STORM WATER RUNOFF TREATMENT

STRUCTURAL POLLUTION CONTROL MEASURES

CDS SEPARATION TECHNOLOGY

Continuous Deflective Separation (CDS) is an innovative technology that separates solids from liquids and is an accepted Best Management Practice (BMP) well suited to treat a large range of storm water flows and conditions. The CDS Technology employs multiple primary clarification treatment processes to remove pollutants from storm flows in a very small footprint: Deflective Screening / Filtration, Swirl Concentration, Diffusion Settlement and Baffling.

Treatment flows are introduced into the deflective separation chamber tangentially by the CDS unit's inlet structure located above the cylindrical screen. The flow is introduced smoothly along the circumference of the stainless steel screen cylinder. A balanced set of hydraulic forces is produced in the separation chamber. These balanced hydraulics provide continuous moving flows across the stainless steel screen surface, preventing any clogging of the apertures in the expanded metal screen as well as establishing 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 with a centrally located underdrain. The CDS Separation process is more than a gravity based separation process.

The continuous deflective separation process produces a low energy, quiescent zone in the center 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. Dense particles (Specific Gravity >1) ultimately settle into the sump located below the separation chamber.

Figure 1 illustrates that screened water from the CDS unit's separation chamber exits radially.

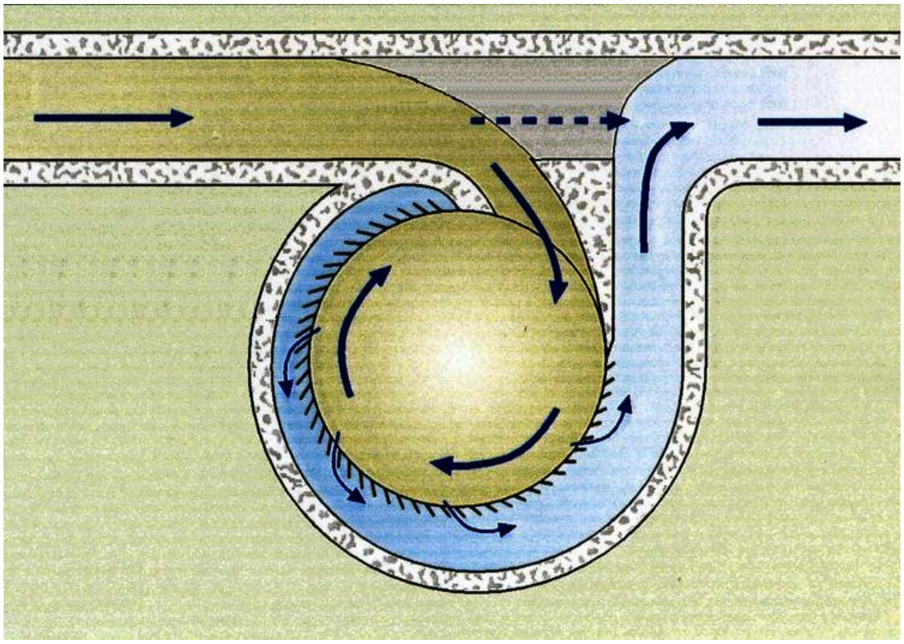

Figure 1. Typical "Offline" CDS Model PSW, PSWC or CSW system shown diverting flows from main storm water channel into its separation chamber.

All CDS units are equipped with sumps to accommodate the storage of deposition material below the separation chamber. The CDS sump is isolated from the separation chamber by a separation slab at the bottom of the separation chamber, which creates a hydraulic shear plain, minimizes the influence of scouring. The pollutants captured in the sump are isolated from high velocity bypass flows through the unit preventing the scouring loss of captured pollutants.

Figure 2 shows the CDS screening mechanism. 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.

This turbulent boundary layer and deflective force make the CDS system more effective in retaining particles compared to classic smooth-walled swirl concentrators. In comparison, the gravity-based smooth-wall swirl concentrators predominately rely on toroidal forces to separate solids from liquids in swirl chamber. And these toroidal forces are present in equal or greater magnitude within a CDS unit.

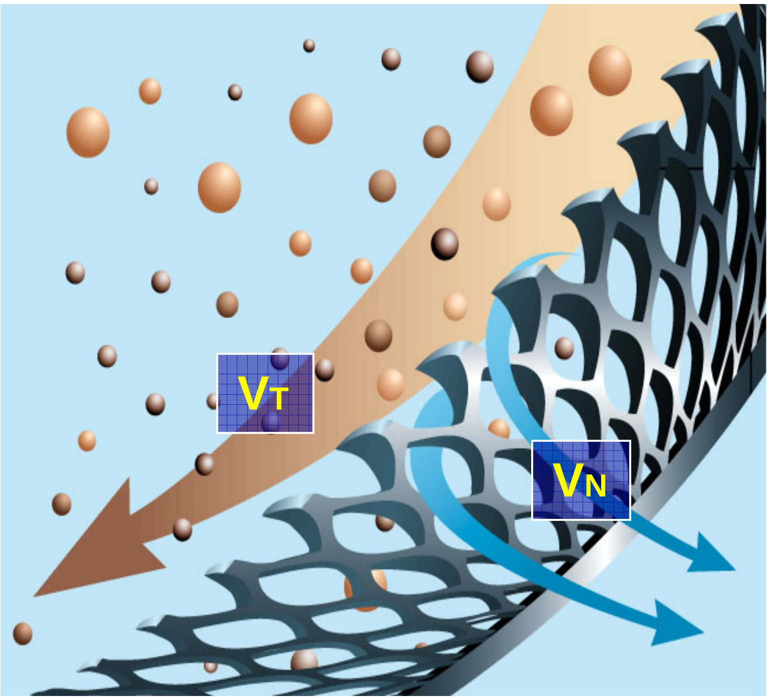

Figure 2. Illustration of Fluid Velocity Flows in CDS Unit Screening Mechanism

The toroidal flow motion with in the separation chamber of a CDS unit is shown as the red circular flow lines (Figure 3). 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 where they settle into the sump later on.

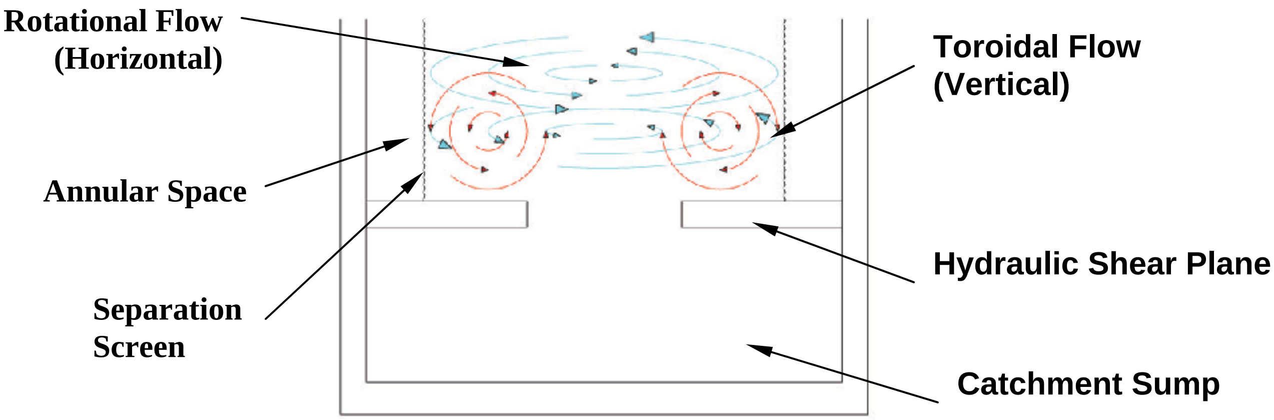

Figure 3. Toroidal Pattern in a CDS Unit

Treated water travels through the entire screen cylinder surface area, and then exits the separation chamber. This is a very large flow path area, resulting 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 center of the swirl separation chamber, low flow velocities also occur in the annular spaces behind the screen (Figure 3). The flow passing through the stainless steel separation screen is greatly dispersed. After crossing the screen surface into the annular space, the flow has extremely low velocity compared to the entrance, separation chamber and exit velocities. Quiescent settling occurs in this annular space before the flow travels beneath the oil baffle and exits the unit.

