DRAINAGE DESIGN MANUAL

CITY OF DALLAS

PUBLIC WORKS

MAY 1993

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1. PURPOSE

The purpose of this "Drainage Design Manual" is to provide guidelines for designing facilities in the City of Dallas. This manual is for use by the Department of Public Works (DPW), other City departments, consulting engineers employed by the City, and engineers for private development in the City. It is not intended to limit the design capabilities or engineering judgement of the design professional or the use of new technical developments in engineering. Special problems may require special methods. Unusual circumstances or special designs requiring variance from standards within this manual may be approved by the Director of Public Works. All requests for variance must be submitted in writing to the Director of Public Works or the appropriate Division Manager. Predesign meetings to discuss strategies and concepts are recommended for most projects.

2. SCOPE

The guidelines contained in this manual have been developed from a comprehensive review of basic design technology as contained in various engineering publications, and through the experience of individual engineers who have contributed to the content. This manual addresses storm drainage situations which are generally relative to the City of Dallas and its immediate geographical area. Accepted engineering principles are applied to these situations in detailed documented procedures. The documentation is not intended to limit initiative but rather is included as a standardized format to aid in design and as a record source for the City.

Additional information on the City of Dallas regarding drainage design can be found in the Development Code under the Floodplain, Escarpment, or Platting Regulations and in adopted Floodplain Management Plans.

3. ORGANIZATION OF MANUAL

This manual is divided into the following five sections:

Section I, INTRODUCTION, is a general discussion of the intended use of the material and an explanation of its organization.

Section II, DRAINAGE DESIGN CRITERIA, lists criteria and parameters for the design of various drainage related facilities, and demonstrates the design procedures and methodology used by the Department of Public Works.

Section III, CONSTRUCTION PLAN PREPARATION, provides DPW requirements regarding construction plans, as well as helpful information to assist the design engineer expedite the plan review process.

Section IV, APPENDIX, contains charts and nomographs to assist with computations, tables containing design information, and a checklist for plan preparation.

Section V, ADDENDUM, contains additional information pertaining to policy changes, approved references, dedication statements, etc.

SECTION II - DRAINAGE DESIGN CRITERIA

1. GENERAL

This section contains the minimum storm drainage design criteria to be followed in the design of storm drainage facilities and demonstrates the design procedures to be used on drainage projects in the City of Dallas.

Applicable forms, tables, charts, nomograph, details and additional information which can be used for the design of various storm drainage facilities are contained in the appendix to this manual.

2. METHODS OF DETERMINING DESIGN DISCHARGE

All drainage systems will be designed to accommodate the flow from the 100-year frequency storm or the flood of record, whichever is greater.

The Rational Formula for computing storm water runoff is to be used for hydraulic design of facilities serving a drainage area less than 130 acres. For drainage areas larger than 130 acres, the runoff is to be calculated using the Soil Conservation Service Unit Hydrograph Method.

2.1 RATIONAL FORMULA

The Rational Formula for computing peak runoff rates is as follows:

$$Q = CIA$$

where

Q = Runoff rate in cfs
C = Runoff coefficient
(Refer to page 1 of Appendix)
I = Rainfall intensity in inches/hour
(Refer to page 2 of Appendix)
A = Drainage area in acres

All runoff calculations shall be based upon a fully developed watershed and existing zoning. Runoff coefficients for various land uses are shown on page 1 of the Appendix. Larger coefficients may be used if considered by the Department of Public Works to be appropriate to the project.

The rainfall intensity value "I", based on the NOAA publication Hydro-35, is the intensity for a duration equal to the time of concentration (T_c) In no case shall the inlet time (T_c for determining Q to an inlet) be more than the time shown on page 1 of the appendix.

Calculations for inlet time should include time for overland, gutter and/or channel flow where applicable. T_c's for points along an enclosed storm drain system may include travel time in pipe in addition to inlet time.

2.2 UNIT HYDROGRAPH METHOD

When a drainage area under consideration is equal to or greater than 130 acres, the City of Dallas recognizes the Soil Conservation Service Unit Hydrograph Method for determining rates and volumes of stormwater runoff. The SCS Unit Hydrograph Method is presented in chapter four of the National Engineering Handbook, and is discussed in the manual entitled Hydrology and Hydraulics of Floodplain Studies for the City of Dallas ("H&H" manual). The City also recognizes the SCS TR20 Flood Routing Program (1967 & 1987 versions), and the microcomputer version of TR20 (entitled PC-TR20) which was developed for distribution by the City in 1988. Where the City has an existing hydrology model, it should be utilized unless the Technical Services Division approves development of a new model. The use of other models which contain the SCS Unit Hydrograph Method must be preapproved by the Technical Services Division of Public Works.

A unit hydrograph is the time discharge relationship, defined at a given point along a water course, which results from a storm producing one inch of runoff uniformly distributed over the watershed. The SCS Unit Hydrograph Method computes the unit hydrograph for a given area and then converts it to the flood hydrograph theoretically resulting from a given rainfall event. The input required to compute the design flood hydrograph includes drainage area, T_c, runoff curve number, rainfall information for the design storm, and a dimensionless unit hydrograph.

2.2.1 RAINFALL

Rainfall depths for greater than 60 minute durations shall be based on the NWS publication TP-40, and for 60 minutes or less on Hydro-35. Area Rainfall Reduction Factors may be used to account for nonuniform distribution of rainfall in large watersheds. Information pertaining to design storm duration and distribution will be provided by the Technical Services Division of Public Works where the City has an existing hydrology model. Where new models are being developed, SCS Type II 24-hour rainfall distribution will be used.

2.2.2 RUNOFF CURVE NUMBER

Rainfall runoff potential, presented in the form of a runoff curve number (CN), is an expression of the imperviousness of the land under fully developed conditions and the runoff potential of the underlying soil. CN computations are discussed in greater detail in chapter VII of the "H&H" manual.

2.2.3 TIME OF CONCENTRATION

The definition for Time of Concentration (T_c) considers the geometric, land use and hydraulic characteristics of the watershed and the channel. T_c can be defined in two ways: The first definition, derived from a consideration of the runoff hydrograph, defines T_c as the time from the end of the rainfall excess to the point of inflection on the receding limb of the hydrograph. The second definition of T_c considers the geometric and hydraulic characteristics of the watershed and channel. It states that T_c is the time required for runoff to travel from the most distant part, hydraulically, of the storm area to the watershed outlet or another point of reference downstream. If the first definition is used, a recorded flood hydrograph must be available.

In order to provide a uniform and versatile equation which can be applied to most situations encountered in the City of Dallas, the T_c shall be considered in three parts: (1) flow time in channel; (2) flow time in pipe; (3) overland flow time or inlet time. The following paragraphs show the T_c equations for each type of flow.

The equation related to channel flow relates velocity, length, and time:

$$T_{cc} = \frac{L_c}{3600 V_c}$$

where

L_c = Effective hydraulic length of ditch or channel in feet,

V_c = Average velocity of ditch or channel flow in feet/second,

T_{cc} = Time of concentration representing stream or channel flow in hours.

The velocity (V_c) in the channel can be obtained directly from water surface profile computations, but is dependent on an assumed discharge. When water surface profiles are not available for a reach, channel velocity can be estimated from the following equation:

$$V_C = 26.5\ S_C\ 0.232$$

where

V_c = Velocity in channel
S_c = Slope of channel

The previous equation applies to natural channels with slopes between 0.0002 to 0.02 feet per foot and velocities from 2 f.p.s. to 12 f.p.s. Estimation of velocity in modified channels shall be calculated using Manning's formula and "n" values listed in the "H & H" manual.

The equation for travel time in a pipe is as follows:

$$T_{cp} = \frac{L_p}{3600 V_p}$$

where

L_p = Length of the conduit in feet
V_p = Average velocity of the design discharge in the conduit in feet per second
T_{cp} = Time of concentration representing conduit flow in hours (for simplification purposes, a full flow condition may be assumed in the conduit)

The overland flow time of concentration can be divided into two components, sheet flow and shallow flow. The following equation can be used to estimate the sheet flow travel time. Ordinarily, sheet flow will occur for a distance of less than 300 feet.

$$T_{cs} = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5}(S_0)^{0.4}}$$

where

n	=	roughness (page 1A of the Appendix)
L	=	flow length in feet (< 300 feet)
P_2	=	2-year 24-hour rainfall in inches (Dallas = 4.0")
S_o	=	Slope of hydraulic grade in feet per foot
T_{cs}	=	Time of concentration representing sheet flow

The equation for shallow concentrated flow travel time is as follows:

$$T_{csc} = \frac{L_{sc}}{3600V_{sc}}$$

where

L_{csc}	=	Length of shallow concentrated flow in feet
V_{sc}	=	Average velocity in feet per second (page 1B of the Appendix)
T_{csc}	=	Time of concentration representing shallow concentrated flow

Combining Time of Concentration for channel, pipe and overland flow yields the following equation:

$$T_c = \frac{L_c}{3600V_c} + \frac{L_p}{3600V_p} + \frac{0.007(nL)^{0.8}}{(P_2)^{0.5}(S_o)^{0.4}} + \frac{L_{sc}}{3600V_{sc}}$$

2.2.4 FLOOD ROUTING

Flood hydrographs generated in the 1967 version of TR-20 are routed downstream using the Convex Routing Method which utilizes a routing coefficient "C" described below;

$$C = \frac{V}{V + 1.7}$$

where V is the steady-flow water velocity related to the reach travel time for steady-flow discharge.

The value of V is determined using cross-section data to estimate velocities for discharges along the hydrograph which are equal or greater than one-half the peak discharge rate.

For preliminary routings, an estimated "C" value can be used. This is done by estimating the velocity for a discharge 0.75 times the estimated peak discharge rate, then computing a value for "C" to use as input to the TR-20 model.

3. HYDRAULIC DESIGN CRITERIA FOR DRAINAGE RELATED STRUCTURES

Refer to checklist in the appendix for other guidelines and additional information.

3.1 DESIGN OF ENCLOSED STORM DRAIN SYSTEMS

Runoff from paved areas being discharged into natural creeks or channels shall be conveyed through enclosed storm drain systems. All enclosed systems shall be hydraulically designed using Manning's Equation:

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

where

Q	=	flow in cubic feet per second
A	=	cross sectional area of the conduit in square feet,
n	=	roughness coefficient of the conduit
R	=	hydraulic radius which is the area of flow divided by the wetted perimeter.
S_f	=	slope of the energy gradient,
P	=	wetted perimeter in feet.

The hydraulic gradient and velocity shall be calculated using the design flow, appropriate pipe size, and Manning's equation. Velocity head losses are to be calculated as per 3.1.7 of this Section. The crown of the pipe should be near the elevation of the hydraulic gradient in most cases to minimize excavation.

Roughness coefficients for precast concrete pipe and cast-in-place box culverts are .013 and .012 respectively.

Alignments of proposed storm drain systems should utilize existing easements and rights-of-way. Storm drainage systems are normally aligned so that the necessary trenching will not undermine existing surface structures, utilities or trees. No part of the proposed storm drain is to be designed within the improved subgrade of a proposed pavement.

Horizontal and vertical curve design for storm drains shall take into account joint closure. Half tongue exposure is the maximum opening permitted with tongue and groove pipe. Where vertical and/or horizontal alignment require greater deflection, radius pipe on curved alignment should be used.

End-to-end connections of different size pipes shall match at the crown of the pipe unless utility clearance dictates otherwise.

A minimum grade of 0.3 percent will be maintained in the pipe. Only standard sizes will be used. Pipe sizes shall not be decreased in the downstream direction.

3.1.1 STARTING HYDRAULIC GRADIENT

After computing the runoff rate to each inlet as discussed in part 2 of this section, the size and gradient of pipe required to carry the design storm must be determined. The City of Dallas requires that all hydraulic gradient calculations begin at the outfall of the system. The following are criteria for the starting elevation of the hydraulic gradient:

1. Starting hydraulic grade at an outfall into a creek or channel should be the 100-year water surface unless an approved flood hydrograph is available to provide a coincident flow elevation for the system's peak.
2. When a proposed storm drain is to connect to an undersized existing storm drain system, the hydraulic gradient for the proposed storm drain should start 1 foot above the top of the existing pipe or at the top of the proposed storm drain, whichever is higher.
3. The starting hydraulic grade elevation at sumps can be obtained from Technical Services Division.
4. Starting hydraulic gradient at an outlet shall not be below the top of pipe.
5. The starting hydraulic grade elevation at the Trinity River shall be the stage of the river at reservoir release discharge.

3.1.2 GUTTER FLOW/INLET LOCATION

Inlets shall be placed to ensure that the 100-year flow in a street does not exceed top-of-curb elevation, and that encroachment into the travelway does not violate the dry lane requirements given in part 3.1.3 of this section.

If in the judgment of the engineer the flow in the gutter is still excessive, the storm drain shall be extended to a point where the gutter flow can be effectively intercepted by inlets. The following is a list of guidelines for inlet placement:

1. Placing several inlets at a single location is permitted in areas with steep grades in order to prevent flooding and avoid exceeding street capacities in flatter reaches downstream.
2. To minimize water draining through an intersection, inlets should be placed upgrade from an intersection.
3. Inlets should also be located in alleys upgrade of an intersection and where necessary to prevent water from entering intersections in amounts exceeding allowed street capacity.
4. Inlets should be placed upstream from right angle turns.
5. Any discharge of concentrated flow into streets and alleys requires a hydraulic analysis of street and alley capacities.
6. Inlet boxes designed more than 4.5 deep require a special detail.
7. All "Y" inlets and inlets 10-foot or greater shall have a minimum 21-inch lateral. All smaller inlets shall have a minimum lateral of 18-inch.
8. Inlets at sag points require a minimum of 10-feet of opening.
9. The end of the recessed inlet box shall be at least 10 feet from a curb return or driveway wing; and the inlet shall be located to minimize interference with the use of adjacent property. Inlets shall not be located across from median openings where a drive may be added.
10. Inlets located directly above storm drain lines shall be avoided.
11. Data shown at each inlet shall include paving or storm drain stationing at centerline of inlet, size of inlet, type of inlet, top-of-curb elevation and flow line of inlet.
12. Inlet box depth shall not be less than 4 feet when the lateral is 21 inches.
13. Interconnecting inlets on laterals shall be avoided.
14. Grate type inlets shall be avoided.

In situations where only the lower portion of an enclosed storm drain system is being built, stub-outs for future connections must be included. In this case, it is not necessary to capture all the street flow at the stub-out. As a minimum, there must be enough inlets to capture an amount equal to the total street flow capacity at the stub-out.

In determining inlet capacities, the City of Dallas requires that inlets on streets with grades shall be sized using the charts from pages 7 through 10 of the appendix, or by using the computation form entitled Gutter Flow/Inlet Computations from page 11 of the appendix.

Both the charts and the form were developed using the following equation:

$$L = Q(H_1 - H_2) / .70(H_1^{2.5} - H_2^{2.5})$$

where

L	=	length of inlet required to intercept the gutter flow (feet).
Q	=	gutter flow in cubic feet per second.
H_1	=	depth of flow in the gutter approaching the inlet plus the inlet depression (feet).
H_2	=	inlet depression (feet).

The chart for Ratio of Intercepted to Total Flow is found on page 8 of the appendix.

Sag inlets operate as a weir up to a depth (H_1) equal to 1.4 times the height of opening, and as an orifice for greater depths. The corresponding equations according to the Federal Highway Administration publication, "Drainage of Highway Pavement," are:

$$Q = 2.1(L+1.8W)\ ((H_1-H_2)^{1.5})$$

where

W	=	width of depression in feet (measured transversely from face inlet)
Q	=	inlet capture in cfs

Orifice Flow

$$Q = 0.60\ hL(2g\ (H_1-h/2))^{0.5}$$

where

h	=	height of inlet opening in feet

Assuming that gutter flow is at the top-of-curb elevation for a 6-inch curb, a curb inlet with a 5-inch depression and a 6-inch height of inlet opening in a sag will require 0.5 feet of opening per each 1 cfs of gutter flow.

The coefficients in the above equation have been adjusted to accommodate a 10% loss in capacity due to clogging.

Page 6 of the Appendix shows standard storm drain inlets used in the City of Dallas and typical locations for each.

3.1.3 STREET CAPACITY

As water collects in the street gutter and flows downhill, a portion of the roadway will be flooded. The following table specifies the allowable encroachment limits in the different thoroughfares:

Street Classification	Allowable Encroachment
Minor Arterial and lower classification	Maximum depth of 6" or top of curb
Principal Arterial	One lane of traffic in each direction must remain open.

Page 9 of the appendix, CAPACITY OF TRIANGULAR GUTTERS, applies to all width streets having a straight cross slope varying from 1/8 inch per foot to 1/2 inch per foot. At least 3/16 inch per foot cross-slope shall be provided on straight slope thoroughfare sections. At least 1/4 inch per foot cross-slope should be provided upgrade of inlets to facilitate efficient drainage. A cross-slope of 1/8 inch per foot will be allowed if the slope of the street is one (1) percent or greater.

Pages 10 through 11 of the appendix, CAPACITY OF PARABOLIC GUTTERS, applies to streets with parabolic crowns.

A Manning's roughness coefficient of .0175 shall be used in calculating street flow conditions.

3.1.4 VALLEY GUTTERS

The use of valley gutters to convey storm water across a street intersection is subject to the following criteria:

1. Major and secondary thoroughfares shall not be crossed by a valley gutter.
2. At any intersection, perpendicular valley gutters will not be permitted; and parallel valley gutters may cross only the lower classified street.
3. Valley gutters shall be constructed of 4000 p.s.i. reinforced concrete.

3.1.5 FLOW IN ALLEYS

The detail found in the appendix on page 24 shall be incorporated in alley paving design to ensure proper conveyance through an alley turn. In residential areas where the standard alley section capacity is exceeded, storm drainage systems with inlets shall be provided. Alley capacity shall be calculated using Manning's equation and with an "n" value of .0175.

3.1.6 LATERAL DESIGN

The hydraulic grade line shall be calculated for all proposed laterals and inlets, and for all existing laterals being connected into a proposed drainage system.

Laterals shall intersect the storm drain at a 60-degree angle. Connecting more than one lateral into a storm drain at the same joint localizes head losses; however, a manhole or junction structure must be provided. An exception to this rule may be considered when the diameter of the main line is more than twice as great as the diameter of the largest adjoining lateral.

Laterals shall not outfall into downstream inlets.

All "Y" inlets and inlets 10 feet or larger shall have 21-inch laterals as a minimum. All smaller inlets shall have 18-inch laterals as a minimum. Laterals shall be designed with future developed conditions in mind to facilitate extensions and increased flows.

3.1.7 HEAD LOSSES

Calculations of the hydraulic grade line in the main begin from the downstream starting hydraulic grade line elevation and progress upstream using Manning's formula. Adjustments are made in the hydraulic grade line whenever the velocity in the main changes due to conduit size changes or discharge changes. Laterals in partial flow must be designed appropriately.

Hydraulic grade line "losses" or "gains" for wyes, pipe size changes, and other velocity changes will be calculated by the following formulas:

where $V_1 < V_2$ $V_1 > V_2$

$$\frac{V_2^2}{2g} - \frac{V_1^2}{2g} = H_L \qquad \frac{V_2^2}{4g} - \frac{V_1^2}{4g} = H_L$$

and V_1 is upstream velocity
V_2 is downstream velocity
g is the acceleration of gravity X 32.2 ft./sec./sec.

In determining the hydraulic gradient for a lateral, begin with the hydraulic grade of the trunk line at the junction plus the H_L due to the velocity change. Where the lateral is in full flow, the hydraulic grade is projected along the friction slope calculated using Manning's Equation. At an inlet where the lateral is in full flow, the losses for the inlet are:

$$\frac{1.5V^2}{2g}$$

where V is the velocity in the lateral. The hydraulic grade line within the inlet should be a minimum of 0.5 feet below the top of the inlet.

Head losses or gains for manholes, bends junction boxes and inlets will be calculated as shown on page 5 of the appendix.

3.1.8 MANHOLE PLACEMENT AND DESIGN

The following is a list of guidelines governing the placement and design of storm drain manholes to ensure adequate accessibility of the storm drainage system:

a. Manhole Placement:

1. Storm drain lines 45 inches in diameter or less should have points of access no more than 500 feet apart. A manhole should be provided where this condition is not met.
2. Storm drain lines 48 inches in diameter or larger should be accessible at intervals of no greater than 1000 feet.

3. A manhole may be required where two or more pipes connect into a main at the same joint. The exception to this rule would be the case in which the diameter of the main line is at least twice as large as the diameter of the largest adjoining pipe. A construction detail may be necessary at such locations.
4. In selecting a location for a manhole, pipe size changes and junctions are preferred sites. This will localize and minimize head losses.

b. Manhole Design and Construction:

1. All precast manhole structures will be built in conformity to the <u>N.C.T.C.O.G. Standard Specification for Public Works Construction,</u> Item 2.19.
2. Fiberglass manholes which conform to the <u>N.C.T.C.O.G. Standard Specification,</u> Item 2.20, may be used in lieu of concrete or brick manholes. It is recommended that proof of conformity be required by the engineer or inspector.
3. The size difference between a manhole and the largest adjoining pipe should be no less than 2 feet.
4. The minimum manhole inside diameter is 4 feet. Maximum manhole size should be determined based upon a cost comparison between a manhole and junction box.
5. A minimum outside clearance of 1 foot should be provided between pipes connecting into a manhole.
6. Manholes on junction boxes, box culverts and horseshoes should be located toward the side of the structure such that the steps descending into the structure are aligned vertically. Steps should be made of either plastic or rubber coated steel.
7. The maximum allowable angle for the taper on a manhole riser is 3 vertical to 1 horizontal. Maintaining a minimum distance equal to ((3/2 x diameter) - 3) feet below the bottom of pavement will ensure that this angle is not exceeded. When there is insufficient clearance for proper taper, a flat top may be built over the manhole structure. Flat slab tops will be built in conformity with <u>N.C.T.C.O.G. Standard Specifications for Public Works Construction.</u>

8. Manhole covers on inlet boxes should be located at the same end of the inlet box as the lateral draining the inlet.
9. A more hydraulically efficient manhole design is shown on the right side of page 2008 of the 251D-1 Standard Construction Details. This design (which does not necessarily require brick or tile construction) should be utilized wherever possible. The design extends the pipe through the manhole but provides a leave-out in the top half of the pipe (above the "spring line".

3.1.9 OUTFALL DESIGN

Each outfall situation shall be considered individually. The following are examples of conditions to be considered when determining the need for energy dissipation:

1. Elevation of Competent Rock
2. Normal Water Surface Elevation
3. Channel Lining
4. Alignment of Pipe to Channel
5. Erosive Potential of Channel

Creative approaches to engineering design are encouraged in order to produce the most cost effective and environmentally acceptable system. As an example, if there is stable rock in a creek bottom, the system could outfall at the rock line. Or, if there is concrete channel lining, the pipe could be brought to the concrete at a reasonable grade.

3.2 OPEN CHANNELS

Preservation of creeks in their natural condition is preferred. City Council approval of fill permits for channelization is required when the watershed is 130 acres or larger. All channelization projects are subject to the City of Dallas floodplain regulations, 51-5.100 of the Dallas Development Code. For the channelization of <u>any</u> natural creek, an Erosion Control Plan, an Environmental Impact Statement and a Revegetation Plan will be required.

Excavated open channels may be used to convey storm waters where closed channels are not justified economically. Open channels shall be designed to convey the full design discharge. The bottom 30% of the total design depth in a channel shall be concrete lined. The vertical portion of the lined low-flow channels shall not exceed a height of 3 feet. Unpaved gabion channel bottoms shall not be allowed.

