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Assessment of state highway agency approval requirements for erosion and sediment control products

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Assessment of state highway agency approval requirements for erosion and sediment control products

by

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The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this thesis. The Graduate College will ensure this thesis is globally accessible and will not permit alterations after a degree is conferred.

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DEDICATION

I would like to dedicate this work to my parents Venu Naidu Dokala and Usha Devi Kota for their unconditional support throughout this work and in my life.

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ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ADOT	Arizona Department of Transportation
AML	Approved Materials List
AOS	Apparent Opening Size
APEL	AASHTO Product Evaluation List
APL	Approved Products List
ASTM	American Society for Testing and Materials
BFM	Bonded Fiber Matrix
BMP	Best Management Practice
CCS	Cellular Confinement systems
CDOT	Colorado Department of Transportation
COC	Certificate of Compliance
CRE	Constant-rate-of-extension
CRL	Constant Rate of Load
CRT	Constant Rate of Traverse
CTR	Certified Test Report
DC DOT	District of Columbia Department of Transportation
E&SC	Erosion and Sediment Control
E&SCPs	Erosion and Sediment Control Products
ECB	Erosion Control Blanket
ECP	Erosion Control Products
ECRM	Synthetic Erosion Control and Revegetation Mats

FDOT	Florida Department of Transportation
FGM	Flexible Growth Matrix
GAI	Geosynthetic Accreditation Institute
HDOT	Hawaii Department of Transportation
HECP	Hydraulic Erosion Control Product
IA DOT	Iowa Department of Transportation
ID DOT	Idaho Department of Transportation
IECA	International Erosion Control Association
IL DOT	Illinois Department of Transportation
IN DOT	Indiana Department of Transportation
IN DOT	Indiana Department of Transportation
IRB	Institutional Review Board
KS DOT	Kansas Department of Transportation
KY DOT	Kentucky Department of Transportation
LA DOT	Louisiana Department of Transportation
Mass DOT	Massachusetts Department of Transportation
ME DOT	Maine Department of Transportation
MI DOT	Michigan Department of Transportation
MN DOT	Minnesota Department of Transportation
MO DOT	Missouri Department of Transportation
MPEL	Maryland Product Evaluation List
MS DOT	Mississippi Department of Transportation
MSDS	Material Safety Data Sheet

MT DOT	Montana Department of Transportation
NCDOT	North Carolina Department of Transportation
NCHRP	National Cooperative Highway Research Program
NDDOT	North Dakota Department of Transportation
NE DOT	Nebraska Department of Transportation
NPDES	National Pollution Discharge Elimination System
NPE	New Product Evaluation
NRCS	Natural Resources Conservation Service
NV DOT	Nevada Department of Transportation
NYSDOT	New York State Department of Transportation
OHDOT	Ohio Department of Transportation
OKDOT	Oklahoma Department of Transportation
OMM	Office of Materials Management
PAM	Polyacrylamide
Penn DOT	Pennsylvania Department of Transportation
PEP	Product Evaluation Program
PEU	Product Evaluation Unit
PI	Pre- Inspection
QCML	Qualified Product Evaluation Application
QPL	Qualified Products list
RECP	Rolled Erosion Control Product
RI DOT	Rhode Island Department of Transportation
SCDOT	South Carolina Department of Transportation

SCS	Soil Conservation Service
SDDOT	South Dakota Department of Transportation
SDS	Safety Data Sheet
SES	Soil Erosion Service
SHA	State Highway Agency
SRD	Sediment Retention Device
SRM	Soil Retention Matting
SSM	Soil Stabilization Matting
SWCS	Soil and Water Conservation Service
SWPPP	Stormwater Pollution Prevention Program
TNDOT	Tennessee Department of Transportation
TRM	Turf Reinforcement Mats
TWG	Technical Work Group
Tx DOT	Texas Department of Transportation
USDA	United State Department of Agriculture
USEPA	United States Environmental Protection Agency
UT DOT	Utah Department of Transportation
VADOT	Virginia Department of Transportation
VTDOT	Vermont Department of Transportation
WI DOT	Wisconsin Department of Transportation
WS DOT	Washington State Department of Transportation
WV DOT	West Virginia Department of Transportation
WY DOT	Wyoming Department of Transportation

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ABSTRACT

State Highway Agencies (SHAs) maintain Qualified Products Lists (QPLs) or Approved Materials Lists, which provide a means of approval for the use of selected products. These products can then be used in state and federally funded construction projects. Manufacturing companies who intend their products to be placed on QPLs apply for QPL inclusion processes required by SHAs. Often, approval processes include field evaluations and/or standardized tests. Standards-setting bodies such as the American Society of Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO) develop standardized tests. Approval processes and requirements differ across SHAs. The SHAs' QPL approval processes likewise differ from each other.

This study focused on bringing all SHAs' QPL inclusion processes and standard requirements pertaining to Erosion and Sediment Control Products (E&SCPs) to one more easily accessible location. The data collection process of this study thus included sending a survey to all SHAs; obtaining typical erosion and sediment control (E&SC) practices and QPL inclusion processes of all SHAs; obtaining standard test methods and requirements from SHAs' specifications for highways and bridges; and obtaining testing equipment price estimates from manufacturing companies. 24 SHAs participated in this survey. The data of SHAs that did not participate in the survey were collected from SHAs' official websites. In overall, 50 SHAs and DCDOT QPL E&SCPs QPL inclusion processes were collected, included in the literature review, and used in analyzing inclusion processes. In this study, 109 standardized test methods and specifications pertained with E&SCPs were collected. Out of

109, 48 test methods were selected and summarized in the literature review, and their corresponding SHAs requirements were mentioned.

A catalog that consists of all SHAs' QPL inclusion processes, requirements and standard specifications was developed online and the link is available in chapter-5. This study analyzed present SHAs' QPL evaluation processes and developed recommendations to the most current evaluation processes.

CHAPTER 1 INTRODUCTION

1.1 Background

Soil erosion and sediment-laden runoff at construction sites are among the major stormwater quality problems that are being faced by the United States. To minimize downstream impact, various preventive measures are taken by developers. Even with preventative measures, in 2000, it was estimated that the displacement of soil from construction sites is 10 to 20 times higher than that of agricultural lands and 1,000 to 2,000 times that of forest lands (USEPA 2005). The Natural Resources and Conservation Service (NRCS), United States Environmental Protection Agency (USEPA), Federal Highway Administration (FHWA), and the American Society of Civil Engineers (ASCE), recommend measures to prevent erosion and sediment runoff (ASCE 2017; NRCS 2010; USEPA 2007; USDOT FHWA 2019). The Clean Water Act (CWA) was introduced in 1972 by U.S. Congress with the objective to reinstate and retain the chemical, physical and biological integrity of the nation's waters by preventing pollutants from being introduced into stormwater. The major goals of the CWA were to: (1) eliminate the discharge of pollutants into navigable water by 1985, (2) attain water quality for the sustainability of aquatic life by 1983, (3) prohibition of discharging toxic pollutants, (4) constructing publicly owned wastewater treatment works,(5) state-wide development and implementation of area wide treatment management planning processes, (6) development of technology to eliminate the discharge of pollutants and development, and (7) implementation of programs to control pollution from non-point sources (US Senate 2002). After the CWA and the creation of the National Pollutant Discharge Elimination System (NPDES) permit program with in the CWA to control the water pollution caused by point sources, the primary regulations from the

USEPA addressed the municipal separate storm sewer systems (MS4s) and industrial discharges. Later with water quality data, it was realized that existing pollution is due to nonpoint source stormwater discharge. Therefore, the EPA passed two separate general permits (Phase I, Phase II) to minimize the stormwater pollution at construction sites.

1.2 History of Erosion and Sediment Control

In 1928, Hugh Hammond Bennett, "the father of soil conservation," and William Ridgely Chapline published a compelling article entitled "Soil Erosion: A National Menace" in the United States Department of Agriculture (USDA) bulletin . Later, Bennett pushed for the initiation of a national soil erosion program by publishing articles in magazines (Helms 2010). The USDA bulletin and articles published by Bennett convinced Congress to develop the primary federal soil erosion experiment station in 1929. The conservation of soil and water resources became an immediate high priority at the federal level after the election of President Franklin D. Roosevelt in 1932. President Franklin D. Roosevelt allocated funds for minimizing soil erosion under the "National Industrial Recovery Act" that was legislated in June 1933. In September 1933, the Soil Erosion Service (SES) was formed with Chief of the Department of Interior, Hugh Bennett. Severe dust storms between 1932 and 1935 led to crop failures and exposed the region's underlying soil to the wind. Hugh Bennett succeeded in convincing Congress to establish a permanent soil conservation agency, which resulted in the formation of the Soil Conservation Service (SCS) in the USDA under the Soil Conservation Act of 1936. In 1994, the SCS was renamed to the Natural Resource Conservation Service (NRCS) by Congress (NRCS History 2018).

In 1941, Hugh Bennett held meetings to start a new conservation group with inspired environmental conservationists. In 1943, the Soil Conservation Society of America

was started, and the first summit of the organization happened on December 12-13, 1946, in Chicago. Later in 1987, the SCS was renamed the Soil and Water Conservation Society of America (SWCS) to address both soil and water issues with the aim of broad goals (SWCS History 2018).

In the 1960s, a book called Silent Spring published by Rachel Carson discussed events that lead to air and water pollution. At the beginning of 1970, President Richard Nixon presented a 37- point message to address ongoing contamination activities and assembled a council to minimize pollution. Later, the Nixon introduced a plan with council's recommendations to Congress that would integrate several federal duties under a single agency, a new environmental protection agency that would respond to more significant environmental problems than the past government pollution control programs (USEPA Origins 2018).

In 1971, George Harrison, a Washington State hydroseeding and tree service contractor, surveyed a group of contractors to ascertain their intentions for forming an erosion control contractors group. After the success of the first erosion control conference on January 15, 1972, in Portland, OR the group ended up with the intention of forming an association of erosion control specialists. The second conference with the people from various agencies and organizations that was held on September 2-3, 1972 in Oakland, CA. After two productive conferences, the National Erosion Control Association was established with the primary goals of collecting and disseminating research, encouraging research, promoting professional skills and education, and developing industry standards. On February 18, 1972, the National Erosion Control Association was renamed to the International Erosion Control Association (IECA)(IECA History 2018).

The Clean Water Act (CWA) of 1972 was introduced by the EPA to eliminate pollutants to navigable waters that were being released by point sources (sewage treatment plant outfalls, industrial process wastewater) with an exception for the sources holding an NPDES permit. Later in 1987, with the identification of agriculture and urban stormwater runoff as pollutants for local water bodies, the Water Quality Act (WQA) was introduced and incorporated into the CWA. As a result, the EPA was obliged to create a two-phase permit model to address stormwater issues. With the attachment of the WQA to the NPDES permits, the industrial and municipal dischargers began to be required to apply the Best Available Technology Economically Achievable (BAT) on the project sites and obliged to meet the Best Conventional Pollutant Control Technology (BCT) standards and other precise requirements. (USEPA 2017 NPDES).

On November 16th, 1990 by the section of 402(p)(4) of the CWA, the EPA introduced Phase I stormwater regulations for five-point source discharge categories accountable to NPDES permit requirements such as discharger that obtained NPDES permit before February 4th, 1987. Later, the NPDES authorities discovered that the emissions from industrial and construction activities (i.e. area greater than 5 acres), discharges from large MS4s (i.e., population more than 250,000) and medium MS4s (i.e., population from 100,000 to 250,000) had also been breaching water quality standards. To generate Phase II permits, several interested stakeholders and members (private environmental groups, municipal representatives, trade associations, state regulators, and other experts) across the U.S. who were members of the Federal Advisory Committee (FAC) assisted the EPA's Phase II stormwater permits. The Phase II permits were enacted on December 8, 1999 in 402(p) (6) of the CWA. The Phase II permits covered the stormwater discharges that were

not addressed in Phase I permits such as small MS4s and small construction sites (between 1 and 5 acres). Exemptions from Phase II permits were granted to small construction projects which satisfied the waiver requirements (USEPA 2017 NPDES).

In 1989 the Natural Resources Defense Council (NRDC) along with Public Citizen, a consumer advocacy group, pressed charges against the EPA stating the failure of the agency in enacting section 304(m) of the CWA act. Therefore, in January 1992, the EPA acceded to recommend and take final action on 11 recognized point source categories and produce revised rules for eight other point source categories. Through the inclusion of a Construction and Development (C&D) category in the revised rule category, the EPA was required to produce effluent limitation guidelines (ELGs) by May 15, 2002, which required final action before April 1, 2004. The above consequences made the EPA revise and improve its regulatory options in Phase I and Phase II permits to address the emissions from construction, development and redevelopment sites. In 2004, the EPA affirmed that national ELGs would not be a potential answer for the discharges from C&D sites and switched back to the prior stormwater management rules. With the lawsuit filed by NRDC, Waterkeeper Alliance, and two states against the EPA in 2008 for not satisfying the requirements of the ELGs and New Source Performance Standards (NSPS) from the CWA, the court ordered the EPA to produce the regulations by December 2008 and use and promote the ELGs and NSPS for C&D before December 2009. The Wisconsin Builders Association, the National Association of Home Builders (NAHB), and the utility water group appealed the EPA to revise the rule due to errors found in the calculation of the ELG limit. Thus, the EPA agreed to modify the non-numeric BMP requirements and drop the numeric limit. The Final action was published and enacted in 2014 (Donald 2014; Federal Register

2014). Later in 2014, the EPA published revised ELGs for the C&D category by rectifying amendment errors in the amendatory language (Federal Register 2015).

1.3 Soil Management on Construction Sites

Accordingly, it became mandatory for construction operators to obtain an NPDES Construction General Permit (CGP) for construction activities that have the potential to cause stormwater pollution (Pitt et al. 2007). As a result, before obtaining an NPDES CGP permit, site operators are required to develop a site-specific Stormwater Pollution Prevention Plan (SWPPP). States authorized by the USEPA can grant NPDES CGP permits, while the USEPA acts as the granting authority for the unauthorized states. The SWPPP assists in identifying the origin of potential pollutants at the construction site that could affect local water bodies. The SWPPP plays a vital role in reducing the pollutants in stormwater and helps in implementing Best Management Practices (BMPs) at the construction site(USEPA 2007). One of the BMPs in the SWPPP's criteria is the application of various E&SCPs that could play a significant role in the reduction of pollutants at the construction site. State highway agencies (SHAs) oversee some of the largest construction projects due to the nature of linear construction. Construction site operators/contractors who work on SHA projects are required to apply E&SCPs on construction sites. These products are specified on Qualified Product Lists (QPLs) or Approved Materials Lists (AMLs) by the SHA, hereby referred to as QPLs. QPLs constitute a set of products that are approved by the SHAs for use on their construction projects. Manufacturing companies who intend for their E&SCPs to be on the SHA's QPL are required to pass through an approval process which may include product review, trial/demonstration processes, and/or standardized testing. American Society for Testing and Materials (ASTM) and

American Association of State Highway and Transportation Officials (AASHTO) provide standardized test methods for testing of E&SC practices and products.

1.4 Research Objectives

Manufacturers of E&SCPs apply for SHA's QPL inclusion process in all 50 states. During the consideration process, products may be evaluated and required to pass standardized tests specified by ASTM, AASHTO and specific SHA specifications. Consideration, evaluation, and approval requirements differ from state to state, and thus it can be challenging for E&SC professionals to keep track of state requirements. Therefore, the primary objective of this thesis is to develop a catalog and database tool of standardized test procedures and their requirements.

To achieve the research objective of this project, the following tasks were conducted :

- Conduct a literature review of SHA QPL/ AML inclusion processes and all associated standardized test methods such as ASTM, AASHTO and SHA-specified test procedures.
- Develop and conduct an SHA survey to collect information on QPL/ AML inclusion processes.
- Compare and analyze the erosion and sediment control products QPL approval processes amongst U.S. SHAs.
- Compile a catalog of SHAs QPL evaluation process, standard test methods related to erosion and sediment control products and practices detailing procedures, equipment, and requirements.

This report is divided into five chapters. Following this chapter, Chapter Two: *Means and Methods/ Research Methodology* outlines the methods used in collecting the

information about SHAs' erosion and sediment control practices; SHAs' inclusion processes; test methods pertinent to erosion and sediment control products; and the scope of the survey.

Chapter Three: *Literature Review* examines the erosion and sediment control practices of all SHAs, product inclusion process of all SHAs, and the standard test methods used for testing the erosion and sediment control products.

Chapter Four: *Erosion and Sediment Control Products Survey, Qualified Product Lists Inclusion Process of all State Highway Agencies, and Test Methods Catalog* presents the SHAs' QPL inclusion process survey data analysis; standard test methods and requirements; and a development of test products catalog.

Chapter Five: *Conclusions and Future Work* summarizes the findings of this report, provides recommendations, and discusses future research opportunities.

CHAPTER 2 RESEARCH METHODOLOGY

2.1 Introduction

This chapter explains how the research was conducted for each topic in this study. Various stages in this study are depicted in Figure2.1 The research started with the collection of literature relevant to all SHAs' QPL and QPL inclusion processes. Later, a survey was designed and sent to all SHAs' QPL evaluation personnel and the responses were collected. Simultaneously with the survey, a literature review was conducted for all SHAs' E&SC practices and SHAs' standard specifications and requirements pertinent to E&SC products. The overall data collection of all SHAs' QPL inclusion process and requirements in this study helped in creating a catalog. The data collection processes of various topics in this study are discussed in the following chapter sections.

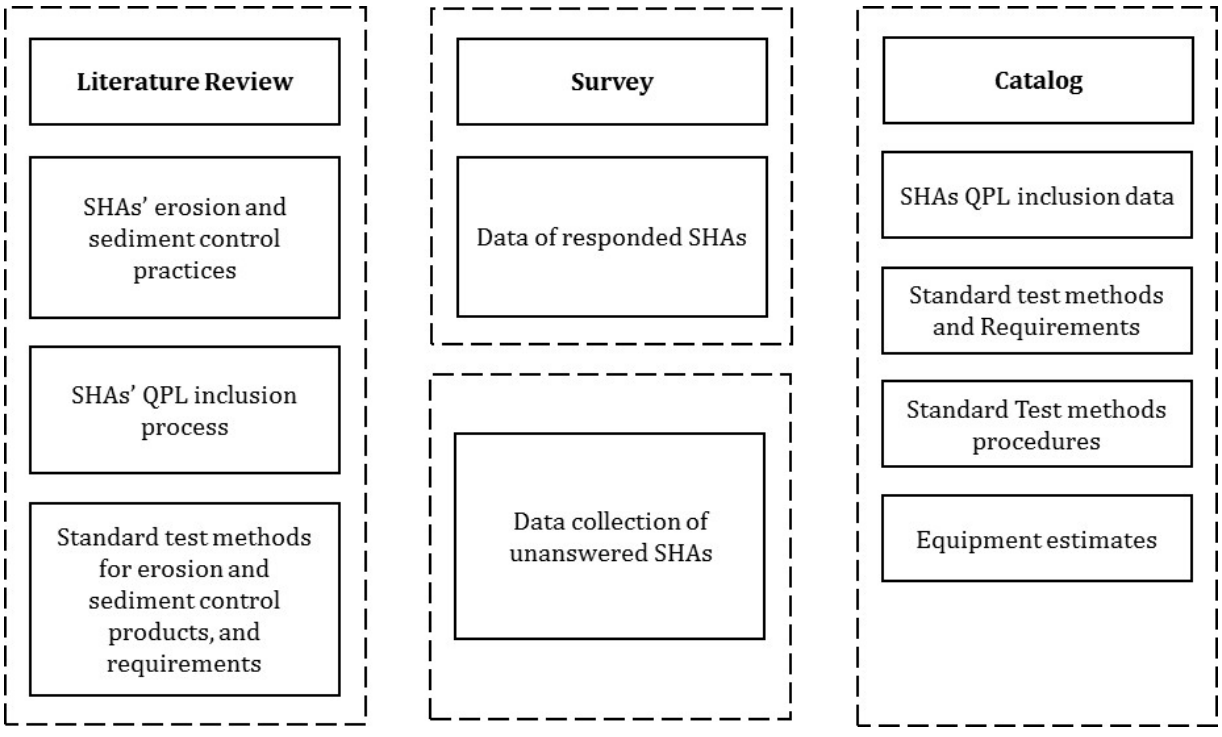


Figure 2.1 Different Stages of the Project

2.2 Literature Review

Most parts of the literature review were conducted from the SHAs' E&SC handbooks, SHAs' standard specifications for highways and bridges, QPLs published by all SHAs, and test methods and specifications published by ASTM and AASHTO for E&SCPs.

2.2.1 Erosion and Sediment Control Handbooks

SHAs' or states' environmental conservation agencies publish E&SC handbooks or manuals on a timely basis. In the handbooks, agencies publish standard E&SC practices that are applicable in their states. Such publications intended to assist designers during creation of the SWPPP plan. These publications help the designers to follow standard guidelines and various suitable E&SC practices.

The E&SC handbooks of all state agencies were collected from their official websites (e.g., DOTs and DNRs). All E&SC practices from all state agencies were put together in one place, and various unique E&SC practices are described in the literature review.

2.2.2 SHAs' QPL Inclusion Process

SHAs evaluate products before listing them on the QPL. The evaluation process begins with the application submitted by the manufacturer for QPL inclusion. The product evaluation applications were collected from all SHAs' websites. These product evaluation processes are collected and discussed in the literature review.

2.2.3 SHAs' Specifications for Highways and Bridges

SHAs publish their standard specifications for highways and bridges on a timely basis. In the specifications, the SHAs publish standard requirements of all products used in SHA projects. The products are required to pass standard test methods specified by SHAs. Most of the SHAs recommend the test methods that are published by AASHTO and ASTM.

SHAs also accept product test data published by NTPEP or any other standard test agency after testing.

2.2.3.1 Test Methods and Specifications Collection

There are two phases in the collection of test methods and specifications used in testing E&SC products. In the first phase, the search was confined to ASTM Compass and AASHTO NTPEP DataMine. Compass is a search tool developed by ASTM for searching the standard test methods. AASHTO NTPEP DataMine is a database developed by AASHTO NTPEP. DataMine publishes the testing data and audit reports of products after testing. In the second phase, the search for test methods and specifications of E&SC products were collected from SHAs' specifications. Various test methods and SHAs' requirements for E&SC products were collected. The test methods were sorted based on SHAs' requirements. After sorting, the important test methods were selected based on the frequency of usage in testing the E&SC products. Selected test methods are discussed in the literature review, and the SHAs that recommend such test methods in testing products used in E&SC practices are additionally mentioned in the Literature Review.

2.3 SHAs Inclusion Process Survey Goals and Questions

The goal of this survey is to analyze the evaluation processes for the approval of E&SC products into the QPL used on construction projects by various SHAs and federal agencies. The survey includes both general and specific questions related to SHAs' standard operating practices for evaluating products. Questions asked in this survey related to various/numerous topics including: E&SC products usage in SHAs; frequency of E&SC product section updates in the QPLs; SHAs' policy regarding allowing the usage of other SHAs' QPL listed E&SC products in projects; the qualification process in approving E&SC

products; testing program usage during evaluation; the revaluation period for QPL listed products; types of E&SC products listed on the QPL; installation details of E&SC practices; and SHAs' opinions on improving the QPL evaluation processes for E&SC products. The Institutional Review Board (IRB) in the Iowa State University approved this study, and the approval details are included in the Appendix.

The survey contains 12 questions related to product testing processes and maintenance of the QPL lists. All questions in the survey were designed in single-choice and multiple-choice formats. Most of the questions in this survey contain multiple-choice options. Some of the questions in this survey contain options for choosing more than one response that can allow participants to select more than one option if applicable to their agencies. Comment boxes were added to some questions allowing participants to explain their choices. For some questions, an 'if logic' was included to display other topic related questions if the respondents preferred to choose some specific options to the questions in the survey. The entire survey questions and responses are presented in the Appendix. total survey was designed on Qualtrics® survey software, an online survey software.

Two to three product testing personnel were identified from each of the official SHA websites. The main idea to identify more personnel from each SHA was to increase the response rate.

The survey was sent through email to all SHAs and DC DOT personnel. The responses of the survey were finalized based on the completion; incomplete responses were not considered for the final analysis. In some cases, two to three different personnel from each SHA answered the survey. In such cases, multiple responses from the SHA were consistently condensed into a single response. The responses were considered complete if

the personnel mentioned the identity of their SHA and finished the entire survey without including their information at the end.

The data analysis conducted in this study are of two kinds. The first type of analysis is done with SHAs' survey responses. In the second type of analysis, the information from unanswered SHAs was gathered and combined with the survey data to present overall SHAs' E&SC product evaluation processes. The information of unanswered SHAs was collected from their official websites.

2.3.1 Survey analysis

The data collected from the responded SHAs was analyzed using Microsoft Excel software. The responses of each question were analyzed, and the results were visualized through bar graphs and maps of the United States, showing individual state characteristics. The maps are included in Chapter 4. Bar graphs help in understanding the results on a nationwide basis, whereas portraying the results on the U.S. maps help in understanding the product evaluation characteristics of each SHA.

2.3.2 Data collection of non-responsive SHAs

The relative data of unanswered SHAs were collected from SHAs' official websites. After the survey analysis discussion, the overall data collected from the survey, including that of unanswered SHAs, were analyzed together and are discussed in Chapter 4.

