Evaluation of Erosion Control Practices Using Rainfall Simulation on 4:1 Slopes across Various Soil Types

by

John Ruffin Cater

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Approved by

Michael A. Perez, Chair, Associate Professor of Civil and Environmental Engineering
Wesley N. Donald, Research Fellow of Civil and Environmental Engineering
Xing Fang, Professor of Civil and Environmental Engineering

ABSTRACT

Construction sites rely on erosion control practices to protect bare slopes and prevent soil loss. This study used large scale rainfall simulators to evaluate various erosion control methods commonly used by the construction stormwater industry on construction sites. The study included the testing of erosion control practices on three different soil types (i.e., clay, sand, and loam) on a 4:1 slope. All testing and data collection is in accordance with ASTM D6459-19, the standard test method for testing Rolled Erosion Control Products (RECP) performance in protecting hillslopes from rainfall-induced erosion. This ASTM method is a full-scale performance assessment of the amount of soil lost on a slope in a storm with varying intensity. Some key aspects in this standard include calibration of equipment, preparation of test plot, documentation of RECP to be tested, installation of RECP, performance of test, collection of runoff and associated sediment yield, analysis of the resultant data, and reporting. In accordance with ASTM D6459-15, the rainfall simulators produced a storm of varying 20-minute increments of 2 in./hr (5.08 cm/hr), 4 in./hr (10.16 cm/hr), and 6 in./hr (15.24 cm/hr). The simulator achieved a natural raindrop size and distribution according to calibration techniques outlined in the standard. Runoff volume and sediment concentration samples were recorded throughout the test. The total sediment lost during the test was collected and recorded for each rainfall intensity interval. Testing for this project began by conducting bare soil tests to analyze the amount of sediment lost without the use of erosion control methods. A total of nine bare soil tests on the 4:1 test plots were performed with an average total soil loss of 1,977 lbs (897 kg), 236 lbs (107 kg), and 114 lbs (52 kg) for sand, loam, and clay, respectively. The average K-factor for each soil type is calculated to be 0.37 (sand), 0.043 (loam), and 0.013 (clay). Nine loose straw tests were performed on the 4:1 plots with an average total soil loss of 44 lbs (20 kg), 7 lbs (3 kg), and 17 lbs (8 kg) for sand, loam, and clay, respectively. Loose straw testing indicated substantial soil loss reduction with average C-factor values of 0.021, 0.047, and 0.193 for sand, loam, and clay applications, respectively. Nine single net straw blanket tests were performed with an average total soil loss of 80 lbs (36 kg), 20 lbs (9 kg), and 17 lbs (8 kg) for sand, loam, and clay, respectively. Single net straw testing indicated less soil loss reduction than loose straw with average C-factor values of 0.042, 0.131, and 0.31 for sand, loam, and clay applications, respectively. In addition to analyzing practice effectiveness, a statistical analysis along with a comparison of soil loss models (RUSLE and MUSLE) were performed.

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CHAPTER 1: INTRODUCTION

1.1 Background

Sediment-laden runoff from construction grading and clearing activities can cause substantial environmental risk to surrounding water bodies and organisms. Two thirds of all pollutants entering U.S. waterways is sediment (Allen 1996). It is estimated that in the United States, six billion tons (5.44 metric tons) of soil erode and can cause up to $27.5 billion (adjusted for inflation 2024) in damages annually (Ziegler and Sutherland 1996). Given the high volume of rainfall in the State of Alabama and the high average length-slope factor of highway projects, the construction stormwater industry has incentive to fully understand the effectiveness of their erosion control products on highway and construction side slopes that can reduce the impact of sediment on the waterways that surround their construction projects.

The purpose of this study is to test erosion control methods used by the construction stormwater industry on different soil types. The soil types examined in this study were clay, sand, and loam. The Auburn University - Stormwater Research Facility (AU-SRF) in previous study had constructed a total of six rainfall simulator plots to be used in this study configured at a 4:1 slope and consisting of sand, loam, and clay soils. All testing and data collection was performed in accordance with ASTM D6459-19.

ASTM D6459-19 “Standard Test Method for Determination of Rolled Erosion Control Product Performance (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion” is the test method used in this study. This ASTM method is a full-scale performance assessment of the amount of soil lost on a slope in a storm with varying intensity. The test method outlines methodology for equipment calibration, plot preparation, product documentation, product installation, test performance, runoff and sediment collection, data analysis, and reporting. All large-scale testing was performed at the AU-SRF, and samples processed at the stormwater lab located on campus. In accordance with ASTM D6459-19, the rainfall simulator produced a storm of 20-minute increments of 2 in./hr (5.08 cm/hr), 4 in./hr (10.16 cm/hr), and 6 in./hr (15.24 cm/hr). The simulator also achieved a natural raindrop size and distribution. Runoff volume and sediment concentration samples were recorded throughout the test. The total sediment lost during the test was collected and recorded for each rainfall intensity interval.

This study began by conducting bare soil tests to analyze the amount of sediment lost without the use of erosion control methods. A total of nine bare soil tests were performed. The bare soil tests were used to determine the K-factor (soil erodibility) of the experimental soils. In addition to bare soil testing, nine loose straw and nine single-net straw practice tests have been performed on the three soil types as well. The results of the product tests were compared to the bare soil tests to determine the C-factor and effectiveness of the products.

1.2 Research Importance

Rainfall induced erosion is the primary catalyst of sediment laden runoff on construction sites. A variety of erosion control practices (ECPs) are implemented to reduce the effects of splash, sheet, and rill erosion. These can include non-proprietary practices such as straw or manufactured products such as RECPs and turf reinforcement mats (TRMs). ECPs serve to reduce stormwater runoff volume and velocity, absorb raindrop impact, and provide cover and anchoring for vegetation to establish. Given the nature of long and steep slopes on highway construction projects along with high average annual precipitation in the state of Alabama, DOTs and contractors rely heavily on ECPs to minimize environmental impact of their construction activities.

If installed properly and used in the correct context, ECPs can be effective at reducing erosion. Little testing has been done on the performance of ECPs on construction side slopes in varying conditions. Recent testing has focused on rainfall simulator testing on a single slope and soil configuration. This study seeks to improve the understanding of where certain practices are most effective. It is entirely possible that the resulting RUSLE cover management factor (C-factor) is different for each soil condition. The results will provide recommendations to the erosion control industry on where best to apply their commonly used practices.

1.3 Rainfall Simulators

To fully understand ECP performance on a construction side slope, the rainfall process must be recreated in a controlled environment. Rainfall simulators provide a method to test erosion control practices and bare soil on a slope under designated target rainfall intensities. A rainfall simulator apparatus mimics the process of rainfall induced erosion typically through a set of sprinklers and a designated test plot. The simulation can be performed on a small, intermediate, and large scale. Calibration is needed to ensure that the testing apparatus used achieves consistent results between tests and achieves a natural raindrop size distribution. In this study, large-scale simulation is used in accordance with ASTM D6459-19 which is the standard test method for large-scale rainfall simulation. Since this study is designed to provide guidance to the construction stormwater industry, ASTM D6459-19 best mimics a highway embankment or construction side slope that would require stabilization.

1.4 Research Objectives and Tasks

The objective of this research was to provide guidance on the performance of loose straw and a single net straw RECP applied to 4:1 slopes made up of sand, loam, and clay. All testing was performed at the AU-SRF using ASTM D6459 rainfall simulation. To meet the research objective, the following tasks were performed:

1.4.1 Test Bare Soil Slopes to Determine Soil Erodibility

To determine the effectiveness of erosion controls, slopes must first be tested with no practices applied to determine the natural erodibility of the soil. The bare soil tests provide a baseline control test for each soil type. In addition to providing a comparison to practice tests, the bare soil tests help to affirm previous understanding of soil erodibility based on soil type.

1.4.2 Test Temporary Erosion Controls on Different Soil Types on a 4:1 Slope

Temporary erosion controls are those that will be in place for a short period of time and are often not vegetative practices. Therefore, the products and practices tested for this scenario are installed on the subgrade (i.e. no topsoil) and tested under standard ASTM D6459 conditions. Each product is tested based upon soil type to determine performance capabilities for each option. Products and practices have been selected by the funding organization of this study.

1.4.3 Determine K-factors and C-factors for the Soils and ECPs Evaluated

A primary objective of this study is to determine K-factors (soil erodibility) and C-factors (cover factor) of the soils and practices tested. Bare soil control testing without an ECP applied to the test plot, allows the researchers to determine a baseline soil loss comparison to the ECP tests. Once an ECP is applied on the test plot, the resulting difference in soil loss from the control tests allows for the determination of the C-factor. This study consisted of calculating soil specific C-factors that help the research team understand how soil condition affects the performance of the ECPs.

1.4.4 Provide an Overview and Comparison of Previous Testing

Report and comment on previous testing at the AU-SRF, various literature, and manufacturer data. Previous data provides a basis of comparison for ECP performance under similar testing methodology and helps draw conclusions that fall outside the scope of testing in this study.

1.4.5 Provide a Statistical Analysis on C-factor Variance by Soil Type and Practice

To further validate any variance observed in C-factor by soil type, a statistical analysis was performed to determine if ECP performances changed significantly with soil type. In addition to a statistical test performed on the soil type performance, a statistical test was run to determine if the loose straw significantly outperformed the straw blanket on the soil types tested.

1.4.6 Compare Soil Loss Calculation Methods

This study and previous study at AU-SRF has focused on using the Revised Universal Soil Loss Equation (RUSLE) to calculate K-factors and C-factors. Since the rainfall simulator produces a single storm event with runoff volume recorded, the Modified Universal Soil Loss Equation (MUSLE) was also used to calculate the factors previously mentioned to determine if the soil loss models provide similar results. A discussion is also provided on whether RUSLE or MUSLE is the best option for rainfall simulator soil loss modeling.

1.5 Report Organization

The following report is organized into the following five chapters: (1) Introduction, (2) Literature Review, (3) Methodology, (4) Results, and (5) Conclusions. The introduction chapter provides background, importance, and research objectives for this project. The literature review chapter provides an overview of erosion control practices, RUSLE equation, and rainfall simulator testing. The methodology chapter provides the methods used for the calibration and testing. The results chapter provides all key results obtained through this research and discussion on their relevance. The conclusions chapter provides closing remarks, research implications, and recommendations for future research.

CHAPTER 2: LITERATURE REVIEW

2.1 Literature Review Overview

Unmanaged construction stormwater runoff poses a severe risk to water quality and downstream ecosystems. With the advent of legislation such as the Clean Water Act (CWA), a series of federal, state, and local regulatory actions have been passed to protect our waterways and the people that depend on them. RECPs are a common best management practice (BMP) used by contractors and DOTs to reduce erosion construction stormwater pollutant discharge. This study seeks to provide a comprehensive overview of RECP classification, background, installation, evaluation, and implementation as a construction stormwater BMP.

2.2 Introduction

Sediment-laden runoff from construction and other land disturbing activities can cause environmental risk to surrounding waterbodies and organisms. As a protective measure, the U.S. Environmental Protection Agency (USEPA) regulates land disturbing activities through the National Pollutant Discharge Elimination System (NPDES) permitting process. DOT's along with other public and private organizations are subject to the NPDES permitting process and must use BMPs to limit the environmental impact of construction activities (Sutherland 1998). There are several factors that contribute to the amount of sediment lost on a given site. In calculating soil loss risk, the main factors considered are rainfall erosivity, soil erodibility, slope-length, and cover management (Blaszczynski 2001). Highway construction is particularly vulnerable to erosion due to its high average slope-length factor. Steeper slopes are subject to higher rates of erosion due to a higher flow velocity from a steeper hydraulic gradient. In a study conducted by the AU-SRF, it was found that highway construction projects are subjected to an enhanced soil loss risk from steep slopes. (Kazaz et al. 2022). To improve the environmental sustainability of transportation infrastructure, a variety of products and best practices are needed to reduce erosion of steep slopes in highway construction. RECPs are a family of products that are commonly used by DOT's and contractors in stabilizing disturbed slopes. RECPs are considered one of the best options to stabilize slopes and facilitate vegetative establishment (Theisen 2005).

2.3 Construction Stormwater Regulations

Regulations are an attempt by the government to protect waterways. Soil erosion regulations seek to mitigate damage to waterbodies along with preventing maintenance costs such as dredging of reservoirs and navigable waters (Tarrer et al. 1995). Legislation in recent decades regarding erosion and sediment control has been a catalyst in the emergence of new BMPs. The CWA of 1972 outlines pollutants that need to be managed that may impact local ecosystems. Sedimentation from construction stormwater is a pollutant managed under the CWA. The EPA enforces the CWA through the NPDES permitting process. An NPDES permit is obtained when an operator submits a Stormwater Pollution Prevention Plan (SWPPP) and the application is approved by the state environmental regulatory agency (Sommer and Luna 2016). An NPDES permit is required for land disturbing activities of one acre (0.405 ha) or greater.

2.4 Defining RECPs

An RECP is defined as a blanket type covering that is used to protect bare soil slopes from rainfall induced erosion (Faulkner 2020). RECPs can come in a variety of material types. They can often be subdivided into low-velocity degradable RECPs, high-velocity degradable RECPs, and long-term non-degradable RECPs (Sutherland 1998). Some common materials used in RECPs are wood, jute, plastic, nylon, paper, and cotton. RECPs are often referred to as either erosion control blankets (ECB) or turf reinforcement mats (TRM). ECBs are considered temporary measures that provide cover before vegetative seeding is fully established. TRMs are a permanent measure that is designed to work in conjunction with permanent vegetative stabilization (Faulkner 2020). An ECB is best used in a short-term scenario where the long-term goal is to stabilize the slope with vegetation such as grass. They do not serve as an anchoring mechanism for the vegetation. A TRM is designed to help anchor the root system of the vegetation and is more resilient to higher shear stresses exerted from the runoff. They are often made of composite materials that are non-degradable.

2.5 Classifying RECPs

The Erosion Control Technology Council (ECTC) has created standard terminology for various RECP products. The ECTC breaks Rolled Erosion Control Products into the following categories: mulch-control netting (MCN), open-weave Textile (OWT), ECBs, and TRMs.

MCN can be defined as a woven natural fiber or geosynthetic mesh used to temporarily anchor loose fiber mulches such as straw or hay. They are typically rolled over a seeded and mulched area and stapled in place. It should be noted that these blankets are not glued to the mulch and are not as resilient as prefabricated blankets. MCNs are best suited for moderate site conditions when costlier erosion control products are not necessary.

OWT are natural, or polymer yarns woven in a matrix that provide soil stability and facilitate vegetative growth. Unlike MCNs, OWTs do not require a layer of loose mulch or straw applied to the slope. Open-weave textiles have a higher tensile strength on average than MCNs thus making them a better fit for steeper slopes. Figure 2-1 below provides an image of an OWT product.

Figure 2-1: Open Weave Textile (Kapfer and Paloski 2011)

ECBs are constructed of degradable organic/synthetic fibers that can be woven, glued, or bound with nettings or meshes. Some of the most common materials in ECBs includes straw, wood excelsior, coconut, polypropylene, or a combination of these materials. ECBs are versatile and can be used for a variety of applications. They are typically rolled out with direct soil contact and anchored with staples, stakes, and anchor trenches. They are a more durable and longer lasting alternative to MCNs and OWTs and can be applied to gradual, steep, and low to moderate flow channel linings. Depending on the application, products can be designed to last anywhere from three months to three years. Figure 2-2 below provides an image of an ECB installed on a side slope around a stabilized outfall.

Figure 2-2: Erosion Control Blanket (Granite Seed 2024)

TRMs are the most robust RECP product available. They are made of non-degradable geosynthetics that are designed for permanent and critical hydraulic applications. They are typically used in channels that flow velocity and shear stress exceed the capacity of the natural soil and vegetation. TRMs act as a permanent anchor for the vegetation root system to take hold. There are two methods for applying TRMs. One method involves applying the TRM directly over a layer of topsoil and seed. This allows the vegetation to grow up through the mat. The other method is to roll out the TRM and apply topsoil and seed over the mat. This allows the vegetation to root down into the mat (Lancaster and Austin 2003). Figure 2-3 below provides an image of the installation of a turf reinforcement mat in the side slopes of a channel.

Figure 2-3: Turf Reinforcement Mat (Ferguson Waterworks 2024)

2.6 Background of RECPs

As awareness increases for the need to reduce stormwater induced sediment runoff, growth in erosion control products has increased exponentially. For example, from the years 1985 to 1994, the amount of erosion and sediment control products increased by 45%. Initial slope erosion control methods began with the use of straw and mulch to temporarily stabilize bare soil slopes. With the performance shortcomings of blown straw and mulch along with the relatively high cost of hard armored systems such as rip rap, RECPs provide a performance advantage to blown straw and mulches due to its ability to capture and retain soil along with facilitating the establishment of vegetation (Allen 1996).

2.7 RECP Installation

Proper installation and maintenance are key to any BMP measure. The ECTC provides guidance on the implementation of RECPs. The key aspects of RECP installation include site preparation, seeding, anchor trench preparation, securing RECP in anchor trench, RECP deployment, staple/staking RECP, and securing RECP at slope toe (ECTC 2014). The following figures show examples from ECTC installation guidelines.

Figure 2-4: Prepared Installation Site (ECTC 2014).

Figure 2-4 above provides a prepared site prior to the installation of an RECP. The site pictured above is free of trash, roots, rocks, and debris and has been graded to the design specifications. A prepared site is critical to a properly installed RECP.

Figure 2-5: Seeding (ECTC 2014).

Figure 2-5 provides an image of seeding before the installation of the RECP product. Any addition of seed or topsoil must be installed prior to the RECP. If the seed is added after the RECP installation, the seed will not be protected and allowed to germinate properly.

Figure 2-6: Anchor Trench Preparation (ECTC 2014).

Figure 2-6 above provides an image of an RECP anchor trench. The anchor trench serves to hold the product at the top of the slope and prevent the blanket from slipping under high runoff volume conditions.

Figure 2-7: Secure RECP in Anchor Trench (ECTC 2014).

Figure 2-7 above provides an image of securing an RECP in an anchor trench. After the anchor trench has been excavated, the blanket can be secured into the trench using sod stables. Once secured, excavated dirt can be used to backfill the trench.

Figure 2-8: Deploy RECP (ECTC 2014).

Figure 2-8 above provides an image of an RECP product deployed on a slope. After the RECP has been secured into the anchor trench, the product can be rolled down the slope.

Figure 2-9: Staple or Stake RECP (ECTC 2014).

Figure 2-9 above provides an image of an RECP stapled on a slope. The RECP manufacturer will provide a pinning detail for varying slope conditions. Spray paint can be used to mark pinning locations and sod staples to secure the blanket directly to the slope.

2.8 ASTM Testing

In evaluating RECPs, ASTM has provided standard test methods for evaluating RECP performance. The following sections provide a summary of each ASTM method that can be used for evaluation.

ASTM D7101 is former standard test method for the "Determination of Unvegetated Rolled Erosion Control Product (RECP) Ability to Protect Soil from Rain Splash and Associated Runoff Under Bench-Scale conditions". The standard has been suspended and is no longer in use. In contrast to large-scale testing methods, this test method uses a bench-scale apparatus that consists of a soil test plot that is 35 in. by 10 in. (900 mm by 250 mm) and meets a minimum slope requirement of 3:1. The rainfall simulator must be capable of producing a uniform drop size distribution with a median diameter of 0.12 in. to 0.14 in. (3.0 mm to 3.5 mm). The simulator must produce target intensities of 2 in./hr, 4 in./hr, and 6 in./hr (51 mm/hr, 102 mm/hr, and 153 mm/hr). Prior to testing, the soil must reach a compaction of 87-93%. The test requires that 5 minutes of rainfall are performed for each test interval with a total of 30 minutes of rainfall. Given that this test methodology is bench-scale it is not as good an indicator of RECP performance as field-scale methodologies. Figure 2-10 below provides a diagram of the apparatus used in ASTM D7101 (ASTM 2013).

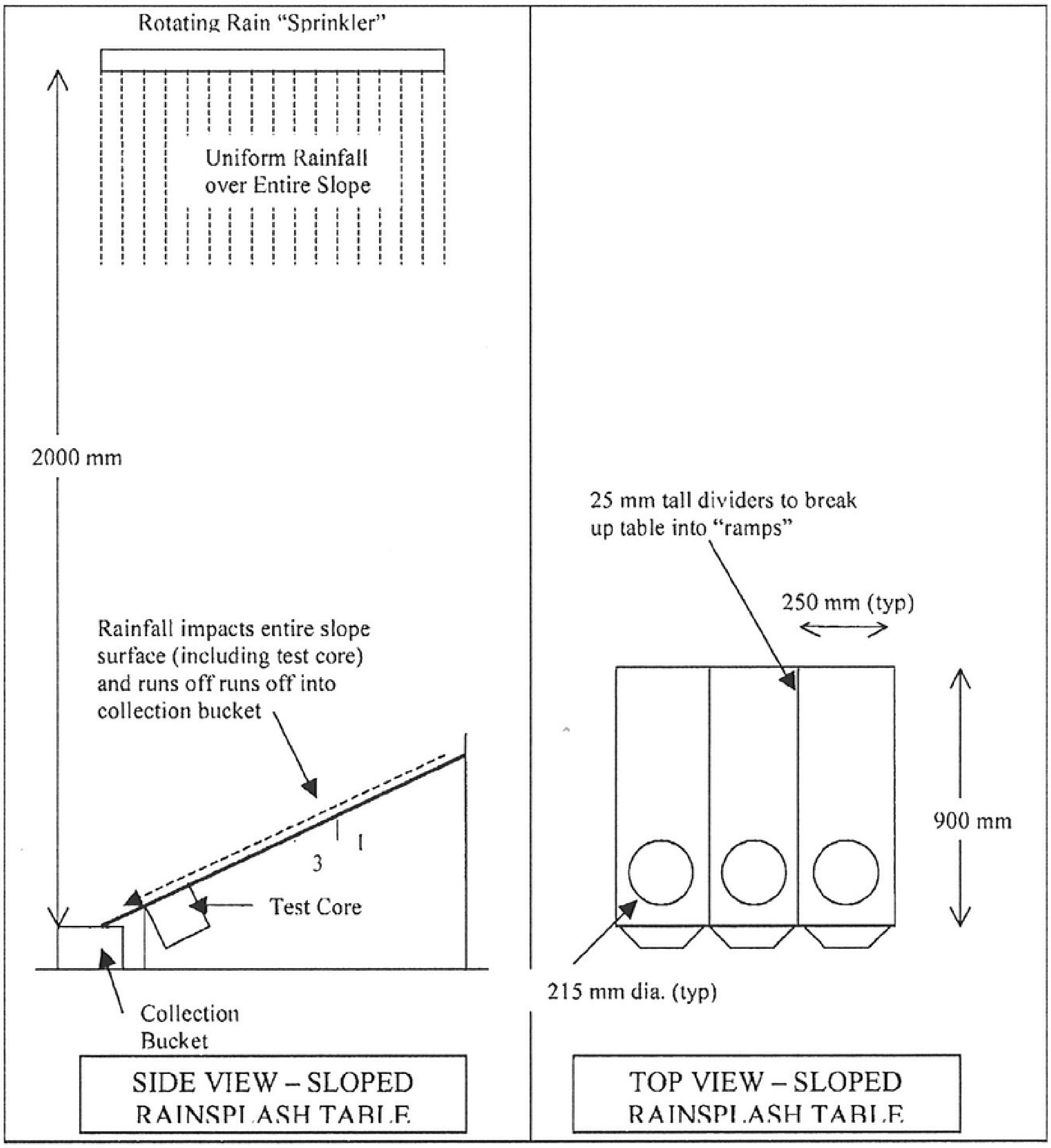


Figure 2-10: ASTM D7101 Test Apparatus (ASTM 2013)

ASTM D6460 is the "Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion". This standard is a field-scale test methodology that evaluates an RECPs ability to protect earthen channels from stormwater-induced erosion. The methodology features a closed-loop water supply system and provides guidance on test channel size, compaction, and side slopes. Figure 2-11 below provides a diagram of a typical ASTM D6460 test set-up (ASTM 2019).

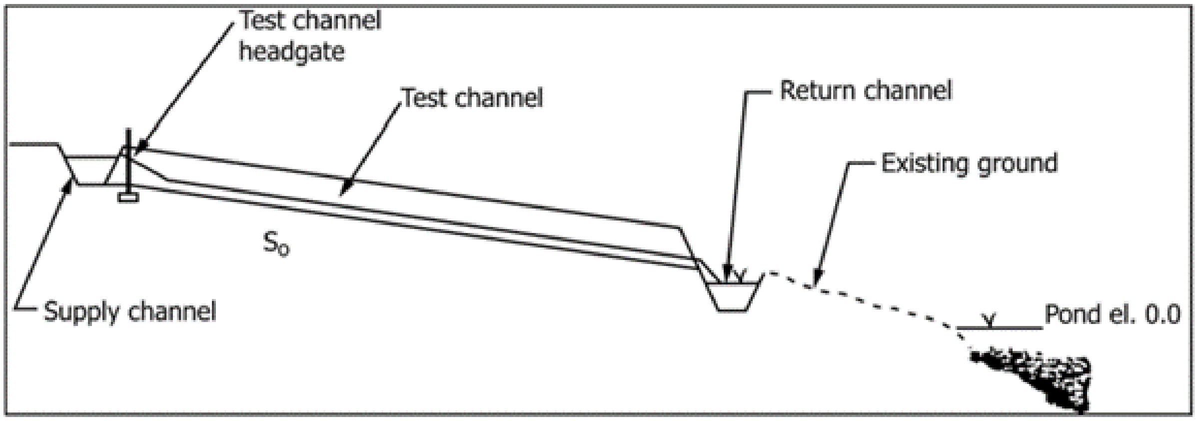


Figure 2-11: ASTM D6460 Test Apparatus (ASTM 2019)

As previously mentioned, to gain a deeper understanding of the effectiveness of RECP products, large-scale long-duration testing is necessary. Rainfall simulation has proven to be an effective means to simulate rainfall at a desired intensity over a specified timeframe. Currently, ASTM D6459 is the standard test method for large-scale testing of RECP performance. The test is performed on an 8 ft X 40 ft plot and runs intensities of 2 in./hr (5.08 cm/hr), 4 in./hr (10.16 cm/hr), and 6 in./hr (15.24 cm/hr) for 20 minutes. The test can determine the soil erodibility (k-factor) and cover management factor (C-factor) of the RECP product. Once the C factor is determined for a particular product, RECP relative performance can be determined (Ricks, 2019). ASTM D6459 is the test methodology used in this study and if further explained in Chapter 3: Methodology.

2.9 Summary of ASTM D6459 Rainfall Simulator Testing at Auburn University

In addition to the current study of ALDOT erosion control practices, a previous study was performed at Auburn University using ASTM rainfall simulation on a single 3:1 sandy loam slope. Bare soil, loose straw, loose straw with tacking agent, loose straw, various erosion control blankets, hydraulic mulches, and soil conditioners were evaluated. The straw mulch test and bare soil plots were evaluated under initial (one hour) and longevity (one more hour) testing and did not follow the ASTM standard. The remaining practices were evaluated under ASTM D6459-19.

The initial testing results for the straw practices yielded a soil loss improvement of 81%, 87%, and 77% for the loose straw, loose straw with tackifier, and loose straw, respectively. The longevity testing results yielded a soil loss improvement of 53%, 79%, and 87% for the loose straw, loose straw with tackifier, and loose straw, respectively. A C-factor was not calculated for the straw products with the key performance indicator being soil loss reduction. The test soil was a sandy loam and did not meet the requirements for ASTM testing.

In addition to testing straw practices, a series of hydraulic mulches and RECPs were tested in accordance with ASTM D6459 on an ASTM loam soil. Using the RUSLE method, the hydraulic mulches yielded C-factor results of 0.55, 0.46, 0.54, 0.33, and 0.33 for Eco-Fiber, Soil Cover, Terra-Wood, ProMatrix, and Edge Pellets, respectively. The RECP products yielded C-factors of 0.05, 0.14, 0.12, and 0.41 for Curlex I, S150, ECX-2, and Jute, respectively.

The testing of practices on the 3:1 sandy loam and loam slope provided insight on the effectiveness of the various erosion control practices. The current rainfall simulation study at Auburn University seeks to understand the performance of practices as the slope and soil configuration varies.

2.10 Previous Studies on RECP Performance

Several studies have been conducted evaluating the overall effectiveness of RECPs. Both small-scale and large-scale testing methods have been used. The results of RECP evaluations can significantly vary depending on testing environment and methodology. In evaluating any erosion control product, it is important to keep in mind which factors are a priority for a particular product.

For example, the Texas DOT defines two critical performance factors for RECP products. These include how well the product protects the seedbed or geometry of a channel and the promotion of the establishment of vegetation (Northcutt and McFalls 1997). According to the U.S. Department of Agriculture (USDA), in determining an appropriate RECP product, the designer should consider type of soil, amount of runoff, frequency of precipitation, peak flows, terrain, run-off direction, and discharge goals (Shepley and Jackson 2002). The following section discusses key findings and methods of various studies evaluating RECPs.

A 2009 Syracuse University study used a rainsplash simulator to evaluate rainsplash erosion performance of 13 types of RECPs. The results indicated that RECPs are effective at minimizing soil erosion and can serve as a key asset for highway departments. It was found that RECPs used in combination with vegetation can reduce soil loss by an average of 95% to 100% in comparison to bare soil. The study also concluded that vegetation provides above-ground and below-ground biomass protection. The addition of RECPs provides two layers of protection (Smith and Bhatia 2009).

A 2007 study at the University of Hawaii evaluated the effectiveness of coir based RECPs in reducing sediment transport. A field-based rainfall simulator was used to compare the runoff and erosion effectiveness of three RECP systems. The study reaffirmed the notion that RECPs can substantially reduce erosion on disturbed side slopes. It was found that the physical properties and architecture of the RECPs have a significant effect on the performance of the products. The physical properties of RECPs can affect splash detachment, infiltration, shear stress, and rill erosion. An understanding of the physical properties of RECPs and their effects on performance can help designers choose the appropriate product (Sutherland and Ziegler 2007).

A study conducted by A.D. Ziegler evaluated the effectiveness of RECP products in reducing raindrop splash detachment of soil particles. The results indicated that splash protection varies over the duration of the rain event and is dependent on surface coverage and thickness. It was noted that in evaluating RECP products, testing should be conducted for an appropriate timeframe to understand the full response. Shorter duration experiments may not last long enough to expose shortcomings in RECP products (Ziegler and Sutherland 1996).

2.11 RUSLE Soil Loss Risk Analysis

In designing and implementing an RECP product, it is important to gain an understanding of the potential amount of soil that may be lost on disturbed slopes during construction. The Revised Universal Soil Loss Equation (RUSLE) is a commonly used erosion model that predicts average annual soil loss. The equation considers rainfall erosivity (R-factor), soil erodibility (K-factor), slope length and steepness (slope-length-factor), cover-management factor (C-factor), and support practice factor (P-factor). The P factor is considered to be 1 for most practical purposes. The equation used in the calculation is listed below (Renard 1997):

$$A = R * K * LS * C * P \tag{2.1}$$

where,

A	=	annual soil loss per acre (tons/acre/year)
R	=	rainfall erosivity factor
K	=	soil erodibility factor
LS	=	length of slope steepness factor
C	=	cover management factor
P	=	support practice factor

With an understanding of the R, K, and LS factors; RECPs with a known C factor can be substituted into the equation to get an estimate of the amount of soil lost with the product applied.

2.12 RECPs as an Industry Solution

Unmanaged soil erosion is a major threat to sustainability. In the case of agriculture, it is estimated that approximately $27 billion is lost due to soil loss. Sediment discharged from construction and agriculture is ultimately discharged into nearby streams and reservoirs. To maintain waterways, the United States spends roughly $520 million annually to dredge streams and reservoirs. Unmanaged sedimentation can lead to flooding of cropland, homes, and businesses. In addition to economic and societal impacts, sedimentation damages the ecology of the watersheds it affects (Pimentel et al. 1995).

Since the 1990s, green infrastructure (GI) has played an increasingly significant role in stormwater and erosion management. In the stormwater and erosion control field, green infrastructure refers to a system of greenways, wetlands, parks, forest preserves, and native vegetation that naturally manages and mitigates the risk associated with stormwater and erosion. A common GI solution is the use of a bioswale. Bioswales are vegetated conveyance systems that manage stormwater runoff. Bioswales can reduce stormwater runoff volume through infiltration and retain pollutants. Since bioswales are dependent on the hydrological function of the vegetation, RECPs can be used as a revetment for bioswales. A study by Arnoldo Coelho assessed the effectiveness of seven RECPs based on biodiversity, dry biomass of the vegetation, structural integrity of swale revetment, vegetative cover, and the occurrence of erosive processes. The study concluded that RECPs demonstrated great potential as a swale revetment. Proper RECP and seed selection can help to increase soil water capacity retention, improve soil fertility, diminish soil acidity, and improve conditions for vegetative growth (Coelho and Galvao 2021). In transportation infrastructure, drainage swales are commonly used to divert stormwater runoff from the road. RECPs can serve as a valuable construction and post-construction stormwater management tool to reduce the effects of sedimentation in transportation infrastructure drainage swales.

