Texas Department of Transportation

IH 635 Managed Lanes Project
Technical Provisions

Attachment 12-1A

Drainage Criteria Manual

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CHAPTER 1 - INTRODUCTION

1.1 PURPOSE

The purpose of this drainage manual is to establish design procedures necessary for the control of storm water runoff for the IH 635 Freeway improvements from Luna Road to US 80 (referred to in this manual as IH 635 corridor). Also included is IH 35E from Royal Lane to Valwood Parkway. The design factors, formulas, graphs, and procedures are intended for use as engineering guides in the solution of drainage problems involving determination of the quantity, rate of flow and conveyance of storm water. The procedures defined herein should be applied by experienced professional drainage Engineers who are ultimately responsible for the design of drainage systems within the IH 635 corridor.

1.2 SCOPE

This manual presents various applications of accepted principles of surface drainage engineering and is a working supplement to the information obtained from standard drainage handbooks and other publications on drainage.

The design criteria presented herein for the IH 635 corridor drainage systems are primarily based on the Texas Department of Transportation's (TxDOT) Hydraulic Design Manual, March 2004. However, additional drainage design guidelines from the cities of Dallas, Farmer's Branch, Garland, and Mesquite were referenced during the development of this manual.

The intent of this manual is to provide clear, concise and uniform principles, guidelines and criteria for use by drainage Engineers designing the storm drainage systems along the IH 635 corridor from Luna Road to US 80. The information provided in this manual has been adjusted to reflect the conditions that generally exist along the Project corridor and is meant to clarify and supplement the TxDOT Hydraulic Design Manual.

Methods of design other than indicated herein may be considered in special cases where experience clearly indicates they are preferable. However, there should be no extensive variations from the practices established herein without express approval from TxDOT.

1.3 DESIGN CRITERIA SUMMARY

A brief summary of the drainage design criteria is provided in Table 1.3.1. For detailed discussions and additional criteria refer to the following chapters.

Table 1.3.1 Design Criteria

Description	General Purpose Lanes	Managed Lanes	Direct Connectors
Method for Determining Peak Runoff			
Less than 200 acres	Rational Method	Rational Method	Rational Method
Greater than 200 acres	Natural Resources Conservation Service Runoff Curve Number Method	Natural Resources Conservation Service Runoff Curve Number Method	Natural Resources Conservation Service Runoff Curve Number Method
Culvert Crossings			
Design Storm	Minor: 50-year	Minor: 50-year	Minor: 50-year
	Major: 100-year	Major: 100-year	Major: 100-year
Check Storm	100-year	100-year	100-year
Headwater Control[1]	< Or = Existing Headwater Elevation	< Or = Existing Headwater Elevation	< Or = Existing Headwater Elevation
Maximum Outlet Velocity	Lined:12 fps	Lined - 12 fps	Lined - 12 fps
	Vegetated clay: 8 fps	Vegetated clay: 8 fps	Vegetated clay: 8 fps
	Vegetated sand: 6 fps	Vegetated sand: 6 fps	Vegetated sand: 6 fps
Minimum Outlet Velocity	Lined: 2.5 fps	Lined: 2.5 fps	Lined: 2.5 fps
	Vegetated: 2 fps	Vegetated: 2 fps	Vegetated: 2 fps
Storm Sewers and Inlets			
Design Storm	50-year	50-year	50-year
Check Storm	100-year	100-year	100-year
Design Storm Allowable Ponding Width	No encroachment into the travel lanes	2 feet of encroachment into the travel lanes	2 feet of encroachment into the travel lanes
Check Storm Allowable Ponding Width	One lane free of encroachment	One lane free of encroachment	One lane free of encroachment
Pipe Material	Concrete	Concrete	Concrete
Minimum Pipe Size	Laterals: 18 inch	Laterals: 18 inch	Laterals: 18 inch
	Trunklines: 24 inch	Trunklines: 24 inch	Trunklines: 24 inch
Minimum Pipe Velocity	2 fps	2 fps	2 fps
Maximum Pipe Velocity	12 fps	12 fps	12 fps

Table 1.3.1 Cont.

Description	Ramps	By-Passes	Elevated Collectors
Method for Determining Peak Runoff			
Less than 200 acres	Rational Method	Rational Method	Rational Method
Greater than 200 acres	Natural Resources Conservation Service Runoff Curve Number Method	Natural Resources Conservation Service Runoff Curve Number Method	Natural Resources Conservation Service Runoff Curve Number Method
Culvert Crossings			
Design Storm	Minor: 50-year	Minor: 50-year	Minor: 50-year
	Major: 100-year	Major: 100-year	Major: 100-year
Check Storm	100-year	100-year	100-year
Headwater Control[1]	< Or = Existing Headwater Elevation	< Or = Existing Headwater Elevation	< Or = Existing Headwater Elevation
Maximum Outlet Velocity	Lined:12 fps	Lined - 12 fps	Lined - 12 fps
	Vegetated clay: 8 fps	Vegetated clay: 8 fps	Vegetated clay: 8 fps
	Vegetated sand: 6 fps	Vegetated sand: 6 fps	Vegetated sand: 6 fps
Minimum Outlet Velocity	Lined: 2.5 fps	Lined: 2.5 fps	Lined: 2.5 fps
	Vegetated: 2 fps	Vegetated: 2 fps	Vegetated: 2 fps
Storm Sewers and Inlets			
Design Storm	50-year	50-year	50-year
Check Storm	100-year	100-year	100-year
Design Storm Allowable Ponding Width	2 feet of encroachment into the travel lanes	2 feet of encroachment into the travel lanes	2 feet of encroachment into the travel lanes
Check Storm Allowable Ponding Width	One lane free of encroachment	One lane free of encroachment	One lane free of encroachment
Pipe Material	Concrete	Concrete	Concrete
Minimum Pipe Size	Laterals: 18 inch	Laterals: 18 inch	Laterals: 18 inch
	Trunklines: 24 inch	Trunklines: 24 inch	Trunklines: 24 inch
Minimum Pipe Velocity	2 fps	2 fps	2 fps
Maximum Pipe Velocity	12 fps	12 fps	12 fps

Table 1.3.1 Cont.

Description	Frontage Roads	Cross Streets
Method for Determining Peak Runoff		
Less than 200 ac	Rational Method	Rational Method
Greater than 200 ac	Natural Resources Conservation Service Runoff Curve Number Method	Natural Resources Conservation Service Runoff Curve Number Method
Culvert Crossings		
Design Storm	Minor: 50-year	Minor: 50-year
	Major: 100-year	Major: 100-year
Check Storm	100-year	100-year
Headwater Control[1]	< Or = Existing Headwater Elevation	< Or = Existing Headwater Elevation
Maximum Outlet Velocity	Lined - 12 fps	Lined - 12 fps
	Vegetated clay: 8 fps	Vegetated clay: 8 fps
	Vegetated sandy: 6 fps	Vegetated sandy: 6 fps
Minimum Outlet Velocity	Lined: 2.5 fps	Lined: 2.5 fps
	Vegetated: 2 fps	Vegetated: 2 fps
Storm Sewers and Inlets		
Design Storm[2]	25-year	25-year
	Depressed: 50-year	Depressed: 50-year
Check Storm	50-year	50-year
	Depressed: 100-ear	Depressed: 100-year
Design Storm Allowable Ponding Width	One-lane for a 2-lane frontage road One-and-a-half lanes for a 3-lane frontage road	One lane open to traffic in each direction
Check Storm Allowable Ponding Width	50-year – no overtopping of curb	50-year – no overtopping of curb
Pipe Material	Concrete	Concrete
Minimum Pipe Size	Laterals: 18 inch	Laterals: 18 inch
	Trunklines: 24 inch	Trunklines: 24 inch
Minimum Pipe Velocity	2 fps	2 fps
Maximum Pipe Velocity	12 fps	12 fps

Notes:
1. This applies to cross structures. Refer to Chapter 7. The same headwater controls that apply to storm sewer apply to internal culverts. For internal drainage hydraulic grade line requirements, refer to Chapter 6.
2. For frontage roads and side streets along IH-35E south of Royal Lane, the 10-year design frequency applies. In all cases for depressed sections, design will be for the 50-year event. For further discussion, refer to Chapter 6.2.

CHAPTER 2 - POLICY AND GUIDELINES

An objective of TxDOT is to construct and maintain facilities that minimize the potential for flooding impacts to the surrounding area. The TxDOT Drainage Policy as stated in Chapter 2 of the TxDOT Hydraulic Design Manual shall govern the design of drainage facilities within the IH 635 corridor. All criteria in this manual have been developed to support this policy. Variances from any of the criteria or policy in this manual must receive prior approval from TxDOT.

TxDOT and the design Engineer shall work together in the preparation of the construction plans for projects within the IH 635 corridor. Throughout the preparation process TxDOT shall review the progress of the design in pre-determined intervals as defined in this manual. Submittals shall be made to TxDOT in the form of half-size sets of construction plans that are eleven inches tall by seventeen inches wide. For all but the final submittal, the construction plans shall have the preliminary seal of the project Engineer that is licensed in the state of Texas. An Engineer licensed in the state of Texas shall seal the final set of construction plans and any bound reports.

The review process is subdivided into four distinct steps, representing levels of completeness. They are: 35 percent complete, 65 percent complete, 95 percent complete, and 100 percent complete. A description of major drainage-related elements required at each step is explained in Chapter 3, Section 4. Refer to TxDOT's PS&E Preparation Manual for additional information.

For improvements at crossings that affect Federal Emergency Management Agency (FEMA) flood hazard areas, the guidelines explained in Chapter 2 of TxDOT's Hydraulic Design Manual should be followed. No rise in water surface for the 100-year storm will be permitted; therefore, Conditional Letters of Map Revision (CLOMR's) will not be necessary. It will be left up to the local community to submit to the FEMA a Letter of Map Revision (LOMR) request. TxDOT will provide the cities with the certified as-built plans for the proposed Project.

Improvements along the IH 635 corridor may impact jurisdictional waters of the United States. The agency responsible for regulating such impacts is the U.S. Army Corps of Engineers (USACE). Applications shall be submitted to the USACE detailing impacts to the waters of the United States and adjacent wetlands, according to the guidelines prescribed by the USACE.

The Engineer shall prepare exhibits that clearly demonstrate proposed work in waters of the U.S. and adjacent wetlands. Any measures to mitigate the impacts to the waters of the United States shall be reviewed and approved by TxDOT. The design Engineer shall prepare other permits or applications that may apply along the IH 635 corridor.

