadway approach is constructed with a reverse grade away from the stream, a diverting structure is not required. See the Standard for Diversions, pg. 15-1, for roadbed diversions.

e. Perimeter soil erosion controls, such as a silt fence, must be employed, when necessary, along and parallel to the banks of stream.

f. All crossings shall have one traffic lane. The minimum width shall be 12 feet.

2. Temporary Culvert

a. Where culverts are installed, Use ASTM C-33, size No. 2 (2 ½ to 1 ½ in) Coarse Aggregate or larger will be used to form the crossing. The depth of stone cover over the culvert shall be a minimum of 12 inches or as recommended by the pipe manufacturer for the design loading. Rip-rap shall be used to protect the sides of the stone from erosion. Typical culvert details are presented in figure 31-2.

b. As a minimum, the culvert shall be designed to pass the flow from a 2-year frequency, 24 hour duration storm without overtopping. In addition the culvert shall be designed to ensure that no erosion will result from the 10-year peak storm.

c. Multiple culverts may be used in place of one large culvert if they have the equivalent capacity of the larger one. The minimum-sized culvert that may be used is 18 inches.

d. All culverts shall be strong enough to support their cross-sectioned area under maximum expected loads.

e. The length of the culvert shall be adequate to extend the full width of the crossing, including side slopes.

f. The slope of the culvert shall be at least 0.25 inch per foot.

g. Crossing Alignment - The temporary culvert crossing shall be at right angles to the stream. Where approach conditions dictate, the crossing may vary 15° from a line drawn perpendicular to the center line of the stream at the intended crossing location.

h. The centerline of the roadway approaches on both sides of the crossing shall coincide with the crossing alignment centerline for a minimum of 50 feet from each bank of the stream crossed. If physical right-of-way restraints preclude the 50 feet minimum, a shorter distance may be provided.

i. The approaches to the structure shall consist of stone pads meeting the following specifications:

- Stone: ASTM C-33, size No. 2 (2 ½ to 1 ½ in)
- Minimum thickness: 6 inches
- Minimum Width: equal to the width of the structure

j. A water diverting structure such as a dike or swale shall be constructed (across the roadway on both roadway approaches) 50 feet (maximum) on either side of the stream crossing. This will prevent roadway surface runoff from directly entering the stream. The 50 feet is measured from the top of the stream bank. If the roadway approach is constructed with a reverse grade away from the stream, a diverting structure is not required. See the Standard for Diversions, pg. 5-1 for roadbed diversions.

Construction Specifications

1. Temporary Bridge

a. Clearing and excavation of the stream bed and banks shall be kept to a minimum.

b. The temporary bridge structure shall be constructed at or above bank elevation to prevent the entrapment of floating materials and debris.

Abutments shall be placed parallel to and on stable banks.

c. Bridges shall be constructed to span the entire channel. If the channel width exceeds 8 feet (as measured from top-of-bank to top-of-bank), then a footing, pier or bridge support may be constructed within the waterway. One additional footing, pier or bridge support will be permitted for each additional 8-foot width of the channel. No footing, pier or bridge support, however, will be permitted within the channel for waterways which are less than 8 feet wide.

d. Stringers shall either be logs, sawn timber, prestressed concrete beams, metal beams, or other approved materials.

e. Decking materials shall be of sufficient strength to support the anticipated load. All decking members shall be placed perpendicular to the stringers, butted tightly. and securely fastened to the stringers. Decking materials must be butted tightly to prevent any soil material tracked onto the bridge from falling into the waterway below.

f. Run planking (optional) shall be securely fastened to the length of the span. One run plank shall be provided for each track of the equipment wheels. Although run planks are optional, they may be necessary to properly distribute loads.

g. Curbs or fenders may be installed along the outer sides of the deck. Curbs or fenders are an option which will provide additional safety.

h. Bridges shall be securely anchored at only one end using steel cable or chain. Anchoring at only one end will prevent channel obstruction in the event that floodwaters float the bridge. Acceptable anchors are large trees, large boulders, or driven steel anchors. Anchoring shall be sufficient to prevent the bridge from floating downstream and possibly causing an obstruction to the flow.

i. All areas disturbed during installation shall be stabilized within 7 calendar days of that disturbance.

j. When the temporary bridge is no longer needed, all structures including abutments and other bridging materials should be removed immediately.

k. Final clean-up shall consist of removal of the temporary bridge from the waterway, protection of banks from erosion, and removal of all construction materials. All removed materials shall be stored outside flood plain of the stream. Removal of the bridge and clean-up of the area shall be accomplished without construction equipment working in the waterway channel.

