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16. Abstract

One of the problems facing designers/engineers in maintaining regulatory compliance with the Environmental Protection Agency (EPA) and the Texas Commission on Environmental Quality (TCEQ) is the lack of quantifiable data to assist in selection effective sediment control best management practices (BMPs). Although the two principles of erosion and sediment control are often used interchangeably, they are two separate issues and require different BMPs for mitigation. Erosion control is any practice that protects the soil surface and minimizes soil particle detachment by water or wind. Sediment control is any practice that traps the soil particles after detachment and transport. Typically, effective sediment control is more difficult and expensive than erosion control. While erosion can never be completely, combining erosion and sediment control practices can significantly reduce sediment loss. To help ensure compliance, TxDOT successfully evaluates the performance of erosion control materials and maintains an Approved Product List (APL). This project will develop the formal protocol for a performance-based, sediment retention device testing program that will assist the designer/engineer in the selection of the most effective sediment control BMP.

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ROADSIDE SEDIMENT CONTROL DEVICE EVALUATION PROGRAM: TECHNICAL REPORT

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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. Mention of trade names or commercial products does not constitute an endorsement or recommendation for use. The researcher in charge of the project was Jett McFalls.

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CHAPTER 1:
INTRODUCTION

Transportation construction activities such as the building of highways, streets, and bridges in the U.S., represent approximately 7 percent ($83 billion) of the total amount of dollars spent annually by the construction industry (U.S. Census Bureau 2002). In Texas, the Texas Department of Transportation (TxDOT) is responsible for construction and maintenance of the 80,000 miles network of state roadways. Construction activities associated with highway projects involve heavy earthmoving operations that disturb several square miles of undisturbed land areas. In 2007 alone, TxDOT reported 1541 active construction contracts throughout Texas that resulted in significant area of topsoil disturbance. The most detrimental environmental impact of highway construction/maintenance results from erosion of the exposed topsoil during storm events. While erosion is a naturally occurring phenomenon, construction activities disturb the natural vegetative cover causing the erosion processes at such sites to proceed at a significantly faster rate than the natural erosion rate.

Landphair et al. (1997) reported that erosion from construction sites in the U.S. deposits approximately 3.5 billion metric tons of sediment into streams and rivers annually. Sediment concentrations released from construction sites range from 10 to 20 times higher than that of agricultural land and 1,000 to 2,000 times higher than naturally forested land (USEPA 2000). Barrett et al. (1995) reported a five-fold increase in suspended solids concentration (SSC) in a creek receiving water from an active construction site during and immediately after storm events. Therefore, a few hours of discharge from a construction site can contribute more sediment to streams and rivers in comparison to what can be deposited from other natural or anthropogenic sources over a much longer time period. This accounts for a potentially large volume of sediment that could be carried off by storm water to the receiving water bodies.

Several problems are associated with soil erosion. Erosion degrades water quality of receiving water bodies and causes other problems like sedimentation in streams. Sediment increases the turbidity of water causing a nuisance to aquatic life, while also affecting the aesthetics of the receiving water body. Furthermore, pollutants like heavy metals and hydrocarbons in runoff water partition onto the soil particles and are transported with the sediments to the receiving water bodies (Viklander 1998, Liebens 2001, Lee et al. 2002). Past studies have indicated that the effects downstream from construction activities are temporary and the total suspended solids concentration normalizes after construction activities have stopped (Barrett et al. 1995). To mitigate the problems associated with sediment migration from construction sites to receiving bodies, it is imperative that proper erosion and sediment control measures be incorporated during construction and post-construction phases of projects until adequate protective vegetative cover has re-established at the disturbed site.

Sediment laden runoff from construction sites can be minimized by either erosion control or sediment control best management practices (BMPs). Though often used interchangeably, erosion control and sediment control are different techniques and require different measures to mitigate. Erosion involves the detachment of soil particles through raindrop impact and the shearing force of overland flow. Erosion control is a source management technique in which the soil surface is protected by a cover and the detachment of soil particles is reduced. Sediment control techniques are employed as a mitigation measure once the soil particles have already been dislodged. Sediment control techniques reduce the solids loading in the runoff by short-term retention, velocity reduction, and filtration. In this sense, erosion control techniques could be defined as prevention measures while sediment control techniques could be defined as remediation measures. Typical erosion control BMPs employed in the field includes temporary and permanent vegetation, plastic sheeting, straw and wood fiber mulches, matting, netting, chemical stabilizers, or some combination of the above. Sediment control BMPs can be further sub-divided into permanent and temporary techniques. Permanent measures include retention ponds (wet ponds), bio-retention systems, hydrodynamic separators, and underground storage tanks. Temporary measures include silt fences, geosynthetic dikes, wattles, berms, bales, and rock check dams. This study will focus on the performance of temporary sediment control devices (SCDs).

Because of environmental regulations, TxDOT, like most other Departments of Transportation (DOTs), is responsible for erosion and sediment control during and after construction. TxDOT spent approximately $59 million on erosion and sediment control from February 2003 through January 2004. This does not include maintenance or items that may have dual purposes.

In 1989, in response to the National Pollutant Discharge Elimination System (NPDES) Phase I construction site requirements for erosion and sediment control, TxDOT, in cooperation with the Texas Transportation Institute (TTI), developed the Hydraulics and Erosion Control

Testing Laboratory (now called the Hydraulics, Sedimentation and Erosion control Laboratory). The laboratory has been in continuous operation since that time.

The purpose of the laboratory-testing program was to develop and maintain an "Approved Products List" for erosion control materials to be used on TxDOT construction and maintenance projects. Because of the unique nature of the facility and the program many other transportation agencies around the country have adopted or use TxDOT's approved materials list in specifying or approving erosion control products. However, to date, the testing protocol used by TxDOT and TTI for approving materials for use in Texas has not included sediment control devices. To assist the designer/engineer in selecting the most effective sediment control practices a formal SCD performance testing program has been developed. This issue of compliance through SCD performance evaluation has been voiced often by the other state DOTs participating in the current TxDOT Pooled Fund Program TPF-5(015).

Like most other state DOTs, TxDOT utilizes many roadside SCDs such as silt fence, straw bales, rock check dams, wattles, etc. in its design references. Despite the common practice of specifying SCDs there is little impartial or non-biased evidence regarding their performance. Since there are no recognized performance test standards for SCDs, end-users and specifiers must rely on marketing claims. In the past, SCDs were not regarded as important because they are temporary devices. However, with the increasing emphasis on construction site water quality as outlined in TxDOT's Environmental Management System, evaluating the performance of different SCDs is becoming increasingly important.

OBJECTIVES

The objective of this study was to develop a formal SCD performance evaluation program that will assist the TxDOT designer/engineer in the selection of the most effective sediment control BMPs for a site-specific application.

The specific tasks carried out during the course of this project are as follows:

- Design a facility to evaluate the performance of SCDs.
- Construct the facility according to the design specifications.
- Develop a testing protocol to evaluate performance of SCDs in the facility.
- Conduct multiple SCD performance tests to determine the ability of the facility and protocol to effectively quantify the performance of SCDs.

APPROACH

Researchers conducted the project in three phases over a period of two years.

1. Phase one consisted of an extensive review of literature pertaining to temporary sediment control technologies used for storm water treatment. Concurrently, researchers also studied existing methods of evaluating the performance of SCDs and conceptualized designs for the testing facility. This phase was completed in January 2008.
2. Phase two involved the selection of the testing facility design best suited for the program and construction of the testing facility at the TxDOT/TTI Hydraulics, Sedimentation and Erosion Control Laboratory (HSECL) facility at the Riverside campus. This phase was completed in December 2008.
3. Researchers developed a protocol for testing temporary sediment control devices in phase three of the project. This phase included intensive testing on the facility to calibrate the system as well as to determine the ability of the facility and protocol to effectively quantify the performance of SCDs. This phase was completed in July 2009.

CHAPTER 2: BACKGROUND INFORMATION

LAWS AND REGULATIONS

The 1987 amendment to the Clean Water Act (CWA) established the Non-point Source Management Program, which mandated the control of storm water, erosion, and sediment at construction sites. The Intermodal Transportation Efficiency Act of 1991 prompted the Federal Highway Administration (FHWA) to adopt Erosion and Sediment Control Rules (23 CFR 65) in 1994. The EPA Phase I rules require construction sites, greater than 5 acres, to have construction permits and pollution prevention plans. The implementation of EPA Phase II rules in 2003 extended the permitting and pollution prevention plans requirement to smaller construction sites between 1 and 5 acres. In 2003, the federally mandated National Pollution Discharge Elimination System Phase II storm water rules went into effect extending the storm water pollution prevention plan requirement to any land-disturbing activity over 0.405 ha (1 acre). Violators can be held in noncompliance with the federal Clean Water Act and can be fined up to $100,000 per day per violation. Implementation of the NPDES and Texas Pollutant Discharge Elimination System (TPDES) requires TxDOT to adopt a variety of storm water quality measures to meet CWA requirements.

In an effort to comply with Section 304(b) of the CWA, the Environmental Protection Agency (EPA) has developed a set of national standards known as Effluent Limitation Guidelines (ELGs). ELGs are intended to reduce pollutants from entering and harming the waters of the U.S. ELGs will be developed on an industry-by-industry basis. The EPA will identify the best available technology that is economically achievable and establish the ELGs base on the performance of that particular technology. Once implemented stormwater runoff from TxDOT construction sites will be collected and analyzed to ensure turbidity does not exceed target limits set by EPA. This project will enable TxDOT engineers and designers to better understand and predict the effectiveness of various SCDs in order to stay in compliance with the ELGs.

SEDIMENT CONTROL ALTERNATIVES

Erosion involves detachment, transport, and subsequent deposition of soil. Raindrop impact and the shearing force of flowing water cause the soil particles to detach from the ground. Erosion caused by raindrop impact is classified as interill erosion, while that caused by shearing force of flowing water is classified as rill erosion. The runoff flowing from the site of detachment is primarily responsible for transporting the sediment. Erosion caused by storm water runoff from construction sites can be minimized by either erosion control or sediment control or a combination of the two. Erosion control is a source management technique in which the ground is protected by a cover and detachment of soil particles is prevented. In this sense, erosion control techniques could be defined as preventive measures. Typical erosion control techniques employed in the field include temporary and permanent vegetation, plastic sheeting, straw and wood fiber mulches, matting, netting, chemical stabilizers, or some combination of the above. Sediment control techniques are employed as a mitigation measure once the soil particles have already been dislodged. In this sense, sediment control techniques could be defined as the second line of defense. Sediment control techniques reduce the solids loading in the runoff by short term retention, velocity reduction, and filtration. Sediment control measures can be further sub-divided into permanent and temporary techniques. Permanent measures are for long-term use and include sedimentation ponds, bio-filtration/retention systems, underground holding tanks, and stormwater treatment vaults. Temporary measures are designed for shorter periods of time and include silt fence, geosynthetic dike, sock, berm, bale, and rock check dams. This study will focus on temporary sediment control devices.

Temporary Sediment Control Measures

Temporary sediment control devices act as sediment barriers and are expected to prevent off-site migration of sediment by runoff discharged from sites disturbed by construction activity. This project studied five temporary sediment control devices: geosynthetic dikes, wattles without coagulant, wattles with coagulant, silt fences, and rock check dams.

Geosynthetic Dike

The Geosynthetic dike is a sediment control structure usually constructed with a triangular-shaped, polyurethane foam core, wrapped in a woven polypropylene fabric. This makes the dike lightweight and, as a consequence, easy to transport, install, and relocate.

Another advantage of the geosynthetic dike is that they are flexible, which allows them to be installed on uneven ground. Geosynthetic dikes are manufactured in sections of standard lengths that can be fit together tightly, providing a continuous barrier of any length. Storm Water Pollution Prevention Plans (SWPPPs) also utilize geosynthetic dikes to create a temporary flow path through an earthwork project. Geosynthetic dike sections are easily restored to their original condition for reuse or storage by washing them with clean water. Geosynthetic dikes serve as a sediment control device by stopping, slowing, or diverting the flow of runoff water.

Wattle

Wattle, sock, tube, or log are terms used for a sediment control structure that consists of compacted straw and/or other fibers encased in tubular netting. Wattles are commonly installed along the contours or at the base of a slope to help reduce soil erosion and retain sediment. They function as slope interruption devices and therefore shorten slope lengths reducing runoff velocity and the potential for sheet erosion and rill formation. Wattles also find use as check dams in channels and ditches, drain inlet protection, and perimeter sediment control. Wattles allow runoff/water to penetrate through the fiber while retaining the sediment. Wattles are often used in conjunction with surface roughening, straw mulching, bonded fiber matrix (BFM), hydro-seeding, and erosion control blankets to further reduce erosion and sediment migration.

Wattle with Flocculants

Wattles are also available with performance enhancing, polyacrylamide polymer powders, emulsions, and flocculants that reduce initial erosion and remove fine particles from storm water runoff. Such sediment control structures are effective in removing clay-size particles, which tend to stay in solutions and cause cloudy discharges.

Silt Fence

A silt fence (also known as filter fence) is a generic name for a sediment control structure made of woven, geo-textile filter fabric often supported by wire mesh and regularly spaced steel or wooden posts. Silt fences are commercially available as rolls of various widths with the most common widths ranging from 6 in. to 36 in. Silt fences are installed along contours or the perimeter of construction sites, with the bottom edge entrenched and backfilled with soil. At highway construction sites, silt fences are typically installed in long, linear runs parallel to a roadway at the toe of the fill slope along the right of way (ROW). Typical highway design procedures recommend that sediment barriers be installed on the contour below the slopes disturbed by construction activity. Although filtration is considered the primary mechanism of sediment removal, silt fences can also bring about sediment removal by reducing the velocity of the runoff and retaining the sediment-laden runoff causing sedimentation and reduction of runoff volume by infiltration of water.

Rock Check Dam

A rock check dam is a temporary barrier constructed across an area of concentrated flow to capture larger soil particles by reducing the velocity of runoff. Such sediment control structures are constructed from small riprap with stone sizes ranging from 3 to 8 in., placed manually or mechanically in an organized pattern. The rip rap is often wrapped in galvanized wire mesh with 1 in. or wider diameter openings to allow water to easily pass through the structure while preventing the dislodging of the stones during concentrated flow events.

LACK OF PROPER METHOD FOR EVALUATING PERFORMANCE OF SCDS

Performance data on erosion control materials is readily available. However, information on the performance of sediment control BMPs is limited. Most designers and engineers are left with no other options other than manufacturer's claims or simple field observations. Establishment and classification of available SCD BMPs based on their measured performance would assist the designers and engineers in selecting the appropriate product and methods for site-specific application. The standard presented in this report is similar to that described by the American Society for Testing of Materials (ASTM) D7351. However, after careful review of the ASTM standard several changes were made to satisfy the needs of TxDOT roadside applications and provide a testing facility that would adequately meet the desired goals of the TxDOT SCD evaluation program.

SEDIMENT REMOVAL MECHANISMS

As discussed previously, SCDs remove sediments that have been dislocated from the site and are being carried in the runoff. Sediment barriers capture eroded solids by filtration, sedimentation, velocity reduction, and volume reduction, all of which contribute to the overall efficiency of a system. It is important to note that more than one of the above mentioned mechanisms could occur simultaneously.

Filtration

Filtration involves interception and straining of suspended particles as the runoff passes through the SCD. Interception is the principal method of removal when the size of the suspended particle size is larger than the filter pores or void size. Particles smaller than the filter pores are removed by straining, which involves attachment of the particles to the filtering surface and bridging across openings. Filtration is often effective for only a short period following installation due to the fact that after the initial storm events clogging of the pores or voids decreases the flow-through rate of the SCD, which can result in catastrophic failure of the silt fence by overtopping. Figure 2.1 illustrates the process of filtration of the suspended sediment concentration (SSC) removed from the runoff and the accumulation accumulated near the upstream face of the SCD resulting in a decrease in SSC in the runoff.

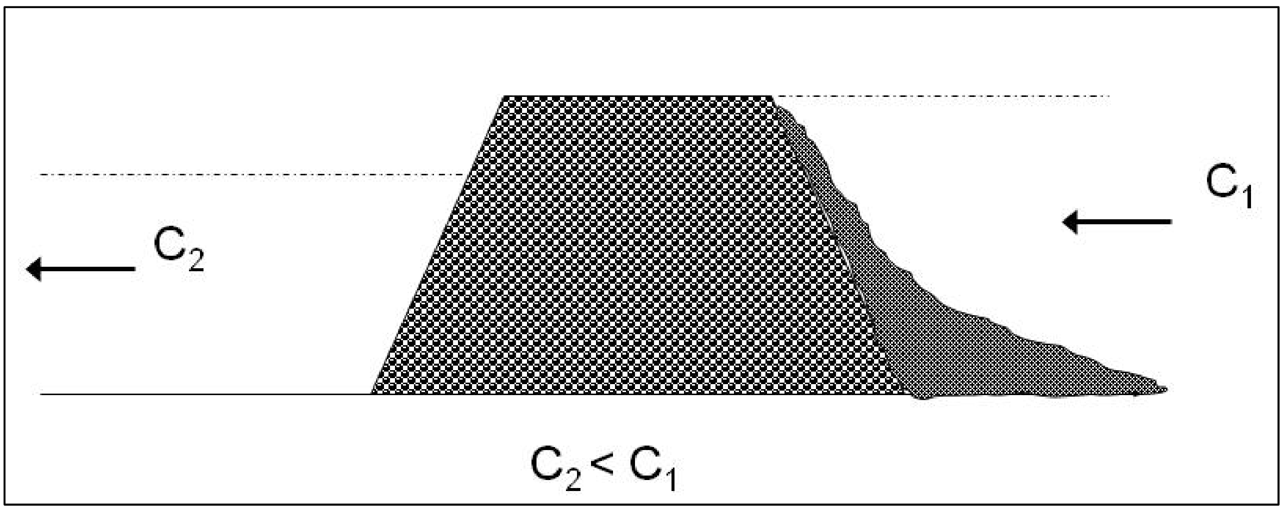


Figure 2.1. Decrease in SSC in Runoff after Passing through the SCD.
(C1 = SSC before passing through SCD and C2 = SSC after passing through SCD.)

Retention and Sedimentation

The most cost effective and widespread treatment of suspended solids in water is retention and sedimentation. When sediment-laden runoff water is retained behind an SCD, the suspended sediments tend to drop out and settle to the bottom. Stokes equation describes the relationship between particle size and the settling velocity of a spherical particle settling in water.

Velocity Reduction

Slowing sediment laden storm water allows the settling of suspended sediment. When the sediment load is greater than its transport capacity, the suspended sediment in the runoff is deposited. Transport capacity is directly proportional to the velocity or shear stress. Thus, slowing down runoff water will decrease the transport capacity and cause sedimentation to occur. Figure 2.2 illustrates the mechanism of velocity reduction, where the velocity of flow is reduced by the SCD resulting in particles settling out of the water.

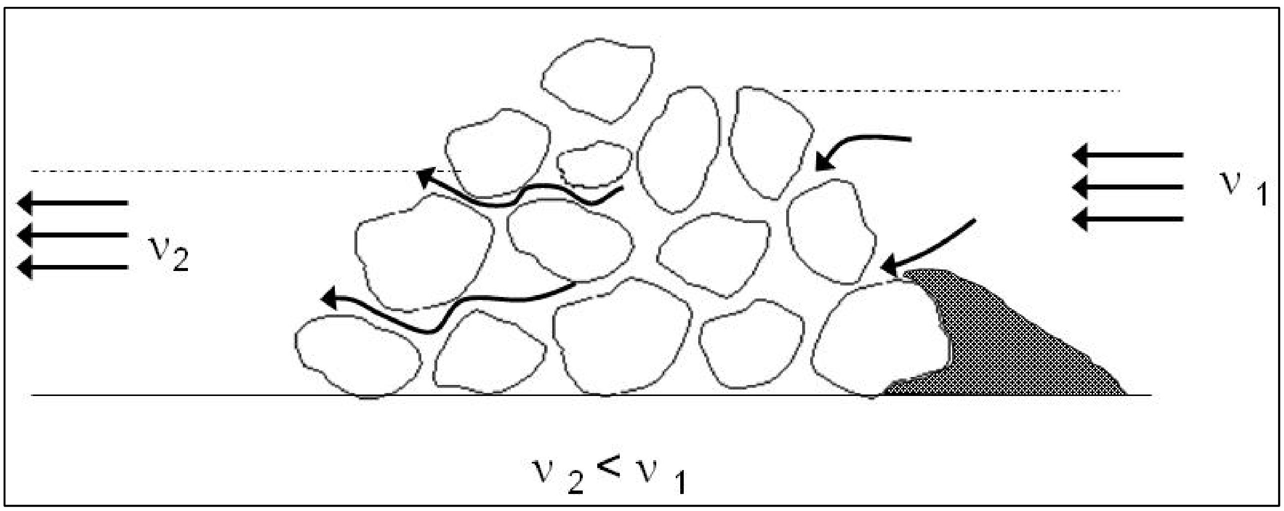


Figure 2.2. Decrease in Runoff Velocity after Passing through SCD.
(v1 = runoff velocity before SCD and v2 = runoff velocity after SCD.)

Volume Reduction

Volume reduction reduces the total volume of sediment-laden water by allowing water to infiltrate into the soil. It must be noted, however, that volume reduction is dependent on the soil characteristics and geology. Porous soils will result in greater volume reduction than non-porous soils. Figure 2.3 illustrates the decrease in total volume of runoff by infiltration.

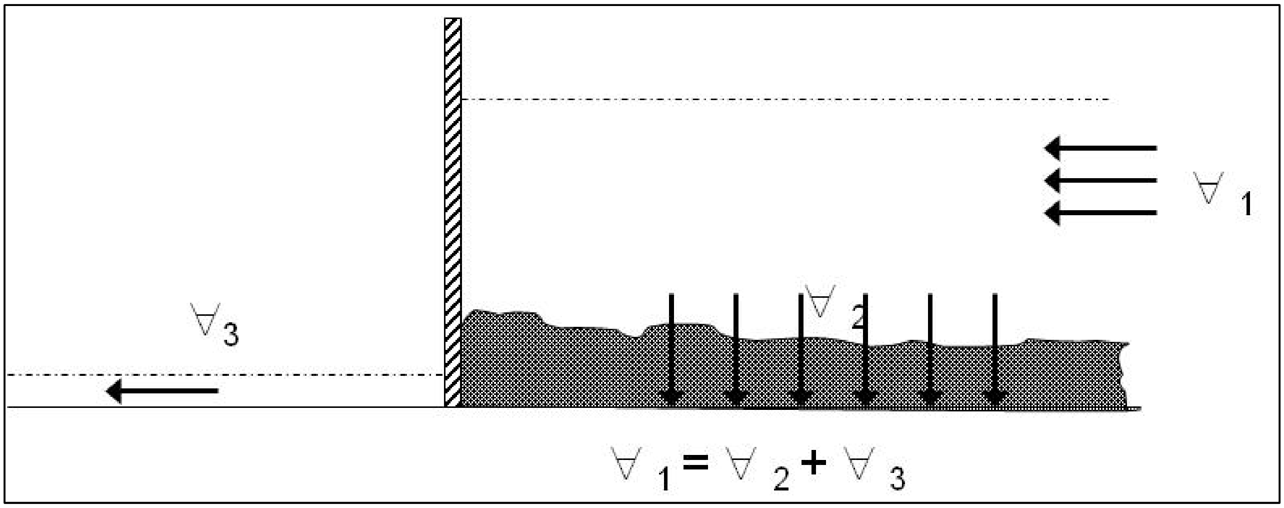


Figure 2.3. Decrease in Runoff Volume after SCD.
(∀1 = runoff volume before SCD, ∀2 = runoff volume infiltrated behind SCD and ∀ 3 = runoff volume after SCD.)

Coagulation/Flocculation

If left untreated, soil particles suspended in water remain in continuous motion due to electrostatic charges, which causes them to repel each other. Flocculating agents neutralize these charges that cause the soil particles to collide and agglomerate into larger flocs. These larger and heavier flocs then settle to the bottom resulting in 'cleaner' water.

PERFORMANCE FACTORS OF SCDS

Some of the factors affecting the performance of SCDs include:

- sediment removal efficiency,
- flow-through rate,
- ponding volume, and
- design capacity.

Common Terminologies

Figure 2.4 illustrates the ponding depth, overtopping depth, and wetted area, as well as, the ponding volume and design capacity for an SCD installed in a testing channel. The SCD (not shown in the figure) height in the figure is assumed to be equal to the depth of the channel.

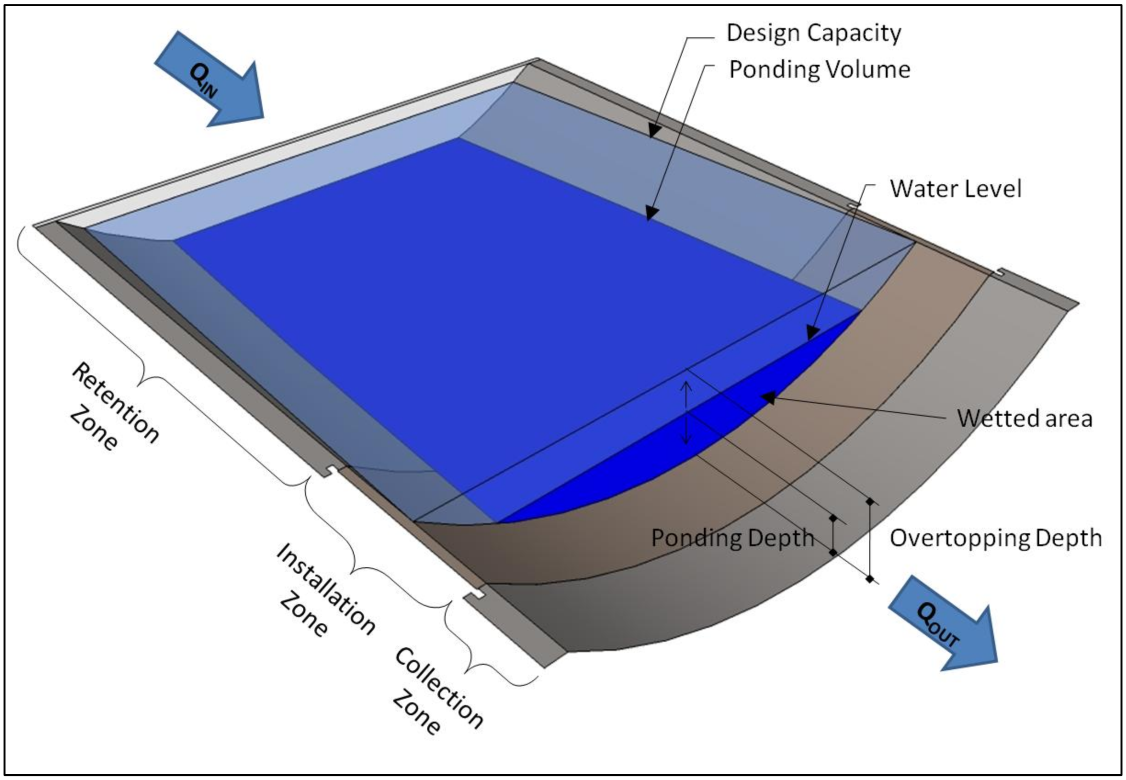


Figure 2.4. Factors Affecting Performance of SCD in the Facility.

Ponding Depth

Ponding depth is the depth of water retained behind the SCD at any given time. It is an indicator of the retention time of the SCD and the distance a sediment particle will have to travel to settle out of the water behind the SCD. Under test conditions ponding depth is dependent on the inflow rate and the permeability (or the flow-through rate) of the SCD being tested. The following conditions hold true (assuming no infiltration):

$Q_{IN} > Q_{OUT}$; Ponding Depth will increase with time

$Q_{IN} < Q_{OUT}$; Ponding Depth will decrease with time

$Q_{IN} = Q_{OUT}$; Ponding Depth will remain constant with time (steady state)

where,

Q_{IN} is the inflow rate

Q_{OUT} is the outflow rate

Overtopping Depth

Overtopping depth is the depth at which water starts to flow over the SCD and can be defined as the maximum ponding depth achieved without detrimentally affecting the performance a SCD. The height of the top of the SCD from the surface of the soil is equal to the overtopping depth. When inflow rate is greater than the outflow rate the ponding depth will exceed the overtopping depth.

Wetted Area

Wetted area is defined as the projection on a vertical plane of the upstream face of a SCD that is in contact with the water at any given time. Wetted depth is a function of the ponding depth and the SCD height.