Highway drainage channels are subject to high velocities and shear stress that can cause severe scouring of the channel bed. In addition to acting as a bioswale revetment, RECPs have been proven to be a cost-effective replacement to hard armor systems such as riprap and stone fill. Hard armor systems can be expensive and time-consuming to install. A study conducted by S.K. Bhatia evaluated the cost and effectiveness of using RECPs as a channel liner on the Munro Road project in New York. The study found that using RECPs instead of hard armor saved the project approximately $95,800. The use of RECPs on the project is expected to lower maintenance costs and provide long-term erosion control benefit (Bhatia et al. 2002). Increased use of RECPs on highway projects can help DOT's reach their Green Infrastructure and sustainability goals.

2.13 Conclusions

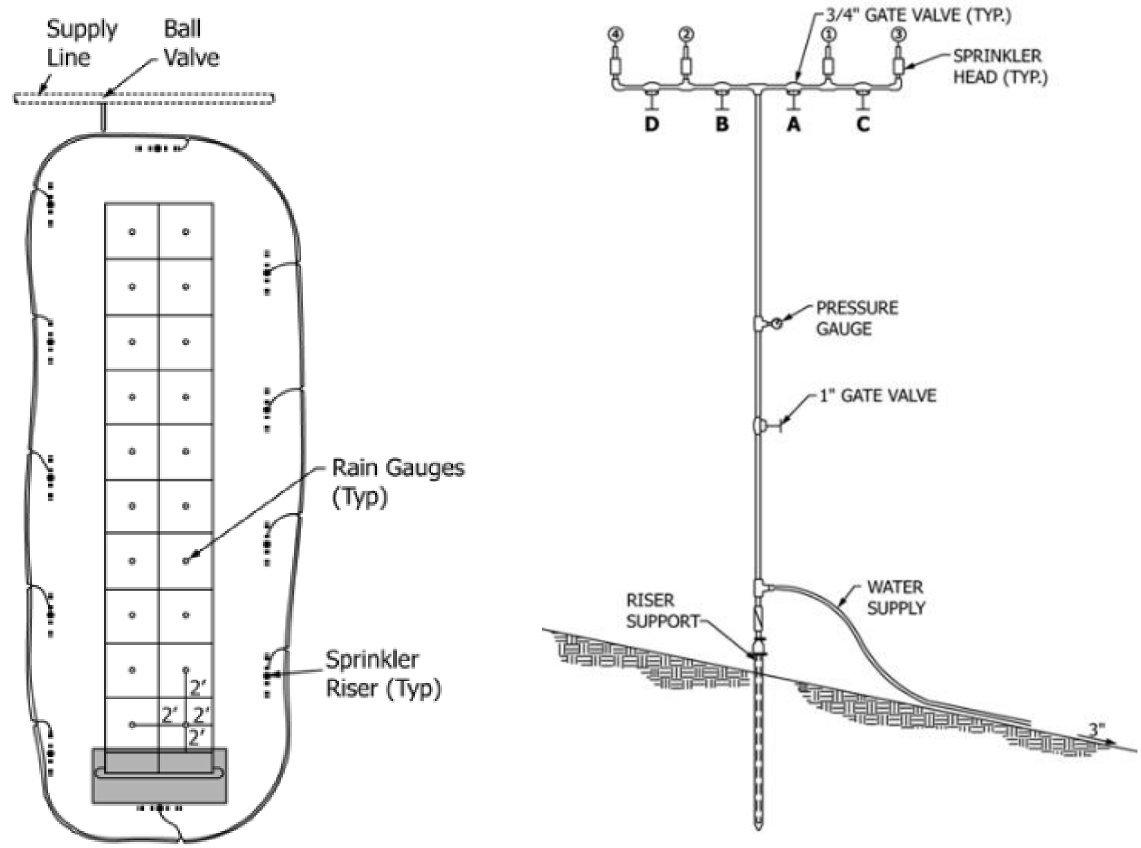
RECPs have proven to be a cost-effective and practical measure to reducing erosion from construction activities. As new technologies and methods emerge, it is important to evaluate their effectiveness as a sustainable solution to transportation infrastructure. This study sought to provide the reader of a general overview of RECPs and how they relate to transportation infrastructure sustainability. It was found the RECPs are an effective tool that can be a valuable addition to transportation infrastructure construction projects. For future research, the author recommends that a life-cycle analysis be performed to determine the environmental impact RECPs have during manufacturing. A potential method to evaluate could be to perform a study on carbon emissions and waste produced in the manufacturing process. If is found that the manufacturing process indicates high levels of risk to the surrounding environment, it could indicate that nature-based products are a better solution than synthetic products. RECPs have been proven to reduce soil erosion, however, there is little information on the impact of their materials on the environment. Once a life-cycle analysis has been performed, it can be further determined if RECP products are truly a sustainable transportation infrastructure solution. In addition to potential damage to the environment in the manufacturing process, synthetic RECP products may become a source of microplastic waste. Rainfall simulator testing could be used to potentially test the concentration of microplastics in the runoff.

CHAPTER 3: METHODOLOGY

The following chapter outlines the methodology used to calibrate and test bare soil and ECPs under ASTM D6459-19 rainfall simulation. The system was calibrated using rainfall gauge depth and the flour pan drop size distribution outlined in the ASTM standard. A summary of ASTM D6459-19 is provided along with documentation of plot preparation, testing, results collection, and TSS/Turbidity analysis procedure at the Auburn University Stormwater Research Facility. Improvements were made to the test facility as well throughout the study and are documented in this chapter. A summary of facility labor and logistics is also provided. Initial Construction of the Phase II rainfall simulator apparatus was performed and detailed by J. Etheridge (2023) and C. Manning (2021).

3.1 ASTM D6459-19

ASTM D6459-19 is titled as “Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall Induced Erosion”. The test method provides guidance on the construction, calibration, testing, and results collection. A typical ASTM large-scale rainfall simulator consists of an 8ft (2.44m) x 40ft (12.19m) test plot on a 3:1 slope surrounded by a set of elevated sprinkler trees. The system must produce target rainfall intensities of 2 in./hr (5.08 cm/hr), 4 in./hr (10.16 cm/hr), and 6 in./hr (15.24 cm/hr). Runoff is collected through a funnel and flashing system and the dry weight of sediment is determined through moisture content samples. The following Figure 3-1 provides the typical rainfall simulator configuration provided in ASTM D6459-19.



(a) Typical Rainfall Simulator Configuration

(b) Typical Sprinkler Riser Configuration

Figure 3-1: Typical ASTM Rainfall Simulator Configuration (ASTM 2019)

In addition to providing guidance on rainfall simulator configuration, the standard specifies that loam, sand, and clay soils can be used for testing. The gradation and plasticity index requirements for the soils used in this study are shown in Figure 3-2 below. The loam, sand, and clay soils tested at AU-SRF meet the ASTM gradation requirements and analysis and selection of test soils was performed and detailed by C. Manning (2021).

Particle size (mm)	Sand	Loam	Clay
D_{100} (mm)	$25 > D_{100} > 3.0$	$10 > D_{100} > 0.3$	$3.0 > D_{100} > 0.02$
D_{85} (mm)	$4.0 > D_{85} > 0.8$	$0.8 > D_{85} > 0.08$	$0.08 > D_{85} > 0.003$
D_{50} (mm)	$0.9 > D_{50} > 0.2$	$0.15 > D_{50} > 0.015$	$0.015 > D_{50} > 0.0008$
D_{15} (mm)	$0.3 > D_{15} > 0.01$	$0.03 > D_{15} > 0.001$	$D_{15} < 0.002$
Plasticity Index	N/A (nonplastic)	$2 < PI < 8$	$10 < PI$

Figure 3-2: Typical Grain Sizes and Plasticity Indices (ASTM 2019)

3.2 Test Facility at AU-SRF

Twelve large-scale ASTM rainfall simulator plots have been constructed at AU-SRF. The facility consists of 3:1 and 4:1 slopes along with three soil types (e.g. sand, clay, loam). Each plot is 8 ft (2.44 m) X 40 ft (12.19 m) and contains a runoff collection funnel and catch basin. The sprinkler system consists of ten 14 ft (4.27 m) sprinkler trees that are connected to the AU-SRF water supply pond. The phase II apparatus allows the testing of products on various combinations of soil types and slopes. Water is distributed to the ten sprinkler trees via a water supply line and manifold. The sprinkler valves are powered by a 12 V deep-cycle marine battery and controlled by a waterproof control box. The following figures provide a diagram of facility plot orientation, test apparatus, water supply manifold, and electrical control box.

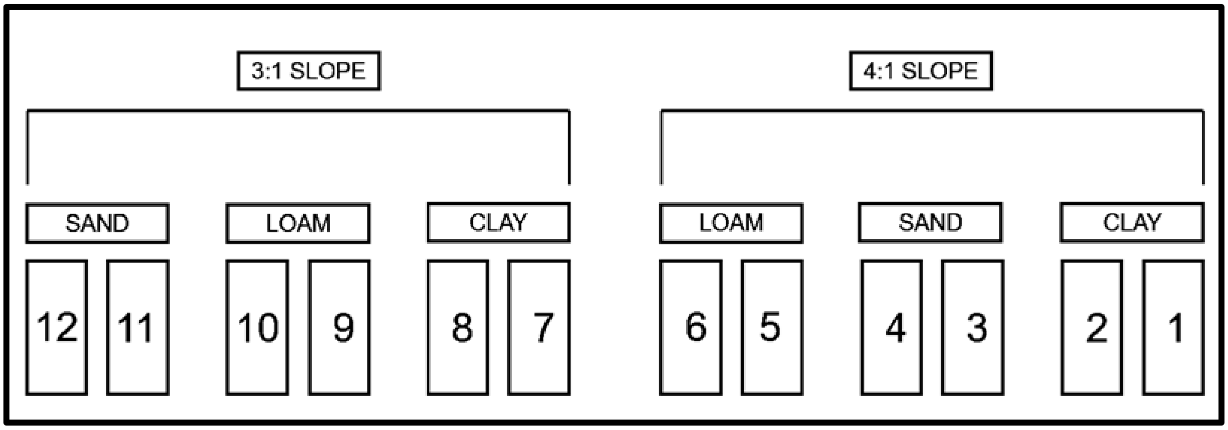
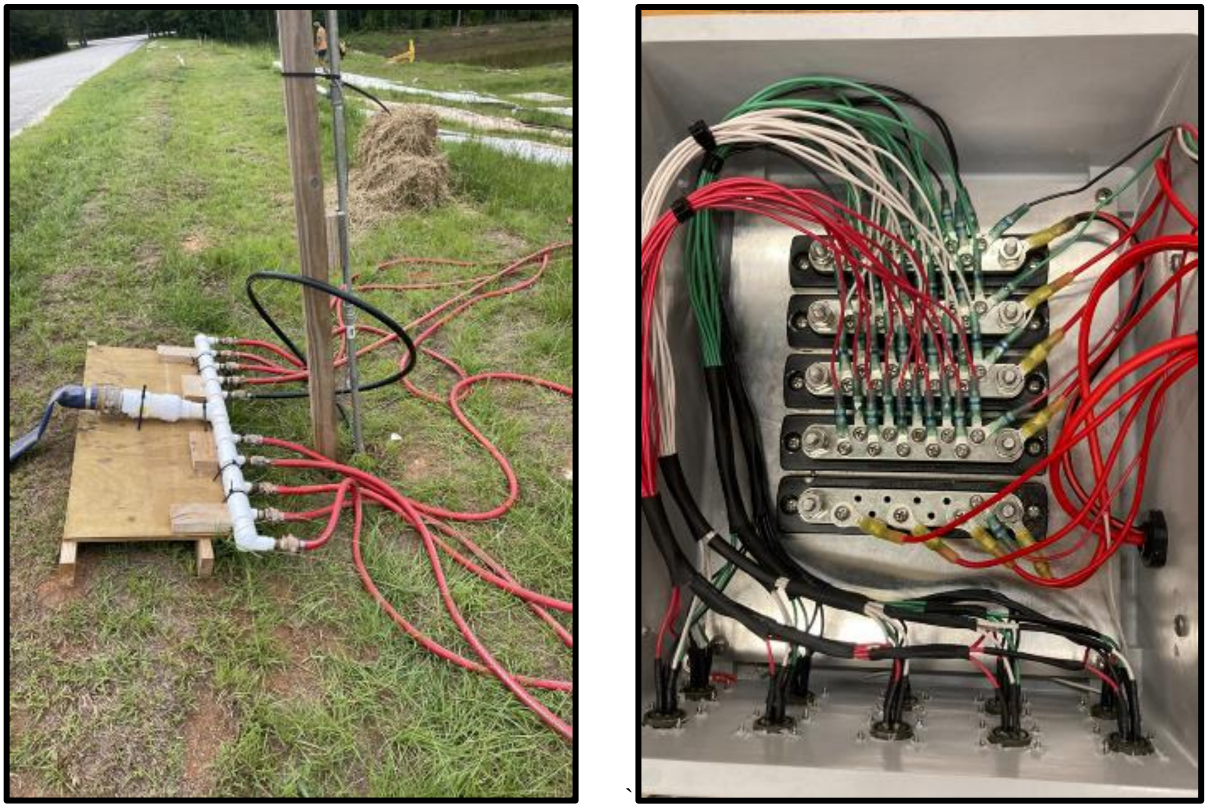


Figure 3-3: Rainfall Simulator Testing Facility Orientation

Figure 3-3 shows the orientation of the large-scale rainfall simulator orientation at AU-SRF. There are a total of 12 plots that are divided into 3:1 and 4:1 slopes. The rainfall simulator sprinkler system can be easily moved to the desired test plot to evaluate products in a variety of conditions.

Figure 3-4: AU-SRF Rainfall Simulator Apparatus

Figure 3-4 is an image of the AU-SRF rainfall simulator during a test. The orientation of the system remains consistent among all 12 plots. The same system was used for all testing.



(a) Manifold (b) Control Box

Figure 3-5: Water Supply and Electrical Controls

Figure 3-5 shows an image of the water supply manifold and electrical control box. The water supply manifold was used to distribute water from the PVC water main into 10 sprinkler trees. The control box was used to power the sprinkler valves and change rainfall intensity.

3.3 Calibration of ASTM D6459-19 Rainfall Simulator

The calibration of the rainfall simulator apparatus was performed using the rainfall gauge and flour pan drop size distribution methods. The following sections detail the results of the two calibration methods and the calculation of the theoretical R-factor used for the calculation of bare soil K-factor (soil erodibility) and C-factor (cover management factor). Novel calibration methods such as the runoff and photography method were further explored and detailed in previous study at AU-SRF (Etheridge 2023).

3.3.1 Rainfall Intensity Calibration

The rainfall intensity calibration was performed on the new rainfall simulator using 20 rain gauges. Per ASTM D5459-19, the rainfall gauge intensities exceeded the Christiansen Uniformity Coefficient value of 80%. The following equation was used to calculate the coefficient value.

$$C_u = 100[1.00 - \sum |d| \div n\bar{X}] \qquad (3.1)$$

Where,

C_u = Christiansen Uniformity Coefficient

d = $X_i - \bar{\bar{\bar{X}}}$

n = number of observations (20 in this case)

X = average depth caught

X_i = depth caught in each rain gauge

Table 3-1 below provides a summary of the results of the intensity calibration of the new rainfall simulator. The Christiansen Uniformity Coefficient is provided for each intensity.

Table 3-1: Intensity Calibration for New Rainfall Simulator Plots (Etheridge 2023)

Parameter	**Values**		
Target Intensity, in./hr (mm/hr)	**2.0 (51)**	**4.0 (102)**	**6.0 (152)**
ASTM D6459-19 20-Rainfall Gauge Test	2.1 (54)	4.2 (106)	6.3 (160)
Christiansen Uniformity (%)	82.24%	83.35%	81.1%
ASTM D6459-19 Method Percent Error from Target Intensity (%)	7.0%	4.5%	4.7%

The intensity calibration method satisfied the ASTM requirements for uniformity of 80%. This provided verification that the new rainfall simulators were working properly and can be used for ASTM testing purposes.

3.3.2 Drop Size Calibration

In addition to verifying the rainfall intensities produced by the simulator, a drop size calibration was performed using the flour pan method in accordance with ASTM D6459-19. A total of three flour pans were used for each rainfall intensity and the pellets were dried, sieved, and weighed according to pellet diameter. Table 3-2 below provides the average mass distribution for each target intensity. The RUSLE R-factor was determined from the mass distribution and was determined to be 148.5. The resulting R-factor is used in all C-factor and K-factor calculations.

Table 3-2: Average Mass Distributions by Target Intensity (Etheridge 2023)

Bin Size (mm)	2.0 in./hr (51 mm/hr)	4.0 in./hr (102 mm/hr)	6.0 in./hr (152 mm/hr)
2.38 to 4.76	0.00%	1.92%	4.52%
2.00 to 2.38	38.39%	35.70%	27.95%
1.68 to 2.00	12.22%	13.32%	31.77%
1.19 to 1.68	21.50%	21.45%	16.09%
0.84 to 1.19	19.27%	18.19%	11.98%
0.60 to 0.84	8.63%	9.42%	7.69%

3.4 ASTM D6459-19 Test Procedure at AU-SRF

Rainfall simulator testing took place across multiple test plots consisting of varying slopes and soil types. To ensure consistent results among bare soil and ECP testing, the following procedures were followed in strict accordance with ASTM D6459-19. The following sections detail the methodology used for plot preparation, test procedure, results collection, and analysis of TSS and turbidity samples.

3.4.1 Plot Preparation and Product Installation

Test plot preparation consists of tilling, raking, compacting, and applying the desired test product. Prior to compaction, the plot must be tilled a minimum of 6 in. (16.24 cm). At the AU-SRF, this was performed using digging forks. Once the soil is loosened to the required depth, the plot surface is raked for an even distribution of soil. The plot is then compacted using a mechanical slide compactor. A proctor compaction test (ASTM D698) is then performed to verify that the plot has been compacted within the required range of 87-93%. A grid (diagram provided below) is used to randomly select three drive cylinder locations on the plot. The compaction values for each cylinder were averaged together to determine the compaction value for the plot. All rainfall simulator testing followed the same plot preparation procedures using the same equipment to maintain consistency between tests. Once the soil had been prepared, products were installed in accordance with the ALDOT specifications and drawings.

(a) Plot Tilling (b) Plot Compaction

Figure 3-6: Plot Preparation

Figure 3-6 provides images of plot preparation. The digging fork was used to till the plot six inches (16.24 cm). The mechanical slide compactor (Mikasa Multiquip Plate Compactor) was run over the plot to obtain 87-93% compaction.

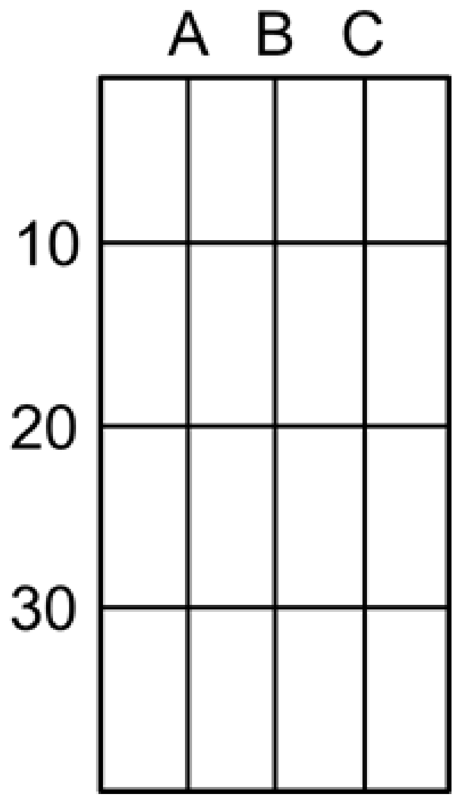


Figure 3-7: Drive Cylinder Compaction Grid

The above figure shows the grid used for determining compaction test cylinder locations. Three random locations are chosen for each test. Drive cylinder compaction is performed in accordance with ASTM D698.

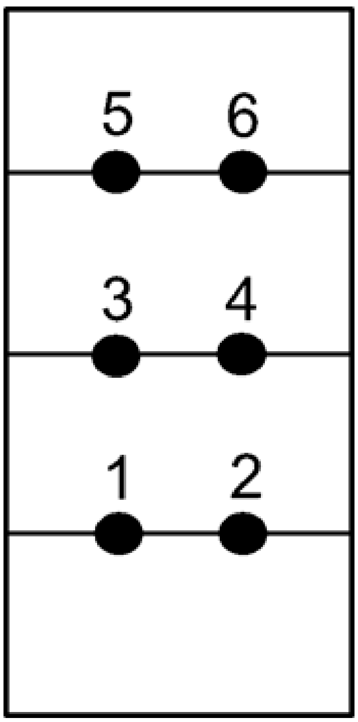
In addition to plot preparation, ECPs were installed in accordance with ALDOT specifications. In this study, straw was applied at a rate of 2.0 tons/acre and spread evenly on the test plot. The single-net straw blanket was trenched at the top of the slope and pinned in accordance with manufacturer detail. The following figure provides examples of crimped straw and single-net straw blanket installations.

(a) Single-Net Straw Blanket Pinning
Figure 3-8: ECP Installation

Figure 3-8 provides examples of ECP installation on a rainfall simulator plot. As shown in the figure, the single-net straw blanket was trenched at the top of the slope and spray paint was used to mark the pinning locations.

3.4.2 Test Procedure

Each rainfall simulator test consists of three 20-minute test intervals of 2 in./hr (5.08 cm/hr), 4 in./hr (10.16 cm/hr), and 6 in./hr (15.24 cm/hr). Prior to testing, a total of six rain gauges are placed on the plot to record the experimental rainfall intensities for each test interval. Photographs were taken before testing to document the pre-test condition of the plot. During each interval, runoff was collected through the funnel and into the catch basin. The runoff was simultaneously pumped into a series of aluminum troughs that have each been designated for a certain intensity. Each trough contains runoff for a certain intensity. Runoff rate was recorded every two minutes using a 100 ml cylinder and TSS/Turbidity samples are collected every three minutes using numbered containers. After each interval, the rain gauge depths are recorded, and photographs are taken of the plot to document the plot's condition. Rain gauge configuration and runoff collection are depicted in the figure below.



(a) Rain Gauge Configuration

(b) Runoff Collection

Figure 3-9: Rainfall and Runoff Collection

Figure 3-9 shows the rain gauge configuration and runoff collection that was used during the test procedure. Rain gauge configuration and runoff collection remain consistent for each test.

3.4.3 Results Collection

After testing sediment is allowed to settle in the troughs for a minimum of 24 hours. The supernatant water was pumped from the troughs and soil is removed and separated into buckets based on moisture content. The buckets were weighed to determine the wet weight of sediment and moisture content samples are recorded to calculate the dry weight. The dry weight of sediment is used in the calculation of K-Factor and C-Factor. The sediment collection troughs were depicted in the figure below.

Figure 3-10: Sediment Collection

Figure 3-10 is an image of the sediment collection troughs used to store test runoff and allow for settling. A separate trough was used to collect the runoff for each test intensity.

3.4.4 Analysis of TSS Samples

To obtain water quality data of the test plot runoff, total suspended solids (TSS) samples were obtained every three minutes of testing. The samples were collected in numbered containers and filled directly from the test plot funnel. All TSS samples were processed at the lab on campus.

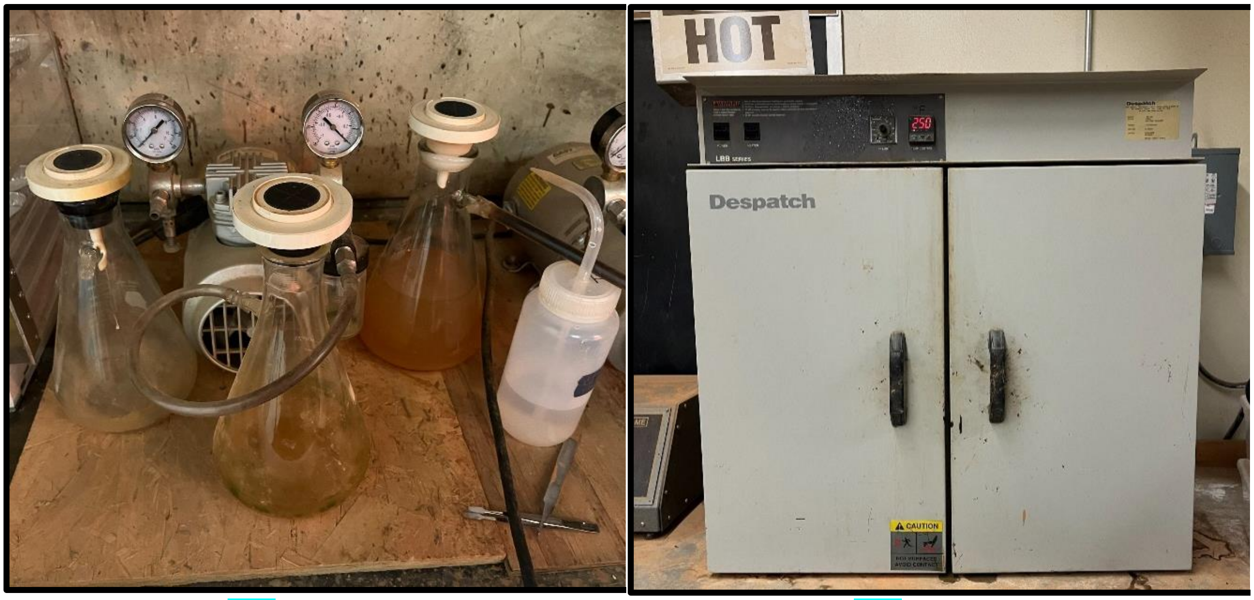
Before processing the samples for TSS, the crinkle dishes and filters were prepared by spraying deionized water onto the dishes and allowing them to dry. To avoid contamination, the filters were handled with tweezers and placed on the dish and then dried in the oven for an hour. To determine the weight of the filter and crinkle dish together without sediment, they were weighed on a precise scale to the ten-thousandth gram. The filter was placed on the vacuum machine directly and a pipette was used to transfer water (10 to 25 ml) directly onto the filter. All water was vacuumed from the filter and the filter was placed back on to the crinkle dish. The crinkle dish with filter was then placed in the oven to dry for at least one hour. The following equation was then used to calculate TSS in mg/L.

$$\mathrm{TSS} = \frac{\mathrm{W_{final}} - \mathrm{W_{initial}}}{\mathrm{V_{sample}}} * 1{,}000{,}000 \qquad (3.2)$$

where,

TSS	=	total suspended solids, mgTSS/L
$\mathrm{W_{final}}$	=	weight of sample after oven drying, g
$\mathrm{W_{initial}}$	=	weight of crinkle dish and filter membrane, g
$\mathrm{V_{sample}}$	=	volume of sample used, mL

Figure 3-11 provides images of the TSS equipment used to process all samples in the lab. The same equipment was used throughout the entirety of the study.



(a) TSS Vacuum (b) Drying Oven

Figure 3-11: TSS Equipment

3.4.5 Analysis of Turbidity Samples

The same sample bottles used for TSS processing were used for turbidity analysis. Before processing samples, the turbidimeter was calibrated using standard methods outlined in the user manual. To eliminate settling within the sample bottle, the bottle was thoroughly shaken before processing. Using a pipette, part of the sample was transferred to a beaker that was inserted into the Hach TL2300 Tungsten Lamp Turbidimeter. The turbidity reading was then recorded and dilutions were made to the sample if necessary. Figure 3-12 below provides an image of the turbidimeter used for all sample processing.

Figure 3-12: Turbidimeter

3.5 Test Facility Improvements

After the conclusion of Phase II rainfall simulator construction, a series of improvements were made to the system throughout the testing process. The following section details all improvements made to the system. Improvements include a manifold redesign and rebuild, electrical system improvements, basin anchoring modifications, drainage improvements, and water supply pipe repair. The following improvements were necessary to maintain consistency of testing and ensure reliability of the system.

3.5.1 Manifold Redesign and Rebuild

Due to the high pressure required for rainfall simulator testing, the original water supply manifold was susceptible to multiple failure points. The rubber gaskets that connected the metal tee to the PVC pipe were prone to slippage and failure during rainfall simulator operation. The original manifold was also prone to a series of leaks that required continuous repair. Figure 3-13 below provides an image of the original manifold.

Figure 3-13: Original Water Supply Manifold

To improve reliability and minimize leaks, a new manifold was designed and constructed. The improved manifold consists of all PVC construction which reduces the risk of failure and leaks. To minimize dirt or debris from entering the system, the manifold is attached to an elevated plywood surface that increases durability and ease of transfer to other test plots. Figure 3-14 below provides an image of the improved water supply manifold.

Figure 3-14: Improved Water Supply Manifold

3.5.2 Electrical System Improvements

During initial rainfall simulator testing, it was observed that there were inconsistencies in control box and battery performance. Some inconsistencies observed include battery life drainage, electrical fires, failure to engage solenoid valves, and battery overheating. A comprehensive review was conducted on the electrical system, and it was determined that a 12V deep cycle marine battery along with the addition of insulation to the solenoid valve wiring was required to maintain reliability and safe operation of the system. Figure 3-15 below provides an image of the wiring that required additional insulation.

Figure 3-15: Solenoid Valve Wiring Without Insulation

The above figure provides an example of the twisting of uninsulated wires that caused overheating and malfunction of the system. To repair this, insulation was added to each individual wire with heat shrink insulation along with an additional layer of insulation that encased all the wires together. The addition of proper insulation prevented future malfunction and added protection from debris and water.

3.5.3 Basin Anchoring Modification

The bottom of each rainfall simulator consists of a synthetic basin that serves as a runoff collection container. Due to high volume of stormwater runoff in the 3:1 slope area, an improved basin anchoring method was needed to prevent the basins from rising out of the ground due to hydrostatic pressure. The method consisted of a gravel base with 4’ X 4’ lumber cross-braced with 2’ X 4’ lumber. The basin was then anchored directly to the wooden bracing system with a series of washers and bolts. An image of the improved basin anchoring is provided in Figure 3-16 below.

Figure 3-16: Improved Basin Anchoring Method

3.5.4 Drainage Improvements

At the conclusion of the initial construction of the rainfall simulator plots, it was observed that drainage improvements were needed in the 3:1 slope area. The first improvement was to expand and armor the existing channel with rip rap by plot 12 to divert water away from the test plot. The channel improvement was performed with the test facility mini excavator and skid steer. The Figure 3-17 below provides an image of the channel after improvement.

Figure 3-17: Improved Drainage Channel

In addition to the channel, slope drains were added in between the 3:1 plots to collect runoff that may drain under the catch basins. Corrugated pipe was used, and excavation was performed with the mini excavator. The pipe was backfilled and tracked in with excavated soil. Figure 3-18 below provides an image of one of the slope drains.

Figure 3-18: Slope Drain Installation

3.5.5 Water Supply Pipe Repair

It was observed during rainfall simulator operation that the underground water supply pipe had been damaged. At one of the tee-connections, a glued joint had failed and disrupted the flow of water to the sprinkler system. Figure 3-19 below provides an image of the failed joint.

