

TECHNICAL REPORT

CONNECTOR PIPE SCREEN DESIGN

FULL CAPTURE TMDL COMPLIANCE
SCREEN AND BYPASS SIZING REQUIREMENTS



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**COUNTY OF LOS ANGELES
DEPARTMENT OF PUBLIC WORKS**

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I. Purpose and Scope

The intent of this report is to establish a conservative sizing criterion for connector pipe screens (CPS) to comply with the Ballona Creek and Los Angeles River Trash Total Maximum Daily Load (Trash TMDL) full capture standard while maintaining the existing level of flood protection for Los Angeles County Flood Control District (LACFCD) facilities.

II. Abstract

CPS devices are vertically oriented screens installed inside a catch basin (CB), directly upstream of the connector pipe as shown in Figure 1. Connector Pipe Screens are fabricated from 5mm mesh screen and are designed to comply with the Regional Water Quality Control Board's (RWQCB) definition of a full capture system.

Engineers from the County of Los Angeles Department of Public Works (Public Works) performed hydrologic analysis to establish a method of calculating the maximum treatment flow resulting from a one-year, one-hour storm. Using this information, they performed hydraulic analyses to establish minimum sizing requirements for the CPS screen. Public Works engineers also established minimum sizes for the bypass opening, which provides flood protection during large storm events.



Figure 1: CPS inside catch basin

III. Background

Public Works has been given the responsibility to bring its flood control facilities into compliance with the TMDLs established by the RWQCB. Public Works has undertaken an aggressive testing program to find devices that may be used to retrofit existing flood control infrastructure. Potential devices are tested for their ability to meet the TMDL requirements and to ensure that they do not reduce flood control protection. As defined by the RWQCB, the standard for full-capture status is the following:

Compliance with the final Waste Load Allocation may be achieved through a full capture system; which is defined as any device or series of devices that traps all particles retained by a 5mm mesh screen and has a design treatment capacity of not less than the peak flow rate (Q) resulting from a one-year, one-hour storm in the sub-drainage area.
(CA RWQCB TENTATIVE RESOLUTION NO. 07-0XX, Sec. 12, page 3, July 12, 2007)

A CPS is a vertical screen with 5 mm openings, installed inside a catch basin directly upstream of the connector pipe in such a manner that all water entering the basin must pass through the device. A vertical opening is provided around the perimeter of the screen to allow storm water to bypass in the event of a large storm or if the screen becomes clogged. Connector Pipe Screens are currently manufactured and installed by Advanced Solutions (Stormtek) and American Storm Water (Debris Dam).

IV. Hydrology Study

Since the majority of LACFCD facilities are designed for a 10-year design storm frequency (Q_{10}), the calculations in this report will design the CPS for a CB designed with a 10-year storm frequency.

In order to determine the 1-year 1-hour TMDL flow, we need to establish a conservative conversion factor, k , from a 10-year storm, Q_{10} , to a TMDL flow (Q_{1-1}) as shown in Equation 1.

Equation 1:
$$Q_{1-1} \leq k \cdot Q_{10}$$

To develop this conversion factor (k), we first compared storm frequency ratios. This involved comparing the magnitude of one 24-hour storm frequency with another 24-hour storm frequency. The results of this analysis are shown in Table 1 as a ratio used to convert one storm frequency to another based only on the 24-hour isohyetal values for different storm frequencies. The ratios are consistent with the ratios provided in the Los Angeles County 2006 Hydrology Manual¹ for scaling storm frequencies.

Storm Frequency Conversion Factor ($Q_x \cdot k = Q_{1-1}$)					
	2-yr	5-yr	10-yr	25-yr	50-yr
k	0.413	0.274	0.224	0.182	0.160

Table 1: Storm frequency conversion factors based on rainfall frequencies

Based on the conversion of storm frequencies, a value of $k = 0.224$ would be appropriate for use in the conversion. However, this value does not take into account the changes to runoff that occur due to changes in infiltration rates and times of concentration.

To better quantify these hydrologic effects, we used the Time of Concentration Calculator² to model over 360,000 different hydrologic scenarios of varying storm frequencies and watershed characteristics. Table 2 shows the values used for the 1-year vs. 10-year flow comparisons.

Watershed Parameter	Values Used
Lengths	1000, 1500, 2000
Area	1 and 10 acres
Soils	2 through 180
Slope	0.01, 0.05, 0.08, 0.10, 0.15, 0.20
Imperviousness	0.15, 0.45, 0.95
10-yr Isohyets	1, 2, 4, 6, 8, 10, 12
Possible Combinations	90,216

Table 2: Runoff analyses variables for 1-yr vs. 10-yr

¹ Available from the Public Works website at <http://www.ladpw.org/wrd/publication/>

² An Excel spreadsheet available from the Public Works website at <http://www.ladpw.org/wrd/publication/>

Hydrologic modeling using the modified rational method provided insight into the combined effects of watershed characteristics on the runoff ratios. The maximum runoff ratio measured in the extensive testing is being used for the k factor. Table 3 contains the maximum value selected for k based on these studies.

Statistics	1-yr/2-yr	1-yr/5-yr	1-yr/10-yr	1-yr/25-yr	1-yr/50-yr
Maximum	0.3023	0.2021	0.1646	0.1345	0.1167
Count	67,662	67,662	90,216	67,662	67,662

Table 3. Statistics of Runoff Frequency Ratios Based on Modified Rational Modeling

Figure 2 is provided to show the probability distributions of the runoff ratios generated during the testing.

