CONTECH STORMWATER SOLUTIONS

APPLICATION TO:

WASHINGTON STATE DEPARTMENT of ECOLOGY WATER QUALITY PROGRAM

For GENERAL USE DESIGNATION –

PRETREATMENT APPLICATIONS

&

CONDITIONAL USE DESIGNATION – OIL TREATMENT

Of The Continuous Deflective Separation (CDS™) Technology

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TABLE OF CONTENTS

List of Tables

List of Figures

Appendixes

Appendix A – Mathematical Graphical Flow Model and Operation Animations

1. Video animation file: "CDS Internal Velocities - FRAMER.EXE"., depicting flow velocities in the separation chamber. Spencer, S., Wells, S. and Berger, C. (2002) "Particle Removal using Continuous Deflection Separation", Portland State University
2. Video animation file: "Modified inline.avi"., animation of the operation of an "inline" CDS Unit
3. Video animation file: "New Planview.avi"., Planview of the flow through an "Offline" CDS Unit
4. Video animation file: "Hydraulic_W_Indeo.avi"., Three dimensional depiction of the flow path through an "Offline" CDS Unit.
5. Video animation file: "Full_Precast.avi"., Three dimensional depiction of construction installation sequence of "Offline" CDS unit components and the flow path through the unit

Appendix B – Project Profile

Appendix C – Particle Size Distribution Report (MACTEC Engineering and Consulting Inc.)

Appendix D – PMSU Test Summary & Analytical Results (TSS) Example

Appendix E – Oil and Grease Removal Studies

Slominski, S, Wells, S. (2003) Oil and Grease Removal using Continuos Deflection Separation with an Oil Baffle, Portland State University (PSU)

Stenstrom, M., Lau, S.L., (1998) Oil and Grease Removal by Floating Sorbent in a CDS Device, University of California, Los Angeles (UCLA)

Appendix F – Example, Site Specific Operation & Maintenance Manual

Appendix G – Field Studies of CDS Unit Performance

Strynchuck, J., Royal, J. and England, G., The Use of a CDS Unit for Sediment Control in Brevard County, Brevard County Surface Water Improvement

Walker T.A., Allison R.A., Wong T.H.F. and Wootton R.M. (1999), *Removal of Suspended Solids and Associated Pollutants by a CDS Gross Pollutant Trap*, Technical Report 99/2, Cooperative Research Centre for Catchment Hydrology

Executive Summary

0.1 Applicability of Evaluations

CONTECH Stormwater Solutions is requesting within this application to evaluate the CDS performance based on previously completed laboratory and field tests.

Laboratory tests were conducted in conformance with Washington State Department of Ecology's (WASDOE's) testing and evaluation protocols. A broad range of particles sizes made up the gradation of sediment used in the solids removal performance evaluations. The results of these evaluations conclusively show that CDS units are capable of removing 50% of the fine total suspended solids (TSS, d_{50}=50-µm) and 80% of the coarse total suspended solids (TSS, d_{50}=125-µm) required to receive approval. A simplistic mass weighted analytical method was employed to verify this performance capacity.

In addition, previous CDS field studies showed that CDS device provided an average of >50% removal for the total suspended solids.

0.2 Current Submittal Objective

This submittal package is prepared to support the detailed performance review and approval of CDS stormwater treatment unit according to **Guidance for Evaluating Emerging Stormwater Treatment Technologies,** Technology Assessment Protocol - Ecology (TAPE June 2004). This submittal includes detailed discussions of the completed evaluation tests and quantified pollutant removal performance evaluations of CDS stormwater treatment units as well as cost, maintenance, construction and installations.

CONTECH Stormwater Solutions is requesting the approval of the CDS units listed in the following table based on the demonstrated performance capacity.

Table 1 CDS Model and Design Treatment Flow Rate Capacities

Precast	CDS Model Numbers	Design Treatment Flow Capacity (cfs)
Inline	PMIU20_15_4	0.7
	PMIU20_15	0.7
	PMSU20_15_4	0.7
	PMSU20_15	0.7
	PMSU20_20	1.1
	PMSU20_25	1.6
	PMSU30_20	2.0
	PMSU30_30	3.0
	PMSU40_30	4.5
	PMSU40_40	6.0
Offline	PSWC20_15	0.7
	PSWC20_20	1.1
	PSWC20_25	1.6
	PSWC30_20	2.0
	PSWC30_30	3.0
	PSWC40_30	4.5
	PSWC40_40	6.0
	PSWC56_40	9.0
	PSWC56_53	14.0
	PSWC56_68	19.0
	PSWC56_78	25.0
Offline	PSW30_30	3.0
	PSW50_42	9.0
	PSW50_50	11.0
	PSW70_70	26.0
	PSW100_60	30.0
	PSW100_80	46.0
	PSW100_100	64.0

PMIU – Precast Manhole Inlet Unit
PMSU – Precast Manhole Storm water Unit
PSW – Precast Storm Water unit
PSWC – Precast Storm Water Concentric unit
CDS units can be left-handed or right-handed configuration.

Table 2a CDS Unit Capacities and Physical Features

		Model* Designation	Treatment Capacity Range		Screen Diameter & Height		Sump Capacity (yd^3)	Depth Below Pipe Invert (ft)	Foot Print Diameter (ft)
			cfs	MGD	(ft)	(ft)			
Precast**	Inline	PMIU20_15 (Drop-in Inlet)	0.7	0.5	2.0	1.5	0.9	5.0	4.8
Precast**	Inline	PMSU20_15_4	0.7	0.5	2.0	1.5	0.9	5.0	4.8
Precast**	Inline	PMSU20_15	0.7	0.5	2.0	1.5	1.5	5.0	6.0
Precast**	Inline	PMSU20_20	1.1	0.7	2.0	2.0	1.5	5.6	6.0
Precast**	Inline	PMSU20_25	1.6	1	2.0	2.5	1.5	5.9	6.0
Precast**	Inline	PMSU30_20	2	1.3	3.0	2.0	2	6.0	7.3
Precast**	Inline	PMSU30_30	3	1.9	3.0	3.0	2.1	6.9	7.3
Precast**	Inline	PMSU40_30	4.5	3	4.0	3.0	5.6	8.6	9.5
Precast**	Inline	PMSU40_40	6	3.9	4.0	4.0	5.6	9.6	9.5
Precast**	Offline	PSWC30_20	2	1.3	3.0	2.0	3.1	7.0	7.2
Precast**	Offline	PSW30_30	3	1.9	3.0	3.0	1.5	6.9	5.4
Precast**	Offline	PSWC30_30	3	1.9	3.0	3.0	2.3	7.2	7.3
Precast**	Offline	PSWC40_30	4.5	3	4.0	3.0	5.6	8.5	8.3
Precast**	Offline	PSWC40_40	6	3.9	4.0	4.0	5.6	9.6	8.3
Precast**	Offline	PSW50_42	9	5.8	5.0	4.2	1.9	9.6	8.0
Precast**	Offline	PSWC56_40	9	5.8	5.6	4.0	5.6	9.6	9.5
Precast**	Offline	PSW50_50	11	7.1	5.0	5.0	1.6	10.3	8.0
Precast**	Offline	PSWC56_53	14	9	5.6	5.3	5.6	10.3	9.5
Precast**	Offline	PSWC56_68	19	12	5.6	6.8	5.6	12.6	9.5
Precast**	Offline	PSWC56_78	25	16	5.6	7.8	5.6	13.6	9.5
Precast**	Offline	PSW70_70	26	17	7.0	7.0	3.6	14.0	10.5
Precast**	Offline	PSW100_60	30	19	10.0	6.0	5.7 or 11.6	12.0	17.5
Precast**	Offline	PSW100_80	50	32	10.0	8.0	5.7 or 11.6	14.0	
Precast**	Offline	PSW100_100	64	41	10.0	10.0	5.7 or 11.6	16.0	

*CDS Model Prefixes
PMIU = Precast Manhole Insert Unit
PMSU = Precast Manhole Stormwater Unit
PSWC = Precast Stormwater Concentric
PSW = Precast Stormwater Concentric
*CDS Model Suffixes
Precast (P), and Stormwater (SW)

**CDS Technologies can customize units to meet specific design flows and sump capacities.

***Sump Capacities and Depth Below Pipe Invert can vary due to specific site design

0.3 Project Specific SQTS Design, Review & Approval Process Request

This submittal also includes this explicit request that WASDOE approve specially designed Stormwater Quality Treatment System (SQTS) that adhere to the 50 percent (%) minimum removal requirement of the mean particle size d_{50}=50-µm material and/or 80 percent (%) minimum removal requirement of the mean particle size d_{50}=125-µm material . These special units would be designed and stamped by a professional engineer registered in the state of Washington. CDS does not anticipate frequent review requests for specially designed units, but there may be the need to generate special designs of cast-in-place units or large diameter manhole units in 10, 12-feet (ft) or larger diameter precast manhole units or CDS units configured in square vertical shafts to meet both the project needs as well as the pollutant removal requirements of municipal or private developments.

With WASDOE's willingness to review specially designed CDS units not listed on Table 1, units that would be designed for unique project applications could be considered for future approval. Significant capital savings that are typically derived from large economy of scale designs, such as cast-in-place CDS units could then be realized. CDS can provide specially designed units able to meet the Ecology's TSS removal goal and treat flows well in excess of 100-cfs (2,850-L/s). Additionally, physical site constraints that may originate from utility conflicts may possibly be easily addressed with a CDS unit configured in large diameter manholes or vertically installed box culvert sections.

The ability of the Continuous Deflective Separation (CDS) Technology to meet specific project needs should not be constrained by only those units listed in Table 1. The application of the CDS water treatment unit process is entirely scalable and can be deployed in a variety of configurations to meet WASDOE's specified solids removal requirement.

1.0 Purpose of Application

The purpose of this application is to seek acceptance of Continuous Deflective Separation (CDS) treatment system provided by **CONTECH Stormwater Solutions,**

for General Use Level Designation (GULD) in the State of Washington for the following Category:

1. Pretreatment Application, and

for Conditional Use Level Designation (CULD) in the State of Washington for the following Category:

2. Oil Treatment

This report demonstrates that a properly sized CDS units can achieve the Washington State Department of Ecology's *guidelines* as listed below per the October 2002 (revised June 2004) "Guidance for Evaluating Stormwater Treatment Technologies" for assessing technologies at less-than-basic treatment levels:

- *Provides mostly coarse solids removal (>500 microns, (µm)) including all litter and debris.*
- *Improves the effectiveness, extends the useful life, or extends the maintenance cycle of a downstream treatment device or infiltration facility.*
- *Results in a more cost-effective treatment system.*

To demonstrate specific compliance with the Ecology-specified pretreatment performance goals, this report contains laboratory studies demonstrating that the CDS technology achieves the following numerical treatment performance goals for pre-treatment application and oil treatment:

- 50% removal of fine (50-µm mean size) total suspended solids or 80% removal of coarser (125-µm mean size) total suspended solids for influent concentration > 100-mg/L but less than 200-mg/L.
- Control of oil: no ongoing or recurring visible sheen, and a maximum daily average total petroleum hydrocarbon concentration ≤ 10-mg/L, and a maximum of 15-mg/L for discrete samples.

This report is structured with supporting performance evaluation test information provided in Section 6 of this report, which explicitly verifies compliance with the guidelines list above as well as demonstrated ability to achieve the numerical treatment performance goals listed above.

This report also contains the following discussion sections as required by the TAPE protocol: Company information, unit process descriptions and its functionality, unit applications, sizing, design, construction, cost, operational & maintenance and safety issues.

2.0 The CDS Treatment System

2.1 Company Profile

CDS Technologies, Inc. (CONTECH Stormwater Solutions now) designs, manufactures, installs and maintains Continuous Deflective Separation water pollution control devices. These devices are designed for separating solids from liquids using a non-blocking, indirect screening technology. Used in storm water systems, they aim to prevent pollutants carried in storm water runoff from reaching receiving waters. The CDS technology is also being applied in the treatment of combined sewer overflows and industrial waste.

The CDS technology was initially developed in Australia in 1992 to address gross pollutants in storm water runoff and has since proven capable of swirl concentration fine solids. The technology operates under both national and international patents and continues to be refined and improved as a result of new research to enhance fine solids and oil and grease removal.

The CDS technology was introduced in the United States with a July 1997 installation in Brevard County Florida. The technology has been widely accepted with over 6,200 installations in the United States and Canada and over 7,000 CDS units worldwide. There are over 1,380 installations in Washington and Oregon.

CDS Technologies, Inc. is an established public company recently purchased in December 2006 by CONTECH Stormwater Solutions here in the United States. In addition to the 18 CDS offices throughout the United States with the US headquarters located in Morgan Hill, CA, CONTECH Stormwater Solutions has more than double the offices and staff of CDS. The CDS staff includes professional engineers and engineers in training with expertise in civil, hydraulic, mechanical, chemical and water quality engineering and technical sales personnel.

2.2 CDS Technology Assessment

Continuous Deflective Separation (CDS) is an innovative technology and has been the subject of independent research: University of California Los Angles (UCLA); Portland State University (PSU); Monash University, Australia and the Co-operative Research Centre for Catchment Hydrology (CRCCH), Australia. The PSU and UCLA work provides the primary basis for oil and grease removal performance claims.

This submission draws on the experience gained from thousands of practical, functioning field applications of the CDS technology and independent field evaluations to describe the pollutant removal and retention features of the CDS device. More than 20 different independent laboratory and field evaluations of the technology have been undertaken in

Australia and the United States. A number of these studies were undertaken to assess the physical and chemical characteristics of the pollutants captured in the CDS sump. Additional field evaluations are underway by the Multi-State TARP (The Technology Acceptance Reciprocity Partnership) program and in various locations across the States.

High trapping efficiencies for suspended solids and gross solids (litter and debris) are reported from laboratory tests (eg. Woodward-Clyde 1998., Wells, et al 1999 and 2002 Wong et al., 1996) and field performance monitoring results of the CDS unit by Allison et al., (1998), Walker et al., (1999) and Caltrans (2001 and 2002). Control of oil is reported from laboratory studies by Stenstrom (1998) at UCLA and Slominski and Wells (2003) at PSU.

Field monitoring studies of the CDS Technology at Coburg Australia, and Brevard County, Florida are also presented to demonstrate the effectiveness in watershed applications.

2.3 CDS Separation Technology

The CDS Technology employs multiple primary clarification treatment processes to remove pollutants from storm runoff flows in a very small footprint: Deflective Screening / Filtration, Swirl Concentration, Diffusion Sedimentation and Baffling.

Treatment flows are introduced into the deflective separation chamber as a tangential flow introduced smoothly along the circumference of the stainless steel screen cylinder by the CDS unit's inlet structure located above the cylindrical screen. A balanced set of hydraulics is produced in the separation chamber. These balanced hydraulics provide washing flows across the stainless steel screen surface that prevent any clogging of the apertures in the expanded metal screen as well as establish the hydraulic regiment necessary to separate solids through continuous deflective separation and swirl concentration separation. Though this flow regime is initially similar in appearance to a vortex, it should be understood that the CDS separation process is not employing the vortex separation process as they exist in a classic, smooth walled cylinder vortex unit with a centrally located underdrain. The CDS Separation process is more than a gravity based separation process.

The following figure illustrates that screened water from the CDS unit's separation chamber exits radially.

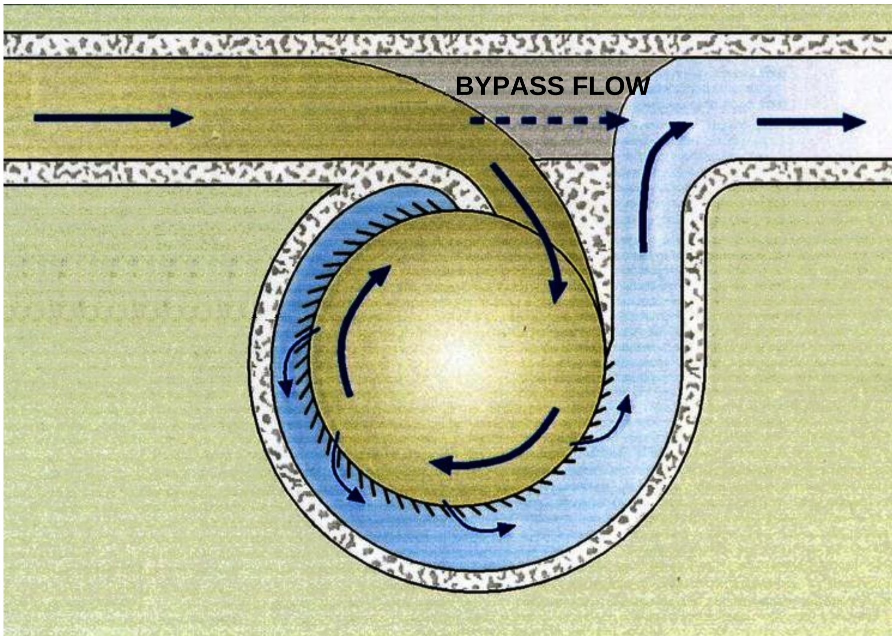


Figure 1 Typical "Offline" CDS Model PSW, PSWC or CSW system shown diverting flows from main storm water channel into its separation chamber.

Appendix A contains a Compact Disk (CD) with video animation depicting the flow through an "Offline" CDS unit.

The continuous deflective separation process produces a low energy, quiescent zone in the middle of the swirling chamber, which is opposite of a vortex separation process. In a simple gravity based vortex system, rotational velocities increase closer to the center of the unit. The quiescent zone in a CDS unit enables effective settlement of fine particles through a much wider range of flow rates than could otherwise be achieved using a simple settling tank in the same footprint. Particles within the diverted treatment flow are retained by the deflective screening chamber and are maintained in a circular motion that diminishes as in the center of the unit, which is best defined as enhanced swirl concentration and screening. Particles heavier than water (specific gravity>1) ultimately settle into the sump located below the separation chamber.

The pollutants captured in the sump located below the screening, swirl concentration separation chamber are isolated from high velocity bypass flows through the unit preventing the scouring loss of trapped pollutants. Scouring losses typically occur in those structural BMP's that are designed with the deposition zone of settled material integral to the treatment flow path. All CDS units have sumps to accommodate the storage of deposition material below the separation chamber to prevent scouring. This CDS sump is cut off from the separation chamber by a hydraulic shear plain at the bottom of the separation chamber, which minimizes the influence of scouring velocities.

A turbulent boundary layer at the screen face impedes small particles from crossing the screen. The detailed configuration and orientation of the expanded screen causes particles to be deflected towards the center of the screen chamber where the quiescent zone (stagnant core) exists. This impedance produced by the turbulent boundary layer and the deflective force assists in overcoming centripetal forces that are exerted on entrained particles enveloped in the screening separation chamber.

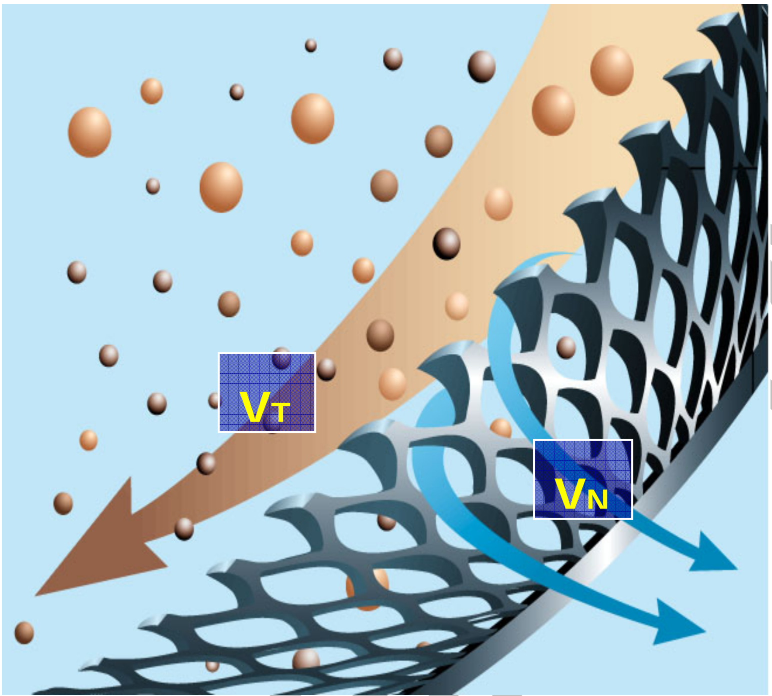


Figure 2 Illustration of Fluid Velocity Flows in CDS Unit Screening Mechanism
(V_T – Tangential velocity, V_N – Normal Velocity, perpendicular to the screen)

This turbulent boundary layer and deflective force make the CDS system materially superior to classic smooth walled swirl concentrators. The CDS separation process employs two additional separation forces that are not available in the simple, gravity based smooth walled swirl concentrators, which predominately rely on toroidal forces to separate solids from liquids in swirl chamber. These toroidal forces are also present in equal or greater magnitude within a CDS unit.

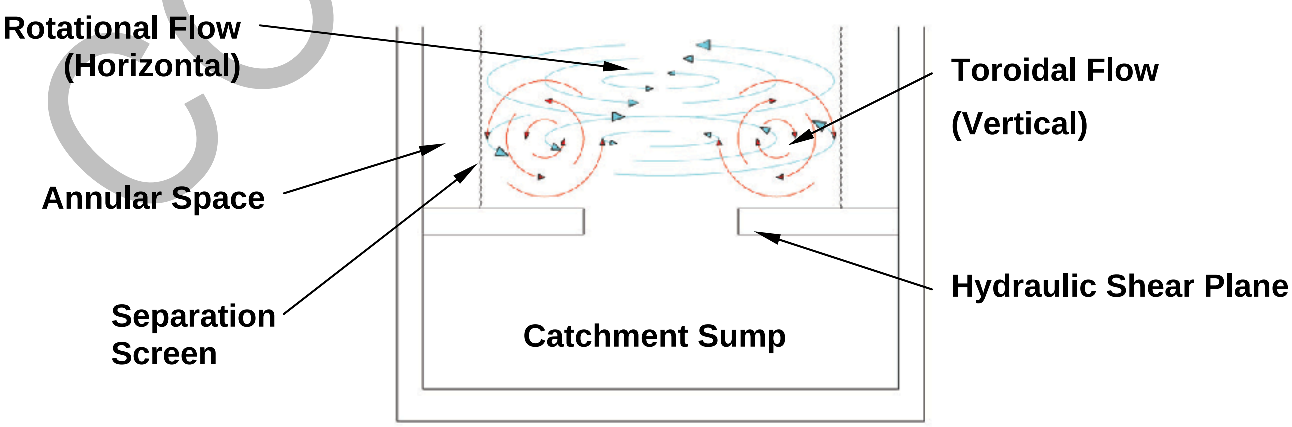


Figure 3 Toroidal Pattern in a CDS Unit

As shown in Figure 3, the toroidal flow motion within the separation chamber of a CDS unit is shown as the red circular flow lines. These toroidal flow forces are perpendicular to the horizontal rotation flow at the screen face and assist in moving particles to the center of the CDS treatment chamber until they settle into the sump.

Treated water flows through the entire screen cylinder surface area to exit this separation chamber. This is a very large flow path area, which results in very low exit velocities (under-flowrate) from the CDS separation chamber.

This low underflow rate greatly enhances the separation capacity of the CDS solids separation process beyond that of a basic smooth cylinder walled vortexing unit. Besides the quiescence zone in the middle of the swirl separation chamber, low flow velocities also occur in the annular and volute spaces behind the screen. The flow passing through the stainless steel separation screen is greatly dispersed / diffused. The flow velocity is very low immediately after crossing the screen face into the annular space behind the screen. It has extremely low velocities in relationship to the entrance, separation chamber and exit velocities. Straight, simple sedimentation settling occurs in this annular space behind the screen before the flow passes beneath the oil baffle and exits the unit. In summary, CDS technology brings together this multitude of primary clarification treatment processes (patented continuous deflective separation, swirl concentration, toroidal separation, separated sump zone, indirect screening, sedimentation and baffling) in one treatment device, which provides the most effective and efficient stormwater treatment.

CDS Separation Screen – Blockage-Free, Self-Cleaning

As mentioned above, the patented continuous deflective separation system is a unique treatment process associated only with the CDS unit and no other structural BMP. This patented process consists of a perforated stainless steel expanded metal screen that is either concentrically or eccentrically located in the separation chamber portion of the unit. This screen cylinder filters stormwater while also enhancing the swirl concentration efficiency of the unit. The perforations in the separation screen are typically elongated in shape and are aligned with the longer axis in the vertical direction. The typical perforation size for use in urban storm water systems is 2400 and 4700-μm.

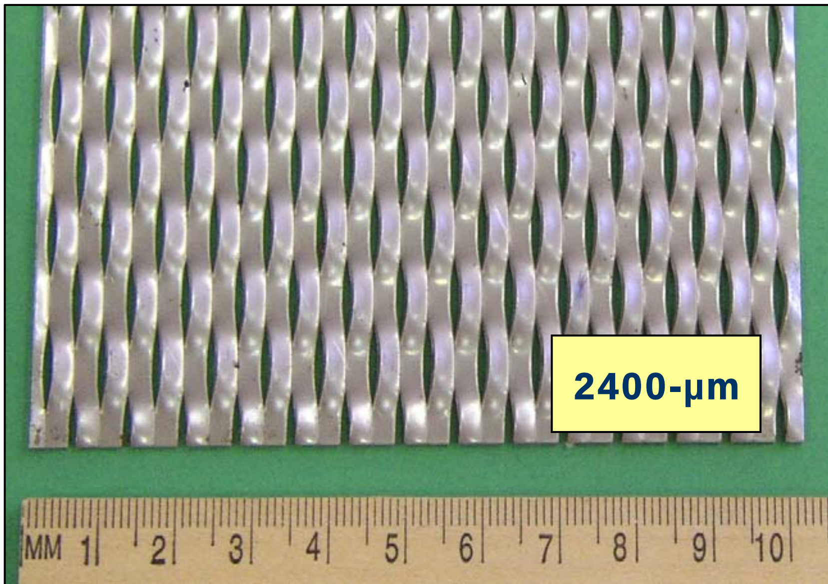


Figure 4 Photo of 2400-µm Screen Section, ASTM 316L Stainless Steel

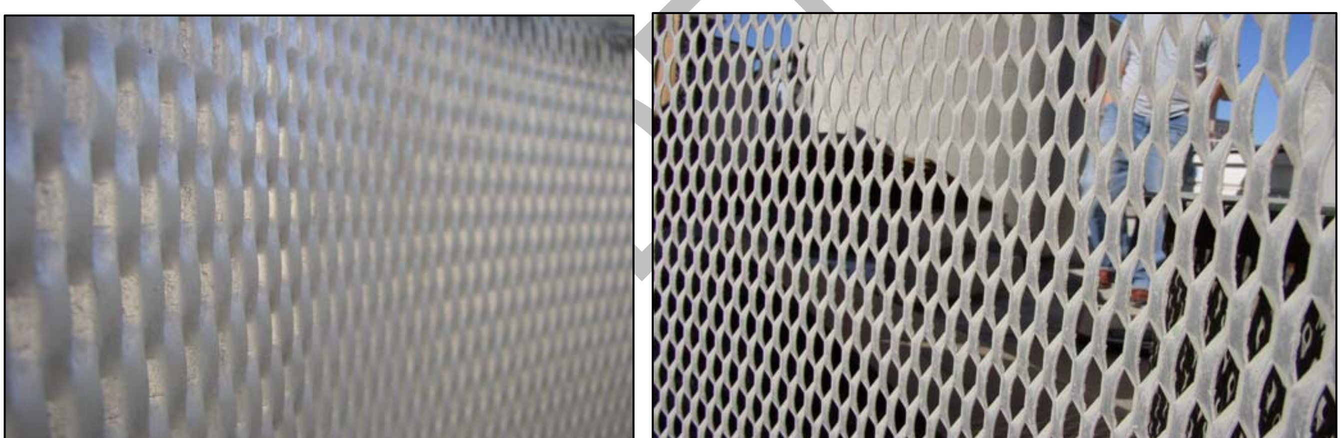


Figure 5 Screen Cylinder (In Field)

Review of the screen cylinder photo shown on the left side of the Figure 5 shows how the flow is introduced on the backside, the blind side of the expanded metal screen cylinder to produce the patented continuous deflect flow pattern. The photo on the right shows the screen openings from a view point opposite the direction of flow in the screen cylinder.

The tangential inflows, cause a rotational motion within the separation chamber that is balanced to exceed the radial flow rate through the screen. The continuous motion in the separation chamber ensures that the tangential force on pollutants that keeps them in rotation is greater than the radial force produced by the flow through the screen. This ensures that the screen is free of blocking by gross solids and can allow flow to reach the outlet. This balanced flow condition will also be discussed in terms of shear stresses caused by shear velocity on the screen as the mechanism for removing material from the screen surface.

Measurements of surface velocities in the swirling chamber (Wong & Wootton, 1995) indicate that the circumferential velocities increase with the radial distance from the center of the chamber (Figure 6). The main flow mode in the chamber behaves like a rotating hollow cylinder. A particle on the outer diameter of this rotating hollow cylinder, which would be right at the inside face of the screen cylinder would experience centrifugal force. Any object in the flow near the screen surface, with a density greater than that of water, will be forced outwards and be pressed against screen. In addition the drag forces associated with the flow component through the perforated screen cylinder will influence objects near the screen; however, these are considered to be negligible in magnitude compared to the centrifugal forces. This centrifugal force is effectively superseded by the combination of the balanced hydraulics producing a rotational force, boundary layer effect, deflect force and toroidal flows.

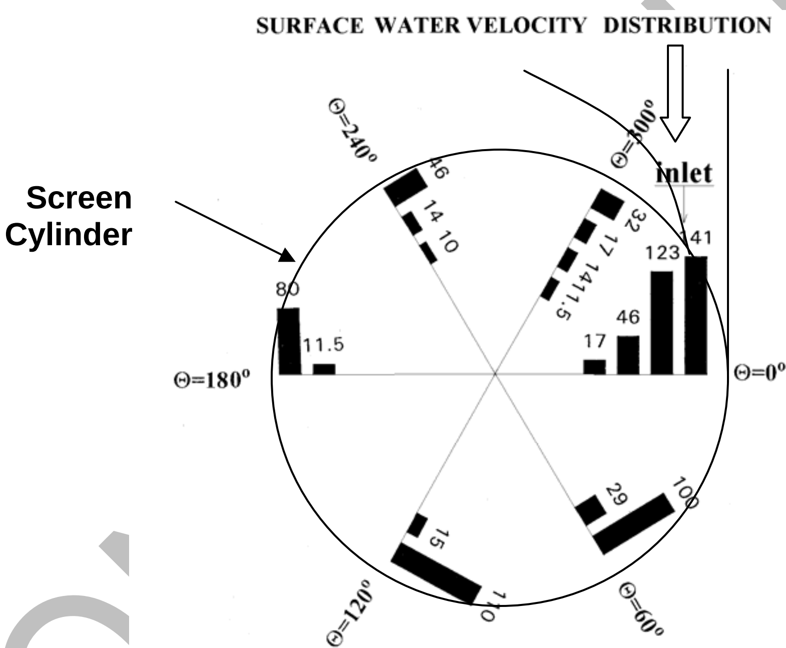


Figure 6 Surface velocity distributions within the separation chamber of a CDS unit, (Wong & Wootton, 1995)

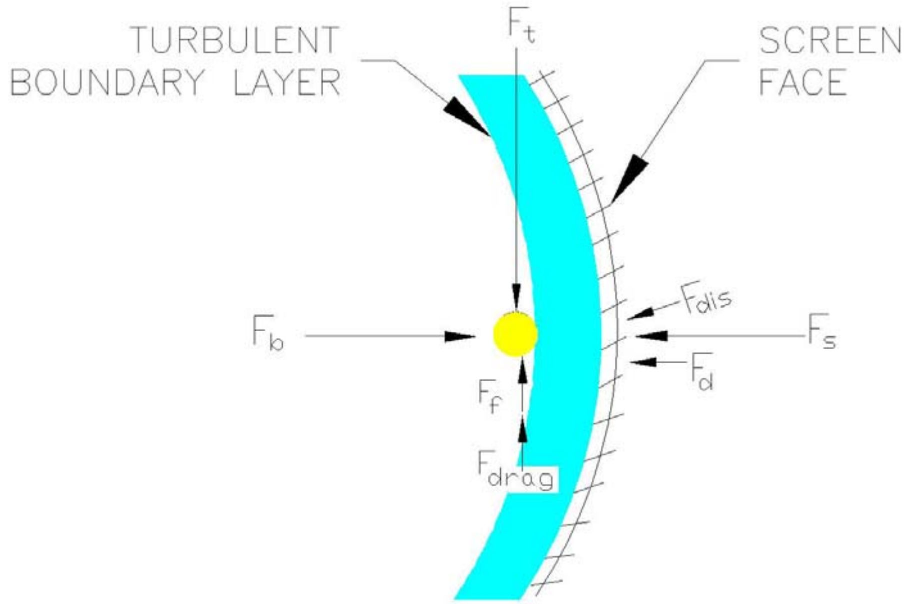


Figure 7 Schematic Drawing - Forces on An Object Near the CDS Screen

Figure 7 illustrates the forces that act on a particle as it travels across the surface of the screen. Illustrating these forces assist in better understanding the non-blocking aspect of the CDS separation system. The particle is influenced by the circular motion of the water inside the chamber forcing the particle outwards, but is prevented from moving to the outside of the chamber by the perforated screen, which appears as a solid wall to particle. Due to the orientation of the expanded metal apertures, the approaching particle within the rotational flow sees only a solid wall rather than the openings, see right most photo of Figure 5. Particles are driven over the screen face by the balanced inflow, which is the tangential flow around the inside of the screen chamber, tangential force (F_t). This rotating motion of the flow inside the screening cylinder produces a centrifugal force (F_b) on the particle, which if left un-opposed, would act to eventually block the screen with debris. This force centrifugal force (F_b), is resisted by an equal but opposite centripetal force (F_s) exerted on the particle by the screen face. The slanted orientation of the expanded metal screen also produces a small deflection force (F_d) on the particle. The turbulent boundary layer generated by the flow over the rough screen face also services to impede particles from crossing the screen face. This turbulent boundary layer has a displacement effect / force (F_{dis}), which also acts against the centrifugal force (F_b). Finally, there also exists drag (F_{drag}) and friction forces friction force (F_f) that act against tangential force (F_t) exerted on the particle.

The particle is kept in motion because the tangential drag force (F_t) is greater than the drag and friction forces (F_{drag} & F_f). The dimensions of the chamber ensure that the ratio between F_t and F_f is always in favour of F_t, regardless of the position of the object around the chamber screen.

Again, it should be understood that the CDS separation process is very much opposite to a vortex in which the rotational velocities are greatest at the center and the entire body of water is rotating. The CDS unit's center is quiescent and the rotational velocities increase as you get further from the center. Unfortunately, the nuances of that differentiate these two treatment flow processes though obvious are too often incorrectly categorized by most people not fully knowledgeable of the definition of these different flow regimes and treatment hydraulics and many find it simply easier to call both processes vortexes or simply categorize such treatment devices as hydrodynamic separators.

Appendix A contains a computer flow model animation file "Frame", developed by Dr. Scott Wells, Portland State University showing the internal velocities in the separation chamber and demonstrating the screen washing characteristics and quiescent conditions at the center of the chamber that allow the solids to settle.

Minimal Operational Head

The head loss affected by the CDS system was thoroughly monitored during storm events by Allison et al (1998) by using flow depth probes, upstream, downstream and along the by-pass channel of the system. The analysis reported that the head loss coefficient is in the order of 1.3, which is less than a typical junction pit. It has been established that the actual head loss under system design flow varies as a function of the velocity head = "$V^2/2g$". The headloss coefficient "K_{CDS}" can vary from as low as 0.75 to as much as 8 or more during extremely high velocity flows. For planning purposes it is normally suggested to start with an initial headloss coefficient assumption of K_{CDS} = 1.3 and V is the design flow velocity in the collection system pipeline without the CDS storm water treatment unit. The small head losses make the CDS system suitable for a range of applications including low-lying areas as well as steeper watersheds.

Additionally, a hydraulic analysis should be done for each CDS installation. This hydraulic analysis should ensure diversion and bypass flows do not unduly exacerbate flooding potential in the storm water collection system upstream of the BMP.

3.0 CDS Unit Configurations

CDS units are available in three different types of configurations and can have either an internal or external diversion weir: Off-line models designated by PSW, PSWC & CSW prefixes have external diversion weirs constructed in a diversion structure installed within the pipeline alignment. This diversion structure is located adjacent to the Off-line CDS unit. In-line models prefaced by PMSU, and Drop-Inlet units denoted by PMIU prefixes have their diversion weirs manufactured as integral components within the units. Figure 8, provides an illustration of a typical Offline PSW, PSWC & CSW model CDS unit, Figure 9 is an illustration of our Inline PMSU model unit and Figure 9 shows our Drop-Inlet storm water treatment units.

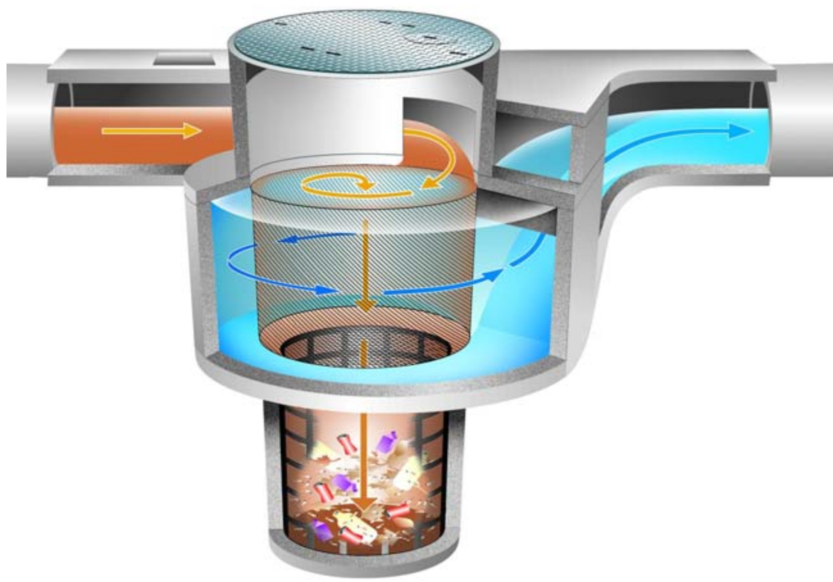


Figure 8 “Offline” configuration, CDS models with prefix: PSW, PSWC or CSW

Off-line Unit: These CDS units are available in precast reinforced concrete modules for all applications processing flows up to 64-cfs (1,813-L/s or 1.8-m^3/s). The diversion weir box structure can be designed to accommodate multiple inlet pipes and bypass very large flood flows. For applications requiring larger flow processing, units are designed complete with construction specifications for cast in place construction.

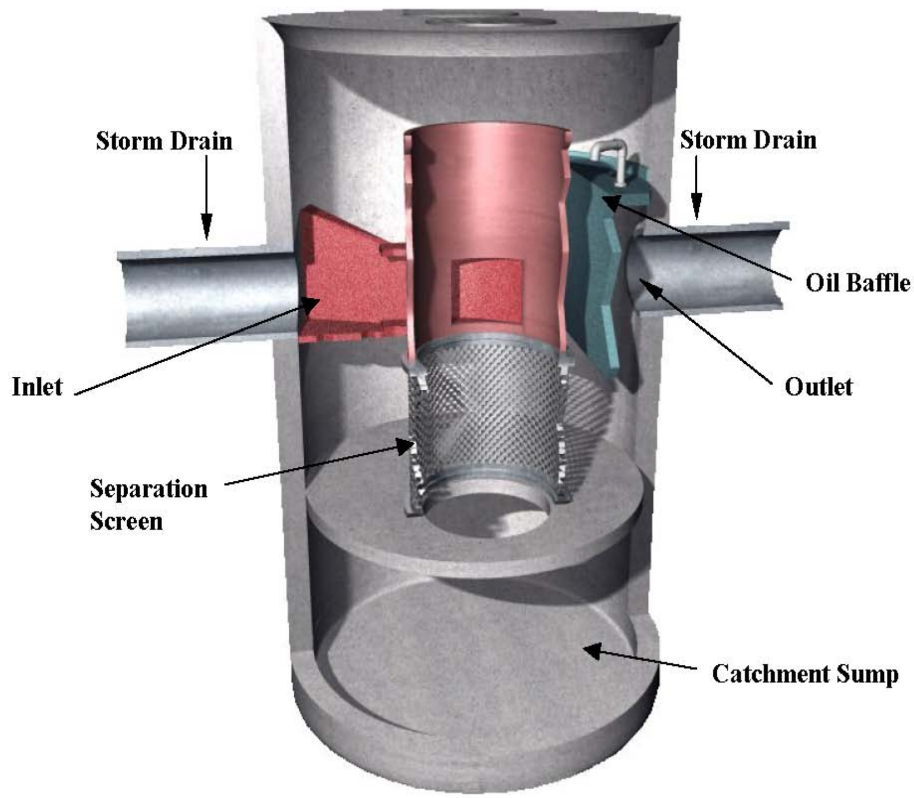


Figure 9 Inline Model PMSU CDS Unit

In-line Unit: These smaller pre-manufactured units are sized to process typical drainage flows of 0.7 to 6-cfs (20 to 171-L/s) from new and existing urban developments. These typical PMSU CDS unit can be placed within new or retrofitted into existing storm water collection systems. Its remarkably small manhole footprint takes little space and requires no supporting infrastructure. These typical PMSU units are ideal for treating runoff from parking lots and vehicle maintenance yards. Larger PMSU units sized to treat flows up to 15-cfs (428-L/s) with bypass capacities greater than 30-cfs (855-L/s) have frequently been designed for deployment inside 10 and 12-foot (3,048 and 3,657-mm) diameter manhole structures. Though not typical, CDS PMSUs are also available to treat/screen and bypass much larger flows. In early 2007, CDS manufactured and installed two PMSU100_100 In-Line units Los Angeles, CA, each having 64-cfs (1.8-m^3/s), treatment / screening capacities with bypass flow capacities of several hundred cubic feet per second up to 700-cfs.

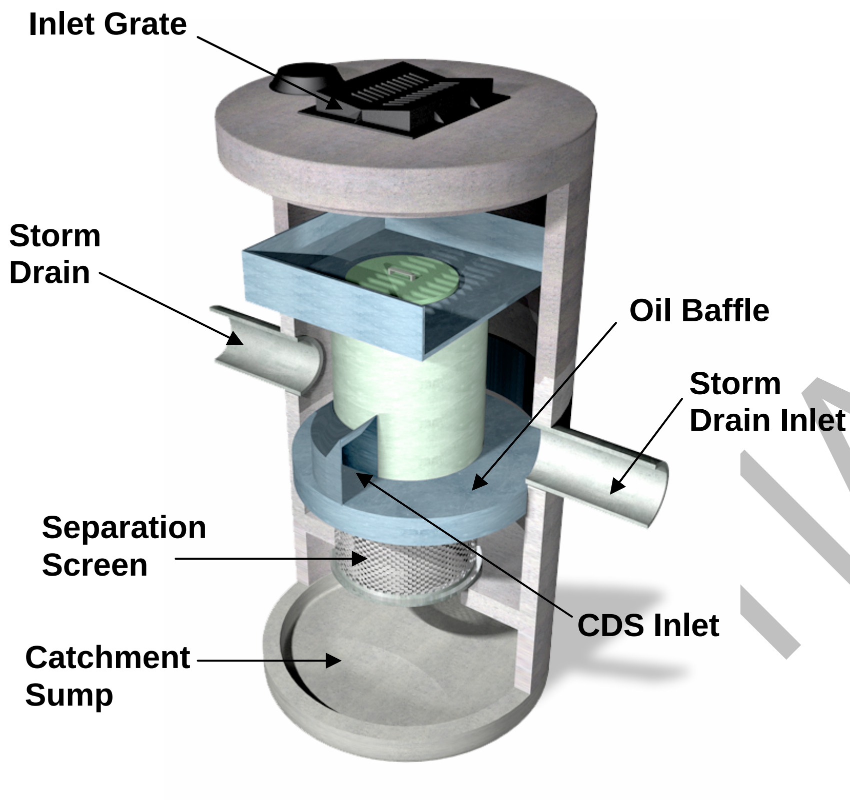


Figure 10 Drop-In (grated inlet), PMIU prefix designated CDS Unit

Drop-in Unit: this pre-manufactured drop-inlet, (PMIU prefix) unit is designed to process flows of 0.7-cfs (20-L/s) or less and is ideal for small drainage areas such as parking lots. This unit is configured inside a small diameter precast manhole that enables the PMIU unit to function as a typical drop-inlet and would be installed in lieu of a catch basin or storm drain inlet.

4.0 Applications of the CDS Technology

CDS technology offers highly efficient separation and capture of gross pollutants, suspended solids, sediment, floatable and neutrally buoyant material for storm water treatment applications. Removal of free oil and grease can be achieved with a standard, conventional oil baffle installed in all CDS units. Oil and grease removal efficiency can be further enhanced when sorbents are applied in the separation chamber.

CDS units are most commonly used as a stand-alone application serving existing development, new and redevelopment projects or as a pre-treatment, primary clarifier for a storm water BMP treatment train. At a minimum, CDS units capture sediments, the pollutants that attach themselves to sediments, oil and grease, and gross pollutants such as styrofoam containers, plastic, paper, vegetation including leaves, cigarette butts, packaging, and syringes that are transported by runoff. Removal of all these pollutants is essential to ensure the effective operation of the unit process BMPs that require pre-treatment to ensure their effective operation such as filtration and infiltration systems, ponds, wetlands, swales and coalescing plate oil/water separators. Each of these secondary treatment BMPs require the removal of majority mass of the suspended sediment and gross pollutants if they can be expected to perform beneficially.

CDS units are certainly beneficial as stand alone treatment units, but a treatment train consisting of primary and second-stage treatment processes is a much more holistic stormwater management approach to maximizing the effectiveness of BMP measures.

CDS units can be installed in-line or at the end of the pipe systems that directly discharge into natural waterways. The units are installed underground with only a small footprint therefore being suitable for prominent urban areas where space is at a premium.

The following list provides some of the storm water applications of CDS units:

- Treatment of storm water runoff from residential, commercial and industrial land uses to remove: *suspended solids and sediments, oil and grease, trash and debris, including vegetation floatable and neutrally buoyant materials*

- Watershed application by providing treatment of storm water runoff to achieve compliance with an element of a comprehensive storm water management program by capturing: *TMDL specific pollutants and pollutants from developments within the watershed where BMPs have not been implemented or are not effective.*

- Treatment of storm water runoff from parking lots and vehicle service and storage facilities to remove: *suspended solids and sediments, trash and debris, oil and greases controlled with a conventional oil baffle within the separation chamber. Enhanced oil and grease removal can be achieved using oil sorbents added to the separation chamber.*

- Pre-treatment (i.e. groundwater recharge, infiltration systems, oil/water separators, storm water reuse treatment systems, diversions to sanitary sewer systems, swales, detention basins and constructed wetlands) to remove: *suspended solids and sediments, trash and debris, including vegetation.*

- Protect storm water pumping facilities from damage by capturing: *rocks, coarse & medium sediment, grit, trash and debris*.

There is a wide range of CDS storm water units available that can treat design flow rates of up to 300-cfs (8.550-m^3/s) serving areas up to 1,500-acres (607-hectares) in size. This large hydraulic capacity of the CDS system provides opportunities for watershed applications:

- Providing a cost effective technology and opportunity to displace multiple small capacity BMPs within a catchment.

- Providing a regional solution to address pollutants from new and existing development.

- That is cheaper to maintain than multiple small capacity BMPs providing greater assurance of maintenance.

A project profile is included in Appendix B. Additional examples and references can be supplied upon request.

5.0 Sizing Methodology

For pretreatment application, the sizing methodology is initiated by entering the characteristics of the drainage area into the Western Washington Hydrology Model. The model uses a roughly 50-year rainfall record to generate 50-years of predicted runoff flow rates from the drainage area. The model output identifies an off-line and an on-line water quality design flow rate. The off-line flow rate is used when the treatment facility has an upstream high flow bypass structure. The bypass structure should direct the incremental portion of flow rates that exceed the off-line flow rate around the treatment facility. The on-line flow rate is used when all predicted flow rates through the 100-year flow rate (also identified by the model) will pass through the treatment device. This pretreatment device should achieve 50% TSS removal at the water quality design flow rate.

Additionally, if single event runoff methods are used, such as the Santa Barbara Urban Hydrograph (SBUH) model, to generate the water quality flow to be treated, Figures 9.6a and 9.6b in Volume V of the 2005 Stormwater Management Manual for Western Washington should be used to adjust the peak flow rate to an equivalent WWHM rate. This is done by dividing the peak 10-minute flow rate predicted by the single event method by the ratio indicated in Figure 9.6a for on-line designs or Figure 9.6b for off-line designs. The adjusted flow rate is then correlated to the appropriate CDS Screening size in Table 1 of this document, to determine the correct model designation to use.