In summary, CDS brings together primary clarification treatment processes (patented continuous deflective separation, swirl concentration, toroidal separation, separated sump zone, indirect screening, sedimentation and baffling), in one treatment device for stormwater treatment control.

CDS Separation Screen – Blockage-Free, Self-Cleaning

CDS consists of a perforated stainless steel expanded metal screen that is either concentrically or eccentrically located in the separation chamber 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. The separation screen is installed with the leading edge of each perforation extending into the flow.

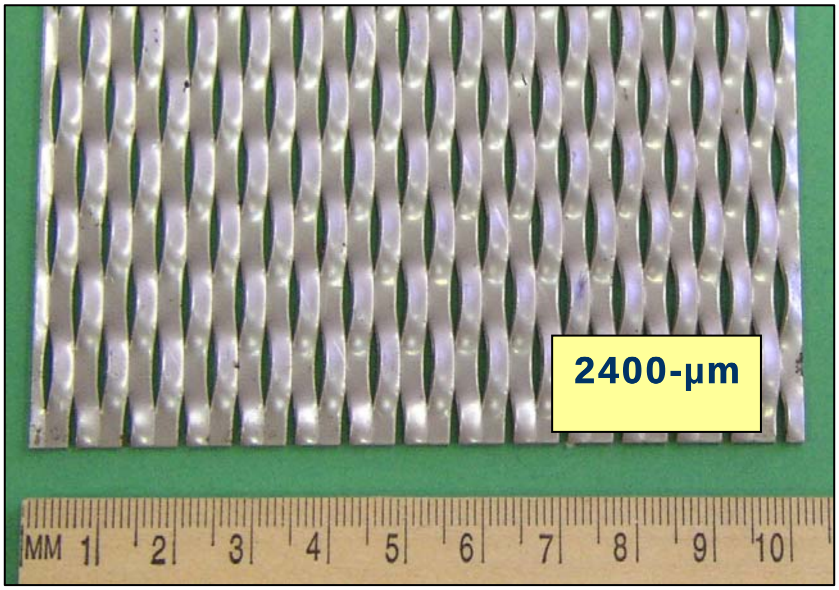

Figure 4 . Photo of 2400-µm Screen Section ASTM 316L Stainless Steel

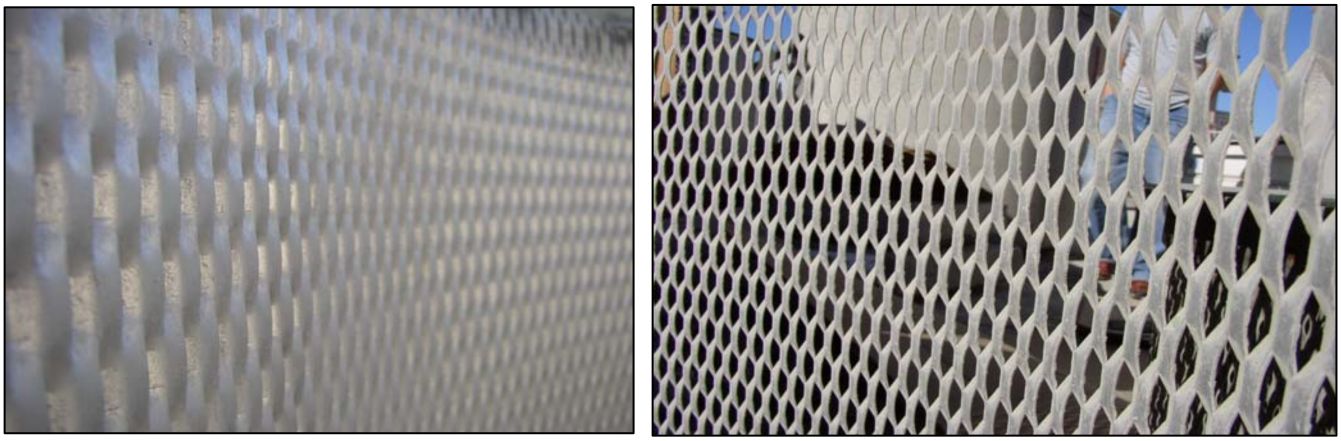

Figure 5. Screen Cylinder (In Field)

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 particles and can allow flow to reach the outlet.

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 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.

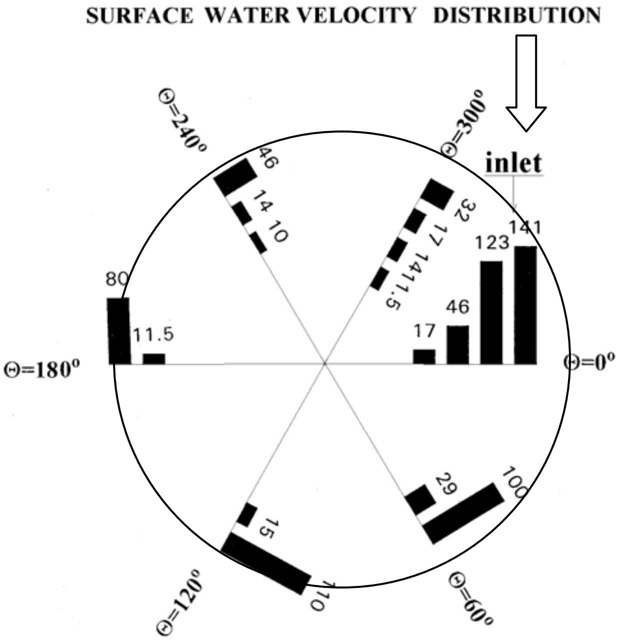

Figure 6 . Surface velocity distributions within the separation chamber of a CDS unit (Wong & Wootton, 1995)

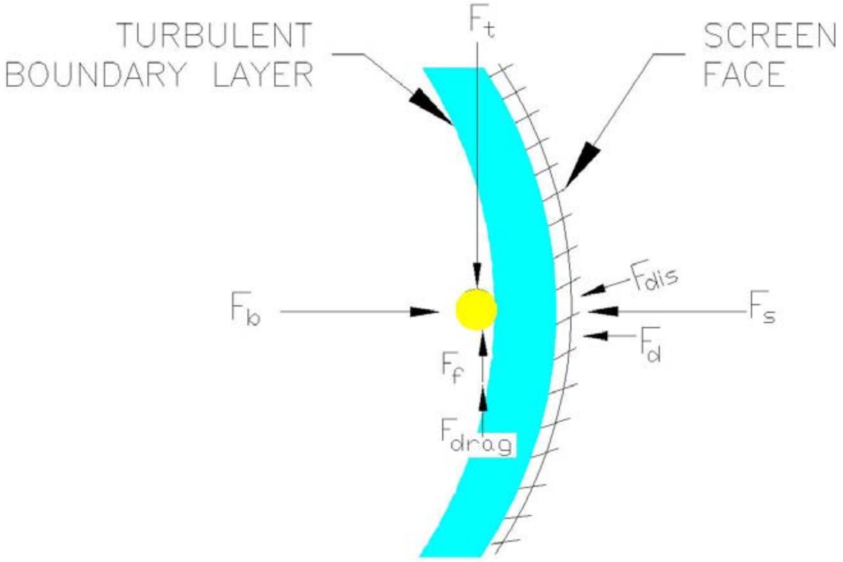

Figure 7. Schematic Drawing - Forces On An Object Near the CDS Screen

Figure 7 illustrates the forces that act on a particle as it travels across the surface of the screen.

The particle is influenced by the circular motion of the water inside the chamber forcing the particle outwards, but is prevented from moving to outside 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. 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-balanced, would act to eventually block the screen with particle. This force centrifugal force (F_b), however, 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.

MULTIPLE 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 (PSW, PSWC & CSW), In-line (PMSU), and Drop-Inlet (PMIU).

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 10 shows our Drop-Inlet storm water treatment units.

