CONNECTICUT DEPARTMENT OF TRANSPORTATION

Guidelines for the Use of Hydrodynamic Separators on CTDOT Projects

Description: Hydrodynamic separators (HDS) are proprietary devices used with closed storm drainage systems for stormwater treatment. These devices, also known as swirl concentrators, commonly rely on a vortex action to remove coarse solids and large oil droplets from the stormwater. They are modifications of traditional oil/particle separators (aka gross particle separators). In HDS structures, stormwater enters as tangential inlet flow into a cylindrical structure. As the stormwater spirals through the chamber, the swirling motion causes the sediments to settle by gravity, removing them from the stormwater. The sediments that settle out accumulate in a chamber within the structure that is accessible for periodic cleaning and maintenance. Some devices also have compartments to trap oil and other floatable materials. The outer walls of these structures are typically constructed of precast reinforced concrete while the internal components may be constructed of other materials.

Use: HDSs are considered a secondary stormwater treatment practice and therefore should only be proposed as a means of pre-treatment for a primary stormwater treatment practice or when the use of a primary treatment practice is not feasible due to site conditions.

An example of pre-treatment would be the inclusion of a hydrodynamic separator to remove sediment from stormwater runoff prior to discharge into an infiltration system which may be susceptible to clogging and not as easily maintained.

Qualified Products: HDSs, like other proprietary products, must be pre-qualified by the Department before they can be used on projects. A list of hydrodynamic separators qualified for use on projects is included in Table 1, Attachment A. The list is also maintained on the Hydraulics & Drainage Section website at List-of-CTDOT-Qualified-Hydrodynamic-Separators. The list includes the product name and the manufacturer's information. Additional information about specific products should be obtained by contacting the manufacturer(s) or researching their website(s). The Department does not endorse the use of a specific product.

The words "qualified product" mean that the listed product has been qualified for use on Department projects based on only a general review of the product's construction, function and treatment capabilities. Therefore, the qualified products list shall not be construed to mean that all products appearing on the list are suitable to any specific project site or drainage design. For example, site specific flow rates, grades or other restricting conditions may eliminate the use of one or more products at a project site. Final product acceptance occurs when the project is in construction and the contractor and/or manufacturer submits working drawings and other documentation demonstrating that the product to be installed satisfies all the requirements of the plans and specifications.

The performance of HDS devices varies greatly depending on a variety of factors. CTDOT utilizes the NJCAT Technology-Verification-Database to evaluate HDS devices on a uniform and equal basis.

In the NJCAT program, treatment efficiencies of the stormwater devices are verified through full-scale testing using a standard laboratory testing procedure prepared by the NJDEP. Upon completion, the NJCAT publishes a verification report that includes treatment flow rates verified under the program. Unfortunately, even as the NJCAT program evolved, not all products were tested or verified using the same particle size distribution and mean particle size, the most important variables in determining treatment efficiency. In addition, the same scaling methodology was not applied for all products which transfers the verified flow rate of a product of a certain model size to the same product but a different model or size, without having to perform testing for each different model.

Currently, in order to be qualified for use on CTDOT projects, HDS devices must be NJCAT verified. The Office of Hydraulics and Drainage will review the NJCAT approval list and subsequently update the CTDOT pre-qualified list (Table 1) and related design tables approximately every six months. Supporting documentation for product qualification should be sent to Hydraulics and Drainage and shall include the following:

- the NJCAT verification report
- detailed drawings of the products being requested for qualification
- specifications
- description of product function
- hydraulic performance (head loss)
- sediment storage capacity
- installation and maintenance requirements
- costs

Design Requirements: The following design requirements shall be used when designing and installing HDS on CTDOT projects.

Structural: The structural design of the hydrodynamic separator and its internal components is the responsibility of the manufacturer/supplier. During construction, the contractor shall submit Working Drawings showing that the selected product meets or exceeds the material and construction requirements established by the Department. Other documentation shall also be submitted showing that the selected product satisfies the performance criteria established by the Department and that the product is compatible with the drainage design shown on the plans.

Flow: HDSs shall be designed and analyzed for the following flow rates:

- the water quality flow (WQF)
- the portion of the peak flow directed to the hydrodynamic separator when the drainage system is operating at the drainage design flow (DDF)

The hydrodynamic separator shall be designed to treat the WQF without bypass. The WQF is the peak flow rate associated with the water quality design storm or water quality volume (WQV). The WQV is the amount of stormwater runoff from any given storm that should be captured and treated in order to remove a majority of stormwater pollutants on an average annual basis. The required WQV, which results in the capture and treatment of the entire runoff volume for 90% of the average annual storm events, is equivalent to the runoff associated with the first one inch of rainfall. In this approach, the HDS must be sized and designed to convey, without bypass, a peak flow equal to or greater than the WQF in order to treat the entire WQV.

The WQF shall be determined using the procedures outlined in Chapter 11, Appendix C of the Drainage Manual (Microsoft Word - 11.C.doc (ct.gov)).

The hydrodynamic separator shall also be evaluated when the storm drainage system is operating at the DDF, a 10-year storm for most systems. This evaluation is required to ensure that the inclusion of the hydrodynamic separator and other appurtenances to the drainage system will not result in an adverse backwater condition or re-suspension of previously trapped stormwater sediment and pollutants.

Layout: Hydrodynamic separators shall be typically installed outside of the Traveled Way, located in areas readily accessible for inspection and maintenance.

Hydrodynamic separators shall be placed off-line from the storm drainage system main line, to allow high flows to bypass the HDS. To accomplish this, two or more junction structures and additional piping may be needed. One structure shall be a flow diversion structure, designed as described below.

Example layouts of an off-line hydrodynamic separator are shown in Figure 1. Layout is dependent on the site and the type of HDS selected.

The Department requires external bypass of the off-line placement of the HDS even if it has internal bypass capabilities. The reasons for this requirement include:

- Trapped sediment and pollutants are less susceptible to re-suspension at lower flows, whereas higher flows can completely pass through and flush sediment out of the hydrodynamic separator.

- Lower flows help limit the size and cost of the structure. The structure size and internal bypass design elements increase with flow rate. The cost of the additional structures and piping for the off-line placement may be made up in a smaller, lower cost HDS.

- The storm drainage system can be designed as if the HDS is not present and the system will not be affected if the hydrodynamic separator is not functioning properly. The function of the storm drainage system over its expected service life will not be dependent on the maintenance schedule or the longevity of the hydrodynamic separator.

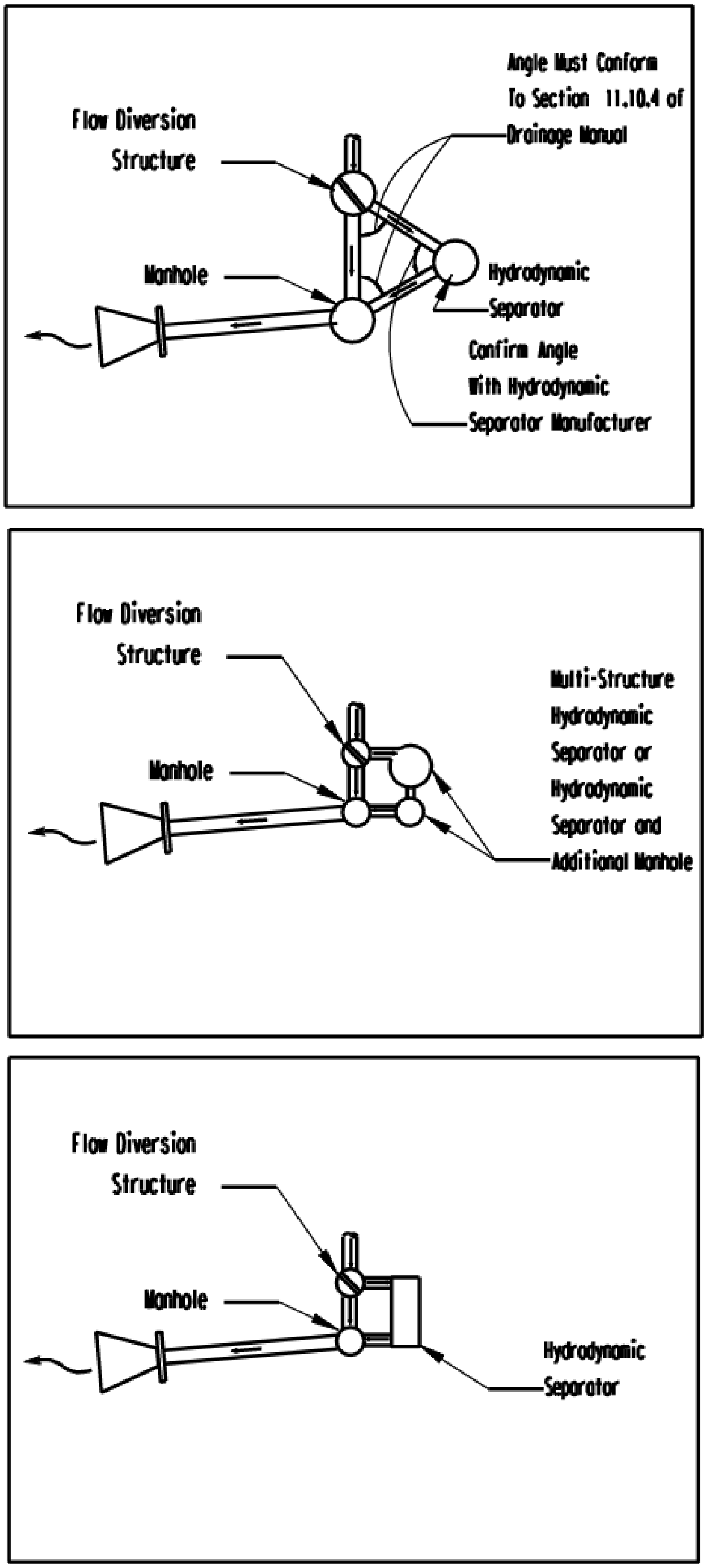


Figure 1 - Example of Layouts of Off-Line Hydrodynamic Separators

In certain cases, such as very small flows or unusual site conditions, on-line placement of the hydrodynamic separator may be allowed; however, such cases must receive prior approval from the Hydraulics & Drainage Section. The decision to design on-line HDS placement shall not be based solely on eliminating a manhole or using small lengths of pipe.

The location of the HDS system must be in an area accessible to a vacuum truck in order to maintain the system. The area must accommodate ingress and egress of the truck and provide direct access to each manhole over the chamber(s) from which debris and sediment will be removed. The manholes to be used for accessing the HDS unit should have covers that are marked "HDS" or equivalent.

Hydraulics: A hydraulic grade line (HGL) analysis shall be required for the evaluation of the hydrodynamic separator and the design of a flow diversion structure. The HGL analysis shall be performed for both the WQF and the DDF. The analysis shall be consistent with the methodology described in Section 11.12 of the Drainage Manual (1112pdf.pdf (ct.gov)) and any requirements of these guidelines.

The HGL analysis shall begin at the drainage system outlet and extend upstream of the flow diversion structure to a point where it has no influence on the rest of the upstream drainage system. In cases where the HDS is proposed to be located in the upper reaches of a multiple system drainage network, the HGL analysis shall begin at a documented hydraulic control in the system.

Structure Losses: Head loss coefficients, to be used in the HGL analysis, shall be determined in accordance with Section 11.12.6 for all structures except the hydrodynamic separator. A benching factor of 1.0 shall be applied to the flow diversion structure.

Head loss coefficients for specific HDS models may be obtained from the manufacturers. In lieu of coefficients obtained from the manufacturers, a head loss coefficient of 1.75 shall be used for an off-line hydrodynamic separator. This is an average value based on pipes entering and exiting a drainage structure at a 90 degree angle with no other correction factors applied.

In unusual cases where on-line placement of the hydrodynamic separator has received prior approval from the Hydraulics & Drainage Section, the head loss coefficient must be obtained from the manufacturer with supporting documentation on how the value was determined.

Flow Diversion Structure: The flow diversion structure is a structure used to divert stormwater from the main line of the storm drainage system to the hydrodynamic separator for treatment. The typical location of the flow diversion structure is shown on Figure 1. Outflow pipes from this structure typically consist of a low-flow pipe and a high-flow pipe. The low-flow pipe directs flow to the HDS. The high-flow pipe, sometimes referred to as the bypass pipe, is generally a part of the drainage system trunk-line and conveys the higher flows toward the main-line drainage system outlet, completely bypassing the HDS.

For the WQF, the flow diversion structure shall be designed so that the low-flow pipe conveys all of this flow to the hydrodynamic separator for treatment without bypass; this part of the design does not take into account the high-flow pipe or any internal bypass components within the hydrodynamic separator. See Figure 2A.

When the storm drainage system is operating under its drainage design flow (DDF), the resulting water surface elevation in the flow diversion structure will produce a head on both the low- and high-flow pipes, and the DDF will be split along the path of each of these pipes.

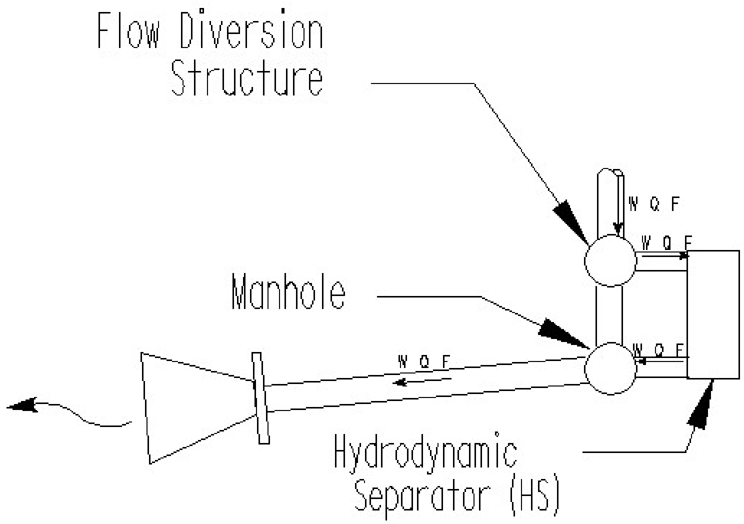


Figure 2 A
Flow Diversion At Water Quality Flow (WQF)

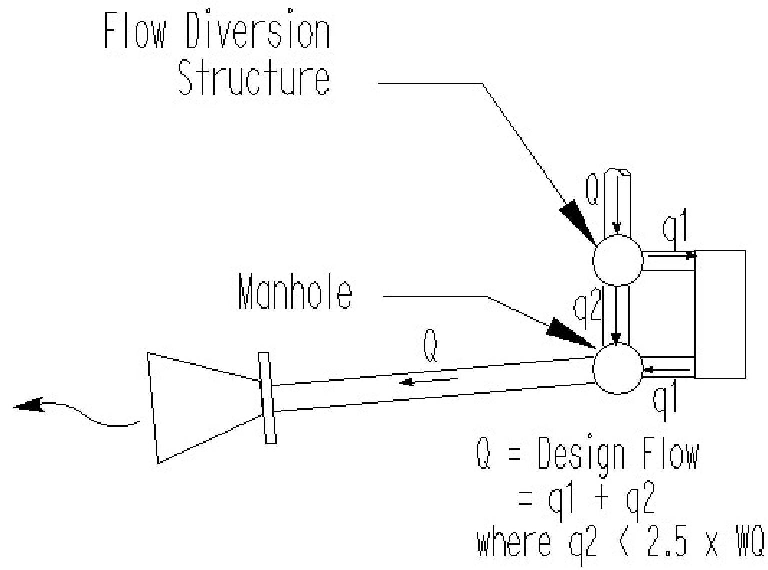


Figure 2B
Flow Split at Drainage System Design Flow

For the DDF, the flow diversion structure and flow split shall be designed to minimize the water surface elevation in the structure, such that the flow directed to the hydrodynamic separator is no more than the maximum flow recommended by the manufacturer, or 2.5 times the WQF, whichever is less. See Figure 2B. The purpose of this flow limitation, established by CTDOT, is to minimize potential re-suspension of trapped sediments as well as to limit the required size of the HDS and its internal components.

The flow diversion structure is typically a standard precast reinforced concrete manhole modified for this purpose. In some cases, a cast-in-place structure may be used. If a standard precast concrete manhole is used for this structure, the floor shall be flat. The flow diversion/split can be accomplished using two common methods.

1. Design Method 1 is used when the outflow pipes are set at or near the same elevation, usually due to grade restrictions. In this case, a baffle wall or weir is constructed on the manhole floor separating the inlet ends of the low- and high-flow pipes. The baffle wall/weir is built to the correct height to divert the WQF to the low-flow pipe and the hydrodynamic separator.

   Figure 3 illustrates this design method. Using this method, the design shall consist of the following:

- The top of the baffle wall/weir is set above the HGL elevation in the structure at the WQF so that no bypass occurs and all of the WQF is diverted to the HDS for treatment.

- For the DDF, it is recommended that the top of the baffle wall/weir elevation also be set above the HGL elevation on the downstream side, so there will be no tailwater on it for the design flow or less. A submerged baffle wall/weir is less efficient than a free flowing one and this condition must be taken into account which would further complicate the design calculations. The flow split in the structure at the DDF must be determined by HGL analysis to ensure that the flow directed to the HDS is less than the maximum flow recommended by the manufacturer or 2.5 times the WQF, whichever is less. Also, the inclusion of the flow diversion structure on the drainage system trunk line should not adversely affect the drainage design (one foot or greater of freeboard should be provided at all drainage structures).

   Changing the relative sizes of the outflow pipes and increasing the structure size to increase baffle wall/weir length are adjustments that can be made to alter the HGL and the resulting flow split at the flow diversion structure.

2. Design Method 2 is similar in concept, except that a baffle wall/weir is not used. Figure 4 illustrates this design method which consists of the following:

- The high-flow pipe invert at the structure is set above the invert of the low-flow pipe at an elevation that is above the HGL of the WQF.

- If a standard precast concrete manhole is used for this structure, the floor shall be angled toward the low-flow pipe.

- For the DDF, the flow split and HGL shall be evaluated as previously described for Design Method 1.