2.4 Cost estimates of the equipment required for testing

The cost estimates of the primary equipment required for testing E&SCPs are presented in this thesis and included in Chapter 4. The cost estimates are discussed only for selected test methods. The data was collected from websites and by contacting the testing equipment manufacturing companies.

2.5 Database/ Catalog

The main purpose in creating a clearinghouse database was to provide all data related to SHAs' QPL evaluation processes and tests conducted during evaluation at a single place. This database enables personnel pertaining to the E&SCPs industry to understand different SHA evaluation programs. E&SCPs manufacturers and researchers can understand different SHA QPL approval processes and specifications for each standardized test during evaluation. Figure 2.2 shows the process involved in creating the database

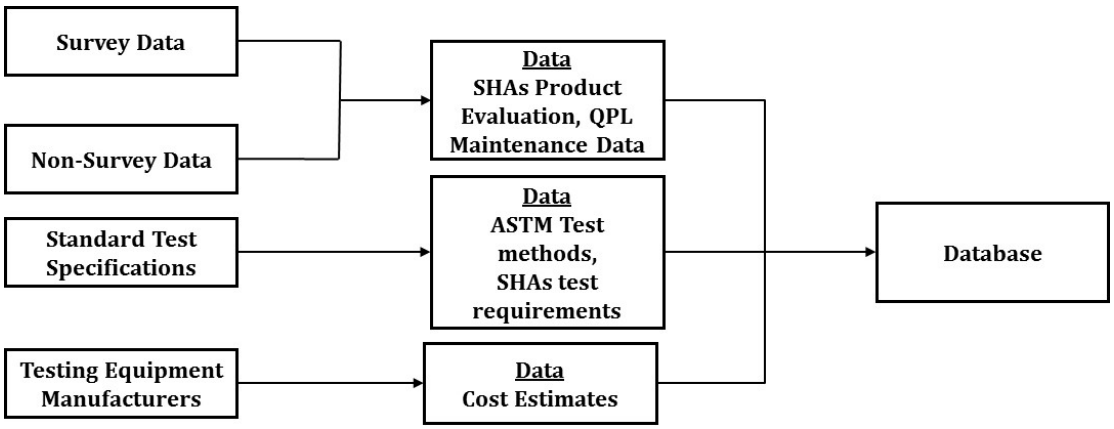


Figure 2.2 Database Creation Process

The database was created with two online tools. The data was loaded into an online website called Caspio, which helps non-technical professionals to create database-centric web applications without coding. Uniform Resource Locators (URLs) generated from the data in Caspio were loaded onto the webpage created with WIX, an online website builder. Figure 2.3 shows the tools used for database creation.

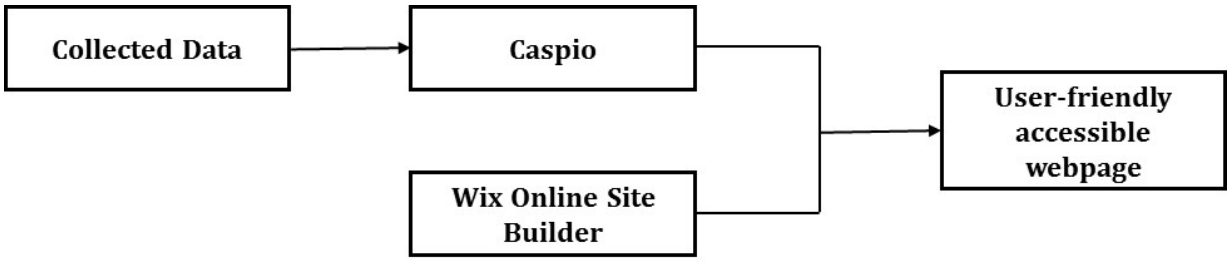


Figure 2.3 Database Creation Tools

2.6 Summary

This chapter summarizes how the literature review relates with various E&SC practices, SHAs' QPL inclusion processes, and SHAs' standard specifications and requirements. The development process of the survey, data collected from SHAs that participated in the survey, data collected from SHAs that did not answer the survey, and data analysis in general are discussed in this chapter. Moreover, data collection processes for testing equipment cost estimates is explained. Finally, the process involved in the creation of a database or catalog is explained.

CHAPTER 3 LITERATURE REVIEW

3.1 NPDES Stormwater Program

The NPDES permit program started with the Clean Water Act (CWA) legislation in 1972. The NPDES permit authorizes a discharger to release a certain amount of pollutant into receiving water bodies. There are individual and general NPDES permits. Individual permits are for individual facilities. Authorities develop permits based on activity type, discharge nature, and discharging water quality. Authorities sanction individual permits for a limited period (i.e., not more than five years) and dischargers are required to reapply after the date of expiration. Authorities issue general permits for a group of identical dischargers within a geographical location. Permitting agencies consider the general permit as a cost-effective permit, as it covers the identical group of discharging facilities in a given geographical location (USEPA 2018a).

According to the CWA Sections 402(b) and 40 CFR part 123, states, tribes, and territories can grant permits after receiving authorization from the NPDES program. To obtain authorization for governing the NPDES program, states, tribes and territories need to submit an application to the EPA. The EPA authorization process contains public review, a comment period, and a public hearing. A state can receive authorization access on one or more components of the NPDES program. The five components are granting NPDES permits, regulating federal facilities, authorizing State pretreatment, general permits and bio solids programs. The EPA continues as permitting authority for that state, tribe, or territory if authorization is declined. The EPA also remains permitting authority for program components that are not granted to corresponding state agencies. The EPA can

sanction NPDES permits on tribal lands if tribes do not have their own NPDES program, even though the states have an NPDES authorization.

As of 2015, the EPA has authorized 46 states to execute the NPDES program as of 2015. Figure 3.1 depicts the status of state's NPDES program authorizations. Later in 2018, EPA gave fully authorized status to the state of Idaho. By July 2021, Idaho will become full authorized state to execute NPDES program (USEPA 2018b.).

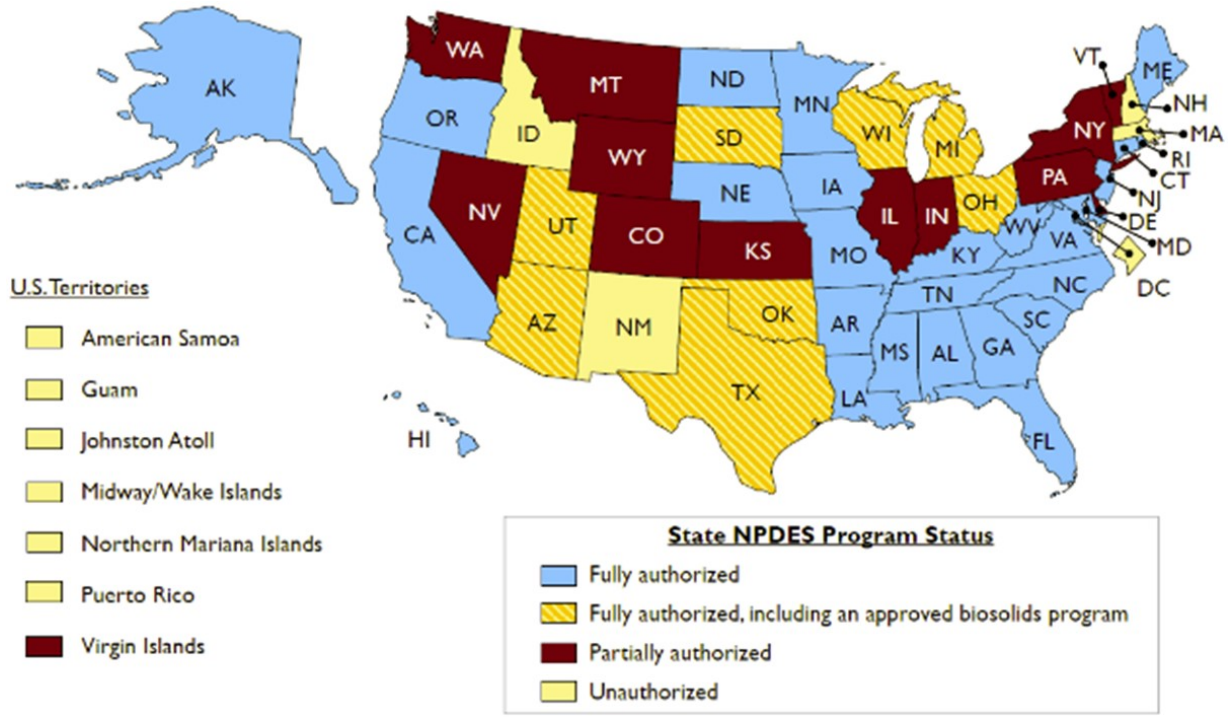


Figure 3.1 SHAs' NPDES Program Status (USEPA 2015).

The EPA and individual states perform continuous oversight activities that could enhance program governance. According to EPA regulations, a citizen can request the EPA to remove state's authority to manage the NPDES program. After receiving a petition, the EPA works with the petitioner and state agency to solve concerns raised and bolster state NPDES programs (USEPA 2018b).

3.2 Stormwater Pollution

Stormwater runoff occurs when rainfall and snow/ice melt, flow over land, paved streets, parking areas, rooftops, etc. It carries pollutants such as sediment, debris, dirt, oils, and chemicals to nearby water bodies. Therefore, construction contractors, industries, and communities are required to utilize best management practices (BMPs) to reduce pollutants from stormwater released into nearby water sources. The NPDES stormwater program manages stormwater discharges from three potential sources including: MS4s, construction, and industrial activities (USEPA "NPDES Stormwater Program" 2018). This section highlights various practices that commonly used by SHA's.

3.3 Site Preparation Practices

To direct contractors and implement possible standards in construction sites, most SHAs in the U.S. publish stormwater manuals to minimize soil erosion and sediment runoff. Most SHA stormwater manuals consist of general planning concepts, E&SC guidelines, state laws, information about SWPPP components and site preparation guidelines. Even though all SHAs work toward controlling soil erosion and sediment runoff, each SHA differs concerning how to minimize stormwater runoff. The primary goal of this section is to provide a general overview of SHAs' E&SC practices, SHAs' QPL evaluation process, and standard erosion and sediment product test methods.

3.3.1 Scheduling and Phasing

Scheduling during land development phase can impact onsite erosion. A well-coordinated schedule during land-disturbing activities and application of suitable E&SC practices according to schedule can help in reducing onsite erosion. Considerations (NCSCC, NCDENR, NCAECS 2013). Coordination between construction phasing and

scheduling during land development activities can decrease land disturbance, which can reduce soil erosion (TDOT DM 2012a). Considerations for scheduling during construction are mentioned in the table 3.1.

Table 3.1 Construction Activities and E&SC Applications Schedule Considerations(NCSCC, NCDENR, NCAECS 2013)

Construction Activity	Schedule Consideration
Construction Access: Construction entrance, routes, equipment parking areas.	Bare areas are required to be stabilized immediately with gravel and temporary vegetation as construction begins.
Sediment traps and barriers.	Installed after construction site is accessed
Runoff Control: Diversions, perimeter dikes, water bars, and outlet protection.	Installed after principal sediment traps and before land grading
Runoff Conveyance system: Streambank stabilization, storm drains, channels, inlet and outlet protection and slope drains.	Installed at required places, stream banks should be stabilized as soon as possible, applied along with runoff-control measures, Installed rest of the system after grading
Land clearing and grading: Site preparation	This should be done after installation of principal sediment and key runoff-control measure. Additional measures are applied during grading.
Surface Stabilization: Temporary and permanent seeding, mulching, sodding, and riprap	Applied temporary or permanent measures on all disturbed areas where work is delayed or complete.
Building construction	Installation of required E&SC practices as work progress.
Landscaping and Final stabilization: Topsoiling, trees and shrubs, permanent seeding, mulching, sodding, and riprap	Final construction phase-stabilizing all open areas and removing and stabilizing all temporary areas.

3.3.2 Stabilized Construction Entrance/ Exit

Vehicles driven on or near construction sites can continuously disturb graded areas specified at sites for vehicle transport and parking which can lead to soil erosion. Wet weather conditions can make construction sites swampy and inaccessible. During such conditions, wheels of construction vehicles can displace high amounts of sediment to neighboring areas (ASCE 2017). To address road stabilization problems, most SHAs and other state environmental agencies recommend various road stabilization measures to control erosion and sediment movement. Tires of vehicles exiting from construction sites can pose a problem by displacing a large amount of sediment to adjacent off-site roadways.

Maintaining stabilized construction exits and scheduling deliveries within available working personnel's time for assistance can help in reducing offsite vehicle tracking of sediment from project areas (Texas DOT SWFI Guide 2004).

Stabilized construction entrances/exits consist of a temporary pad of aggregate with a geotextile underlay(DC DEE 2017). This measure helps minimize track-out by physically agitating and removing soil from rubber tires, thus minimizing displacement onto public roadways (Alaska DEC 2012).

Stabilized construction entrance/exit pads should be applied where construction vehicles have 25 or more trips a day from sites to paved roads or paved areas within 100 feet from construction sites. This measure can minimize sediment transport into local storm sewer systems. The NPDES 1200- CA permit specifies that each construction site should have graveled, paved construction entrance/exits and parking areas (OR DOT ECFM 2006). Figure 3.2 provides a typical schematic diagram for a construction entrance/ exit pad.

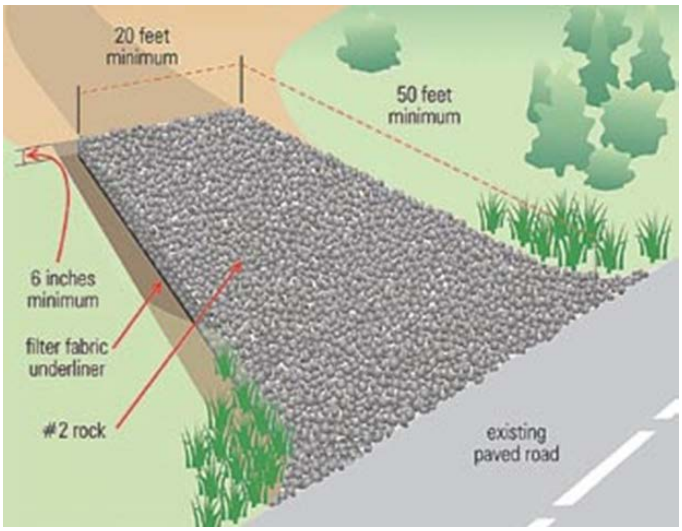


Figure 3.2 Stabilized Construction Entrance/Exit Pad (Scott et al. 2004).

3.3.3 Tire Wash Facility

Tire wash racks or tire wash stations assist in removing sediment from vehicle tires before leaving project areas (DC DEE 2017). This practice is suitable when there is a limited space for stabilized construction entrances/exits or for sites where there is a high scope of sediment attachment to vehicle tires (Nevada DOT SWQM 2017). Figure 3.3 provides a typical schematic diagram for tire wash facility.

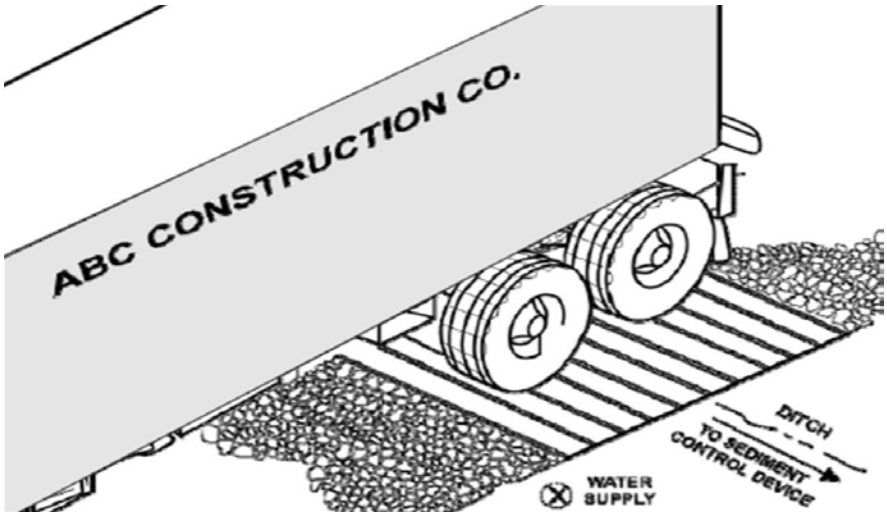


Figure 3.3 Tire Wash Facility (Nevada DOT SWQM 2017)

3.3.4 Surface Roughening

Surface or slope roughening is a method of developing horizontal grooves, furrows, and depressions to reduce velocity of runoff, increase infiltration, control erosion and trap sediment. Surface roughening helps in growth of vegetative cover and creates an adequate environment for seedlings to grow. Flow diversion may be used to avoid erosion during time of vegetative establishment (Idaho DEQ SBMP 2005a).

Surface roughening in the southeast U.S is often referred to as "tracking," and this technique helps in applying fertilizer, lime, and seed during hydroseeding (Alabama SWCC 2009). Surface roughening can be done through disking, furrowing raking and tracking

(Nevada DOT SWQM 2017). Roughening can temporarily stabilize soils that are being exposed due to construction activities and it is a productive technique to minimize erosion on infertile lands (OR DOT ECFM 2006). Most states recommend surface roughening for slopes that are steeper than 3:1. Figure 3.4 provides a schematic diagram for a surface roughening practice on slopes.

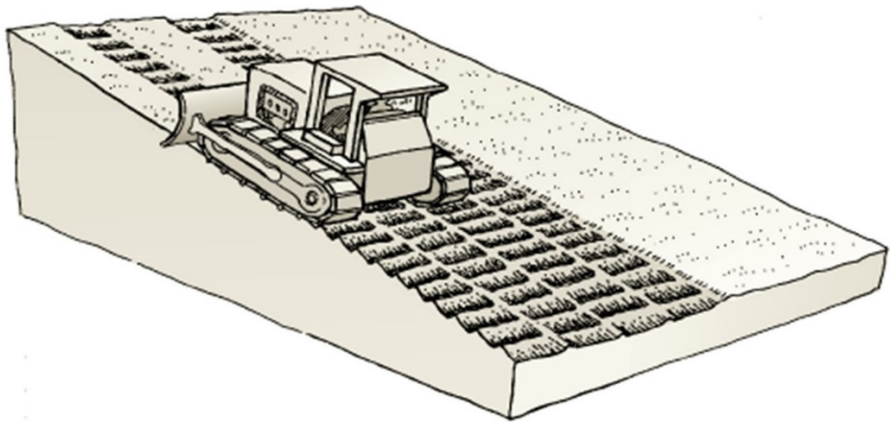


Figure 3.4 Surface Roughening Practice on Slopes (OR DOT ECFM 2006)

Land imprinting is an erosion control practice is similar to soil roughening applied on soil surfaces with a combination of final grading, seeding, and revegetation. In this technique to track soil surfaces, horizontal grooves will be created by mechanical equipment (NM DOT 2012).

3.3.5 Limitation of Disturbed Area

Construction activities such as stockpiling, filling material, hauling roads and staging disturb soils and increase the rate of erosion and sediment runoff. Limiting disturbed soils and reducing exposure time can prevent erosion and sediment runoff (Arkansas SH&TD 2016).

3.3.6 Dust Control

High winds at construction sites can raise un-stabilized soil to atmosphere, and dust can cause on-site damage, off-site damage, health hazard to humans, plant life and wildlife

and decrease traffic visibility. Identifying and reducing wind-generated sources that create dust during construction activities, temporary soil protection methods, seeding, mulching and slope protection can control dust (CT DEP 2002). Figure 3.5 shows watering practice for dust mitigation at a construction site.

Figure 3.5 Watering at a Construction Site to Control Dust (TDOT DM 2012b)

3.3.7 Land Grading

Land grading is reshaping of ground surface, excavation, or both, to obtain planned grades. The main purpose of land grading is to minimize surface runoff, reduce erosion, and establish vegetative cover to graded surfaces (CT DEP 2002).

3.3.8 Topsoiling

Topsoiling is a process of removing and preserving topsoil before construction begins and using it on areas that require vegetation growth. Topsoiling practice is suitable on project sites that are disturbed by excavation, compaction, or filling activities (Alabama SWCC 2009). Figure 3.6 shows topsoiling practice at a construction site.

Figure 3.6 Topsoiling Practice (Iowa DOT 2017)

3.3.9 Stockpile Management

Stockpile management is a practice to contain stockpiled soil in one place and to prevent sediment from running off into nearby waterways. Runoff from stockpiles can be prevented by using perimeter barriers such as silt fencing, berms, sandbags, or dikes (SDDOT CFM 2004). Figure 3.7 shows a stockpile management practice using plastic sheeting and perimeter barrier at a roadside construction area.

Figure 3.7 Stockpile Management at a Construction Site (RI SCC 2014).

3.3.10 Preserving Natural Vegetation

Land development phase in construction projects may increase runoff and cause erosion. To reduce such effects, natural vegetation on job sites should be preserved whenever it is possible. Preserving existing vegetation within construction site right-of-way can reduce soil erosion, sediment transport, and soil tracking from project sites (Arizona DOT 2012; Nevada DOT 2017).

3.3.11 Protection of Adjacent Property

Adjacent properties of land development sites should be preserved from sediment runoff. Vegetated buffer strips around development sites and establishing perimeter controls such as sediment barriers, filters, dikes, or sediment basins can help in protecting adjacent properties (Utah DOT TM 2004).

3.4 Mulching

Mulching is an erosion control practice to protect soil surface by applying straw or appropriate plant materials (DC DEE 2017). Mulch reduces evaporation and weed growth, enhances plant growth, and protects soil surface from forces of raindrop impact and overland flow (NCSCC, NCDENR, NCAES 2013). Specifications of different kinds of mulches used in the federal or state construction projects differ from each SHA to another. Temporary mulching is applied to prevent unused project lands from soil erosion during construction time. During temporary mulching, mulch or a combination of cover crop and temporary seeding can be applied to achieve short-term stabilization (NDOT- DDECM 2006). Permanent mulching is applied in final stages of construction to disturbed areas which are not covered by structures and materials (Missouri DOT SSHS 2018).

3.4.1 Types of Mulches

Dry and Wet mulches are two types of mulch categories. Dry mulches contain organic or inorganic materials such as weed-free hay or straw and wood or bark chips. Wet or hydraulic mulches consists of organic materials and are often applied with hydraulic equipment.

3.4.1.1 Dry mulch

Straw and hay mulches come under dry mulch category prevent erosion and promote seed germination. Application rates should be modified to relevant slope, soil conditions, season and other factors to achieve long term cover. Due to incorrect application, dry mulch can be prone to wind or surface erosion(WY DOT 2011). Straw or Hay mulch requires anchoring to prevent displacement from wind or flowing water (NH DES 2011). Anchoring can be done with punching, crimping mulch into soil or tracking with a punch roller or a knife blade roller (Maine DEP 2016). Figure 3.8 shows dry mulch application after anchoring. Figure 3.9 depicts dry mulch anchoring process.

Figure 3.8 Land after Dry Mulch Application (WY DOT 2011).

Figure 3.9 Dry Mulch Anchoring Process (Iowa DOT 2017).

3.4.1.2 Compost mulch

Composted mulches improve growth of vegetation and reduce soil erosion. The main purpose of compost mulching is to maintain soil moisture and increase seed germination and seedling development. Compost mulching protects soil from wind and water erosion, and delivers temporary surface stabilization (Indiana DEM 2007). Figure 3.10 shows compost mulch application process.

Figure 3.10 Compost Mulching Process (Indiana DEM 2007)

3.4.1.3 Hydraulic mulch

Hydraulic mulch (hydromulch) is a mixture of cut or shaved wood fiber, cellulose fiber, blender fiber, or a bonded fiber matrix, and a stabilizing emulsion or tackifier. Stabilizing emulsion or tackifier helps in binding hydromulch mixture. Hydraulic mulch can be applied with hydro-mulching equipment that ensures temporary erosion protection, increases infiltration, protects against dust, and encourages vegetation growth (Nevada DOT SWQM 2017). Hydraulic mulch maintains soil moisture and gives uniform and temporary slope stabilization economically (SDDOT CFM 2004). Hydro mulching can quickly stabilize areas that are harder to reach and slopes greater than 3H:1V (MN DOT ECH 2006). Hydraulic mulch loses its effectiveness after a year and is only suitable for physically stable slopes (Idaho DEQ 2005b). Wood fiber hydraulic mulches last for a part of growing season, require 24 hours or more to dry, and should not be applied before rainfall. Hydraulic mulch can only be effective on areas where there is no planned future earthwork activities (Caltrans 2017). Spray-on mulch blankets contain fibers bonded by adhesives and photodegradable synthetic fibers(CDOT 2011). Figure 3.11 shows a slope after application of hydraulic mulch.

Figure 3.11 Slope after Application of Hydraulic Mulch (Caltrans 2017)

3.4.1.3.1 Short, Moderate, and Long-Term Hydraulic Mulches

Short-term, moderate-term, and long-term mulches are to be applied with a hydromulcher and mixed with seed and fertilizer. Short and moderate term mulches require a curing time of 24-48 hours, whereas long-term mulch require 2-4 hours of curing time. No three mulches can control concentrated flows. Life span of short-term mulch is 3-6 months, moderate mulch is 6-12 months, and long-term mulch is 12-18 months under normal conditions (WS DOT 2014). Applying mulch with seeds on soil surface can function as short-term non-living protection. Mulch anchor seeds and act as cover for seeds during extreme weather conditions (CT DEP 2002).

