COUNTY OF LOS ANGELES

DEPARTMENT OF PUBLIC WORKS

"To Enrich Lives Through Effective and Caring Service"

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GAIL FARBER, Director

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September 22, 2011

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CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
LOS ANGELES REGION

Mr. Ivar Ridgeway
Stormwater Chief
California Regional Water Quality
Control Board – Los Angeles Region
320 West 4th Street, Suite 200
Los Angeles, CA 90013-2343

Dear Mr. Ridgeway:

CATCH BASIN BEST MANAGEMENT PRACTICES
FULL-CAPTURE DEVICE

County of Los Angeles Department of Public Works is continually testing new Best Management Practices to comply with Trash Total Maximum Daily Load requirements imposed throughout the County. Our research is focused on trash removal Best Management Practices that are cost-effective, easy to maintain, and meet the Regional Water Quality Control Board's standard for full-capture status as defined in your Board's Resolution No. 04-023, dated March 4, 2004:

> *A full capture system is any single device or series of devices that traps all particles retained by a 5 mm 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 subdrainage area....*

Pursuant to our ongoing research, we recently tested another trash separation device that employs the Coanda Effect and found that it meets the full-capture standard.

The enclosed Technical Report describes the design, operation, and test results of the Coanda Screen and its associated debris fence.

We recommend that the Regional Board approve this type of device as a full-capture device for removing trash from runoff up to and including that of the Trash Total Maximum Daily Load design storm.

Should you require further information or have any comments, please contact Mr. Bill DePoto at (626) 458-4313 or bdepoto@dpw.lacounty.gov.

Very truly yours,

GAIL FARBER
Director of Public Works

GARY HILDEBRAND
Assistant Deputy Director
Watershed Management Division

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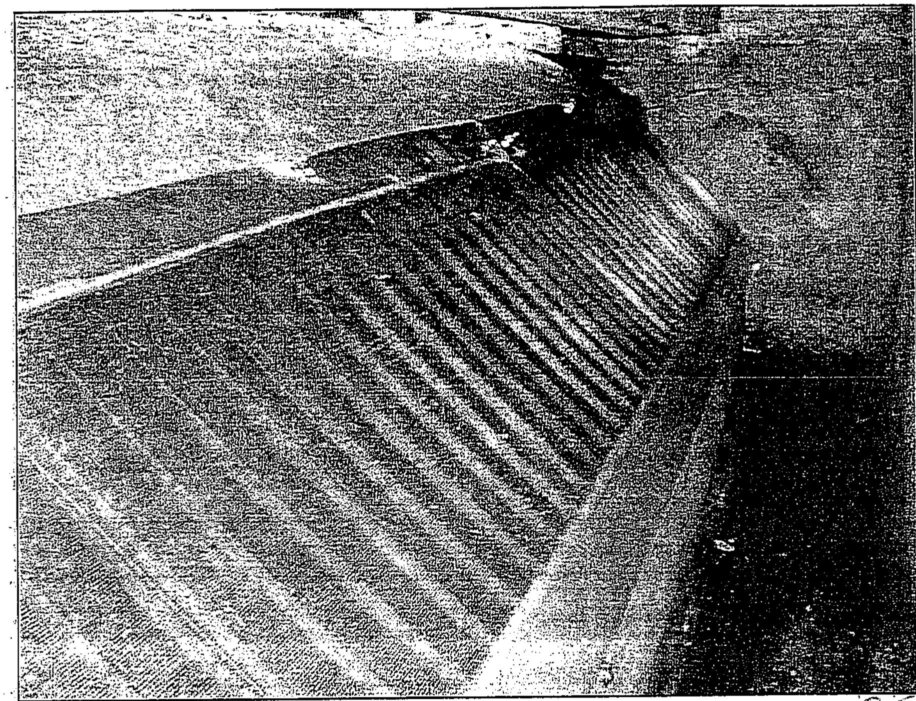
Technical Report
Coanda Screen Design
Application for Full Capture TMDL Compliance



Screen and Bypass Sizing Requirements

Prepared by
Steven E. Esmond, P.E.
Coanda, Inc.
for:

COUNTY OF LOS ANGELES
DEPARTMENT OF PUBLIC WORKS

May 2011

Contents

I. Purpose and Scope

The purpose of this report is to establish conservative design criteria for the Coanda Screen BMP in order to comply with the Los Angeles River and similar Trash Total Maximum Daily Load (TMDL) requirements for trash. The device must not only comply with the TMDL, but must also maintain the existing level of flood protection for Los Angeles County Flood Control District (LACFCD) facilities.

