Drainage Criteria Manual for Drainage District No. 6

Jefferson County, Texas

December 2007

Foreword

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The Jefferson Drainage District No. 6 Master Drainage Plan was prepared pursuant to House Bill 919 which authorizes drainage districts to review and approve drainage plans for proposed development if such a master plan is adopted. Preparation of the Master Drainage Plan, the District's drainage regulations, and this Drainage Criteria Manual, were supported with funding from the Texas Water Development Board. An advisory committee provided guidance throughout the effort. The committee included the District, Jefferson County, the City of Beaumont, and two local developers, a surveyor, and an engineer who are familiar with development, drainage and flooding in the area.

The Master Drainage Plan, the drainage regulations, and this manual were made available for public review. Comments were solicited and changed made, as determined appropriate by the District. The District's Board of Directors adopted the Master Drainage Plan on February 27, 2007. The drainage regulations and this manual were adopted on December 11, 2007, and made effective January 1, 2008.

The drainage regulations and the drainage criteria manual are available online at http://www.dd6.org.

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1. General Provisions

1.1 Authority and Purpose

This Drainage Criteria Manual is issued to support the Master Drainage Plan and Drainage Regulations that were adopted by the Jefferson County Drainage District No. 6 pursuant to the authority set forth in the Texas Water Code §49.211. The regulations are accessible online at www.dd6.org. Paper copies may be obtained at the offices of the District, and viewed at the City of Beaumont (Planning Division or the Public Works Department) and Jefferson County (Engineering Department).

The express intent of the Drainage Regulations is that the 100-year peak flow runoff within the boundaries of subdivisions and developments, and the 100-year peak flow discharge that flows from subdivisions and developments, be conveyed safely, that these flows have flow paths to the most appropriate District outfalls, that along the flow paths property is not adversely impacted by these flows, and that it be demonstrated that the receiving District outfalls and ditches have the capacity to convey the additional flows without increasing downstream flooding.

The manual is for users with knowledge and experience in the applications of standard engineering principles and practices of drainage design and management. It is the purpose of this Drainage Criteria Manual to outline criteria and guidance to be used by developers, engineers, and land surveyors in the design of drainage measures to manage rainfall-runoff. These criteria shall be used unless otherwise approved by the District Engineer.

1.2 Interpretation

The responsibility for interpretation of the criteria and guidance contained in this manual rests solely with the District Engineer who shall construe them in the best interests of the District. The criteria and guidance shall be considered the minimum necessary for promotion of the public health, safety and welfare with respect to stormwater runoff and drainage and reduction of flood hazards.

1.3 Conflict

This manual is not intended to interfere with, abrogate, or annul any other ordinance, rule, or regulation, statute, or other provision of law. Where any provision imposes restrictions different from those imposed by Jefferson County or an incorporated municipality within the boundaries of the District, whichever provisions are more restrictive or impose higher standards shall control.

1.4 Definitions

Terms used in these regulations may be defined in the Drainage Regulations. Terms that are not specifically defined shall have the meanings commonly used by engineers and others engaged in managing stormwater.

1.5 Pipelines and Utility Permits

These regulations do not address pipelines and utilities. The District has administrative procedures for applications for construction, maintenance, and repair of pipelines and utilities that are proposed within the District's facilities and easements. Contact the District's office to obtain the Pipeline/Utility Permit Application Packet.

2. Approval Process

2.1 Overview of Approval Process

The District's procedures are described in the Drainage Regulations. The following is an overview of the review and approval process (see flow chart below). In the event of conflict, the regulations shall prevail.

A pre-submission conference is required. The District acknowledges that drainage concerns, the adequacy of the existing drainage system and access for maintenance, and solutions to address inadequacies and flooding that may be exacerbated by new development vary from location to location. The purpose of the pre-submission conference is to improve understanding of the existing drainage system in the vicinity of and downstream of the proposed subdivision or development site and to discuss measures that are necessary and appropriate to address drainage and flooding. The District Engineer may provide information, data and computer models from the District's engineering studies, and evidence of drainage and flooding concerns based on observations and data collected from past storm and flood events.

> For commercial and industrial site development in the City of Beaumont, the District's requirement for a pre-submission conference may be satisfied during the City's required pre-submission meeting. The District will participate in these meetings and advise applicants regarding drainage. Depending on the site conditions and drainage needs in the vicinity of any given proposed development site, the District reserves the right to require a pre-submission conference.

To schedule a pre-submission conference, the Applicant/Owner submits a Concept Approval form to the District (available at http://www.dd6.org). For this purpose, the information requested includes:

A. The current land Owner(s) and the Applicant(s), if different from the Owner(s), and their addresses, telephone numbers, facsimile numbers, and e-mail addresses.

B. Designation of the Applicant/Owner's authorized representative, if any, who is authorized explicitly to act on the Applicant/Owner's behalf to obtain the District's approval, and the authorized representative's address, telephone number, facsimile number, and e-mail address.

C. The location of the proposed subdivision or development and the legal description, the tax tract number assigned by the Jefferson County Appraisal District, or the subdivision lot and block numbers.

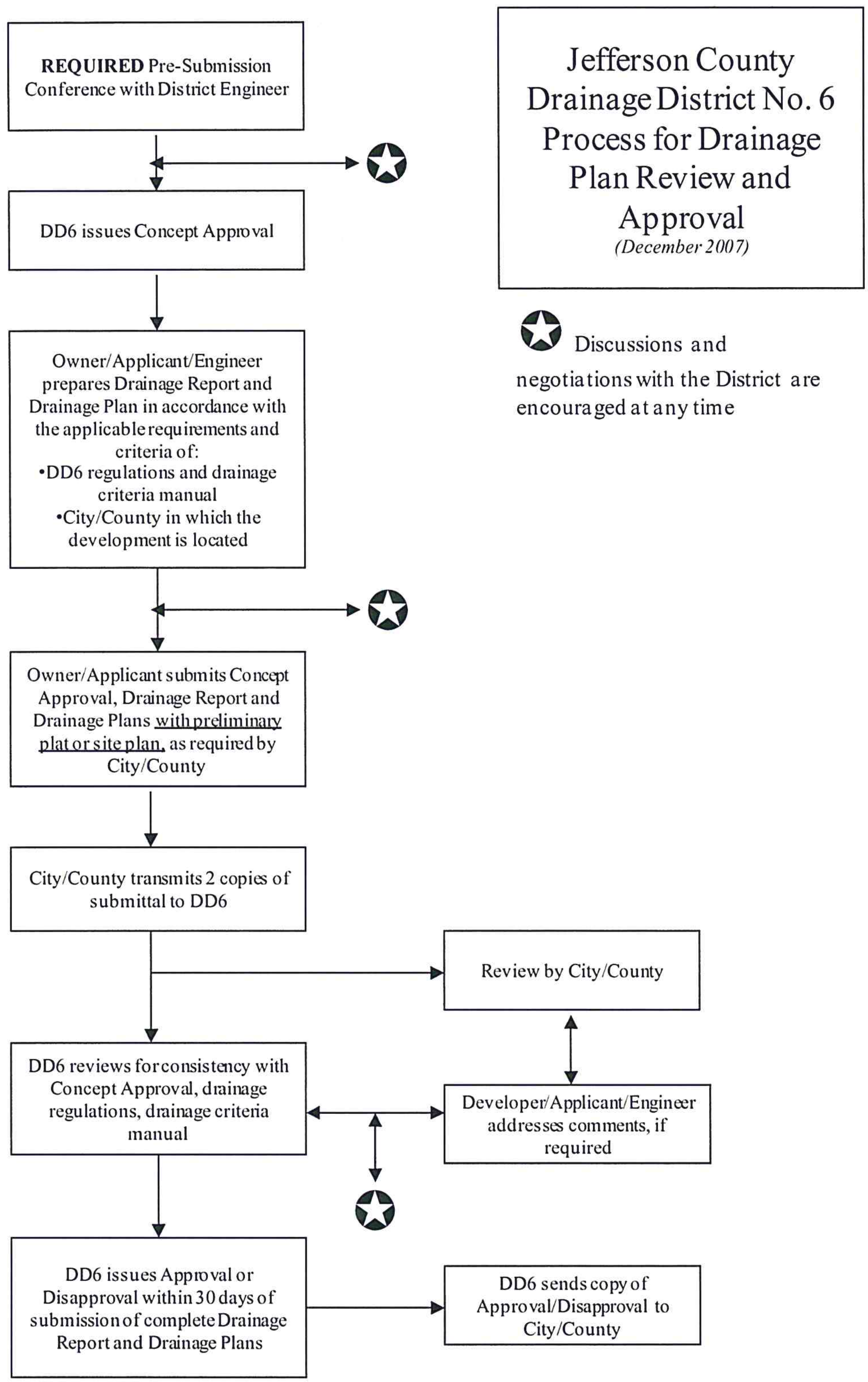
D. A general description of the proposed subdivision or development.

