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Evaluation of Sediment Barrier Practices using Large-Scale Testing Techniques

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EXECUTIVE SUMMARY

Perimeter controls [i.e. sediment barriers (SBs) or sediment retention devices (SRDs)] are typically used on construction sites to retain sediment within the limits of the site and prevent polluted stormwater runoff from adversely affecting the environment by degrading aquatic habitats and clogging storm sewers. However, little data exists regarding the performance of the various products and practices used as perimeter controls. Often, design parameters are based upon rules-of-thumb and field observation that lack scientific data that establishes expected performance capabilities. SB practices used as perimeter controls must be capable of intercepting sheet flow stormwater runoff, effectively treating sediment-laden flow such that sediment removal is achieved, and efficiently discharging treated stormwater so that sediment resuspension is minimized. Nonetheless, products and practices are typically evaluated through field performance testing with little monitoring and data collection associated with installation, runoff characteristics, and water quality performance. If data is available from field evaluations, the data is site and climatic specific, making it difficult to compare the performance between practices and geographic areas. Therefore, researchers at the Auburn University – Erosion and Sediment Control Testing Facility developed a test apparatus and methodology to evaluate different SB practices using full-scale testing methods. The test apparatus and methodology is designed to replicate in-field rainfall runoff rates for purposes of conducting full-scale experiments on various SBs. This apparatus allows for performance testing and direct comparisons between various SB products, practices, and installations. The overall intent of conducting full-scale testing is to improve design criteria and enhance the in-field performance of SBs.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Construction activities create unstabilized areas near stormwater runoff conveyances and bodies of water. Runoff emanating from these disturbed areas takes the form of sheet, shallow concentrated, and concentrated flows. The result of these flows is soil loss and transport in the form of interrill, rill, and gully erosion. Sheet and shallow concentrated flows are either collected by diversions and conveyance channels or by perimeter controls. If intercepted and collected by perimeter controls, these sediment control devices become the final treatment practice prior to discharging stormwater beyond the construction boundaries. Construction sites produce 20 to 1,000 times more sediment discharge that other land uses (i.e., agriculture, forestry, and natural conditions) (*Schuler 1997*). The U.S. Environmental Protection Agency (USEPA) construction general permit (CGP) requires a 50 ft natural buffer or erosion and sediment controls (ESCs) that provide an equivalent sediment load reduction between earth disturbing activities and any nearby surface waters that will receive discharge from construction sites. The CGP further states that the buffer does not replace typical ESC practices and that sediment controls are also required around the downslope perimeter of the site disturbance (*USEPA 2017*).

The EPA provides three alternative scenarios for protecting adjacent water bodies beyond required ESC practices: (1) provide and maintain a 50 ft undisturbed natural vegetative buffer, (2) provide and maintain an undisturbed natural buffer that is less that a 50 ft buffer and is supplemented by ESC practices that achieve, in combination, the sediment load reduction equivalent to a 50 ft undisturbed natural buffer, and (3) if no buffer can feasibly be maintained, ESC practices must be implemented to create an equivalent sediment removal efficiency of a 50 ft natural buffer (*USEPA 2017*). The EPA provides tables for determining sediment removal efficiencies of 50 ft buffers, but leaves determining the amount of sediment removal efficiencies for the supplemental erosion and sediment control practices to the designer. This can be accomplished by using a number of available modeling programs or calculators. These modeling programs typically do not provide exact reductions for specific products, installation practices, or new practices that have not been included in the program database, thereby limiting feasible options for the designer. Due to a lack of scientific data that provides performance expectations of various perimeter control practices, a need exists for conducting performance evaluations on common perimeter control practices, as well as, innovative sediment retention devices.

1.2 PURPOSE OF EROSION & SEDIMENT CONTROL

Controlling erosion and sediment transport on construction sites has been deemed a top priority for environmental agencies such as the US Environmental Protection Agency and the Alabama Department of Environmental Management (ADEM). The most critical environmental problem facing the construction industry is the impairment of nearby water bodies caused from sediment-laden stormwater discharges off-site (*USDA 2006*). Sediment transport increases when erosion rates are accelerated by rainfall impacts on unprotected and unvegetated areas disturbed during earthwork activities. This problem can be compounded by soil compaction, which reduces infiltration, increases runoff volume, and increases velocity thereby increasing erosion potential. Perimeter controls are used to intercept and treat runoff that is not captured and treated in sediment basins or by other erosion and sediment control practices. Untreated stormwater discharged from construction sites can increase turbidity of nearby waterways causing a degradation of water quality by preventing sunlight from penetrating the water, inhibiting aquatic plant growth, and adversely affecting the aquatic ecosystem (*USDA 2006*). Sedimentation in waterways and storm sewers decreases flow capacity that can result in flooding, stifle natural vegetative growth, and destroy fish spawning areas (*USDA 2006*; *Willet 1980*). Sediment particles can also transport other pollutants (i.e., hydrocarbons, phosphates, metals etc.) that originate from construction equipment and fertilizer used to establish vegetative cover, further increasing the importance for controlling sediment transport. Impacts from sediment-laden stormwater discharges from construction sites and the need to implement preventative measures was recognized as a serious pollution problem by the U.S. Congress during the Clean Water Act of 1972 and the Water Quality Act of 1987 (*U.S. Congress 1972*; *U.S. Congress 1987*). Thus, it is extremely important to properly understand the efficacy of ESC practices to improve stormwater runoff quality and minimize sediment discharge from construction site into nearby water bodies.

1.3 SEDIMENT BARRIER PRACTICES

ESC practices [i.e., diversion swales, erosion control blankets, sediment basins, sediment barriers (SBs), etc.] are used to minimize erosion and sediment-related pollution. SBs are devices typically installed as perimeter controls on construction sites to intercept, capture, and contain sheet to shallow concentrated flows before discharged off-site. When used as a perimeter control, SBs should be installed prior to major clearing and grubbing actives and remain in place until final stabilization occurs. Depending on the project area, minor clearing activities may need to be completed in order to facilitate effective perimeter control installations. In such instances, soil disturbance should be limited to the width of the clearing mechanism and all debris removed should be windrowed upstream of the SB to aid in sediment control and minimize potential SB damage during successive clearing activities. SB installation should immediately follow perimeter clearing actives and all perimeter controls should be installed prior to beginning large-scale clearing and grubbing activities. This approach establishes clearing limits and prevents unnecessary land disturbance beyond the project area.

SBs are categorized as sediment retention devices (SRDs) due to the removal of sediment primarily through sedimentation and, to a lesser degree, filtration (*ASTM Standard D7351 2013*, *Barrett et al. 1998*). As an impoundment forms upstream of a SB, particles settle out of suspension due to gravity and are retained on-site. SB materials play only a minor role in directly removing sediment. The filtration efficiency of SB material is based upon, and is limited by, the size of the pore passages often resulting in small soil particles passing through void spaces within the material medium (*Barrett et al. 1998*). In addition, the flow-through capacity of materials degrade over time as pores become clogged with sediment, thereby restricting flow-through capacity (*Haan et al. 1994*). Typical SBs implemented on construction sites include: silt fence, wattles, brush barriers, mulch tubes, compost filter socks, fiber rolls, filter berms, straw bales, rock, and vegetated buffers. Each of these practices has inherent limitations and performs differently due to differing dimensions, component materials, and installation methods.

Typically, stormwater runoff is conveyed through one or more on-site sediment control practices prior to discharging off-site into receiving waters and adjacent property (*Perez et al.*

2016). Nonetheless, these devices can be overloaded by both runoff and sediment accumulation due to inadequate design, improper installation, and insufficient maintenance, which can lead to nonpoint source (NPS) pollution. Due to the wide acceptance of silt fence within the construction industry, several studies have focused on sediment removal performance of silt fence practices (Barrett et al. 1995, Barrett et al. 1998, Keener et al. 2007, Risse et al. 2008, Robichaud et al. 2001). Barrett et al. (1995) indicated that sediment-trapping efficiency is not a function of filtration, rather the ability of creating an upstream impoundment area, which in turn promotes particle settlement. Robichaud et al. (2001) illustrated an effective method for installing silt fence and further reported trapping efficiency of 73 to 100% for hillside installations. Risse et al. (2008) performed sediment removal tests on the Silt-Saver® Belted Strand Retention Fence™ (BSRF), as well as the Georgia Soil and Water Conservation Commission (GSWCC) Type-C silt fence. Results indicated that the BSRF reduced turbidity and retained sediment more effectively than the Type-C silt fence. Troxel (2013) evaluated six sediment control devices: Type-A silt fence (polypropylene monofilament woven fabric with wooden stakes), Type-C silt fence (polypropylene monofilament heat bonded fabric with 4 in. [10 cm] square steel wire mesh and steel fence posts), mulch berm, straw bales, and two compost socks with diameters of 18 in. (45 cm) and 12 in. (30 cm). Results indicated TSS removal efficiencies of 98.4%, 97.6%, 95%, 91.2%, 92.9% and 88.2%, respectively. However, due to the upstream sampling point being located at the tank discharge, no determination could be made if the reduction was a result of upstream impoundment generated by the device, or filtration.

Breaches in SBs are often common on construction sites; however, possible modifications to traditional installation practices may result in increased performance. Typical installation failures observed include: scouring, overtopping, flow bypass, structural deflection, sag, detachment, and decomposition (Stevens et al. 2004). Donald et al. (2016) evaluated the performance of nonwoven wire-backed silt fence installations used as a ditch check and determined that: (1) cutting a weir into the filter fabric helps control discharge so flows are contained within the channel, (2) placing a splash pad downstream reduces scour, and (3) pinning filter fabric to the channel eliminates the need for trenching. Perez et al. (2015) conducted experiments on nonwoven wire-backed inlet protection practices. Ultimately, a design enhancement that incorporated 2 by 4 in. (5.1 by 10.2 cm) lumber bracing and a dewatering board was found to be the most feasible and structurally sound installation. Unfortunately, a lack of published research on SB performance, when used as a perimeter control, exists. Installation details and guidelines provided by government agencies and manufacturers are typically based on rules-of-thumb, field evaluations, and trial-and-error (Bugg et al. 2017). Therefore, a need exists for evaluating current SBs and possible installation improvements to gain an understanding of individual aspects affecting overall performance.

1.4 SB DESIGN CRITERIA

According to the USEPA (2012), most construction sites use silt fence, installed along the perimeter, as a SB. Since the use of silt fence as a perimeter control is so common, the USEPA and state environmental regulatory agencies have published criteria for the design and installation of this practice. However, limited design guidance exists for the application of other SBs. Design guidance that exists is typically based on rules-of-thumb or manufacturer installation recommendations of proprietary products, which vary widely.

Though design criteria for silt fence are much more prevalent than other SBs, silt fence specifications are inconsistent across regulatory jurisdictions. Design and installation criteria for silt fence are critical to ensure effective performance in field applications. Factors to consider include the contributing drainage area, gradient (% slope), and slope length up-gradient from the practice. These design factors affect the stormwater runoff volume, flow rate, and corresponding sediment load. Silt fence design specifications also include minimum installed height, maximum post spacing, minimum trenching depth, geotextile material properties (i.e., flow through, puncture resistance, tensile strength, etc.), and reinforcement. Table 1 shows a summary of the maximum design criteria used for determining appropriate contributing drainage area, slope gradient, and slope length for the proper application of silt fence as a perimeter control from the USEPA and ten southeastern states. The various states in Table 1 were selected because each has a Revised Universal Soil Loss Equation (RUSLE) rainfall energy (*R)* value of 250 or greater within their geographic boundaries based on the USEPA isoerodent map of the Eastern U.S. (*USEPA 2001*). As a result, the southeastern portion of the U.S. has the greatest potential for erosion due to higher *R* values when compared to the rest of the U.S., as well as highly erodible soils (*Pitt et al. 2007*).

Table 1. Design Criteria for Silt Fence Sediment Barrier Applications (Bugg et al. 2017)

State	Criteria	Source(s)
USEPA	▪ EPA-833-F-11-008 "rule of thumb": 10,000 ft^2 (929 m^2) of area per 100 ft (30.5 m) of silt fence or ≈ ¼ ac (0.10 ha) per 100 ft (30.5 m) of silt fence ▪ EPA-833-R-06-004 states ¼ ac (0.10 ha) per 100 ft (30.5 m) of silt fence	USEPA 2012; USEPA 2007
Alabama	▪ ¼ ac (0.10 ha) per 100 ft (30.5 m) unreinforced silt fence ▪ ½ ac (0.20 ha) per 100 ft (30.5 m) reinforced silt fence	AL-SWCC 2014
Arkansas	▪ ¼ ac (0.10 ha) per 100 ft (30.5 m) of silt fence ▪ Maximum upgrade slope perpendicular to the fence line ≤ 1*H*:1*V*	AHTD 2009
Florida	▪ 1 ac (0.41 ha) per 100 ft (30.5 m) of silt fence ▪ SB defined as two rows of silt fence, 4 to 6 ft (1.2 to 1.8 m) apart ▪ silt fence should allow a flow through rate of 70 gal/min/ft^2 (753.5 L/min/m^2)	FDOT and FDEP 2013
Georgia	▪ ¼ ac (0.10 ha) per 100 ft (30.5 m) of silt fence	GSWCC 2016
Louisiana	▪ ¼ ac (0.10 ha) per 100 ft (30.5 m) of silt fence ▪ Maximum slope gradient perpendicular to the fence is 2*H*:1*V*	LA DOTD 2007
Mississippi	▪ ¼ ac (0.10 ha) per 100 ft (30.5 m) unreinforced silt fence ▪ ½ ac (0.20 ha) per 100 ft (30.5 m) reinforced silt fence	MDEQ 2011
North Carolina	▪ Drainage area should be ≤ ¼ ac (0.10 ha) per 100 ft (30.5 m) of silt fence ▪ Silt fence should be stable for the 10-yr peak design rainfall event runoff ▪ Depth of impounded water shall not exceed 1.5 ft (0.6 m) behind fence ▪ Silt fence shall not be used alone below graded slopes > 10 ft (3.0 m) in height	NC-SCC, DNER, NC-AES 2013
South Carolina	▪ Max. slope length upslope of the silt fence is 100 ft (30.5 m) ▪ Max. slope gradient perpendicular to the fence is 2*H*:1*V* ▪ Sheet flow should not exceed 0.25 ft^3/s (7.08 L/s) ▪ Max. % slope and length: 3-5%, 100 ft (30.5 m) max.; 5-10%, 75 ft (22.9 m) max.; 10-20%, 50 ft (15.2 m) max.; 20-50%, 25 ft (7.6 m) max.	SCDOT 2014
Tennessee	▪ The maximum drainage area for a continuous fence without backing (unreinforced) shall be ¼ ac (0.10 ha) per 100 ft (30.5 m) of fence length, up to a max. area of 2 ac (0.81 ha). The max. slope length upslope of the fence on the upslope side should be 110 ft (33.5 m) (as measured along the ground surface) ▪ The max. drainage area for a continuous silt fence with backing (reinforced) shall be 1 ac (0.41 ha) per 150 ft (45.7 m) of fence length. The slope length above the silt fence with backing should be no more than 300 ft (91.4 m)	TNEC 2012
Texas	▪ ¼ ac (0.10 ha) per 100 ft (30.5 m) of silt fence ▪ Steel posts required ▪ Woven wire backing required	TxDOT 2012

In addition to the design and installation criteria contained in Table 1, Alabama, Georgia, Mississippi, North Carolina, and Tennessee also use the design criteria summarized in Table 2, which stipulates the maximum slope length allowed upslope of the silt fence.

Table 2. Maximum Slope Length Criteria for Silt Fence (Bugg et al. 2017)

Criteria Reference	Slope	Max. Slope Length, ft (m)	Source
AL | GA | MS | NC | TN	<2%	100 (30.5)	AL-SWWC 2014; GSWCC 2016; MDEQ 2011; NCSCC, DENR, NCAES 2013; & TNEC 2012
	2 to 5%	75 (22.9)	
	5 to 10%	50 (15.2)	
	10 to 20%	25 (7.6)	
	>20%	15 (4.6)	

Another design and installation consideration is that silt fence perimeter control applications must be limited to areas experiencing only sheet flow. Richardson and Middlebrooks (*1991*) state that sheet flow is maintained for flow velocity less than 1.0 ft/s (0.3 m/s). They also state that this velocity can be maintained when the slope length is a maximum of 100 ft (30.5 m) when the slope steepness is less than 2.0%. The flow velocity of surface water is a function of slope gradient, slope length, and surface roughness. By making a conservative assumption that the ground is smooth, the flow velocity of surface water can be limited by reducing the allowable upstream slope length as the inclination of the slope increases. This principle is the basis for the various state design criteria shown in Table 2. Using this criteria, the drainage area is limited to less than ¼ ac (0.10 ha) per 100 ft (30.5 m) of silt fence. This is, therefore, the maximum contributory area allowed per 100 ft (30.5 m) of silt fence, provided the slope is less than 2.0%. The drainage area becomes much smaller as the slope gradient increases. Nevertheless, a drainage area of ¼ ac (0.10 ha) per 100 ft (30.5 m) of silt fence has become a widely adopted design criteria by the USEPA and most southeastern states regardless of the slope gradient and length upstream of the installed silt fence. Some states, (i.e., Alabama and Mississippi) allow up to ½ ac (0.20 ha) per 100 ft (30.5 m) of silt fence if it is reinforced with a wire backing.

1.5 CURRENT SB TESTING METHODS AND PROTOCOLS

ASTM recognizes two standards for testing SB performance: (1) ASTM D5141, *Standard Test Method for Determining Filtering Efficiency and Flow Rate of the Filtration Component for a Sediment Retention Device (SRD)* and (2) ASTM D7351, *Standard Test Method for Determination of Sediment Retention Device (SRD) Effectiveness in Sheet Flow Applications*. In addition, TRI/Environmental, Inc. has applied a modified version of a proposed standard test method for evaluating SBs (*Sprague and Sprague 2012*).

Tests performed conforming to the procedures contained in ASTM D5141, shown in Figure 1(a), are small-scale and conducted in a laboratory setting. The test apparatus consists of a 49.2 in. (125 cm) long by 33.5 in. (85 cm) wide flume and a 19.8 gallon (75 L) container with a mechanical stirrer used to introduce sediment-laden flow into the flume. Test results are limited to determining the tested SRDs material properties, such as filtering efficiency and flow-through rate. This test procedure is not designed to evaluate installation methods, structural integrity, or full-scale field performance. Risse et al. (*2008*) used the procedures contained in ASTM D5141 to evaluate flow rate, turbidity reduction, and sediment removal characteristics of Silt-Saver BSRF and traditional GSWCC Type C silt fence that were previously discussed.

The ASTM D7351 standard test method, shown in Figure 1(b), introduces sediment-laden flow by mixing 5,005 lbs (2,270 kg) of water and 300 lbs (136 kg) of sediment prior to testing with a tank equipped with an internal agitator. The tank is positioned on a scale and the weight of the tank is monitored at regular intervals while discharging sediment-laden water at a constant flow rate of 198.4 lb/min (90 kg/min) during a 30-minute test. Test conditions are designed to simulate the peak 30 minutes of a 10-yr, 6-hr storm event in the mid-Atlantic region that produces 4 in. (10.1 cm) of rainfall. The flow and sediment load were determined by assuming 25% of the rainfall from the 10-yr, 6-hr storm occurs in the peak 30 minutes of the storm event and that 50% of the precipitation infiltrates into the ground. The associated sediment load resulting from erosion was calculated using the Modified Universal Soil Loss Equation (MUSLE)

(*Williams and Berndt 1977*), which allows the calculation of a storm specific quantity of sediment yield. The sediment-laden flow is directed down an impervious 3*H*:1*V* slope to the 20 ft (6 m) wide impervious test area where the SRD is installed. The flow passing through the SRD is collected and directed toward a collection tank where effluent weight is measured using a scale. Though the tanks provide a measurement of the amount of sediment-laden runoff discharged and collected, the flow rate for the 30-minute test is limited by the capacity of the tank. In addition, the scales only provide the total weight of sediment-laden water and does not have the ability to differentiate between the composition of sediment or water.

Rainfall simulators are used to generate rainfall induced erosion on earth embankments while also being able to simulate different rainfall intensities. TRI/Environmental Inc. followed a modified version of a proposed test standard published by Sprague and Sprague (*2012*), shown in Figure 1(c), and used rainfall simulation to generate sediment-laden runoff emanating from a slope to evaluate the installation, structural integrity, and sediment containment capabilities of an SRD. This procedure was also used as a comparative tool for evaluating the performance between various perimeter control SRD practices (i.e., silt fence, compost filter logs, etc.). Simulated rainfall, applied to a 3*H*:1*V* constructed embankment plot, was used to simulate the natural erosion process to introduce sediment-laden flow to the SRD. The plot was 8 ft (2.4 m) wide by 27 ft (8.2 m) long with the SRDs installed at the toe of the embankment. A collection system was used to channel flow passing through the SRD into a collection tank. This method introduces a series of variables that are difficult to control: the sediment load generated by the erosion process is dependent upon the preparation of the earthen test bed prior to testing, the simulated rainfall intensity, and the speed and direction of the wind. Factors (i.e., moisture content of the test bed, compaction, and surface roughness prior to testing) can impact the amount of soil erosion and sediment transport resulting from simulated rainfall. Preparing the test bed so that moisture content and soil compaction remain consistent over a large number of testing cycles requires considerable effort and is critical to producing meaningful test results that are repeatable and comparable.

As shown in Table 1, the most widely recognized design criteria for unreinforced silt fence is ¼ ac (0.10 ha) drainage area per 100 ft (30.5 m) of installed fence. Using this criterion, the length of the drainage area upstream of the installed fence is 108.9 ft (33.2 m). SB research performed to date (*Sprague and Sprague 2012*, *Dubinsky 2014*, *Gogo-Abite and Chopra 2013*) using rainfall simulators uses a fixed slope, which limits the size and slope of the drainage area that can be used to subject the SB to field-like runoff conditions. Some researchers have overcome the slope limitations by using an 8 ft (2.4 m) wide by 30 ft (9.1 m) long tilting test bed for SB testing, as shown in Figure 1(d) (*Dubinsky 2014; Gogo-Abite and Chopra 2013*). The test bed is capable of simulating a maximum slope of 2*H*:1*V*. Nonetheless, the maximum drainage basin area this test apparatus can simulate is limited to 240 ft^2 (22.3 m^2). This drainage area is much smaller than the criteria for maximum allowable area by some agencies of ½ ac (0.20 ha) per 100 ft (30.5 m) of silt fence shown in Table 1. Therefore, it is not possible to test SBs using currently devised rainfall simulators under realistic, worst-case field conditions using the currently accepted silt fence design criteria due to the drainage area limitations inherent to these methodologies and apparatuses.

(a) ASTM D5141 (*Sprague 2006*)

(b) ASTM D7351 (*Sprague 2007*)

(c) TRI/Environmental, Inc. (*Sprague and Sprague 2012*)

(d) tilting test bed with rainfall simulator (*Gogo-Abite and Chopra 2013*)

Figure 1. Sediment barrier test apparatuses.

1.6 RESEARCH OBJECTIVES

This research was divided into three main components associated with the design, evaluation, and improvement of SB practices.

The specific objectives of this research are as follows:

(1) Develop a full-scale testing methodology, protocols, and testing apparatus to improve standardized testing strategies for evaluating SB practices,
(2) Identify installation deficiencies and provide structural improvements to achieve the most effective wire-backed nonwoven silt fence installation configuration, and
(3) Provided performance-based direct comparisons between various innovative and manufactured SB practices.

The project was divided into the following tasks to satisfy the defined research objectives as follows:

(1) Identify, describe, evaluate, and critically assess pertinent literature on the state-of-the-practice regarding SBs used by state agencies,

(2) Design and construct a full-scale SB testing apparatus to conduct full-scale testing of SB practices,
(3) Develop an applicable methodology and testing protocols for performance-based evaluations of SBs based upon an Alabama 2-yr, 24-hr design storm and current testing methods and technology,
(4) Conduct a series of full-scale experiments on various wire-backed nonwoven silt fence installation configurations,
(5) Analyze structural, hydraulic, sediment, and water quality data collected and establish the most effective wire-backed nonwoven silt fence installation design,
(6) Conduct full-scale experiments on innovative and manufactured SB practices, and
(7) Analyze collected data and evaluate the stormwater treatment effectiveness of each innovative and manufactured SB practice.

1.7 EXPECTED OUTCOMES

The outcomes of this study are to provide ALDOT and the erosion and sediment control industry with the knowledge, resources, and educational outreach opportunities needed to maintain design proficiency as to conform to evolving stormwater regulations. Scientifically backed results from this study enable new and improved guidelines for properly designing and installing SB practices based on quantifiable data. Additionally, results provide controlling agencies with a platform to guide and govern designers, inspectors, and contractors. This research will provide a comprehensive understanding and knowledge base on SB practice in-field performance capabilities, as well as their limitations. Additional research efforts should emanate from this project allowing further opportunities for increasing knowledge on erosion and sediment control practices implemented on construction projects.

1.8 ORGANIZATION OF FINAL REPORT

This final report is divided into five chapters that organize, illustrate, and describe the steps taken to meet the defined research objectives. Following this chapter, Chapter Two: *Sediment Barrier Test Apparatus Design and Testing Methodology*, outlines the testing apparatus, experimental design, testing methods, and procedures developed for preparing and conducting full-scale SB experiments. Chapter Three: *Performance Evaluations of Wire-Backed Silt Fence Installation Configurations*, details alternative silt fence installation strategies and results of performed experiments. This chapter includes data, observations, and analyses conducted for nonwoven silt fence installations. Chapter Four: *Performance Evaluations of Innovative and Manufactured Sediment Barrier Practices*, details the design characteristics, installation guidelines, and experimental findings. This chapter includes data, observations, and analyses conducted for each innovative and manufactured SB practice evaluated as part of this study. Chapter Five: *Conclusions and Recommendation*, provides a summary of the tasks accomplished through this study and identifies areas in which further research can be conducted to advance this body of knowledge.

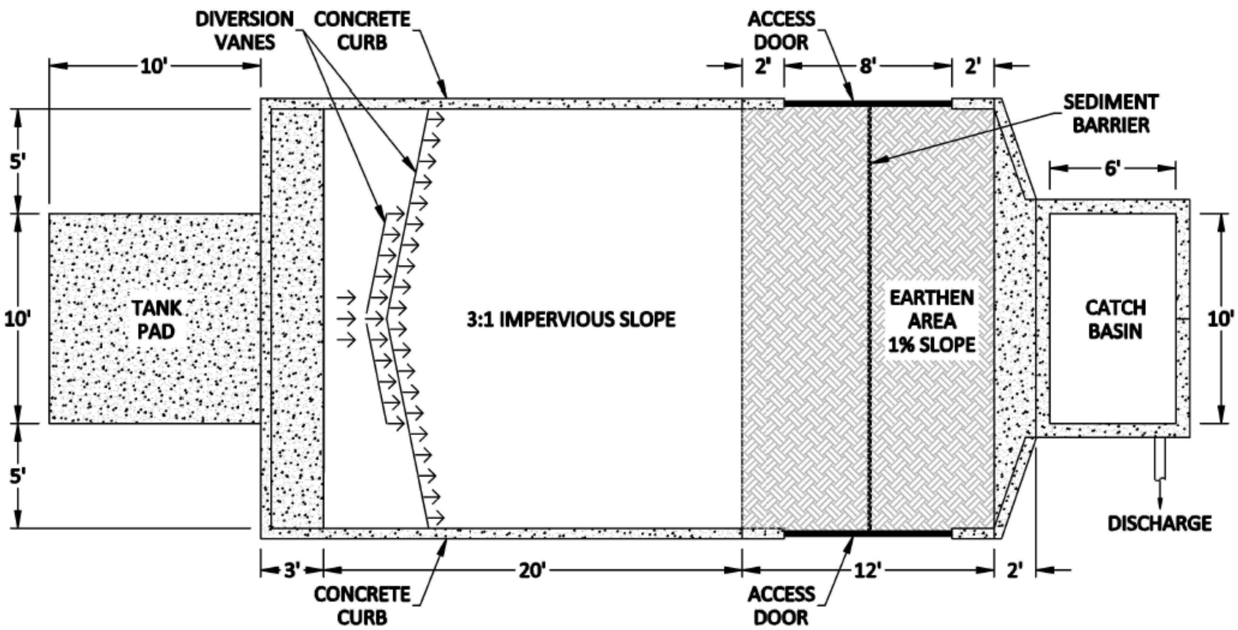
CHAPTER 2: SEDIMENT BARRIER TEST APPARATUS DESIGN AND TESTING METHODOLOGY

2.1 INTRODUCTION

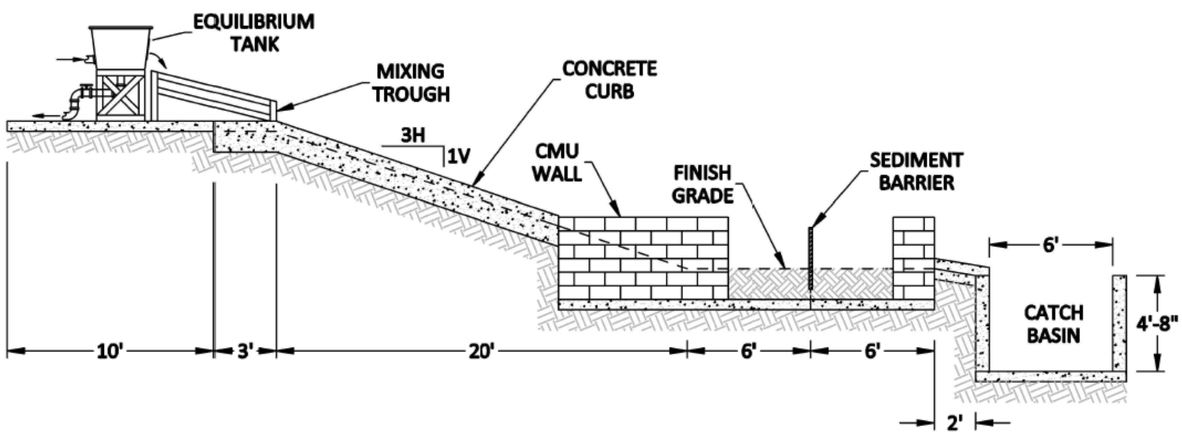
This section describes SB test apparatus design, testing methodology, and data collection process developed for the large-scale testing of SBs. The testing apparatus and methodology developed in this study are based on current testing methods, as well as an in-depth literature review on SB performance evaluations. The apparatus was constructed to mimic typical grade conditions upstream of SB installations on ALDOT projects, while also providing a means for introducing accurate flow rates and sediment loads associated with 2-yr, 24-hr design storm for the State of Alabama. The methodology aims to identify and quantify performance characteristics of SB practices such that comparisons between various practices can be conducted. Additionally, the methodology allows installation improvement strategies to be tested under identical conditions of the standard, which provides a means for assessing slight changes in installation techniques and material properties.

2.2 SEDIMENT BARRIER TEST APPARATUS DESIGN

Based on information gathered from literature and testing needs of the Alabama Department of Transportation (ALDOT), a SB performance evaluation method was developed and an apparatus was designed and constructed at the Auburn University – Erosion and Sediment Control Testing Facility (AU-ESCTF). Performance evaluation of SBs are based on structural integrity, sediment retention, hydrodynamics, water quality properties, and statistical analyses. A schematic design of the test apparatus is shown in Figure 2 and consists of the following features: (1) water and sediment introduction pad, (2) concrete curbing, (3) impervious *3H*:1*V* slope, (4) diversion vanes, (5) earthen test area, (6) removable steel access doors, and (7) catch basin.



(a) plan view



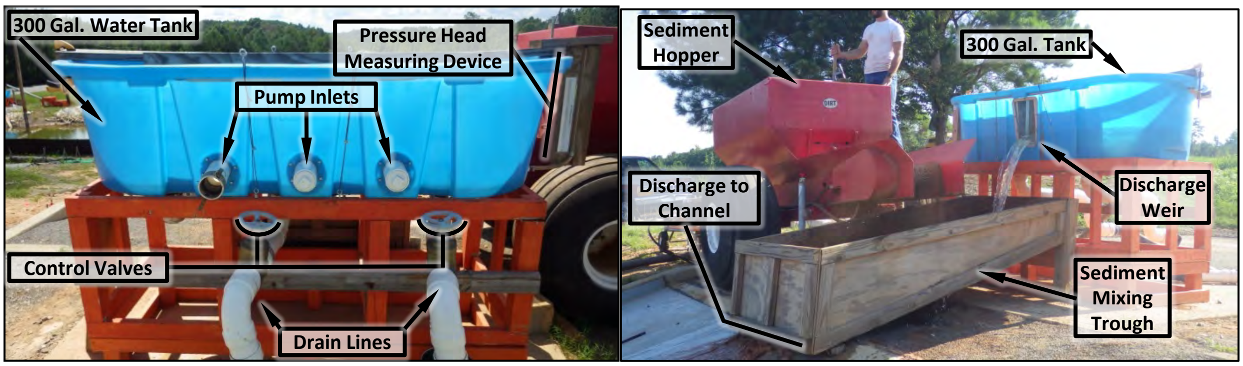
(b) profile view

Figure 2. SB test apparatus.

2.3 WATER AND SEDIMENT INTRODUCTION SYSTEM

Simulated flow is introduced to the system with a 3 in. (7.62 cm) trash pump that draws water from a supply pond. Water is pumped into a 300 gallon (1,135 L) water equilibrium tank [Figure 3(a)] that uses a series of valves and orifices to control flow over a calibrated weir prior to entering a mixing trough. The calibrated weir is monitored with a pressure tube that indicates flow rate across the weir. Adjustments to weir flow rate is accomplished via water tank discharge lines fitted with gate valves. The weir discharges into a mixing trough where sediment is introduced at a controlled rate and mixed with highly turbulent flowing water [Figure 3(b)].

Sediment introduction is accomplished using a steel hopper equipped with a hydraulic driven conveyor chain that allows sediment to be metered at a constant rate of 37.6 lbs/min (16.9 kg/min) into the mixing trough. The conveyor chain is calibrated to assure the desired sediment introduction rate is achieved. After mixing has occurred, the sediment-laden water enters the top of the 3*H*:1*V* impervious slope of the test apparatus. The concentrated flow exiting the bottom of the mixing trough is converted to sheet flow using slotted diversion vanes mounted to the impervious slope. For sediment-laden tests to be replicable, a stockpile of soil native to the state of Alabama and classified as a sandy loam (57% sand, 32% silt, 11% clay), according to the United States Department of Agriculture (USDA), is used.



(a) water equilibrium tank (b) water/sediment introduction

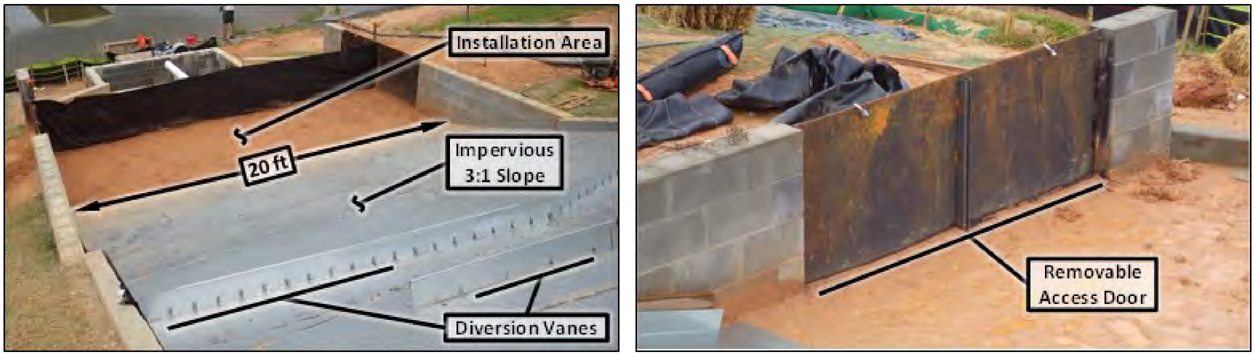
Figure 3. Water/sediment introduction system.

2.4 TEST SLOPE

The test slope [Figure 4(a)] that conveys flow to the test area is 20 ft (6.1 m) wide and has a gradient of 3*H*:1*V*. This width allows field-like installations of SBs as found on construction site. This width also allows test scalability to simulate the design criteria for drainage areas of ¼ to ½ ac (0.10 to 0.20 ha) per 100 ft (30.5 m) of installed non-reinforced or wire reinforced SBs. The impervious slope is constructed of a 14 gage (2.0 mm) galvanized sheet metal lining and is removable. This lining allows the introduction of a controlled, consistent amount of water and sediment flow across the width of the test apparatus. The slope is bordered by an 8 in. (2.03 cm) tall concrete curb. Slotted diversion vanes are installed at the top of the slope to spread the sediment-laden flow evenly across the entire width of the test apparatus, creating sheet flow conditions. The upstream diversion vane has 1.0 in. (2.5 cm) wide, 2.0 in. (5.1 cm) tall openings cut 12 in. (30.5 cm) on center and extends 5 ft (1.5 m) on either side of the centerline of the impervious slope. The downstream diversion vane has 1.0 in (2.5 cm) wide, 2.0 in (5.1 cm) tall openings cut 6.0 in. (15.2 cm) on-center and extends across the entire width of the impervious slope. The combination of the slope length, gradient, and the diversion vanes ensure consistent delivery of sediment-laden sheet flow across the slope to the test area.

2.5 EARTHEN TEST AREA

The earthen test area is 20 ft (6.1 m) wide, perpendicular to the flow and 12 ft (3.7 m) long longitudinally, in the direction of flow. The area is bordered by a 4.0 ft (1.2 m) tall concrete filled concrete masonry unit (CMU) wall. The width of the test area allows for the installation of a representative section of a SBs including hardware and reinforcement (i.e. posts, stakes, wire reinforcement, etc.). CMU wall height is sufficient in that common SBs overtop due to upstream impoundment without releasing water outside of the test area. The earthen test area can accommodate the installation of a single SB or a series of SBs. The test area is equipped with water-tight, steel access doors that are 8 ft (2.4 m) wide [Figure 4(b)] that can be removed to accommodate tractor-pulled silt fence slicing machines, as well as other SBs requiring additional installations lengths.



(a) impervious slope and test area (b) removable access door

Figure 4. Test apparatus features.

2.6 CATCH BASIN

Flow passing SBs is discharged into a catch basin that is 10 ft (3.0 m) wide by 6 ft (1.8 m) long by 4.67 ft (1.5 m) deep, downstream of the test area. Water depth measurements within the basin are recorded throughout testing. The collection tank is fitted with a discharge pipe and inline valve, allowing controlled discharge of flow from the basin.

2.7 EARTHEN SOIL PREPARATION

Prior to testing, the earthen portion of the test area is prepared using standardized earthwork preparation, compaction, and monitoring practices to ensure repeatability. Soil is added to the earthen test area and tilled using a rear tined tiller to produce a homogenous mixture with in-place soil [Figure 5(a)]. The test area is graded on a 1% slope in the direction of flow and is level perpendicular to the direction of flow. Final grading is achieved using an aluminum screed [Figure 5(b)] supported by wooden depth gages [Figure 5(c)] on either end to account for soil compaction. Final compaction is accomplished using an upright jumping-jack with a compaction plate of 14 by 11.5 in. (35.6 by 29.2 cm), blow count of 600 blows/min., and compaction force of 2,700 lb (1,225 kg) [Figure 5(d)]. Once compaction is complete, soil density is determined using ASTM D3937 *Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method* [Figure 5(e)]. For each installation, density samples are collected randomly within the earthen test area and weighted [Figure 5(f)]. Once weights were recorded, representative samples were collected from within each drive cylinder and processed in accordance with ASTM D2216 *Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*.

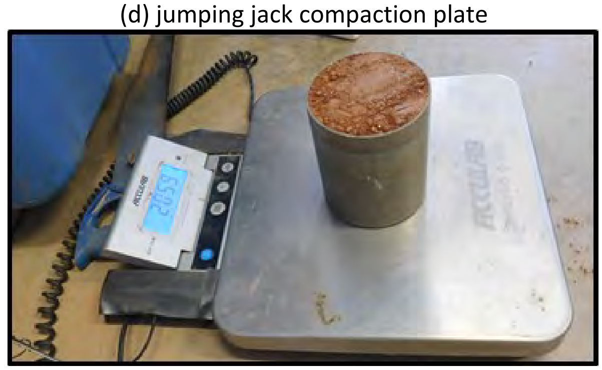
(a) rear tined tiller

(b) aluminum screed

(c) wooden depth gages

(d) jumping jack compaction plate

(e) obtaining density sample



(f) weighting density sample

Figure 5. Earthen soil preparation.

Based on the results of ASTM D698 *Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort*, the maximum dry unit weight of soil in the earthen test area was 113.1 lb/ft^3 with an optimum moisture content of 15.0%. The acceptable dry density range selected for this research was 95% of maximum. Once the desired density was obtained, the SB practices was installed and tested. The compaction curve of the soil used in the earthen test area is shown in Figure 6.

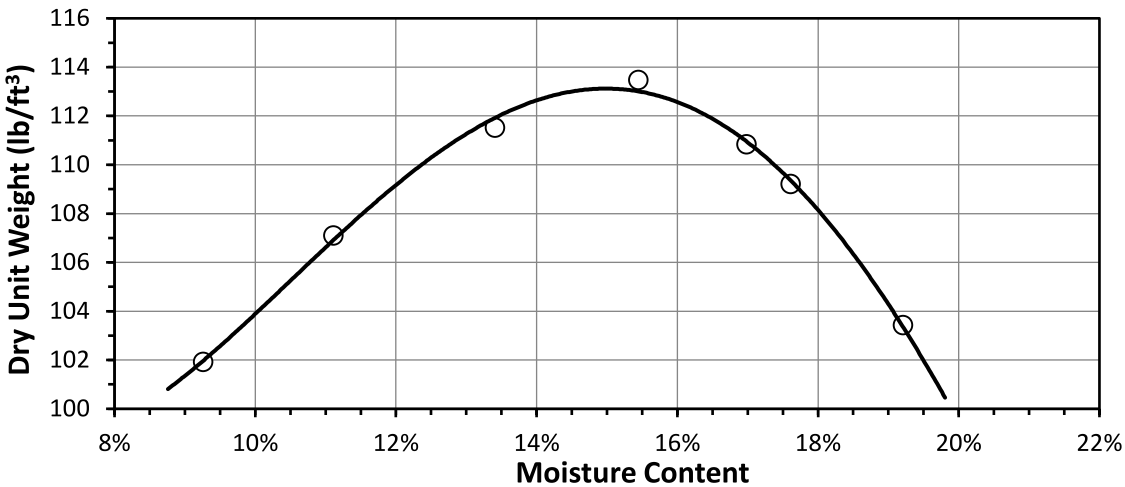


Figure 6. Compaction curve for SB test soil.

2.8 TESTING METHODOLOGY

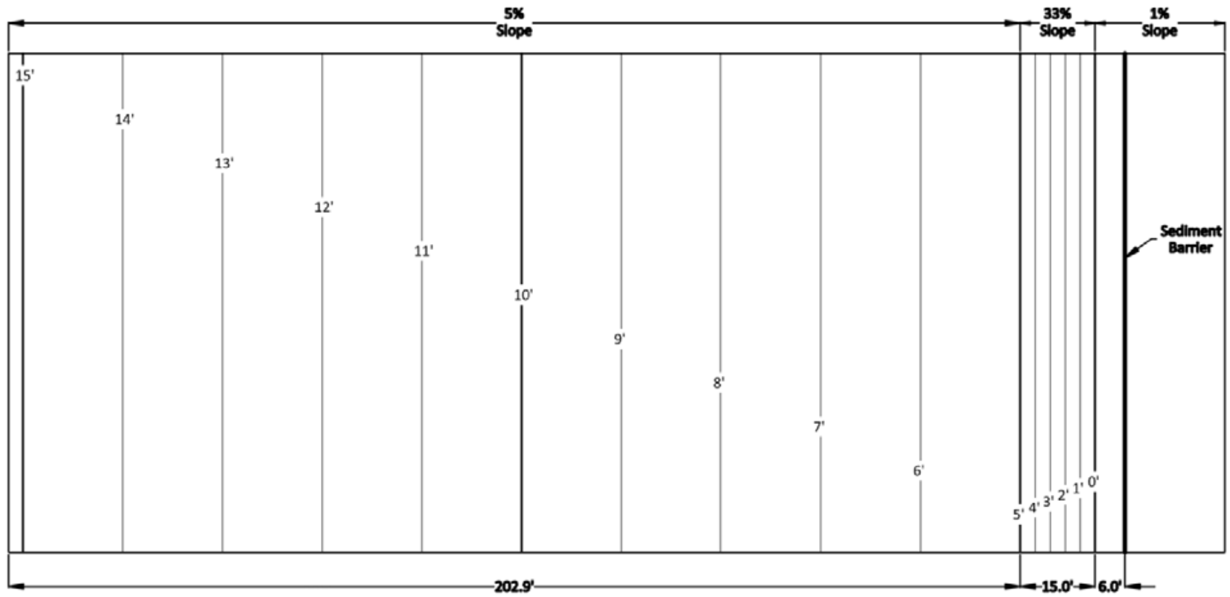
To develop a testing methodology that replicates flow and sediment transport conditions similar to field-like conditions, emphasis was applied in determining a representative flow rate and sediment introduction rate used throughout testing.

2.8.1 Theoretical Flow Introduction Rate

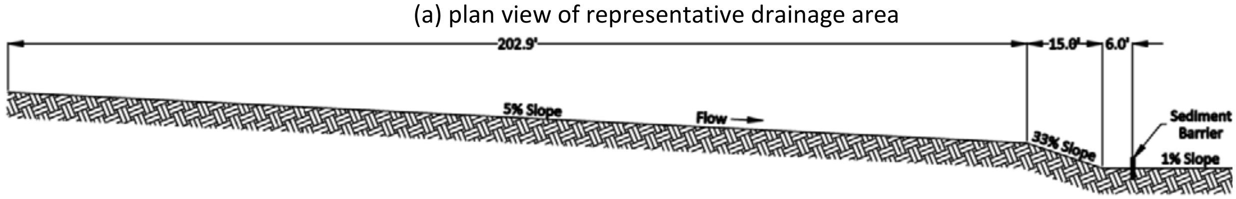
Test flow rate was determined based on the current design requirement for the State of Alabama which states that SBs are to contain eroded sediment onsite that result from a 2-yr, 24-hr rainfall event (*ADEM 2016*). The design criteria applicable to silt fence for the State of Alabama (*AL-SWCC 2014*) are summarized below:

- The drainage area shall not exceed ¼ ac (0.10 ha) or ½ ac (0.20 ha) per 100 ft (30.5 m) of non-reinforced or wire reinforced silt fence, respectively
- The maximum slope length above the fence for slopes greater than 20% is 15 ft (4.6 m).

ALDOT requires that silt fence, reinforced with 14 gauge (2.0 mm) steel wire mesh, be installed on each construction project (*ALDOT 2016*). Thus, ALDOT design criterion for reinforced silt fence was used to design the initial experimental protocol. The maximum slope length of the drainage area up-gradient of the silt fence based on the design criterion was calculated to be 217.9 ft (66.4 m). The maximum allowable drainage area of ½ ac (0.20 ha) per 100 ft (30.5 m) of wire reinforced silt fence was scaled down to an equivalent for the 20 ft (6.1 m) width of the test apparatus resulting in a drainage area of 0.10 ac (0.04 ha). The profile of the theoretical basin used to calculate test flow rate and sediment load for the initial SB testing protocol is shown in Figure 7. A 3*H*:1*V* slope directly up-gradient of the SB was selected as it is representative of typical road embankments and cut/fill areas where earthwork is required on construction sites. The remainder of the slope was assumed to be 5% as this is considered the worst case scenario while still maintaining sheet flow conditions up-gradient of the 3*H*:1*V* slope.



(a) plan view of representative drainage area



(b) profile of representative drainage area

Figure 7. Plan and profile of representative drainage area.

The flow rate for testing was calculated using Bentley® PondPack™ for the average 2-yr, 24-hr rainfall event for Alabama, which has an average precipitation depth of 4.43 in. (11.7 cm). The curve number (*CN*) used in the calculations was 88.5, which is the average *CN* for newly graded areas for Alabama based upon GIS analysis (*Perez et al. 2015*). The time of concentration for a disturbed area 20 ft (6.1 m) wide with a flow length of 217.9 ft (66.1 m) was estimated to be 5 minutes. Based on this information, the peak 30 minutes average flow rate for a 2-yr, 24-hr design rainfall event was calculated to be 0.20 ft^3/s (0.006 m^3/s), as shown in Figure 8.

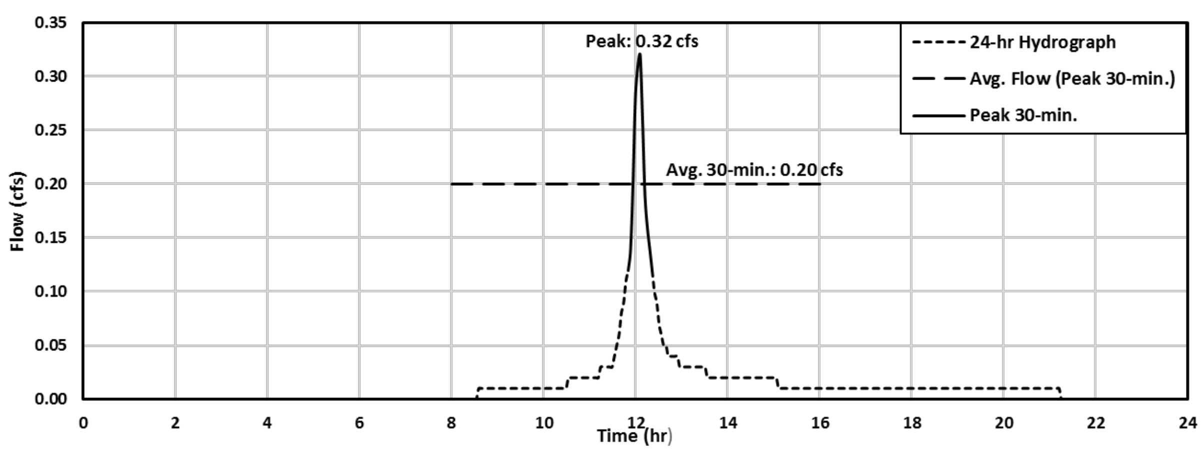


Figure 8. Hydrograph for 0.10 acre (0.04 ha) representative drainage area.

Essentially, flow will be introduced at a rate of 0.20 cfs (0.006 m^3/s) for 30 minutes during SB testing. A summary of the theoretical areas, flow rates, and volumes for SB testing is shown in Table 3.

