Basic Hydraulics

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June 2007

Overview

- Open Channel Flow
- Manning Equation
- Basic Culvert Design
- Sanitary Sewer
  - Design Flow, Velocity
- Stormwater Sewer
  - Design Flow, Velocity

Open Channel Flow

Fluid passage way that allows part of the fluid to be exposed to the atmosphere

- **Natural Waterways**
- **Canals**
- **Flumes**
- ***Culverts***
- ***Pipes flowing under the influence of gravity (pressure conduits always flow full.)***

Open Channel Flow

Difficulties with Open Channel Flow

- Variations in cross sections and roughness
- More empirical & less exact than pressure conduit flow
- Run-off calculations also imprecise

Parameters Used in Open Channel Flow

- Q = Flow Quantity/Volume
- *A* = Cross-sectional Area of Flow
- *v* = Velocity (mean velocity)
- R = Hydraulic Radius
- P = Wetted Perimeter
- S = Slope
- *n* = Manning Roughness Coefficient

Mean Velocity

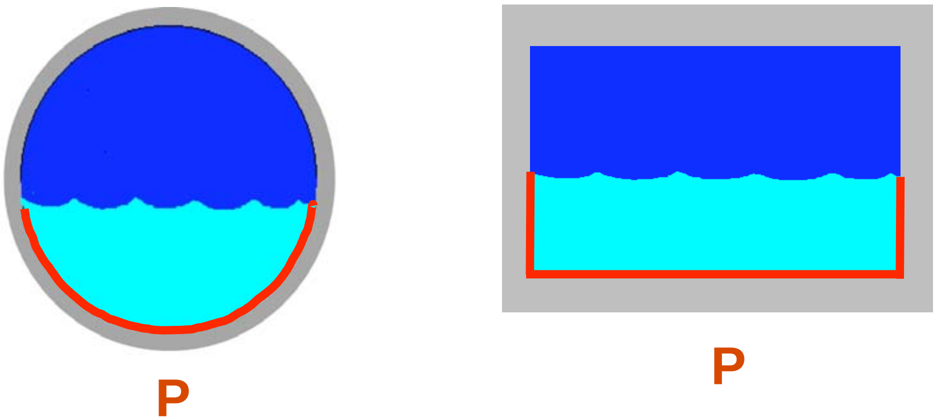
- **Mean velocity (*v*) multiplied by flow area (A) gives flow quantity (Q).**

$$Q = Av$$

Hydraulic Radius

The ratio of the area in flow to the wetted perimeter.

$$R = \frac{A}{P}$$



Hydraulic Radius

- **For a circular pipe flowing full or half full:**

$$R = \frac{D}{4}$$

Governing Equations

- **Continuity Equation**

$$A_1 v_1 = A_2 v_2$$

- **Chezy Equation - 1768**

$$v = C\sqrt{RS} \qquad C = \sqrt{\frac{8g}{f}}$$

- **Manning Equation – 1888**

$$C = \left(\frac{1.49}{n}\right) R^{\frac{1}{6}}$$

Governing Equations

- **Continuity Equation**

$$A_1 v_1 = A_2 v_2$$

- **Chezy Equation - 1768**

$$v = C\sqrt{RS} \qquad C = \sqrt{\frac{8g}{f}}$$

- **Manning Equation – 1888**

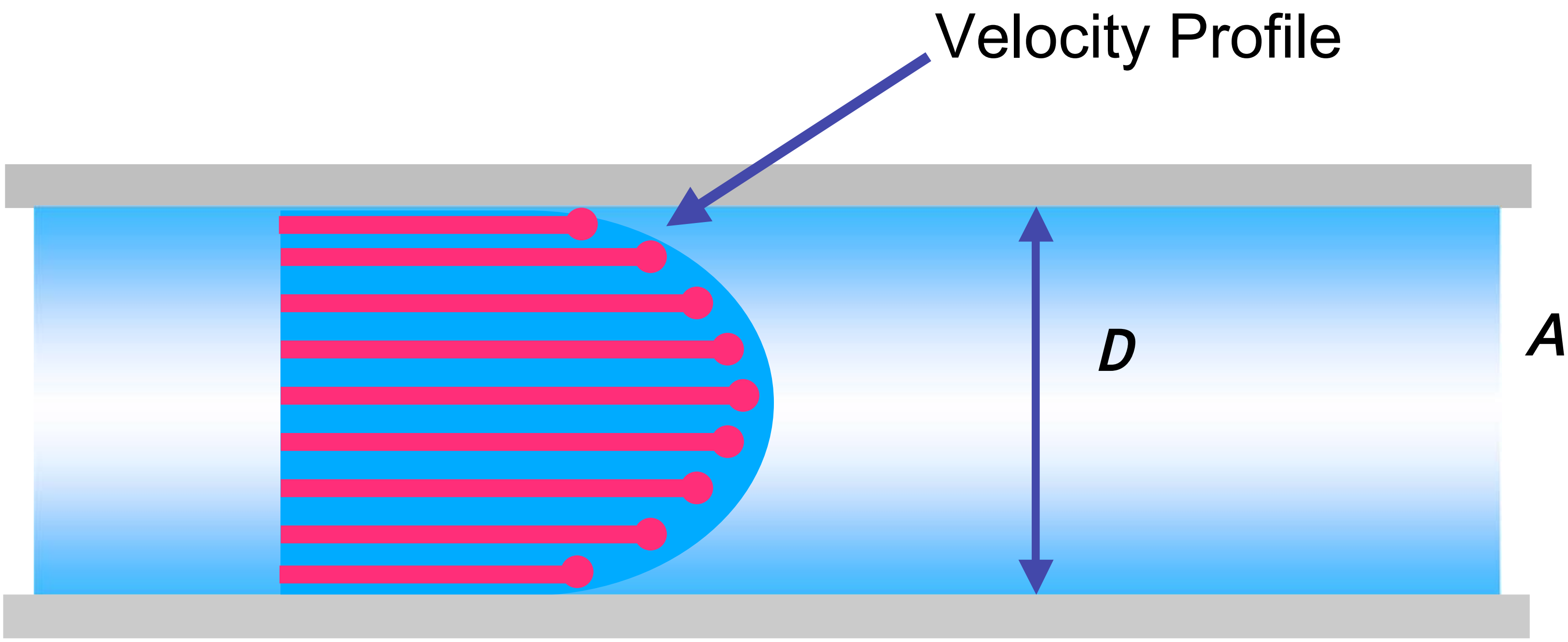
$$C = \left(\frac{1.49}{n}\right) R^{\frac{1}{6}}$$