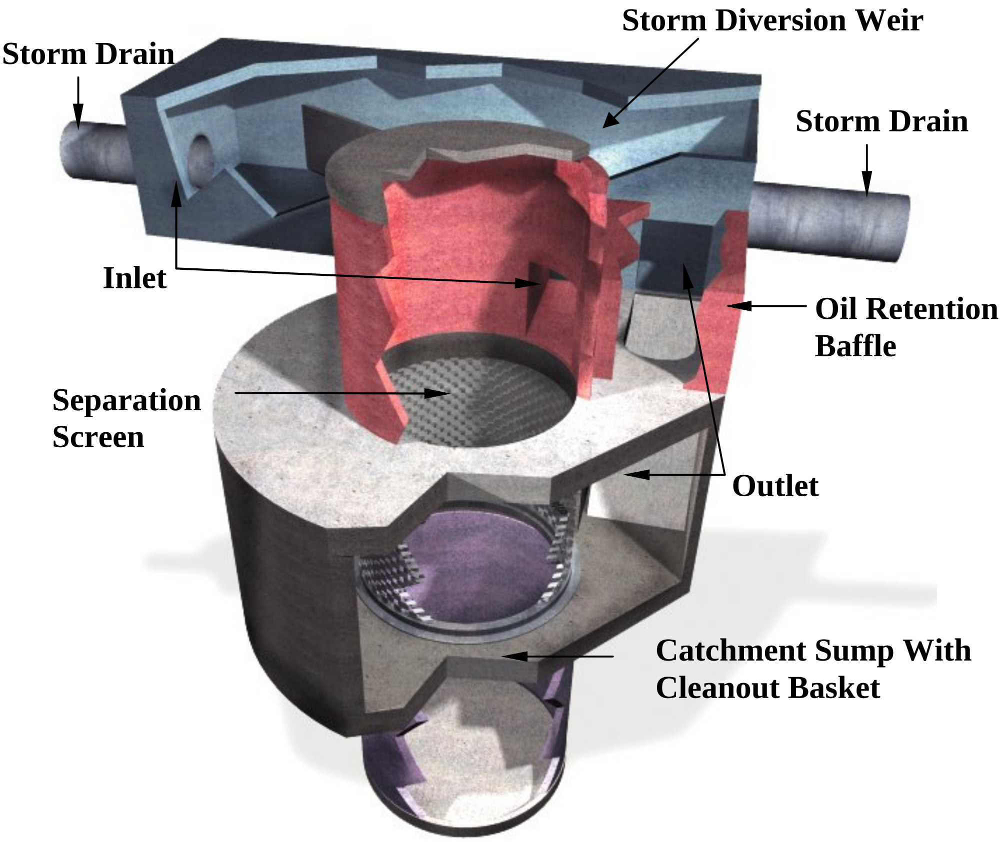

Figure 8. Schematic of an Offline CDS Unit

Off-line Units: CDS off-line units are available in precast (PSW & PSWC prefix models) and cast-in-place (CSW prefix models) reinforced concrete structures. These Offline units can also be installed in parallel or series. The precast PSW & PSWC models are standard units, designed to treat flows up to 1813-l/s (64-cfs*).* The cast-in-place, CSW prefix models, can be constructed to treat flows up to 8.4-m^3/s (300-cfs). 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.

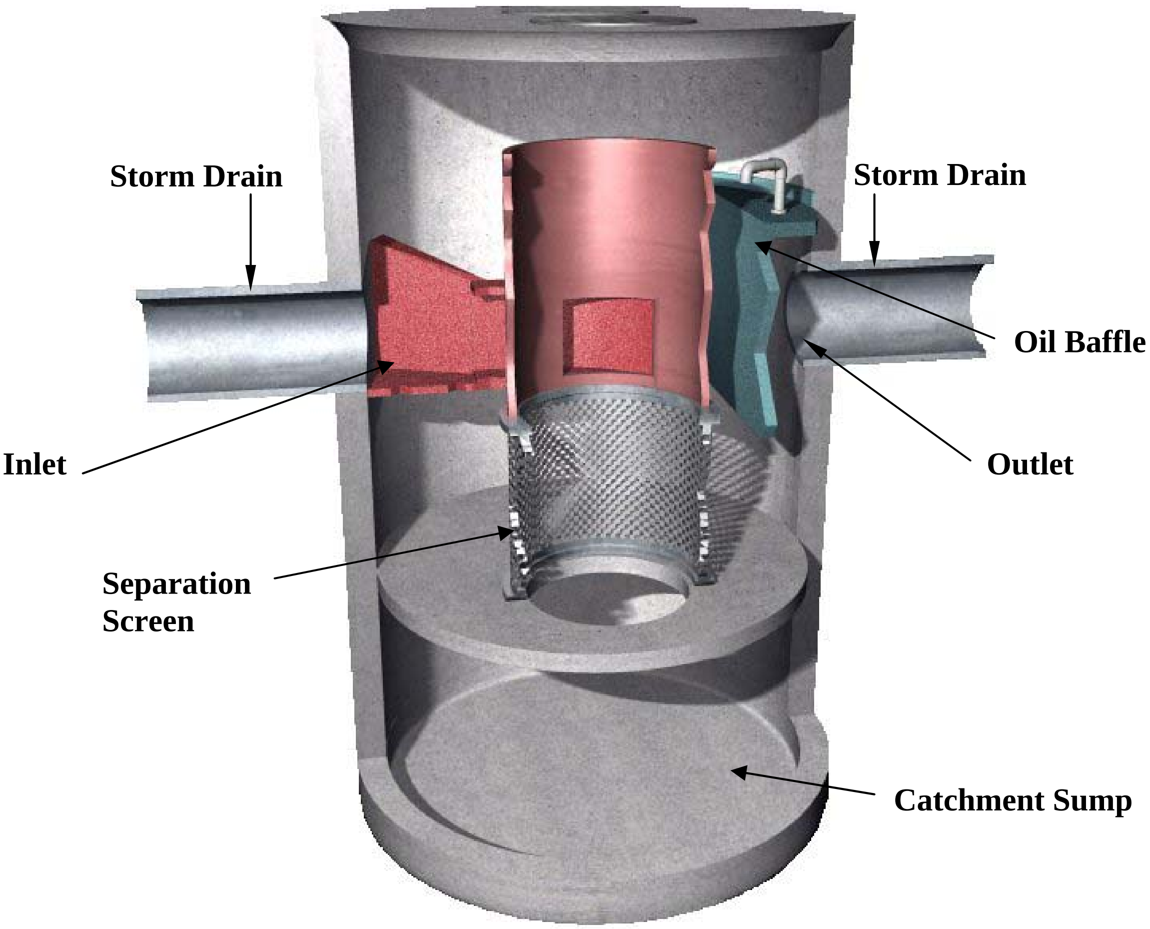

Figure 9. Schematic of an In-line CDS Unit

In-line Units: CDS In-line (PMSU prefix model) units are smaller pre-manufactured systems configured inside standard precast manhole structures. These Inline (PMSU) units are sized to process flows from 20 to 171-l/s (0.7 to 6-cfs) for new and existing urban developments. The CDS unit can be placed within new or retrofitted into existing storm water collection systems. Its remarkably small footprint takes little space and requires no supporting infrastructure. These smaller PMSU units are ideal for treating the runoff from parking lots and vehicle maintenance yards.