Table 3. Summary of Theoretical Flow Values for SB Testing

Representative Drainage Area ac (ha)	Scaled-Down Drainage Area ac (ha)	Peak Flow ft^3/s (m^3/s)	Avg. Flow for 30 Min Peak ft^3/s (m^3/s)	Total Vol. 30 Min Test ft^3 (m^3)	Total Vol. 30 Min Test Gal (L)
0.50 (0.20)	0.10 (0.04)	0.32 (0.01)	0.20 (0.0062)	360 (10.2)	2,693 (10194.1)

Note: Average 2-year, 24-hour storm for Alabama = 4.43 inches. NRCS Type III rainfall distribution. Average CN = 88.5 for Alabama; 1 ac = 0.4 ha; 1 ft^3/s = 0.028 m^3/s; 1 ft^3 = 0.028 m^3; 1 gal = 3.79 L

2.8.2 THEORETICAL SEDIMENT INTRODUCTION RATE

The quantity of sediment required for SB testing was calculated using the MUSLE. The MUSLE determines total sediment yield resulting from storm specific runoff volumes and peak flow rates. The use of runoff variables rather than erosivity enables the MUSLE to estimate sediment yields for individual rainfall events. The empirical version of the MUSLE equation is shown in Equation 1 (*Williams and Berndt 1977*):

$$S = 11.8(Qq_p)^{0.56} * K * LS * C * P \quad \text{(Eq. 1)}$$

Where:

S = sediment yield from an individual storm (metric ton)
Q = volume of runoff (m^3)
q_p = peak flow (m^3/s)
K = erodibility factor
LS= length-slope factor
C = cover management factor
P = erosion practice factor

Based upon flow calculations conducted for the state of Alabama, the MUSLE was applied to the peak 30 minutes of the design 2-yr, 24-hr rainfall event, which produces 396.0 ft^3 (11.21 m^3) of runoff with a peak flow (q_p) of 0.32 ft^3/s (0.009 m^3/s). From Pitt et al. (*2007*), the K factor of 0.15 for a *loamy sand, loamy fine sand, sandy loam, loamy, silty loam* was used. To account for the geography of the drainage area, an LS factor of 1.04 was used for a 15 ft (4.6 m) slope length for 33% slope and a 202.8 ft (61.8 m) slope length at a 5% slope. C and P factors of 1.0 were assumed for bare ground, no cover, and no conservation practices (e.g., contouring, strip-cropping, terracing, etc.) upstream of the installed SB. The total resulting sediment load for a 30-minute test is 1,127.8 lb (0.51 metric tons) of soil, which is introduced at a constant rate of 37.6 lb/min (0.017 metric tons/min). Table 4 summarizes the MUSLE values used for calculating sediment yield.

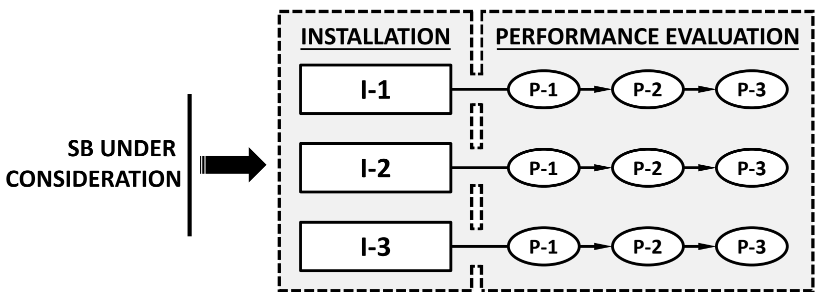
Table 4. Summary of Theoretical Sediment Yield for SB Testing

Drainage Area (ac)	Q ft^3 (m^3)	q_p ft^3/s (m^3/s)	K	LS	C	P	S (Metric Tons)	S (U.S. Tons)	S (lb)
0.10	396.0 (11.2)	0.32 (0.009)	0.15	1.04	1	1	0.51	0.56	1127.8

Note: MUSLE equation was used to calculate sediment expected resulting from the average 2-year, 24-hour storm for Alabama for 0.10 acres; 1 ft^3/s = 0.028 m^3/s; 1 Metric Ton = 1.10 U.S. Ton = 2,204.6 lb

2.9 TESTING REGIME

A series of full-scale experiments introducing sediment-laden flow at a constant rate for 30 minutes are conducted to evaluate the performance of each SB tested. Three replicate performance evaluations are performed for each SB. One performance evaluation consists of installing the SB in the test area and conducting three, 30 minute tests on each installation with sediment-laden flow to evaluate initial performance during the first test and performance over time as the practices are subjected to two additional simulated rainfall events. This results in three replicate installations per SB consisting of three, 30 minute tests per installation resulting in nine total tests per SB. The performance based testing regime for SBs is summarized in Figure 9.



Notes: 1. Three installations (I-1, I-2, and I-3) are performed to obtain replicate data sets and show reproducibility.
2. Three performance tests (P-1, P-2, and P-3) are conducted sequentially per installation to evaluate the performance and longevity of a SB.
3. Nine total tests per sediment barrier are performed.

Figure 9. SB performance based testing regime (*Bugg et al. 2017*).

2.10 DATA COLLECTION

The evaluation of SB performance is based on data and observations collected throughout the duration of the experiment. These parameters are used to assess the overall performance of the tested SBs and make comparisons between various SBs tested.

2.10.1 Structural Performance

Photographs are taken pre-test, during the test, and post-test from the locations shown in Figure 10. These photographs are used to document the test conditions as well as the post-test condition of the SB. Video documentation is collated throughout testing to that structural failures can be analyzed to identify modes of scouring, overtopping, and/or structural instabilities. A string line is installed across the test area [Figure 10] to measure the deflection of the SB support structures, if applicable. This data is used to evaluate the structural performance of SBs, as well as to identify avenues to improved performance.

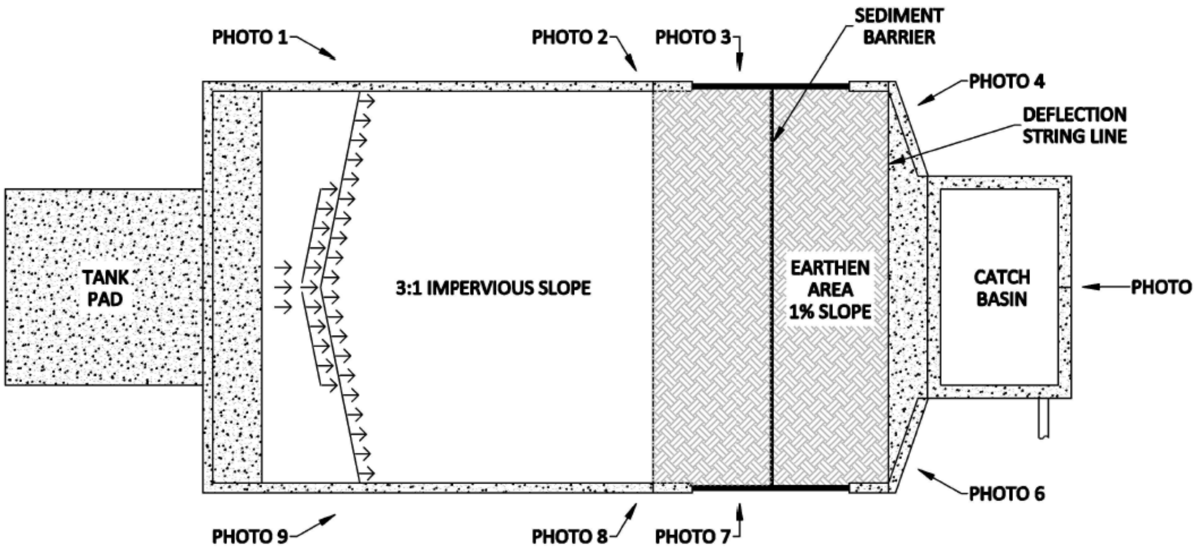
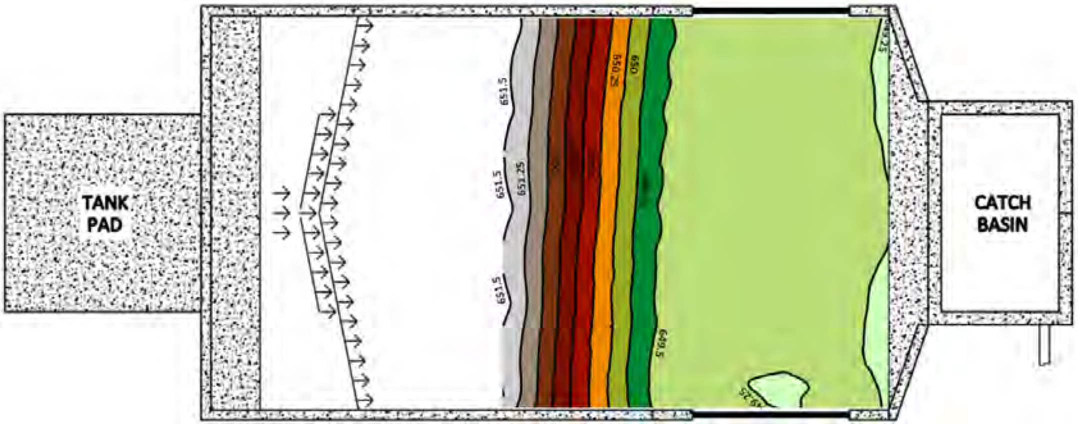


Figure 10. Sediment barrier data acquisitions locations.

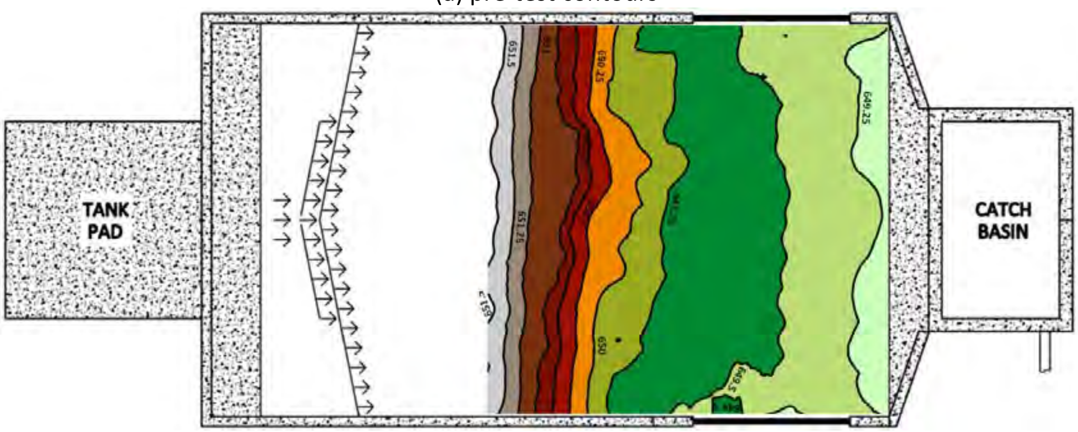
2.10.2 Sediment Retention

Complete topographical surveys of the test area are conducted pre- and post-test to record sediment retention. The surveys are performed using a Trimble® robotic total station [Figure 11] and analysis of the topographic data is conducted using computer-aided design software. This software converts raw data points into a triangulated irregular network for a three-dimensional representation of the test area surface which allows for a comparison of the pre- and post-test channel topography, as shown in Figure 12(a) and 12(b) respectively.

Figure 11. Robotic total station setup and survey.



(a) pre-test contours



(b) post-test contours

Figure 12. Three-dimension representation of surveyed sediment deposition.

Note: Colored regions between contour intervals are intended to aid visual representations of elevation change from pre to post test

2.10.3 Hydraulic Conductivity

Water ponding depth, pool length, and discharge flow rates are monitored and recorded during testing. Ponding depth and pool length are measured using a depth gauge at five-minute intervals for the 30-minute test duration and continuing after the test at five-minute intervals for 15 minutes; at 15 minute intervals for the following 15 minutes; and at 30 minute intervals for the final 60 minutes. Maximum depth and pool length are confirmed by monitoring, marking, and measuring the high water marks at the conclusion of each test. Catch basin water depth is also measured at the same intervals detailed above. The collection of this data allows for the evaluation of the SB's ability to impound water and for the quantification of flow rate passing through the SB when subjected to sediment-laden flow.

2.10.4 Turbidity and Total Suspended Solids (TSS)

Water quality data is analyzed from numbered 8.0 oz. (240 mL) grab samples [Figure 13(a)] collected from the test flow. Samples are collected every five minutes at five sample locations: along the impervious slope (SL1), upstream of SB on the surface of the impoundment (SL2), upstream of SB along the bottom of the impoundment via sampling pump (SL3), downstream of the SB (SL4), and as water discharged into the catch basin (SL5). Figure 14 illustrates each of the sample locations. The grab samples are processed and analyzed to determine turbidity and total suspended solids (TSS) at each location. Turbidity is measured using a Hach® 2100Q Portable Turbidimeter [Figure 13(b)] that measures water transparency in nephelometric turbidity unit (NTU). TSS is reported in mg/l and is assessed by passing a well-mixed 25 mL (0.85 oz.) water sample through a membrane filter and determining the quantity of solids captured by the filter [Figure 13(c)], thereby quantifying the amount of suspended solids in the sample. A comparison of the turbidity and TSS at locations SL1 and SL2 are used to determine the effect on water quality resulting from the impoundment. A comparison between locations SL2 and SL3 demonstrates the effect on water quality resulting from the impoundment upstream of the tested SB. The comparison between locations SL3 and SL4 indicates the change in water quality after passing through the SB. Finally, SL4 and SL5 indicate the effects after flow travels over the bare soil between the SB and the catch basin.

(a) grab sample container (b) turbidity meter (c) TSS filtering apparatus

Figure 13. Water quality measuring equipment.

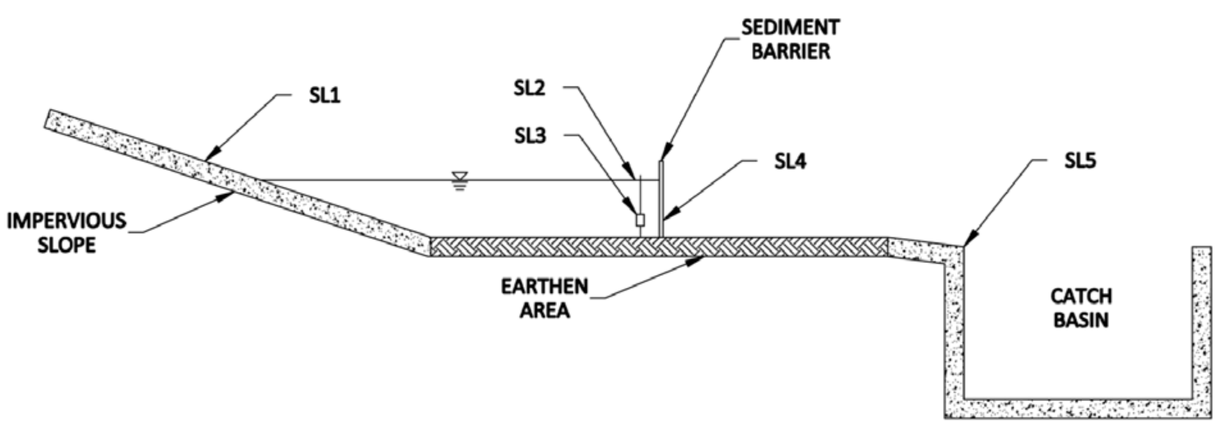


Figure 14. Water sampling locations.

2.11 SUMMARY

This section provides an overview of the SB test apparatus design, experimental methodology, and data collection processes developed for evaluating SB practices as part of this research. A comparison of existing SB test methods identified in the literature and the test method developed at the AU-ESCTF are shown in Table 5. The full-scale test apparatus allows for representative flows and sediment loads that SBs typically experience when installed on roadway construction site. The test apparatus and methodology developed at the AU-ESCTF is the only test method that allows for full-scale testing of SBs subjected to realistic field-like conditions. Design parameters listed in Table 5 were the basis of design, which mimics and simulates typical field conditions in which SBs are installed on ALDOT projects.

Table 5. Comparison of Various Test Methods and Test Requirements (*Bugg et al. 2017*)

Study	Focus	Design Storm	Drainage Basin ac (ha)	Flow Rate ft^3/s (m^3/s)	Sediment Load lb (kg)	Test Duration (min)
TRI/Environmental ASTM D7351	Performance	10-yr, 6-hr	0.05 (0.02)	0.04 (0.001)	300 (136.1)	30
Gogo-Abite, Chopra UCF	Performance	1.0– 5.0in./hr (25.4-127 mm/hr)	0.005 (0.002)	0.0071- 0.0283 (0.0002 - 0.0008)	N/A	30
ASTM D5141	Filtering Efficiency and Flow Rate	N/A	N/A	0.177 (0.005)	0.33 (0.15)	0.17
ALDOT AU-ESCTF	Performance & Longevity	2-yr, 24-hr	0.50 (0.20)	0.22 (0.006)	1,127.8 (511.6)	30

Note: 1 ac = 0.4 ha; 1 ft^3/s = 0.028 m^3/s; 1 lb = 0.45 kg

CHAPTER 3: PERFORMANCE EVALUATIONS OF SILT FENCE INSTALLATION CONFIGURATIONS

3.1 INTRODUCTION

This chapter evaluates nonwoven silt fence sediment barrier installations, as well as alternative installations methods that focus on improving structural stability. The research presented exhibits the performance characteristics of Standard ALDOT silt fence installations and the effect small design and installation changes have on structural performance of silt fence when exposed to a replicable 2-yr, 24-hr design storm. A statistical analysis was conducted on T-post deflection data to determine individual aspect functionality as it relates to structural performance. Sediment retention rates, water quality analyses, and an effective means for dewatering impounded stormwater is also presented.

3.2 SILT FENCE INSTALLATION MATERIALS

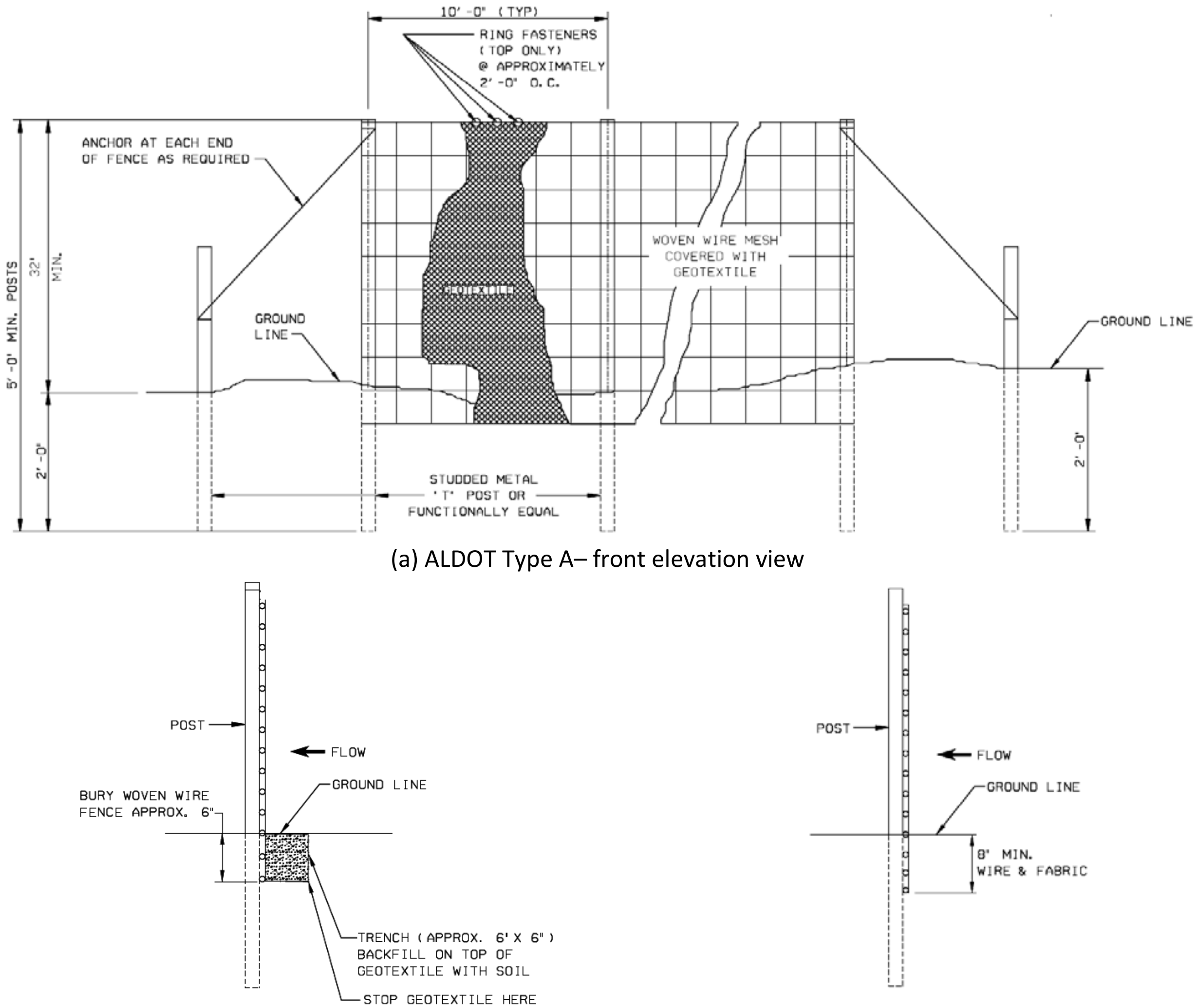
The following outlines the materials used during performance testing.

- *filter fabric:* 3.5 oz./yd^2 (130 g/m^2), nonwoven, 48 in. (121.9 cm) wide fabric that conform to the American Association of State Highway and Transportation Officials (AASHTO) M288 standard (*AASHTO 2017*). Fabric was attached along the top of wire reinforcing using c-ring clips approximately 2 ft (0.61 m) on-center. Fabric was placed into a 6 in. by 6 in. (15.2 cm by 15.2 cm) trench and backfilled.
- *wire reinforcing:* 17 gauge (1.14 mm) steel woven wire reinforcement with maximum vertical spacing of 6 in. (15.2 cm) and horizontal spacing of 12 in. (30.5 cm). Wire reinforcing was used to support filter fabric.
- *studded T-post:* 5 ft (1.5 m) and 4.3 ft (1.3 m) studded T-post, 0.95 lb/ft (1.4 kg/m) and 1.25 lb/ft (1.9 kg/m), driven into ground 24 in. (61 cm), spaced 10 ft (3.0 m) and 5 ft (1.5 m) on-center. T-posts were used as vertical supports for reinforcing wire and filter fabric.
- *wire ties:* three 6.5 in. (15.6 cm), 11 gauge (3.175 mm), aluminum wire ties were used to attach reinforcing wire to each studded t-post.
- *c-ring clips:* 11/16 in. (1.75 cm), 16 gauge (1.29 mm), galvanized steel c-ring clips were used to secure filter fabric to reinforcing wire.

To accurately evaluate the performance of each silt fence installation configuration, the filter fabric manufacturer (DDD Erosion Control 3D 3.5 NW) and weight (3.5 oz/yd^3) were kept consistent throughout testing.

3.3 STANDARD ALDOT SILT FENCE INSTALLATIONS

The ALDOT standard wire-reinforced, nonwoven, trenched and sliced silt fence configuration, as illustrated in the ALDOT Standard Drawing ESC-200-4 (*ALDOT 2017*) shown in Figure 15 was evaluated. Results established the performance baseline for which installation modifications were compared. The standard ALDOT silt fence installation specifies constructing a silt fence that is: (1) a minimum of 32 in. (81.3 cm) above the ground surface, (2) supported by studded metal T-posts spaced 10 ft (3 m) on-center, and (3) entrenched 6 in. by 6 in. (15.2 cm by 15.2 cm) or sliced 8 in. (20.3 cm) into the ground.



(a) ALDOT Type A– front elevation view

(b) ALDOT Type A – Trenched

(c) ALDOT Type A - Sliced

Figure 15. ALDOT standard silt fence installation (*ALDOT 2017*).

3.4 NONWOVEN SILT FENCE INSTALLATION TESTS

The SB test apparatus was prepared in accordance with the experimental specifications outlined in Chapter 2 for each installation configuration to minimize inconsistencies between tests. Two standard installations and eight alternative installation configurations were evaluated to determine overall performance. Each standard installation was installed per the design drawings and each alternative trenching installation was installed in the same manner as the standard ALDOT installation but minor modifications were implemented, as noted below.

- *Standard ALDOT Trenched (STD-T):* 32 in. (81.3 cm) fence height, 10 ft (3.0 m) T-posts spacing, 0.95 lb/ft (1.4 kg/m) T-posts, and entrenched 6 in.by 6 in. (15.2 cm by 15.2 cm)
- *Standard ALDOT Sliced (STD-S):* 32 in. (81.3 cm) fence height, 10 ft (3.0 m) T-posts spacing, 0.95 lb/ft (1.4 kg/m) T-posts, and sliced 8 in. (20.3 cm)
- *Modification 1 (M1):* 0.95 lbs/ft (1.4 kg/m) T-posts were replaced with 1.25 lbs/ft (1.9 kg/m) T-posts.

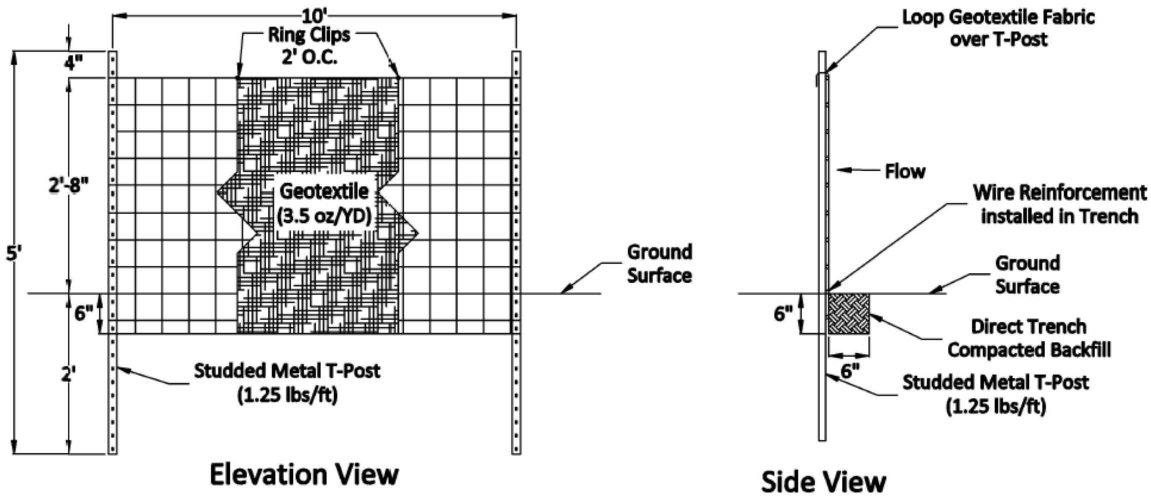
- *<u>Modification 2 (M2)</u>:* 0.95 lbs/ft (1.4 kg/m) T-posts spacing was reduced from 10 ft (3.0 m) on-center to 5 ft (1.5 m) on-center.
- *<u>Modification 3 (M3)</u>:* 0.95 lbs/ft (1.4 kg/m) T-posts were replaced with 1.25 lbs/ft (1.9 kg/m) T-posts and T-posts spacing was reduced from 10 ft (3.0 m) on-center to 5 ft (1.5 m) on-center.
- *<u>Modification 4 (M4)</u>:* fence height was reduced from 32 in. (81.3 cm) to 24 in. (61.0 cm).
- *<u>Modification 5 (M5)</u>:* fence height was reduced from 32 in. (81.3 cm) to 24 in. (61.0 cm) and T-post spacing was reduced from 10 ft (3.0 m) on-center to 5 ft (1.5 m) on-center.
- *<u>Modification 6 (M6)</u>:* fence height was reduced from 32 in. (81.3 cm) to 24 in. (61.0 cm) and 0.95 lbs/ft (1.4 kg/m) T-posts were replaced with 1.25 lbs/ft (1.9 kg/m) T-posts.
- *<u>Modification 7 (M7)</u>:* fence height was reduced from 32 in. (81.3 cm) to 24 in. (61.0 cm), 0.95 lbs/ft (1.4 kg/m) T-posts were replaced with 1.25 lbs/ft (1.9 kg/m) T-posts, and T-post spacing was reduced from 10 ft (3.0 m) on-center to 5 ft (1.5 m) on-center.
- *<u>Modification 8 (M8)</u>:* mimics Modification 7; however, T-post were offset 6 in. (15.2 cm) downstream of the trench.

A summary of the variations between each installation configuration is provided in Table 6 and installation details for each modification are illustrated in Figure 16(a) – 16(h).

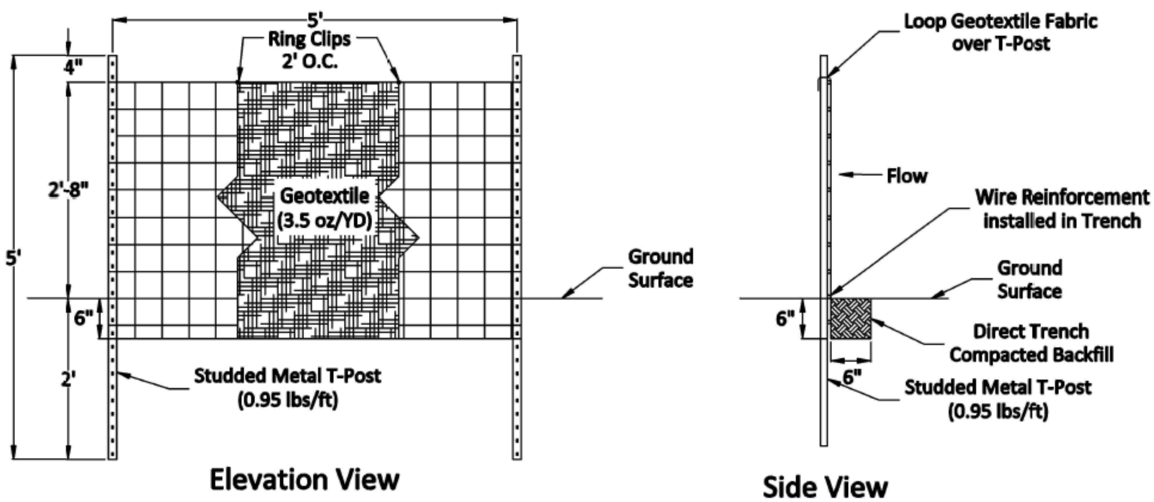
Table 6. Summary of Silt Fence Installations

Installation	Fence Height in. (cm)	T-Post Weight lbs/ft (kg/m)	T-Post Spacing ft (m)	Embedment in. x in. (cm x cm)
STD-T	32 (81.3)	0.95 (1.4)	10 (3.0)	6 x 6 (15.2 x 15.2)
STD-S	32 (81.3)	0.95 (1.4)	10 (3.0)	Sliced 8 (20.3)
M1	32 (81.3)	1.25 (1.9)	10 (3.0)	6 x 6 (15.2 x 15.2)
M2	32 (81.3)	0.95 (1.4)	5 (1.5)	6 x 6 (15.2 x 15.2)
M3	32 (81.3)	1.25 (1.9)	5 (1.5)	6 x 6 (15.2 x 15.2)
M4	24 (61.0)	0.95 (1.4)	10 (3.0)	6 x 6 (15.2 x 15.2)
M5	24 (61.0)	0.95 (1.4)	5 (1.5)	6 x 6 (15.2 x 15.2)
M6	24 (61.0)	1.25 (1.9)	10 (3.0)	6 x 6 (15.2 x 15.2)
M7	24 (61.0)	1.25 (1.9)	5 (1.5)	6 x 6 (15.2 x 15.2)
M8	24 (61.0)	1.25 (1.9)	5 (1.5)	Offset 6 x 6 (15.2 x 15.2)

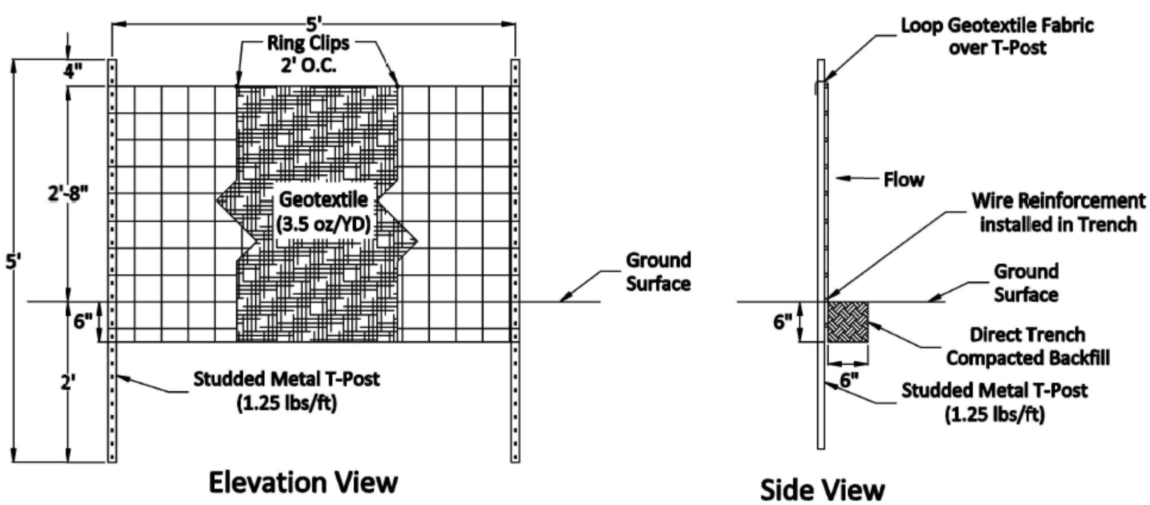
Note: STD-T = Standard ALDOT Installation Trenched; STD-S = Standard ALDOT Installation Sliced;
M = Modification to Standard ALDOT Installation; 1 in. = 2.54 cm; 1 lb/ft = 1.5 kg/m; 1 ft = 0.3 m



(a) modification 1

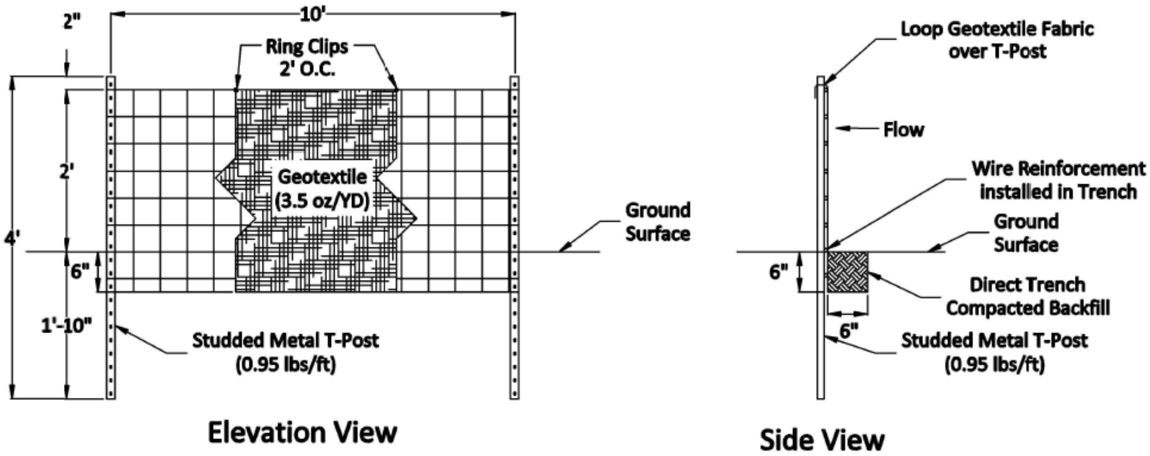


(b) modification 2

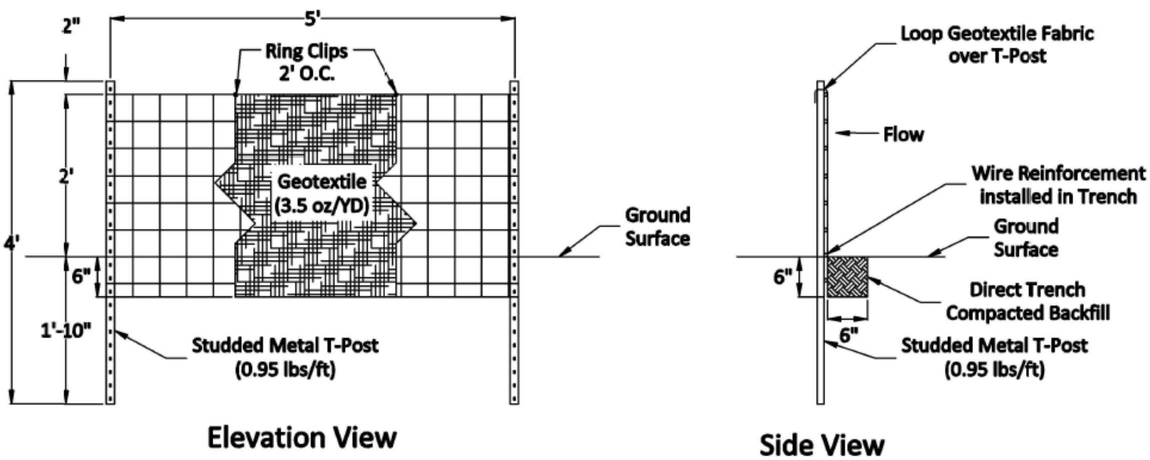


(c) modification 3

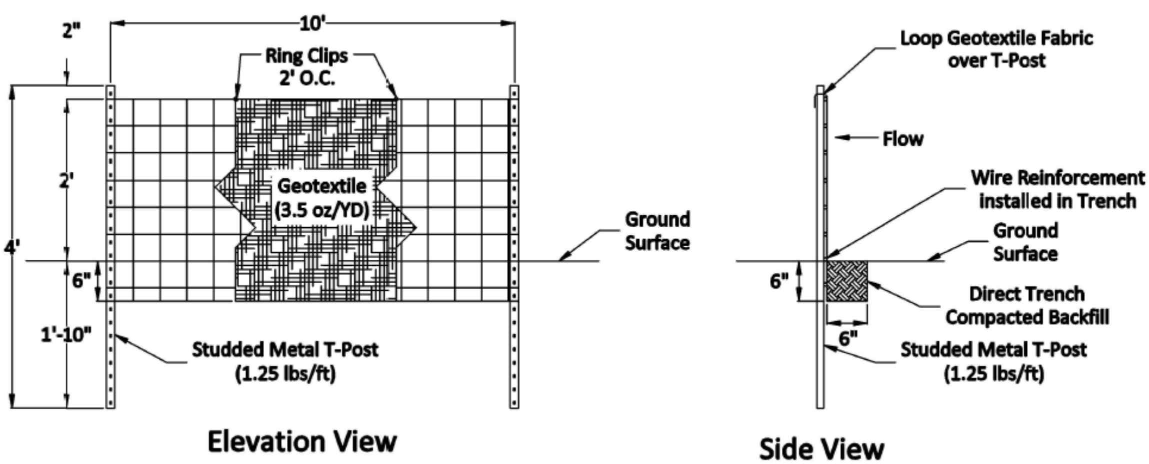
Figure 16. Silt fence modification details.



(d) modification 4

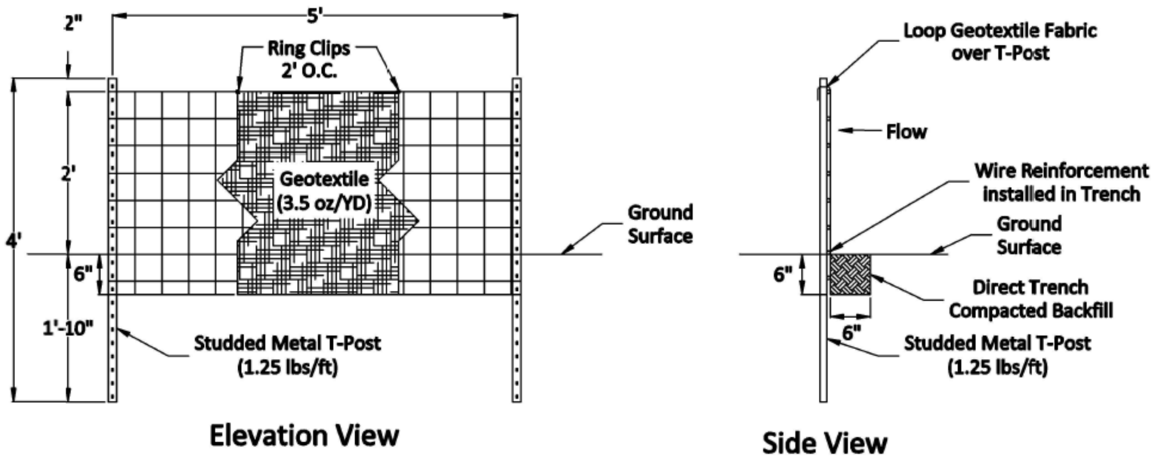


(e) modification 5

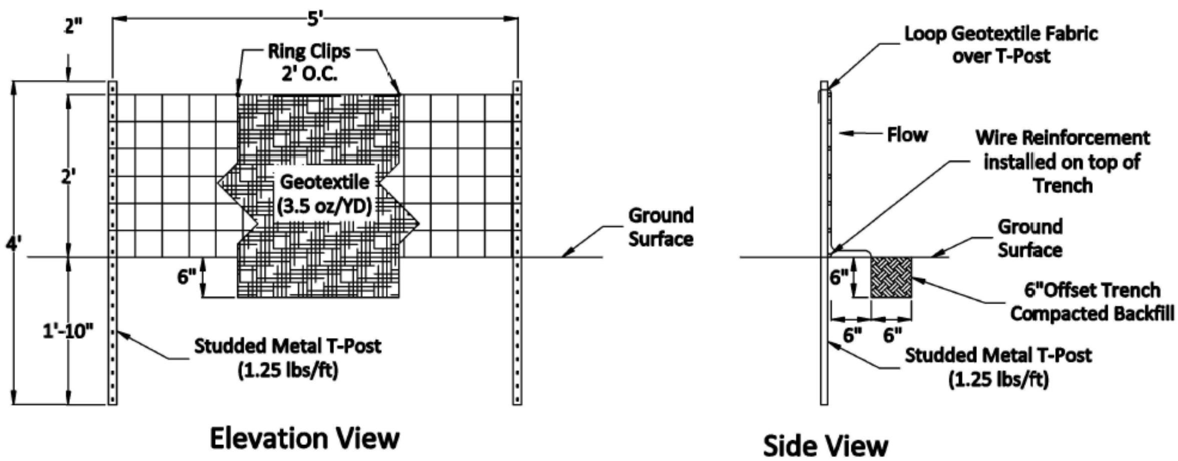


(f) modification 6

Figure 16 (cont'd). Silt fence modification details.



(g) modification 7



(h) modification 8

Figure 16 (cont'd). Silt fence modification details.

3.5 STATISTICAL ANALYSIS

Statistical analysis was used to evaluate the effect that each installation variable had on the performance of the silt fence installation. This was achieved by developing a traditional multiple linear regression model that was used to determine the significance of each installation variable (e.g., fence height, post weight, post spacing, and trench offset). The multiple linear regression model independently evaluates the effect each variable has on reducing T-post deflection. The magnitude of T-post deflection correlates to the structural failure of the installation created by the fence falling backwards. Installation components were first recoded into unique binary independent variables that took values of 1 or 0, depending on whether the installation modified the component or not. The dependent variables were coded as deflection lengths, which ranged between 0.03 ft (0.01 m) and 0.72 ft (0.22 m). The objective for conducting the regression analysis was to determine the relative impact of each component on final fence deflection, independent of other components. It is important to recognize that because some installations were only evaluated once (e.g., M1, M2, M3, M4, M5, and M6), model results are not statistically significant enough to predict deflections. However, the model does provide valid quantifiable measures to support the remaining evaluation criteria described in the following section, as previously seen in work completed by Donald et al. (2013). Using this model, the most effective means for improving structural stability can be determined. The model equation can be written as:

$$f(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 \qquad \textit{(Eq. 2)}$$

Where,

$f(x)$ = dependent variable (e.g., silt fence deflection)

β_0 = coefficient intercept

β_i = ordinary least squares coefficients

x_i = independent variables (e.g., fence height, post weight, post spacing, offset trench)

3.6 RESULTS AND DISCUSSION

The following is a summary of results and observations made over the course of nonwoven silt fence experiments. The initial phase of this investigation identified and evaluated the performance baselines for Standard ALDOT silt fence installations. The second phase was dedicated to developing and evaluating alternative installation strategies that improved upon baseline performance data. During this phase, precedence for improvements were placed in the following order: (1) structural integrity, (2) sediment retention, and (3) water quality. The final phase of the investigation focused on the development and evaluation of an effective means for dewatering concentrated impoundment areas, upstream of a silt fence installation, while maintaining optimal performance characteristics achieved during phase two.

3.6.1 Structural Performance

The structural integrity of a silt fence installation is critical to achieve the desired water quality improvements of stormwater runoff prior to site discharge. As outlined previously, the ability of a silt fence installation to efficiently removing sediment is largely dependent on stormwater impoundment capabilities. To achieve desired efficiencies, two common failure modes must be addressed. First, silt fence installations should be able to structurally withstand the hydrostatic pressure imposed by stormwater that impounds upstream of the installation. Second, silt fence geotextiles should be securely entrenched as to prevent flow bypass and undermining of the installation. Figure 17 shows these common failure modes.

(a) overtopping (b) undermining

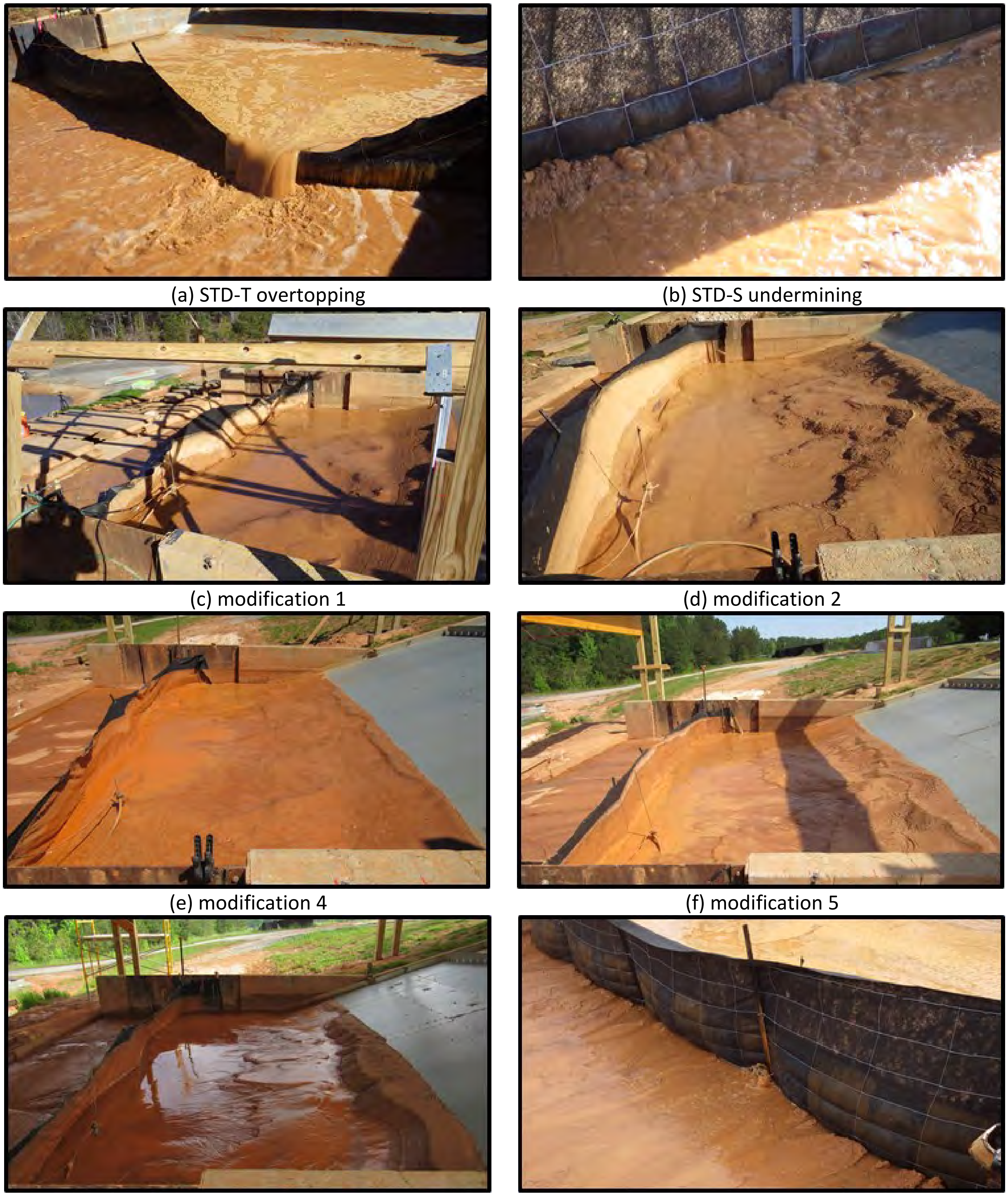
Figure 17. Common construction site silt fence structural failures.

Structural performance observations of the *Standard ALDOT Silt Fence – Trenched* installation, which will be referred to as *STD-T*, were conducted over the course of three installations. For each installation, maximum impoundment depth increased, as well as T-post deflection, with each of the three simulated storm events due to geotextile blinding. As a result, structural failure occurred when hydrostatic forces reached the maximum allowable bending moment of the T-post. Post deflection continued until overtopped water reduced hydrostatic pressure on the installation to the point that equilibrium within the system was established. This failure mode occurred during the third simulated storm event for installation 1 and 2 (i.e., I1 and I2) but during the second simulated storm event for installation 3 (i.e., I3). The maximum horizontal T-post deflection measured during *STD-T* testing was 2.67 ft (0.81 m). Additionally, significant fence sag was observed during evaluations. Flow overtopping occurred midway between T-post installation locations, which also corresponds to the position in which maximum fence sag occurred, as shown in Figure 18(a). Due to extensive fence sag between T-posts, maximum impoundments measured during testing were 0.82 ft (0.25 m), 0.90 ft (0.27 m), and 0.85 ft (0.26 m), respectively. Each of the *STD-T* installations evaluated failed in the manners identified above. Results indicate that while the *STD-T* installation can structural withstand a single 2-yr, 24-hr storm event, the installation configuration is subject to structural failure when exposed to multiple field rainfall events.

