SECTION 111 - OPEN CHANNELS

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This section covers the evaluation of the capacity and stability of natural drainage channels, and design of constructed drainage channels, swales, and roadside ditches.

111.1 GENERAL DESIGN CONSIDERATIONS

Except for roadside ditches and swales, open channels are nearly always a component of the **major** (emergency) drainage system. There are a number of factors which must be considered in determining whether to specify an open drainageway as opposed to an underground storm drain: material and installation cost, maintenance costs and problems, acceptability to the developer or home buyer, public safety, appearance, etc. Effective planning and design of open drainageways can significantly reduce the cost of storm drainage facilities, while enhancing the quality of the development.

In planning a subdivision, the designer should begin by determining the location and the width of existing drainageways. Streets and lots should be laid out in a manner to preserve the existing drainage system to the greatest degree practical. In addition to reducing the cost of the drainage system, sediment and erosion control costs will also be reduced. Constructed channels should be used only when it is not practical or feasible to utilize existing drainageways.

111.2 GENERAL DESIGN REQUIREMENTS

111.2.1 Design Flow

Open channels shall be designed to convey the peak flow rate resulting from a storm having a rainfall intensity corresponding to the time of concentration at the point of interest or a duration which produces the maximum runoff rate at the point of interest, depending upon the method used for computing runoff. Open channels draining less than two hundred (200) acres can be designed for runoff rates computed by the Rational Method. The peak flow rate considered shall be determined using fully urbanized conditions in the watershed. Effects of detention basins in reducing peak flow rates in the upstream watershed will be considered only if the detention basins are included in a hydrologic model used to estimate the peak flow rate and provided the detention basins are located in permanent drainage easements.

The design storm frequency shall be as follows:

Total drainage area less than one (1) square mile: 25-year (4% AEP) storm
Total drainage area one (1) square mile or more: 100-year (1% AEP) storm

111.2.2 Maximum Depth

Unless otherwise approved due to unavoidable physical or right-of-way constraints, the maximum depth for the 25-year storm shall be three feet (3') in constructed channels.

111.2.3 Freeboard

For channels designed for subcritical flow conditions, a minimum of one foot (1') of freeboard shall be provided between the design high water elevation and the top of the channel.

Freeboard shall be increased on the outside of curves according to the following formula (Reference 111.1):

$$h = \frac{\left[V^2 T\right]}{g r_c} \geq 0.5\,ft.$$

h = superelevation (feet)
V = average channel velocity (feet/second)
T = top width of flow (feet)
g = acceleration due to gravity (32.2 ft/s^2)
r_c = centerline radius of channel (feet)

For channels designed for supercritical flow, additional freeboard may be required depending upon the risk of damage which could occur if flow were to become subcritical due to debris or other obstructions.

111.2.4 Horizontal Alignment

The centerline of constructed channels shall be aligned parallel with property lines unless otherwise approved. A radius shall be provided whenever the alignment of a constructed channel changes by ten (10) degrees or more. The minimum centerline radius shall be three (3) times the top width of the design flow.

Horizontal curve data shall be shown on the plans.

111.2.5 Easements

All constructed channels shall be located within drainage easements. Natural channels draining five (5) or more acres shall be located in drainage easements. The minimum easement width shall be the top width of the 100-year peak flow rate. Adequate means of access shall be provided for maintenance equipment. Additional easement width shall be provided if required to provide maintenance access.

Except in the A-1, Agriculture Zoning District, no fences or obstructions of any type are permitted within drainage easements containing open channels. In the A-1, Agriculture District, only open strand barbed wire fences are allowed within the easement.

111.2.6 Grades

Unless otherwise approved due to unavoidable physical constraints, the minimum centerline grade for various channels shall be as follows:

Concrete channels	0.25%
Composite channels with concrete inverts	0.5%
Grass channels	1.0%
Grass channels with concrete trickle channels	0.5%
Riprap and gabion channels	1.0%
All other channel types	Will be considered on a case by case basis

111.2.7 Allowable Velocities

The maximum average channel velocity shall be as follows for the design flow rate:

Channel Lining Type	Maximum Average Velocity, V
Grass	5 feet/second
Concrete	15 feet/second
Riprap, gabion	10 feet/second

Where reduction in velocity due to a reduction in slope would allow a transition from a concrete to a grass-lined channel, a grouted riprap lining shall be provided from the point where the theoretical average channel velocity would be five feet (5') per second or less, for a distance downstream equal to five (5) times the theoretical top width of the grass channel. The height of the riprap lining shall be equal to the height of the concrete lining upstream.

111.2.8 Utility Clearances

A minimum clear distance of twelve inches (12") vertically from any other utility line shall be maintained below the channel lining, unless otherwise approved. Utilities will not be permitted to cross through the channel flow area.

111.2.9 Plan Requirements

Each channel shown on the plan shall be numbered or lettered (Line 1, Storm 1, Line A, etc.). Channel segments shall be included in profiles of the storm sewer lines of which they are a component. Stationing shall begin at the downstream end of the channel and proceed upstream. Stations shall be called out on the plan and profile at all changes in direction or points of curvature and tangency.

111.3 HYDRAULIC DESIGN

111.3.1 Uniform Flow

Open channels having a design flow rate less than five hundred (500) cfs may be designed assuming uniform flow conditions in conjunction with computed headwater depths at culverts and other hydraulic structures or reservoir stages at detention and sediment basins. Water surface profiles using techniques for gradually varied flow may be required for design flow rates less than five hundred (500) cfs where accurate determination flooding depths is necessary to ensure flood safety.

Under steady state, uniform flow conditions channel capacity shall be computed using Manning's Equation:

$$Q = \frac{1.49}{n} A\ R^{2/3} S^{1/2}$$, where

Q = rate of flow, cubic feet per second
n = Manning's roughness coefficient (See Table 111.1 below)
A = cross sectional area of flow, square feet
P = wetted perimeter, feet
R = hydraulic radius = A/P, feet
S = S_f = friction slope

TABLE 111.1
MANNING'S ROUGHNESS COEFFICIENT FOR VARIOUS CHANNEL LININGS

Type of Surface	Manning's n Value
Concrete, float finish	0.013-0.015
Gunite, shotcrete	0.016-0.019
Concrete bottom, with pre-cast masonry unit sides	0.020-0.030
Gravel bottom with pre-cast masonry unit sides	0.023-0.033
Riprap, Note 3	0.050-0.060
Grouted riprap, Note 3	0.023-0.030
Grass Channels, VR>10	0.030-0.035
VR<10	0.030-0.200 (See Section 111.4.2)
Stream Channels: gravel, cobbles, few boulders	0.040-0.050
Floodplains	
Short grass pasture, hayfield	0.030-0.035
Tall grass pasture, hayfield	0.035-0.050
Mature field crops	0.040-0.050
Heavy weeds, scattered brush	0.050-0.070
Light brush and trees	0.060-0.080
Medium to dense brush	0.100-0.160
Heavy stand of timber, a few down trees, little undergrowth	0.100-0.120

NOTES TO TABLE 111.1

1. Values in this Table were obtained from Appendix A of Federal Highway Administration, HDS-5, Design of Roadside Drainage Channels (Reference 111.5). Values for channels with precast masonry unit sides use the values given in the reference for dry rubble lining.