The maximum slopes and velocities for various types of channels are shown in the table below:

TYPE OF CHANNEL	MAXIMUM SIDE SLOPES	MAXIMUM VELOCITIES
Earth unlined vegetated clay soils	3:1	8 fps
Earth unlined vegetated sandy soils	3:1	6 fps
Partially Lined	3:1 above lining	12 fps
Fully Lined	2:1	15 fps (N.A. at drop structures)

Supercritical flow shall not be allowed in channels except at drop structures and other energy dissipators.

At transitions from lined to unlined channels, velocities must be reduced to 8 fps or less. Velocities must be reduced before the flow reaches the natural channel using either energy dissipators and/or a wider channel. Unlined, unvegetated swales are not allowed.

Channel armoring for erosion control shall be provided on curves where deemed necessary by the City.

If the channel cannot be maintained from the top of the bank, a maintenance access ramp shall be provided.

Open channels with narrow bottom widths are characterized by high velocities, difficult maintenance, and should be avoided. Minimum channel bottom widths are recommended to be equal to twice the depth. Any permanent open channel shall have a bottom width of 5 feet except for grass lined shallow swales and temporary construction ditches. If maintenance vehicles are required to travel the channel bottom, width shall be increased to 8 feet. Parallel access roads can also be used to facilitate maintenance.

All open channels require a minimum freeboard of 2-feet below top of bank.

Page 22 of the Appendix gives allowable ranges for roughness coefficients of channels.

3.3 HYDRAULIC DESIGN OF CULVERTS

All culverts, headwalls and wingwalls shall be designed in conformity to Texas Department of Transportation details and standards.

In sizing culverts, the engineer shall keep head losses and velocities within reasonable limits while selecting the most economical structure. This normally requires selecting a structure which creates a slight headwater condition and has a flow velocity at or below the allowed maximum. Velocities in culverts are normally limited to the maximum allowed in the downstream channel unless there is some form of energy dissipation at the outfall.

In the hydraulic design of culverts, an investigation must be made into the type of flow condition through the culvert. The flow will be controlled, or limited, either at the culvert entrance or the outlet, and is designated either inlet or outlet control, respectively. Inlet control exists when the barrel capacity exceeds the culvert inlet capacity, and the tailwater elevation is too low to control. In other words, the headwater depth and entrance geometry at the inlet will control the amount of water entering the barrel. The roughness, length of culvert barrel, and outlet conditions do not affect capacity for culverts with inlet control. Outlet control exists when the culvert inlet capacity exceeds the barrel capacity or the tailwater elevation causes a backwater effect through the culvert. In this case, the tailwater elevation, slope, length and roughness of the culvert barrel will determine the hydraulic capacity of the culvert even though the entrance conditions are such that a larger flow could be conveyed.

In waterways where the drainage area is greater than 130 acres, culverts shall not increase the water surface elevation of the 100-year flow or flood of record.

Freeboard, the vertical clearance between the design water surface and the top-of-curb elevation, is included as a safety factor in the event of clogging of the culvert. Two feet of freeboard above the 100-year water surface is required.

Culverts should always be aligned to follow the natural stream channel. Survey information of the stream channel should be provided for 100 feet upstream and downstream from the proposed culverts, so that the channel alignment is evident.

In single-family, multi-family and townhouse residential developments, no more than four barrel box culverts should be permitted for stream crossings.

A minimum height of 6 feet should be maintained in box culverts for maintenance purposes, unless the road/flowline differential dictates otherwise.

To minimize the undesirable backwater effects and erosive conditions produced where the total width of box culverts exceeds the bottom width of the channel, a transition upstream and downstream of the culverts must be provided. The transition should have a minimum bottom width transition of 2 to 1 and include warping of side slopes as required. The 2 to 1 transition is 2 along the centerline of the channel and 1 perpendicular to the centerline.

The City of Dallas recognizes the Bureau of Public Roads method of culvert hydraulics. This method is contained in the City's version of the WSP computer program. For creeks which have been modeled on the HEC-2 program, culverts may be sized using the HEC-2 model.

Box culverts with equal height and width dimensions have the greatest flow capacities per unit cost. For large systems, cast-in-place box culverts are generally more cost effective and use less space than pre-cast concrete pipe.

3.3.1 HEADWALLS AND ENTRANCE CONDITIONS

Headwalls and endwalls refer to the entrances and exits of structures, respectively, and are usually formed of cast-in-place concrete and located at either end of the drainage system. Wingwalls are vertical walls which project out from the sides of a headwall or endwall. The purpose of these structures are;

1. To retain the fill material and reduce erosion of embankment slopes;
2. To improve hydraulic efficiency; and
3. To provide structural stability to the culvert ends and serve as a counterweight to offset buoyant or uplift forces.

Headwalls, with or without wingwalls and aprons, shall be designed to fit the conditions of the site, and constructed according to the City of Dallas Standard Construction Details, 251D-1, page 2007, or the Texas State Department of Highways and Public Transportation Details. The following are general guidelines governing the use of various types of headwalls;

1. Straight headwalls (Type A) should be used where the approach velocity in the channel is below 6 feet per second.
2. Headwalls with wingwalls and aprons (Type B) shall be used where the approach velocity is from 6 to 12 feet per second and downstream channel protection is recommended.

3. Special headwall and wingwall configurations will be required where approach velocities exceed 12 feet per second, and where the flow must be redirected in order to enter the culvert more efficiently.

While the immediate concern in the design of headwalls, wingwalls, and endwalls is hydraulic efficiency, consideration should also be given to the safety aspect of culvert end treatments. The use of flared and/or sloped end sections may enhance safety significantly, since the end section conforms to the natural ground surface. For any headwall adjacent to vehicular or pedestrian traffic, either 6-gauge galvanized steel fencing (251D-1, p. 9002) or a guard rail shall be installed. Fence poles shall be set in concrete at the time of construction.

A table of culvert entrance data is shown on the Culvert Design Calculation table on page 15 in the appendix. The values of the entrance coefficient K_e represent a combination of the effects of entrance and approach conditions. Losses shall be computed using the following formula:

$$H_e = K_e \frac{V^2}{2_g}$$

where

H_e	=	entrance head loss (ft);
K_e	=	entrance loss coefficient as shown in the table in the appendix on page 15
V	=	velocity of flow in culvert (fps)

3.3.2 OUTLET VELOCITY

The flow velocity at a culvert or storm drain outlet will tend to be greater than the velocity in the natural channel. This usually results in erosion downstream. Culvert/storm drain discharge velocities shall be limited to those shown in the following table:

DOWNSTREAM CHANNEL MATERIAL	MAXIMUM ALLOWABLE DISCHARGE VELOCITY
Earth unlined vegetated clay soils	8 fps
Earth unlined vegetated sandy soils	6 fps
Dry riprap (ungrouted)	10 fps
Partially lined	12 fps
Natural rock or finished concrete	15 fps

Maximum outfall velocities in the Escarpment Zone and Geologically Similar Areas are given in the Escarpment Ordinance.

3.4 DETENTION DESIGN

Stormwater detention is sometimes required to temporarily impound (detain) excess storm water, thereby reducing peak discharge rates. This detention is required (1) by City ordinance (e.g., Escarpment Regulations), (2) due to existing downstream storm drainage facilities being designed for less than 100-year capacity, (3) due to increased zoning resulting in a significant increase in runoff, or (4) by downstream cities with detention requirements. Alternate means of detention (i.e., parking lots) may be used in appropriate areas.

The following are minimum criteria for detention basins within the City of Dallas. Criteria established by the State of Texas for dam safety and impoundment of state waters shall apply where required by the state, and where, in the engineer's judgment, the potential hazard requires these more stringent criteria.

Design Frequency - The 100-year frequency event is to be used in determining required detention volume.

In areas such as the Geologically Similar Areas upstream of the escarpment zone or any area with an existing erosion problem, the peak runoff rate from a 5-year frequency event as well as the 100-year event must be held to the pre-development rate. This will reduce the erosion which can result from the more frequent events.

Outflow Velocity - The outflow structure will discharge flows at a nonerosive rate. This rate is specified as 3 fps for areas above the Escarpment Zone and 5 fps for Geologically Similar Areas below the Escarpment Zone. In areas not regulated by the Escarpment Regulations, the allowed velocity shall not exceed velocities described in this manual.

Detention Storage - Basins without upstream detention areas and with drainage areas of 130 acres or less can be designed using the Modified Rational Method. This method estimates peak rates using the Rational Equation and storage requirements using inflow minus outflow hydrograph volume at the time of peak outflow.

Basins with drainage areas greater than 130 acres or where the Modified Rational Method is not applicable are to be designed using the Unit Hydrograph Method. The design hydrograph routings through the detention basin are to be done using the Modified Puls Method.

Freeboard and Emergency Spillway - Where earth embankments are used to temporarily impound the required detention, the top of the embankment will be a minimum of 2.0 feet above the maximum 100-year pool level. In addition, an emergency spillway or overflow area will be provided at the maximum 100-year pool level to ensure that the 500-year frequency event does not overtop the embankment.

For detention basins serving drainage areas of 130 acres or less, the chart on page 28 of the appendix can be used to estimate the required capacity for the emergency spillway. If the emergency spillway capacity is to be provided over the embankment, the spillway will be structurally designed to prevent erosion and consequent loss of structural integrity. If the capacity is to be provided in a vegetated earth spillway separate from the embankment, the required width for a trapezoidal spillway with a control section can be estimated by the equation:

$$*Bw = \frac{0.36Q - 0.7ZD}{D^{3/2}}$$

where

Bw = bottom width
Q = emergency spillway capacity (cfs)
D = design depth above spillway crest (ft.)
Z = side slope, i.e., horizontal distance to 1 foot vertical

The minimum width for a vegetated earth spillway is 4.0 feet.

*USDA, SCS, dimensions for farm pond spillways where no exit channel is required.

Outflow Structure - Where the outflow structure conveys flow through the embankment in a conduit, the conduit shall be reinforced concrete designed to support the external loads with an adequate factor of safety. It shall withstand the internal hydraulic pressures without leakage under full external load or settlement. It must convey water at the design velocity without damage to the interior surface of the conduit.

Earth Embankment Design - The steepest side slope permitted for a vegetated earth embankment is 4:1 and 2:1 for rock dam or as determined by geotechnical investigation. The minimum crown width is as follows:

Total Height of Embankment (Feet)	Minimum Crown Width (Feet)
14 or less	8
15 - 19	10
20 - 24	12
25 - 34	14

Basin Grading - Detention basins to be excavated must provide positive drainage with a minimum grade of 0.3%. The steepest side slope permitted for an excavated slope not in rock is 4:1.

Earth Embankment Specifications - Earth embankments used to temporarily impound required detention volume must be constructed according to specifications to fill. These specifications should, at a minimum, be adequate for levee embankments and be based on N.C.T.C.O.G. Standard Specifications for Public Works Construction for embankment, topsoil, sodding, and seeding. Where permanent impoundment is to be provided, more stringent specifications are required based on geotechnical investigations of the site.

Fencing - Security fencing with a minimum height of 4 feet shall encompass the basin area when required due to potential safety hazards created by prolonged storage of floodwater. Design shall be such as not to restrict the inflow or outfall of the basin. Adequate access for maintenance equipment shall be provided. In basins to be used for recreation areas during dry periods, pedestrian access may be provided with the approval of Public Works.

Maintenance Provisions - Access must be provided in detention basin design for periodic desilting and debris removal. Basins with permanent storage must include dewatering facilities to provide for maintenance. Detention basins with a drainage area of 320 acres or more must include a desilting basin for the upstream pool area.

3.5 BRIDGE HYDRAULIC DESIGN

The City of Dallas requires that head losses and depth of flow through bridges be determined with the WSP or HEC-2 computer programs. The following guidelines pertain to the hydraulic design of bridges:

1. Design water surface must not be increased upstream.
2. Excavation of the natural channel is not normally allowed as compensation for loss of conveyance.
3. Channelization upstream or downstream of the proposed bridge will normally only be permitted when necessary to realign the flow to a more efficient angle of approach.
4. All bridge hydraulics are to be reviewed by Technical Services Section.
5. Side swales may be used to provide additional conveyance downstream of and through bridges. (Swales are subject to the criteria contained in the Floodplain Ordinance).
6. Bridges are to be designed with the lowest point (low beam) at least 2 feet above the water surface elevation of the design storm.
7. Bents should not be in channel when possible. Bents will be aligned parallel to flow.

3.6 ENERGY DISSIPATORS

Energy dissipators are used to eliminate the excess specific energy of flowing water. Effective energy dissipators must be able to retard the flow of fast moving water without damaging the structure or the channel below the structure. The City of Dallas recognizes the Bureau of Reclamation's publications on the Hydraulic Design of Stilling Basins and Energy Dissipators as an accepted reference for the design of energy dissipators.

Impact-type energy dissipators direct the water into an obstruction (baffle) that diverts the flow in many directions to reduce energy. Baffled outlets and baffled aprons are two impact-type energy dissipators. Impact-type energy dissipators should be assured of a low-flow outfall.

Other energy dissipators use the hydraulic jump to dissipate excess energy. In this type of structure, water moving in supercritical flow is forced into a hydraulic jump when it encounters a tailwater condition equal to conjugate depth. Stilling basins are structures of this type where the flow plunges into a pool of water created by a weir or sill placed downstream of the outfall.

Baffled aprons are used to dissipate the energy in the flow over an apron. To accomplish this, baffle blocks are constructed on the sloping surface of the apron. If the channel bottom downstream of the apron is not lined, at least one row of baffles should be buried below grade at the bottom of the apron. Scour normally will occur in the channel immediately below the apron creating a natural stilling basin.

Impact-type energy dissipators are generally considered to be most effective for outfalls of enclosed storm drainage systems. They also tend to be smaller and more economical structures. Baffled aprons and stilling basins are most frequently used downstream of a spillway or drop structure.

All energy dissipators should be designed to facilitate maintenance. The design of outlet structures in or near parks or residential areas must give special consideration to appearance.

3.7 RETAINING WALLS IN WATERWAYS

All retaining structures/walls located within a 100-year floodplain in the City of Dallas shall be constructed of reinforced concrete or other materials approved by the Director of Public Works, and shall be designed for the specific onsite conditions. Special structural designs, including modifications of the 251D-1 Standard Construction Details, shall be submitted with supporting calculations.

Retaining walls shall be designed to achieve a minimum factor of safety of 2 against overturning and 1.5 against sliding, unless otherwise approved by the Director of Public Works.

Retaining wall design shall consider the following parameters/criteria:

1. Allowable soil and/or rock bearing capacity;
2. Surcharge loadings, existing and future;
3. Hydrostatic pressure due to stormwater, groundwater, irrigation, etc.;
4. Backfill drainage (perforated pipe or weep holes);
5. Uplift if applicable;
6. Resistance to sliding; (The potential for future deterioration of materials at the toe of the structure, and the subsequent decrease in passive resistance pressures should be considered).
7. Location of slip plane for proposed conditions (must ensure that plane is not located below wall footing).
8. Erosion at the ends of the wall over top of wall and undermining at the toe;
9. Adequate room or right-of-way for construction of the footing;
10. Placement of construction and expansion joints;
11. Potential for impact or abrasion; (Gabions and similar materials should be avoided in areas subject to direct impact from debris or falling water).
12. Maintenance requirements.
13. Lateral loads due to onsite material or select fill.
14. Proper compaction of backfill.

Any wall taller than 4 feet in height will require a building permit and an engineer's certification that the wall is structurally sound and built as per plan specifications.

4. EROSION AND SEDIMENTATION CONTROL

All projects shall be designed so that erosion is minimized during construction as well as after the construction is completed. The volume, rate and quality of storm water runoff originating from development must be controlled to prevent soil erosion. Specific efforts shall be made to keep sediment out of street and water courses.

Where an EPA/NPDES Storm Water Permit is required for construction of a project (under regulations contained in 40 CFR Part 122, as amended, under the authority of the Clean Water Act, 33 U.S.C. 1251 et seq.), a Storm Water Pollution Prevention Plan (SWPPP) meeting, the permit requirements must be prepared and included with the plans and specifications.

In addition, all projects shall comply with the requirements for storm water management at construction sites as set forth in the City's Municipal Separate Storm Sewer System (MS4) Permit. Construction plans and specifications must include the types of management, structural, and source control measures, known as best Management Practices (BMPS), as identified by the City of Dallas for use on Public Works Projects.

Technical guidance for the preparation of a Storm Water Pollution Prevention Plan and implementation of Best Management Practices for construction sites may be referenced in the NCTCOG Storm Water Quality Best Management Practices For Construction Activities manual upon approval by the Director of Public Works, until such time that a similar manual for BMPs is prepared and adopted by the City of Dallas.

The owner is responsible for maintenance of erosion and sedimentation control measures, and must remove sediment from City right-of-way or storm drainage systems that occurs during the construction phase.

SECTION III - CONSTRUCTION PLAN PREPARATION

1. GENERAL

This section outlines the steps involved in preparing construction plans for the City. Some variation for private development plans is expected; specific guidance should be obtained from the Private Development Division. Refer to the Paving Design Manual for additional requirements for storm drainage plans submitted with paving plans and for drafting standards.

2. PRELIMINARY DESIGN PHASE

The preliminary design phase consists of the development of the project in sufficient detail to allow review for compliance with design criteria. Preliminary submittal for City projects shall conform to requirements given in the engineering services contract. Topographic surveys developed by approved methods should be furnished to allow establishment of alignment, grades and right-of-way requirements for all City projects. Any methods other than field survey shall be field verified. Field notes shall be furnished for all Public Works projects. For Private Development where offsite easements are proposed, field notes shall be signed and sealed by a Registered Professional Land Surveyor and shall begin at an established point such as a street intersection or a corner of an established subdivision. The notes shall be accompanied by a deed of ownership and a location map. All easements pertaining to Private Development should be submitted to Development Activities. Surveys submitted on tape will require a level list.

The hydraulic design is to be based on the criteria outlined in Section II of this manual, DRAINAGE DESIGN CRITERIA. All calculations shall be submitted with the preliminary plans.

The designer shall be responsible for determining the elevation and location of a utility which may be close to a proposed storm drain line and for showing the utility accurately on the plans with station, elevation and source of elevation given in the profile. Utilities suspected to be within 5 feet of proposed facilities shall be field located by probing or exposure. Each utility company shall be contacted with regard to its policies and procedures for uncovering its respective utility.

The proposed alignment plan/profile sheets, drainage area map and horizontal control sheet (if required) shall be submitted in sufficient sets as directed by the engineer or engineering services contract. These drawings shall be labeled "Preliminary Plans." Channel cross sections shall be included, if applicable. All plans, profiles and cross-sections shall be drawn on 24-inch by 36-inch sheets.

3. FINAL DESIGN PHASE

The final design phase consists of preparing construction plans in final form. All sheets shall be drawn on a 24 inch x 36 inch (3 mil or greater) mylar in ink either by hand or on a compatible computer medium. The drawings shall be executed in such a manner that they shall be legible when reduced to half size. If it is a computerized drawing, a level list shall be submitted.

Review comments shall be addressed, additional data incorporated, and final design and drafting completed. Grades, elevations, pipe sizes, utility locations and elevations, items and quantities should be checked. Each plan profile sheet should reference two permanent bench marks shown on the plan in their correct location and annotated on the lower right corner of the plan view. Permanent bench marks shall be located outside the limits of construction. Structural detail sheets, quantity sheets, and horizontal control sheets (if required by the engineer) shall be completed and submitted.

Structural analysis computations should be provided in a legible form for any proposed structure not included in the City of Dallas 251D-1 Standard Construction Details. Items on the plans requiring special provisions and special construction techniques should be clearly delineated on the plans and should be specifically called to the City's attention by letter prior to final plan submission.

A written statement from the consulting engineer shall be placed on the drainage area map stating that he has field verified the drainage boundaries and the onsite and offsite drainage structures.

4. PLAN REQUIREMENTS

4.1 DRAINAGE AREA MAP

The drainage area map is the one single most important item that affects the entire project design. It should show all onsite and offsite drainage, and any watercourses adjacent to the project. The map should be drawn to a 1" = 200' scale or larger and be easily legible. The following items/information shall be included:

1. Acres, runoff coefficient and rainfall intensity for each drainage subarea:
2. Inlets, their size and location, the flow-by for each, the direction of flow indicated by flow arrows, the centerline station;
3. Chart including data shown shall be submitted with the first review and included on the map with the final review;
4. Existing and proposed storm sewers;
5. Subareas for alleys, streets, and offsite areas;

6. Zoning boundaries and zoning for each area;
7. Points of concentration;
8. Runoff to all inlets, dead-end streets, and alleys or to adjacent additions and/or lots;
9. A table for runoff computations or unit hydrograph input data and peak discharges;
10. Flow arrows to indicate all crests, sags, and street and alley intersections;
11. North arrow and scale;
12. Any offsite drainage shall be included;
13. Streets and street names shall be indicated;
14. All pertinent files; 421Q, 428Q, and 515D numbers shall be shown on the map, and a single line indication of the location of the pipes and other facilities shall be included. These numbers shall be obtained from Development Activities, Public Works Department;
15. 100-year Floodplain shall be indicated on the Drainage Area Map;
16. Drainage divides shall be field verified;
17. Existing ground shall be shown on 5′ contours.

There shall be no diversion of drainage between watersheds.

4.2 PLAN/PROFILE SHEETS

Plan-profile sheets shall be prepared on a horizontal scale of 1 inch equals 20 feet and a vertical scale of 1 inch equals 6 feet. Unusually large conduits may require different scales to adequately show the system. Any variation in scale must be approved in advance by the City Engineer.

In the plan view, the storm drain designation, size of pipe, and item number shall be shown adjacent to the storm drain. The drain plan shall be stationed at 100-foot intervals, and each sheet shall begin and end with even or 25-foot stationing.

The plan of the storm drain shall be drawn with a centerline and two sides of the conduit with changes in size clearly indicted as they occur. The conduit shall be shaded for emphasis.

If the storm drain alignment requires a horizontal curve, the following curve data shall be shown on the plan:

P.I. Station
Deflection Angle
Radius
Tangent Distance
Length of Curve

At the beginning and ending of the curve, the PC station and PT station shall be shown. The size of lateral and its item number shall be shown on the plan. Manholes shall be provided and shown on the plan-profile sheet as required in Section II, part 3.1.8.

Existing topography, storm drains, sprinkler heads, double check assemblies, inlets, curbs, driveways, pavement, manholes, meters, valve boxes, trees, shrubs, and fences, etc., within the right-of-way, shall be shown on the plan with existing pavement type and thickness noted. Item numbers shall be shown for all items of work to be accomplished. A summary of quantities sheet is to be provided. Two permanent bench marks shall be referenced in the lower right corner of each plan view sheet. All bench marks shall be checked out by a level circuit submitted to the City.

The storm drain profile is to be positioned on the sheet so that the stationing in the plan is approximately adjacent to the stationing in the profile. Even 100-foot stations shall be shown at the bottom of the profile, and elevations at 5-foot intervals shall be shown at the left and right sides of the profile sheet. Stationing for drainage and paving profiles must be oriented in the same direction.

Laterals shall be shown in the profile when they cross an existing utility, when they drain a sag or when they exceed 12 feet in length.

The profile portion of the storm drain plan-profile sheet shall show the following:

1. Elevations of rock line (at boring locations)
2. Soffit
3. Invert
4. Hydraulic grade line
5. Top of pipe
6. Existing ground and proposed finished grade at centerline of pipe
7. Elevation of intersecting utilities
8. Diameter of the proposed pipe
9. Pipe grade in percent

Hydraulic data for each length of storm drain between interception points shall be shown on the profile. This data shall consist of the following:

1. Pipe diameter in inches
2. Design discharge in cubic feet per second
3. Slope of hydraulic gradient (in ft./ft.)
4. Capacity of pipe in cubic feet per second (Assuming the hydraulic gradient equals the pipe grade).
5. Velocity in feet per second
6. Velocity head in feet $\frac{(V^2)}{2g}$
7. Limits and velocity of partial flow where applicable.

