CHAPTER DR-07
INLETS & STORM SEWERS

DR-07.900 EXHIBITS

CHAPTER DR-07
INLETS & STORM SEWERS

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DR-07.100 FUNDAMENTALS

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DR-07.110 General

Two or more inlets connected by pipes are classified as a storm sewer system in determining the hydraulics and materials for the design. (See Chapter 6 for exceptions.) The function of a storm sewer system is to collect storm runoff and then convey the water to a disposal site. The designer must first calculate the amount of discharge, then space the collection points at locations that will limit the spread of the water on the pavement, and finally, determine the type and size of storm sewer pipe required to convey the total runoff collected to the outfall or disposal area.

A sanitary sewer system carries domestic, industrial and/or commercial waste-water. Projects affecting sanitary sewers will usually relocate existing sewers and not require the hydraulic design of a system. Relocation or adjustment of sanitary sewers is normally handled as a utility item. Allowable material requirements are different from storm sewers and will be discussed later.

A combined sewer system transports both storm runoff and waste-water. This type of system should be avoided due to the extra load on waste treatment facilities. The size of this system is usually determined by the storm runoff and the material requirements are determined by the waste water. The last storm sewer inlet prior to connection into a combined sewer system must be constructed with a trap to contain gases and odors from the sanitary sewer system.

Drainage folder requirements for storm sewers are located in Section 03.300 of this manual. Examples of the requirements for plans are found in EXHIBITS 03.900 and 07.900.

NOTES AND COMMENTS

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DR-07.200 INLETS
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DR-07.210 Inlet Types

The drainage inlets (catch basins) used in this state are categorized as curb inlets, drop inlets, and special purpose inlets. Curb inlets are further classified as curb-opening, grated, or combination inlets. Drop inlets are primarily used in ditches, depressed medians, and as yard drains. Special purpose inlets are those such as bridge deck drains (scuppers), spring boxes, and others.

The drainage inlets are designed to be used in a multitude of situations which may be encountered. Notes on the Standard Drawings also allow minor modifications to the inlet as detailed. Most curb inlets can be used with any curb shape and pipe chambers are designed to fit a variety of combinations of pipe sizes. Slopes of drop inlets may be flattened and aprons may be eliminated or added, just to name a few modifications. The Standard Drawings generally state the primary purpose of the inlet. In all instances where structural limits for a proposed installation exceed that of the Standard Drawings, the designer shall provide a separate detail sheet for the plans depicting the modifications. The modifications in structural aspects of the inlet shall be reviewed and approved by the Division of Bridges prior to use on the project. This is not meant in any way to discourage innovative ideas with respect to modifying any inlet to fit the site-specific conditions.

DR-07.220 Curb Inlets

These inlets are usually located next to the curb or incorporated into the design of a raised median, and may be one of several configurations. Most of these inlets are divided into either two or three parts for construction purposes: Bottom Phase, Riser, and Top Phase, or Bottom Phase and Top Phase. The bottom phase is also known as the Pipe Chamber.

Curb-opening inlets have a depressed slot (the curb-opening or throat) constructed through the curb for water to pass into the inlet pipe chamber. Access to the pipe chamber is by way of a manhole lid on top of the inlet which is located behind the curbline.

Grated inlets do not have a slot or throat through the curb. They are simply a pipe chamber (with or without a riser section) using a variety of grate configurations to cover the access to the pipe chamber. These inlets may be located in gutterlines, parking lots, and other areas where curbs are present. The back portion of the inlet is usually formed to match adjacent curbs.

Slotted drain pipe is not a curb inlet in the strictest sense, but functions much the same as a curb-opening inlet. It is usually located in areas associated with curbs. This is a circular corrugated metal culvert with a grate assembly riser welded along the top of the pipe to allow water to enter. The riser assembly is tall enough to allow the pipe to be located at or near the subgrade level. The riser then extends upward through the top of the pavement to intercept sheet flow and/or reduce ponding of surface runoff. This pipe is hydraulically designed as a storm sewer. Lengths and spacings shall be determined by the same equations used for curb-opening inlets.

Combination inlets may consist of curb-opening with a grate in the gutter or slotted drain pipe with grate in the gutter.

The following material lists the current curb inlets available to the designer and a description of each:

CURB BOX INLET TYPE A

A curb-opening inlet, with its local depression, may be used to intercept flow along the outside gutters of urban streets. Curb Box Inlet Type A is designed with a top phase and a bottom phase which allows it to accommodate most curb inlet situations. The top phase will match adjoining curb shapes. A 2-inch minimum drawdown is provided with throat lengths of 5', 10', 15' and 20'. The 10' throat length is recommended with the other lengths limited to cases where site conditions restrict the throat length or the longer throats are required for 100% interception. The bottom phase consists of a riser and a pipe chamber which will accommodate up to a maximum circular pipe size of 48 inches.

This type of inlet is noted on the plans, pipe sheets, and drainage summary as a Curb Box Inlet Type A, followed by two numbers and a box height. The first number is the bottom phase size and the second number is the top phase size as shown in the Standard Drawings. Inlet sizes shown on the plans are the minimums for controlling pipe sizes. The Designer has the option of increasing the bottom phase inlet size for purposes of standardization and/or simplicity of design.

The 2" minimum drawdown for a 2' gutter at the inlet is in addition to the normal 1/2" drop in the 2' gutter and is developed by warping the gutter line beginning 3' above the curb opening and ending 2' below the curb opening. This drawdown increases the capacity of the curb opening inlet.

Two allowable modifications to the above standards are: (1) use of greater than 2" drawdown to increase inlet capacity; and (2) use of greater than 1/4":1' gutter cross slope through the length of the gutter to increase capacity. The use of a combination section (1/4":1' pavement cross slope with 1/2":1' gutter cross slope) would show the same inlet capacity but would reduce the spread of water on the pavement. The use of greater than 1/2":1' gutter cross slopes for a normal crown roadway should be discouraged due to breakover grade limits and problems which will develop with pavement over-lays.

A desirable design is to match the gutter cross slope and the pavement cross slope and provide a 2" drawdown for the curb opening inlets. The use of a gutter cross slope up to two times the pavement cross slope or the use of greater than two inch drawdown will require concurrence from the Drainage Section. The use of a gutter cross slope greater than two times the pavement cross slope or the use of greater than four inch drawdown will require approval of the Director, Division of Design.

Minimum cover over the pipe shall be one foot to the bottom of the subgrade if under pavement and one foot to the top of the ground if away from the pavement.

Concrete quantities in the Standard Drawing tables are based on: the height of the pipe diameter, plus the pipe thickness, plus one foot of cover, plus an estimated pavement thickness (top phase height) of one foot eight inches (D + t + 1'0" + 1'8"). When situations occur where a bare minimum height of inlet must be used, and a pipe does not pass under the throated portion, use the following guidelines:

(a) For cross drainage (pipe under pavement), the minimum height is: the pipe diameter, plus the pipe thickness, plus one foot cover, plus pavement thickness (D + t + 1'0" + pavement thickness).

(b) For pipes outside cross drainage limits parallel to or leading away from the roadway, a minimum height may be calculated by summing: the pipe diameter, plus the pipe thickness, plus 1'0" cover, measured from the gutter line elevation to the top of the pipe (D + t + 1'0").

These inlet structures may be constructed to a maximum height (H dimension) of 15'0". If any of the structural criteria for this inlet is exceeded, the modification must first be approved by the Drainage Section. The Designer must prepare a Special Drawing depicting the modifications for insertion into the project plans.

CURB BOX INLET TYPE B

Curb Box Inlet Type B is a combination inlet which has a very narrow top phase width. This inlet is used for bridge end drainage, and in urban areas where a narrow inlet is needed because of existing utilities behind the inlet. Another location where this inlet may be useful is in storage lanes of narrow raised medians.

MEDIAN BARRIER BOX INLET

This combination inlet is used to provide a collection point for surface runoff where a median barrier is constructed. The pipe chamber is accessed through a grate. It may be constructed where it will intercept flow from either one or both sides of the median barrier.

CURB BOX INLET TYPE F

This curb box inlet is used primarily for situations where very little capacity is needed or lack of space prevents use of larger inlets. A typical application would be in the parking zone of a rest area or at a side street approach where little runoff or truck traffic is expected. This inlet is designed for use with a standard curb shape.

BARRIER CURB BOX INLET TYPE 1

This type of inlet is used in situations similar to where a Standard Curb Box Inlet Type F is employed and in conjunction with a barrier curb.

DR-07.230 Slotted Drain Pipes

Slotted drain pipes are effective in pavement drainage and have a variety of applications. They can be used on curbed or uncurbed sections and offer little interference to traffic operations.

Slotted drain pipes essentially function in the same manner as Curb-opening inlets, as weirs with flow entering from the side. The interception capacity is dependent upon the flow depth, inlet length, and total flow.

It is more economical to add length to a slotted drain pipe to increase interception capacity than it is to add length to a curb-opening inlet. The slotted drain pipe should be considered for economical reasons in all projects. See Section 07.230 for more information.

Slotted drain pipe installations do not require the use of drop boxes. There are instances where site conditions, increased costs caused by inlet construction, and/or best engineering practices may dictate the use of slotted pipe alone. Likewise, a drop box inlet with a section of slotted pipe can be used as a combination inlet.

DR-07.240 Drop Box Inlets

These inlets consist of an opening in the top of a pipe chamber covered by one or more grates. Several grate designs are used, based on the purpose of the inlet.

The interception capacity of a grate inlet depends on the amount of water flowing over the grate, the size and configuration of the grate, and the velocity of flow in the ditch, median, or gutter. The efficiency also depends on these factors and the total flow in the gutter as well.

Ditch inlets are grated inlets used to intercept flow where the ditch has reached design capacity. Or in some cases, where the flow must be intercepted, such as in a sag vertical or other ponding condition. They are used in place of headwalls where traffic safety is a consideration. Ditch inlets are to be used where a clear zone is provided.

It should be noted that grates for Drop Box Inlet Types 1 & 3, 2 & 4, and 5 & 6 are interchangeable. Replacement of the grate should be considered when an existing facility is proposed to be reconstructed and development has changed the environment of the location.

DROP BOX INLET TYPE 1

This inlet accommodates pipe sizes of 15", 18" and 24". It is to be used on projects where traversal by a pedestrian or bicyclist is not anticipated. Generally, this inlet should be applied in rural locations.

DROP BOX INLET TYPE 2

This inlet accommodates pipe sizes of 30" and 36". It is to be used on the same type projects recommended for a Drop Box Inlet Type 1.

DROP BOX INLET TYPE 3

This inlet accommodates pipe sizes of 15", 18" and 24" and is designed similar to a Drop Box Inlet Type 1 except for the grate which is bicycle-safe. It is to be used on projects where traversal by a pedestrian or bicyclist is anticipated. Generally, this type of inlet should be employed in urban locations.

DROP BOX INLET TYPE 4

This inlet accommodates pipe sizes of 30" and 36" and is designed similar to a Drop Box Inlet Type 2 except for the grate which is bicycle-safe. It is to be used on the same type of projects recommended for a Drop Box Inlet Type 3.

DROP BOX INLET TYPE 5

This inlet is to be used in the depressed median on projects where pedestrian or bicycle traffic is not anticipated.

DROP BOX INLET TYPE 6

This inlet is to be used in the depressed median on projects where pedestrian or bicycle traffic is anticipated.

DROP BOX INLET TYPE 7

This inlet is intended for large pipe sizes.

DROP BOX INLET TYPE 10

This inlet is primarily designed for use with the valley gutter.

DROP BOX INLET TYPE 11

This inlet is primarily designed for use at interior locations of parking lots.

DROP BOX INLET TYPE 12

This inlet is primarily designed to intercept sheet flow from driveways and approaches.

The length of the inlet will normally be the width of any driveway or approach. A minimum length of 6 feet shall be required. Even two feet increments in length should be used.

The assumption is made that the inlet will intercept 100% of the water that flows across it. The normal minimum depth is 8 inches with a minimum slope of 1/2" per foot which will provide 5.8 cfs capacity. If additional capacity is needed, the box depth can be increased.

DROP BOX INLET TYPE 13

This type of inlet is primarily designed for use with raised medians. The curb on the box shall be constructed to match the adjoining curb. The inlet shall be constructed in two phases

Along the outside gutter of urban streets, where the local depression or compound section used in a Curb-Box Inlet Type A is not desirable, a Drop Box Inlet Type 13 may be used.

This inlet is not very useful in large open areas such as parking lots due to the configuration of the vaned grate. This grate, however, is highly efficient in curbed locations. It provides the same efficiency, that is, intercepts the same amount of water as a 15-foot long curb-opening inlet.

DROP BOX INLET TYPES 14 & 15

These two inlets are primarily used as yard drains. Type 14 has a radial grate and is to be used in areas where yard maintenance is anticipated. Type 15 has a beehive grate and is to be used in non-residential areas where low or no yard maintenance is anticipated and where clogging might occur, if a flat grate were used.

DROP INLET TYPE 16

This is a combination inlet which uses a vaned grate and a slotted drain pipe in the gutter. It is a modification of Drop Box Inlet Type 13. It has the same high-efficient grate as the Type 13, but its interception efficiency is enhanced by the addition of various lengths of slotted drain.

DR-07.250 Special Purpose Inlets

These inlets have been designed for various special applications and do not fit into the previous inlet classifications.

SPRING BOX INLET TYPE A

This inlet is to be used to protect springs that would be covered by a highway fill of ten or more feet.

SPRING BOX INLET TYPE B

This inlet is to be used to protect springs that would be covered by a highway fill of less than 10 feet.

BRIDGE DECK INLETS

These inlets are located on bridges to intercept runoff captured by the bridge deck. Several designs are in use: small rectangular grated scuppers, round pipes through the deck, and slots through the bridge rails.

Bridge deck drainage is essential to traffic safety and bridge maintenance. Standing water will ice over on bridge decks faster than roadways, hazardous to the traffic passing over it, and the corrosive action of deicing agents on the bridge structure are the two most important reasons for consideration of quick and efficient removal of water from bridge decks.

Bridge decks are most effectively drained where the gradient is sufficient to convey water off the deck for interception. Depending on the gradient, cross slope, and design spread, the number of inlets can be decreased on the bridge deck if roadway drainage is intercepted upgrade of the bridge.

The principles of inlet interception on bridge decks are the same as for roadway inlets. However, requirements of deck drainage systems differ in the following respects from roadway drainage systems:

(1) Total or near total interception is desirable upgrade of expansion joints in order to prevent unnecessary flow from making its way into joints, resulting in deterioration of the structure.

(2) Deck drainage systems are highly susceptible to clogging.

(3) Inlet spacing is often predetermined by bent spacing.

(4) Inlet sizes are often constrained by structural considerations.

As a rule of thumb, bridge decks with an area of over 2000 square feet require deck drains. Grated scuppers are spaced using grated curb inlet spacing equations. Slots through bridge rails are spaced using curb-opening inlet spacing equations.

Another alternative is available to the designer. If the allowable spread of water on the bridge deck is not exceeded, the designer may elect to use bridge end drainage inlets. Bridge end drainage inlets also may be used in conjunction with bridge deck drains should structural constraints prohibit placing an adequate number of drains on the bridge. See Standard Drawings in the RBB and RBC Series for bridge end drainage details. The DBI Type 16 or the Slotted Drain Pipe may be used for bridge end drainage.

NOTES AND COMMENTS

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DR-07.300 INLET HYDRAULICS
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DR-07.310 General

The interception capacity of a Curb-opening inlet is primarily dependent upon the flow depth at the curb and the length of the curb opening. The use of a gutter depression at the curb-opening or a depressed gutter to increase the proportion of the total flow at the curb increases the effective depth at the curb. This will increase both interception capacity and efficiency.

Inlets are divided into two groups for the purpose of design hydraulics: curb inlets and drop inlets. Curb inlets are designed to intercept relatively shallow depths of flow controlled by a maximum allowable spread of water. Drop inlets are spaced at intervals which are based on varying depths of flows controlled by an allowable elevation.

DR-07.320 Gutter Capacity

The spacing of curb inlets involves two steps: (1) Capacity of the gutter at various points must be determined; and (2) Inlets must be selected for those points where maximum allowable spread is attained.

The cross section of a roadway gutter is governed by the typical sections for the road under design and may be found in the Standard Drawings. Capacity of the gutter will vary with its cross section, longitudinal slope, roughness, and maximum allowable depth or spread. The gutter capacity may be determined by the formula:

$$Q = 0.56 \quad (z/n) \quad S^{0.50} \quad Y^{2.67}$$, or from Exhibit 07.911

Where:

Q	=	maximum allowable discharge (cfs)
Sx	=	roadway cross slope (ft/ft)
z	=	1/Sx
n	=	Manning's roughness coefficient
S	=	longitudinal slope of roadway (ft/ft)
Y	=	maximum allowable depth of flow (ft)

or (for composite gutters):

$$Q = (0.56/n)S^{0.5}(S_x^{1.67}(T-W)^{2.67} + S_w^{1.67}((W + (T-W)*(S_x/S_w))^{2.67} - ((T-W)(Sx/Sw))^{2.67}))$$

Where:

T	=	Spread of water relative to gutter line (ft)
W	=	Gutter width (ft)
S_w	=	Gutter cross slope (ft/ft)

Capacity of gutters with non-uniform sections may be determined by referring to Exhibit 07.912.

The discharge to be carried by the gutter shall be calculated by the Rational Formula, Q = CIA. A rainfall intensity for a 10-Year storm shall be used. The area contributing runoff will be the product of the average width of the roadway plus the adjacent property draining to the gutter and the distance between curb inlets.

DR-07.330 Allowable Spread

The allowable spread of water on the pavement shall be limited to the following or to a curb depth of four(4) inches, whichever occurs first. For bridge decks, the limits are four feet of spread or one inch depth.

For pavement inlets on the right hand side of the driving lane, the allowable spread of water shall be limited as follows:

- Design Speed 45 MPH, or less: 6 ft in driving lane, and 8 ft with 2 ft gutter

- Design Speed greater than 45 MPH: 4 ft in driving lane, and 6 ft with 2 ft gutter

For pavement inlets on the median side of the driving lane, the allowable spread of water shall be limited as follows:

- Design Speed 45 MPH, or less: 4 ft in driving lane, and 6 ft with 2 ft gutter

- Design Speed greater than 45 MPH: 2 ft in driving lane, and 4 ft with 2 ft gutter

DR-07.340 Inlet Flow

Flow interception by slotted drain pipes and curb-opening inlets is similar in that each is a side weir, and its flow is subjected to lateral acceleration due to the cross slope of the pavement. The interception capacity of these inlets depends on the flow depth and the inlet length while efficiency depends on flow depth, inlet length, and total flow.

The length for total interception of curb opening inlets and slotted drain pipes with slot widths greater than or equal to 1.75 inches can be computed by the equation:

$$LTI = 0.6\ (Q^{0.42})\ (S^{0.3})\ [\ 1/(n*Sx)\ ]^{0.6}$$

Where:

- LTI = Curb opening/Slotted pipe length for 100% interception
- Sx = Pavement cross slope (ft/ft)
- S = Longitudinal slope of pavement
- n = Manning's roughness coefficient for pavement.

FHWA Hydraulic Engineering Circular 12 has a chart, shown in Exhibit 7-915, that is a nomographical solution to this equation, and is good for curb openings/slotted pipe inlets. The efficiency of the inlet shorter than the length required for total interception is de-fined as:

$$E = 1 - (1 - [\ L/LTI\ ])^{1.8}$$

Where:

- E = Efficiency of inlet
- L = Length of inlet
- LTI = Length of inlet required for 100% interception

See also Exhibit 7-916.

It is more economical to add length to a slotted inlet to increase interception capacity than it is to add length to a curb opening inlet. The slotted drain pipe should be considered for economical reasons in all projects.

DR-07.350 Grate Inlets On Grade

The capacity of an inlet depends upon its geometry and the cross slope, longitudinal slope, total gutter flow, depth of flow and pavement roughness. The depth of water next to the curb is the major factor in the interception capacity of both gutter inlets and curb opening inlets. At low velocities, all of the water flowing in the section of gutter occupied by the grate, called frontal flow, is intercepted by grate inlets, and a small portion of the flow along the length of the grate, termed side flow, is intercepted. On steep slopes, only a portion of the frontal flow will be intercepted if the velocity is high or the grate is short and splash-over occurs (vane grates in many situations are efficient). For grates less than 2 feet long, intercepted flow is small.

Inlet interception capacity has been investigated by agencies and manufacturers of grates. For inlet efficiency data for various sizes and shapes of grates, refer to Hydraulic Engineering Circular No. 12 Federal Highway Administration and inlet grate capacity charts prepared by the grate manufacturers.

A parallel bar grate is the most efficient type of gutter inlet; however, when crossbars are added, for bicycle safety, the efficiency is greatly reduced. Where bicycle traffic is a design consideration, the curved vane grate and the tilt bar grate are recommended for both their hydraulic capacity and bicycle safety features. They are efficient in debris handling as shown in Table 07-3. In certain locations where leaves may create constant maintenance problems, the parallel bar grate may be used more efficiently if bicycle traffic is prohibited.

Where debris is a problem, consideration should be given to debris handling efficiency rankings of grate inlets from laboratory tests in which an attempt was made to qualitatively simulate field conditions. Table 07-3 presents the results of debris handling efficiencies of several grates.

Table 07-3 Grate Debris Handling Efficiencies

Rank	Grate	Longitudinal Slope (0.005)	0.04)
1	CV - 3-1/4 - 4-1/4	46	61
2	30 - 3-1/4 - 4	44	55
3	45 - 3-1/4 - 4	43	48
4	P - 1-7/8	32	32
5	P - 1-7/8 - 4	18	28
6	45 - 2-1/4 - 4	16	23
7	Recticuline	12	16
8	P - 1-1/8	9	20

Source: "Drainage of Highway Pavements" (HEC-12), Federal Highway Administration, 1984.