2. Use the high value in the range for determining channel capacity. Use the low value for determining maximum velocity.

3. City of Tulsa Design Criteria (Reference 111.3).

4. For pictorial examples of different channel roughnesses, see Chow, Open Channel Hydraulics (Reference 111.2).

Definitions

Critical depth, dc - the depth of flow at which the specific energy is a minimum for a given flow rate and channel cross shape, and a unique relationship exists between depth and specific energy.

Normal depth, dn - the depth at which uniform flow occurs when the discharge rate is constant. Friction and gravity forces are in balance.

Subcritical flow - lower energy, lower velocity flow, which occurs when the normal depth is greater than the critical depth. Subcritical flow is controlled by downstream conditions.

Supercritical flow - high energy, high velocity flow, which occurs when the normal depth is less than the critical depth. Supercritical flow is controlled by upstream conditions.

Froude number, $F_r = \frac{V}{\sqrt{gD}}$, where

D = hydraulic depth (feet) = A/T
A = cross sectional area of design flow (square feet)
V, g and T are as defined in Section 111.2.3

For supercritical flow, $F_r > 1$
For subcritical flow, $F_r < 1$
For critical flow, $F_r = 1$

Specific energy, E, is the energy per unit weight of fluid

$$E = d + \frac{V^2}{2g}$$, where

E = specific energy in feet
V and g are as defined above
d = depth of flow in feet

Specific force, Fm, is the sum of forces due to velocity plus hydrostatic pressure per unit weight of fluid

$$F_m = \frac{Q^2}{gA} + A\bar{y}$$, where

F_m = specific force in cubic feet
$\bar{y}$ = depth to center of gravity of the cross section in feet
Q and A are as defined above

Conjugate depth (also known as alternate depth) is the corresponding subcritical or supercritical depth having the same value of specific energy or specific force.

Computations for all channels designed for uniform flow conditions shall indicate whether flow is subcritical, critical or supercritical. It is preferred that channels be designed for subcritical flow conditions. Critical flow ($0.9 < F_r < 1.2$) should be avoided, if possible, since flow is unstable. Where channels must be designed for supercritical flow and the Froude number is greater than two point five (2.5), the conjugate depth for specific force must be determined. Freeboard up to the conjugate depth may be required if necessary to provide adequate flood protection.

111.3.2 Gradually Varied Flow

Open channels having a design flow rate of five hundred (500) cfs or more and which are not relatively long with a uniform cross section, shall be designed for gradually varied flow. Manual computations shall be done using the Direct Step Method or Standard Step Method (Reference 111.1). Water surface profiles can be computed using the Corps of Engineers HEC-2 Water Surface Profiles program (Reference 110.2) or the Federal Highway Administration WSPRO program (Reference 110.1).

111.3.3 Rapidly Varied Flow

Rapidly varied flow conditions shall be avoided when possible. Where drop structures are required for grass lined or composite channels, the location of the hydraulic jump and the length of erosion protection to be provided shall be determined in accordance with the procedures set forth in Section 111.4.5.

Check dams and other special hydraulic structures shall be designed as set forth in the ASCE

Design Manual (Reference 111.1)

111.4 DESIGN & CONSTRUCTION REQUIREMENTS

111.4.1 Natural Channels

Perennial Streams and Losing Streams

The stream channel of perennially flowing streams or intermittent streams classified as losing streams in the Missouri Clean Water Laws shall not be modified or channelized except where unavoidable to construct road crossings or to repair erosion and stabilize the stream channel.

Trees and vegetation shall not be removed within twenty-five feet (25') of the stream bank. Clearing of brush and undergrowth shall be minimal. It is preferred that existing vegetation remain within one hundred feet (100') of the stream bank.

Any work within a Federally designated floodplain requires a Floodplain Development Permit. A Conditional Letter of Map Revision (CLOMR) must be obtained for any filling within the floodway. Work within the stream channel may require a Department of the Army "404" permit.

Tributary Watercourses

Intermittent streams which have a defined channel should not be modified or channelized except where unavoidable for road crossings or to repair erosion and stabilize the stream channel. No clearing is permitted within twenty-five feet (25') of the stream bank except to remove underbrush and fallen timber.

Natural watercourses in which flow is broad and shallow, and which have no defined channel should not be modified or channelized. Removal of trees and vegetation within the watercourse should be avoided as much as practical.

Determining Flooding Limits for Watercourses

The area inundated by the peak flow from the 100-year (1% AEP) storm is considered to be the flooding area for any watercourse, whether or not it is designated on the Flood Insurance Rate Maps for Greene County. An implicit drainage easement is considered to exist along the area inundated by the peak flow from the 1% AEP (100-year) storm.

For the purpose of preliminary planning and design, the approximate limits of the floodplain can be determined using approximate methods.

In determining the capacity and depth of flow in natural watercourses, they shall be analyzed by selecting the most restrictive channel section for each reach and determining the normal depth by analyzing the channel as an irregular section using representative "n" values for each segment of the channel cross-section.

Development Guidelines

Where the width of the existing drainageway cannot accommodate the needs of the development, the fringe areas of the drainageway can be filled, and tributary watercourses may be channelized within the limitations described above. The combination of filling and channeling shall not increase the estimated high water elevation for the 100-year (1% AEP) peak flow rate by more than one foot (1') over pre-project conditions at the upstream boundary or any point upstream of the site.

Where the effects of increased frequency of flow or increased velocity may significantly effect the stability or the stream channel, measures such as grade checks, check dams or bank stabilization may be required.

A typical natural channel cross section is shown in Figure 111.1.

111.4.2 Grass Channels

Grass lined channels shall have a minimum slope of 1% (one percent). The bottom slope may be decreased to 0.5% (five-tenths percent) if a concrete trickle channel is provided.

Maximum side slopes shall be 3:1, with 4:1 preferred.

In order to establish growth in the channel bottom, the bottom twelve inches (12") of the channel depth shall be lined with sod, or suitable erosion control blanket.

A typical grass lined channel cross section is shown in Figure 111.2.

Manning's roughness coefficient ("n", also known as the retardance coefficient) for grass channels shall be determined based upon the product of the velocity and the hydraulic radius (V x R) using the chart shown in Figure 111.3 (Reference 111.7). Retardance curve "C" shall be used in determining channel capacity. Retardance curve "D" shall be used in determining velocity.

111.4.3 Low Flow (Trickle) Channels

Trickle channels shall be provided in *constructed* grass channels (not natural channels) where base flow or perennial flow prevents the establishment or re-establishment of a sod bottom. Types of trickle channels are as follows:

A. Concrete Trickle Channels

Trickle channel capacity shall be approximately five percent (5%) of the design flow rate. A standard concrete trickle channel cross-section is shown in Figure 111.4. Other shapes may be used, provided capacity calculations are submitted and construction details are provided on the plans.

Concrete trickle channels may be unreinforced up to a total width of five feet (5'). For total widths of five feet (5') to ten feet (10'), the trickle channel shall be reinforced with 6 X 6-10-10 welded wire mesh. For widths greater than ten feet (10'), see requirements for concrete channels.

Trickle channel alignment shall be the same as the overall channel alignment. Radii at changes in direction shall be the minimum radius required based upon the channel top width.