CHAPTER 3 - DATA COLLECTION, EVALUATION, AND DOCUMENTATION

3.1 GENERAL

The purpose of this chapter is to clarify documentation and data collection procedures for the IH 635 corridor. Because drainage improvements along the IH 635 corridor may be designed by several Engineers, it is imperative that a clear procedure for documentation is followed. This will ensure that information is adequately relayed and a uniform design within the corridor is achieved. Chapters 3 and 4 of TxDOT's Hydraulic Design Manual discuss the standard documentation and data collection procedures. The following chapter clarifies specific aspects of those procedures as they apply to the IH 635 corridor for the following design elements:

1. Hydraulic reports
2. Drainage plans preparation
3. Submittals

3.2 HYDRAULIC REPORTS

All data gathered and used in analysis and design should be included in hydraulic reports. For each major hydraulic crossing as defined in Table 4.2.1 the following information shall be included when available:

1. Stream/Structure location
2. Site description
3. Maps
   a. Local zoning maps
   b. Flood insurance studies
   c. USGS quadrangle maps
   d. Aerial photos
   e. Soil maps
4. Field survey information
   a. Existing hydraulic facilities
   b. Existing controls
   c. Profiles of existing roadway
5. Ground level photographs
6. Flood history
7. Flood insurance studies (FIS by FEMA)

8. Geotechnical information
    a. Soil properties
    b. Stream stability
    c. Existing erosion/scour problems
    d. Historic scour data from bridge inspection records for existing bridges and other crossings on the same and nearby streams.
    e. Boring logs where available
9. Drainage area maps
    a. Scale
    b. North arrow
    c. Delineated areas and size
    d. Runoff coefficients/Runoff Curve Numbers (RCN)
    e. Slopes
    f. Contours
10. Hydrologic methods and programs
11. Hydrologic calculations
12. Flood frequency analysis
    a. Peak discharges for design and check events
    b. Runoff hydrographs for design and check events
13. Hydraulic method or program used
14. Channel data
    a. Cross sections
        i. Location
        ii. Subdivisions and “n” values
    b. Thalweg profiles
    c. Flow controls
    d. Design criteria and assumptions
15. Structure data
    a. Size and configuration
    b. Abutment protection for bridges
    c. Stream bank stabilization
    d. Allowable headwater and outlet velocities for design and check events
    e. Magnitude and frequency of overtopping event

   f. Scour calculations and estimated scour envelope for bridges
16. Hydraulic computations including stage-discharge data
17. Water surface elevations for the design and check events including headwater elevations at structures
18. Average velocities for design and check events
19. Analysis of existing conditions for comparison
    a. Velocities through existing structures
    b. Water surface elevations
    c. Erosion and sedimentation problems
20. Channel improvements/easements
21. Outlet protection/control

3.3 DRAINAGE PLANS PREPARATION

The drainage construction plans for the IH 635 corridor shall include the following sheets and information:

1. Drainage Area Maps
   a. Overall/Offsite drainage area maps
      i. Scale
      ii. North arrow
      iii. Centerline of IH 635
      iv. Cross structure drainage designation and size
      v. Drainage boundary for major divides
      vi. Contours with elevation label at a readable increment (when available)
      vii. Runoff direction arrows
      viii. Drainage area sizes
      ix. Design flows
   b. Roadway/Onsite drainage area maps
      i. Scale
      ii. North arrow
      iii. Centerline of IH 635
      iv. Existing topography
      v. Inlets and cross structures visible

   vi. Runoff direction arrows
   vii. Drainage area label/identification
2. Major culvert hydraulic computation sheets
   a. Culvert size and length
   b. Method of hydraulic analysis
   c. Design and check storm flow
   d. Design and check storm headwater and tailwater elevations
   e. Design and check storm velocities
      i. Through proposed structure
      ii. Through existing structure
   f. Culvert flowlines upstream and downstream
   g. Allowable and existing headwater elevations
3. Storm sewer hydraulic calculation sheets (refer to Tables 6.10.1 through 6.10.5) for required information
   a. Runoff computations
   b. Inlet configuration
   c. Inlet computations
   d. Storm sewer configuration
   e. Storm sewer computations
4. Culvert layout sheets
   a. North arrow
   b. Vertical and horizontal scales
   c. Plan view
      i. Proposed contours and grading
      ii. Existing contours, grading, or features to match at R.O.W.
      iii. Proposed roadway linework
      iv. Roadway centerline/baseline callouts and stationing
      v. Right-of-way and drainage easement linework and callouts
      vi. Culvert size and length (normal length and skew length, if applicable)
      vii. Culvert, headwall, inlet, storm sewer linework
      viii. Culvert stationing
      ix. Callouts for headwalls and junctions on culvert
   d. Profile view

i. Culvert profile facing the direction of increasing roadway stationing
ii. Culvert stationing
iii. Culvert elevation callouts at grade breaks and junctions
iv. Linework and callouts for pipes/culverts tying to cross structure
v. Centerline slopes upstream and downstream of structure
vi. Proposed flows for the design and check events
vii. Proposed headwater and tailwater elevations for the design and check events
viii. Proposed velocities for the design and check events
ix. Proposed and existing ground along the centerline of the culvert
x. Applicable culvert and end treatment/headwall standard details reference

5. Storm sewer plan and profile sheets
    a. Plan view
        i. Scale
        ii. North arrow
        iii. Topography
        iv. Proposed roadway linework
        v. Callouts for the reference roadway centerlines/baselines
        vi. Culvert, storm sewer trunk line and lateral, inlet, and ditch centerline linework
        vii. Node identification - headwall, inlet, bend, and junction designations
        viii. Pipe/link designations, pay lengths, and diameter/size
        ix. Utilities in critical locations
    b. Profile view
        i. Scale
        ii. Link profile linework
        iii. Callouts for headwalls, inlets, junctions, bends, and grade breaks
            1. Flowline elevations
            2. Type of node
            3. Reference roadway station/offset
            4. Top of pavement/grade or lip of gutter where applicable
            5. Depth of inlet/manhole
        iv. Callouts for pipe/link pay length, diameter/size, and slope

v. Trench excavation protection limits and length
vi. Hydraulic grade line for design event
vii. Existing ground and proposed (finished) grade along centerline of link

6. Special ditch grading
   a. Ditch designation – shown on storm sewer plan view
   b. Table summarizing ditch design – on separate special ditch grading summary sheet
      i. Reference roadway station, offset and elevation for beginning, end, grade breaks, and shape changes
      ii. Ditch flowline elevations
      iii. Ditch bottom width
   c. Ditch typical sections shown on roadway typical sections or on special ditch grading summary sheets
7. Drainage details and standard details

3.4 SUBMITTALS

Documentation review stages shall be as follows:

1. 35 Percent Submittal – Preliminary Design
   a. 11” x 17” half-size bond with preliminary seal
   b. Preliminary hydraulic report for effective review
   c. Overall drainage area maps essentially complete for final review
   d. Major creek crossings
      i. Final hydrologic and hydraulic calculations
      ii. Water surface elevations
      iii. Bridge layouts essentially complete for final review
      iv. Culvert plan and profile sheets with final layouts and sizes
      v. Utility locations in critical locations
   e. Minor culvert crossings – design substantially complete for effective review
      i. Final hydrologic calculations
      ii. Preliminary hydraulic calculations
      iii. Culvert layout
      iv. Preliminary size and profile

      v. Preliminary water surface elevations
   f. Preliminary box culvert supplement sheet if applicable
2. 65 Percent Submittal – Plans Adequate
   a. 11” x 17” half-size bond with preliminary seal
   b. Incorporated TxDOT comments from 35% submittal
   c. Preliminary storm sewer design
      i. Trunk line layout and preliminary size
      ii. Preliminary trunk line profile
      iii. Known inlet locations
      iv. Sample inlet drainage area map
      v. Outfall location, description, and tailwater information
      vi. Utility locations in critical locations
   d. Minor culvert design complete
      i. Final hydraulic calculations
      ii. Final culvert plan and profile sheets
   e. Provide plans and reports for review by adjacent cities
   f. Provide plans adequate for utility adjustments
3. 95 Percent Submittal – District Review
   a. 11” x 17” half-size bond with preliminary seal
   b. Incorporated TxDOT comments from 65% submittal
   c. Final storm sewer design
      i. Final inlet locations and inlet drainage area maps
      ii. Final hydrologic and hydraulic calculations
      iii. Final storm sewer plan and profiles sheets – trunk lines and laterals
   d. Final bridge design and construction plans
4. 100 Percent Submittal – Final Mylars
   a. 11” x 17 “ half-size sealed mylar
   b. Incorporated TxDOT comments from 95% submittal
   c. Final drainage construction plans and detail sheets
   d. TxDOT standard details
5. As-Built Plans
   a. 11” x 17” half-size sealed mylar
   b. Incorporated TxDOT approved field changes of 100% submittal

CHAPTER 4 - HYDROLOGY

4.1 GENERAL

The requirements regarding the computations of runoff from the watersheds located along the IH 635 corridor are based primarily on the TxDOT's Hydraulic Design Manual, Chapter 5. The information contained herein offers clarification to that manual and specifies some site-specific requirements related to the IH 635 corridor.

For the purposes of the IH 635 corridor, all computed existing and design discharges will be based on the assumption that the offsite contributing watershed is completely developed. In other words, only fully-urbanized discharges will be used to size proposed improvements. Sufficient documentation such as zoning maps, as-builts, site plans, etc., must be provided to support the computation of both the existing and fully-developed runoff discharges.

4.2 DESIGN FREQUENCY

The frequency of a storm refers to the probability that, in any given year, a certain magnitude of rainfall event will occur or be exceeded. Table 4.2.1 summarizes the frequencies that are to be used for the various drainage structures within the IH 635 corridor. Table 4.2.1 also specifies the criteria that are to be used for both design storms and check storms. The design and check storm conditions as they relate to the roadway facilities are given in Chapter 6, 7 and 8.

Table 4.2.1 Design Frequencies

Hydraulic Crossings	Design Storm	Check Storm
Major Bridge Crossings		
- Farmers Branch	100-year	
- Farmers Branch Tributary	100-year	
Major Culvert Crossings		
- Cooks Branch	100-year	
- Long Branch	100-year	
- Audelia	100-year	
- Jackson	100-year	
- Dixon	100-year	
Other major culverts (DA > 200 ac)	100-year	
Minor culvert crossings (DA < 200 ac)	50-year	100-year
Storm Drainage		
Frontage road and cross streets	25- and 50*-Year	50- and 100-Year
Mainlanes/General Purpose, ramps, collector/distributor and Managed HOV	50-Year	100-Year

*Depressed Section

4.3 FREQUENCIES OF COINCIDENTAL OCCURRENCES

Coincidental Occurrence was applied in the hydrologic design for the IH 635 corridor. Coincidental Occurrences refer to the varying amount of time it takes for different size drainage basins to reach peak flow. A smaller basin with a relatively quick time of concentration is going to achieve its peak discharge before a larger basin with a longer time of concentration. Therefore, when the smaller basin's peak flow is achieved the larger basin has only reached a fraction of its peak flow. The percent of the larger basin's peak flow that is reached depends on the ratio of drainage areas for the two basins. Table 4.3.1 lists the possible frequency combinations in the IH 635 corridor. Refer to Section 6.2 for further guidance involving coincidental occurrences.

Table 4.3.1 Frequency Combinations

Area Ratio	Storm Drain Frequency		
Receiving Stream Area to Storm Drain Area	25-Year	50-Year	100-Year
1,000:1	5	5	10
100:1	10	10	25
10:1	10	25	50
1:1	25	50	100

4.4 TIME OF CONCENTRATION

The computation of the time of concentration will be based on TxDOT's Hydraulic Design Manual for urbanized areas which subdivides the flow path into three categories: overland flow (sheet flow), shallow concentrated flow (gutter flow), and conduit and/or open channel flow. Typically, the overland or sheet flow consists of water flow over plane surfaces before it collects as shallow concentrated flow. Because only fully urbanized conditions will be considered for the IH 635 corridor, the shallow concentrated flow is most often carried through the gutter to an inlet and then into a storm sewer pipe or to a discharge point at a creek or channel. The runoff continues in the pipe and/or creek until it reaches IH 635 corridor or the design point.