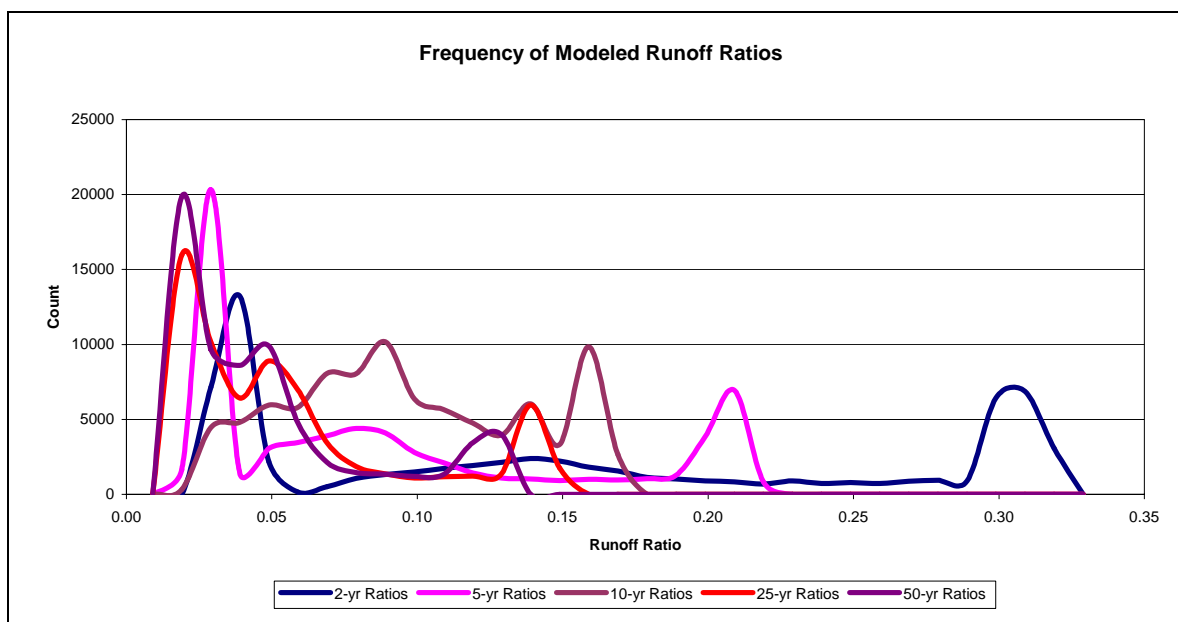


Figure 2. Frequency of runoff ratios resulting from modified rational modeling

Based on a comparison of Table 1 and 3, k values from Table 1 have been verified to be a very conservative values for converting an n -year frequency storm to a 1-year frequency storm. A 10-year frequency storm conversion is shown in Equation 2.

Equation 2:
$$Q_{1-1} \leq 0.22 \cdot Q_{10}$$

This k value will be a conservative assumption that compensates for different land uses, soil types, areas, slopes, isohyets, and travel path lengths.

In most cases of the CPS design, the bypass flow requirements will govern the design, and the screen capacity will be more than adequate to pass the Q_{1-1} flow. Currently, LACFCD is not installing BMP devices on deficient systems (5 year frequency capacity and less) due to uncertainty of flooding risk and maintenance liability.

V. Catch Basin Flow

A conservative (i.e. maximum) estimate of catch basin flows based on curb opening widths must be determined in order to calculate the Q_{1-1} . The bypass structure must also be able to pass the maximum catch basin flow in order to provide proper flood protection.

Two parameters of catch basin flow (curb flow depth and street slope) must be conservatively assumed in order to calculate the design flow into a catch basin. Based on the LACFCD Hydraulic Manual³ (Chart D-10D), the street slope does not have a large impact on side-opening catch basin flow, as shown in Table 4 and Figure 3.

Street Width (ft)	Street Slope (ft/ft)			
	0.005	0.01	0.03	0.05
3.5	3.7	4	4.3	4.6
7	7.3	7.8	8.4	9
10	10.1	11	11.9	12.7
14	13.7	14.9	16	17.2
21	18.7	20.7	22.6	24.3
28	23	25.5	27.8	30.1

Table 4: Catch basin flow (cfs) for various street slopes
(depth of flow = 8", local depression=2")