II. Abstract

Coanda screens are diagonally oriented, tilted wedgewire screens which can be installed inside of conventional curb entry storm water catch basins. Figure 1 shows the Coanda installation at the County of Los Angeles Department of Public Works test facility at the San Gabriel Dam in March 2011. Coanda screens can also be designed for small open channel applications. This technical report will address retrofit applications meant for curb inlet catch basins.

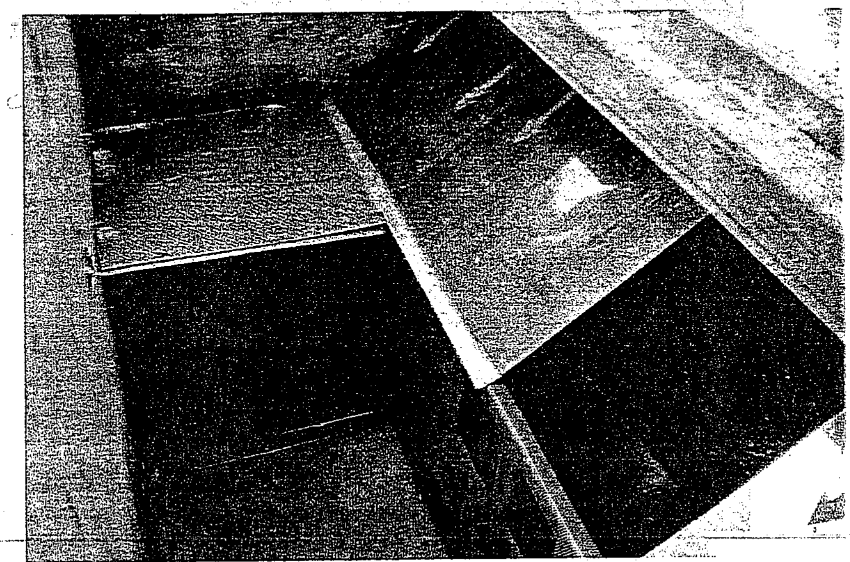


Figure 1 - Coanda Installation at LA County Test Facility

Coanda effect screens have been used for decades to screen small aquatic organisms and debris from water diversions. For more technical information on the theory and practical application of Coanda screens, refer to the U.S. Bureau of Reclamation web site.[1] Applications of Coanda screens designed specifically to remove debris from urban storm water have become increasingly popular across the United States, due in part to the screens' advantages. *"These screens have large flow capacities and are hydraulically self-cleaning without moving parts, so they require minimal maintenance."*[2]

III. Coanda BMP Description

The Coanda curb inlet BMP is designed entirely of 304 stainless steel, a material which provides superior corrosion resistance and high strength. The tilted wedgewire Coanda screen is designed to divert all runoff that enters the catch basin in a downward, vertical direction upon making contact with the Coanda screen. The Coanda screen is typically mounted immediately inside the catch basin at a diagonal orientation of 35 to 55 degrees from horizontal. The Coanda screen shown in Figure 1 is marked with directional arrows. Note that a narrow section

[1] US Bureau of Reclamation, http://www.usbr.gov/pmts/hydraulics_lab/twahl/coanda/.

