

STORM SEWER SYSTEM HYDRAULIC DESIGN  
SITE PLAN LOCATED BETWEEN BRICKEL AVENUE AND WASHINGTON AVE, NEAR PITTSBURGH,  
PENNSYLVANIA.

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## 1. INTRODUCTION

In this report, we present the hydraulic design for the storm sewer system of a site plan proposed for a warehouse. The site is located near Pittsburgh, Pennsylvania. The storm sewer system has already been laid out and the key drainage structures such as Inlet locations, incremental drainage areas, and pipe segments (including length and slope) have already been determined.

In this project, two major tasks are considered. The computation of the peak flow discharge resulting from the storm water at each intercept point and the estimation of the size of a pipe capable to pass the design peak rate of the storm water flow. The peak flow discharge is calculated using rational method [1], and the size of the pipes is estimated using nomograph design charts provided in Appendix A-4 [1].

## 2. DESCRIPTION OF EXISTING CONDITIONS

The Inlet locations have already been determined and the incremental drainage areas tributaries to the Inlets have been measured. The storm system layout is shown in Figure 1. The time of concentration and the runoff coefficient for each incremental drainage area are given. The pipe slopes are also given. The length of each pipe is measured from the layout. The given design parameters of the sewer system and the measured length of the pipes are listed in Table 1.

Table 1: Design parameters.

Segment	A - Incremental Area (acres)	C - Runoff Coefficient	tc - Time of Concentration (min)	Slope (%)	Pipe Length (ft)
1-2	0.65	0.62	16	2.5	80
2-5	0.34	0.34	15	2.1	55
3-4	1.16	0.28	18.5	1.1	130
4-5	1.79	0.26	19.0	2.4	30
5-10	-	-	-	1.0	130
6-7	0.31	0.89	6	2.8	70
7-10	0.15	0.65	12	3.5	140
8-9	0.29	0.90	6	1.0	110
9-10	1.10	0.66	10	2.2	25
10-11	-	-	-	3.0	50
11-12	-	-	-	1.0	44