The District will issue a Concept Approval after the pre-submission conference. The Concept Approval will summarize the concepts, proposals, and agreements discussed at the pre-submission conference. The Concept Approval is not the District's final approval.

The Applicant/Owner will submit to the applicable local jurisdiction, the Concept Approval and a minimum of two (2) copies of the drainage report and drainage plans that are prepared in accordance with the District's drainage regulations and this manual. Addressing the District's requirements does not relieve the Applicant/Owner of the responsibility to fulfill the requirements of the applicable local jurisdiction.

The District will review the drainage report and drainage plans for consistency with the Concept Approval, the District's drainage regulations, and this manual. Additional information may be requested if necessary to perform the District's review.

At any time, Applicants/Owners and designated representatives are encouraged to contact the District, especially if it is determined that the provisions of a Concept Approval are no longer applicable due to differing conditions.


Jefferson County Drainage District No. 6 Process for Drainage Plan Review and Approval
(December 2007)
Discussions and negotiations with the District are encouraged at any time
REQUIRED Pre-Submission Conference with District Engineer
DD6 issues Concept Approval
Owner/Applicant/Engineer prepares Drainage Report and Drainage Plan in accordance with the applicable requirements and criteria of:
•DD6 regulations and drainage criteria manual
•City/County in which the development is located
Owner/Applicant submits Concept Approval, Drainage Report and Drainage Plans with preliminary plat or site plan, as required by City/County
City/County transmits 2 copies of submittal to DD6
Review by City/County
DD6 reviews for consistency with Concept Approval, drainage regulations, drainage criteria manual
Developer/Applicant/Engineer addresses comments, if required
DD6 issues Approval or Disapproval within 30 days of submission of complete Drainage Report and Drainage Plans
DD6 sends copy of Approval/Disapproval to City/County

3. Advisories

3.1 Engineering Judgment

The design requirements, criteria, and schematics included in this manual establish uniform practices for design of drainage associated with subdivisions and developments. However, the requirements of this manual neither replace the need for engineering judgment on behalf of designers, nor does it preclude the use of methods not presented. Other accepted methods and procedures may be used with prior approval of the District Engineer.

3.2 Deviations

Deviations from the District's drainage regulations and this manual, if known or anticipated, shall be identified and discussed at the pre-submission conference. Deviations are to be identified in the drainage report and the technical justification for such deviations, including computations as appropriate, shall be provided. The acceptability of the deviations shall be determined by the District Engineer.

3.3 Requirements of Other Jurisdictions

It is the responsibility of the Applicant/Owner to obtain any and all approvals required by Jefferson County, the City of Beaumont, or the other municipalities, or any other agency of the State of Texas or the United States of America. Evidence that such approvals have been applied for or obtained may be required by the District prior to issuance of an Approval.

4. Hydrologic Design Criteria

4.1 Acceptable Methods

Estimating peak flow discharges and routing flow hydrographs for the pre-development and post-development conditions is necessary for the planning, analysis, and design of drainage improvements and drainage facilities. The following hydrologic methods and models are accepted by the District:

A. **HEC-1, Flood Hydrograph Package:** developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center. Specific parameters that shall be used are described in Section 3.1.

B. **HEC-HMS, Hydrologic Modeling System:** developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center. Specific parameters that shall be used are described in Section 4.1.

C. **Rational Method:** used for peak flow discharge estimation for small rural drainage basins and is the most widely used method for urban drainage design for small drainage areas. The Rational Method equation is given below:

Q = CIA

where:

Q = peak flow (cfs)

C = dimensionless runoff coefficient

I = rainfall intensity (in/hr)

A = drainage area (acres)

4.2 Specific Design Parameters for HEC Models

Sound engineering judgment shall be used to select the parameters required and in the construction of HEC-1 and HEC-HMS models. Unless approved by the District Engineer, the following design parameters shall be used.

A. **Soil Coefficient.** The exponential loss rate function using parameters in Table 4-1, or USDA Soil Conservation Service runoff curve numbers (Appendix A), may be used.

Table 4-1. Exponential Loss Rate Parameters for Jefferson County and Beaumont

Initial Storage (STRKK)	0.3
Initial Accumulation (DLRKR)	0.0
Rate of Change (RTIOL)	0.7
Amount of Impervious Cover (RTIMP)	*

* To be calculated carefully, based on evaluation of drainage area

B. **Precipitation Distribution.** The hypothetical 24-hour, 100-year storm rainfall distribution shall be used to calculate flow rates. Rainfall shall be distributed as shown in Table 4-2.

Table 4-2. Tabulation of Rainfall from TP-40*

Frequency →	2 Year	5 Year	10 Year	25 Year	100 Year
Duration ↓	Rainfall Amount (inches)				
5 min	0.70	0.89	1.00	1.15	1.37
15 min	1.37	1.73	1.95	2.23	2.66
1 hr	2.50	3.10	3.42	3.82	4.70
2 hr	3.10	3.80	4.40	5.00	6.20
3 hr	3.40	4.25	4.80	5.65	7.00
6 hr	4.00	5.10	6.10	7.00	8.80
12 hr	4.60	6.20	7.50	8.60	11.00
24 hr	5.50	7.50	8.80	10.20	13.00

* Technical Paper 40, "Rainfall Frequency Atlas of the United States" (U.S. Weather Bureau, 1959)

C. **Storage Coefficient (R).** Clark's storage coefficient shall be determined by the following formula:

$$R = 1.6T_c$$

where:

R = Clark's storage coefficient (hrs)

T_c = time of concentration (hrs)

D. **Time of Concentration (T_c).** The time of concentration for a drainage area is a function of characteristics that can be estimated from available maps and topographic data, including the length and type of flow path that is taken by runoff. Time of concentration typically has three components: overland flow, ditch flow, and storm sewer flow. For use in HEC models, the following apply:

Basin Characteristics

where:

L_o = length of overland flow path (ft)
L_d = length of ditch flow path (ft)
L_s = length of storm sewer flow path (ft)
S_o = slope overland flow path (ft/ft)
S_d = slope of ditch flow path (ft/ft)
S_s = slope of storm sewer flow path (ft/ft)
V_d = velocity of ditch flow (ft/sec)
V_s = velocity of storm sewer flow (ft/sec)
H_r = hydraulic radius of ditch flow calculated by area divided by wetted perimeter (ft)
D = diameter of storm sewer pipe (ft)

It is assumed that the time of concentration is the time necessary for runoff to travel from the most hydraulically distant point to the outlet of the drainage area. The total travel time is the combination of travel through all flow paths: overland flow, ditch flow, and storm sewer flow. Using the basin characteristics, the formulas to calculate time of concentration are as follows:

$$T_c = T_o + T_d + T_s$$

where:

T_c = time of concentration (hrs)

T_o = overland flow travel time (hrs)

T_d = ditch flow travel time (hrs)

T_s = storm sewer flow travel time (hrs)

where:

$$T_o = 0.00013 \left[\frac{L}{S_o^{0.5}}\right]^{0.77}$$

$$T_d = \frac{L}{3600V_d}$$

$$V_d = \frac{1.49}{n} H_r^{2/3} S_d^{1/2}$$

$$T_s = \frac{L}{3600V_s}$$

$$V_s = \frac{1.49}{n}\left[\frac{D}{4}\right]^{2/3} S_s^{1/2}$$

4.3 Specific Design Parameters for Rational Method

Unless approved by the District Engineer, the following design parameters shall be used in the Rational Method equation.

A. **Runoff Coefficient "C".** The runoff coefficient "C" represents the combined effects of infiltration, surface detention, and other rainfall losses. Values of the runoff coefficient shall be as shown in Table 4-3. For drainage areas within the City of Beaumont and the Extra-Territorial Jurisdictional area of the City of Beaumont, runoff coefficients shall the smaller of values shown in Table 4-3 or the values required by the City.