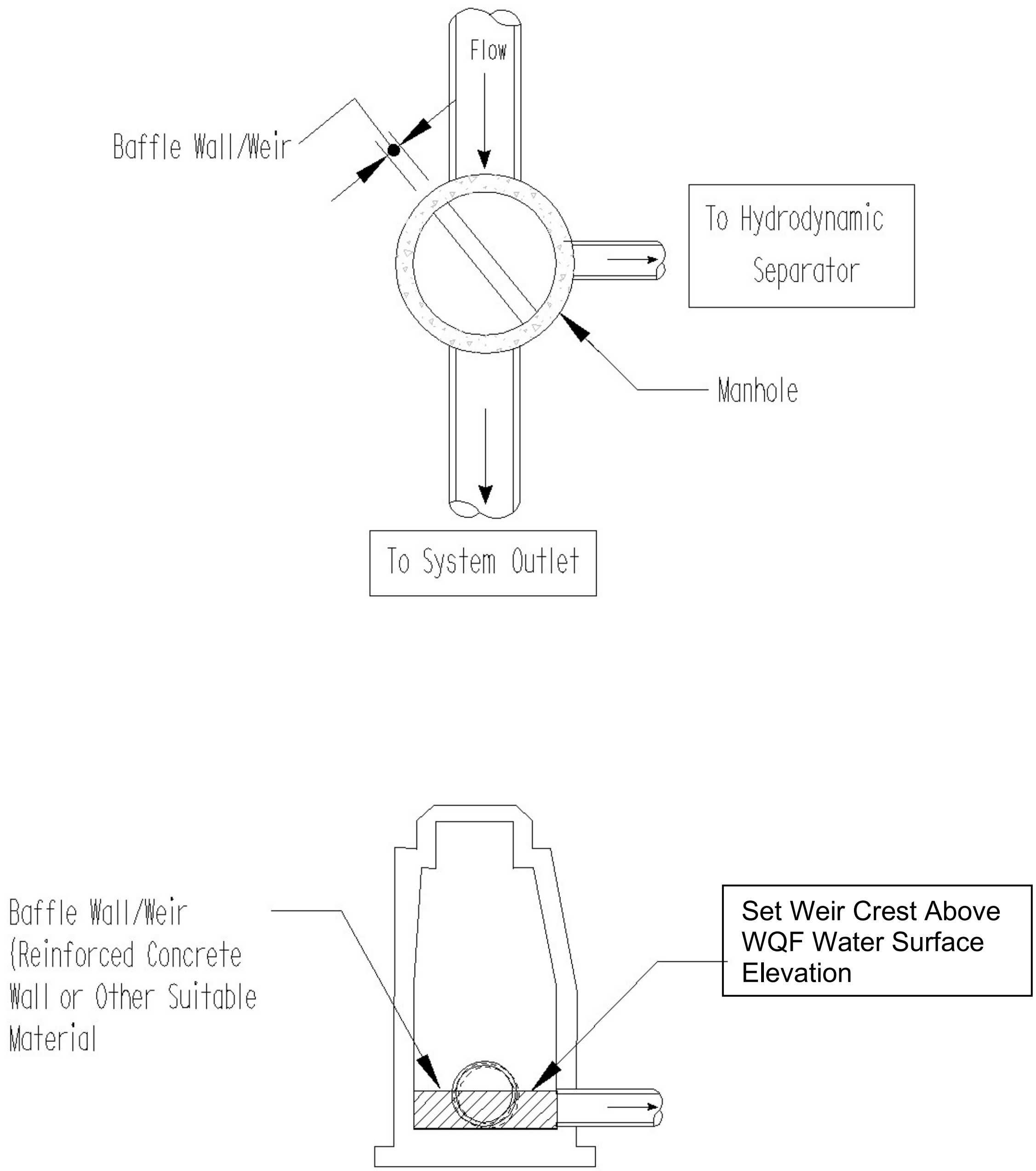


Figure 3- Flow Diversion Structure Design Method 1

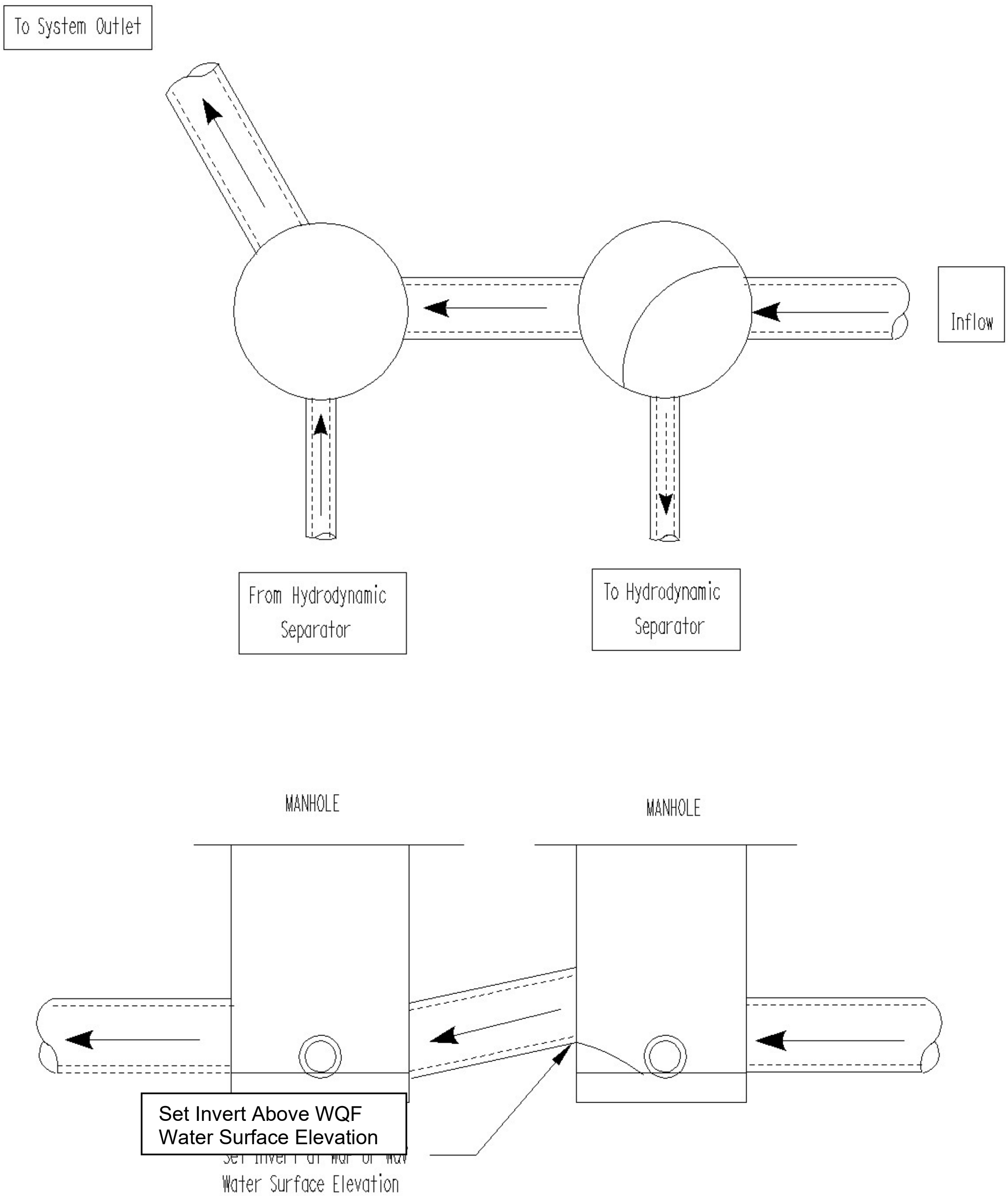


Figure 4- Flow Diversion Structure Design Method 2

Sediment Storage: Settleable solids shall accumulate in a location within the hydrodynamic separator accessible for cleaning and maintenance but not susceptible to re-suspension. Direct access through manhole openings shall be provided to the sediment storage chamber and all other chambers to facilitate maintenance.

The structure shall provide a minimum of 1.0 cubic yard of sediment storage. For comparative purposes, the standard sumps of a Type “C” Catch Basin and a Type “C” Double Grate, Type II Catch Basin have storage volumes of approximately 1 and 1.5 cubic yards, respectively; therefore, the HDS shall have a similar minimum sediment storage capacity.

The sediment storage capacity of the HDS shall be determined using a sediment accumulation rate of one-half (0.5) cubic yard per impervious acre per year but not less than the 1.0 cubic yard minimum required. This is because the maintenance cycle for these structures is once per year.

Performance Criteria: The sizing of the HDS shall be performance-based and shall satisfy the minimum sediment storage capacity requirements, which shall be determined using Tables 2 and 3 provided in Attachment B.

As indicated in the “Qualified Products” tables in this document, and as previously mentioned, CTDOT uses the results of the NJCAT verification program to determine product performance, verifying treatment efficiencies and establishing treatment flow rates for the stormwater devices.

The 2004 Connecticut Stormwater Quality Manual indicates that one of the guiding principles of stormwater quality management is to reduce the average annual TSS loading in stormwater runoff by 80%. Ideally, the performance of a hydrodynamic separator should be measured by a treatment efficiency of at least 80% to achieve this goal, however, some studies have shown efficiencies to be much less, especially when the sediment particles were less than 100 microns in diameter. For this reason and others, these devices are considered secondary treatment practices.

The NJDEP, which partners with the NJCAT in certifying stormwater manufactured treatment devices, has set a minimum treatment efficiency of 50% for hydrodynamic separators under their certification program. The NJCAT verified treatment efficiencies of products currently acceptable for use on CTDOT projects ranges from 50-75%, based on the NJDEP testing protocols.

The treatment flow rates or water quality flows (WQF) for the various qualified product models shown in Table 2, Attachment B, are based on the results of the NJCAT verification.

The sediment storage capacities for the various qualified product models shown in Table 3, Attachment B, are values based on standard structure dimensions and anticipated maintenance requirements. Some standard hydrodynamic separator models may be modified as determined by the manufacturer to increase the sediment storage capacity. When a modification is proposed by increasing the depth of the standard structure, the sediment storage capacity of the proposed structure shall be determined in accordance with Table 4, “SEDIMENT STORAGE CAPACITY CALCULATION,” Attachment B.

Design Data: Hydrologic and hydraulic data for the portion of the storm drainage system in the vicinity of the HDS shall be shown on the Hydrodynamic Separator Design Data Sheet. The Design Data Sheet shall include a sketch showing the drainage structure and pipe layout in relation to the HDS and the flow diversion structure. If the flow diversion structure uses an internal baffle wall or weir to divert the drainage system flow, the weir elevation, length and discharge coefficient shall be shown. The HGL analysis table on the Sheet shall include the pipe flows, types, sizes, lengths, flow-line elevations, ground elevations and structure head loss coefficients as well as the results of the HGL analysis for both the WQF and the DDF conditions. At a minimum, the HGL analysis shall be shown from the system outlet or a documented hydraulic control in the drainage system, to the flow diversion structure including the hydrodynamic separator.

Connecticut Department Of Transportation Hydrodynamic Separator Design Data Sheets (Form A - Design) (Figures 5-1 and 5-2) shall be prepared in the design phase of the project by the designer. A separate Form A shall be provided for each HDS on the project, which shall be included in the Drainage Report and the special provisions. The data shall be used by the manufacturer and/or the contractor's engineer to determine the size and specific model for installation on the project.

Connecticut Department Of Transportation Hydrodynamic Separator Design Data Sheets (Form B – Contractor Proposal) (Figures 6-1 and 6-2) shall be prepared by the manufacturer of the hydrodynamic separator or the contractor's engineer during the construction phase of the project. A separate Form B shall be submitted by the Contractor with the Working Drawings for each HDS on the project, along with other documentation for the hydrodynamic separator(s) as required by the special provisions.

Plans: Hydrodynamic separators are incorporated into a contract by means of the plans and special provisions. The device shall be shown on the plans and called out as "Hydrodynamic Separator." The plans shall also include the pay limits showing all the components of the system that are included in this lump sum pay item.

Although the designer may have a particular product in mind, the product name, model number or other specific product information is not to be included in the plans or special provisions.

The designer is to include a detail for the flow diversion structure in the plans. All pipe sizes, types, lengths and flow-line elevations shall be shown on plans for the hydrodynamic separator and flow diversion structure as is required for all drainage structures. The detail shall also show the HGL elevation in the structure for the WQF and the DDF. Multiple hydrodynamic separators on a project shall be designated by site number, roadway and station location. The center coordinates of the HDS shall be shown on the plans for future reference in the Department's Master Stormwater Management Plan for compliance with the National Pollutant Discharge Elimination System (NPDES) Phase II Stormwater Program.

CONNECTICUT DEPARTMENT OF TRANSPORTATION HYDRODYNAMIC SEPARATOR DESIGN DATA SHEETS (FORM A - DESIGN)

Project No		Route No.		Prepared By:		Date:	
Town		Location/Station		Checked By:		Date:	

HYDROLOGIC DATA

Drainage Area (Acres)	
Percent Impervious Area %	
Time of Concentration (min.)	
Drainage Design Flow (cfs)	
Drainage Design Frequency (yr)	
Water Quality Flow (cfs)	

Company:

HYDRODYNAMIC SEPARATOR (HS)

Coordinates:		Datum:	
X:		Horiz.	
Y:		Vert.	
Head loss coefficient			
Sediment Storage Capacity (cy):		HGL Elevation:	
Required		@ WQF	
		@ Design Q	
Maximum Flow to HS at Drainage Design Flow (cfs)			

Comments:

FLOW DIVERSION STRUCTURE

Type			
Weir and/or Bypass Elev.			
Weir Length (ft.)		Weir Coeff. (C)	
HGL Elevation:		Flow Split @ Drainage Design Flow	
@ WQF		To HS	
@ Design Q		Bypassing HS	

Sketch (NTS) - Indicate Pay limits

Comments:

Sheet 1 of 2

CONNECTICUT DEPARTMENT OF TRANSPORTATION HYDRODYNAMIC SEPARATOR DESIGN DATA SHEETS (FORM A - DESIGN)

Project No: **Location/Station:** **Date:**

HYDRAULIC GRADE LINE ANALYSIS

Pipe	Downstream Str.	Pipe Size (in)	Flow (cfs)	Ground Elev. OUT (ft)	Invert Elev. OUT (ft)	HGL OUT (ft)	Depth OUT (ft)	Vel. Head OUT (ft)	EGL OUT (ft)	Length (ft)	Friction Slope (ft/ft)	Friction Loss (ft)	EGL IN (ft)	Vel. Head IN (ft)	HGL IN (ft)	Depth IN (ft)	Invert Elev. IN (ft)	Ground Elev. IN (ft)	Upstream Str.	Headloss Coeff.	Str. headloss (ft.)

Sheet 2 of 2

CONNECTICUT DEPARTMENT OF TRANSPORTATION HYDRODYNAMIC SEPARATOR DESIGN DATA SHEETS (FORM B - CONTRACTOR PROPOSAL)

Project No		Route No.	
Town		Location/Station	

PE Signature:			
Name:		Date:	
License No:		State:	
Company:			

HYDROLOGIC DATA (Copy from FORM A - DESIGN)	
Drainage Area (Acres)	
% Impervious Area	
Time of Concentration (min.)	
Drainage Design Flow (cfs)	
Drainage Design Frequency (yr)	
Water Quality Flow (cfs)	

HYDRODYNAMIC SEPARATOR (HS)			
Manufacturer			
Model Name			
Model No.			
Coordinates:		Datum:	
X:		Horiz.	
Y:		Vert.	
Sediment Storage Capacity (cy):		HGL Elevation:	
Required		@ WQF	
Installed		@ Design Q	
Head loss coefficient			

FLOW DIVERSION STRUCTURE			
Type			
Weir and/or Bypass Elev.			
Weir Length (ft.)		Weir Coeff. (C)	
HGL Elevation:		Flow Split @ Drainage Design Flow (cfs):	
@ WQF		To HS	
@ Design Q		Bypassing HS	

Sketch (NTS)

Comments:

Sheet 1 of 2

CONNECTICUT DEPARTMENT OF TRANSPORTATION HYDRODYNAMIC SEPARATOR DESIGN DATA SHEETS (FORM B - CONTRACTOR PROPOSAL)

Project No:		Location/Station:		Date:	

HYDRAULIC GRADE LINE ANALYSIS

Pipe	Downstream Str.	Pipe Size (in)	Flow (cfs)	Ground Elev. OUT (ft)	Invert Elev. OUT (ft)	HGL OUT (ft)	Depth OUT (ft)	Vel. Head OUT (ft)	EGL OUT (ft)	Length (ft)	Friction Slope (ft/ft)	Friction Loss (ft)	EGL IN (ft)	Vel. Head IN (ft)	HGL IN (ft)	Depth IN (ft)	Invert Elev. IN (ft)	Ground Elev. IN (ft)	Upstream Str.	Headloss Coeff.	Str. headloss (ft.)

Sheet 2 of 2

Working Drawings: Working Drawings in accordance with Article 1.05.02–2 shall be required for the system selected by the contractor. The Working Drawings shall include the HGL analysis and all other computations.

If revisions to the layout of the system within the designed pay limits of this item are required to accommodate the selected HDS, the Working Drawings shall also show the required revisions to the position of the HDS unit(s), and all revisions to connecting structures, pipes, elevations, and details, including the details within the flow diversion structure. The revised project plans shall also include the pay limit showing all the components of the system that are included in this lump sum pay item.

Working Drawings shall also show details for construction, reinforcing joints, internal and external components, any cast-in-place appurtenances, locations and elevations of pipe openings, access manhole locations and elevations, and type / method of sealing pipe entrances. All access manhole covers should be shown in the Working Drawings as having "HDS" or equivalent stamped on them. This will allow them to be easily identified in the field and differentiated from normal storm or sanitary sewer manholes.

Working Drawings for each HDS on the project shall have all appropriate vertical dimensions referenced with elevations that are consistent with the plans. In addition to any other structural, material or installation requirements, the Working Drawings shall clearly indicate the following information:

1. The elevation and flow rate when internal flow bypass would occur within the device.

2. The location, dimensions and volume (capacity) of the sediment storage area within the device.

The Working Drawings shall be sealed by a Professional Engineer licensed in the state where the devices are manufactured and said Engineer shall certify the HDS meets the requirements of CTDOT Standards.