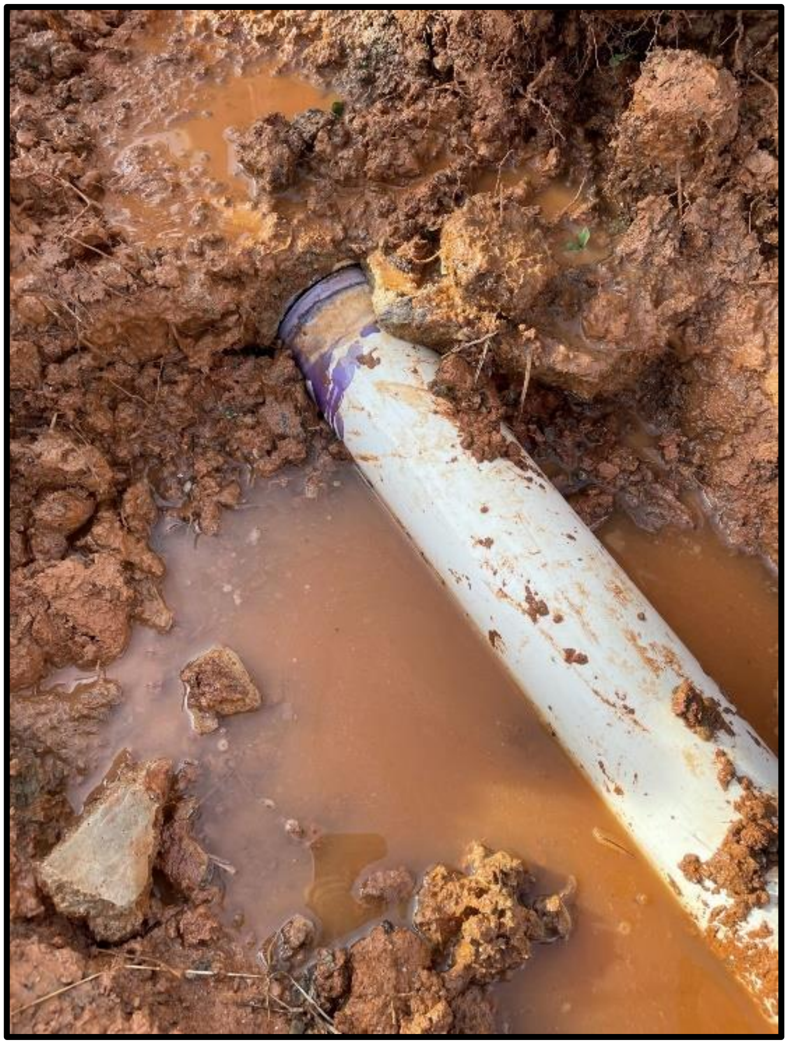


Figure 3-19: Failed PVC Connection

To repair the failed joint, the pipe was cut in three places and the tee-connection was completely removed. The tee-connection was reassembled, glued, and concreted in to add thrust protection. An expansion coupling was used to complete the repair, and several were purchased to keep on hand in case of additional pipe failure. Figure 3-20 below provides an image of the tee-connection reconstruction and the expansion coupling.

(a) Tee Reconstruction

(b) Expansion Coupling (Home Depot 2024)

Figure 3-20: Tee Reconstruction and Expansion Coupling

3.6 Facility Labor and Logistics

Large-scale rainfall simulation required significant facility and labor resources. Facility labor was required for the plot preparation, testing, collection of results, and movement of the rainfall simulator. The following sections provide the labor logistics for each phase of the testing process. A standard operating procedure (SOP) is included in the appendix.

3.6.1 Plot Preparation Labor

Plot preparation required a minimum of two laborers to till, rake, and compact the soil. If the soil level on the plot was low, the skid steer was required to add soil from the corresponding soil stockpile. In addition to plot preparation, a trained laborer also performed the compaction test and reported the results to the graduate student or research technician.

In addition to plot preparation, two laborers were required for the ECP installation. A graduate student or research technician was required to ensure that the ECP was installed in accordance with ALDOT and manufacturer guidelines.

3.6.2 Testing Labor

For a rainfall simulator test, a graduate student or research technician along with two laborers were required. The grad student or research technician was responsible for ensuring that the test was set up properly and oversees the operation of the water supply pump and pressure release valve. They were also responsible for instructing the laborers along with recording the rainfall gauge levels after each testing interval.

The two laborers were responsible for assisting with the test set up and the collection of runoff and TSS/turbidity samples. They were also responsible for emptying the runoff collection bucket after each test interval along with the operation of the submersible pump and generator.

3.6.3 Results Collection Labor

A graduate student or research technician was responsible for training and ensuring that the results collection was performed within ASTM D6459-19 guidelines. Once the sediment collection troughs reached minimum settling time, a minimum of three laborers were required for the transfer of sediment in the troughs to buckets. The facility generator, submersible pump, and shop vacuum were required to pump the excess water out of the troughs.

CHAPTER 4: RESULTS AND DISCUSSION

This chapter details the results of ASTM D6459-19 rainfall simulation on three soil types (sand, clay, and loam) on a 4:1 slope. Bare soil tests were performed on the slopes to determine the K-factor (soil erodibility) of each soil type. Loose straw and a single net erosion control blanket were installed to determine the C-factor of each practice. Each bare soil and ECP installation was performed three times for a total of 27 tests. The following sections provide details on soil loss for each rainfall intensity, recorded test rainfall, turbidity, TSS, runoff, calculated K-factor, and calculated C-factor. A discussion is also provided on the effect of soil type on ECP performance.

4.1 Bare Soil Sand Results

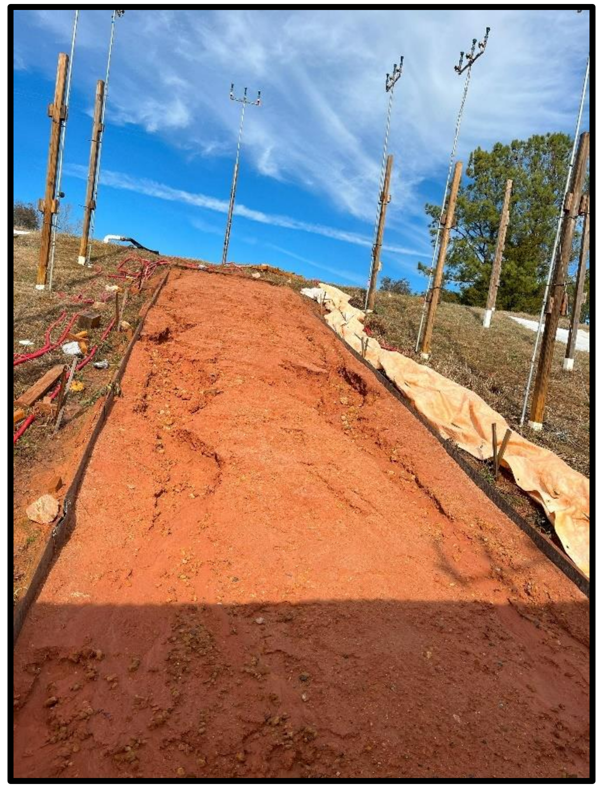
Bare soil tests were performed on sand, clay, and loam soils to determine a K-factor (soil erodibility) for each soil type. The following section provides a summary of the results of each bare soil test performed on a 4:1 ASTM sand test plot. Details and results of the K-factor calculations are provided as well.

Table 4-1: Bare Soil Sand Test 1 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.3 (57.2)	4.4 (110.5)	6.1 (154.9)
Sediment, lb (kg)	136.4 (61.9)	268.1 (121.6)	620.5 (281.5)
Runoff, gal. (L)	96.9 (366.7)	234.1 (886.0)	446.5 (1690.2)
Average turbidity (NTU)	50,287	52,490	104,522
Average TSS (mg/L)	40,209	63,872	185,161

As seen in Table 4-1, the first bare soil sand test yielded a soil loss of 136.4 lb (61.9 kg), 268.1 lb (121.6 kg), and 620.5 lb (281.5 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr) test intervals, respectively. The peak average turbidity and total suspended solids recorded during the test were 104,522 NTU and 185,161 mg/L, respectively. The recorded compaction prior to testing was 88.2% and the moisture content was recorded to be 14.8%. The recorded experimental rainfall depths along with corresponding sediment loss are used in the calculation of K-factor in the following section.

(a) During Test



(b) After Test

Figure 4-1: Bare Soil Sand Test 1 Photos

Figure 4-1 above displays the photos taken during the first bare soil sand test. As seen in the figure, the sand is highly erodible and was subjected to two large visible rills.

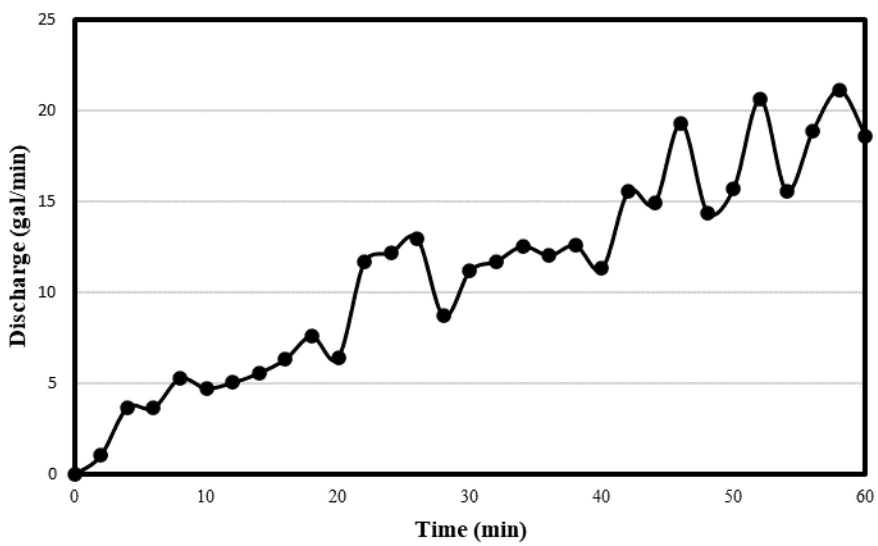


Figure 4-2: Bare Soil Sand Test 1 Hydrograph

Figure 4-2 above displays the hydrograph produced from the first bare soil sand test. The peak discharge was determined to be 22 gal/min (83 L/min) and a total runoff volume of 778 gallons (2945 L).

Table 4-2: Bare Soil Sand Test 2 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.6 (64.8)	4.8 (120.7)	5.7 (144.8)
Sediment, lb (kg)	297.8 (135.1)	423.6 (192.2)	650.5 (295.1)
Runoff, gal. (L)	140.1 (530.2)	301.0 (1139.3)	633.7 (2399.0)
Average turbidity (NTU)	49,128	50,522	-
Average TSS (mg/L)	37,139	41,051	-

*Four water quality samples were lost in the 6 in./hr and an average turbidity/TSS is not reported

As seen in Table 4-2, the second bare soil sand test yielded a soil loss of 297.8 (135.1 kg) lb, 423.6 lb (192.2 kg), and 650.5 lb (295.1 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr) test intervals, respectively. Due to a handling error, the average turbidity and TSS is not available for this test for the 6 in./hr (152 mm/hr) test interval. The recorded compaction prior to testing was 90.7% and the moisture content was recorded to be 10.2%. The recorded experimental rainfall depths along with corresponding sediment loss are used in the calculation of K-factor in the following section.

(a) During Test (b) After Test

Figure 4-3: Bare Soil Sand Test 2 Photos

Figure 4-3 above displays the photos taken during the second bare soil sand test. Several large visible rills were observed on the test plot and the soil was observed to be highly erodible like the first sand test.

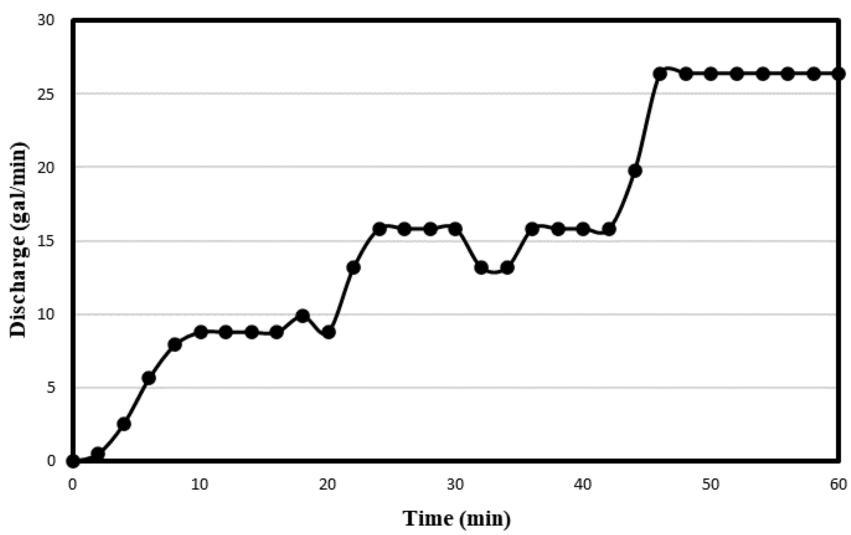


Figure 4-4: Bare Soil Sand Test 2 Hydrograph

Figure 4-4 above displays the hydrograph produced from the second bare soil sand tests. The peak discharge was determined to be 26 gal/min (98 L/min) and a total runoff volume of 1075 gallons (4069 L).

Table 4-3: Bare Soil Sand Test 3 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.6 (25.4)	3.5 (87.6)	5.2 (132.1)
Sediment, lb (kg)	543.6 (246.6)	162.1 (73.5)	2831.0 (1284.1)
Runoff, gal. (L)	115.0 (435.2)	285.8 (1081.7)	722.2 (2733.7)
Average turbidity (NTU)	64,674	88,940	93,270
Average TSS (mg/L)	79,560	201,180	188,013

As seen in Table 4-3, the third bare soil sand test yielded a soil loss of 543.6 lb (246.6 kg), 162.1 lb (73.5 kg), and 2831.0 lb (1284.1 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr) test intervals, respectively. The peak average turbidity and total suspended solids recorded was 93,270 NTU and 201,180 mg/L in the 6 in./hr (152 mm/hr) and 4 in./hr (102 mm/hr) test intervals, respectively. The recorded compaction prior to testing was 86.4% and the moisture content was recorded to be 8.8%. The recorded experimental rainfall depths along with corresponding sediment loss are used in the calculation of K-factor in the following section.

(a) During Test (b) After Test

Figure 4-5: Bare Soil Sand Test 3 Photos

Figure 4-5 above displays the photos taken during the third bare soil sand test. During the test, a large failure occurred on the left side of the plot resulting in a significantly larger soil loss than the first two tests. This resulted in a larger calculated K-factor than the first two tests. The research team concluded from bare soil sand testing that the test soil presents a high risk of erosion and can be unpredictable.

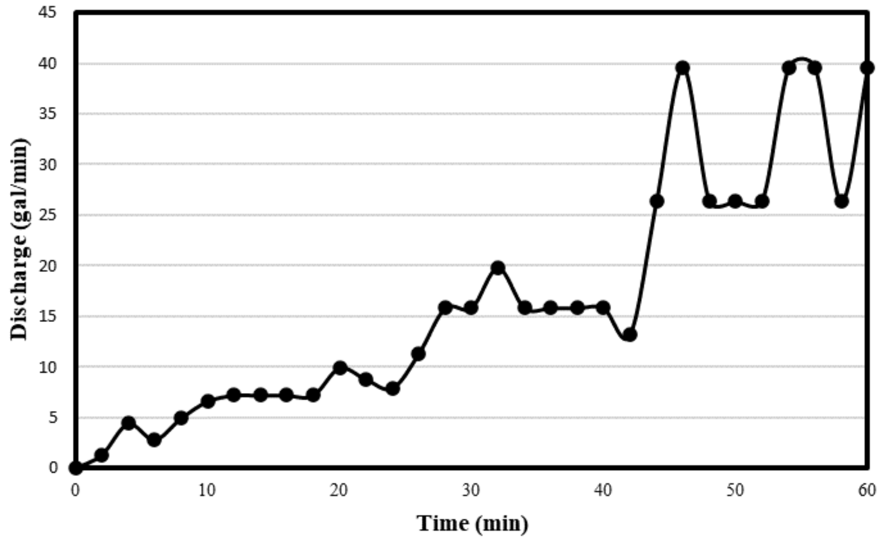


Figure 4-6: Bare Soil Sand Test 3 Hydrograph

Figure 4-6 displays the hydrograph from the third bare soil sand test. The peak discharge was determined to be 40 gal/min (151 L/min) and a total runoff volume of 1123 gallons (4251 L).

4.1.1 Sand K-factor Calculation

To fully understand erosion control practice performance on the sand test plot, the K-factor (soil erodibility) must be calculated. The RUSLE equation serves as the fundamental analysis of soil erodibility and product performance in this study. The RUSLE equation is provided in Chapter 2: Literature Review as equation 2.1.

The theoretical R-factor obtained from previous calibration was determined to be 148.5 and is adjusted based on the recorded experimental rainfall intensities. The LS factor was determined from a 4:1 slope to be 2.23. For a bare soil test, the C-factor and P-factor are assumed to be 1. The soil loss variable (tons/acre/year) is recorded directly from the soil loss during the test and plotted as a function of experimental R-factor. The soil loss values in tons/acre/year used in the calculation were 60.91, 73.21, and 234. 70 for tests 1,2, and 3, respectively. The soil loss variable for each test is determined from a normalized function of sediment loss and adjusted R-factor. Rearranging the equation, the K-factor can be calculated as the function below:

$$K = \frac{A}{R * LS * C * P} \tag{4.1}$$

where,

A	=	annual soil loss per acre (tons/acre/year)
R	=	rainfall erosivity factor
K	=	soil erodibility factor
LS	=	length of slope steepness factor
C	=	cover management factor
P	=	support practice factor

Table 4-4 below provides a summary of the calculated K-factor for each bare soil sand test. The average calculated K-factor is then used to determine the C-factor of an applied erosion control practice.

Table 4-4: Sand K-factor Results

Test	K-Factor
1	0.18
2	0.22
3	0.71
Average	0.37

For future determination of C-factor on the sand test plot, a K-factor of 0.37 will be used. Test 3 yielded a much higher K-factor due to a large failure and higher sediment loss. It should be noted that the K-factor determined in this study is only representative of the sand used for testing at the AU-SRF. The following table displays the values used in the calculation for each test.

Table 4-5: RUSLE Factors for Sand Tests

RUSLE Factor	Test 1	Test 2	Test 3
A, ton/ac/yr	60.91	73.21	234.70
Theoretical R	148.5	148.5	148.5
LS	2.23	2.23	2.23
C	1	1	1
P	1	1	1
K	0.18	0.22	0.37

4.2 Bare Soil Clay Results

The following section provides a summary of the results of each bare soil test performed on a 4:1 ASTM clay test plot. Details and results of the K-factor calculations are provided as well.

Table 4-6: Bare Soil Clay Test 1 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.7 (69.3)	4.5 (114.3)	7.4 (186.7)
Sediment, lb (kg)	4.3 (2.0)	50.1 (22.7)	123.4 (56.0)
Runoff, gal. (L)	23.9 (90.4)	178.1 (674.0)	284.1 (1075.4)
Average turbidity (NTU)	9,453	17,849	23,549
Average TSS (mg/L)	7,493	16,509	18,960

As seen in Table 4-6, the first bare soil clay test yielded a soil loss of 4.3 lb (2.0 kg), 50.1 lb (22.7 kg), and 123.4 lb (56.0 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr) test intervals, respectively. The peak average turbidity and total suspended solids recorded during the test were 23,549 NTU and 18,960 mg/L, respectively. The recorded compaction prior to testing was 92.2% and the moisture content was recorded to be 22.0%. The recorded experimental rainfall depths along with corresponding sediment loss are used in the calculation of K-factor in the following section.

(a) During Test (b) After Test

Figure 4-7: Bare Soil Clay Test 1

Figure 4-7 above displays photos taken during the first bare soil clay tests. It was observed that the clay soil was much less erodible than sand soil. No visible rills were formed on the test plot and is in accordance with the relatively low sediment loss and K-factor.

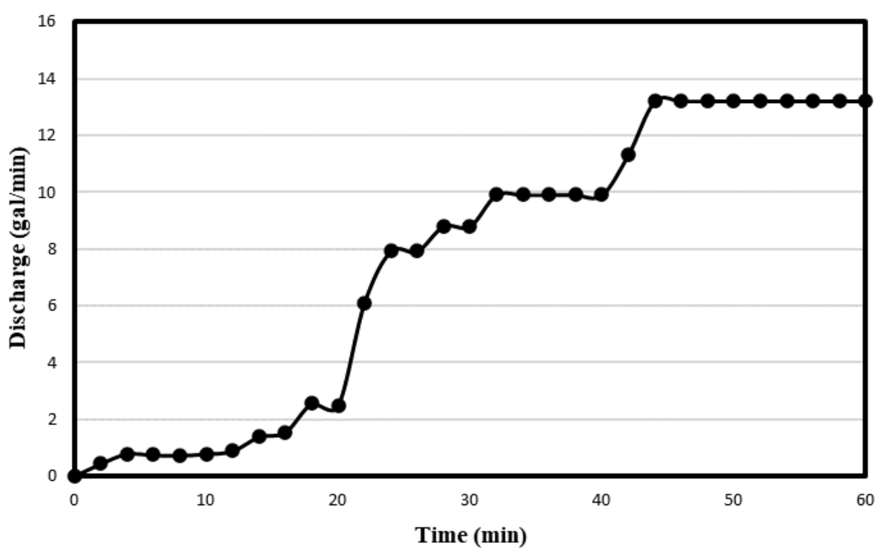


Figure 4-8: Bare Soil Clay Test 1 Hydrograph

Figure 4-8 above displays the hydrograph from the first bare soil clay test. The peak discharge was determined to be 13 gal/min (49 L/min) and a total runoff volume of 486 gallons (1840 L).

Table 4-7: Bare Soil Clay Test 2 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.6 (64.8)	4.4 (110.5)	6.9 (175.3)
Sediment, lb (kg)	10.1 (4.6)	10.2 (4.6)	63.5 (28.8)
Runoff, gal. (L)	12.8 (48.6)	73.2 (277.1)	239.8 (907.6)
Average turbidity (NTU)	-	-	-
Average TSS (mg/L)	4,167	7,056	9,239

*Turbidity not available for this test due to handling error.

As seen in table Table 4-7, the second bare soil clay test yielded a soil loss of 10.1 lb (4.6 kg), 10.2 lb (4.6 kg), and 63.5 lb (28.8 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr) test intervals, respectively. The turbidity analysis is not available for this test due to a handling error in the laboratory. The peak average total suspended solids for this test was 9,239 mg/L during the 6 in./hr (152 mm/hr) test interval. The recorded compaction prior to testing was 88.4% and the moisture content was recorded to be 24.8%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of K-factor in the following section.

(a) During Test

(b) During Test

Figure 4-9: Bare Soil Clay Test 2 Photos

Figure 4-9 above displays photos taken during the second bare soil clay test. It was observed that like the first test, minimal rills formed on the plot and resulted in a relatively low sediment loss.

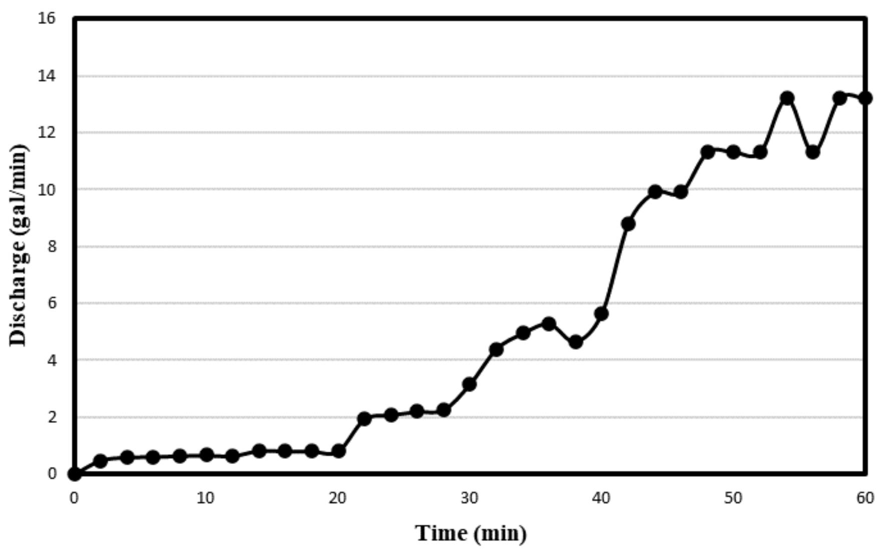


Figure 4-10: Bare Soil Clay Test 2 Hydrograph

Figure 4-10 above displays the hydrograph from the second bare soil clay test. The peak discharge was determined to be 13 gal/min (49 L/min) and the total runoff volume of 326 gal (1234 L).

Table 4-8: Bare Soil Clay Test 3 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.2 (54.6)	4.4 (111.8)	6.6 (167.6)
Sediment, lb (kg)	0.7 (0.3)	5.6 (2.5)	74.6 (33.8)
Runoff, gal. (L)	6.2 (23.4)	17.1 (64.8)	335.3 (1269.3)
Average turbidity (NTU)	10,034	11,103	11,454
Average TSS (mg/L)	6,997	10,471	11,839

A seen in Table 4-8, the third bare soil clay test yielded a soil loss of 0.7 lb (0.3 kg), 5.6 lb (2.5 kg), and 74.6 lb (33.8 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 11,454 NTU and 11,839 mg/L in the 6 in./hr (152 mm/hr) test interval. The recorded compaction prior to testing was 89.3% and the moisture content was recorded to be 26.0%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of K-factor in the following section.

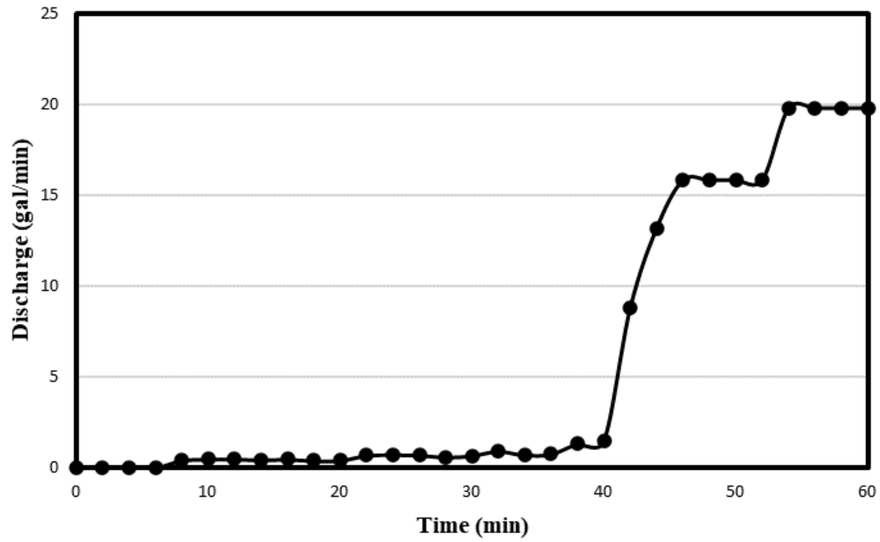


Figure 4-11: Bare Soil Clay Test 3 Hydrograph

Figure 4-11 above displays the hydrograph from the third bare soil clay test. The peak discharge was determined to be 20 gal/min (76 L/min) and the total runoff volume of 359 gallons (1359 L).

4.2.1 Clay K-factor Calculation

To evaluate the K-factor for the clay soil, the same method was used in the analysis of the sand soil. The theoretical R-factor of 148.5 was used along with an LS factor of 2.23. The soil loss values in (tons/acre/year) were determined to be 7.73, 3.50, and 3.33 for tests 1,2, and 3, respectively. With the assumption of the C-factor and P-factor having a value of 1, the K-factors for each clay test was determined from equation 4.1. Table 4-9 displays the K-factor determined for each test along with the average. The average K-factor of 0.013 is used in the calculation of C-factor on future ECP testing. It should be noted that the K-factor determined in this study is only representative of the clay used for testing at the AU-SRF.

Table 4-9: Clay K-factor Results

Test	K-Factor
1	0.02
2	0.01
3	0.01
Average	0.013

Table 4-10 below provides a summary of the RUSLE factors used in the calculation for each test.

Table 4-10: RUSLE Factors for Clay Tests

RUSLE Factor	Test 1	Test 2	Test 3
A, ton/ac/yr	7.73	3.50	3.33
Theoretical R	148.5	148.5	148.5
LS	2.23	2.23	2.23
C	1	1	1
P	1	1	1
K	0.02	0.01	0.01

4.3 Bare Soil Loam Results

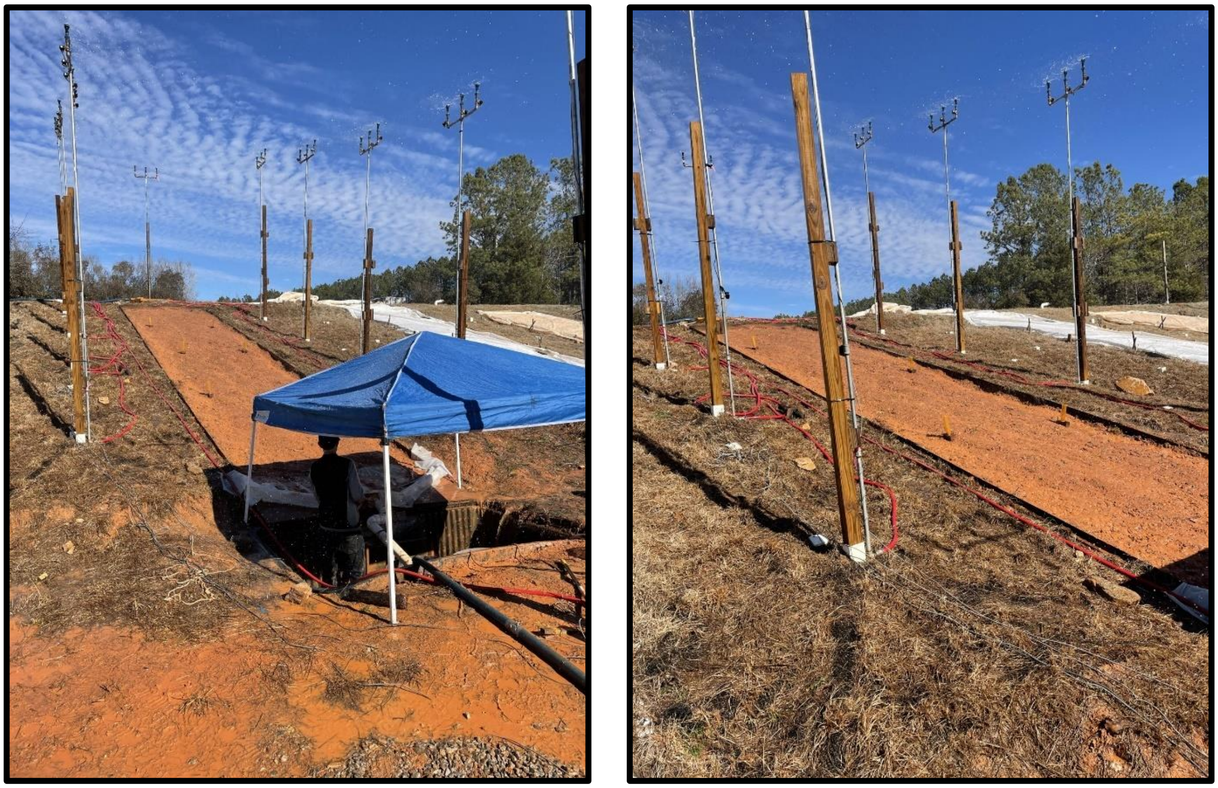
The following section provides a summary of the results of each bare soil test performed on a 4:1 ASTM loam test plot. Details and results of the K-factor calculations are provided as well.

Table 4-11: Bare Soil Loam Test 1 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.3 (57.2)	4.0 (101.6)	5.9 (148.6)
Sediment, lb (kg)	18.9 (8.6)	82.9 (37.6)	188.7 (85.6)
Runoff, gal. (L)	78.5 (297.2)	316.7 (1199.0)	516.8 (1956.2)
Average turbidity (NTU)	21,408	22,498	13,811
Average TSS (mg/L)	11,541	15,096	10,613

A seen in Table 4-11, the first bare soil loam test yielded a soil loss of 18.9 lb (8.6 kg), 82.9 lb (37.6 kg), and 188.7 lb (85.6 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 22,498

NTU and 15,096 mg/L in the 4 in./hr (102 mm/hr) test interval. The recorded compaction prior to testing was 87.7% and the moisture content was recorded to be 18.8%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of K-factor in the following section.



(a) During Test (b) During Test

Figure 4-12: Bare Soil Loam Test 1 Photos

Figure 4-12 above displays the photos taken during the first bare soil loam tests. It was observed that the loam soil did not form rills like the sand soil. This resulted in substantially less sediment loss than the bare soil loam tests.

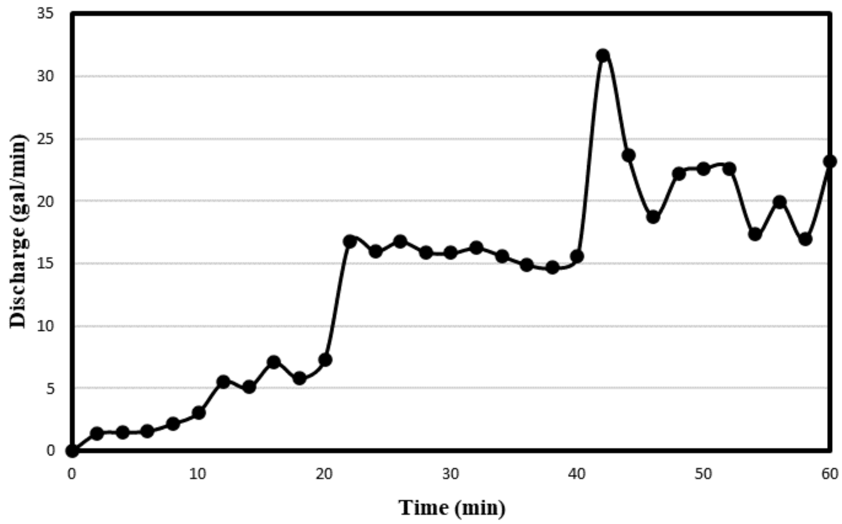


Figure 4-13: Bare Soil Loam Test 1 Hydrograph

Figure 4-13 above displays the hydrograph from the first bare soil loam test. The peak discharge was determined to be 31 gal/min (117 L/min) and the total runoff volume of 912 gallons (3452 L).