The Manning Equation

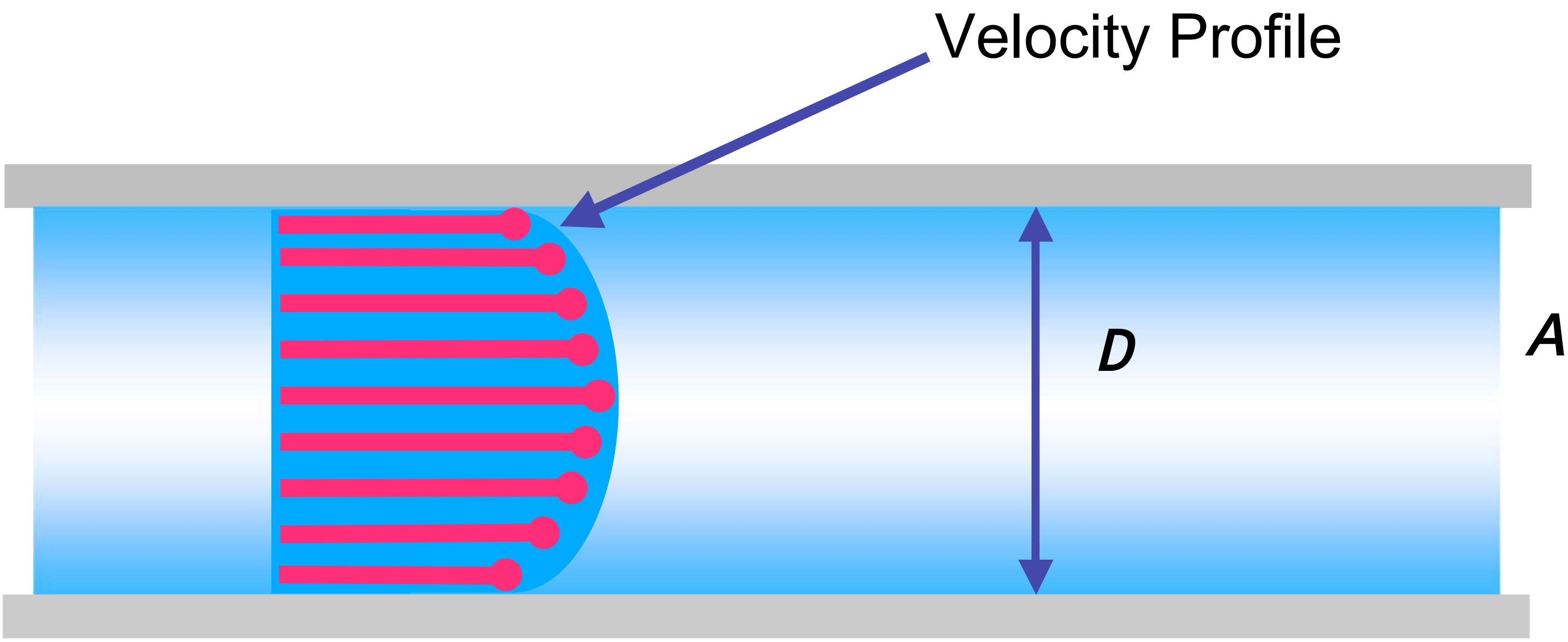
$$Q = vA = \left(\frac{1.49}{n}\right) A\, R^{\frac{2}{3}} \sqrt{S}$$

$$v = \left(\frac{1.49}{n}\right) R^{\frac{2}{3}} \sqrt{S}$$

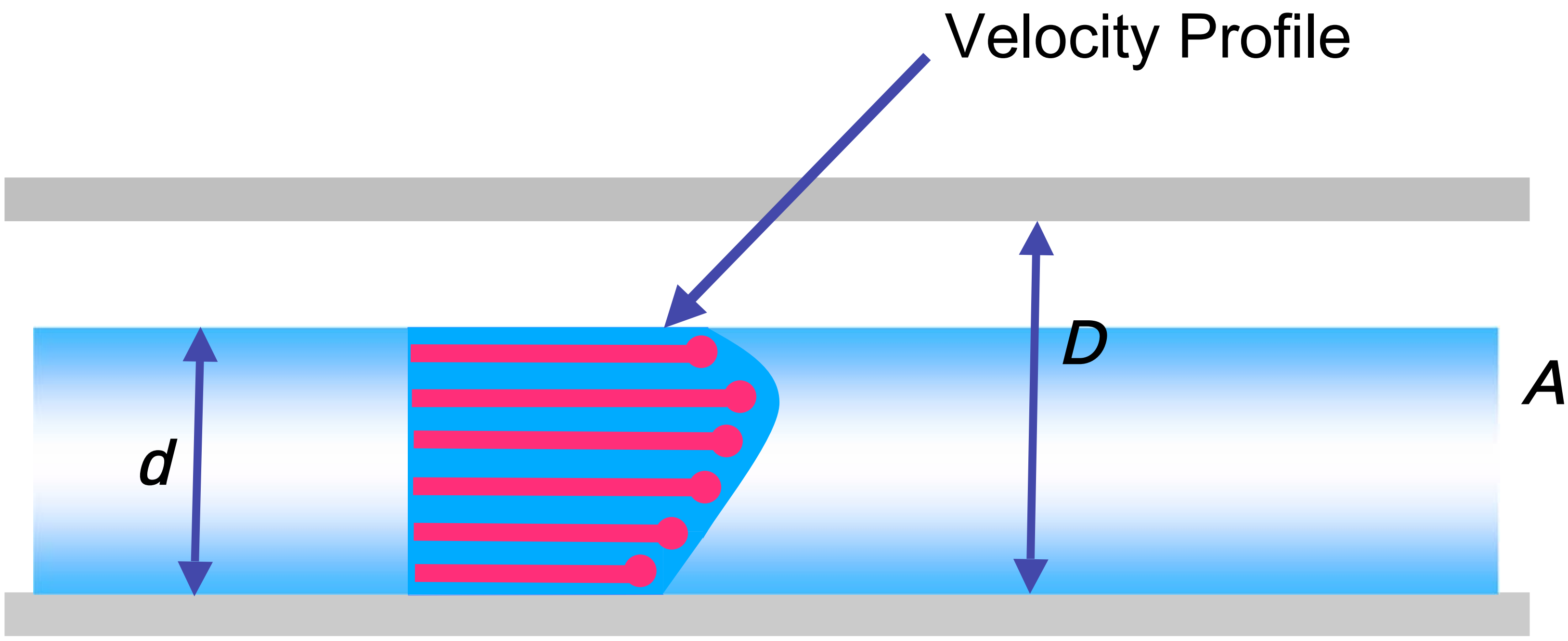
Velocity Profile Full Pipe
Laminar Flow



Velocity Profile Full Pipe Turbulent Flow



Velocity Profile “Open Channel”



Manning Coefficient (*n*)

- **Judgment is used in selecting *n* values.** Additional Design Data – click here
- ***n* varies with depth of flow**
- **For most calculations *n* is assumed to be constant.**
- **To consider variable *n* - use tables or graphs for *n*.**

Additional Info in the Concrete Design Manual - click here

Manning Equation
Manning Coefficient (*n*)

Circular Channel Ratios

$\frac{d}{D}$	$\frac{Q}{Q_{full}}$	$\frac{v}{v_{full}}$
0.1	0.02	0.31
0.2	0.07	0.48
0.3	0.14	0.61
0.4	0.26	0.71
0.5	0.41	0.80
0.6	0.56	0.88
0.7	0.72	0.95
0.8	0.87	1.01
0.9	0.99	1.04
0.95	1.02	1.03
1.00	1.00	1.00

Manning Coefficient (*n*)

- **For smooth wall pipes (concrete, plastic) laboratory tests have shown that "*n*" range between 0.009 and 0.010.**
- **Engineers typically use 0.012 or 0.013 to account for differences between laboratory and installed conditions.**

Manning Coefficient (*n*)

