# Site Stormwater Analysis Report

## Hawthorne Capacitor Bank Addition Project

## 160 Hawthorne Drive

## Fairfield, Connecticut

**Document Number: 188336-0001**

**July 15, 2015**

***Prepared for:***

The United Illuminating Company
Connecticut Financial Center
157 Church St #16
New Haven, CT 06510

***Prepared by:***
Black & Veatch Corporation
11401 Lamar Avenue
Overland Park, Kansas 66211

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## LIST OF ATTACHMENTS

## 1.0 Engineer's Certification of Stormwater Review

Professional Certification. I hereby certify that these documents were prepared or approved by me, and that I am a duly licensed professional engineer under the laws of the State of Connecticut, License No. 25295, Expiration Date: 1/31/2016.

**Prepared by:**
Black & Veatch

David J. Koehler

**Printed Name of Registered Professional Engineer**

STATE OF CONNECTICUT
DAVID J. KOEHLER
No. 25295
LICENSED
PROFESSIONAL ENGINEER

David J. Koehler

**Signature of Registered Professional Engineer**

**Date**

## 1.0 Project Description

The Hawthorne Substation is located on an R-3 zoned area of a 2.8 acre parcel at 160 Hawthorne Drive (Rear) in the City of Fairfield. The existing parcel is bounded to the east and south by residential buildings, to the north and west by vegetation and General Electric Company property. Eversource transmission easement, occupied by 115 kV overhead transmission lines, extends across the southern portion of the property. The expansion work will be adjacent to the Eversource transmission line easement. Two 115kV 20MVAR transmission capacitor banks will be installed along the west side of the existing Hawthorne substation with the existing 115 kV equipment/buswork remaining in place. Refer to Attachment A.

## 2.0 Topographic Features of the Project Site

Across the project site the elevation varies 20 feet. The highest elevations (279.0 – 259.0) of the site are in the southwest corner. The elevation within the substation is relatively flat. Stormwater runoff from the western portion of the project site generally flows north across the substation yard before crossing the property boundary. The stormwater runoff from the eastern portion of the project site runs along the existing asphalt roadway and exits from the southeast corner of the property, pooling at an existing catch basin.

The majority of the area outside the substation fence is wooded. Aggregate surfacing comprises the majority of the area within the substation fence. The access road to the substation is paved and a small portion of the access road adjacent to the control building is paved. Refer to Figure 1.

## 3.0 Stormwater Analysis – Design Basis

The Connecticut Siting Council has requested an analysis of the stormwater runoff from the project site. The purpose of this analysis is to evaluate the runoff from the site including potential effects on the adjacent wetland and abutting properties and assess the effectiveness of the existing access road catch basin. The analysis compares the site characteristics and runoff flow rates of the pre-construction project site to the post construction project site. Once this comparison is completed, further investigation on the effect of this change in runoff will occur.

Using the Rational method, the difference in runoff from pre-development to post-development can be analyzed. The results will be correctly sizing the catch basin located in the southeast corner of the site as well as ensuring protection of the wetland area and the feeding grounds of the Eastern Box Turtle.

The property area for the Hawthorne substation is approximately 2.8 acres. This can be subdivided into eastern and western drainage subbasins. Refer to Attachment A. Estimated runoff volumes for each subbasin drainage area have been calculated using the Rational Method in conjunction with the ConnDOT Drainage Manual. The runoff coefficient for this drainage area is calculated using a weighted average of the runoff coefficients (c) for unimproved cover, aggregate cover, asphalt pavement, and roof cover. These areas are shown in Figure 1. Referencing chapter 6 of the ConnDOT Drainage Manual, the small site area allows an assumption that the time of concentration is the minimum of 5 minutes. Using the time of concentration, the rainfall intensity can be found for the 10-year, 25-year, and 100-year storms. These intensity values are from the ConnDOT Drainage Manual Table B-2.1 as shown below in Table 1.

**Table 1 – Rainfall Intensity for Storm Events**

| RAINFALL INTENSITY (in/hr) | | | |
|---|---|---|---|
| Duration (min) | 10 YR | 25 YR | 100 YR |
| 5 | 6.0 | 6.7 | 7.8 |

The estimated runoff volume is calculated using Equation 6.2 from the ConnDOT Drainage Manual

$$Q = C_w * C_f * I * A$$

$Q$ =Stormwater Runoff (cfs)
$C_w$ =Weighted runoff coefficient
$C_f$ = Frequency factor
$I$ =Rainfall Intensity (in/hr)
$A$ =Area (ac)

## 4.0 Pre-Construction Characteristics and Peak Flow Rates

The existing substation area is predominantly unimproved land with aggregate surfacing, an asphalt paved road on the eastern side of the site, and a control building. The calculated runoff coefficients are as shown in Tables 2 and 3.

**Table 2 – Pre Construction Weighted Coefficient (West)**

| Pre-Construction Weighted C ($C_w$) | | | | | | |
|---|---|---|---|---|---|---|
| | ASPHALT PAVING | AGGREGATE SURFACING | ROOF | UNIMPROVED | TOTAL | WEIGHTED C |
| c | 0.95 | 0.60 | 0.95 | 0.20 | | 0.31 |
| AREA (ac) | 0.06 | 0.24 | 0.03 | 1.16 | 1.49 | |

**Table 3 – Pre-Construction Weighted Coefficient (East)**

| Pre-Construction Weighted C ($C_w$) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | ASPHALT PAVING | AGGREGATE SURFACING | ROOF | UNIMPROVED | TOTAL | WEIGHTED C |
| c | 0.95 | 0.60 | 0.95 | 0.20 | | 0.43 |
| AREA (ac) | 0.20 | 0.30 | 0.05 | 0.76 | 1.31 | |

Runoff peak flow rates (Q) for the 10-year and 100-year storms are shown in Tables 4 and 5 and calculated as described above in section 3.0.

**Table 4 – Pre-Construction Peak Flow Rates - West**

| West Pre-Construction Peak Flow Rates - Q(cfs) | | | | | |
|---|---|---|---|---|---|
| Rainfall Event (yr) | $C_w$ | $C_f$ | I (in/hr) | A (ac) | Q (cfs) |
| 10-yr | 0.31 | 1.00 | 6.00 | 1.49 | 2.77 |
| 100-yr | 0.31 | 1.25 | 7.80 | 1.49 | 4.50 |

**Table 5 – Pre-Construction Peak Flow Rates - East**

| East Pre Construction Peak Flow Rates - Q(cfs) | | | | | |
|---|---|---|---|---|---|
| Rainfall Event (yr) | $C_w$ | $C_f$ | I (in/hr) | A (ac) | Q (cfs) |
| 10-yr | 0.43 | 1.00 | 6.00 | 1.31 | 3.38 |
| 25-yr | 0.43 | 1.10 | 6.70 | 1.31 | 4.15 |
| 100-yr | 0.43 | 1.25 | 7.80 | 1.31 | 5.49 |

## 5.0 Post Construction Characteristics and Peak Flow Rates

The development occurring on site will replace unimproved land with aggregate surfacing. The calculated weighted runoff coefficients are shown in Tables 6 and 7.

**Table 6 – Post Construction Weighted Coefficient (West)**

| Post-Construction Weighted C ($C_w$) | | | | | | |
|---|---|---|---|---|---|---|
| | ASPHALT PAVING | AGGREGATE SURFACING | ROOF | UNIMPROVED | TOTAL | WEIGHTED C |
| c | 0.95 | 0.60 | 0.95 | 0.20 | | 0.48 |
| AREA (ac) | 0.06 | 0.89 | 0.03 | 0.51 | 1.49 | |

**Table 7 – Post Construction Weighted Coefficient (East)**

| Post-Construction Weighted C ($C_w$) | | | | | | |
|---|---|---|---|---|---|---|
| | ASPHALT PAVING | AGGREGATE SURFACING | ROOF | UNIMPROVED | TOTAL | WEIGHTED C |
| c | 0.95 | 0.60 | 0.95 | 0.20 | | 0.49 |
| AREA (ac) | 0.18 | 0.53 | 0.05 | 0.55 | 1.31 | |

Runoff peak flow rates (Q) for the 10-year and 100-year storms are shown in Tables 8 and 9 and calculated as described above in section 3.0.

**Table 8 – Post Construction Peak Flow Rates - West**

| West Post Construction Peak Flow Rates - Q(cfs) | | | | | |
|---|---|---|---|---|---|
| Rainfall Event (yr) | $C_w$ | $C_f$ | I (in/hr) | A (ac) | Q (cfs) |
| 10-yr | 0.48 | 1.00 | 6.00 | 1.49 | 4.29 |
| 100-yr | 0.48 | 1.25 | 7.80 | 1.49 | 6.97 |

**Table 9 – Post Construction Peak Flow Rates – East**

| East Post-Construction Peak Flow Rates - Q(cfs) | | | | | |
|---|---|---|---|---|---|
| Rainfall Event (yr) | $C_w$ | $C_f$ | I (in/hr) | A (ac) | Q (cfs) |
| 10-yr | 0.49 | 1.00 | 6.00 | 1.31 | 3.85 |
| 25-yr | 0.49 | 1.10 | 6.70 | 1.31 | 4.73 |
| 100-yr | 0.49 | 1.25 | 7.80 | 1.31 | 6.26 |

# 6.0 Summary of Peak Flow Rates

**Table 10 – Post Construction Peak Flow Rates - East**

| Summary of Peak Flow Rates - Q (cfs) | | | | |
|---|---|---|---|---|
| Rainfall Event (yr) | West | | East | |
| | Pre Q | Post Q | Pre Q | Post Q |
| 10 | 2.77 | 4.29 | 3.38 | 3.85 |
| 25 | - | - | 4.15 | 4.73 |
| 100 | 4.50 | 6.97 | 5.49 | 6.26 |