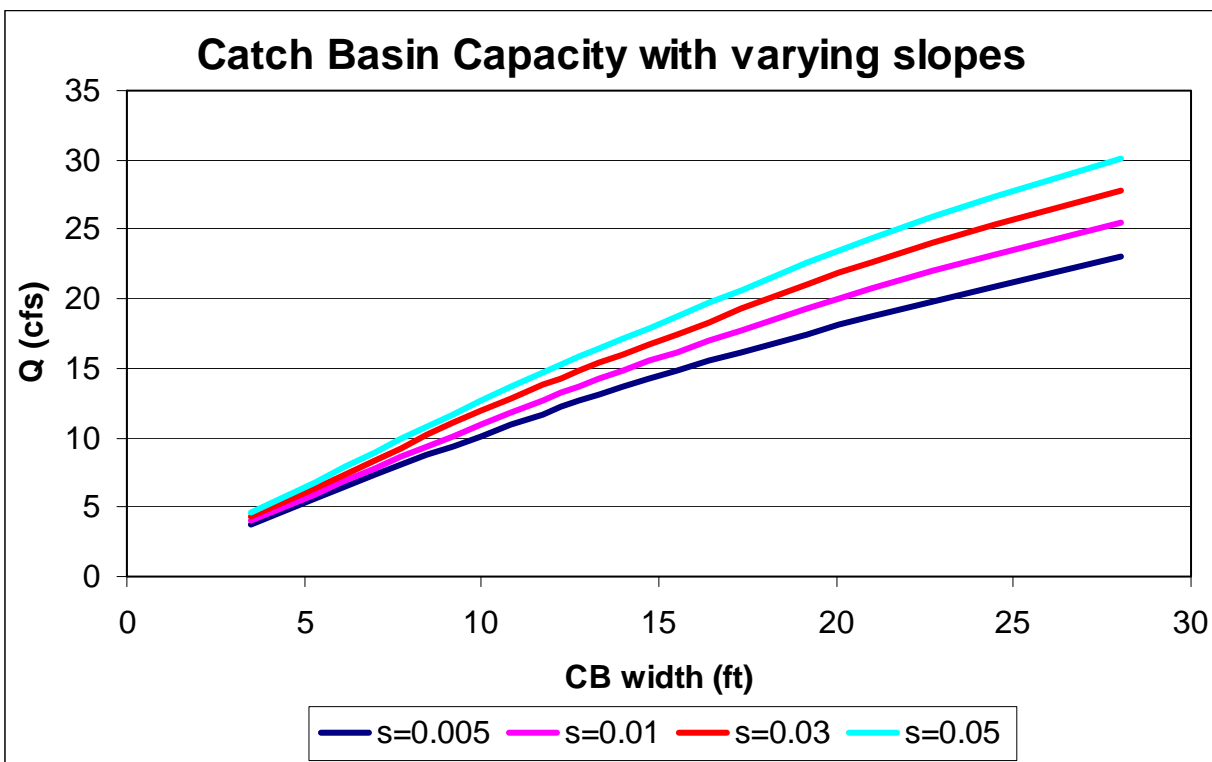


Figure 3: Catch basin flow for various street slopes

³ Available for download at http://www.ladpw.org/wrd/publication/Engineering/design_manual.pdf

Street Slope

Although street slope does not have a major impact on CB flows, flows do increase slightly as the slope increases. Curb opening catch basins are not installed on slopes larger than 0.04, so a slope of 0.04 can be assumed to be the maximum slope

Local Depression

The local depression will also impact the flow to the catch basin up to 25%. However, the vast majority of Public Works catch basins have a local depression of 2 inches, so 2 inches will be used in this study.

Curb Flow Depth

A depth of 6-inches can be assumed to be a conservative value for the depth of flow. A depth of flow of 8-inches (up to the curb height) would be very unlikely, especially on a steeply inclined street (slope ≥ 0.04).

Analysis Parameters

In summary, the criteria used for the hydraulic analysis of catch basins was:

Basin type: Side Opening Catch Basin (SPPWC Standard Plan 300)

Depth of flow: 6"

Street slope: 0.04 ft/ft

Local depression: 2"

Results for the maximum flow for different catch basins of various widths are shown in the center column of Table 5. Using Equation 2, we can calculate the Q_{1-1} for catch basins of various widths as shown in the right column of Table 5.

CB width (ft)	Max Q_{10} (cfs)	Max Q_{1-1} (cfs)
3.5	2.8	0.6
7	5.3	1.2
10	7.5	1.7
14	10.0	2.2
21	13.9	3.1
28	17.3	3.8

Table 5: Maximum Q_{1-1} flow

VI. Screen Flow Calculations

To calculate the loss in hydraulic head and flow through the CPS screen, we used an orifice equation to determine the theoretic flow rate. See Figure 4.

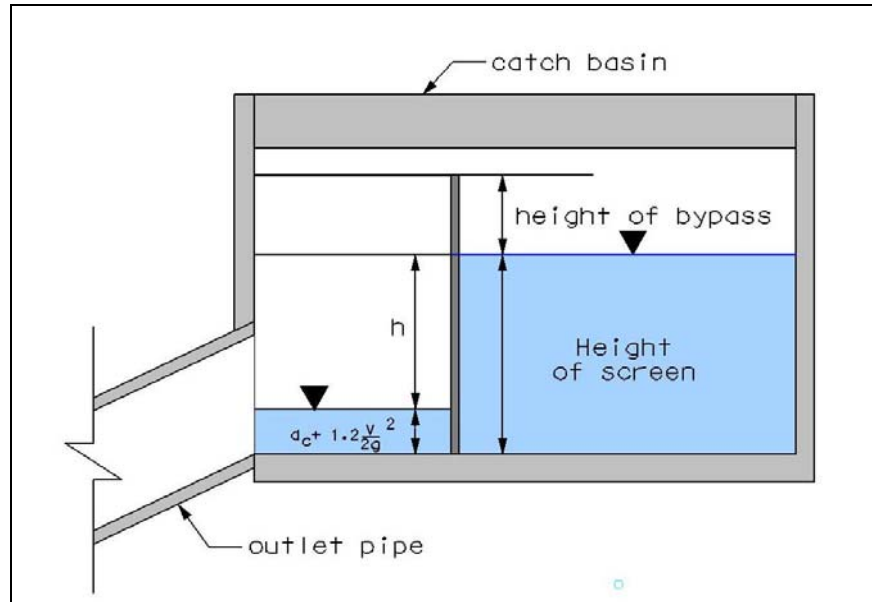


Figure 4: Catch basin profile

Equation 3:
$$Q_{screen} = cA_{screen}\sqrt{2gh}$$

The flow through the screen is a function of the open area (A) of the screen and the differential head between the upstream and downstream side of the screen, h . The orifice coefficient, c , is an empirically determined constant which accounts for friction and turbulence at the orifice. This coefficient is unique to each orifice geometry, and was established in our hydraulic laboratory at the San Gabriel Dam (See Section VII).