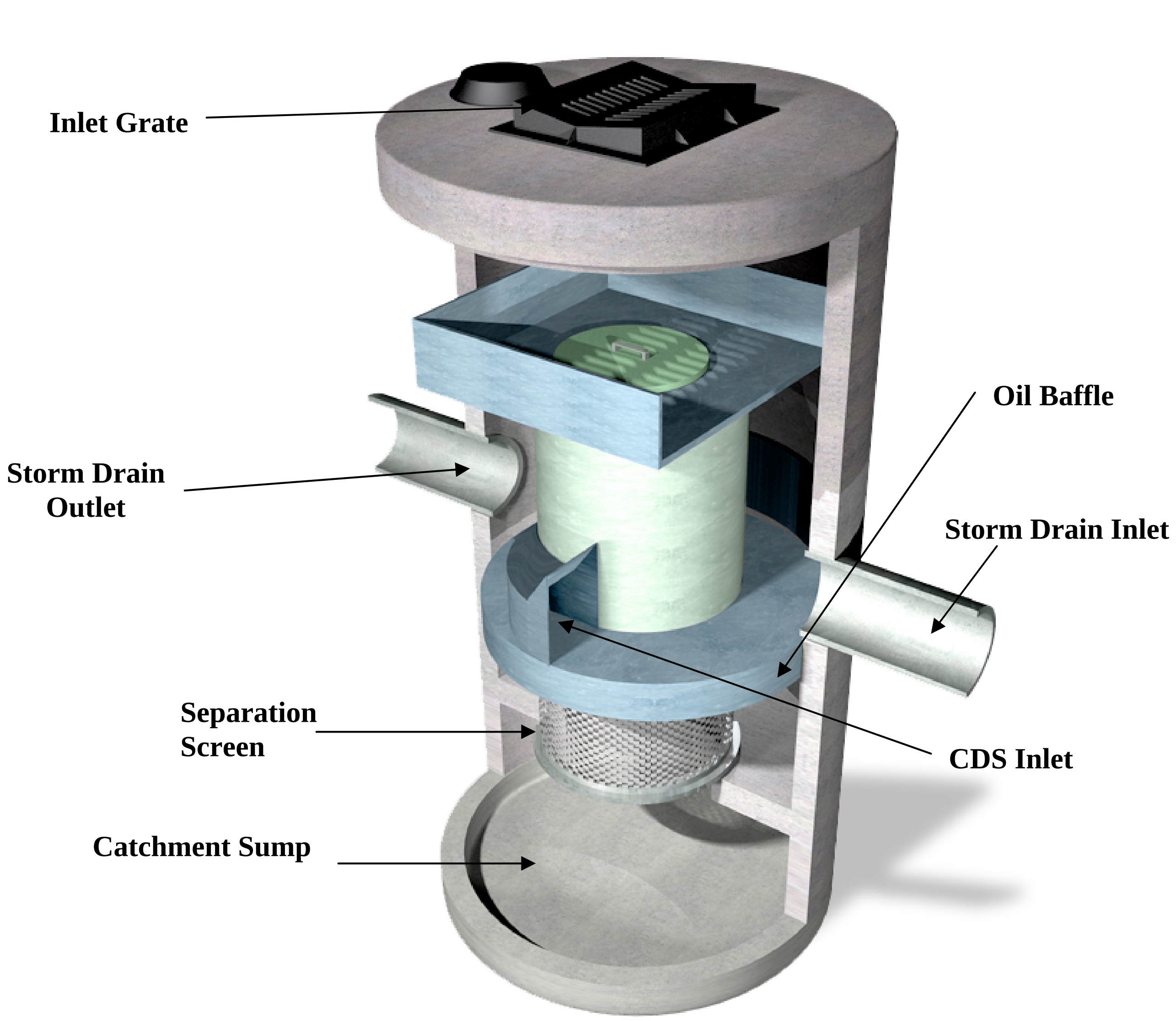

Figure 10. Schematic of a Drop Inlet Inline CDS Unit

Drop-Inlet Unit: This pre-manufactured drop-inlet (PMIU) unit is designed to process flows up to 20-l/s (0.7-cfs) 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.

STORM WATER POLLUTION CONTROL APPLICATIONS

CDS storm water treatment systems are appropriate structural BMPs to treat the storm water runoff from:

- Retail, Commercial, Industrial and Residential Developments
- Parking Lots, Vehicle Maintenance Yards
- Road Improvement Projects
- Inter-modal Transportation Facilities
- Solid Waste Management Facilities and Transfer Stations
- Pretreatment for Wetlands, Detention and Retention Ponds
- Pretreatment for Storm Water Pump Stations
- Pretreatment for Landscape-based BMPs (i.e. swales)
- Pretreatment for Filtration System

CDS units effectively capture the following storm water pollutants of concern.

- Medium and Coarse Sediments (> 75 μm)
- Oil & Grease
- Trash, Debris, Vegetation
- Floatables
- Neutrally Buoyant Material
- Particulate associated contaminent - Nutrients (Phosphorus) & Heavy metals
- Particulate associated biomass

LABORATORY STUDIES AND FIELD PERFORMANCE EVALUATIONS

Gross Pollutants

Regardless of the size of the storm event being treated, CDS storm water treatment units will ensure the permanent removal of 100% of floatables as well as 100% of the solids equal to or larger than the 4.7 mm or 2.4-mm screen openings for flows up to and including their full hydraulic treatment capacities.

CDS units are the only storm water treatment devices available that can guarantee 100% removal of any particles equal to or larger than the screen aperture dimension (screen apertures used for storm water are either 4700 or 2400 microns) regardless of the specific gravity of those particles. In contrast, BMPs that depend on baffles and detention time are not effective in removal of debris which does not float or sink well (neutrally buoyant) especially during high flow events where turbulence results in most debris behaving as if it were neutrally buoyant. In a CDS unit, debris is retained by a physical screening process, material previously captured cannot wash out during high flow and the CDS unit will retain 100% of the material captured.

Cooperative Research Centre (CRC) Case Studies

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 11. 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.

In CRC’s report “Removal of Suspended Solids and Associated Pollutants by a CDS Gross Pollutant Trap” (Walker, T. et al 1999), monitoring program was conducted to investigate the performance of a CDS unit in removing Total Suspended Solid (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) under wet and dry weather flow conditions.

During storm flow conditions, water samples were collected using automated samplers and inflow TSS, TP and TN concentrations from the Coburg catchment were observed to be as high as 570 mg/L, 4.3 mg/L and 6.0 mg/L respectively. In the case of TSS, the CDS unit effectively reduced concentration levels above 75 mg/L, with a mean removal efficiency of approximately 70%. For concentration levels below 75 mg/L TSS removal was highly variable. This is thought to be due to flow turbulence maintaining a larger fraction of the inflow particles in suspension. Removal rates for TP were found to be approximately 30%.

During dry weather flow conditions, the data suggest that the CDS unit has a small effect on the TSS, TP and TN concentrations. The CDS unit was found to have consistently removed TN under dry weather flow conditions.

Case Study in Brevard County, Florida

Stormwater sedimentation is a primary source of pollutant 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 are suspended solids, phosphorous, and nitrogen. Suspended solids and turbidity reduce sunlight penetration in the Lagoon which negatively impacts sea grass growth. Phosphorous and nitrogen are nutrients which promote algae growth and reduce oxygen levels in the Lagoon.

In July, 1997, Brevard County’s Stormwater Utility Program installed a 4050 GPM CDS unit (Model PSW50_42) with a 4700 micron screen opening along a ditch at the north end of Brentwood Drive, north of Cocoa and close to the Indian River. This was the first United States installation of the CDS technology. Over an 18-month period 5 storm events were monitored for 6 parameters: pH, TSS, BOD, COD, turbidity and total phosphorous. In addition, sediment samples were collected and tested for 61 parameters. (Strynchuck et al., 1999)

The monitoring program reported in “CDS Unit for Sediment Control in Brevard County, Florida” (2000) included over 18 months period detailed monitoring and analysis of 5 storm events. The CDS unit designed for 9 cfs using a 4700-micron screen achieved effective removals of 52% TSS and 31% phosphorus.

Case Studies – Analyses of the Sediments in CDS Unit Sump

The City of Issaquah, Washington, installed two CDS stormwater treatment units to provide water quality treatment for urban stormwater runoff in 2000. One unit (Model PSW30_28) with a 2400 micron screen and a 1350 GPM nominal maximum flow rate capacity is located on NW Birch Place, treats stormwater from a 45-acre area (approximately 52% is covered by impervious surfaces) with mixed commercial and residential land uses, and discharges into Issaquah Creek. Sampling of sump material was conducted on January 4, 2001 and July 2, 2002 to correspond with the end of the fall and winter/spring monitoring periods, respectively.

The study conducted by Brisbane City involved three “clean outs” and found that 27% of the material trapped in the CDS sump was silt/clay size category, 50% was sand size category and 23% was classified as gravel.

The results of above two independently conducted studies involving five separate sump “cleanout” events are shown in Figure 12. It showed that median particle size in the CDS sump ranged from 50 to 450-μm.