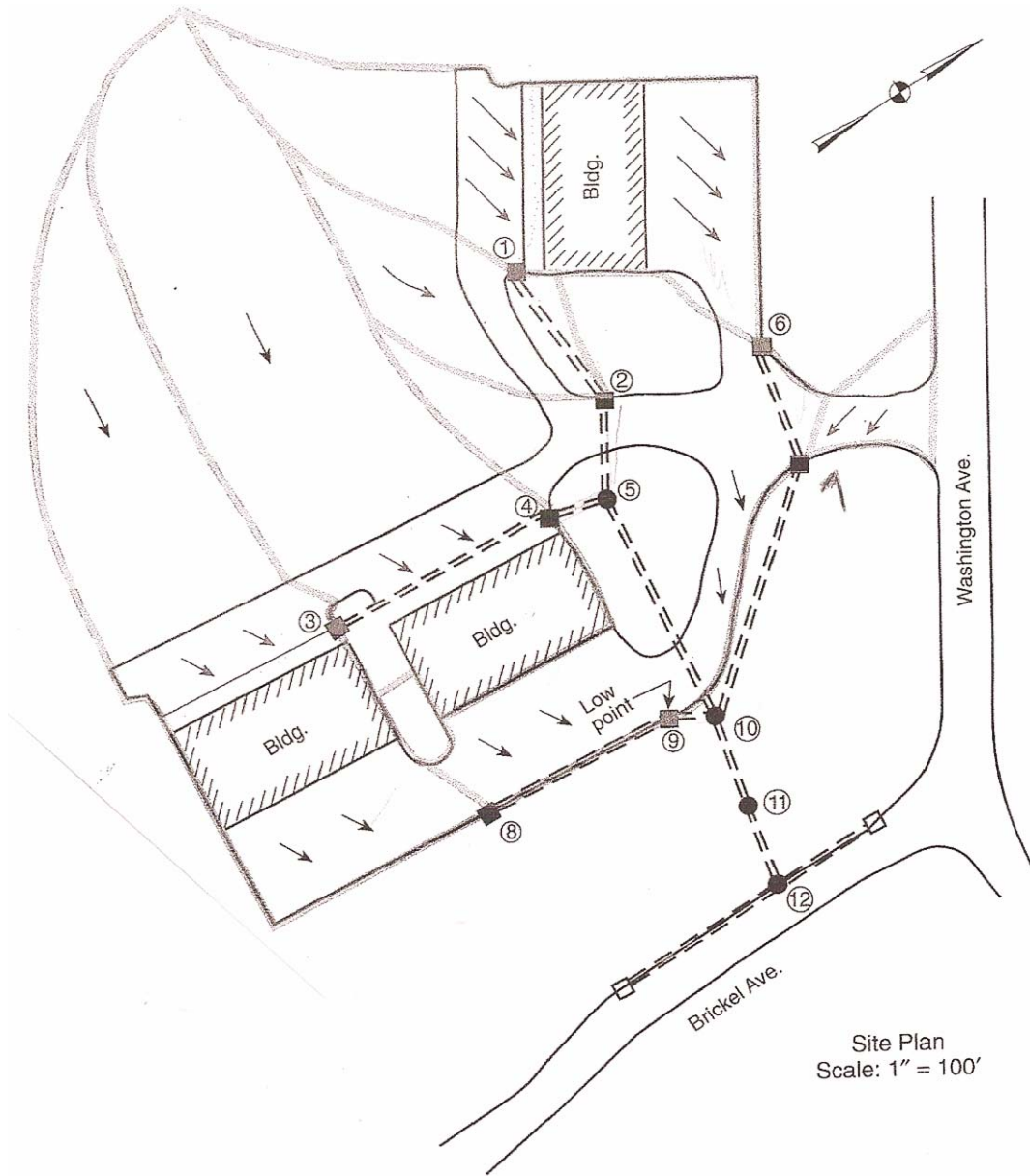


Figure 1: Site plan showing drainage area tributary to the Inlets.

The key parameters used in the hydraulic design process are as follows:

Design storm frequency:	15-year
Pipe material:	Reinforced concrete
Pipe Manning n-value:	0.012
Minimum pipe size:	12 inches.

### 3. STORM SEWER SYSTEM DESIGN PROCEDURE

The design starts at the upper end of the storm sewer system and proceeds downstream, following the flow direction. The following steps are followed in the design of our storm sewer system:

- Step 1:** Determine the total drainage area contributing to the intercept point (Inlet/Manhole).
- Step 2:** Compute composite runoff coefficient.
- Step 3:** Compute time of concentration,  $t_c$ , for the intercept point (the longest of all possible hydraulic paths), including sewer flow time in upstream pipe section that has been already designed.
- Step 4:** Find rainfall intensity,  $I$ , corresponding to the storm duration period and to the time of concentration.
- Step 5:** Compute the peak flow,  $Q_p$ , using the rational method, at the intercept point, including flow in upstream pipe section.
- Step 6:** Design the pipe section immediately downstream (pipe between the current intercept point and next one).
- Step 7:** Repeat Step 1 to Step 6 for next intercept point, until reaching the outlet of the sewer system.

The design of the pipe section (**Step 6**) is carried on by following the next sub-steps:

- (1) Determine pipe slope (given in our case study).
- (2) Choose the pipe size necessary to just flow full under uniform flow condition and capable to carry the design flow capacity (Using nomograph design charts).
- (3) Determine velocity for the design flow (Using nomograph design charts).
- (4) Calculate travel time in pipe.