Since Q_{1-1} flows are small relative to design flows and most connector pipes have steep slopes (>0.10) and therefore supercritical flow, critical depth and critical velocity losses can be assumed to be a conservative approximation of the water depth on the downstream face of the screen. The velocity head multiplier (1.2) in Equation 4 is the loss encountered at the entrance of the connector pipe per the LACFCD hydraulic manual.

Equation 4:
$$\text{Downstream depth } (D_d) = d_c + 1.2 \frac{V^2}{2g}$$

To find the flow through the screen, Equations 3 and 4 must be solved simultaneously using an iterative process since the critical depth is a function of the flow passing through the screen.

VII. Field Testing

Due to the fact that orifice conditions for the screen holes differ substantially from the conditions used to determine the standard orifice coefficients, Design Division performed field tests at the San Gabriel Dam catch basin testing facility (Figure 5) in order to determine the coefficient c_{screen} for Equation 3. Figure 6 and Table 6 present results of the field-testing data.



Figure 5: CPS Testing

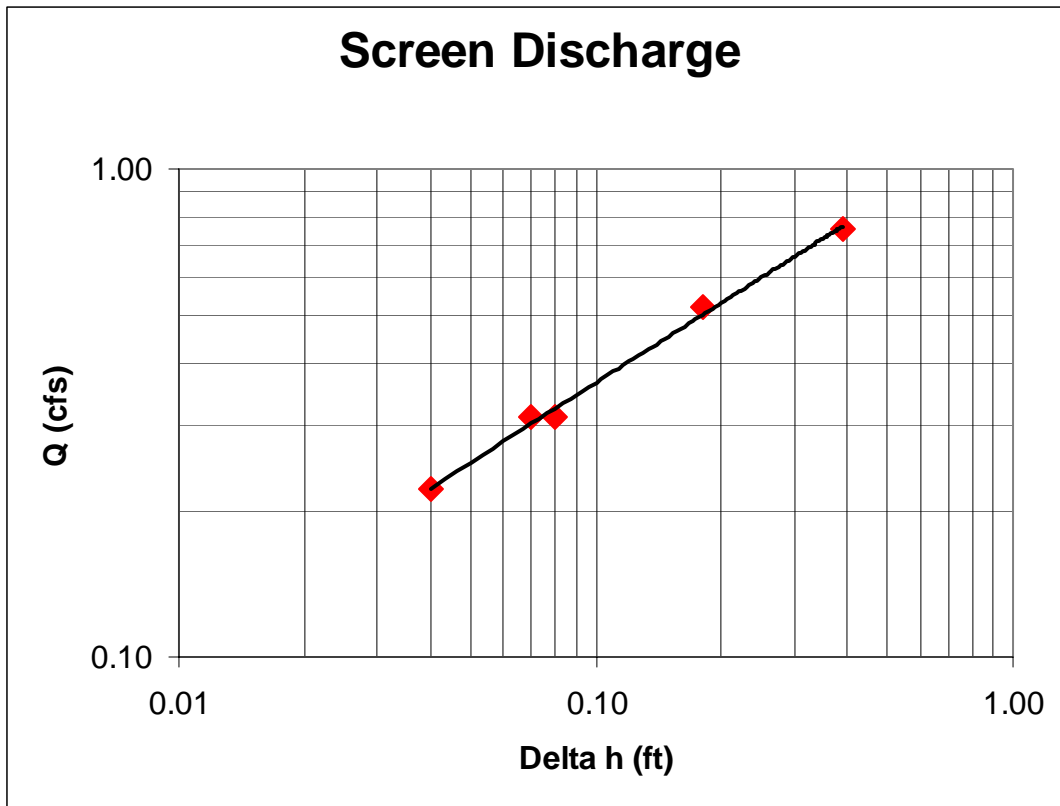


Figure 6: Field test data

Run	Q (cfs)	U/S screen depth (ft)	D/S screen depth (ft)	h (ft)	Area (ft ²)	Orifice coefficient, c
1	0.31	1.62	1.55	0.07	0.228	0.640
2	0.52	1.80	1.62	0.18	0.253	0.603
3	0.75	2.00	1.61	0.39	0.282	0.532
4	0.22	1.61	1.57	0.04	0.248	0.553
5	0.31	1.67	1.59	0.08	0.257	0.531
Average c_{screen}						0.572

Table 6: Field test data

Figure 6 shows that there is clearly a relationship between Q and h, which confirms that Equation 3 is applicable. The varying values for c_{screen} in Table 6 can be attributed to debris lodged in the screen, which is difficult to measure. Even the slightest change in area can drastically impact the c_{screen} coefficient. We will use the smallest, most conservative value, $c_{screen} = 0.53$, in our calculations.

VIII. Bypass Flow Calculations

For the bypass flow calculation, an orifice equation can also be used. A weir equation can be used but since the maximum water depth will be above the bypass area, an orifice equation is more appropriate (See Equation 5). The maximum depth of flow can be assumed to be anywhere between the flow line or 6-inches below the flow line. Figure 7 shows this situation more clearly.