The ratio of frontal flow to total gutter flow, E_o, for straight cross slope is determined by Exhibit 7-914 or as expressed by the following equation:

$$E_o = Q_w/Q = 1 - (1 - W/T)^{2.67} \qquad (07.7)$$

where:

Q = total gutter flow, cfs
Q_w = flow in width W, cfs
W = width of depressed gutter or grate, ft
T = total spread of water in the gutter, ft

The ratio of side flow, Q_s, to total gutter flow is:

$$Q_s/Q = 1 - Q_w/Q = 1 - E_o \qquad (07.8)$$

The ratio of frontal flow intercepted to total frontal flow, R_f, is determined by Exhibit 7.917a or as expressed by the following equation:

$$R_f = 1 - 0.09\ (V - V_0) \qquad (07.9)$$

where:

V = velocity of flow in the gutter, ft/s
V_o = gutter velocity where splash-over first occurs

This ratio is equivalent to frontal flow interception efficiency. Exhibit 7.913 is a nomograph to solve for velocity in a triangular gutter section with known cross slope, slope and spread.

The ratio of side flow intercepted to total side flow, R_s, or side flow interception efficiency, is determined by Exhibit 7.917b or is expressed by:

$$R_s = 1\ /\ [1 + (0.15V^{1.8}/S_xL^{2.3})] \qquad (07.10)$$

where:

L = length of the grate, ft

The efficiency, E, of a grate is expressed as:

$$E = R_fE_o + R_s(1 - E_o) \qquad (07.11)$$

The interception capacity of a grate inlet on grade is equal to the efficiency of the grate multiplied by the total gutter flow:

$$Q_i = EQ = Q[R_f E_o + R_s(1 - E_o)] \qquad (07.12)$$

Spacing of drop box inlets in depressed medians shall be based on 1.0 ft. maximum depth of flow for the minimum longitudinal grades and 0.6 ft. depth of flow for the maximum longitudinal grades. Maximum depths of flow for intermediate longitudinal grades will be a proportional value. Maximum spacing for a Drop Box Inlet Type 5 for median grades of 0.005 ft./ft. and greater is shown in Table 7-1 below:

TABLE 7-1
MAXIMUM SPACING DROP BOX INLET TYPE 5

Inlet Type	Roadway	Median Width	Max. Spacing
5A & 5B	4 Lane	Under 40′	1200′
5C & 5D	6 Lane	40′	1200′
	6 Lane	60′	1200′
5E	4 Ln (6 Ult.)	60′	1000′
	6 Lane	60′	1000′
5F	Variable	Variable	1000′ to 1200′

The minimum longitudinal grade for adequate drainage of grass-covered ditches is 0.005 ft./ft. This minimum grade should be maintained when the roadway grade is less than 0.005 ft./ft. by rolling the grade of the median ditch.

The two types of inlets for depressed medians are denoted by a number and an alphabetic suffix. This suffix corresponds to the median cross slope as shown in Table 7-2.

TABLE 7-2

Drop Box Inlet Code	Median Cross Slope
A	12:1
B	6:1
C	5:1
D	4:1
E	3:1
F	As specified by engineer

DR-07.360 Inlets in a Sag

Exhibit 7.918 may be used to determine the capacity of drop inlets in a sag. Debris problems and inlet capacity may dictate that flanking inlets (0.2 feet higher) be required for grated inlets in a sag.

Exhibit 7.919 may be used to determine the capacity of curb opening or slotted pipe in a sump. Exhibit 7.920 may be used when these inlets are depressed.

NOTES AND COMMENTS

DR-07.400 STORM SEWERS SYSTEMS

DR-07.410 General

A storm sewer system normally consists of a series of tangent sections of pipe with inlets or manholes at all changes in direction or elevation and at all junction points. The purpose of this arrangement is to allow access to the ends of all sections of pipe in the system in order to clear obstructions, should they occur. While developing the total storm sewer system, the designer should keep in mind the relative elevations between the outfall pipe and the inlets and/or manholes proposed.

Inlets and/or manholes shall be provided at every break in horizontal or vertical alignment. The maximum distance between inlets and/or manholes may range from 200 to 350 feet, depending upon the pipe size.

DR-07.420 Storm Sewer Pipe

The following pipe culverts may be used for storm sewers:

PIPE TYPES	ABBREVIATION
Reinforced Concrete Pipe	RCP
with Extra Protection	EPRCP
Reinforced Concrete Pipe Arch	RCPA
with Extra Protection	EPRCPA
Reinforced Concrete Elliptical Pipe	RCEP
with Extra Protection	EPRCEP
Corrugated Steel Pipe	CSP
Bituminous Coated	BCCSP
Fiber Bonded	FBBCCSP
Fully Lined	BCCSPFL
Polymer Coated	PCCSP
Aluminized Type 2	CSPA2
Spiral Ribbed Steel Pipe	SRSP
Bituminous Coated	BCSRSP
Corrugated Steel Pipe Arch	CSPA
Bituminous Coated	BCCSPA
Fully Lined	BCCSPAFL
Corrugated Steel Elliptical Pipe	CSEP
Bituminous Coated	BCCSEP
Fully Lined	BCCSEPFL
Aluminized Type 2	CSEPA2
Corrugated Aluminum Alloy Pipe	CAP

Bituminous Coated	BCCAP
Fully lined	BCCAPFL
Corrugated Aluminum Alloy Pipe Arch	CAPA
Bituminous Coated	BCCAPA
Fully Lined	BCCAPAFL
Corrugated Aluminum Alloy Elliptical Pipe	CAEP
Bituminous Coated	BCCAEP
Fully Lined	BCCAEPFL
Spiral Ribbed Aluminum Alloy Pipe	SRAP
Bituminous Coated	BCSRAP
Polyethylene Pipe (Double Wall)	PEP

Special designs shall be submitted for review by the Director of the Division of Design. Alternate bidding of storm sewers (if pipe) shall be required.

DR-07.430 Sanitary or Combined Sewer Pipe

The following design criteria and procedures shall apply to adjustment or relocation of sanitary or combined sewers (gravity type).

The type of pipe to be used shall be that type which is most commonly used in the existing system, if it is one of the types listed below. The exception, a pipe that is 15 inches in diameter or less, shall use Extra Strength Vitrified Clay Pipe. Also, Extra Strength Vitrified Clay Pipe shall be used for those sewer line sections when the waste water flows for the first five or more years will produce velocities greater than 2 feet per second, and when the velocities will not be greater than 15 feet per second.

1. Vitrified Clay Sewer Pipe, Extra Strength
2. Plain Concrete Sewer Pipe
   (a) Standard
   (b) Extra Strength
3. Reinforced Concrete Pipe
4. Cast-Iron Pipe (may be used in any size in special circumstances)

No alternate bidding of sanitary sewer pipe is required.

DR-07.440 Trapped Inlets

A trap for an inlet functions similar to P-traps used in residential drainage systems. Standard Drawing RDX-020 provides a typical trap for a storm drain inlet. These traps shall be constructed on the last storm inlet before connecting to a sanitary or combined sewer system.

NOTES AND COMMENTS

DR-07.500 STORM SEWER HYDRAULICS

DR-07.510 General

The hydraulic design of a storm sewer system consists of determining the location, sizes, slopes, and elevations for a system of underground conduits necessary to transport surface runoff to a disposal site.

The following data is necessary for a storm sewer system design:

1. Location and geometric design of the highway including elevation
2. Location and elevation of existing outlets
3. Location and elevation of existing inlets
4. Strip map delineating drainage areas and pertinent topography
5. Location of underground utilities, bridge substructures, buildings and other installations that may affect the location of the storm sewer.
6. Locations of existing or planned, future, storm sewers that may connect to the system being designed.

DR-07.520 Design Procedures

The first step in the hydraulic design of a storm sewer system is to locate and determine the capacity of the outlets. As a general rule, the drainage patterns to these outlets should be maintained.

Next, the types of inlets to be used must be selected. The Drop inlets that will be connected to the system must be located, and the curb inlets must be spaced to intercept the expected design discharges for the allowable spread.

On a strip map or schematic drawing of the project, a storm sewer system should be laid out, connecting all inlets to available outfall areas. The designer must remember to work the existing drainage patterns into the design as determined in the first step.

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A profile of the proposed highway and existing ground surface must be plotted along the proposed location of the storm sewer. On this profile, locate the manholes and plot a profile of the proposed storm sewer. It is desirable to avoid abrupt changes in slope from steep to mild. Slopes should be steep enough to maintain a velocity of at least 2 ft/sec to avoid deposition of sediment. Another factor to consider is avoidance of deep trenches, particularly in rock or where shoring will be required. The maximum permissible depth of trench with-out shoring varies with the nature and condition of the soil. However, the location of utilities is a consideration, particularly those that cannot be changed in grade or otherwise disturbed, such as sanitary sewers, especially those constructed of brick, and the location of any new construction such as bridge piers, abutments or other foundations of structures.

Start at the most remote intake structure of the storm sewer system and number each manhole systematically. This will be referred to as Manhole or Inlet (MH) #1. Determine the CA (runoff coefficient times drainage area, in acres) contributing runoff to this point. This may be determined by adding the values of CA for areas with different runoff potential.

Estimate the time of concentration (duration) to this first manhole. This will be the sum of the overland flow time plus the pipe flow time from any inlet contributing to this manhole. Determine the rainfall intensity for a storm of that duration having the selected design frequency and for the location of the project. See Section 04.210 on return period for a discussion of design frequency. The product of this rainfall intensity (I), and the total CA for the manhole in question is the discharge for the section of pipe from MH #1 to MH #2 (Q=CIA).

Using the pipe flow charts, Exhibits 7.940 through 7.952, or the proportional parts charts for other pipes (See Exhibits 7.960 through 7.966), select a size that will carry the discharge from MH #1 to MH #2.

Use n = 0.012 for (EP)RCP, (EP)RCPA, (EP)RCEP, (BC)SRSP,
BCCSPAFL, BCCSEPFL, BCCAPFL, BCCAPAFL,
BCCAEPFL, SRAP, BCSRAP, or PEP all sizes,
or
(FB)(PC)(BC)CSP, or (BC)CAP (24" or smaller).

At MH #2, determine the value of CA for the additional area contributing at that point, and add this value to the CA for MH #1.

Compute the time of flow in the storm sewer from MH #1 to MH #2 in minutes, and add that value to the time of concentration at MH #1. Check the time of concentration for the area contributing directly to MH #2, and use the larger of these two values as the duration for a new value of rainfall intensity for computing the discharge from MH #2 to MH #3. Compute the discharge for the section of storm sewer from MH #2 to MH #3, using the new rainfall intensity and the total CA at MH #2 (CA for MH #1 + CA added at MH #2). Do not reduce the discharge in a system from one manhole to the next. Select a size of pipe from flow charts as before.

Repeat the above procedure for the remainder of the system obtaining a new value of rainfall intensity and a new increased value of discharge at each manhole.

The above procedure is simplified by use of the Form TC 61-505. A typical example indicating the procedure required is shown in Exhibit 07.921.

DR-07.530 Storm Sewer Pipe Size

The minimum size of pipe permitted in any storm sewer system with regards to traffic is:

Away from Pavement or Traffic--

1. 12" for lengths under 25'
2. 15" for lengths over 25'

Under Pavement or Subject to Traffic--

1. 18" for all lengths:
   a. Where water from two or more curb or drop inlets on the opposite side of the road must be transported under the pavement to join the main storm sewer trunk.
   b. Where inlet end of pipe has a headwall or is projecting and subject to possible debris problems.
2. 15" for all lengths:
   a. Where an isolated curb or drop inlet on the opposite side of the road must be joined into the main storm sewer trunk.

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An isolated curb or drop inlet is one which functions alone and is not connected to any other run off source.

The storm sewer system shall be sized by using the Manning equation. The individual structures shall have a flow capacity equal to or greater than the discharge. The flow capacity of a structure is usually assumed to be the capacity of the structure at a flow depth 0.8 times the rise, or diameter. Site limitations may not allow this. If the discharge causes all, or part, of the system to operate under pressure (full flow), outlet control calculations(Energy Grade Line) will be required for the system. Losses described in Chapter 6 shall have to be determined the components.

The outlet control loss coefficient for storm sewer is assumed zero instead of 1.0 as in culvert design. To determine the Energy Grade Line (EGL), check the normal depth of flow for each of the structures and the outfall.

If the normal depth, or tailwater, causes a structure to flow full, start the EGL calculations at the downstream end of this structure and proceed upstream. The EGL elevation at the point where the system starts to flow full is equal to the diameter or rise of the structure plus the velocity head (V^2 / 2g) or the tailwater elevation.

The slope of the EGL is the slope necessary to cause the structure to have a capacity equal to the discharge, considering the entire area and wetted perimeter of the structure. This slope times the length results in the rise of the EGL through the structure.

Losses at junctures are determined by assuming the following:

$$VH = V^2/2g \qquad \text{(one Velocity Head)}$$

90 Degree Bend in the Mainline	*0.7 VH*
Through Flow in Mainline	0.2 VH
Through Flow with Large Lateral	0.5-1.5 VH
First Inlet in the System	1.5 VH
End of System	1.0 VH

See Exhibit 7.922 for an example.

NOTES AND COMMENTS

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DR-07.600 MANHOLES AND JUNCTIONS
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DR-07.610 Applications

Certain material requirements contained in the proposal address criteria useful in developing a preferred design. Some of these requirements are included in the following paragraphs.

The concrete pipe cone may be concentric or eccentric as shown on the plans and as approved by the Engineer.

A precast concrete pipe section that is used to receive intercepted pipe shall have the openings prefabricated at the plant by the manufacturer, and shall not be over 2" larger than the entering pipe.

A precast concrete pipe section may be used in the base portion of Manholes Type A and B only when one line of intercepted pipe runs in a straight line and on the same grade. When this condition is exceeded, a cast-in-place concrete pipe section should be constructed at an elevation of one foot above and one foot below the outside diameter of the pipe, using the same material requirements as the perimeter of a cast-in-place base.

The periphery limitations for each 4' vertical brick section shall be as follows:

1. Opening for intercepted pipe shall not exceed 60% of the full sectional area.

2. A minimum of 1'-6" along the outer circumference shall be maintained between extremities of openings for adjacent pipe.

3. If No. 1 or 2 is violated, a cast-in-place bottom unit shall be required as shown for Manhole Type B.

DR-07.620 Manhole Types

Manhole Type A:
This manhole is known as a Precast Concrete Stub Manhole, further identified on Standard Drawing RDM-001. Limitations for its height have been placed at a maximum of 9'-0". It may be constructed of either precast concrete, cast-in-place concrete, or brick. The maximum size of intercepted pipe shall be 27 inches.

Manhole Type B:

This manhole is a combination of a Concrete Manhole Type A and a Brick Manhole as detailed on Standard Drawing RDM-001. Its limitation in height has been placed at 9'-1" to 60'-0" and may be constructed of precast concrete pipe sections, cast-in-place concrete, or brick under 12'-0". The maximum size of intercepted pipe shall be 27".

Manhole Type C:

This manhole will accommodate pipe sizes from 30" through 72", both circular and elliptical. Class A and Class B Towers are shown and must be specified on the Pipe Drainage Summary by the designer. The Class A Tower is to be manufactured of precast concrete pipe or cast-in-place concrete and is applicable for heights from 3' to 51' and may be constructed of brick, when less than 12' in height. A Type B Tower is a precast concrete stub, constructed of cast-in-place concrete or brick, and contains a precast, flat top slab.

DR-07.630 Frame and Lids

Frame and Lid Type 1:

This is a reversible, lightweight frame and lid for use in the current designs for a Curb Box Inlet Type A and for the non-traffic manhole applications. New designations have been adopted showing the Type 1 Series; the A, B, and C refer to the type of sewer. Previously, the sewer type was not designated. Therefore, it is mandatory that the type of lid be shown in the remarks column on the Pipe Drainage Summary. Drawings for a Type A Box have been changed to specify the type of frame and lid.

Frame and Lid Type 2:

This drawing replaces Standard Drawing Number RDM-010. The frame has been redesigned to reduce its weight without affecting its structural capacity. The present lid design has not been changed, except as previously noted. However, minor modifications have been made in the adjusting ring. New or old rings are interchangeable. Sewer types have the same designation as Type 1.

DR-07.640 Junction Boxes

Junction boxes can be used where a pipe changes direction or size. These junction boxes can be used in place of manholes for certain situations.

Obviously, on mild slopes or in low velocity flow situations, junction boxes would not be recommended, since debris would have a tendency to collect in these boxes, therefore causing frequent maintenance difficulties. Due to the low cost of installation, they should be considered where they would be structurally feasible. Junction boxes are bid by the unit and by the largest pipe dimension in the box.

The boxes are permitted to be used for non-circular pipe, provided the box size selected will accommodate the controlling dimensions of the non-circular pipes. These boxes are limited in size and height and should be used only within their limitations. Boxes needed outside these limitations shall be individually designed.

DR-07.650 Other Junctions

There are other means of creating a junction between two runs of pipe. For instance, a concrete collar could be constructed, or the designer could use an Intermediate Anchor (Standard Drawing RDX-060). For metal pipe, a variety of manufactured bends, Y and T connections, are available.

The designer is cautioned that in cases where existing concrete pipe is to be extended, and the difference in the grade of the existing pipe and the extension is greater than 0.002 ft/ft, a junction structure must be used.

NOTES AND COMMENTS

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DR-07.700 FIELD AND PLANS
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Exhibits 7-932.1, 7-932.2, 7-932.3, and 7-933 contain examples depicting the required storm sewer details in the plans.

NOTES AND COMMENTS

CHAPTER DR-07
INLETS & STORM SEWERS

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DR-07.900 EXHIBITS
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CHAPTER DR-07
INLETS & STORM SEWERS

INLET SPACING FOR GRATED, CURB-OPENING, & SLOTTED INLETS : TC 61-120 (Rev. 6-93) : Page 1 of 1

County ADAIR **Route** US 61 **Proj. No. SSP 001 0061 001-005** **Item No.** 8-100.00

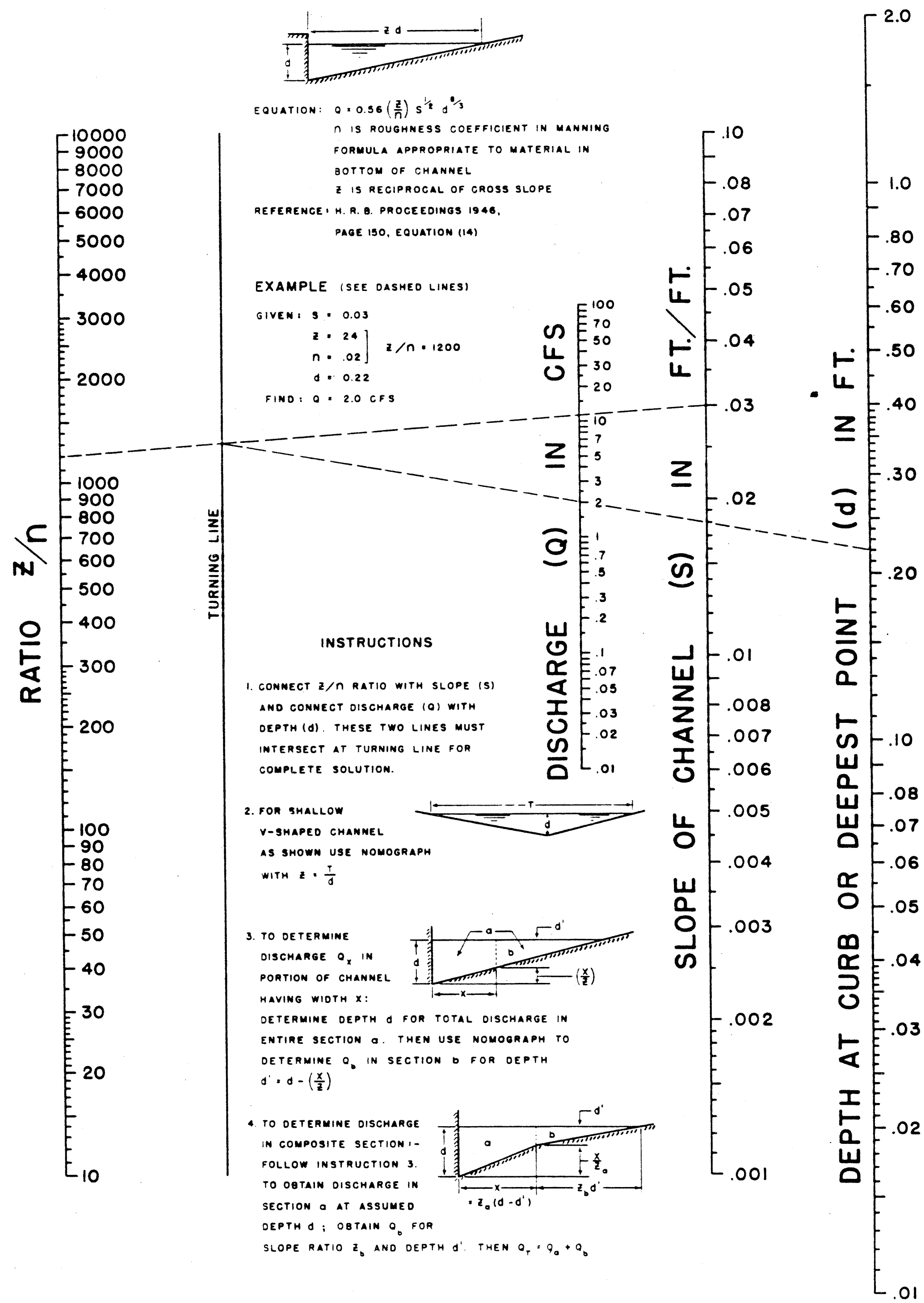
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Sta. Loc.	CA	Q	Qc	Qa	Sx	Sw / Sx	So	T/W	T	d	V	W/T	Eo	Se	Lt	L/Lt	Rf	1-Eo	Rs	E	Qi	Qc
							10' CURB OPENING INLET OR 10' SLOTTED PIPE															
LT. 11 +00	0.51	2.04	0.65	2.69	.032	1	.028	3.2	6.4	0.20	-	0.31	0.62	.082	17	0.59	-	-	-	0.80	2.15	0.56
							DROP BOX INLET TYPE 13															
LT. 11 +00	0.51	2.04	0.65	2.69	.032	1	.028	3.2	6.4	0.20	3.1	0.31	0.62	-	-	-	1.0	0.38	0.16	0.68	1.83	0.68
							DROP BOX INLET TYPE 16 WITH 10' SLOTTED PIPE															
LT. 11 +00	0.51	2.04	0.65	2.69	.032	1	.028	3.2	6.4	0.20	-	0.31	0.62	.032	32	0.31	-	-	-	0.47	1.26	1.43
LT. 11 +00				1.43				2.4	4.8		3.5	0.42	0.77	-	-	-	1.0	0.23	0.15	0.80	1.14	
																					2.40	0.29