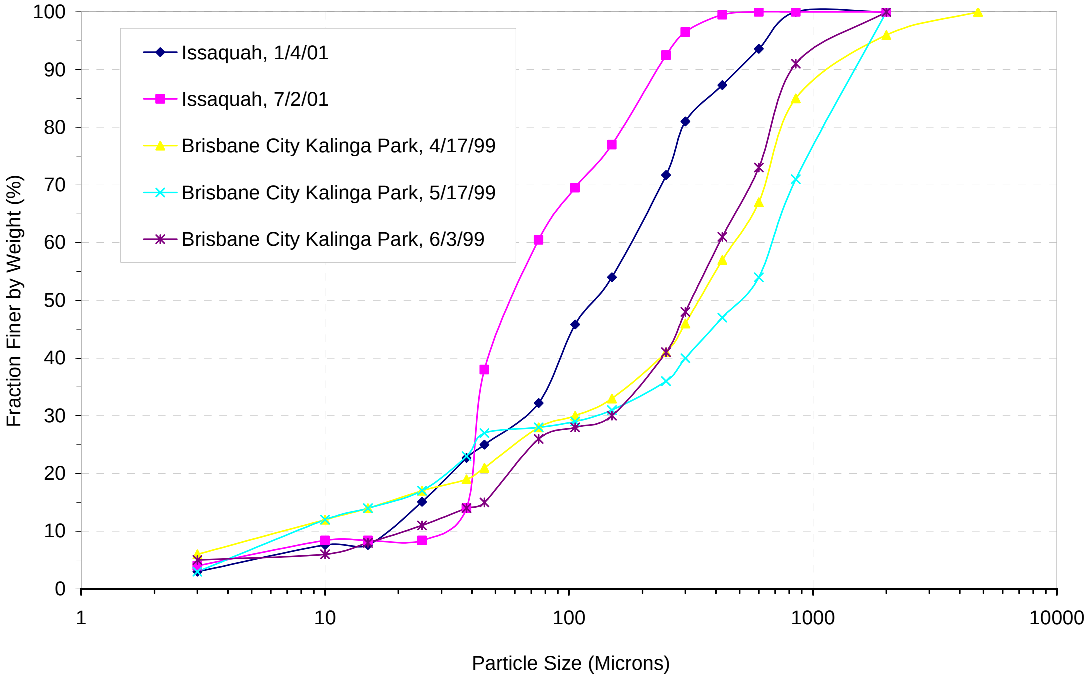

Figure 12. Particle Size Distribution of Sediments Captured in CDS Units Sump

Total Suspended Solids/Sediment Removal

Portland State University Studies

Numerous lab studies have been conducted on CDS unit. Earlier Portland State University (Wells and Berger 2002) conducted multiple test runs to establish CDS removal efficiencies using particles ranging from 0 to 600-microns (µm), [0.0 to 0.6 mm] in size on CDS units 20_15 series and 20_20 series operating at varying flow rates up to and including the CDS's low flow treatment capacity. Design capacity for the 20_15 series and 20_20 series are 0.7 and 1.1 cfs respectively.

The results from this study have shown that CDS units operating at 100% of their treatment capacity were demonstrated to remove, on average, greater than 70% of the TSS. At flowrates less than the low flow treatment capacity of a given CDS unit, TSS removal efficiency increases.

When the Particle Size Distribution of the TSS / Sediment used in the Portland State University study are compared with 23 field evaluations of Particle Size Distributions of Solids found on streets or suspended in road runoff (Walker, et al.), it is shown that the particles used in the Portland State University study have a mean particle size comparable with that of the TSS and sediment found in our urban catchments. This comparison provides the basis of reasonable forecasts.

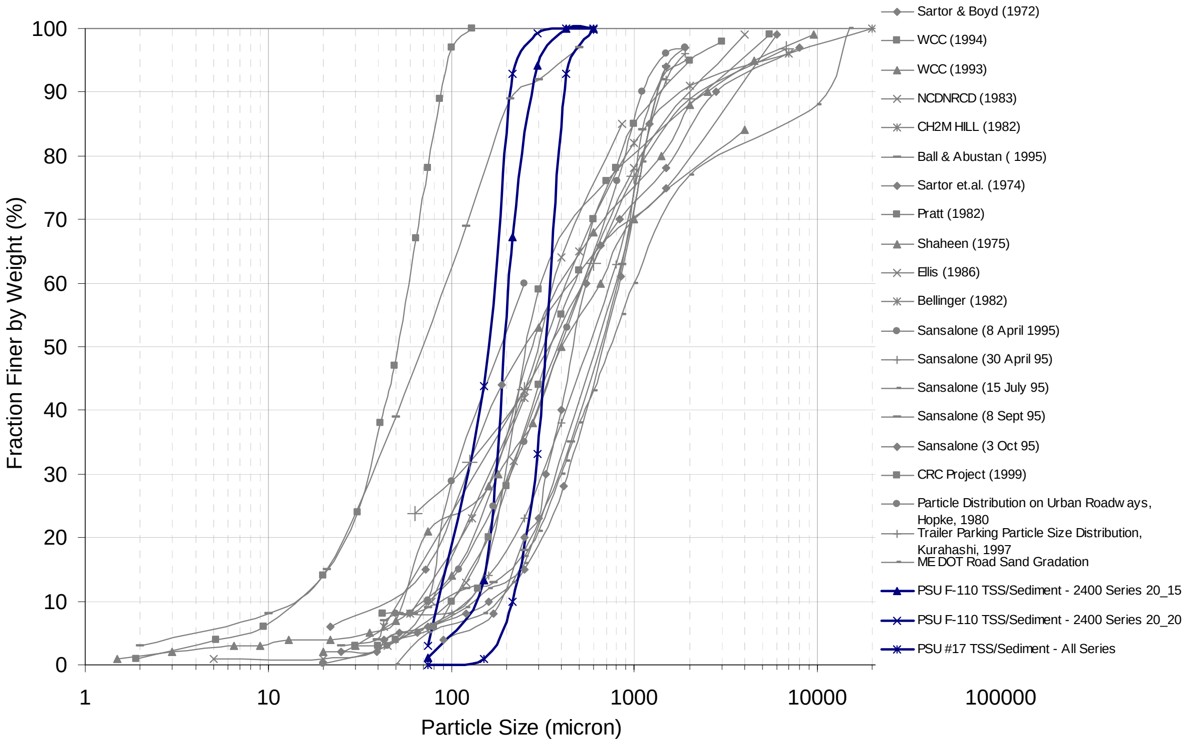

Figure 13. Particle Size Distribution of Solids Found on Street & Suspended in Road Runoff

Portland State University (Howard, 2003), as part of its continuing evaluation of CDS unit performance for sediment control, conducted fine sand removal tests on the previously tested Model PMSU20_20. The base material used in the Portland State testing was developed by repeated washing and decanting of the fines from the parent material (Sil-Sol-Sil 106 silica sand) to achieve the ultimate test gradation. Figure 14 showed the particle size distributions of the material used in the testing. The influent concentrations were controlled at 200-mg/L.

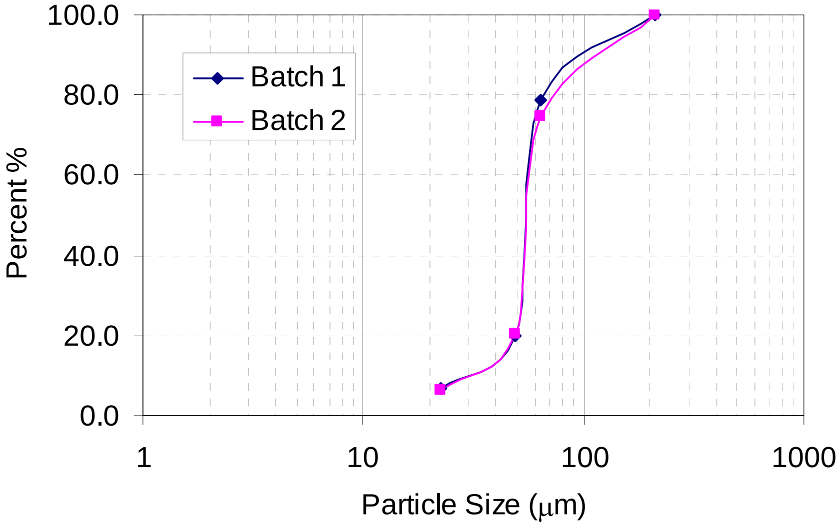

Figure 14. Particle Size Distribution of Materials used in the Fine Particles Removal Testing in Portland State University

The modifications to the standard CDS unit is that the oil baffle was removed and replaced with a sediment control outlet baffle.