The Working Drawing submission shall consist of the following documents:

1. Working Drawings for each hydrodynamic separator proposed for installation on the project.

2. Hydraulic design calculations including the head loss documentation and completed Hydrodynamic Separator Design Data Sheets (Form B – Contractor Proposal) with PE signature for each hydrodynamic separator.

3. Copies of the pertinent construction plan, profile, cross section and detail sheets that have been annotated with any proposed drainage revisions that are required for the installation of the proposed hydrodynamic separator. If no changes are required, the submittal shall note same.

4. An Operations and Maintenance Manual for each hydrodynamic separator describing operations, inspection, maintenance procedures and any applicable warranty information.

Special Provisions: A special provision is required for the hydrodynamic separator which refers to the list of Department qualified products, includes performance criteria, and a Hydrodynamic Separator Design Data Form B for each hydrodynamic separator on the project.

The project contractor may choose a product from the qualified list for installation on the project provided that the product satisfies all of the requirements of the special provisions and is suitable for the site conditions and drainage design depicted on the plans. Therefore, the contractor must be aware that not all products appearing on the qualified list are suitable to any given project site.

A template special provision for Item #05071XXA Hydrodynamic Separator (Site No. X) [l.s.] can be obtained from the Department. Please note that it is the project designer's responsibility to read and understand the special provision and to tailor it as necessary for a specific project.

Selection Process: The process of how the hydrodynamic separator is called out in the design phase and then selected in the construction phase of the project is summarized below.

I. Design Phase

1. A hydrodynamic separator will be incorporated into the drainage design for stormwater treatment based on the water quality flow (WQF) and minimum sediment storage that have been calculated in accordance with the requirements. Select the available product(s) from Table 2, Attachment B (**PERFORMANCE MATRIX FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS**) that meet or exceed the WQF treatment required.

2. Using Table 3, Attachment B (**STANDARD SEDIMENT STORAGE CAPACITY FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS**), check whether the initially selected product(s), meet or exceed the minimum sediment storage requirement. In some cases, the required sediment storage capacity will govern the model size required for the project. Be aware that some standard product models may be modified to increase the sediment storage capacity in lieu of selecting a larger model to accommodate the sediment storage requirement. The manufacturer should be consulted about these modifications.

3. When the HDS models that satisfy both the WQF and minimum sediment storage capacity requirements have been identified, the designer should review the overall size (potential footprint and depth) and configuration of these products to determine if any or all are suitable for installation at the site(s). The designer shall ensure that at least one product from the list will satisfy the design and performance requirements to avoid any significant design changes during construction.

4. The designer shall prepare HGL calculations for the drainage system and design the flow diversion structure assuming a particular model of hydrodynamic separator will be chosen.

5. Pertinent portions of the design calculations are to be summarized on the Hydrodynamic Separator Design Data Sheets (Form A - Design) in accordance with the design requirements.

6. A "generic" hydrodynamic separator and the flow diversion structure are to be shown on the plan sheets. **SPECIFIC HYDRODYNAMIC SEPARATOR PRODUCT NAMES, MODEL NUMBERS, ETC., SHALL NOT BE CALLED OUT ON THE PLANS NOR SHALL ANY DETAILS BE INCLUDED THAT IMPLY THE INSTALLATION OF A SPECIFIC PRODUCT.** A simple detail showing the layout of the hydrodynamic separator and the flow diversion structure along with the inflow and outflow pipe sizes, invert elevations, weir elevation, pay limits and other plan requirements shall be included in the plans.

7. The special provision is prepared by the designer for the hydrodynamic separator(s) which includes the completed Hydrodynamic Separator Design Sheets (Form A – Design) for each hydrodynamic separator on the project. The correct number of Hydrodynamic Separator Data Design Sheets (Form B – Contractor Proposal) are to be included in the contract.

II. Construction Phase

1. The contractor initially selects the potential hydrodynamic separator model(s) to be installed from the qualified product list using the information from the Hydrodynamic Separator Design Sheets (Form A – Design) and Table 2, Attachment B. (Same as Step 1, Design Phase.)

2. Using Table 3, Attachment B (**STANDARD SEDIMENT STORAGE CAPACITY FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS**), the contractor shall check whether the initially selected model(s), meet or exceed the minimum sediment storage requirement specified on the Hydrodynamic Separator Design Data Sheets (Form A - Design). In some cases, the required sediment storage capacity will govern the model size required for the project. In lieu of selecting a larger model to accommodate the sediment storage requirement, the contractor may submit Working Drawings, showing how a standard model can be modified as recommended by the manufacturer to satisfy the sediment storage requirement. When a modification is proposed by increasing the depth of the standard structure, Table 4, Attachment B (**SEDIMENT STORAGE CAPACITY CALCULATION**) shall be used to determine the sediment storage capacity of the proposed structure.

3. When the product model(s) that satisfy both the WQF and minimum sediment storage capacity requirements have been identified, the contractor shall verify the constructability of the selected HDS in relation to dimensional, structural, geotechnical and right-of-way constraints at each installation site. If revisions to the drainage design, including the system layout, are required to accommodate the proposed separator model(s), the contractor shall be required to provide Working Drawings showing the revised layout, including the position of the hydrodynamic separator and the number, positions and types of connecting structures, the design of the flow diversion structure, and any other components of the system within the pay limits. The Working Drawings shall be prepared in sufficient detail to perform a hydraulic analysis and confirm that the layout will fit the constraints of each site.

4. Upon selection of a hydrodynamic separator that satisfies the WQF, sediment storage and constructability requirements, the contractor shall prepare or have prepared a HGL analysis that includes the selected HDS. Since the model(s) selected by the contractor may be different in type, configuration and performance than the assumed model(s) in the design phase, the manufacturer or the contractor's engineer must replicate the hydraulic calculations performed for the drainage design. These calculations shall reflect any adjustments necessary to the drainage design for installation of the selected product, such as different flow-line elevations, head loss coefficient, pipe sizes, modifications to the flow diversion structure, etc. The calculations shall be performed in accordance with the design requirements section and to the same limits as shown on Hydrodynamic Separator Design Data Sheets (Form A - Design). The Hydrodynamic Separator Design Data Sheets (Form B – Contractor Proposal) shall be prepared by the manufacturer or the contractor's engineer based on the results of revised hydraulic calculations and shall be signed by a licensed Professional Engineer.

5. The Hydrodynamic Separator Design Data Sheets (Form B – Contractor Proposal) shall be compared to the Form A that was prepared in the design phase. Ideally, the selected hydrodynamic separator shall be designed/installed in such a manner to minimize or eliminate the need for changes or additional analysis of the drainage design shown on the plans. Should the results of the hydraulic analysis for the selected HDS show changes that potentially impact the drainage design, the hydraulic analysis may need to be extended to a point upstream that is not influenced by the proposed changes. The results must show that the revised drainage design meets the design requirements of CTDOT's Drainage Manual.

6. The contractor shall submit the Working Drawings, calculations and other documentation for the selected hydrodynamic separator in accordance with Article 1.05.02 and the special provision, including the Hydrodynamic Separator Design Data Sheets (Form B – Contractor Proposal). For Consultant Design projects, the Department will forward a copy of this information to the design engineers for their review. *Acceptance of the submission by the Department must be obtained by the contractor prior to the purchase or installation of any units.*

7. Contractor's proposals that do not meet the requirements of the special provision or the design requirements in these guidelines shall be rejected.

Compliance: It is recognized that each stormwater product manufacturer has their own methods of designing, sizing and analyzing HDS structures; however, any product design submission or proposed installation, either in the design or the construction phase, that does not meet the project special provisions or the design requirements, shall be rejected.

The following list highlights items that should be checked to ensure compliance to the design requirements in both the design and construction phases:

- The water quality flow (WQF) has been determined using the procedures outlined in Chapter 11, Appendix C of the Drainage Manual.

- The hydrodynamic separator has been placed off-line of the storm drainage system. In rare cases of online placement, prior approval has been obtained from the Hydraulics & Drainage section.

- A HGL analysis has been performed and submitted consistent with the methodology described in Section 11.12 of the Drainage Manual and any requirements of the hydrodynamic separator section of this document.

- The head loss coefficient for the hydrodynamic separator has been provided with supporting documentation.

- The HGL analysis has been performed and submitted for the both the WQF and the drainage system design flow.

- The HGL elevation at the **flow diversion structure** for the WQF is below the elevation of flow bypass, so that all of the WQF is directed to the hydrodynamic separator for treatment. Check the HGL elevation with the detail for the flow diversion structure.

- The HGL elevation at the **hydrodynamic separator** for the WQF is below the elevation of internal flow bypass, so that all of the WQF is treated by the device. Check the HGL elevation with the Working Drawings for the hydrodynamic separator.

- The HGL elevation and flow split has been determined at the flow diversion structure for the DDF and the flow directed toward the hydrodynamic separator is no more than recommended by the manufacturer or 2.5 times the WQF, whichever is less.

- The sediment storage capacity of each hydrodynamic separator on the project equals or exceeds 0.5 cubic yard per impervious acre of drainage area per year or 1.0 cubic yard, whichever is greater.

- Hydrodynamic Separator Design Data Sheets (Form A - Design) have been completed in entirety for each hydrodynamic separator on the project and copies of these forms have been included in the drainage report and special provisions.

- Hydrodynamic Separator Design Data Sheets (Form B – Contractor Proposal) have been completed in entirety for each hydrodynamic separator proposed for installation on the project by the contractor and copies of these forms have been included with the Working Drawings and other documentation being submitted in accordance with Article 1.05.02 and the special provisions.

- The submitted documentation is complete and includes information showing that each hydrodynamic separator on the project meets the Department's performance criteria.

Design Example: An example illustrating the WQF calculation, flow diversion structure design, HGL analysis and the completion of the Hydrodynamic Separator Design Data Sheets (Form A – Design) is included in Attachment C of this document.

TABLE 1 – CTDOT LIST OF QUALIFIED HYDRODYNAMIC SEPARATOR MANUFACTURERS

<table>
<tr><th>HYDRODYNAMIC SEPARATOR NAME</th><th>COMPANY INFORMATION</th></tr>
<tr><td>Barracuda</td><td>BaySaver Technologies, LLC
1030 Deer Hollow Drive
Mt. Airy, MD 21771
(800)-229-7283
https://baysaver.com/</td></tr>
<tr><td>Cascade</td><td rowspan="2">Contech Engineered Solutions
9025 Centre Point Dr.
West Chester, OH 45069
(800)-338-1122
https://www.conteches.com/</td></tr>
<tr><td>CDS</td></tr>
<tr><td>Concentrator</td><td rowspan="2">AquaShield Inc.
2733 Kanasita Drive Suite 111
Chattanooga, TN 37343
(423)-870-8888
https://www.aquashieldinc.com/</td></tr>
<tr><td>Xcelerator</td></tr>
<tr><td>Downstream Defender</td><td rowspan="2">Hydro International
94 Hutchins Drive
Portland, ME 04102
(207)-756-6200
https://hydro-int.com/en</td></tr>
<tr><td>First Defense</td></tr>
<tr><td>DVS</td><td>Oldcastle Infrastructure
7000 Central Prkwy, Suite 800
Atlanta, GA 30328
(888)-965-3227
https://oldcastleinfrastructure.com/</td></tr>
<tr><td>HydroDome</td><td rowspan="2">Hydroworks, LLC
257 Cox St.
Roselle, NJ 07203
(848)-235-5950
https://hydroworks.com/</td></tr>
<tr><td>HydroStorm</td></tr>
<tr><td>SciClone</td><td rowspan="2">BioClean Envr. Services
5796 Armada Dr. Suite 250
Carlsbad, CA 92008
(855)-566-3938
https://biocleanenvironmental.com/</td></tr>
<tr><td>SciCloneX</td></tr>
</table>

TABLE 2 - PERFORMANCE MATRIX FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS

Max WQF (cfs)	Product Model											
	Barracuda	*Cascade*	*CDS*	*Concentrator*	*Downstream Defender*	*DVS*	*First Defense*	*HydroDome*	*HydroStorm*	*SciClone*	*SciCloneX*	*Xcelerator*
0.1	Barracuda S3(3)	CS-3(3)	CDS-3(3)	AS-2(2.5)	4ft(4)	DVS-36(3)	3ft(3)	HD3(3)	HS3(3)	SC-3(3)	SCX-3(3)	XC-2(2.5)
0.2	Barracuda S3(3)	CS-3(3)	CDS-3(3)	AS-2(2.5)	4ft(4)	DVS-36(3)	3ft(3)	HD3(3)	HS3(3)	SC-3(3)	SCX-3(3)	XC-2(2.5)
0.3	Barracuda S3(3)	CS-3(3)	CDS-3(3)	AS-2(2.5)	4ft(4)	DVS-36(3)	3ft(3)	HD3(3)	HS3(3)	SC-3(3)	SCX-3(3)	XC-2(2.5)
0.4	Barracuda S3(3)	CS-3(3)	CDS-3(3)	AS-3(3.5)	4ft(4)	DVS-36(3)	3ft(3)	HD3(3)	HS3(3)	SC-4(4)	SCX-3(3)	XC-2(2.5)
0.5	Barracuda S3(3)	CS-3(3)	CDS-3(3)	AS-3(3.5)	4ft(4)	DVS-36(3)	3ft(3)	HD3(3)	HS3(3)	SC-4(4)	SCX-3(3)	XC-2(2.5)
0.6	Barracuda S3(3)	CS-3(3)	CDS-4(4)	AS-3(3.5)	4ft(4)	DVS-48(4)	3ft(3)	HD3(3)	HS4(4)	SC-4(4)	SCX-3(3)	XC-3(3.5)
0.7	Barracuda S3(3)	CS-3(3)	CDS-4(4)	AS-3(3.5)	4ft(4)	DVS-48(4)	3ft(3)	HD3(3)	HS4(4)	SC-4(4)	SCX-3(3)	XC-3(3.5)
0.8	Barracuda S4(4)	CS-3(3)	CDS-4(4)	AS-4(4.5)	4ft(4)	DVS-48(4)	3ft(3)	HD3(3)	HS4(4)	SC-5(5)	SCX-3(3)	XC-3(3.5)
0.9	Barracuda S4(4)	CS-3(3)	CDS-4(4)	AS-4(4.5)	4ft(4)	DVS-48(4)	4ft(4)	HD4(4)	HS5(5)	SC-5(5)	SCX-3(3)	XC-3(3.5)
1.0	Barracuda S4(4)	CS-3(3)	CDS-5(5)	AS-4(4.5)	4ft(4)	DVS-48(4)	4ft(4)	HD4(4)	HS5(5)	SC-5(5)	SCX-3(3)	XC-3(3.5)
1.1	Barracuda S4(4)	CS-4(4)	CDS-5(5)	AS-4(4.5)	4ft(4)	DVS-60(5)	4ft(4)	HD4(4)	HS5(5)	SC-6(6)	SCX-4(4)	XC-3(3.5)
1.2	Barracuda S4(4)	CS-4(4)	CDS-5(5)	AS-5(5)	6ft(6)	DVS-60(5)	4ft(4)	HD4(4)	HS5(5)	SC-6(6)	SCX-4(4)	XC-4(4.5)
1.3	Barracuda S5(5)	CS-4(4)	CDS-5(5)	AS-5(5)	6ft(6)	DVS-60(5)	4ft(4)	HD4(4)	HS5(5)	SC-6(6)	SCX-4(4)	XC-4(4.5)
1.4	Barracuda S5(5)	CS-4(4)	CDS-5(5)	AS-5(5)	6ft(6)	DVS-60(5)	4ft(4)	HD4(4)	HS6(6)	SC-6(6)	SCX-4(4)	XC-4(4.5)
1.5	Barracuda S5(5)	CS-4(4)	CDS-5(5)	AS-6(6)	6ft(6)	DVS-60(5)	4ft(4)	HD4(4)	HS6(6)	SC-6(6)	SCX-4(4)	XC-4(4.5)
1.6	Barracuda S5(5)	CS-4(4)	CDS-6(6)	AS-6(6)	6ft(6)	DVS-72(6)	5ft(5)	HD5(5)	HS6(6)	SC-7(7)	SCX-4(4)	XC-4(4.5)
1.7	Barracuda S5(5)	CS-4(4)	CDS-6(6)	AS-6(6)	6ft(6)	DVS-72(6)	5ft(5)	HD5(5)	HS6(6)	SC-7(7)	SCX-4(4)	XC-4(4.5)
1.8	Barracuda S5(5)	CS-4(4)	CDS-6(6)	AS-6(6)	6ft(6)	DVS-72(6)	5ft(5)	HD5(5)	HS6(6)	SC-7(7)	SCX-4(4)	XC-4(4.5)

TABLE 2 - PERFORMANCE MATRIX FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS (continued)

