Drainage Report
Storm Drain Group 968
August 2019

10/27/2020

Prepared By:

City of San Diego Public Works department

Nicole Salem, Senior Civil Engineer

Jamal Sherzai, Project Manager

Bobak Madgedi, Project Engineer

525 B Street Suit 700, San Diego CA 92101

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Project Description

This project proposes to replace an existing deteriorated 18" corrugated metal storm drainpipe with approximately 180 LF of new 18" reinforced concrete pipe and install a new energy dissipater at the bottom of the slope. The project is located within City of San Diego Right of Way along Roseview Place between Maple Street and Home Avenue. This location is within the Mid-City-City Heights Community Panning Group of Council District 9. The project is also bundled with Water Group Job 968. Presented in this report is a summary of hydrology calculations, hydraulic calculations and recommendations for the proposed design.

Project Location Map

WATER AND STORM DRAIN GROUP 968

COMMUNITY NAME: MID-CITY HEIGHTS

COUNCIL DISTRICT: 9

WBS: B-14099 (W)

WBS: B-15028 (SD)

DATE: JULY 18, 2019

LEGEND:

STORM DRAIN REPLACEMENT

WATER MAIN REHAB

N

W

E

S

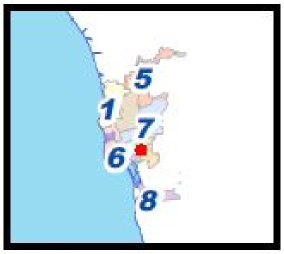
NO SCALE

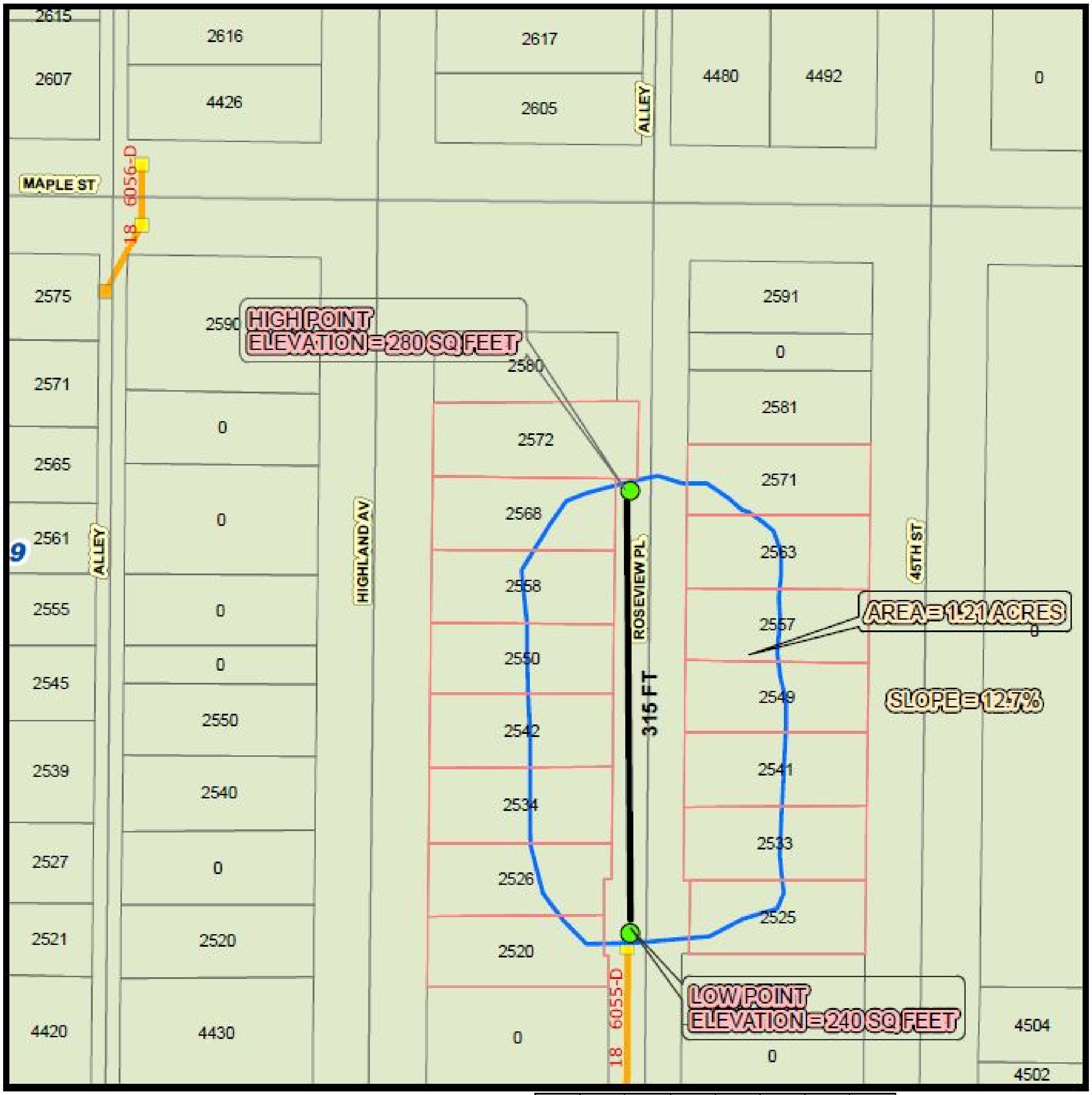
SITE MAP

SHEET NO. 9

The City of SAN DIEGO Public Works

Exhibit A Draining Area Map





0 62.5 125 250 Feet

Legend

Parcel Ownership

Hydrology/Hydraulics Method

Methodology 1: Rational Method

The City of San Diego's Drainage Design Manual (DDM) shall be used as the basis of design for this storm drain:

1. 1) Per section "2.1 Discharge Flow Methods" the Rational Method is utilized for determining storm discharge flows since this project's watershed is less than 0.5 square miles
