APPENDIX I

MANHATTAN, KANSAS

STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

100% EMPLOYEE - OWNED Burns & McDonnell ENGINEERS - ARCHITECTS - CONSULTANTS

BG CONSULTANTS, INC.
Engineers-Architects-Surveyors

MAY 1994

CITY OF MANHATTAN, KANSAS
STORMWATER MANAGEMENT CRITERIA

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1.0 GENERAL

1.1 Introduction: This document provides uniform procedures for designing and checking the design of storm drainage systems under the rainfall and land characteristics typical of Manhattan, Kansas. Specific criteria have been developed and are applicable to the types of drainage systems and facilities ordinarily encountered in local urban and suburban areas. Other special situations may be encountered that require added criteria or more complex technology than included herein. Any design procedure conforming to current accepted engineering practice, including the application of computers, may be used for the design of storm drainage systems in lieu of the computation methods presented in these criteria providing equivalent results are obtained.

1.2 Applicability: These criteria are applicable to all new storm drainage systems and facilities and to the rehabilitation of existing drainage system facilities.

1.3 General Requirements: The design shall be accomplished under the direction of a Registered Professional Engineer. The design shall also be based on land use in the tributary area as zoned, actually developed, or indicated by the City's current comprehensive land use plan, whichever basis produces the greatest runoff.

1.4 Definitions:

A. **Bank Line:** The line of intersection, above the normal depth of flow at design capacity, of the side slope of an open channel and the adjacent ground.

B. **City:** The municipality or body having jurisdiction and authority to govern.

C. **City Engineer:** The municipal engineer having jurisdiction and authority to review and approve plans and designs for storm drainage systems.

D. **Developer:** Any person, partnership, association, corporation, public agency, or governmental unit proposing to engage or currently engaged in "development" as defined below excluding the widening, resurfacing, or other improvement to existing streets, alleys, and sidewalks.

E. **Development:** Any activity, including construction of a subdivision, that alters the surface of the land to create additional impervious surfaces, including, but not limited to, pavement, buildings, and structures. Exceptions to these activities include:

1. Additions to, improvements, and repair of existing single-family and duplex dwellings.
2. Construction of any buildings, structures, and/or appurtenant service roads, drives, and walks on a site having previously provided storm water control as part of a larger unit of development.
3. Remodeling, repair, replacement, and improvements to any existing structure or facility and appurtenances that does not cause an increased area of impervious surface on the site in excess of 10 percent of that previously existing.
4. Improvements on any site having a gross land area of one-half acre or less, regardless of land use.
5. Construction of any one new single-family or duplex dwelling unit, irrespective of the site area on which the same may be situated.

F. **Easement**: Authorization by a property owner for the use by another for a specified purpose, of any designated part of the property.

G. **Floodplain**: The normally dry land adjoining rivers, streams, lakes or other bodies of water that is inundated during flood events. In order to provide a standard national procedure for floodplain management, the U.S. Federal Emergency Management Agency (FEMA) has adopted the 100-year flood as the base flood.

H. **Floodway**: The channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment in order for the 100-year flood to be carried without substantial increase in flood heights. FEMA's minimum standards allow an increase in flood height of 1.0 foot.

I. **Flowage Easement**: Easement acquired for the right to periodically use an open channel and its overbank floodway, or the overflow channel above an enclosed system element, to convey drainage. Flowage easements preclude any improvement to the land occupied by the easement.

I. **Freeboard**: The difference in elevation between the top of a structure, such as a dam or open channel, and the maximum design water surface elevation or high water mark. It is an allowance against overtopping by waves or other transient disturbances.

J. **Improved Channel**: Any channel constructed or changed by grading or by the construction of lining materials.

K. **Natural Channel**: An existing channel that has not been altered by previous construction.

L. **Owner**: The owner of record of real property.

M. **Registered Professional Engineer**: A licensed engineer who is registered with and authorized by the "State Board" to practice within the state of registration.

N. **Return Period:** Also referred to as return frequency or recurrence interval. A statistical term for the average frequency that a given event may be expected to occur although it does not imply that the event will occur regularly at even intervals. It can also be defined as the reciprocal of the probability of an event. i.e. A 50-year storm has a probability of 0.02 (2%) of occurring in any given year.

O. **Site:** A tract, or contiguous tracts, of land owned and/or controlled by a developer or owner. Platted subdivisions, industrial and/or office-commercial parks, and other planned unit developments shall be considered a single site.

P. **Storm Drainage System:** All of the natural and man-made facilities and appurtenances such as ditches, natural channels, pipes, culverts, bridges, open improved channels, street gutters, inlets, and detention facilities which serve to convey surface drainage.

Q. **Storm Water Detention Facility:** Any structure, device, or combination thereof with a controlled discharge rate less than its inflow rate.

1. Controlled Area: That part of the tributary area for which a detention facility is designed to control peak discharge rates.
2. Detention Storage: The volume occupied by water between the levels of the principal and emergency spillway crests during operation of the facility.
3. Dry Detention Facility: Any detention facility designed to permit no permanent impoundment of water.
4. Emergency Spillway: A device or devices used to discharge water under conditions of inflow that exceed the design inflow. The emergency spillway functions primarily to prevent damage to the detention facility that would permit the sudden release of impounded water.
5. Principal Spillway: A device such as an inlet, pipe, weir, etc., used to discharge water during operation of the facility under the conditions of the 100-year or less return frequency.
6. Private Detention Facility: Any detention facility located on a site wholly owned and controlled by one owner or entity and not platted for future subdivision of ownership. Also, all facilities incorporating detention storage of storm water in or on any of the following:

    a. Roofs of buildings or structures also used for other purposes.
    b. Paved or surfaced areas also used for other purposes.
    c. Enclosed underground pipes or structures on private property when the surface is used for other purposes.

7. Public Detention Facility: Any detention facility controlling discharge from a tributary area owned by more than one owner and/or platted for future subdivision of ownership, except as defined as a private detention facility herein.

8. Sediment Storage: The volume allocated to contain accumulated sediments within the detention facility.

9. Wet Detention Facility: A detention facility that is designed to include permanent storage of water in addition to the temporary storage used to control discharge rates from the facility.

R. **Tributary Area**: All land draining to the point of consideration, regardless of ownership.

1.5 **Return Frequencies**: All enclosed and improved open channel conveyance system components shall be designed for the 10-year return period peak flow or the capacity of the existing upstream improved system, whichever is greater with the following exceptions:

1. Facilities located within the floodway of the 100-year flood shall be designed for the 100-year peak flow.
2. Bridges, pipes and culverts crossing arterial streets shall be designed for the 50-year peak flow, unless subject to the requirements of No. 1, above.

1.6 **System Types and Applications:**

A. **Enclosed Pipe-Inlet Systems**: Enclosed systems consisting of underground pipes, culverts, curb inlets and similar functional underground structures <u>shall</u> be used to convey stormwater under the following conditions.

1. Within the right-of-way of improved streets, regardless of system design capacity.
2. In all areas:
   a. Where the design peak discharge of a 10-year return period storm is less than 200 cubic feet per second (CFS).
   b. Where the bank line of an open channel, either natural or improved, would be within 30 feet of any existing or proposed habitable structure, regardless of system design capacity.
4. In residential areas:
   a. Where more than one lot or ownership tract is tributary and the 10-year peak discharge equals or exceeds 8 CFS.
   b. Where the bank line of an open channel, either natural or improved, would be within 60 feet of any existing or proposed residential structure.

Enclosed systems may be used to convey stormwater at all locations where open systems are permitted.

B. **Improved Channels**: Open systems consisting of improved open channels with intermittent culverts or bridges crossing streets and other surfaced areas may be used to convey stormwater in:

1. All areas where the 10-year design discharge is greater than or equal to 200 CFS.
2. All areas other than residential where bank lines are 30 feet or more from any habitable structure.
3. Residential areas where bank lines are 60 feet or more from any residential structure.

Lining of an improved channel is required in all developed areas where the 10-year design discharge is equal to or greater than 200 CFS and less than or equal to 500 CFS.

C. **Natural Channels:** Existing natural channels may be retained in the drainage system of a developed area where the 10-year design discharge is equal to or greater than 500 CFS and flow velocity of the 1-year peak discharge does not exceed the following based on soils present in the channel bed and bank.

Soil Type	Max. Velocity of 1-yr. Peak Flow (FPS)
Fine sand, sandy loam	2
Silt loam, noncolloidal silts	3
Colloidal clays & silts, fine gravel	4
Coarse gravel, cobbles	5
Shale	6
Limestone bedrock	15

D. **Overflow Systems:** As an integral part of the stormwater drainage system, whether enclosed or open, overflow channels shall be required in all areas in addition to, and above, the 10-year conveyance elements. Each overflow component shall have sufficient hydraulic capacity, when combined with the capacity of the conveyance element, to convey the 100-year peak discharge without damage to land or buildings.

1. The combined conveyance system shall provide sufficient capacity so that the 100-year stage, plus one foot of freeboard, is at an elevation equal to or below the lowest elevation at which water may enter any proposed or existing building or structure.
2. An overflow depth not exceeding seven (7) inches at the lowest point of the travelled way will be permitted where culverts cross streets.
3. Permissible concurrent surface uses of overflow areas include lawns, gardens or other open uses; vehicular parking; or any other use not permanently obstructing the floodway.
4. Prohibited concurrent surface uses include fencing; structures such as sheds, garages or outbuildings; materials storage; or any other use obstructing the floodway.

E. **Stormwater Detention Facilities:** Detention facilities shall be provided in connection with the development of land where such facilities are recommended by the City's current Stormwater Management Master Plan.

1. Performance requirements shall be based on maximum release rates as outlined in Section 7.2.
2. Public and private detention facilities may be either wet or dry. Joint uses, such as parking and recreation, not interfering with detention functions are permitted for dry facilities.

1.7 **Existing Drainage System:** Existing drainage system component pipes, structures, and appurtenances within the project limits may be retained as elements of an improved system providing:

1. They are in sound structural condition.
2. Their hydraulic capacity, including surcharge, is equal to or greater than the capacity required by these criteria.
3. Easements exist or are dedicated to allow operation and maintenance.

Discharge from an existing upstream storm drainage system shall be computed in accordance with the requirements of these criteria. The computed discharge shall be used to design the new downstream system even though the actual capacity of the existing upstream system may be less.

1.8 **Waivers:** The City Engineer may waive specific criteria or requirements to provide specific types of stormwater facilities as follows:

A. **Detention Facilities:** Provision to provide detention, if required by the City's Stormwater Management Master Plan, may be waived and/or release rates other than those required by Section 9.2 may be approved when the developer makes satisfactory arrangements to improve or provide a downstream conveyance system of hydraulic capacity meeting these criteria for peak rates of discharge to the system, including discharge from the developer's site. The City Engineer may also permit combined downstream conveyance system improvements and other detention combinations that provide an equal or better level of control.

B. **Study:** The Developer provides an adequate study by a registered professional engineer that quantifies the problems and demonstrates that a waiver of a specific requirement is appropriate.

C. **Overflow Channels:** In previously developed areas, requirements to provide for 100-year storm conveyance by means of overflow channels may be reduced in circumstances where 100-year protection is not reasonably attainable due to the location of damageable improvements with respect to the drainage system.

1.9 **Other References:** Other agencies have technical and administrative criteria and regulations pertaining to the design, permitting and operation of drainage systems which are in addition to and which may complement these criteria. When conflicts are encountered, the most rigorous criteria shall govern.

A. **Federal Insurance Agency - Floodplain Regulations and Implementing Ordinances Adopted By Municipalities:** Drainage systems designed within the limits of the designated 100-year floodplain on the principal stream shall be designed to convey the flood as defined by applicable published floodplain information studies. For areas located in FIA Zone "A" outside the detailed study area, the developer shall prepare studies and calculations establishing the floodplain, elevation and width. These calculations shall be submitted to the reviewing agency for approval.

B. **Kansas Department of Agriculture**: Rules and regulations of the Division of Water Resources dealing with such issues as stream obstructions, channel changes, dams, and permits shall apply.

2.0 HYDROLOGIC CRITERIA AND METHODS

2.1 **Scope**: This section sets forth the hydrologic methods and parameters to be used for computations of runoff and peak rates to be accommodated by the storm drainage system.

2.2 **Computation Methods for Runoff**: Runoff rates to be accommodated by each element of the proposed storm drainage system shall be calculated using the criteria for land use runoff factors, rainfall, and system time outlined in the following sections. The following alternative computation methods are acceptable. Other methods, including computer models, may be utilized so long as they produce calculated runoff to the system that is substantially the same as that calculated by the following criteria.

A. **Rational Method**: The Rational Method may be used to calculate peak rates of runoff to elements of enclosed and open channel systems, including inlets, when the total upstream area tributary to the point of consideration is less than 300 acres or to detention facilities with tributary areas of less than 10 acres. The Rational Method is defined as follows:

$Q = C\ i\ A$, where

Q = Peak rate of runoff to system in C.F.S.

C = Runoff coefficient

i = Rainfall intensity in inches per hour

A = Tributary drainage area in acres

Rainfall intensity, used only for the Rational Method, shall be as indicated in Table A corresponding to the calculated time of concentration.

B. **Hydrograph Methods**: The application of hydrograph methods is required for all conveyance systems having greater than 300 tributary acres and for all detention facilities having greater than 10 tributary acres. Computer models or manual methods are permissible.

1. Acceptable computer models
   a. SCS Technical Release No. 55 (TR-55) - "Urban Hydrology for Small Watersheds," 2nd. Edition, June, 1986.
   b. SCS Technical Release No. 20 - "Project Formulation - Hydrology", 2nd Edition, May 1983.
   c. U.S. Army Corps of Engineers, Hydrologic Engineering Center- "HEC-1 Flood Hydrograph Package," Version 4.0, September, 1990.

   Copies of the above are available for purchase through National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA., 22161. The HEC-1 and TR-55 packages are also available through PC-TRANS Software Distribution Service, University of Kansas Transportation Center, 2011 Learned Hall, Lawrence, Kansas, 66045.

2. Acceptable manual methods shall include sequential calculation of the mass (in cubic or acre-feet) and the peak rate (in CFS) of runoff at 5-minute increments for:
   a. Direct surface runoff.
   b. Routed hydrographs at each point of interest on both enclosed and open channel systems using the "storage indication" method.
   c. Inflow hydrographs to each detention facility.
   d. Storage volume and elevation in each detention facility.
   e. Discharge hydrographs from each detention facility.

   The Rainfall Mass Hyetograph for use with manual methods is indicated in Table B.

2.3 **Runoff Coefficients**: Runoff coefficients relative to development and land use shall be as indicated in Table C. The indicated "C" values are applicable to the Rational Method and the "CN" values to hydrograph methods.

Coefficients shall be based on the more runoff-intensive surface condition of either planned future land use or existing developed land use. Future land use shall be defined by the City's adopted comprehensive land use plan.

Undeveloped areas not zoned, but for which future land use is defined by the City's land use plan, shall be assigned runoff coefficients for the land use indicated by such plan. Undeveloped areas designated as agricultural or those for which no specific future land use is indicated shall be assigned a minimum of 35 percent impervious surface for purposes of the design of storm drainage systems.

As an alternative to the coefficients and for areas not listed in Table C, a composite runoff coefficient based on the actual percentages of pervious and impervious surfaces shall be used.

2.4 **Time of Concentration (Tc):** The time of concentration, TC, shall be calculated as the sum of the overland flow time, the shallow concentrated flow time and the system flow (travel) time.

A. **Overland Flow Time:** Determined from Figure 1. The maximum sheet flow distance for calculations shall not be greater than 300 feet.

B. **Shallow Concentrated Flow Time:** Determined from Table D or E. The maximum shallow concentrated flow distance for calculations shall not be greater than 400 feet. Shallow concentrated flow includes flow along side and rear lot swales and overland surfaces with no defined channel beginning at the point that the flow length exceeds 300 feet.

C. **System Flow (Travel) Time:** Determined from Figure 2. The "system" includes flow in street gutters; street ditches; enclosed pipe or box storm sewers; and improved or natural open channels. System flow time shall not be less than 5.0 minutes regardless of the calculated time.

To provide for future development when the upstream channel is unimproved, the following table shall be used for calculating system flow time. The time shall be calculated as the length of travel in the system divided by the velocity of flow.

AVERAGE CHANNEL SLOPE, PERCENT	VELOCITY IN FT/SEC
<2	7
2 TO 5	10
>5	15

D. **Lag Time:** For use in the HEC-1 computer model, lag time shall be equal to 0.6 * Time of Concentration.

3.0 EASEMENTS

3.1 **General Requirements:** Developers shall be required to dedicate (plat) easements for all system components to be maintained by the City including enclosed pipe systems, improved channels, and public detention facilities as well as maintenance access connections to street rights-of-way. Easements are also required, although not for City maintenance purposes, along open channels and around private detention facilities as indicated below and in all other areas deemed necessary by the City Engineer.

3.2 **Permanent Drainage Easement Requirements:**

A. **Enclosed Systems:** 15 feet minimum width or the structure/pipe O.D. plus 6 feet on each side.

B. **Improved Channels:** 30 feet minimum width or the top of bank width plus 10 feet on each side. The top of one bank shall have a 10-foot wide strip graded for vehicle access with a maximum slope of 12 percent perpendicular to the contours.

C. **Detention Facilities:** 15 feet clear of any structure and 10 feet clear around the perimeter of the greatest of 1) the top of bank lines, 2) the 100-year water-surface contour, or 3) 1 foot outside of security fences.

3.3 **Access Easements:** Access easements for maintenance shall be connected to public street rights-of-way and shall not be spaced greater than 800 feet apart, measured along the permanent easement. The maximum slope perpendicular to the contours shall be 12 percent. Access easements shall extend to the bottom of all improved channels with bottom widths greater than 7 feet and to the top of bank for narrower channels. These easements may overlay other permanent easements subject to maximum grade requirements.

3.4 **Flowage Easements:** Flowage easements shall be required in addition to and overlaying other permanent easements where applicable, including other public and private utility easements, where the 10-year peak discharge exceeds 100 CFS. The flowage easement shall cover the overflow area for the conveyance element, whether open channel or enclosed system, determined as the 100-year flood elevation plus one foot. Flood elevations shall be on file with the City and easement lines indicated on plats or permit plans. Limitations on permanent obstructions shall be included in the dedication with all other concurrent uses reserved to the property owner.

3.5 **Natural Channels:** For natural channels retained in the storm drainage system, permanent easements for undeveloped green space including the channel itself, shall be platted at a width of 60 feet, or the average bottom width of the channel plus, on each side, three times the bank height (top to toe) plus 10 feet, whichever is greater. (See Figure 3 for illustration.) These easements will be dedicated to the City but maintenance of the green space and the channel will be the responsibility of the individual property owner.

4.0 HYDRAULIC CALCULATION METHODS

4.1 **Pipes and Open Channels:** Flow shall be calculated by Manning's equation.

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

Q = Discharge in cubic feet per second.

A = Cross sectional area of flow in square feet.

n = Roughness Coefficient (see Table F).

R = Hydraulic radius (R = A/P) in feet.

S = Slope in feet per foot.

P = Wetted perimeter in feet.

Head losses, except friction losses, shall be calculated by

$h = k (V^2/2g)^{1/2}$ where:

h = Head loss in feet.

V = Velocity of flow in feet per second at point of interest.

2g = 64.4 feet per second per second.

k = Coefficient as shown in Table G.

4.2 **Street Gutters:** Flow shall be determined from Figure 4, Figure 5, or Figure 6 as applicable for the standard street section being used. In cases where a standard street section is not used, flow shall be calculated by Izzard's formula, below. (See Figure 7 for graphical solution.)

$$Q = \frac{0.56 (z) (S^{1/2})(D^{8/3})}{n}$$ where:

Q = The gutter flow in cubic feet per second.

Z = The reciprocal of the average cross-slope, including gutter section in feet per foot.

S = The longitudinal street grade in feet per foot.

D = The depth of flow at curb face in feet.

n = Manning's "n" as shown in Table F.

The following formula shall be used to determine the street grade (Sx) at any point on a vertical curve for use in calculating gutter flow. Grades shall be "plus" when ascending forward and "minus" when descending forward with all grades in feet per foot.

$$Sx = S1 + \frac{X}{L} (S2 - S1)$$ where:

Sx = The street grade on a vertical curve at point x.

S1 = The street grade at the PC of a vertical curve.

S2 = The street grade at the PT of a vertical curve.

X = The distance, in feet, from the PC of the curve to point x.

L = The total length of a vertical curve, in feet.

4.3 **Head Losses:** The following values for head losses in inlets, manholes and junction boxes may be used for design.

Structure	Head Loss (Ft.)
Inlet - One exit pipe only	0.5
Inlet - Thru flow @ less than 45° angle (one entry & one exit line)	0.1
Inlet - Thru flow @ greater than 45° angle (one entry & one exit line)	0.2
Inlet - Two or more entering lines	0.3

4.4 **Culverts:** Culvert flow capacity shall be calculated using Figures 8.1 through 9.6 as applicable to particular installation conditions.

4.5 **Computer Methods:** Computer models may be used for hydraulic calculations. For open channels the following models are permissible.

1. U.S. Army Corps of Engineers, Hydrologic Engineering Center-"HEC-2 Water Surface Profiles"
2. Federal Highway Administration - "HY-7 WSPRO - A Computer Model for Water Surface Profile Computations"

5.0 ENCLOSED SYSTEM DESIGN

5.1 **General Requirements:** All enclosed drainage system components (pipes, culverts and structures except bridges) shall be structurally designed for an H-20 live load, a unit weight of 120 pcf for soil cover, and minimum lateral earth pressure of 40 pcf equivalent fluid pressure. The lateral earth pressure shall be increased as necessary for special conditions when present on a project.

5.2 **Pipes and Culverts:**

A. **Minimum Cover:** Minimum cover over all pipes and culverts shall be equal to 1.5 feet.

B. **Minimum Size:** Minimum pipe size shall be 15-inch diameter.

C. **Downstream Conduit Size:** Conduit sizes, based on square feet of end area shall not decrease from upstream to downstream regardless of the calculated capacity of each conduit.

D. **Surcharge:** Surcharging of pipes under entrance control is permitted in structures subject to freeboard criteria for the structure and provision for pressure joints throughout the surcharged lengths.

E. **Pipe Slopes:** Minimum invert slopes shall conform to the following:

Pipe Dia. (in.)	Min. Invert Slope (%) for Round or Arch Pipe RCP	CSP
12	1.9	3.5
15	1.4	2.6
18	1.1	2.0
21	0.9	1.6
24	0.8	1.4
30	0.6	1.0
36	0.4	0.8
42	0.4	0.7
48	0.3	0.5
54	0.3	0.5
60	0.2	0.4
66	0.2	0.4
72	0.2	0.3

5.3 **Inlets:**

A. **Inlet Types:** Only Type "A" Curb Inlets shall be permitted in street installations. (See Figure 12 for standard plan.) Gutter castings or deflectors will be required for all inlets except in sump conditions. In off-street locations, only grated area-type inlets sized and designed for the specific location shall be permitted.

B. **Configuration:** In street installations, the following dimensions apply to curb inlets.

Clear opening length	5.0 ft (min)
Clear opening height	5.0 in (min)
Clear inside width, perpendicular to curb line	3.0 ft (min)
Gutter depression depth at inlet	4.0 in (min)
Gutter transition length	
(a) Both sides in sump and upstream side on slopes	5.0 ft (min)
(b) Downstream side on slopes	3.0 ft (min)

C. **Capacity:** Inlet hydraulic capacity for new construction shall be determined from Figure 13 for curb-opening inlets on slopes and from Figure 14 for curb-opening inlets in sumps. For area inlets in off-street locations, submit calculations based on specific inlet configuration, size, etc.

For calculation of bypass (carryover) from an existing upstream system, the hydraulic capacity of the existing inlets may be determined from Figure 22 for grated inlets in sumps and from Figures 23 through 25 for combination inlets where existing inlets are of the applicable type.

D. **Location Requirements:** Inlets shall be located along streets as required to limit the depth of flow in the gutters during the 10-year discharge to 0.35 feet, equal to the crown of a standard 31-foot street section. This depth limitation shall apply in all cases to wider arterial streets allowing a water-free driving lane near the centerline of the street.

In residential areas, cross flow over the crown will be allowed if both gutters are not flowing at the 0.35-foot depth and at sump locations, the allowable depth of ponded water shall be increased to 0.5 foot. Gutter flows equal to curb depth will be allowed in residential areas for storms of greater magnitude than the 10-year storm; however, the 0.35-foot depth limitation will be required on residential streets at or near their intersection with arterial streets.

The relationship of flow, velocity, street slope and gutter spread for the standard street sections may be determined from Figures 4 through 6.

E. **Freeboard Requirements:** At inlets and other points of surface water entry into the enclosed drainage system, a minimum of 0.5-ft. shall be required between the peak design water surface elevation in the structure and the lowest elevation of the inlet opening. (Figure 15 illustrates the freeboard requirement.) The water surface elevation in the structure shall be calculated as follows:

1. Invert elevation of the exit/outlet line (pipe), plus;
2. Depth (diameter) of the exit/outlet line (pipe), plus;
3. Minor losses, "h".

Minor losses shall be calculated by the equation, $h = k * (V^2/2g)$ where the coefficient "k" is determined from Table G and "V" is the velocity of the exiting line determined by dividing the flow, Q, by the area, A, of the exiting line.

F. **Other Requirements:**

1. A minimum drop across the invert of inlets, manholes and junction boxes shall be required as follows.

For flow angle change equal to or less than 30°	0.1 ft.
For flow angle change greater than 30°	0.2 ft.

For three or more lines, all flow angles, 0.3 ft.

2. The crown elevation(s) of pipe(s) entering a structure shall be at or above the crown of the pipe exiting the structure.

6.0 STREET CROSSINGS

6.1 General Requirements: The following requirements apply both to culverts and/or bridges on open channels and to enclosed system conduits which cross arterial streets.

A. Hydraulic Capacity: The hydraulic capacity of the culvert or conduit shall be the 50-year peak discharge with 0.5 ft. minimum freeboard at the lowest point in the street gutter grade. The capacity of the culvert or conduit shall be increased as required to provide the 0.5-ft. minimum freeboard below the lowest point of entry to any existing upstream habitable structure.

B. Overflow: Overflow of the street is permitted at the 100-year peak discharge with the depth of flow over the street not to exceed 0.6 ft.

6.2 Enclosed Systems: In addition to the same general requirements listed above, the following also apply to enclosed systems.

A. Surcharge: Surcharge of the conduit is permitted.

B. Inlet Requirements: Inlets are required at both the upstream and downstream ends of an enclosed system conduit to allow for entry and exit of discharge from less frequent storms than the 10-year design storm.

7.0 ENERGY DISSIPATION

A. General Requirements: Energy dissipation shall be required where enclosed systems or detention basin spillways discharge to open channels with outlet velocities greater than the following.

System Discharge Velocity (FPS)	Receiving Channel Lining Type
4.0	Natural, unlined
5.0	Constructed, turf-lined
7.0	Reinforced vegetation
12.0	Riprap or gabions
15.0	Concrete
15.0	Natural limestone

7.2 **Structure Types:**

A. **Pipes and Pipe-Arches (d≤24"):** For pipes and pipe-arches less than 24-inches in diameter, either

1. Prefabricated end sections with cast-in-place toe walls, or
2. Enclosed vertical drop structures in accordance with Figure 16.

B. **Enclosed System (Q<100 CFS):** For enclosed system structures having a design discharge capacity less than 100 CFS, one of the following.

1. Enclosed vertical drop structures in accordance with Figure 16.
2. Impact basin (Bureau of Reclamation Basin VI - Figure 17).
3. KDOT Standard 521.

C. **Enclosed System (100 CFS ≤ Q ≤ 400 CFS):** For enclosed system structures having a design discharge greater than or equal to 100 CFS but less than 400 CFS, one of the following.

1. Impact basin (Bureau of Reclamation Basin VI - Figure 17).
2. Baffled chute (Bureau of Reclamation Basin IX - Figure 18).
3. KDOT Standard 521.