Table 4-3. Runoff Coefficient "C"

Description of Area	"C"
Residential Districts	
Lots larger than ¾ acres	0.35
Lots between ¼ and ¾ acre	0.45
Lots smaller than ¼ acre	0.55
Multi-Family Areas	
Fewer than 20 dwelling units/acre	0.65
20 or more dwelling units/acre	0.80
Business/Industrial Districts	
Business	0.80
Light Industrial	0.65
Heavy Industrial	0.75
Railroad Yard	0.30
Other	
Parks, open areas	0.18

B. **Time of Concentration (T_c).** See Section 4.1(D).

C. **Intensity "I".** Rainfall intensity is a measure of the rate of rainfall over a drainage area and is expressed as a uniform rate for a period equal to the time of concentration of the drainage area. Intensity values are a function of the time of concentration, variable runoff coefficients, and the storm frequency investigated. Intensity values shall be determined by the following formula, using the coefficient values shown in Table 4-4.

$$I = b/(T_c + d)^e$$

where:

I = rainfall intensity

T_c = time of concentration

e, b, and d = runoff coefficients

Table 4-4. Rainfall Intensity Coefficients

Frequency → Runoff Coefficients ↓	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
e	0.799	0.733	0.727	0.730	0.710	0.687
b	74	65	74	86	87	84
d	9.2	7.5	7.5	7.5	7.5	9.2

Source: Texas Bridge Division Hydraulic Manual

5. Hydraulic Design Criteria

5.1 General

Determination of the water surface profile and the hydraulic gradeline is essential to the design and analysis of existing or proposed channels, detention basins, and closed conduits. Analyses involve calculating energy losses due to friction, obstructions, transitions, bends, and confluences. When calculating water surface profiles either by hand or with a computer program, all relevant sources of headloss are to be included. Design of channels and closed conduits generally focus on minimizing energy losses (results in a smaller channel/conduit) and controlling dissipation of excessive energy (reduces erosion problems).

The design of proposed drainage improvements shall ensure that the 100-year peak flow runoff within the boundaries of subdivisions and developments, and the 100-year peak flow discharge(s) that flow(s) from subdivisions and developments, is conveyed safely, and that these flows have flow paths to the most appropriate District outfalls.

Hydraulic designs are based on Manning's Equation expressed as follows:

$$Q = \frac{1.486}{n}(A)(R^{2/3})(S_f^{1/2})$$

where:

Q = flow (cu ft/sec)

n = roughness coefficient (Manning's "n")

A = cross sectional area (sq ft)

R = hydraulic radius (wetted perimeter)

S_f = slope of the hydraulic gradient

5.2 Acceptable Models

The following hydraulic models are accepted by the District.

A. **HEC-RAS, River Analysis System:** developed by the U.S. Army Corps of Engineers' Hydrologic Engineering Center. Specific parameters that shall be used are described in Section 5.1.

B. **Other Hydraulic Models:** with the approval of the District Engineer.

5.3 Specific Design Parameters

A. **Manning's "n" for Open Channels and Overbanks.** Values of Manning's "n" for open channels and overbank areas are selected based on engineering judgment. The selected values shall be the higher of the value required by the County, City of Beaumont, as applicable, or the values in Table 5-1.

Table 5-1. Manning's "n" for Open Channels and Overbanks

Type of Channel, Natural Stream, or Floodplain	Description	Minimum	Normal	Maximum
Cement:	Neat, surface	0.010	0.011	0.013
	Mortar	0.011	0.013	0.015
Concrete:	Trowel finish	0.011	0.013	0.015
	Float finish	0.013	0.015	0.016
	Finished, gravel bottom	0.015	0.017	0.020
	Unfinished	0.014	0.017	0.020
	Gunite, good section	0.016	0.019	0.023
	Gunite, wavy section	0.018	0.022	0.025
	On good excavated rock	0.017	0.020	--
	On irregular excavated rock	0.022	0.027	--
Concrete bottom float finished with sides of:	Dressed stone in mortar	0.015	0.017	0.020
	Random stone in mortar	0.017	0.020	0.024
	Cement rubble masonry, plastered	0.016	0.020	0.024
	Cement rubble masonry	0.020	0.025	0.030
	Dry rubble or riprap	0.020	0.030	0.035
Gravel bottom with sides of:	Formed concrete	0.017	0.020	0.025
	Random stone in mortar	0.020	0.023	0.026
	Dry rubble or riprap	0.023	0.033	0.036
Brick:	Glazed	0.011	0.013	0.015
	In cement mortar	0.012	0.015	0.018
Masonry:	Cemented rubble	0.017	0.025	0.030
	Dry rubble	0.023	0.032	0.035

Type of Channel, Natural Stream, or Floodplain	Description	Minimum	Normal	Maximum
Asphalt:	Smooth	0.013	0.013	--
	Rough	0.016	0.016	--
Vegetal lining		0.030	--	0.500
Excavated or dredged earth (straight and uniform)	Clean, recently completed	0.016	0.018	0.020
	Clean, after weathering	0.018	0.022	0.025
	Gravel, uniform section, clean	0.022	0.025	0.030
	With short grass, few weeds	0.022	0.027	0.033
Excavated or dredged earth (winding and sluggish)	No vegetation	0.023	0.025	0.030
	Grass, some weeds	0.025	0.030	0.033
	Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
	Earth bottom and rubble sides	0.028	0.030	0.035
	Stony bottom and weedy banks	0.025	0.035	0.040
	Cobble bottom and clean sides	0.030	0.040	0.050
Dragline – excavated or dredged	No vegetation	0.025	0.028	0.033
	Light brush on banks	0.035	0.050	0.060
Rock cuts	Smooth and uniform	0.025	0.035	0.040
	Jagged and irregular	0.035	0.040	0.050
Channels not maintained, weeds and brush uncut	Dense weeds, high as flow depth	0.050	0.080	0.120
	Clean bottom, brush on sides	0.040	0.050	0.080
	Same, highest stage of flow	0.045	0.070	0.110
	Dense brush, high stage	0.080	0.100	0.140
Minor natural streams (top width at flood stage < 100 ft); low slope topography	Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
	Same as above, but more stones and weeds	0.030	0.035	0.040
	Clean, winding, some pools and shoals	0.033	0.040	0.045
	Same as above, but some weeds and stones	0.035	0.045	0.050
	Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
	Same as above, but with some weeds and more stones	0.045	0.050	0.060

Type of Channel, Natural Stream, or Floodplain	Description	Minimum	Normal	Maximum
	Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
	Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Natural mountain streams, no vegetation in channels, banks usually steep, trees and brush along banks submerged at high stages	Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
	Bottom: cobbles with large boulders	0.040	0.050	0.070
Floodplains, pasture, no brush	Short grass	0.025	0.030	0.035
	High grass	0.030	0.035	0.050
Floodplains, cultivated areas	No crop	0.020	0.030	0.040
	Mature row crops	0.025	0.035	0.045
	Mature field crops	0.030	0.040	0.050
Floodplains, brush	Scattered brush, heavy weeds	0.035	0.050	0.070
	Light brush and trees, in winter	0.035	0.050	0.060
	Light brush and trees, in summer	0.040	0.060	0.080
	Medium to dense brush, in winter	0.045	0.070	0.110
	Medium to dense brush, in summer	0.070	0.100	0.160
Floodplains, trees	Dense willows, summer, straight	0.110	0.150	0.200
	Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
	Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
	Heavy stand of timber, few trees down, little undergrowth, flood stage below branches	0.080	0.100	0.120
	Same as above, but with flood stage reaching branches	0.100	0.120	0.160
Major streams (top width at flood stage > 100ft).	Regular section with no boulders or brush	0.025	--	0.06
	Irregular and rough section	0.035	--	0.100

Source: Open-Channel Hydraulics by V.T. Chow, 1959 (reproduced as Table 3-1 in the District's study by Bernard Johnson)

B. **Manning's "n" for Closed Conduits.** Values of Manning's "n" for closed conduits (pipes and culverts) are selected based on the type of material and engineering judgment. The selected values shall be the higher of the value required by the County, City of Beaumont, as applicable, or the values in Table 5-2.

Table 5-2. Manning's "n" for Closed Conduits

Reinforced Concrete Pipe	0.012
Reinforced Concrete Box	0.012
Smooth Flow Metal Pipe[1]	
Asphaltic Lining	0.012
Double Wall	0.012
Concrete Lining	0.012
Ultra Flow	0.012
Corrugated Metal Pipe[2]	0.024
Structural Plate Pipe[3]	0.027 – 0.036
Long Span Structural Pipe	0.031[1]

[1] For composite perimeters (e.g., partial smooth flow), a weighted roughness coefficient based upon relative perimeters must be calculated.

[2] For helically-corrugated metal pipe of diameters less than 36-inch, an improved roughness coefficient is possible. Consult the Texas Department of Transportation's Hydraulic Manual, "Hydraulic Flow Resistance Factors for Corrugated Metal Conduits", FHWA.

[3] Due to the number of variations in structural plate pipe, there are many possibilities for roughness coefficient.