2. Temporary Culvert

a. Clearing and excavation of the stream bed and banks shall be kept to a minimum.

b. The invert elevation of the culvert shall be installed on the natural streambed grade to minimize interference with fish migration. In addition, no construction or removal of a temporary access culvert will be permitted during the following periods critical to spawning along such waters as identified in the Department of Environmental Protection's report entitled "Classification of New Jersey Waters as related to Their Suitability for Trout":

check updated trout production dates.

i. Brook Trout/Brown Trout Production Watercourses: September 15 through March 15 inclusive

ii. Rainbow Trout Production Watercourses: February 1 through April 30, inclusive

iii. Trout Production Watercourses: September 15 through March 15 inclusive

iv. Trout Stocked Watercourses, or within one mile upstream of Trout Stocked Watercourses and Trout

Maintenance Watecourses: March 15 through June 15 inclusive.

Waivers of the timing restrictions may be granted if approved, in writing, by the Department of Environmental Protection's Division of Fish Game and Wildlife.

c. Filter cloth shall be placed on the streambed and streambanks prior to placement of the pipe culvert(s) and aggregate. The filter cloth shall cover the streambed and extend a minimum of six inches and a maximum of one foot beyond the end of the culvert and bedding material. Filter cloth reduces settlement and improves crossing stability. This requirement should not be confused with the installation of conduit outlet protection (item f. below).

d. The culvert(s) shall extend a minimum of one foot beyond the upstream and downstream toe of the aggregate placed around the culvert. In no case shall the culvert exceed 40 feet in length.

e. The culvert(s) shall be covered with a minimum of one foot of aggregate. If multiple culverts are used, they shall be separated by at least 12 inches of compacted aggregate fill. At a minimum, the bedding and fill material used in the construction of the temporary access culvert crossings shall conform with the aggregate requirements cited in part "i" under "Temporary Culvert Crossing."

f. The Standard for Conduit Outlet Protection (pg. 12-1) shall be addressed for the temporary culvert. The 10 year design storm peak flow shall be used for apron and stone sizing.

g. When the crossing has served its purpose, all structures including culverts, bedding and filter cloth materials shall be removed. Removal of the structure and clean-up of the area shall be accomplished without construction equipment working in the waterway channel.

h. Upon removal of the structure, the stream shall immediately be shaped to its original cross-section and properly stabilized. Restoration may include the application of Soil Bioengineering techniques where applicable. See the standard for Soil Bioengineering, pg. 26-1.

II. Permanent Crossings

Planning

This standard pertains primarily to flow capacity and resistance to washout of the structure. Planning, alignment, structural design and other considerations shall be in conformance with the appropriate municipal, county, state or federal requirements and regulations.

Where a natural stream bed is to be provided through the structure to benefit aquatic species, consideration shall be given to flow velocity and potential for bed erosion and scour. Where velocity exceeds the threshold for a stable condition, the need for lining of the stream bed, or use of conduits or box culverts, shall be evaluated.

Design

1. Permanent Culvert

a. Design criteria shall be as prescribed by the appropriate authority.

b. For natural stream bed designs:

Three (3) areas of concern should be must be considered for natural stream bed or three (3) sided "bottomless culvert" designs:

1. The corners and abutments of the Inlet section of the culvert
2. The barrel section of the culvert
3. The outlet or discharge section of the culvert

The Corners and Abutments of the Inlet Section of the Culvert:

Designs should avoid significant reductions in flow width transition from the approach channel to the inlet of the structure, which could cause abutment or contraction scour at the inlet. When it is determined that the potential for abutment or contraction scour exists at the inlet, the areas of concern shall be provided with a structural lining, such as riprap. See the Standard for Riprap and the Standard for Channel Stabilization.

The Barrel Section of the Culvert:

The potential for erosion through the structure shall be evaluated by comparing expected flow velocity against the allowable velocity for the soil texture found in the stream bed, see Standard for Channel Stabilization.

When the allowable velocity is exceeded, use of a channel lining, designed to withstand the expected velocity shall be incorporated, or the use of a conduit or box culvert, shall be considered.

Designs shall avoid abrupt changes in the flow profile through the barrel section of the culvert, which would cause a transition in the water surface profile from Super-Critical Flow to Sub-Critical Flow, creating a Hydraulic Jump.