3.4.1.3.2 Wood mulch

Wood mulch is a mix of shredded bark, wood chips, or tree trimmings that provides temporary cover and stabilizes landscapes. Conditions of project sites influence selection of relevant wood mulch and it is essential to obtain permission from regional landscape architects before applying at project sites (Caltrans 2017). Some disadvantages of wood mulch are that it can instigate unwanted weeds, light weight wood mulch can be prone to

erosion during rainfall, and heavy winds might carry it away from installed areas (Nevada DOT SWQM 2017).

3.4.1.3.3 Pellet mulch

Pellet mulch is comprised of shredded recycled paper compressed in shape of pellets. Pellets lose their shape after watering and form a thin layer to provide protective cover. Pellet mulch gives best results on flatter areas such as turf grass (Penn DOT 2012).

3.4.1.3.4 Flexible Growth Matrix (FGM):

Flexible growth matrix (FGM) is made from combination of chemical and mechanical bonding techniques that help in keeping matrix in one place. FGM consists of manufactured fibers, organic fibers, and performance-enhancing additives that help in developing a lofty and interlocking matrix. Airspaces and water- absorbing cavities in FGM help in enhancement of seed germination, decrease effect of rain drop energy on seeds, and reduce soil loss. FGM can be applied on slopes until 2H: 1V, as an infill for TRM on slopes higher than 2H: 1V, on environmentally sensitive areas, and on sites that need immediate protection, a high factor of design safety, fast vegetation, or one year soil protection (SC DHEC 2005). Figure 3.12 shows application of flexible growth matrix on a slope.

Figure 3.12 FGM on Slope after Application (Construction ECO Services 2019)

3.4.1.3.5 Bonded Fiber Matrix (BFM):

Bonded fiber matrix (BFM) consists of non-toxic, degradable, enlarged fiber particles that are contained together by water insoluble bonding agents. BFM does not obstruct plant growth, has a high water-holding capacity that minimizes direct impact of raindrops on soil, and helps eliminate spaces between product and soil. BFM can be applied on slopes up to 1H: 1V, sites that require a life span of 6 months or less, and areas that do not have heavy rainfall (SC DHEC 2005). Figure 3.13 shows the closer look of bonder fiber matrix after application.

Figure 3.13 Bonded Fiber Matrix after Application (Ecosorb International 2019).

3.4.2 Rolled Erosion Control Products

Rolled Erosion Control Products (RECPs) are either manufactured or fabricated products intended to decrease soil erosion and enhance vegetation growth. There are three types of RECPs: Erosion Control Blankets, Nettings, and Erosion Control Mattings (NCSCC, NCDENR, NCAECS 2013).

Erosion control blankets are made of straw, jute, wood or other plant fibers to minimize erosion with an immediate protective cover to soil surfaces. ECBs are efficient on slopes and channels where erosion rate is high and plant growth is low. ECBs are often used as an alternative to mulching, as they provide a fixed layer of erosion protection. Important factors that influence selection of ECBs are soil conditions, slope steepness, slope length, type and duration of protection needed to vegetation growth, and probable sheer stress (Alabama SWCC 2009). According to the USDA Soil Survey, ECBs are recommended for use on slopes steeper than 3H:1V or more, and soils with higher hazard ratings. ECBs are applied on areas where other BMPs cannot be used, slopes and

shorelines adjacent to waterways or environmentally sensitive areas, and areas at shoulders where traffic can blow away mulch (Illinois DOT 2010). Based on application and usage, erosion control blankets are divided into temporary and permanent erosion control blankets.

3.4.3 Temporary Erosion Control Blankets

Temporary ECBs are made of natural fibers that decompose quickly and help in controlling erosion. Temporary ECBs protect seeds from displacement due to rainfall impact, and retain moisture, enhance germination and distribute runoff (Mississippi DEQ 2011). Figure 3.14 shows application of erosion control blankets on a slope.

Figure 3.14 Slope after Application of Erosion Control Blankets (Caltrans 2017).

3.4.4 Permanent Erosion Control Blankets

Permanent ECBs are also called permanent soil reinforcing mats or turf reinforcement mats. They are made of synthetic materials that forms multi-layered matrix. Overtime, roots pierce into matrix of blankets and become attached to blankets. Vegetation growth on surface assists in reducing high-velocity water flows. Matrix structure in permanent ECBs stops sediment runoff from high velocity flows (Mississippi DEQ 2011).

3.4.4.1 Turf reinforcement mats (TRMs)

Turf reinforcement matting is a synthetic, three-dimensional flexible geotextile product that can stabilize soil surface permanently. TRMs provide structural support and enhance vegetation growth on low survival areas. The three dimensional matrix of TRMs binds with roots and strengthens soil matrix (Maine DEP 2016; SC DHEC 2005). Table 3.2 provides information about different kinds of TRMs based on application, calculated design shear stress, and design flow velocity. Figure 3.15 shows the application of TRM on steep slopes, different layers of TRMs.

Table 3.2 Types of Turf Reinforcement Mats *(SC DHEC 2005)*

Types	Application	Calculated Design Shear Stress	Design Flow Velocity
Type 1	2H:1V or flatter	4.0 lb./ft^2 or less	Up to 10 fps
Type 2	1.5H:1V or flatter	6.0 lb./ft^2 or less	Up to 15 fps
Type 3	1H:1V or flatter	8.0 lb./ft^2 or less	Up to 20 fps
Type 4	1H:1V or greater	Up to 12 lb./ft^2	Up to 25 fps

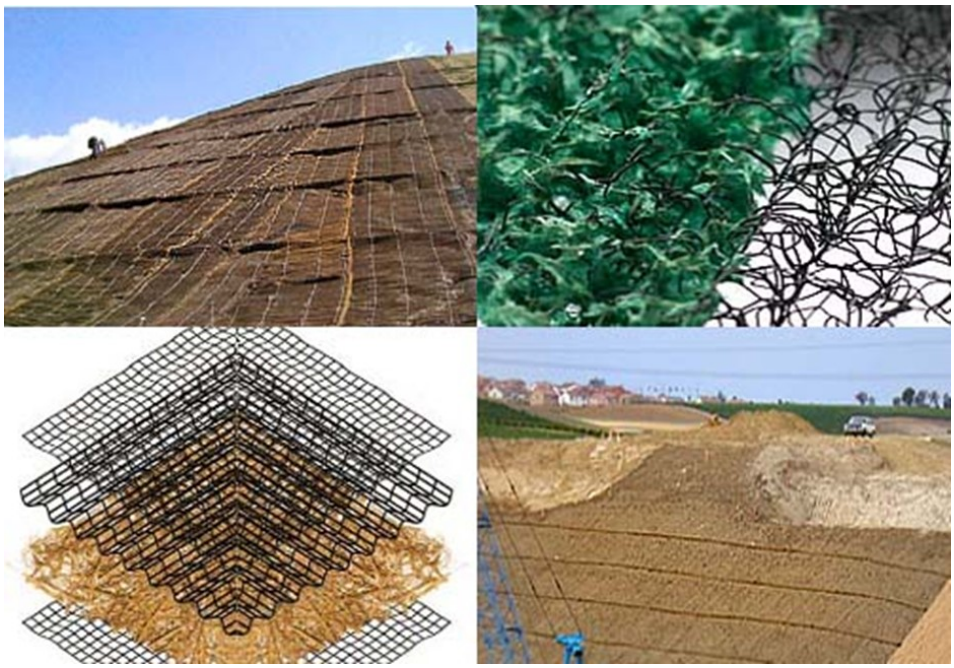


Figure 3.15 Structure of a TRM and TRMs on Slopes after Application (Caltrans 2018).

3.4.5 Loose Stabilization Blankets

Loose stabilization blankets are made of various materials applied on developed planting areas to minimize rain splash and sheet erosion and enhance vegetative stabilization. Loose blankets are suitable for rocky, frozen, flat or steep surfaces. Loose blankets can be utilized on streambanks, road cuts and embankments. Loose blankets minimize stormwater runoff as sheet flow at construction sites (New York DEC 2016).

3.4.6 Compost Blankets

Compost blankets are used to stabilize slopes, prevent erosion and develop vegetation at construction sites. Compost blanket application is a temporary erosion control practice and helps in establishing permanent vegetative cover. Compost blankets can be used on rocky slopes and shallow or infertile soils for vegetation growth. Compost blankets are inapplicable in frequently flooded areas (DC DEE 2017). Figure 3.16 shows the application of compost blankets on steep slopes.

Figure 3.16 Compost on Slopes Covered by RECPs (Caltrans 2019a).

3.4.7 Organic Erosion Control Blankets/ Mats:

Organic ECBs/ Mats are non- woven blankets, bio- degradable mesh mats or organic materials attaching both sides with netting. Organic ECBs/ Mats protect seeded area from effect of rain drops and help in reducing potential washout of seeds (Penn DOT 2012).

3.4.8 Erosion control and High Velocity Erosion Control Mulch Blankets:

Erosion control mulch blankets consist of organic, biodegradable mulches fixed to one side of netting, whereas high velocity erosion control mulch blankets contain mulch on both sides. The life span of these blankets varies between one to two years based on presence of organic matter around mulch layer (Penn DOT 2012).

3.5 Chemical Stabilization:

Chemical stabilization is an erosion control practice that requires use of chemical products that hold soil particles to one place and protect soil surface from wind and water erosion. Chemical products such as soil binders, soil stabilizers and water-soluble polyacrylamide are used for this process. Chemical products are applied along with temporary seedlings or at mulching areas that require extra protection against erosion. Chemical stabilization products are not productive in concentrated flow areas (Alabama SWCC 2009).

3.5.1 Soil Binders

Soil binders are used on exposed soil surfaces at construction sites that are prone to water-induced erosion. Soil binders can be a short-term erosion control practice for controlling soil, wind and dust erosion. A soil binder's performance depends upon temperature, humidity and traffic at applied areas. There are various types of soil binders, some of them are short-lived plant-based soil binders, long-lived plant-based soil binders,

polymeric emulsion blends, and cementitious-based binders (Caltrans 2017; Illinois DOT 2010). Figure 3.17 shows the application of soil binder along with mulch on land surface.

Figure 3.17 Application of Soil Binder along with Mulch (USDA 2014).

3.5.2 Soil Stabilizers/ Dust Palliatives:

Soil stabilizers and dust palliatives are water soluble materials combined with water to spray on disturbed soils that can create a sub-base which helps in reducing air pollution at construction sites. Various commercial soil stabilizers and dust palliatives such as fiber reinforcement, polymer products, organic non-petroleum-based products, enzymes and clay additive products are available based on type of application. To reach full potential, soil stabilizers and dust palliatives require a curing time of 24 hours or the time recommended by manufacturer. The application of these substances can reduce infiltration and plant growth. Performance of soil stabilizers and dust palliatives can differ under low humidity conditions, low temperatures, and constant rainy conditions (Nevada DOT SWQM 2017). Figure 3.18 shows the application of dust palliatives on gravel roads.

Figure 3.18 Dust Palliatives Application on a Gravel Road (Alaska DAQ 2012).

3.5.2.1 Soil stabilizer type- B (Land application of polymers)

Type-B soil stabilizers are efficient in stopping construction site erosion. This type of application can protect sites during winter, as the weather can prevent seed germination. Type-B soil stabilizers can be effective in rough grading operations, phased construction projects, winter shutdown sites, etc. Type- B soil stabilizers can lose their effectiveness in two to six months due to weather condition and ultraviolet light exposure (WI DOT FDM 2013).

3.5.2.2 Compost combined with binder/ stabilizer

During turf establishment, applying a mixture of binder/ stabilizer and compost on soil surfaces stabilizes compost and reduces soil erosion. Compost with binder/ stabilizer mixtures are applicable on hard ground surfaces or poor soil nutrient content that requires vegetative establishment, and soil surfaces that require temporary protection prior to permanent stabilization (Illinois DOT 2010).

3.5.3 Polyacrylamide (PAM):

Polyacrylamide (PAM) is a long- chain organic polymer used for short-term erosion and sediment control on construction sites and agricultural sites. Cationic PAM is harmful to aquatic life, so anionic PAM is preferred. Different PAMs are available in emulsions, powders, gel bars, or logs. Application of PAM improves soil particle cohesion, and resists shear-induced detachment and sediment runoff. PAM increases pore space and infiltration capacity of soil particles. PAM can hold large amounts of silt, clay or colloidal soils. PAM is often recommended in addition to other E&SC practices rather than a sole practice. PAM can be applied on inactive rough graded soils, final graded soils, and temporary haul roads before installment of crushed rock surfacing, compacted soil road base, construction staging, material storage layout areas, soil stockpiles, areas that require mulching, and recently excavated traps and basins. Ultraviolet exposure and delay between product mixing and application might reduce performance of some products (DC DEE 2017; Illinois DOT 2010; SC DHEC 2005).

3.5.4 Tackifier

Tackifier is a chemical substance mixed with mulch before it is applied on soil surface. Most mulch materials are susceptible to wind erosion or sliding downslope. Application of tackifier with mulch helps in anchoring mulch to ground surface and retains moisture(Georgia SWCC 2016).

3.5.5 Flocculants/Coagulants:

Flocculants/ Coagulants are chemicals used to separate suspended solid particles from water. Flocculants reduce turbidity level of stormwater discharges from construction sites. Addition of flocculants into to turbid construction water streams settles clay or silt

particles immediately. Flocculants can be an immediate solution where vegetative stabilization practices and sediment traps are ineffective or extra treatment to discharged water is needed (Georgia SWCC 2016).

3.5.6 Active Treatment Systems:

An active treatment system (ATS) is a treatment system that contains automatic chemical dispensing, mechanical aeration, pumps and/or mechanical filtration that uses chemical coagulation, chemical flocculation, or electrocoagulation to decrease turbidity (Alaska DEC 2012). Figure 3.19 shows ATS plant at a construction site.

Figure 3.19 Active Treatment Systems Plant at a Construction Site (Active Treatment Systems 2019).

3.6 Slope treatment

Slope stabilization reduces soil erosion and sediment runoff from slopes, reduces chance of potential slope failure, and guards soil surface from erosive forces of concentrated runoff. Slopes can be stabilized either temporarily or permanently based on the requirements. Riprap, stone aggregates, erosion control blankets, geotextiles, cellular confinement systems, gabions and articulating blocks are some materials used for slope stabilization practices (RI SCC 2014).

3.6.1 Riprap Protection

Riprap is a permanent erosion control practice that consists of large, loose, angular stone. Riprap protects soil surface from erosive forces of concentrated runoff, high velocity stream flows and wave action. Riprap reduces high velocity stream flows, increases infiltration, and stabilizes slopes that have seepage problems and enhances soil structure. Riprap can be used on cut –and-fill slopes that are bound to seepage or weathering and during conditions that resist vegetation growth (NCSCC, NCDENR, NCAES 2013; CT DEP 2002) .

For lengthy slopes, large stones are recommended to use at embankment bases with stones gradually becoming smaller towards top. Slope stabilization with riprap consists of a surface armor layer of rough and angular rocks, a filter layer that protects soil surfaces from washing, and toe protection strengthens slope and blocks movement of riprap (Maine DEP 2016). Figure 3.20 provides a typical schematic diagram for riprap protection on slope

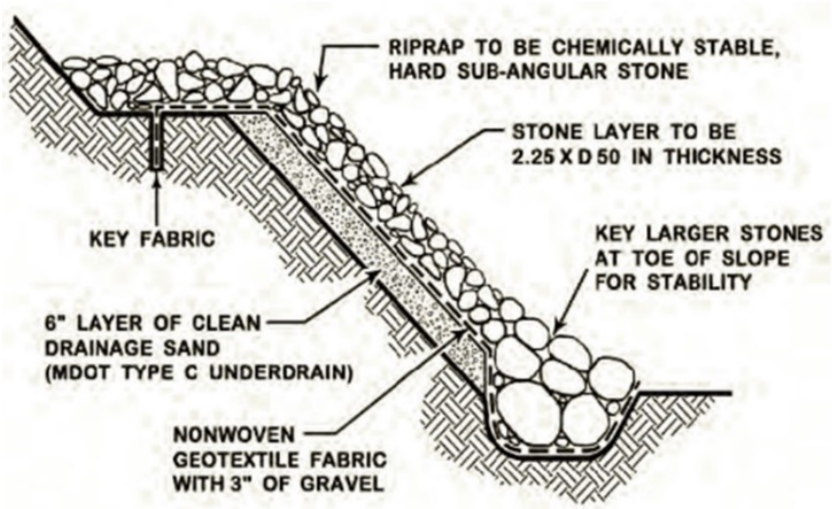


Figure 3.20 Riprap Slope Application Schematic Diagram (Maine DEP 2016).

3.6.2 Cellular Confinement Systems (CCS)

Cellular Confinement Systems (CCS) also called geo-webs or geo-cells are designed to contain soil or aggregate within their three-dimensional, honeycomb structure made of High-Density Polyethylene (HDPE) plastic. CCS can mechanically stabilize slopes, channels, and ground surfaces. The extended panels and interlocking matrix in CCS help in retaining large volumes of soil, reducing soil erosion, and promoting vegetation growth on steep slopes (kentucky DOC&DOW 2005; Maine DEP 2016; NDOT- DDECM 2006). Figure 3.21 gives a closer look at cellular confinement systems holding the aggregate.

Figure 3.21 Cellular Confinement Systems Holding the Aggregate (Maine DEP 2016).

3.6.3 Synthetic Erosion Control and Revegetation Mats (ECRMs).

Synthetic Erosion Control and Revegetation Mats (ECRMs) are developed to hold mulch and to protect steeper slopes and channels with average flow velocities. ECRMs are synthetic material mats that are stronger than ECBs and are designed to last more than two years. ECRMs provide good grass cover and do not require separate mulch application. ECRMs do not have three dimensional void space that is suitable for soil filling and due to this, elongation can happen due to little dimensional stability(Penn DOT 2012).

3.6.4 Plastic Sheeting/ Covering

Plastic sheeting/ covering can provide temporary coverage for cut/fill slopes. As plastic sheeting/covering blocks filtration, it is essential to transfer complete rainwater to another place to avoid erosion issues. If possible, it is necessary to prevent clean water runoff from plastic sheeting mixing with bare soil. Plastic increases rainwater flow velocity and hence, it is essential to use velocity dissipation devices in conjunction with plastic sheeting. Wind can blow away plastic sheeting, therefore overlapping at ends is needed (WS DOT 2014). Figure 3.22 shows a plastic sheeting installed on slope to prevent erosion.

Figure 3.22 Temporary Plastic Sheeting on a Slope (Encore Environmental LLC 2019).

3.6.5 Gabions

Gabions are flexible wire baskets filled with stones that are used to protect loose soil slopes. Group of gabions can be stacked together as a retaining wall or revetment that provides structural strength to non-stable slopes(Kentucky DOC&DOW 2005; Maine DEP 2016). Figure 3.23 shows a group of gabions placed to together as retaining wall to prevent soil displacement on to the road during slope failure.

Figure 3.23 Gabions Installed to Protect Slope Failures (Cirtex Civil 2018).

Placing live branch cuttings between gabion layers can help in promoting vegetation and controls soil erosion and sediment runoffs (Vermont EC 2006).

3.6.6 Buffer zone

A buffer zone is an undisturbed area of natural vegetation or planted vegetation used to prevent erosion and sediment runoff into water bodies. Stream banks, ponds, wetlands, swales and lakes are suitable areas for buffer zones. Buffer zones are also referred to as filter strips or buffer strips. They control erosion, filter sediment, and increase infiltration. Buffer zones do not require high maintenance and they increase wildlife habitats(Georgia SWCC 2016; OR DOT ECFM 2006). Figure 3.24 shows the installation of multiple buffers on the banks of a creek.

Figure 3.24 Buffer Zone at Bear Creek in Story County, Iowa (USDA 2017)

3.6.7 Methods for Cut and Fill slopes

Slopes with cut and fill activities are more disturbed and more prone to erosion compared to other slopes. Fill, steepness, watershed size, and water content are factors that determine extent of erosion on fill slopes. Cut slopes are more stable than fill slopes, as fill slopes require proper soil compaction. These slopes require special methods in preventing erosion and sediment runoff. Terracing slopes decreases surface runoff, and improves vegetation by maintaining moisture content (Maine DEP 2016).

3.6.7.1 Brush layering

Brush layering is a biotechnical slope protection method of placing long branches into slope areas to stabilize cut and fill slopes (Vermont EC 2006). Figure 3.25 shows multiple branches pieced into the slope surface for slope stabilization.

Figure 3.25 Brush Layering (Caltrans 2019b).

3.6.7.2 Gradient terracing

Gradient terracing is a ridge and channel arrangement constructed on slopes at regular intervals. Gradient terracing can control erosion by trapping surface runoff and diverting it to stormwater outlets. Gradient terracing decreases runoff velocity contains moisture content better than normal slopes and decreases sediment runoff. Steep slopes, rocky or sandy soil slopes are not suitable for gradient terracing because they are suitable for vegetation growth. Gradient terracing application is effective at places where necessary runoff outlets are available(Idaho DEQ 2005a).

3.6.8 Slope Drain

A slope drain is a pipe that intercepts and directs groundwater runoff from top of a slope to a water body, trapping device or stabilized area without causing any erosion. Cut and fill slopes at construction sites are prone to soil erosion prior to installment of permanent erosion control practices. Application of slope drains on cut or fill slopes will help in conveying runoff from disturbed areas of slopes to safe outlets without causing erosion. Slope drain application can be an effective erosion control practice on steep

slopes. Installing well sized pipes and proper maintenance of slope drains is essential, as failure of slope drains can cause extreme soil erosion(NH DES 2011; TDOT DM 2012b). Figure 3.26 shows a slope drain installed on a slope to convey the runoff from top.

Figure 3.26 Temporary Slope Drain (Mass DEP 2019).

3.6.9 Slope Tracking

Slope tracking is an erosion control practice to develop various checks on a slope to reduce velocity of down flowing water. Tracks are created by the tire tracks of heavy construction vehicle. Slope tracking increases efficiency of other erosion control practices, is cost effective, and decreases extent of erosion by 20-40%(MN DOT ECH 2006).

3.6.10 Contour Field Cultivation of Slopes

Cultivating contour fields of slopes roughens foreslope or backslope in horizontal strips and helps in controlling rill erosion. The concentrated stream of water is dispersed into a sheet flow as it spreads over cultivated contours (NDOT-DDECM 2006).

3.6.11 Fiber Roll

Fiber rolls reduce sheet flow erosion on slopes and decrease velocity across streambanks and channels. A fiber roll is made of coconut fiber, straw, or excelsior roll

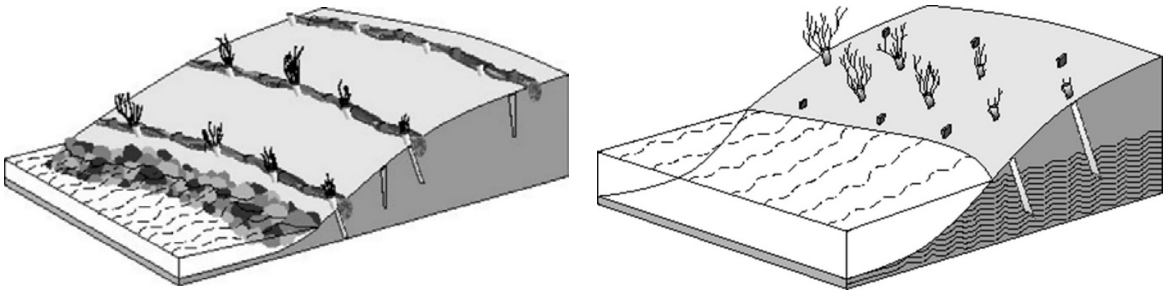
enclosed in jute netting, nylon or burlap. Fiber rolls work best where water surface levels are constant (New York DEC 2016). Figure 3.27 shows a fiber roll installed on a slope.

Figure 3.27 Fiber Rolls on a Slope (New York DEC 2016).

3.6.12 Live Fascines and Live Staking

Live fascines technique requires a bunch of branches piled into shallow trenches. Soil filled shallow trenches are placed in multiple rows across contours to stabilize slopes (Vermont EC 2006). Figure 3.28(a) provides a typical schematic diagram for live fascines application on slopes.

Live stakes are used in this application help in the generation of roots and therefore stabilizes soil by strengthening and binding soil particles. Bottom ends of large stakes or poles are sharpened and pierced vertically about one foot into soil surface along the waterline. Mechanical piercing is required, if pole size is bigger. Poles create a barrier and help in containing the flow (Kentucky DOC&DOW 2005; Vermont EC 2006). Figure 3.28(b) provides a typical schematic diagram for live staking on slopes.



(a) live fascines application (b) live staking application

Figure 3.28 Schematic Diagrams of Slope Armoring with Vegetation (FISRWG 1998).

3.7 Establishing Vegetation

3.7.1 Tree, Shrubs, Vines, and Ground Covers

This practice can be effective on disturbed areas by establishing vegetative cover of trees, shrubs, vines, or ground covers where it is hard to apply and maintain seed or sod, and mowing is not practicable. This application can be used on steep or rocky slopes (Louisiana DNR 2008; NCSS, NCDENR, NCAECS 2013).

