City of Tyler

Design Guidelines for Subdivision Improvements

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City of Tyler
Design Guidelines for Subdivision Improvements

Table of Contents

City of Tyler
Design Guidelines for Subdivision Improvements

Chapter 1 - General Information

I. Purpose

The purpose of these Guidelines is to inform Developers and Engineers of the requirements for construction plans for public facilities, which will be owned and maintained by the City of Tyler, in subdivisions located within the City Limits of the City of Tyler, as well as within the Extra Territorial Jurisdiction (ETJ) of the City of Tyler. These requirements are for use as a guideline only, and are not to be construed as a waiver by the City of Tyler of the right to require a more stringent or lenient design, as conditions warrant.

II. Designs

All construction plans for subdivision improvements are to be prepared under the direction and supervision of a qualified Professional Engineer licensed in the State of Texas and such plans shall bear the seal and signature of that Engineer.

III. Construction Plans

The following chapters outline the detailed requirements for the preparation of construction plans for water, sanitary sewer, paving and drainage. These various plans may be combined into one complete set, as long as the clarity and usefulness of the drawings is not diminished.

A. Submittal: Two complete sets of construction plans and specifications shall be submitted to the Development Services Department for review, when the final plat is submitted to the Director of Planning for Planning and Zoning Commission consideration.

B. Content: Completed plans shall include the following sheets, as needed:
   1. Title sheet showing names of subdivision, Developer, Engineer, Managing Director of Utilities and Public Works, City Manager, City Councilmembers, date, location map and any other pertinent information. It should also provide a space for signature of approval from the Development Services Engineer.
   2. Final plat, as submitted. A copy of the approved final plat will be required before plans are approved as final.
   3. Overall water and sanitary sewer layout sheet showing street layout, lots and lot dimensions, curve data, and any other pertinent information necessary for surveying all lots and streets. This may be a modified print of the subdivision final plat.
   4. Drainage area map and drainage computation sheet showing contours at two foot intervals for the entire drainage basin of all structures planned for

the subdivision and flood plains shown on the plat. Where two foot contour intervals are not available, four foot contour intervals shall be used. See the Design Guideline for Storm Drainage System Improvements for further details.

5. Plan-profile sheets showing all improvements in accordance with the Design Guidelines for those improvements.
6. Detail sheets for special construction and City of Tyler standard details.

C. Approval: The Engineer shall provide one set of reproducible plans for final approval by the Development Services Engineer.

IV. Contractor Procurement

Water and sanitary sewer improvements must be constructed under a 3-way contract using an approved utility contractor and in accordance with City of Tyler Code of Ordinance Section 19-11 through 19-17.

For paving and drainage improvements, the City of Tyler is not a party to the contract and the Developer shall secure Contractors by whatever means (sealed bids, price quotes, force account, etc.) that may be deemed appropriate.

When the City of Tyler is to participate in the cost of improvements in accordance with the City's cost sharing policy, and the City's portion of the cost is 25% of the total costs or greater, the Contractor must be secured by competitive sealed bids.

V. Inspection

An inspector for the City of Tyler known as the Project Representative, or other designated agent, will inspect construction of the improvements described herein. Inspection is provided for quality assurance purposes only. The Contractor shall be responsible to provide quality control.

The Engineer shall be available to consult with and assist the Project Representative from time to time as the need arises. No work of any nature shall begin without notification given to the Project Representative. The Contractor shall cooperate with the Project Representative in coordinating construction and inspections, and shall notify the Project Representative so that the Project Representative may be present to inspect construction. Failure to notify the Project Representative properly may result in the City of Tyler not accepting that work. The Contractor would then be required to remove and reconstruct the improvements. The Project Representative shall not have the authority to approve defective work and acceptance of work will not constitute any waiver of the Contractor's responsibility in adhering to the construction plans and specifications, nor the designing Engineer's responsibility for the inspection of the construction of the Engineer's design.

City of Tyler
Design Guidelines for Subdivision Improvements

Chapter 2 - Water System Improvements

I. General

The purpose of this Guideline is to assist the Engineer in design and preparation of plans and specifications for the construction of public water system improvements. All water lines constructed within the City of Tyler shall be designed and constructed in accordance with the most current guidelines as promulgated by the Texas Commission on Environmental Quality (TCEQ), American Water Works Association (AWWA), United States Health Service, and the Environmental Protection Agency (EPA). All water improvements shall also be designed and constructed in accordance with this Design Guideline, City of Tyler Standard Specifications and City of Tyler Standard Details. Where the City of Tyler Standard Specifications are in conflict with these criteria, the Standard Specifications shall govern. The design and construction shall also be in compliance with current City Ordinances and the most current City of Tyler Water Master Plan. Where any questions arise as to the interpretation of the standards of design, the decision of the City of Tyler will be final.

II. Design Criteria

A. Materials for Water Lines: The materials for water line construction shall comply with City of Tyler Standard Specifications. Material types and pipe class or dimension ratio (DR) rating shall be noted on both the plans and bid proposal. Allowable materials for water lines shall be:

1. Water lines shall be either ductile iron pipe (DIP) or polyvinyl chloride (PVC) pipe.
2. Water lines may be bar wrapped concrete pressure pipe where approved by the Director of Utilities.
3. PVC pipe shall be used in cases where the corrosivity factor is 10 or greater.

The type of materials installed is required to be shown on all record drawings.

B. Location of Water Lines / Easements: Water mains shall be constructed in a dedicated street, alley, or easement to the City of Tyler which shall be filed in the public records. Water mains shall generally be located in the north one-third and west one-third of street rights-of-way, except where otherwise approved by the Director of Utilities. Water valves and other appurtenances shall not be located within the curb or gutter.

Construction of water lines shall extend to the boundaries of the development.

Easements will be provided for water lines located outside of public rights-of-way in accordance with the City of Tyler Unified Development Code. In addition, water line easements must be provided by separate easement instrument. A center line description of any off-site easement required for water mains to be constructed in conjunction with said project shall be furnished with the final plans and specifications for water mains. Center line descriptions shall be prepared by a Registered Public Land Surveyor.

C. Depth of Cover: The minimum cover for all water lines shall be 60" below the finshed top of curb elevation when under pavement or the finished grade when not under pavement. Water lines shall be laid higher in elevation than sewer lines, where possible.

D. Minimum Pipe Size: The minimum inside diameter size requirement for water lines is 8" except where smaller lines are justified (such as cul-de-sac) or recommended by a registered engineer and approved by the Director of Utilities. In no case shall mains be less than 6" in diameter.

E. Sizing Water Lines: Water lines shall be designed to carry a minimum of 750 gallons per minute while maintaining a minimum of 20 pounds per square inch gauge pressure at any connection (combined fire and drinking water flow conditions). The City of Tyler's pressure plane datum is 725 feet above mean sea level. The maximum head loss allowable is 10 feet per thousand feet of pipe. In commercial areas, the minimum flow shall be 1,500 gallons per minute and in mercantile or industrial areas the minimum flow shall be 3,000 gallons per minute. Shopping centers with 10 acres or more shall be considered mercantile areas. Assuming a pipe flow coefficient of C = 140 based on the Hazen-Williams Formula and the maximum head loss, the available flows are as shown in the following table:

Table 1
Available Flow at Maximum Head Loss

Pipe Size (inches)	**Available Flow (gpm)**
6	380
8	780
10	1,400
12	2,260

F. Looping: All lines shall be looped except where lines will enter a future subdivision, in which case a dead end will be allowed. The maximum length of looped 8" water line shall be 3,000 feet. The maximum length of unlooped 8" water line shall be 1,500 feet. An automatic flush valve shall be installed at the end of all dead end lines. Automatic flush valves shall be designed to discharge through a pipe into a nearby drainage system, if available. If a drainage system is not available, the valve shall be designed to discharge through holes in the valve cover at ground level and the valve shall be installed with a concrete pad around it to minimize erosion. Automatic flush valves shall be as specified in the City of Tyler Water Standard Specification "Valves for Water Service". The dead end line shall have a gate valve installed on the line and a minimum of one 18' joint of pipe past the valve. The end of the line shall be plugged and blocked with concrete to prevent line and valve blow-off.

G. Polyethylene Encasement: When used, all ductile iron pipe shall be wrapped in polyethylene.

H. Water Line Grades: The grades for water lines 12" in diameter and larger shall be set and staked in the ground for construction by the Engineer and the Contractor shall lay them to the proposed grades. Grade stakes for water lines smaller than 12" in diameter are not required. However, the Engineer may include grades in the profile at his option. Water lines shall not be laid to a grade less than 0.2 percent.

I. Fire Hydrants: In residential areas, fire hydrants shall be spaced at least every 500 feet or closer to provide a maximum distance of 500 feet from any point to the nearest fire hydrant. In commercial areas, fire hydrants shall be spaced at least every 300 feet or closer to provide a maximum distance of 300 feet from any point to the nearest fire hydrant.

Each fire hydrant shall be positively restrained. Fire hydrants shall be equipped with Pentagon operating nuts. Minimum lead size shall be 6". Each fire hydrant shall have an individual 6" gate valve to allow the fire hydrant to be shut off for service.

J. Isolation Valves: Main lines shall be valved at least every three blocks. However, the maximum distance between valves shall be 1500 feet. In addition, each branch line shall be valved. Valves shall be located in intersections where possible.

Valve boxes for valves used to define controlled pressure zones shall be painted red to designate that they should be closed.

In pipes greater than 30" in diameter, butterfly valves shall be used.

K. Air Release and Blow-Off Valves: For lines smaller than 12", a 1" corporation stop shall be installed at each low spot and each high point. There shall be a temporary 1" copper tubing and 1" meter stop installed at each of these stops for blowing off air and for testing the lines. After testing, these lines shall be removed. If a service connection is located where a blow-off is needed, the service may be used as a blow-off.

For lines 12" and larger, a 6" diameter blow-off line is required at each low spot and an adequately sized combination vacuum breaker, air release valve is required at each high point.

L. Development in Areas with High Water Pressure: The City of Tyler operates its potable water system on a single pressure zone at elevation 725' MSL. In low lying areas (i.e. areas with a static pressure greater than or equal to 80 psi), pressure reducing valves may be required.

M. Development in Areas with Low Water Pressure: Development above elevations of 610’ MSL requires special consideration regarding meeting the State required minimum water pressure. A predevelopment meeting will be required for any development at or above 610’ MSL. No building permits will be issued without first consulting Tyler Water Utilities regarding the plan to meet the State required minimum water pressure.

N. Service Connections: Service lines may be either copper or polyethylelene (PE) pipe. Each service line shall be installed to a point three feet (3’) behind the curb at each lot. Construction plans shall show the location of the end of all water service lines.

Each service line shall have a corporation stop on the main line and a curb stop at the end of the service. Each service line shall be permanently marked with a “W” on the curb where the service line crosses the curb and with a ½" diameter x 3' steel rod driven at the end of the service line.

Magnetic tracer wire shall be installed on each service line from the main line to the end of service. The tracer wire shall either be an integral part of the pipe or installed separately and immediately above the pipe.

O. Erosion and Sediment Control: In the construction plans, the Engineer shall include plans for erosion and sediment control during construction and permanent erosion and sediment control once construction is complete. Plans for erosion and sediment control shall be in accordance with Chapter 10, Article VII, Division E “Erosion and Sediment Control” in the City of Tyler Unified Development Code, as well as Chapters 6 and 7 of these Design Guidelines.

III. Plans

A. Preliminary Plans: The Developer shall submit with the preliminary plat, a plan showing the proposed location and sizes of water lines, prepared, signed, and sealed by a Professional Engineer licensed in the State of Texas. The plan shall include the location of lots, minimum finished floor elevations, streets, water lines, valves, fire hydrants and sewer lines along with the design calculations for the size of the water lines. The preliminary plat should reflect the most current City of Tyler Water Master Plan for the total area to be developed.

There shall be one copy of the preliminary plan showing the coverage of the area by fire hydrants. For residential areas, this preliminary plan shall have a circle scribed around each fire hydrant with a 500-foot radius. For commercial areas this preliminary plan shall have a circle scribed around each fire hydrant with a 300-foot radius.

The preliminary plans will be on a scale of not more than one hundred feet to the inch (1" = 100').

B. Construction Plans: The Developer shall submit with the final plat, two sets of the proposed plans complete, prepared, signed and sealed by a Professional Engineer licensed in the State of Texas. The City of Tyler will review the plans and specifications for conformance with State and City requirements. After the review, the Developer shall incorporate into the plans and specifications any additions or corrections required.

The City of Tyler may require that the construction plans be submitted to the TCEQ for their review, following staff review.

The construction plans shall include a location map showing the location of proposed water lines, valves, and fire hydrants. The map may be on the same scale as the preliminary plan. The construction plans shall include plan sheets and profile sheets when required showing the location of all water lines, valves, and fire hydrants.

1. Plan Section: The plan section shall be prepared on either combined plan and profile sheets or plan sheets with separate profile sheets. Unless otherwise approved by the City of Tyler, paper size shall be a minimum of 22" x 34" and the plan section shall be drawn to scale of not more than twenty feet to the inch (1" = 20'). The plan section shall include, but not be limited to, the following items:
   a. Horizontal control point on datum acceptable to the City of Tyler
   b. Stationing of proposed water lines from left to right on sheet
   c. Streets, side streets, and easements
   d. Lot lines, lot numbers, subdivision lines and City limit lines
   e. Existing topographic features such as utility poles, fire hydrants, driveways, culverts, inlets, lakes, watercourses, etc.
   f. Underground utilities, including but not limited to sanitary sewer lines, water lines, storm sewer lines, gas lines, power lines and poles, telephone lines and television cable lines, located as accurately as possible
   g. Location of soil borings, if any
   h. Locations where house service lines are to be installed
   i. All valves, fire hydrants, any branch line connections and concrete blocking

j. North arrow
k. Graphic scale
l. Special notes, if any
m. Engineer’s seal and signature and firm registration number

2. Profile Section: Profile sections shall be required for water lines greater than or equal to 12" in diameter. Profiles shall have grid increments of less than 1". Unless otherwise approved by the City, paper size shall be a minimum of 22" X 34". Drafting medium, lettering, layout, etc. are all optional except to the extent required herein. The profile section shall be drawn to a scale to match the plan horizontally and not more than five feet to the inch (1" = 5') vertically and shall include, but not be limited to, the following items:
   a. Grade of the water line, the existing ground line, and the proposed ground line where it is different from the existing.
   b. Proposed and/or existing underground utilities crossing the construction alignment of the proposed water line.
   c. Benchmark description and elevation on each sheet with temporary bench marks set at intervals of not more than 500 feet. All bench mark and profile elevations shall be tied to the National Geodetic Survey Datum (formerly The U. S. Coastal & Geodetic Survey Datum). Assumed datums will not be allowed.

C. Record Drawings: The Engineer shall prepare a set of record drawings based on the construction plans. The record drawings shall show any deviations made during construction from the approved construction plans as to the location of valves, fire hydrants, service connections, alignment and/or grade of water lines. In addition, the type of pipe materials installed is required to be shown on all record drawings. The Project Representative will assist the Engineer in procurement of information needed to develop the record drawings. The following shall be provided to the City of Tyler within thirty (30) days of written final acceptance of the improvements:
   1. One set of conformed plans in pdf format, to be provided by the Developer.
   2. One set of GPS points of all valves, fire hydrants and water service tie-in locations, to be provided by the Project Representative.

City of Tyler
Design Guidelines for Subdivision Improvements

Chapter 3 - Sanitary Sewer and Reclaimed Water System Improvements

I. General

The purpose of this Guideline is to assist the Engineer in design and preparation of plans and specifications for the construction of public sanitary sewer improvements. All sewer lines constructed within the City of Tyler shall be designed and constructed in accordance with the most current guidelines as promulgated by the Texas Commission on Environmental Quality (TCEQ), American Water Works Association (AWWA), United States Health Service, and the Environmental Protection Agency (EPA). All sewer improvements shall also be designed and constructed in accordance with this Design Guideline, City of Tyler Standard Specifications and City of Tyler Standard Details. Where City of Tyler Standard Specifications are in conflict with these criteria, the Standard Specifications shall govern. The design and construction shall also be in compliance with current City Ordinances and the most current City of Tyler Wastewater Master Plan. Where any questions arise as to the interpretation of the standards of design, the decision of the City of Tyler will be final.

II. Design Criteria

A. Materials for Sewer Lines: The materials for sewer line construction shall comply with City of Tyler Standard Specifications. Allowable materials for sewer lines shall be:

1. Gravity lines shall be vitrified clay pipe (VCP) with premolded gaskets, polyvinyl chloride (PVC) pipe or cement lined asphaltic coated ductile iron pipe (DIP).
2. Water line crossings shall be in accordance with TCEQ requirements.
3. Creek crossings, highway and railroad crossings, shallow lines, lines laid in areas with a high water table and lines laid in unsuitable soil conditions shall be constructed as follows:

	DIP	Encasement	PVC	Encasement
Creek Crossings: (aerial and below ground crossings)	✓	steel	✓	steel
Highway and/or Railroad Crossings	✓	steel		
Shallow Lines:	✓			
High Water Table:	✓			
Unsuitable Soils:	✓	concrete	✓	concrete

The Director of Utilities may require concrete encasement in other circumstances at his or her discretion.

The type of materials installed is required to be shown on all record drawings.

B. Location of Sewer Lines / Easements: Sanitary sewer mains shall be constructed in a dedicated street, alley, or easement to the City of Tyler which shall be filed in the public records. Sanitary sewer mains shall generally be located in the south one-third and east one-third of street rights-of-way except where otherwise approved by the Director of Utilities. Manholes and cleanouts shall not be located within the curb or gutter.

Construction of sewer mains shall extend to the boundaries of the development where feasible (i.e., where elevations will allow the main to be extended through the developed parcel to an adjacent parcel while maintaining positive grade).

Easements will be provided for sewer lines located outside of public rights-of-way in accordance with the City of Tyler Unified Development Code. In addition, sewer line easements must be provided by separate easement instrument. A center line description of any off-site easement required for outfall, interceptor, approach or lateral lines to be constructed in conjunction with said project shall be furnished with the final plans and specifications for sanitary sewer mains. Center line descriptions shall be prepared by a Registered Public Land Surveyor.

C. Depth of Cover: The minimum cover for sewer lines shall normally be five feet with a minimum clearance of one foot below established flow line of creeks and drainage ways. Sewer lines shall normally be at a lower elevation than any water line at crossings. Refer to pipe material specifications and standard details for bedding requirements.

D. Depth of Mains: Sewer mains greater than 20 feet deep require the approval of Tyler Water Utilities.

E. Minimum Pipe Size: The minimum inside diameter size requirement for gravity sanitary sewer lines is 8" except where smaller lines are justified or recommended by a registered engineer and approved by the Director of Utilities. In no case shall mains be less than 6" in diameter.

F. Sizing Sewer Lines: In residential development, gravity sewers shall be designed to carry an average daily flow of 140 gallons per capita per day based on 3.3 persons per single family unit. The line shall be designed to carry a peak flow of 4.0 times the average daily flow for 6" lines, and 2.5 times average daily flow for lines 8" and larger. For developments other than residential, the Engineer shall use the recommended design flows as set forth by the TCEQ, unless the City of Tyler has data to require greater design flows.

G. Polyethylene Encasement: When used, all ductile iron pipe shall be wrapped in polyethylene except in cases where a single stick of ductile iron pipe is used to cross other utilities.

H. Sewer Line Grades: Size, velocity and minimum grade requirements shall be in accordance with current TCEQ rules.

The grades for sewer lines shall be set by the Engineer and the Contractor shall lay them to the proposed grades. Grade stakes are required for all sewer lines. The minimum number of grade stakes required will be one stake between every two manholes or one stake between the last manhole and the end of line cleanout. Sewers shall be laid in a straight alignment with uniform grade between manholes.

I. Manholes: Manholes shall be designed and built in accordance with TCEQ requirements, City of Tyler Standard Specifications and City of Tyler Standard Details. Manholes shall be placed at points of changes in alignment, grade or size of sewer. Manholes shall also be placed at all street intersections, at intersections of sewers, and the end of all sewer lines that will be extended at a later date.

Manhole spacing shall be a maximum of 400 feet for 6" and 8" sewer lines. Manhole spacing for lines greater than 8” shall be in accordance with TCEQ requirements. The minimum inside diameter of a manhole shall be 4 feet.

Manholes in floodplains require bolted and gasketed covers and require an alternate means of venting at maximum intervals of 1500'. Vents must be located a minimum of 1 foot above the 100-year flood elevation.

All new manholes shall be fitted with watertight inserts in accordance with City of Tyler Standard Specifications.

J. Cleanouts: Cleanouts may be used in lieu of manholes at the end of sewers which are not to be extended in the future.

K. Lift Stations and Pressure Lines: In general, the City of Tyler will not permit the construction of lift stations and pressure lines, unless it is impossible to connect to a gravity system. If a lift station is required, complete design, including site work, an all-weather access road, etc. shall be included in the plans and specifications. At the option of the City of Tyler, the design may include service to an area, in addition to the property being developed, with the City of Tyler participating in the excess capacity cost in accordance with Chapter 19 of the City Tyler Code of Ordinances. The lift station shall be designed in compliance with current state and federal requirements and shall have either dual electrical supply or a stand-by generator. The minimum lift station capacity shall be 100 gallons per minute and shall have at least two pumps. The minimum size for a pressure line shall be 4-inches.

L. Service Connections: A minimum 4" service line shall be installed to a point at least six feet (6') inside the property line of each lot. Construction plans shall show the location of the end of all sewer service lines. Each service line shall have a tapping saddle or wye fitting installed in the branch line for each service. Service connections 6" and larger shall be installed in a manhole.

Each service line shall be permanently marked with an "S" on the curb where the service line crosses the curb and with a ½" diameter x 3' steel rod driven at the end of the service line. The service line shall be at least 4' deep at the curb and, where possible, shall be deep enough to allow a 2 foot per 100 foot drop in the service line from the back of the lot or lowest point in the lot to the property line, plus an adequate depth for the plumbing. Minimum finished floor elevations for sanitary sewer service shall be shown on the plat for lots requiring fill.

Magnetic locator tape shall be installed directly above the sewer service pipe from the main line to the end of the service.

M. Reclaimed Water Systems: Reclaimed water systems shall be designed in accordance with the City of Tyler's requirements for potable water systems except that all pipe, valve boxes, etc. shall be purple.

N. Erosion and Sediment Control: In the construction plans, the Engineer shall include plans for erosion and sediment control during construction and permanent erosion and sediment control once construction is complete. Plans for erosion and sediment control shall be in accordance with Chapter 10, Article VII, Division E "Erosion and Sediment Control" in the City of Tyler Unified Development Code, as well as Chapters 6 and 7 of these Design Guidelines.

III. Plans

A. Preliminary Plans: The Developer shall submit with the preliminary plat, a plan showing the proposed location and sizes of sewer lines, prepared, signed, and sealed by a Professional Engineer licensed in the State of Texas. The plan shall include the location of lots, minimum finished floor elevations, streets, sewer lines, manholes, cleanouts and water lines along with the design calculations for the size of the sewer lines. The preliminary plat should reflect the most current City of Tyler Wastewater Master Plan for the total area to be developed.

The preliminary plans will be on a scale of not more than one hundred feet to the inch (1" = 100').

B. Construction Plans: The Developer shall submit with the final plat, two sets of the proposed plans complete, prepared, signed and sealed by a Professional Engineer licensed in the State of Texas. The City of Tyler will review the plans and specifications for conformance with State and City requirements. After the review, the Developer shall incorporate into the plans and specifications any additions or corrections required.

The City of Tyler may require that the construction plans be submitted to the TCEQ for their review, following City staff review.

The construction plans shall include a location map showing the location of proposed sewer lines, manholes and cleanouts. The map may be on the same scale as the preliminary plan. The construction plans shall include plan and profile sheets showing the location of all sewer lines, manholes and cleanouts.

1. Plan Section: The plan section shall be prepared on either combined plan and profile sheets or plan sheets with separate profile sheets. Unless otherwise approved by the City of Tyler, paper size shall be a minimum of 22" x 34"and the plan section shall be drawn to scale of not more than twenty feet to the inch (1" = 20'). The plan section shall include, but not be limited to, the following items:
   a. Horizontal control point on datum acceptable to the City of Tyler
   b. Stationing of proposed sewer lines from left to right on sheet
   c. Streets, side streets, and easements
   d. Lot lines, lot numbers, subdivision lines and City limit lines
   e. Existing topographic features such as utility poles, fire hydrants, driveways, culverts, inlets, lakes, watercourses, etc.
   f. Underground utilities, including but not limited to sanitary sewer lines, water lines, storm sewer lines, gas lines, power lines and poles, telephone lines and television cable lines, located as accurately as possible
   g. Location of soil borings, if any
   h. Locations where house service lines are to be installed

i. All manholes, cleanouts, ductile iron pipe, concrete encasement and any branch line connections
j. North arrow
k. Graphic scale
l. Special notes, if any
m. Engineer's seal and signature and firm registration number

2. Profile Section: Profiles shall have grid increments of less than 1". Unless otherwise approved by the City of Tyler, paper size shall be a minimum of 22" x 34". Drafting medium, lettering, layout, etc., are all optional except to the extent required herein. The profile shall be drawn to a scale to match the plan horizontally and not more than five feet to the inch (1" = 5') vertically and shall include, but not be limited to the following list:
   a. Grade of the sewer line, the existing ground line, and the proposed ground line where it is different from the existing.
   b. Proposed and/or existing underground utilities crossing the construction alignment of the proposed sewer line.
   c. Benchmark description and elevation on each sheet with temporary bench marks set at intervals of not more than 500 feet. All bench mark and profile elevations shall be tied to the National Geodetic Survey Datum (formerly The U. S. Coastal & Geodetic Survey Datum). Assumed datums will not be allowed.

C. Record Drawings: The Engineer shall prepare a set of record drawings based on the construction plans. The record drawings shall show any deviations made during construction from the approved construction plans as to the location of manholes, cleanouts, service connections, alignment and/or grade of sewer lines. In addition, the type of materials installed is required to be shown on all record drawings. The Project Representative will assist the Engineer in procurement of information needed to develop the record drawings. The following shall be provided to the City of Tyler within thirty (30) days of written final acceptance of the improvements:
   1. One set of conformed plans in pdf format, to be provided by the Developer.
   2. One set of GPS points of all manholes, cleanouts and sewer service tie-in locations, to be provided by the Project Representative.

City of Tyler
Design Guidelines for Subdivision Improvements

Chapter 4 - Paving Improvements

I. General

The purpose of this Guideline is to assist the Engineer in design and preparation of plans and specifications for the construction of public paving improvements. All paving improvements shall be designed and constructed in accordance with this Design Guideline, City of Tyler Standard Specifications and City of Tyler Standard Details. Materials and construction methods for paving improvements (technical specifications) shall conform to "Texas Department of Transportation Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges", latest revision, except where specifically superseded in this Guideline, City of Tyler Standard Specifications or City of Tyler Standard Details. Where any questions arise as to the interpretation of the standards of design, the decision of the City of Tyler will be final.

II. Design Criteria

A. Roadway Pavement Section Design: The City of Tyler does not have a typical or standard pavement section. Therefore, this chapter presents the method for the thickness design of roadway pavements. It contains the design requirements for various street widths and traffic conditions, various subgrade support soils, and various types of pavement materials. Pavement design options are based on a combination of the above variables.

Step 1 Determine the structural support of the roadway's existing subgrade. The subgrade strength is defined by having a California Bearing Ratio (CBR) Test performed in accordance with ASTM D1883 by a geotechnical and construction materials testing lab.

Location of borings to obtain soil samples are to be placed along the proposed roadway to provide a representative view of the existing subgrade. Laboratory tests are to be performed on these representative soil samples to determine natural moisture content, liquid and plastic limits, and percent passing the No. 200 sieve. These tests are to be performed in accordance with ASTM D2216, D4318, and D422, respectively. Additional CBR tests are to be performed where above lab tests on soil samples of the existing subgrade reveal variations in the subgrade soil according to the "Unified Soil Classification". Unified Soil Classifications are to be determined using procedures in accordance with ASTM D2487. Additional CBR tests are to be performed on soil samples where roadway grades produce cuts into varying subgrade soils.

The existing subgrade shall always be able to provide a stable working platform when the soil is compacted to a density of 95% of standard proctor at optimum moisture content according to ASTM D698. All organic and unstable material is to be removed during construction and replaced with select fill.

Step 2 Identify the class of the street to be built. Street classifications are determined by the following table and by the City of Tyler "Master Street Plan", latest edition. Choose the street type which matches the design roadway's attributes. If a design roadway's attributes fall between street classes, for example, a street that has both residential and commercial zoning, choose the street class which produces the most stringent pavement design.

Table 1
Street Classification

Master Street Plan Classification	Zoning	Maximum Average Vehicle per Day (vpd)
Local	Residential	< 2,500
Collector	Residential	2,500 – 5,000
Major Collector	Commercial/Industrial	5,000 – 8,500
Minor Arterial	All	8,500 - 24,000
Major Arterial	All	24,000 – 36,000

Step 3 Determine the total thickness of the pavement section for each type of pavement design. Three pavement design tables are provided: one for flexible base pavement, one for full-depth hot mix asphaltic concrete pavement, and one for concrete pavement. See Tables 2, 3 and 4, respectively below. Each design table is divided into street classification columns and subgrade CBR% rows. Using the street class identified in Step 2, follow this column down until it intersects the subgrade CBR% row determined in Step 1. This number represents the total thickness of pavement section, in inches, to be used.

Step 4 Determine the thickness of base. The minimum surface thickness is found at the bottom of each street class column. To obtain the thickness of base, subtract the surface thickness from the total thickness of the pavement section. On roadways that have an existing subgrade CBR% greater than 12, step 4 often provides the most economical design and the design process could be stopped (see Example Problem 1). However, for roadways that have subgrade CBR% less than 12, the design process should continue to provide an economical design.

Step 5 Select a suitable subbase material if the process is continued. Subbase material can be the existing subgrade treated with lime, flyash, cement or other approved material; a select fill material, such as iron ore topsoil; or a native subgrade material recompacted to a density to achieve the design CBR value. The subbase material is sampled and the subbase strength is defined by having a CBR test performed.

Step 6 Determine the new thickness of base and surfacing. Taking into account the subbase CBR% value and using the pavement design table again, follow the same street class column down until it intersects the subbase CBR% determined in Step 5. This number represents the total thickness in inches of base and surfacing. The base thickness is found by subtracting the surface thickness from the total thickness of base and surfacing.

Step 7 Determine the thickness of the subbase material selected in Step 5. This is found by subtracting the total thickness of base and surfacing in Step 6 from the total thickness of the pavement section in Step 3. However, the minimum thickness of a subbase material is 6".