Max WQF (cfs)	Product Model											
	Barracuda	*Cascade*	*CDS*	*Concentrator*	*Downstream Defender*	*DVS*	*First Defense*	*HydroDome*	*HydroStorm*	*SciClone*	*SciCloneX*	*Xcelerator*
1.9	Barracuda S5(5)	CS-5(5)	CDS-6(6)	AS-6(6)	6ft(6)	DVS-72(6)	5ft(5)	HD5(5)	HS6(6)	SC-7(7)	SCX-5(5)	XC-5(5.5)
2.0	Barracuda S6(6)	CS-5(5)	CDS-6(6)	AS-6(6)	6ft(6)	DVS-72(6)	5ft(5)	HD5(5)	HS7(7)	SC-7(7)	SCX-5(5)	XC-5(5.5)
2.1	Barracuda S6(6)	CS-5(5)	CDS-6(6)	AS-6(6)	6ft(6)	DVS-72(6)	5ft(5)	HD5(5)	HS7(7)	SC-7(7)	SCX-5(5)	XC-5(5.5)
2.2	Barracuda S6(6)	CS-5(5)	CDS-7(7)	AS-7(7)	6ft(6)	DVS-72(6)	5ft(5)	HD5(5)	HS7(7)	SC-8(8)	SCX-5(5)	XC-5(5.5)
2.3	Barracuda S6(6)	CS-5(5)	CDS-7(7)	AS-7(7)	6ft(6)	DVS-84(7)	5ft(5)	HD5(5)	HS7(7)	SC-8(8)	SCX-5(5)	XC-5(5.5)
2.4	Barracuda S6(6)	CS-5(5)	CDS-7(7)	AS-7(7)	6ft(6)	DVS-84(7)	6ft(6)	HD6(6)	HS7(7)	SC-8(8)	SCX-5(5)	XC-5(5.5)
2.5	Barracuda S6(6)	CS-5(5)	CDS-7(7)	AS-7(7)	6ft(6)	DVS-84(7)	6ft(6)	HD6(6)	HS7(7)	SC-8(8)	SCX-5(5)	XC-5(5.5)
2.6	Barracuda S6(6)	CS-5(5)	CDS-7(7)	AS-7(7)	8ft(8)	DVS-84(7)	6ft(6)	HD6(6)	HS7(7)	SC-8(8)	SCX-5(5)	XC-5(5.5)
2.7	Barracuda S6(6)	CS-5(5)	CDS-7(7)	AS-7(7)	8ft(8)	DVS-84(7)	6ft(6)	HD6(6)	HS8(8)	SC-8(8)	SCX-5(5)	XC-5(5.5)
2.8	Barracuda S6(6)	CS-5(5)	CDS-7(7)	AS-7(7)	8ft(8)	DVS-84(7)	6ft(6)	HD6(6)	HS8(8)	SC-8(8)	SCX-5(5)	XC-6(6.5)
2.9	Barracuda S8(8)	CS-6(6)	CDS-8(8)	AS-8(8)	8ft(8)	DVS-84(7)	6ft(6)	HD6(6)	HS8(8)	SC-9(9)	SCX-6(6)	XC-6(6.5)
3.0	Barracuda S8(8)	CS-6(6)	CDS-8(8)	AS-8(8)	8ft(8)	DVS-84(7)	6ft(6)	HD6(6)	HS8(8)	SC-9(9)	SCX-6(6)	XC-6(6.5)
3.1	Barracuda S8(8)	CS-6(6)	CDS-8(8)	AS-8(8)	8ft(8)	DVS-96(8)	6ft(6)	HD6(6)	HS8(8)	SC-9(9)	SCX-6(6)	XC-6(6.5)
3.2	Barracuda S8(8)	CS-6(6)	CDS-8(8)	AS-8(8)	8ft(8)	DVS-96(8)	6ft(6)	HD6(6)	HS8(8)	SC-9(9)	SCX-6(6)	XC-6(6.5)
3.3	Barracuda S8(8)	CS-6(6)	CDS-8(8)	AS-8(8)	8ft(8)	DVS-96(8)	6ft(6)	HD6(6)	HS8(8)	SC-9(9)	SCX-6(6)	XC-6(6.5)
3.4	Barracuda S8(8)	CS-6(6)	CDS-8(8)	AS-8(8)	8ft(8)	DVS-96(8)	7ft(7)	HD6(6)	HS8(8)	SC-9(9)	SCX-6(6)	XC-6(6.5)
3.5	Barracuda S8(8)	CS-6(6)	CDS-8(8)	AS-8(8)	8ft(8)	DVS-96(8)	7ft(7)	HD7(7)	HS8(8)	SC-9(9)	SCX-6(6)	XC-6(6.5)
3.6	Barracuda S8(8)	CS-6(6)	CDS-8(8)	AS-8(8)	8ft(8)	DVS-96(8)	7ft(7)	HD7(7)	HS9(9)	SC-10(10)	SCX-6(6)	XC-6(6.5)

TABLE 2 - PERFORMANCE MATRIX FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS (continued)

Max WQF (cfs)	Product Model											
	Barracuda	*Cascade*	*CDS*	*Concentrator*	*Downstream Defender*	*DVS*	*First Defense*	*HydroDome*	*HydroStorm*	*SciClone*	*SciCloneX*	*Xcelerator*
3.7	Barracuda S8(8)	CS-6(6)	CDS-8(8)	AS-8(8)	8ft(8)	DVS-96(8)	7ft(7)	HD7(7)	HS9(9)	SC-10(10)	SCX-6(6)	XC-6(6.5)
3.8	Barracuda S8(8)	CS-6(6)	CDS-10(10)	AS-9(9)	8ft(8)	DVS-96(8)	7ft(7)	HD7(7)	HS9(9)	SC-10(10)	SCX-6(6)	XC-6(6.5)
3.9	Barracuda S8(8)	CS-6(6)	CDS-10(10)	AS-9(9)	8ft(8)	DVS-96(8)	7ft(7)	HD7(7)	HS9(9)	SC-10(10)	SCX-6(6)	XC-7(7.5)
4.0	Barracuda S8(8)	CS-6(6)	CDS-10(10)	AS-9(9)	8ft(8)	DVS-96(8)	7ft(7)	HD7(7)	HS9(9)	SC-10(10)	SCX-6(6)	XC-7(7.5)
4.1	Barracuda S8(8)	CS-8(8)	CDS-10(10)	AS-9(9)	8ft(8)	DVS-120(10)	7ft(7)	HD7(7)	HS9(9)	SC-10(10)	SCX-7(7)	XC-7(7.5)
4.2	Barracuda S8(8)	CS-8(8)	CDS-10(10)	AS-9(9)	8ft(8)	DVS-120(10)	7ft(7)	HD7(7)	HS9(9)	SC-10(10)	SCX-7(7)	XC-7(7.5)
4.3	Barracuda S8(8)	CS-8(8)	CDS-10(10)	AS-9(9)	8ft(8)	DVS-120(10)	7ft(7)	HD7(7)	HS9(9)	SC-10(10)	SCX-7(7)	XC-7(7.5)
4.4	Barracuda S8(8)	CS-8(8)	CDS-10(10)	AS-9(9)	8ft(8)	DVS-120(10)	7ft(7)	HD7(7)	HS9(9)	SC-11(11)	SCX-7(7)	XC-7(7.5)
4.5	Barracuda S8(8)	CS-8(8)	CDS-10(10)	AS-9(9)	10ft(10)	DVS-120(10)	7ft(7)	HD7(7)	HS10(10)	SC-11(11)	SCX-7(7)	XC-7(7.5)
4.6	Barracuda S8(8)	CS-8(8)	CDS-10(10)	AS-9(9)	10ft(10)	DVS-120(10)	7ft(7)	HD7(7)	HS10(10)	SC-11(11)	SCX-7(7)	XC-7(7.5)
4.7	Barracuda S8(8)	CS-8(8)	CDS-10(10)	AS-9(9)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS10(10)	SC-11(11)	SCX-7(7)	XC-7(7.5)
4.8	Barracuda S8(8)	CS-8(8)	CDS-10(10)	AS-10(10)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS10(10)	SC-11(11)	SCX-7(7)	XC-7(7.5)
4.9	Barracuda S8(8)	CS-8(8)	CDS-10(10)	AS-10(10)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS10(10)	SC-11(11)	SCX-7(7)	XC-7(7.5)
5.0	Barracuda S8(8)	CS-8(8)	CDS-10(10)	AS-10(10)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS10(10)	SC-11(11)	SCX-7(7)	XC-7(7.5)
5.1	Barracuda S10(10)	CS-8(8)	CDS-10(10)	AS-10(10)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS10(10)	SC-11(11)	SCX-7(7)	XC-7(7.5)
5.2	Barracuda S10(10)	CS-8(8)	CDS-10(10)	AS-10(10)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS10(10)	SC-11(11)	SCX-7(7)	XC-8(8.5)
5.3	Barracuda S10(10)	CS-8(8)	CDS-10(10)	AS-10(10)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS10(10)	SC-12(12)	SCX-7(7)	XC-8(8.5)
5.4	Barracuda S10(10)	CS-8(8)	CDS-10(10)	AS-10(10)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS10(10)	SC-12(12)	SCX-7(7)	XC-8(8.5)

TABLE 2 - PERFORMANCE MATRIX FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS (continued)

Max WQF (cfs)	Product Model											
	Barracuda	*Cascade*	*CDS*	*Concentrator*	*Downstream Defender*	*DVS*	*First Defense*	*HydroDome*	*HydroStorm*	*SciClone*	*SciCloneX*	*Xcelerator*
5.5	Barracuda S10(10)	CS-8(8)	CDS-10(10)	AS-10(10)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS11(11)	SC-12(12)	SCX-7(7)	XC-8(8.5)
5.6	Barracuda S10(10)	CS-8(8)	CDS-10(10)	AS-10(10)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS11(11)	SC-12(12)	SCX-8(8)	XC-8(8.5)
5.7	Barracuda S10(10)	CS-8(8)	CDS-10(10)	AS-10(10)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS11(11)	SC-12(12)	SCX-8(8)	XC-8(8.5)
5.8	Barracuda S10(10)	CS-8(8)	CDS-10(10)	AS-10(10)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS11(11)	SC-12(12)	SCX-8(8)	XC-8(8.5)
5.9	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-11(11)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS11(11)	SC-12(12)	SCX-8(8)	XC-8(8.5)
6.0	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-11(11)	10ft(10)	DVS-120(10)	8ft(8)	HD8(8)	HS11(11)	SC-12(12)	SCX-8(8)	XC-8(8.5)
6.1	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-11(11)	10ft(10)	DVS-120(10)		HD10(10)	HS11(11)	SC-12(12)	SCX-8(8)	XC-8(8.5)
6.2	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-11(11)	10ft(10)	DVS-120(10)		HD10(10)	HS11(11)	SC-12(12)	SCX-8(8)	XC-8(8.5)
6.3	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-11(11)	10ft(10)	DVS-144(12)		HD10(10)	HS11(11)	SC-12(12)	SCX-8(8)	XC-8(8.5)
6.4	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-11(11)	10ft(10)	DVS-144(12)		HD10(10)	HS11(11)	SC-13(13)	SCX-8(8)	XC-8(8.5)
6.5	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-11(11)	10ft(10)	DVS-144(12)		HD10(10)	HS11(11)	SC-13(13)	SCX-8(8)	XC-8(8.5)
6.6	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-11(11)	10ft(10)	DVS-144(12)		HD10(10)	HS11(11)	SC-13(13)	SCX-8(8)	XC-8(8.5)
6.7	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-11(11)	10ft(10)	DVS-144(12)		HD10(10)	HS12(12)	SC-13(13)	SCX-8(8)	XC-9(9.5)
6.8	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-11(11)	10ft(10)	DVS-144(12)		HD10(10)	HS12(12)	SC-13(13)	SCX-8(8)	XC-9(9.5)
6.9	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-11(11)	10ft(10)	DVS-144(12)		HD10(10)	HS12(12)	SC-13(13)	SCX-8(8)	XC-9(9.5)
7.0	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-11(11)	10ft(10)	DVS-144(12)		HD10(10)	HS12(12)	SC-13(13)	SCX-8(8)	XC-9(9.5)
7.1	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)	HS12(12)	SC-13(13)	SCX-8(8)	XC-9(9.5)
7.2	Barracuda S10(10)	CS-8(8)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)	HS12(12)	SC-13(13)	SCX-8(8)	XC-9(9.5)

TABLE 2 - PERFORMANCE MATRIX FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS (continued)

Max WQF (cfs)	Product Model											
	Barracuda	*Cascade*	*CDS*	*Concentrator*	*Downstream Defender*	*DVS*	*First Defense*	*HydroDome*	*HydroStorm*	*SciClone*	*SciCloneX*	*Xcelerator*
7.3	Barracuda S10(10)	CS-10(10)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)	HS12(12)	SC-13(13)	SCX-10(10)	XC-9(9.5)
7.4	Barracuda S10(10)	CS-10(10)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)	HS12(12)	SC-14(14)	SCX-10(10)	XC-9(9.5)
7.5	Barracuda S10(10)	CS-10(10)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)	HS12(12)	SC-14(14)	SCX-10(10)	XC-9(9.5)
7.6	Barracuda S10(10)	CS-10(10)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)	HS12(12)	SC-14(14)	SCX-10(10)	XC-9(9.5)
7.7	Barracuda S10(10)	CS-10(10)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)	HS12(12)	SC-14(14)	SCX-10(10)	XC-9(9.5)
7.8	Barracuda S10(10)	CS-10(10)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)	HS12(12)	SC-14(14)	SCX-10(10)	XC-9(9.5)
7.9		CS-10(10)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)	HS12(12)	SC-14(14)	SCX-10(10)	XC-9(9.5)
8.0		CS-10(10)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)		SC-14(14)	SCX-10(10)	XC-9(9.5)
8.1		CS-10(10)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)		SC-14(14)	SCX-10(10)	XC-9(9.5)
8.2		CS-10(10)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)		SC-14(14)	SCX-10(10)	XC-9(9.5)
8.3		CS-10(10)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)		SC-14(14)	SCX-10(10)	XC-10(10.5)
8.4		CS-10(10)	CDS-12(12)	AS-12(12)	12ft(12)	DVS-144(12)		HD10(10)		SC-14(14)	SCX-10(10)	XC-10(10.5)
8.5		CS-10(10)		AS-13(13)	12ft(12)	DVS-144(12)		HD10(10)		SC-14(14)	SCX-10(10)	XC-10(10.5)
8.6		CS-10(10)		AS-13(13)	12ft(12)	DVS-144(12)		HD10(10)			SCX-10(10)	XC-10(10.5)
8.7		CS-10(10)		AS-13(13)	12ft(12)	DVS-144(12)		HD10(10)			SCX-10(10)	XC-10(10.5)
8.8		CS-10(10)		AS-13(13)	12ft(12)	DVS-144(12)		HD10(10)			SCX-10(10)	XC-10(10.5)
8.9		CS-10(10)		AS-13(13)	12ft(12)	DVS-144(12)		HD10(10)			SCX-10(10)	XC-10(10.5)
9.0		CS-10(10)		AS-13(13)	12ft(12)	DVS-144(12)		HD10(10)			SCX-10(10)	XC-10(10.5)

TABLE 2 - PERFORMANCE MATRIX FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS (continued)

Max WQF (cfs)	Product Model											
	Barracuda	*Cascade*	*CDS*	*Concentrator*	*Downstream Defender*	*DVS*	*First Defense*	*HydroDome*	*HydroStorm*	*SciClone*	*SciCloneX*	*Xcelerator*
9.1		CS-10(10)		AS-13(13)	12ft(12)			HD10(10)			SCX-10(10)	XC-10(10.5)
9.2		CS-10(10)		AS-13(13)	12ft(12)			HD10(10)			SCX-10(10)	XC-10(10.5)
9.3		CS-10(10)		AS-13(13)	12ft(12)			HD10(10)			SCX-10(10)	XC-10(10.5)
9.4		CS-10(10)		AS-13(13)	12ft(12)			HD10(10)			SCX-10(10)	XC-10(10.5)
9.5		CS-10(10)		AS-13(13)	12ft(12)			HD12(12)			SCX-10(10)	XC-10(10.5)
9.6		CS-10(10)		AS-13(13)	12ft(12)			HD12(12)			SCX-10(10)	XC-10(10.5)
9.7		CS-10(10)		AS-13(13)	12ft(12)			HD12(12)			SCX-10(10)	XC-10(10.5)
9.8		CS-10(10)		AS-13(13)	12ft(12)			HD12(12)			SCX-10(10)	XC-10(10.5)
9.9		CS-10(10)			12ft(12)			HD12(12)			SCX-10(10)	XC-10(10.5)
10.0		CS-10(10)			12ft(12)			HD12(12)			SCX-10(10)	XC-10(10.5)
10.1		CS-10(10)						HD12(12)			SCX-10(10)	XC-10(10.5)
10.2		CS-10(10)						HD12(12)			SCX-10(10)	XC-11(11.5)
10.3		CS-10(10)						HD12(12)			SCX-10(10)	XC-11(11.5)
10.4		CS-10(10)						HD12(12)			SCX-10(10)	XC-11(11.5)
10.5		CS-10(10)						HD12(12)			SCX-10(10)	XC-11(11.5)
10.6		CS-10(10)						HD12(12)			SCX-10(10)	XC-11(11.5)
10.7		CS-10(10)						HD12(12)			SCX-10(10)	XC-11(11.5)
10.8		CS-10(10)						HD12(12)			SCX-10(10)	XC-11(11.5)

TABLE 2 - PERFORMANCE MATRIX FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS (continued)

Max WQF (cfs)	Product Model											
	Barracuda	*Cascade*	*CDS*	*Concentrator*	*Downstream Defender*	*DVS*	*First Defense*	*HydroDome*	*HydroStorm*	*SciClone*	*SciCloneX*	*Xcelerator*
10.9		CS-10(10)						HD12(12)			SCX-10(10)	XC-11(11.5)
11.0		CS-10(10)						HD12(12)			SCX-10(10)	XC-11(11.5)
11.1		CS-10(10)						HD12(12)			SCX-10(10)	XC-11(11.5)
11.2		CS-10(10)						HD12(12)			SCX-10(10)	XC-11(11.5)
11.3		CS-10(10)						HD12(12)			SCX-10(10)	XC-11(11.5)
11.4		CS-12(12)						HD12(12)			SCX-12(12)	XC-11(11.5)
11.5		CS-12(12)						HD12(12)			SCX-12(12)	XC-11(11.5)
11.6		CS-12(12)						HD12(12)			SCX-12(12)	XC-11(11.5)
11.7		CS-12(12)						HD12(12)			SCX-12(12)	XC-11(11.5)
11.8		CS-12(12)						HD12(12)			SCX-12(12)	XC-11(11.5)
11.9		CS-12(12)						HD12(12)			SCX-12(12)	XC-11(11.5)
12.0		CS-12(12)						HD12(12)			SCX-12(12)	XC-11(11.5)
12.1		CS-12(12)						HD12(12)			SCX-12(12)	XC-11(11.5)
12.2		CS-12(12)						HD12(12)			SCX-12(12)	XC-12(12.5)
12.3		CS-12(12)						HD12(12)			SCX-12(12)	XC-12(12.5)
12.4		CS-12(12)						HD12(12)			SCX-12(12)	XC-12(12.5)
12.5		CS-12(12)						HD12(12)			SCX-12(12)	XC-12(12.5)
12.6		CS-12(12)						HD12(12)			SCX-12(12)	XC-12(12.5)

TABLE 2 - PERFORMANCE MATRIX FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS (continued)