Also, the hydraulic grade adjustment at each interception point shall be shown. Partial flow shall be shown by labeling starting and ending stations clearly.

Elevations of the flow line of the proposed storm drain are to be shown at 50-foot intervals on the profile. Stationing and flow line elevations are shown at all pipe grade changes, pipe size changes, lateral connections, manholes and wye connections. Pipe wyes connecting to the storm drain shall be made centerline to centerline, shown in the profile with the size of lateral, flow line of wye and stationing of storm sewer indicated.

Boring locations with elevations of top of rock should be included on the drainage plans, as well as all existing and proposed drainage easements, rights-of-way, letters of permission and required temporary easements.

In preparing the final plans, the Engineer shall ensure that inlet elevations and stations are correctly shown on the storm drainage, structural and paving plans as applicable. Inlet locations on storm drain plans shall conform with inlet locations as shown on the drainage area map. Proposed pavement location shall be cross-referenced and agree horizontally and vertically with paving plans, storm drain plans, structural plans and cross-sections, and existing topographic features.

4.3 SPECIAL DETAILS

Details not shown in the Standard Construction Details, File 251D-1, furnished by the Department of Public Works, are to be included in the plans as Special Details. Structural details for bridges, special retaining walls, headwalls, junction boxes, culverts, channel lining, and special inlets should be provided as well as bridge and hand railings, special barricades (permanent and temporary) and warning signs. Detour and traffic control plans shall be provided when required by the City Engineer.

5. PLATTING/DEDICATION OF WATER COURSES AND BASINS

Property developments containing either Floodway Management Areas, Floodway Easements, Detention Easements, or Drainage Easements shall have on the plat standard language addressing the easements and management areas, and on-ground monumentation.

Fill or development is prohibited in designated or undesignated 100-year floodplain areas except as allowed under the floodplain fill/permit process (Part I of the Dallas Development Code, Division 51-5.100). Reclamation projects in floodplain of waterways draining 130 acres or more require City Council approval.

a. Floodway Easements

Floodway Easements are to be used for open waterways in nonresidential areas. They will be maintained by the property owner.

b. Floodway Easements (Common Areas)

Floodway Common Areas are allowed in residential areas and are owned and maintained by a neighborhood association.

c. Floodway Management Areas

Floodway Management Areas are to be used for natural waterways in residential areas with individual lot ownership (where lot lines do not extend into the 100-year floodplain). These areas are dedicated fee simple and will be maintained in a natural condition by the City.

d. Drainage Easements

A Drainage Easement is used for a manmade drainage channel, storm drain or drainage structure in an area not owned by the City but maintained by the City.

In commercial/industrial areas, open channels are retained in Floodway Easements.

e. Detention Area Easements

Detention basins shall be maintained in Detention Area Easements. Detention basins constructed through Private Development Activities shall be maintained by the property owner or neighborhood association. Detention basins constructed for the City shall be maintained by City Forces.

f. Access Easement

All Floodway Management Areas, Floodway Easements, Detention Easements, and Drainage Easements shall include provisions for adequate maintenance such as dedicated and maintained Access Easements. These shall be sufficient to provide ingress and egress for maintenance. Access Easements are needed only when the area to be maintained does not border a public right-of-way.

SECTION IV - APPENDIX

RUNOFF COEFFICIENTS AND MAXIMUM INLET TIMES

Zone	Zoning District Name	Runoff Coefficient "C"	Max. Inlet Time In Minutes
A(A)	Agriculture	0.30	20
R - 1ac(A)	Residential	0.45	20
R - 1/2ac(A)	Residential	0.45	20
R - 16(A)	Residential	0.55	15
R - 13(A)	Residential	0.55	15
R - 10(A)	Residential	0.65	15
R - 7.5 (A)	Residential	0.65	15
R - 5(A)	Residential	0.65	15
D(A)	Duplex	0.70	10
TH - 1(A)	Townhouse	0.80	10
TH - 2(A)	Townhouse	0.80	10
TH - 3(A)	Townhouse	0.80	10
CH	Clustered Housing	0.80	10
MF - 1(A)	Multifamily Residential	0.80	10
MF - 2(A)	Multifamily Residential	0.80	10
MF - 3(A)	Multifamily Residential	0.80	10
MF - 4(A)	Multifamily Residential	0.80	10
MH(A)	Mobile Home	0.55	15
NO(A)	Neighborhood Office	0.80	10
LO - 1	Limited Office - 1	0.90	10
LO - 2	Limited Office - 2	0.90	10
LO - 3	Limited Office - 3	0.90	10
MO - 1	Midrange Office - 1	0.90	10
MO - 2	Midrange Office - 2	0.90	10
GO(A)	General Office	0.90	10
NS(A)	Neighborhood Services	0.90	10
CR	Community Retail	0.90	10
RR	Regional Retail	0.90	10
CS	Commercial Service	0.90	10
LI	Light Industrial	0.90	10
IR	Industrial Research	0.90	10
IM	Industrial Manufacturing	0.90	10
CA - 1(A)	Central Area - 1	0.95	10
CA - 2(A)	Central Area - 2	0.95	10
MU - 1	Mixed Use - 1	0.80	10
MU - 2	Mixed Use - 2	0.80	10
MU - 3	Mixed Use - 3	0.90	10
MC - 1	Multiple Commercial - 1	0.90	10
MC - 2	Multiple Commercial - 2	0.90	10
MC - 3	Multiple Commercial - 3	0.90	10
MC - 4	Multiple Commercial - 4	0.90	10
P(A)	Parking	0.95	10

NON-ZONED LAND USES

Land Use	Runoff Coefficient "C"
Church	0.8
School	0.7
Park	0.4
Cemetery	0.4

Table 3-1.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

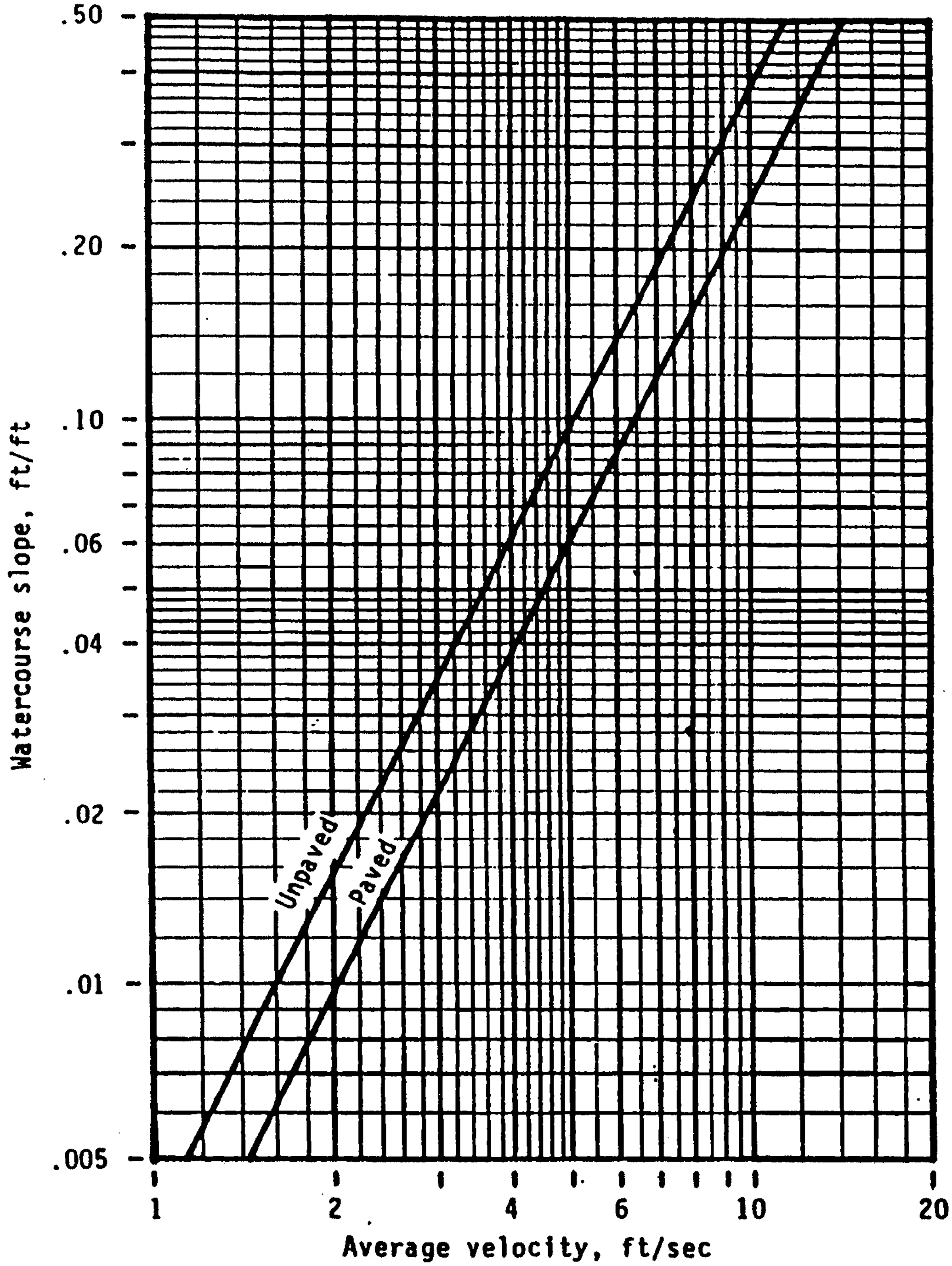
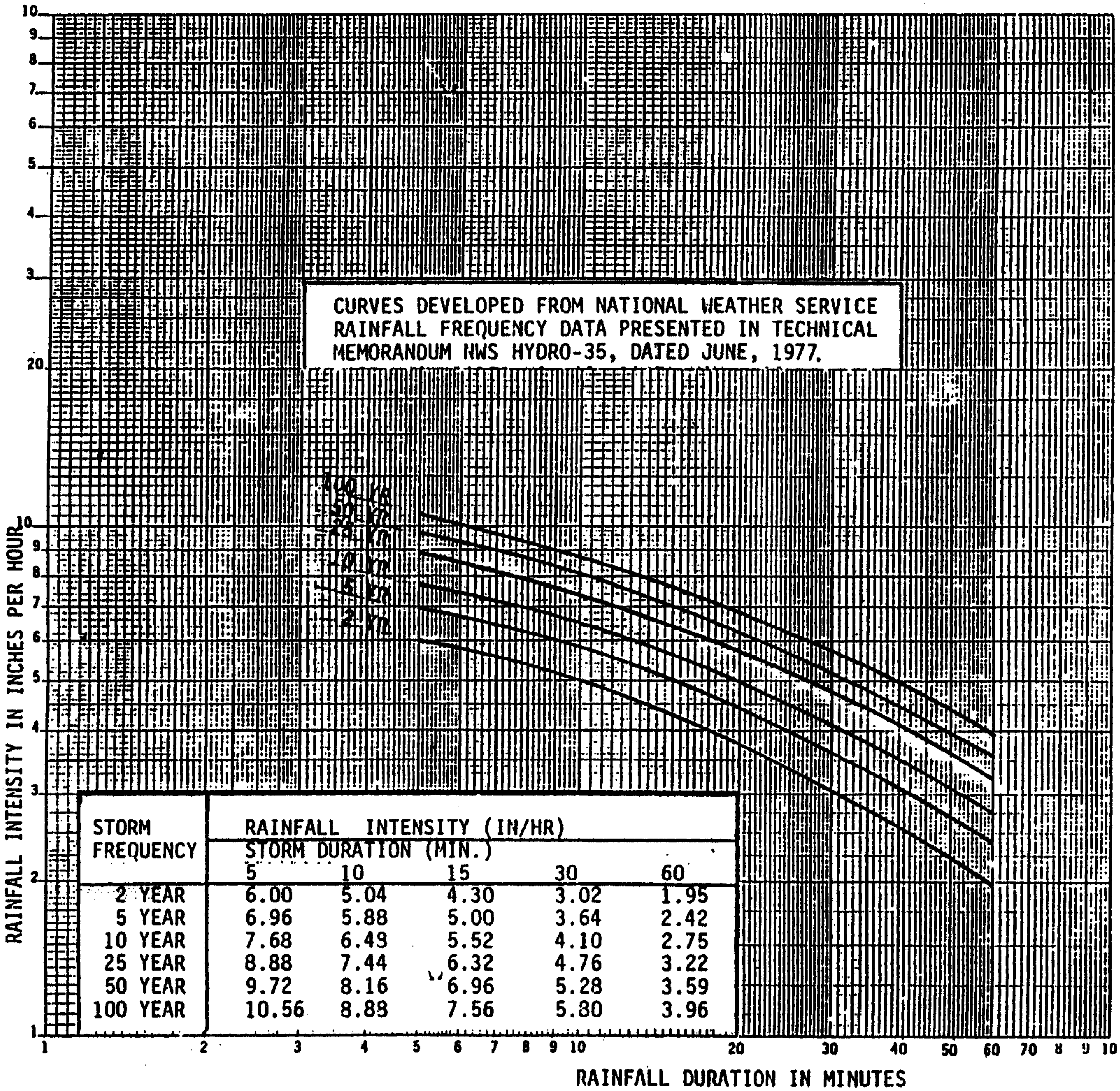


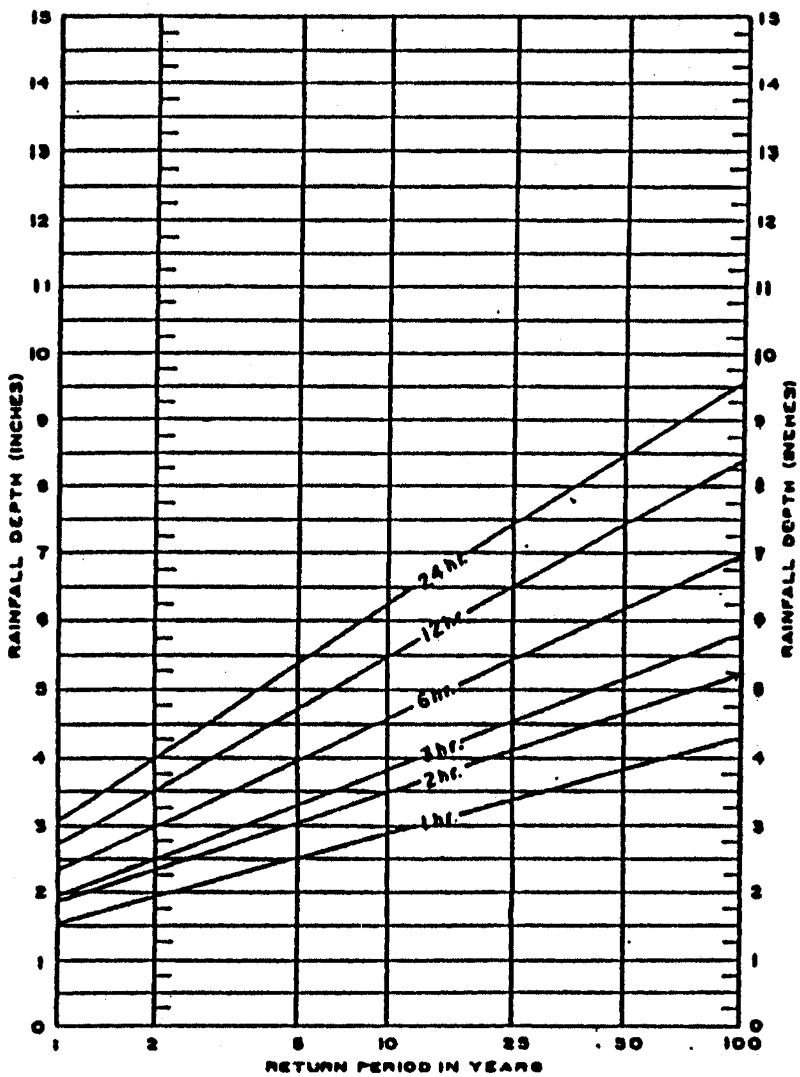
Figure 3-1.—Average velocities for estimating travel time for shallow concentrated flow.

(210-VI-TR-55, Second Ed., June 1986)

RAINFALL INTENSITY CHART



STORM FREQUENCY	RAINFALL INTENSITY (IN/HR)				
	STORM DURATION (MIN.)				
	5	10	15	30	60
2 YEAR	6.00	5.04	4.30	3.02	1.95
5 YEAR	6.96	5.88	5.00	3.64	2.42
10 YEAR	7.68	6.49	5.52	4.10	2.75
25 YEAR	8.88	7.44	6.32	4.76	3.22
50 YEAR	9.72	8.16	6.96	5.28	3.59
100 YEAR	10.56	8.88	7.56	5.80	3.96



DEVELOPED FROM WEATHER BUREAU, TECHNICAL PAPER NO.40, DATED MAY, 1961

Rainfall Depth, Duration and Frequency

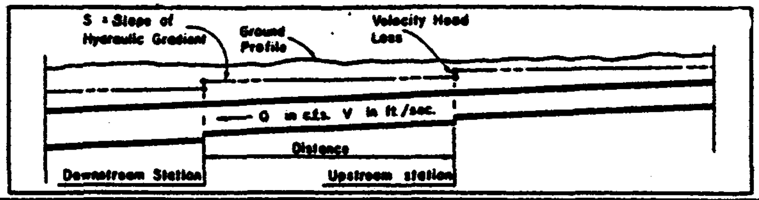
CITY OF DALLAS PROJECT ____________________

____

FILE NO. ____________

STORM SEWER LINE ____________________

INITIAL INLET TIME_____MINUTES

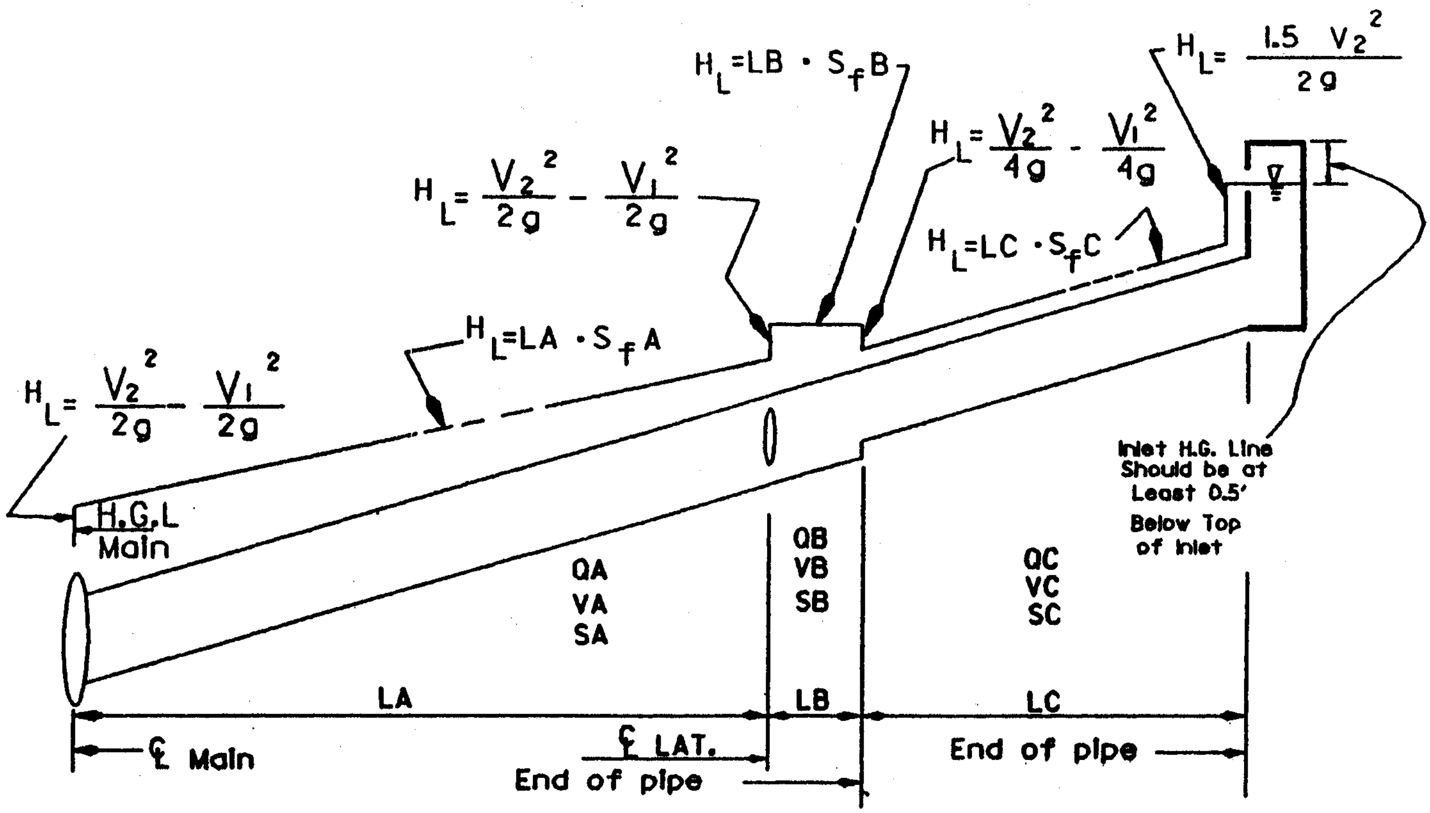


STORM SEWER CALCULATIONS

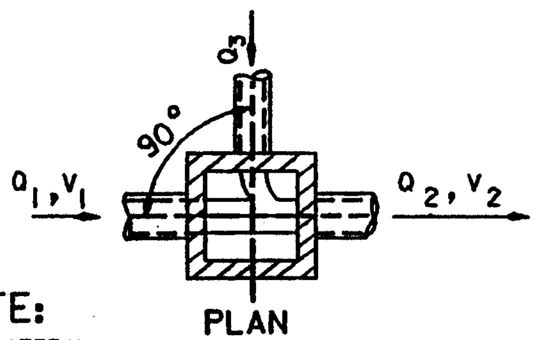
BY ____________________

DATE ____________________

RUNOFF COLLECTION POINT (Inlet or Manhole)		Distance Between Collection Points	INCREMENTAL DRAINAGE AREA				Accumulated "CA"	Time at Upstream Station (minutes)	Design Storm Frequency (yrs.)	Intensity "I" (inches/hr)	Storm Water Runoff "Q" (c.f.s.)	Slope of Hydraulic Gradient "S" (ft./ft.)	Selected Storm Sewer Size	Velocity in Sewer Between Collection Points "V" (f.p.s.)	Head Loss Coeff. K_j	Velocity Head Loss at Upstream Station $K_j \frac{V^2}{2g}$ (feet)	Flow Time in Sewer $\frac{\text{Distance}}{V \times 60}$ (minutes)	Time at Downstream Station (minutes)	REMARKS
UPSTREAM STATION	DOWNSTREAM STATION		Area No.	Drainage Area "A" (Acres)	Runoff Coeff. "C"	Incremental "CA"													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20



HEAD LOSSES AND GAINS FOR LATERALS



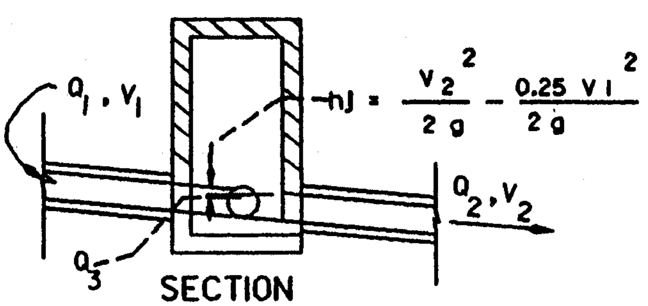
NOTE:

60° LATERAL

$$hJ = \frac{V_2^2}{2g} - \frac{0.35\ V_1^2}{2g}$$

45° LATERAL

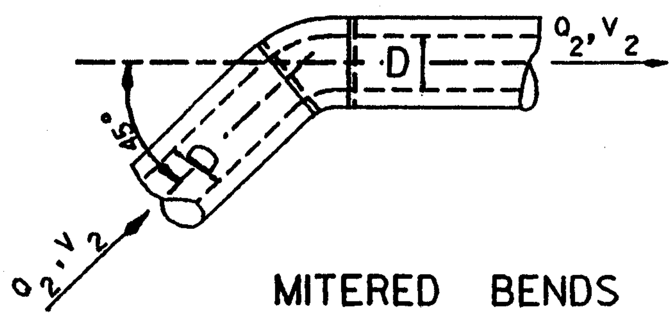
$$hJ = \frac{V_2^2}{2g} - \frac{0.50\ V_1^2}{2g}$$



SECTION

90° LATERAL

MANHOLE ON MAIN LINE



MITERED BENDS

NOTE:

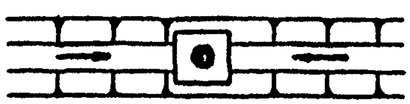
HEAD LOSS APPLIED AT BEGINING OF BEND. BENDS TO BE USED ONLY WITH THE PERMISSION OF THE DRAINAGE DESIGN ENGINEER.