Step 8 Determine the overall pavement section design. Add the surface thickness and base thickness found in Step 6 to the subbase thickness found in Step 7. See Example Problem 2. To determine the most economical and efficient roadway pavement design, the above process should be performed using each pavement design table, varying the subbase materials, and then applying current construction costs.

Step 9 The design submittal, including the roadway pavement section designs performed and the roadway pavement design recommended to the City for approval, shall be made on the forms provided. See Form 1. The results of the CBR test performed by a geotechnical and construction materials testing lab shall also be submitted to the City.

Table 2

Flexible Base Pavement Design

Design Period = 20 Years

Total Pavement Thickness					
Subgrade or Subbase CBR%	**Local Residential (inches)**	**Collector Residential (inches)**	**Collector Commercial (inches)**	**Major Collector Industrial (inches)**	**Minor or Major Arterial (inches)**
2	32	35	36.5	38	39
3	24	27.5	29	30	31
4	21	23	24	24.5	25
5	18	19.5	20.5	21	21.5
6	16	17.5	18	18.5	19
7	14	16	16.5	17	17.5
8	13	14.5	15	15.5	16
9	12	13.5	14	14.5	15
10	11	12.5	13	13	13.5
12	9.5	10.5	11	11.5	12
15	8	9	9.5	10	10
20	7.5	8	9	9.5	10
25	7.5	8	9	9.5	10
Minimum Surface and Base Thickness					
HMAC	2	2	2	2.5	3
Base	5.5	6	7	7	7
Minimum Stabilized Subbase Thickness					
Subbase	6	6	6	6	6
Flexible Base Specifications					
Texas Department Transportation “Texas Department of Transportation Standard Specifications for Construction of Highways, Streets and Bridges”, latest revision, Item 247 shall govern except California Bearing Ratio Tests will replace Triaxial Classes and the maximum PI = 9. The base shall be compacted to a density of 95% of modified proctor at optimum moisture content according to ASTM Method D1557.					
Grade	1, 2, 3	1, 2, 3	1, 2	1, 2	1, 2
Minimum CBR% of Base	60	60	70	70	80

Table 3
Hot Mix Asphaltic Concrete Pavement Design
Design Period = 20 Years

Total Pavement Thickness					
Subgrade or Subbase CBR%	**Local Residential (inches)**	**Collector Residential (inches)**	**Collector Commercial (inches)**	**Major Collector Industrial (inches)**	**Minor or Major Arterial (inches)**
2	12.5	14	15.5	16	16.5
3	10.5	12	13.5	13.5	14
4	9.5	10.5	12	12	12.5
5	8.5	9.5	11	11	11.5
6	8	9	10	10	10.5
7	7.5	8.	9.5	9.5	10
8	7.5	58	9	9	9.5
9	7	7.5	8.5	8.5	9
10	6.5	7.5	8	8.5	9
12	6	7	7.5	8	8
15	5.5	6.5	7	7.5	7.5
20	5.5	6	7	7	7
25	5.5	6	6.5	7	7
Minimum Surface and Base Thickness					
Type "D"	2	2	2	2.5	3
Type "B"	3.5	4	4.5	4.5	4
Minimum Stabilized Subbase Thickness					
Subbase	6	6	6	6	6
Hot Mix Asphaltic Concrete Specifications					
Texas Department of Transportation "Texas Department of Transportation Standard Specifications for Construction of Highways, Streets and Bridges" latest revision, Item 340 with coarse aggregate being crushed so that a minimum of 50% of particles retained on # 4 sieve shall have more than one crushed face when tested in accordance with Test Method Tex-460-A (Particle Count).					

Table 4
Concrete Pavement Design
Design Period = 35 Years

Total Pavement Thickness					
Subgrade or Subbase CBR%	**Local Residential (inches)**	**Collector Residential (inches)**	**Collector Commercial (inches)**	**Major Collector Industrial (inches)**	**Minor or Major Arterial (inches)**
2	8	9	10	11	11
3	7	8	9	10	10
4	7	8	9	10	10
5	6	7	8	9	9
6	6	7	8	9	9
7	6	7	8	9	9
8	6	7	8	9	9
9	6	7	8	9	9
10	6	7	8	8	8
12	6	6	7	8	8
15	6	6	7	7	7
20	5	6	7	7	7
25	5	6	6	7	7
Minimum Stabilized Subbase Thickness					
Subbase	6	6	6	6	6
Concrete Specifications					
Texas Department of Transportation "Texas Department of Transportation Standard Specifications for Construction of Highways, Streets and Bridges" latest revision, Item 360 with a minimum compressive strength of 4,000 psi at 28 days with #4 rebar on 18" c-c each way. A steel reinforcement design by a licensed professional engineer will be required for Major Collectors and larger.					

Example Problem 1

Required: Determine a pavement section for a collector street in a commercial area.

Solution A: FLEXIBLE BASE PAVEMENT SECTION

Step 1 From testing the roadway's existing subgrade, a CBR of 12% was obtained.

Step 2 From Table 1 and the "Master Street Plan", the street classification was determined to be a major commercial/industrial collector street.

Step 3 From Table 2, the total thickness of the pavement section was determined to be 11.5".

Step 4 The thickness of base without a subbase is found by subtracting the minimum surface from the total thickness, i.e. 11.5" – 2.5" = 9". The design process could stop here with an overall pavement section design of 2.5" HMAC Surface on 9" Flexible Base. However, a treated subgrade may produce a more economical design.

Step 5 The existing subgrade is treated with lime (say 6%) and testing shows the new subbase material has a CBR of 20%.

Step 6 From Table 2, the new total thickness of the pavement section is 9.5". The new thickness of base without a subbase is found by subtracting the minimum surface from the new total thickness, i.e. 9.5" – 2.5" = 7".

Step 7 The subbase thickness is found by subtracting the total thickness found in Step 6 from the total thickness found in Step 3, i.e. 11.5" – 9.5" = 2". However, minimum subbase thickness is 6".

Step 8 The new overall pavement section design is 2.5" HMAC Surface on 7" Flexible Base on 6" Lime Treated Subbase.

Solution B: FULL DEPTH HMAC PAVEMENT SECTION

Step 1 From testing the roadway's existing subgrade, a CBR of 12% was obtained.

Step 2 From Table 1 and the "Master Street Plan", the street classification was determined to be a major commercial/industrial collector street.

Step 3 From Table 3, the total thickness of the pavement section was determined to be 8".

Step 4 The thickness of base without a subbase is found by subtracting the minimum surface from the total thickness, i.e. 8" – 2.5" = 5.5". The design process can stop here with an overall pavement section design of 2.5" HMAC Surface on 5.5" HMAC Base.

Solution C: CONCRETE PAVEMENT SECTION

Step 1 From testing the roadway's existing subgrade, a CBR of 12% was obtained.

Step 2 From Table 1 and the "Master Street Plan", the street classification was determined to be a major commercial/industrial collector street.

Step 3 From Table 4, the total thickness of the pavement section was determined to be 8". The design process can stop here with an overall pavement section design of 8" Concrete Pavement on untreated subgrade.

Example Problem 2

Required: Determine a pavement section for a local street in a residential subdivision.

Solution A: FLEXIBLE BASE PAVEMENT SECTION

Step 1 From testing the roadway's existing subgrade, a CBR of 3% was obtained.

Step 2 From Table 1 and the "Master Street Plan", the street classification was determined to be a local residential street.

Step 3 From Table 2, the total thickness of the pavement section was determined to be 24".

Step 4 The thickness of base without a subbase is found by subtracting the minimum surface from the total thickness, i.e. 24" – 2" = 22". A base thickness of 22" is excessive, and the design process should continue to find a more economical design.

Step 5 The existing subgrade is treated with lime (say 6%) and testing shows the new subbase material has a CBR of 9%.

Step 6 From Table 2, the new total thickness of the pavement section is 12". The new thickness of base without a subbase is found by subtracting the minimum surface from the new total thickness, i.e. 12" – 2" = 10".

Step 7 The subbase thickness is found by subtracting the total thickness found in Step 6 from the total thickness found in Step 3, i.e. 24" – 12" = 12".

Step 8 The new overall pavement section design is 2" HMAC Surface on 10" Flexible Base on 12" Lime Treated Subbase.

Solution B: FULL DEPTH HMAC PAVEMENT SECTION

Step 1 From testing the roadway's existing subgrade, a CBR of 3% was obtained.

Step 2 From Table 1 and the "Master Street Plan", the street classification was determined to be a local residential street.

Step 3 From Table 3, the total thickness of the pavement section was determined to be 10.5".

Step 4 The thickness of base without a subbase is found by subtracting the minimum surface from the total thickness, i.e. 10.5" - 2" = 8.5". A base thickness of 8.5" is excessive, and the design process should continue to find a more economical design.

Step 5 The existing subgrade is treated with lime (say 6%) and testing shows the new subbase material has a CBR of 9%.

Step 6 From Table 2, the new total thickness of the pavement section is 7". The new thickness of base without a subbase is found by subtracting the minimum surface from the new total thickness, i.e. 7" - 2" = 5".

Step 7 The subbase thickness is found by subtracting the total thickness found in Step 6 from the total thickness found in Step 3, i.e. 10.5" – 7" = 3.5". However, minimum subbase thickness is 6".

Step 8 The new overall pavement section design is 2" HMAC Surface on 5" Flexible Base on 6" Lime Treated Subbase.

Solution C: CONCRETE PAVEMENT SECTION

Step 1 From testing the roadway’s existing subgrade, a CBR of 3% was obtained.

Step 2 From Table 1 and the “Master Street Plan”, the street classification was determined to be a local residential street.

Step 3 From Table 4, the total thickness of the pavement section was determined to be 7".

Step 4 The design process could stop here with an overall pavement section design of 7" concrete pavement on untreated subgrade. However, a treated subgrade may produce a more economical design.

Step 5 The existing subgrade is treated with lime (say 6%) and testing shows the new subbase material has a CBR of 9%.

Step 6 From Table 4, the new total thickness of pavement is 6".

Step 7 The subbase thickness is found by subtracting the total thickness found in Step 6 from the total thickness found in Step 3, i.e. 7" – 6" = 1". However, minimum subbase thickness is 6".

Step 8 The new overall pavement section design is i.e. 6" Concrete Pavement on 6" lime treated subbase.

B. Width: Pavement widths shall conform to the requirements of the City of Tyler "Master Street Plan", latest edition, but shall in no case be less than the widths shown in the following table:

Table 5
Paving Widths

Type Street	Minimum Paving Width [1]
Local - Residential:	28' or 24' [2]
Collector - Residential	32'
Major Collector - Commercial/Industrial:	40'
Minor Arterial - All:	77' or 87' w/bike lane
Major Arterial - All:	101'
Alley - Residential:	15'
Alley - other than residential:	20'

Notes: 1. Dimensions are from face of curb to face of curb or edge of pavement to edge of pavement, centered in right of way.
2. In subdivisions with all lots greater than 2 acres.

Cul-de-sacs shall be designed in accordance with current City of Tyler ordinances. The minimum radius shall be 46 feet from center to face of curb.

C. Grades: Street profile grades shall be set on top of curb for all streets. Profile grades shall not be less than 0.5' rise or fall in 100 feet (0.5%). Profile grades shall not be greater than 12' rise or fall in 100 feet (12%) on local streets, not greater than 9' rise or fall in 100 feet (9%) on collector streets, and not greater than 6' rise or fall in 100 feet (6%) on arterial streets. Grade changes exceeding 1' rise or fall in 100 feet (1%) shall be made with vertical curves. To satisfy requirements of minimum sight distance, comfort and appearance, calculate the minimum vertical curve length as follows:

$$L = K \times A$$

Where: L = minimum vertical curve length, feet (ft)
K = Factor from Table 6, below
A = Algebraic difference of grades, in percent

Table 6
Minimum K Values

Design Speed [1]	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**
Crest Vertical Curve	30	40	60	80	110	150	190	230
Sag Vertical Curve [2]	40	50	60	70	90	100	120	130

Notes: 1. The design speed shall be established by the City of Tyler.
2. Length of sag vertical curve may be shortened by the City of Tyler to reduce siltation.

Unless otherwise allowed by the City of Tyler, top of curb grades shall be set low enough below the adjacent land to facilitate proper drainage from the residential lot to the street. Curb separation shall not exceed crown height except in situations of super elevated curves, divided roadways, cul-de-sacs or intersections. Divided roadways shall have a straight cross slope downward from median to outside curb rather than a parabolic crown on each lane. Divided roadways shall not be designed, unless approved by the City of Tyler.

Superelevation is required for all street classifications except for local residential streets and alleys. Superelevated street sections shall be in accordance with AASHTO design criteria based on design speed and degree of horizontal curvature.

D. Street Alignment: Street alignment design shall consider not only the best use of the land, but also traffic safety. The maximum degree of horizontal curvature for an arterial shall be 7 degrees. The maximum degree of curvature on a collector shall be 22.9 degrees (minimum radius shall be 250'). The horizontal curvature on commercial or residential streets shall be designed so as to eliminate sharp reverse curves that are hazardous. The minimum tangent length between reverse curves shall be 50'. All horizontal curve lengths, degree of curvature, curve super elevations and other elements of traffic safety must be approved by the City of Tyler during the approval of the subdivision plans.

E. Intersections: All intersections should intersect at an angle of 90 degrees. Intersections at angles less than 90 degrees shall be approved by the City. In no case shall the angle of the intersection be less than 70 degrees.

When intersecting a street in a horizontal or vertical curve, sight distance shall be in accordance with the City of Tyler Unified Development Code. Curb returns at intersections on residential streets shall have a minimum radius of 20' measured to the face of curb.

At the intersections of collectors and collectors; collectors and arterials; and arterials and arterials, the radius will be a minimum of 30' measured to the face of curb, unless otherwise approved by the City of Tyler. A larger radius may be required by the City of Tyler to accommodate traffic movement.

F. Concrete Headers: Concrete headers shall be installed at the termination of all asphalt pavements, unless otherwise approved by the City of Tyler.

G. Curb and Gutter: Concrete curb and gutter is required on all streets constructed within the City of Tyler and its Extra Territorial Jurisdiction (ETJ), except in subdivisions with all lots 2 acres and greater in size. All curb and gutter will be designed in accordance with the Design Guideline for Storm Drainage System Improvements and City of Tyler Standard Details.

H. Concrete Valley Gutters: Where water runoff conditions dictate, all valley gutters crossing streets or intersections within a subdivision shall be constructed of reinforced concrete, unless otherwise approved by the City of Tyler, to prevent asphalt pavement deterioration.

I. Subsurface Drainage: Ground water is prevalent in Tyler and its surrounding ETJ. The Engineer will design and provide for the construction of underdrain systems in the construction plans. Even if the Engineer provides no underdrain, the City of Tyler may require the installation of underdrain.

J. Erosion and Sediment Control: In the construction plans, the Engineer shall include plans for erosion and sediment control during construction and permanent erosion and sediment control once construction is complete. Plans for erosion and sediment control shall be in accordance with Chapter 10, Article VII, Division E "Erosion and Sediment Control" in the City of Tyler Unified Development Code, as well as Chapters 6 and 7 of these Design Guidelines.

K. Testing Frequency: The City of Tyler recommends testing frequencies as shown in the City of Tyler Standard Detail "Testing Requirements for Paving".

III. Plans

A. Construction Plans: Following approval of final plat and the incorporation of changes required by the City of Tyler, six complete sets of construction drawings shall be submitted to the City of Tyler for distribution.

1. Plan Section: The plan section shall be prepared on either combined plan and profile sheets or plan sheets with separate profile sheets. Unless otherwise approved by the City of Tyler, paper size shall be a minimum of 22" x 34" and the plan section shall be drawn to scale of not more than twenty feet to the inch (1" = 20'). The plan section shall include, but not be limited to, the following items:
    a. Horizontal control point on datum acceptable to the City of Tyler
    b. Right of way, easements, and street pavement widths
    c. Stationing of proposed street from left to right on sheet and stationing of intersecting streets
    d. Angles and stations of intersections
    e. Street names
    f. Horizontal curve data
    g. Existing topographic features such as utility poles, fire hydrants, driveways, culverts, inlets, lakes, watercourses, etc.
    h. Lot lines, lot numbers, subdivision lines and City limit lines
    i. Curb radii, and special curb grade points such as end of radius returns and mid-points and top of inlet, etc.
    j. Underground utilities, including but not limited to sanitary sewer lines, water lines, storm sewer lines, gas lines, power lines and

poles, telephone lines and television cable lines, located as accurately as possible

k. Location of soil borings, if any
l. Limits of significant cut or fill
m. Directional arrows showing direction of drainage in gutters
n. Crown transition in intersections
o. North arrow
p. Graphic scale
q. Special notes, if any
r. Engineer’s seal, signature and firm registration number

2. Profile Section: Profiles shall have grid increments of less than 1". Unless otherwise approved by the City of Tyler, paper size shall be a minimum of 22" x 34". Drafting medium, lettering, layout, etc., are all optional except to the extent required herein. The profile shall be drawn to a scale to match the plan horizontally and not more than five feet to the inch (1" = 5') vertically and shall include, but not be limited to the following list:
   a. Existing ground profiles along the centerline and each right of way line.
   b. Proposed top of curb and existing top of curb line where curb has previously been built. If the new street does not have curb and gutter, proposed top of pavement profile along centerline and flowline of ditches on both sides.
   c. Vertical curve data including the K value, curve length, vertical point of intersection station and elevation, high point or low point station and elevation. Percent grades shall be shown on all tangents.
   d. Top of curb grades shall be shown at not more than 50 foot intervals in tangents and 25 foot intervals in vertical curves. The PC, PT and PI shall be shown in profile with station and elevation.
   e. Benchmark description and elevation on each sheet with temporary bench marks set at intervals of not more than 500'. All bench mark and profile elevations shall be tied to the National Geodetic Survey Datum (formerly The U. S. Coastal & Geodetic Survey Datum). Assumed datums will not be allowed.
   f. Proposed (if available) and/or existing storm sewer, sanitary sewer, water, electrical, gas and telephone lines.

B. Record Drawings: The Engineer shall prepare a set of record drawings based on the construction plans. The record drawings shall show any deviations made during construction from the approved construction plans. The Project Representative will assist the Engineer in procurement of information needed to develop the record drawings. The following shall be provided to the City of Tyler within thirty (30) days of written final acceptance of the improvements:
   1. One set of conformed drawings in pdf format, to be provided by the Developer.

Form 1

CITY OF TYLER
ROADWAY PAVEMENT SECTION DESIGN

Subdivision/Project Name: ______________________________

Street Name: ______________________________

Step 1 California Bearing Ratio Test (CBR) of Existing Subgrade:

Boring #	Station #	Offset Distance	Depth of Material Tested	CBR%

Step 2 Street Classification:

Street Classification: ______________________________

Step 3 Total Thickness of Pavement Section:

Flexible Base	Full Depth HMAC	Concrete
____________	____________	____________

Step 4 Thickness of Base:

		Flexible Base		Full Depth HMAC
Total Thickness of Pavement Section (Step 3):		____________		____________
Minimum Surface Thickness:	(-)	____________	(-)	____________
Base Thickness:	=	____________	=	____________

Step 5 Subbase Material (if used):

	Flexible Base	Full Depth HMAC	Concrete
Type of Subbase Material:	____________	____________	____________
CBR% of Subbase:	____________	____________	____________

Step 6 Thickness of Base and Surfacing (if a Subbase is used):

		Flexible Base		Full Depth HMAC		Concrete
Total Thickness of Base and Surfacing:		________		________		________
Surface Thickness:	(-)	________	(-)	________	(-)	________
Base Thickness:	=	________	=	________	=	________

Step 7 Thickness of Subbase Material (if a Subbase is used):

		Flexible Base		Full Depth HMAC		Concrete
Total Pavement Section Thickness (Step 3):		________		________		________
Total Thickness of Base and Surfacing (Step 6):	(-)	________	(-)	________	(-)	________
Subbase Thickness (minimum 6"):	=	________	=	________	=	________

Step 8 Overall Pavement Section Design:

	Flexible Base	Full Depth HMAC	Concrete
Surface Thickness:	________	________	________
Base Thickness:	________	________	________
Subbase Thickness:	________	________	________

RECOMMENDATION:	Thickness	Material
Surface:	________	________
Base:	________	________
Subbase:	________	________

Signature: ____________________

Title: ____________________

Date: ____________________

Seal

City of Tyler
Design Guidelines for Subdivision Improvements

Chapter 5 - Storm Drainage System Improvements

I. General

The purpose of this Guideline is to assist the Engineer in design and preparation of plans and specifications for the construction of public storm drainage improvements. All drainage improvements shall be designed and constructed in accordance with these Design Guidelines, City of Tyler Standard Details and City of Tyler Code of Ordinances. Materials and construction methods for drainage improvements (technical specifications) shall conform to "Texas Department of Transportation Standard Specifications for Construction of Highways, Streets and Bridges", latest revision, except where specifically superseded in this Guideline, City of Tyler Standard Specifications or City of Tyler Standard Details. Where any questions arise as to the interpretation of the standards of design, the decision of the City of Tyler will be final.

II. Development Criteria

A. Platting of Drainage Improvements: Drainage facility needs caused by the development or use of property must be identified and provided for in appropriate stages of development. During the platting process, the flood hazard areas shall be identified and drainage easements dedicated to the public on the final plat. The objectives of drainage planning and facilities are twofold: (a) to protect the uses of the platted property and the safety of the citizens of Tyler who use the platted property in the future, and (b) to prevent development and usage of the platted property from adversely affecting others. The owners and Developers of property have the duty to accommodate ultimate development conditions for upstream and adjacent drainage areas and to study the effect of each runoff from each new development on existing downstream drainage facilities. In cases where existing downstream capacity is not available, the owner and/or the Developer must provide adequate storm drainage facilities to mitigate the deficiency.

B. Improvements in Small Watersheds: Drainage improvements required for tracts impacted by drainage systems having a contributing watershed area of less than one square mile or which are upstream from the Limit Of Detailed Study as shown on the most current "Flood Insurance Rate Map" for Smith County and Incorporated Areas, prepared by the Federal Emergency Management Agency, shall be provided in accordance with these Design Guidelines and with Chapter 10, Article VII, Division A "Drainage and Water Utility Improvements" of the City Tyler Code of Ordinances.

Permanent improvements shall be constructed in drainage easements dedicated to the public. When the construction is approved by the City of Tyler, the City will assume maintenance of the portion of such improvements that are within the City limits of the City of Tyler. Exceptions to the minimum standards may be granted by the Planning and Zoning Commission on recommendation by the Development Services Engineer when such improvements are not warranted.

C. Improvements in Large Watersheds: For drainage improvements required for a tract impacted by drainage systems having a contributing watershed area one square mile or greater, the control of drainage, erosion and flooding shall be in accordance with Chapter 10, Article VII, Division A "Drainage and Water Utility Improvements" of the City Tyler Code of Ordinances. A tract will be considered to be impacted when part of the property lies within the flood plain of a stream or watershed area one square mile or greater, or where the bed or banks of such a stream touches or crosses part of the tract.

D. Development in Floodplains: Any development within a designated 100-year floodplain must be permitted through the City's Development Services Department. To develop property within a designated 100-year floodplain, the Developer must submit documentation to the Floodplain Administrator that proves the development of the lot will not encroach into the 100-year floodway.

If channel modifications are to be done to recover land in the floodplain, the Developer must submit documentation to the Floodplain Administrator to send to FEMA that proves the proposed modifications will revise the floodplain accordingly. The Floodplain Administrator will request a Conditional Letter of Map Revision (CLOMR). This CLOMR must be received prior to approval of channel modifications. Upon completion of channel modifications, documentation must be submitted to the Floodplain Administrator to send to FEMA showing that modifications have been completed and the Floodplain Administrator will request a Letter of Map Revision (LOMR) which actually revises the floodplain maps.

E. Development in Jurisdictional Waters: When development occurs in an area that impacts jurisdictional waters, the Developer shall provide a copy of the section 404 permit. The City may, at its discretion, require a letter of concurrence from the USACE indicating no jurisdictional waters are present.

III. Calculation of Runoff

A. Rational Method: The Rational Method is recommended for small urban and rural watersheds of less than 200 acres. This includes all watersheds in the City of Tyler and its Extra Territorial Jurisdiction (ETJ). However, for any sized development it is incumbent upon the Engineer to determine the hydrologic method that seems best suited for the specific situation and to provide sufficient justification for the use of a different method.

The Rational Method estimates the peak rate of runoff at any point in a watershed as a function of drainage area, runoff coefficient and average rainfall intensity at a duration equal to the time of concentration. The rational formula is expressed as:

$$Q = C \times I \times A$$

Where: Q = peak runoff rate, cubic feet per second (cfs)
C = runoff coefficient
I = average rainfall intensity, inches per hour (in/hr)
A = drainage area, acres (ac)

The methods of determining values for the runoff coefficient and the rainfall intensity are as follows.

B. Runoff Coefficient: The determination of the runoff coefficient, or C, is somewhat subjective, depending on topography, land use and vegetal cover, among other factors. Values should be determined from Table 1, below, according to the future planned uses of the land. Future land uses may be determined by zoning designations or the City's current "Future Land Use" map. Zoning and future land use information may be obtained from the City of Tyler Planning and Zoning Department.

In the event the watershed includes areas not shown on the zoning and "Future Land Use" maps, generally such areas are to be considered as residential land. If other development is anticipated within the reasonable future in these areas, the engineer shall make a rough estimate of such uses.

Table 1
Runoff Coefficients

Land Use	**Runoff Coefficient, C**
Lawns	0.05 – 0.35
Pasture	0.05 – 0.30
Unimproved Areas	0.10 – 0.30
Forest	0.10 – 0.15
Parks and Cemeteries	0.10 – 0.25
Playgrounds (except asphalt or concrete)	0.20 – 0.35
Railroad Yard Areas	0.20 – 0.35
Gravel Areas	0.50
Driveways, Walkways and Roofs	0.75 – 0.95

Table 1
Runoff Coefficients (cont'd)

Land Use	**Runoff Coefficient, C**
Streets:	
- Asphalt and Concrete	0.70 – 0.95
- Brick	0.70 – 0.85
Residential:	
- Single Family, lots < 1 acre	0.50 – 0.65
- Single Family, lots > 1 acre	0.30 – 0.45
- Apartments	0.50 – 0.70
- Multiplexes, detached	0.40 – 0.60
- Multiplexes, attached	0.60 – 0.75
Downtown Areas	0.70 – 0.95
Commercial / Industrial:	
- Light	0.50 – 0.80
- Heavy	0.60 – 0.90

When the watershed contains more than one land use, a weighted average runoff coefficient for the watershed is to be estimated by determining the C value and area for each different land use. The formula for calculating the weighted average runoff coefficient is as follows:

$$C_{avg} = \frac{(C_1A_1 + C_2A_2 + \ldots C_nA_n)}{(A_1 + A_2 + \ldots A_n)}$$

Where: C_{avg} = the weighted average runoff coefficient for the watershed
n = the number of different kinds of land use within watershed
C_n = the runoff coefficient for each of the different land uses
A_n = the area of each of the different land uses which corresponds with the runoff coefficient for that particular area, acres (ac)

C. Time of Concentration: Use of the rational formula requires the time of concentration for each design point within the watershed. The time of concentration is assumed to be equal to the duration of rainfall and is used to estimate the rainfall intensity, which is discussed in more detail below.

The time of concentration is defined as the time at which the entire watershed begins to contribute to runoff. It is calculated as the time taken for runoff to flow from the most hydraulically remote point of the drainage basin to the point of investigation. Determining the path that results in the longest travel time is a matter of trial and error, as there may be more than one possible path.

There are generally three components that characterize the progression of runoff along a travel path: 1) overland flow, such as across open paved or grassed areas, 2) shallow concentrated flow, such as in gutters and swales, and 3) concentrated channel flow, such as in conduits and open channels.

Figure A-1, presented in Appendix A, shall be used to estimate the overland and shallow concentrated flow times in order to determine the velocity for a chosen path length.

Flow time for pipes and open channel can be determined by the use of Manning's equation. The Manning’s equation is presented in Section IV.A, below. For open channels, velocity should be based on the assumption that the main channel is flowing full without flow in the overbanks. For pipe flow in a proposed storm drain system, velocity should be calculated at a uniform depth based on the computed upstream discharge. For existing storm drain systems, velocity should be calculated based on full flow conditions.

Once the velocity for each component along the travel path is calculated, the travel time for each component is determined by dividing the component path length by the velocity.

$$t = \frac{L}{60 \times V}$$

Where: t = travel time over the component, minutes (min)
L = length of component along the flow path, feet (ft)
V = flow velocity for the component, feet per second (fps)

The time of concentration, t_c, is the sum of the travel times for each component along the travel path.

The time of concentration should be found for the path with the longest travel time, which may result in an iterative process. The minimum time of concentration that should be used is 10 minutes. Therefore, if the maximum calculated time of concentration is less than 10 minutes, then use 10 minutes. Otherwise, use the actual maximum calculated time of concentration.

D. Rainfall Intensity: Rainfall intensity is the average rainfall rate for a specific duration and selected frequency. The rainfall duration is assumed to be equal to the time of concentration. Rainfall intensity is calculated using the following formula:

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

Where: I = rainfall intensity, inches per hour (in/hr)
t_c = time of concentration, minutes (min)
e, b, d = Rainfall Intensity-Duration-Frequency Coefficients, as presented in Table 3 below

Table 2
Rainfall Intensity-Duration-Frequency Coefficients

Storm Frequency	e	b	d
2-yr	0.865	82.6	14.7
5-yr	0.782	70.7	13.8
10-yr	0.747	68.7	13.5
25-yr	0.714	69.7	13.2
50-yr	0.695	71.6	13.0
100-yr	0.680	73.9	12.8

Source: Derived from the City of Tyler "Master Drainage Study", April 2008

Solutions for rainfall intensity, I, based on the above coefficients are given in Table C-1 in Appendix C.

E. Master Drainage Study: As an alternative to the method outlined above, the Engineer may use the City of Tyler "Master Drainage Study", latest revision, in locations where areas of detailed study are provided.

IV. Design of Storm Flow Structures

A. Manning's Equation: The Manning's equation shall be used to calculate the flow in all drainage structures. The Manning's equation is given by the following:

$$V = \frac{1.49}{n} \times R^{\frac{2}{3}} \times \sqrt{S}$$

Where: V = velocity, feet per second (fps)
n = Manning roughness coefficient
R = hydraulic radius, feet (ft), which is defined as the ratio of the area to the wetted perimeter = $\frac{A}{P}$
S = slope of the hydraulic elevation, feet of fall per horizontal foot (ft/ft)

Values for the Manning's roughness coefficient, n, shall be as provided in Table 3 or as stated hereinafter for each type of structure.