Max WQF (cfs)	Product Model											
	Barracuda	*Cascade*	*CDS*	*Concentrator*	*Downstream Defender*	*DVS*	*First Defense*	*HydroDome*	*HydroStorm*	*SciClone*	*SciCloneX*	*Xcelerator*
12.7		CS-12(12)						HD12(12			SCX-12(12)	XC-12(12.5)
12.8		CS-12(12)						HD12(12			SCX-12(12)	XC-12(12.5)
12.9		CS-12(12)						HD12(12			SCX-12(12)	XC-12(12.5)
13.0		CS-12(12)						HD12(12			SCX-12(12)	XC-12(12.5)
13.1		CS-12(12)						HD12(12			SCX-12(12)	XC-12(12.5)
13.2		CS-12(12)						HD12(12			SCX-12(12)	XC-12(12.5)
13.3		CS-12(12)						HD12(12			SCX-12(12)	XC-12(12.5)
13.4		CS-12(12)						HD12(12			SCX-12(12)	XC-12(12.5)
13.5		CS-12(12)						HD12(12			SCX-12(12)	XC-12(12.5)
13.6		CS-12(12)						HD12(12			SCX-12(12)	XC-12(12.5)
13.7		CS-12(12)									SCX-12(12)	XC-12(12.5)
13.8		CS-12(12)									SCX-12(12)	XC-12(12.5)
13.9		CS-12(12)									SCX-12(12)	XC-12(12.5)
14.0		CS-12(12)									SCX-12(12)	XC-12(12.5)
14.1		CS-12(12)									SCX-12(12)	XC-12(12.5)
14.2		CS-12(12)									SCX-12(12)	XC-12(12.5)
14.3		CS-12(12)									SCX-12(12)	XC-12(12.5)
14.4		CS-12(12)									SCX-12(12)	XC-13(13)

TABLE 2 - PERFORMANCE MATRIX FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS (continued)

Max WQF (cfs)	Product Model											
	Barracuda	*Cascade*	*CDS*	*Concentrator*	*Downstream Defender*	*DVS*	*First Defense*	*HydroDome*	*HydroStorm*	*SciClone*	*SciCloneX*	*Xcelerator*
14.5		CS-12(12)									SCX-12(12)	XC-13(13)
14.6		CS-12(12)									SCX-12(12)	XC-13(13)
14.7		CS-12(12)									SCX-12(12)	XC-13(13)
14.8		CS-12(12)									SCX-12(12)	XC-13(13)
14.9		CS-12(12)									SCX-12(12)	XC-13(13)
15.0		CS-12(12)									SCX-12(12)	XC-13(13)
15.1		CS-12(12)									SCX-12(12)	XC-13(13)
15.2		CS-12(12)									SCX-12(12)	XC-13(13)
15.3		CS-12(12)									SCX-12(12)	XC-13(13)
15.4		CS-12(12)									SCX-12(12)	XC-13(13)
15.5		CS-12(12)									SCX-12(12)	XC-13(13)
15.6		CS-12(12)									SCX-12(12)	
15.7		CS-12(12)									SCX-12(12)	
15.8		CS-12(12)									SCX-12(12)	
16.0		CS-12(12)									SCX-12(12)	
16.2		CS-12(12)									SCX-12(12)	
16.3											SCX-12(12)	
22.2											SCX-14(14)	

TABLE 3 - STANDARD SEDIMENT STORAGE CAPACITY FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS

Sediment Storage (cubic yards)	**Product Model**											
	Barracuda	***Cascade***	***CDS***	***Concentrator***	***Downstream Defender***	***DVS***	***First Defense***	***HydroDome***	***HydroStorm***	***SciClone***	***SciCloneX***	***Xcelerator***
0.05												XC-2
0.10				AS-2				HD3	HS-3			
0.15		CS-3				DVS-36	3ft			SC-3		XC-3
0.20	Barracuda S3			AS-3				HD4	HS-4			
0.25			CDS-3								SCX-3	XC-4
0.30		CS-4		AS-4	4ft	DVs-48	4ft			SC-4		
0.35	Barracuda S4							HD5	HS-5			
0.40				AS-5								XC-5
0.45			CDS-4								SCX-4	
0.50		CS-5				DVS-60	5ft	HD6	HS--6	SC-5		
0.55												
0.60	Barracuda S5			AS-6								XC-6
0.65												
0.70			CDS-5					HD7	HS-7		SCX-5	
0.75		CS-6				DVS-72	6ft			SC-6		
0.80				AS-7								XC-7
0.85	Barracuda S6											
0.90								HD8	HS-8			
0.95												
1.00 (Minimum)			CDS-6		6ft							XC-8

TABLE 3 - STANDARD SEDIMENT STORAGE CAPACITY FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS

Sediment Storage (cubic yards)	Product Model											
	Barracuda	*Cascade*	*CDS*	*Concentrator*	*Downstream Defender*	*DVS*	*First Defense*	*HydroDome*	*HydroStorm*	*SciClone*	*SciCloneX*	*Xcelerator*
1.05				AS-8		DVS-84	7ft			SC-7	SCX-6	
1.10												
1.15									HS-9			
1.20												
1.25												
1.30												XC-9
1.35		CS-8		AS-9		DVS-96	8ft			SC-8		
1.40			CDS-7								SCX-7	
1.45								HD10	HS-10			
1.50	Barracuda S8											
1.55												
1.60												XC-10
1.65				AS-10								
1.70												
1.75									HS-11	SC-9		
1.80												
1.85			CDS-8								SCX-8	
1.90												XC-11
1.95												
2.00												

TABLE 3 - STANDARD SEDIMENT STORAGE CAPACITY FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS

Sediment Storage (cubic yards)	**Product Model**											
	Barracuda	***Cascade***	***CDS***	***Concentrator***	***Downstream Defender***	***DVS***	***First Defense***	***HydroDome***	***HydroStorm***	***SciClone***	***SciCloneX***	***Xcelerator***
2.05				AS-11				HD12	HS-12			
2.10												
2.15		CS-10				DVS-120				SC-10		
2.20												
2.25												XC-12
2.30					8ft							
2.35												
2.40	Barracuda S10			AS-12								
2.45												XC-13
2.50												
2.55												
2.60										SC-11		
2.65												
2.70												
2.75												
2.80												
2.85				AS-13								
2.90			CDS-10								SCX-10	
2.95												
3.00												

TABLE 3 - STANDARD SEDIMENT STORAGE CAPACITY FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS

Sediment Storage (cubic yards)	**Product Model**											
	Barracuda	***Cascade***	***CDS***	***Concentrator***	***Downstream Defender***	***DVS***	***First Defense***	***HydroDome***	***HydroStorm***	***SciClone***	***SciCloneX***	***Xcelerator***
3.05												
3.10		CS-12				DVS-144				SC-12		
3.15												
3.20												
3.25												
3.30												
3.35												
3.40												
3.45												
3.50												
3.55												
3.60												
3.65										SC-13		
3.70												
3.75												
3.80												
3.85												
3.90												
3.95												
4.00												

TABLE 3 - STANDARD SEDIMENT STORAGE CAPACITY FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS

Sediment Storage (cubic yards)	Product Model											
	Barracuda	*Cascade*	*CDS*	*Concentrator*	*Downstream Defender*	*DVS*	*First Defense*	*HydroDome*	*HydroStorm*	*SciClone*	*SciCloneX*	*Xcelerator*
4.05												
4.10												
4.15			CDS-12								SCX-12	
4.20												
4.25										SC-14		
4.30					10ft							
4.35												
4.40												
4.45												
4.50												
4.75												
5.00												
5.25												
5.50												
5.70											SCX-14	
6.00												
6.25												
6.50												
7.00												
7.25					12ft							

TABLE 4 - SEDIMENT STORAGE CAPACITY CALCULATION

Product	Sediment Storage Capacity (Volume) Calculation (cubic feet)
Barracuda	Inside Diameter^2 * π/4 (ft^2) X 1.67 (ft)
Cascade	Inside Diameter^2 * π/4 (ft^2) X 1.5 (ft)
CDS	Inside Diameter^2 * π/4 (ft^2) X 2 (ft)
Concentrator	Inside Diameter^2 * π/4 (ft^2) X 1.17 (ft)
Downstream Defender	Inside Diameter^2 * π/4 (ft^2) X 1.5 (ft)
DVS	Inside Diameter^2 * π/4 (ft^2) X 1.5 (ft)
First Defense	Inside Diameter^2 * π/4 (ft^2) X 1.5 (ft)
HydroDome	Inside Diameter^2 * π/4 (ft^2) X 1 (ft)
HydroStorm	Inside Diameter^2 * π/4 (ft^2) X 1 (ft)
SciClone	Inside Diameter^2 * π/4 (ft^2) X 1.5 (ft)
SciCloneX	Inside Diameter^2 * π/4 (ft^2) X 2 (ft)
Xcelerator	Inside Diameter^2 * π/4 (ft^2) X 1 (ft)
Note: 1 cubic foot = 0.037 cubic yard or 1 cubic yard = 27 cubic feet	

Example - Flow Diversion and Piping Design for Off-line Hydrodynamic Separator

Background

A storm drainage system has been designed for a State highway reconstruction project. Stormwater treatment is a concern where the proposed system has 11 catch basins and discharges within 50 feet of a regulated area. A schematic of the system is shown in Figure EX-1. During preliminary design when the storm drainage outlet points were investigated and established, stormwater treatment alternatives were considered for compliance with the CTDOT/DEEP guidelines as related to the General Permit for Stormwater discharge and NPDES Phase II regulations. It was determined and documented in the Stormwater Quality section of the Drainage Report that a primary treatment practice such as a water quality swale or stormwater pond could not be incorporated into the project due to site constraints. As a result, it was decided that a hydrodynamic separator (HDS) would be provided in addition to the standard catch basin sumps, as a means of stormwater treatment prior to discharge to the regulated area.

The hydrodynamic separator will be constructed off-line of the storm drainage system trunk –line, in accordance with CTDOT design practice, and is proposed to be located between structures J-1 and J-2 shown on Figure EX-1. Figure EX-2 is a detail of the proposed system near the drainage system outlet which shows the location and configuration of the HDS.

Proposed drainage structure J-1 will be designed as a flow diversion structure in accordance with the design requirements of the Drainage Manual. A standard manhole with a weir in the bottom of the structure will be used.

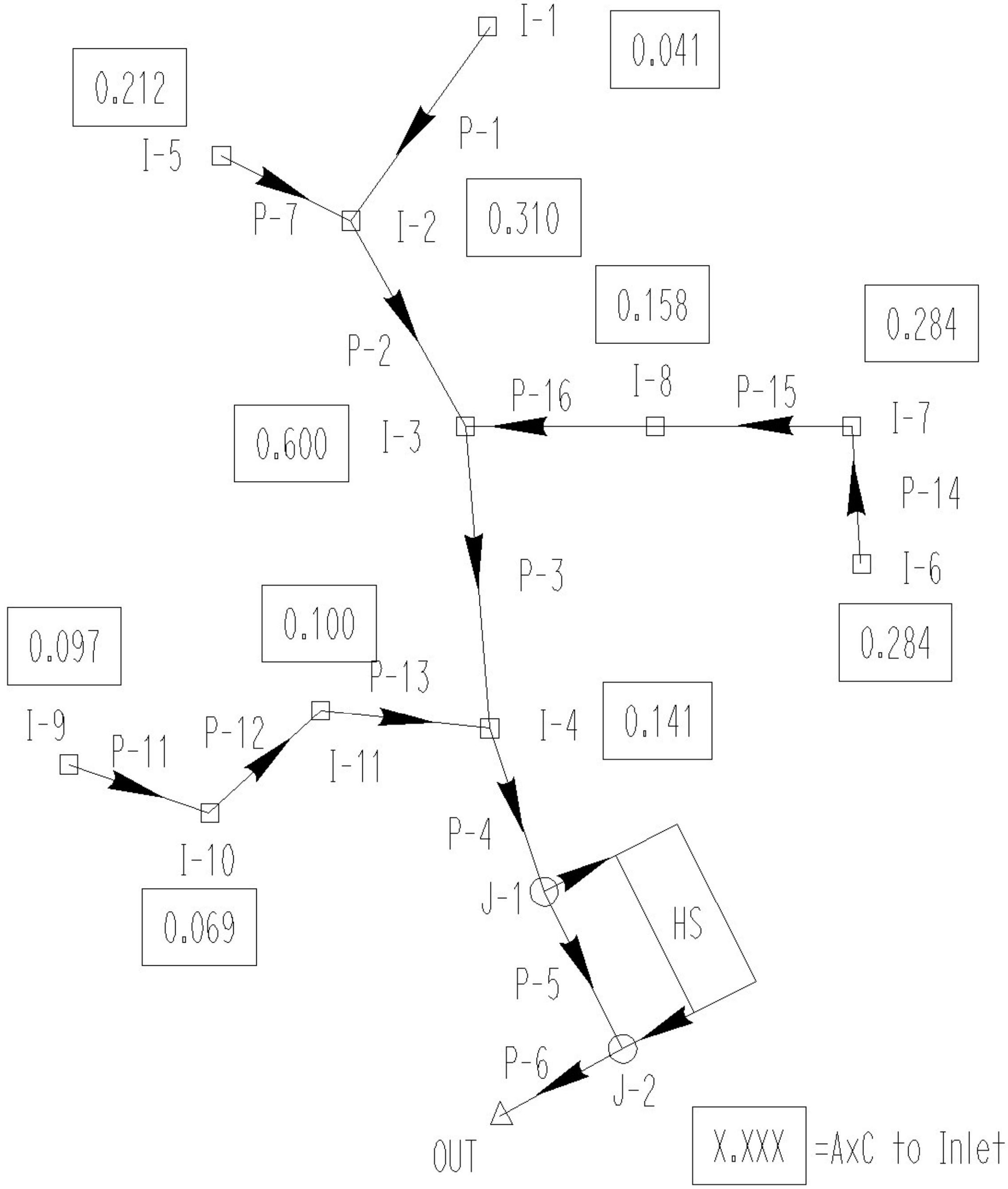


Figure EX-1
Schematic of Example Drainage System

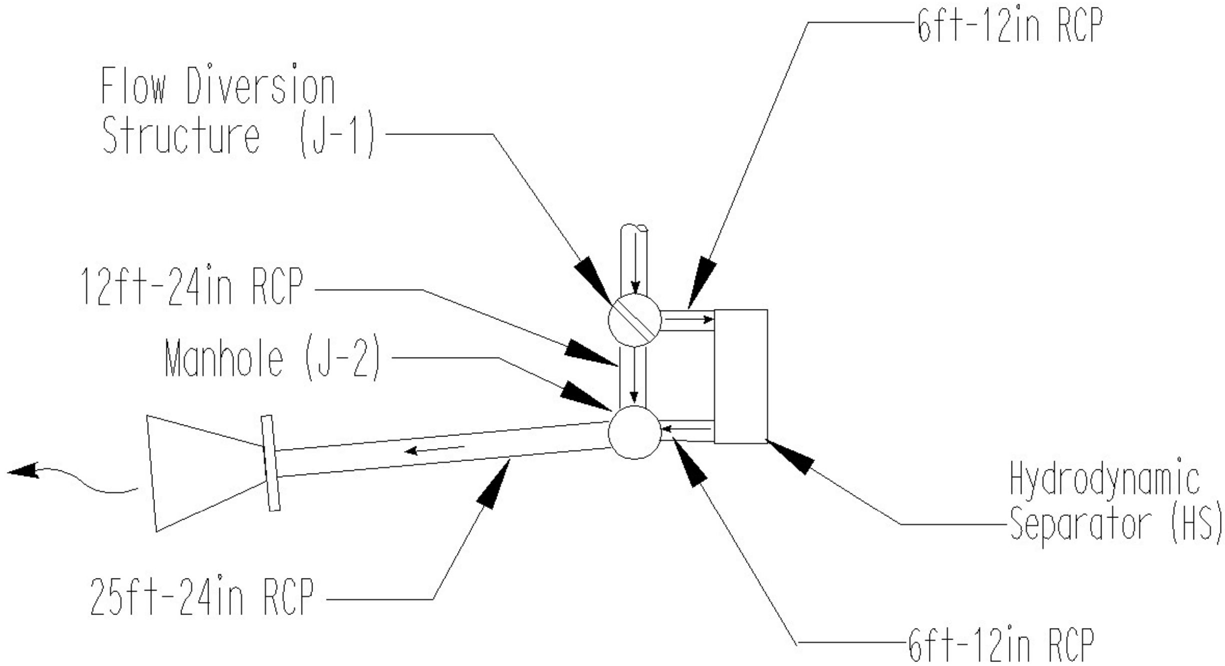


Figure EX-2

Sketch Showing Outlet & Hydrodynamic Separator Location

Design Calculations

I. Determine WQF

In order to calculate the WQF, the following drainage area and ground cover information was extracted from the drainage calculations and tabulated below:

Contributing catch basin	Grass Area (Acres)	Paved Area (Acres)	Total Area (Acres)
I-1	0.011	0.042	0.053
I-2	0	0.344	0.344
I-3	1.731	0.086	1.817
I-4	0	0.157	0.157
I-5	0	0.235	0.235
I-6	0	0.316	0.316
I-7	0	0.316	0.316
I-8	0	0.176	0.176
I-9	0	0.108	0.108
I-10	0	0.077	0.077
I-11	0	0.111	0.111
Σ	1.742 Ac	1.968 Ac	3.710 Ac

- Total Drainage Area to system @ treatment location = 3.71 Acres = 0.0058 mi^2
- Percent of Impervious Cover = 1.968/3.71 x 100 = 53%

The accumulated flow time in the drainage system at the treatment location is approximately 11 minutes as shown in the attached Storm Drain Computation Sheet (Figure EX-3).

- The time of concentration (T_c) for the WQF = 11minutes = 0.18 hours

To compute the WQF, use the above information and the WQF calculation sheet. Note that the WQF sheet is based on a Precipitation depth (P) of 1", CTDOT's water quality storm event.

- Enter the Percent Impervious Cover on the top graph of the sheet to obtain the Runoff Depth (Q) and the Initial Abstraction (I_a) from the respective curves.

For 53%, Q = 0.525 and I_a = 0.125

$I_a/P = 0.125/1 = 0.125$

- Enter T_c on the bottom graph of the sheet to the curve corresponding to the computed I_a/P value (You may interpolate between the curves shown).