- **Recommended *n* values:**

0.012 for storm sewer applications

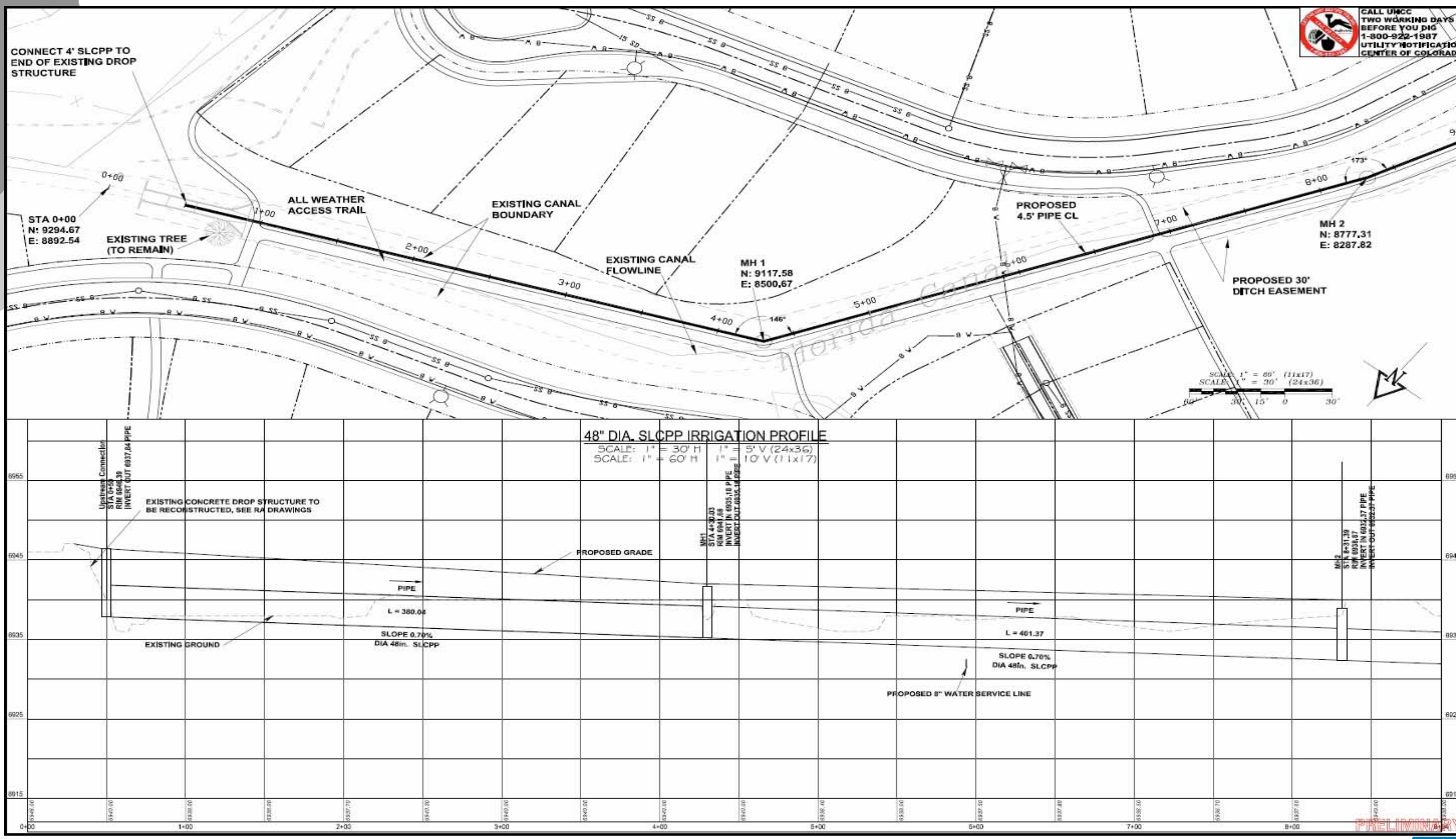
0.013 for sanitary sewers applications

Hazen-Williams 1920s

$$v = 1.318 \cdot CR^{0.63} S^{0.54}$$

- **Water flows with high Reynolds Number.**
- **Occasionally used – fire, irrigation & water distribution systems.**
- **Only for water within "normal" ambient conditions.**
- **Primarily Advantage: C depends only on the roughness, not the fluid characteristics.**
- **Primarily Disadvantage: C depends only on the roughness, not the fluid characteristics – professional judgment required when choosing C.**

Examples



CONNECT 4' SLCPP TO END OF EXISTING DROP STRUCTURE
STA 0+00
N: 9294.67
E: 8892.54
EXISTING TREE (TO REMAIN)
ALL WEATHER ACCESS TRAIL
EXISTING CANAL BOUNDARY
EXISTING CANAL FLOWLINE
MH 1
N: 9117.58
E: 8500.67
PROPOSED 4.5' PIPE CL
MH 2
N: 8777.31
E: 8287.82
PROPOSED 30' DITCH EASEMENT
CALL UNCC TWO WORKING DAYS BEFORE YOU DIG 1-800-922-1987 UTILITY NOTIFICATION CENTER OF COLORADO
Florida Canal
48" DIA. SLCPP IRRIGATION PROFILE
SCALE: 1" = 30' H 1" = 5' V (24x36)
SCALE: 1" = 60' H 1" = 10' V (11x17)
EXISTING CONCRETE DROP STRUCTURE TO BE RECONSTRUCTED, SEE RA DRAWINGS
PROPOSED GRADE
PIPE
L = 380.04
SLOPE 0.70%
DIA 48in. SLCPP
EXISTING GROUND
PIPE
L = 401.37
SLOPE 0.70%
DIA 48in. SLCPP
PROPOSED 8" WATER SERVICE LINE
PRELIMINARY