90° BEND $hJ = 0.80 \frac{V_2^2}{2g}$ 60° BEND $hJ = 0.60 \frac{V_2^2}{2g}$

45° BEND $hJ = 0.50 \frac{V_2^2}{2g}$ 30° BEND $hJ = 0.45 \frac{V_2^2}{2g}$

MINOR HEAD LOSSES DUE TO TURBULENCE AT STRUCTURES

STORM DRAIN INLETS

INLET TYPE	INLET DESCRIPTION	COMMON INLET SIZES	WHERE USED
I	 STANDARD CURB OPENING INLET ON GRADE	5', 10' 14'	ALL MINOR STREETS
IA	 STANDARD CURB OPENING INLET AT LOW POINT	5', 10' 14'	ALL MINOR STREETS.
II	 RECESSED CURB OPENING INLET ON GRADE	5', 10' 14'	All divided Secondary and major streets.
IIA	 RECESSED CURB OPENING INLET AT LOW POINT	5', 10', 14'	ALL DIVIDED SECONDARY AND MAJOR STREETS.
III	 GRATE INLET (CURB TYPE) ON GRADE	SINGLE DOUBLE TRIPLE	COMBINATION INLETS TO BE USED ONLY WHERE SPACE BEHIND CURB PROHIBITS OTHER INLET TYPES AND IN ALLEYS.
IIIA	 GRATE INLET (CURB TYPE) AT LOW POINT	SAME	DO NOT USE EXCEPT WITH PERMISSION OF THE DRAINAGE DESIGN ENGINEER
IV	 GRATE INLETS (GUTTER TYPE)	SPECIAL 2 GRATE 4 GRATE 6 GRATE 8 GRATE	INLET LOCATION WITH NO CURB ALLEYS — DRIVEWAYS
V		"Y"	OPEN CHANNELS — DITCHES

GUTTER FLOW / INLET COMPUTATIONS

INLET ID	INLET LOCATION	D.A. No.	Q cfs	CO cfs	Qa cfs	z	n	s ft/ft	y ft	w ft	a ft	qL cfs/ft	Lr ft	La ft	La/Lr	a/y	QI/QA	QI cfs	QI-Qa cfs	Carry-over to:	Remarks

Q Discharge Calculated for DA

CO Carryover from upstream inlet

Qa Actual discharge=Q+CO

z reciprocal of cross slope (can use average slope equivalent for parabolic crown)

n manning's roughness (.0175 normal)

s Gutter Slope

y Gutter Depth of flow= $\left(\dfrac{Qa}{0.56\ (z/n)\ S^{1/2}}\right)^{3/8}$

w Width of street conveying flow = z (y)

a depth of depression

ql Capture per foot of inlet with 100% interception = $\left(\dfrac{.7}{y}\right)\left[(a+y)^{\frac{5}{2}} - (a)^{\frac{5}{2}}\right]$

Lr Required inlet for 100% interception $= \dfrac{Q_a}{q_L}$

La Actual inlet length

QI/QA From Figure (10)

QI Actual inlet interception

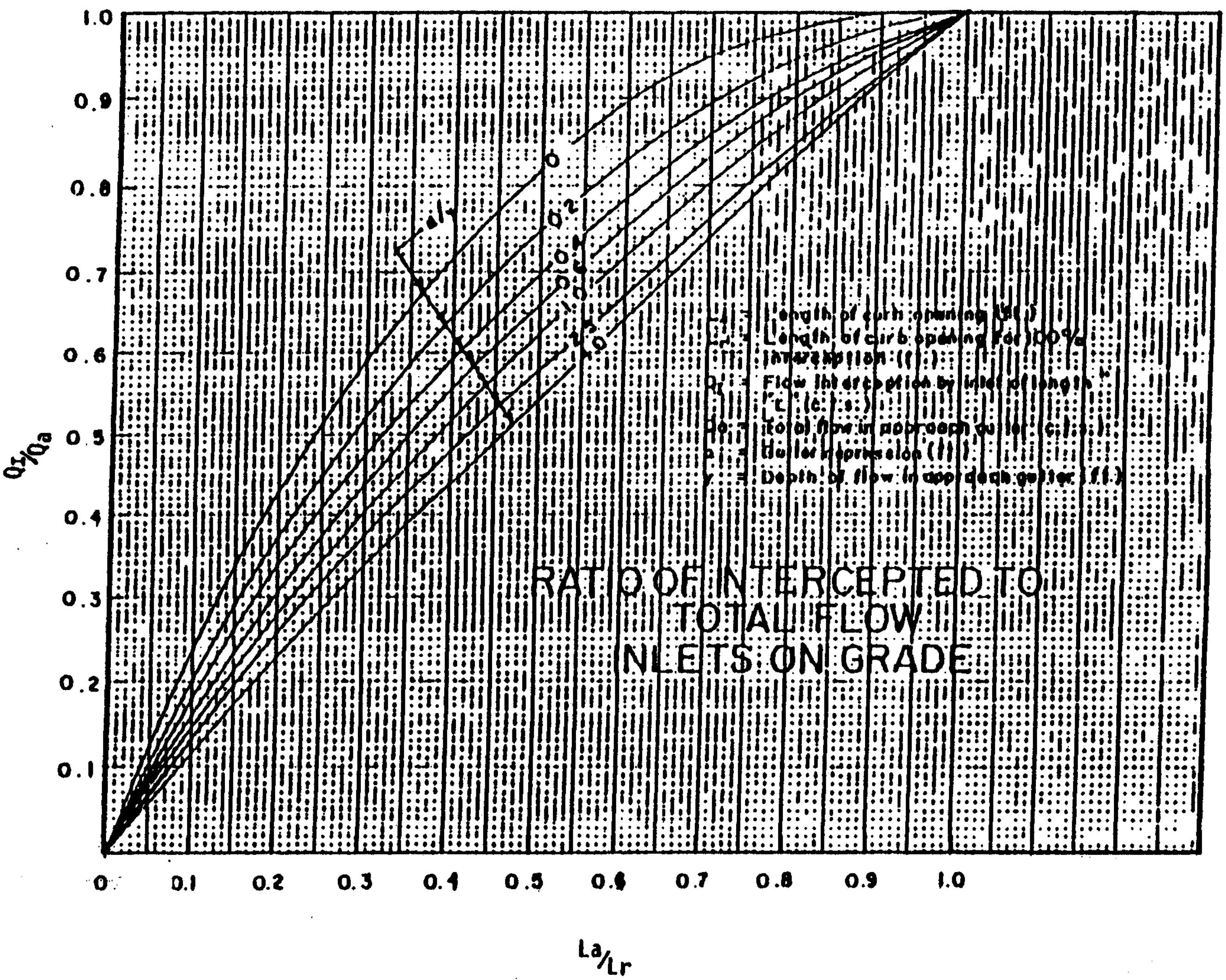

RATIO OF INTERCEPTED TO
TOTAL FLOW
NLETS ON GRADE
Qi/Qa
La/Lr
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

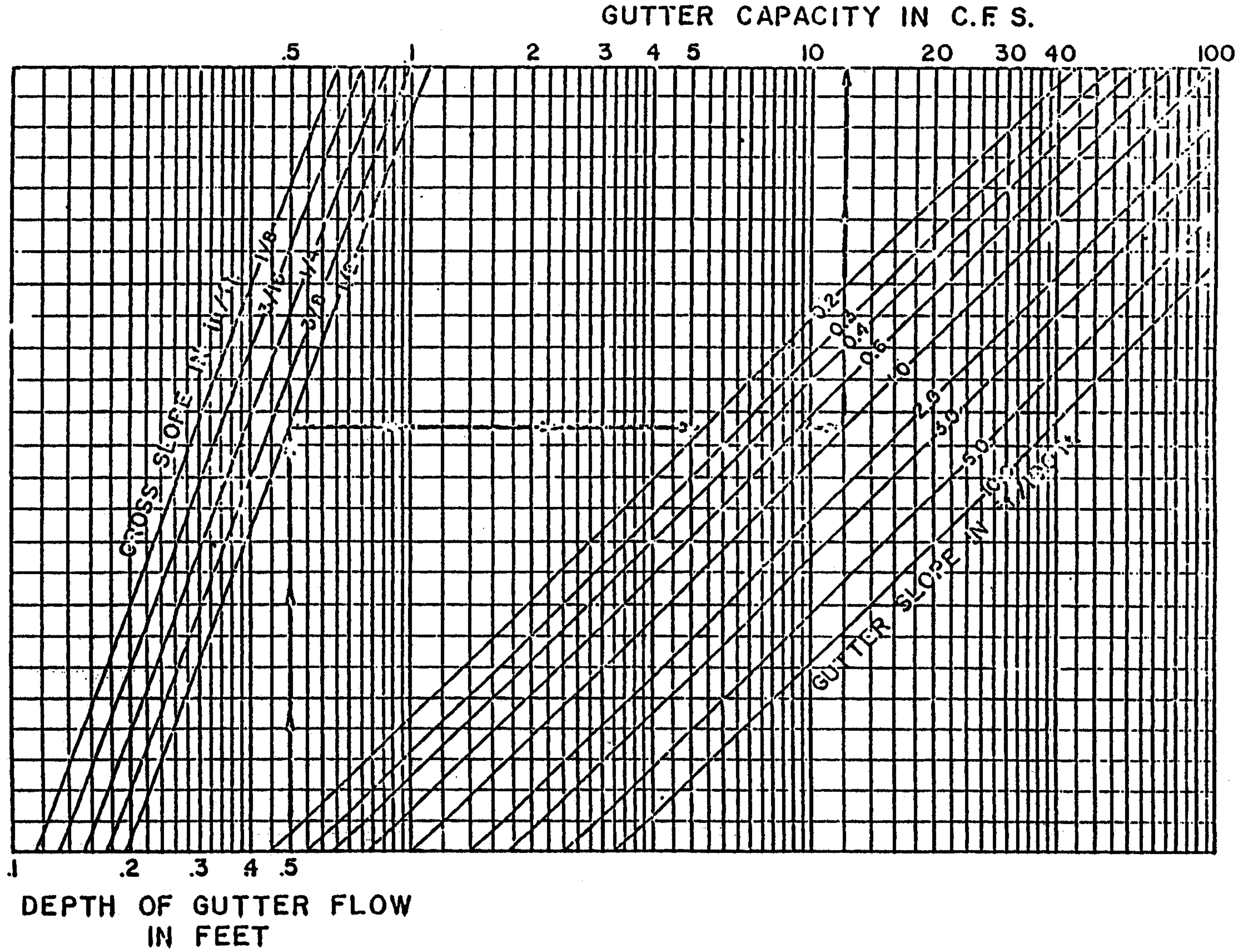
Figure 10

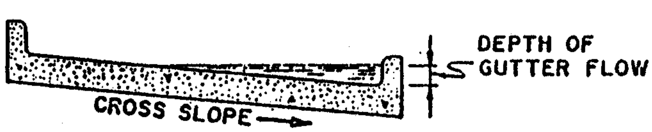
EXAMPLE

Known:
- Major Street, Type MB
- Pavement Width = 33'
- Gutter Slope = 1.0%
- Pavement Cross Slope = 1/2"/1'
- Depth of Gutter Flow = .5'

Find:
- Gutter Capacity

Solution:
- Enter Graph at .5'
- Intersect Cross Slope = 1/2"/1'
- Intersect Gutter Slope = 1.0%
- Read Gutter Capacity = 12 c.f.s.

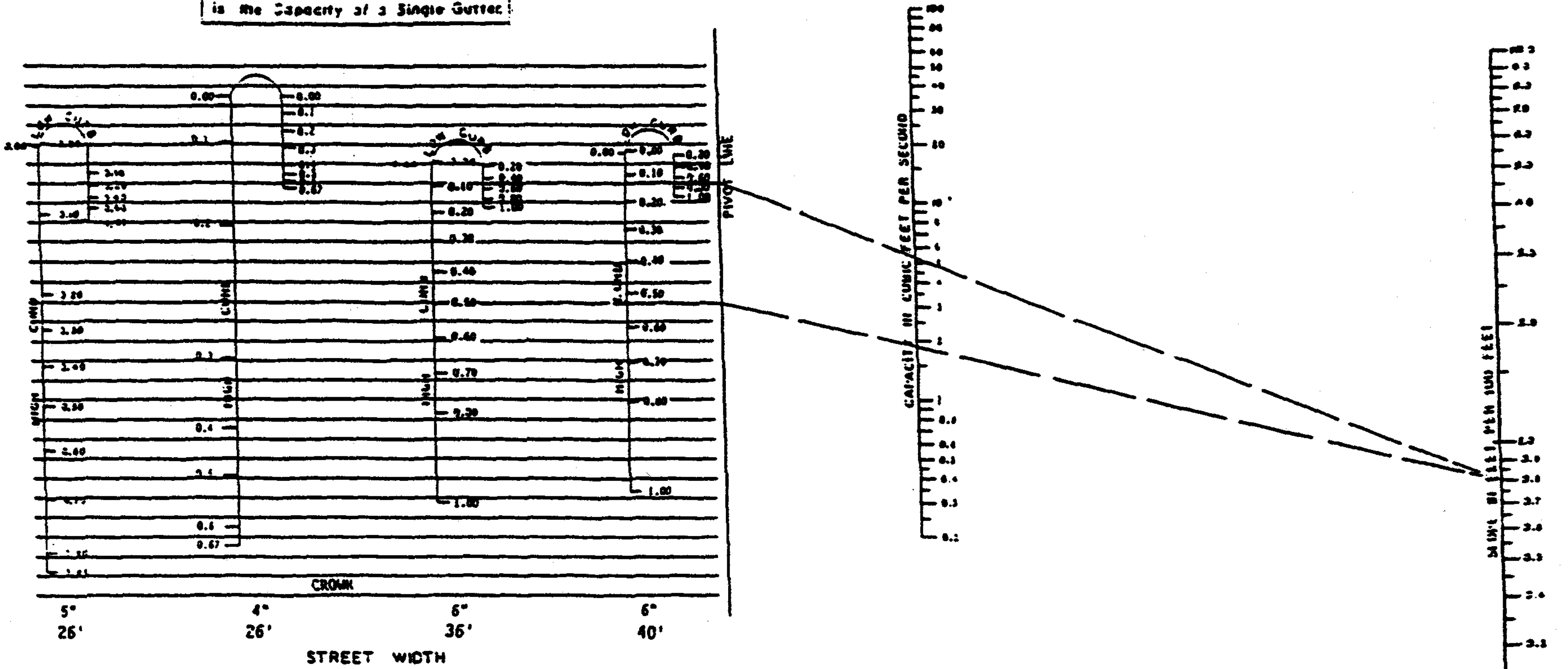




CAPACITY OF TRIANGULAR GUTTERS

(Roughess Coefficient n = .0175)

When Both Curbs are at the Same Elevation the Capacity Obtained from this Nomograph is the Capacity of a Single Gutter



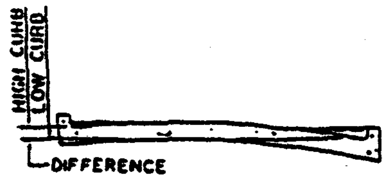
EXAMPLE

Known:

Minor Street, Type B
Pavement Width = 36'
Gutter Slope = 0.80%
Gutter Difference = 0.5'

Find:

Gutter Capacity of High Curb
Gutter Capacity of Low Curb



Solution:

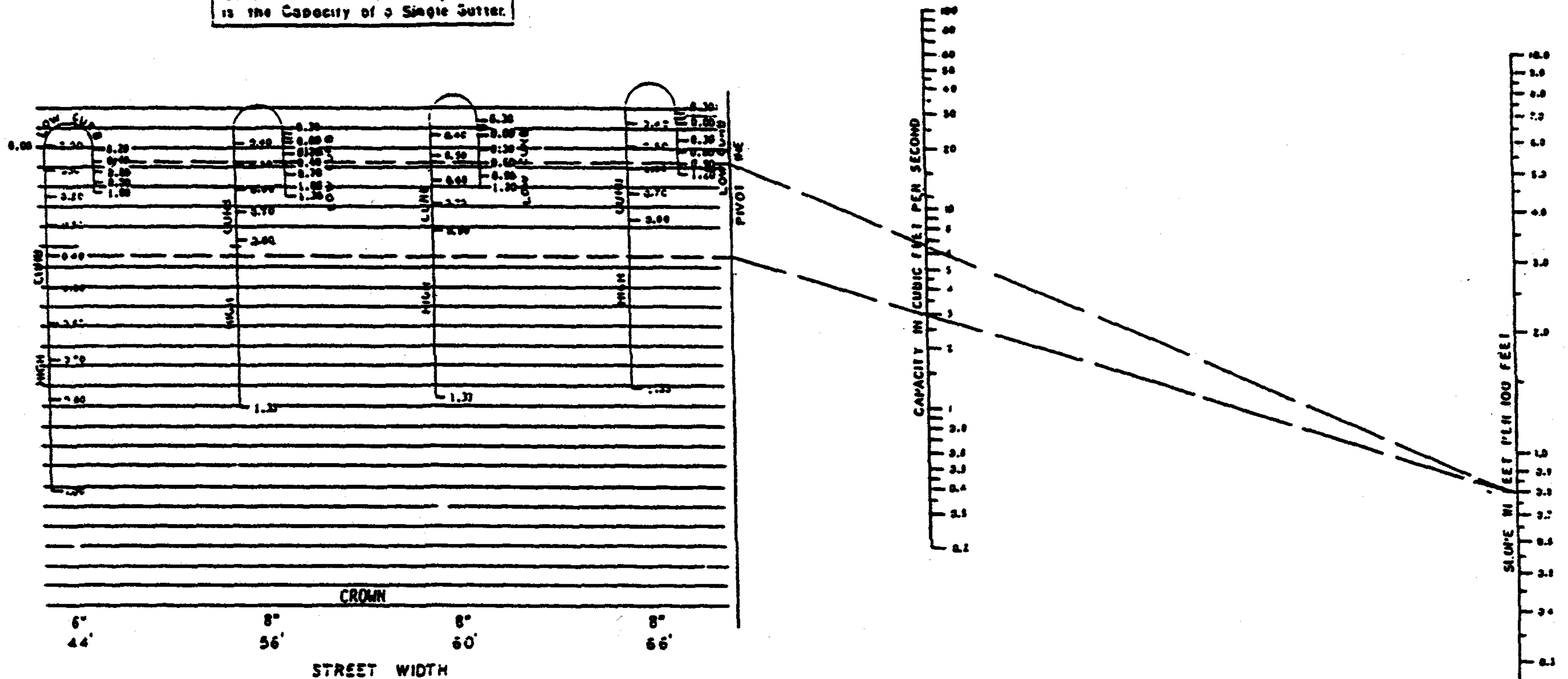
From 0.5' on the Low Curb Project Horizontally to the Pivot Line. From the Pivot Line Draw a Straight Line to Gutter Slope = 0.80%
Read Q = 5.7 c.f.s. for Low Curb

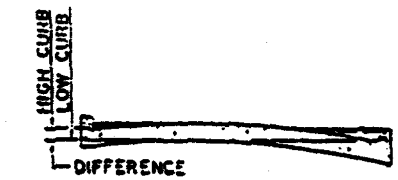
From 0.5' on the High Curb Project Horizontally to the Pivot Line. From the Pivot Line Draw a Straight Line to Gutter Slope = 0.80%
Read Q = 1.9 c.f.s. for High Curb

CAPACITY OF PARABOLIC GUTTERS

(26', 36', 40' STREET WIDTHS)

When Both Curbs are at the Same Elevation the Capacity Obtained from this Nomogram is the Capacity of a Single Gutter.