6.0 CDS Performance Reviews

The following application sections provide performance evaluation tests, which demonstrate that the CDS device is able to meet the following numerical performance goals within Ecology's guidelines:

1. Ecology specified Solids removal performance goal For Pretreatment Applications:

   The pretreatment menu facility choices are intended to achieve 50% removal of fine (50-µm - mean size, d_{50}= 50-µm) or 80% removal of coarse (125-µm - mean size, d_{50}= 50-µm) total suspended solids for influent concentrations that are greater than 100-mg/L, but less than 200-mg/L. For influent concentrations less than 100-mg/L, the facilities are intended to achieve effluent goals of 50-mg/L and 20-mg/L total suspended solids, respectively.

2. For Oil Treatment:

The oil control menu facility choices are intended to achieve the goals of no ongoing or recurring visible sheen, and a daily average total petroleum hydrocarbon concentration no greater than 10-mg/L, and a maximum of 15-mg/L for a discrete (grab) sample.

6.1 Solid's Removal Performance - Application of CDS PMSU20_20 Unit Controlled Test to Washington Department of Ecology Evaluation

In an effort to meet the increasing demands of the established and pending accreditation programs throughout the United States, a CDS PMSU20_20 hydrodynamic separation unit with 2400-μm and 4700-μm screen cylinders was tested at the University of Florida, Gainesville facility from June to July, 2006.

This full scale CDS unit was configured and plumbed on the site to enable it being evaluated under controlled laboratory conditions of pumped influent and the controlled addition of sediment.

Our goal in conducting this evaluation was to generate research quality performance data of unquestionable veracity that would enable the distribution of reliable documentation on the performance of the CDS separation process to address specific particle removal requirements throughout the nation.

The scope of this CDS unit evaluation program provides performance results applicable to the Washington Department of Ecology's approval criteria for Treatment Train, Retrofits and Pretreatment Applications. This evaluation program provides verified performance removal results on a broad range of particles sizes. Ecology requires performance results on suspended solids having a mean particle size (d_{50}) of 50-μm or 125-μm. The database from this performance evaluation is used to determine the removal performance on a mean particle size d_{50}=50-μm (fine total suspended solids) and d_{50}=125-μm (coarse total suspended solids) per Ecology's TAPE program.

The present testing results from this controlled study is able to support the definitive removal performance claim:

- 50% removal of total suspended solids with d_{50} of 50-μm
  And
- 80% removal of total suspended solids with d_{50} of 125-μm.

Figure 11 shows a constructed Particle Size Distribution with d_{50} of 50-μm. Figure 12 showed a constructed Particle Size Distribution with d_{50} of 125-μm. These PSDs will be used to demonstrate the CDS performance of 50% removal of fine solids and 80% removal of coarse total suspended solids at water quality design flow rate based on the performance evaluation data developed using various test sands.

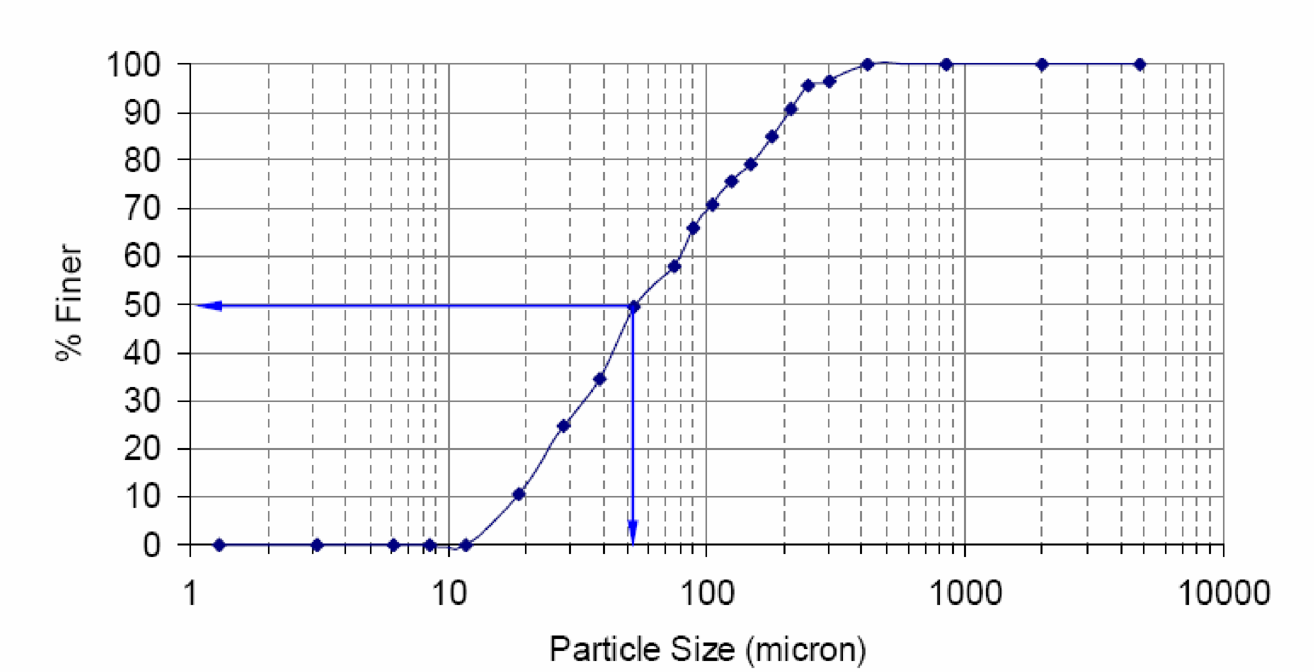


Figure 11 Particle Size Distributions for Ecology Defined PSD (d_{50} = 50-µm)

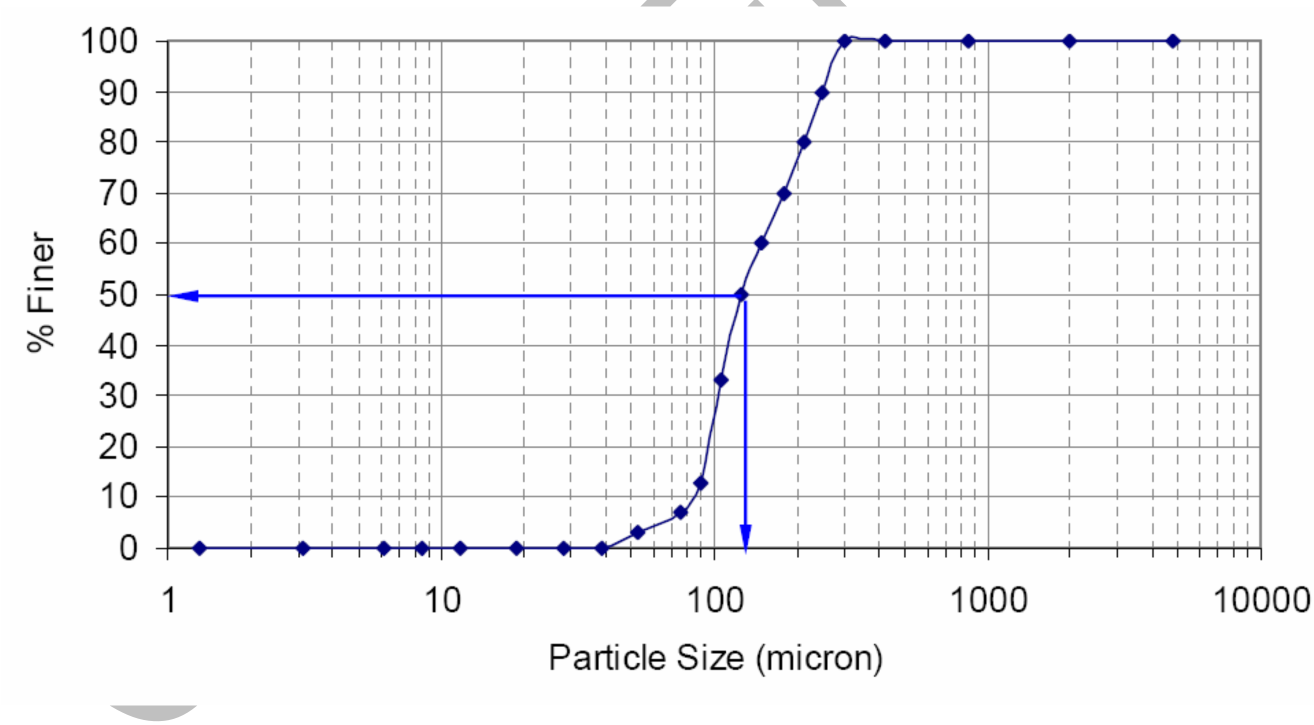


Figure 12 Particle Size Distributions for Ecology Defined PSD (d_{50} = 125-µm)

Particle Size Distribution of Testing Material

Two different sediment gradations of silica sand material were tested in the PMSU20_20 unit for this performance evaluation. The particle size distributions of these test sand mixtures were analyzed using standard method "Gradation ASTM D-422 with Hydrometer" by MACTEC Engineering and Consulting Inc. in Jacksonville, FL, a certified laboratory. The PSD report is attached in Appendix C.

"UF Sediment" Test Material: One gradation of sand material used in the recent CDS performance evaluation is the result of combining three (3) different U.S. Silica Sand products commercial referred to as: "Sil-Co-Sil 106", "#1 DRY" and "20/40 Oil Frac". The final mix of these three sands used in the test is referred to in this report as "UF Sediment". As shown in the PSD report in Appendix C, analysis of the three different grab samples of the UF sand mixture (UF mix No.1, No. 2 and No. 3) is a very fine gradation (d_{50} = 20 to 30-μm) covering a wide size range (uniform coefficient C_u averaged at 10.6).

OK-110 Test Material: The other material tested was OK-110 silica sand, which is also a commercial product of U.S. Silica Sand. The gradation analysis of this material shows that 99.9% of the OK-110 sand is finer than 250-μm, with a d_{50} of 106-μm.

Laboratory Testing Protocol

Test runs were conducted to quantify the CDS PMSU20_20 unit (1.1-cfs capacity) performance at the following flow rates:

Table 3 Test Flow Rates

% of Design Flow Rate	Actual Flow Rate (gpm)
1	5
5	25
10	49
15	74
35	173
50	247
75	371
100	494
125	618

These tests were conducted using influent concentrations of 200-mg/L.

Solids were mixed with tap water and the slurry was fed into the CDS test unit at a designated feeding rate using a peristatic pump.

Six samples were taken at the effluent locations at equal time intervals across the entire duration of each test run. These samples were then poured into a Dekaport Cone sample splitter (Figure 13) to obtain sub-samples for TSS and PSD analysis. Using a cone splitter ensures representative sub-sampling. Replicate effluent samples for each run were randomly selected from the sub-samples and delivered to Test America Analytical Testing, Portland, Oregon for TSS analysis (Ecology defined TSS analytical method).

Additionally, particle size analyses for effluent samples were conducted immediately after the test run by CDS staff. A Portable Model Laser In-Situ Scattering and Transmissometry (LISST) (Figure 14) particle size analyzer (manufactured by Sequoia Scientific, Inc., Bellevue, Washington) was utilized.

Figure 13 Dekaport Cone sample splitter

Figure 14 LISST Portable Particle Analyzer for PSD analysis

Laboratory Testing Results

The target influent concentration was 200-mg/L. The concentration of the influent solid mass referred to as (TSS) is calculated using the measured slurry feed rate and the measured water inflow rate, and the duration of runs. Effluent quality from CDS unit was analyzed using Ecology TSS method by Test America, Portland, OR.

Cumulative testing results for UF Sediment and OK-110 sands over the entire range of test flow rates are summarized in Figure 15.

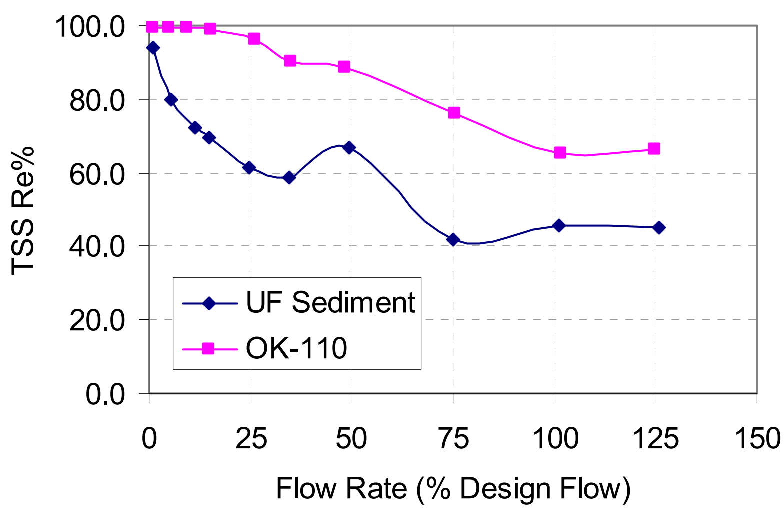


Figure 15 Cumulative Measured TSS removal – Analytical results for PMSU20_20 Test 2400-micron Screen, TSS=200-mg/L (UF Sediment & OK-110 sand)

It is noted that there are two abnormalities in the TSS Removal curves shown above:

- One variation exist only in the UF Sediment curve that shows a TSS removal performance (Re%) increase spike at 50% of the design flow rate. This variation was due to the influent solids feed concentration of 278-mg/L instead of the desired 200-mg/L, which leans some validity to the argument that higher influent solids concentrations lead to the reporting of higher removal efficiencies for swirl concentrators.

- The second abnormality exists in both curves, which both show a flatting as well as slight upward slope of the removal curve at the higher inflow rates from 80 to 125% of the design treatment rate. This slight increase, as well as leveling of removal performance at higher flow rates is counter intuitive to the known performance curves of all other classic smooth walled swirl concentrators. However, this slight increase and leveling off of removal efficiencies was also document by CDS in a limited evaluation supervised by Professor Scott Wells and his graduate student Spencer Slominski, Department of Civil Engineering in a May, 2003 performance test of the sub 100-μm silica particles at Portland State University. Given the repeated measurement of this slight increase and flattening of the removal performance curve at higher flow rates, CONTECH Stormwater Solutions is evaluating design modifications that will hopefully enhance this unique capacity of the Continuous Deflective Separation technology that will translate into a more efficient solids removal unit in the near future.

In order to evaluate the existing CDS unit's performance for the Ecology defined PSDs, the following analyses was conducted.

The solid mass that was added into the CDS test unit was pre-weighed in grams (g). Influent concentrations (mg/L) associated with each particle size gradation was determined by the total influent concentration (200-mg/L) and the percentage (% finer) for each particle size gradation from the PSD provided by MACTAC.

Effluent TSS was measured using Ecology TSS method by Test America Laboratory. Effluent concentration (mg/L) associated with discrete particle size gradations were determined by the total effluent mass (TSS) and the particle size distribution (% for each gradation) analyzed using the LISST portable particle analyzer. Use of the LISST enables the measurement of discrete particle gradations.

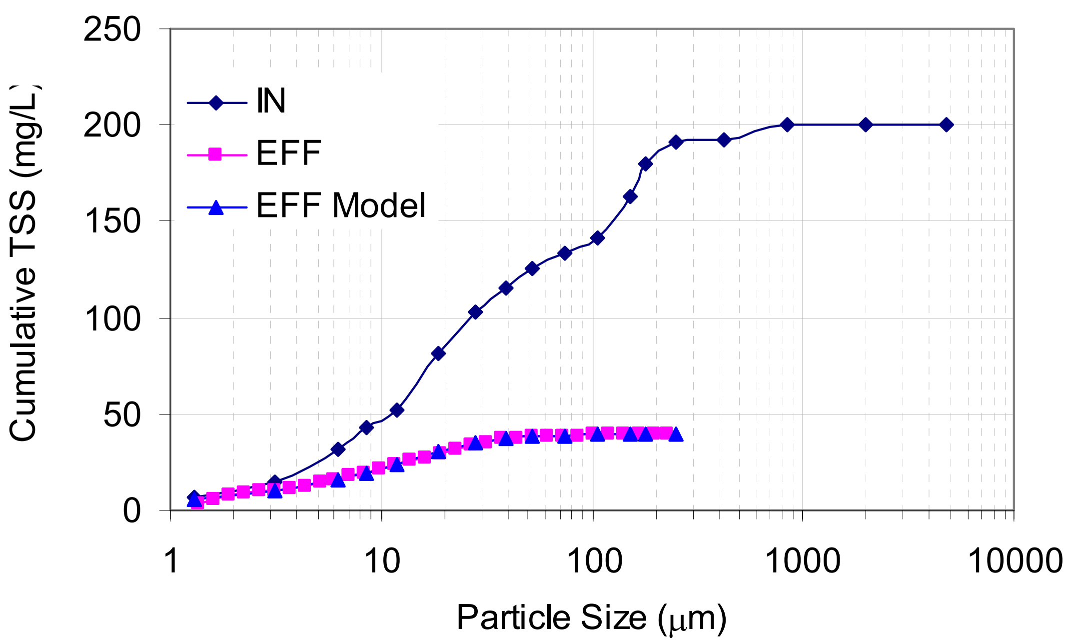


Figure 16 Influent and Effluent PSDs (PMSU20_20 Test 2400-micron Screen, TSS=200-mg/L, 5% flow rate, UF Sediment)

As shown in Figure 16, the cumulative influent TSS curve is developed through the actual measured influent TSS and influent PSD (from PSD report, MACTEC). Effluent cumulative TSS curve is developed from measurements provided by the LISST portable particle analyzer results, which can measure particles as large as 250-μm.

A fitted regression curve has also been developed to model the effluent cumulative TSS and is shown on the graph in Figure 16. Incremental TSS removals for specific particle sizes were calculated. Since particles less than 250-µm represents 95.5% of the UF Sediment, it is a valid model for particles no larger than 250-µm.

Table 4 Example: Incremental TSS Removal calculation from PSDs (PMSU20_20 unit, 2400-micron screen, 5% design flow rate)

Sieve Size	Influent				Effluent		Re% (Incremental)
	UF Sediment		Incremental TSS (mg/L)	Cumulative TSS (mg/L)	*Cumulative TSS (mg/L)	Incremental TSS (mg/L)	
(µm)	% Finer	% Incremental	200				
4760	100.0	0.0	0.00	200.0			
2000	100.0	0.0	0.07	200.0			
850	100.0	3.5	7.07	199.9			
425	96.4	0.9	1.80	192.9			
250	95.5	5.8	11.60	191.1	39.16	0.00	100.00
180	89.7	8.4	16.87	179.5	39.16	0.00	100.00
150	81.3	10.8	21.67	162.6	39.16	0.01	99.94
106	70.5	3.6	7.27	140.9	39.15	0.13	98.26
75	66.8	4.1	8.27	133.7	39.02	0.63	92.36
52.1	62.7	4.7	9.47	125.4	38.39	1.32	86.05
38.7	58.0	6.8	13.53	115.9	37.07	2.51	81.46
28.1	51.2	10.4	20.80	102.4	34.56	4.50	78.35
18.9	40.8	15.0	29.93	81.6	30.06	6.28	79.02
11.8	25.8	4.2	8.33	51.7	23.78	4.23	49.24
8.5	21.7	5.9	11.73	43.3	19.55	3.61	69.26
6.2	15.8	8.4	16.73	31.6	15.94	5.91	64.68
3.1	7.4	4.2	8.33	14.9	10.03	4.08	51.00
1.3	3.3	3.3	6.53	6.5	5.95	5.95	8.97

*Cumulative TSS for effluent in this column for the corresponding particle sizes of influent is calculated from the regression curve developed from LISST portable PSD data.

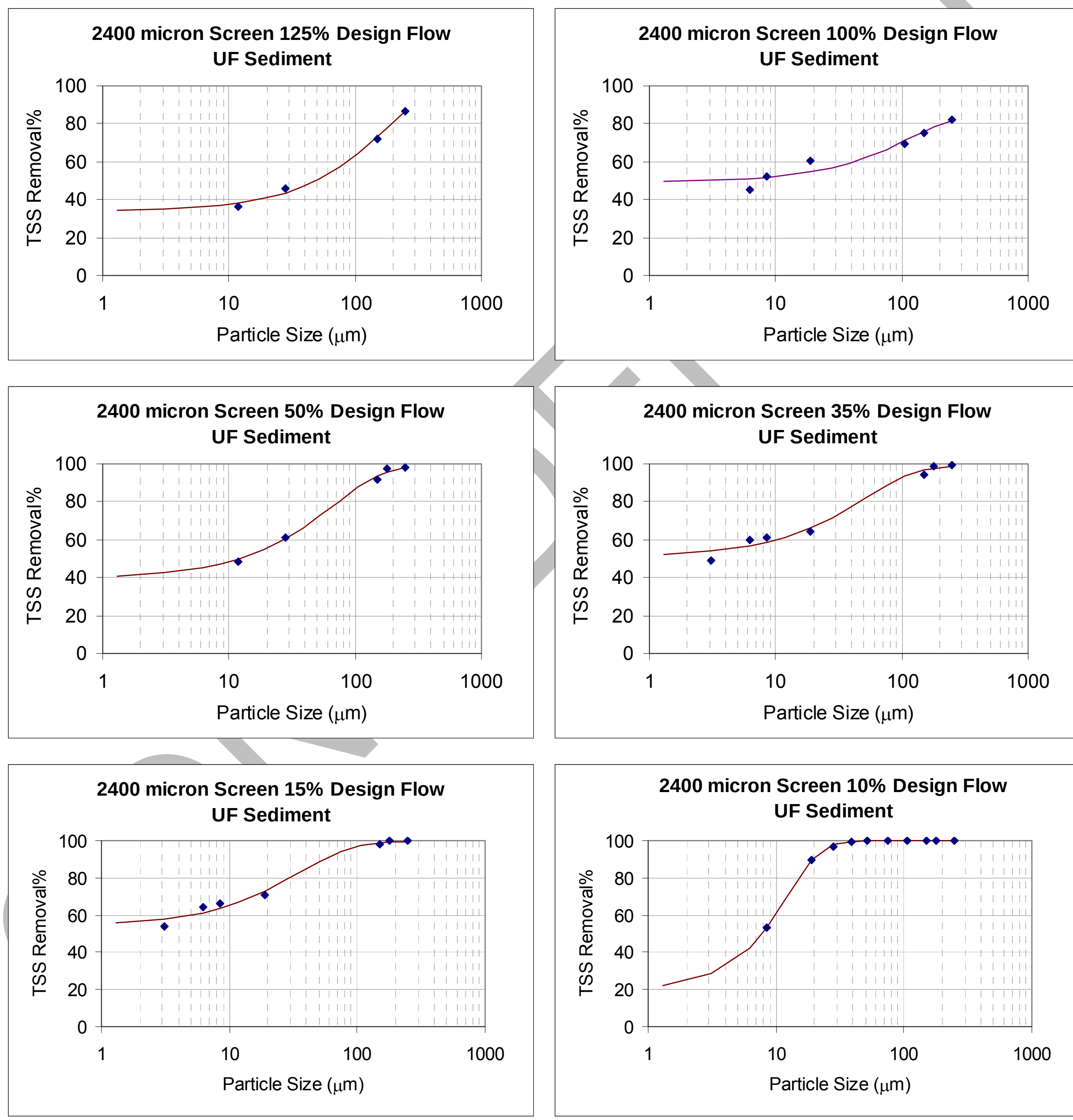
Additionally, the following criteria have been applied to examine the validity of the particle separation efficiency of each particle size gradation.

- Separation efficiency of each size class of particles can not exceed 100%.
- Separation efficiency of fine particles can not be higher than that of coarse particles under same influent flowrate.

CDS Unit Performance Model Development and Calibration

TSS removal as a function of particle size for various flow rates was obtained as illustrated in Table 3 above. The TSS removal % is plotted against particle size (Figure 17). Meanwhile, a regression analysis was used to develop a fitting curve for the scattered data points.

Below, Figure 17 shows the regression results plotted as a solid line curve against the measured data points for UF Sediment TSS removal as a function of particle size for each test flow rate using a 2400-micron screen in the CDS unit.



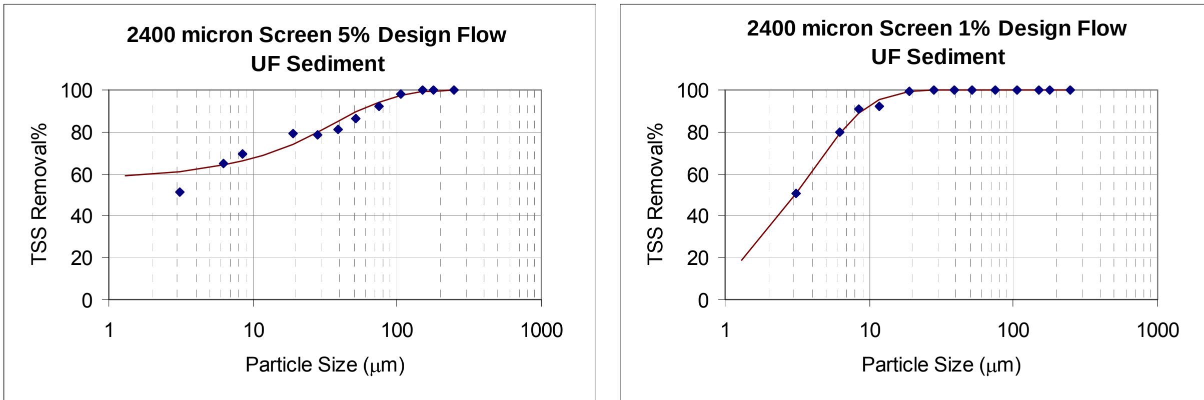


Figure 17 CDS Unit Performance – TSS Removal as a function of particle size for various flows (Data and Model Curves for 2400-micron screen unit)

* Result from 75% design flow is not available due to the LISST PSD data process error.

In the above regression analysis, a sigmoid function was used to model the TSS removal as a function of particle size for various flow rates. The mathematical form of the sigmoid function is shown as in the following equation:

$$y = \frac{a}{1 + e^{-\left(\frac{x - x_0}{b}\right)}} + y_0 \qquad (1)$$

Where: y = TSS Removal (%) x = particle size: 10 to 250-µm

&

Parameters; a, b, x_0 and y_0 were determined for each flow rates.

The parameters obtained under each flow rate are summarized as follows:

Parameters	*125%*	*100%*	*50%*	*35%*	*15%*	*10%*	*5%*	*1%*
a	*753.74*	*2133.97*	*706.08*	*663.51*	*549.42*	*99.83*	*1602.12*	*1747.10*
b	*174.66*	*67.06*	*61.72*	*47.30*	*33.44*	*5.14*	*36.57*	*3.46*
y_0	*-648.92*	*-2034.93*	*-606.86*	*-564.77*	*-449.94*		*-1502.33*	*-1647.32*
x_0	*-395.34*	*-208.07*	*-147.34*	*-121.03*	*-80.58*	*7.81*	*-132.00*	*-9.16*

For the Ecology defined PSD (Figure 11 & 12), TSS removal under each flow rate can then be calculated. An example sheet is included in Appendix D.

Below, Figure 18 shows the comparison of TSS removal efficiencies determined using the calibrated model along with the measure TSS removal results from the analytical lab. For the TSS removal efficiency using the developed model, only particles greater than 10-microns are considered, because of less confidence for the accuracy of the PSD analysis for particles less than 10-microns using current instruments and methods.

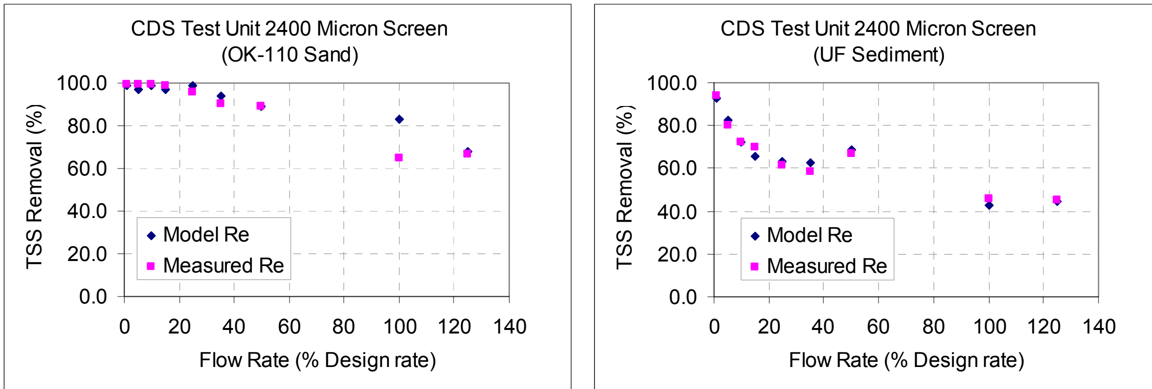


Figure 18 CDS Unit Performance Model Calibration (2400-μm screen) TSS Removal calculated from the model compared with analytical results from the lab for two test sands: OK-110 and UF Sediment

As seen in Figure 18, the TSS removal (%) calculated from the developed model is compared with the actual measured values for both UF Sediment (d_{50}=30-μm) and U.S. silica OK-110 sand (d_{50}=106-μm) test. The plotted data shows the same removal performance trends for each sediment tested, which is reduced TSS removal efficiency with increased flow rate under same influent concentrations. For the UF Sediment, the differences between the model results and actual measured values are all within an acceptable error (<10%).

The differences between the model results and actual measured values for the OK-110 sand are all within an acceptable error (<10%) except for one test (100% run, 1.1-cfs, 30-L/s inflow rate), see the left graph of Figure 18. At this single flow rate, the discrepancy between measured result and modeled result is significant. It is only for the OK-110 sand run at this single flow rate that the model overestimates the removal efficiency. Otherwise the calibrated model correlates well with the finer UF Sediment test material and all other measured removal performance of the OK-110 sand. Additional tests will be conducted to evaluate the TSS removal at this flow (100% design flow rate) using the OK-110 sand and further refine the regression model for this more coarse material.

CDS Unit Performance Curve (2400 micron screen unit)

For this Ecology application, the calibrated model derived from the discrete measurements of removal efficiencies of specific particle sizes over a range of flows from 1% to 125% of the treatment design capacity of the CDS unit were applied to the two constructed Ecology PSDs with d_{50} of 50-μm and d_{50} of 125-μm as shown in Figure 11 and 12 to determine the cumulative TSS removal. In short, the measured removal efficiency of the CDS unit on a specific particle size was value weighted to match the percentage of that particle size in both

Ecology PSDs. The TSS removal of a CDS unit configured with a 2400-micron screen as a function of flow rate are presented for these two PSDs below in Figures 19 and 20.

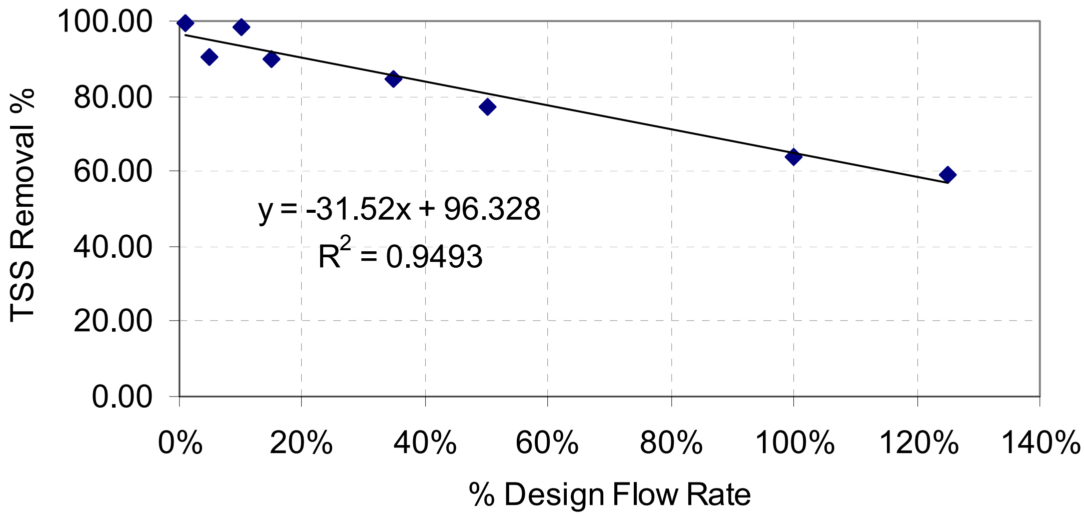


Figure 19 CDS Unit (2400-micron Screen) Performance for Constructed Ecology PSD d_{50}=50-µm

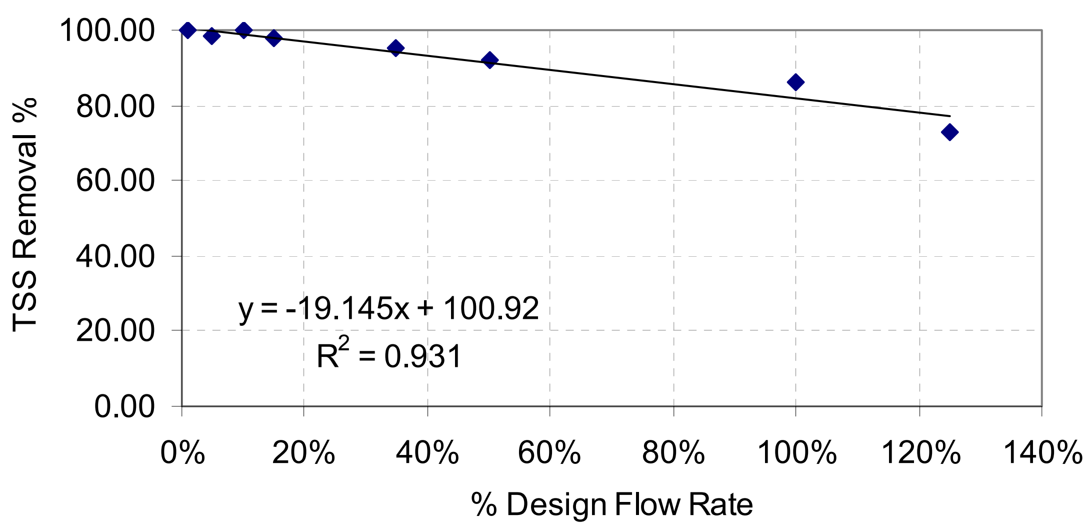


Figure 20 CDS Unit (2400-micron Screen) Performance for Constructed Ecology PSD d_{50}=125-µm

As shown in Figures 19 and 20 above, at 100% design flow rate and influent concentration of 200-mg/L, a CDS unit with 2400-micron screen achieves 64.8% TSS removal for fine suspended solids (d_{50} = 50-µm) and 81.8% TSS removal for coarse suspended solids (d_{50} = 125-µm).

<u>Demonstrated Performance Goal Achievement:</u>

The CDS unit with a 2400-micron screen has demonstrated the ability to achieve the Ecology specified TSS performance removal goal of 50% for d_{50} = 50-µm fine suspended solids and 80% for d_{50} = 125-µm coarse suspended solids at the design flow rate for influent concentrations that are greater than 100-mg/L, but less than 200-mg/L.

CDS Unit Performance Curve (4700 micron screen unit)

Similarly, the measured removal efficiency of the CDS unit on a specific particle size was value weighted to match the percentage of that particle size in both Ecology PSDs. The TSS removal of a CDS unit configured with a 4700-micron screen as a function of flow rate are presented for these two PSDs below in Figures 21 and 22.

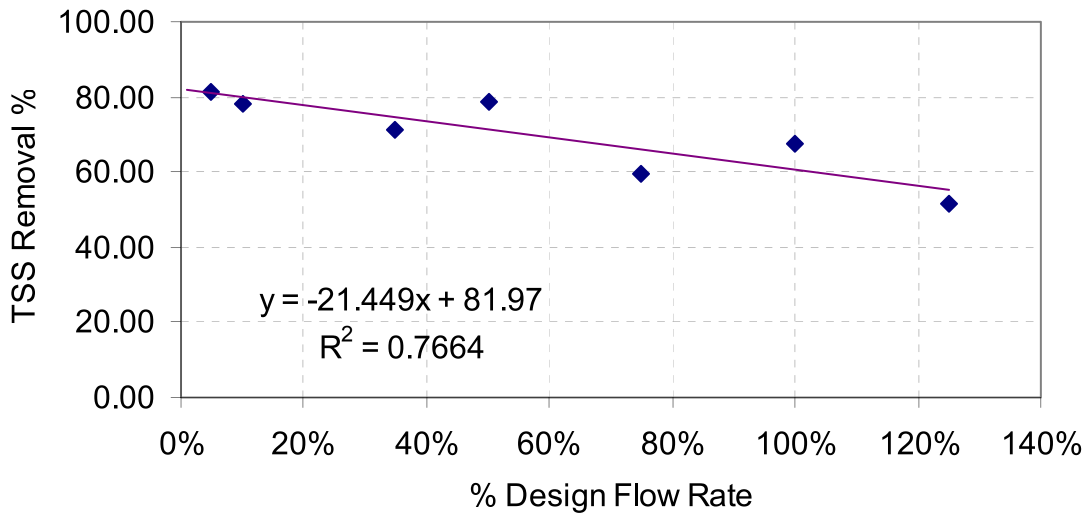


Figure 21 CDS Unit (4700-micron Screen) Performance for Constructed Ecology PSD d_{50}=50-µm

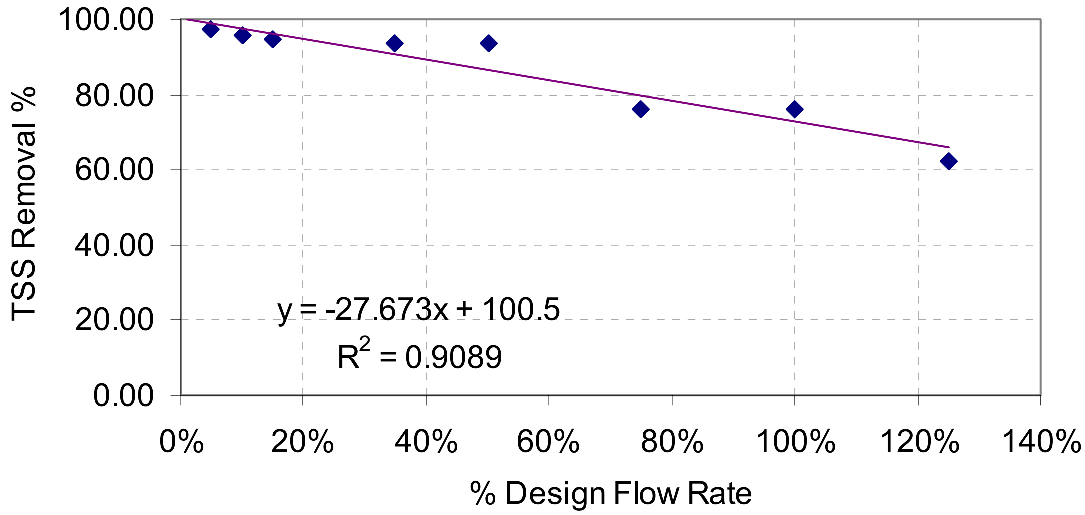


Figure 22 CDS Unit (4700-micron Screen) Performance for Constructed Ecology PSD d_{50}=125-μm

Performance Goal Achievement:

The CDS unit with a 4700-micron screen has the ability to achieve TSS removal of 60.5% for d_{50} = 50-μm fine suspended solids and 72.8% for d_{50} = 125-μm coarse suspended solids at the design flow rate for influent concentrations that are greater than 100-mg/L, but less than 200-mg/L.

6.2 Oil and Grease (O & G) Removal

A number of studies have characterized the concentration of oil, grease and total petroleum hydrocarbons (TPH) in stormwater runoff from various land uses.

The Oregon Association of Clean Water Agencies (ACWA) reported oil and grease levels from multiple land uses runoff for the period 1991-1996 shown in Table 4.

Table 5 Oil & Grease Concentrations for Various Land-Use Types

Land Use	Median Concentration (mg/L)	Concentration Range (mg/L)
Residential	1.2	ND* – 12.6
Commercial	2.4	ND – 18
Industrial	2.0	ND – 107.6 (12 mg/L next highest)
Mixed	1.0	ND – 28

*ND – Non-detectable

There are several other prominent storm water researchers and field studies that looked into oil and grease in storm water. Pitt (2004) reported the median concentration of oil and grease was 4-mg/L and the average concentration at 24-mg/L through analysis of 1,834 samples in the nationwide MS4 Stormwater Quality Database. Caltran's (2002) studies showed that the average concentrations of oil and grease from highway runoff flow was about 4-mg/L where average annual daily traffic (AADT) volumes are greater than 30,000 and 22-mg/L where AADT volumes are less than 30,000. It is thought (Currier 2005) that lower concentrations are more common and likely the result of gradual build-up on paved surfaces from leaking vehicles. Extremely high but rare concentrations are suspected to result from spills or illegal disposal (Currier 2005).

Ecology Oil and Grease Removal Performance Goal

The Ecology-specified treatment performance goal for the oil treatment is to achieve a no ongoing or recurring visible sheen, and a daily average total petroleum hydrocarbon (TPH) concentration no greater than 10-mg/L, and a maximum of 15-mg/L for a discrete (grab) sample.

Laboratory Studies – Oil and Grease Removal with Standard CDS Unit without Sorbent, Portland State University 2003

Scott and Slominski at Portland State University (2003) conducted tests on a CDS Model PMSU 20_20, 1.1-cfs (494-gpm) treatment capacity unit equipped with a 2400-µm screen and a conventional oil baffle. Tests were conducted at 25, 50 and 75 percent of the unit's hydraulic capacity, 125, 250 and 375-gpm respectively. These tests were run to determine removal efficiency of a CDS unit, equipped with a conventional / standard oil baffle on used motor oil at influent concentrations of 10, 25 and 50-mg/L. Summary of the test are shown below in Tables 5 through 7.

Table 6 Summary of Oil and Grease Tests Influent Concentrations: 7 to 11-mg/L

Flow Rate (gpm)	Flow Rate (%)	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Removal Efficiency (Re %)
125	25	7.2	3.5	51
250	50	9.9	2.0	80
375	75	10.5	7.5	29

Table 7 Summary of Oil and Grease Tests Influent Concentrations: 18 to 23-mg/L

Flow Rate (gpm)	Flow Rate (%)	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Removal Efficiency (Re %)
125	25	18.3	1.5	92
250	50	22.8	5.0	78
375	75	21.9	16	27

Table 8 Summary of Oil and Grease Tests Influent Concentrations: 45 to 47-mg/L

Flow Rate (gpm)	Flow Rate (%)	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Removal Efficiency (Re %)
125	25	46.2	3.5	92
250	50	45.6	7.5	84
375	75	46.9	27	42

As shown in Tables 5 and 6 above, when the influent concentration is less than 25-mg/L, the effluent concentration is less than 10-mg/L for flow rates up to 375-gpm (0.834-cfs), which is approximately 75.9% of the 1.1-cfs treatment capacity of the test unit.

Demonstrated Performance Goal: This PSU study along with the recorded typical concentrations of oil and grease concentrations in storm water shows that the CDS unit can be designed to achieve the effluent concentration less than 10-mg/L.

This PSU evaluation also included an oil spill test that was performed at a flow rate of 50-gpm, which is approximately 10% of the treatment design capacity of the tested CDS unit. This spill test consisted of twenty gallons of used motor oil being added into the unit over a time period of four minutes. This gave an influent concentration of approximately 82,000-mg/L.

No recirculation was required for this test, so sampling was only conducted at the effluent side of the unit. An initial sample was taken before the addition of oil to the unit, and after the background sample, additional samples were collected at one-minute intervals from the outlet for the duration of the test. The test lasted twenty-five minutes which is equivalent to two (2) tank turnovers after all the oil had been added.

Samples were analyzed by Columbia Inspection, Inc. according to the EPA 1664a protocol. The detection limit using in this method is 2-mg/L. Non-detect (ND) results were reported as being at half of the detection limit or 1-mg/L.

For this spill test, the average percent capture was 94.5% with a standard deviation of 2.3%. This gave a recovery range of 83.9% to 99.0% for this test. The unit performed extremely well in the oil spill test, with the peak oil concentration in the effluent occurring right as the addition of oil to the unit stopped. The peak effluent concentration was less then 90-mg/L, which accounts for less then 0.11% of the total amount of oil added to the unit.

If the concentration of the effluent for each sampling interval was assumed to be that of the sample taken at the beginning of the one minute interval duration, a total mass of approximately 148-grams can be assumed to have come out of the unit during this test. When compared to the input of over 65,000-gram this shows a capture more then 99.75% of the oil dumped into the unit. This would be a very effective means of containing an oil spill.

This PSU Oil and Grease study is provided in Appendix E.

Laboratory Studies – Oil and Grease Removal with Sorbents in CDS Units University of California, Los Angeles (UCLA)

Studies by Stenstrom and Lau (1998) demonstrated that the CDS unit with sorbents can achieve 80 to 90 percent of oil and grease removal at concentrations ranging from 13.6-mg/L to 41.1-mg/L. Test results showed that the effluent oil and grease concentrations were less than 10-mg/L.

The conventional oil baffle was not installed within the CDS unit during this evaluation. The objective of this study was to evaluate the effectiveness of various sorbent material to control the typically low concentrations of free oil and grease found in urban stormwater runoff when applied within the separation chamber of a CDS unit. The sorbents were allowed to float on the surface of the separation chamber of the CDS device. Different amounts of each sorbent were used because of the varying properties of the sorbents (density and surface area).

A series of nine (9) laboratory experiments were performed on a CDS unit having a preliminary design treatment capacity of 125-gpm (0.28-cfs) to determine its ability to remove free oil and grease using sorbents (Stenstrom and Lau, 1998). One control experiment was performed without a sorbent. Again, it needs to be explicitly understood that the conventional oil baffle was not installed in this unit during these tests and the purpose of the these series of tests were to determine the efficiency of various commercially available oil sorbents to remove the typically low concentrations of oil and grease from stormwater when added to a CDS unit.

Tests were performed using a 2400-micron screen for 30 minute duration at 125-gpm (approximately 40% of the CDS unit's nominal flow capacity). Used motor oil having a Specific Gravity = 0.86 (SG=0.86)) was introduced into the feed of the CDS at concentrations of approximately 25-mg/L, which is generally the upper limit of oil and grease concentrations found in stormwater runoff. Oil and grease were measured at various times (influent / effluent) to determine the removal efficiency. Background oil and grease was measured as well as oil and grease released from the sorbents after the influent oil and grease was reduced to zero.

Prior to the beginning of each test, the freeboard of the CDS unit was wiped clean and a small amount of new sorbent was used to remove any oil that remained from the previous test. This sorbent was removed prior to the beginning of the test. A weighed amount of test sorbent was then dumped into the separation chamber of the CDS unit. Sorbents were removed using a large fine mesh sieve.

Five commercially available sorbents were evaluated. Two sorbents were found particularly effective and they are:

1. OARS™ (AbTech Industries, 4110N. Scottsdale Rd., Suite 235, Scottsdale, AZ 85251)

2. Rubberizer™ (Haz-Mat Response Technologies, Inc., 4626 Santa Fe Street, San Diego, CA 92109)

The experiments were conducted with sufficient sorbent to cover the top of the CDS unit. Results from the sorbent laboratory study (Stenstrom and Lau, 1998) are shown below:

Table 9 Performance of Oil and Grease Removal – Sobents in the CDS Units

Sorbent Type	Sorbent Mass (g)	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Percent Removal (%)	Flow Rate (gpm)
OARS	2600	19.6	2.7	86	125
OARS	2600	24.0	4.3	82	190
OARS	2600	30.7	1.7	94	75
OARS[1]	2600	21.0	3.5	83	125
Rubberizer	1030	27.2	3.9	86	125

The sorbents generally retained the sorbed oil and grease. Effluent concentration of oil for the OARS™ sorbent was less than 1.0-mg/L. Effluent concentration of oil for the Rubberizer™ sorbent was higher (1.96-mg/L). This may have resulted from the higher mass of removed oil and grease per unit mass of sorbent (approximately three times higher).

The overall conclusion from this UCLA oil and grease control testing was that the CDS unit is effective at removing oil and grease from stormwater. CDS units are equipped with a conventional oil baffle to capture and retain oil, grease and other Total Petroleum Hydrocarbons (TPH) pollutants as they are transported through the storm drain system during dry weather (gross spills) and wet weather flows. CDS units with the addition of oil sorbents can ensure the permanent removal of the free oil and grease from the stormwater runoff.

This UCLA Oil and Grease removal study is provided in Appendix E.

Oil and Grease Field Monitoring – Caltrans

Monitoring of two fiberglass CDS units for 17 events at two sites by Caltrans (2002) showed that TPH-heavy oil levels in runoff ranged from 0.66 to 2.3-mg/L at the Orcas Avenue site and 1.1 to 8.6-mg/L at the Filmore Street site. Effluent values for TPH-Heavy oil averaged 1.78-mg/L at the Orcas site and 4.14-mg/L at the Filmore site.