Sediment Removal Efficiency

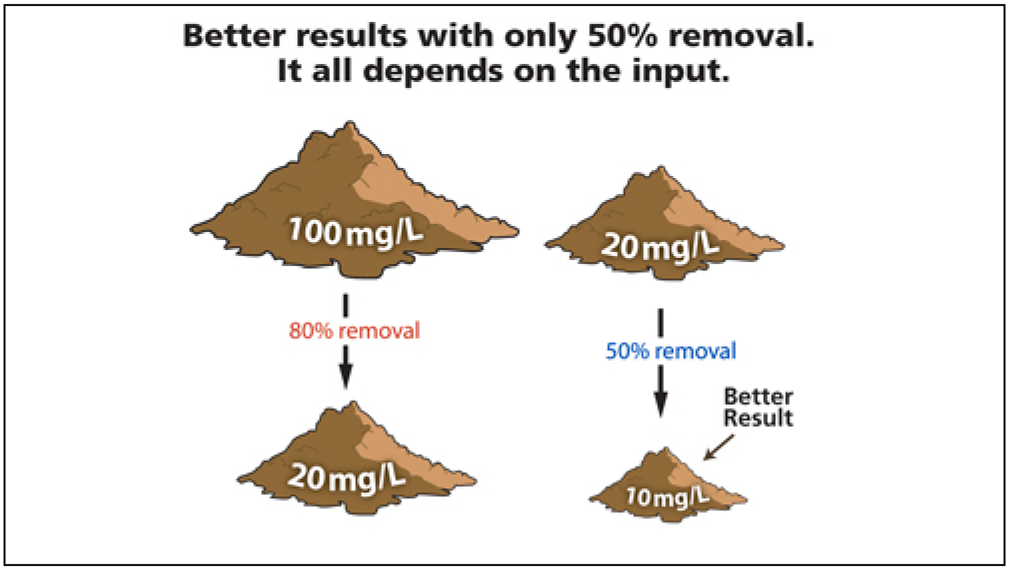
Sediment removal efficiency is defined as the percent decrease in sediment load of runoff after passing through a SCD (Equation 2.1).

$$\text{Sediment Removal Efficiency } (\eta) = \frac{(M_{IN} - M_{OUT})}{M_{IN}} \times 100 = \frac{(C_{IN} - C_{OUT})}{C_{IN}} \times 100$$

where,

M_{IN} is the mass of sediment in the untreated runoff before passing through a SCD,
M_{OUT} is the mass of sediment in the runoff after passing through a SCD,
C_{IN} is the SSC in untreated runoff before passing through a SCD, and
C_{OUT} is the SSC in runoff after passing through a SCD.

This criterion can be misleading if considered as the sole indicator of the quality of water treated by SCD. It is evident from Equation 2.1 that the sediment removal efficiency is a function of the initial suspended sediment concentration in runoff to be treated. Thus, the same SCD would exhibit high sediment removal efficiency with the untreated runoff water having high SSC (as compared to one with low SSC) regardless of the actual SSC in the effluent runoff. As Figure 2.5 illustrates, 80 percent sediment removal results in an effluent SSC higher than with 50 percent sediment removal.



Source: EPA http://cfpub.epa.gov/npdes/stormwater/urbanbmp/bmptopic.cfm

Figure 2.5. Sediment Removal Efficiency Can Be Misleading.

Flow-through Rate

Flow-through rate is defined as the rate at which sediment-laden runoff passes through the SCD. Flow-through rate can be expected to decrease with time and additional runoff events as the sediments are retained behind the SCD and its porosity is decreased. Flow-through rate is a function of the depth of water retained behind the SCD and wetted area of the SCD at any given time.

Ponding Volume

Ponding volume is the volume of water retained behind the SCD at any given time. If the rate of water entering the channel is greater than the rate of water leaving the channel then the ponding volume will increase with time and vice versa. When the rate of water entering the channel is equal to the rate of water leaving the channel a steady state is achieved and the ponding depth will remain constant with time.

The relationship between ponding depth, ponding volume, and wetted area for any given channel can be determined mathematically. This information will give the researchers useful insight on the performance of the SCD.

Design Capacity

Design capacity is the volume of water that can be retained behind a SCD. When ponding volume exceeds design capacity the sediment-laden water will flow over the top of the SCD.

CHAPTER 3:
TESTING FACILITY DESIGN

The SCD performance testing facility was constructed at the TxDOT/TTI HSECL facility located at the Texas A&M University's (TAMU) Riverside Campus.

COMPONENTS

The testing facility consists of five components, namely, the mixing tank, delivery and monitoring system, testing channel, collection and monitoring system, and the monitoring equipment. Each component is described in detail below.

Mixing Tank

The mixing tank serves the purpose of mixing and delivering the sediment into the testing channel. The mixing tank is a 1600-gal polypropylene cylindrical tank with a conical hopper bottom with a 6-in. butterfly valve. A 3-phase electric motor and double mixing paddles ensure proper mixing of the sediment-laden test water. Figure 3.1 shows the mixing tank with the motor at its present location in the testing facility.

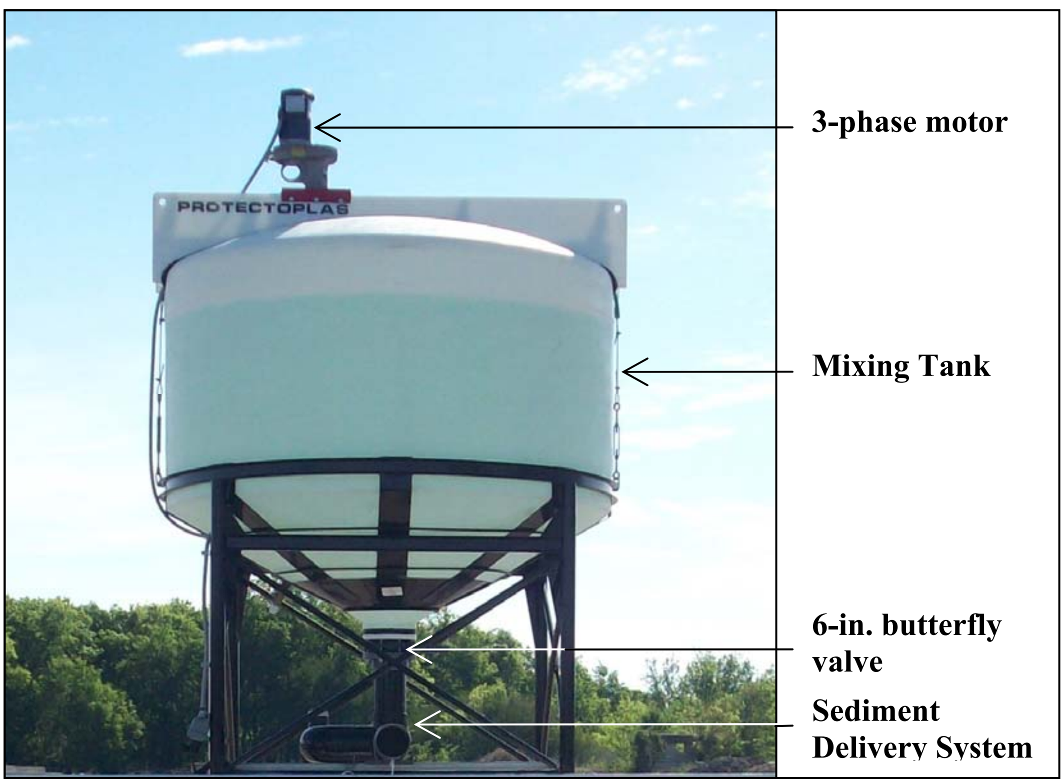


Figure 3.1. Polypropylene Tank to Mix Sediment and Create a Slurry of Known SSC.

Delivery and Monitoring System

To deliver water to all three zones of the flume (Figure 3.2) the delivery system was designed and consists of a system of 6 in. ID pipes. A reduced T-joint was inserted in the piping to access point for the inlet turbidity probe. The contact point between the probe and the reduced T-joint was sealed with an aluminum retaining ring and the piping system includes two 90-degree elbows after the reduced T-joint to prevent light interference to the turbidity probe (Figure 3.3 a). The bubbler tube of the flow meter was secured inside the pipe about 18 in. before the falloff point (Figure 3.3 b).

Testing Channel

The testing channel is made up of three distinct zones: the retention zone, the installation zone, and the collection zone. The overall length of the channel is 18 ft.

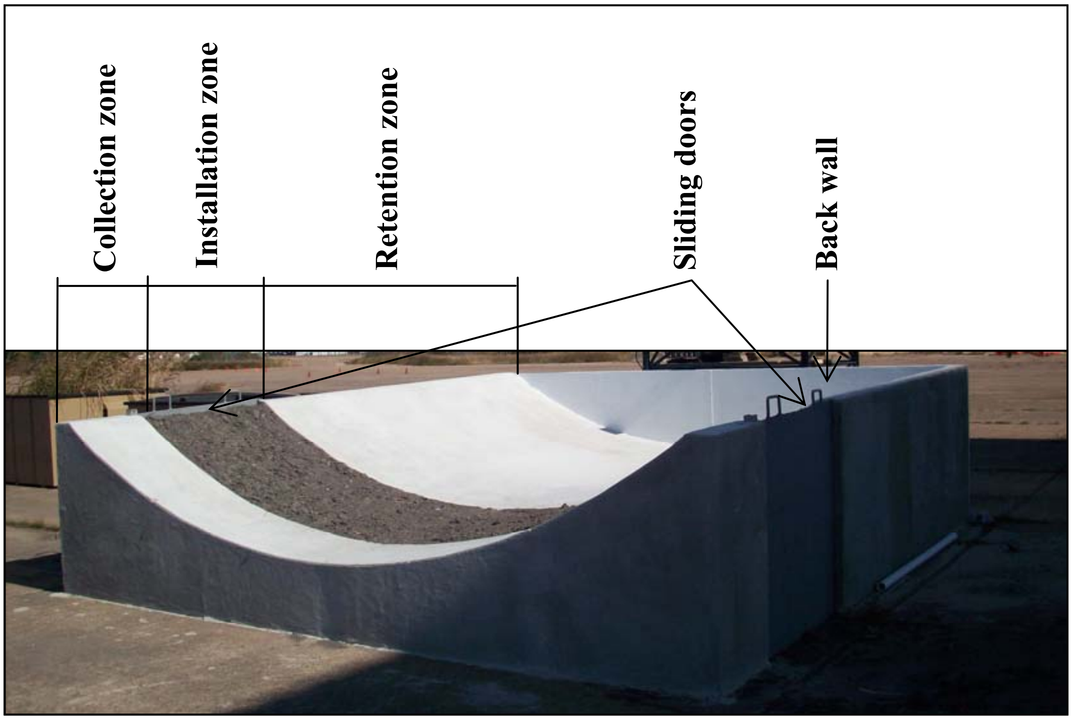


Figure 3.2. Testing Channel from SCD Evaluation.

Retention Zone

The retention zone is a longitudinal section of a cylinder 25 ft in diameter and 12 ft long. The channel is 12 ft long, 15 ft wide with a maximum depth of 2.5 ft. The channel maintains a constant 3 percent slope. The channel was constructed of concrete and surfaced with waterproofing grout.

Installation Zone

The installation zone is a 4-ft opening between the retention zone and collection zone with metal sliding gates on either side. The installation zone can be filled with any type of test soil. The proposed soil for testing SCD's is a high plasticity index (PI) clay. The surface of the clay in the installation zone was shaped to match the profile of the channel.

Collection Zone

The shape of the collection zone was designed exactly like the retention zone except it was only 2 ft long. The collection zone provides an area to channel the flow toward the collection and monitoring system.

Collection and Monitoring System

The collection and monitoring system consists of a collection tray and 6-in. collection pipes. The collection tray was made of galvanized sheet metal and is 7.5 ft wide. The collection tray channels the water into the 6-in. pipes, which has a reduced T-joint to serve as an access point for the outlet turbidity probe. The contact point between the probe and the reduced T-joint is sealed with an aluminum retaining ring, and the piping system has one 90-degree elbow after the reduced T-joint to prevent light interference to the turbidity probe. The bubbler tube of the flow meter is secured inside the pipe about 18 in. before the falloff point.

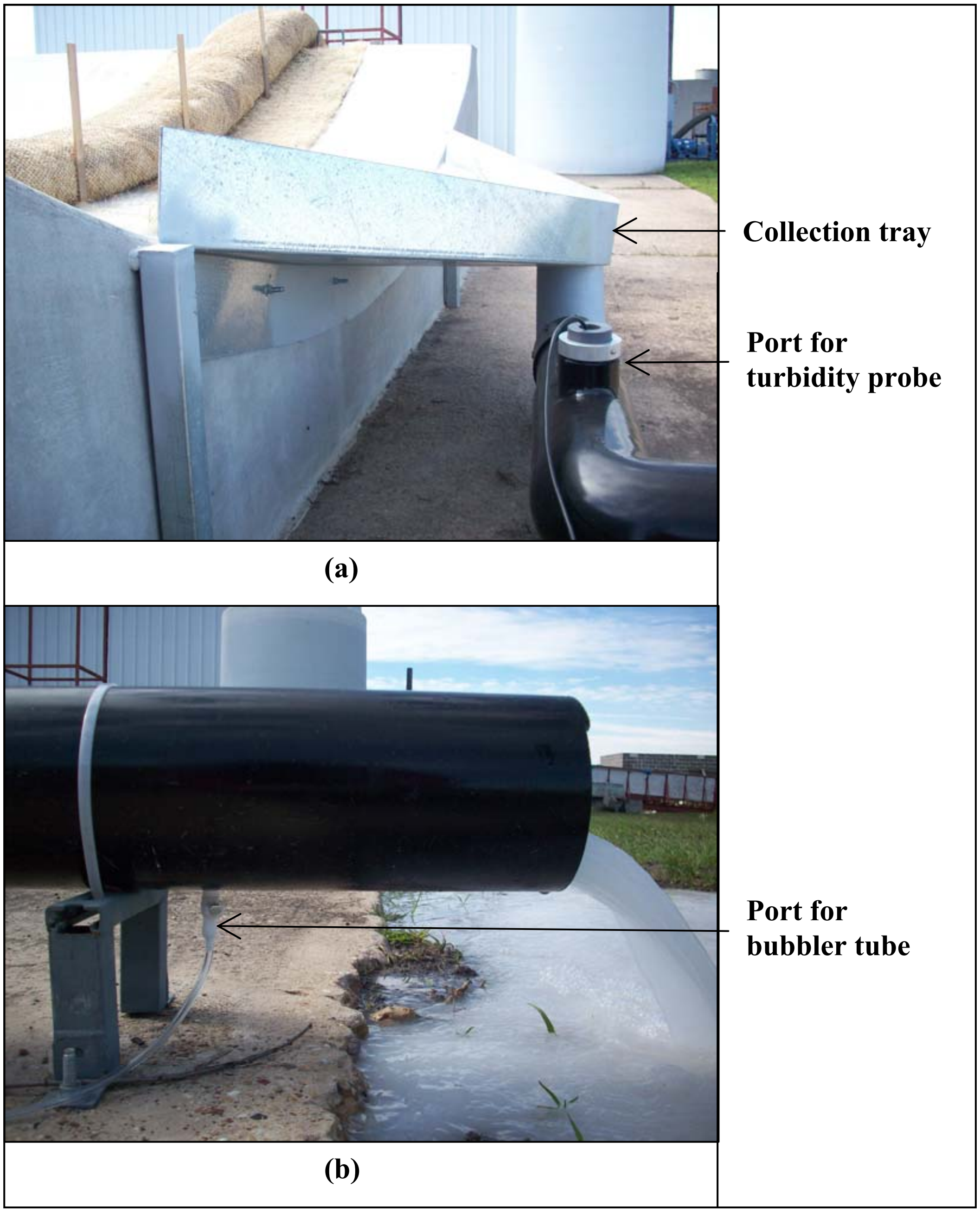


Figure 3.3. Sediment Collection System from Testing Channel (a) Collection Tray and Port for Turbidity Probe; (b) Port for Bubbler Tube.

Monitoring Equipment

Two turbidity probes connected to a single controller system and two flow meters are used to monitor the turbidity and flow rate, respectively.

Turbidity Meter

Two turbidity sensors (Hach SOLITAX® model TS-line sc), installed at the inlet and outlet, continuously measure (5 second intervals) and record the turbidity of the water entering and leaving the channel. Both sensors are connected to a controller system (Hach model sc100). Datacom, software available on the Hach website, facilitates the retrieval of the turbidity data from the controller system to a field laptop.

Flow Meter

Two bubbler flow meters (ISCO® model 4230) are used to monitor the flow at inlet and outlet of the channel.

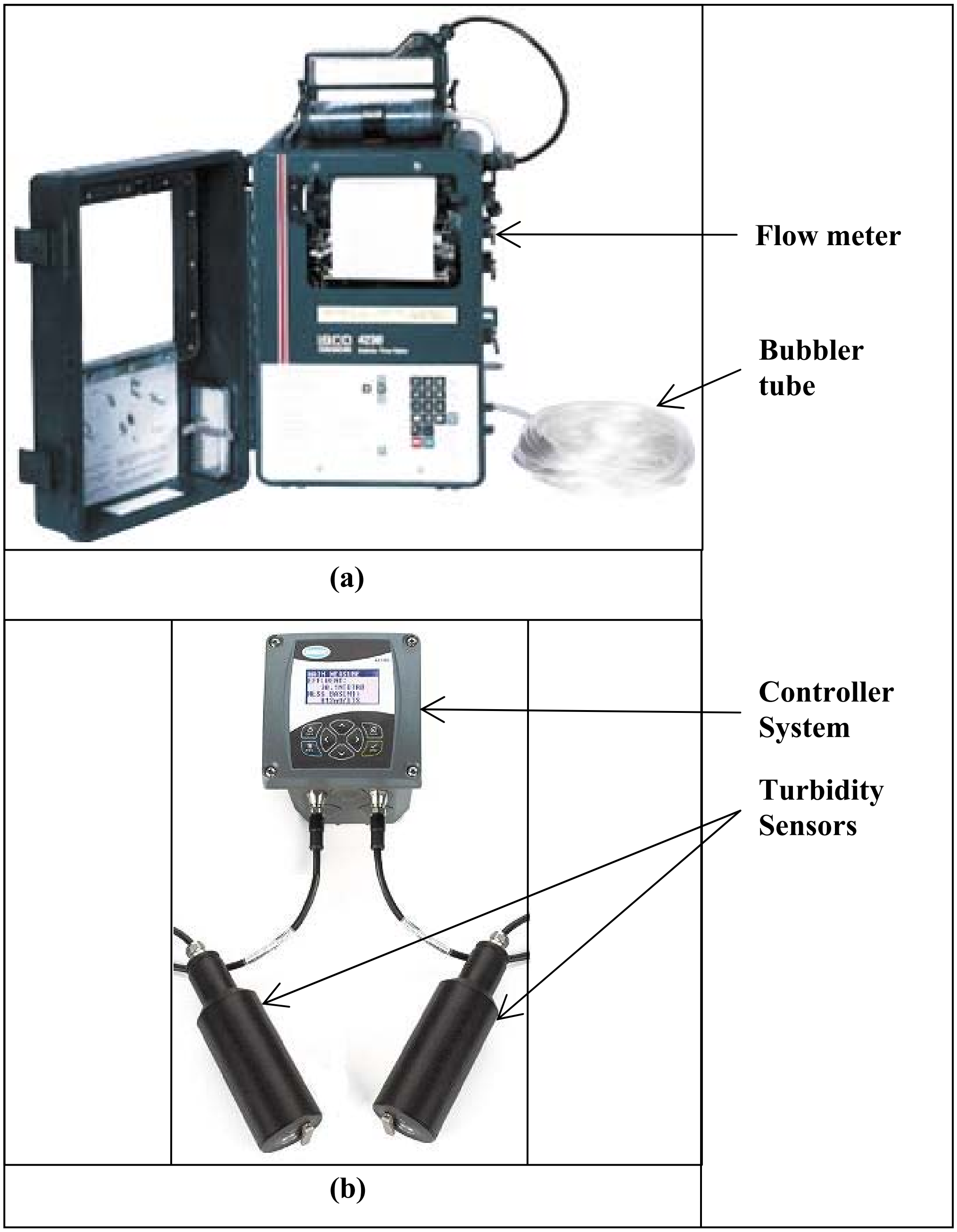


Figure 3.4. Monitoring System Used to Collect Data (a) ISCO® Model 4230 Bubbler Flow Meter; (b) Hach Model sc100 Controller System and Two Hach SOLITAX® model TS-line sc Turbidity Sensors.

Sediment Used for Testing

TTI researchers examined a variety of both commercially available and on-site sands and clays to use in the testing program. The desire of the research staff was to use a soil type that was readily available but also had a uniform particle size distribution (PSD). On site sands and clays were originally used in the initial calibration attempts; however, these soils proved to have too many variations in particle size distribution and composition from batch to batch. The on-site soils also often contained small gravel and occasional large rocks that could potentially cause damage to the testing system and monitoring equipment. Because of this, the researchers decided to use commercially available sediment which was uniform in composition and graded to have a uniform PSD. The first test runs were performed using only ground silica, Sil-co-sil, as the sediment additive; however the use of only silica presented a problem for many SCDs. Several commercially available SCDs use anionic polyacrylamide (Anionic PAM) as a flocculating agent. These SCDs target the smallest soil particles, fine silts, clays, and colloidal materials (5–10 microns in size). Because these flocculating agents are routinely used, there was a need to add a fine particulate clay to the sediment mix. The TTI researchers chose a commercially available ball clay (due to its uniform PSD and uniform electrostatic charge) and decided to use this in conjunction with the ground silica as the sediment additives for the testing facility. Details regarding the exact PSD and mix ratios used for the Sil-co-sil and ball clay will be discussed in Chapter 4.

CHAPTER 4:
CALIBRATION OF TESTING FACILITY

Before testing SCDs in the testing facility, researchers characterized the channel and sediment and calibrated the measuring instruments. Researchers studied the geometry of the channel to determine the relationship between ponding depth and factors that would help quantify the performance of SCDs tested in the channel. The particle size distribution of sediment was determined based on information provided by manufactures. The flow meters and turbidity meters were calibrated to determine their ability to accurately measure the flow rate and turbidity, respectively.

CHANNEL

The testing channel has a known geometry for which the ponding volume, wetted area, and length of SCD can be determined from the ponding depth. Figure 4.1 shows the testing facility with a channel designed as a longitudinal section of a 25 ft (D = 300 in.) diameter cylinder inclined at a 3 percent slope (Φ = 1.72 degrees).

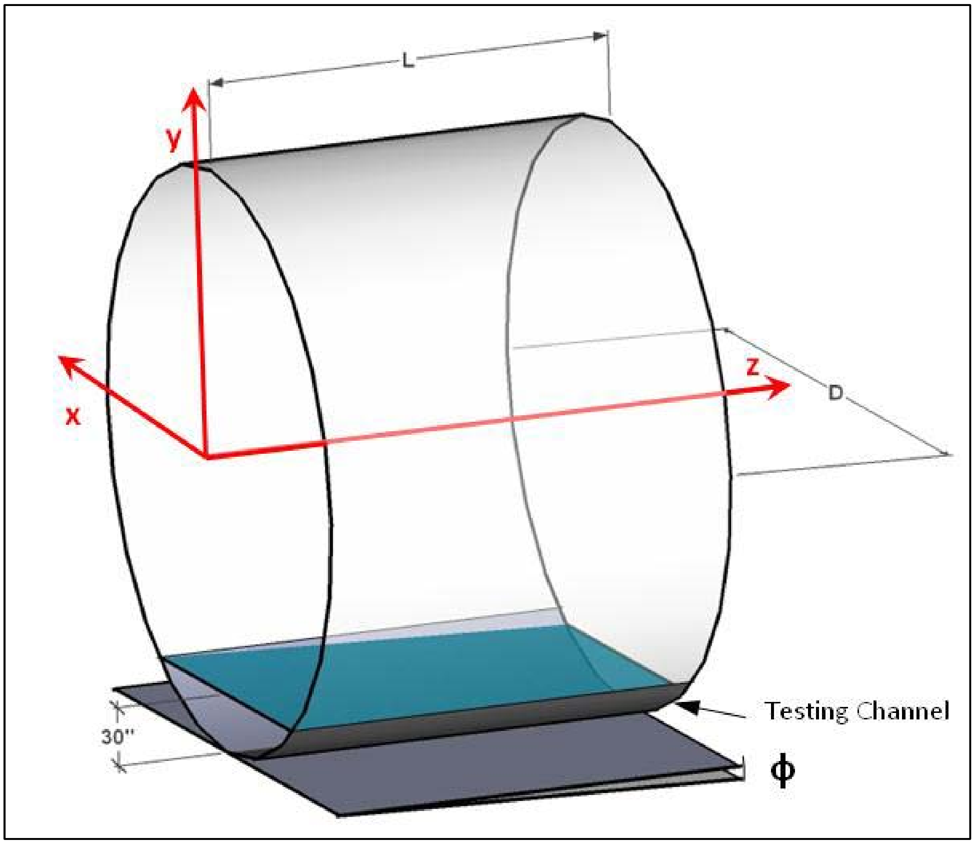


Figure 4.1. Testing Channel Designed as a Longitudinal Section of an Inclined Cylinder.

The x, y, and z-axis are aligned with the cylinder and the z-axis runs longitudinal to the cylinder. The length of channel (L) can range from 12 to 16 ft (or 144 to 192 in.) depending on the location of the SCD within the installation zone.

Ponding Volume

Ponding volume is the volume of water retained behind a SCD and is a function of ponding depth at any given time. Figure 4.2 shows the water retained behind SCDs of five different ponding depths.

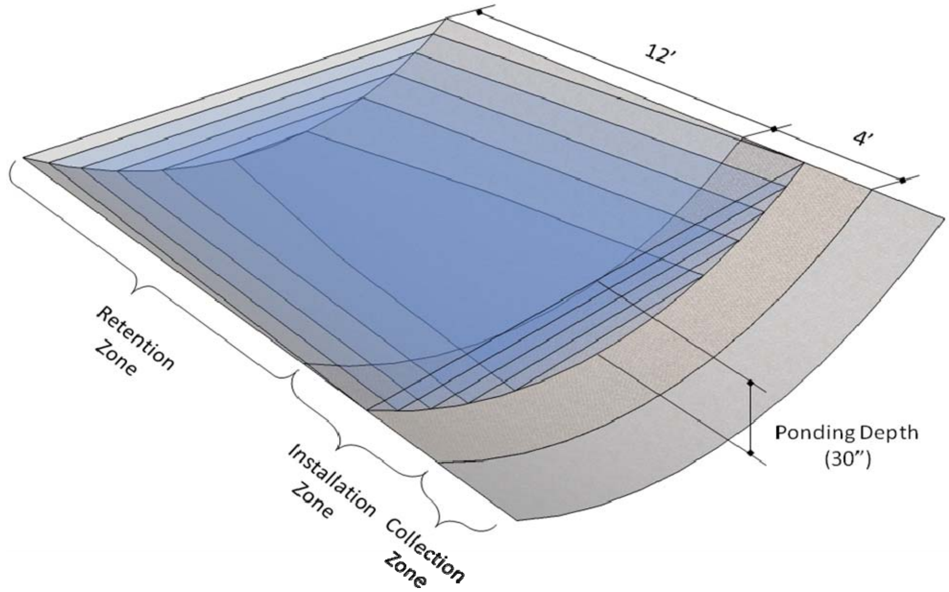


Figure 4.2. Water Ponding behind SCD Set Up in the Center of Installation Zone.

Figure 4.3 shows the water retained behind a 1-ft tall SCD installed at different locations in the installation zone. Ponding volume will also vary depending on the location of the SCD within the installation zone.

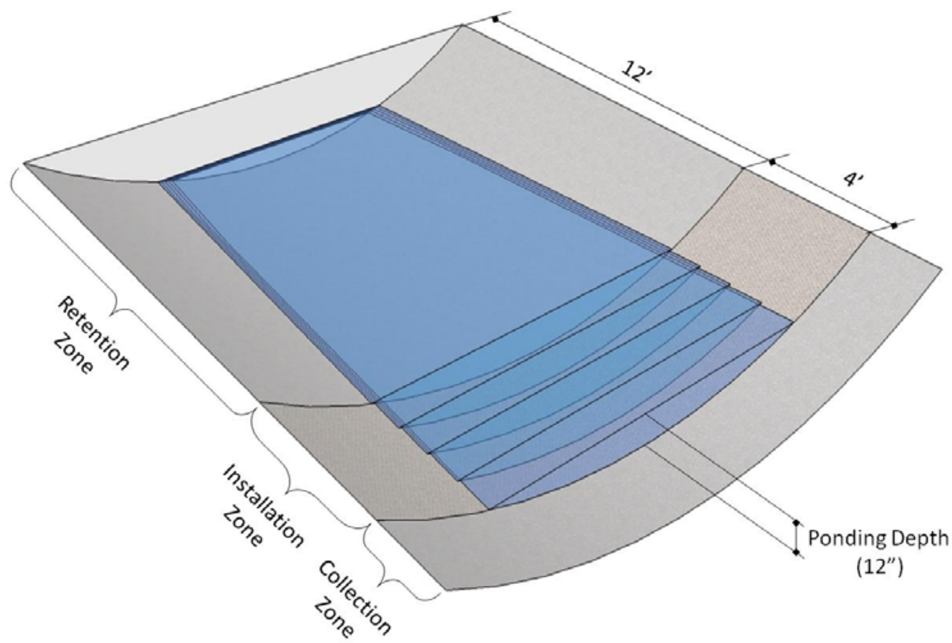


Figure 4.3. Water Ponding behind 1-ft Tall SCD Set Up at Different Locations within the Installation Zone.

The liquid in the cylinder, shown in Figure 4.1, is the volume bounded by four surfaces: the liquid surface, the cylinder wall, the bottom end of the cylinder, and the top end of the cylinder. The relationship between SCD height and ponding volume for the testing channel used to evaluate SCDs in this study was determined by mathematically solving the following equation.

$$\forall = \int_{-\left(S+\frac{r}{tan\emptyset}-\frac{\frac{2r}{\cos\emptyset}-H}{sin\emptyset}\right)tan\emptyset}^{r} \int_{-\sqrt{r^2-y^2}}^{\sqrt{r^2-y^2}} \int_{0}^{\frac{y}{tan\emptyset}+S+\frac{r}{tan\emptyset}-\frac{\frac{2r}{\cos\emptyset}-H}{sin\emptyset}} dxdydz$$

where, ∀ is the ponding volume,

y is the coordinates along y-axis as shown in figure (inches),

r is the radius of the cylinder (inches),

∅ is the slope of the channel (radians),

S is the distance along channel bottom from SCD to depth measurement location (inches), and

H is the ponding depth measured at a distance S from the SCD (inches).