3.7.2 Landscape irrigation

Landscape irrigation can be essential when vegetation on landscape requires water to for its growth. Water can be supplied through typical construction site irrigation systems such as temporary pressure piping, spray heads, stationary water tanks, drip emitters, hose water applications. It is essential to make sure that supplied water does not wash out or discharge offsite and into waterways (Nevada DOT SWQM 2017). Water may be required for certain types of erosion control practices. Seeds in erosion control blankets or mats might need watering to maintain moisture that can help in germination (Iowa DOT 2017).

3.7.3 Seeding

Seeding provides vegetative cover on exposed areas of construction project sites. Seeding requires minimal surface preparation and establishes temporary or permanent vegetative cover quickly. Seeding limits erosion, sediment runoff, and decreases dust from

surfaces of construction sites. Temporary or permanent seeding is essential in safeguarding earthen structures such as dikes, diversions, grass- lined channels, and banks and dams of sediment basins (Alabama SWCC 2009; NCSCC, NCDENR, NCAES 2013; TDOT DM 2012b).

Temporary Seeding:

Until establishment of permanent stabilization on construction sites, temporary seeding is used for establishing short-lived temporary cover to prevent erosion and sediment runoff. Temporary seeding is applicable on any soil surface that requires vegetated cover less than a year. Temporary seeding can be used on diversions, dams, temporary sediment basins, temporary road banks and topsoil stockpiles. Applying temporary seeding can help in avoiding high cost maintenance operations such as construction of sediment basins and sediment barriers (Alabama SWCC 2009; NCSCC, NCDENR, NCAES 2013).

Permanent Seeding:

Permanent seeding on construction sites helps in establishing lifelong vegetative cover. Application of permanent seeding is inexpensive and controls erosion and decreases sediment-laden stormwater runoff to streams or groundwater basins. This method is not applicable on slopes that are steeper than 2:1. Permanent seeding is applicable on any graded surface that needs long-term vegetation for soil stabilization. Usage of permanent seeding is necessary on filter strips, buffer areas, vegetated swales, steep slopes and stream banks. Selecting native seed species based on geographical location, soil type, planting time in year, climate, and establishment rate play a crucial role in establishing permanent

vegetation (Alabama SWCC 2009; Mass Dep 1997; Mississippi DEQ 2011; NCSCC, NCDENR, NCAES 2013; CT DEP 2002).

Hydroseeding:

Hydroseeding is mixture of wood, fiber, seed, fertilizer, and stabilizing emulsion sprayed on unstable soil surfaces and slopes with hydromulch equipment. Hydroseeding gives a short-term protection to disturbed soils from water and wind until permanent stabilization. Hydroseeding is ineffective to strong winds and cold climate areas (Caltrans 2017; Nevada DOT SWQM 2017). Figure 3.29 shows hydroseeding application on a slope.

Figure 3.29 Hydroseeding Application on a Slope (Caltrans 2017)

Dormant Seeding and Frost Seeding:

Dormant Seeding is a process of applying seeds in fall period, once after soils turned too cold for germination and growth of vegetation. Dormant seeding can be either temporary or permanent application (Indiana DEM 2007; MN DOT ECH 2006).

Frost seeding is a process of applying temporary or permanent application in late winter when soils are in freeze-thaw stage. Frost seeding helps in repairing surfaces, which have thin vegetative cover (Indiana DEM 2007).

Interseeding into existing vegetation:

Interseeding can be applied on surfaces when the existing vegetation failed in stabilizing the surfaces (MN DOT ECH 2006).

Covercrop seeding:

Covercrop seeding is a temporary erosion control practice helps in establishing vegetative cover with suitable and fast-growing annual plants. Cover crop seeding can be applicable on surcharge areas, soil stockpiles, dikes, dams, banks of sediment basins, temporary road banks (NDOT- DDECM 2006).

3.8 Sodding

Sodding is an application of cut pieces of turf that provide vegetative cover and instant erosion control on disturbed sites. Sod is a layer of thick that consists of soil with grass and thick plant roots. Sodding can be applied on areas such as grass-lined channels, slopes round storm drain inlets and outlets, diversions, swales, cut and fill slopes and filter strips. Sodding restricts growth of weed (Alabama SWCC 2009; Idaho DEQ 2005a; CT DEP 2002). Dormant Sodding practice is applied on disturbed soils at the end of fall can be stabilized with sodding , which can help in reducing potential sediment runoff in winter due to melting snow (MN DOT ECH 2006). Figure 3.30 shows the application of sodding on roadside.

Figure 3.30 Sodding Application Process (Alabama SWCC 2009).

3.9 Run-off Control measures/ Run-off Conveyance measures

3.9.1 Diversions

Diversions are constructed across slopes to intercept surface water runoff and deflect it to a stable outlet or sediment trapping device. Diversion is a channel built by excavation, berm or dike placement or a conjunction of all of three practices (NH DES 2011). Installation of diversions around sensitive construction sites reduces need for temporary sediment basins. Temporary fill berms, water bars, temporary diversions, and permanent diversions are some diversion measures (CT DEP 2002). Figure 3.31 shows a diversion channel and installation of upland sediment controls.

Figure 3.31 Temporary Stream Diversion. (Iowa DOT 2017).

3.9.1.1 Permanent diversion

A permanent diversion is a ridge or channel or combination of both built on a designed grade across lower side of slopes. Permanent diversion can be applicable on construction sites where drainage area is more than 5 acres or when required usage is more than a year. It is also required to be as an essential part of permanent water management system if runoff from higher areas can damage lower areas or if sloping uplands are being damaged due to surface and/or shallow subsurface flow. Permanent

diversions need to be designed according to construction site requirements. (NCSCC, NCDENR, NCAECS 2013; CT DEP 2002).

3.9.1.2 Temporary diversion

A temporary diversion is constructed with a tamped berm or compacted soil to divert flows. This measure can be applicable on sites where discharge area is less than five acres or usage time span will be less than one year (NCSCC, NCDENR, NCAECS 2013; CT DEP 2002).

3.9.1.3 Clear water diversion

A clear water diversion consists of setting up structures around construction project sites to divert water without reducing quality due to construction operations. Clear water diversion is applied next to waterways keep construction project sites dry and reduce sediment runoff mixing into clear water. Materials used to establish clear water diversion are ditches, berms, dikes, slope drains, rock, gravel, wood, aqua barriers, coffer dams, sheet piles, silt fencing, drainage and interceptor swales, pipes, or flumes (Nevada DOT SWQM 2017). Figure 3.32 provides a typical schematic diagram for clear water diversion.

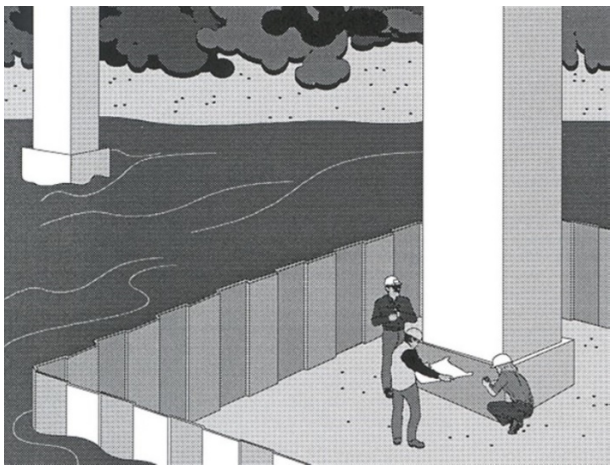


Figure 3.32 Schematic Diagram of Coffer Dam Constructed for Water Diversion (NVDOT SWQM 2017).

3.9.1.4 Temporary instream diversion

Temporary instream diversions are applied at construction projects where there is an incoming stream at project sites. Instream diversions divert flow of streams, prevent sediment runoff and help in construction of culvert boxes, box bridges, or slab bridges (TDOT DM 2012b). Figure 3.33 show installation of temporary instream diversion barriers to prevent water contamination.

Figure 3.33 Temporary Instream Diversion at a Channel (TDOT DM 2012b).

3.9.1.5 Temporary diversion culvert or Pipe diversion

A temporary diversion culvert or pipe diversion helps in finishing construction work in dry conditions and minimizes sediment runoff due to instream water. A temporary diversion culvert is built under an existing roadway to divert instream flow during construction of bridges, culverts or box culverts. Due to backfill of compacted granular material, this measure allows passage of through traffic (TDOT DM 2012b). Figure 3.34 shows temporary culvert crossing installation at a construction site.

Figure 3.34 Temporary Culvert Crossing at Development Stage (TDOT DM 2012b).

3.9.1.6 Temporary fill diversion

A temporary fill diversion is a channel with a ridge that is braced on lower side and is constructed on top of earth fill to divert runoff from an exposed fill slope to a stabilized outlet or sediment trapping structure. This application is more suitable where runoff from top of fill drain towards unprotected slopes and makes temporary diversion dike (see section 2.11.1.8) application inefficient (Virginia DEQ 1992).

3.9.1.7 Temporary right of way diversion

A temporary right of way diversion is constructed with a ridge of compacted soil or loose gravel over a right of way to reduce length of flow in disturbed strip and channel runoff to a stabilized outlet. Soil diversions can be constructed where there is no construction traffic, whereas gravel diversions are preferred where there is vehicular traffic (Virginia DEQ 1992).

3.9.1.8 Diversion dikes

Diversion dikes help to divert runoff from upstream areas away from construction sites and exposed soil. Diversion dikes can be applied on the upslope of disturbed areas to prevent runoff entering into exposed areas; on the downslope of the construction site to

block sediment runoff from the site and divert it to the sediment trapping outlet; and to obstruct the runoff from paved areas (Illinois DOT 2010).

An intercepting embankment is considered as a permanent diversion dike. Permanent diversion dikes are constructed only on top of back slopes in the cut areas to stop overflow of adjacent drainages from passing over or down the back slopes (WI DOT FDM 2013).

3.9.1.8.1 Perimeter dike

A perimeter diversion dike is applied along the perimeter of a construction area to block the storm water runoff from entering or exiting the work area (NCSCC, NCDENR, NCAECS 2013). The drawing in Figure 3.35 depicts a perimeter dike around the project site for conveying runoff to an outlet

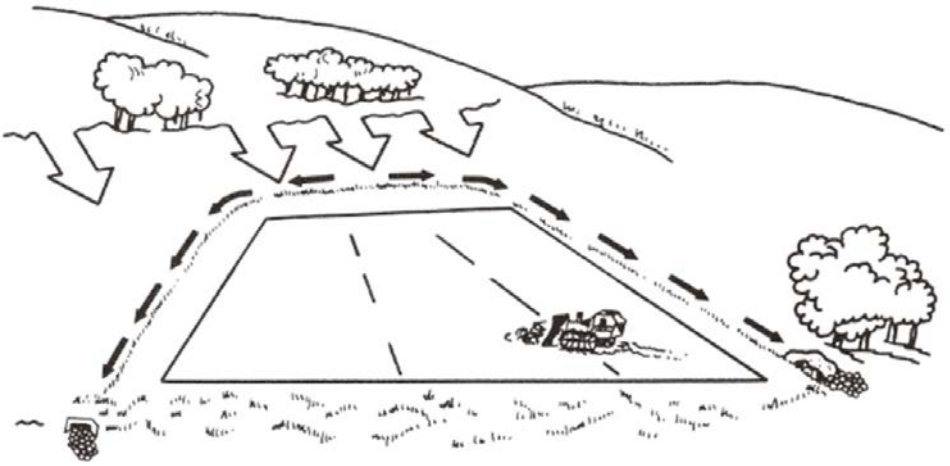


Figure 3.35 Schematic Diagram of a Perimeter Dike (NCSCC, NCDENR, NCAECS 2013).

3.9.1.9 Diversion fence

A diversion fence is a short-term barrier constructed with an impermeable sheeting and chain link fence to convey sediment-laden runoff to a stabilized sediment trapping device or to divert runoff away from exposed areas (DC DEE 2017).

3.9.1.10 Diversion ditch

A diversion ditch is constructed at the boundaries of disturbed areas to obstruct and direct the runoff of undisturbed areas away from the exposed or disturbed areas (Penn DOT 2012). Figure 3.36 shows a permanent diversion ditch with RECPs installed on ditch slopes.

Figure 3.36 Permanent Diversion Ditch (Campco Engineering INC 2019).

3.9.1.11 Water bar

A water bar is a ridge, or a combination ridge and channel developed diagonally across sloping roads that are susceptible to erosion. Water bars divert runoff into a stabilized outlet and thus decrease erosive forces and sediment runoff (Mass DEP 1997). Figure 3.37 shows a water bar installed across a gravel road.

Figure 3.37 Water Bar Installed on Road (St. John Tradewinds 2019).

3.9.1.11.1 Crown ditch

A crown ditch application is used to intercept, divert and direct sheet flow on a slope to an outlet or a water course (Arizona DOT 2012). Figure 3.38 shows a crown ditch constructed to convey runoff from top of the slope.

Figure 3.38 Gabion-style crown ditch (Arizona DOT 2012).

3.9.2 Swale

A swale is a temporary excavated drainage way to stop sediment-laden runoff going into the exposed construction areas by diverting it into a stabilized sediment outlet or sediment trapping device (Delaware DWS 2013). Figure 3.39 shows a swale developed on a slope.

Figure 3.39 Swale on a Rainy Day (Great Escape Farms 2019).

3.9.2.1 Vegetated swale

Vegetated swales are wide channels that can be formed naturally or developed with dense vegetation. Vegetated swales reduce runoff velocity, increases infiltration and may separate particulate pollutants from stormwater runoff (Mass DEP 1997). Figure 3.40 shows a vegetated swale developed between on the median.

Figure 3.40 Vegetated Swale (Mass DEP 2019).

3.9.2.2 Riprap-lined swale

A riprap-lined swale is constructed with erosion resistant rock to direct runoff to a stabilized outlet. This practice is applicable at extended flow areas, high channel grades, erodible soils and on areas that are not suitable for vegetation (Mississippi DEQ 2011). Figure 3.41 shows a rip-rap swale developed on the slope to convey the runoff.

Figure 3.41 Rip-rap Lined Swale (OH DNR 2016)

3.9.2.3 Lined swale

A lined swale is a permanent runoff control practice designed to direct runoff to a stabilized outlet. Lined swales are constructed on steep slopes and in areas where soils are erodible (Mississippi DEQ 2011).

3.9.2.4 Temporary berms

Temporary berms are constructed with compacted soil or stone to direct runoff to a specified outlet, which helps in reducing erosion and sedimentation (Delaware DWS 2013). Figure 3.42 shows a berm constructed with compacted soil. Figure 3.43 provides a typical schematic diagram for a temporary berm constructed with compacted aggregate.

Figure 3.42 Temporary Berm Constructed with Compacted Soil (MN PCA 2019a)

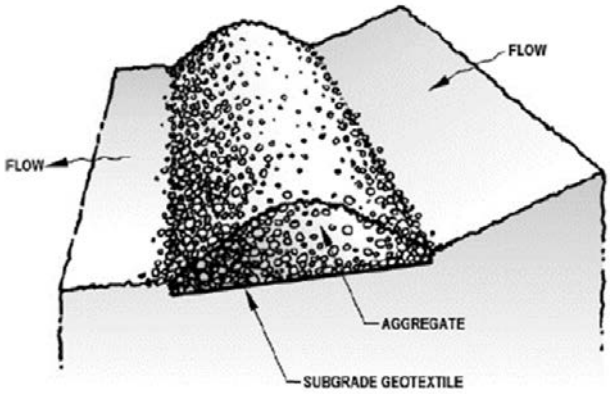


Figure 3.43 Schematic Diagram of a Stone Berm (MN PCA 2019b).

3.9.3 Channels

Channels are established around construction sites to direct runoff into a stabilized outlet without causing erosion(MN DOT ECH 2006). Channels can be lined or unlined. Typical channel linings are vegetated, rock and temporary liners.

Grass-lined channels are developed across areas that are suitable for vegetation. The vegetation can stabilize channel surfaces. Grass-lined channels are used on slopes that are less than 5% (Kentucky DOC&DOW 2005). Figure 3.44 shows a channel developed on a slope vegetated with grass.

A rock lined channel is constructed with rock or riprap where conditions are not suitable for vegetation and design velocity is greater than two feet per second or if the design velocity is greater than recommended velocity for grass-lined channels (Kenctucky DOC&DOW 2005). Figure 3.45 shows a channel developed with rocks.

A temporary lined channel is constructed for short-term use with a flexible geomembrane or other erosion resistant covering to reduce erosion of concentrated runoff. Temporary lined channels are established at construction sites area until permanent channels are established or until project completion (RI SCC 2014). Figure 3.46 shows a temporary lined channel covered with plastic sheeting.

Figure 3.44 Grass-Lined Channel (Kentucky DOC&DOW 2005).

Figure 3.45 Rock Lined Channel (Kentucky DOC&DOW 2005).

Figure 3.46 Temporary Lined Channel (Rachel Calabro 2012).

3.9.4 Check Dams/ Ditch Checks (Energy Dissipaters)

Check dams/ Ditch Checks are built across a swale, ditch or channel to decrease the velocity of flow and channel erosion and help in gravitating the sediment. Check dams can be constructed with rock, wattles, sand bags or other acceptable materials (Alabama SWCC 2009; Arizona DOT 2012).

3.9.4.1 Erosion log check dam

An erosion log check dam is constructed by placing two-inch erosion logs into the soil or on the soil retention blankets. Staking plays a crucial role in the operation of erosion logs (CDOT 2011). Figure 3.47 shows a check dam constructed with series of staked erosion logs.

Figure 3.47 Staked Erosion Log Check dams (Scott and Rich 2015).

3.9.4.2 Hay bale check dam

A hay bale check dams is a temporary practice to control runoff and is used on low concentrated runoff areas. Hay bales have a relatively short life-span and help in establishing vegetation (Mississippi DEQ 2011). Figure 3.48 shows a check dam constructed across with hay bales.

Figure 3.48 Hay Bale Check Dam (Challenger Construction Corp. 2015).

3.9.4.3 Rock check dam

A rock check dam is established across ditches, swales, channels or other areas of concentrated flow to control runoff and decrease the velocity of stormwater flow. Rock check dams are constructed with aggregate and geotextile fabric. This practice is useful on channels in areas where the permanent stabilization practices are inapplicable (Indiana DEM 2007; TDOT DM 2012b). Figure 3.49 shows a check dam constructed with rocks to interrupt the upstream flow.

Figure 3.49 Rock Check Dam with perimeter barriers around the upstream basin.

3.9.4.4 Gabion check dam

Gabion Check dams are constructed with gabion baskets across swales, drainage ditches or channels for stopping the erosion, reducing velocity of the flow, and gravitating the sediment (TDOT DM 2012b). Figure 3.50 shows a check dam built with stacked gabions across a ditch.

Figure 3.50 Gabion Check Dams (Gabion Supply 2019).

3.9.5 Slope Drains

A slope drain is a rigid pipe or a tube that intercepts and conveys the surface runoff to a stabilized outlet. Slope drains are used along with diversion dikes or channels to direct runoff from the top to bottom of cut or fill slopes without causing erosion. Slope drains on construction sites reduce the erosion caused by runoff. Slope drains can also be used as an emergency spilling for a sediment basin. (Arizona DOT 2012; Caltrans 2017; Illinois DOT 2010).

3.9.5.1 Permanent and Temporary slope drains

Permanent Slope drains are applied on cut fill slopes where the existing soil and planned vegetative cover cannot contain the concentrated runoff flow without causing erosion (CT DEP 2002).

Temporary slope drains are made of flexible or rigid tubing or conduit fixed on unvegetated slopes to convey stormwater runoff from top to base of the slopes without causing erosion (Indiana DEM 2007).

3.9.5.2 Grade stabilization structure

Grade stabilization structures are used to reduce the "head cutting" in natural or artificial channel flows. The erosion that occurs due to immediate change of elevation to a downward step in the channel can be termed as head cutting. Grade stabilization structures help in channeling water from higher elevation to lower elevation without causing erosion and help in reducing velocity of the flow. Concrete, metal, rock riprap, or pipe drops are used in constructing this structure (RI SCC 2014). Figure 3.51 shows a grade stable structure where aggregate is installed on the slope to prevent head cutting.

Figure 3.51 Grade Stabilization Structure (NRCS 2014).

3.9.6 Outlet Protection

Outlet protection devices stop scouring and minimize the velocity of runoff. Outlet protection devices are established at the outlet of pipes, drains, culverts, slope drains, diversion ditches, swales, conduits, channels or outlets that are prone to flash floods (Caltrans 2017). In the Figure 3.52, riprap is installed at the outlet to reduce runoff velocity.

Figure 3.52 Riprap Outlet Protection (MN PCA 2016a).

3.9.6.1 Level spreader

A level spreader is a non-erosive outlet constructed to distribute the concentrated run off from a diversion across a stabilized slope as sheet flow. Level Spreaders are a cost-effective practice designed to discharge small volumes safely without causing erosion(DC DEE 2017; Mississippi DEQ 2011). Figure 3.53 shows level spreader installed on surface to distribute concentrated runoff into sheet flow.

Figure 3.53 Level Spreader (CFB Contracting LLC 2019).

3.9.6.2 Plunge pool

A plunge pool is an excavation fill with riprap established at an outlet to reduce the energy of the discharge and stop scouring (Maryland SSSESC 2011). Figure 3.54 shows plunge pool constructed with riprap stilling basin at the outlet

Figure 3.54 Plunge Pool (Minnesota Pollution Control Agency 2016b).

3.10 Sediment Control Practices

3.10.1 Inlet Protection

Inlet protection is a temporary pervious barrier established around inlets to block sediment from running into stormwater drains and waterways. Inlet protection devices can be constructed with gravel and stone with a wire mesh filter, or with block and gravel, sod, sediment trapping bags, racks, or filter fabric (Idaho DEQ 2005a; RI SCC 2014).

3.10.1.1 Storm drain inlet protection

Storm drain inlet protection is a practice where temporary barriers are applied before the permanent stabilization of the disturbed areas. Storm drain inlets protectors are established around the storm drain inlets to prevent sediment entering into the storm drains, and where the stormwater runoff from the construction sites enters into the conveyance systems such as drain inlets, drop inlets, and curb inlets (Pitt et al. 2007; WI DOT FDM 2013). Figure 3.55 shows a storm drain inlet is protected by installing wattle around inlet.

Figure 3.55 Storm Drain Inlet Protection (Eastcoast Site Work Inc 2019).

3.10.1.2 Drop Inlet protection

There are multiple types of drop inlet protections. First, excavated drop inlet protection is a short-term sediment control practice applied at the construction project sites. This practice is established by excavating the soil around the area of the storm drain drop inlet (Indiana DEM 2007). In Figure 3.56, the area around the inlet is excavated to allow sediment laden water to enter and sandbags are installed around inlet to prevent sediment entering inlet.

Figure 3.56 Excavated Drop Inlet Protection (Indiana DEM 2007).

Second, straw bale inlet protection is practiced where straw bales are installed around drop inlets at construction sites to prevent sediment entering the inlet. The maximum life of this practice is less than three months (Indiana DEM 2007). Figure 3.57 shows haybales installed around inlet to prevent sediment entering the inlet.

Figure 3.57 Straw Bale Inlet Protection (Indiana DEM 2007).

Third, gravel donut drop inlet protection is practiced where an aggregate is placed around the drop inlet to prevent the sediment runoff into the inlet (Indiana DEM 2007). Figure 3.58 shows gravel placed around inlet to prevent sediment entering the inlet.

Figure 3.58 Gravel Donut Drop Inlet Protection (Indiana DEM 2007).

Fourth, geotextile fabric drop inlet protection is a short-term sediment control practice where a temporary geotextile fabric barrier is established around the inlet to block the sediment runoff. The maximum life of this practice is six months (Indiana DEM 2007). In Figure 3.59, a reinforced geotextile is installed around an inlet to prevent sediment entering the inlet.

Figure 3.59 Geotextile Fabric Drop Inlet Protection (Indiana DEM 2007).

Fifth, sod drop inlet protection is a permanent sediment control practice where a grass sod filter area is constructed around the drop inlet in a vegetated area to prevent the sediment runoff into the inlets (NCSCC, NCDENR, NCAECS 2013). Figure 3.60 provides a schematic diagram for a sod drop inlet protection.

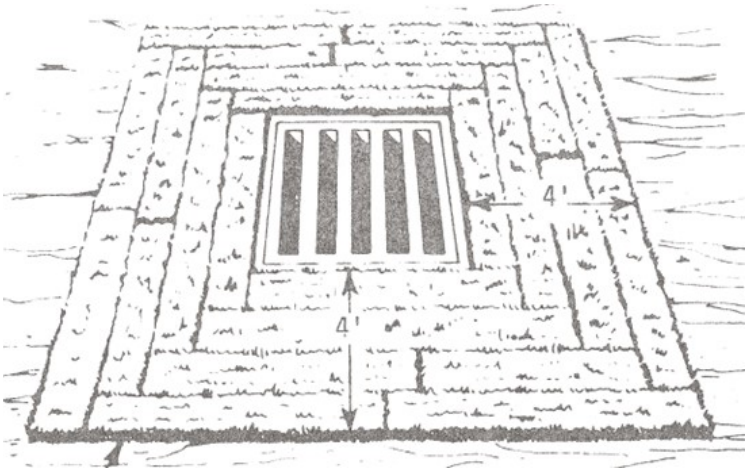


Figure 3.60 Sod Drop Inlet Protection (NCSCC, NCDENR, NCAECS 2013).