ALL INLETS : da = ______ Ta = ______ I = ______ n = ______ Wg = ______ Lg = ______ a = ______ Li = ______

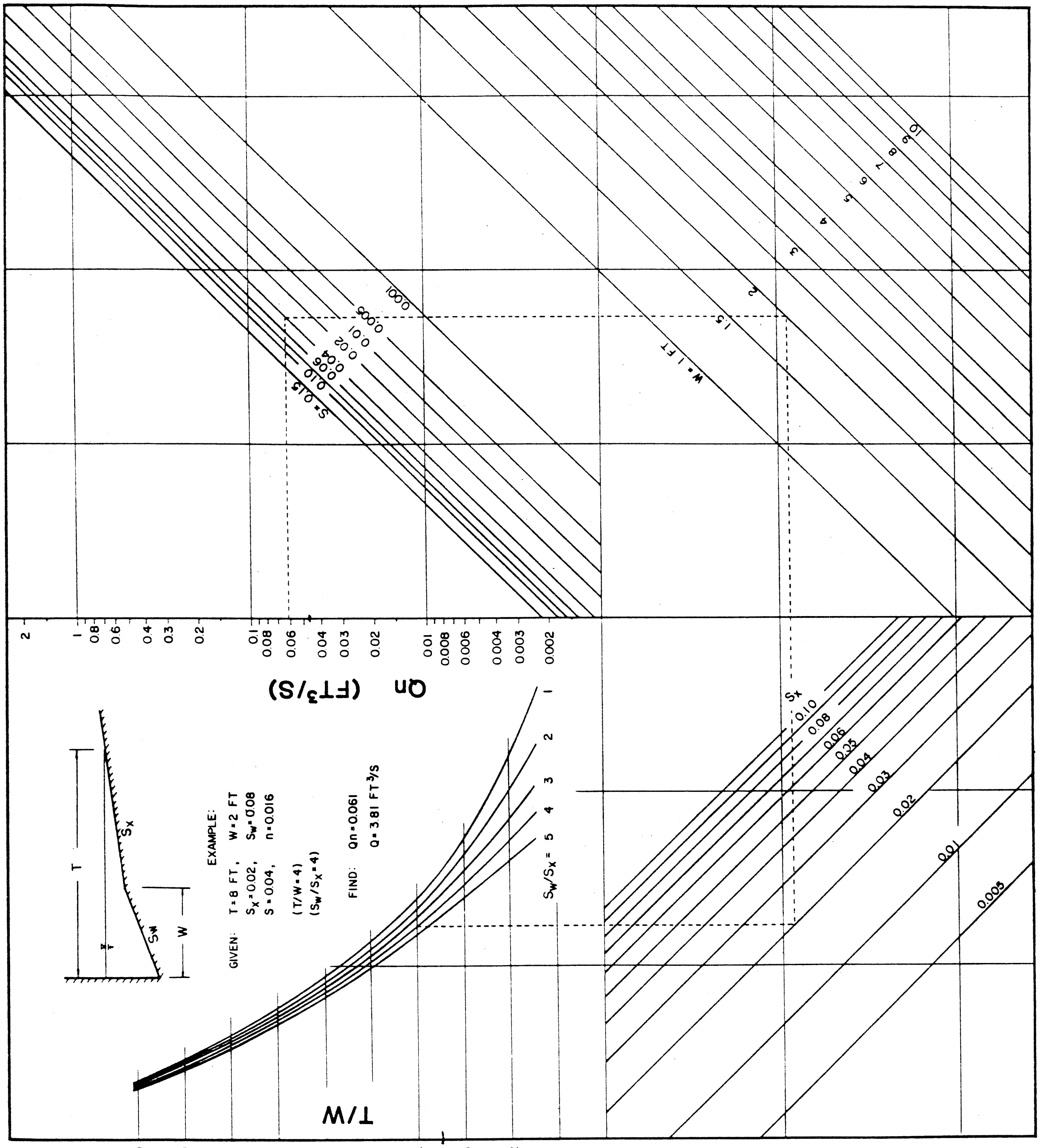
SAG INLETS : Q_{SUM} = ______________ Cw = ______ Co = ______ h = ______ do = ______ A/2 = ______ P/2 = ______

COL.	ITEM	INSTRUCTIONS
1	STA / LOC	Station and Location of Inlet.
2	CA	C x A : Weighted Runoff Coefficient times Drainage Area to Inlet in Acres.
3	Q	Rational Discharge = (2)x I (Intensity).
4	Qc	Carryover from Previous inlet Upstream.
5	Qa	Total Gutterflow Available = (3) + (4).
6	Sx	Pavement Cross-slope at Inlet. Use minimum of 0.001 for inlet placed 50 feet back of flat spot in Superelevated Roadway.
7	Sw / Sx	Ratio of Gutter Cross Slope (Sw) to (6).
8	So	Longitudinal Slope. Use Minimum of 0.001 for inlet in a Sag Vertical Curve.
9	T / W	Ratio of Top Width (Spread) to Gutter Width.
10	T	Top Width flow at Inlet (Spread).
11	d	Depth of flow at Inlet.
12	V	Velocity at Inlet = (3) / Area.
13	W / T	Ratio of Gutter Width to Top Width.
14	Eo	Ratio of Gutter Flow to Total Flow = Qw / (3) = $1-(1-W/T)^{2.67}$.
15	Se	Equivalent Cross Slope at Depressed Inlets = Sx + Sw x Eo.
16	Lt	Length of Curb Opening Inlet required for total interception = $0.6Q^{0.42}So^{0.3}(1/nSe)^{0.6}$.
17	L / Lt	Ratio of Length of Inlet to Curb Opening Length Required for Total Interception.
18	Rf	Ratio of Grate Frontal Flow intercepted to Total Frontal Flow = 1 - 0.09(V - Vo), where Vo = gutter velocity where grate splash-over first occurs (See HEC-12).
19	1-Eo	Ratio of Grate side flow, Qs, to total gutter flow = Qs/Q = 1-Qw/Q = 1-Eo.
20	Rs	Ratio of Grate side flow intercepted to total side flow = $1/[1+(0.15V^{1.8})/(SxLg^{2.3})]$, where Lg is the length of the grate.
21	E	Efficiency of : Grate = RfEo + Rs(1-Eo) Curb Opening = $1 - (1 - L/Lt)^{1.8}$.
22	Qi	Total Discharge intercepted by the inlet. Qi = EQ.
23	Qc	Carryover Discharge (not intercepted) to next inlet, Qc = Q - Qi.

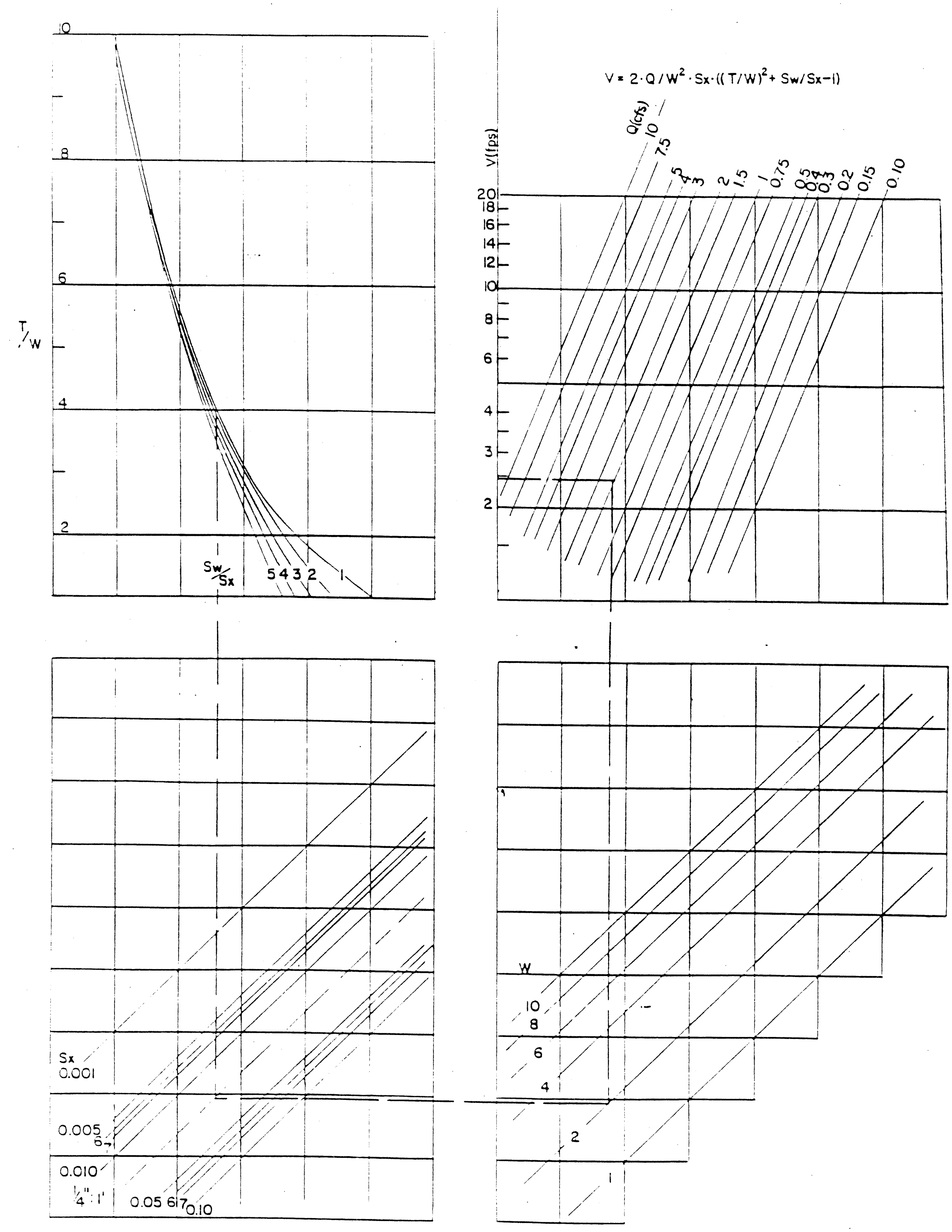
da	Depth at curb face times gutter depression.
Ta	Top Width times gutter depression.
I	Rainfall Intensity.
n	Manning's Roughness Coefficient for pavement.
Wg	Width of Grate.
Lg	Length of Grate.
a	Gutter Depression at inlet in feet.
Li	Length of Curb Opening Inlet.
Q_{SUM}	Sum of Total Gutter Flow in Sag.
Cw	Weir Coefficient.
Co	Orfice Coefficient.
do	Effective Head on the Center of the orfice throat of Curb Opening Inlet, do = d - (h/2)Sin Θ, where h is height of curb opening orfice and Θ is the angle of the orfice opening. See HEC-12.
A/2	Area of Clear Grate opening divided by 2.
P/2	Perimeter of Grate divided by 2.

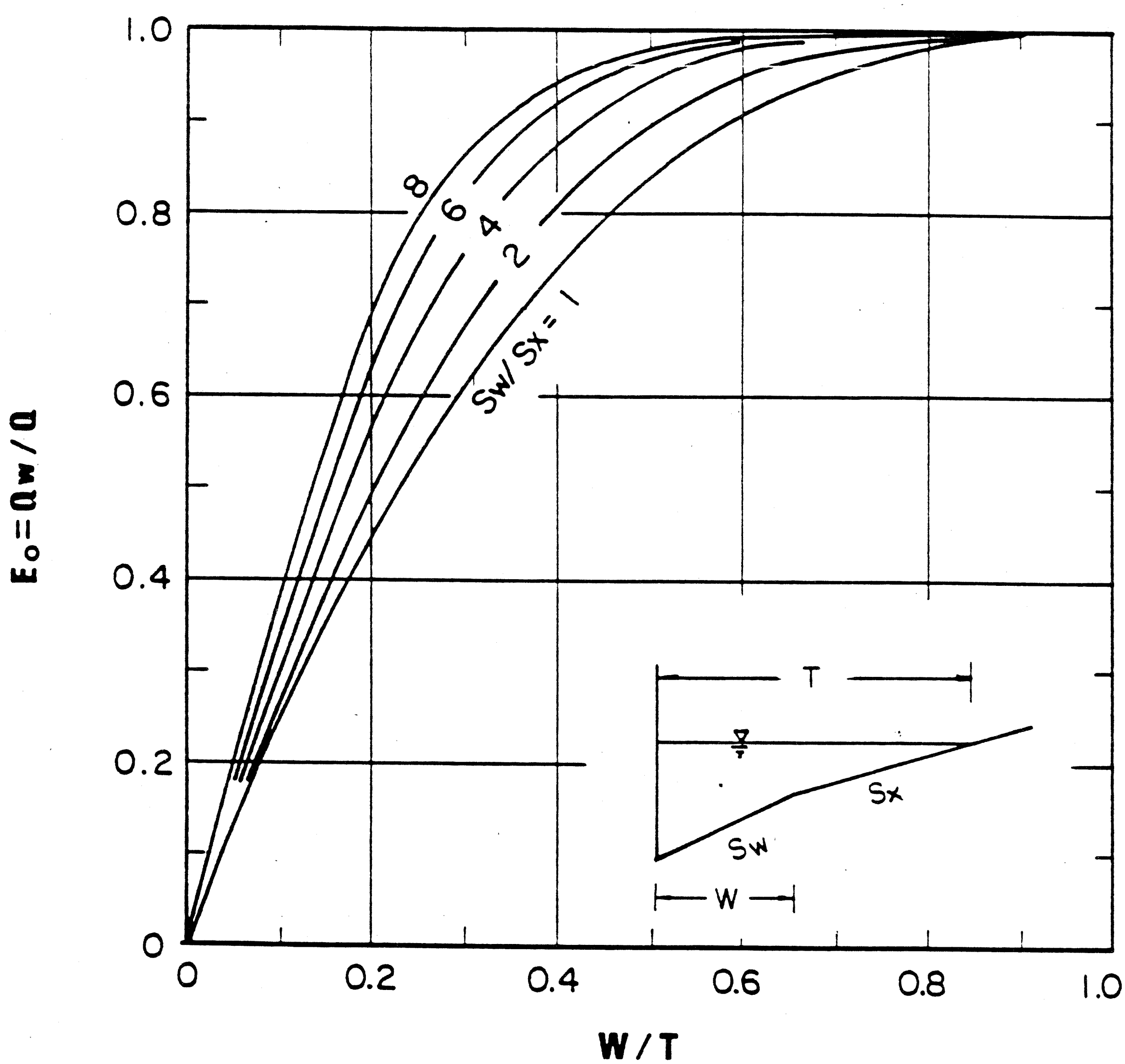


z d
d
EQUATION: Q = 0.56 (z/n) S^1/2 d^8/3
n IS ROUGHNESS COEFFICIENT IN MANNING FORMULA APPROPRIATE TO MATERIAL IN BOTTOM OF CHANNEL
z IS RECIPROCAL OF CROSS SLOPE
REFERENCE: H. R. B. PROCEEDINGS 1946, PAGE 150, EQUATION (14)
EXAMPLE (SEE DASHED LINES)
GIVEN: S = 0.03
z = 24
n = .02
z/n = 1200
d = 0.22
FIND: Q = 2.0 CFS
RATIO z/n
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
TURNING LINE
DISCHARGE (Q) IN CFS
100
70
50
30
20
10
7
5
3
2
1
.7
.5
.3
.2
.1
.07
.05
.03
.02
.01
SLOPE OF CHANNEL (S) IN FT./FT.
.10
.08
.07
.06
.05
.04
.03
.02
.01
.008
.007
.006
.005
.004
.003
.002
.001
DEPTH AT CURB OR DEEPEST POINT (d) IN FT.
2.0
1.0
.80
.70
.60
.50
.40
.30
.20
.10
.08
.07
.06
.05
.04
.03
.02
.01
INSTRUCTIONS
1. CONNECT z/n RATIO WITH SLOPE (S) AND CONNECT DISCHARGE (Q) WITH DEPTH (d). THESE TWO LINES MUST INTERSECT AT TURNING LINE FOR COMPLETE SOLUTION.
2. FOR SHALLOW V-SHAPED CHANNEL AS SHOWN USE NOMOGRAPH WITH z = T/d
T
d
3. TO DETERMINE DISCHARGE Qx IN PORTION OF CHANNEL HAVING WIDTH X: DETERMINE DEPTH d FOR TOTAL DISCHARGE IN ENTIRE SECTION a. THEN USE NOMOGRAPH TO DETERMINE Qb IN SECTION b FOR DEPTH d' = d - (X/z)
a
b
d'
d
X
(X/z)
4. TO DETERMINE DISCHARGE IN COMPOSITE SECTION:- FOLLOW INSTRUCTION 3. TO OBTAIN DISCHARGE IN SECTION a AT ASSUMED DEPTH d ; OBTAIN Qb FOR SLOPE RATIO zb AND DEPTH d'. THEN QT = Qa + Qb
a
b
d'
d
X/za
X
= za(d - d')
zb d'



$$Q = \frac{0.56}{n} \cdot S^{1/2} \left[S_x^{5/3} \cdot (T-W)^{8/3} + S_W^{5/3} \cdot \left\{ \left(W + (T-W)\frac{S_X}{S_W} \right)^{8/3} - \left((T-W)\frac{S_X}{S_W} \right)^{8/3} \right\} \right]$$


V = 2·Q / W² · Sx·((T/W)² + Sw/Sx−1)
Q(cfs)
10
7.5
5
4
3
2
1.5
1
0.75
0.5
0.4
0.3
0.2
0.15
0.10
V(fps)
20
18
16
14
12
10
8
6
4
3
2
T/W
10
8
6
4
2
Sw/Sx
5 4 3 2
1
Sx
0.001
0.005
0.010
¼":1'
0.05
0.10
W
10
8
6
4
2
1

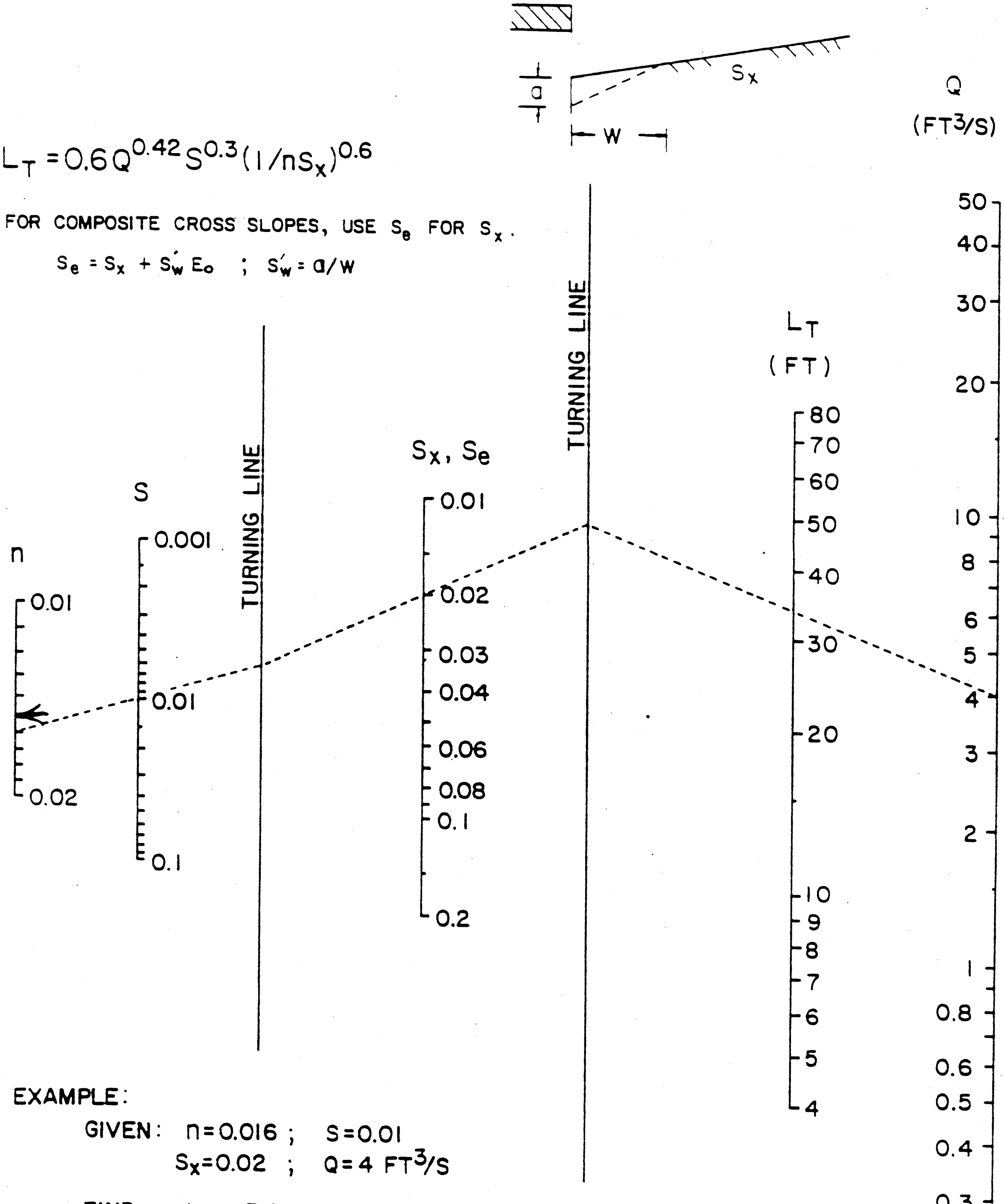


$$E_o = \frac{1}{1 + \dfrac{\frac{S_w}{S_x}}{\left[1 + \dfrac{\frac{S_w}{S_x}}{\frac{1}{\frac{W}{T}} - 1}\right]^{8/3} - 1}}$$

$L_T = 0.6\,Q^{0.42} S^{0.3} (1/nS_x)^{0.6}$

FOR COMPOSITE CROSS SLOPES, USE S_e FOR S_x.