Table 3
Manning Roughness Coefficient

Channel Material	Manning Roughness Coefficient, n
Plastic (PVC and ABS)	0.009
HDPE	0.012
Concrete	0.013
Brick	0.016
Rubble Masonry	0.017
Corrugated Metal Pipe	0.024
Natural Channels (good condition)	0.025
Riprap	0.035
Natural Channels (with stones and weeds)	0.035
Natural Channels (poor condition)	0.060

Use of charts and/or tables for flow based on Manning's equation with the proper value of "n" in handbooks, text books, or other reference works is acceptable in lieu of making mathematical calculations where practical. A nomograph to solve Manning's equation for the velocity, V, is presented as Figure B-1 in Appendix B.

The flow rate can then be found as follows:

$$Q = A \times V$$

Where: Q = volumetric flow rate, cubic feet per second, (cfs)
A = cross-sectional area, square feet (ft^2)
V = velocity, feet per second, (ft/sec)

B. Streets: Sufficient means of diverting water from streets shall be provided so that there is a minimum 10 foot wide traffic lane left unflooded with a 10-year frequency storm and so that the water is not more than curb deep with a 100-year frequency storm. The requirement for a 10 foot wide traffic lane does not apply to streets less than 40 feet wide. The method of calculating the flow of the water in streets shall be Manning's equation, using a value of 0.013 for "n". The standard dimension of streets shall be in accordance with the City of Tyler "Master Street Plan", latest edition.

C. Storm Sewers:

1. Materials for Storm Sewers: All pipe used in the storm sewer system shall be reinforced concrete pipe conforming to ASTM C76, latest revision, or high density polyethylene (HDPE) pipe conforming to ASTM F2306, latest revision. Reinforced concrete pipe is required under public pavement (e.g. public roadways). HDPE may be used in locations outside of pavement and under private pavement (e.g. private roadways, parking lots, driveways, etc.). Upon approval by the City of Tyler, storm sewer pipe running parallel to the roadway (i.e. from inlet box to inlet box) may be HDPE depending on the proximity of the box to the pavement. Changes in pipe material must be made at an inlet or junction box.

   The type of materials installed is required to be shown on all record drawings.

2. Location of Storm Sewers / Easements: All storm sewer pipe located outside of public rights-of-way shall be placed in a drainage easement, except where pipe is carrying storm water runoff solely from one property that likely will not be subdivided or where approved by the City of Tyler. Easements will be provided in accordance with the City of Tyler Unified Development Code.

   Where not dedicated by plat, a center line description of any off-site easement required for storm sewer mains to be constructed in conjunction with said project shall be furnished with the final plans and specifications for storm sewer mains. Center line descriptions shall be prepared by a Registered Public Land Surveyor.

3. Discharge of Storm Sewers: Storm sewers should discharge into natural streams or into other storm sewers. No new unimproved channels may be constructed to carry storm water runoff, although existing channels may be improved and realigned per applicable City Ordinance(s).

   Proposed storm sewer systems may be connected into existing systems as long as the proposed combined discharge will not exceed the capacity of the existing system. Where two or more storm sewers intersect, a storm sewer manhole or junction box shall be used. Additional drainage areas shall not be directed into a watershed from another watershed.

4. Depth of Cover: Unless otherwise authorized by the City of Tyler, the top of storm sewer pipes must have at least 18 inches of earth cover over the top of the barrel of the pipe. Wherever practical, the hydraulic water level is to be kept at or below the top of the storm sewer pipe. Where the hydraulic water elevation is above the top of storm sewer pipes, it shall be kept at least 6-inches below ground level. Where the hydraulic water elevation is above the top of a storm sewer pipe, the flow in the pipe shall be calculated by the hydraulic grade rather than the pipe grade.

5. Pipe Size: Minimum pipe size, regardless of materials used, shall be 18-inches in diameter for storm sewer systems to be dedicated to and maintained by the City.

   Maximum allowable pipe size for HDPE pipe for both public and private storm sewer systems shall be 24" inside diameter.

6. Access Points: Access points shall be provided at a maximum spacing of 400 feet. Access points include curb inlets, junction boxes or storm sewer manholes.

7. Sizing Storm Sewers: Storm sewer pipes shall be designed in accordance with the State Department of Highways and Public Transportation Hydraulic Manual, December 1985 edition, as provided in Appendix D, except as otherwise stated herein. Storm sewers shall be designed to handle a 100-year frequency flood flow. The value of "n" to be used shall be in accordance with Table 3, above. However, if the Engineer can show evidence from the pipe manufacturer or other sources that a different value of "n" is justified, such will be accepted.

   If the Engineer wishes to use a flow chart from a handbook, text book, manufacturer's brochure, or other suitable reference work rather than calculating the flow, such flow charts are acceptable as long as the value of "n" used in preparing the chart is acceptable. Trenching, backfill, method of making pipe joints, and minimum cover (if more than 18 inches) shall be in accordance with the pipe manufacturer's recommendations.

8. Storm Sewer Line Grades: All storm sewer pipe shall be laid on a uniform grade which will produce a minimum velocity of 2 feet per second when the pipe is flowing full. The minimum grade for storm sewer pipe shall be as follows:

Table 4
Minimum Grade for Selected Pipe Diameters, %

Size of Pipe, inches	Concrete Pipe	HDPE Pipe
18	0.11	0.10
24	0.08	0.07
27	0.07	n/a
30	0.06	n/a
36	0.05	n/a
42	0.05	n/a
48	0.05	n/a
54	0.05	n/a
60	0.05	n/a

In no case shall the minimum grade be less than 0.05 percent.

D. Catch Basins and Area Sumps: Catch basins and area sumps shall be designed in accordance with the State Department of Highways and Public Transportation Hydraulic Manual, December 1985 edition, as provided in Appendix D, except as otherwise stated herein. Generally, catch basins are to be of the side drop inlet type. Side drop inlets on grade which are not depressed are not allowed. Grate inlet catch basins are to be used only in special cases in which they are more suitable for the location than a standard catch basin. The size of the catch basin inlets shall be adequate to pass a 100-year frequency flood. Area sumps (Y-inlets) are to be installed where needed to drain water from a median strip or other area without the storm water passing into a street. Catch basins with multiple inlets and storm sewer pipe between multiple catch basins shall have adequate means for transferring the water from the various inlets to the main storm sewer or receiving stream. All catch basins and area sumps shall be in accordance with City of Tyler Standard Details and the Texas Department of Transportation Standard Details, latest revision.

E. Culverts: Culverts under all streets shall be designed to carry a 100-year frequency flood without the water level on the upstream side of the culvert exceeding a level at least two foot below the top of the curb in the adjacent street.

Calculations for head loss across culverts shall include three types of losses which must be added together to determine the total head loss:

1. Velocity Head Loss:

$$H_V = \frac{V_2^2 - V_1^2}{64.4}$$

Where: H_V = velocity head loss due to the increase in velocity of the water passing through the culvert, feet (ft)
V_2 = velocity of the water inside of the culvert, feet per second (fps)
V_1 = velocity of the water approaching the culvert, feet per second (fps)

2. Entrance Loss:

$$H_e = \frac{KV^2}{64.4}$$

Where: H_e = entrance loss due to the increase in velocity of the water passing through the culvert, feet (ft)
V_2 = velocity of the water inside of the culvert, feet per second (fps)
K = coefficient for type of entrance

The value of the entrance coefficient, K, depends on the type of inlet to the culvert. Typical values of the entrance coefficient are:

Table 5
Entrance Coefficient, K

Pipe Structures:	**K**
Projecting from fill, socket end (groove end)	0.2
Projecting from fill, square cut end	0.5
Headwall or headwall and wingwalls:	
- Socket end of pipe (groove end)	0.2
- Square edge	0.5
- Rounded (radius 1/12 D)	0.2
Mitered to conform to fill slope	0.7
End section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Box Structures:	
Headwall parallel to embankment (no wingwalls):	
- Square-edged on 3 edges	0.5
- Rounded on 3 edges to radius of 1/12 barrel dimension, or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel:	

- Square-edged at crown	0.4
- Crown edge rounded to radius of 1/12 barrel dimension, or beveled top edge	0.2
Wingwall at 10° to 25° to barrel, square-edged at crown	0.5
Wingwalls parallel (extension of sides), square-edged at crown	0.7
Side- or slope-tapered inlet	0.2

3. Friction Loss:

$$H_f = \left[\frac{Q \times n}{1.49 \times A \times R^{\frac{2}{3}}} \right]^2 \times L$$

Where: H_f = friction loss due to water passing through the culvert, feet (ft)
Q = volumetric flow rate inside culvert, cubic feet per second (cfs)
n = Manning roughness coefficient
A = cross-sectional area of culvert, square feet (ft^2)
R = hydraulic radius, feet (ft), which is defined as the ratio of the area to the wetted perimeter = $\frac{A}{P}$
L = length of culvert, feet (ft)

In using this formula, the value of "n", the roughness coefficient, shall be suitable for the type of culvert to be used.

For the purposes of these Design Guidelines, it is assumed that all culverts will be flowing full at their peak design storm flow.

In general, the upstream water elevation should be determined by calculating both inlet and outlet flow conditions and the highest water level of the two calculations should be used. Culverts are sized properly when the upstream water elevation is maintained at least two feet or more below the top of the curb in the adjacent street.

F. Open Channels: Open channels shall be designed to carry a 100-year frequency flood with at least 12 inches of freeboard in the channel. Lining of open channels shall extend across the bottom of the channel and up the sides to the maximum flood flow from a 100-year frequency storm.

The depth of flow in open channels is to be calculated by the Manning's equation, using an appropriate "n" from Table 3.

G. Bridges: Bridges and channels under all bridges shall be so designed that the maximum flood water elevation from a 100-year frequency storm is at least 12 inches below the lowest part of the bridge deck.

H. TxDOT Standard Details: Reinforced concrete bridges, box culverts, headwalls, wingwalls, safety end treatments, piers and bents shall conform to the latest revision of Texas Department of Transportation standard details for such structures, except as may be noted elsewhere in these Design Guidelines or in the City of Tyler Standard Details. Headwalls or wingwalls are required on all culverts and on the discharge point of storm sewer pipe.

I. Erosion and Sediment Control: In the construction plans, the Engineer shall include plans for erosion and sediment control during construction and permanent erosion and sediment control once construction is complete. Energy dissipating devices such as concrete or rock riprap, splash basins, baffles and other structures to minimize erosion shall be incorporated into the design of storm drainage facilities. Plans for erosion and sediment control shall be in accordance with Chapter 10, Article VII, Division E "Erosion and Sediment Control" in the City of Tyler Unified Development Code, as well as Chapter 6 of these Design Guidelines.

J. Private Facilities: Storm drain facilities which will be privately owned and maintained, including but not limited to driveway culverts and storm sewer laterals and mains, are exempt from the requirements of this Design Guideline. Tying in privately owned storm drain systems to those systems that are owned and maintained by the City of Tyler shall not be done without prior authorization.

V. Plans

A. Construction Plans: Following approval of final plat and the incorporation of changes required by the development engineer, six complete sets of construction drawings shall be submitted to the City of Tyler for signature prior to commencing construction.

1. Drainage Area Map: An overall drainage area contour map with 2 foot contour intervals of the subdivision shall be shown divided into sub-basins for each structure or floodplain. Each sub-basin shall be marked with an identifying number or letter and the acreage. Runoff computations, curb inlet design computations, and storm sewer design computations shall all be shown in a tabular format in the construction plans.

2. Plan Section: The plan section shall be prepared on either combined plan and profile sheets or plan sheets with separate profile sheets. Unless

otherwise approved by the City of Tyler, paper size shall be a minimum of 22” x 34” and the plan section shall be drawn to scale of not more than twenty feet to the inch (1” = 20’). The plan section shall include, but not be limited to, the following items:

a. Horizontal control point on datum acceptable to the City of Tyler
b. Stationing of proposed drainage improvements from left to right on sheet
c. Right of way, easements, and street pavement widths
d. Lot lines, lot numbers, subdivision lines and City limit lines
e. Existing topographic features such as utility poles, fire hydrants, driveways, culverts, inlets, lakes, watercourses, etc.
f. Underground utilities, including but not limited to sanitary sewer lines, water lines, storm sewer lines, gas lines, power lines and poles, telephone lines and television cable lines, located as accurately as possible
g. Location of all proposed or existing inlets, pipe, culverts, manholes, headwalls and wingwalls
h. Location of all channels and streams to be filled, improved, or used as discharge points for the system
i. Curve data, angle points, or other survey data necessary to install the storm sewer facilities or to locate the facilities and easements after installation
j. Location of soil borings, if any
k. Typical cross sections for improved earthen or concrete lined channels
l. Limits of significant cut or fill
m. Directional arrows showing direction of drainage in gutters
n. Minimum finished floor elevation for each lot within or adjacent to a 100 year floodplain or drainage easement
o. North arrow
p. Graphic scale
q. Special notes, if any
r. Engineer’s seal and signature and registration number

3. Profile Section: Profiles shall have grid increments of less than 1". Unless otherwise approved by the City of Tyler, paper size shall be a minimum of 22" x 34". Drafting medium, lettering, layout, etc., are all optional except to the extent required herein. The profile shall be drawn to a scale to match the plan horizontally and not more than five feet to the inch (1" = 5') vertically and shall include, but not be limited to the following list:

a. Existing surface profile above centerline of storm sewer pipe, culverts, and existing high bank and flowline profiles for open drainage channels.
b. Water surface profile for the one hundred year flood for open channels within the subdivision and hydraulic grade line for storm sewer pipe.

c. Proposed drainage structures with flowline (invert) elevation at not more than fifty foot intervals.

d. Proposed top of curb profile.

e. Proposed and/or existing underground utilities crossing the construction alignment of the proposed storm drainage improvements.

f. Vertical curve data for flowline including the curve length and the vertical point of intersection station and elevation.

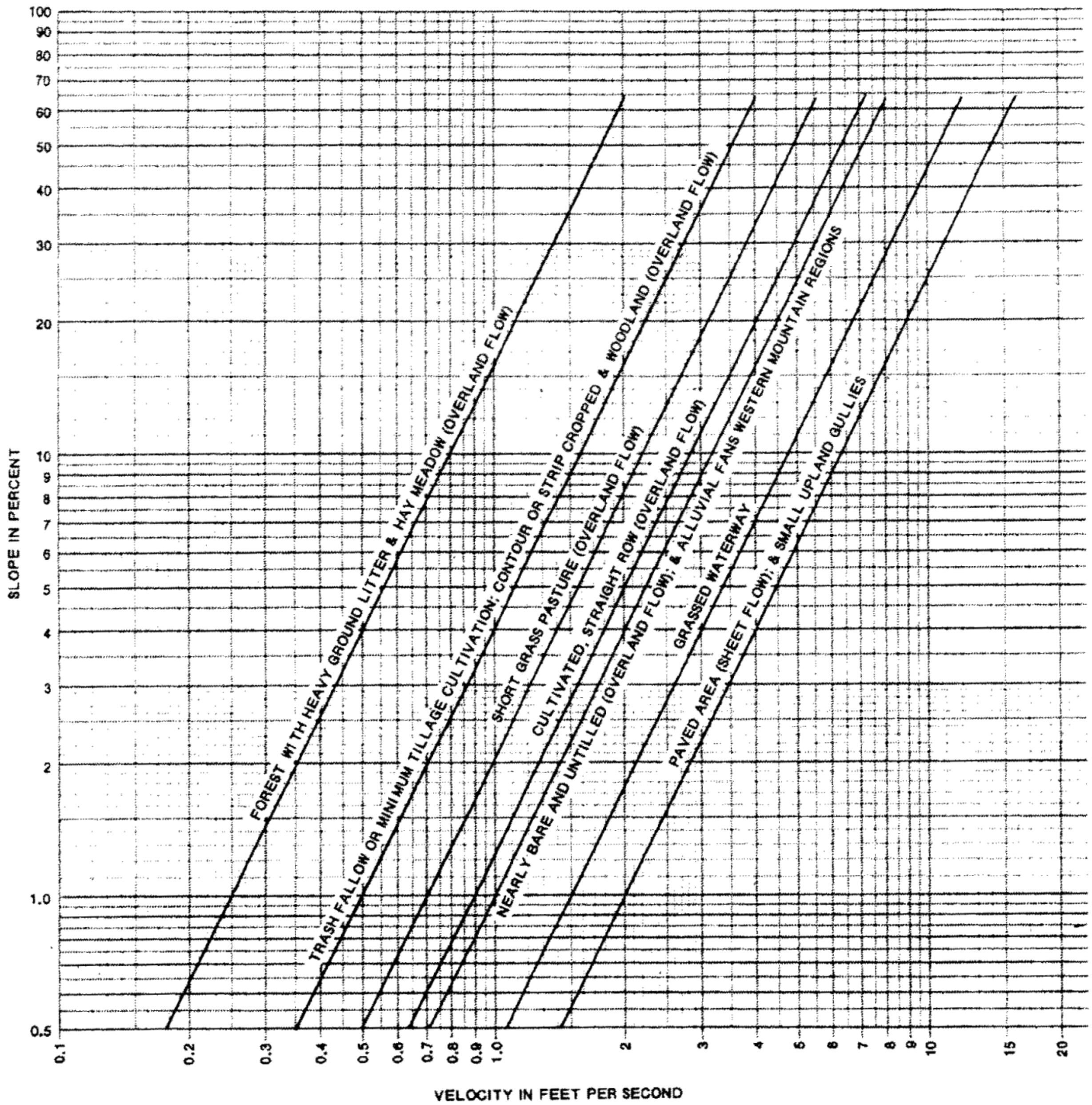
g. Benchmark description and elevation on each sheet with temporary bench marks set at intervals of not more than 500 feet. All bench mark and profile elevations shall be tied to the National Geodetic Survey Datum (formerly The U. S. Coastal & Geodetic Survey Datum). Assumed datums will not be allowed.

B. Record Drawings: The Engineer shall prepare a set of record drawings based on the construction plans. The record drawings shall show any deviations made during construction from the approved construction plans as to the location of storm sewers, inlets, culverts or bridges, or to changes in finished grades or elevations. In addition, the type of materials installed is required to be shown on all record drawings. The Project Representative will assist the Engineer in procurement of information needed to develop the record drawings. The following shall be provided to the City of Tyler within thirty (30) days of written final acceptance of the improvements:

1. One set of conformed plans in pdf format, to be provided by the Developer.
2. One set of GPS points of all inlets, culverts, bridges and locations of discharge points for the system, to be provided by the Project Representative.

APPENDIX A

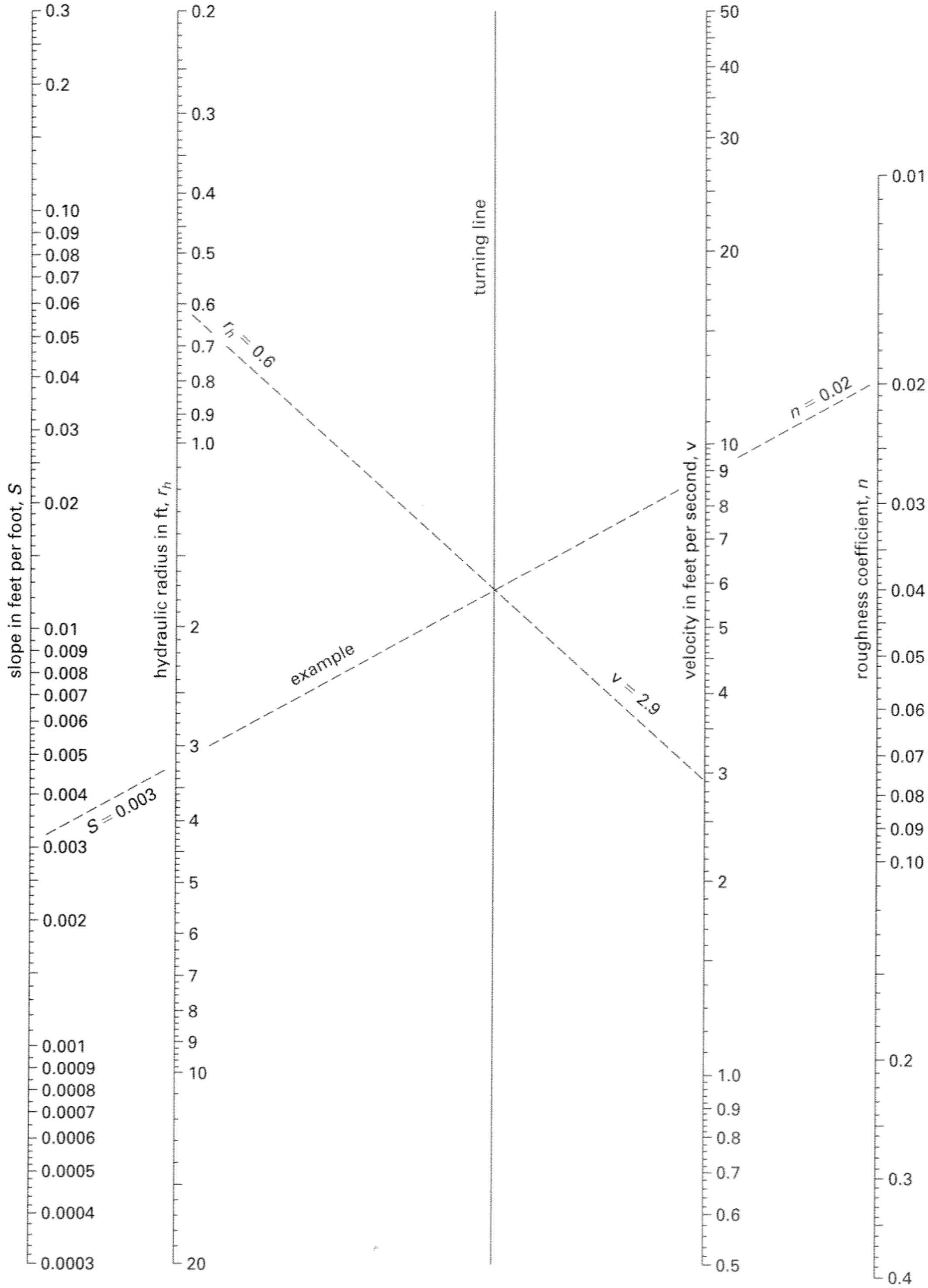
Figure A-1
Velocities for Upland Method of Estimating T_c
(from National Engineering Handbook, Section 4 Hydrology, August 1972)



APPENDIX B

Figure B-1
Manning Equation Nomograph

(solves $V = \frac{1.49}{n} \times R^{\frac{2}{3}} \times \sqrt{S}$ *)*



APPENDIX C

Table C-1
Rainfall Intensity, inches per hour (in/hr)
(solves $I = \frac{b}{(t_c + d)^e}$ *)*

T_c Hrs:Min	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
0:10	5.15	5.92	6.50	7.40	8.10	8.80
0:11	4.97	5.73	6.31	7.18	7.86	8.55
0:12	4.81	5.55	6.12	6.97	7.64	8.31
0:13	4.66	5.39	5.95	6.78	7.44	8.09
0:14	4.52	5.24	5.78	6.60	7.24	7.89
0:15	4.39	5.10	5.63	6.43	7.06	7.69
0:16	4.27	4.96	5.49	6.27	6.89	7.51
0:17	4.15	4.84	5.35	6.13	6.73	7.34
0:18	4.04	4.72	5.23	5.98	6.58	7.17
0:19	3.93	4.60	5.11	5.85	6.44	7.02
0:20	3.84	4.50	4.99	5.72	6.30	6.87
0:21	3.74	4.40	4.88	5.60	6.17	6.74
0:22	3.65	4.30	4.78	5.49	6.05	6.60
0:23	3.57	4.21	4.68	5.38	5.93	6.48
0:24	3.49	4.12	4.59	5.28	5.82	6.36
0:25	3.41	4.04	4.50	5.18	5.71	6.24
0:26	3.34	3.96	4.41	5.08	5.61	6.13
0:27	3.27	3.88	4.33	4.99	5.51	6.03
0:28	3.21	3.81	4.25	4.91	5.42	5.93
0:29	3.14	3.74	4.18	4.82	5.33	5.83
0:30	3.08	3.67	4.11	4.74	5.24	5.74
0:31	3.02	3.61	4.04	4.67	5.16	5.65
0:32	2.97	3.55	3.97	4.59	5.08	5.56
0:33	2.91	3.49	3.91	4.52	5.00	5.48
0:34	2.86	3.43	3.84	4.45	4.93	5.40
0:35	2.81	3.38	3.79	4.39	4.86	5.32
0:36	2.76	3.32	3.73	4.32	4.79	5.25
0:37	2.72	3.27	3.67	4.26	4.72	5.18
0:38	2.67	3.22	3.62	4.20	4.66	5.11
0:39	2.63	3.17	3.57	4.14	4.59	5.04
0:40	2.59	3.13	3.52	4.09	4.53	4.98
0:41	2.55	3.08	3.47	4.03	4.47	4.91
0:42	2.51	3.04	3.42	3.98	4.42	4.85
0:43	2.47	3.00	3.38	3.93	4.36	4.79

Table C-1
Rainfall Intensity, inches per hour (in/hr)
(cont'd)

Time Hrs:Min	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
0:44	2.43	2.96	3.33	3.88	4.31	4.73
0:45	2.40	2.92	3.29	3.83	4.26	4.68
0:46	2.36	2.88	3.25	3.79	4.21	4.62
0:47	2.33	2.84	3.21	3.74	4.16	4.57
0:48	2.30	2.81	3.17	3.70	4.11	4.52
0:49	2.27	2.77	3.13	3.66	4.06	4.47
0:50	2.24	2.74	3.10	3.61	4.02	4.42
0:51	2.21	2.70	3.06	3.57	3.98	4.37
0:52	2.18	2.67	3.02	3.53	3.93	4.33
0:53	2.15	2.64	2.99	3.50	3.89	4.28
0:54	2.12	2.61	2.96	3.46	3.85	4.24
0:55	2.10	2.58	2.92	3.42	3.81	4.20
0:56	2.07	2.55	2.89	3.39	3.77	4.16
0:57	2.05	2.52	2.86	3.35	3.74	4.12
0:58	2.02	2.50	2.83	3.32	3.70	4.08
0:59	2.00	2.47	2.80	3.29	3.66	4.04
1:00	1.98	2.44	2.77	3.25	3.63	4.00
1:01	1.95	2.42	2.75	3.22	3.59	3.96
1:02	1.93	2.39	2.72	3.19	3.56	3.93
0:03	1.91	2.37	2.69	3.16	3.53	3.89
1:04	1.89	2.34	2.67	3.13	3.50	3.86
1:05	1.87	2.32	2.64	3.10	3.46	3.82
1:06	1.85	2.30	2.62	3.08	3.43	3.79
1:07	1.83	2.28	2.59	3.05	3.40	3.76
1:08	1.81	2.25	2.57	3.02	3.37	3.73
1:09	1.79	2.23	2.55	3.00	3.35	3.69
1:10	1.77	2.21	2.52	2.97	3.32	3.66
1:11	1.75	2.19	2.50	2.94	3.29	3.63
1:12	1.74	2.17	2.48	2.92	3.26	3.61
1:13	1.72	2.15	2.46	2.90	3.24	3.58
1:14	1.70	2.13	2.44	2.87	3.21	3.55
1:15	1.69	2.11	2.42	2.85	3.19	3.52
1:16	1.67	2.10	2.40	2.83	3.16	3.49
1:17	1.65	2.08	2.38	2.80	3.14	3.47

Table C-1
Rainfall Intensity, inches per hour (in/hr)
(cont'd)

Time Hrs:Min	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
1:18	1.64	2.06	2.36	2.78	3.11	3.44
1:19	1.62	2.04	2.34	2.76	3.09	3.42
1:20	1.61	2.03	2.32	2.74	3.07	3.39
1:21	1.59	2.01	2.30	2.72	3.04	3.37
1:22	1.58	1.99	2.28	2.70	3.02	3.34
1:23	1.57	1.98	2.26	2.68	3.00	3.32
1:24	1.55	1.96	2.25	2.66	2.98	3.30
1:25	1.54	1.94	2.23	2.64	2.96	3.27
1:26	1.53	1.93	2.21	2.62	2.94	3.25
1:27	1.51	1.91	2.20	2.60	2.91	3.23
1:28	1.50	1.90	2.18	2.58	2.89	3.21
1:29	1.49	1.89	2.16	2.56	2.87	3.18
1:30	1.48	1.87	2.15	2.55	2.86	3.16
1:32	1.45	1.84	2.12	2.51	2.82	3.12
1:34	1.43	1.82	2.09	2.48	2.78	3.08
1:36	1.41	1.79	2.06	2.45	2.75	3.04
1:38	1.38	1.77	2.03	2.41	2.71	3.01
1:40	1.36	1.74	2.01	2.38	2.68	2.97
1:42	1.34	1.72	1.98	2.35	2.64	2.93
1:44	1.32	1.69	1.95	2.32	2.61	2.90
1:46	1.30	1.67	1.93	2.30	2.58	2.87
1:48	1.29	1.65	1.91	2.27	2.55	2.83
1:50	1.27	1.63	1.88	2.24	2.52	2.80
1:52	1.25	1.61	1.86	2.22	2.50	2.77
1:54	1.23	1.59	1.84	2.19	2.47	2.74
1:56	1.22	1.57	1.82	2.17	2.44	2.71
1:58	1.20	1.55	1.80	2.14	2.42	2.69
2:00	1.19	1.53	1.78	2.12	2.39	2.66
2:02	1.17	1.52	1.76	2.10	2.37	2.63
2:04	1.16	1.50	1.74	2.08	2.34	2.60
2:06	1.14	1.48	1.72	2.06	2.32	2.58
2:08	1.13	1.47	1.70	2.04	2.30	2.55
2:10	1.11	1.45	1.68	2.02	2.27	2.53
2:12	1.10	1.43	1.67	2.00	2.25	2.51

Table C-1
Rainfall Intensity, inches per hour (in/hr)
(cont'd)