Source: City of Beaumont, Public Works Department, Procedure Manual, Specifications and Details

C. **Starting Water Surface Elevation.** For drainageways that directly discharge to a District outfall, the starting water surface elevation (tailwater condition) will be provided by the District Engineer at the pre-submission conference. For other drainageways, the design shall assume that the receiving ditch is flowing full (top of bank).

6. Design Criteria for Channels

6.1 General

The requirements of this section apply to drainageways and channels that are designed to convey drainage. Acceptable designs will provide for adequate conveyance of design discharges, incorporate measures to address potential erosion, and be designed to allow for access and maintenance.

Earthen, grass-lined channels generally produce lower flow velocities and more channel storage; they generally require more right-of-way, are more vulnerable to erosion, and require periodic mowing and maintenance. Concrete-lined channels generally convey flows at higher velocities with less storage, which may increase downstream peak flows and discharges; they generally require less right-of-way and are more stable under higher flow velocities.

6.2 Channels to be Conveyed to the District

Unless otherwise approved by the District Engineer, the following design criteria apply to channels to be conveyed to the District.

A. **General Performance Requirement.** Open channels shall be designed to convey the design discharge such that the water surface elevation is a minimum of one (1) foot below the top of the channel section. This provides a minimum margin of safety in the event of channel obstructions or sedimentation, unaccounted changes in upland drainage, and for flows that exceed the design discharge.

B. **Maximum Velocity in Open Channels.** Open channels shall be designed such that velocities during the 100-year peak flow discharge will not cause erosion at any point along the channel.

C. **Maximum Velocity in Conduits and Pipes.** Conduits and pipes shall be designed to convey the 100-year peak flow discharge at velocities that do not exceed 7 feet per second.

D. **Channel Alignment and Transitions.** Changes in horizontal channel alignment (bends and curves), transitions in cross section size, geometry, and changes in channel type, are to be gradual to minimize head losses, changes in flow regime, deposition of sediment, and potential for erosion.

E. **Erosion Protection.** Earthen, grassed channels and transitions from earthen, grassed channels to lined channels, shall have erosion protection if the velocities associated with the design discharge indicate the potential for erosion. Erosion protection may be appropriate along curved channels sections, at bridge and culvert transitions, at confluences, where side ditches outfall into the channel, in areas with erodible soils, and other locations based on a review of site conditions and flow velocities.

F. **Minimum Channel Dimensions – Earthen, Grassed Channels.** Unless site constraints or other conditions warrant other dimensions, the minimum dimensions are:

- Bottom width: 10 feet
- Side slopes: 3 horizontal to 1 vertical

G. **Minimum Channel Dimensions – Concrete-Lined Channels.** The minimum dimensions are:

- Bottom width: 8 feet
- Side slopes: 1.5 horizontal to 1 vertical
- Width and depth of low flow section formed in bottom: to be determined on a case-by-case basis

6.4 Channels Not to be Conveyed to the District

For channels not conveyed to the District, the minimum dimensions shall be those required by the applicable local jurisdiction.

7. Design Criteria for District Outfalls

7.1 General

The requirements of this section apply to the District's outfalls. Outfalls are defined in the District's drainage regulations to include the receiving District ditch, the point at which a contributory open drainage ditch discharges into the District's ditch, and/or the end of a drainage pipe that discharges into a District ditch. The term includes slope paving or other means to control erosion if provided or required at the outfall.

7.2 Performance Expectations and Design Requirements

Unless otherwise approved by the District, proposed work that affects or modifies District outfalls shall be demonstrated to meet the following requirements:

A. Improvements to outfalls shall be designed to convey the 100-year peak flow discharge.

B. Receiving outfalls shall be demonstrated to convey additional flows without increasing downstream flooding associated with the 100-year peak flow discharge.

C. Where new drainageways confluence with District outfall channels, the angle of intersection between the channels shall be between 15 degrees and 45 degrees, to provide for smooth transitions and reduce the potential for scour.

D. Expansions and contractions are to be designed to minimize energy losses.

E. Erosion protection shall be used where engineering judgment and experience suggest it is appropriate to protect the District's drainage facilities.

F. Erosion protection shall be used where velocities are calculated to be greater than 5.0 feet per second or where soil conditions dictate.

7.3 Design Schematics

For guidance, the District provides the sample schematics shown in Appendix B to illustrate designs that have been effective:

A. Pipe tie-in at low-flow lined ditch

B. Pipe tie-in at concrete lined ditch

C. Pipe tie-in at earthen ditch

D. 100-year peak flow discharge overflow at District right-of-way

E. Curb cut overflow and swale overflow

F. Typical earthen ditch section

G. Typical concrete ditch section
H. Typical box culvert transition to earthen or concrete channel

The requirements of this section apply to new, replacement or modified bridges and culverts that cross the District's drainage facilities.

8. Design Criteria for Roadways Crossing District Facilities

8.1 Performance Expectations and Design Requirements for New Crossings

Unless otherwise approved by the District, new bridges and new culverts that are proposed for roadways that will cross the District's drainage facilities shall:

A. Be designed to maintain the direction of flow in the District's drainage facility.

B. Be designed so as not to encroach into the District's drainage facility nor to impede the flow of water in the District's drainage facilities under normal flow conditions and under flood conditions.

C. Be designed so as not to impede the flow of drainage to the District's drainage facilities.

D. Convey the 100-year peak flow discharge with no increase in base flood elevation that increases flooding on any property.

E. Be designed to convey the 100-year peak flow with a maximum flow velocity of 7 feet per second.

F. Be designed to span completely the District's drainage facility; if not feasible, the design of bridge piers or separation between multiple culverts shall minimize the potential for debris blockage; additional freeboard between the base flood elevation and the low chord of the bridge or top of the culvert may be required.

G. For bridges, be designed with the lowest chord at least one-foot above the higher of the base flood elevation or the top of bank of the channel.

H. For culverts, be designed to convey the 100-year peak flow discharge with 6-inch total head loss (for flowing full condition).

I. Be designed to minimize transitions and head losses associated with expansions and contractions (see Schematic 8 in Appendix B).

J. Not encroach on the FEMA-designated floodway unless such encroachment is approved by FEMA through issuance of a Conditional Letter of Map Revision. It is the Applicant/Owner's responsibility to submit the required documentation to FEMA. The District will not review a submittal that proposes a floodway encroachment unless the Conditional Letter of Map Revision is included.

K. Be designed to protect against erosion during passage of the 100-year peak flow discharge.

L. Be designed with adequate bottom width and side slopes to allow for maintenance by the District.

M. Not be designed to involve alteration of the District's facility as a means to compensate for loss of cross-sectional area.

8.2 Performance Expectations and Design Requirements for Replacement or Modified Crossings

Unless otherwise approved by the District, replacement bridges, replacement culverts, or modifications of existing bridges and culverts shall:

A. Match the roadway approach and alignment, unless otherwise required by the owner or the applicable local jurisdiction; if changes are required the crossing shall, to the extent practical, conform to the performance expectations and design requirements for new crossings in Section 8(A).

B. Improve transitions to minimize expansion and contraction losses.

C. Be designed to reduce obstructions, especially if the District has evidence that the existing crossing is subject to blockage by debris or sedimentation.

D. Be designed to address known erosion problems at the crossing.

8.3 Design Schematics

For guidance, the District provides Schematic 8, shown in Appendix B to illustrate configurations that minimize transitions and head losses associated with expansions and contractions.

9. Drainage and Flood Hazard Reduction Criteria

9.1 General

Drainage reports and drainage plans for subdivisions and developments shall demonstrate that design of the proposed drainage system will manage increases in runoff in ways that are consistent with the District's drainage regulations and this manual.

If drainage designs developed in accordance with the District's drainage regulations and this manual are determined to be inadequate to address increases in runoff, specific drainage and flood hazard reduction measures will be discussed at the pre-submission conference. The effectiveness of alternatives will be determined based on adequacy of existing drainage capacity and existing flooding problems.

10. On-Site Detention and Retention Criteria

10.1 General

The District does not encourage privately-owned, on-site detention and on-site retention facilities. A detention facility is designed to store runoff, while releasing discharges continuously at acceptable rates through flow-limiting outlet structures, thus controlling downstream peak flows. A retention facility, often designed to have a permanent pool, is designed to store runoff and release it after passage of peak flows.

On-site facilities may be required if receiving District drainage facilities do not have the capacity to convey the additional flows from a proposed development or subdivision without increasing downstream flooding of any property, or if other approaches for managing increases in runoff do not adequately meet the performance expectation that 100-year peak flow discharge be conveyed safely along adequate flow paths to the most appropriate District outfalls without adversely impacting any properties.