FIGURE 1

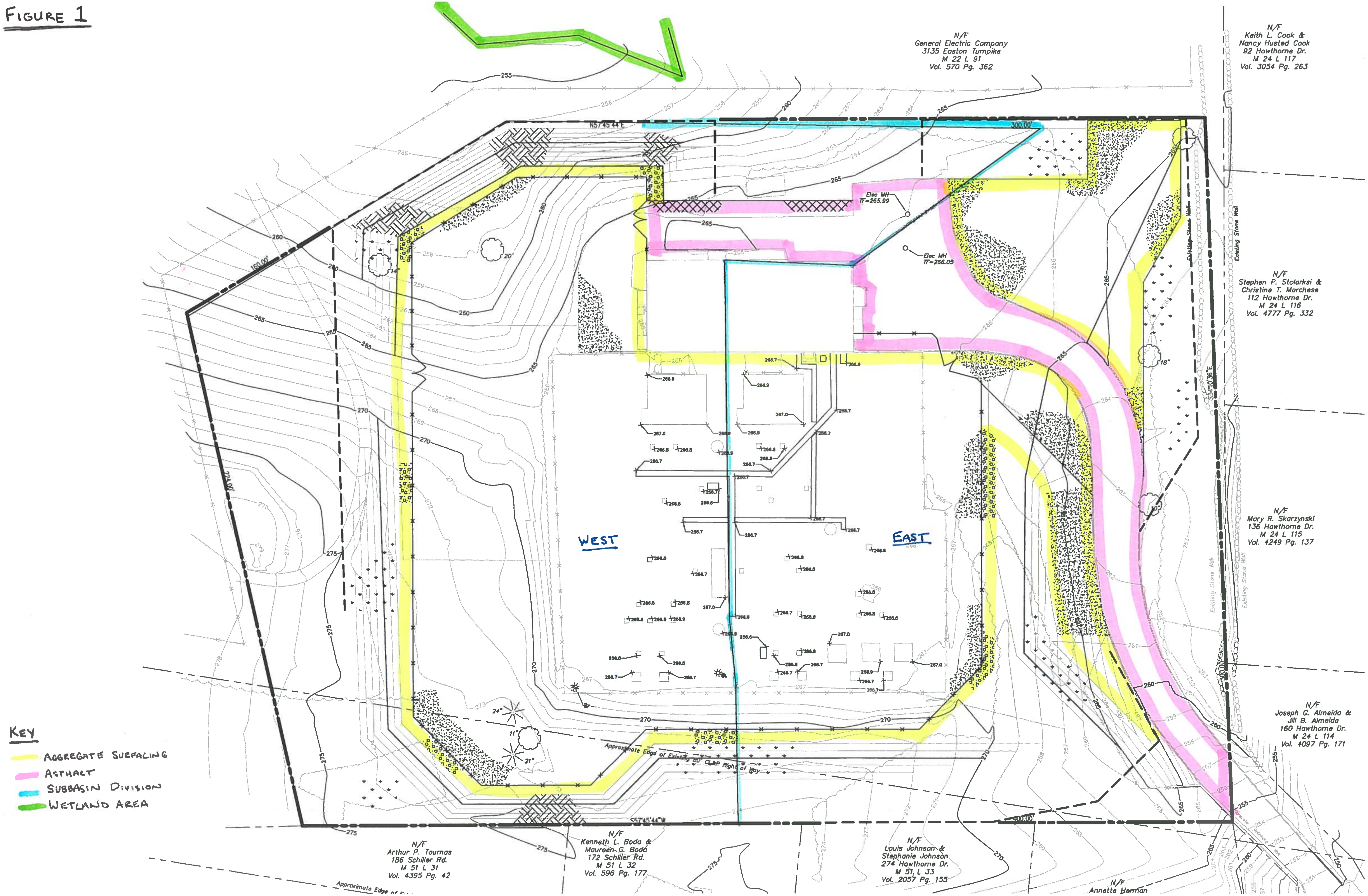

N/F
General Electric Company
3135 Easton Turnpike
M 22 L 91
Vol. 570 Pg. 362
N/F
Keith L. Cook &
Nancy Husted Cook
92 Hawthorne Dr.
M 24 L 117
Vol. 3054 Pg. 263
N/F
Stephen P. Stolarksi &
Christine T. Marchese
112 Hawthorne Dr.
M 24 L 116
Vol. 4777 Pg. 332
N/F
Mary R. Skarzynski
136 Hawthorne Dr.
M 24 L 115
Vol. 4249 Pg. 137
N/F
Joseph G. Almeida &
Jill B. Almeida
160 Hawthorne Dr.
M 24 L 114
Vol. 4097 Pg. 171
N/F
Arthur P. Tournas
186 Schiller Rd.
M 51 L 31
Vol. 4395 Pg. 42
N/F
Kenneth L. Boda &
Maureen G. Boda
172 Schiller Rd.
M 51 L 32
Vol. 596 Pg. 177
N/F
Louis Johnson &
Stephanie Johnson
274 Hawthorne Dr.
M 51 L 33
Vol. 2057 Pg. 155
N/F
Annette Herman
WEST
EAST
Elec MH
TF=265.99
Elec MH
TF=266.05
N57°45'44"E
S57°45'44"W
S34°10'36"E
300.00'
400.00'
160.00'
274.00'
Existing Stone Wall
Approximate Edge of Existing 50' CL&P Right of Way
KEY
AGGREGATE SURFACING
ASPHALT
SUBBASIN DIVISION
WETLAND AREA


FIGURE 2

# 7.0 Recommendations

## 7.1 Existing Catch Basin

The existing catch basin located down gradient of the substation on the western edge of the access road. This catch basin is outside of the southeast property boundary. The peak flow rate for the 25-year rainfall event was used as the basis for the analysis of the adequacy of the catch basin and outlet pipe. See attached Figure 2.

Based on the existing contours and estimated routing of the outlet pipe from the catch basin, the pipe slope is estimated to be approximately 6%. Information obtained during a site walk down indicates that the outlet pipe diameter is 4 inches. Multiple pipe slope scenarios were evaluated using the hydraulic software FlowMaster to analyze current capacity and develop a range of outlet pipe sizes.

The existing 4 inch corrugate high density polyethylene pipe (CHDPE) pipe at 6% slope has a full flow capacity of 0.50 cfs as shown in Table 11.

**Table 11 – Existing Catch Basin Capacity**

| 4 inch CHDPE Capacity | |
|---|---|
| Slope (%) | Capacity (cfs) |
| 0.5 | 0.15 |
| 2.0 | 0.29 |
| 4.0 | 0.41 |
| 6.0 | 0.50 |

Preliminary calculations on catch basin resizing were done with multiple pipe scenarios ran in FlowMaster. For each of the pipe slope scenarios, the Manning's coefficient remained constant. The pre-construction 25 year peak flow rate is 4.15 cfs. Table 12 shows the results of these scenarios.

**Table 12 – Recommended Pre-Construction Catch Basin Outlet Pipe Resizing**

| CHDPE Pre-Construction Outlet Pipe Sizing | | |
|---|---|---|
| Slope (%) | Calculated Diameter (in) | Recommended Diameter (in) |
| 0.5 | 14.0 | 15 |
| 2.0 | 10.8 | 12 |
| 4.0 | 9.5 | 12 |
| 6.0 | 8.8 | 12 |

Preliminary calculations on catch basin resizing were done with multiple pipe scenarios ran in FlowMaster. For each of the pipe slope scenarios, the Manning's coefficient and peak flow rate remained constant. Table 13 shows the results of these scenarios.

**Table 13 – Recommended Post-Construction Catch Basin Outlet Pipe Resizing**

| CHDPE Post Construction Outlet Pipe Sizing | | |
|---|---|---|
| Slope (%) | Calculated Diameter (in) | Recommended Diameter (in) |
| 0.5 | 14.8 | 15 |
| 2.0 | 11.4 | 12 |
| 4.0 | 10.0 | 12 |
| 6.0 | 9.2 | 12 |

As shown in Table 11, the existing catch basin outlet pipe is inadequately sized to handle the runoff quantity draining to the existing catch basin. The site expansion will create additional impervious area which will generate more runoff and increase the amount of water that may pond at the existing catch basin. To address the existing water ponding and outlet pipe size issue, the existing outlet pipe (4" diameter) should be removed and a 15" diameter pipe installed. Calculations for the post-construction site conditions indicate that installing a 15" diameter CHDPE outlet pipe will effectively handle the design flow.

Therefore, it is recommended that a 15" diameter CHDPE pipe be installed at the existing pipe slope and alignment to resolve the existing drainage issue and account for the future site expansion.

## 7.2 Wetland Degradation

The calculated increase in runoff from the existing site to the post-development site is shown in Table 14.