For T_c = 0.18 hr and I_a/P = 0.125, q_u = 570 csm/in

WQF = (q_u) (A) (Q) = (570) (0.0058) (0.525) = 1.7 cfs

The completed WQF Calculation Sheet is shown as Figure EX-4.

Storm Drain Computation Sheet – English

Computed HD Date 12/12/05

Checked DM Date 12/12/05

Project Example
Route 0
Station XX+XX
Town Somewhere

Station		Flow Time, T_c (min)			A x C		(8)	(9)	Pipe							(17)	Velocity (fps)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)			(10)	(11)	(12)	(13)	Invert Elevation (ft)		(16)		(18)	(19)
													(14)	(15)				
From	To	To Inlet	In Pipe	Accumulated	Increment	Total	Rainfall Intensity, I (in/hr)	Total Flow in System, CIA = Q (cfs)	Size	Type	"n"	Length (ft)	Upstream	Downstream	Slope (ft/ft)	Full Capacity, Q_F (cfs)	Flowing Full, V_F	Design Flow, V
I-1	*I-2*	*5*	*0.35*	*5.00*	*0.041*	*0.041*	*6.0*	*0.25*	*12*	*RCP*	*0.012*	*50*	*106.32*	*105.53*	*.0063*	*3.06*	*3.9*	*2.4*
I-2	*I-3*	*5*	*0.43*	*5.35*	*0.522*	*0.563*	*5.9*	*3.32*	*15*	*RCP*	*0.012*	*112*	*105.28*	*104.73*	*.0049*	*4.90*	*4.0*	*4.3*
I-3	*I-4*	*10*	*0.55*	*10.00*	*1.326*	*1.889*	*4.8*	*9.07*	*24*	*RCP*	*0.012*	*185*	*104.59*	*103.67*	*.005*	*17.33*	*5.5*	*5.6*
I-4	*J-1*	*5*	*0.25*	*10.55*	*0.407*	*2.296*	*4.7*	*10.79*	*24*	*RCP*	*0.012*	*88*	*103.67*	*103.23*	*.005*	*17.33*	*5.5*	*5.8*
J-1	*J-2*	—	*0.03*	*10.80*	—	*2.296*	*4.7*	*10.79*	*24*	*RCP*	*0.012*	*12*	*103.23*	*103.16*	*.0058*	*18.66*	*5.9*	*6.2*
J-2	*Out*	—	*0.07*	*10.83*	—	*2.296*	*4.7*	*10.79*	*24*	*RCP*	*0.012*	*25*	*103.16*	*103.04*	*.0048*	*16.98*	*5.4*	*5.7*

Figure EX-3

CONNECTICUT DEPARTMENT OF TRANSPORTATION HYDRODYNAMIC SEPARATOR DESIGN DATA SHEETS
(FORM A - DESIGN)

Project No: | **Location/Station:** | **Date:**

HYDRAULIC GRADE LINE ANALYSIS

Pipe	Downstream Str	Pipe Size (in)	Flow (cfs)	Ground Elev. OUT (ft)	Invert Elev. OUT (ft)	HGL OUT (ft)	Depth OUT (ft)	Vel. Head OUT (ft)	EGL OUT (ft)	Length (ft)	Friction Slope (ft/ft)	Friction Loss (ft)	EGL IN (ft)	Vel. Head IN (ft)	HGL IN (ft)	Depth IN (ft)	Invert Elev. IN (ft)	Ground Elev. IN (ft)	Upstream Str.	Headloss Coeff.	Str. headloss (ft.)

Sheet 2 of 2

II. Determine the Required Sediment Storage Capacity

Per the CTDOT guidelines, the required storage capacity of the proposed hydrodynamic separator shall be determined using a sediment accumulation rate of 0.5 cubic yard per impervious acre per year but not less than the 1.0 cubic yard minimum required based on a maintenance cycle of once per year.

In the WQF calculations, it was determined that 53% of the 3.7 acre system drainage area is impervious cover which is equivalent to 2 acres of impervious area.

(2 impervious acres) x (0.5 c.y./impervious acre/yr.) = 1.0 cy/yr.

Therefore, the required sediment storage capacity of the proposed hydrodynamic separator is 1.0 cubic yards, which is equal to the 1.0 cubic yard minimum. This will be used when checking which HDS models can be used.

III. Flow Diversion Structure Design and HGL Analysis

A proposed flow diversion structure will be constructed using a standard precast reinforced concrete manhole without the benching at the bottom of the structure. A reinforced concrete weir will be used in the bottom of the structure to divert the WQF to the hydrodynamic separator. Figure EX-5 shows a sketch of the proposed flow diversion structure.

The drainage system was designed for a 10-year storm frequency. The design flow at the system outlet is 10.8 cfs as seen in Figure EX-3. The WQF is 1.7 cfs.

The HGL analysis was performed with the aid of computer software. The HGL analysis has been abbreviated to show only the portion of the system needed to design and evaluate the flow diversion structure and the hydrodynamic separator.

Head loss coefficients used in the HGL analysis were determined in accordance with Section 11.12.6 of the Drainage Manual for all structures except the hydrodynamic separator. A benching factor of 1.0 was applied to the proposed flow diversion structure (J-1). A head loss coefficient of 1.75 was used for the proposed hydrodynamic separator (HDS). Due to the arrangement of the inflowing pipes, a half bench condition was assumed at the downstream manhole (J-2).

Standard manholes, 4 ft. interior diameter, will be used for the flow diversion structure and the junction manhole downstream of the hydrodynamic separator.

The outlet discharges into a relatively open area and by inspection was determined to be a “free” outlet. For this system, the tailwater or starting water surface was normal flow depth just inside the pipe outlet.

The design and hydraulic calculations were performed in the following steps:

1. The HGL was calculated for the drainage system design from the system outlet to structure I-4, ignoring the hydrodynamic separator and the proposed weir in the flow diversion structure (J-1). Refer to Figure EX-1 for the system layout.

2. The HGL was calculated for the WQF from the system outlet to the flow diversion structure (J-1) along the flow path illustrated in Figure 2A.

3. The HGL was calculated for a series of discharges between the WQF (1.7 cfs) to 2.5 times the WQF (4.25 cfs) from the system outlet to the flow diversion structure (J-1) along the flow path illustrated in Figure 2A and in step 2.

   The results of these calculations are shown in the same tabular format as required on the Hydrodynamic Separator Design Data Sheet, Form A. Figure EX-6 shows the results of the calculations performed for steps 1 and 2. Figure EX-7 shows the results of the calculations performed for step 3.

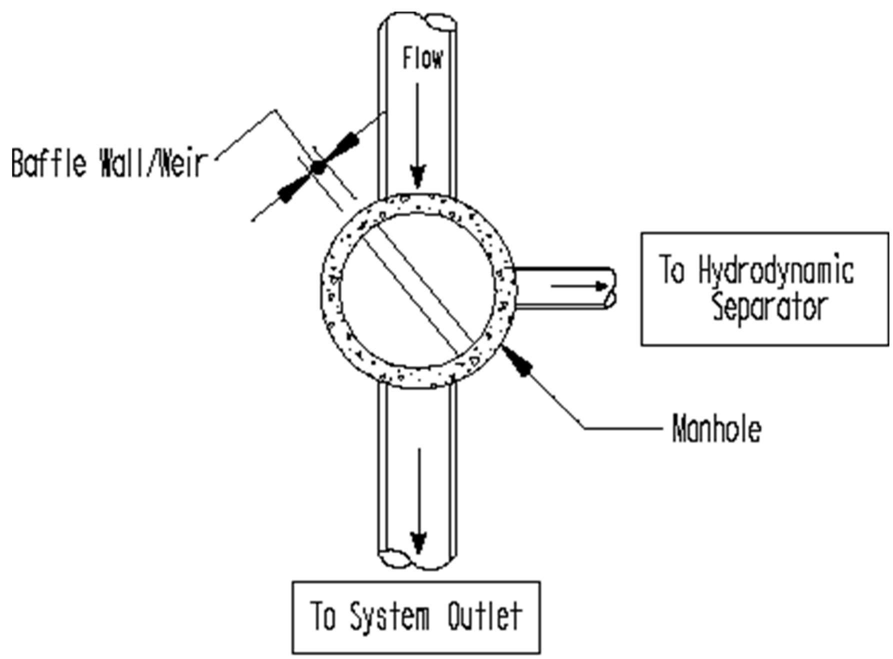


Figure EX-5
Sketch of Flow Diversion Structure

Row No.	Pipe	Downstream Str.	Size (in)	Flow (cfs)	Ground Elev. OUT (ft)	Crown Elev. OUT (ft)	Invert Elev. OUT (ft)	HGL OUT (ft)	Depth OUT (ft)	Vel. Head OUT (ft)	EGL OUT (ft)	Length (ft)	Friction Slope (ft/ft)	Friction Loss (ft)	EGL IN (ft)	Vel. Head IN (ft)	HGL IN (ft)	Depth IN (ft)	Invert Elev. IN (ft)	Crown Elev. IN (ft)	Ground Elev. IN (ft)	Upstream Str.	Headloss Coeff.	Str. headloss (ft.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
(1)				DESIGN																				
(2)	P-6	OUT	24	10.80	106.48	105.04	103.04	104.20	1.16	0.51	104.71	25	0.0048	0.12	104.83	0.49	104.34	1.18	103.16	105.16	108.86	J-2	0.08	0.04
(3)	P-5	J-2	24	10.80	108.86	105.16	103.16	104.38	1.22	0.45	104.83	12	0.0056	0.07	104.90	0.49	104.41	1.18	103.23	105.23	109.19	J-1	0.07	0.03
(4)	P-4	J-1	24	10.80	109.19	105.23	103.23	104.44	1.21	0.46	104.90	88	0.0050	0.44	105.34	0.49	104.85	1.18	103.67	105.67	112.96	I-4	0.11	0.05
(5)	P-3	I-4	24	9.10	112.96	105.87	103.87	104.90	1.03	0.48	105.38	185	0.0050	0.93	106.31	0.43	105.88	1.08	104.80	106.80	109.55	I-3		
(6)				WQF																				
(7)	P-6	OUT	24	1.70	106.48	105.04	103.04	103.47	0.43	0.19	103.65	25	0.0047	0.12	103.77	0.16	103.61	0.45	103.16	105.16	108.86	J-2	0.01	0.00
(8)	P-8	J-2	12	1.70	108.86	104.16	103.16	103.71	0.55	0.23	103.94	6	0.0058	0.03	103.97	0.21	103.76	0.57	103.19	104.19	108.86	HS	1.75	0.37
(9)	P-7	HS	12	1.70	108.86	104.19	103.19	104.13	0.94	0.08	104.21	6	0.0017	0.01	104.22	0.08	104.14	0.91	103.23	104.23	109.19	J-1	0.82	0.06
(10)								104.20																

Figure EX-6

Row No.	Pipe	Downstream Str.	Size (in)	Flow (cfs)	Ground Elev. OUT (ft)	Crown Elev. OUT (ft)	Invert Elev. OUT (ft)	HGL OUT (ft)	Depth OUT (ft)	Vel. Head OUT (ft)	EGL OUT (ft)	Length (ft)	Friction Slope (ft/ft)	Friction Loss (ft)	EGL IN (ft)	Vel. Head IN (ft)	HGL IN (ft)	Depth IN (ft)	Invert Elev. IN (ft)	Crown Elev. IN (ft)	Ground Elev. IN (ft)	Upstream Str.	Headloss Coeff.	Str. headloss (ft.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
(1)	P-6	OUT	24	10.8	106.48	105.04	103.04	104.20	1.16	0.51	104.71	25	0.0048	0.12	104.83	0.49	104.34	1.18	103.16	105.16	108.86	J-2	0.06	0.03
(2)	P-8	J-2	12	2.50	108.86	104.16	103.16	104.37	1.21	0.16	104.53	6	0.0042	0.03	104.56	0.16	104.40	1.21	103.19	104.19	108.86	HS	1.75	0.28
(3)	P-7	HS	12	2.50	108.86	104.19	103.19	104.68	1.49	0.16	104.84	6	0.0042	0.03	104.87	0.16	104.71	1.48	103.23	104.23	109.19	J-1	1.08	0.17
(4)		J-1						104.88																
(5)																								
(6)	P-6	OUT	24	10.80	106.48	105.04	103.04	104.20	1.16	0.51	104.71	25	0.0048	0.12	104.83	0.49	104.34	1.18	103.16	105.16	108.86	J-2	0.05	0.02
(7)	P-8	J-2	12	3.00	108.86	104.16	103.16	104.36	1.20	0.23	104.59	6	0.0060	0.04	104.63	0.23	104.40	1.21	103.19	104.19	108.86	HS	1.75	0.40
(8)	P-7	HS	12	3.00	108.86	104.19	103.19	104.80	1.61	0.23	105.03	6	0.0060	0.04	105.07	0.23	104.84	1.61	103.23	104.23	109.19	J-1	1.14	0.26
(9)		J-1						105.10																
(10)																								
(11)	P-6	OUT	24	10.80	106.48	105.04	103.04	104.20	1.16	0.51	104.71	25	0.0048	0.12	104.83	0.49	104.34	1.18	103.16	105.16	108.86	J-2	0.05	0.02
(12)	P-8	J-2	12	3.50	108.86	104.16	103.16	104.36	1.20	0.31	104.67	6	0.0082	0.05	104.72	0.31	104.41	1.22	103.19	104.19	108.86	HS	1.75	0.54
(13)	P-7	HS	12	3.50	108.86	104.19	103.19	104.95	1.76	0.31	105.26	6	0.0082	0.05	105.31	0.31	105.00	1.77	103.23	104.23	109.19	J-1	1.21	0.37
(14)		J-1						105.37																
(15)																								
(16)	P-6	OUT	24	10.80	106.48	105.04	103.04	104.20	1.16	0.51	104.71	25	0.0048	0.12	104.83	0.49	104.34	1.18	103.16	105.16	108.86	J-2	0.04	0.02
(17)	P-8	J-2	12	4.25	108.86	104.16	103.16	104.36	1.20	0.46	104.82	6	0.0121	0.07	104.89	0.46	104.43	1.24	103.19	104.19	108.86	HS	1.75	0.80
(18)	P-7	HS	12	4.25	108.86	104.19	103.19	105.23	2.03	0.46	105.68	6	0.0121	0.07	105.76	0.46	105.30	2.07	103.23	104.23	109.19	J-1	1.33	0.61
(19)		J-1						105.91																

Figure EX-7

"What are all these numbers???" (How to review the results on the HGL analysis table)

Refer to the tables on Figures EX-6 and EX-7: Columns 1 thru 7, 12 and 19 thru 22 are given; Columns 8 thru 11 represent the HGL and Energy Grade Line (EGL) Information at the pipe outlet; Columns 13 & 14, the energy loss in the pipe; Columns 15 thru 18, the HGL and EGL Information at the pipe inlet; Columns 23 & 24, the structure (junction) loss.

Column 8, HGL Out, is the HGL elevation at the outlet end of the pipe. The HGL elevation is the elevation based on the flow depth in the pipe or the tailwater elevation, whichever is higher.

Flow depth

When using a computer program for partially full flow conditions, the flow depth and HGL elevation in the pipe are determined by gradually varied flow analysis along the length of pipe. In gradually varied flow analysis, the depth of flow at one end of the pipe is known or assumed and the flow depth at the other end is computed using either the standard step method (segmental length assumed and depth computed) or direct step method (depth assumed and segmental length computed). Please refer to open channel flow hydraulic texts for further details of gradually varied flow and the computational methods of analysis.

When performing these calculations for partially full flow conditions, critical depth and normal flow depth are usually assumed at either end of the pipe depending on the flow regime.

Tailwater

The tailwater elevation at the drainage system outlet is determined in accordance with Section 11.12.2 of the Drainage Manual. The tailwater elevation on an inflow pipe at a junction structure is determined by adding the structure head loss to the HGL elevation of the outflow pipe (Column 24 plus Column 17).

Example 1 – Figure EX-6 - Outlet

The outlet pipe (P-6) was determined to be a free outlet and at Q10 and WQF the pipe flow is supercritical. For Q10, critical depth is 1.18 ft. and normal depth is 1.16 ft. The program computed normal depth (Row 2, Column 9) at the outlet and used it as the starting HGL elevation (Row 2, Column 8), which is acceptable.

Example 2 – Figure EX-6 - Structure J-2 & Pipe P-8

For the WQF, the head loss at structure J-2 was computed to be less than 0.005 ft.; therefore the reported head loss is 0.00 ft. on the table (Row 7, Column 24). The tailwater elevation for the inflow pipe (P-8) to structure J-2 is determined by adding the structure head loss, 0.00 ft., to the HGL elevation of the outflow pipe (P-6), 103.61 (Row 7, Column 17). The tailwater elevation is 103.61 + 0.00 = 103.61 ft.

The flow depth at the outlet end of pipe P-8 is 0.55 ft. (Row 7, Column 9). Adding this depth to the outlet invert elevation of the pipe, 103.16 (Row 7, Column 7), results in a water surface elevation (103.16 + 0.55) of 103.71 ft. Since the elevation of 103.71 based on the flow depth in the pipe is greater than the tailwater elevation of 103.61 ft., 103.71 ft. is reported on the table (Row 8, Column 8) and is used for the HGL analysis proceeding upstream.

Example 3 – Figure EX-6 - Hydrodynamic Separator (HDS) & Pipe P-7

For the WQF, the head loss at the HDS was computed to be 0.37 ft. (Row 8, Column 24). The tailwater elevation for the inflow pipe (P-7) to the HDS is determined by adding the structure head loss, 0.37 ft., to the HGL elevation of the outflow pipe (P-8), 103.76 (Row 8, Column 17). The tailwater elevation is 103.76 + 0.37 = 104.13 ft. which results in a depth above the invert elevation of the pipe of 0.94 ft. (104.13 – 103.19 = 0.94). This depth is greater than the normal flow depth in the pipe. HGL elevation 104.13 ft. and depth of 0.94 ft. are reported on the table (Row 9, Column 8 and 9, respectively) and are used for the HGL analysis proceeding upstream.

Column 9, Depth Out, is the depth of the HGL at the outlet end of the pipe (Column 8 minus Column 7).