The *Standard ALDOT Silt Fence – Sliced* installation, referred to as *STD-S*, was also evaluated over the course of three installations. Observations from tests indicate that failure of each installation was due to undermining on the initial simulated storm event. Failures were similar in nature in that the entrenched geotextile dislodged from the mechanically formed trench 8 to 12 minutes after flow introduction thus allowing flow to undermining the installations. Maximum measured impoundment depths measured during testing for each installation (i.e., I1, I2, and I3) were 0.37 ft (0.11 m), 0.48 ft (0.15 m), and 0.49 ft (0.15 m), respectively. The undermining failure mode observed is shown in Figure 18(b). Results indicate that the *STD-S* installation, as installed using the EnFencer® mechanical slicing machine, would not perform structurally when exposed to a 2-yr, 24-hr field rainfall event.

Silt fence installation methods (i.e., trenching and slicing) have typically been based on installation needs, costs, equipment, and labor availability. Slicing is considered a more efficient means of installation compared to trenching because the use of a tractor-drawn slicing implement is less labor intensive than trenching. Nonetheless, results indicate that the structural integrity of the *STD-T* installation is more reliable than that of the *STD-S* installation.

Based on the observations and evaluations of the *STD-T* installation, modifications to the standard installation were developed, tested, and assessed. Failure mechanisms observed throughout modification testing were: post deflection, fence sagging, overtopping, and undermining. The maximum and minimum post deflections for test P3 were 2.04 ft (0.62 m) (*M2*) and 0.15 ft (0.05 m) (*M8*), respectfully. Each installation using 0.95 lb/ft (1.9 kg/m) T-post and/or 10 ft (3 m) T-post spacing, experienced significant post deflection, which resulted in overtopping (Figure 18(c), 18(d), 18(e), 18(f), and 18(g)). Excessive fence sag was observed in each installation using a 10 ft (3 m) T-post spacing (Figure 18(c), 18(e), and 18(g)). Undermining was observed at multiple T-post locations during several tests (Figure 18(h)). Although a definitive reason for this occurrence could not be determined, it was speculated that lack of compaction around T-posts due to their placement within the trench resulted in these failures. Table 7 summarizes the structural performance of all nonwoven silt fence installations.



(a) STD-T overtopping (b) STD-S undermining

(c) modification 1 (d) modification 2

(e) modification 4 (f) modification 5

(g) modification 6 (h) undermining of modification 2

Figure 18. Silt fence installation configurations and failure modes.

Table 7. Silt Fence Failure Modes

Description	Installation	Test	Overtopping Time (min:sec)	Structural Failure
STD-T	I1	P1, P2	--	No Failure
		P3	15:15	Post Deflection, Fence Sagging, Overtopping
	I2	P1,P2	--	No Failure
		P3	14:30	Post Deflection, Fence Sagging, Overtopping
	I3[a]	P1	--	No Failure
		P2	15:30	Post Deflection, Fence Sagging, Overtopping
STD-S	I1[b]	P1	--	Undermining
	I2[b]	P1	--	Undermining
	I3[b]	P1	--	Undermining
M1	I1[a]	P1	--	No Failure
		P2	18:45	Post Deflection, Overtopping, Fence Sagging, Undermining
M2	I1	P1	--	No Failure
		P2	--	Undermining
		P3	26:40	Post Deflection, Overtopping
M3	I1	P1, P2, P3	--	No Failure
M4	I1[a]	P1	--	Undermining
		P2	16:28	Post Deflection, Fence Sagging, Overtopping
M5	I1	P1	--	Undermining
		P2	--	No Failure
		P3	26:00	Post Deflection, Overtopping
M6	I1	P1, P2	--	No Failure
		P3	13:10	Post Deflection, Fence Sagging, Overtopping
M7	I1	P1, P2, P3	--	No Failure
	I2	P1, P2, P3	--	No Failure
	I3	P1, P2, P3	--	No Failure
M8	I1	P1, P2, P3	--	No Failure
	I2	P1, P2, P3	--	No Failure
	I3	P1, P2, P3	--	No Failure

Note: [a] = test P3 was not conducted due to test P2 failure; [b] = test P2 & P3 were not conducted due to test P1 failure; -- = overtopping did not occur.

In addition to increasing T-post weight and decreasing T-post spacing, improvements to the standard installation were analyzed. While conducting tests on M1, it was noted that securing the nonwoven fabric to the T-post by cutting a slit in the fabric and looping it over the T-post [Figure 19(a)] decreased fence sag caused by hydrostatic pressure between T-post, as shown in Figure 19(b) and 19(c). This installation method also reduced pressure applied to the c-ring fasteners [Figure 19(d)] along the top of the fence, which failed during the “no loop” test.

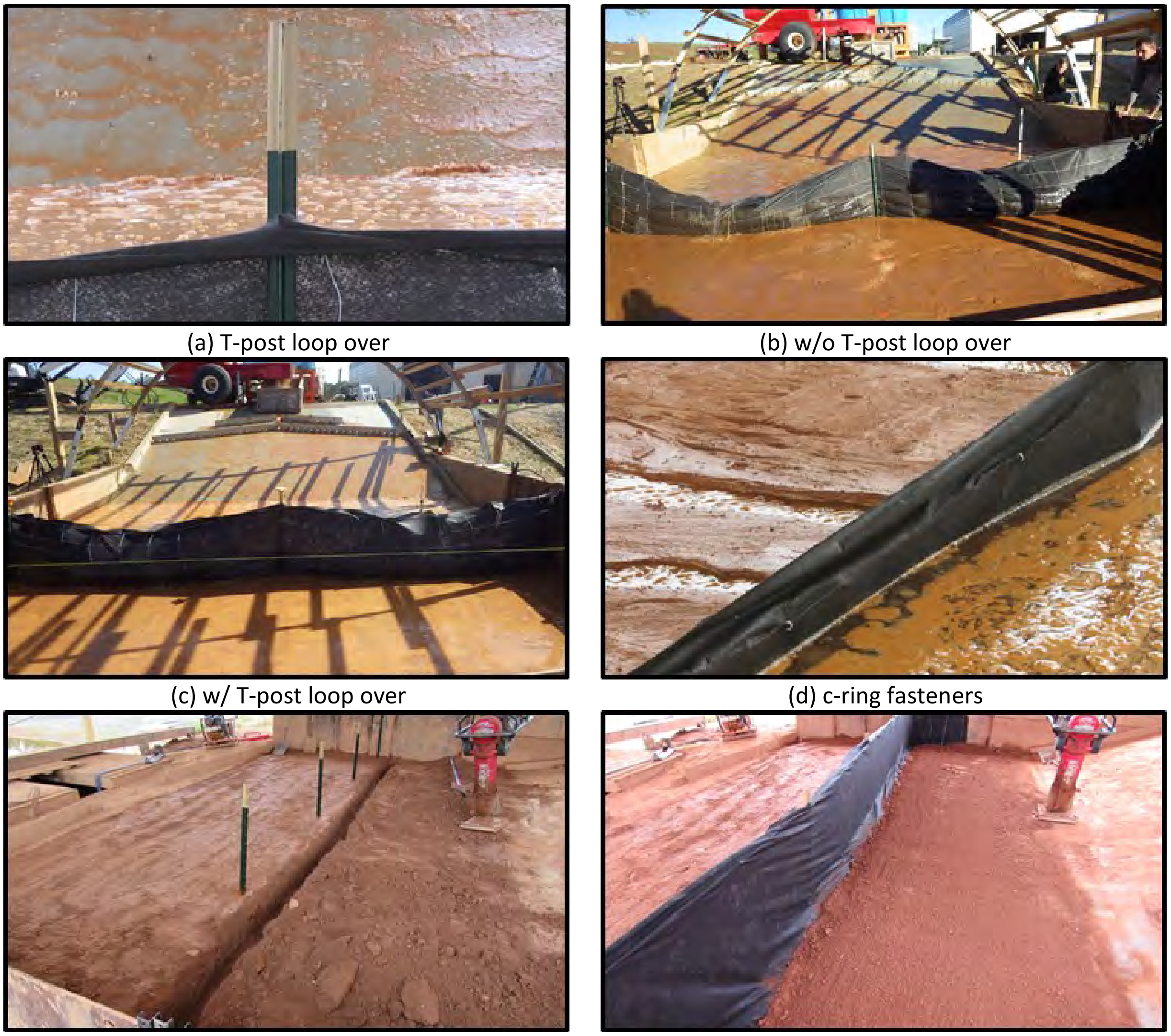

(a) T-post loop over (b) w/o T-post loop over
(c) w/ T-post loop over (d) c-ring fasteners
(e) offset trench (f) offset silt fence installation

Figure 19. Silt fence improvement strategies.

Although scouring was not a significant factor affecting sediment retention performance for each configuration, installation improvements for reducing the reoccurrence of scouring were tested. Figure 19(e) and 19(f) show the offset trench installation implemented. Even though a justifiable metric that indicates the benefits of the offset trench in regards to scoring was not obtained, a slight increase in impoundment depth [approximately 0.12 ft (0.04 m)] was noted when compared to direct trenching method. This observation indicates that the offset trench, which was mechanically compacted, may minimize flow under the installation as compared to direct trenching, which requires hand compaction to avoid damaging the installation.

3.6.2 Sediment Retention

Topographical surveys of the test area were performed using a total station to gather elevation points pre- and post-simulated events. The data points were used to develop three-dimensional surface models of sediment deposition caused by the impoundment of the silt fence installations. Pre- and post-test surfaces for each simulated event were compared and the volumetric difference between the two was calculated. These volumes, along with the volumes of soil introduced as sediment, were analyzed to determine a retained volume. Average sediment retention rates for installations that did and did not fail structurally (indicated by [a] in Table 8) were 78% and 95%, respectively. The sediment retention rates for each installation are shown in Table 8.

Table 8. Sediment Retention of Nonwoven Silt Fence Installations

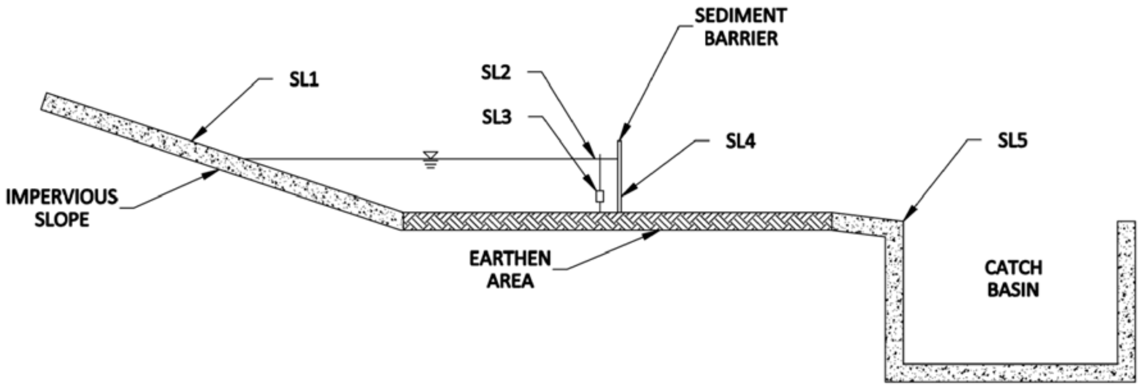
Description	Installation	Sediment Retained
STD-T	I1	87%
	I2	87%
	I3	75%
STD-S	I1	60%
	I2	68%
	I3	73%
M1	I1	53%
M2	I1	76%
M3	I1[a]	87%
M4	I1	90%
M5	I1	95%
M6	I1	96%
M7	I1[a]	100%
	I2[a]	100%
	I3[a]	96%
M8	I1[a]	90%
	I2[a]	91%
	I3[a]	98%

Note: [a] = failure did not occur.

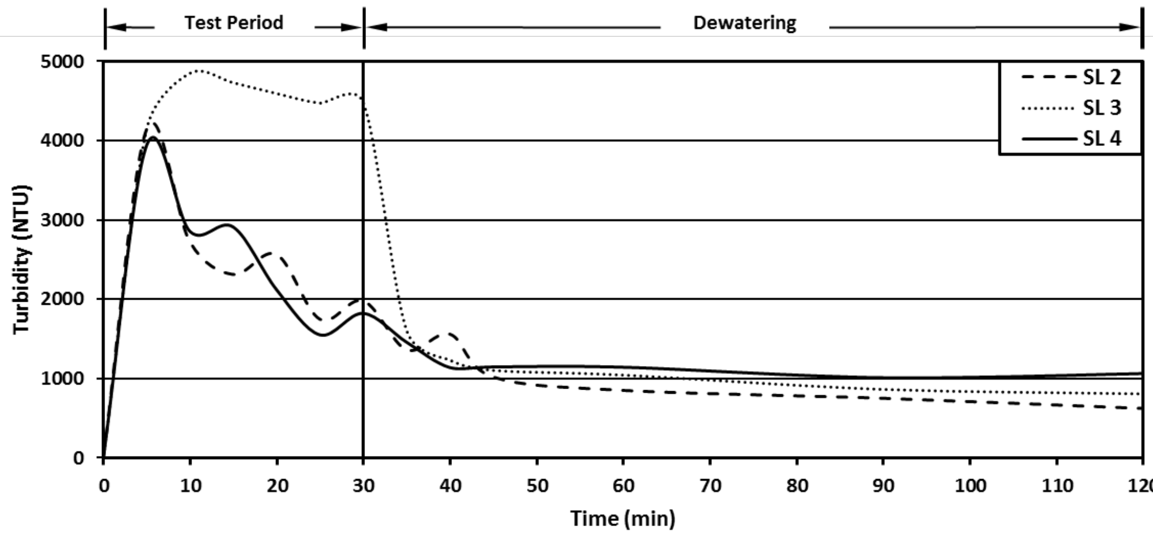
When comparing sediment retention rates for M7 and M8, it appears that M7 outperforms M8. While this could be true, it should be noted that volumetric analyses are based on topographic points collected via total station. Although survey personnel are adequately trained and protocols are in place to insure consistent data acquisition, minor elevation variations can result from slightly unleveled equipment, out-of-plumb instrument rod and prism, incorrect barometric pressure and temperature inputs, and human error. Under typical survey conditions, elevation errors of a few hundredths are negligible due to vastness of the area under evaluation; however, the area under evaluation during SB evaluations is under 320 ft^2 (29.7 m^2) with elevation changes as small as one hundredth of a foot. Thus, highly accurate data acquisition methods for quantifying volumetric difference has proven to be challenging. In this, these results should not be taken as highly accurate retention rates (e.g., $in.^3$) but instead practical retention rates (e.g., ft^3). Nonetheless, these finding are consistent with the result reported by Donald et al. (*2016*) for sediment retention rates of silt fence used as ditch checks. The majority of particle sedimentation occurred along the impervious slope, creating a cliff like deposition as shown in Figure 18(f). This sediment consisted of large granular particles that settled rapidly when velocity was reduced by the impoundment. Sediment particle size gradually decreased, as well as sedimentation depth along the flow direction. Sediment not retained by the silt fence was most likely smaller than the silt fence pores, thus were discharged in the effluent.

3.6.3 Water Quality

Throughout each simulated storm event, water samples were taken to evaluate the effect each installation had on water quality. Figure 20(a) illustrated grab sample locations. Since each installation used the same geotextile fabric, the results obtained were very similar between tests that did not experience structural failure. As shown in Figure 20(b), the difference in upstream-top of water (SL2) and downstream (SL4) water quality is negligible. As the test progresses, the water quality at each of these locations consistently improves (i.e., turbidity decreases). This improvement is most likely due to impoundment depth increasing as blinding of the fabric occurs along the face of the silt fence, creating a longer impoundment, resulting in a longer time period for sediment particles to fall out of suspension prior to reaching the silt fence fabric. When comparing upstream-top of water (SL2) and downstream (SL4) to upstream-bottom of water (SL3), it is further evident that impoundment depth directly affects water quality. On average, for installations that did not fail due to overtopping, a 56% reduction in turbidity was measured between SL3 and SL4 thirty minutes into each tests. Extreme variations in water quality were only observed when failures, such as overtopping or undermining, occurred.



(a) water sample locations



(b) typical turbidity graph for non-woven silt fence

Figure 20. Water quality sample locations and representative turbidity data.

3.6.4 Statistical Relevance

To statistically determine the effects of different installation configurations; a multiple linear regression model was developed. Each installation had a corresponding combination of independent variables considered in the analysis: (1) fence height, (2) T-post weight, (3) T-post spacing, and (4) trench offset. For this regression model, the Standard ALDOT Installation was considered the base installation, from which each installation variation was compared. The dependent variable selected for the analysis, which is directly affected by each independent variable, was T-post deflection. Deflections obtained from P1 tests were used within the model due to consistent initial conditions (i.e., unclogged filter fabric pores and plumb T-posts). A brief summary of T-post deflections used within the model is shown in Figure 21. The R^2 of the estimated model was 0.93, indicating a well-fitted linear model when compared to measured observations. Results of the analysis, along with statistical significances, are shown in Table 9.

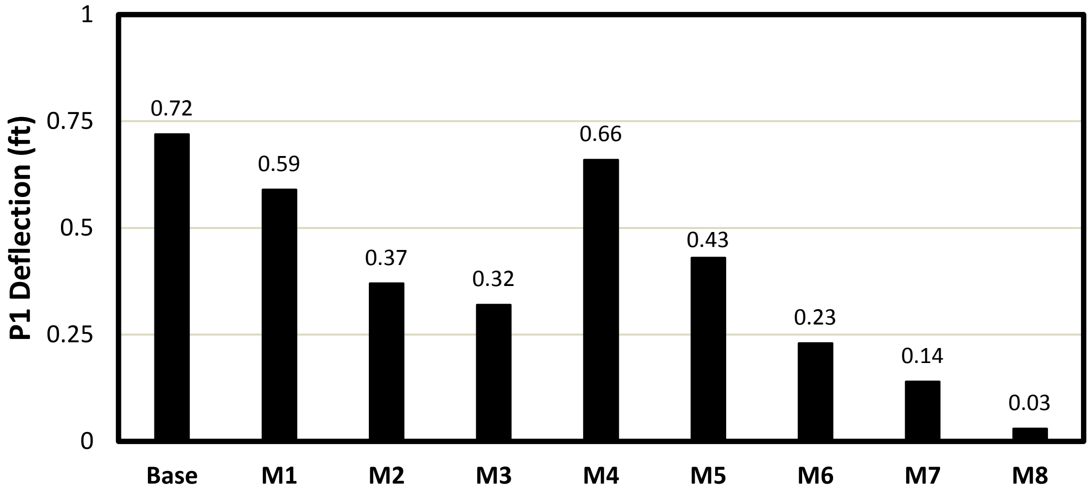


Figure 21. T-post deflection summary.

Table 9. Statistical Relationship of Installation Components

Installation Component	Statistical Significance	
	Coefficients	p-value[a]
Base (STD-T)	0.73	N/A
Fence Height	-0.13	0.024
T-Post Weight	-0.22	0.001
T-Post Spacing	-0.23	0.000
Trench Offset	-0.11	0.096

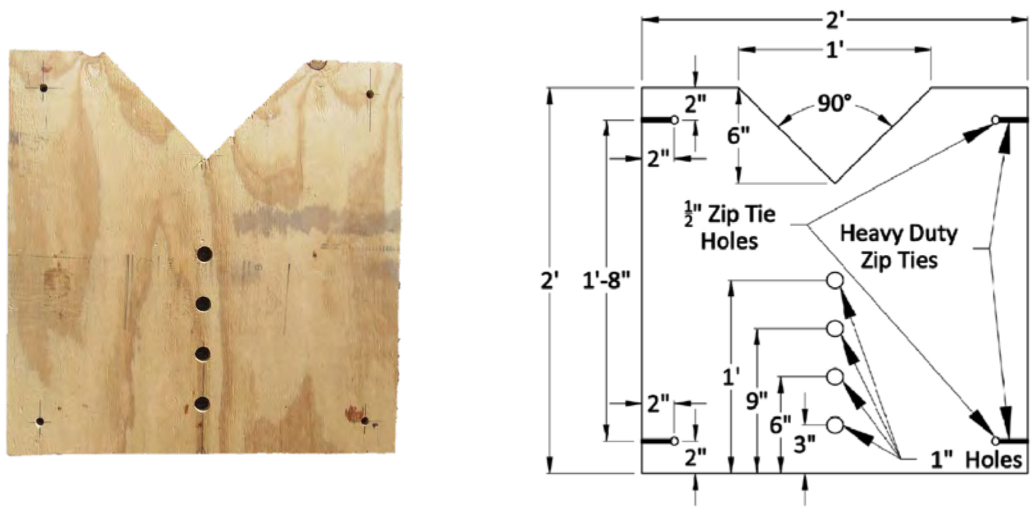
Note: [a] = comparison to effects of ALDOT Standard Silt Fence at 90% confidence interval and P-values <0.10.

Based on the statistical significance generated by the model, the following conclusions were drawn: (1) each installation component independently reduces fence deflection relative to the standard ALDOT installation, as evident by the negative coefficients (i.e., positive values indicate increased deflections, therefore negative values indicate decreased deflections), (2) each coefficient is statistically significant at a 90% confidence level, as indicated by p-values less than 0.1, thus signifying a positive effect on installation performance, (3) fence height and trench offsetting have the least effects on performance, and (4) T-post spacing and T-post weight have the greatest effects on performance. These statistical conclusions correlate to the structural failure mode observations outlined in Table 9, as well as sediment retention rates outlined in Table 8. When comparing measureable performance standards of each installation modification to the standard ALDOT installation, it is evident that each alteration facilitates a performance improvement.

3.7 SILT FENCE DEWATERING MECHANISM

During the performance evaluations of various silt fence installation modifications, a common reoccurrence was observed with each structurally sound installation. While upstream impoundment is critical to facilitate sedimentation, prolonged impoundment periods delay the drying effect once a storm event has occurred. During performance testing, impoundment periods for nonwoven silt fence installations were in excess of 24 hours from the conclusion of a simulated storm event. Due to excessive impoundment periods, a need was identified for an effective means for discharging impounded stormwater while promoting sediment retention upstream of the installation and minimizing effluent impacts to receiving waters. Thus, an objective was set to design, construct, and evaluate a cost effective device capable of preforming effectively when exposed to a 2 yr-24 hr design storm for the state of Alabama. Based on the knowledge obtained throughout silt fence testing and published literature, a silt fence dewatering weir was developed.

The dewatering weir was constructed out of ¾ in. (1.9 cm) plywood measuring 2 ft by 2 ft (0.6 m by 0.6 m) and supported by two 1.25 lb/ft (1.9 kg/m) steel T-post. The plywood was secured to the top and bottom of each T-post by drilling ½ in. (1.3 cm) holes in each corner of the plywood and installing heavy duty zip ties through each hole and around the T-post. The v-notch weir was cut at a 90-degree angle with a base elevation of 1.5 ft (0.46 m) from the earthen test area. Four, 1 in. (2.5 cm) holes are placed along the centerline of the plywood at elevations 0.25, 0.5, 0.75, and 1.0 ft (0.08, 0.15, 0.23, and 0.30 m) from the earthen test area. Figure 22(a) shows the plywood dewatering weir used during testing and Figure 22(b) illustrates dimensional details of the weir. Geotextile fabric was installed along the upstream face of the dewatering weir per M8 installation standards and a heavy duty staple gun was used to secure the fabric around each dewatering hole and along the v-notch weir opening. Once secured, a carpenter's knife was use to cut opening at each hole location. A 6 ft by 3 ft (1.8 m by 0.9 m) geotextile fabric underlay was installed downstream of the dewatering weir and secured using 6 in. (15.2 cm) circle top pins. Riprap was placed on top of geotextile underlay to facilitate energy dispersion as flow passed through each hole and across the weir.



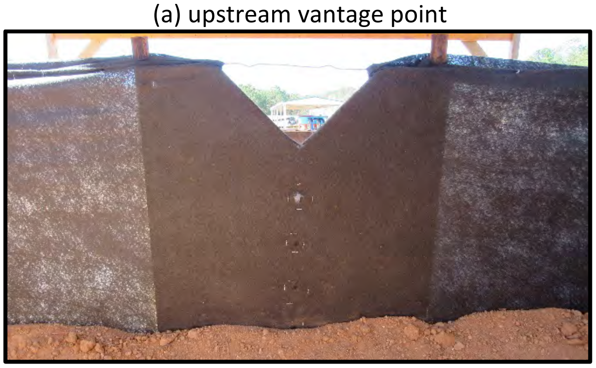
(a) plywood dewatering weir (b) weir detail

Figure 22. Silt fence dewatering weir details.

Performance tests were conducted on one installation of silt fence Modification 8 with the inclusion of the dewatering weir (i.e., Modification 9). In total, four performance tests were conducted on the installation. It is imperative that installers understand that in order for a dewatering weir to work effectively in field applications, the weir has to be installed in an area of concentrated impoundment, which is typically where silt fence structural failure occurs. The dewatering weir installation took minimal effort to install and proved to be a cost effective means for silt fence dewatering. Figure 23(a) – 23(d) shows the dewatering weir installation and Figure 24 provides installation details.


(a) upstream vantage point


(b) downstream vantage point


(c) front of weir


(d) back of weir

Figure 23. Dewatering weir installation.

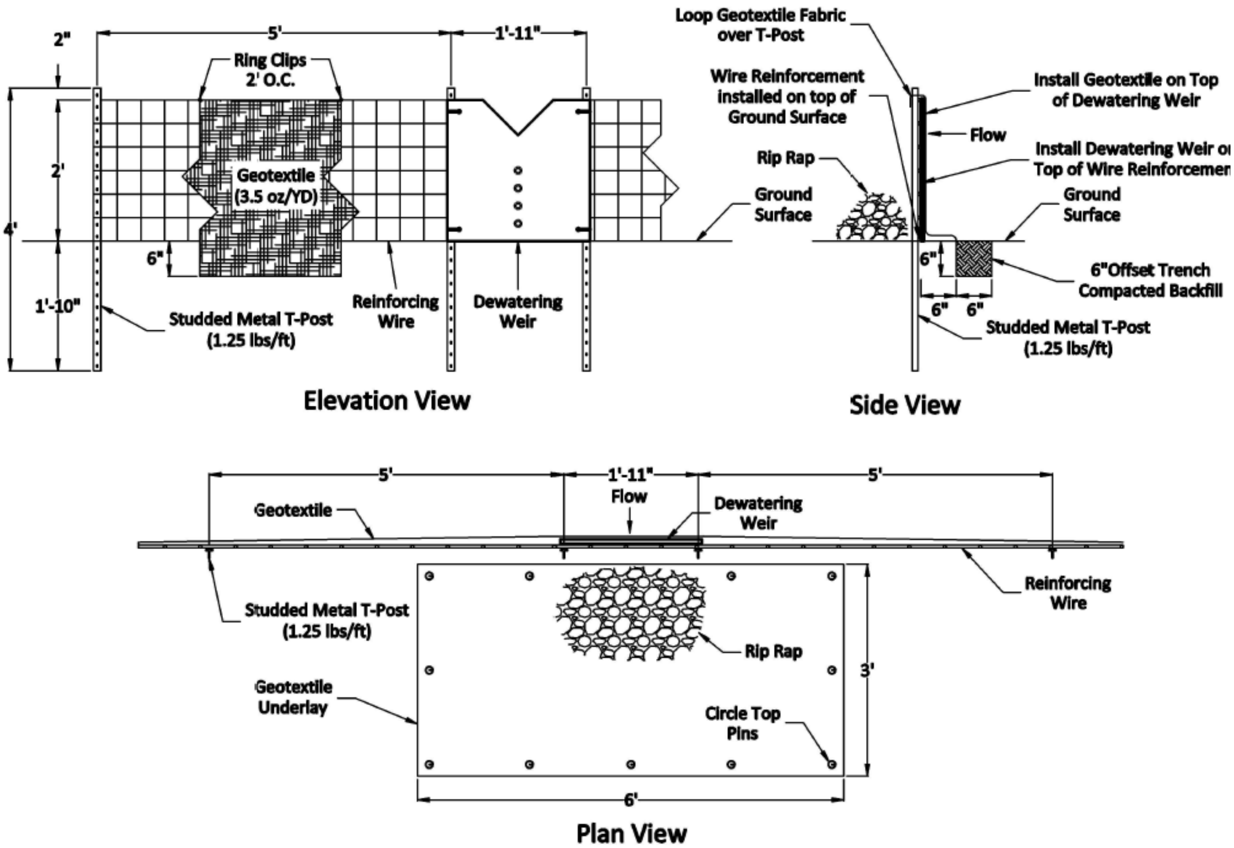


Figure 24. Dewatering weir installation detail.

Test results indicate that incorporating a dewatering weir into a structurally sound silt fence installation allows for a reliable and effective means for discharging impounded stormwater. Figure 25(a) shows sediment deposition that occurred during performance test 3 and Figure 25(e) shows downstream erosion resulting from three simulated storm event. When visually comparing post performance test 3 sediment deposition features of M9 (i.e., weir) to M8 (i.e., no weir), observations are consistent between tests [Figure 25(a) and 25(b)]. Due to the incorporation of a dewatering weir, downstream flow rates associated with M9 are significantly greater than those of M8. In addition, the increased flow rate is concentrated into a centralized area as opposed to being evenly distributed across the installation, which minimized downstream erosive forces. In order to minimize downstream erosive forces for M9, a riprap energy dissipater [Figure 25(c)] was installed along with a flow dispersion geotextile underlay [Figure 25(d)]. The implementation of these two components facilitated energy reduction in flow downstream of the dewatering weir which resulted in comparable downstream erosion rates for M9 and M8 [Figure 25(e) and 25(f)]. Soil erosion is less likely to occur in areas which vegetation has been established downstream of the dewatering weir; nonetheless, an energy dissipater should be installed to assist in soil stabilization. Figure 25(g) and Figure 25(h) show a silt fence field installation equipped with a dewatering weir.

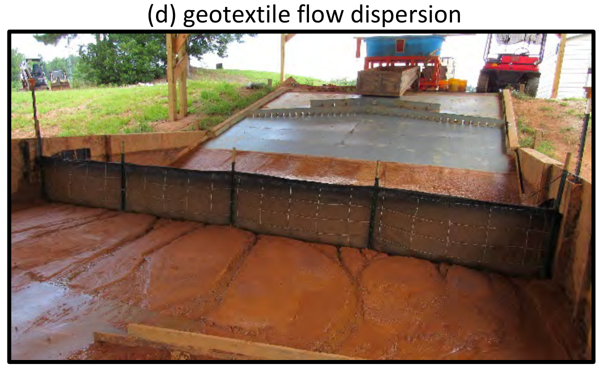
(a) M9 sediment deposition

(b) M8 sediment deposition

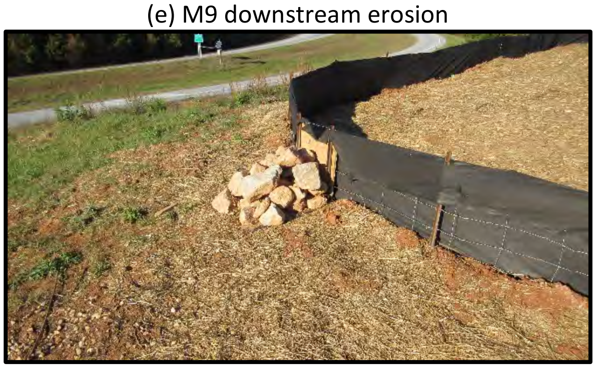
(c) riprap energy dissipater

(d) geotextile flow dispersion

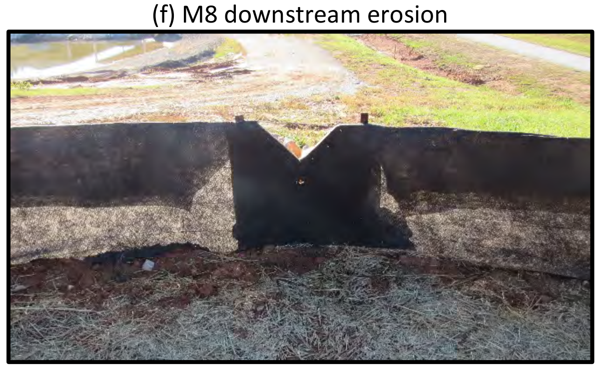
(e) M9 downstream erosion



(f) M8 downstream erosion



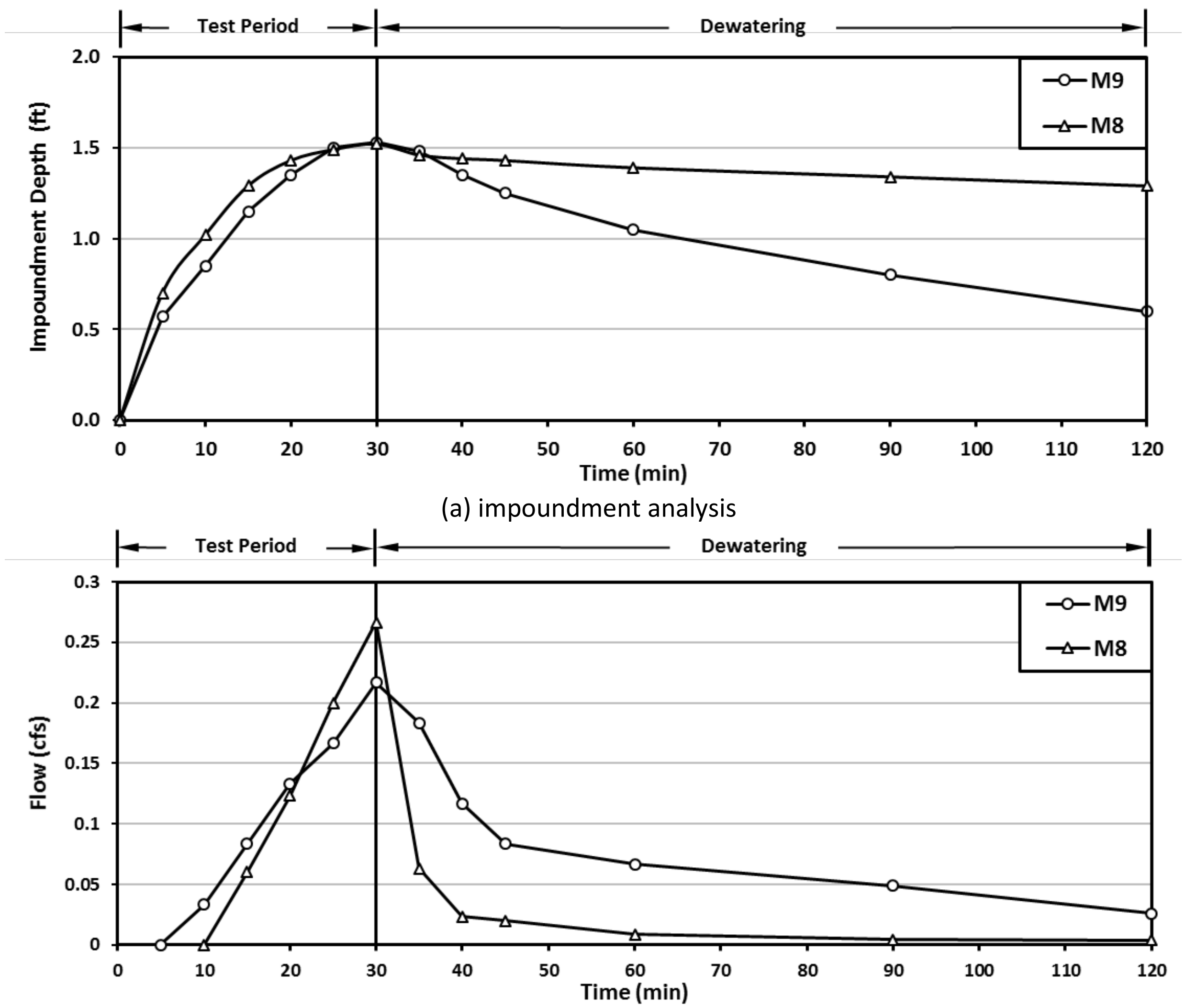
(g) field installation - downstream



(h) field installation - upstream

Figure 25. Dewatering weir performance comparison and field installation.

Sediment retention obtained during performance testing was 96% over four performance tests. This retention rate is comparable to the rates obtained from performance evaluations of M7 and M8, which had an overall average of 96%. Nevertheless, the inherent advantage gained by incorporating a dewatering weir is time savings associated with discharging impounded stormwater. The dewatering weir installation was able to reduce dewatering time from 24+ hours (i.e., M7 and M8) to 4 hours (i.e., M9) when measured from the conclusion of the simulated storm events. Figure 26(a) provides an impoundment depth analysis of performance test 3 for M9 and M8. During the test period, the impoundment depth for M9 is slightly less than M8 until an impoundment of 1.5 ft (0.46 m) is achieved. Once the test period concludes and dewatering begins, the rate of depth change for M9 is significantly greater than M8. To quantify the differences between rates of change, a regression analysis was conducted to determine the theoretical time required for each to dewater completely based upon recorded impoundment depths over the dewatering period. The theoretical dewatering times for M9 and M8 were estimated at 4 hours (i.e., as observed during testing) and 2.3 days, respectively. Theoretical equations and R^2 values are shown in Table 10. As illustrated in Figure 26(b), the average discharge flow rate of M9 during dewatering was 6.2 times greater than M8. These finding indicate that M9 adequately impounds water upstream to facilitate sedimentation while also discharging flow in a time effective manner.



(b) flow rate analysis

Figure 26. Dewatering weir hydraulic comparison.

Table 10. Theoretical Dewatering Correlation Equations

Description	Regression Equation	R^2
M8	$y = 1635.2x^2 – 4998.6x + 3848.7$ (Eq. 3)	0.9972
M9	$y = -95.37ln(x) + 68.929$ (Eq. 4)	0.9931

Note: x = impoundment depth (ft); y = dewatering time (minutes)

Figure 27 compares water quality from the surface of the impoundment and that which passed through the dewatering weir. The initial 5 minutes of testing consist of highly turbulent flow impoundment in which resuspension of sediment occurs. Between 5 and 10 minutes, a transition occurs in which turbulence is reduced due to increasing impoundment depth. At approximately 10 minutes, soil particle settlement within the impoundment enters a consistent state that improves slightly as impoundment increases. Once the simulated storm event concludes (i.e., 30 minutes into testing), water quality for each location quickly coverage to an average of 944 NTU for the remaining samples. Overall water quality differences between the sample locations is relatively small when compared to the sediment-laden flow introduced during testing, which typical ranges between 10,000 and 15,000 NTU. Using the turbidity data obtained during the dewatering period, a water quality correlation was developed based on impoundment duration. The theoretical duration estimated to reduce turbidity to under 100 NTU by means of particle settlement was approximately 5 days. The theoretical correlation is reported as duration (min) = $2E+10^8x^{-2.213}$ (Eq. 5), where x is turbidity in NTU. R^2 is reports as 0.9674.

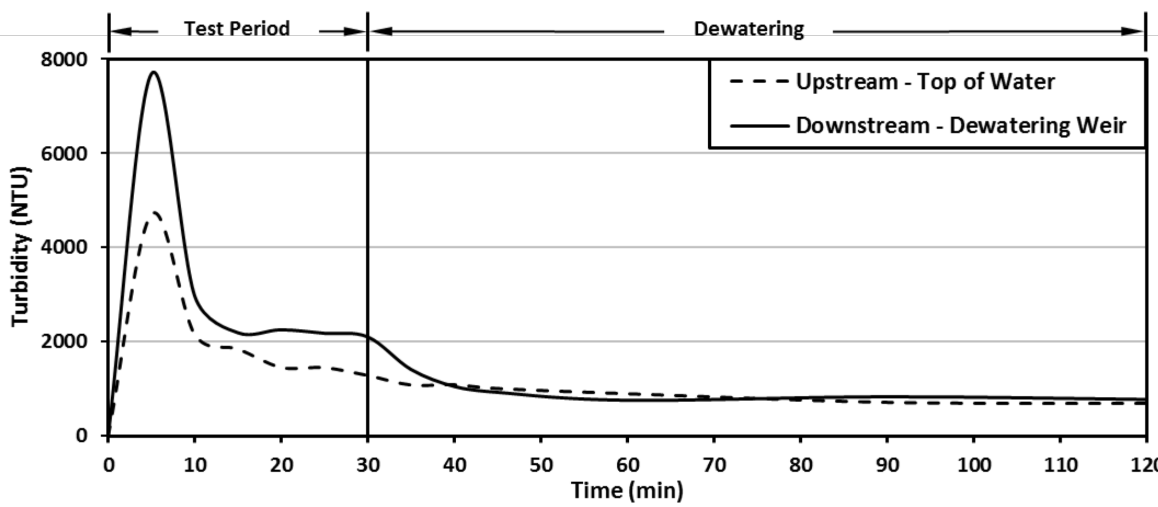


Figure 27. Dewatering weir water quality analysis.

3.8 SUMMARY

Current wire-backed, nonwoven silt fence installation practices implemented by ALDOT lack the structural ability to create and sustain impoundments required to promote sedimentation. The hydrostatic loading imposed on an installation by an impoundment may cause structural failures, thus resulting in untreated sediment-laden stormwater discharges to the surrounding environment. The research team at the AU-ESCTF evaluated the structural performance of eight silt fence installation configurations and demonstrated that a structurally sound silt fence practice is achievable.

The information obtained through this study shows that increasing T-post weight and decreasing T-post spacing greatly improves the structural integrity of silt fence installations. Additionally, reducing fence height and implementing an offset trench only provided slight structural improvements. However, from an installation standpoint, offset trenching allows for mechanical compaction, which ultimately has the potential to reduce the occurrence of scouring. Observations during testing suggest additional filter fabric support can be achieved by looping the fabric over each T-post. The volumetric analysis conducted on retained sediment shows that structurally sound silt fence installations have a retention rate of 95% as opposed to 83% for those that overtop. Water quality data indicated that as impoundment depth increases, water along the surface of the impoundment and downstream of the silt fence decreases in turbidity. Based on these finding, modification 8 had the best overall performance characteristics of the installation variations tested. As this installation method only varies in approach and not necessarily in equipment and effort needed, this method can easily be applied in the field with only minimal training of field personnel to improve silt fence structural performance. Structural performance and retention efficiency of an installation in the field can be effectively increased by implementing routine inspections and conducting preventive maintenance by removing accumulated sediment after storm events. Finally, incorporating a dewatering mechanism, such as a dewatering weir, can greatly reduce dewatering time while also achieving desired performance characteristics.

CHAPTER 4: PERFORMANCE EVALUATIONS OF INNOVATIVE AND MANUFACTURED SEDIMENT BARRIER PRACTICES

4.1 INTRODUCTION

This chapter describes the design characteristics of innovative and manufactured SB practices, recommended installation guidelines, and the results of performance evaluations. Each SB practice structure and material properties outlined are based on manufacturer's published product specifications. The aim for presenting this information is to provide insight into the vast array of products and materials currently available to the ESC industry. Installation guidelines provide guidance as to how each practice is constructed in field applications and the associated installation effort. Performance evaluations offer an unprecedented means for side-by-side comparisons of SB practices, as well as a scientifically backed approach for identifying and improving inefficiencies associated with practices.

The purpose for these experimental tests are to evaluate the overall performance capabilities of innovative and manufactured SB practices. Evaluations are based on installation feasibility, structural integrity, impoundment capability, effluent flow rate, sediment retention, and filtering capability. The innovative and manufactured SB practices selected for testing were grouped into three categories: (1) manufactured silt fence systems, (2) sediment retention barriers (SRBs), and (3) manufactured SB products. The practices that fall into each of these categories were selected for testing based on ALDOT perimeter control needs identified by the Project Advisory Committee (PAC).

4.2 MANUFACTURED SILT FENCE SYSTEMS

Though silt fence is a common practice used on construction sites, a subcategory of silt fence is what will be referred to as "manufactured silt fence systems." These two dimensional manufactured systems have fabric attached to reinforcement and support posts prior to distribution for sale. Therefore, only installation is required with no site assembly necessary. A component of this research study was to evaluate two-dimensional manufactured silt fence systems. The tested practices included Georgia Type C-Polypropylene on Polypropylene (C-POP) [Figure 28(a)] and Silt Saver-Stage Release Silt Fence (SRSF) [Figure 28(b)]. The C-POP system was tested per the GSWCC (*2016*) installation details for type C silt fence and the SRSF system was tested per the manufacturer's installation details and instruction. No attempts or iterations were made to improve the product's installation that would modify the design or fabrication of the systems. Currently, there are no manufactured silt fence systems approved for use as perimeter controls on ALDOT projects (*ALDOT 2018*).

(a) C-POP

(b) Silt Saver SRSF

Figure 28. Manufactured silt fence systems.

4.2.1 C-POP Sediment Barrier System

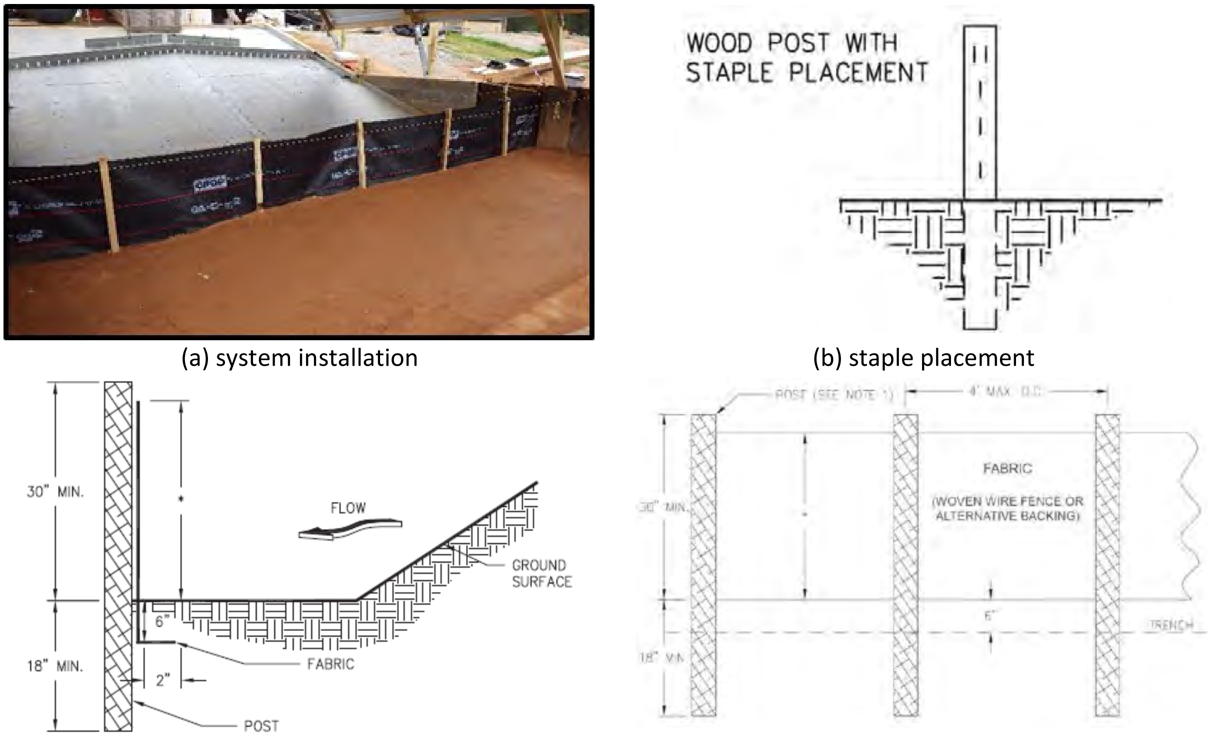
The C-POP SB system [Figure 30(a)] is a manufactured perimeter control device assembled within a factory environment prior to site delivery. The system is comprised of woven polypropylene geotextile, polypropylene support mesh, and hardwood posts. The woven geotextile fabric is 36 in. (91.4 cm) wide with a consistent monofilament weave texture throughout and conforms to the Georgia Department of Transportation (GDOT) Type C silt fence specification, which are shown in Table 11. Support mesh extends the entire width of the geotextile fabric and has an apparent opening size of 0.9 in. (2.3 cm) by 1.45 in. (3.7 cm). The reinforcement is necessary because this system is classified for sensitive applications in which the geotextile fabric may be exposed to particularly high flows or where slopes exceed 10 ft (3 m) in vertical height (*GSWCC 2016*). The system is supported by 2 in. (5.1 cm) by 2 in. (5.1 cm) hard wood posts that have a minimum length of 4 ft (1.2 m). Post are spaced 4 ft (1.2 m) on-center and attached to the geotextile fabric and support mesh via 17 gauge (1.14 mm) by 0.5 in. (1.3 cm) wire staples. Each post is required to have five wire staples supporting the geotextile fabric and mesh. Wire staple placement for each post is illustrated in Figure 29(b).

Table 11. GDOT Type C Geotextile Specifications (*GSWCC 2016*)

Property	Test Method	Requirement
Tensile Strength (lb min.)	ASTM D4632	MD 260 X-MD 180
Elongation (% max)	ASTM D4632	40
AOS (max. sieve size)	ASTM D4751	#30
Flow Rate (gal/Min./ft^2)	GDT-87	70
UV Stability (% retained @ 300 hr)	ASTM D4355	80
Bursting Strength (psi min.)	ASTM D3786	175

Note: AOS = apparent opening size

Installation details shown in Figure 29(c) and 29(d) illustrate that posts should be driven a minimum of 18 in. (45.7 cm) into the ground and be exposed a minimum of 30 in. (76.2 cm) above the ground surface. The geotextile height is not specified in the details but typical systems are assembled with 28 in. (71.1 cm) of geotextile attached above the ground surface. The geotextile is secured in the ground by entrenching the fabric 6 in. (15.2 cm) deep by 2 in. (5.1 cm) horizontally and compacting the backfill material. This process minimizes the occurrence of flow bypass underneath the installation during storm events.