The overland flow and shallow concentrated flow can be computed by using Figure 5-4 of the TxDOT Hydraulic Design Manual. The overland flow length shall not be greater than 200 feet for urban watersheds and 400 feet for all other watersheds.

Conduit flow and open channel flow can be computed from basic hydraulic principles. The velocity for open channels shall be computed using full bank flow conditions (channel full with no flow in the overbanks) for a typical stream cross-section. If no detailed information or as-built plans are available, the United States Geographical Maps (USGS) may be used. Conduit flow velocity shall be computed at uniform depth based on the computed discharge.

Actual time of concentration shall be computed, input into storm drain analysis, and accumulated along system, even if less than 10 minutes. Actual time is not used until accumulated total exceeds 10 minutes.

If the computed discharge is unknown, the velocity shall be computed using the full capacity of the pipe. The minimum time of concentration shall be 10 minutes.

4.5 RATIONAL METHOD

The Rational Method shall be used for drainage areas that are less than 200 acres. The TxDOT Hydraulic Design Manual provides a specific description of the theory and assumptions for the Rational Method. Table 4.5.1 summarizes various runoff coefficients that are to be used for the IH 635 corridor.

Table 4.5.1 Runoff Coefficients (C) for Urban Watersheds for 2-year, 5-year, and 10-year Frequencies

Type of Drainage Area	Runoff Coefficients (C)
Business	
• Downtown areas	0.90
• Neighborhood areas	0.80
Residential	
• Single-family development	0.60
• Multi-family development	0.85
Industrial	0.90
Parks, cemeteries, open grass areas	0.35
Yards	0.40
Streets	
• Asphalt	0.95
• Concrete	0.95

The runoff coefficients listed in Table 4.5.1 apply to storm events of 2, 5, and 10-year frequencies. Higher frequency storms require modifying the runoff coefficient because infiltration and other abstractions have a proportionally smaller effect on runoff. In order to adjust the runoff coefficients in Table 4.5.1 to represent higher frequency events, multiply them by the factor C_f as indicated in Table 4.5.2. In no cases should the product of C and C_f exceed 1.00.

Table 4.5.2 Runoff Coefficient Adjustment Factors for Rational Method

Recurrence Intervals (years)	C_f
25	1.10
50	1.20
100	1.25

The Rational formula then becomes:

$$Q = CC_f IA$$

Where,

Q = Design frequency discharge (cfs)
C = Runoff coefficient from Table 4.5.1
C_f = Correction factor for 25, 50, and 100-year frequencies from Table 4.5.2
I = Design Storm Rainfall Intensity (in/hr)
A = Drainage Area (acres)

Each city within the IH 635 corridor has determined the rainfall intensity for various storm events. The values determined by the Cities are published in their respective drainage manuals. A comparison made between the intensities published in these manuals and those computed using TxDOT's criteria revealed that the Cities' 100-year intensities were generally lower than the 25-year intensities computed by TxDOT's criteria for times of concentration less than 20 minutes. Therefore, the rainfall intensity to be used for the IH 635 corridor is based on the following equation from the TxDOT manual:

$$I = \frac{b}{(t_c + d)^e}$$

Where,

I = Rainfall intensity (in/hr)
t_c = Time of concentration (min)
e, b, d = coefficients for specific frequencies that are based on rainfall frequency-duration data contained in the National Weather Service Technical Paper 40 (TP 40) for each county in Texas. See Table 4.5.3.

Table 4.5.3 Intensity Coefficients for Dallas County

Design Storm	Coefficients		
	e	b	d
2-Year	0.791	54	8.3
5-Year	0.782	68	8.7
10-Year	0.777	78	8.7
25-Year	0.774	90	8.7
50-Year	0.771	101	8.7
100-Year	0.762	106	8.3

4.6 NRCS RUNOFF CURVE NUMBER METHOD

The Natual Resources Conservation Services Runoff Curve Number Method (NRCS RCN Method) with a TY II 15-minute rainfall distribution shall be used to compute runoff for drainage areas greater than 200 acres. A detailed discussion of the NRCS RCN methodology can be found in Chapter 5, Section 7 of the TxDOT Hydraulic Design Manual. Within the IH 635 corridor, HEC-1, HEC-HMS, or other TxDOT approved software may be used to compute the runoff and a dimensionless unit hydrograph. With any modeling software, the computational interval shall not exceed one-third of the shortest lag time of any basin in the model. Refer to Chapter 5, Section 8 of the TxDOT Hydraulic Design Manual for a detailed discussion of the NRCS Type II unit hydrograph.

Table 4.6.1 summarizes the curve numbers that are to be used for the IH 635 corridor. This table is based on values from the TxDOT Hydraulic Design Manual, and includes only those categories that represent development within the IH 635 corridor.

Table 4.6.1 Runoff Curve Numbers for Urban Areas

Cover Type and Hydrologic Condition	Average Percent Impervious Area	A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.)		68	79	86	89
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
• Paved; curbs and storm drains (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
Urban districts:					
• Commercial and business	85	89	92	94	95
• Industrial	72	81	88	91	93
Residential districts:					
• Town houses and apartments	65	77	85	90	92
• Residential lots	38	61	75	83	87

Notes: Values are for average runoff condition, and I_a = 0.2S. The average percent impervious area shown was used to develop the composite RCNs. Other assumptions are: impervious areas are directly connected to the drainage system, impervious areas have a RCN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.

4.7 FLOOD HYDROGRAPH ROUTING METHODS

A detailed description of Flood Hydrograph Routing techniques can be found in Chapter 5, Section 9 of the TxDOT Hydraulic Design Manual. Along streams that have detailed studies, the routing techniques should not be modified. However, for watersheds that have no existing study, HEC-1, HEC-HMS, or other TxDOT approved software may be used for flood hydrograph routing computation. The Modified Puls Method is to be used for channel routing. This will require development of a storage-discharge relationship from the hydraulic model (HEC-2 or HEC-RAS). Where there are detention ponds, a storage-elevation-discharge relationship is to be determined.

CHAPTER 5 - HYDRAULIC CROSSINGS

5.1 GENERAL

A detailed discussion of hydraulic principles and theory can be found in Chapter 6 of the TxDOT Hydraulic Design Manual. The following guidelines apply to open channels, including creeks, ditches, and channels along the IH 635 corridor. The analysis for these open channels within the IH 635 corridor shall be performed using HEC-RAS. See Section 6.8 for additional Roadside Ditch Criteria.

5.2 SURVEY

Cross-section information used in the hydraulic modeling of open channels shall be based on surveyed information. The cross sections shall be spaced no greater than 500 feet apart, and shall provide enough detail to sufficiently define the channel geometry as illustrated by Figure 5.2.1.

Existing bridges and culverts shall be modeled using the field survey information. The upstream and downstream limits of the hydraulic model for a culvert or bridge crossing shall extend 1,000-feet or to the nearest hydraulic control point which may include structure crossings or any point in the channel that controls the water surface elevation.

5.3 ROUGHNESS COEFFICIENTS

The roughness coefficients used for the hydraulic models shall be defined so that they vary horizontally along the cross section depending on the type of land cover. Table 5.3.1 lists typical values of roughness coefficients. Cross-sections should be subdivided to have a minimum 3 subsections, left overbank, channel, and right overbank. Typically, these 3 subsections will be adequate to define the section.

Figure 5.2.1 Typical Surveyed Cross Section with Five Points in the Channel

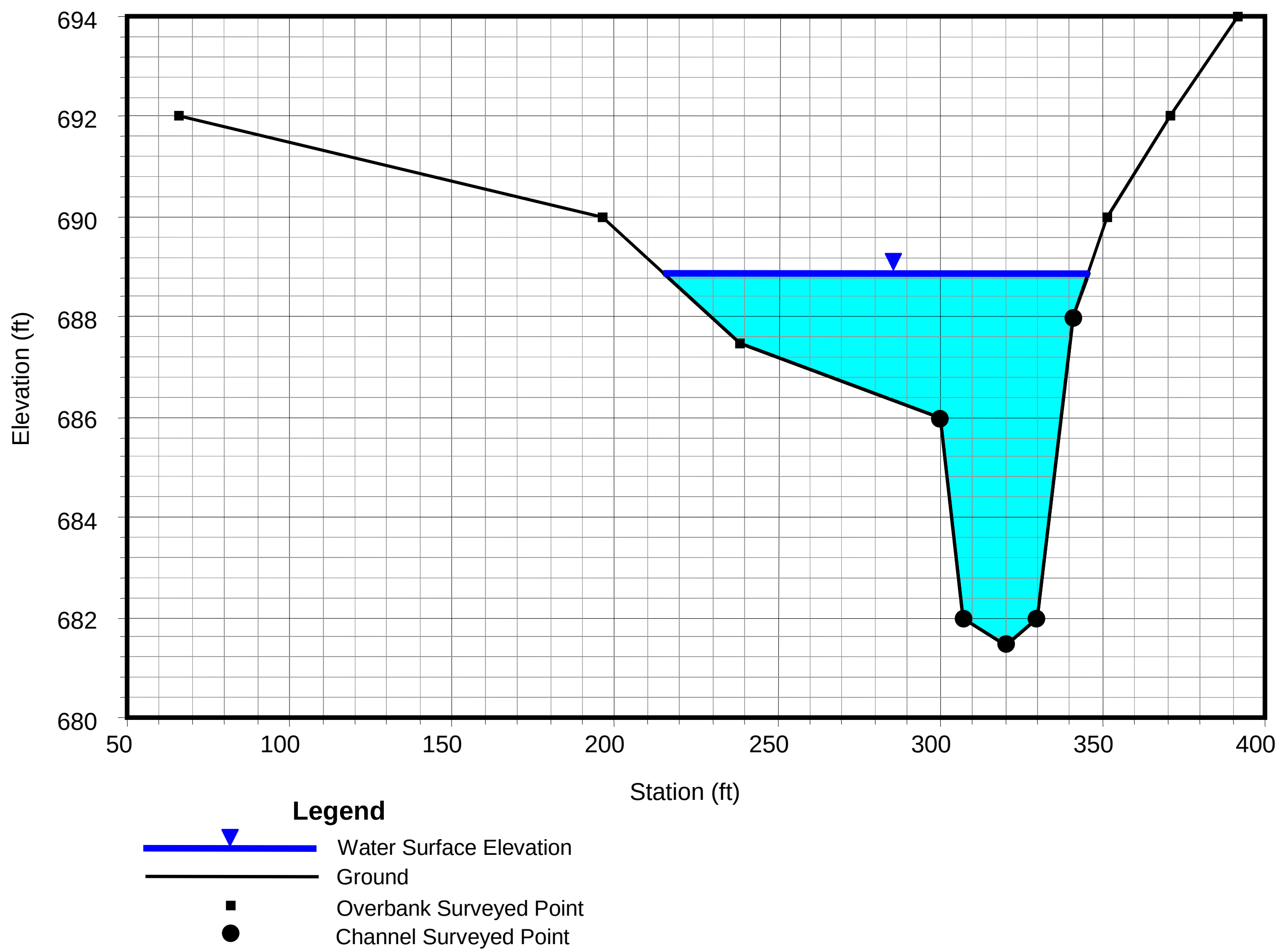


Table 5.3.1 Manning's "n" Values

Channel Description	"n" value
Channel Roughness Coefficients:	
Well Defined Natural Channel	
Rock bottom	0.035
Dirt lined with light vegetation	0.040
Moderate vegetation on banks	0.060
Heavy vegetation on banks	0.070
Channel Description	**"n" value**
Irregular Channel with Meanders and Pools	
Rock bottom	0.047
Dirt lined with light vegetation	0.052
Moderate vegetation on banks	0.072
Heavy vegetation on banks	0.080
Lined Channel	
Concrete-lined channel	0.020
Grouted riprap	0.035
Ungrouted riprap	0.040
Gabion mattress	0.033
Geotextile fabric with established vegetation	0.043
Maintained grass-lined channel	0.035
Non-maintained grass-lined channel	0.060
Overbank Roughness Coefficients:	
Undeveloped Overbank	
Short grass, no brush	0.050
Tall grass, no brush	0.060
Grass with moderate tree cover	0.080
Grass with heavy tree cover	0.120
Developed Overbanks	
Residential	0.150
Developed commercial or industrial	0.100
Parks, manicured open space	0.035