2. 2) Per section "2.2 Design Storm Frequency" of the DDM, this analysis shall be based upon a 50-year frequency storm since this project's storm drain will be underground, the area is not within floodplain nor floodplain fringe areas and the tributary area is less than one square mile.
3. 3) Per section "2.3 Soil Type" of the DDM, this analysis shall assume Type D soil for all areas.

Watershed boundaries were delineated from referencing the shown topography lines in the Drainage Map. These boundaries provide the areas, as well as the limits that were needed to determine the runoff coefficients.

Methodology 2: Total storm water flow from the surrounding watersheds

The Flow Rate (Q) shall be calculated using equation A-1 of the DDM:

$$Q = C\ I\ A$$

Where:

- ❖ Q= Flow Rate (cubic feet per second)
- ❖ C = Runoff Coefficient (unitless)
- ❖ I = Rainfall Intensity (inches per hour)
- ❖ A = Drainage Basin Area (acres)

The Runoff Coefficient (C) will be calculated per section "A.1.2 Runoff Coefficient" of the DDM. This section requires that the runoff coefficient be calculated on a weighted basis from the percent of land use type and the associated runoff coefficient for that land use type, as outlined in "Table A-1 Runoff Coefficients for Rational Method" of the DDM.

The Rainfall Intensity (I) will be calculated per section "A.1.3 Rainfall Intensity" of the DDM. In order to derive a rainfall intensity value, the 50-year line will be used along with a calculated.

The Drainage Basin Area (A) is calculated from the total area within the watershed boundaries delineated in Exhibit XX.