D. **Enclosed System (Q ≥ 400 CFS):** For enclosed system structures having a design discharge greater than or equal to 400 CFS,

1. Baffled chute (Bureau of Reclamation Basin IX - Figure 18).
2. SAF Basin (Bureau of Reclamation Basin III - Figure 19).

7.3 **Channel Lining**

A. **Lengths:** Channel lining shall be required for a distance of 50 feet downstream from all energy dissipating structures except prefabricated end sections. Where enclosed system pipes or structures, which are part of the major system, discharge into a channel, either improved or natural, at an angle greater than 15 degrees from the axis of the channel, lining shall be required for a distance of 30 feet along the channel, centered on the structure outlet. The major system is defined for the purposes of this paragraph as all drainage facilities equivalent to or larger than a 36-inch diameter pipe.

B. **Materials:** Acceptable lining materials are riprap, gabions, concrete or in-situ limestone.

8.0 IMPROVED CHANNELS

8.1 **Geometric Criteria:**

A. **Bottom Width:** The minimum bottom width for improved channels shall be 4.0 feet.

B. **Side Slopes:** The maximum side slopes for trapezoidal channels shall be as follows:

1. 4 horizontal to 1 vertical for turf or reinforced vegetative lining and the overflow channel area above the lining materials.
2. 2 horizontal to 1 vertical for all other lining materials except vertical concrete or gabion walls.
3. Flatter if necessary for stability of slopes.

C. **Invert Lining:** The invert of all constructed channels shall be lined with concrete, riprap or gabions to a minimum height of 6 inches above the invert.

D. **Alignment Changes:** Alignment changes shall be achieved by circular curves only having a minimum radius of:

$$R = \frac{V^2W}{8D}$$ where:

R = Radius on channel centerline, in ft.

V = Velocity of 10-year design flow, in feet per second

W = Channel width at 10-year water surface elevation, in ft.

D = Depth of 10-year design flow, in ft.

8.2 **Lining Height:**

A. **Minimum Height:** Channel lining material shall extend above the channel invert to the depth of the 10-year design discharge plus 6 inches of freeboard.

B. **Increase on Curves:** Along the outer side of horizontal curves, the lining height shall be increased as follows:

$$y = \frac{D}{4}$$ where:

y = Increased vertical height of lining, in feet.

D = Depth of 10-year design flow, in feet.

Increased lining height shall be transitioned from "y" feet to zero feet over a minimum of:

1. 30(y) feet downstream from the point of tangency (P.T.) of the channel curve.

2. 10(y) feet upstream from the point of curvature (P.C.) of the channel curve.

8.3 **Lining Material Requirements:** The following types of lining materials are acceptable alternates based on the peak flow velocity in the channel. Other types of lining materials not specifically listed above may be used when approved by the City Engineer.

10-Year Peak Velocity (FPS)	Permitted Lining Material
> 12.0	Sound in-situ limestone Concrete Grouted riprap
>7.0 to 12.0	Sound in-situ limestone Concrete Grouted riprap Gabions Riprap
5.1 to 6.9	In-situ limestone Concrete Grouted riprap Gabions Riprap Reinforced Turf above invert lining
5.0 and less	In-situ limestone Concrete Grouted riprap Gabions Riprap Reinforced Turf above invert lining Turf above invert lining

8.4 **Optional Design for Improved Channels:** In lieu of sloping banks and linings as specified above, vertical walls may be constructed for improved channels conveying greater than 400 CFS with the following requirements.

A. **Vertical Walls:** Shall be designed and constructed as retaining wall structures.

B. **Materials:** Acceptable materials for vertical walls are reinforced concrete or gabions.

C. **Wall Height:** The minimum wall height shall be the greater of 1.5 feet or the depth of the 1-year peak water surface plus 0.5 ft. The height shall be increased at transitions and bends.

D. **Fence:** In residential areas, chain link or equivalent fencing 42" or greater in height shall be installed along the wall lines on both sides of the channel.

E. **Access:** Adequate provisions shall be made for pedestrian entry/exit from the channel.

8.5 **Subdrainage for Linings:** All channel linings, except turf, shall provide for relieving back pressures and water entrapment beneath and/or behind the lining material.

A. **Materials:** The following are acceptable alternate methods for providing subdrainage.

1. Non-woven geotextile filter fabrics.
2. Graded aggregate filter material with a minimum thickness of 4 inches and gradation based on filter design criteria.

B. **Weep Holes:** For concrete or riprap-lined channels, screened 4-inch diameter "weep holes" shall be required located at the base of the sloped sides, at a maximum spacing of 15 feet on-center.

9.0 STORMWATER DETENTION

9.1 **Other Regulatory Requirements:** In addition to these criteria, the requirements of the Kansas State Board of Agriculture, Division of Water Resources shall apply to all detention dams impounding greater than 30.0 acre-feet of water. Such facilities shall be classified as Hazard Class C -High Hazard.

9.2 **Maximum Release Rates:** The performance of a detention facility shall be based on the following maximum release rates, regardless of the size of the facility, which vary with storm return periods.

Return Period (Yrs.)	Maximum Release Rate (CFS per Tributary Acre)
2	1.2
10	1.5
100	2.0
>100	Less than or equal to the peak rate of inflow

9.3 **Storage Volume Requirements:**

A. **General:** Detention storage for all facilities shall be established by hydrograph routing methods. The volume shall be as required to limit the release rates to the maximums indicated.

B. **Additional Requirements:** All detention facilities shall provide additional storage volume (beyond required flood storage) below the elevation of the principal spillway for five years of sediment accumulation in accordance with Figure 20. In addition, all facilities designed as wet basins shall provide permanent storage volume as necessary to maintain a minimum water depth of 3.0 feet.

9.4 Hydrograph Routing Methods:

A. **General:** Hydrograph routing is required for each return period to determine maximum inflow, detention volume and release rates.

B. **Rainfall Distribution:** To compute the design inflow hydrograph, a Soil Conservation Service (SCS) Type-2 rainfall distribution with a 24-hour duration shall be used for developing the hydrographs. For manual routing methods, the rainfall mass shall be obtained from Table B.

C. **Runoff Computation:** Runoff shall be computed by the SCS curve number method. Applicable curve numbers shall be obtained from Table C. The curve number shall be weighted by proportional land use in the tributary area.

D. **Routing Interval:** The routing time (hydrograph ordinate) interval shall be 5 minutes.

E. **Routing Method:** Detention routing shall be by the storage-indication, or Modified Puls, method.

F. **Required Steps:** In designing a detention facility, the following steps are required.

1. From proposed spillway characteristics, calculate rating curves of spillway(s) stage vs. discharge.
2. Calculate detention stage vs. storage volume from pond configuration and depth.
3. Develop inflow mass hydrograph by methods.
4. Perform storage routing through the proposed detention facility.

G. **Simplified Design:** A simplified design method is acceptable only for detention facilities having 10.0 acres or less of tributary area.

1. The SCS TR-55 computer model may be utilized for computer methods.
2. By manual methods, use Figure 21 to determine required storage volume.

9.5 Principal Spillways (Outlets):

A. **General:** The principal spillway shall be designed to convey all discharge from the detention facility from the 100-year and more frequent (inflow and discharge equal to or less than the 100-year) storms and shall function without mechanical or electrical components.

B. **Hydraulic Characteristics:** The principal spillway shall have the hydraulic characteristics of a weir, pipe or orifice, or a combination of these.

C. **Capacity:** The spillway shall have sufficient capacity to discharge 80 percent of the detention storage volume within 24 hours after the peak inflow has entered the basin.

D. **Trash Racks:** Trash racks, screens, etc., shall be provided at the principal spillway as necessary to keep the facility fully operational.

9.6 Emergency Spillways:

A. **Required Installations:** Emergency spillways shall be required for all detention facilities formed by earth embankments or dams greater than 10.0 feet in height.

B. **Return Period for Operation:** Emergency spillways shall operate only for storms less frequent (higher inflow and discharge) than the 100-year storm.

C. **Regulatory Criteria:** The Division of Water Resources criteria shall apply to the design of emergency spillways with sufficient capacity to discharge the 6-hour PMP hydrograph without overtopping the dam.

D. **Exemptions:** Emergency spillways are <u>not</u> required for

1. Excavated detention basins.
2. Detention basins on structure roofs.
3. Detention basins utilizing surface parking areas.
4. Detention in underground structures.

9.7 Other Requirements:

A. **Wet Basins:** The design of wet detention facilities shall include provisions for complete drainage to permit sediment removal and other periodic maintenance activities.

B. **Dry Basins:** Dry detention facilities with storage on other than paved surfaces shall have the bottom graded at a minimum of 0.5 percent to drain to an interior gutter. The concrete drainage gutter shall be 4.0 feet or greater in width.

C. **Side Slopes:** Slopes on the banks, dams, dikes or berms around and forming the basin shall not be steeper than:

1. 2:1 below the elevation of the principal spillway for excavated bank slopes.
2. 3:1 for all other excavation and embankment slopes.

Flatter slopes shall be required if necessary for stability with a safety factor of 2.0 for dams greater than 10 feet in height, and 1.5 for all other slopes.

D. **Erosion Control:** Principal spillways and outlet works, as well as conveyance system entrances to detention basins, shall be equipped with energy dissipating devices as necessary to limit the peak discharge velocity in conformance with Section 7.0.

E. **Rooftop Detention:** Detention storage may be met in total or in part by detention on roofs. Details of such designs shall include the depth and volume of storage, details of outlet devices and downdrains, and elevations and details of overflow scuppers. Connections of roof drains to sanitary sewers are prohibited. Design loadings and special building and structural details shall be subject to approval by the City Engineer. Rooftop detention areas are exempt from sediment storage requirements.

F. **Parking Lot Detention:** Paved parking lots may be designed to provide temporary detention storage of stormwater on a portion of their surfaces. Generally, such detention areas shall be in the more remote portions of such parking lots. Depths of storage shall be limited to a maximum depth of seven inches, and such areas shall be located so that access to and from parking areas is not impaired. Parking lot detention areas are exempt from sediment storage requirements.

G. **Other Detention:** All or a portion of the detention storage may also be provided in underground or surface detention areas, including, but not limited to, oversized storm sewers, vaults, tanks, swales, etc.

9.8 Construction, Operation and Maintenance:

A. Public Facilities:

1. Public detention facilities shall be constructed by the developer where approved by the City and after plan approval and issuance of a permit. Dedication of easements to the City will be required.
2. Operation and maintenance shall become the responsibility of the City after dedication of the easements and acceptance of the facility by the City.

B. Private Facilities:

1. Private detention facilities shall be constructed by the property owner after plan approval and issuance of a permit by the City. Dedication of easements to the City will be required.
2. Operation and maintenance of private detention facilities shall be the responsibility of the property owner and successors.

C. **Maintenance Activities:** For both public and private facilities, required maintenance activities include the following.

1. Debris removal and cleaning.
2. Cutting of vegetation.
3. Repair of erosion.
4. Removal of silt.
5. Maintenance of structural facilities, including outlet works.

10.0 CONSTRUCTION PLAN REQUIREMENTS

10.1 **Scope:** This section governs the preparation of plans for stormwater system projects.

10.2 **General:** The plans shall include all information necessary to build and check the design of storm drainage systems. The plans shall be arranged as required by the City Engineer. Standard details of the City may be included by reference. Plans shall be sealed by a Registered Professional Engineer and shall be submitted to the City Engineer for review and approval.

10.3 **Scale:** Plans shall be drawn at the following minimum scales. Larger scales may be needed to clearly present the design. Bar scales shall be shown on each sheet for each scale.

Plan:		1-inch =	50 feet
Profile:			
	Vertical:	1-inch =	5 feet
	Horizontal:	1-inch =	50 feet
Drainage Area Map:			
	On site:	1-inch =	200 feet
	Off site:	1-inch =	1,000 feet
Structural Plans:		1/4-inch =	1 foot
Graphic Drawings:	Varies		

10.4 **Required Information:**

A. **Drainage Area Map:** A drainage area map shall be included and shall indicate the following:

1. Ridge line of the area tributary to each principal element of the system.
2. The area in acres.
3. The runoff coefficient "C" for each area.

B. **Plan View:** All designed storm drainage systems shall be drawn in plan view and shall contain the following:

1. North arrow and bar scale.
2. Ties to permanent reference points for each system located outside of the street right-of-way.
3. Identification and location of each pipe, culvert, inlet, structure, and existing utility affecting construction.
4. Right-of-way, property, and easement lines, and the 100-year flood-plain and setback from the top of bank of an open channel to any building.
5. Existing man-made and natural topographic features, such as buildings, fences, trees, channels, ponds, streams, etc., and all existing and proposed utilities.
6. Location of test borings.
7. Existing and finish grade contours at intervals of 2.0 feet or less in elevation or equivalent detail indicating existing and finish grades and slopes.
8. A uniform set of symbols subject to approval by the City Engineer.
9. The centerline of open channels within 50 feet of an enclosed drainage system and showing the direction of flow.

C. **Profile View:** All designed storm drainage systems shall be drawn in profile view and shall contain the following:

1. Existing and finish surface grade along the centerline of pipe except street centerline may be used when construction includes street construction.
2. Length, size and slope of each line or channel segment. Slope shall be expressed in percent.
3. Headwater elevation at the inlet end of each culvert.
4. Flow line (invert elevation in and out) at each structure.
5. Each existing utility line crossing the alignment shall be properly located and identified as to type, size and material.
6. Test borings.
7. All station and invert elevations of manholes, junction boxes, inlets or other structures.
8. The profile shall show existing grade above the centerline as a dashed line and proposed finish grades or established street grades by solid lines. It shall also show the flow line of any drainage channel, either improved or unimproved, within 50 feet on either side of the centerline. Each line shall be properly identified. The proposed storm sewer shall be shown as double solid lines properly showing the top of the pipe.
9. All manholes, inlets or other structures shall be shown and labeled with appropriate "Standard Drawing" designation.

D. **Design Information for Each Part of the System:** The plans shall present design information for each culvert, structure, facility, pipe and channel segment and shall contain the following:

1. Tributary area in acres.
2. Design discharge and capacity in cubic feet per second.

3. Runoff coefficient "C", design storm return frequency, rainfall intensity and Manning's "n" value.
4. Discharge velocity at design flow.
5. Hydraulic grade line.
6. Type and grade of material (gage, class, etc.).

Schedules which indicate all variable dimensions and elevations covered by standards or "typical" drawings shall be shown on the plans. All design details for nonstandard structures shall be indicated on the plans. A minimum of one plan view and one sectional view shall be shown on the plans for each structure. Additional views may be required if necessary to clearly define the design. A reinforcing bar list is not required. However, the grade, type, size and location of the bars shall be clearly indicated on the plans.

* * * * *

THIS TABLE CONTAINS AVERAGE RAINFALL INTENSITIES
IN INCHES PER HOUR

DURATION, HR:MIN	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
0:05	4.63	5.40	6.48	7.26	8.41	9.31	10.20
0:06	4.40	5.15	6.21	6.97	8.09	8.97	9.84
0:07	4.21	4.94	5.98	6.73	7.82	8.67	9.52
0:08	4.05	4.76	5.77	6.50	7.56	8.40	9.22
0:09	3.90	4.59	5.58	6.29	7.32	8.13	8.93
0:10	3.77	4.44	5.39	6.08	7.08	7.86	8.64
0:11	3.65	4.30	5.22	5.88	6.85	7.60	8.36
0:12	3.53	4.16	5.05	5.70	6.63	7.36	8.09
0:13	3.43	4.03	4.90	5.52	6.42	7.13	7.84
0:14	3.32	3.91	4.75	5.36	6.42	6.92	7.61
0:15	3.22	3.80	4.62	5.21	6.06	6.73	7.40
0:16	3.13	3.69	4.49	5.07	5.91	6.56	7.21
0:17	3.04	3.59	4.38	4.94	5.76	6.40	7.04
0:18	2.95	3.49	4.27	4.28	5.63	6.26	6.89
0:19	2.87	3.40	4.17	4.71	5.51	6.12	6.74
0:20	2.79	3.31	4.07	4.61	5.39	6.00	6.60
0:21	2.71	3.23	3.98	4.51	5.28	5.88	6.48
0:22	2.64	3.15	3.89	4.42	5.18	5.77	6.36
0:23	2.57	3.08	3.81	4.33	5.08	5.66	6.24
0:24	2.51	3.01	3.73	4.25	4.98	5.56	6.13
0:25	2.45	2.94	3.66	4.17	4.90	5.46	6.03
0:26	2.39	2.88	3.59	4.09	4.81	5.37	5.93
0:27	2.34	2.82	3.52	4.02	4.73	5.28	5.83
0:28	2.29	2.77	3.46	3.95	4.65	5.19	5.74
0:29	2.24	2.71	3.40	3.88	4.57	5.11	5.65
0:30	2.20	2.66	3.34	3.82	4.50	5.03	5.56
0:31	2.15	2.61	3.28	3.75	4.43	4.95	5.48
0:32	2.11	2.56	3.23	3.69	4.36	4.88	5.39
0:33	2.07	2.52	3.18	3.64	4.29	4.80	5.31
0:34	2.04	2.48	3.12	3.58	4.23	4.73	5.23
0:35	2.00	2.44	3.08	3.52	4.17	4.66	5.16
0:36	1.97	2.40	3.03	3.47	4.10	4.60	5.09
0.37	1.93	2.36	2.98	3.42	4.05	4.53	5.01
0:38	1.90	2.32	2.94	3.37	3.99	4.47	4.94
0:39	1.87	2.29	2.90	3.32	3.93	4.40	4.88
0:40	1.84	2.25	2.85	3.28	3.88	4.34	4.81
0:41	1.81	2.22	2.81	3.23	3.82	4.29	4.74
0:42	1.79	2.19	2.77	3.19	3.77	4.23	4.68
0:43	1.76	2.15	2.74	3.14	3.72	4.17	4.62
0:44	1.73	2.12	2.70	3.10	3.67	4.12	4.56

THIS TABLE CONTAINS AVERAGE RAINFALL INTENSITIES
IN INCHES PER HOUR

DURATION, HR:MIN	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
0:45	1.71	2.09	2.66	3.06	3.62	4.06	4.50
0:46	1.69	2.07	2.63	3.02	3.58	4.01	4.44
0:47	1.66	2.04	2.59	2.98	3.53	3.96	4.39
0:48	1.64	2.01	2.56	2.94	3.49	3.91	4.33
0:49	1.62	1.98	2.53	2.90	3.44	3.86	4.28
0:50	1.60	1.96	2.49	2.87	3.40	3.81	4.22
0:51	1.58	1.93	2.46	2.83	3.36	3.77	4.17
0:52	1.55	1.91	2.43	2.80	3.32	3.72	4.12
0:53	1.53	1.88	2.40	2.76	3.28	3.67	4.07
0:54	1.52	1.86	2.37	2.73	3.24	3.63	4.02
0:55	1.50	1.84	2.34	2.70	3.20	3.59	3.97
0:56	1.48	1.82	2.32	2.66	3.16	3.54	3.93
0:57	1.46	1.79	2.29	2.63	3.12	3.50	3.88
0:58	1.44	1.77	2.26	2.60	3.09	3.46	3.84
0:59	1.42	1.75	2.23	2.57	3.05	3.42	3.79
1:00	1.41	1.73	2.21	2.54	3.02	3.38	3.75
1:05	1.33	1.63	2.09	2.40	2.85	3.20	3.55
1:10	1.25	1.54	1.98	2.28	2.70	3.03	3.36
1:15	1.19	1.47	1.88	2.16	2.56	2.88	3.19
1:20	1.13	1.39	1.78	2.06	2.44	2.74	3.04
1:25	1.08	1.33	1.70	1.96	2.23	2.61	2.90
1:30	1.03	1.27	1.63	1.87	2.23	2.50	2.77
1:35	0.98	1.21	1.56	1.79	2.13	2.39	2.65
1:40	0.94	1.17	1.49	1.72	2.05	2.30	2.55
1:45	0.91	1.12	1.44	1.65	1.97	2.21	2.45
1:50	0.87	1.08	1.38	1.59	1.89	2.13	2.36
1:55	0.84	1.04	1.33	1.54	1.83	2.05	2.27
2:00	0.81	1.01	1.29	1.48	1.76	1.98	2.20
2:05	0.79	0.97	1.25	1.44	1.71	1.91	2.12
2:10	0.76	0.94	1.21	1.39	1.65	1.85	2.06
2:15	0.74	0.91	1.17	1.35	1.60	1.80	1.99
2:20	0.72	0.89	1.14	1.31	1.55	1.74	1.93
2:25	0.70	0.86	1.10	1.27	1.51	1.70	1.88
2:30	0.68	0.84	1.07	1.24	1.47	1.65	1.83
2:35	0.66	0.82	1.05	1.21	1.43	1.61	1.78
2:40	0.65	0.80	1.02	1.17	1.39	1.56	1.73
2:45	0.63	0.78	1.00	1.15	1.36	1.53	1.69
2:50	0.62	0.76	0.97	1.12	1.33	1.49	1.65
2:55	0.60	0.74	0.95	1.09	1.30	1.46	1.61
3:00	0.59	0.73	0.93	1.07	1.27	1.42	1.58

THIS TABLE CONTAINS AVERAGE RAINFALL INTENSITIES IN INCHES PER HOUR

DURATION, HR:MIN	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
3:15	0.55	0.68	0.87	1.00	1.19	1.33	1.48
3:30	0.52	0.64	0.82	0.94	1.12	1.26	1.39
3:45	0.49	0.61	0.78	0.89	1.06	1.19	1.32
4:00	0.47	0.58	0.74	0.85	1.01	1.13	1.25
4:15	0.45	0.55	0.70	0.81	0.96	1.08	1.20
4:30	0.43	0.53	0.67	0.77	0.92	1.03	1.14
4:45	0.41	0.50	0.64	0.74	0.88	0.99	1.10
5:00	0.39	0.48	0.62	0.71	0.85	0.95	1.05
5:15	0.38	0.46	0.60	0.69	0.82	0.92	1.02
5:30	0.36	0.45	0.57	0.66	0.79	0.88	0.98
5:45	0.35	0.43	0.55	0.64	0.76	0.85	0.95
6:00	0.34	0.42	0.54	0.62	0.74	0.83	0.92
6:30	0.31	0.39	0.50	0.58	0.69	0.78	0.86
7:00	0.30	0.37	0.47	0.55	0.65	0.73	0.81
7:30	0.28	0.35	0.45	0.52	0.62	0.70	0.77
8:00	0.26	0.33	0.43	0.49	0.59	0.66	0.73
8:30	0.25	0.31	0.41	0.47	0.56	0.63	0.70
9:00	0.24	0.30	0.39	0.45	0.54	0.60	0.67
9:30	0.23	0.28	0.37	0.43	0.51	0.58	0.64
10:00	0.22	0.27	0.36	0.41	0.49	0.56	0.62
10:30	0.21	0.26	0.34	0.40	0.47	0.54	0.60
11:00	0.20	0.25	0.33	0.38	0.46	0.52	0.57
11:30	0.19	0.24	0.32	0.37	0.44	0.50	0.55
12:00	0.19	0.23	0.31	0.36	0.43	0.48	0.54
13:00	0.18	0.22	0.29	0.34	0.40	0.45	0.50
14:00	0.17	0.21	0.27	0.32	0.38	0.43	0.47
15:00	0.16	0.20	0.26	0.30	0.36	0.40	0.45
16:00	0.15	0.19	0.24	0.28	0.34	0.38	0.43
17:00	0.14	0.18	0.23	0.27	0.32	0.36	0.40
18:00	0.14	0.17	0.22	0.26	0.31	0.35	0.39
19:00	0.13	0.16	0.21	0.25	0.30	0.33	0.37
20:00	0.13	0.16	0.20	0.24	0.28	0.32	0.35
21:00	0.12	0.15	0.20	0.23	0.27	0.31	0.33
22:00	0.12	0.15	0.19	0.22	0.26	0.30	0.33
23:00	0.11	0.14	0.18	0.21	0.25	0.28	0.32
24:00	0.11	0.14	0.18	0.21	0.24	0.27	0.30

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

RAINFALL INTENSITY TABLE
MANHATTAN AND RILEY COUNTY

TABLE A-3

THIS TABLE CONTAINS CUMULATIVE RAINFALL
IN INCHES

DURATION, HR:MIN	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
1:00	0.0104	0.0132	0.0170	0.0198	0.0227	0.0255	0.0283
2:00	0.0208	0.0264	0.0340	0.0396	0.0453	0.0510	0.0566
3:00	0.0312	0.0397	0.0510	0.0595	0.0680	0.0765	0.0850
4:00	0.0415	0.0529	0.0680	0.0793	0.0906	0.1020	0.1133
5:00	0.0522	0.0703	0.0903	0.1054	0.1205	0.1355	0.1506
6:00	0.0803	0.1022	0.1314	0.1533	0.1752	0.1971	0.2190
7:00	0.1154	0.1496	0.1889	0.2204	0.2519	0.2833	0.3148
8:00	0.1606	0.2044	0.2628	0.3066	0.3504	0.3942	0.4380
9:00	0.1957	0.2491	0.3202	0.3737	0.4271	0.4805	0.5338
10:00	0.2861	0.3641	0.4681	0.5462	0.6242	0.7022	0.7802
11:00	0.3722	0.4738	0.6091	0.7106	0.8122	0.9137	1.0152
12:00	0.4699	0.5981	0.7690	0.8971	1.0253	1.1534	1.2816
12:30	0.5280	0.6720	0.8640	1.0080	1.1520	1.2960	1.4400
12:40	0.5535	0.7045	0.9058	1.0567	1.2077	1.3586	1.5096
12:50	0.5790	0.7370	0.9475	1.1054	1.2634	1.4213	1.5792
13:00	0.6046	0.7694	0.9893	1.1542	1.3190	1.4839	1.6488
13:10	0.6494	0.8266	1.0627	1.2398	1.4170	1.5941	1.7712
13:20	0.6943	0.8837	1.1362	1.3255	1.5149	1.7042	1.8936
13:30	0.7392	0.9408	1.2096	1.4112	1.6128	1.8144	2.0160
13:40	0.8257	1.0509	1.3512	1.5764	1.8016	2.0268	2.2520
13:50	0.9123	1.1611	1.4928	1.7416	1.9904	2.2392	2.4880
14:00	0.9988	1.2712	1.6344	1.9068	2.1792	2.4516	2.7240
14:10	1.2748	1.6225	2.0861	2.4338	2.7814	3.1291	3.4768
14:20	1.5509	1.9738	2.5379	2.9608	3.3837	3.8067	4.2297
14:30	1.8269	2.3252	2.9895	3.4878	3.9860	4.4843	4.9825
14:40	1.9156	2.4380	3.1346	3.6670	4.1795	4.7019	5.2243
14:50	2.0043	2.5509	3.2797	3.8263	4.3729	4.9195	5.4662
15:00	2.0929	2.6637	3.4248	3.9956	4.5664	5.1372	5.7080
15:10	2.1147	2.6914	3.4604	4.0371	4.6138	4.1906	5.7672
15:20	2.1364	2.7191	3.4960	4.0786	1.6613	5.2440	1.8266
15:30	2.1582	2.7468	3.5316	4.1202	4.7087	5.2973	5.8859
16:00	2.2184	2.8234	3.6301	4.2351	4.8402	5.4452	6.0502
17:00	2.3238	2.9576	3.8026	4.4363	5.0701	5.7039	6.3376
18:00	2.4091	3.0662	3.9422	4.5992	5.2563	5.9133	6.5703
19:00	2.4493	3.1173	4.0079	4.6759	5.3439	6.0119	6.6798
20:00	2.5145	3.2003	4.1147	4.8005	5.4862	6.1720	6.8578
21:00	2.5396	3.2322	4.1557	4.8484	5.5410	6.2336	6.9262
22:00	2.5748	3.2770	4.2132	4.9154	5.6176	6.3198	7.0221

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

RAINFALL MASS HYETOGRAPH

TABLE B-1

THIS TABLE CONTAINS CUMULATIVE RAINFALL IN INCHES

DURATION, HR:MIN	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
23:00	2.6392	3.3589	4.3186	5.0384	5.7582	6.4779	7.1977
24:00	2.6400	3.3600	4.3200	5.0400	5.7600	6.4800	7.2000

TIME OF PEAK PERIODS

DURATION	BEGIN	END
30 Minutes	14:00	14:30
One Hour	14:00	15:00
Two Hours	13:00	15:00
Three Hours	12:30	15:30

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

RAINFALL MASS HYETOGRAPH

TABLE B-2

LAND USE	PROPORTIONAL SURFACE CONDITION IMPERV.	PROPORTIONAL SURFACE CONDITION TURF OR =	SCS CURVE NUMBER	RATIONAL METHOD "C"
Residential Low-Medium Density (Single Family & Duplex)	0.35	0.65	80	0.43
Residential Medium-high Density (6 or fewer D.U. per bldg. and mobile home parks)	0.60	0.40	87	0.59
Residential High Density (Over 6 D.U. per bldg.)	0.80	0.20	92	0.72
Commercial/ Business	0.85	0.15	94	0.75
Central Business District	1.00	0.00	98	0.85
Industrial	0.75	0.25	91	0.69
Developed Parks and Recreation	0.20	0.80	76	0.33
Public/Semi-Public (Schools, Gov't.,Institutional)	0.70	0.30	90	0.66
Open Space	0.10	0.90	73	0.27
Agricultural				
Existing Use	0.05	0.95	71	0.23
Future Use	0.40	0.60	81	0.46
All Land Uses:				
100 % Impervious Surfaces			98	0.85
100 % Pervious Surfaces (With maintained turf cover or =)			70	0.20

Note: Coefficients developed for SCS Hydrologic Class B-C Soils typical of predominant Manhattan surficial soils.