[2] Wahl, Tony L., "Design Guidance for Coanda-Effect Screens," US Department of the Interior, Bureau of Reclamation, Technical Service Center, Water Resources Research Laboratory, Denver, Colorado, Report No. R-03-03, July 2003, http://www.usbr.gov/pmts/hydraulics_lab/pubs/R/R-2003-03.pdf.

of Coanda screen in Figure 1 was temporarily removed for the purpose of the photograph in order to expose the area underneath the screen, which is the pathway for filtered water to exit the catch basin after proceeding through the screen. Clear spaces between adjacent wedgewires typically fall within the range of 0.5 mm to 2.0 mm., in which no debris of that size or larger would be able to continue with the flow. As all storm runoff is diverted through the Coanda screen, debris is left behind to slide down the face of the screen into a debris compartment in the lower left quadrant of the catch basin. Hence, debris and storm runoff are instantaneously and permanently separated at the face of the Coanda screen. This concept is further illustrated on Figure 2, and can be viewed by video.[3]

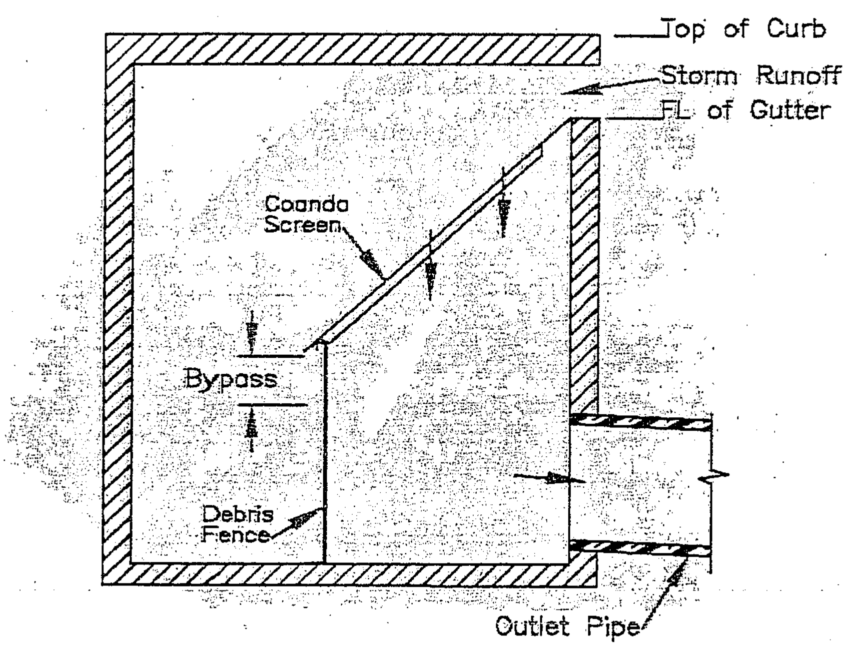


Figure 2 – Typical Coanda Curb Inlet Cross Section

The Coanda screen itself can be designed to treat the flow associated with any trash TMDL. In a properly sized Coanda catch basin BMP, all incoming storm water will flow through the Coanda screen. Only minor drippage associated with debris should make it to the debris compartment. Separated debris is not stored in a wet sump and is essentially stored dry.

For example, debris will slide down the face of the Coanda screen into the debris compartment in the lower left-hand quadrant of the catch basin in Figure 2 and will remain there until it can be removed by maintenance crews. The separation device beneath the Coanda screen but between the debris compartment and the pathway of treated storm water is called a debris fence. This debris fence, also made of 304 stainless steel, is a perforated plate material with numerous holes arranged in a tight pattern. Each hole is typically 4 mm to 5 mm in diameter. Thus, there is no opening anywhere in the catch basin larger than 5 mm. The net open area of the debris fence perforated plate material is approximately 50 percent.

LACFCD requires all catch basin BMPs to have some type of emergency bypass during peak flows in the event of blockage of a primary screen or filter caused by entrained debris. LACFCD also requires that the minimum size of an individual bypass opening be no smaller than 6 inches by 6 inches. Therefore, in each Coanda catch basin BMP a bypass section is provided along the top of the debris fence. The bypass section consists of a series of 6 inch square openings arranged in sequence at the top of the debris fence, lined up in a row, each opening spaced about 6 inches apart. The necessary number of openings of this size is dictated by the hydraulic requirements of the bypass flow rate. A sufficient number of openings will be provided

[3] http://www.coanda.com/video2.htm

to hydraulically pass the full incoming peak or maximum flow. The bypass openings can be seen in the photograph on Figure 1.