The Outlet Section or the Discharge end of the Culvert:

If the structure causes a reduction in the design flow top width within the channel, and the outlet velocity exceeds the allowable velocity for the soil the culvert is discharging onto, as referenced in Table 12-1, the discharge end of the structure shall meet the Standard for Conduit Outlet Protection.

The upmost consideration shall be give to the protection of the structure.

Transition area riprap for areas disturbed adjacent to the culvert may be required as referenced within the Standard for Conduit Outlet Protection.

Measures to protect intrusion into the areas of the natural stream bed that are proposed to remain undisturbed, during construction shall be provided.

Construction Specifications

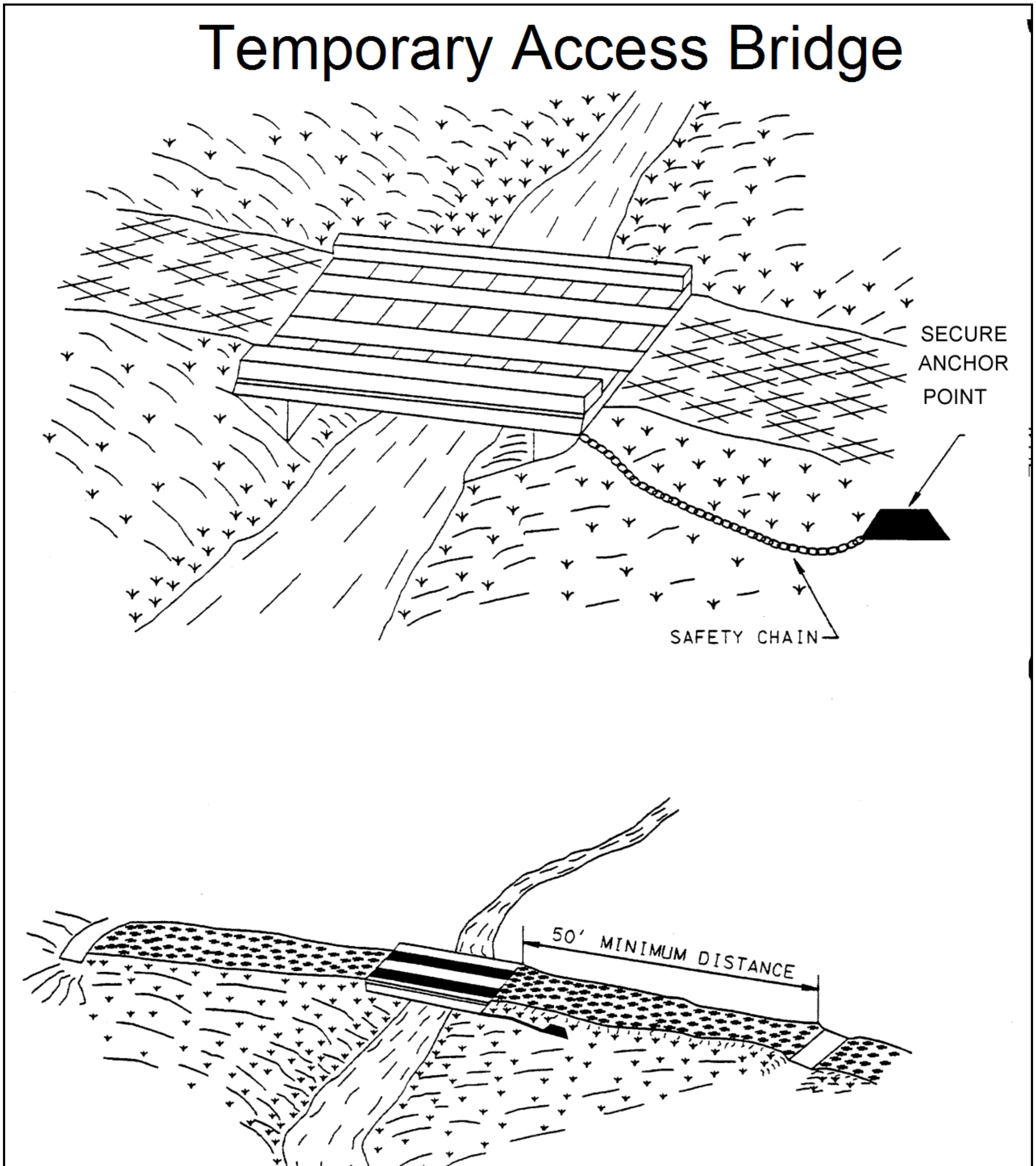
Permanent Crossings

Construction specifications for permanent crossings shall be as prescribed by the appropriate authority and shall be in compliance with all federal, state, and local regulations. All applicable standards, such as permanent vegetation, sediment barriers, land grading etc. shall be addressed when designing permanent crossings.