Solving this equation using the online software created by LMNO Engineering, Research, and Software, Ltd. (available at http://www.lmnoeng.com/Volume/InclinedCyl.htm) and substituting different values of H and L, we can develop a set of curves defining the relationship between ponding volume and ponding depth (Figure 4.4).

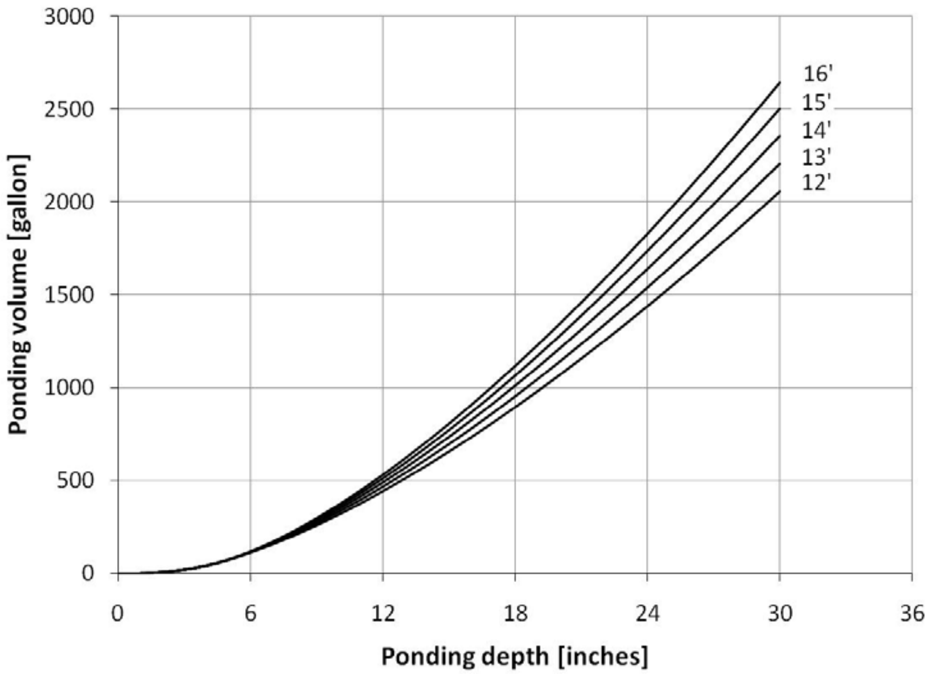


Figure 4.4. Relationship between Ponding Depth and Ponding Volume for Different Lengths of Channel.

Wetted Area

The wetted area is mathematically computed by using simple geometry. Figure 4.5 shows the wetted area (blue color) of a SCD of height equal to ED.

$$Wetted\ Area\ (ADBE) = Area\ of\ Sector\ (ADBO) - Area\ of\ Triangle\ (AOB)$$

$$Wetted\ Area\ (ADBE) = r^2 \times \tan^{-1}\left(\frac{\sqrt{r^2 - (r - ED)^2}}{(r - ED)}\right) - \sqrt{r^2 - (r - ED)^2} \times (r - ED)$$

where, r is the radius of the cylinder (= 150 inches) and

ED is the ponding depth (inches).

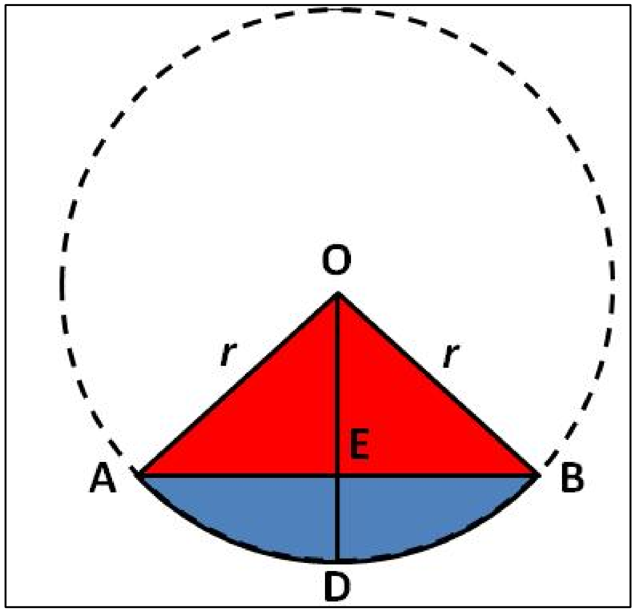


Figure 4.5. Diagramatic Representation of Wetted Area.

The relationship between wetted area and ponding depth developed in equation above is illustrated graphically in Figure 4.6.

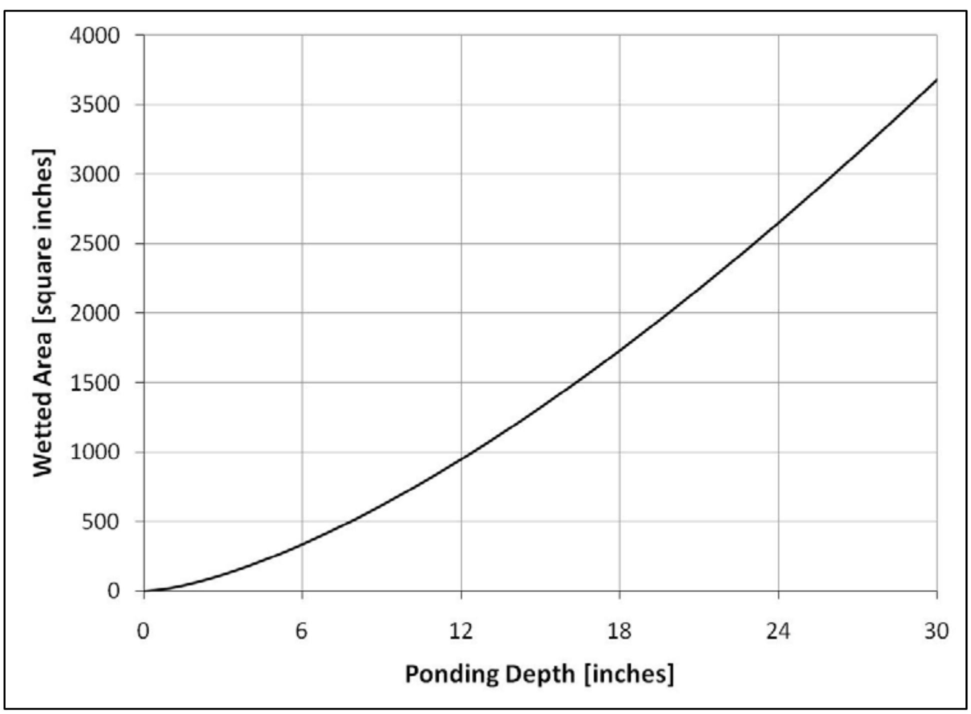


Figure 4.6. Relationship between Ponding Depth and Wetted Area of SCD.

Length of SCD

The length of SCD can be used to convert the data acquired from testing into performance per unit length of SCD.

$$Length\ of\ SRD = \alpha \times \cos^{-1}\frac{(r - ED)}{r} \times r$$

where, α is a factor ($\alpha = 1$ for channel application; $\alpha = 0.5$ for perimeter application)

r is the radius of the cylinder (inches), and

ED is the ponding depth (inches).

The relationship between ponding depth and length of SCD developed in equation above is illustrated graphically in Figure 4.7.

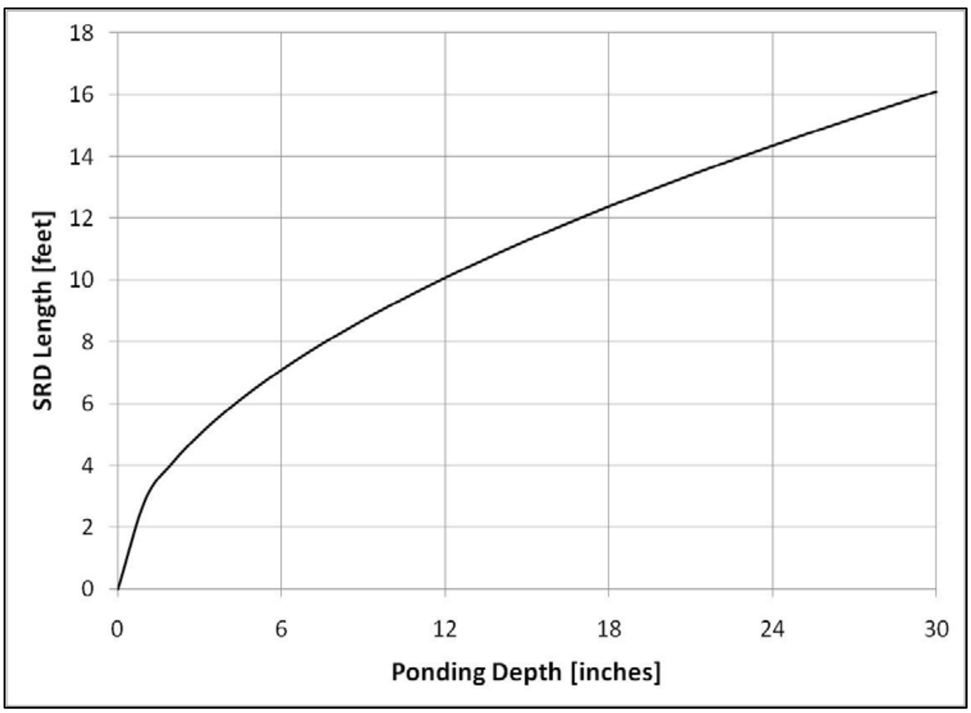


Figure 4.7. Relationship between Ponding Depth and Length of SCD.

SEDIMENT

As discussed in Chapter 3, researchers determined that a combination of two types of sediments, silica and ball clay, were the best candidates for creating runoff having known suspended solids concentrations and uniform composition. These two types of sediment would provide uniform and repeatable sediment mixing and would also provide consistent electrostatic charge properties when evaluating the performance of SCD containing flocculent(s).

The particle size distributions of four different silica sediment combinations, as provided by the manufacturer, are shown in Figure 4.8. Figure 4.9 shows the particle size distribution of the ball clay, as provided by the manufacturer. After examining the particle size distribution of each of the silica sands and performing laboratory standardization tests of the turbidity probes with each of the silica grades, it was determined that SIL-CO-SIL® 49 was the most accurate, potential sediment to be used for testing. Because of the need to mix the silica with ball clay, a 50-50 mixture (by weight) of SIL-CO-SIL®49 and ball clay was also examined as potential sediment to be used for testing. Figure 4.10 provides the particle size distribution (PSD) of such a mixture.

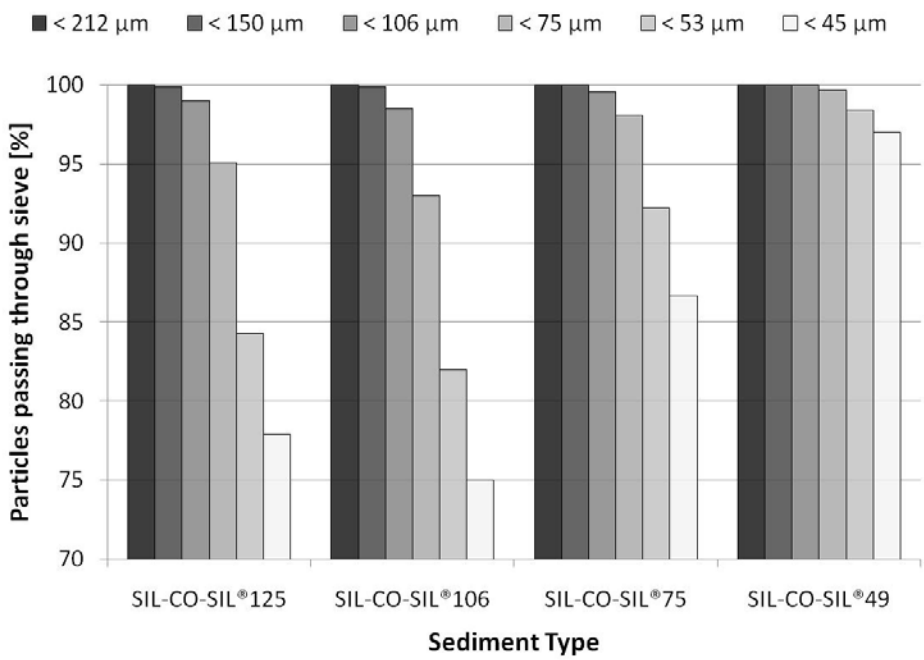


Figure 4.8. Particle Size Distribution of Silica Examined for Use as Sediment in the Testing.

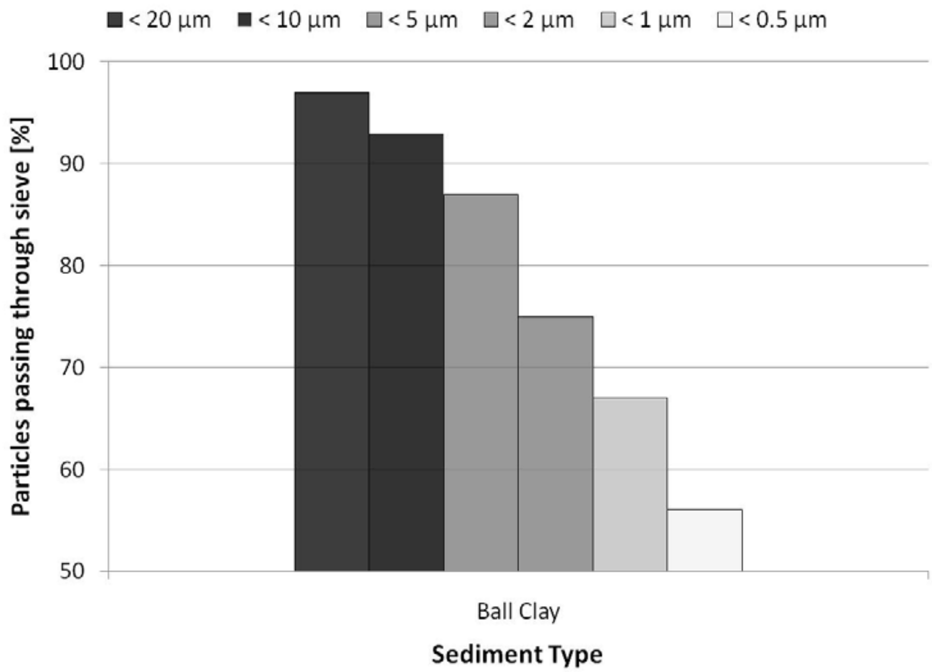


Figure 4.9. Particle Size Distribution of Ball Clay Examined for Use as Sediment in the Testing.

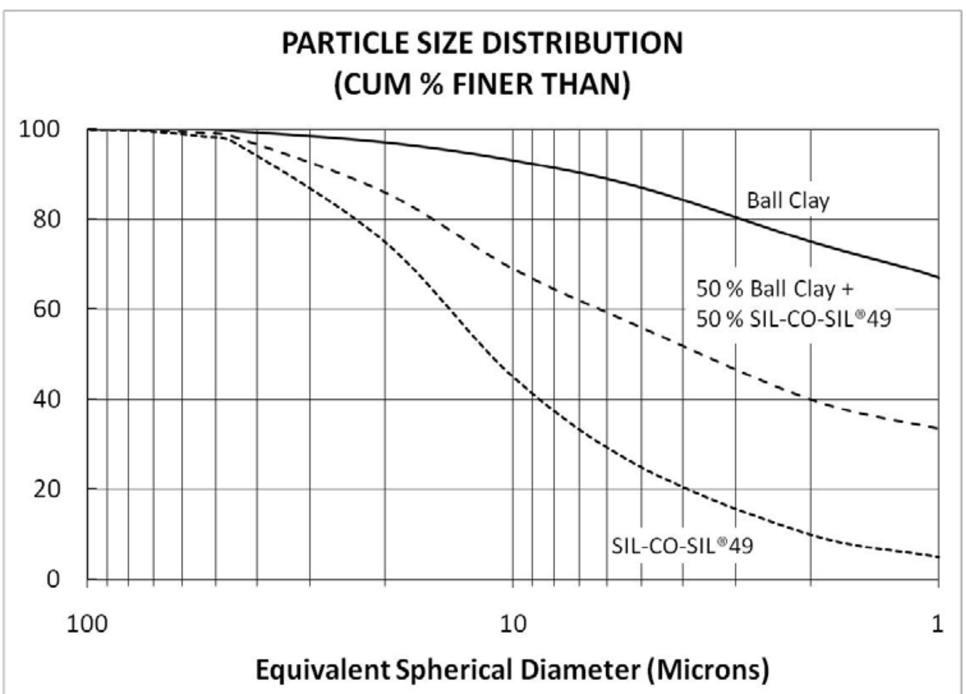


Figure 4.10. Particle Size Distribution of Silica, Ball Clay, and a 50-50 Mixture (by Weight) of SIL-CO-SIL®49 and Ball Clay.

MONITORING EQUIPMENT

The turbidity meters and probes were calibrated to determine the ability of these instruments to accurately measure the turbidity and flow rate, respectively.

Turbidity Meter

The turbidity meters and probes were calibrated by measuring the turbidity of known concentrations of water using SIL-CO-SIL®49, ball clay, and a 50-50 mixture (by weight) of SIL-CO-SIL®49 and ball clay. A 2-ft long section of a 6-in. diameter PVC pipe was cut and the ends of the pipe were capped to form a watertight chamber. A hole was drilled in this chamber 1 ft from either ends to insert the turbidity probe. A predetermined amount of SIL-CO-SIL®49 was weighed and mixed thoroughly with 2 L of water to prepare artificial sediment-laden water with known suspended solids concentration. This artificial sediment-laden water was poured into this chamber and the turbidity was measured using both the probes. Turbidity was measured for suspended solids concentrations ranging from 0 to 5000 mg/L or until the measurement limit of the turbidity probes was exceeded. This process was repeated using ball clay and a 50-50 mixture (by weight) of SIL-CO-SIL®49 and ball clay.

Figures 4.11, 4.12, and 4.13 show the relationship between suspended solids concentrations and turbidity for both probes using SIL-CO-SIL®49, ball clay, and a 50-50 mixture (by weight) of SIL-CO-SIL®49 and ball clay, respectively.

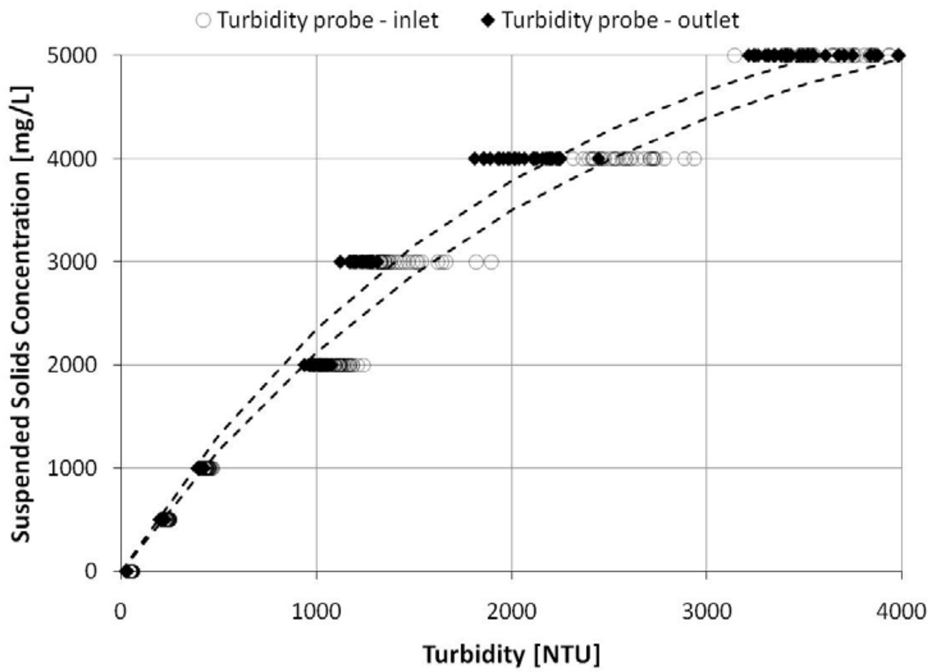


Figure 4.11. Relationships between Turbidity and SSC for the Inlet and Outlet Turbidity Probes Using SIL-CO-SIL®49.

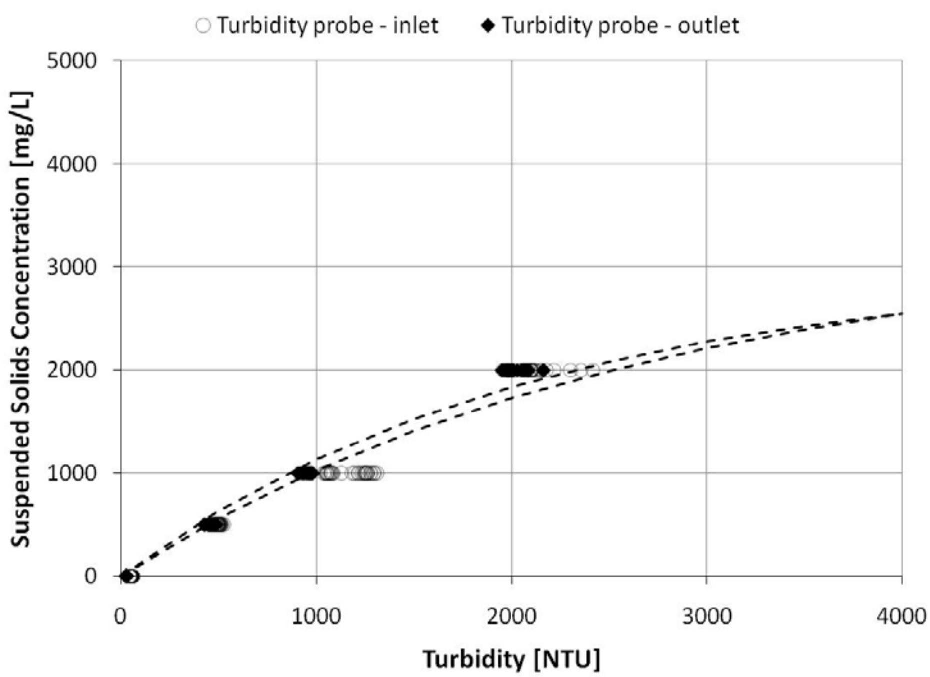


Figure 4.12. Relationship between Suspended Solids Concentration and Turbidity for Ball Clay.

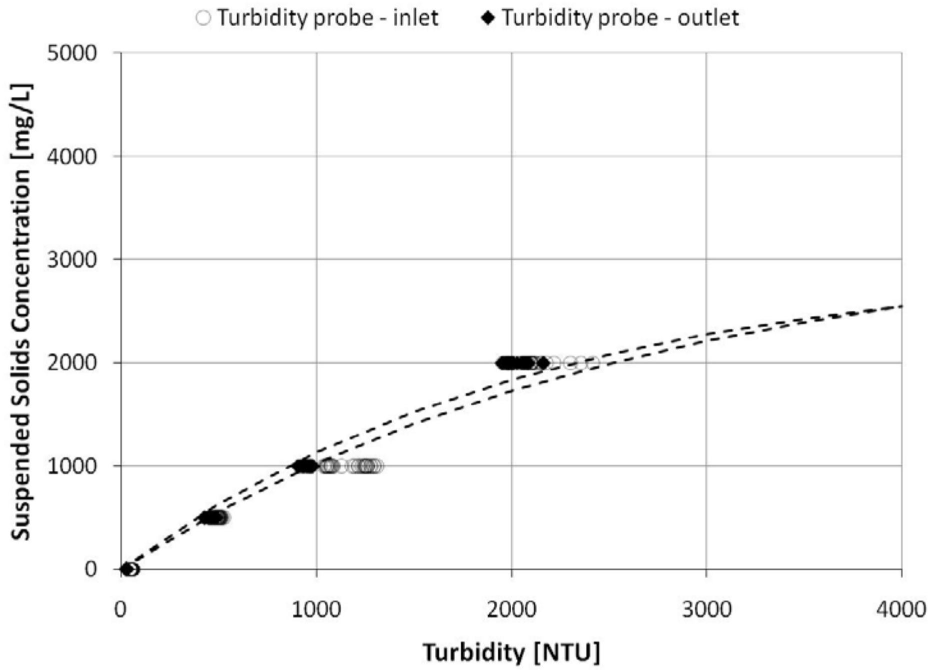


Figure 4.13. Relationship between Suspended Solids Concentration and Turbidity for 50-50 Mixture of SIL-CO-SIL®49 and Ball Clay.

After the turbidity meters were calibrated in the laboratory, multiple test runs were conducted in the SCD testing facility with actual sediment control devices to further evaluate the effectiveness and accuracy of these instruments. The trial runs, which will be discussed in Chapter 5, verified the results of the turbidity calibration experiments from the laboratory and showed that the turbidity probes were accurate and consistent during the testing trials.

Flow Meters

The ISCO 4230 flowmeters were calibrated by conducting clear water runs in the sediment retention device facility. The sediment mixing tank was filled with a known volume of water and the flowmeters were inserted into their ports in the inlet and outlet pipes, respectively. The water was then released from the mixing tank at a known rate of flow and the flow meters were calibrated for both total flow volume accuracy and for instantaneous flow accuracy. These runs were conducted multiple times to ensure the accuracy and repeatability of the ISCO flowmeters.

CHAPTER 5:
TESTING PROTOCOL DEVELOPMENT

EFFECT OF TESTING CONDITIONS ON PERFORMANCE OF SCDS

Calibration tests were conducted on various SCDs to determine the effect of sediment type, initial sediment concentration, and overtopping on removal efficiency. For the initial runs a geosynthetic dike was used as the sediment retention device. It was not critical what type of device was used during these initial experiments, as they were conducted simply to evaluate the effect that various testing conditions would have regarding performance. A geosynthetic dike was chosen simply to evaluate the performance using one type of SCD.

Effect of Sediment type

Researchers conducted tests with three types of sediments;

1. Silica sediment (SIL-CO-SIL®49),
2. Ball clay sediment, and
3. 50:50 mixture (by weight) of silica and ball clay sediment.

The runoff slurry used in this experiment had an inlet SSC of 2000 mg/L. Figure 5.1 shows that the removal efficiency of the SCD was highest for the silica sediment and lowest for the ball clay sediment. The 50:50 mixture (by weight) of the silica and the ball clay sediment results in a sediment removal efficiency between that for the silica and ball clay sediment.

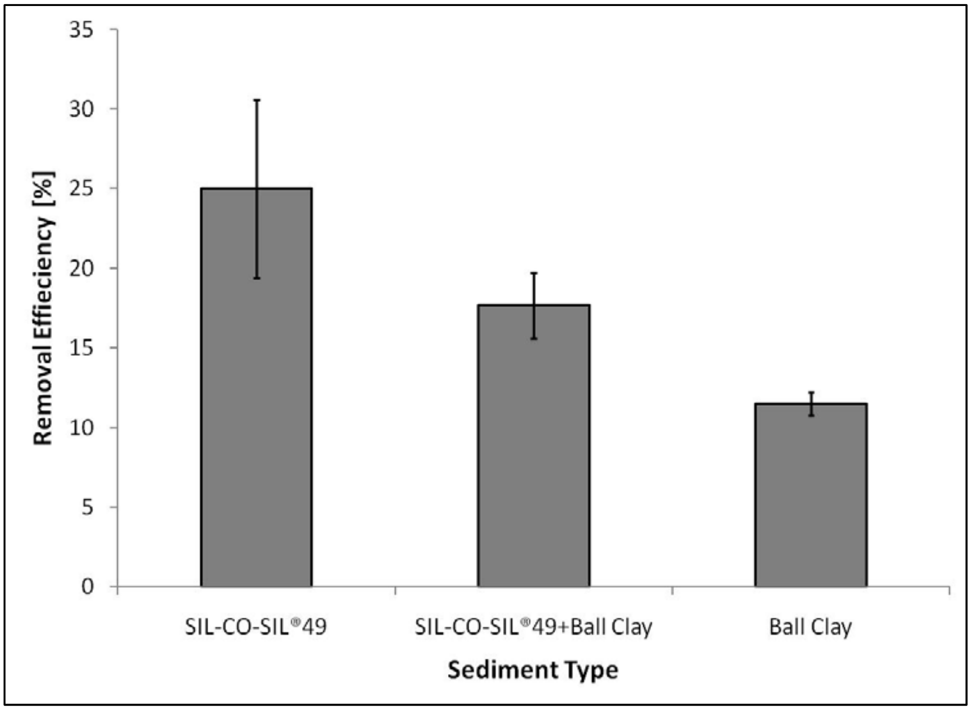


Figure 5.1. Removal Efficiency Measured Using Geosynthetic Dikes for Three Sediment Types (SSC_{IN}=2000 mg/L): SIL-CO-SIL®49, SIL-CO-SIL®49+Ball Clay, and Ball Clay.

Silica particles are larger than ball clay particles and thus settle faster. Many SCDs, due to their composition, target these large particles. However, many SCDs use flocculants and are designed to remove finer ball clay particles that have a surface electrostatic charge. Researchers decided that because of the many variations in sediment control devices, a sediment mix prepared by combining silica and ball clay would be the best option for evaluating and comparing the performance of all SCDs.

Effect of Sediment Concentration

As discussed in Chapter 2, the SSC in the runoff to be treated affects the removal efficiency of the SCD. Researchers tested two concentrations of silica sediment with and without overtopping to determine the effect of initial SSC concentration on removal efficiency of the SCD. Figure 5.2 illustrates that the removal efficiency of the geosynthetic dike increased when the SSC in the runoff to be treated was doubled from 2000 mg/L to 4000 mg/L.