Equation 5:
$$Q_{bypass} = c_{bypass} A_{bypass} \sqrt{2gH}$$

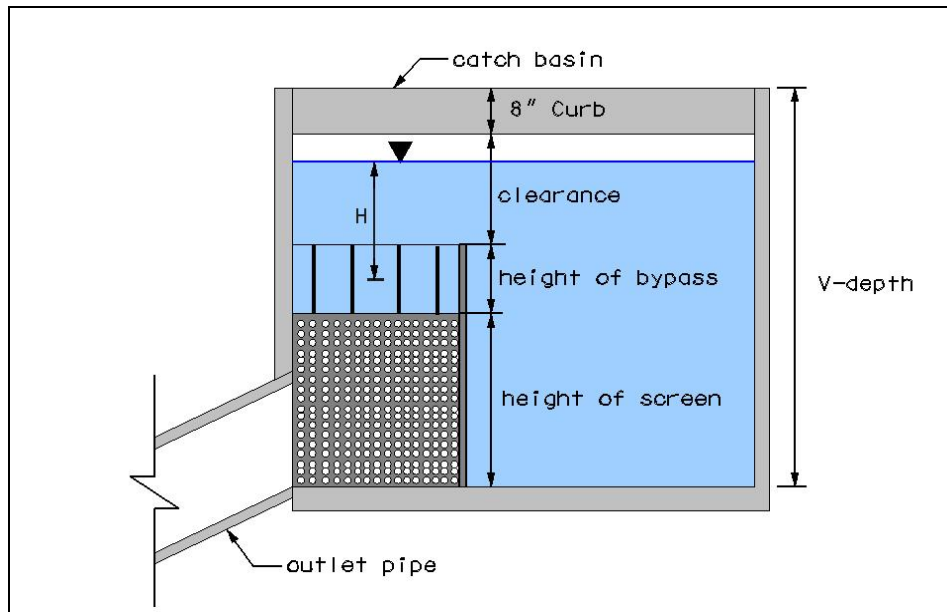


Figure 7. Catch Basin with screen and bypass with zero freeboard.

As part of our retrofit program, Public Works is also intending to use automatic retractable screens (ARS) to further limit trash entering the catch basin. A minimum clearance of 4-inches is required between the top of the bypass and the flow line due to physical restrictions from the ARS See Figure 8.



Figure 8. Minimum clearance due to ARS

IX. Results

The bypass height (H_{bypass}) and length (L) requirements to pass the design flow were first established. With a given bypass height, a height for the screen can be calculated using the remaining depth of the catch basin while ensuring the minimum 6-inch clearance between the flow line and top of the bypass structure. The required length (as shown in Figure 9) of the bypass will be the same length for the screen. The screen capacity was calculated to ensure that the height and length of the screen will pass the Q_{1-1} flow. The freeboard was encroached when necessary.

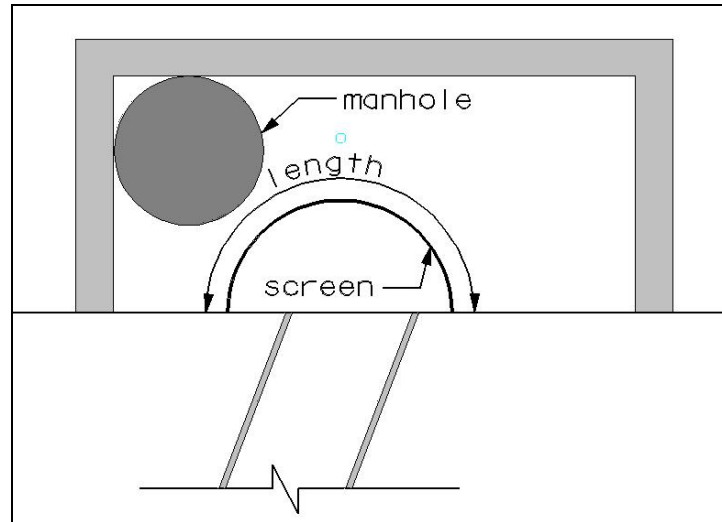


Figure 9: Plan view of catch basin

The following assumptions are made in these calculations:

Screen Clogged % = 50% (conservative assumption from observation)

Open area of screen = 44% (area open for a Stormwater screen, min. area open)

Example Calculation

For V depth = 3.5', CB Width = 3.5', $Q_{10} = 2.8$ cfs, $Q_{1-1} = 0.6$ cfs,
assume $H_{bypass} = 6''$, $H_{screen} = 18''$

Check Clearance:

$$= V\text{-depth} - H_{screen} - H_{bypass} - \text{curb height}$$

$$= 3.5' - 1.5' - 0.5' - 8/12' = 10 \text{ inches clearance to flow line} > \text{min. } 4''$$

Size Bypass Using Equation 5, $Q_{bypass} = c_{bypass} A_{bypass} \sqrt{2gH} = c_{bypass} H_{bypass} L \sqrt{2gH}$

$H_{bypass} = 6$ inches, with $c_{bypass} = 0.6$, $g = 32.2$,

$$H = \frac{H_{bypass}}{2} + 10'' - 6'' \text{ freeboard}$$

$$= \frac{6''}{2} + 10'' - 6'' = 7''$$

$$Q_{bypass} = c_{bypass} H_{bypass} L \sqrt{2gH}$$

$$2.8 = 0.6 \times 0.5' \times L \sqrt{2 \times 32.2 \times 7 / 12}$$

$$L = 1.52 \text{ feet}$$

Then using Equation 3, the screen area can be checked to see if it can pass the Q_{1-1} . Based on a $L=1.53$ feet and a height of 1.5 feet, the screen can pass 1.5 cfs which is greater than the 0.6 cfs it needs to pass, thus the dimensions are satisfactory.

The following Table 7 provides an example of sizing recommendations for screen and bypass heights and lengths for a V-depth of 3.5 feet. To use this table, a designer would find the row corresponding to the CB width, and would then size a screen that met the minimum height and length.