The travel time in pipe is calculated using the following formula:

$$\text{Travel time} = \text{Length of pipe} / \text{Velocity.} \quad (\text{Equation 1})$$

### 4. METHODS USED IN THE DESIGN PROCESS

**Peak runoff:** The peak runoff is calculated using the Rational Method. The peak runoff is calculated according to the following formula:

$$Q_p = A.I.C \quad (\text{Equation 2})$$

Where  $Q_p$  is the peak discharge (cfs),  $A$  is the drainage area (acres),  $I$  is the rainfall intensity (in/hr), and  $C$  is the runoff coefficient (dimensionless).

**Rainfall Intensity:** The rainfall intensity is determined using the corresponding IDF curve of the region of interest. The IDF curve of Pennsylvania (Region 1) is provided in Appendix C-3 [1]. Interpolation method is used to determine the rainfall intensity for the 15-year duration storm from the rainfall intensities of 10-year and 25-year storms.

**Pipe Size and Velocity:** To select the appropriate pipe size, we use nomograph design charts found in Appendix A-4 [1]. Those nomographs are based on Manning's equation. Those charts provide the velocity at the pipe for the flow design at the corresponding slope and manning's coefficient. To choose the pipe size, we start by the minimum size (However, it should not be less than the size of upstream pipes). Then we check the capacity in full with the given manning's coefficient and segment slope. If the capacity is greater than the computed peak runoff, the assumed pipe size is accepted. Otherwise, the assumed pipe size is not accepted, and a greater pipe size is checked until the computed peak runoff is less than the full capacity of the pipe.

Once the pipe size is selected, we find the flow velocity by entering the nomograph design chart at the computed peak runoff discharge and tracing upward to the corresponding slope line. From that point, we trace to the left to the velocity scale and read the corresponding velocity.

## 5. SAMPLE CALCULATIONS

In this section, we present the calculations of the design parameters of the sewer system (peak runoff and pipe size for each segment).

### Pipe Segment 1-2:

This segment is located at the beginning of the system and therefore. The drainage area ( $A$ ), runoff coefficient ( $C$ ), time of concentration ( $t_c$ ) are given.

$$\begin{aligned} A &= 0.65 \text{ acres} \\ C &= 0.6 \\ t_c &= 16.0 \text{ min} \end{aligned}$$

Rainfall intensity for duration of 16.0 minutes was found to be

$$I = 3.3 \text{ in/hr.}$$

Peak runoff is then computed by using Equation 2:

$$\begin{aligned} Q_p &= A.C.I \\ &= (0.65)(0.62)(3.3) = 1.33 \text{ cfs.} \end{aligned}$$

Now, we select the pipe size. We start by assuming the minimum pipe size of 12 inches. The full capacity of the pipe is determined using the corresponding nomograph design chart as explained in section 4 of this report.

Pipe Size: 12 inches

Slope: 2.5 %

Pipe Capacity (full) = 6.3 cfs (From Chart 35 [1, page 433])

Since this capacity is greater than the design peak runoff of 1.33 cfs, the 12-inch is accepted.

Now, we proceed with the rest of the pipe design and calculate the travel time in the pipe. Here we first find the velocity which corresponds to the design peak runoff (as

explained in section 4 of this report), and then we calculate the travel time using Equation 1.

Velocity: 6.2 fps (From Chart 35 [1, page 433])

Pipe Length: 80 ft

Travel Time:  $(80/6.2)/60 = 0.22$  min

### Pipe Segment 2-5:

Drainage area is equal to the sum of upstream incremental areas.

$$\begin{aligned} A &= 0.65 + 0.34 \\ &= 0.99 \text{ acres} \end{aligned}$$

Composite runoff coefficient is the weighted average of the runoff coefficients of the upstream incremental areas:

$$\begin{aligned} C &= [(0.65)(0.62) + (0.34)(0.34)] / 0.99 \\ &= 0.52 \end{aligned}$$