Manning Equation, Ex.1

Example No. 1

48-inch Diameter RCP

pipe invert out = 6932.37 ft

pipe invert in = 6937.84 ft

length = 781.41 ft

Use n = 0.012

Find Q_{full}

Manning Equation, Ex.1

$$Q_{full} = \left(\frac{1.49}{n}\right) A\, R^{\frac{2}{3}} \sqrt{S}$$

- **n=0.012**
- **48” Dia = 12.57 ft²**

Manning Equation, Ex.1

- **For a circular pipe flowing full or half full:**

$$R = \frac{D}{4}$$

$$R = \frac{4\text{ ft.}}{4} = 1.0\text{ ft.}$$

Manning Equation, Ex.1

- **Calculate S**

$$\frac{rise}{run} \rightarrow \frac{(6937.84 - 6932.37)}{781.41}$$

$$S = 0.007$$

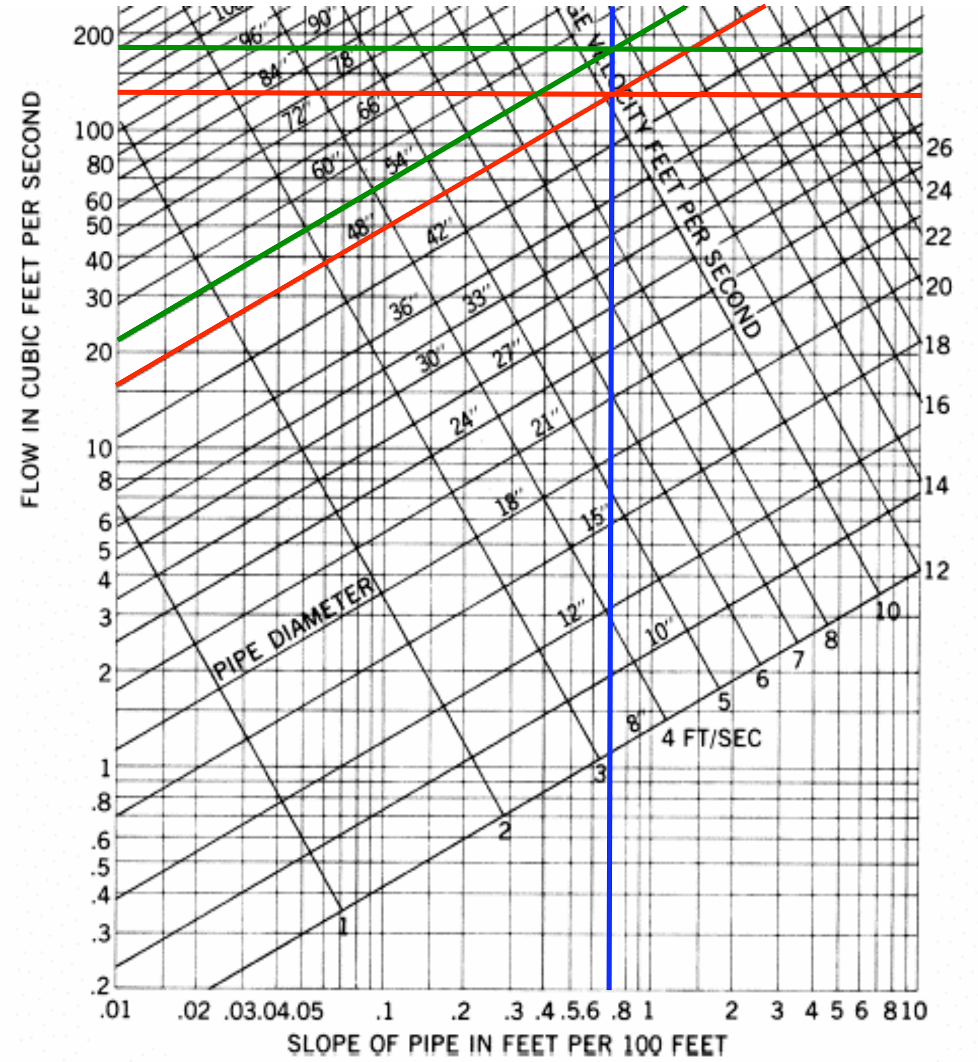
Manning Equation, Ex.1

- **Result:**

$$Q_{full} = \left(\frac{1.49}{0.012} \right) \cdot (12.57) \cdot (1.0)^{\frac{2}{3}} \cdot \left(\sqrt{0.007} \right)$$

$$= 130.6 \text{ cfs}$$

Flow for Circular Pipe Flowing Full Based on Manning's Equation n=0.012



Manning Equation, Ex.2

Using a 54-inch pipe for the 150 cfs flow what is the depth of flow and velocity?

Manning Equation, Ex.2

Example No. 2

54-inch Diameter RCP

length = 781.41 ft

$n = 0.012$

$S = 0.007$

$R = (4.5/4) = 1.13$ ft

$A = 15.90\ ft^2$

Find Q_{full}

Manning Equation, Ex.2

$$Q_{full} = \left(\frac{1.49}{n}\right) A\, R^{\frac{2}{3}} \sqrt{S}$$

$$Q_{\mathrm{full}} = \left(\frac{1.49}{0.012}\right) \cdot (15.90) \cdot (1.13)^{\frac{2}{3}} \cdot \left(\sqrt{0.007}\right)$$

$$= 179.2\ \mathrm{cfs}$$

Manning Equation, Ex.2

Circular Channel Ratios

$\frac{d}{D}$	$\frac{Q}{Q_{full}}$	$\frac{v}{v_{full}}$
0.1	0.02	0.31
0.2	0.07	0.48
0.3	0.14	0.61
0.4	0.26	0.71
0.5	0.41	0.80
0.6	0.56	0.88
0.7	0.72	0.95
0.8	0.87	1.01
0.9	0.99	1.04
0.95	1.02	1.03
1.00	1.00	1.00

Manning Equation, Ex.2

Find the depth of flow in the pipe

$$\frac{d}{D} = \frac{d}{4.5\,\text{ft.}}$$

$$\frac{Q}{Q_{\text{full}}} = \frac{150.0\,\text{cfs}}{179.2\,\text{cfs}} = 0.84$$

Manning Equation, Ex.2

Circular Channel Ratios

$\frac{d}{D}$	$\frac{Q}{Q_{full}}$	$\frac{v}{v_{full}}$
0.1	0.02	0.31
0.2	0.07	0.48
0.3	0.14	0.61
0.4	0.26	0.71
0.5	0.41	0.80
0.6	0.56	0.88
0.7	0.72	0.95
0.8	0.87	1.01
0.9	0.99	1.04
0.95	1.02	1.03
1.00	1.00	1.00

Manning Equation, Ex.2

$$\frac{y - y_0}{y_1 - y_0} = \frac{x - x_0}{x_1 - x_0}$$

$$\frac{\left(\frac{d}{D}\right) - 0.7}{0.8 - 0.7} = \frac{0.84 - 0.72}{0.87 - 0.72}$$

$$\frac{d}{D} = 0.78\,;\ \ \mathrm{D} = 4.5\,\mathrm{ft.} \rightarrow \mathrm{d} = 3.51\,\mathrm{ft.}$$

Manning Equation, Ex.2

- **Find the velocity:**

$$v_{\text{full}} = \frac{Q_{\text{full}}}{A} = \frac{179.2\ \text{cfs}}{15.90\ \text{ft}^2} = 11.27\ \text{ft/s}$$

$$\frac{v}{v_{\text{full}}} = \frac{v}{11.27\ \text{ft/s}}$$

$$\frac{Q}{Q_{\text{full}}} = \frac{150.0\ \text{cfs}}{179.2\ \text{cfs}} = 0.84$$

Manning Equation, Ex.2

Circular Channel Ratios

$\frac{d}{D}$	$\frac{Q}{Q_{full}}$	$\frac{v}{v_{full}}$
0.1	0.02	0.31
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0.9	0.99	1.04
0.95	1.02	1.03
1.00	1.00	1.00

Manning Equation, Ex.2

$$\frac{y - y_0}{y_1 - y_0} = \frac{x - x_0}{x_1 - x_0}$$

$$\frac{\left(\frac{v}{v_{\text{full}}}\right) - 0.95}{1.01 - 0.95} = \frac{0.84 - 0.72}{0.87 - 0.72}$$

$$\frac{v}{v_{\text{full}}} = 0.998\,; \; v_{\text{full}} = 11.27 \text{ ft/s} \rightarrow v = 11.25 \text{ ft/s}$$

Basic Culvert Hydraulics

- **Conduit passing water under or around an obstructing feature (usually manmade).**
- **Used to restore a water natural path that has become obstructed.**