The Time of Concentration (TC) will be calculated per section "A.1.4 Time of Concentration" of the DDM. Since this project is located in an urban drainage system, the time of concentration can be expressed using the following formula:

$$T_C = T_i + T_t$$

Where:

- T_C = Time of Concentration (hours)
- T_i = Inlet Time (hours)
- T_t = Travel Time (hours)

The Inlet Time (T_i) will be calculated using the formula provided in "Figure A-4 Rational Method Formula – Overland Time of Flow Nomograph" of the DDM. The Inlet Time can be expressed using the following formula:

$$T_i = \frac{1.8 \times (1.1 - C) \times \sqrt{D}}{\sqrt[3]{s}}$$

Where:

- T_i = Inlet Time (hours)
- C = Runoff Coefficient (weighted) [unitless]
- D = Watercourse Distance (also known as Length of Longest Path) [feet]
- s = Slope (%)

The Travel Time (T_t) will be calculated using the description from section "A.1.4 Time of Concentration" of the DDM. The Inlet Time can be expressed using the following formula:

$$T_t = \frac{L}{V}$$

Where:

- T_t = Travel Time (hours)
- L = Length of Storm Drain Segment (ft)
- V = Flow Velocity inside Storm Drain (ft/s)

The Flow Velocity (V) will be calculated from the flow capacity of each individual pipe segment. The flow capacity will be calculated per section "4.2.3 Storm Drain Analysis – Uniform Flow" and "Equation 4-3 Uniform Flow Equation" of the DDM. Then, flow velocity will be derived from the calculated flow rate using the following formula:

$$V = \frac{Q}{A}$$

Where:

- V = Flow Velocity inside Storm Drain (ft/s)
- Q= Flow Rate (cubic feet per second)
- A = Drainage Basin Area (acres)

Methodology 3: Storm drain pipe design

The Flow Capacity ($Q_{Capacity}$) will be calculated per section "4.2.3 Storm Drain Analysis–Uniform Flow" and "Equation 4-3 Uniform Flow Equation" of the DDM. The flow capacity can be expressed using the Uniform Flow Equation given as follows:

$$Q_{Capacity} = \frac{1.49}{n} \times A \times R^{2/3} \times S_f^{1/2}$$

Where:

- ❖ $Q_{Capacity}$ = Flow Capacity (ft^3/s)
- ❖ n = Manning Roughness Coefficient (unitless)
- ❖ A = Cross-Sectional Area of the Flow (ft_2)
- ❖ R = Hydraulic Radius (ft)
- ❖ S_f = Slope of Storm Drain (unitless)

The Manning Roughness Coefficient (n) will be found from "Table C-2 Average Manning Roughness Coefficients for Closed Conduits" of the DDM.

The Cross-Sectional Area (A) will be calculated per "Equation 4-4 Simplified Flow Area and Hydraulic Radius for Circular Pipe" of the DDM. A full-flow condition will be used for the cross-sectional area of the pipe since this analysis is interested in comparing the full capacity of the proposed storm drain system. The formula for the cross-sectional area of the flow is given as

follows:

$$A = \frac{\pi D^2}{4}$$

Where:

- ❖ D = Pipe Diameter (inches)

The Hydraulic Radius (R) will also be calculated per "Equation 4-4 Simplified Flow Area and Hydraulic Radius for Circular Pipe" of the DDM and will similarly be calculated from a full-flow condition. The formula for the hydraulic radius is given as follows:

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

Where:

D = Pipe Diameter (inches)

Methodology 4: Storm drain inlet design

From Exhibit XX, it can be seen that the proposed storm drain inlet for this storm drain is located at the lowest elevation on La Jolla Farms Road within the project area. This means that water will flow into the inlet from both sides. Per section "3.2.2.2 Curb Inlets in Sag" of the DDM, this is considered an inlet in "sag" condition. The design for an inlet in sag can be analyzed using "Equation 3-3 Shallow Depth Weir" and "Equation 3-4 Higher Flow Depth Curb Inlet" of the DDM. The goal of these equations is to solve for the length of the inlet opening (L). When the length of the inlet opening is solved for, one length value will be provided from each equation and the larger of the two lengths will be used for the proposed design. "Equation 3-3 Shallow Depth Weir" can be expressed as:

$$L_w = \frac{Q}{C_w d^{3/2}}$$

Where:

- L_W = Weir Length (ft)
- Q = Inlet Capacity (ft^3/s)
- C_W = Weir Discharge Coefficient (unitless)
- d = Flow Depth (ft)

The inlet capacity (Q) is calculated in methodology 1.