The results of the laboratory testing demonstrate that the CDS device does capture 75-μm particles. The results (Figure 15) showed that the mass removal of particles less than 75-μm was well above 70% through the flow rates tested (5% up to 50% CDS unit's capacity). In addition, the overall efficiencies were well above 80%. These results are generally better than those shown in the most recent Portland State study. This is attributed to the fact that a sediment control outlet baffle was deployed in lieu of the oil baffle used in recent Portland State study, and the utilization of particle counting to actually determine the effluent particle size distribution and mass. The linear regression of overall removal efficiency data showed that the removal efficiency decreased with increased flow rate (Figure 15).

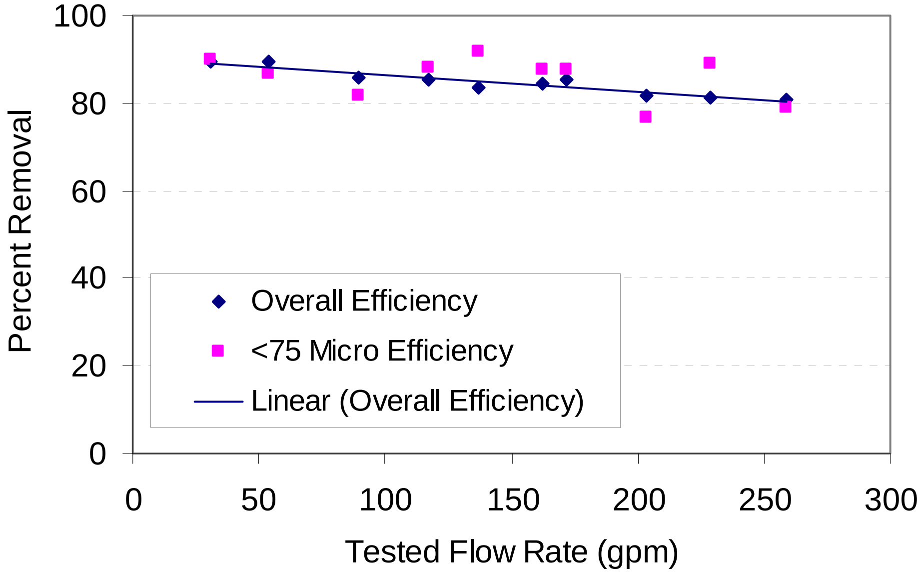

Figure 15. Portland State University CDS Unit Fine Particle Removal Testing

PMSU 20_20 Controlled Test in Gainesville, FL

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.

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 16 shows a constructed Particle Size Distribution with d_{50} of 50-µm. Figure 17 shows 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 prediction model developed using numerous test data.

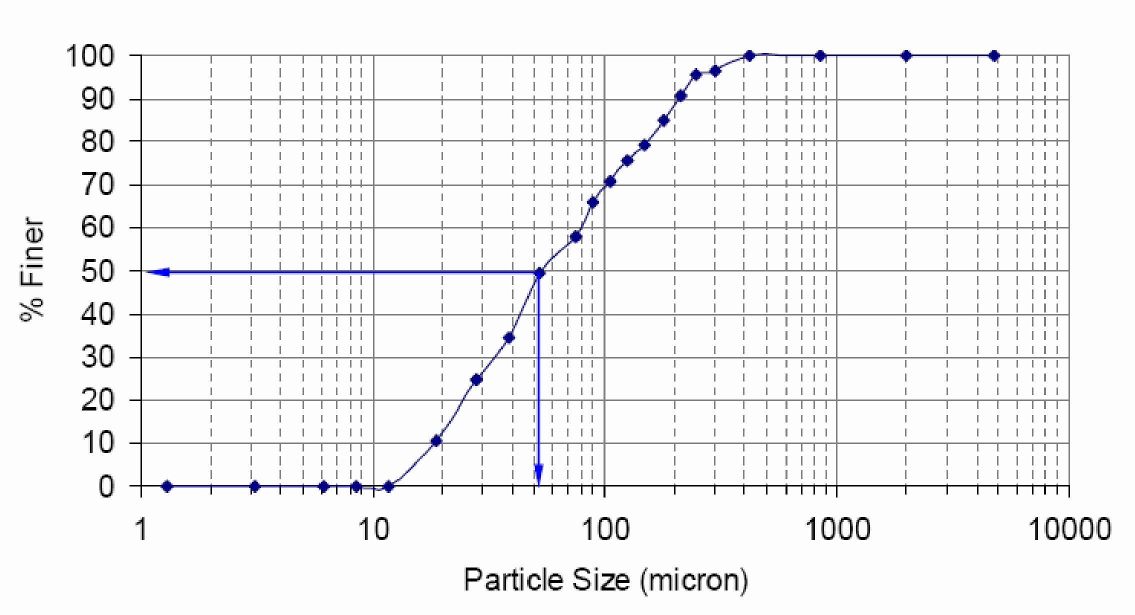

Figure 16. **Particle Size Distributions for Ecology Defined PSD (d50 = 50-µm)**

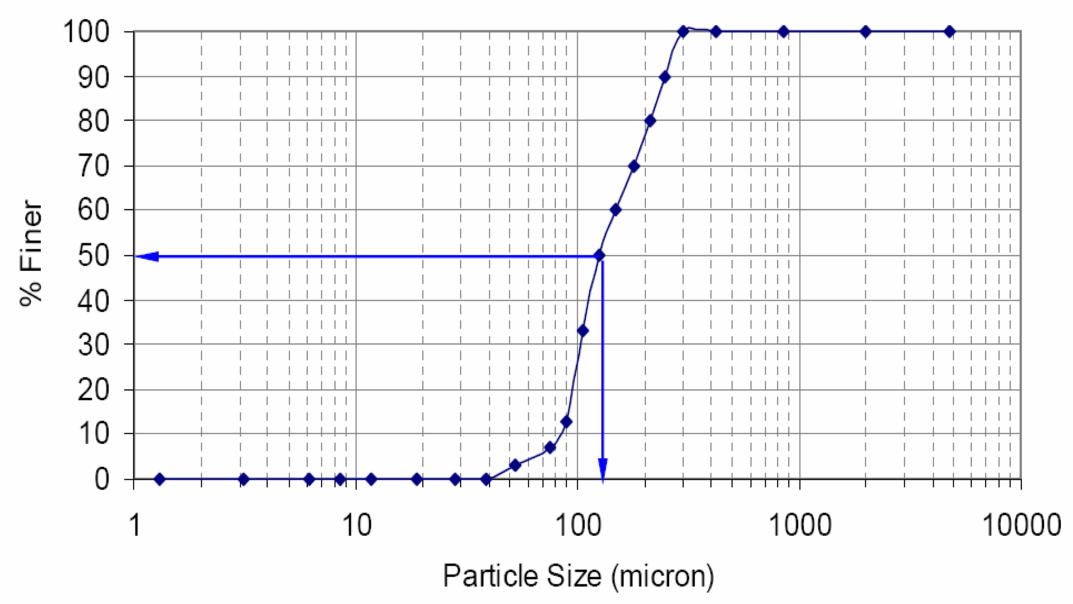

Figure 17 . **Particle Size Distributions for Ecology Defined PSD (d_{50} = 125-µm)**

Particle Size Distribution of Testing Material

Two different sediment gradations of silica sand material ("UF Sediment" & OK-110) 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" and a PSD report is prepared by MACTEC Engineering and Consulting Inc. in Jacksonville, FL, a certified laboratory.

"UF Sediment" Test Material: One gradation of sand material used in the 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 as "UF Sediment". 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 1 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.

Test sands 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 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 (Washington Department of 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) particle size analyzer (manufactured by Sequoia Scientific, Inc., Bellevue, Washington) was utilized.

Laboratory Testing Results

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

Testing results for UF Sediment and OK-110 sands over the entire range of test flow rates are summarized in Figure 18.