The monitoring at Filmore site (10 events) only found one detectable level (0.44-mg/L) for TPH-diesel, and the concentration in the effluent for that event was non-detectable. The monitoring at Orcas Avenue site (7 events) found no detectable level for TPH-diesel, and the concentration in the effluent was non-detectable for all events.

The monitoring at Filmore site (10 events) only found no detectable level for TPH-gasoline, and the concentration in the effluent for that event was non-detectable as well. The monitoring at Orcas Avenue site (7 events) found one detectable level (0.17-mg/L) for TPH-gasoline, and the concentration in the effluent for that event was 0.23-mg/L.

6.3 Field Monitoring of CDS Unit – Performance on TSS

6.3.1 Brevard County CDS Unit Monitoring

Brevard County Surface Water Improvement in July 1997 installed a CDS PSW50_42, 9-cfs capacity treatment unit serving a 61.5-acre catchment that includes 6.7-acres of highway, 19.9-acres of industrial park, 23.4-acres of vacant land and 11.4-acres of commercial property. Over an 18-month period five (5) storm events were monitored for pH, TSS, BOD, COD, turbidity and Total Phosphorus. Samples of sediment collected in the sump were analysed for 61 parameters. Strynchuck et al. (Appendix G) reported an average of 52% removal for the total suspended solids.

The monitoring result for storm #5 is illustrated in Table 9.

Table 10 Storm # 5 Water Quality Analysis - CDS Performance on Total Suspended Solids (TSS) in Brevard County Study

Sample Set #	Total Suspended Solids		
	Influent mg/L	Effluent mg/L	Removal %
#1	49	11	78
#2	59	19	68
#3	23	21	9
#4	39	15	62
#5	35	13	63

This field study is one of the earliest BMP monitoring studies in the United States. Sampling was accomplished using autosamplers placed upstream and downstream of the CDS unit. The first three storms were monitored using flow weighted composite samples and the last two used discrete samples collected by the auto samplers. This monitoring effort experienced significant difficulties with equipment failure. Storm event 5 was the only event in which all equipment operated correctly and accurate flow was measured. Observations by the authors of this report during the sampling period confirmed deficiencies with the sampling equipment installation and placement of sample intakes and agreed with the report's conclusion that data collected during the initial four events were not representative.

In addition, due to the inefficiency of the sampling techniques and analytical method (TSS method), influent samples were not representatives and the true sediment removal rate was not able to be obtained because the bedload was not sampled. Cleanout of the units showed that approximately 3,582 pounds of sediments and 34 cubic feet of trash and debris were removed from the CDS sump on two occasions during the 18-month period.

6.3.2 Cooperative Research Centre Case Studies - Gross Pollutants

Cooperative Research Centre (CRC) for Catchment Hydrology conducted several monitoring programs to test the performance of various storm water gross pollutants trapping devices.

In the Stormwater Gross Pollutants Industrial Report (Allison R. et al. 1997), the results demonstrate that CDS devices are efficient gross pollutant traps. During three months of monitoring, practically all gross pollutants transported by the stormwater were trapped by the CDS device (i.e. 100 percent removal rate). In addition, the device appears to cause minimal interference to flow in the stormwater drain, and is therefore suitable for most urban areas. CDS devices require infrequent cleaning (about once every 3 months) at one location within a catchment.

Figure 23 Gross Pollutants Captured in the CDS Units Sump

In the report From Roads to Rivers, Gross Pollutant Removal from Urban Waterways (Allison, R. et al 1999), an extensive 18-month field study was completed on determining transportation of pollutants in storm water and the trapping efficiency of various storm water treatment systems under real service conditions. The performance of CDS devices was assessed in terms of its trapping efficiency for gross pollutants, its influence on the water quality parameters in the Stormwater, the hydraulic characteristics of the unit, and the required maintenance for long term operation. The field studies suggest that CDS unit is an efficient gross pollutant trap. During 12 months of monitoring 100% material greater than the minimum aperture size of the separation screen (4.7-mm) was retained in the separation chamber and the hydraulic impedance of the unit appears to be quite low compared to other trapping techniques.

6.3.3 Coburg, Australia Study - TSS

Walker et al. (1999) conducted a detailed study of the effectiveness of the CDS device for removal of suspended solids and associated pollutants.

The Coburg research catchment is situated approximately five miles north of Melbourne's central business district in Victoria, Australia. The research catchment covers an area of approximately 50 hectares (124 acres) of the inner city suburb of Coburg, which consists of 35% commercial and 65% residential land use.

The CDS unit in this catchment was the site of numerous CRCCH (Cooperative Research Center for Catchment Hydrology) and associated industry studies described by Allison et al. (1998). The Coburg City Council has continued to carry out typical municipal street litter management and stormwater system maintenance practices in the research catchment during the monitoring period.

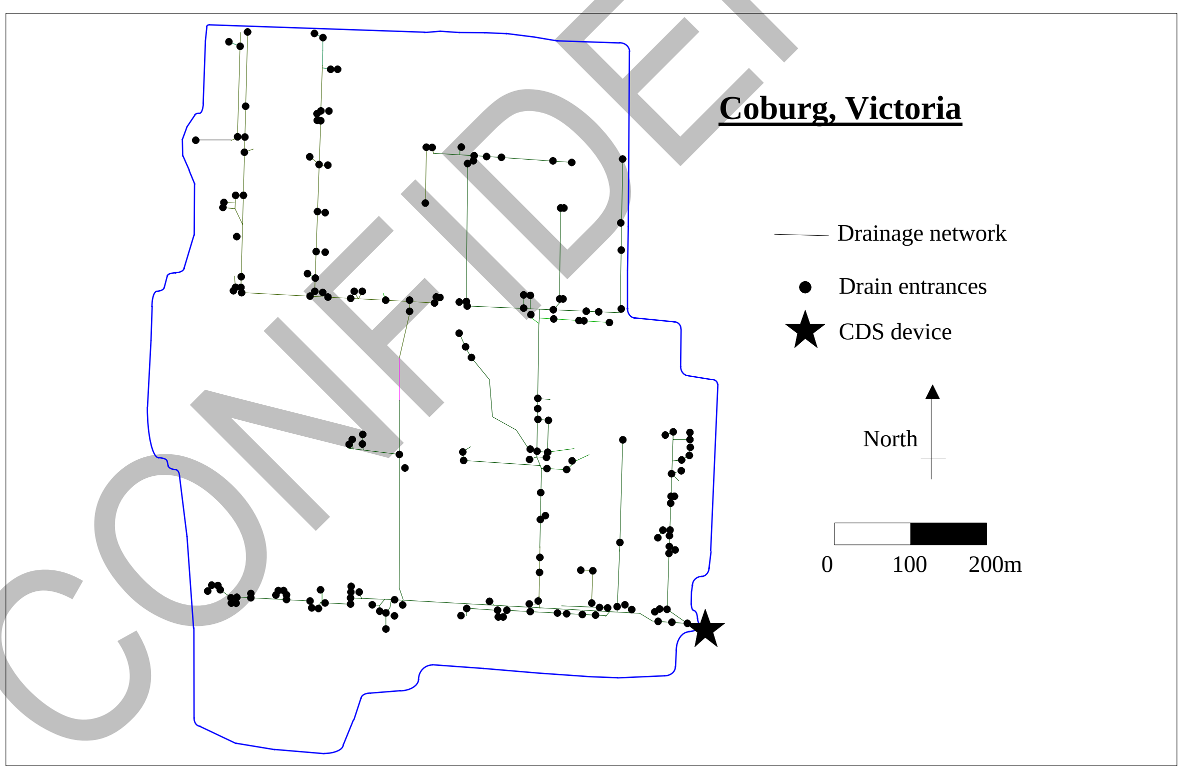


Figure 24 Drainage configuration in Coburg Research Catchment

A total of 15 storm events were monitored during a 22-month monitoring period. Storm events monitored ranged from 1 mm to 5 mm in rainfall depth. Samples at upstream and downstream of CDS units were taken using ISCO automatic water samplers. Inflow TSS concentrations were observed to be as high as 570-mg/L. Analyses of inflow and outflow

TSS data indicated that the CDS unit effectively reduced TSS concentration levels above 75-mg/L with an average removal of 70%. TSS removal was more variable for inflow concentrations less than 75-mg/L. An estimated annual TSS load removal is 65%.

Given the limitations of the auto sampler, it was anticipated that sediment particles larger than 1-mm are unlikely to be picked up during sampling.

Particle size distribution analyses were not conducted in the above study. However, earlier studies on the gross pollutant removals using same CDS unit (Allison et al. 1998) indicated that 70% of the captured material in the CDS sump was less than 400-μm in size.

__Demonstrated Performance:__ Though the correlation of field data to support solids removal performance claims for Ecology specifically defined PSDs having either d_{50}=50-μm or d_{50}=125-μm appears beyond the information acquisition scope of these previous studies, field monitoring of CDS unit clearly demonstrated that the CDS unit can removal nearly all gross pollutants and a significant portion of finer pollutants. An average of TSS remove above 50% is achievable using CDS device.

7.0 Design, Construction, Operation and Maintenance

7.1 Structural Design

All CDS units are designed to withstand equivalent fluid pressures that the unit may experience during its life. The water table at the installation site should be known, or a conservative estimate will be made on the maximum expected. Units are analyzed and designed conservatively, assuming that it is empty and full buoyant force acting on it. The foundation material is designed to provide adequate support for the structure's weight without allowing differential settlement.

In areas with solely pedestrian traffic, lightweight covers can be used to reduce the weight of lids and the time taken to remove for cleaning. For installations that will be traffic bearing, covers are designed with adequate strength to withstand vehicular traffic loads and comply with structural design standards.

All cast in place concrete designs are based on using structural concrete with minimum ultimate strength of 3,000 pounds per square inch (psi) or 20.7 Mega Pascal (MPa), with steel reinforcement having a minimum ultimate yield strength of 60,000 psi (413.7-MPa).

CDS units are designed to have a life of 50-years before replacement. The screens are the only component that may require replacement if they should become damaged due to passive galvanic corrosion or possibly as a result of large rocks, logs, etc entering the separation chamber and damaging the screen. If this should occur the screen panels can be easily replaced. CDS will provide assistance in these rare events.

7.2 Construction

High quality construction, use of precast techniques for standard units with design flows up to 64-cfs (1.81-m^3/s), short product lead times, and safe installation techniques mean CDS units are installed quickly and efficiently. Typically an installation can be performed on-site within a week depending on the complexity of the installation and contractors' experience. CDS has developed a relationship with Hanson Pipe and Concrete to manufacture the CDS units that results in lead time that are less than four weeks for the Pacific Northwest. The construction of CDS units in standard precast manhole, inline configuration, allows for this separation technology to be applied to retrofitting situations where existing storm lines are very deep. CDS has designed, manufacture and installed units for pipe invert depths of 40-feet. CDS Technologies provides technical support in the installation to ensure construction is performed according to the design.

An advantage of the CDS system is the ability to construct the separation chamber off-line from the main storm water flows, thus reducing the time the construction site is exposed to flows through the conveyance network. Once the separation chamber is in place, the conveyance system can be broken into, the diversion weir installed and the unit becomes operational.

7.3 Construction Materials

CDS units are available in pre-cast reinforced concrete modules for flows up to 64-cfs (1.81-m^3/s). For the most economical treatment of flows between 50 and 150-cfs, (1.41 to 4.24-m^3/s), two (2) precast units are typically configured in parallel, on either side of a diversion structure. For applications requiring larger flow processing up to 300-cfs (8.5-m^3/s), units are designed complete with construction specifications for cast in place construction.

7.4 Modular Pre-cast Process

Pre-casting reinforced concrete units was identified as the preferred construction technique for stormwater and sanitary sewer overflows for several reasons: construction period could be reduced to about a third of that required for in-situ construction; costs and quality could be more closely controlled; and there is greater product uniformity.

7.5 Pre-assembled Screens

Screens are pre-assembled under controlled conditions to ensure consistent and reliable performance and are constructed of ASTM 316L grade stainless steel.

7.6 Issues during Construction

A complete survey of existing utility services (such as electricity and telephone lines) is required prior to installation of a CDS unit. As the systems are installed underground unexpected utility services can delay construction times and add to installation costs.

A geotechnical report of the site is recommended to ensure the development of an adequate engineer's installation estimate. If a geotechnical report is not available then budgeting consideration should be made for the construction phase to allow for potential additional costs to be borne by the purchaser. The costs for shoring, rock excavation and control and disposal of ground water intrusion into the excavation are typically set out in contract documents prior to commencement of work.

7.7 Costs

CDS units are best defined as an infrastructure capital investment, intended to provide easier less expensive maintenance than other BMPs, because of reduced life-cycle costs. In addition the large capacities of the CDS systems provide a lower unit cost per volume treated.

7.8 Operation and Maintenance

Captured materials in the CDS unit sump can be removed in three ways depending on the site condition and unit size, suction via a vacuum truck (typically for smaller units), a containment basket that can be lifted out of the unit or removal by an excavator (large units). Vacuum trucks are the most frequently used method of cleaning small CDS units. When baskets are used, the basket is placed in the containment sump and cleaned by a truck-mounted hydraulic crane used to lift the basket out of the sump. An excavator is used on very large units.

Maintenance is limited to removal of accumulated sediments and floatables. It is typically performed on as needed basis, dependant on the rainfall during a given period as well as the characteristics of the catchment (such as the pollutant loads). In a catchment with high leaf litter loads and where controls of total phosphorous and volatile sediments are objectives then strategic cleanout following leaf fall should be conducted.

The optimum maintenance frequency is determined during the first year after installation when pollutant build-up is monitored. Once accumulated pollutants in the containment sump reach a critical level (typically 85% of the sump depth) the device should be scheduled for cleaning. Experience from the first year of operation allows an estimate to be made of the required long-term maintenance frequency. The time or man-hours required to perform maintenance will depend on the size of the unit, method of cleanout: vacuum or basket, availability of sites to dispose of decanted water and solids and the experience of maintenance personnel. Experience indicates that smaller sized units can be cleaned in 20 to 30-minutes while very large units that have accumulated tons of material can take a full workday.

Should a CDS unit not be maintained for an extended period and becomes full of solids, the drainage system can still operate effectively because of the by-pass system. The by-pass system will simply be engaged earlier and flow directed over the diversion weir. In addition, collected pollutants will be retained within the separation chamber and prevented from washing downstream, until such time as the device is cleaned.

For new installations a check of the condition of the unit after every runoff event for the first 30 days is recommended. Checking includes a visual inspection to ascertain that the unit is functioning properly and measuring the amount of deposition that has occurred in the unit. This can be done with a "dip stick" that is calibrated so the depth of deposition can be tracked. Based on the behaviour of the unit relative to storm events, inspections can be scheduled on projections using storm events versus pollutant build-up.

For ongoing operations during the wet season, units should be included on a regular inspection schedule once every thirty days would be the initial recommendation until pollutant loading is calibrated. The floatables should be removed and the sump cleaned when the sump is above 85% full. At least once a year, the unit should be pumped down and the screen inspected for damage and to ensure that it is properly fastened. Ideally, the screen should be power washed for the inspection. This inspection can be performed from the ground surface and does not require confined space entry. The only time that confined space entry is required is that rare incident when the screen is damaged and requires replacement. Properly trained people equipped with required safety gear will be required to enter the unit to perform replacement of the damaged screen panel.

Appendix F includes a site specific Operation and Maintenance as an example of what can be provided for every installation.

Vendor Maintenance

Upon request, CDS Technologies will provide maintenance services for customers based on actual costs plus 15%. CDS generally contracts with experienced private companies that have vacuum truck capabilities and provides oversight during the cleanout operations. CDS will also obtain the necessary approvals for disposal of decant water and solids in compliance with all local, state and federal regulatory requirements, certification of compliance with those requirements and a report of the complete operation.

Safety Issues

CDS units are generally located below ground, fitted with traffic rated lids. Tamper-proof lids are available, to prevent unauthorized entry. In open channel installations, exclusion bars at the entry and exit to the system prevent access into the CDS units. Because the CDS technology uses indirect screening, dangerous items such as hypodermic needles do not become lodged in the units' screens, so do not require manual handling to remove them.

CDS units require a minimum of manual handling, meaning that maintenance personnel are exposed to fewer health risks from broken glass, used hypodermic needles and pathogens. Only during the rare replacement of damaged screens are personnel required to enter the separation chamber.

Disposal of Pollutants

CDS units retain all gross pollutants - fast food packaging, plastic bottles, food scraps, glass, syringes with needles and vegetation - as well as sediments and potentially spilled oils and greases. The disposal of these material and sorbents when applied is required to be performed in an approved manor – depending on the location, local and state regulations governing waste disposal.

8.0 Summary

The independent laboratory and field monitoring studies provided in this application demonstrate that the CDS technology achieves the Ecology-specified treatment performance goals for treatment train, retrofits and pre-treatment application and oil treatment.

- CDS unit has demonstrated the capability to capture 100% gross pollutants and all litter, debris or neutrally buoyant materials at various land use types.
- CDS unit has demonstrated the capability to remove greater than 50% Total Suspended Solids in the field monitoring
- CDS unit has demonstrated 80% removal of coarse (125-µm mean size) total suspended solids and 50% removal of fine (50-µm mean size) total suspended solids.
- CDS unit equipped with a standard oil baffle achieves the TAPE objectives for control of typical oil and grease in storm water runoff.

CDS unit as a Pretreatment has proved to improve effectiveness and operation of downstream BMP facilities.

- Proven record of providing effective pretreatment for storm water reclamation facilities, low flow diversions, infiltration and filtration BMPs, wetlands and oil/water separators.
- Significantly reduces suspended sediments that block filtration and infiltration systems.

Cost-effective treatment system

- Large hydraulic treatment capacity allows regional solutions addressing pollutants from both existing and new development and displacing small capacity BMPs.
- Inexpensive to install and maintain than multiple small capacity BMPs providing greater assurance of maintenance.

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Appendix A

Mathematical Graphical Flow Model

And

Operation Animations

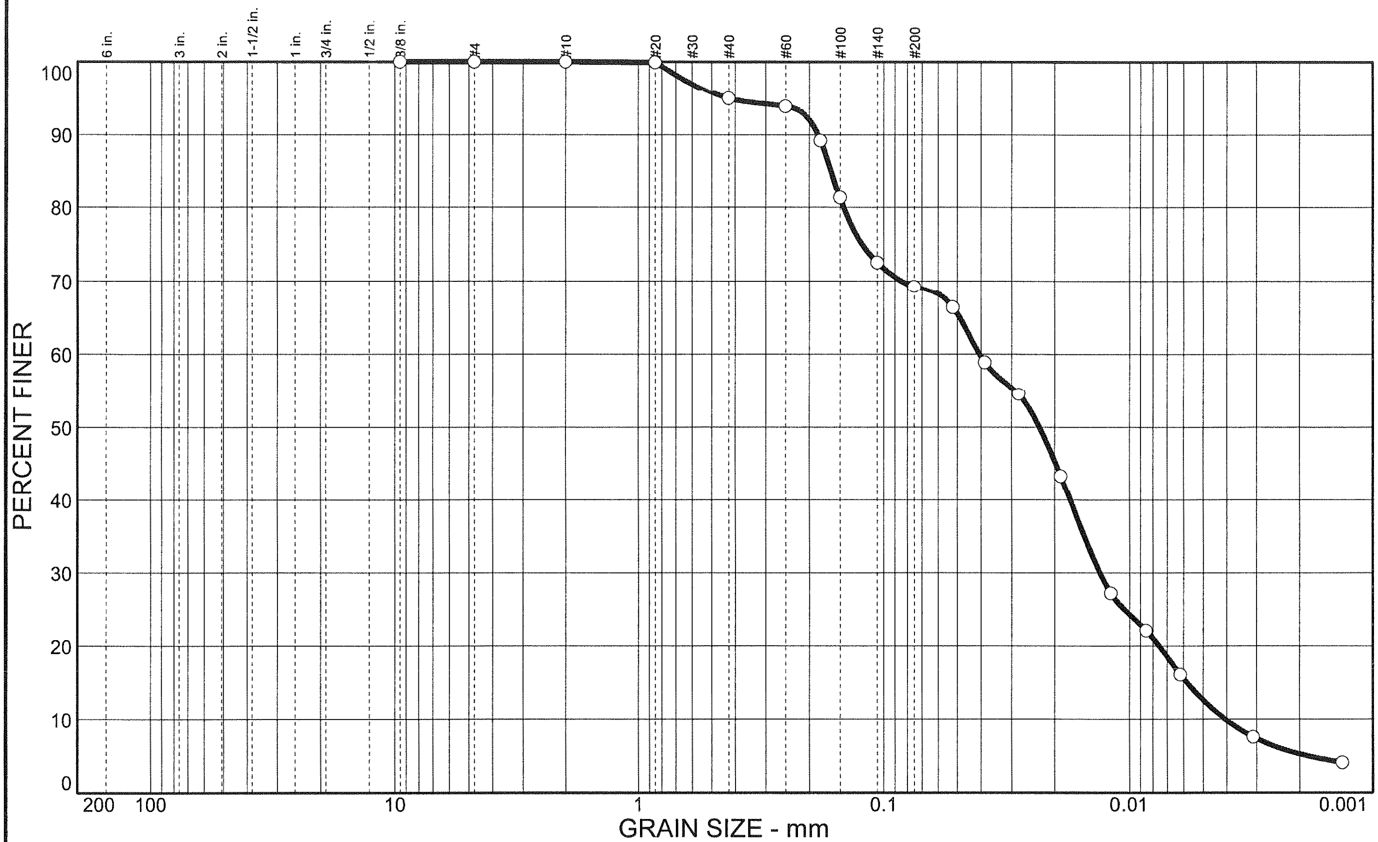
Appendix B

Project Profile

Appendix C

Particle Size Distribution (PSD) Report (MACTEC Engineering & Consulting)

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○			30.8	56.6	12.6	ML	A-4(0)		

SIEVE inches size	PERCENT FINER ○		
.375	100.0		
	GRAIN SIZE		
D_{60}	0.0406		
D_{30}	0.0131		
D_{10}	0.0041		
	COEFFICIENTS		
C_c	1.04		
C_u	10.02		

SIEVE number size	PERCENT FINER ○		
#4	100.0		
#10	100.0		
#20	99.9		
#40	94.9		
#60	93.8		
#80	89.2		
#100	81.3		
#140	72.5		
#200	69.2		

SOIL DESCRIPTION

○ White Silica

REMARKS:

○

○ Source:

Sample No.: UF Mix No. 1

MACTEC ENGINEERING. AND CONSULTING, INC.

Client: CDS Technologies

Project: CDS Material Testing

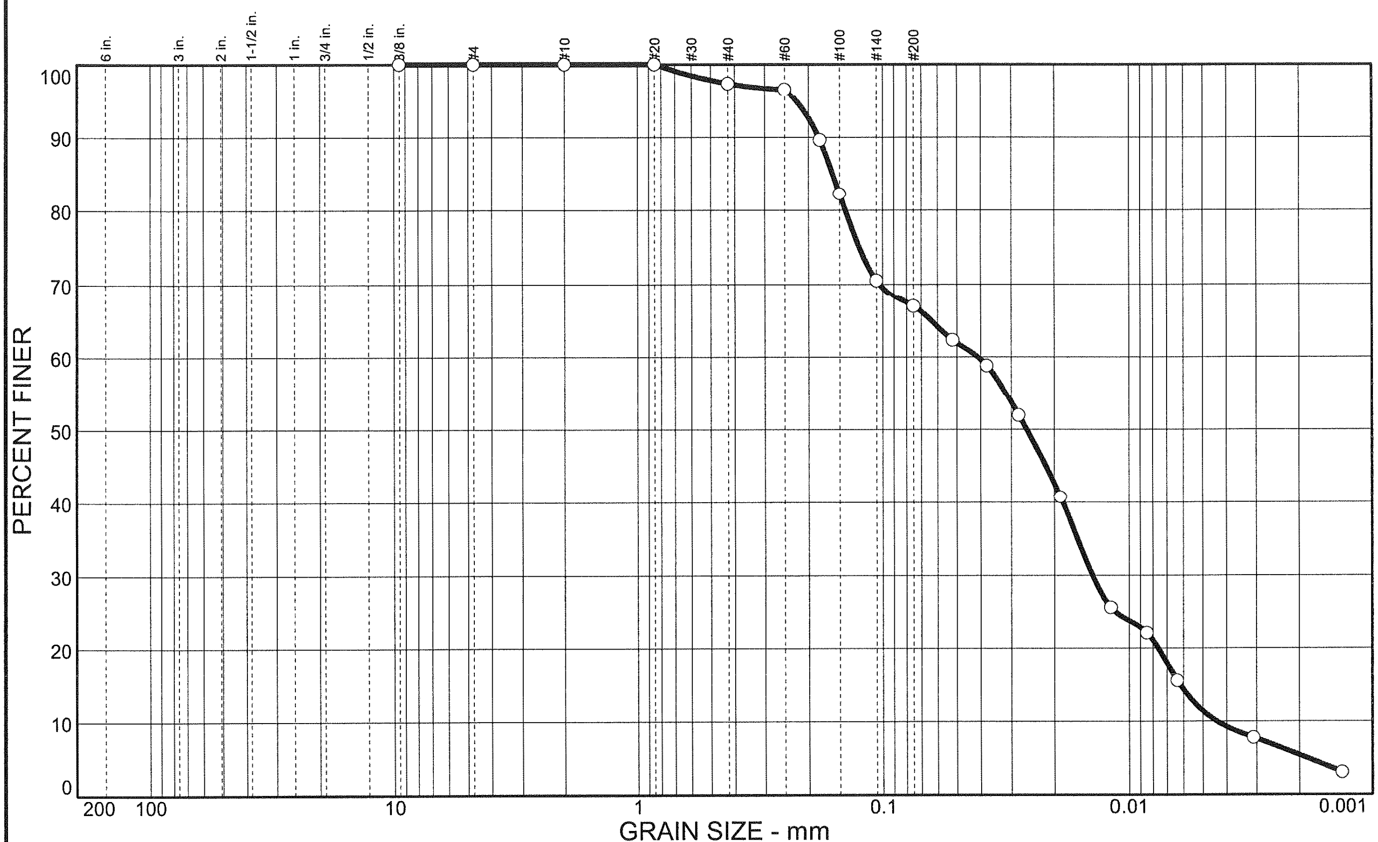
Project No.: 6738-06-4698-01

Rajni Sukhwani

Reviewed By

RAJNI SUKHWANI

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○			33.1	55.5	11.4	ML	A-4(0)		

SIEVE inches size	PERCENT FINER ○		
.375	100.0		
	GRAIN SIZE		
D_{60}	0.0412		
D_{30}	0.0140		
D_{10}	0.0044		
	COEFFICIENTS		
C_c	1.08		
C_u	9.41		

SIEVE number size	PERCENT FINER ○		
#4	100.0		
#10	100.0		
#20	100.0		
#40	97.4		
#60	96.6		
#80	89.6		
#100	82.3		
#140	70.5		
#200	66.9		

SOIL DESCRIPTION

○ Wkite Silica

REMARKS:

○

○ Source:

Sample No.: UF Mix No. 2

MACTEC ENGINEERING. AND CONSULTING, INC.

Client: CDS Technologies

Project: CDS Material Testing

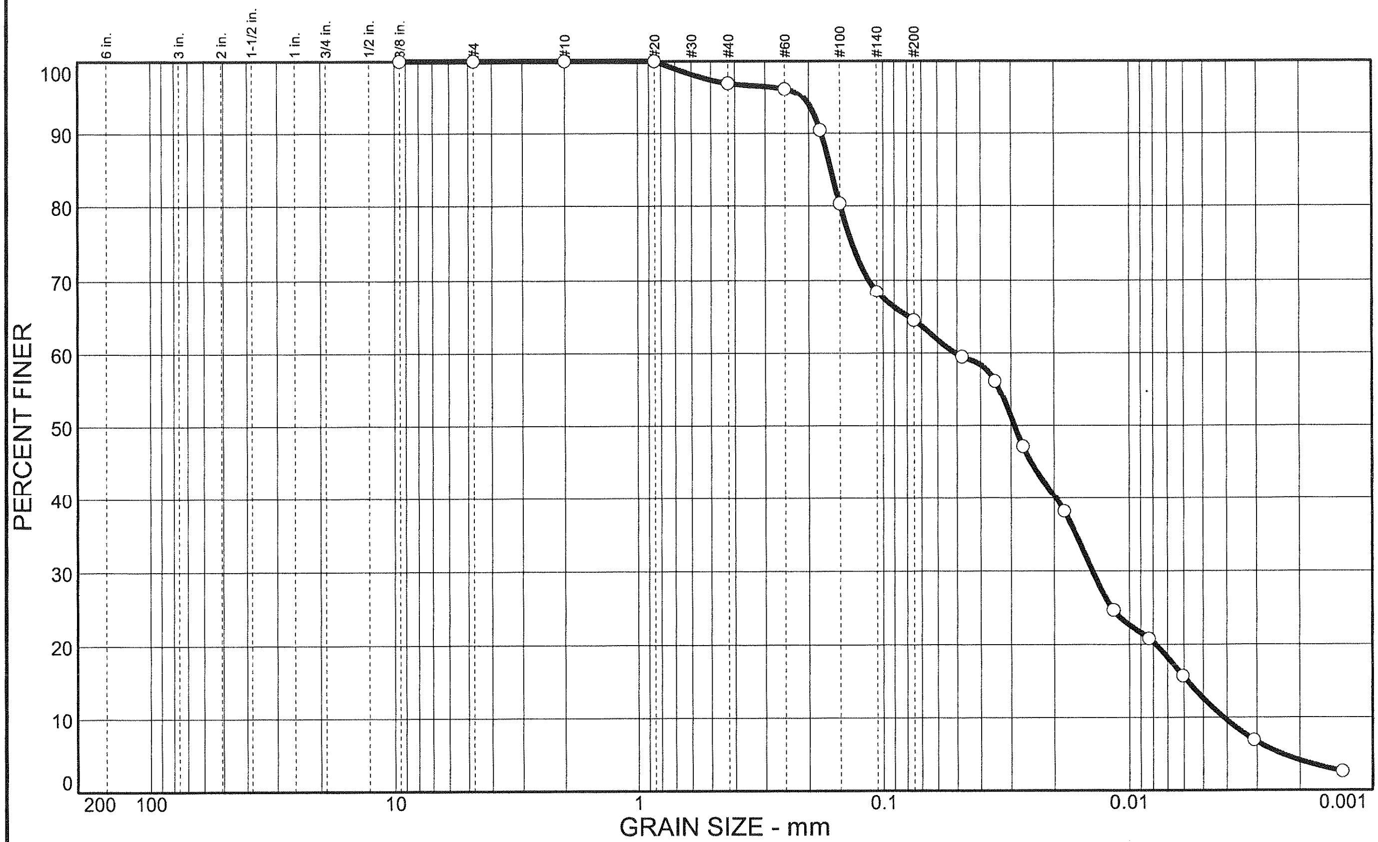
Project No.: 6738-06-4698-01

Rajni Sukhwani

Reviewed By

RAJNI SUKHWANI

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○			35.6	51.8	12.6	ML	A-4(0)		

SIEVE inches size	PERCENT FINER ○		
.375	100.0		

	GRAIN SIZE		
D_{60}	0.0508		
D_{30}	0.0140		
D_{10}	0.0041		

	COEFFICIENTS		
C_c	0.93		
C_u	12.33		

SIEVE number size	PERCENT FINER ○		
#4	100.0		
#10	100.0		
#20	100.0		
#40	97.0		
#60	96.2		
#80	90.4		
#100	80.3		
#140	68.4		
#200	64.4		

SOIL DESCRIPTION

○ White Silica

REMARKS:

○

○ Source:

Sample No.: UF Mix No. 3

MACTEC ENGINEERING. AND CONSULTING, INC.

Client: CDS Technologies

Project: CDS Material Testing

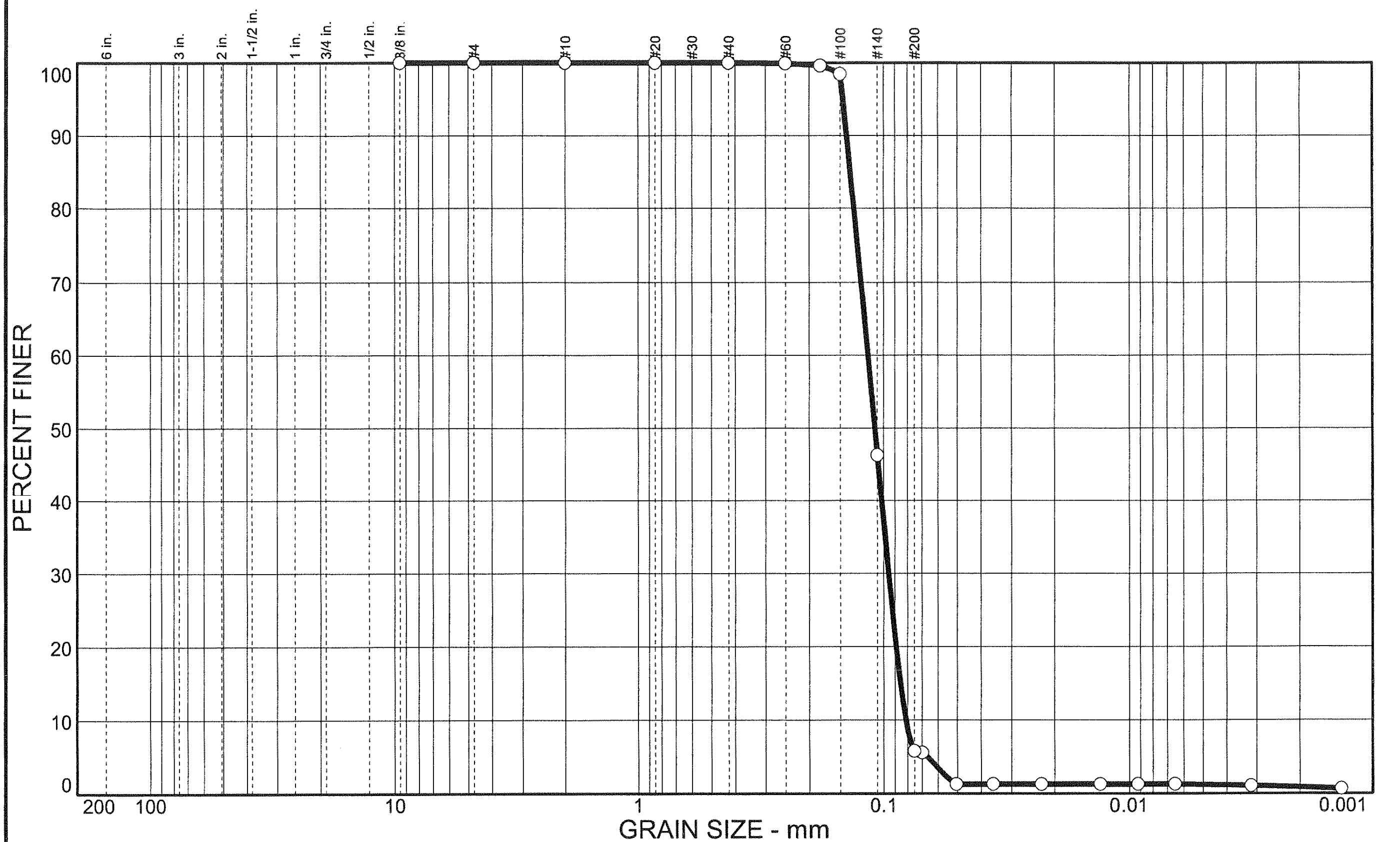
Project No.: 6738-06-4698-01

Rajni Sukhwani

Reviewed By

RAJNI SUKHWANI

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○			94.2	4.6	1.2	SP-SM	A-3		

SIEVE inches size	PERCENT FINER ○		
.375	100.0		
	GRAIN SIZE		
D_{60}	0.116		
D_{30}	0.0956		
D_{10}	0.0812		
	COEFFICIENTS		
C_c	0.97		
C_u	1.42		

SIEVE number size	PERCENT FINER ○		
#4	100.0		
#10	100.0		
#20	100.0		
#40	100.0		
#60	99.9		
#80	99.6		
#100	98.5		
#140	46.4		
#200	5.8		

SOIL DESCRIPTION

○ White Silica

REMARKS:

○

○ Source:

Sample No.: OK 110 No. 1

MACTEC ENGINEERING. AND CONSULTING, INC.

Client: CDS Technologies

Project: CDS Material Testing

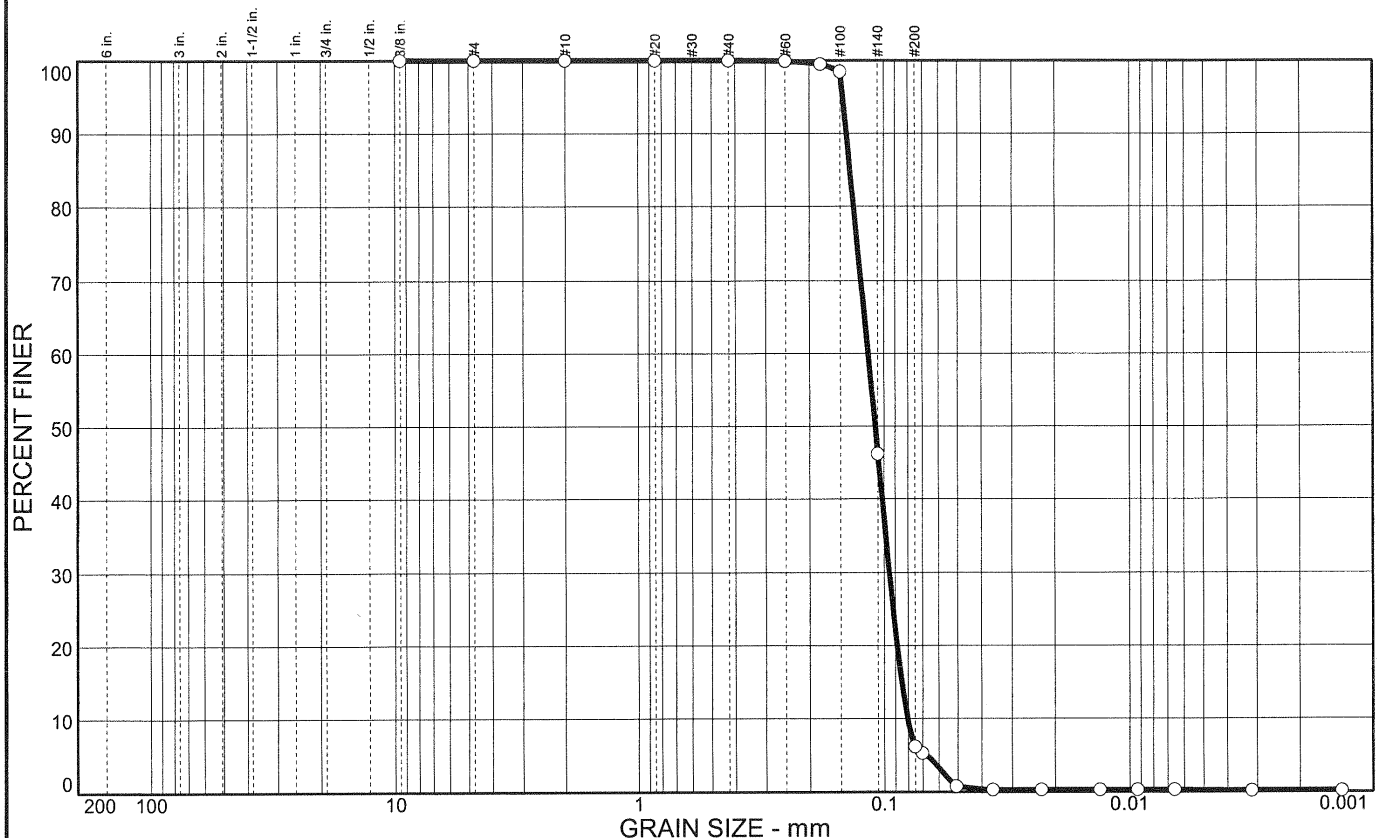
Project No.: 6738-06-4698-01

Rajni Sukhwani

Reviewed By

RAJNI SUKHWANI

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○			93.8	5.9	0.3	SP-SM	A-3		

SIEVE inches size	PERCENT FINER ○		
.375	100.0		
	GRAIN SIZE		
D_{60}	0.116		
D_{30}	0.0953		
D_{10}	0.0804		
	COEFFICIENTS		
C_c	0.98		
C_u	1.44		

SIEVE number size	PERCENT FINER ○		
#4	100.0		
#10	100.0		
#20	100.0		
#40	100.0		
#60	99.9		
#80	99.5		
#100	98.5		
#140	46.3		
#200	6.2		

SOIL DESCRIPTION

○ White Silica

REMARKS:

○

○ Source:

Sample No.: OK 110 No. 2

MACTEC ENGINEERING. AND CONSULTING, INC.

Client: CDS Technologies

Project: CDS Material Testing

Project No.: 6738-06-4698-01

Rajni Sukhwani

Reviewed By

RAJNI SUKHWANI

Appendix D

PMSU Test Summary & Analytical Results (Lab Report Example)

UF PMSU20_20 Test Run
2400-μm screen

UF Sediment (d_{50}=30 μm)

Test Run ID	Flow Rate (%)	Flow (gpm)	Actual Flow Rate (gpm)	Actual Flow Rate %	Actual Influent TSS (mg/L)	EFF mg/L		EFF avg	EFF std. dev.	Re%
1	1	4.9	5.05	1.02	211	12.5	12.3	12.4	0.14	94.1
2	5	24.7	26.0	5.26	200	39.7	40.4	40.1	0.49	80.0
3	10	49.4	55.0	11.13	197	54.7	53.5	54.1	0.85	72.5
4	15	74.1	72.0	14.57	198	60.1	59.4	59.8	0.49	69.8
5	25	123.5	122.0	24.70	207	80.2	79.9	80.1	0.21	61.3
6	35	172.9	170.0	34.41	217	92.3	87.9	90.1	3.11	58.5
7	50	247.0	243.0	49.19	274	90.5	92.5	91.5	1.41	66.6
8	75	370.5	371.0	75.10	201	115	118	116.5	2.12	42.0
9	100	494.0	500.0	101.21	199	107	109	108.0	1.41	45.7
10R	125	617.5	622.0	125.91	203	112	110	111.0	1.41	45.3

OK-110 Sand (d_{50}=106 μm)

Test Run ID	Flow Rate (%)	Flow (gpm)	Actual Flow Rate (gpm)	Actual Flow Rate %	Actual Influent TSS (mg/L)	EFF mg/L		EFF avg	EFF std. dev.	Re%
14*	1	4.9	5.5	1.11	184	1.29	1.30	1.30	0.01	99.3
15*	5	24.7	24.3	4.92	214	1.28	1.32	1.30	0.03	99.4
16*	10	49.4	47.0	9.51	214	1.32	1.33	1.33	0.01	99.4
17	15	74.1	75.0	15.18	198	2.10	2.50	2.30	0.28	98.8
18	25	123.5	130.0	26.32	191	7.45	7.77	7.61	0.23	96.0
19	35	172.9	174.0	35.22	212	20.3	21.0	20.65	0.49	90.3
20	50	247.0	240.0	48.58	278	29.0	33.5	31.3	3.18	88.8
27	75	370.5	373.0	75.51	199	46.4	49.7	48.1	2.33	75.9
22	100	494.0	503.0	101.82	198	69.5	68.6	69.1	0.64	65.1
23	125	617.5	617.0	124.90	202	66.9	68.3	67.6	0.99	66.5

* Effluent results (TSS) are below the detection limit. The numbers used are method reporting limit (MRL).

UF PMSU20_20 Test Run
4700-μm screen

UF Sediment (d_{50}=30 μm)

Test Run ID	Flow Rate (%)	Flow (gpm)	Actual Flow Rate (gpm)	Actual Flow Rate %	Actual Influent TSS (mg/L)	EFF mg/L		EFF avg	EFF std. dev.	Re%
34	1	4.9	5.42	1	187	21.6	21.8	21.7	0.14	88.4
35	5	24.7	26.9	5	188	67.0	66.7	66.9	0.21	64.4
36	10	49.4	50.1	10	199	78.6	51.0	64.8	19.52	67.4
37	15	74.1	75.0	15	202	107	110	108.5	2.12	46.3
38	25	123.5	122.0	25	206	102	104	103.0	1.41	50.0
39	35	172.9	170.0	34	206	95.7	95.8	95.8	0.07	53.5
40	50	247.0	244.0	49	273	113	114	113.5	0.71	58.4
41	75	370.5	365.0	74	206	112	115	113.5	2.12	44.9
42	100	494.0	496.0	100	201	101	104	102.5	2.12	49.0
43	125	617.5	610.0	123	204	125	126	125.5	0.71	38.5

OK-110 Sand (d_{50}=106 μm)

Test Run ID	Flow Rate (%)	Flow (gpm)	Actual Flow Rate (gpm)	Actual Flow Rate %	Actual Influent TSS (mg/L)	EFF mg/L		EFF avg	EFF std. dev.	Re%
44*	1	4.9	5.2	1	195	2.53	2.72	2.63	0.13	98.7
45*	5	24.7	25.7	5	195	1.36	1.41	1.39	0.04	99.3
46	10	49.4	50.8	10	196	1.70	1.82	1.76	0.08	99.1
47	15	74.1	74.0	15	245	5.59	6.25	5.92	0.47	97.6
48	25	123.5	123.0	25	204	15.7	21.5	18.60	4.10	90.9
49	35	172.9	175.0	35	199	26.1	21.8	23.95	3.04	88.0
50A	50	247.0	249.0	50	268	42.6	43.3	43.0	0.49	84.0
50B	50	247.0	246.0	50	271	48.5	47.3	47.9	0.85	82.3
51	75	370.5	377.0	76	199	62.2	79.8	71.00	12.45	64.3
52	100	494.0	510.0	103	195	66.6	68.4	67.5	1.27	65.4
53	125	617.5	622.0	126	200	105	115	110.0	7.07	45.0

* Effluent results (TSS) are below the detection limit. The numbers used are method reporting limit (MRL).

Appendix E

Oil and Grease Removal Studies

Oil and Grease Removal using Continuous Deflection Separation with an Oil Baffle

by

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And

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16360 Monterey Road Suite 250
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November 4, 2003

Table of Contents

List of Figures

List of Tables

Introduction

CDS Technologies, Inc., is a storm water management company that specializes in separators for removal of trash and debris, suspended solids and oil/grease in storm water runoff. The technology deployed for pollution control is known as continuous deflective separation (CDS). A CDS unit is generally cylindrical in shape. The primary components of a unit consist of a sump for storing settleable material, a separation chamber that contains a stationary cylindrical stainless steel screen, an inlet that introduces flow into the interior of the screen, a hood oil baffle over the outlet that exits from the external shell of the separation chamber. The CDS technology employs multiple separation principles to effect pollution reduction in storm water. These include deflective screening/solids separation, swirl concentration/vortexing concentration, diffusion quiescent settling, baffling and/or skimming. Treatment flows are introduced above the screen cylinder with the flow entering tangentially to the inside of the cylinder. The flow establishes a balanced set of hydraulic conditions whereby the entry velocity is transitioned into a vortexing flow with adequate washing velocity along the screen face that keeps it free from blockage (See Figure 1 for a plan view schematic of the treatment flow path). Water passes through the screen, reversing direction as it passes through the screen where it enters into a quiescent zone allowing separation of fine particles and creates an opportunity for oil to rise to the quiescent water surface. The water moves from this zone, under an oil baffle to its outlet from the treatment unit.

A series of pictures of the CDS unit are shown in Appendix 1. Operationally, floatables are captured in the inner-chamber, as they are unable to flow through the apertures of the screen. Settleable suspended material settles into a sump at the bottom of the separation chamber, as water flows out through openings in the screen. Fine settleable material separates from the water in the quiescent zone as water makes its way under an oil baffle to the unit's outlet. A 3-dimensional view of the unit with the baffle is shown in Figure 2 and a cross-sectional view is shown in Figure 3.

During the past three years, PSU has tested this technology for its effectiveness in controlling both fine and coarse sediments. Those reports are found under separate covers. This report is prepared to document the effectiveness of the CDS device to remove oil/grease in storm water using its oil baffle as the single means to remove the oil. This work is a follow-up to oil control testing done by UCLA where the device, without an oil baffle, demonstrated effective oil control through sorbent applications in the swirl chamber.