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

SURFACE RUNOFF COEFFICIENTS

TABLE C

FLOW LENGTH (FEET)	SHALLOW CONCENTRATED FLOW TIME IN MINUTES PAVED SURFACE SLOPE IN PERCENT										
	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.23	0.16	0.12	0.09	0.08	0.07	0.07	0.06	0.06	0.05	0.05
40	0.46	0.33	0.23	0.19	0.16	0.15	0.13	0.12	0.12	0.11	0.10
60	0.70	0.49	0.35	0.28	0.25	0.22	0.20	0.19	0.17	0.16	0.16
80	0.93	0.66	0.46	0.38	0.33	0.29	0.27	0.25	0.23	0.22	0.21
100	1.16	0.82	0.58	0.47	0.41	0.37	0.33	0.31	0.29	0.27	0.26
120	1.39	0.98	0.70	0.57	0.49	0.44	0.40	0.37	0.35	0.33	0.31
140	1.62	1.15	0.81	0.66	0.57	0.51	0.47	0.43	0.41	0.38	0.36
160	1.86	1.31	0.93	0.76	0.66	0.59	0.54	0.50	0.46	0.44	0.41
180	2.09	1.48	1.04	0.85	0.74	0.66	0.60	0.56	0.52	0.49	0.47
200	2.32	1.64	1.16	0.95	0.82	0.73	0.67	0.62	0.58	0.55	0.52
220	2.55	1.80	1.28	1.04	0.90	0.81	0.74	0.68	0.64	0.60	0.57
240	2.78	1.97	1.39	1.14	0.98	0.88	0.80	0.74	0.70	0.66	0.62
260	3.01	2.13	1.51	1.23	1.07	0.95	0.87	0.81	0.75	0.71	0.67
280	3.25	2.30	1.62	1.33	1.15	1.03	0.94	0.87	0.81	0.77	0.73
300	3.48	2.46	1.74	1.42	1.23	1.10	1.00	0.93	0.87	0.82	0.78
320	3.71	2.62	1.86	1.51	1.31	1.17	1.07	0.99	0.93	0.87	0.83
340	3.94	2.79	1.97	1.61	1.39	1.25	1.14	1.05	0.99	0.93	0.88
360	4.17	2.95	2.09	1.70	1.48	1.32	1.20	1.12	1.04	0.98	0.93
380	4.41	3.12	2.20	1.80	1.56	1.39	1.27	1.18	1.10	1.04	0.99
400	4.64	3.28	2.32	1.89	1.64	1.47	1.34	1.24	1.16	1.09	1.04

Flow is channelized after unconcentrated length exceeds 400 ft

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

SHALLOW CONCENTRATED FLOW TIME OVER PAVED SURFACES

TABLE D

FLOW LENGTH (FEET)	SHALLOW CONCENTRATED FLOW TIME IN MINUTES UNPAVED SURFACE SLOPE IN PERCENT										
	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.29	0.21	0.15	0.12	0.10	0.09	0.08	0.08	0.07	0.07	0.07
40	0.58	0.41	0.29	0.24	0.21	0.18	0.17	0.16	0.15	0.14	0.13
60	0.88	0.62	0.44	0.36	0.31	0.28	0.25	0.23	0.22	0.21	0.20
80	1.17	0.83	0.58	0.48	0.41	0.37	0.34	0.31	0.29	0.28	0.26
100	1.46	1.03	0.73	0.60	0.52	0.46	0.42	0.39	0.37	0.34	0.33
120	1.75	1.24	0.88	0.72	0.62	0.55	0.51	0.47	0.44	0.41	0.39
140	2.05	1.45	1.02	0.83	0.72	0.65	0.59	0.55	0.51	0.48	0.46
160	2.34	1.65	1.17	0.95	0.83	0.74	0.67	0.62	0.58	0.55	0.52
180	2.63	1.86	1.31	1.07	0.93	0.83	0.76	0.70	0.66	0.62	0.59
200	2.92	2.07	1.46	1.19	1.03	0.92	0.84	0.78	0.73	0.69	0.65
220	3.21	2.27	1.61	1.31	1.14	1.02	0.93	0.86	0.80	0.76	0.72
240	3.51	2.48	1.75	1.43	1.24	1.11	1.01	0.94	0.88	0.83	0.78
260	3.80	2.69	1.90	1.55	1.34	1.20	1.10	1.02	0.95	0.90	0.85
280	4.09	2.89	2.05	1.67	1.45	1.29	1.18	1.09	1.02	0.96	0.91
300	4.38	3.10	2.19	1.79	1.55	1.39	1.27	1.17	1.10	1.03	0.98
320	4.67	3.31	2.34	1.91	1.65	1.48	1.35	1.25	1.17	1.10	1.05
340	4.97	3.51	2.48	2.03	1.76	1.57	1.43	1.33	1.24	1.17	1.11
360	5.26	3.72	2.63	2.15	1.86	1.66	1.52	1.41	1.31	1.24	1.18
380	5.55	3.93	2.78	2.27	1.96	1.76	1.60	1.48	1.39	1.31	1.24
400	5.84	4.13	2.92	2.39	2.07	1.85	1.69	1.56	1.46	1.38	1.31

Flow is channelized after unconcentrated length exceeds 400 ft.

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

SHALLOW CONCENTRATED FLOW TIME OVER UNPAVED SURFACES

TABLE E

TYPE OF CHANNEL	n
Closed Conduits	
Reinforced Concrete Pipe	0.013
Reinforced Concrete Elliptical Pipe	0.013
Corrugated Metal Pipe:	
2-2/3 x 1/2 in Annular Corrugations unpaved -plain	0.024
2-2/3 x 1/2 in Annular Corrugations paved invert	0.021
3 x 1 in Annular Corrugations unpaved - plain	0.027
3 x 1 in Annular Corrugations paved invert	0.023
6 x 2 in Corrugations unpaved - plain	0.033
6 x 2 Corrugations paved invert	0.028
Vitrified Clay Pipe	0.013
Asbestos Cement Pipe	0.012
Open channels (Lined)	
Gabions	0.025
Concrete	
Trowel Finish	0.013
Float Finish	0.015
Unfinished	0.017
Concrete, bottom float finished, with sides of	
Dressed Stone	0.017
Random Stone	0.020
Cement Rubble Masonry	0.025
Dry Rubble or Riprap	0.030
Gravel bottom, side of	
Random Stone	0.023
Riprap	0.030
Grass (Sod)	0.035
Open Channels (Unlimited) Excavated or Dredged	
Earth, straight and uniform	0.027
Earth, winding and sluggish	0.035
Natural Stream	
Clean stream, straight	0.030
Stream with pools, sluggish reaches, heavy underbrush	0.100
Flood Plains	
Grass, no brush	0.030
With some brush	0.090
Street Curbing	0.014

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

MANNING'S ROUGHNESS COEFFICIENTS (n)

TABLE F

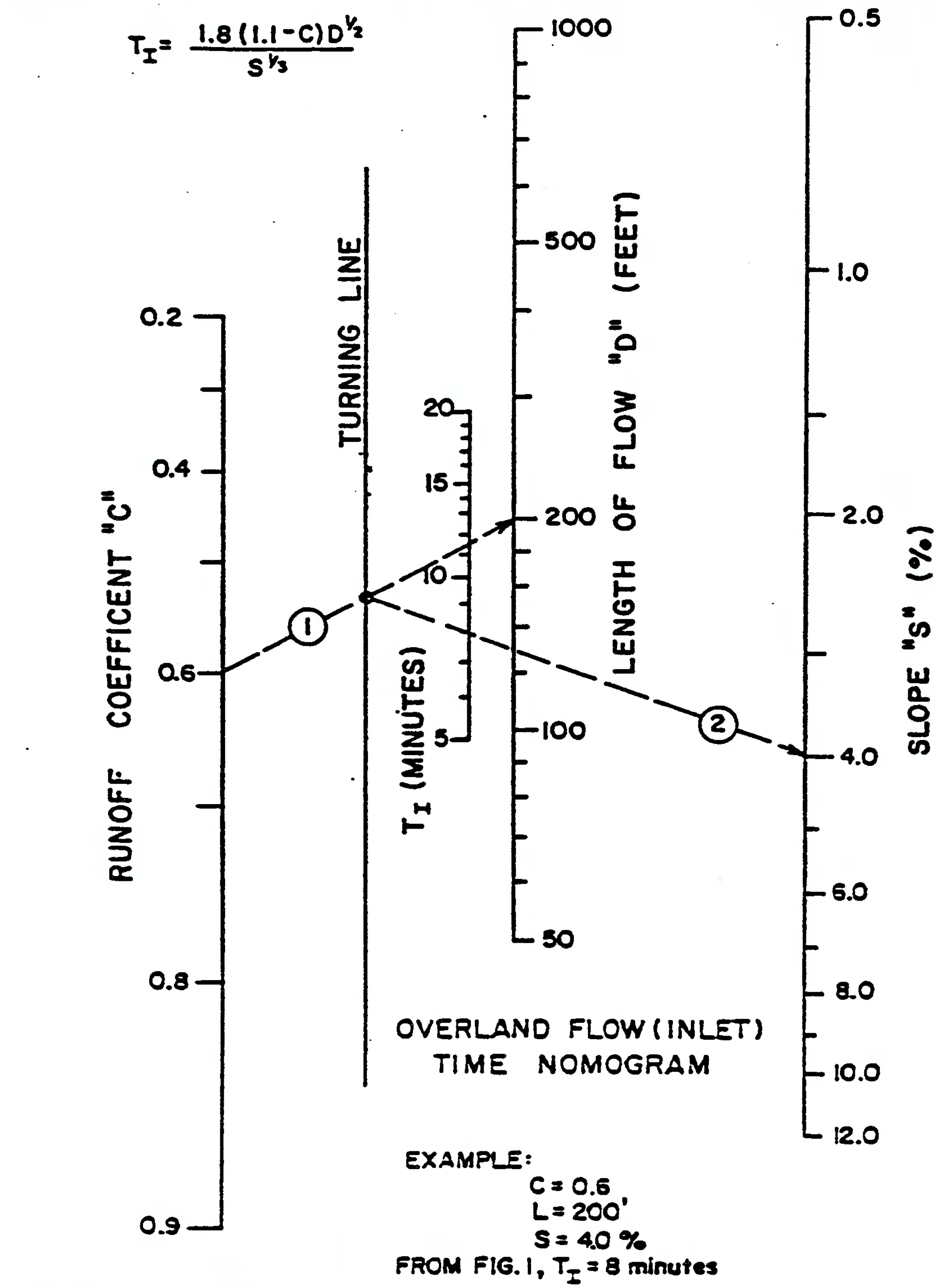
CONDITIONS	k
Manhole, junction boxes and inlets with shaped inverts:	
Thru Flow	0.15
Junction	0.4
Contraction Transition	0.1
Expansion Transition	0.2
90 degree bend	0.4
45 degree and less bends	0.3
Culvert outlet	1.0
Culvert inlets:	
Pipe, Concrete	
Projecting from fill, socket end (grooved end)	0.2
Projecting from fill, sq cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (grooved end)	0.2
Square edge	0.5
Round (radius = 1/12D)	0.2
Mitered to conform to fill slope	0.7
Standard end section	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side-or-slope-tapered inlet	0.2
Pipe, or Pipe-Arch, corrugated Metal	
Projecting from fill (not headwall)	0.9
Headwall or headwall and wingwalls square edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
Standard end section	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side-or-slope-tapered inlet	0.2
Box Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square edge on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dimension, or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel	
Square edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension, or beveled top edge	0.20
Wingwall at 10° to 25° to barrel	
Square edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square edged at crown	0.7
Side-or-slope-tapered inlet	0.2

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

HEAD LOSS COEFFICIENTS (k) FOR HYDRAULIC CALCULATIONS

TABLE G

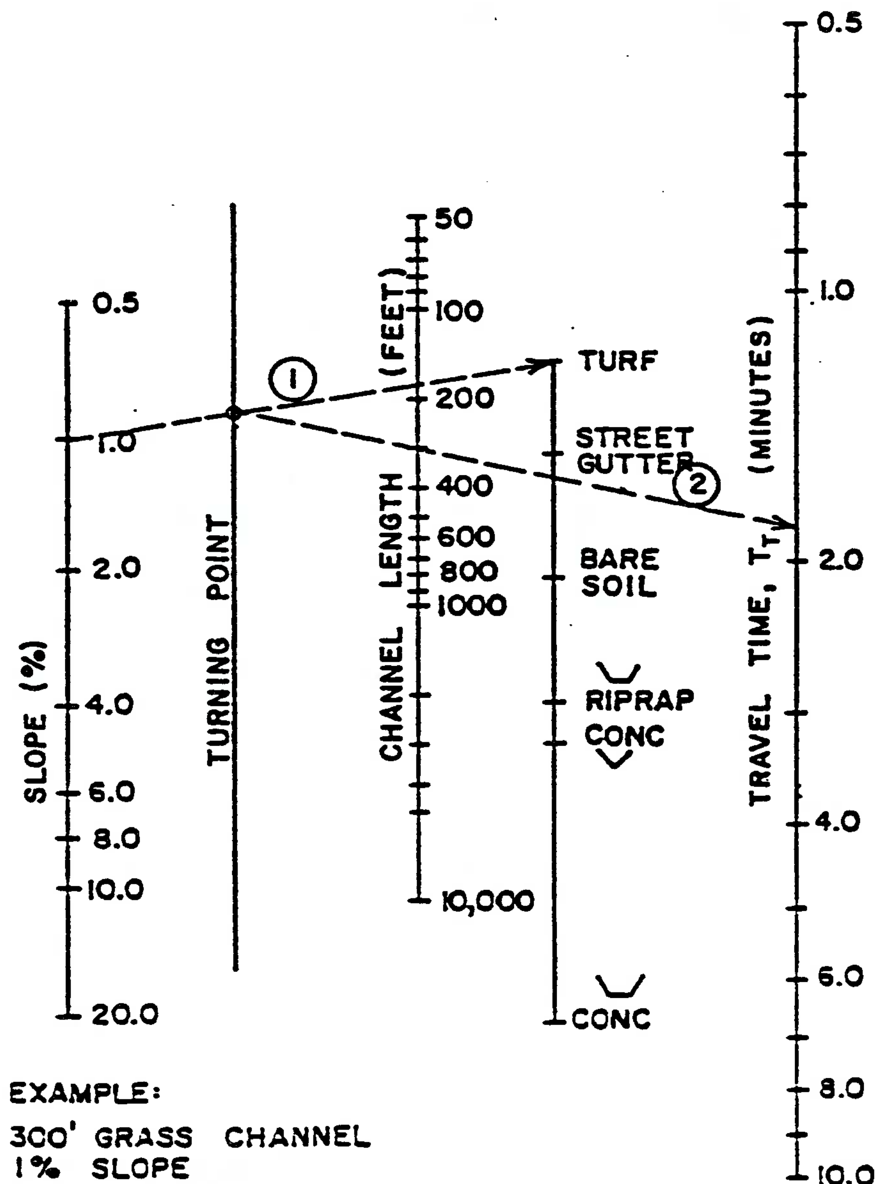


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

OVERLAND FLOW TIME OF CONCENTRATION

FIGURE 1



EXAMPLE:

300' GRASS CHANNEL
1% SLOPE
T_T = 1.85 MIN.

① Connect Slope & Channel Condition to locate point on Turning Line

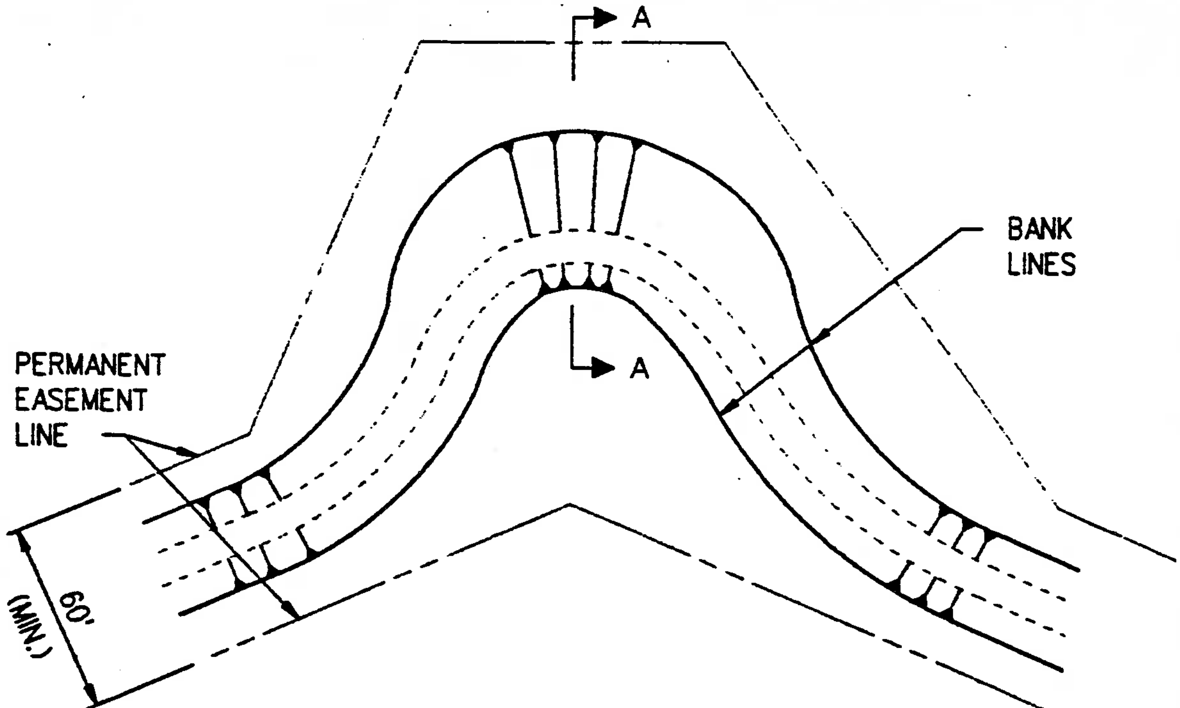
② Extend line from Turning Line through Channel Length, Read T_T

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

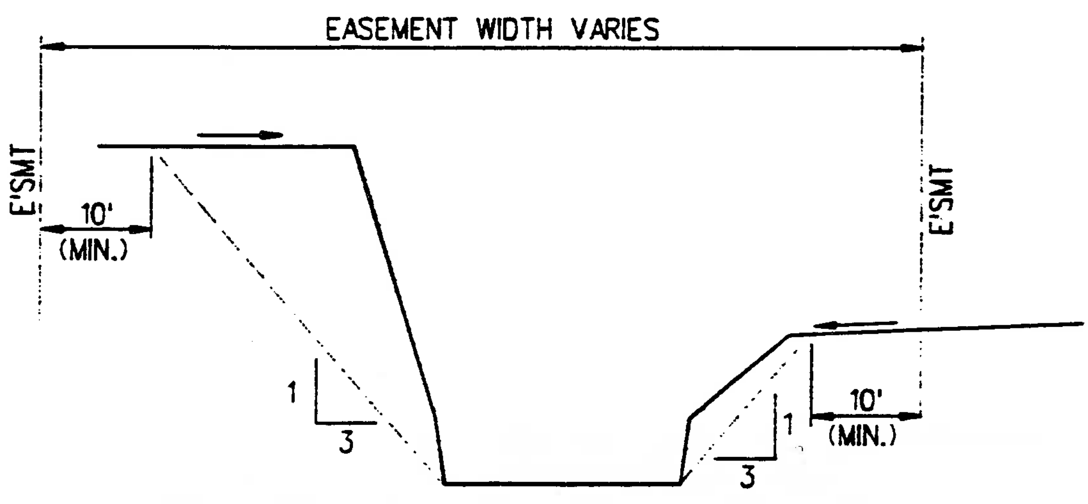
THE CITY OF MANHATTAN KANSAS The Little Apple

CHANNEL FLOW TIME

FIGURE 2



SCHEMATIC PLAN
NOT TO SCALE

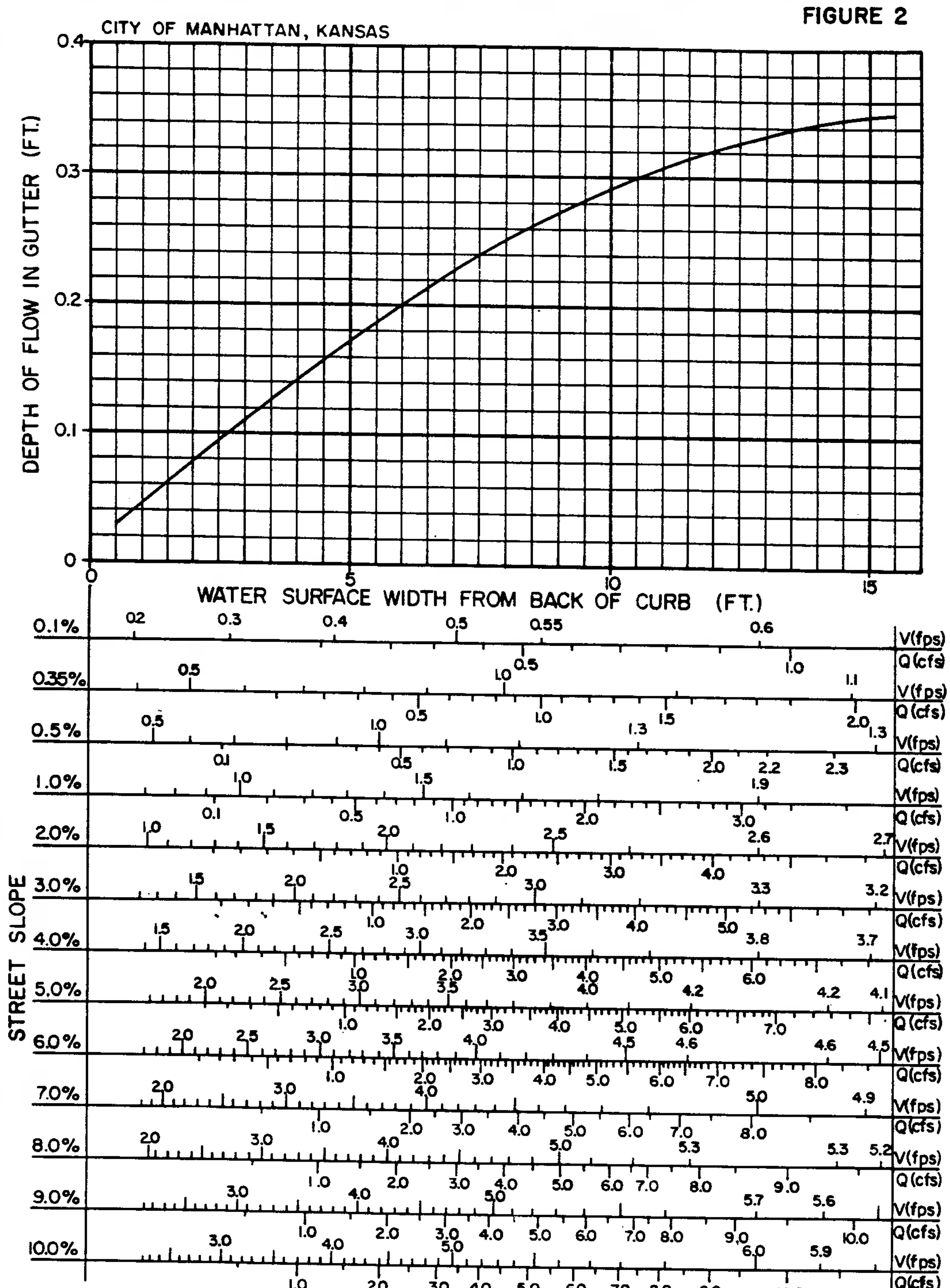


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

PERMANENT EASEMENT FOR NATURAL CHANNELS & STREAMS

FIGURE 3



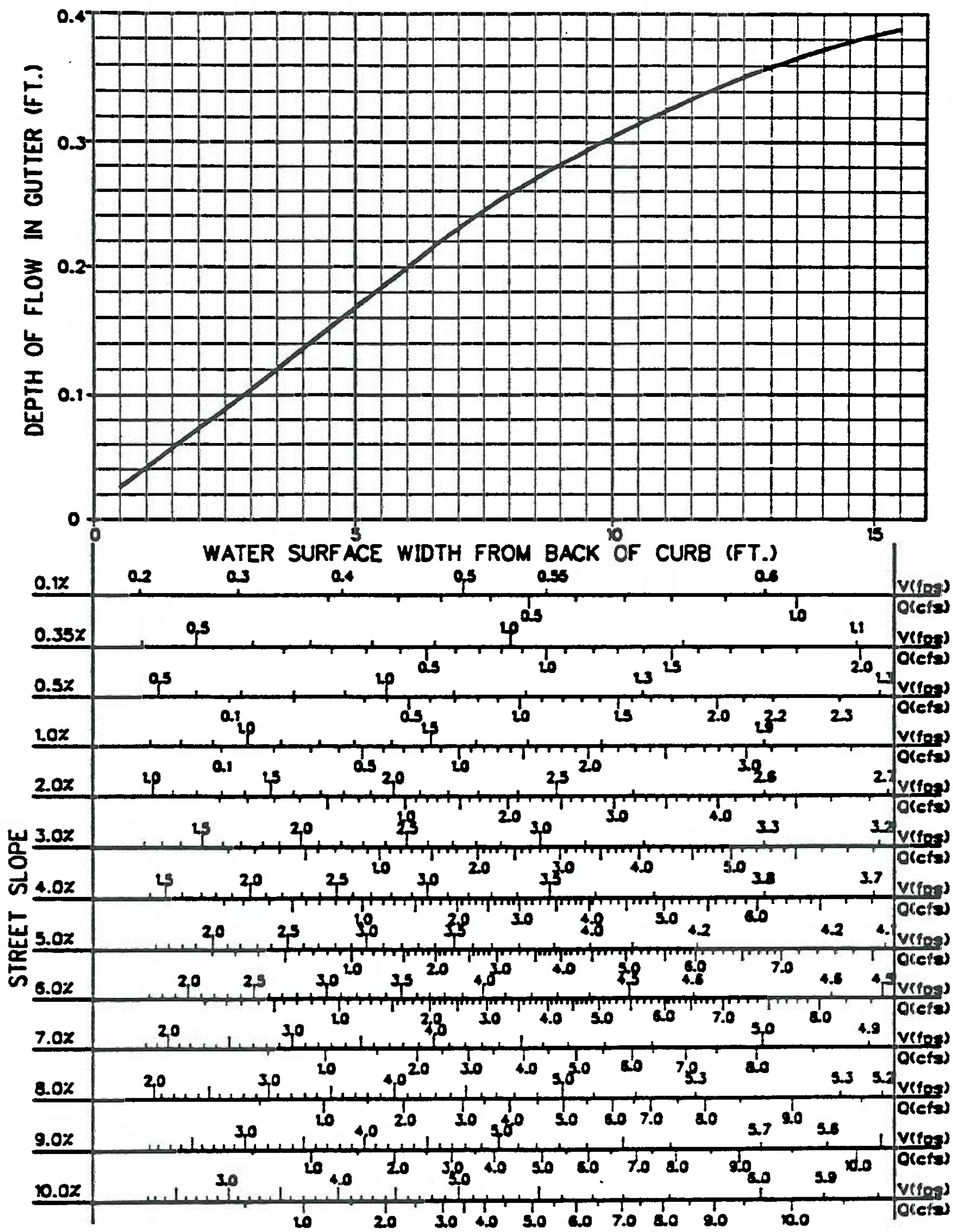
GUTTER FLOW FOR STANDARD 31'-0" PARABOLIC STREET SECTION