Sixth, hardware cloth/wire mesh and gravel inlet protection is a temporary sediment control practice constructed with hardware cloth and gravel around the drop inlets to prevent the sediment runoff entering into storm drains (NCSCC, NCDENR, NCAECS

2013). Figure 3.61 provides a schematic diagram for a longitudinal section of hardwire cloth/wire mesh gravel inlet protection.

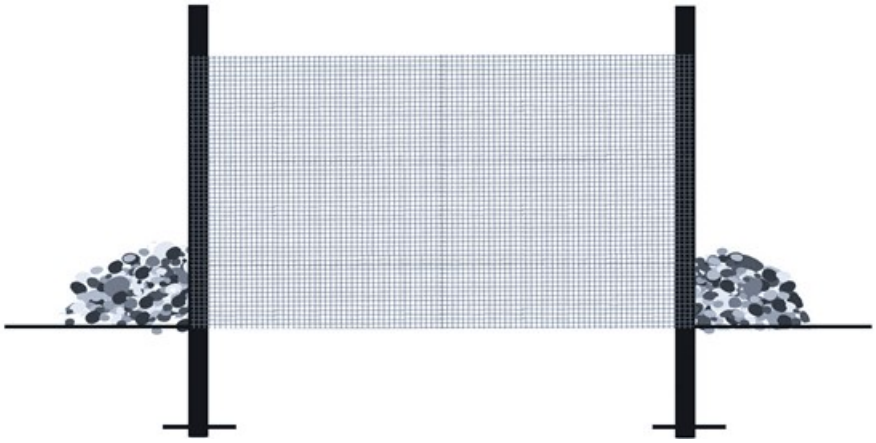


Figure 3.61 Longitudinal Section of. Hardwire Cloth/Wire Mesh Gravel Inlet Protection (NCSCC, NCDENR, NCAECS 2013).

Seventh, inlet filter bags that are fitted to the structure of drainage drop are used to prevent the sediment runoff into the stormwater sewer system (Illinois DOT 2010). Figure 3.62 shows an inlet filter bag that is fitted to the curb inlet.

Figure 3.62 Inlet Filter Bag (Hanes Geo Components 2019).

Eight, rolled barriers that are made of wood excelsior or equivalent material is established around the drop inlet to prevent the sediment entering into the drop inlet

(Illinois DOT 2010). Figure 3.63 shows staked wattles installed around an inlet to prevent sediment runoff into inlet.

Figure 3.63 Wattles Used for Inlet Protection (Forestry Suppliers Inc. 2019).

Ninth, A block and gravel inlet protector is a short-term device constructed around an inlet with concrete blocks and gravel to prevent the sediment entering the inlet. This practice can is applicable to curb inlets where heavy flows are anticipated (Indiana DEM 2007; NCSCC, NCDENR, NCAECS 2013). Figure 3.64 shows a concrete block is installed on the inlet and gravel is placed around the block to block sediment entering the inlet.

Figure 3.64 Block and Gravel Drop Inlet protection (Indiana DEM 2007).

3.10.1.3 Culvert inlet protection

Culvert inlet protection consists of placing a sediment filter at the inlets to prevent sediment entering the culvert. This is a short-term practice applied at the disturbed areas until the establishment of permanent stabilization (Illinois DOT 2010).

3.10.1.4 Curb inlet protection

Curb inlet protection is a practice of establishing sediment control structures on or around curbs. This practice is suitable for construction project sites where there is high chance of sediment runoff into the local stormwater sewer system. This practice is intended to function efficiently without the requirement of stakes or trenches (TDOT DM 2012b). Figure 3.65 shows wattles that are installed around curb inlet to prevent sediment entering inlet.

Figure 3.65 Curb Inlet Protection with Fiber Logs (1st Resource Solutions LLC 2019).

Stone bag Curb Inlet Protection is a short-term sediment control structure constructed around storm drain curb inlets with bags filled with stones or aggregate (Indiana DEM 2007).

3.10.1.5 Fence backed bale inlet protection structure

Fence backed bale inlet protection structures are constructed with the combination of silt fence and bale to prevent the sediment runoff into the inlet. The bale is placed around the inlet and the silt fence is established outside the bales that act as a support (ND DOT ESCM 2004).

3.10.1.6 Pipe (culvert) inlet protection

Installing silt fences, straw bales or planting buffers around the pipe (culvert) functions as a barrier and helps in preventing sediment runoff from the construction project entering the pipe (culvert) inlet (Illinois DOT 2010).

3.10.2 Sediment Barriers

Sediment barriers on construction sites block and help in settling the sediment-laden runoff to the bottom. Sediment barriers also help the ponding of runoff water, which helps in decreasing the velocity of the incoming stream. If the pond level reaches the height of sediment barriers, then the water starts flowing over the barriers (KS DOT TECM 2007). Sediment barriers can be constructed with straw bales, biofilter bags, straw rolls (wattles), brush barriers, filter berms, or pre-fabricated barrier systems (OR DOT ECFM 2006).

3.10.2.1 Bale barriers

Straw bale barriers are short term sediment control barriers fixed to the ground surface. Bale barriers can be installed at the foot of the slopes which are prone to sheet or rill erosion, along a street or sidewalk, or at the wetlands where silt fences might fail due to soft soils. The maximum life span of bale barriers is up to 3 months. Bale barriers are suitable on continuous stream channels and rocky areas (Mass DEP 1997; WI DOT FDM

2013). Figure 3.66 shows bale barriers installed at the perimeter controls to prevent sediment displacement onto road surface.

Figure 3.66 Straw or Hay bale Perimeter Barriers (Mass DEP 2019)

3.10.2.2 Brush barrier

Brush barriers are a temporary dam like structure constructed at project sites with leftover wood and non-woven geotextile fabric to contain sediment runoff. This practice is suitable at sites that have less drainage area (Alabama SWCC 2009). Figure 3.67 provides a schematic diagram for a brush barrier that contains a geotextile fabric holing wood on slope.

Figure 3.67 Schematic Diagram of a Brush Barrier (Alaska DEC 2012)

3.10.2.3 Wattles

Wattles are used on slopes to obstruct the runoff, decrease runoff speed, minimize sediment runoff, and to increase infiltration and seed germination. Wattles are made of weed-free wheat, rice straw, or excelsior wood fiber bound into dense tube shaped rolls and covered with natural fiber netting or UV-degradable polypropylene netting (Arizona DOT 2012). Figure 3.68 shows staked wattles installed on a steep slope.

Figure 3.68 Wattles on Slopes (Superior Hydroseeding Inc 2019).

Live wattles consist of the mixture of onsite clear and grubbed materials, and seed mixtures bound with filter cloth. They are applied on the slopes to promote sedimentation, filtration, and vegetation (NM DOT 2012).

3.10.2.4 Flexible sediment barrier

Flexible sediment barriers are used as a substitute to natural barriers. Flexible sediment barriers are composed of geosynthetic fabric with a urethane foam-filled core and a fabric apron that prevent sediment scouring (Caltrans 2017). Figure 3.69 shows flexible sediment barrier installed on a road.

Figure 3.69 Flexible Sediment Barrier (Caltrans 2017).

3.10.2.5 Floating turbidity barrier

Floating turbidity barriers are installed within or adjacent to the water body. They are made with a geotextile material and have floats fixed on top and weights fixed on bottom and an anchorage system to reduce sediment runoff. This practice increases sedimentation and reduces turbidity levels of water bodies. Floating turbidity barriers can be applicable in non-tidal and tidal water bodies, where the sediment runoff is inevitable due to nearby permitted construction activities (Alabama SWCC 2009). Figure 3.70 shows a yellow turbidity curtain installed within channel.

Figure 3.70 Turbidity Curtain (Alabama SWCC 2009).

3.10.2.6 Perimeter barriers

Application of perimeter barriers can help in holding the sediment within the borders of the construction project site to reduce the velocity and erosive forces of sheet flow. Compost socks are one type of perimeter barrier which is made of compost bound in geotextile material, or rolled barriers that are made of wood excelsior, or relevant material. Other types of perimeter barriers include silt fence barriers and straw bale barriers. Perimeter control devices are always recommended to apply along with erosion control practices (Illinois DOT 2010; Penn DOT 2012). Figure 3.71 shows silt fence installed as a perimeter barrier to prevent sediment laden water coming on to the road

Figure 3.71 Perimeter barrier (Bowman Construction Supply Inc 2019).

3.10.2.7 Sandbag barrier

Sandbag barriers are a short-term sediment barrier applied along the perimeter of project sites, streams, channels, stockpile areas, and exposed slopes to reduce the runoff flow velocity and prevent sediment-laden sheet flow runoff (Caltrans 2017). Figure 3.72 shows installed sandbag barriers at a disturbed area.

Figure 3.72 Sandbag Barriers (CCI SUPPLIES 2019).

3.10.3 Sediment Trap

A sediment trap is a small, short-term ponding area developed through excavation to settle sediment runoff within a construction area. Sediment traps can be constructed at the outlets of diversions, channels, slope drains, and other runoff conveyance systems that release sediment-laden water. Sediment traps can also be built with the combination of a rock check dam or a gabion check dam (NCSCC, NCDENR, NCAECS 2013; TDOT DM 2012b). Figure 3.73 shows a sediment trap constructed on a slope surface.

Figure 3.73 Sediment Trap (MN PCA 2019c).

Curb cutback measures are used on road construction projects where some section of pavement is removed to create a ponding area that can trap sediment before entering into storm drains (Caltrans 2017). Figure 3.74 as curb cut back that is constructed with sandbags, plastic sheeting, and perimeter controls along a roadside.

Figure 3.74 Curb Cutback (Caltrans 2017).

3.10.4 Silt Fence

Silt fence is a permeable geotextile fabric established with stakes to settle the sediment and reduce the velocity of sediment-laden sheet flow runoff leaving from the construction site. Silt fence can be applied to the foot of erodible slopes, perimeter of temporary stockpiles and construction project sites, and along streams and channels. Silt Fence is also used to construct ditch checks (Caltrans 2017; KS DOT TECM 2007). Figure 2.79 shows a top view of a staked silt fence; sediment deposition on the upstream can be seen in this picture

Silt fence can be enhanced with a wire fence and steel posts. Wire fence helps in reinforcing the silt fence fabric, and steel posts support the silt fence. The enhanced silt fence is constructed across swales, drainage ditches, or concentrated flow areas. The

enhanced silt fence helps in blocking the sediment runoff and filters the stormwater (TDOT DM 2012b). Figure 3.75 shows silt fence that is reinforced with wires and steel posts installed across a slope.

Figure 3.75 Reinforced Silt Fence (TDOT DM 2012b).

3.10.5 Sediment Basin

A sediment basin is an earthen embankment constructed to capture sediment at the construction site and to minimize sediment runoff into streams, lakes, and drainage ways. Emergency spillway systems and porous baffles are installed in the basin. Emergency spillway systems help in reducing spillway erosion, whereas porous baffles reduce the turbulence within the basin. Flocculants are used in the sediment basin to settle the sediment (Alabama SWCC 2009; NCSCC, NCDENR, NCAECS 2013). Figure 3.76 shows a typical sediment basin; The baffles are installed in the basin at regular intervals to reduce turbidity.

Figure 3.76 Sediment Basin (Alabama SWCC 2009).

3.10.6 Flocculation

Flocculation is a chemical process in which soil particles in water collide together to form flocs. Flocculants are added to sediment traps and sediment basins to reduce the turbidity of water. Flocculants consists of both artificial and natural polymers, some of which are buffered alum, PAM, and ferric chloride (Alabama SWCC 2009). Figure 3.77 shows water before flocculation in left jar and water after flocculation on right jar.

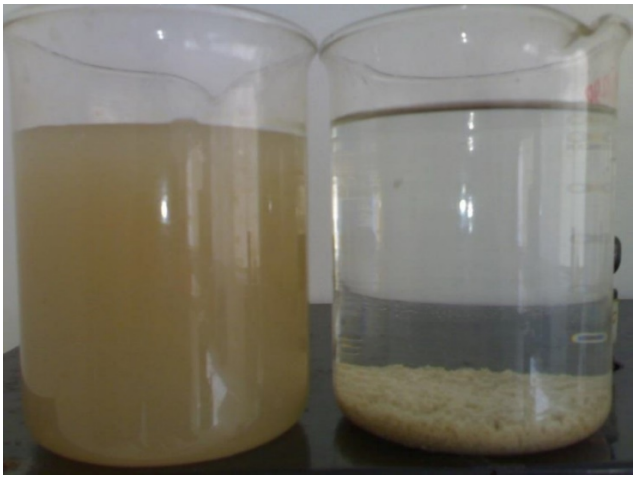


Figure 3.77 Pre-flocculation and Post-flocculation of water (Alabama SWCC 2009).

3.10.7 Sediment Logs

Sediment Logs are made of wood excelsior, rice straw, wheat straw, or coconut fibers that are made into a tight roll. Sediment logs are applied at the toe and top of the

slope, perimeter of the project sites, exposed slopes, and around temporary stockpiles to prevent runoff and decrease the velocity of sheet flow. Sediment logs are also known as wattles, fiber rolls, fiber roll barriers, coir rolls or coir logs, and filter tubes or socks (Nevada DOT SWQM 2017).

Filter tube/ filter sock is a short-term sediment control barrier made of geotextile fabric or non-biodegradable net matrix fill with aggregate, compost, excelsior, or straw, etc. Filter tube/filter socks block the sediment from the runoff and decrease the sheet flow velocity. Filter tube/ filter sock are applied at the slopes, channels, swales, drop inlets, etc. (Indiana DEM 2007). Figure 3.78 shows a filter tube installed at the perimeter to prevent sediment entering on the road

Figure 3.78 Perimeter Filter Barrier (Indiana DEM 2007).

3.10.8 Pumped Water Filter bags

Pumped water filter bags are made of geotextile to filter sediment-laden water before discharging to the off-site (DC DEE 2017). Figure 3.79 shows Sediment water is being pumped into the bag before discharging to the water body

Figure 3.79 Pumped Water Filter Bag. (Midwest Construction Products 2019).

3.11 E&SCPs-SHAs QPL Inclusion Process

This section discusses the QPL evaluation process of all SHAs. In general, SHAs' inclusion processes consists of three main stages: 1) application submission stage, 2) application review period and field testing, and 3) decision, and notification to manufacturer. Submitters are required to provide all information and attach required documents in the application. After receiving an application, the SHA personnel may review application and previous test data of product or may forward product to laboratory/field for testing. After reviewing test data, the SHA personnel decide and notify submitter about QPL inclusion. SHAs QPL inclusion process lightly differs from one another. SHAs such as Delaware DOT, Illinois DOT follow different inclusion process compared to other SHAs. North Dakota DOT does not maintain QPL, but the SHA has product evaluation criteria before applying in projects. The flow chart in figure 3.80 demonstrates the general QPL evaluation process of most of SHAs reviewed through this study. Figure 3.80 shows a flow chart covers most of the SHAs' QPL inclusion process with an exception of few SHAs.

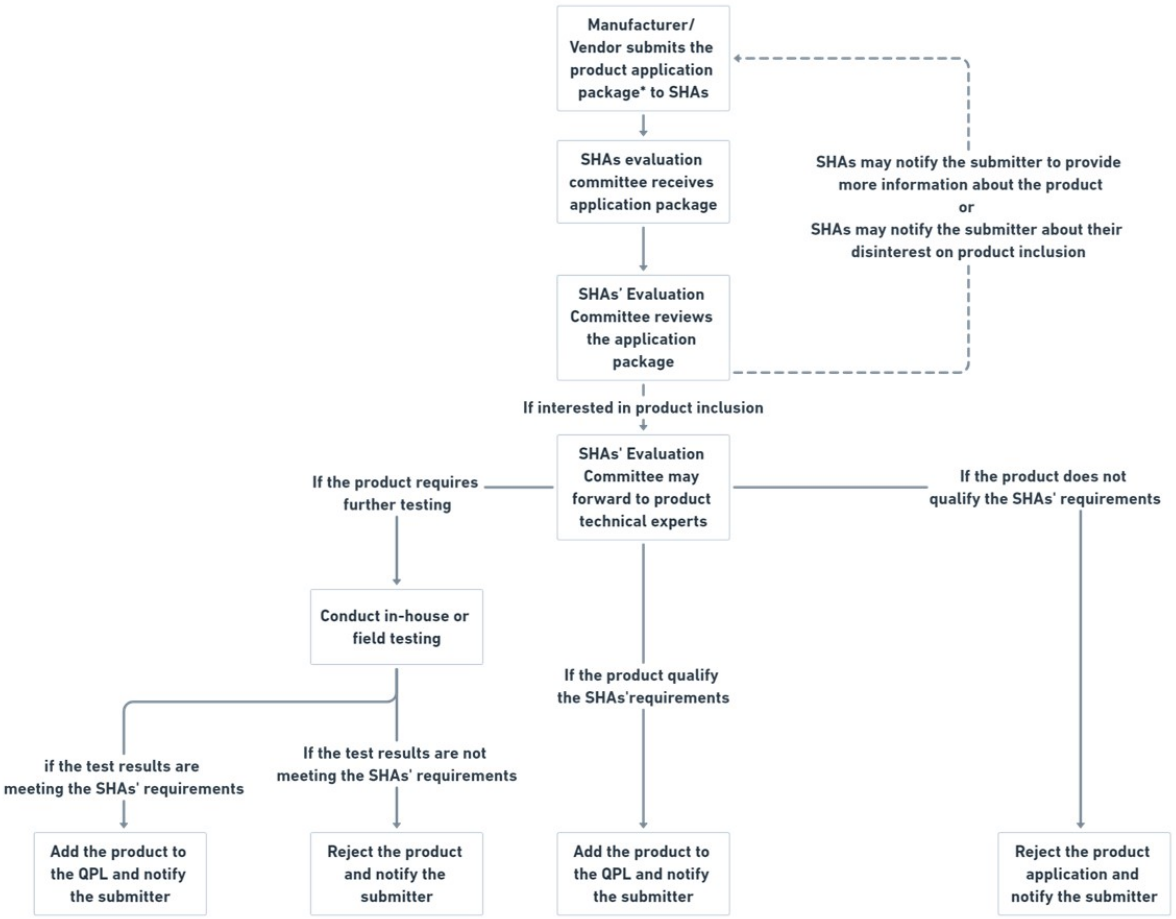


Figure 3.80 Generalized SHAs' QPL Inclusion Process Flow chart

3.11.1 Alabama DOT

Alabama DOT's QPL evaluation process starts with the submission of a new product evaluation form. Submitters are required to include product information: product description, type, uses, advantages, manufacturer details, previous product evaluation history, material composition, and patent details; standardized testing data: NTPEP, independent lab test reports and others; information on the product status on meeting specifications: ALDOT, AASHTO, ASTM, MUTCD, federal; inspections, cost, availability and warranty information; details about other SHAs considerations; and required documentation: drawings, sketches, pictures, installation details, MSDS, product/ material

literature, test data/ laboratory reports, certifications, and warranty. The application fee is $50. After the submission, ALDOT's Product Evaluation Section verifies the application and gives the Project Evaluation Board (PEB) number. If the product meets current specifications, it will be forwarded to lab testing. Based on test results, the product may be approved for inclusion on the QPL (AL DOT Process Flowchart 2019, AL DOT NPAF 2017).

3.11.2 Alaska DOT

Alaska DOT includes products on the QPL system after satisfying standard specifications. Alaska DOT specifies QPL products into two categories: (1) highway construction products and (2) airport construction products. Manufactures and suppliers can submit an online application with supporting documents of their product for QPL inclusion. Approved products are listed in the Alaska DOT QPL for three years, before requiring for re-evaluation (AK DOT QPL 2019).

3.11.3 Arizona DOT

Arizona DOT's (ADOT) approved product list (APL) evaluation process includes an application submission for product inclusion. In the application, the submitter is required to provide product details, applicable categories, answers to a product-related questionnaire, past evaluations information, Globally Harmonized System (GHS) and Safety Data Sheets (SDS) information, NTPEP data, other state DOT approval data, product description, uses, and specifications and test procedures from ADOT, ASTM, and AASHTO. Additional documents, i.e., safety data sheets, product information/specifications sheets, test data, design sheets, laboratory report, certification of analysis, and a certificate of compliance, should be submitted through email. The response regarding the product

evaluation is anticipated within two weeks. The recertification period for E&SCPs is 5 years. (AZ DOT AF 2017, Arizona DOT APL 2019).

3.11.4 Arkansas DOT

Arkansas DOT QPL evaluation process includes sending a request letter by the manufacturer/submitter for product evaluation to the materials engineer. Manufacturers/submitters can find details about the approval process and specifications of each product type in the QPL. Arkansas DOT accepts recent NTPEP audits, AASHTO requirements, and ASTM testing procedures. The time span for the evaluation process to complete is three months. After the product evaluation, the results will be notified to the manufacturer. Prior to the inclusion on QPL, the manufacturer is required to sign a certification agreement (Arkansas DOT FAQ 2018).

3.11.5 California DOT

California DOT's new product evaluation process includes an application submission from the manufacturer/vendor. The manufacturers/vendors are required to include their company information, product information and answers to a product related questionnaire, NTPEP evaluation information, and details about the product meeting Caltrans, AASHTO, ASTM, FHWA, other DOTs, and national agency specifications. Test methods specified by ASTM, AASHTO, and another national agency should be included. The package list for this process consists of the new product evaluation submittal form, product literature, test data, SDS, a quality control plan, a contact or reference list, other related information, suggested specification language, and a product warranty. After applying, the Program Evaluation Coordinator will review the overall application and send it to the Technical Committee Chair (TCC) and the Office of Health and Safety (OHS). After a review

by both offices, the priority of the product will be decided, and the offices further verify the data and attached documents. The product may be sent to testing if it is needed, or the vendor will be notified about the acceptance if the testing is not required. The average time for the product evaluation is 90 days (Caltrans Flowchart 2019.; Caltrans 2018).

3.11.6 Colorado DOT

Colorado DOT's (CDOT) product acceptance process consists of four methods, i.e., Pre- Inspection (PI), Certified Test Report (CTR), Certificate of Compliance (COC), and Pre-Approved. PI is performed at the manufacturer's facility, CTR and COC are submitted along with the products that are delivered to the projects, and Pre-Approved products are tested and placed on the CDOT's APL. CDOT's product evaluation includes submitting a pre-approved product evaluation request and summary. The submitter should include product details; category; description; specifications, i.e., CDOT, ASTM, AASHTO, FHWA and others; COC; product testing CTR from NTPEP- AASHTO, FHWA and others; and other state DOTs approvals. A Product Evaluation Coordinator will review the application and forward the product to the relative CDOT Expert Product Evaluator (EPE) or Subject Matter Expert (SME). The experimental feature of the product is sent to the Research Director. A decision will be made after evaluation: if accepted, then the product will be added to the QPL. The recertification period for E&SCPs is 5 years (CDOT Notice 2019a, CDOT Application Form 2019b).

3.11.7 Connecticut DOT

Connecticut DOT's new product evaluation includes an application submission to the CDOT personnel. The application form can be obtained by sending an e-mail with detailed information, value of the product, material or process. The application is not

available online. New product applications are reviewed at quarterly meetings. The personnel will notify the submitter on the decision (Conn DOT Product Evaluation 2019).

3.11.8 Delaware DOT

Delaware DOT recommends the manufacturers to submit their products to the contractors who work on DOT projects. The contractors will send the new products to the materials and research section that verifies the products meeting standard specifications. Delaware DOT accepts NTPEP testing data for RECPs (Delaware DOT evaluation 2019).

3.11.9 Florida DOT

Florida DOT's product evaluation process includes submitting a 'Request for product consideration' application. The application form requires adding product and manufacturer details, FDOT's specification section numbers that are mentioned in DOT specifications, test reports or material certifications, plans, and drawings. After receiving the application from manufactures/submitters, the DOT's personnel will proceed after confirming QPL requirements for the product and the completion of the application. Incomplete applications will be returned to the manufacturer/submitters. A Technical Expert (TE) will review the application package with the available standard specification and technical data (NTPEP). After verification, the TE will inform product evaluation process about product compliance to the standard specifications. The decision on the inclusion will be notified to the manufacturer/submitters. If the submitted product requires field testing, the program evaluator may ask to provide a certificate about the product posing no harm on DOT's test deck. According to the Florida DOT, all approved products should be recertified on a timely basis. The recertification schedule varies between products. Erosion control products and geosynthetic materials require to be

notarized for every two years. The DOT's recertification program ensures that the properties of approved products remain constant. The state program evaluation administrator may investigate the products that are not complying with the department documents. If any deficiencies are found, the product may be removed from the APL, and a notification will be sent to the manufacturer (FDOT Evaluation Process 2019, FDOT Flow Chart 2003, FDOT Application 2016a, FDOT Recertification b).

3.11.10 Georgia DOT

Georgia DOT's new product evaluation includes an application submitted by the product manufacturer/supplier. The manufacturer/suppliers are required to provide product and representor information; patent details; information about the country in which the material was produced; product description; advantages; material compositions; relative comparable product details; specifications, including AASHTO, ASTM, and federal specifications; cost and installation details; corresponding educational courses; company description; and previous proposals. Manufacturer/suppliers are also required to attach details about specifications, drawings, sketches, pictures, warranty, installation instructions, Material Safety Data Sheet (MSDS), product literature, and test data. The fee for product evaluation is $100. An initial review of the submitted product application is done by a New Product Evaluation (NPE) committee member. In the preliminary study, documentation, performance details, and the necessity and economic efficiency of the product are reviewed. After initial review, the committee member, along with pertained technical experts, may review the product to make a decision. The decision may be postponed to NPE meetings. The NPE committee meets quarterly. The NPE committee may delay the decision and may recommend the product for testing. The manufacturer is

required to pay a $500 fee for testing. The testing may be done in a lab or in the field. The field evaluation is further divided into two types: standard field test and a proposed pilot field test. Based on the collected test data, the committee may decide and notify the result to the manufacturer (GA DOT Application 2017a, GA DOT NPE Guidelines b).