Additional Design Data – click here

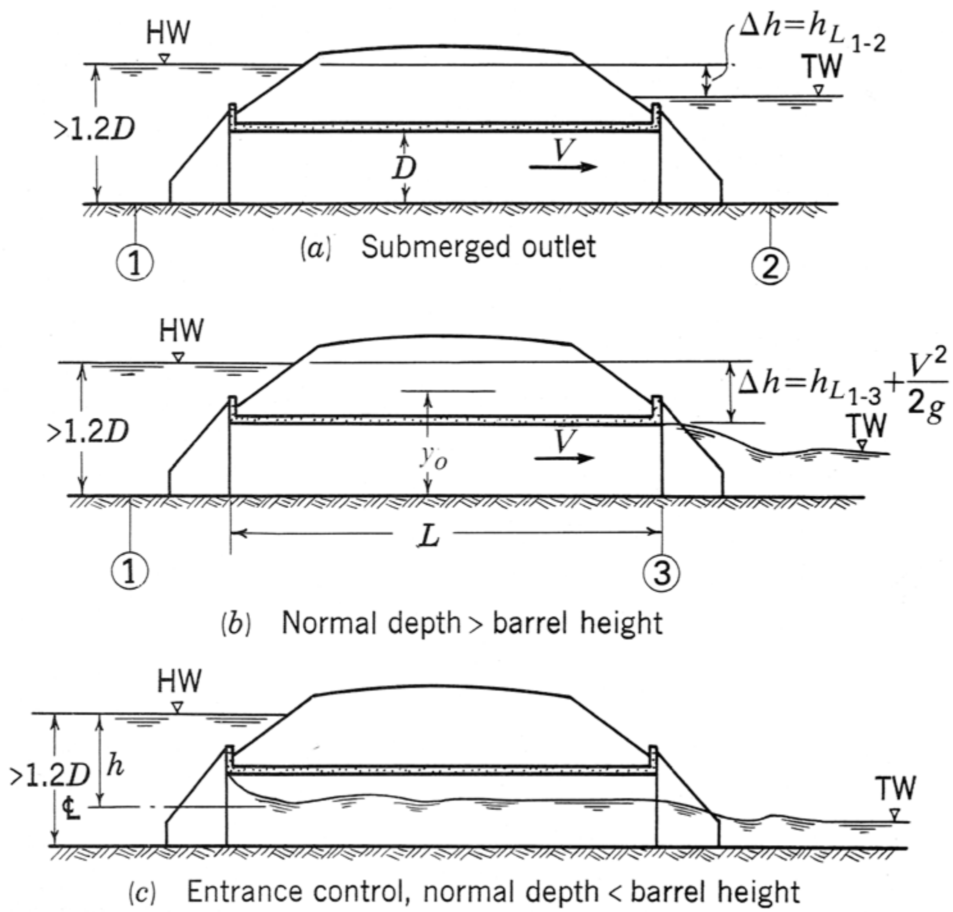
Basic Culvert Hydraulics

- **Headwater -** click here
  - **Depth of water at the upstream face of the culvert**
- **Outlet velocity -** click here
  - **Similar to channel velocity to protect downstream end**
- **Tailwater -** click here
  - **Depth of water downstream of the culvert measured from the outlet culvert**

Additional Info in the Concrete Design Manual

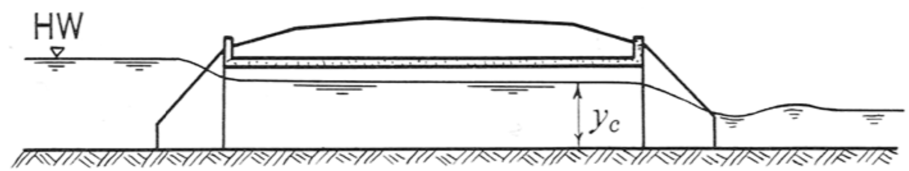
Basic Culvert Hydraulics

- **Submerged Entrance**

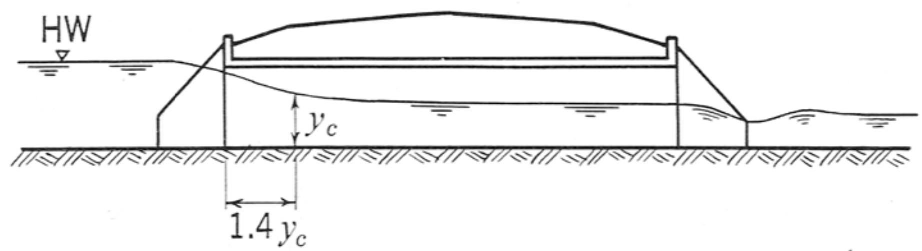


Basic Culvert Hydraulics

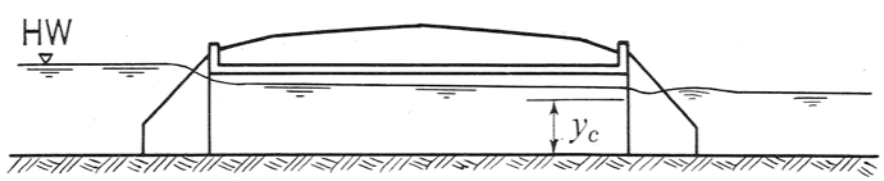
- **Free Entrance**



(*a*) Mild slope, low tailwater



(*b*) Steep slope, low tailwater



(*c*) Mild slope, tailwater submerges y_c

Parameters Used in Culvert Design

- HW_i = headwater depth above the inlet control section invert (ft)
- D = interior height of the culvert barrel (ft)
- *Q* = discharge (cfs)
- *A* = full cross-sectional area of the culvert barrel (ft^2)
- *c*, *Y*, *M* = constants based on shape and material
- Z = term for culvert barrel slope correction factor (ft/ft).

  For mitered inlets use Z=0.7S

  For all other conditions use Z=-0.5S

Basic Culvert Hydraulics

Characteristics of Flow

- **Inlet Control -** click here
- **Outlet Control -** click here
- **Outlet Velocity**

Additional Info in the Concrete Design Manual

Basic Culvert Hydraulics

- **Inlet Control**
  - **Barrel hydraulic capacity is higher than that of the inlet.**
  - **Typical flow condition is critical depth near the inlet and supercritical flow in the culvert barrel.**
  - **Due to constriction at entrance, the inlet configuration has a significant effect on hydraulic performance.**

Additional Design Data – click here

- **Outlet Control**
  - **Barrel hydraulic capacity has a smaller hydraulic than the inlet does.**
  - **Typical flow condition is that the full or partially full culvert barrel for all or part of its length.**
  - **Flow regime is always subcritical, so the control of flow is either at the downstream end of the culvert or further downstream of the culvert outlet.**

Basic Culvert Hydraulics

Inlet Control

- **Submerged Condition (orifice)**

$$\left[\frac{HW_i}{D}\right] = c\left[\frac{Q}{AD^{0.5}}\right]^2 + Y + Z \rightarrow \text{for}\left[\frac{\text{Q}}{\text{AD}^{0.5}}\right] \geq 4.0$$

- **Unsubmerged Condition (weir)**

$$\left[\frac{HW_i}{D}\right] = \left[\frac{Q}{AD^{0.5}}\right]^M \rightarrow \text{for}\left[\frac{\text{Q}}{\text{AD}^{0.5}}\right] \leq 3.5$$