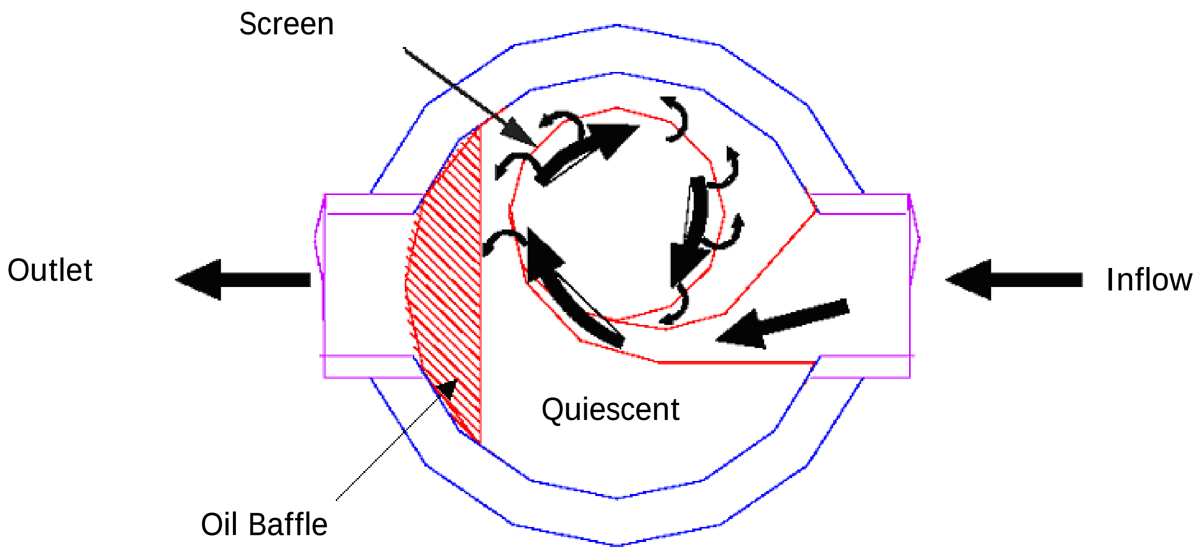

Figure 1. Schematic of the CDS unit – plan view

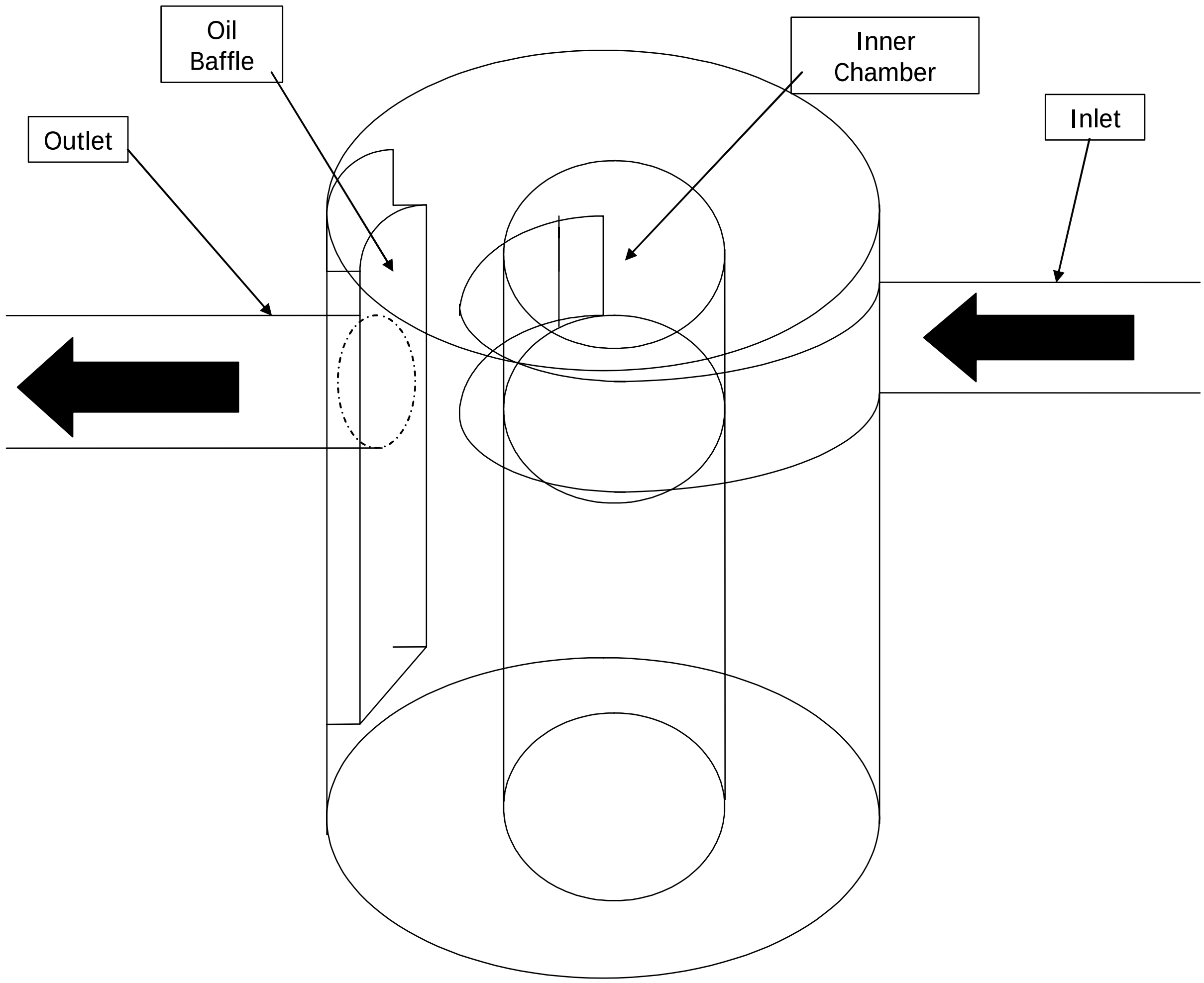

Figure 2. Schematic of the CDS unit – cross-sectional view

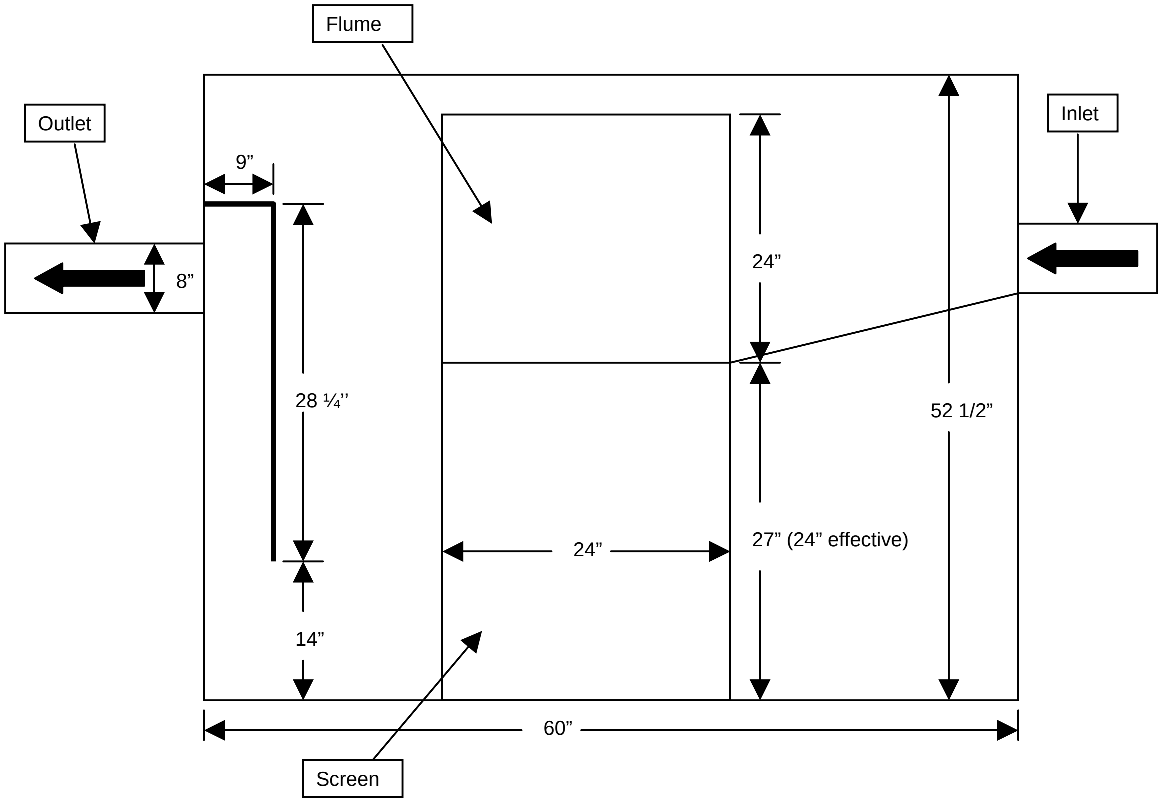

Figure 3. Cross-sectional view of CDS unit

This report describes the testing procedure setup and contains the results for laboratory testing on a CDS Model PMSU20_20 with a 2400-micron screen. A plan view representation of the laboratory setup used for testing when non-recirculation occurred is shown in Figure 4. For tests where recirculation occurred, water from the CDS unit was put back into the flume rather than into the effluent tanks. The sampling point when recirculation occurred was at the exit from the CDS unit before it discharged into the flume.

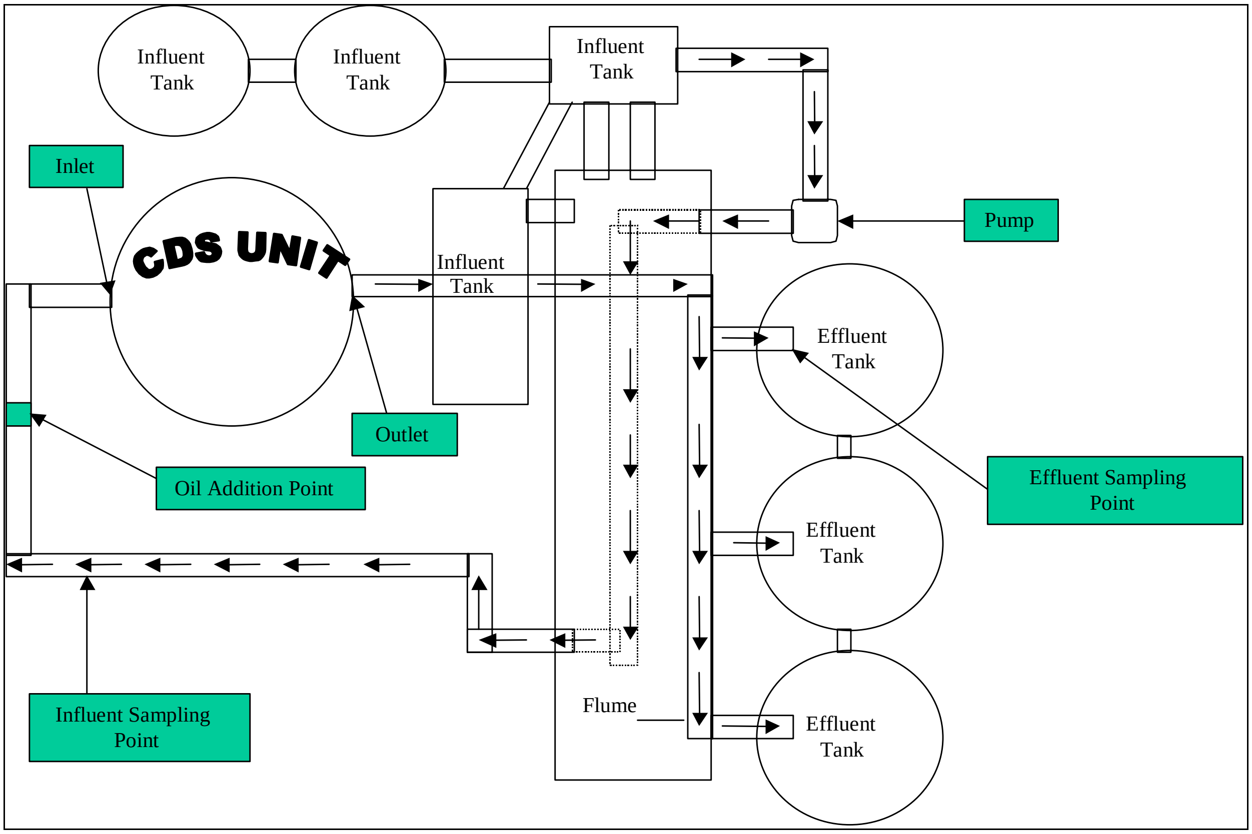

Figure 4. Plan view of laboratory setup

Experimental Procedures

Three flow rates were tested with three target oil inflow concentrations. These flow rates were 125, 250, and 375 GPM. Target influent oil concentrations for the three flow rates were 10, 20, and 50 mg/L. Additionally, an oil spill was simulated during a low flow to evaluate performance during an oil spill.

Used motor oil was obtained from a local maintenance facility and was metered into the influent water flow using a peristaltic pump. Appropriate representative samples of effluent and influent were taken throughout the multiple runs, and were sent to a certified laboratory for analysis. A summary of the tests performed are shown in Table 1.

Flow Rate, GPM	Influent Concentration, mg/L
125	10
125	20
125	50
250	10
250	20
250	50
375	10
375	20
375	50
50	82000

Table 1. Summary of tests performed

For each test~~s~~ the peristaltic pump was initially calibrated to deliver the approximate concentration of oil to the CDS unit. The oil was pumped out of a volumetric flask and at the end of each trial the total volume of oil was determined by subtracting the original amount in the flask by the amount remaining after the trial. The actual influent concentration was then determined using Equation 1.

$$\frac{(X)(C_1)}{(Y)(5\min)\left(\frac{3.785L}{1gal}\right)} = \text{Influent Concentration, mg/L}$$

Equation 1. Formula used to determine inflow concentration

Where:

X is the volume of oil pumped into the inlet over the duration of the test in mL

Y is the flow rate in gallons per a minute

C_1 is the specific gravity of oil, 900 mg/mL

The CDS unit was thoroughly cleaned between each test. For the cleaning process the majority of the oil was skimmed off the water surface inside of the unit, as well as ~~at~~ the effluent tanks, and influent tanks if applicable. The units were then drained, scrubbed, and rinsed. The unit and tanks were then filled with water and the system was run for approximately one hour with three cups of dish washer detergent added to act as a degreaser. Following the degreasing the unit was scrubbed, drained, rinsed, scrubbed, and rinsed again to ensure that as much oil as possible was removed from the unit. The unit was then filled with water and the next test was performed.

All samples were gathered and collected according to procedures documented by EPA (1999) according to the oil and grease method 1664a. QA/QC was performed according to section 9 of the EPA(1999) methodology. Spiked samples were created with a concentration of 40 mg/L. Average percent recovery was taken by averaging the percent recovery for each of the spiked samples and was calculated separately for the various tests. The standard deviation for the recovery was computed using Equation 1 from section 9.2.2.2 in Appendix 2. The recovery interval was calculated as being the average percent capture +/- twice the standard deviation of the capture.

Procedure for 125 GPM testing

Three tests were performed at different influent concentrations to determine the effective capture rate of oil and grease for the CDS unit.

The oil was injected into a port in the inlet pipe approximately two feet before the entrance to the unit. A picture of the injection setup can be seen in Figure 15.

The total time for each of the tests was seven minutes. This time was chosen because it was the maximum time at this flow rate that could be used without having to re-circulate water back through the system. Oil was injected into the inlet continuously for a period of five minutes starting at the beginning of each of the tests. After five minutes had passed, the oil pump was shut-off but the water continued to run at the same flow rate, 125 GPM for an additional two minutes. Actual influent concentrations were 7.3, 18.3, and 46.2 mg/L using Equation 1.

Sampling was conducted at the first of the three outlet pipes, since this was the one with the greatest amount of flow. The outlet pipes can be seen in Figure 16. An initial background sample was taken at the beginning of each test to determine if any residual oil existed in the tank. The sample was taken on the influent line, upstream of the oil injection point (see Figure 4). After the background sample, effluent samples were collected at one-minute intervals from the outlet for the duration of the test, giving a total of eight samples for each of the tests.

Samples were analyzed by Columbia Inspection, Inc. according to the EPA 1664a protocol. The detection limit using this method is 2 mg/L. Non-detects were reported as being at half of the detection limit or 1 mg/L.

The average percent capture was 96.3 % for these three tests with a standard deviation of 0.3%. This gave a capture range of 95.7% - 96.9% for these tests.

Procedure for 250 and 375 GPM testing

These flow rates required water to be recirculated through the system to achieve the volumetric turnover necessary to determine representative system performance.

The total time for each of these tests was twenty minutes. During each test, oil was injected into the inlet continuously for a period of five minutes at a target concentration of 10 mg/L. After the five minutes had passed, the influent target concentration was increased to approximately 20 mg/L. After another five minutes the target influent concentration was increased to approximately 50 mg/L. After five minutes of pumping in oil at a concentration of 50 mg/L the peristaltic pump was shut off, while water was still being pumped through the unit at a constant flow rate. The unit was then run with no oil being added for a time period of five minutes.

Calculated oil inflow concentrations for the 250 GPM test were 9.9, 22.8, and 45.6 mg/L, respectively, for the 10, 20, and 50 mg/L target inflow concentrations. Calculated inflow concentrations for the 375 GPM test were 10.5, 21.9, and 46.9 mg/L, respectively, for the 10, 20, and 50 mg/L target inflow concentrations.

Sampling was conducted at the inlet sampling point located approximately three feet upstream of the peristaltic pump injecting the oil, as well as at the same effluent sampling point as used in the 125 GPM test. Initial background samples, at the inlet and the outlet, were taken at the beginning of each trial to determine if any residual oil existed in the tank. After the background sample, samples continued to be collected at one-minute intervals at the inlet and outlet sample points for the duration of the test, giving a total of forty-two samples for each of the tests.

Samples were analyzed by Columbia Inspection, Inc. according to the EPA 1664a protocol (EPA, 1999). The detection limit using this method is 2 mg/L. Non-detects were reported as being at half of the detection limit or 1 mg/L.

The average percent capture was 86.6% for the 250 GPM test with a standard deviation of 1.9%. This gave a capture range of 82.9% - 90.3% for this test.

The average percent capture was 94.3% for the 375 GPM test with a standard deviation of 0.8%. This gave a capture range of 92.7% - 95.8% for this test.

Procedure for Oil Spill Test

The oil spill test was performed at a flow rate of 50 GPM and consisted of adding twenty gallons of used motor oil into the influent stream upstream of the CDS unit over a time period of four minutes. This gave an influent concentration of approximately 82,000 mg/L.

No recirculation was required for this test, so sampling was only conducted at the effluent side of the CDS unit. An initial background sample was taken before the addition of oil to the unit, and after the background sample, additional samples were collected at one-minute intervals from the outlet for the duration of the test. The test lasted twenty-five minutes which is equivalent to two tank turnovers after all the oil had been added.

Samples were analyzed by Columbia Inspection, Inc. according to the EPA 1664a protocol. The testing procedure is given in Appendix 2. The detection limit using this method is 2 mg/L. Non-detects were reported as being at half of the detection limit or 1 mg/L.

The average percent capture was 94.5% with a standard deviation of 2.3%. This gave a recovery range of 83.9% - 99.0% for this test.

Experimental Results

The experimental results for each of the runs were organized as a function of flow rate and are listed in Table 2.

Table 2. Summary of oil and grease tests.

Flow Rate (GPM)	Influent Conc. (mg/L)	Average Effluent Conc. (mg/L)	Removal Efficiency (%)
125	7.2	3.5	51
125	18.3	1.5	92
125	46.2	3.5	92
250	9.9	2	80
250	22.8	5	78
250	45.6	7.5	84
375	10.5	7.5	29
375	21.9	16	27
375	46.9	27	42

Results for 125 GPM testing

The results for the three 125 GPM tests with influent concentrations of 7.2, 18.3, and 46.2 mg/L are shown below in Figure 5, Figure 6, and Figure 7, respectively.

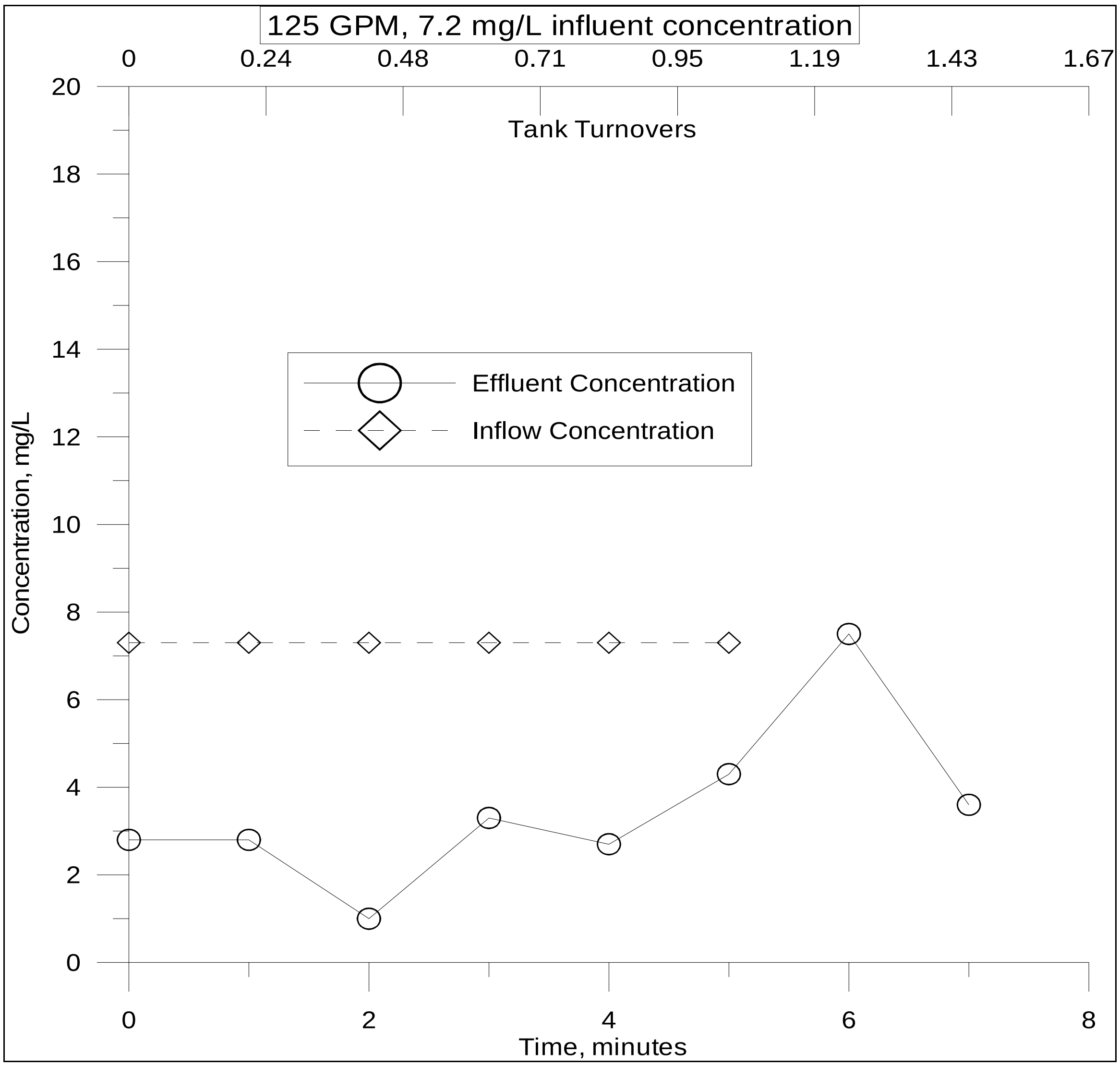

Figure 5. Results for 125 GPM test with a 7.3 mg/L influent (Note: 1 tank turnover is the time required for 1 volume of the tank to pass through the unit.)

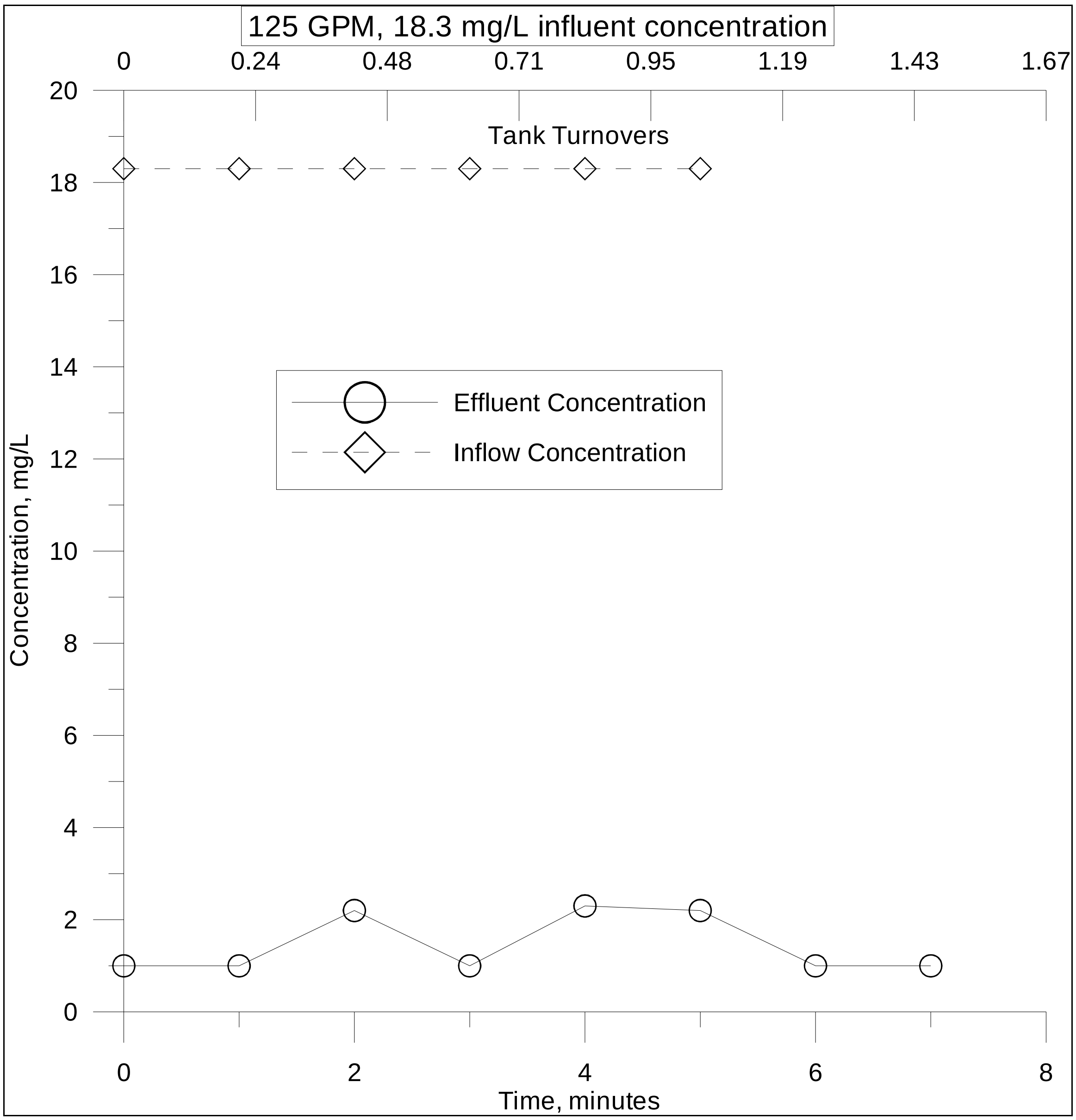

Figure 6. Results for 125 GPM test with an 18.3 mg/L influent (Note: 1 tank turnover is the time required for 1 volume of the tank to pass through the unit.)

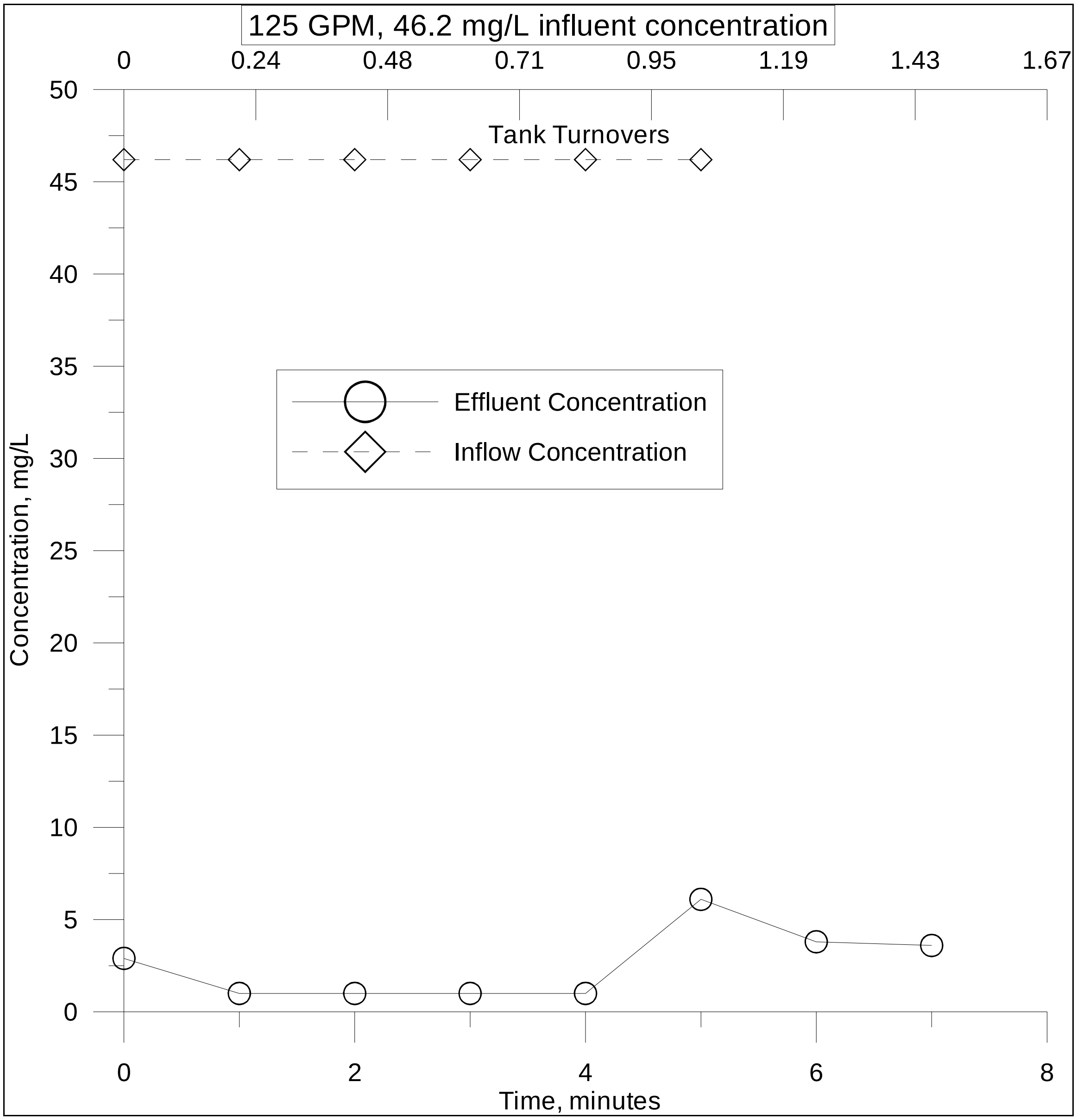

Figure 7. Results for 125 GPM test with a 46.2 mg/L influent (Note: 1 tank turnover is the time required for 1 volume of the tank to pass through the unit.)

Results for the 250 GPM test

The results for the 250 GPM test are shown below. Figure 8 displays the oil input contributed by the peristaltic pump and inflow from the effluent tanks separately. Figure 9 displays the oil input from the peristaltic pump and inflow from the effluent tank together.

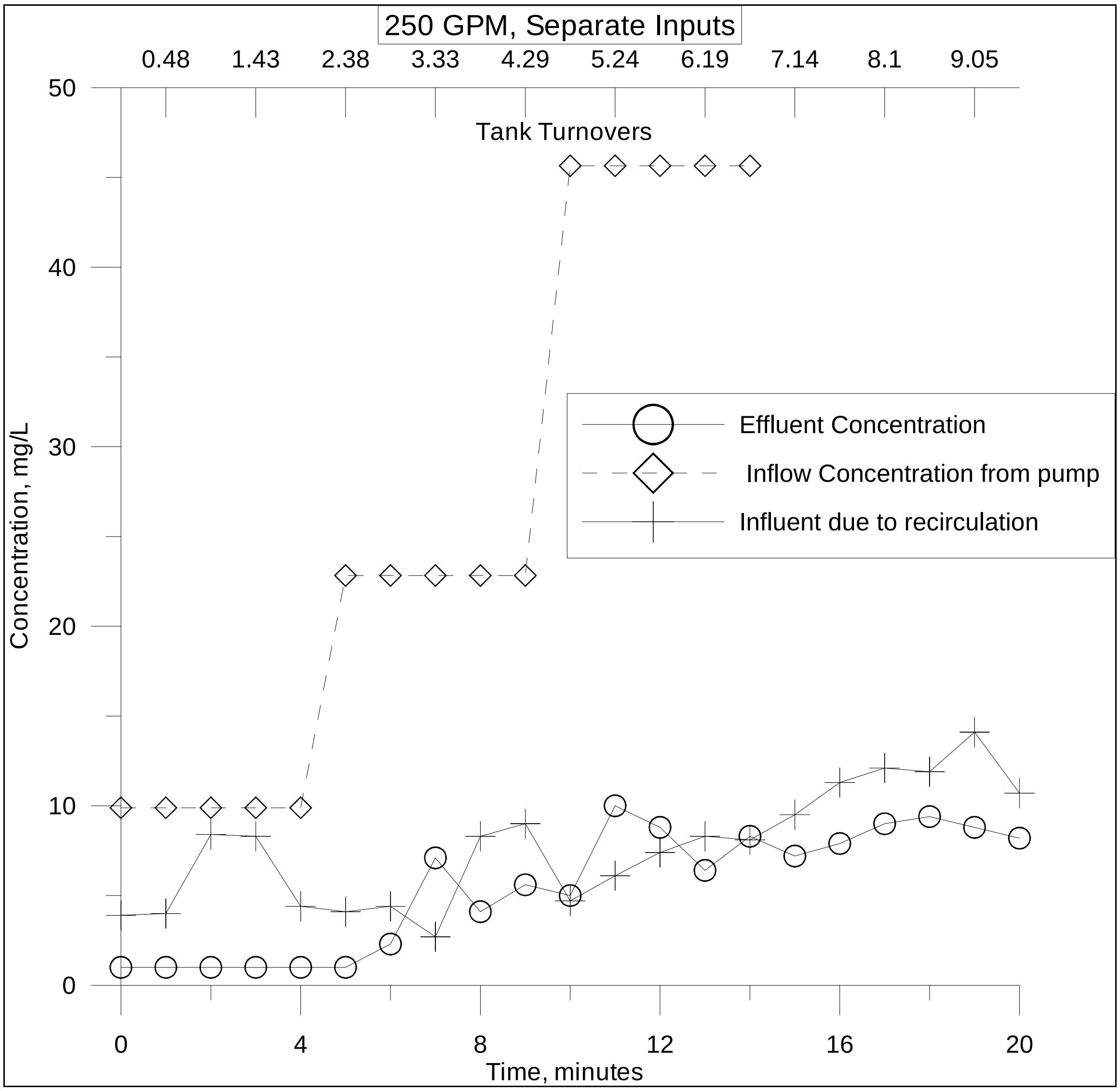

Figure 8. 250 GPM test results with separate oil inputs (Note: 1 tank turnover is the time required for 1 volume of the tank to pass through the unit.)

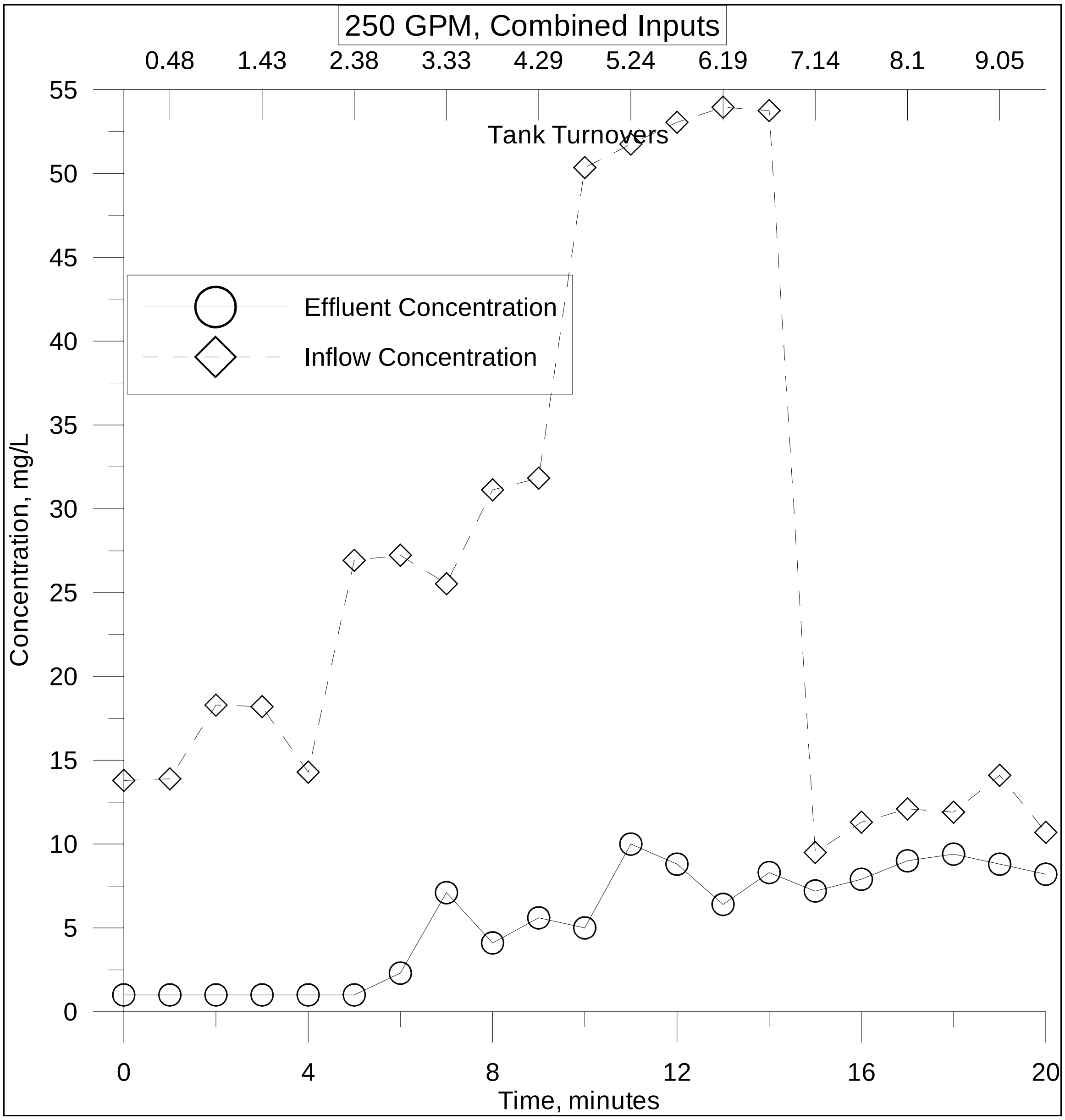

Figure 9. 250 GPM test results with combined oil inputs (Note: 1 tank turnover is the time required for 1 volume of the tank to pass through the unit.)

Results for the 375 GPM test

The results for the 375 GPM test are shown below. Figure 10 displays the oil input contributed by the peristaltic pump and inflow from the effluent tanks separately. Figure 11 displays the oil input from the peristaltic pump and inflow from the effluent tank together.

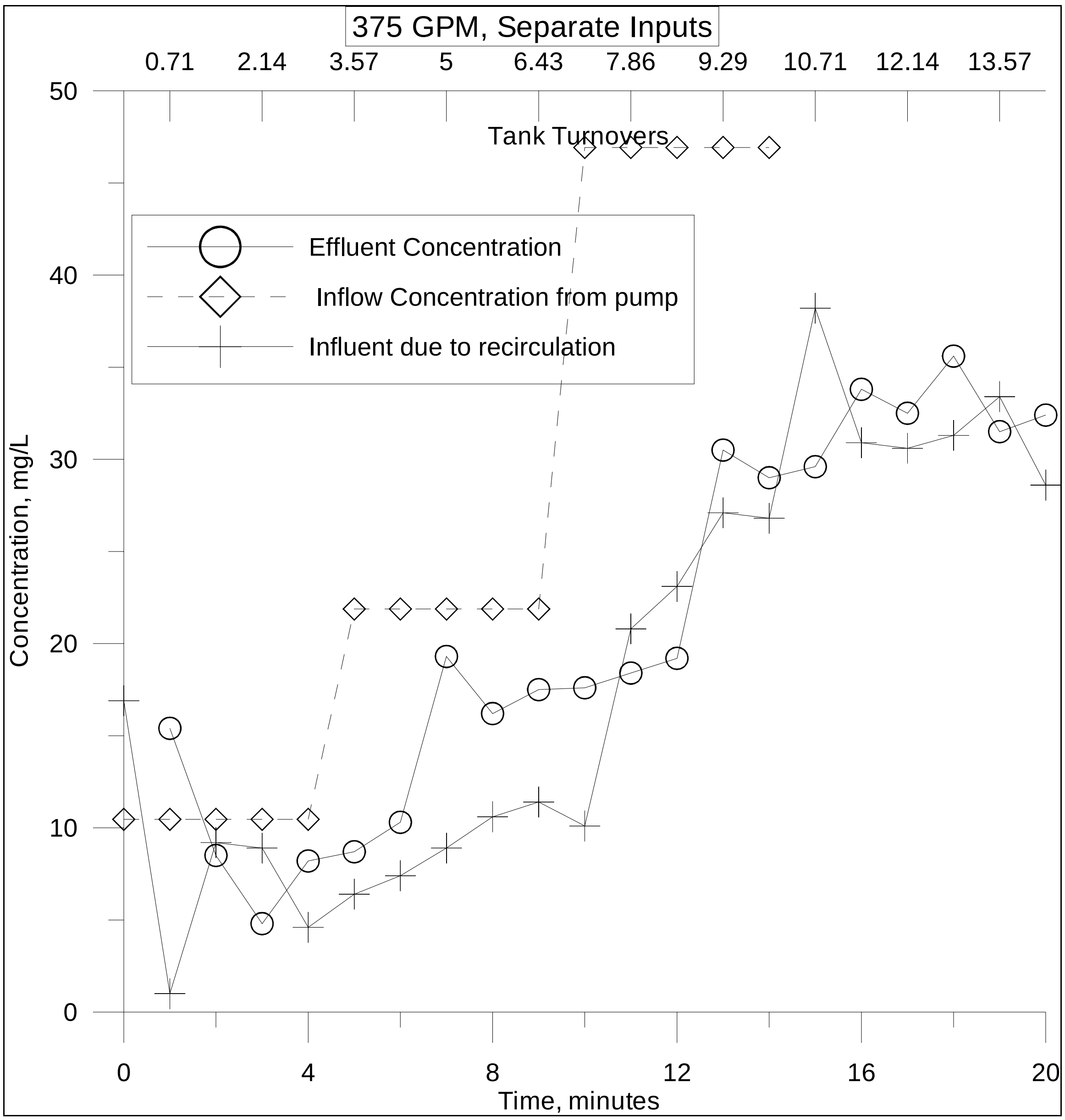

Figure 10. 375 GPM test results with oil inputs given separately (Note: 1 tank turnover is the time required for 1 volume of the tank to pass through the unit.)

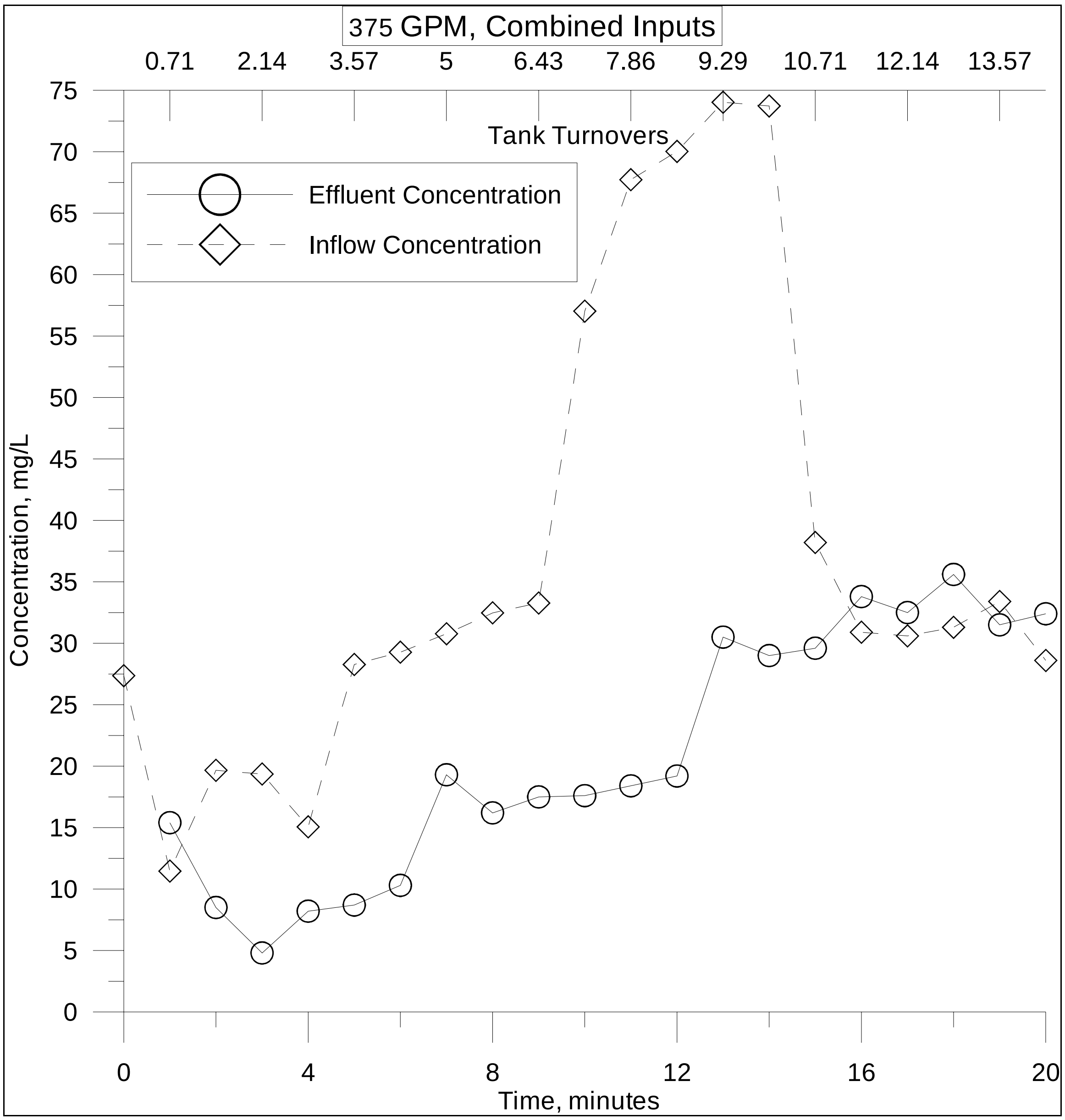

Figure 11. 375 GPM results with combined oil inputs (Note: 1 tank turnover is the time required for 1 volume of the tank to pass through the unit.)

Results for the Oil Spill Test

The results for the oil spill test are shown below in Figure 12.