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

GUTTER FLOW FOR STANDARD 31 FT. PARABOLIC STREET SECTION

FIGURE 4

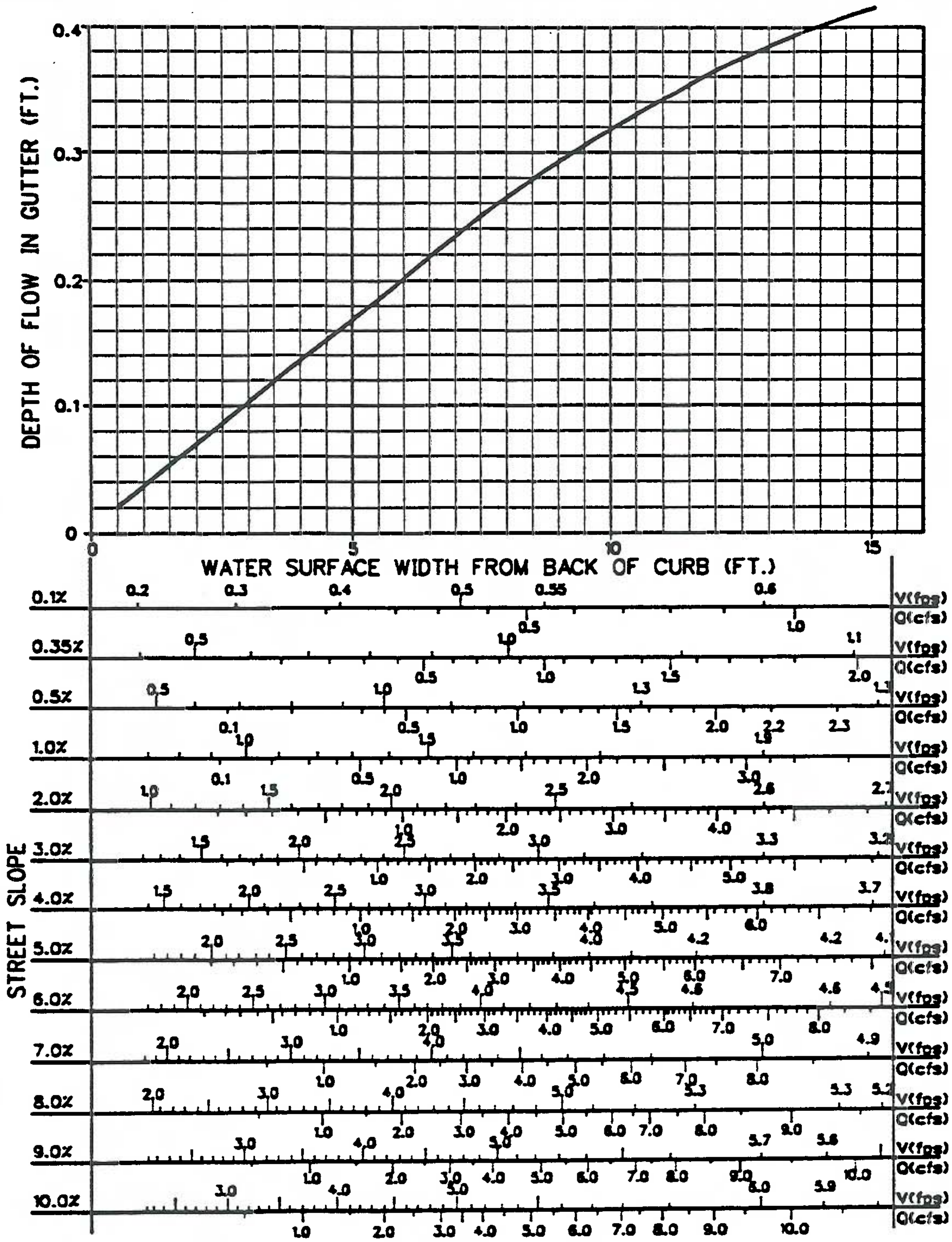


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

GUTTER FLOW FOR STANDARD 37 FT. PARABOLIC STREET SECTION

FIGURE 5

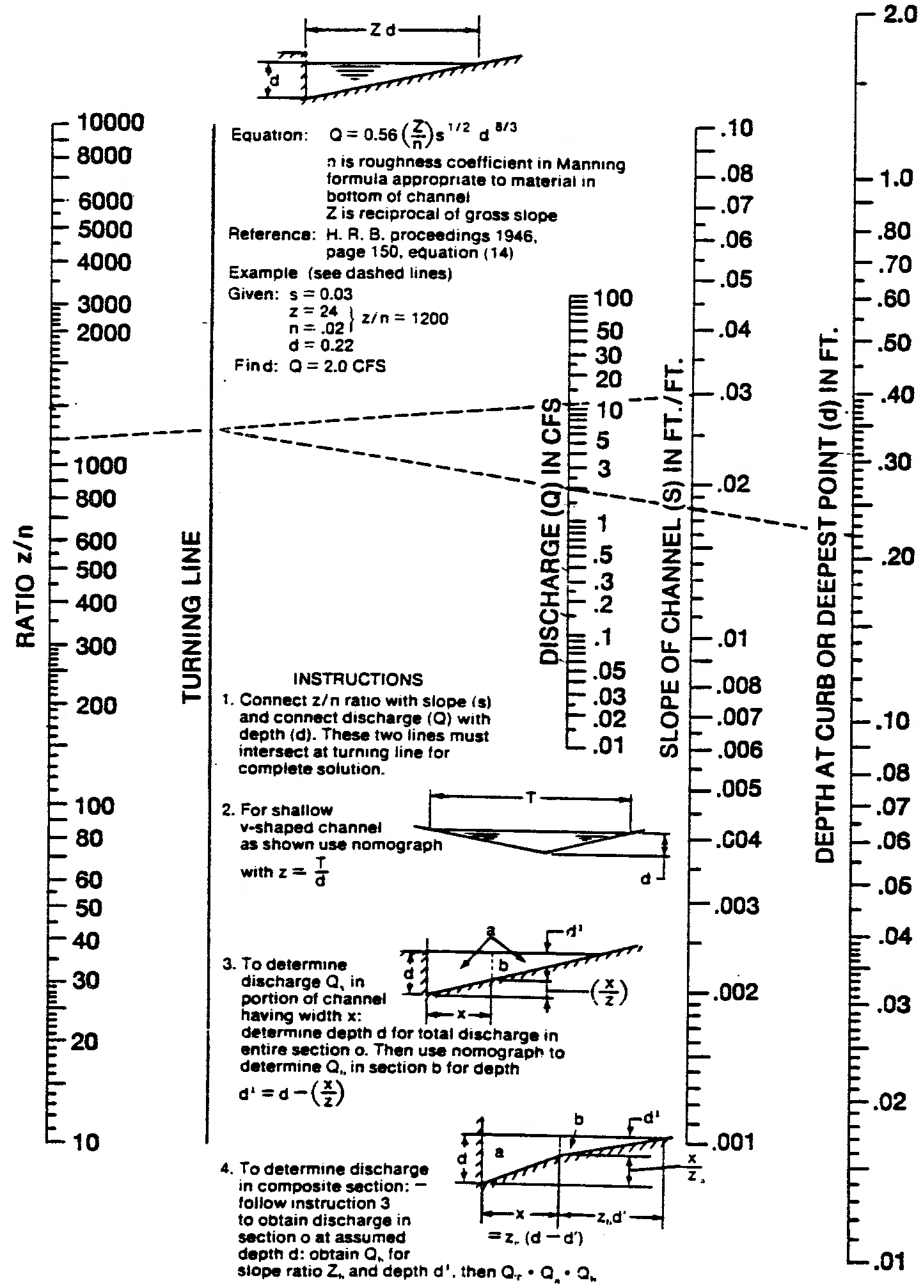


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS

GUTTER FLOW FOR STANDARD 45 FT. PARABOLIC STREET SECTION

FIGURE 6

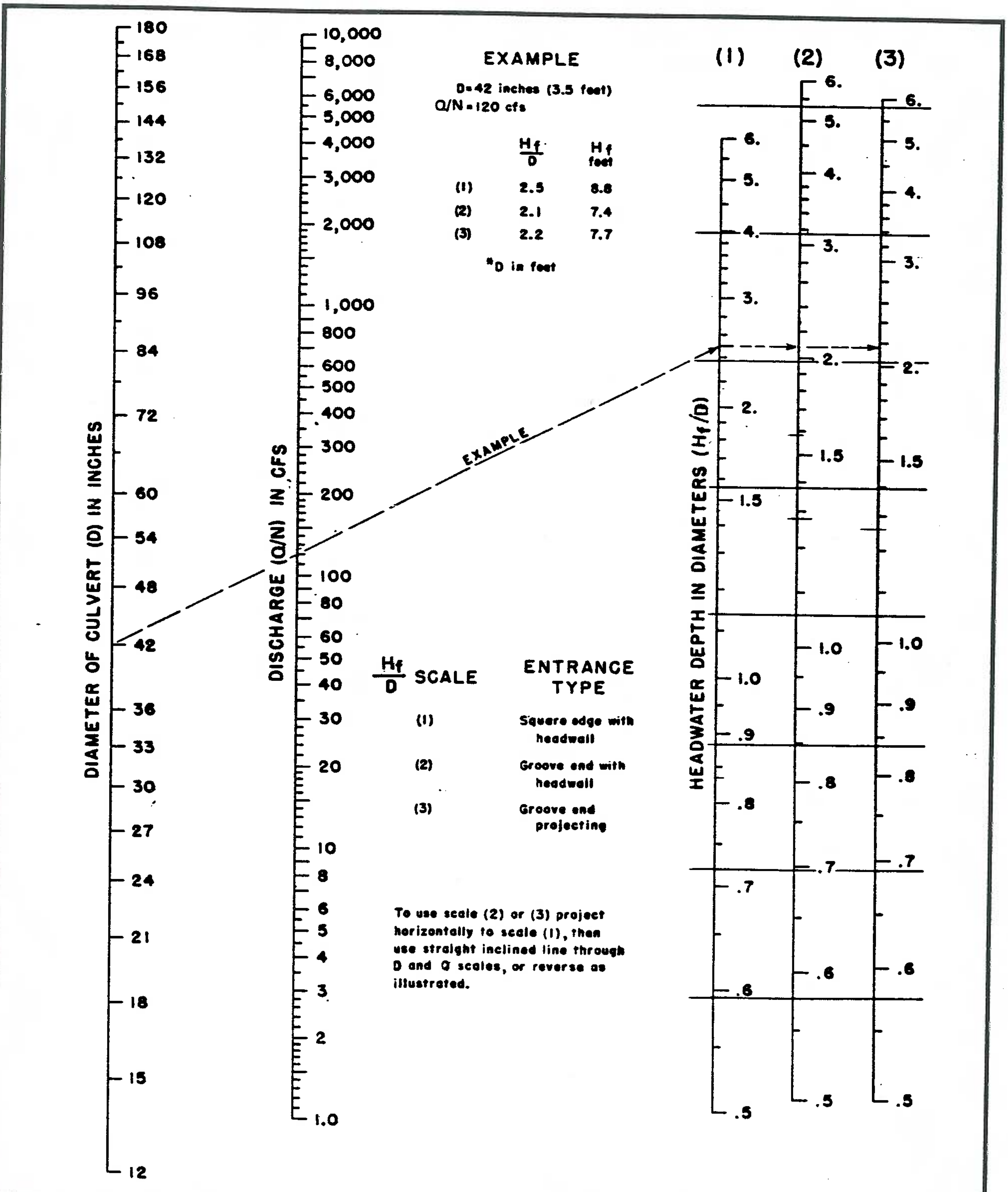


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

STREET GUTTER HYDRAULICS
(BY IZZARD'S FORMULA)