3.11.11 Hawaii DOT

Hawaii DOT's (HDOT) new product evaluation contains an application submission by the manufacturer. Manufacturers are required to include their company information, product details such as HDOT specification numbers, product description, and specifications including AASHTO, ASTM, and HDOT. Submitters are required to include physical sample and relevant HDOT specifications, a Quality Control Plan, a Quality Control Test Report, HDOT Material Testing and Research Branch Test Data, other independent lab test data, and product literature. Previous performance, maintenance practices, and environmental problems may be examined during the approval process. The APL may be updated once every year. Manufacturers may need to submit a recertification request one month before the expiry date. HDOT may conduct a random testing and auditing for the material at the manufacturing plant, project sites, and other locations. HDOT holds the right to remove products from the QPL at any time if the standard requirements are not met during testing. The erosion control products require to be renewed once a year (HDOT APL process 2019, HDOT application form 2017).

3.11.12 Idaho DOT

Idaho DOT's new product evaluation application for QPL inclusion can be submitted by manufacturers, distributors, sales representatives, and contractors. All submitters except the contractor can directly submit to the program administrator, and the contractor

is required to send the application to the local engineer. Submitters are required to include information such as product applications, satisfying specifications, advantages, plans, product demonstrations, instructions for installation and application, product availability, information about testing by the AASHTO NTPEP product panel, other DOTs approval information, product-specific questionnaire, and manufacturer details. Product review teams pertained to the specific products are responsible for reviewing the products. The products may be approved, provisionally approved, or disapproved. There is no particular time limit for evaluations; applications from contractors may be prioritized, which can ease up in applying the products on current construction projects. Approved products may require appropriate testing and certifications to use in the project; provisional approved products may require additional requirements. The product may be removed from the QPL if the performance does not match the specifications. Existing product and manufacturer name changes may be requested by sending a change application with previous test results, updated product data sheets, MSDS, and test reports. According to the Idaho DOT, all products on QPL are required to recertify every five years (ID DOT QPL 2019, ID DOT QPL Review 2019, ID DOT FAQ 2019, ID DOT QPL application 2006).

3.11.13 Illinois DOT

Illinois DOT's QPL inclusion process consists of producer/supplier approvals. The producers/suppliers are required to be authorized by the DOT personnel to supply their products for the projects. In-state material producers/suppliers may begin the process for approval by calling the regional DOT materials representative. Out-of-state producers/ suppliers can contact the central office. The representative allocates a unique identifier code (P/S number) for each producer and supplier. After obtaining the P/S number, the

producers/suppliers can decide the materials and assign a related material code to the P/S number. The regional district inspector may plan to visit the manufacturing plant for material inspection and further decide on testing (ILDOT approval process 2019).

3.11.14 Indiana DOT

Indiana DOT's (IN DOT) APL inclusion process differs from product to product. The approval process begins by sending a request for product approval by the submitter to the office of materials management. For geotextiles, the submitter should include product and manufacturer details; SDS; product testing certifications specified on the IN DOT's form 'ITM-804', NTPEP test report; details about product meeting the ASTM requirements; manufacturing facility's annual ISO-9001 certification. The geotextile manufacturers are required to pass the NTPEP audit process to maintain their products on APL. The product may be removed if the products fail in testing or meeting the IN DOT's required performance standards, or manufacturer fails in notifying any product changes or completing NTPEP audit process and ISO certification (Indiana DOT Requirements 2019).

3.11.15 Iowa DOT

Iowa DOT's (IA DOT) QPL approval process varies from product to product. The approval process for each product type is described in the QPL section. Erosion control products are required to satisfy the IA DOT specifications. Manufacturers are required to submit product information to the office of construction and materials for obtaining the approval. The product information should include product identification, brand name, product number, product sample for testing, NTPEP test data, company and contact information, and product literature. Wattles and filter socks are an exception for the

approval process; these products may be accepted with certifications submitted by the manufacturer (IA DOT Approval process 2019).

3.11.16 Kansas DOT

Kansas DOT's (KS DOT) QPL approval process relies on the product type and its reference in the plans and/or specifications. The product approval process is categorized into three types: products that are approved on certification; products that require prequalification; and products that require both certification and prequalification. Manufacturers/Submitters are recommended to verify their product standards with KS DOT standard specifications, special provisions, and pre-qualified materials list. If the products are meeting the standard specifications and require prequalification, the manufacturers/submitters can submit product-related documents and samples to the materials and research center for testing. Manufacturers/submitters may submit the products that are not mentioned in the specifications by providing product information in form 1190, product engineering package, marketing brochure, test data, and other relevant information (KS DOT Approval Process 2019).

3.11.17 Kentucky DOT

Kentucky DOT's (KY DOT) AML inclusion process differs from product to product. The approval process for each product type is mentioned in the AML. The standards of erosion control products should confirm with NTPEP data section, and products may be removed but not added from the AML if the test data does not match with the field performance. Geotextile and Geosynthetics manufacturers or suppliers are recommended to participate in the NTPEP program, submit three months of quality control data, and provide samples for testing. Geotextile and Geosynthetic products will be added to the

AML after reviewing the documentation and test data of the submitted samples. Geotextiles and Geosynthetic field samples will be taken down from the project applications or considered at a reduced price if they are not meeting standard specifications. Also, if the products were continuously failing and found defective for three times during laboratory analysis within the calendar year, the product will be removed from the AML. KY DOT updates the AML daily (KY DOM&DOH 2019).

3.11.18 Louisiana DOT

Louisiana DOT's (LA DOT) new product approval process includes an application form submitted by the manufacturers. In the application, the manufacturer should include the company and its product representative information, advantages, composition, NTPEP submittal number, installation details, product-related tutorials, drawings, warranty, MSDS, materials literature, test data sheets, certifications, and test data. Submitted products may be tested in the field and the laboratories. After evaluation, the submitter will be notified about the product inclusion in the AML. The DOT has the right to re-evaluate any material at any time. Also, manufacturers are required to submit a COC of the product every two years to be in the AML. The DOT authorities may remove any product from the AML if any discrepancies are found (LA DOT Application Form 2017a, LA DOT Geotextiles testing b, LA DOT ECP testing c).

3.11.19 Maine DOT

Maine DOT's (ME DOT) QPL approval process begins with the submission of an application by the manufacturer/vendor. In the new product submittal form, the manufacturer/vendor should provide company, submitter, and product distributor details as well as product information. Submitters are recommended to attach the test data of

NTPEP, AASHTO, ASTM, FHWA, and any other nationally recognized agency. Overall, manufacturers should provide a submittal form, product literature, SDS, and a contact list of other agencies. After receiving the application from the manufacturer/vendor, the application is added to the database and forwarded to the relevant sub-committee for review. After review, the sub-committee may recommend the product for pre-qualification or trail use, ask for additional information, or express no interest in the product. If the product trail use is successful, the product may be added to QPL, and the manufacturer/ vendor will be notified. The product may be rejected if the manufacturer/vendor fails in providing the information (ME DOT Evaluation Flow Chart 2008, Maine DOT Application Form 2018).

3.11.20 Maryland DOT

Maryland DOT's (MD DOT) QPL inclusion process begins with manufacturer/vendor registration on the Maryland Product Evaluation List (MPEL) website. After registering, manufacturer/vendor can request product inclusion on MPEL and submit contact information, product name, description, and uses. After submitting the application, the DOT request the manufacturer/vendor complete any one of three actions: statewide new products, traffic new products, and the QPL. The manufacturers/vendors are required to attach third-party test data, MSDS, and payment information. Concerned sub-coordinators verify the submitted information, test data complying to the specifications, and test fee payment. The sub-coordinator also guarantees that the sample reaches the testing laboratory and updates the QPL and MPEL after testing. Manufacturers/Vendors are required to submit NTPEP data and pay a testing fee of $200 for geotextiles. Rejected

products are ineligible for reevaluation for six months (MD DOT Evaluation Procedures 2016, MD DOT Geotextile evaluation 2018).

3.11.21 Massachusetts DOT

Massachusetts DOT's (Mass DOT) Qualified Construction Material List (QCML) approval process starts with the submission of an application by the manufacturer. The submitter is required to provide a product description; supplier information; confirmation standards such as AASHTO, ASTM, FHWA, and Mass DOT Highway Division; previous evaluation information; and costs. Submitters are required to attach Product data sheets, MSDS, testing data from an independent lab that confirms Mass DOT highway division specifications, and other states' product approval information. The application will be evaluated by the Material Management Quality Assurance Program Engineer and forwarded to the New Product Evaluation Committee for further evaluation. The submitter will be notified about the decision on adding the product to the QCML after evaluation (Mass DOT QCML 2018).

3.11.22 Michigan DOT

Michigan DOT's (MI DOT) product approval process consists of application submissions by the manufacturer. The manufacturer is required to include their company and product information plus standards that are confirmed by the product such as: AASHTO, ASTM, federal Specifications, Michigan and Others, and previous evaluation history. After receiving the request, the new product evaluations are given to MI DOT's Subject Matter Expert. In the preliminary review, the SME will decide whether further product evaluation is needed or not. The SME may close the application if the product has been previously tested by MI DOT. After the preliminary review, the SME may contact the

manufacturer for more product-related information. After the final evaluation, the SME may reject the product, accept the product to QPL, or stall the decision for further study (MI DOT 1022Q 2017, MI DOT evaluation process 2018) .

3.11.23 Minnesota DOT

Minnesota DOT's (MN DOT) product approval process begins with the submission of a product-based application by the manufacturer. The manufacturer is required to provide their company and distribution information, erosion control products that meet MN DOT specifications, previous test results, MSDS, and other product-related questionnaires. If the erosion control product comes in the HECP category, the manufacturer is required to answer HECP related questions. The submitter is required to provide samples to MN DOT if the product is either RECP or silt fence. The evaluation process contains the application review, a preliminary environmental evaluation, an engineering evaluation, and the final decision. Products on APL may be decertified at any time if the product performance does not comply to standard specifications. The product evaluation process may take up to 90 days. The products on APL expire after five years, and reapplication is needed to list on QPL (MN DOT Approval Process 2015a, MN DOT E&SC Application Form b).

3.11.24 Mississippi DOT

Mississippi DOT's (MS DOT) product approval process consists of submitting a product evaluation form by the manufacturer. The manufacturer should provide product details, company information, product uses and specifications, NTPEP test data and previous proposal history. Products are required to meet MS DOT standard specifications as well as AASHTO and FHWA standards (MS DOT APL 2019, MS DOT Evaluation Form 2018).

3.11.25 Missouri DOT

Missouri DOT's (MO DOT) product approval process begins with the submission of a new product evaluation form by the manufacturer. The manufacturer should provide their company information, product details, AASHTO, ASTM, federal specifications, NTPEP information, and other product-related questionnaires. Missouri DOT's APL adopts erosion control products from Texas DOT's APL (MO DOT ECB 2014, MO DOT Application Form 2016).

3.11.26 Montana DOT

Montana DOT's (MT DOT) QPL inclusion process starts with the submission of a request form by the manufacturer. The manufacturer should include submitter details, product descriptions and uses, ASTM, AASHTO, MT DOT, other specifications, and other states' product approval information. Submitters should also provide product samples; photographs; technical data sheets; MSDS; test reports from NTPEP; state, federal, or independent testing agencies; and quality control plans. The submitted product is required to be in production for six months to qualify for evaluation. The MT DOT may add the new product to the QPL if it meets all requirements. The MT DOT holds rights to test and audit the products at any time and may disqualify the products that are not in compliance with MT DOT requirements (MT DOT QPL Process 2019, MT DOT Request Form 2019).

3.11.27 Nebraska DOT

Nebraska DOT's (NE DOT) APL inclusion process consists of submitting a new product evaluation form by the manufacturer. The manufacturer is required to provide product information; specification details: AASHTO, ASTM, federal, and NE DOT specifications; and NTPEP test data. The product review team reviews the application if

the manufacturer provides NTPEP testing data, and the DOT may test the product if the manufacturer does not provide previous testing data. After evaluation, the product review team may approve and add into the QPL or reject the product. The Nebraska DOT has specified approval procedures for E&SCPs. All RECPs used in the NE DOT are required to submit testing data from NTPEP. Large scale testing must be performed to RECPs within 18 months to stay in QPL. The NE DOT recommends full-scale testing to find minimum permissible shear stress and conduct slope erosion protection tests at a pre-approved testing facility. Pre-approved testing facilities are the Texas Transportation Institute, College Station, Texas; Colorado State University, Fort Collins, Colorado; San Diego State University, California; Utah State University, Logan, Utah; and the Erosion Lab, Rice Lake, Wisconsin. The NE DOT also reserves the right to test or temporarily approve new products or techniques for understanding the product feasibility in the state of Nebraska. The product may be removed from NE DOT's APL if they fail in 3-6 consecutive tests. Re-certification is required for RECPs every three years (NE DOR APL Policy 2004, NE DOR E&SC APL Testing Process 2007a, NE DOR APL Flow Chart b; NE DOT Application Form 2018).

3.11.28 Nevada DOT

Nevada DOT's (NV DOT) QPL approval process consists of submitting a new product evaluation form by the manufacturer/vendor/distributor. The submitter is required to include their information and product details, other product-related questionnaires, and attach applicable documents. Documents should include FHWA letters, SHA acceptance letters, certifications, SDS, lab analysis, plans, drawings, pictures, product data, specifications, NTPEP test data, handling precautions, health hazards, etc. The evaluation

process shall start after confirming all documentation from the submitter. The application package will be forwarded to the relative division personnel to verify the product meeting current specifications. The product may be added to the QPL if testing is not required, or the product may be forwarded to field testing. In some cases, considering product evaluation, the division personnel may also recommend revising specifications (NV DOT RM 2006, NV DOT Evaluation Form 2014).

3.11.29 New Hampshire DOT

New Hampshire DOT's product evaluation process includes submitting an application form by the manufacturer. The submitter is required to include NTPEP specification number, product details, AASHTO, ASTM, federal specifications, and other product-related questionnaires. The Product Evaluation Unit (PEU) reviews the information and documents included in the application form with the NHDOT specifications. Some products may be forwarded to NTPEP testing or required to meet NTPEP testing standards. The Product Evaluation Subcommittee may approve the products and list them on the QPL if the products meet the NHDOT requirements (NH DOT QPL Submittal Form 2015, NH DOT QPL Evaluation 2018).

3.11.30 New Jersey DOT

New Jersey DOT's qualified products inclusion process begins with a submission of a "New Technologies and Product Evaluation Form" by the manufacturer. The submitter should include their company information; product details; MSDS; NTPEP data; details about products confirming AASHTO, ASTM, federal, and NJDOT specifications; and other product-related questionnaires. The DOT's subject matter experts will review and prioritize the applications. After formal evaluation, the SME may ask the submitters for a

formal presentation. Later, the tests are conducted, and results are submitted to the SMEs. The SMEs shall review and decide on the product addition into the QPL. The evaluation process may take two to three years (NJDOT FAQ 2019, NJDOT Flow Chart 2011, NJ DOT Evaluation Form 2018).

3.11.31 New Mexico DOT

New Mexico DOT 's APL inclusion process consists of an application submission to the program evaluation coordinator. The submitter should include their information, manufacturer, and distributor details; details about the product meeting NMDOT, AASHTO, ASTM, federal, and other DOT specification numbers; MSDS; and other product-related questionnaires. The product evaluation coordinator reviews the application and may add to the QPL or request for testing. Products listed on the QPL will expire in five years and renewal is required before the expiration date (NM DOT PE Instructions 2014, NM PE Application 2016).

3.11.32 New York State DOT

New York State DOT's (NYSDOT) new product evaluation process begins with an application submitted by the manufacturer. The submitter is required to provide their company information; the product maintenance description; details about the product meeting standard specifications such as AASHTO, ASTM, FHWA, and/or NYSDOT; previous evaluations; costs; and department contacts. After submission, the application may be forwarded to New Product Evaluation Committee members for review. After review, the committee members may decide and notify the submitter (NYS DOT Application 2014).

3.11.33 North Carolina DOT

North Carolina DOT's (NCDOT) product approval process consists of an online application submission by the manufacturer. The Technical Work Group (TWG) in the NCDOT's Product Evaluation Program (PEP) reviews the product application to see if the product is needed. After review, the TWG may assess the product standards with NCDOT specifications; if there are no specifications, then the evaluation criteria is designed. After evaluation, a decision will be made on product inclusion, and the submitter will be notified. If denied, the submitter can send an appeal to the PEP engineer that they are not satisfied with the product status. PEP sends recertification requests to vendors annually. Manufacturers who submit geotextiles for APL inclusion are required to maintain a "complaint" status in the current NTPEP audit. NTPEP does not perform testing for some properties such as wide width tensile strength. In such cases, the geotextile products are to be tested in laboratories accredited by Geosynthetic Accreditation Institute (GAI) to find the properties that are available on NTPEP (NCDOT VMO 2018; NCDOT PEP 2017).

3.11.34 North Dakota DOT

North Dakota DOT (ND DOT) does not maintain the APL. The contractors are required to use products that satisfy the contract requirements. Contractors should notify the engineer about the product, and the engineer may approve with COC, sampling, testing, and inspection. The engineer may waive the material inspection if the material value is less than $5000. Manufacturers may apply for new product inclusion if the performance of their products exceeds ND DOT specifications. Manufacturers are required to include their company information; product details; meeting specifications such as NDDOT, AASHTO, ASTM, federal, and other DOTs; test data reports from NTPEP, AASHTO Product Evaluation

List (APEL), National Cooperative Highway Research Program (NCHRP), and others; product literature; technical data sheets; test data; SDS; and product samples. Submitted applications will be forwarded to the Technical Experts and New Product Review Teams. The teams will have ten days to comment on the application and material. The teams may reject, approve, or forward the application for further evaluation (NDDOT Specs 2014, NDDOT Application Form 2018a, NDDOT Product Evaluation b).

3.11.35 Ohio DOT

Ohio DOT's (OHDOT) QPL inclusion process consists of manufacturers sending a product description to the Office of Materials Management (OMM) to obtain the OHDOT's product requirements. The OMM may review the product description and send the product requirements to the submitter based on in-house historical data. If there is no in-house historical data, the OMM may evaluate the material variability, manufacturers efficiency in producing quality material, other state approval methods, and costs for product testing. If there is in-house historical data, the OMM may evaluate previous performance of producers and test data, historical variability of the material, other states approval process, and costs for product testing. The OMM is responsible for developing new product acceptance criteria for inclusion on the QPL. The manufacturers can apply for inclusion of their products on the QPL by submitting the requirements. The OMM will evaluate and may add the products to the QPL if they comply with OHDOT's requirements. Manufacturers are required to recertify the products by January 1st of every calendar year, and uncertified materials will be removed from the QPL by February 1st. The OMM may conduct random testing on QPL materials. If the products fail in meeting the requirements, the manufacturers will be notified and are required to respond within 15 days.

Manufacturers have the right to dispute the validity of department test results. Failing to respond within 15 days may result in removal of the products from the QPL, and they will not be reviewed for reinstatement for a year (OH DOT QPL 2019, OH DOT QPL Process 2014).

3.11.36 Oklahoma DOT

Oklahoma DOT's (OKDOT) QPL approval process consists of a "New or Equal Product Evaluation Request" submission by the manufacturer. The manufacturer is required to provide product and their company information, patent details, other product-related questionnaires, NTPEP test data, AASHTO, ASTM requirements, MSDS, and other product-related information. "Equal products" are the products that are specified in the OKDOT specifications and currently mentioned in OKDOT specifications, whereas "New products" are not specified in current OKDOT standards. After evaluation, the products may be accepted and added to the QPL, accepted for conditional use, rejected, or approved for trial installation. Unsatisfactory performance of QPL products may lead to rejection and removal from the QPL at any time (OK DOT QPL Evaluation 2017).

3.11.37 Oregon DOT

Oregon DOT's (ORDOT) QPL approval process consists of an application submission by the manufacturer. The manufacturer is required to provide a description; advantages; specifications such as ORDOT, AASHTO, ASTM, and others; other agency approvals; MSDS; drawings; installation instructions; test reports; and samples. The materials section confirms the application by the submitter and may forward it to the evaluator. The evaluator reviews the application and may ask the submitter for more information or to send the application to the product evaluation committee. The product evaluation

committee may approve the product and add it to the QPL, conditionally approve and recommend it for field evaluation, or reject the product. The products on the QPL will expire within two years, and the manufacturers are required to apply for an extension (ORDOT QPL Evaluation 2004, ORDOT QPL Application 2018).

3.11.38 Pennsylvania DOT

Pennsylvania DOT's (Penn DOT) approval process consists of an online product evaluation application submission by the manufacturer. According to section 106.02 of bulletin 15 released by Penn DOT on the QPL for construction, manufacturers are not required to submit a product evaluation application for project-specific materials. Project-specific E&SC materials are temporary and permanent RECPs, inlet filter bags, Compost Filter Socks, Compost Blankets, and Compost Filter Berms. Contractors who intend to use such materials in their projects are required to list them on form CS-200 and submit the form for local approval (Penn DOT QPL 2019).

3.11.39 Rhode Island DOT

Rhode Island DOT's (RI DOT) new product evaluation process consists of application submission by the manufacturer. The manufacturer is required to provide their company information; product details; installation details; information about the product meeting specifications such as AASHTO, ASTM, federal, and RIDOT; and other product-related questionnaires in addition to attaching MSDS. The submitter may be notified about the decision after evaluation(RI DOT APL Application Form 2014).

3.11.40 South Carolina DOT

South Carolina DOT's (SCDOT) E&SCPs approval process is based on submitting the AASHTO NTPEP test data and certifications. Acceptance into the QPL may be granted by

the Office of Materials and Research (OMR). The manufacturers should send relative documentation to the OMR such as quality control program sheets, laboratory testing information, and installation instructions. Approved geotextiles for slope applications are listed on QPL for 3 years (SCDOT Geotextile Policy 2007, SCDOT ECB Policy 2014).

3.11.41 South Dakota DOT

South Dakota DOT's (SDDOT) product evaluation process begins with the submission of an application by the manufacturer. The submitter is required to include their information; product details; meeting specifications such as ASTM, AASHTO, SDDOT, and others; physical samples; photographs; product technical data sheets; MSDS; NTPEP test reports; state or federal agency test reports; independent laboratory test reports; and distributor information. The primary screening of applications is done by the certification engineer, and results may be forwarded to the committee if the application has required information and the product shows strong potential. The committee reviews the application and may evaluate the sample. Based on the results, a decision will be made after the evaluation, and the manufacturer will be notified (SD DOT QPL Application 2009, SD DOT QPL Procedure 2016).

3.11.42 Tennessee DOT

Tennessee DOT's (TNDOT) QPL approval process consists of application submission by the manufacturer. The manufacturer should include their company and product information; NTPEP test data; AASHTO, ASTM, federal, and TNDOT specifications; drawings, sketches, and pictures; warranty information; installation details; MSDS; product/material literature; test data; and certifications. The Research and Product Evaluation Section reviews the application and may evaluate the product. The TNDOT

holds the rights to remove the products from the QPL if the performance of the products is not matched with the requirements (TN DOT QPL Evaluation 2019, TN DOT Evaluation Form 2012a).

3.11.43 Texas DOT

Texas DOT's (TxDOT) product evaluation process begins with a request submitted by the manufacturer. The submitters are required to include their company and product information specifications such as ASTM and NCHRP, MSDS, test reports, and other documentation. The Research and Technology Implementation (RTI) Division in the TxDOT receives and reviews the application. The preliminary evaluation is completed based on the submitted information. The Product Evaluation Committee (PEC) may contact the TxDOT district offices to know their interest in using the product. The PEC may send a 'No Interest' letter if the TxDOT district offices do not show any interest. The RTI division may determine the type of evaluation used for the product. The approval of E&SCPs into the QPL is based upon the field performance results. The evaluation process is conducted in the Sedimentation and Erosion Control laboratory of Environmental and Planning Program of the Texas Transportation Institute (TxDOT Evaluation Process 2019, Texas Evaluation Form 2018a, Texas DOT SEC Lab b).

3.11.44 Utah DOT

Utah DOT's (UT DOT) APL process consists of an application submission by the manufacturer. The submitter is required to provide a product description, details about the product meeting ASTM or AASHTO standard specifications, and other product-related questionnaires. The submitters should include product data sheets, installation details, specifications, handling information, MSDS, and limitations. The project engineer may

review the product's compliance with APL standards and may notify the submitter about the decision (UTDOT APL2019; UT DOT Application 2016).

3.11.45 Vermont DOT

Vermont DOT's (VTDOT) APL inclusion process begins with the submission of a submittal form by the manufacturer. The submitter is required to include their company information; NTPEP test number; specifications such as AASHTO, ASTM, and federal; and MSDS. The Material Acceptance Program reviews the application and evaluates the product using VTDOT standard specifications that support the Quality Assurance Program (VTDOT Form 2018).