Time Hrs:Min	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
2:14	1.09	1.42	1.65	1.98	2.23	2.48
2:16	1.08	1.40	1.63	1.96	2.21	2.46
2:18	1.06	1.39	1.62	1.94	2.19	2.44
2:20	1.05	1.38	1.60	1.92	2.17	2.42
2:22	1.04	1.36	1.59	1.90	2.15	2.39
2:24	1.03	1.35	1.57	1.89	2.13	2.37
2:26	1.02	1.33	1.56	1.87	2.11	2.35
2:28	1.01	1.32	1.54	1.85	2.09	2.33
2:30	1.00	1.31	1.53	1.84	2.08	2.31
2:32	0.99	1.30	1.51	1.82	2.06	2.30
2:34	0.98	1.28	1.50	1.80	2.04	2.28
2:26	0.97	1.27	1.49	1.79	2.02	2.26
2:38	0.96	1.26	1.47	1.77	2.01	2.24
2:40	0.95	1.25	1.46	1.76	1.99	2.22
2:42	0.94	1.24	1.45	1.74	1.98	2.20
2:44	0.93	1.23	1.44	1.73	1.96	2.19
2:46	0.92	1.22	1.42	1.72	1.94	2.17
2:48	0.91	1.21	1.41	1.70	1.93	2.15
2:50	0.90	1.20	1.40	1.69	1.91	2.14
2:52	0.89	1.19	1.39	1.68	1.90	2.12
2:54	0.89	1.18	1.38	1.66	1.89	2.11
2:56	0.88	1.17	1.37	1.65	1.87	2.09
2:58	0.87	1.16	1.36	1.64	1.86	2.08
3:00	0.86	1.15	1.35	1.63	1.85	2.06
3:10	0.83	1.10	1.30	1.57	1.78	1.99
3:20	0.79	1.06	1.25	1.52	1.72	1.93
3:30	0.76	1.03	1.21	1.47	1.67	1.87
3:40	0.73	0.99	1.17	1.42	1.62	1.81
3:50	0.71	0.96	1.13	1.38	1.57	1.76
4:00	0.68	0.93	1.10	1.34	1.53	1.72
4:10	0.66	0.90	1.07	1.30	1.49	1.67
4:20	0.64	0.88	1.04	1.27	1.45	1.63
4:30	0.62	0.85	1.01	1.24	1.41	1.59
4:40	0.60	0.83	0.99	1.21	1.38	1.55

Table C-1
Rainfall Intensity, inches per hour (in/hr)
(cont'd)

Time Hrs:Min	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
4:50	0.59	0.81	0.96	1.18	1.35	1.52
5:00	0.57	0.79	0.94	1.15	1.32	1.48
5:10	0.55	0.77	0.92	1.13	1.29	1.45
5:20	0.54	0.75	0.90	1.10	1.26	1.42
5:30	0.53	0.73	0.88	1.08	1.24	1.39
5:40	0.51	0.72	0.86	1.06	1.21	1.37
5;50	0.50	0.70	0.84	1.04	1.19	1.34
6:00	0.49	0.69	0.82	1.02	1.17	1.32
6:20	0.47	0.66	0.79	0.98	1.13	1.27
6:40	0.45	0.63	0.76	0.95	1.09	1.23
7:00	0.43	0.61	0.74	0.91	1.05	1.19
7:20	0.41	0.59	0.71	0.89	1.02	1.15
7:40	0.40	0.57	0.69	0.86	0.99	1.12
8:00	0.38	0.55	0.67	0.83	0.96	1.09
8:20	0.37	0.54	0.65	0.81	0.94	1.06
8:40	0.36	0.52	0.63	0.79	0.91	1.03
9:00	0.35	0.50	0.61	0.77	0.89	1.01
9:20	0.34	0.49	0.60	0.75	0.87	0.98
9:40	0.33	0.48	0.58	0.73	0.85	0.96
10:00	0.32	0.47	0.57	0.71	0.83	0.94
10:20	0.31	0.45	0.56	0.70	0.81	0.92
10:40	0.30	0.44	0.54	0.68	0.79	0.90
11:00	0.29	0.43	0.53	0.67	0.77	0.88
11:20	0.29	0.42	0.52	0.65	0.76	0.86
11:40	0.28	0.41	0.51	0.64	0.74	0.85
12:00	0.27	0.41	0.50	0.63	0.73	0.83
12:20	0.27	0.40	0.49	0.62	0.72	0.82
12:40	0.26	0.39	0.48	0.60	0.70	0.80
13:00	0.26	0.38	0.47	0.59	0.69	0.79
13:20	0.25	0.37	0.46	0.58	0.68	0.78
13:40	0.24	0.37	0.45	0.57	0.67	0.76
14:00	0.24	0.36	0.44	0.56	0.66	0.75
14:20	0.23	0.35	0.44	0.55	0.65	0.74
14:40	0.23	0.35	0.43	0.55	0.64	0.73

Table C-1
Rainfall Intensity, inches per hour (in/hr)
(cont'd)

Time Hrs:Min	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
15:00	0.23	0.34	0.42	0.54	0.63	0.72
15:20	0.22	0.34	0.42	0.53	0.62	0.71
15:40	0.22	0.33	0.41	0.52	0.61	0.70
16:00	0.21	0.32	0.40	0.51	0.60	0.69
16:20	0.21	0.32	0.40	0.51	0.59	0.68
16:40	0.21	0.31	0.39	0.50	0.58	0.67
17:00	0.20	0.31	0.39	0.49	0.57	0.66
17:20	0.20	0.31	0.38	0.48	0.57	0.65
17:40	0.20	0.30	0.37	0.48	0.56	0.64
18:00	0.19	0.30	0.37	0.47	0.55	0.63
18:20	0.19	0.29	0.36	0.47	0.55	0.63
18:40	0.19	0.29	0.36	0.46	0.54	0.62
19:00	0.18	0.28	0.35	0.45	0.53	0.61
19:20	0.18	0.28	0.35	0.45	0.53	0.60
19:40	0.18	0.28	0.35	0.44	0.52	0.60
20:00	0.18	0.27	0.34	0.44	0.51	0.59
20:20	0.17	0.27	0.34	0.43	0.51	0.58
20:40	0.17	0.27	0.33	0.43	0.50	0.58
31:00	0.17	0.26	0.33	0.42	0.50	0.57
21:20	0.17	0.26	0.33	0.42	0.49	0.57
21:40	0.17	0.26	0.32	0.41	0.49	0.56
22:00	0.16	0.25	0.32	0.41	0.48	0.55
22:20	0.16	0.25	0.31	0.41	0.48	0.55
22:40	0.16	0.25	0.31	0.40	0.47	0.54
23:00	0.16	0.25	0.31	0.40	0.47	0.54
23:20	0.15	0.24	0.30	0.39	0.46	0.53
23:40	0.15	0.24	0.30	0.39	0.46	0.53
24:00	0.15	0.24	0.30	0.39	0.45	0.52

APPENDIX D

through the storm drain from the upper end of the storm drain to the point in question. This is true unless the time for another branch or inlet at that point is greater. Each component of the time of concentration may be estimated by the relation:

$$t_c = \frac{L}{(V \times 60)} \qquad (6\text{-}2)$$

where: t_c = time of concentration (in minutes), L = length of water course over which runoff must travel (in feet), and V = estimated or calculated velocity (in feet per second) of runoff movement. (This velocity is based upon normal depth of flow for design discharge in a run of pipe).

In municipal areas, the time of concentration is seldom less than five minutes nor more than twenty minutes. A minimum time of concentration of ten minutes is recommended for general use.

6-202. OTHER HYDROLOGIC METHODS

There may be instances when the specific urban area under consideration will have its own, region-specific hydrologic method. Because of some funding arrangements, it may be necessary for the Department designer to use a special (and specified) hydrologic method. For example, if a city is funding the surface drainage facilities, that city may insist upon the use of its own specific hydrologic method. Usually, such special methods are very similar to the ordinary Rational method with some minor variations.

Some situations may lend themselves to the use of some variation of SCS hydrologic estimating methods. Others may involve the use of the SCS TR-55 procedure or the USGS Urban Hydrology procedure. In still other situations, the use of a unit hydrograph procedure will be in order. Refer to Chapter 2 for detailed information on the USGS Urban Hydrology procedure. Contact the D-5 Hydraulic Section for information on the SCS TR-55 procedure.

6-203. DETENTION

Detention is accommodated, to some extent, by the process of building a design flow through the storm drain as described in Section 6-500. By recalculating the time of concentration and, in sequence, a new intensity and discharge, the significant effects of detention by the carrier pipe itself are reflected in the design. A more direct application of detention, however, involves the use of 'holding ponds', usually in the contributing watersheds, and often immediately upstream of the entrance to the storm drain system. A proper accommodation of such 'holding ponds' requires a reservoir routing procedure such as is presented in Chapter 8 of this manual. By introducing detention ponds, the designer is able to attenuate the peak of the runoff hydrograph, thus reducing the immediate discharge rate for which he is designing. The same approach for peak flow attenuation is valid and particularly useful in a storm drain system in which there are substantial lengths of large diameter pipes. In such systems, the storage capacity of the pipes can have a substantial effect on the final shape of the runoff hydrograph. Consultation with the D-5 Hydraulic Section is recommended in such cases.

6-300. PAVEMENT DRAINAGE CONSIDERATIONS

6-301. PONDING REQUIREMENTS/CONSIDERATIONS

As a general rule, inlets should be placed at all low points in the roadway surface and at suitable intervals along extended gutter slopes as necessary to prevent excessive ponding on any section of the roadway.

The flow of water in the gutter should be restricted to a depth and corresponding width which will not cause the water to spread out over the travelled portion of the roadway in such amount and depth as to obstruct or cause a definite hazard to traffic. The depth of flow naturally depends upon the quantity of water involved, the gutter gradient, the coefficient of roughness or frictional coefficient of the gutter and paving material, the cross slope of the roadway, and inlet spacing.

The following limiting widths are recommended for use:

> For Interstate and Controlled Access Highways: Limit ponding to one-half the width of the outer lane.

For Major Highways: Limit ponding to the width of the outer lane.

For Minor Highways: Limit ponding to a width and depth which will allow passage of one lane of traffic with safety.

6-302. HYDROPLANING

As precipitation falls on the roadway surface, the water accumulates to some depth before overcoming surface tension and running off. In the process of runoff, water becomes concentrated in its flow. When a vehicle encounters this accumulation of water in either or both forms, a phenomenon called hydroplaning occurs. The vehicle tires tend to plane on top of the accumulated water and slide across the water surface with the water itself acting as a sort of lubricant for that sliding process. The phenomenon of hydroplaning is a function of the water depth, the speed of the vehicle, the air pressure and the condition of the vehicle tires, and the condition and character of the pavement. Once the vehicle is hydroplaning, because tire contact with the pavement is lost, the driver has little or no control over the vehicle operation and is at the mercy of the basic laws of motion and inertia. While the general public is typically unaware of the technicalities of hydroplaning, very few drivers have not experienced the unnerving and, sometimes catastrophic, effects of the phenomenon on rain-slickened roadways.

Hydroplaning of vehicles is the single most important cause of accidents in wet weather. Therefore, a basic aim of the highway drainage designer, particularly in urban areas, is to avoid or eliminate physical characteristics which might be a cause of hydroplaning. The following sections cover some of the aspects of pavement and drainage design which are useful in avoiding situations which can cause hydroplaning.

In the general area of hydroplaning, there are some effective measures that may be taken by the use of slotted drain pipe (See also Section 6-401.). If there are large expanses of pavement, sheet flow may be a serious problem (as opposed to concentrated, gutter flow). Sheet flow may be accomodated by strategically placed slotted pipe installations (with appropriate outfalls) to intercept that flow. These types of installations may occur within the travelled way, either transversely or longitudinally. Where drainage is to the inside of lanes and against median barriers, an installation of slotted pipe with appropriate outfall can be effective in removing accumulated runoff. Where such slotted pipe installations are made, the designer should insure structural integrity either by adequate structural characteristics of the pipe or encasement in concrete such as illustrated in Figure 1.

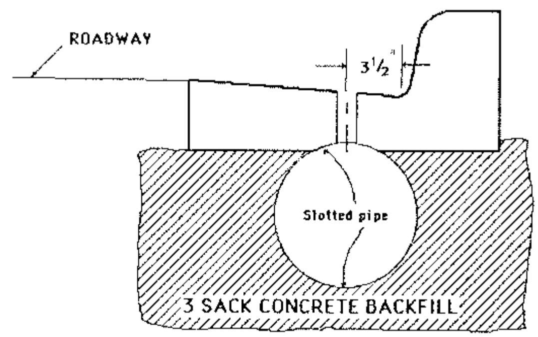


Figure 1

6-303. PAVEMENT GEOMETRIC EFFECTS ON DRAINAGE

6-303.1 CROSS-SLOPES

Except in cases of super-elevation for horizontal roadway curves, pavement cross slope is usually a compromise between the need for cross slopes adequate for proper drainage and relatively flat cross slopes amenable to driver comfort. Generally, cross slopes of no steeper than 2 percent have little effect on driver effort or vehicle operation.

If the cross slope is too flat, more depth of water accumulation is necessary to overcome surface tension and, once water accumulates into a concentrated flow, the spread of the flow is very wide. These characteristics are the chief causes of hydroplaning situations (See Section 6-302.). Therefore, an adequate cross slope is a very important countermeasure against hydroplaning. Water depth on pavements can be effectively reduced by increasing the cross slope for each successive lane in a multi-lane facility. In very wide multi-lane facilities, the inside lanes may be sloped toward the median, however, median areas should not be drained across traveled lanes. In transitions into horizontal curve super-elevation, flat cross slopes should be minimized.

6-303.2 LONGITUDINAL SLOPES/CHARACTERISTICS

Gutter grades should not be usually less than 0.3 percent for curbed pavements. There may be some locations in Texas where such a minimum is difficult to maintain. In such situations, a rolling profile may be necessary or the cross slope may be warped to achieve a rolling gutter profile.

Extremely long sag vertical curves are discouraged since they incorporate relatively long flat grades at the sag.

6-303.3 SURFACE TEXTURE

The pavement texture is an important consideration for roadway surface drainage. Hydroplaning (See Section 6-302.) may be forestalled to some extent where the pavement is of a rough texture. Cross cutting (grooving) of the pavement is useful for removing small amounts of water such as in a light drizzle. Longitudinal grooving is discouraged because it usually causes problems in vehicle handling. A very rough pavement texture is beneficial to inlet interception but, in a contradictory sense, unfavorable because it causes a wider spread of water in the gutter with the associated unfavorable effects on vehicular traffic.

6-304. MEDIAN/MEDIAN BARRIER CONSIDERATIONS

Medians are commonly used to separate opposing lanes of traffic on divided highways. It is preferable to slope median areas and inside shoulders to a center depression to prevent drainage from the median area from running across the travelled pavement. Where median barriers are used and, particularly on horizontal curves with associated super-elevations, it is necessary to provide for some relief for the water which accumulates against the barrier. This can be done with 'weep' holes in the barrier. In order to minimize flow across traveled lanes, a more preferred method of relief is to collect the water into a subsurface system which ultimately connects with the main storm drain system.

6-400. INLETS AND MANHOLES

6-401. GENERAL

Either curb opening inlets (Figure 2), slotted drain inlets (Figure 3), grate inlets (Figure 4), or a combination of curb opening and grate inlets (Figure 5) may be used for intercepting run-off. Curb opening inlets are often preferred because of their self-cleansing ability. From the standpoint of economy and adaptability, the slotted drain inlet is a useful choice. It is esthetically pleasing, requires no depression in the gutter, can be overlaid with successive thicknesses of pavement without affecting its hydraulic characteristics, and can infringe on driveway areas without unfavorable effects. Since the slotted drain inlet is a type of grate inlet, it is prone to catch debris (although, on-grade slotted drain inlets have excellent self-cleaning properties). For this reason, it is recommended that slotted drain inlets not be used in sag configurations. Many other types of grate inlets clog with debris easily. In some instances however, the use of grates will be found necessary either with or without curb openings in combination. Where grates are used, the design and placing of the grates should be such that the grate bars will be parallel to the direction of flow of the water rather than perpendicular to the flow. Experiments have shown that this minimizes the clogging by small debris and increases the capacity of the grate. Use of recessed curb inlets (where the face of the inlet is set back from the normal curb line) is discouraged in this Department because the hydraulic characteristics of such inlets is suspect and generally, unproven by controlled inlet studies. Some municipalities in the state prefer recessed curb inlets because of their non-interference with traffic flow. If the design must include recessed inlets, it is recommended that the D-5 Hydraulic Section be consulted.

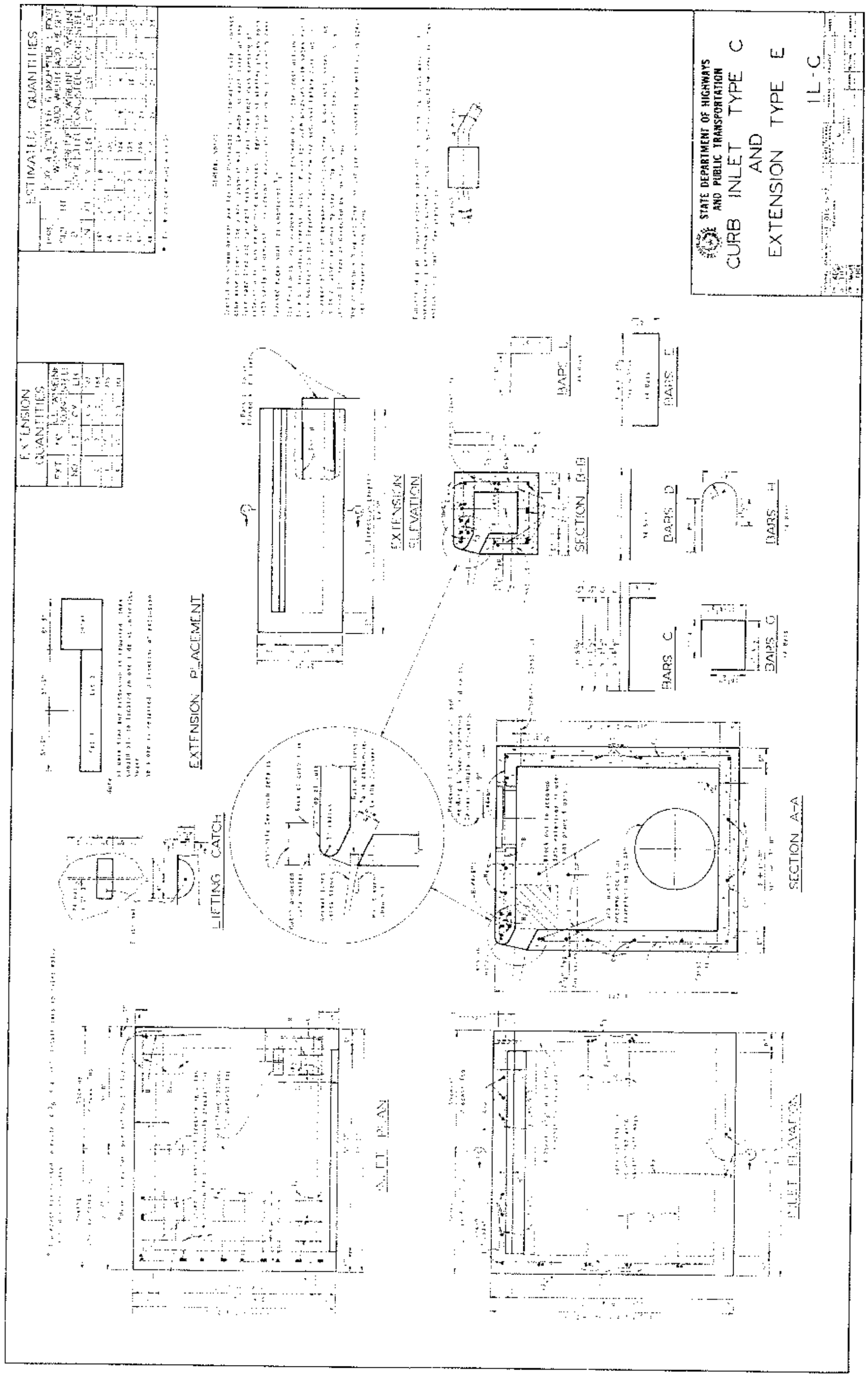

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
CURB INLET TYPE C
AND
EXTENSION TYPE E
IL-C
ESTIMATED QUANTITIES
EXTENSION QUANTITIES
EXTENSION PLACEMENT
LIFTING CATCH
EXTENSION ELEVATION
SECTION B-B
SECTION A-A
BARS C
BARS D
BARS E
BARS G
BARS H
BARS L
INLET PLAN
INLET ELEVATION

Figure 2

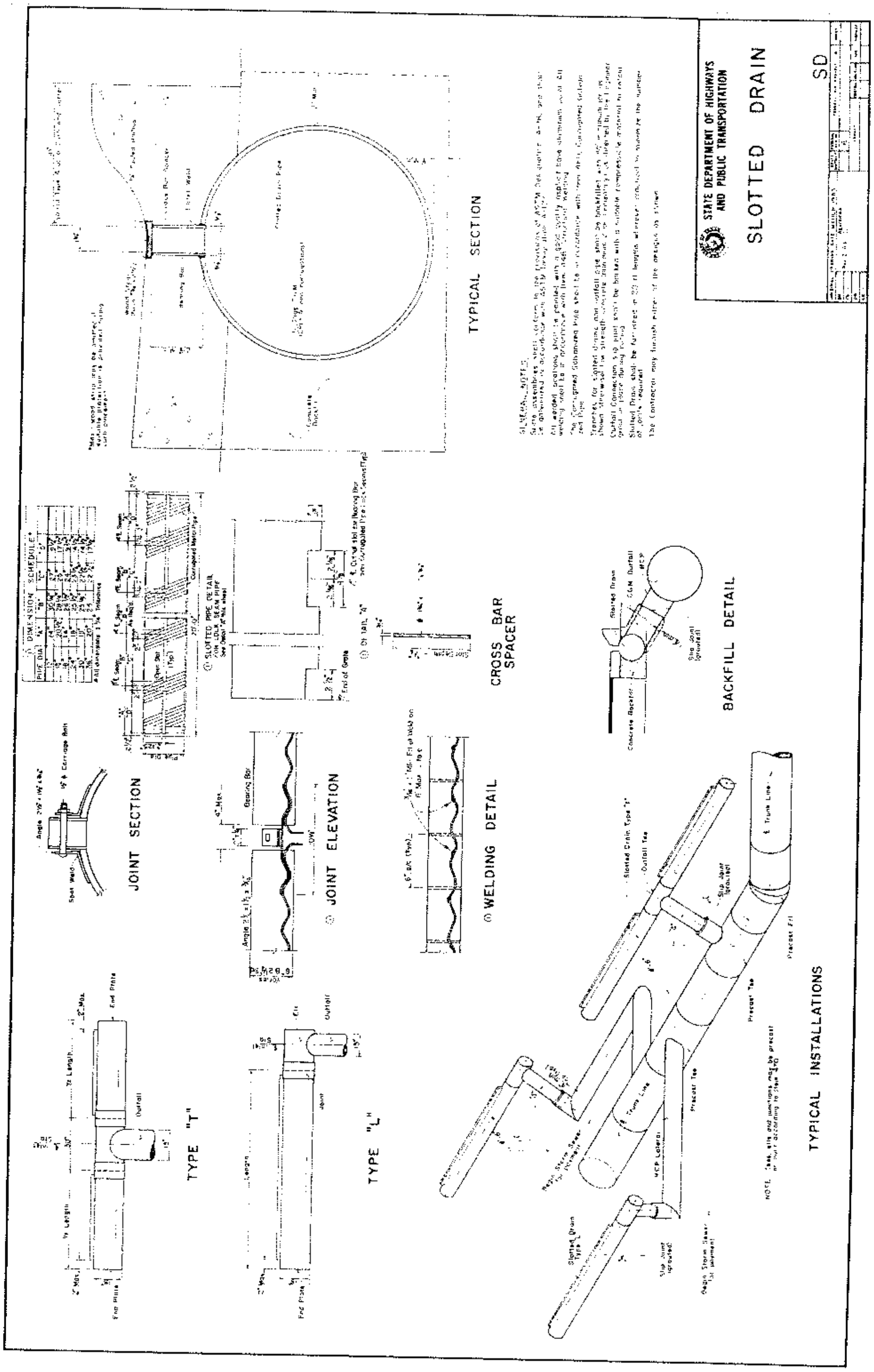


Figure 3

BRIDGE DIVISION HYDRAULIC MANUAL 12-85
6 - 7

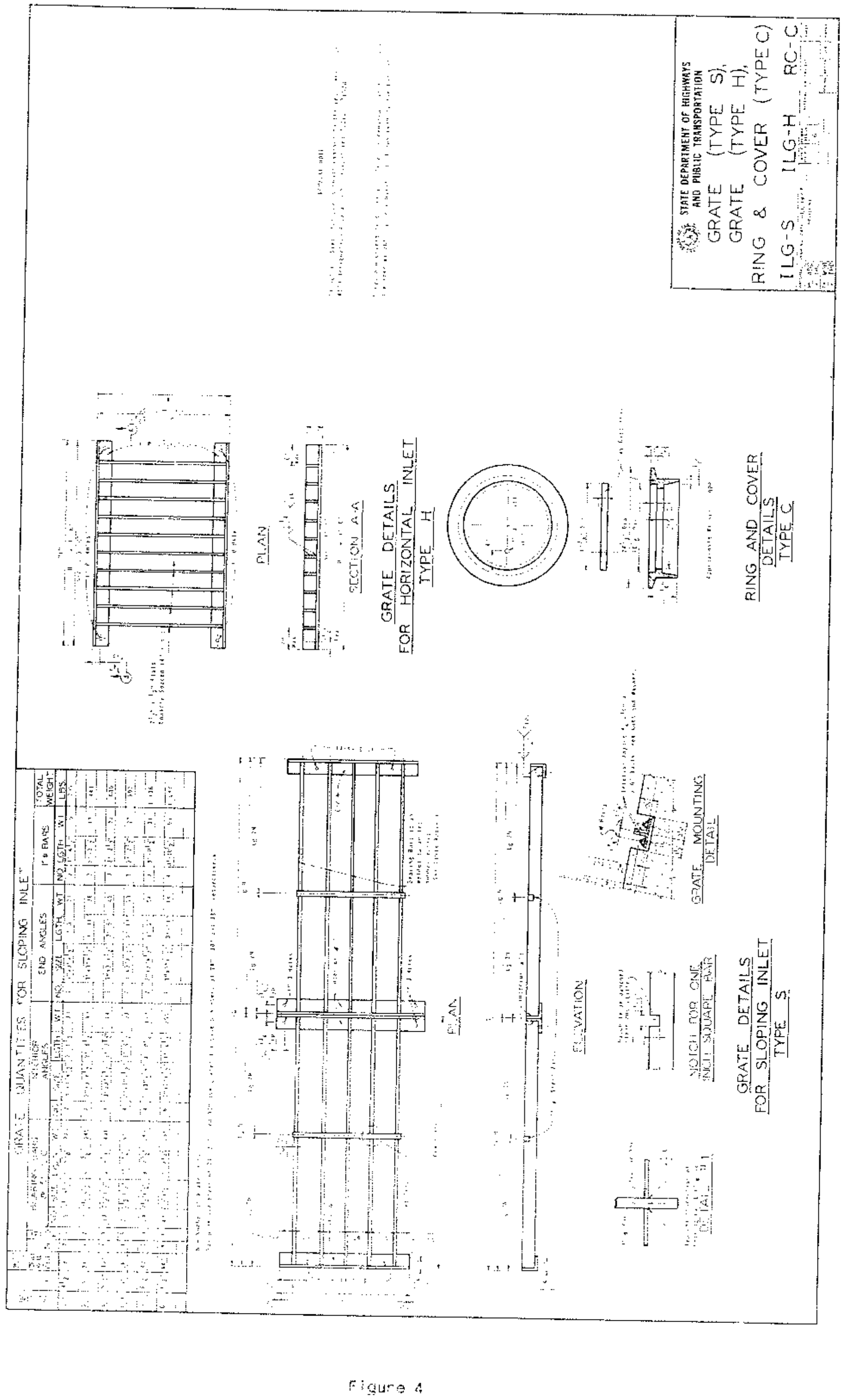


Figure 4

12-85

BRIDGE DIVISION HYDRAULIC MANUAL
6 - 8

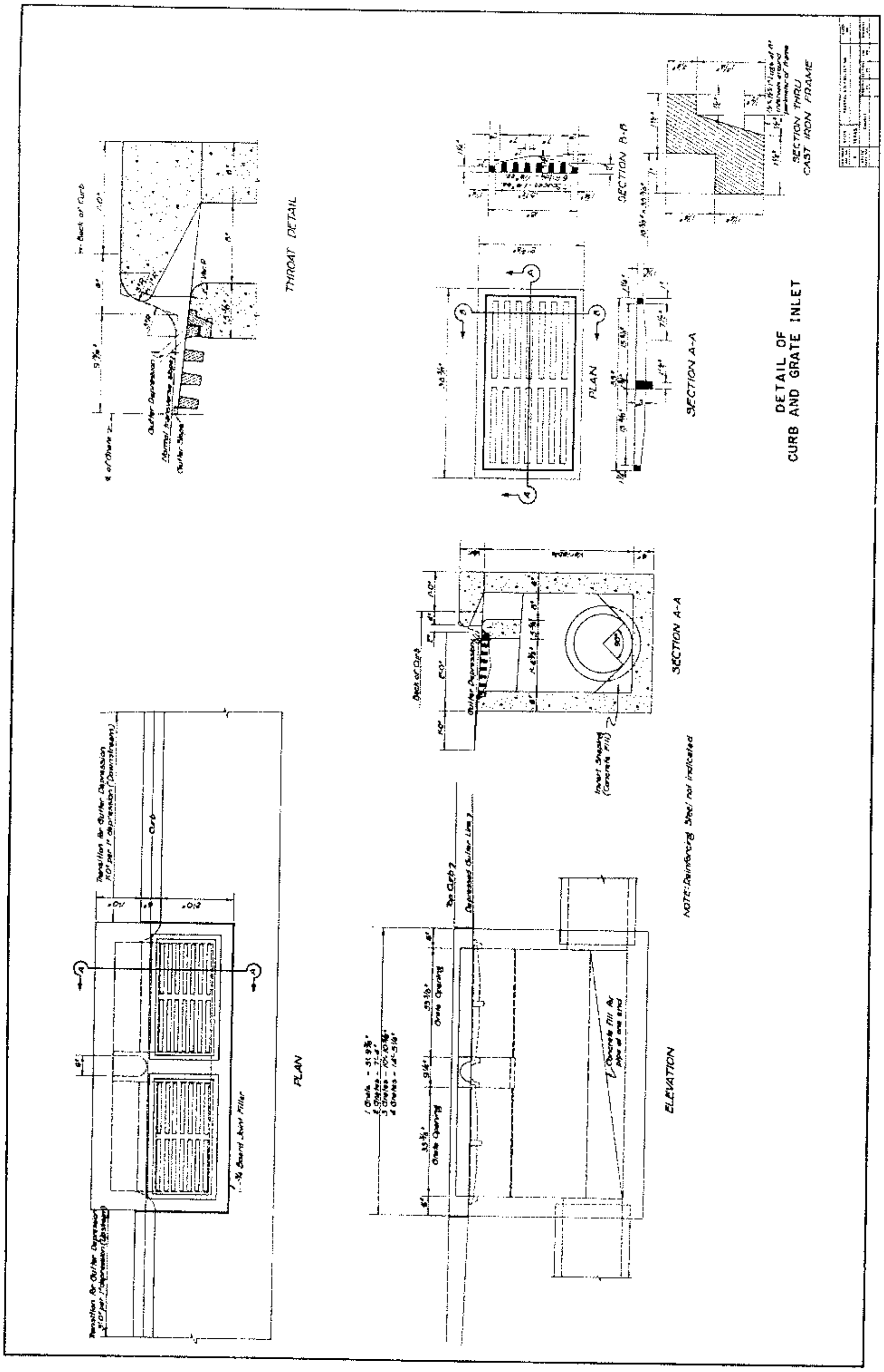


Figure 5

BRIDGE DIVISION HYDRAULIC MANUAL 12-85

6 - 9

6-402. INLETS ON GRADE

For slotted drain inlets, the amount of water which will be intercepted by the inlet may be estimated by the following process.