Table 4-12: Bare Soil Loam Test 2 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.9 (72.4)	4.5 (113.0)	6.4 (161.3)
Sediment, lb (kg)	7.4 (3.4)	22.5 (10.2)	75.5 (34.3)
Runoff, gal. (L)	99.2 (375.6)	238.5 (903.0)	442.4 (1674.7)
Average turbidity (NTU)	11,537	18,459	17,242
Average TSS (mg/L)	7,848	17,544	17,471

A seen in Table 4-12, the second bare soil loam test yielded a soil loss of 7.4 lb (3.4 kg), 22.5 lb (10.2 kg), and 75.5 lb (34.3 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 18,459 NTU and 17,544 mg/L in the 4 in./hr (102 mm/hr) test interval. The recorded compaction prior to testing was recorded to be 93.8% and the moisture content was recorded to be 19.5%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of K-factor in the following section.


(a) During Test


(b) During Test

Figure 4-14: Bare Soil Loam Test 2 Photos

Figure 4-14 displays photos taken during the second bare soil sand test. Like the other bare soil loam tests, no major rills formed on the plot like the sand bare soil tests.

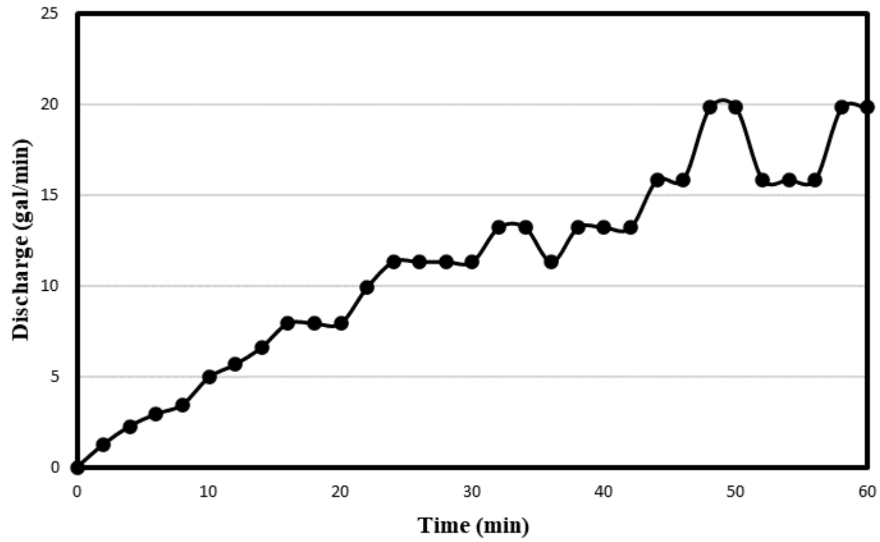


Figure 4-15: Bare Soil Loam Test 2 Hydrograph

Figure 4-15 above displays the hydrograph from the second bare soil loam test. The peak discharge was determined to be 20 gal/min (76 L/min) and the total runoff volume of 780 gallons (2953 L).

Table 4-13: Bare Soil Loam Test 3 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	1.9 (47.0)	3.5 (87.6)	5.8 (147.3)
Sediment, lb (kg)	22.2 (10.1)	118.6 (53.8)	167.3 (75.9)
Runoff, gal. (L)	40.6 (153.6)	191.4 (724.5)	397.0 (1502.7)
Average turbidity (NTU)	26,813	31,463	19,329
Average TSS (mg/L)	16,239	31,544	19,991

A seen in Table 4-13, the third bare soil loam test yielded a soil loss of 22.2 lb (10.1 kg), 118.6 lb (53.8 kg), and 167.3 lb (75.9 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 31,463 NTU and 31,544 mg/L in the 4 in./hr (102 mm/hr) test interval. The recorded compaction prior to testing was 89.3% and the moisture content was recorded to be 17.2%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of K-factor in the following section.

(a) During Test (b) During Test

Figure 4-16: Bare Soil Loam Test 3 Photos

Figure 4-16 displays photos taken during the third bare soil loam test. Consistent with the other bare soil loam tests, minimal rills formed on the plot and the soil remained stable.

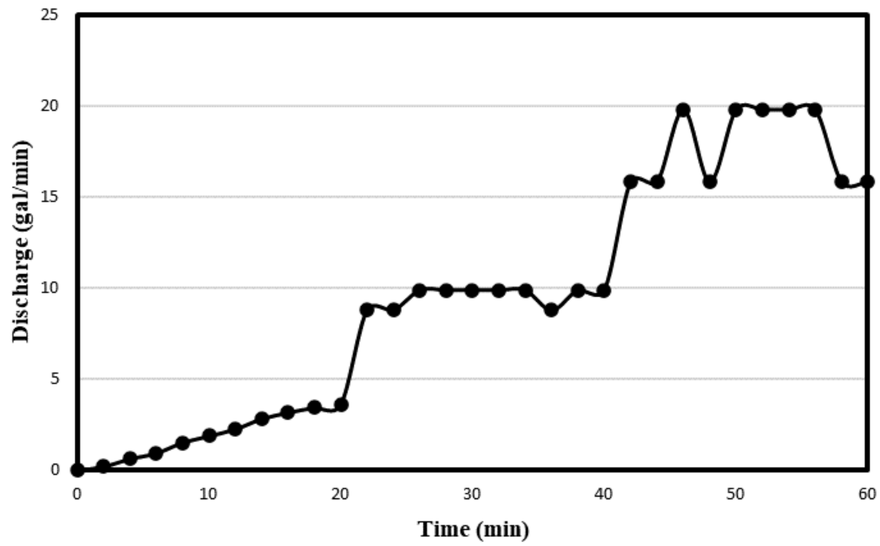


Figure 4-17: Bare Soil Loam Test 3 Hydrograph

Figure 4-17 above displays the hydrograph from the third bare soil loam test. The peak discharge was determined to be 20 gal/min (76 L/min) and the total runoff volume of 629 gallons (2381 L).

4.3.1 Loam K-factor Calculation

To evaluate the K-factor for the loam soil, the same method was used in the analysis of the sand and clay soil. The theoretical R-factor of 148.5 was used along with an LS factor of 2.23. The soil loss values in (tons/acre/year) were determined to be 19.18, 4.57, and 20.28 for tests 1,2, and 3, respectively. With the assumption of the C-factor and P-factor having a value of 1, the K-factors for each loam test were determined from equation 4.1. Table 4-14 displays the K-factor determined for each test along with the average. The average K-factor of 0.043 is used in the calculation of C-factor on future ECP testing. It should be noted that the K-factor determined in this study is only representative of the loam used for testing at the Auburn University Stormwater Research Facility.

Table 4-14: Loam K-Factor Results

Test	K-Factor
1	0.06
2	0.01
3	0.06
Average	0.043

Table 4-15 below provides a summary of the RUSLE factors used in the calculation for each test.

Table 4-15: RUSLE Factors for Loam Tests

RUSLE Factor	Test 1	Test 2	Test 3
A, ton/ac/yr	19.18	4.57	20.28
Theoretical R	148.5	148.5	148.5
LS	2.23	2.23	2.23
C	1	1	1
P	1	1	1
K	0.06	0.01	0.06

4.4 Loose Straw Sand Results

To determine the performance of loose straw on the test soils, straw was applied at a rate of 2 tons/acre to the test plot and spread evenly on the test plot. The following sections provide the results of loose straw applied on a 4:1 ASTM test plot on a sand soil. Details and results of the C-factor calculation are provided as well.

Table 4-16: Loose Straw Sand Test 1 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.3 (58.4)	4.2 (105.4)	6.4 (162.6)
Sediment, lb (kg)	6.1 (2.8)	12.1 (5.5)	32.0 (14.5)
Runoff, gal. (L)	73.6 (278.6)	107.4 (406.7)	254.7 (964.0)
Average turbidity (NTU)	6,094	3,494	2,757
Average TSS (mg/L)	2,228	2,217	2,136

A seen in Table 4-16, the first loose straw sand test yielded a soil loss of 6.1 lb (2.8 kg), 12.1 lb (5.5 kg), and 32.0 lb (14.5 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 6,094 NTU and 2,228 mg/L in the 2 in./hr (51 mm/hr) test interval. The recorded compaction prior to testing was 90.6% and the moisture content was recorded to be 10.2%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-18: Loose Straw Sand Test 1 Photos

Figure 4-18 displays pictures taken during the first loose straw sand test. The loose straw was effective at reducing soil loss and no visible rills were observed during the test.

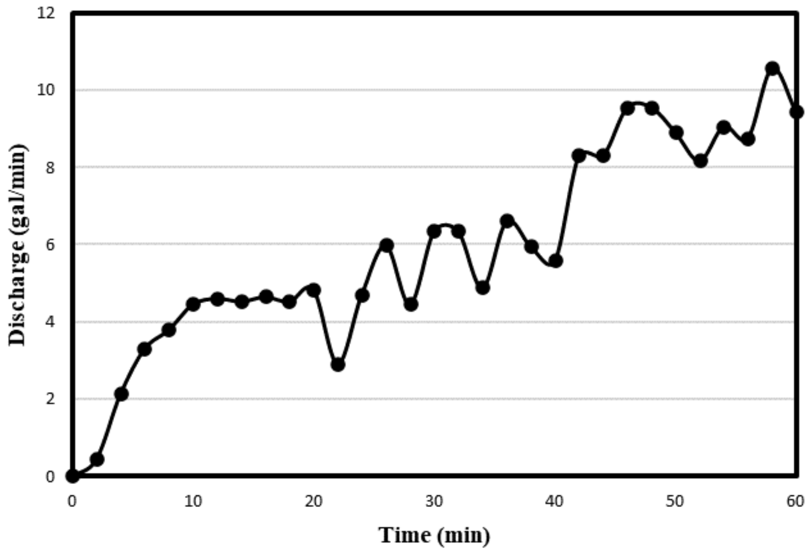


Figure 4-19: Loose Straw Sand Test 1 Hydrograph

Figure 4-19 above displays the hydrograph from the first loose straw sand test. The peak discharge was determined to be 11 gal/min (42 L/min) and a total runoff volume of 436 gallons (1650 L).

Table 4-17: Loose Straw Sand Test 2 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.3 (59.2)	4.3 (108.7)	6.2 (157.5)
Sediment, lb (kg)	3.5 (1.6)	6.4 (2.9)	21.6 (9.8)
Runoff, gal. (L)	7.4 (27.9)	122.8 (464.7)	232.9 (881.6)
Average turbidity (NTU)	517	729	1,342
Average TSS (mg/L)	727	934	880

A seen in Table 4-17, the second loose straw sand test yielded a soil loss of 3.5 lb (1.6 kg), 6.4 lb (2.9 kg), and 21.6 lb (9.8 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 1,342 NTU and 934 mg/L in the 6 in./hr (152 mm/hr) and 4 in./hr (102 mm/hr) test intervals, respectively. The recorded compaction prior to testing was 91.6% and the moisture content was recorded to be 8.9%.

The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

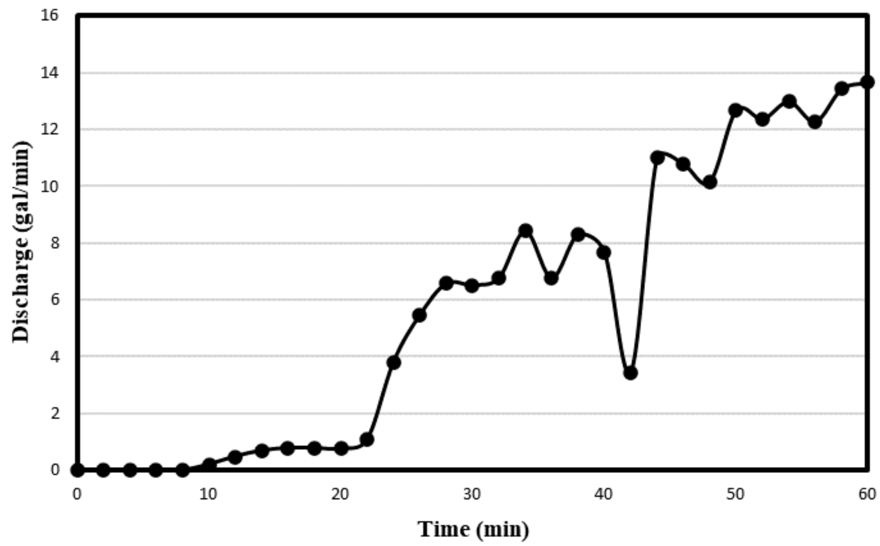


Figure 4-20: Loose Straw Sand Test 2 Hydrograph

Figure 4-20 above displays the hydrograph from the second loose straw sand test. The peak discharge was determined to be 14 gal/min (53 L/min) and a total runoff volume of 363 gallons (1374 L).

Table 4-18: Loose Straw Sand Test 3 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.3 (59.4)	4.1 (104.1)	6.4 (162.6)
Sediment, lb (kg)	0.8 (0.4)	18.1 (8.2)	32.4 (14.7)
Runoff, gal. (L)	13.1 (49.6)	238.7 (903.7)	266.7 (1009.5)
Average turbidity (NTU)	2,153	3,371	5,135
Average TSS (mg/L)	3,386	5,929	8,207

A seen in Table 4-18, the third loose straw sand test yielded a soil loss of 0.8 lb (0.4 kg), 18.1 lb (8.2 kg), and 32.4 lb (14.7 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 5,135 NTU and 8,207 mg/L in the 6 in./hr (152 mm/hr) test interval. The recorded compaction prior to testing was 91.2% and the recorded moisture content was 10.8%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-21: Loose Straw Sand Test 3 Photos

Figure 4-21 displays pictures taken during the third loose straw sand test. As seen in the prior sand tests, the straw was effective at protecting the slopes and no visible rills formed.

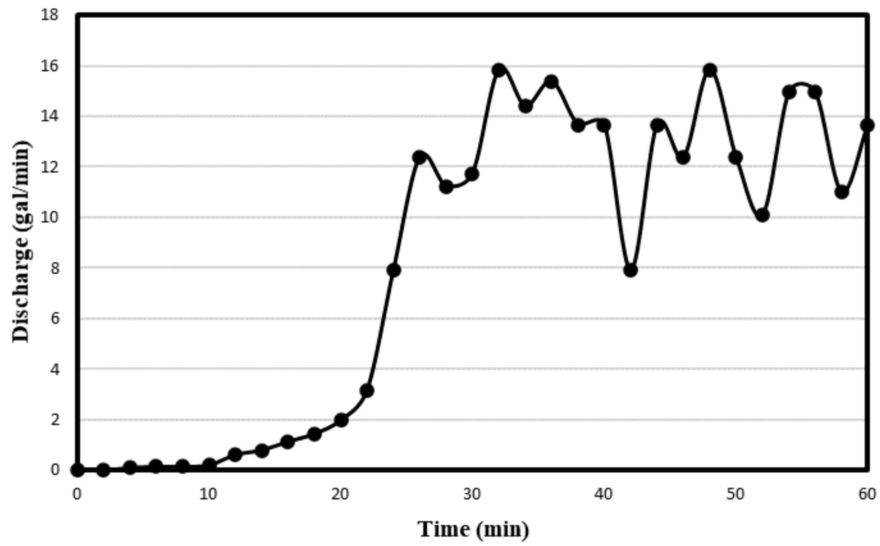


Figure 4-22: Loose Straw Sand Test 3 Hydrograph

Figure 4-22 above displays the hydrograph from the third loose straw sand test. The peak discharge was determined to be 16 gal/min (61 L/min) and a total runoff volume of 519 gallons (1965 L).

4.4.1 Loose Straw Sand C-factor Calculation

To evaluate the C-factor for loose straw on the sand soil, the same method was used in the calculation of K-factor. This time the average K-factor of 0.37 determined from sand bare soil testing was used and the C-factor is no longer assumed to be 1. The theoretical R-factor of 148.5 was used along with an LS factor of 2.23. The soil loss values in (tons/acre/year) were determined to be 2.88, 1.80, and 2.93 for tests 1,2, and 3, respectively. With the assumption of the P-factor having a value of 1, the C-factors for each sand test were determined from the equation below.

$$C = \frac{A}{R * LS * K * P} \tag{4.2}$$

where,

A = annual soil loss per acre (tons/acre/year)

R = rainfall erosivity factor

K = soil erodibility factor

LS = length of slope steepness factor

C = cover management factor

P = support practice factor

Table 4-19 displays the C-factors determined for each test along with the average.

Table 4-19: Loose Straw Sand C-Factor Results

Test	C-Factor
1	0.023
2	0.015
3	0.024
Average	0.021

Table 4-20 below provides a summary of the RUSLE factors used in the calculation for each test.

Table 4-20: RUSLE Factors for Loose Straw Sand Tests

RUSLE Factor	Test 1	Test 2	Test 3
A, ton/ac/yr	2.88	1.80	2.93
Theoretical R	148.5	148.5	148.5
LS	2.23	2.23	2.23
K	0.37	0.37	0.37
P	1	1	1
C	0.023	0.015	0.024

4.5 Loose Straw Clay Results

The following section provides the results of loose straw applied on a 4:1 ASTM test plot on a clay soil. Details and results of the C-factor calculation are provided as well.

Table 4-21: Loose Straw Clay Results Test 1

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.7 (68.6)	4.5 (113.0)	6.3 (160.0)
Sediment, lb (kg)	3.1 (1.4)	4.6 (2.1)	8.5 (3.9)
Runoff, gal. (L)	7.9 (30.0)	14.6 (55.3)	47.0 (177.8)
Average turbidity (NTU)	2,556	4,258	-
Average TSS (mg/L)	2,439	3,619	-

*Two samples were lost in a handling error in the 6 in./hr test interval and an average TSS and Turbidity values are not reported.

A seen in Table 4-21, the first loose straw clay test yielded a soil loss of 3.1 lb (1.4 kg), 4.6 lb (2.1 kg), and 8.5 lb (3.9 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids are not recorded due to a handling error in the 6 in./hr (152 mm/hr) test interval. The recorded compaction prior to testing was 92.1% and the recorded moisture content was 19.3%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-23: Loose Straw Clay Test 1 Photos

Figure 4-23 displays photos taken during the first loose straw clay test. No visible rills formed on the test plot.

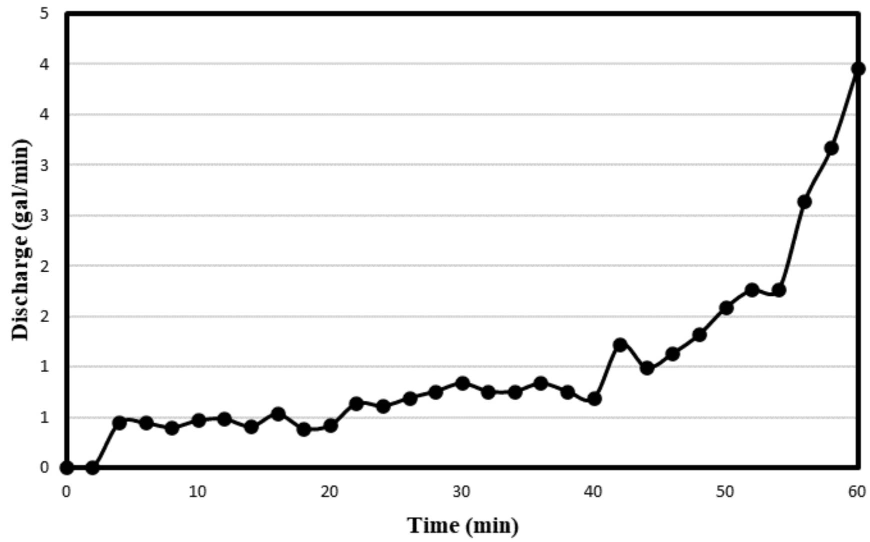


Figure 4-24: Loose Straw Clay Test 1 Hydrograph

Figure 4-24 above displays the hydrograph from the first loose straw clay test. The peak discharge was determined to be 4 gal/min (15 L/min) and a total runoff volume of 70 gallons (265 L).

Table 4-22: Loose Straw Clay Results Test 2

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.3 (58.4)	4.9 (124.5)	7.1 (179.1)
Sediment, lb (kg)	0.6 (0.3)	0.9 (0.4)	1.9 (0.9)
Runoff, gal. (L)	5.9 (22.2)	15.0 (56.9)	109.9 (416.0)
Average turbidity (NTU)	1,4588	10,103	2,393
Average TSS (mg/L)	7,327	8,039	2,803

A seen in Table 4-22, the second loose straw clay test yielded a soil loss of 0.6 lb (0.3 kg), 0.9 lb (0.4 kg), and 1.9 lb (0.9 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 14,588 NTU and 8,039 mg/L in the 2 in./hr (51 mm/hr) and 4 in./hr (102 mm/hr) test intervals, respectively. The recorded compaction prior to testing was 93.3% and the recorded moisture content was 25.4%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-25: Loose Straw Clay Test 2 Photos

Figure 4-25 displays photos taken during the second loose straw clay test. In consistency with the other clay test, no visible rills formed on the test plot.

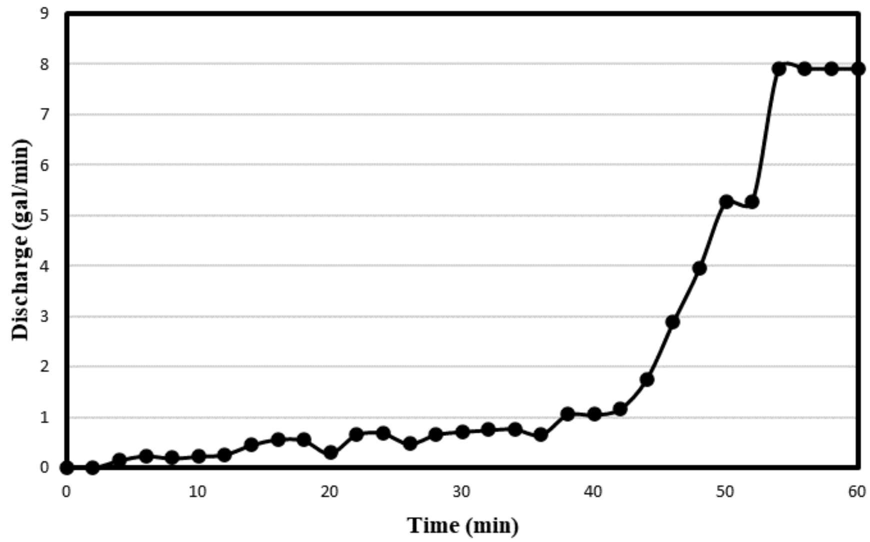


Figure 4-26: Loose Straw Clay Test 2 Hydrograph

Figure 4-26 above displays the hydrograph from the second loose straw clay test. The peak discharge was determined to be 8 gal/min (30 L/min) and a total runoff volume of 131 gallons (496 L).

Table 4-23: Loose Straw Clay Results Test 3

Parameter	Values		
Target Intensity, in./hr (mm/hr)	**2.0 (51)**	**4.0 (102)**	**6.0 (152)**
Intensity, in./hr (mm/hr)	2.4 (59.7)	4.7 (119.4)	6.9 (175.3)
Sediment, lb (kg)	1.2 (0.5)	2.8 (1.3)	27.7 (12.6)
Runoff, gal. (L)	4.6 (17.3)	11.4 (43.0)	72.7 (275.4)
Average turbidity (NTU)	11,697	12,845	17,116
Average TSS (mg/L)	5,829	8,044	11,486

A seen in Table 4-23, the third loose straw clay test yielded a soil loss of 1.2 lb (0.5 kg), 2.8 lb (1.3 kg), and 27.7 lb (12.6 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 17,116 NTU and 11,486 mg/L in the 6 in./hr (152 mm/hr) test interval. The recorded compaction prior to testing was 88.8% and the recorded moisture content was 20.3%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-27: Loose Straw Clay Test 3 Photos

Figure 4-27 displays photos taken during the third loose straw clay test. Like the other clay tests, no visible rills formed on the test plot.

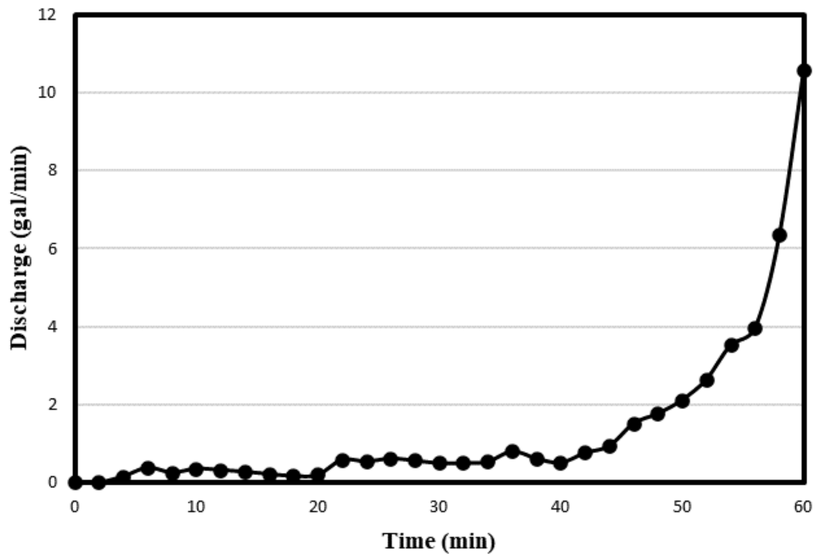


Figure 4-28: Loose Straw Clay Test 3 Hydrograph

Figure 4-28 above displays the hydrograph from the third loose straw clay test. The peak discharge was determined to be 11 gal/min (42 L/min) and a total runoff volume of 89 gallons (337 L).

4.5.1 Loose Straw Clay C-factor Calculation

To evaluate the C-factor for loose straw on the clay soil, the same method was used in the calculation of K-factor. This time the average K-factor of 0.013 determined from clay bare soil testing was used and the C-factor is no longer assumed to be 1. The theoretical R-factor of 148.5 was used along with an LS factor of 2.23. The soil loss values in (tons/acre/year) were determined to be 0.92, 0.17, and 1.40 for tests 1,2, and 3, respectively. With the assumption of the P-factor having a value of 1, the C-factors for each clay test were determined from equation 4.2. Table 4-24 displays the C-factors determined for each test along with the average.

Table 4-24: Loose Straw Clay C-factor Results

Test	C-Factor
1	0.21
2	0.04
3	0.33
Average	0.193

Table 4-25 below provides a summary of the RUSLE factors used in the calculation for each test.

Table 4-25: RUSLE Factors for Loose Straw Clay Tests

RUSLE Factor	Test 1	Test 2	Test 3
A, ton/ac/yr	0.92	0.17	1.40
Theoretical R	148.5	148.5	148.5
LS	2.23	2.23	2.23
K	0.013	0.013	0.013
P	1	1	1
C	0.21	0.04	0.33

4.6 Loose Straw Loam Results

The following section provides the results of loose straw applied on a 4:1 ASTM test plot on a loam soil. Details and results of the C-factor calculation are provided as well.

Table 4-26: Loose Straw Loam Test 1 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.2 (54.6)	4.0 (100.3)	5.5 (139.7)
Sediment, lb (kg)	0.09 (0.04)	0.3 (0.2)	0.1 (0.06)
Runoff, gal. (L)	11.7 (44.4)	61.4 (232.5)	206.6 (781.9)
Average turbidity (NTU)	5,051	3,340	748
Average TSS (mg/L)	2,355	2,609	923

A seen in Table 4-26, the first loose straw loam test yielded a soil loss of 0.09 lb (0.04 kg), 0.3 lb (0.2 kg), and 0.1 lb (0.06 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 5,051 NTU and 2,609 mg/L in the 2 in./hr (51 mm/hr) and 4 in./hr (102 mm/hr) test intervals. The recorded compaction prior to testing was 86.8% and the recorded moisture content was 17.2%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) During Test

Figure 4-29: Loose Straw Loam Test 1 Photos

Figure 4-29 displays photos taken during the first loose straw loam test. It was noted that the straw remained stable during the test and no visible rills formed on the test plot.

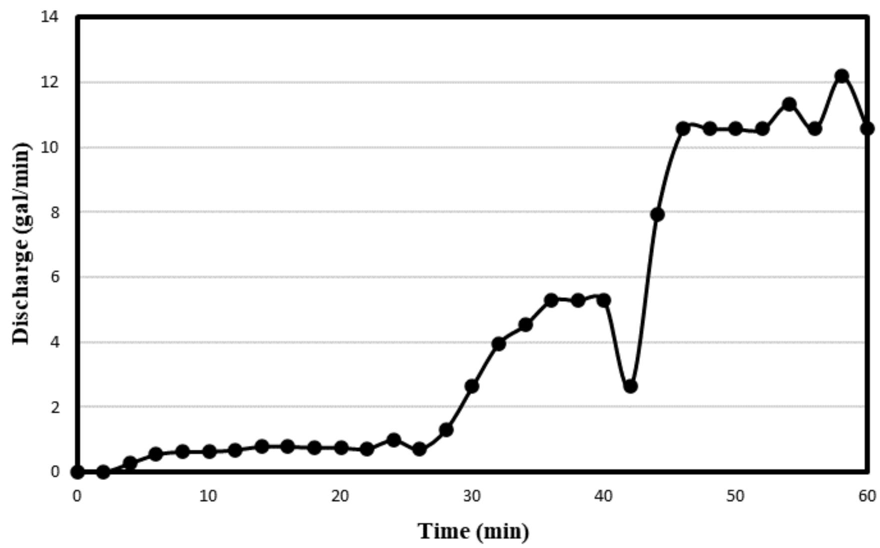


Figure 4-30: Loose Straw Loam Test 1 Hydrograph

Figure 4-30 above displays the hydrograph from the first loose straw loam test. The peak discharge was determined to be 12 gal/min (45 L/min) and a total runoff volume of 280 gallons (1060 L).

Table 4-27: Loose Straw Loam Test 2 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.5 (63.5)	4.2 (105.4)	4.9 (123.2)
Sediment, lb (kg)	1.2 (0.6)	3.2 (1.4)	4.8 (2.2)
Runoff, gal. (L)	7.2 (27.1)	51.2 (194.0)	182.7 (691.7)
Average turbidity (NTU)	3,769	2,458	-
Average TSS (mg/L)	2,229	2,145	-

*Two samples lost in the 6 in./hr and an average turbidity/TSS is not reported.

A seen in Table 4-27, the second loose straw loam test yielded a soil loss of 1.2 lb (0.6 kg), 3.2 lb (1.4 kg), and 4.8 lb (2.2 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids are not reported for this test due to a handling error. The recorded compaction prior to testing was 87.2% and the recorded moisture content was 15.1%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-31: Loose Straw Loam Test 2 Photos

Figure 4-31 displays photos taken during the second loose straw loam test. Like the first test, the straw remained stable and no visible rills formed on the test plot.

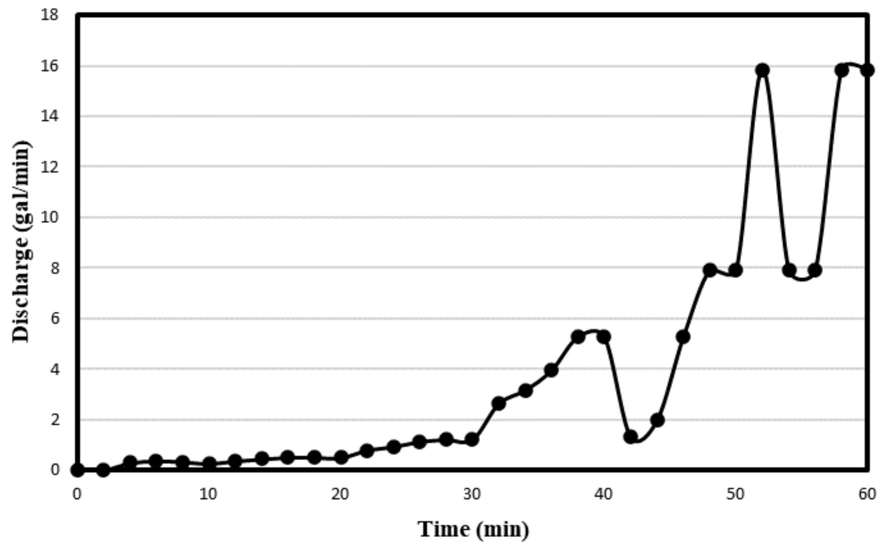


Figure 4-32: Loose Straw Loam Test 3 Hydrograph

Figure 4-32 above displays the hydrograph from the third loose straw loam test. The peak discharge was determined to be 16 gal/min (61 L/min) and a total volume of 241 gallons (912 L).