Capacity of grass channels with trickle channels may be determined as a composite cross-section in accordance with Section 111.4.3 , or the additional capacity of the trickle channel can be ignored.

A typical cross section of a grass channel with a concrete trickle channel is shown in Figure 111.5.

Erosion potential at the grass/concrete interface should be checked. Shear stress or tractive force shall be determined as follows and shall be limited to the maximum values set forth below:

Shear force, $\tau = \lambda ds$, where

τ = unit shear stress (pounds per square foot)
λ = unit weight of water = 62.4 pounds per cubic foot
s = channel slope (feet per foot)
d = distance from the water surface to the channel lining at the point of interest (feet)

TABLE 111.2

Maximum Allowable Shear Stress for Various Lining Types

Lining Type	Maximum Shear Stress
Grass, sod	0.60 psf
Jute fiber net	0.40 psf
Straw erosion control blanket with attached netting	1.45 psf
Excelsior (wood fiber) erosion control blanket with netting	1.55 psf
Synthetic erosion control blanket	2.00 psf

The foregoing values were obtained from Table 9.5 of the ASCE Design Manual (Reference 111.1) Manufacturer's data shall be submitted for erosion control blankets specified.

B. Other Types of Trickle Channels

Trickle channels of porous pavers, gravel filled Geoweb, submerged flow wetlands, natural stone and other materials can be specified, and are encouraged to improve aesthetics and water quality. However, assurance must be given that quality control will be maintained during construction and that adequate maintenance will be provided after construction.

Complete computations and construction specifications must be submitted for alternative types of trickle channel linings.

111.4.4 Composite Channels

Many different channel shapes and lining types are possible. Different shapes and lining types can be combined in a composite design. In determining the capacity and depth of flow in composite channels, they shall be analyzed as an irregular section using representative "n" values for each segment of the channel cross-section. Velocity limitations set forth above shall be adhered to for each lining type. Allowable shear stress at the interface between grass or other erodible linings and erosion resistant linings may not exceed the maximum values set forth in Table 111.4.3.

A typical cross section of a channel with a concrete invert and grass slopes is shown in Figure 111.6.

111.4.5 Concrete Channels

Where velocities or slopes cannot be limited to values required for natural, grass, or composite channels due to right-of-way or other constraints, concrete channels may be utilized. Concrete channel shapes will typically be trapezoidal or rectangular. Other shapes may be used, but are less efficient.

Crushed rock bedding and pore pressure relief are required whenever the lining height exceeds twelve inches (12"). Whenever the concrete channel bottom is wide enough to accommodate construction or maintenance equipment (generally eight feet (8') wide or more), it shall be designed to carry an HS-20 leading and shall be reinforced. Welded wire mesh or steel reinforcing bars shall may by used.

Concrete channels shall be designed for subcritical flow where possible. Where flow is supercritical, the conjugate depth must be checked and additional freeboard may be required as provided in Section 111.2.3.

Where slopes must be decreased to provide stability or maintain subcritical flow, drop structures should be provided.

Trapezoidal Concrete Channels

Maximum side slopes shall be 2:1. Total channel depth is limited to three feet (3') unless otherwise approved. For depths greater than twelve inches (12"), the channel slopes shall be reinforced with 6 X 6-10-10 welded wire mesh. A typical trapezoidal concrete channel section is shown in Figure 111.7.

Rectangular Concrete Channels

Vertical side walls shall be reinforced to withstand earth pressure and other anticipated loads. Design for hydrostatic pressure is not required if weep holes are provided for relief.
A typical rectangular concrete channel section is shown in Figure 111.8.

A toe wall extending a minimum of eighteen inches (18") below grade shall be provided at the downstream end of any concrete channel section, and should be provided at maximum intervals of about one hundred feet (100') along the channel.

111.4.6 Riprap Linings

The use of riprap for channel linings is discouraged primarily due to poor construction practice. Because of the amount of labor required to properly place and chink stones into a stable mass, loose riprap is seldom stable. Further, gradations of stone tend to be highly variable and poorly controlled.

Loose riprap is susceptible to silting in, encouraging growth of weeds and vegetation, and creating a maintenance and appearance problem. These problems can be overcome somewhat by grouting the riprap; however, construction practice for grouted riprap is equally poor resulting in a highly variable penetration by the grout.

Riprap linings are best specified for only short distances in zones where erosion potential is high. Where riprap is specified it should be grouted to minimize maintenance problems, unless the installation is temporary. The maximum stone size should be twelve inches (12"). The riprap shall be laid over a non-woven filter fabric in order to prevent undercutting of the subgrade.

A typical riprap lining is shown in Figure 111.9.

111.4.7 Other Types of Erosion Resistant Channel Linings

Designers are encouraged to use other types of linings in order to reduce cost and improve appearance of drainage channels. Invert lining materials include concrete, reno mattresses, gravel filled Geoweb, Geoweb filled with lean concrete, etc.

Sidewall lining materials include gabions, and precast concrete units, such as Keystone blocks, Loffelstein units, Windsor stone, and many other types of precast units.

In specifying any type of these linings, the manufacturer's installation instructions shall be strictly followed.

111.4.8 Drop Structures

Where the channel slope must be decreased to provide stability, maintain subcritical flow, or reduce velocity to acceptable levels, drop structures may be provided. Grass lined channels shall be provided with erosion resistant linings downstream to the point at which the average channel velocity has returned to the allowable rate for the type of channel lining provided. Drop structures for vertical wall channels shall be designed in accordance with the ASCE Design Manual (Reference 111.1) or the U.S. Bureau of Reclamation Design of Small Canal Structures (Reference 111.4). Drop structures for trapezoidal channels shall be designed in accordance with the City of Tulsa Design Criteria (Reference 111.3) or King's Handbook of Hydraulics (Reference 111.8).

111.5 ROADSIDE DITCHES

Roadside ditches shall be designed for a maximum depth of two feet (2') measured from the roadway shoulder, and maximum 3:1 side slopes. Roadside ditches shall be grass lined and shall conform to the same velocity requirements as grass lined channels. The bottom six inches (6") of the ditch depth shall be lined with sod or erosion control blanket, or the developer must assume maintenance responsibility for the ditch until growth is firmly established. A security agreement or performance bond will be required during the maintenance period.

Where the full flow velocity in the ditch exceeds five feet (5') per second, a concrete ditch liner as shown in Figure 111.10 shall be provided.

111.6 FLOODPLAIN REQUIREMENTS

Design of channels within floodplains shown on the Flood Insurance Rate Maps for Greene County must be done in accordance with requirements of Article XIX, Floodplain Management Ordinance of the Greene County Zoning Regulations.

111.7 REFERENCES

1. American Society of Civil Engineers Manuals and Reports of Engineering Practice No. 77 (WEF Manual of Practice FD-20), Design and Construction of Urban Stormwater Management Systems, Chapters 6 and 8. American Society of Civil Engineers, New York, NY, 1992.

2. Chow, V.T. Open Channel Hydraulics. McGraw-Hill Book Company, 1959.

3. City of Tulsa, Storm Drainage Criteria Manual, Department of Stormwater Management, Tulsa, OK, 1991.

4. U.S. Bureau of Reclamation, Design of Small Canal Structures, USBR Water Resources Technical Publication, Washington, D. C., 1974.