The length required for interception of all of the water in the gutter is calculated by the equation:

$$L_r = \frac{0.706 Q_D^{0.442} S^{E} Z^{0.849}}{n^{0.384}} \qquad (6\text{-}3)$$

where:

L_r = length required for total interception of gutter flow

Q_D = discharge in gutter (cfs)

S = gutter slope (ft/ft)

z = reciprocal of cross slope (ft/ft)

n = roughness coefficient (usually about 0.015)

E = an exponent to S (function of S and z and found in Table 1. Also see 6-600., Column 15.)

The proposed length of inlet (L_a) is divided by L_r and the amount of discharge not intercepted by the inlet (called "carryover") may be estimated by the equation:

$$C.O. = 0.918 Q_D (1 - L_a/L_r)^{1.769} \qquad (6\text{-}4)$$

or estimated from Figure 6.

Slotted drain systems may be optimized for economy by providing actual lengths (L_a) to required lengths (L_r) in a ratio of about 0.65. This implies a usual design with carryover for on-grade inlets. Slotted drain inlets at sags are not recommended. The process described above for the design of slotted drains is valid for most types of slotted drain fabrication and particularly for the type illustrated by Figure 1. Since a contractor may bid any of several types of slotted drain pipe inlets, it is recommended that, if a system of slotted drain inlets comprises a significant total amount, the D-5 Hydraulic Section be consulted.

The amount of water which will be intercepted by a curb inlet for a given configuration may be determined directly from the charts included in this chapter in Figures 9 and 10. The illustrative problem explains the use of these charts. It should be noted that it is not always necessary or desirable to intercept all the water in the gutter at any given point. As with

TABLE 1 - EXPONENT FOR SLOTTED DRAIN

RECIPROCAL OF TRANSVERSE SLOPE (z)

SLOPE ft./ft.	24	28	32	36	40	44	48	52	56	60	64	68
0.002	0.320	0.327	0.331	0.331	0.328	0.322	0.313	0.301	0.285	0.266	0.244	0.219
0.004	0.323	0.329	0.332	0.332	0.329	0.323	0.313	0.301	0.285	0.265	0.243	0.217
0.006	0.325	0.331	0.334	0.334	0.330	0.323	0.313	0.300	0.284	0.264	0.242	0.216
0.008	0.328	0.333	0.336	0.335	0.331	0.324	0.313	0.300	0.283	0.263	0.240	0.214
0.010	0.330	0.335	0.337	0.336	0.332	0.324	0.313	0.299	0.282	0.262	0.238	0.212
0.012	0.332	0.337	0.338	0.337	0.332	0.324	0.313	0.299	0.281	0.260	0.236	0.209
0.014	0.334	0.338	0.339	0.338	0.332	0.324	0.313	0.298	0.280	0.259	0.234	0.207
0.016	0.336	0.340	0.340	0.338	0.333	0.324	0.312	0.297	0.278	0.257	0.232	0.204
0.018	0.337	0.341	0.341	0.338	0.333	0.323	0.311	0.296	0.277	0.255	0.230	0.201
0.020	0.339	0.342	0.342	0.339	0.332	0.323	0.310	0.294	0.275	0.253	0.227	0.199
0.022	0.340	0.343	0.342	0.339	0.332	0.322	0.309	0.293	0.273	0.251	0.225	0.196
0.024	0.341	0.343	0.343	0.339	0.332	0.321	0.308	0.291	0.271	0.248	0.222	0.192
0.026	0.342	0.344	0.343	0.339	0.331	0.320	0.306	0.289	0.269	0.246	0.219	0.189
0.028	0.343	0.344	0.343	0.338	0.330	0.319	0.305	0.287	0.267	0.243	0.216	0.186
0.030	0.343	0.345	0.343	0.338	0.329	0.318	0.303	0.285	0.264	0.240	0.213	0.182
0.032	0.344	0.345	0.342	0.337	0.328	0.316	0.301	0.283	0.262	0.237	0.209	0.178
0.034	0.344	0.345	0.342	0.336	0.327	0.315	0.299	0.281	0.259	0.234	0.206	0.174
0.036	0.344	0.345	0.341	0.335	0.326	0.313	0.297	0.278	0.256	0.230	0.202	0.170
0.038	0.344	0.344	0.341	0.334	0.324	0.311	0.295	0.276	0.253	0.227	0.198	0.166
0.040	0.344	0.344	0.340	0.333	0.323	0.309	0.293	0.273	0.250	0.223	0.194	0.161
0.042	0.344	0.343	0.339	0.331	0.321	0.307	0.290	0.270	0.246	0.220	0.190	0.157
0.044	0.344	0.342	0.338	0.330	0.319	0.305	0.287	0.267	0.243	0.216	0.185	0.152
0.046	0.343	0.341	0.336	0.328	0.317	0.302	0.284	0.263	0.239	0.212	0.181	0.147

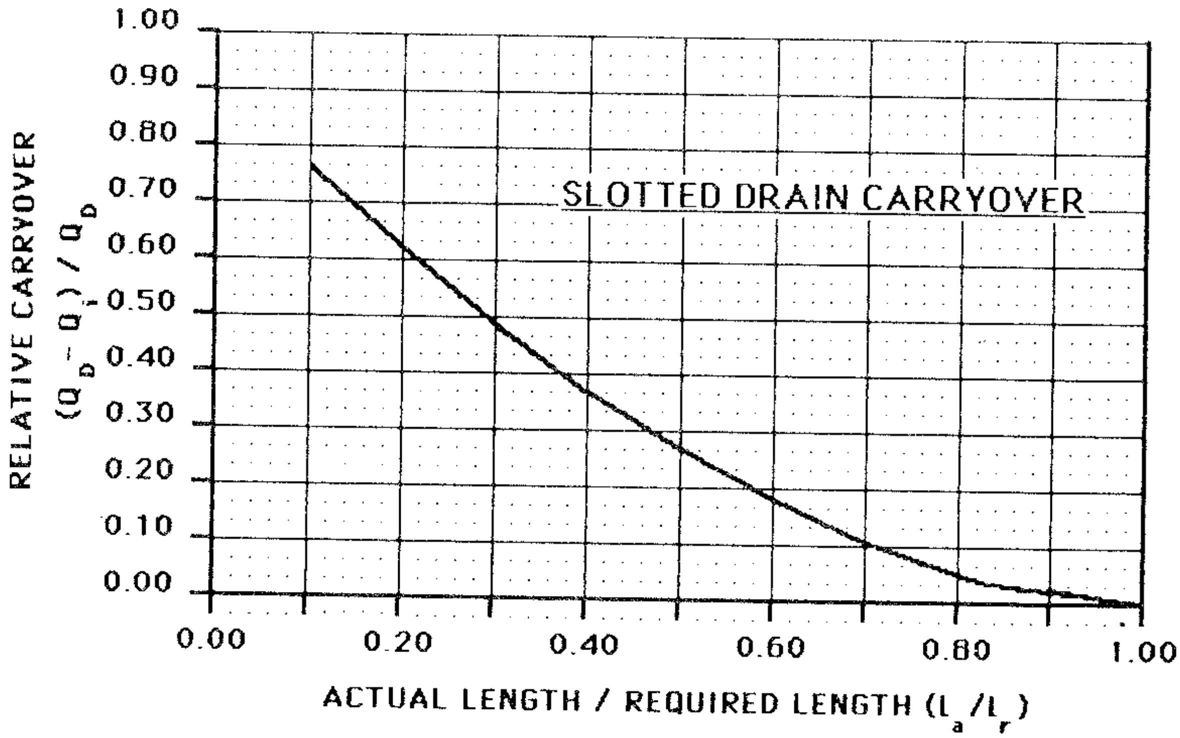


Figure 5

BRIDGE DIVISION HYDRAULIC MANUAL 12-85
6 - 11

slotted drain inlets, it will often be satisfactory, efficient, and economical to allow a portion of the water (carryover) to flow past an inlet to succeeding inlets. The proper handling of carryover is covered in the illustrative problem included in Section 6-600.

The calculation process for grate inlets on grade is highly variable due to the wide variety of grate inlets in use. The calculations are rather tedious but adaptable to the specific type of grate inlet to be used. The designer is advised to contact the D-5 Hydraulic Section for assistance and guidance in the analysis/design of grate inlets on grade.

Use of combination inlets is generally discouraged but design procedures and considerations are covered in Section 6-405.

6-403. INLETS IN SAGS

Use of slotted drain inlets in sag configurations is generally discouraged because of the propensity of such inlets to intercept debris in sags.

Under all ordinary conditions, the flow of water through a curb opening inlet located at a sag or low point in the grade may be computed by the weir formula:

$$Q = 3.087Lh^{(3/2)} \qquad (6\text{-}5)$$

where

Q = the discharge in cubic feet per second

L = the length of opening in feet, and

h = the head or depth of water at the opening in feet

Where the depth of water is such that the curb inlet is completely submerged, the proper orifice formula should be used in computing the discharge rather than the weir formula. This is an unlikely condition, since the sizing of inlets should be such as to preclude ponding in sufficient depth to submerge the inlet. It is also not a desirable condition since adjacent property may be inundated and traffic flow would be stopped.

6-404. GRATE INLETS IN SAGS

The flow of water through grate openings may be treated in the same manner as flow of water through rectangular orifices. The formula in most general use for flow through orifices is as follows:

$$Q = CA\sqrt{2gh} \qquad (6\text{-}6)$$

where

Q = the discharge in cubic feet per second

C = the coefficient of discharge (usually 0.7)

A = the area of orifice (the net area of the openings in the grate) in square feet

g = acceleration due to gravity (32.2 feet per second per second)

h = head on grate in feet

This formula gives the theoretical capacity of the grate inlet. Since the grate inlets are subject to considerable clogging it is recommended that, for practical purposes, the capacity of the grate inlet be taken as 1/2 of the value given by this formula; or conversely, that the net area of the grate be twice as large as the theoretical area required when calculated by the above formula.

6-405. COMBINATION INLETS

Combinations of curb slots and grate inlets may be used to advantage under certain special conditions. Combination inlets are generally not a good buy for the highway dollar because experience and many studies indicate that the additional cost of such inlets is rarely justified due to the relatively small additional capacity afforded. The theory commonly advanced by proponents of combination curb slot-grate inlets is that floating debris will be carried on the surface of the water. Investigations conducted by various hydraulic research laboratories, however, have not revealed any substantial gain resulting from such combinations. Authentic data concerning the true capacities of such combinations are insufficient to allow the establishment of any very accurate factors for determining the true capacity of a combination inlet. For design purposes, however, it is believed reasonable to assume that the capacity of the combination inlet will be about 50% of the sum of the individual capacities of the grate and the curb slot, computed in the manner described in the preceding paragraphs. In other words, it is recommended that the capacity of the curb inlet and the grate inlet (without reduction) be computed separately, added together, and the working capacity of the combination be taken as 50% of this sum.

Whenever either the slotted drain or curb opening type of inlet can be used it will generally prove to be more economical and more desirable than the grate type of inlet, and the use of grates should ordinarily be confined to those instances where it is impractical to provide any curb opening at all or where the length of opening which can be provided is not sufficient to intercept all the water which must be accommodated.

6-406. MANHOLES

Manholes or combination manholes and inlets should be placed wherever necessary for clean-out and inspection purposes. It is good engineering practice to place manholes at changes in direction, junctions of pipe runs, and at intervals of 300 to 500 feet in long pipe runs where the size or direction is not changed. The invert of the manhole section should be rounded to match the inverts of the pipes entering the manhole in order to reduce eddying and resultant head losses. For manholes which are larger than the incoming or outgoing pipes, expansion losses can sometimes be significant. Consult the D-5 Hydraulic Section for further information. At junctions of pipe lines, right angle intersections should be avoided if possible and the two lines should be brought together at an acute angle to minimize head losses. (See Figure 7 for standard manhole details.)

6-500. DESIGNING PIPE RUNS

After the tentative specific locations of inlets, pipe runs, and outfalls with tailwaters have been determined and the inlets sized, the next logical step is the computation of the rate of discharge to be carried by each pipe run and the determination of the size and gradient of pipe required to care for this discharge. This is done by proceeding in steps from upstream of a line to downstream to the point at which the line connects with other lines or the outfall, whichever is applicable. The discharge for a run is calculated, the pipe serving that discharge is sized, and the process is repeated for the next run downstream. This process is illustrated by the example in Section 6-600. It should be recognized that the rate of discharge to be carried by any particular section of pipe is not necessarily the sum of the inlet design discharge rates of all inlets above that section of pipe, but as a general rule is somewhat less than this total. It is useful to understand that the time of concentration is most influential and as the time of concentration grows larger, the proper rainfall intensity (presumably with the same e, b, and d factors) to be used in the design grows smaller. In determining the rate of flow in the design of any particular run of pipe, the time required for the water to flow from the most remote point on the drainage area should be computed and the corresponding value of rainfall intensity derived. The discharge rate is then calculated by the Rational method.

$$Q = CIA \qquad (6-7)$$

For all ordinary conditions, pipe runs should be sized on the assumption that they will flow full or practically full under the design discharge but will not be placed under pressure head. Manning's formula is recommended for use. (Nomographs B and F, Chapter 4.) If a pressure run is necessary (all sides wetted, with the hydraulic gradient above the top of the pipe or box), then Nomograph B in this chapter is applicable for boxes, and Nomograph F, Chapter 4 is applicable for circular pipes (use full flow point on d/D ratio line when solving for full pipe flow friction slope).

6-501. HYDRAULIC GRADIENT

The hydraulic gradient is the locus of elevations to which the water would rise in successive piezometer tubes if the tubes were installed along a pipe run. The difference in elevation for the water surfaces in the successive tubes would represent the friction loss for that length of pipe, and the slope of the line between water surfaces would be the friction slope. Therefore, if a pipe run were placed on a calculated friction slope corresponding to a certain rate of discharge, cross-section, and roughness

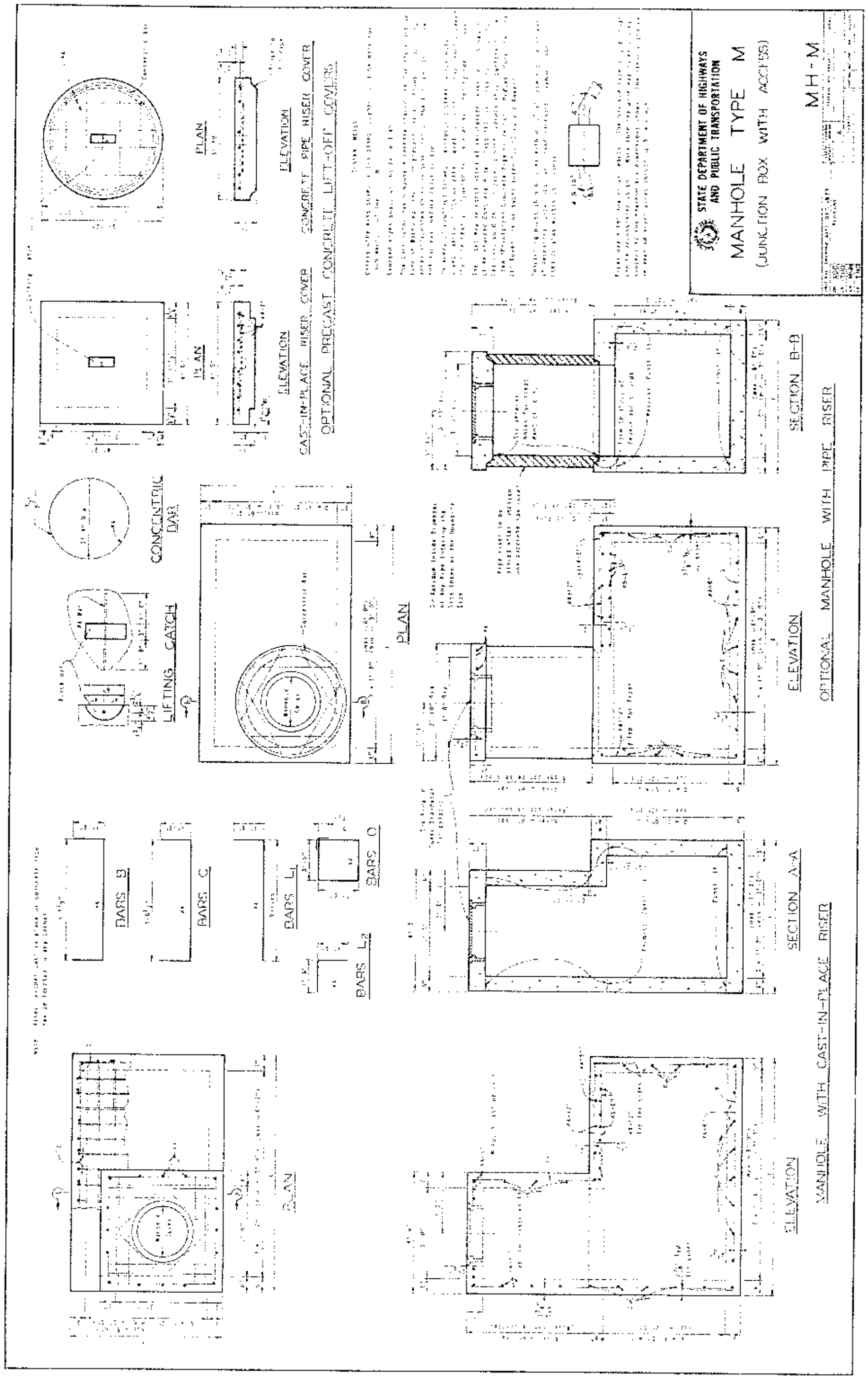

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
MANHOLE TYPE M
(JUNCTION BOX WITH ACCESS)
MH-M
CAST-IN-PLACE RISER COVER
CONCRETE PIPE RISER COVER
OPTIONAL PRECAST CONCRETE LIFT-OFF COVERS
ELEVATION
PLAN
LIFTING CATCH
CONCENTRIC BAR
BARS B
BARS C
BARS L1
BARS L2
BARS O
SECTION A-A
SECTION B-B
OPTIONAL MANHOLE WITH PIPE RISER
MANHOLE WITH CAST-IN-PLACE RISER

Figure 7

coefficient, the surface of flow (hydraulic gradient) would be parallel to the top of the conduit, and the pipe run would not be under pressure. From the standpoint of design, this is desirable. If there is reason to place the pipe run on a slope less than friction slope, then the hydraulic gradient would be steeper than the slope of the pipe run. Depending on the elevation of the hydraulic gradient at the downstream end of the run in question, it is possible to have the hydraulic gradient rise to above the top of the conduit; which would mean the conduit is under pressure until, at some point upstream, the hydraulic gradient is once again at or below the top of the conduit.

It will not be necessary to compute the hydraulic gradient of a pipe run where the slope and the run sizes are chosen such that: (1) the slope is equal to or greater than friction slope, (2) the top surfaces of successive runs are lined up at changes in size rather than the inverts, (3) the surface of the water at the point of discharge is not above the top of the outlet. In such cases, the pipe will not operate under pressure at design discharge and the slope of the water surface under that discharge will be approximately parallel to the slope of the invert of the pipe. There will be small head losses at inlets, manholes, etc., but if these appurtenances are properly designed, these losses will be minor and may usually be neglected.

Whenever all of these conditions do not exist, however, and particularly in those instances where the inverts in the pipes are placed on the same grade at changes in pipe size (thus forcing the smaller pipe to discharge against a head) or when it is desired to analyze the pipe system with a larger flood than that used in the sizing of the pipes, it will be necessary to compute the hydraulic grade line of the entire pipe system. This is done by starting with the tailwater elevation at the point where the water exits the pipe system and working back up along the entire pipe system, computing the friction loss for each run, and plotting the elevation of the total head thus computed at each manhole and inlet.

A realistic tailwater elevation should be used as the basis for the hydraulic gradient calculation. If the outfall tailwater is a function of a relatively large watershed area, such as in a large stream, and the contribution from the storm drain system is based on a relatively small total watershed area, it would not be realistic to use a tailwater elevation based upon the same frequency as the storm drain design frequency. Such situations occur often and the designer should consult with the D-5 Hydraulic Section for assistance and guidance when they are encountered.

If the plotted hydraulic grade line does not rise above the top of any manhole or above the gutter invert of any inlet, the pipe system is considered satisfactory. Wherever it does rise above any of these points, however, "blow-outs" through inlet slots and manhole covers will probably occur during a design storm. Pipe sizes or gradients should be increased as necessary to eliminate such "blow-outs".

Note that any hydraulic gradient must have an original base elevation no lower than the outlet tailwater elevation. Therefore, the backwater effects of a significant tailwater elevation should be checked very carefully.

6-502. GENERAL RULES FOR SIZING PIPE RUNS

a. Do not use pipe sizes less than 18" diameter for main trunk lines or for long laterals and not less than 12" diameter for short laterals.

b. Place all pipes or boxes on such a slope that the velocity of flow when full will not be less than 2' per second. Where slopes are comparatively flat, it is desirable that the pipe sections and slopes be so designed that the velocity of flow will increase progressively, or at least will not appreciably decrease, in passing from the first inlet to the outlet of the pipe system. This is so that solids washed into the system and transported by the flow will be carried on through and out of the system and will not be dropped at some point due to a sharp decrease in velocity.

c. Do not use non-standard sizes of pipe. Stockpiled metal pipe will ordinarily be in standard sizes, however, metal pipe can usually be fabricated to any size specified.

d. The roughness coefficient (n value) recommended for Department use for reinforced concrete pipe or smooth-flow metal pipe is n = 0.012. For corrugated metal pipe, the value should be 0.024. If helically corrugated pipe is used, some improvement in the n value is possible. This improvement is discussed in Chapter 4 and further information and assistance is available through the D-5 Hydraulic Section.

e. Avoid discharging the flow of a larger pipe or box into a smaller one even though the capacity of the smaller pipe or box may technically be greater due to a steeper slope.

f. At changes in size of pipe or box, attempt to place the soffits or top inside surfaces of the two pipes at the same level rather than placing the flow lines at the same level. Where flow lines are placed at the same level, the smaller pipe often must discharge against a head and it will be necessary to plot hydraulic grade lines in order to determine the effects of that head on the system operation. It may not be feasible to follow this rule in every instance, but the effort should be made whenever practicable.

g. Laterals should be analyzed to compare critical depth with uniform depth. If the critical depth is greater than uniform depth, (technically defined as a steep slope regime) the unit will probably be operating under entrance control instead of the originally assumed uniform flow. If so, it may be found that the headwater caused at the upstream inlet for the lateral in question is unacceptable. The headwater may be determined by the use of the proper entrance control nomograph in Chapter 4. It may be necessary to resize the lateral or, in some way, improve the inlet characteristics to overcome any unfavorable effects of entrance control. Usually, steep units in the trunk lines are not affected by entrance control as the velocity head loss and associated entrance loss are relatively negligible.

h. Losses due to junctions, bends, manholes, and other common features of a storm drain system which represent an interference or interruption of smooth flow characteristics are usually minor and negligible. In a very large system, however, their combined effect may be significant. Methods are available for the estimation of these losses if they appear to be important. The hydraulic effects of these storm drain features may be minimized to some extent by careful design (e.g., severe bends may be replaced by gradual curves in the pipe run where ROW is sufficient and cost is not a problem.) Consult with the D-5 Hydraulic Section for further information on the subject.

i. Determine a tailwater depth (TW) for the outfall channel by means of procedures discussed in Chapter 3. Always calculate the hydraulic gradient when the tailwater surface at the outlet is greater than the height of the outlet pipe or boxes. If the system is designed as a non-pressure system, the hydraulic gradient will eventually fall below the soffit of the pipe somewhere in the system, at which point the hydraulic gradient calculation is no longer necessary.

6-600. EXAMPLE PROBLEM

Given: The drainage area map (See Figure 8) shows the layout of the highway and cross streets to be drained, the typical cross-sections of the highway and the cross streets, as well as the type and area of the surfaces to be drained.

Design Frequency: 5 years (20% chance of exceedance)
Minimum time of concentration: 10 minutes
Minimum curb inlet length: 5 feet
Minimum slotted drain inlet length: 20 feet
Allowable gutter depression on Monroe Avenue: 3 inches
Allowable gutter depression, cross streets: 3 - 5 inches

Permissible width of ponding:

10 feet on Monroe Ave. (business)

15 feet on Monroe Ave. (residential)

Full roadway width on cross streets

Required: Design a storm drain system which will adequately dispose of the design discharge.

Solution:

Step 1 - Prepare a carefully considered system plan as discussed in Section 6-102. Assure that there are no 'dead' spots where water has no outlet. Establish the general location of inlets, laterals, and trunk-lines.

Step 2 - Runoff computations: The runoff computations are tabulated on Figure 8. The

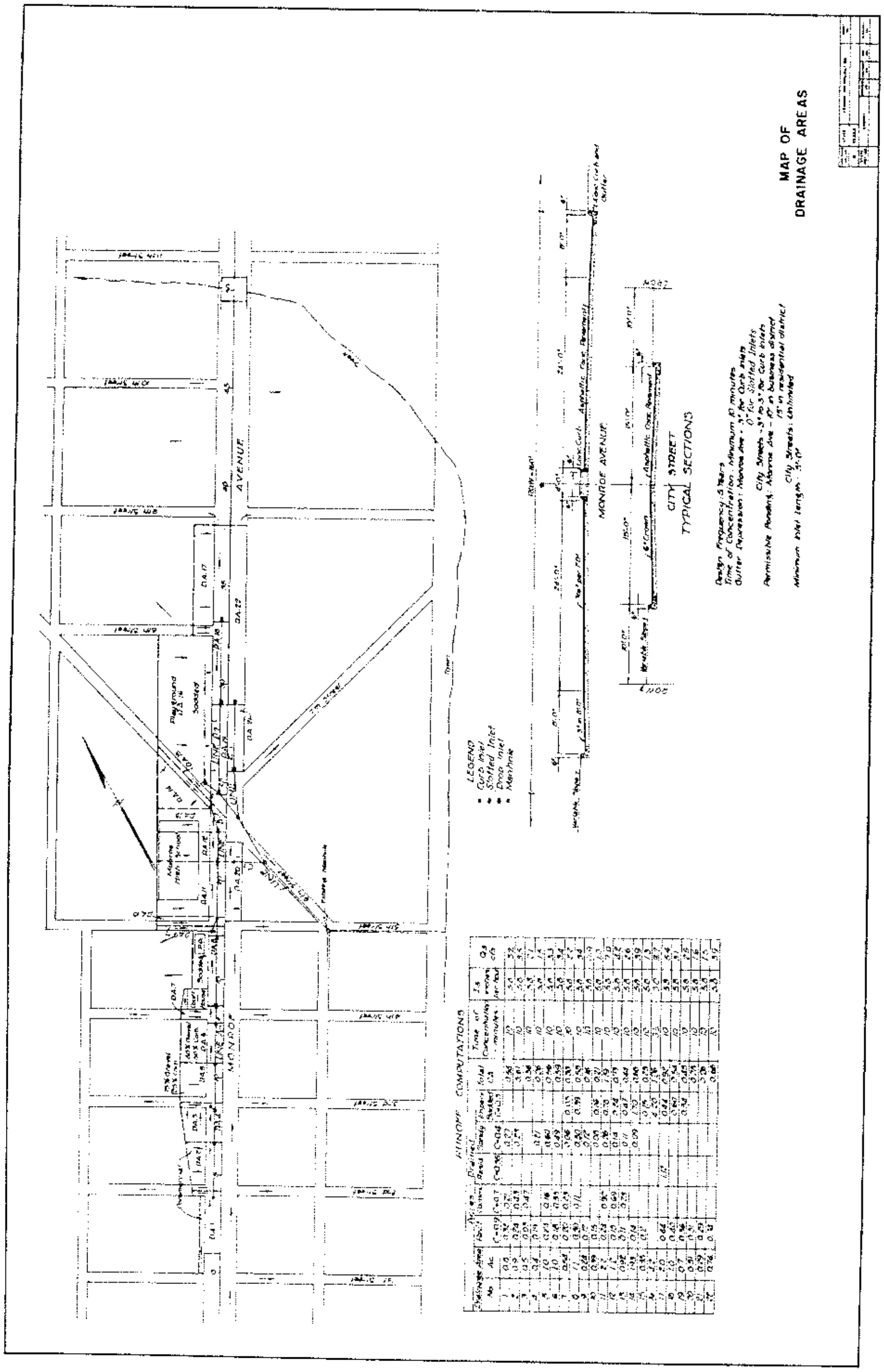


Figure 8

BRIDGE DIVISION HYDRAULIC MANUAL
6 - 17

12-85

first six columns of this tabulation are self-explanatory. The total CA as shown in the 7th column is computed by multiplying each incremental area by its corresponding coefficient of runoff and totaling the sum of these incremental products. As an example, the total CA for drainage area No. 1 is computed as follows:

Type	Acreage		C		CA
Paved	0.32	X	0.9	=	0.288
Commercial	0.21	X	0.7	=	0.147
Gravel	0.27	X	0.4	=	0.108
		Total			0.543

use 0.54

The time of concentration is computed by dividing the distance from the most remote point of the drainage area by the assumed velocity of approach flow. Since it has already been established that a minimum time of concentration will be used, this value should be inserted in the table. Whenever this time is greater than 10 minutes, the derivation of the time should be shown in the same manner as for drainage area No. 16 in the sample tabulation.

The intensity of rainfall is based upon the equation (6-1) where e = 0.78, b = 56, and d = 8.2.