$S_e = S_x + S'_w E_o$; $S'_w = a/W$

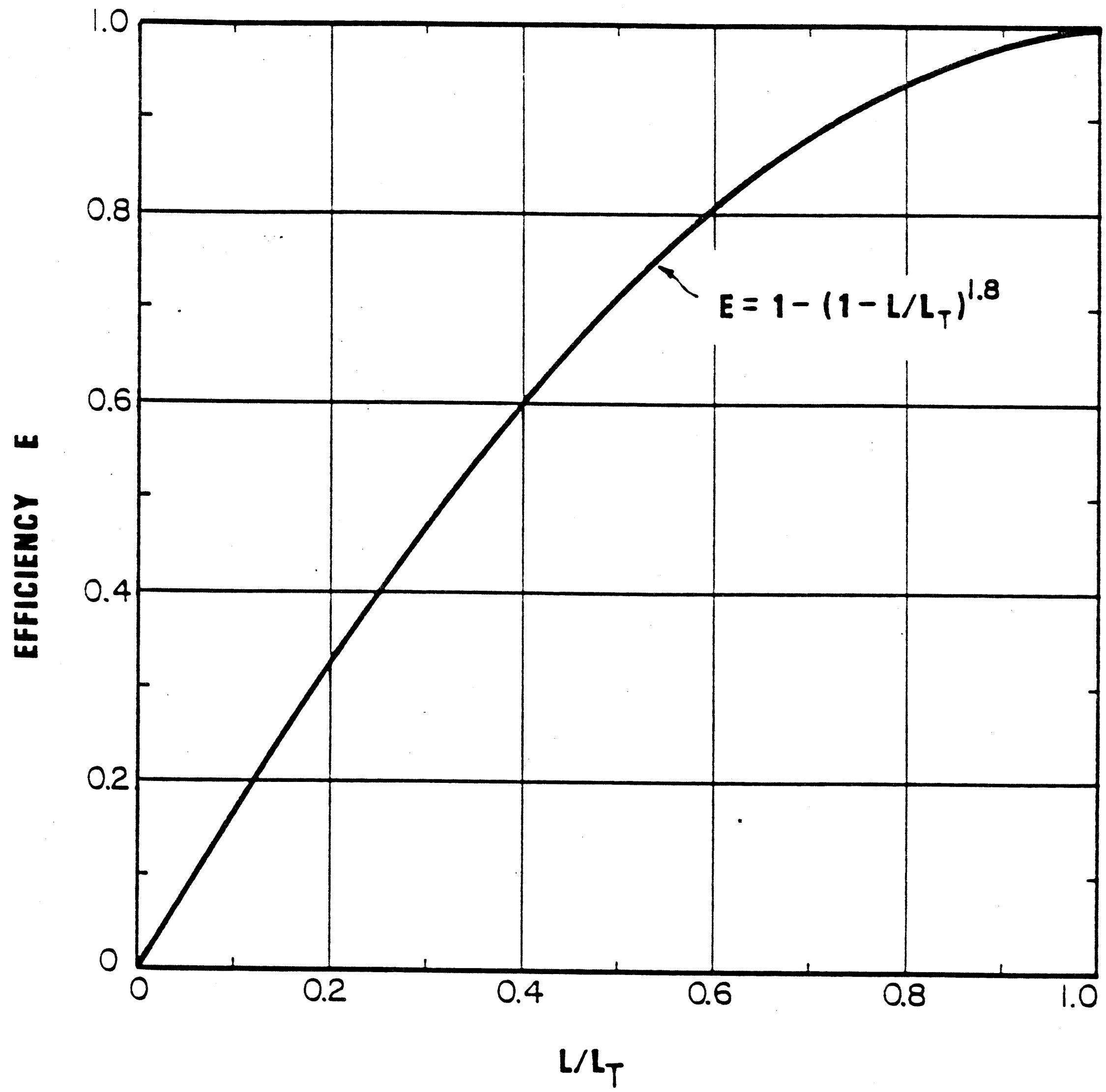


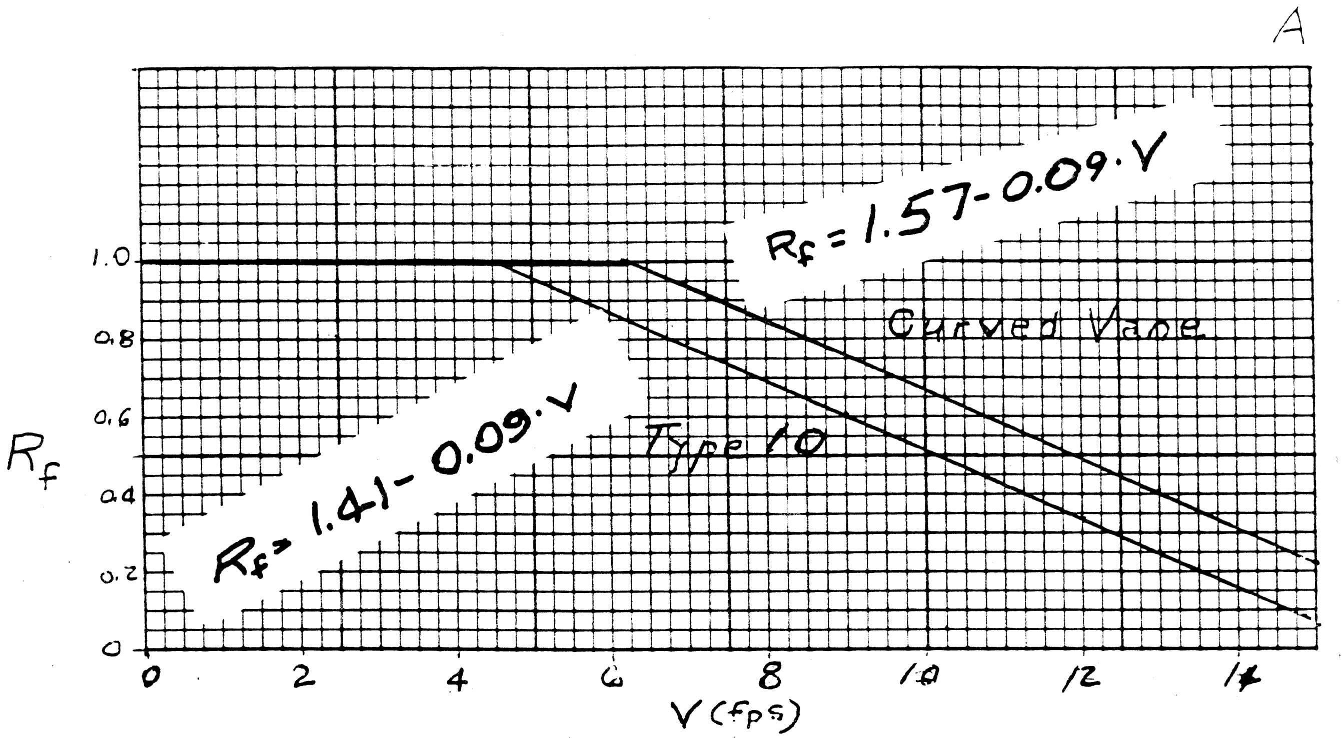
EXAMPLE:

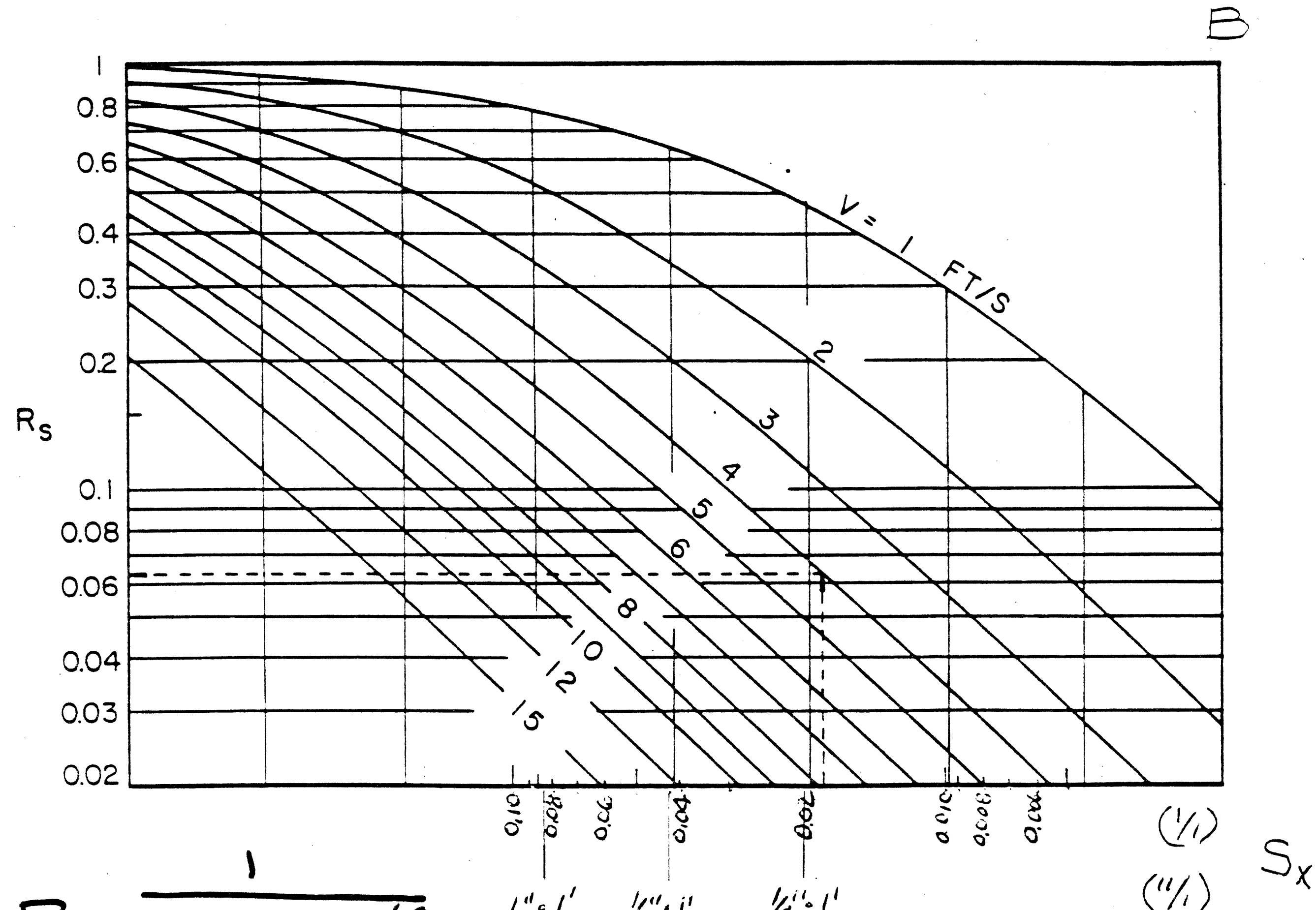
GIVEN: n=0.016 ; S=0.01

S_x=0.02 ; Q=4 FT^3/S

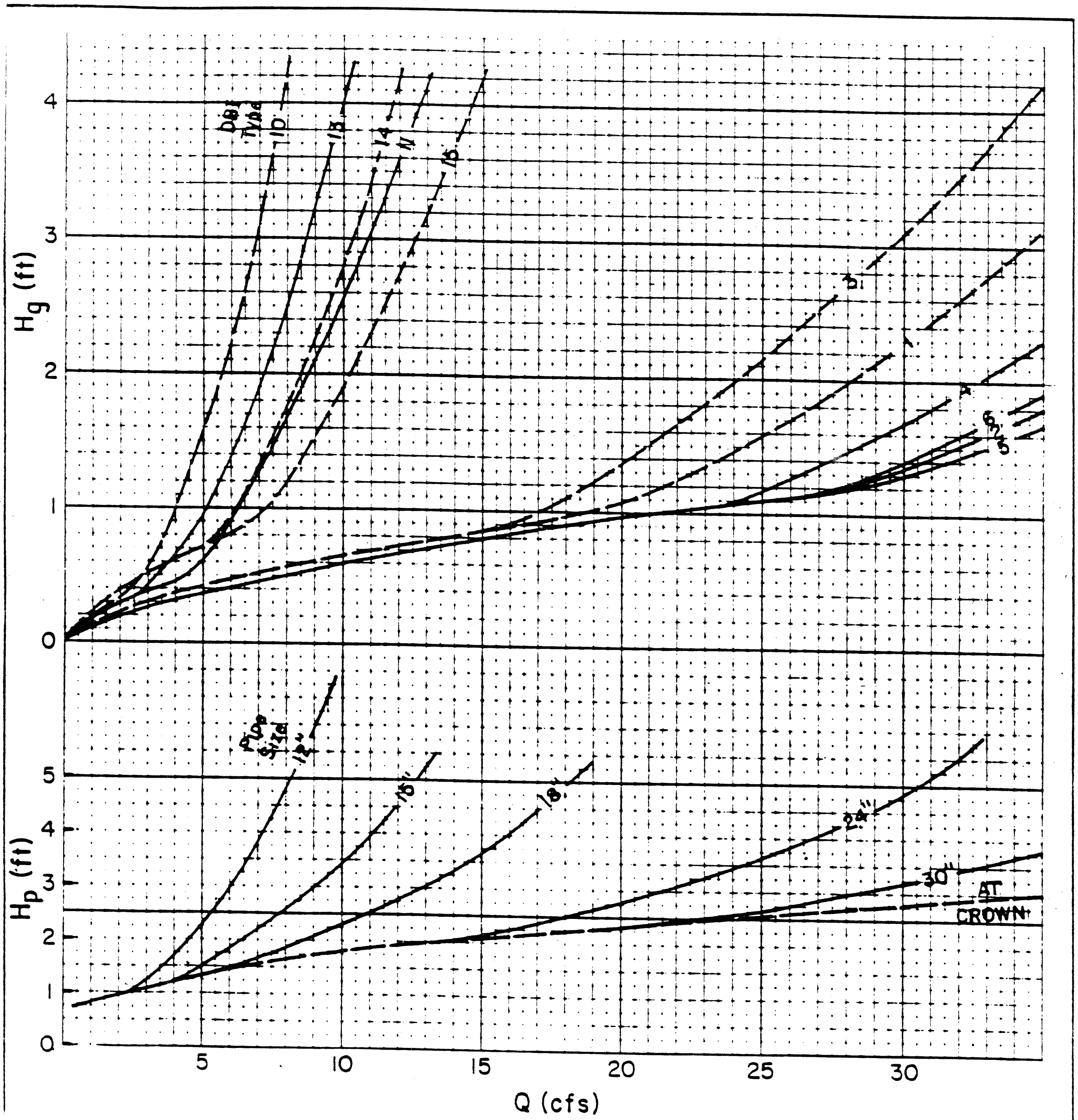
FIND: L_T = 34 FT

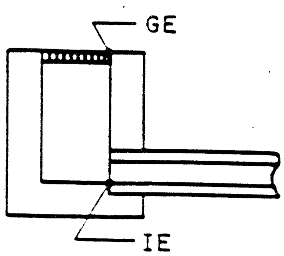

1.0
0.8
0.6
0.4
0.2
0
EFFICIENCY E
0
0.2
0.4
0.6
0.8
1.0
L/L_T
E = 1 - (1 - L/L_T)^1.8





$$R_s = \frac{1}{1 + \dfrac{0.15 \cdot V^{1.8}}{S_x L^{2.3}}}$$

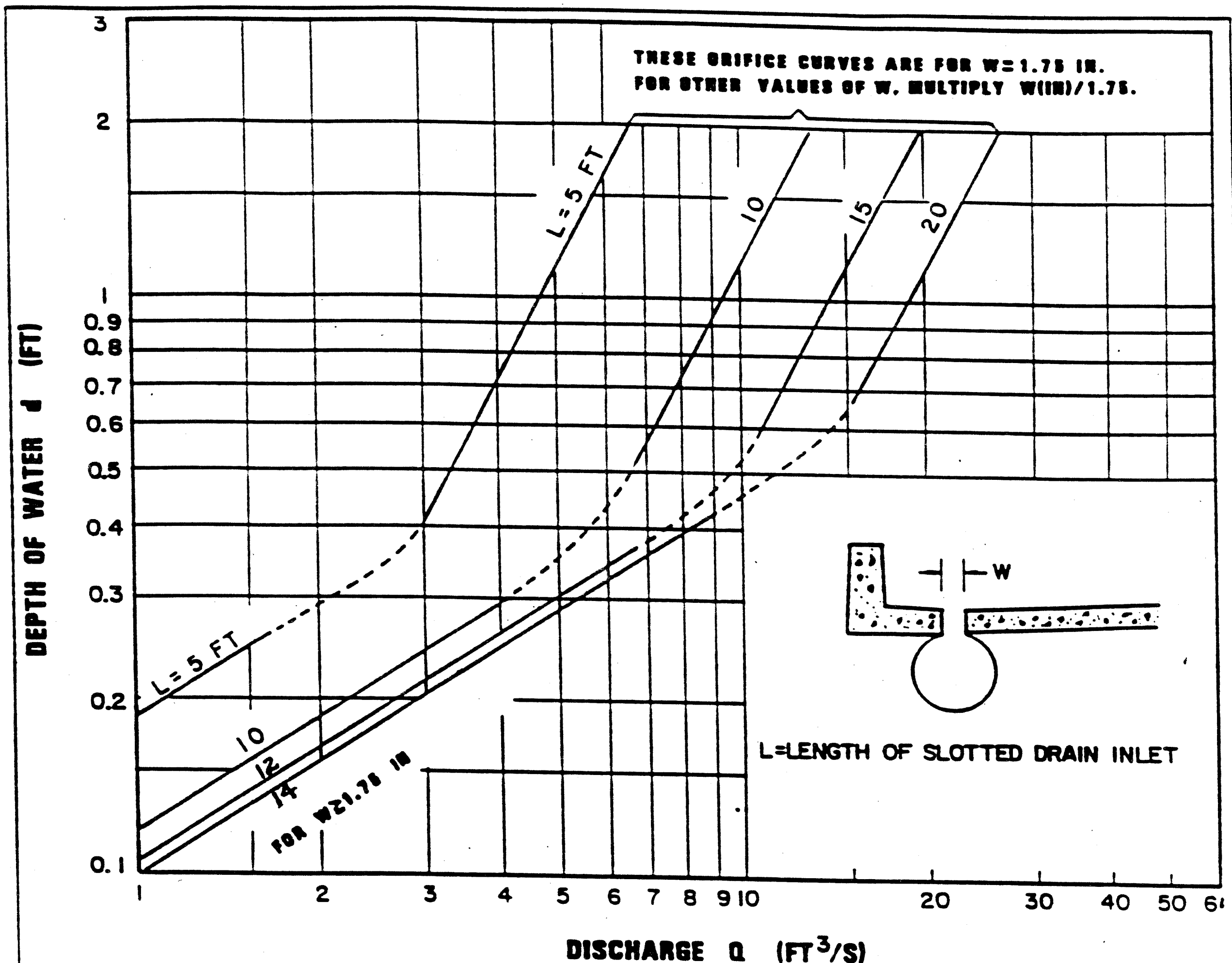




$$HW = GE + H_g$$

or

$$IE + H_p$$

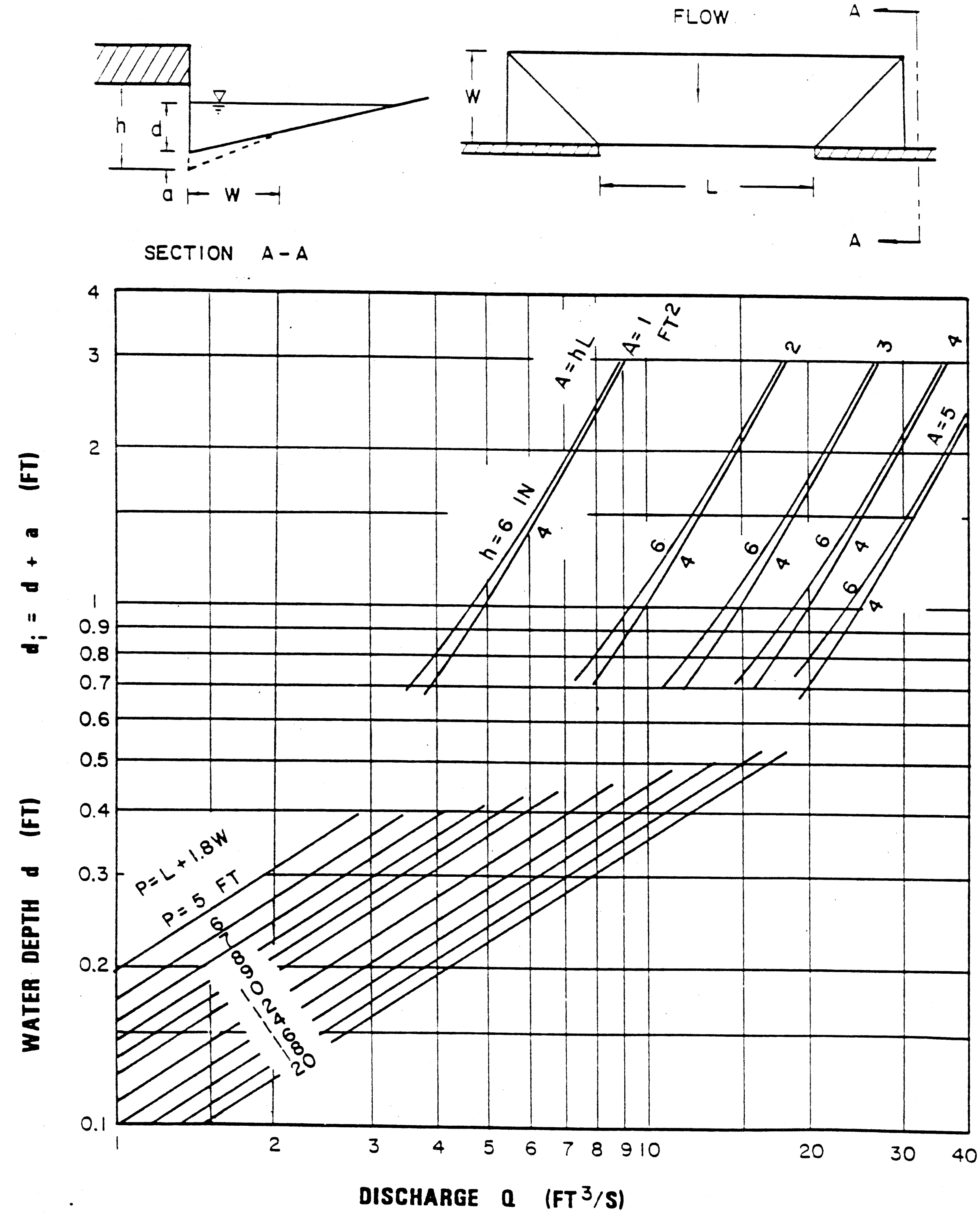


$d < 0.4'$

$Q_i = 2.3 \cdot L \cdot d^{1.5}$

$d \geq 0.4'$

$Q_i = 0.94 \cdot L \cdot d^{0.5}$



$d < 0.4'$

$Q_i = 2.3 \cdot (L + 1.8 \cdot W) d^{1.5}$

$d \geq 0.4'$

$Q_i = 0.28 \cdot L \sqrt{2 \cdot g \cdot (d - 0.10)}$

COMPUTATION TABLE FOR STORM SEWER DESIGN : TC 61-505 (Rev. 6-93) Page 1 of 1

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1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Inlet or M. H.	Station	Δ Acre	"C"	Δ CA	Σ CA	Δ T	Σ T	I 10Yr	Q	Pipe Length	Pipe Slope	Pipe Size	Mean Velocity	Full Pipe Flow	
No.		Acre		Acre	Acre	min	min	in /hr	cfs	LF	ft / ft	in	fps	cfs	
1		1.7	0.8	1.36	1.36	-	25	3.4	4.6						
						0.8				200	.004	18"	4.4	7.1	
2		1.1	0.6	0.64	2.00		26	3.4	6.8						
						1.1				300	.003	18"	4.4	6.8 <	Press.
Outlet	Channel						27	(3.3)	6.8						
								use 3.4			2' FB	2:1 SS			
											1' Deep	n=.04			