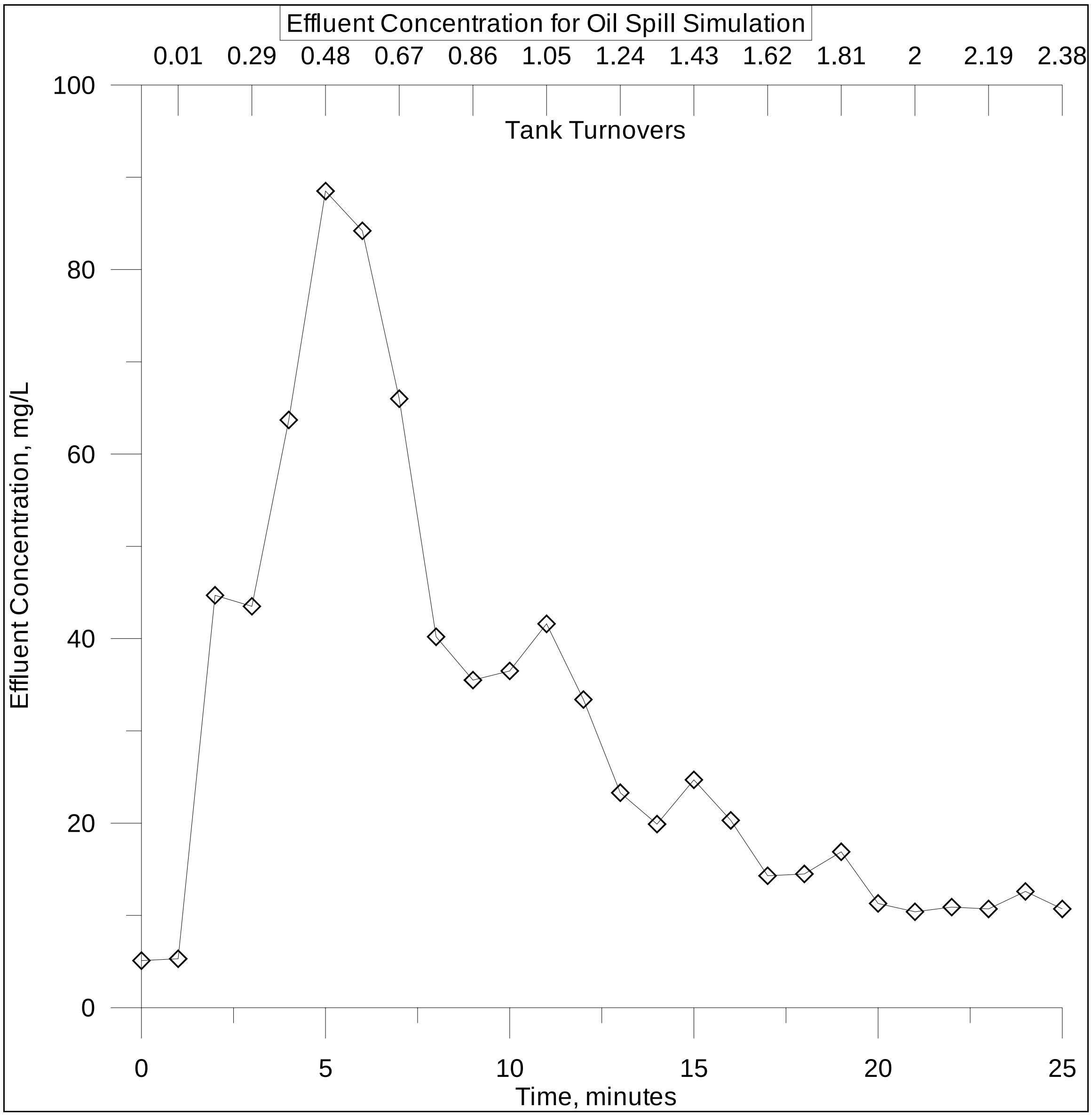

Figure 12. Results for oil spill simulation (Note: 1 tank turnover is the time required for 1 volume of the tank to pass through the unit.)

Summary and Conclusions

A CDS Model PMSU20_20 equipped with a 2400 micron screen and oil baffle with a design capacity of 500 gpm was evaluated to determine its effectiveness to remove oil and grease at concentrations typically found in storm water runoff. The unit was also evaluated in its ability to capture an oil spill during low flow storm conditions. Tests were conducted at 125, 250 and 375 gpm, or at 25, 50 &75% of the unit's capacity with influent oil concentrations of about 10, 20 & 50 mg/L.

Initial background testing indicated that for each of the tests performed there was some, albeit a small amount of, residual oil in the system prior to the testing, even though the unit had been scrubbed and cleaned between each test. This could also be a result of the laboratory testing process

The 125 GPM test results showed oil removal rates at about 90% removal. For the three tests the average effluent concentration was between 1.5 and 3.5 mg/L for inputs ranging from 7 to 46 mg/L.

The 250 GPM results showed oil removal rates generally in the 80% range. As the influent concentration was increased from 9.9 mg/L to 22.8 mg/L, the effluent concentration increased from a non-detect to 2.3 mg/L and then up to 7.1 mg/L.

The 375 GPM results showed removal rates in the 30-40% range.

Another way of evaluating the data was to calculate the percent oil capture of the CDS unit. This was calculated by taking the influent concentration and dividing it by the effluent concentration sampled the minute afterward. Capture percentages for the 250 GPM and 375 GPM tests are shown in Figure 13 and Figure 14, respectively.

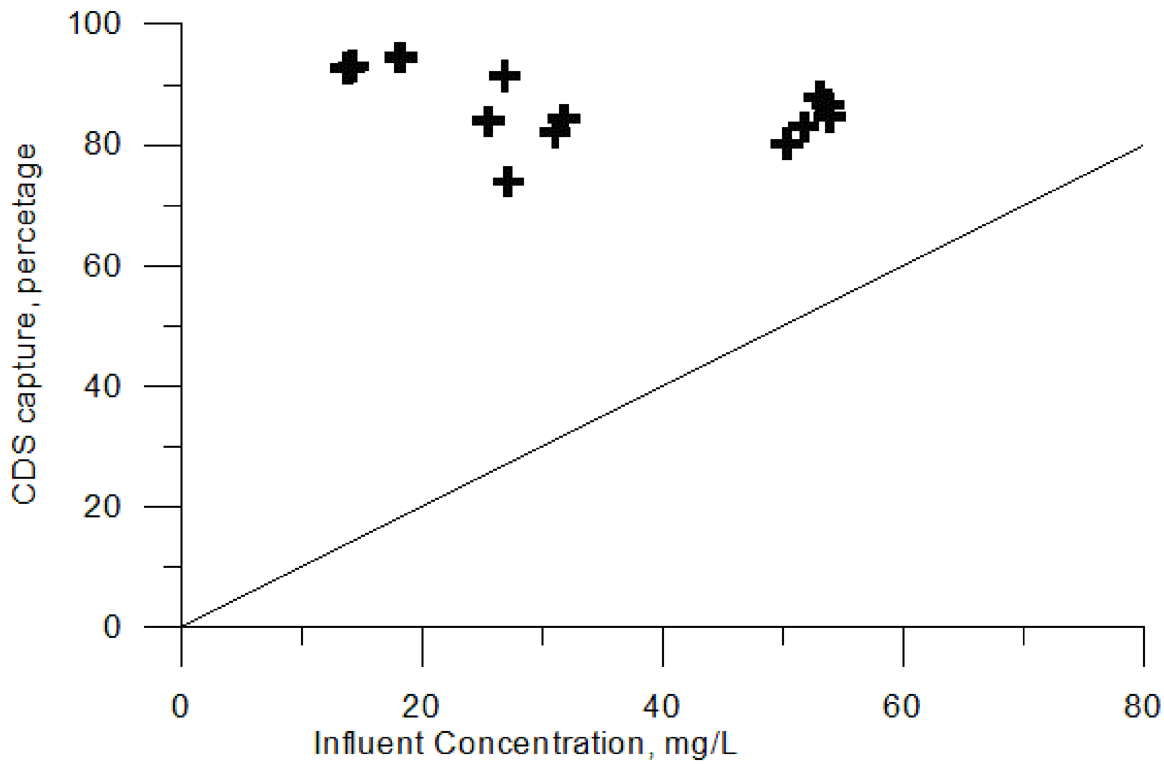

Figure 13. Capture percentage at 250 GPM

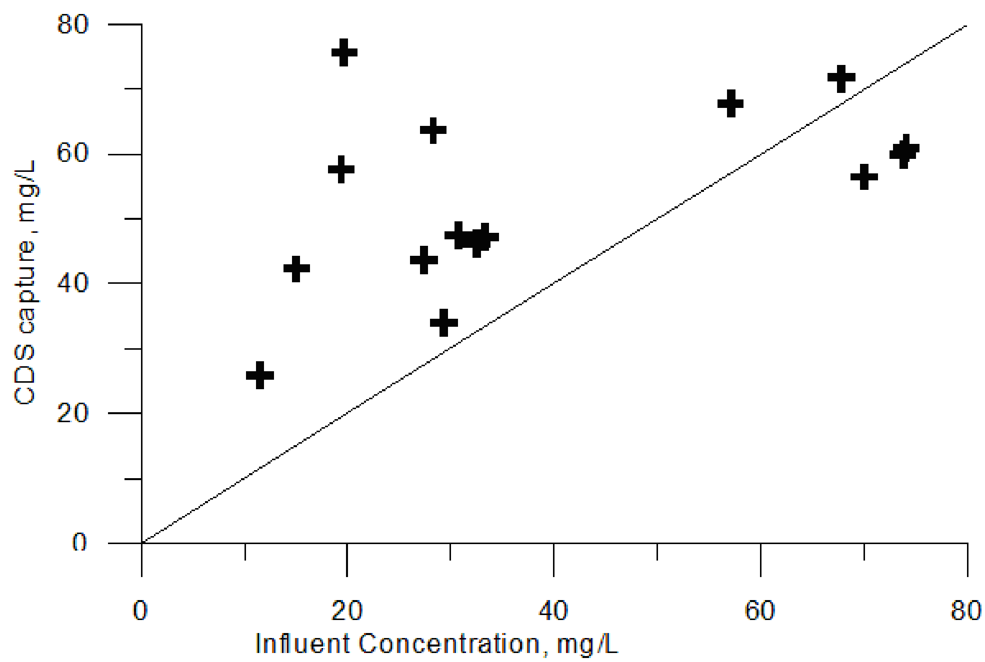

Figure 14. Capture percentage at 375 GPM

The unit performed extremely well in the oil spill test, with the peak oil concentration in the effluent occurring right as the addition of oil to the unit stopped. The peak effluent concentration was less then 90 mg/L, which accounts for less then 0.11 % of the total amount of oil added to the unit. If the concentration of the effluent for each sampling interval was assumed to be that of the sample taken at the beginning of the one minute interval duration. A total mass of approximately 148 grams can be assumed to have come out of the unit during this test. When compared to the input of over 65,000 grams this shows a capture more then 99.75% of the oil dumped into the unit. This would be a very effective means of containing an oil spill.

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Appendix 1

Figure 15. Peristaltic pump and oil inlet

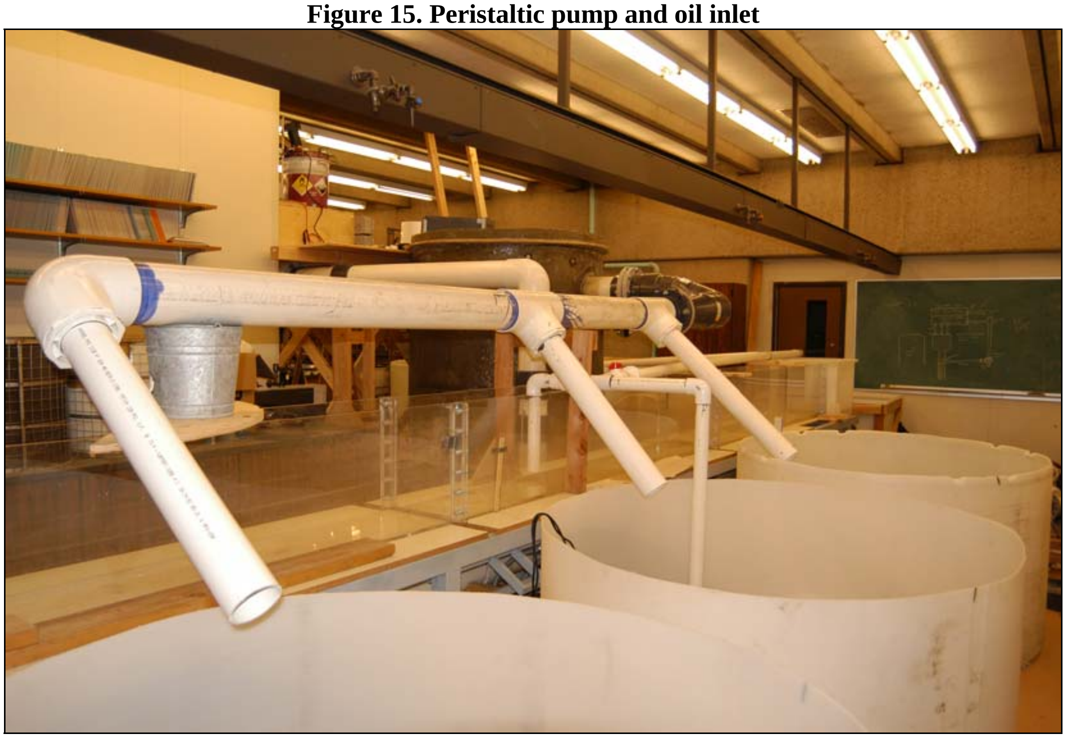

Figure 16. Effluent Pipes

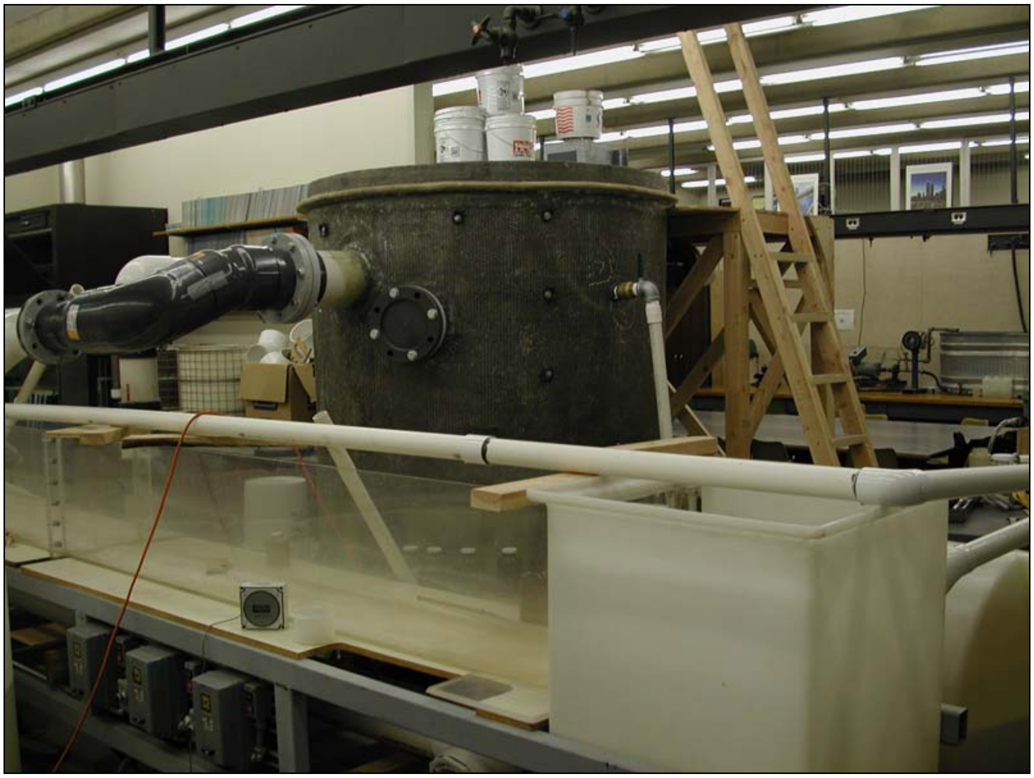

Figure 17. CDS unit

Figure 18. Spencer near the effluent sample point

Figure 19. Outer chamber after 250 GPM test

Figure 20. Inner chamber after 250 GPM test

Figure 21. Adding oil in for the dump test

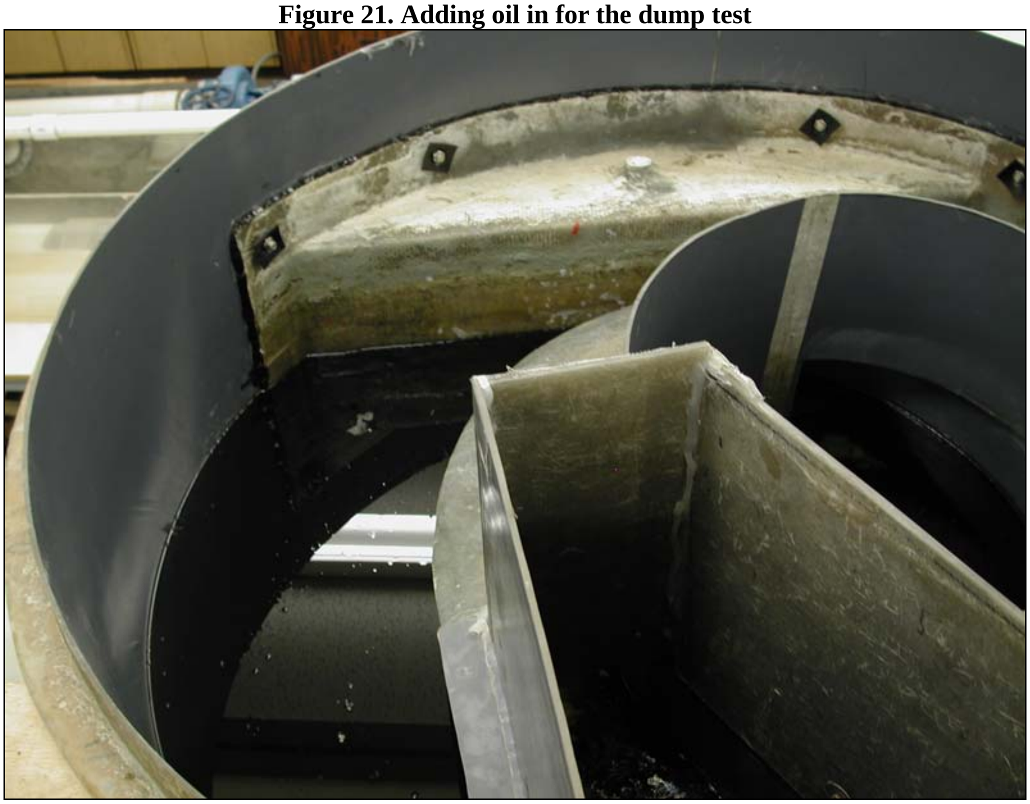

Figure 22. After the oil dump test

Oil and Grease Removal by Floating Sorbent in a CDS Device

by

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Executive Summary

A series of experiments were performed in a small but full-scale CDS device to determine its ability to remove free oil and grease from polluted waters using sorbents. Nine experiments were performed using five different sorbents. One control experiment was performed without a sorbent. The sorbents were allowed to float on the surface of the separation chamber of the CDS device. The CDS unit was not modified to accept the sorbents. Different amounts of each sorbent were used because of the varying properties of the sorbents (density and surface area).

Tests were performed using a 2400-micron screen over 30 minutes at 125 GPM (approximately 50% of the CDS unit's nominal flow capacity). Used motor oil was introduced into the feed of the CDS at approximately 25 mg/L, which is generally the upper limit of oil and grease concentrations found in stormwaters. Oil and grease was measured at various times to determine the removal efficiency. Background oil and grease was measured as well as oil and grease released from the sorbents after the influent oil and grease was reduced to zero. Removal efficiencies for most sorbents varied from 63 to 96% depending upon conditions. One sorbent removed only 18%. Sorbent saturation was not achieved in any of the experiments. Very little oil and grease (generally less than 1 to 2 mg/L) was released from sorbents when the influent oil and grease was reduced to zero.

Without a sorbent, the CDS unit removed 80% of the influent oil and grease, but released it after the oil and grease in the influent was reduced to zero. This suggests that the CDS unit might be effective in capturing a spill, if the unit could be isolated after the spill to allow oil and grease recovery.

Introduction

Woodward-Clyde Consultants, Psomas and UCLA (Civil and Environmental Engineering Department) performed a catch basin insert study for a group of Southern California Cities and the Santa Monica Bay Restoration Project (the project was lead by the City of Santa Monica). As an amendment of this study, a CDS unit (which is not a catch basin insert - see references 1 to 3) was evaluated. The unit was assembled in a laboratory at UCLA using tap water to simulate storm water, and evaluated for its ability to remove trash and suspended solids. This setup was used in a further study, not associated with catch basin insert study, to evaluate the unit's ability to remove oil and grease.

CDS contracted with the Civil and Environmental Engineering Department at UCLA to perform this work. Professor Michael K. Stenstrom directed the work.

Oil and grease removal by various sorbents was evaluated. Free oil and grease was introduced at approximately 25 mg/L into the feed of the CDS unit. The sorbents were allowed to float in the top of the CDS unit. No modifications were made to the CDS unit to accommodate the sorbents. Most experiments were conducted at 125 gallons per minute (125 GPM), which is approximately 50% of the test CDS unit's nominal capacity (for the particular size unit evaluated - CDS units are produced in a range of sizes). Oil and grease was measured at various times in the effluent to determine removal efficiency.

This report describes the research and results.

Experimental Methods

Sorbents. A great deal of research has been performed previously at UCLA on oil and grease in stormwaters and its removal. Sorbents have been evaluated for this purpose. They have been proposed for this application for many years, but very few studies by independent investigators have been performed. This study builds upon earlier work and uses many of the previously developed concepts and techniques (Lau and Stenstrom, 1995, 1997).

These materials are called "sorbents" as opposed to "adsorbers" or "absorbers" because both absorption and adsorption mechanism are present. It is sometimes difficult to know which mechanisms are important.

Five sorbents were evaluated. They were obtained from the manufacturers or from dealers in the Los Angeles area. Most are marketed for oil spill clean up. Table 1 shows the size analysis for all sorbents except the Nanofiber (mesh size is not applicable to this sorbent). The numbers in the table are percent of the sorbent, by weight, that is retained on an ASTM standard wire screen for the mesh size or opening size shown. Table 2 shows the bulk sorber density. This was determined by filling a tarred container of known volume with sorbent and measuring its weight. This density is not the particle density, which excludes void spaces.

1. **OARS**. OARS™ (AbTech Industries, 4110 N. Scottsdale Rd., Suite 235, Scottsdale, AZ 85251) is a "rubber" type of sorbent. It can be manufactured in any desired size fraction. The material is sintered into larger particles from smaller particles. The material used in this study was originally intended for use in catch basin inserts, and is somewhat larger than optimal for this application. The manufacturer generally believes that the removal mechanism is absorption. Of the sorbents evaluated in this study, the AbTech sorbent is most similar to the Rubberizer sorbent. The material is denser than the other sorbents and tends to wet better in the separation chamber of the CDS device.

2. **Rubberizer**. Rubberizer™ is a sorbent that is marketed by Haz-Mat Response Technologies, Inc (4626 Santa Fe Street, San Diego, CA 92109) as a clean up sorbent for various types of solvents, oils and fuels. It is composed of a mixture of hydrocarbon polymers and additives. It can be purchased in as a particle (used in this test) or water gel or assembled into pillows and booms. It is similar to the touch as the OARS sorbent.

3. **Aluminum Silicate**. Aluminum silicate is a popular material for oil and grease sorption. It is lightweight and hydrophobic. It is also used to add bulk to soil. Two types were used in this study: the first product is marketed as Xsorb™ (Impact Absorbent Technologies, P.O. Box 1131, Atascadero, CA 93423) and is sold for stormwater applications; 2) the second type is Sponge Rok™ type 23 (Paramount Perlite Co., Paramount, CA, 90723) and our understanding it is that is primarily sold as a soil bulking agent. Xsorb is approximately 8 mesh and the particles have sharp edges, as if they were recently fractured. Sponge Rok is larger, with a mesh size of 3.5, and has rounded edges. Both materials easily abrade to create a fine powder.

4. **Nanofiber**. Nanofiber™ (Nanofiber Technology Inc, 205 Artillery Road, NC, 29837) is a polypropylene fiber adsorbent. It is similar to fibers made by 3M for uses in pillows, pads and sausage sorbers for oil spill control. Nanofiber and other similar materials were used extensively in a previous study by the authors (Lau and Stenstrom, 1995).

The sorbers all have different bulk densities, specific surface areas and costs. It was not possible to create an equivalent mass of each sorbent on any common basis. Therefore the experiments were conducted with sufficient sorbent to cover the top of the CDS unit. When these sorbents are used to clean up oil spills they are exposed to either pure oil and very concentrated mixtures of oil and water. Under these circumstances, they will sorb many times their weight.

Table 1. Sorbent sizes (numbers are percent retained on each screen size)

Screen size (mm)	Screen Mesh	Rubberizer	OARS	Xsorb	Sponge Rok
26.7	-	0.0	39.7	0.0	0.0
13.3	-	0.0	50.0	0.0	0.0
5.7	3.5	0.4	9.9	11.1	87.1
4.7	4	0.2	0.2	12.6	5.4
2.4	8	99.2	0.2	73.8	3.8
<2.4	< 8	0.2	0.1	2.4	3.7

Table 2. Bulk sorbent density.

Sorbent	Density (g/ml)
Rubberizer	0.26
OARS	0.22
Xsorb	0.13
Sponge Rok	0.10

For the applications investigated in this report, they sorb much less because they are only exposed to very dilute mixtures of oil and water.

Oil and Grease Analysis. Oil and grease was measured using a solid phase extraction (SPE) technique developed earlier by the authors (Lau and Stenstrom, 1997). This technique uses a known volume of sample (generally 500 ml for this study) which is pumped through an SPE column at a constant but low rate (e.g., 5 ml/min). The oil and grease in the sample is sorbed on the SPE column. After the sample is pumped through the column, it is eluted with a small volume of solvent (5 ml): methylene chloride and hexane. The sample bottle is also washed with a small volume of solvent (isopropanol). The two solvent volumes are combined and placed in a tarred container. The solvents are allowed to dry at 50°C using a gentle nitrogen purge. The residue is weighed. The results are reported as mg/L based upon the original sample volume. This method is not yet a standard method, but is being developed by the US EPA and others as a standard method. It has the advantages of higher recovery, especially for the more volatile components in oil and grease, and using less solvent (the solvents used for traditional oil and grease analyses are usually flammable, toxic and either green house gases or ozone depleting gases). By using different sample volumes is it possible to have low detection limits, and the limit with 500-ml sample volume is typically 0.25 mg/L. This method does not quantitatively measure oil and grease adsorbed to solids and an alternate technique must be used for particle-bound oil and grease. However, this is not important for this study because no particles were added to the tap water used for testing.

CDS Unit. Figure 1 shows the CDS unit. This is a schematic diagram and not to scale. The manufacturer should be consulted for manufactured sizes and exact dimensions. The screen was 23.375 inches in internal diameter by 24.5 inches tall. The screen size was 2400 microns (1200 and 600 micron screens were used in the previous study to test solids removal but were not used in this study). The screen openings are elliptical.

The unit was connected to a high-pressure tap water line in the Engineering I building at UCLA through a cut off valve (not shown) and a metering valve. Small amounts of air were introduced into the pipeline to allow an ultrasonic (Doppler effect) velocity meter to be used. The meter was used in a three-inch diameter section of pipe that was flowing full under all test conditions. Figure 2 is a schematic of the piping.

Oil was introduced at a reducing tee, which allowed the pipe size to increase from 3 inches to 6 inches ("trade" sizes used for all pipe dimensions). A Masterflex peristaltic pump was used to deliver the oil to the 6-inch line. Flow rate was determined by pumping from a graduate cylinder and noting the reduction in volume over time. The oil flow rate was set to deliver the desired concentration (25 mg/L) for each flow rate. The oil specific gravity was measured as 0.86 g/cm^3. The 6-inch pipe was flanged to the CDS unit. The 6-inch pipe did not flow full at all flow rates. The effluent pipe was also six inches in diameter and discharged into a plywood box that contained the turbulence and splash. The effluent was then sent to a sanitary sewer.

Influent samples were collected from the surface of the CDS unit by dipping a sample container below the surface in the influent water jet. Effluent samples were collected at the end of the discharge pipe (a free waterfall).

Prior to the beginning of each test, the freeboard of the CDS unit was wiped clean and a small amount of new sorbent was used to remove any oil that remained from the previous test. This sorbent was removed prior to the beginning of the test. A weighed amount of test sorbent was then dumped into the separation chamber of the CDS unit. Sorbents were removed using a large fine mesh sieve.

Test Sequence. Tests were begun by collecting a background sample prior to the introduction of any oil to the influent. Next the oil-metering pump was turned on. Effluent samples were collected approximately every 5 minutes for the test duration, which was usually 30 minutes. At the end of the test, the oil-metering pump was turned off and the influent was allowed to continue for another 30 minutes. Two influent samples were collected at approximately 10 and 20 minutes. At the end of the second 30 minutes (total elapsed time of 60 minutes), a sample was collected to determine if any oil was desorbing. After collecting the sample the influent water was turned off and the used sorbent was recovered and disposed. The CDS unit was then drained and prepared for the next test. Oil and greases samples were generally analyzed within 16 hours after the tests were completed. Tap water temperature during the test was 15 ± 2 °C .

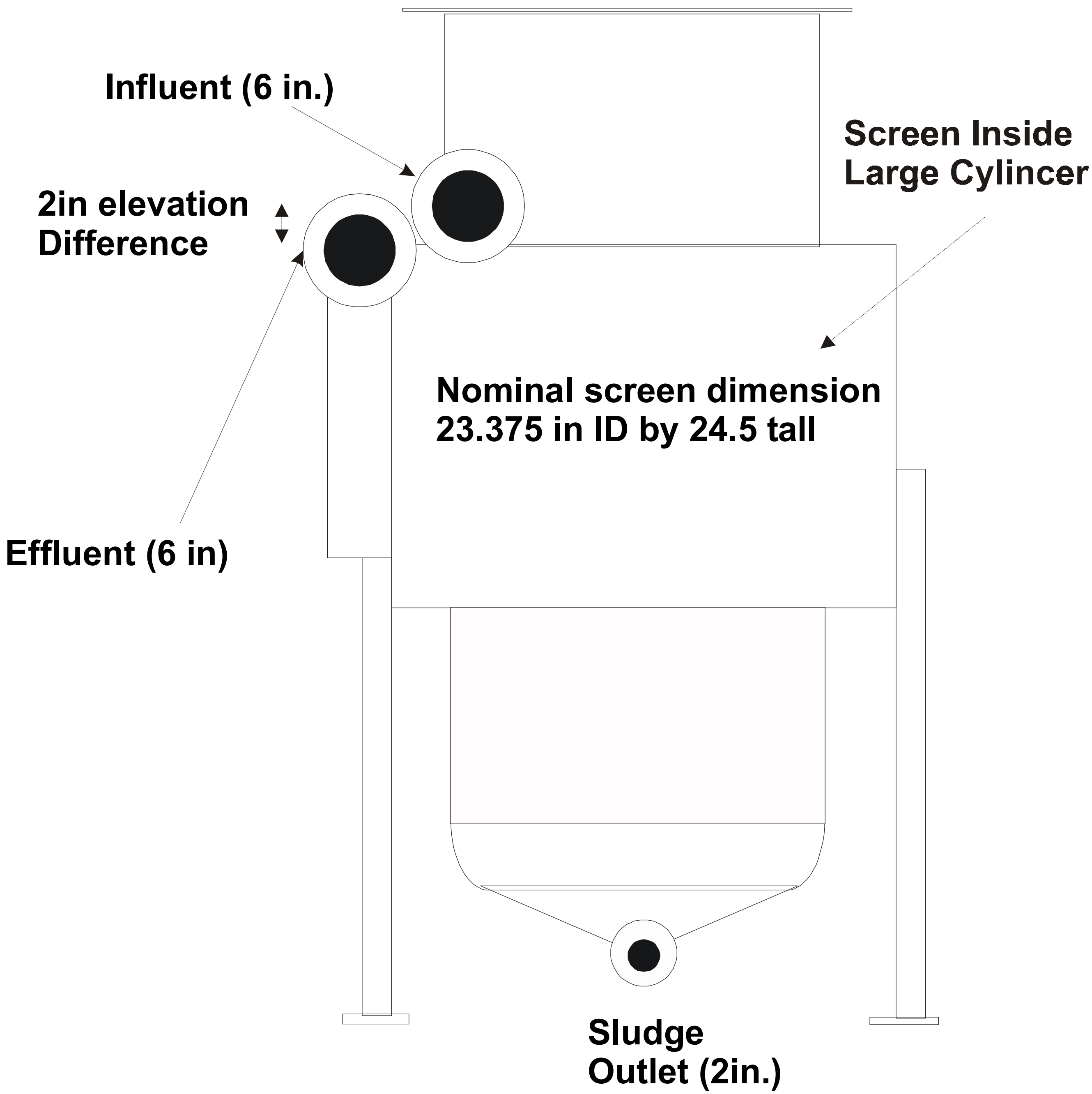

Figure 1. Schematic of the CDS unit (not to scale). Nominal screen dimensions are 23.375 by 24.5 inches. The screen is in the middle section and is installed or removed from the top. Influent and effluent pipes were six in diameter with flanges. Unit sits on three legs and is approximately 60 inches tall.

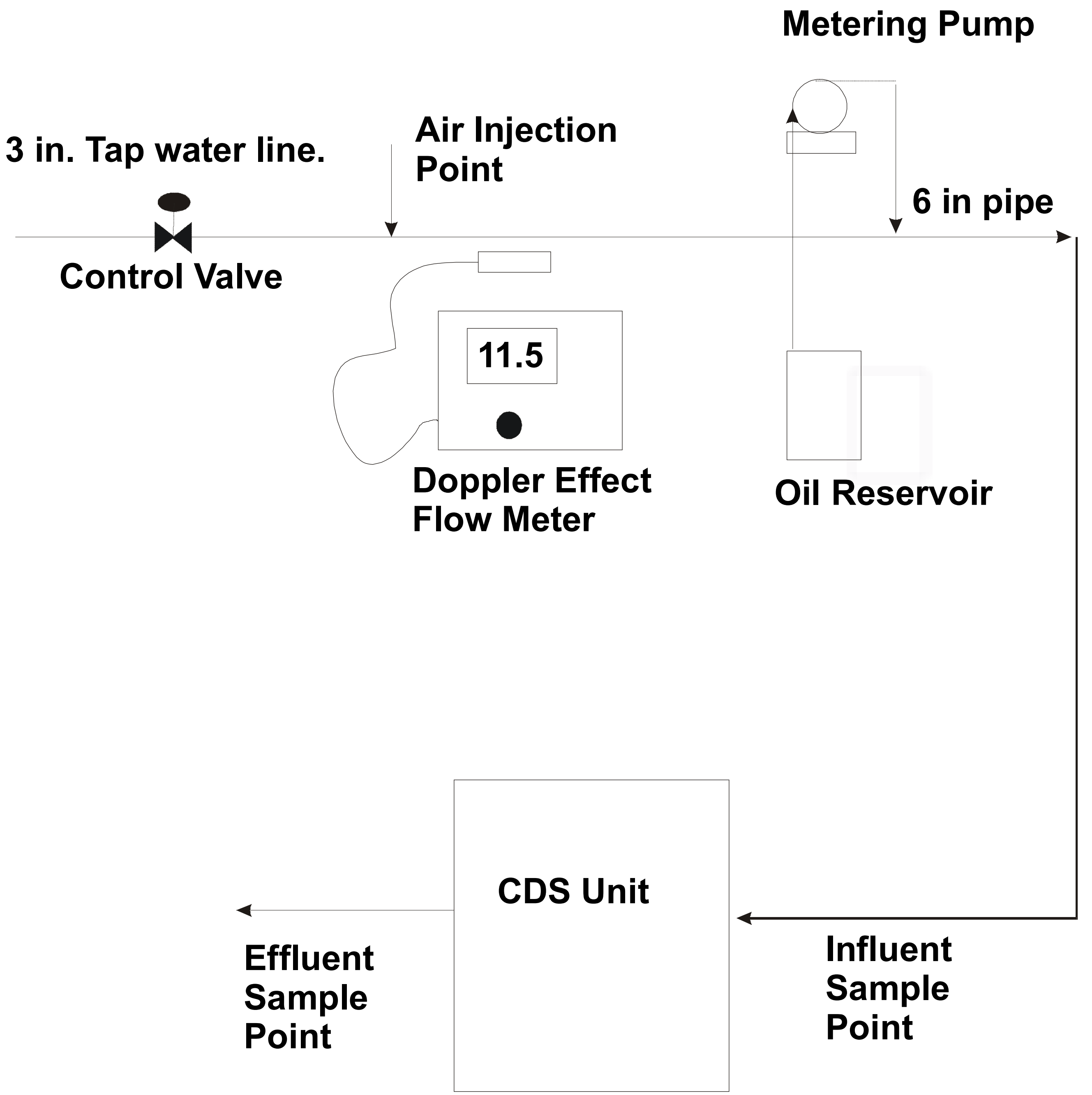

Figure 2. Process flow diagram.

Results and Discussion

A total of 9 tests were performed using various types of sorbents. One test was performed without a sorbent to determine the efficiency of the CDS unit to remove oil and grease by itself. Table 3 shows the final, averaged results of all tests.

The tests are sorted by sorbent name, in alphabetical order with the test without sorbent last. The second column shows the amount of sorbent used during the test. The next two columns show the average influent and effluent oil and grease concentrations. The percent removal column was calculated based upon the average influent and effluent concentrations. The flow column shows the flow rate used during the tests. All were conducted at 125 GPM except for two tests with OARS sorbent, which were conducted at 75 and 190 GPM. These tests were conducted to show the impact of flow rate on removal rates. Test 5 was conducted for 125 minutes to saturate the sorbent (unsuccessful – the sorbent was not saturated).

Table 3. Test results

Test No.	Sorbent Type	Sorbent Mass (g)	Inf. (mg/L)	Eff. (mg/L)	Percent Removal	Flow (gpm)	mass (mg)	Q (mg/g)	Residual (mg/L)
1	Nanofiber	570	29.3	3.8	87	125	3.62 E+05	635	0.08
2	OARS	2600	19.6	2.7	86	125	2.39 E+05	92	0.5
3	OARS	2600	24.0	4.3	82	190	4.25 E+05	164	0.84
4	OARS	2600	30.7	1.7	94	75	2.47 E+05	95	0.68
5	OARS (125)	2600	21.0	3.5	83	125	1.02 E+06	392	-
6	Rubberizer	1030	27.2	3.9	86	125	3.30 E+05	321	1.96
7	Sponge Rok	660	41.1	7.2	41	125	481 E+04	729	0.74
8	Xsorb	661	13.6	2.9	79	125	1.53 E+05	231	0.74
9	No Sorbent	0	19.7	4.5	77	125	-	-	3.35

The more dense sorbents (OARS and Rubberizer) generally have greater efficiencies that the lighter sorbents such as Xsorb and Sponge Rok. This is because the lighter sorbents float on top of the water and have less contact with influent water and oil and grease. In some cases, there was poor mixing of the sorbents with the influent. The OARS and Rubberizer sorbents floated just below the fluid surface and had much better circulation patterns.

The column Q represents the mass of removed oil and grease per unit mass of sorbent. The units are mg per gram (or gram per kilogram). A sorbent with a Q of 1,000 would remove oil and grease equal to its weight. In oil spill control, these same sorbents may remove many times their weight. The reduced Q in these experiments results because of the low concentrations of oil and grease in simulated stormwater, as compared to oil spill conditions. Since none of the sorbents in these tests were saturated, higher Q's should be anticipated. Generally sorbents will produce lower effluent concentrations at lower Q's. As saturation occurs, the Q is maximized but effluent quality suffers.

The sorbents generally retained the sorbed oil and grease. Effluent concentrations were less than 1.0 mg/L except for the Rubberizer which as almost 2 mg/L. This may have resulted because of its high Q.

The test with no sorbent is interesting. The CDS unit by itself removed approximately 77% of the incoming oil and grease. The effluent concentration after oil and grease injection ended was still high (4.5 mg/L), and the unit without a sorbent would probably have lost all the retained oil and grease to the effluent.

This behavior suggests a removal mechanism for the CDS/sorbent combination. The CDS unit is functioning as a gravity oil/water separator. The free oil and grease rises to the surface due to the influence of gravity. Once at the surface the oil is captured by a sorbent which retains it.

The tests conducted at different flow rates show the impact of flow rate or retention time on removal efficiency. The efficiency at the low flow rate was 94% as compared to 82 and 83% at the higher flow rates.

The CDS unit retained the sorbents and released none into the effluent, with the exception of the Nanofiber. Fine fibers could be seen in the effluent when using Nanofiber.

Figures 3 to 9 show the results of the various tests. The spikes in concentration are mostly likely due to poor mixing and are more common with the light sorbents. Figure 10 shows a progression of oil sorption on the OARS sorbent. Figure 11 shows an electron micrograph of the Nanofiber sorbent.

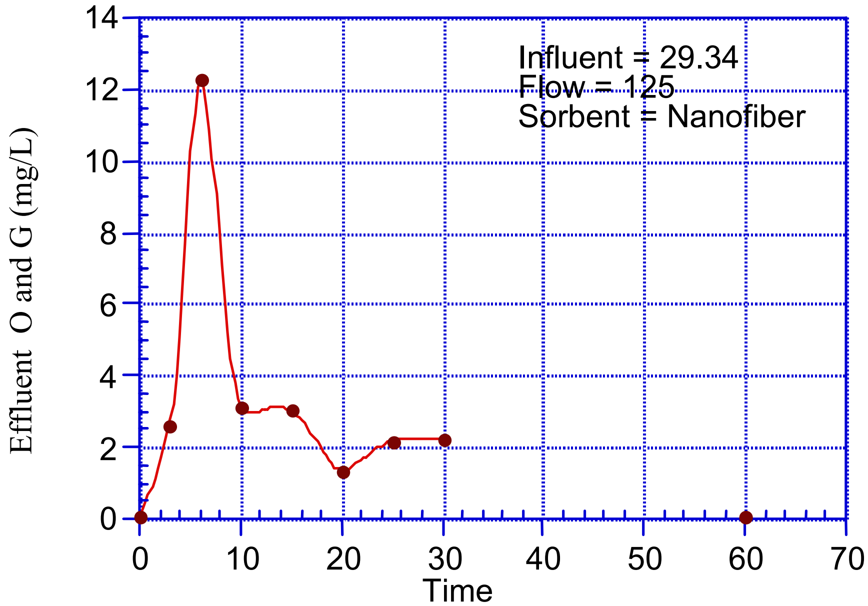

Figure 3. Test No. 1 using Nanofiber at flow rate of 125 GPM.

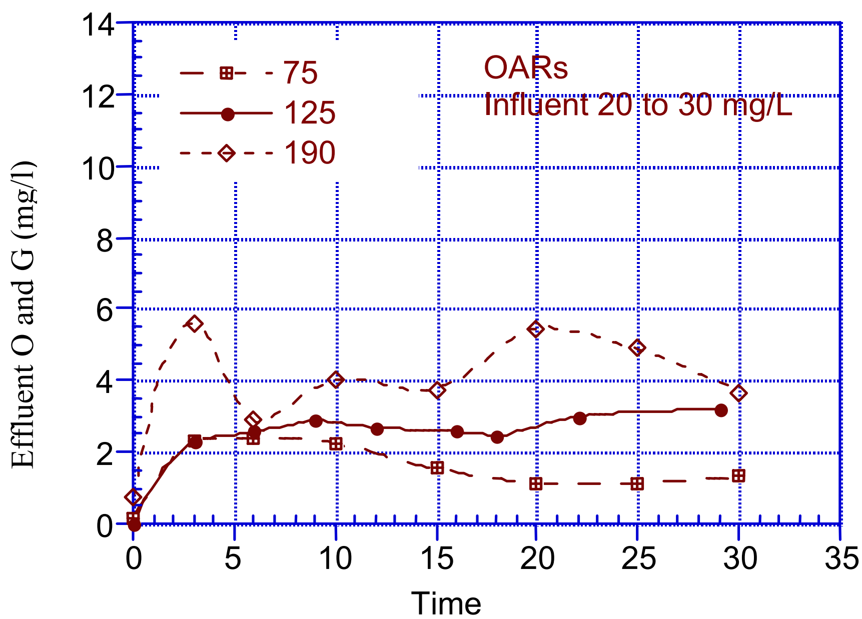

Figure 4. Tests No. 2 – 4 using OARS at various flow rates.

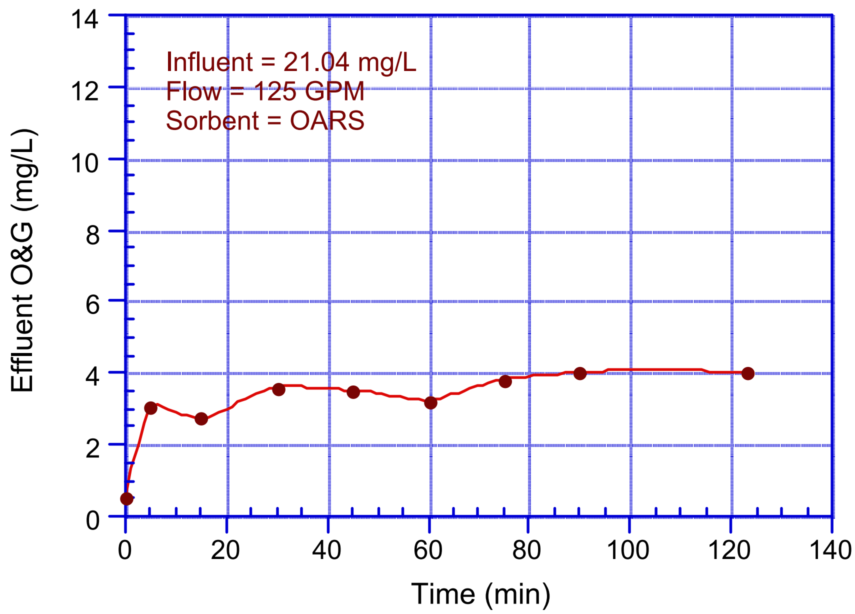

Figure 5. Test No. 5 using OARS at flow rate of 125 GPM.

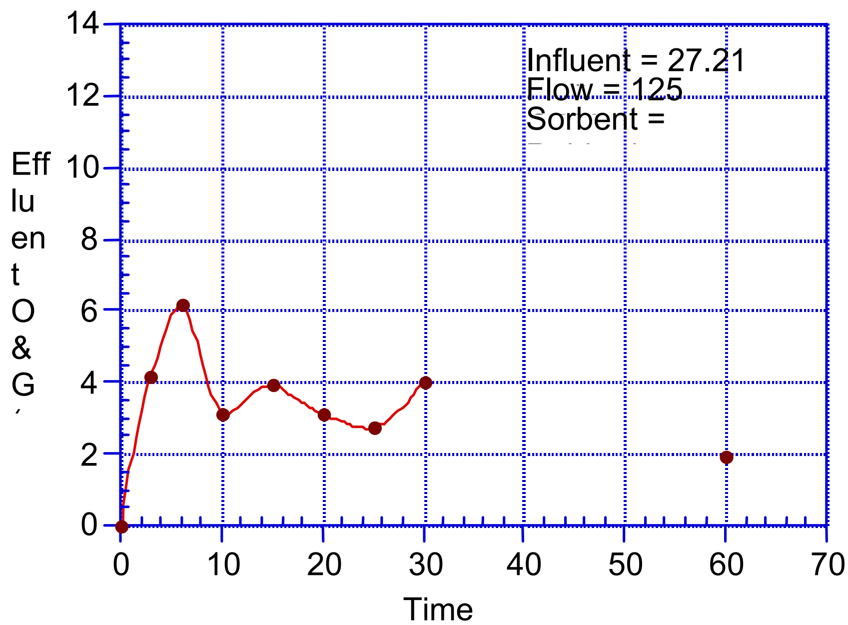

Figure 6. Test No. 6 using Rubberizer at flow rate of 125 GPM.

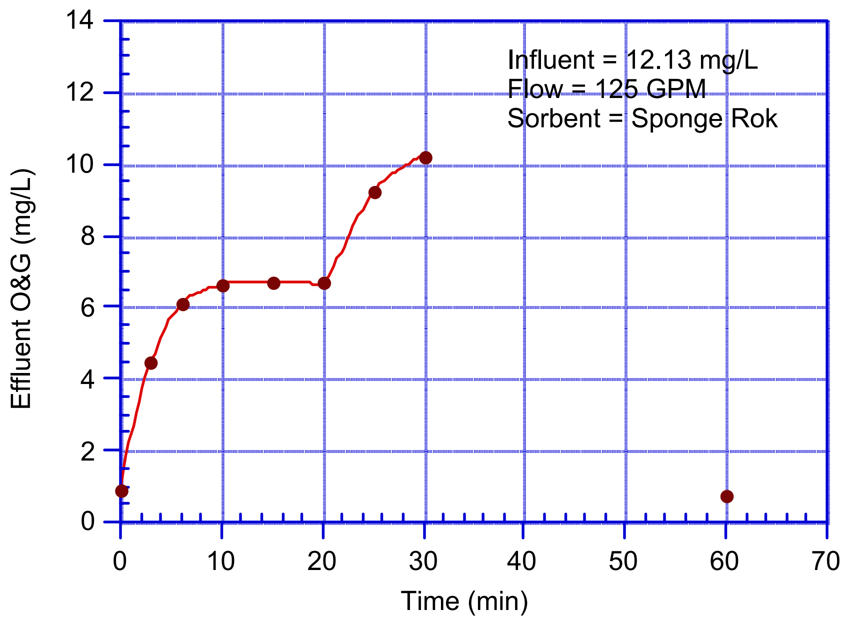

Figure 7. Test No. 7 using Sponge Rok at flow rate of 125 GPM.