Time of concentration is based on the hydraulic path with the longest travel time. Two hydraulic paths are present for Inlet 2. One is through hydraulic path to Inlet 1 and then from Inlet 1 to Inlet 2 through the pipe segment 1-2. Hence,

$$tc_1 = 16.0 + 0.22 = 16.2 \text{ min}$$

The other hydraulic path corresponds to the incremental drainage area of Inlet 2.

$$tc_2 = 15.0 \text{ min}$$

Therefore, the time of concentration is:

$$t_c = 16.2 \text{ min}$$

Rainfall intensity for duration of 16.2 minutes was found to be

$$I = 3.2 \text{ in/hr.}$$

Peak runoff is then computed by using Equation 2:

$$\begin{aligned} Q_p &= A.C.I \\ &= (0.99)(0.52)(3.2) = 1.66 \text{ cfs.} \end{aligned}$$

### Pipe Design:

Pipe Size:

Pipe Size: 12 inches

Slope: 2.1 %

Pipe Capacity (full) = 5.9 cfs (From Chart 35 [1, page 433])

Since this capacity is greater than the design peak runoff of 1.66 cfs, the 12-inch is accepted.

Travel Time in Pipe:

Velocity: 6.5 fps (From Chart 35 [1, page 433])

Pipe Length: 55 ft

Travel Time:  $(55/6.2)/60 = 0.14$  min

### Pipe Segment 3-4:

This segment is another branch of the system and therefore treated as though it at the beginning. Drainage area, runoff coefficient, and time of concentration are given.

$$\begin{aligned}
 A &= 1.16 \text{ acres} \\
 C &= 0.28 \\
 t_c &= 18.5 \text{ min}
 \end{aligned}$$

Rainfall intensity for duration of 18.5 minutes was found to be

$$I = 2.9 \text{ in/hr.}$$

Peak runoff is then computed by using Equation 2:

$$\begin{aligned}
 Q_p &= A.C.I \\
 &= (1.16)(0.28)(2.9) \\
 &= 0.94 \text{ cfs.}
 \end{aligned}$$

#### Pipe Design:

Pipe Size:

$$\begin{aligned}
 \text{Pipe Size: } &12 \text{ inches} \\
 \text{Slope: } &1.1 \% \\
 \text{Pipe Capacity (full)} &= 4.0 \text{ cfs (From Chart 35 [1, page 433])}
 \end{aligned}$$

Since this capacity is greater than the design peak runoff of 0.94 cfs, the 12-inch is accepted.

Travel Time in Pipe:

$$\begin{aligned}
 \text{Velocity: } &4.6 \text{ fps (From Chart 35 [1, page 433])} \\
 \text{Pipe Length: } &130 \text{ ft} \\
 \text{Travel Time: } &(130/4.6)/60 = 0.47 \text{ min}
 \end{aligned}$$

#### Pipe Segment 4-5:

Drainage area is equal to the sum of upstream incremental areas.

$$\begin{aligned}
 A &= 1.16+1.79 \\
 &= 2.95 \text{ acres}
 \end{aligned}$$

Composite runoff coefficient is the weighted average of the runoff coefficients of the upstream incremental areas:

$$\begin{aligned}
 C &= [(1.16)(0.28)+(1.79)(0.26)] / 2.95 \\
 &= 0.27
 \end{aligned}$$

Two hydraulic paths are present for Inlet 4. One is through hydraulic path to Inlet 3 and then from Inlet 3 to Inlet 4 through the pipe segment 3-4. Hence,

$$t_{c_1} = 18.5 + 0.47 = 19.0 \text{ min}$$

The other hydraulic path corresponds to the incremental drainage area of Inlet 4.

$$t_{c_2} = 19.5 \text{ min}$$

Therefore, the time of concentration is:

$$t_c = 19.5 \text{ min}$$

Rainfall intensity for duration of 19.5 minutes was found to be

$$I = 2.85 \text{ in/hr.}$$

Peak runoff is then computed by using Equation 2:

$$\begin{aligned}
 Q_p &= A.C.I \\
 &= (2.95)(0.27)(2.85) = 2.25 \text{ cfs.}
 \end{aligned}$$

Pipe Design:

## Pipe Size:

Pipe Size: 12 inches

Slope: 2.4 %

Pipe Capacity (full) = 6.2 cfs (From Chart 35 [1, page 433])

Since this capacity is greater than the design peak runoff of 2.25 cfs, the 12-inch is accepted.