5. U.S. Department of Transportation, Design of Roadside Drainage Channels, Hydraulic Design Series No. 4 (HDS-4) Federal Highway Administration, Washington, D.C., 1983.

6. U.S. Department of Transportation, Design of Stable Channels with Flexible Linings, Hydraulic Engineering Circular No. 15 (HEC-15)< Federal Highway Administration, Washington, D.C., 1975.

7. U. S. Soil Conservation Service, Handbook of Channel Design for Soil and Water

Conservation. Publications No. SCS-TP-61, U.S. Government Printing Office, Washington, D.C., 1954.

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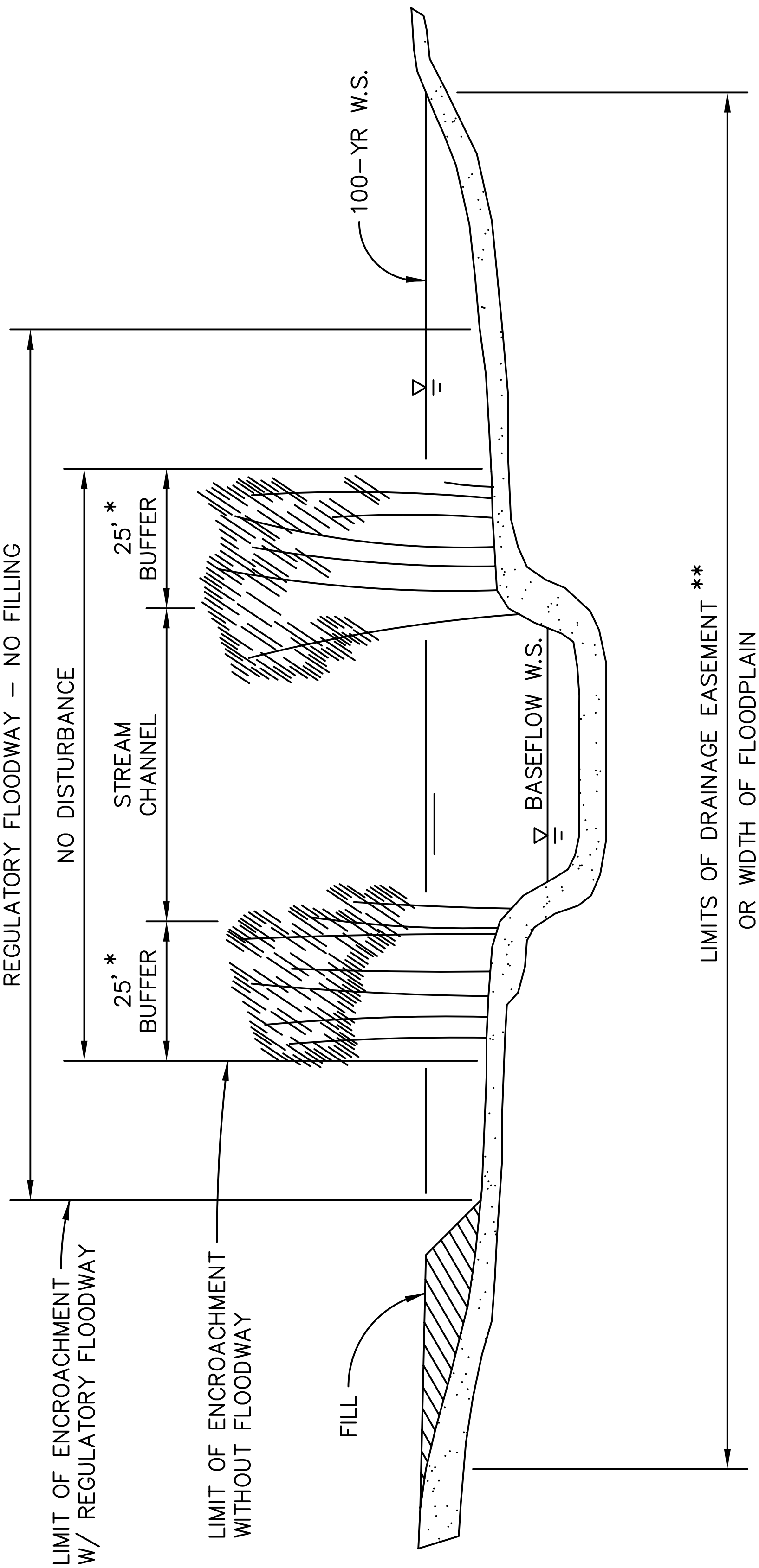

* EXISTING VEGETATION TO REMAIN. 100' WIDTH PREFERRED.