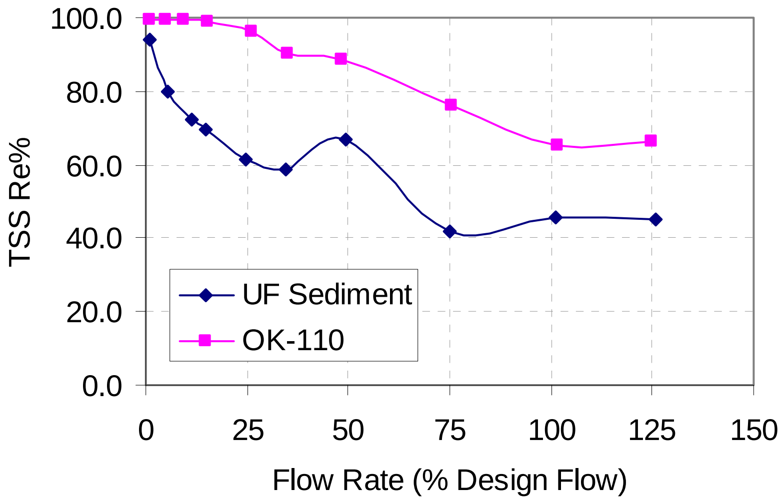

Figure 18 . Cumulative Measured TSS removal – Analytical results for PMSU20_20 Test 2400-µm Screen, TSS=200-mg/L (UF Sediment & OK-110 sand)

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 performance test (Portland State University 2003) of the sub 100-µm silica particles. 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.

CDS Unit Performance Model Development and Calibration

TSS removal as a function of particle size for various flow rates was calculated and a regression analysis was done to develop a fitting curve for data.

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.

Below, Figure 19 shows the comparison of TSS removal efficiencies determined using the regression model with the measured TSS removal results from the analytical sample data. 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.

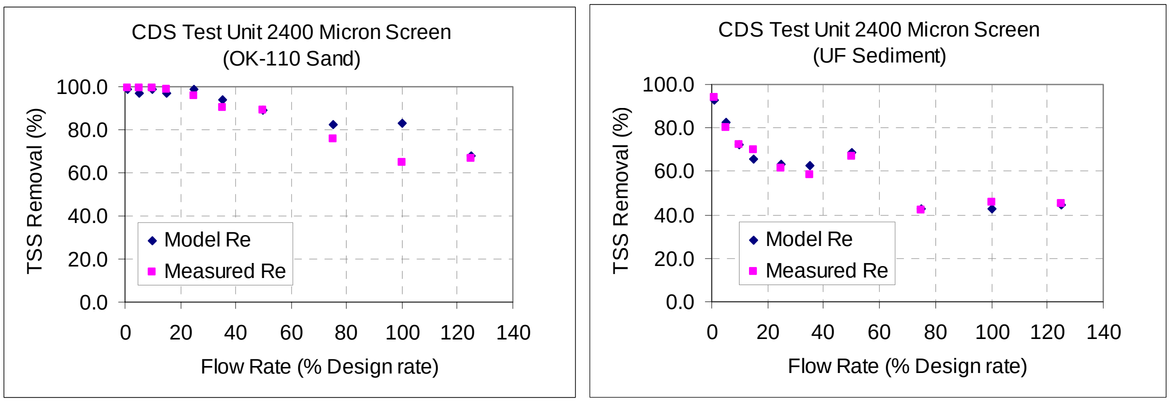

Figure 19. CDS Unit Performance Model Calibration (2400-µm screen) TSS Removal calculated from the model compared with analytical results from the lab for two test sands: OK-110 and UF Sediment

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. In Figure 19, 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.

In general, the calibrated model correlates well with the finer UF Sediment test material and the OK-110 sand. 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 19. It is only for the OK-110 sand run at this single flow rate that the model overestimates the removal efficiency. Additional tests will be conducted to further refine the regression model for this more coarse material at this flow rate.

CDS Unit Performance Curve (2400 micron screen unit)

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 PSDs with d_{50} of 50-µm and d_{50} of 125-µm as previously shown in Figure 16 and 17.

Figure 20 and Figure 21 showed the predicted TSS removal of a CDS unit configured with a 2400-micron screen as a function of flow rate for the two gradations.

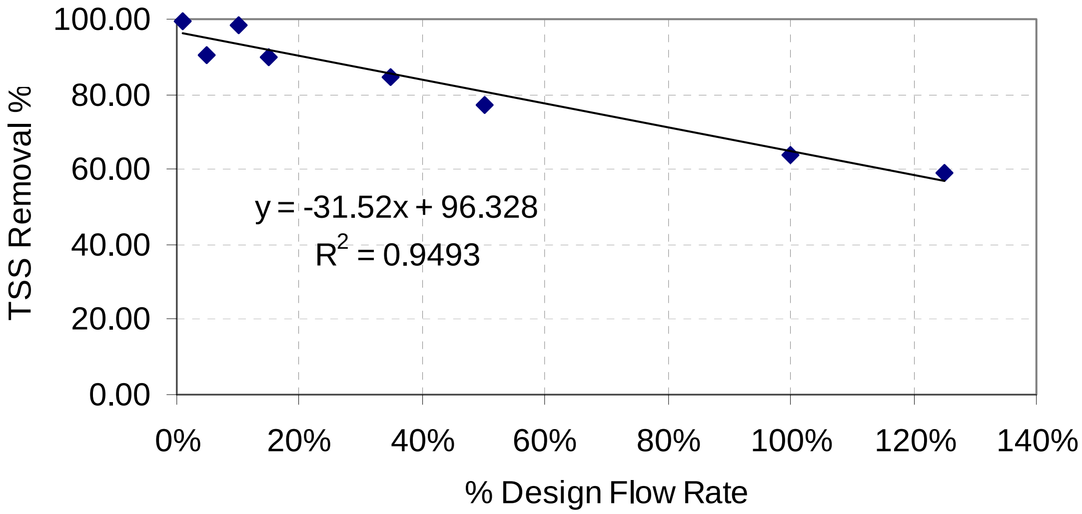

Figure 20. CDS Unit (2400-micron Screen) Performance for Constructed Ecology PSD d_{50}=50-µm

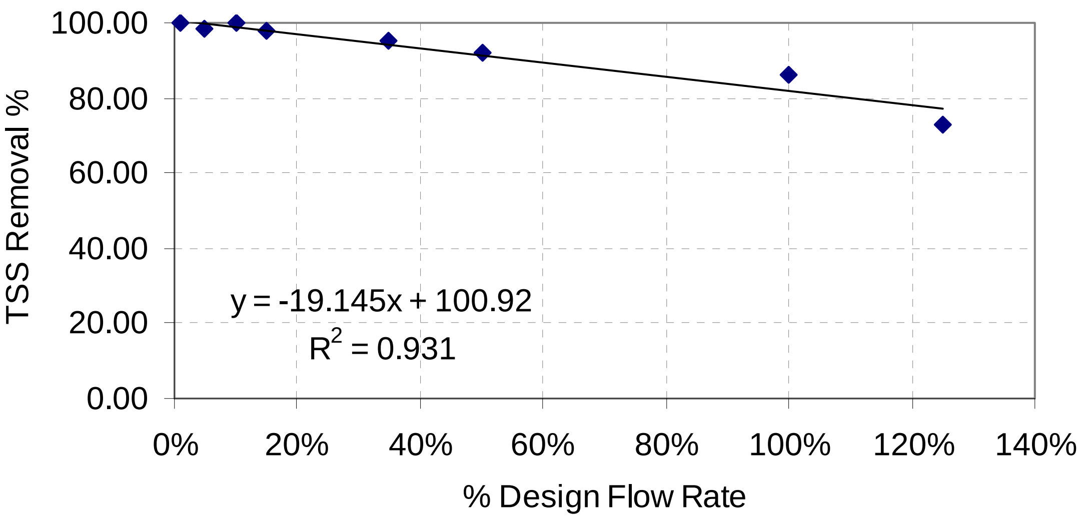

Figure 21. **CDS Unit (2400-micron Screen) Performance for Constructed Ecology PSD d_{50}=125-µm**

As demonstrated above, at 100% design flow rate and influent concentration of 200-mg/L, a CDS unit with 2400-micron screen is able to achieve 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).

CDS Unit Performance Curve (4700 micron screen unit)

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 22 and 23.