**Table 14 – Flow Rate Summary**

| Summary of Flow Rates - Q (cfs) | | | | | | |
|---|---|---|---|---|---|---|
| Rainfall Event (yr) | West | | | East | | |
| | Pre Q | Post Q | ΔQ | Pre Q | Post Q | ΔQ |
| 10 | 2.77 | 4.29 | 1.52 | 3.38 | 3.85 | 0.47 |
| 25 | - | - | - | 4.15 | 4.73 | 0.58 |
| 100 | 4.50 | 6.97 | 2.47 | 5.49 | 6.26 | 0.77 |

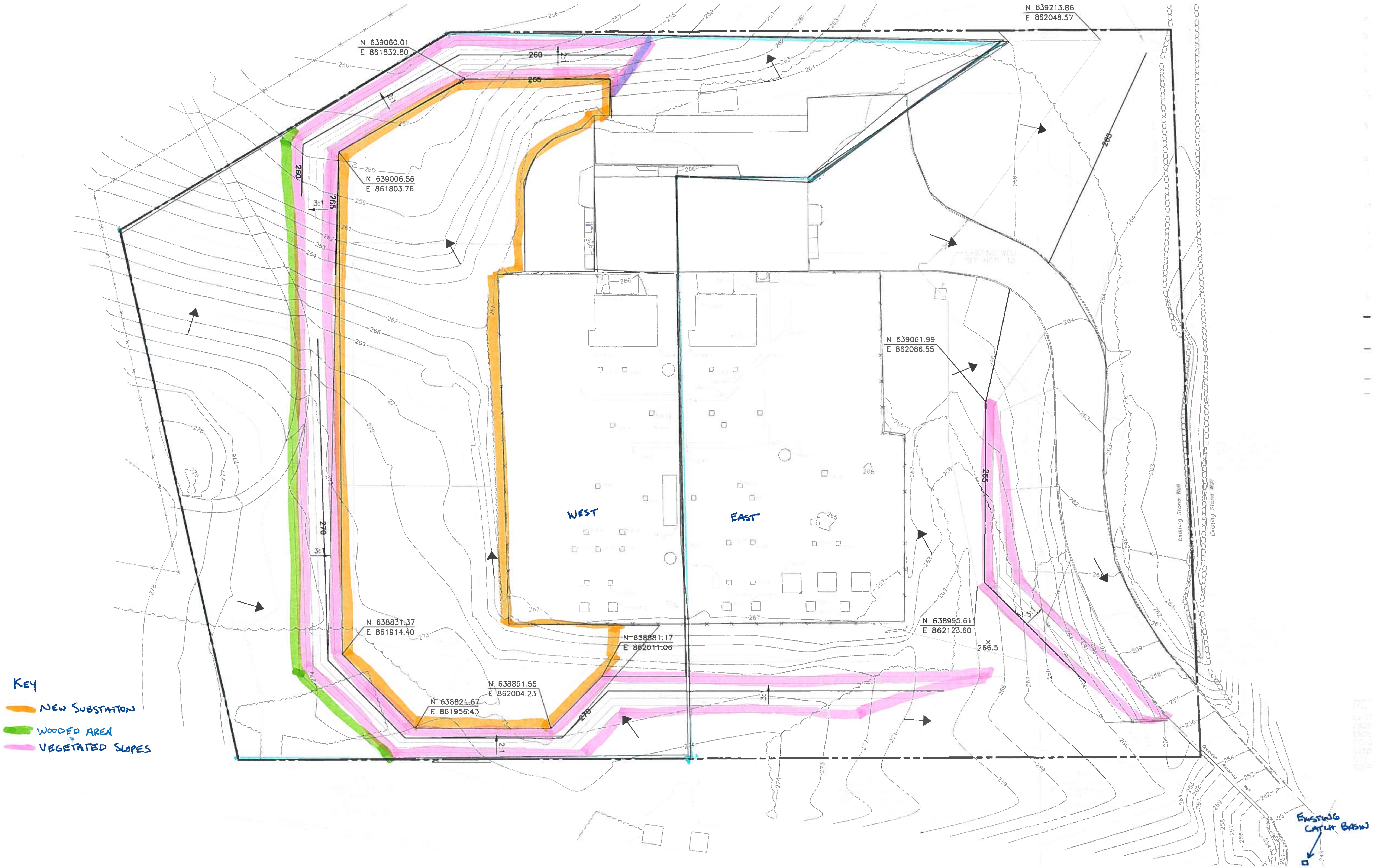
The primary expansion area for the Hawthorne Substation is located on the western side of the project site. This area will be expanded to allow for the installation of additional equipment. Surface area that does not become foundations or structures will be aggregate surfaced in accordance Black & Veatch Drawing 25252-414D. The runoff from this additional area will flow north across the substation pad, traverse the pad side slopes and continue into a delineated wetland north of the property line, approximately 18 feet. Figure 1 demonstrates the drainage area and flow pattern for the western portion of the substation. Wetlands are a sensitive ecological area and measures will be taken to prevent degradation caused by sediment or other potential pollutants transported by the runoff.

To ensure water quality protection for the wetland area, the following best management practices will be installed as part of the substation expansion project.

> Erosion control blanket – the blanket will be installed along the 2 (H) : 1 (V) slope on the northern western substation pad. The erosion blanket will prevent erosion of the soil slope by "locking" the slope together and promoting seed growth for re-vegetation.
>
> Re-vegetation of side slopes – after construction the earthen slopes will be susceptible to erosion control. The slopes will be seeded/re-vegetated to deter erosion on the slopes. After the slope is considered stabilized (70% uniform cover) with vegetation, the vegetation will reduce the velocity of stormwater runoff and will provide soil interlock to prevent erosion of the slope.
>
> Compost filter sock – at the transition of the new slope and the existing site slope, a compost filter sock will be installed. The compost filter sock will enhance the runoff water quality in multiple ways. The compost filter sock will prevent soil erosion in the transition area by minimizing the potential for turbulence caused by the transition of slopes. Installing compost filter socks is considered a high quality best management practice. The compost filter socks filter the runoff and remove sediment or other pollutants from the runoff.
>
> Vegetated buffer – the existing vegetated/wooded area between the site boundary and the wetland will not be disturbed during construction. The width of this buffer is approximately 18 feet. Stormwater runoff flowing to the wetland area will be flow through this vegetated/wooded buffer which will provide additional filtering of sediment and reduce the velocity of the runoff.

# Attachment A

Site Drawing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N 638831.37
E 861914.40
N 638881.17
E 862011.08
N 638851.55
E 862004.23
N 638821.67
E 861956.43
N 638995.61
E 862123.60
266.5
WEST
EAST
Existing Stone Wall
Existing Stone Wall
Existing Catch Basin
Key
New Substation
Wooded Area
Vegetated Slopes

# Attachment B

BV Calculation - 188336.58.1003

Pre vs. Post Construction Stormwater Runoff, Rev 1, July 15, 2015

| BLACK & VEATCH Building a world of difference. | CALCULATION RECORD |
|---|---|

Client Name The United Illuminating Company Page 1 of 27

Project Name Hawthorne Substation Project No. 188336

Calculation Title Pre vs. Post Construction Stormwater Runoff

Calculation No./File No. 188336.58.1003

Verification Method: ☒ Check and Review ☐ Alternate Calculations

**Objective:** To compare pre-construction versus post-constrution to determine the change in stormwater runoff from the project site.

| Unverified Assumptions Requiring Subsequent Verification | | | |
|---|---|---|---|
| **No.** | **Assumption** | **Verified By** | **Date** |
| | | | |
| | | | |
| | | | |
| | | | |

Refer to Page ______ of this calculation for additional assumptions.

**This Section Used for Software-Generated Calculations**

Program Name/Number FlowMaster Version V8i

Standard B&V Application Used? ☒ Yes ☐ No

If no, list approved deviation permit number below and attach approved deviation permit.

**Review and Approval**

| Rev | Prepared By | Date | Verified By | Date | Approved By | Date |
|---|---|---|---|---|---|---|
| 0 | Abigail Allgood | 07/08/2015 | Stephen Reitz | 07/08/2015 | David Koehler | 07/08/2015 |
| 1 | Abigail Allgood | 07/15/2015 | Stephen Reitz | 07/15/2015 | David Koehler | 07/16/2015 |
| | | | | | | |
| | | | | | | |
| | | | | | | |

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## LIST OF ATTACHMENTS

## 1. REFERENCES

1.1. Connecticut Department of Transportation (ConnDOT); "ConnDOT: Drainage Manual" accessed 7/1/2015

1.2. US Department of Agriculture; "Urban Hydrology for Small Watersheds, 2nd Edition;" Technical Release 55 (TR-55), June 1986

## 2. DESIGN BASIS

2.1. Surface drainage is required to convey stormwater runoff from the Hawthorne Substation northwest to surrounding wetlands and south to an existing catch basin.

2.2. The peak flow rates will be calculated using the Rational Method. This will require defining the drainage areas , determining the time of concentration for each drainage area and computing the runoff coefficient for the drainage area. The design rainfall events will be the 10-Year, 25-Year and the 100-Year per reference 1.1.

2.3. The existing catch basin outlet pipe will be analyzed in FlowMaster using the calculated 25-Year peak flow rate.

## 3. DEFINITIONS OF UNITS & CONSTANTS

| | | | | | |
|---|---|---|---|---|---|
| In/hr | inches/hour | ft/s | feet/second | ID | Inside diameter |
| cfs | cubic feet per second | ac | acres | ft2 | square feet |

## 4. ANALYSIS & DESIGN

4.1. FLOW CALCULATION - PRE-CONSTRUCTION

The drainage area of the site is such that the minimum time of concentration can be used. Chapter 6 of the ConnDOT Drainage Manual (Ref 1.1) states that a minimum Time of Concentration is 5 minutes. A schematic of the site including runoff area and time of concentration path can be found in Attachment A. Calculation results for $C_{WEIGHTED}$ are shown in Attachment C.

#### 4.1.1. C value (C)

##### 4.1.1.1. Western Subbasin

| | |
|---|---|
| Asphalt Paving area = 0.06 acres | $C_{ASPHALT}$ = 0.95 |
| Roof Surface area = 0.03 acres | $C_{ROOF}$ = 0.95 |
| Aggregate Surface area = 0.24 acres | $C_{AGGREGATE}$ = 0.60 |
| Unimproved Surface area = 1.16 acres | $C_{UNIMPROVED}$ = 0.20 |
| Total drainage area = 1.49 acre | $C_{WEIGHTED}$ = 0.31 |

##### 4.1.1.2. Eastern Subbasin

| | |
|---|---|
| Asphalt Paving area = 0.20 acres | $C_{ASPHALT}$ = 0.95 |
| Roof Surface area = 0.05 acres | $C_{ROOF}$ = 0.95 |
| Aggregate Surface area = 0.30 acres | $C_{AGGREGATE}$ = 0.60 |
| Unimproved Surface area = 0.76 acres | $C_{UNIMPROVED}$ = 0.20 |
| Total drainage area = 1.31 acre | $C_{WEIGHTED}$ = 0.43 |

#### 4.1.2. Time of Concentration ($T_c$)

Time of Concentration is considered the time for runoff to travel from the hydraulically most distant point of the drainage area to a point of interest within the drainage area. Time of concentration is assumed to be the minimum due to the short flow paths and combination of surfacing. Per reference 1.1, minimum time of concentration is 5 minutes. The following values were used to determine $T_c$:

$T_c$ = 5 min (minimum $T_c$ per Reference 1.1) to be used

#### 4.1.3. Rainfall Intensity

Time of Concentration will be used to determine the rainfall intensity.