The total runoff Q is determined by multiplying CA by I.

Step 3 - Inlet computations: The inlet computations are shown in Table 2. A detailed explanation of this tabulation follows.

Column 1. All inlets should be properly classified and given a designated number as follows:

CI-3 - Curb inlet No. 3
DI-1 - Drop (grate) inlet No. 1
SI 2 - Slotted drain inlet No. 2

Column 2. The location of the inlets as established on the plan-profile sheets should be listed for cross reference and ready identification.

Columns 3 and 4. The respective drainage area numbers and corresponding discharges are taken from the runoff computation tabulation which appears on the drainage area map.

Column 5. The carry-over in this column is the rate of discharge which has passed by the last upstream (gutter) inlet. The rate of carry-over from any inlet should never be neglected and should always be accounted for. Unaccommodated carry-over rates can be very troublesome items and can cause severe traffic interruption problems. If any carry-over rate is not picked up by another inlet, then some explanation of its disposal should appear in the "Remarks" column. (See remark for inlet SI-8)

Column 6. The total runoff Q_a is the sum of the runoff from the subject drainage area and any applicable carry-over.

Column 7. The reciprocal of the cross slope "z" is determined from the roadway cross-sections and is illustrated by the following examples:

Transverse slope 1/4 inch per foot:
z = 12/(1/4) = 48
Transverse slope 3 inches in 8 feet:
z = (8X12)/3 = 32
Transverse slope 6 inches in 15 feet:
z = (15X12)/6 = 30

For circular or parabolic roadway crowns, use the average slope for the desired width of ponding in the determination of z.

Column 8. The ratio z/n is self-explanatory and is used for entry into Figure 1 to determine depth of gutter flow "y" (See column 10). In the example problem, a roughness coefficient "n" of 0.015 is used. This is a usual value, however, it may vary from 0.012 to 0.025, depending upon the pavement surface and gutter texture.

Column 9. The gutter slope "S" is expressed in feet per feet and is obtained from established grade lines as indicated on the plan-profile sheets.

Column 10. The value of y is the depth of flow in feet in the gutter for the configuration of Q, S, and z/n and may be determined from Nomograph A. If two z values are indicated when the pavement slope changes, a composite calculation for y is necessary.

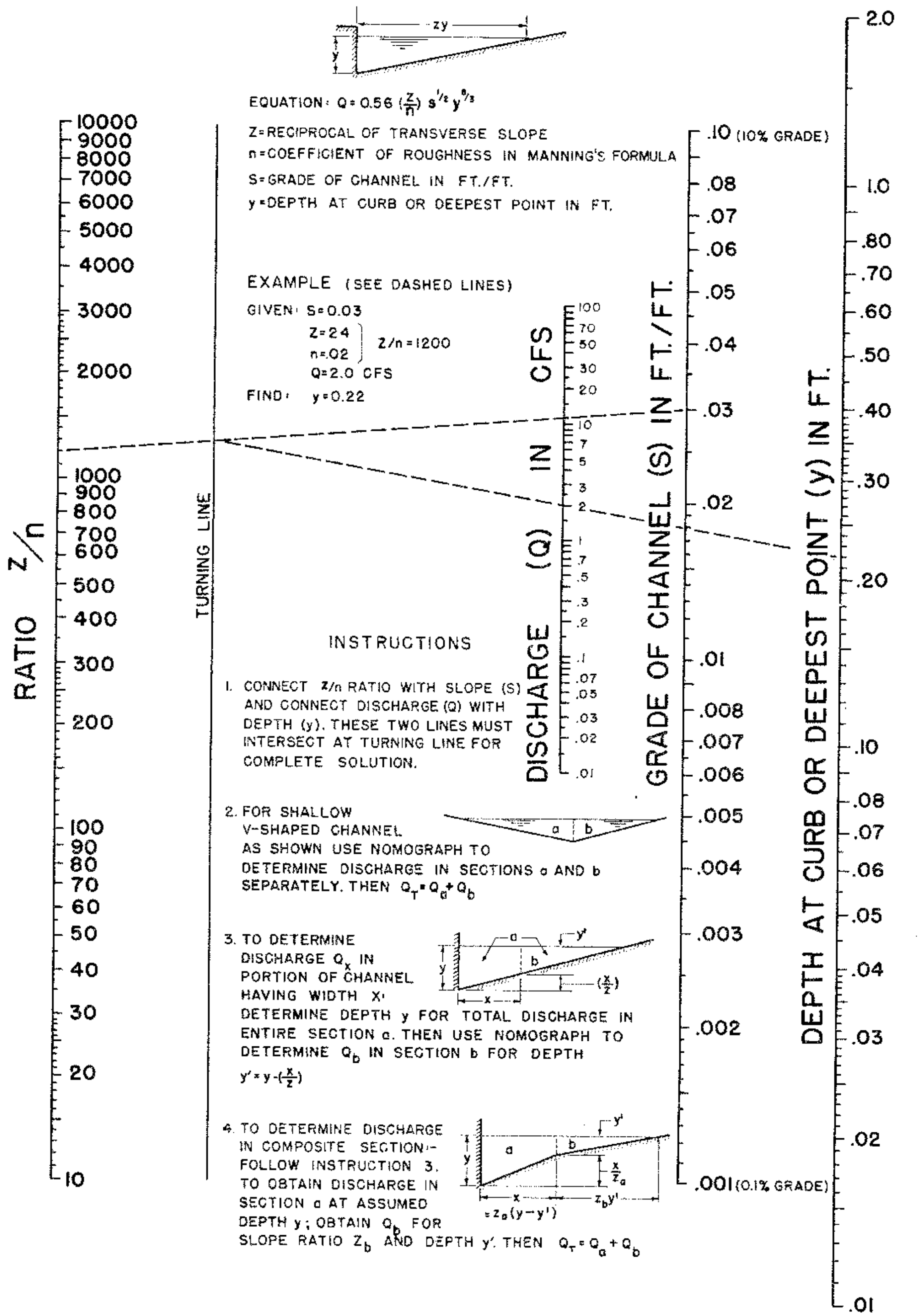
The value of y is not necessary for the direct

Inlet ID 1	Location 2	D. A. No 3	Q cfs 4	CO cfs 5	Qa cfs 6	z 7	z/n 8	s ft/ft 9	y ft 10	P ft 11	a ft 12	qL cfs 13	Lr Curb ft 14	'E' Slot 15	Lr Slot ft 16	La ft 17	La/Lr 18	a/y 19	Qi/Qa Curb 20	Qi/Qa Slot 21	Qi cfs 22	Ql-Qa cfs 23	Carry over to: 24	Remarks 25
CI-1	3+80 Lt.	1	3.1		3.10	32	2133	0.0125	0.24	7.80	0.25	0.402	7.71			10	1.30	1.03	1.13		3.50			
CI-2	6+70 Lt.	2	3.5		3.50	32	2133	0.0125	0.26	8.17	0.25	0.412	8.50			5	0.59	0.98	0.71		2.48	1.02	CI-3	
CI-3	8+31 Lt.	4	1.5	1.02	2.52	32	2133	0.0125	0.19	5.94	0.25	0.355	7.11			5	0.70	1.35	0.79		1.98	0.54	CI-4	
CI-4	8+60 Lt.	3	2.1	0.54	2.64	30	2000	0.0025	0.29	8.76	0.33	0.581	4.54			5	1.10	1.13	1.05		2.78			
CI-5	10+75 Lt.	5	3.3		3.30	32	2133	0.0125	0.25	7.99	0.25	0.407	8.10			10	1.23	1.00	1.10		3.64			
CI-6	12+80 Lt.	6	3.4		3.40	32	2133	0.0125	0.25	8.08	0.25	0.410	8.30			10	1.20	0.99	1.09		3.72			
SI-1	13+68 Lt.	7	2.2		2.20	32	2133	0.0125	0.21	6.86				0.339	21.56	20	0.93			0.99	2.18	0.02	SI-2	
SI-2	17+31 Lt.	8	3.4	0.02	3.42	32	2133	0.0125	0.25	8.08				0.339	26.21	25	0.95			1.00	3.41	0.01	SI-3	
SI-3	17+60 Lt.	9	0.9	0.01	0.91	30	2000	0.0050	0.19	5.60				0.332	10.50	15	1.43							
CI-7	18+18 Lt.	10	1.3		1.30	32	2133	0.0125	0.18	5.63	0.25	0.347	3.75			5	1.33	1.42	1.17		1.53			
CI-10	24+18 Lt.	15	1.3	0.09	1.39	30	2000	0.0010	0.29	8.69	0.33	0.579	2.40			5	2.08	1.14	1.26		1.75			
CI-9	23+75 Lt.	14	3.9		3.90	30	2000	0.0010	0.44	13.12	0.33	0.725	5.38			5	0.93	0.75	0.97		3.77	0.13	CI-8	
CI-8	22+60 Lt.	13	2.6	0.13	2.73	48	3200	0.0030	0.26	12.30	0.25	0.413	6.62			5	0.75	0.98	0.84		2.31	0.42	DI-2	
DI-2	21+00 Lt.	11, 12	11.2	0.42	11.62																			Drop Inlet - 4 grate
CI-11	21+00 Rt.	20	1.6		1.60	48					0.04	0.390	4.28			10	2.34							Low point curb Inlet
SI-6	33+18 Lt.	17	5.4		5.40	48	3200	0.0050	0.31	14.70				0.313	37.93	30	0.79			0.94	5.09	0.31	SI-5	
SI-5	29+00 Lt.	18	3.1	0.31	3.41	48	3200	0.0050	0.25	11.94				0.313	30.96	25	0.81			0.95	3.24	0.17	SI-4	
SI-4	24+35 Lt.	19	2.5	0.17	2.67	48	3200	0.0030	0.25	12.12				0.313	23.70	20	0.84			0.97	2.58	0.09	CI-10	
DI-1	25+00 Lt.	16	3.7		3.70																			Drop inlet - 2 grate
SI-7	29+00 Rt.	22	3.9		3.90	48	3200	0.0050	0.27	13.01				0.313	32.85	30	0.91			0.99	3.85	0.05	CI-8	
SI-8	25+60 Rt.	21	1.5	0.05	1.55	48	3200	0.0030	0.21	10.01				0.313	18.62	15	0.81			0.95	1.47	0.08		Drain along 7th str.

Form 1020
Revised 1-86 3310ERF.DGN

INLET CALCULATIONS

Table 2



Nomograph A

NOMOGRAPH FOR FLOW IN TRIANGULAR CHANNELS

12-85

BRIDGE DIVISION HYDRAULIC MANUAL

6 - 20

determination of L_r (length required for total interception) for slotted drains. However, it must be calculated in order to check the width of ponding.

Column 11. The width of ponding "P" should not exceed the limits as given in the design criteria. In the example problem, the maximum permissible ponded width is 10 feet for the section of Monroe Avenue within the business area and 15 feet for the section which is within the residential area.

If the width of ponding criterion is exceeded, the usual adjustment is to space the inlets closer together. This effectively removes the water from the surface more often and limits the accumulated discharge causing the unacceptable ponding. On the other hand, if the width of ponding is significantly less than the allowable, it may be economical to reduce the number of inlets in the system.

The ponded width is the product of y and z (columns 10 and 7). If two values of "z" are indicated to describe a transverse slope, the ponded width for such a situation is calculated as illustrated in the following example:

> The total depth of water in the gutter "y" = 0.30 feet. In the eight feet of width nearest the curb, there is a rise of 3 inches. This leaves a remaining depth of flow of y' = 0.30 - 0.25 = 0.05 feet. The width of ponding beyond this point is 0.05 X 64 = 3.2. The total width of ponding is 8.0 + 3.2 = 11.2 feet.

Column 12. The dimension "a" is the gutter depression (the vertical distance from the normal gutter line to the throat of the curb inlet) expressed in feet. As the value of "a" increases in curb inlets, the rate of gutter flow interception at the inlet increases. However, a very large value of "a" is objectionable to traffic flow moving near the gutter line. Therefore, a compromise is in order when selecting an appropriate value for "a". As a general guide, the depth of depression "a" should vary from 0 to 1 inch where the gutter is within the theoretical traffic lane; from 1 inch to 3 inches where the gutter is outside the traffic lane or in the parking lane; and up to a maximum of about 5 inches for lightly travelled city streets not on a highway route.

Since slotted drain inlets do not require an inlet depression for their proper hydraulic function, no "a" is considered.

Column 13. The value "q_L" is the rate of flow per lineal foot of inlet for a given depth "y" and depression "a". This value is determined directly from Figure 9 and is applicable to curb inlets only.

Column 14. The value of L_r, length of curb inlet necessary to intercept all of the discharge, is equal to Q_a/q_L. The curb inlet Ci-2 will be used as an example. Its length, for total interception, is 3.50/0.412 = 8.50 feet.

Column 15. This is the value of an exponent "E" to be used in the required length equation for slotted drain inlets. It is a function of z and S and is defined by the following equation:

$$E = 0.207 - 19.084S^2 + 2.613S - 0.0001z^2 + 0.007z - 0.049Sz \qquad (6-8)$$

A tabulation of E values is also given in Table 1.

Column 16. The value "L_r" is the length of slotted drain inlet in feet which is necessary to intercept all of the gutter flow "Q_a". For slotted drain inlets, Sl-2 will be used as an example. The design of slotted drain inlets requires the use of the equation (6-3). The exponent "E" is defined for Column 14.

Care should be exercised when using equations (6-3) and (6-8). The range of the parameters legitimately applicable are as follows:

$Q_d \leq 5.5$ cfs
$S \leq 0.09$
$16 \leq z \leq 64$
$0.011 \leq n \leq 0.017$

L_r values based upon values of these parameters outside the above-indicated limits are suspect.

The length for total interception for Sl-2 is computed to be 26.21 feet (using an exponent "E" of 0.339.)

If it were necessary to intercept all of the water in the gutter flow at this inlet, at least 26.21 feet of inlet would be required. Likewise, the total required curb inlet length for CI-2 is 8.50 feet. In this case, however, a small carry-over is allowable and a standard 5 feet long inlet is used for CI-2 and 25 feet for SI-2.

Column 17. The dimension "L_a" is the actual length of inlet which is to be provided. For curb inlets, it is recommended that no less than 5 feet of length be used with standardized increments of 5 feet. (e.g., 5 feet, 15 feet, etc.) For slotted drain inlets, because of standard pipe lengths of 20 feet, it is recommended that no less than 20 feet of length be used with standardized increments of 5 feet. (e.g., 20 feet, 35 feet, 45 feet, etc.)

Column 18. The ratio of the length of inlet provided to the length of inlet required for total interception is used for the determination of the amount of water actually intercepted. For example, at inlet CI-2, the value of the ratio is: 5.0/8.5 = 0.59. At inlet SI-2, the ratio is 25.0/26.21 = 0.95.

Column 19. The gutter depression at the inlet divided by the depth of flow in the gutter "a/y" is another ratio which is used in determining the percent of interception for curb inlets. For inlet CI-2, this value a/y = 0.25/0.26 = 0.98. For slotted drain inlets, this computation is not necessary.

Column 20. This column shows the relative percentage of runoff which is intercepted by the inlet. For curb inlets, that percentage is determined from Figure 10, using the values from Columns 18 and 19. For inlet CI-2, the L_a/L_r ratio (from Column 18) is 0.59, and the a/y ratio (from Column 19) is 0.98. By entering the chart in Figure 10 with these values it is found that the relative percentage of interception, Q_i/Q_a, is 0.71.

Column 21. For slotted drain inlets, the chart on Figure 6 or equation (6-3) may be used to determine the relative percentage of interception. For inlet SI-2, the value of L_a/L_r is 0.95 and the associated relative percentage of interception is 0.995.

Column 22. The value Q_i shown in this column is the rate of discharge which the inlet actually intercepts. It is the product of Q_a from Column 6 and the relative percentage of interception from Column 20 or 21. For inlet CI-2, as an example, the value of Q_i equals 0.71 X 3.50 = 2.48 cfs. For inlet SI-2, the value of intercepted Q_i is 3.41 cfs.

Column 23. The carry-over is the amount of water which passes an inlet, and is the difference between the total gutter flow "Q_a" (Column 6), and the intercepted flow "Q_i" (Column 22). For inlet CI-2, the carry-over is $Q_a - Q_i$ = 3.50 - 2.48 = 1.02 cfs. For inlet SI-2, the carryover is 0.01 cfs. The rate of carry-over should never be neglected and should always be accounted for. If it is not picked up by a succeeding inlet, some explanation of its disposal should be made in the "Remarks" column. See the comment in the Remarks column for inlet SI-8.

The preceding method of proportioning inlets applies only to inlets in gutters which have a longitudinal grade. For low point inlets the method previously described for "Inlets in Sags" should be applied. As an example, consider the inlet CI-11 which is to carry 1.60 cfs of water. Reference is made to Figure 11, "Low Point Inlets". Furthermore, assume that, for this location, a gutter depression of only 1.75 inches is allowed.

Using the allowable ponding width of 10 feet and z = 48, it is found that the allowable depth of water above the normal gutter line will be 2.50 inches, which, when added to the allowable gutter depression of 1/2 inch, gives a total head of the curb opening of 3.00 inches.

From Figure 11, it is found that the curb slot will carry about 0.39 cfs of water per foot length of opening. Therefore, the length of curb inlet required for this location is L_r = 1.60/0.39 = 4.28 feet. Since a low point inlet such as this can not clean itself (accumulated debris in the water has no other place to go), it is recommended that a safety factor be applied to design lengths for such inlets. Usually a safety factor of about 2 is sufficient. Therefore, multiply L_r by 2 (4.28 X 2 = 8.56 feet) and round to the nearest standard incremental size. In this case, a 10 feet inlet would be appropriate.

Because of the inherent debris-catching characteristics of slotted drain inlets, their use is discouraged in low point or sag gutter configurations.

As an example of the use of a grate inlet, consider DI-1 at Station 25+00 left. This inlet is to be designed to carry 3.70 cfs of water.

Q_a = 3.70 cfs.

Grate Opening: 14 slots, 15-3/8" x 1-1/4"
Gross Area One Grate = 1.87 sq. ft.
Assumed Efficiency of Grate = 50%
Effective Net Area One Grate = .50 x 1.87 = 0.93 sq. ft.
Assumed Allowable Head = 4" = .33'

$Q = CA\sqrt{2gh}$ (Orifice Formula)

$A = Q/C/\sqrt{2gh} = 3.70/.7/((64.4 \times 0.33)^{.5}) = 1.15$ sq. ft.

Use two grates. Effective area = 2 x 0.93 = 1.86 sq. ft.

Additional columns (24 and 25) may be in order for full documentation of inlet design. These may be a column indicating the destination of carry-over rates and a column for "Remarks".

Step 4 - Proportioning drain pipes: The computations involved in the proportioning of the various runs of drain pipe are summarized in the tabulation sheet titled "Drain Pipe Calculations", (Table 3). A detailed explanation of this tabulation follows:

Columns 1 through 5. Figures shown in these columns are self-explanatory.

Column 6. The length of each run as shown in this column is the length from center to center of inlets or manholes. This length is used in determining the time of flow from one inlet or manhole to another. (Note that these lengths are not to be used as pay lengths of pipe since the standard specifications provide that pay lengths shall include only the actual net length of pipe and shall not include the distance across inlets or manholes where no pipe actually is placed.)

Columns 7, 8, and 9. The time of concentration is the time required for water to flow from the most remote part of the drainage area or areas involved to the upper end of the pipe run under consideration. For the first run, the time of concentration is the inlet time for the first inlet. For all succeeding runs, the time of concentration may be either the time as computed along the drain line or the inlet time of the inlet at the beginning of the run under consideration, whichever time period is longer. Accordingly, both times are shown in the tabulation for purposes of comparison and the larger of the two is used in determining intensity and then, discharge. If this larger value is less than 10 minutes (the minimum time of concentration), the established minimum time of 10 minutes is used.

The time of concentration shown in column 7 is computed by summing the time of concentration for the preceding run and the time required for water to flow through the preceding run to the beginning of the run under consideration. At junctions of lines, the larger value of the time of concentration is used. In the tabulation, for example, lines A and B join to discharge into line C. Since the time of concentration for line A is greater than that for line B, this larger value is carried through in calculating times of concentration for line C.

Columns 10 and 11. Intensity and discharge are computed in the same manner as explained under "Inlet Computations."

Columns 12, 13, and 14. The size and slope of pipe as shown in columns 12 and 13 must be chosen in such manner that the pipe, when flowing full but not under head, will carry a rate of flow approximately equal to or greater than the computed discharge, Q. In other words, the "Capacity" shown in column 14 must be approximately equal to or greater than the value of discharge shown in column 11. This is known as a "non-pressure flow design". Obviously, drain pipe lines may be designed as "pressure flow" but this is discouraged due to a certain loss of any built-in safety factor. If pipe lines are to be designed as "pressure flow", the D-5 Hydraulic Section should be consulted.

The capacity may be calculated by Manning's formula

$$Q = \frac{1.486AR^{(2/3)}S^{0.5}}{n}$$

or the capacity can be taken directly from the appropriate uniform flow nomograph in Chapter 4. If the pipe run is to be designed to flow under

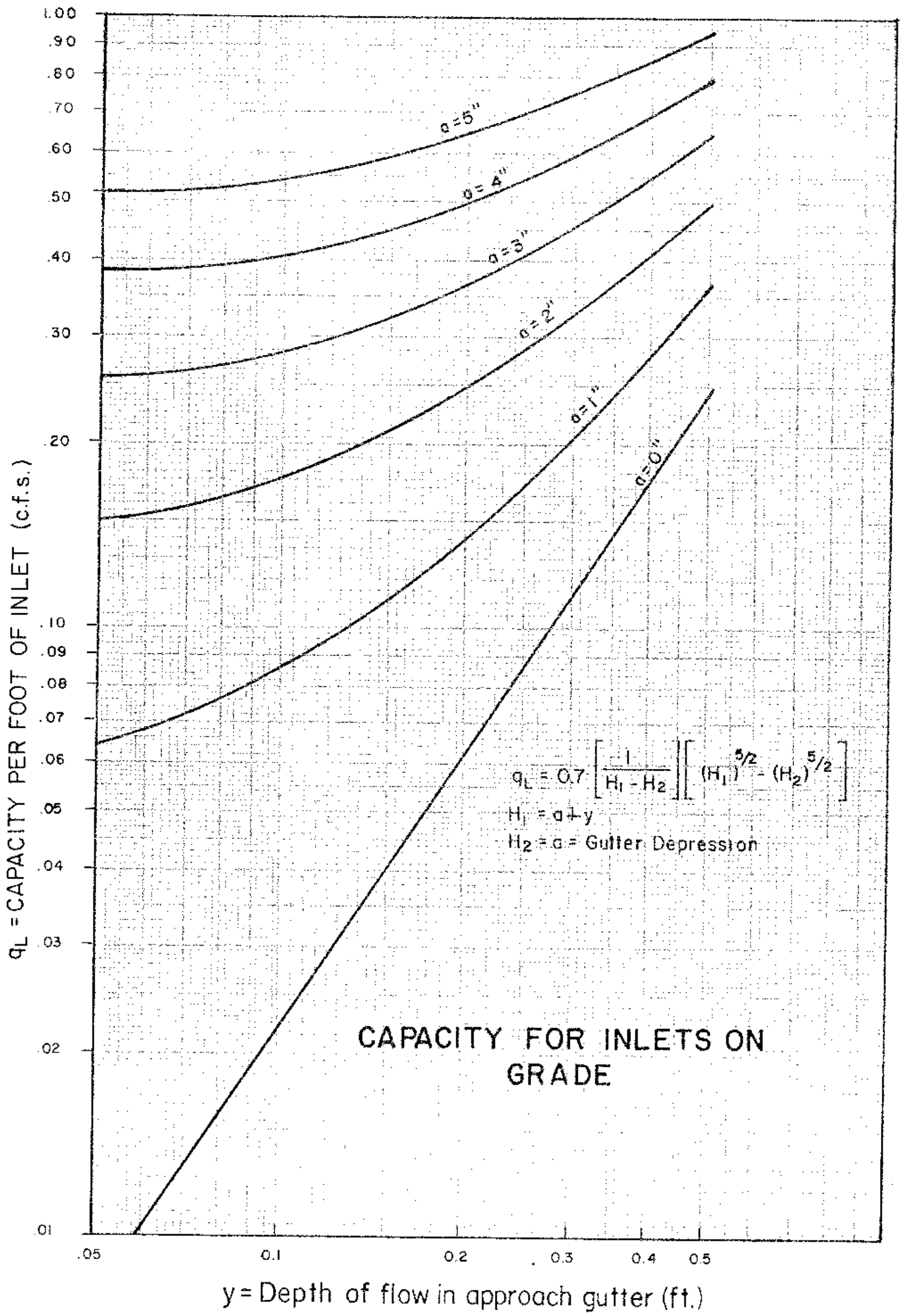


Figure 9

12-85

BRIDGE DIVISION HYDRAULIC MANUAL
6 - 24

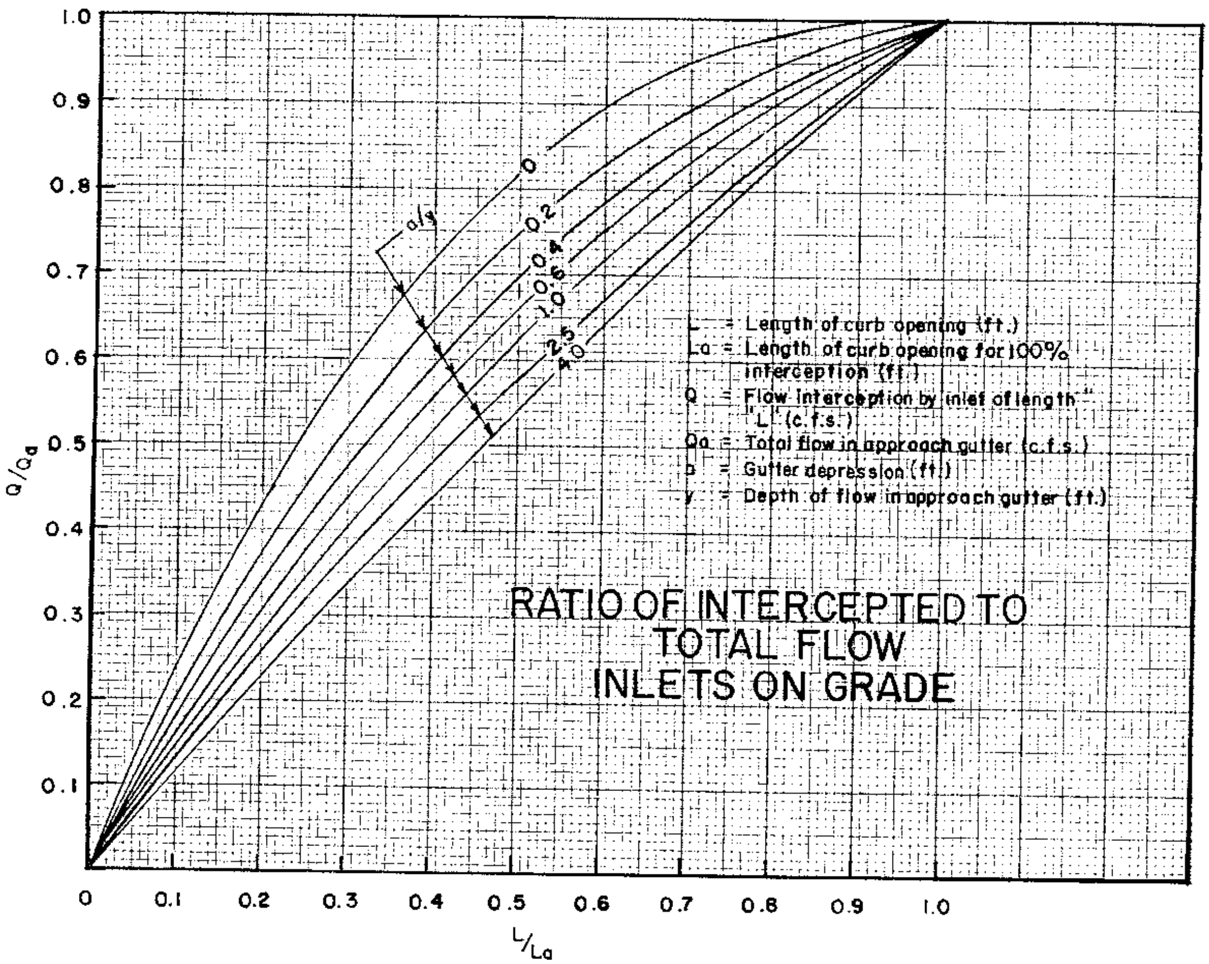
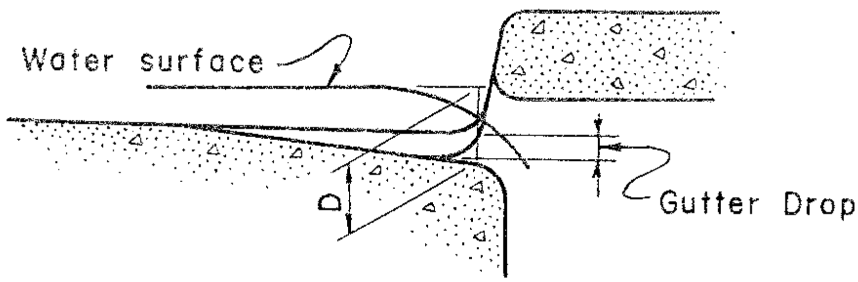
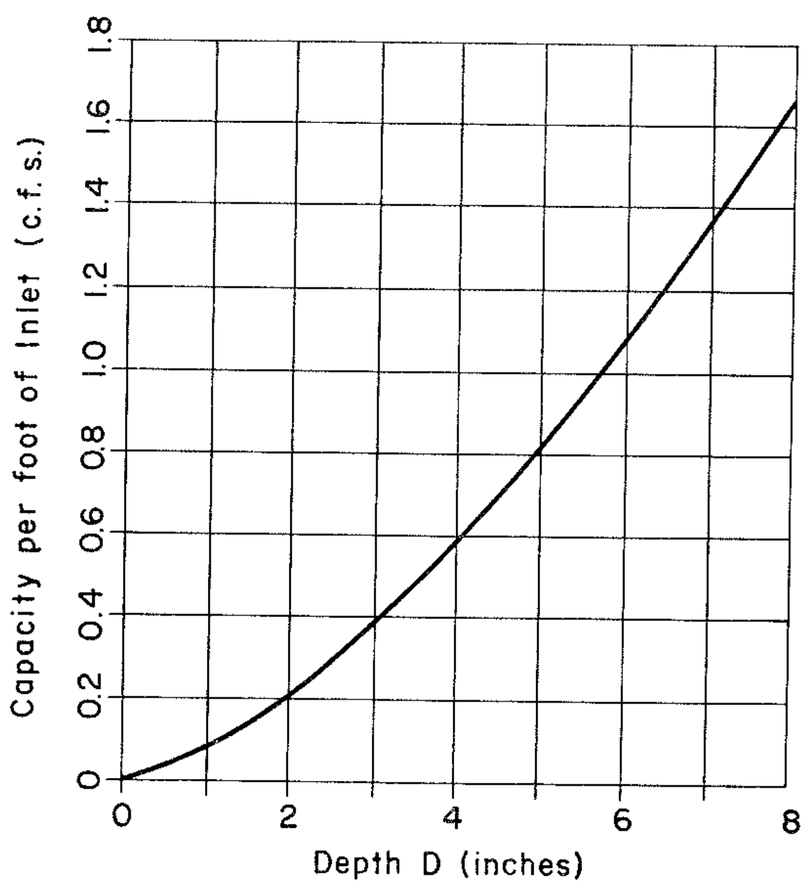