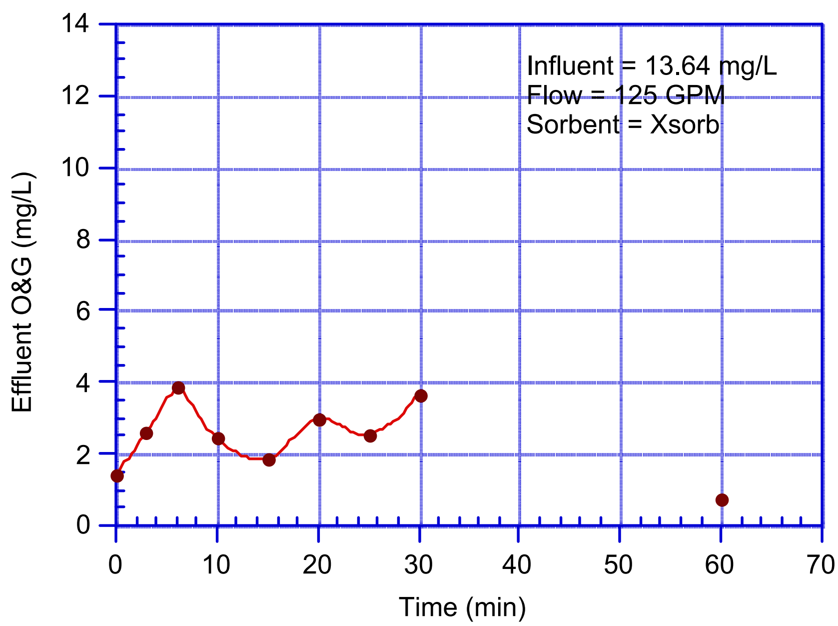

Figure 8. Test No. 8 using Xsorb at flow rate of 125 GPM.

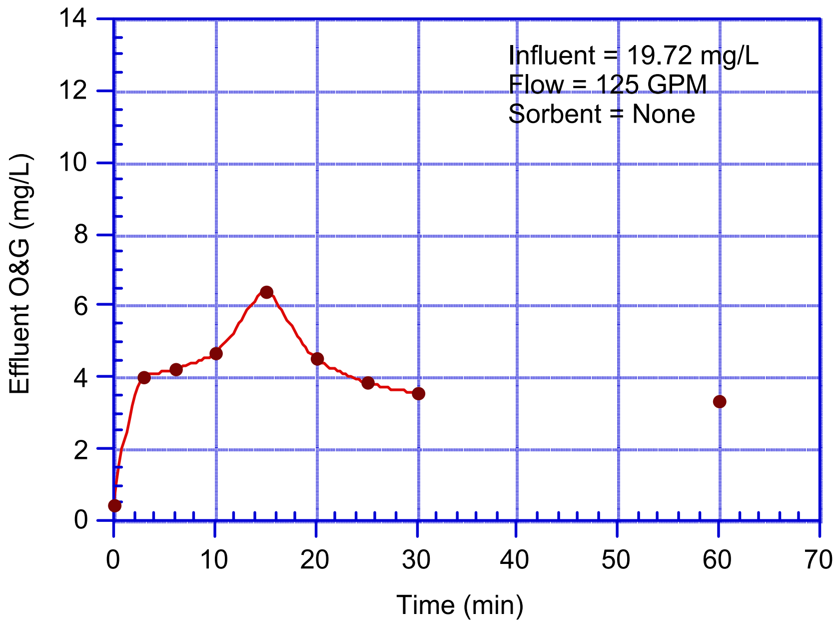

Figure 9. Test No. 9 using Xsorb at flow rate of 125 GPM.

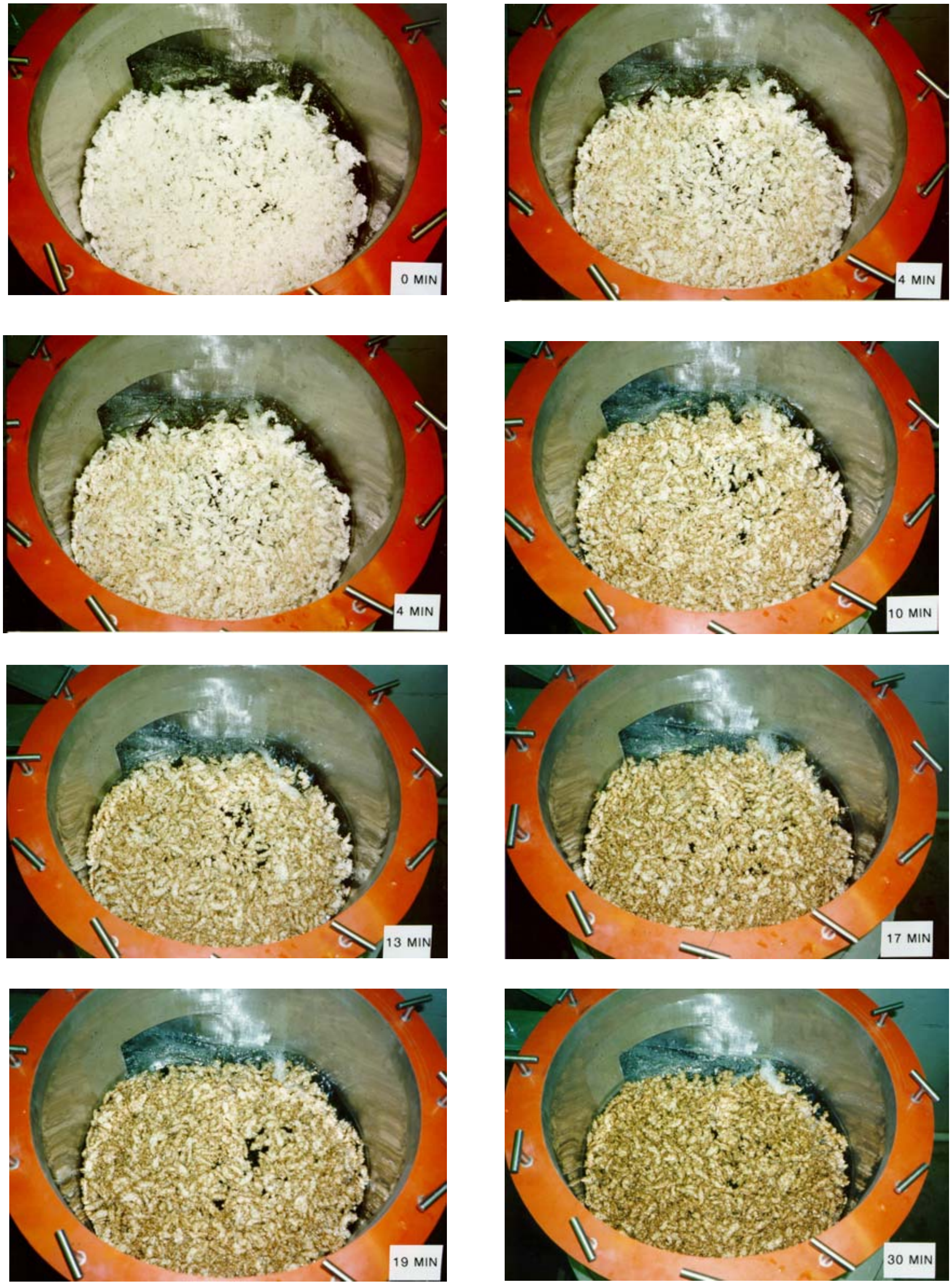

Figure 10. Oil and Grease sorption as a function of time (OARS sorbent, time series progression from 0, before oil and grease addition to 4, 7, 10, 13, 17, 19 and 30 minutes)

Figure 11. Electron microscope photograph of Nanofiber.

Conclusions and Recommendations

The short series of tests preformed in short project demonstrate that the combination of a CDS unit with sorbents can remove 80 to 90 of the oil and grease at concentrations typically found in stormwaters. The removal efficiencies are in the same range as removals obtained in sorbent columns evaluated in a recently completed study in our laboratory.

The results suggest that the combination is a promising alternative for stormwater treatment. This results in large part because of the CDS unit's previously demonstrated ability to remove trash, debris and suspended solids. These materials tend to clog column sorbers.

The choice of the best sorber is still an open question. The sorbers which traditionally have very high Q's (e.g. polypropylene fibers) may not be best in this application because of their tendency to float on top of the water and poorly mix with the influent (a large portion of these sorbents never contacts the oil and grease because it is above the liquid surface). None of the sorbents evaluated were saturated in these tests. Additionally testing must be performed to determine each sorbent's maximum capacity for this application.

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Appendix – Raw Data.

Test No.	Sorbent	Flow rate (GPM)	Time (min)	Sample vol. (ml)	O&G mass (mg)	O&G conc. (mg/L)	% Removal
1	Nanofiber	125	Influent	500	14.67	29.34	-
			0	515	0.02	0.04	-
			3	510	1.34	2.63	91.04
			6	510	6.26	12.27	58.16
			10	515	1.60	3.11	89.41
			15	500	1.51	3.02	89.71
			20	505	0.68	1.35	95.41
			25	500	1.09	2.18	92.57
			30	500	1.13	2.26	92.30
			60	500	0.04	0.08	-
2	OARS	125	Influent	510	9.98	19.57	-
			0	500	0.00	0.00	-
			3	520	1.21	2.33	88.11
			6	500	1.29	2.58	86.82
			9	520	1.51	2.90	85.16
			12	510	1.37	2.69	86.27
			16	510	1.32	2.59	86.77
			18	530	1.31	2.47	87.37
			22	520	1.55	2.98	84.77
			29	510	1.63	3.20	83.67
			35	510	3.72	7.29	62.73
			60	520	0.26	0.50	-
3	OARS	190	Influent	500	12.02	24.04	-
			0	500	0.36	0.72	-
			3	500	2.80	5.60	76.71
			6	500	1.44	2.88	88.02
			10	500	2.00	4.00	83.36
			15	500	1.88	3.76	84.36
			20	500	2.73	5.46	77.29
			25	500	2.45	4.90	79.62
			30	500	1.84	3.68	84.69
			38	500	0.42	0.84	-
4	OARS	75	Influent	1200	36.88	30.73	-
			0	500	0.60	0.12	-
			3	500	1.15	2.30	92.52
			6	500	1.21	2.42	92.13
			10	500	1.13	2.26	92.65
			15	500	0.77	1.54	94.99

Test No.	Sorbent	Flow rate (GPM)	Time (min)	Sample vol. (ml)	O&G mass (mg)	O&G conc. (mg/L)	% Removal
			20	500	0.57	1.14	96.29
			25	500	0.57	1.14	96.29
			30	500	0.67	1.34	95.64
			38	500	0.34	0.68	-
5	OARS	125	Influent	500	10.52	21.04	-
			0	500	0.26	0.52	-
			5	500	1.53	3.06	85.46
			15	500	1.38	2.76	86.88
			30	500	1.80	3.60	82.89
			45	500	1.76	3.52	83.27
			60	500	1.62	3.24	84.60
			75	500	1.91	3.82	81.84
			90	500	2.01	4.02	80.89
			123	500	2.00	4.00	80.99
6	Rubberizer	125	Influent	1000	27.21	27.21	-
			0	500	0.00	0.00	-
			3	500	2.08	4.16	84.71
			6	500	3.10	6.20	77.21
			10	500	1.57	3.14	88.46
			15	500	1.96	3.92	85.59
			20	500	1.56	3.12	88.53
			25	510	1.39	2.73	89.98
			30	510	2.06	4.04	85.16
			60	505	0.99	1.96	-
7	Sponge Rok	125	Influent	1000	12.13	12.13	-
			0	500	0.46	0.92	-
			3	500	2.24	4.48	63.07
			6	500	3.05	6.10	49.71
			10	500	3.32	6.64	45.26
			15	500	3.36	6.72	44.60
			20	500	3.34	6.68	44.93
			25	500	4.60	9.20	24.15
			30	500	5.11	10.22	15.75
			60	500	0.37	0.74	-
8	Xsorb	125	Influent	500	6.82	13.64	-
			0	500	0.7	1.40	-
			3	520	1.35	2.60	80.97
			6	500	1.95	3.90	71.41
			10	500	1.22	2.44	82.11

Test No.	Sorbent	Flow rate (GPM)	Time (min)	Sample vol. (ml)	O&G mass (mg)	O&G conc. (mg/L)	% Removal
			15	500	0.93	1.86	86.36
			20	500	1.49	2.98	78.15
			25	500	1.27	2.54	81.38
			30	500	1.84	3.68	73.02
			60	500	0.37	0.74	-
9	None	125	Influent	500	9.86	19.72	-
			0	500	0.24	0.48	-
			3	505	2.03	4.02	79.62
			6	500	2.11	4.22	78.60
			10	500	2.33	4.66	76.37
			15	500	3.19	6.38	67.65
			20	500	2.28	4.56	76.88
			25	510	1.97	3.86	80.41
			30	500	1.79	3.58	81.85
			60	520	1.74	3.35	-

Appendix F

Example

Site Specific Operations and Maintenance Manual

Operation & Maintenance Manual
Kohl's
Vancouver, WA.


CDS Technologies, Inc.
PO Box 11305
755 NE Columbia Blvd.
Portland, OR 97211
503-240-3529
503-978-3742 fax

TECHNOLOGIES

OPERATIONS AND MAINTENANCE GUIDELINES
For the CDS Technologies Models PMSU, PSW & PSWC
CONTINUOUS DEFLECTIVE SEPARATION UNIT
Located at

Kohl's
Vancouver, WA

INTRODUCTION

The CDS unit is an important and effective component of your storm water management program and proper operation and maintenance of the unit are essential to demonstrate your compliance with local, state and federal water pollution control requirements.

The CDS technology features a patented non-blocking, indirect screening technique developed in Australia to treat water runoff. The unit is highly effective in the capture of suspended solids, fine sands and larger particles. Because of its non-blocking screening capacity, the CDS unit is un-matched in its ability to capture and retain gross pollutants such as trash and debris. In short, CDS units capture a very wide range of organic and in-organic solids and pollutants that typically result in tons of captured solids each year: total suspended solids (TSS), sediments, oil and greases and captured trash and debris (including floatables, neutrally buoyant, and negatively buoyant debris) under very high flow rate conditions.

CDS units are equipped with conventional oil baffles to capture and retain oil and grease. Laboratory evaluations show that the CDS units are capable of capturing up to 70% of the free oil and grease from storm water. CDS units can also accommodate the addition of oil sorbents within their separation chambers. The addition of the oil sorbents can ensure the permanent removal of 80% to 90% of the free oil and grease from the storm water runoff.

OPERATIONS

The CDS unit is a non-mechanical self-operating system and will function any time there is flow in the storm drainage system. The unit will continue to effectively capture pollutants in flows up to the design capacity even during extreme rainfall events when the design capacity may be exceeded. Pollutants captured in the CDS unit's separation chamber and sump will be retained even when the units design capacity is exceeded.

CDS UNIT CLEANOUT

The frequency of cleaning the CDS unit will depend upon the generation of trash and debris and sediments in your application. Cleanout and preventive maintenance schedules will be determined based on operating experience unless precise pollutant loadings have been determined. The unit should be periodically inspected to determine the amount of accumulated pollutants and to ensure that the cleanout frequency is adequate to handle the predicted pollutant load being processed by the CDS unit. The recommended cleanout of solids within the CDS unit's sump should occur at 75% of the sump capacity. However, the sump may be completely full with no impact to the CDS unit's performance.

Access to the CDS unit is typically achieved through two manhole access covers – one allows inspection and cleanout of the separation chamber (screen/cylinder) & sump and another allows inspection and cleanout of sediment captured and retained behind the screen. The PSW & PSWC off-line models have an additional access cover over the weir of the diversion vault. For units possessing a sizable depth below grade (depth to pipe), a single manhole access point would allow both sump cleanout and access behind the screen.

CDS Technologies Recommends The Following:

NEW INSTALLATIONS – Check the condition of the unit after every runoff event for the first 30 days. The visual inspection should ascertain that the unit is functioning properly (no blockages or obstructions to inlet and/or separation screen), measuring the amount of solid materials that have accumulated in the sump, the amount of fine sediment accumulated behind the screen, and determining the amount floating trash and debris in the separation chamber. This can be done with a calibrated “dip stick” so that the depth of deposition can be tracked. Refer to **Appendix A – Annual Record of Maintenance & Cleanout Elevation View** for allowable deposition depths and critical distances. Schedules for inspections and cleanout should be based on storm events and pollutant accumulation.

ONGOING OPERATION – During the rainfall season, the unit should be inspected at least once every 30 days. The floatables should be removed and the sump cleaned when the sump is 75-85% full. If floatables accumulate more rapidly than the settleable solids, the floatables should be removed using a vactor truck or dip net before the layer thickness exceeds one to two feet.

Cleanout of the CDS unit at the end of a rainfall season is recommended because of the nature of pollutants collected and the potential for odor generation from the decomposition of material collected and retained. This end of season cleanout will assist in preventing the discharge of pore water from the CDS® unit during summer months.

USE OF SORBENTS – It needs to be emphasized that the addition of sorbents is not a requirement for CDS units to effectively control oil and grease from storm water. The conventional oil baffle within a unit assures satisfactory oil and grease removal. However, the addition of sorbents is a unique enhancement capability special to CDS units, enabling increased oil and grease capture efficiencies beyond that obtainable by conventional oil baffle systems.

Under normal operations, CDS units will provide effluent concentrations of oil and grease that are less than 15 parts per million (ppm) for all dry weather spills where the volume is less than or equal to the spill capture volume of the CDS unit. During wet weather flows, the oil baffle system can be expected to remove between 40 and 70% of the free oil and grease from the storm water runoff.

CDS Technologies only recommends the addition of sorbents to the separation chamber if there are specific land use activities in the catchment watershed that could produce exceptionally large concentrations of oil and grease in the runoff, concentration levels well above typical amounts. If site evaluations merit an increased control of free oil and grease then oil sorbents can be added to the CDS unit to thoroughly address these particular pollutants of concern.

Recommended Oil Sorbents

Rubberizer® Particulate 8-4 mesh or OARS™ Particulate for Filtration, HPT4100 or equal. Rubberizer® is supplied by Haz-Mat Response Technologies, Inc. 4626 Santa Fe Street, San Diego, CA 92109 (800) 542-3036. OARS™ is supplied by AbTech Industries, 4110 N. Scottsdale Road, Suite 235, Scottsdale, AZ 85251 (800) 545-8999.

The amount of sorbent to be added to the CDS separation chamber can be determined if sufficient information is known about the concentration of oil and grease in the runoff. Frequently the actual concentrations of oil and grease are too variable and the amount to be added and frequency of cleaning will be determined by periodic observation of the sorbent. As an initial application, CDS recommends that approximately 4 to 8 pounds of sorbent material be added to the separation chamber of the CDS units per acre of parking lot or road surface per year. Typically this amount of sorbent results in a ½ inch to one (1”) inch depth of sorbent material on the liquid surface of the separation chamber. The oil and grease loading of the sorbent material should be observed after major storm events. Oil Sorbent material may also be furnished in pillow or boom configurations.

The sorbent material should be replaced when it is fully discolored by skimming the sorbent from the surface. The sorbent may require disposal as a special or hazardous waste, but will depend on local and state regulatory requirements.

CLEANOUT AND DISPOSAL

A vactor truck is recommended for cleanout of the CDS unit and can be easily accomplished in less than 30-40 minutes for most installations. Standard vactor operations should be employed in the cleanout of the CDS unit. Disposal of material from the CDS unit should be in accordance with the local municipality’s requirements. Disposal of the decant material to a POTW is recommended. Field decanting to the storm drainage system is not recommended. Solids can be disposed of in a similar fashion as those materials collected from street sweeping operations and catch-basin cleanouts.

MAINTENANCE

The CDS unit should be pumped down at least once a year and a thorough inspection of the separation chamber (inlet/cylinder and separation screen) and oil baffle performed. The unit’s internal components should not show any signs of damage or any loosening of the bolts used to fasten the various components to the manhole structure and to each other. Ideally, the screen should be power washed for the inspection. If any of the internal components is damaged or if any fasteners appear to be damaged or missing, please contact CDS Technologies to make arrangements to have the damaged items repaired or replaced:

CDS Technologies, Inc.
16360 Monterey Road, Suite 250
Morgan Hill, CA 95037-5406

Phone, Toll Free: (888) 535-7559
Fax: (408) 782-0721

The screen assembly is fabricated from Type 316 stainless steel and fastened with Type 316 stainless steel fasteners that are easily removed and/or replaced with conventional hand tools. The damaged screen assembly should be replaced with the new screen assembly placed in the same orientation as the one that was removed.

CONFINED SPACE

The CDS unit is a confined space environment and only properly trained personnel possessing the necessary safety equipment should enter the unit to perform maintenance or inspection procedures. Inspections of the internal components can, in most cases, be accomplished through observations from the ground surface.

RECORDS OF OPERATION AND MAINTENANCE

CDS Technologies recommends that the owner maintain annual records of the operation and maintenance of the CDS unit to document the effective maintenance of this important component of your storm water management program. The attached **Annual Record of Operations and Maintenance** form (see **Appendix A**) is suggested and should be retained for a minimum period of three years.

Date: 11/30/2005

Project: Kohl's

Subject: Maintenance Pump Volume – Replacement Oil Sorbent Quantity

Location: Vancouver, WA

CDS Model Number: PMSU30_30 (1)

The CDS PMSU30_30, 3.0 unit installed at the Kohl's project in Vancouver, WA is designed with 6.41 cubic yards (173 cubic feet) (1295 gallons) of storage volume. This volume includes the pounds of sediments that will settle inside of the sump, fine sediment on the separation slab, trash and debris along with the water. Once the unit is maintained the above listed volume of water should be added to the cleaned unit to prepare for treatment of the next storm event.

If oil sorbent material is to be used in this unit, 36 sorbent booms are recommended to be installed inside the fiberglass cylinder on the water surface. This material will provide 80% removal of floatable oil and grease in storm water at an average concentration of 15 ppm. It is recommended that booms are replaced more frequently if higher oil and grease loadings occur.

Please contact CDS Technologies to coordinate ordering new oil sorbent material or see page 3 of this manual for manufacturers of the sorbent material if you wish to order it direct.

APPENDIX A

ANNUAL RECORD OF

OPERATIONS AND MAINTENANCE

&

CLEANOUT ELEVATION VIEW
(PROJECT SPECIFIC)

CDS TECHNOLOGIES

ANNUAL RECORD OF

OPERATION AND MAINTENANCE

OWNER ____

ADDRESS ____

OWNER REPRESENTATIVE ____________________ **PHONE** ____________________

INSTALLATION:

MODEL DESIGNATION ____________________ **DATE** ____________

SITE LOCATION ____

INSPECTIONS:

DATE/ INSPECTOR	SCREEN/INLET INTEGRITY	FLOATABLES DEPTH	DEPTH TO SEDIMENT (inches)	SEDIMENT VOLUME* (CUYDS)	SORBENT DISCOLORATION

DEPTH FROM COVER TO BOTTOM OF SUMP (SUMP INVERT) ________________

DEPTH FROM COVER TO SUMP @ 75% FULL ________________________

VOLUME OF SUMP @ 75% FULL = 1.57 **CUYD**

VOLUME/INCH DEPTH 2.36 **CUFT/IN OF SUMP**

VOLUME/FOOT DEPTH 1.04 **CUYD/FT OF SUMP**

1,410 gals = VOLUME OF LIQUID & SOLIDS IN UNIT TO BE VACUUMED

***Calculate Sediment Volume = (Depth to Sump Invert – Depth to Sediment)*(Volume/inch)**

OBSERVATIONS OF FUNCTION: ____

____

____

CLEANOUT:

DATE	VOLUME FLOATABLES	VOLUME SEDIMENTS	METHOD OF DISPOSAL OF FLOATABLES, SEDIMENTS, DECANT AND SORBENTS

OBSERVATIONS:

____

____

____

____

SCREEN MAINTENANCE:

DATE OF POWER WASHING, INSPECTION AND OBSERVATIONS:

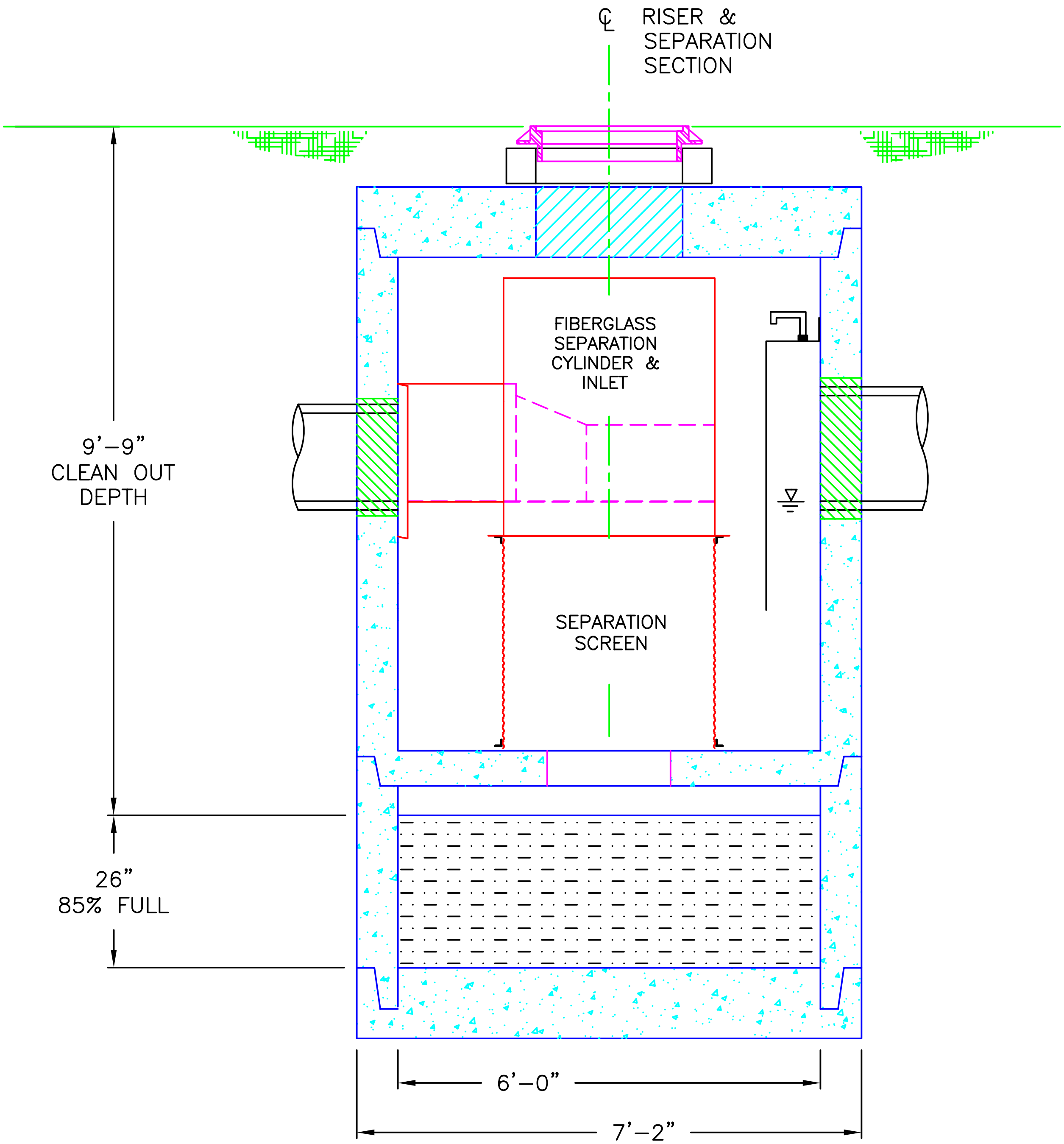
____

____

CERTIFICATION: ______________ **TITLE:** ____________ **DATE:** ________

CLEAN OUT VIEW

CDS MODEL PMSU30_30 3.0 CFS CAPACITY
STORM WATER TREATMENT UNIT



KOHL'S
VANCOUVER, WA

DATE	10/03/05	SCALE	1"=3'
DRAWN	MB	SHEET	C1
APPROV.			

CDS™ TECHNOLOGIES
PATENTED

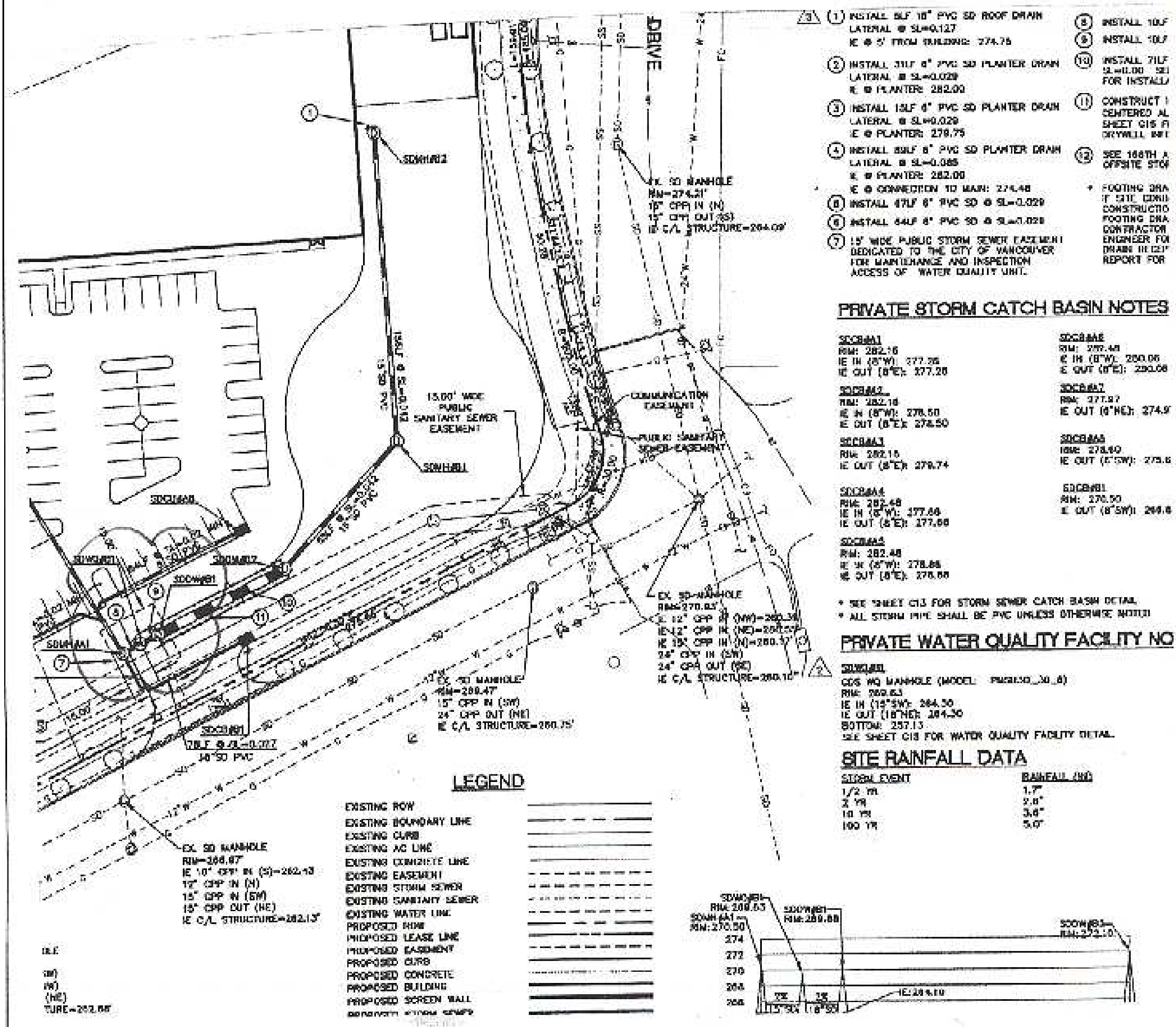
APPENDIX B

SITE LOCATION PLANS

(PROJECT SPECIFIC)

SITE PLAN VIEW

CDS MODEL PMSU30_30 3.0 CFS CAPACITY STORM WATER TREATMENT UNIT



CDS TECHNOLOGIES™ PATENTED	KOHL'S VANCOUVER, WA	DATE 10/03/05	SCALE 1"=3'
		DRAWN MB	SHEET
		APPROV.	S1

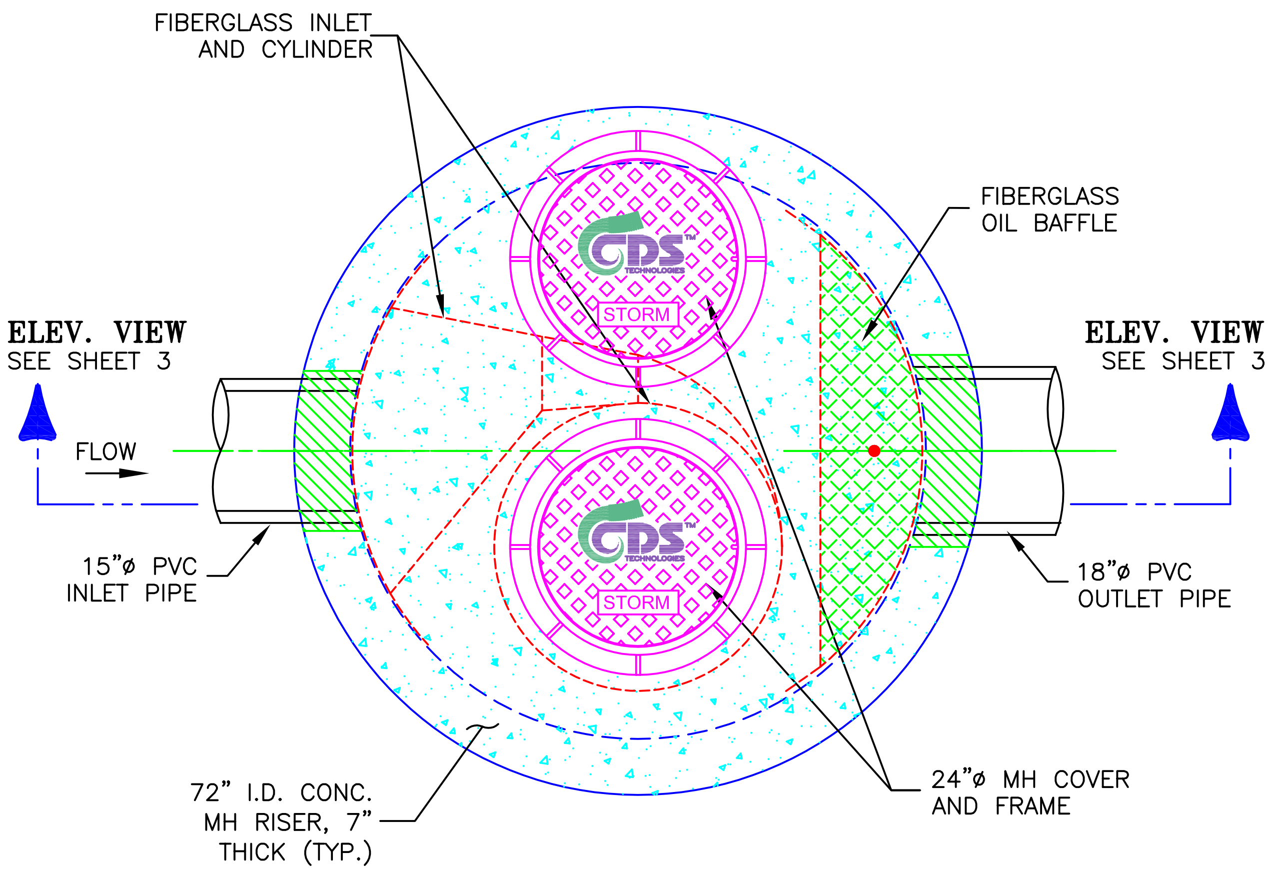
APPENDIX C

PLAN & PROFILE DRAWINGS

(PROJECT SPECIFIC)

PLAN VIEW

CDS MODEL PMSU30_30, 3.0 CFS CAPACITY STORM WATER TREATMENT UNIT

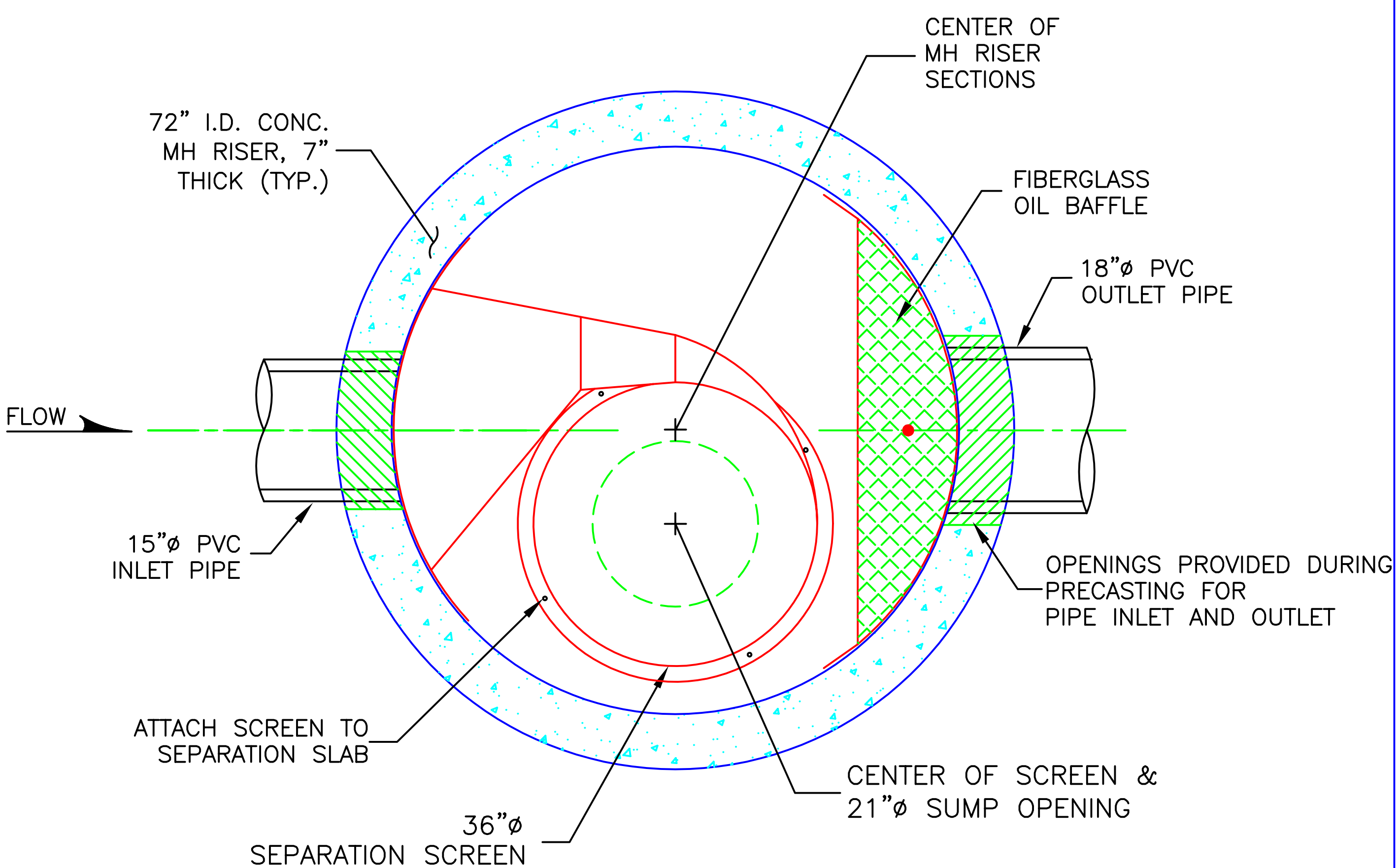


NOTE: CDS UNIT COMES COMPLETE WITH FIBERGLASS INLET/DIVERSION STRUCTURE, OIL BAFFLE AND SCREEN CYLINDER PRE-INSTALLED.

CDS TECHNOLOGIES™ PATENTED	KOHL'S VANCOUVER, WA	DATE 10/03/05	SCALE 1"=2'
		DRAWN MB	SHEET 1
		APPROV.	

SECTION CUT

CDS MODEL PMSU30_30, 3.0 CFS CAPACITY
STORM WATER TREATMENT UNIT

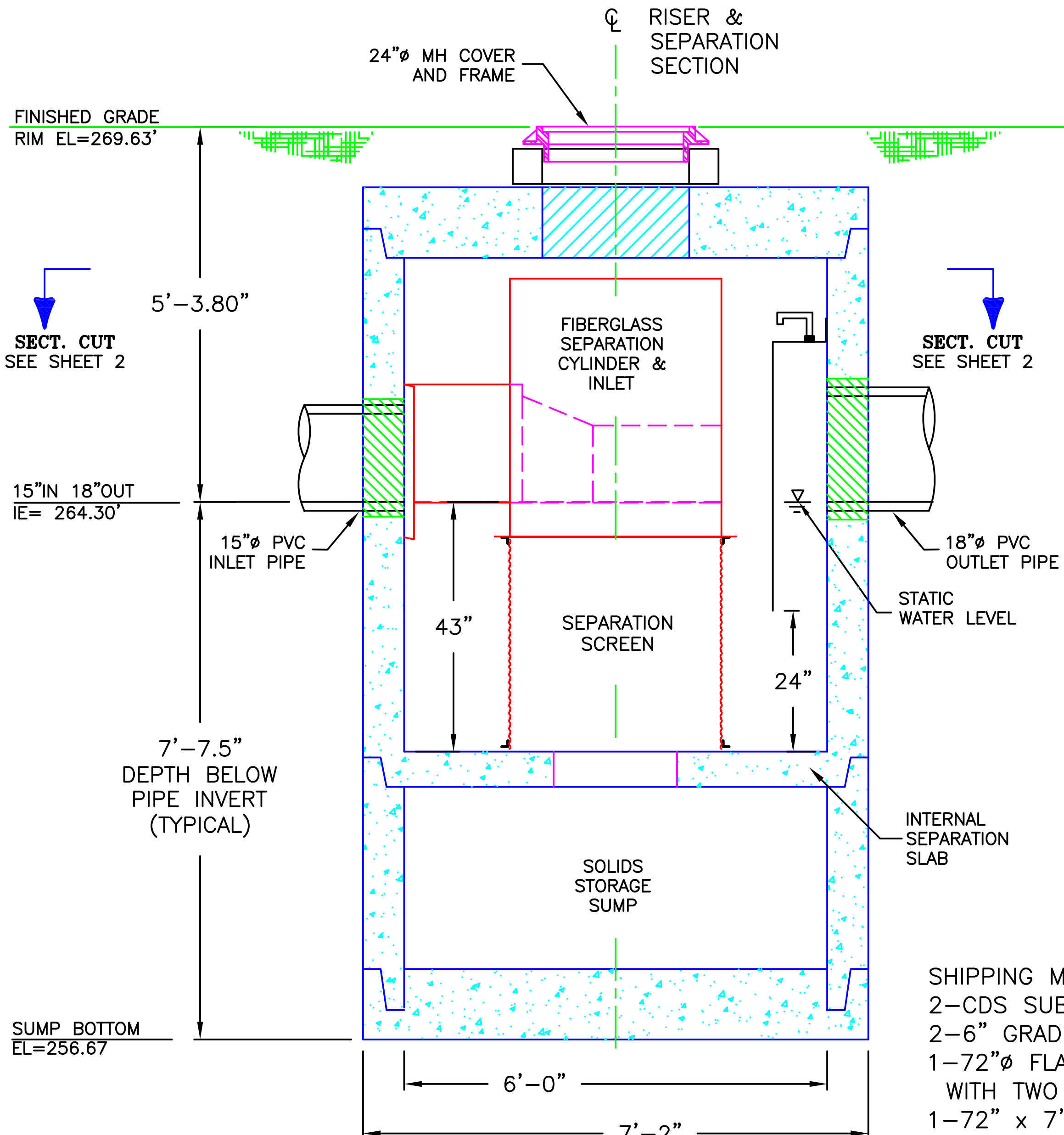


NOTE: CDS UNIT COMES COMPLETE WITH FIBERGLASS INLET/DIVERSION STRUCTURE, OIL BAFFLE AND SCREEN CYLINDER PRE-INSTALLED.

CDS TECHNOLOGIES™ PATENTED	KOHL'S VANCOUVER, WA	DATE 10/03/05	SCALE 1"=2'
		DRAWN MB	SHEET 2
		APPROV.	

ELEVATION VIEW

CDS MODEL PMSU30_30 3.0 CFS CAPACITY STORM WATER TREATMENT UNIT



SHIPPING MATERIAL:
2–CDS SUB F&C'S
2–6" GRADE RINGS
1–72"ø FLAT CAP
WITH TWO 25"ø ACCESS
1–72" x 7'–6" RUBBER
GASKET SECT
W/SEPARATION
SLAB & HOLES
1–72" x 3'–0"
BASE
1–72" RUBBER GASKET
1–SMALL PIPE SLICK

NOTE:

CDS UNIT COMES COMPLETE WITH FIBERGLASS INLET/DIVERSION STRUCTURE, OIL BAFFLE AND SCREEN CYLINDER PRE–INSTALLED.

CDS TECHNOLOGIES™ PATENTED

KOHL'S
VANCOUVER, WA

DATE	10/03/05	SCALE 1"=3'
DRAWN	MB	SHEET 3
APPROV.		

Appendix G

Field Studies of CDS Unit Performance

THE USE OF A CDS UNIT FOR SEDIMENT CONTROL IN BREVARD COUNTY

Justin Strynchuk, John Royal and Gordon England, P.E.
Brevard County Surface Water Improvement
2725 Judge Fran Jamieson Way, Suite A203
Viera, FL 32940
(407) 633-2014

EXECUTIVE SUMMARY

In July 1997, Brevard County's Stormwater Utility Program installed a new type of trash and sedimentation control device called a CDS unit. This was the first American installation using the continuous deflection separation (CDS) technology developed in Australia. This location served a drainage basin of 24.87 hectares (62.45 acres) of mixed industrial, commercial, and vacant land. Over an 18 month period 5 storm events were monitored for 6 parameters: pH, TSS, BOD, COD, turbidity, and Total Phosphorus. In addition, sediment samples were collected and tested for 61 parameters.

Sampling was accomplished using autosamplers placed upstream and downstream of the CDS unit. The first three storms were monitored using flow weighted composite samples and the last two used discrete samples. This sampling program proved to be quite a challenge for the personnel relatively inexperienced in the use of autosamplers and stormwater sampling techniques. The lessons learned in monitoring techniques are discussed in detail and illustrate the difficulty in evaluating new technologies.

Sediment sampling showed no significant accumulations of hydrocarbons or heavy metals. In fact, few of the sampled parameters were above detectable limits. The stormwater samples showed a wide range of removal efficiencies; most of which could be explained by problems with equipment failure or improper equipment set up. It is estimated that the CDS unit provided an average of 52% removal efficiency for total suspended solids and 31% removal efficiency for phosphorus.

INTRODUCTION

Stormwater sedimentation is a primary source of pollution to the Indian River Lagoon in Brevard County, Florida. The Indian River Lagoon is an estuary of National Significance and is part of the National Estuary Program. Pollutants targeted in the Lagoon by the State of Florida's TMDL program are suspended solids, phosphorus, and nitrogen. Suspended solids and turbidity reduce sunlight penetration in the Lagoon which negatively impacts seagrass growth. Phosphorus and nitrogen are nutrients which promote algae growth and reduce oxygen levels in the Lagoon.

Sediment traps such as the CDS unit are principally designed to reduce suspended solids and floating trash. Typically about 30% of phosphorus in stormwater loadings is in particulate form and can be removed with suspended solids. The remaining 70% of the phosphorus, as well virtually all of the nitrogen forms, are dissolved and are not effectively treated by sediment traps. Where land is available, properly designed detention ponds can often provide the 80% removal of suspended solids from stormwater flows which is targeted by State of Florida standards. When retrofitting existing development and land is not available for a pond, alternative, less effective, treatment methods must be used. Brevard County has pioneered the use of several innovative sediment devices and wished to compare the CDS unit with other types of devices.

The CDS technology was initially developed in Australia to provide an effective method for trash and solids removal from stormwater flows. The screening action within the unit provides for 100% removal of trash and particles down to 4700 microns. In addition, the unique circular design creates centrifugal action within the round concrete box which propels suspended solids to the center of the box and down into the storage chamber.

METHODS

The location chosen for the CDS unit installation is along a ditch at the north end of Brentwood Drive, north of Cocoa and close to the Indian River. The drainage basin for this location is 24.87 hectares (61.45 acres) in area. This basin has Type A soils along a sand ridge. The land uses are: 24.87 hectares (6.7 acres) of roadway (US Highway 1), 8.04 hectares (19.87 acres) of industrial park, 9.47 hectares (23.39 acres) of vacant land, and 4.65 hectares (11.49 acres) of commercial property. The industrial area has a permitted stormwater system. A significant land feature is a 2.02 hectares (5 acre) dirt parking lot, 152 meters (500 feet) upstream of the site adjacent to the Corky Bells restaurant. This parking lot has a steep slope and is composed of fine white base material. There is evidence of heavy silt buildup in the inlets and pipes downstream of this parking lot along US 1.