3.11.46 Virginia DOT

Virginia DOT's (VA DOT) new product inclusion process consists of an application submission by the manufacturer. The submitter is required to provide their company information; satisfying specifications such as AASHTO, ASTM, and NTPEP data; product literature; test data; safety data sheets; and instructions. The information included in the application will be reviewed in the initial evaluation. The new products committee may further evaluate the product and contact the submitters for more details. The product may be added to the QPL based on the results (Virginia DOT Evaluation 2017).

3.11.47 Washington State DOT

Washington State DOT's (WS DOT) approval product inclusion process consists of an application form submitted by the manufacturer. The manufacturer is required to contact the QPL engineer before applying. The submitter is required to provide their company information; product details and its benefits; and details about products meeting standard specification such as AASHTO, ASTM, federal, NTPEP, and other agencies. The

submitters are required to make a payment of $250 for evaluation. The WS DOT may accept the product application and add the product to the QPL after evaluation. The WS DOT may remove products from the QPL if their performance does not match WS DOT standard specifications (WSDOT QPL 2019, WSDOT QPL Application 2018).

3.11.48 West Virginia DOT

West Virginia DOT's (WV DOT) product inclusion process begins with the submission of an application by the manufacturer. The submitters are required to include their company and product information; material composition and specifications; plan drawings, pictures, and/or sketches; AASHTO, ASTM specifications, and NTPEP data; other SHA approvals; and other product-related questionnaires. The Material Control, Soils and Testing Division receives the applications and forwards them to the districts/divisions for review. If the districts/divisions show interest in using the products, they may be accepted and added to the QPL or forwarded elsewhere for further evaluation. Based on the results, a decision will be made on products being added to the QPL (WV DOT Evaluation Process 2016a, WV DOT Application Form b).

3.11.49 Wisconsin DOT

Wisconsin DOT's (WI DOT) Product Acceptability List (PAL) approval process begins with sending a product submittal package through an email by the manufacturer to the New Products Engineer. The WI DOT developed approval requirements for each type of product, and the requirements for each erosion control product defer from one another. The required documents to be included in this package are product data, installation instructions, MSDS, NTPEP test data, and material properties information. The WI DOT accepts erosion control products review applications for approximately 11 months from

April 1st to March 31st, and the annual update on the approvals will be posted by April 31st. WI DOT holds the right to remove the products from PAL at any time if there are any discrepancies in the performance (WI DOT PAL 2019).

3.11.50 Wyoming DOT

Wyoming DOT's (WY DOT) online QPL application does not contain erosion and sediment control criteria. The manufacturers who intend their products to be used in the WY DOT's projects are required to submit their certification or materials certification. The manufacturers should include their information, WY DOT's bid item number, product details, specifications met by the product such as AASHTO, ASTM, WYDOT, etc. WY DOT does not require materials certification if a standard testing agency tests them (WY DOT Spec 2010, WY DOT Certification 2012).

3.11.51 District of Columbia

District of Columbia DOT's (DC DOT) requires 'Compliance Certification Form' of all manufactured materials from the construction contractors before applying in the project. Along with the compliance certification, the contractors are required to provide their information, product testing reports, etc. The materials used in the project may be sampled and tested at any time to ensure the products' compliance with the DC DOT's standard requirements (DC DOT Specifications 2013).

The following figures2.86 and 2.87 are summarized maps about SHAs that accept NTPEP data and execute field or laboratory testing in the QPL evaluation process

3.11.52 Summary of SHAs' QPL inclusion process

This section in the literature review summarized the QPL inclusion process of all SHAs. The general findings of this section are depicted in figure 3.81 and figure 3.82.

Figure 3.81 displays the information pertained with the SHAs that accept AASHTO-NTPEP test data and the SHAs that do not AASHTO-NTPEP test data. Out of 51 SHAs, 65% of SHA accept AASHTO-NTPEP test data, 23% of SHAs do not accept AASHTO-NTPEP test data, and the data of 12% of SHAs' (includes DCDOT) data is unavailable. Figure 3.82 depicts the information pertained with the SHAs that recommend products for laboratory/field testing during the QPL inclusion process. Out of 51 SHAs 41% of SHAs requires lab/field testing if needed, 8% SHAs requires lab/field testing, 6% of SHAs does not require lab/ field testing, 4% SHAs use products for trail use at construction sites, and 41% of SHAs' data is unavailable.

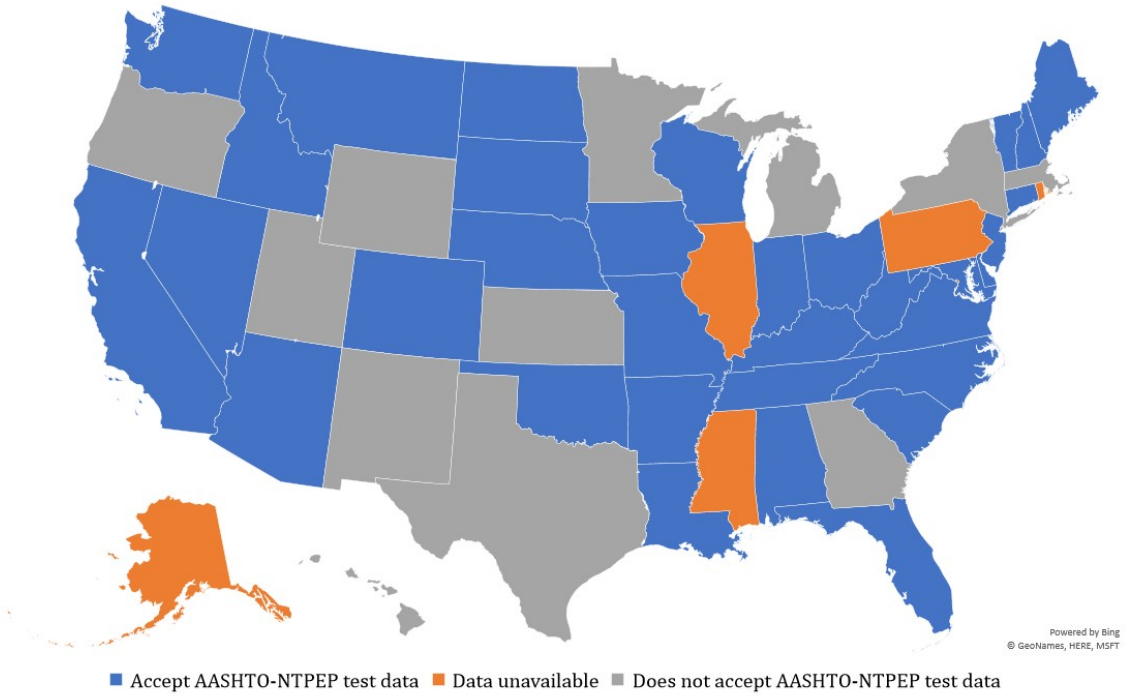


Figure 3.81 SHAs that Accept NTPEP Testing data for QPL Inclusion Process

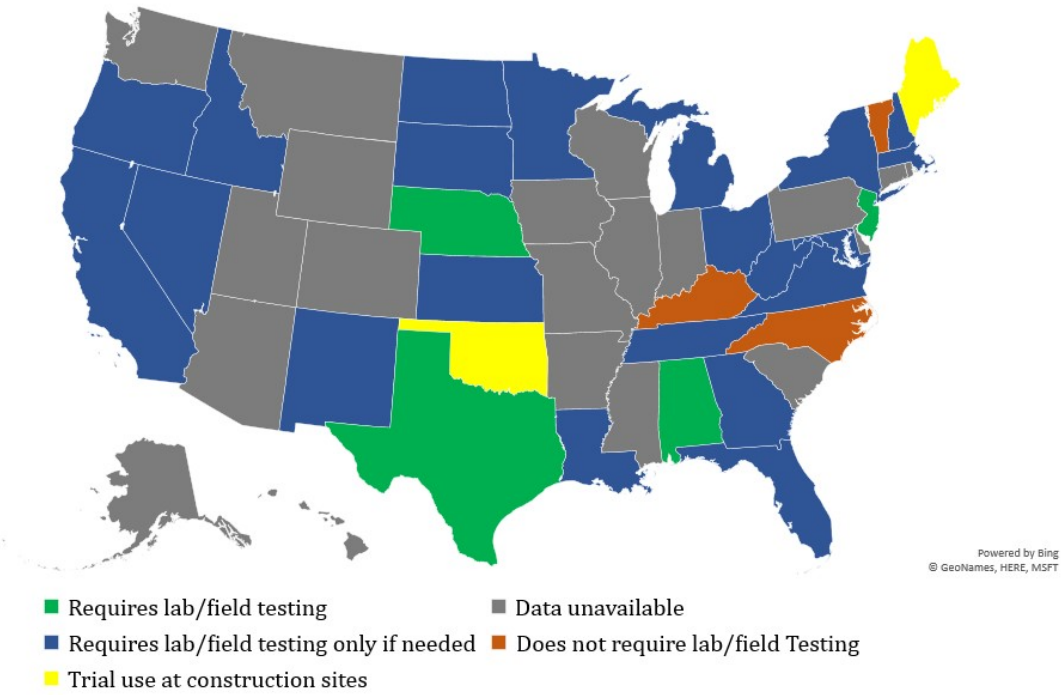


Figure 3.82 SHAs that Recommend Product for Laboratory/ Field Testing during QPL Inclusion Process

3.12 Test Methods and Specifications for Geosynthetics / Erosion Control Products

ASTM and AASHTO develop test methods and specifications mentioned in this section. Test procedures, equipment required for testing, standard testing conditions, and results to be reported after testing for each test method are discussed. The SHAs that recommend the test methods for testing geosynthetics / erosion control products used in erosion control and sediment control practices are tabulated.

3.12.1 Standard Specification for Metallic-Coated, Steel-Woven Wire Fence Fabric (ASTM A116)

ASTM A116 specifies metallic coated, woven steel woven wire fence fabric that is used for various fencing purposes (railroad right-of-way, highway, farm fencing). This document includes multiple fence fabric designs, tensile strength grades, and metallic coating types and grades. This document specifies general requirements (construction, horizontal wires, splices, stay wires, and fence fabric length breaking strength), permissible variations in dimensions (wire diameter, out-of-roundness, fabric height, stay wire spacing, horizontal wire spacing, fence fabric length), sampling and testing (sampling, testing for weight of coating, tests for breaking strength, pretesting of wire inspection for general workmanship), retests and rejection, certification, and packaging and package marking (ASTM A116 2015a). California DOT recommends this specification for testing wire mesh used in Silt Fence.

3.12.2 Standard Test Method for Thickness of Textile Materials (ASTM D1777)

ASTM D1777 is a standard test method for measuring the thickness of most textile materials (woven fabrics, air bag fabrics, blankets, napped fabrics, knitted fabrics, layered fabrics, pile fabrics). This test method is applied to fabrics that may be untreated, heavily sized, coated, resin-treated, or otherwise treated. The equipment required for this test

method is a thickness gauge with an optional microprocessor data gathering system; spring force or compression test apparatus; and cutting dies or templates. The test should be conducted in standard atmospheric conditions. Specimens should be handled carefully to keep them in their natural shape. Each sample should be placed on the anvil of gauge, and then gradual pressure should be applied with presser foot. The thickness can be directly measured from thickness gauge or data collection system. Average thickness and coefficient of variation should be calculated with obtained data (ASTM D1777 2015b). Table 3.3 provides details of SHAs that recommend ASTM D1777 for testing E&SCPs.

Table 3.3 Summary of Recommendations by SHAs for ASTM D1777

State	Practice Type	Material / Component
Illinois	Inlet filters	Geotextile for Outer Reinforcement Bag
South Carolina	RECP	Jute Netting
West Virginia	Permanent Erosion Matting	Permanent Erosion Mat

3.12.3 Standard Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method (ASTM D1907)

ASTM D 1907 is a standard test method for determining linear density of all yarn types in package form. This test method is applicable for the yarns that stretch less than 5% when tension is between 0.008 to 0.026 ozf/tex (0.25 to 0.75 gf/tex), or for yarns that are finer than 2000 tex. Equipment and reagents required are reels, weighing balance, drying oven, facilities for scouring, weighing cans, and auxiliary facilities. Linear density of yarn is calculated from the mass and length of the skein. Another way to calculate linear density is to weigh the yarn after scouring and based on selected option, mass of the skein is observed after oven drying or air conditioning. The results that need to be reported are average yarn linear density, coefficient of variation of yarn linear density, perimeter of the used reel, length of test skeins, method used to find the linear density, and number of tested specimens (ASTM D1907 2018a).

Mississippi DOT and South Carolina DOT recommend this test method for testing polymer roving used in ditch lining to find the linear density.

3.12.4 Standard Test Method for End (Wrap) and Pick (Filling) Count of Woven Fabrics (ASTM D3775)

ASTM D 3775 is a standard test method that specifies measuring end (warp) and pick (filling) count. This test method applies to all kinds of woven fabrics. The required equipment includes pick glass, rule and pointer, microfilm reader or projection equipment, and a scale. This test should be conducted in low moisture recovery and standard atmosphere conditions such as 70 ± 4 °F (21 ± 2 °C) and 65 ± 5% relative humidity. The total number of end and picks per unit distance are counted with relative magnifying glasses and counting devices, or by untangling yarn from fabrics. The average number of ends and picks per inch (cm) is computed to nearest yarn count. The distance where each count is taken and the total yarns at each place should be noted (ASTM D3775 2017a).

South Carolina DOT and Wyoming DOT recommend this test method for testing jute netting used in RECPs to find yarn warp count.

3.12.5 Standard Test Methods for Mass per Unit Area (Weight) of Fabric (ASTM D3776/ D3776M)

ASTM D 3776 is a standard test method used to find the weight (mass per unit area) of most fabrics. This test method has four approved options in finding the mass per unit area of fabrics. They are option A (full piece, roll, bolt or cut), option B (full-width sample), option C (small swatch of fabric), and option D (narrow fabrics). The equipment required includes scale and balance with a sensitivity to weigh within ±0.1% of the mass of specimens being tested and cutting die that can be square or round with a minimum area of 2 in^2 (13cm^2). This test should be conducted in standard atmospheric conditions (70 ± 4 °F

[21 ± 2 °C] and 65 ± 5% relative humidity). Fabric mass is to be noted to three significant figures. Fabric width needs to be mentioned if the mass is reported in mass per linear yard (meter). It is necessary to mention if the fabric weight contains or does not contain selvages (ASTM D3776/ D3776M 2017b). Table 3.4 provides details of SHAs that recommend ASTM D3776 for testing E&SCPs.

Table 3.4 Summary of Recommendations by SHAs for ASTM D3776

SHA	Practice Type	Material / Component
California	Erosion Control Blanket	Jute Mesh, Netting
Illinois	Silt Fence	Geotextile
Illinois	Inlet filters	Geotextile for Outer Reinforcement Bag
Illinois	Filter fabric for riprap	Geotextile Filter Fabric
Illinois	Above grade inlet filters	Fitted Geotextile filter
New Jersey	Sediment Control Bag	Geotextile
North Carolina	Stilling Basin	Geotextile for Stilling Basin
Pennsylvania	Pumped water filter bag	Non-Woven Geotextile Bag
South Carolina	RECP	Jute Netting
South Carolina	Inlet Filters	Geotextiles

3.12.6 Standard Test Method for Bursting Strength of Textile Fabrics – Diaphragm Bursting Strength Test Method (ASTM D3786/ D3786M)

ASTM D3786 standard test method used to measure the resistance of textile fabrics to bursting. This test method is suitable for different kinds of textile products, stretch, and woven industrial fabrics. The equipment required is an inflated diaphragm bursting tester. The sample is clamped to an expandable diaphragm. The diaphragm should be enlarged by fluid pressure to the point where the specimen bursts. The difference between the total pressure required to burst the specimen and inflate specimen can be recorded as the bursting strength. The bursting strengths of each specimen and their average in psi (kPa) should be reported. If the fabric did not burst, it should be stated that the maximum bursting pressure of the instrument and the sample did not burst at the maximum pressure. Also, the type of bursting tester used should be mentioned (ASTM D3786/

3786M 2018b). Table 3.5 provides details of SHAs that recommend ASTM D3786 for testing E&SCPs.

Table 3.5 Summary of Recommendations by SHAs for ASTM D3786

State	Practice Type	Material / Component
Colorado	Aggregate bag	Woven geotextile fabric
Colorado	Strom Drain inlet protection	Woven geotextile fabric (Type 1, 2, 3)
Dist. of Columbia	Sediment Barriers and Filters	Inlet filter bags
Georgia	Silt Fence	Silt fence type a, b, c
Georgia	Triangular Silt Barrier	Filter fabric
Illinois	Silt Fence	Geotextile
Illinois	Filter fabric for riprap	Geotextile filter fabric
Illinois	Urethane Foam/Geotextile	Geotextile
Illinois	Above grade inlet filters	Fitted Geotextile filter
Michigan	Silt Fence	Silt fence
Michigan	Geotextile for filtration applications	Non-Woven Geotextile Separator
Michigan	Trench lining Ditch lining,	Non-Woven Geotextile Separator
Michigan	Streambed protection	Non-Woven Geotextile Separator
Michigan	Pipe wrap, Joint wrap, Drain hole and Weep hole filter	Non-Woven Geotextile Separator
Michigan	Granular blanket Separation	Non-Woven Geotextile Separator
Michigan	Filter bags	Non-Woven Geotextile Separator
Michigan	Turbidity Curtain	Stabilization geotextile
New Hampshire	Silt Fence	Silt Fence
New Jersey	Inlet Filter	Geotextile
New Jersey	Sediment Control Bag	Geotextile
Pennsylvania	Pumped water filter bag	Non-Woven Geotextile Bag
Pennsylvania	Storm Drain Inlet Protection (Inlet Filter Bag)	Geotextile
South Carolina	Inlet Filters	Geotextile Filter Fabric

3.12.7 Standard Test Method for Bursting Strength of Textiles: Constant-Rate-of-Traverse (CRT) Ball Burst Test (ASTM D3787)

ASTM D 3787 test method is used to measure the bursting strength of textiles or garments that show a high degree of ultimate elongation. The equipment includes Constant-Rate-of-Traverse (CRT) tensile testing machine, and Ball-Burst Attachment. The specimens tested can be either in the shape of a circle (5 in. [125mm] in diameter) or square (5 in. [125mm]). The specimen is fastened without tension between grooved,

circular plates of the ball burst attachment that is fixed to the movable pulling jaw of the Constant Rate of Traverse (CRT) testing machine (12 ± 0.5 in./min [305 ± 13mm/min]). The force is applied on the specimen by a polished, hardened steel ball that is attached to the fixed pendulum actuating clamp of the CRT machine, until the specimen bursts. The average bursting force should be calculated to the nearest 0.1lb (0.5 N). The bursting strength of each specimen and average bursting strength of five specimens to the nearest 0.1lbf (0.5N) should be reported (ASTM D 3787 2016a). Figure 3.83 depicts ball burst arrangement in the equipment during testing.

Figure 3.83 Ball Burst Arrangement (ASTM D3787 2016a).

Louisiana DOT recommends this test method to test geotextile used in temporary construction entrance practice.

3.12.8 Standard Practice for Fluorescent Ultraviolet (UV) Lamp Apparatus Exposure of Plastics (ASTM D4329)

ASTM D 4329 is a standard practice used to measure the retention capacity of plastics to UV light exposure. This method uses a fluorescent UV apparatus that consists of corrosion resistant testing chamber, light source, devices that control temperature and relative humidity, radiometer, thermometer, and water spray. The test should be

conducted in an area where the temperature is between 65°F to 85°F (18°C to 27°C) and a minimum of 300mm from walls or other equipment. The room should be ventilated to let away the heat and moisture. The specimens are fixed to racks inside the equipment, and if specimens do not fill all the racks, empty racks should be filled with blank panels. The testing device should be programmed into three test cycles. Between cycles, specimens should be repositioned horizontally and vertically to minimize the effects of temperature and UV light variation. Total exposure time, type of light and dark-water condensation or spray cycle used, operating black panel temperature, total solids, and silica gel used in the water spray should be documented. Unless measured directly during exposure, irradiance or radiant exposure do not need to be reported. Specimen repositioning to guarantee equal exposure time should be included. Overall, the retention of UV exposure should be calculated according to ASTM D 5870 practice (ASTM D4329 2013a).

Minnesota DOT recommends this practice for testing different kinds of nettings (wood cellulose fiber, wood fiber, straw, synthetic, coconut fiber) used in RECPs.

3.12.9 Standard Practice for Sampling of Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing (ASTM D4354)

ASTM D 4353 is a standard practice that describes three different procedures for the sampling of geosynthetics and RECPs for testing. The first procedure is the sampling of production units for the manufacturer's quality control (MQC). The second procedure is the sampling of production units for the manufacturer's quality assurance (MQA). The third practice is dividing shipments of geosynthetics and RECPs into lots (a lot is a unit of production taken for sampling or statistical examination) and determining the lot sample size for purchaser specification conformance testing (ASTM D4354 2009).

North Carolina DOT and Indiana DOT recommend this practice for sampling geosynthetics.

3.12.10 Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture, and Heat in a Xenon Arc-Type Apparatus (ASTM D 4355/4355M)

ASTM D4355 is a standard test method to find the decline in tensile strength of geotextiles from exposure to xenon arc radiation, moisture, and heat. The equipment required includes a xenon arc apparatus and strength testing device. The specimens of geotextile should be exposed in the xenon arc device for 0, 150, 300 and 500 hours in the machine direction and cross-section direction. Each exposure cycle consists of 120-minute cycles with 90 minutes of only light at 149 ± 37.4°F (65 ± 3°C) uninsulated black panel temperature and 50 ± 10% relative humidity, and light and water spray for the remaining 30 minutes. After each exposure period, the specimens are required to undergo a cut or ravel strip tensile test. The average breaking strength of the geotextile in each direction should be compared with the average breaking strength in each direction of the control specimens. The degradation curve should be plotted with the percentage of retained strength versus the exposure period (ASTM D4355 2018c). Figure 3.84 shows different geotextile fabrics that are being attached in the chamber of xenon-arc apparatus. Table 3.6 and table 3.7 provides details of SHAs that recommend ASTM D4355 for testing E&SCPs.

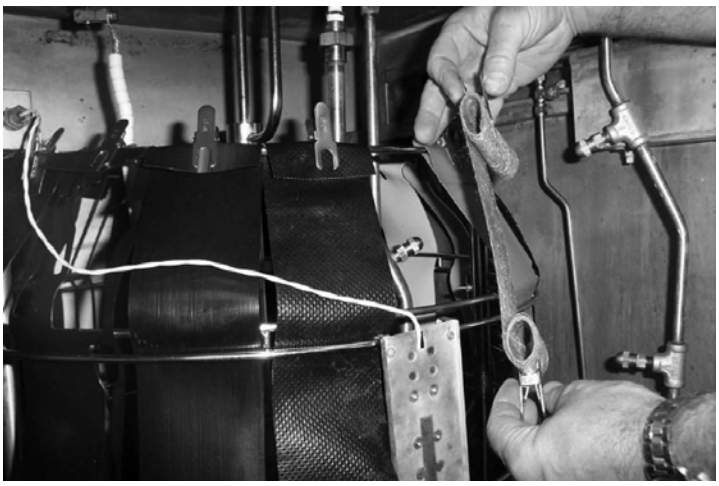


Figure 3.84 Geotextile Fabrics in the Xenon arc Apparatus (ASTM D4355 2018c).