Maintenance

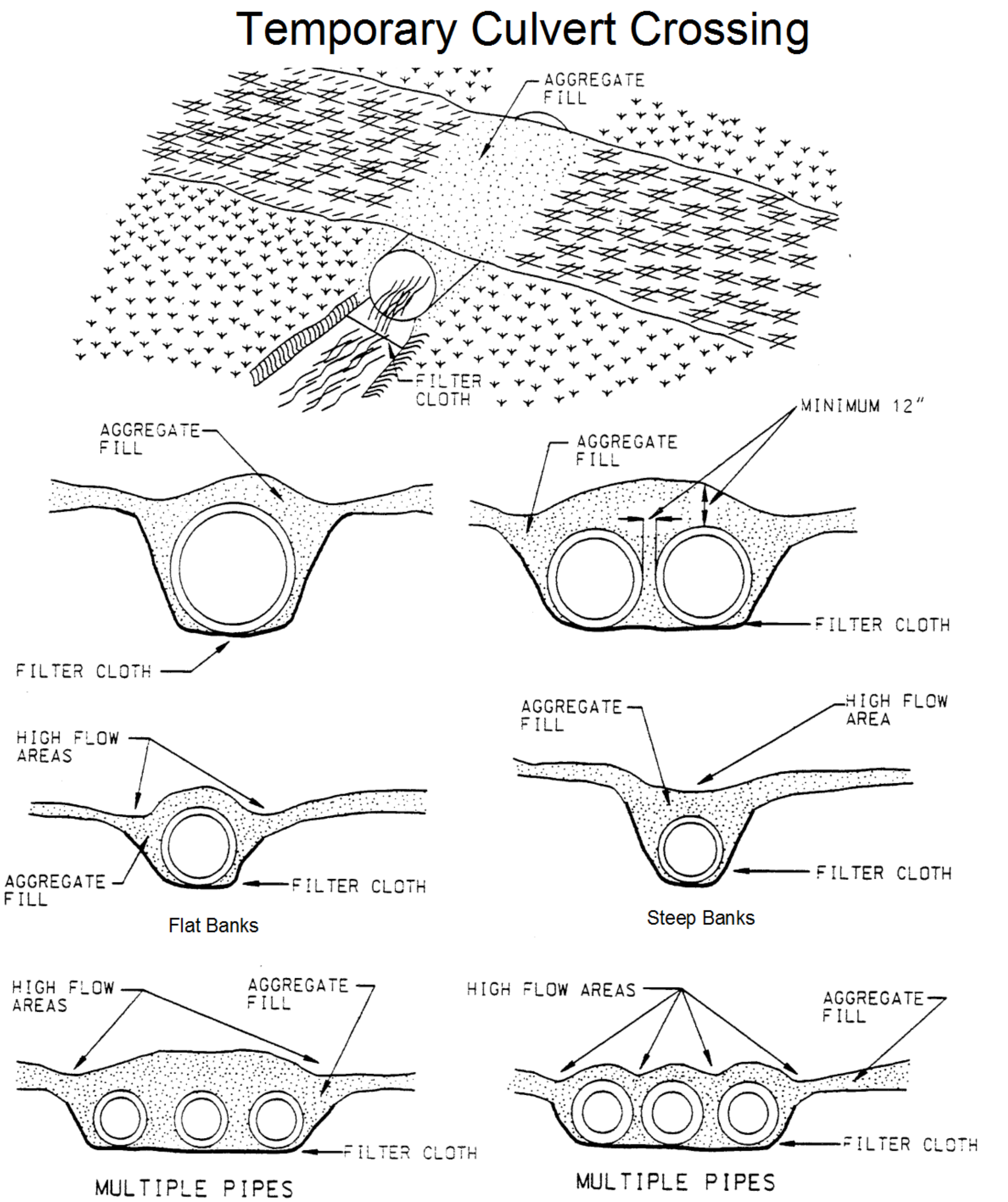
Temporary and permanent installations shall be inspected after every rainfall and at least once a week, whether it has rained or not, and all damages repaired immediately.