IV. Hydraulic Design Criteria

The Regional Water Quality Control Board (RWQCB) definition of a full capture system is as follows:

> *A full capture system is any single device or series of devices that traps all particles retained by a 5 mm 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 subdrainage area.*[4]

Coanda screens employed in storm water applications typically have openings of 0.5 mm to 2.0 mm, the most common size being 0.5 mm and the largest being 2.0 mm. The Coanda Effect does not come into play when screen openings exceed 2.0 mm. Therefore, Coanda screens will always meet RWQCB particle size requirements.

Coanda screen installations must also satisfy the Los Angeles Department of Public Works hydrologic design criteria. Since the majority of LACFCD facilities are designed for a 10-year design storm frequency (Q_{10}),[5] the catch basin BMP must, at a minimum, be designed to handle the 10-year storm frequency. This ensures that flood protection will be maintained at current levels for all of Los Angeles County Flood Control District facilities.

The basis of design for any catch basin BMP is ultimately derived from the hydraulic capacity of the catch basin itself. The applicable hydraulic capacity can be determined from Chart D-10D of the LACFCD Hydraulic Manual.[6] The LACFCD states, *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.*[7] Since steeper slopes yield higher flow capacities, the maximum flow for any catch basin should not exceed that which is based on a street slope of 0.04 percent. Using the data on LACFCD Chart D-10D, and applying a street slope of 0.04, the following equation was derived to describe the relationship between maximum flow Q and catch basin width:

Equation 1: $Q = 70\,(1-\exp^{-0.02 \times CB})$, cfs

where CB = catch basin width, ft.

There may be instances in which the designer could use a flatter street slope when it is known, or an approved flow rate other than the maximum capacity of the catch basin. The following equations are extracted from the LACFCD methodology to be used to compute Q_{10} and $Q_{1\text{-}1}$:

Equation 2: $Q_{10} = 0.75\,Q$

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[4] LARWQCB, http://www.waterboards.ca.gov/losangeles/water_issues/programs/tmdl/full_capture_certification.shtml

[5] LA County Department of Public Works Submittal for Full Capture Screens, April 2007, http://www.waterboards.ca.gov/losangeles/water_issues/programs/tmdl/fcc/la%20county%20full%20capture%20request%20package.pdf.

[6] "Hydrology Manual," Los Angeles county Department of Public Works, January 2006, http://www.ladpw.org/wrd/publication/.

[7] LACFCD Submittal to LARWQCB, April 2007, p. 6.

Equation 3: $Q_{1\text{-}1} = 0.22\ Q_{10}$

Once the proper design flow rates have been established, whether Q, Q_{10}, or $Q_{1\text{-}1}$, the designer is ready to proceed with the design of the Coanda catch basin BMP.

V. Catch Basin BMP Design

Figure 3 depicts the catch basin in elevation, featuring the critical dimensional components. The first step is to calculate the Coanda screen length, L_c, which is determined from the hydraulic design one-year, one-hour flow rate $Q_{1\text{-}1}$. For urban storm water applications involving screen openings of 0.5 mm, with the Coanda screen mounted at an angle that generally ranges from 35 to 55 degrees, a very conservative hydraulic loading is 250 gpm per sq.ft. Substantially higher loadings can be derived using USBR design criteria, this loading set intentionally low enough to allow for the interference of debris and long term wear and tear over a 50 year life cycle.