10.2 State Jurisdiction

The District's requirements are independent of any requirements that may be imposed by the State. Detention and retention facilities for which the height of the dam (embankments) is greater than six (6) feet are subject to Title 31 Texas Administrative Code, Chapter 200 (sub chapters A through E), and all subsequent changes. For the purpose of this determination, the height of the dam is defined as the distance from the lowest point on the crest of the dam, excluding spillways, to the lowest elevation on the centerline or downstream toe of the dam, including the natural stream channel.

10.3 District Approval

The District may withhold approval of a facility that is subject to State jurisdiction unless provided evidence that an application has been submitted to the State or a permit or approval has been received from the State.

10.4 Performance Expectations and Design Requirements

Unless otherwise approved by the District, proposed on-site detention and retention facilities shall be demonstrated to meet the following requirements:

A. Commercial computer programs are available for designing detention and retention facilities and their associated inflow and outflow structures; early coordination with the District Engineer is recommended to ensure the proposed program is acceptable.

B. A detailed soils investigation by a geotechnical engineer shall be undertaken and included in the Drainage Report.

C. The maximum post-development discharge for the 100-year peak flow, measured where drainage leaves the Applicant/Owner's property, shall not exceed the pre-development 100-year peak flow discharge at that location. The modified pulse routing method may be used to calculate flows from detention and retention facilities.

D. Drainage of the detention facility shall be free drainage only (gravity drainage); pumped detention facilities shall not be approved unless it is demonstrated to the satisfaction of the District Engineer that other methods are infeasible or do not provide the necessary management of drainage.

E. Erosion protection shall be provided at the discharge point and downstream to where it is determined that the drainage path will be stable during the 100-year peak flow discharge.

F. The facility shall be sized such that the water surface resulting from the inflowing 100-year peak discharge will be below the top of the embankment.

G. An emergency spillway or overflow structure shall be provided to handle discharges that exceed the 100-year peak flow discharge.

H. Adequate access for inspection and maintenance shall be provided.

10.5 Inspection and Maintenance Agreement

Applicant/Owners will be required to execute an agreement that addresses inspection and maintenance, in addition to any provision required by the State or the applicable local jurisdiction. The agreement shall:

A. Address routine and periodic inspection and maintenance to provide for the designed detention or retention function.

B. Address inspection after floods and maintenance and repairs that may be required to restore the designed function.

C. Clearly identify the property owner as responsible for inspection and maintenance, and shall provide for action by the property owner upon notification by the District that maintenance or repairs may be required.

D. Be recorded with the deed and shall convey the inspection and maintenance responsibilities to future owners and assigns.

APPENDIX A. SCS RUNOFF CURVE NUMBER TABLES

Table 2-2a: Runoff curve numbers for urban areas

Table 2-2b: Runoff curve numbers for cultivated agricultural lands

Table 2-2c: Runoff curve numbers for other agricultural lands

Table 2-2d: Runoff curve numbers for arid and semiarid rangelands

Source: U.S.D.A. Soil Conservation Service, *Urban Hydrology for Small Watersheds*, Technical Release No. 55 (2nd Edition, June 1986). Accessible online at: ftp://ftp.wcc.nrcs.usda.gov/downloads

Table 2-2a Runoff curve numbers for urban areas [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1 Average runoff condition, and $I_a = 0.2S$.

2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2-2b Runoff curve numbers for cultivated agricultural lands [1]

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment [2]	Hydrologic condition [3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

1 Average runoff condition, and I_a=0.2S
2 Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.
3 Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 2-2c Runoff curve numbers for other agricultural lands [1/]

Cover description: Cover type	Hydrologic condition	Curve numbers for hydrologic soil group: A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. [2/]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3/]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4/]	48	65	73
Woods—grass combination (orchard or tree farm). [5/]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6/]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4/]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.

2 *Poor:* <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.

3 *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

4 Actual curve number is less than 30; use CN = 30 for runoff computations.

5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

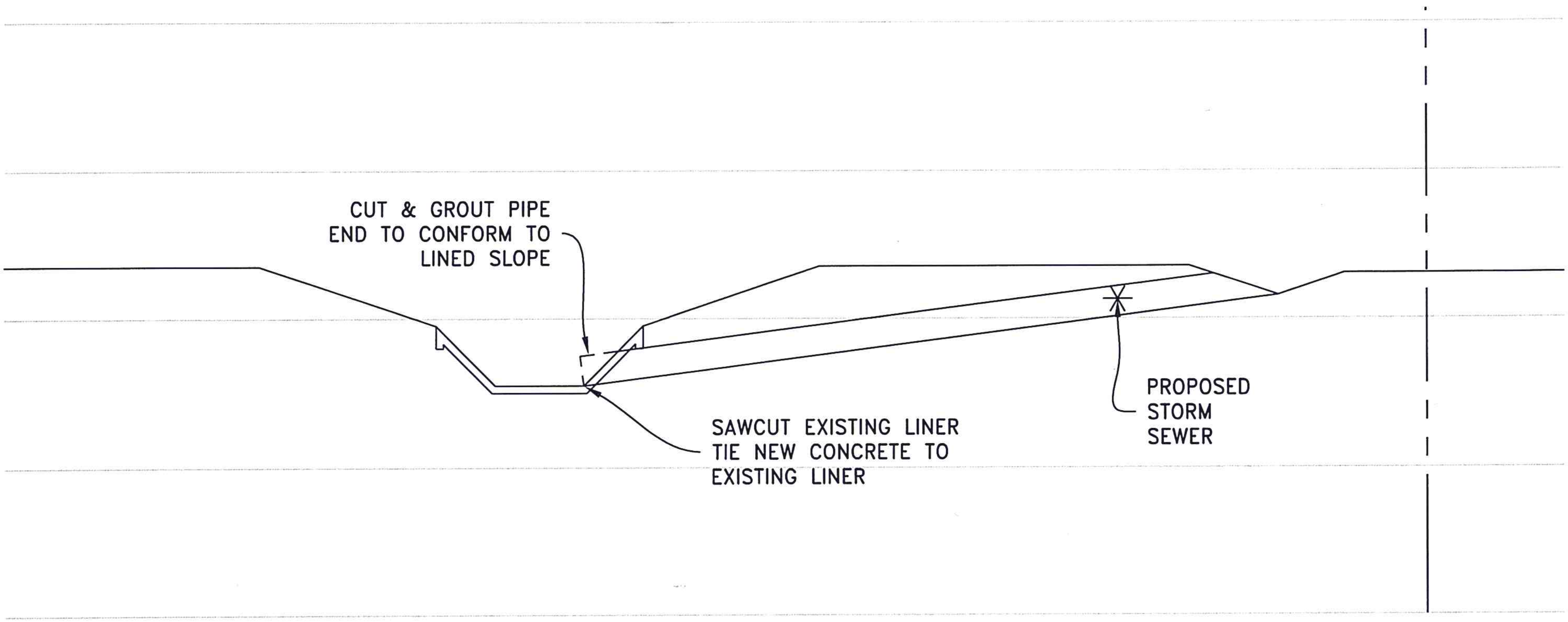
Table 2-2d Runoff curve numbers for arid and semiarid rangelands [1/]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition [2/]	A [3/]	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

1 Average runoff condition, and I_a, = 0.2S. For range in humid regions, use table 2-2c.
2 Poor: <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: > 70% ground cover.
3 Curve numbers for group A have been developed only for desert shrub.

APPENDIX B. SAMPLE DESIGN SCHEMATICS

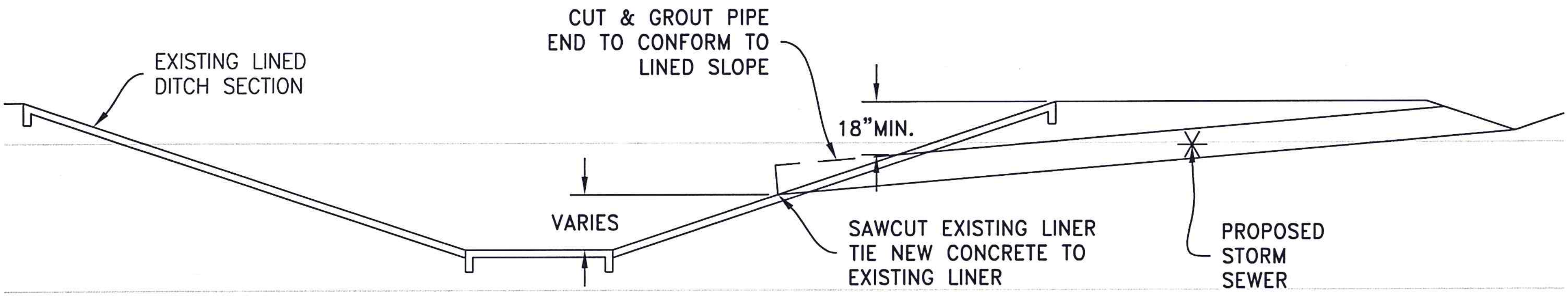
Schematic 1: Pipe tie-in at low-flow lined ditch
Schematic 2: Pipe tie-in at concrete lined ditch
Schematic 3: Pipe tie-in at earthen ditch
Schematic 4: 100-year peak flow discharge overflow at District right-of-way
Schematic 5: Curb cut overflow and swale overflow
Schematic 6: Typical earthen ditch section
Schematic 7: Typical concrete ditch section
Schematic 8: Typical box culvert transition to earthen or concrete channel



TYPICAL DITCH CROSS SECTION
NEW STORM SEWER TIE-IN
LOW FLOW LINED SECTION

ALL STORM SEWERS ENTERING A DD6 OUTFALL WITH CONCRETE LINING ARE REQUIRED TO ENTER THROUGH LINING WHERE PRACTICAL. IF NOT PRACTICAL, AN ALTERNATIVE WILL BE DESIGNED AND DETAILED BY APPLICANT AND APPROVED BY DD6.