1Figure 29-1: Stream Crossing - Temporary Bridge



Source: USDA - NRCS

2Figure 29-2: Stream Crossing - Culvert Installation



Source: USDA - NRCS

STANDARD
FOR
SUBSURFACE DRAINAGE

Definition

Removal of water through the soil by conduit, such as tile, pipe, or tubing, installed beneath the ground surface to collect and convey drainage water.

Purpose

A drain may serve one or more of the following purposes:

1. Improve vegetation by lowering the water table.

2. Intercept and prevent water movement into a potentially wet area.

3. Relieve artesian pressures.

4. Reduce surface runoff.

5. Serve as an outlet for other drains.

6. Replace natural subsurface drainage patterns which are interrupted by construction operations.

Conditions Where Practice Applies

Drains are used in areas having a high water table where benefits of lowering groundwater or controlling surface runoff justify the installation of such a system.

The soil shall have enough depth and permeability to permit installation of an effective system. On-site investigations are required.

An outlet for the drainage system shall be available, either by gravity flow or by pumping. The outlet shall be adequate for the quantity and quality of effluent to be disposed of with consideration of possible damages above or below the point of discharge.

Water Quality Enhancement

The use of subsurface drainage will prevent surface ponding of runoff, which can kill stabilizing vegetation. Loss of this vegetation can result in increased erosion and an increase in discharge of nutrients and fertilizers without the aid of filtration and adsorption from vegetative cover.

Design Criteria

The design and installation shall be based on adequate surveys and investigations.

Design Inflow

The design inflow can be determined by the use of the method described in reference (9), the use of Table 30-1, or by other accepted methods.

TABLE 30-1

INFLOW RATES FROM DIFFERENT SOIL TEXTURES [1/ 2/]

SOIL TEXTURE	UNIFIED SOIL CLASSIFICATION	INFLOW RATE PER 1000 FT. OF LINE IN CFS
Coarse sand and gravel	GP, GW, SP, SW	0.15 to 1.00
Sandy or gravelly loam	SM, SC, GM, GC	0.07 to 0.25
Silt loam	CL, ML	0.04 to 0.10
Clay and clay loam	CL, CH, MH	0.02 to 0.20

1/ Required inflow rates for interceptor lines on sloping land should be increased by 10% for slopes 2% to 5%; 20% for slopes 5% to 12%; and 30% for slopes over 12%.

2/ For complete drainage systems, use the lower value in the above table for the given soil texture.

Size of Drain

The size of drains shall be computed by applying Manning's formula, or by the method contained in Chapter 14, Ref. (1).

The minimum drain shall be equivalent to a 4-inch diameter pipe.

Depth, Spacing, and Location

The depth, spacing, and location of the drain shall be based on site conditions including soils, groundwater conditions, topography, and outlets.

Minimum Velocity and Grade

In areas with no siltation hazard, the minimum grades shall be 0.1%. Where it is determined that a siltation hazard exists, velocity of not less than 1.4 feet per second shall be used to establish the minimum grades if site conditions permit. Otherwise, provisions shall be made for prevention of siltation by filters or collection and removal of silt by use of silt traps.

Maximum Grade and Protection

On sites where topographic conditions require the use of drain lines on grades steeper than 2% or where design velocities will be greater than indicated in Table 30-2 special measures shall be used. These measures shall be specified for each job based on the particular conditions of the job site. Possible protective measures include the following:

1. Lay the drains so as to secure a tight fit with the inside of one section matching that of the adjoining section.

2. Wrap open joints with geotextile filter.

3. Select the least erodible soil available for hand placing on sides and top of conduit, which must be tamped before backfilling. Tamped thickness of this material over conduit shall be a minimum of two inches.

4. For continuous pipe or tubing with perforations, completely enclose the pipe with geotextile filter material, or properly graded sand and gravel as specified under filters and filter materials on page 30-4.

5. Install relief vents where changes in grade exceed 5 percent.

TABLE 30-2

MAXIMUM PERMISSIBLE VELOCITIES IN DRAINS WITHOUT PROTECTIVE MEASURES

SOIL TEXTURE	VELOCITY - FEET PER SECOND
Sandy loam	2.5
Silt and silt loam	4.0
Silty clay loam	5.0
Clay and clay loam	6.0
Coarse sand and gravel	8.0

Materials for Drains

"Drains" include conduits of clay, concrete, metal, plastic, or other materials of acceptable quality.

The conduit shall meet strength and durability requirements of the site.