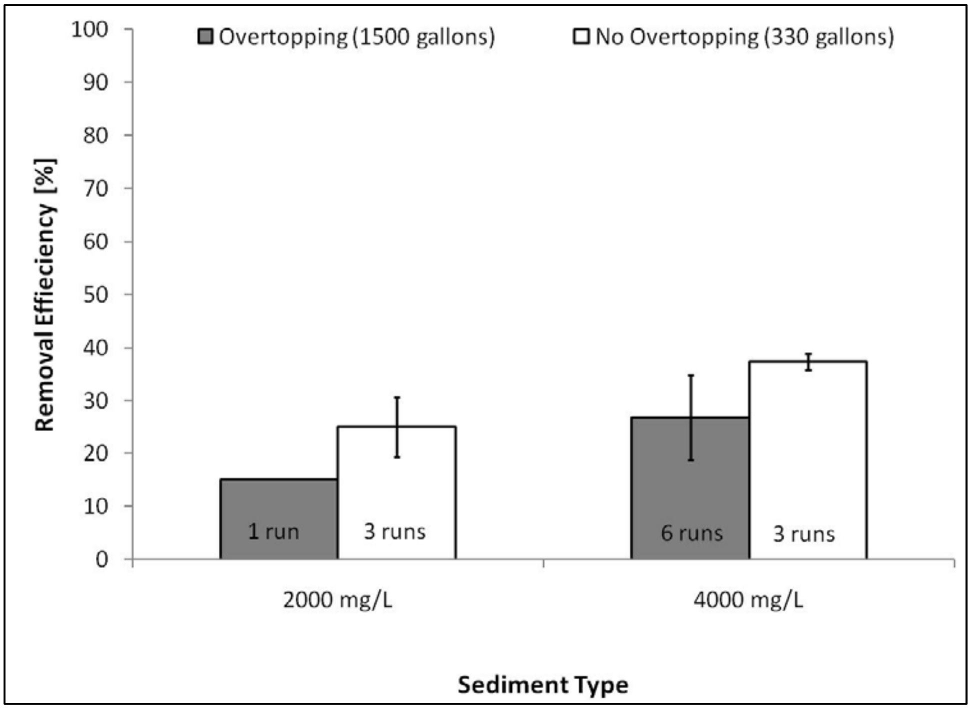


Figure 5.2. Removal Efficiency Measured Using Geosynthetic Dikes for SIL-CO-SIL®49 (Overtopping and No Overtopping) at 2000 and 4000 mg/L.

Effect of Overtopping

Overtopping can cause water to leave the site without getting treated. Researchers conducted experiments using silica sediment (SIL-CO-SIL®49) on a SCD (geosynthetic dike). The overtopping experiments delivered 1500 gal of sediment-laden water into the channel. The experiments with no overtopping delivered sediment-laden water into the channel until overtopping was observed. Once overtopping was observed, the delivery of sediment-laden water into the channel was stopped. Figure 5.3 shows that the removal efficiency increased when water was not allowed to overtop the SCD (geosynthetic dike).

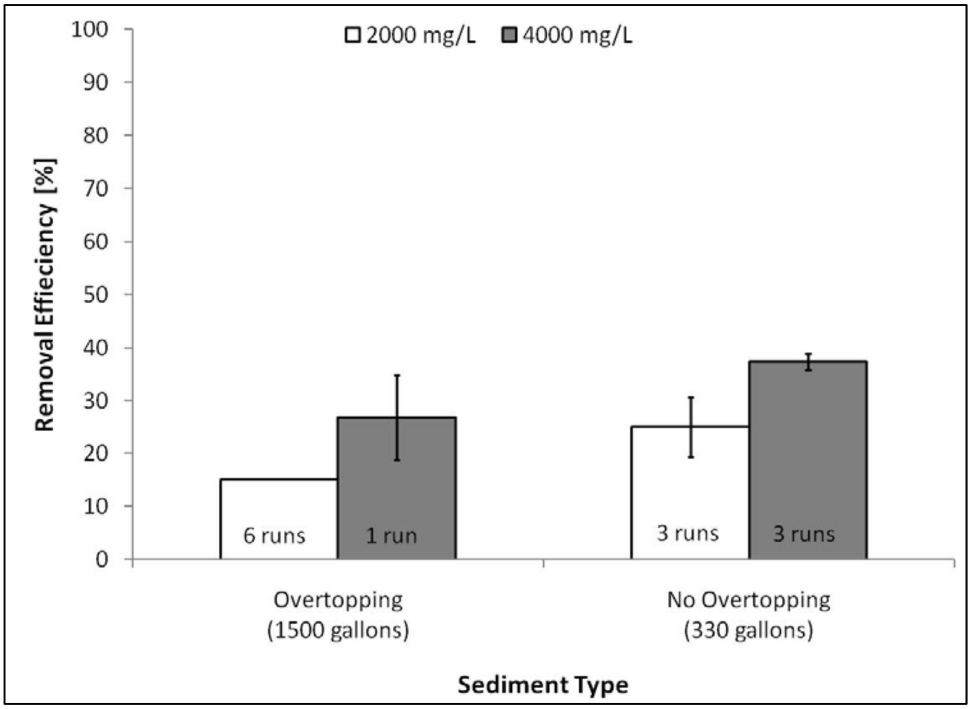


Figure 5.3. Removal Efficiency Measured Using Geosynthetic Dikes for SIL-CO-SIL®49 (C_{IN}=2000 and 4000 mg/L) under Two Conditions: Overtopping and No Overtopping.

SCD TESTING

After examining the effects of various sediment concentrations and examining results of overtopping versus non-overtopping tests, researchers decided to conduct comparative testing on five different types of SCDs. These SCDs were not tested to evaluate their individual sediment retention effectiveness but to evaluate the testing protocol itself. Geosynthetic dikes, untreated wattles, wattles treated with flocculants, silt fences, and rock check dams were evaluated during these test runs.

Ponding Volume

Figure 5.4 shows that the geosynthetic dike, and wattles (untreated and treated) retained water equal to their design capacity, while silt fence and rock check dam did not retain water equal to their design capacity. Both silt fence and rock check dam had a very high design capacity and flow-through rate, which resulted in a smaller volume of sediment-laden water retained behind these SCDs than the design capacity.

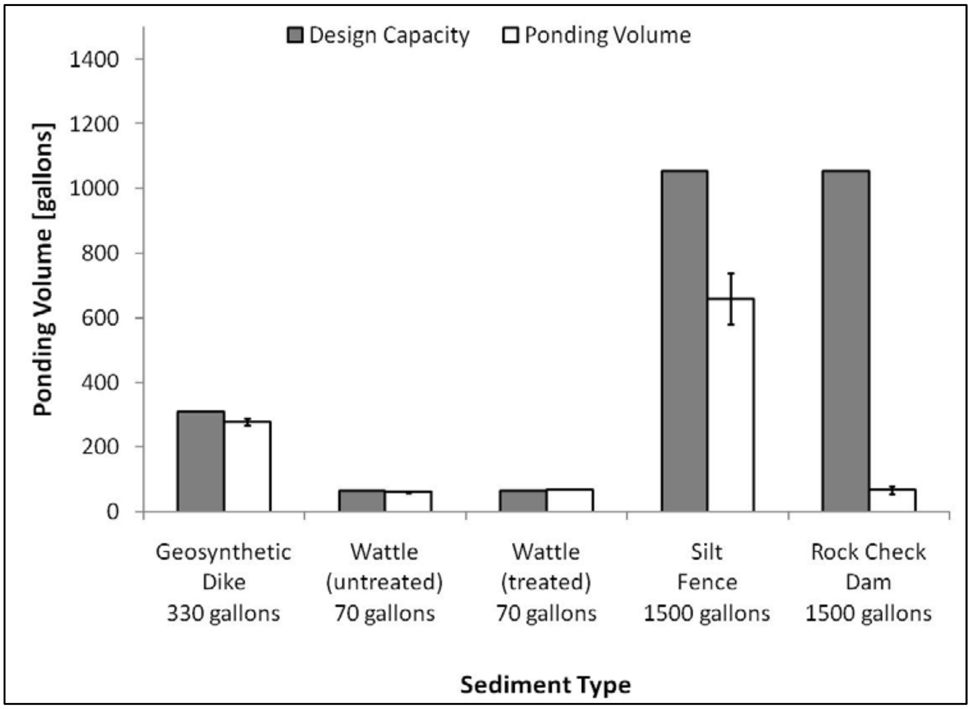


Figure 5.4. Design Capacity and Ponding Volume for Five SCDs. Values below SCD Name Indicate the Total Volume of Sediment-Laden Water Treated.

Table 5.1 contains the data comparing the design capacity and ponding volume from the tests conducted on the five SCDs.

Table 5.1. Design Capacity and Ponding Volume of the Five SCDs Tested at the Channel.

Sediment Control Device	Height cm (in.)	Design capacity L (gal)	Ponding Volume L (gal)
Geosynthetic Dike	22.5 (9)	1170 (309)	1090 (288)
	22.5 (9)	1170 (309)	1052 (278)
	22.5 (9)	1170 (309)	1011 (267)
Wattle – untreated	10.8 (4.25)	246 (65)	223 (59)
	10.8 (4.25)	246 (65)	227 (60)
	10.8 (4.25)	246 (65)	238 (63)
Wattle – treated	10.8 (4.25)	246 (65)	250 (66)
	10.8 (4.25)	246 (65)	250 (66)
	10.8 (4.25)	246 (65)	250 (66)
Silt Fence	45.7 (18)	3994 (1055)	2635 (696)
	45.7 (18)	3994 (1055)	2695 (712)
	45.7 (18)	3994 (1055)	2143 (566)
Rock Check Dam	45.7 (18)	3994 (1055)	223 (59)
	45.7 (18)	3994 (1055)	238 (63)
	45.7 (18)	3994 (1055)	307 (81)

Sediment Removal Efficiency

Two sediment types (silica and ball clay) were examined to determine which sediment to use in testing. Figure 5.5 indicates the sediment removal efficiency of each of the five SCDs. To further evaluate the performance of each of the 5 SCDs the mass load sediment removal needs to be examined. This can be calculated through determining the influent and effluent sediment load. Figures 5.6 and 5.7 indicate these values.

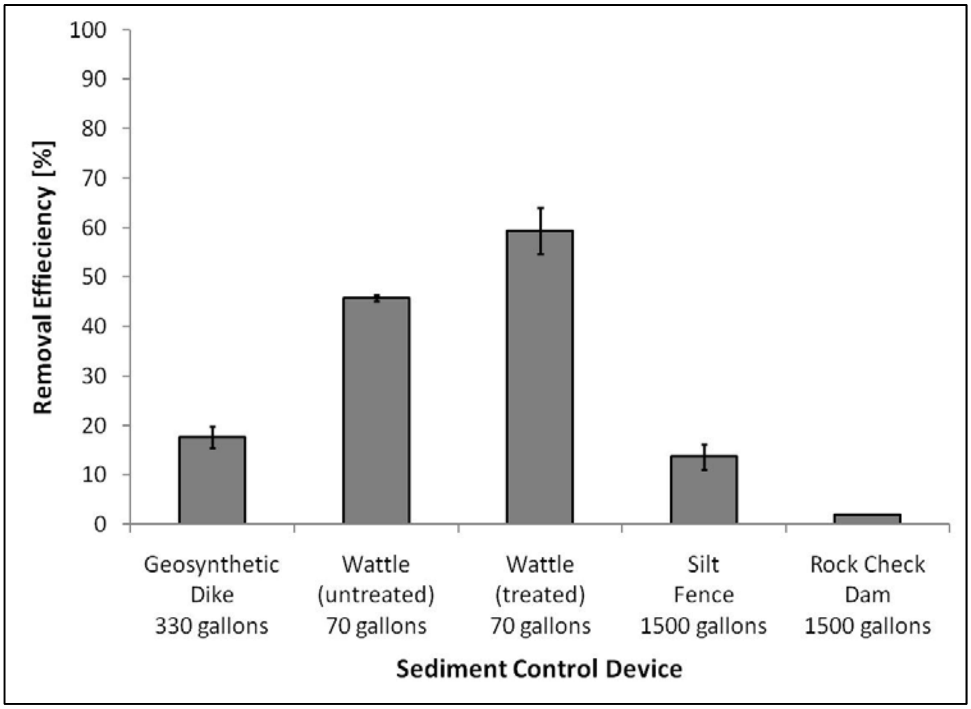


Figure 5.5. Sediment Removal Efficiency for Five SCDs. Values below SCD Name Indicate the Total Volume of Sediment-Laden Water Treated.

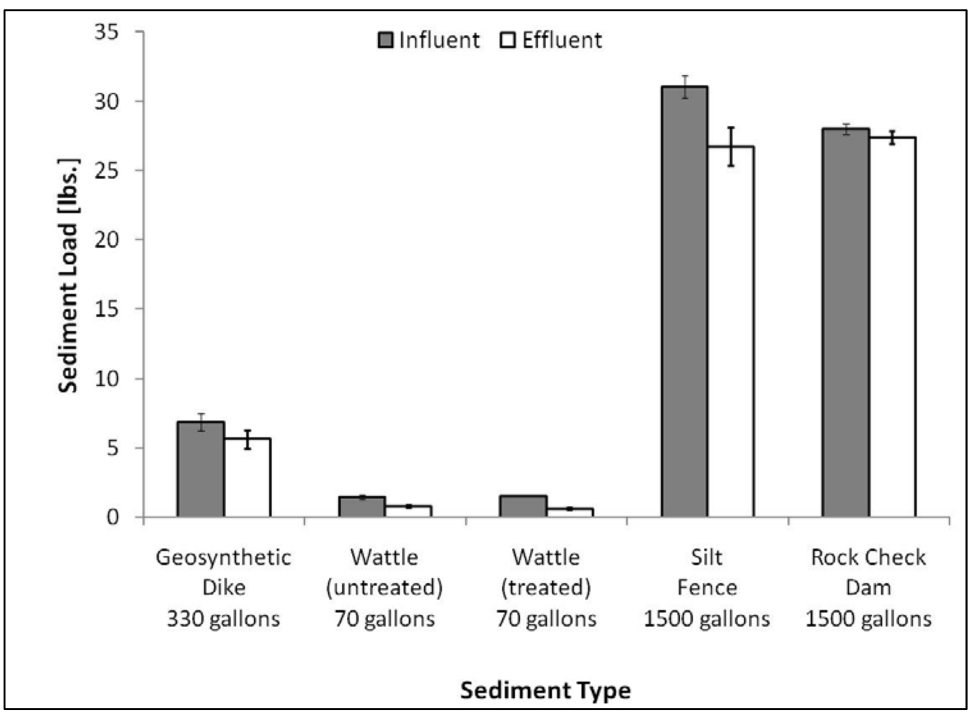


Figure 5.6. Influent and Effluent Sediment Load from Tests Conducted on Five SCDs. Values below SCD Name Indicate the Total Volume of Sediment-Laden Water Treated.

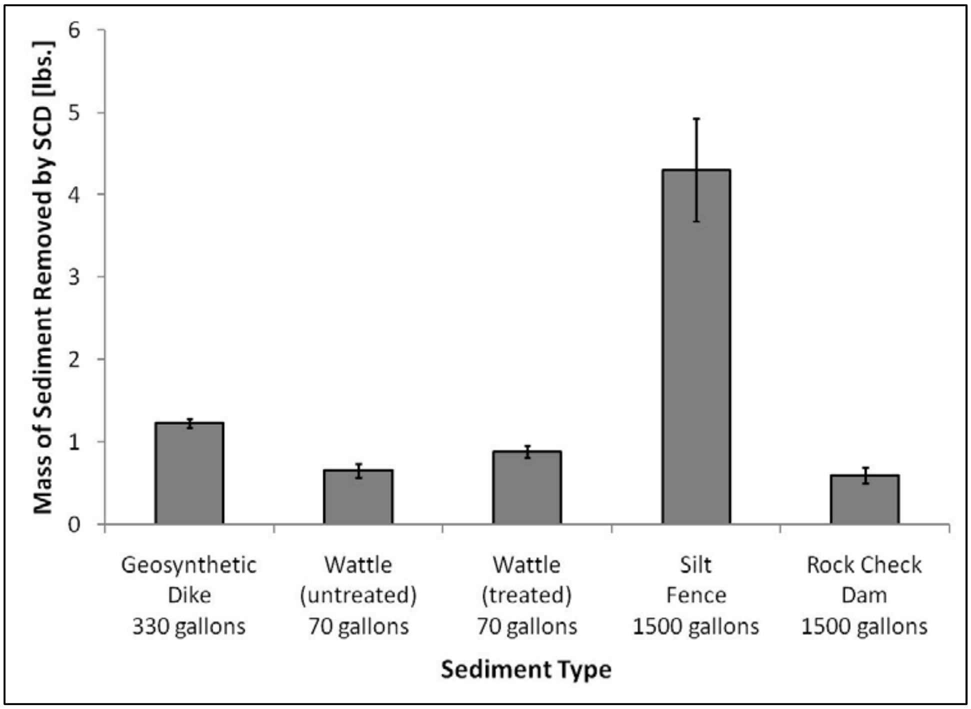


Figure 5.7. Mass of Sediment Removed by Five SCDs. Values below SCD Name Indicate the Total Volume of Sediment-Laden Water Treated.

Table 5.2. Sediment Removal of the Five SCDs Tested at the Channel.

Sediment Control Device	Mass In kg (lb)	Mass Out kg (lb)	Removal Efficiency %
Geosynthetic Dike	2.8 (6.1)	2.2 (4.8)	20
	3.3 (7.2)	2.7 (6.0)	16
	3.3 (7.2)	2.7 (6.0)	17
Wattle – untreated	0.58 (1.3)	0.31 (0.69)	46
	0.65 (1.4)	0.36 (0.79)	45
	0.71 (1.6)	0.39 (0.85)	46
Wattle – treated	0.67 (1.47)	0.24 (0.54)	63
	0.70 (1.54)	0.28 (0.61)	61
	1.47 (1.47)	0.30 (0.67)	54
Silt Fence	14.3 (31.4)	12.2 (26.9)	14
	14.3 (31.6)	12.7 (28.0)	11
	13.7 (30.1)	11.5 (25.3)	16
Rock Check Dam	12.7 (28.0)	12.4 (27.3)	2
	12.5 (27.6)	12.2 (27.0)	2
	12.9 (28.4)	12.7 (27.9)	2

Flow-through Rate

Two bubbler flow meters (ISCO® model ts-line sc) were used to monitor the turbidity at inlet and outlet of channel. Data were downloaded using FlowLink software. Figure 5.8 indicates the flow-through rates of the SCDs evaluated in the calibration process.

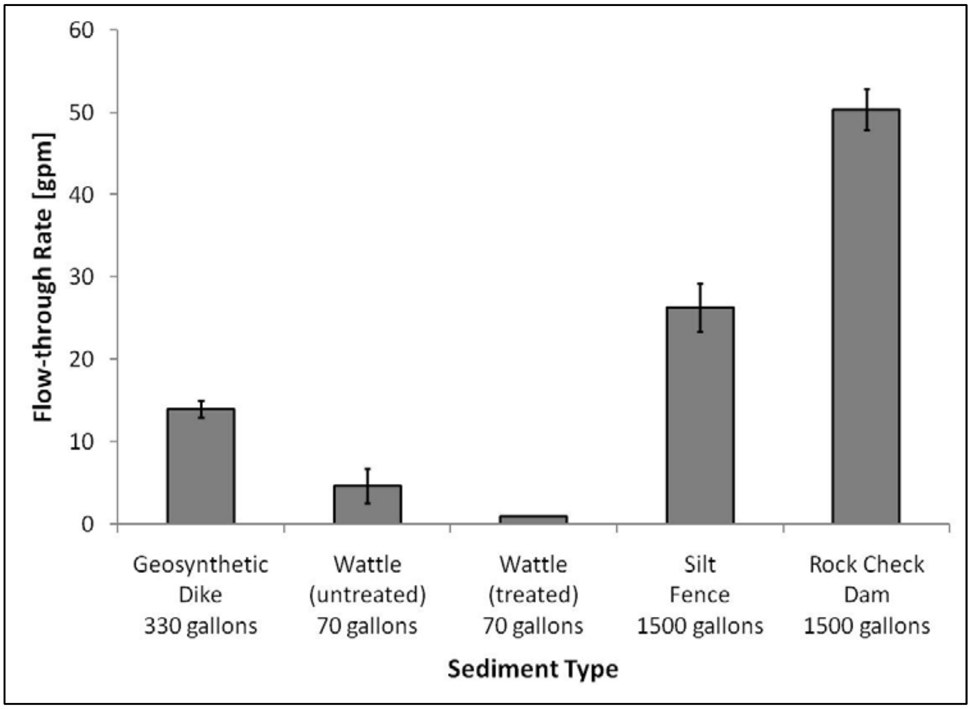


Figure 5.8. Flow-Through Rate of Five SCDs. Values below SCD Name Indicate the Total Volume of Sediment-Laden Water Treated.

CHAPTER 6:
RECOMMENDATIONS AND FUTURE WORK

TESTING PROTOCOL

Based on the 2008–2009 test results discussed above the TTI researchers have developed an evaluation protocol for SCDs. This protocol is designed to effectively, consistently, and fairly test the many various types of SCDs available to TxDOT construction and maintenance divisions.

1. ***Preparing the channel:***
   The testing channel shall be cleaned and the soil in the installation zone shall be resurfaced to match the channel profile.
2. ***Installing the SCD:***
   The SCD shall be installed in the installation zone according to manufacturer's instructions. (Note: In the absence of specific instruction from manufacturer, SCD installation shall be carried out according to technicians' discretion). The installation details like number of stakes, spacing between stakes, presence/absence of apron, trenching depth, and height of SCD after installing shall be recorded.
3. ***Testing:***
   - 3.1. <u>*Instrumentation:*</u>
     The turbidity probes and bubbler tubes shall be connected to the appropriate locations at inlet and outlet. Technicians shall ensure that the flow meters and turbidity meter are recording data correctly (Note: While connecting the turbidity probes and bubbler tubes, special attention shall be directed to ensure that the locations are dirt free.).
   - 3.2. <u>*Test to determine SCD flow-through characteristics: This step is optional if the manufacturer can provide TTI staff with the product's established flow-through rate(s).*</u>
     - 3.2.1. *Sediment preparation:*
       No sediment shall be added to 1500 gal of water in the mixing during this process.

3.2.2. *Test Flow:*

Water shall be released into the channel at a flow rate of ~ 60 gpm by controlling the butterfly valve on the mixing tank. The valve shall be closed and flow of water into the channel shall be stopped when water begins to overtop the SCD. The maximum flow rate at the outlet shall be recorded and shall determine the inflow rate to be applied during performance testing on the SCD. For example, if the maximum flow rate observed at the outlet in 15 gpm, then the SCD falls in the 10–20 gpm flow category and a maximum inflow rate of 20 gpm will be applied during performance testing on the SCD.

3.3. *Performance testing on SCD:*

Three repetitions of this test will be conducted on SCD before removing it from the installation zone.

3.3.1. *Sediment preparation:*

Mix 12.5 lb of SIL-CO-SIL®49 and 12.5 lb of ball in 1500 gal of water to create sediment-laden water having a SSC of 2000 mg/L. The sediment-laden water shall be kept stirred in the mixing tank until the test has ended.

3.3.2. *Testing Flow:*

Water shall be released into the channel, at a flow rate defined by the SCD flow category, by controlling the butterfly valve on the mixing tank. The entire 1500 gal of sediment-laden water shall be emptied into the channel. The test will continue until there is no water retained behind the SCD.

3.4. *Data processing:*

Data from the flow meter and turbidity meter shall be downloaded to the field laptop. All relevant calculations will be performed using excel spreadsheet.

4. Data Recording

The following data will be reported to TxDOT following each product evaluation:

- Product installation details,
- Flow-through rate (cfs),
- Maximum Flow Rate (gpm),
- Ponding Volume (gal),

- Turbidity (NTU) at inlet and outlet,
- SSC (mg/L) at inlet and outlet,
- Mass Loading (lb), and
- Removal Efficiency (%).

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APPENDIX A: WATER QUALITY TEST TABLES

1. Testing details and results from Run 1.

Table A-1.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 1.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	50	0	1500	4000	Overtopping

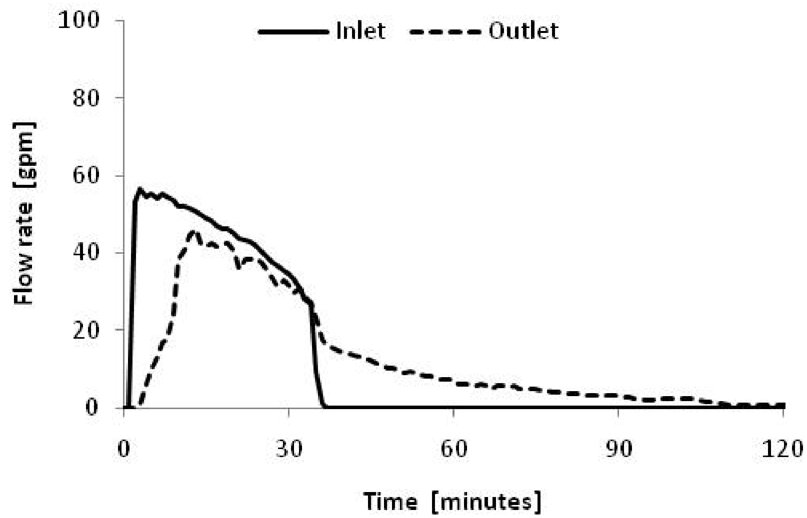

Figure A-1.1. Flow Rates Measured at Inlet and Outlet – Run 1.

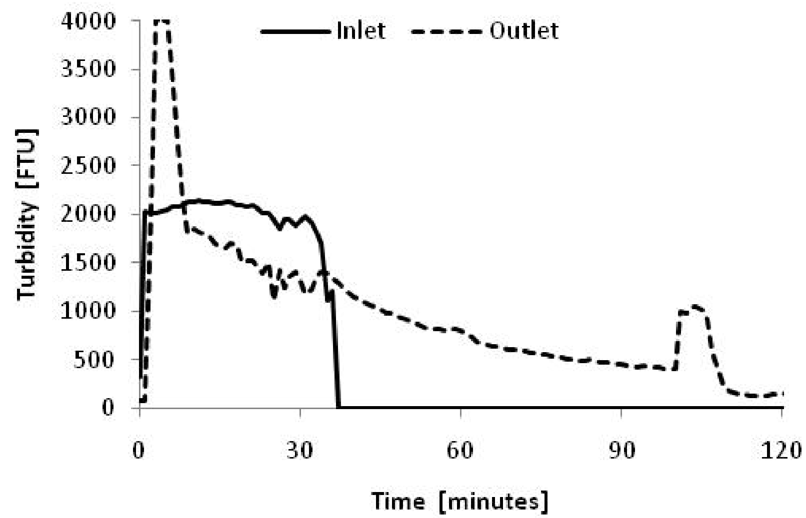

Figure A-1.2. Turbidity Measured at Inlet and Outlet – Run 1.

Table A-1.2. Results Describing SCD Performance from Run 1.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
57 (0.126)	46 (0.103)	469	1935 ± 354	953 ± 752	3392 ± 527	2054 ± 1131	44.27	36.17	18

2. Testing details and results from Run 2

Table A-2.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 2.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	50	0	1500	4000	Overtopping

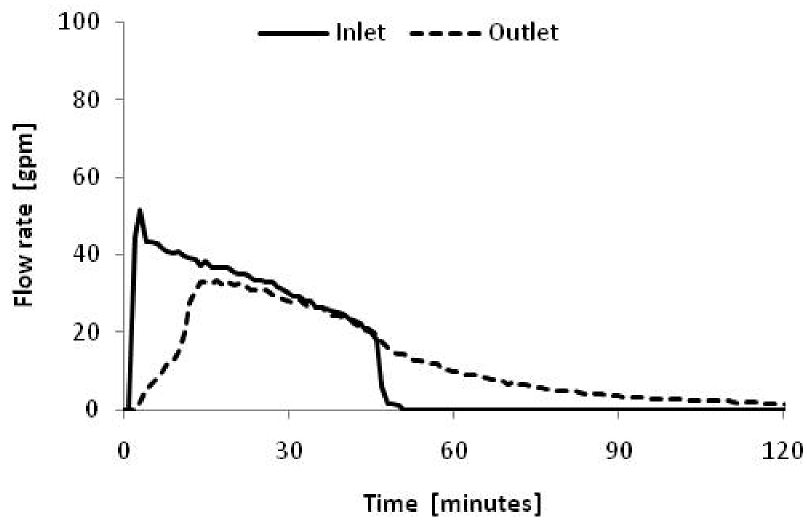

Figure A-2.1. Flow Rates Measured at Inlet and Outlet – Run 2.