## Travel Time in Pipe:

Velocity: 7.3 fps (From Chart 35 [1, page 433])

Pipe Length: 30 ft

Travel Time:  $(30/7.3)/60 = 0.07$  minPipe Segment 5-10:

Since no runoff can enter through the top of the Manhole, it has no tributary drainage area; consequently, the drainage area is equal to the sum of the upstream incremental areas:

$$\begin{aligned} A &= 0.65+0.34+1.16+1.79 \\ &= 3.94 \text{ acres} \end{aligned}$$

The composite runoff coefficient is the weighted average of the runoff coefficients of the upstream incremental areas:

$$\begin{aligned} C &= [(0.65)(0.62)+(0.34)(0.34)+(1.16)(0.28)+(1.79)(0.26)]/3.94 \\ &= 0.33 \end{aligned}$$

Two hydraulic paths are present for Inlet 5. One is through hydraulic path to Inlet 2 and then from Inlet 2 to Inlet 5 through the pipe segment 2-5. Hence,

$$tc_1 = 16.2 + 0.14 = 16.3 \text{ min}$$

The other path is through hydraulic path to Inlet 4 and then from Inlet 4 to Inlet 5 through the pipe segment 4-5. Hence,

$$tc_2 = 19.5 + 0.07 = 19.6 \text{ min}$$

Therefore, the time of concentration is:

$$t_c = 19.6 \text{ min}$$

Rainfall intensity for duration of 19.6 minutes was found to be

$$I = 2.82 \text{ in/hr.}$$

Peak runoff is then computed by using Equation 2:

$$\begin{aligned} Q_p &= A.C.I \\ &= (3.94)(0.33)(2.82) = 3.67 \text{ cfs.} \end{aligned}$$

Pipe Design:

## Pipe Size:

Pipe Size: 12 inches

Slope: 1.0 %

Pipe Capacity (full) = 3.8 cfs (From Chart 35 [1, page 433])

Since this capacity is greater than the design peak runoff of 3.67 cfs, the 12-inch is accepted.

Travel Time in Pipe:

Velocity: 5.8 fps (From Chart 35 [1, page 433])

Pipe Length: 130 ft

Travel Time:  $(130/5.8)/60 = 0.37$  min

### Pipe Segment 6-7:

This segment is another branch of the system and therefore treated as though it at the beginning. Drainage area, runoff coefficient, and time of concentration are given.

$A = 0.31$  acres

$C = 0.89$

$t_c = 6.0$  min

Rainfall intensity for duration of 6.0 minutes was found to be

$I = 5.2$  in/hr.

Peak runoff is then computed by using Equation 2:

$$\begin{aligned} Q_p &= A \cdot C \cdot I \\ &= (0.31)(0.89)(5.2) \\ &= 1.43 \text{ cfs.} \end{aligned}$$

### Pipe Design:

Pipe Size:

Pipe Size: 12 inches

Slope: 2.8 %

Pipe Capacity (full) = 6.7 cfs (From Chart 35 [1, page 433])

Since this capacity is greater than the design peak runoff of 1.43 cfs, the 12-inch is accepted.