5.4 REQUIREMENTS

The study of existing open channels within the IH 635 corridor involves the study of both existing and proposed improvements using fully-developed conditions. In addition to complying with the USACE's requirements and TxDOT's requirements, the following guidelines must be met:

- There shall be no rise in water surface elevation between the existing conditions and the proposed conditions for the design storm. Existing conditions are defined as fully-developed offsite design flows and existing onsite (within existing right-of-way) through the existing structure and over the road, if applicable. Proposed conditions are based on fully-developed design flows through the proposed structure.
- The proposed conditions shall not increase the design storm channel velocity above the amount specified in Table 5.5.1.
- The study limits for major crossings shall extend either 1,000 feet upstream and downstream or to the next control structure, whichever is closer.

Valley storage shall be considered on those streams that are part of the Certificate Development Corridor (CDC) program.

5.5 CHANNELS

Chapter 7 of the TxDOT Hydraulic Design Manual discusses in detail the analysis and design of proposed channel improvements. In addition to the guidelines listed here, other requirements that involve state and federal agencies must be met for permits as they apply to any proposed improvements. This includes, but is not limited to, the following:

- Federal Emergency Management Agency National Flood Insurance Program (FEMA NFIP)
- U.S. Corps of Engineers (USACE) Section 404 permit
- Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System permit requirements
- TPDES permit for industrial activity (construction)
- EPA Endangered Species Act provisions
- Texas Commission of Environmental Quality (TCEQ) 401 Permit

Table 5.5.1 Types of Channel Lining

Type of Channel Lining	Maximum Velocity	Minimum Side Slopes (Hor.: Vert.)	Desired Shape	Minimum Velocity
Grouted riprap	12 feet/sec	3:1	Trapezoidal	2.5 feet/sec
Rock riprap	12 feet/sec	3:1	Trapezoidal	2.5 feet/sec
Gabion	12 feet/sec	N/A	N/A	2.5 feet/sec
Vegetated clay channels	8 feet/sec	3:1	Trapezoidal	2 feet/sec *
Vegetated sandy channels	6 feet/sec	3:1	Trapezoidal	2 feet/sec *****

* The minimum velocities apply to proposed channels. Any modifications to existing channels shall match the existing channel as close as possible.

Proposed channel improvements shall be lined with native material such as grasses, crushed rock, and earth where possible. In such a case, the side slopes shall be no steeper than 3 to 1. Other lining material may be necessary to accommodate hydraulic, aesthetic, economics, safety, and environment. Table 5.5.1 summarizes the requirements for various types of channel lining that are to be used in the IH 635 corridor.

5.6 STREAM ANALYSIS

For a detailed discussion of stream morphology and channel analysis refer to Chapter 7 of the TxDOT Hydraulic Design Manual. This manual also discusses environmental mitigation alternatives and stream stabilization measures that should be reviewed during the design of any channel improvements in the IH 635 corridor.

CHAPTER 6 - STORM DRAINAGE SYSTEMS

6.1 GENERAL

The drainage systems shall include all drainage and erosion control appurtenances such as:

- curb inlets
- grate inlets
- manholes
- junction boxes
- headwalls
- ditches
- underdrains
- safety end treatments
- storm sewer pipes
- box or pipe culverts
- lined channels

Drainage shall be designed to:

- Ensure the proper collection and disposal of storm runoff disrupted or generated by the Project and its associated construction.
- Ensure the continuing service of all drainage systems during Project construction.
- Provide protection from erosion of all slopes and ditches in the IH 635 corridor and on adjacent property.
- Maintain clear roadways for the design storm.
- Provide subgrade drainage, where required.

6.2 DESIGN FREQUENCIES

All inlet and storm drain design and check frequencies are listed in Table 4.2.1.

Depressed and at-grade mainlane/general purpose lane, ramp, and Managed HOV lane storm inlets and conduit shall be designed as given here and Table 4.2.1. These criteria with the ponding and the Hydraulic Grade Line (HGL) requirements given in Sections 6.4 through 6.7 meet the Federal Highway Administration (FHWA) and TxDOT's criteria for depressed sections.

The FHWA defines depressed sections as pavement areas on interstate highways where ponded water can only be removed through the storm conduit. The TxDOT Dallas district's policy adds mainlanes/general purpose lanes, direct connectors, ramps, Managed HOV lanes and frontage roads bounded by barrier or retaining wall to the "depressed" category. Because the majority of the IH 635 corridor falls within these two descriptions, all mainlane/general purpose lane, direct connector, ramp, and Managed HOV lane storm drain will be designed at the same frequency.

When a depressed frontage road section ties to a non-depressed frontage road section trunk line, the trunk line downstream of the junction shall be designed to maintain the 50-year HGL at critical elevations. All laterals that tie to this trunk line will be designed for full flow at the 25-year storm event. Figures 6.2.1 and 6.2.2 show examples of the proper design event for various locations. Critical elevations are given in Sections 6.5 and 6.7.

When a storm drain system ties to a cross structure of a larger drainage basin, coincidental occurrence may be applied to determine the storm drain's beginning HGL. The following example references the Table 4.3.1 in Chapter 4, Section 3.

Trunk line design for the 25-year event tying to a cross culvert.

Cross Structure Drainage A = 357 acres

Total Storm Drain Area = (DA_a+DA_b+DA_c+DA_d) = 18.7 acres

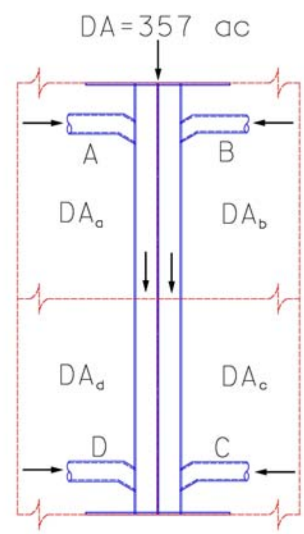
Ratio 357/18.7 = 19.1

Go to Table 4.3.1

Ratio 10:1 (round to the nearest ratio in table)

25-year design

Main stream = 10 year



Use the cross structure's 10-year water surface elevation as the starting tailwater elevation for each trunk line.

An acceptable alternative to the above method would be to evaluate the flood hydrograph in the outfall channel and base the tailwater elevation on the water level in the outfall at the time of the peak discharge from the trunk line.

Figure 6.2.1 Depressed and Non-Depressed Frequencies

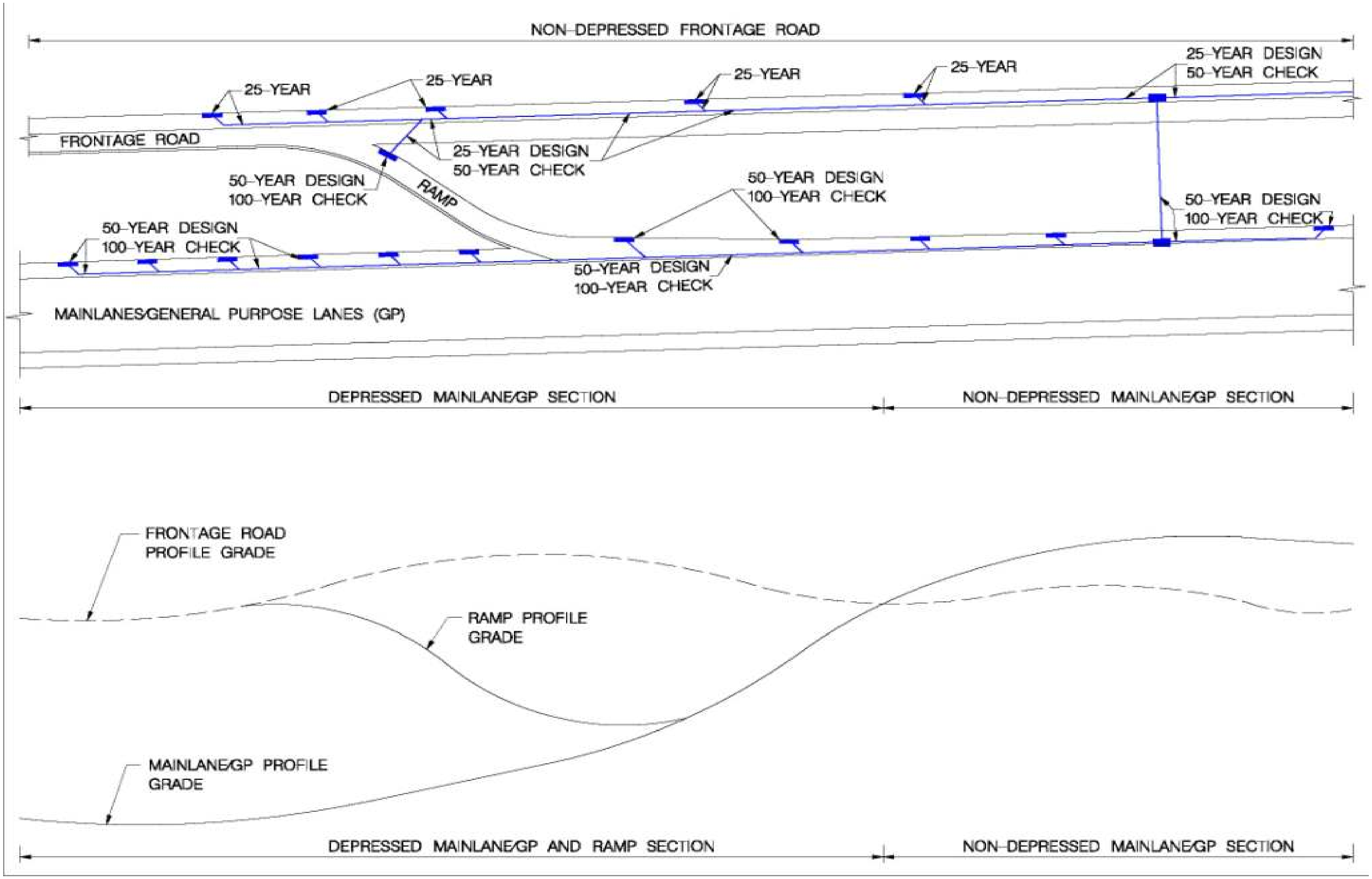
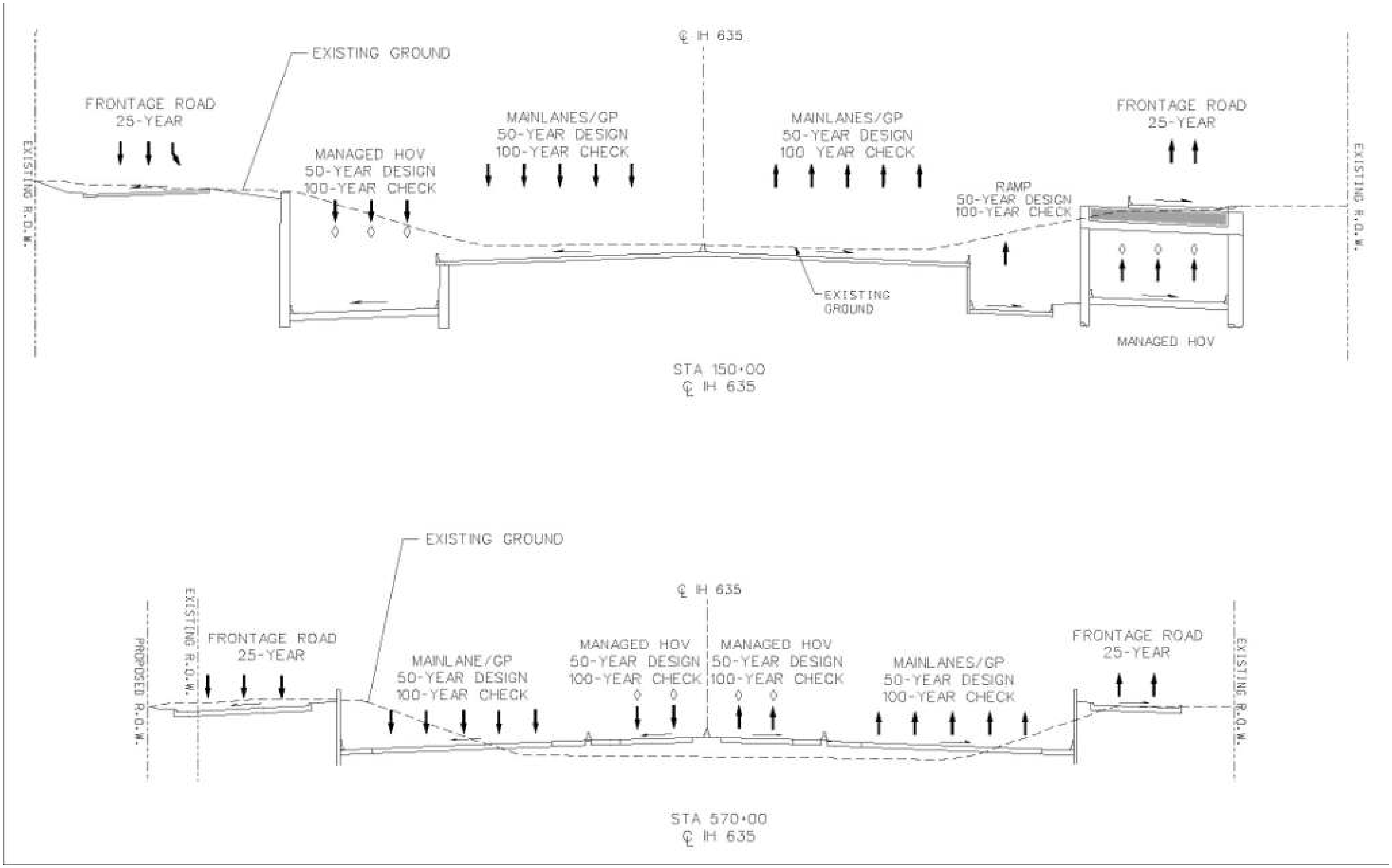