Time of Concentration ($T_c$) = 5 minutes

Rainfall intensity will be determined using the method from the ConnDOT Drainage Manual Table B-2.1 (per reference 1.1) for 10 YR, 25 YR, and 100 YR storms.

$I_{10}$ = 6.0 in/hr
$I_{25}$ = 6.7 in/hr
$I_{100}$=7.8 in/hr

#### 4.1.4. Flow Calculation

The Rational Method will be used to determine the 10-YR, 25-YR and 100-YR peak flow rates. The calculation tables are shown in Attachment D.

$$Q = C_w \times C_f \times I \times A$$

Q = Discharge, $ft^3/s$
$C_w$ = Weighted runoff coefficient
$C_f$ = Correction factor
From reference 1.1, Table 6.2: $C_{f10} = 1.00$
$C_{f25} = 1.10$
$C_{f100}=1.25$
I = Rainfall intensity, in/hr
A = Total Drainage Area, $ft^2$

<u>WESTERN SUBBASIN</u>

$Q_{10}$ = 0.31x (1.0) x (6.0 in/hr) x (1.49 ac) = 2.77 cfs

$Q_{100}$ = 0.31x (1.25) x (7.8 in/hr) x (1.49 ac) = 4.50 cfs

<u>EASTERN SUBBASIN</u>

$Q_{10}$ = 0.43 x (1.0) x (6.0 in/hr) x (1.31 ac) = 3.38 cfs

$Q_{25}$ = 0.43 x (1.10) x (6.7 in/hr) x (1.31 ac) = 4.15 cfs

$Q_{100}$ = 0.43 x (1.25) x (7.8 in/hr) x (1.31 ac) = 5.49 cfs

### 4.2. FLOW CALCULATION - POST CONSTRUCTION

The drainage area of the site is such that the minimum time of concentration can be used. Chapter 6 of the ConnDOT Drainage Manual (Ref 1.1) states that a minimum Time of Concentration is 5 minutes. A schematic of the site including runoff area and time of concentration path can be found in Attachment A. Calculation results for $C_{WEIGHTED}$ are shown in Attachment C.

### 4.2.1. C value (C)

#### 4.2.1.1. Western Subbasin

| | |
|---|---|
| Asphalt Paving area = 0.06 acres | $C_{ASPHALT}$ = 0.95 |
| Roof Surface area = 0.03 acres | $C_{ROOF}$ = 0.95 |
| Aggregate Surface area = 0.89 acres | $C_{AGGREGATE}$ = 0.60 |
| Unimproved Surface area = 0.51 acres | $C_{UNIMPROVED}$ = 0.20 |
| Total drainage area = 1.49 acre | $C_{WEIGHTED}$ = 0.48 |

#### 4.2.1.2. Eastern Subbasin

| | |
|---|---|
| Asphalt Paving area = 0.18 acres | $C_{ASPHALT}$ = 0.95 |
| Roof Surface area = 0.05 acres | $C_{ROOF}$ = 0.95 |
| Aggregate Surface area = 0.53 acres | $C_{AGGREGATE}$ = 0.60 |
| Unimproved Surface area = 0.55 acres | $C_{UNIMPROVED}$ = 0.20 |
| Total drainage area = 1.31 acre | $C_{WEIGHTED}$ = 0.49 |

### 4.2.2. Time of Concentration ($T_c$)

Time of Concentration is considered the time for runoff to travel from the hydraulically most distant point of the drainage area to a point of interest within the drainage area. Time of concentration is assumed to be the minimum due to the short flow paths and combination of surfacing. Per reference 1.1, minimum time of concentration is 5 minutes. The following values were used to determine $T_c$:

$T_c$ = 5 min (minimum $T_c$ per Reference 1.1) to be used

### 4.2.3. Rainfall Intensity

Time of Concentration will be used to determine the rainfall intensity.

Time of Concentration ($T_c$) = 5 minutes

Rainfall intensity will be determined using the method from the ConnDOT Drainage Manual Table B-2.1 (per reference 1.1) for 10 YR, 25 YR, and 100 YR storms.

$I_{10}$ = 6.0 in/hr
$I_{25}$ = 6.7 in/hr
$I_{100}$=7.8 in/hr

#### 4.2.4. Flow Calculation

The Rational Method will be used to determine the 10-YR and 100-YR design storm discharge. The calculation tables are shown in Attachment D.

$$Q = C_w \times C_f \times I \times A$$

Q = Discharge, $ft^3/s$
$C_w$ = Weighted runoff coefficient
$C_f$ = Correction factor
From reference 1.1, Table 6.2: $C_{f10} = 1.00$
$C_{f25} = 1.10$
$C_{f100} = 1.25$
I = Rainfall intensity, in/hr
A = Total Drainage Area, $ft^2$

WESTERN SUBBASIN

$Q_{10}$ = 0.48 x (1.0) x (6.0 in/hr) x (1.49 ac) = 4.29 cfs

$Q_{100}$ = 0.48 x (1.25) x (7.8 in/hr) x (1.49 ac) = 6.97 cfs

EASTERN SUBBASIN

$Q_{10}$ = 0.49 x (1.0) x (6.0 in/hr) x (1.31 ac) = 3.85 cfs

$Q_{25}$ = 0.49 x (1.0) x (6.7 in/hr) x (1.31 ac) = 4.73 cfs

$Q_{100}$ = 0.49 x (1.25) x (7.8 in/hr) x (1.31 ac) = 6.26 cfs

| Summary of Peak Flow Rates - Q (cfs) | | | | |
|---|---|---|---|---|
| Rainfall Event (yr) | West | | East | |
| | Pre Q | Post Q | Pre Q | Post Q |
| 10 | 2.77 | 4.29 | 3.38 | 3.85 |
| 25 | - | - | 4.15 | 4.73 |
| 100 | 4.50 | 6.97 | 5.49 | 6.26 |

## 5. CATCH BASIN PIPE SIZE DESIGN

### 5.1. SITE TO CATCH BASIN

The current capacity of the catch basin was analyzed using hydraulic software FlowMaster. The pre construction capacity of the existing 4" CHDPE pipe was determined by running analyses with various slopes. The detailed reports of these scenarios are shown in Attachment E.

| 4in CHDPE Capacity | |
|---|---|
| Slope (%) | Capacity (cfs) |
| 0.5 | 0.15 |
| 2.0 | 0.29 |
| 4.0 | 0.41 |
| 6.0 | 0.50 |

The pre-construction design runoff of 4.15cfs was used to determine a recommended pipe size for the existing catch basin. The detailed reports are shown in Attachment E.

| CHDPE Pre Construction Pipe Sizing | | |
|---|---|---|
| Slope (%) | Calculated Diameter (in) | Recommended Diameter (in) |
| 0.5 | 14.0 | 15 |
| 2.0 | 10.8 | 12 |
| 4.0 | 9.5 | 12 |
| 6.0 | 8.8 | 12 |

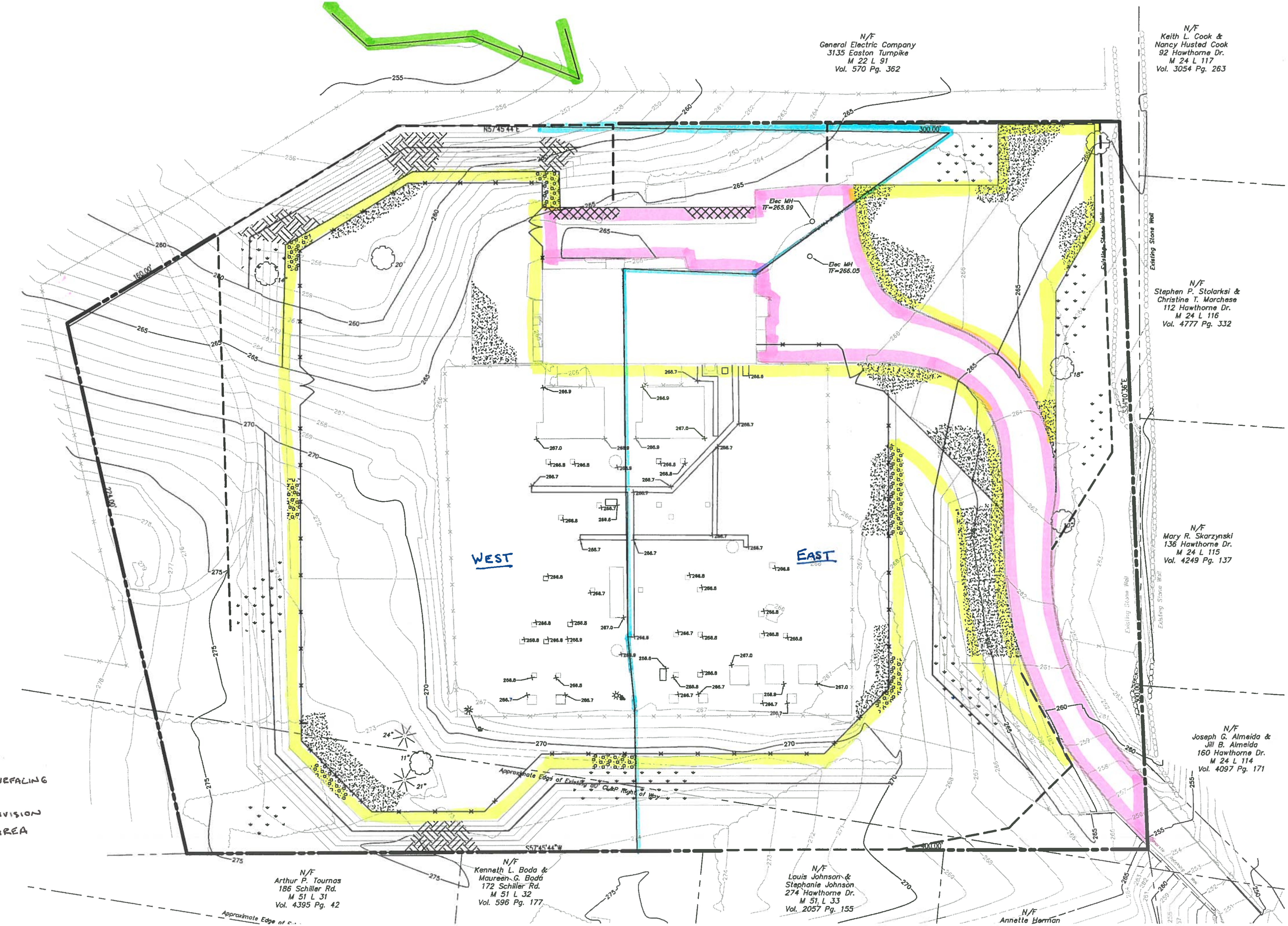
Preliminary calculations to resize the catch basin outlet pipe were performed in FlowMaster with the design basis of a CHDPE pipe with various slopes and the post construction capacity of 4.73 cfs. The detailed reports are shown in Attachment E