Table 4-28: Loose Straw Loam Test 3 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.2 (55.9)	3.6 (91.4)	5.8 (147.3)
Sediment, lb (kg)	1.4 (0.6)	2.1 (0.9)	7.0 (3.2)
Runoff, gal. (L)	3.5 (13.4)	42.5 (161.0)	227.2 (859.9)
Average turbidity (NTU)	6,850	5,276	4,064
Average TSS (mg/L)	3,231	3,743	4,150

A seen in Table 4-28, the third loose straw loam test yielded a soil loss of 1.4 lb (0.6 kg), 2.1 lb (0.9 kg), and 7.0 lb (3.2 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 6,850 NTU and 4,150 mg/L in the 2 in./hr (51 mm/hr) and 6 in./hr (152 mm/hr) test interval, respectively. The recorded compaction prior to testing was 88.5% and the recorded moisture content was 13.2%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test

(b) After Test

Figure 4-33: Loose Straw Loam Test 3 Photos

Figure 4-33 displays photos taken during the third loose straw loam test. Like the other tests, no visible rills and the straw remained stable on the test plot.

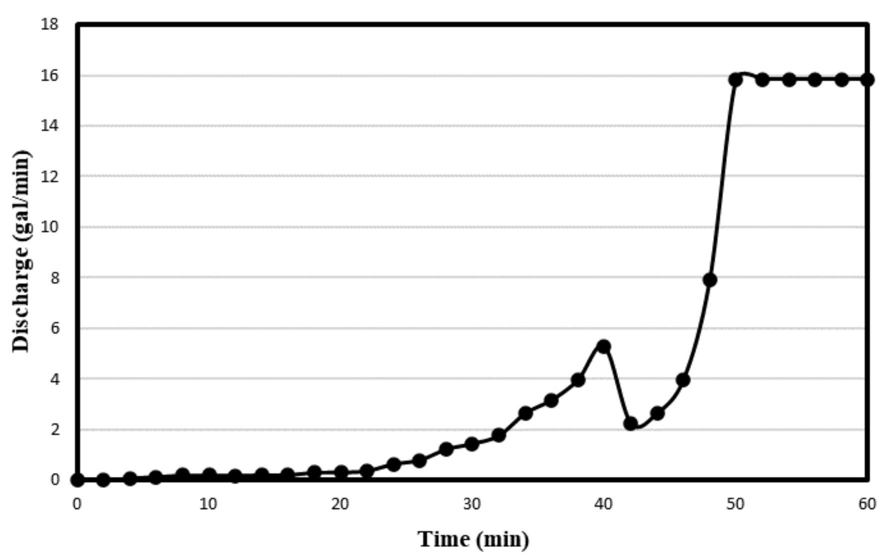


Figure 4-34: Loose Straw Loam Test 3 Hydrograph

Figure 4-34 above displays the hydrograph from the third loose straw loam test. The peak discharge was determined to be 16 gal/min (61 L/min) and a total volume of 273 gallons (1033 L).

4.6.1 Loose Straw Loam C-factor Calculation

To evaluate the C-factor for loose straw on the loam soil, the same method was used in the calculation of K-factor. This time the average K-factor of 0.043 determined from loam bare soil testing was used and the C-factor is no longer assumed to be 1. The theoretical R-factor of 148.5 was used along with an LS factor of 2.23. The soil loss values in (tons/acre/year) were determined to be 0.04, 1.20, and 0.77 for tests 1,2, and 3, respectively. With the assumption of the P-factor having a value of 1, the C-factors for each loam test were determined from equation 4.2. Table 4-29 displays the C-factors determined for each test along with the average.

Table 4-29: Loose Straw Loam C-factor Results

Test	C-Factor
1	0.003
2	0.084
3	0.054
Average	0.047

Table 4-30 below provides a summary of the RUSLE factors used in the calculation for each test.

Table 4-30: RUSLE Factors for Loose Straw Loam Tests

RUSLE Factor	Test 1	Test 2	Test 3
A, ton/ac/yr	0.04	1.20	0.77
Theoretical R	148.5	148.5	148.5
LS	2.23	2.23	2.23
K	0.043	0.043	0.043
P	1	1	1
C	0.003	0.084	0.054

4.7 Single Net Straw Sand Results

The following section provides the results of a single-net straw blanket applied on a 4:1 ASTM test plot on a sand soil. Details and results of the C-factor calculation are provided as well.

Table 4-31: Single Net Straw Sand Test 1 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.5 (62.2)	5.2 (132.1)	6.0 (152.4)
Sediment, lb (kg)	3.3 (1.5)	23.7 (10.7)	67.1 (30.4)
Runoff, gal. (L)	2.9 (11.1)	157.1 (594.6)	293.3 (1,110.4)
Average turbidity (NTU)	1,207	3,898	3,388
Average TSS (mg/L)	2,450	6,791	2,984

A seen in Table 4-31, the first single net straw test yielded a soil loss of 3.3 lb (1.5 kg), 23.7 lb (10.7 kg), and 67.1 lb (30.4 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 3,898 NTU and 6,791 mg/L in the 4 in./hr (102 mm/hr) test interval. The recorded compaction prior to testing was 91.7% and the recorded moisture content was 9.3%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-35: Single Net Straw Sand Test 1 Photos

Figure 4-35 displays photos taken during the first single net straw sand test. It was observed that the straw blanket displayed more visual signs of erosion than the loose straw. Minor rills were observed in the center of the test plot.

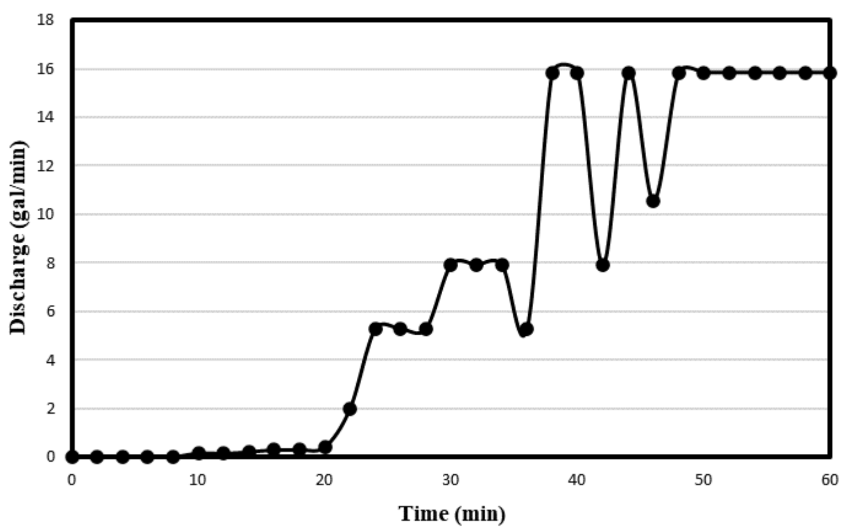


Figure 4-36: Single Net Straw Sand Test 1 Photos

Figure 4-36 above displays the hydrograph from the first single net straw sand test. The peak discharge was determined to be 16 gal/min (61 L/min) and a total runoff volume of 453 gallons (1715 L).

Table 4-32: Single Net Straw Test 2 Results

Parameter	**Values**		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.0 (49.5)	4.0 (100.3)	4.8 (121.9)
Sediment, lb (kg)	3.8 (1.7)	24.7 (11.2)	42.6 (19.3)
Runoff, gal. (L)	45.1 (170.7)	196.0 (741.9)	341.3 (1291.8)
Average turbidity (NTU)	7,507	10,960	8,317
Average TSS (mg/L)	3,315	6,416	5,860

A seen in Table 4-32, the second single net straw test yielded a soil loss of 3.8 lb (1.7 kg), 24.7 lb (11.2 kg), and 42.6 lb (19.3 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 10,960 NTU and 6,416 mg/L in the 4 in./hr (102 mm/hr) test interval. The recorded compaction prior to testing was 92.5% and the recorded moisture content was 11.2%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-37: Single Net Straw Sand Test 2

Figure 4-37 displays photos taken during the second single net straw test. Like the first test, it was observed that the straw yielded more visible signs of erosion than the loose straw. Some minor rills formed on the right and center of the test plot.

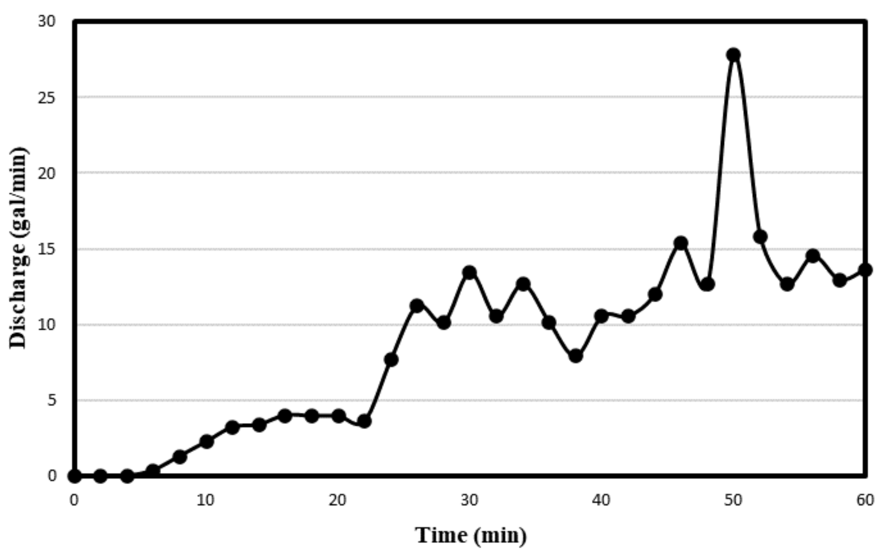


Figure 4-38: Single Net Straw Sand Test 2 Hydrograph

Figure 4-38 above displays the results from the second single net straw sand test. The peak discharge was determined to be 28 gal/min (106 L/min) and a total runoff volume of 582 gallons (2203 L).

Table 4-33: Single Net Straw Test 3 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.1 (53.3)	4.2 (106.7)	5.2 (130.8)
Sediment, lb (kg)	2.9 (1.3)	19.8 (9.0)	52.1 (23.6)
Runoff, gal. (L)	8.7 (33.0)	147.5 (558.3)	181.1 (685.4)
Average turbidity (NTU)	-	-	-
Average TSS (mg/L)	-	-	-

* A handling error was made in the lab, and the wrong set of samples were processed. No turbidity/TSS data available for this test

A seen in Table 4-33, the third single net straw test yielded a soil loss of 2.9 lb (1.3 kg), 19.8 lb (9.0 kg), and 52.1 lb (23.6 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were not recorded for this test. The recorded compaction prior to testing was 89.4% and the recorded moisture content was 11.3%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-39: Single Net Straw Sand Test 3 Photos

Figure 4-39 displays photos taken during the third single net straw sand test. Like the other sand tests, there were more visible signs of erosion on the test plot than the loose straw sand tests. The left and right sides of the test plot formed minor rills.

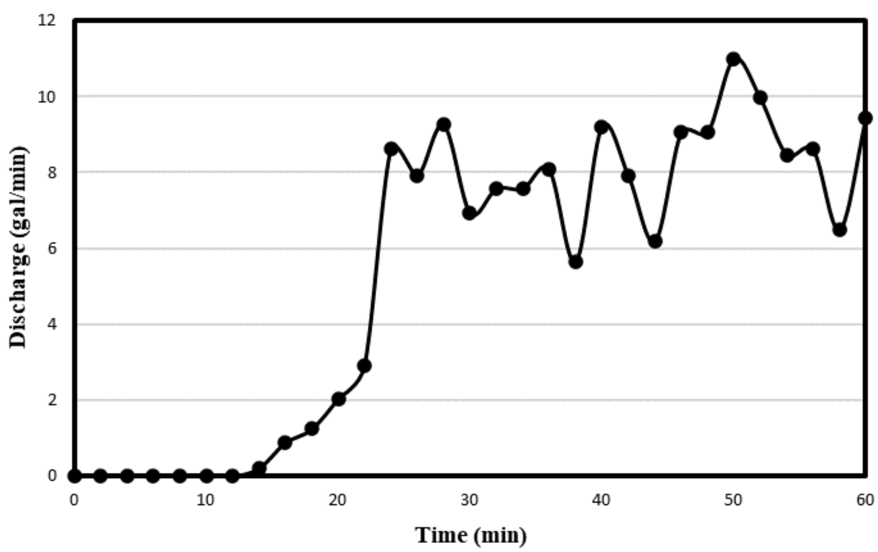


Figure 4-40: Single Net Straw Sand Test 3 Hydrograph

Figure 4-40 above displays the hydrograph from the third single net straw sand test. The peak discharge was determined to be 11 gal/min (42 L/min) and a total runoff volume of 337 gallons (1276 L).

4.7.1 Single Net Straw Sand C-factor Calculation

To evaluate the C-factor for the single net straw blanket on the sand soil, the same method was used in the calculation of K-factor. This time the average K-factor of 0.37 determined from sand bare soil testing was used and the C-factor is no longer assumed to be 1. The theoretical R-factor of 148.5 was used along with an LS factor of 2.23. The soil loss values in (tons/acre/year) were determined to be 4.73, 6.09, and 5.52 for tests 1,2, and 3, respectively. With the assumption of the P-factor having a value of 1, the C-factors for each sand test were determined from equation 4.2. Table 4-34 displays the C-factors determined for each test along with the average.

Table 4-34: Single Net Straw Sand C-factor Results

Test	C-Factor
1	0.039
2	0.050
3	0.037
Average	0.042

Table 4-30 below provides a summary of the RUSLE factors used in the calculation for each test.

Table 4-35: RUSLE Factors for Single Net Straw Sand Tests

RUSLE Factor	Test 1	Test 2	Test 3
A, ton/ac/yr	4.73	6.09	5.52
Theoretical R	148.5	148.5	148.5
LS	2.23	2.23	2.23
K	0.37	0.37	0.37
P	1	1	1
C	0.039	0.050	0.037

4.8 Single Net Straw Clay Results

The following section provides the results of a single-net straw blanket applied on a 4:1 ASTM test plot on a clay soil. Details and results of the C-factor calculation are provided as well.

Table 4-36: Single Net Straw Clay Test 1 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.1 (53.3)	3.9 (99.1)	5.2 (132.1)
Sediment, lb (kg)	2.1 (0.9)	1.1 (0.5)	20.2 (9.2)
Runoff, gal. (L)	4.3 (16.2)	12.1 (45.9)	191.2 (723.9)
Average turbidity (NTU)	3,081	6,164	10,344
Average TSS (mg/L)	2,037	5,196	7,917

As seen in Table 4-36, the first single net straw test yielded a soil loss of 2.1 lb (0.9 kg), 1.1 lb (0.5 kg), and 20.2 lb (9.2 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 10,344 NTU and 7,917 mg/L in the 6 in./hr (152 mm/hr) test interval. The recorded compaction prior to testing was 92.6% and the recorded moisture content was 22.2%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-41: Single Net Straw Clay Test 1 Photos

Figure 4-41 displays photos taken during the first single net straw clay test. Minimum visual signs of erosion occurred on the plot as no visible rills or dislocated sediment was observed.

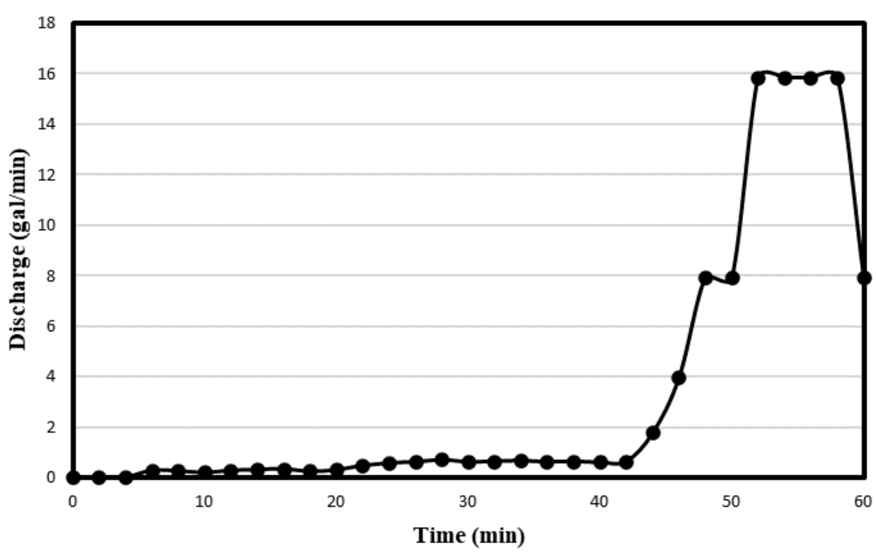


Figure 4-42: Single Net Straw Clay Test 1 Hydrograph

Figure 4-42 above displays the hydrograph from the first single net straw clay test. The peak discharge was determined to be 16 gal/min (61 L/min) and a total runoff volume of 208 gallons (787 L).

Table 4-37: Single Net Straw Clay Test 2 Results

Parameter	**Values**		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.0 (50.8)	4.0 (101.6)	5.1 (128.3)
Sediment, lb (kg)	1.3 (0.6)	2.5 (1.2)	10.2 (4.6)
Runoff, gal. (L)	4.3 (16.2)	16.7 (63.0)	204.9 (775.7)
Average turbidity (NTU)	9,219	6,673	2,332
Average TSS (mg/L)	5,744	6,873	3,056

A seen in Table 4-37, the second single net straw test yielded a soil loss of 1.3 lb (0.6 kg), 2.5 lb (1.2 kg), and 10.2 lb (4.6 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 9,219 NTU and 6,873 mg/L in the 2 in./hr (51 mm/hr) and 4 in./hr (102 mm/hr) test intervals, respectively. The recorded compaction prior to testing was 91.1% and the recorded moisture content was 26.2%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-43: Single Net Straw Clay Test 2 Photos

Figure 4-43 displays photos taken during the second single net straw clay test. Like the first test, minimum visual signs of erosion were observed.

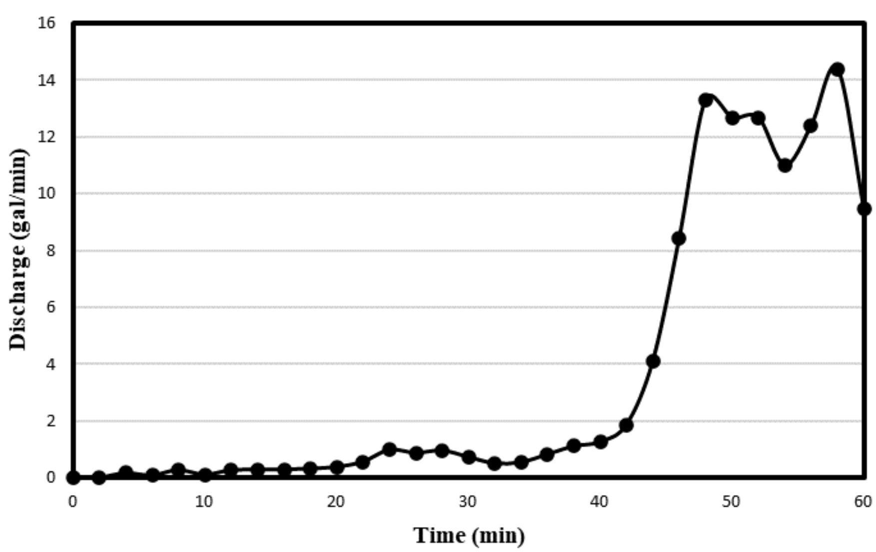


Figure 4-44: Single Net Straw Clay Test 2 Hydrograph

Figure 4-44 above displays the hydrograph from the second single net straw clay test. The peak discharge was determined to be 14 gal/min (53 L/min) and a total runoff volume of 226 gallons (866 L).

Table 4-38: Single Net Straw Clay Test 3 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.6 (66.0)	3.4 (86.4)	4.6 (115.6)
Sediment, lb (kg)	1.2 (0.5)	1.7 (0.8)	9.4 (4.3)
Runoff, gal. (L)	5.3 (19.9)	12.4 (46.9)	153.6 (581.3)
Average turbidity (NTU)	6,005	5,568	2,847
Average TSS (mg/L)	2,815	3,719	2,787

A seen in Table 4-38, the third single net straw test yielded a soil loss of 1.2 lb (0.5 kg), 1.7 lb (0.8 kg), and 9.4 lb (4.3 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 6,005 NTU and 3,719 mg/L in the 2 in./hr (51 mm/hr) and 4 in./hr (102 mm/hr) test intervals, respectively. The recorded compaction prior to testing was 90.8% and the recorded moisture content was 24.9%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test

(b) After Test

Figure 4-45: Single Net Straw Clay Test 3 Photos

Figure 4-45 displays photos taken during the third single net straw clay test. Minimal signs of erosion occurred on the test plot consistent with the other clay tests.

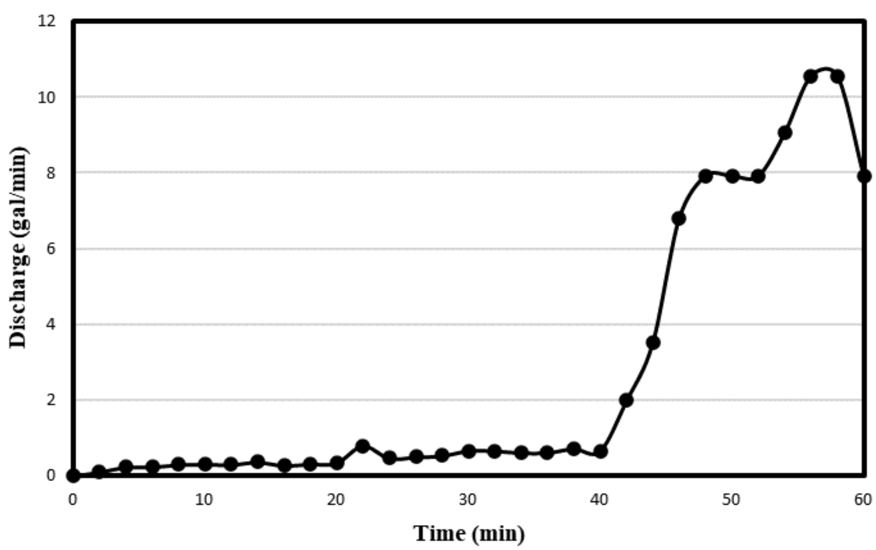


Figure 4-46: Single Net Straw Clay Test 3 Hydrograph

Figure 4-46 above displays the hydrograph from the third single net straw clay test. The peak discharge was determined to be 11 gal/min (42 L/min) and a total runoff volume of 171 gallons (647 L).

4.8.1 Single Net Straw Clay C-factor Calculation

To evaluate the C-factor for the single net straw blanket on the clay soil, the same method was used in the calculation of K-factor. This time the average K-factor of 0.013 determined from clay bare soil testing was used and the C-factor is no longer assumed to be 1. The theoretical R-factor of 148.5 was used along with an LS factor of 2.23. The soil loss values in (tons/acre/year) were determined to be 1.74, 1.09, and 1.15 for tests 1,2, and 3, respectively. With the assumption of the P-factor having a value of 1, the C-factors for each clay test were determined from equation 4.2. Table 4-39 displays the C-factors determined for each test along with the average.

Table 4-39: Single Net Straw Clay C-factor Results

Test	C-Factor
1	0.40
2	0.25
3	0.27
Average	0.31

Table 4-40 below provides a summary of the RUSLE factors used in the calculation for each test.

Table 4-40: RUSLE Factors for Single Net Straw Clay Tests

RUSLE Factor	Test 1	Test 2	Test 3
A, ton/ac/yr	1.74	1.09	1.15
Theoretical R	148.5	148.5	148.5
LS	2.23	2.23	2.23
K	0.013	0.013	0.013
P	1	1	1
C	0.40	0.25	0.27

4.9 Single Net Straw Loam Results

The following section provides the results of a single-net straw blanket applied on a 4:1 ASTM test plot on a loam soil. Details and results of the C-factor calculation are provided as well.

Table 4-41: Single Net Straw Loam Test 1 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	1.9 (47.0)	3.5 (87.6)	4.9 (124.5)
Sediment, lb (kg)	1.0 (0.5)	5.1 (2.3)	6.9 (3.1)
Runoff, gal. (L)	3.6 (13.7)	51.3 (194.1)	209.7 (793.8)
Average turbidity (NTU)	7,132	10,404	7,858
Average TSS (mg/L)	4,003	8,999	6,699

A seen in Table 4-41, the first single net straw test yielded a soil loss of 1.0 lb (0.5 kg), 5.1 lb (2.3 kg), and 6.9 lb (3.1 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 10,404 NTU and 8,999 mg/L in the 4 in./hr (102 mm/hr) test interval. The recorded compaction prior to testing was 91.3% and the recorded moisture content was 16.0%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-47: Single Net Straw Loam Test 1 Photos

Figure 4-47 displays photos taken during the first single net straw loam test. It was observed that no visual rills formed on the plot and the test plot remained stable throughout the test.

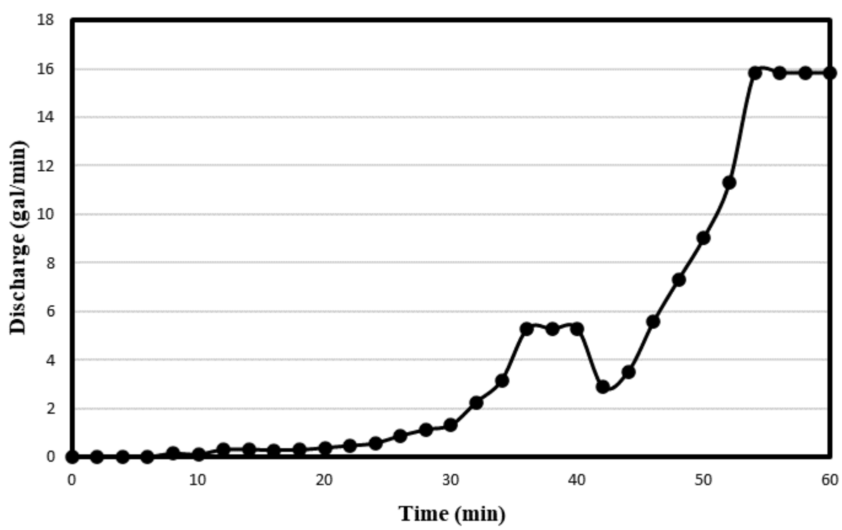


Figure 4-48: Single Net Straw Loam Test 1 Hydrograph

Figure 4-48 above displays the hydrograph for the first single net straw loam test. The peak discharge was determined to be 16 gal/min (61 L/min) and a total runoff volume of 265 gallons (1,003 L).

Table 4-42: Single Net Straw Loam Test 2 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	2.6 (64.8)	4.4 (111.8)	5.8 (147.3)
Sediment, lb (kg)	2.4 (1.1)	6.2 (2.8)	18.4 (8.4)
Runoff, gal. (L)	12.2 (46.1)	101.7 (385.1)	331.1 (1253.3)
Average turbidity (NTU)	23,421	7,954	7,872
Average TSS (mg/L)	2,572	2,451	2,949

A seen in Table 4-42, the second single net straw test yielded a soil loss of 2.4 lb (1.1 kg), 6.2 lb (2.8 kg), and 18.4 lb (8.4 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 23,421 NTU and 2,949 mg/L in the 2 in./hr (51 mm/hr) and 6 in./hr (152 mm/hr) test intervals, respectively. The recorded compaction prior to testing was 88.3% and the recorded moisture content was 13.4%. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test

(b) After Test

Figure 4-49: Single Net Straw Loam Test 2 Photos

Figure 4-49 displays photos taken during the second single net straw loam test. Like the first test, no visual rills were observed and the test plot remained stable during the test.

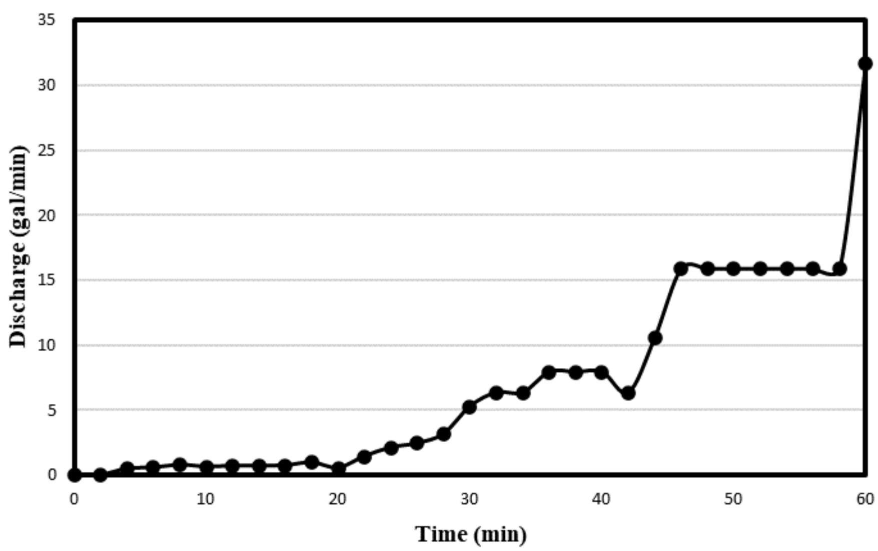


Figure 4-50: Single Net Straw Loam Test 2 Hydrograph

Figure 4-50 above displays the hydrograph from the second single net straw loam test. The peak discharge was determined to be 33 gal/min (125 L/min) and a total runoff volume of 445 gallons (1,685 L).

Table 4-43: Single Net Straw Loam Test 3 Results

Parameter	Values		
Target Intensity, in./hr (mm/hr)	2.0 (51)	4.0 (102)	6.0 (152)
Intensity, in./hr (mm/hr)	1.9 (48.8)	3.8 (96.0)	5.46 (138.7)
Sediment, lb (kg)	5.7 (2.6)	13.6 (6.2)	17.8 (8.1)
Runoff, gal. (L)	104.5 (395.7)	301.0 (1139.4)	738.1 (2794.0)
Average turbidity (NTU)	12170	10731	5346
Average TSS (mg/L)	2944	3181	2156

A seen in Table 4-43, the third single net straw test yielded a soil loss of 5.7 lb (2.6 kg), 13.6 lb (6.2 kg), and 17.8 lb (8.1 kg) for the 2 in./hr (51 mm/hr), 4 in./hr (102 mm/hr), and 6 in./hr (152 mm/hr), respectively. The peak average turbidity and total suspended solids were 12,170 NTU and 3181 mg/L in the 2 in./hr (51 mm/hr) and 4 in./hr (102 mm/hr) test intervals, respectively. The recorded experimental rainfall depths along with the corresponding sediment loss are used in the calculation of C-factor in the following section.

(a) Before Test (b) After Test

Figure 4-51: Single Net Straw Loam Test 3 Photos

Figure 4-51 above displays photos taken during the third single net straw loam test. Like the first two tests, no visible rills were formed on the test plot.

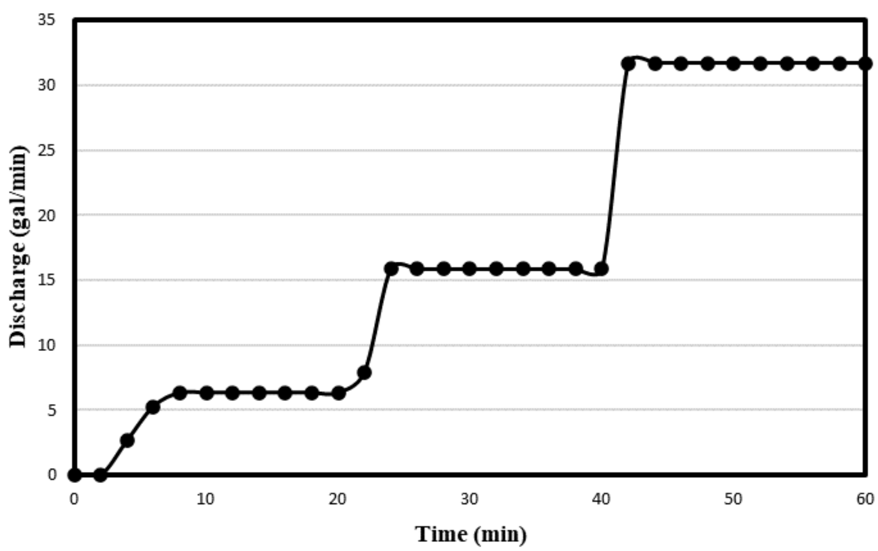


Figure 4-52: Single Net Straw Loam Test 3 Hydrograph

Figure 4-52 above displays the hydrograph from the third single net straw loam test. The peak discharge was determined to be 32 gal/min (121 L/min) and a total runoff volume of 1,144 gallons (4331 L).