The weir discharge coefficient (CW) will be taken from "Table 3-1 Weir Discharge Coefficients for Inlets in Sag Locations" of the DDM.

The flow depth (d) will be found from "Figure 3-2 Gutter and Roadway Discharge-Velocity Chart (6" Curb)" of the DDM.

"Equation 3-4 Higher Flow Depth Curb Inlet" can be expressed as:

$$L_W = \frac{Q}{0.67 \times h \times \sqrt{2 \times g \times d_o}}$$

Where:

- Q = Inlet Capacity (ft_3/s)
- h = curb opening height (ft)
- g = gravitational acceleration (ft/s^2)
- d_o = effective depth of flow at curb face (ft)

The inlet capacity (Q) is calculated in methodology 1.

The curb opening height (h) can be found from "SDD-116 Curb Inlet – Type B" of "The City of San Diego Standard Drawings for Public Works Construction, 2018 Edition". Per section "3.1.2.3 Standard Drawing Types" of the DDM, Type B Curb Inlets (as shown by "SDD-116 Curb Inlet – Type B") are to be used as the basic inlet to intercept street drainage.

The gravitation acceleration (g) is given from "Equation 3-4 Higher Flow Depth Curb Inlet" as 32.2 ft/s^2.

The effective depth of flow at curb face (d_o) can be calculated from "Equation 3-5 Effective Depth of Flow at Curb Face" of the DDM:

$$d_o = (y + a) - \frac{h}{2}\sin\theta$$

Where:

- d_o = Effective Depth of Flow at Curb Face (ft)
- y = Depth of Flow in Adjacent Gutter (ft)
- a = Curb Inlet Depression (ft)
- $\frac{1}{2}h\sin\theta$ = Adjustment for curb inlet throat width and angle of throat incline

The depth of flow in adjacent gutter (y) will be found from "Figure 3-2 Gutter and Roadway Discharge-Velocity Chart (6" Curb)" of the DDM.

The curb inlet depression (a) is given in the explanation of "Equation 3-2 Gutter and Roadway Discharge-Velocity Chart (6" Curb)" of the DDM as 0.33.

The adjustment for curb inlet throat width and angle of throat incline ($\frac{1}{2}h\sin\theta$) is given in the explanation of "Equation 3-5 Effective Depth of Flow at Curb Face" of the DDM as 0.26 ft.

Methodology 5: Storm drain energy dissipater

The storm drain concrete dissipater will be designed per "SDD-105 Concrete Energy Dissipater" of "The City of San Diego Standard Drawings for Public Works Construction, 2018 Edition".

Project Data

Drainage Basin

Length of Path (D)	315
Elevation of High Point	280
Elevation of Low Point	240
Slope (%)	12.70

Hydraulics Analysis Conclusions

Conclusion 1: Total storm water flow from the surrounding watersheds

From the design criteria laid out in the DDM, in use with the Rational Method that the DDM provides, it was determined that the total storm water flow from the surrounding watersheds (Q_{Actual}) into the storm drain system was equal to 1.82 ft^3/s.

Conclusion 2: Storm drain pipe design

From the design criteria laid out in the DDM, in use with the Uniform Flow Equation that the DDM provides, it was determined that the total capacity ($Q_{capacity}$) of flow that this storm drain pipe can handle was equal to 53.91 for the area of the storm drain pipe. Since each of these flow capacities are greater than the total storm water flow from the surrounding watersheds ($Q_{Capacity}>Q_{Actual}$), it can be concluded that this storm drain pipe design is appropriate.

Conclusion 3: Storm drain inlet design

From the design criteria laid out in the DDM, in use with the curb inlet equations that the DDM provides, as well as the design criteria laid out in "The City of San Diego Standard Drawings for Public Works Construction, 2018 Edition", it was determined that the curb inlet length (L) for the proposed storm drain inlet was equal to 8 ft. Since this storm drain inlet was designed using the total flowrate from the drainage basin adjacent to it, it can be concluded that this storm drain inlet design is appropriate.