Figure 6.2.2 Depressed Sections



6.3 RUNOFF CALCULATIONS

Storm drain design should maintain the pre-project drainage boundaries when possible to avoid diverting runoff flows from one major watershed to another.

The time of concentration in storm drainage design consists of the time required for water to flow from the most distant point of the drainage area to the inlet and the travel time of the flow within the storm drain pipe. For the IH 635 corridor, the minimum time of concentration shall be 10-minutes. (Refer to Chapter 4, Section 5 for additional information.)

Refer to Chapter 4, Sections 5 and 6 for appropriate runoff calculation methods.

6.4 PAVEMENT DRAINAGE

Table 6.4.1 summarizes the allowable ponding widths.

Table 6.4.1 Allowable Ponding Widths

Location	Design Events	Check Event
Mainlanes/General Purpose Lanes	No encroachment into the travel lanes.	One lane free of encroachment
Managed HOV lanes, ramps, direct connectors and collector distributors	2-feet encroachment into the travel lanes.	One lane free of encroachment
Frontage roads	One-lane for a 2-lane frontage road. One-and-a-half lanes for a 3-lane frontage road.	50-year – no overtopping of curb 50-year – no overtopping of curb
Cross streets	One lane open to traffic in each direction.	50-year – no overtopping of curb
Note: Isolated instances of ponding width greater than those shown in the table may be allowed based on the Engineer's judgment and approval of TxDOT.		

For the design frequency, the allowable ponding width shall not be exceeded, nor shall the depth of flow exceed the curb height on curbed roadways. During the 100-year flood event, one-lane should be free of encroachment on the mainlanes/general purpose lanes, direct connectors and ramps to allow for emergency vehicle access.

Gutter flow and ponding spread should be calculated using the methods given in Chapter 10 Section 4 of the TxDOT Hydraulic Design Manual. Appropriate Manning's "n" values are 0.015 for concrete gutter with asphalt pavement and 0.016 for concrete pavement. For ponding at approaches to sag locations, the longitudinal slopes used to evaluate ponding widths should be one-half of the tangent grades.

6.5 STORM DRAIN INLETS

Inlet types to be used in the IH 635 corridor are listed in Table 6.5.1. These refer to TxDOT Dallas District Standard Details.

Inlet runoff interception calculations should be based on equations and methods listed in Chapter 10, Section 5 of the TxDOT Hydraulic Design Manual.

Inlet input information for inlet capacity calculations are listed in Table 6.5.2 and Table 6.5.3.

Table 6.5.1 Inlet Types

Inlet Type	Standard Detail Sheet Name	General Location
Curb inlet	Curb Inlet TY I	Frontage roads, cross streets
Grate inlet	Drop Inlet TY C, Drop Inlet TY C & G	Gore areas, separation ditches, swales behind retaining walls
	Drop Inlet TY E & F	Mainlanes/General Purpose lanes, gore areas
Combination inlet	Curb and Grate Inlet TY II	Frontage roads, cross streets (where needed)[a]
Barrier inlet	Curb & Grate Inlet TY III Curb & Grate Inlet TY V	Mainlanes/General Purpose Lanes, Managed HOV lanes, ramps
Slotted drain[b]	Roadway Drain Details[c] (Slotted Drain) SD	Mainlanes/General Purpose Lanes against median barrier (where needed)[d], at entrances to tunnel sections

[a] If a Curb Inlet TY I is not sufficient to meet ponding and interception requirements
[b] Statewide Standard
[c] If other inlet types are not sufficient to meet ponding and interception requirements
[d] Not to be used at sag points and at locations where there are flexible joints in the roadway structure

Table 6.5.2 Curb Inlet Input

Dallas District Standard Detail Sheet Name	Curb Length	Gutter Depression	Depression Width	Inlet Opening Height	Critical Elevation	Maximum Ponded Depth
Curb Inlet TY I[a]	5', 10', 15'	3"	2'	4"	1.0' below gutter depression	Satisfies ponding requirements & < curb height
Curb & Grate Inlet TY II[a]	5', 10', 15'[b]	3"	3'	4"	1.0' below gutter depression	Satisfies ponding requirements & < curb height
Curb & Grate Inlet TY III	5'[b]	3"	3'	4"	1.0' below gutter depression	Satisfies ponding requirements
Curb & Grate Inlet TY V[a]	5', 10', 15'[b]	3"	3'	3"	1.0' below gutter depression	Satisfies ponding requirements

[a] Starting Curb length is 5' and larger lengths increase in 5' increments.
[b] Where the grate and curb opening overlap, the capacity of the greater of the two will be used.

Grate inlets should be aligned so that grate bars are parallel to the gutter flow except on side streets where bicycle safety is concerned and as stated above. Figure 6.5.1 shows typical grate inlet orientation.

All on-grade inlets, slotted drains excluded, shall be designed to intercept a minimum of 65% of the approaching flow of the design event, but inlets shall be designed to be cost effective. Carryover shall be limited upstream of intersections, driveways, superelevation transitions, bridges, and downstream of exit and entrance ramps so that no more than 0.10 cfs shall be allowed to concentrate and flow across travel lanes. If this is not possible, the potential for hydroplaning shall be checked based on guidelines listed in Chapter 10, Section 4 of the TxDOT Hydraulic Design Manual. At Dallas Area Rapid Transit (DART) light rail crossings, inlets shall be coordinated with the street profile so that no runoff enters the trackway.