"V-depth" (ft)	CB Width (ft)	Max Q_{10} (cfs)	Bypass Height (in)	Free-board (in)	Screen Height (in)	Q_{1-1} (cfs)	Clearance (in)	Screen Length (ft)	Screen Capacity (cfs)
3.5	3.5	2.8	6.0	6.0	18	0.6	10.00	1.5	1.5
3.5	7	5.3	6.0	6.0	18	1.2	10.00	2.9	2.9
3.5	10	7.5	6.0	5.0	18	1.7	10.00	3.8	3.8
3.5	14	10.0	8.0	0.0	18	2.2	8.00	3.1	3.1
3.5	21	13.9	8.0	0.0	18	3.1	8.00	4.3	4.3
3.5	28	17.3	12.0	0.0	18	3.8	4.00	3.9	3.9

Table 7: Recommended values for a V=3.5' catch basin

Note that these are only recommended values. Different values may have capacity to pass the design and TMDL flows. Please see the attached appendix for CPS sizing recommendations for most common catch basin sizes.

Some combinations of V-depths and connector pipe sizes made installation of a practically sized CPS impossible, thus the height of the screen had to be reduced below our recommended standards (the total area and therefore treatment capacity of the screen is still adequate even in these unusual scenarios).

A size recommendation was made based on the most practical size. For example, a 15" radius screen, with a 180-degree angle will result in a length of 3.9 feet, or a 15" radius screen with a 90-degree angle will result in a length of 1.96 feet. Thus, the bypass height, screen height were calculated with the goal to calculate a length close to 3.9 feet or 1.9 feet. Increasing the radius or installing rectangular screens to increase the lengths can accommodate any lengths larger than the recommended value.

The screen does not have to be a semi-circular arc, as long as the minimum length and height requirements are satisfied, it will pass the TMDL and design flow regardless of shape. Figure 10 shows an example of a non-circular screen.



Figure 10. Rectangular screen across CB corner

X. Catch Basins in Series

For parallel catch basins in series (See Figure 10A), only the upstream catch basin shall have a CPS, since the low flow will only enter the upstream basin. The upstream CPS can be sized just like an individual basin.

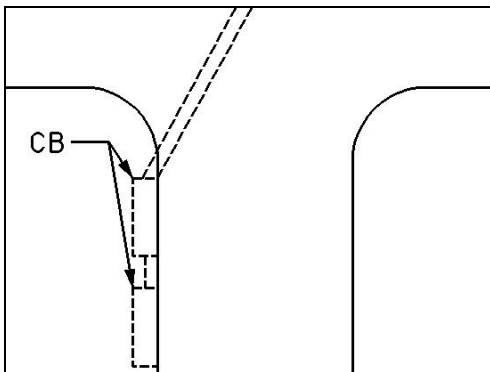


Figure 10A: Same side catch basin in series

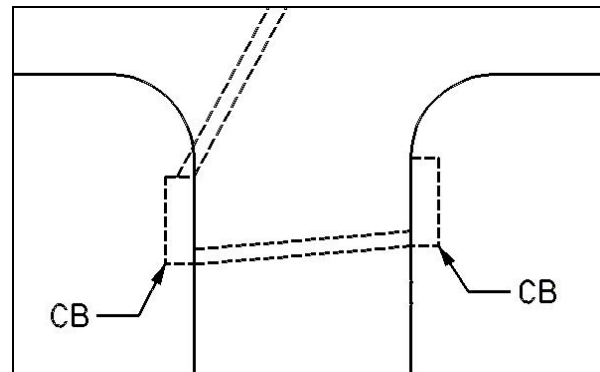


Figure 10B: Opposite side catch basin in series

For catch basins in series across from each other (See figure 10B), the upstream and downstream CB CPS shall be designed as individual basins. However, the downstream basin will need to bypass its design flow and the upstream design flow. The downstream basin shall be designed such that the width of the basin is the sum of the downstream and upstream basin. For example, for two seven-foot basins, the downstream basin shall be designed as a 14-foot basin.

XI. Maintenance Requirements

The purpose of a Connector Pipe Screen (CPS) is to contain trash within a catch basin, excluding it from the storm drain system. Routine maintenance will be necessary to remove trash from the catch basin to prevent it from accumulating to a point that would affect the performance of the CPS or the catch basin itself.

Proposed Maintenance Approach

- Inspect and clean each catch basin between May 1 and September 30 of each year.
- Inspect and provide additional cleaning of any catch basin that is at least 40% full of trash and/or debris.

Based on field testing at the San Gabriel Dam catch basin testing facility, visual observation of City of Los Angeles Vertical screens, and recommendations from the City of Los Angeles, the following physical requirements were established.

- Minimum V-depth = 3.5
- Minimum screen height = diameter of connector pipe
- 6" spacing for vertical bars for bypass
- 6" minimum bypass height
- 4" minimum clearance from flow line to top of bypass structure.
- When low flows have the potential to fall from the curb to behind the CPS, a deflector or screen must be installed on the top of the structure.
- Where manhole access is impeded due to the internal screen, a new manhole shall be constructed.