** USE FULLY URBANIZED CONDITIONS FOR PEAK FLOW RATE.

GREENE COUNTY MISSOURI - STORM WATER DESIGN STANDARDS

TYPICAL NATURAL CHANNEL

FIGURE 111.1

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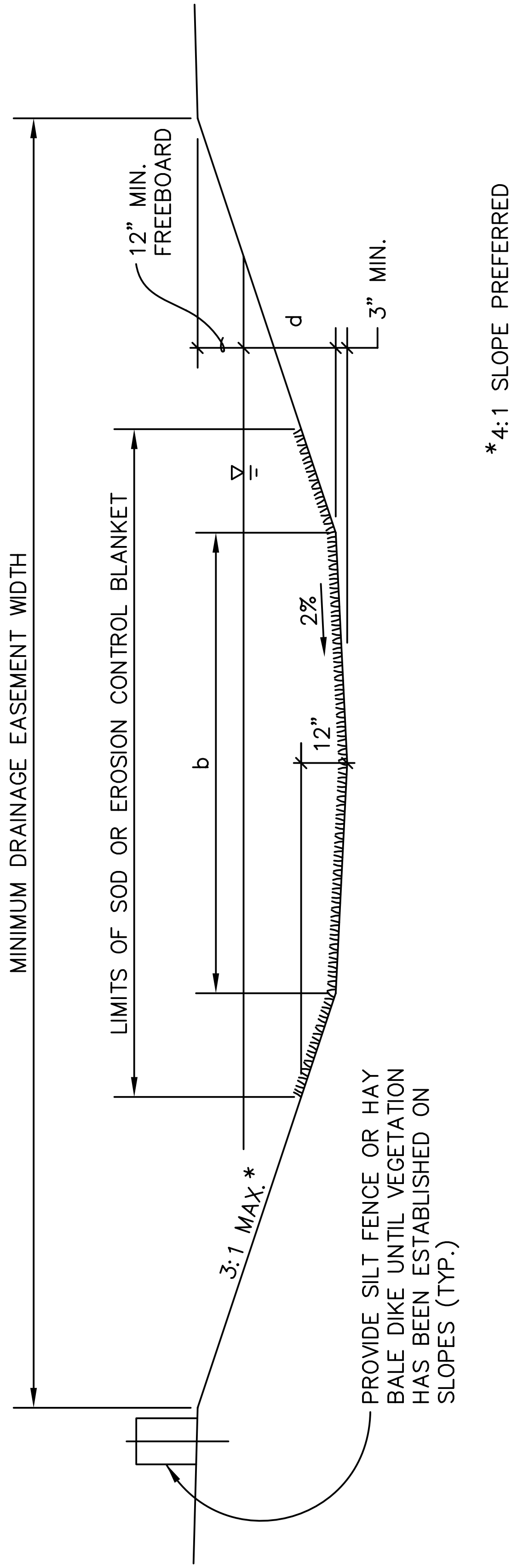
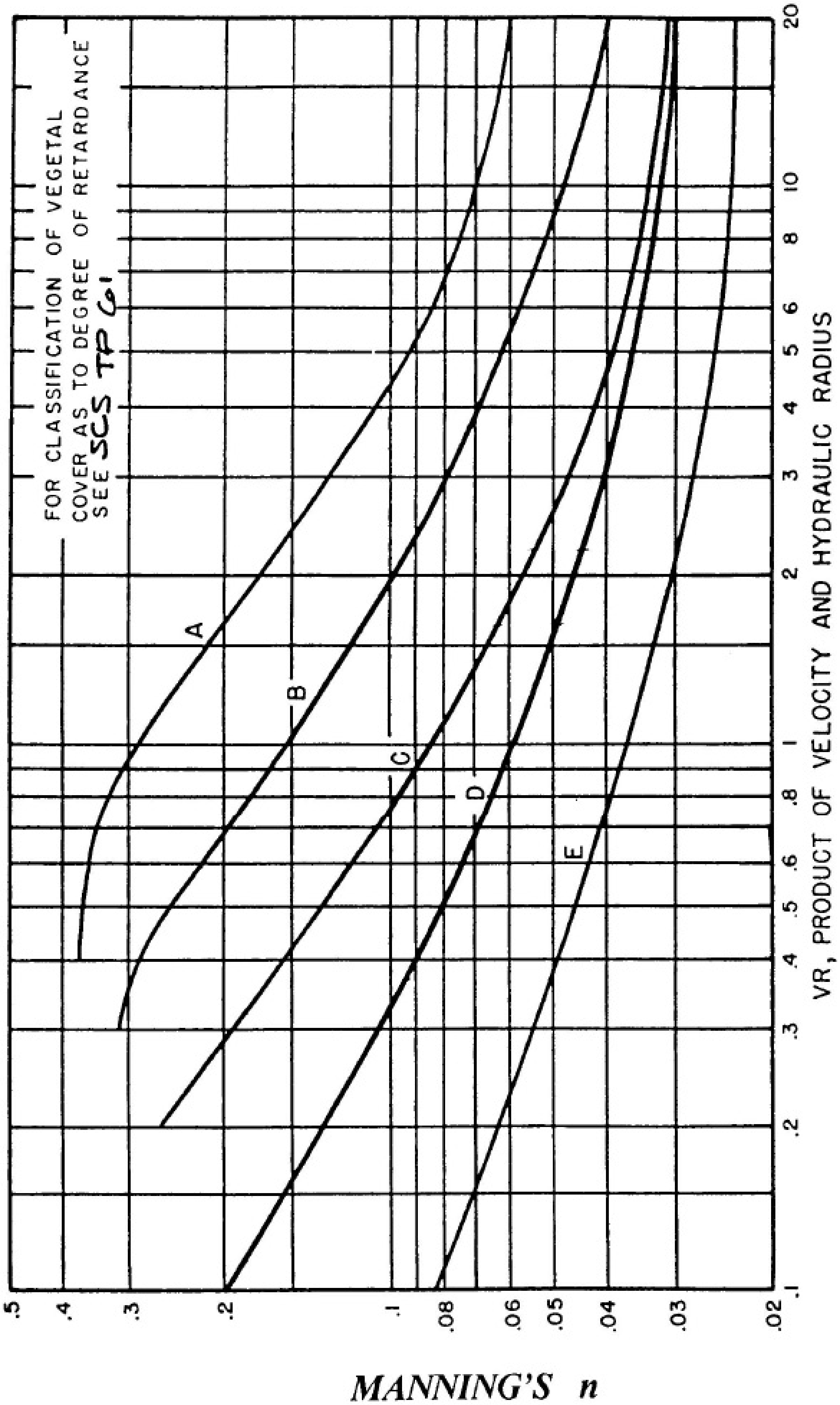


GREENE COUNTY MISSOURI – STORM WATER DESIGN STANDARDS

TYPICAL GRASS–LINED CHANNEL	**FIGURE 111.2** FILE: f11102.dwg DATE: 04/05/99



Manning n for vegetal-lined channels (from handbook of channel design for soil and water conservation SCS-TP-61 revised June 1964).

GREENE COUNTY MISSOURI – STORM WATER DESIGN STANDARDS

MANNING'S *n* FOR GRASS–LINED CHANNELS

FIGURE 111.3

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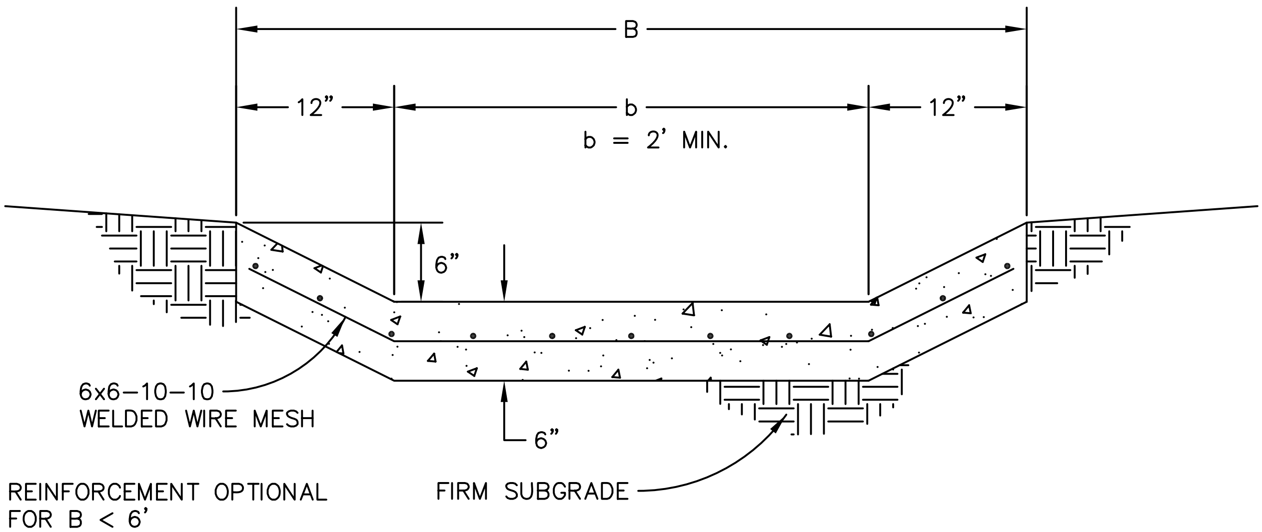

NOTE: CONCRETE WORK SHALL CONFORM TO THE REQUIREMENTS OF CHAPTER VII OF THE CITY OF SPRINGFIELD TECHNICAL SPECIFICATIONS FOR PUBLIC WORKS CONSTRUCTION.