There is an earthen ditch running eastward 76 meters (250 feet) upstream from the project location. At the project site there is an existing 122 centimeter (48 inch) RCP driveway culvert in the ditch which discharges to a concrete channel running 152 meters (500 feet) eastward to the Indian River. The time of concentration to the site is 63 minutes, with a 10 year flow of 1,557 L/sec (55 cfs) and mean annual flow of 1,177 L/s (38.2 cfs). In Brevard County, the 10 year storm is 20.1 centimeters (7.9 inches) of rainfall and the mean annual storm is 13.97 centimeters 5.5 inches) of rainfall. There is no base flow at this location.

A diversion weir 68.58 centimeters (27 inches) tall was placed in front of the 122 centimeter (48 inch) culvert giving and off-line design which effectively diverted flows under 254 L/sec (9 cfs) through the CDS unit. In 18 months of observations the water level rose over the weir one time. A 76.2 centimeter (30 inch) concrete pipe was constructed adjacent to the existing 122 centimeter pipe in order to transport the diverted flows to the CDS unit. The 76.2 centimeter pipe enters the CDS unit tangentially to the round chamber to start the circular flow within the unit.

The CDS unit consists of three (3) circular, concrete chambers stacked on top of each other. The top chamber, where the water enters the unit, has a 1.524 meter (5 feet) inner diameter and is 188 centimeters (74 inches) tall. The middle chamber has a 2.44 meter (8 feet) inner diameter and is 127.54 centimeters (51 inches) tall. In the middle chamber is a 1.524 meter (5 foot) diameter stainless steel screen matching the walls of the top chamber. The screen has 4700 micron holes to filter larger materials. The bottom chamber has a 1.22 meter (4 feet) inner diameter by a 1.22 meter (4 feet) tall sediment sump.

Water enters the unit in a clockwise rotation. When the water passes through the screen it then flows counter clockwise between the screen and outer wall until it reaches a 76.2 centimeter (30 inch) concrete pipe. This exit pipe is again tangentially placed for smooth exit flows. The elevation of the exit pipe rises 96.52 centimeters (38 inches) from the lower chamber to the outflow channel downstream of the 122 centimeter (48 inch) culvert. This rise in elevation keeps the normal water level in the unit near the top of the 2nd chamber at all times. There is no base flow at this location.

The top of the unit is flush with the surrounding ground and has a 0.91 meter (3 foot) square, lockable, stainless steel access cover. This feature allows for easy access with a vacuum truck for cleaning purposes.

The CDS unit was installed on July 17, 1997 at a cost of approximately $55,000. Installation took two (2) days with the precast structures. A large crane was required to lift the chambers into place. A 4.57 meter (15 foot) deep hole was excavated to place the structure in.

In conjunction with the CDS unit installation, County personnel cleaned the ditch upstream of the unit. Two (2) days latter a significant rainfall event occurred and 2,294 kilograms (6,600 pounds) of sediment from the upstream ditch were trapped in the unit. After that storm the ditch was reworked and sod was laid. The sod greatly reduced the volume of sediment washing into the unit.

Cleanouts were also performed on November 17, 1997, with 626.84 kilograms (1382 pounds) of sediment and 2.88 meters (34 cubic feet) of trash and debris, and again on May 6, 1998 with 998 kilograms (2200 pounds) of sediment. The solids removed from unit are taken to the Brevard County landfill for disposal. The volume of water stored in the unit is greater than the vacuum truck capacity so decanting is performed on nearby sandy soils to avoid a second trip to the landfill for disposal.

All samples, associated blanks, and duplicates were collected in accordance with Brevard County's state certified Comprehensive Quality Assurance Plan and with the EPA NPDES Stormwater Sampling Guidance Document (July 1992).

Rainfall observations illustrate the extremely localized nature of storm events in Brevard County. The CDS unit is located about 50 meters from the Indian River. It is common for storm cells to move in from the west in the afternoon as the land mass heats up. These cells often stall out as they reach the cooler river and do not move eastward to the barrier island. Only a few acres of the drainage basin are immediately north or south of the CDS unit. The remaining drainage basin is located a few hundred meters west of the CDS unit, on the other side of US 1. A rain gauge is located at the CDS site. This gauge usually did not show enough rain falling to trip the autosampler. About 1.6 kilometers north of the site was another gauge at the Orlando Utilities Commission (OUC) power plant. The rainfall records from the OUC gauge typically showed 2-3 times as much rainfall as at the CDS site. These rainfall records more closely matched the recorded flow rates in the autosamplers. Another rain gauge 7.2 kilometers south of the CDS site was used for some of the storm events, and it showed different rates than either of the other two sites. Therefore the amount of rainfall which fell in the 24.87 hectare drainage basin is unknown for this report. A more accurate measure used for these samples is the maximum flow rate recorded by the autosamplers.

DATA

An in depth discussion of each of the 5 storm events sampled is provided below. A comparison of the sample results is provided in the RESULTS section.

STORM #1

Storm samples were collected at the CDS unit on April 20, 1998. This storm event was captured after a dry period of approximately 25 days, or dry since March 25, 1998. Rainfall was not recorded at the immediate site, however, a gauge at the Orlando Utilities Commission (OUC) power generating plant 5.6 kilometers to the north, registered rainfall of 0.10 inch on that day (FDEP Shellfish Assessment data).

Water levels were recorded during this storm event on two ISCO flowmeters with bubbler tubes both mounted on the 90-degree notch inlet weir. The recorded levels were correlated to flow, and the samples were manually composited to give a flow-weighted composite sample from each sampler. Maximum flow recorded during this storm was approximately 87 GPM. The recorded flow from this storm lasted approximately 67 minutes after the trigger point of two inches over the weir was reached.

Both sample sets were composited identically, in accordance with the EPA NPDES Stormwater Sampling Guidance Document (July 1992), and the laboratory results are presented in Table 1.

CDS Storm # 1 Water Quality Analysis

Site: CDS Storm 1	pH SU	Total Suspended Solids mg/l	Turbidity NTU	BOD5-Day mg/l	COD mg/l	Total Phosphorous mg/l
CDS Inlet	7.6	220	180	28	150	1.4
CDS Outlet	7.4	110	100	23	110	1
Change	0.2	100	80	5	40	0.4
Percent Reduction	**3%**	**50%**	**44%**	**18%**	**27%**	**29%**

Table 1

Field observations were also made of the appearance of the sample jars, each containing a water sample which had been collected at progressive ten-minute intervals throughout the storm.

On the intake side of the CDS unit, the following observations were made:

- Sample jar #1 water was highly colored, but was not considered turbid,
- Samples 2-12 of the same unit were considered to be uniformly turbid ("milky"),
- Samples 9-12 also had a slight, uniform amount of fine sediment on their bottoms

Of the outflow samples, the following observations were made:

- Sample #1 was highly colored but not turbid,
- Sample #2 was also colored and slightly turbid ("milky"),
- Sample # 3 was noticeably more turbid than #2, and still slightly colored,
- A much more gradual progression through samples 4-12 towards being more turbid and less colored.
- All outlet samples appeared to be less turbid than the corresponding inlet samples, and also had less sediment on their bottoms.

An observation was made of the water surface inside the CDS unit proper. There appeared to be a thick layer of floating grass and other vegetation, an oil sheen, glass and plastic bottles, plastic sheets and bits, seeds and nuts, sticks, a turtle, and a surprising amount of Styrofoam cups and particles. It was quite impressive to think that this trash would have been washed out into the lagoon during a normal rain (though the collection time since cleanout was undetermined at this observation) prior to installation of this BMP.

STORM #2

The second storm samples were collected at the CDS unit on May 1, 1998 utilizing the same setup and procedures as the first event. This storm event was captured after a dry period of approximately 11 days, or dry since April 20, 1998. Rainfall was recorded at the site as being 0.03 inches, while at a gauge at the OUC power plant recorded 0.70 inches for this storm event.

As with the previous sample event, water levels were recorded during this storm event by two ISCO flowmeters with bubbler tubes both mounted on the 90-degree notch inlet weir. The recorded levels correlated to flow, and the samples manually composited to give a flow-weighted composite sample from each sampler. Maximum flow recorded during this storm was approximately 133 gpm. The recorded flow from this storm lasted approximately 68 minutes after the trigger point of two inches over the weir was reached. The results are shown in Table 2.

CDS Storm # 2 Water Quality Analysis

Site: CDS STORM 2	pH SU	Total Suspended Solids mg/l	Turbidity NTU	BOD5-Day mg/l	COD mg/l	Total Phosphorous mg/l
CDS Inlet	8.4	350	440	8.2	20	0.86
CDS Outlet	8.2	350	340	8.2	20	0.86
Change	0.2	0	100	0	0	0
Percent Reduction	**2%**	**0%**	**23%**	**0%**	**0%**	**0%**

Table 2

While turbidity showed a 23% reduction, the other parameters showed no reduction during this storm. It was suspected that equipment error was to blame for these unexpected results and this data set was not used.

Field observations were also made of the appearance of the sample jars, each containing a water sample, which had been collected at progressive ten-minute intervals throughout the storm flow. There was no apparent difference in the color, or sediment accumulation in the sample jars of water in either of the samplers, nor in any of the bottles collected within each sampler during the course of the storm.

An observation was made of the water surface inside the CDS unit proper. There appeared to be a thick layer of floating grass and other vegetation, an oil sheen, glass and plastic bottles, plastic sheets and bits, seeds and nuts, sticks, a turtle, and a surprising amount of Styrofoam cups and particles.

STORM #3

Background

It was intended that the third sample event would include a mass balance calculation. The CDS unit sump was thoroughly cleaned utilizing a VAC-truck to assure that the material collected was a result of the one storm to be evaluated. Inlet and outlet stormwater composite samples were again collected, with the addition of a sediment and water column sample from the sump.

A visual inspection of the unit a week later revealed that the unit had not been filling with groundwater, and was well sealed.

The third storm samples were collected from the CDS unit on July 7. This storm event was captured after a dry period of approximately 65 days, or dry since May 1, 1998. Rainfall was recorded at the site as being 0.5 inches, while a gauge approximately 3.5 miles to the north (OUC power plant) recorded 1.60 inches for this storm event.

Methodology

In addition to a composite sample from each of the upstream and downstream samplers, a grab sample was taken from mid-depth in the CDS sump, and a composited sediment sample was taken from the sump bottom. Water levels were recorded during this storm event on two ISCO flowmeters with bubbler tubes. The upstream, or intake flowmeter bubble tube was mounted on the 90-degree notch inlet weir as it was for previous sample events. The downstream bubbler however was moved and attached to the downstream discharge pipe. This change was necessary to account for the lag time between when the first sampler received flow (at the beginning of the storm) the time required to fill the sump. (approximately 2144 gallons) and discharge to occur providing flow past the second sampler several minutes later. The upstream sampler was set to trigger at two inches of water over the weir, while the downstream bubbler was set to trigger at one inch above the strainer. While the upstream intake was clean before the storm, it was sanded over after the storm. This condition was a possible source of error in the samples taken.

Observations

Field observations and photographs were also made of the sample's appearance in the jars, each (with the exception of the missed sample) containing a water sample which had been collected at progressive intervals throughout the storm flow.

Visual impressions of the intake bottle set were as follows. There was:

- an apparent increase in the turbidity with time from initiation,
- a decrease in the color of the water as the samples were collected over time,
- approximately 7/8" of clean sand in bottles 1-2, with a thin (1/8") layer of finer (dark, possibly organic) particulates on top of the sand,

- no sand in any of the other bottles of this set, but the thin layer of particulate matter diminished to less than 1/16" in sample jars 5-12.

Looking at the outflow samples, there was:
- no sand in any of the bottles,
- an increase in turbidity with time from initiation,
- a decrease in color with time,
- a layer of fine particulates present in all the bottles, apparently of the same composition as those observed in the upstream bottles. The particulate layer was approximately 1/16" thick.

An observation was also made of the water surface inside the CDS unit proper. There appeared to be a thick layer of floating grass, grass clippings, pine needles, leaves and other vegetation, plastic bottles, plastic sheets and bits, burlap, sticks, and also Styrofoam cups and particles. A dead armadillo was present, in an advanced state of decomposition.

Water Sample Results

The sampler on the downstream of the CDS unit did not collect one of the 6 - 2 bottle sets; missing sample bottles 5 and 6. This was reported to have been due to a bottle overflow according to the internal sampler diagnostics. However, no overflow condition was noted when the unit was opened. The actual reason for the missed sample was unknown. Since the samples were composited based on the flow rate at the time the sample was collected, and flow was roughly linear across the point of the missed sample, it is felt that the composited samples still reflected the average storm event inlet and outlet loadings.

The recorded levels were correlated to flow (see "Problems" below), and the samples were manually composited to give a flow-weighted composite sample from each sampler. Maximum flow recorded during this storm was approximately 1120 gpm (2.5 cfs) across the (upstream) weir, and 2374 gpm (5.29 cfs) out the outlet pipe.

Based on a depth of 13.21 centimeters, a sump diameter of 1.22 meters (4 feet) and an estimated 1,410.6 kg/m3 (88 lb/ft^3), (based on previous sediment weight evaluation) approximately 217.3 kilograms (479.2 pounds) of sediment was collected in the unit from storm three. Based on the concentrations measured, 126.07 grams (4.44 ounces) BOD 5, 33.58 grams (1.18 ounces) of metals, and 122.81 grams (4.33 ounces) of TKN were removed.

Problems

The water level measurement and resulting flow discrepancies were due to several reasons.

- *Not all the water that passed over the weir passed into the CDS unit.* The upstream calibrated weir overtopped at 12 inches of water rise, after which the water flowed over the sand bag "shoulders" holding the weir in place. When the water level rose even further, the adjacent concrete diversion weir also overflowed. Once the calibrated weir overtopped, the depth of the water was still being recorded, but flow was no longer confined to the calibrated weir and therefore depth of water could not be correlated to actual flow values. The actual flow through the CDS unit could easily have been triple this amount.

- *The flow limiting plate on the discharge pipe restricted flow within the CDS unit*. This was evident by a water line visible in the outfall pipe, several inches above the lower edge of the aluminum plate. This plate may have caused the tailwater flow to back up inside the CDS unit and possibly up to the calibrated weir; causing an artificial increase in pressure (interpreted as an increase in depth by the bubbler units) without an actual increase in water depth.

- *Recorded flows varied greatly between the upstream and downstream samplers*. The upstream sampler bubbler gave a maximum calculated flow of 1120 gpm (2.5 cfs). This was the maximum volume determinable before the calibrated weir was overtopped. Water levels continued to rise after this one-foot elevation, completely filling the CDS unit inflow pipe, pressurizing it, then eventually overtopping the 30-inch high diversion weir.

The outlet pipe flow was deemed to be more representative once the system began to back up, and the 2377 gpm (5.29 cfs) calculated value for flow through the CDS unit system is felt to be closer to the actual flow through the system. Recorded flow from this storm lasted approximately 90 minutes after the trigger point of two inches over the weir was reached at the upstream site; and approximately 113 minutes at the downstream site according to the downstream sampler. This time discrepancy may have been due to slight leakage around the upstream weir, caused by the severity of the storm and extremely high upstream water levels. The results are shown in Table 3.

It was anticipated that the difference between the inlet and outlet loadings for the storm event should closely approximate the combined loadings calculated for the sediment and the water contained in the sump following the storm. Unfortunately, because of the uncertainties of the actual flow rates, this scenario did not occur, and it was not possible to conduct the mass balance calculation. There is a strong suspicion that the samples collected by the samplers were not collected at the same times, and therefore were not directly comparable. However, comparison of percent removals between storm event 3 and the other storms did not show significant disparities.

CDS Storm # 3 Water Quality Analysis

Site: CDS STORM 3	pH SU	Total Suspended Solids(mg/l)	Turbidity NTU	BOD5-Day mg/l	COD mg/l	Total Phosphorous mg/l
CDS Inlet	7.6	300	110	12	71	1.3
CDS Outlet	7.6	150	86	8.2	53	0.95
Change	0	150	24	3.8	18	0.35
Percent Reduction	0	50	21.8	31.7	25.4	27

Table 3

CDS Sump Water Quality Data

An analysis was made of the water overlying the sediments in the sump of the CDS unit immediately after the storm. Water samples were obtained via peristaltic pump from mid-depth-center of the CDS unit. The results are presented in Table 4.

PARAMETER	RESULT	UNITS	RDL
Aluminum	0.37	mg/l	0.05
Arsenic	ND	mg/L	0.0050
Barium	ND	mg/L	0.010
BOD5	10	mg/L	2.0
Cadmium	ND	mg/L	0.0010
Chromium	ND	mg/L	0.0020
COD	70	mg/L	5.0
Copper	0.0058	mg/L	0.0020
Iron	0.29	mg/L	0.040
Lead	0.0042	mg/L	0.0030
Mercury	ND	mg/L	0.00050
Nickel	ND	mg/L	0.0050
pH*	7.7	SU	0.2
Selenium	ND	mg/L	0.0050
Silver	ND	mg/L	0.0010
TOC	23	mg/L	2.0
Total Kjeldahl Nitrogen	2.5	mg/L	1.0
Total Phosphorus	0.91	mg/L	0.0036
TSS*	54	mg/l	10
Turbidity*	3.2	NTU	0.09
Zinc	ND	mg/L	0.050

** Sample held beyond acceptable holding time*

Table 4

Sediments Measurements

Depths were measured at five locations, four from the corners of the lid opening and once in the center of the opening. The CDS unit was last cleaned May 6, 1998. Measurements were made of the total depth from bottom of the CDS unit to top of the aluminum lid, depth from lid to first resistance at accumulation, and depth from lid to sand. Measurements were taken at 5 points for each parameter. First resistance reached when the (aluminum) range pole was felt to contact the uppermost regions (grasses, pine needles, etc.) above the sand. This provided an estimate of the layer thickness of the organic and fine materials. The rod was then rammed repeatedly to the bottom until concrete was felt, to provide depth of sand readings. The results are shown in Table 5.

CDS Sump Sediment Sampling

A series of bottom sediment grabs were taken with a petite Ponar dredge from each of the sediment measurement depth sites within the sump. The samples were composited manually, duplicates were obtained, and the sediments analyzed. A separate grab series was performed with the Ponar to provide material for a sediment particle size analysis, also conducted in duplicate. Each sediment sample was dried and passed through a series of standard sieves. The fraction, which remained on each sieve, was analyzed independently for organic content, or Volatile Total Solids (VT.). The total volume of material caught on each sieve must equal 100%; so the organic/inorganic components of each fraction can be determined by merely subtracting the VTS value from 100. The resulting number is the inorganic, or non-volatile total solids, value. The results of this analyses are presented in the Figure 1.

SEDIMENT DEPTH MEASUREMENT
AFTER STORM #3

Location	Depth to Fines inches	Depth to Sand inches	Fines Thickness inches	Sand Thickness inches
A	161	159	-2	18
B	160	161.5	1.5	15.5
C	154	164.5	10.5	12.5
D	154	164	10	13
E	157	162.5	5.5	14.5
Average	157.2	162.3	5.1	14.7

Table 5

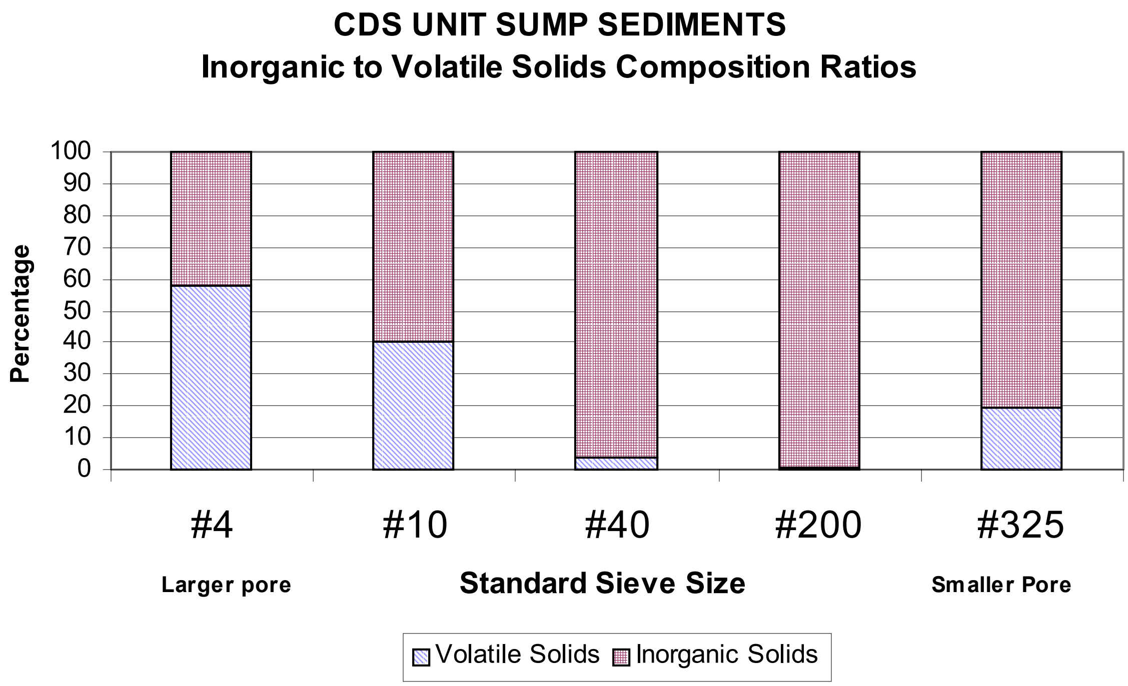


Figure 1

This data indicates that most of the sediment is inorganic, rather than decomposing organic debris; thus making the sediment samples fairly representative of the TSS loads from storm flows.

Sediment Chemical Analysis

Sampling results from sediment grabs obtained from CDS Unit Sump are listed in the Table 6. The analytes that returned a value greater than the detection limit for that particular test are identified by bold font. There were no unusually high levels of metals or hydrocarbons present, except for iron.

PARAMETER	Sediment Grab	Grab Duplicate	Average Value	Detection Limit	UNITS
Arsenic	0.096	0.11	0.103	0.069	mg/Kg
Barium	3.4	2.9	3.15	0.14	mg/Kg
Benzo(b)fluoranthene	260	ND*	250*	240	ug/kg
BOD5	650	510	580	2.7	MG/L
Cadmium	0.03	0.033	0.0315	0.014	mg/Kg
Chromium	1.1	1.1	1.1	0.027	mg/Kg
Copper	1.2	0.95	1.075	0.027	mg/Kg
Iron	220	260	240	0.55	mg/Kg
Lead	2	2.2	2.1	0.041	mg/Kg
Nickel	0.4	0.36	0.38	0.069	mg/Kg
Silver	0.16	0.059	0.1095	0.014	mg/Kg

Total Kjeldahl Nitrogen	450	680	565	37	mg/Kg
Total Phosphorus	79	230	154.5	9.2	mg/Kg
Zinc	14	14	14	0.27	mg/Kg
2-Methylnaphthalene	ND	ND	ND	240	ug/kg
4,4'-DDD	ND	ND	ND	6.4	ug/kg
4,4'-DDE	ND	ND	ND	6.4	ug/kg
4,4'-DDT	ND	ND	ND	6.4	ug/kg
Acenaphthene	ND	ND	ND	240	ug/kg
Acenaphthylene	ND	ND	ND	240	ug/kg
Aldrin	ND	ND	ND	6.4	ug/kg
alpha-BHC	ND	ND	ND	6.4	ug/kg
Anthracene	ND	ND	ND	240	ug/kg
Aroclor-1016	ND	ND	ND	26	ug/kg
Aroclor-1221	ND	ND	ND	26	ug/kg
Aroclor-1232	ND	ND	ND	26	ug/kg
Aroclor-1242	ND	ND	ND	26	ug/kg
Aroclor-1248	ND	ND	ND	26	ug/kg
Aroclor-1254	ND	ND	ND	26	ug/kg
Aroclor-1260	ND	ND	ND	26	ug/kg
Benzo(a)anthracene	ND	ND	ND	240	ug/kg
Benzo(a)pyrene	ND	ND	ND	240	ug/kg
Benzo(g,h,i)perylene	ND	ND	ND	240	ug/kg
Benzo(k)fluoranthene	ND	ND	ND	240	ug/kg
beta-BHC	ND	ND	ND	6.4	ug/kg
Chlordane	ND	ND	ND	6.4	ug/kg
Chrysene	ND	ND	ND	240	ug/kg
delta-BHC	ND	ND	ND	6.4	ug/kg
Dibenz(a,h)anthracene	ND	ND	ND	240	ug/kg
Dieldrin	ND	ND	ND	6.4	ug/kg
Endosulfan I	ND	ND	ND	6.4	ug/kg
Endosulfan II	ND	ND	ND	6.4	ug/kg
Endosulfan sulfate	ND	ND	ND	6.4	ug/kg
Endrin	ND	ND	ND	6.4	ug/kg
Endrin aldehyde	ND	ND	ND	6.4	ug/kg
Fluoranthene	ND	ND	ND	240	ug/kg
Fluorene	ND	ND	ND	240	ug/kg
gamma-BHC (Lindane)	ND	ND	ND	6.4	ug/kg
Heptachlor	ND	ND	ND	6.4	ug/kg
Heptachlor epoxide	ND	ND	ND	6.4	ug/kg
Indeno(1,2,3-cd)pyrene	ND	ND	ND	240	ug/kg

Mercury	ND	ND	ND	0.043	mg/Kg
Methoxychlor	ND	ND	ND	26	ug/kg
Naphthalene	ND	ND	ND	240	ug/kg
Phenanthrene	ND	ND	ND	240	ug/kg
Pyrene	ND	ND	ND	240	ug/kg
Selenium	ND	ND	ND	0.069	mg/Kg
Toxaphene	ND	ND	ND	32	ug/kg

Notes: Equipment Blank Water Yielded ND for all listed analytes. *The benzo(b)fluoranthene mean value was calculated with the RDL as the lower value for the duplicate.

Table 6

Observations

A dead armadillo was observed floating in the 2-3 inches of clean water in the system sump. Apparently this creature had wandered in through the widely spaced guard bars of the intake or upstream side, and had fallen to its death. The creature was not removed, this being deemed to be a typical and normal possible occurrence for this type of setup. It is conceivable that if the unit was full of water, small creatures that entered might again find their way out, if the water level within the unit had not dropped below the lip of the intake flume. Visual inspections of this system to date revealed that a wide variety of snakes, turtles, and frogs enter this system. It is not known whether they were washed in dead or died once washed into the system.

The small area of pavement in this drainage basin and the grassed swale upstream of the CDS unit account for the lack of hydrocarbons in the samples.

STORM #4

Methodology

Due to the problems encountered in storm event 3, the following changes were made to the sampling set up.

- The flow limiting plate was removed from the outfall pipe orifice.
- A Doppler area-velocity flow meter was installed in the outfall pipe, approximately 3 feet from the discharge end of the pipe.
- Both samplers were set to trigger the Doppler flow meter at the same time through the use of a splitter. This allowed the collection of comparable samples for analysis. The setup was truly sampling "what goes in-must come out" samples.
- The upstream bubbler was reset to record water levels over the calibrated weir. This was also be used to measure and compare inflows and outflows through the system, particularly at lower velocities.

Storm samples were collected at the CDS unit on January 3, 1999. This storm event was captured after a dry period of only 7 days, which was sufficient to meet the minimum "dry" criteria of a 72 hour dry spell prior to sampling. During the previous 40 days no rainfall sufficient enough to trigger the samples. Rainfall recorded directly at the site during the sampling totaled approximately 0.05 mm for the hour-long storm. However, two gauges located approximately 4.5 miles south of the sampling area registered rainfall of 0.33 mm (gauge #1) and 1.1 mm (gauge #2) respectively, during this period.

Water levels, velocities, and flow rates were recorded during this storm event by an ISCO flowmeter equipped with a Doppler area-velocity flow meter. This probe was mounted in the outfall tube of the CDS unit. A paper chart recording of the storm effects was made. The water level rose from a background level of approximately 8 inches to a maximum of 1.68 feet. The water rose swiftly, peaking only 5 minutes into the storm and diminished to near background levels within 55 minutes. Measurable flow stopped at 110 minutes after the start of the storm. The water velocities peaked at 0.75 fps between 2 and 13 minutes after initiation. The flow rate through this unit was recorded at a maximum peak of 2.13 cfs , occurring between 4 and 13 minutes after sampler initiation. After the peak, the flow rate dropped sharply to 1 cfs and then tapered off gradually to be below detectable levels by 45 minutes after sampler initiation.

Samples were collected at sampler initiation, and at 10-minute intervals during the storm. During previous sample excursions samples were manually composited. Due to the high content of suspended solids, much of which were heavy particles including sand that rapidly settled in the sample container, it was questioned whether the composite samples were truly representative of the solids collected. Individual 2 bottle sets collected every 10 minutes were sent to the laboratory without being composited. The sample bottle set for set # Outlet 4 was not collected by the autosampler. This was eventually traced to a programming conflict within the autosampler, and was resolved for sample 5.

Results

After the samples were collected, an observation was made of the water surface inside the CDS unit proper. There was an approximately 20.3 cm (8 in) thick layer of floating grass and other vegetation, paper, an oil sheen, glass and plastic bottles, plastic sheets and bits, seeds and nuts, sticks, and Styrofoam particles. The results from the laboratory analysis of water samples from storm 01/03/1999 are presented in the Table 7.

The CDS unit was designed so that the deep sump collected virtually all of the heavier settleable particulates and sand. In contrast to the samples collected just after construction of this unit, grass had now grown in at upstream channel leading to the CDS. The majority of the naturally present sand and heavier pollutants were trapped in the grassy swale prior to these pollutants entering the CDS unit. After storm #4, inspection of the CDS unit revealed several inches of coarse grained sand in the throat of the outflow pipe. From size particle analysis, this sand appears to have come from the sandbags that had been holding the calibrated weir in place on the upstream side of the CDS unit. As is typical in pipes with low velocities, the large sediment particles accumulate in the bottom of the pipe until high flow storms clean the pipe. When the sample were retrieved, there was very little settled particulate matter present in either the Inlet or Outlet bottles.

During this storm an interesting observation was made illustrating the time of concentration related to this location. The drainage basin consisted of two sub-basins: 4-5 acres of paved parking lot and residential area adjacent to the unit, and the remainder of the basin coming from across US 1 through two culverts. The initial flow of water came from the nearby basin off the parking lot and was relatively clear with heavy sand particles. This was evidenced by the first non-turbid sample taken at the beginning of the storm. After about 20 minutes water started flowing through the culverts under US 1 and into the CDS unit. This water was very milky white form the dirt parking lot across the highway. Samples taken at subsequent time intervals show a high degree of turbidity and lessor amounts of large sand particles. This change of the constituents of the pollutant loading accounts for some of the variability of removal efficiency with the discrete samples. It also points to some of the complexities of comparing different BMPs at different locations.

CDS Storm # 4 Water Quality Analysis

Sample **Set 1** @ initiation	BOD5-Day (mg/l)	COD (mg/l)	pH (SU)	Total Phosphorous (mg/l)	Total Suspended Solids (mg/l)	Turbidity (NTU)
Inlet	2.1	2*	8	0.32	690	99
Outlet	5.4	2*	7.8	0.19	320	120
Change	+3.3	0*	-0.2	-0.13	-370	+21
Percent Change	+157%	0*%	-3%	-41%	-54%	+18%

Sample **Set 2** @ 10 minutes	BOD5-Day (mg/l)	COD (mg/l)	pH (SU)	Total Phosphorous (mg/l)	Total Suspended Solids (mg/l)	Turbidity (NTU)
Inlet	6.6	15	8.3	1.2	1400	1800
Outlet	7	18	8.4	0.94	1600	1000
Change	+0.4	-3	+0.1	-0.26	+200	-800
Percent Change	+6%	+17%	+1%	-22%	+13%	-44%

Sample **Set 3** @20 minutes	BOD5-Day (mg/l)	COD (mg/l)	pH (SU)	Total Phosphorous (mg/l)	Total Suspended Solids (mg/l)	Turbidity (NTU)
Inlet	6.7	25	8.2	1.2	830	530
Outlet	6.7	24	8.3	1.5	550	430
Change	0	-1	+0.1	+0.3	-280	-100
Percent Change	0%	-4%	+1%	+20%	-34%	-19%

Sample **Set 4** @30 minutes	BOD5-Day (mg/l)	COD (mg/l)	pH (SU)	Total Phosphorous (mg/l)	Total Suspended Solids (mg/l)	Turbidity (NTU)
Inlet	6.3	45	8.1	1.6	330	200
Outlet	NT	NT	NT	NT	NT	NT
Change	na	na	Na	na	na	na
Percent Change	na	na	Na	na	na	na

Sample **Set 5** @40 minutes	BOD5-Day (mg/l)	COD (mg/l)	pH (SU)	Total Phosphorous (mg/l)	Total Suspended Solids (mg/l)	Turbidity (NTU)
Inlet	5.6	33	8	1.6	290	300
Outlet	6.4	30	8.2	1.6	170	260

Change	+0.8	-3	+0.2	0	-120	-40
Percent Change	+13%	-9%	+2%	0%	-41%	-13%

Sample **Set 6** @50 minutes	BOD5-Day (mg/l)	COD (mg/l)	pH (SU)	Total Phosphorous (mg/l)	Total Suspended Solids (mg/l)	Turbidity (NTU)
Inlet	6	39	7.9	1.6	220	120
Outlet	6.3	33	8.2	1.5	270	230
Change	+0.3	-6	+0.3	-0.1	+50	+110
Percent Change	+5%	-15%	+4%	-6%	+19%	+48%

Table 7

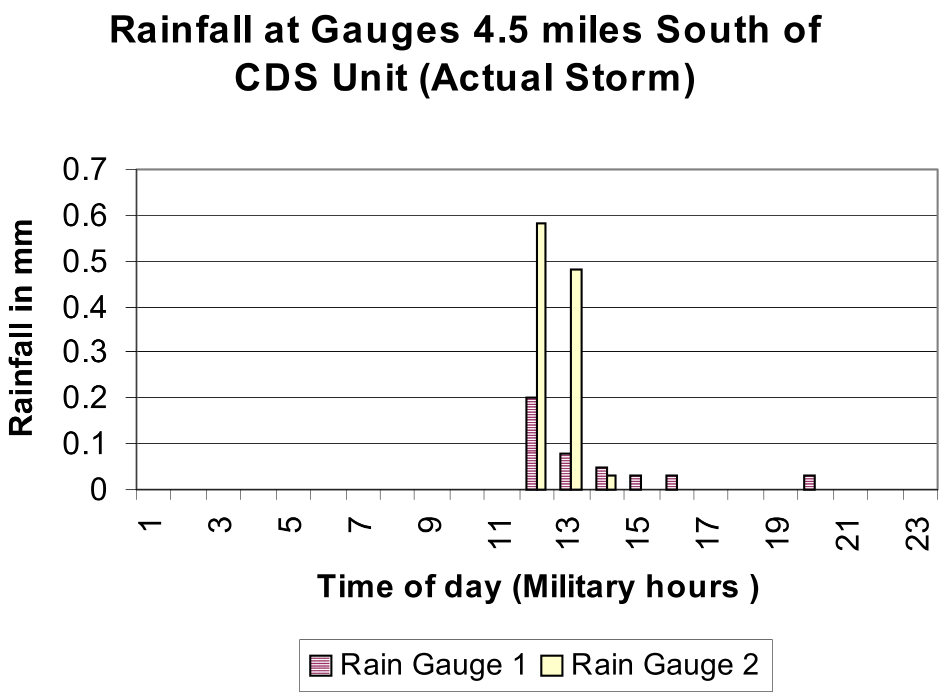


Figure 2

Discussion

Turbidity, that pollutant fraction present in the water which absorbs or reflects back light, was reduced by 44 % during the peak storm flow (Sample set 2, Inlet/Outlet #2). While there actually appeared to be an increase in the turbidity values of the stormwater stream at the very beginning and end of the storm (Inlet/Outlet sets 1, 6), these values become almost inconsequential when you consider the flow present through the system.

The total suspended solids values at the outlet during peak flow, (sample set Outlet 2) were 13% greater than those of the associated Inlet sample. This implies that there was some resuspension of materials during the peak storm flow.

The same situation occurred for the phosphorous values for sample set Inlet/Outlet #3. This may have been caused by a resuspension of bottom sediments laden with particulate phosphorous, but is more likely to have occurred as a result of physical abrasion or grinding of organic debris caused by the swirling action of water through the CDS unit. This abrasion would release small particles of organics, which would then make their way out of the unit in the effluent stream.

When reviewing the analytes individually, the following pages of graphs and discussions were developed.

Analyte: Turbidity

Overall, the CDS unit did a very good job removing turbidity, one of the major pollutants this BMP is designed to specifically control. Suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and plankton and other microscopic organisms causes turbidity in water. (Standard Methods for the Examination of Water and Wastewater, 17th Ed.)

The turbidity of the stormwater entering the CDS unit rose sharply, with the inlet samples reaching 1800 mg/l during the peak flow of the storm. Passing through the unit caused a 44% reduction in turbidity concentrations at sample set Inlet/Outlet 2. This is most significant in that this reduction took place at the sampling point in the storm that had the highest water level, velocity, and flow rate. As the water levels and corresponding flow rates dropped, the CDS unit removed 19 % of the turbidity at the third sample.

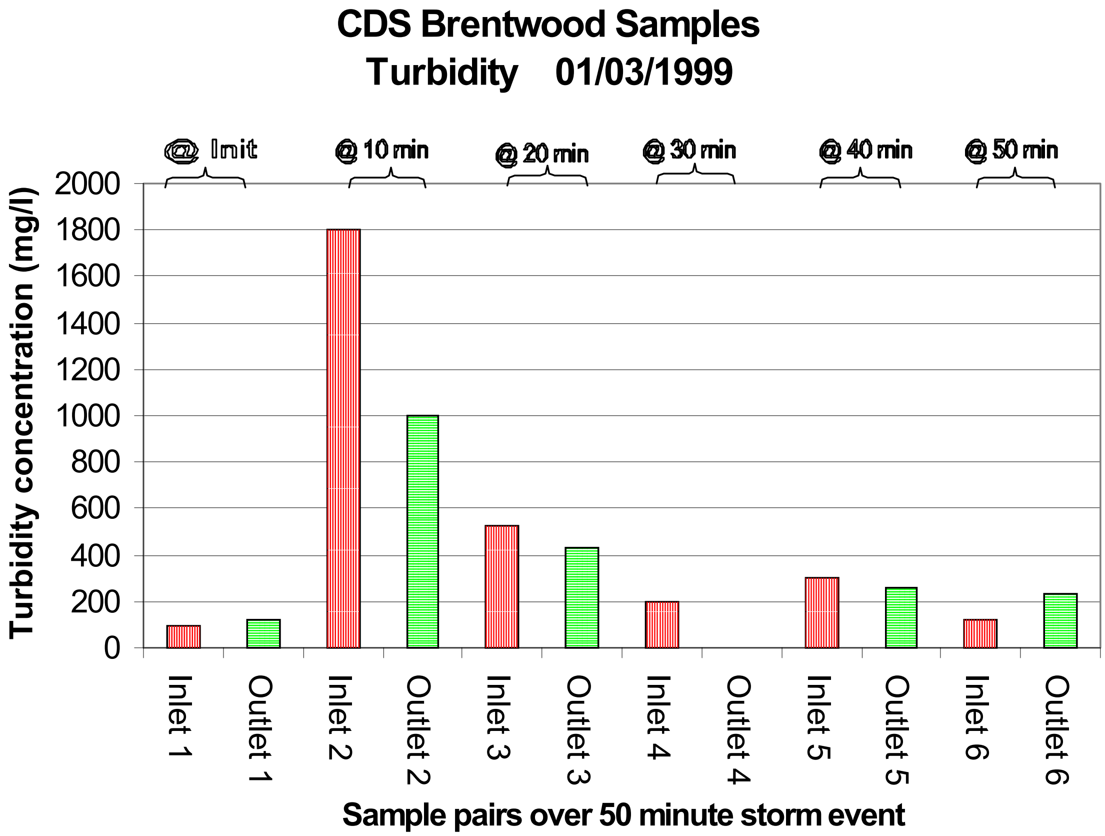


Figure 3

Analyte: Total Suspended Solids

Suspended solids include matter suspended in the water that would be retained on a filter. The total suspended solids concentrations of the stormwaters entering the CDS unit correlated strongly to the water velocity passing through the unit. At sampler initiation (Inlet/Outlet 1), the unit reduced the TSS concentration by 53%. This reduction is further reflected in Inlet/Outlet sets 3, 5, and possibly sample set 6 also. During the peak of the flow through the unit (Inlet/Outlet 2, corresponding to 2.2 cfs), there appeared to be some resuspension of materials previously captured in the sump of the unit, as evidenced by the 12% increase in values within this sample set. The difference between the values for Inlet and Outlet 6 was 18 %, and may have been due in part to scouring of the outflow pipe bottom by the decreased water levels in the inflow and outflow pipes. The loading released at sample set 6 is deemed to be minor once the reduced velocity and flow rate are taken into account.

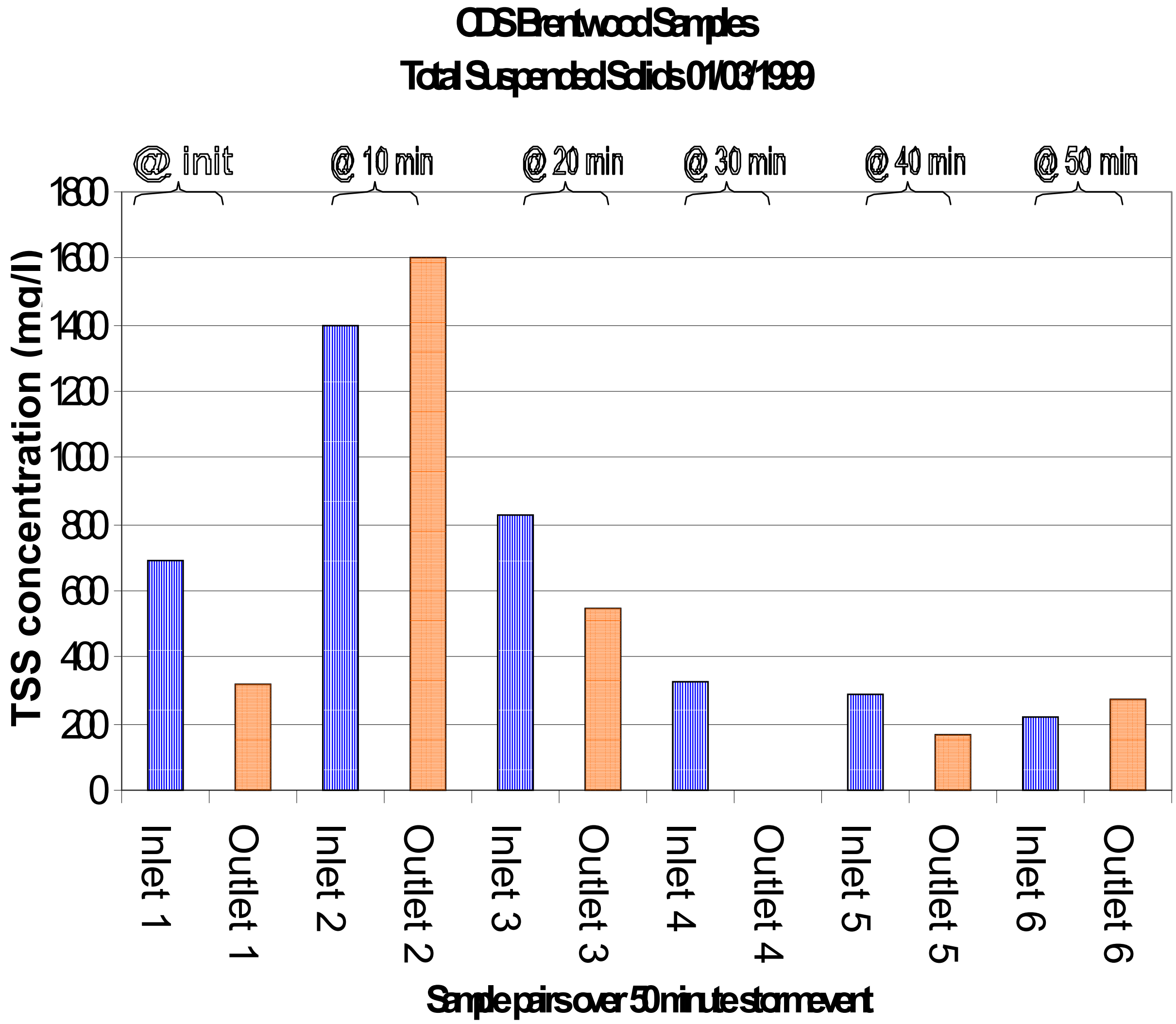


Figure 4

Analyte: Total Phosphorous as P

The concentrations of phosphorous present in the storm water generally rose with storm flow duration. It appeared that the CDS unit reduced the concentration of phosphorous in the stormwater during the initial storm stages. Sample sets #1 and #2 were reduced by 41% and 22%, respectively, while set #3 rose by 20%. The phosphorous concentration in the effluent water dropped by 6% at sample set # 6, taken at 50 minutes into the storm. As the flow rate dropped to below detectable levels at this point, it may be that the particles which phosphorous tends to typically bind to began to settle out of the stormwater stream.

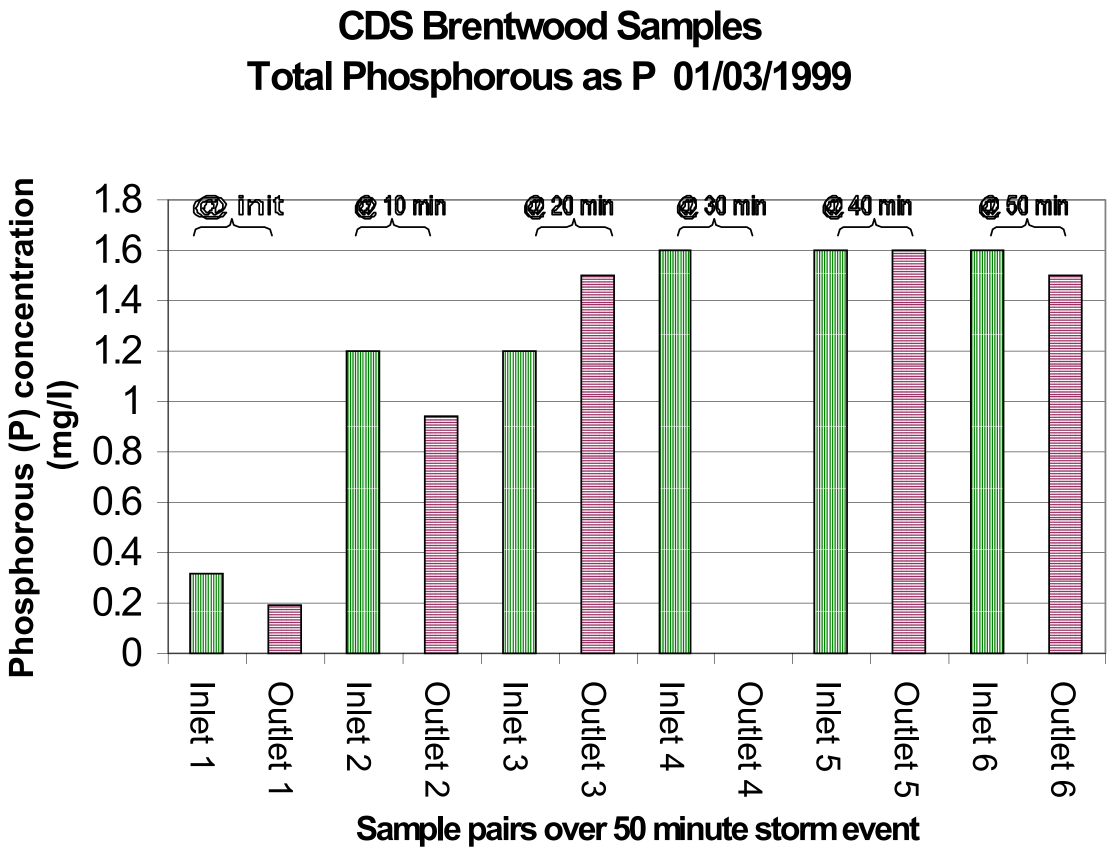


Figure 5

Analyte: Biochemical Oxygen Demand 5-Day

For the biochemical oxygen demand 5 day test (BOD5), there appeared to be levels some 2.5 times higher in the outflow water than in the incoming water for the first sample (Inlet 1, Outlet 1) set taken at initial outflow from the unit. This was due to the large volume of standing water resident within the CDS unit, a volume of approximately 2,000 gallons. During periods of little flow through the unit, the waters within the sump area go anaerobic, or get oxygen starved. When stormwater enters the system from a subsequent rain, it mixes with this stagnant water, and pushes some of this oxygen-starved water out. This water rapidly "pulls" the oxygen from the "new" stormwater, resulting in a high oxygen demand, or BOD.

The "Inlet" samples should be used as the background, or pre BMP values; however, even these demonstrate a rise in the BOD5 values as the stormwater carried in (and along) more organics. Reviews of the other sample sets indicate only a very slight variation between the inlet and outlet BOD5 values, deemed to be insignificant and normal variations. If the first sample set is disregarded, during this storm event the BOD5 averaged between 5.5 and 7 mg/l, with an average influent value of 6.3 mg/l; and an effluent value of 6.6 mg/l.