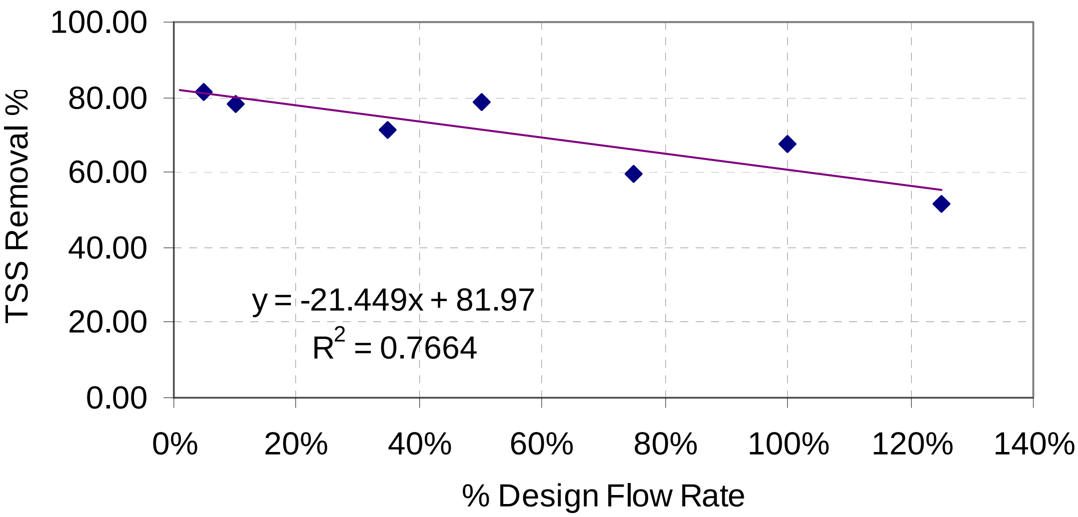

Figure 22 **CDS Unit (4700-micron Screen) Performance for Constructed Ecology PSD d_{50}=50-µm**

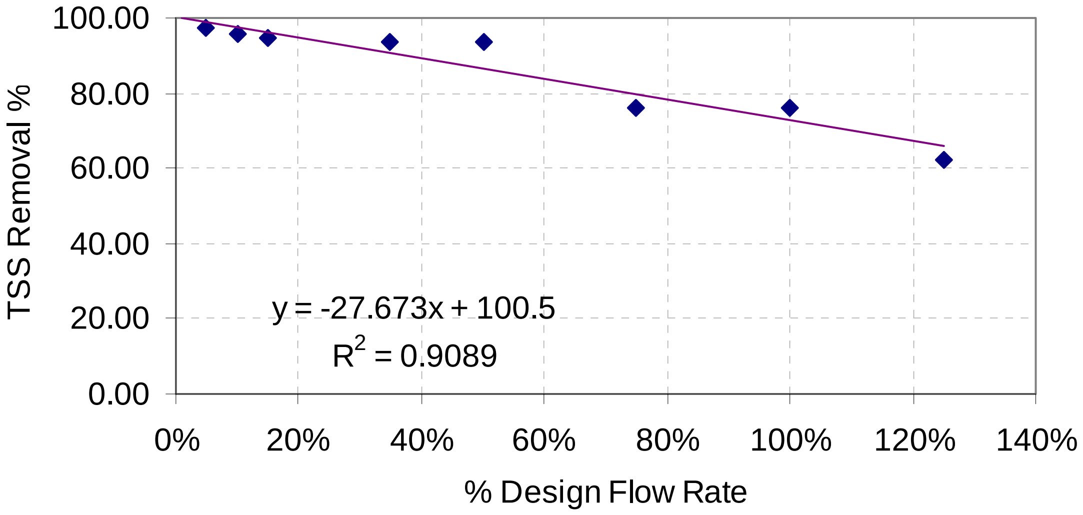

Figure 23 CDS Unit (4700-micron Screen) Performance for Constructed Ecology PSD d_{50}=125-µm

In summary, 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.

Oil & Grease Removal

Sediments with the attached oil and grease have been found to block direct filtering or infiltration systems and removal of this material will improve the useful life and extend the maintenance cycle.

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.

Table 2 **Concentration of TPH in Stormwater Runoff**

Land Use	Median (mg/L)	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

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.

Laboratory Studies – Oil and Grease Removal with CDS Units with Sorbent 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.

A series of nine (9) laboratory experiments were performed on a CDS unit (Model PMSU20_15) to determine its ability to remove free oil and grease using sorbents. (Stenstrom and Lau, 1998). One control experiment was performed without a sorbent. The focus 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 conventional oil baffle was not installed within the CDS unit during this evaluation. 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).

Tests were performed using a 2400-micron screen over 30 minutes at 125 GPM (approximately 40% of the CDS unit's nominal flow capacity). Used motor oil (Specific Gravity = 0.86) 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 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.

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

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

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

Results from the sorbent laboratory study (Stenstrom and Lau, 1998) are shown below:

Table 3 Performance of Oil and Grease Removal of CDS Units

Test No.	Sorbent Type	Sorbent Mass(g)	Influent (mg/L)	Effluent (mg/L)	Percent Removal	Flow (gpm)
2	OARS	2600	19.6	2.7	86	125
3	OARS	2600	24.0	4.3	82	190
4	OARS	2600	30.7	1.7	94	75
5	OARS[1]	2600	21.0	3.5	83	125
6	Rubberizer	1030	27.2	3.9	86	125

Effluent concentration of oil for the OARS™ sorbent was less than 1.0 mg/L. Effluent concentration of oil for the Rubberizer™ sorbent was 1.96 mg/L.

CDS unit itself was demonstrated to remove approximately 77% oil and grease in this study. Hoffman (1982) has reported that 83 to 93% of the hydrocarbons in runoff are associated with particulate material and particularly the settleable solid fraction. The oil and grease bounded with particulate solid in the runoff could be removed successfully from the stream by CDS unit alone.

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

Scott and Slominski at Portland State University conducted tests on a CDS Model PMSU 20_20 unit equipped with a 2400 micron screen and oil baffle (2003). Tests were conducted at 25, 50 and 75 percent of the unit's hydraulic capacity (500-gpm) for the removal of used motor oil with influent concentrations of 10, 25 and 50-mg/L. Summary of the test is shown in Table

Table 4 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

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.

Oil Spill Test

In addition to the regular capture test performed to measure the removal of free oil and grease from storm water, Wells (2003) also performed an oil spill 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. This showed a capture rate of more than 99.75% of the oil dumped into the unit (82,000 mg/L). This would be a very effective means of containing an oil spill. An oil storage capacity chart for the CDS unit is available on request.

A CDS unit makes an ideal pretreatment for oil/water separators by preventing the concentration of solids in the storm water runoff or effluent from wash racks from overwhelming and clogging conventional oil/water separators.

It appears to be quite common for installed oil/water separators, consisting of coalescing plate modules, or corrugated plate packs to become ineffective, because of the significant vegetation, sediment and debris loading that interfere with the coalescing of oil and grease globules. Many of these oil/water separator installations represent significant capital improvement projects that never achieve their design performance due to the solids content in the storm water runoff or wash rack effluent. The additional expenditure for the installation of a CDS unit as a pre-treatment to these oil/water separators usually represents a small percentage of the project cost and will assure the efficient performance of the oil water separator.

SUMMARY

CONTECH Stormwater Solutions is continuing its efforts to improve our products. Additional lab and field tests are underway. The information will be periodically updated to include new updates on the product and the test data on various pollutants of concerns.

We hope you find this information package useful in selecting the post construction storm water treatment BMP and we look forward to discussing potential applications of CDS units for your projects.

We welcome the opportunity to arrange a demonstrative presentation of the CDS storm water treatment technology with a working tabletop model of a CDS unit that replicates the performance of full size CDS units. The presentation typically covers planning, design, construction and maintenance issues.

For more information regarding CDS unit's performance and this performance review package, please contact Dr. Hong Lin at linh@contech-cpi.com or Mr. Walt Stein at steinw@contech-cpi.com. Please visit our website at **www.contechstormwater.com** for more information on other stormwater treatment technologies and CONTECH stormwater treatment products.

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