Basic Culvert Hydraulics

- **Inlet Control Continued**
  - **Unsubmerged Condition (weir)**

Based on the specific head at critical depth

$$\left[\frac{HW_i}{D}\right] = \left[\frac{H_c}{D}\right] + K\left[\frac{Q}{AD^{0.5}}\right]^M + Z \rightarrow \text{for}\left[\frac{\text{Q}}{\text{AD}^{0.5}}\right] \leq 3.5$$

Basic Culvert Hydraulics

- **Outlet Control**

$$h_o = \max\left[TW, (d_c + D)/2\right]$$

$$d_c = \sqrt[3]{\frac{q^2}{g}}$$

Basic Culvert Hydraulics

- **Outlet Control**
  - **Losses $h_{ex}+h_e+h_f$**

$$H = \left(1 + k_e + \frac{29n^2L}{R^{1.33}}\right)\cdot\left(\frac{V^2}{2g}\right)$$

$$HW_{out} = H + h_o - S_oL$$

Basic Culvert Hydraulics

- Once the inlet control headwater, HW_i and the outlet control headwater, HW_{out} are computed, the controlling headwater is determined by comparing HW_i and HW_{out}
  - if $HW_i > HW_{out}$, the culvert is inlet controlled
  - if $HW_{out} > HW_i$, the culvert is outlet controlled

Basic Culvert Design

Culvert Design Procedures (AASHTO)

- Establishment of Hydrology
- Design of downstream channel
- Assumption of a trial configuration
- Computation of inlet control headwater
- Computation of outlet control headwater at inlet
- Evaluation of the controlling headwater
- Computation of discharge over the roadway & total discharge
- Computation of outlet velocity and normal depth

Basic Culvert Design Example

- **Design a reinforced concrete box culvert for a roadway crossing to pass a 50-year discharge of 400 cfs.**
  - **Shoulder elevation = 155 ft.**
  - **Streambed elevation at culvert face = 140 ft.**
  - **Natural stream slope = 1.5%**
  - **Tailwater depth -= 3.0 ft.**
  - **Culvert length = 200 ft.**
  - **Downstream channel approximate 10′ x 10′**
  - **Inlet is not depressed**

Basic Culvert Design Example

- **Step 1: 50-year design discharge is given as 400/cfs.**
- **Step 2: Downstream geometry is given 10' x 10' rectangular**
- **Step 3: Use a 7' x 5' reinforced concrete box culvert with 45 degree wing wall flares, beveled edges entrance loss coefficient of 0.2 Constants for inlet control 30-70 degree wing wall flares: c=0.0385, Y=0.81**

Basic Culvert Design Example

- **Step 4: Determine inlet control headwater – *HW_i***

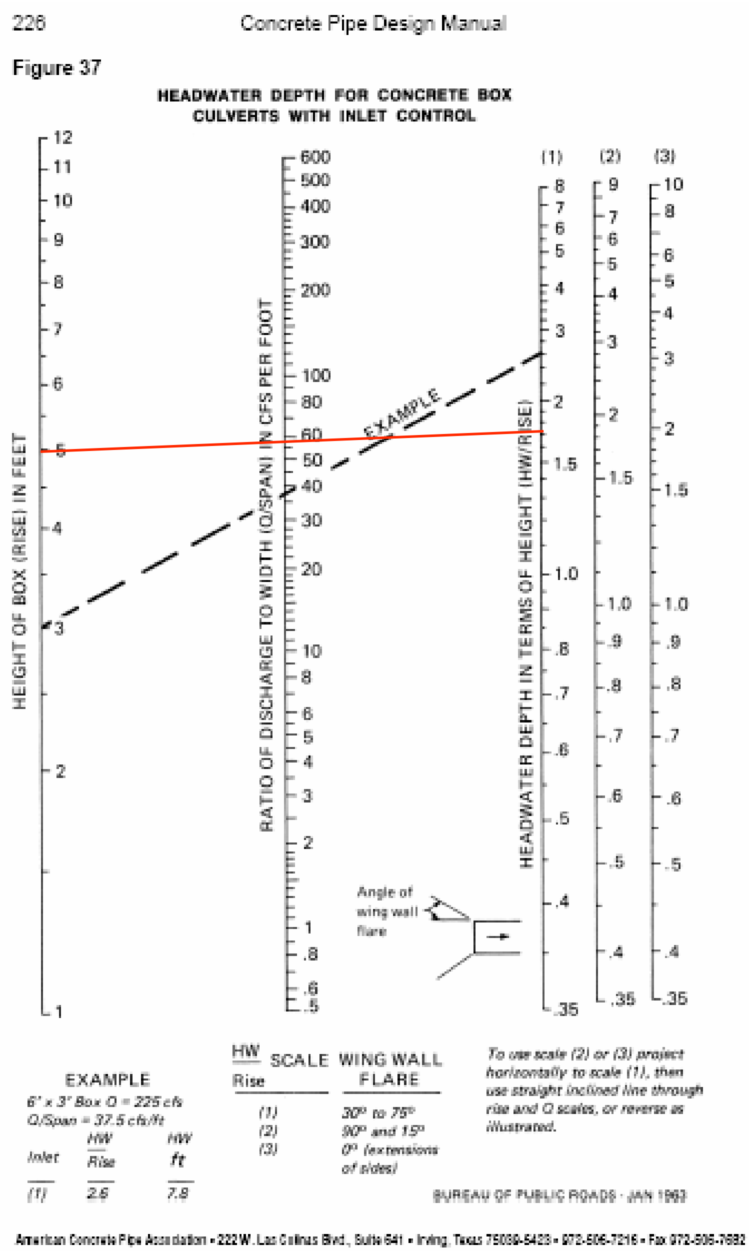
$$\left[\frac{\mathrm{Q}}{\mathrm{AD}^{0.5}}\right] = \left[\frac{400}{(35)(5^{0.5})}\right] = 5.11 \quad \geq \quad 4.0$$

$$\left[\frac{HW_i}{D}\right] = c\left[\frac{Q}{AD^{0.5}}\right]^2 + Y + Z$$

$$\left[\frac{HW_i}{5.0}\right] = 0.0385\left[\frac{400}{(35)(5)^{0.5}}\right]^2 + 0.81 - 0.5(0.015)$$

$$HW_i = 9.04\ \mathrm{ft}$$

Culverts


226
Concrete Pipe Design Manual
Figure 37
HEADWATER DEPTH FOR CONCRETE BOX CULVERTS WITH INLET CONTROL
HEIGHT OF BOX (RISE) IN FEET
RATIO OF DISCHARGE TO WIDTH (Q/SPAN) IN CFS PER FOOT
HEADWATER DEPTH IN TERMS OF HEIGHT (HW/RISE)
(1)
(2)
(3)
EXAMPLE
Angle of wing wall flare
EXAMPLE
6' x 3' Box Q = 225 cfs
Q/Span = 37.5 cfs/ft
Inlet | HW/Rise | HW ft
(1) | 2.6 | 7.8
HW/Rise SCALE | WING WALL FLARE
(1) | 30° to 75°
(2) | 90° and 15°
(3) | 0° (extensions of sides)
To use scale (2) or (3) project horizontally to scale (1), then use straight inclined line through rise and Q scales, or reverse as illustrated.
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Basic Culvert Design Example

- **Step 5 Determine the outlet control headwater depth at inlet.**
  - **Tailwater is given = 3.0 ft.**

    Find Critical Depth

    q($ft^3/s/ft$), unit discharge = total discharge/culvert width

    g = gravitational acceleration, 32.2 ft/s^2

$$d_c = \sqrt[3]{\frac{q^2}{g}} = \sqrt[3]{\frac{(400/7)^2}{32.2}} = 4.7\text{ ft.}$$

Basic Culvert Design Example

- h_0=is bigger value of tailwater or $(D+d_c)/2$.
  - Tailwater is 3.0 ft.
  - (4.7+5)/2=4.85 ft.