(a) system installation (b) staple placement

(c) side view (d) front view

Figure 29. Georgia type C silt fence product details. (*GSWCC 2016*)

4.2.2 SILT-SAVER (SILT-SAVER®, INC.) STAGE RELEASE SILT FENCE

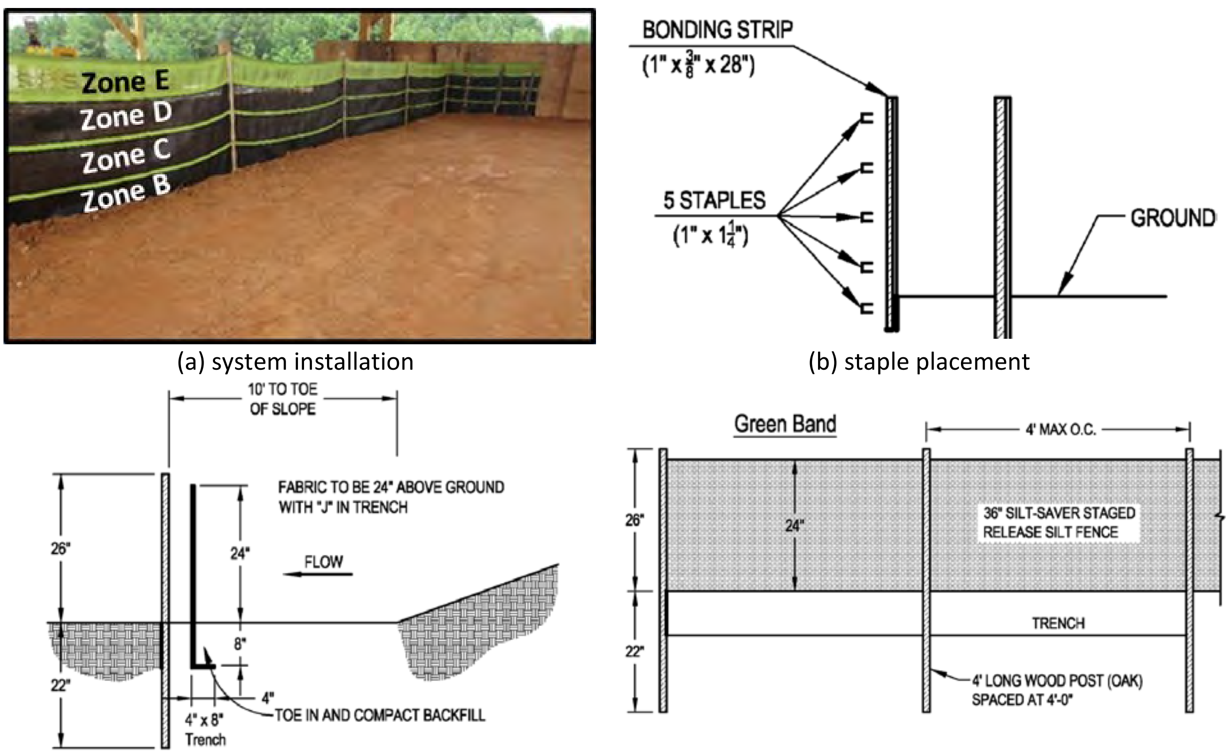
The Silt Saver-Stage Release Silt Fence (SRSF) is a silt fence system that allows increased flow-through capacity of stormwater runoff as impoundment depth increases upstream of the practice. This manufactured product is made of a woven monofilament geotextile that incorporates five slit-film spacing specifications in the machine direction based on horizontal regions. As shown in Figure 30(a), the geotextile is divided into five zones with woven reinforcement belts separating each. Zone A is the portion of geotextile that is entrenched during installation, while Zones B-E capture and impound stormwater runoff. The flow rate associated with each of the impoundment zones increases with depth, as shown in Table 12. Interwoven reinforcement belts (green belts) provide structural support to the systems, as the slit-film strands within the belted regions are denser than each of the zones. As with the C-POP system, support in provided by 2 in. (5.1 cm) by 2 in. (5.1 cm) hard wood posts that have a minimum length of 4 ft (1.2 m) and spaced 4 ft (1.2m) on center. As shown in Figure 30(b), the geotextile is attached to support posts using 1 in. (2.54 cm) by 1.25 in. (3.18 cm) wire staples and a wood bonding strip, which distributes the support force applied with each wire staple.

Table 12. Silt Saver – SRSF Geotextile Specification (Silt Saver 2015)

Property		Zone A	Zone B	Zone C	Zone D	Zone E
Zone Width (in.)		11.75	6.75	5.25	5.00	3.25
Tensile Strength (lb)	MD	458	537	458	420	301
	X-MD	234	254	234	238	209
AOS (US sieve size)		20	40	20	20	20
Flow Rate (gal/Min./ft^2)		210	141	210	235	324

Note: MD = machine direction; X-MD = cross machine direction

The installation details for the SRSF are slightly different from that of GDOT. Figure 30(c) and (d) illustrate a post depth of 22 in. (55.9 cm) below ground and a post height of 26 in. (66.0 cm) above the ground surface. Geotextile height is 24 in. (61.0 cm) with an entrenchment of 8 in. (20.3 cm) deep by 4 in. (10.2 cm) horizontal with compacted backfill. Additionally, the detail specifies that the silt fence system should be installed 10 ft (3.0 m) from the toe of the upstream slope. This provides an adequate upstream impoundment pool to facilitate particle sedimentation. However, in order to compare performance results from SRSF testing with other practices, a 6 ft (1.8 m) installation distance from the toe of the impervious test slope was used.



(a) system installation (b) staple placement

(c) side view (d) front view

Figure 30. SRSF product details. (Silt Saver 2015)

4.3 SEDIMENT RETENTION BARRIERS (SRB)

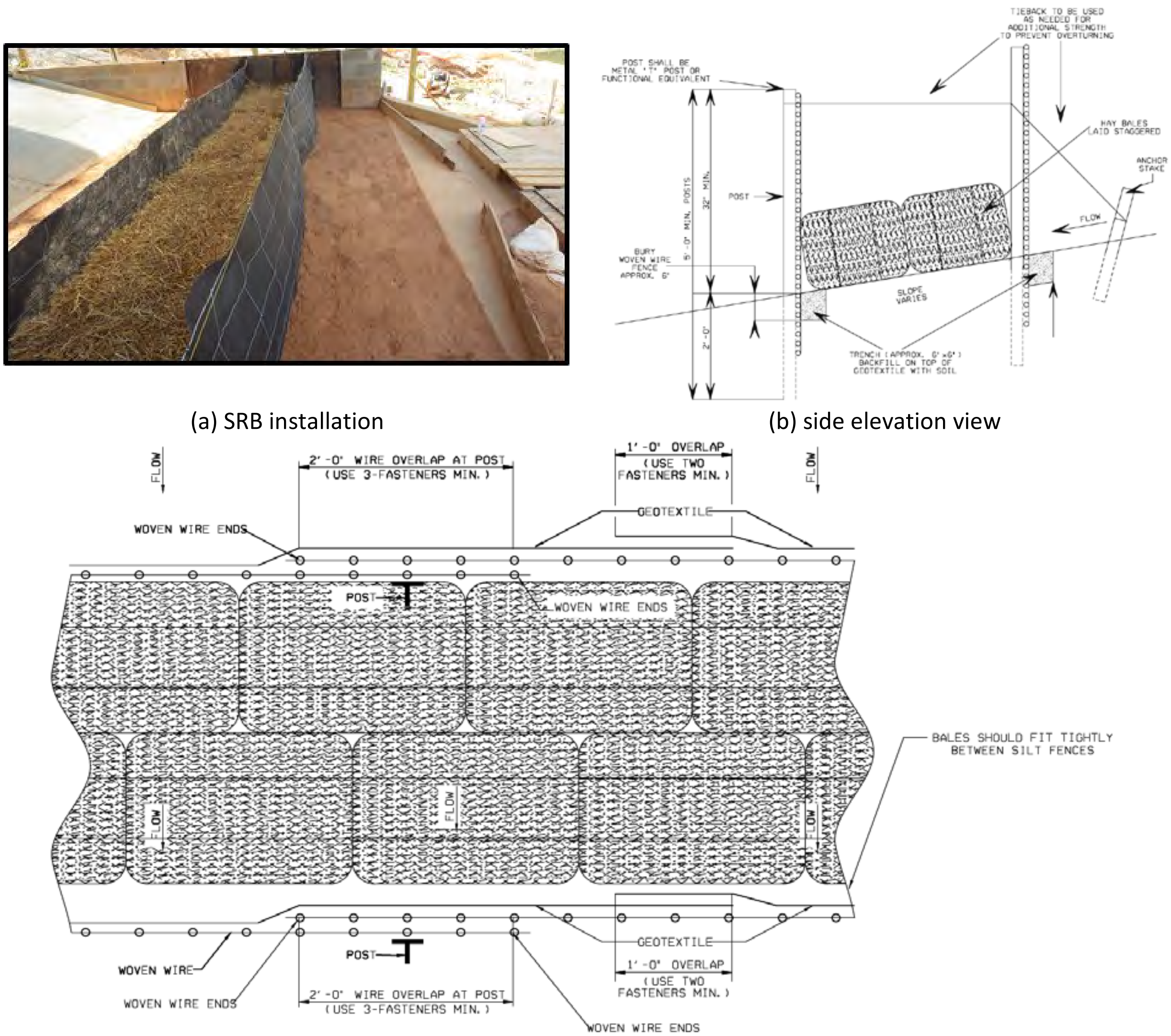
SRBs are designed to provide additional treatment to stormwater runoff above that of a single silt fence installation. Traditional silt fence installations treat stormwater using a single geotextile installed in a planer dimension. Once flow passes the geotextile, additional improvements to water quality are dependent on natural sediment removal processes such as vegetated buffers. SRBs apply a multi-faceted approach in which an additional dimension is incorporated to facilitate improved effluent water quality. Performance evaluations were conducted on three SRBs, which include: (1) Alabama Department of Transportation SRB, (2) Alabama Handbook SRB without flocculant, and (3) Alabama Handbook with flocculant. Installations followed the ALDOT and Alabama Handbook design specifications and no attempts were made to enhance the installation or performance of the SRBs. Common materials used throughout testing to construct each of the different types of SRBs are pictured in Figure 31(a) – 31(h). The nonwoven geotextile fabric [Figure 31(c)] was only used during ALDOT SRB testing while jute matting [Figure 31(d)] and polypropylene netting [Figure 31(e)] were only used during AL Handbook SBR testing.

(a) studded T-post
(b) reinforcing wire
(c) nonwoven geotextile fabric
(d) jute matting
(e) polypropylene netting
(f) wheat straw bales
(g) c-ring clips
(h) aluminum wire ties

Figure 31. Common SRB installation materials.

4.3.1 ALDOT SRB

The ALDOT SRB is an alternative to the ALDOT silt fence practice, in that it can be implemented in areas down grade of newly graded fill slopes and adjacent to streams and channels where overland flow is low to moderate. The installation and details shown in Figure 32(a) – 32(c) consist of two ALDOT silt fence installations running parallel with staggered wheat straw bales placed tightly between the fences. Silt fence installation details associated with the SRB are the same as a single ALDOT silt fence installation. Each SRB silt fence is installed in a 6 by 6 in. (15.2 by 15.2 cm) trench using 0.95 lb/ft (1.4 kg/m) T-posts spaced 10 ft (3.0 m) on center and driven 24 in. (61 cm) into the ground. Reinforcing wire is placed in the trench and secured to T-posts using wire clips. The geotextile is secured to the wire reinforcement using c-ring clips spaced 24 in. (61 cm) on center. The geotextile is placed in the trench in a "J" configuration and backfill with soil. This installation requires stormwater runoff to pass through two nonwoven silt fence installations, as well as wheat straw bales prior to site discharge.



(a) SRB installation

(b) side elevation view

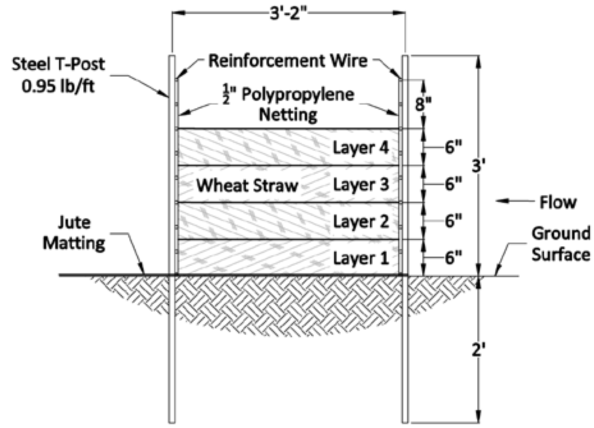
(c) plan view

Figure 32. ALDOT SRB installation details. (*ALDOT 2017*)

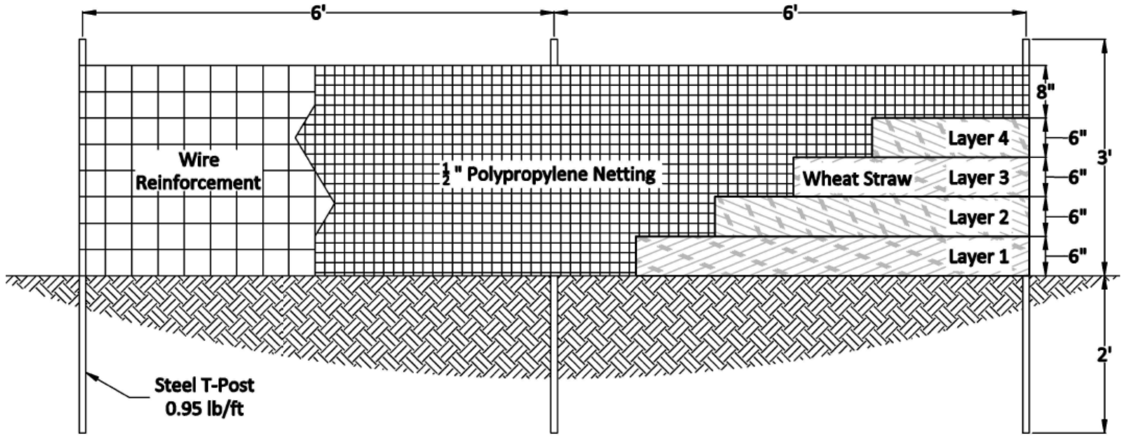
4.3.2 ALABAMA HANDBOOK SRB

The Alabama Handbook (HB) SRB resembles a double row silt fence installation but is only intended to be used as a polishing tool to reduce turbidity in stormwater discharged to sensitive areas. It should not be used as a replacement or alternative for perimeter controls. The SRB information provided within the Alabama Handbook is limited regarding materials and installation guidelines, thus manufacturers and distributors who have experience with SRB practices were consulted to development an effective installation method. The resulting practice consists of two parallel rows of 0.5 in. (1.3 cm) polypropylene netting supported by wire reinforcement and 0.95 lb/ft (1.4 kg/m) T-posts spaced 6 ft (1.8 m) on center. Jute matting is installed along the ground surface between the parallel rows, as well as downstream of the installation to facilitate sediment capture. Loose wheat straw is placed on top of the jute matting in 6 in. (15.2 cm) lifts between the parallel rows of netting to a depth of 24 in. (61.0 cm). Evaluations were conducted on configurations of the installation that did and did not incorporated granulated flocculant powder. When adding flocculant to the SRB, manufactures recommendations should be followed to insure proper application rates. During flocculant testing, APS 700 Series Silt Stop Powder was applied between the double rows of netting at a rate of 0.67 lb/ft (1.0 kg/m) of SRB. This granulated flocculant was anionic (i.e., negatively charged), which has not been proven to harmfully affect aquatic life (*Peng and Di 1994*, *Qian et al. 2004*, *USEPA 2005*, *Sojka et al. 2007*). Flocculant was placed in five lifts (i.e., on top of jute matting and on top of each wheat straw layer) to achieve an even distribution within the medium. Additionally, flocculant was applied on top of the jute matting downstream of the practice at a rate of 25 lb/ac (28 kg/ha). Field applications of this practice should insure an adequate perimeter control practice be installed downstream to removed flocculated sediment from the treated stormwater discharge. This system should not be used directly upstream of flow conveyance systems, such as creeks and streams, due to insufficient means of offsite sediment capture. Figure 33(a) – 33(d) illustrates the AL HB SRB installation and associated details followed during performance evaluations.

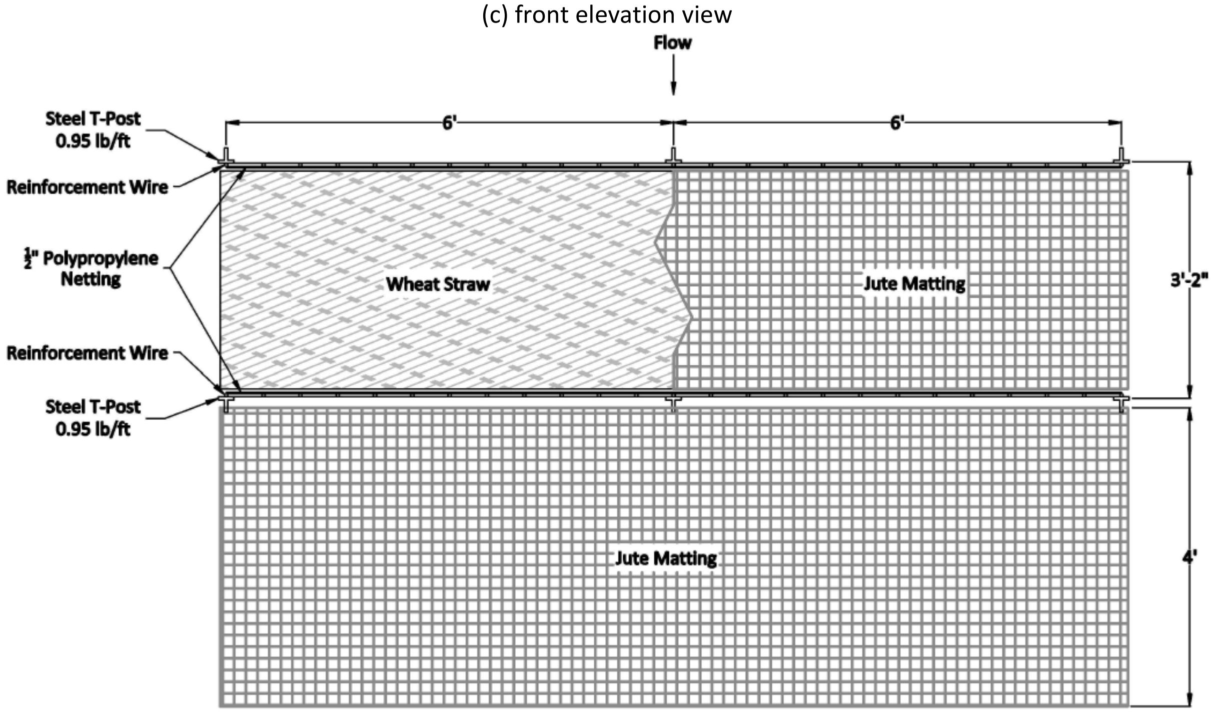
(a) SRB installation



(b) side elevation view



(c) front elevation view



(d) plan view

Figure 33. Alabama Handbook SRB details.

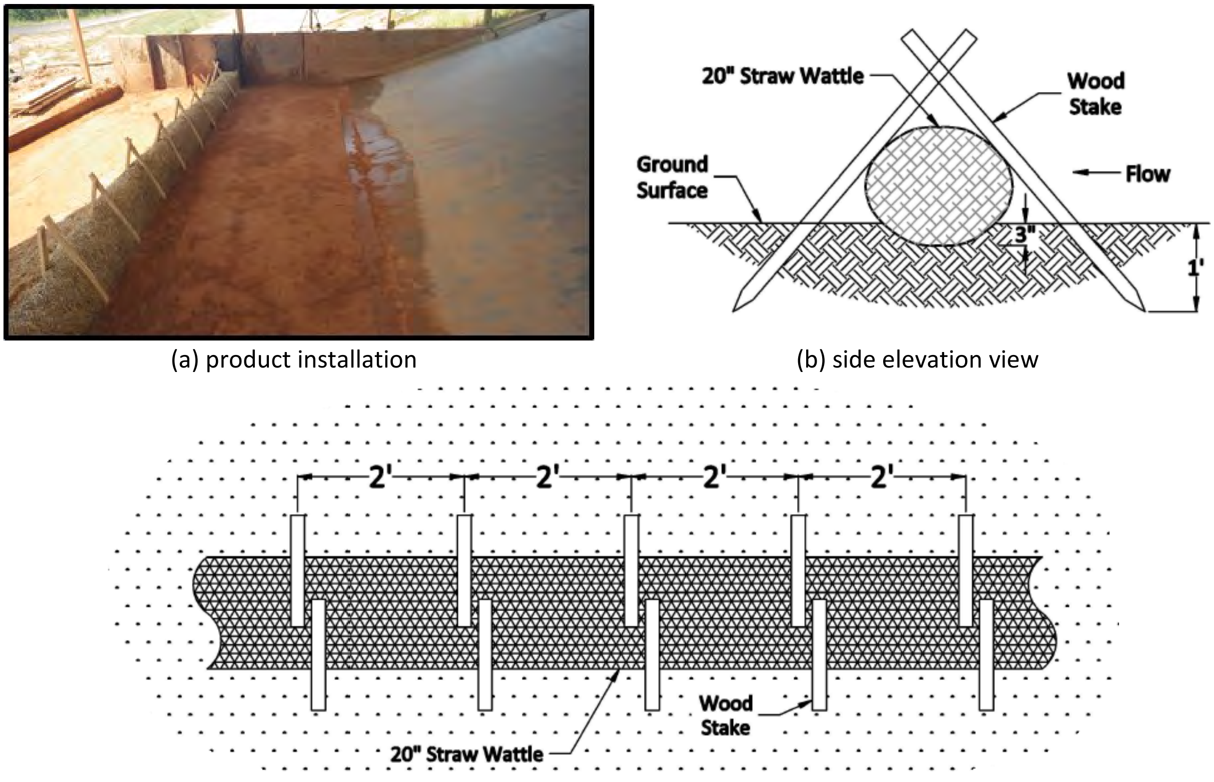
4.4 MANUFACTURED SEDIMENT BARRIER PRODUCTS

The erosion and sediment control industry has a vast array of proprietary products that can be installed as perimeter control devices. The ALDOT Standard Drawings detail three specific perimeter control practice installations, which consist of silt fence, SRBs, and temporary brush barriers (*ALDOT 2017*). The exception to these standard drawing details is the inclusion of a 20 in. (50.8 cm) wattle, within a silt fence installation, as a water release mechanism. The ALDOT Standard Specifications for Highway Construction state that SBs installed adjacent to construction limits or along live stream may consist of silt fence, hay bales, sand bags, silt dikes, or wattles (*ALDOT 2016*). However, the ALDOT Temporary Erosion and Sediment Control Products List II-24 does not provided a section indicating approved products for perimeter control applications (*ALDOT 2018*). Due to limited guidance regarding sediment control product applicability (e.g., ditch check, inlet protection, and perimeter control), SB evaluations were conducted on three proprietary sediment control devices to determine overall performance characteristics and limitation when installed as a perimeter control. The tested products included: (1) Western Excelsior – Excel Straw Logs™, (2) Filtrexx® – SiltSoxx™, and (3) American Excelsior – Curlex Bloc. Manufactured products were tested under modified installation details to facilitate upstream impoundment and minimize flow bypass; however, no attempts were made to improve the design or fabrication of the product itself. Currently, the Western Excelsior – EXCEL Straw Log and Filtrexx – Siltsoxx are approved wattles for use on ALDOT projects (*ALDOT 2018*) per ALDOT List II-24.

4.4.1 WESTERN EXCELSIOR – EXCEL STRAW LOGS™

Western Excelsior – Excel Straw Logs are designed to be implemented as slope interrupters, ditch checks, and inlet protection. Excel straw logs are available in 9, 12, 18, and 20 in. (23, 30, 46 and 51 cm) diameters and 10, 20, and 25 ft (3.0, 6.0, and 7.6 m) lengths. Manufacturing is achieved by filling a 0.5 by 0.5 in. (1.3 by 1.3 cm) tubular heavy duty synthetic net with a straw fiber matrix until the specified diameter density is achieved. Each end of the log is securely closed using hog rings clips (*Western Excelsior 2017*).

ALDOT currently does not have a standard installation detail for wattles installed as perimeter controls; however, standard installation details for wattles used as ditch checks and inlet protection are available (*ALDOT 2017*). In each of these details, wattles are installed on top of the ground surface using a teepee-staking pattern. The main difference between the two installations is the inclusion of a geotextile underlay when installed as a ditch check. The manufacturer's published perimeter guard installation detail illustrates placing the straw log in a 3 in. (7.6 cm) deep trench and backfilling (*Western Excelsior 2018*). Once compaction is achieved, wood stakes are driven through the center of the straw log and imbedded 12 in. (30.5cm) into underlying soil. Considering each of these details as a feasible installation technique, a hybrid installation approach was developed that incorporated teepee staking and trenching [Figure 34(a)]. This installation procedure is shown in Figure 34(b) and was implemented during performance evaluations of installations I1 and I2. To evaluate an additional installation strategy, trenching was eliminated and a geotextile underlay was incorporated, as shown in the ALDOT ditch check detail, during the performance evaluation of installation I3. The manufacturer's installation details do not specify wood stake spacing; however, ALDOT required a 2 ft (0.6 m) stake spacing. Thus, a 2 ft (0.61 m) stake spacing was implemented during performance evaluations, as shown in Figure 34(c).



(a) product installation (b) side elevation view

(c) plan view

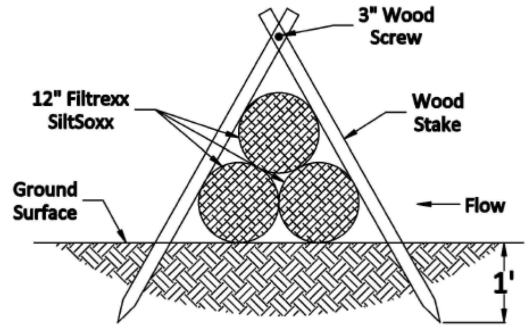
Figure 34. Wattle installation.

4.4.2 FILTREXX® – SILTSOXX™

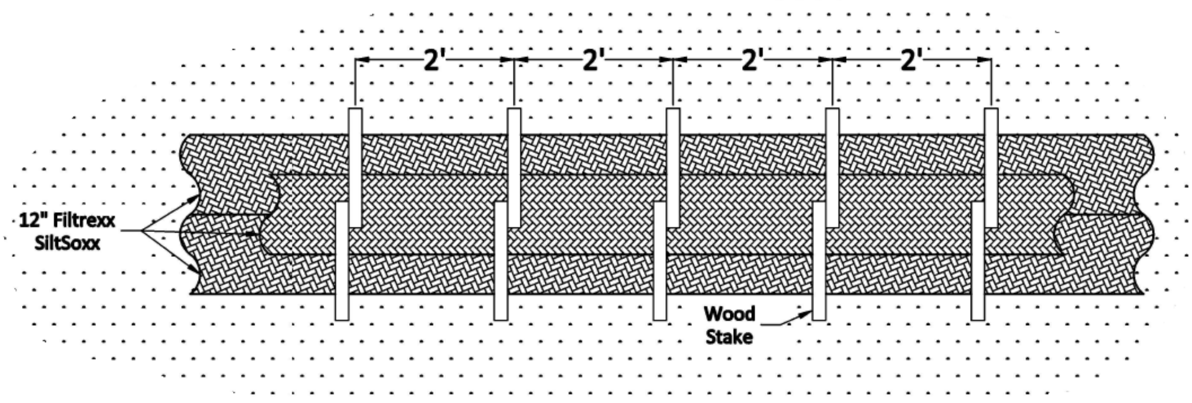
The SiltSoxx is a tubular manufactured sediment control product that can be implemented in a variety of stormwater treatment applications. The product is available in 5 to 32 in. (13 to 81 cm) diameters and lengths up to 200 ft (61 m). For applications requiring large diameters and/or extensive lengths, the containment system can be filled with media material on-site. Containment systems are available in a wide variety of cotton, high density polyethylene (HDPE), and multi-filament polypropylene (MFPP) materials, each having unique material specifications and applications. Media material within the containment system consist of compost that is produced from organic matter using an aerobic composting process (*Filtrexx 2015*). When compared to similar products containing straw and excelsior fiber, this product is considerably denser per unit volume.

The Filtrexx design manual illustrates two installation details for perimeter controls. The single SiltSoxx installation calls for the product to be placed on level ground and secured using 2 in. (5 cm) wooden stakes driven through the center of the SiltSoxx every 10 ft (3 m). Alternatively, three SiltSoxxs can be installed in a pyramid fashion with two products places on level ground, side by side, and a third placed on top. This method calls for teepee wood staking through the SiltSoxxs spaced 10 ft (3 m) on center. Tie wire is used to secure the exposed ends of the teepee stakes to promote downward pressure on the installation. Additionally, wood stakes are driven through the center of each SiltSoxx in contact with ground surface. These stakes are placed intermittently between teepee stake locations. Filtrexx installation details are provided in Appendix B. As shown in Figure 35(a-c), the installation method implemented during performance evaluations varied slightly from the manufactories pyramid installation recommendation. Teepee staking was used to secure the SiltSoxxs in place but the HDPE containment netting was not punctured. Stakes were placed 2 ft (0.6 m) on center and wood screws were used in lieu of tie wire to facilitate improved ground contact over the length of the installation.

(a) product installation



(b) side elevation view



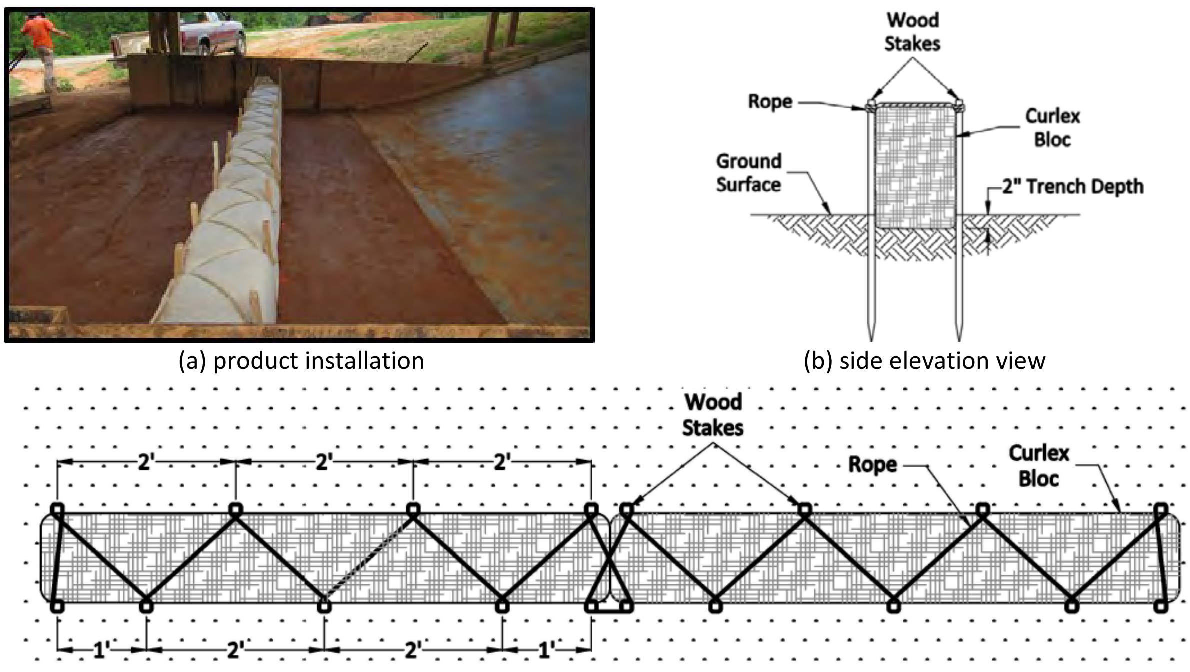
(c) plan view

Figure 35. SiltSoxx installation.

4.4.3 American Excelsior Company® – Curlex® Bloc

The third manufactured product evaluated was the Curlex Bloc. This product is designed for a wide variety of construction applications, as well as shoreline and streambank restoration. Curlex Blocs are composed of an excelsior fiber matrix contained within a biodegradable tubular cotton netting. The excelsior matrix is made from great lakes aspen wood that has curled, interlocking fibers with barbed edges that provide added strength and stability to the product. A unique feature of the Curlex Bloc is its rectangular cross-sectional shape and flat footprint, which promotes increased ground contact as compared to traditional tubular products. Typical nominal dimensions of the Curlex Bloc are 18 by 16 in. (46 by 41 cm) with lengths of 4 and 8 ft (1.2 and 2.4 m) (*American Excelsior Company 2018*).

The manufacturer's product installation guidelines and detail drawings indicate that the product can be installed on bare soil or over roller erosion control products. When implementing the Curlex Bloc as a perimeter control, an optional trenching installation is provided to improve sediment reduction in stormwater effluent. Each Curlex Bloc is manufactured with an extra flap of containment material attached to one end that can be pulled over an adjoining Curlex Bloc to form a seamless joint, thus creating a continuous installation. The product is secured in place using 1 by 1 in. (3 by 3 cm) wooden stakes and non-stretching rope. Stakes are driven tightly against each side of the Curlex Bloc every 2 ft (0.6 m) in an alternating pattern. Details illustrate that each stake be notched approximately 2 in. (5 cm) from the top as to provide a mean for securing the rope to the stake. Stakes are to be driven into the soil until approximately 4 in. (10 cm) of stake is remaining above the Curlex Bloc. Rope is then installed according to the details [Figure 36(c)] and tightly wrapped around each notch. Stakes are then driven down to tighten the rope [Figure 36(a) and 36(b)] and achieve an installation that is secured firmly to the ground.



(c) plan view

Figure 36. Curlex Bloc installation.

4.5 RESULTS AND DISCUSSION

The evaluation of innovative and manufactured SB practice performance is based on data and observations collected throughout experimentation. Observational data gathered during testing includes still imagery and video from multiple perspectives. Physical data collected includes: impoundment length and depth, downstream catch basin depth, sediment deposition surveys, and water quality grab samples. These parameters were used to assess the overall performance of each innovative and manufactured SB practice.

4.5.1 INSTALLATION & STRUCTURAL EVALUATION

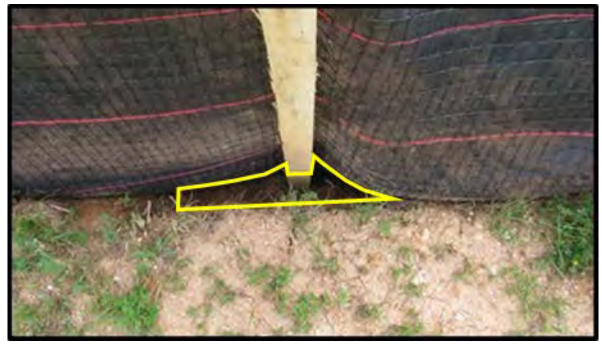
Performance results of SB practices will be comparatively evaluated in three representative categories: Manufactured Silt Fence Systems, Sediment Retention Barriers, and Manufactured Sediment Barrier Products.

4.5.1.1 Manufactured Silt Fence Systems

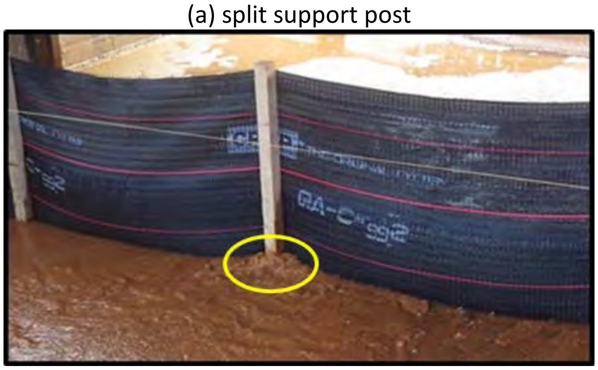
Manufactured silt fence systems are available for a range of site specific applications. The systems selected for this study are designed for 0.5 ac (0.2 ha) drainage areas with high overland flows. The installation process is similar to traditional silt fence in which the geotextile is entrenched to facilitate upstream impoundment. However, installation economics associated with manufactured silt fence systems is advantageous due to practice preassembly. In-field labor efforts for installation consist of excavating a trench, unrolling the system, driving wooded support post, backfilling the trench, and compacting the soil. Common issues associated with such installations included insufficient soil compaction during trench back filling, broken support post [Figure 37(a)] and downstream post voids [Figure 37(b)]. Support posts can be easily damaged during installation and during construction activities. Defective support post can affect the performance of an installation by inadequately supporting the geotextile upon hydrostatic loading, resulting in uncontrolled stormwater discharge due to overtopping. Post voids are created when support posts are driven into the bottom of an excavated trench and inadequately backfilled and compacted downstream of the installation. During C-POP testing, this proved to be a significant factor affecting the performance of the system. As shown in Figure 37(c), undermining occurred at a post installation due to insufficient soil compaction. To insure undermining would not reoccur during SRSF testing, extra dirt was added downstream of the installation and compacted using a sledgehammer [Figure 37(d)]. Although this method proved effective during performance testing, in-field backfill compaction downstream of the installation is highly unlikely. A possible alternative would be to implement an offset trench installation in which the support posts are driven into undisturbed soil 6 in. (15 cm) downstream of the trench, thus eliminating the interference posts have with trench backfill and compaction.

The overall structural integrity of each system proved to perform exceptionally during longevity testing. Each system incorporates hardwood support posts spaced 4 ft (1.2 m) on center, as called for in the temporary silt fence requirement of AASHTO M 288-17 (*AASHTO 2017*). Maximum horizontal post deflections measured over the course of three simulated storm events for C-POP and Silt Saver – SRSF were each 0.13 ft (0.04 m). These measurements indicate that hardwood support posts provided adequate structural stability to the system when subjected to multiple design storms. Geotextile reinforcement for each system is unique in that C-POP incorporates polypropylene netting sown to the downstream face of the geotextile and SRSF uses high strength belts horizontally interwoven into the geotextile. Observations made during testing indicate that each of these reinforcement methods performed effectively in lieu of wire reinforcement given the design specifications (e.g., 4 ft [1.2 m] post spacing and high flow geotextile) of each system. When compared to a nonwoven fabric, the woven monofilament geotextiles used in these systems were observed to be less susceptible to pour clogging due to a larger apparent opening size. This resulted in reduced hydrostatic loading on the silt fence systems over the course of multiple simulated storm events.

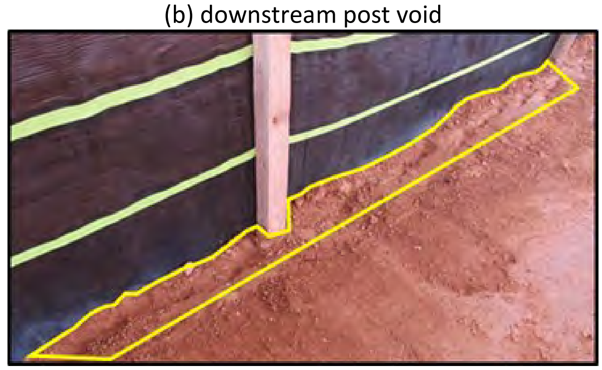
(a) split support post



(b) downstream post void



(c) post undermining



(d) downstream compacted backfill

Figure 37. Manufactured silt fence system installation evaluation.

4.5.1.2 Sediment Retention Barriers (SRBs)

The standard ALDOT SRB calls for two parallel Type A silt fence installations with bales placed tightly between each fence with staggered end abutments. Bales can consist of hay or straw with a minimum volume of 5 ft^3 (0.14 m^3), weight of 35 lb (16 kg), and length of 3 ft (0.9 m) (*ALDOT 2016*). The concept behind this installation is not for the bales to improve water quality, but provided structural support to the upstream silt fence installation. This is accomplished by distributing and transferring the hydrostatic load placed on the upstream silt fence to the downstream silt fence via the bale media. Additionally, bales act as energy dissipaters when impounded stormwater overtops the upstream silt fence installation. The structural concept behind the load transfer design functions effectively until the resultant load placed on the downstream silt fence support posts reach their yield point and plastic deformation begins to occur. For this scenario, resultant load is the combination of forces transferred through the bale media and the hydrostatic force of the increasing impoundment between the two silt fence installations caused by overtopping flow. As shown in Figure 38(a), the resultant force caused the downstream silt fence installation to deflect significantly more than the upstream silt fence installation, resulting in failure and uncontrolled discharge. Obviously, structural integrity would be improved by implementing larger support post and decreasing the associated spacing; however, an alternative strategy would be to exchange the nonwoven geotextile on the downstream silt fence installation with a woven monofilament geotextile that provides a high flow through rate, which in turn would reduce hydrostatic loading.

To capture suspended particles from SB effluent, the Alabama Handbook recommends installing a SRB (herein referred to as the AL HB SRB) as a secondary treatment practice. As shown in Figure 38(b), the installation process is simplistic in that flocculant-laden wheat straw is layered on top of jute matting and held in place using support posts, reinforcing wire, and polypropylene netting. The installation does not require a trenched excavation and is not designed to impound stormwater. Observations during testing indicate that the structural integrity of the AL HB SRB is more than adequate for the intended purpose and that structural materials (e.g., steel post and wire reinforcement) of the installation could be replaced with more cost effective alternatives (e.g., hardwood post and polypropylene reinforcement). Additionally, the overall height of the AL HB SRB could be reduced as flow only passes through the bottom portion (i.e., approximately 6 in. (15 cm)) of the installation.

(a) ALDOT SRB overtopping

(b) AL HB SRB support structure

Figure 38. SRB installation evaluation.

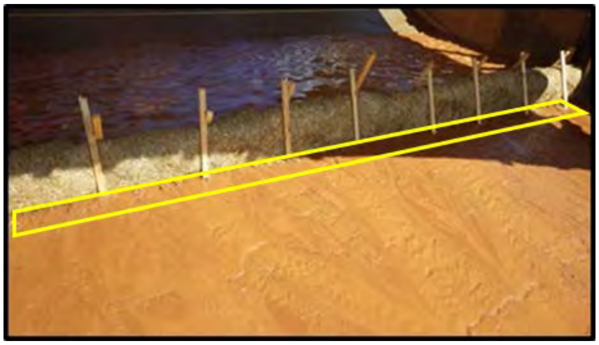
4.5.1.3 Manufactured Sediment Barrier Products

Installation methods for manufactured SB products are dependent upon intended application and the physical properties (e.g., size, shape, density, etc.) of the product. Each of the three SB products tested required a means for securing the product in-place so that dislodgement would not occur during flow introduction and impoundment. Wooden stakes are commonly used in industry for such purposes, and thus were implemented as the means for securement. Each product was held in place using wooden stakes; however, the methods in which the stakes were installed varied. During Excel Straw Log evaluations, wooden stakes were installed in a teepee fashion. Additionally, the product was entrenched 3 in. (8 cm) into the earthen test area in an attempt to minimize flow bypass. Test observations of this installation indicated that undermining of the product still occurred and that flow passed underneath the product as opposed to passing through the product, as shown in Figure 39(a). To minimize undermining of the product, a trenchless installation modification was implemented that incorporated a nonwoven geotextile undelay. As shown in Figure 39(b), undermining was not observed but flow passed readily between the underlay and product. The installation of sod staples to facilitate product ground contact has been shown to improve impoundment capabilities, however were not incorporated during testing due to being excluded in ALDOT wattle standard installation details. Based on past wattle performance data when installed as a ditch check and inlet protection practice, the inclusion of sod staples during perimeter control testing would have resulted in improved performance. Throughout all evaluations of the Excel Straw Log, overtopping nor flow through the entire medium of the product was observed. These observations can be attributed to insufficient product ground contact and a large apparent opening size of filler material, resulting in a high flow through rate.

Using performance observations made during Excel Straw Log testing, as well as installation guidelines provided by manufacturers, the wooden teepee installation technique was modified to facilitate downward pressure during SiltSoxx performance evaluations. This was achieved by firmly pressing each stake within a teepee configuration downward, against the tubes, and securing the tops using a wood screw, as shown in Figure 39(c). SiltSoxx installation also consisted of three products, installed on the ground surface in a pyramid configuration, as opposed to the singular entrenched Excel Straw Log installation. Structural observations over the course of three installation performance tests indicate that undermining occurred during installations I1 and I3. As illustrated in Figure 39(d), extensive undermining occurred on the upstream leading edge of the pyramid installation resulting in flow bypass, soil erosion, and stake unearthing. This failure resulted from a combination of factors including increased impoundment pressure and soil saturation. In-field failures such as this would require extensive maintenance not only to repair, but also to insure similar failures do not occur along the remaining soil interface. The incorporation of a geotextile underlay would have likely reduced the probability of such extensive undermining during testing.

When comparing manufactured SB product installation processes, the Curlex Bloc was the most labor intensive and challenging to implement. Curlex Blocs are held in place using rope that is woven stake-to-stake along the length of the installation. Installation guidelines specify that each wooden stake be notched to provide a means for rope securement. During installation, pre-notched stakes broke at notch location while being driven into the earthen soil, as illustrated in Figure 39(e). Because of this, an alternate rope securement method was established that called for the partial insertion of 2 in. (5 cm) wood screws into the outward facing side of each wooden stake. As shown in Figure 39(f), rope was looped around each stake in such a manner that each screw acted as a rope anchor when stakes were completely driven into the earthen soil. This method proved to work effectively as long as extensive shear force was not applied to the screw during rope tensioning. In rare scenarios where shear force exceeded screw capacity, failure would occur and a new screw would be installed.

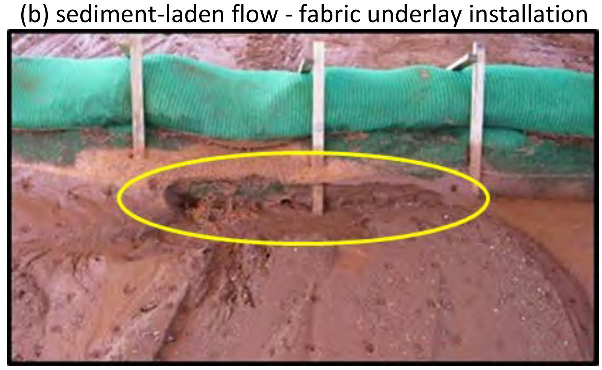
Since Curlex Blocs are only available in 4 and 8 ft (1.2 and 2.4 m) lengths, three units were joined to create an installation that extended the entire width of the earthen test area. Each Bloc was firmly abutted against the adjacent Bloc and the extra flaps of containment material were securely pulled over to create seamless joints. Once the initial installation of the product was complete, voids were observed along the earthen surface at each abutment joint due to the rounded geometry of Bloc ends, as shown in Figure 39(g). Observations during the initial installation performance evaluation indicated that abutment voids were a means of direct flow conveyance and downstream sediment transport. Figure 39(h) shows sediment-laden flow rapidly passing through the abutment void and undermining the installation. Based on these observations, void fillers were installed by compacting loose excelsior fiber into each opening using a sledgehammer. This solution proved to be ineffective in that flow was still able to pass though the void with little to no resistance or water quality improvement. During subsequent installations, rounded excelsior fiber Bloc ends were removed from the containment netting, loosened by hand, and firmly packed back into the containment material to minimize abutment voids. Additionally, a 6 in. (15 cm) soil wedge was placed and compacted along the upstream interface to minimize flow bypass underneath the product. These installation modifications facilitated increased upstream impoundment and flow through the product; however, minor undermining was still observed during testing.



(a) undermining – trenched installation

(b) sediment-laden flow - fabric underlay installation

(c) modified teepee installation – wood screw



(d) undermining – pyramid installation

(e) rope installation - broken notched stakes

(f) rope installation – wood screw catch

(g) rounded end abutment void

(h) undermining through abutment

Figure 39. Manufactured product installation evaluation.

In-field applications of these manufactured SB products, when implemented as a perimeter control substitute for nonwoven silt fence installations would require extensive labor efforts to achieve installations capable of intercepting and effectively treating sheet flow runoff. Based on observations made during performance evaluations, the likelihood of installation failure due to undermining would be increasingly high. While these products and the associated installation guidelines implemented may not be structural sound, providing reliable perimeter control practices, innovative applications and installation strategies may provide the necessary elements to improve performance.

4.5.2 INSTALLATION AND STRUCTURAL SUMMARY

As shown through testing, the major failure mode of innovative and manufactured SB practices was undermining. Consideration should be taken when specifying such products to ensure effective installation methods are implemented so that flow bypass does not occur. Installation on less erodible areas such as undisturbed vegetation may decrease undermining potential. This installation scenario was not a testing option for this project. A comprehensive summary of structural failures and associated times for each innovative and manufactured SB practice is provided in Table 13. Structural observations made during the Standard ALDOT silt fence testing and M8 testing are included for comparison. Recommended installation details for manufactured products are provided in Appendix B.