Loading

The allowable loads on drain conduits shall be based on the trench and bedding conditions specified for the job. A factor of safety of not less than 1.5 shall be used in computing the maximum allowable depth of cover for a particular type of conduit.

Filters and Filter Material

Suitable filters shall be used, where required by site conditions, to prevent sediment accumulation in the conduit. The need for a filter shall be determined by the characteristics of the soil materials at drain depth and the velocity of flow in the conduit.

Not less than three inches of filter material shall be used for sand-gravel filters.[1]

Envelopes shall be used around drains where necessary to improve flow characteristics of groundwater into the conduit.

Installation Requirements

All drains shall be laid to line and grade, and covered with not less than three inches of approved hand placed backfill and/or filter material. The upper end of all drain lines shall be closed with concrete or other durable material unless connected to a structure.

Earth backfill material shall be placed in the trench in such a manner that displacement of the drain will not occur, and so that the filter material, after backfilling, will meet the requirements of the design.

The gap between drain pipe joints shall not exceed one-fourth inch for mineral soils or one-half inch for organic soils. Openings wider than these shall be covered with geotextile filter or other suitable material.

If the conduit is to be placed in a rock-trench, or where rock is exposed in the bottom of the trench, the rock shall be removed below grade deep enough so that the trench may be backfilled, compacted, and bedded so that the conduit is not less than two inches from rock.

When iron sulfide chemical reaction causes sealing of joints or perforations, the drain shall be enclosed in a clean sand-gravel filter. Riser pipes for flushing the line shall be provided at intervals not to exceed 500 feet.

[1] A recommended method of installation is to place filter material to a depth of three inches under the drain, and cover the drain and filter with a sheet of plastic. The filter shall be designed to prevent the material in which the installation is made from entering the drain. Not more than 10% of the filter shall pass the No. 60 sieve.

STANDARD FOR TRAFFIC CONTROL

Definition

The control of on-site construction traffic (construction equipment, service vehicles, autos, etc.) during development of a parcel of land.

Purpose

To minimize land disturbance.

Where Applicable

Any area where vehicular traffic disturbs the land to the extent of reducing protective vegetation, compacting soil, or otherwise deteriorating the environment.

Water Quality Enhancement

Managing construction traffic to minimize the damage or loss of protective vegetative cover and minimize the compaction of soils will help to minimize off-site erosion and transportation of associated pollutants.

Planning Criteria

Restrict construction traffic to predetermined routes according to types and numbers of vehicles anticipated. Markers or temporary fencing may be helpful.

Avoid damage to waterways by construction of suitable crossing facilities and avoid traffic in or along streams.

Predetermine steep banks and vegetative areas to be avoided by traffic.

Traffic during wet weather should be minimized.

Sediment from tire washing operations shall be retained on site. Water shall be conveyed to a stable outlet.

Soil compaction resulting from construction traffic can impact the infiltration rate of the soil. Restoration of compacted soils through deep tillage (6" to 12") and the addition of organic matter may be required, in accordance with the Standards for Topsoiling and Land Grading, in planned pervious areas to enhance the infiltration rate of the disturbed soil.

STANDARD
FOR
FLOATING TURBIDITY BARRIER

Definition

A temporary floating barrier at streams or waterways within the construction site.

Purpose

To prevent the siltation of streams or waterways that pass through or about the construction site.

Conditions Where Practice Applies

Floating turbidity barriers shall be used whenever construction operations are directly located in a stream or water course, or where a drainage pipe that may carry silt discharges into a stream or waterway.

Water Quality Enhancement

This practice will limit the dispersion of runoff-borne sediment (and floatable material) to the immediate area of construction, thereby facilitating maintenance and cleanup. Sediment trapped behind the barrier will be permitted to drop out of suspension before being carried further downstream.

Design Criteria

1. Barrier material will be a Polyethylene Plastic sheet, 10 mil., or suitable alternate to fit existing conditions.

2. Weights will be at 10' intervals along the entire length. They shall be 5 pounds and extend 12" below the bottom of the material.

3. Floats will be at 5' intervals; there will be two floats at each location, one on either side of the material.

4. Rope will be 1/4" nylon or manila.

Placement

1. Barrier will be set on a 50' radius from the point of discharge when discharging through a conduit. If the radius cannot be accommodated, barrier shall be placed in accordance with no. 3 below.

2 Barrier will extend parallel to the channel bank(s) for the full length of the work area for shoreline disturbances.

3. Barrier will extend across the entire channel when work is performed within the channel.

Figure 32-1: Placement of Floating Turbidity Barrier