EXAMPLE

Known:

Secondary Street, Type S-A
Pavement Width = 44'
Gutter Slope = 0.76%
Gutter Difference = 0.4'

Find:

Gutter Capacity of High Curb
Gutter Capacity of Low Curb

Solution:

From 0.4' on the Low Curb Project Horizontally to the Pivot Line. From the Pivot Line Draw a Straight Line to Gutter Slope = 0.76%
Read Q = 6.6 c.f.s. for Low Curb

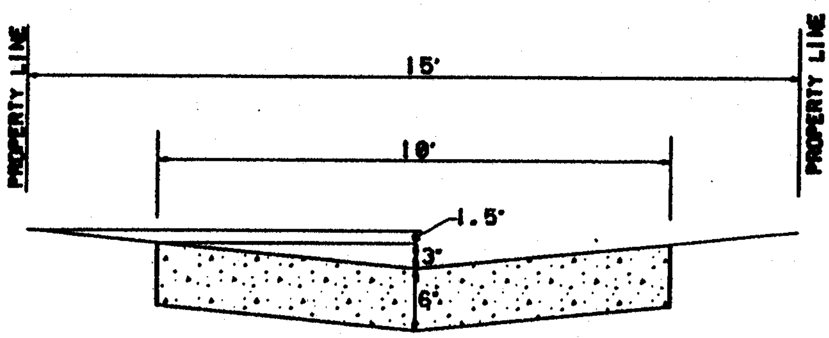
From 0.4' on the High Curb Project Horizontally to the Pivot Line. From the Pivot Line Draw a Straight Line to Gutter Slope = 0.76%
Read Q = 3.2 c.f.s. for High Curb

CAPACITY OF PARABOLIC GUTTERS (44', 56', 60', 66' STREET WIDTHS)

ALLEY CONVEYANCE

EXAMPLES

A) ALLEY WITHOUT CURB



GIVEN

Concrete n = .0175
Grass n = .035
Alley width = 10′
D = Alley depression = 3" = 0.25′
Alley easement width = 15′
D = Alley easement depression = 4.5" = 0.375′
Gutter slope = S_r (check your profile; assume normal flow conditions)

REQUIRED

(1) Concrete Alley Conveyance

$$K = \frac{1.486}{n} A R^{2/3}$$

(2) Alley Easement Conveyance

(3) Gutter Flow $Q = K S_r^{1/2}$

(assuming S_r = 2.2%)

SOLUTION

(1) Concrete Alley Conveyance:

D = 0.25′
n = 0.0175

$$A = \frac{10' * 0.25'}{2} = 1.25 \text{ ft}^2$$

$$P = 2[(0.25)^2 + (5)^2]^{1/2} = 10.012 \text{ ft}$$

$$R = \frac{A}{P} = \frac{1.25 \text{ ft}^2}{10.012 \text{ ft}} = 0.125 \text{ ft}$$

$$K = \frac{1.486}{n} A R^{2/3} = 26.51 \text{ ft}^3$$

$$Q = K S_r^{1/2} = (26.51)(0.022)^{1/2} = 3.93 \text{ cfs}$$

(2) Alley Easement Conveyance:

D = 0.375′
n = 0.0233

$$A = \frac{15' * 0.375'}{2} = 2.813 \text{ ft}^2$$

$$P = 2[(0.375)^2 + (7.5)^2]^{1/2} = 15.019 \text{ ft}$$

$$R = \frac{A}{P} = 0.187 \text{ ft}$$

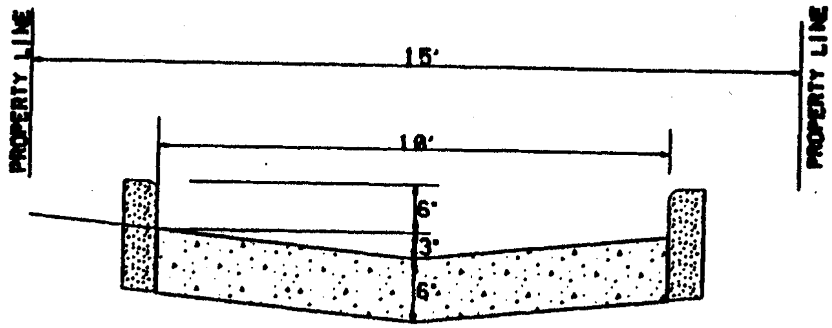
Weighted (perimeter) "n" value:

$$n = \frac{(10.012')(0.0175) + (5.006')(0.035)}{15.018'} = 0.0233$$

$$K = \frac{1.486}{n} A R^{2/3} = 58.71 \text{ ft}^3$$

$$Q = K S_r^{1/2} = (58.71)\ (0.022)^{1/2} = 8.71 \text{ cfs}$$

B) ALLEY WITH CURB



Concrete Alley Conveyance:

$$A = \frac{(10' * 0.25')}{2} + (10' * 0.5') = 6.25\ ft^2$$

$$P = 2[(0.25)^2 + (5)^2]^{1/2} + 2(0.5) = 11.012\ ft$$

$$R = \frac{A}{P} = \frac{6.25\ ft^2}{11.012\ ft} = 0.568\ ft$$

$$K = \frac{1.486}{n} AR^{2/3} = 363.80\ ft^3$$

$$Q = KS_r^{1/2} = (368.80)\ (0.022)^{1/2} = 53.96\ cfs$$

FULL FLOW COEFFICIENT VALUES
PRECAST CONCRETE BOX SECTIONS

Box Size Span x Rise (Feet)	A Area (Square Feet)	R Hydraulic Radius (Feet)	$C = 1.486/n(A \times R^{2/3})$ n = 0.012	n = 0.013	Box Size Span x Rise (Feet)	A Area (Square Feet)	R Hydraulic Radius (Feet)	$C = 1.486/n(A \times R^{2/3})$ n = 0.012	n = 0.013
3 X 2	5.78	0.63	524	484	9 X 5	43.88	1.67	7060	7070
3 X 3	8.78	0.78	923	852	9 X 6	52.88	1.87	9950	9180
4 X 2	7.65	0.69	743	686	9 X 7	61.88	2.05	12400	11400
4 X 3	11.65	0.90	1340	1240	9 X 8	70.88	2.20	14800	13700
4 X 4	15.65	1.04	1990	1840	9 X 9	79.88	2.33	17400	16100
5 X 3	14.50	0.98	1770	1630	10 X 5	48.61	1.73	8690	8020
5 X 4	19.50	1.16	2660	2460	10 X 6	58.61	1.95	11300	10462
5 X 5	24.50	1.30	3620	3340	10 X 7	68.61	2.14	14100	13000
6 X 3	17.32	1.04	2200	2030	10 X 8	78.61	2.31	17000	15700
6 X 4	23.32	1.25	3350	3100	10 X 9	88.61	2.46	20000	18500
6 X 5	29.32	1.42	4590	4240	10 X 10	98.61	2.59	23000	21300
6 X 6	35.32	1.56	5880	5430	11 X 4	42.32	1.52	6930	6390
7 X 4	27.11	1.33	4050	3740	11 X 6	64.32	2.02	12730	11700
7 X 5	34.11	1.52	5590	5160	11 X 8	86.32	2.41	19200	17700
7 X 6	41.11	1.68	7200	6650	11 X 10	108.32	2.72	26100	24100
7 X 7	18.11	1.82	8880	8200	11 X 11	119.32	2.85	29700	27400
8 X 4	31.11	1.39	4790	4420	12 X 4	46.00	1.55	7630	7050
8 X 5	39.11	1.60	6630	6120	12 X 6	70.00	2.08	14100	13000
8 X 6	47.11	1.78	8760	7920	12 X 8	94.00	2.50	21400	19800
8 X 7	55.11	1.94	10600	9790	12 X 10	118.00	2.83	29300	27000
8 X 8	63.11	2.07	12700	11700	12 X 12	142.00	3.11	37500	34600

FULL FLOW COEFFICIENT VALUES
CIRCULAR CONCRETE PIPE

D Pipe Diameter (inches)	A Area (Square Feet)	R Hydraulic Radius (Feet)	Value of $C_1 = \frac{1.486}{n} \times A \times R^{2/3}$			
			n=0.010	n=0.011	n=0.012	n=0.013
8	0.349	0.167	15.8	14.3	13.1	12.1
10	0.545	0.208	28.4	25.8	23.6	21.8
12	0.785	0.250	46.4	42.1	38.6	35.7
15	1.227	0.312	84.1	76.5	70.1	64.7
18	1.767	0.375	137	124	114	105
21	2.405	0.437	206	187	172	158
24	3.142	0.500	294	267	245	226
27	3.976	0.562	402	366	335	310
30	4.909	0.625	533	485	444	410
33	5.940	0.688	686	624	574	530
36	7.069	0.750	867	788	722	666
42	9.621	0.875	1308	1189	1090	1006
48	12.566	1.000	1867	1698	1556	1436
54	15.904	1.125	2557	2325	2131	1967
60	19.635	1.250	3385	3077	2821	2604
66	23.758	1.375	4364	3967	3636	3357
72	28.274	1.500	5504	5004	4587	4234
78	33.183	1.625	6815	6195	5679	5242
84	38.485	1.750	8304	7549	6920	6388
90	44.170	1.875	9985	9078	8321	7681
96	50.266	2.000	11850	10780	9878	9119
102	56.745	2.125	13940	12670	11620	10720
108	63.617	2.250	16230	14760	13530	12490
114	70.882	2.375	18750	17040	15620	14420
120	78.540	2.500	21500	19540	17920	16540
126	86.590	2.625	24480	22260	20400	18830
132	95.033	2.750	27720	25200	23100	21330
138	103.870	2.875	31210	28370	26010	24010
144	113.100	3.000	34960	31780	29130	26890

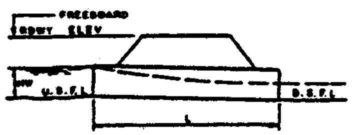
FULL FLOW COEFFICIENT VALUES
ELLIPTICAL CONCRETE PIPE

Pipe Size R x S (HE) S x R (VE) (Inches)	Approximate Equivalent Circular Diameter (Inches)	A Area (Square Feet)	R Hydraulic Radius (Feet)	Value of $C_1 = \frac{1.486}{n} \times A \times R^{2/3}$			
				n = 0.010	n = 0.011	n = 0.012	n = 0.013
14 x 23	18	1.8	0.367	138	125	116	108
19 x 30	24	3.3	0.490	301	274	252	232
22 x 34	27	4.1	0.546	405	368	339	313
24 x 38	30	5.1	0.613	547	497	456	421
27 x 42	33	6.3	0.686	728	662	607	560
29 x 45	36	7.4	0.736	891	810	746	686
32 x 49	39	8.8	0.812	1140	1036	948	875
34 x 53	42	10.2	0.875	1386	1260	1156	1067
38 x 60	48	12.9	0.969	1878	1707	1565	1445
43 x 68	54	16.6	1.106	2635	2395	2196	2027
48 x 76	60	20.5	1.229	3491	3174	2910	2686
53 x 83	66	24.8	1.352	4503	4094	3753	3464
58 x 91	72	29.5	1.475	5680	5164	4734	4370
63 x 98	78	34.6	1.598	7027	6388	5856	5406
68 x 106	84	40.1	1.721	8560	7790	7140	6590
72 x 113	90	46.1	1.845	10300	9365	8584	7925
77 x 121	96	52.4	1.967	12220	11110	10190	9403
82 x 128	102	59.2	2.091	14380	13070	11980	11060
87 x 136	108	66.4	2.215	16770	15240	13970	12900
92 x 143	114	74.0	2.340	19380	17620	16150	14910
97 x 151	120	82.0	2.461	22190	20180	18490	17070
106 x 166	132	99.2	2.707	28630	26020	23860	22020
116 x 180	144	118.6	2.968	36400	33100	30340	28000

FULL FLOW COEFFICIENT VALUES
CONCRETE ARCH PIPE

Pipe Size R x S (Inches)	Approximate Equivalent Circular Diameter (Inches)	A Area (Square Feet)	R Hydraulic Radius (Feet)	Value of $C_1 = \frac{1.486}{n} \times A \times R^{2/3}$			
				n = 0.010	n = 0.011	n = 0.012	n = 0.013
11 x 18	15	1.1	0.25	65	59	54	50
13½ x 22	18	1.6	0.30	110	100	91	84
15½ x 26	21	2.2	0.36	165	150	137	127
18 x 28½	24	2.8	0.45	243	221	203	187
22½ x 36¼	30	4.4	0.56	441	401	368	339
26⅝ x 43¾	36	6.4	0.68	736	669	613	566
31⁵⁄₁₆ x 51⅛	42	8.8	0.80	1125	1023	938	866
36 x 58½	48	11.4	0.90	1579	1435	1315	1214
40 x 65	54	14.3	1.01	2140	1945	1783	1646
45 x 73	60	17.7	1.13	2851	2592	2376	2193
54 x 88	72	25.6	1.35	4641	[illegible]	3867	3569
62 x 102	84	34.6	1.57	6941	6310	5784	5339
72 x 115	90	44.5	1.77	9668	8789	8056	7436
77¼ x 122	96	51.7	1.92	11850	10770	9672	9112
87⅛ x 138	108	66.0	2.17	16430	14940	13690	12640
96⅞ x 154	120	81.8	2.42	21975	19977	18312	16904
106½ x 168¾	132	99.1	2.65	28292	25720	23577	21763

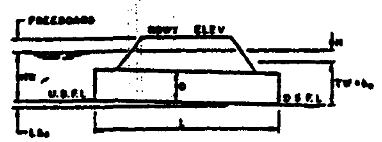
INLET CONTROL



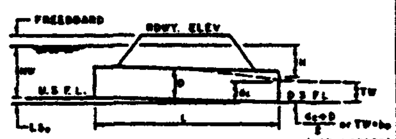
CASE I
INLET NOT SUBMERGED

CASE II
INLET SUBMERGED

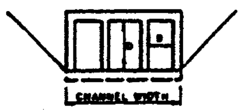
OUTLET CONTROL



CASE III
OUTLET SUBMERGED



CASE IV
OUTLET NOT SUBMERGED

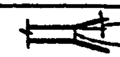


TYPICAL BOX CULVERT

TYPICAL PIPE CULVERT

CULVERT ENTRANCE DATA

CONCRETE BOX CULVERT



TYPE	FLARE ANGLE	ENTRANCE EDGE	K_e
1A	30° to 75°	Square	0.4
1B	30° to 75°	Round	0.3
2A	15° to 30° & 75° to 90°	Square	0.5
2B	15° to 30° & 75° to 90°	Round	0.3
3A	0° (Extension of Sides)	Square	0.7
3B	0° (Extension of Sides)	Round	0.5

CONCRETE PIPE

TYPE	ENTRANCE DESCRIPTION	K_e
4	Spigot End With Headwall	0.5
5	Bell End With Headwall	0.2
6A	Bell End Projecting With No Headwall	0.3
6B	Spigot End Projecting With No Headwall	0.6

CULVERT DESIGN CALCULATIONS

BY__________ DATE__________

PROJECT__________ FILE NO.__________

CULVERT LOCATION__________

__________ LENGTH, L__________

TOTAL DISCHARGE, Q__________ DESIGN STORM FREQ.__________

ROUGHNESS COEFF., n__________ MAX. VEL.__________

TAILWATER__________ D.S. CHANNEL WIDTH__________

ENTRANCE DESCRIPTION__________

RDWY. ELEV.__________ U.S. CULV. F.L.__________

U.S. CULV. F.L.__________ D.S. CULV. F.L.__________

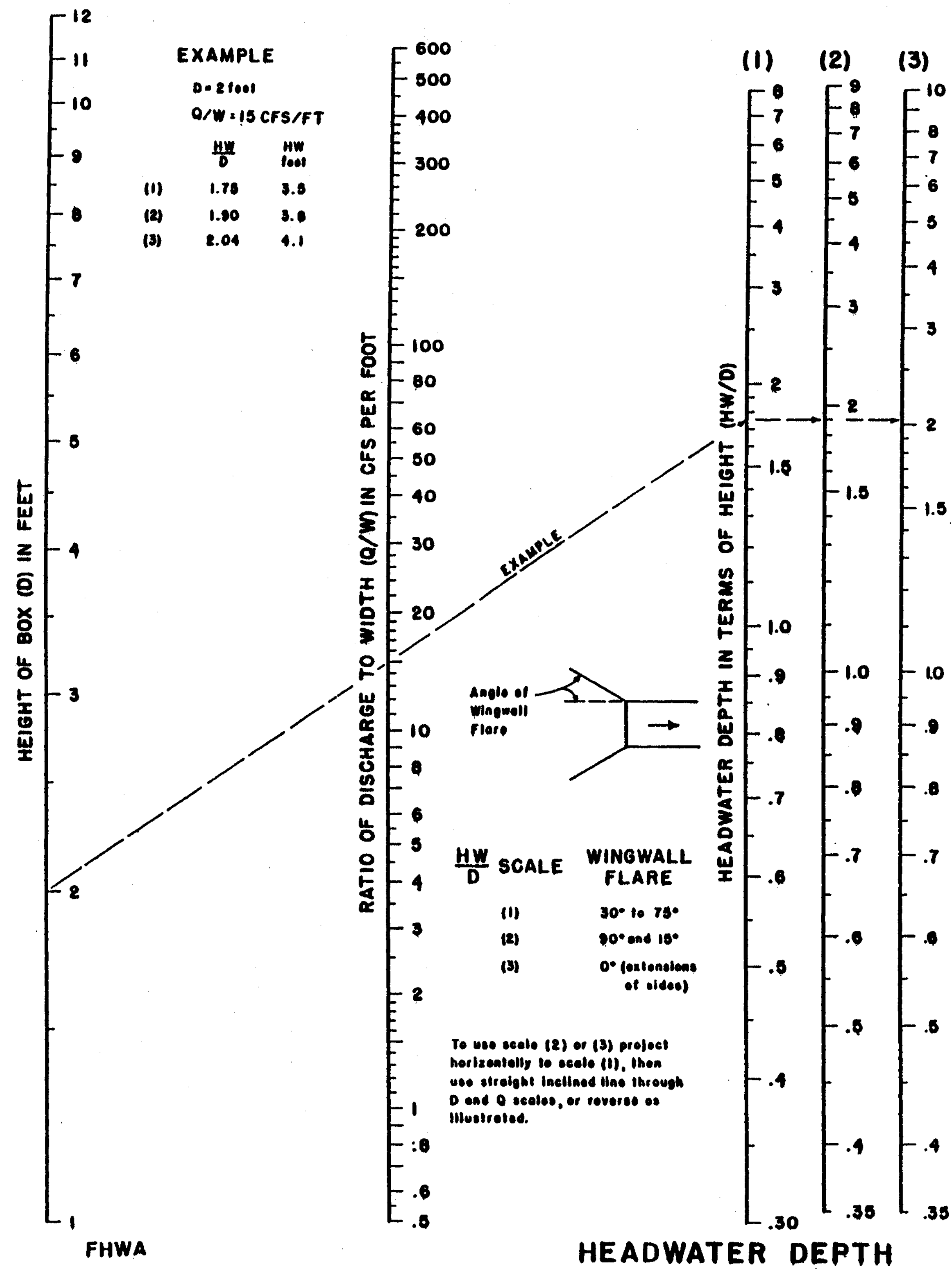
DIFFERENCE__________ DIFFERENCE__________

REQD. FREEBOARD______ FT. CULV. SLOPE, $S_0 = \frac{\text{DIFF. FT.}}{\text{LENGTH FT.}}$

ALLOW. HEADWATER______ FT. S_0 =__________

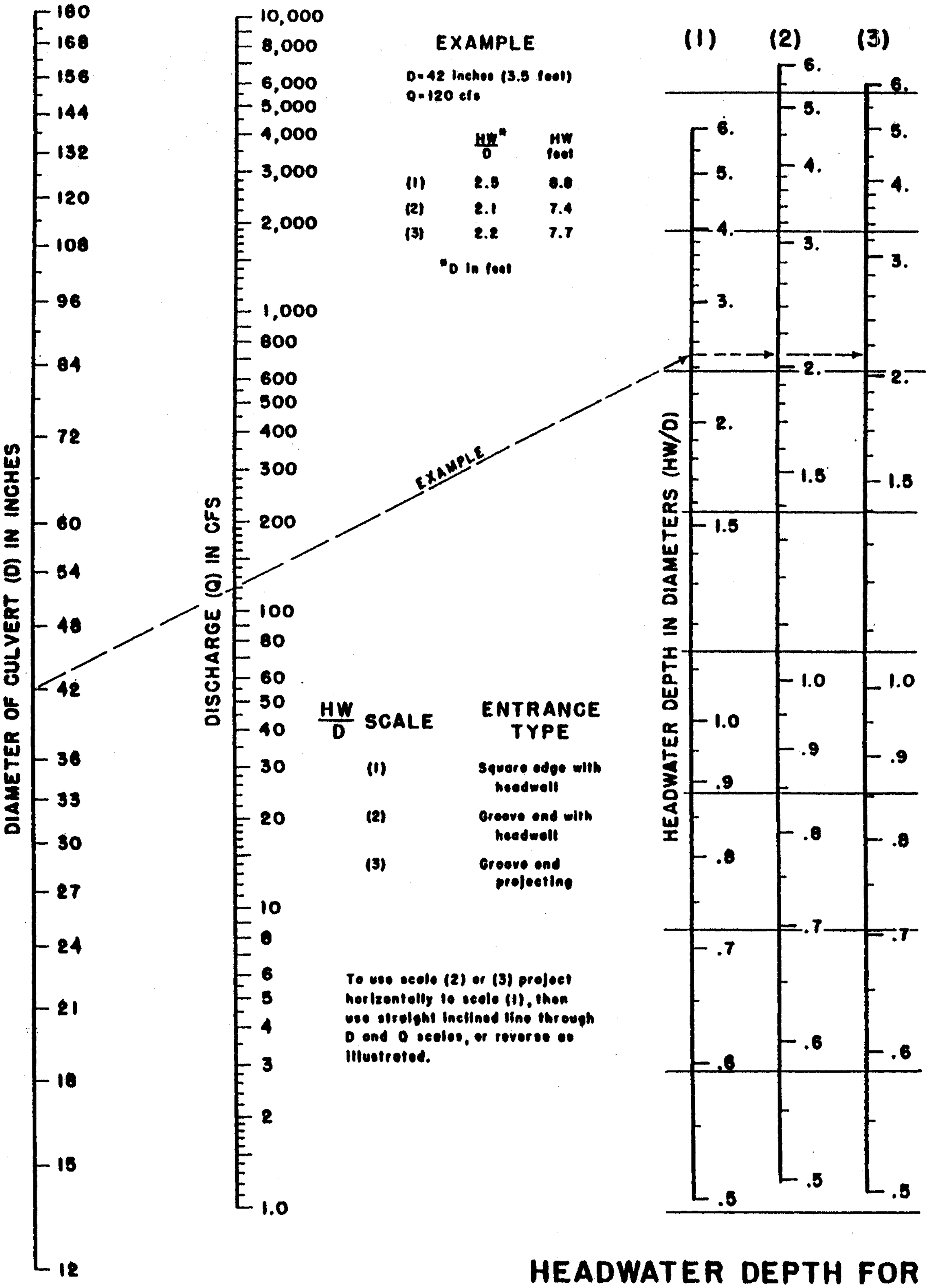
TRIAL CULVERT										HEADWATER CALCULATION																	The Greater Controlling Head Water (Inlet or Outlet) (feet)	SELECTED CONDUIT SIZE
Trial Area of Opening $T\text{-}A_c = \frac{Q}{V_{max.}}$ (sq. ft.)	Channel Width "W" (feet)	DEPTH RANGE D. R.		Try Depth "D" (feet)	POSSIBLE CULVERT SIZES					INLET CONTROL (See Figure 25 & 26)					OUTLET CONTROL (See Figure 27, 28, 29, & 30)													
															Entrance Coeff. K_e	CASE III $HW = H + TW - L \times S_0$ (feet)				CASE IV $HW = H + h_0 - L \times S_0$ (feet)								
																					$h_0 = \frac{d_c + D}{2}$ or $h_0 = TW$ (USE LARGER)							
		$\frac{T\text{-}A_c}{W}$ (feet)	AHW (feet)		No. Openings	Width of Box "B" (feet)	Box Depth or Pipe Dia. "D" (feet)	Total Culvert Area "A_c" (sq. ft.)	"Q" Each Opening (c.f.s.)	Entrance Type	Case No.	$\frac{Q}{B}$ (c.f.s.)	$\frac{HW}{D}$ (figure 25 & 26)	HW		"H" (feet) (figure 27 & 28)	"TW" (feet)	$L \times S_0$ (feet)	"HW" (feet)	"H" (feet) (figure 27 & 28)	d_c (figure 29 & 30) (feet)	$\frac{d_c + D}{2}$ (feet)	TW (feet)	h_0 (feet)	$L \times S_0$ (feet)	"HW" (feet)		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29