Table 13. Innovative and Manufactured SB Structural Observation

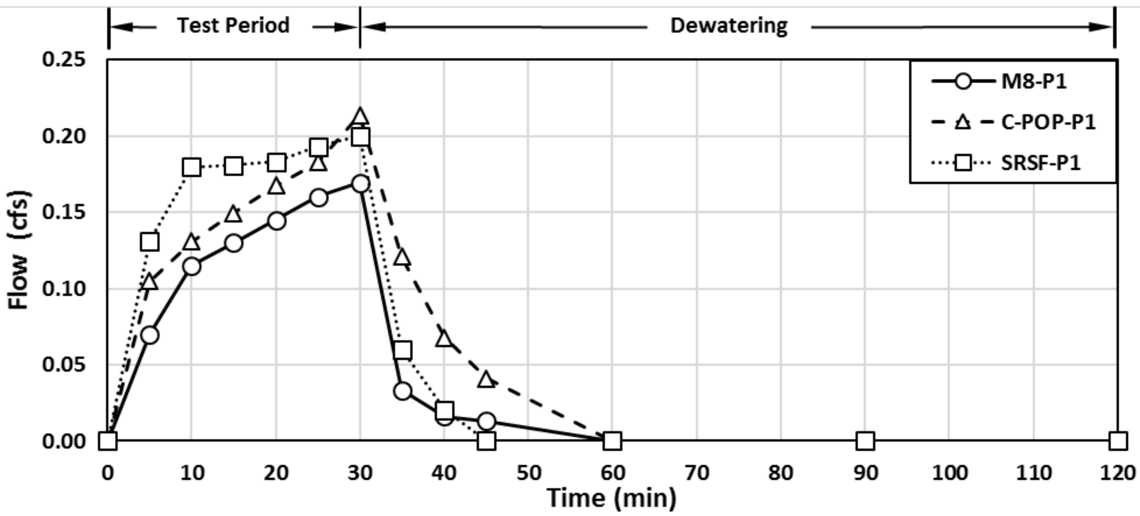
SB	Installation	Test	Failure Time (min:sec)	Failure Mode
STD-T	I1	P1, P2	--	No Failure
		P3	15:15	Post Deflection, Overtopping
	I2	P1,P2	--	No Failure
		P3	14:30	Post Deflection, Overtopping
	I3	P1	--	No Failure
		P2	15:30	Post Deflection, Overtopping
		P3	n/a	n/a
M8	I1	P1, P2, P3	--	No Failure
	I2	P1, P2, P3	--	No Failure
	I3	P1, P2, P3	--	No Failure
C-POP	I1	P1, P2, P3	--	No Failure
	I2	P1	28:00	Undermining
		P2, P3	--	No Failure
	I3	P1, P2	--	No Failure
		P3	25:00	Undermining
Silt Saver SRSF	I1	P1, P2, P3	--	No Failure
	I2	P1, P2, P3	--	No Failure
	I3	P1, P2, P3	--	No Failure
ALDOT SRB	I1	P1, P2	--	No Failure
		P3	19:30	Post Deflection, Overtopping
	I2	P1	--	No Failure
		P2	22:56	Post Deflection, Overtopping
		P3	14:00	Post Deflection, Overtopping
	I3	P1	--	No Failure
		P2	21:00	Post Deflection, Overtopping
		P3	16:11	Post Deflection, Overtopping
AL HB SRB w/o Flocculant	I1	P1, P2, P3	--	No Failure
	I2	P1, P2, P3	--	No Failure
	I3	P1, P2, P3	--	No Failure
AL HB SRB w/ Flocculant	I1	P1, P2, P3	--	No Failure
	I2	P1, P2, P3	--	No Failure
	I3	P1, P2, P3	--	No Failure
Western Excelsior Excel Straw Log	I1[a]	P1	2:20	Undermining
	I2[a]	P1	2:10	Undermining
	I3[a],[b]	P1	--	Flow bypass
Filtrexx SiltSoxx	I1	P1	15:00	Undermining
		P2, P3	--	No Failure
	I2	P1, P2, P3	--	No Failure
	I3	P1	28:00	Undermining
		P2	5:00	Undermining
		P3	23:00	Undermining
American Excelsior Curlex Bloc	I1	P1, P2, P3	00:30	Undermining
	I2	P1, P2, P3	--	No Failure
	I3	P1	10:00	Undermining
		P2	--	No Failure
		P3	21:50	Overtopping

Notes: [a] = installed with a geotextile underlay
[b] = test P2 & P3 were not conducted due to excessive flow bypass between the wattle and the geotextile underlay

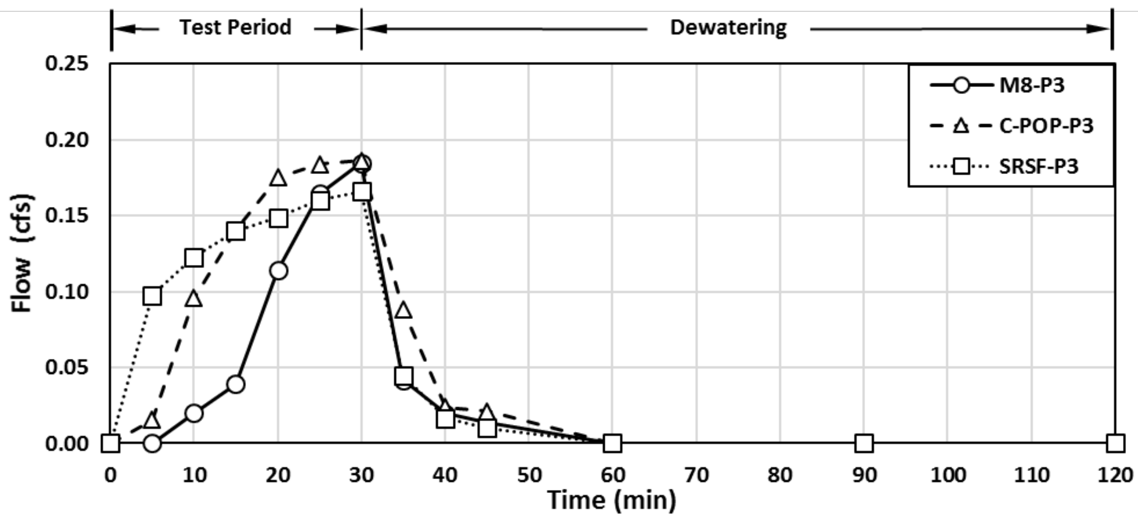
4.5.3 HYDRAULIC & SEDIMENT RETENTION EVALUATION

4.5.3.1 Manufactured Silt Fence Systems

Measurements gathered throughout testing provide means for evaluating SB performance through direct comparisons of impoundment, effluent flow rate, and sediment capture. Impoundment depths and effluent flow rates measured during manufactured silt fence testing indicate that on average, C-POP had a 64% increase in impoundment capability and a 13% reduction in effluent flow when compared to SRSF. These findings correspond to the design specifications of each system, in that geotextile apparent opening size increases with height for SRSF and remains consist for C-POP. When comparing C-POP and SRSF to nonwoven geotextile properties (i.e., M8), impoundment decreases 25% and 55% while flow increases 27% and 45%, respectively. While these evaluations provide insight into how these systems relate to one another, longevity evaluations indicate how the performance of a system changes when subjected to multiple storm events. Base effluent flow rates (i.e., unclogged geotextile pores during P1 tests) for M8, C-POP, and SRSF were 0.13, 0.16, and 0.18 ft^3/s (0.004, 0.005, and 0.005 m^3/s), respectfully. Measurements taken over the course of three C-POP installations (i.e., I1, I2, and I3), each subjected to three simulated storm events (i.e., P1, P2, and P3), indicate that P2 and P3 effluent flow rates were reduced by 5% and 16%, respectively, when compared to P1. Similar results were also calculated for SRSF, where P2 and P3 were reduced by 6% and 22%, respectively. In comparison, the nonwoven silt fence installation (i.e., M8) experienced reductions of 22% and 34% in effluent flow rates, which are considerably higher than those of C-POP and SRSF. These increased reductions over time coupled with a decreased base effluent flow rate results in increased impoundments and water retention over time when compared to each of the manufactured silt fence systems. Figure 40 (a) and (b) illustrate the change in effluent flow rates for P1 and P3 performance evaluations for each practice.



(a) P1 effluent flow



(b) P3 effluent flow

Figure 40. Manufactured silt fence effluent flow rate analysis.

Sediment deposition surveys indicate the volume of rapidly settable solids captured upstream of SB practices. Manufactured silt fence systems survey results indicate average sediment retention rates of 90% and 85% for C-POP and SRSF, respectively. When compared to M8 retention rates, sediment capture is reduced by 3% for C-POP and 9% for SRSF. These sediment capture differences can be attributed to the different hydraulic properties associated with each geotextile. However, results from a single factor ANOVA indicated, with a 95% confidence level, that the differences in sediment retention rates between the two manufactured silt fence systems and M8 are not significant.

These full-scale performance evaluations provide insight into how these manufactured silt fence systems function in field applications. Side-by-side comparisons of impoundment, effluent discharge, and sediment deposition observed during testing for each manufactured silt fence system are provided in Figure 41(a) – 41(f).

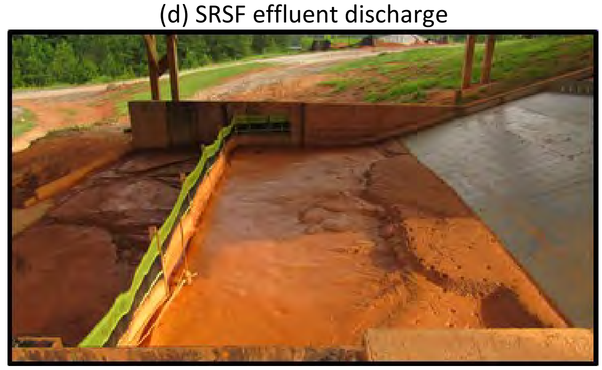
(a) C-POP impoundment

(b) SRSF impoundment

(c) C-POP effluent discharge

(d) SRSF effluent discharge

(e) C-POP sediment deposition



(f) SRSF sediment deposition

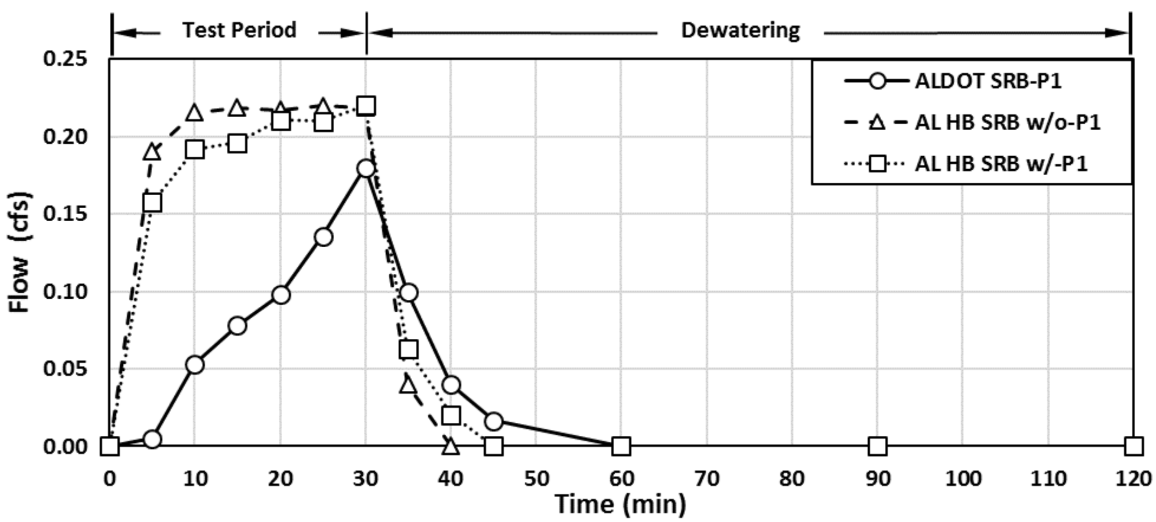
Figure 41. Manufactured Silt Fence System performance observations.

4.5.3.2 Sediment Retention Barriers (SRBs)

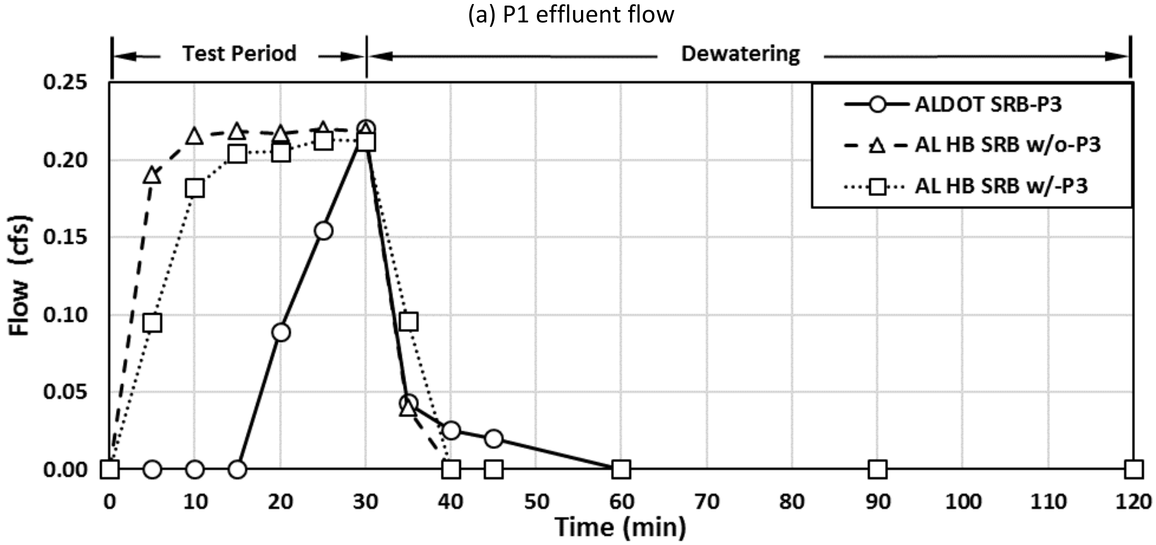
Measurements obtained during testing indicate that the ALDOT SRB achieved a maximum average impoundment depth of 1.76 ft (0.54 m), which was greater than all practice impoundment measurements obtained throughout this study. On the other hand, the calculated base effluent flow rate for the ALDOT SRB was 0.09 ft^3/s (0.003 m^3/s), which was lower than all evaluated practices. When comparing these values to those achieved during M8 testing, impoundment capability is increased 14% while base effluent flow is reduced by 31%. ALDOT SRB longevity tests indicate that effluent flow is reduced by 25% between P1 and P2 tests; however, due to structural failures and overtopping flows during P3 tests, calculated flow reductions during P3 tests are unrepresentative of that of the practice.

Each configuration of the AL HB SRB (i.e., with and without flocculant) had slightly differing impoundments and effluent flow rates. When flocculant was <u>not</u> added to the installation, the average maximum impoundment and base effluent flow rate was 0.15 ft (0.05

m) and 0.21 ft^3/s (0.006 m^3/s), respectively. In comparison, flocculant-laden installations resulted in an average maximum impoundment of 0.52 ft (0.16 m) and a base effluent flow rate of 0.20 ft^3/s (0.005 m^3/s). These slight changes in hydraulic performance can be attributed to the hydration of granulated flocculant, which creates a tacky wheat straw matrix that slightly reduces flow through capacity. Figure 43(a) – 43(d) show hydraulic performance observations made during testing for each SRB. AL HB SRB longevity testing indicated reductions in effluent flow rates for tests P2 and P3 of 2% and 3% for no flocculant installations, while flocculant-laden installations experienced reductions of 5% and 6%, respectively. As shown in Figure 42(a) and 42(b), the P1 and P3 effluent flow rates observed over time for the ALDOT SRB varies considerably when compared to the P1 and P3 effluent flow rates for each installation configuration of the AL HB SRB. This variation in flow capacity over time is a direct result of geotextile blinding, as observed during nonwoven silt fence testing.



(a) P1 effluent flow



(b) P3 effluent flow

Figure 42. Sediment retention barrier effluent flow rate analysis.

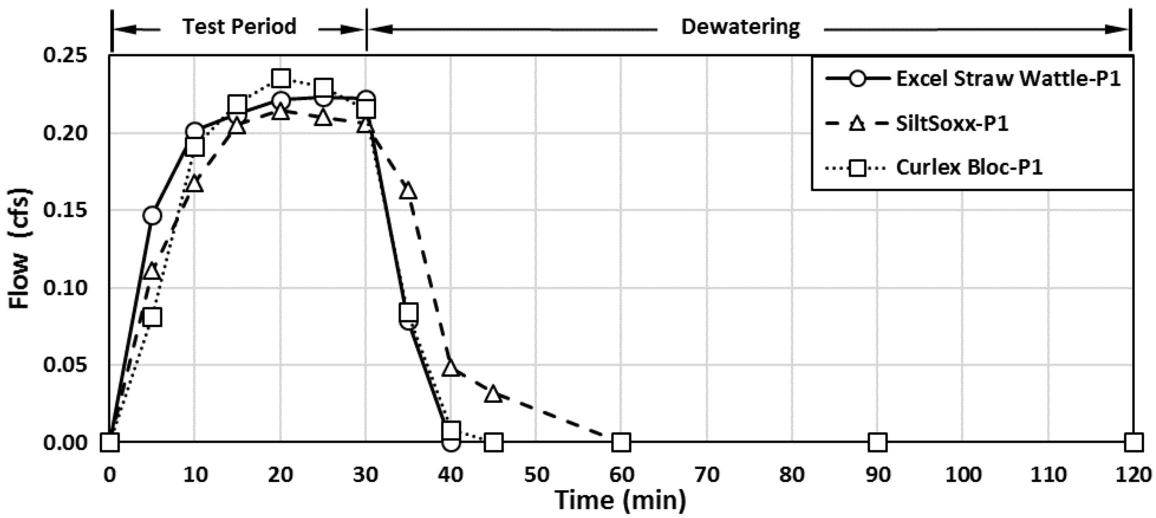
Results from each SRB survey analysis were compiled to determine the sediment capture rates for each of the practices. On average, the ALDOT SRB retained 91% of sediment introduced, while the AL HB SRB retained 63% and 83% in the no flocculant and flocculant-laden configurations, respectively. In comparison to M8 (e.g., 93%), sediment capture for these practices were reduced by 2% (ALDOT SRB), 32% (AL HB SRB w/o), and 11% (AL HB SRB w/). Sediment deposition observations made after testing for each SRB are shown in Figure 43(e) and 43(f).

(a) ALDOT SRB impoundment
(b) AL HB SRB impoundment
(c) ALDOT SRB discharge
(d) AL HB SRB discharge
(e) ALDOT SRB sediment deposition
(f) AL HB SRB sediment deposition

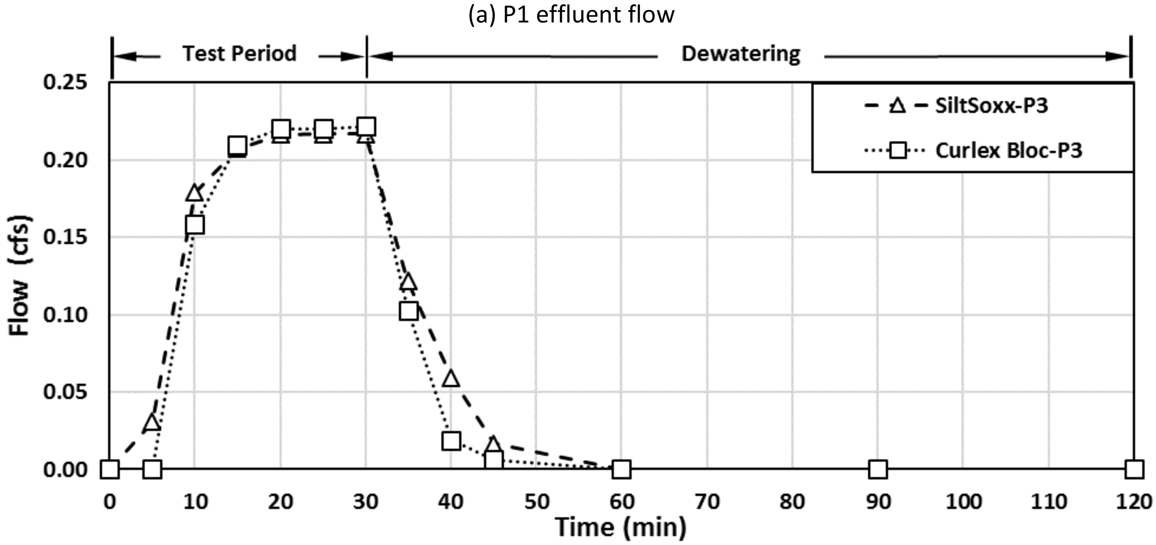
Figure 43. SRB performance observations.

4.5.3.3 Manufactured Sediment Barrier Products

Average maximum impoundment depths measured during Excel Straw Log, SiltSoxx, and Curlex Bloc testing were 0.38, 0.51, and 0.77 ft (0.12, 0.16, 0.23 m), respectively. Figure 45(a) – 45(c) shows maximum impoundments accomplished during testing by each of these manufactured SB products. When compared to M8 (e.g., 1.54 ft), impoundment capabilities for each product were reduced by 75%, 67%, and 50%, respectively. However, overtopping did occur during Curlex Bloc testing, thus indicating maximum attainable impoundment had been achieved. Additionally, the Curlex Bloc was the only product evaluated in which stormwater was observed flowing from the downstream face of the product, as shown in Figure 45(d). Observations made during Excel Straw Log and SiltSoxx testing indicated that flow discharged from within the product along the earthen surface interface. These observations suggest that the majority of the three-dimensional matrix in which flow is intended to pass to obtain water quality improvement is not utilized. Base effluent flow rates for each product were similar in that the Excel Straw Log and Curlex Bloc achieved 0.20 ft^3/s (0.006 m^3/s) and the SiltSoxx achieved 0.19 ft^3/s (0.005 m^3/s). A unique observation made during SiltSoxx testing was the products ability to repel and bead water along the surface of containment material, as shown in Figure 45(e). This material property may be directly related to the slight decrease in effluent flow observed during testing. Longevity analyses for the SiltSoxx indicated flow reductions of 0% (P2) and 4% (P3). In comparison, flow was reduced by 15% for both P2 and P3 tests during Curlex Bloc evaluations. Due to extensive undermining during Excel Straw Log P1 evaluations, longevity tests were not conducted. Figure 44(a) and 44(b) illustrate the similarity between time variable effluent flow rates for each of the manufactured SB products for P1 and P3 evaluations.



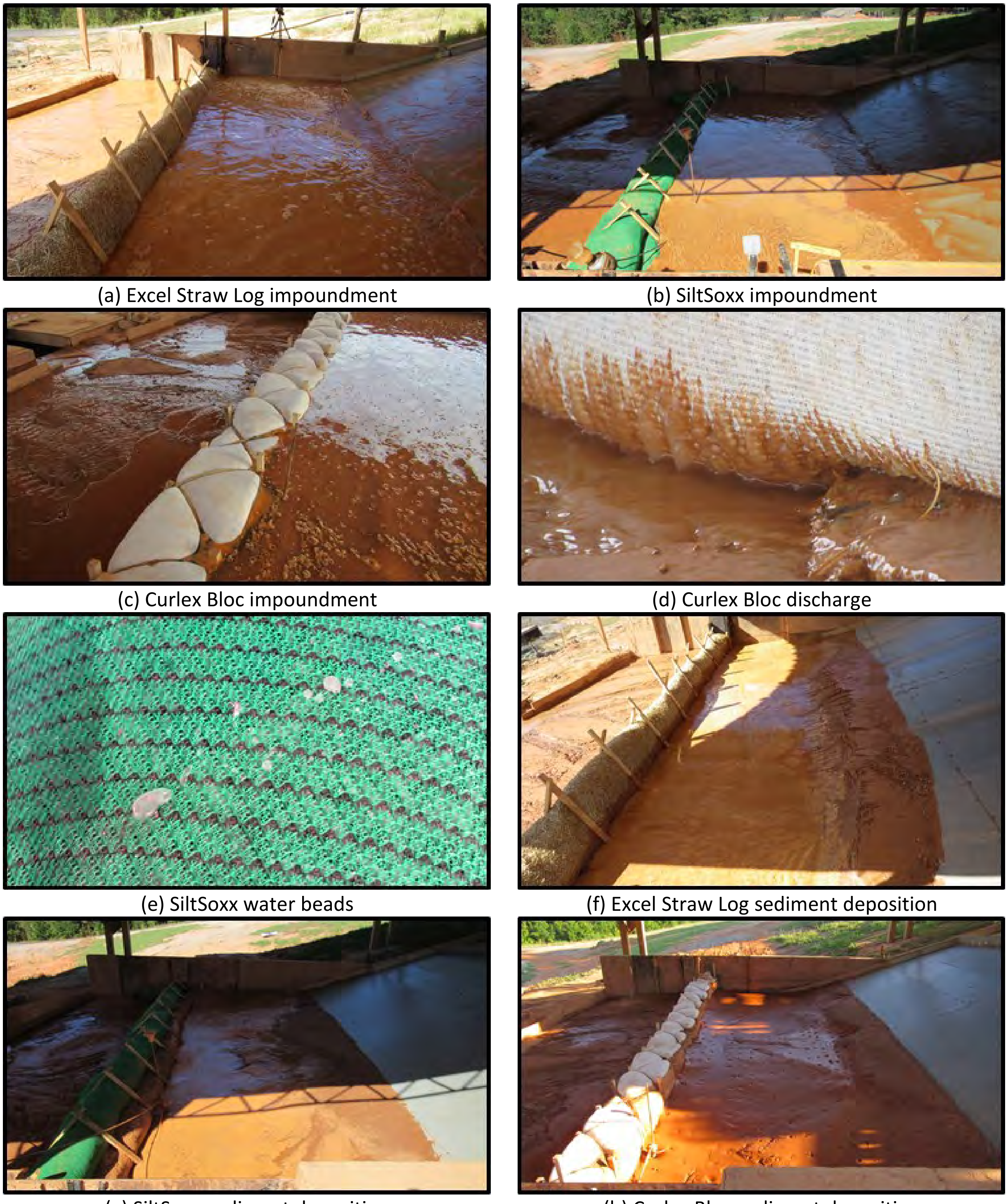
(a) P1 effluent flow



(b) P3 effluent flow

Figure 44. Manufactured sediment barrier product effluent flow rate analysis.

Sediment capture rates for the tested products were calculated to be 82% (Excel Straw Log), 80% (SiltSoxx), and 84% (Culex Blox). Sediment deposition observed after testing for each product is shown in Figure 45(f) – 45(h). When evaluated against M8, these products have reduced retention rates by 12% (Excel Straw Log), 14% (SiltSoxx), and 10% (Curlex Bloc). Despite installation challenges and undermining incidences, these products achieve respectable retention rates during performance testing.



(a) Excel Straw Log impoundment (b) SiltSoxx impoundment
(c) Curlex Bloc impoundment (d) Curlex Bloc discharge
(e) SiltSoxx water beads (f) Excel Straw Log sediment deposition
(g) SiltSoxx sediment deposition (h) Curlex Bloc sediment deposition

Figure 45. Sediment barrier product performance observations.

4.5.4 HYDRAULIC AND SEDIMENT RETENTION SUMMARY

Performance testing has shown practices with the ability to create repeatable upstream impoundment depths greater than 1 ft (0.3 m) have consistent sediment capture rates of at least

90%. More importantly, impoundment depths greater than 1.5 ft (0.46 m) do not facilitate improved sediment capture. These observations suggest that optimized sediment capture is achieved when a SB practice has an effective upstream impoundment depth between 1 and 1.5 ft (0.3 and 0.46 m). A complete performance summary of each practice evaluated is provided in Table 14, as well as the results for STD silt fence and M8 testing.

Table 14. Innovative and Manufactured SB Performance Analysis

SB	Installation	Sediment Retained	Impoundment Depth ft (m)	Flow-Through Rate[c] ft^3/s (m^3/s)
STD-T	I1	87%	0.80 (0.24)	0.15 (0.004)
	I2	87%	0.90 (0.27)	0.16 (0.005)
	I3	75%	0.85 (0.26)	0.16 (0.005)
M8	I1	90%	1.63 (0.50)	0.11 (0.003)
	I2	91%	1.38 (0.42)	0.11 (0.003)
	I3	98%	1.62 (0.49)	0.10 (0.003)
C-POP	I1	90%	1.11 (0.34)	0.15 (0.004)
	I2[a]	91%	1.19 (0.36)	0.14 (0.004)
	I3[a]	90%	1.16 (0.35)	0.13 (0.004)
Silt Saver SRSF	I1	96%	0.63 (0.19)	0.16 (0.005)
	I2	76%	0.64 (0.20)	0.17 (0.005)
	I3	82%	0.84 (0.26)	0.15 (0.004)
ALDOT SRB	I1	90%	1.58 (0.48)	0.07 (0.002)
	I2	92%	1.75 (0.53)	0.09 (0.003)
	I3	90%	1.95 (0.59)	0.09 (0.003)
AL HB SRB w/o Flocculant	I1	64%	0.13 (0.04)	0.21 (0.006)
	I2	63%	0.18 (0.05)	0.21 (0.006)
	I3	62%	0.15 (0.05)	0.21 (0.006)
AL HB SRB w/ Flocculant	I1	81%	0.64 (0.20)	0.17 (0.005)
	I2	84%	0.44 (0.13)	0.18 (0.005)
	I3	85%	0.49 (0.15)	0.19 (0.005)
Western Excelsior Excel Straw Log	I1[b]	82%	0.30 (0.09)	0.20 (0.006)
	I2[b]	84%	0.42 (0.13)	0.20 (0.006)
	I3[b]	81%	0.43 (0.13)	0.20 (0.006)
Filtrexx SiltSoxx	I1[a]	93%	0.53 (0.16)	0.18 (0.005)
	I2	81%	0.57 (0.17)	0.18 (0.005)
	I3[b]	67%	0.43 (0.13)	0.19 (0.005)
American Excelsior Curlex Bloc	I1[b]	67%	0.51 (0.16)	0.20 (0.006)
	I2	95%	0.91 (0.28)	0.17 (0.005)
	I3[a]	90%	0.88 (0.27)	0.17 (0.005)

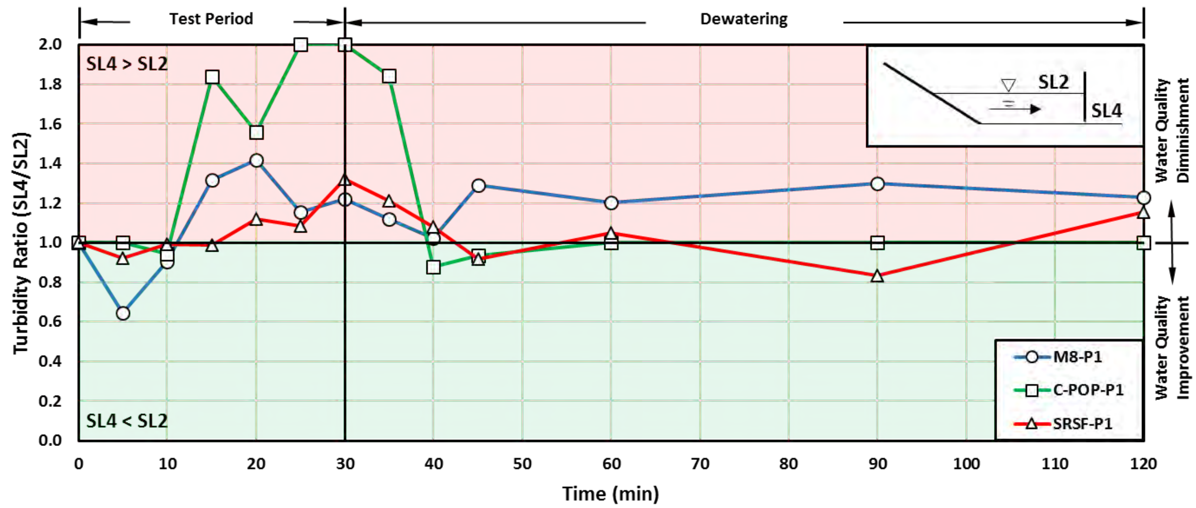
Notes: [a] minor undermining
[b] major undermining
[c] average effluent flow rate during 30 minute test period for 3 sequential storm events
n/a = not available
1 ft = 0.3 m
1 ft^3/s = 0.028 m^2/s

4.5.5 WATER QUALITY EVALUATION

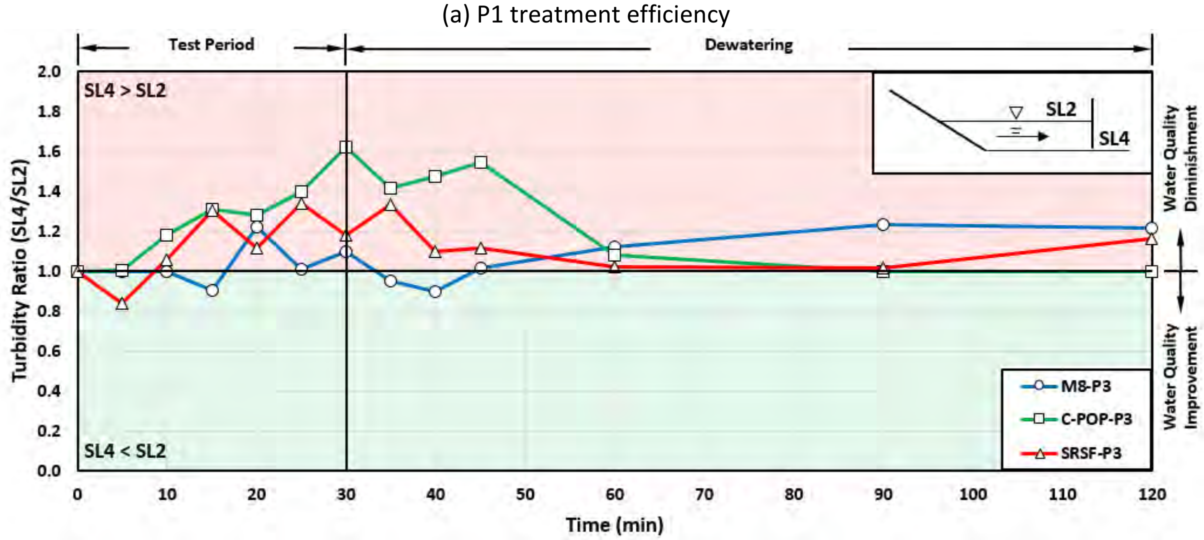
The average turbidity results of three installations (i.e., I1, I2, and I3) were obtained from grabs samples collected every five minutes at five sample locations (i.e., SL1, SL2, SL3, SL4, and SL5). In order to compare and quantify the treatment efficiency of each practice, a standardized means for water quality analysis was applied. Standardization was achieved by dividing downstream turbidity (i.e., SL4) by impoundment surface turbidity (i.e., SL2) for each sample time to determine the efficiency in turbidity reduction from upstream to downstream of the SB practice. These sample locations were chosen because water quality on the surface of the upstream impoundment is typically the least sediment-laden when compared to other upstream locations and effluent flow exiting the practice has yet to be contaminated by bare soil downstream of the installation. Points below 1.0 (shaded in green) on the generated turbidity ratio graphs indicate that there was a reduction in turbidity between upstream and downstream, while points above 1.0 (shaded in red) indicate there was an increase in turbidity. The further a point lies from 1.0 the greater the extent of the change.

4.5.5.1 Manufactured Silt Fence Systems

A comparison of P1 and P3 treatment efficiencies for M8 and each manufactured silt fence system is shown in Figure 46(a) and 46(b). From the plots, it is evident that each of the silt fence practices achieved minimal to no water quality improvements during the testing period. It was observed that turbulence reduction during the dewatering period (e.g., 30 – 120 min) does not result in significant effluent water quality improvement. The average P1 turbidity ratios for M8, C-POP, and SRSF were 1.140, 1.308, and 1.052, each of which indicates a diminishment in effluent water quality. Based on these evaluations SRSF out performed M8 and C-POP by minimizing diminishment; however, average P3 turbidity ratios indicate that the treatment efficiency of SRSF (1.122) decreased during longevity testing where as M8 (1.051) and C-POP (1.254) improved. These changes in treatment efficiency would be difficult to correlate to long term, in-field performance expectations without additional longevity replicate tests for statistical comparison.



(a) P1 treatment efficiency

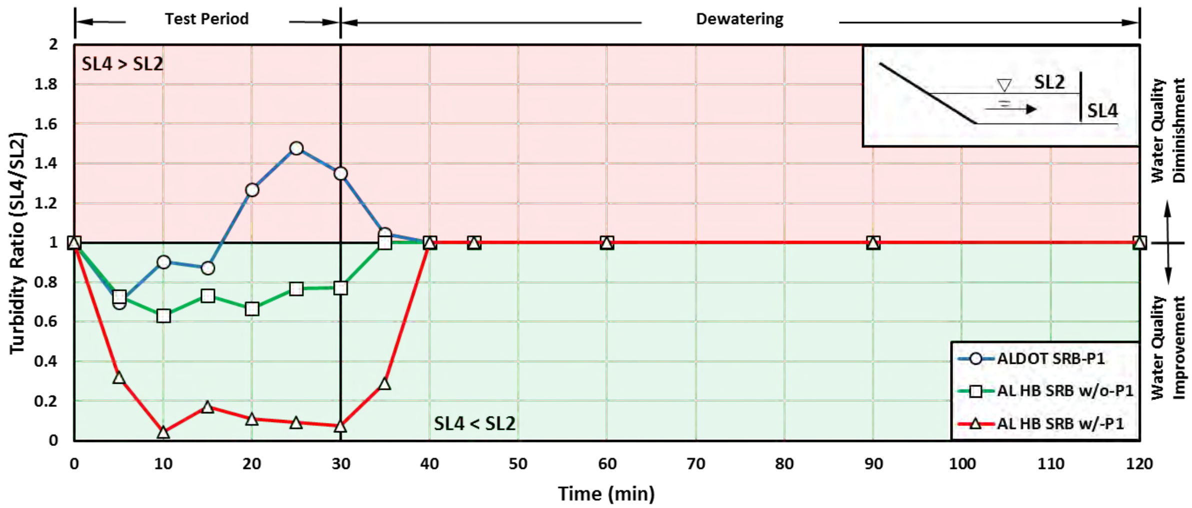


(b) P3 treatment efficiency

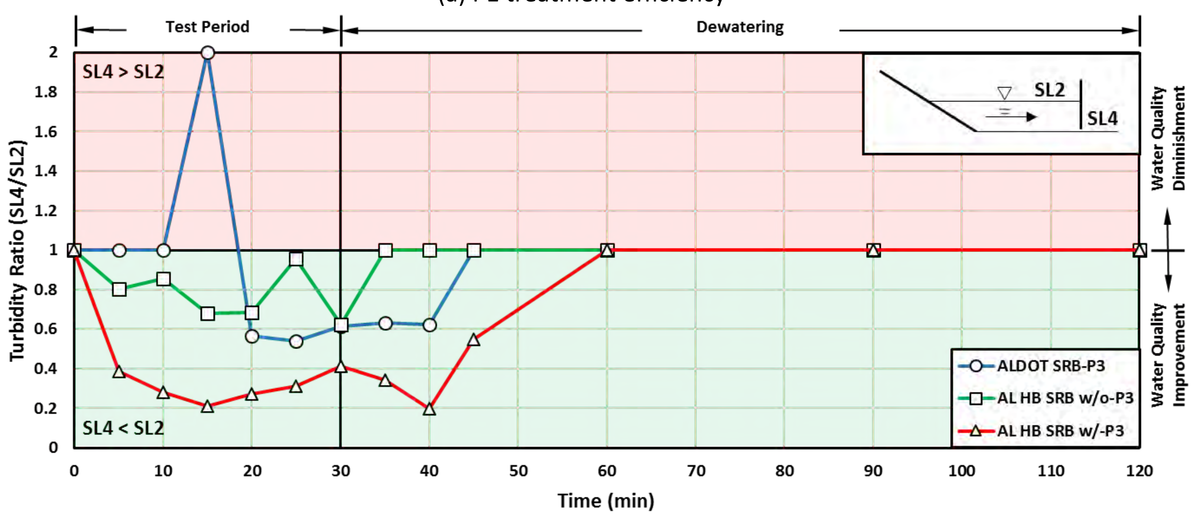
Figure 46. Manufactured silt fence system turbidity ratio comparison.

4.5.5.2 Sediment Retention Barriers (SRBs)

The P1 and P3 ratio comparisons for SRBs are shown in Figure 47(a) and 47(b). From the plots, it is evident that SRBs outperform manufactured silt fence systems. During P1 evaluations, the ALDOT SRB, AL HB SRB w/o flocculant, and AL HB SRB w/ flocculant achieved average ratios of 1.048, 0.870, and 0.546. These values indicate a slight water quality diminishment for the ALDOT SRB, but substantial water quality improvements for each AL HB SRB configuration. Longevity tests results show that filtering capabilities improved for the ALDOT SRB (0.922) while each AL HB SRB (0.892 w/o and 0.536 w/flocculant) remained consistent. Out of all practices evaluated, the AL HB SRB w/ flocculant was the most effective at reducing turbidity as the flow passed through the medium.



(a) P1 treatment efficiency

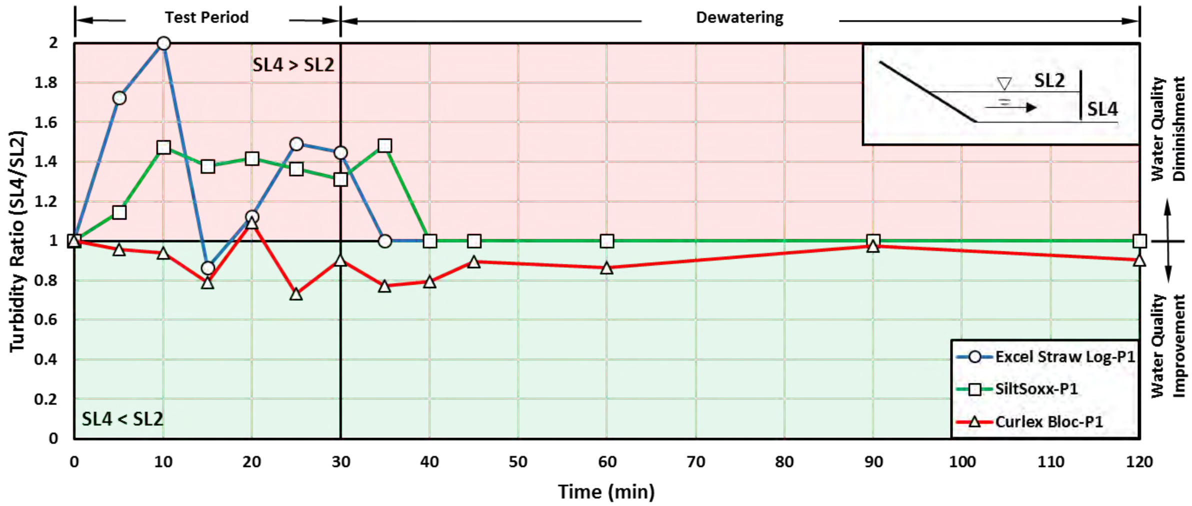


(b) P3 treatment efficiency

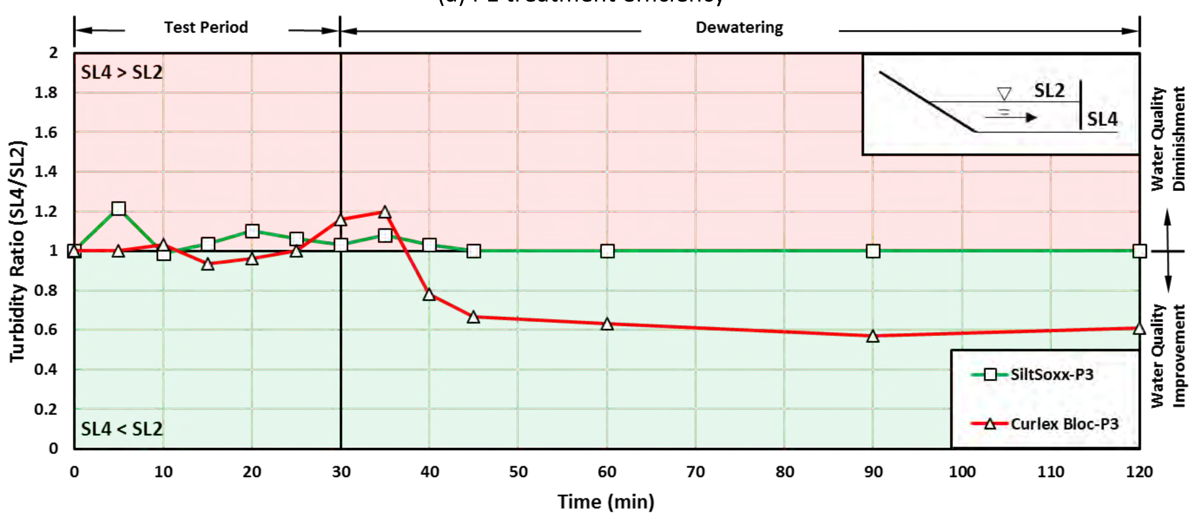
Figure 47. Sediment retention barrier turbidity ratio comparison.

4.5.5.3 Manufactured Sediment Barrier (SB) Products

Manufactured SB product turbidity ratio plots are illustrated in Figure 48(a) and (b). As shown in the P1 treatment efficiency plot, the Curlex Bloc outperformed the Excel Straw Log and SiltSoxx. Interestingly, the Curlex Bloc was the only product to achieve an improvement in effluent water quality. Average P1 ratios for the Excel Straw Log, SiltSoxx, and Curlex Bloc were 1.204, 1.199, and 0.894, respectively. When comparing these values to longevity P3 ratios, the diminishment associated with SiltSoxx is reduced to a ratio of 1.042 and the Curlex Bloc further improves water quality to a turbidity ratio of 0.889. Longevity tests were not conducted on the Excel Straw Log, thus data is not available for evaluating treatment efficiency after repeated storm events. The most notable ratios from the plots is that of the Curlex Bloc during the dewatering period. When compared to all practices evaluated in this study, the Curlex Bloc was the only practice to consistently achieve an improvement in effluent water quality during dewatering. Additionally, the Curlex Bloc was the only practice that achieved noticeable improvements in treatment efficiency during longevity testing.



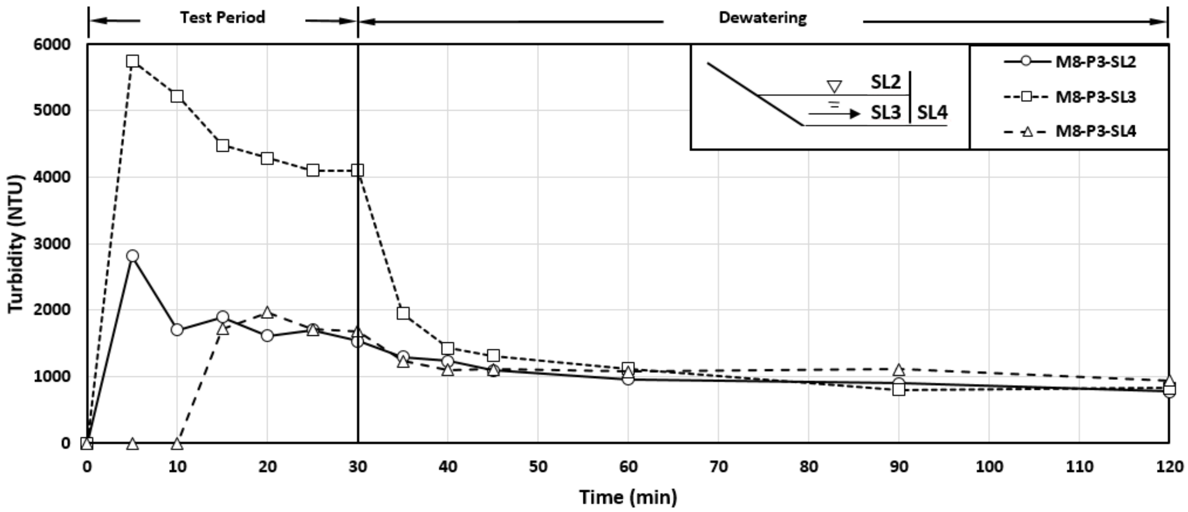
(a) P1 treatment efficiency



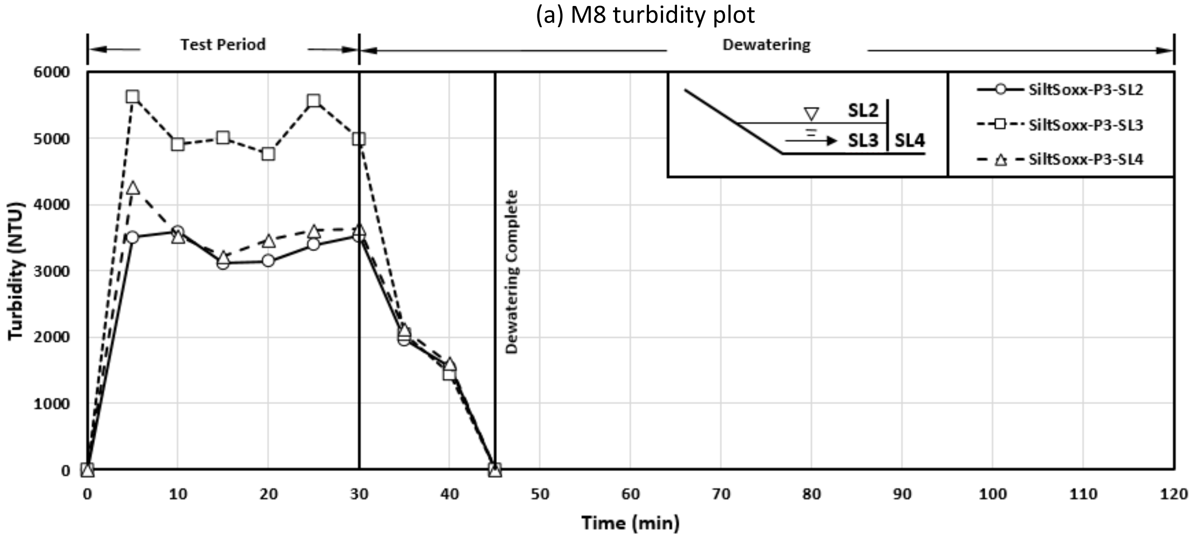
(b) P3 treatment efficiency

Figure 48. Manufactured sediment barrier product turbidity ratio comparison.

Time variable turbidity plots from P3 tests of M8 and SiltSoxx are shown in Figure 49(a) and 49(b). From the plots, it is evident that SL2 (i.e., impoundment surface) is consistently lower than SL3 (i.e., bottom of impoundment) for both practices. These improvements in water quality are facilitated by stormwater impoundment upstream of the installations. Furthermore, comparing the two plots during the test period, M8 had a 60% reduction from SL3 to SL2, where SiltSoxx only had a 34% reduction. This difference in reduction can be directly linked to the maximum impoundment depths achieved during testing, which on average were 1.54 ft (0.47 m) for M8 and 0.51 ft (0.15 m) for SiltSoxx. These findings indicate that not only do upstream impoundment pools improve water quality, but that the magnitude of the depth also affects water quality. Analyzing this even further, an impoundment depth upper limit of 1.5 ft (0.46 m) was identified as being the optimum depth due to minimal water quality improvements beyond this point. As shown in the M8 plot, turbidity is only reduced 208 NTU along the impoundment surface (SL2) when transitioning from the test period (i.e., highly turbulent impoundment) to dewatering (i.e., static impoundment). Based on water quality data, turbidity levels within the system are minimized during dewatering. In order to match these levels along the impoundment surface during the test period, an impractical impoundment depth upstream of the SB would most likely need to be formed to minimize turbulence in order to obtain such a small reduction in turbidity.



(a) M8 turbidity plot



(b) SiltSoxx turbidity plot

Figure 49. Effects of impoundment depth capability on water quality.

4.5.6 Water Quality Evaluation Summary

Performance testing has shown that the treatment efficiency of innovative and manufactured SB practices vary product to product, as well as over longevity testing. Turbidity ratio graphs do not take into consideration the extent of impoundment surface turbidity associated with each practice. For example, average impoundment surface turbidity during M8 and AL HB SRB w/o flocculant testing was 2,020 NTU and 7,470 NTU, respectively. These values are significantly different because of the impoundment depth capabilities associated with each practice. Based on these turbidity values, a theoretical reduction of 1000 NTU would be a major achievement for M8 because turbidity would essentially be reduced by half; on the other hand, the same reduction for the AL HB SRB w/o flocculant would be considered effective but to a lesser degree. Treatment efficiency results reported provide scientifically backed filtering capabilities associated with each practice; however, it is imperative that the selection of SB practices not solely be based on treatment efficiencies. As shown through performance based testing, impoundment plays a major role in water quality improvement. When selecting a SB practice for implementation, consideration should be given to each of the performance standards evaluated within this study. Site-specific requirements should be used for selecting the most feasible practice(s) based on their capabilities identified within this study. Additional time variable turbidity results that illustrate water quality changes at sample locations SL2, SL3, and SL4 for each practice are provided in Appendix C. Furthermore, treatment efficiency plots that illustrate the changes between P1, P2, and P3 for each practices are provided in Appendix D.