Full Capture CPS Hydraulic Analysis and Sizing

"V-depth" (ft)	CB Width (ft)	No. Grates	Max Q ₁₀ (cfs)	Bypass Height (in)	Free-board (in)	Screen Height (in)	Q ₁₋₁ (cfs)	Clearance (in)	Curb Height (in)	Head (ft)	Screen Length (ft)	Screen Capacity (cfs)
CB 300												
18" connector pipe												
3.5	3.5	–	2.8	6.0	6.0	18	0.6	10.00	8.00	0.58	1.5	1.5
	7	–	5.3	6.0	6.0	18	1.2	10.00	8.00	0.58	2.9	2.9
	10	–	7.5	6.0	5.0	18	1.7	10.00	8.00	0.67	3.8	3.8
	14	–	10.0	8.0	0.0	18	2.2	8.00	8.00	1.00	3.1	3.1
	21	–	13.9	8.0	0.0	18	3.1	8.00	8.00	1.00	4.3	4.3
	28	–	17.3	12.0	0.0	18	3.8	4.00	8.00	0.83	3.9	3.9
CB 300												
24" connector pipe												
3.5	3.5	–	2.8	6.0	0.0	24	0.6	4.00	8.00	0.58	1.5	2.0
	7	–	5.3	6.0	0.0	24	1.2	4.00	8.00	0.58	2.9	3.8
	10	–	7.5	6.0	0.0	24	1.7	4.00	8.00	0.58	4.1	5.4
	14	–	10.0	6.0	0.0	18	2.2	10.00	8.00	1.08	4.0	4.0
	21	–	13.9	9.0	0.0	18	3.1	7.00	8.00	0.96	3.9	3.9
	28	–	17.3	12.0	0.0	18	3.8	4.00	8.00	0.83	3.9	3.9
CB 300												
18" or 24" connector pipe												
4.0	3.5	–	2.8	6.0	6.0	24	0.6	10.00	8.00	0.58	1.5	2.0
	7	–	5.3	6.0	6.0	24	1.2	10.00	8.00	0.58	2.9	3.8
	10	–	7.5	8.0	6.0	24	1.7	8.00	8.00	0.50	3.3	4.4
	14	–	10.0	10.0	6.0	24	2.2	6.00	8.00	0.42	3.9	5.1
	21	–	13.9	12.0	3.0	24	3.1	4.00	8.00	0.58	3.8	5.0
	28	–	17.3	12.0	0.0	24	3.8	4.00	8.00	0.83	3.9	5.2
4.5	3.5	–	2.8	6.0	6.0	24	0.6	16.00	8.00	1.08	1.1	1.5
	7	–	5.3	6.0	6.0	24	1.2	16.00	8.00	1.08	2.1	2.8
	10	–	7.5	6.0	6.0	24	1.7	16.00	8.00	1.08	3.0	4.0
	14	–	10.0	8.0	6.0	24	2.2	16.00	8.00	1.17	3.1	4.1
	21	–	13.9	10.0	6.0	24	3.1	12.00	8.00	0.92	3.6	4.8
	28	–	17.3	12.0	6.0	24	3.8	10.00	8.00	0.83	3.9	5.2

Full Capture CPS Hydraulic Analysis and Sizing

"V-depth" (ft)	CB Width (ft)	No. Grates	Max Q ₁₀ (cfs)	Bypass Height (in)	Free-board (in)	Screen Height (in)	Q ₁₋₁ (cfs)	Clearance (in)	Curb Height (in)	Head (ft)	Screen Length (ft)	Screen Capacity (cfs)
CB 300	18" or 24" connector pipe											
5.0	3.5	–	2.8	6.0	6.0	30	0.6	16.00	8.00	1.08	1.1	1.8
	7	–	5.3	6.0	6.0	30	1.2	16.00	8.00	1.08	2.1	3.5
	10	–	7.5	6.0	6.0	30	1.7	16.00	8.00	1.08	3.0	5.0
	14	–	10.0	8.0	6.0	30	2.2	16.00	8.00	1.17	3.1	5.1
	21	–	13.9	10.0	6.0	30	3.1	12.00	8.00	0.92	3.6	6.0
	28	–	17.3	12.0	6.0	30	3.8	10.00	8.00	0.83	3.9	6.5
5.5	3.5	–	2.8	6.0	6.0	36	0.6	16.00	8.00	1.08	1.1	2.2
	7	–	5.3	6.0	6.0	36	1.2	16.00	8.00	1.08	2.1	4.2
	10	–	7.5	6.0	6.0	36	1.7	16.00	8.00	1.08	3.0	6.0
	14	–	10.0	8.0	6.0	36	2.2	16.00	8.00	1.17	3.1	6.2
	21	–	13.9	10.0	6.0	36	3.1	12.00	8.00	0.92	3.6	7.1
	28	–	17.3	12.0	6.0	36	3.8	10.00	8.00	0.83	3.9	7.7
6.0	3.5	–	2.8	6.0	6.0	42	0.6	16.00	8.00	1.08	1.1	2.5
	7	–	5.3	6.0	6.0	42	1.2	16.00	8.00	1.08	2.1	4.9
	10	–	7.5	6.0	6.0	42	1.7	16.00	8.00	1.08	3.0	6.9
	14	–	10.0	8.0	6.0	42	2.2	16.00	8.00	1.17	3.1	7.2
	21	–	13.9	10.0	6.0	42	3.1	12.00	8.00	0.92	3.6	8.3
	28	–	17.3	12.0	6.0	42	3.8	10.00	8.00	0.83	3.9	9.0