| CHDPE Post Construction Pipe Sizing | | |
|---|---|---|
| Slope (%) | Calculated Diameter (in) | Recommended Diameter (in) |
| 0.5 | 14.8 | 15 |
| 2.0 | 11.4 | 12 |
| 4.0 | 10.0 | 12 |
| 6.0 | 9.2 | 12 |

# Attachment A

Schematic of Drainage Area and Proposed Surfacing

FIGURE 1


KEY
AGGREGATE SURFACING
ASPHALT
SUBBASIN DIVISION
WETLAND AREA
WEST
EAST
N/F
General Electric Company
3135 Easton Turnpike
M 22 L 91
Vol. 570 Pg. 362
N/F
Keith L. Cook &
Nancy Husted Cook
92 Hawthorne Dr.
M 24 L 117
Vol. 3054 Pg. 263
N/F
Stephen P. Stolarksi &
Christine T. Marchese
112 Hawthorne Dr.
M 24 L 116
Vol. 4777 Pg. 332
N/F
Mary R. Skarzynski
136 Hawthorne Dr.
M 24 L 115
Vol. 4249 Pg. 137
N/F
Joseph G. Almeida &
Jill B. Almeida
160 Hawthorne Dr.
M 24 L 114
Vol. 4097 Pg. 171
N/F
Arthur P. Tournas
186 Schiller Rd.
M 51 L 31
Vol. 4395 Pg. 42
N/F
Kenneth L. Boda &
Maureen G. Boda
172 Schiller Rd.
M 51 L 32
Vol. 596 Pg. 177
N/F
Louis Johnson &
Stephanie Johnson
274 Hawthorne Dr.
M 51 L 33
Vol. 2057 Pg. 155
N/F
Annette Herman
Elec MH
TF=265.99
Elec MH
TF=266.05
Existing Stone Wall
Approximate Edge of Existing 50' CL&P Right of Way
N57°45'44"E
S57°45'44"W
S34°10'36"E
300.00'
400.00'
160.00'
274.00'

# Attachment B

ConnDOT Drainage Manual: Select Pages

## 6.9 Rational Method

### 6.9.1 Introduction

The rational method is recommended for estimating the design storm peak runoff for areas as large as 81 ha (200 ac). This method, while first introduced in 1889, is still used in many engineering offices in the United States. Even though it has frequently come under criticism for its simplistic approach, no other drainage design method has received such widespread use.

### 6.9.2 Application

Some precautions should be considered when applying the rational method.

- The first step in applying the rational method is to obtain a good topographic map and define the boundaries of the drainage area in question. A field inspection of the area should also be made to determine if the natural drainage divides have been altered.
- In determining the runoff coefficient C value for the drainage area, thought should be given to future changes in land use that might occur during the service life of the proposed facility that could result in an inadequate drainage system.
- The charts, graphs and tables included in this section are not intended to replace reasonable and prudent engineering judgment which should permeate each step in the design process.

### 6.9.3 Characteristics

Characteristics of the rational method which limit its use to 81 ha (200 ac) include:

(1) The rate of runoff resulting from any rainfall intensity is a maximum when the rainfall intensity lasts as long or longer than the time of concentration. That is, the entire drainage area does not contribute to the peak discharge until the time of concentration has elapsed.

This assumption limits the size of the drainage basin that can be evaluated by the rational method. For large drainage areas, the time of concentration can be so large that constant rainfall intensities for such long periods do not occur and shorter more intense rainfalls can produce larger peak flows. For this reason, the rational method is inappropriate for watersheds greater than about 81 ha (200 ac).

(2) The frequency of peak discharges is the same as that of the rainfall intensity for the given time of concentration.

Frequencies of peak discharges depend on rainfall frequencies, antecedent moisture conditions in the watershed, and the response characteristics of the drainage system. For small and largely impervious areas, rainfall frequency is the dominant factor. For larger drainage basins, the response characteristics control. For drainage areas with few impervious surfaces (less urban development), antecedent moisture conditions usually govern, especially for rainfall events with a return period of 10 years or less.

(3) The fraction of rainfall that becomes runoff (C) is independent of rainfall intensity or volume.

The assumption is reasonable for impervious areas, such as streets, rooftops and parking lots. For pervious areas, the fraction of runoff varies with rainfall intensity and the accumulated volume of rainfall. Thus, the art necessary for application of the rational method involves the selection of a coefficient that is appropriate for the storm, soil and land use conditions. Many guidelines and tables have been established, but seldom, if ever, have they been supported with empirical evidence.

(4) The peak rate of runoff is sufficient information for the design.

Modern drainage practice often includes detention of urban storm runoff to reduce the peak rate of runoff downstream. With only the peak rate of runoff, the rational method severely limits the evaluation of design alternatives available in urban and in some instances, rural drainage design.

### 6.9.4 Equation

The rational formula estimates the peak rate of runoff at any location in a watershed as a function of the drainage area, runoff coefficient and mean rainfall intensity for a duration equal to the time of concentration (the time required for water to flow from the most remote point of the basin to the location being analyzed). The rational formula is expressed as follows:

$$\mathbf{Q = 0.00278\ CIA \qquad (Q = CIA)} \qquad \mathbf{(6.1)}$$

where: Q = maximum rate of runoff, $m^3/s$ ($ft^3/s$)
C = runoff coefficient representing a ratio of runoff to rainfall
I = average rainfall intensity for a duration equal to the time of concentration, for a selected return period, mm/h (in/h)
A = drainage area tributary to the design location, ha (acres)

### 6.9.5 Infrequent Storm

The runoff coefficients given in Tables 6-3 through 6-5 are applicable for storms of 2-year to 10-year frequencies. Less frequent, higher intensity storms will require modification of the runoff coefficient because infiltration and other losses have a proportionally smaller effect on runoff (Wright-McLaughlin 1969). The adjustment of the rational method for use with major storms can be made by multiplying the right side of the rational formula by a frequency factor $C_f$. The rational formula now becomes:

$$\mathbf{Q = 0.00278\ CC_fIA \qquad (Q = CC_fIA)} \qquad \mathbf{(6.2)}$$

$C_f$ values are listed in Table 6-2. The product of $C_f$ times C shall not exceed 1.0.

**Table 6-2 Frequency Factors For Rational Formula**

| Recurrence Interval (years) | $C_f$ |
|---|---|
| 25 | 1.1 |
| 50 | 1.2 |
| 100 | 1.25 |

## 6.9.6 Procedures

The results of using the rational formula to estimate peak discharges are very sensitive to the parameters that are used. The designer must use good engineering judgment in estimating values that are used in the method. Following is a discussion of the different variables used in the rational method.

### Time Of Concentration

The time of concentration is the time required for water to flow from the hydraulically most remote point of the drainage area to the point under investigation. Use of the rational formula requires the time of concentration ($t_c$) for each design point within the drainage basin. The duration of rainfall is then set equal to the time of concentration and is used to estimate the design average rainfall intensity (I).

Appendix C (Travel Time Estimation) at the end of this chapter describes the method based on the NRCS Technical Release No. 55 (2nd Edition). This method shall be used for the rational method. Note: under certain circumstances, where tributary areas are very small or completely paved, the computed time of concentration would be very short. For design purposes the minimum time of concentration for paved areas shall be 5 minutes and 10 minutes for grassed areas.

### Common Errors

Two common errors should be avoided when calculating $t_c$. First, in some cases runoff from a portion of the drainage area which is highly impervious may result in a greater peak discharge than would occur if the entire area were considered. In these cases, adjustments can be made to the drainage area by disregarding those areas where flow time is too slow to add to the peak discharge. Sometimes it is necessary to estimate several different times of concentration to determine the design flow that is critical for a particular application.

Second, when designing a drainage system, the overland flow path is not necessarily perpendicular to the contours shown on available mapping. Often the land will be graded and swales will intercept the natural contour and conduct the water to the streets which reduces the time of concentration.

### Rainfall Intensity

The rainfall intensity (I) is the average rainfall rate mm/h (in/h) for a duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and a time of concentration calculated for the drainage area, the rainfall intensity can be determined from Rainfall-Intensity-Duration curves. The rainfall intensity can be determined from rainfall-intensity-duration Table B-2 which can be found in Appendix B.

**Runoff Coefficient**

The runoff coefficient C is the variable of the rational method least susceptible to precise determination and requires judgment and understanding on the part of the designer. While engineering judgment will always be required in the selection of runoff coefficients, a typical coefficient represents the integrated effects of many drainage basin parameters, the following discussion considers only the effects of soil groups, land use and average land slope.

Methods for determining the runoff coefficient are presented based on hydrologic soil groups and land slope (Table 6-3), land use (Table 6-4) and a composite coefficient for complex watersheds (Table 6-5).