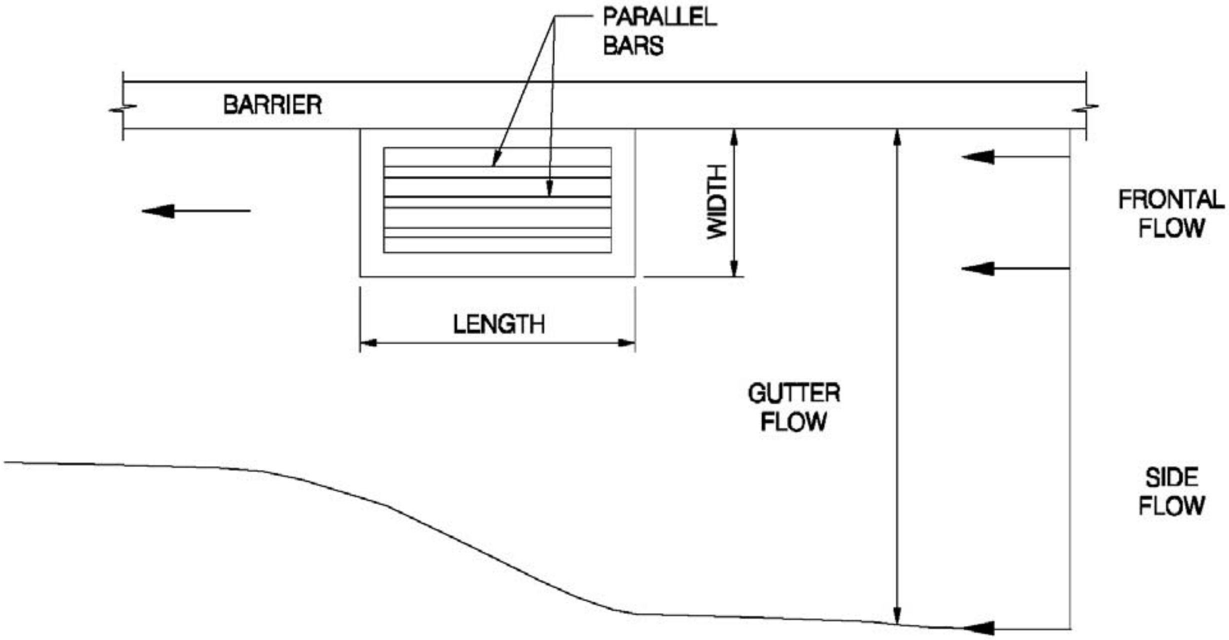
Table 6.5.3 Grate Inlet Input

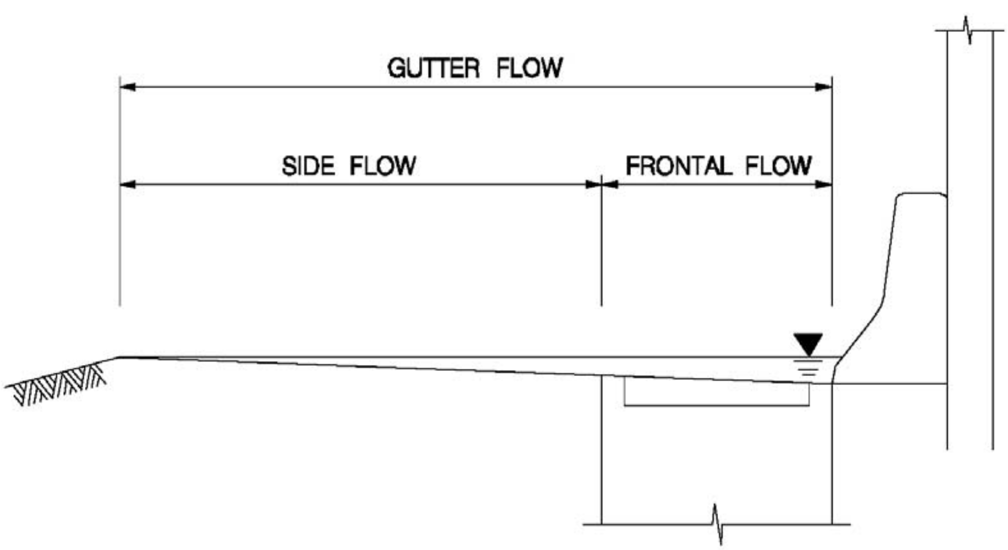
Dallas District Standard Detail Sheet Name	Critical Elevation	Grate Type	Maximum Ponded Depth	Number of Grates	Grate Width	Grate Length	Effective Grate Area In Sag	Effective Grate Perimeter in Sag - 3-sided	Effective Grate Perimeter in Sag - 4-sided	Safety Reduction Factor in Sag
Drop Inlet TY C	1.0' below top of grate	Parallel	1' of freeboard[a]	1	2'	2.38'	3.14 ft^2	3.14'	8.25'	50%
				2	2'	4.73'	6.38 ft^2	6.38'	13.04'	50%
				3	2'	7.08'	9.59 ft^2	9.59'	17.75'	50%
Drop Inlet TY C & G*	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Drop Inlet TY E & F	1.0' below top of grate	Parallel	1' of freeboard[a]	1	2.5'	1.22'	3.36 ft^2		7.54'	50%
				2	5.43'	1.22'	6.72 ft^2		11.54'	50%
				3	8.35'	1.22'	10.07 ft^2		15.54'	50%
Curb & Grate Inlet TY II	1.0' below gutter depression	Transverse	Satisfies ponding requirements & < curb height	1	1.52'	2.49'	3.09 ft^2	4.97'	NA	NA
Curb & Grate Inlet TY III	1.0' below gutter depression	Transverse	Satisfies ponding requirements	1	1.52'	2.49'	3.09 ft^2	4.97'	NA	NA
Curb & Grate Inlet TY V	1.0' below gutter depression	Transverse	Satisfies ponding requirements	1	1.52'	2.49'	3.09 ft^2	4.97'	NA	NA
Roadway Drain Details (Slotted Drain) SD	1.0' below drain guide opening	NA	NA	NA	NA	20'	NA	NA	NA	NA

[a] Refer to Figure 6.8.1

[b] Grate used in this detail is the same as the on used in the Drop Inlet TY C standard detail sheet so input is the same.

Figure 6.5.1 Parallel Grate Inlet





6.6 LOCATION OF STORM DRAIN APPURTENANCES / CONDUIT RUNS

Storm conduit and inlets shall be designed so that conflicts with major utilities are avoided.

Geometric controls may determine inlet location in addition to the ponding requirements given in Section 6.4. Examples of such locations are as follows:

- Low points in the gutter grade.
- Immediately upstream of entrance/exit ramp gores, cross walks and street intersection.
- Immediately upgrade of bridges (to prevent pavement runoff from flowing onto bridge decks).
- Immediately downstream of bridges (to intercept bridge deck drainage).
- Immediately upgrade of cross slope reversals.

6.7 CONDUIT SYSTEMS

Table 6.7.1 lists all storm drainage conduit criteria.

Table 6.7.1 Conduit System Design Criteria

Component	Design Criteria
Pipe class	Class III or greater, D-loads calculated according to Chapter 14 in the TxDOT Hydraulic Design Manual
Diameters	Laterals - minimum of 18" reinforced concrete pipe (RCP) Trunk lines - minimum of 24" RCP Standard sizes - 18", 24", 36", etc. in 6" increments Maximum pipe size - 60" then use reinforced concrete box Minimum box culvert height - 3'
Cover	Pavement - top of pipe clears pavement base structure Non-Pavement - a minimum of 1-ft from top of pipe to finished grade
Roughness coefficient "n"	Concrete pipe - 0.013 Concrete box - 0.012
Manhole spacing	24" - 300' 36" - 375' 42"-54" - 450' 60" - 900'
Bends	15, 30, 45, and 60 degree angles 90 degree angle if unavoidable
Lateral tie-ins	One lateral junction - 45 and 60 degree wyes Two or more lateral junction - A manhole or junction box unless the trunkline is more than twice the diameter of the largest ajoining lateral
Velocities	Minimum - 2 fps Maximum - 12 fps
Conduit flow	Design event - non-pressure flow Check event - see Hydraulic Grade Line
Hydraulic grade line	Design: Inlets - meet critical elevation requirements listed in Tables 6.5.2 and 6.5.3 Mahholes - a minimum of 1.0' below the top of the manhole cover Check: Frontage road and side streets - 50-year HGL below top of curb. Mainlanes, ramps, HOV, collector/distributor, depressed frontage roads - 100-year HGL allows for one travel lane to be free of encroachment

6.8 ROADSIDE CHANNELS

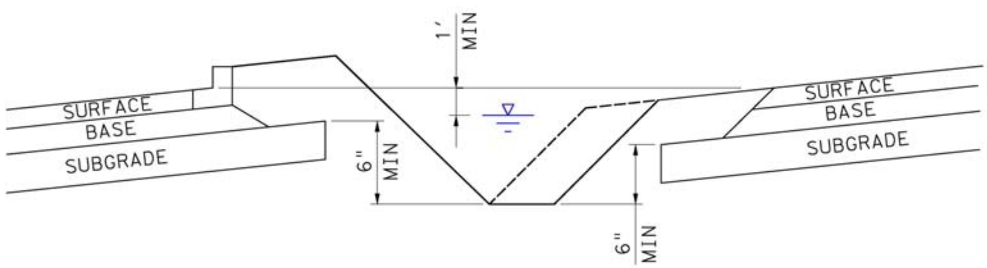
For the IH 635 corridor, roadside channels are those open channels, which convey runoff within the proposed right-of-way. Design shall meet criteria given in Section 5.5 and in Chapter 7, Section 3 of the TxDOT Hydraulic Design Manual. A summary of additional design requirements is listed in Table 6.8.1. Where possible, ditches parallel to DART light rail shall meet DART drainage design criteria.

Table 6.8.1 Roadway Channel Design Criteria

Component	Design Criteria
Minimum longitudinal slope	0.50%
Maximum side slope	Within clear zone[a] Mainlanes/General Purpose and Ramps – 6:1 Frontage Roads – 4:1 Outside of clear zone Mainlanes/General Purpose and Ramps – 4:1 Frontage Roads – 3:1 Backslope Trapezoidal bottom – 4:1 V-shaped bottom – 3:1
Water surface elevation	Design event – 1-foot below pavement surface[b]
Depth	Minimum of 6 inches below subgrade crown[b]

[a] Maximum side slopes without positive protection.
[b] Refer to Figure 6.8.1 for further explanation.

Figure 6.8.1 Roadside Channels



6.9 HEAD LOSSES

Hydraulic grade line losses associated with junctions, manholes, wyes, bends and pipe size changes will be calculated as shown in Table 6.9.1.

Table 6.9.1 Headloss Coefficients

Description of Condition		Coefficient K	Equation h =
Inlet on mainline		0.50	$(V_2^2/2g) - (K*V_1^2/2g)$
Inlet on mainline with branch lateral		0.25	$(V_2^2/2g) - (K*V_1^2/2g)$
Manhole on mainline with:	90° 60° 45° 30° 15°	0.25 0.35 0.50 0.60 0.90	$(V_2^2/2g) - (K*V_1^2/2g)$
Wye connection or cut in:	60° 45°	0.60 0.75	$(V_2^2/2g) - (K*V_1^2/2g)$
Inlet or manhole at beginning of line		1.25	$K*V_2^2/2g$
Bends:	90° 60° 45° 30° 15°	0.70 0.56 0.47 0.35 0.19	$K*V_2^2/2g$
Conduit connection to cross culvert		N/A	Headloss negligible

V_1 is upstream velocity and V_2 is downstream velocity.

6.10 OUTPUT

Drainage design calculations may be done with Winstorm, Geopak Drainage or other TxDOT approved methods. Required output is shown in Tables 6.9.1 through 6.9.5.

Table 6.10.1 Example Drainage Area Output

DRAINAGE AREA	PAVEMENT C = 0.95 (AC)	COMMERCIAL DOWNTOWN C = 0.90 (AC)	COMMERCIAL NEIGHBRHD. C = 0.70 (AC)	INDUSTRIAL C = 0.85 (AC)	RESIDENTIAL MULTI C = 0.75 (AC)	RESIDENTIAL SINGLE C = 0.50 (AC)	OPEN AREA GRASS C = 0.40 (AC)	OPEN AREA PARKS C = 0.30 (AC)	TOTAL AREA (AC)	COMPOSITE C VALUE	Tc ACTUAL (MIN)	Tc USED (MIN)	INTENSITY 25 yr (IN/HR)	DISCHARGE 25 yr (CFS)	INTENSITY 50 yr (IN/HR)	DISCHARGE 50 yr (CFS)	INTENSITY 100 yr (IN/HR)	DISCHARGE 100 yr (CFS)
1-A1	0.24	0.12	0.00	0.62	0.00	0.00	0.05	0.00	1.03	0.86	7.15	10.00	9.33	9.09	10.56	11.22	11.57	12.81
1-A3	0.16	0.45	0.00	0.00	0.00	0.00	0.08	0.00	0.69	0.85	5.27	10.00	9.33	6.02	10.56	7.43	11.57	8.48
2-A1	0.06	0.00	0.23	0.00	0.45	0.70	0.04	0.10	1.58	0.60	9.62	10.00	9.33	9.73	10.56	12.01	11.57	13.71
2-B1	1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.39	0.95	7.06	10.00	9.33	13.55	10.56	16.73	11.57	19.10