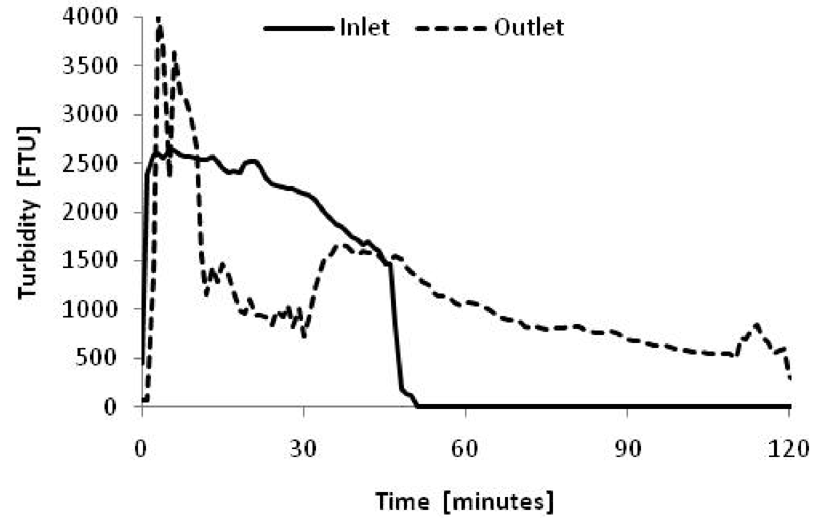

Figure A-2.2. Turbidity Measured at Inlet and Outlet – Run 2.

Table A-2.2. Results Describing SCD Performance from Run 2.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
51 (0.115)	33 (0.074)	427	2042 ± 663	1040 ± 696	3426 ± 960	2249 ± 1005	47.16	33.80	28

3. Testing details and results from Run 3.

Table A-3.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 3.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	50	0	1500	4000	Overtopping

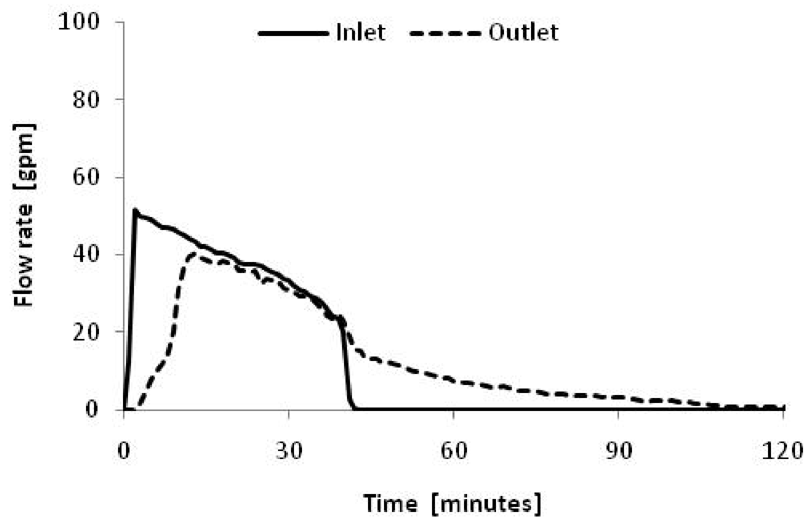

Figure A-3.1. Flow Rates Measured at Inlet and Outlet – Run 3.

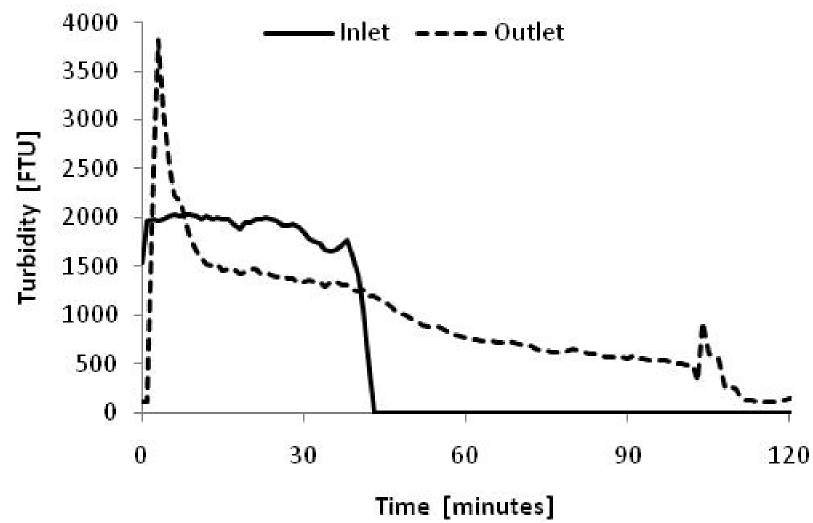

Figure A-3.2. Turbidity Measured at Inlet and Outlet – Run 3.

Table A-3.2. Results Describing SCD Performance from Run 3.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
51 (0.114)	40 (0.090)	414	1839 ± 278	898 ± 629	3294 ± 398	1998 ± 1074	42.65	34.98	18

4. Testing details and results from Run 4.

Table A-4.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 4.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	50	0	1500	4000	Overtopping

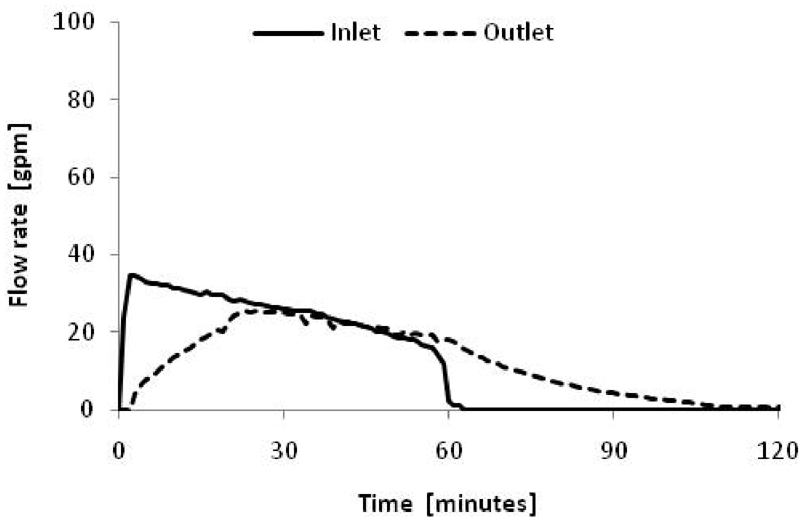

Figure A-4.1. Flow Rates Measured at Inlet and Outlet – Run 4.

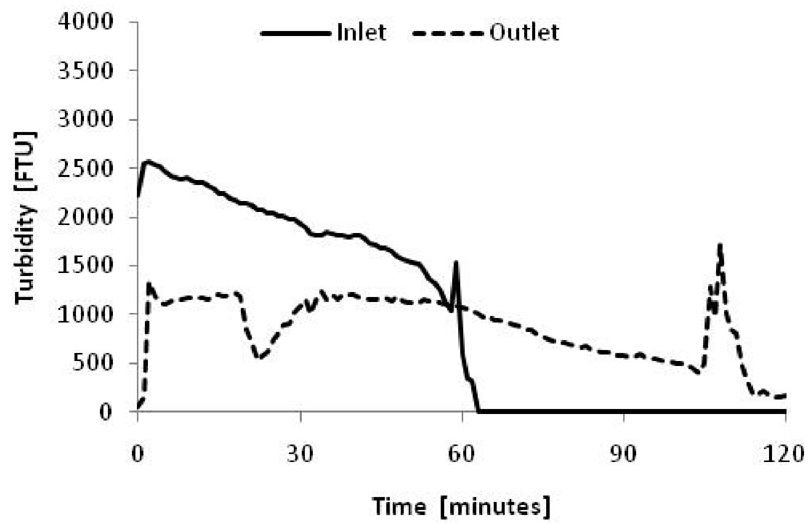

Figure A-4.2. Turbidity Measured at Inlet and Outlet – Run 4.

Table A-4.2. Results Describing SCD Performance from Run 4.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_θ	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
35 (0.077)	26 (0.057)	396	1875 ± 490	721 ± 427	3293 ± 671	1714 ± 993	43.60	29.10	33

5. Testing details and results from Run 5.

Table A-5.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 5.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	50	0	1500	4000	Overtopping

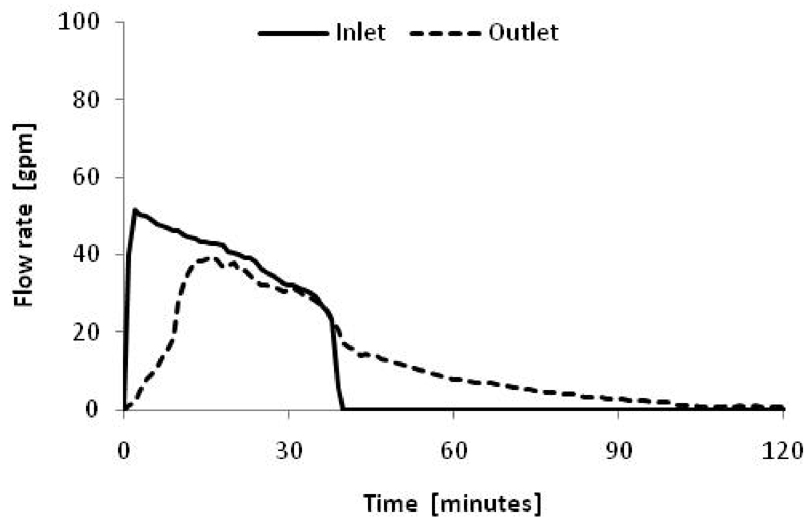

Figure A-5.1. Flow Rates Measured at Inlet and Outlet – Run 5.

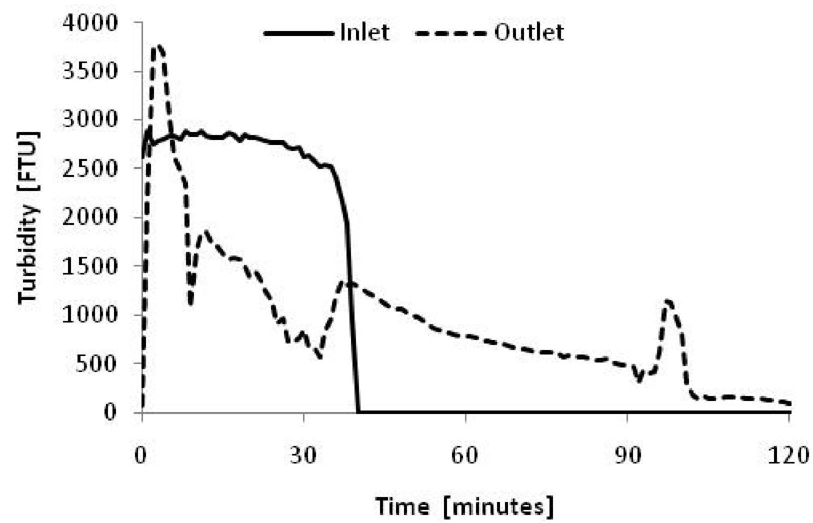

Figure A-5.2. Turbidity Measured at Inlet and Outlet – Run 5.

Table A-5.2. Results Describing SCD Performance from Run 5.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
51 (0.115)	40 (0.088)	459	2677 ± 340	899 ± 741	4122 ± 378	1959 ± 1273	52.52	32.42	38

6. Testing details and results from Run 6.

Table A-6.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 6.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	50	0	1500	4000	Overtopping

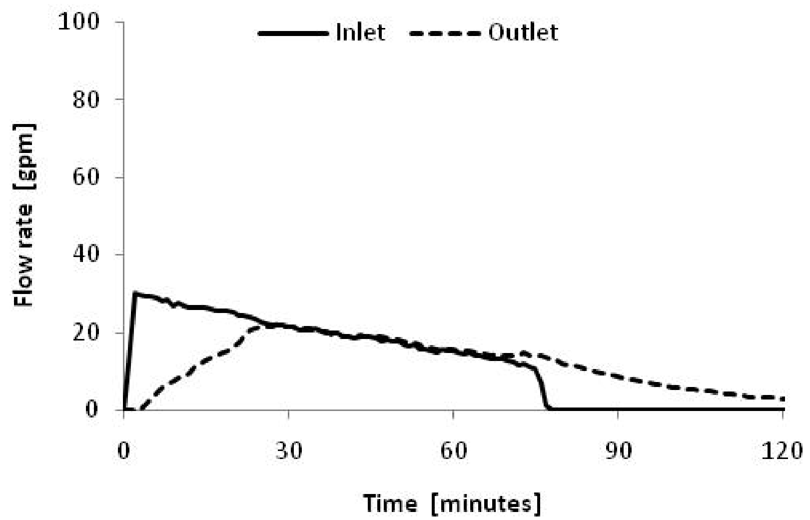

Figure A-6.1. Flow Rates Measured at Inlet and Outlet – Run 6.

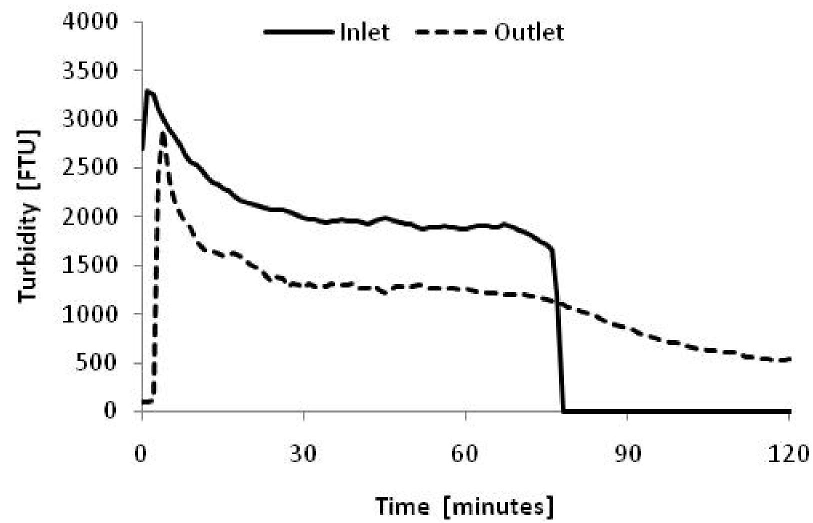

Figure A-6.2. Turbidity Measured at Inlet and Outlet – Run 6.

Table A-6.2. Results Describing SCD Performance from Run 6.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
30 (0.067)	22 (0.049)	384	2095 ± 368	1057 ± 478	3574 ± 355	2360 ± 833	45.68	33.62	26

7. Testing details and results from Run 7.

Table A-7.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 7.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	50	0	330	4000	No Overtopping

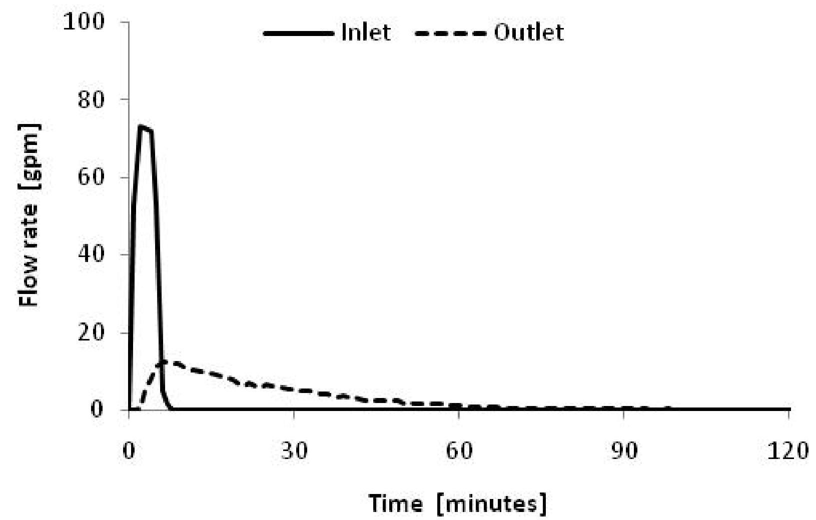

Figure A-7.1. Flow Rates Measured at Inlet and Outlet – Run 7.

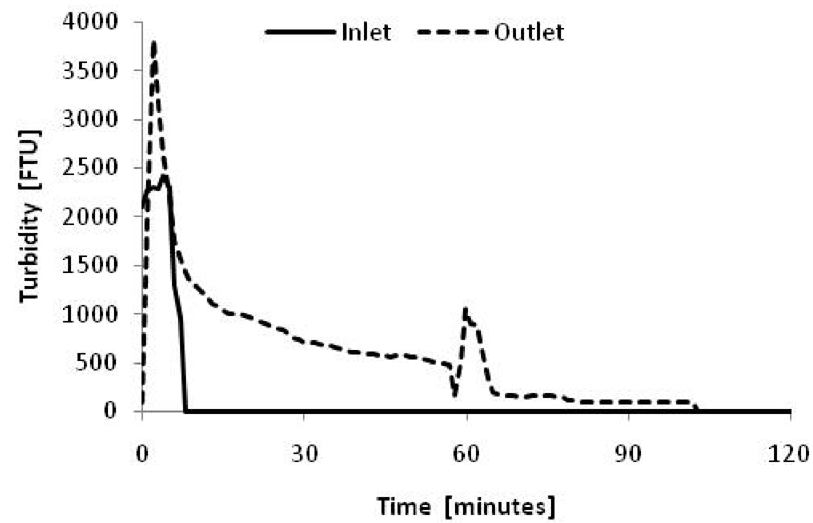

Figure A-7.2. Turbidity Measured at Inlet and Outlet – Run 7.

Table A-7.2. Results Describing SCD Performance from Run 7.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
73 (0.163)	12 (0.027)	299	1999 ± 551	633 ± 640	3430 ± 701	1441 ± 1105	10.49	6.43	39

8. Testing details and results from Run 8.

Table A-8.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 8.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	50	0	330	4000	No Overtopping

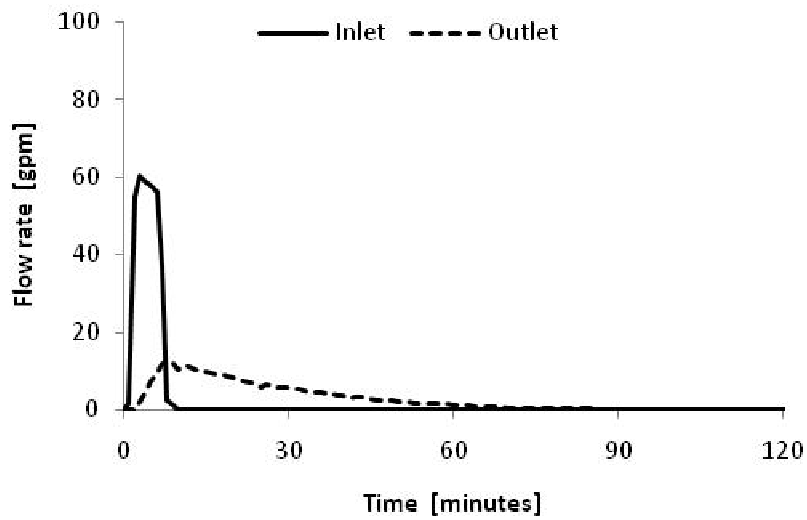

Figure A-8.1. Flow Rates Measured at Inlet and Outlet – Run 8.

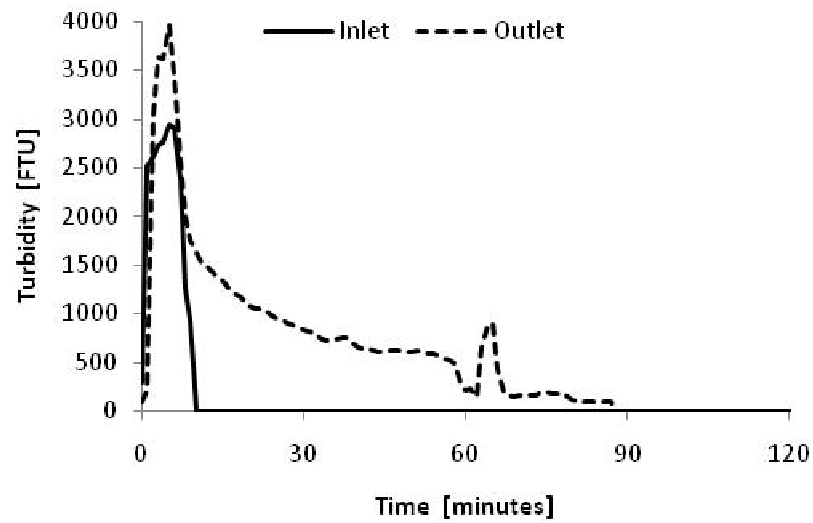

Figure A-8.2. Turbidity Measured at Inlet and Outlet – Run 8.

Table A-8.2. Results Describing SCD Performance from Run 8.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
60 (0.134)	12 (0.027)	291	2136 ± 942	837 ± 825	3439 ± 1240	1783 ± 1231	11.50	7.26	37

9. Testing details and results from Run 9.

Table A-9.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 9.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	50	0	330	4000	No Overtopping

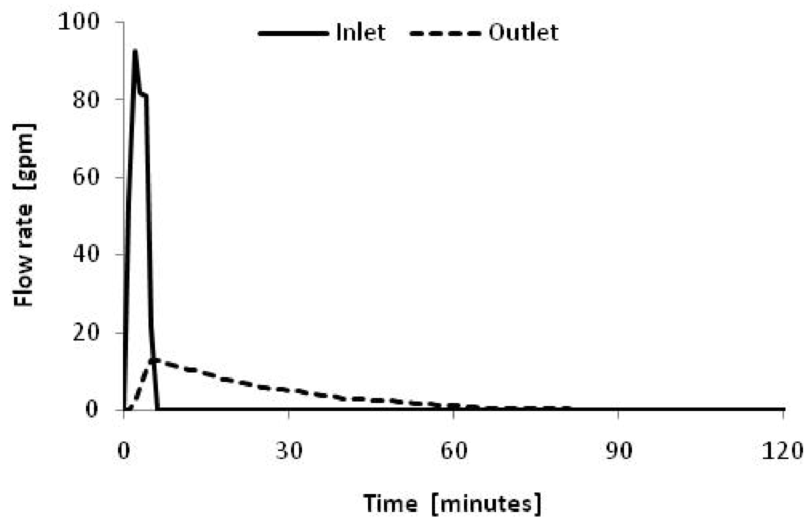

Figure A-9.1. Flow Rates Measured at Inlet and Outlet – Run 9.

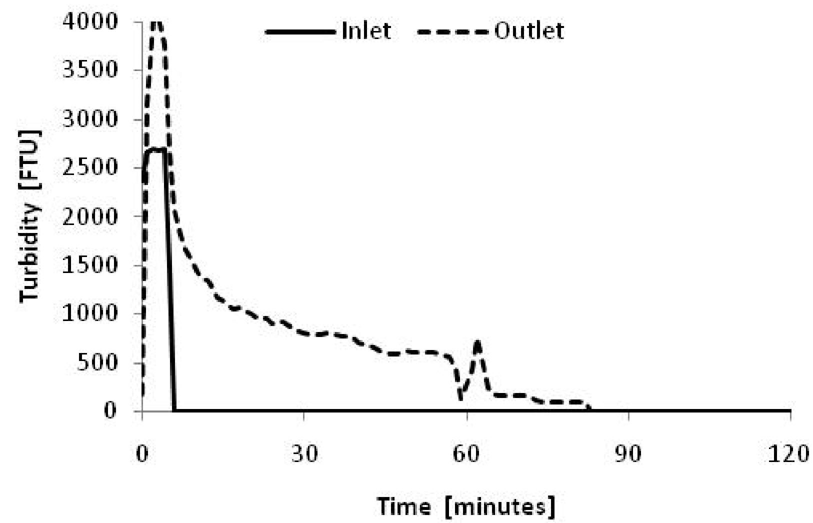

Figure A-9.2. Turbidity Measured at Inlet and Outlet – Run 9.

Table A-9.2. Results Describing SCD Performance from Run 9.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
92 (0.206)	13 (0.028)	299	2431 ± 483	846 ± 819	3891 ± 518	1811 ± 1194	11.21	7.21	36

10. Testing details and results from Run 10.

Table A-10.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 10.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	25	0	330	2000	No Overtopping

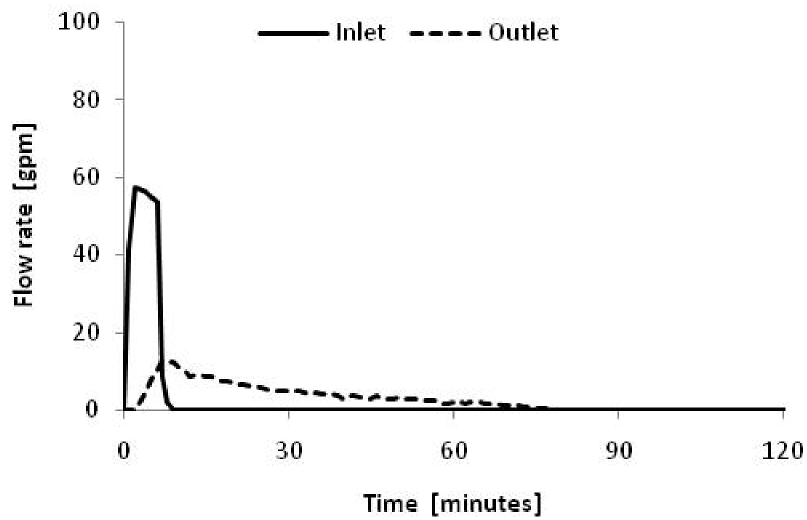

Figure A-10.1. Flow Rates Measured at Inlet and Outlet – Run 10.

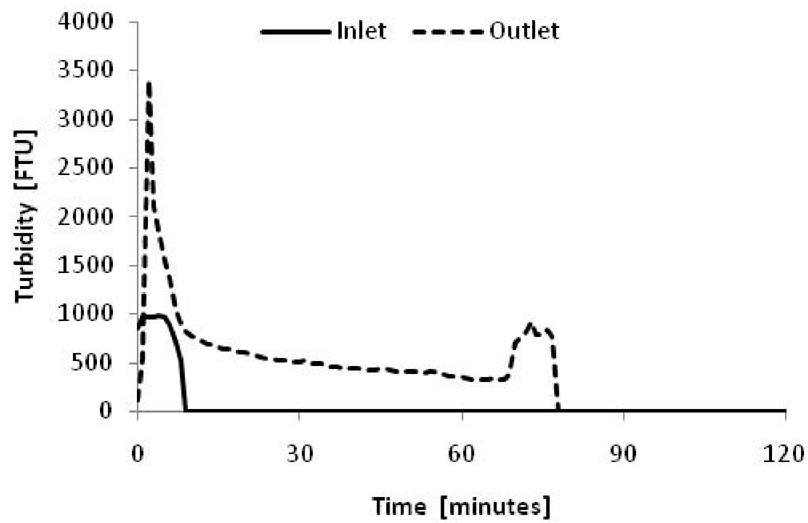

Figure A-10.2. Turbidity Measured at Inlet and Outlet – Run 10.

Table A-10.2. Results Describing SCD Performance from Run 10.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
57 (0.127)	12 (0.028)	295	873 ± 158	627 ± 452	1892 ± 297	1524 ± 715	5.61	4.53	19

11. Testing details and results from Run 11.

Table A-11.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 11.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	25	0	330	2000	No Overtopping

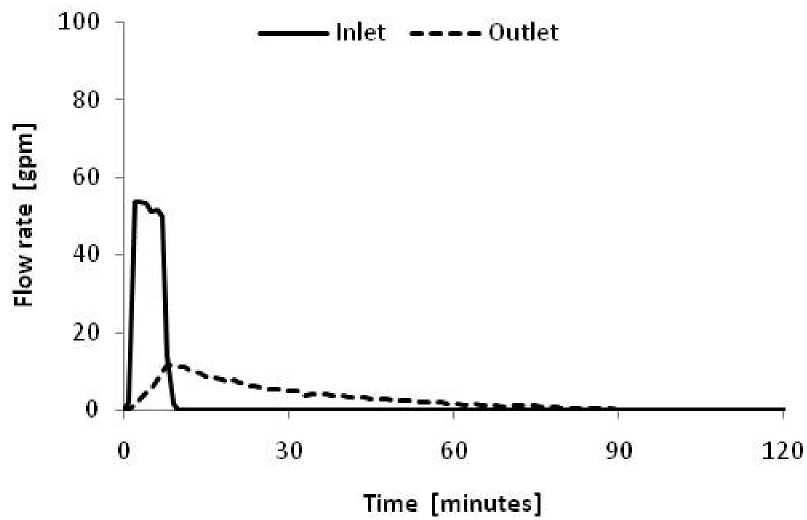

Figure A-11.1. Flow Rates Measured at Inlet and Outlet – Run 11.

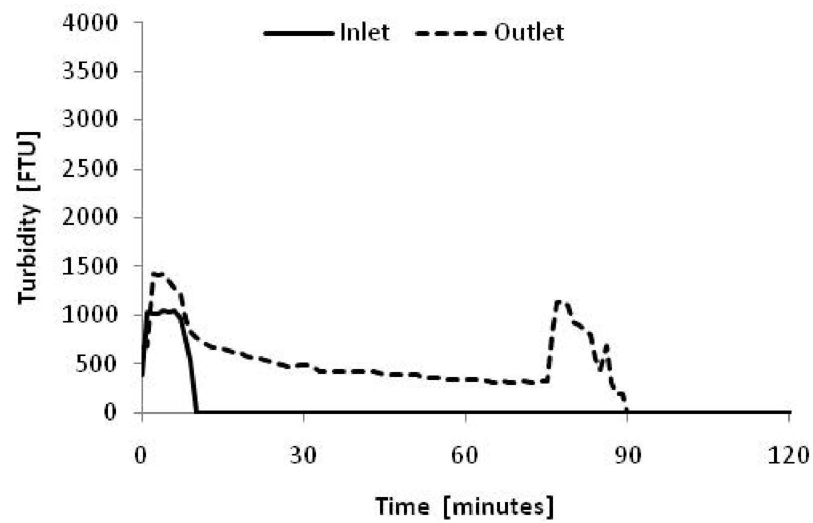

Figure A-11.2. Turbidity Measured at Inlet and Outlet – Run 11.