COL.	ITEM	INSTRUCTION
1	Inlet/Manhole	Inlet, Manhole, or Junction Number.
2	Station	Plan Location of (1).
3	Δ Acre	Increment of area added at this point.
4	C	Weighted Runoff Coefficient.
5	Δ CA	(4) x Increment Area, A, x (3).
6	Σ CA	Total CA to this point : (5) + (6) of previous line.
7	Δ T	Time of Flow in this section of Pipe. Time to first inlet or Manhole may be estimated by use of overland flow principles.
8	Σ T	Total time to this point.
9	I	Rainfall Intensity for time T (8) from appropriate Intensity-Duration Equation.
10	Q	Rational Discharge : CIA = (6) x (9).
11	L	Length of Pipe (use unnumbered lines).
12	So	Slope of pipe from Center of Manhole to Center of Manhole.
13	Pipe Size	Size determined from pipe flow charts (Chapter 7 Exhibits).
14	Vo	Mean Velocity from pipe flow charts (Chapter 7 Exhibits).
15	Full Pipe Flow	Pipe Capacity flowing full from pipe flow charts (Chapter 7 Exhibits).

ENERGY GRADE LINE FOR STORM SEWERS : TC 61-XXX (Rev. 6-93) **Page 1 of 1**

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Station	Struct	Q	Inlet Elev.	Inlet								Pipe			HW	Comments
				H/D	H	dc	(dc+D)/2	V	VH	Coeff	H	L	Sf	Hf		
															100.00’	Outlet Inv.
Outlet	2’ FB	6.8												0.9	100.90’	Tailwater
	300’ 18"					1.0	1.25								101.25’	Governs
								4.4	0.3						101.55’	
												300	.0035	1.05	102.60’	
MH #1								4.4	0.3	0.2	0.06				102.66’	
	200’ 18"											200	.0016	0.3’	102.96’	
MH #2								4.4	0.3	1.5	0.4				103.36’	

DRAINAGE SUMMARY (SHEET 2 OF 2)

COUNTY OF	FISCAL YEAR	SHEET NO.
CHRISTIAN		29

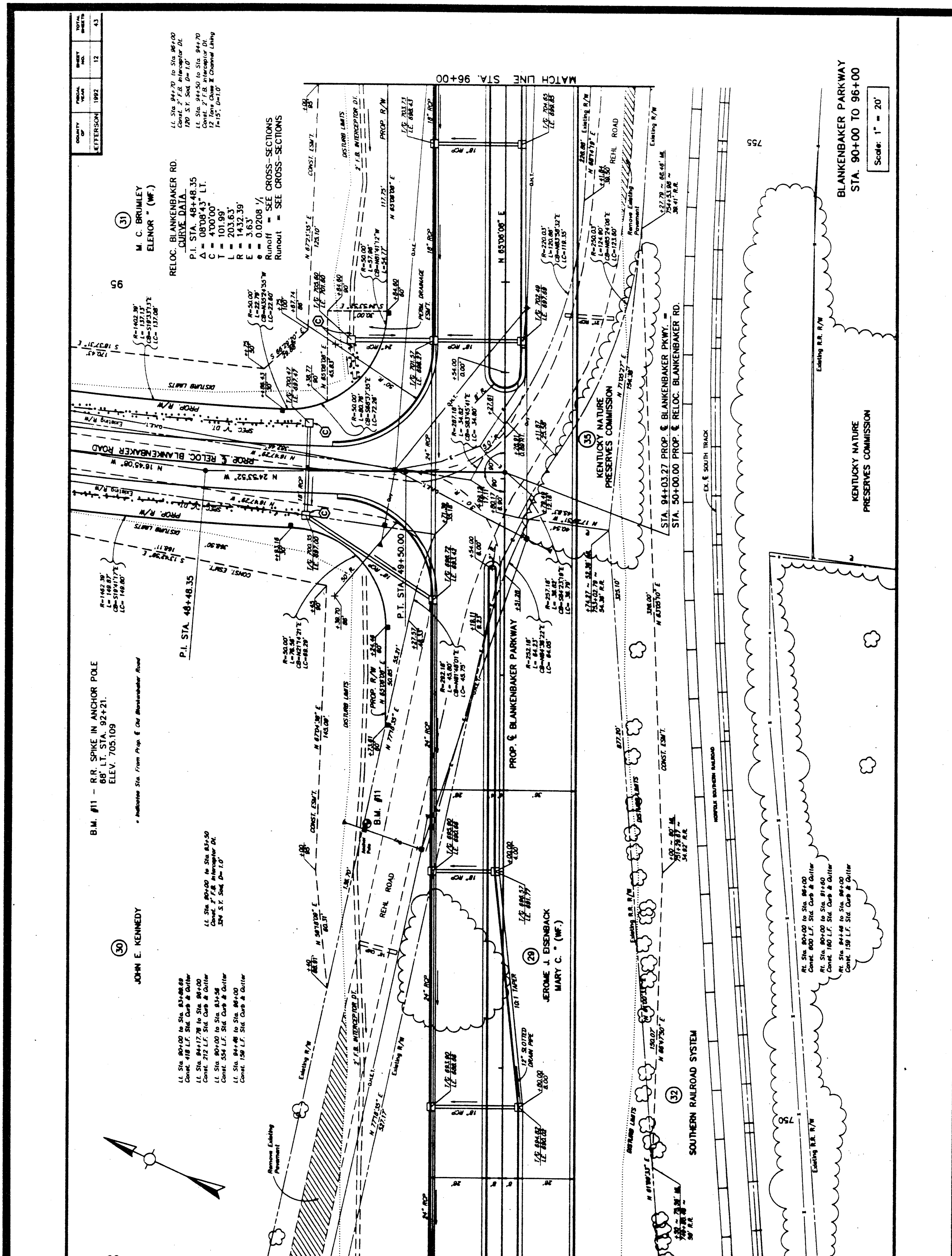
FSP 024 8524 018D

SHEET NO.	LOCATION AND STATION	SKEW	CULVERT PIPE 18" RCP CLASS III OR BCCSP, 16 GA. OR BCCAP, 16 GA.	CULVERT PIPE 24" RCP CLASS III OR BCCSP, 14 GA. OR BCCAP, 14 GA.	CULVERT PIPE 30" RCP CLASS III OR BCCSP, 14 GA. OR BCCAP, 14 GA.	CULVERT PIPE 36" RCP CLASS III OR BCCSP, 12 GA. OR BCCAP, 12 GA.	CULVERT PIPE 36" RCP CLASS III OR BCCSPFL, 12GA. OR BCCAPFL, 12GA.	CULVERT PIPE 42" RCP CLASS III OR BCCSP, 12 GA. OR BCCAP, 12 GA.	CULVERT PIPE 42" RCP CLASS III OR BCCSPFL, 12 GA. OR BCCAPFL, 12 GA.	CULVERT PIPE 54" RCP CLASS III OR BCCSPFL, 12 GA. OR BCCAPFL, 12 GA.	CULVERT PIPE 60" RCP CLASS III OR BCCSPFL, 10 GA. OR BCCAPFL, 10 GA.	CULVERT PIPE 60" RCP CLASS III		
ITEM CODE			462	464	466	468	468	469	469	471	① 472	472		
UNIT TO BID ON			LINEAR FOOT											
33	327+00	0°	68											
35	334+50	0°			170									
35	343+50	0°	75											
35	344+00 97' LT.	—												
35	344+00 91' RT.	—												
37	345+50	0°						163						
37	354+50	0°		77										
39	362+50 75' LT.	—												
39	362+50 92' RT.	—												
39	363+00	0°		73										
39	372+50	0°		156										
	KY 695													
41	106+00 42' RT.	—												
43	116+18 48' RT.	—												
	KY 272													
45	17+50 42' LT.	—												
45	17+50 42' RT.	—												
45	20+37	37° LT.												
45	20+75 70' LT.	—												
47	28+50 40' RT.	—												
47	33+29 26' RT.	—												
	US 68													
39	674+75 6' RT.	0°												
	TOTALS		746	1226	922	166	159	527	174	239	206	168		

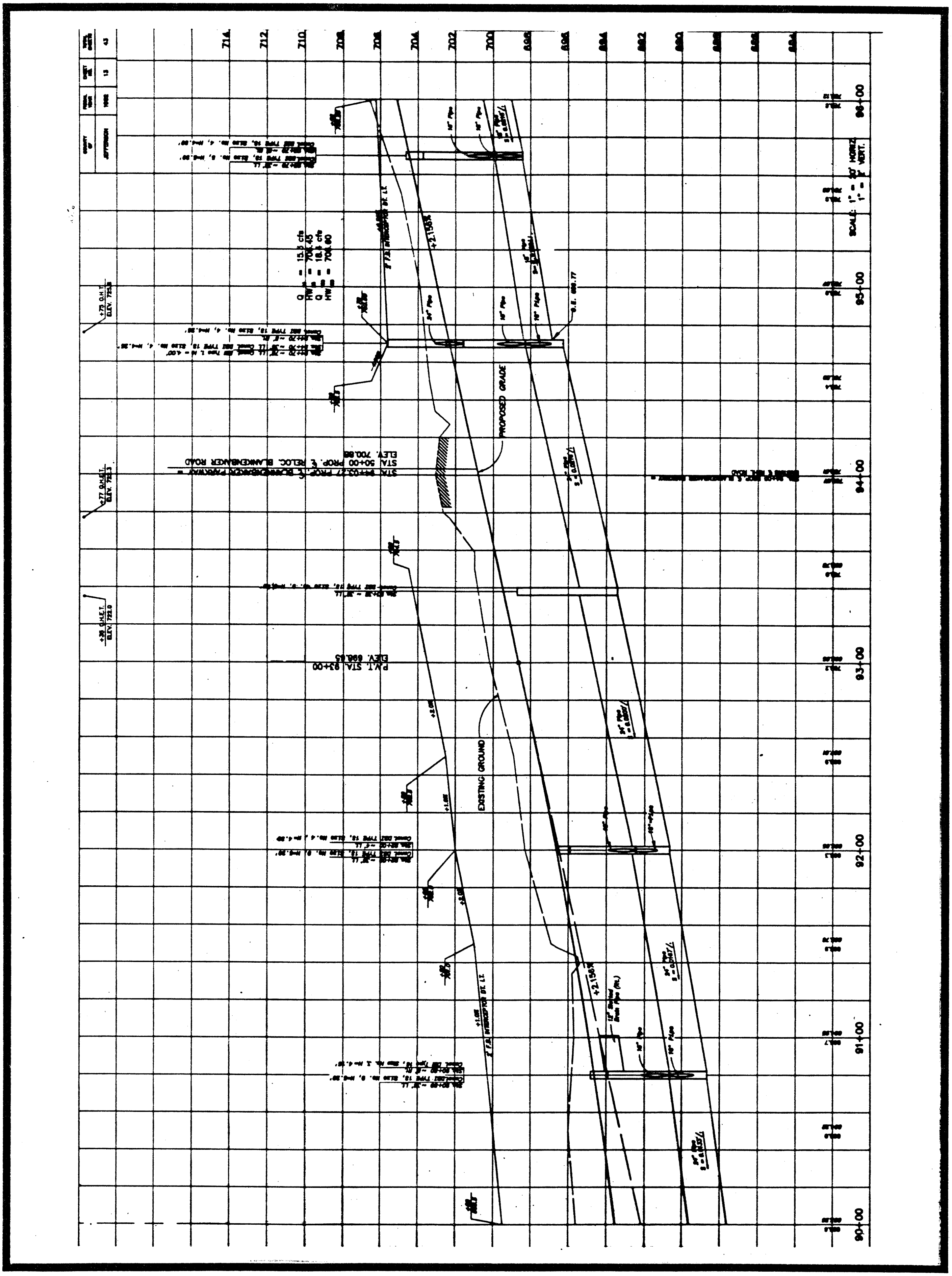
SHEET NO.	LOCATION AND STATION	ENTRANCE PIPE 15"	ENTRANCE PIPE 18"	ENTRANCE PIPE 24"	ENTRANCE PIPE 30"	CHANNEL LINING CLASS II	CHANNEL EXCAVATION	18" SLOPED BOX OUTLET TYPE 1	24" SLOPED BOX OUTLET TYPE 1	24" SLOPED & FLARED BOX INLET & OUT.	30" SLOPED & FLARED BOX INLET & OUT.	36" SLOPED & FLARED BOX INLET & OUT.	DROP BOX INLET TYPE 2	DROP BOX INLET TYPE 5B	DROP BOX INLET TYPE 5C	DROP BOX INLET TYPE 5F	DROP BOX INLET TYPE 7- 5 & 16	CLASS "A" CONCRETE	STEEL REINFORCEMENT	REMARKS
ITEM CODE		440	441	443	445	② 2483	②	1433	1434	1451	1452	1453	1493	1505	1508	1517	1538	② 8100	② 8150	
UNIT TO BID ON						TON	CU. YD.	EACH										CU. YD.	LB.	
33	327+00					12		1						1						DBI No. 22 (h = 3.0')
35	334+50					20												3.36	281	2-30" STD. HDWLS.
35	343+50					4										1		0.93	8	DBI No.23(h=3.0')1-S.&F.HDWL.
35	344+00 97' LT.			62																NO HDWLS.
35	344+00 91' RT.			54																NO HDWLS.
37	345+50					47												5.35	430	2-42" STD. HDWLS.
37	354+50								1						1					DBI NO.24 (h = 3.5')
39	362+50 75' LT.			48																NO HDWLS.
39	362+50 92' RT.			140																2-24" PIPES. NO HDWLS.
39	363+00								1					1						DBI NO.25 (h = 3.5')
39	372+50					16				2										
	KY 695																			
41	106+00 42' RT.		38																	NO HDWLS.
43	116+18 48' RT.				38															NO HDWLS.
	KY 272																			
45	17+50 42' LT.	40																		NO HDWLS.
45	17+50 42' RT.	40																		NO HDWLS.
45	20+37					80														133' OF 10'x5' R.C.B.C.
45	20+75 70' LT.				200															4-30" PIPES. NO HDWLS.
47	28+50 40' RT.	34																		NO HDWLS.
47	33+29 26' RT.	32																		NO HDWLS.
	US 68																			
39	674+75 6' RT.															1				DBI NO. 26 (h = 4.77')
	TOTALS	182	140	792	828	1173	233	8	11	4	5	4	1	14	2	7	2	74.22	5671	

① CORRUGATED IRON, STEEL OR ALUMINUM ALLOY PIPE FABRICATED WITH 5% VERTICAL ELONGATION.
② TOTALS FOR THESE ITEMS ARE CARRIED OVER AND INCLUDED IN THE GENERAL SUMMARY SHEET.