Travel Time in Pipe:

Velocity: 6.8 fps (From Chart 35 [1, page 433])

Pipe Length: 70 ft

Travel Time:  $(70/6.8)/60 = 0.17$  min

### Pipe Segment 7-10:

Drainage area is equal to the sum of upstream incremental areas.

$$\begin{aligned} A &= 0.31 + 0.15 \\ &= 0.46 \text{ acres} \end{aligned}$$

Composite runoff coefficient is the weighted average of the runoff coefficients of the upstream incremental areas:

$$\begin{aligned} C &= [(0.31)(0.89) + (0.15)(0.65)] / 0.46 \\ &= 0.81 \end{aligned}$$

Two hydraulic paths are present for Inlet 7. One is through hydraulic path to Inlet 6 and then from Inlet 6 to Inlet 7 through the pipe segment 6-7. Hence,

$$t_{c1} = 6.0 + 0.17 = 6.2 \text{ min}$$

The other hydraulic path corresponds to the incremental drainage area of Inlet 7.

$$t_{c_2} = 12.0 \text{ min}$$

Therefore, the time of concentration is:

$$t_c = 12.0 \text{ min}$$

Rainfall intensity for duration of 12.0 minutes was found to be

$$I = 3.8 \text{ in/hr.}$$

Peak runoff is then computed by using Equation 2:

$$\begin{aligned} Q_p &= A.C.I \\ &= (0.46)(0.81)(3.8) \\ &= 1.42 \text{ cfs.} \end{aligned}$$

### Pipe Design:

Pipe Size:

Pipe Size: 12 inches

Slope: 3.5 %

Pipe Capacity (full) = 7.7 cfs (From Chart 35 [1, page 433])

Since this capacity is greater than the design peak runoff of 1.42 cfs, the 12-inch is accepted.

Travel Time in Pipe:

Velocity: 7.3 fps (From Chart 35 [1, page 433])

Pipe Length: 140 ft

Travel Time:  $(140/7.3)/60 = 0.32 \text{ min}$

### Pipe Segment 8-9:

This segment is another branch of the system and therefore treated as though it at the beginning. Drainage area, runoff coefficient, and time of concentration are given.

$$A = 0.29 \text{ acres}$$

$$C = 0.90$$

$$t_c = 6.0 \text{ min}$$

Rainfall intensity for duration of 6.0 minutes was found to be

$$I = 5.2 \text{ in/hr.}$$

Peak runoff is then computed by using Equation 2:

$$\begin{aligned} Q_p &= A.C.I \\ &= (0.29)(0.90)(5.2) \\ &= 1.36 \text{ cfs.} \end{aligned}$$

### Pipe Design:

Pipe Size:

Pipe Size: 12 inches

Slope: 1.0 %

Pipe Capacity (full) = 3.8 cfs (From Chart 35 [1, page 433])

Since this capacity is greater than the design peak runoff of 1.36 cfs, the 12-inch is accepted.

**Travel Time in Pipe:**

Velocity: 4.7 fps (From Chart 35 [1, page 433])  
 Pipe Length: 110 ft  
 Travel Time:  $(110/4.7)/60 = 0.9$  min

**Pipe Segment 9-10:**

Drainage area is equal to the sum of upstream incremental areas.

$$A = 0.29 + 1.10 \\ = 1.39 \text{ acres}$$

Composite runoff coefficient is the weighted average of the runoff coefficients of the upstream incremental areas:

$$C = [(0.29)(0.90) + (1.10)(0.66)] / 1.39 \\ = 0.71$$

Two hydraulic paths are present for Inlet 9. One is through hydraulic path to Inlet 8 and then from Inlet 8 to Inlet 9 through the pipe segment 8-9. Hence,

$$tc_1 = 6.0 + 0.39 = 6.4 \text{ min}$$

The other hydraulic path corresponds to the incremental drainage area of Inlet 9.

$$tc_2 = 10.0 \text{ min}$$

Therefore, the time of concentration is:

$$t_c = 10.0 \text{ min}$$

Rainfall intensity for duration of 10.0 minutes was found to be

$$I = 4.2 \text{ in/hr.}$$

Peak runoff is then computed by using Equation 2:

$$Qp = A.C.I \\ = (1.39)(0.71)(4.2) \\ = 4.15 \text{ cfs.}$$

**Pipe Design:****Pipe Size:**

Pipe Size: 12 inches  
 Slope: 2.2 %  
 Pipe Capacity (full) = 6.1 cfs (From Chart 35 [1, page 433])

Since this capacity is greater than the design peak runoff of 4.15 cfs, the 12-inch is accepted.