Conclusion 4: Storm drain energy dissipater design

For the proposed 18-inch storm drain pipe, the chart shown in SDD-105 of "The City of San Diego Standard Drawings for Public Works Construction, 2018 Edition" notes that the max flow rate that this design is acceptable for is 21 ft^3/s. Since it has been shown earlier that the total stormflow from the surrounding watersheds is 1.82 ft^3/s, which is less than 21 ft^3/s, it can be concluded that this concrete energy dissipater design is appropriate.

<u>2.2 Hydraulics Analysis Calculations</u>

In this section the calculations will be shown for how the proposed storm drain was designed.

Calculation 1: Total storm water flow from the surrounding watershed

Total storm water flow from the surrounding watershed = Q Actual

Q Actual = C * I * A

Need to find C, I, and A.

<u>Calculate C:</u>

From "Table A-1 Runoff Coefficients for Rational Method" of the DDM, this project is composed of the following land uses:

Residential: Single Family (C = 0.55)
Industrial: 90% Impervious (C = 0.95) – this is for the sidewalk and street pavement

From Hydrology Map, the basin areas and impervious area can be found. The total area of Basin is 1.21 acres. The total area of the impervious area in Basin is 0.39 acres. The boundary share is the center of the impervious street.
Therefore, the impervious area within Basin, separately, is: 0.82 acres

To find the weighted C, the following steps are taken:

Area Basin, Single Family = 1.21 acres – 0.39 acres =0.82 acres
Area Basin, 95% Impervious = 0.39 acres

C Basin = (0.82 acres ∗ 0.55) + (0.39 acres ∗ 0.95)/1.21 acers = **0.68**

<u>Calculate I:</u>

Need to find TC in order to use "Figure A-1 Intensity-Duration-Frequency Design Chart" of the DDM to find I.

$T_C = T_i + T_t$

Need to find T_i and T_t

Calculate T_i:

$$T_i = \frac{1.8 \times (1.1 - C) \times \sqrt{D}}{\sqrt[3]{S}}$$

S (Slope) = Δ Elevation / Δ Distance

From the topography lines shown – Hydrology Map:

Slope of Longest Path Basin1 = (280 ft − 240 ft) / (315 ft) * 100 =12.70%

$$T_i = \frac{1.8 \times (1.1 - C) \times \sqrt{D}}{\sqrt[3]{s}} = \frac{1.8 \times (1.1 - 0.68) \times \sqrt{315}}{\sqrt[3]{12.7}} = 5.77\ Min = 0.0961\ Hr$$

Calculate T_t:

$$T_t = \frac{L}{V}$$

From the profile shown in Exhibit A – Proposed Project Plans, it can be observed that there is one segment for the storm drain pipe. The travel time for the basin (T_t) calculated and Time of Travel for the entire storm drain (T_t Storm Drain Total).

From Exhibit C-Proposed Project Plans:

L Segment = 315 ft

Need to find V for pipe segment.

V = Q/A

Where:
V = Flow Velocity inside Storm Drain (ft/s)
Q = Capacity of each pipe segment (ft^3/s)
A = cross-sectional area of each pipe segment (ft^2)

Need to find Q and A for each segment.

Calculate A:

Each pipe segment is 18-inch RCP, therefore each segment will have the same cross-sectional area.

$$A = \frac{\pi D^2}{4} = \frac{\pi \left(\frac{18}{12}\right)^2}{4} = 1.767\ ft^2$$

Calculate R:

$$R = \frac{D}{4} = \frac{(\frac{18}{12})}{4} = 0.375$$

From Exhibit C-Proposed Project Plans:
S_f =22.60%

Calculate Q:

$$Q = \frac{1.49}{n} \times A \times R^{2/3} \times S_f^{1/2} = \frac{1.49}{0.013} \times 1.21 \times 0.375^{2/3} \times \sqrt{0.262} = 53.91\ ^{ft^3}/_{s}$$

From “Table C-2 Average Manning Roughness Coefficients for Closed Conduits” of the DDM, a manning roughness (n) value of 0.013 will be selected because the pipe material of the storm drain is RCP.