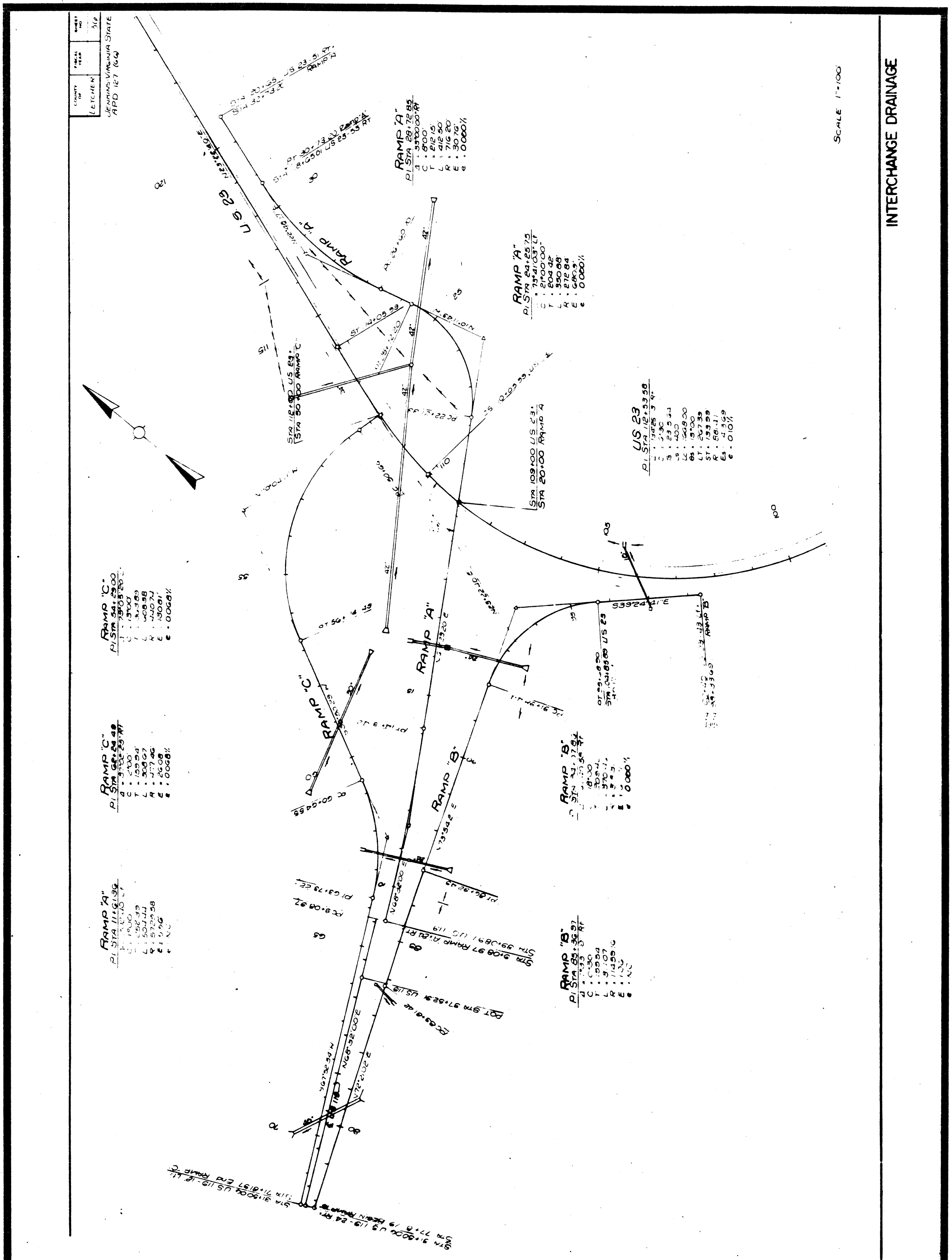
DRAINAGE S



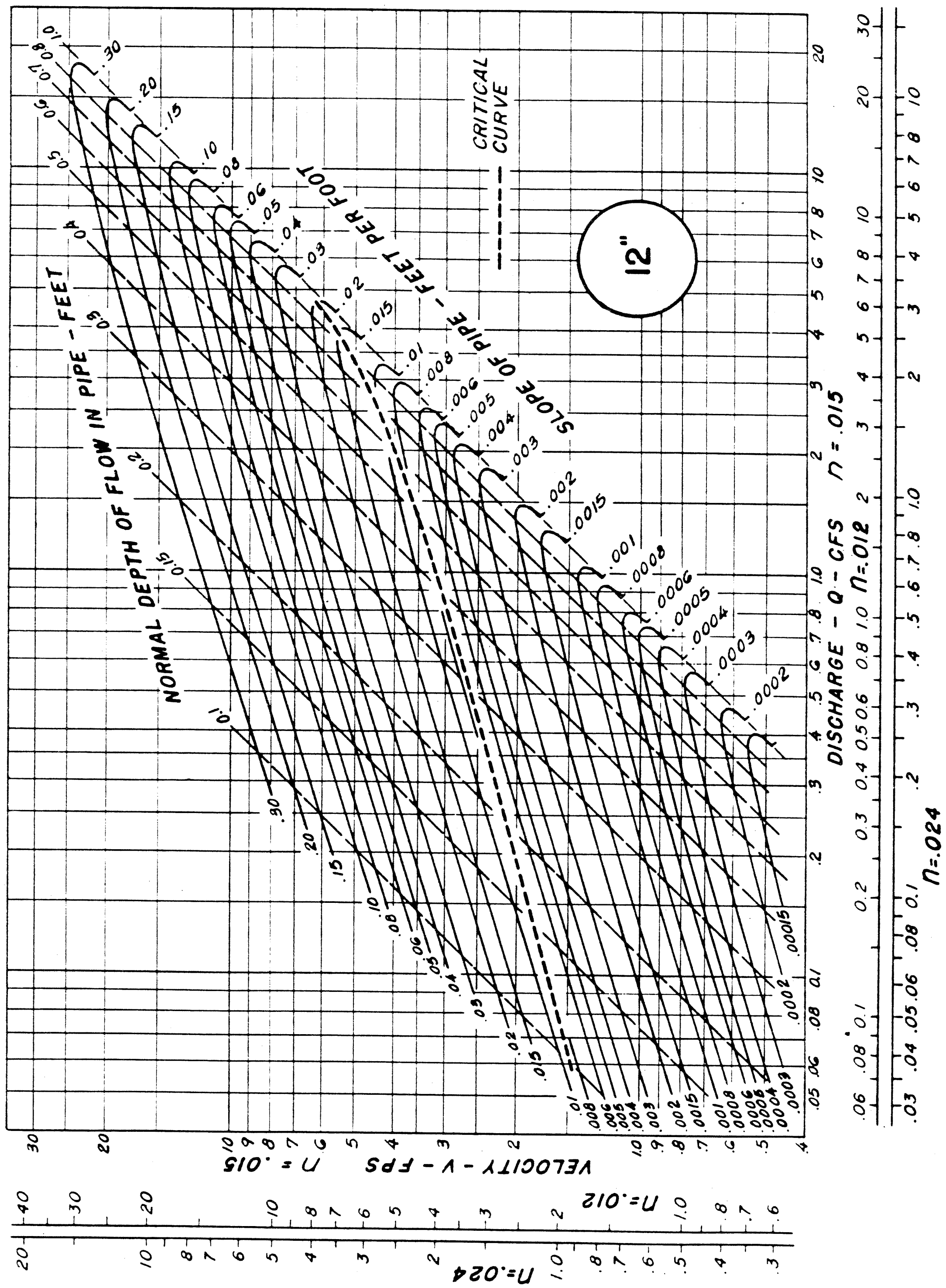
BLANKENBAKER PARKWAY
STA. 90+00 TO 96+00
Scale: 1" = 20'
MATCH LINE STA. 96+00
MATCH LINE STA. 90+00
PROP. ℄ BLANKENBAKER PARKWAY
KENTUCKY NATURE PRESERVES COMMISSION
SOUTHERN RAILROAD SYSTEM
JOHN E. KENNEDY
JEROME J. EISENBACK
MARY C. * (WF.)
M. C. BRUMLEY
ELENOR * (WF.)
REHL ROAD
P.I. STA. 48+48.35
P.T. STA. 49+50.00


714
712
710
708
706
704
702
700
PROPOSED GRADE
EXISTING GROUND
90+00
91+00
92+00
93+00
94+00
95+00
96+00

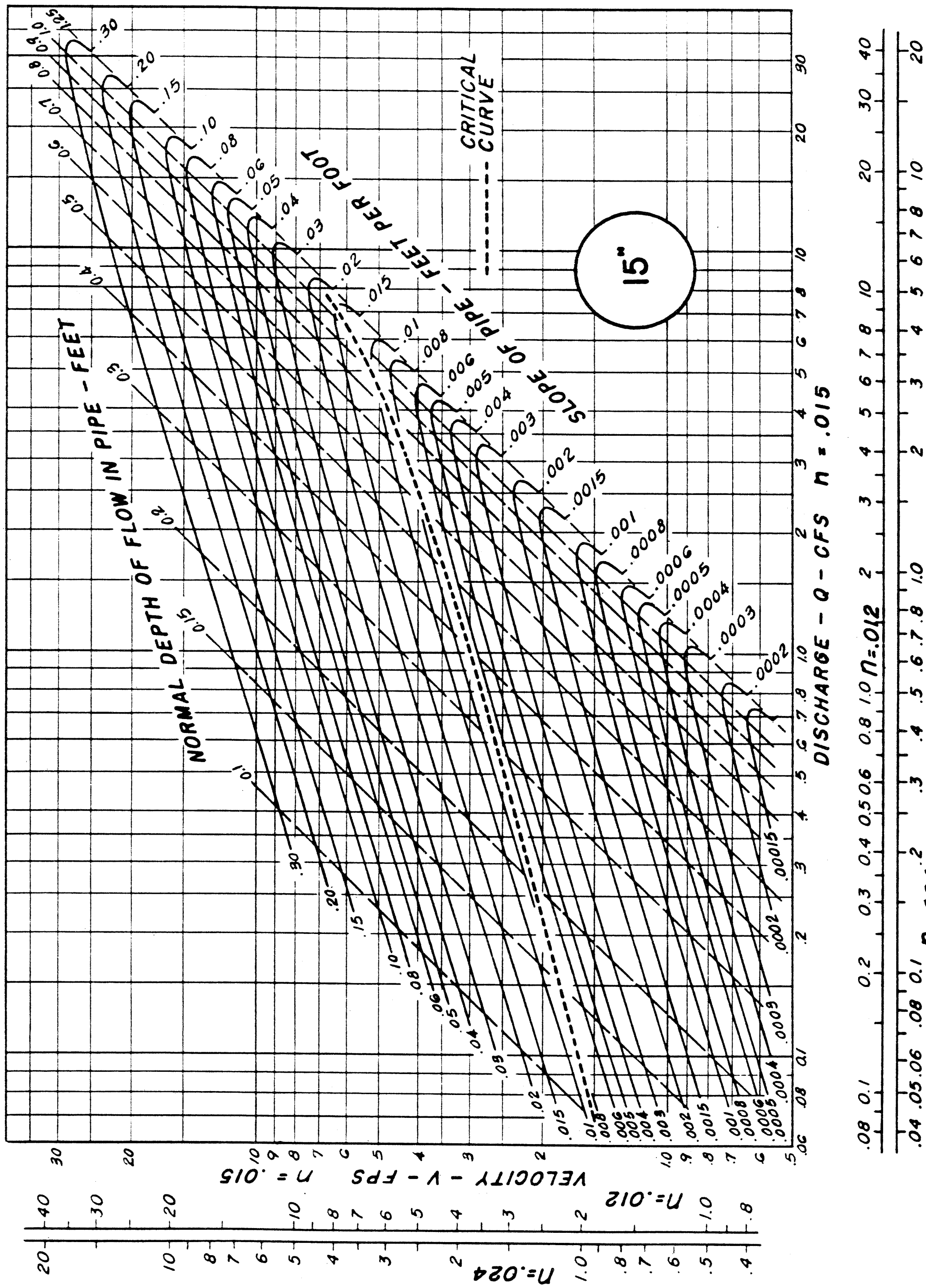
01-01-93	EXAMPLE PLAN LAYOUT	EXHIBIT DR-07.933



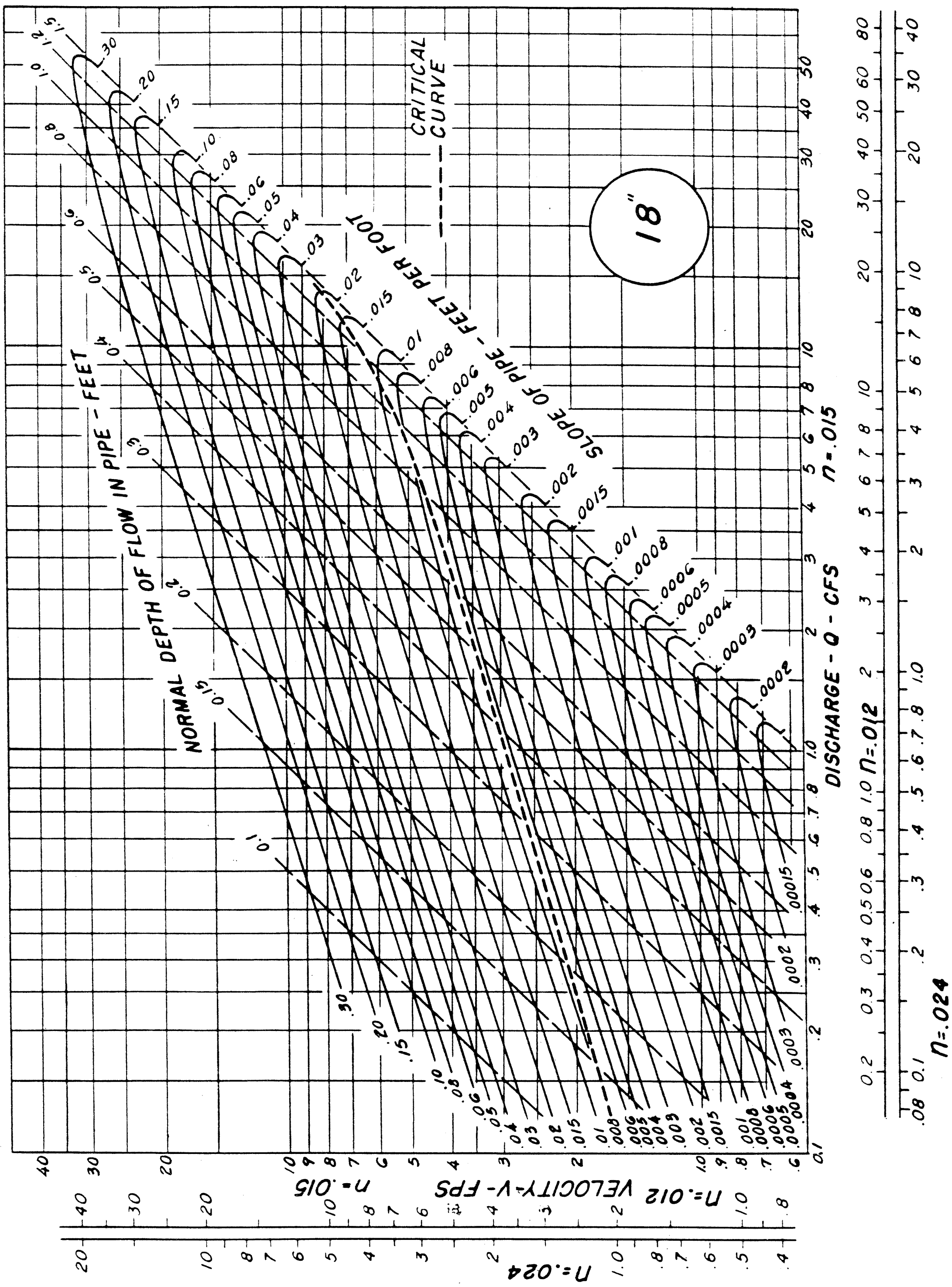
01-01-93	12" CIRCULAR PIPE FLOW CHART	EXHIBIT DR-07.940



01-01-93	15" CIRCULAR PIPE FLOW CHART	EXHIBIT DR-07.941

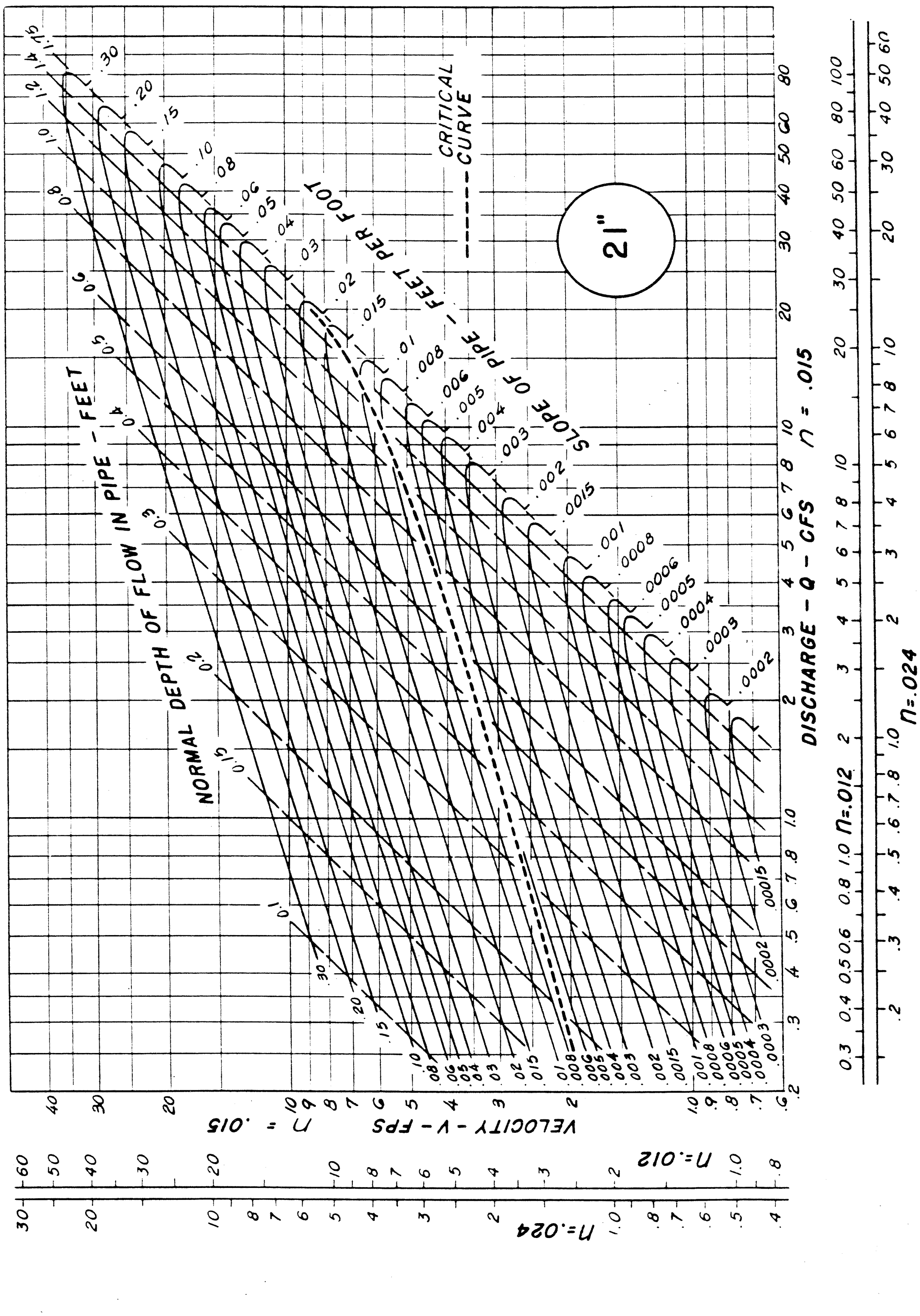


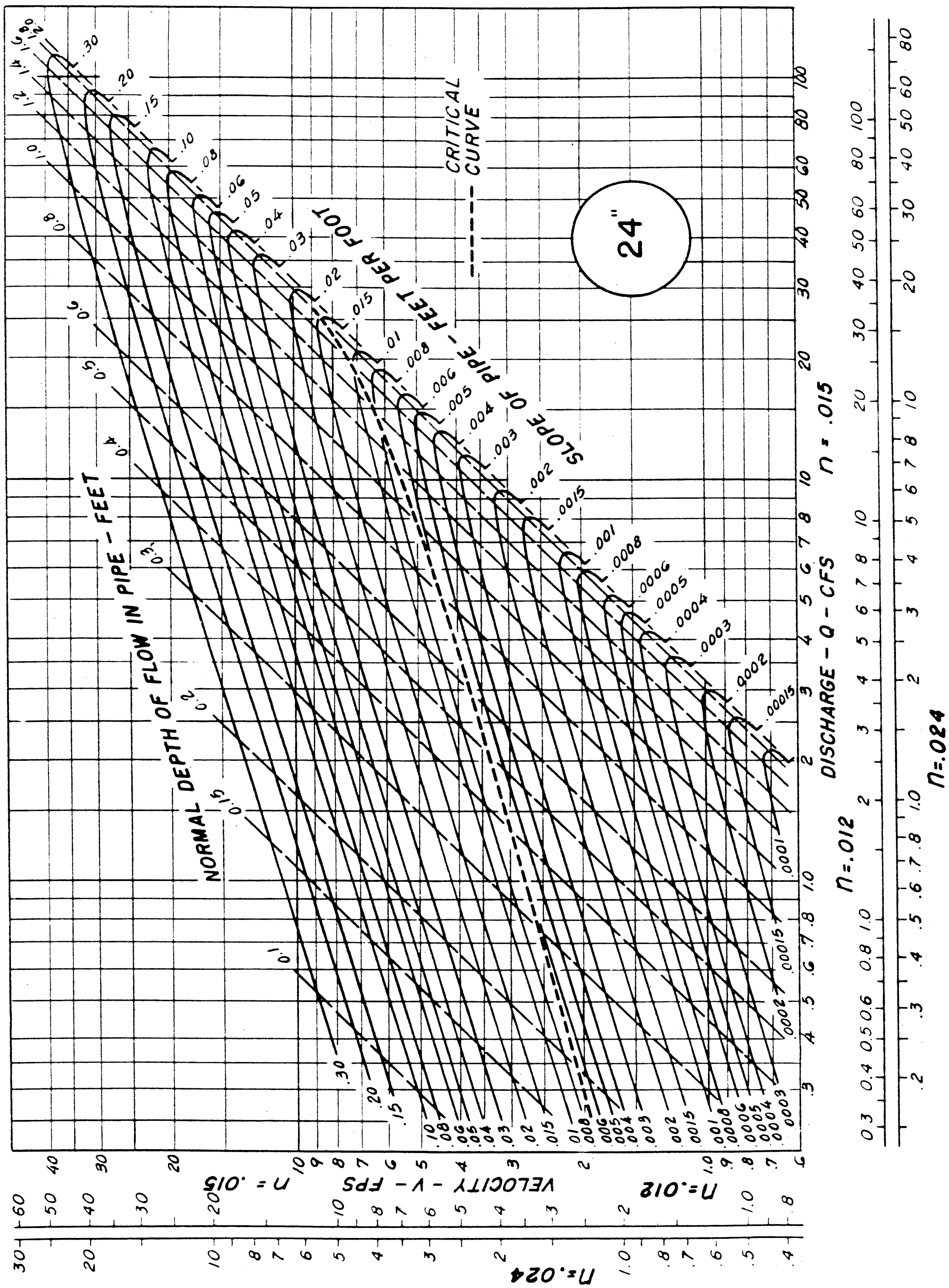
01-01-93	18" CIRCULAR PIPE FLOW CHART	EXHIBIT DR-07.942



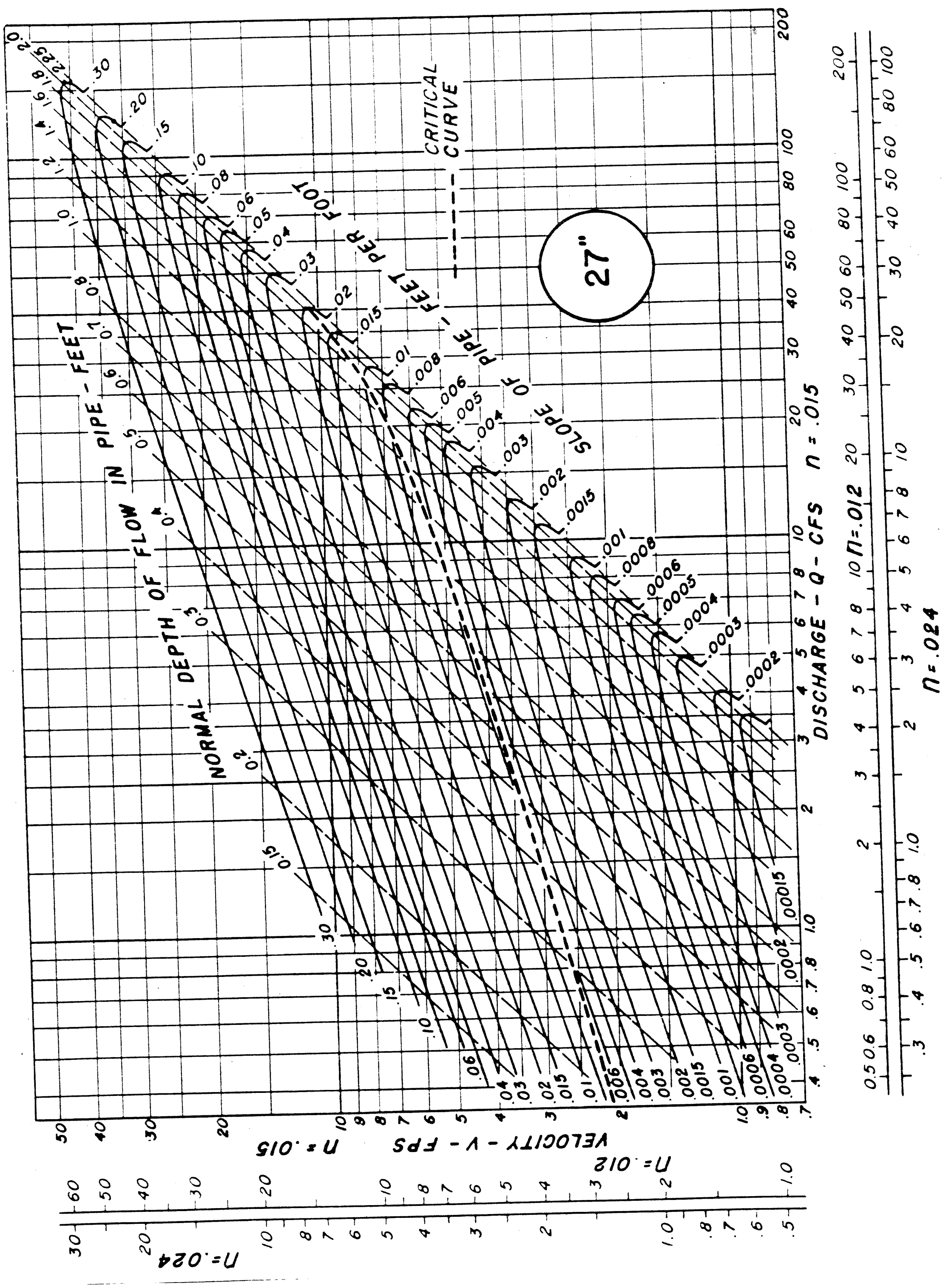
01-01-93 | 21" CIRCULAR PIPE FLOW CHART | EXHIBIT DR-07.943