FORM F



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

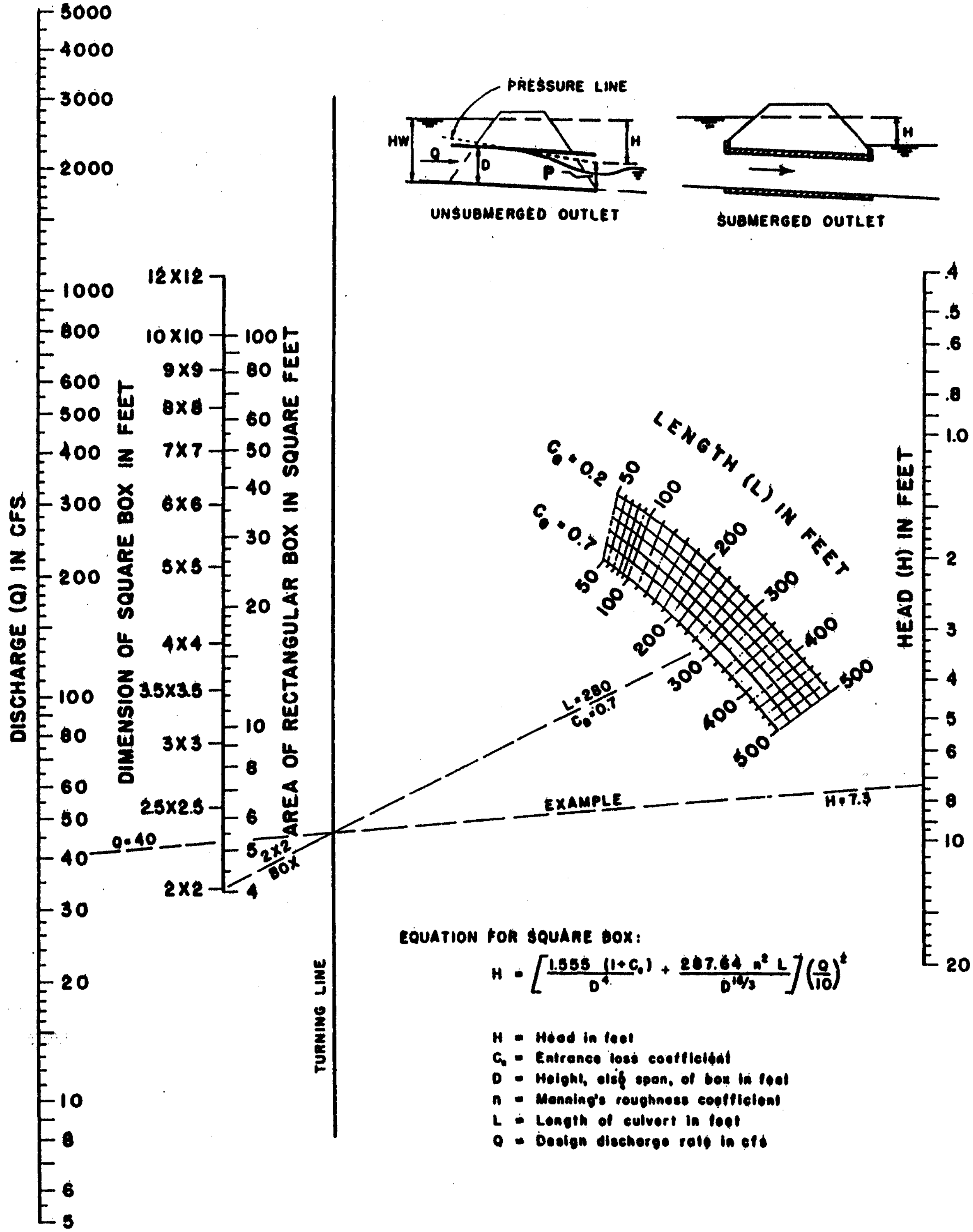
NOMOGRAPH C



FHWA

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

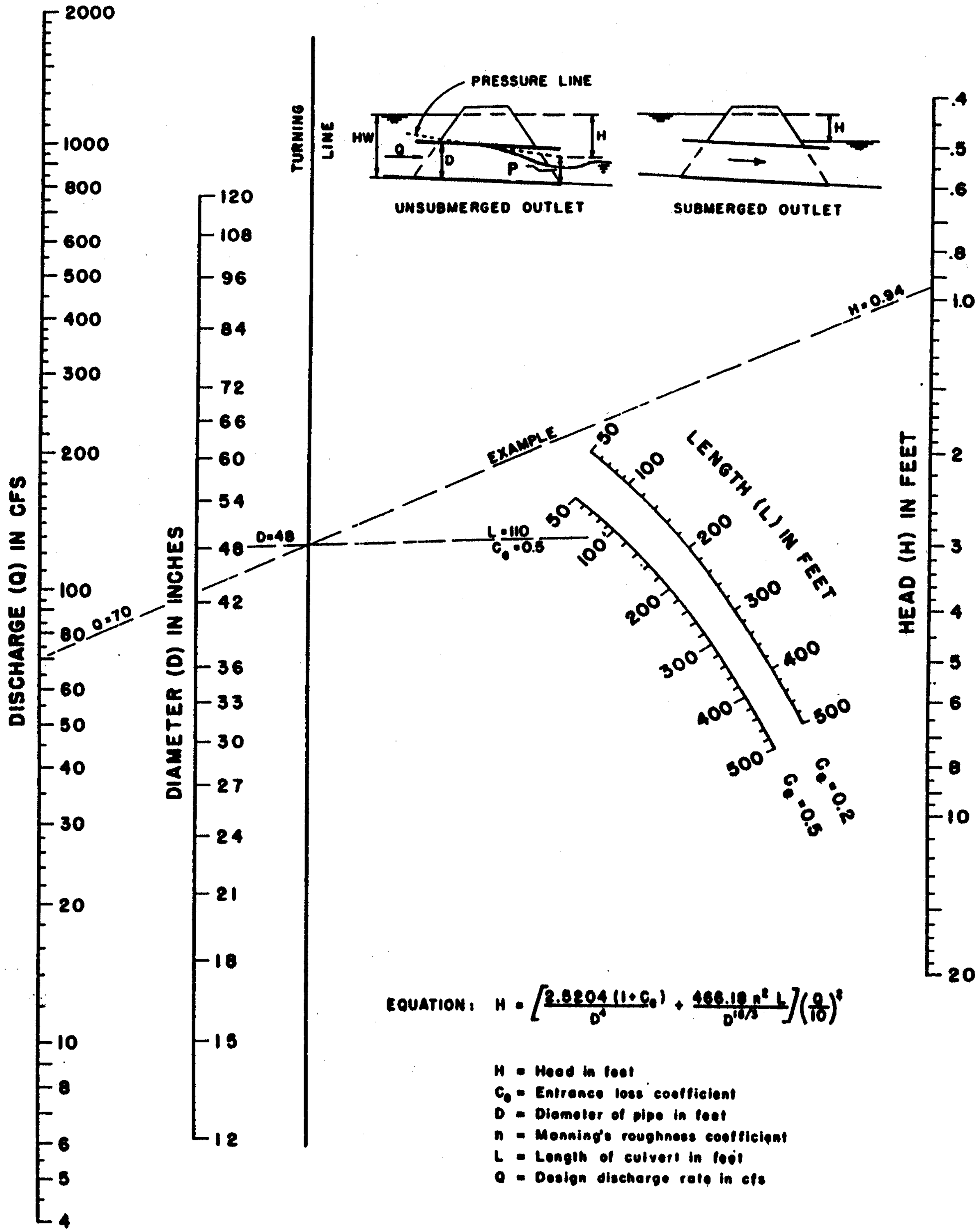
NOMOGRAPH I



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

FHWA

NOMOGRAPH D



FHWA

HEAD FOR CONCRETE PIPE CULVERTS FLOWING FULL n = 0.012

NOMOGRAPH K

Known:

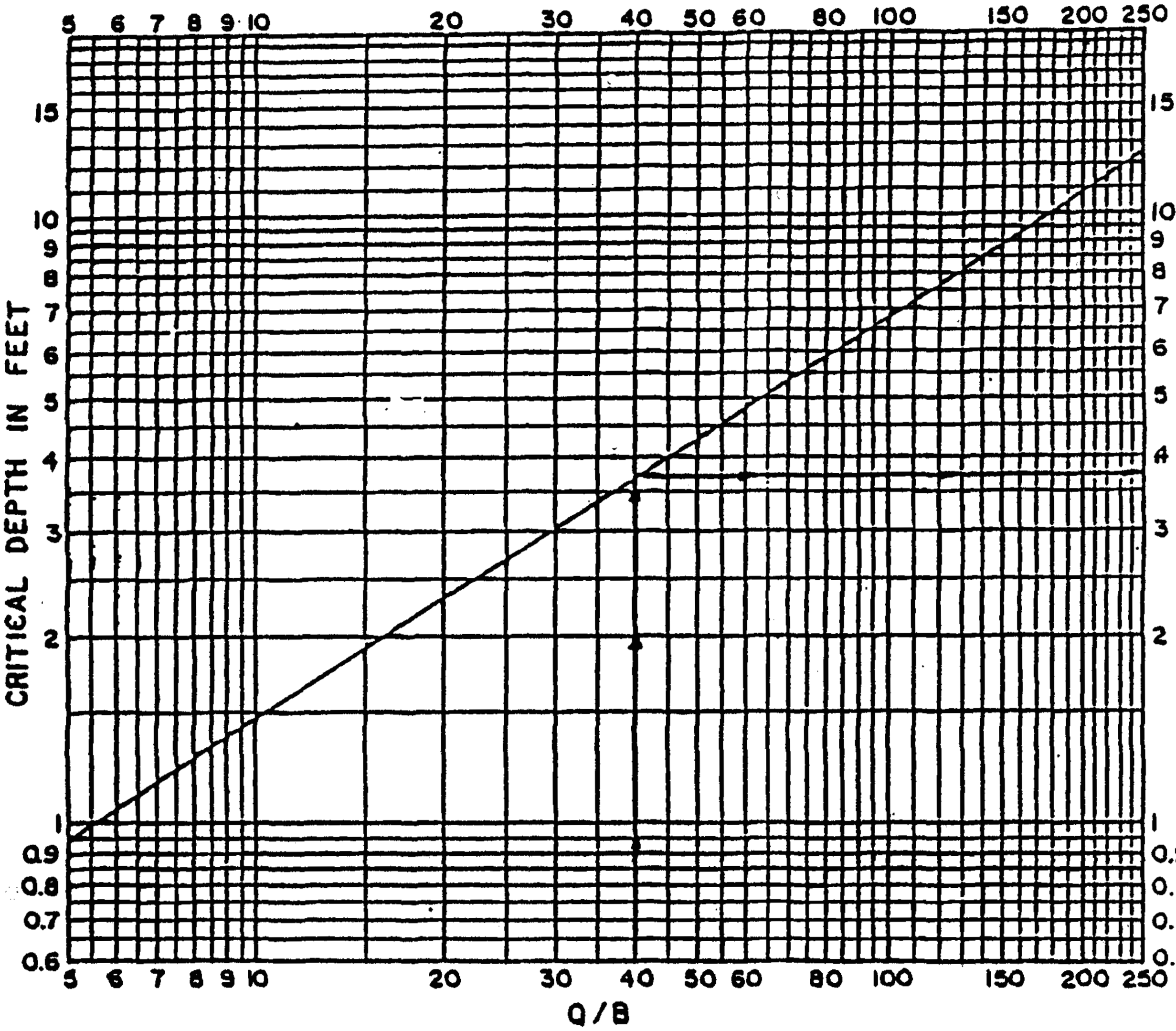
Discharge = 200 c.f.s.
Width of Conduit = 5'
Q/B = 40

Find:

Critical Depth

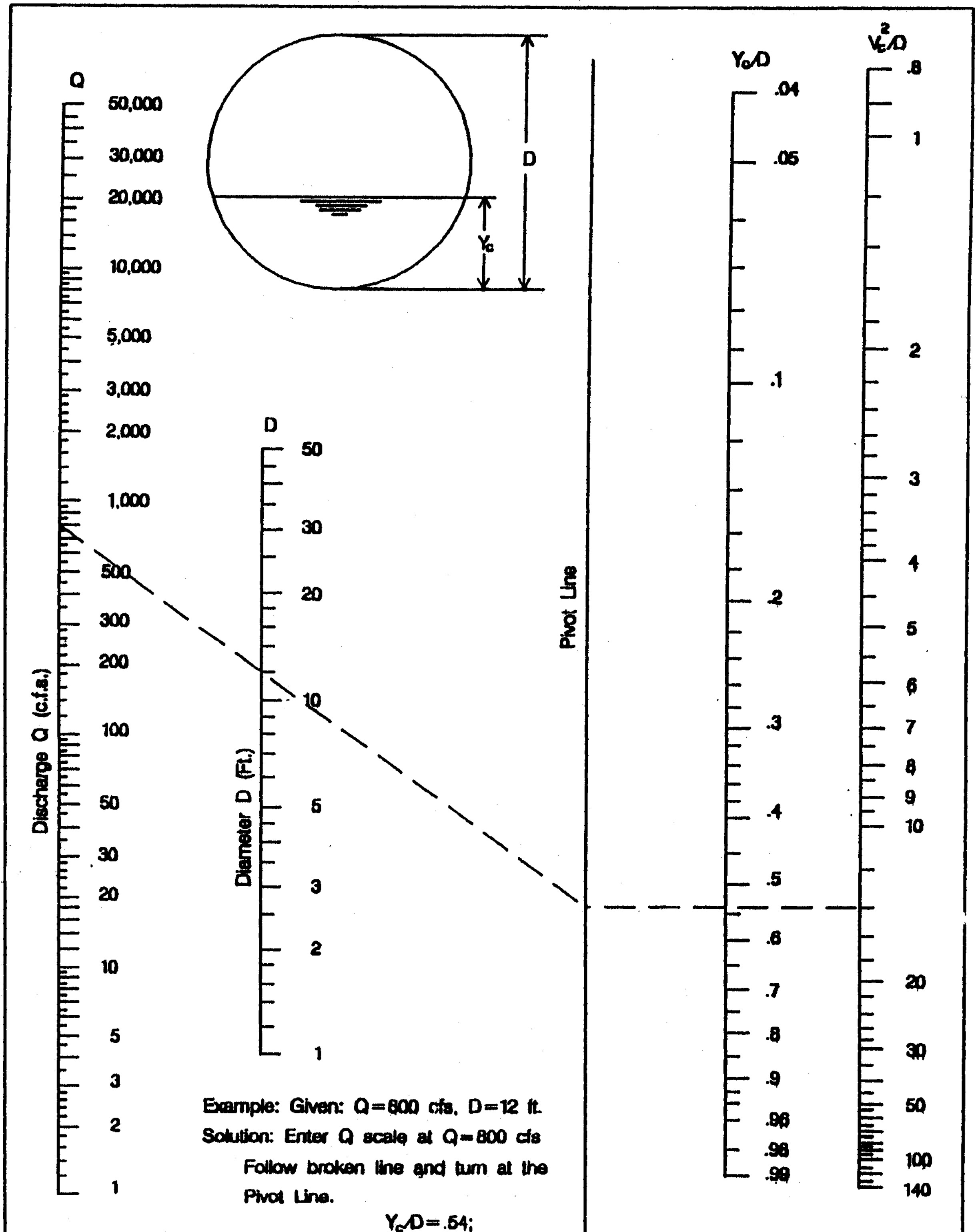
Solution:

Enter Graph at Q/B = 40
Intersect Critical Depth
at 3.7



CRITICAL DEPTH OF FLOW FOR RECTANGULAR CONDUITS

Critical Flow and Critical Velocity in Circular Conduits



Example: Given: Q=800 cfs, D=12 ft.

Solution: Enter Q scale at Q=800 cfs

Follow broken line and turn at the Pivot Line.

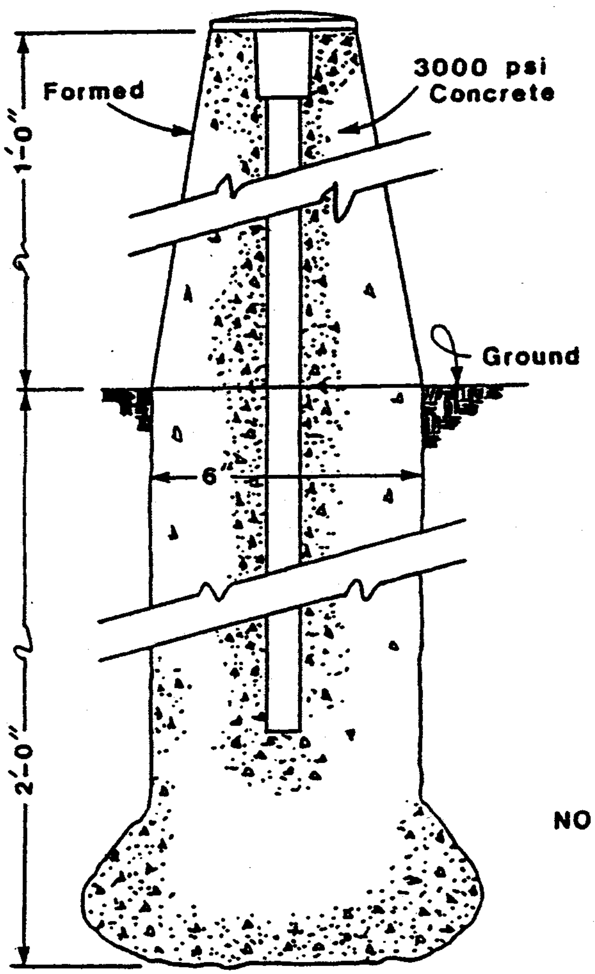
$Y_c/D = .54$;

$Y_c = 6.48$ ft

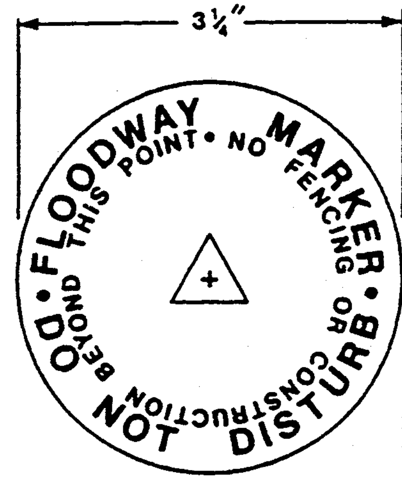
$V_c^2/D = 14$; $V_c = 12.95$ ft/sec.

ROUGHNESS COEFFICIENTS FOR OPEN CHANNELS

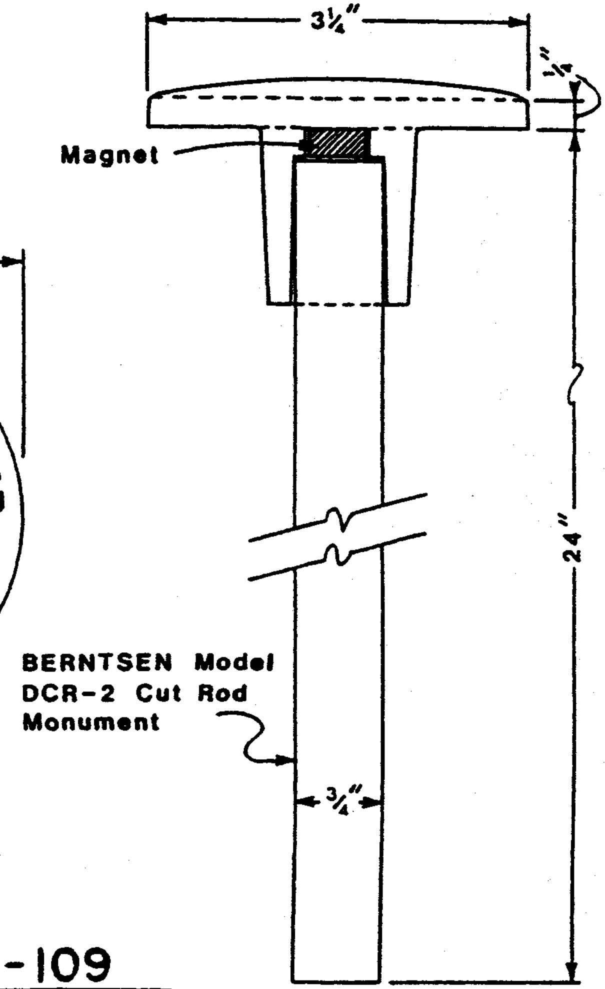
Channel Description	Roughness Coefficient Minimum	Normal	Maximum	Maximum Velocity
MINOR NATURAL STREAMS				
Moderately Well Defined Channel				
Grass and Weeds, Little Brush	0.025	0.030	0.033	8
Dense Weeds, Little Brush	0.030	0.035	0.040	8
Weeds, Light Brush on Banks	0.030	0.035	0.040	8
Weeds, Heavy Brush on Banks	0.035	0.050	0.060	8
Weeds, Dense Willows on Banks	0.040	0.060	0.080	8
Irregular Channel with Pools and Meanders				
Grass and Weeds, Little Brush	0.030	0.036	0.042	8
Dense Weeds, Little Brush	0.036	0.042	0.048	8
Weeds, Light Brush on Banks	0.036	0.042	0.048	8
Weeds, Heavy Brush on Banks	0.042	0.060	0.072	8
Weeds, Dense Willows on Banks	0.048	0.072	0.096	8
Flood Plain, Pasture				
Short Grass, No Brush	0.025	0.030	0.035	8
Tall Grass, No Brush	0.030	0.035	0.050	8
Flood Plain, Cultivated				
No Crops	0.025	0.030	0.035	8
Mature Crops	0.030	0.040	0.050	8
Flood Plain, Uncleared				
Heavy Weeds, Light Brush	0.035	0.050	0.070	8
Medium to Dense Brush	0.070	0.100	0.160	8
Trees with Flood Stage below Branches	0.080	0.100	0.120	8
MAJOR NATURAL STREAMS				
The roughness coefficient is less than that for minor streams of similar description because banks offer less effective resistance.				
Moderately Well Defined Channel	0.025	---	0.060	8
Irregular Channel	0.035	---	0.100	8
UNLINED VEGETATED CHANNELS				
Mowed Grass, Clay Soil	0.025	0.030	0.035	8
Mowed Grass, Sandy Soil	0.025	0.030	0.035	6
UNLINED NONVEGETATED CHANNELS				
Clean Gravel Section	0.022	0.025	0.030	8
Shale	0.025	0.030	0.035	10
Smooth Rock	0.025	0.030	0.035	15
LINED CHANNELS				
Smooth Finished Concrete	0.013	0.015	0.020	15
Riprap (Rubble)	0.030	0.040	0.050	10



BERNTSEN, Inc.
P.O. Box 8666
Madison, Wisconsin 53708
800 356-7388



LOGO CAP
ID# 4011

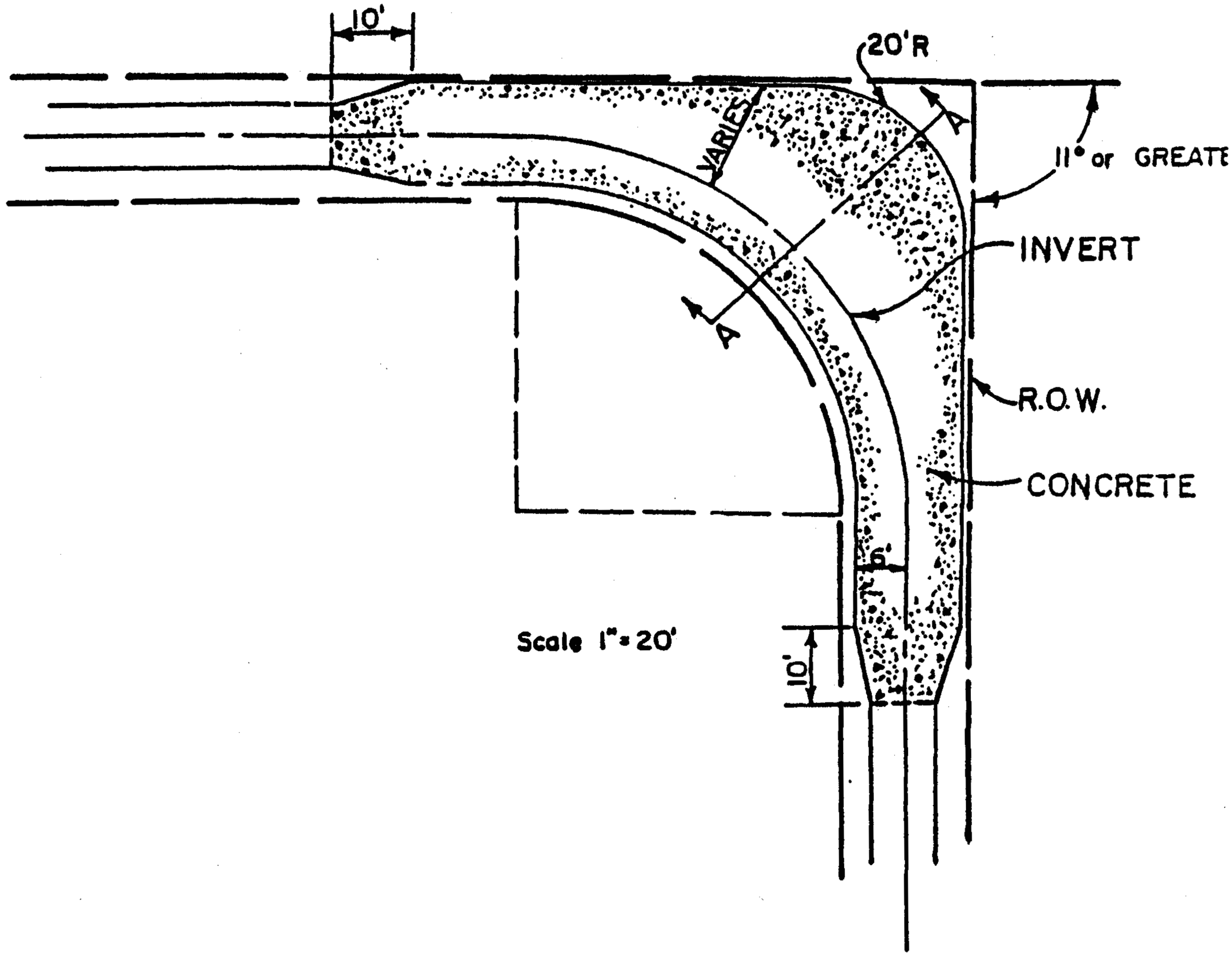


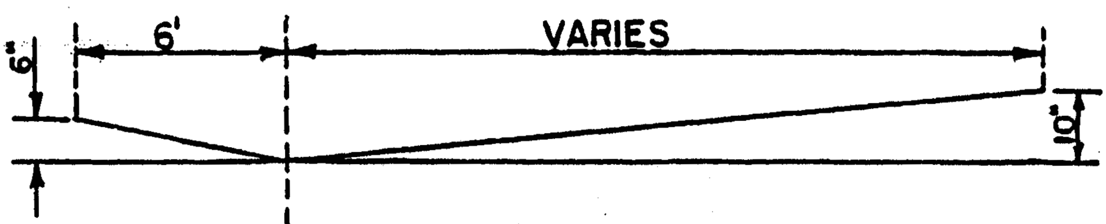
NO SCALE

FILE NO. 424-109

STANDARD CITY OF DALLAS
FLOOD-MANAGEMENT MONUMENT
DEPARTMENT OF PUBLIC WORKS

10/83





SECTION A-A

Scale 1" = 5'H
1" = 2'V

DETAIL OF ALLEY PAVING AT A TURN

MODIFIED RATIONAL METHOD
DETENTION BASIN DESIGN
EXAMPLE

GIVEN: A 10-acre site, currently agricultural use, is to be developed for townhouses. The entire area is the drainage area of the proposed detention basin.