4.6 SUMMARY

This study has shown the need for full-scale, reproducible SB testing methodologies to evaluate and improve current practices and to achieve greater in-field performance. The study provided full-scale performance evaluation results for two manufactured silt fence systems (C-POP and Stage Release Silt Fence), three SRBs (ALDOT SRB, AL HB SRB w/o Flocculant, and AL HB SRB w/ Flocculant), and three manufactured SB products (Excel Straw Log, SiltSoxx, and Curlex Bloc). Evaluations were conducted on installation feasibility, structural integrity, impoundment capability, effluent flow rate, sediment retention, and water quality improvement. Results from the standardized performance based testing provide researches with a means for evaluating and comparing new and innovative SB products emerging within industry. Results from this investigation can also be used to provide performance based installation enhancement strategies in future testing efforts and field applications. Furthermore, these results provide designers and installers with scientifically backed performance capabilities when subjected to hydraulic and sediment loads resulting from a typical 2-yr, 24-hr storm event in the State of Alabama.

An in-depth discussion was presented identifying materials and associated properties used to manufacture and construct each of the SB practices. Recommended installation guidelines were evaluated and alternative installation strategies were developed to facilitate upstream impoundment and promote particle settlement. Installation efforts and observed deficiencies were presented to increase general knowledge and minimize reoccurrence in field applications. Observed results showed that undermining and flow bypass was a major failure mode for many practices throughout testing. Sediment capture was optimized when upstream impoundments were between 1 and 1.5 ft (0.3 and 0.46 m), which resulted in at least 90% retention. Impoundment depths greater than 1.5 ft (0.46 m) did not significantly improved sediment capture. Minimal to no water quality improvements were observed during manufactured silt fence system testing based upon filtration sampling from directly upstream and downstream of the silt fence fabric. SRBs were the most effective practices for improving water quality as flow passed through the medium. Finally, the Curlex Bloc was the only manufactured SB product to achieve consistent water quality improvements between simulated storm events based solely upon the products filtration capability.

Future research efforts should emanate from this project, allowing for further improvements to enhance the performance of innovative and manufactured SB practices. Additional practices can be evaluated using the full-scale SB testing apparatus and developed test methodology to identify performance capabilities and associated limitations prior to in-field applications.

CHAPTER 5: CONCLUSIONS & RECOMMENDATIONS

5.1 INTRODUCTION

The USEPA general construction permit mandates that ESC practices achieve equivalent sediment load reduction to that of a 50 ft (15 m) natural buffer when earth-disturbing activities are within 50 ft (15 m) of a water of the U. S. and a natural buffer cannot be maintained (*USEPA 2017*). In order for a designer engineer to select appropriate practices to meet this requirement, performance capabilities of various SB practices need to be available. This research effort was undertaken to provide a comprehensive understanding of SB capabilities and improve their overall performance. The research presented in this final report outlines the design, development, and implementation of a full-scale testing apparatus and methodology for quantifiably evaluating SB practices, explore improvements made in the design and installation of wire-backed nonwoven silt fence installations, and assess the overall effectiveness and applicability of common innovative and manufactured SB practices employed within the construction industry.

5.2 CONCLUSIONS

This section summarizes the conclusions of each research objective investigated in the report. This work will ultimately provide useful, improved practices that are designed, implemented, and installed correctly on construction sites. Ultimately, this study will assist in minimizing the amount of sediment leaving construction sites and reaching surface waters thus protecting the nation's water resources.

5.2.1 Sediment Barrier Test Apparatus Design and Testing Methodology

The first objective of this research was achieved through the design and construction of a scientifically sound SB testing apparatus that allowed performance-based testing of many different SB practices, products, and installation strategies. The experimental setup was repeatable, created conditions that allowed for direct comparisons, and were conducive of field-like conditions. A literature review of past and current SB testing experiments and standards was conducted to facilitate an effective design and testing methodology that would be suitable for the prescribed experimental needs. Furthermore, water and sediment introduction systems were constructed and calibrated to achieve the desired introduction rates that were determined appropriate through hydrologic and soil loss analysis for the state of Alabama. Data collection procedures and analysis were developed to evaluate installation tactics, structural integrity, hydraulic conductivity, sediment retention, and effects on water quality.

5.2.2 Performance Evaluations of Various Wired-Backed Nonwoven Silt Fence Installation Configurations

The second research task was to evaluate standard ALDOT silt fence installations, identify structural deficiencies, and provide improvements that result in a structurally sound wire-backed nonwoven silt fence installation. This objective was achieved by developing and testing eight alternative installation configurations that individually and jointly varied the standard silt fence height, T-post weight, T-post spacing, and entrenchment location. Variations to the standard parameters include (1) reducing fence height from 32 in. (81.3 cm) to 24 in. (61.0 cm), (2) increasing minimum T-post weight from 0.95 lb/ft (1.4 kg/m) to 1.25 lb/ft (1.9 kg/m), (3) reducing T-post maximum spacing from 10 ft (3.0 m) to 5 ft (1.5 m), and (4) trench offsetting. Ultimately, the offset 24 in. (61.0 cm) fence with 1.25 lb/ft (1.9 kg/m) T-post spaced 5 ft (1.5 m) on-center resulted in the best overall improvement, retaining an average of 93% of sediment and deflecting only 0.18 ft (0.05 m) over the course of three simulated store events. Additionally, the development and implementation of a dewatering mechanism within a silt fence installation was found to be an effective mean for controlled dewatering.

5.2.3 Performance Evaluations of Innovative and Manufactured Sediment Barrier Practices

The third objective was to conduct performance-based direct comparisons between various innovative and manufactured SB practices. This objective was satisfied by conducting full-scale experiments on common innovative and manufactured SB practices used within the construction industry following the developed protocols and testing regime. Tests were conducted on two manufactured silt fence systems [(1) C-POP and (2) SRSF], three SRBs [(1) ALDOT SRB, (2) AL HB SRB w/o Flocculant, and (3) AL HB SRB w/ Flocculant], and three manufactured SB products [(1) Excel Straw Log, (2) SiltSoxx, (3) Curlex Bloc]. Installation details were analyzed and amendments were made to promote stormwater impoundment and minimize flow bypass. Test observations indicated that a major failure mode of manufactured SB practices was undermining. Performance based comparisons of sediment retention rates, maximum impoundment heights, effluent flow rates, and treatment efficiencies were determined for each practices. Longevity tests were conducted to evaluate how each of these parameters change over multiple storm events. Overall performance evaluations indicate practices which achieve impoundment depths between 1 and 1.5 ft (0.3 and 0.46 m) achieve sediment capture rates of at least 90% and reduce impoundment surface turbidity up to 60% when compared to turbidity along the bottom of the impoundment.

5.3 SEDIMENT BARRIER RECOMMENDATIONS

5.3.1 Design Guidelines

Optimizing erosion and sediment control practices on construction sites has been the focus of this research study for ALDOT. Currently, ALDOT does not provide specific design criteria for SBs other than installation details shown in ALDOT standard drawings. The 2018 edition of the ALDOT Standard Specifications states "SBs shall be constructed at the locations shown on the plans, the accepted SWMP or where directed by the Engineer to intercept sheet flow runoff and to treat concrete washout wastewater" (*ALDOT 2018*). To insure consistency between SWMPs, ALDOT Standard Specifications could adopt silt fence design criteria outlined within the current edition of the Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas or reference the criteria within the Standard Specifications. The criteria indicate maximum drainage area up-slope of silt fence installations, as well as maximum slope length above silt fence installations. Additionally, the 2018 edition of the Alabama Handbook incorporates many of the silt fence installation improvements identified through this study.

5.3.2 ALDOT STANDARD DRAWING DETAILS

A lack of scientific knowledge has resulted in an industry need for performance-based testing of SBs in a controlled, full-scale environment. Existing ASTM International (ASTM) standard test methods have limitations; not allowing for full-scale installations, and failing to expose practices to typical flow conditions experienced in field applications. The results of this study show how full-scale testing was conducted to improve current standard silt fence installation designs. Installation improvements identified through this research provided structural enhancements to silt fence installations so that failure does not occur up to design storm events. The improved silt fence installation was designed to maximize impoundment volume and provide efficient dewatering. Based on the performance observations and analyses conducted during this study, the following recommendation for revision are made for ALDOT Standard Drawing Details for Silt Fence Installations and SRBs:

(a) Reduce minimum fence height to 24 in.(61.0 cm),
(b) Specify a minimum T-post weight of 1.25 lb/ft (1.9 kg/m),
(c) Reduce geotextile ring fastener spacing to 1 ft (0.3 m) on-center,
(d) Indicate geotextile fabric be looped over the T-posts,
(e) Reduce maximum T-post spacing to 5 ft (1.5 m) in areas where impoundment will be concentrated,
(f) Incorporate a dewatering weir in areas where impoundment will be concentrated,
(g) Indicate silt fence installations be installed a minimum of 6 ft (1.8 m) from the toe of the slope to allow for adequate storage volume,
(h) Implement a 6 in. (15.2 cm) offset trench/slice, and
(i) Indicate maintenance be conducted when sediment accumulation reaches half the height of the silt fence installation

5.3.3 INNOVATIVE SEDIMENT BARRIER PRACTICES

The results of this research identified performance capabilities of innovative and manufactured SB practices when implemented as perimeter controls. Currently, the ALDOT Temporary Erosion and Sediment Control Products List II-24 does not provide a category for manufactured SB practices. As a result of this research effort, the research team recommends that ALDOT revise List II-24 to include a SB category with representative sub-categories (e.g., wattles, silt fence, etc.). An example List II-24 revision is provided in Appendix E. It is recommended that all future SB products seeking ALDOT Product Evaluation Board (PEB) approval and inclusion on List II-24 be evaluated to determine associated installation feasibility, structural integrity, impoundment capability, effluent flow rate, sediment retention, and effect on water quality using the performance criteria methodology developed during this study. Lastly, we recommend comparing performance capabilities of products seeking approval to the capabilities of practices evaluated and presented in this report to determine in-field feasibility.

5.4 LIMITATIONS AND RECOMMENDED FURTHER RESEARCH

The following section describes general limitations of the research performed and explores avenues by which the knowledge base can be expanded by performing additional studies and investigations.

5.4.1 Full-Scale Performance Evaluations of Silt Fence Installations Configurations

Tests were performed on various full-scale silt fence installations. While the evaluations indicated increased T-post weights and reduced T-post spacing were key components to improving structural stability, evaluations were limited to only two T-post weights and two T-post spacing scenarios.

5.4.1.1 Structural Testing of various T-Post Weights

To better understand current silt fence applications, a comprehensive review of DOT, ASTM, and AASHTO silt fence specifications was conducted to determine current design standards implemented within the southeast region of the U.S. Results indicate that a vast array of T-post weights, T-post spacing, fence heights, and trenching dimensions are specified among authorities, as shown in Table 15. Steel manufacturer reviews indicated that there are five common weights of T-posts [0.85, 0.95, 1.15, 1.25, and 1.33 lb/ft (1.3, 1.4, 1.7, 1.9 and 2.0 kg/m)] available within the industry. Based on these findings, a need exists to scientifically identify yield stress and plastic hinge (i.e., bending failure) limits of readily available silt fence T-post. Using these parameters, as well as maximum fence height and maximum T-post spacing, an optimized silt fence design could be developed.

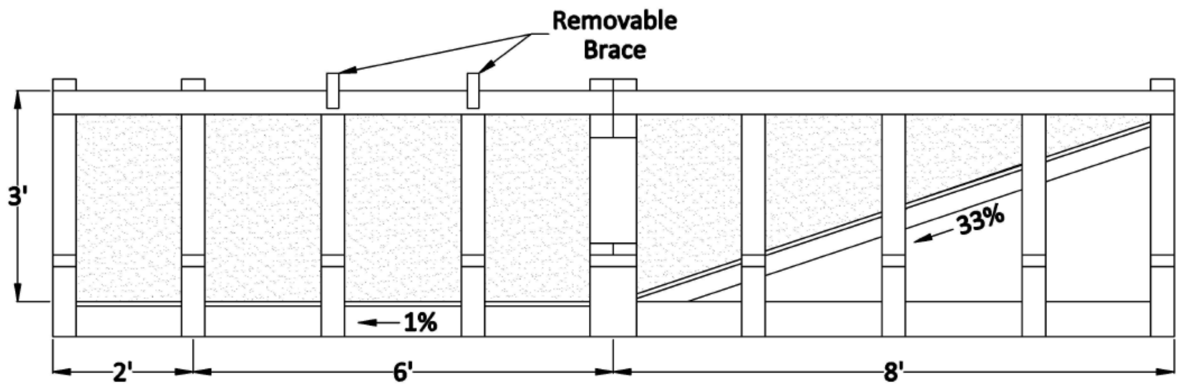
Table 15. Silt Fence Specification by Controlling Authority

Specification Authority	T-Post Weight lb/ft (kg/m)	Yield Strength Ksi (MPa)	T-Post Spacing ft (m) max	Fence Height in. (cm)	Trench Size in. by in. (cm by cm)
ALDOT	--	--	10 (3.0)	32 (81.3) min.	6 x 6 (15.2 x 15.2)
GSWCC	1.3 (1.9)	--	4 (1.2)	28 (72.1) min.	2 x 6 (5.1 x 15.2)
MDOT	1.33 (2.0)	--	10 (3.0)	26 (66.0) min.	6 x 6(15.2 x 15.2)
NC-SCC	1.25 (1.9)	--	8 (2.4)	24 (61.0) max	4 x 8 (10.2 x 20.3)
SCDOT	1.25 (1.9)	50 (345)	6 (1.8)	24 (61.0) min.	6 x 6 (15.2 x 15.2)
TNDOT	1.25 (1.9)	--	6 (1.8)	26 (66.0) min.	4 x 6 (10.2 x 15.2)
TxDOT	1.25 (1.9)	50.4 (347)	8 (2.4)	24 (61.0) min.	6 x 6 (15.2 x 15.2)
AL SWCC	1.3 (1.9)	--	10 (3.0)	32 (81.3) min.	6 x 6 (15.2 x 15.2)
TNEC	1.25 (1.9)	--	6 (1.8)	26 (66.0) min.	4 x 6 (10.2 x 15.2)
AASHTO M 288-15	1.32 (2.0)	--	4 (1.2)	29.5 –35.4 (74.9-89.9)	5.9 (15.0)[a]
ASTM A702-13	1.33 (2.0)	50 (345)	--	--	--
ASTM D6461/D6464M-16a	1.15 (1.7)	--	10 (3.0)	18–30 (45.7-73.2)	6 (15.2)[a]
ASTM D6462-03	1.3 (1.9)	--	4 (1.2)	24 (61.0) min.	4 x 8 (10.2 x 20.3)

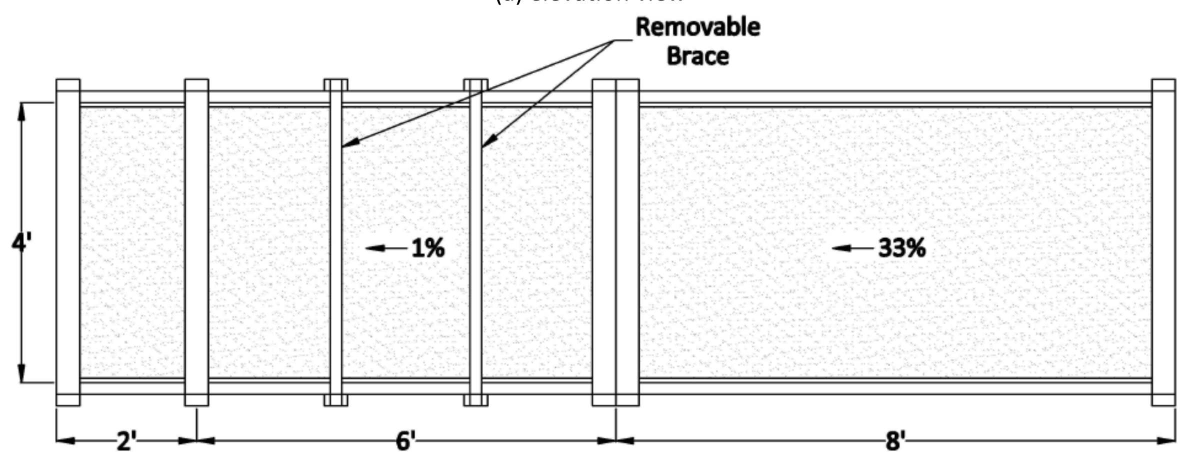
Note: [a] = trench width not specified; -- = specification not available
1 lb/ft = 1.49 kg/m; 1 Ksi = 6.89 MPa; 1 ft = 0.3 m; 1 in. = 2.54 cm

5.4.1.2 Small-scale Testing of Various Silt Fence Fabrics

Additionally, the behavior of each silt fence installation configuration was evaluated using the same brand and weight nonwoven geotextile fabric. The results and finding of this research are limited to the physical properties of the fabric and further research would be required to gain a better understanding of performance against varying geotextile fabrics. In order to evaluate additional geotextiles, a small-scale sediment barrier testing apparatus could be employed. The design width can be scaled down to 1/5th that of the full-scale test apparatus (i.e., 20 ft to 4 ft), which would allow for representative sections of geotextiles to be installed and evaluated in a time effective manner. Flow and sediment introduction rates would also be scaled down to 1/5th of the rates used during large-scale testing. Figure 50 shows the schematic to a conceptual design for the described small-scale sediment barrier testing apparatus.



(a) elevation view



(b) plan view

Figure 50. Small-scale sediment barrier test apparatus schematic.

5.4.1.3 In-Field Investigations of Silt Fence Installations

The sediment barrier testing apparatus and protocols used in this study had the advantage of evaluating performance within a controlled environment (i.e., flow rate, soil loading, sheet flow conditions, etc.). In-field investigations could be conducted to assess the capabilities of the silt fence design improvements on active construction projects, which are susceptible to unforeseen and uncontrollable variables. A field study could provide further insight on the performance of the installation across a wide range of rainfall, sediment loading, and topographical scenarios. Furthermore, a field study many highlight the importance of proper installation to achieve desired performance.

5.4.2 Full-Scale Performance Evaluations of Innovative Sediment Barrier Practices

The full-scale testing efforts on innovative sediment barrier practices mainly focused on evaluating the performance capabilities of the practices. While determining performance capabilities was the main object, iterative attempts at improving the baseline performance capabilities associated with each practices were not conducted. A study could be performed to systematically vary installations components (e.g., trenching, pinning, staking, underlay, etc.) to improve treatment capabilities associated with each practice. Furthermore, materials used to manufacture products (e.g., geotextile, casement netting, filler materials, etc.) could also be evaluated. These results could be useful in the development of revolutionary products, as well as aid designers in selecting practices and products with improved installation methods that provide optimum water quality improvements.

5.5 ACKNOWLEDGEMENTS

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APPENDIX A

ALDOT STANDARD HIGHWAY DRAWING FOR

EROSION AND SEDIMENT CONTROL

REFERENCE PROJECT NO	FISCAL YEAR	SHEET NO

NOTES:

1. "J-HOOK" CONFIGURATION SILT FENCE APPLICATIONS ARE TO BE USED IN CONJUNCTION WITH PERIMETER SILT FENCE WHEN STORMWATER RUNOFF IS IN TWO DIRECTIONS (DOWN A FILL SLOPE AND DOWN GRADIENT ALONG THE RIGHT-OF-WAY).

2. "SMILE CONFIGURATION" APPLICATIONS ARE TO BE USED AS PERIMETER SILT FENCE WHEN THERE IS ONE-DIRECTIONAL FLOW DOWN A SLOPE.

3. SAND BAGS CAN BE USED AS DIVERSION BERMS TO PREVENT SEDIMENT FROM BEING WASHED ONTO OR ACROSS HARD SURFACES, OR TO HELP SLOW SHEET FLOW VELOCITY WHEN DRAINING AWAY FROM HARD SURFACES.

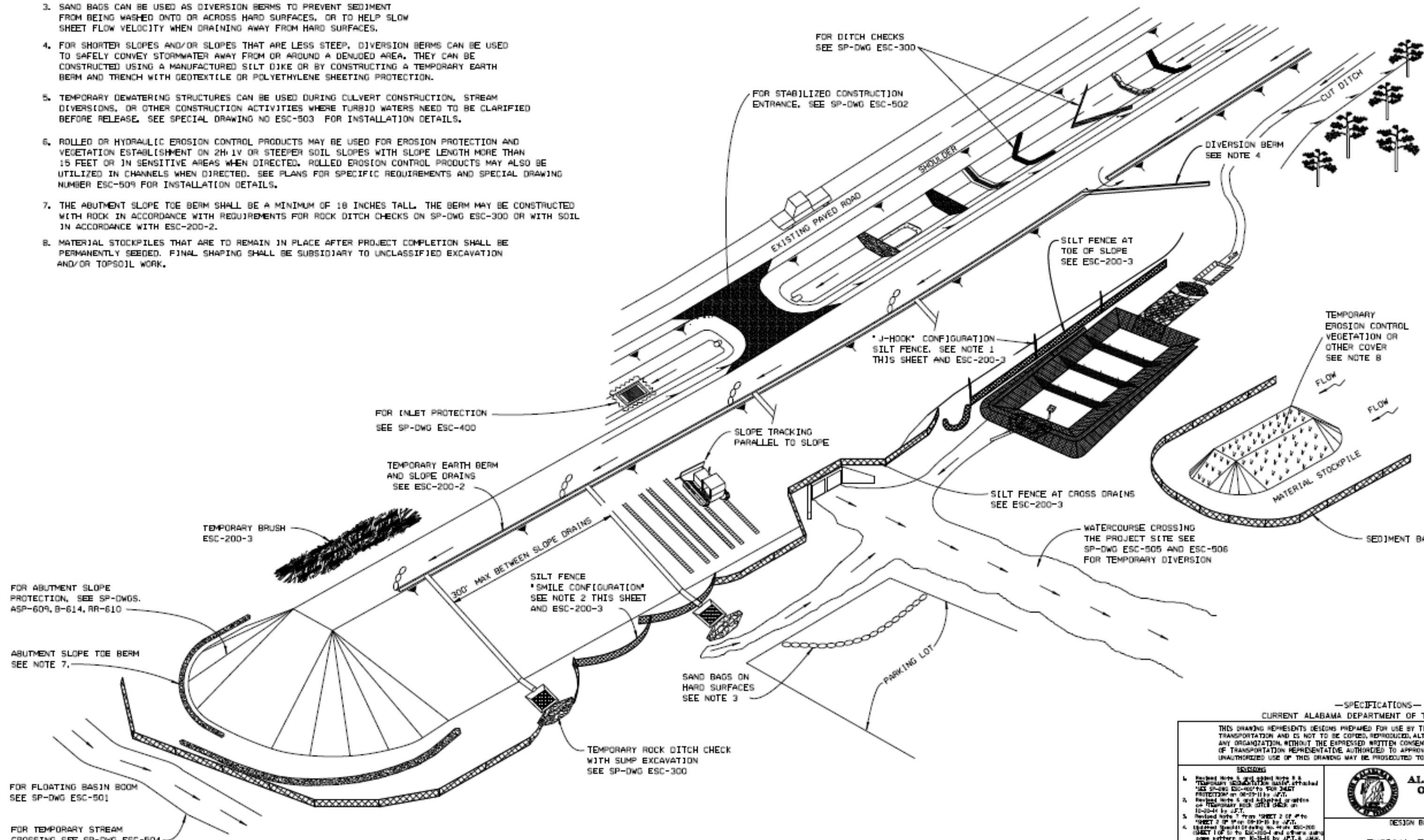
4. FOR SHORTER SLOPES AND/OR SLOPES THAT ARE LESS STEEP, DIVERSION BERMS CAN BE USED TO SAFELY CONVEY STORMWATER AWAY FROM OR AROUND A DENUDED AREA. THEY CAN BE CONSTRUCTED USING A MANUFACTURED SILT DIKE OR BY CONSTRUCTING A TEMPORARY EARTH BERM AND TRENCH WITH GEOTEXTILE OR POLYETHYLENE SHEETING PROTECTION.

5. TEMPORARY DEWATERING STRUCTURES CAN BE USED DURING CULVERT CONSTRUCTION, STREAM DIVERSIONS, OR OTHER CONSTRUCTION ACTIVITIES WHERE TURBID WATERS NEED TO BE CLARIFIED BEFORE RELEASE. SEE SPECIAL DRAWING NO ESC-503 FOR INSTALLATION DETAILS.

6. ROLLED OR HYDRAULIC EROSION CONTROL PRODUCTS MAY BE USED FOR EROSION PROTECTION AND VEGETATION ESTABLISHMENT ON 2H:1V OR STEEPER SOIL SLOPES WITH SLOPE LENGTH MORE THAN 15 FEET OR IN SENSITIVE AREAS WHEN DIRECTED. ROLLED EROSION CONTROL PRODUCTS MAY ALSO BE UTILIZED IN CHANNELS WHEN DIRECTED. SEE PLANS FOR SPECIFIC REQUIREMENTS AND SPECIAL DRAWING NUMBER ESC-509 FOR INSTALLATION DETAILS.

7. THE ABUTMENT SLOPE TOE BERM SHALL BE A MINIMUM OF 18 INCHES TALL. THE BERM MAY BE CONSTRUCTED WITH ROCK IN ACCORDANCE WITH REQUIREMENTS FOR ROCK DITCH CHECKS ON SP-DWG ESC-300 OR WITH SOIL IN ACCORDANCE WITH ESC-200-2.

8. MATERIAL STOCKPILES THAT ARE TO REMAIN IN PLACE AFTER PROJECT COMPLETION SHALL BE PERMANENTLY SEEDED. FINAL SHAPING SHALL BE SUBSIDIARY TO UNCLASSIFIED EXCAVATION AND/OR TOPSOIL WORK.



—SPECIFICATIONS—
CURRENT ALABAMA DEPARTMENT OF TRANSPORTATION

REVISIONS

ALABAMA DEPARTMENT OF TRANSPORTATION
1409 COLISEUM BOULEVARD
MONTGOMERY, AL 36130-3050

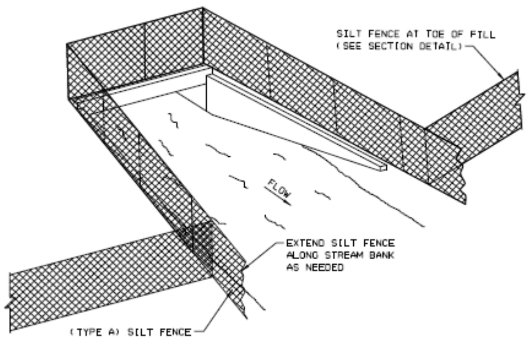
DESIGN BUREAU SPECIAL DRAWING

TYPICAL TEMPORARY EROSION/ SEDIMENT CONTROL APPLICATIONS

Bureau Std Engr: L.V.S.
DRAWN BY: ______ DATE DRAWN: 2006

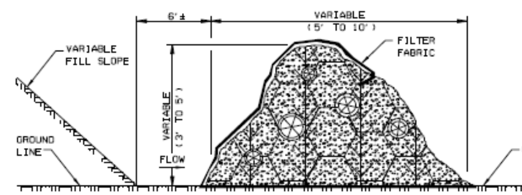
SPECIAL DRAWING NO: ESC-200-1
INDEX NO: 1161

NOT TO SCALE



SEDIMENT BARRIER AT CROSS DRAIN

REAR ELEVATION

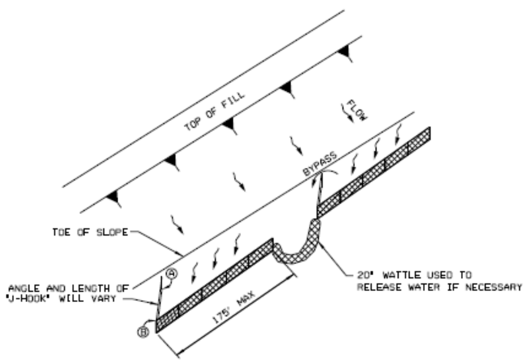


SIDE ELEVATION

TEMPORARY BRUSH BARRIER

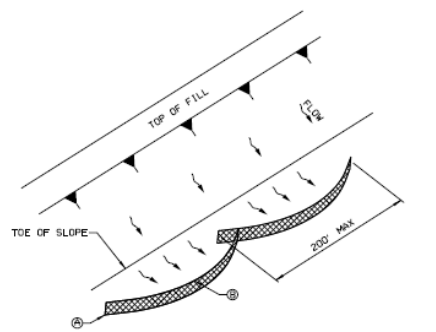
NOTES:
1. BRUSH BARRIER MAY BE USED WHERE NATURAL GROUND IS LEVEL OR SLOPING AWAY FROM PROJECT.
2. PLACE BRUSH, LOG AND TREE LAPS APPROXIMATELY PARALLEL TO TOE OF FILL SLOPE WITH SOME OF THE HEAVIER MATERIALS BEING PLACED ON TOP TO PROPERLY SECURE THE BARRIER AS DETAILED AT LOCATIONS SHOWN ON PLANS OR AS DIRECTED OR PERMITTED BY THE ENGINEER.
3. TO ALLOW WATER TO SEEP THROUGH BRUSH BARRIER, INTERMINGLE THE BRUSH, LOG AND TREE LAPS SO AS NOT TO FORM A SOLID DAM.
4. THE BRUSH BARRIER SHALL BE CHOKED WITH FILTER FABRIC.

NOTE:
1. ANCHOR AND INSTALL SILT FENCE PER DETAILS SHOWN ON SPECIAL DRAWING No. ESC-200-4.



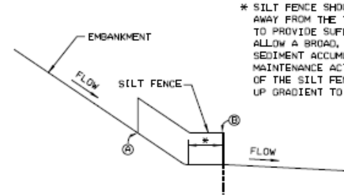
"J-HOOK" SILT FENCE APPLICATION

THE ELEVATION AT THE BOTTOM OF THE DISTANT END OF THE "J-HOOK" Ⓐ SHOULD BE THE SAME AS THE LOWEST POINT ALONG THE TOP OF SILT FENCE Ⓑ.



"SMILE-CONFIGURATION" SILT FENCE APPLICATION

NOTE:
1. EL Ⓐ = EL Ⓑ TO MAXIMIZE STORAGE.



* SILT FENCE SHOULD BE LOCATED AWAY FROM THE TOE OF THE SLOPE TO PROVIDE SUFFICIENT SPACE TO ALLOW A BROAD, FLAT AREA FOR SEDIMENT ACCUMULATION AND MAINTENANCE ACTIVITIES. THE ENDS OF THE SILT FENCE SHOULD BE TURNED UP GRADIENT TO MAXIMIZE STORAGE.

SILT FENCE SECTION AT TOE OF FILL

—SPECIFICATIONS—
CURRENT ALABAMA DEPARTMENT OF TRANSPORTATION

REVISIONS

ALABAMA DEPARTMENT OF TRANSPORTATION
1409 COLISEUM BOULEVARD
MONTGOMERY, AL 36130-3050

DESIGN BUREAU SPECIAL DRAWING

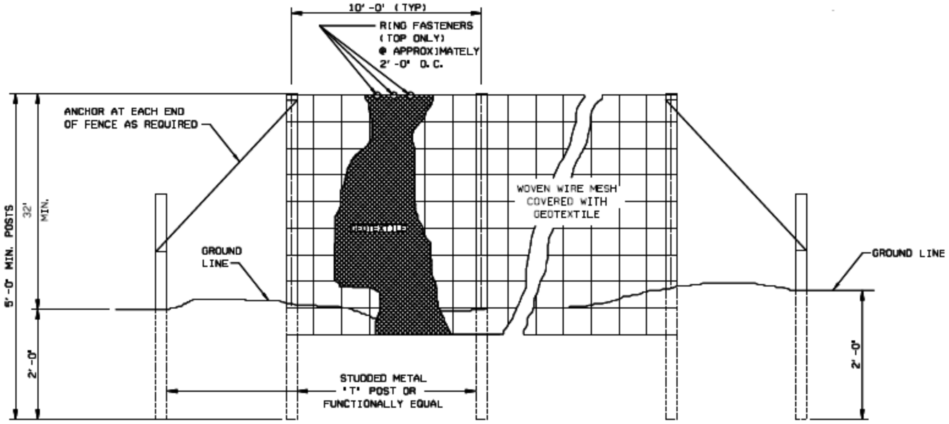
DETAILS OF SEDIMENT BARRIER APPLICATIONS

Bureau Std Engr. ______
DRAWN BY: ______ DATE DRAWN: 2006

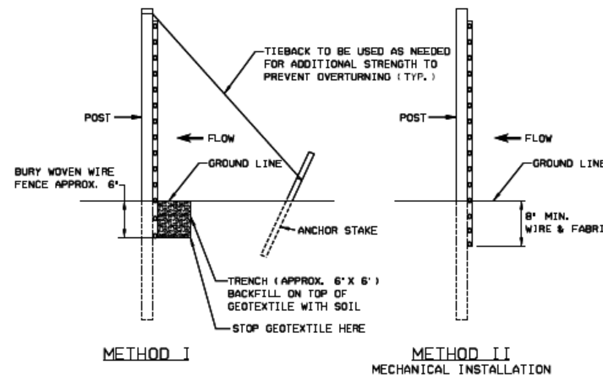
SPECIAL DRAWING NO: ESC-200-3
INDEX NO: 1161-B

NOT TO SCALE

REFERENCE PROJECT NO	FISCAL YEAR	SHEET NO



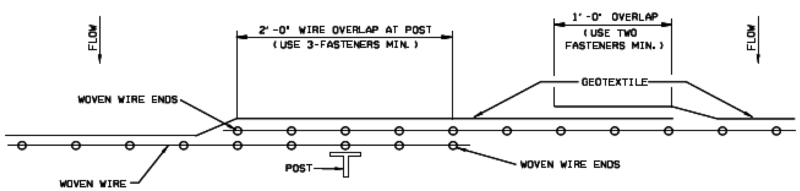
ELEVATION VIEW



SIDE VIEW

NOTES:

1. METHOD II FENCE INSTALLATION ALSO TO INCLUDE ANCHORS AND TIEBACKS AS REQUIRED.
2. SILT FENCE SHALL BE USED IN AREAS WHERE FLOW IS LOW TO MODERATE OR AS DIRECTED BY THE ENGINEER.
3. SILT FENCES ARE TEMPORARY SEDIMENT CONTROL ITEMS THAT SHALL BE ERECTED DOWN GRADE OF ERODIBLE AREAS SUCH AS NEWLY GRADED FILL SLOPES AND ADJACENT TO STREAMS AND CHANNELS.
4. SILT FENCE SHOULD BE PLACED WELL INSIDE RIGHT-OF-WAY AND ALONG EDGE OF CLEARING LIMITS. THIS WILL ALLOW ROOM FOR ADDITIONAL BEST MANAGEMENT PRACTICES SUCH AS VEGETATED BUFFERS.
5. WHEREVER POSSIBLE SILT FENCES SHALL BE CONSTRUCTED ACROSS A LEVEL AREA IN THE SHAPE OF A SMILE. THIS AIDS IN PONDING OF RUNOFF AND FACILITATES SEDIMENTATION.
6. THE CONTRACTOR MAY ELECT TO USE EITHER INSTALLATION METHOD I OR METHOD II.
7. METHOD II INSTALLATION SHALL BE ACCOMPLISHED USING AN IMPLEMENT THAT IS MANUFACTURED FOR THE APPLICATION AND PROVIDES A CONFIGURATION MEETING THE REQUIREMENTS OF THE DETAIL.
8. SEE ALDOT LIST II-3 FOR APPROVED SILT FENCE GEOTEXTILES.



PLAN VIEW

REQUIRED LAPPING

—SPECIFICATIONS—
CURRENT ALABAMA DEPARTMENT OF TRANSPORTATION

REVISIONS

1. Revised Fence height and deleted (Type A) from the Silt Fence description on 07-12-07 by W.A.
2. Revised Notes 2, 3, 4, 6 and added 8 on 08-24-11 by J.T.
3. Updated Special Drawing No. from ESC-200 (SHEET 4 OF 5) to ESC-200-4 on 10-31-16 by J.T. AND J.W.

ALABAMA DEPARTMENT OF TRANSPORTATION
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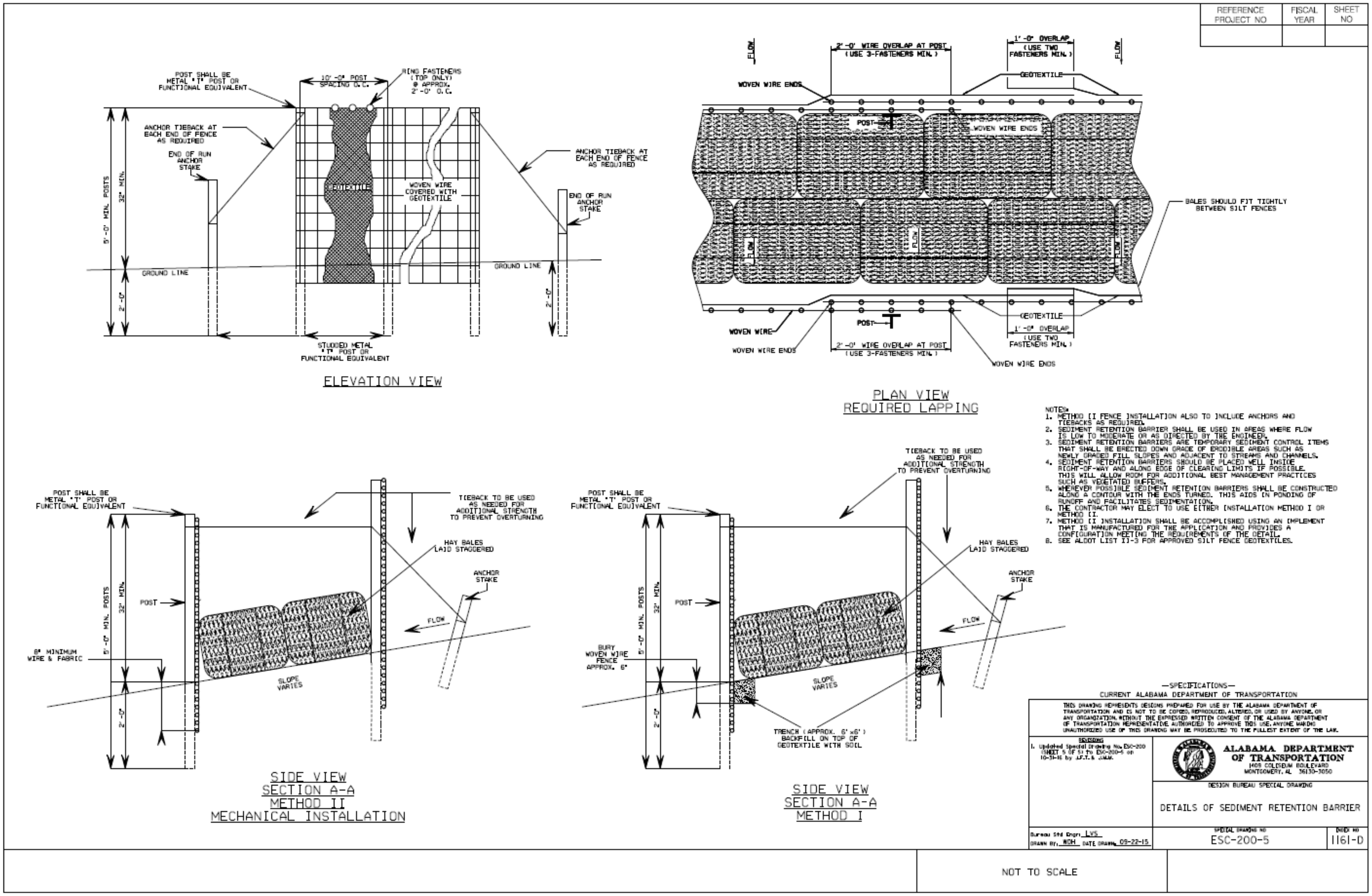
DESIGN BUREAU SPECIAL DRAWING

DETAILS OF SILT FENCE INSTALLATION

Bureau Std Engr: LVS
DRAWN BY: ______ DATE DRAWN: 2006

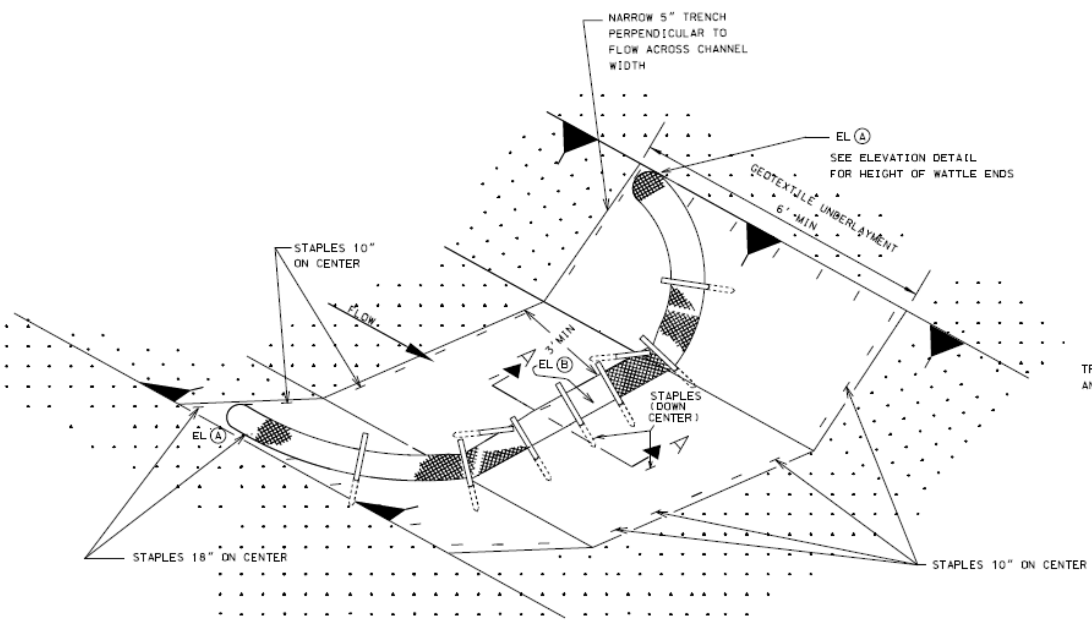
SPECIAL DRAWING NO: ESC-200-4
INDEX NO: 1161-C

NOT TO SCALE

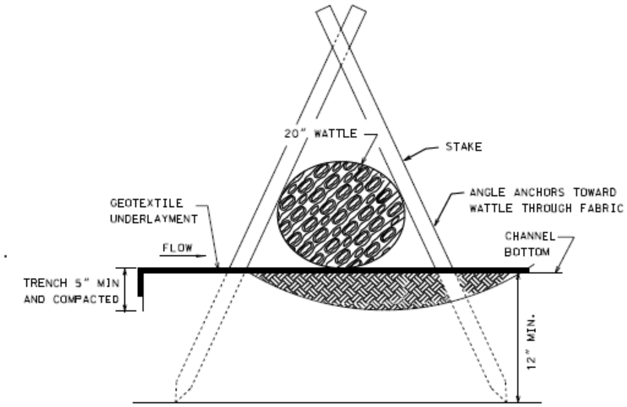


REFERENCE PROJECT NO
FISCAL YEAR
SHEET NO
POST SHALL BE METAL "T" POST OR FUNCTIONAL EQUIVALENT
10'-0" POST SPACING O.C.
RING FASTENERS (TOP ONLY) @ APPROX. 2'-0" O.C.
ANCHOR TIEBACK AT EACH END OF FENCE AS REQUIRED
END OF RUN ANCHOR STAKE
GEOTEXTILE
WOVEN WIRE COVERED WITH GEOTEXTILE
5'-0" MIN. POSTS
32" MIN.
GROUND LINE
2'-0"
STUDDED METAL "T" POST OR FUNCTIONAL EQUIVALENT
ELEVATION VIEW
FLOW
2'-0" WIRE OVERLAP AT POST (USE 3-FASTENERS MIN.)
1'-0" OVERLAP (USE TWO FASTENERS MIN.)
WOVEN WIRE ENDS
POST
BALES SHOULD FIT TIGHTLY BETWEEN SILT FENCES
WOVEN WIRE
PLAN VIEW
REQUIRED LAPPING
NOTES:
1. METHOD II FENCE INSTALLATION ALSO TO INCLUDE ANCHORS AND TIEBACKS AS REQUIRED.
2. SEDIMENT RETENTION BARRIER SHALL BE USED IN AREAS WHERE FLOW IS LOW TO MODERATE OR AS DIRECTED BY THE ENGINEER.
3. SEDIMENT RETENTION BARRIERS ARE TEMPORARY SEDIMENT CONTROL ITEMS THAT SHALL BE ERECTED DOWN GRADE OF ERODIBLE AREAS SUCH AS NEWLY GRADED FILL SLOPES AND ADJACENT TO STREAMS AND CHANNELS.
4. SEDIMENT RETENTION BARRIERS SHOULD BE PLACED WELL INSIDE RIGHT-OF-WAY AND ALONG EDGE OF CLEARING LIMITS IF POSSIBLE. THIS WILL ALLOW ROOM FOR ADDITIONAL BEST MANAGEMENT PRACTICES SUCH AS VEGETATED BUFFERS.
5. WHEREVER POSSIBLE SEDIMENT RETENTION BARRIERS SHALL BE CONSTRUCTED ALONG A CONTOUR WITH THE ENDS TURNED. THIS AIDS IN PONDING OF RUNOFF AND FACILITATES SEDIMENTATION.
6. THE CONTRACTOR MAY ELECT TO USE EITHER INSTALLATION METHOD I OR METHOD II.
7. METHOD II INSTALLATION SHALL BE ACCOMPLISHED USING AN IMPLEMENT THAT IS MANUFACTURED FOR THE APPLICATION AND PROVIDES A CONFIGURATION MEETING THE REQUIREMENTS OF THE DETAIL.
8. SEE ALDOT LIST II-3 FOR APPROVED SILT FENCE GEOTEXTILES.
TIEBACK TO BE USED AS NEEDED FOR ADDITIONAL STRENGTH TO PREVENT OVERTURNING
HAY BALES LAID STAGGERED
ANCHOR STAKE
POST
8" MINIMUM WIRE & FABRIC
SLOPE VARIES
SIDE VIEW
SECTION A-A
METHOD II
MECHANICAL INSTALLATION
BURY WOVEN WIRE FENCE APPROX. 6"
TRENCH (APPROX. 6"x6") BACKFILL ON TOP OF GEOTEXTILE WITH SOIL
SIDE VIEW
SECTION A-A
METHOD I
—SPECIFICATIONS—
CURRENT ALABAMA DEPARTMENT OF TRANSPORTATION
THIS DRAWING REPRESENTS DESIGNS PREPARED FOR USE BY THE ALABAMA DEPARTMENT OF TRANSPORTATION AND IS NOT TO BE COPIED, REPRODUCED, ALTERED, OR USED BY ANYONE, OR ANY ORGANIZATION, WITHOUT THE EXPRESSED WRITTEN CONSENT OF THE ALABAMA DEPARTMENT OF TRANSPORTATION REPRESENTATIVE AUTHORIZED TO APPROVE THIS USE. ANYONE MAKING UNAUTHORIZED USE OF THIS DRAWING MAY BE PROSECUTED TO THE FULLEST EXTENT OF THE LAW.
REVISIONS
1. Updated Special Drawing No. ESC-200 (SHEET 5 OF 5) to ESC-200-5 on 10-31-16 by J.F.T. & J.M.M.
ALABAMA DEPARTMENT OF TRANSPORTATION
1409 COLISEUM BOULEVARD
MONTGOMERY, AL 36130-3050
DESIGN BUREAU SPECIAL DRAWING
DETAILS OF SEDIMENT RETENTION BARRIER
Bureau Std Engr: LVS
DRAWN BY: WDH DATE DRAWN: 09-22-15
SPECIAL DRAWING NO
ESC-200-5
INDEX NO
1161-D
NOT TO SCALE

REFERENCE PROJECT NO	FISCAL YEAR	SHEET NO



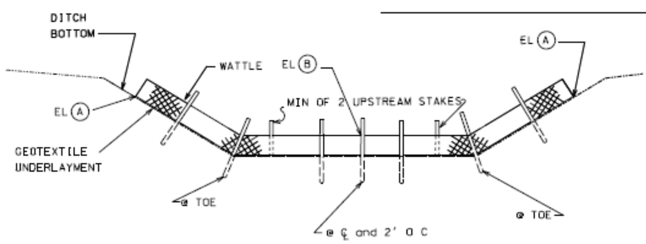
DETAIL (DITCH CHECK)



SECTION A-A

NOTES:

1. MINIMUM RECOMMENDED PLACEMENT INTERVAL BETWEEN WATTLE DITCH CHECK IS 100 FEET UNLESS SHOWN OTHERWISE ON THE PLANS OR APPROVED BY THE ENGINEER. SEE SPACING GUIDANCE ON ESC-300-1.
2. ANCHORING STAKES SHALL BE SIZED, SPACED, DRIVEN, AND BE OF A MATERIAL THAT EFFECTIVELY SECURES THE CHECK. STAKE SPACING SHALL BE A MAXIMUM OF TWO FEET.
3. WATTLES SHOULD NOT BE USED IN HARD BOTTOM CHANNELS.
4. STAPLES SPACED 18 INCHES APART, ALONG THE CHANNEL EDGES AND DOWN THE CENTER OF THE CHANNEL. STAPLES SPACED 10 INCHES APART, ACROSS THE UPSTREAM AND DOWNSTREAM EDGES.



ELEVATION DETAIL

NOTE: END POINTS (A) MUST BE HIGHER THAN FLOWLINE POINT (B)

WATTLE DITCH CHECK SELECTION GUIDELINES

WATTLE DITCH CHECKS ARE APPROPRIATE FOR VELOCITY REDUCTION AND CONTROL OF SEDIMENT TRANSPORT UNDER LOW TO MEDIUM FLOW CONDITIONS NOT EXCEEDING 1.0 CU FT/SEC.