4.9.1 Single Net Straw Loam C-factor Calculation

To evaluate the C-factor for the single net straw blanket on the loam soil, the same method was used in the calculation of K-factor. This time the average K-factor of 0.043 determined from clay bare soil testing was used and the C-factor is no longer assumed to be 1. The theoretical R-factor of 148.5 was used along with an LS factor of 2.23. The soil loss values in (tons/acre/year) were determined to be 1.19 and 1.61 for tests 1 and 2, respectively. With the assumption of the P-factor having a value of 1, the C-factors for each loam test were determined from equation 4.2. Table 4-44displays the C-factors determined for each test along with the average.

Table 4-44: Single Net Straw Loam C-factor Results

Test	C-Factor
1	0.084
2	0.113
3	0.196
Average	0.13

Table 4-45 below provides a summary of the RUSLE factors used in the calculation for each test.

Table 4-45: RUSLE Factors for Single Net Straw Loam Tests

RUSLE Factor	Test 1	Test 2	Test 3
A, ton/ac/yr	1.19	1.61	2.80
Theoretical R	148.5	148.5	148.5
LS	2.23	2.23	2.23
K	0.043	0.043	0.043
P	1	1	1
C	0.084	0.113	0.196

4.10 Summary and Discussion of K-Factor and C-Factor Results

The following section provides a summary and discussion of the key results obtained in the previous sections. Three soil types (sand, loam, and clay) were tested and their average results for bare soil and ECP testing are summarized and discussed.

4.10.1 Bare Soil Tests and K-factor Results Discussion

The results obtained from the bare soil testing provided evidence that the soil loss rates of the sand, clay, and loam soils is consistent with the current understanding of erosion rates with varying soil types. It was observed that sand was the most erodible soil followed by loam and clay, respectively. The following tables provide a summary of the average results for each soil type along with the average calculated K-factor.

Table 4-46:Results of Bare Soil 4:1 Sand Tests

Parameter	**Values**		
Target Rainfall Intensity, in./hr (cm./hr)	2.0 (5.1)	4.0 (10.2)	6.0 (15.2)
Avg. Measured Rainfall Intensity, in./hr (cm./hr)	2.5 (6.2)	4.2 (10.6)	5.7 (14.4)
Avg. Dry Weight Sediment, lbs (Kg)	326.0 (147.9)	284.6 (129.1)	1367.3 (620.2)
K-Factor Avg. (Sand)	**0.37**		

Table 4-46 above displays the average results of bare soil testing on a 4:1 sand slope. As expected, this soil proved to be the most erodible of the soil types tested. With a calculated average K-factor of 0.37, sand had a substantially higher erosion rate than the loam and clay soils.

Table 4-47: Results of Bare Soil 4:1 Loam Tests

Parameter	Values		
Target Rainfall Intensity, in./hr (cm./hr)	2.0 (5.1)	4.0 (10.2)	6.0 (15.2)
Avg. Measured Rainfall Intensity, in./hr (cm./hr)	2.3 (5.9)	4.0 (10.1)	6.0 (15.2)
Avg. Dry Weight Sediment, lbs (Kg)	16.2 (7.3)	74.7 (33.9)	145.3 (65.9)
K-Factor Avg. (Loam)		**0.043**	

Table 4-47 above displays the average results of bare soil testing on a 4:1 loam slope. As expected, the loam soil erodibility fell between the sand and clay erodibility. The calculated average K-factor of 0.043 was substantially less than the sand soil.

Table 4-48: Results of Bare Soil 4:1 Clay Tests

Parameter	Values		
Target Rainfall Intensity, in./hr (cm./hr)	2.0 (5.1)	4.0 (10.2)	6.0 (15.2)
Avg. Measured Rainfall Intensity, in./hr (cm./hr)	2.5 (6.3)	4.4 (11.2)	7.0 (17.7)
Avg. Dry Weight Sediment, lbs (Kg)	5.1 (7.3)	22.0 (33.9)	87.2 (65.9)
K-Factor Avg. (Clay)		**0.013**	

Table 4-48 above displays the average results of bare soil testing on a 4:1 clay slope. As expected, the clay soil was the least erodible of the three soil types tested. The calculated average K-factor of 0.013 was substantially less than the sand or loam soils.

The bare soil testing provided the research team with information on the inherent soil erodibility and K-factors that could be used for calculating erosion control practice C-factors.

4.10.2 Loose Straw Tests and C-factor Results Discussion

The results obtained from the loose straw testing provided evidence that straw application can substantially reduce soil loss in comparison to the bare soil control tests. A soil specific C-factor was determined for the sand, loam, and clay soils. It was determined that loose straw performance was dependent on the soil it was applied. The following tables provide a summary of the average results for each soil type along with the average calculated C-factor.

Table 4-49: Results of Loose Straw 4:1 Sand Tests

Parameter	Values		
Target Rainfall Intensity, in./hr (cm./hr)	2.0 (5.1)	4.0 (10.2)	6.0 (15.2)
Avg. Measured Rainfall Intensity, in./hr (cm./hr)	2.3 (5.9)	4.2 (10.6)	6.3 (16.1)
Avg. Dry Weight Sediment, lbs (Kg)	3.5 (7.6)	12.2 (26.9)	28.7 (63.2)
C-Factor Avg. (Sand)		**0.021**	

Table 4-49 above displays the average results of loose straw testing on a 4:1 sand slope. It was found that loose straw was most effective in terms of C-factor in reducing erosion rates with a calculated average C-factor of 0.021.

Table 4-50: Results of Loose Straw 4:1 Loam Tests

Parameter	Values		
Target Rainfall Intensity, in./hr (cm./hr)	2.0 (5.1)	4.0 (10.2)	6.0 (15.2)
Avg. Measured Rainfall Intensity, in./hr (cm./hr)	2.3 (5.8)	3.9 (9.9)	5.4 (13.7)
Avg. Dry Weight Sediment, lbs (Kg)	0.9 (0.4)	1.9 (0.8)	4.0 (1.8)
Avg. C-Factor (Loam)		**0.047**	

Table 4-50 above displays the average results of loose straw testing on a 4:1 loam slope. It was found that loose straw performed second to sand in terms of C-factor with a calculated average C-factor of 0.047.

Table 4-51: Results of Loose Straw 4:1 Clay Tests

Parameter	Values		
Target Rainfall Intensity, in./hr (cm./hr)	2.0 (5.1)	4.0 (10.2)	6.0 (15.2)
Avg. Measured Rainfall Intensity, in./hr (cm./hr)	2.5 (6.2)	4.7 (11.9)	6.8 (17.2)
Avg. Dry Weight Sediment, lbs (Kg)	1.6 (0.7)	2.8 (1.3)	12.7 (5.8)
C-Factor (Clay)		**0.193**	

Table 4-51 above displays the average results of loose straw testing on a 4:1 clay slope. It was found that loose straw performed the worst on the clay soil in terms of C-factor with a calculated average C-factor of 0.193.

4.10.3 Single Net Straw Blanket Tests and C-factor Results Discussion

The results obtained from the single net straw blanket tests indicated that like the loose straw, it is effective at reducing soil loss in comparison to the bare soil control tests. A soil specific C-factor was determined for the sand, clay, and loam soils. Testing on the 4:1 sand and clay plots are complete, and one test remains on the loam plot. Based on the results of the sand and clay tests, it was found that product performance was dependent on the soil type. Further testing on the loam slope and future 3:1 slope testing will help to further substantiate this claim. The following tables give a summary of the average results for each soil type along with the average calculated C-factor.

Table 4-52: Results of Single Net Straw 4:1 Sand Tests

Parameter		**Values**	
Target Rainfall Intensity, in./hr (cm./hr)	2.0 (5.1)	4.0 (10.2)	6.0 (15.2)
Avg. Measured Rainfall Intensity, in./hr (cm./hr)	2.2 (5.5)	4.5 (11.3)	5.3 (13.5)
Avg. Dry Weight Sediment, lbs (Kg)	3.3 (1.5)	22.7 (10.3)	53.9 (24.5)
C-Factor Avg. (Sand)		**0.042**	

Table 4-52 above displays the average results of single net straw testing on a 4:1 sand slope. It was found that the single net straw was effective in reducing soil loss but yielded a higher C-factor than the loose straw on sand which had an average C-factor of 0.021. The results of this study indicate that loose straw is twice as effective at reducing soil loss than single net straw on a 4:1 sand slope.

Table 4-53: Results of Single Net Straw 4:1 Clay Tests

Parameter		**Values**	
Target Rainfall Intensity, in./hr (cm./hr)	2.0 (5.1)	4.0 (10.2)	6.0 (15.2)
Avg. Measured Rainfall Intensity, in./hr (cm./hr)	2.2 (5.7)	3.8 (9.6)	4.9 (12.6)
Avg. Dry Weight Sediment, lbs (Kg)	1.5 (0.7)	1.8 (0.8)	13.3 (6.0)
C-Factor Avg. (Clay)		**0.31**	

Table 4-53 displays the average results of single net straw testing on a 4:1 clay slope. It was found that the single net straw was less effective at reducing soil loss on the clay soil than the sand. It should also be noted that loose straw was more effective than the single net straw blanket at reducing soil loss on the clay soil. The loose straw yielded an average C-factor of 0.193 on the clay soil opposed to 0.31 with the single net straw blanket.

Table 4-54: Results of Single Net Straw 4:1 Loam Tests

Parameter		**Values**	
Target Rainfall Intensity, in./hr (cm./hr)	2.0 (5.1)	4.0 (10.2)	6.0 (15.2)
Avg. Measured Rainfall Intensity, in./hr (cm./hr)	2.1 (5.3)	3.9 (9.9)	5.4 (13.7)
Avg. Dry Weight Sediment, lbs (Kg)	3.0 (1.4)	8.3 (3.8)	14.4 (6.5)
C-Factor Avg. (Loam)		**0.131**	

Table 4-54 displays the average results of single net straw testing on a 4:1 loam slope. It was found that the single net straw blanket on a loam slope was more effective at reducing soil loss on the clay slope and less effective than the sand slope. It should be noted that loose straw was more effective at reducing soil loss than the single net straw on the loam soil.

4.10.4 Summary Tables of K -Factors and C-Factors

The following section gives a summary of the average K-factors and C-factors determined for each soil type. The purpose of testing was to determine soil specific K-factor and C-factors that can be used to determine suitable practices with varying site conditions.

Table 4-55: Summary of Bare Soil K-factor Results

Soil Type	Test	K-Factor
Sand	1	0.18
	2	0.22
	3	0.71
	Average	**0.37**
Loam	1	0.06
	2	0.01
	3	0.06
	Average	**0.043**
Clay	1	0.02
	2	0.01
	3	0.01
	Average	**0.013**

Table 4-55 above displays all K-factor results from 4:1 slope bare soil testing. The Bare soil testing provided K-factor values that provided insight into the erodibility of the test soils used at the AU-SRF and values that could be used in the calculation of C-factor. The results were in line with current understanding of soil erodibility in that Sand was the most erodible followed by loam and clay, respectively. The K-factors determined for each soil type are only representative of the soils used at AU-SRF and should not be used for other soils without verification.

Table 4-56: Summary of Loose Straw C-factor Results

Soil Type	Test	C-Factor
Sand	1	0.023
	2	0.015
	3	0.024
	Average	**0.021**
Loam	1	0.003
	2	0.084
	3	0.054
	Average	**0.047**
Clay	1	0.21
	2	0.04
	3	0.33
	Average	**0.193**

Table 4-56 above displays all C-factor results from 4:1 slope loose straw testing. The loose straw testing results indicated that ECP performance can vary with soil conditions. It was found that loose straw was most effective on sandy soil. The clay testing indicated substantially worse performance than the sand and loam soils. A potential reason could be that due to the properties of the clay soil, the straw tended to slide across the surface of the wet soil.

Table 4-57: Summary of Single Net Straw C-factor Results

Soil Type	Test	C-Factor
Sand	1	0.039
	2	0.050
	3	0.037
	Average	**0.042**
Loam	1	0.084
	2	0.113
	3	0.196
	Average	**0.13**
Clay	1	0.40
	2	0.25
	3	0.27
	Average	**0.31**

Table 4-57 above displays all C-factor results from 4:1 slope single net straw testing. In consistency with the loose straw testing, it was found that ECP performance can vary with soil conditions. It should be noted that the loose straw was more effective on the sand, loam, and clay soils than the single net straw. This was unexpected as the straw blanket has a higher cost, more labor intensive to install, and has a more robust anchoring system.

4.10.5 Results Comparison to Previous ASTM D6459 Testing at AU-SRF

As mentioned previously in Chapter 2, the AU-SRF conducted large-scale ASTM D6459 testing on a 3:1 slope. Previous testing of loose straw did not meet the ASTM requirements and a C-factor was not calculated. Instead, the primary result was represented as a soil loss reduction percentage. The soil loss reduction calculated for loose straw was 0.19 which roughly equates to a C-factor of 0.19. Of the soil types tested in Phase II, loose straw recorded a higher soil loss reduction with calculated average C-factors of 0.021 and 0.047 on the sand and loam soils, respectively. The loose straw performed similarly to the Phase I loose straw results on the clay soil with an average C-factor of 0.193. To fully understand the difference in performance of the loose straw between Phase I and Phase II testing, the author recommends that ASTM D6459 testing be performed on the loam soil used in Phase I.

In addition to testing loose straw, Phase I included ASTM testing of multiple ECBs. The ECBs tested included Curlex I, S150, ECX-2, and Jute. The products yielded C-factors using the RUSLE method of 0.05, 0.14, 0.12, and 0.41, respectively. The Curlex I, which was the single net straw blanket tested in the current study performed similarly to the Phase I testing on the sand slope with an average C-factor of 0.042. It should be noted that all Phase I testing was performed on a 3:1 slope and all Phase II testing to-date has been performed on a 4:1 slope. Future 3:1 testing during Phase II will help to further validate the comparisons.

4.11 Statistical Analysis of C-Factor Variance

The following section details a statistical analysis of the variance in C-factor by soil type and the difference in calculated C-factors for the loose straw and single-net straw blanket. An unpaired t-test is used to analyze the statistical relationships of the C-factor with soil type and practice.

4.11.1 Statistical Analysis of C-factor Variance with Soil Type

An unpaired t-test was used to determine if the C-factors for the loose straw and single-net straw blanket had a statistically significant difference. The following table displays the results and parameters of an unpaired t-test comparing the average C-factor of the loose straw for the sand soil and loam soil. A 95% confidence interval was used, and the hypotheses are as follows:

$$H0: \mu_{\text{sand C-factor}} = \mu_{\text{loam C-factor}}$$

$$H1: \mu_{\text{sand C-factor}} \neq \mu_{\text{loam C-factor}}$$

where,

$\mu_{\text{sand C-factor}}$ = Average C-factor determined for sand soil for loose straw

$\mu_{\text{loam C-factor}}$ = Average C-factor determined for loam soil for loose straw

Table 4-58: Loose Straw Sand vs. Loam C-factor Unpaired t-test

Parameter	Values
t-calc	1.11
p-value	0.33
Significant	No

Table 4-58 above displays the values calculated from the unpaired t-test. It was determined that although there was a substantial difference in the average C-factor of the sand and loam soils, it was not a statistically significant difference at a 95% confidence level.

An unpaired t-test was also used to determine if the loose straw produced statistically significant different C-factors for the sand and clay soils. A 95% confidence interval was used, and the hypotheses are as follows:

$$H0: \mu_{\text{sand C-factor}} = \mu_{\text{loam C-factor}}$$

$$H1: \mu_{\text{clay C-factor}} \neq \mu_{\text{clay C-factor}}$$

where,

$\mu_{\text{sand C-factor}}$ = Average C-factor determined for sand soil for loose straw

$\mu_{\text{clay C-factor}}$ = Average C-factor determined for clay soil for loose straw

Table 4-59: Loose Straw Sand vs. Clay C-factor Unpaired t-test

Parameter	Values
t-calc	2.05
p-value	0.11
Significant	No

Table 4-59 above displays the values calculated from the unpaired t-test. It was determined that although there was a substantial difference in the average C-factor of the sand and clay soils, it was not a statistically significant difference at a 95% confidence interval.

An unpaired t-test was also used to determine if the loose straw produced statistically significant C-factors from the loam and clay soils. A 95% confidence interval was used, and the hypotheses are as follows:

$$H0: \mu_{\text{loam C-factor}} = \mu_{\text{clay C-factor}}$$

$$H1: \mu_{\text{loam C-factor}} \neq \mu_{\text{clay C-factor}}$$

where,

$\mu_{\text{sand C-factor}}$ = Average C-factor determined for loam soil for loose straw

$\mu_{\text{clay C-factor}}$ = Average C-factor determined for clay soil for loose straw

Table 4-60: Loose Straw Loam vs. Clay C-factor Unpaired t-test

Parameter	Values
t-calc	1.67
p-value	0.17
Significant	No

Table 4-60 above displays the values calculated from the unpaired t-test. It was determined that although there was a substantial difference in the average C-factor of the loam and clay soils, it was not a statistically significant difference at a 95% confidence interval.

In summary, while the average C-factors calculated for the various soil types provided substantial differences, the variance in C-factors was not statistically significant by soil based on a 95% confidences interval across the three soil types. More testing is recommended to further evaluate the relationship between C-factor and soil type.

4.11.2 Statistical Analysis of Variance in C-factor with Practice

It was observed from average calculated C-factors that there was a substantial difference in the soil specific C-factors calculated for the loose straw and single-net straw blanket. Based on the average C-factors, the loose straw produced an average C-factor lower than the single-net straw blanket for each soil type. An unpaired t-test was performed to determine if the loose straw performed statistically better for each soil type than the single-net straw blanket.

An unpaired t-test was performed to determine if the loose straw produced a statistically significant less C-factor than the single-net straw blanket on the sand soil. A 95% confidence interval was used, and the hypotheses are as follows:

$$H0: \mu_{\text{loose straw C-factor}} \geq \mu_{\text{single-net straw C-factor}}$$

$$H1: \mu_{\text{loose straw C-factor}} < \mu_{\text{single-net straw C-factor}}$$

where,

$\mu_{\text{loose straw C-factor}}$ = Average C-factor determined for loose straw on sand soil

$\mu_{\text{single-net straw C-factor}}$ = Average C-factor determined for single-net straw on sand soil

Table 4-61: Loose Straw vs. Single-Net Straw Sand C-Factor Unpaired t-test

Parameter	Values
t-calc	-4.31
p-value	0.0062
Significant	Yes

Table 4-61 above displays the values calculated from the unpaired t-test. It was determined that the loose straw produced a statistically significant lower C-factor than the single-net straw on the sand soil at a 95% confidence interval.

An unpaired t-test was performed to determine if the loose straw produced a statistically less C-factor than the single-net straw blanket on the loam soil. A 95% confidence interval was used and the hypotheses are as follows:

$$H0: \mu_{\text{loose straw C-factor}} \geq \mu_{\text{single-net straw C-factor}}$$

$$H1: \mu_{\text{loose straw C-factor}} < \mu_{\text{single-net straw C-factor}}$$

where,

$\mu_{\text{loose straw C-factor}}$ = Average C-factor determined for loose straw on loam soil

$\mu_{\text{single-net straw C-factor}}$ = Average C-factor determined for single-net straw on loam soil

Table 4-62: Loose Straw vs. Single-Net Straw Loam C-Factor Unpaired t-test

Parameter	Values
t-calc	-2.04
p-value	0.11
Significant	No

Table 4-62 above displays the values calculated from the unpaired t-test. It was determined that the loose straw did not produce a statistically significant lower C-factor than the single-net straw on the loam soil at a 95% confidence interval.

An unpaired t-test was performed to determine if the loose straw produced a statistically less C-factor than the single-net straw blanket on the clay soil. A 95% confidence interval was used, and the hypotheses are as follows:

$$H0: \mu_{\text{loose straw C-factor}} \geq \mu_{\text{single-net straw C-factor}}$$

$$H1: \mu_{\text{loose straw C-factor}} < \mu_{\text{single-net straw C-factor}}$$

where,

$\mu_{\text{loose straw C-factor}}$ = Average C-factor determined for loose straw on clay soil

$\mu_{\text{single-net straw C-factor}}$ = Average C-factor determined for single-net straw on clay soil

Table 4-63: Loose Straw vs. Single-Net Straw Clay C-Factor Unpaired t-est

Parameter	Values
t-calc	-1.18
p-value	0.15
Significant	No

Table 4-63 above displays the values calculated from the unpaired t-test. It was determined that the loose straw did not produce a statistically significant less C-factor than the single-net straw blanket on the clay soil at a 95% confidence interval.

In summary, the loose straw yielded a statistically significant lower C-factor on the sand soil in comparison to the straw blanket. No statistical difference was recorded on the other soil types. While substantial reduction in C-factors were observed, more testing is recommended to further evaluate the relationship between practice and C-factor.

4.12 Analysis of K-Factor and C-Factor using MUSLE

Previous analysis of K-factors and C-factors used the RUSLE equation. Since the rainfall simulator tests produce a single-storm event, the MUSLE equation was used to determine if the erosion risk factors were consistent with the RUSLE equation factors. The MUSLE equation is defined as follows:

$$S = 95(\mathrm{Qp_p})^{0.56}\mathrm{KL}S\mathrm{CP} \tag{4.3}$$

where,

S	=	soil loss for a single event (tons)
Q	=	total runoff (acre-ft)
$\mathrm{p_p}$	=	peak discharge (ft^3/s)
K	=	soil erodibility factor
LS	=	length of slope steepness factor
C	=	cover management factor
P	=	support practice factor

Given that sediment yield was collected directly from the test plot and runoff rate and volume determined through sampling, the K-factor and C-factors can be determined by rearranging equation 4.3. For K-factor calculations determined from bare soil testing, the C-factor is assumed to have a value of one. The following equation gives the expression for determining K-factor from the MUSLE equation:

$$K = \frac{S}{95(Qp_p)^{0.56}LSCP} \tag{4.4}$$

where,

S	=	soil loss for a single event (tons)
Q	=	total runoff (acre-ft)
p_p	=	peak discharge (ft^3/s)
K	=	soil erodibility factor
LS	=	length of slope steepness factor
C	=	cover management factor
P	=	support practice factor

In addition, the C-factor can be calculated in a similar fashion to the K-factor. The average K-factor determined from bare soil testing is used in the calculation. The following equation gives the expression for determining C-factor from the MUSLE equation:

$$C = \frac{S}{95(Qp_p)^{0.56}LSKP} \tag{4.5}$$

where,

S	=	soil loss for a single event (tons)
Q	=	total runoff (acre-ft)
p_p	=	peak discharge (ft^3/s)
K	=	soil erodibility factor
LS	=	length of slope steepness factor
C	=	cover management factor
P	=	support practice factor

4.12.1 MUSLE Calculation of K-factor for Sand Bare Soil Tests

The following section details the calculation of K-factor from the sand bare soil tests using the MUSLE equation. Table 4-64 displays the results from the calculation for each test along with the average.

Table 4-64: Bare Soil Sand K-factor Results MUSLE

Test	K-Factor
1	0.42
2	0.42
3	0.83
Average	0.56

Table 4-65 below provides a summary of the MUSLE factors used in the calculation for each test. For tests 1, 2, and 3 values of 0.42, 0.42, and 0.83 were reported, respectively with an average value of 0.56. The RUSLE equation yielded K-factor values of 0.18, 0.22, and 0.71 for tests 1, 2, and 3, respectively.

Table 4-65: MUSLE Factors for Bare Soil Sand Tests

RUSLE Factor	Test 1	Test 2	Test 3
S, tons	0.51	0.69	1.77
Q, ac-ft	0.0021	0.0029	0.0031
P_p, ft^3/s	0.047	0.059	0.088
LS	2.23	2.23	2.23
C	1.0	1.0	1.0
P	1.0	1.0	1.0
K	0.42	0.42	0.83

4.12.2 MUSLE Calculation of K-factor for Loam Bare Soil Tests

The following section details the calculation of K-factor from the loam bare soil tests using the MUSLE equation. Table 4-66 displays results the from the calculation of each test along with the average.

Table 4-66: Bare Soil Loam K-factor Results MUSLE

Test	K-Factor
1	0.090
2	0.045
3	0.14
Average	0.092

Table 4-67 below provides a summary of the MUSLE factors used in the calculation for each test. For tests 1, 2, and 3 values of 0.090, 0.045, and 0.14 were reported, respectively with an average value of 0.092. The RUSLE equation yielded K-factor values of 0.06, 0.01, and 0.06 for tests 1, 2, and 3, respectively.

Table 4-67: MUSLE Factors for Bare Soil Loam Tests

RUSLE Factor	Test 1	Test 2	Test 3
S, tons	0.15	0.053	0.15
Q, ac-ft	0.0026	0.0021	0.0018
P_p, ft^3/s	0.071	0.044	0.044
LS	2.23	2.23	2.23
C	1.0	1.0	1.0
P	1.0	1.0	1.0
K	0.090	0.045	0.14

4.12.3 MUSLE Calculation of K-factor for Loam Bare Soil Tests

The following section details the calculation of K-factor from the clay bare soil tests using the MUSLE equation. Table 4-68 below displays the results from each calculation of each test along with the average.

Table 4-68: Bare Soil Clay K-factor Results MUSLE

Test	K-Factor
1	0.12
2	0.07
3	0.05
Average	0.08

Table 4-69 below provides a summary of a summary of the MUSLE factors used in the calculation for each test. For tests 1, 2, and 3 values of 0.12, 0.07, and 0.05 were reported, respectively with an average value of 0.08. The RUSLE equation yielded K-factor values of 0.02, 0.01, and 0.01 for tests 1, 2, and 3, respectively.

Table 4-69: MUSLE Factors for Bare Soil Clay Tests

RUSLE Factor	Test 1	Test 2	Test 3
S, tons	0.089	0.042	0.040
Q, ac-ft	0.0014	0.00096	0.0011
P_p, ft^3/s	0.029	0.029	0.044
LS	2.23	2.23	2.23
C	1.0	1.0	1.0
P	1.0	1.0	1.0
K	0.12	0.07	0.05

4.12.4 MUSLE Calculation of C-factor for Sand Loose Straw Tests

The following section details the calculation of C-factor for the sand loose straw tests using the MUSLE equation. Table 4-70 below displays the results from the calculation of each test along with the average.

Table 4-70: Loose Straw Sand C-factor Results MUSLE

Test	C-Factor
1	0.077
2	0.045
3	0.054
Average	0.059

Table 4-71 below provides a summary of the MUSLE factors used in the calculation for each test. For tests 1, 2, and 3 values of 0.077, 0.045, and 0.054 were reported, respectively with an average value of 0.059. The RUSLE equation yielded C-factor values of 0.023, 0.015, and 0.024 for tests 1, 2, and 3, respectively.

Table 4-71: MUSLE Factors for Loose Straw Sand Tests

RUSLE Factor	Test 1	Test 2	Test 3
S, tons	0.025	0.016	0.026
Q, ac-ft	0.0011	0.0011	0.0016
P_p, ft^3/s	0.024	0.030	0.035
LS	2.23	2.23	2.23
K	0.56	0.56	0.56
P	1.0	1.0	1.0
C	0.077	0.045	0.054

4.12.5 MUSLE Calculation of C-factor for Loam Loose Straw Tests

The following section details the calculation of C-factor for the loam loose straw tests using the MUSLE equation. Table 4-72 below displays the results from the calculation of each test along with the average.

Table 4-72: Loose Straw Loam C-factor Results MUSLE

Test	C-Factor
1	0.006
2	0.088
3	0.090
Average	0.061

Table 4-73 below provides a summary of the MUSLE factors used in the calculation for each test. For tests 1, 2, and 3 values of 0.006, 0.088, and 0.090 were reported, respectively with an average value of 0.061. The RUSLE equation yielded C-factor values of 0.003, 0.084, and 0.054 for tests 1, 2, and 3, respectively.

Table 4-73: MUSLE Factors for Loose Straw Loam Tests

RUSLE Factor	Test 1	Test 2	Test 3
S, tons	0.00029	0.0046	0.0052
Q, ac-ft	0.00082	0.00072	0.00083
P_p, ft^3/s	0.027	0.035	0.035
LS	2.23	2.23	2.23
K	0.092	0.092	0.092
P	1.0	1.0	1.0
C	0.006	0.088	0.090

4.12.6 MUSLE Calculation of C-factor for Clay Loose Straw Tests

The following section details the calculation of C-factor for the clay loose straw tests using the MUSLE equation. Table 4-74 below displays the results from the calculation of each test along with the average.

Table 4-74: Loose Straw Clay C-factor Results MUSLE

Test	C-Factor
1	0.83
2	0.079
3	0.79
Average	0.57

Table 4-75 below provides a summary of the MUSLE factors used in the calculation for each test. For tests 1, 2, and 3 values of 0.83, 0.079, and 0.79 were reported, respectively with an average value of 0.57. The RUSLE equation yielded C-factor values of 0.21, 0.04, and 0.33 for tests 1, 2, and 3, respectively.

Table 4-75: MUSLE Factors for Loose Straw Clay Tests

RUSLE Factor	Test 1	Test 2	Test 3
S, tons	0.0081	0.0017	0.016
Q, ac-ft	0.00019	0.00038	0.00026
P_p, ft^3/s	0.0088	0.018	0.024
LS	2.23	2.23	2.23
K	0.08	0.08	0.08
P	1	1	1
C	0.83	0.079	0.79

4.12.6 MUSLE Calculation of C-factor for Sand Single-Net Straw Tests

The following section details the calculation of C-factor for the sand single-net straw tests using the MUSLE equation. Table 4-76 below displays the results from the calculation of each test along with the average.

Table 4-76: Single-Net Straw Sand C-factor Results MUSLE

Test	C-Factor
1	0.10
2	0.050
3	0.12
Average	0.090

Table 4-77 below provides a summary of the MUSLE factors used in the calculation for each test. For tests 1, 2, and 3 values of 0.10, 0.053, and 0.12 were reported, respectively with an average value of 0.091. The RUSLE equation yielded C-factor values of 0.039, 0.050, and 0.037 for tests 1, 2, and 3, respectively.

Table 4-77: MUSLE Factors for Single-Net Straw Sand Tests

RUSLE Factor	Test 1	Test 2	Test 3
S, tons	0.047	0.036	0.037
Q, ac-ft	0.0014	0.0016	0.0010
P_p, ft^3/s	0.035	0.062	0.025
LS	2.23	2.23	2.23
K	0.56	0.56	0.56
P	1.0	1.0	1.0
C	0.10	0.050	0.12

4.12.7 MUSLE Calculation of C-factor for Loam Single-Net Straw Tests

The following section details the calculation of C-factor for the loam single-net straw tests using the MUSLE equation. Table 4-78 below displays the results from the calculation of each test along with the average.

Table 4-78: Single-Net Straw Loam C-factor Results MUSLE

Test	C-Factor
1	0.12
2	0.13
3	0.11
Average	0.12

Table 4-79 below provides a summary of the MUSLE factors used in the calculation for each test. For tests 1, 2, and 3 values of 0.12, 0.13, and 0.11 were reported, respectively with an average value of 0.12. The RUSLE equation yielded C-factor values of 0.084, 0.113, and 0.196 for tests 1, 2, and 3, respectively.

Table 4-79: MUSLE Factors for Single-Net Straw Loam Tests

RUSLE Factor	Test 1	Test 2	Test 3
S, tons	0.0065	0.014	0.019
Q, ac-ft	0.00080	0.0013	0.0032
P_p, ft^3/s	0.035	0.071	0.071
LS	2.23	2.23	2.23
K	0.092	0.092	0.092
P	1	1	1
C	0.12	0.13	0.11

4.12.8 MUSLE Calculation of C-factor for Clay Single-Net Straw Tests

The following section details the calculation of C-factor for the clay single-net straw tests using the MUSLE equation. Table 4-80 below displays the results from the calculation of each test along with the average.

Table 4-80: Single-Net Straw Clay C-factor Results MUSLE

Test	C-Factor
1	0.29
2	0.17
3	0.20
Average	0.22

Table 4-81 below provides a summary of the MUSLE factors used in the calculation for each test. For tests 1, 2, and 3 values of 0.29, 0.17, and 0.20 were reported, respectively with an average value of 0.22. The RUSLE equation yielded C-factor values of 0.40, 0.25, and 0.27 for tests 1, 2, and 3, respectively.