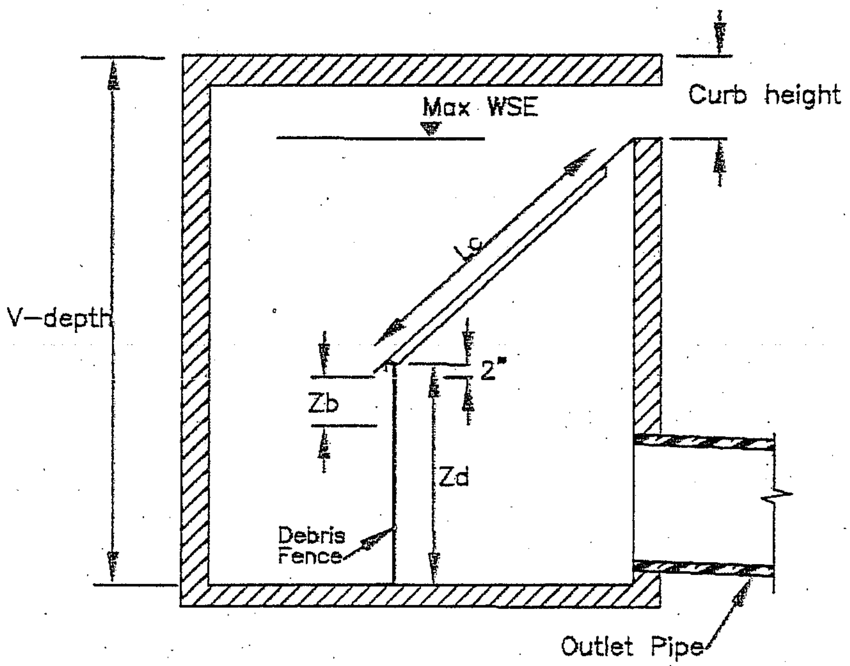

Figure 3 – Coanda BMP Dimensional Variables

Calculate L_c

The length of the Coanda screen L_c can be calculated by the following equation:

Equation 4: $$Lc = \frac{Q}{250\ CB}\text{, feet}$$

where Q is the $Q_{1\text{-}1}$ in gallons per minute, CB is catch basin width in feet.

Next, the designer will establish the angle of the screen. The range as stated above should be between 35 to 55 degrees with respect to horizontal. Contributing to this decision will in part be the depth (V-depth) and width of the catch basin.

Each Coanda screen comes with a stainless steel approach plate welded along the top which is securely anchored to the catch basin using stainless steel anchor bolts, and a stainless steel toe plate welded along the bottom which is securely anchored to the debris fence using stainless steel bolts. The top of the Coanda screen approach plate is located just inside the catch basin at or below the flow line of the gutter, therefore does not interfere with anything at or on the street. The Coanda screen will not interfere with street sweepers or with other types of screens if they happen to be installed in the gutter against the catch basin opening. Since these installations have no mechanical devices above the gutter elevation, there need not be any allowance for freeboard. Thus, the maximum depth of flow can be taken as the distance from the flowline of the gutter to the floor of the catch basin. In Figure 3, this distance is the V-depth minus the curb height, and the curb height is generally 8 inches in most cases.

Calculate Z_d

Next, the designer will determine the height of the debris fence Z_d shown in Figure 3. One may seek to maximize the height of the debris fence Z_d in order to maximize the volume of debris compartment. It is often the case that the designer will locate the debris fence along the midpoint or centerline of the catch basin. Thus, the value of Z_d is ultimately derived from the angle and length of the Coanda screen as well as of the geometry of the catch basin itself.

The hydraulic properties of the Coanda BMP are illustrated in Figure 4.