—SPECIFICATIONS—
CURRENT ALABAMA DEPARTMENT OF TRANSPORTATION

REVISIONS

1. Added in "SECTION A-A" REQUIRED TRENCHING and deleted Note 5. Deleted "FLOCCULANT ZONE (SEE NOTE 5)" on 08-24-11 by J.F.T.
2. Revised and updated "DETAIL (DITCH CHECK)" and "ELEVATION DETAIL". Revised text of "WATTLE DITCH CHECK SELECTION GUIDELINES" and adjusted and revised "SECTION A-A" on 08-24-12 by J.F.T.
3. Revised Notes 1 and 4 on 10-20-14 by J.F.T.
4. Updated Special Drawing No. from ESC-300 (SHEET 4 OF 8) to ESC-300-4 on 10-31-16 by J.F.T. & J.W.M.

Bureau Std Engr: ______
DRAWN BY: ______ DATE DRAWN: 2006

ALABAMA DEPARTMENT OF TRANSPORTATION
1409 COLISEUM BOULEVARD
MONTGOMERY, AL 36130-3050

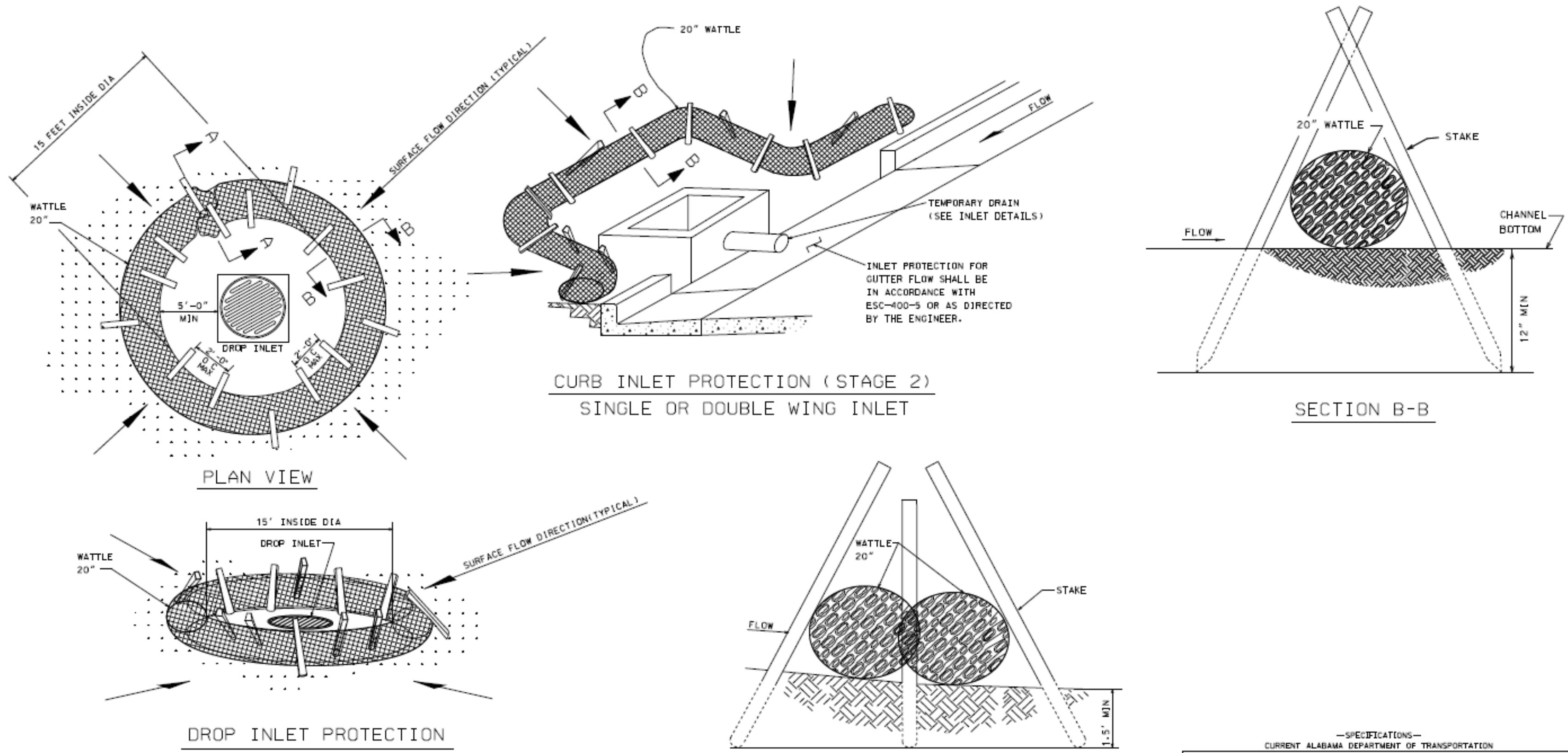
DESIGN BUREAU SPECIAL DRAWING

DETAILS OF EROSION CONTROL
WATTLE DITCH CHECK

SPECIAL DRAWING NO: ESC-300-4
INDEX NO: 1162-C

NOT TO SCALE

REFERENCE PROJECT NO	FISCAL YEAR	SHEET NO



NOTES:

1. ANCHORING STAKES SHALL BE SIZED, SPACED, AND BE OF A MATERIAL THAT EFFECTIVELY SECURES THE WATTLE. STAKE SPACING SHALL BE A MAXIMUM OF TWO FEET.
2. OVERLAP ENDS OF WATTLES PER MANUFACTURERS RECOMMENDATIONS (1'MIN.3'MAX).
3. SEE ALDOT LIST II-24 FOR APPROVED WATTLES.
4. SILT FENCE OR SAND BAGS MAY ALSO BE USED FOR THIS APPLICATION. HAY BALES NOT ACCEPTABLE DURING THIS STAGE.

—SPECIFICATIONS—
CURRENT ALABAMA DEPARTMENT OF TRANSPORTATION

REVISIONS

1. Revised note on "CURB INLET PROTECTION (STAGE 2)" from "5 OF 5" to "4 OF 4" and added "REQUIRED TRENCHING" on SECTION A-A and "SECTION B-B" on 08-24-11 by A.P.T.
2. Revised and updated "CURB INLET PROTECTION (STAGE 2)", "DROP INLET PROTECTION", "SECTION A-A" and "SECTION B-B" to show new staking w/o trenching on 09-24-12 by A.P.T.
3. Deleted a "NOTE" and replaced and revised Note 4. Revised and updated "PLAN VIEW" on 07-11-13 by J.P.T.
4. Updated Special Drawing No. from ESC-400 (SHEET 3 OF 5) to ESC-400-3 on 10-31-16 by J.P.T. & J.W.W.

ALABAMA DEPARTMENT OF TRANSPORTATION
1409 COLISEUM BOULEVARD
MONTGOMERY, AL 36130-3050

DESIGN BUREAU SPECIAL DRAWING

INLET PROTECTION DETAILS OF WATTLES

Bureau Std Engr: ______
DRAWN BY: ______ DATE DRAWN: 2006

SPECIAL DRAWING NO: ESC-400-3
INDEX NO: 1163-B

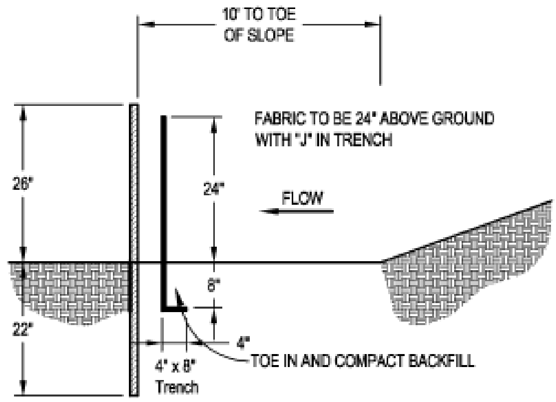
NOT TO SCALE

APPENDIX B

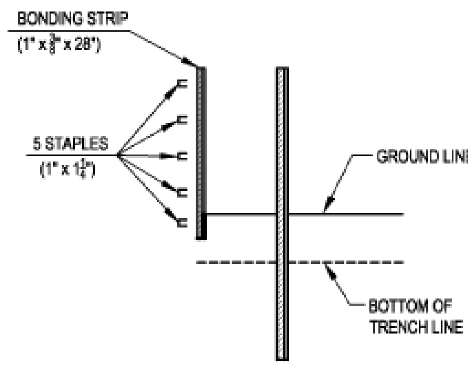
MANUFACTURER’S INSTALLATION DETAILS

SILT - SAVER

EROSION AND SEDIMENT CONTROL PRODUCTS



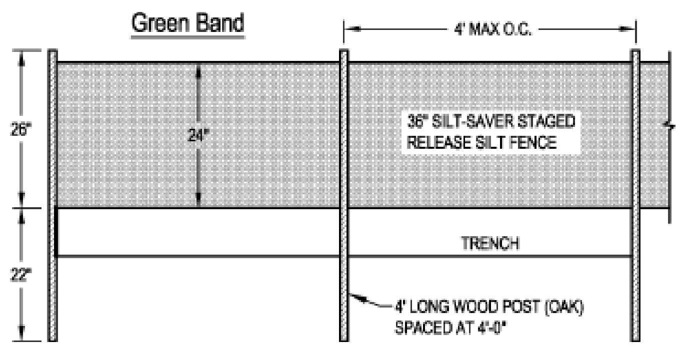
SIDE VIEW



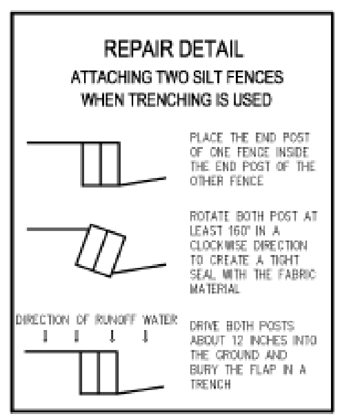
POST (OAK)

($1\frac{3}{4}$" x $1\frac{1}{4}$" x 48")

(OR EQUAL DENSITY)



FRONT ELEVATION



PLAN VIEW

STAGED RELEASE SILT FENCE	FRAME MATERIAL: OAK OR SIMILAR
	FILTER FABRIC MATERIAL: REFER TO SPEC
	SCALE: NOT TO SCALE
	LAST UPDATED: FEBRUARY 2015

SILT-SAVER, INC. 1094 CULPEPPER DRIVE, CONYERS, GA 30094 PHONE: (770) 388-7818 FAX: (770) 388-7640 TOLL FREE: 1-888-382-SILT (7458) www.siltsaver.com

Installation Instructions
Logs and Wattles

Step 1 - Site Preparation

Prepare site to design profile and grade. Remove debris, rocks, clods, etc.. Ground surface should be smooth prior to installation to ensure log remains in contact with slope.

Step 2 - Staple Selection

At a minimum, 1 in. by 1 in. by 24 in., stakes are to be used to secure the log to the ground surface. Installation in rocky, sandy or other loose soil may require longer stakes.

Slope Installation

Place RECP along slope to provide upstream apron for log. Secure RECP according to standard slope installation instructions including upstream anchor trench. Secure log to blanket, ensuring log remains in intimate contact with the RECP over the length of the installation. A minimum of one foot upstream apron and two foot downstream apron are required for installation. Subsequent, downslope rows of logs should be spaced appropriately for site conditions to minimize acceleration of flow. Further, log seams are to be offset to ensure continuous filtration. Figure A presents a schematic of a slope installation in profile view.

Channel Installation

Place RECP along channel to provide upstream and downstream apron for log identically to slope installation. Secure log to blanket, ensuring log remains in intimate contact with the RECP over the length of the installation. A minimum of one foot upstream apron and two foot downstream apron are required for installation. Subsequent, downslope rows of logs should be spaced appropriately for site conditions to minimize acceleration of flow. Further, log seams are to be offset to ensure continuous filtration. Figure A / Figure C presents a schematic of a channel installation.

Drain Filter Installation

Surround drain inlet to be protected with log, ensuring seams are overlapping to minimize flow circumventing log. Secure logs to ground surface ensuring the log remains in intimate contact with the ground surface over the entire installation. Provide RECP apron secured to the ground surface between drain and log.

Please contact Western Excelsior Technical Support Division at 800-967-4009 with specific questions or for further information.

Slope/Channel Installation

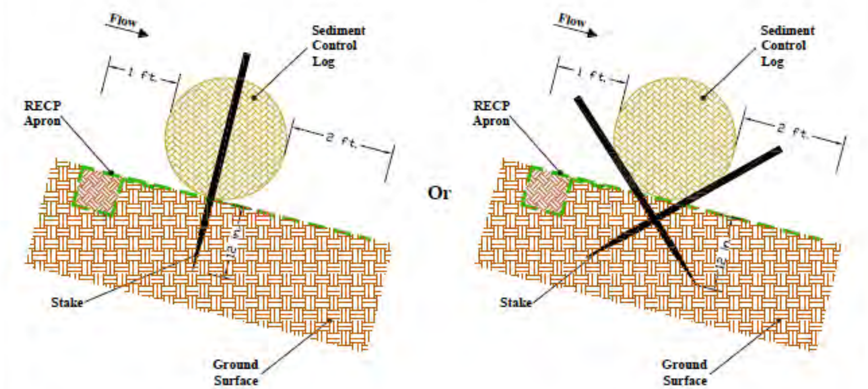


Figure A - Profile View

Flat Ground (Perimeter Guard) Installation

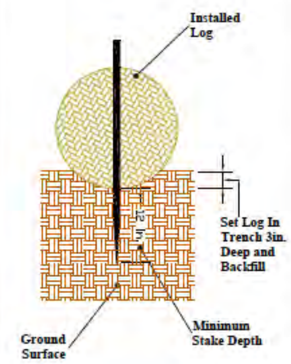


Figure B - Profile View

Channel Installation

Minimum stake in ground, 12 in.

Do not allow flow to overtop installation.

Figure C - Cross-Section View

Drain Filter

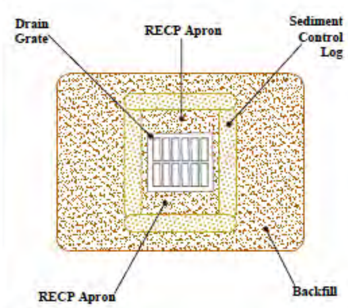


Figure D - Cross-Section View

Curbside Installation

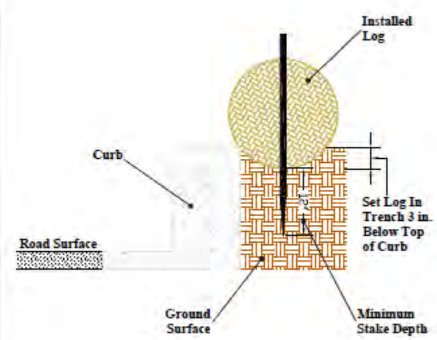
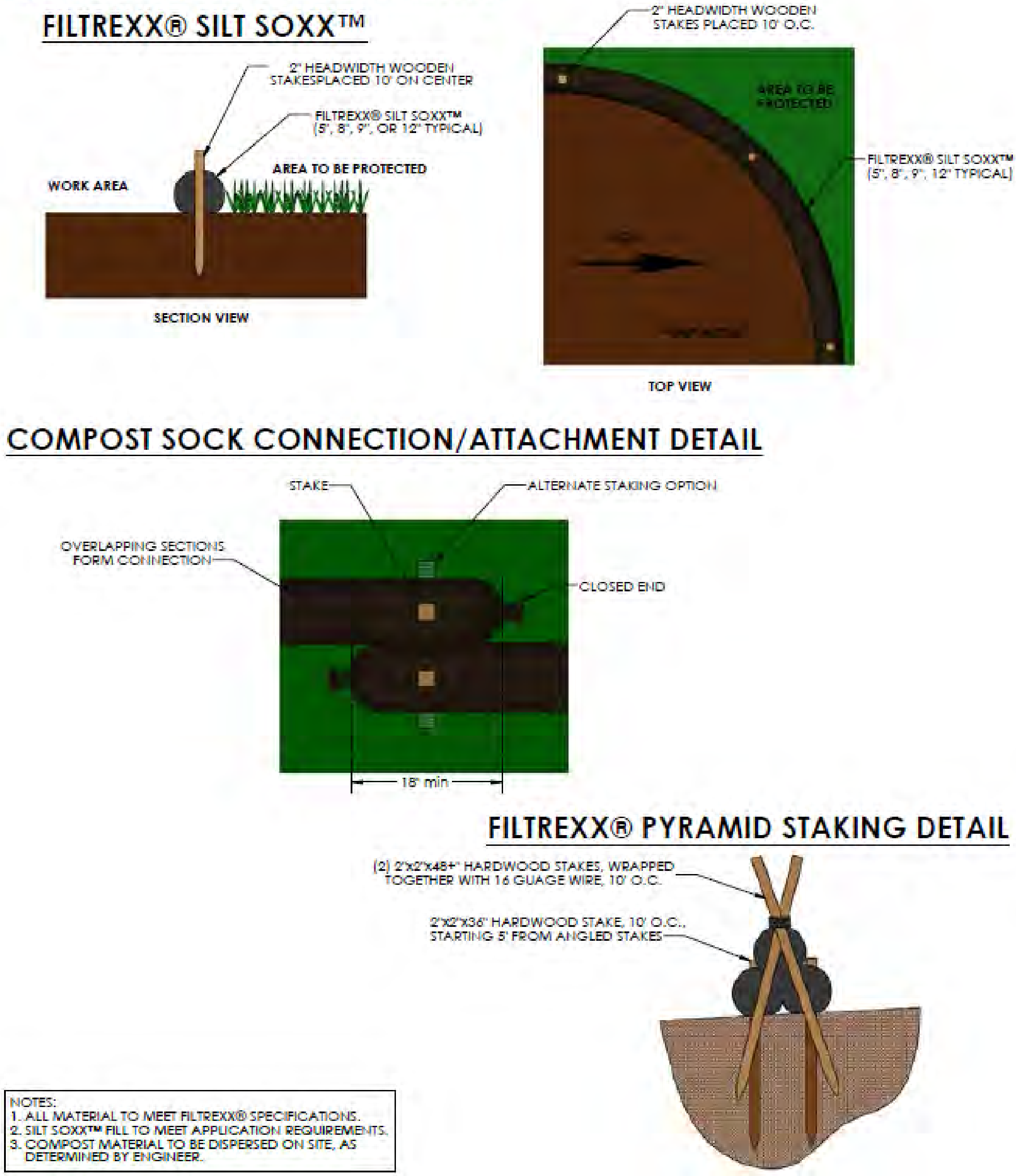
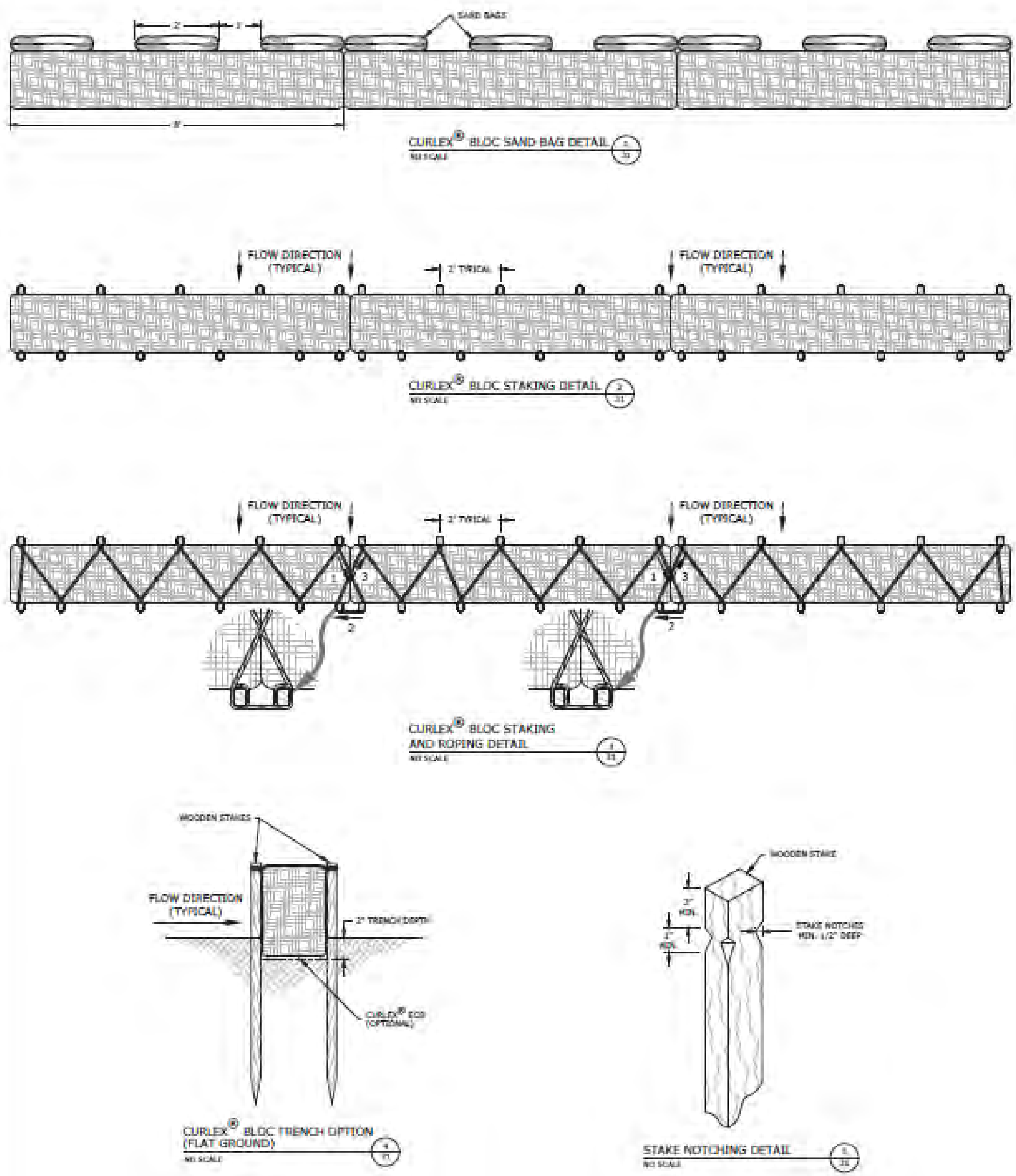


Figure E - Cross-Section View

Document # WE_EXCEL_LOG_II

Figure 1.1. Engineering Design Drawing for Perimeter Control





INSTALLATION NOTES:
1) NON-STRETCHING ROPE WHEN WET.
2) 1½" x 1½" x 48" WOODEN STAKES ARE RECOMMENDED.
3) POUND STAKES TIGHTLY NEXT TO CURLEX® BLOC LEAVING APPROXIMATELY 4" OF STAKE ABOVE SURFACE OF CURLEX® BLOC.
4) INSTALL ROPE ACCORDING TO DRAWING (ENSURE ROPE IS WRAPPED "TIGHTLY" IN STAKE NOTCHES).
5) KNOT OFF ROPE TO STAKE AT LEAST EVERY 25 FEET OF ROPE.
6) POUND DOWN STAKES FLUSH WITH SURFACE OF CURLEX® BLOC AFTER ALL IS INSTALLED TO TIGHTEN ROPE.
7) ABUT ADJOINING CURLEX® BLOCS TIGHTLY AND SECURE WITH STAKES AND ROPE ACCORDING TO DRAWING.
8) [illegible] CURLEX® BLOC [illegible], ADJUST STAKING AND ROPING PATTERN ACCORDINGLY IF USING A LONGER CURLEX® BLOCK.

NOTE:
1) TRENCHING OF CURLEX® BLOC IS OPTIONAL FOR INLET OR OUTLET PROTECTION, [illegible] CONTROL, RUNOFF DIVERSION AND FILTERING APPLICATIONS.
2) INSTALL ON BARE SOIL & ECB
3) USE ON HARD SURFACE (CONCRETE, FROZEN GROUND, ETC.)
4) SAND BAG SIZE 14" x 24", [illegible].

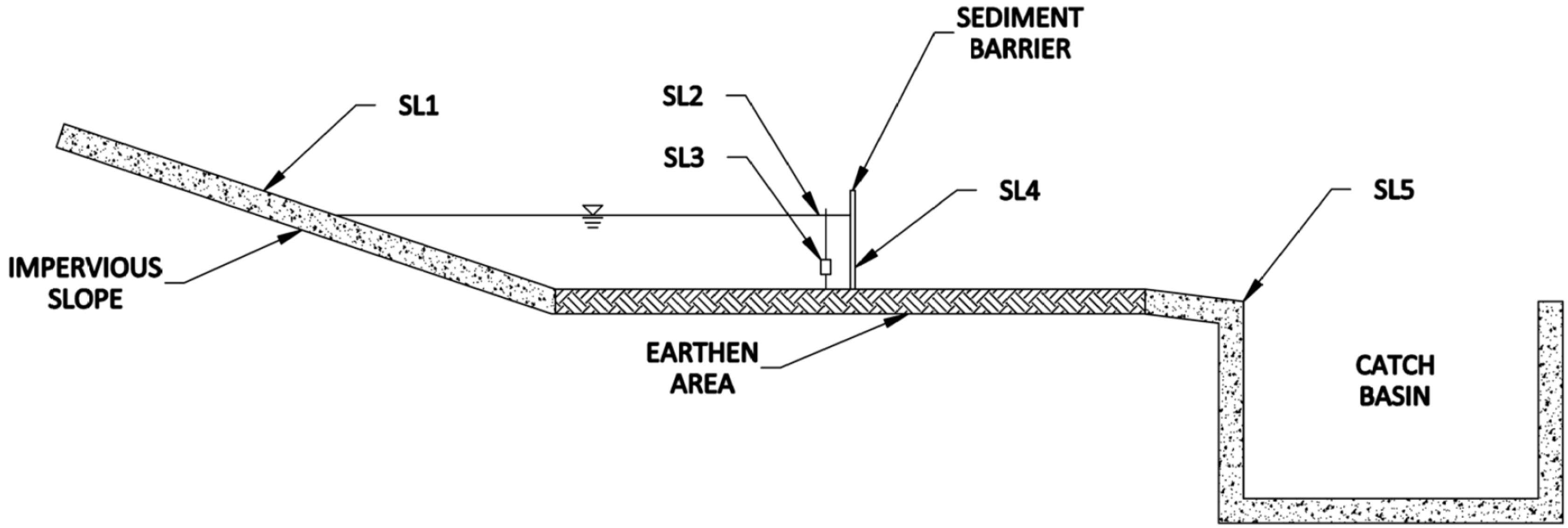
American Excelsior Company®
Earth Science Division

AMERICAN EXCELSIOR COMPANY ARLINGTON, TEXAS	SHEET DESCRIPTION CURLEX® BLOC ANCHORING TECHNIQUES DETAIL	DATE 3/27/17	DRAWN BY	
		SCALE NONE	PROJECT NO.	SHEET NO. 31

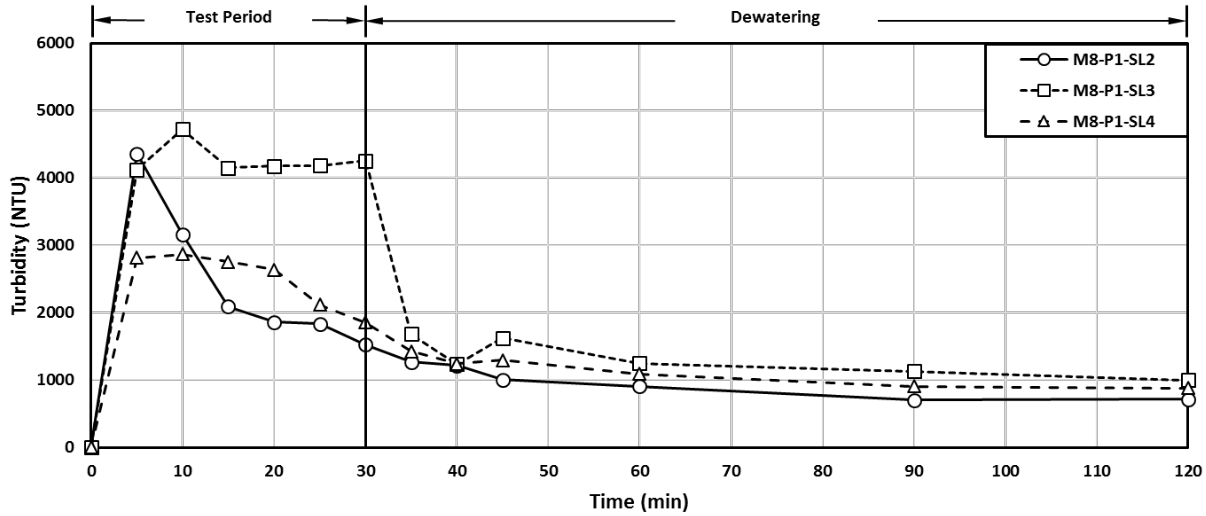
APPENDIX C

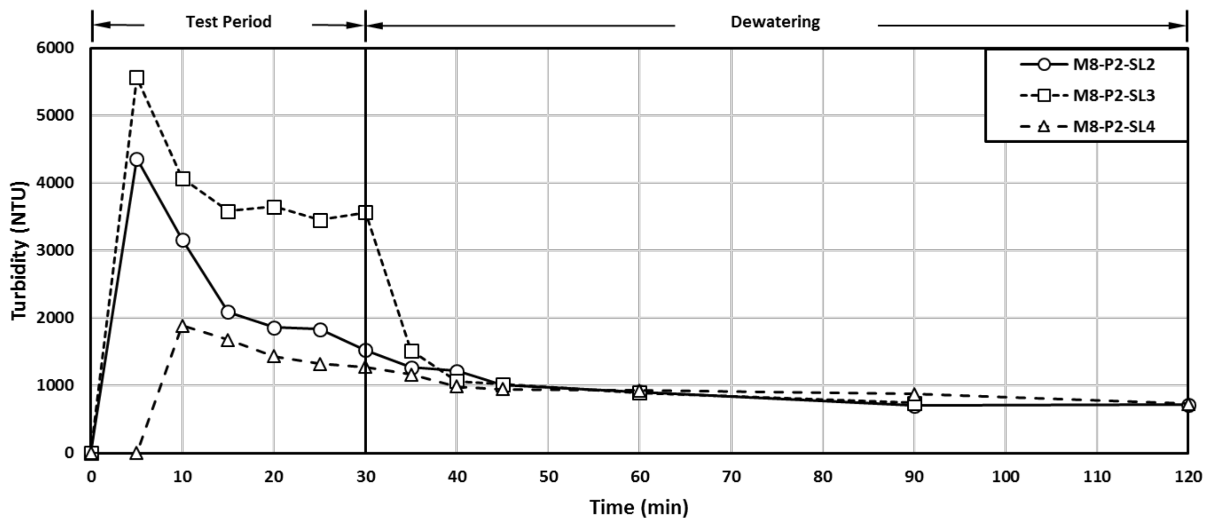
WATER QUALITY ANALYSIS GRAPHS

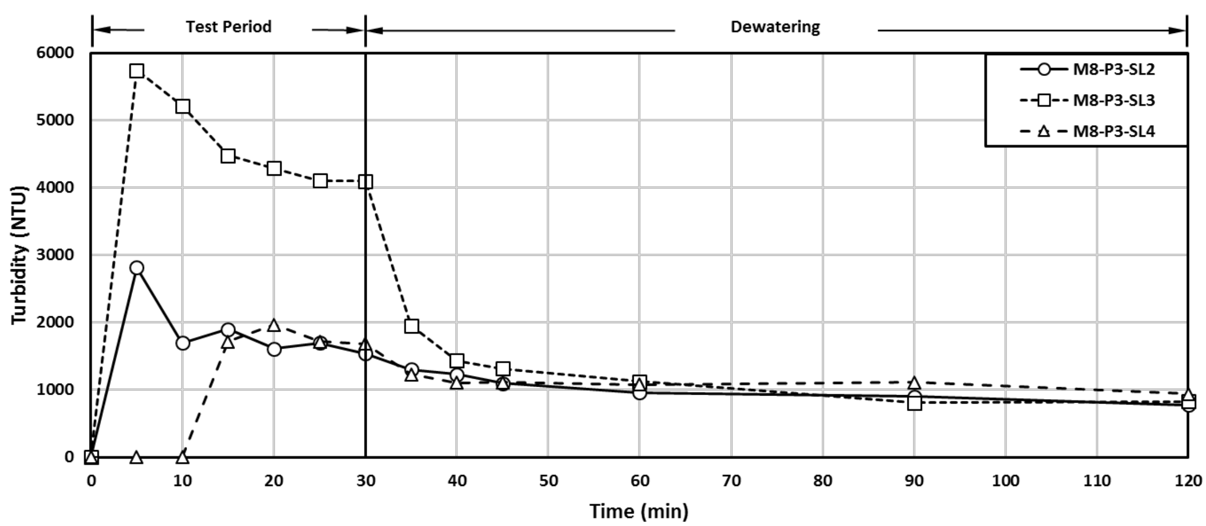
WATER SAMPLE LOCATIONS



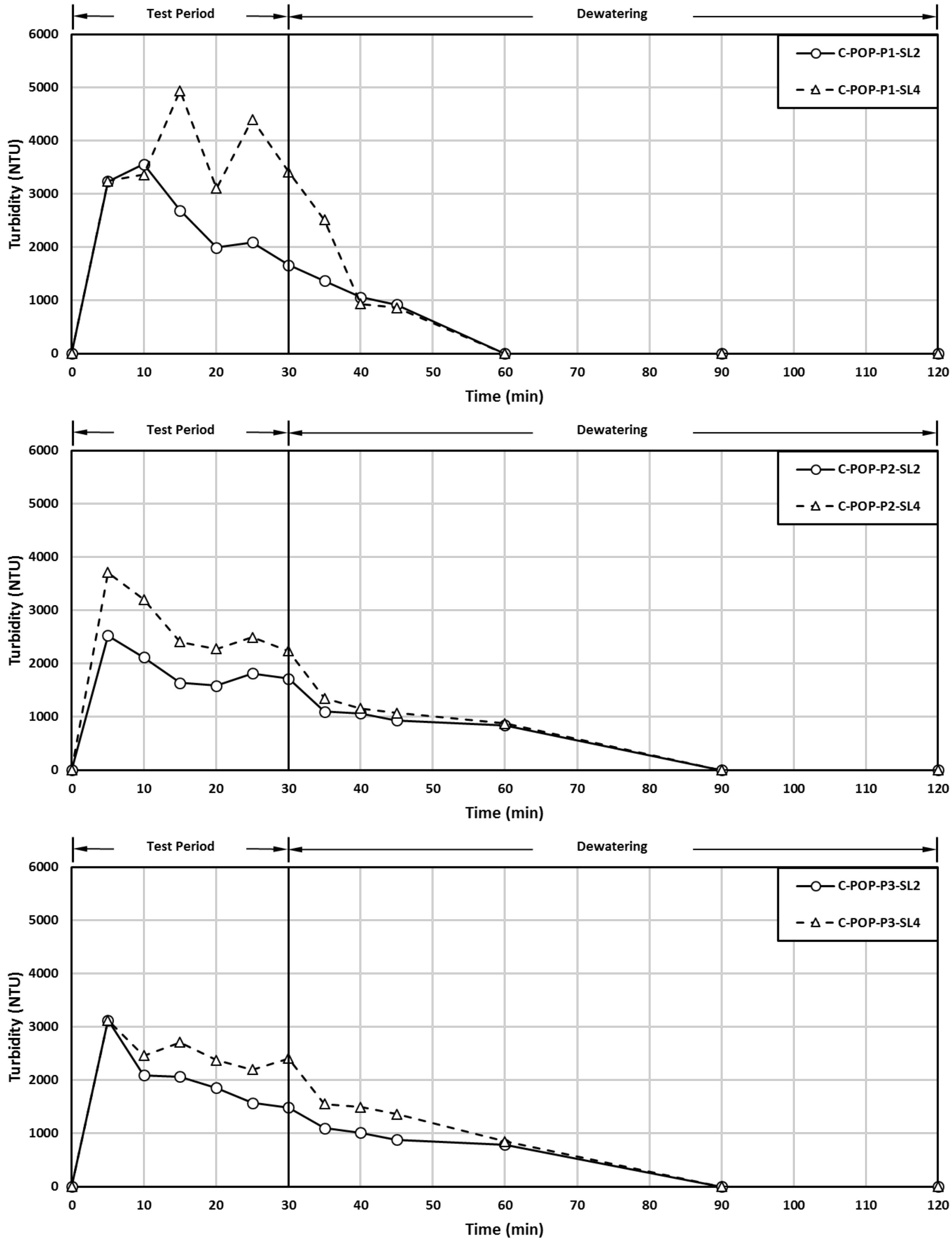
M8


Test Period
Dewatering
M8-P1-SL2
M8-P1-SL3
M8-P1-SL4
Turbidity (NTU)
Time (min)


Test Period
Dewatering
M8-P2-SL2
M8-P2-SL3
M8-P2-SL4
Turbidity (NTU)
Time (min)

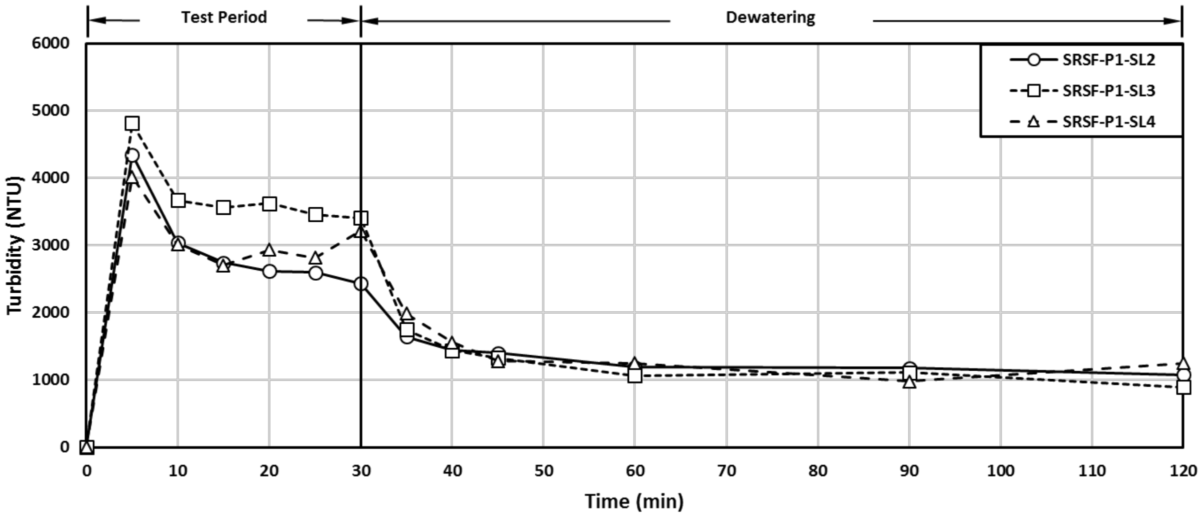

Test Period
Dewatering
M8-P3-SL2
M8-P3-SL3
M8-P3-SL4
Turbidity (NTU)
Time (min)

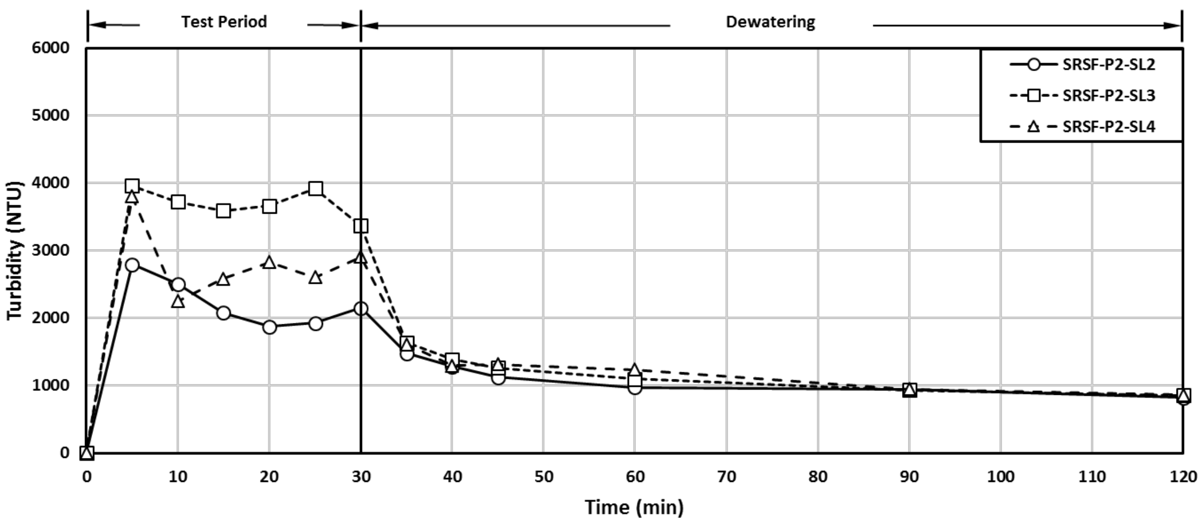
C-POP

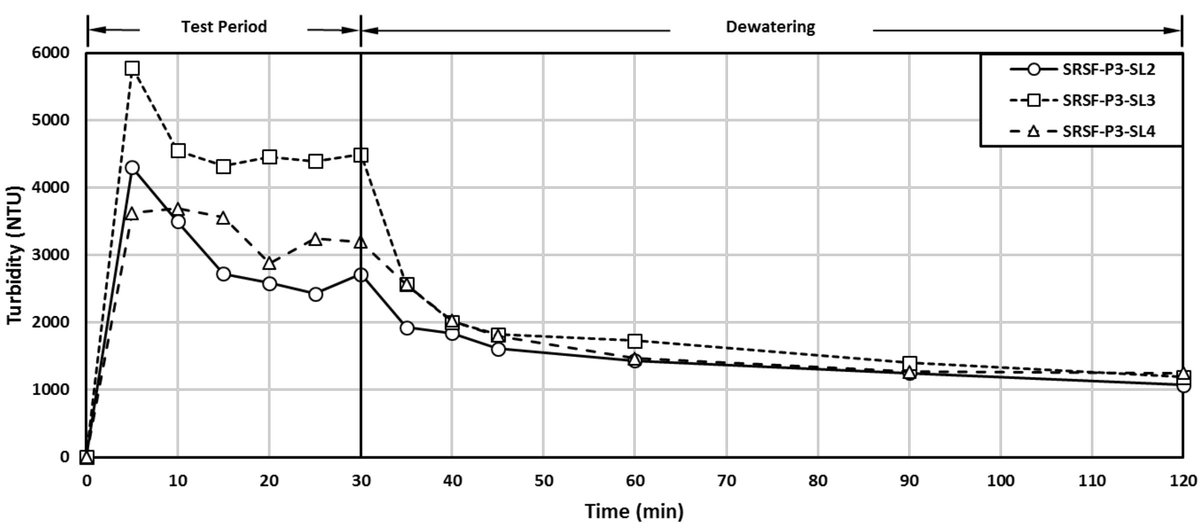


Test Period
Dewatering
C-POP-P1-SL2
C-POP-P1-SL4
Turbidity (NTU)
Time (min)
0
1000
2000
3000
4000
5000
6000
0
10
20
30
40
50
60
70
80
90
100
110
120
Test Period
Dewatering
C-POP-P2-SL2
C-POP-P2-SL4
Turbidity (NTU)
Time (min)
Test Period
Dewatering
C-POP-P3-SL2
C-POP-P3-SL4
Turbidity (NTU)
Time (min)

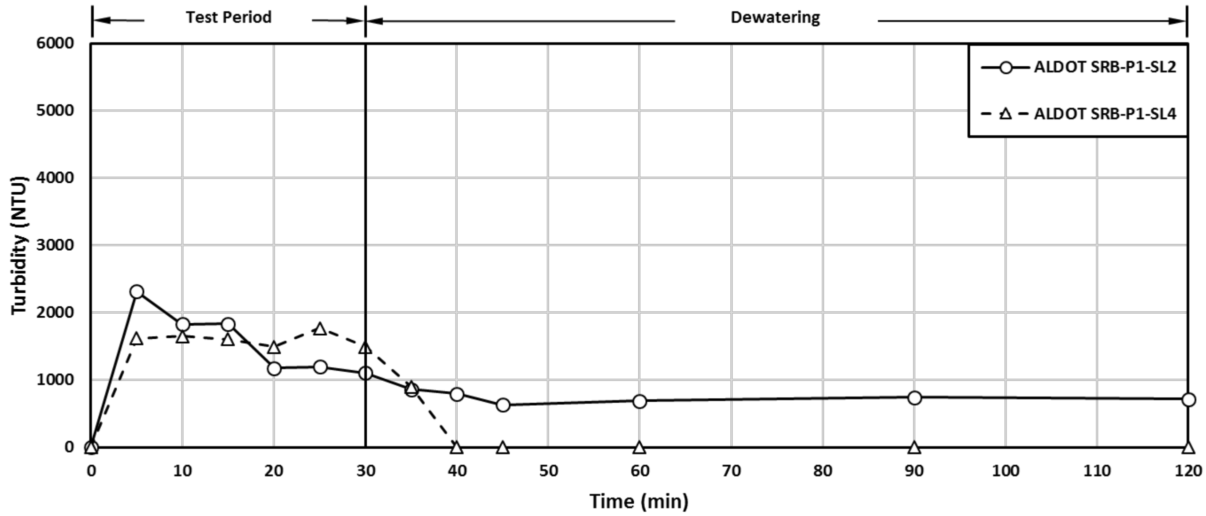
SRSF


Test Period
Dewatering
Turbidity (NTU)
Time (min)
SRSF-P1-SL2
SRSF-P1-SL3
SRSF-P1-SL4
0
1000
2000
3000
4000
5000
6000
0
10
20
30
40
50
60
70
80
90
100
110
120

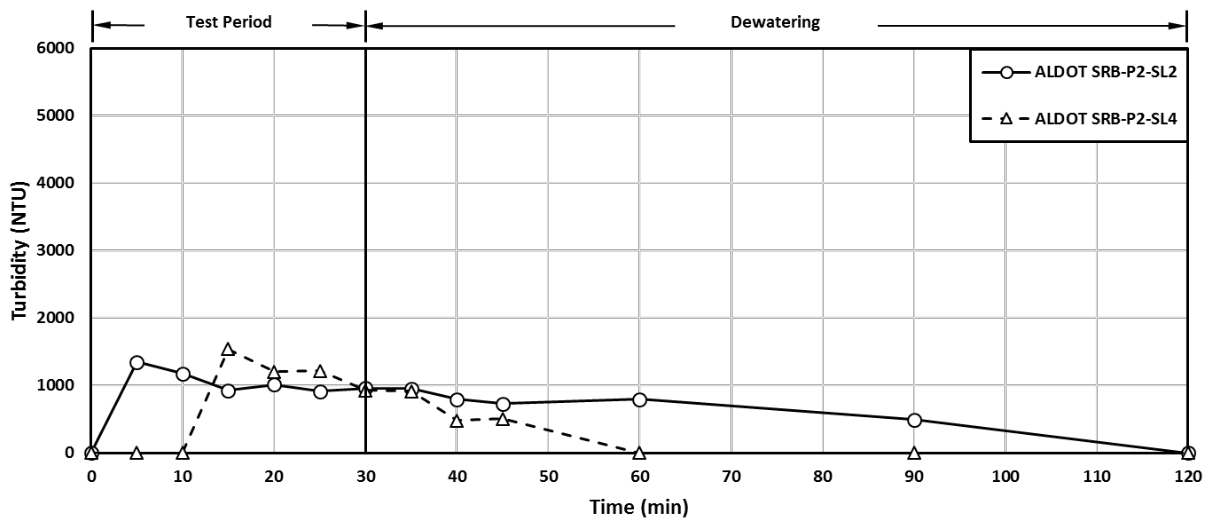

Test Period
Dewatering
Turbidity (NTU)
Time (min)
SRSF-P2-SL2
SRSF-P2-SL3
SRSF-P2-SL4
0
1000
2000
3000
4000
5000
6000
0
10
20
30
40
50
60
70
80
90
100
110
120


Test Period
Dewatering
Turbidity (NTU)
Time (min)
SRSF-P3-SL2
SRSF-P3-SL3
SRSF-P3-SL4
0
1000
2000
3000
4000
5000
6000
0
10
20
30
40
50
60
70
80
90
100
110
120

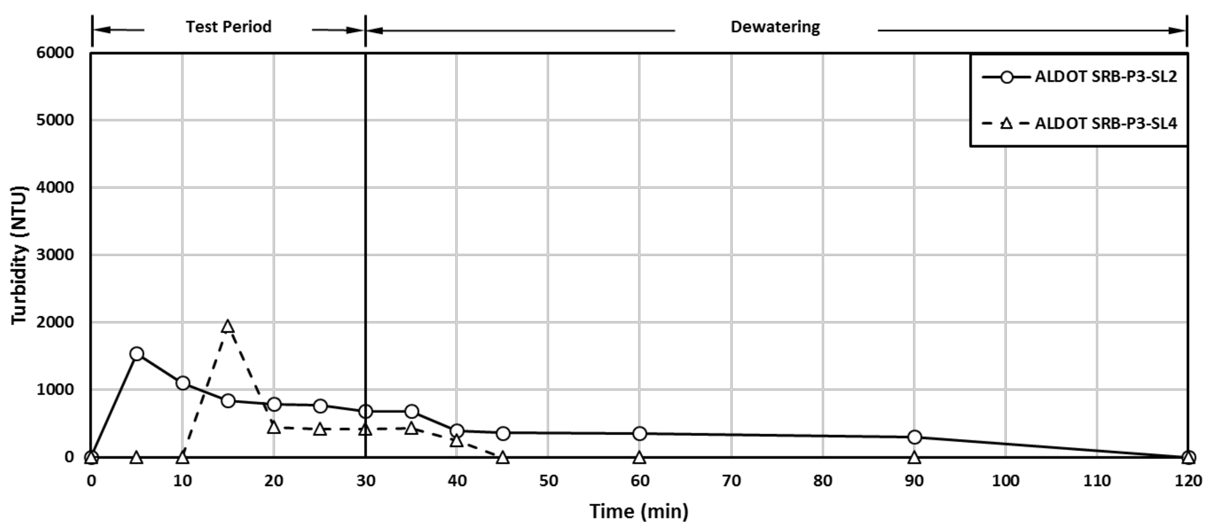
ALDOT SRB



Test Period
Dewatering
ALDOT SRB-P1-SL2
ALDOT SRB-P1-SL4
Turbidity (NTU)
Time (min)