Table 4-81: MUSLE Factors for Single-Net Straw Clay Tests

RUSLE Factor	Test 1	Test 2	Test 3
S, tons	0.012	0.0070	0.0061
Q, ac-ft	0.00062	0.00068	0.00051
P_p, ft^3/s	0.035	0.032	0.024
LS	2.23	2.23	2.23
K	0.08	0.08	0.08
P	1.0	1.0	1.0
C	0.29	0.17	0.20

4.12.9 Summary of MUSLE Calculation Results

The following section gives a summary of the average K-factors and C-factors determined for each soil type using the MUSLE equation.

Table 4-82: Summary of Bare Soil K-factor Results using MUSLE

Soil Type	Test	K-Factor
Sand	1	0.42
	2	0.42
	3	0.83
	Average	**0.56**
Loam	1	0.090
	2	0.045
	3	0.14
	Average	**0.092**
Clay	1	0.12
	2	0.07
	3	0.05
	Average	**0.08**

Table 4-82 above displays a summary of the K-factor values determined for each soil type. Like the RUSLE method, the MUSLE K-factors showed that the most erodible soil was sand followed by loam and clay, respectively. The average RUSLE factors determined for the sand, loam, and clay soils were 0.37, 0.043, and 0.013. It was observed that the MUSLE method produced consistently higher K-factor values than the RUSLE method.

Table 4-83: Summary of Loose Straw C-factor Results using MUSLE

Soil Type	Test	C-Factor
Sand	1	0.077
	2	0.045
	3	0.054
	Average	**0.059**
Loam	1	0.006
	2	0.088
	3	0.090
	Average	**0.061**
Clay	1	0.83
	2	0.079
	3	0.79
	Average	**0.57**

Table 4-83 above displays a summary of the C-factor values determined for each soil type for loose straw. Like the RUSLE method, there was a variance in average C-factor with soil type. The average RUSLE factors determined for the sand, loam and clay soils were 0.021, 0.047, and 0.193. It was observed that the MUSLE method produced consistently higher average C-factors than the RUSLE method for each soil type.

Table 4-84: Summary of Single Net Straw C-factor Results using MUSLE

Soil Type	Test	C-Factor
Sand	1	0.10
	2	0.050
	3	0.12
	Average	**0.090**
Loam	1	0.12
	2	0.13
	3	0.11
	Average	**0.12**
Clay	1	0.29
	2	0.17
	3	0.20
	Average	**0.22**

Table 4-84 above displays a summary of the C-factor values determined for each soil type for the single-net straw blanket. Like the trend observed in the RUSLE method and MUSLE method, the C-factors varied with soil type. The average RUSLE factors determined for the sand, loam, and clay soils were 0.042, 0.099, and 0.31.

CHAPTER 5: CONCLUSIONS

The following chapter provides a summary of the project objectives met in this study and the major findings. The purpose of this study was to evaluate commonly used erosion control practices on varying soil types. This study evaluated the erodibility of the sand, clay, and loam soils along with the performance of loose straw and a single net straw blanket on a 4:1 slope. In addition to recording soil loss, soil specific K and C-factors were determined for the sand, loam, and clay soils. A statistical analysis was performed on the variation in C-factor and soil type along with a comparison of the performance of loose straw and single-net straw blanket. In addition to providing K and C-factors with the RUSLE method, the MUSLE method was used to calculate soil specific factors to provide a comparison of soil loss methods. The following chapter provides further detail on each of the key research objectives mentioned.

5.1 Bare Soil Testing

Three bare soil tests were performed on each soil type with nine tests performed in total. As expected, the sand was the most erodible soil followed by loam and clay, respectively. The average K-factors determined from the bare soil tests were 0.37, 0.043, and 0.013 for the sand, loam, and clay soils, respectively. The bare soil testing provided the research team with a baseline soil loss comparison to the ECP tests. The testing also confirmed previous understanding that soil type affects erodibility. The soil types used for testing were all collected from within the State of Alabama and are likely to be encountered on ALDOT construction projects.

5.2 Loose Straw Testing

Three loose straw tests were performed on each soil type to better understand how a lower-cost non-proprietary practice performed on varying soil types. The loose straw proved to be a cost-effective means of reducing soil loss and provided evidence that ECP performance can vary with soil type. The loose straw seemed to be most effective on the sand and loam soils and least effective on the clay soil. The soil specific C-factors determined for the loose straw were 0.021, 0.047, and 0.193 for the sand, loam, and clay soils, respectively. A potential reason for the drop in performance on the clay soil is that straw tended to slip on the surface of the clay soil after wetting. In addition to providing a performance advantage over the single-net straw blanket, the loose straw was roughly 60% the material cost of the blanket. The author recommends further evaluation of the loose straw on steeper slopes to determine if a drop of performance occurs.

5.3 Single Net Straw Testing

To provide a comparison to the performance of loose straw, three single net straw blanket tests were performed on each soil type. Like loose straw, the single-net straw blanket performance varied with soil type. The results of the single net straw tests indicated the loose straw was more effective at reducing soil loss on the sand, loam, and clay soils. The soil specific C-factors determined for the single-net straw blanket were 0.042, 0.131, and 0.31. The drop in performance provided evidence that loose straw may be a cost-effective alternative to straw blankets on sand, loam, and clay soils. To further evaluate the effectiveness of the blanket, the author recommends further test on steeper slope configurations. It is possible that the increased cost and robust anchoring system provides a performance advantage on the steeper slopes.

5.4 Statistical Analysis of C-Factor Variance

In addition to calculating soil specific C-factors using the RUSLE method, a statistical analysis was performed to determine if that variance provided a statistically significant difference. An unpaired t-test along with a 95% confidence interval was used to evaluate the C-factor datasets. The results of the statistical tests analyzing the variance of C-factor with soil type indicated that there was not a statistically significant difference of C-factor. While a substantial difference was observed, the author recommends that future testing be conducted to further evaluate the relationship between C-factor and soil type. In addition to conducting a statistical analysis on the soil type variance, the relationship between loose straw and single-net straw was analyzed. It was found that a statistically significant difference was observed in C-factor on the sand soil between the loose straw and blanket. For the loam and clay soils, no statistical difference was found. More testing is recommended to further evaluate the relationship between the practice performance.

5.6 Comparison of Soil Loss Models

Two commonly used soil loss models are the RUSLE and MUSLE equations. The RUSLE equation uses rainfall energy determined from rainfall quantity and drop size distribution. The MUSLE equation uses total runoff volume and peak runoff rate. This study and previous study at AU-SRF has used the RUSLE equation for all K and C-factor calculations. To provide a comparison, the MUSLE equation was used to calculate the K and C-factors. Table 4-85 below provides a summary of the calculated RUSLE and MUSLE factors.

Table 4-85: Summary of RUSLE and MUSLE Factors

Soil Type	Parameter	RUSLE Factor	MUSLE Factor
Sand	Avg. K-factor	0.37	0.56
	Avg. Loose Straw C-factor	0.021	0.059
	Avg. Single-Net Straw C-factor	0.042	0.090
Loam	Avg. K-factor	0.043	0.092
	Avg. Loose Straw C-factor	0.047	0.061
	Avg. Single-Net Straw C-factor	0.131	0.12
Clay	Avg. K-factor	0.013	0.080
	Avg. Loose Straw C-factor	0.193	0.57
	Avg. Single-Net Straw C-factor	0.31	0.22

For the bare soil testing, it was observed that the MUSLE equation produced substantially larger K-factors than the RUSLE equation. Like the RUSLE equation the MUSLE calculation method confirmed that sand is the most erodible soil followed by loam and clay. A potential reason for the difference in magnitude is that the MUSLE equation models runoff volume and rate as the driving factor of erosion in contrast to rainfall energy.

Like the RUSLE method, the C-factors did vary with soil type. Like the RUSLE method, the MUSLE calculation indicated that the loose straw performed best on the sand soil followed by the loam and clay. In consistency with the RUSLE method and loose straw results, the straw blanket performed best on the sand soil. It was also observed that the MUSLE method produced higher C-factors than the RUSLE method. A potential reason could be that the MUSLE model puts more emphasis on runoff volume, runoff rate, and cover practice while the RUSLE equation places more emphasis on soil erodibility and rainfall energy. In contrast to laboratory studies, large-scale testing is subject to variation in temperature, compaction, and moisture content. It should be noted that the variables mentioned are not accounted for in the RUSLE or MUSLE equation. The author recommends that further study be conducted on whether rainfall energy or runoff volume has a more significant impact on sediment loss. It is also possible that in smaller rain events when little runoff occurs, the RUSLE method overestimates the amount of soil loss. It could also be that in addition to anchoring soil and providing cover, ECPs should focus more on reducing runoff rate and volume.

5.7 Future Research Recommendations

Future testing on the 3:1 slopes will help to provide more data on soil erodibility and practice performance. In addition to performance variance with soil type, it is possible that practice performance is dependent on the slope as well. More testing will help to improve the current data set and provide a more comprehensive understanding. It is possible that the single net straw blanket may perform better on a steeper slope due to its more robust anchoring system than the loose straw.

The author would also like to recommend that further evaluation be conducted on the relationship between rainfall energy, runoff, and sediment loss. The RUSLE and MUSLE methods differ in their approach to the driving factor of erosion and more evaluation is necessary to determine which method best models rainfall induced erosion. The addition of 3:1 slope testing will also provide data on the impact of slope in the RUSLE and MUSLE soil loss models.

In addition to further ASTM D6459 testing on the 3:1 slopes, the author would like to recommend that the rainfall simulators be used to evaluate hydrologic soil groups and curve number through test runoff data. This could help verify the curve number values that are currently used for hydrologic and hydraulic design by engineers. The rainfall simulators could also be used to simulate post-construction stormwater BMPs such as infiltration swales.

5.8 Test Apparatus and Facility Improvement

The author would like to recommend the following improvements to the ASTM D6459 rainfall simulator to improve testing efficiency.

Replace the current electrical system with a mechanical valve system. This would eliminate the need for an electrical control box, electrical wires, solenoid valves, and battery. The electrical system has required continual system maintenance, and the solenoid valves are easily subjected to debris and may malfunction as a result. The mechanical system would require fewer system components and make the process of moving the rainfall simulators to different plots more efficient. The transition to mechanical valves has already begun at the AU-SRF and the figure below provides an image of the improved system.

Figure 5-1: Mechanical Valve System

The construction of a roof system over the rainfall simulator test plots could allow testing during rain events. Currently, rainfall simulator testing cannot occur at the AU-SRF during wind or rain events. A roof with wind screens could help to allow testing on days that are currently not an option due to inclement weather.

5.9 Disclosure Statement

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APPENDICES

Appendix A: Experimental Data

APPENDIX A

EXPERIMENTAL DATA FROM ASTM D6459-19 RAINFALL SIMULATOR TESTING

TABLE A.1: Bare Soil Sand Test 1

Date:	1/20/2023	
Test Total Intensity:	4.2	in.
Test Start Time:	9:30	AM
Test Finish Time:	11:00	AM

Drive Cylinder Compaction Data

Cylinder Number	1	2	3
Test Location Number	C10	A17	B23
Depth of Soil Sample (in)	2.77	2.00	3.83
Volume of Soil in Drive Cylinder (in^3)	32.67	23.59	45.12
Weight of Soil (g)	953.4	731.2	1308.7
Wet Weight of Soil (g)	138.0	168.2	107.2
Dry Weight of Soil (g)	115.3	147.9	90.3
Moisture Content (%)	16.4	12.1	15.8
Wet Density (lb/ft^3)	111.18	118.10	110.49
Dry Density (lb/ft^3)	95.48	105.38	95.45
Maximum Dry Density (lb/ ft^3)	112	112	112
Percent Compacted (%)	85.3	94.1	85.2
Average Percent Compacted (%)		88.2	

Collected Sediment Loss

Test Interval	2 in./hr	4 in./hr	6 in./hr
Dry Weight, lb	136.4	268.1	620.5
Total Dry Weight of Sediment, lb		1024.9	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	21	2680	1.4063	1.7975	56280	9780
2	6	21	2333	1.4352	2.0616	48993	62640
3	9	21	2486	1.4349	1.9150	52206	40008
4	12	-	-	-	-	-	-
5	15	21	2257	1.3945	1.8951	47397	50060
6	18	21	2217	1.4029	1.8656	46557	38558
7	21	21	2344	1.4392	2.2006	49224	76140
8	24	21	2511	1.4070	2.1329	52731	72590
9	27	21	3228	1.4506	1.7533	67788	30270
10	30	-	-	-	-	-	-
11	33	21	2266	1.4013	1.8942	47586	49290
12	36	21	3462	1.4185	2.0695	72702	65100
13	39	21	1186	1.4295	2.3279	24906	89840
14	42	21	4040	1.4041	2.0455	84840	64140
15	45	31	2761	1.4218	2.4295	85591	100770
16	48	21	3900	1.4129	2.1411	81900	72820
17	51	31	4159	1.4537	4.1538	128929	270010
18	54	31	3667	1.4160	4.1362	113677	272020
19	57	31	4155	1.4475	4.76	128805	331250
20	60	31	3481	1.4271	3.2783	107911	185120

TABLE A.2: Bare Soil Sand Test 2

Date:	3/29/2023	
Test Total Intensity:	4.3	in.
Test Start Time:	9:00	AM
Test Finish Time:	11:00	AM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	C10	C19	A22
Depth of Soil Sample (in)	3.5	3.4	3.4
Volume of Soil in Drive Cylinder (in^3)	41.3	40.1	40.1
Weight of Soil (g)	1146.0	1258.0	1730.1
Wet Weight of Soil (g)	103.7	107.4	98.7
Dry Weight of Soil (g)	91.5	98.5	88.2
Moisture Content (%)	11.8	8.3	10.6
Wet Density (lb/ft^3)	105.8	119.5	110.2
Dry Density (lb/ft^3)	94.6	110.4	99.6
Maximum Dry Density (lb/ ft^3)	112	112	112
Percent Compacted (%)	84.5	98.5	89.0
Average Percent Compacted (%)		90.7	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	297.8	423.6	650.5
Total Dry Weight of Sediment, lb		1371.9	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	10	1957	1.4008	1.5257	19570	3123
2	6	20	1354	1.4142	1.9162	27080	50200
3	9	20	3762	1.4207	1.9954	75240	47892
4	12	20	3079	1.4319	1.9045	61580	39383
5	15	20	2832	1.4180	1.8406	56640	42260
6	18	20	2733	1.3944	1.8741	54660	39975
7	21	20	2065	1.4121	1.8380	41300	42590
8	24	20	2294	1.4243	1.7938	45880	36950
9	27	20	2703	1.4286	1.8471	54060	41850
10	30	20	2693	1.4033	1.7748	53860	37150
11	33	20	2907	1.4282	1.8968	58140	46860
12	36	20	2430	1.4377	1.8393	48600	40160
13	39	20	2591	1.3832	1.8012	51820	41800
14	42	20	3041	1.4250	1.9475	60820	52250
15	45	20	3534	1.4030	2.1343	70680	73130
16	48	20	3750	1.4021	2.0379	75000	63580
17	51	-	-	-	-	-	-
18	54	-	-	-	-	-	-
19	57	-	-	-	-	-	-
20	60	-	-	-	-	-	-

TABLE A.3: Bare Soil Sand Test 3

Date:	4/5/2023	
Test Total Intensity:	3.7	in.
Test Start Time:	10:00	AM
Test Finish Time:	12:00	PM

Drive Cylinder Compaction Data

Cylinder Number	1	2	3
Test Location Number	C4	B17	C30
Depth of Soil Sample (in)	3.5	4.1	3.2
Volume of Soil in Drive Cylinder (in^3)	41.8	47.8	37.7
Weight of Soil (g)	1138.6	1346.0	1035.0
Wet Weight of Soil (g)	230.5	137.2	269.8
Dry Weight of Soil (g)	213.7	121.8	248.6
Moisture Content (%)	7.3	11.2	7.9
Wet Density (lb/ft^3)	103.9	107.4	104.5
Dry Density (lb/ft^3)	96.8	96.5	96.9
Maximum Dry Density (lb/ ft^3)	112	112	112
Percent Compacted (%)	86.5	86.2	86.5
Average Percent Compacted (%)		86.4	

Collected Sediment Loss

Test Interval	2 in./hr	4 in./hr	6 in./hr
Dry Weight, lb	543.6	162.1	2831.0
Total Dry Weight of Sediment, lb		3536.7	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	20	2787	1.4138	2.0918	55740	16950
2	6	20	1863	1.4066	1.6867	37260	28010
3	9	20	3588	1.4148	2.2785	71760	71975
4	12	30	3757	1.4109	4.0406	112710	219142
5	15	30	1897	1.4122	2.4332	56910	102100
6	18	30	3390	1.4045	3.5497	101700	178767
7	21	30	1817	1.4337	2.0831	54510	64940
8	24	30	3871	1.4228	4.1512	116130	272840
9	27	30	2765	1.4370	3.3751	82950	193810
10	30	30	4132	1.4081	5.8074	123960	439930
11	33	30	2661	1.4261	2.9982	79830	157210
12	36	30	3192	1.4286	3.0836	95760	165500
13	39	30	3482	1.4089	4.9367	104460	352780
14	42	30	2709	1.4379	2.5394	81270	110150
15	45	30	2857	1.4080	3.9662	85710	255820
16	48	30	3360	1.4375	3.0861	100800	164860
17	51	30	2668	1.4212	3.8385	80040	241730
18	54	30	3281	1.4195	2.9631	98430	154360
19	57	30	3594	1.3931	3.4617	107820	206860
20	60	30	3294	1.4336	3.2567	98820	182310

TABLE A.4: Bare Soil Loam Test 1

Date:	1/27/2023	
Test Total Intensity:	4.0	in.
Test Start Time:	10:00	AM
Test Finish Time:	11:30	AM

Drive Cylinder Compaction Data

Cylinder Number	1	2	3
Test Location Number	B8	A17	B25
Depth of Soil Sample (in)	3.1	3.2	3.2
Volume of Soil in Drive Cylinder (in^3)	36.6	37.7	37.7
Weight of Soil (g)	958.0	1057.8	1019.2
Wet Weight of Soil (g)	83.2	68.7	114.6
Dry Weight of Soil (g)	69.2	54.2	93.5
Moisture Content (%)	16.8	21.1	18.4
Wet Density (lb/ft^3)	99.8	106.8	102.9
Dry Density (lb/ft^3)	85.5	88.2	86.9
Maximum Dry Density (lb/ ft^3)	99	99	99
Percent Compacted (%)	86.3	89.1	87.8
Average Percent Compacted (%)		87.7	

Collected Sediment Loss

Test Interval	2 in./hr	4 in./hr	6 in./hr
Dry Weight, lb	18.9	82.9	188.7
Total Dry Weight of Sediment, lb		290.6	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	5	454	1.4414	1.4526	0	280
2	6	5	3726	1.4279	1.5233	18630	9540
3	9	8.5	2308	1.4668	1.6388	19618	14333
4	12	8.5	3652	1.4084	1.5911	31042	15225
5	15	8.5	3761	1.4168	1.5822	31969	16540
6	18	8.5	3199	1.4154	1.5753	27192	13325
7	21	8.5	3561	1.4400	1.6627	30269	22270
8	24	8.5	2519	1.4188	1.5677	21412	14890
9	27	8.5	2710	1.3860	1.5382	23035	15220
10	30	8.5	3002	1.4086	1.5568	25517	14820
11	33	8.5	2245	1.4043	1.5400	19083	13570
12	36	8.5	2395	1.3940	1.5225	20358	12850
13	39	8.5	2096	1.4105	1.5310	17816	12050
14	42	8.5	1970	1.4072	1.5325	16745	12530
15	45	8.5	1345	1.4047	1.5193	11433	11460
16	48	8.5	1715	1.3899	1.4981	14578	10820
17	51	8.5	1623	1.4011	1.5084	13796	10730
18	54	8.5	1506	1.4283	1.5223	12801	9400
19	57	8.5	1638	1.4118	1.5143	13923	10250
20	60	8.5	1577	1.4197	1.5107	13405	9100

TABLE A.5: Bare Soil Loam Test 2

Date:	3/15/2023	
Test Total Intensity:	4.6	in.
Test Start Time:	9:00	AM
Test Finish Time:	11:00	AM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	C5	A17	C30
Depth of Soil Sample (in)	2.7	2.4	2.5
Volume of Soil in Drive Cylinder (in^3)	31.8	28.3	29.5
Weight of Soil (g)	882.5	796.8	825.3
Wet Weight of Soil (g)	100.7	100.7	100.7
Dry Weight of Soil (g)	81.1	81.1	81.1
Moisture Content (%)	19.5	19.5	19.5
Wet Density (lb/ft^3)	105.6	107.3	106.6
Dry Density (lb/ft^3)	88.4	89.8	89.3
Maximum Dry Density (lb/ ft^3)	95	95	95
Percent Compacted (%)	93.0	94.5	94.0
Average Percent Compacted (%)		93.8	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	7.4	22.5	75.5
Total Dry Weight of Sediment, lb		105.5	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	6	1216	1.4086	1.4726	7296	1600
2	6	6	1959	1.4205	1.5202	11754	9970
3	9	6	1978	1.3991	1.4957	11868	8050
4	12	6	2013	1.4364	1.5437	12078	8942
5	15	6	1935	1.4179	1.5243	11610	10640
6	18	6	1729	1.4082	1.5028	10374	7883
7	21	6	4114	1.4296	1.6625	24684	23290
8	24	6	3812	1.4022	1.5915	22872	18930
9	27	6	2902	1.4111	1.5873	17412	17620
10	30	6	2783	1.4234	1.5866	16698	16320
11	33	6	2668	1.3909	1.5484	16008	15750
12	36	6	2930	1.4272	1.5803	17580	15310
13	39	6	2326	1.4033	1.5592	13956	15590
14	42	6	3018	1.4397	1.6032	18108	16350
15	45	6	2786	1.4203	1.5970	16716	17670
16	48	6	3252	1.4146	1.6245	19512	20990
17	51	6	2977	1.4061	1.5631	17862	15700
18	54	6	2687	1.4076	1.5837	16122	17610
19	57	6	2521	1.4176	1.5894	15126	17180
20	60	6	2875	1.4227	1.5907	17250	16800

TABLE A.6: Bare Soil Loam Test 3

Date:	3/24/2023	
Test Total Intensity:	3.7	in.
Test Start Time:	9:30	AM
Test Finish Time:	11:30	AM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	B3	C14	B24
Depth of Soil Sample (in)	4.0	4.0	4.0
Volume of Soil in Drive Cylinder (in^3)	47.2	47.2	46.7
Weight of Soil (g)	1206.5	1180.1	1295.5
Wet Weight of Soil (g)	119.3	123.1	145.9
Dry Weight of Soil (g)	97.8	102.6	121.1
Moisture Content (%)	18.0	16.7	17.0
Wet Density (lb/ft^3)	97.4	95.3	105.7
Dry Density (lb/ft^3)	82.6	81.7	90.3
Maximum Dry Density (lb/ ft^3)	95	95	95
Percent Compacted (%)	86.9	86.0	95.1
Average Percent Compacted (%)		89.3	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	22.2	118.6	167.3
Total Dry Weight of Sediment, lb		308.1	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	20	2446	1.3937	1.4114	48920	443
2	6	20	438	1.3781	1.4543	8760	7620
3	9	20	1053	1.4208	1.6291	21060	17358
4	12	20	1269	1.3859	1.6313	25380	20450
5	15	20	1336	1.4243	1.6921	26720	26780
6	18	20	1502	1.4305	1.7279	30040	24783
7	21	20	2064	1.4299	1.8509	41280	42100
8	24	10	3338	1.3861	1.7008	33380	31470
9	27	10	3535	1.4175	1.7214	35350	30390
10	30	10	3110	1.4234	1.7098	31100	28640
11	33	10	2753	1.4064	1.7295	27530	32310
12	36	10	2649	1.4225	1.7275	26490	30500
13	39	6	4185	1.4057	1.6597	25110	25400
14	42	6	3521	1.4105	1.6118	21126	20130
15	45	6	3396	1.4309	1.6334	20376	20250
16	48	6	3350	1.4282	1.6550	20100	22680
17	51	6	2896	1.4127	1.5987	17376	18600
18	54	6	2869	1.3990	1.5804	17214	18140
19	57	6	3214	1.4359	1.6512	19284	21530
20	60	6	3304	1.4202	1.6063	19824	18610

TABLE A.7: Bare Soil Clay Test 1

Date:	2/15/2023	
Test Total Intensity:	4.9	in.
Test Start Time:	9:00	AM
Test Finish Time:	11:00	AM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	B4	B13	A27
Depth of Soil Sample (in)	2.1	2.4	2.9
Volume of Soil in Drive Cylinder (in^3)	24.8	28.3	34.2
Weight of Soil (g)	649.1	712.2	904.5
Wet Weight of Soil (g)	154.3	164.1	171.3
Dry Weight of Soil (g)	127.4	122.0	132.2
Moisture Content (%)	17.4	25.7	22.8
Wet Density (lb/ft^3)	99.9	95.9	100.8
Dry Density (lb/ft^3)	85.0	76.3	82.0
Maximum Dry Density (lb/ ft^3)	88	88	88
Percent Compacted (%)	96.6	86.7	93.2
Average Percent Compacted (%)		92.2	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	4.3	50.1	123.4
Total Dry Weight of Sediment, lb		177.8	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	5	824	1.4061	1.4426	4120	913
2	6	5	1145	1.4502	1.4964	5725	4620
3	9	5	1416	1.3968	1.4628	7080	5500
4	12	5	1656	1.4078	1.4824	8280	6217
5	15	5	2493	1.4099	1.4928	12465	8290
6	18	10	2317	1.4234	1.6564	23170	19417
7	21	5	2764	1.4388	1.5274	13820	8860
8	24	10	1984	1.4327	1.6394	19840	20670
9	27	10	1724	1.4000	1.6019	17240	20190
10	30	10	2198	1.4328	1.6256	21980	19280
11	33	10	1607	1.4015	1.5414	16070	13990
12	36	15	1189	1.4241	1.6092	17835	18510
13	39	10	1816	1.4569	1.5975	18160	14060
14	42	10	2418	1.4301	1.6136	24180	18350
15	45	10	2765	1.4313	1.6339	27650	20260
16	48	10	2289	1.4058	1.6039	22890	19810
17	51	10	2776	1.4123	1.5896	27760	17730
18	54	10	2319	1.4054	1.5912	23190	18580
19	57	10	1947	1.4136	1.6019	19470	18830
20	60	10	1970	1.447	1.6386	19700	19160

TABLE A.8: Bare Soil Clay Test 2

Date:	2/24/2023	
Test Total Intensity:	4.6	in.
Test Start Time:	9:00	AM
Test Finish Time:	11:00	AM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	B7	B19	C26
Depth of Soil Sample (in)	3.2	2.7	2.1
Volume of Soil in Drive Cylinder (in^3)	37.7	31.8	24.8
Weight of Soil (g)	997.8	825.3	661.3
Wet Weight of Soil (g)	149.9	145.0	155.7
Dry Weight of Soil (g)	111.5	107.5	119.8
Moisture Content (%)	25.6	25.9	23.1
Wet Density (lb/ft^3)	100.7	98.7	101.7
Dry Density (lb/ft^3)	80.2	78.5	82.7
Maximum Dry Density ($lb/\ ft^3$)	91	91	91
Percent Compacted (%)	88.1	86.2	90.8
Average Percent Compacted (%)		88.4	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	10.1	10.2	63.5
Total Dry Weight of Sediment, lb		83.8	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	-	-	1.4117	1.5268	-	2878
2	6	-	-	1.4369	1.4801	-	4320
3	9	-	-	1.4059	1.4501	-	3683
4	12	-	-	1.4209	1.4595	-	3217
5	15	-	-	1.4061	1.4700	-	6390
6	18	-	-	1.3896	1.4438	-	4517
7	21	-	-	1.4081	1.4606	-	5250
8	24	-	-	1.4110	1.4792	-	6820
9	27	-	-	1.4067	1.4762	-	6950
10	30	-	-	1.4088	1.4862	-	7740
11	33	-	-	1.4055	1.4803	-	7480
12	36	-	-	1.4122	1.4851	-	7290
13	39	-	-	1.4177	1.4963	-	7860
14	42	-	-	1.4208	1.5210	-	10020
15	45	-	-	1.4076	1.4986	-	9100
16	48	-	-	1.4220	1.5104	-	8840
17	51	-	-	1.4195	1.5056	-	8610
18	54	-	-	1.4017	1.4856	-	8390
19	57	-	-	1.3994	1.4839	-	8450
20	60	-	-	1.4293	1.5419	-	11260

TABLE A.9: Bare Soil Clay Test 3

Date:	3/22/2023	
Test Total Intensity:	4.4	in.
Test Start Time:	10:00	AM
Test Finish Time:	12:00	PM

Drive Cylinder Compaction Data

Cylinder Number	1	2	3
Test Location Number	B8	C20	B25
Depth of Soil Sample (in)	2.3	2.5	2.7
Volume of Soil in Drive Cylinder (in^3)	27.2	29.5	31.8
Weight of Soil (g)	662.6	781.6	864.9
Wet Weight of Soil (g)	106.8	108.8	116.6
Dry Weight of Soil (g)	79.3	80.4	86.1
Moisture Content (%)	25.7	26.1	26.2
Wet Density (lb/ft^3)	92.7	101.0	103.5
Dry Density (lb/ft^3)	73.7	80.1	82.0
Maximum Dry Density (lb/ ft^3)	88	88	88
Percent Compacted (%)	83.7	91.0	93.2
Average Percent Compacted (%)		89.3	

Collected Sediment Loss

Test Interval	2 in./hr	4 in./hr	6 in./hr
Dry Weight, lb	0.7	5.6	74.6
Total Dry Weight of Sediment, lb		80.9	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	6	1097	1.4480	1.5084	6582	1510
2	6	6	1860	1.4136	1.4949	11160	8130
3	9	6	1835	1.4204	1.5031	11010	6892
4	12	6	1555	1.4112	1.4841	9330	6075
5	15	6	2111	1.4234	1.5340	12666	11060
6	18	6	1576	1.4252	1.5250	9456	8317
7	21	6	1575	1.4137	1.5279	9450	11420
8	24	6	2768	1.4023	1.6008	16608	19850
9	27	6	972	1.4284	1.4945	5832	6610
10	30	6	1169	1.4052	1.4598	7014	5460
11	33	6	1876	1.4141	1.4987	11256	8460
12	36	6	2235	1.4356	1.5273	13410	9170
13	39	6	2359	1.3845	1.5078	14154	12330
14	42	6	2442	1.4041	1.5507	14652	14660
15	45	6	2070	1.4228	1.5368	12420	11400
16	48	6	1593	1.3962	1.4840	9558	8780
17	51	6	1617	1.417	1.5065	9702	8950
18	54	6	1605	1.4258	1.5143	9630	8850
19	57	6	1924	1.4069	1.5848	11544	17790
20	60	6	2112	1.4304	1.5548	12672	12440

TABLE A.10: Loose Straw Sand Test 1

Date:	11/9/2023	
Test Total Intensity:	4.3	in.
Test Start Time:	1:30	PM
Test Finish Time:	3:30	PM

Drive Cylinder Compaction Data

Cylinder Number	1	2	3
Test Location Number	B8	B11	C22
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	1730.0	1730.0	1730.0
Wet Weight of Soil (g)	149.0	151.1	166.0
Dry Weight of Soil (g)	130.4	135.3	153.1
Moisture Content (%)	12.5	10.5	7.8
Wet Density (lb/ft^3)	111.8	111.8	111.8
Dry Density (lb/ft^3)	99.4	101.2	103.7
Maximum Dry Density (lb/ ft^3)	112	112	112
Percent Compacted (%)	88.7	90.4	92.6
Average Percent Compacted (%)		90.6	

Collected Sediment Loss

Test Interval	2 in./hr	4 in./hr	6 in./hr
Dry Weight, lb	6.1	12.1	32.0
Total Dry Weight of Sediment, lb		50.1	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	3	3756	1.4060	1.4605	11268	1363
2	6	3	2512	1.4022	1.4403	7536	3810
3	9	3	1935	1.4285	1.4619	5805	2783
4	12	3	1390	1.3885	1.4089	4170	1700
5	15	3	1464	1.4092	1.4301	4392	2090
6	18	3	1131	1.4081	1.4276	3393	1625
7	21	3	1794	1.4039	1.4326	5382	2870
8	24	3	1292	1.4084	1.4301	3876	2170
9	27	3	929	1.4096	1.4298	2787	2020
10	30	3	980	1.4123	1.4328	2940	2050
11	33	3	1445	1.4181	1.4451	4335	2700
12	36	3	896	1.4069	1.4270	2688	2010
13	39	3	817	1.4346	1.4516	2451	1700
14	42	3	1271	1.4135	1.4410	3813	2750
15	45	3	910	1.3990	1.4177	2730	1870
16	48	3	775	1.4112	1.4269	2325	1570
17	51	3	846	1.43	1.4479	2538	1790
18	54	3	847	1.4303	1.4539	2541	2360
19	57	3	914	1.4327	1.4554	2742	2270
20	60	3	870	1.4308	1.4542	2610	2340