Column 10, Vel. Head Out, is the velocity head at the outlet end of the pipe based on the flow depth and velocity in the pipe or based on the full cross sectional area and velocity if the pipe is submerged or flowing full.

Example 1 – Figure EX-6 - Pipe P-8 @ WQF

At the outlet end of pipe P-8, the depth and velocity head are 0.55 ft. (Row 8, Column 9) and 0.23 ft. (Row 8, Column 10), respectively. At a depth of 0.55 ft., the flow area is 0.445 ft^2 and the velocity is 3.82 fps. Velocity head = $v^2/2g = (3.82)^2 / (2)(32.2) = 0.23$ Example

2 - Figure EX-7 Pipes P-8 & P-7 @ 2.5 cfs

Refer to Rows 2 & 3. The velocity head is 0.16 ft. at the outlet and inlet of both pipes at a flow of 2.5 cfs. Both pipes are surcharges and flowing full. The full cross sectional area of the 12" pipe is 0.785 sf. Velocity = Q/A = 2.5/0.785 = 3.18 fps. Velocity head = $v^2/2g = (3.18)^2 / (2)(32.2) = 0.16$ ft.

Column 11, EGL Out, is the EGL elevation at the outlet end of the pipe determined by adding the velocity head to the HGL elevation (Column 9 plus Column 10).

Column 13, Friction Slope, is the friction slope or slope of the EGL.

When using a computer program for partially full flow conditions, the friction slope is calculated by gradually varied flow analysis. When performing hand calculations, HEC- 22 suggests setting the friction slope equal to the pipe slope. If the pipe is flowing full or surcharged, the friction slope is computed using the full barrel area and wetted perimeter for either hand or computer calculations.

Example (Full flow) - Figure EX-7 Pipes P-8 & P-7 @ 2.5 cfs

Refer to Rows 2 & 3. Pipes P-8 & P-7 are flowing full at 2.5 cfs and the friction slope is 0.0042 ft./ft. The full cross sectional area (A) is 0.785 sf. and the wetted perimeter (P) is $2\pi r = 2\ (\pi)\ (0.5) = 3.14$ *ft. The hydraulic radius (R) = A/P = 0.785/3.14 = 0.25 ft. The friction slope* (S_f) *is computed by rearranging the Manning's Equation as* $S_f = [Q\ (n)\ /\ 1.486\ (A)\ (R)^{2/3}]^2 =$
$[2.5\ (0.012)\ /\ 1.486\ (0.785)\ (0.25)^{2/3}]^2 = 0.0042$ *ft./ft.*

Column 15, EGL In, is the EGL elevation at the inlet end of the pipe and is equal to EGL elevation at the outlet end of the pipe plus the friction loss (Column 14 plus Column 11).

Column 16, Vel. Head In, is the velocity head at the inlet end of the pipe based on the flow depth and velocity in the pipe or based on the full cross sectional area and velocity if the pipe is submerged or flowing full.

Column 17, HGL In, is the HGL elevation at the inlet end of the pipe and is equal to the EGL elevation at the inlet minus the velocity head (Column 15 minus Column 16).

Column 18, Depth In, is the depth of the HGL at the inlet end of the pipe and is equal to the HGL elevation minus the invert elevation of the pipe inlet (Column 17 minus Column 19).

Column 23, Structure Head loss Coeff., is the head loss coefficient of the junction structure determined in accordance with Section 11.12.6 of the Drainage Manual (1.75 for off-line hydrodynamic separators or based on manufacturer's documentation).

Example 1 – Figure EX-6 - Structure J-2 @ WQF

Figure EX-8 shows how the junction loss coefficient was determined for structure J-2 at the WQF in accordance with Section 11.12.6 of the Drainage Manual. The pipes at the junction are set at the same elevation. Note that for the WQF there is only inflow to this junction from one pipe (12" RCP); therefore the correction factor for relative flow is 1.0.

Example 2 - Figure EX-7 Structure J-2 @ Drainage System Design Flow (based on flow split @ Structure J-1, Step 4)

Figure EX-9 shows how the junction loss coefficient was determined for structure J-2 at the drainage system design flow in accordance with Section 11.12.6 of the Drainage Manual. Note that for the design flow there is inflow to this junction from both the 24" and 12" RCPs; therefore the correction factor for relative flow is computed based on the inflow from each pipe. The higher of the two head loss coefficients was used in the HGL analysis at this structure. Figure EX-9 is the junction loss coefficient calculation based on the inflow from the 24" RCP. Figure EX-10 is the junction loss coefficient calculation based on the inflow from the 12" RCP.

Column 24, Structure Head loss, is the head loss in the structure determined by multiplying the head loss coefficient times the velocity head of the structure outflow pipe (Column 23 times Column 16).

The HGL elevation in the structure is determined by adding the head loss to the HGL elevation of the outflow pipe. (Column 24 plus Column 17). This elevation will be used as the tailwater for the inflow pipe to the structure (See Column 9, Example 3).

Structure Loss Coeff. Calc. Sheets Page 1 of 3 ConnDOT Drainage Manual

Figure EX-8

Connecticut Department of Transportation					
Project No.	**Example**	**Station & Offset**	**XX+XX**		
Route No.	**0**	**Prepared by**	**HD**	**Date**	**1/17/2006**
Town	**Somewhere**	**Checked by**	**DM**	**Date**	**1/17/2006**
Structure	**J-2, 4 ft. diameter standard manhole**				

Structure Losses (Section 11.12.6 of ConnDOT Drainage Manual)

Energy loss is approximated as K $(V_o^2/2g)$.

$$K = K_o C_d C_Q C_p C_B$$

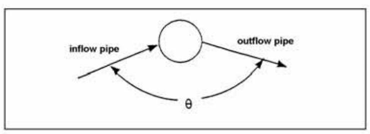
K = **0.01**

1. Relative Manhole Size

$$K_o = 0.1(b/D_o)(1-\sin\theta) + 1.4(b/D_o)^{0.15}\sin\theta$$

K_o = 0.32

θ = the angle between the inflow and outflow pipes	=	175	*(Meaured from plans)*
b = structure diameter, mm (in)	=	48	*(4 ft. dia. Manhole)*
Do = outlet pipe diameter, mm (in)	=	24	



2. Compute the ratio d/D_o

d = water depth in structure above outlet pipe invert, mm (in)	=	5.4	*(0.45 ft- Fig EX-6 Row 6, Column 18)*
D_o = outlet pipe diameter, mm (in)	=	24	

d/D_o = 0.225

2. Pipe Diameter

When the depth in the structure to outlet pipe diameter ratio, d/Do, is greater than 3.2 otherwise CD is set equal to 1.0.

$$C_D = (D_o / D_i)^3$$

C_D = 1.00

D_i = incoming pipe diameter, mm (in)	=	12
D_o = outgoing pipe diameter, mm (in)	=	24

Structure Loss Coeff. Calc. Sheets | Page 2 of 3 | ConnDOT Drainage Manual

Figure EX-8

3. Flow Depth *(For free surface flow or low pressures, when d/Do ratio is less than 3.2 . In cases where this ratio is greater than 3.2, Cd is set equal to 1.0)*

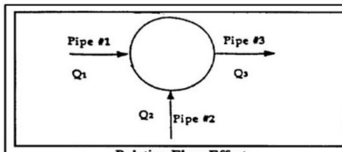
$$C_d = 0.5(d/ D_o)^{0.6}$$

C_d = 0.20

4. Relative Flow

The correction factor is only applied to situations where there are three or more pipes entering the structure at approximately the same elevation. Otherwise, the value of CQ is equal to 1.0.

$$C_Q = (1 - 2\sin\ \theta)\ (1 - \frac{Qi}{Qo})^{0.75} + 1$$



Relative Flow Effect

C_Q = correction factor for relative flow — C_Q = 1.00

Number of pipes at structure		=	2
θ =	the angle between the inflow and outflow pipes (degrees)	=	175
Q_i =	flow in the inflow pipe, m^3/s (ft^3/s)	=	1.7
Q_o =	flow in the outlet pipe, m^3/s (ft^3/s)	=	1.7

(At WQF, only the low flow pipe is is conveying flow therefore C_Q = 1)

5. Plunging Flow

$$C_p = 1 + 0.2\ [\frac{h}{D_o}]\ [\frac{(h - d)}{D_o}]$$

This correction fac-tor corresponds to the effect of another inflow pipe or surface flow from an inlet, plunging into the structure, on the inflow pipe for which the head loss is being calculated. The correc-tion factor is only applied when h > d, otherwise, the value of Cp is equal to 1.0. Additionally, the correction factor is only applied when a high elevation flow plunges into the structure that has both an inflow and outflow in the bottom of the structure.

Cp = correction for plunging flow — *Cp* = 1.00

h =	vertical distance of plunging flow from flow line of higher elevation incoming pipe to the center of outlet pipe, m (ft)	=	
d =	water depth in structure above outlet pipe invert, m (ft)	=	
Do =	outlet pipe diameter, m (ft)	=	

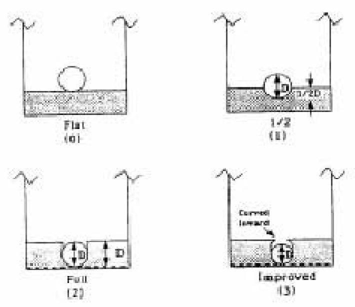
Structure Loss Coeff. Calc. Sheets | Page 3 of 3 Figure EX-8 | ConnDOT Drainage Manual

6. Benching

C_B = correction for benching in the structure

C_B = 0.15

(half bench assumed for this design)



Bench Type	Correction Factors, C_B	
	Submerged*	Unsubmerged**
Flat floor	1.00	1.00
Half Bench	0.95	0.15
Full Bench	0.75	0.07
Improved	0.40	0.02

*pressure flow, $d/D_o > 3.2$
**free surface flow, $d/D_o < 1.0$

Benching tends to direct flow through the structure, resulting in a reduction in head loss

For flow depths between the submerged and unsubmerged conditions, a linear interpolation is performed

Schematic Representation Of Benching Types | **Correction for Benching**

Structure Loss Coeff. Calc. Sheets | Page 1 of 3 | ConnDOT Drainage Manual

Figure EX-9

Connecticut Department of Transportation					
Project No.	Example	Station & Offset	XX+XX		
Route No.	0	Prepared by	HD	Date	1/24/2006
Town	Somewhere	Checked by	DM	Date	1/24/2006
Structure	J-2, 4 ft. diameter standard manhole				

Structure Losses (Section 11.12.6 of ConnDOT Drainage Manual)

Energy loss is approximated as K ($V_o^2/2g$).

$$K = K_o C_d C_Q C_p C_B$$

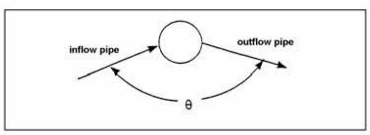
K = **0.05**

1. Relative Manhole Size

$$K_o = 0.1(b/D_o)(1-\sin\theta) + 1.4(b/D_o)^{0.15}\sin\theta$$

K_o = 1.55

θ = the angle between the inflow and outflow pipes	=	86.4	*(Meaured from plans)*
b = structure diameter, mm (in)	=	48	*(4 ft. dia. Manhole)*
Do = outlet pipe diameter, mm (in)	=	24	



2. Compute the ratio d/D_o

d = water depth in structure above outlet pipe invert, mm (in)	=	14.16	*(1.18 ft - Row 8, Column 18 Figure EX-12)*
D_o = outlet pipe diameter, mm (in)	=	24	

d/D_o = 0.59

2. Pipe Diameter

When the depth in the structure to outlet pipe diameter ratio, d/Do, is greater than 3.2 otherwise CD is set equal to 1.0.

$$C_D = (D_o / D_i)^3$$

C_D = 1.00

D_i = incoming pipe diameter, mm (in)	=	24
D_o = outgoing pipe diameter, mm (in)	=	24

Structure Loss Coeff. Calc. Sheets | Page 2 of 3 | ConnDOT Drainage Manual

Figure EX-9

3. Flow Depth *(For free surface flow or low pressures, when d/Do ratio is less than 3.2 . In cases where this ratio is greater than 3.2, Cd is set equal to 1.0)*

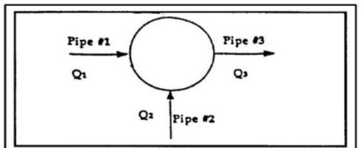
$$C_d = 0.5(d/ D_o)^{0.6}$$

C_d = 0.36

4. Relative Flow

The correction factor is only applied to situations where there are three or more pipes entering the structure at approximately the same elevation. Otherwise, the value of CQ is equal to 1.0.

$$C_Q = (1 - 2\sin\ \theta)\ (1 - \frac{Qi}{Qo})^{0.75} + 1$$



Relative Flow Effect

C_Q = correction factor for relative flow — C_Q = 0.60

Number of pipes at structure	=	3	*At the drainage system design flow, there is inflow to the junction from both the 24" and 12" RCPs. This calculation is based on the flow from the 24" RCP.*
θ = the angle between the inflow and outflow pipes (degrees)	=	86.4	
Q_i = flow in the inflow pipe, m^3/s (ft^3/s)	=	7.6	
Q_o = flow in the outlet pipe, m^3/s (ft^3/s)	=	10.8	

5. Plunging Flow

$$C_p = 1 + 0.2\ [\frac{h}{D_o}]\ [\frac{(h - d)}{D_o}]$$

This correction fac-tor corresponds to the effect of another inflow pipe or surface flow from an inlet, plunging into the structure, on the inflow pipe for which the head loss is being calculated. The correc-tion factor is only applied when h > d, otherwise, the value of Cp is equal to 1.0. Additionally, the correction factor is only applied when a high elevation flow plunges into the structure that has both an inflow and outflow in the bottom of the structure.

Cp = correction for plunging flow — *Cp* = 1.00

h = vertical distance of plunging flow from flow line of higher elevation incoming pipe to the center of outlet pipe, m (ft)	=	
d = water depth in structure above outlet pipe invert, m (ft)	=	
Do = outlet pipe diameter, m (ft)	=	

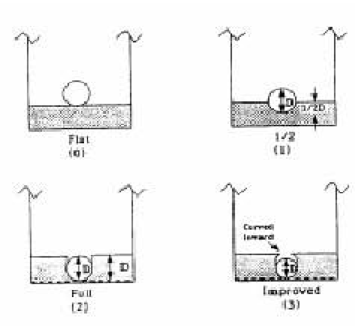
Structure Loss Coeff. Calc. Sheets | Page 3 of 3 Figure EX-9 | ConnDOT Drainage Manual

6. Benching

C_B = correction for benching in the structure

C_B = 0.15

(half bench assumed for this design)



Bench Type	Correction Factors, C_B	
	Submerged*	Unsubmerged**
Flat floor	1.00	1.00
Half Bench	0.95	0.15
Full Bench	0.75	0.07
Improved	0.40	0.02

*pressure flow, $d/D_o > 3.2$
**free surface flow, $d/D_o < 1.0$

Benching tends to direct flow through the structure, resulting in a reduction in head loss

Schematic Representation Of Benching Types

For flow depths between the submerged and unsubmerged conditions, a linear interpolation is performed

Correction for Benching

Structure Loss Coeff. Calc. Sheets — Page 1 of 3, Figure EX-10 — ConnDOT Drainage Manual

Connecticut Department of Transportation					
Project No.	Example	Station & Offset	XX+XX		
Route No.	0	Prepared by	HD	Date	1/24/2006
Town	Somewhere	Checked by	DM	Date	1/24/2006
Structure	J-2, 4 ft. diameter standard manhole				

Structure Losses (Section 11.12.6 of ConnDOT Drainage Manual)

Energy loss is approximated as K $(V_o^2/2g)$.

$$K = K_o C_d C_Q C_p C_B$$

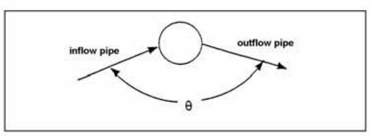
$K =$ 0.03

1. Relative Manhole Size

$$K_o = 0.1(b/D_o)(1-\sin\theta) + 1.4(b/D_o)^{0.15}\sin\theta$$

$K_o =$ 0.32

θ = the angle between the inflow and outflow pipes	=	175	*(Meaured from plans)*
b = structure diameter, mm (in)	=	48	*(4 ft. dia. Manhole)*
Do = outlet pipe diameter, mm (in)	=	24	



2. Compute the ratio d/D_o

d = water depth in structure above outlet pipe invert, mm (in)	=	14.16	*(1.18 ft - Row 8, Column 18 Figure EX-12)*
D_o = outlet pipe diameter, mm (in)	=	24	

$d/D_o =$ 0.59

2. Pipe Diameter

When the depth in the structure to outlet pipe diameter ratio, d/Do, is greater than 3.2 otherwise CD is set equal to 1.0.

$$C_D = (D_o / D_i)^3$$

$C_D =$ 1.00

D_i = incoming pipe diameter, mm (in)	=	24
D_o= outgoing pipe diameter, mm (in)	=	24

Structure Loss Coeff. Calc. Sheets | Page 2 of 3 Figure EX-10 | ConnDOT Drainage Manual

3. Flow Depth *(For free surface flow or low pressures, when d/Do ratio is less than 3.2 . In cases where this ratio is greater than 3.2, Cd is set equal to 1.0)*

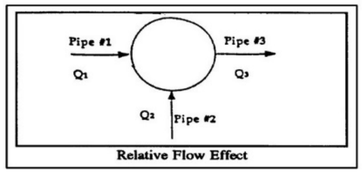
$$C_d = 0.5(d/ D_o)^{0.6}$$

C_d = 0.36

4. Relative Flow

The correction factor is only applied to situations where there are three or more pipes entering the structure at approximately the same elevation. Otherwise, the value of CQ is equal to 1.0.

$$C_Q = (1 - 2\sin\theta)(1 - \frac{Qi}{Qo})^{0.75} + 1$$



C_Q = correction factor for relative flow — C_Q = 1.63

Number of pipes at structure	=	3	*At the drainage system design flow, there is inflow to the junction from both the 24" and 12" RCPs. This calculation is based on the flow from the 12" RCP.*
θ = the angle between the inflow and outflow pipes (degrees)	=	175	
Q_i = flow in the inflow pipe, m^3/s (ft^3/s)	=	3.2	
Q_o = flow in the outlet pipe, m^3/s (ft^3/s)	=	10.8	

5. Plunging Flow

$$C_p = 1 + 0.2\ [\frac{h}{D_o}]\ [\frac{(h - d)}{D_o}]$$

This correction fac-tor corresponds to the effect of another inflow pipe or surface flow from an inlet, plunging into the structure, on the inflow pipe for which the head loss is being calculated. The correc-tion factor is only applied when h > d, otherwise, the value of Cp is equal to 1.0. Additionally, the correction factor is only applied when a high elevation flow plunges into the structure that has both an inflow and outflow in the bottom of the structure.