Table A-11.2. Results Describing SCD Performance from Run 11.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
53 (0.119)	11 (0.026)	285	882 ± 239	558 ± 291	1897 ± 454	1411 ± 600	5.86	4.31	26

12. Testing details and results from Run 12.

Table A-12.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 12.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	25	0	330	2000	No Overtopping

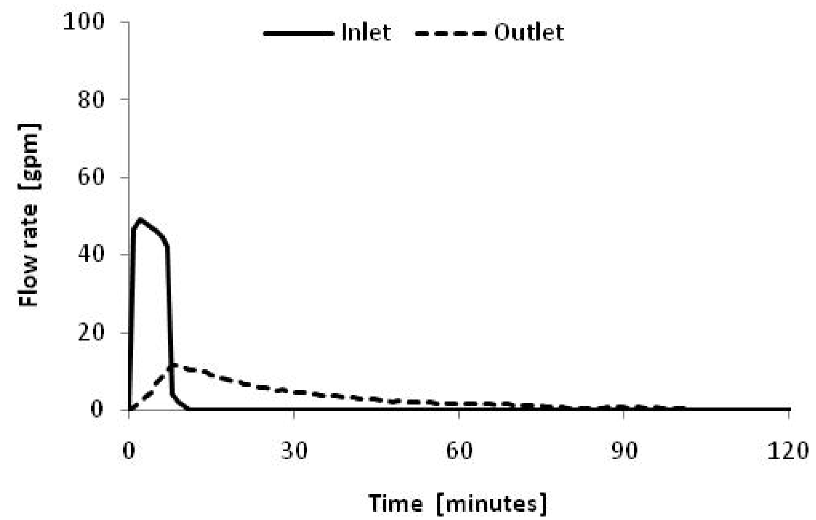

Figure A-12.1. Flow Rates Measured at Inlet and Outlet – Run 12.

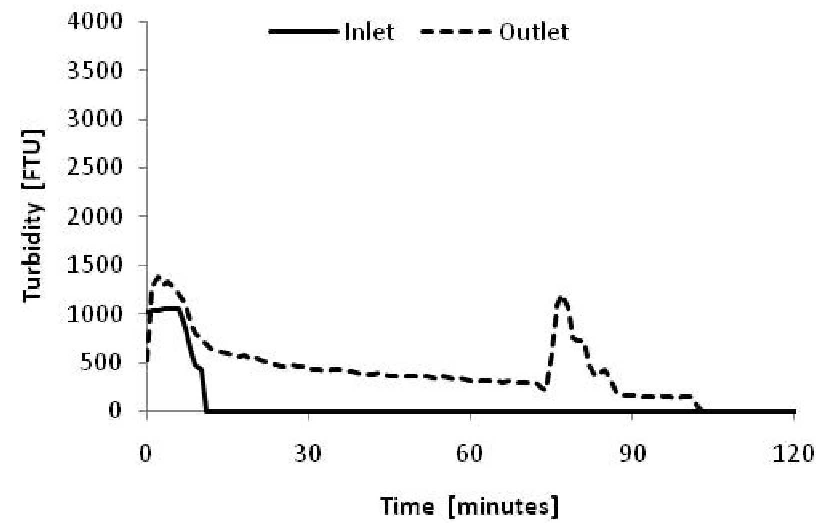

Figure A-12.2. Turbidity Measured at Inlet and Outlet – Run 12.

Table A-12.2. Results Describing SCD Performance from Run 12.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
49 (0.109)	11 (0.025)	287	886 ± 248	472 ± 298	1901 ± 467	1208 ± 640	5.91	4.11	30

13. Testing details and results from Run 13.

Table A-13.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 13.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	25	0	1500	2000	Overtopping

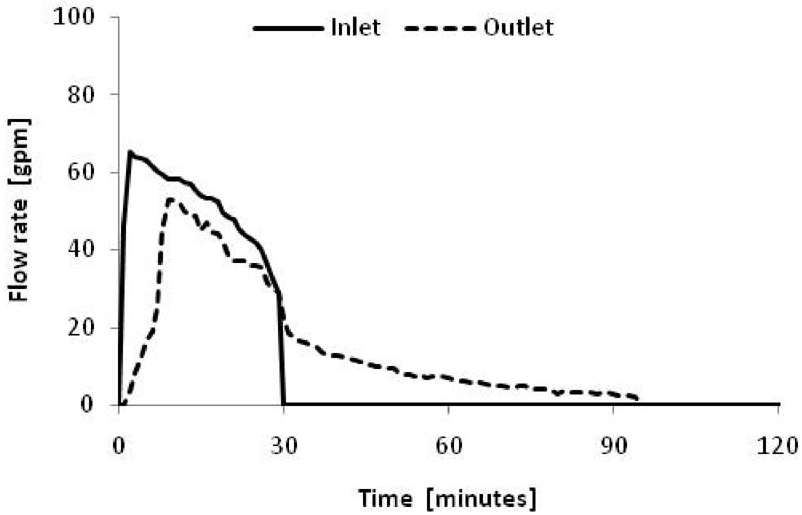

Figure A-13.1. Flow Rates Measured at Inlet and Outlet – Run 13.

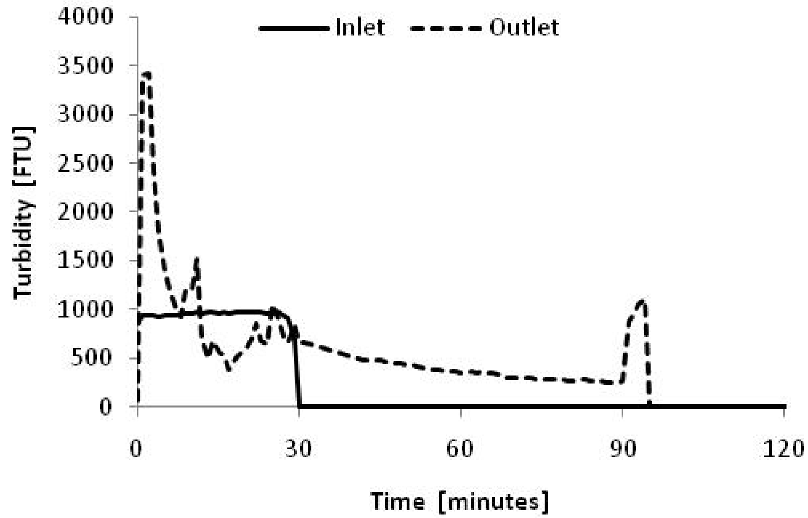

Figure A-13.2. Turbidity Measured at Inlet and Outlet – Run 13.

Table A-13.2. Results Describing SCD Performance from Run 13.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
65 (0.145)	53 (0.117)	497	946 ± 54	624 ± 549	2028 ± 97	1476 ± 864	25.55	21.69	15

14. Testing details and results from Run 14.

Table A-14.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 14.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	0	25	1500	2000	Overtopping

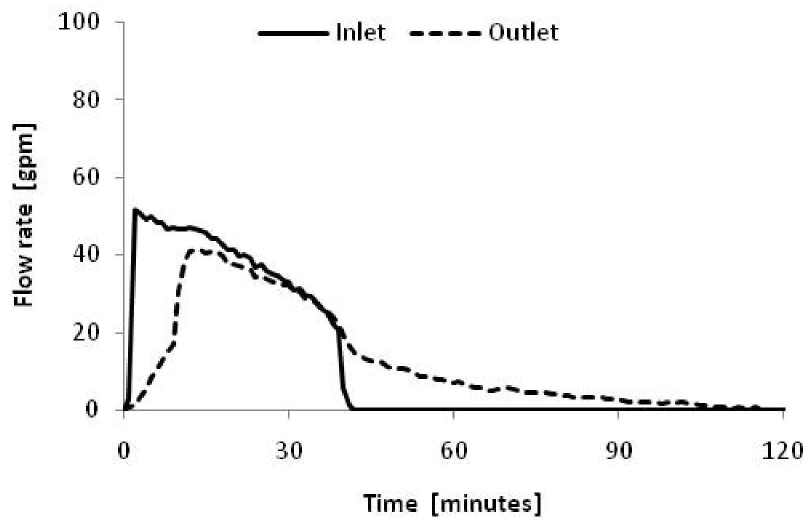

Figure A-14.1. Flow Rates Measured at Inlet and Outlet – Run 14.

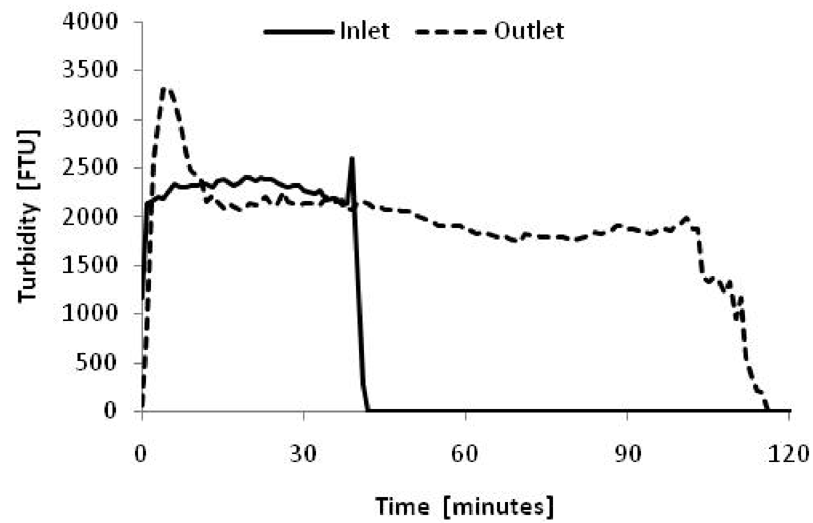

Figure A-14.2. Turbidity Measured at Inlet and Outlet – Run 14.

Table A-14.2. Results Describing SCD Performance from Run 14.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
51 (0.115)	41 (0.092)	405	2197 ± 395	1907 ± 508	1821 ± 285	1747 ± 360	23.68	23.75	0

15. Testing details and results from Run 15.

Table A-15.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 15.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	0	25	330	2000	No Overtopping

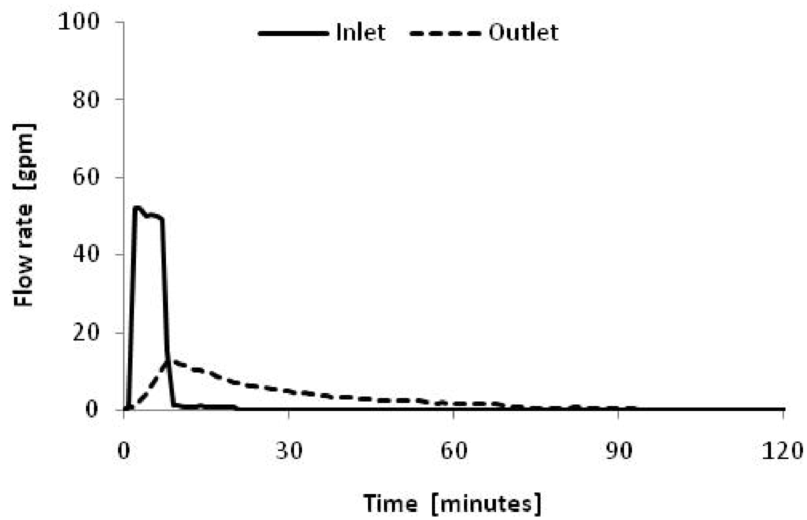

Figure A-15.1. Flow Rates Measured at Inlet and Outlet – Run 15.

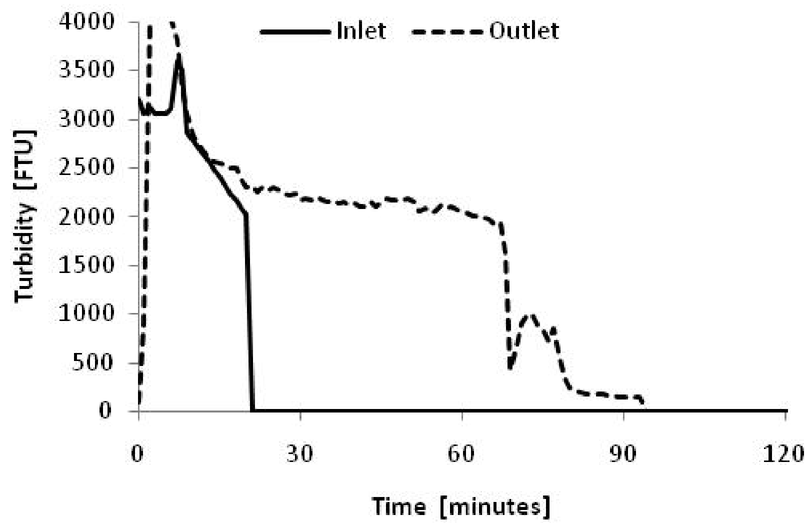

Figure A-15.2. Turbidity Measured at Inlet and Outlet – Run 15.

Table A-15.2. Results Describing SCD Performance from Run 15.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_θ	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
52 (0.116)	12 (0.028)	273	2762 ± 455	1830 ± 1030	2098 ± 201	1580 ± 722	6.25	5.56	11

16. Testing details and results from Run 16.

Table A-16.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 16.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	0	25	330	2000	No Overtopping

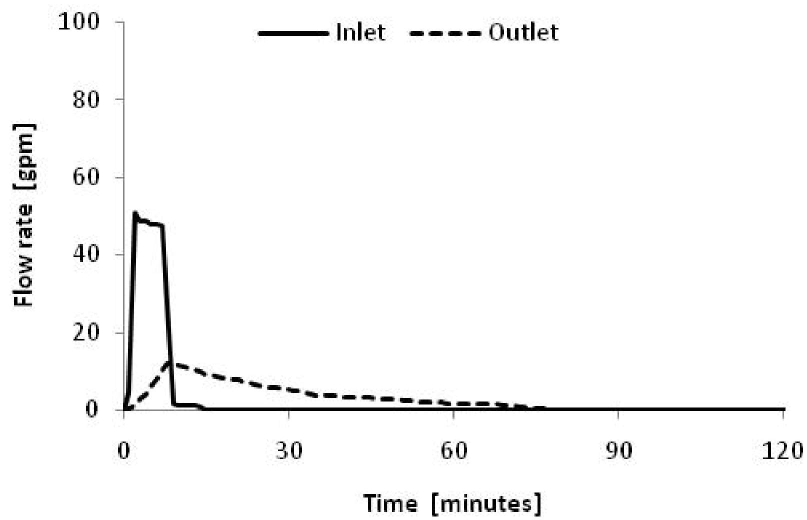

Figure A-16.1. Flow Rates Measured at Inlet and Outlet – Run 16.

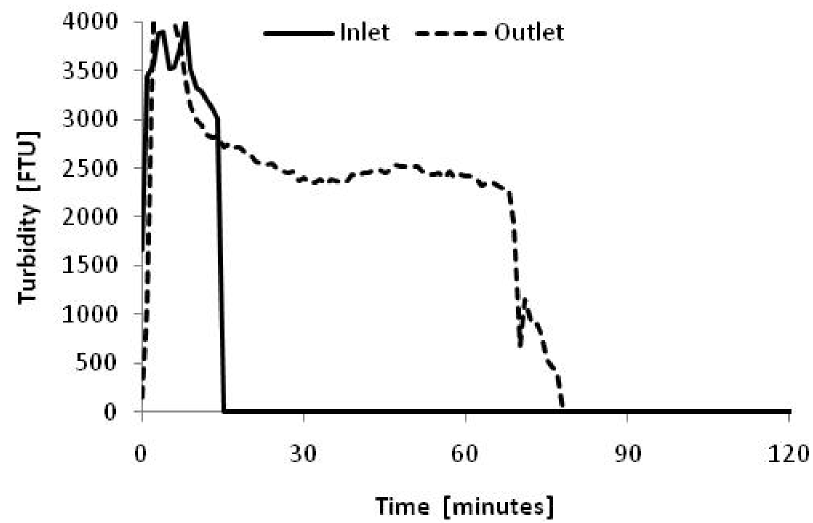

Figure A-16.2. Turbidity Measured at Inlet and Outlet – Run 16.

Table A-16.2. Results Describing SCD Performance from Run 16.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
51 (0.113)	12 (0.027)	278	3380 ± 556	2400 ± 794	2333 ± 244	1960 ± 471	6.77	5.92	12

17. Testing details and results from Run 17.

Table A-17.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 17.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	12.5	12.5	330	2000	No Overtopping

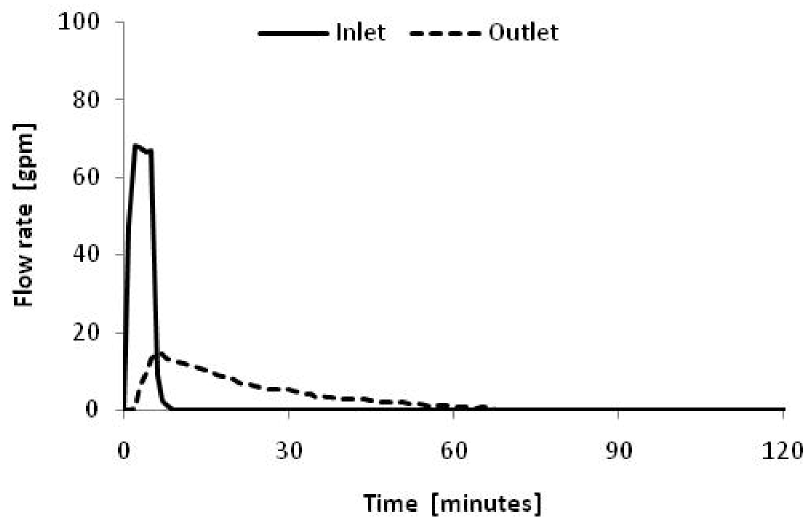

Figure A-17.1. Flow Rates Measured at Inlet and Outlet – Run 17.

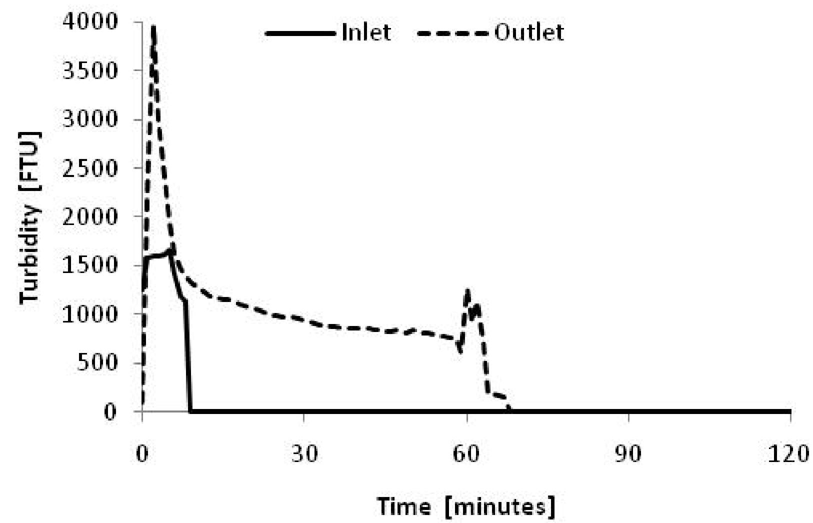

Figure A-17.2. Turbidity Measured at Inlet and Outlet – Run 17.

Table A-17.2. Results Describing SCD Performance from Run 17.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
68 (0.152)	15 (0.033)	288	1445 ± 205	1040 ± 584	2030 ± 225	1520 ± 644	6.05	4.84	20

18. Testing details and results from Run 18.

Table A-18.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 18.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	12.5	12.5	330	2000	No Overtopping

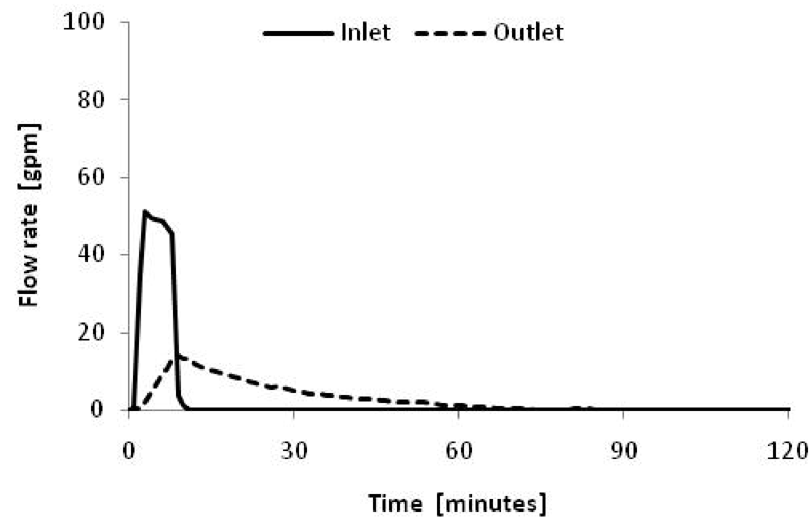

Figure A-18.1. Flow Rates Measured at Inlet and Outlet – Run 18.

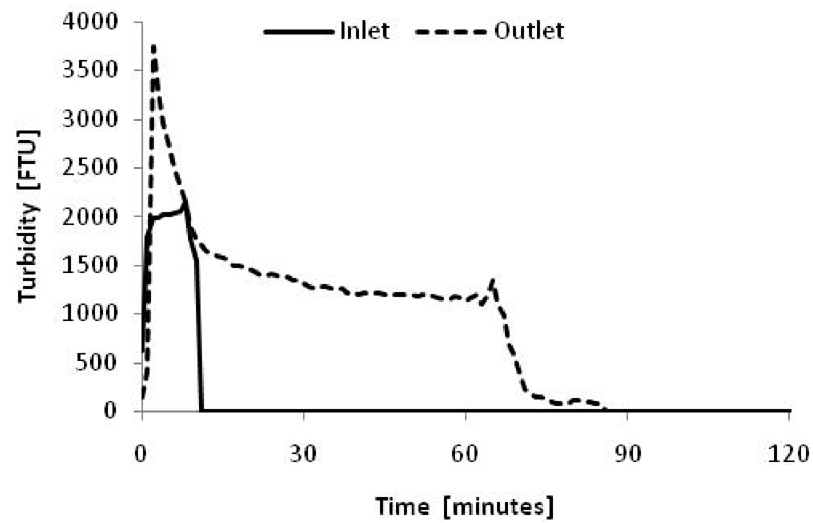

Figure A-18.2. Turbidity Measured at Inlet and Outlet – Run 18.

Table A-18.2. Results Describing SCD Performance from Run 18.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
51 (0.114)	14 (0.031)	278	1821 ± 433	1176 ± 712	2385 ± 485	1661 ± 865	7.19	6.02	16

19. Testing details and results from Run 19.

Table A-19.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 19.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Geosynthetic Dike	9	309	12.5	12.5	330	2000	No Overtopping

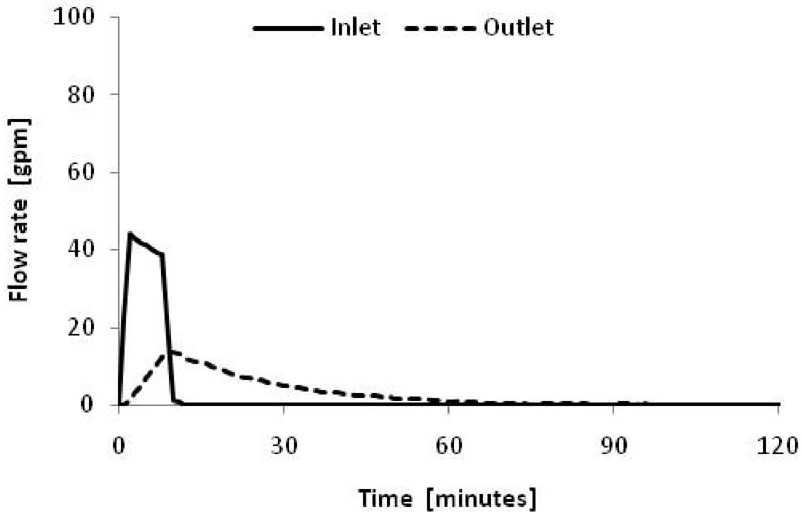

Figure A-19.1. Flow Rates Measured at Inlet and Outlet – Run 19.

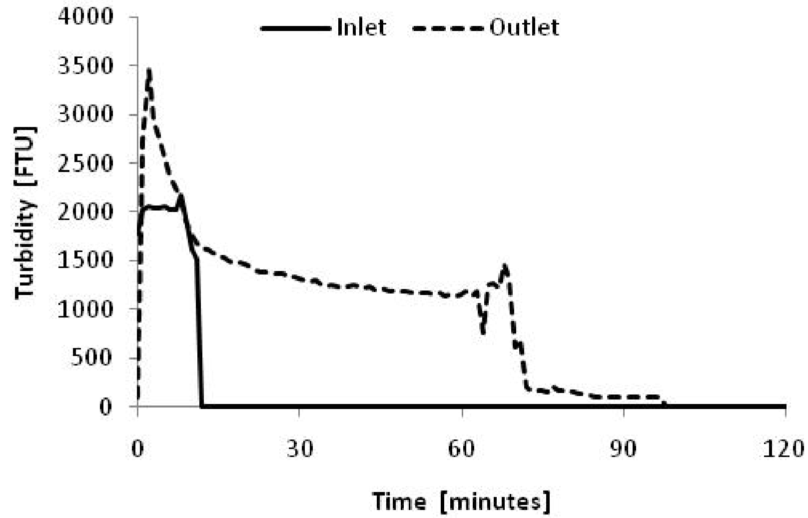

Figure A-19.2. Turbidity Measured at Inlet and Outlet – Run 19.

Table A-19.2. Results Describing SCD Performance from Run 19.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
44 (0.099)	13 (0.030)	267	1948 ± 199	1078 ± 726	2528 ± 187	1530 ± 922	7.23	5.98	17

20. Testing details and results from Run 20.

Table A-20.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 20.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Wattle (Untreated)	4.12	60	12.5	12.5	750	2000	Overtopping

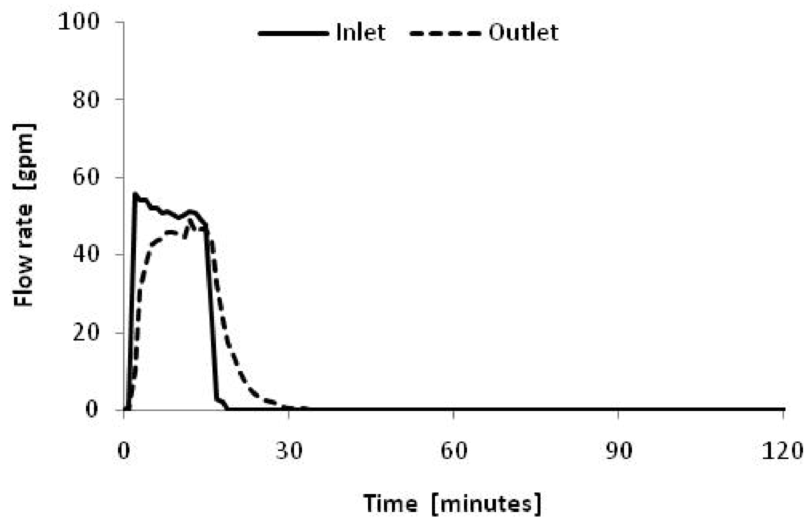

Figure A-20.1. Flow Rates Measured at Inlet and Outlet – Run 20.

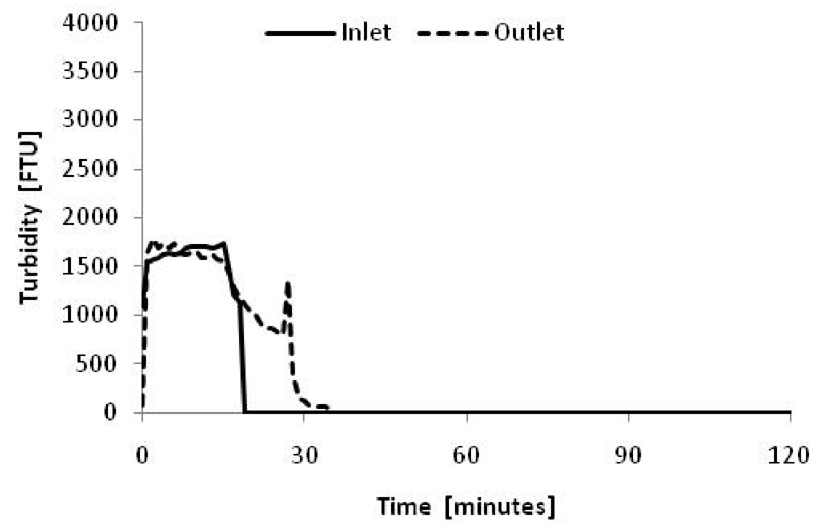

Figure A-20.2. Turbidity Measured at Inlet and Outlet – Run 20.