DESIGN FLOW RATE (cfs)	RECOMMENDED TRICKLE CHANNEL WIDTH, b (ft)
< 150	2'
150 – 200	3'
200 – 250	4'
250 – 350	5'
> 350	DETERMINE ON CASE BY CASE BASIS

GREENE COUNTY MISSOURI – STORM WATER DESIGN STANDARDS

CONCRETE TRICKLE CHANNEL

FIGURE 111.4

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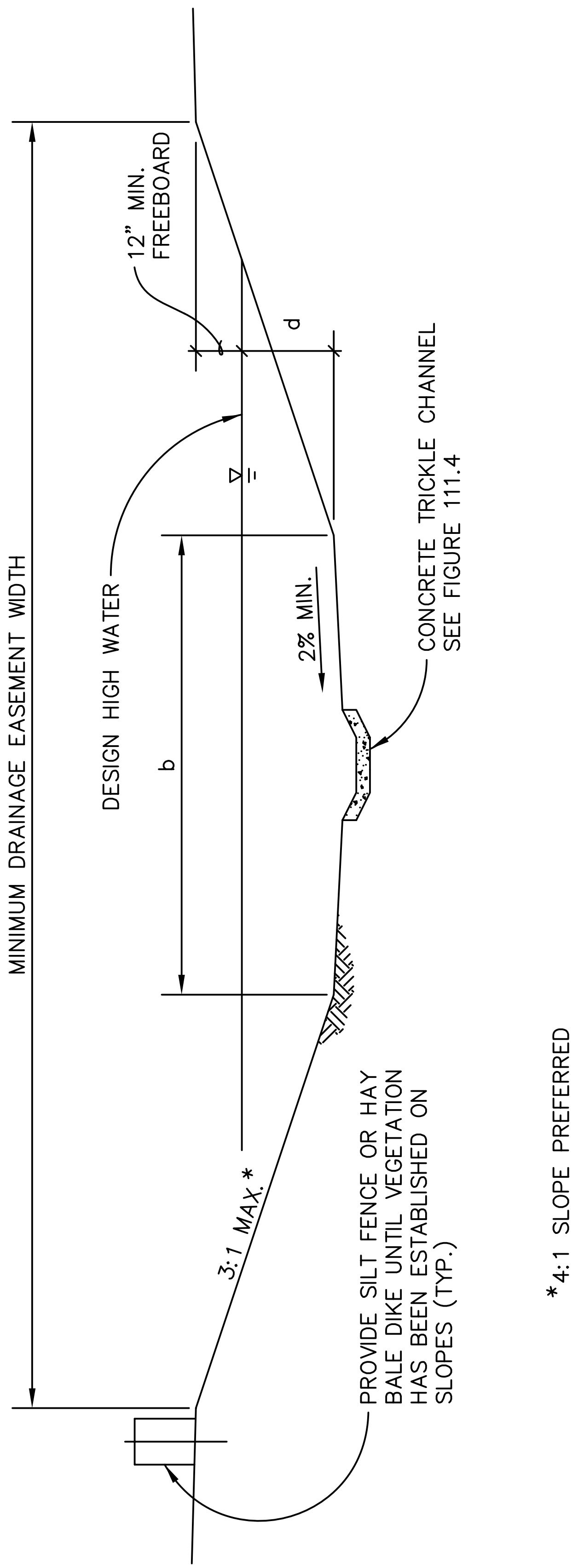

GREENE COUNTY MISSOURI – STORM WATER DESIGN STANDARDS

TYPICAL GRASS–LINED CHANNEL
WITH CONCRETE TRICKLE CHANNEL

FIGURE 111.5

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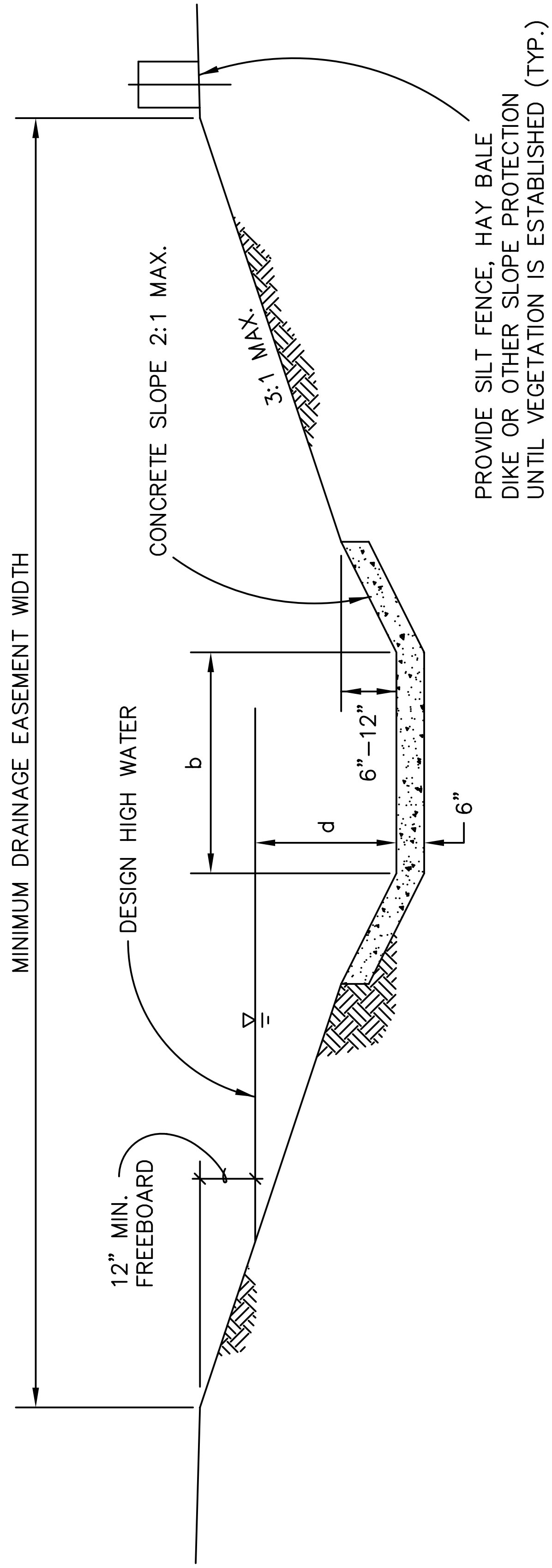

NOTES:

1. CONCRETE WORK SHALL CONFORM TO THE REQUIREMENTS OF CHAPTER VII OF THE CITY OF SPRINGFIELD TECHNICAL SPECIFICATIONS FOR PUBLIC WORKS CONSTRUCTION.