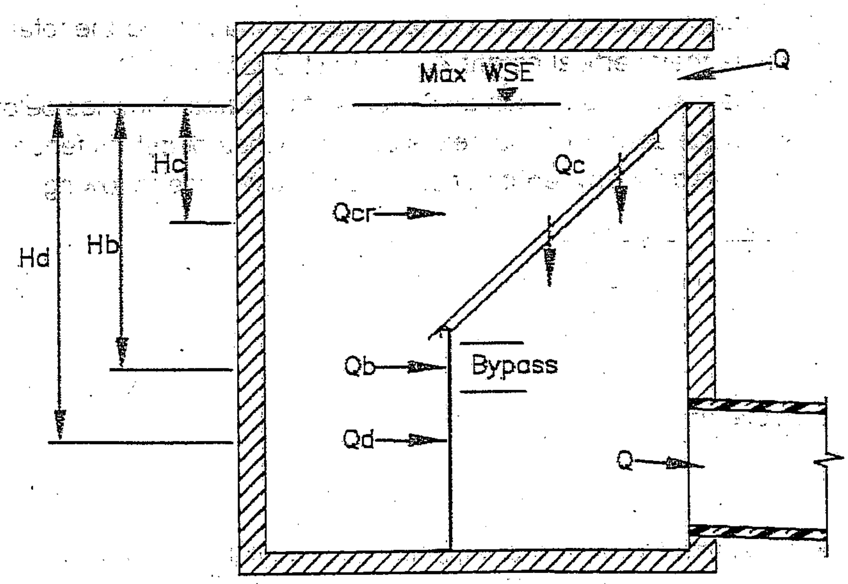

Figure 4 – Coanda BMP Hydraulics

The designer will determine the hydraulic capacity of the debris fence using the orifice equation:

Equation 5: $Q = CA\sqrt{2gH}$, cfs

For all calculations involving Equation 5, the value of g = 32.2 ft sec^{-2}. In keeping with LACFCD standard practice, the orifice coefficient C for the bypass is 0.60, and for the debris fence is 0.53.[8] The cross sectional area A is the area of the debris fence in square feet (less the area of the bypass A_b), multiplied by the ratio of the net clear opening, which for typical perforated plate debris fence material is 0.50. The value of the head H is equal to H_d (shown in Figure 4), being the distance in feet from the maximum water surface to the vertical centroid of the debris fence.

Using this information, the value of Q_d (flow rate through the debris fence) can be calculated. The calculated value of Q_d should be equal to or greater than the maximum flow Q. Should the calculation reveal a hydraulic deficiency, the designer should re-visit the geometry of the catch basin or change the Coanda screen angle in order to adjust the size of the debris fence accordingly.

Calculate Z_b

Next, the designer will determine the hydraulic capacity of the bypass section. Refer to Figure 3. Having determined the height of the debris fence Z_d, the top of the bypass openings will normally be set 2 inches below the top of the debris fence. The minimum bypass opening Z_b (having been set by regulation) is 6 inches. Typically, Z_b will be set at 6 inches unless a greater value is needed to handle the bypass flow.

The designer will again employ Equation 5, using a C-coefficient of 0.60 and H set at the value of H_b (shown in Figure 4), which is the distance from the maximum water surface to the centroid of the bypass openings. The total bypass opening area is determined by multiplying the total length of the bypass openings L_b times their vertical height Z_b. In most Coanda BMP installations, the bypass section will be a series of 6-inch by 6-inch slots located 2 inches below the top of the debris fence, each slot separated from the next slot by 6 inches of debris fence. Thus, the value of L_b can be approximated for any length of catch basin using the following equation:

Equation 6: $L_b = (CB - 1) \times 6$ (inches)

where CB = width of catch basin in feet.

The area of the bypass can be calculated as follows:

Equation 7: $A_b = L_b \times Z_b$

Using Equation 5, substituting A_b for A and H_b for H, the designer will calculate the bypass flow rate Q_b. If this calculation reveals the bypass has insufficient hydraulic capacity, then the designer will increase the values of L_b and/or Z_b accordingly, taking into account the practical implications on the geometry of the debris fence and its necessary function.

[8] Ibid, p. 9.

Optional Calculation of Reverse Coanda Screen Flow Q_{cr}

As a final but optional check, the designer can evaluate what might happen if both the debris fence and the bypass were to become plugged, and if the water were to enter the catch basin without passing through the Coanda screen. This condition would be analogous to Q_{cr} (shown in Figure 4), where the flow would go in a reverse direction through the Coanda screen openings. In this situation, the Coanda screen would behave as a simple orifice. The designer could use Equation 5, taking A as the area of the Coanda screen times 0.30 (typically the net clear opening for most Coanda screens), H set at a value of H_c (Figure 4), corresponding to the distance from the maximum water elevation to the centroid of the Coanda screen, and a C-coefficient of 0.53. Such a condition is almost never seen in practice, but was intentionally created at the County of Los Angeles Department of Public Works test facility at the San Gabriel Dam on March 2, 2011. Both the debris fence and the bypass were intentionally covered and taped with plastic, forcing all flow to go through the Coanda screen either in the normal or reverse direction. Flow was increased to the maximum that could be delivered to the catch basin, causing some flow to shoot past the Coanda screen upon entry. The combination of Q_c and/or Q_{cr} were able to handle the total flow, as can be seen in the video.[9]

VI. Example Calculation

Assume that a standard Los Angeles County catch basin that is 10 feet wide and has a V-depth of 3.5 feet, is to be retrofitted with a Coanda BMP.