Table 6-3 gives the recommended coefficient C of runoff for pervious surfaces by selected hydrologic soil groupings and slope ranges. From this table the C values for non-urban areas such as forest land, agricultural land, and open space can be determined. Soil properties influence the relationship between runoff and rainfall since soils have differing rates of infiltration. Infiltration is the movement of water through the soil surface into the soil. Based on infiltration rates, the NRCS has divided soils into four hydrologic soil groups as follows:

Group A Soils having a low runoff potential due to high infiltration rates. These soils consist primarily of deep, well drained sands and gravels.

Group B Soils having a moderately low runoff potential due to moderate infiltration rates. These soils consist primarily of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

Group C Soils having a moderately high runoff potential due to slow infiltration rates. These soils consist primarily of soils in which a layer exists near the surface that impedes the downward movement of water or soils with moderately fine to fine texture.

Group D Soils having a high runoff potential due to very slow infiltration rates. These soils consist primarily of clays with high swelling potential, soils with permanently high water tables, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious parent material.

The NRCS has developed detailed soil surveys for all counties within Connecticut. From these documents, the designer can determine the nature and relative percentages of the soils within a given watershed. It is important to note that the level of effort required in the determination of soil types is commensurate with the size of the watershed and the design objectives. Normally, in the computation of discharge quantities for gutter flow analysis and related storm drainage design, a detailed evaluation of soil types is not necessary, as contributing areas adjoining highways are usually relatively small. However, in the design of cross culverts, channels or interceptor ditches the determination of soil types will provide valuable assistance to the design engineer in the evaluation of the runoff potential from a particular watershed.

The second factor for consideration in the determination of a runoff coefficient is land use. As unimproved areas are developed, the potential for increased runoff becomes greater due to the loss of vegetative cover, the reduction in retention by surface depressions and the increase in impervious surface area. Table 6-4 lists recommended ranges for the runoff coefficient value classified with respect to the general character of the tributary area. **The potential for future watershed development should be considered by the designer.**

The final element to be factored into the determination of runoff coefficients is the land slope. As the slope of the drainage basin increases, the selected C value should also increase. This is caused by the fact that as the slope of the drainage area increases, the velocity of overland and channel flow will increase allowing less opportunity for water to infiltrate the ground surface. Thus, more of the rainfall will become runoff from the drainage area.

In summary, it should be reiterated that in assigning a value to the runoff coefficient for use in the rational method, the engineer must rely heavily on experience and judgement.

**Table 6-3 Recommended Coefficient Of Runoff For Pervious Surfaces By Selected Hydrologic Soil Groupings And Slope Ranges**

| Slope | A | B | C | D |
|---|---|---|---|---|
| Flat (0 - 1%) | 0.04-0.09 | 0.07-0.12 | 0.11-0.16 | 0.15-0.20 |
| Average (2 - 6%) | 0.09-0.14 | 0.12-0.17 | 0.16-0.21 | 0.20-0.25 |
| Steep (Over 6%) | 0.13-0.18 | 0.18-0.24 | 0.23-0.31 | 0.28-0.38 |

Source: Storm Drainage Design Manual, Erie and Niagara Counties Regional Planning Board.

**Table 6-4 Recommended Coefficient Of Runoff Values For Various Selected Land Uses**

| Description of Area | | Runoff Coefficients |
|---|---|---|
| Business: Downtown areas | | 0.70-0.95 |
| Neighborhood areas | | 0.50-0.70 |
| Residential: | Single-family areas | 0.30-0.50 |
| | Multi units, detached | 0.40-0.60 |
| | Multi units, attached | 0.60-0.75 |
| | Suburban | 0.25-0.40 |
| Residential (0.5 ha (1.2 ac) lots or more) | | 0.30-0.45 |
| Apartment dwelling areas | | 0.50-0.70 |
| Industrial: | Light areas | 0.50-0.80 |
| | Heavy areas | 0.60-0.90 |
| Parks, cemeteries | | 0.10-0.25 |
| Playgrounds | | 0.20-0.40 |
| Railroad yard areas | | 0.20-0.40 |
| Unimproved areas | | 0.10-0.30 |

**Table 6-5 Coefficients For Composite Runoff Analysis**

| Surface | | Runoff Coefficients |
|---|---|---|
| Street: | Asphalt | 0.70-0.95 |
| | Concrete | 0.80-0.95 |
| Drives and walks | | 0.75-0.85 |
| Roofs | | 0.75-0.95 |

| | | RAINFALL INTENSITY (in/hr) | | | | | |
|---|---|---|---|---|---|---|---|
| DURATION (min) | DURATION (hr) | 2 Yr | 5 Yr | 10 Yr | 25 Yr | 50 Yr | 100 Yr |
| 5 | 0.08 | 4.6 | 5.5 | 6.0 | 6.7 | 7.3 | 7.8 |
| 6 | 0.10 | 4.4 | 5.2 | 5.8 | 6.5 | 7.0 | 7.5 |
| 7 | 0.12 | 4.2 | 5.0 | 5.5 | 6.2 | 6.8 | 7.2 |
| 8 | 0.13 | 4.0 | 4.8 | 5.3 | 6.0 | 6.5 | 7.0 |
| 9 | 0.15 | 3.8 | 4.6 | 5.1 | 5.7 | 6.2 | 6.7 |
| 10 | 0.17 | 3.6 | 4.3 | 4.8 | 5.5 | 6.0 | 6.5 |
| 11 | 0.18 | 3.4 | 4.2 | 4.7 | 5.3 | 5.8 | 6.3 |
| 12 | 0.20 | 3.3 | 4.0 | 4.5 | 5.1 | 5.6 | 6.1 |
| 13 | 0.22 | 3.1 | 3.8 | 4.3 | 5.0 | 5.4 | 5.9 |
| 14 | 0.23 | 3.0 | 3.7 | 4.2 | 4.8 | 5.3 | 5.7 |
| 15 | 0.25 | 2.8 | 3.5 | 4.0 | 4.6 | 5.1 | 5.5 |
| 16 | 0.27 | 2.8 | 3.5 | 3.9 | 4.5 | 5.0 | 5.4 |
| 17 | 0.28 | 2.7 | 3.4 | 3.8 | 4.4 | 4.9 | 5.4 |
| 18 | 0.30 | 2.7 | 3.3 | 3.8 | 4.4 | 4.8 | 5.3 |
| 19 | 0.32 | 2.6 | 3.2 | 3.7 | 4.3 | 4.7 | 5.2 |
| 20 | 0.33 | 2.5 | 3.2 | 3.6 | 4.2 | 4.6 | 5.1 |
| 21 | 0.35 | 2.5 | 3.1 | 3.5 | 4.1 | 4.5 | 5.0 |
| 22 | 0.37 | 2.4 | 3.0 | 3.4 | 4.0 | 4.4 | 4.9 |
| 23 | 0.38 | 2.3 | 2.9 | 3.4 | 3.9 | 4.3 | 4.8 |
| 24 | 0.40 | 2.3 | 2.9 | 3.3 | 3.8 | 4.2 | 4.7 |
| 25 | 0.42 | 2.2 | 2.8 | 3.2 | 3.7 | 4.2 | 4.6 |
| 26 | 0.43 | 2.2 | 2.7 | 3.1 | 3.7 | 4.1 | 4.5 |
| 27 | 0.45 | 2.1 | 2.7 | 3.0 | 3.6 | 4.0 | 4.4 |
| 28 | 0.47 | 2.0 | 2.6 | 3.0 | 3.5 | 3.9 | 4.3 |
| 29 | 0.48 | 2.0 | 2.5 | 2.9 | 3.4 | 3.8 | 4.2 |
| 30 | 0.50 | 1.9 | 2.4 | 2.8 | 3.3 | 3.7 | 4.1 |

**Rainfall Intensity/Duration/Frequency Relationship for Connecticut (English Units)**
**Table B-2.1**

# Attachment C

$C_{WEIGHTED}$ Calculations

$$C_{WEIGHTED} = \frac{C_{ASPHALT}(A_{ASPHALT}) + C_{ROOF}(A_{ROOF}) + C_{AGGREGATE}(A_{AGGREGATE}) + C_{UNIMPROVED}(A_{UNIMPROVED})}{A_{TOTAL}}$$

| West Pre-Construction Weighted C ($C_w$) | | | | | | |
|---|---|---|---|---|---|---|
| | ASPHALT PAVING | AGGREGATE SURFACING | ROOF | UNIMPROVED | TOTAL | WEIGHTED C |
| c | 0.95 | 0.60 | 0.95 | 0.20 | | 0.31 |
| AREA (ac) | 0.06 | 0.24 | 0.03 | 1.16 | 1.49 | |

| East Pre-Construction Weighted C ($C_w$) | | | | | | |
|---|---|---|---|---|---|---|
| | ASPHALT PAVING | AGGREGATE SURFACING | ROOF | UNIMPROVED | TOTAL | WEIGHTED C |
| c | 0.95 | 0.60 | 0.95 | 0.20 | | 0.43 |
| AREA (ac) | 0.20 | 0.30 | 0.05 | 0.76 | 1.31 | |

| West Post-Construction Weighted C ($C_w$) | | | | | | |
|---|---|---|---|---|---|---|
| | ASPHALT PAVING | AGGREGATE SURFACING | ROOF | UNIMPROVED | TOTAL | WEIGHTED C |
| c | 0.95 | 0.60 | 0.95 | 0.20 | | 0.48 |
| AREA (ac) | 0.06 | 0.89 | 0.03 | 0.51 | 1.49 | |

| East Post-Construction Weighted C ($C_w$) | | | | | | |
|---|---|---|---|---|---|---|
| | ASPHALT PAVING | AGGREGATE SURFACING | ROOF | UNIMPROVED | TOTAL | WEIGHTED C |
| c | 0.95 | 0.60 | 0.95 | 0.20 | | 0.49 |
| AREA (ac) | 0.18 | 0.53 | 0.05 | 0.55 | 1.31 | |
| | | | | | | |