2. PROVIDE 6x6–10–10 WELDED WIRE MESH OR EQUIVALENT REINFORCEMENT FOR b > 4 FEET.

GREENE COUNTY MISSOURI – STORM WATER DESIGN STANDARDS

TYPICAL CHANNEL WITH CONCRETE INVERT AND GRASS SIDE SLOPES

FIGURE 111.6

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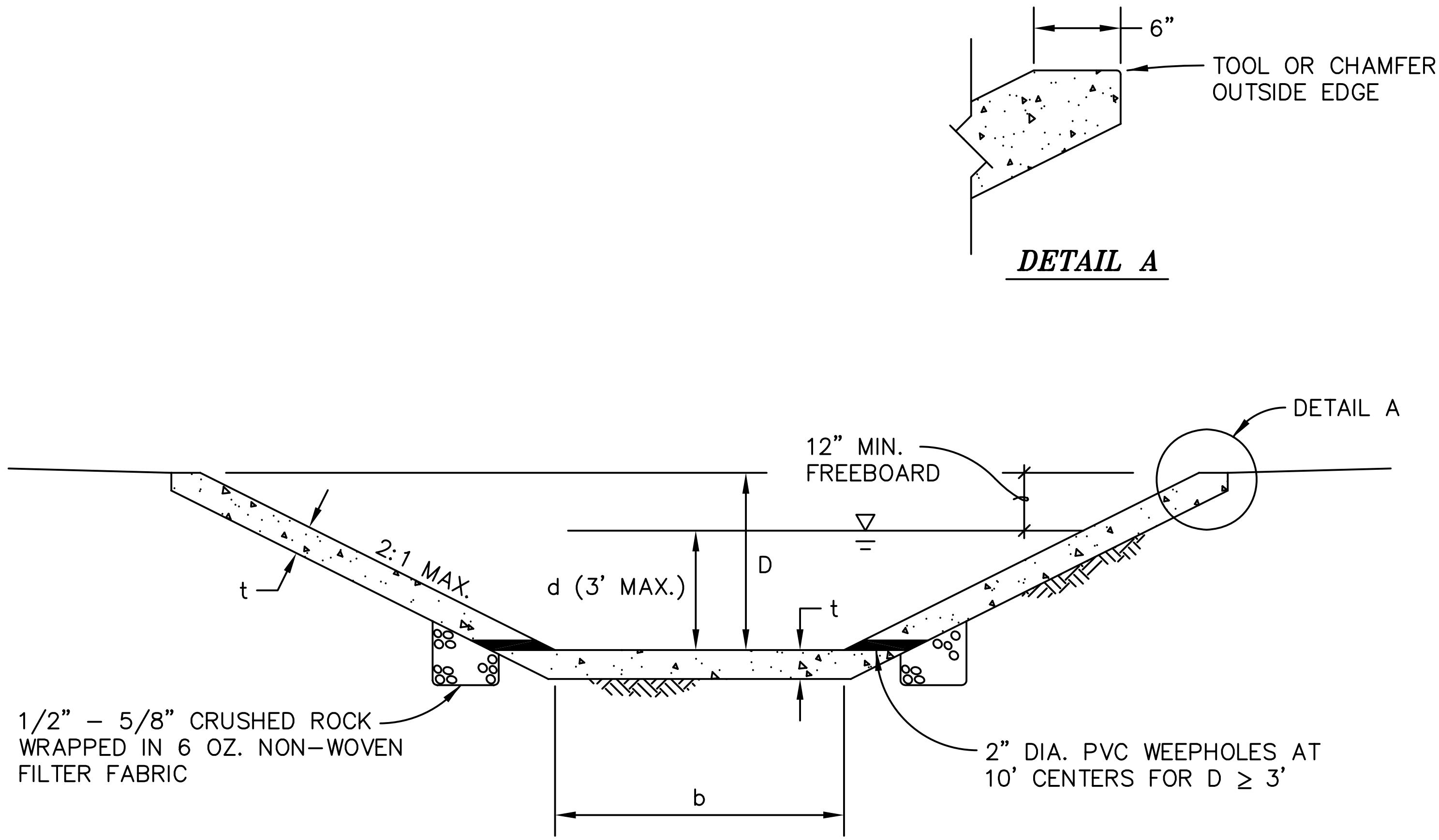

NOTES:

1. B ≤ 5’, t = 6” REINFORCE WITH 6x6–10–10 WWM
   B > 5’, t = 8” REINFORCE WITH #4’s @ 12” TRANSVERSE, #4’s @ 18” LONGITUDINAL

2. CONCRETE WORK SHALL CONFORM TO THE REQUIREMENTS OF CHAPTER VII OF THE CITY OF SPRINGFIELD TECHNICAL SPECIFICATIONS FOR PUBLIC WORKS CONSTRUCTION.

GREENE COUNTY MISSOURI – STORM WATER DESIGN STANDARDS

TRAPEZOIDAL CONCRETE CHANNEL

FIGURE 111.7

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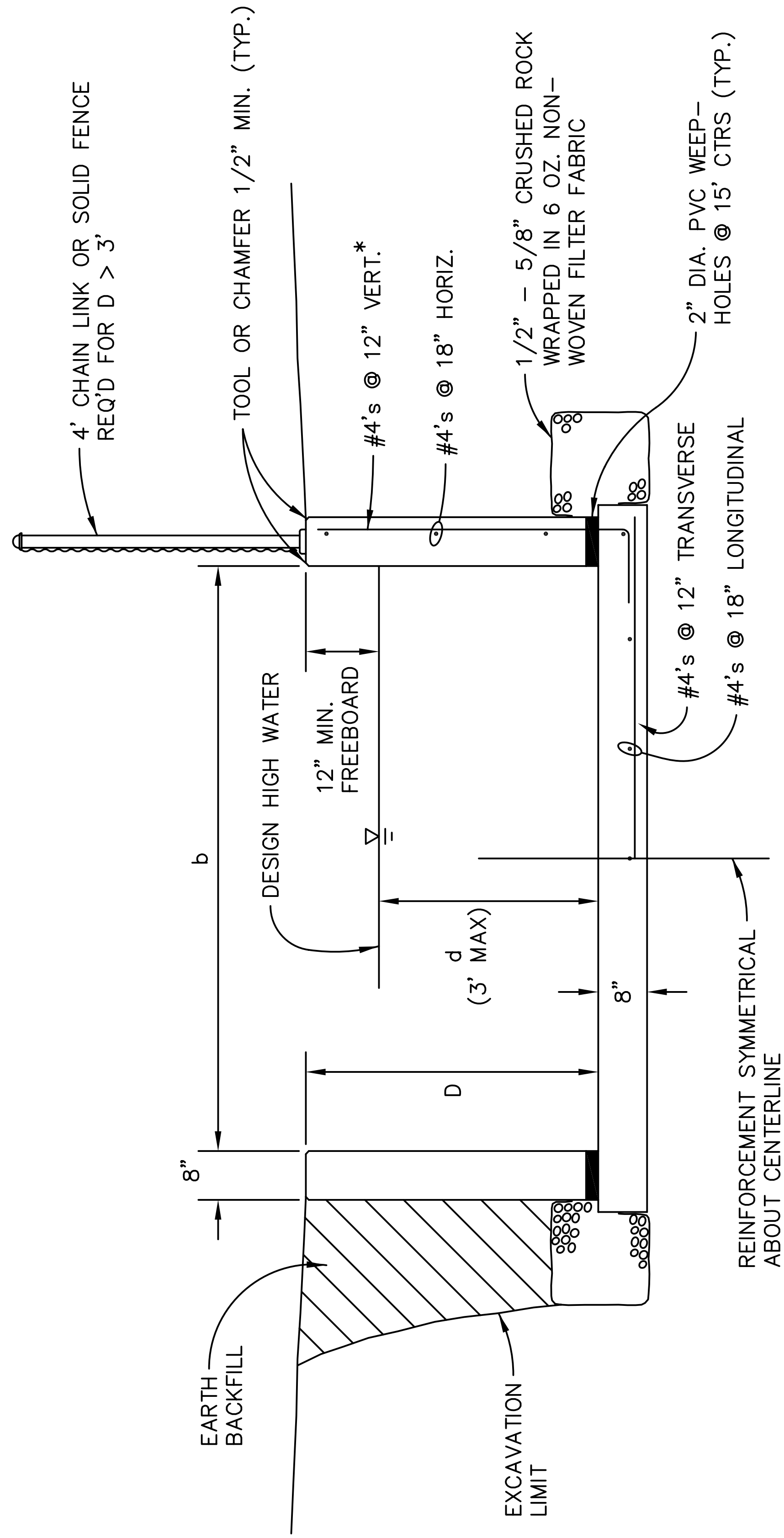

*FOR D ≤ 5'. DESIGNER MUST SPECIFY WHEN D > 5'.