Flows

Using Equation 1: $Q = 70\,(1\text{-}\exp^{-0.02 \times CB})$, cfs

where CB = catch basin width = 10 ft, Q = 12.7 cfs.

Using Equation 2: $Q_{10} = 0.75\ Q = 9.5$ cfs

Using Equation 3: $Q_{1\text{-}1} = 0.22\ Q_{10} = 2.1$ cfs

Coanda Screen

Using Equation 4: $Lc = \frac{Q}{250\,CB}$, feet

where Q is the $Q_{1\text{-}1}$ flow = 2.1 cfs or 945 gallons per minute, and CB is 10 feet. In the vast majority of applications, the width of the Coanda screen will be the same as the catch basin width CB, which in this example is 10 feet. Using Equation 4 above, L_c = 0.38 feet or 5 inches. At this point, the designer may choose to designate either a longer screen or add approach and toe plate to provide a practical working length of screen material. It is generally recommended that the debris fence would sit no closer than 12 inches from the interior wall of the catch basin, thus, when oriented on a 45 degree angle, the total length of screen plus approach and toe

[9] Video showing Coanda BMP undergoing testing at LACFCD San Gabriel Dam Test Facility, March 2, 2011, http://www.youtube.com/watch?v=8EB8OAI3T-q

plates would be $12 x \sqrt{2} = 17$ inches. The Coanda screen could comprise as little as 5 inches of the 17, leaving a total of 12 inches for toe plate and approach plate.

Debris Fence

The next step is to determine the height of the debris fence. Assuming the Coanda screen is mounted on a 45 degree angle, using the V-depth of 42 inches, from simple geometry the height of the debris fence Z_d = 24 inches = 2.0 feet.

Next, calculate the bypass open area A_b. Use Equation 6 to calculate the required length of bypass openings L_b = (CB – 1) x 6 = 54 inches = 4.5 feet. Thus, according to Equation 7, using bypass height of 6 inches, the total bypass area $A_b = L_b \times Z_b$ = 4.5 x 0.50 = 2.25 sq.ft.

The net open area of the debris fence = (Z_d x CB – A_b) x 0.50 = (2.0 x 10 -2.25) x 0.50 = 8.87 sq.ft. The average hydraulic head on the debris fence is estimated to be 23 inches or 1.91 feet. Using Equation 5, with C = 0.53, A = 8.87, and H = 1.91, the resulting Q_d = 52.1 cfs. (The debris fence must have a hydraulic capacity of at least Q or 12.7 cfs, therefore, the debris fence is adequate to carry the maximum flow.)

Bypass

Having previously calculated the bypass area A_b to be 2.25 sq.ft., the hydraulic head acting upon the bypass open area is estimated to be 15 inches or 1.25 feet. Using Equation 5, with C = 0.60, A = 2.25, and H = 1.25, the resulting Q_b = 12.1 cfs. The bypass section must have a hydraulic capacity of at least Q or 12.7 cfs, therefore, the bypass openings need to be increased from a 6 inch width to 7 inches. Using Equation 6, the revised bypass opening would be: L_b = (CB – 1) x 7 = 63 inches = 5.25 feet. Changing the bypass width from 6 to 7 inches therefore increases the value of A_b from 2.25 sq.ft. to 2.63 sq.ft. Re-calculating the bypass hydraulic capacity using Equation 5, with C = 0.60, A = 2.63, and H = 1.25, the resulting Q_b = 14.1 cfs. The bypass section must have a hydraulic capacity of at least Q or 12.7 cfs, therefore, 7 inch wide x 6 inch high bypass openings will be more than adequate to carry the maximum flow.