# Attachment D

Flow Rate Calculations

$$Q = C_W * C_f * I * A$$

| West Pre-Construction Peak Flow Rates - Q(cfs) | | | | | |
|---|---|---|---|---|---|
| Rainfall Event (yr) | $C_w$ | $C_f$ | I (in/hr) | A (ac) | Q (cfs) |
| 10-yr | 0.31 | 1.00 | 6.00 | 1.49 | 2.77 |
| 100-yr | 0.31 | 1.25 | 7.80 | 1.49 | 4.50 |
| | | | | | |

| East Pre-Construction Peak Flow Rates - Q(cfs) | | | | | |
|---|---|---|---|---|---|
| Rainfall Event (yr) | $C_w$ | $C_f$ | I (in/hr) | A (ac) | Q (cfs) |
| 10-yr | 0.49 | 1.00 | 6.00 | 1.31 | 3.85 |
| 25-yr | 0.49 | 1.10 | 6.70 | 1.31 | 4.73 |
| 100-yr | 0.49 | 1.25 | 7.80 | 1.31 | 6.26 |

| West Post Construction Peak Flow Rates - Q(cfs) | | | | | |
|---|---|---|---|---|---|
| Rainfall Event (yr) | $C_w$ | $C_f$ | I (in/hr) | A (ac) | Q (cfs) |
| 10-yr | 0.48 | 1.00 | 6.00 | 1.49 | 4.29 |
| 100-yr | 0.48 | 1.25 | 7.80 | 1.49 | 6.97 |

| East Post Construction Peak Flow Rates - Q(cfs) | | | | | |
|---|---|---|---|---|---|
| Rainfall Event (yr) | $C_w$ | $C_f$ | I (in/hr) | A (ac) | Q (cfs) |
| 10-yr | 0.43 | 1.00 | 6.00 | 1.31 | 3.38 |
| 25-yr | 0.43 | 1.10 | 6.70 | 1.31 | 4.15 |
| 100-yr | 0.43 | 1.25 | 7.80 | 1.31 | 5.49 |

# Attachment E

FlowMaster Results

# Worksheet for 4 in CHDPE 0.5% Slope

## Project Description

| | | | |
|---|---|---|---|
| Friction Method | Manning Formula | | |
| Solve For | Full Flow Capacity | | |

## Input Data

| | | | |
|---|---|---|---|
| Roughness Coefficient | | 0.012 | |
| Channel Slope | | 0.00500 | ft/ft |
| Normal Depth | | 0.33 | ft |
| Diameter | | 0.33 | ft |
| Discharge | | 0.15 | ft³/s |

## Results

| | | | |
|---|---|---|---|
| Discharge | | 0.15 | ft³/s |
| Normal Depth | | 0.33 | ft |
| Flow Area | | 0.09 | ft² |
| Wetted Perimeter | | 1.05 | ft |
| Hydraulic Radius | | 0.08 | ft |
| Top Width | | 0.00 | ft |
| Critical Depth | | 0.21 | ft |
| Percent Full | | 100.0 | % |
| Critical Slope | | 0.00897 | ft/ft |
| Velocity | | 1.67 | ft/s |
| Velocity Head | | 0.04 | ft |
| Specific Energy | | 0.38 | ft |
| Froude Number | | 0.00 | |
| Maximum Discharge | | 0.16 | ft³/s |
| Discharge Full | | 0.15 | ft³/s |
| Slope Full | | 0.00500 | ft/ft |
| Flow Type | SubCritical | | |

## GVF Input Data

| | | | |
|---|---|---|---|
| Downstream Depth | | 0.00 | ft |
| Length | | 0.00 | ft |
| Number Of Steps | | 0 | |

## GVF Output Data

| | | | |
|---|---|---|---|
| Upstream Depth | | 0.00 | ft |
| Profile Description | | | |
| Profile Headloss | | 0.00 | ft |
| Average End Depth Over Rise | | 0.00 | % |

# Worksheet for 4 in CHDPE 2.0% Slope

## Project Description

| | |
|---|---|
| Friction Method | Manning Formula |
| Solve For | Full Flow Capacity |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.012 | |
| Channel Slope | 0.02000 | ft/ft |
| Normal Depth | 0.33 | ft |
| Diameter | 0.33 | ft |
| Discharge | 0.29 | ft³/s |

## Results

| | | |
|---|---|---|
| Discharge | 0.29 | ft³/s |
| Normal Depth | 0.33 | ft |
| Flow Area | 0.09 | ft² |
| Wetted Perimeter | 1.05 | ft |
| Hydraulic Radius | 0.08 | ft |
| Top Width | 0.00 | ft |
| Critical Depth | 0.30 | ft |
| Percent Full | 100.0 | % |
| Critical Slope | 0.01778 | ft/ft |
| Velocity | 3.34 | ft/s |
| Velocity Head | 0.17 | ft |
| Specific Energy | 0.51 | ft |
| Froude Number | 0.00 | |
| Maximum Discharge | 0.31 | ft³/s |
| Discharge Full | 0.29 | ft³/s |
| Slope Full | 0.02000 | ft/ft |
| Flow Type | SubCritical | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Average End Depth Over Rise | 0.00 | % |

# Worksheet for 4 in CHDPE 4.0% Slope

## Project Description

| | | | |
|---|---|---|---|
| Friction Method | Manning Formula | | |
| Solve For | Full Flow Capacity | | |

## Input Data

| | | | |
|---|---|---|---|
| Roughness Coefficient | | 0.012 | |
| Channel Slope | | 0.04000 | ft/ft |
| Normal Depth | | 0.33 | ft |
| Diameter | | 0.33 | ft |
| Discharge | | 0.41 | ft³/s |

## Results

| | | | |
|---|---|---|---|
| Discharge | | 0.41 | ft³/s |
| Normal Depth | | 0.33 | ft |
| Flow Area | | 0.09 | ft² |
| Wetted Perimeter | | 1.05 | ft |
| Hydraulic Radius | | 0.08 | ft |
| Top Width | | 0.00 | ft |
| Critical Depth | | 0.32 | ft |
| Percent Full | | 100.0 | % |
| Critical Slope | | 0.03502 | ft/ft |
| Velocity | | 4.72 | ft/s |
| Velocity Head | | 0.35 | ft |
| Specific Energy | | 0.68 | ft |
| Froude Number | | 0.00 | |
| Maximum Discharge | | 0.44 | ft³/s |
| Discharge Full | | 0.41 | ft³/s |
| Slope Full | | 0.04000 | ft/ft |
| Flow Type | SubCritical | | |

## GVF Input Data

| | | | |
|---|---|---|---|
| Downstream Depth | | 0.00 | ft |
| Length | | 0.00 | ft |
| Number Of Steps | | 0 | |

## GVF Output Data

| | | | |
|---|---|---|---|
| Upstream Depth | | 0.00 | ft |
| Profile Description | | | |
| Profile Headloss | | 0.00 | ft |
| Average End Depth Over Rise | | 0.00 | % |

# Worksheet for 4 in CHDPE 6.0% Slope

## Project Description

| | | | |
|---|---|---|---|
| Friction Method | Manning Formula | | |
| Solve For | Full Flow Capacity | | |

## Input Data

| | | | |
|---|---|---|---|
| Roughness Coefficient | | 0.012 | |
| Channel Slope | | 0.06000 | ft/ft |
| Normal Depth | | 0.33 | ft |
| Diameter | | 0.33 | ft |
| Discharge | | 0.50 | ft³/s |

## Results

| | | | |
|---|---|---|---|
| Discharge | | 0.50 | ft³/s |
| Normal Depth | | 0.33 | ft |
| Flow Area | | 0.09 | ft² |
| Wetted Perimeter | | 1.05 | ft |
| Hydraulic Radius | | 0.08 | ft |
| Top Width | | 0.00 | ft |
| Critical Depth | | 0.33 | ft |
| Percent Full | | 100.0 | % |
| Critical Slope | | 0.05420 | ft/ft |
| Velocity | | 5.78 | ft/s |
| Velocity Head | | 0.52 | ft |
| Specific Energy | | 0.85 | ft |
| Froude Number | | 0.00 | |
| Maximum Discharge | | 0.54 | ft³/s |
| Discharge Full | | 0.50 | ft³/s |
| Slope Full | | 0.06000 | ft/ft |
| Flow Type | SubCritical | | |

## GVF Input Data

| | | | |
|---|---|---|---|
| Downstream Depth | | 0.00 | ft |
| Length | | 0.00 | ft |
| Number Of Steps | | 0 | |

## GVF Output Data

| | | | |
|---|---|---|---|
| Upstream Depth | | 0.00 | ft |
| Profile Description | | | |
| Profile Headloss | | 0.00 | ft |
| Average End Depth Over Rise | | 0.00 | % |

# Worksheet for Pre-Construction CHDPE 0.5% Slope, 25YR Storm

## Project Description

| | | |
|---|---|---|
| Friction Method | Manning Formula | |
| Solve For | Full Flow Diameter | |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.012 | |
| Channel Slope | 0.00500 | ft/ft |
| Normal Depth | 1.17 | ft |
| Diameter | 1.17 | ft |
| Discharge | 4.15 | ft³/s |

## Results

| | | |
|---|---|---|
| Diameter | 1.17 | ft |
| Normal Depth | 1.17 | ft |
| Flow Area | 1.08 | ft² |
| Wetted Perimeter | 3.68 | ft |
| Hydraulic Radius | 0.29 | ft |
| Top Width | 0.00 | ft |
| Critical Depth | 0.84 | ft |
| Percent Full | 100.0 | % |
| Critical Slope | 0.00669 | ft/ft |
| Velocity | 3.86 | ft/s |
| Velocity Head | 0.23 | ft |
| Specific Energy | 1.40 | ft |
| Froude Number | 0.00 | |
| Maximum Discharge | 4.46 | ft³/s |
| Discharge Full | 4.15 | ft³/s |
| Slope Full | 0.00500 | ft/ft |
| Flow Type | SubCritical | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Average End Depth Over Rise | 0.00 | % |