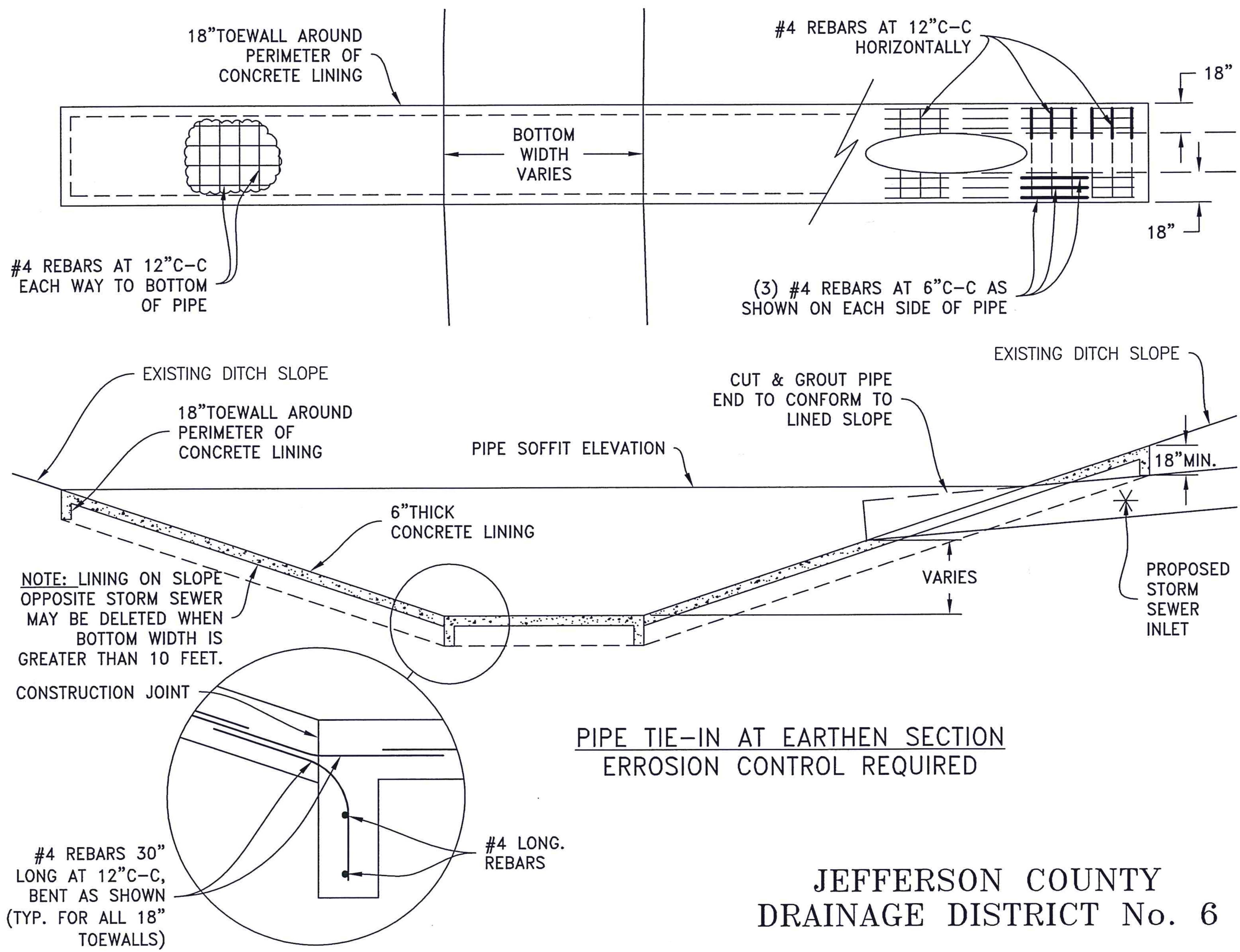
JEFFERSON COUNTY
DRAINAGE DISTRICT No. 6



TYPICAL DITCH CROSS SECTION
NEW STORM SEWER TIE-IN
AT CONCRETE LINED DITCH

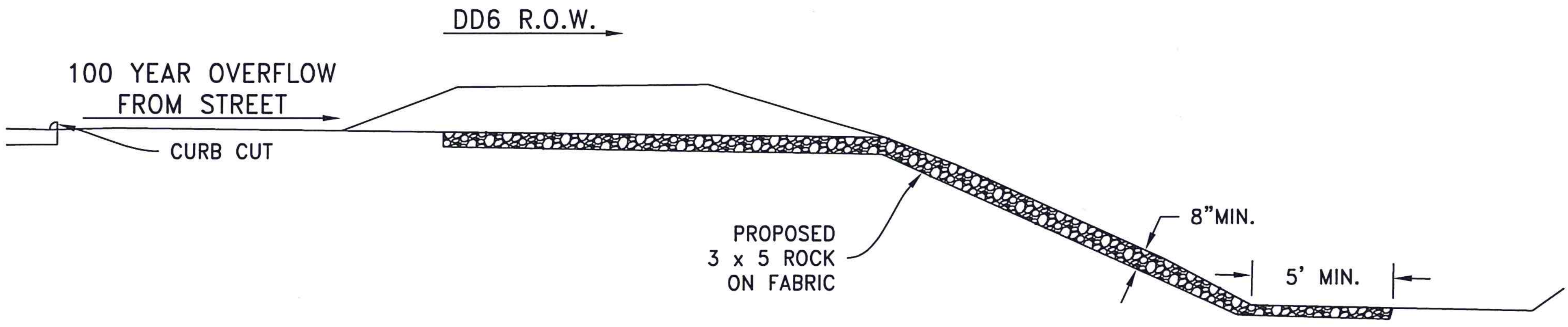
ALL STORM SEWERS ENTERING A DD6 OUTFALL WITH CONCRETE LINING ARE REQUIRED TO ENTER THROUGH LINING WHERE PRACTICAL. IF NOT PRACTICAL, AN ALTERNATIVE WILL BE DESIGNED AND DETAILED BY APPLICANT AND APPROVED BY DD6.

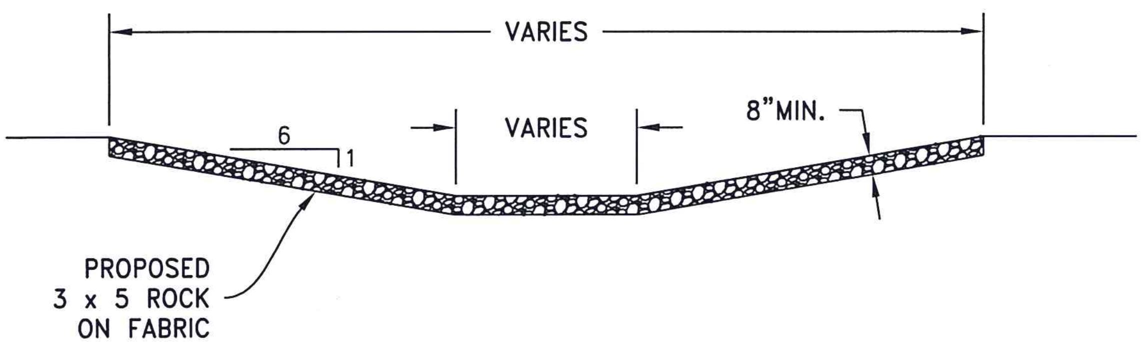
JEFFERSON COUNTY
DRAINAGE DISTRICT No. 6