DETERMINE: Maximum release rate and required detention storage.

SOLUTION:

1. Determine 100-year peak runoff rate prior to site development. This is the maximum release rate from site after development.

   NOTE: Where a basin is being designed to provide detention for both its drainage area and a bypass area, the maximum release rate is equal to the peak runoff rate prior to site development for the total of the areas minus the peak runoff rate after development for the bypass area. This rate for the bypass area will vary with the duration being considered.

2. Determine inflow Hydrograph for Storms of various durations in order to determine maximum volume required with release rate determined in Step 1.

   NOTE: Incrementally increase durations by 10 minutes to determine maximum required volume. The duration with a peak inflow less than maximum release rate, or where required storage is less than storage for the prior duration, is the last increment.

Step 1.

Present Conditions $Q = CIA$

C = .30
T_c = 20 min.
I_{100} = 7.0 in./hr.
Q_{100} = .30 X 7.0 X 10 = 21.0 cfs (Maximum release rate)

Step 2.

Future Conditions (Townhouses)

C = .80
T_c = 15 min.
I_{100} = 7.7 in./hr.
Q_{100} = .80 X 7.7 X 10 = 61.6 cfs

Check various duration storms

20 min.	I = 7.0	Q = .80 x 7.0 x 10 =	56.0 cfs
30 min.	I = 5.8	Q = .80 x 5.8 x 10 =	46.4 cfs
40 min.	I = 5.0	Q = .80 x 5.0 x 10 =	40.0 cfs
50 min.	I = 4.4	Q = .80 x 4.4 x 10 =	35.2 cfs
60 min.	I = 4.0	Q = .80 x 4.0 x 10 =	32.0 cfs
70 min.	I = 3.7	Q = .80 x 3.7 x 10 =	29.6 cfs
80 min.	I = 3.4	Q = .80 x 3.4 x 10 =	27.2 cfs
90 min.	I = 3.1	Q = .80 x 3.1 x 10 =	24.8 cfs

Maximum Storage Volume is determined by deducting the volume of runoff relased during the time of inflow from the total inflow for each duration.

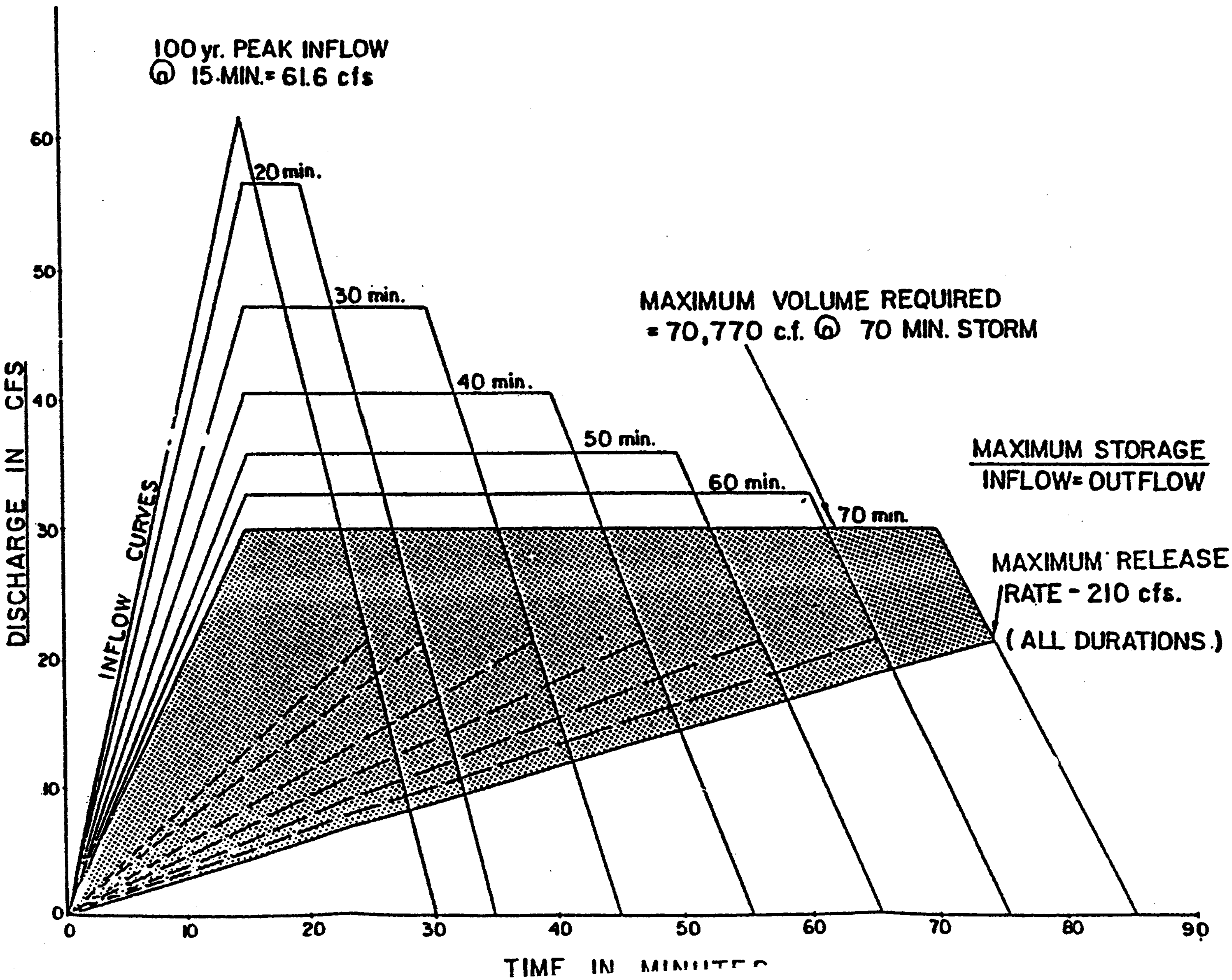
Inflow = Storm duration X respective peak discharge X 60 sec./min.

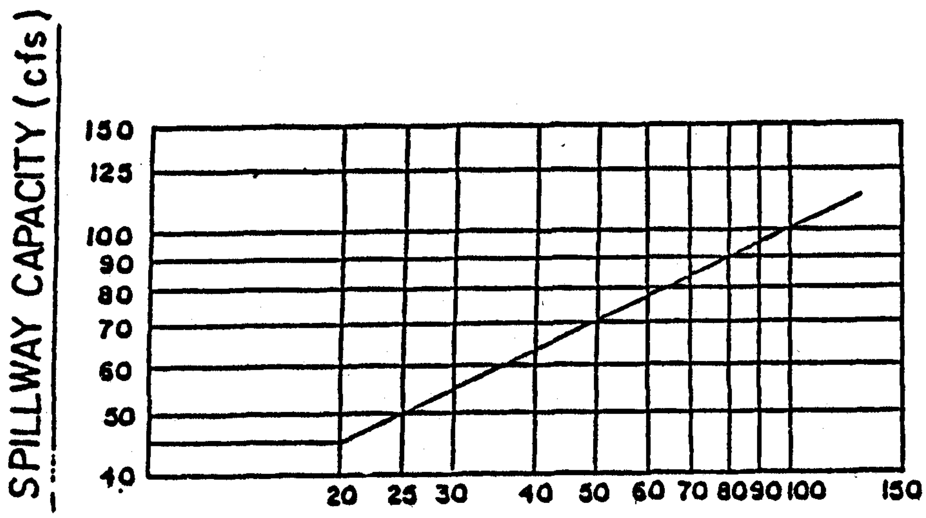
Outflow = Half of the respective inflow duration x control release discharge X 60 sec./min. (See following Discharge vs. Time Graph).

15 min. Storm	Inflow 15 X 61.6 X 60 sec./min.	=	55,440 cf
	Outflow 0.5 X 30 X 21.0 X 60 sec./min.	=	18,900 cf
	Storage	=	36,540 cf
20 min. Storm	Inflow 20 X 56.0 X 60 sec./min.	=	67,200 cf
	Outflow 0.5 X 35 X 21.0 X 60 sec./min.	=	22,050 cf
	Storage	=	45,150 cf
30 min. Storm	Inflow 30 X 46.4 X 60 sec./min.	=	83,520 cf
	Outflow 0.5 X 45 X 21.0 X 60 sec./min.	=	28,350 cf
	Storage	=	55,170 cf
40 min. Storm	Inflow 40 X 40.0 X 60 sec./min.	=	96,000 cf
	Outflow 0.5 X 55 X 21.0 X 60 sec./min.	=	34,650 cf
	Storage	=	61,350 cf
50 min. Storm	Inflow 50 X 35.2 X 60 sec./min.	=	105,600 cf
	Outflow 0.5 X 65 X 21.0 X 60 sec./min.	=	40,950 cf
	Storage	=	64,650 cf
60 min. Storm	Inflow 60 X 32.0 X 60 sec./min.	=	115,200 cf
	Outflow 0.5 X 75 X 21.0 X 60 sec./min.	=	47,250 cf
	Storage	=	67,950 cf
70 min. Storm	Inflow 70 X 29.6 X 60 sec./min.	=	124,320 cf
	Outflow 0.5 X 85 X 21.0 X 60 sec./min.	=	53,550 cf
	Storage	=	70,770 cf

80 min. Storm	Inflow 80 X 27.2 X 60 sec./min.	= 130,560 cf
	Outflow 0.5 X 95 X 21.0 X 60 sec./min.	= 59,850 cf
	Storage	= 70,710 cf
90 min. Storm	Inflow 90 X 24.8 X 60 sec./min.	= 133,920 cf
	Outflow 0.5 X 105 X 21.0 X 60 sec./min.	= 66,150 cf
	Storage	= 67,770 cf

Maximum volume required is 70,770 cfs at the 70 min. Storm duration.


100 yr. PEAK INFLOW
@ 15 MIN. = 61.6 cfs
20 min.
30 min.
40 min.
50 min.
60 min.
70 min.
MAXIMUM VOLUME REQUIRED
= 70,770 c.f. @ 70 MIN. STORM
MAXIMUM STORAGE
INFLOW = OUTFLOW
MAXIMUM RELEASE
RATE - 210 cfs.
(ALL DURATIONS.)
INFLOW CURVES
DISCHARGE IN CFS
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
TIME IN



DRAINAGE AREA (ACRES)

MINIMUM EMERGENCY SPILLWAY CAPACITY-cfs

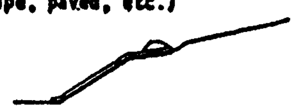
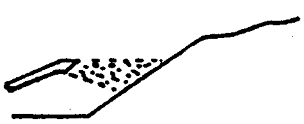
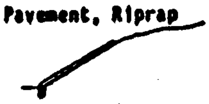
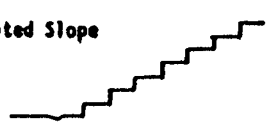
FIGURE-2

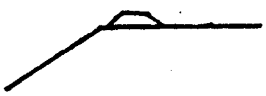
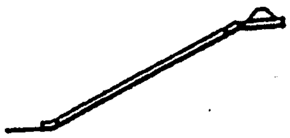
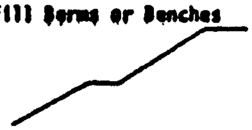
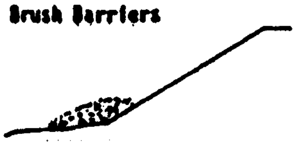
SEDIMENT AND EROSION CONTROL

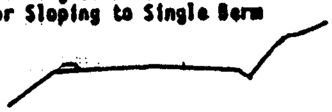
The U.S.D.A. Soil Conservation Service has extensive experience in sediment and erosion control. They have recently published a Manual of Standards and Specifications for Control of Soil Erosion and Sediment in Areas Undergoing Urban Development, a limited number of which are available from the state SCS office in Athens. This manual contains many ideas for methods for controlling erosion from construction sites.

The following list of treatment practices is presented as an overview of the techniques that have successfully been used for controlling erosion.

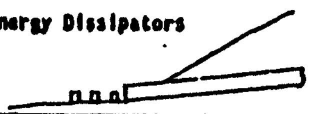
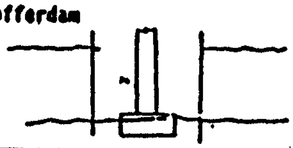
Treatment Practice	Advantages	Problems
BORROW AREAS		
Selective Grading and Shaping	Water can be directed to minimize off-site damage Flatter slopes enable mulch to be cut into soil	May not be most economical work method for contractor
Stripping and Replacing of Topsoil	Provides better seed bed Conventional equipment can be used to stockpile and spread topsoil	May restrict volume of material that can be obtained for a site Topsoil stockpiles must be located to minimize sediment damage Cost of rehandling material
Dikes, Berms Diversion Ditches Settling Basins Sediment Traps Seeding & Mulch	See other practices	See other practices

Treatment Practice	Advantages	Problems
CUT SLOPES		
Berm @ top of cut 	Diverts water from cut Collects water for slope drains/paved ditches May be constructed before grading is started	Access to top of cut Difficult to build on steep natural slope or rock surface Concentrates water and may require channel protection or energy dissipation devices Can cause water to enter ground, resulting in sloughing of the cut slope
Diversion Dike 	Collects and diverts water at a location selected to reduce erosion potential May be incorporated in the permanent project drainage	Access for construction May be continuing maintenance problem if not paved or protected Disturbed material or berm is easily eroded
Slope Benches 	Slows velocity of surface runoff Collects sediment Provides access to slope for seeding, mulching, and maintenance Collects water for slope drains or may divert water to natural ground	May cause sloughing of slopes if water infiltrates Requires additional ROW Not always possible due to rotten material etc. Requires maintenance to be effective Increases excavation quantities
Slope Drains (pipe, paved, etc.) 	Prevents erosion on the slope Can be temporary or part of permanent construction Can be constructed or extended as grading progresses	Requires supporting effort to collect water Permanent construction is not always compatible with other project work Usually requires some type of energy dissipation
Seeding/Mulching 	The end objective is to have a completely grassed slope. Early placement is a step in this direction. The mulch provides temporary erosion protection until grass is rooted. Temporary or permanent seeding may be used. Mulch should be anchored. Larger slopes can be seeded and mulched with smaller equipment if stage techniques are used.	Difficult to schedule high production units for small increments Time of year may be less desirable May require supplemental water Contractor may perform this operation with untrained or unexperienced personnel and inadequate equipment if stage seeding is required
Sodding 	Provides immediate protection Can be used to protect adjacent property from sediment and turbidity	Difficult to place until cut is complete Sod not always available May be expensive
Slope Pavement, Riprap 	Provides immediate protection for high risk areas and under structures May be cast in place or off site	Expensive Difficult to place on high slopes May be difficult to maintain
Temporary Cover	Plastics are available in wide rolls and large sheets that may be used to provide temporary protection for cut or fill slopes Easy to place and remove Useful to protect high risk areas from temporary erosion	Provides only temporary protection Original surface usually requires additional treatment when plastic is removed Must be anchored to prevent wind damage
Serrated Slope 	Lowers velocity of surface runoff Collects sediment Holds moisture Minimizes amount of sediment reaching roadside ditch	May cause minor sloughing if water infiltrates Construction compliance

Treatment Practice	Advantages	Problems
FILL SLOPES		
Berms at Top of Embankment 	Prevent runoff from embankment surface from flowing over face of fill Collect runoff for slope drains or protected ditch Can be placed as a part of the normal construction operation and incorporated into fill or shoulders	Cooperation of construction operators to place final lifts at edge for shaping into berm Failure to compact outside lift when work is resumed Sediment buildup and berm failure
Slope Drains 	Prevent fill slope erosion caused by embankment surface runoff Can be constructed of full or half section pipe, bituminous, metal, concrete, plastic, or other waterproof material Can be extended as construction progresses May be either temporary or permanent	Permanent construction as needed may not be considered desirable by contractor Removal of temporary drains may disturb growing vegetation Energy dissipation devices are required at the outlets
Fill Berms or Benches 	Slows velocity of slope runoff Collects sediment Provides access for maintenance Collects water for slope drains May utilize waste	Requires additional fill material if waste is not available May cause sloughing Additional ROW may be needed
Seeding/Mulching	Timely application of mulch and seeding decreases the period a slope is subject to severe erosion Mulch that is cut in or otherwise anchored will collect sediment. The furrows made will also hold water and sediment	Seeding season may not be favorable Not 100 percent effective in preventing erision Watering may be necessary Steep slopes or locations with low velocities may require supplemental treatment
PROTECTION OF ADJACENT PROPERTY		
Brush Barriers 	Use slashing and logs from clearing operation Can be covered and seeded rather than removed Eliminates need for burning or disposal off ROW	May be considered unsightly in urban areas
Straw Bale Barriers 	Straw is readily available in many areas When properly installed, they filter sediment and some turbidity from runoff	Require removal Subject to vandal damage Flow is slow through straw requiring considerable area
Sediment Traps 	Collect much of the sediment spill from fill slopes and storm drain ditches Inexpensive Can be cleaned and expanded to meet need	Do not eliminate all sediment and turbidity Space is not always available Must be removed (usually)
Sediment Pools 	Can be designed to handle large volumes of flow Both sediment and turbidity are removed May be incorporated into permanent erosion control plan	Require prior planning, additional ROW and/or flow easement If removal is necessary, can present a major effort during final construction stage Clean-out volumes can be large Access for clean-out not always convenient

Treatment Practice	Advantages	Problems
ROADWAY DITCHES		
Check Dams 	Maintain low velocities Catch sediment Can be constructed of logs, shot rock, lumber, masonry or concrete	Close spacing on steep grades Require clean-out Unless keyed at sides and bottom, erosion may occur
Sediment Traps/ Straw Bale Filters 	Can be located as necessary to collect sediment during construction Clean-out often can be done with on-the-job equipment Simple to construct	Little direction on spacing and size Sediment disposal may be difficult Specification must include provisions for periodic clean-out May require seeding, sodding or pavement when removed during final cleanup
Sodding 	Easy to place with a minimum of preparation Can be repaired during construction Immediate protection May be used on sides of paved ditches to provide increased capacity	Requires water during first few weeks Sod not always available Will not withstand high velocity or severe abrasion from sediment load
Seeding with Mulch and Matting 	Usually least expensive Effective for ditches with low velocity Easily placed in small quantities with inexperienced personnel	Will not withstand medium to high velocity
Paving, Riprap, Rubble	Effective for high velocities May be part of the permanent erosion control effort	Cannot always be placed when needed because of construction traffic and final grading and dressing Initial cost is high
ROADWAY SURFACE		
Crowning to Ditch or Sloping to Single Berm 	Directing the surface water to a prepared or protected ditch minimizes erosion.	None - should be part of good construction procedures
Compaction	The final lift of each day's work should be well compacted and bladed to drain to ditch or berm section. Loose or uncompacted material is more subject to erosion	None - should be part of good construction procedures
Aggregate Cover 	Minimizes surface erosion Permits construction traffic during adverse weather May be used as part of permanent base construction	Requires reworking and compaction if exposed for long periods of time Loss of surface aggregates can be anticipated
Seed/Mulch	Minimizes surface erosion	Must be removed or is lost when construction of pavement is commenced

Source: Highway Research Board

Treatment Practice	Advantages	Problems
PROTECTION OF ADJACENT PROPERTY (continued)		
Energy Dissipators 	Slow velocity to permit sediment collection and to minimize channel erosion off project	Collect debris and require cleaning Require special design and construction of large shot rock or other suitable material from project
Level Spreaders 	Convert collected channel or pipe flow back to sheet flow Avoid channel easements and construction off project Simple to construct	Adequate spreader length may not be available Sodding of overflow berm is usually required Must be a part of the permanent erosion control effort Maintenance forces must maintain spreader until no longer required
PROTECTION OF STREAM		
Construction Dike 	Permits work to continue during normal stream stages Controlled flooding can be accomplished during periods of inactivity	Usually requires pumping of work site water into sediment pond Subject to erosion from stream and from direct rainfall on dike
Cofferdam 	Work can be continued during most anticipated stream conditions Clear water can be pumped directly back into stream No material deposited in stream	Expensive
Temporary Stream Channel Change	Prepared channel keeps normal flows away from construction	New channel usually will require protection Stream must be returned to old channel and temporary channel refilled
Riprap	Sacked sand with cement or stone easy to stockpile and place Can be installed in increments as needed	Expensive
Temporary Culverts for Haul Roads 	Eliminate stream turbulence and turbidity Provide unobstructed passage for fish and other water life Capacity for normal flow can be provided with storm water flowing over the roadway	Space not always available without conflicting with permanent structure work May be expensive, especially for larger sizes of pipe Subject to washout
Rock-lined Low-Level Crossing 	Minimizes stream turbidity Inexpensive May also serve as ditch check or sediment trap	May not be fordable during rainstorms During periods of low flow passage of fish may be blocked

CHECKLIST FOR STORM DRAINAGE PLANS

A. DRAINAGE AREA MAP

1. Use 1"=200′ scale for onsite and 1"=400′ for creeks off site and show match lines between any two or more maps.
2. Show existing and proposed storm drains and inlets.
3. Indicate subareas for each alley, street and offsite areas.
4. Indicate contours on map for on and offsite.
5. Use design criteria as shown in design manual.
6. Indicate zoning on drainage area.
7. Show points of concentration.
8. Indicate runoff at all inlets, dead-end streets and alleys, or to adjacent additions or acreage.
9. Provide runoff calculations for all areas showing acreage, runoff coefficient, inlet time.
10. For cumulative runoff, show calculations.
11. Indicate all crests, sags and street and alley intersections with flow arrows.
12. Identify direction of north.
13. Show limits of 100-year flood plain on drainage area map.