Cp = correction for plunging flow — *Cp* = 1.00

h	vertical distance of plunging flow from flow line of higher elevation incoming pipe to the center of outlet pipe, m (ft)	=	
d	water depth in structure above outlet pipe invert, m (ft)	=	
Do	outlet pipe diameter, m (ft)	=	

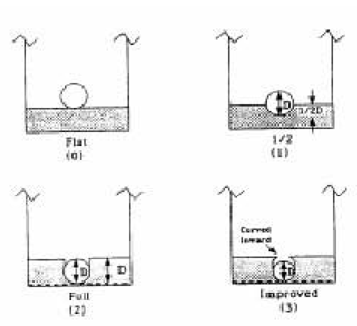
Structure Loss Coeff. Calc. Sheets | Page 3 of 3 | Figure EX-10 | ConnDOT Drainage Manual

6. Benching

C_B = correction for benching in the structure

C_B = 0.15

(half bench assumed for this design)



Bench Type	Correction Factors, C_B	
	Submerged*	Unsubmerged**
Flat floor	1.00	1.00
Half Bench	0.95	0.15
Full Bench	0.75	0.07
Improved	0.40	0.02

*pressure flow, $d/D_o > 3.2$
**free surface flow, $d/D_o < 1.0$

Benching tends to direct flow through the structure, resulting in a reduction in head loss

Schematic Representation Of Benching Types

For flow depths between the submerged and unsubmerged conditions, a linear interpolation is performed

Correction for Benching

4. Flow Diversion Structure – Weir elevation

Referring to the calculations performed in steps 1 and 2 and the results shown on Figure EX-6, the *HGL* elevation on the downstream side of the flow diversion structure (J-1) at the system design flow (10.8 cfs) is 104.41 ft. (Row 3, Column 17) and the *HGL* elevation in the structure at the WQF (1.7 cfs) is 104.20 ft. (Row 10, Column 8). The weir crest elevation will be set at 104.50 ft.

- At elevation 104.50 ft., all of the WQF will be diverted to the hydrodynamic separator for treatment because the weir is set above the HGL elevation (104.20 ft.) in the structure at the WQF, satisfying the design requirement.
- At elevation 104.50 ft., the weir crest elevation is set above the tailwater elevation (104.41) at the system design flow so that the weir is free flowing and not submerged for the system design flow or less, satisfying the design recommendation. At a crest elevation of 104.50 ft., the weir will be approximately 1.27 ft. (15 inches) above the invert elevation of the outflow pipe which is not unreasonably high.

5. Flow Diversion Structure - Flow Split

The proposed flow split at the flow diversion structure for the drainage system design flow (10.8 cfs) will be determined using the following calculations.

a) *HGL* calculations –A summary table and a rating curve (Elevation vs. Discharge) are developed at the flow diversion structure based on the calculations performed in step 3 (Figure EX-7). The summary and rating curve are shown on Figure EX-11.

b) Weir calculations – The weir flow is the flow from the flow diversion structure going to the high flow pipe that bypasses the hydrodynamic separator. The weir will be centered in the flow diversion structure (4 ft. diameter manhole) making the length 4 ft. The crest elevation is 104.50 ft. as determined in step 4. The weir flow will be calculated using the formula for a broad crested weir ($Q = CLH^{3/2}$) with a coefficient of 3.3. A summary table and a rating curve (Elevation vs. Discharge) are developed at the flow diversion structure based on these calculations and are also shown on Figure EX-11.

c) The rating curves determined in steps 5a and 5b are combined to show the total flow with respect to elevation at the flow diversion structure. The combined or total flow curve is shown on Figure EX-11.

FLOW DIVERSION STRUCTURE

LOW FLOW PIPE (Discharge to 12" RCP low flow pipe)	
ELEV. (ft.)	Q (cfs)
103.23	0.00
104.20	1.70
104.88	2.50
105.10	3.00
105.37	3.50
105.91	4.25
From Fig. EX-8	

WEIR (Discharge to 24" RCP high flow pipe)		
ELEV. (ft.)	H (ft.)	Q (cfs)
104.50	0.00	0.00
104.88	0.38	3.09
105.10	0.60	6.13
105.37	0.87	10.71
105.91	1.41	22.10
Crest=104.50 L=4' C=1.33		

TOTAL DISCHARGE (Weir + 12" RCP)	
ELEV. (ft.)	Q (cfs)
103.23	0.00
104.20	1.70
104.88	5.59
105.10	9.13
105.37	14.21
105.91	26.35

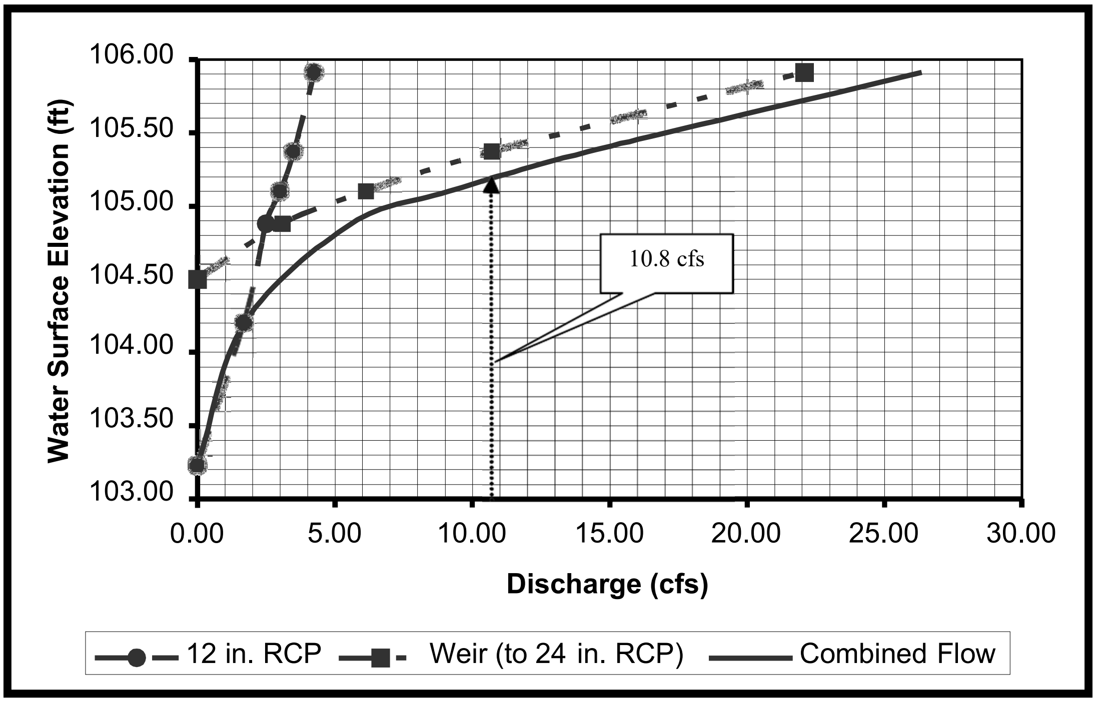


Figure EX-11

d) Entering 10.8 cfs onto the combined rating curve determined in step 5c, the *HGL* elevation at the flow diversion structure for the system design flow is approximately 105.20 ft. At this elevation, the flow split can be determined by entering the individual rating curves developed in steps 5a and 5b. At the design flow, the flow toward the hydrodynamic separator (12" RCP) is 3.2 cfs and the flow over the weir (24" RCP) is 7.6 cfs.

e) At 3.2 cfs as determined in step 5d, the flow toward the hydrodynamic separator (12" RCP) at the drainage system design flow is less than 2.5 times the WQF (4.25 cfs), satisfying the design requirement.

6. The tailwater effect from the proposed flow diversion structure (J-1) is investigated for the drainage system design flow. In step 1, the *HGL* was determined at structure J-1 without the weir in place and the resulting elevation was 104.44 ft. With the weir in place, the HGL elevation is 105.20 ft. or 0.76 ft. higher as determined in step 5d.

   Refer to Figure EX-12. Using 105.20 ft. as a starting HGL elevation at J-1 (Row 5, Column 8), the HGL upstream of this structure was calculated and compared to the HGL with 104.44 at J-1 (Row 2, Column 8). The results of this analysis show that the HGL at Structure I-4 increases by 0.43 ft. to 105.33 ft. with the weir (Row 6, Column 8), vs.104.90 ft. (Row 3, Column 8) without the weir. The HGL converges at the inlet of pipe P-3 at elevation 105.88 ft. (Row 6, Column 17 and Row 3, Column 17) with or without the weir at J-1, therefore the flow diversion structure and hydrodynamic separator will have no influence on the drainage system upslope of structure I-3.

   Further review indicates that the HGL is contained within the system and the freeboard at all drainage structures exceeds one foot. The system, including the flow diversion structure and hydrodynamic separator is acceptable as designed.

7. Hydrodynamic Separator Design Data

   The Hydrodynamic Separator Design Data Sheets (Form A – Design) are prepared which includes the results of the *HGL* analysis for the WQF (step 2) and the drainage system design flow. The HGL for the design flow is based on the proposed flow split at the flow diversion structure (J-1) determined in step 4d. The completed Hydrodynamic Separator Design Data Sheets (Form A – Design) for this example are shown in Figures EX-13-1 and EX-13-2.

CONNECTICUT DEPARTMENT OF TRANSPORTATION HYDRODYNAMIC SEPARATOR DESIGN DATA SHEETS
(FORM B - CONTRACTOR PROPOSAL)

Project No: Location/Station: Date:

HYDRAULIC GRADE LINE ANALYSIS

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Sheet 2 of 2

CONNECTICUT DEPARTMENT OF TRANSPORTATION HYDRODYNAMIC SEPARATOR DESIGN DATA SHEETS (FORM A - DESIGN)

Project No	*Example*	Route No.	*0*	Prepared By:	*HD*	Date:	*4/1/2010*
Town	*Somewhere*	Location/Station	*Site 1*	Checked By:	*DM*	Date:	*4/1/2010*
				Company:	*ConnDOT*		

HYDROLOGIC DATA

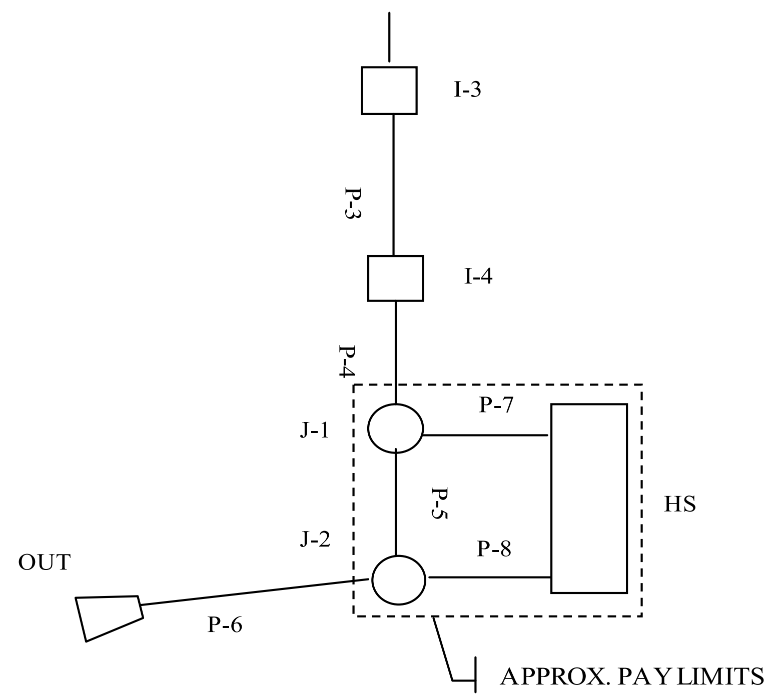
Drainage Area (Acres)	*3.7*
Percent Impervious Area %	*53*
Time of Concentration (min.)	*11*
Drainage Design Flow (cfs)	*10.8*
Drainage Design Frequency (yr)	*10*
Water Quality Flow (cfs)	*1.7*

HYDRODYNAMIC SEPARATOR (HS)

Coordinates:		Datum:	
X:	*XXX,XXX*	Horiz.	*State Plane NAD83*
Y:	*YYY,YYY*	Vert.	*NGVD-1929*
Head loss coefficient		*1.75*	
Sediment Storage Capacity (cy):		HGL Elevation:	
Required	*1.0*	@ WQF	*104.13*
		@ Design Q	*104.85*
Maximum Flow to HS at Drainage Design Flow (cfs)			*4.3*
Comments:			

FLOW DIVERSION STRUCTURE

Type	*4' Diameter Manhole*		
Weir and/or Bypass Elev.	*104.50*		
Weir Length (ft.)	*4*	Weir Coeff. (C)	*3.3*
HGL Elevation:		Flow Split @ Drainage Design	
@ WQF	*104.20*	To HS	*3.2*
@ Design Q	*105.20*	Bypassing HS	*7.6*



Sketch (NTS) - Indicate Pay limits

Comments:

Sheet 1 of 2

CONNECTICUT DEPARTMENT OF TRANSPORTATION HYDRODYNAMIC SEPARATOR DESIGN DATA SHEETS (FORM A - DESIGN)

Project No:	*Example*	**Location/Station:**	*Site 1*	**Date:**	*4/1/2010*

HYDRAULIC GRADE LINE ANALYSIS

Pipe	Downstream Str.	Pipe Size (in)	Flow (cfs)	Ground Elev. OUT (ft)	Invert Elev. OUT (ft)	HGL OUT (ft)	Depth OUT (ft)	Vel. Head OUT (ft)	EGL OUT (ft)	Length (ft)	Friction Slope (ft/ft)	Friction Loss (ft)	EGL IN (ft)	Vel. Head IN (ft)	HGL IN (ft)	Depth IN (ft)	Invert Elev. IN (ft)	Ground Elev. IN (ft)	Upstream Str.	Headloss Coeff.	Str. headloss (ft.)
			WQF																		
P-6	OUT	24	1.70	106.48	103.04	103.47	0.43	0.19	103.65	25	0.0047	0.12	103.77	0.16	103.61	0.45	103.16	108.86	J-2	0.01	0.00
P-8	J-2	12	1.70	108.86	103.16	103.71	0.55	0.23	103.94	6	0.0058	0.03	103.97	0.21	103.76	0.57	103.19	108.86	HS	1.75	0.37
P-7	HS	12	1.70	108.86	103.19	104.13	0.94	0.08	104.21	6	0.0017	0.01	104.22	0.08	104.14	0.91	103.23	109.19	J-1	0.82	0.06
P-4	J-1	24	1.70	109.19	103.23	104.20	0.97														
	10	YR	DESIGN	FLOW																	
P-6	OUT	24	10.80	106.48	103.04	104.20	1.16	0.51	104.71	25	0.0048	0.12	104.83	0.49	104.34	1.18	103.16	108.86	J-2	0.05	0.02
P-8	J-2	12	3.20	108.86	103.16	104.36	1.20	0.26	104.62	6	0.0069	0.04	104.66	0.26	104.40	1.21	103.19	108.86	HS	1.75	0.45
P-7	HS	12	3.20	108.86	103.19	104.85	1.66	0.26	105.11	6	0.0069	0.04	105.15	0.26	104.89	1.66	103.23	109.19	J-1	1.18	0.31
P-4	J-1	24	10.80	109.19	103.23	105.20	1.97	0.18	105.38	88	0.0018	0.16	105.54	0.24	105.30	1.63	103.67	112.96	I-4	0.11	0.03
P-3	I-4	24	9.10	112.96	103.87	105.33	1.46	0.22	105.55	185	0.0041	0.76	106.31	0.43	105.88	1.08	104.80	109.55	I-3		
P-6	OUT	24	10.80	106.48	103.04	104.2	1.16	0.51	104.71	25	0.0048	0.12	104.83	0.49	104.34	1.18	103.16	108.86	J-2	0.05	0.02
P-5	J-2	24	7.60	108.86	103.16	104.36	1.20								104.36	1.13	103.23	109.19	J-1		

Sheet 2 of 2

IV. Example Hydrodynamic Separator Product Selection Using Tables 2 & 3

The proposed hydrodynamic separator at Site 1 shall treat a WQF = 1.7 cfs and have a minimum sediment storage capacity of 1.0 c.y. as shown on the Hydrodynamic Separator Design Data Sheets (Form A – Design), Figure EX-13-1.

First, using Table 2, PERFORMANCE MATRIX FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS, the Maximum WQF, Column 1, must equal or exceed the design WQF of 1.7 cfs. Therefore, reading the 1.7 cfs line from the table, the product models that satisfy the WQF requirement are:

Product	Model
Barracuda	Barracuda S5
Cascade	CS-4
CDS	CDS-6
Concentrator	AS-6
Downstream Defender	6ft
DVS	DVS-72
First Defense	5ft
HydroDome	HD5
HydroStorm	HS6
SciClone	SC-7
SciCloneX	SCX-4
Xcelerator	XC-4

Next, using Table 3, STANDARD SEDIMENT STORAGE CAPACITY FOR CTDOT QUALIFIED HYDRODYNAMIC SEPARATORS, the standard sediment storage capacities of the initially selected product models are checked and the results are shown below:

Product	Model	Sediment Storage Capacity (cy)
CDS	CDS-6	1.04
Downstream Defender	6ft	1.04
SciClone	SC-7	1.07

The proposed hydrodynamic separator must have a sediment storage capacity of at least 1.0 c.y. in order to be qualified for installation on the project. A review indicates that the product models that will satisfy both the WQF and sediment capacity requirements are the CDS-6, Downstream Defender 6ft, and SC-7. In order to use other products, the standard model must be modified to increase the sediment storage capacity or, alternatively subsequent models with a larger sediment capacity may be used.