PIPE TIE–IN AT EARTHEN SECTION
ERROSION CONTROL REQUIRED

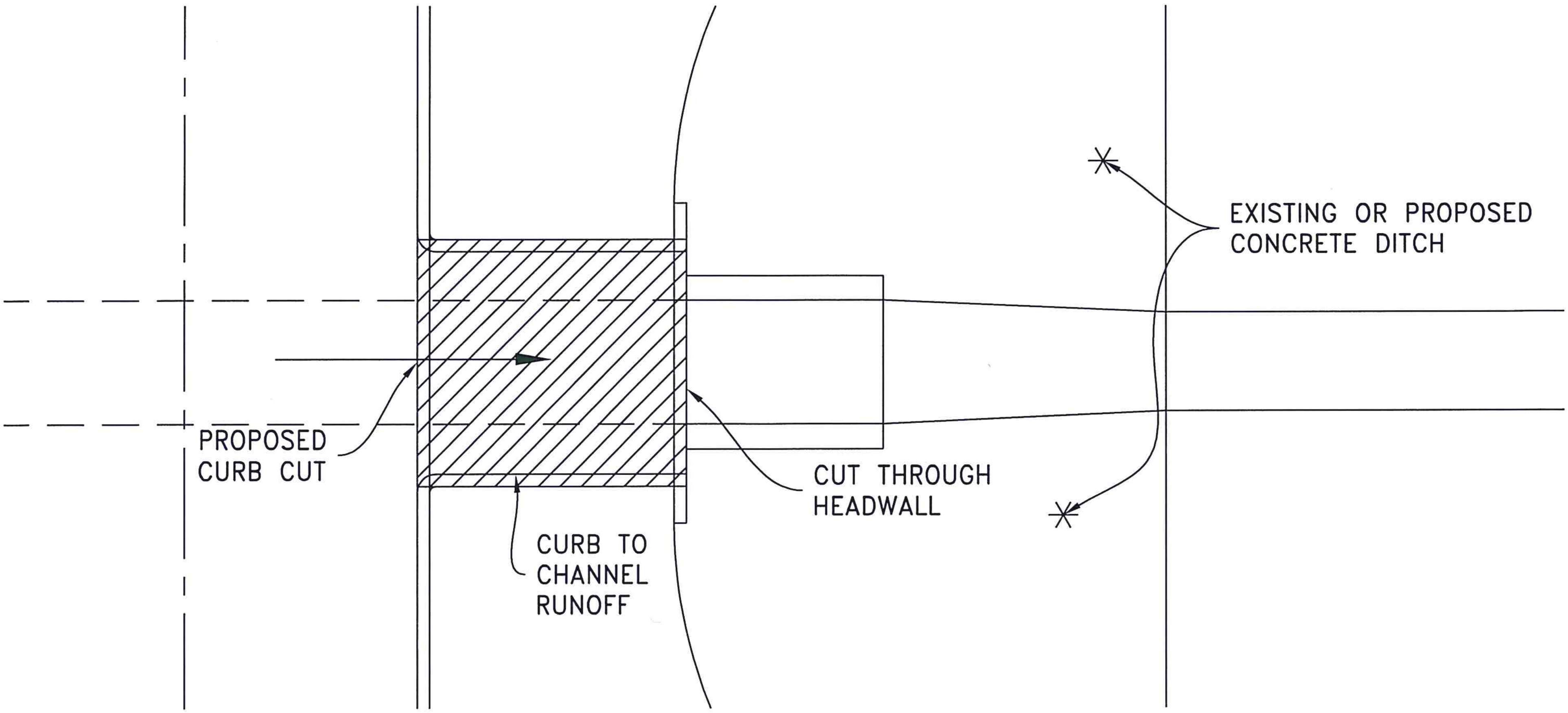
JEFFERSON COUNTY
DRAINAGE DISTRICT No. 6

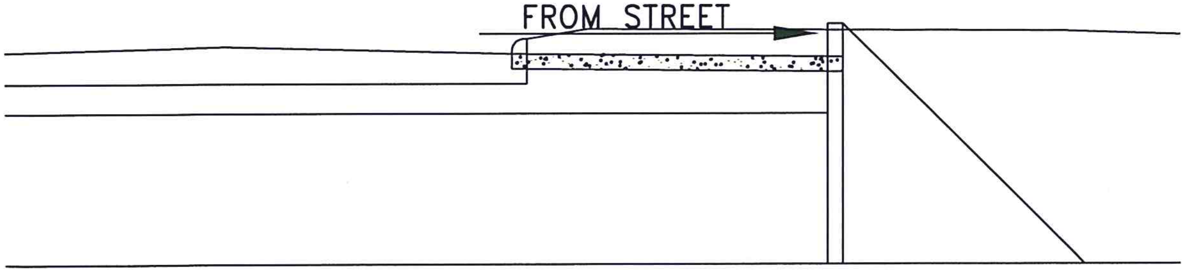




100 YEAR OVERFLOW AT
DISTRICT RIGHT-OF-WAY

JEFFERSON COUNTY
DRAINAGE DISTRICT No. 6





CURB CUT SECTION

OVERFLOW SHALL BE PROVIDED TO RELIEF STREET FLOODING WHEN THE UNDERGROUND SYSTEM CAPACITY IS EXCEEDED.
THE OVERFLOW MAY BE AT DITCH CROSSINGS OR SWALES PROVIDED TO DELIVER RUNOFF TO NEAREST OUTFALLS.

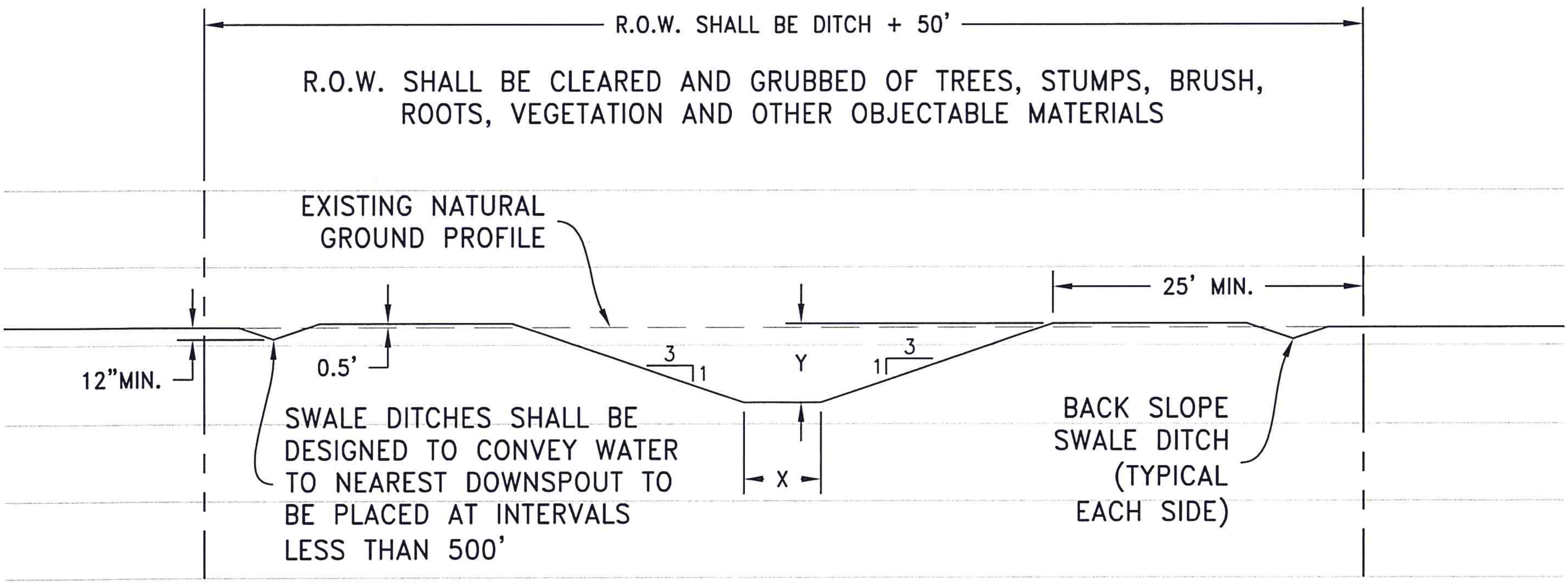
JEFFERSON COUNTY
DRAINAGE DISTRICT No. 6

AS A MINIMUM, R.O.W. SHALL BE SEEDED AS FOLLOWS:

APRIL – SEPTEMBER	20 lbs PER ACRE BERMUDA
	40 lbs PER ACRE MILLETT
OCTOBER – MARCH	20 lbs PER ACRE HOLLAND BERMUDA
	20 lbs PER ACRE UNHOLLAND BERMUDA
	40 lbs PER ACRE ANNUAL RYEGRASS

AS A MINIMUM, R.O.W. SHALL BE FERTILIZED WITH 600 lbs PER ACRE 13–13–13 GRANULATED OR PERLATED FERTILIZER.