Table 6.10.2 Example Inlet Configuration Output

Inlet ID	Inlet Description	Inlet Station	Inlet Offset (ft)	Inlet Ref Chain	Inlet Elev (ft)	Inlet Type	Profile Type	Spread X-sect Slope 1 (%)	Spread X-sect Width 1 (ft)	Curb Length (ft)	Curb Depression (ft)	Curb Height (ft)	Curb Depression Width (%)	Grate Type	Grate Length (ft)	Grate Width (ft)	Grate Area (sf)	Grate Perimeter (sf)	Grate Area Reduction	Grate Perimeter Reduction	Remarks
1-A1	Curb Inlet Ty C w/ 1 ext (10')	910+00	0.00	EBFR	658.54	Curb	On Grade	3.06	38.00	10	0.33	0.50	2.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	CURB INLET
1-A3	Curb Inlet Ty C w/ 1 ext (10')	912+00	0.00	EBFR	653.51	Curb	On Grade	2.77	40.00	10	0.33	0.50	2.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	CURB INLET
2-A1	Inlet Ty C-1	913+15	5' RT	EBFR	642.21	Grate	Sag	16.61	6.00	n/a	n/a	n/a	n/a	Parallel 1 1/8	2.48	4.96	4.87	9.44	0.5	0.5	DITCH GRATE INLET
2-B1	Inlet Ty C-1	915+00	69.17 LT	CL-IH635	635.54	Grate	On Grade	2.54	52.00	n/a	n/a	n/a	n/a	Parallel 1 1/8	2.48	4.96	4.87	6.95	n/a	n/a	GRATE INLET

Table 6.10.3 Example Inlet Hydraulics Output

Inlet ID	Inlet Type	Inlet Profile Type	Inlet Station	Inlet Ref Chain	Discharge (cfs)	Capacity (cfs)	By Pass Flow (cfs)	By Pass To Node	By Pass Flow Into Node (cfs)	Inlet Length Actual (ft)	Inlet Length Required (ft)	Computed Ponded Width (ft)	Computed Ponded Depth (ft)	Longitudinal Slope (on grade) (%)	Gutter Spread Width (ft)	Junction Loss (ft)	Spread n	Remarks
1-A1	Curb	On Grade	910+00	EBFR	9.09	2.33	0.00		0.00	10.00	9.60	6.51	0.17	3.45	6.51	0.06	0.015	
1-A3	Curb	On Grade	912+00	EBFR	6.02	3.20	0.00	1-A1	0.00	10.00	9.95	8.26	0.22	1.83	8.26	0.10	0.015	
2-A1	Grate	Sag	913+15	EBFR	9.73	23.01	0.00		0.00	n/a	n/a	0.00	0.01	n/a	0.00	0.00	0.016	
2-B1	Grate	On Grade	915+00	CL-IH635	13.55	9.45	0.00		0.00	n/a	n/a	0.77	0.18	n/a	0.77	0.00	0.016	

Table 6.10.4 Example Link Configuration Output
Hydraulic Data: Proposed Storm Sewer (50-Year Frequency)

Link/Run No.	From Node	To Node	Drainage Area No.	Total DA	Weighted C-Value	Cumulative Tc (min)	Intensity (in/hr)	Design Q (cfs)	Conduit Size	Number of Barrels	Flowline U.S. (ft)	Flowline D.S. (ft)	Hydraulic Length (ft)	Slope (%)	Manning's n-value
IH 635 Eastbound Frontage Road Trunk Line (West of DNT)															
1	DP1	DP2	EF DP 1	2.45	0.915	10.00	10.56	23.72	30" RCP	1	626.35	623.02	664.73	0.50	0.013
2	DP2	DP3	EF DP 1-2	5.76	0.842	10.00	10.56	51.20	36" RCP	1	622.52	615.33	1037.64	0.69	0.013
3	DP3	DP4	EF DP 1-3	6.92	0.868	10.00	10.56	63.46	36" RCP	1	615.33	606.42	810.48	1.10	0.013
4	DP4	DP5	EF DP 1-4	17.88	0.845	10.00	10.56	159.62	4'X4' BC	1	605.42	600.56	441.36	1.10	0.012
5	DP5	DP6	EF DP 1-5	45.41	0.939	12.88	9.46	403.29	6'X6' BC	1	598.56	593.11	1010.63	0.54	0.012
6	DP6	DP6A	EF DP 1-6	60.85	0.951	14.22	9.03	522.27	6'X6' BC	1	593.11	589.75	589.63	0.57	0.012

Table 6.10.5. Example Link Hydraulics Output

Hydraulic Data: Proposed Storm Sewer (50-Year Frequency)

Link/Run No.	From Node	To Node	Critical Elevation (ft)	HGL U.S. (ft)	HGL D.S. (ft)	Friction Slope (%)	Depth		Velocity		Q (cfs)	Capacity (cfs)	Junction Loss (ft)	Remarks
							Uniform (ft)	Actual (ft/s)	Uniform (ft)	Actual (ft/s)				
1	DP1	DP2	631.40	629.22	627.00	0.334	1.72	2.50	6.59	4.83	23.72	29.01	0.000	
2	DP2	DP3	629.80	627.00	620.48	0.589	2.27	3.00	8.91	7.24	51.19	55.52	0.408	
3	DP3	DP4	627.10	620.48	612.52	0.905	2.24	3.00	11.22	8.98	63.46	69.96	0.626	
4	DP4	DP5	616.60	612.52	608.88	0.649	2.78	4.00	14.35	9.98	159.61	207.81	0.773	
5	DP5	DP6	611.70	608.88	603.09	0.477	4.88	6.00	13.79	11.20	403.29	429.26	0.975	
6	DP6	DP6A	619.60	603.09	596.74	0.799	5.91	6.00	14.74	14.51	522.27	441.04	1.635	

CHAPTER 7 - CULVERTS

7.1 GENERAL

Culvert design shall be based on procedures outlined in Chapter 8 of TxDOT's Hydraulic Design Manual. The guidelines included here are intended to supplement that manual. Downstream tailwater shall be calculated as stated in Chapter 7 of TxDOT's Hydraulic Design Manual. Refer to Table 5.3.1 for Channel roughness coefficients to be used in IH 635 corridor.

Chapter 8, Section 2 of the TxDOT Hydraulic Manual discusses design considerations for culverts and Chapter 8, Section 3 discusses design procedure. The following discussion clarifies these sections as they relate specifically to the IH 635 corridor.

7.2 RUNOFF CALCULATIONS

Refer to Chapter 6 for appropriate runoff calculation methodology.

Major crossings or crossings with an upstream drainage area greater than 200 acres shall be designed based on the 100-year storm frequency. Minor crossings with upstream contributing drainage areas less than 200 acres shall be designed based on the 50-year storm frequency. For minor culvert crossings, the 100-year storm frequency shall be used as a check of the performance of the culvert. See section 7.5 for check criteria.

7.3 TAILWATER DETERMINATION

The tailwater refers to the water surface elevation downstream of the culvert crossing. The tailwater is used as starting conditions for the computation of the hydraulic grade line through the culvert. Within the IH 635 corridor there are two types of tailwater conditions and they include culverts that tie into a downstream channel and culverts that tie into a closed storm drain system.

7.3.1 Culverts That Tie Into a Downstream Channel

The tailwater for instances where the culvert discharges into a channel shall be computed based on standard backwater procedures as prescribed in Chapter 7 of the TxDOT Hydraulic Design Manual. Cross sections shall be obtained downstream to the first downstream control point or 1000-feet whichever is shorter. The procedure for obtaining cross sections and creating hydraulic models is discussed in Chapter 5. Where the culvert is located along a major creek crossing, HEC-RAS or HEC-2 hydraulic models shall be used to determine the tailwater and to design the culvert. When two culverts along the same channel are separated by 1,000-foot or less, the downstream culvert must be included in the backwater computations.

7.3.2 Culverts That Tie Into a Closed System

The hydraulic grade line of the appropriate design frequency for the downstream drainage system shall be used as a tailwater for the proposed culvert. The frequency for the hydraulic grade line shall be the same frequency that is being used to size the culvert.

7.4 HYDRAULIC COEFFICIENTS

The Manning's roughness coefficient that is to be used for concrete boxes is 0.012. For concrete pipe the roughness coefficient is 0.013. Metal or plastic culverts shall not be used for culvert crossings within the IH 635 corridor.

The entrance loss coefficient is based on the culvert entrance geometry. Table 7.4.1 defines the entrance loss coefficients to be used for the various entrance types allowed within the IH 635 corridor. The exit loss coefficient shall be 1.0.

Table 7.4.1 Entrance Loss Coefficients

Type of Structure/Design of Entrance	Coefficient C_e
Pipe, Concrete	
Headwall or headwall and wingwalls	0.5
Straight wingwalls or pipe cut (mitered) to match embankment side slope	0.7
Box, Reinforced Concrete	
Beveled edges on three sides	0.20
45° flared wingwalls	0.40
180° parallel wingalls	0.50
Straight wingwalls (extension of sides)	0.70

7.5 HEADWATER

The headwater is the depth of the upstream water surface measured from the invert at the culvert entrance. Refer to Chapter 8 of TxDOT's Hydraulic Design Manual for headwater computation procedure. The design of the culvert shall begin by establishing the headwater and the upstream water surface elevations resulting from the existing culvert passing the fully-urbanized discharges as defined in Sections 4.1 and 5.4. The flow used for culvert design shall include the runoff from all drainage areas contributing flow to the culvert. For culverts within the IH 635 corridor, the total flow will be assumed to enter the upstream culvert entrance.

Once the existing water surface elevations are set, the proposed culvert must be designed so that the design storm's headwater is no greater than the existing water surface elevation at the location of the proposed culvert entrance. The check storm shall be used to ensure the headwater does not encroach onto the IH 635 mainlanes/general purpose lanes. In addition, the headwater elevation for the check storm must not be greater than the elevation of the culverts drainage divides.

The hydraulic grade line for the culverts will be a straight line interpolation between the proposed headwater and tailwater unless a hydraulic jump or hydraulic drop occurs inside the box.

7.6 CULVERT SECTIONS

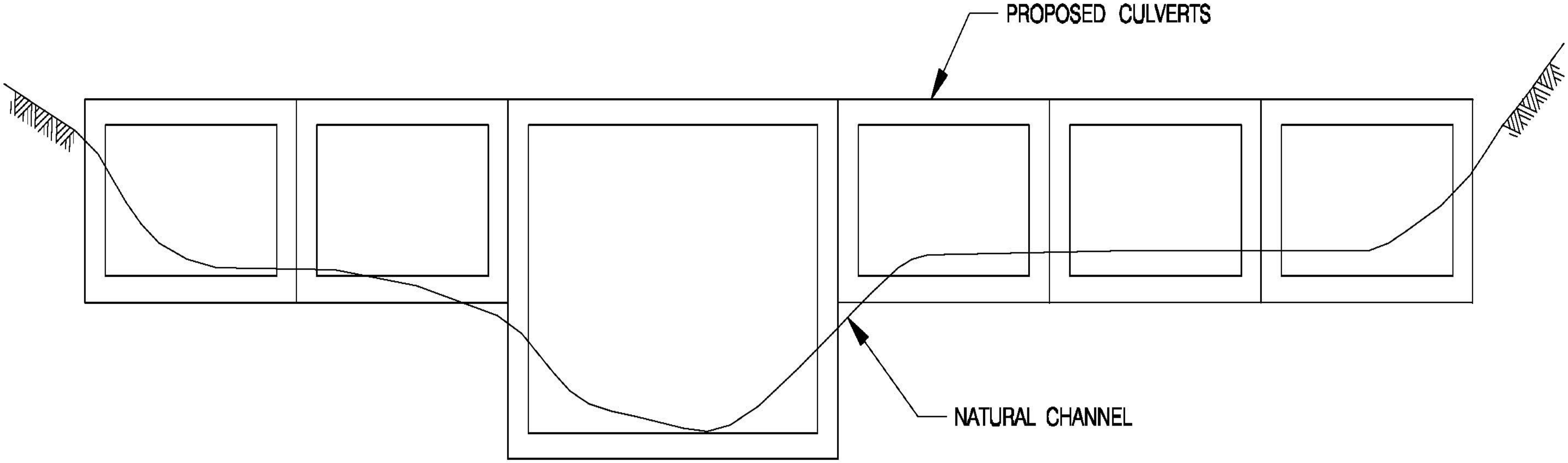
For the IH 635 corridor only concrete box culverts or concrete pipe culverts will be allowed for cross drainage. The smallest pipe diameter allowed is 24-inches. The shortest concrete box culvert height that is allowed is three-feet. The culverts span to height ratio must be no less than 1:1/2 as site conditions allow. When multiple box culverts are necessary they may be placed at various elevations to best match the natural or pipe channel section as shown in Figure 7.6.1.