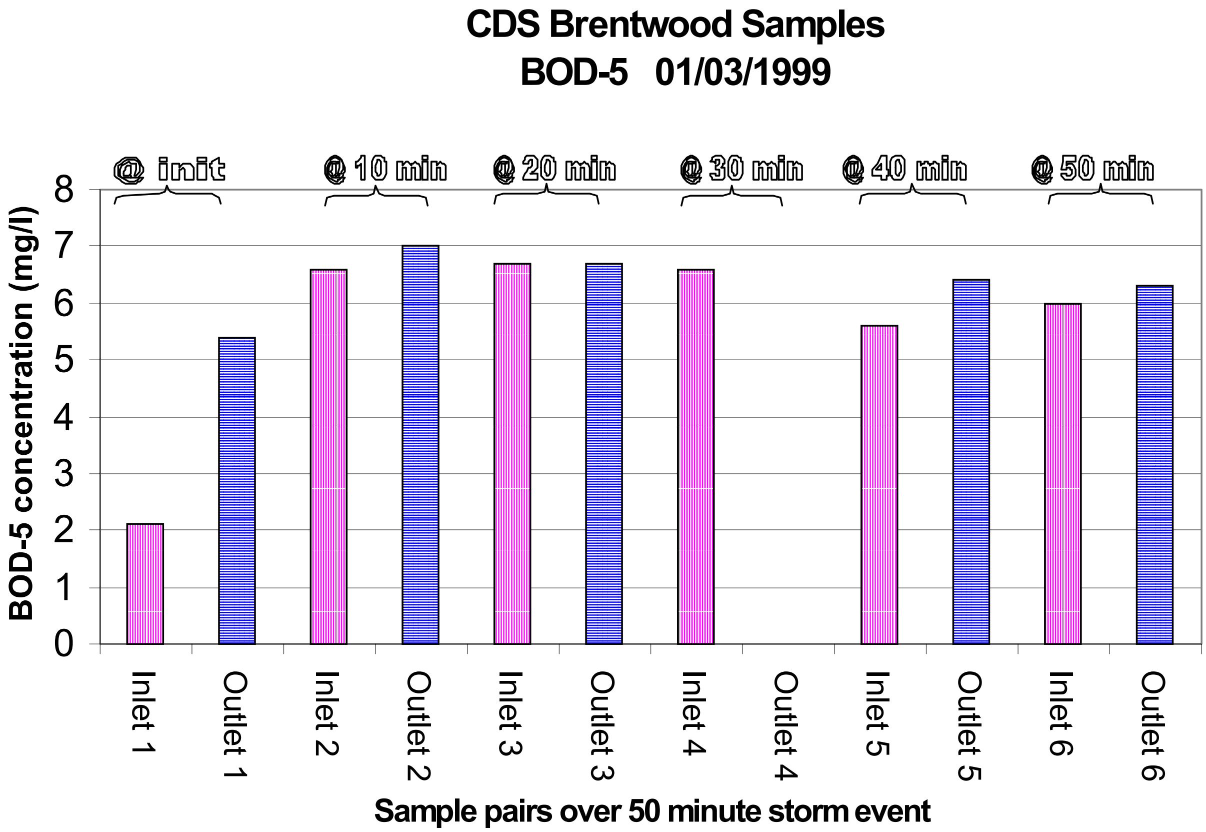


Figure 6

Analyte: Chemical Oxygen Demand

Chemical oxygen demand (COD) is the measurement of use or "demand" of oxygen when exposed to a strong chemical oxidant. The chemical oxygen demand (COD) values obtained during this storm showed little variation between inlet and outlet pairs. Overall, the COD rose with time of storm flow, going from an initial value of less than 2 mg/l (2 being the minimum detection limit for this test, and thus the default value for these calculations and figures); to average approximately 37 mg/l at sample set six. The CDS unit appeared to reduce the concentration of COD in the effluent during this storm at concentrations above 25 mg/l.

The spike to 45 mg/l at Inlet sample 4 must be disregarded because of the lack of substantiation of its missing outlet sample, and somewhat lower values obtained from all other sets. Given the nature of storm water, collection devices, handling, and analytical techniques, it is not unusual to have values such as this spike occur.

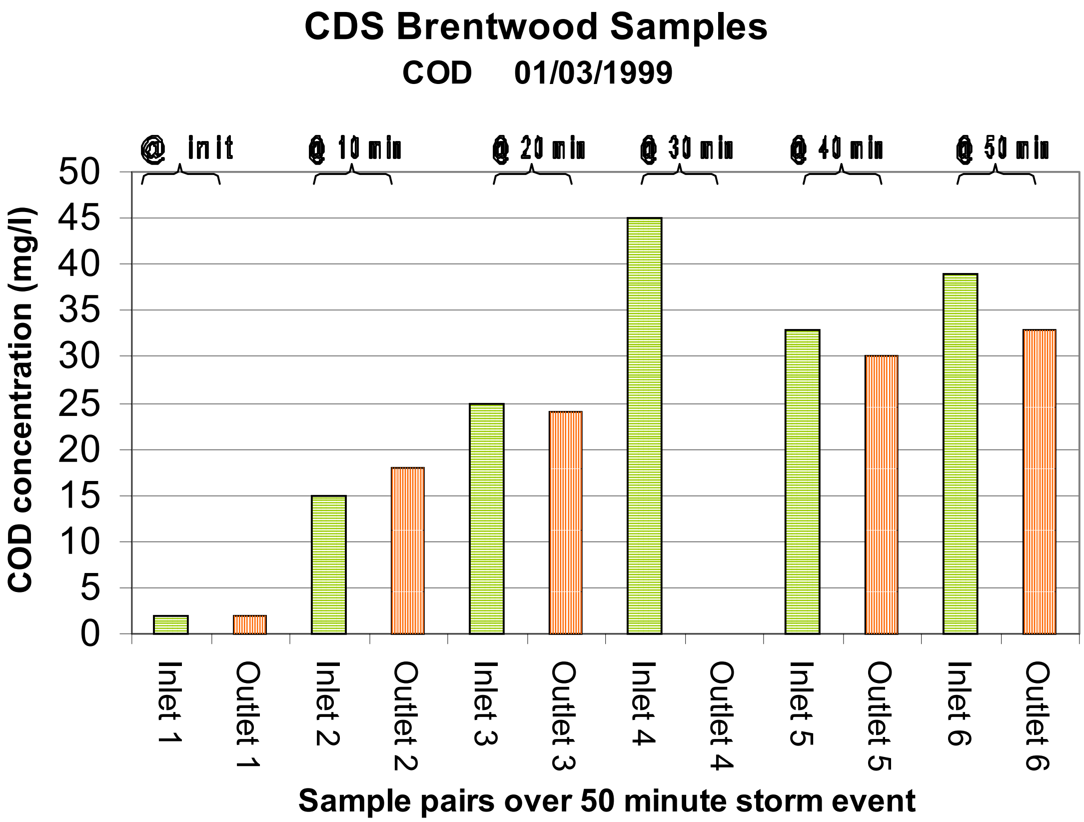


Figure 7

Analyte: pH

The pH of the stormwater passing through the CDS unit followed a skewed bell curve, with the majority of change (with time) in pH values taking place within the first 10 minutes of storm flow. The outlet values for each pair are greater than the inlet values, indicating that some increase is taking place within the unit. This may be explained by the release of gasses (carbon dioxide and oxygen) from the anaerobic plug of water in the sump, causing the alkalinity of the effluent to rise upon mixing. Further reaction with organic and inorganic components could easily explain these differences.

The pH averaged 8.1 during this storm. While there appears to be a great variation between values when graphed, the difference (change) between the lowest and highest reading is only 0.6 units. The graph scale has been chosen to maximize this variation. This minor change in pH is not felt to cause a problem once mixed with the brackish receiving waters of the Indian River.

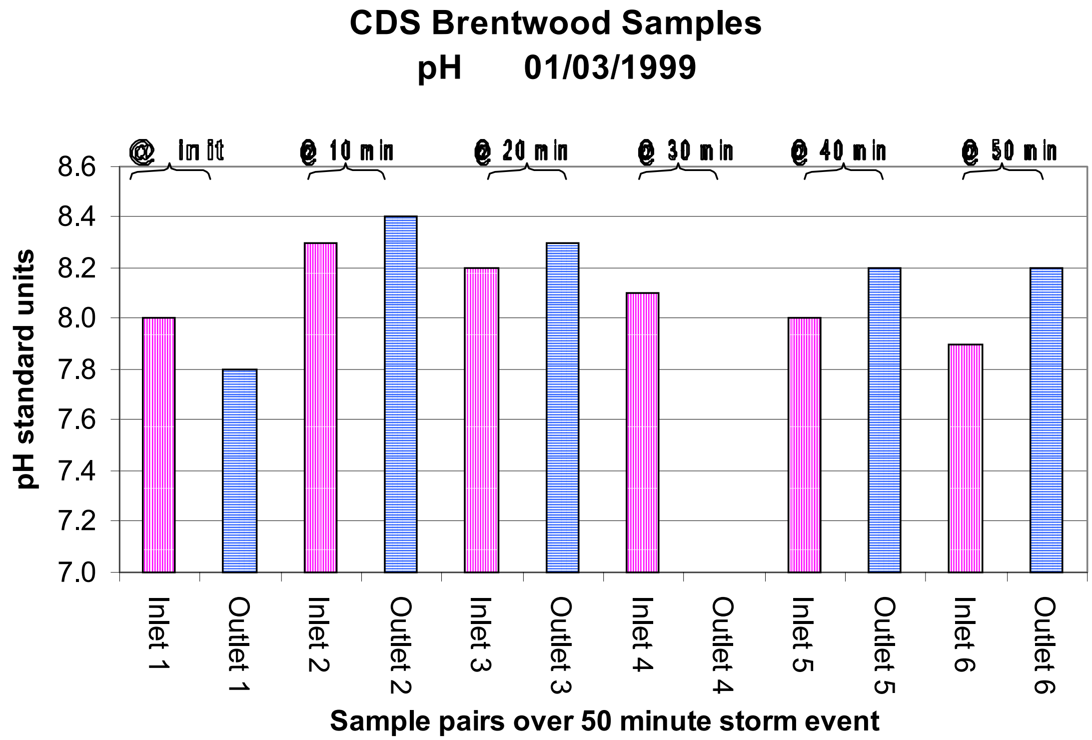


Figure 8

STORM # 5

Storm samples were collected at the CDS unit on March 15, 1999 after a dry period of approximately 2 1/2 months (last recorded rain on January 3). Rainfall measured directly on site peaked at a rate of 2.4 inches per hour (0.04 inches per minute), but this lasted for only a few minutes. The recorded rainfall over the entire 22 minutes of precipitation at the CDS unit averaged 0.01 inches per minute; for a rainfall total of approximately 0.23 inches falling in the immediate vicinity of the sampler. For comparison, two gauges located approximately 4.5 miles south of the sampling area registered peak rainfalls of 0.6 inches (rain gauge #1) and 0.5 inches (rain gauge #2) per minute respectively, during this same period. Duration of rainfall was recorded as approximately 40 minutes at gauge 1, and 70 minutes at the second gauge.

The water level rose very sharply from a background level of approximately 20.3 cm (8 in) to a maximum total depth of 24.6 cm (9.7 in); a rise of only 4.3 cm (1.7 in). The water level recordings indicate that the storm waters entered the CDS unit in a plug of water rather than a gradual increase. (This may also have been the result of initial storm flow topping off the CDS sump prior to overflowing out the outlet pipe) The water velocities peaked at 0.03 m/s (0.09 fps) immediately after sampler initiation, then tapered off gradually to be below detectable levels by 50 minutes after sampler initiation. (Figure 1). The storm flow ended after the fifth set of samples was collected.

Two-bottle sample sets were collected at sampler initiation, and also at 10-minute intervals during the storm. As with the previous sample event, sample sets were not composited but sent for analysis as 6 individual 2 bottle sets. The sample bottles for bottle sets 6 were not collected due to insufficient water to cover intake strainers.

After the samples were collected, an observation was made of the water surface inside the CDS unit proper. There appeared to be a thick layer of floating dead grasses, palmetto frond bits, and various other leaves, seeds, nuts and other plant fruits. Paper, an oil sheen, glass and plastic bottles, plastic sheets and bits, sticks, and Styrofoam particles, were all also noted. The results from the laboratory analysis of water samples from storm 03/15/1999 are presented in the Table 7.

CDS Storm # 5 Water Quality Analysis

Sample Set 1 @ initiation	BOD5-Day	COD	pH	Total Phosphorous	Total Suspended Solids	Turbidity
	(mg/l)	(mg/l)	(SU)	(mg/l)	(mg/l)	(NTU)
Inlet	4.6	68	7.8	0.23	49	16
Outlet	4.0	18	7.9	0.18	11	4.3
Change	-0.6	-50	+.1	-0.05	-38	-11.7
Percent Change	13%	74%	1%	22%	78%	73%

Sample Set 2 @ 10 minutes	BOD5-Day	COD	pH	Total Phosphorous	Total Suspended Solids	Turbidity
	(mg/l)	(mg/l)	(SU)	(mg/l)	(mg/l)	(NTU)
Inlet	10	51	7.8	0.25	59	38
Outlet	3.8	23	7.9	0.18	19	6.9
Change	-6.2	-28	+.1	-0.07	-40	-31.1
Percent Change	62%	55%	1%	28%	68%	82%

Sample Set 3 @ 20 minutes	BOD5-Day	COD	pH	Total Phosphorous	Total Suspended Solids	Turbidity
	(mg/l)	(mg/l)	(SU)	(mg/l)	(mg/l)	(NTU)
Inlet	13	55	8.2	0.3	23	23
Outlet	4.7	33	7.6	0.18	21	12
Change	-8.3	-22	-0.6	-0.12	-2	-11
Percent Change	64%	40%	7%	40%	9%	48%

Sample Set 4 @ 30 minutes	BOD5-Day	COD	pH	Total Phosphorous	Total Suspended Solids	Turbidity
	(mg/l)	(mg/l)	(SU)	(mg/l)	(mg/l)	(NTU)
Inlet	9.9	53	9.2	0.35	39	61
Outlet	3.9	29	7.7	0.18	15	7.2
Change	-6	-24	-1.5	-0.17	-24	-53.8
Percent Change	61%	45%	16%	49%	62%	88%

Sample Set 5 @ 40 minutes	BOD5-Day	COD	pH	Total Phosphorous	Total Suspended Solids	Turbidity
	(mg/l)	(mg/l)	(SU)	(mg/l)	(mg/l)	(NTU)
Inlet	9.6	53	9.4	0.29	35	56
Outlet	3.4	27	7.6	0.17	13	9.4
Change	-6.2	-26	-1.8	-0.12	-22	-46.6
Percent Change	65%	49%	19%	41%	63%	83%

Table 8

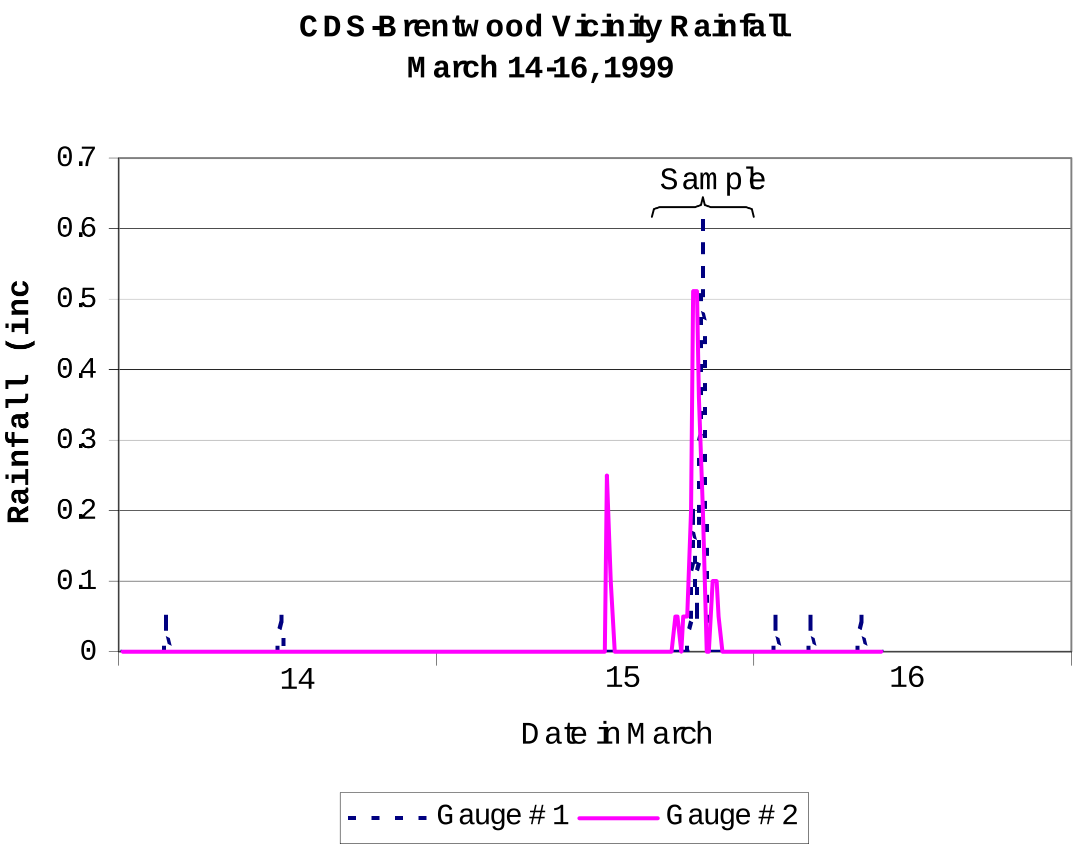


Figure 9

Analyte: Turbidity

Turbidity, that pollutant fraction present in the water that absorbs or reflects back light, was reduced between 48% and 88% during the storm flow. Peak flow through the system occurred during sampler initiation, and the concentrations are depicted for sample set #1. This yielded a 73% reduction in turbidity, with the concentration of turbidity dropping from 16 NTU to 4.3 NTU.

The lowest percent reduction in turbidity for stormwater (lowest removal rate) passing through the CDS system was at sample set number 3. At the time of this sample, incoming waters had a reported turbidity of 23 NTU, while outflow waters had a turbidity of 12 NTU, indicating a reduction of 11 NTU, or 48%. When the percent removal and actual values for these sample sets were examined, it appeared that this sample (Inlet 3) had a lower turbidity for the incoming water than those of the previous or subsequent samples. There was only a very slight and short-lived increase in rainfall between sample sets 2 and 3, with no resultant increase or deviation in the water level through the system to indicate increased flow due to local or upper watershed rainfall to explain this. It was felt that the value reported for sample set 3, (Inlet 3) of 23 NTU was too low, and therefore suspect. This was explained by the inherent difficulties in accurately sampling for and reporting turbidities due to rapid settling of particulates.

Overall, during this storm event the CDS unit did an excellent job of lowering turbidity, one of the major pollutants this BMP is designed to specifically control.

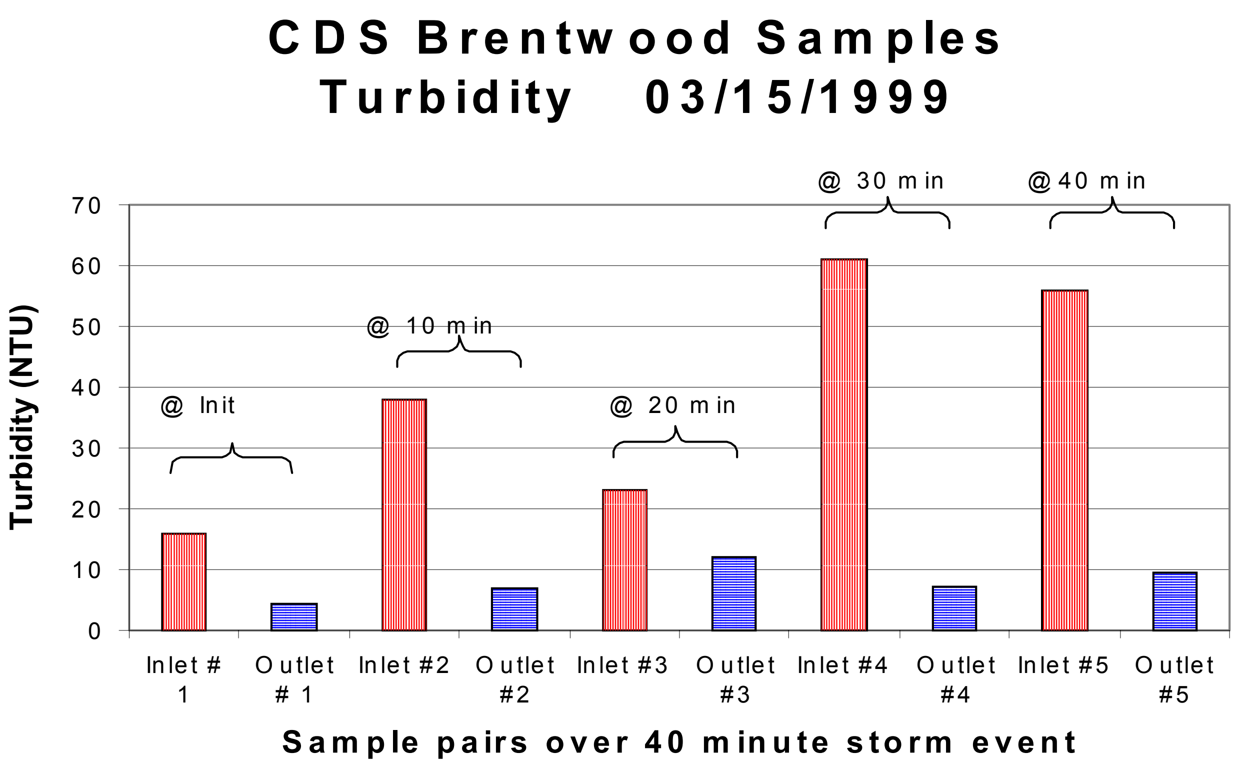


Figure 10

Analyte: Total Suspended Solids

The total suspended solids values demonstrate a similar anomaly to that noted in the turbidity analysis at sample set Intake 3, taken at 20 minutes into the storm flow. According to the hydrograph and rainfall, this value should be somewhere between 39 and 59 mg/l; the bracketing values for samples 2 and 4. This hypothesis is given even more weight when contemplating the outlet values. The outlet values of the storm water flows followed a classic bell curve for concentrations. The reduction in the TSS values for water passing through this system ranged from 62% to 78%, if one disregards the 9% reduction value obtained at Inlet/Outlet sample set #3. On the assumption that the removal rates were consistent throughout this minor storm event, the inlet water for sample set # 3 probably registered between 61 and 47 mg/l; rather than the 23 mg/l reported by the lab.

Of further interest was the relatively consistent low values of outflow TSS concentration (10 mg/l - 20 mg/l) regardless of the inflow concentrations. This could indicate that the CDS unit is more effective at low flow than high flow rates. It is unfortunate that higher intensity rainfall events were not monitored at this site to test this hypothesis.

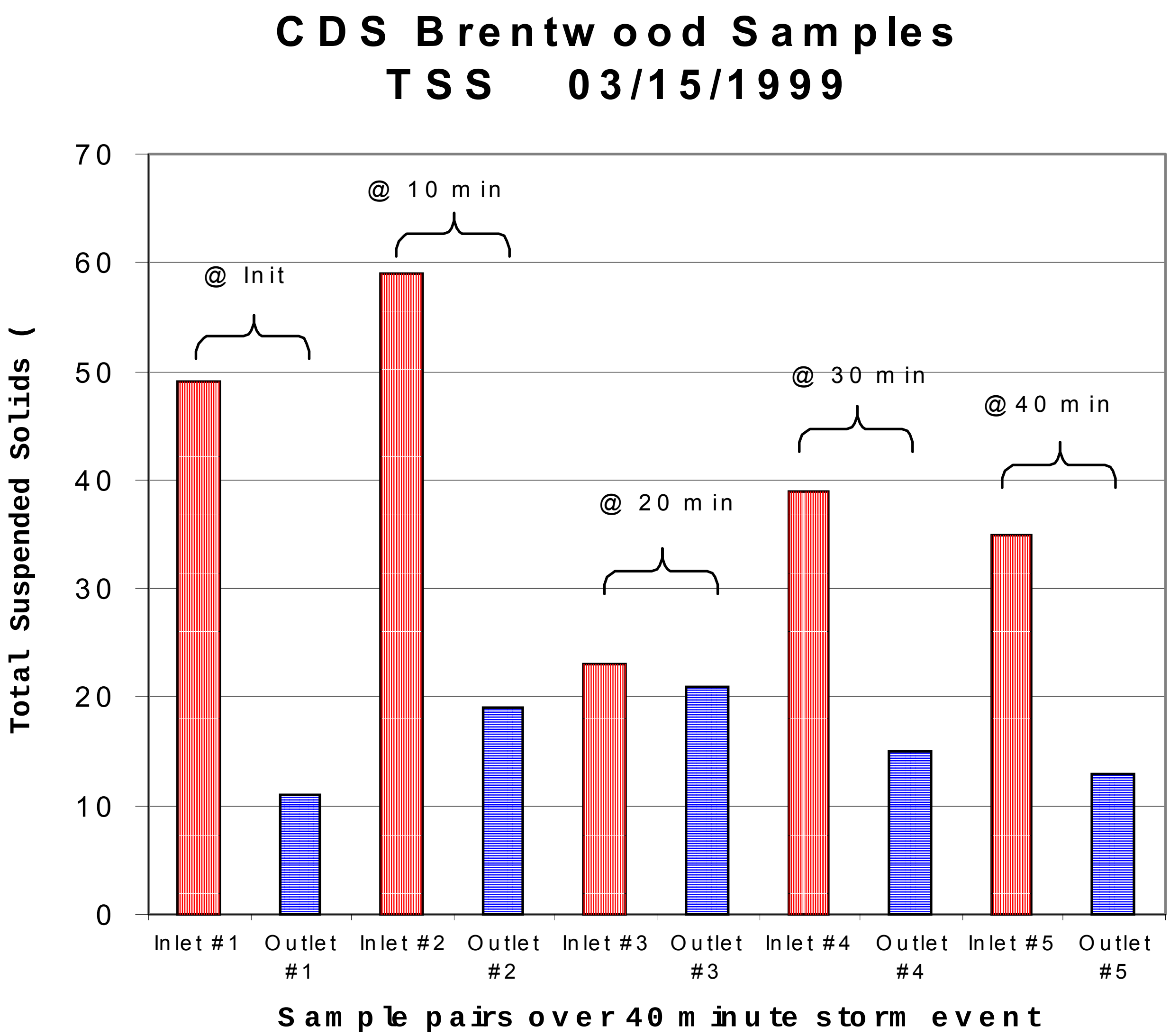


Figure 11

Analyte: Total Phosphorous as P

The phosphorous values for the inlet waters rose with time until after the fourth sample set, after which they began to fall off. This correlates poorly to water level through the system, which was highest at sample set 1 or initiation, but again, gives credence to the concept of erroneous low values for sample set #3. Phosphorous tends to bind to particles, and if there are fewer particles, the total phosphorus as P should be lower, not higher. This was not the case at this inlet bottle set (Inlet # 3), and therefore further justifies the error assumption.

Values ranged from 0.23 mg/l to 0.35 mg/l for the inlet waters, but the outlet waters yielded a very even response across the storm averaging 0.18 mg/l. So, while the percent reduction of total phosphorus as P by this system varied from 22% to 49%, the absolute concentration at release (0.18 mg/l) appeared to be independent of Inlet water phosphorous concentrations.

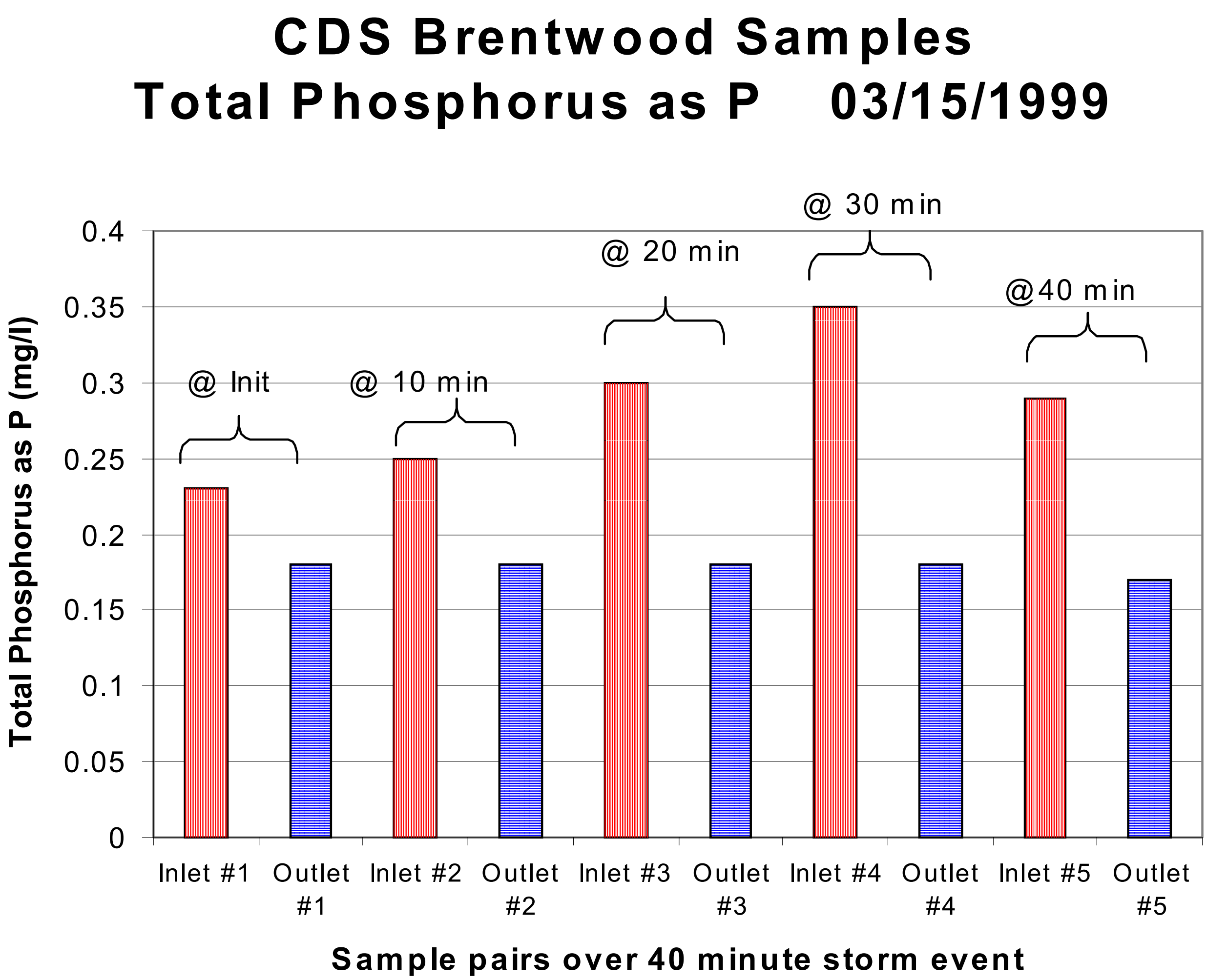


Figure 12

Analyte: Biochemical Oxygen Demand 5-Day

The BOD of the inlet waters followed a classic bell-curve, rising during the storm from a background level of 4.6 mg/l to a peak of 13.0 mg/l observed at sample set # 3, taken 20 minutes after sampler initiation. The outlet values ranged between 3.4 mg/l and 4.7 mg/l, indication that the CDS unit was between 13 % and 65 % efficient in reducing the BOD values of the waters passing through it. The lowest removal rate (13 %) was noted at sampler initiation, sample set Inlet/Outlet #1. If this first flush of relatively clean water is disregarded, the average removal efficiency throughout the rest of this storm event was 63%.

The case could be made that the BOD of 4.6 mg/l observed at initiation, (sample set Inlet # 1,) could be considered very clean as far as stormwaters go; and did not have to be treated by this system to achieve the 4.0 mg/l value upon release. It may also be that this BMP has a minimum level to which it can remove this pollutant, regardless of incoming pollutant concentrations. During this storm the effluent BOD values maintained a relatively steady range between 3.4 mg/l and 4.7 mg/l.

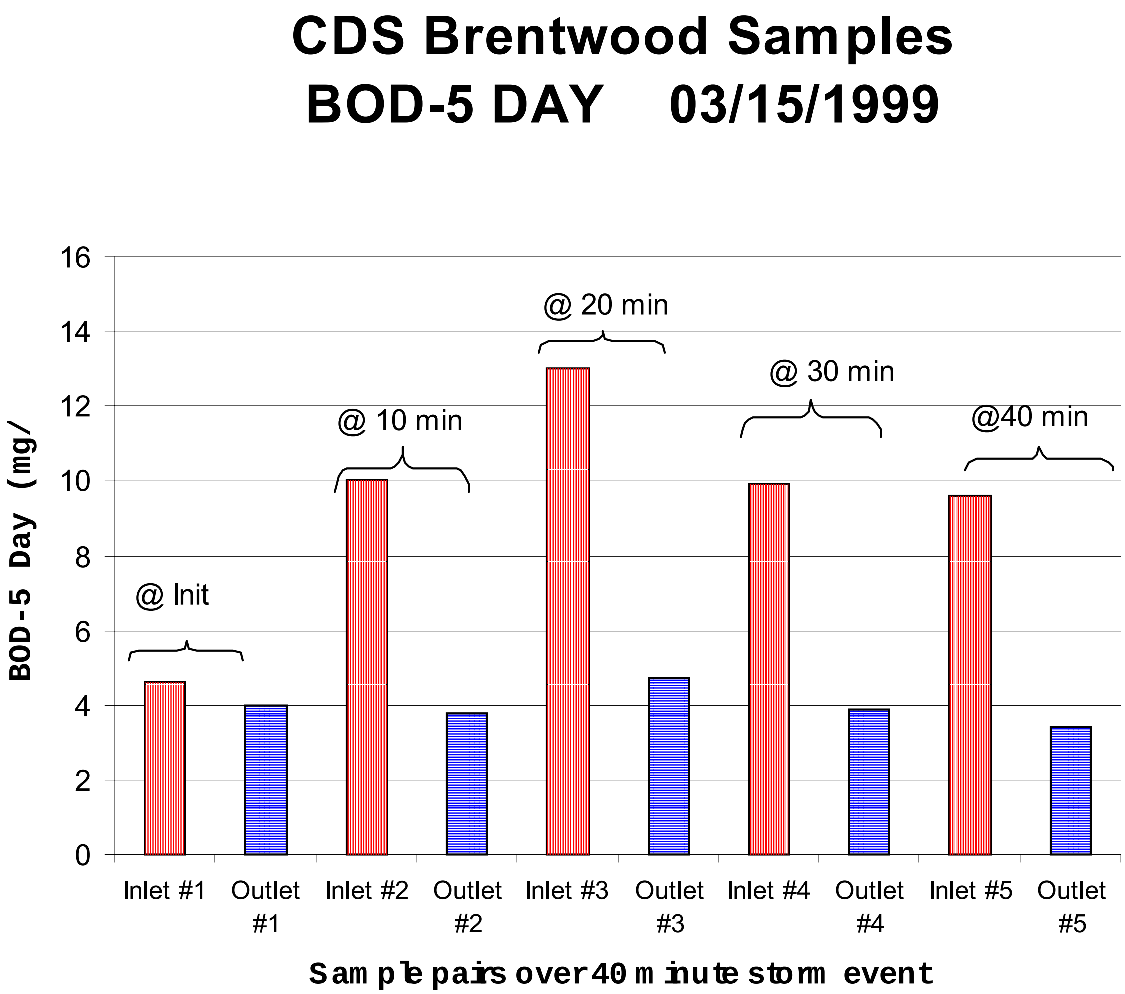


Figure 13

Analyte: Chemical Oxygen Demand

Chemical oxygen demand (COD) is the measurement of use or "demand" of oxygen when exposed to a strong chemical oxidant. This differs from the BOD test in that the BOD uses bacteria to break down chemical and physical components of the sample. BOD can be loosely labeled as those components or reactions that are readily available and prone to occur in the environment, usually at a more accelerated rate than that observed in a COD reaction.

The COD of the incoming waters ranged between 51 mg/l (Set #2) and 68 mg/l (Set #1). Effluent sample analysis revealed concentrations of 18 to 33 mg/l of COD. Percent reduction of COD for this storm varied from 40% to 74 %, averaging 53%. Outlet sample COD concentrations exhibited a bell-curve, while inlet samples exhibited more of a "first-flush" type gradient; with a high initial value followed by diminished concentrations.

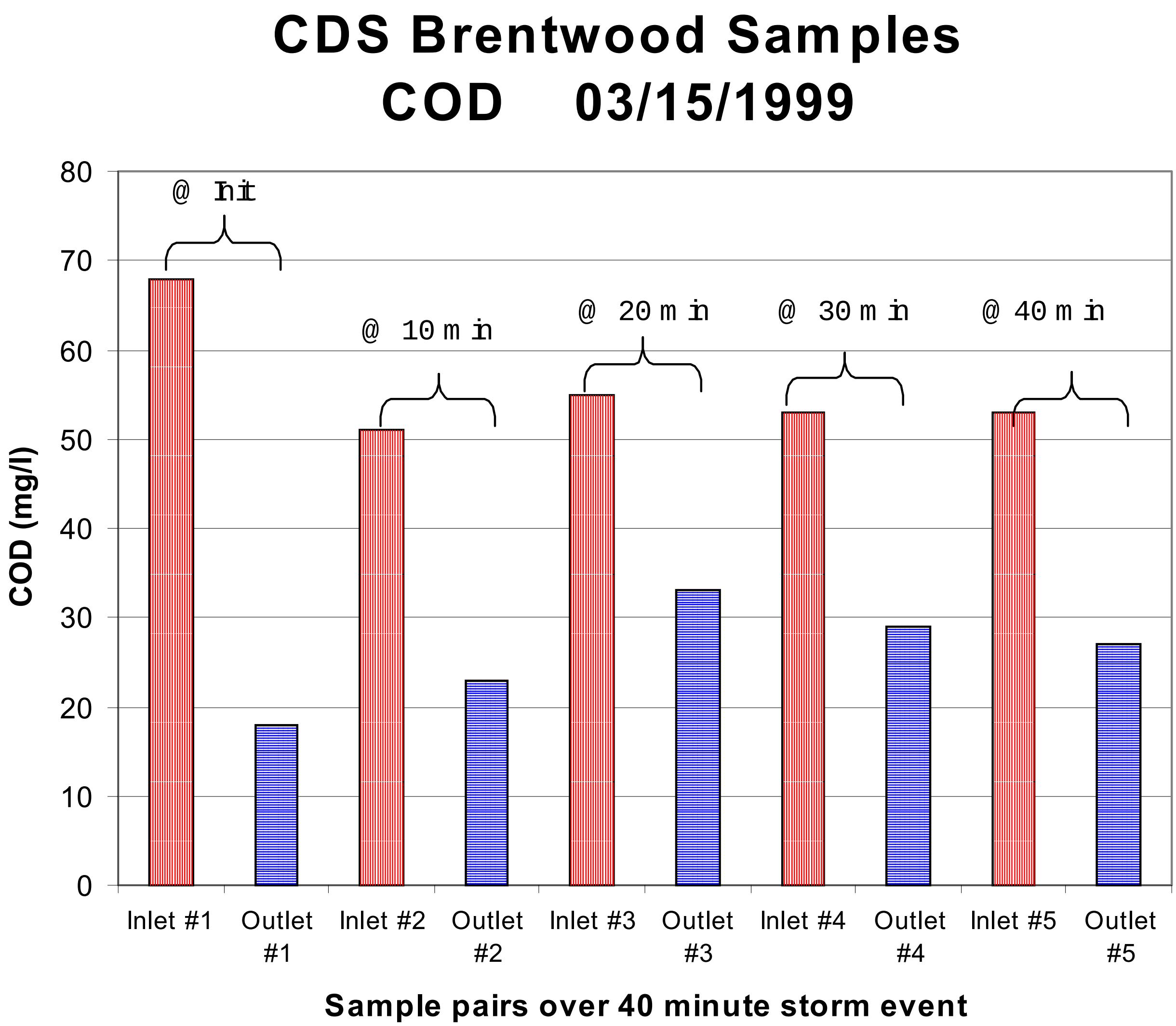


Figure 14

Analyte: pH

Units for the measurement of pH are based on a logarithmic system rather than a simple additive scale. The pH of the stormwater passing through the CDS unit rose sharply from an initial value of 7.8. to a high of 9.4 standard pH units by storms end. This may have been caused by the fine alkaline soils washing down from the drainage basin.

The outlet pH averaged 7.7 S.U. during this storm. The pHs of the receiving water in the adjacent Indian River Lagoon tend towards 8.3, buffered by the calcium and other ions in the water. This minor change in pH is not felt to cause a problem once the storm waters are mixed with the brackish receiving waters of the Indian River.

The CDS unit took incoming waters with steadily increasing pH, and reduced the pH of these waters prior to discharging them. At no time were any outlet sample pH's recorded which would not normally be found in the local freshwater environments.

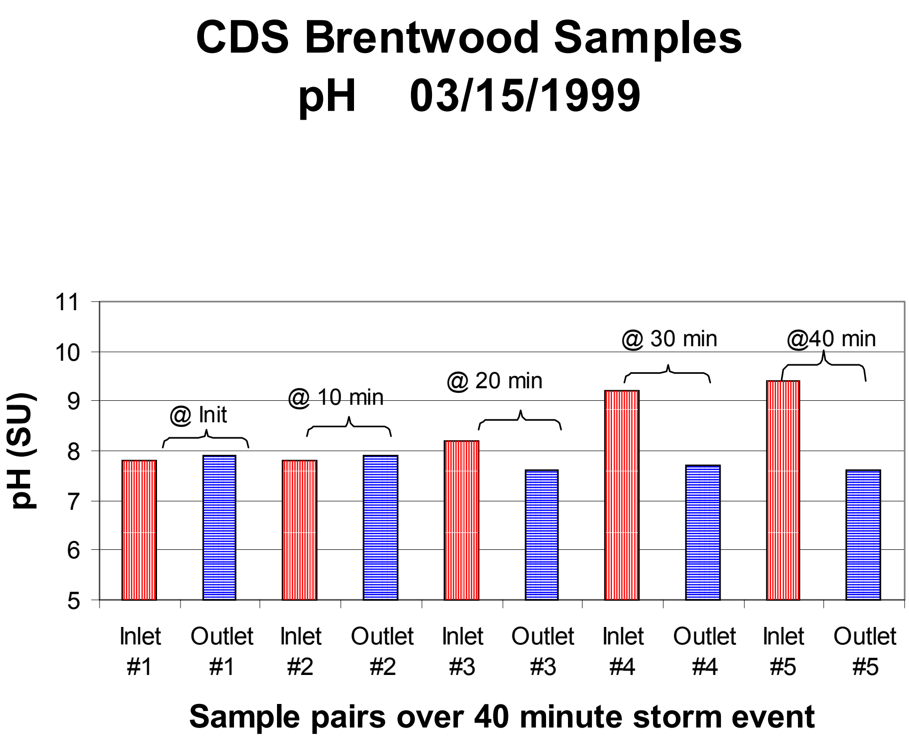


Figure 15

SUMMARY

Over the course of a year and a half of monitoring the CDS unit, there were 5 storm events in which successful samples were taken with autosamplers. In the first 3 storms sampled, composite flow weighted samples were taken using bubbler flow meters. There were significant problems encountered in trying to program the autosamplers, upgrade the autosamplers when repairs were needed, measure and calibrate the flows, position sampling tubes so that they collected representative pollutant samples without becoming clogged with sand and debris, and create composited samples when there were significant volumes of large undissolved sand particles in the sample sets. These problems led to inconsistent results for removal rates for storm #2 .

Storms 1 and 3 showed TSS removal rates of 50% and Phosphorus removal rates of 27% and 29%. These parameters are the two main pollutants in question for this type of BMP. The attempt to perform a mass loading analysis to account for the large volumes of sand and debris failed when the water level in the channel rose over the diversion weir causing an unknown amount of pollutants to bypass the CDS unit.

Sediment analysis from the CDS unit did not show any unusual pollutant concentrations which would cause concern.

Storm events #4 and #5 were sampled using discrete samples, rather than composite samples, in an effort to better understand the dynamics of variable pollutant loadings during the course of a storm. The first flush effect was very pronounced visually as well as numerically. The first and second sample sets, at times 0 and 10 minutes after the water level rose 2 inches over the inflow weir, showed significantly higher concentrations of all sampled parameters except pH, which was relatively constant.

In storm event #4, the outlet sample #4 was not taken due to autosampler error. In addition, several sample sets showed net export of pollutants. While this might have been attributed to resuspension of pollutants from the bottom of the unit, there was no evidence of resuspension exhibited in other storm events. Therefore, it was concluded that the samples taken during storm #4 were suspect due to autosampler error.

Storm event #5 was the only event in which all equipment operated correctly and accurate flow rates were measured. While the flow rates were low, 0.005 cfs, removal efficiencies were comparable with storm events #1 and #3, showing and average removal of 55% for TSS and 36% for Phosphorus.

After every rainfall event a visual inspection of the water surface of the CDS unit showed large volumes of trash, debris, and organic matter. The CDS unit is one of the most, if not "the" most, effective trash traps available at this time. The 47 micron screen traps virtually all debris larger than this size.

CONCLUSIONS

This report illustrates the difficulty and challenges of monitoring pollutant removal effectiveness for stormwater best management practices. The use of innovative new BMPs leads to nontraditional setups for flow meters and autosamplers. Careful planning and a certain degree of experimentation are required to correctly obtain accurate samples in these situations. This in turn leads to a significant degree of uncertainty in trying to compare different BMPs. While manufacturers, engineers, and communities all wish to determine which BMPs are "best", it is not felt that the state of the sampling art is advanced enough at this time to make these determinations.

The high variability of monitoring equipment, rainfall patterns, pollutant loadings, and site conditions make it impossible to have scientifically repetitive results that can accurately compare one BMP against another when in field conditions. While general trends for different types of BMPs, such as ponds, swales, or sediment traps, can be stated within reasonable ranges, any attempt to refine these trends to an accuracy of within 5%-10% is not viable at this time. With the new generation of BMPs, the smaller devices such as CDS units, baffle boxes, etc. are more appropriately tested in laboratory conditions where a wide range of velocities, pollutant concentrations, sediment sizes, and device sizes and configurations can be tightly controlled and repeated. This can lead to accurate comparisons between BMPs.

Much of the sediment was large sand particles which rolled down the inflow pipe of the CDS unit, rather than being considered suspended solids. While total suspended solids removal was measured around 50%, the true sediment removal rate was much higher if the rolling solids were considered. Because of the configuration of the CDS unit, very little of the heavy rolling sand actually passes through the screen and out the unit.

The phosphorus removal performance was around 30%, which was expected since particulate phosphorus is usually around 30% of the total phosphorus load in stormwater.

Sediment traps such as the CDS unit which trap and store leaves, grass, and organic debris in wet conditions will not effectively remove nutrients since the organic material has been shown to leach out to the water within 1-22 days, depending on the pollutant. This means that to prevent the nutrient laden water in a BMP such as this from flushing out with the next rainfall, these BMPs must be cleaned every week or two, which is impractical.

The CDS unit is extremely easy to clean and maintain with a vacuum truck. The unique screen design is self cleaning and the sediment sump showed no evidence of resuspension.

The biggest constraint in using a CDS unit, or other types of sediment traps, is the head losses required to drive the unit. This is where a trap such a baffle box has an advantage since the only head losses in a baffle box are the same as those associated with any manhole. It is recommended that an offline configuration be used to optimize first flush trapping abilities of the CDS unit without having to design the unit for peak flows. This saves on construction cost unless the peak flows are relatively low, then an in-line design would be more appropriate.

The low number of storms and cleanout events does not yet allow for a determination of cleanout costs on a $/pound of sediment removed basis, but this will be calculated as more cleanout data is accumulated. Although a method of monetary measure of benefit is not yet available, there is a definite benefit to removal of the large volumes of trash, debris, and organic matter which are trapped in the CDS unit.

RECOMMENDATIONS

Further monitoring of the CDS unit would refine the removal efficiencies calculated in this report. A successful mass loading test would allow a determination of removal efficiencies for various suspended solid particle sizes. Also, testing under higher flow conditions would be desirable.

Based on the monitoring of BMPs performed by Brevard County over several years, it is felt that in order to compare removal efficiencies of different sediment trap type BMPs, mass loadings under laboratory conditions are needed. Any attempt to measure sediment loadings without accounting for the base loads which roll slowly down a pipe system will not be accurate. This can be performed in a lab, but we do not know how to effectively do this in the field at this time.