R.O.W. WILL NOT BE ACCEPTED UNTIL GERMINATION AND A GOOD STRAND OF GRASS IS ESTABLISHED.



TYPICAL EARTHEN DITCH CROSS SECTION

NOTES:
X = DITCH BOTTOM WIDTH
Y = DITCH DEPTH

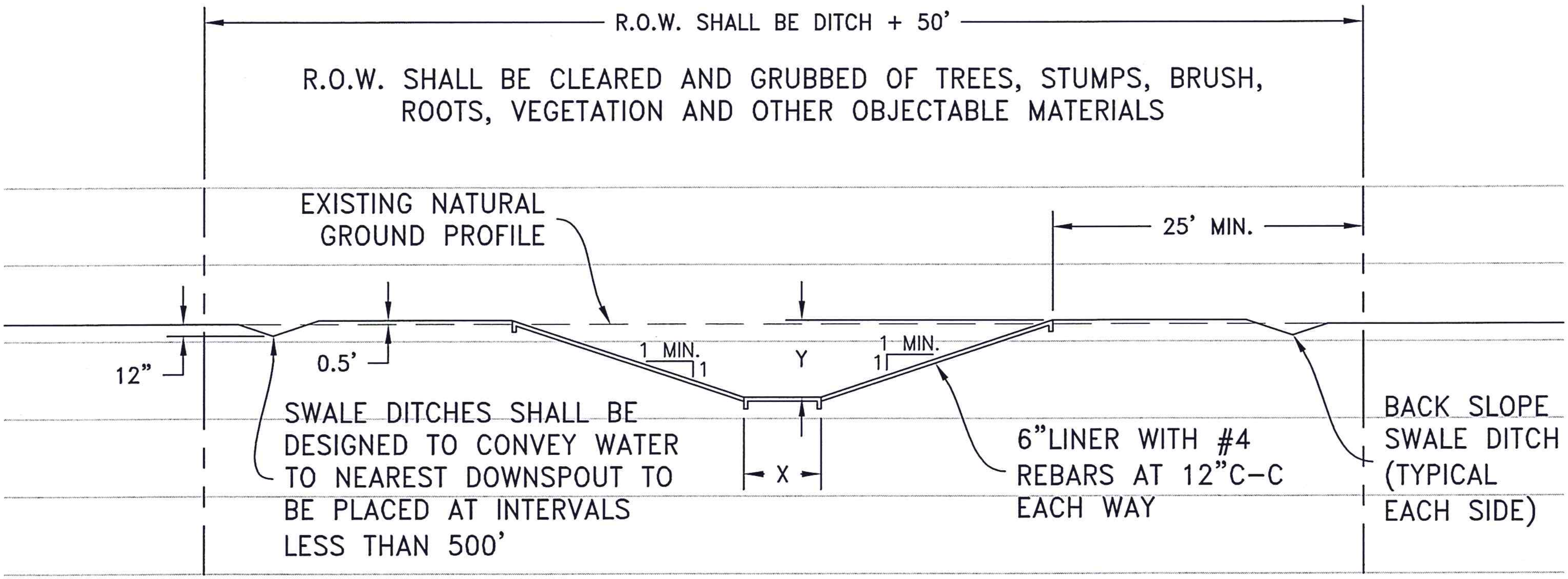
JEFFERSON COUNTY DRAINAGE DISTRICT No. 6

AS A MINIMUM, R.O.W. SHALL BE SEEDED AS FOLLOWS: APRIL – SEPTEMBER
20 lbs PER ACRE BERMUDA
40 lbs PER ACRE MILLETT

OCTOBER – MARCH
20 lbs PER ACRE HOLLAND BERMUDA
20 lbs PER ACRE UNHOLLAND BERMUDA
40 lbs PER ACRE ANNUAL RYEGRASS

AS A MINIMUM, R.O.W. SHALL BE FERTILIZED WITH 600 lbs PER ACRE 13–13–13 GRANULATED OR PERLATED FERTILIZER.

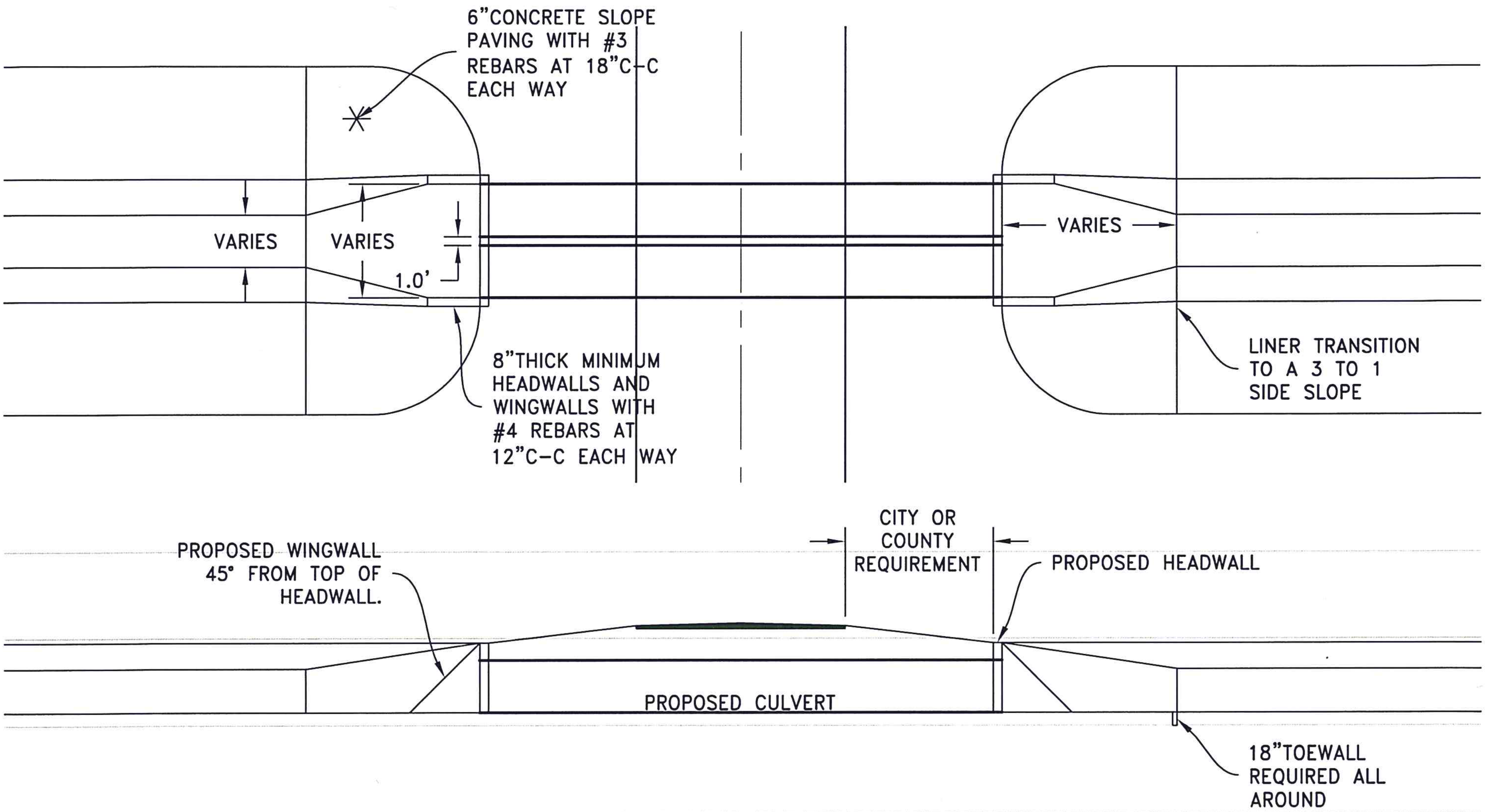
R.O.W. WILL NOT BE ACCEPTED UNTIL GERMINATION AND A GOOD STRAND OF GRASS IS ESTABLISHED.



TYPICAL LINED DITCH CROSS SECTION

NOTES:
X = DITCH BOTTOM WIDTH
Y = DITCH DEPTH

JEFFERSON COUNTY
DRAINAGE DISTRICT No. 6



TYPICAL BOX CULVERT TRANSITION
TO EARTHEN OR CONCRETE
CHANNEL

JEFFERSON COUNTY
DRAINAGE DISTRICT No. 6