**Travel Time in Pipe:**

Velocity: 8.0 fps (From Chart 35 [1, page 433])  
 Pipe Length: 25 ft  
 Travel Time:  $(25/8.0)/60 = 0.05$  min

**Pipe Segment 10-11:**

Since no runoff can enter through the top of the Manhole, it has no tributary drainage area; consequently, the drainage area is equal to the sum of the upstream incremental areas:

$$A = 0.65+0.34+1.16+1.79+0.31+0.15+0.29+1.10$$

$$= 5.79 \text{ acres}$$

The composite runoff coefficient is the weighted average of the runoff coefficients of the upstream incremental areas and is equal to:

$$C = 0.46$$

Three hydraulic paths are present for Manhole 10. One is through hydraulic path to Inlet 7 and then from Inlet 7 to Manhole 10 through the pipe segment 7-10. Hence,

$$tc_1 = 12.0 + 0.32 = 12.3 \text{ min}$$

The second path is through hydraulic path to Manhole 5 and then from Manhole 5 to Manhole 10 through the pipe segment 5-10. Hence,

$$tc_2 = 19.6 + 0.37 = 20.0 \text{ min}$$

The third path is through hydraulic path to Inlet 9 and then from Inlet 9 to Manhole 10 through the pipe segment 9-10. Hence,

$$Tc_3 = 10.0 + 0.39 = 10.4 \text{ min}$$

Therefore, the time of concentration is:

$$t_c = 20.0 \text{ min}$$

Rainfall intensity for duration of 20.0 minutes was found to be

$$I = 2.80 \text{ in/hr.}$$

Peak runoff is then computed by using Equation 2:

$$Q_p = A.C.I$$

$$= (5.97)(0.46)(2.80)$$

$$= 7.46 \text{ cfs.}$$

#### Pipe Design:

Pipe Size:

Pipe Size: 12 inches

Slope: 3.0 %

Pipe Capacity (full) = 7.0 cfs (From Chart 35 [1, page 433])

Since this capacity is less than the design peak runoff of 7.46 cfs, the 12-inch is not accepted.

We upgrade the pipe size to 15 inches and check its capacity,

Pipe Size: 15 inches

Slope: 3.0 %

Pipe Capacity (full) = 10.3 cfs (From Chart 36 [1, page 434])

Since this capacity is greater than the design peak runoff of 7.46 cfs, the 15-inch is accepted.

Travel Time in Pipe:

Velocity: 10.0 fps (From Chart 36 [1, page 434])

Pipe Length: 50 ft

Travel Time:  $(50/10.0)/60 = 0.08 \text{ min}$

Pipe Segment 11-12:

Since all runoff entering the Manhole 11 are coming from the Manhole 10, the drainage area and the composite runoff coefficient are consequently the same:

$$\begin{aligned} A &= 5.79 \text{ acres} \\ C &= 0.46 \end{aligned}$$

The time of concentration to Manhole 11 is equal to the time of concentration to Manhole 10 plus the travel time in the pipe connecting the two Manholes. Hence,

$$t_c = 20.0 + 0.08 = 20.1 \text{ min}$$

Rainfall intensity for duration of 20.1 minutes was found to be

$$I = 2.78 \text{ in/hr.}$$

Peak runoff is then computed by using Equation 2:

$$\begin{aligned} Q_p &= A.C.I \\ &= (5.97)(0.46)(2.78) \\ &= 7.40 \text{ cfs.} \end{aligned}$$

Pipe Design:

## Pipe Size:

Here we start checking the capacity of a pipe with size equal to the one just upstream which in this case was 15-inches.

$$\begin{aligned} \text{Pipe Size: } &15 \text{ inches} \\ \text{Slope: } &1.0 \% \\ \text{Pipe Capacity (full)} &= 7.0 \text{ cfs (From Chart 36 [1, page 434])} \end{aligned}$$

Since this capacity is less than the design peak runoff of 7.40 cfs, the 12-inch is not accepted.