Therefore:

$$V = \frac{Q}{A} = \frac{53.91}{1.767} = 30.50\ ^{ft}/_{s}$$

Therefore:

$$T_t = \frac{L}{V} = \frac{192}{30.50} = 6.29\ Sec = 0.00175\ hr$$

Therefore:

$T_C = T_i + T_t = 0.0961 + 0.00175 = 0.09785\ Hr$

Now, from using T_C and “Figure A-1 Intensity-Duration-Frequency Design Chart” of the DDM:
Basin = 4 **inches per hour**

Calculate A:

From Exhibit D – Hydrology Map:
Area Basin 1 = **1.21 acres**

Calculate Q:
Q = C * I * A
$Q = C.I.A = 0.68 * \left(4 \frac{Inch}{hour} * \frac{1\ ft}{12\ Inches}\right) * \left(1.21\ Acre\ \frac{43{,}560\ ft^2}{1\ Acre}\right) = 1.82\ ^{ft^3}/_{s}$

Calculation 2: Storm drain pipe design

To know if storm drain pipe design is appropriate, the flow capacity ($Q_{Capacity}$) of the pipe must be calculated.

$$Q_{Capacity} = \frac{1.49}{n} \times A \times R^{\frac{2}{3}} \times S_f^{\frac{1}{2}}$$

Must find n, A, R, and S_f.

Calculate n:
From "Table C-2 Average Manning Roughness Coefficients for Closed Conduits" of the DDM, a manning roughness (n) value of 0.013 will be selected because the pipe material of the storm drain is RCP.

Calculate A:
Each pipe segment is 18-inch RCP, therefore each segment will have the same cross-sectional area (A).

$$A = \frac{\pi D^2}{4} = \frac{\pi \left(\frac{18}{12}\right)^2}{4} = 1.767\ ft^2$$

Calculate R:
Each pipe segment is 18-inch RCP, therefore each segment will have the same hydraulic radius (R).

$$R = \frac{D}{4} = \frac{(\frac{18}{12})}{4} = 0.375$$

<u>Calculate Sf:</u>
From Exhibit C – Proposed Project Plans:
S_f = 22.60%
Calculate Q:

$$Q_{Capacity} = \frac{1.49}{n} \times A \times R^{2/3} \times S_f^{1/2} = \frac{1.49}{0.013} \times 1.21 \times 0.375^{2/3} \times \sqrt{0.262} = 53.91\ {ft^3}/{s}$$

Calculation 3: Storm drain inlet design
To know if storm drain pipe inlet design is appropriate, the length of inlet opening (L) must be calculated using the total storm water flow from the surrounding watershed (Q_{Actual}). The larger of the lengths calculated between "Equation 3-3 Shallow Depth Weir" and "Equation 3-4 Higher Flow Depth Curb Inlet" of the DDM will be used for the proposed inlet design.
Calculate "Equation 3-3 Shallow Depth Weir":

$$L_w = \frac{Q}{C_w d^{3/2}}$$

Must find Q, d, and C_W.
Calculate Q:
Q = Q_{Basin} = **1.82 ft^3/s**

Calculate d:

For this proposed storm drain inlet, a 6 inch curb will be used. Therefore, “Figure 3-2 Gutter and Roadway Discharge-Velocity Chart (6” Curb)” of the DDM can be used to find the flow depth (d). To use this figure, discharge and street slope must be known.
Discharge = Q_{Basin} = 1.82 ft^3/s

Street Slope can be found from Exhibit E – Roseview Place - From this exhibit, it can be seen that the slope near the proposed inlet is 22.6%.

Average Street Slope = 12.70%

Therefore, using “Figure 3-2 Gutter and Roadway Discharge-Velocity Chart (6” Curb)” of the DDM, it can be seen that the flow depth (d) = **0.27 ft**.