# Worksheet for Pre-Construction CHDPE 2.0% Slope, 25YR Storm

## Project Description

| | | | |
|---|---|---|---|
| Friction Method | Manning Formula | | |
| Solve For | Full Flow Diameter | | |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.012 | |
| Channel Slope | 0.02000 | ft/ft |
| Normal Depth | 0.90 | ft |
| Diameter | 0.90 | ft |
| Discharge | 4.15 | $ft^3/s$ |

## Results

| | | | |
|---|---|---|---|
| Diameter | | 0.90 | ft |
| Normal Depth | | 0.90 | ft |
| Flow Area | | 0.64 | $ft^2$ |
| Wetted Perimeter | | 2.83 | ft |
| Hydraulic Radius | | 0.23 | ft |
| Top Width | | 0.00 | ft |
| Critical Depth | | 0.84 | ft |
| Percent Full | | 100.0 | % |
| Critical Slope | | 0.01729 | ft/ft |
| Velocity | | 6.49 | ft/s |
| Velocity Head | | 0.65 | ft |
| Specific Energy | | 1.56 | ft |
| Froude Number | | 0.00 | |
| Maximum Discharge | | 4.46 | $ft^3/s$ |
| Discharge Full | | 4.15 | $ft^3/s$ |
| Slope Full | | 0.02000 | ft/ft |
| Flow Type | SubCritical | | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Average End Depth Over Rise | 0.00 | % |

# Worksheet for Pre-Construction CHDPE 4.0% Slope, 25YR Storm

## Project Description

| | |
|---|---|
| Friction Method | Manning Formula |
| Solve For | Full Flow Diameter |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.012 | |
| Channel Slope | 0.04000 | ft/ft |
| Normal Depth | 0.79 | ft |
| Diameter | 0.79 | ft |
| Discharge | 4.15 | ft³/s |

## Results

| | | |
|---|---|---|
| Diameter | 0.79 | ft |
| Normal Depth | 0.79 | ft |
| Flow Area | 0.49 | ft² |
| Wetted Perimeter | 2.49 | ft |
| Hydraulic Radius | 0.20 | ft |
| Top Width | 0.00 | ft |
| Critical Depth | 0.78 | ft |
| Percent Full | 100.0 | % |
| Critical Slope | 0.03585 | ft/ft |
| Velocity | 8.42 | ft/s |
| Velocity Head | 1.10 | ft |
| Specific Energy | 1.89 | ft |
| Froude Number | 0.00 | |
| Maximum Discharge | 4.46 | ft³/s |
| Discharge Full | 4.15 | ft³/s |
| Slope Full | 0.04000 | ft/ft |
| Flow Type | SubCritical | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Average End Depth Over Rise | 0.00 | % |

# Worksheet for Pre-Construction CHDPE 6.0% Slope, 25YR Storm

## Project Description

| | |
|---|---|
| Friction Method | Manning Formula |
| Solve For | Full Flow Diameter |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.012 | |
| Channel Slope | 0.06000 | ft/ft |
| Normal Depth | 0.73 | ft |
| Diameter | 0.73 | ft |
| Discharge | 4.15 | ft³/s |

## Results

| | | |
|---|---|---|
| Diameter | 0.73 | ft |
| Normal Depth | 0.73 | ft |
| Flow Area | 0.42 | ft² |
| Wetted Perimeter | 2.31 | ft |
| Hydraulic Radius | 0.18 | ft |
| Top Width | 0.00 | ft |
| Critical Depth | 0.73 | ft |
| Percent Full | 100.0 | % |
| Critical Slope | 0.05539 | ft/ft |
| Velocity | 9.80 | ft/s |
| Velocity Head | 1.49 | ft |
| Specific Energy | 2.23 | ft |
| Froude Number | 0.00 | |
| Maximum Discharge | 4.46 | ft³/s |
| Discharge Full | 4.15 | ft³/s |
| Slope Full | 0.06000 | ft/ft |
| Flow Type | SubCritical | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Average End Depth Over Rise | 0.00 | % |

# Worksheet for CHDPE 0.5% Slope, 25YR Storm

## Project Description

| | |
|---|---|
| Friction Method | Manning Formula |
| Solve For | Full Flow Diameter |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.012 | |
| Channel Slope | 0.00500 | ft/ft |
| Normal Depth | 1.23 | ft |
| Diameter | 1.23 | ft |
| Discharge | 4.73 | ft³/s |

## Results

| | | | |
|---|---|---|---|
| Diameter | | 1.23 | ft |
| Normal Depth | | 1.23 | ft |
| Flow Area | | 1.19 | ft² |
| Wetted Perimeter | | 3.86 | ft |
| Hydraulic Radius | | 0.31 | ft |
| Top Width | | 0.00 | ft |
| Critical Depth | | 0.89 | ft |
| Percent Full | | 100.0 | % |
| Critical Slope | | 0.00662 | ft/ft |
| Velocity | | 3.99 | ft/s |
| Velocity Head | | 0.25 | ft |
| Specific Energy | | 1.48 | ft |
| Froude Number | | 0.00 | |
| Maximum Discharge | | 5.09 | ft³/s |
| Discharge Full | | 4.73 | ft³/s |
| Slope Full | | 0.00500 | ft/ft |
| Flow Type | SubCritical | | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Average End Depth Over Rise | 0.00 | % |

# Worksheet for CHDPE 2.0% Slope, 25YR Storm

## Project Description

| | | | |
|---|---|---|---|
| Friction Method | Manning Formula | | |
| Solve For | Full Flow Diameter | | |

## Input Data

| | | | |
|---|---|---|---|
| Roughness Coefficient | | 0.012 | |
| Channel Slope | | 0.02000 | ft/ft |
| Normal Depth | | 0.95 | ft |
| Diameter | | 0.95 | ft |
| Discharge | | 4.73 | ft³/s |

## Results

| | | | |
|---|---|---|---|
| Diameter | | 0.95 | ft |
| Normal Depth | | 0.95 | ft |
| Flow Area | | 0.71 | ft² |
| Wetted Perimeter | | 2.98 | ft |
| Hydraulic Radius | | 0.24 | ft |
| Top Width | | 0.00 | ft |
| Critical Depth | | 0.89 | ft |
| Percent Full | | 100.0 | % |
| Critical Slope | | 0.01728 | ft/ft |
| Velocity | | 6.70 | ft/s |
| Velocity Head | | 0.70 | ft |
| Specific Energy | | 1.65 | ft |
| Froude Number | | 0.00 | |
| Maximum Discharge | | 5.09 | ft³/s |
| Discharge Full | | 4.73 | ft³/s |
| Slope Full | | 0.02000 | ft/ft |
| Flow Type | SubCritical | | |

## GVF Input Data

| | | | |
|---|---|---|---|
| Downstream Depth | | 0.00 | ft |
| Length | | 0.00 | ft |
| Number Of Steps | | 0 | |

## GVF Output Data

| | | | |
|---|---|---|---|
| Upstream Depth | | 0.00 | ft |
| Profile Description | | | |
| Profile Headloss | | 0.00 | ft |
| Average End Depth Over Rise | | 0.00 | % |

# Worksheet for CHDPE 4.0% Slope, 25YR Storm

## Project Description

| | | | |
|---|---|---|---|
| Friction Method | Manning Formula | | |
| Solve For | Full Flow Diameter | | |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.012 | |
| Channel Slope | 0.04000 | ft/ft |
| Normal Depth | 0.83 | ft |
| Diameter | 0.83 | ft |
| Discharge | 4.73 | ft³/s |

## Results

| | | | |
|---|---|---|---|
| Diameter | | 0.83 | ft |
| Normal Depth | | 0.83 | ft |
| Flow Area | | 0.54 | ft² |
| Wetted Perimeter | | 2.61 | ft |
| Hydraulic Radius | | 0.21 | ft |
| Top Width | | 0.00 | ft |
| Critical Depth | | 0.82 | ft |
| Percent Full | | 100.0 | % |
| Critical Slope | | 0.03589 | ft/ft |
| Velocity | | 8.69 | ft/s |
| Velocity Head | | 1.17 | ft |
| Specific Energy | | 2.01 | ft |
| Froude Number | | 0.00 | |
| Maximum Discharge | | 5.09 | ft³/s |
| Discharge Full | | 4.73 | ft³/s |
| Slope Full | | 0.03999 | ft/ft |
| Flow Type | SubCritical | | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Average End Depth Over Rise | 0.00 | % |

# Worksheet for CHDPE 6.0% Slope, 25YR Storm

## Project Description

| | | |
|---|---|---|
| Friction Method | Manning Formula | |
| Solve For | Full Flow Diameter | |

## Input Data

| | | |
|---|---|---|
| Roughness Coefficient | 0.012 | |
| Channel Slope | 0.06000 | ft/ft |
| Normal Depth | 0.77 | ft |
| Diameter | 0.77 | ft |
| Discharge | 4.73 | ft³/s |

## Results

| | | |
|---|---|---|
| Diameter | 0.77 | ft |
| Normal Depth | 0.77 | ft |
| Flow Area | 0.47 | ft² |
| Wetted Perimeter | 2.42 | ft |
| Hydraulic Radius | 0.19 | ft |
| Top Width | 0.00 | ft |
| Critical Depth | 0.76 | ft |
| Percent Full | 100.0 | % |
| Critical Slope | 0.05545 | ft/ft |
| Velocity | 10.12 | ft/s |
| Velocity Head | 1.59 | ft |
| Specific Energy | 2.36 | ft |
| Froude Number | 0.00 | |
| Maximum Discharge | 5.09 | ft³/s |
| Discharge Full | 4.73 | ft³/s |
| Slope Full | 0.05999 | ft/ft |
| Flow Type | SubCritical | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Average End Depth Over Rise | 0.00 | % |