NOTE: CONCRETE SHALL CONFORM TO THE REQUIREMENTS OF CHAPTER VII OF THE CITY OF SPRINGFIELD TECHNICAL SPECIFICATIONS FOR PUBLIC WORKS CONSTRUCTION.

GREENE COUNTY MISSOURI – STORM WATER DESIGN STANDARDS

RECTANGULAR CONCRETE CHANNEL

FIGURE 111.8

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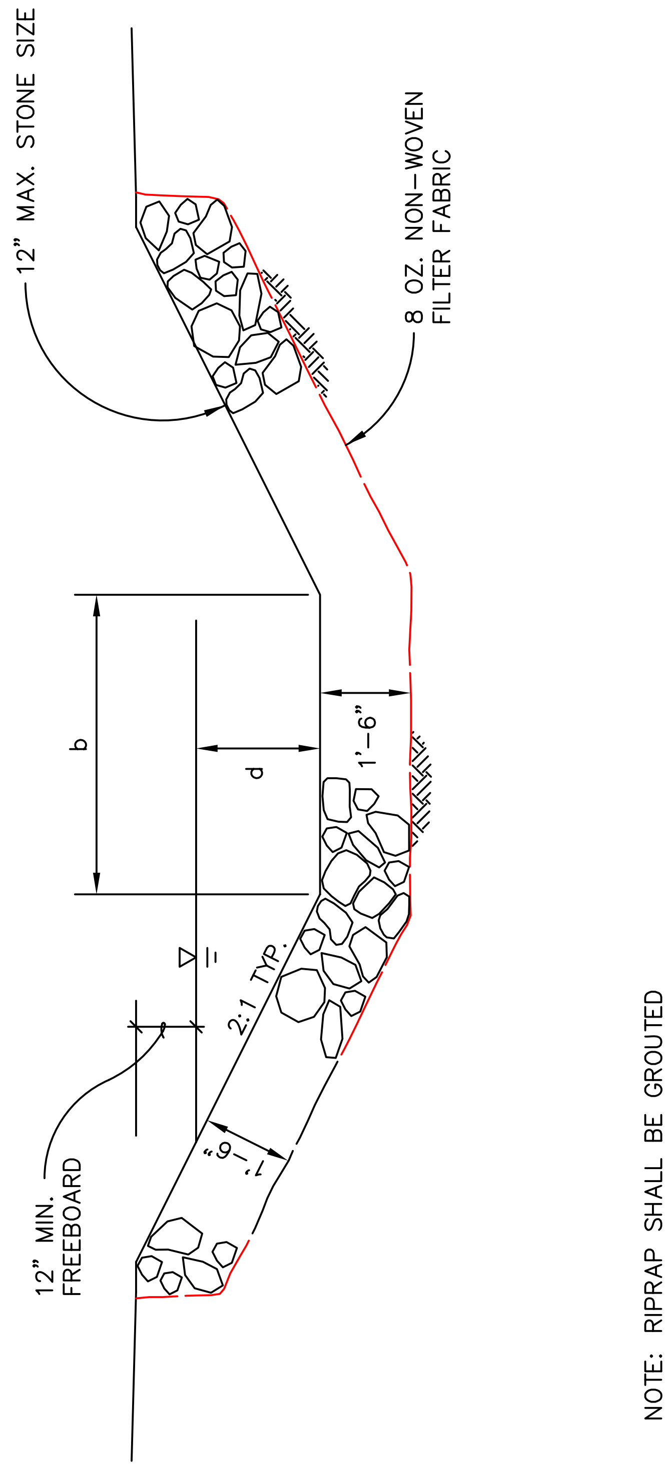

GREENE COUNTY MISSOURI – STORM WATER DESIGN STANDARDS

TYPICAL RIPRAP LINED CHANNEL

FIGURE 111.9

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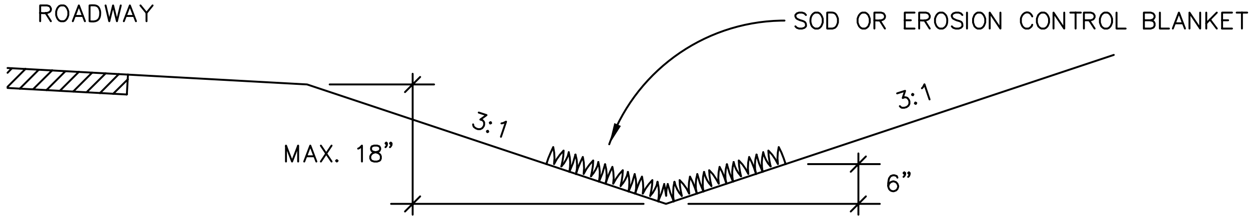
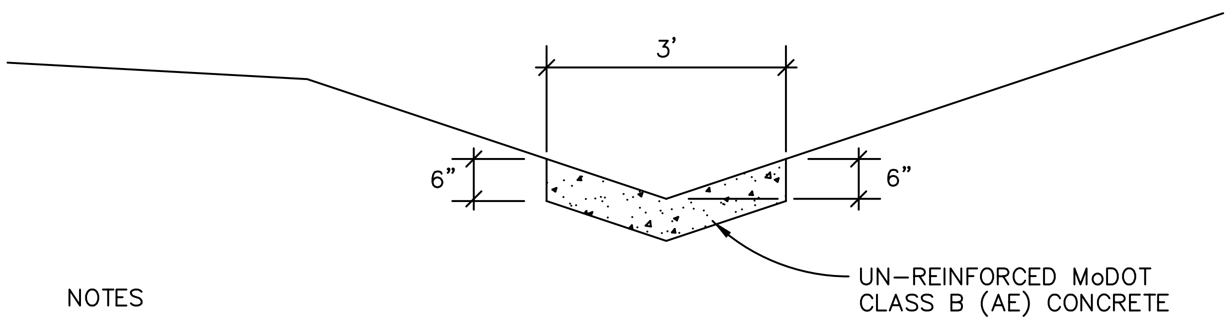


GRASS LINING



NOTES

1. PROVIDE TOOLED OR SAWCUT CONTRACTION JOINTS AT MAXIMUM 10' SPACING.
2. PROVIDE EXPANSION JOINT WITH 1/2" EXPANSION MATERIAL AT MAXIMUM 50' SPACING.

CONCRETE LINING

GREENE COUNTY MISSOURI - STORM WATER DESIGN STANDARDS

ROADSIDE DITCHES

FIGURE 111.10

FILE: f11110.dwg
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