FIGURE 7

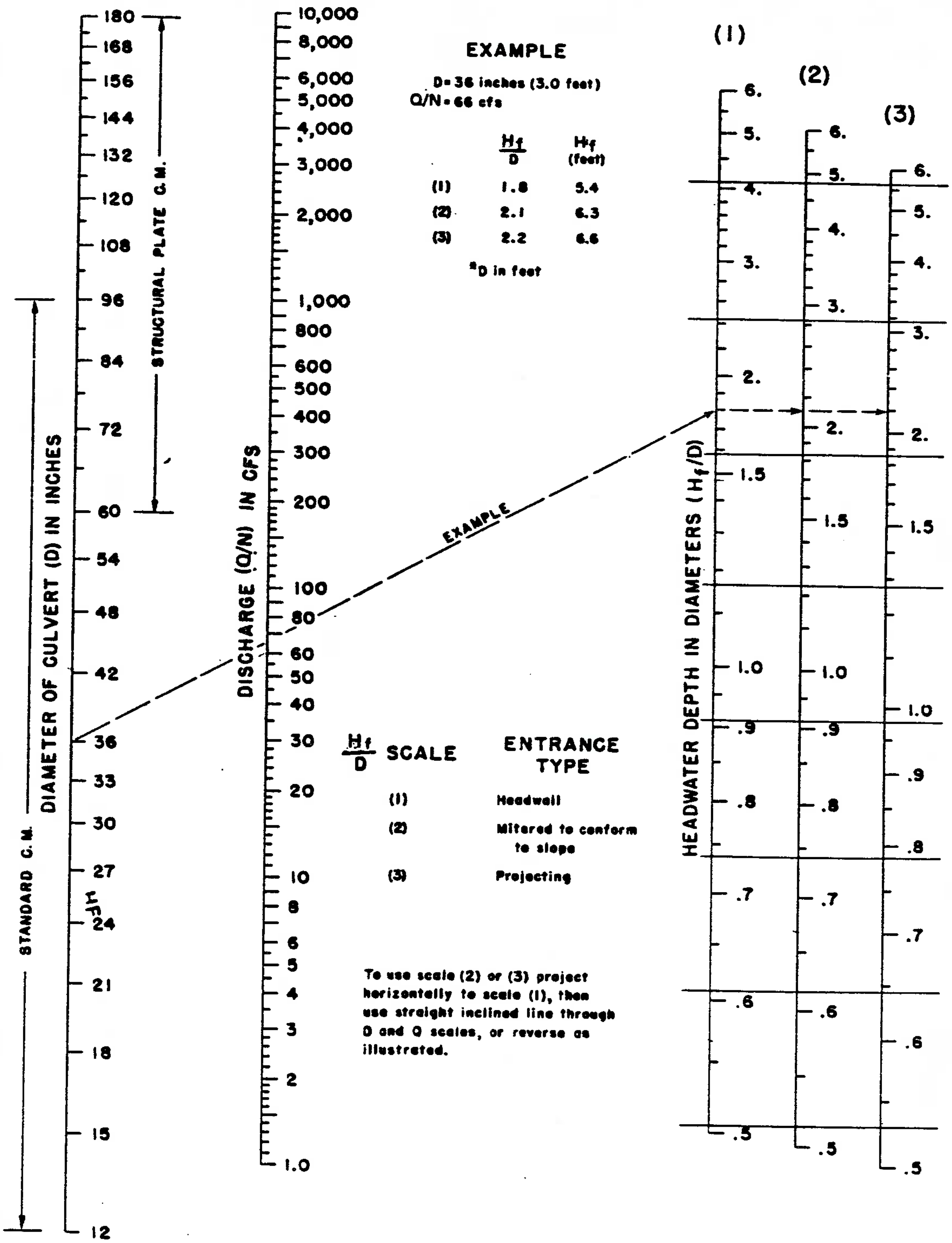


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

FIGURE 8.1

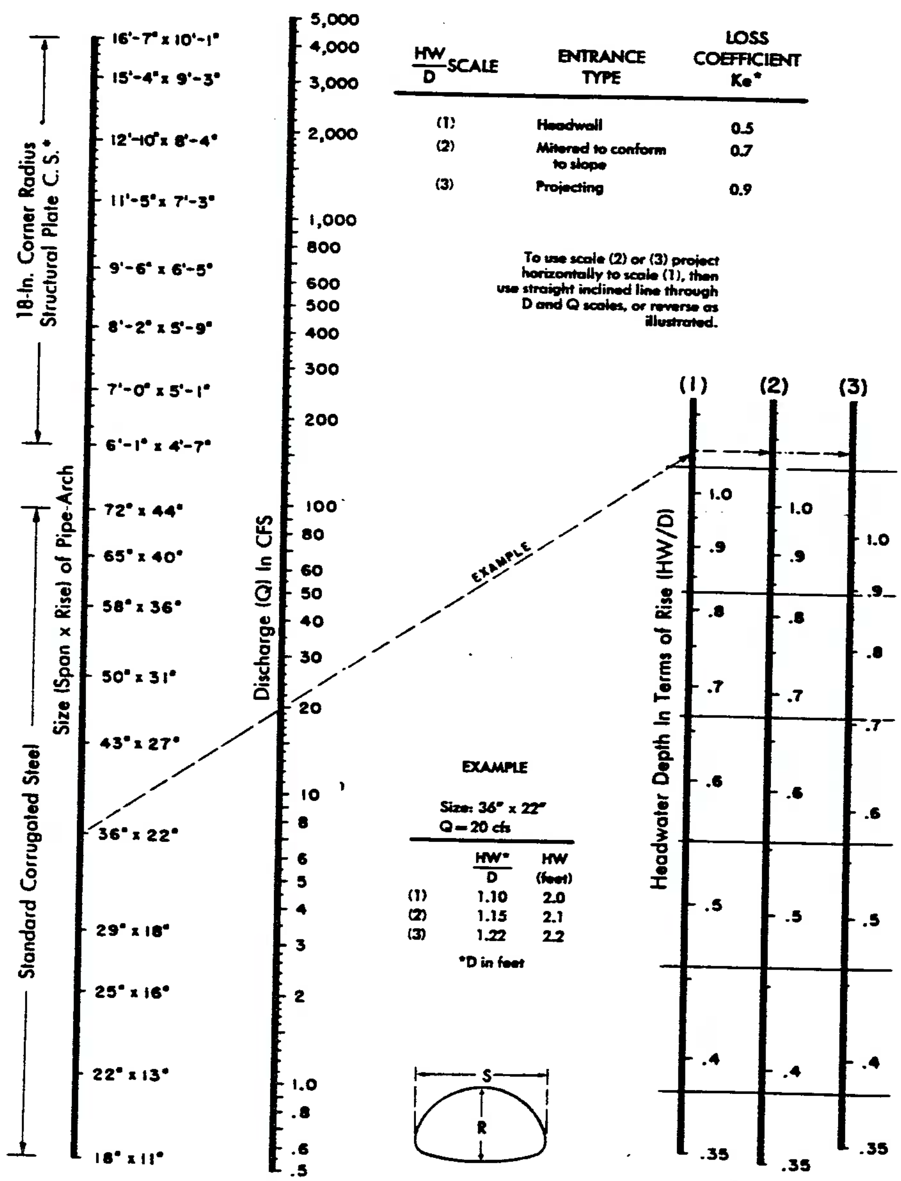


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

HEADWATER DEPTH FOR C.M. CULVERTS WITH INLET CONTROL

FIGURE 8.2

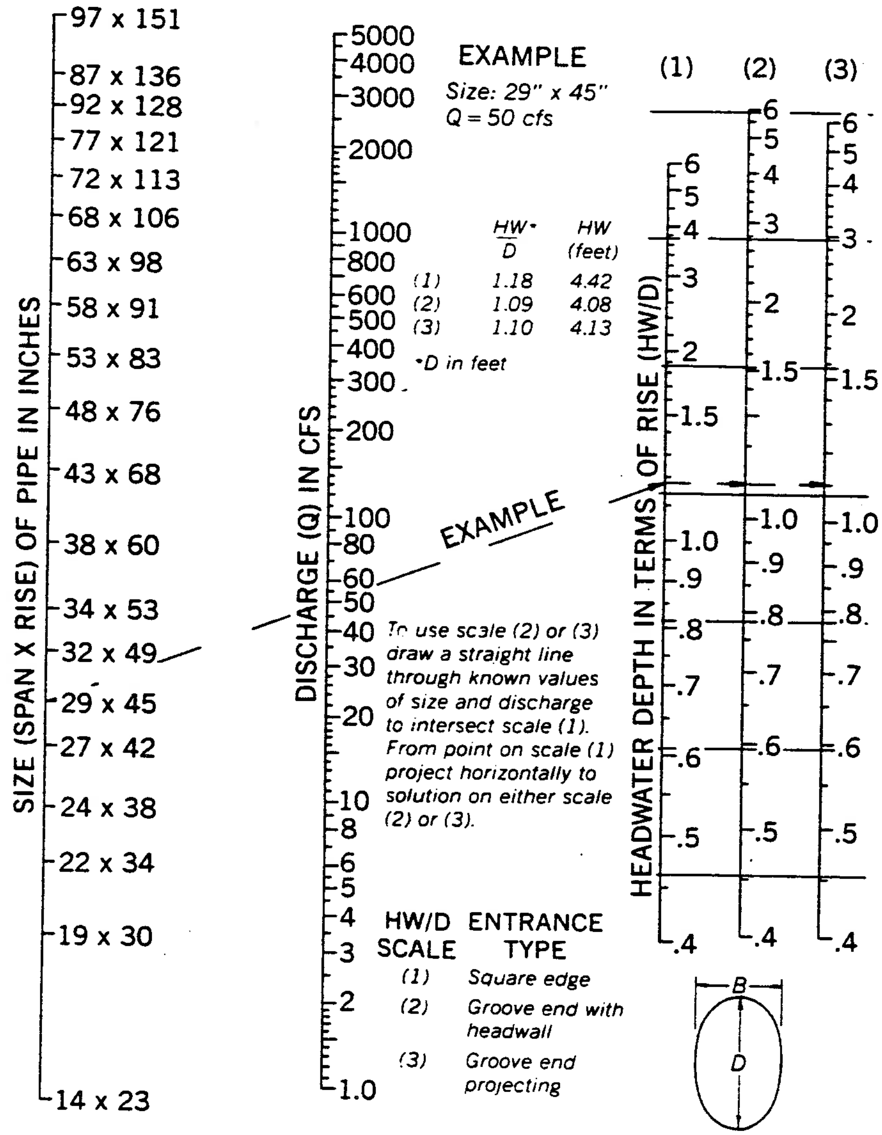


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

HEADWATER FOR C.M. PIPE-ARCH WITH INLET CONTROL

FIGURE 8.3

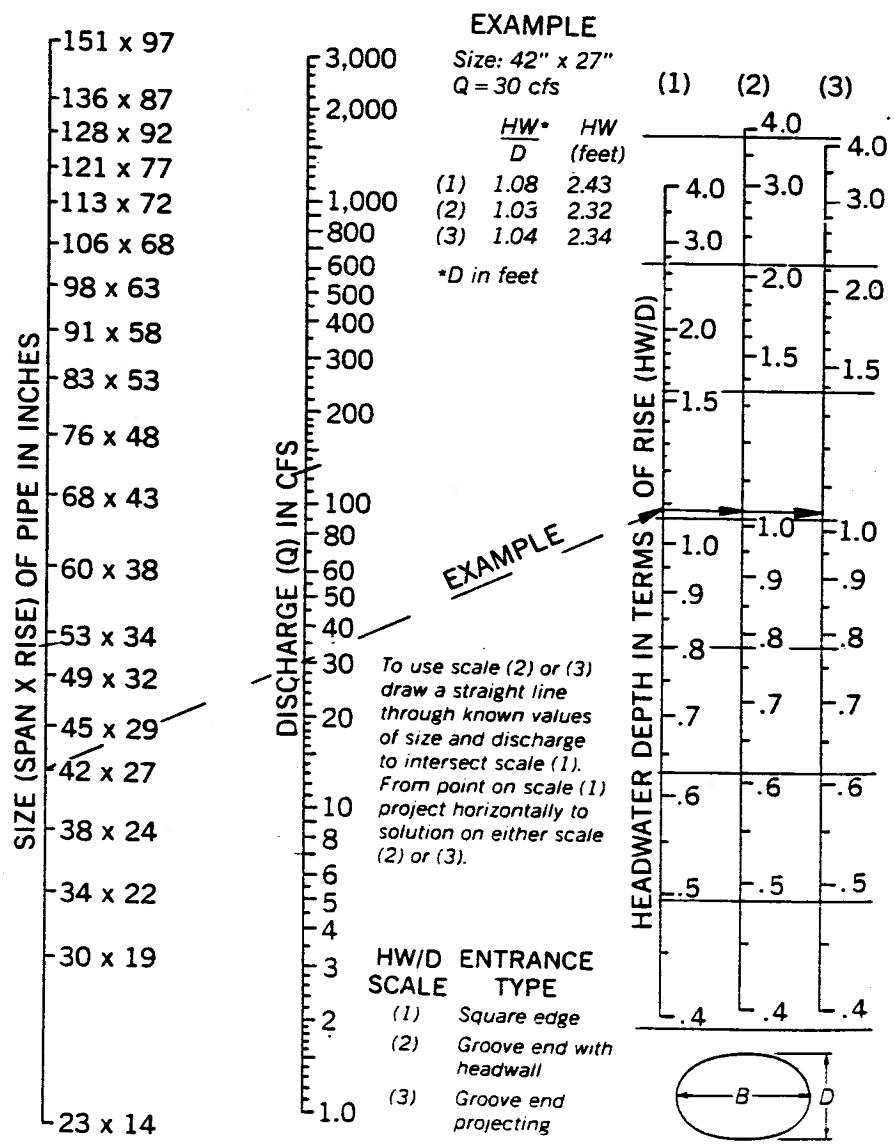


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

HEADWATER DEPTH FOR OVAL CONCRETE PIPE (VE) INLET CONTROL

FIGURE 8.4

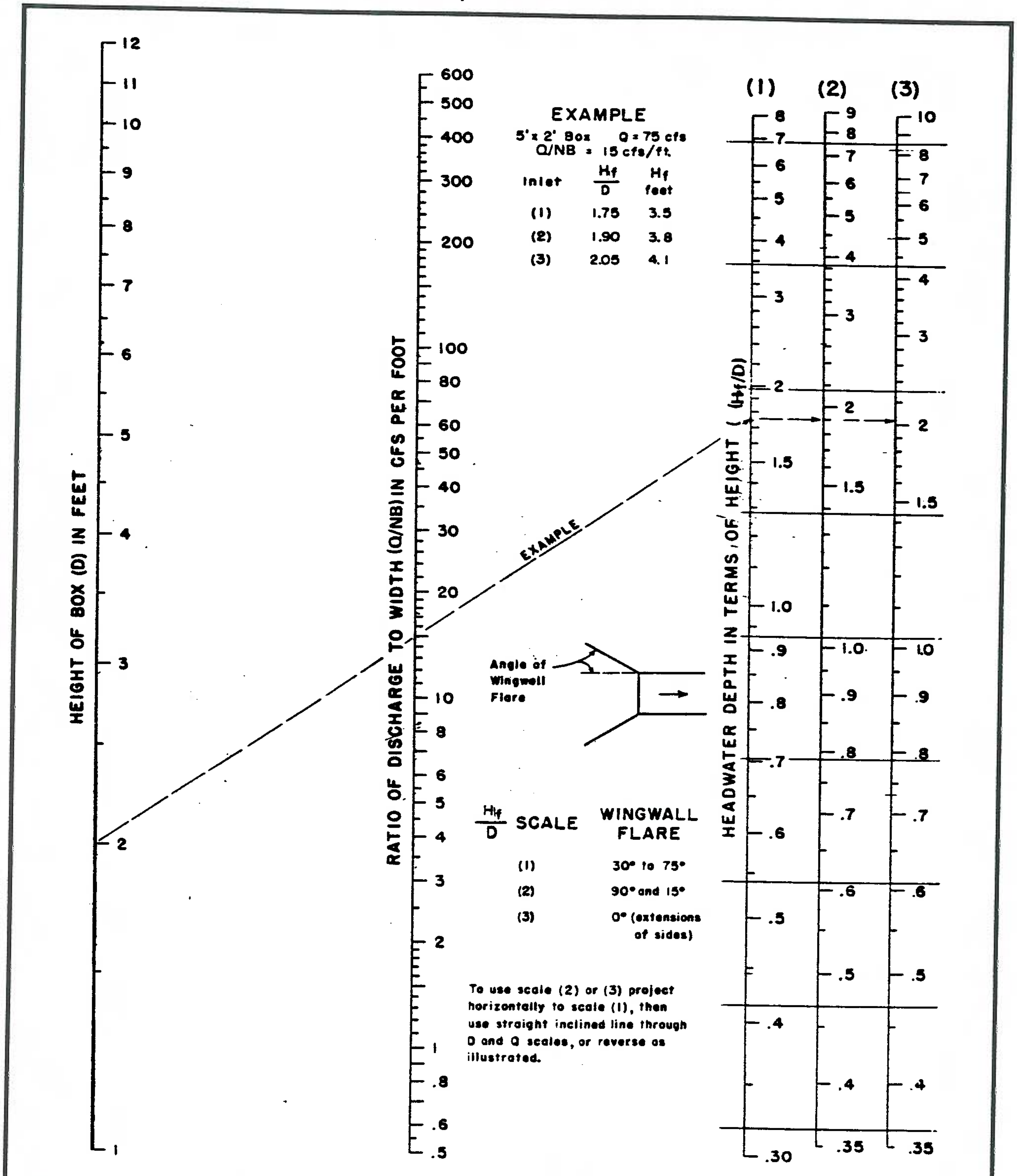


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

HEADWATER DEPTH FOR OVAL CONCRETE PIPE (HE) INLET CONTROL

FIGURE 8.5

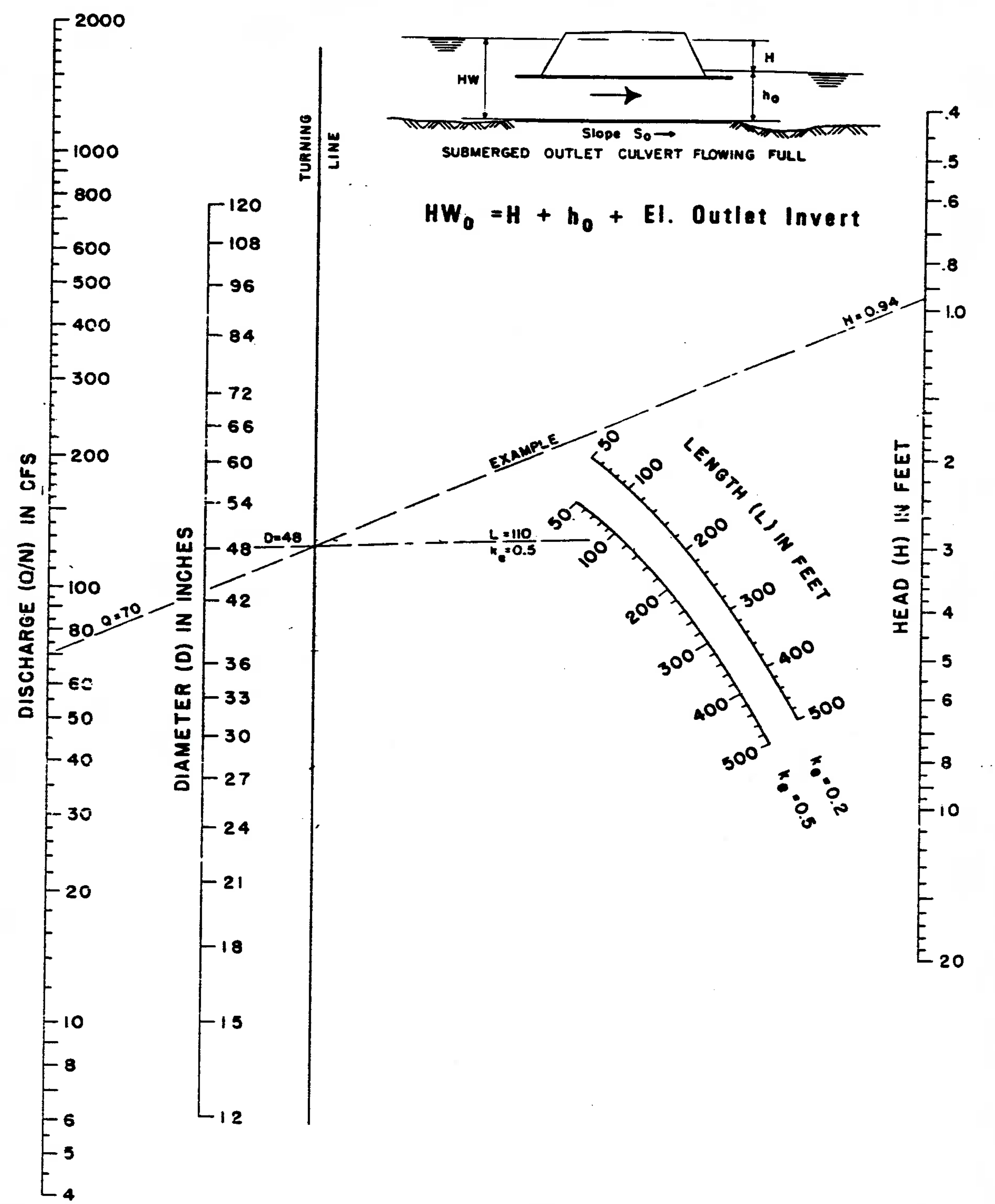


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

FIGURE 8.6

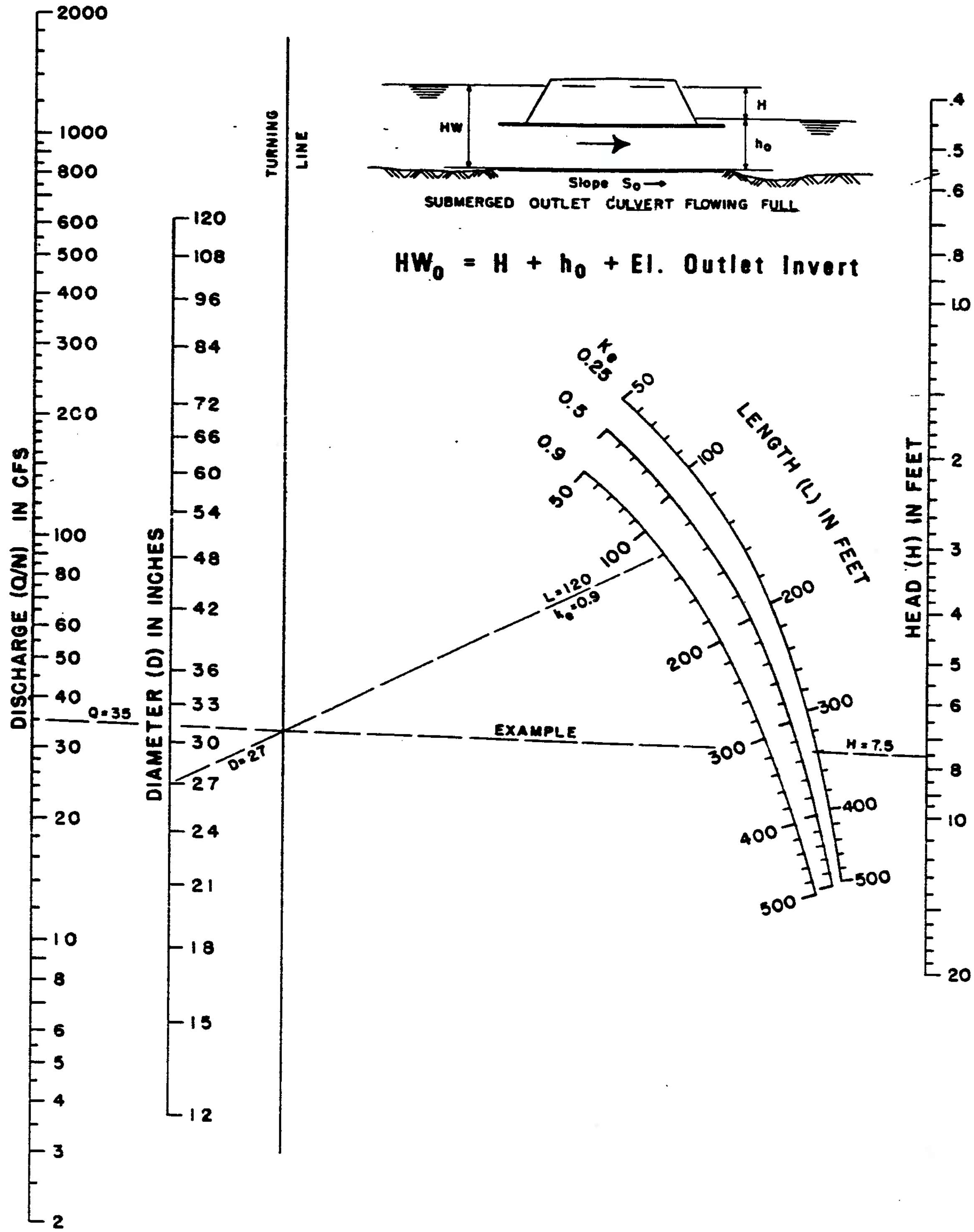


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

HEAD FOR CONCRETE PIPE CULVERTS FLOWING FULL

FIGURE 9.1

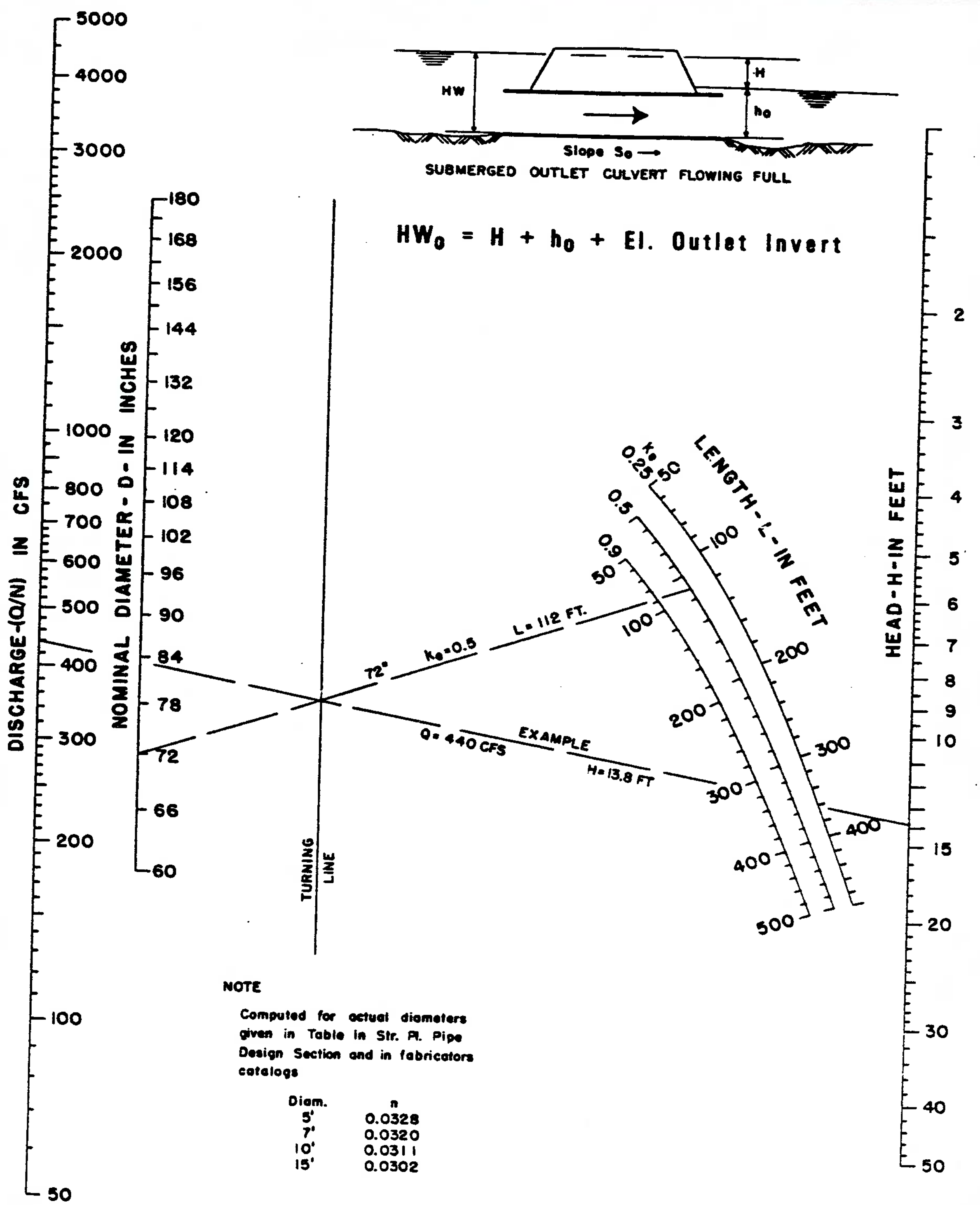


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

HEAD FOR STANDARD CORRUGATED METAL PIPE CULVERTS FLOWING FULL

FIGURE 9.2

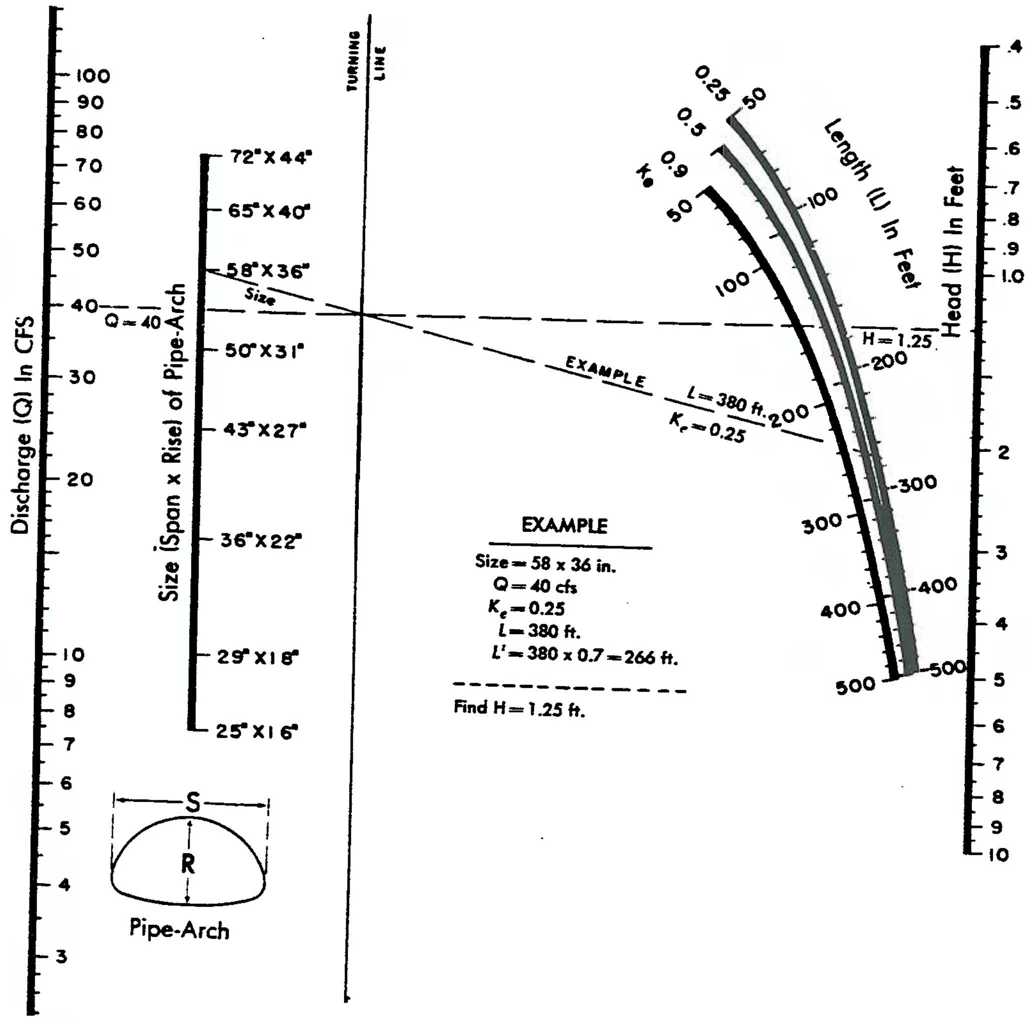


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

HEAD FOR STRUCTRUAL PLATE CORRUGATED METAL PIPE CULVERTS FLOWING FULL

FIGURE 9.3

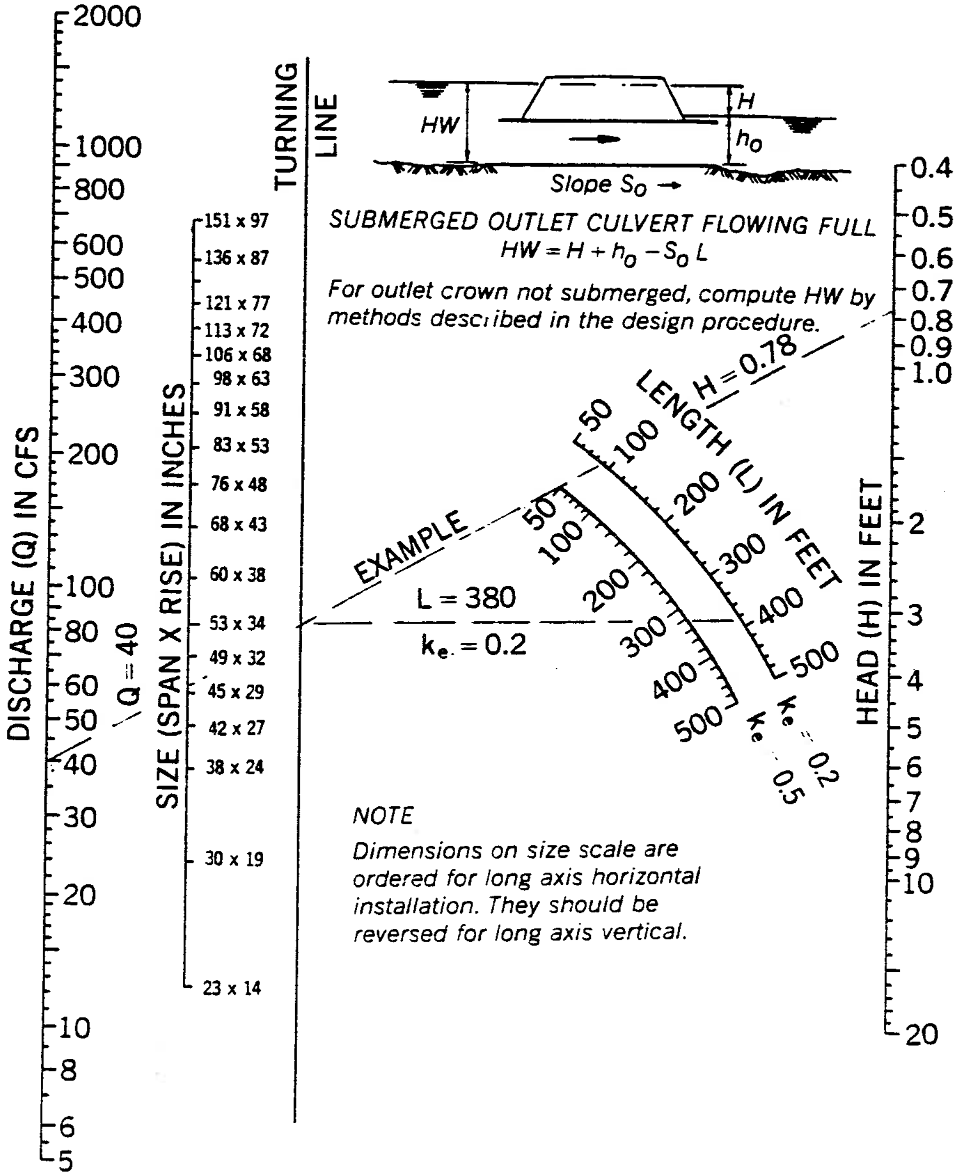


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

HEAD FOR STANDARD C.M. PIPE-ARCH CULVERTS FLOWING FULL

FIGURE 9.4

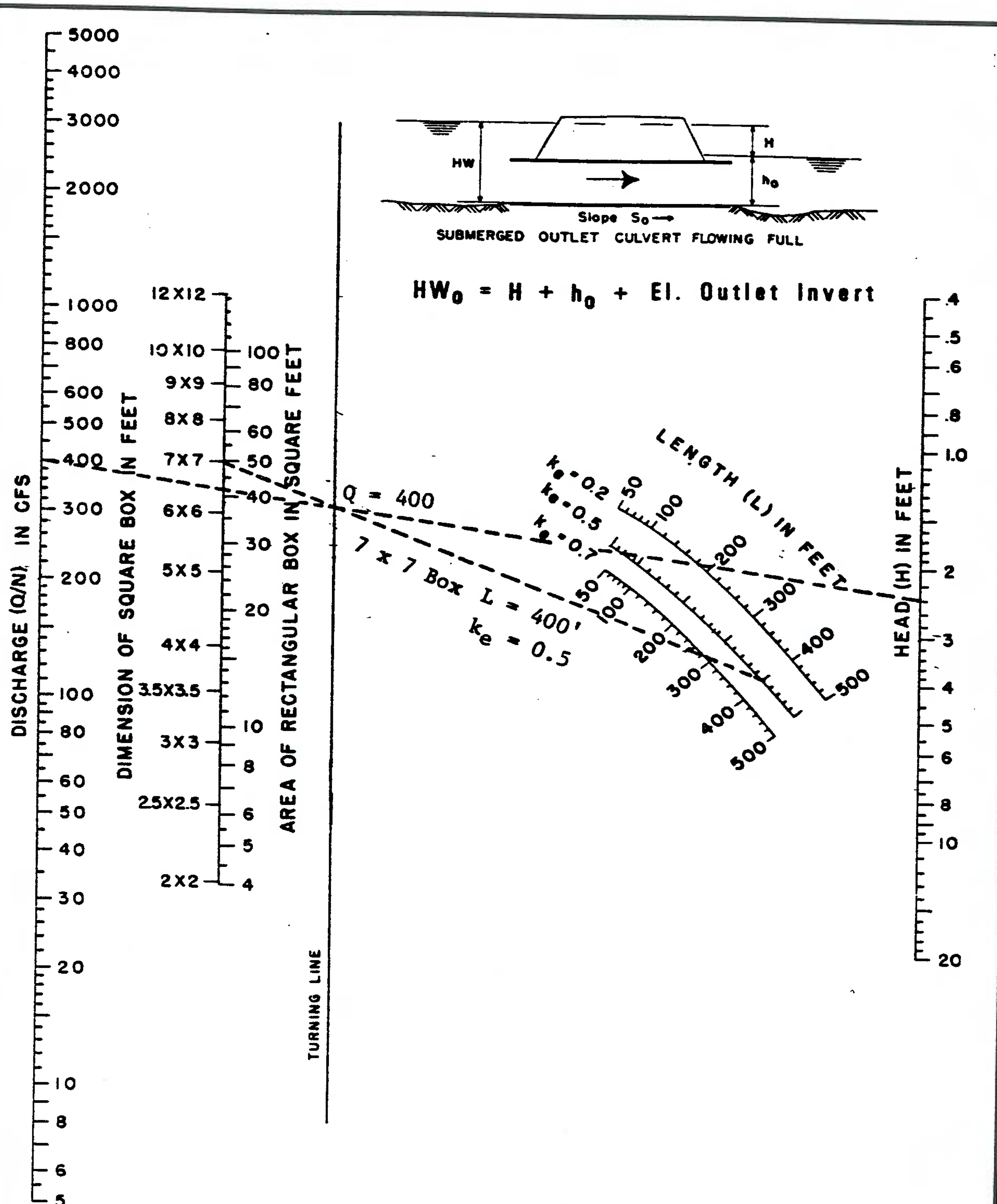


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

HEAD FOR OVAL CONCRETE PIPE CULVERTS FLOWING FULL (LONG AXIS HORIZONTAL OR VERTICAL)