Table A-20.2. Results Describing SCD Performance from Run 20.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_θ	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
56 (0.124)	49 (0.110)	142	1948 ± 199	1078 ± 726	2528 ± 187	1530 ± 922	14.10	13.50	4

21. Testing details and results from Run 21.

Table A-21.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 21.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Wattle (Untreated)	4.12	60	12.5	12.5	750	2000	Overtopping

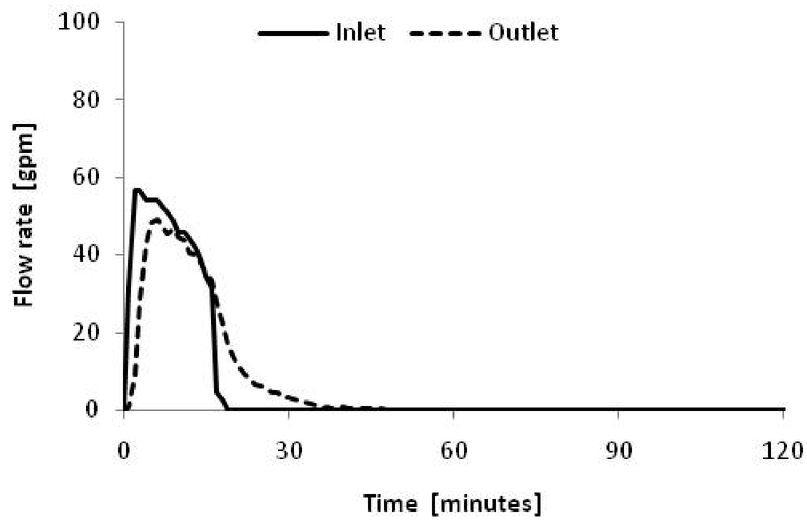

Figure A-21.1. Flow Rates Measured at Inlet and Outlet – Run 21.

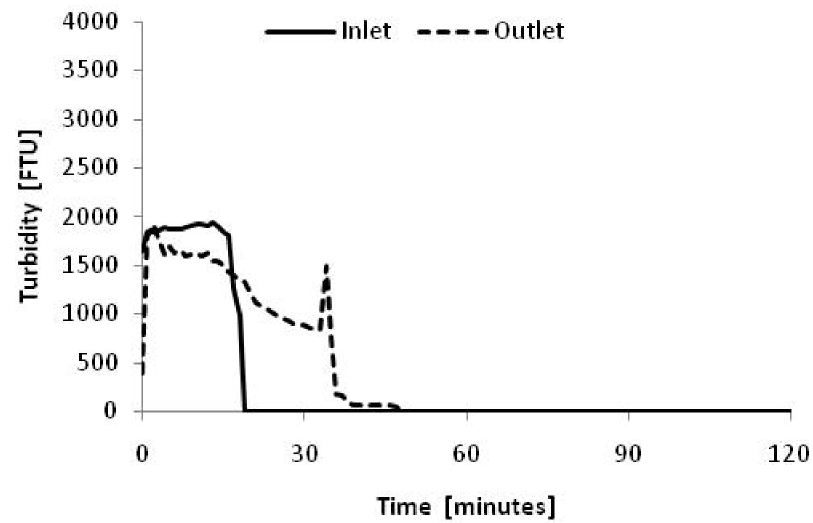

Figure A-21.2. Turbidity Measured at Inlet and Outlet – Run 21.

Table A-21.2. Results Describing SCD Performance from Run 21.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
57 (0.126)	49 (0.109)	154	1788 ± 248	987 ± 620	2375 ± 264	1433 ± 854	15.43	13.36	13

22. Testing details and results from Run 22.

Table A-22.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 22.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Wattle (Untreated)	4.12	60	12.5	12.5	70	2000	No Overtopping

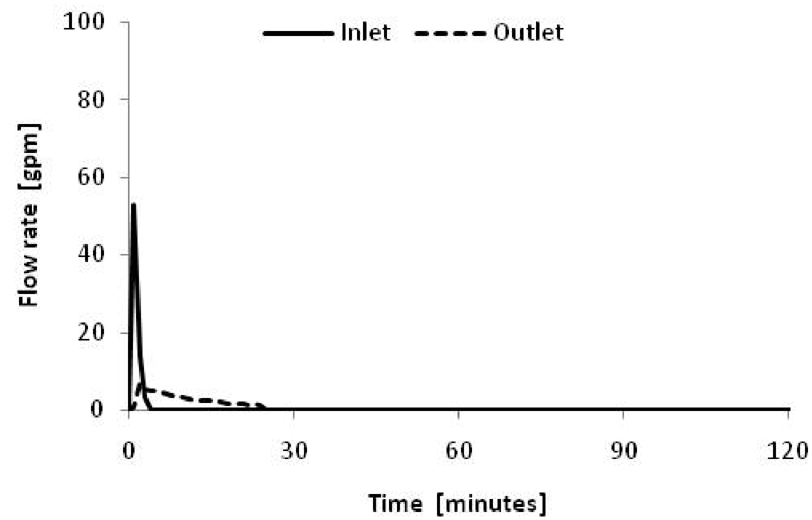

Figure A-22.1. Flow Rates Measured at Inlet and Outlet – Run 22.

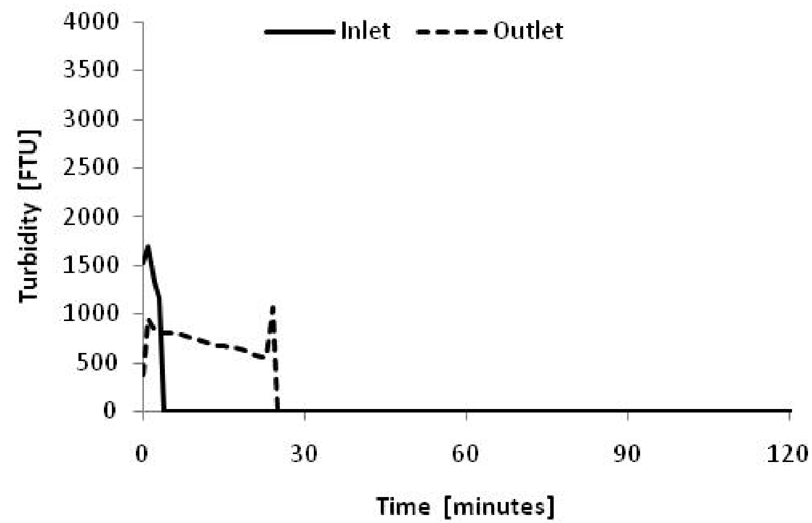

Figure A-22.2. Turbidity Measured at Inlet and Outlet – Run 22.

Table A-22.2. Results Describing SCD Performance from Run 22.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
53 (0.118)	7 (0.016)	59	1427 ± 231	712 ± 139	2010 ± 251	1126 ± 198	1.28	0.69	46

23. Testing details and results from Run 23.

Table A-23.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 23.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Wattle (Untreated)	4.12	60	12.5	12.5	70	2000	No Overtopping

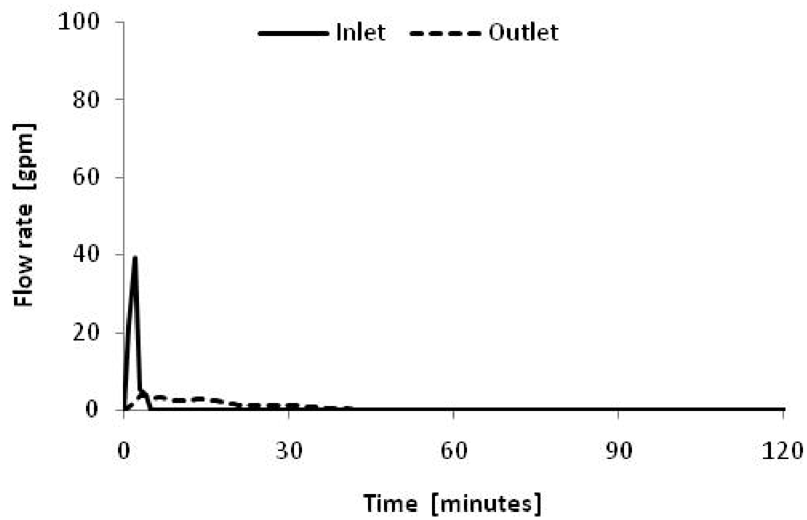

Figure A-23.1. Flow Rates Measured at Inlet and Outlet – Run 23.

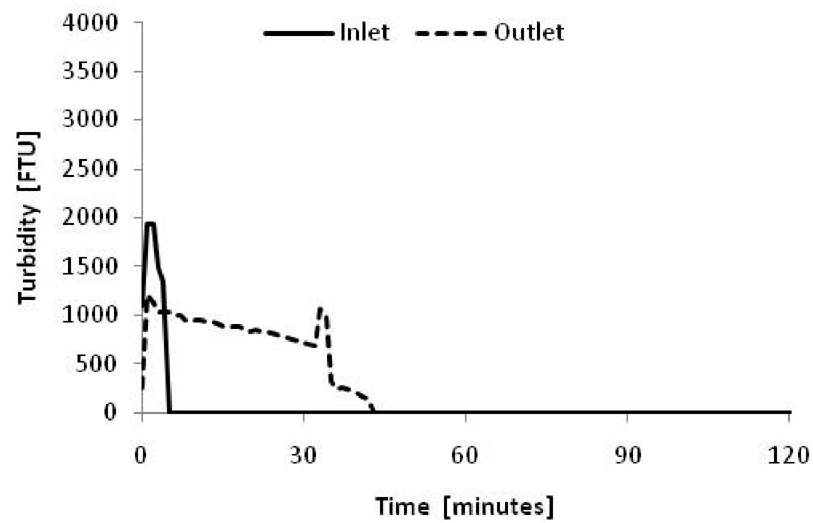

Figure A-23.2. Turbidity Measured at Inlet and Outlet – Run 23.

Table A-23.2. Results Describing SCD Performance from Run 23.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
39 (0.087)	4 (0.008)	60	1560 ± 369	754 ± 296	2139 ± 384	1172 ± 437	1.43	0.79	45

24. Testing details and results from Run 24.

Table A-24.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 24.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Wattle (Untreated)	4.12	60	12.5	12.5	70	2000	No Overtopping

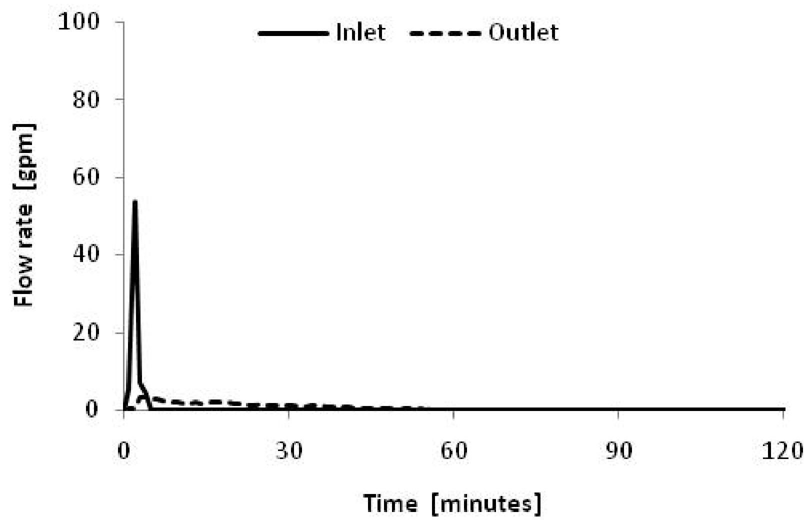

Figure A-24.1. Flow Rates Measured at Inlet and Outlet – Run 24.

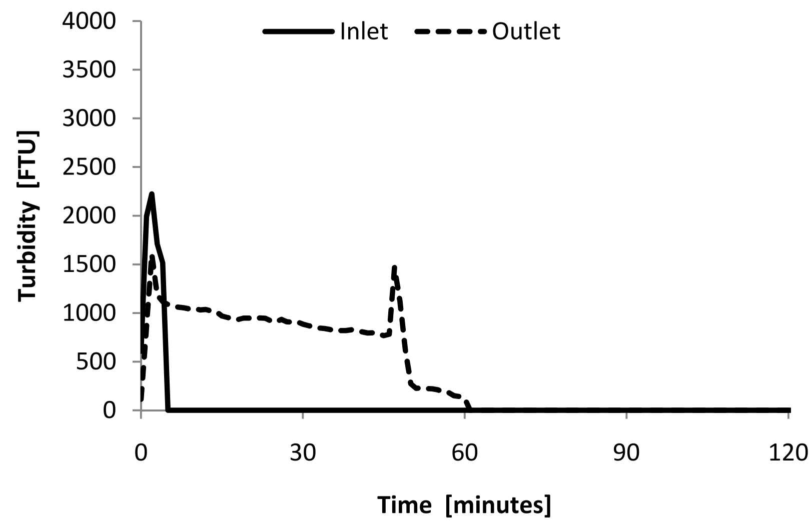

Figure A-24.2. Turbidity Measured at Inlet and Outlet – Run 24.

Table A-24.2 Results Describing SCD Performance from Run 24.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
54 (0.119)	3 (0.007)	63	1610 ± 622	798 ± 338	2150 ± 698	1228 ± 490	1.56	0.85	46

25. Testing details and results from Run 25.

Table A-25.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 25.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Wattle (Treated)	4.12	60	12.5	12.5	750	2000	Overtopping

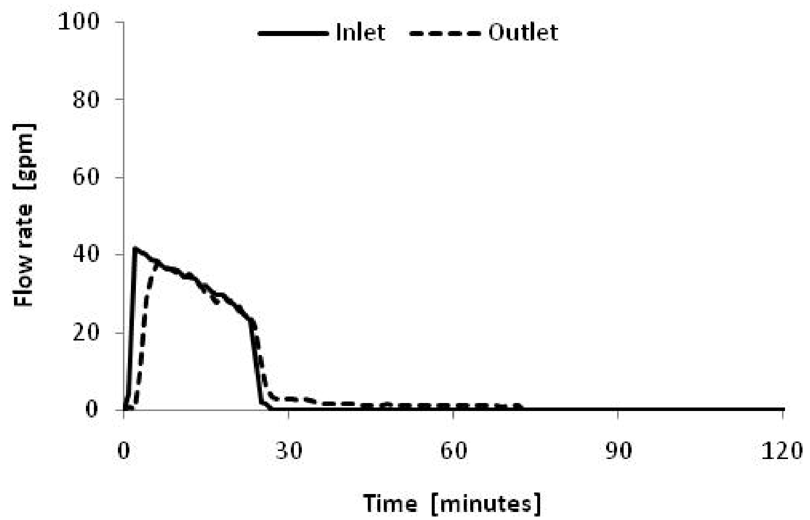

Figure A-25.1. Flow Rates Measured at Inlet and Outlet – Run 25.

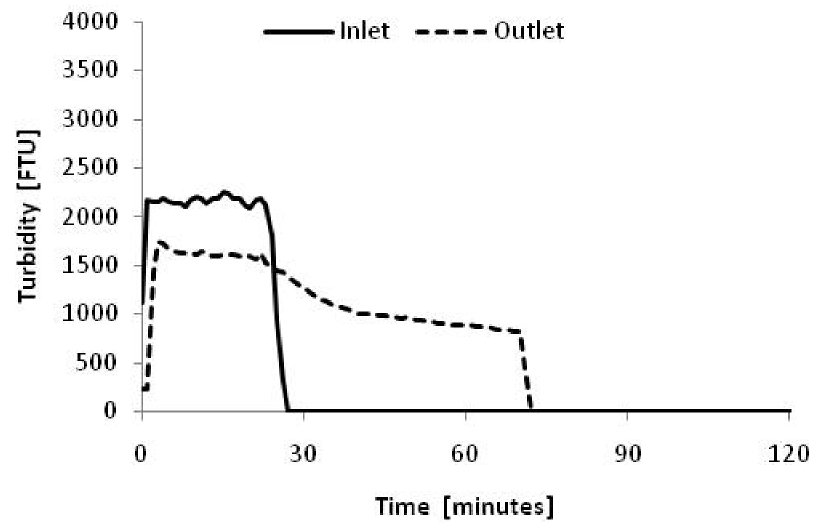

Figure A-25.2. Turbidity Measured at Inlet and Outlet – Run 25.

Table A-25.2. Results Describing SCD Performance from Run 25.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_θ	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
42 (0.093)	38 (0.084)	98	1996 ± 457	1153 ± 381	2539 ± 512	1694 ± 494	16.93	13.65	19

26. Testing details and results from Run 26.

Table A-26.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 26.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Wattle (Treated)	4.12	60	12.5	12.5	70	2000	No Overtopping

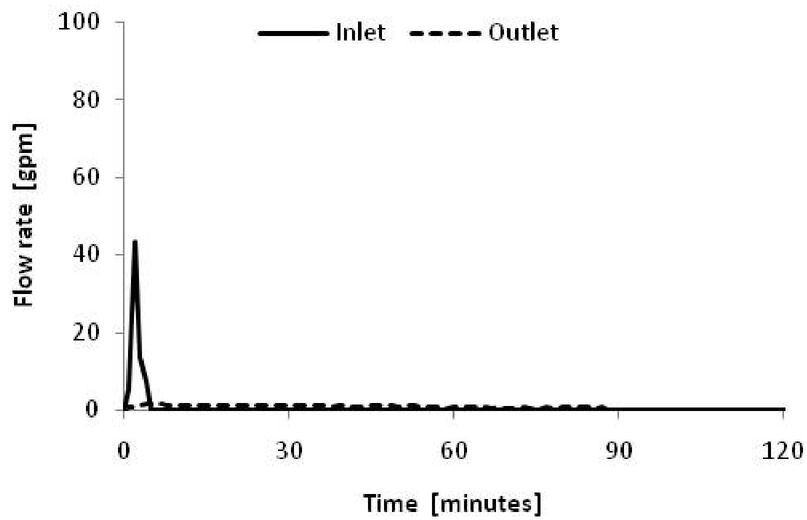

Figure A-26.1. Flow Rates Measured at Inlet and Outlet – Run 26.

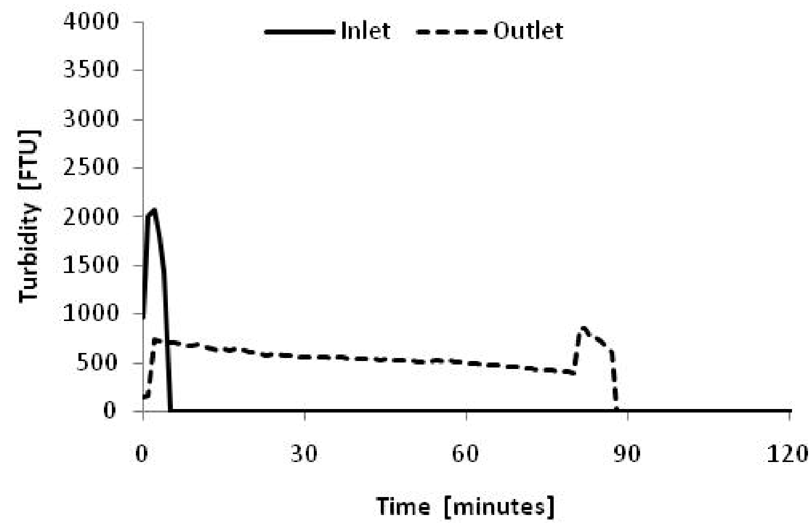

Figure A-26.2. Turbidity Measured at Inlet and Outlet – Run 26.

Table A-26.2. Results Describing SCD Performance from Run 26.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_θ	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
43 (0.096)	1 (0.003)	66	1654 ± 459	556 ± 115	2223 ± 484	899 ± 173	1.47	0.54	63

27. Testing details and results from Run 27.

Table A-27.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 27.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Wattle (Treated)	4.12	60	12.5	12.5	70	2000	No Overtopping

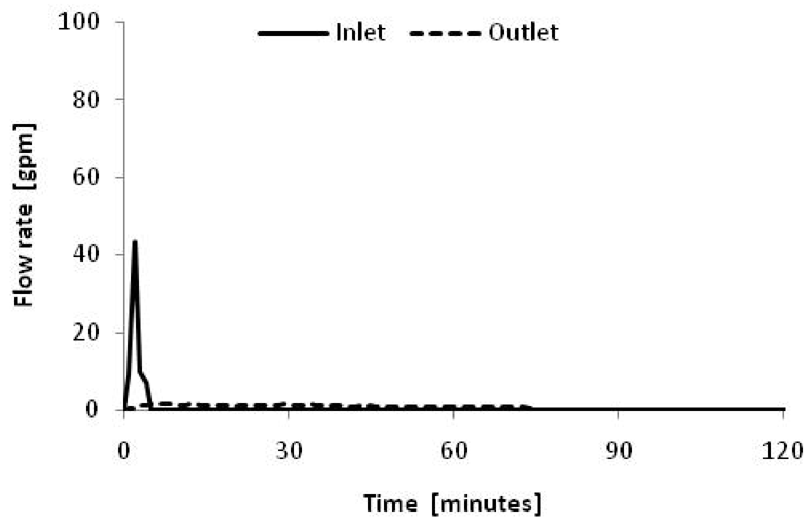

Figure A-27.1. Flow Rates Measured at Inlet and Outlet – Run 27.

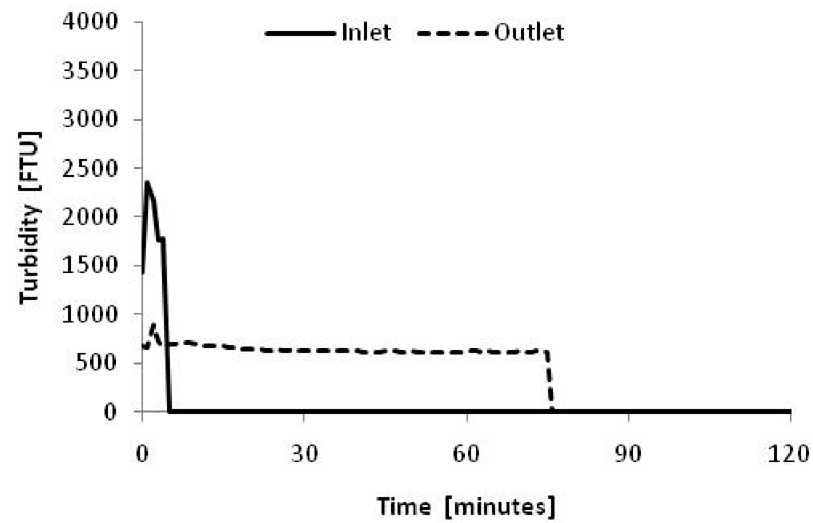

Figure A-27.2. Turbidity Measured at Inlet and Outlet – Run 27.

Table A-27.2. Results Describing SCD Performance from Run 27.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
43 (0.096)	1 (0.003)	66	1903 ± 364	646 ± 41	2476 ± 335	1035 ± 59	1.54	0.61	61

28. Testing details and results from Run 28.

Table A-28.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 28.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Wattle (Treated)	4.12	60	12.5	12.5	70	2000	No Overtopping

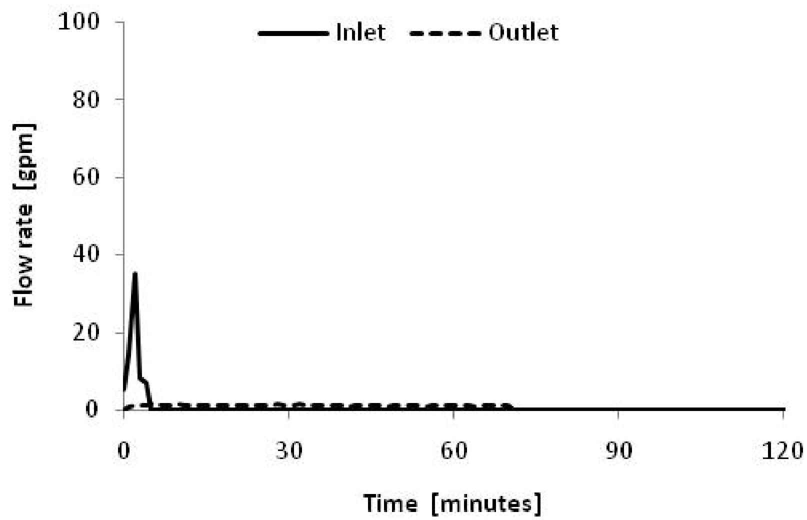

Figure A-28.1. Flow Rates Measured at Inlet and Outlet – Run 28.

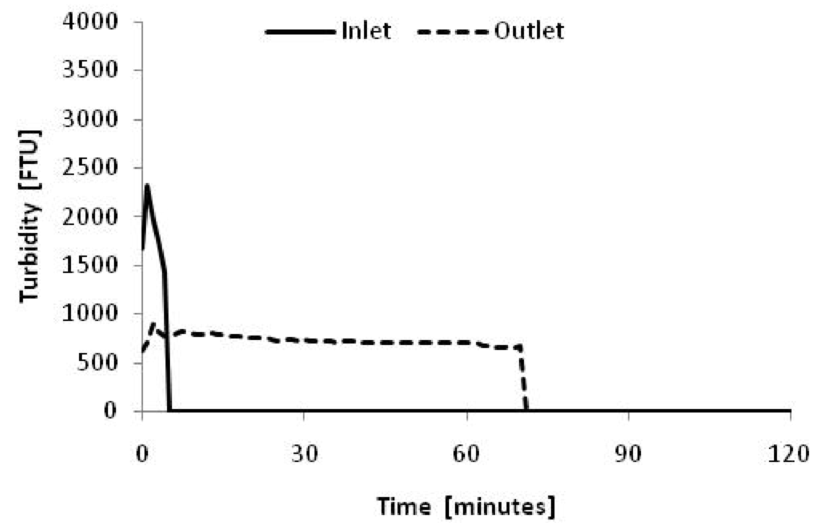

Figure A-28.2. Turbidity Measured at Inlet and Outlet – Run 28.

Table A-28.2. Results Describing SCD Performance from Run 28.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
35 (0.078)	1 (0.003)	66	1829 ± 335	723 ± 47	2409 ± 310	1146 ± 67	1.47	0.67	54

29. Testing details and results from Run 29.

Table A-29.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 29.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Silt Fence	18		12.5	12.5	1500	2000	No Overtopping

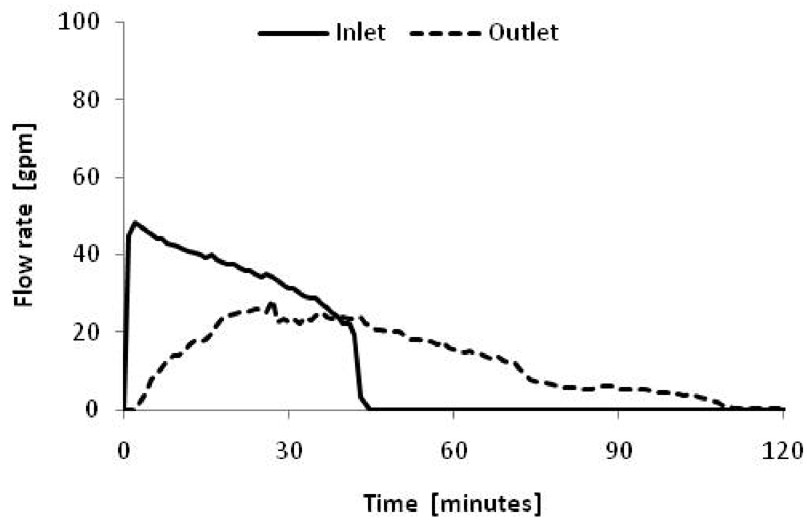

Figure A-29.1. Flow Rates Measured at Inlet and Outlet – Run 29.

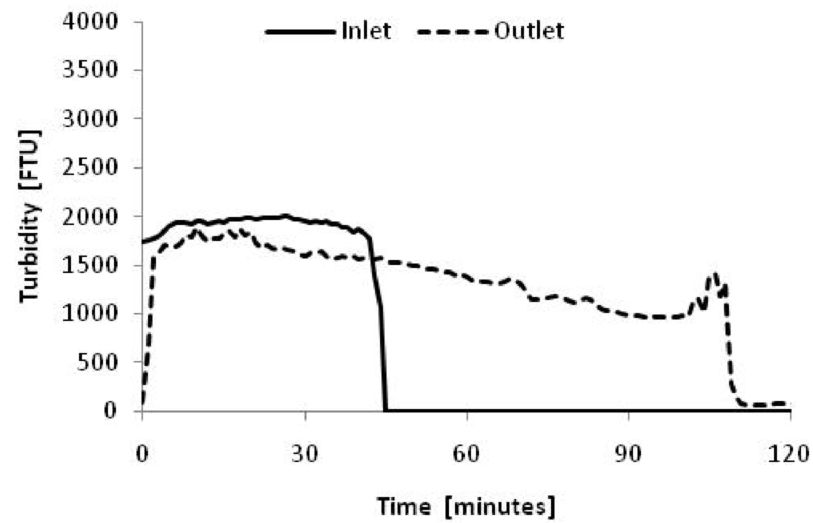

Figure A-29.2. Turbidity Measured at Inlet and Outlet – Run 29.

Table A-29.2. Results Describing SCD Performance from Run 29.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_θ	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
48 (0.108)	28 (0.063)	696	1890 ± 164	1232 ± 516	2476 ± 169	1769 ± 699	31.43	26.88	14

30. Testing details and results from Run 30.

Table A-30.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 30.

	SCD		Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Silt Fence	18		12.5	12.5	1500	2000	No Overtopping

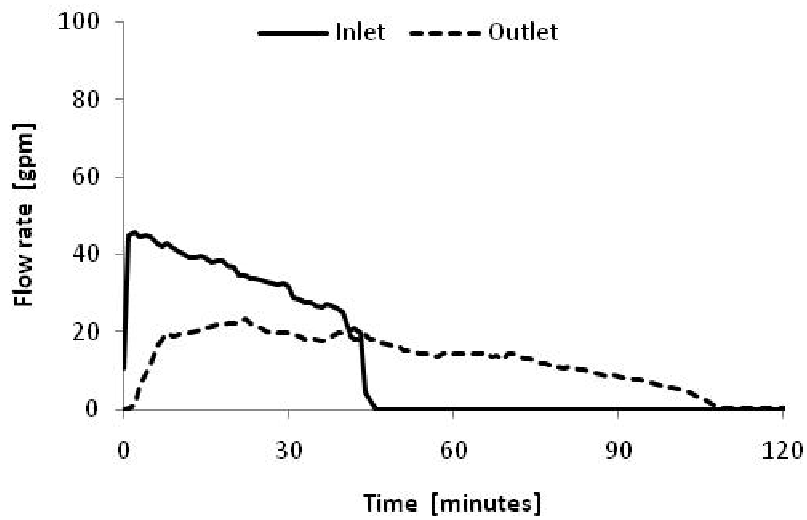

Figure A-30.1. Flow Rates Measured at Inlet and Outlet – Run 30.