Reverse Flow Through Coanda Screen

The net open area for the Coanda screen (A_{cr}) is its length times its width times the net clear opening, which is 0.30. Thus, $A_{cr} = L_c$ x CB x 0.30 = 0.38 x 10 x 0.30 = 1.14 sq.ft. The hydraulic head acting upon the Coanda screen is estimated to be 6 inches or 0.50 feet. Using Equation 5, with C = 0.53, A = 1.14, and H = 0.50, the resulting Q_{cr} = 3.4 cfs. The Coanda screen in this example is designed to carry the $Q_{1\text{-}1}$ flow of 2.1 cfs. If the designer wishes to increase Q_{cr}, this can be accomplished by increasing the length of the Coanda screen L_c from 5 inches to as much as 17 inches in this example. Note that the BMP design does not depend on Q_{cr} at all, because the debris fence and the emergency overflow are each designed to carry the maximum flow Q.

VII. Value Added Benefits

This report has demonstrated that the Coanda screen BMP meets Trash TMDL design criteria. Most Coanda urban storm water BMPs are equipped with 0.5 mm screens, a few have 1.0 mm screens. Coanda removes much smaller particles than the Trash TMDL requirement of 5.0 mm. Debris is stored in an essentially dry state, eliminating the concern of nutrients leaching into a wet sump. In addition, the existing level of flood protection of the Los Angeles County Flood Control District facilities is not compromised in any way.

All materials of construction are stainless steel, structurally designed to withstand the maximum loadings to comply with the California Building Code. The life cycle of a typical Coanda BMP installation should be 40 to 50 years. As previously referenced, the US Bureau of Reclamation states that these screens have the ability to handle high flow capacities, they self-clean hydraulically without any moving parts, and have minimal maintenance requirements.

Coanda screens remove preproduction plastic pellets or nurdles greater in size than the screen spacing with 100 percent efficiency. These tiny plastic materials have become an environmental nuisance. They are often spherical or elliptical in shape, with a minimum size typically in the range of 2.5 to 4.0 mm in diameter. The Coanda BMP readily removes all nurdles, as can be seen on video.[10]

VIII. Maintenance Requirements

The Coanda curb inlet should be cleaned and debris removed on a periodic basis. Experience indicates that cleaning cycles may vary from one to three times per year, depending upon the acreage draining into the curb inlet, land use, and other characteristics of the watershed.

Captured debris should dry quickly and remain inert in the debris compartment. If there happen to be illicit discharges in dry weather runoff, cooling condensate water, or irrigation overflows, these could pose a nuisance and could keep captured debris moist in other types of trash BMPs. However, the Coanda curb inlet is designed so that low flow runoff should not make direct contact with captured debris. If this type of problem occurs and persists, contact the manufacturer.

Debris removal and cleaning can be carried out in most typical curb inlets within about 30 minutes using ordinary hand tools. The tools most helpful are:

1. Square-blade scoop
    a. Long handle for very large curb inlets
    b. Short handle for most other curb inlets
2. Straw broom
3. Metal dust pan

At least one alternative to manual cleaning would involve debris removal using a vacuum truck.

When carrying out a cleaning operation, observe the following guidelines:

1. Work in teams of two persons.
2. Do not enter the curb inlet unless a confined space entry program has been implemented, and then follow permit confined space program requirements.
3. Wear long sleeve shirt, full length pants, gloves and a hat.
4. When possible, in the interest of safety, park a vehicle along the curb with emergency flashing light in front of the curb inlet.

[10] http://www.coanda.com/video3.htm

5. Install traffic cones, yellow caution tape, and/or create barriers around the access cover to divert pedestrian movement around the access.
6. Remove the access cover.
7. Clean the curb inlet and place all debris in plastic bags.
8. Seal the plastic bags and immediately place on a truck for transport to disposal.
9. Should there be any debris on top of the Coanda screen, brush it off with a broom.
10. If animals are found in the curb inlet, notify animal control.
11. Note any unusual conditions and do not attempt to remove anything except ordinary debris.
12. If there has been any damage to the Coanda screen or debris fence, contact the manufacturer immediately.