FIGURE 9.5

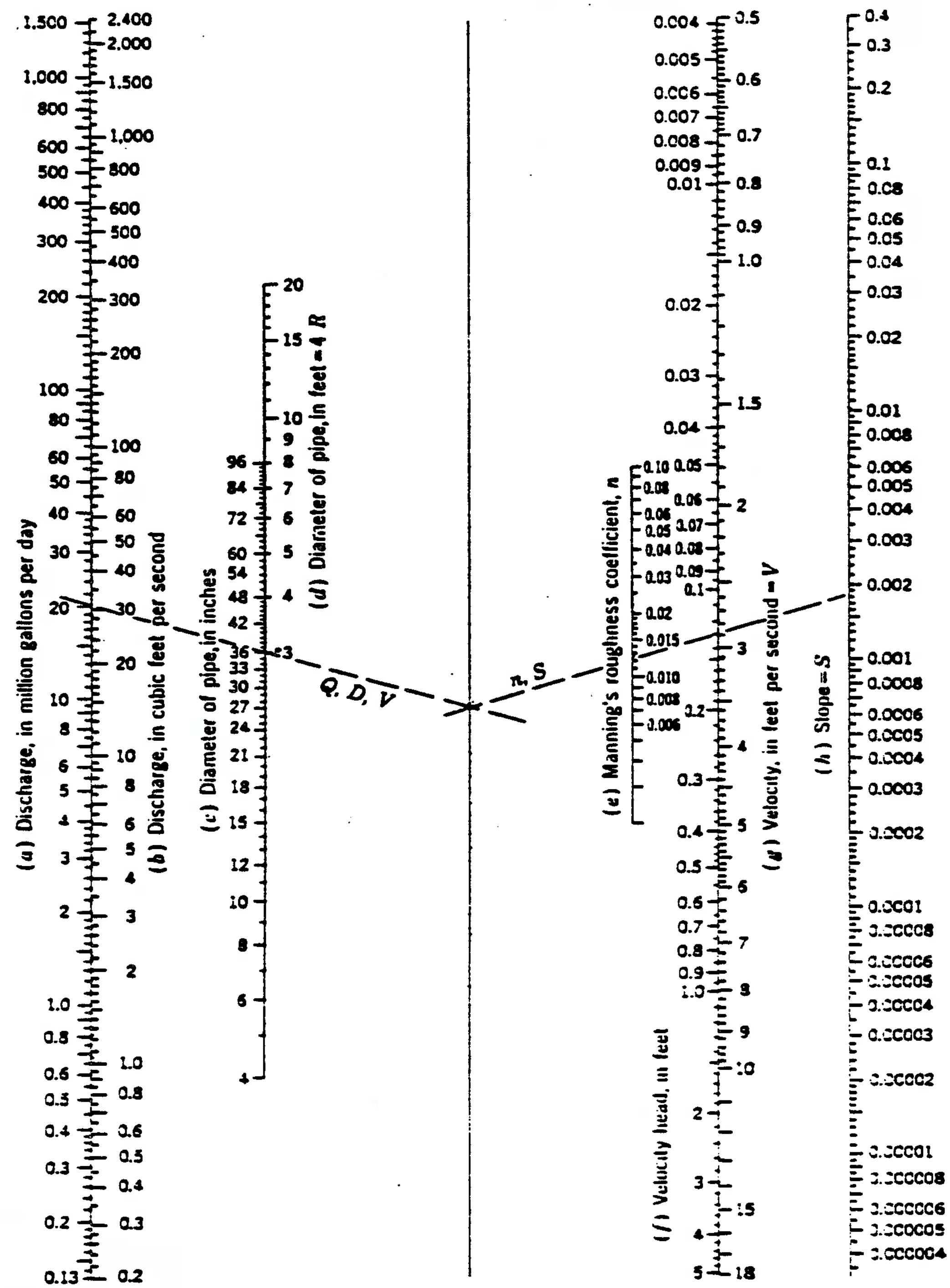


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS

HEAD FOR CONCRETE BOX CULVERTS FLOWING FULL

FIGURE 9.6

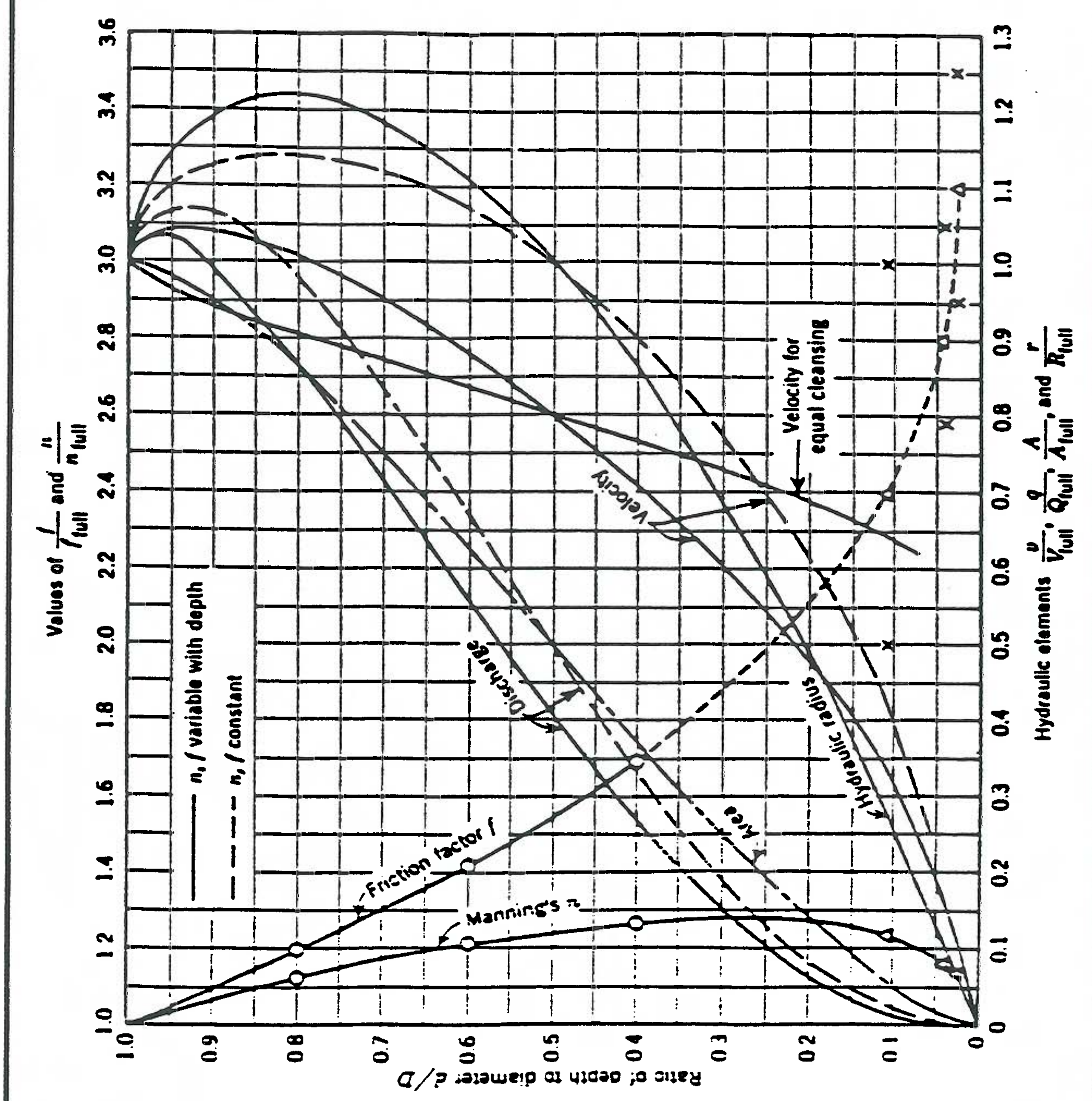


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

ALIGNMENT CHART FOR FLOW IN PIPES (MANNING'S FORMULA)

FIGURE 10

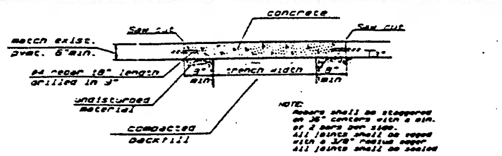


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

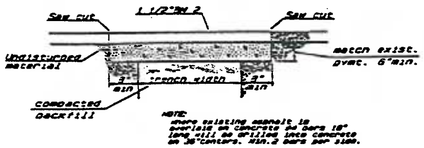
THE CITY OF MANHATTAN KANSAS — The Little Apple

HYDRAULIC ELEMENTS OF CIRCULAR CONDUITS

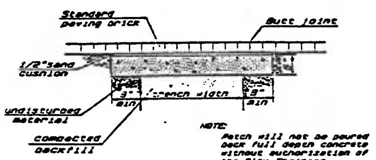
FIGURE 11



CONCRETE PATCH REPLACEMENT



ASPHALT PATCH REPLACEMENT

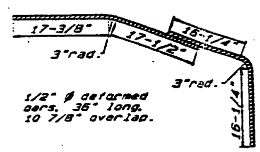


BRICK PATCH REPLACEMENT

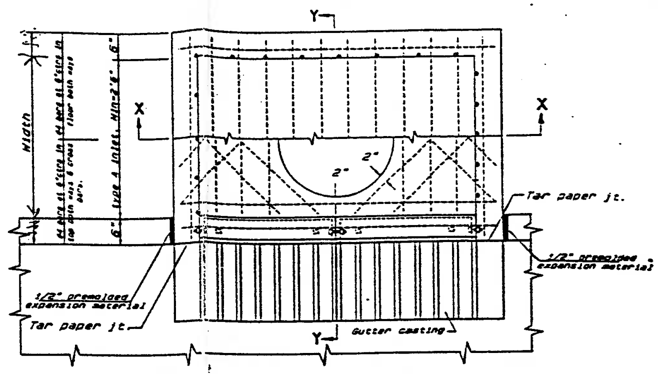
NOTES:
At the Contractors option, inlet boxes may be constructed of reinforced concrete as shown, or of 4" solid concrete blocks built on a poured concrete base, and with a poured reinforced concrete top slab. Solid concrete block shall not be used when "H" (Height) is greater than eight (8) feet.
All reinforced concrete storm sewer pipe shall be class III or better.
The ring and cover shall be Clay and Bailey No. 2023 or approved equivalent when the manhole is within street pavement. Other locations shall be Clay and Bailey No.2084-3 or approved equivalent.
Gutter castings shall be Clay and Bailey No. 2086-2 or approved equivalent, and shall be installed when the inlet is not located in a sump.

TYPE	WIDTH *	LENGTH
A-5	2'- 6" min	5'0"
A-7.5	2'- 6" min	7'6"
A-10	2'- 6" min	10'0"

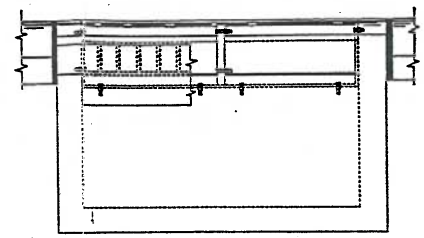
* For pipes up to 24" in diameter width shall be 2'6". For pipes larger than 24" in diameter width shall be the outside diameter of the pipe plus 3" clearance on each side.



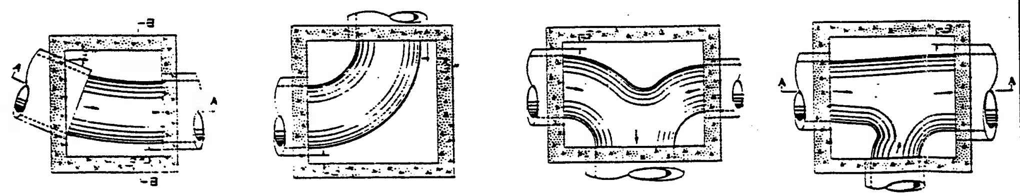
BENDING DIAGRAM



PLAN



FRONT ELEVATION

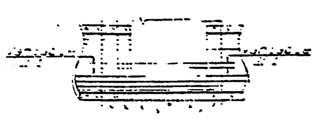


FLOOR PLAN I

FLOOR PLAN II

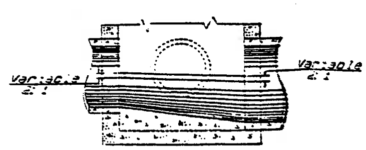
FLOOR PLAN III

FLOOR PLAN IV

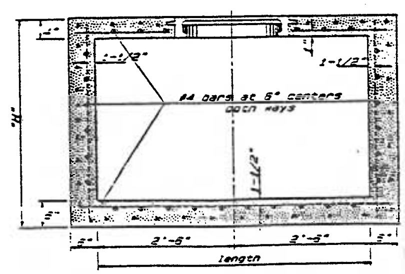


SECTION A-A (FLOOR PLAN I)

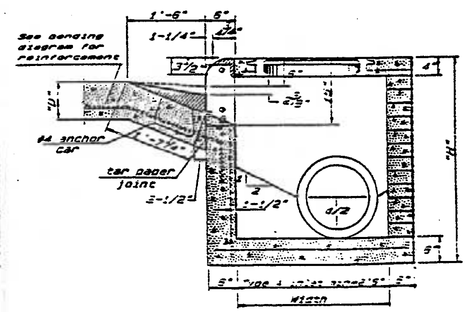
TYPICAL INVERT SHAPING DETAILS



SECTION A-A (FLOOR PLAN IV)



SECTION X-X



SECTION Y-Y

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

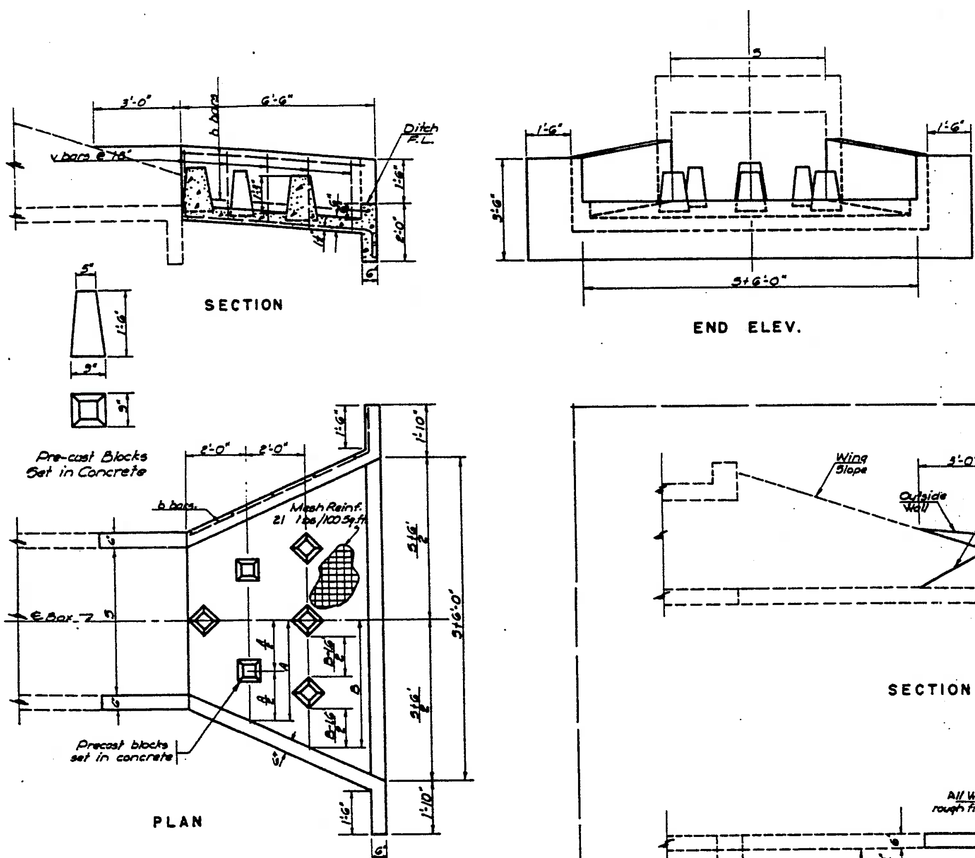
THE CITY OF MANHATTAN KANSAS The Little Apple

TYPE 'A' CURB INLET

FIGURE 12

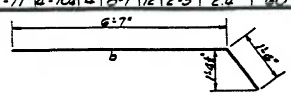
FHWA REG. NO.	STATE	PROJECT NO.	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
7	KANSAS				

TYPE "B"

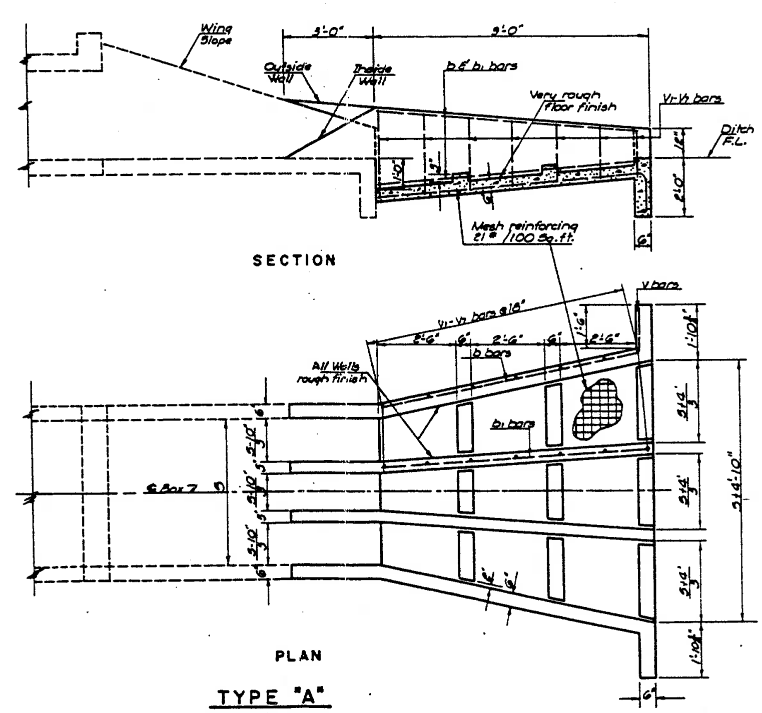


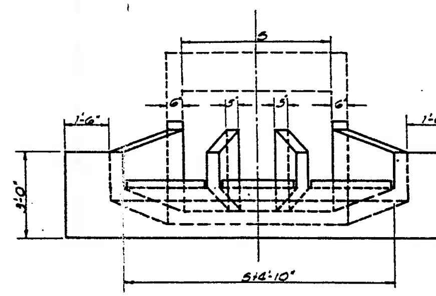
ALL BARS ARE # 4

S	A	B	b bars No.	b bars Lgth.	v bars No.	v bars Lgth.	Class A Conc. Cu. Yds.	Reinf. Steel Lbs.
3'-0"	2'-5"	3'-4½"	4	8'-1"	12	2'-3"	2.0	50
4'-0"	2'-11"	3'-10½"	4	8'-1"	12	2'-3"	2.2	60
5'-0"	3'-5"	4'-4½"	4	8'-1"	12	2'-3"	2.3	60
6'-0"	3'-11"	4'-10½"	4	8'-1"	12	2'-3"	2.4	60



TYPE "A"

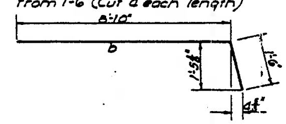




ALL BARS ARE #4

S	b bars No.	b bars Lgth.	b1 bars No.	b1 bars Lgth.	v bars No.	v bars Lgth.	V1-V7 Bars No.	V1-V7 Bars Lgth.	Class A Conc. Cu. Yds	Reinf. Steel lbs.
3'-0"	4	10'-4"	4	8'-9"	2	2'-9"	28	*	2.9	110
4'-0"	4	10'-4"	4	8'-9"	2	2'-9"	28	*	3.1	120
5'-0"	4	10'-4"	4	8'-9"	2	2'-9"	28	*	3.3	120
6'-0"	4	10'-4"	4	8'-9"	2	2'-9"	28	*	3.5	120

* V1-V7 bars increase by 3" increments from 1'-6" (Cut 4 each length)



NOTE:

Wire reinforcing mesh shall be electrically welded and shall be composed of No. W 1.4 wire at 6" centers each way. Weight of reinforcing mesh shall be classified as pounds of reinforcing steel.

Class A concrete shall be used thruout.

Bevel all exposed edges with a ¾" triangular moulding unless otherwise noted.

At the contractor's option Class A concrete (AE) may be used thruout, but payment shall be made as Cu. Yds. of Class A concrete.

NO.	DATE	REVISIONS	BY	APP'D
3	9-10-73	Wire Reinf. Mesh Changed to W1.4	W.L.H.	K.G.
2	10-27-72	Wire Size AASHO Des. M32-72 I	W.L.H.	K.G.
1	12-63	Added Concrete option	A.L.R.	K.G.

KANSAS DEPARTMENT OF TRANSPORTATION

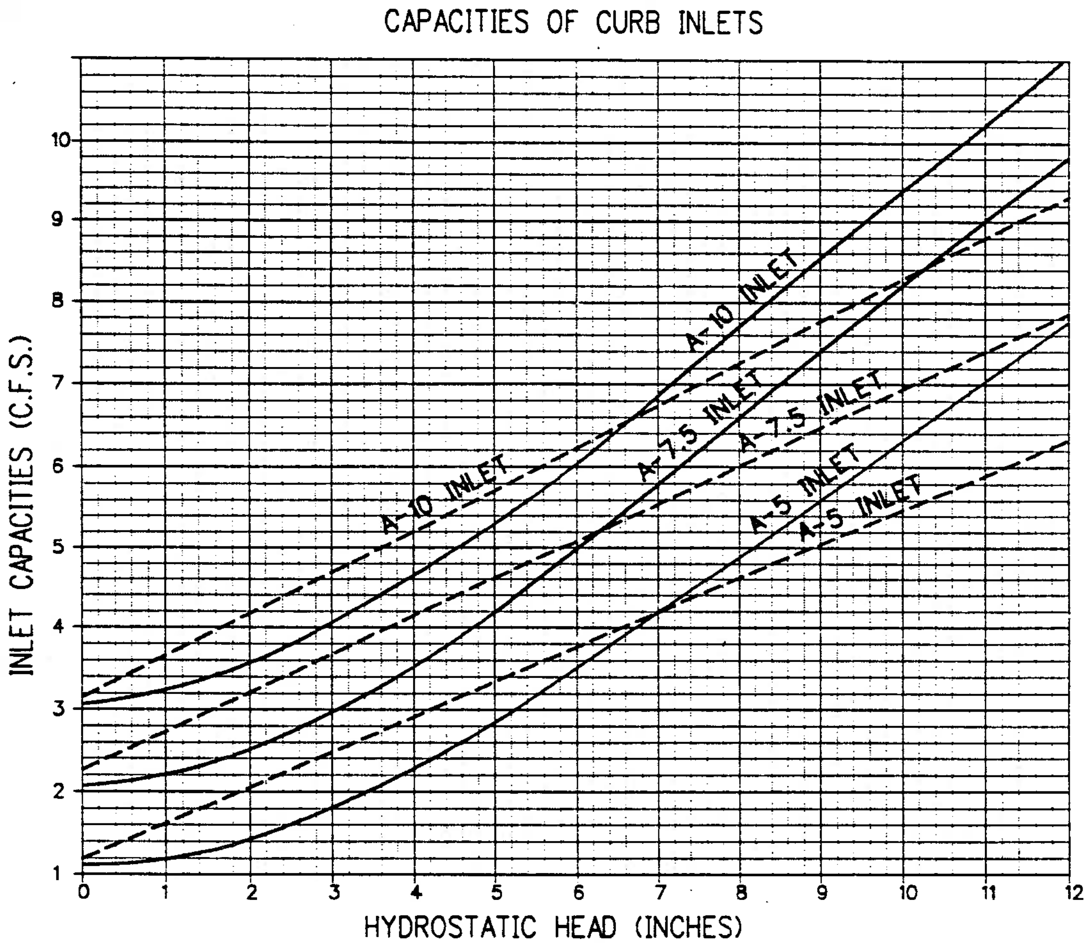
OUTLET SCOUR PROTECTION

STD. NO. 521

Scale ½" = 1'-0"

Designed T.W.O. Detailed E.S. Quantities E.S. Quan. CK. C.D.C.

Jan. 1955



- - - - - GUTTER GRADE = 1%

———— GUTTER GRADE = 2%

NOTE: FOR GUTTER GRADES FLATTER THAN 1% USE CURVES SHOWN FOR 1% TO AND INCLUDING 0.5%, AND; & BELOW 0.5% USE THE APPROX. EQUATION Q=HL/10 WHERE
H=HYDROSTATIC HEAD IN INCHES
L=LENGTH OF INLET IN FEET

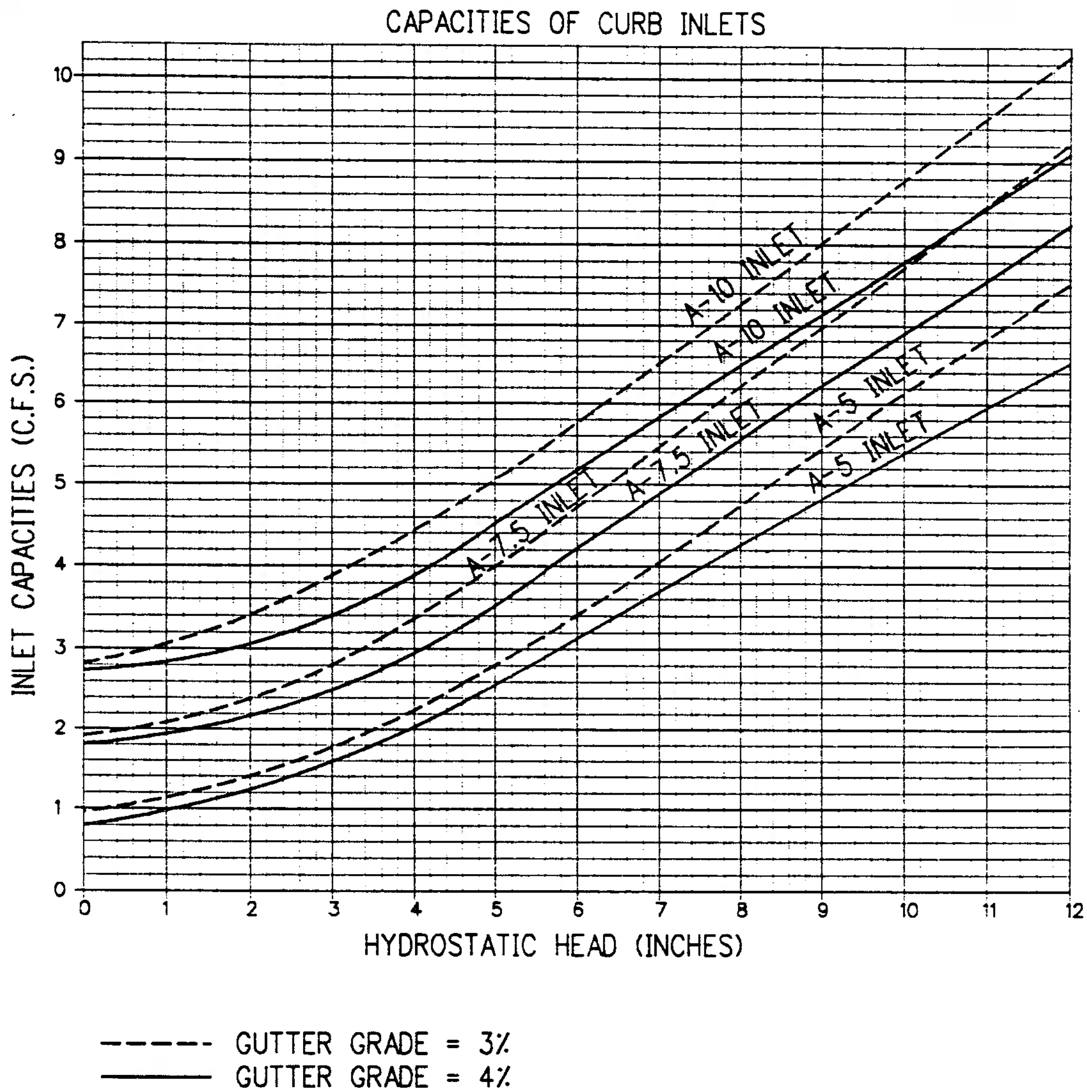
NOTE: HYDROSTATIC HEAD IS THE DIFFERENCE IN ELEVATION BETWEEN THE GUTTER AT THE INLET AND THE WATER SURFACE AT THE LOWEST POINT OF OVERFLOW BELOW INLET.