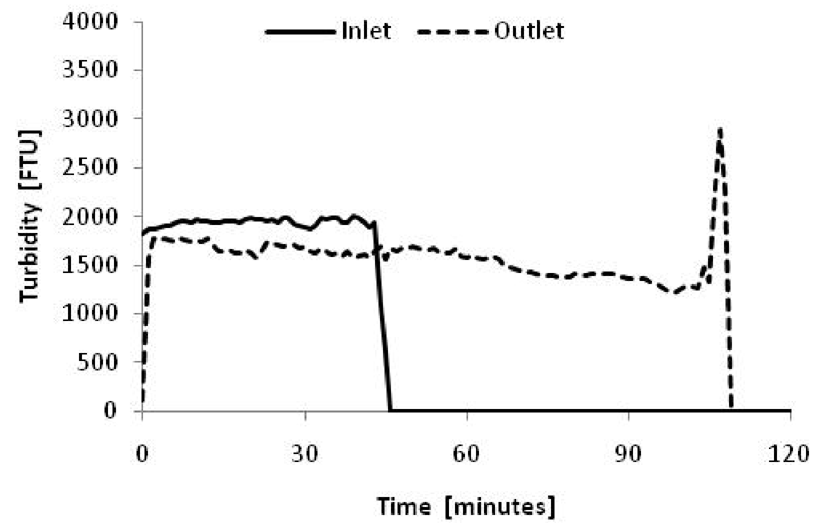

Figure A-30.2. Turbidity Measured at Inlet and Outlet – Run 30.

Table A-30.2. Results Describing SCD Performance from Run 30.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
46 (0.102)	23 (0.052)	712	1892 ± 234	1563 ± 262	2473 ± 263	2196 ± 302	31.56	28.02	11

31. Testing details and results from Run 31.

Table A-31.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 31.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Silt Fence	18		12.5	12.5	1500	2000	No Overtopping

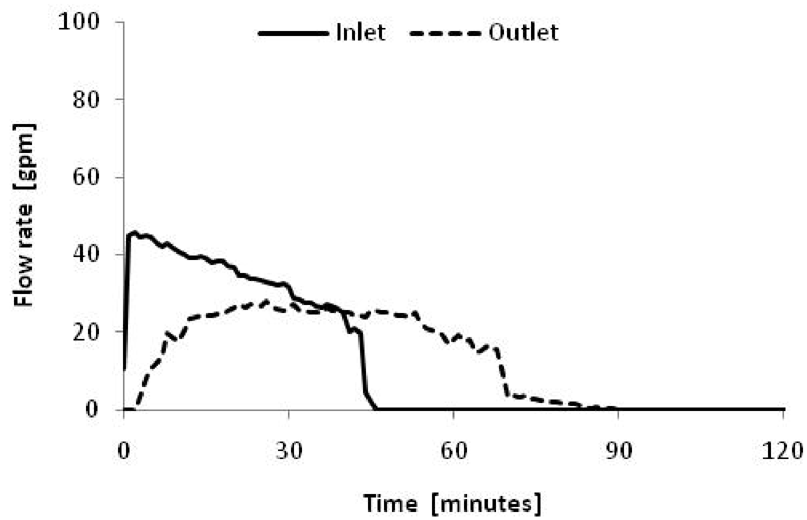

Figure A-31.1. Flow Rates Measured at Inlet and Outlet – Run 31.

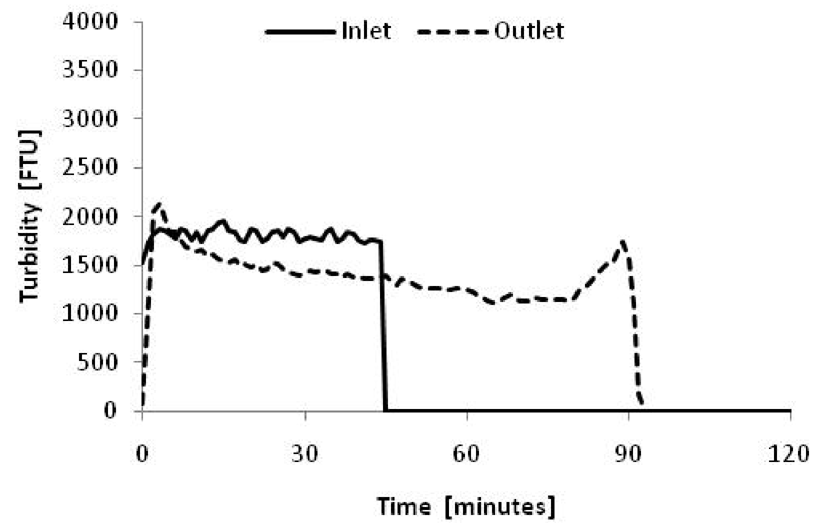

Figure A-31.2. Turbidity Measured at Inlet and Outlet – Run 31.

Table A-31.2. Results Describing SCD Performance from Run 31.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_0	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
46 (0.102)	28 (0.063)	566	1803 ± 70	1368 ± 282	2399 ± 67	1968 ± 356	30.10	25.34	16

32. Testing details and results from Run 32.

Table A-32.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 32.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Rock Check Dam	24		12.5	12.5	1500	2000	No Overtopping

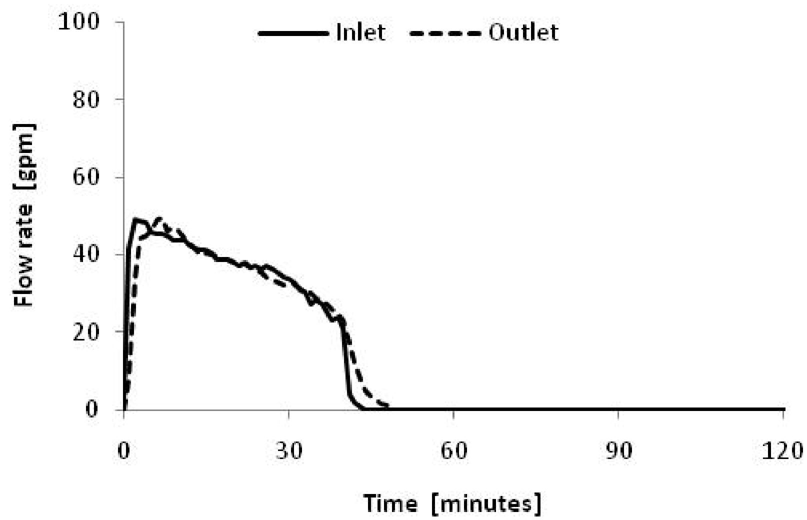

Figure A-32.1. Flow Rates Measured at Inlet and Outlet – Run 32.

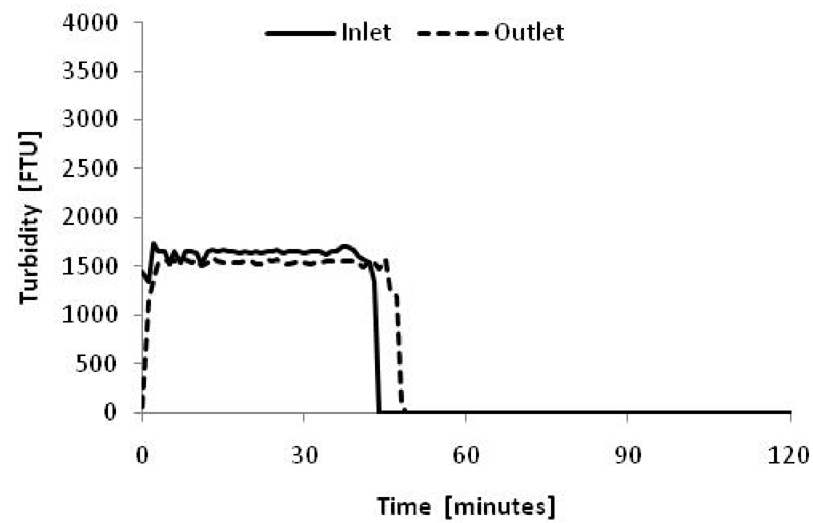

Figure A-32.2. Turbidity Measured at Inlet and Outlet – Run 32.

Table A-32.2. Results Describing SCD Performance from Run 32.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
49 (0.109)	50 (0.111)	59	1623 ± 80	1459 ± 305	2222 ± 84	2071 ± 423	27.97	27.27	2

33. Testing details and results from Run 33.

Table A-33.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 33.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Rock Check Dam	24		12.5	12.5	1500	2000	No Overtopping

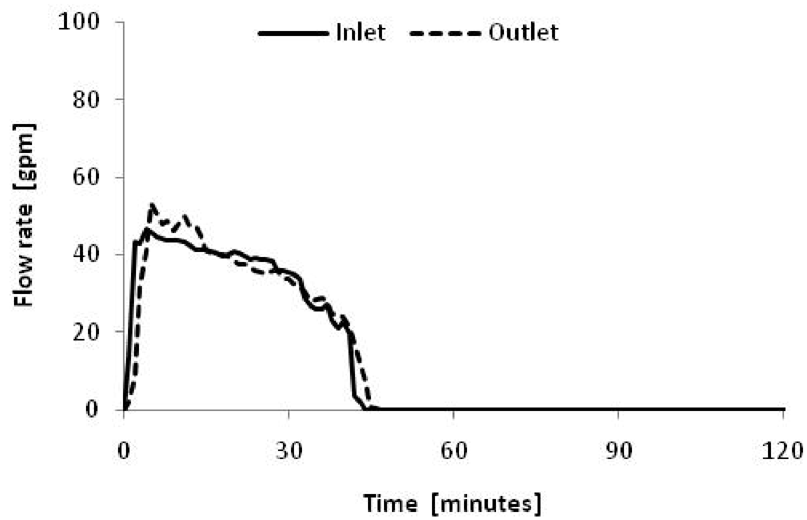

Figure A-33.1. Flow Rates Measured at Inlet and Outlet – Run 33.

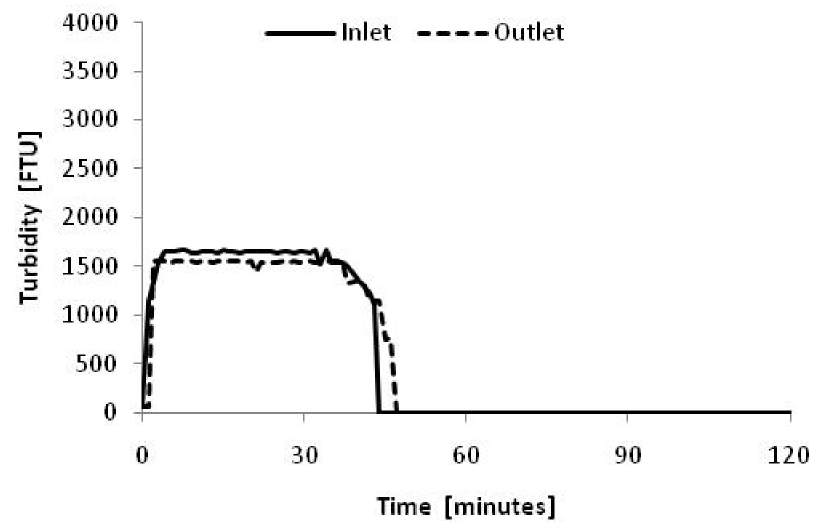

Figure A-33.2. Turbidity Measured at Inlet and Outlet – Run 33.

Table A-33.2. Results Describing SCD Performance from Run 33.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
47 (0.104)	53 (0.119)	63	1538 ± 271	1406 ± 344	2121 ± 349	2006 ± 469	27.64	27.02	2

34. Testing details and results from Run 34.

Table A-34.1. Details of SCD, Sediment, Water Volume, and Testing Condition for Run 34.

SCD			Sediment		Slurry		Testing Condition
Type	Height H_{SCD} [in.]	Design Capacity [gal]	Silica Sil-Co-Sil®49 [lb]	Ball Clay [lb]	Volume V_{IN} [gal]	Concentration C_{IN} [mg/L]	
Rock Check Dam	24		12.5	12.5	1500	2000	No Overtopping

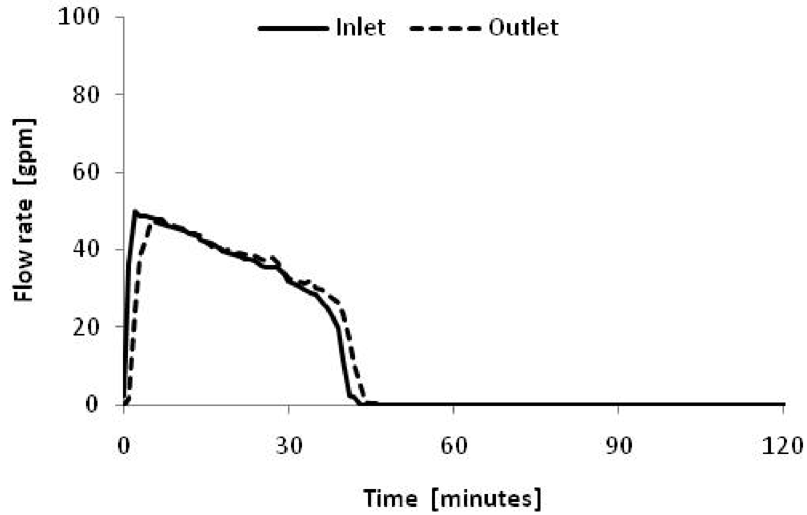

Figure A-34.1. Flow Rates Measured at Inlet and Outlet – Run 34.

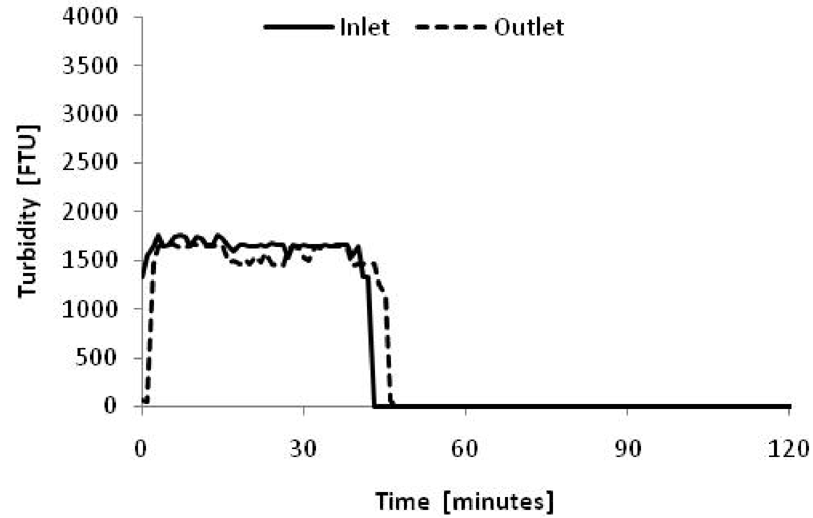

Figure A-34.2. Turbidity Measured at Inlet and Outlet – Run 34.

Table A-34.2. Results Describing SCD Performance from Run 34.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal]	Turbidity (Avg. ± SD) [NTU]		SSC (Avg. ± SD) [mg/L]		Mass Loading [lb]		Removal Efficiency [%]
Q_{IN}	Q_{OUT}	V_{θ}	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	
50 (0.111)	48 (0.106)	81	1639 ± 98	2238 ± 102	1460 ± 386	2062 ± 533	28.36	27.85	2

APPENDIX B: DATA RECORDING TEMPLATE

Sediment Control Device: ______________________________________ pg 1 of 5

Comments: ____

____

____

Installation Details: Date: ____________ Time: ____________

Number of stakes: ____________

Spacing between stakes: ____________

Apron: ____________

Trenching depth: ____________

Comments: ____

____

____

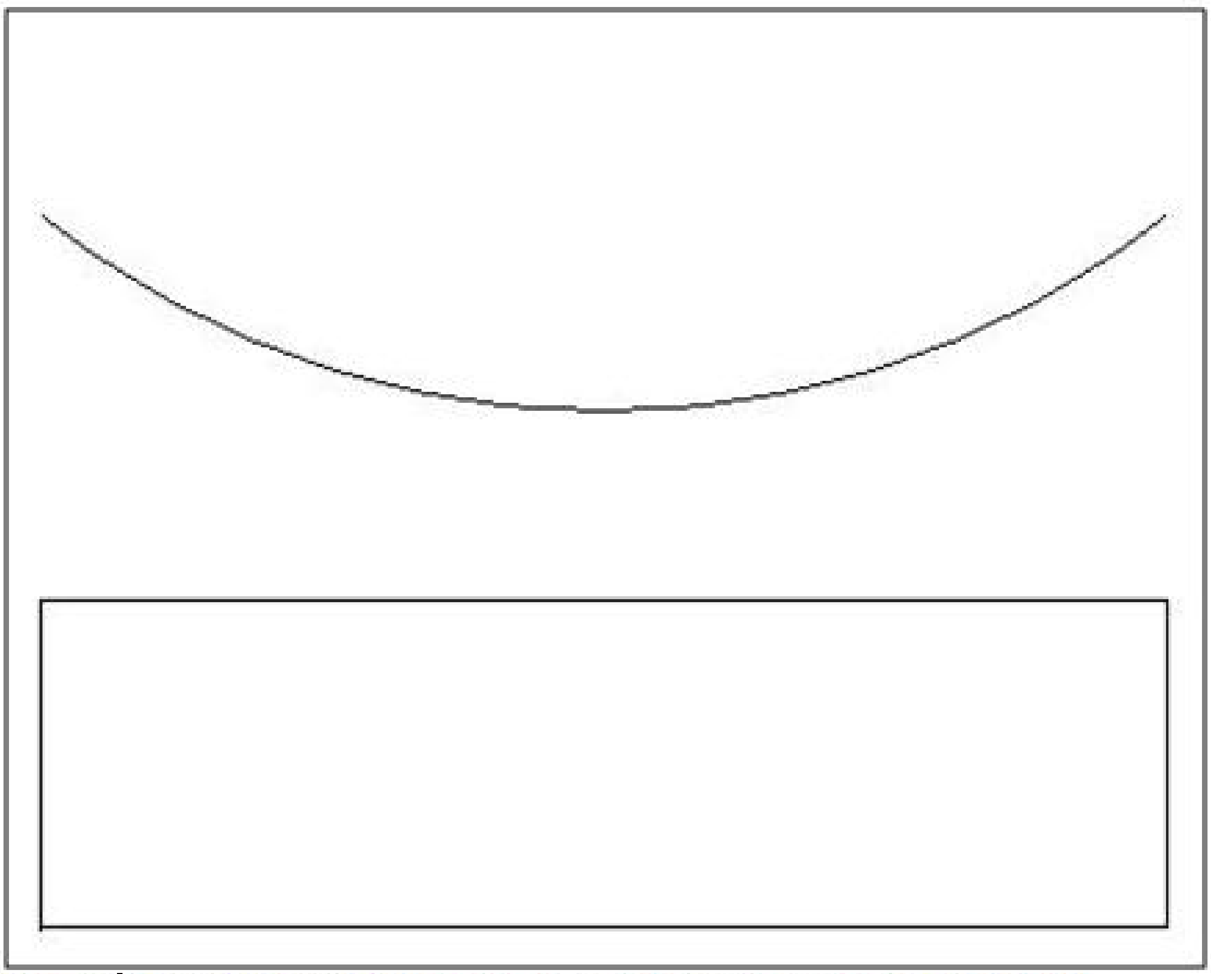

Figure 0.1. Installation details (stake position and spacing, apron, trenching depth).

Sediment Control Device: ______________________________

Test to determine flow category: Date: __________ Time: __________

Max. flow rate at outlet: __________

Flow category: __________

Comments: ______________________________

Performance testing on SCD:

Run: 1 Date: __________ Time: __________

Inflow start time: __________

Inflow end time: __________

Outflow start time: __________

Outflow end time: __________

Comments: ______________________________

Run: 2 Date: __________ Time: __________

Inflow start time: __________

Inflow end time: __________

Outflow start time: __________

Outflow end time: __________

Comments: ______________________________

Run: 3 Date: __________ Time: __________

Inflow start time: __________

Inflow end time: __________

Outflow start time: __________

Outflow end time: __________

Comments: ______________________________

Sediment Control Device: __________

Table 1.1 Details of SCD, sediment, water volume and testing condition – Run 1.

SCD		Sediment		Slurry		Testing Condition
Height H_{SRD} in.	Design Capacity [gal.]	Silica Sil-Co-Sil®49 lbs	Ball Clay lbs	Volume V_{IN} gal	Concentration C_{IN} mg/L	

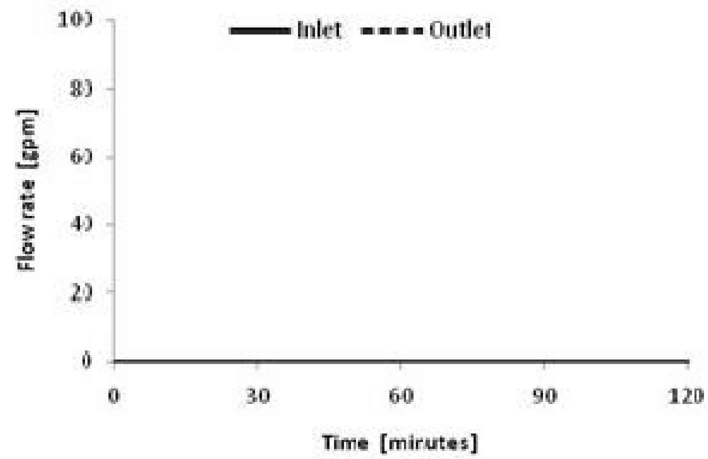

Figure 1.1 Flow rates measured at inlet and outlet – Run 1.

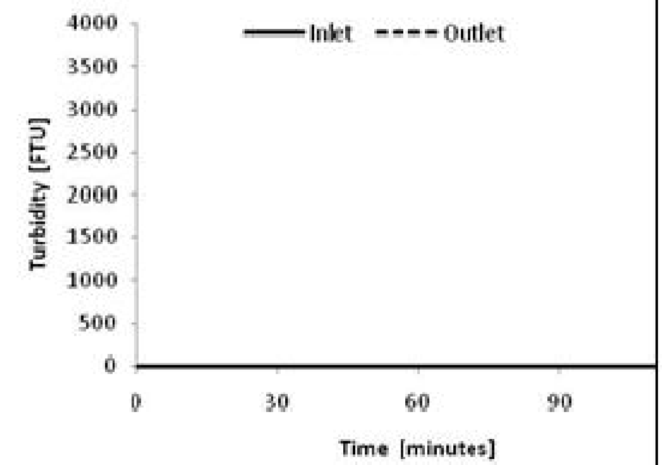

Figure 1.2 Turbidity measured at inlet and outlet - Run 1.

Table 1.2 Results describing SCD performance – Run 1.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal.]	Turbidity (Avg. ± SD) NTU		SSC (Avg. ± SD) mg/L		Mass Loading lb		Removal Efficiency %
Q_{IN}	Q_{OUT}	V_A	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	

Sediment Control Device: ______________________________

Table 2.1 Details of SCD, sediment, water volume and testing condition – Run 2.

SCD		Sediment		Slurry		Testing Condition
Height H_{SRD} in.	Design Capacity [gal.]	Silica Sil-Co-Sil®49 lbs	Ball Clay lbs	Volume V_{IN} gal.	Concentration C_{IN} mg/L	

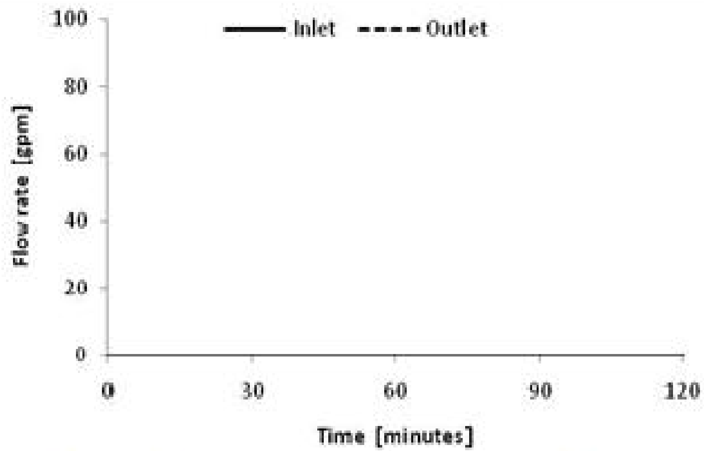

Figure 2.1 Flow rates measured at inlet and outlet – Run 2.

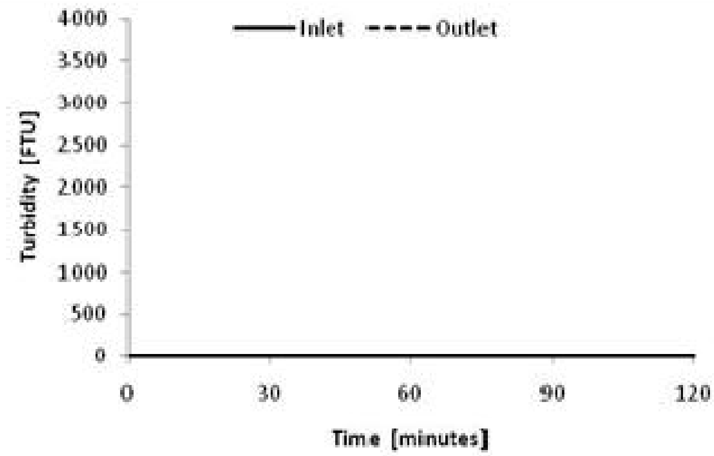

Figure 2.2 Turbidity measured at inlet and outlet - Run 2.

Table 2.2 Results describing SCD performance – Run 2.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal.]	Turbidity (Avg. ± SD) NTU		SSC (Avg. ± SD) mg/L		Mass Loading lb		Removal Efficiency %
Q_{IN}	Q_{OUT}	V_s	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	

Sediment Control Device: ____________________

Table 3.1 Details of SCD, sediment, water volume and testing condition – Run 3.

SCD		Sediment		Slurry		Testing Condition
Height H_{SRD} in.	Design Capacity [gal.]	Silica Sil-Co-Sil®49 lbs	Ball Clay lbs	Volume V_{IN} gal.	Concentration C_{IN} mg/L	

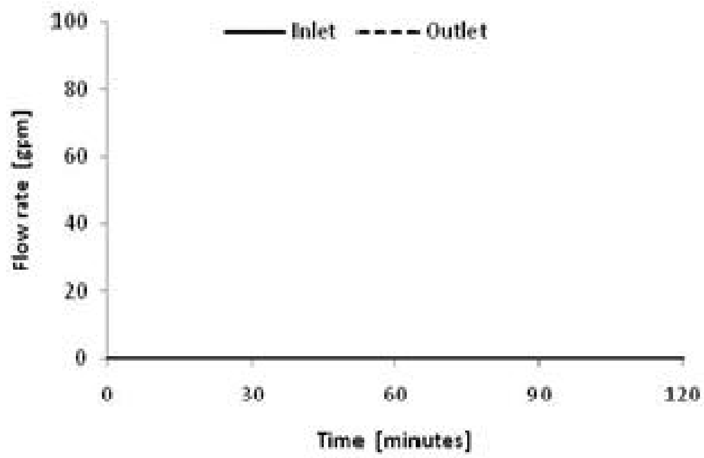

Figure 3.1 Flow rates measured at inlet and outlet – Run 3.

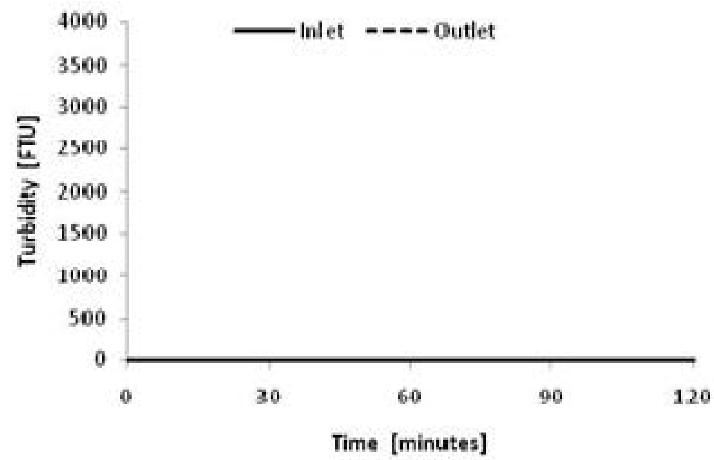

Figure 3.2 Turbidity measured at inlet and outlet - Run 3.

Table 3.2 Results describing SCD performance – Run 3.

Maximum Flow Rate gpm (cfs)		Ponding Volume [gal.]	Turbidity (Avg. ± SD) NTU		SSC (Avg. ± SD) mg/L		Mass Loading lb		Removal Efficiency %
Q_{IN}	Q_{OUT}	V_4	T_{IN}	T_{OUT}	C_{IN}	C_{OUT}	M_{IN}	M_{OUT}	