B. PLAN PROFILE AND DETAIL SHEETS

1. Show plan and profile of all storm drains.
2. Specify Class III pipe unless otherwise noted in profile.
3. Provide inlets where street capacity is exceeded. Provide inlets where alley runoff exceeds intersecting street capacity.
4. Indicate property lines along storm drainage and show easements with dimensions.
5. Show all existing utilities in plan and profile of storm drains with elevations.
6. Indicate existing and proposed ground line and improvements on all street, alley, and storm drain profiles.
7. Show all hydraulics, velocity head changes, gradients, computations and profile outfall with typical section and computations. (See page 9 of text).
8. Show laterals on trunk profile with stations.
9. Indicate size of inlet on plan view, lateral size and flow line, paving station and top-of-curb elevation.
10. Indicate runoff concentrating at all inlets and direction of flow. Show runoff for all stub outs, pipes and intakes.
11. Show future streets and grades where applicable.
12. Do not use 90-degree turns on storm drains or outfall. Provide good alignment with junction structures or manholes (for small systems).

13. Discharge storm drains at the flow line of creeks and channels unless competent rock is present. Is Energy Dissipation necessary?
14. Show water surface at outfall of storm drain.
15. Where fill is proposed for trench cut in creeks or outfall ditches, specify compacted fill.
16. Use type "Y" or special "Y" inlets in ditches.
17. Where connections are made to existing storm drain, show computations of existing system when available.
18. Show pipe sizes in plan and profile.
19. Provide separate plan and profile for both storm drain and paving plans. The storm drain pipes should also be shown on paving plans with a dashed line.
20. Use heavier than Class III pipes where crossing railroads, deep fill and heavy loads.
21. Show details of all junction boxes, headwalls on storm drain, flumes and manholes when more than one pipe intersects the manhole or any other item not a standard detail.
22. All "Y"-inlets and inlets 10 feet or greater have a minimum 21" lateral and all smaller inlets have a minimum 18" lateral.
23. Provide headwalls for all storm drains at outfall.
24. Check the need for curbing at all alley turns and "T" intersections. Flatten grades ahead of turn and intersection.
25. Calculate hydraulic grade line for laterals and inlets to insure collection of storm water. For inlets, provide H.G.L. on profile for all profiled laterals with hydraulic data. Laterals longer than 80 feet require special analysis.
26. Where inlets are placed in alley, provide curbing for 10 feet on each side of inlet and on other side of alley, where the top of inlet elevation is even with high edge of alley pavement. The width between curbs shall be equal to or greater than 10 feet.
27. Use standard curb inlets in streets and alleys. Use recessed inlets in divided streets. Do not use grate or curb and grate inlet unless other solution is not available.
28. Provide 7 1/2-inch curb on alleys parallel to creek or channel on creek side of alley.
29. Indicate flow line elevations of storm drains on profile, show percent grade. Match top inside of pipe where adjacent to other size pipe.
30. Where laterals tie into trunk line, channel or creek, place at 60 degree angle with centerlines. Connect them so that the longitudinal centers intersect.
31. Show curve data for all storm drains.
32. Tie storm drain stationing with paving stations.
33. Do not flow storm water from streets into alleys.
34. On all dead-end streets and alleys, show grade out for drainage on the profiles and provide erosion control.

35. Specify concrete strength for all structures. The minimum allowable is 3600 p.s.i.
36. Where quantities of runoff are shown on plan or profile, indicate storm frequency design.
37. Provide sections for road, railroad and other ditches with profiles and hydraulic computations. Show design water surface on profile.
38. Investigation shall be made by the engineer to validate the adequacy of the storm drain outfall.
39. Do not use high velocities in storm drain design. The maximum discharge velocity should not exceed 8 f.p.s. in clay or 6 f.p.s. in sandy soil at the outfall.
40. Flumes may not be allowed unless specifically designated.
41. If time of concentration is different, provide the calculation for inlet time and pipe travel time. For inlet time calculations, use the Schaake, Geyer, and Knapp formula given in <u>Runoff Coefficients in the Rational Method,</u> Technical Report No. 1, Page 29, as developed in the Council-approved document, Hydrology and Hydraulic of <u>Flood Plain Studies for the City of Dallas</u>, PP V1127.
42. Provide lateral profiles for laterals exceeding 12 feet in length.
43. Proposed driveway turnouts must be 10 feet from any existing or proposed inlet.
44. Do not use bends for pipe sizes less than 30-inch diameter unless specifically authorized by the appropriate project engineer or project manager.

STATEMENTS

45. Any offsite drainage work or discharge to downstream property will require a letter of permission or easements. Submit field notes for offsite easement that may be required.
46. Provide written statement signed by a Professional Engineer acknowledging that he has analyzed the proposed storm drainage outfall effects on the adjoining property, and that the discharge will not adversely affect or jeopardize this property. Provide letter of acceptance from adjoining property owner, if post-development discharges exceed pre-development rates (Development Only).
47. Check for escarpment area restrictions. If in the Geologically Similar Areas, design in accordance with escarpment ordinance.

BRIDGES

48. Clear the lowest member of the bridges by 2 feet above the design water surface unless otherwise directed by the City.
49. Show geotechnical soil boring information on plans.
50. Show bridge sections upstream and downstream.

51. Provide hydraulic calculations on all sections.
52. Provide structural details and calculations with dead load deflection diagram.
53. Provide vertical and horizontal alignment.
54. Provide drainage area map and show all computations for runoff affecting a detention basin.
55. Provide a plot plan with existing and proposed contours for a detention basin and plan for structural measures.
56. Where earth embankment is proposed for impoundment, furnish a typical embankment section and specifications for fill; include profile for the structural outfall structure and geotechnical report.
57. Provide structural details and calculations for any item and geotechnical report not a standard detail.
58. Provide detention basin volume calculations and elevations versus storage curve.
59. Provide hydraulic calculations for outflow structure and elevation versus discharge curve for a detention basin.
60. Provide unit hydrograph routings, or modified rational, where permitted for 130 acres or less for a detention basin.

SECTION V - ADDENDUM

"FLOODWAY MANAGEMENT AREA"

This plat is approved by the Director of Public Works of the City of Dallas and accepted by the Owner, subject to the following conditions which shall be binding upon the owner, his heirs, grantees, successors, and assigns:

The "FLOODWAY MANAGEMENT AREAS" within the limits of this addition are to remain in a natural state, and will receive a "Natural Level of Maintenance", which defined, means the removal of fallen trees or other debris that would be an obstruction to drainage. No alterations or improvements are to be made in the "FLOODWAY MANAGEMENT AREAS" without written approval from the Director of Public Works.

Floodway Management Monuments shall be installed prior to filing of plat, along all rear or side lot lines that are adjacent to the creek per C.O.D. Drawing 424-109. The surveyor shall provide signed and sealed documentation that the Floodway Marker monuments have been installed prior to obtaining the signature of the Director of Public Works.

Ramon F. Miguez, P.E., Director of Public Works

REVISED: 08/28/87

FLOODWAY EASEMENT STATEMENT

This plat is approved by the Director of Public Works of the City of Dallas and accepted by the Owner, subject to the following conditions which shall be binding upon the Owner, his heirs, grantees. successors, and assigns:

The existing water courses, creek or creeks described as Floodway Easement traversing along Block ____________ within the limits of this addition, will remain as an open channel at all times and will be maintained by the individual owners of the lot or lots that are traversed by or adjacent to the drainage courses in Block ___________. The City of Dallas will not be responsible for the maintenance and operation of said water courses, creek or creeks or for any damage to private property or person that results from the flow of water along said creek, or for the control or erosion in the Floodway Easement.

No obstruction to the natural flow of stormwater run-off shall be permitted by filling or by construction of any type of dam, building, bridge, fence, walkway or any other structure within the Floodway Easements, as hereinafter defined in Block __________, unless approved by the Director of Public Works. Provided, however, it is understood that in the event it becomes necessary for the City of Dallas to erect any type of drainage structure in order to improve the storm drainage that may be occasioned by the streets and alleys in or adjacent to the subdivision, then in such event, the City of Dallas shall have the right to enter upon the Floodway Easement at any point, or points, to erect, construct and maintain any drainage facility deemed necessary for drainage purposes. Each property owner shall keep the Floodway Easements traversing or adjacent to his property clean and free of debris, silt, and any substance which would result in unsanitary conditions and the City of Dallas shall have the right of ingress and egress for the purpose of inspection and supervision of maintenance work by the property owner to alleviate any undesirable conditions which may occur.

The natural drainage channels and water courses through Block _________, as in the case of all natural channels are subject to stormwater overflow and natural bank erosion to an extent which cannot be definitely defined. The City of Dallas shall not be held liable for any damages of any nature resulting from the occurrence of these natural phenomena, nor resulting from the failure of any structure or structures, within the Floodway Easement.

The natural drainage channel crossing each lot is shown by the Floodway Easement line as shown on the plat.

Building areas outside the Floodway Easement line should be filled to a minimum elevation of __________. The minimum floor elevations on houses built within this subdivision shall be ____________.

Floodway Marker monuments shall be installed, delineating the proposed Floodway Easement line, prior to filing of plat, along all rear or side lot lines that are adjacent to the creek as per City of Dallas drawing 424-109. The surveyor shall provide signed and sealed documentation that the Floodway Marker monuments have been installed prior to obtaining the signature of the Director of Public Works.

____

Ramon F. Miguez, P.E., Director of Public Works

REVISED: 08/28/87

FLOODWAY EASEMENT STATEMENT
(within common areas)

This plat is approved by the Director of Public Works of the City of Dallas and accepted by the Owner, subject to the following conditions which shall be binding upon the Owner, his heirs, grantees, successors, and assigns:

The existing water courses, creek or creeks described as Floodway Easement traversing along Block ____________ within the limits of this addition, will remain as an open channel at all times and will be maintained by the Homeowners' Association and the individual owners of the lot or lots that are traversed by or adjacent to the drainage courses in Block ____________. The City of Dallas will not be responsible for the maintenance and operation of said water courses, creek or creeks or for any damage to private property or person that results from the flow of water along said creek, or for the control or erosion in the Floodway Easement.

No obstruction to the natural flow of stormwater run-off shall be permitted by filling or by construction of any type of dam, building, bridge, fence, walkway or any other structure within the Floodway Easements, as hereinafter defined in Block _________, unless approved by the Director of Public Works. Provided, however, it is understood that in the event it becomes necessary for the City of Dallas to erect any type of drainage structure in order to improve the storm drainage that may be occasioned by the streets and alleys in or adjacent to the subdivision, then in such event, the City of Dallas shall have the right to enter upon the Floodway Easement at any point, or points, to erect, construct and maintain any drainage facility deemed necessary for drainage purposed. The Homeowners' Association and each property owner shall keep the Floodway Easements traversing or adjacent to his property clean and free of debris, silt, and any substance which would result in unsanitary conditions and the City of Dallas shall have the right of ingress and egress for the purpose of inspection and supervision of maintenance work by the Homeowner's Association and the property owner to alleviate any undesirable conditions which may occur.

The natural drainage channels and water courses through Block _________, as in the case of all natural channels, are subject to stormwater overflow and natural bank erosion to an extent which cannot be definitely defined. The City of Dallas shall not be held liable for any damages of any nature resulting from the occurrence of these natural phenomena, nor resulting from the failure of any structure or structures, within the Floodway Easement.

The natural drainage channel crossing each lot is shown by the Floodway Easement line as shown on the plat.

Building areas outside the Floodway Easement line should be filled to a minimum elevation of ___________. The minimum floor elevations on houses built within this subdivision shall be ____________.

Floodway Marker monuments shall be installed, delineating the proposed Floodway Easement line, prior to filing of plat, along all rear or side lot lines that are adjacent to the creek as per City of Dallas drawing 424-109. The surveyor shall provide signed and sealed documentation that the Floodway Marker monuments have been installed prior to obtaining the signature of the Director of Public Works.

____

Ramon F. Miguez, P.E., Director of Public Works

REVISED:

DETENTION AREA EASEMENT

THIS PLAT IS APPROVED BY THE DIRECTOR OF PUBLIC WORKS OF THE CITY OF DALLAS AND ACCEPTED BY THE OWNER, SUBJECT TO THE FOLLOWING CONDITIONS WHICH SHALL BE BINDING UPON THE OWNER, HIS HEIRS, GRANTEES, SUCCESSORS, AND ASSIGNS:

THE PROPOSED DETENTION AREA(S) ALONG BLOCK__________ WITHIN THE LIMITS OF THIS ADDITION, WILL REMAIN AS DETENTION AREAS TO THE LINE AND GRADE SHOWN ON THE PLANS AT ALL TIMES AND WILL BE MAINTAINED BY THE INDIVIDUAL OWNERS OF THE LOT OR LOTS THAT ARE TRAVERSED BY OR ADJACENT TO THE DETENTION AREAS IN BLOCK________. THE CITY OF DALLAS WILL NOT BE RESPONSIBLE FOR THE MAINTENANCE AND OPERATION OF SAID DETENTION AREAS OR FOR ANY DAMAGE OR INJURY TO PRIVATE PROPERTY OR PERSON THAT RESULTS FROM THE FLOW OF WATER ALONG, INTO OR OUT OF SAID DETENTION AREAS, OR FOR THE CONTROL OF EROSION.

NO OBSTRUCTION TO THE NATURAL FLOW OF STORM WATER RUN-OFF SHALL BE PERMITTED BY FILLING OR BY CONSTRUCTION OF ANY TYPE OF DAM, BUILDING, BRIDGE, FENCE, WALKWAY OR ANY OTHER STRUCTURE WITHIN THE DESIGNATED DETENTION AREAS, AS HEREINAFTER DEFINED IN BLOCK __________, UNLESS APPROVED BY THE DIRECTOR OF PUBLIC WORKS. PROVIDED, HOWEVER, IT IS UNDERSTOOD THAT IN THE EVENT IT BECOMES NECESSARY FOR THE CITY OF DALLAS TO ERECT ANY TYPE OF DRAINAGE STRUCTURE IN ORDER TO IMPROVE THE STORM DRAINAGE THAT MAY BE OCCASIONED BY THE STREETS AND ALLEYS IN OR ADJACENT TO THE SUBDIVISIONS, THEN IN SUCH EVENT, THE CITY OF DALLAS SHALL HAVE THE RIGHT TO ENTER UPON THE DETENTION AREAS AT ANY POINT, OR POINTS TO ERECT, CONSTRUCT AND MAINTAIN ANY DRAINAGE FACILITY DEEMED NECESSARY FOR DRAINAGE PURPOSES. EACH PROPERTY OWNER SHALL KEEP THE DETENTION AREAS TRAVERSING OR ADJACENT TO HIS PROPERTY CLEAN AND FREE OF DEBRIS, SILT AND ANY SUBSTANCE WHICH WOULD RESULTS IN UNSANITARY CONDITIONS OR BLOCKAGE OF THE DRAINAGE. THE CITY OF DALLAS SHALL HAVE THE RIGHT OF INGRESS AND EGRESS FOR THE PURPOSE OF INSPECTION AND SUPERVISION OF MAINTENANCE WORK BY THE PROPERTY OWNER, OR TO ALLEVIATE ANY UNDESIRABLE CONDITIONS WHICH MAY OCCUR.

THE DETENTION AREA IN BLOCK ________, AS IN THE CASE OF ALL DETENTION AREAS ARE SUBJECT TO STORM WATER OVERFLOW TO AN EXTENT WHICH CANNOT BE CLEARLY DEFINED. THE CITY OF DALLAS SHALL NOT BE HELD LIABLE FOR ANY DAMAGES OF ANY NATURE RESULTING FOR THE OCCURRENCE OF THESE NATURAL PHENOMENA, NOR RESULTING FROM THE FAILURE OF ANY STRUCTURE OR STRUCTURES, WITHIN THE DETENTION AREAS OR THE SUBDIVISION STORM DRAINAGE SYSTEM.

THE DETENTION AREAS SERVING THE PLAT ARE SHOWN BY THE DETENTION AREA EASEMENT LINE AS SHOWN ON THE PLAT.

____

Ramon F. Miguez, P.E., Director of Public Works

NOW THEREFORE, KNOW ALL MEN BY THESE PRESENTS:
THAT I ______________________________ do hereby adopt this plat, designating the herein above described property as______________ ________________________an addition to the City of Dallas, Texas and do hereby dedicate, in fee simple, to the public use forever the streets, alleys, and Floodway Management areas shown thereon. The easement shown thereon are hereby reserved for the purposes indicated. The utility and fire lane easements shall be open to the public, fire and police units, garbage and rubbish collection agencies, and all public and private utilities for each particular use. The maintenance of paving on the utility and fire lane easements is the responsibility of the property owner. No buildings, fences, trees, shrubs or other improvements or growths shall be constructed, reconstructed or placed upon, over or across the easements as shown. Said easements being hereby reserved for the mutual use and accommodation of all public utilities using or desiring to use same. All, and any public utility shall have the right to remove and keep removed all or parts of any buildings, fences, trees, shrubs or other improvements or growths which in any way may endanger or interfere with the construction, maintenance or efficiency of its respective system on the easements and all public utilities shall at all times have the full right of ingress and egress to or from and upon the said easements for the purpose of constructing, reconstructing, inspecting, patrolling, maintaining and adding to or removing all or parts of its respective systems without the necessity at any time or procuring the permission of anyone. (Any public utility shall have the right of ingress and egress to private property for the purpose of reading meters and any maintenance or service required or ordinarily performed by that utility.)

Water main and sanitary sewer easements shall also include additional area of working space for construction and maintenance of the systems. Additional easement area is also conveyed for installation and maintenance of manholes, cleanouts, fire hydrants, water services and sewer services from the main to the curb or pavement line, and description of such additional easements herein granted shall be determined by their location as installed.

This plat approved subject to all platting ordinances, rules, regulations and resolutions of the City of Dallas, Texas. Sidewalks shall be constructed by the builder as required by City Council Resolution No. 68-1038 and in accordance with the requirements of the Director of Public Works.

WITNESS, my hand at Dallas, Texas, this the _____________ day of _____________ 199____.

By:

____

Authorized Signature

Memorandum

CITY OF DALLAS

DATE May 28, 1986

TO Fred Timm, Subdivision Administrator
Department of Planning & Development

SUBJECT Floodway Easement Acceptance

As per our discussion on Friday, May 23, 1986, regarding the replat of Lot 1, Block 6/6740 of Bruton Terrace No. 15, I have drafted the following paragraph which should be placed in the signature block language on the plat. This paragraph adopts the floodway easement statement which is shown elsewhere on the plat. This paragraph should be inserted between the first paragraph and the second paragraph of the current signature block language.

The new paragraph reads as follows:

> Notwithstanding the general easement language recited above, the floodway easement shown on this plat is hereby dedicated to the public use forever, and may not be used in a manner inconsistent with the FLOODWAY EASEMENT STATEMENT recited on this plat, which statement is hereby adopted and accepted."

This paragraph should be inserted in the signature block language any time the floodway easement statement appears on a plat. It has also come to my attention that the department of public works may place similar statements on plats regarding retention basins, drainage basins, and floodway management areas. A paragraph in the signature block referring to the "easements" is imperative to carrying out the intent of the "statements" by the department of public works since it must be the owner of the property that grants easements and subjects the property to conditions.

Should you have any questions regarding this memo, please contact me.

THOMAS H. KEEN
Assistant City Attorney

0019R/87

SUBMITTAL OF FLOODWAY STATEMENTS FOR DIRECTOR'S SIGNATURE

When a parcel being platted contains a floodway or detention area, a dedication statement must be included on the plat and signed by the Director of Public Works before the plat may be filed with the County. The following guidelines should be observed to expedite the process of acquiring the Director's signature:

1. Planning and Development must have a release from all twenty-six reviewing parties before plat is submitted for signing.

2. All mylars and blacklines submitted for Director's signature must have original signatures of the owner, surveyor and notary with required seals affixed.

3. The appropriate floodway statements must be used. Floodway Management areas must be dedicated along R, D and TH Districts. Floodway Easements are used elsewhere. Floodway Easements within Common Areas may be used in residential areas where there is a corporate entity of record (Homeowner's Association) in existence to maintain the floodway. Any exceptions must be approved by Stormwater Management.

4. When a Floodway or Detention Easement is dedicated, the owner's dedication statement must include the easement "acceptance statement". The text for this additional paragraph may be obtained from City Planning or Development Activities.

5. Floodway or detention dedication statements must be current. Check with Development Activities at _______ for any revisions to the statements.

6. Floodway marker monuments must be installed prior to submission for signature.

7. Minimum fill and floor elevations must be shown on the plat and/or given in the statement.

8. Blueline copies may only used for plats being filed with Denton County.

Plats must be submitted to Development Activities division of Public Works and will then be routed to the Director of Public Works.

Contact ____________ at ________ for any additional information.

DETENTION BASIN DESIGN
ACCESS/MAINTENANCE REQUIREMENTS

When proposed detention basins are to be maintained by the City of Dallas, the following requirements shall be considered during the design and construction:

1. Access - access from an adjacent street will be constructed to the detention basin and the outlet structure for normal removal of debris and desiltation. The access will be of a level cross-section, 15 feet in width, maximum 6:1 grade, sloped to drain, and positioned outside of and at least 3 feet above the detention basin floor. If access is between platted lots, concrete paving (to City alley standards) will be required. Rock (e.g., caliche, mixed crushed rock less than 3 inch, or other suitable material) a minimum of 10 inch in depth may be compacted to form an all weather driving surface in other locations.

2. Fencing - guardrail will be installed between streets and detention basins when distance is less than 20 feet. Fencing of the detention easement will not be required on those portions adjacent to a platted lot(s). Chain link fencing will be placed on any portion of the boundary not adjacent to platted lots. Detention easements which do not have a normal pool level may be delineated using post and cable in lieu of the fencing. This is to delineate the easement and control unauthorized access.

3. Access points from streets will be controlled by a locked chain or gate.

4. The developer will be responsible for maintenance of the basin until all construction on adjacent lots is complete (i.e., the basin is not to be used for disposal of waste building materials), required vegetation is established, and it has been accepted by the City.

5. Concrete paved low flow channels will be used to control meandering and minimize erosion.

6. Concrete aprons and wingwalls will be used at all outlet structures.

7. All pipes discharging into a detention basin will be discharged at the basin's flowline with adequate erosion control.

8. The following slope protection guidelines will be used.

   flatter than 3:1 - established vegetation
   steeper than 3:1 - concrete or gabions

APPROVED SOURCE LIST

1. Hydrology and Hydraulics of Flood Plain Studies for the City of Dallas
2. Escarpment Ordinance
3. City Code
4. Flood Plain Ordinance
5. Standard Details (251-D)
6. City of Dallas Plat Regulations