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

Capacity of Curb Opening Inlets on Continuous Grade (1% & 2%)

Figure 13a

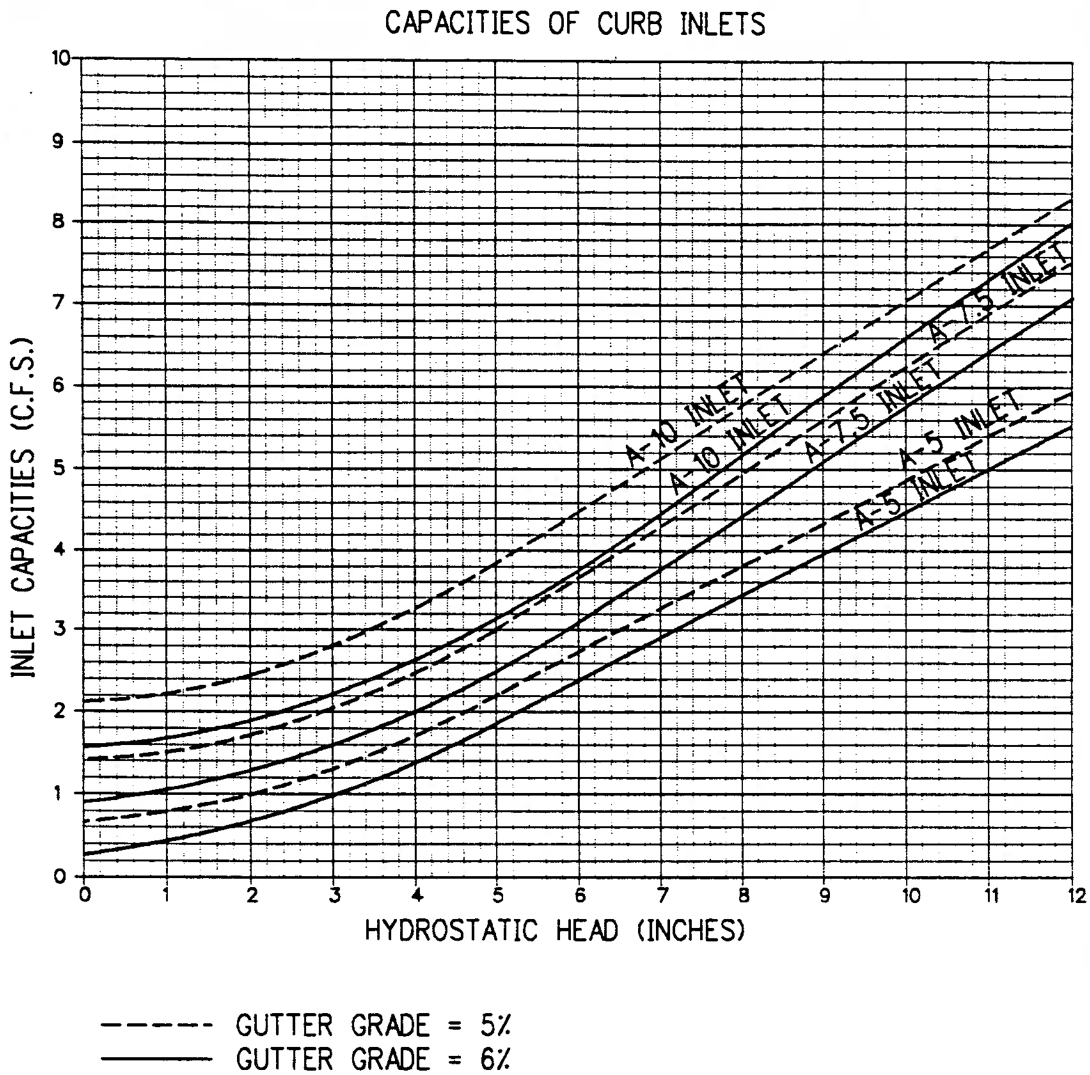


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

Capacity of Curb Opening Inlets on Continuous Grade (3% & 4%)

Figure 13b

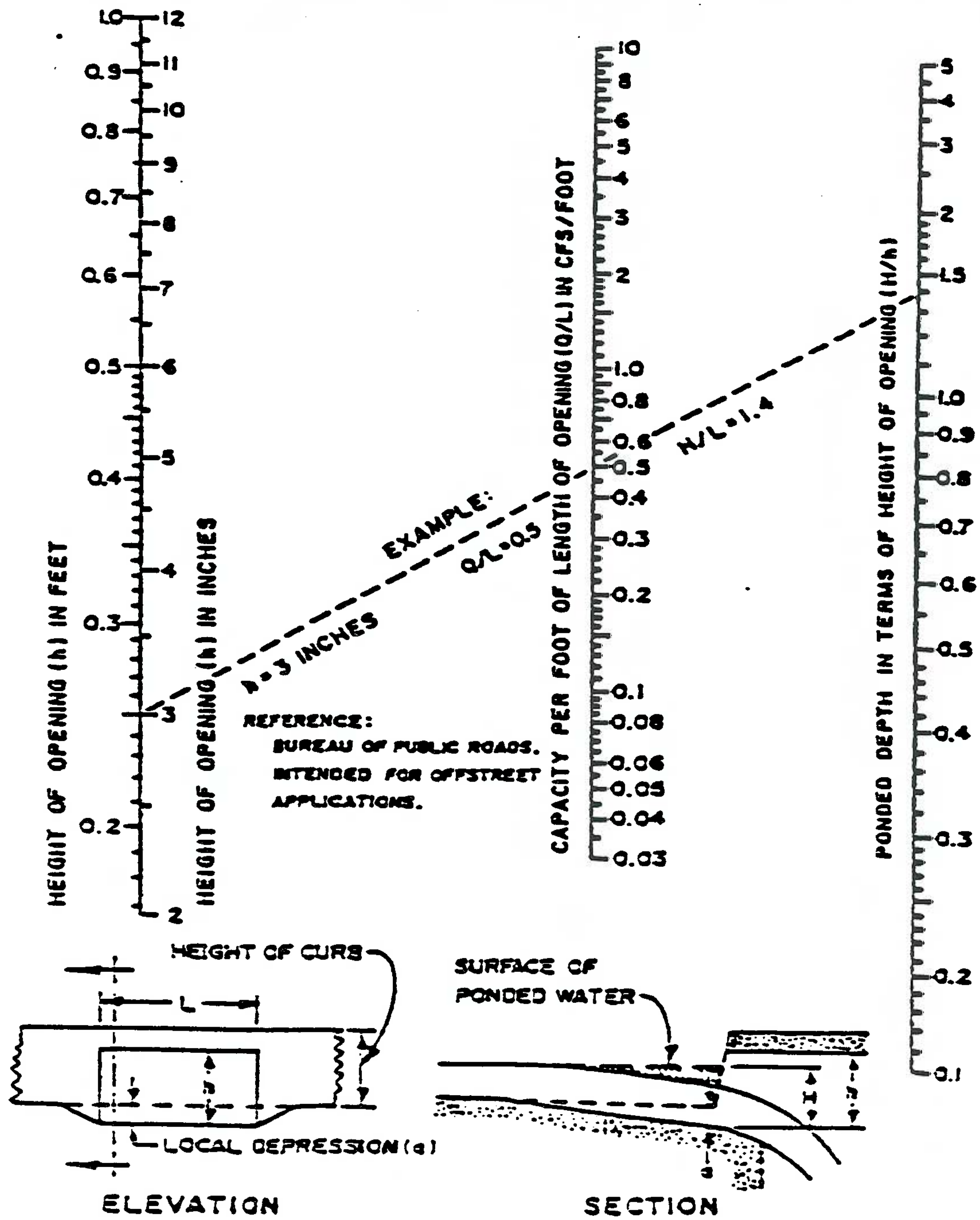


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

Capacity of Curb Opening Inlets on Continuous Grade (5% & 6%)

Figure 13c

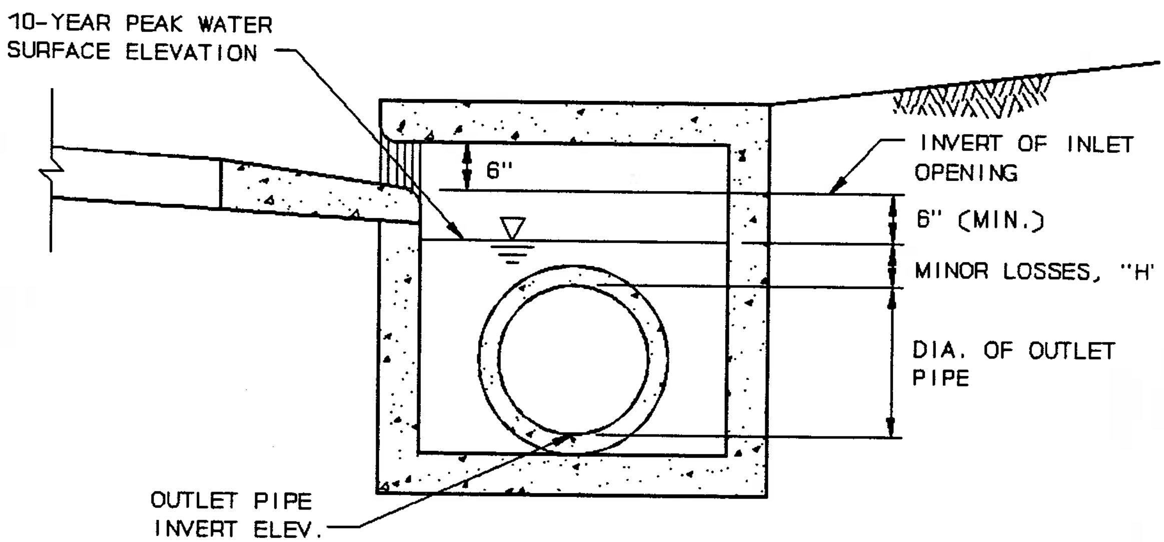


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

CURB OPENING INLETS CAPACITY IN SUMP LOCATIONS

FIGURE 14



$$"H" = K(V^2/2G)$$

NOTES:

1. SEE TABLE F FOR VALUES OF "K".

2. V = Q/A WHERE
   Q = FLOW, IN CFS
   A = CROSS-SECTIONAL AREA OF OUTLET PIPE, IN SQ. FT.

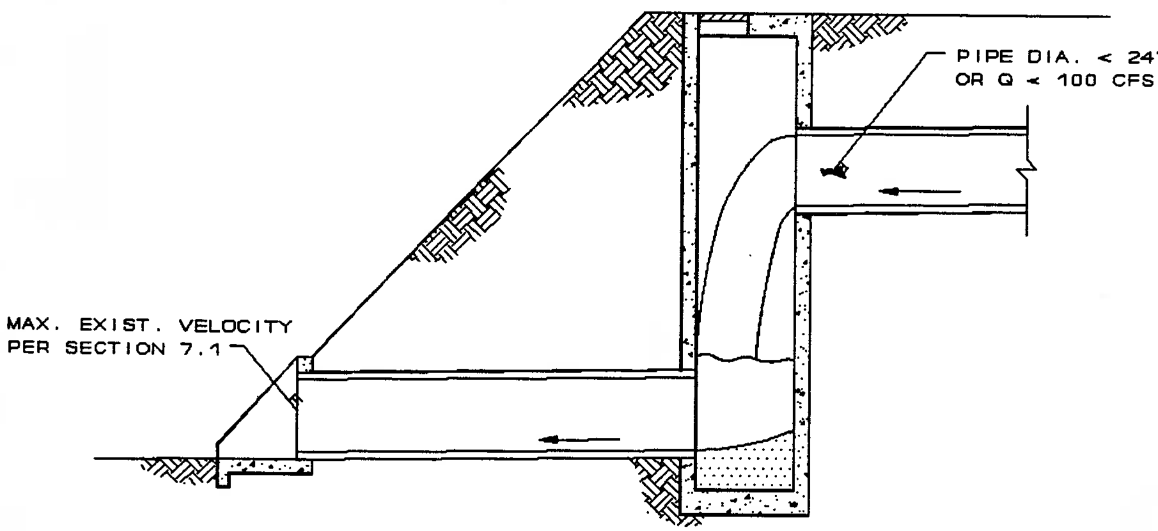
3. 2G = 64.4 FT. PER SEC. PER SEC.

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

CURB OPENING INLETS HYDRAULIC DIMENSIONAL CRITERIA

FIGURE 15



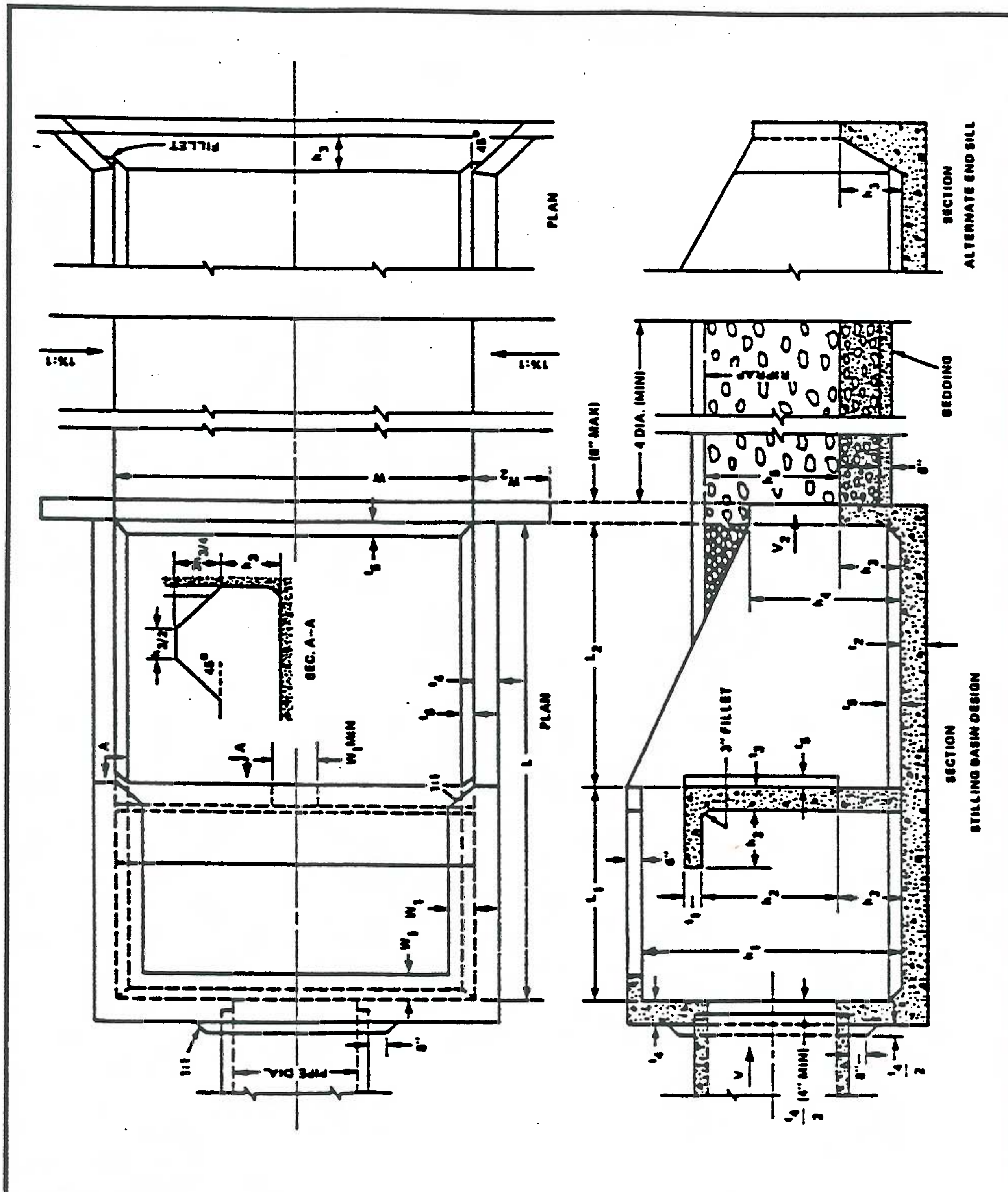
SECTION

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

ENCLOSED VERTICAL DROP ENERGY DISSIPATOR

FIGURE 16

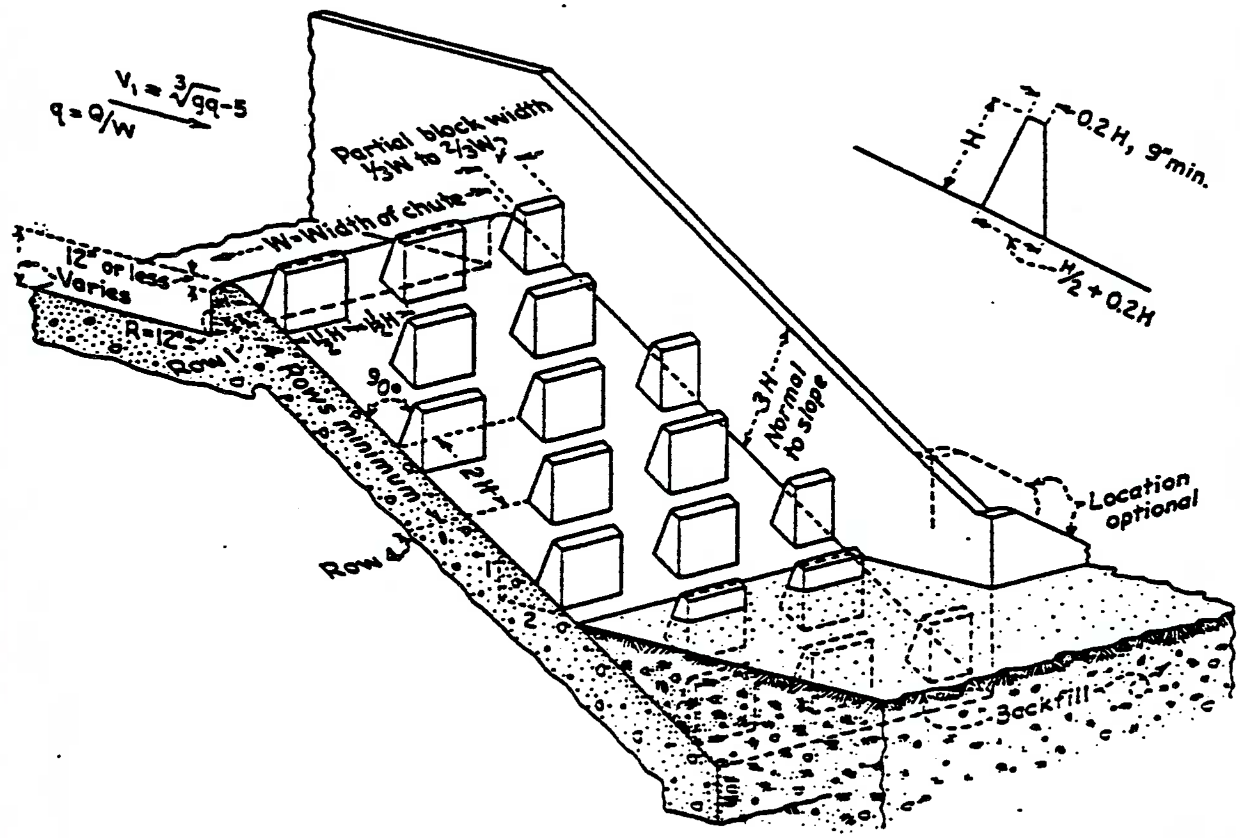


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

BUREAU OF RECLAMATION TYPE VI BASIN

FIGURE 17

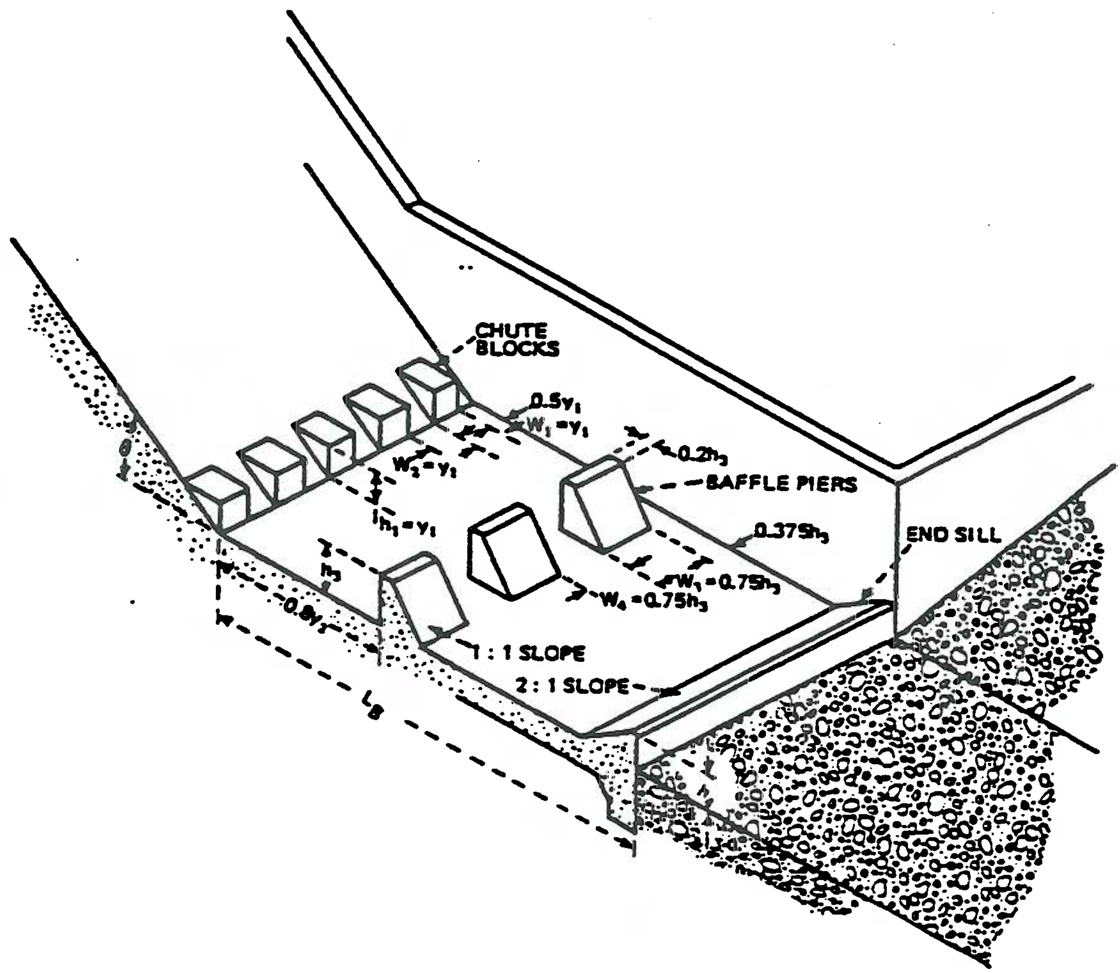


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

BUREAU OF RECLAMATION TYPE IX BASIN

FIGURE 18



CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS The Little Apple

BUREAU OF RECLAMATION
TYPE III BASIN

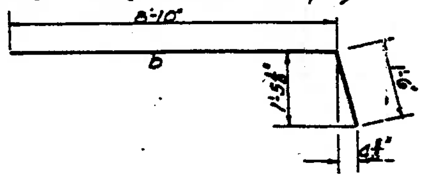
FIGURE 19

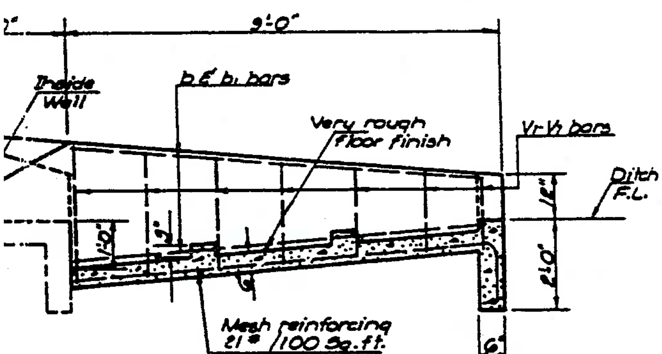
FHWA REG. NO.	STATE	PROJECT NO	FISCAL YEAR	SHEET NO	TOTAL SHEETS
7	KANSAS				

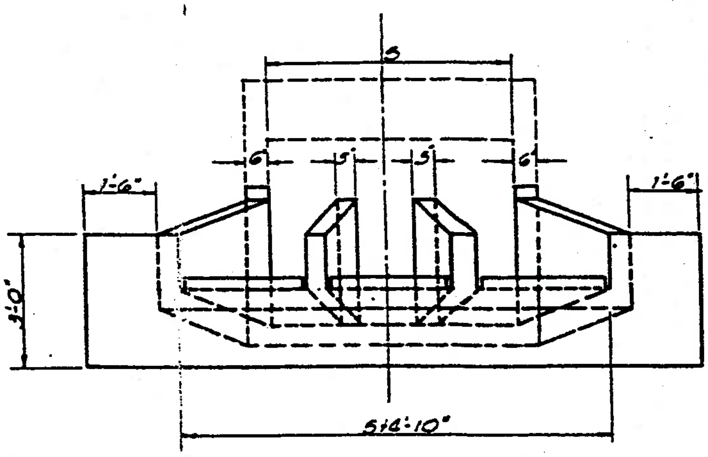
ALL BARS ARE #4

S	b bars		b1 bars		v bars		v1-v1 bars		Class A Conc.	Reinf. Steel
	No.	Lgth.	No.	Lgth.	No.	Lgth.	No.	Lgth.	Cu. Yds	lbs.
3'-0"	4	10'-4"	4	8'-9"	2	2'-9"	28	*	2.9	110
4'-0"	4	10'-4"	4	8'-9"	2	2'-9"	28	*	3.1	120
5'-0"	4	10'-4"	4	8'-9"	2	2'-9"	28	*	3.3	120
6'-0"	4	10'-4"	4	8'-9"	2	2'-9"	28	*	3.5	120

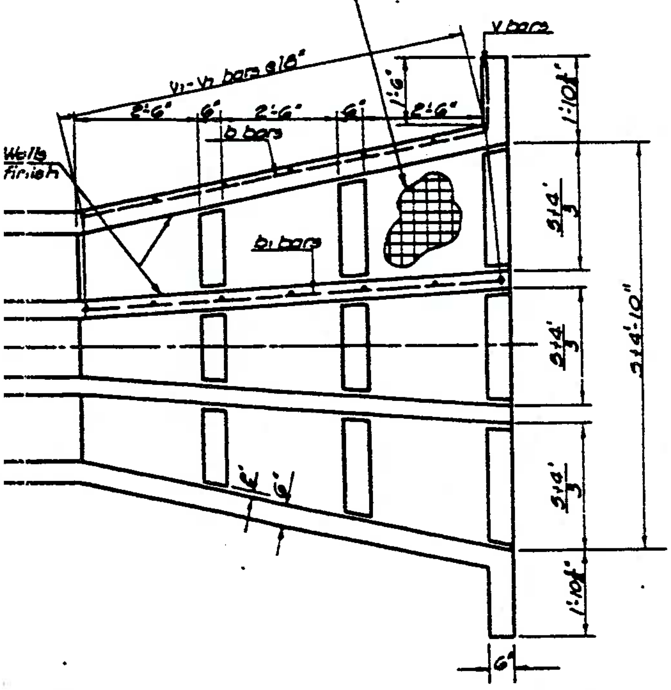
* v1-v1 bars increase by 3" increments from 1'-6" (Cut 4 each length)







END ELEV.



NOTE:
Wire reinforcing mesh shall be electrically welded and shall be composed of No. W 1.4 wire at 6" centers each way. Weight of reinforcing mesh shall be classified as pounds of reinforcing steel.
Class A concrete shall be used thruout.
Bevel all exposed edges with a ¾" triangular moulding unless otherwise noted.
At the contractor's option Class A concrete (AE) may be used thruout, but payment shall be made as Cu. Yds. of Class A concrete.

No.	Date	Revisions	By	App.
3	9-10-73	Wire Reinf. Mesh Changed to W1.4	W.L.H.	K.G.
2	10-27-72	Wire Size AASHO Des. M32-72I	W.L.H.	K.G.
1	12-63	Added Concrete option	E.L.R.	K.G.