Use h_0=4.85 ft.

Basic Culvert Design Example

- **Find H**
  - **A=(7)(5)=35 ft²**
  - **V=400/35=11.4 ft/s**
  - **R=A/P=35/(7+7+5+5)=1.46 ft**

$$H = \left(1 + k_e + \frac{29n^2L}{R^{1.33}}\right) \cdot \left(\frac{V^2}{2g}\right)$$

$$H = \left(1 + 0.2 + \frac{29(0.012)^2(200)}{(1.46)^{1.33}}\right) \cdot \left(\frac{(11.4)^2}{2(32.2)}\right) = 3.44\ \text{ft}$$

Basic Culvert Design Example

- **Step 6 Compute controlling headwater**

$$HW_{out} = H + h_o - S_o L$$

$$HW_{out} = 3.44 + 4.85 - (0.015)(200) = 5.29 \text{ ft}$$

$$HW_i = 9.04 \text{ ft}$$

$$HW_i \text{ controls, so culvert is inlet control}$$

Basic Culvert Design Example

- **Step 7 Calculate the depth over the roadway, HW_r**

  140.00 ft + 9.04 ft = 149.04 ft < 155 ft

  does not flow over the roadway, depth = 0

Basic Culvert Design Example

- **Step 8 Compute total discharge.**
- **400 cfs, since no flow over roadway.**

Basic Culvert Design Example

- **Step 9 Compute depth for culvert and velocity.**

$$Q = \left(\frac{1.49}{n}\right) A\, R^{\frac{2}{3}} \sqrt{S}$$

$$400 = \left(\frac{1.49}{0.012}\right) 7d_n \left(\frac{7d_n}{(7+2d_n)}\right)^{\frac{2}{3}} \sqrt{0.015}$$

$$d_n = 2.8 \text{ ft}$$

Basic Culvert Design Example

- **Velocity at the culvert outlet:**

$$V_o = \frac{400}{(7)(2.8)} = 20.4 \text{ ft/s}$$

Sanitary Sewer

- **Design Flow -** click here
  - **Average Flow**
  - **Peak Flow**

Additional Design Data – click here

- **Design Velocity -** click here
  - **Minimum Velocity**
    - **Full Flow 2 ft/s**

Additional Info in the Concrete Design Manual

Sanitary Sewer

- **Design Flow considers**
  - **Average Flow**
    - **Design based on existing data or state/local agencies will specify minimum average flows.**
  - **Peak Flow**
    - **Peaking factor**
  - **Minimum Flow**
    - **Is the self cleaning velocity of 2 ft/s maintained?**

Sanitary Sewer

- **Average Flow**
  - **Needs to include I & I**
  - **Different for wet and dry months**

Sanitary Sewer

- **Peaking Factor**
  - **3:1 for large sewers serving stable populations**
  - **20:1 for small sewers serving growing populations where domestic wastewater is major component of the total flow.**

Sanitary Sewer

- **Example**
  - **10.5 acre site for retail space**
  - **Floor Area Ratio (FAR) of 0.25**
  - **What is the wastewater flow that could be expected to be produced?**

Sanitary Sewer

Retail space available:

(10.5 acre)(0.25)=114345.5 ft^2

Worst case = restaurant

	Population /unit	Equivalent pop/1,000 sq-ft	Total Units (or sq ft/1000)	Total Population
COMMERCIAL/INDUSTRIAL UNITS				
Single-Family	3.0		-	-
Multi-Family	2.5		-	-
COMMERCIAL/INDUSTRIAL UNITS				
Office, Warehouse		1.17	-	-
Retail (includes restaurant)		2.1	114.35	240.14
Hotel	0.5		-	-

Total Equivalent Population (EP)		240.14
Per Capita Dry Weather Flow, gpcd		
Average Dry Weather Flow, gpd (x 70)		16,809.45
Average Dry Weather Flow, gpm (/ 1440)		11.67
Peak Flow Factor, PF=[18+EP/1000)^0.5]/[4+(EP/1000)^0.5]		4.12
Maximum Dry Weather Flow, gpd		69,221.57
Maximum Dry Weather Flow, gpm		48.07
Minimum Flow Factor, MF = 0.2*(EP/1000)^0.198		0.15
Minimum Dry Weather Flow, gpd		2,534.62
Minimum Dry Weather Flow, gpm		1.76
Infiltration/inflow to sewer, gpd; contributing area in acres	16.60	16,600.00
Maximum Wet Weather Flow, gpd		85,821.57
Maximum Wet Weather Flow, gpm		59.60

Storm Sewer

- **Design Flow -** click here
  - **The Rational Method: Q=C*i*A**
- **Design Velocity**
  - **Minimum Velocity**
    - **Full Flow 3 ft/s**

Additional Info in the Concrete Design Manual

Storm Sewer

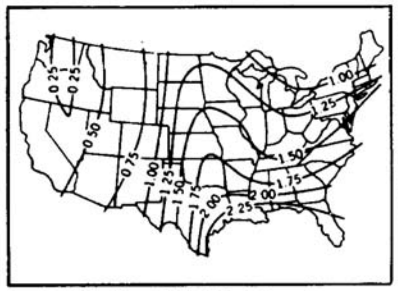
- Rational method assumes that the maximum rate of runoff for a given intensity occurs when the duration of the storm is long enough such that all parts of the watershed are contributing to runoff at the interception point.

Additional Info in the Concrete Design Manual - click here

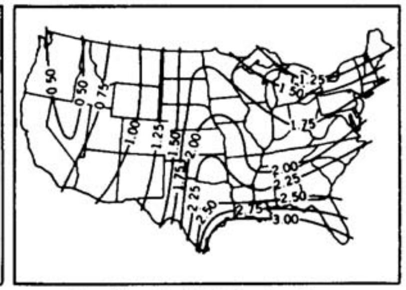
Storm Sewer Rational Method

- **$Q=CiA$**
  - **C is the ratio of the average rate of rainfall on an area to the maximum rate of run off.**
  - **i is the amount of rainfall measured in inches/hr that would be expected in a storm event of a certain duration and frequency.**
  - **A is drainage area in acres contributing to watershed**
  - **Time of Concentration – time required for a drop of water to fall at the most remote part of the drainage area and flow to a point in the system**