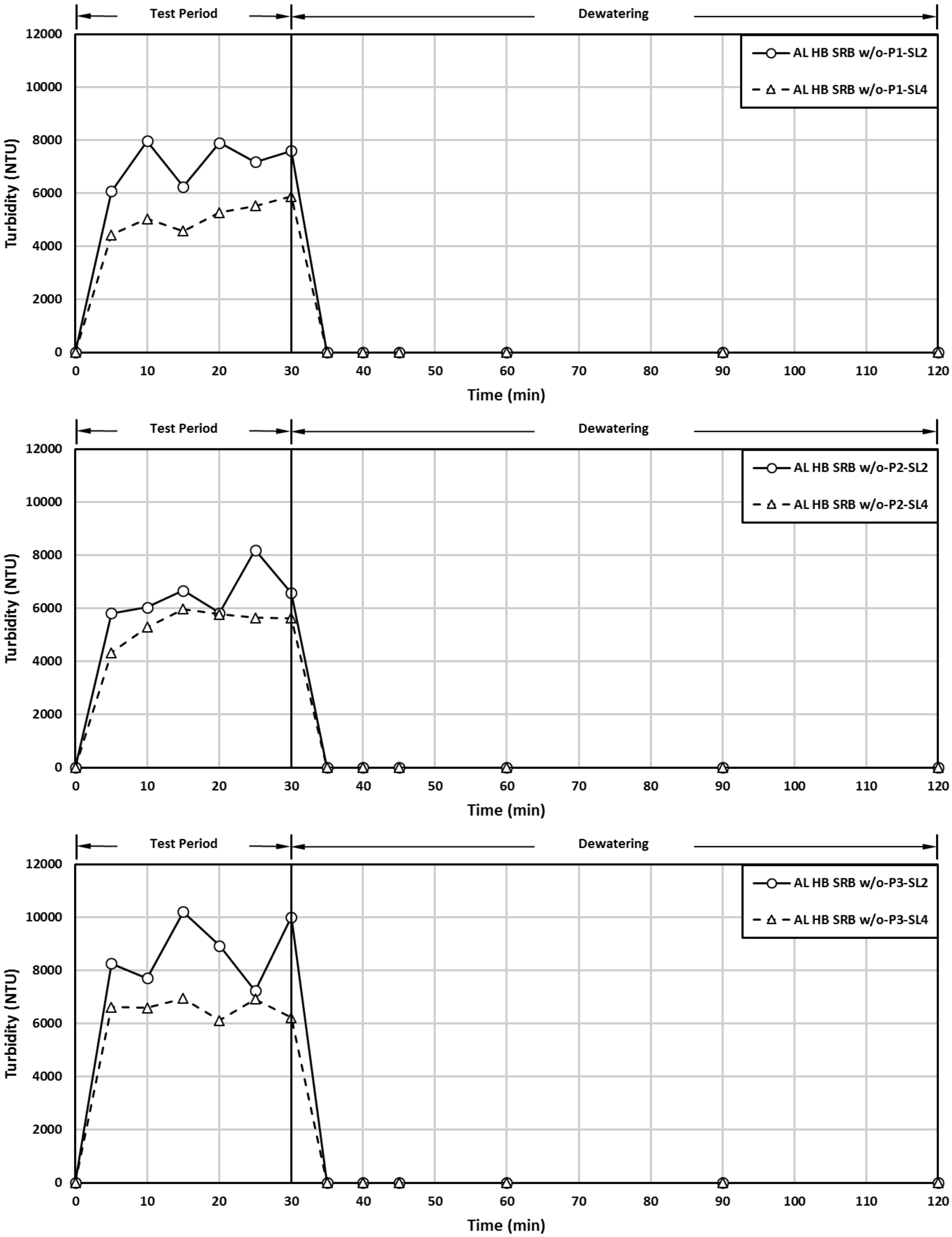


Test Period
Dewatering
ALDOT SRB-P2-SL2
ALDOT SRB-P2-SL4
Turbidity (NTU)
Time (min)

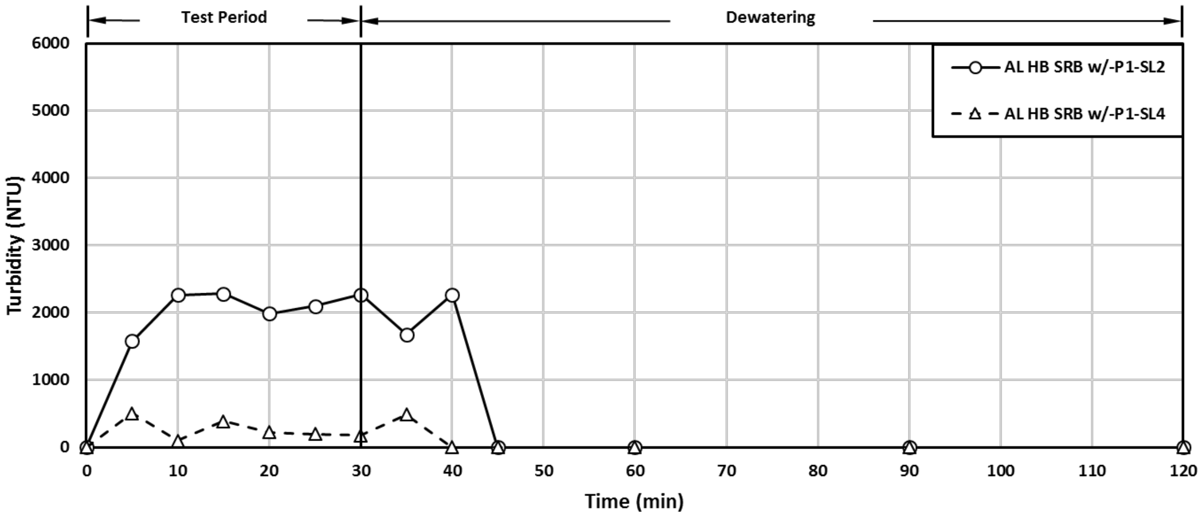


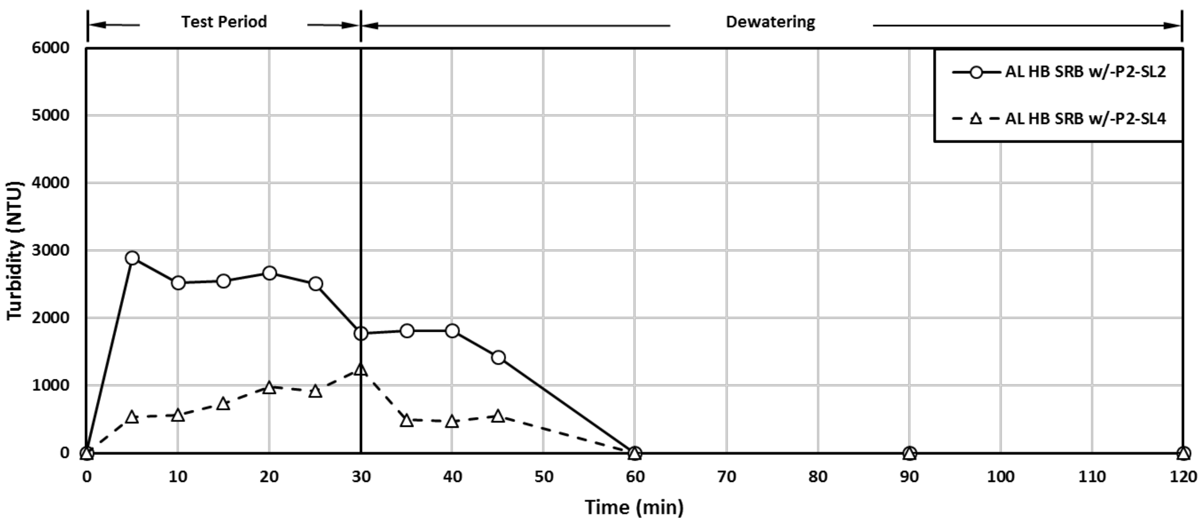
Test Period
Dewatering
ALDOT SRB-P3-SL2
ALDOT SRB-P3-SL4
Turbidity (NTU)
Time (min)

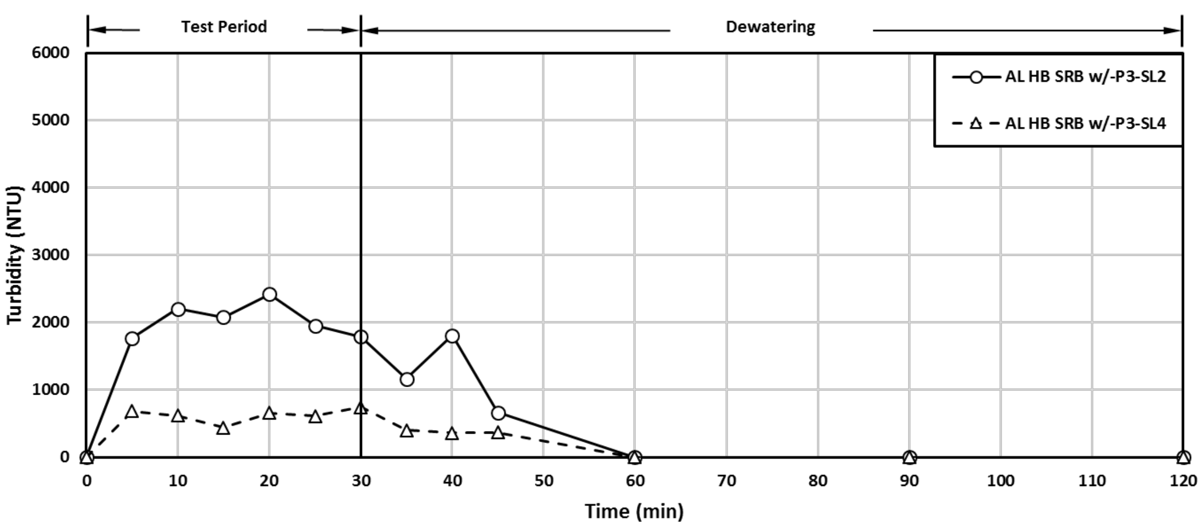
AL HB SRB w/o Flocculant

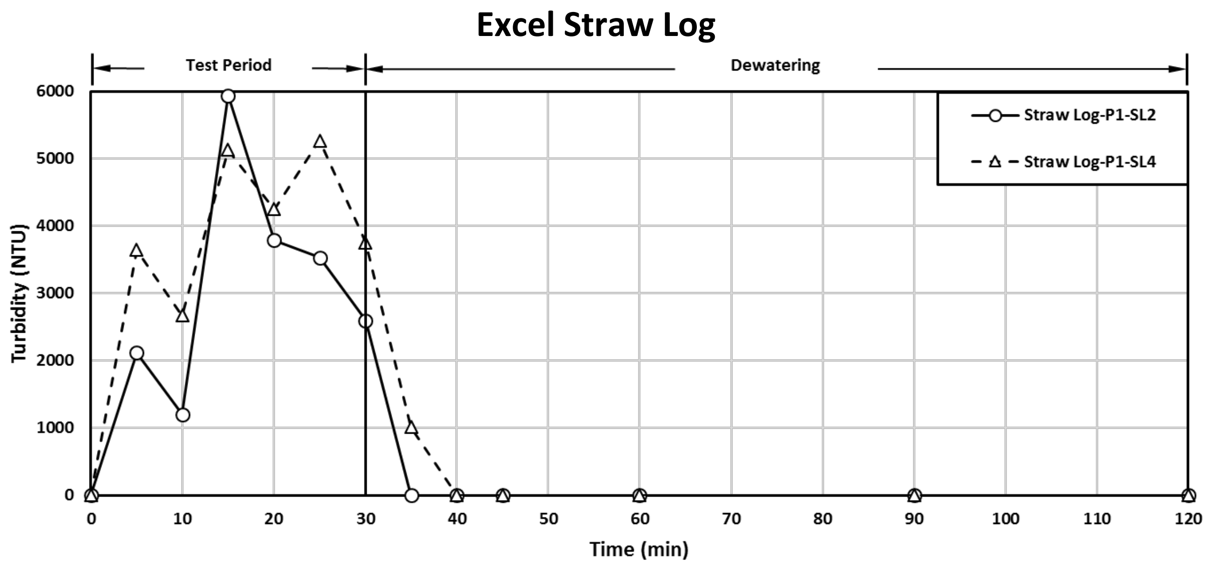


AL HB SRB w/ Flocculant

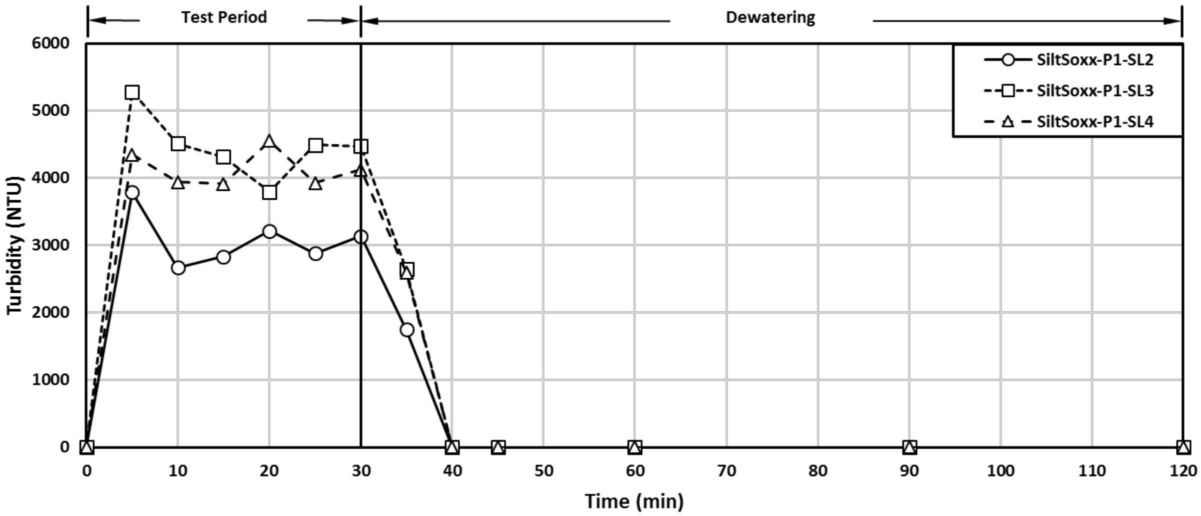


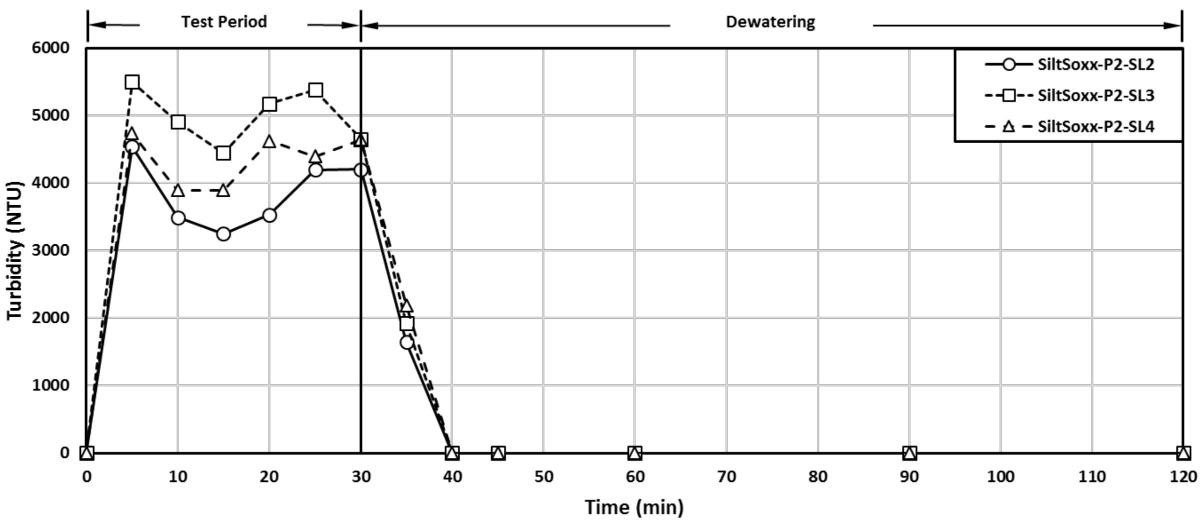


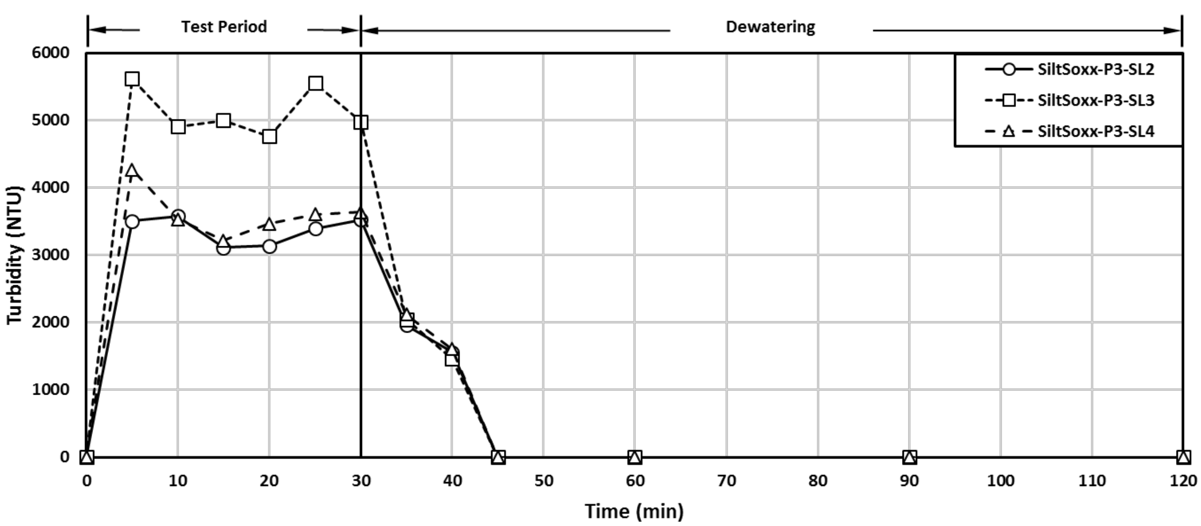



Excel Straw Log
Test Period
Dewatering
Straw Log-P1-SL2
Straw Log-P1-SL4
Turbidity (NTU)
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60
70
80
90
100
110
120
Time (min)

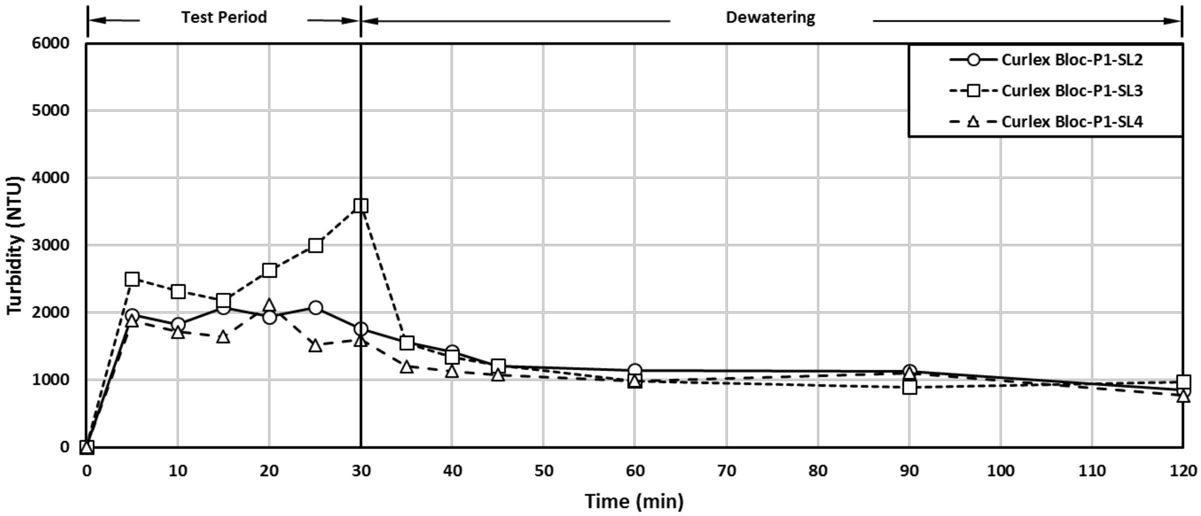
SiltSoxx

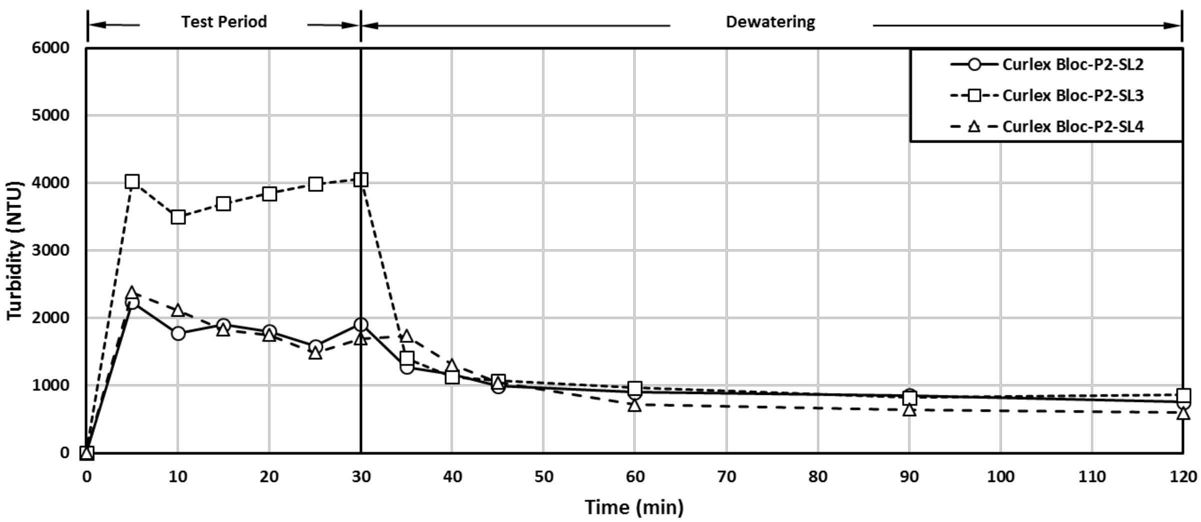

Test Period
Dewatering
SiltSoxx-P1-SL2
SiltSoxx-P1-SL3
SiltSoxx-P1-SL4
Turbidity (NTU)
Time (min)

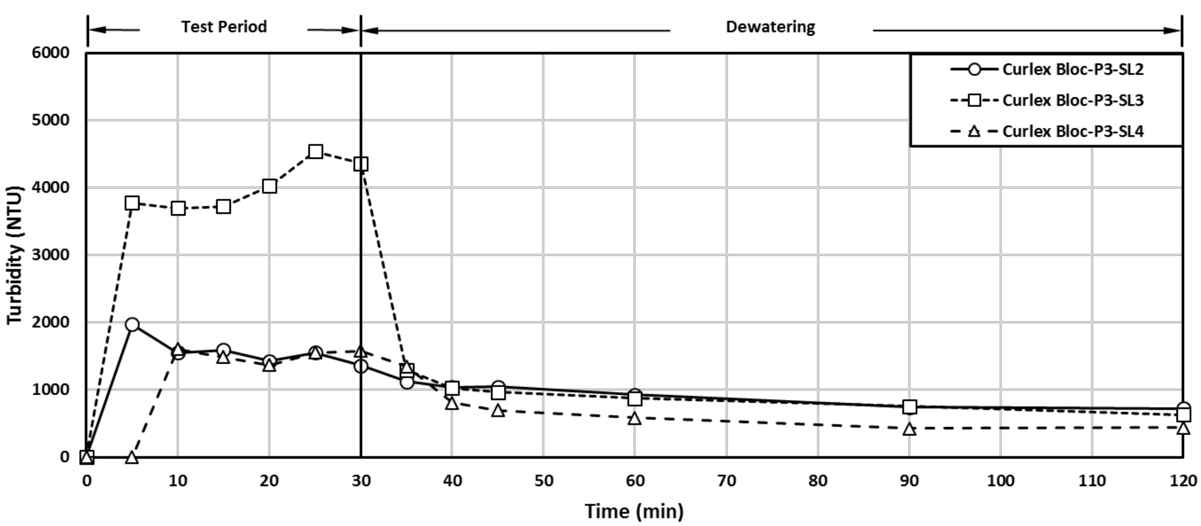

Test Period
Dewatering
SiltSoxx-P2-SL2
SiltSoxx-P2-SL3
SiltSoxx-P2-SL4
Turbidity (NTU)
Time (min)


Test Period
Dewatering
SiltSoxx-P3-SL2
SiltSoxx-P3-SL3
SiltSoxx-P3-SL4
Turbidity (NTU)
Time (min)

Curlex Bloc


Test Period
Dewatering
Turbidity (NTU)
Time (min)
Curlex Bloc-P1-SL2
Curlex Bloc-P1-SL3
Curlex Bloc-P1-SL4

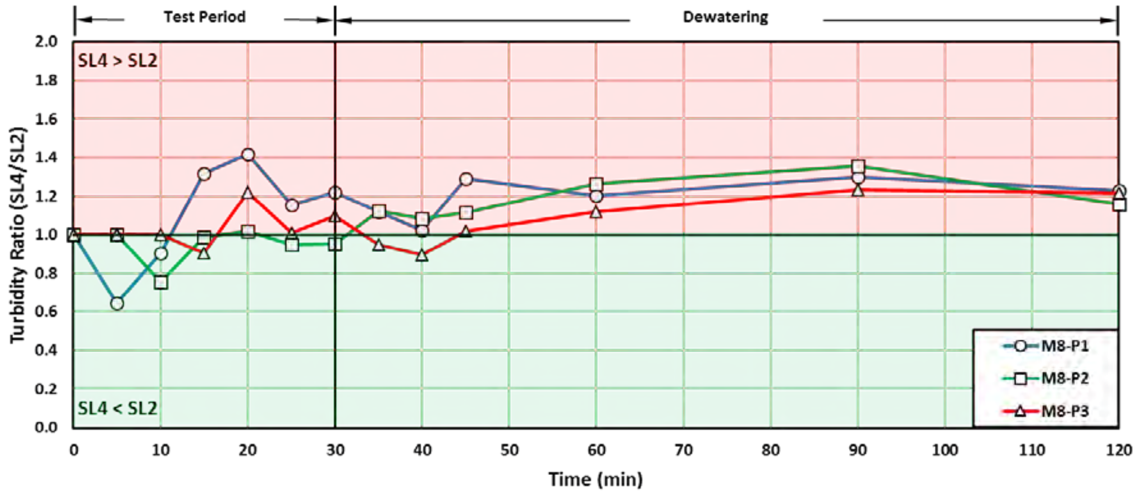

Test Period
Dewatering
Turbidity (NTU)
Time (min)
Curlex Bloc-P2-SL2
Curlex Bloc-P2-SL3
Curlex Bloc-P2-SL4


Test Period
Dewatering
Turbidity (NTU)
Time (min)
Curlex Bloc-P3-SL2
Curlex Bloc-P3-SL3
Curlex Bloc-P3-SL4

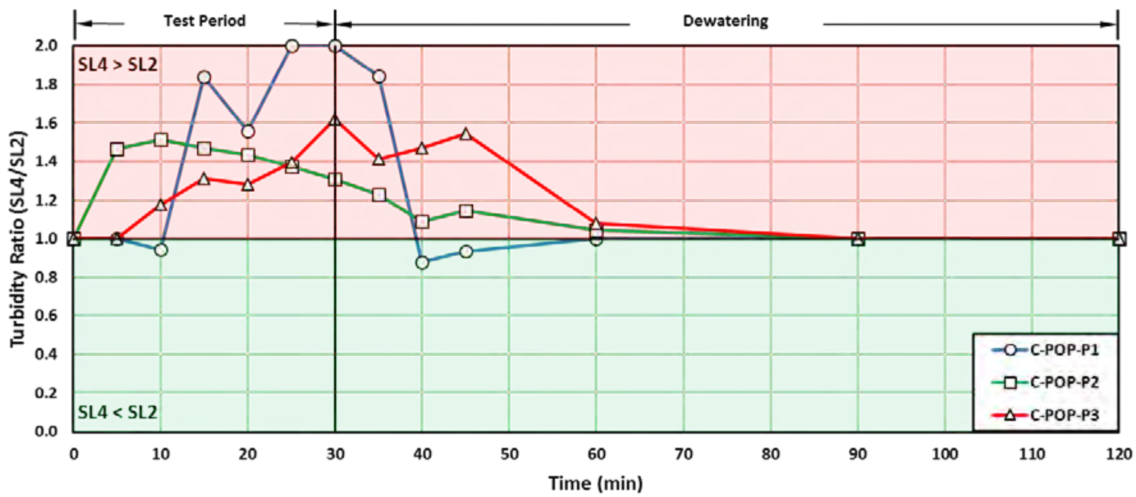
APPENDIX D

Sediment Barrier Practice Treatment Efficiency

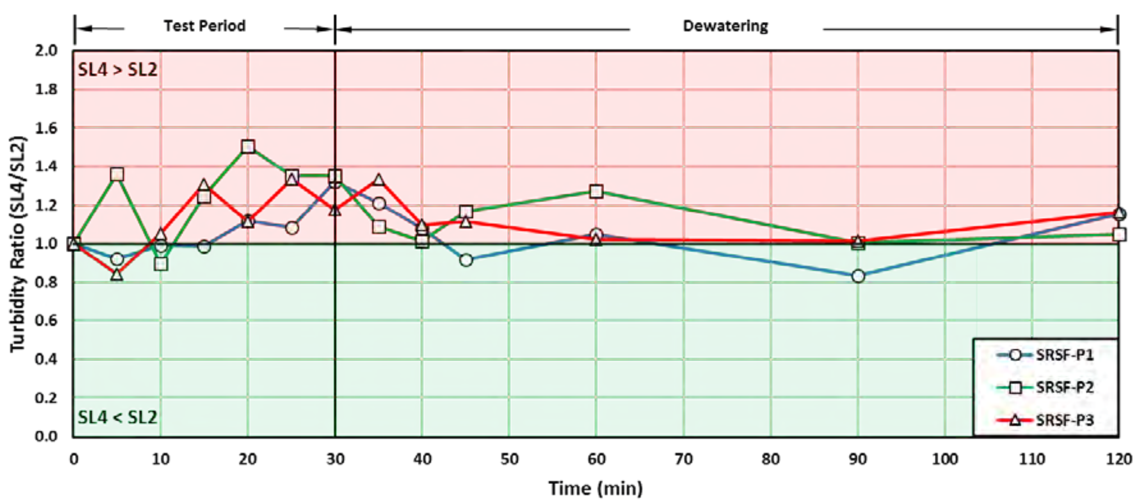
M8


Test Period
Dewatering
SL4 > SL2
SL4 < SL2
Turbidity Ratio (SL4/SL2)
Time (min)
M8-P1
M8-P2
M8-P3

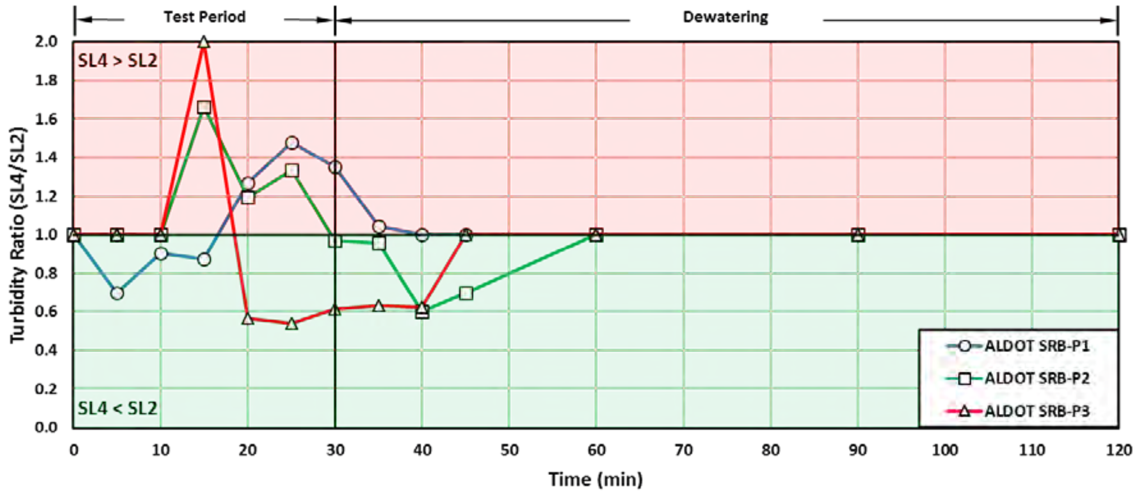
C-POP


Test Period
Dewatering
SL4 > SL2
SL4 < SL2
Turbidity Ratio (SL4/SL2)
Time (min)
C-POP-P1
C-POP-P2
C-POP-P3

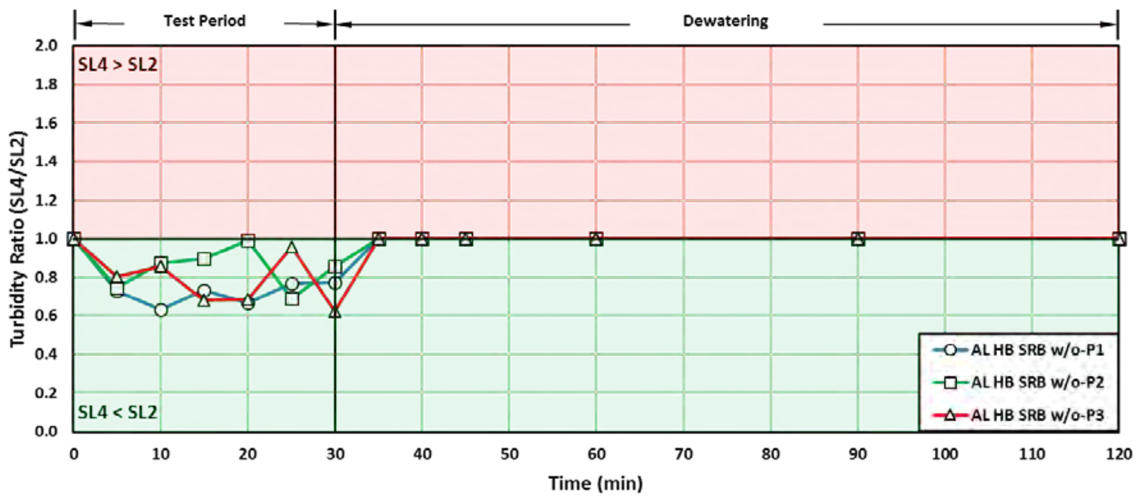
SRSF


Test Period
Dewatering
SL4 > SL2
SL4 < SL2
Turbidity Ratio (SL4/SL2)
Time (min)
SRSF-P1
SRSF-P2
SRSF-P3

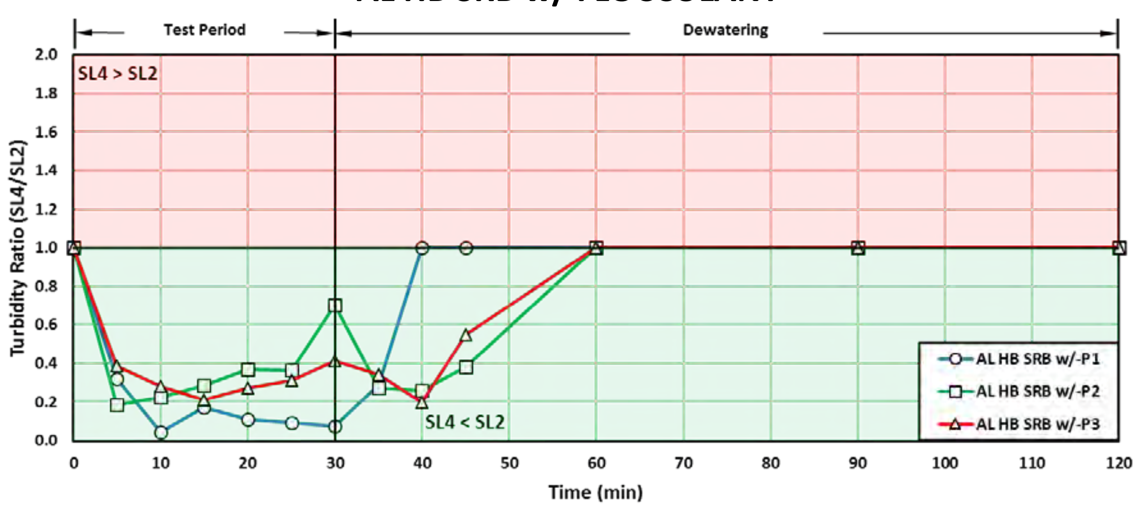
ALDOT SRB



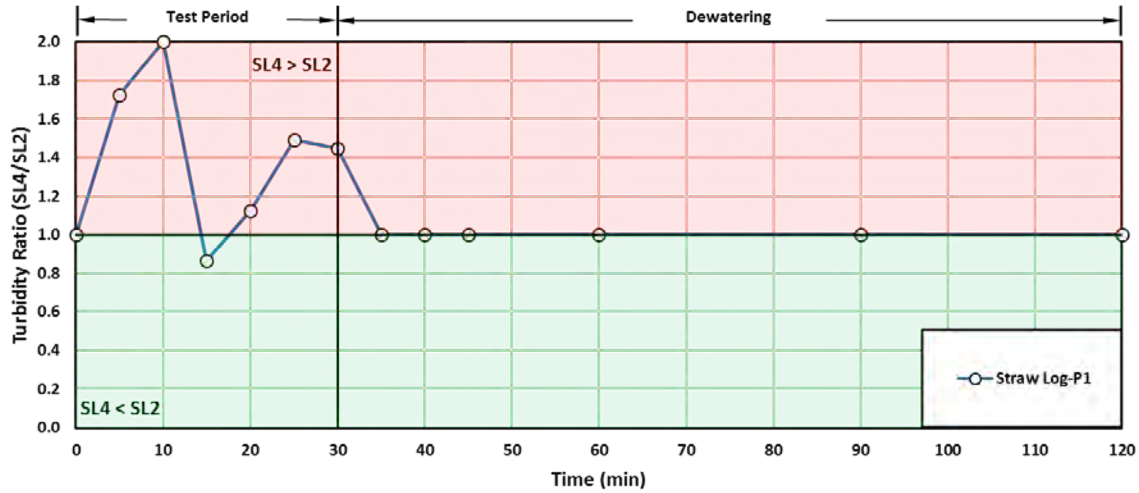
AL HB SRB w/o FLOCCULANT



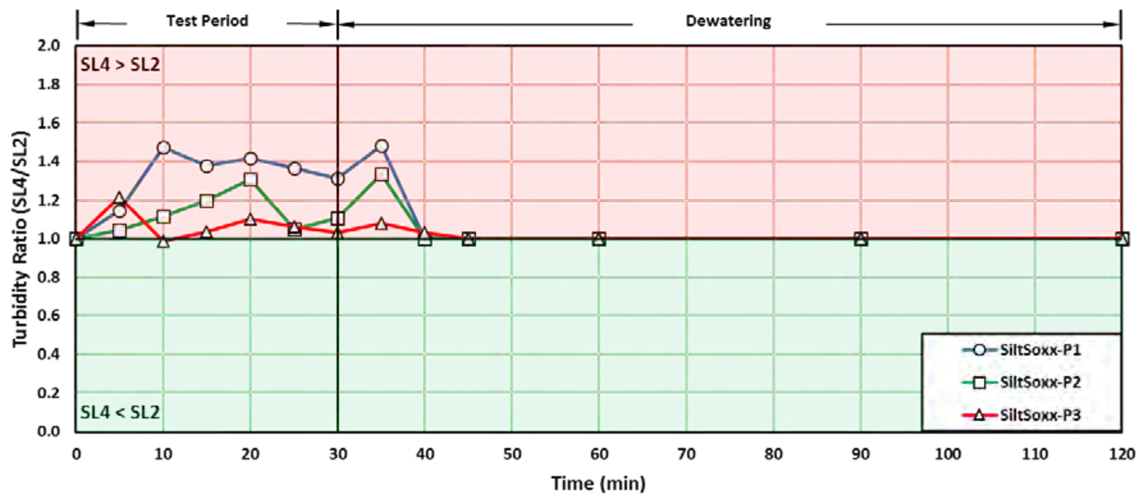
AL HB SRB w/ FLOCCULANT



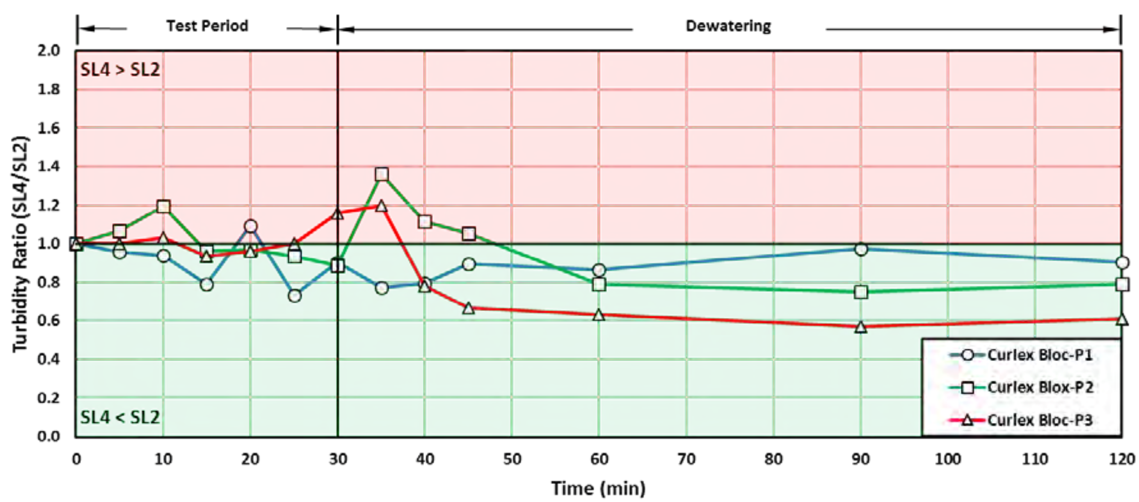
EXCEL STRAW LOG



SILTSOXX



CURLEX BLOC



APPENDIX E

List II-24 Modification

TEMPORARY EROSION and SEDIMENT CONTROL PRODUCTS

(for SILT FENCE see List II-3 GEOTEXTILES)

		PEB#	Product Name	Approved Manufacture	Approval Date
FLOW BAFFLES		2590	EC-7y Coir Mat	East Coast Erosion - Bernville, PA	08/01/11
		3013	Coir Mat 700 grams	Hanes Geo Components - Winston Salem, NC	01/07/13
		4590	KoirMat 700	Nedia Enterprises, Inc. - Ashburn, VA	11/07/16
TURBIDIMETERS		2599	2100Q with USB+Power Module	Hach Company - Loveland, CO	08/01/11
		4041	HI 98703	Hanna Instruments - Woonsocket, RI	05/06/13
		4473	2020we	LaMotte Company – Chestertown, MD	033/07/16
FLOCCULANT*	POWDERS	1264	APS 700 Series Silt Stop Powder (705, 712, 730, 740)	Applied Polymer Systems - Woodstock, GA	
		1232	EnviroPam (Granular)	Innovative Turf Solutions - Cincinnati, OH	04/02/12
	BLOCKS	1264	APS 700 Series Floc Log (703d, 703#d, 706b)	Applied Polymer Systems - Woodstock, GA	
	SOCKS	2362/2363	StormKlear DBP-2100 FS & Gel Floc (System)	HaloSource, Inc. - Bothell, WA	08/01/11

For use with 2012 Standard Specifications and GASP12-0399

	PEB#	Product Name	Approved Manufacture	Approval Date
FLOCCULANTS**	1264	APS 700 Series	Applied Polymer Systems - Woodstock, GA	
	1232	EnviroPam (Granular)	Innovative Turf Solutions - Cincinnati, OH	04/02/12
	2907	FLOC	Innovative Turf Solutions - Cincinnati, OH	05/06/13
	4018	HaloKlear/StormKlear DBP-2100 & Gel Floc (System)	HaloSource, Inc. - Bothell, WA	05/06/13
	4549	Tigerfloc	Floc Systems, Inc. - Surrey (Province) B.C. Canada	02/06/17

***For use with GASP 12-0399(3) and 12-0575, Section 672 – Stormwater Turbidity Control.*

	PEB#	Product Name	Approved Manufacture	Approval Date
Basin Dewatering Devices	2996	IAS Water Quality Skimmer	Innovative Applied Solutions - Jamestown, NC	01/06/14
	4140	ESC Skimmer	Erosion Supply Company - Raleigh, NC	01/06/14
	4182	Faircloth Skimmer Surface Drain	J.W. Faircloth & Son, Inc. - Hillsborough, NC	04/07/14
	4246	Marlee Float Skimmer (#1, #2, #3)	SW FeeSaver - Greenville, SC	05/04/15

Category	Type	PEB#	Product Name	Max Flow	Approved Manufacture	Installation Method	Approval Date
DITCH CHECK	WATTLES (SINGLE-20 IN.)	1397	Curlex Sediment Log	1.875 cfs	American Excelsior - Arlington, TX	ALDOT STD. DETAIL	05/03/04
		1597	Aspen Excelsior Logs	1.875 cfs	Western Excelsior - Mancos, CO	ALDOT STD. DETAIL	12/06/04
		1758	EXCEL Straw Logs	1.25 cfs	Western Excelsior - Mancos, CO	ALDOT STD. DETAIL	06/06/06
		1851	ECWattles 100% Agricultural Straw	1.25 cfs	East Coast Erosion - Bernville, PA	ALDOT STD. DETAIL	03/05/07
		1866	Wheat Straw Sediment Logs	1.25 cfs	Erosion Tech - Juliette, GA	ALDOT STD. DETAIL	06/05/07
		2114	AEC Premier Straw Wattles	1.25 cfs	American Excelsior - Arlington, TX	ALDOT STD. DETAIL	09/14/09
		2008	GeoWattle	1.25 cfs	GeoHay - Spartanburg, SC	ALDOT STD. DETAIL	11/02/09
		1994	Straw Wattle	1.25 cfs	US Erosion Control Products - Pearson, GA	ALDOT STD. DETAIL	03/03/14
	WATTLES (STACKED)	1849	Erosion Eel	1.25 cfs	Friendly Environmental - Shelbyville, TN	ALDOT STD. DETAIL	08/13/07
		1649	Filtrexx Filter Soxx	1.25 cfs	Filtrexx International – Grafton,OH	ALDOT STD. DETAIL	11/05/07
		4500	RocSoxx Gabion Soxx	1.875 cfs	RocSoxx – Defuniak Springs, FL	MANF. DETAIL	02/06/17
	SILT FENCE		Check-Pop System	1.875 cfs	C-Pop Systems	MANF. DETAIL	
	BAG TYPE		GRS VersaShield	1.875 cfs	Guardian Retention Systems	MANF. DETAIL	
	OTHER		Triangular Silt Dike	1.875 cfs	Triangular Silt Dike Company	MANF. DETAIL	
INLET PROTECTION	WATTLES (SINGLE)	1397	Curlex Sediment Log		American Excelsior - Arlington, TX	ALDOT STD. DETAIL	05/03/04
		1597	Aspen Excelsior Logs		Western Excelsior - Mancos, CO	ALDOT STD. DETAIL	12/06/04
		1758	EXCEL Straw Logs		Western Excelsior - Mancos, CO	ALDOT STD. DETAIL	06/06/06
		1851	ECWattles 100% Agricultural Straw		East Coast Erosion - Bernville, PA	ALDOT STD. DETAIL	03/05/07
		1866	Wheat Straw Sediment Logs		Erosion Tech - Juliette, GA	ALDOT STD. DETAIL	06/05/07
		2114	AEC Premier Straw Wattles		American Excelsior - Arlington, TX	ALDOT STD. DETAIL	09/14/09
		2008	GeoWattle		GeoHay - Spartanburg, SC	ALDOT STD. DETAIL	11/02/09
		1994	Straw Wattle		US Erosion Control Products - Pearson, GA	ALDOT STD. DETAIL	03/03/14
	WATTLES (STACKED)	1849	Erosion Eel		Friendly Environmental - Shelbyville, TN	ALDOT STD. DETAIL	08/13/07
		1649	Filtrexx Filter Soxx		Filtrexx International – Grafton,OH	ALDOT STD. DETAIL	11/05/07
		4500	RocSoxx Gabion Soxx		RocSoxx – Defuniak Springs, FL	MANF. DETAIL	02/06/17
	SILT FENCE		Check-Pop System		C-Pop Systems	MANF. DETAIL	
	BAG TYPE		GRS VersaShield		Guardian Retention Systems	MANF. DETAIL	
	DOME TYPE	1323	SS-100A or SS-200A (w/ DOT Filter)		Silt Saver - Conyers, GA	MANF. DETAIL	02/17/03
	OTHER	1905	GeoBale		GeoHay - Spartanburg, SC	MANF. DETAIL	11/02/09

		PEB#	Product Name	Approved Manufacture	Installation Method	Approval Date
SEDIMENT BARRIERS	WATTLES (SINGLE)	1397	Curlex Sediment Log	American Excelsior - Arlington, TX	ALDOT STD. DETAIL	05/03/04
		1597	Aspen Excelsior Logs	Western Excelsior - Mancos, CO	ALDOT STD. DETAIL	12/06/04
		1758	EXCEL Straw Logs	Western Excelsior - Mancos, CO	ALDOT STD. DETAIL	06/06/06
		1851	ECWattles 100% Agricultural Straw	East Coast Erosion - Bernville, PA	ALDOT STD. DETAIL	03/05/07
		1866	Wheat Straw Sediment Logs	Erosion Tech - Juliette, GA	ALDOT STD. DETAIL	06/05/07
		2114	AEC Premier Straw Wattles	American Excelsior - Arlington, TX	ALDOT STD. DETAIL	09/14/09
		2008	GeoWattle	GeoHay - Spartanburg, SC	ALDOT STD. DETAIL	11/02/09
		1994	Straw Wattle	US Erosion Control Products - Pearson, GA	ALDOT STD. DETAIL	03/03/14
	WATTLES (STACKED)	1849	Erosion Eel	Friendly Environmental - Shelbyville, TN	ALDOT STD. DETAIL	08/13/07
		1649	Filtrexx Filter Soxx	Filtrexx International – Grafton,OH	ALDOT STD. DETAIL	11/05/07
		4500	RocSoxx Gabion Soxx	RocSoxx – Defuniak Springs, FL	MANF. DETAIL	02/06/17
	SILT FENCE		C-Pop	C-Pop Systems	MANF. DETAIL	
	BAG TYPE		GRS FlexiShield	Guardian Retention Systems	MANF. DETAIL	
	OTHER					