We upgrade the pipe size to 18 inches and check its full capacity,

$$\begin{aligned} \text{Pipe Size: } &18 \text{ inches} \\ \text{Slope: } &1.0 \% \\ \text{Pipe Capacity (full)} &= 10.2 \text{ cfs (From Chart 337 [1, page 435])} \end{aligned}$$

Since this capacity is greater than the design peak runoff of 7.40 cfs, the 18-inch is accepted.

## 6. SUMMARY:

The hydraulic design is presented in chart form as shown in Table 2, where column 5 represents the total area contributing to the Inlet/Manhole, column 6 represents the composite runoff, column 7 the time of concentration, column 8 represents the rainfall intensity, and column 9 represents the peak discharge at the Inlet/Manhole. Columns 9 through 15 lists the parameters of the pipe design, where column 10 represents the length of the pipe, column 11 represents the slope, column 12 represents the size of the pipe, column 13 represents the full capacity, column 14 represents the velocity of the flow at the design flow, and column 15 represents the travel time in the pipe.

Table 2: Drainage Calculation Chart (15-Year Storm, n=0.012)

(1) Pipe Segment		(2) A - Incremental Area (acres)	(3) C - Runoff Coefficient	(4) $t_c$ - Incremental Time of Concentration (min)	(5) A - Total Area (acres)	(6) C - Composite Runoff Coefficient	(7) $t_c$ - Time of Concentration (min)	(8) I - Rainfall Intensity (in/h)	(9) Q <sub>p</sub> - Peak Discharge (cfs)	(10) Pipe Length (ft)	(11) Slope (%)	(12) Size (in)	(13) Full Capacity (cfs)	(14) Velocity (fps) (Design Flow)	(15) Travel Time in Pipe (min)
From	To														
1	2	0.65	0.62	16.0	0.65	0.62	16.0	3.30	1.33	80	2.5	12	6.3	6.2	0.22
2	5	0.34	0.34	15.0	0.99	0.52	16.2	3.20	1.66	55	2.1	12	5.9	6.5	0.14
3	4	1.16	0.28	18.5	1.16	0.28	18.5	2.90	0.94	130	1.1	12	4.0	4.6	0.47
4	5	1.79	0.26	19.0	1.79	0.27	19.5	2.85	2.25	30	2.4	12	6.2	7.3	0.07
5	10	-	-	-	3.94	0.33	19.6	2.82	3.67	130	1.0	12	3.8	5.8	0.37
6	7	0.31	0.89	6.0	0.31	0.89	6.0	5.20	1.43	70	2.8	12	6.7	6.8	0.17
7	10	0.15	0.65	12.0	0.46	0.81	12.0	3.80	1.42	140	3.5	12	7.7	7.3	0.32
8	9	0.29	0.90	6.0	0.29	0.90	6.0	5.20	1.36	110	1.0	12	3.8	4.7	0.39
9	10	1.10	0.66	10.0	1.39	0.71	10.0	4.20	4.15	25	2.2	12	6.1	8.0	0.05
10	11	-	-	-	5.79	0.46	20.0	2.80	7.46	50	3.0	15	10.3	10.0	0.08
11	12	-	-	-	5.79	0.46	20.1	2.78	7.40	44	1.0	18	10.2	7.0	-

**References:**

1. Gribbin, John E., *Introduction to Hydraulics and Hydrology*, 3<sup>rd</sup> edition, Prentice Hall, 2007.