21" CIRCULAR PIPE FLOW CHART

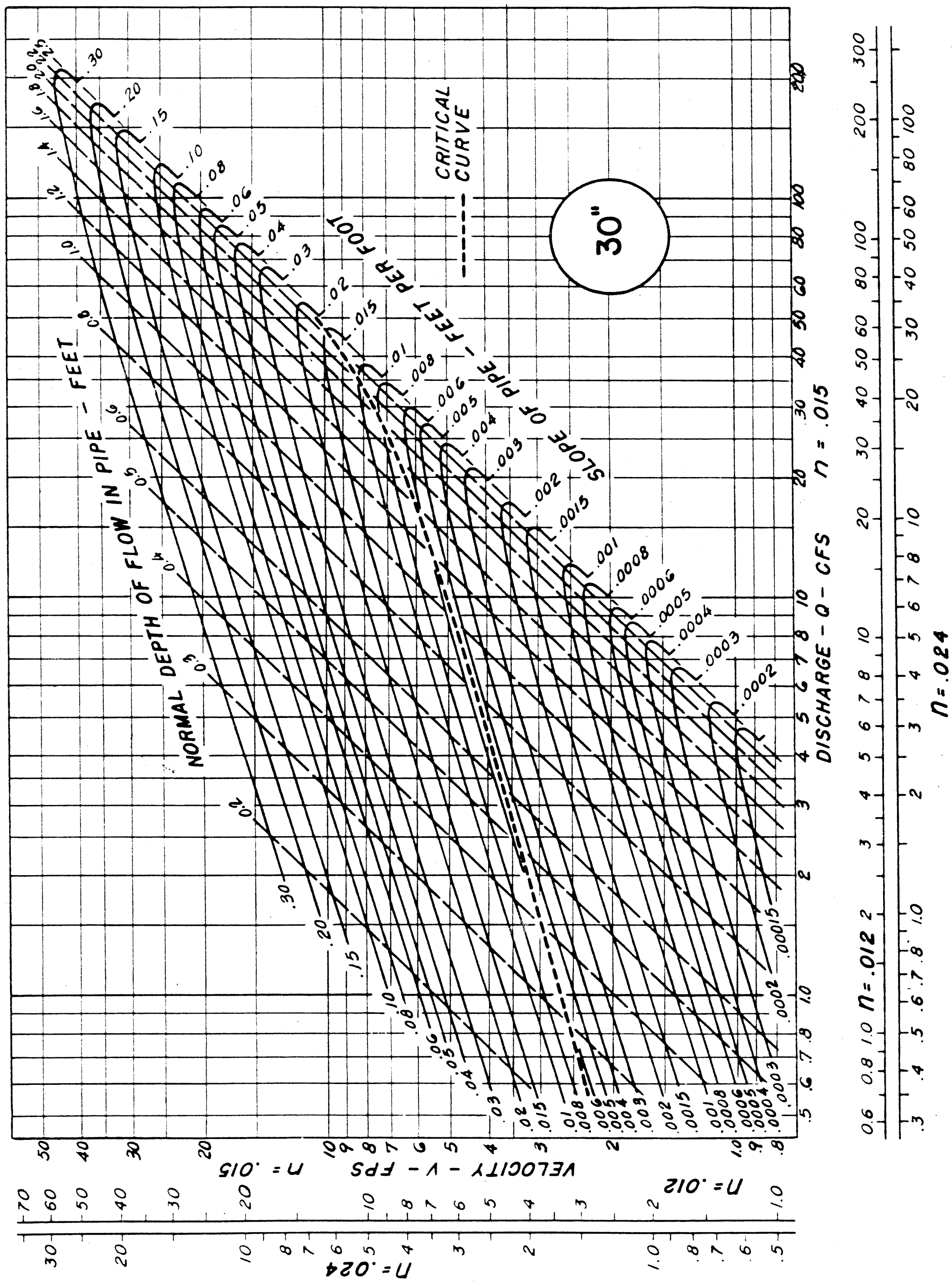


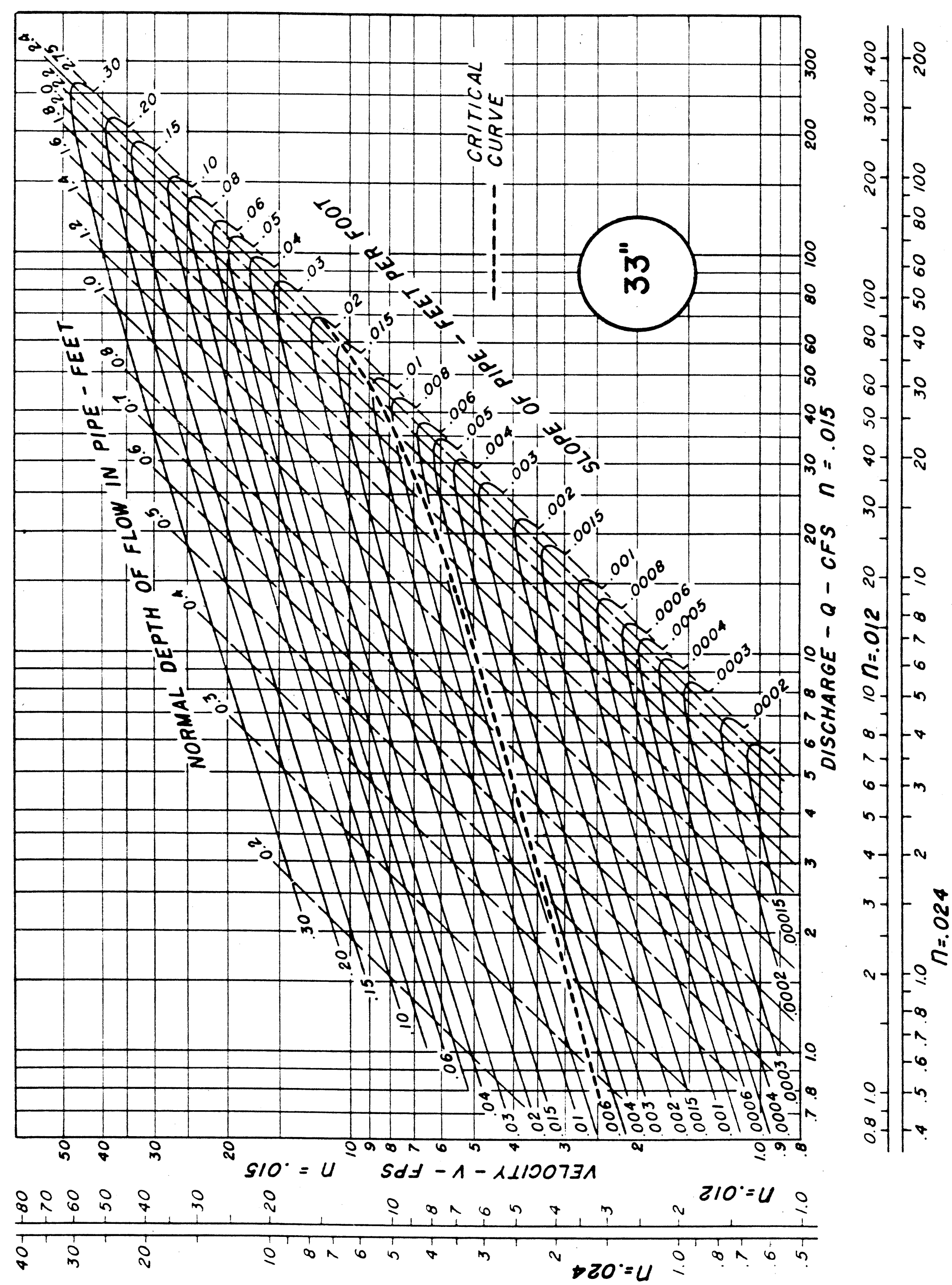

24"
CRITICAL CURVE
SLOPE OF PIPE - FEET PER FOOT
NORMAL DEPTH OF FLOW IN PIPE - FEET
DISCHARGE - Q - CFS
VELOCITY - V - FPS
n = .015
n=.012
n=.024

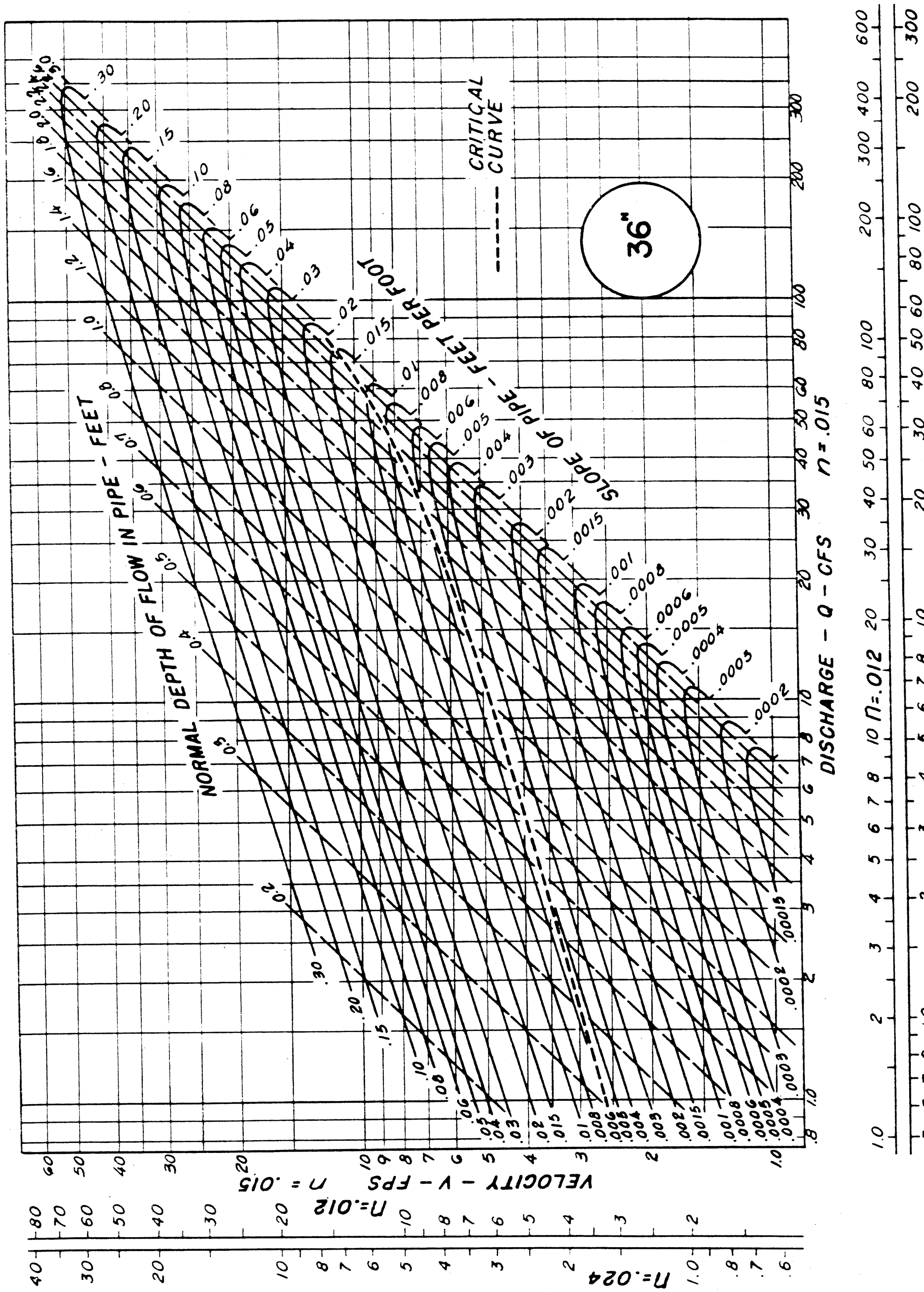
01-01-93	27" CIRCULAR PIPE FLOW CHART	EXHIBIT DR-07.945



01-01-93	30" CIRCULAR PIPE FLOW CHART	EXHIBIT DR-07.946

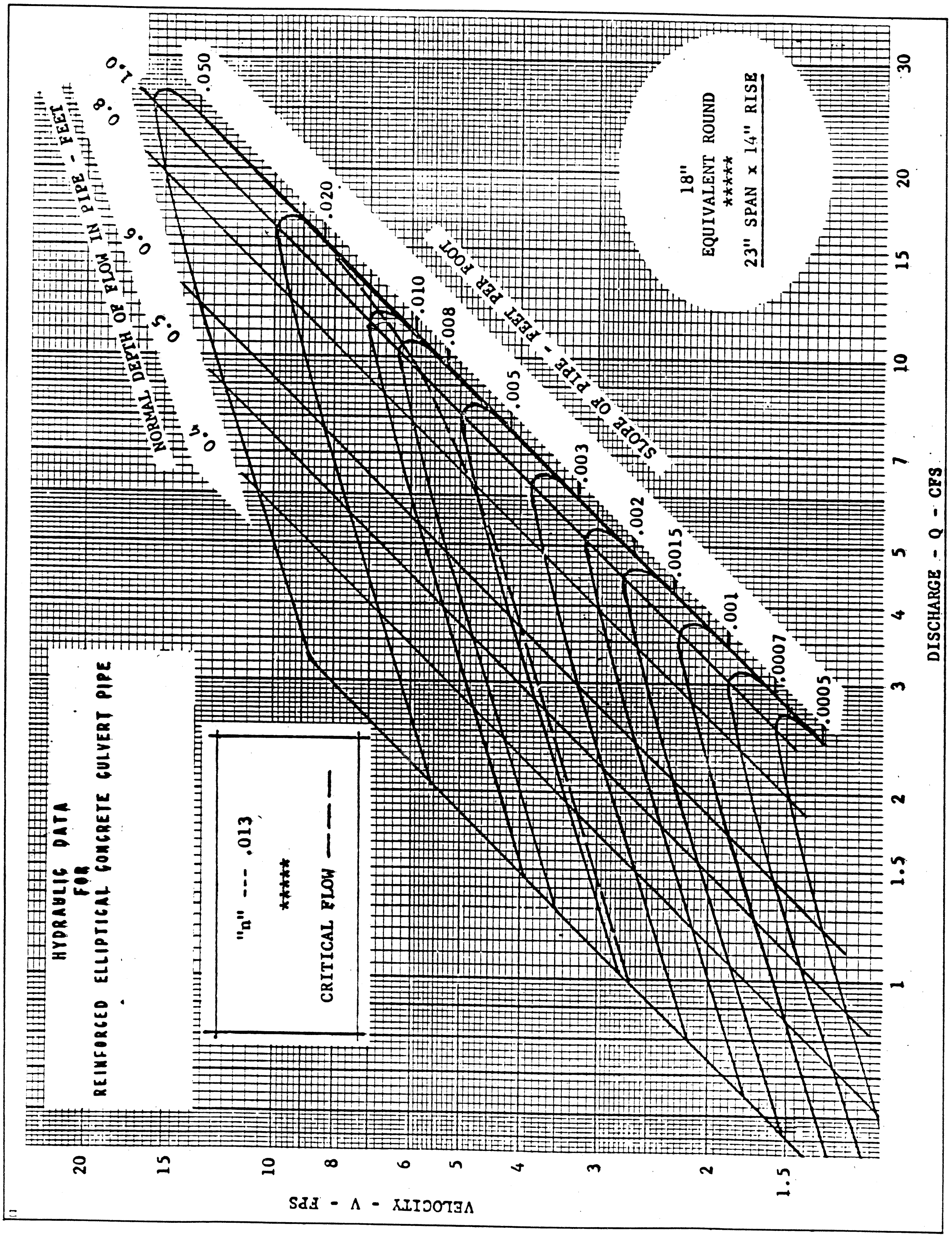



33"
CRITICAL CURVE
SLOPE OF PIPE - FEET PER FOOT
NORMAL DEPTH OF FLOW IN PIPE - FEET
DISCHARGE - Q - CFS n = .015
n=.012
n=.024
VELOCITY - V - FPS n = .015
n=.012
n=.024

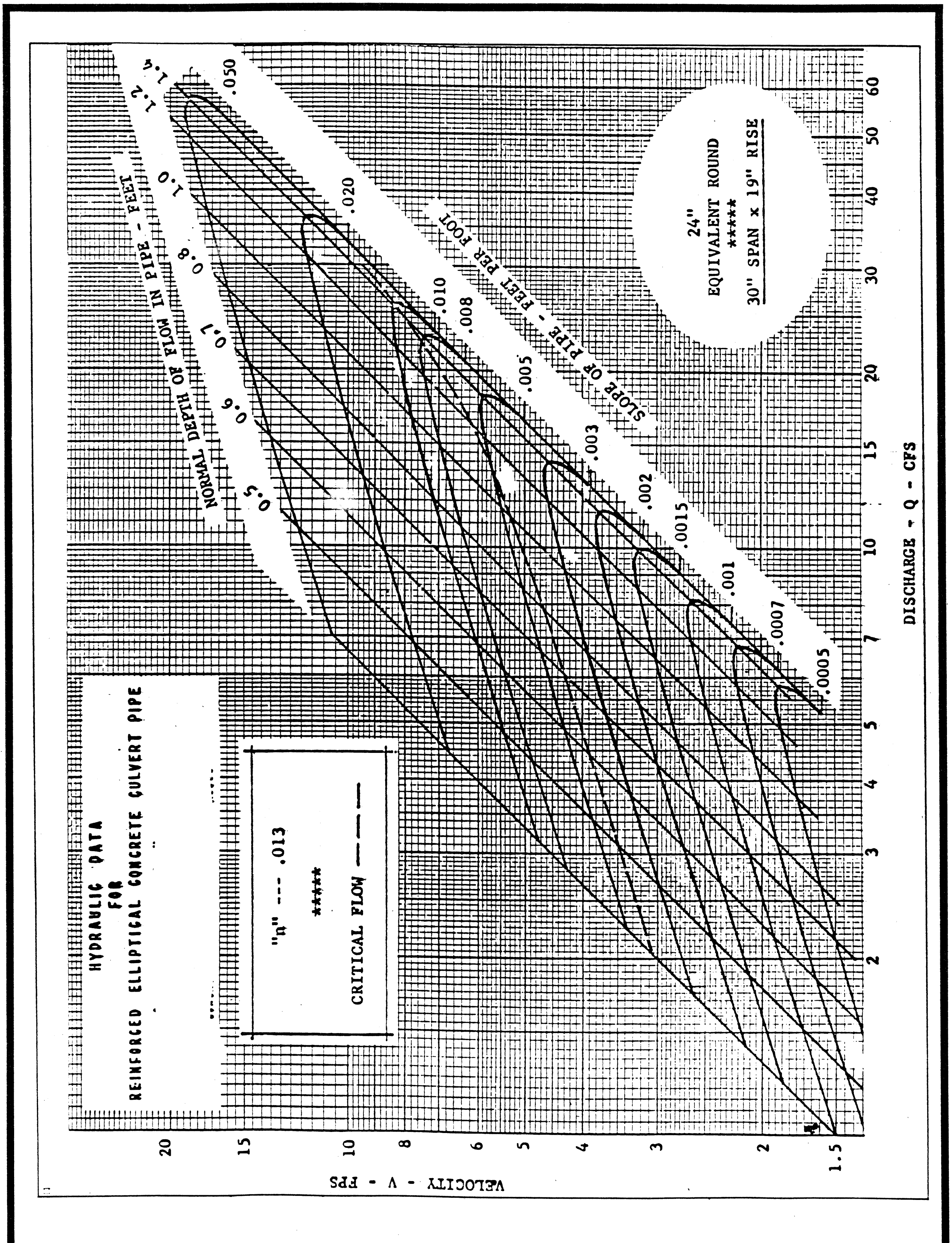


CRITICAL CURVE
36"
SLOPE OF PIPE - FEET PER FOOT
NORMAL DEPTH OF FLOW IN PIPE - FEET
DISCHARGE - Q - CFS
n = .015
n=.012
n=.024
VELOCITY - V - FPS
n = .015
n=.012
n=.024