Figure 10

BRIDGE DIVISION HYDRAULIC MANUAL 12-85
6 - 25



SECTION



INLET CAPACITY FOR LOW POINT INLETS

Figure 11

12-85

BRIDGE DIVISION HYDRAULIC MANUAL

6 - 26

From 1	To 2	Drainage Area No. 3	Total D.A. Ac. 4	Total CA 5	Length ft. 6	Time of Concentration - Minutes: Along Drain Line 7	Inlet Time 8	Used in Design 9	I In./Hr. 10	Q cfs 11	Design: Dia. In. 12	Slope ft/ft 13	Cap. cfs 14	Vel. ft/sec. 15	Remarks 16
CI-1	CI-2	1	0.80	0.54	290	*470/60 = 7.8	10.0	10.0	5.8	3.1	18.00	0.01250	12.72	5.9	
CI-2	CI-3	1 & 2	1.70	1.15	161	7.8 + 290/(5.9X60) = 8.6	10.0	10.0	5.8	6.7	18.00	0.01250	12.72	7.5	
CI-4	CI-3	3	0.50	0.36	44	* 3	10.0	10.0	5.8	2.1	12.00	0.00350	2.28	3.2	Lateral A
CI-3	CI-5	1 to 4	2.60	1.77	244	8.6 + 161/(7.5X60) = 8.9	10.0	10.0	5.8	10.3	18.00	0.01250	12.72	8.0	
CI-5	CI-6	1 to 5	3.60	2.34	205	8.9 + 244/(8.0X60) = 9.4	10.0	10.0	5.8	13.6	21.00	0.01250	19.19	8.5	
CI-6	SI-1	1 to 6	4.60	2.93	88	9.4 + 205/(8.5X60) = 9.8	10.0	10.0	5.8	17.1	21.00	0.01250	19.19	9.1	
SI-1	SI-2	1 to 7	5.14	3.31	363	9.8 + 88/(9.1X60) = 10.0	10.0	10.0	5.8	19.3	24.00	0.01250	27.39	9.5	
SI-2	CI-7	1 to 9	6.48	4.05	87	10 + 363/(9.5X60) = 10.6	10.0	10.6	5.7	23.0	24.00	0.01250	27.39	9.7	
SI-3	CI-7	9	0.24	0.16	68	* 3	10.0	10.0	5.8	0.9	12.00	0.00200	1.73	2.3	Lateral B
CI-7	DI-2	1 to 10	6.87	4.27	282	10.6 + 87/(9.7X60) = 10.7	10.0	10.7	5.7	24.2	24.00	0.01250	27.39	9.9	
CI-10	CI-9	15	0.35	0.23	46	*200/(0.5X60) = 6.7	10.0	10.0	5.8	1.3	12.00	0.00197	1.71	2.3	
CI-9	CI-8	15 & 14	2.28	0.90	125	6.7 + 46/(2.3X60) = 7.0	10.0	10.0	5.8	5.2	18.00	0.00255	5.74	3.7	
CI-8	DI-2	13 to 15	3.20	1.35	160	7.0 + 125/(3.7X60) = 7.6	10.0	10.0	5.8	7.9	18.00	0.00550	8.44	5.5	
DI-2	CI-11	1 to 15	13.47	7.55	70	10.7 + 282/(9.9X60) = 11.2	10.0	11.2	5.5	41.8	30.00	0.01100	46.60	10.7	
CI-11	MH-2	20, 1 -15	13.78	7.83	145	11.2 + 70/(10.7X60) = 11.3	10.0	11.3	5.5	43.2	30.00	0.01150	47.64	11.0	
MH-2	MH-3	1 to 22	22.71	11.91	480	34.0 + 240/(7.3X60) = 34.5	-	34.5	3.0	35.7	36.00	0.00400	45.69	5.5	
SI-6	SI-5	17	2.00	0.92	418	*620/(1.0X60) = 10.3	10.0	10.3	5.8	5.3	18.00	0.00255	5.74	3.7	
SI-5	SI-4	17 & 18	3.00	1.46	465	10.3 + 418/(3.7X60) = 12.2	10.0	12.2	5.3	7.8	18.00	0.00570	8.59	5.5	
DI-1	SI-4	16	4.20	1.26	100	*1000/(0.5X60) = 33.3	33.3	33.3	3.1	3.9	12.00	0.01750	5.10	7.0	Lateral C
SI-4	MH-1	16 to 19	7.90	3.15	160	33.3 + 100/(7.0X60) = 33.5	10.0	33.5	3.1	9.6	21.00	0.00500	12.13	5.8	
MH-1	MH-2	16 to 22	9.24	4.36	240	33.5 + 160/(5.8X60) = 34.0	-	34.0	3.0	13.2	21.00	0.00820	15.54	7.3	
SI-7	SI-8	22	0.74	0.67	340	*450/(1.0X60) = 7.5	10.0	10.0	5.8	3.9	18.00	0.00570	8.59	4.8	
SI-8	MH-1	21 & 22	1.03	0.93	250	7.5 + 340/(4.8X60) = 8.7	10.0	10.0	5.8	5.4	18.00	0.00570	8.59	5.2	

Form 1021
Revised 1-86 3310ERF.DGN

*Overland flow

DRAIN PIPE CALCULATIONS

Table 3

BRIDGE DIVISION HYDRAULIC MANUAL
6 - 27

12-85

pressure, use Nomograph F, Chapter 4, or Nomograph B (for box conduits) in this chapter.

Wherever a pipe run is designed in such a manner that the capacity of a pipe as shown in column 14 is less than the computed discharge shown in column 11, a check of the hydraulic gradient above this run should be made to insure that the backwater head created by such a design is not large enough to cause "blowouts" at inlets or manholes upstream of the run. The same is true for pipe runs of larger diameter discharging into runs of smaller diameter or in instances where it is impossible to line up the soffits of pipe runs at changes of pipe size.

In our example, it will be noted on the plan profile sheet, (Figure 12), that line C is to be connected to an existing 54" pipe drain and will theoretically discharge against a 4.5' head. Analyzing the pipe run from manhole 3 to manhole 2, it is found that an effective slope of 0.24% will be required to pass the design discharge of 35.7 cfs. Projecting this grade from elevation 84.0, the soffit of the 54" diameter pipe,and also the level of the hydraulic gradient in the 54' pipe, a backwater elevation 85.15 feet at manhole 2 is determined. This procedure should be repeated in an upstream direction, until the hydraulic gradient elevation drops below the top of a pipe run. This occurs in this instance between SI-1 and SI-2 on line A. Since the backwater elevations are well below the throats of the inlets, the system as designed is satisfactory.

The above method of evaluating the hydraulic gradient does not take into account all items such as head losses in inlets, head losses or gains due to changes in velocity, etc., but it is considered accurate enough for all practical purposes so long as the hydraulic gradient is kept well below the throats of inlets. The Department conventionally ignores these minor losses as negligible. If their consideration is necessary because of involvement with other governmental entities, consult with the D-5 Hydraulic Section for technical guidance.

Column 15. The velocities shown in this column are based upon the design flow and its associated normal depth of flow (uniform depth) and can be obtained from the appropriate nomograph in Chapter 4 or calculated. They are used in column 7 in determining the time of flow through each run of pipe.

Column 16. In a usual tabulation of storm drain design notes, a "Remarks" column can be very useful. It is used in this example to identify three remote laterals.

6-700. UNDERDRAINS

In certain areas of the state, ground water can be a significant problem as it attacks foundations, substructures, subgrades, and other aspects of highway components. In most soils where ground water is a problem, a system of underdrains, installed for the removal of excess moisture, can be a very useful feature in the overall roadway design. Underdrains may take the form of networks of perforated (or otherwise permeable) pipe, French drains, or collector fields. Where such appurtenances are needed, the additional expense in their installation is usually fully justified in terms of future savings in roadway and structure maintenance costs.

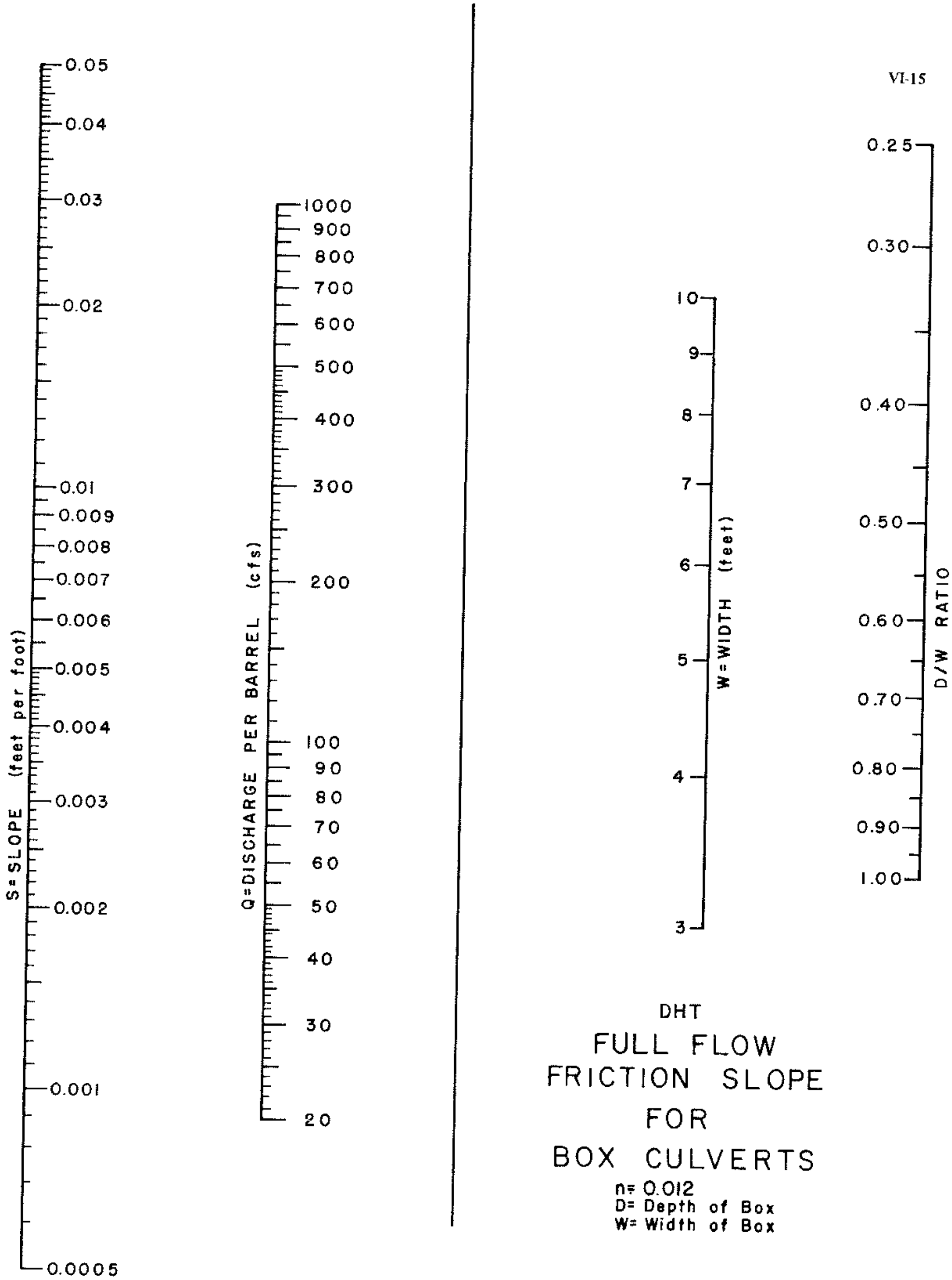
Percolation rates for ground water may be obtained from Soil Conservation Service offices, measured, or simply estimated. Collector pipe sizes and networks may then be established for the removal of that water. French drains can be very useful where the unwanted ground water percolation rates are relatively high. See Figure 13 for a typical French drain detail. Collector fields may be useful where reasonable outfalls for ground water are not available. All of the above appurtenances may be enhanced by the use of some type of geo-textile filter material. Consult with the D-5 Hydraulic Section for assistance and further information on this subject.

6-800. THYSYS

The Texas Hydraulic System (THYSYS) of computer routines dealing with highway drainage includes a stand-alone subsystem SEWER which deals with the analysis and design of storm drain systems according to the general principles of storm drain design discussed in this chapter. Included in the options are sections dealing with runoff, inlets (surface drainage), and pipe systems. Hydraulic and geometric documentation and graphical outputs represent thorough documentation for reference and plans application by the user.

The rational method is used for runoff computations and is capable of accommodating up

VI-15



DHT
FULL FLOW
FRICTION SLOPE
FOR
BOX CULVERTS

n = 0.012
D = Depth of Box
W = Width of Box

Nomograph B

BRIDGE DIVISION HYDRAULIC MANUAL 12-85
6 - 29

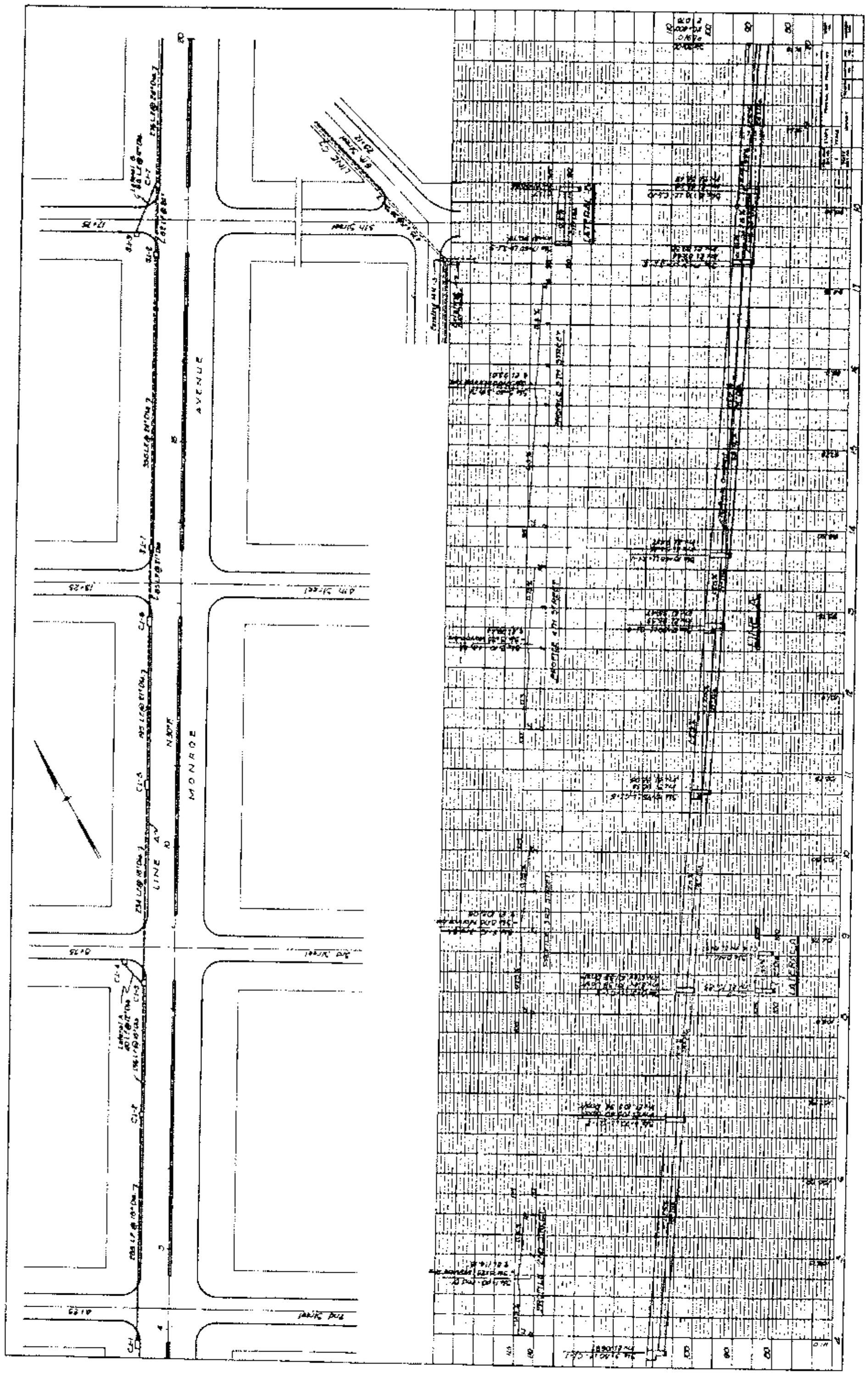


Figure 12a

12-85

BRIDGE DIVISION HYDRAULIC MANUAL
6 - 30

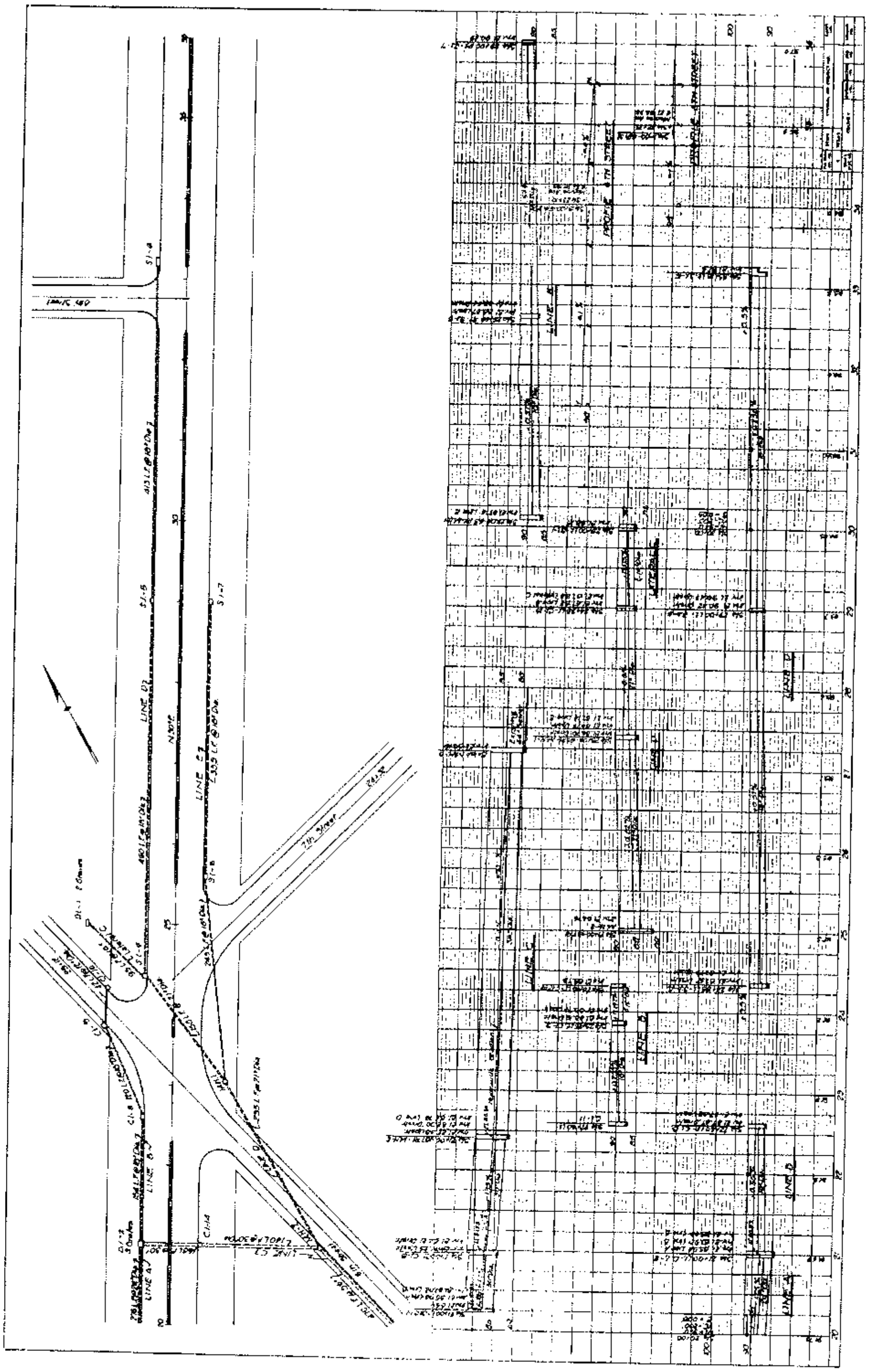
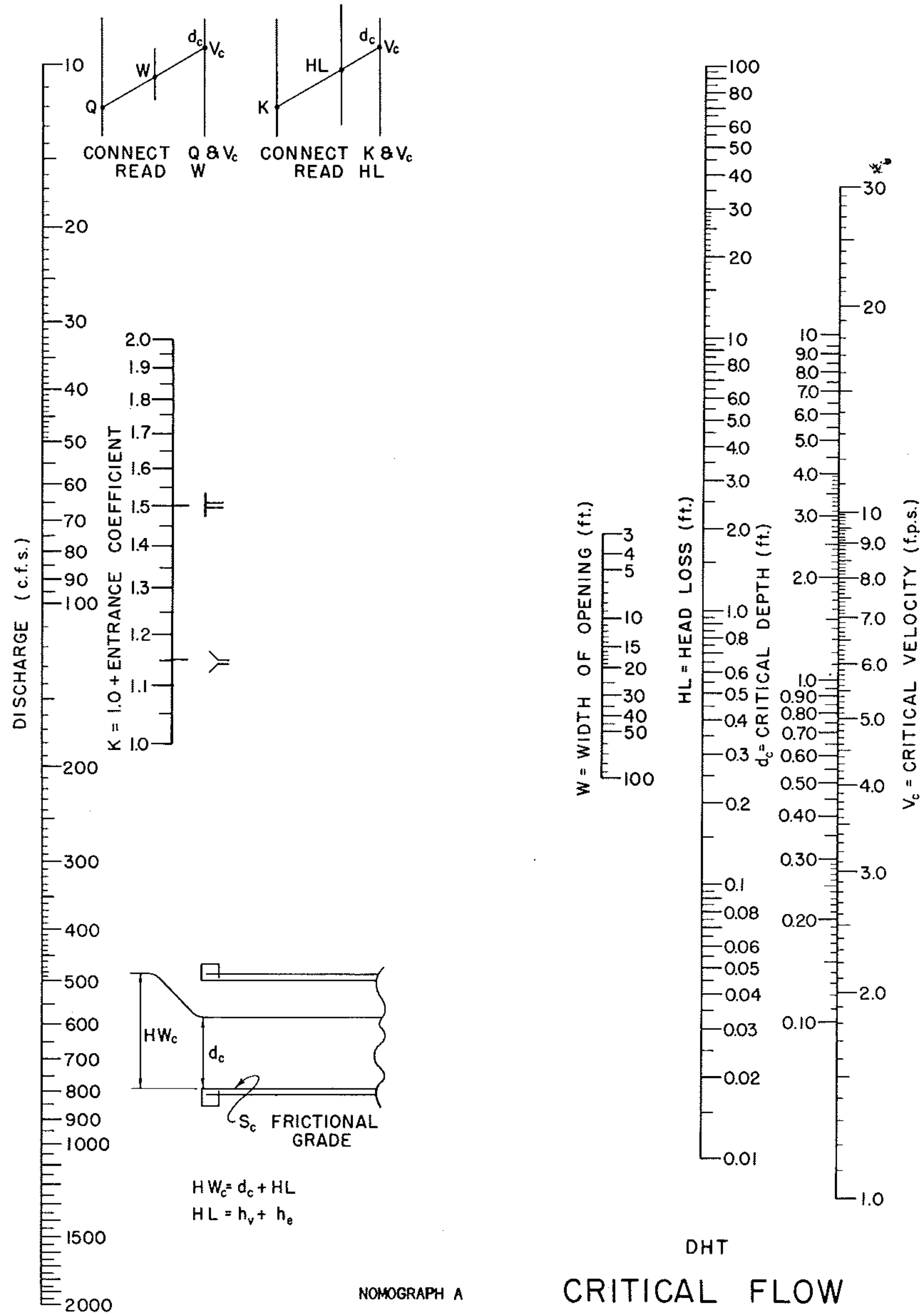


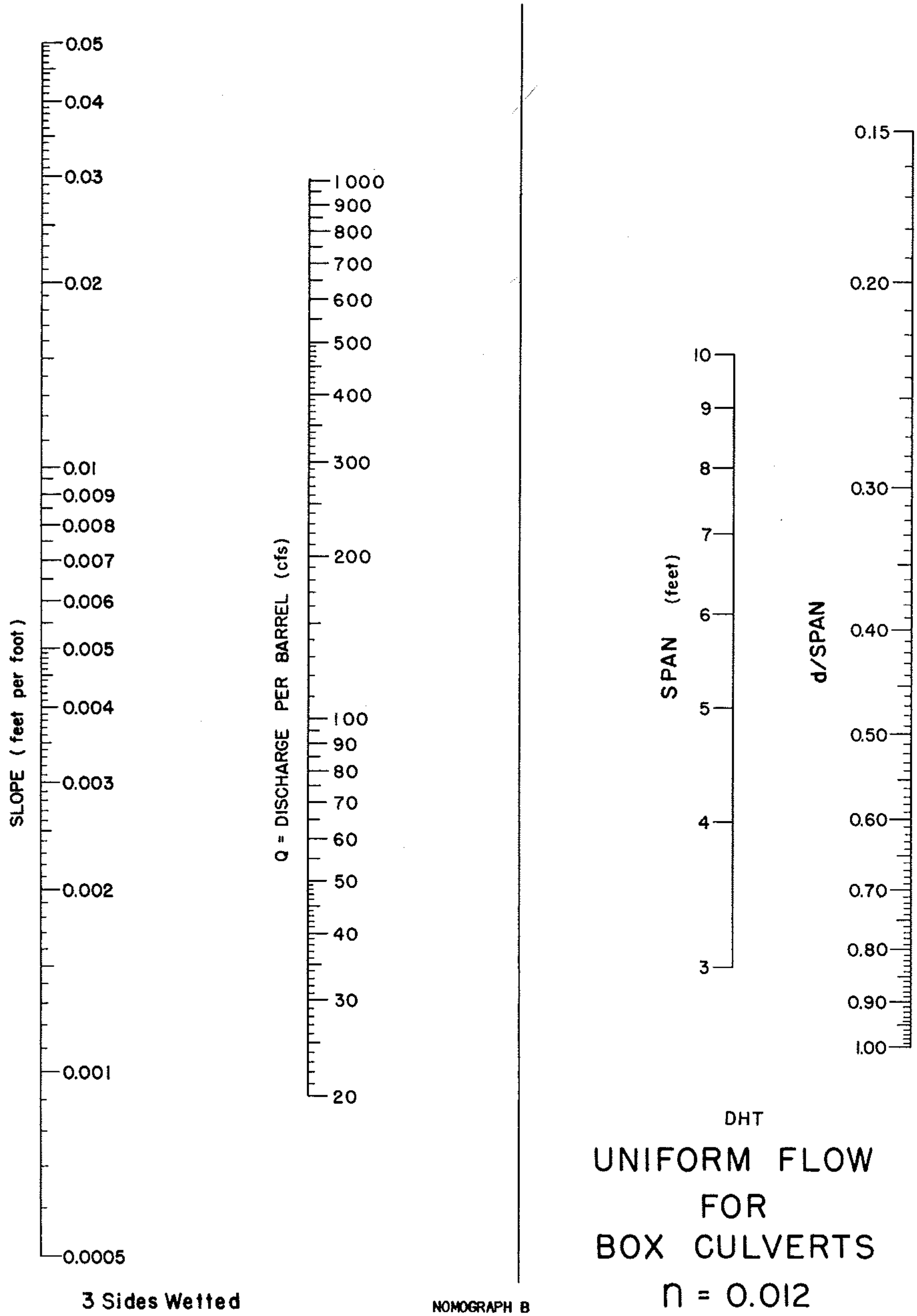
Figure 12b

BRIDGE DIVISION HYDRAULIC MANUAL 12-85
6 - 31



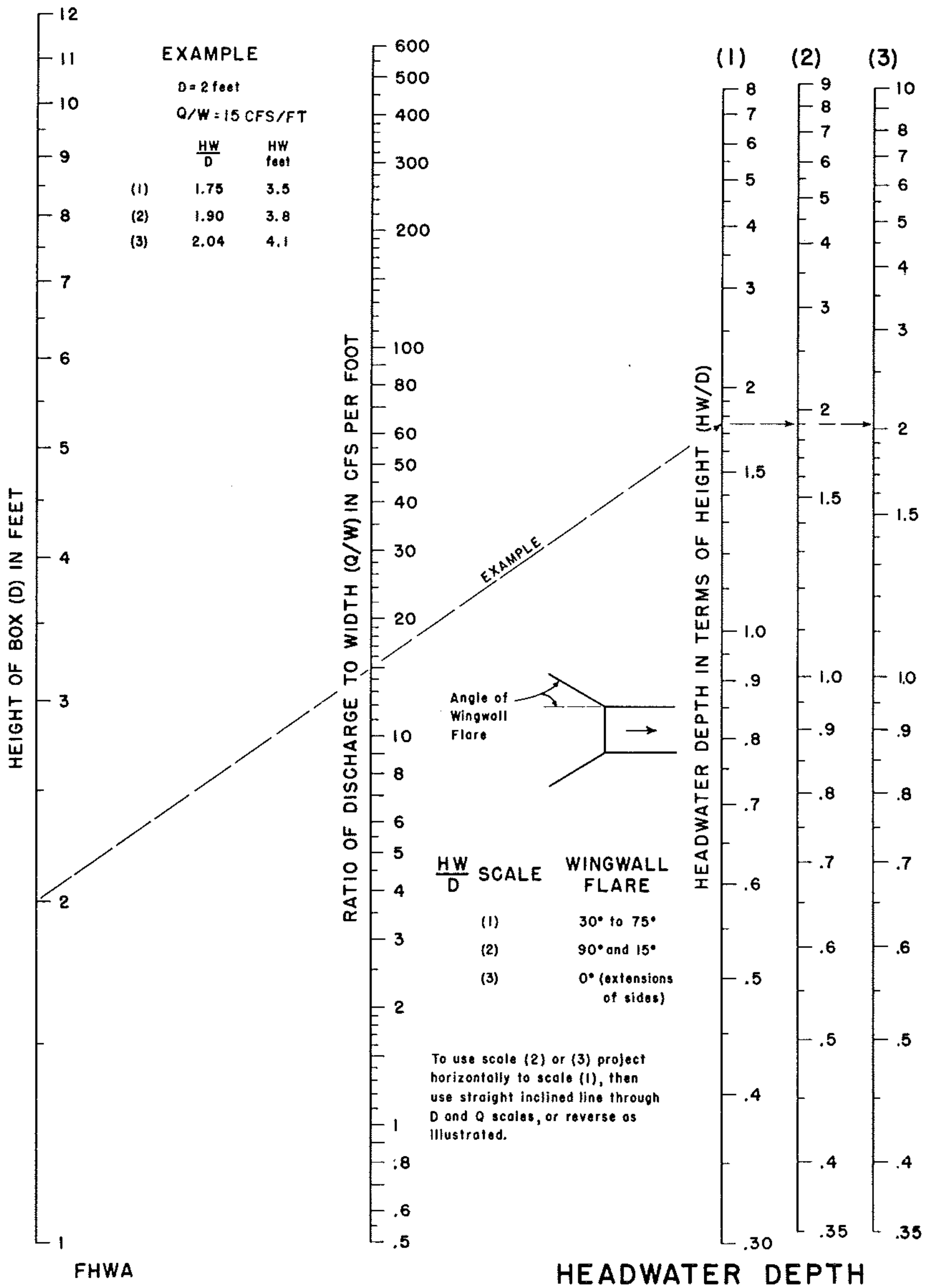
CRITICAL FLOW
FOR BOX CULVERTS
$n = 0.012$