Calculate C_W:
Per “Table 3-1 Weir Discharge Coefficients for Inlets in Sag Locations” of the DDM, the flow depth (d) and the curb opening height (h) must be known in order to choose an inlet type. Must find d and h.
d = 0.27 ft

From “SDD-116 Curb Inlet - Type B” of “The City of San Diego Standard Drawings for Public Works Construction, 2018 Edition”, h = **0.4 ft**.
Therefore, since d = 0.27 ft and h = 0.4 ft, d < h. Now, using “Table 3-1 Weir Discharge Coefficients for Inlets in Sag Locations” of the DDM, the “Inlet Type” can be selected as “Curb Opening” since d < h satisfies the “Equation Valid” column of the table. Therefore, it is given that C_W = **3.00**.

Calculate L_W:

$$L_w = \frac{Q}{C_w d^{3/2}} = \frac{1.82}{3 * 0.27^{3/2}} = 4.33\, ft$$

The inlet length will be rounded up to **5.00 ft** for practical construction.

Calculate “Equation 3-3 Shallow Depth Weir”:

$$L_W = \frac{Q}{0.67 \times h \times \sqrt{2 \times g \times d_o}}$$

Must find Q, h, g, and d0.

Calculate Q:

Q = Q Basin = **1.82 ft^3/s**

Calculate h:

The curb opening height (h) can be found from SDD-116 of "The City of San Diego Standard Drawings for Public Works Construction, 2018 Edition" as h = **0.4 ft**.

Calculate g:
The gravitation acceleration (g) is given from "Equation 3-4 Higher Flow Depth Curb Inlet" as **32.2 ft/s^2**.

Calculate d_0:

$$d_o = (y + a) - \frac{h}{2}\sin\theta$$

Need to find y, a, h

Calculate y:
The depth of flow in adjacent gutter (y) is equivalent to the depth of flow (d) that was previous found using "Figure 3-2 Gutter and Roadway Discharge-Velocity Chart (6" Curb)" of the DDM. Therefore:
y = d = **0.27 ft**

Calculate a:
The curb inlet depression (a) is given in the explanation of "Equation 3-2 Capacity of Curb Inlet" in the DDM as **0.33 ft**.

Calculate h/2 * 2sinθ:
The adjustment for curb inlet throat width and angle of throat incline (h/2 * sinθ) is given in the explanation of "Equation 3-5 Effective Depth of Flow at Curb Face" of the DDM as **0.26 ft**.
Therefore:

$$d_o = (y + a) - \frac{h}{2}\sin\theta = (0.27 + 0.33) - 0.26 = \mathbf{0.34}\ ft$$

Calculate L:

$$L_W = \frac{Q}{0.67 \times h \times \sqrt{2 \times g \times d_o}} = \frac{1.82}{0.67 \times 0.4 \times \sqrt{2 \times 32.2 \times 0.34}} = 1.45\ ft$$

The inlet length will be rounded up to **2.00 ft** for practical construction.
Since "Equation 3-3 Shallow Depth Weir" of the DDM calculated an inlet length of 5.0 ft and "Equation 3-4 Higher Flow Depth Curb Inlet" of the DDM calculated an inlet length of 2.0 ft, the larger value of 5.0 ft will be used for the proposed inlet design.

Calculation 4: Storm drain energy dissipater design
Given that this proposed storm drain has a pipe diameter of 18inchs, the chart for "SDD-105 Concrete Energy Dissipater" of "The City of San Diego Standard Drawings for Public Works Construction, 2018 Edition" will indicate what dimensions are to be used for the design of the concrete energy dissipater.

References

City of San Diego Drainage Design Manual, January 2017 Edition

City of San Diego Standard Drawings for Public Works Construction, 2018 Edition

Exhibits

See following sheets for exhibits.

Exhibit A – Location Map

Exhibit B – Proposed Project Plans Location Map

Exhibit C – Hydrology Map