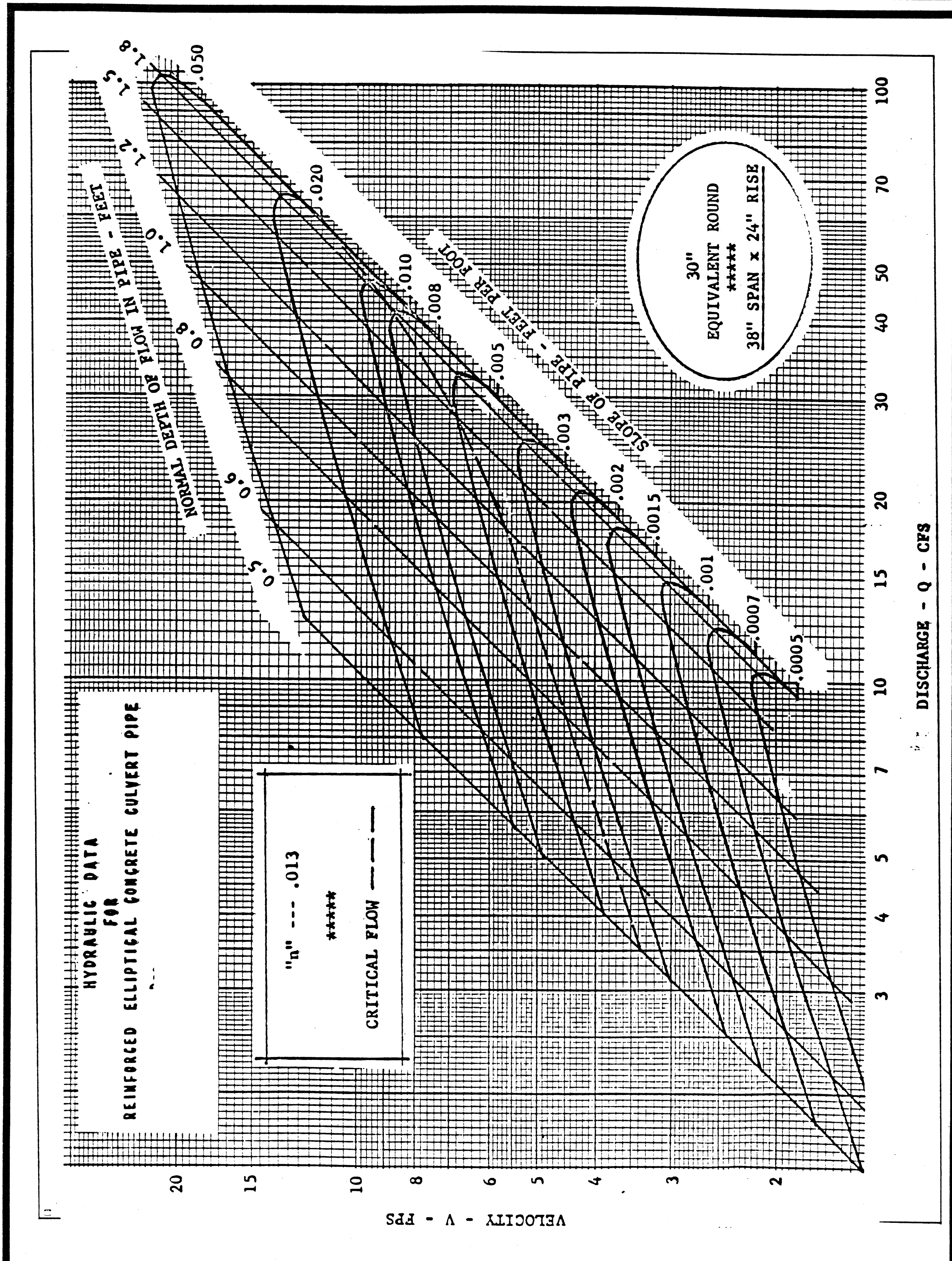
01-01-93	18" ELLIPTICAL PIPE FLOW CHART	EXHIBIT DR-07.949

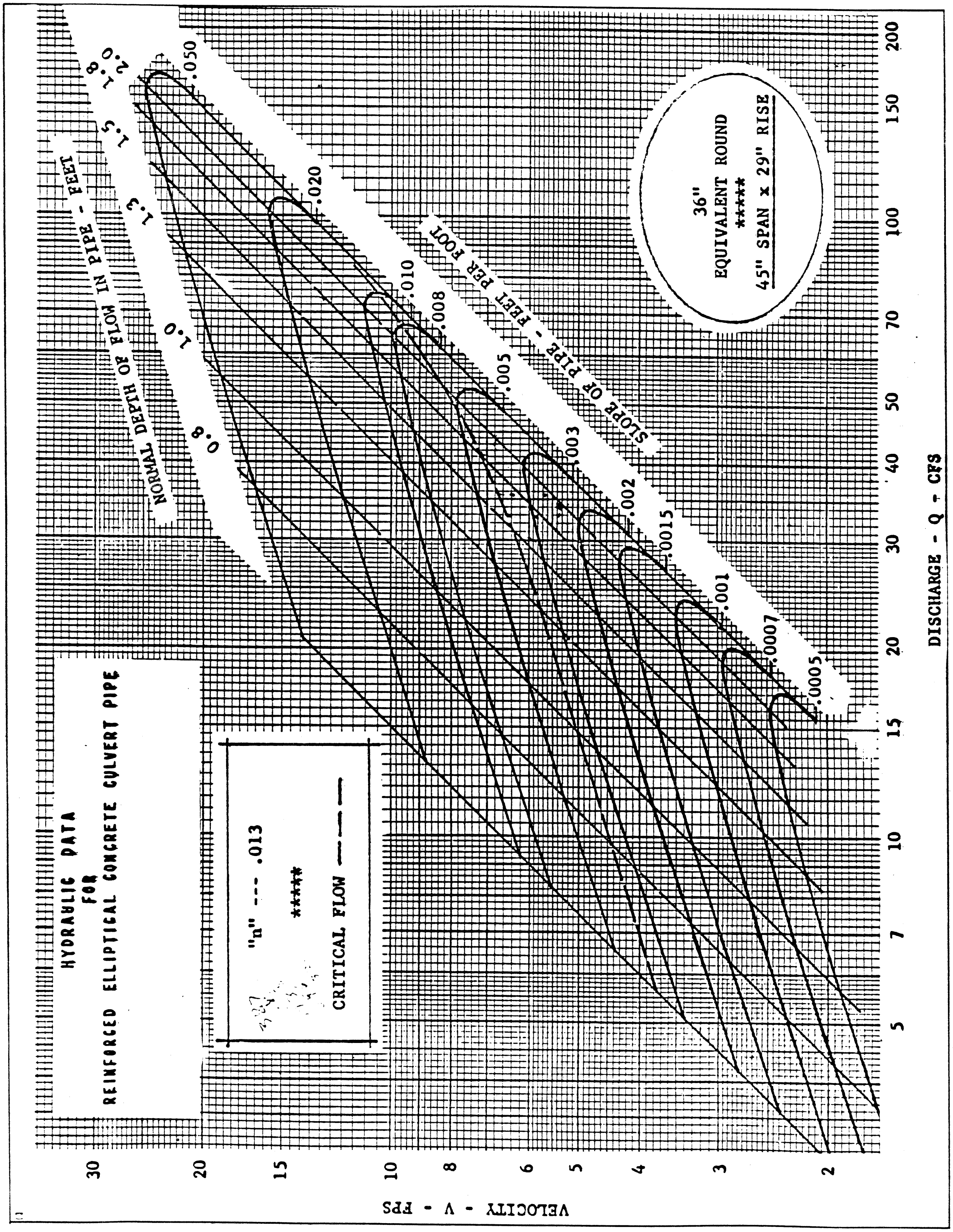


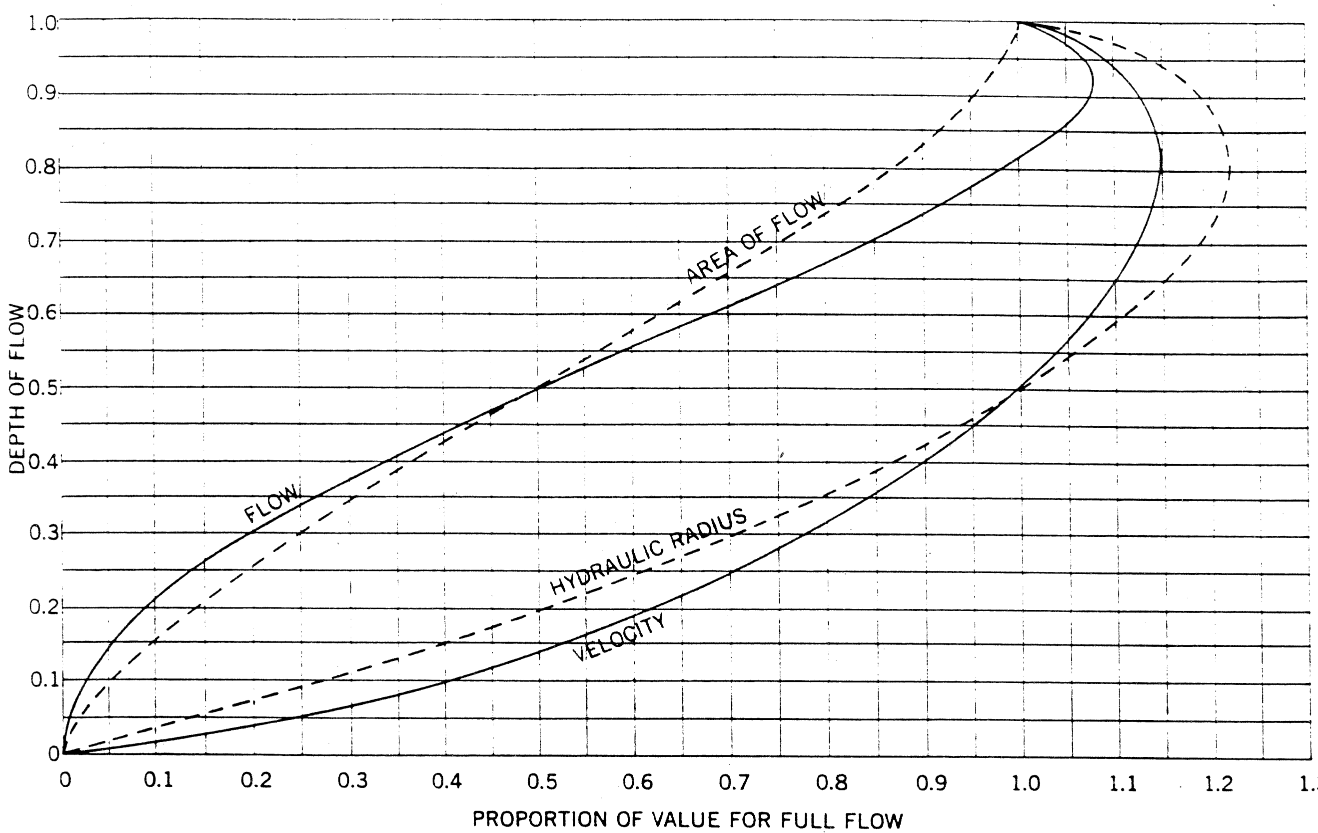
01-01-93	24" ELLIPTICAL PIPE FLOW CHART	EXHIBIT DR-07.950

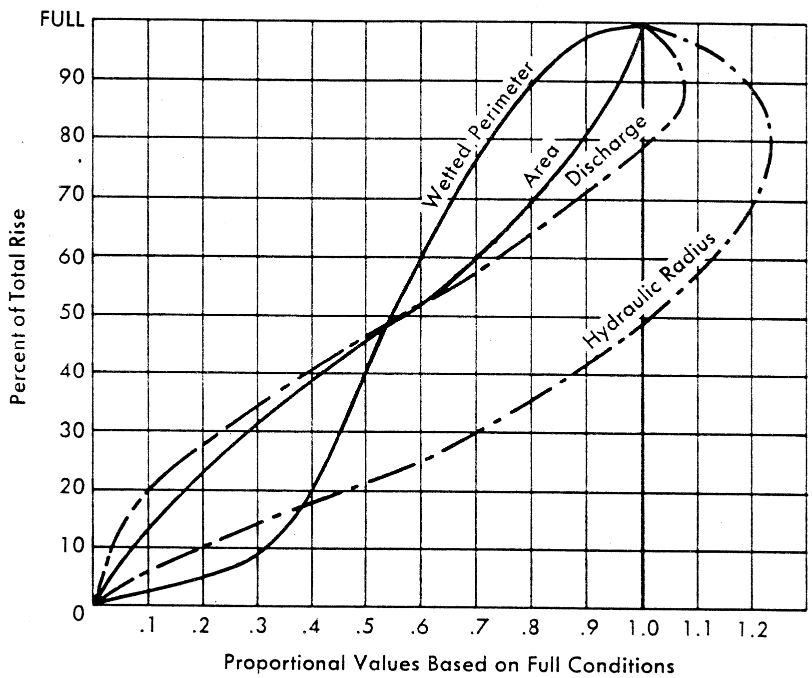


01-01-93	30" ELLIPTICAL PIPE FLOW CHART	EXHIBIT DR-07.951

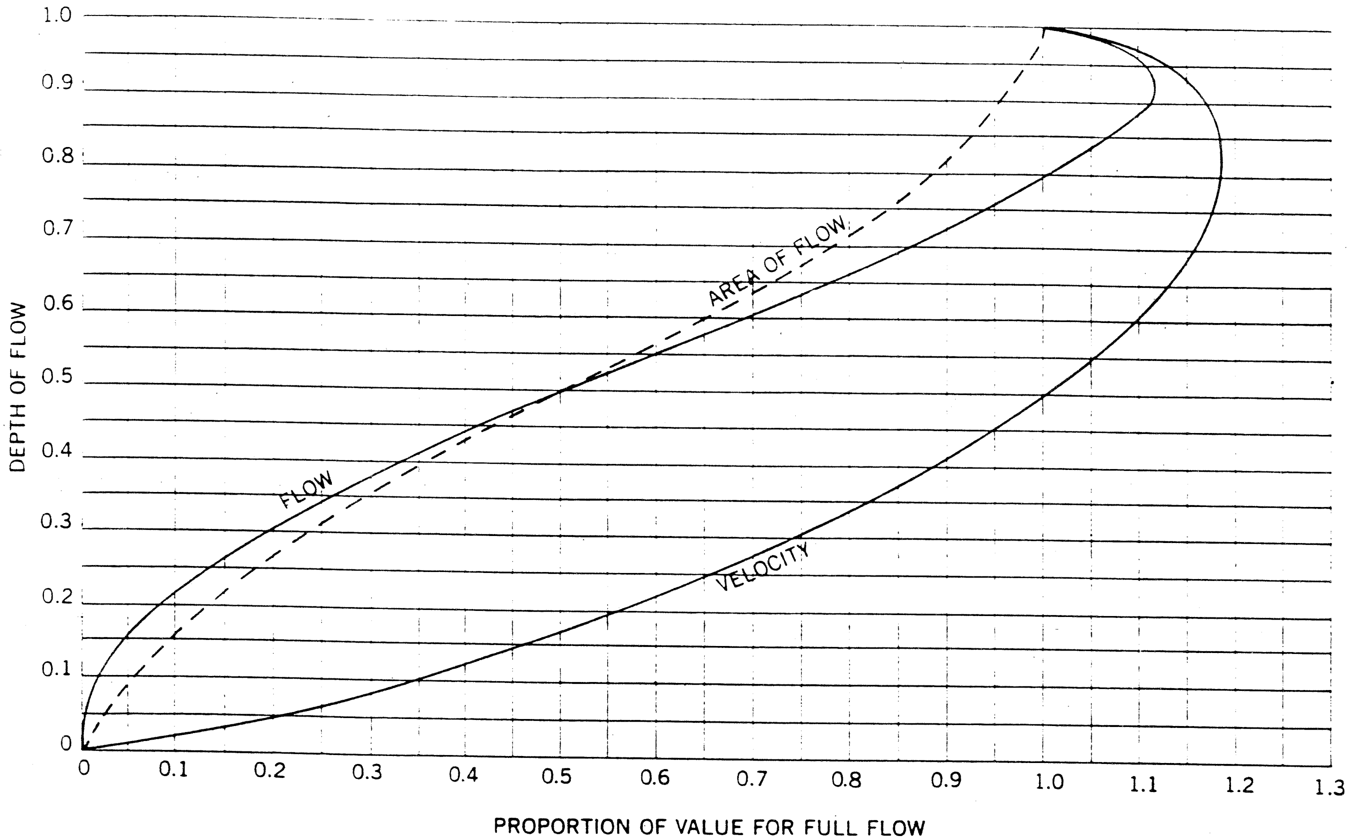



HYDRAULIC DATA
FOR
REINFORCED ELLIPTICAL CONCRETE CULVERT PIPE
"n" --- .013
*****
CRITICAL FLOW
36"
EQUIVALENT ROUND
*****
45" SPAN x 29" RISE
NORMAL DEPTH OF FLOW IN PIPE - FEET
0.8
1.0
1.3
1.5
1.8
2.0
SLOPE OF PIPE - FEET PER FOOT
.050
.020
.010
.008
.005
.003
.002
.0015
.001
.0007
.0005
DISCHARGE - Q - CFS
VELOCITY - V - FPS


DEPTH OF FLOW
PROPORTION OF VALUE FOR FULL FLOW
FLOW
AREA OF FLOW
HYDRAULIC RADIUS
VELOCITY
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3


FULL
90
80
70
60
50
40
30
20
10
0
Percent of Total Rise
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
Proportional Values Based on Full Conditions
Wetted Perimeter
Area
Discharge
Hydraulic Radius

01-01-93	PROPORTIONAL PARTS CHART - ELLIPTICAL PIPE	EXHIBIT DR-07.962



SIZE	INSIDE DIAMETER	AREA	PERIMETER	HYDRAULIC RADIUS (R)	$R^{4/3}$
Inches	Feet	Square Feet	Feet	Feet	
12	1.00	.79	3.14	0.250	0.158
15	1.25	1.23	3.93	0.312	0.212
18	1.50	1.77	4.71	0.375	0.270
20	1.67	2.18	5.25	0.415	0.310
21	1.75	2.41	5.50	0.438	0.332
24	2.00	3.14	6.28	0.500	0.397
27	2.25	3.97	7.07	0.563	0.465
30	2.50	4.91	7.85	0.625	0.534
33	2.75	5.94	8.63	0.688	0.607
36	3.00	7.07	9.43	0.750	0.681
42	3.5	9.62	11.00	0.875	0.837
48	4.0	12.57	12.57	1.000	1.000
54	4.5	15.90	14.14	1.125	1.170
60	5.0	19.64	15.71	1.25	1.347
66	5.5	23.76	17.28	1.38	1.536
72	6.0	28.27	18.85	1.50	1.717
78	6.5	33.18	20.42	1.63	1.918
84	7.0	38.49	21.99	1.75	2.109
90	7.5	44.18	23.56	1.88	2.320
96	8.0	50.27	25.13	2.00	2.520
102	8.5	56.75	26.70	2.12	2.723
108	9.0	63.62	28.27	2.25	2.948

EQUIV. CIRC. PIPE DIA.	SPAN	RISE	AREA	PERIMETER	HYDRAULIC RADIUS (R)	$R^{4/3}$
Inches	Inches	Inches	Square Feet	Feet	Feet	
15	17	13	1.1	3.93	0.280	0.183
18	21	15	1.6	4.71	0.339	0.236
24	28	20	2.8	6.28	0.446	0.341
30	35	24	4.4	7.85	0.560	0.462
36	42	29	6.4	9.43	0.679	0.597
42	49	33	8.7	11.00	0.792	0.733
48	57	38	11.4	12.57	0.908	0.879
54	64	43	14.3	14.14	1.011	1.014
60	71	47	17.6	15.71	1.120	1.163
66	77	52	21.3	17.28	1.233	1.322
72	83	57	25.3	18.85	1.342	1.480

EQUIV. CIRC. PIPE DIAMETER	SPAN	RISE	AREA	PERIMETER	HYDRAULIC RADIUS (R)	$R^{4/3}$
Inches	Inches	Inches	Square Feet	Feet	Feet	
18	23	14	1.84	5.01	.367	.263
24	30	19	3.27	6.67	.490	.386
27	34	22	4.08	-	-	-
30	38	24	5.11	8.34	.613	.521
33	42	27	6.19	-	-	-
36	45	29	7.37	10.01	.736	.665
39	49	32	8.80	-	-	-
42	53	34	10.21	11.76	.868	.828
48	60	38	12.91	13.23	.976	.968
54	68	43	16.59	15.00	1.106	1.144
60	76	48	20.49	16.67	1.229	1.316
66	83	53	24.78	18.33	1.352	1.495
72	91	58	29.50	20.00	1.475	1.679

EQUIV. CIRC. PIPE DIA.	SPAN	RISE	AREA	PERIMETER	HYDRAULIC RADIUS (R)	$R^{4/3}$
Inches	Feet-Inches	Feet-Inches	Square Feet	Feet	Feet	
66	6-1	4-7	22	17.28	1.273	1.380
-	6-4	4-9	24	18.06	1.329	1.462
72	6-9	4-11	26	18.85	1.379	1.535
-	*7-0	5-1	28	19.64	1.426	1.605
78	7-3	5-3	31	20.42	1.518	1.745
-	7-8	5-5	33	21.21	1.556	1.803
84	7-11	5-7	35	21.99	1.592	1.859
-	*8-2	5-9	38	22.78	1.668	1.978
90	8-7	5-11	40	23.56	1.698	2.026
-	8-10	6-1	43	24.34	1.767	2.136
96	9-4	6-3	46	25.13	1.830	2.238
-	9-6	6-5	49	25.92	1.890	2.337
102	9-9	6-7	52	26.70	1.948	2.433
-	10-3	6-9	55	27.48	2.001	2.522
108	10-8	6-11	58	28.27	2.052	2.607
-	10-11	7-1	61	29.05	2.100	2.689
114	*11-5	7-3	64	29.84	2.145	2.767
-	11-7	7-5	67	30.63	2.187	2.839
120	11-10	7-7	71	31.41	2.260	2.996
-	12-4	7-9	74	32.20	2.298	3.032
126	12-6	7-11	78	32.98	2.365	3.151
-	12-8	8-1	81	33.77	2.399	3.211
132	*12-10	8-4	85	34.55	2.460	3.321
-	13-5	8-5	89	35.34	2.518	3.425
138	13-11	8-7	93	36.12	2.575	3.530
-	14-1	8-9	97	36.91	2.629	3.628
144	14-3	8-11	101	37.69	2.680	3.723
-	14-10	9-1	105	38.48	2.729	3.813
150	*15-4	9-3	109	39.26	2.776	3.901
-	15-6	9-5	113	40.05	2.821	3.986
156	15-8	9-7	118	40.83	2.890	4.117
-	15-10	9-10	122	41.62	2.931	4.195
162	16-5	9-11	126	42.40	2.972	4.273
-	*16-7	10-1	131	43.19	3.003	4.391

* Most economical size for a given number of plates per ring.