TABLE A.11: Loose Straw Sand Test 2

Date:	11/17/2023	
Test Total Intensity:	4.3	in.
Test Start Time:	1:00	PM
Test Finish Time:	3:00	PM

Drive Cylinder Compaction Data

Cylinder Number	1	2	3
Test Location Number	B8	B11	A22
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	1680.0	1780.0	1730.0
Wet Weight of Soil (g)	127.4	125.8	140.8
Dry Weight of Soil (g)	115.9	112.9	130.3
Moisture Content (%)	9.0	10.3	7.5
Wet Density (lb/ft^3)	108.5	115.0	111.8
Dry Density (lb/ft^3)	99.6	104.3	104.0
Maximum Dry Density (lb/ ft^3)	112	112	112
Percent Compacted (%)	88.9	93.1	92.9
Average Percent Compacted (%)		91.6	

Collected Sediment Loss

Test Interval	2 in./hr	4 in./hr	6 in./hr
Dry Weight, lb	3.5	6.4	21.6
Total Dry Weight of Sediment, lb		31.5	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	0	0	0.0000	0.0000	0	0
2	6	1	685	1.4183	1.4250	685	670
3	9	1	771	1.4019	1.4232	771	1775
4	12	1	568	1.4295	1.4397	568	850
5	15	1	697	1.3883	1.3959	697	760
6	18	1	378	1.4008	1.4045	378	308
7	21	1	454	1.4021	1.4201	454	1800
8	24	1	1049	1.4043	1.4189	1049	1460
9	27	1	813	1.4263	1.4363	813	1000
10	30	1	649	1.4128	1.4190	649	620
11	33	1	781	1.4326	1.4396	781	700
12	36	1	759	1.4133	1.4187	759	540
13	39	1	599	1.4487	1.4529	599	420
14	42	1	1322	1.4341	1.4438	1322	970
15	45	1	1700	1.4229	1.4337	1700	1080
16	48	1	1237	1.4322	1.4402	1237	800
17	51	1	1233	1.4284	1.4359	1233	750
18	54	1	1214	1.4394	1.4473	1214	790
19	57	1	1274	1.3826	1.3913	1274	870
20	60	1	1411	1.4349	1.4439	1411	900

TABLE A.12: Loose Straw Sand Test 3

Date:	11/30/2023	
Test Total Intensity:	4.3	in.
Test Start Time:	2:00	PM
Test Finish Time:	4:00	PM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	B8	B11	A22
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	1680.0	1730.0	1830.0
Wet Weight of Soil (g)	157.5	149.4	150.0
Dry Weight of Soil (g)	130.3	135.4	141.2
Moisture Content (%)	17.3	9.4	5.9
Wet Density (lb/ft^3)	108.5	111.8	118.2
Dry Density (lb/ft^3)	92.6	102.2	111.7
Maximum Dry Density (lb/ ft^3)	112	112	112
Percent Compacted (%)	82.6	91.2	99.7
Average Percent Compacted (%)		91.2	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	0.8	18.1	32.4
Total Dry Weight of Sediment, lb		51.3	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	0	0	0.0000	0.0000	0	0
2	6	1	1397	1.4093	1.5016	1397	9230
3	9	1	3085	1.4390	1.4737	3085	2892
4	12	1	2910	1.4070	1.4362	2910	2433
5	15	1	3214	1.4112	1.4449	3214	3370
6	18	1	2311	1.4222	1.4509	2311	2392
7	21	3	1025	1.4113	1.4635	3075	5220
8	24	3	1434	1.3824	1.4500	4302	6760
9	27	3	1229	1.4317	1.4927	3687	6100
10	30	3	1026	1.4264	1.4876	3078	6120
11	33	3	1058	1.4383	1.5244	3174	8610
12	36	3	1046	1.4051	1.4643	3138	5920
13	39	3	1048	1.3998	1.4275	3144	2770
14	42	3	1809	1.4094	1.4961	5427	8670
15	45	3	1753	1.4065	1.4406	5259	3410
16	48	3	1622	1.4233	1.5082	4866	8490
17	51	3	2768	1.4244	1.5390	8304	11460
18	54	3	2294	1.4078	1.4993	6882	9150
19	57	3	906	1.4084	1.5003	2718	9190
20	60	3	830	1.4268	1.4976	2490	7080

TABLE A.13: Loose Straw Loam Test 1

Date:	8/29/2023	
Test Total Intensity:	3.9	in.
Test Start Time:	1:30	PM
Test Finish Time:	3:30	PM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	B5	A13	B26
Depth of Soil Sample (in)	4.1	3.7	4.5
Volume of Soil in Drive Cylinder (in^3)	48.4	43.6	53.1
Weight of Soil (g)	1270.8	1060.0	1357.6
Wet Weight of Soil (g)	191.2	286.7	184.8
Dry Weight of Soil (g)	155.6	245.1	150.6
Moisture Content (%)	18.6	14.5	18.5
Wet Density (lb/ft^3)	100.1	92.5	97.5
Dry Density (lb/ft^3)	84.4	80.8	82.2
Maximum Dry Density (lb/ ft^3)	95	95	95
Percent Compacted (%)	88.9	85.1	86.6
Average Percent Compacted (%)		86.8	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	0.09	0.34	0.14
Total Dry Weight of Sediment, lb		0.57	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	5	1960	1.4226	1.4849	9800	1558
2	6	5	938	1.4051	1.4405	4690	3540
3	9	5	818	1.4067	1.4320	4090	2108
4	12	5	874	1.4327	1.4593	4370	2217
5	15	5	776	1.4374	1.4658	3880	2840
6	18	5	695	1.4131	1.4355	3475	1867
7	21	5	590	1.4283	1.4454	2950	1710
8	24	5	723	1.4115	1.4409	3615	2940
9	27	5	1281	1.4043	1.4483	6405	4400
10	30	5	843	1.4105	1.4352	4215	2470
11	33	5	743	1.4172	1.4447	3715	2750
12	36	5	282	1.4035	1.4302	1410	2670
13	39	5	214	1.5557	1.5689	1070	1320
14	42	1	948	1.4214	1.4311	948	970
15	45	1	1287	1.4132	1.4262	1287	1300
16	48	1	899	1.4122	1.4246	899	1240
17	51	1	617	1.413	1.4216	617	860
18	54	1	486	1.4379	1.4451	486	720
19	57	1	518	1.4222	1.4292	518	700
20	60	1	479	1.4181	1.4248	479	670

TABLE A.14: Loose Straw Loam Test 2

Date:	9/8/2023	
Test Total Intensity:	3.8	in.
Test Start Time:	8:30	AM
Test Finish Time:	10:30	AM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	B5	A17	C27
Depth of Soil Sample (in)	4.3	3.4	4.3
Volume of Soil in Drive Cylinder (in^3)	50.7	40.1	50.7
Weight of Soil (g)	1273.1	1104.9	1144.0

Wet Weight of Soil (g)	50.0	50.2	49.9
Dry Weight of Soil (g)	42.3	41.3	43.8
Moisture Content (%)	15.4	17.7	12.2

Wet Density (lb/ft^3)	95.6	105.0	85.9
Dry Density (lb/ft^3)	82.9	89.2	76.6
Maximum Dry Density (lb/ ft^3)	95	95	95
Percent Compacted (%)	87.2	93.9	80.6
Average Percent Compacted (%)		87.2	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	1.2	3.2	4.8
Total Dry Weight of Sediment, lb		9.2	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	5	939	1.4441	1.4785	4695	860
2	6	5	761	1.4257	1.4620	3805	3630
3	9	1	3572	1.4164	1.4403	3572	1992
4	12	5	667	1.4398	1.4628	3335	1917
5	15	5	888	1.4049	1.4383	4440	3340
6	18	5	553	1.4126	1.4322	2765	1633
7	21	5	702	1.4535	1.4884	3510	3490
8	24	1	2734	1.4360	1.4586	2734	2260
9	27	1	2839	1.3977	1.4224	2839	2470
10	30	1	2921	1.4148	1.4358	2921	2100
11	33	1	1959	1.4134	1.4304	1959	1700
12	36	1	1618	1.4434	1.4630	1618	1964
13	39	1	1622	1.4172	1.4275	1622	1030
14	42	1	1175	1.4204	1.4354	1175	1500
15	45	1	1884	1.4280	1.4433	1884	1530
16	48	1	1287	1.4375	1.4515	1287	1400
17	51	1	1300	1.4092	1.4224	1300	1320
18	54	1	1251	1.4043	1.4194	1251	1510
19	57	5	939	1.4441	1.4785	4695	860
20	60	5	761	1.4257	1.4620	3805	3630

TABLE A.15: Loose Straw Loam Test 3

Date:	9/19/2023	
Test Total Intensity:	3.9	in.
Test Start Time:	2:00	PM
Test Finish Time:	4:00	PM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	B7	B15	B25
Depth of Soil Sample (in)	4.7	4.0	4.5
Volume of Soil in Drive Cylinder (in^3)	55.1	47.2	53.4
Weight of Soil (g)	1398.7	1641.6	2000.0
Wet Weight of Soil (g)	379.3	209.8	231.2
Dry Weight of Soil (g)	339.5	175.2	201.8
Moisture Content (%)	10.5	16.5	12.7
Wet Density (lb/ft^3)	96.7	86.5	102.0
Dry Density (lb/ft^3)	87.5	74.3	90.5
Maximum Dry Density (lb/ ft^3)	95	95	95
Percent Compacted (%)	92.1	78.2	95.2
Average Percent Compacted (%)		88.5	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	1.4	2.1	7.0
Total Dry Weight of Sediment, lb		10.5	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	10	103	1.4164	1.4198	1030	85
2	6	5	1528	1.4167	1.4614	7640	4470
3	9	5	1403	1.4289	1.4683	7015	3283
4	12	5	1763	1.4368	1.4805	8815	3642
5	15	5	1889	1.4317	1.4767	9445	4500
6	18	5	1431	1.4302	1.4711	7155	3408
7	21	5	1138	1.4169	1.4568	5690	3990
8	24	5	1779	1.4047	1.4520	8895	4730
9	27	5	1367	1.4190	1.4618	6835	4280
10	30	5	980	1.4002	1.4427	4900	4250
11	33	5	816	1.4090	1.4433	4080	3430
12	36	1	3604	1.4385	1.4665	3604	2800
13	39	5	586	1.4131	1.4403	2930	2720
14	42	5	1723	1.4068	1.4831	8615	7630
15	45	5	1034	1.4250	1.4663	5170	4130
16	48	5	887	1.4237	1.4729	4435	4920
17	51	1	3738	1.4092	1.4543	3738	4510
18	54	1	2642	1.4165	1.4552	2642	3870
19	57	1	2297	1.4075	1.4327	2297	2520
20	60	1	1549	1.4178	1.4325	1549	1470

TABLE A.17: Loose Straw Clay Test 2

Date:	10/17/2023	
Test Total Intensity:	4.8	in.
Test Start Time:	1:30	PM
Test Finish Time:	3:30	PM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	B5	C17	A23
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	1610.0	1680.0	1640.0
Wet Weight of Soil (g)	110.0	110.0	115.0
Dry Weight of Soil (g)	80.0	80.0	90.0
Moisture Content (%)	27.3	27.3	21.7
Wet Density (lb/ft^3)	104.0	108.5	106.0
Dry Density (lb/ft^3)	81.7	85.3	87.0
Maximum Dry Density (lb/ ft^3)	88	88	88
Percent Compacted (%)	92.9	96.9	90.0
Average Percent Compacted (%)		93.3	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	0.6	0.9	1.9
Total Dry Weight of Sediment, lb		3.4	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	0	0	0.0000	0.0000	0	0
2	6	5	3960	1.4097	1.5203	19800	11060
3	9	5	3080	1.4350	1.5178	15400	6900
4	12	5	3250	1.3986	1.4795	16250	6742
5	15	5	3748	1.4287	1.5269	18740	9820
6	18	10	1734	1.4358	1.5491	17340	9442
7	21	10	957	1.4033	1.4740	9570	7070
8	24	10	1021	1.4393	1.5301	10210	9080
9	27	10	959	1.4370	1.5133	9590	7630
10	30	10	1181	1.4049	1.4962	11810	9130
11	33	10	974	1.4129	1.4893	9740	7640
12	36	10	1149	1.4096	1.4943	11490	8470
13	39	10	831	1.4147	1.4872	8310	7250
14	42	10	399	1.3916	1.4423	3990	5070
15	45	5	573	1.4129	1.4427	2865	2980
16	48	5	760	1.4158	1.4597	3800	4390
17	51	5	441	1.41	1.4358	2205	2580
18	54	1	1866	1.4183	1.4407	1866	2240
19	57	1	1159	1.3872	1.4001	1159	1290
20	60	1	864	1.39	1.4007	864	1070

TABLE A.18: Loose Straw Clay Test 3

Date:	11/3/2023	
Test Total Intensity:	4.7	in.
Test Start Time:	2:30	PM
Test Finish Time:	4:30	PM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	A5	B18	C23
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	1390.7	1535.0	1385.0
Wet Weight of Soil (g)	186.2	143.0	177.9
Dry Weight of Soil (g)	146.2	111.6	147.0
Moisture Content (%)	21.5	22.0	17.4
Wet Density (lb/ft^3)	89.9	99.2	89.5
Dry Density (lb/ft^3)	74.0	81.3	76.2
Maximum Dry Density (lb/ ft^3)	88	88	88
Percent Compacted (%)	84.1	92.4	90.0
Average Percent Compacted (%)		88.8	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	1.2	2.8	27.7
Total Dry Weight of Sediment, lb		31.7	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	10	1207	1.4162	1.5159	12070	2493
2	6	5	2438	1.4324	1.5017	12190	6930
3	9	10	878	1.4073	1.4809	8780	6133
4	12	10	1679	1.4060	1.5058	16790	8317
5	15	5	3174	1.4320	1.5076	15870	7560
6	18	10	448	1.4205	1.4630	4480	3542
7	21	10	2114	1.4423	1.5834	21140	14110
8	24	10	1429	1.4110	1.4933	14290	8230
9	27	5	3952	1.4083	1.4916	19760	8330
10	30	5	1144	1.4073	1.4486	5720	4130
11	33	5	1013	1.4028	1.4409	5065	3810
12	36	10	1756	1.4295	1.5523	17560	12280
13	39	10	640	1.4087	1.4629	6400	5420
14	42	10	974	1.4183	1.4907	9740	7240
15	45	10	2768	1.3862	1.5268	27680	14060
16	48	10	1012	1.4168	1.5238	10120	10700
17	51	5	4184	1.4149	1.5255	20920	11060
18	54	5	3802	1.4422	1.5370	19010	9480
19	57	5	3241	1.4126	1.5192	16205	10660
20	60	5	3228	1.4232	1.5952	16140	17200

TABLE A.19: Single Net Straw Sand Test 1

Date:	2/1/2024	
Test Total Intensity:	4.6	in.
Test Start Time:	9:30	AM
Test Finish Time:	11:30	AM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	B4	C17	B27
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	1780.0	1680.0	1755.0
Wet Weight of Soil (g)	131.6	126.0	116.7
Dry Weight of Soil (g)	118.3	114.3	106.7
Moisture Content (%)	10.1	9.3	8.6
Wet Density (lb/ft^3)	115.0	108.5	113.4
Dry Density (lb/ft^3)	104.4	99.3	104.4
Maximum Dry Density (lb/ ft^3)	112	112	112
Percent Compacted (%)	93.3	88.7	93.3
Average Percent Compacted (%)		91.7	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	3.3	23.7	67.1
Total Dry Weight of Sediment, lb		94.0	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	1	0	0.0000	0.0000	0	0
2	6	1	0	0.0000	0.0000	0	0
3	9	1	0	0.0000	0.0000	0	0
4	12	1	0	0.0000	0.0000	0	0
5	15	1.2	3841	1.4166	1.4967	4609.2	8010
6	18	1.2	2193	1.4197	1.5000	2631.6	6692
7	21	1.2	2496	1.3991	1.4751	2995.2	7600
8	24	1.2	3676	1.4189	1.4946	4411.2	7570
9	27	1.2	3397	1.4204	1.5001	4076.4	7970
10	30	1.2	3035	1.3859	1.4663	3642	8040
11	33	1.2	2653	1.4123	1.4638	3183.6	5150
12	36	1.2	4145	1.4301	1.4844	4974	5430
13	39	1.2	3334	1.4027	1.4605	4000.8	5780
14	42	1.2	3385	1.4306	1.4699	4062	3930
15	45	1.2	2144	1.4248	1.4728	2572.8	4800
16	48	1.2	2407	1.4041	1.4534	2888.4	4930
17	51	1.2	2054	1.408	1.4176	2464.8	960
18	54	1.2	2236	1.4192	1.4395	2683.2	2030
19	57	1.5	2049	1.4225	1.4331	3073.5	1060
20	60	3	1990	1.4319	1.4637	5970	3180

TABLE A.20: Single Net Straw Sand Test 2

Date:	2/7/2024	
Test Total Intensity:	3.6	in.
Test Start Time:	1:30	PM
Test Finish Time:	3:30	PM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	B3	A8	C16
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	1794.0	1810.0	1745.0

Wet Weight of Soil (g)	149.4	138.1	145.2
Dry Weight of Soil (g)	132.0	122.6	129.6
Moisture Content (%)	11.6	11.2	10.7

Wet Density (lb/ft^3)	115.9	116.9	112.7
Dry Density (lb/ft^3)	103.8	105.1	101.8
Maximum Dry Density (lb/ ft^3)	112	112	112
Percent Compacted (%)	92.7	93.9	90.9
Average Percent Compacted (%)		92.5	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	3.8	24.7	42.6
Total Dry Weight of Sediment, lb		71.0	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	1	0	0.0000	0.0000	0	0
2	6	6	1414	1.4058	1.4606	8484	5480
3	9	6	1507	1.4044	1.4460	9042	3467
4	12	6	1428	1.4185	1.4573	8568	3233
5	15	6	1613	1.4148	1.4569	9678	4210
6	18	6	1545	1.4300	1.4720	9270	3500
7	21	6	2036	1.4130	1.5000	12216	8700
8	24	6	1440	1.4129	1.4763	8640	6340
9	27	6	2690	1.4237	1.4970	16140	7330
10	30	6	1927	1.4280	1.4914	11562	6340
11	33	6	1597	1.4231	1.4790	9582	5590
12	36	6	1604	1.4150	1.4672	9624	5220
13	39	6	1493	1.4387	1.4926	8958	5390
14	42	6	1414	1.4139	1.4646	8484	5070
15	45	6	2050	1.4321	1.4999	12300	6780
16	48	6	977	1.4052	1.4703	5862	6510
17	51	6	1224	1.405	1.4642	7344	5920
18	54	6	1280	1.4130	1.4652	7680	5220
19	57	6	1547	1.4198	1.477	9282	5720
20	60	6	1211	1.4238	1.4818	7266	5800

TABLE A.21: Single Net Straw Sand Test 3

Date:	2/15/2024	
Test Total Intensity:	3.8	in.
Test Start Time:	10:20	AM
Test Finish Time:	12:20	PM

Drive Cylinder Compaction Data

Cylinder Number	1	2	3
Test Location Number	B4	B15	C25
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	1710.0	1785.0	1680.0

Wet Weight of Soil (g)	108.1	100.9	103.7
Dry Weight of Soil (g)	95.7	89.1	92.7
Moisture Content (%)	88.5	92.2	87.6

Wet Density (lb/ft^3)	110.5	115.3	108.5
Dry Density (lb/ft^3)	99.1	103.3	98.1
Maximum Dry Density (lb/ ft^3)	112	112	112
Percent Compacted (%)	88.5	92.2	87.6
Average Percent Compacted (%)		89.4	

Collected Sediment Loss

Test Interval	2 in./hr	4 in./hr	6 in./hr
Dry Weight, lb	2.9	19.8	52.1
Total Dry Weight of Sediment, lb		74.7	

TABLE A.22: Single Net Straw Loam Test 1

Date:	4/17/2024	
Test Total Intensity:	3.4	in.
Test Start Time:	1:30	PM
Test Finish Time:	3:00	PM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	A9	B23	C15
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	1665.0	1665.0	1340.0
Wet Weight of Soil (g)	113.8	105.6	110.5
Dry Weight of Soil (g)	96.4	88.9	91.8
Moisture Content (%)	15.3	15.8	16.9
Wet Density (lb/ft^3)	107.6	107.6	86.6
Dry Density (lb/ft^3)	93.3	92.9	74.0
Maximum Dry Density (lb/ ft^3)	95	95	95
Percent Compacted (%)	98.2	97.8	77.9
Average Percent Compacted (%)		91.3	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	1.0	5.1	6.9
Total Dry Weight of Sediment, lb		13.0	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	0	0	0.0000	0.0000	0	0
2	6	0	0	0.0000	0.0000	0	0
3	9	3	3268	1.3924	1.4444	9804	4333
4	12	4	3051	1.3949	1.4817	12204	7233
5	15	4	3147	1.4116	1.4967	12588	8510
6	18	3	2732	1.4255	1.4728	8196	3942
7	21	4	3394	1.4257	1.5456	13576	11990
8	24	4	2882	1.4087	1.4966	11528	8790
9	27	4	3519	1.3981	1.5292	14076	13110
10	30	3	3551	1.4041	1.4855	10653	8140
11	33	3	2552	1.4200	1.4962	7656	7620
12	36	3	2821	1.4201	1.4950	8463	7490
13	39	3	2293	1.4295	1.4880	6879	5850
14	42	3	2176	1.3811	1.4368	6528	5570
15	45	3	2017	1.4132	1.4742	6051	6100
16	48	3	3638	1.4161	1.4913	10914	7520
17	51	3	3311	1.4339	1.5255	9933	9160
18	54	3	2564	1.4432	1.5104	7692	6720
19	57	3	2478	1.4077	1.4713	7434	6360
20	60	3	2152	1.4312	1.4858	6456	5460

TABLE A.23: Single Net Straw Loam Test 2

Date:	6/5/2024	
Test Total Intensity:	4.3	in.
Test Start Time:	1:00	PM
Test Finish Time:	3:00	PM

Drive Cylinder Compaction Data

Cylinder Number	**1**	**2**	**3**
Test Location Number	B5	A17	C27
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	1374.0	1523.0	1524.0

Wet Weight of Soil (g)	142.5	122.3	124.3
Dry Weight of Soil (g)	125.8	106.3	105.0
Moisture Content (%)	11.7	13.1	15.5

Wet Density (lb/ft^3)	88.8	98.4	98.5
Dry Density (lb/ft^3)	79.5	87.0	85.2
Maximum Dry Density (lb/ ft^3)	95	95	95
Percent Compacted (%)	83.6	91.6	89.7
Average Percent Compacted (%)		88.3	

Collected Sediment Loss

Test Interval	**2 in./hr**	**4 in./hr**	**6 in./hr**
Dry Weight, lb	2.4	6.2	18.4
Total Dry Weight of Sediment, lb		27.0	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	15	3306	1.4327	1.4968	49590	1603
2	6	15	2362	1.4260	1.4747	35430	4870
3	9	6	3017	1.4124	1.4425	18102	2508
4	12	6	2688	1.4422	1.4710	16128	2400
5	15	6	1914	1.3897	1.4127	11484	2300
6	18	3	3264	1.4001	1.4211	9792	1750
7	21	3	3862	1.4283	1.4560	11586	2770
8	24	3	3043	1.3980	1.4216	9129	2360
9	27	3	2444	1.4372	1.4590	7332	2180
10	30	3	2448	1.4044	1.4280	7344	2360
11	33	3	2158	1.3890	1.4112	6474	2220
12	36	3	2503	1.3998	1.4287	7509	2890
13	39	3	2102	1.4101	1.4339	6306	2380
14	42	3	3562	1.4023	1.4331	10686	3080
15	45	3	2752	1.4151	1.4437	8256	2860
16	48	3	2919	1.4146	1.4650	8757	5040
17	51	3	2590	1.4311	1.4568	7770	2570
18	54	3	2220	1.4120	1.4387	6660	2670
19	57	3	2303	1.4132	1.4368	6909	2360
20	60	3	2021	1.4307	1.4513	6063	2060

TABLE A.24: Single Net Straw Loam Test 3

Date:	7/22/2024	
Test Total Intensity:	3.7	in.
Test Start Time:	1:45	PM
Test Finish Time:	3:45	PM

Collected Sediment Loss

Test Interval	2 in./hr	4 in./hr	6 in./hr
Dry Weight, lb	5.7	13.6	17.8
Total Dry Weight of Sediment, lb		37.0	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	5	2692	1.4106	1.4628	13460	1305
2	6	3	3902	1.4047	1.4398	11706	3510
3	9	5	2255	1.4064	1.4418	11275	2950
4	12	3	4131	1.4048	1.4422	12393	3117
5	15	3	4067	1.4246	1.4600	12201	3540
6	18	5	2397	1.4096	1.4485	11985	3242
7	21	4	3540	1.4151	1.4586	14160	4350
8	24	4	3168	1.3994	1.4393	12672	3990
9	27	3	4001	1.4161	1.4508	12003	3470
10	30	3	3450	1.4020	1.4325	10350	3050
11	33	3	3218	1.4265	1.4521	9654	2560
12	36	3	3123	1.4378	1.4639	9369	2610
13	39	3	2304	1.4412	1.4636	6912	2240
14	42	3	2415	1.5653	1.5964	7245	3110
15	45	3	2446	1.4095	1.4348	7338	2530
16	48	3	1794	1.4040	1.4254	5382	2140
17	51	3	1622	1.4228	1.4418	4866	1900
18	54	3	1290	1.4159	1.4361	3870	2020
19	57	3	1389	1.4109	1.4275	4167	1660
20	60	3	1517	1.4137	1.431	4551	1730

TABLE A.25: Single Net Straw Clay Test 1

Date:	2/21/2024	
Test Total Intensity:	3.7	in.
Test Start Time:	1:15	PM
Test Finish Time:	3:15	PM

Drive Cylinder Compaction Data

Cylinder Number	1	2	3
Test Location Number	B7	A13	B29
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	1560.0	1590.0	1700.0
Wet Weight of Soil (g)	110.0	130.0	125.0
Dry Weight of Soil (g)	80.0	105.0	100.0
Moisture Content (%)	27.3	19.2	20.0
Wet Density (lb/ft^3)	100.8	102.7	109.8
Dry Density (lb/ft^3)	79.2	86.2	91.5
Maximum Dry Density (lb/ ft^3)	88	88	88
Percent Compacted (%)	90.0	97.9	90.0
Average Percent Compacted (%)		92.6	

Collected Sediment Loss

Test Interval	2 in./hr	4 in./hr	6 in./hr
Dry Weight, lb	2.1	1.1	20.2
Total Dry Weight of Sediment, lb		23.4	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	1	0	0.0000	0.0000	0	0
2	6	1	0	0.0000	0.0000	0	0
3	9	3	327	1.3989	1.4113	981	1037
4	12	3	1604	1.4382	1.4767	4812	3208
5	15	3	494	1.4296	1.4396	1482	1000
6	18	3	3736	1.4144	1.4981	11208	6975
7	21	3	747	1.4046	1.4375	2241	3290
8	24	3	951	1.4055	1.4482	2853	4270
9	27	3	864	1.3964	1.4297	2592	3330
10	30	3	3702	1.4167	1.4824	11106	6570
11	33	3	800	1.4092	1.4438	2400	3460
12	36	3	3589	1.4108	1.4869	10767	7610
13	39	3	3729	1.4321	1.5105	11187	7840
14	42	6	2402	1.4192	1.5116	14412	9240
15	45	3	799	1.4103	1.4457	2397	3540
16	48	3	3980	1.4123	1.4950	11940	8270
17	51	3	4199	1.4048	1.4830	12597	7820
18	54	6	1984	1.4128	1.4955	11904	8270
19	57	6	1808	1.411	1.507	10848	9600
20	60	6	1385	1.4267	1.5135	8310	8680

TABLE A.26: Single Net Straw Clay Test 2

Date:	3/19/2024	
Test Total Intensity:	3.7	in.
Test Start Time:	2:45	PM
Test Finish Time:	4:30	PM

Drive Cylinder Compaction Data

Cylinder Number	1	2	3
Test Location Number	C4	B17	A27
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	1625.0	1515.0	1585.0
Wet Weight of Soil (g)	113.3	118.1	121.8
Dry Weight of Soil (g)	83.8	88.2	88.7
Moisture Content (%)	26.0	25.3	27.2
Wet Density (lb/ft^3)	105.0	97.9	102.4
Dry Density (lb/ft^3)	83.3	78.1	80.5
Maximum Dry Density (lb/ ft^3)	88	88	88
Percent Compacted (%)	94.7	88.8	90.0
Average Percent Compacted (%)		91.1	

Collected Sediment Loss

Test Interval	2 in./hr	4 in./hr	6 in./hr
Dry Weight, lb	1.3	2.5	10.2
Total Dry Weight of Sediment, lb		14.0	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	1	0	0.0000	0.0000	0	0
2	6	6	2522	1.4010	1.4915	15132	9050
3	9	6	2058	1.4187	1.4916	12348	6075
4	12	6	1849	1.4135	1.4916	11094	6508
5	15	6	1758	1.4025	1.4835	10548	8100
6	18	6	1032	1.4216	1.4784	6192	4733
7	21	6	1560	1.4044	1.4856	9360	8120
8	24	6	1433	1.4362	1.5403	8598	10410
9	27	6	1767	1.4111	1.5266	10602	11550
10	30	6	1106	1.4147	1.4784	6636	6370
11	33	6	726	1.4122	1.4560	4356	4380
12	36	6	993	1.4299	1.4960	5958	6610
13	39	6	200	1.3980	1.4047	1200	670
14	42	3	629	1.4066	1.4313	1887	2470
15	45	3	859	1.4350	1.4949	2577	5990
16	48	6	751	1.4077	1.4595	4506	5180
17	51	6	736	1.4219	1.4670	4416	4510
18	54	6	112	1.4266	1.4338	672	720
19	57	6	328	1.4331	1.4543	1968	2120
20	60	6	50.2	1.4269	1.4309	301.2	400

TABLE A.27: Single Net Straw Clay Test 3

Date:	4/8/2024	
Test Total Intensity:	3.5	in.
Test Start Time:	1:30	PM
Test Finish Time:	3:30	PM

Drive Cylinder Compaction Data

Cylinder Number	1	2	3
Test Location Number	C4	B17	A21
Depth of Soil Sample (in)	5	5	5
Volume of Soil in Drive Cylinder (in^3)	59.0	59.0	59.0
Weight of Soil (g)	2095.0	2130.0	2095.0
Wet Weight of Soil (g)	115.4	106.9	121.2
Dry Weight of Soil (g)	85.3	83.1	89.3
Moisture Content (%)	26.1	22.3	26.3
Wet Density (lb/ft^3)	98.5	100.8	98.5
Dry Density (lb/ft^3)	78.1	82.4	78.0
Maximum Dry Density (lb/ ft^3)	88	88	88
Percent Compacted (%)	88.8	93.7	90.0
Average Percent Compacted (%)		90.8	

Collected Sediment Loss

Test Interval	2 in./hr	4 in./hr	6 in./hr
Dry Weight, lb	1.2	1.7	9.4
Total Dry Weight of Sediment, lb		12.3	

TSS and Turbidity Data

Sample ID	Time (min)	Dilution Factor	Turbidity Reading (NTU)	Filter + Crinkle Dish (g)	Dry Filter + Soil + Crinkle Dish (g)	Turbidity (NTU)	TSS (mg/L)
1	3	3	2212	1.4051	1.4456	6636	1013
2	6	3	1588	1.4299	1.4612	4764	3130
3	9	3	2184	1.4128	1.4505	6552	3142
4	12	3	2520	1.4040	1.4454	7560	3450
5	15	3	2209	1.4189	1.4554	6627	3650
6	18	3	1296	1.4170	1.4471	3888	2508
7	21	3	1560	1.4085	1.4406	4680	3210
8	24	3	2111	1.4380	1.4770	6333	3900
9	27	3	1869	1.4397	1.4752	5607	3550
10	30	3	1967	1.4168	1.4552	5901	3840
11	33	3	2042	1.3880	1.4319	6126	4390
12	36	3	1869	1.4277	1.4649	5607	3720
13	39	3	1573	1.4039	1.4381	4719	3420
14	42	3	1656	1.3980	1.4409	4968	4290
15	45	3	1264	1.3843	1.4206	3792	3630
16	48	3	950	1.4139	1.4424	2850	2850
17	51	3	846	1.4258	1.4512	2538	2540
18	54	3	646	1.4176	1.4389	1938	2130
19	57	3	628	1.4288	1.4495	1884	2070
20	60	3	654	1.3985	1.4185	1962	2000