Full Capture CPS Hydraulic Analysis and Sizing

"V-depth" (ft)	CB Width (ft)	No. Grates	Max Q ₁₀ (cfs)	Bypass Height (in)	Free-board (in)	Screen Height (in)	Q ₁₋₁ (cfs)	Clearance (in)	Curb Height (in)	Head (ft)	Screen Length (ft)	Screen Capacity (cfs)
CB 301												
18" connector pipe												
3.5	7	1	10.7	8	0.0	18	2.4	8.00	8.00	1.00	3.3	3.3
	10.5	2	13.0	10	0.0	18	2.9	8.00	8.00	1.08	3.4	3.4
	14	1	13.6	10	0.0	18	3.0	7.00	8.00	1.00	3.5	3.5
	17.5	2	15.3	10	0.0	18	3.4	6.00	8.00	0.92	4.0	4.0
CB 301												
24" connector pipe												
3.5	7	1	10.7	8	0.0	18	2.4	8.00	8.00	1.00	3.3	3.3
	10.5	2	13.0	10	0.0	18	2.9	8.00	8.00	1.08	3.4	3.4
	14	1	13.6	10	0.0	18	3.0	7.00	8.00	1.00	3.5	3.5
	17.5	2	15.3	10	0.0	18	3.4	6.00	8.00	0.92	4.0	4.0
CB 301												
18" or 24" connector pipe												
4.0	7	1	10.7	8	0.0	24	2.4	8.00	8.00	1.00	3.3	4.4
	10.5	2	13.0	10	0.0	24	2.9	6.00	8.00	0.92	3.4	4.5
	14	1	13.6	10	0.0	24	3.0	6.00	8.00	0.92	3.5	4.7
	17.5	2	15.3	10	0.0	24	3.4	6.00	8.00	0.92	4.0	5.3
4.5	7	1	10.7	8	6.0	24	2.4	8.00	8.00	0.50	3.3	4.4
	10.5	2	13.0	10	6.0	24	2.9	6.00	8.00	0.42	3.4	4.5
	14	1	13.6	10	6.0	24	3.0	6.00	8.00	0.42	3.5	4.6
	17.5	2	15.3	10	6.0	24	3.4	6.00	8.00	0.42	4.0	5.3
5.0	7	1	10.7	8	6.0	30	2.4	8.00	8.00	0.50	3.3	5.5
	10.5	2	13.0	10	6.0	30	2.9	6.00	8.00	0.42	3.4	5.6
	14	1	13.6	10	6.0	30	3.0	6.00	8.00	0.42	3.5	5.8
	17.5	2	15.3	10	6.0	30	3.4	6.00	8.00	0.42	4.0	6.6
5.5	7	1	10.7	8	6.0	36	2.4	8.00	8.00	0.50	3.3	6.6
	10.5	2	13.0	10	6.0	36	2.9	6.00	8.00	0.42	3.4	6.7
	14	1	13.6	10	6.0	36	3.0	6.00	8.00	0.42	3.5	6.9
	17.5	2	15.3	10	6.0	36	3.4	6.00	8.00	0.42	4.0	7.9
6.0	7	1	10.7	8	6.0	42	2.4	8.00	8.00	0.50	3.3	7.6
	10.5	2	13.0	10	6.0	42	2.9	6.00	8.00	0.42	3.4	7.9
	14	1	13.6	10	6.0	42	3.0	6.00	8.00	0.42	3.5	8.1
	17.5	2	15.3	10	6.0	42	3.4	6.00	8.00	0.42	4.0	9.3

Full Capture CPS Hydraulic Analysis and Sizing

"V-depth" (ft)	CB Width (ft)	No. Grates	Max Q ₁₀ (cfs)	Bypass Height (in)	Free-board (in)	Screen Height (in)	Q ₁₋₁ (cfs)	Clearance (in)	Curb Height (in)	Head (ft)	Screen Length (ft)	Screen Capacity (cfs)
CB 303												
18" connector pipe												
3.5	–	1	9.7	8	0.0	18	2.1	8.00	8.00	1.00	3.0	3.0
	–	2	10.9	8	0.0	18	2.4	8.00	8.00	1.00	3.4	3.4
	–	3	12.4	8	0.0	18	2.7	8.00	8.00	1.00	3.9	3.8
CB 303												
24" connector pipe												
3.5	–	1	9.7	8	0.0	18	2.1	8.00	8.00	1.00	3.0	3.0
	–	2	10.9	8	0.0	18	2.4	8.00	8.00	1.00	3.4	3.4
	–	3	12.4	8	0.0	18	2.7	8.00	8.00	1.00	3.9	3.9
CB 303												
18" or 24" connector pipe												
4.0	–	1	9.7	8	0.0	24	2.1	8.00	8.00	1.00	3.0	4.0
	–	2	10.9	8	0.0	24	2.4	8.00	8.00	1.00	3.4	4.5
	–	3	12.4	8	0.0	24	2.7	8.00	8.00	1.00	3.9	5.2
4.5	–	1	9.7	6	6.0	24	2.1	10.00	8.00	0.58	3.0	4.0
	–	2	10.9	8	6.0	24	2.4	8.00	8.00	0.50	3.4	4.5
	–	3	12.4	8	6.0	24	2.7	8.00	8.00	0.50	3.9	5.2
5.0	–	1	9.7	6	6.0	30	2.1	16.00	8.00	1.08	3.0	5.0
	–	2	10.9	6	6.0	30	2.4	16.00	8.00	1.08	3.4	5.6
	–	3	12.4	8	6.0	30	2.7	14.00	8.00	1.00	3.9	6.5
5.5	–	1	9.7	8	6.0	36	2.1	8.00	8.00	0.50	3.0	6.0
	–	2	10.9	8	6.0	36	2.4	8.00	8.00	0.50	3.4	6.7
	–	3	12.4	8	6.0	36	2.7	8.00	8.00	0.50	3.9	7.7
6.0	–	1	9.7	6	6.0	42	2.1	16.00	8.00	1.08	3.0	6.9
	–	2	10.9	6	6.0	42	2.4	16.00	8.00	1.08	3.4	7.9
	–	3	12.4	8	6.0	42	2.7	14.00	8.00	1.00	3.9	9.0