KANSAS DEPARTMENT OF TRANSPORTATION

OUTLET SCOUR PROTECTION

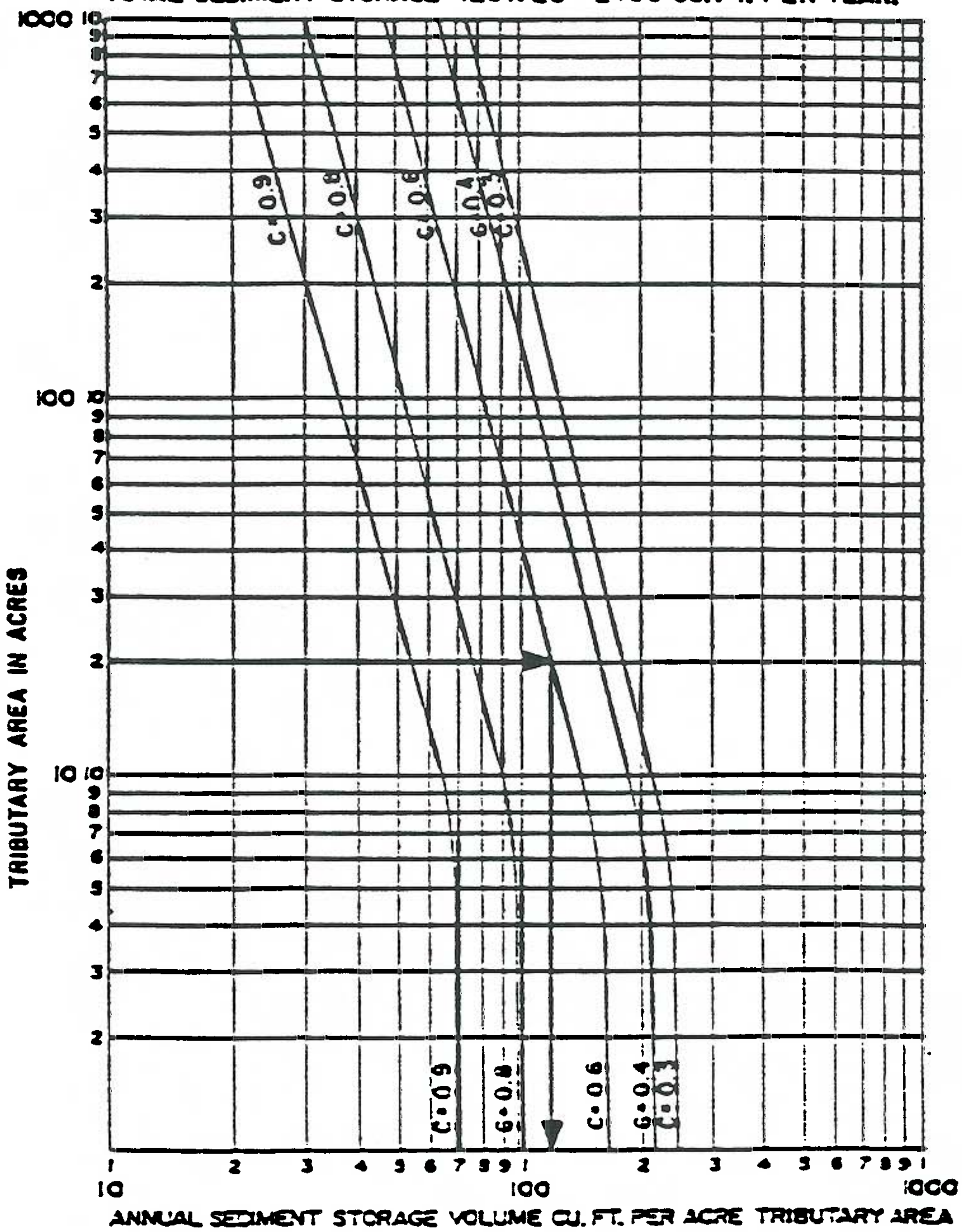
STD. NO. 521

SHEET NO / OF — SCALE ½" = 1'-0" — APP'D
DESIGNED T.W.O. — DETAILED E.S. — QUANTITIES E.S. — TRACED
DESIGN CK — DETAIL CK — QUAN. CK E.D.C. — TRACE CK

Jan. 1955

EXAMPLE:

TRIBUTARY AREA = 20 ACRES
RATIONAL METHOD RUNOFF COEFFICIENT "C" = 0.6
SEDIMENT STORAGE = 120 CU. FT. PER ACRE PER YEAR
TOTAL SEDIMENT STORAGE = 120 X 20 = 2400 CU. FT. PER YEAR.

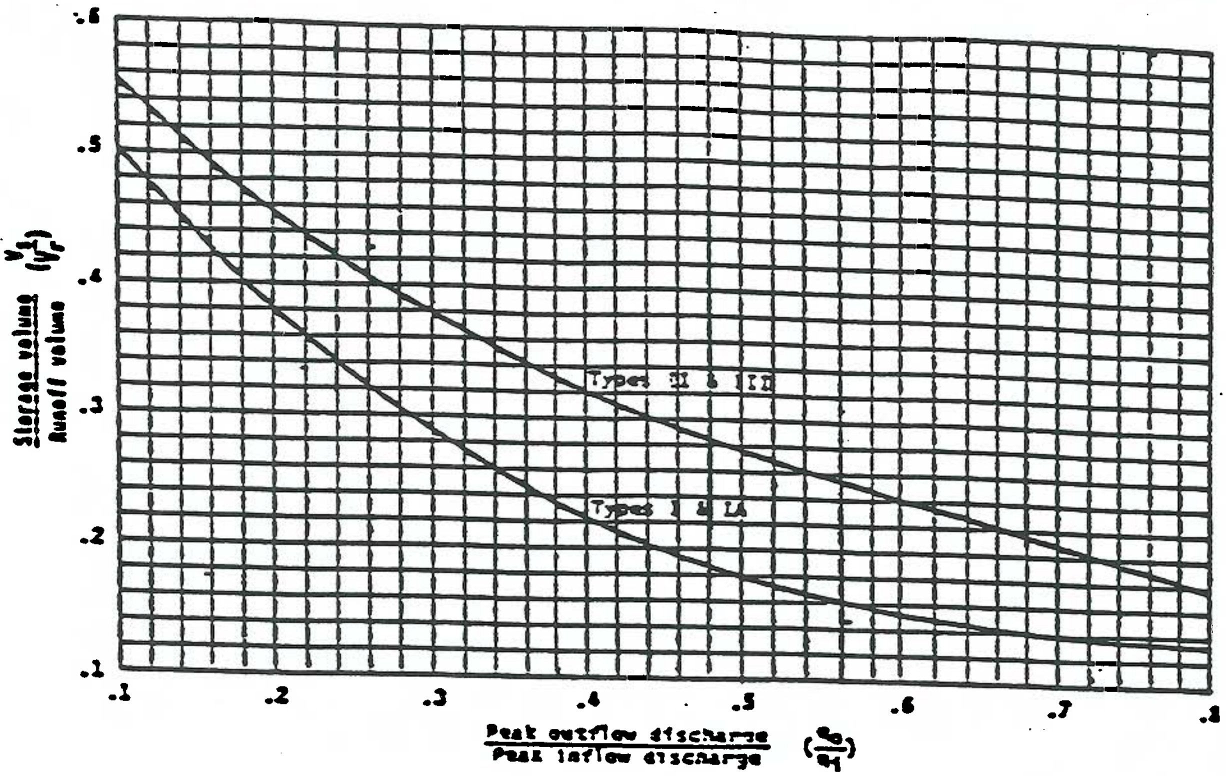


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

ANNUAL SEDIMENT STORAGE ACCUMULATION

FIGURE 20



EQUATIONS

S = (1000/CN)-10.0 where:
CN = SCS Curve Number from Table C
Q = (P-0.2S)^2/(P+.8S) where:
Q = Runoff in inches
P = 24 hr. rainfall in inches Table B
VR = (Q/12)*A*43,560 where:
VR = Cu. Ft. Inflow to detention
A = Acres tributary to detention

Qi = Peak CFS inflow to detention Calculated by either:
* Rational Method
* Hydrograph routing

Qr = Peak CFS disch. from detention Criteria Max. (CFS/Trib. Acre)
* 1.2 CFS - 2 year
* 1.5 CFS - 10 year
* 2.0 CFS - 100 year

EXAMPLE FOR 10 YEAR STORAGE

A = 8.0 Acres
CN = 90 (C=.65)
Qr = 8*1.5 = 12 CFS
Tc = 15.0 min. (i = 5.21)
P = 5.04"

Qi = (.65*8.0*5.21) = 27 CFS
S = (1000/90)-10 = 1.11
Q = 3.92" (24 hour runoff)
VR = (3.92/12)*8*43560 = 113,716 Cu.Ft.

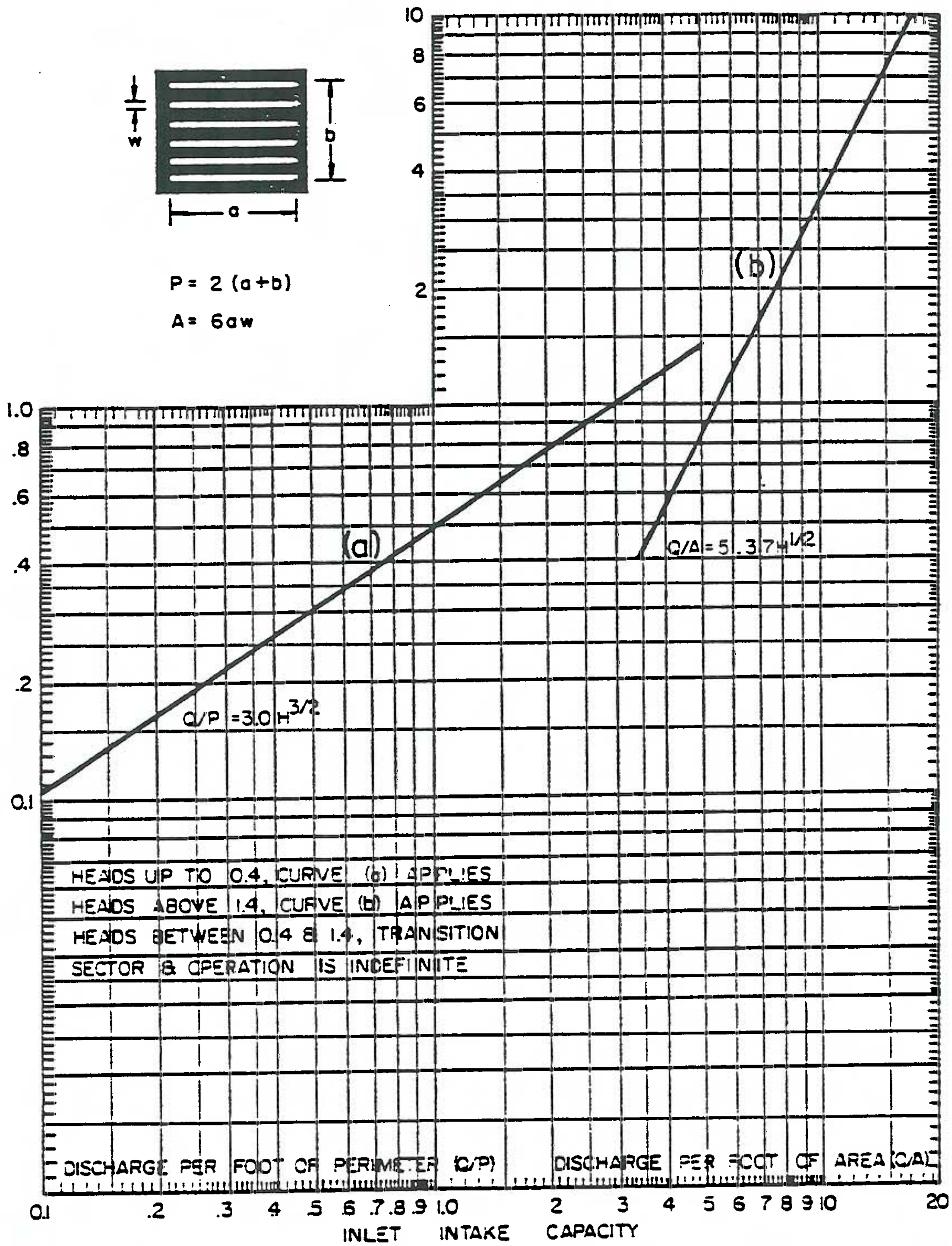
Qr/Qi = (12/27) = 0.44
FROM GRAPH, TYPE II STORM: Vs/Vr = 0.3
Vs Required = 0.3*113,716 = 34,114 cu. ft. = 0.78 acre ft.

CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

SIMPLIFIED DETENTION STORAGE ROUTING (BASINS LESS THAN 10 ACRES TRIBUTARY)

FIGURE 21

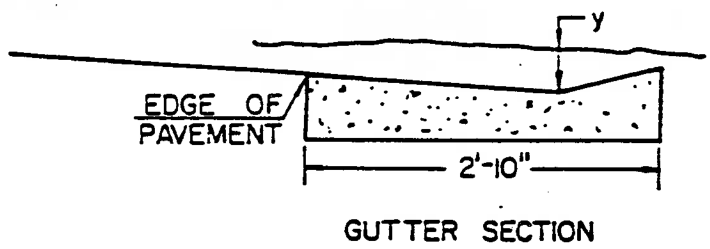


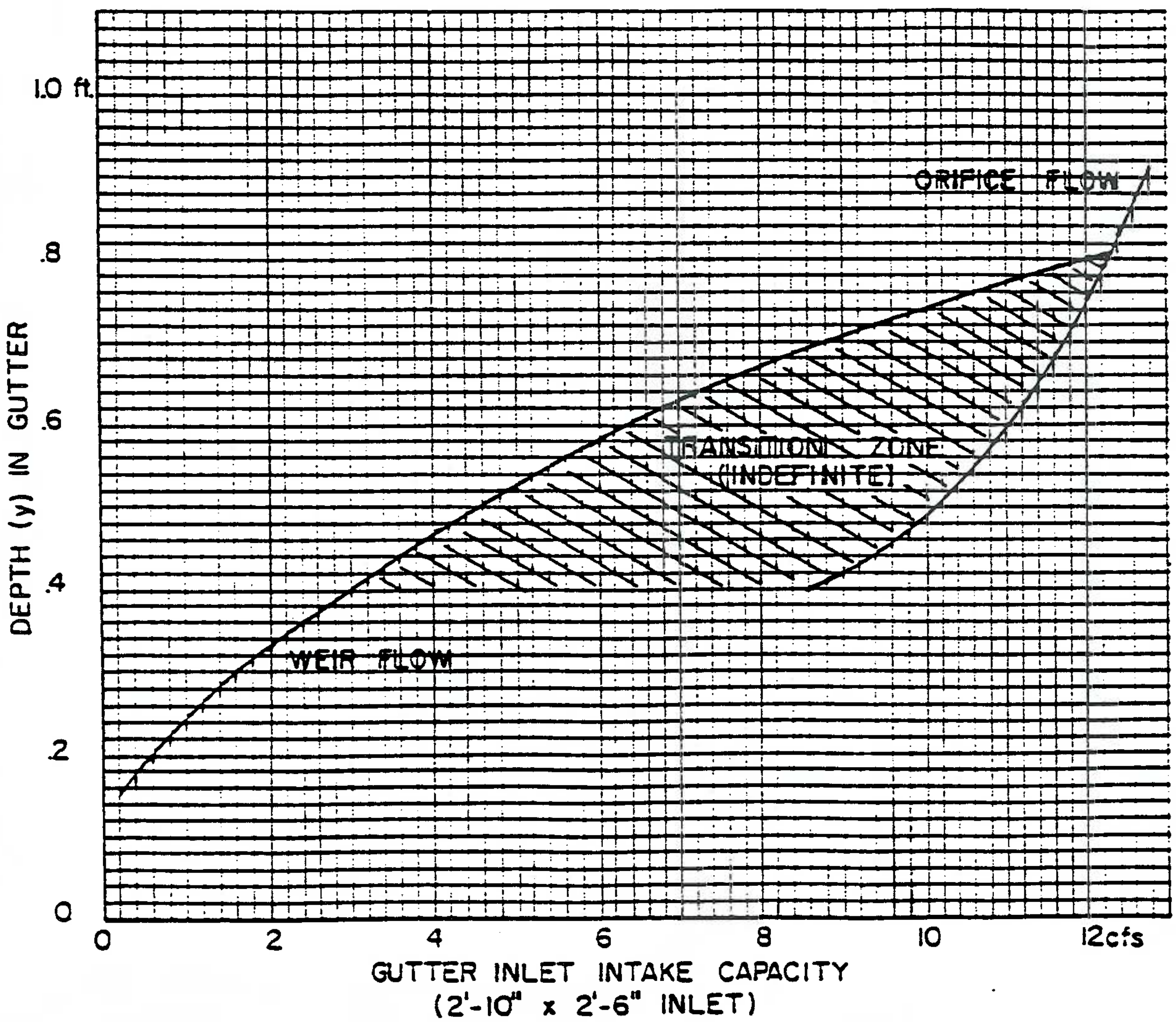
CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

GRATE INLET IN SUMP, WATER PONDED ON GRATE

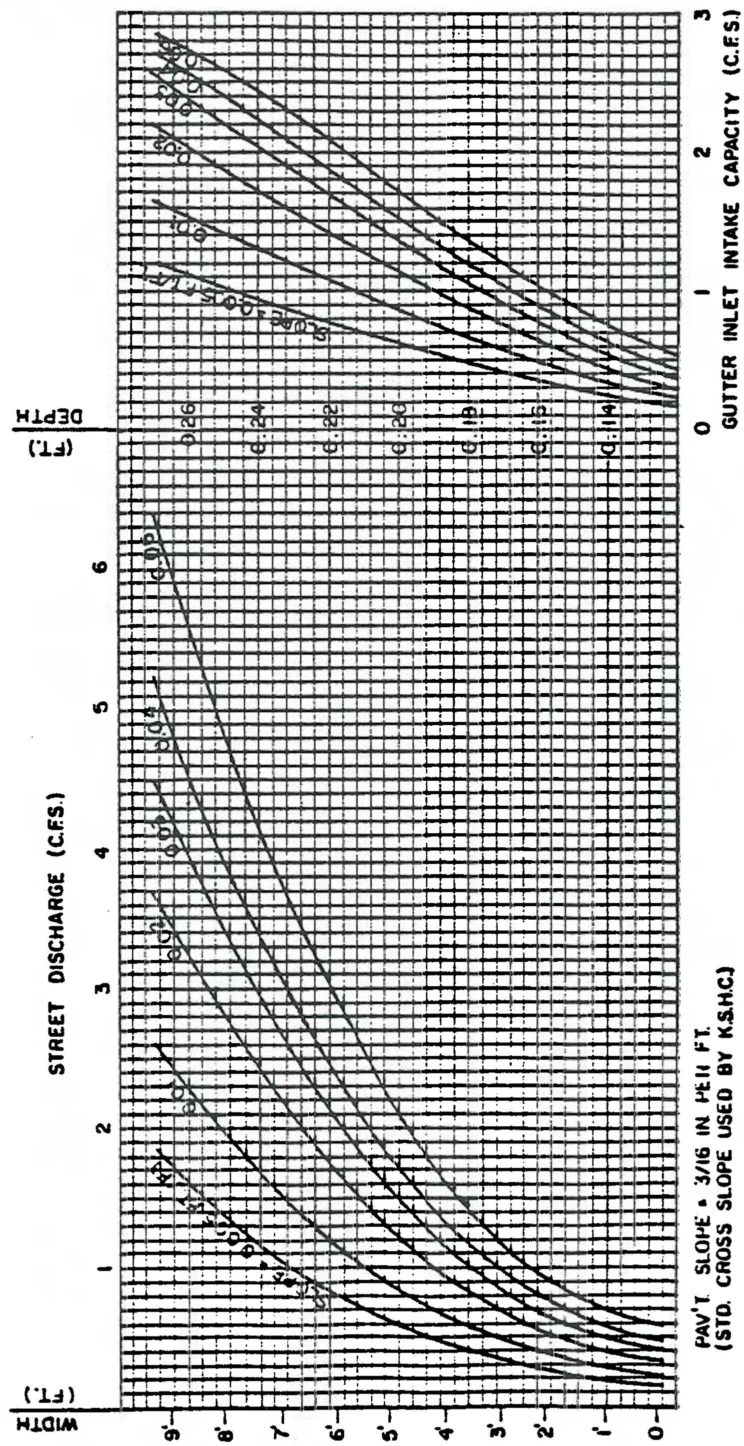
FIGURE 22





CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple	**STANDARD GUTTER GRATE INLET IN SUMP**
	FIGURE 23

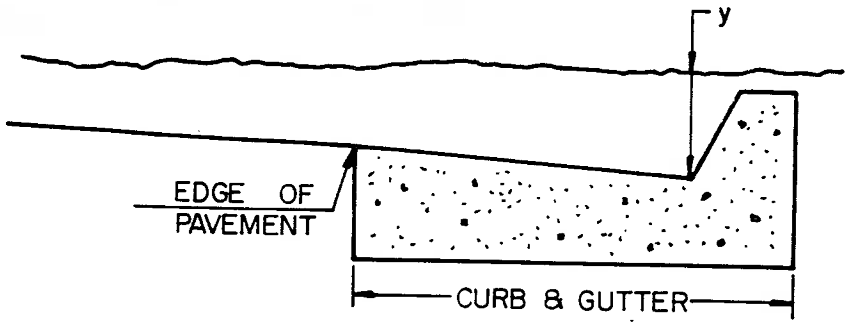


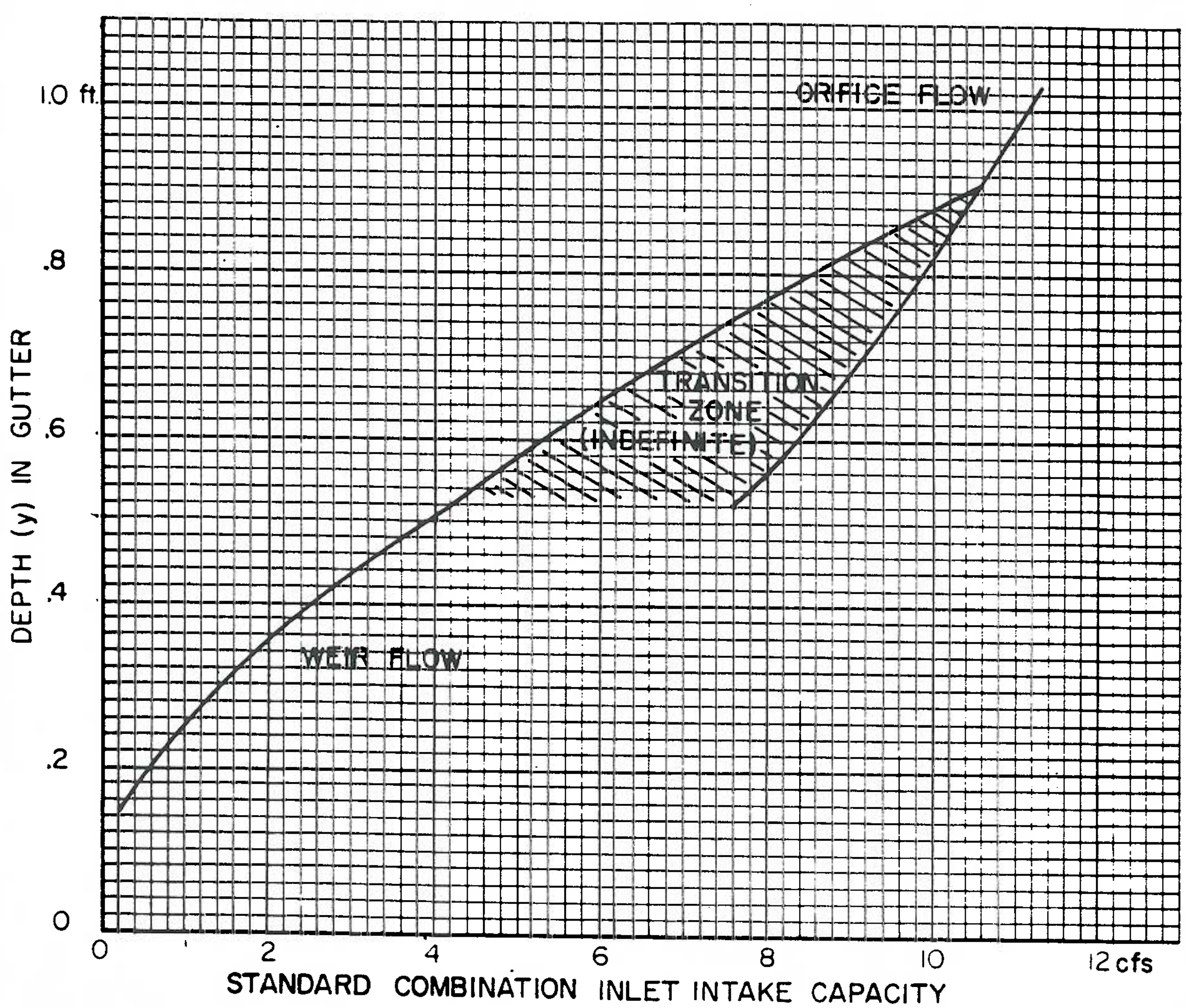
CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple

STANDARD GUTTER GRATE INLET ON SLOPE

FIGURE 24



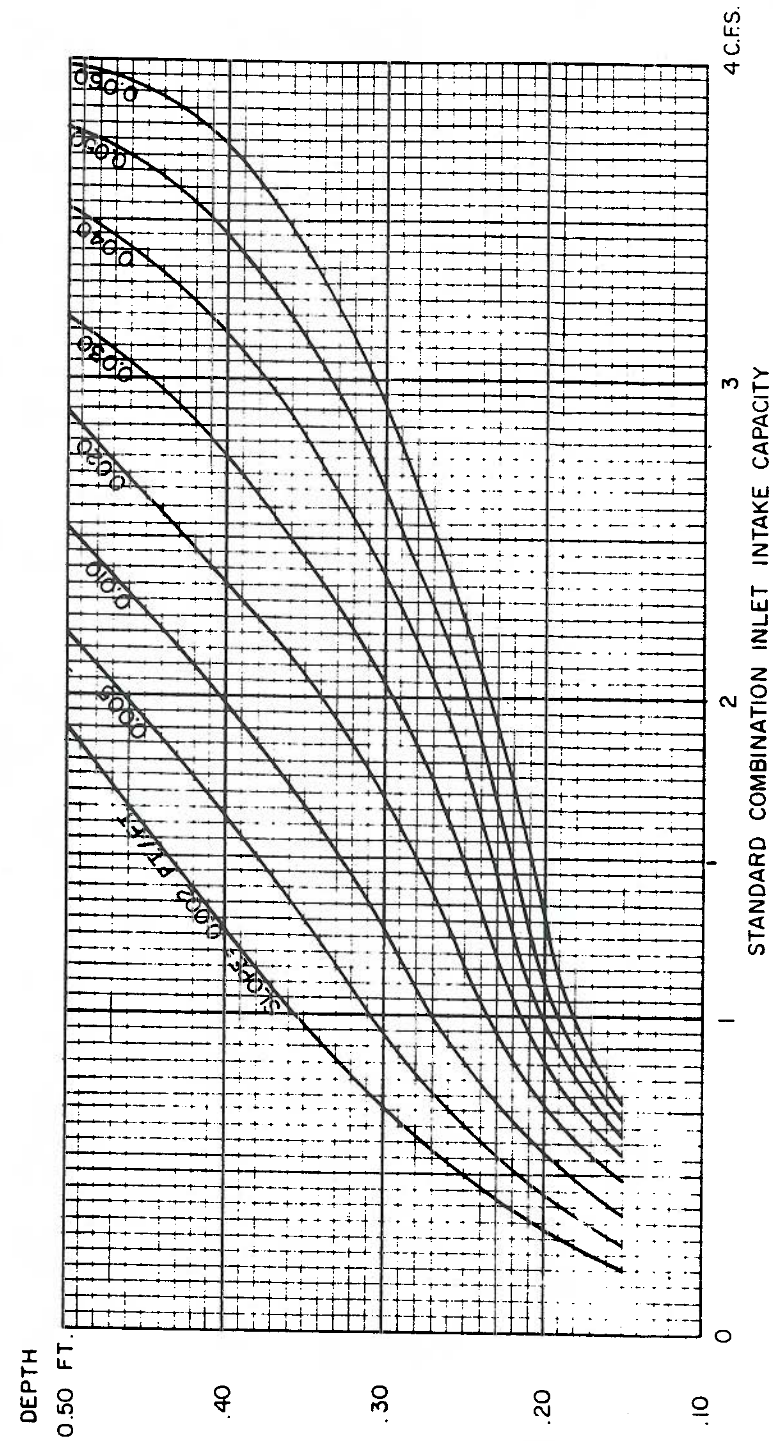


CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF **MANHATTAN** *KANSAS* — The Little Apple

STANDARD COMBINATION INLET IN SUMP

FIGURE 25



CITY OF MANHATTAN, KANSAS STORMWATER MANAGEMENT CRITERIA

THE CITY OF MANHATTAN KANSAS — The Little Apple	**STANDARD COMBINATION INLET ON SLOPE**
	FIGURE 26