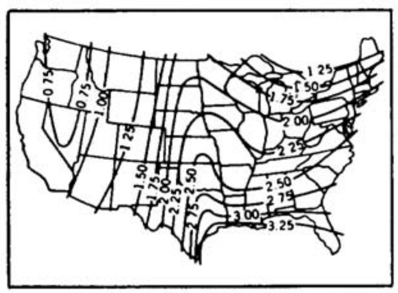
Storm Sewer Rational Method



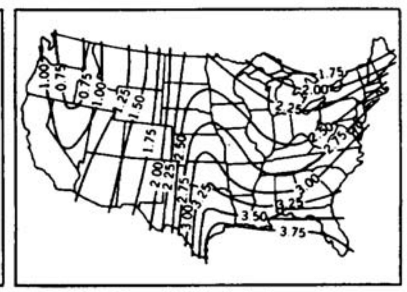
One Hour Rainfall, Inches, to Be Expected Once in 2 Years



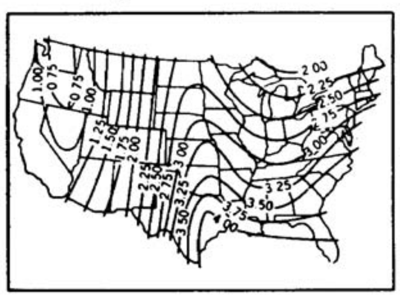
One Hour Rainfall, Inches, to Be Expected Once in 5 Years

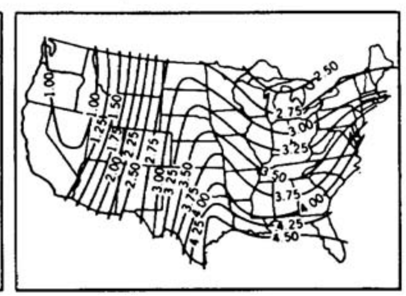


One Hour Rainfall, Inches, to Be Expected Once in 10 Years



One Hour Rainfall, Inches, to Be Expected Once in 25 Years





Storm Sewer Rational Method

- Highly absorbent surfaces = little runoff
- Occurs when rainfall intensity exceeds infiltration rate into the surface
- Topographic variables
  - Land use
  - Type of soil
  - Area
  - Land shape or form
  - Elevation
  - Slope
  - Orientation
- Estimated by hydrographs or rational method

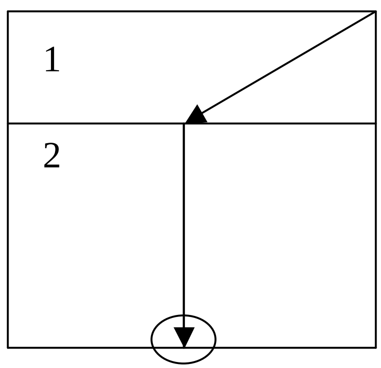
Storm Sewer Rational Method

- Instantaneous peak runoff
- For areas less than 1 to 2 miles^2
- Q = C I A
  - A is area in acres
  - Q is in ac. – in./hr. or ft^3/sec.
  - C is run off co-efficient
  - Typical values of C

forest	0.059 - 0.2
asphalt	0.7 - 0.95
concrete	0.8 - .95
farmland	0.05 - 0.3
unimproved	0.1 - 0.3
downtown	0.7 - 0.95
RESIDENTIAL:	
single family	0.3 - 0.5
apartments	0.5 - 0.7

Example

Given: Two adjacent fields, contribute runoff to a collector whose capacity is to be determined. The intensity after 25 min is 3.9 in / hr.



collector

A_1 =2ac	A_2 =4ac
C_1 = 0.35	C_2 = 0.65
T_1 = 15 min	T_2 = 10 min

Find: The peak flow using the rational method

Solution:

Total time: $t = 15 \text{ min} + 10 \text{ min} = 25 \text{ min}$

Total runoff coefficient: Use contributing areas

$$C = \frac{(2ac)(0.35) + (4ac)(0.65)}{2ac + 4ac} = 0.55$$

Total Area: $A = 2 \text{ ac} + 4 \text{ ac} = 6 \text{ ac}$

Peak Flow: $Q = CIA$

$Q = (0.55)(3.9 \text{ in/hr})(6ac)$

$Q = 12.9 \text{ ac-in/hr } (ft^3 / sec)$

Congratulations! You are almost finished.

Please see remaining slides for the exam questions and submittal form.

PDH for this course: 1.0
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Instructions for Submitting Exam

- Print out the exam submittal form and test.
- Complete the exam by circling the answers on the form.
- Complete submittal form.
- Mail your exam, submittal form and payment (if applicable) to:

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  8445, Freeport Pkwy, Suite 350

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  Attn: Professional Membership – Online Exam
- Your exam will be graded by the ACPA and the results provided to you within 60 days.

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Telephone: ____________________ Fax: ____________________

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Certification of ethical completion: I certify that I read the course presentation, understood the learning objective, and completed the exam questions to the best of my ability. Additionally, the contact information provided above is true and accurate

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PDH Value: Your exam answers will be graded by The American Concrete Pipe Association. If you answer at least 75 percent of the questions correctly, you will receive a certificate of completion from The American Concrete Pipe Association within 90 days and will be awarded 1.0 professional development hour (equivalent to 0.1 continuing education unit in most states). *Note: It is the responsibility of the licensee to determine if this method of continuing education meets his or her board(s) of registration's requirements.*

Instructions: Select one answer for each exam question and clearly circle the appropriate letter.

1)	a	b	c	d	5)	a	b	c	d
2)	a	b	c	d	6)	a	b	c	d
3)	a	b	c	d	7)	a	b	c	d
4)	a	b	c	d	8)	a	b	c	d

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Exam

- **What are the difficulties of Open Channel Flow?**
  - a) Variations in cross sections and roughness
  - b) More empirical and less exact than pressure conduit flow
  - c) Imprecise run-off calculations
  - d) All of the above
- **True or False: Due to constriction at entrance, the inlet configuration has a significant effect on hydraulic performance of basic culverts.**
  - a) True
  - b) False
- **What is headwater?**
  - a) Depth of water downstream of the culvert measured from the outlet culvert
  - b) Depth of water at the upstream face of the culvert
  - c) Similar to channel velocity to protect downstream end
  - d) Velocity at the downstream face of the culvert
- **Name one of the basic culvert uses dealing with hydraulics?**
  - a) Restoration of a natural waterway that has become obstructed
  - b) Sanitary Sewer
  - c) Reinforcing Foundation
  - d) Tunnel

Exam (cont.)

1. **Which control has the smaller Barrel hydraulic capacity?**
   a) Inlet
   b) Outlet
2. **What range of numbers is used by engineers as the manning coefficient, n, for smooth wall pipes?**
   a) 0.005 or 0.008
   b) 0.009 or 0.010
   c) 0.012 or 0.013
   d) 0.015 or 0.025
3. **What is the time required for a drop of water to fall at the most remote part of the drainage area and flow to a point in the system called?**
   a) Time of Concentration
   b) Time of Flow
   c) Average Flow
   d) Design Flow
4. **How is Average Flow calculated?**
   a) Rational Method
   b) Product of the manning coefficient and Peak Flow
   c) Based on existing data or specified
   d) Product of the Peaking Factor and Inlet Headwater

For more information:

http://www.fhwa.dot.gov/engineering/hydraulics/

Thank you for participating in ACPA's online training.

Please send us an email at info@concretepipe.org if you would like to suggest a training topic to be added in the future. In the subject line include "online training topic."

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