For the IH 635 corridor, all culverts not tying to closed systems must have headwalls. Wingwalls shall project from the headwall at angles allowed by TxDOT standard details for headwalls and wingwalls. The edges of the culvert entrance shall be beveled as shown in TxDOT standard details for box culverts.

7.7 CULVERT VELOCITY

Modifications to the existing culvert shall not raise the velocities greater than the erosive limits for either the design storm or the check storm. The erosive limits are specified in Table 5.5.1 of this manual. If the proposed design causes a rise in the channel velocity greater than erosive limits, the proposed design must be modified to lower the velocity or the channel must be armored.

Figure 7.6.1 Multiple Box Culvert Placement



Armoring the channel experiencing high velocities may consist of materials shown in Table 5.5.1 such as gabions or rock rip-rap. The armoring shall be extended downstream or upstream to a point where the channel velocities are not erosive. Methods of reducing the proposed velocities are discussed in Chapter 8, Section 5 of TxDOT's Hydraulic Design Manual.

7.8 OUTPUT

There are a number of different tools to analyze culvert systems including: HEC-RAS, HY8, Culvert Master, etc. For the IH 635 corridor, regardless of the analytical tool used to design the culvert, the following data must be provided:

- Number and size of culvert structure
- Lowest top of curb above the culvert
- Upstream and downstream flowline (for each barrel, if necessary)
- Tailwater used for the design and check storm
- Headwater calculated for the design and check storms
- Length of box
- Slope of box
- Discharge for the design storm and check storm

CHAPTER 8 - BRIDGES

8.1 GENERAL

There are four hydraulically designed bridges in the IH 635 corridor. They are the crossings over Farmer's Branch Creek, its tributary, Cooks Branch, and the Lower Long Branch Creek of Duck Creek. These bridge crossings shall be designed based on methods provided in Chapter 9 of TxDOT's Hydraulic Design Manual. Chapter 9, Section 3 covers design considerations and Sections 4 through 6 cover design procedures. The information provided here supplements these sections as they apply to the IH 635 corridor.

8.2 RUNOFF CALCULATIONS

Refer to Chapter 4 for the appropriate runoff calculation methods. All bridge crossings are considered major creek crossings and shall be designed for the ultimate 100-year storm frequency as described in Section 5.4.

8.3 BRIDGE SECTIONS

Bridges shall span the creek so that no bents are located within the main channel when possible. Bents and headers shall be oriented so that they are parallel to the stream lines at the 100-year flow with standard skew angles to the floodplain such as 15°, 30°, 45°, etc. where possible. For skewed stream crossings where the skew angle is greater than 20°, the effective area of opening shall be reduced. Documentation shall be provided in the hydraulic report in the event that bridge or culvert skew is considered.

8.4 HYDRAULIC OPERATION

Because all hydraulically designed bridges are located at major creek crossings, HEC-2 or HEC-RAS hydraulic models shall be used to design the openings and determine tailwater and headwater. Farmer's Branch Creek and its tributary are in HEC-RAS, while Cooks Branch and Upper Long Branch will remain in HEC-2. The limits of analysis and cross section update requirements are given in Section 5.2. Manning's "n" values are given in Table 5.3.1.

Headwater shall be determined with methods listed in Chapter 9 Section 4 of TxDOT's Hydraulic Design Manual. The design storm headwater elevation must not be greater than the bridge's drainage divide elevation. Bridge low chord elevations shall be designed for a minimum of 2-feet above the 50-year water surface elevation and a desirable freeboard of 1-foot above the 100-year water surface elevation. The 100-year headwater shall not encroach onto the IH 635 mainlanes/general purpose lanes. Bridges shall be designed to maintain their integrity during a 500-year event.

Maximum velocities for various types of channel lining are given in Section 5.5 in Table 5.5.1. Where velocities greater than these exist, the channel shall be protected.

8.5 BRIDGE SCOUR

Refer to “Evaluating Scour at Bridges” (HEC 18, 2001) for detailed scour discussion and analysis procedures.

Refer to FHWA IH-97-030, “Bridge Scour and Stream Instability Countermeasures” (HEC-23) for discussion on selection of scour protection measures.

To prevent scour from impacting the stability of the proposed bridges in non-lined channels, the following two methods shall be used to protect the columns and foundations:

- Design the bridge columns and foundations to withstand the maximum total potential scour for the structure. This includes the assumption that all of the material down to the maximum potential scour limit has been removed when determining the point of rigidity. It is also advisable in areas where a layer of highly erosion resistant bedrock, such as shale or limestone, is relatively shallow, to design these foundations as if the soil above the bedrock is removed completely by the scour process.
- Provide scour protection at the base of columns by installing an apron of rock riprap. Rock riprap is preferred over the use of gabions for scour protection. Riprap protection must be combined with a regular maintenance program to repair any scour that does occur at the base of the columns and regular inspection program of columns subject to scour, especially after major flood events. Guidelines based on HEC-23 for use of rock riprap are as follows:

    - The individual rocks should be sized to withstand the expected velocities.
    - The top of the apron should be at the streambed elevation.
    - The thickness of the apron should be a minimum of 3 times the D_{50}, and no shallower than the D_{100}.
    - The maximum size rock should be no greater than 2 times the D_{50}.

- The extent of the riprap apron around the column should be at least 2 times the column dimension measured perpendicular to the flow, measured from the column face. However, the extent of the apron downstream of the column should be no less than 10 feet.

8.6 OUTPUT

In the IH 635 corridor, HEC-RAS will be used for hydraulic modeling, except where an existing HEC-2 hydraulic model is available. With either software, the design models will be provided in the hydraulic report, and a summary of that documentation shall be incorporated into the construction plans as given in Chapter 3.

Scour calculations shall be performed in accordance with HEC-18. The required scour analysis output is shown in Table 8.6.1. An example of the required scour analysis results is shown in Table 8.6.2.

Table 8.6.1 Sample Scour Calculations

IH 635 LBJ FREEWAY
HYDRAULIC ANALYSIS

SCOUR ANALYSIS

NOTES AND SOURCES OF DATA:

MAXIMUM ALLOWABLE SCOUR:

Original Embedment (ft):	-
Existing Scour (ft):	-
Diameter / Section (inches):	-
Total column length (ft):	-
Column length above bracing (ft):	-
Based on bearing stability = 0.5 * Embedment (ft) - Exist. Scour:	-
Based on allowable unsupported length (ft):	-
Column/Drill Shaft = 1.5 x diameter (inches) - Exposed length:	-
Trestle Pile = 2.0 x diameter (inches) - Exposed length:	-
H or Square Pile = 2.0 x section depth (inches) - Exposed length:	-
Timber Pile = 1.0 x diameter (inches) - Exposed length:	-

PIER SCOUR: $Y_s = 2*Y_1*K_1*K_2*K_3*K_4*(a/Y_1)^{0.65}*Fr^{0.43}$

where:

	angle of attack:	-
L = pier length	L (ft):	-
a = pier width	a (ft):	-
K_1 = pier shape correction (chp 4, table 2 in HEC -18)	K1:	-
K_2 = correction for angle of attack (chp 4, table 3 in HEC-18)	K2:	-
K_3 = correction for bed condtion (chapter 4, table 4 in HEC-18)		
K_4 = correction for armoring by bed material size (chp 4, eqn 24 and table 5 in HEC-18)		
Y_1 = depth of flow directly upstream of the pier	Y1 (ft):	-
V_1 = velocity upstream of pier	V1 (fps):	-
$Fr = V_1/(gy)^{0.5}$	Fr:	-
Y_s = pier scour depth	Ys (ft):	-

CHECK FOR LIVE BED SCOUR: $V > V_{cr}$?, $V_{cr} = 11.52\ Y^{1/6} d_{50}^{1/3}$

where:

V = avg. through bridge velocity for subarea	V (fps):	-
Y = avg. flow depth in subarea	Y (ft):	-
d_{50} = median particle size diameter	d50 (ft):	-
V_{cr} = critical velocity for incipient motion	Vcr (ft):	-

LIVE BED CONTRACTION SCOUR: $Y_2/Y_1 = (Q_t/Q_c)^{0.857}(W_1/W_2)^{.069}$

where:

Y_1 = avg. depth of flow in upstream channel	Y_1 (ft):	-
W_1 = bottom width of the upstream main channel	W_1 (ft):	-
W_2 = bottom width of contracted channel	W_2 (ft):	-
Q_c = main channel flow upstream of contraction	Q_c (cfs):	-
Q_t = main channel flow in contracted section	Q_t (cfs):	-
Y_2 = avg. flow depth in contracted section	Y_2 (ft):	-
Y_s = contraction scour = $Y_2 - Y_1$	Y_s (ft):	-

CLEAR WATER CONTRACTION SCOUR: $Y_2 = (Q^2 / 120\ d_{50}^{2/3} W^2)^{3/7}$

where:

Q = flow in the clear water section	Q (cfs):	-
W = width in clear water section less pier widths	W (ft):	-
Y_2 = avg. flow depth in section + c/w scour	Y_2 (ft):	-
Y_s = contraction scour = $Y_2 - Y$	Y_s (ft):	-

SUMMARY OF SCOUR DEPTHS:

Pier scour (ft):	-
Contraction scour (ft):	-
Total (pier + contraction) scour (ft):	-
Maximum allowable scour depth (ft):	-

Table 8.6.2 Scour Results

Contraction Scour Variables and Depths							
Proposed Structure	Y_1 U/S Depth of Flow (ft)	W_1 Bottom Width of Main Channel (ft)	W_2 Bottom Width of Contracted Channel (ft)	Q_C Main Channel Flow U/S of Contraction (cfs)	Q_t Main Channel Flow Contracted Section (cfs)	Y_2 Avg. Flow Depth Contracted Section (ft)	Maximum Computed Potential Contraction Scour (ft)

Pier Scour Variables and Depths									
Proposed Structure	a Pier Width (ft)	K_1 Pier Shape Factor	K_2 Attack Angle Factor	K_3 Bed Condition Factor	K_4 Amoring Factor	Y_1 Hydraulic Depth (ft)	V_1 Velocity (fps)	Fr Froude Number	Maximum Computed Potential Pier Scour (ft)