BRIDGE DIVISION HYDRAULIC MANUAL 12-85
4 - 19



BRIDGE DIVISION HYDRAULIC MANUAL 12-85

4 - 21

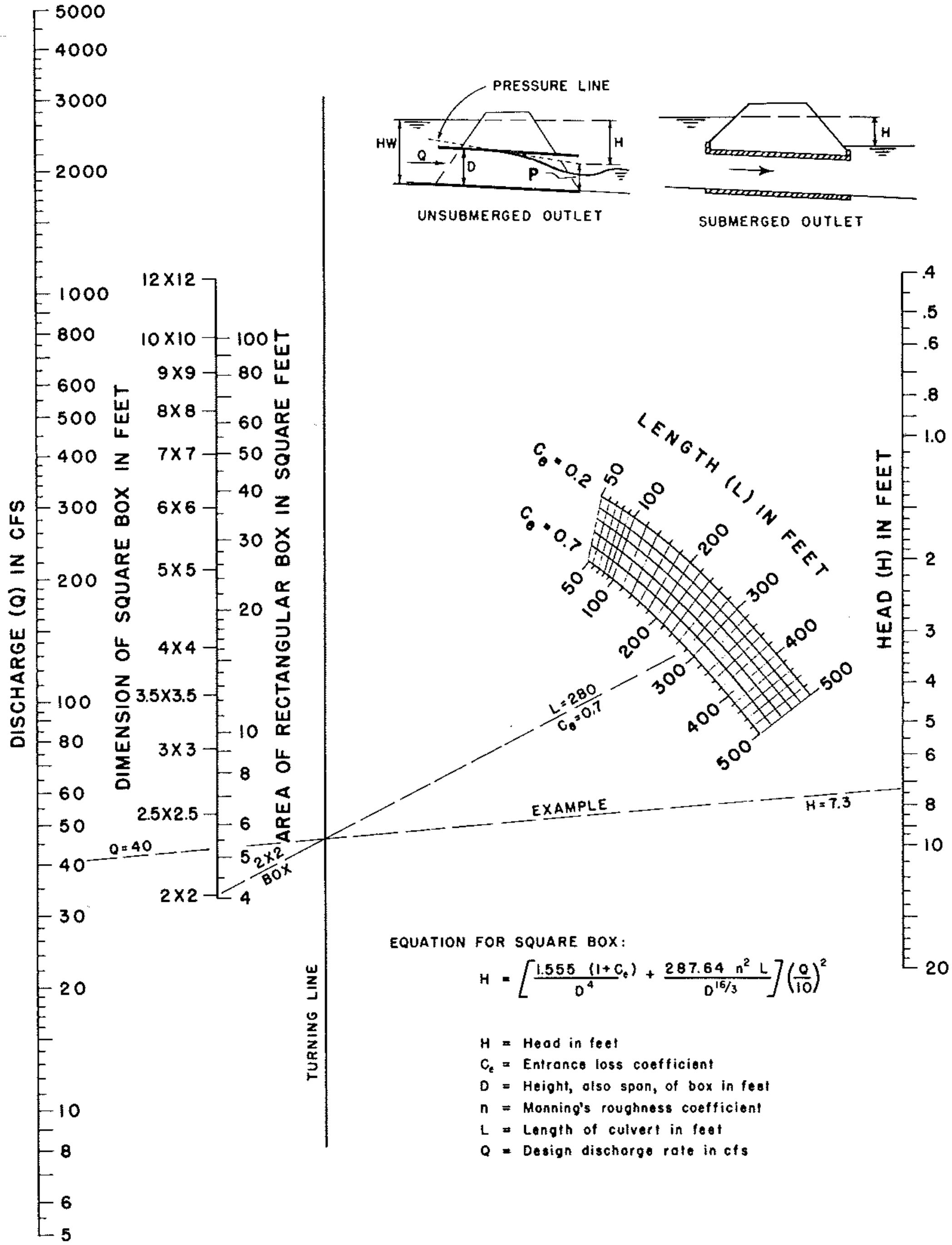


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

NOMOGRAPH C

BRIDGE DIVISION HYDRAULIC MANUAL 12-85

4 - 23

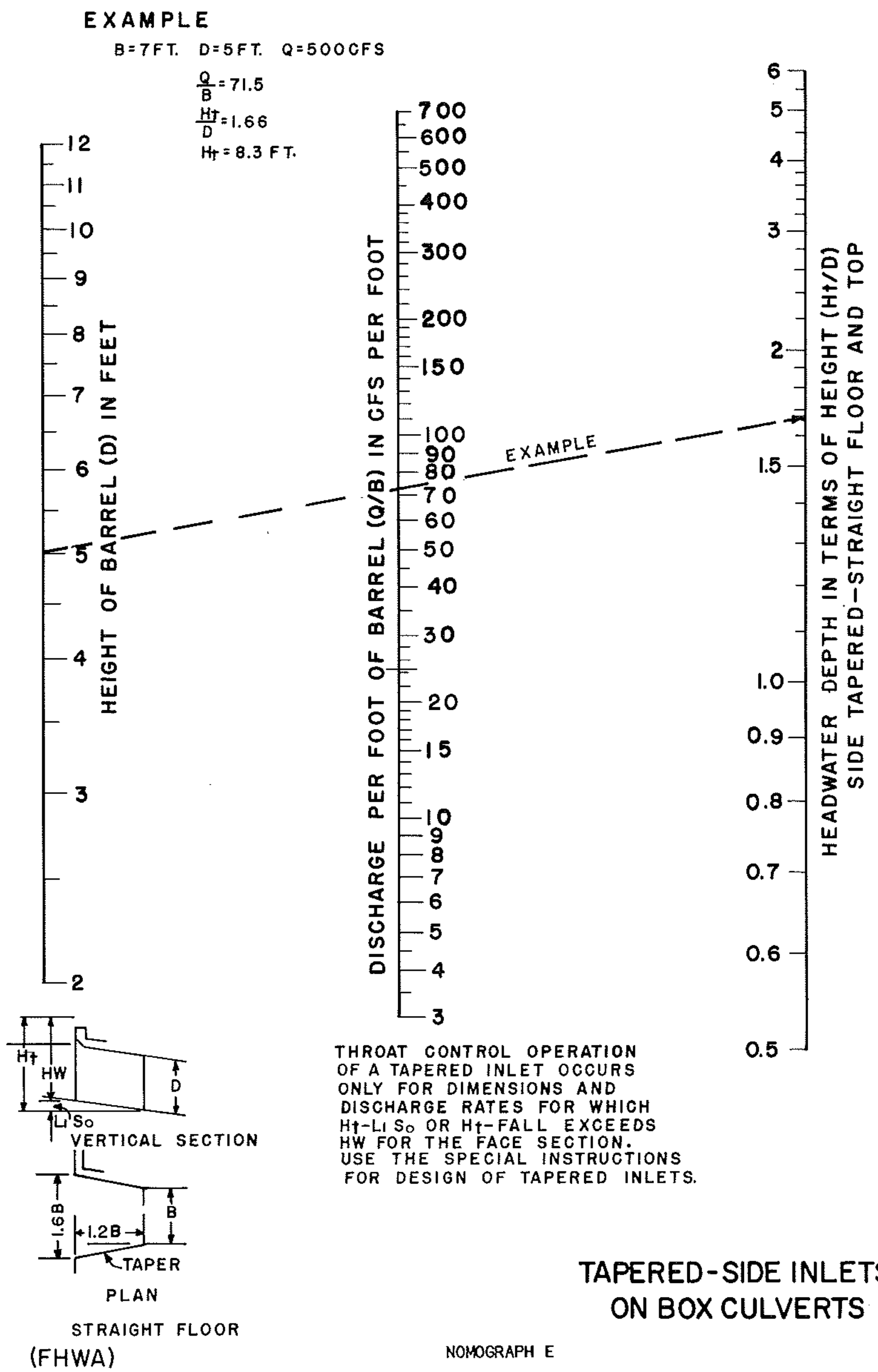


HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
$n = 0.012$

FHWA

NOMOGRAPH D

BRIDGE DIVISION HYDRAULIC MANUAL 12-85
4 - 25



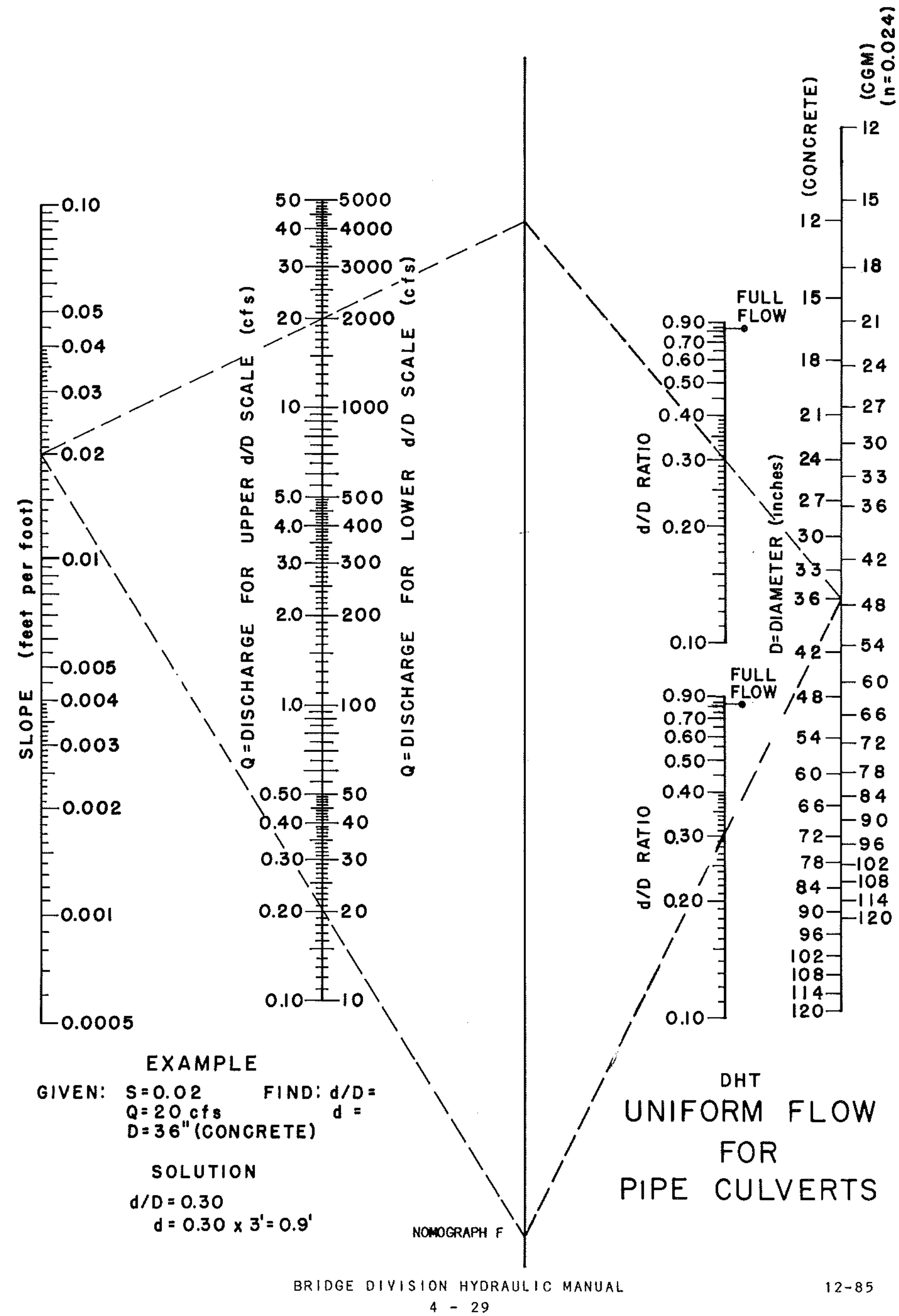
THROAT CONTROL OPERATION OF A TAPERED INLET OCCURS ONLY FOR DIMENSIONS AND DISCHARGE RATES FOR WHICH Ht-Li So OR Ht-FALL EXCEEDS HW FOR THE FACE SECTION. USE THE SPECIAL INSTRUCTIONS FOR DESIGN OF TAPERED INLETS.

TAPERED-SIDE INLETS ON BOX CULVERTS

NOMOGRAPH E

BRIDGE DIVISION HYDRAULIC MANUAL 12-85

4 - 27


SLOPE (feet per foot)
Q=DISCHARGE FOR UPPER d/D SCALE (cfs)
Q=DISCHARGE FOR LOWER d/D SCALE (cfs)
d/D RATIO
FULL FLOW
D=DIAMETER (inches)
(CONCRETE)
(CGM) (n=0.024)
EXAMPLE
GIVEN: S=0.02 FIND: d/D=
Q=20 cfs d =
D=36" (CONCRETE)
SOLUTION
d/D=0.30
d=0.30 x 3'=0.9'
NOMOGRAPH F
DHT
UNIFORM FLOW
FOR
PIPE CULVERTS
BRIDGE DIVISION HYDRAULIC MANUAL 12-85
4 - 29

City of Tyler
Design Guidelines for Subdivision Improvements

Chapter 6 - SWPPP Design and Implementation

I. General

The purpose of this Guideline is to assist the Engineer in the preparation of a construction Storm Water Pollution Prevention Plan (SWPPP), the primary tool for minimizing erosion and sediment loss from a construction site along with the control of construction related chemicals and wastes.

II. Design & Implementation

For projects requiring permit coverage, it is recommended that the storm water pollution prevention plan be developed in accordance with Chapter 10, Article VII, Division E "Erosion and Sedimentation Control" of the City Tyler Code of Ordinances and the TPDES Construction General Permit.

III. BMP Selection Guide

In preparing the SWPPP, the Engineer can first use the BMP selection guide below to determine BMPs applicable to the site. The Efficiency Ratings listed for the BMPs are the assumed efficiencies in reducing erosion or trapping sediment for the BMP, assuming the BMPs are designed, installed, and maintained in accordance with acceptable practices and based on accommodating the flow and volumes from the applicable design storm.

Additional information to help in the selection, design, installation and maintenance of BMPs can also be found at the EPA website.

Table 1
Construction BMP Selection Guide

BMP Type	BMP	Primary Purpose	Efficiency Rating
Construction Site Planning and Management	Construction Sequencing	Stabilizing on one part of the site before grading and construction commence at another part	Effective
	BMP Inspection and Maintenance	Provide routine inspections, inspections performed before rain events, and inspections performed after rain events to ensure effectiveness of BMPs	Varies
	Land Grading	Provide suitable topography for buildings, facilities, and other land uses while controlling surface runoff, soil erosion, and sedimentation during and after construction	Varies
	Preserving Natural Vegetation	Protecting desirable trees, vines, bushes, and grasses from damage during project development to provide erosion control, stormwater detention, biofiltration, and aesthetic values to a site during and after construction activities	Effective
Erosion Prevention and Control	Interceptor Swale	Route flows around areas of disturbance	1.00
	Diversion Dike	Route flows around area of disturbance	1.00
	Pipe Slope Drain	Route overland flow on a slope into a pipe to protect slope	Varies
	Chemical Stabilization	Provide soil stabilization by spraying soil binders or soil palliatives such as vinyl, asphalt, or rubber	0.70 - 0.90
	Seeding/Sodding/Hydromulching	Provide natural soil protection through seeding, hydromulch or phasing	0.90
	Mulching	Protect disturbed soil with a layer of hay, straw or other material	0.90
	Compost Blanket	Protect disturbed soil with a layer of loosely applied composted material	0.75
	Erosion Control Blanket	Protect disturbed soil with a layer of hay, straw or other material	0.90
	Geotextiles	Protect disturbed soil with a layer of porous fabric	Varies
Erosion Prevention and Control	Soil Retention	Structures or practices, such as grading or reshaping the ground to lessen steep slopes or shoring excavated areas with wood, concrete, or steel structure, that hold soil in place or keep it contained within a site boundary	Varies
	Soil Roughening	A temporary erosion control practice often used in conjunction with grading	Moderately effective for short term use
	Channel Protection/Riprap	Protects soil through the use of grass-lining, turf reinforcement or riprap	Varies
	Dust Control	Techniques to limit wind erosion and airborne soil particles from leaving site	Varies
	Temporary Stream Crossing	Provide a safe, stable way for construction vehicle traffic to cross a watercourse	Varies
	Wind / Sand Fence	Barriers erected to reduce wind velocity and to trap blowing sand	Effective

Table 1
Construction BMP Selection Guide
(cont'd)

BMP Type	BMP	Primary Purpose	Efficiency Rating
Sediment Controls	Brush Barrier	Perimeter sediment control structures constructed of material such as small tree branches, root mats, stone, or other debris left over from site clearing and grubbing	Effective
	Silt Fence	Slow and filter runoff to retain sediment	0.75
	Organic Filter Berm	Slow and filter runoff to retain sediment	0.75
	Organic Filter Sock	Slow and filter runoff to retain sediment	0.75
	Triangular Sediment Filter Dike	Similar to silt fence but more portable, reusable and sturdy with high flows	0.75
	Fiber Roll	Slow and filter runoff to retain sediment	0.75
	Filter Berm	Slow and filter runoff to retain sediment	0.75
	Inlet Protection	Intercept sediment at curb and field inlets. Should be used in conjunction with other onsite techniques	Varies
	Stone Outlet Sediment Trap	Intercept and filter small concentrated flows such as small creeks and defined waterways	0.85
	Sediment Basin	Large pond with controlled outflow which allows sediment to settle out of runoff	0.90
	Check Dam	Provide minor detention and retention of sediment for small swales and concentrated flows	0.50
	Sediment Filter / Chamber	Sediment-trapping devices typically used to remove pollutants (mainly particulates) from stormwater runoff	0.60 - 0.85
	Sediment Trap	Small impoundments that allow sediment to settle out of construction runoff	0.60
	Straw or Hay Bale	Slow and filter runoff to retain sediment	Not Recommended
	Stabilized Construction Entrance	Reduce offsite sediment tracking from trucks and construction equipment	Varies
	Wheel Wash	Reduce offsite sediment tracking from trucks and construction equipment	N/A
	Vegetated Buffer	Areas of natural or established vegetation maintained to protect the water quality of neighboring areas	0.90
Good Housekeeping / Materials Management	Debris and Trash Management	Techniques for management of paper, packaging, general building materials, etc.	Very effective
	Chemical Management	Techniques for management of paints, chemicals, fertilizer, oil and grease, etc.	Very effective
	Concrete Waste Management	techniques for disposal of concrete washout, demolished concrete, etc.	Very effective
	Concrete Sawcutting Waste Management	Techniques for disposal of concrete cuttings from concrete sawing	Effective
	Sandblasting Waste Management	Techniques for disposal of sandblasting waste and containment of wastes during operations	Effective
	Lime Stabilization Management	Concrete lime runoff from areas being stabilized with hydrated or quicklime	Effective
	Sanitary Facilities	Techniques for control of sanitary waste	Effective

City of Tyler
Design Guidelines for Subdivision Improvements

Chapter 7 - Storm Water Controls

I. General

The purpose of this Guideline is to assist the Engineer in the design of structural storm water controls - engineered facilities intended to treat storm water runoff and/or mitigate the effects of increased storm water runoff peak rate, volume, and velocity due to urbanization.

A structural storm water control, or set of structural controls, must meet the following objectives:

- **Water Quality**: Remove pollutants in storm water runoff to protect water quality;
- **Streambank Protection**: Regulate discharge from the site to minimize downstream bank and channel erosion; and
- **Flood Control**: Control conveyance of runoff within and from the site to minimize flood risk to people and properties.

The requirements of this chapter shall be in accordance with Chapter 10, Article VII, Division F "Control of Post Construction Stormwater Runoff" in the City of Tyler Unified Development Code.

II. Storm Water Control Categories

Chapter 10, Article VII, Division F "Control of Post Construction Stormwater Runoff" in the City of Tyler Unified Development Code provides a list of storm water control practices, which are generally divided in to two categories:

A. Primary Controls: Primary structural storm water controls have the ability to fully address one or more of the objectives stated above if designed appropriately. Structural controls are recommended for use with a wide variety of land uses and development types. These structural controls have a demonstrated ability to effectively treat the Water Quality Volume (WQ_V) and have been shown to be able to remove 70% to 80% of the annual average total suspended solids (TSS) load in typical post-development urban runoff when designed, constructed, and maintained in accordance with recommended specifications. Several of these structural controls can also be designed to provide primary control for downstream streambank protection (SP_V) and flood control (Q_f). These structural controls are recommended storm water management facilities for a site wherever feasible and practical.

B. Secondary Controls: A number of structural controls are recommended only for limited use or for special site or design conditions. Generally, these practices either: 1) do not have the ability on their own to fully address one or more of the stated objectives, 2) are intended to address hotspot or specific land use constraints or conditions, and/or 3) may have high or special maintenance requirements that may preclude their use. These types of structural controls are typically used for water quality treatment only. Some of these controls can be used as a pretreatment measure or in series with other structural controls to meet pollutant removal goals. Such structural controls should be considered mostly for commercial, industrial, or institutional developments.

C. Using Other or New Structural Storm Water Controls: Innovative technologies are encouraged provided there is sufficient documentation as to their effectiveness and reliability. Engineers and designers may propose controls not included in this Guideline at their discretion, but should not do so without submitting independently derived information concerning performance, maintenance, application requirements, and limitations.

III. Suitability of Storm Water Controls

A. Water Quality: Pollutant removal capabilities for a given structural storm water control practice are based on a number of factors including the physical, chemical, and/or biological processes that take place in the structural control and the design and sizing of the facility. In addition, pollutant removal efficiencies for the same structural control type and facility design can vary widely depending on the tributary land use and area, incoming pollutant concentration, flow rate, volume, pollutant loads, rainfall pattern, time of year, maintenance frequency, and numerous other factors.

Where the pollutant removal capabilities of an individual structural storm water control are not deemed sufficient for a given site application, additional controls may be used in series in a “treatment train” approach.

B. Streambank Protection: These controls have the ability to detain the volume and regulate the discharge of the 1-year, 24-hour storm event to protect natural waterways downstream of the development. Controls that provide streambank protection include detention, energy dissipation, storm water ponds, storm water wetlands, and pipe systems.

C. Flood Control:

1. On-Site: These controls have the ability to safely convey storm water through a development to minimize the flood risk to persons and property on-site. On-site flood control structures include channels, culverts, detentions, enhanced swales, open conveyance channels, storm water ponds, conveyance components (inlets and pipe systems), and storm water wetlands.

2. Downstream: These controls have the ability to detain the volume and regulate the discharge from the controlling storm event, as determined by

downstream assessment and to minimize flood risk to persons and property downstream of the development. Downstream flood controls include open channels, pipe systems, detention, storm water ponds, and storm water wetlands.

IV. Storm Water Control Selection

A. Site Design Feasibility: Stormwater management practices for a site shall be chosen based on the physical conditions of the site. Among the factors that should be considered:
1. Topography
2. Maximum Drainage Area
3. Depth to Water Table
4. Soils
5. Slopes
6. Terrain
7. Head
8. Location in relation to environmentally sensitive features or ultra-urban areas

B. Conveyance Issues: All stormwater management practices shall be designed to convey stormwater to allow for the maximum removal of pollutants and reduction in flow velocities. This shall include, but not be limited to:
1. Maximizing of flowpaths from inflow points to outflow points.
2. Protection of inlet and outfall structures.
3. Elimination of erosive flow velocities.
4. Providing of underdrain systems, where applicable.

C. Pretreatment Requirements: If used, the stormwater treatment practice shall have an acceptable form of water quality pretreatment. Certain stormwater treatment practices are prohibited even with pretreatment in the following circumstances:
1. Stormwater is generated from highly contaminated source areas known as “hotspots”.
2. Stormwater is carried in a conveyance system that also carries contaminated, non- stormwater discharges.
3. Stormwater is being managed in a designated groundwater recharge area.
4. Certain geologic conditions exist (e.g., karst) that prohibit the proper pretreatment of stormwater.

D. Treatment/Geometry Conditions: All stormwater management practices shall be designed to capture and treat stormwater runoff.

E. Location and Permitting Considerations: The checklist included as Table A-1 in Appendix A provides a condensed summary of current restrictions as they relate to common site features that may be regulated under local, state, or federal law. These restrictions fall into one of three general categories:

1. Locating a structural control within an area when expressly prohibited by law.
2. Locating a structural control within an area that is strongly discouraged, and is only allowed on a case by case basis. Local, state, and/or federal permits shall be obtained, and the applicant will need to supply additional documentation to justify locating the storm water control within the regulated area.
3. Structural storm water controls must be setback a fixed distance from a site feature.

The checklist is only intended as a general guide to location and permitting requirements as they relate to siting of storm water structural controls. Consultation with the appropriate regulatory agency is the best strategy.

APPENDIX A

Table A-1
Location and Permitting Checklist

Site Feature	Location and Permitting Guidance
Jurisdictional Wetland (Waters of the US) U.S. Army Corps of Engineers Regulatory Permit	• Jurisdictional wetlands should be delineated prior to siting structural control. • Use of natural wetlands for storm water quality treatment is contrary to the goals of the Clean Water Act and should be avoided. • Storm water should be treated prior to discharge into a natural wetland. • Structural controls may also be restricted in local buffer zones. Buffer zones may be utilized as a non-structural filter strip (i.e., accept sheet flow). • Should justify that no practical upland treatment alternatives exist. • Where practical, excess storm water flows should be conveyed away from jurisdictional wetlands.
Stream Channel (Waters of the US) U.S Army Corps of Engineers Section 404 Permit	• All Waters of the U.S (streams, ponds, lakes, etc.) should be delineated prior to design. • Use of any Waters of the U.S. for storm water quality treatment is contrary to the goals of the Clean Water Act and should be avoided. • Storm water should be treated prior to discharge into Waters of the U.S. • In-stream ponds for storm water quality treatment are highly discouraged. • Must justify that no practical upland treatment alternatives exist. • Temporary runoff storage preferred over permanent pools. • Implement measures that reduce downstream warming.
Stream Channel (Waters of the State) Texas Parks and Wildlife Mussel Survey and Aquatic Resource Relocation Plan	• All Waters of the State (streams, ponds, lakes, etc.) should be delineated prior to design. • Review by TPWD is required for all construction or maintenance activities that take place in or near Public Waters. • Includes but is not limited to: pipelines, boring, trenching, road or bridge construction, dam work, boat ramp work, dewatering, coffer dams, stream bank restoration, etc.
Groundwater Management Areas Texas Commission on Environmental Quality	• Conserve, preserve, protect, recharge, and prevent waste of groundwater resources through Groundwater Conservation Districts. • Detailed mapping available from Texas Alliance of Groundwater Districts.

Table A-1
Location and Permitting Checklist

Site Feature	Location and Permitting Guidance
Surface Water Quality Standards Texas Commission on Environmental Quality	• Specific stream and reservoir buffer requirements. • May be imperviousness limitations. • May be specific structural control requirements. • TCEQ provides water quality certification - in conjunction with 404 permit. • Mitigation will be required for impacts to existing aquatic and terrestrial habitat.
100 Year Floodplain Local Storm Water Review Authority	• Grading and fill for structural control construction is generally discouraged within the 100 year floodplain, as delineated by FEMA flood insurance rate maps, FEMA flood boundary and floodway maps, or more stringent local floodplain maps. • Floodplain fill cannot raise the floodplain water surface elevation by more than limits set by the appropriate jurisdiction.
Stream Buffer Check with appropriate review authority whether stream buffers are required	• Consult local authority for storm water policy. • Structural controls are discouraged in the streamside zone (within 25 feet or more of streambank, depending on the specific regulations).
Utilities Local Review Authority	• Call appropriate agency to locate existing utilities prior to design. • Note the location of proposed utilities to serve development. • Structural controls are discouraged within utility easements or rights of way for public or private utilities.
Roads TxDOT	• Consult TxDOT for any setback requirement from local roads. • Consult DOT for setbacks from State maintained roads. • Approval must also be obtained for any storm water discharges to a local or state-owned conveyance channel.
Structures Local Review Authority	• Consult local review authority for structural control setbacks from structures. • Recommended setbacks for each structural control group are provided in the performance criteria in this manual.
Septic Drain Fields Local Health Authority	• Consult local health authority. • Recommended setback is a minimum of 50 feet from drain field edge or spray area.
Water Wells Local Health Authority	• 100-foot setback for storm water infiltration. • 50-foot setback for all other structural controls.