Table 3.6 Summary of Recommendations by SHAs for ASTM D4355 (States Alabama through Oregon)

State	Practice Type	Material / Component
Alabama	Inlet Protection	Filter Fabric
Arizona	Silt Fence	Temporary Silt Fence Fabric
California	Erosion Control Blanket	TRM- Type A, B, C
California	Temporary Sediment Control	Rigid Plastic Barriers
California	Temporary liner Sediment Barriers	Foam Barriers
California	Sediment Control	Silt Fence Fabric, Nonwoven silt fence, Gravel filled geotextile bag, Woven and Non-Woven Sediment filter bag
Colorado	Silt Fence	Wire Supported and Self Supported Silt Fence
Colorado	Aggregate bag	Woven geotextile fabric
Colorado	Strom Drain inlet protection	Woven geotextile fabric-Type 1, 2, 3
Colorado	ECB/RECP	TRM Type 1,2,3
Dist. of Columbia	Sediment Barriers and Filters	Inlet Filter Bags
Dist. of Columbia	Dewatering	Pumped Water Filter Bags
Florida	Silt Fence	E1- Stake Silt Fence
Florida	Plastic erosion mat	TRM-Type 1,2,3
Georgia	Silt Fence	Silt Fence-Type A, B, C
Hawaii	Geotextiles for Permanent Erosion Control Applications.	Woven Monofilament Geotextiles and all other geotextiles
Hawaii	Geotextiles for Temporary Silt Fence Applications	Silt Fence
Idaho	Riprap/Erosion Geotextile	Geotextile-Type-1,2
Idaho	Temporary Silt Fence	Geotextile
Illinois	Inlet filters	Geotextile fabric bag
Illinois	Urethane Foam/Geotextile	Geotextile
Illinois	Above grade inlet filters	Fitted Geotextile filter
Indiana	Silt Fence	Wire Supported and Self supported geotextile
Iowa	Turf Reinforcement Mat	TRM Type 1,2,3,4
Iowa	Transition Mat	Mat
Maryland	Silt Fence	Geotextile, Woven and Non- Woven
Maryland	Soil Stabilization Matting	Matting Type B, C
Michigan	Silt Fence	Silt Fence Geotextile Sandbags-Polypropylene fabric
Minnesota	Sandbags	
Mississippi	Silt fence	Silt Fence Type 1,2
Montana	Permanent Erosion Control	Geotextile Type A, B, C
Montana	Silt Fence	Stabilized and Un-stabilized Silt Fence
New Jersey	ECB	Turf Reinforcement Mat Type-3 mat
New Jersey	Sediment Control Bag	Geotextile
North Carolina	Stilling Basin	Stilling Basin Geotextile
Oregon	Construction Entrance, Tire Wash Facility, Inlet protection, Temporary Energy Dissipater, Temporary Sediment Trap, Concrete Washout	Woven and Non-Woven Geotextile Type 1, 2
Oregon	Sediment Fence	Geotextile

Table 3.7 Summary of Recommendations by SHAs for ASTM D4355 (States Pennsylvania through Wyoming)

State	Practice Type	Material / Component
Pennsylvania	RECP- TRM	TRM type 5A, 5B, 5C
Pennsylvania	Sediment Control, Silt Barrier Fence, Heavy Duty Silt Fence, Sediment Trap	Woven and Non-Woven Silt Film Geotextile
Pennsylvania	Sediment Control, Rock Construction Entrance, Outlet protection, Temporary Slope Pipe, Pumped water filter bag, Sediment Trap and Sediment trap-riser, Sediment Basin	Needle punched non-Woven geotextile
Pennsylvania	Pumped water filter bag	Non-Woven Geotextile Bag
Pennsylvania	Storm Inlet Protection	Geotextile Inlet Filter Bag
South Carolina	TRM	TRM Type 1,2,3,4
South Carolina	Fiber Roving	Polymer Roving
South Carolina	Inlet Filters	Geotextile
South Carolina	Silt Fence	Silt Fence filter Fabric
Texas	Temporary Sediment Control Fence.	Woven geotextile fabric
Utah	Inlet Barrier	Geotextile
Utah	RECP- TRM	TRM
Vermont	Geotextile under stone	Woven or Non-Woven Geotextile
Vermont	Silt Fence	Woven Silt Fence
Virginia	TRM	TRM Type 1,2,3
Virginia	Dewatering bag	Non-woven Geotextile
Washington State	Silt Fence	Unsupported and Supported Geotextile Fabric
West Virginia	Permanent Erosion Matting	Permanent Erosion Matting Type 1,2,3
Wisconsin	Silt Fence	Silt Fence Geotextile
Wisconsin	Turbidity Barriers	Turbidity barrier fabric
Wisconsin	Rock bags	High-density polyethylene or Geotextile
Wyoming	Erosion Control	Geotextile, Silt Fence, and Non-Woven separation and stabilization Geotextile

3.12.11 Standard Test Methods for Water Permeability of Geotextiles by Permittivity (ASTM D4491/D4491M)

ASTM D 4491 is a test method for determining the uncompressed hydraulic conductivity (water permittivity) of geotextiles. The hydraulic conductivity property indicates the amount of water that can pass through a geotextile. In this test method, three kinds of test procedures were described: constant head, falling head, and air flow. The constant head and falling head methods require a water flow apparatus consisting of a manometer to measure the head loss. The air flow method requires an airflow apparatus that contains a clean gas pressure source and pressure sensor. In the constant head test

method, a constant head of 1.9 in (50 mm) of water is maintained on the geotextile. Values of time (t) and quantity of flow (Q) readings are recorded from the discharge pipe. This test method is preferable to the falling head test method when the flow rate of water through the geotextile is high, since the head change readings versus time are difficult to record. In the falling head method, a column of water is allowed to pass through the geotextile. Readings of head changes versus time are obtained. To record precise readings, the flow rate passing through the geotextile must be low. The technician who performs the test should decide which test method (constant or falling head) to use. In the airflow test method, the geotextile specimen is exposed to increasing flow rate, and flow rate and pressure should be recorded. Two data points are recorded when the pressure reaches 250 and 500 pascals; these data points are used to calculate the characteristic flow equation. Specimens used and description of material sampled for the test, the test method used, and the temperature of test water should be reported. The permittivity of the individual specimen, average permittivity, and standard deviation and coefficient of variation should be calculated (ASTM D4491 2017c). Figure 3.85 shows a constant head and falling head apparatus. Table 3.8 and Table 3.9 provides details of SHAs that recommend D4491 for testing E&SCPs.

Figure 3.85 Constant Head and Falling Head Apparatus (ASTM D4491 2017c).

Table 3.8 Summary of Recommendations by SHAs for ASTM D4491(States Alabama through Illinois)

State	Practice Type	Material / Component
Alabama	Manufactured Inlet Protection Device	Filter Fabric
California	Temporary Sediment Control	Rigid Plastic Barriers
California	Temporary liner Sediment Barriers	Foam Barriers
California	Sediment Control	Woven and Nonwoven Silt Fence
California	Sediment Control	Gravel Filled Bag
California	Sediment Control	Woven and Non-Woven Sediment Filter Bag
Colorado	Silt Fence	Wire and Self Supported Silt Fence
Colorado	Strom Drain inlet protection	Woven geotextile fabric Type 1, 2, 3
Dist. of Columbia	Sediment Barriers and Filters	Inlet Filter Bags
Dist. of Columbia	Dewatering	Pumped Water Filter Bags
Florida	Silt Fence	Stake Silt Fence
Hawaii	Geotextiles for Permanent Erosion Control Applications.	Woven Monofilament Geotextiles and All other Geotextile
Hawaii	Geotextiles for Temporary Silt Fence Applications	Silt Fence Geotextile
Idaho	Riprap/Erosion Geotextile	Geotextile Type 1, 2
Idaho	Silt Fence	Temporary Silt Fence Geotextile
Illinois	Inlet filters	Geotextile fabric bag
Illinois	Filter fabric for riprap	Geotextile
Illinois	Above grade inlet filters	Fitted Geotextile filter

Table 3.9 Summary of Recommendations by SHAs for ASTM D4491 (States Indiana through Wyoming)

State	Practice Type	Material / Component
Indiana	Silt Fence	Wire and self-supported silt fence geotextile
Louisiana	Silt Fence	Wire and self-supported silt fence geotextile
Louisiana	Temporary Construction Entrance	Geotextile
Maryland	Silt Fence	Woven Geotextile
Michigan	Silt Fence	Silt Fence Geotextile
Michigan	Geotextile for filtration applications, including trench lining, ditch lining, streambed protection, pipe wrap, joint wrap, drain hole and weep hole filter, granular blanket separation, and filter bags	Non-Woven Geotextile
Michigan	Turbidity Curtain	Geotextile
Minnesota	Silt Fence	Woven Geotextile
Mississippi	Silt fence	Silt Fence Type 1, 2
Montana	Permanent Erosion Control Geotextile	Non-woven Geotextile- Type A, B, C
Montana	Silt Fence	Stabilized and Unstabilized Silt Fence
New Jersey	Geotextile	Sediment Control Bag
North Carolina	Stilling Basin	Stilling Basin Geotextile
Oregon	Construction Entrance, Tire Wash Facility, Inlet protection_Type-2, Temporary Energy Dissipater, Temporary Sediment Trap, Concrete Washout	Woven and Non-Woven Geotextile Type 1, 2
Oregon	Sediment Fence	Geotextile
Pennsylvania	Sediment Control, Silt Barrier Fence, Heavy Duty Silt Fence, Sediment Trap	Woven Geotextile Type A, B
Pennsylvania	Sediment Control, Rock Construction Entrance, Outlet protection, Temporary Slope Pipe, Pumped water filter bag, Sediment Trap and Sediment trap- riser, Sediment Basin	Non-Woven Geotextile Type A
Pennsylvania	Storm Inlet Protection	Woven Geotextile Inlet Filter Bag
South Carolina	Inlet Filters	Geotextile
South Carolina	Silt Fences	Silt Fence Geotextile
Texas	Temporary Sediment Control Fence	Unsupported Woven Geotextile
Utah	Inlet Barrier	Geotextile
Vermont	Geotextile under stone	Woven and Non-Woven Geotextile
Vermont	Silt Fence	Woven Geotextile Silt Fence
Virginia	Dewatering bag	Non-woven Geotextile
Washington State	Silt Fence	Unsupported and Supported Geotextile
Wisconsin	Silt Fence	Silt Fence Geotextile
Wisconsin	Turbidity Barriers	Geotextile Fabric
Wyoming	Erosion Control	Silt Fence, Non-Woven Separation and Stabilization Geotextile

3.12.12 Standard Test Method for Trapezoid Tearing Strength of Geotextiles (ASTM D4533/D4533M)

ASTM D4533 is an index text method to measure the strength needed to promulgate a tear in geotextiles using the trapezoid method. This test method is applicable for woven, nonwoven, layered, and knitted geotextiles. The equipment includes a tensile testing machine, clamps, and trapezoidal template. This test method requires atmospheric conditions of 70 ± 4 °F (21 ± 2 °C) and 65 ± 5% relative humidity. An isosceles trapezoidal shape should be drawn on a rectangular specimen cut. The nonparallel sides of the trapezoid-marked specimen should be fixed to the jaws of the testing machine. The separation between the jaws is gradually increased to develop a tear across the specimen. Simultaneously, the force is recorded, and the tearing strength (the maximum value of tearing force) can be deduced from autographic force versus extension curve (ASTM D4533 2015c). Figure 3.86 shows optional tearing force dies and geotextile test specimens. Figure 3.87 shows the elongation behavior of a woven geotextile during testing for finding trapezoidal tearing strength. Table 3.10 and Table 3.11 provides details of SHAs that recommend ASTM D4533 for testing E&SCPs.

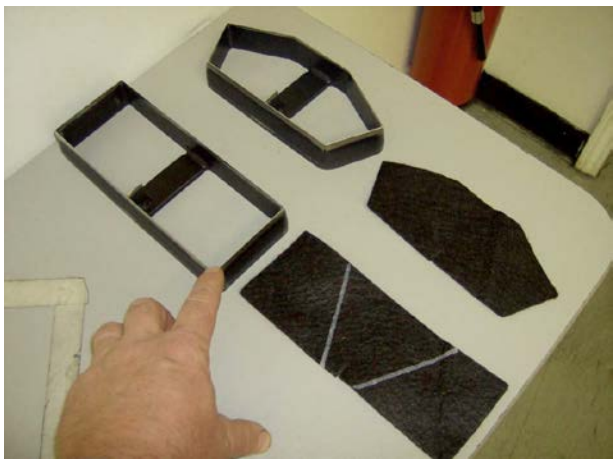


Figure 3.86 Optional tearing force dies and geotextile test specimens (ASTM D4533 2015c).

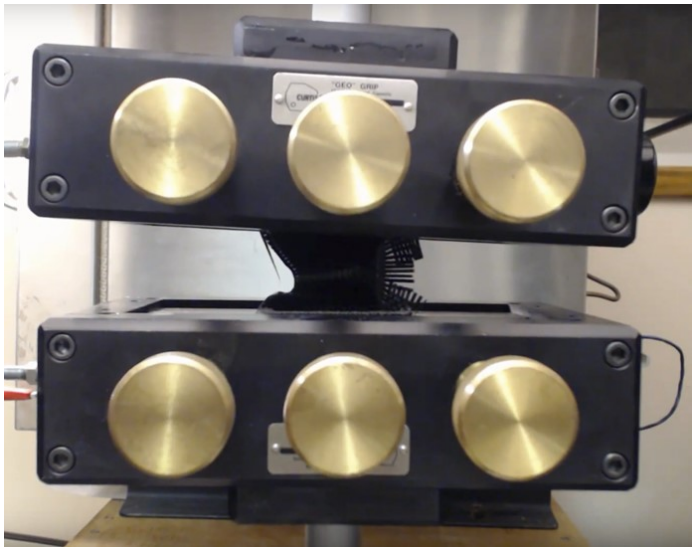


Figure 3.87 Elongation of woven geotextile during testing (Geosynthetic Institute 2018a)

Table 3.10 Summary of Recommendations by SHAs for ASTM D4533 (States Colorado through Oregon)

State	Practice Type	Material / Component
Colorado	Aggregate bag	Woven geotextile fabric
Colorado	Strom Drain inlet protection	Woven geotextile fabric Type 1, 2, 3
Dist. of Columbia	Sediment Barriers and Filters	Inlet Filter Bags
Hawaii	Geotextiles for Permanent Erosion Control Applications.	Woven Monofilament Geotextiles and All other geotextiles
Hawaii	Geotextiles for Temporary Silt Fence Applications	Silt Fence
Idaho	Riprap/Erosion Geotextile Criteria	Geotextile Type 1, 2
Illinois	Silt Fence	Silt Fence Geotextile
Illinois	Inlet filters	Geotextile fabric bag
Illinois	Above grade inlet filters	Geotextile
Illinois	Fabric for riprap	Geotextile Filter Fabric
Louisiana	Temporary Construction Entrance	Geotextile
Maryland	Silt Fence	Woven Geotextile Silt Fence
Michigan	Silt Fence	Geotextile Silt Fence
Michigan	Geotextile for filtration applications, including trench lining, ditch lining, streambed protection, pipe wrap, joint wrap, drain hole and weep hole filter, granular blanket separation, and filter bags	Non-Woven Geotextile
Michigan	Turbidity Curtain	Geotextile
Montana	Permanent Erosion Control Geotextile	Non-Woven Geotextile
New Hampshire	Silt Fence	Geotextile Silt Fence
Oregon	Construction Entrance, Tire Wash Facility, Inlet protection_Type-2, Temporary Energy Dissipater, Temporary Sediment Trap, Concrete Washout	Woven and Non-Woven Geotextile Type 1, 2

Table 3.11Table 3.10 Summary of Recommendations by SHAs for ASTM D4533 (States Pennsylvania through Wyoming)

State	Practice Type	Material / Component
Pennsylvania	Sediment Control, Silt Barrier Fence, Heavy Duty Silt Fence, Sediment Trap	Woven Geotextile Type A, B
Pennsylvania	Sediment Control, Rock Construction Entrance, Outlet protection, Temporary Slope Pipe, Pumped water filter bag, Sediment Trap and Sediment trap- riser, Sediment Basin	Non-Woven Geotextile Type A
Pennsylvania	Pumped water filter bag	Non-Woven Geotextile Bag
Pennsylvania	Storm Inlet Protection	Woven Geotextile Inlet Filter Bag
South Carolina	Inlet Filters	Geotextile
Texas	Temporary Sediment Control Fence	Unsupported Woven Geotextile
Vermont	Geotextile under stone	Woven and Non-Woven Geotextile
Vermont	Silt Fence	Geotextile Silt Fence
Wyoming	Erosion Control	Silt Fence, Non-Woven Separation and Stabilization Geotextile

3.12.13 Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method (ASTM D4595)

ASTM D 4595 is a test method to measure tensile properties of geotextiles using the wide-width strip specimen tensile method. This test method includes measuring tensile strength and elongation; and calculating initial modulus, offset modulus, secant modulus, and breaking toughness of geotextiles. This test method is applicable for woven, nonwoven, layered, knitted and felt geotextiles. The equipment and reagents include CRE tensile testing machine, clamps, external extensometers, an area measuring device, distilled water, and nonionic wetting agent. This test method requires atmospheric conditions of 70 ± 4 °F (21 ± 2 °C) and 65 ± 5% relative humidity. The width of the specimen is fixed to the clamps of the CRE tensile testing machine. The machine requires a specified extension rate that applies a longitudinal force to rupture the specimen. Force observed at the rupturing point needs to be recorded. Tensile strength of specimens can be calculated from maximum force per unit width that creates a rupture to the specimen. Elongation of specimens should be reported in terms of percentage increase in length. Average breaking

force per unit width in lbf/in.(N/m) and average elongation in percent should be reported. If requested, average initial and secant modulus, average breaking toughness, and force-elongation curve should be included (ASTM D4595 2017d). Figure 3.88 depicts elongation behavior of a woven textile during testing. Table 3.12 provides details of SHAs that recommend ASTM D4595 for testing E&SCPs.

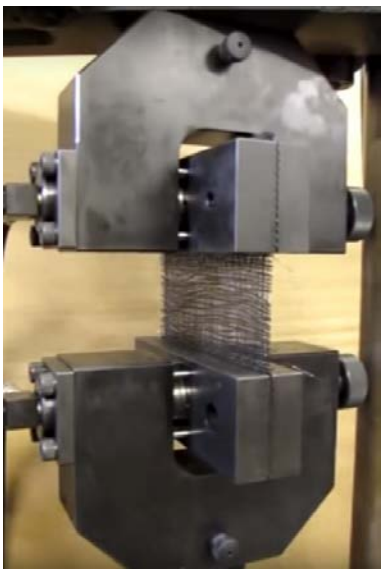


Figure 3.88 Elongation of Woven Geotextile during testing (The Universal Grip Company 2015).

Table 3.12 Summary of Recommendations by SHAs for ASTM D4595

State	Practice Type	Material / Component
Alabama	Mulching	Mulch Control Netting
Dist. of Columbia	Sediment Barriers and Filters	Silt Fence/ Super silt Fence
Montana	Temporary RECP	RECP Type II, III, IV
Pennsylvania	Sediment Control, Silt Barrier Fence, Heavy Duty Silt Fence, Sediment Trap	Woven Geotextile
Pennsylvania	Sediment Control, Rock Construction Entrance, Outlet protection, Temporary Slope Pipe, Pumped water filter bag, Sediment Trap and Sediment trap- riser, Sediment Basin	Non-Woven Geotextile
Utah	RECP	TRM
Virginia	RECP	RECP Type 1, 2, 3, 4
Virginia	TRM	TRM Type 1, 2, 3
West Virginia	Permanent Erosion Matting	Permanent Erosion Matting Type 1, 2, 3

3.12.14 Standard Test Method for Grab Breaking Load and Elongation of Geotextiles (ASTM D4632/4632M)

ASTM D4632 is an index test method to measure the breaking load and elongation using the grab method in both wet and dry conditions. This test method does not apply to knitted geotextiles. The equipment includes tensile testing machine and clamps. This test method requires atmospheric conditions of 70 ± 4 °F (21 ± 2 °C) and 65 ± 5% relative humidity. A constant load is applied longitudinally on to the specimen until rupture occurs. Breaking load and elongation values are recorded from the test machines. Breaking load and apparent elongation values are deduced separately for the machine direction and cross-section direction specimens. In the results, average grab breaking load and average grab percent elongation of specimens in each direction, number of specimens used in each direction, condition of the specimen, and type of testing machine should be reported (ASTM D4632 2015d). Figure 3.89 shows elongation of nonwoven geotextile during testing Table 3.13 and Table 3.14 provides details of SHAs that recommend ASTM D4632 for testing E&SCPs.

Figure 3.89 Elongation of Nonwoven Geotextile during Testing (Geosynthetic Institute 2018b).

Table 3.13 Summary of Recommendations by SHAs for ASTM D4632 (States Alabama through Montana)

State	Practice Type	Material / Component
Alabama	Manufactured Inlet Protection Device	Filter Fabric
Arizona	Silt Fence	Temporary Silt Fence
California	Temporary Sediment Control	Rigid Plastic Barriers
California	Temporary liner Sediment Barriers	Foam Barriers
California	Sediment Control	Woven and Non-Woven Silt Fence; Geotextile bag for gravel filling; Woven and Non-woven sediment filter bag;
Colorado	Silt Fence	Wire and Self supported Silt Fence Geotextile
Colorado	Aggregate bag	Woven Geotextile Fabric
Colorado	Strom Drain inlet protection	woven geotextile fabric- Type 1, 2, 3
Dist. of Columbia	Sediment Barriers and Filters	Inlet Filter Bags
Dist. of Columbia	Dewatering	Pumped Water Filter Bags
Florida	Silt Fence	Stake Silt Fence
Florida	Wind screen	Geotextile
Georgia	Silt Fence	Silt Fence Type A, B, C
Georgia	Triangular Silt Barrier	Filter Fabric
Hawaii	Geotextiles for Permanent Erosion Control Applications.	Woven Monofilament Geotextiles, all other geotextiles, and Silt Fence
Idaho	Riprap/Erosion Geotextile Criteria	Geotextile Type 1, 2
Idaho	Temporary Silt Fence	Temporary Silt Fence Geotextile
Illinois	Silt Fence	Silt Fence Geotextile
Illinois	Inlet filters	Geotextile for inner fabric bag
Illinois	Filter fabric for riprap	Geotextile fabric bag
Illinois	Above grade inlet filters	Fitted Geotextile filter
Indiana	Silt Fence	Wire and Self supported Silt Fence Geotextile
Louisiana	Silt Fence	Wire and Unsupported Silt Fence Geotextile Class F, G
Louisiana	Temporary Construction Entrance	Geotextile Class D
Maryland	Silt Fence	Woven Silt Fence Geotextile
Michigan	Geotextile for filtration applications, including trench lining, ditch lining, streambed protection, pipe wrap, joint wrap, drain hole and weep hole filter, granular blanket separation, and filter bags	Non-Woven Geotextile
Michigan	Turbidity Curtain	Geotextile
Minnesota	Silt Fence	Woven and Non-Woven Silt Fence geotextile
Minnesota	Floating silt curtain	Heavy duty and Light duty Floatation Geotextile Silt Curtain
Minnesota	Sandbags	Polypropylene fabric for sandbags
Mississippi	Silt fence	Silt Fence Type 1, 2, 3
Montana	Permanent Erosion Control Geotextile	Moderate and High Survivability Woven and Non-Woven Geotextile Type A, B, C
Montana	Silt Fence	Stabilized and Unstabilized Silt Fence Geotextile

Table 3.14 Summary of Recommendations by SHAs for ASTM D4632 (States New Hampshire through Wyoming)

State	Practice Type	Material / Component
New Hampshire	Silt Fence	Silt Fence Geotextile
New Jersey	Geotextile	Geotextile for Sediment Control Bag
North Carolina	Silt Fence	Silt Fence Geotextile
North Carolina	Gravel Construction Entrance, Temporary Stream Crossing	Geotextile under the riprap
North Carolina	Stilling Basin	Geotextile for Stilling Basin
Oregon	Construction Entrance, Tire Wash Facility, Inlet protection, Temporary Energy Dissipater, Temporary Sediment Trap, Concrete Washout	Woven and Non-Woven Geotextile Type 1, 2
Oregon	Sediment Fence	Geotextile for Sediment Fence
Pennsylvania	Sediment Control, Silt Barrier Fence, Heavy Duty Silt Fence, Sediment Trap	Woven Geotextile Type A, B
Pennsylvania	Sediment Control, Rock Construction Entrance, Outlet protection, Temporary Slope Pipe, Pumped water filter bag, Sediment Trap and Sediment trap-riser, Sediment Basin	Needle punched non-woven Geotextile
Pennsylvania	Pumped water filter bag	Non-Woven Geotextile Bag
Pennsylvania	Inlet Filter Bag	Polypropylene Geotextile Bag
South Carolina	RECP	Jute Netting
South Carolina	Inlet Filters	Geotextile
South Carolina	Silt Fence	Silt Fence Geotextile
Texas	Temporary Sediment Control Fence	Woven Geotextile Fabric
Vermont	Geotextile under stone	Woven or Non-Woven Geotextile
Vermont	Silt Fence	Woven Silt Fence Geotextile
Virginia	Dewatering bag	Non-woven Geotextile
Washington State	Silt Fence	Unsupported and Supported Silt Fence
Wisconsin	Silt Fence	Silt Fence Geotextile
Wisconsin	Turbidity Barriers	Geotextile Fabric
Wisconsin	Rock bags	High-Density Polyethylene or Geotextile
Wyoming	Erosion Control	Geotextile, Silt Fence Geotextile, Non-Woven Separation and Stabilization Geotextile

3.12.15 Standard Test Methods for Determining Apparent Opening Size of a Geotextile (ASTM D4751)

ASTM D4751specifies test methods to measure the apparent opening size (AOS) of a geotextile. The test methods are by dry sieving glass beads through a geotextile (method A) and using a capillary porometer (method B). The equipment includes mechanical sieve shaker, pan, cover, 8-inch (200mm) diameter sieves, spherical glass beads, and balance. In

method A, a geotextile specimen is positioned into a sieve frame, and sized glass beads are put on the geotextile surface. The geotextile and frame are shaken sideways to obtain the jarring motion which causes the beads to pass through the specimen. This process can be redone with different glass beads until the AOS is found. In method B, the air flow rate and pressure are calculated. This process is repeated by increasing air pressure with the same geotextile specimen dampened with mineral oil. The AOS is determined with collected data by using standard capillary theory (ASTM D4751 2016b). Figure 3.90 shows a sieve shaker balance and sieve holder used in testing finding the AOS of a geotextile. Table 3.15 and Table 3.16 provides details of SHAs that recommend ASTM D4751 for testing E&SCPs.

Figure 3.90 Ro-Tap Sieve Shaker Balance and Sieve (Geosynthetic Institute 2018c).

Table 3.15 Summary of Recommendations by SHAs for ASTM D4751 (States Alabama through Pennsylvania)

State	Practice Type	Material / Component
Alabama	Manufactured Inlet Protection Device	Filter Fabric
Arizona	Silt Fence	Temporary Silt Fence Geotextile
California	Sediment Control	Woven and Non-Woven Silt Fence Geotextile, Woven and Non-Woven Geotextile Sediment Filter Bag
Dist. of Columbia	Sediment Barriers and Filters	Geotextile Inlet Filter Bags
Dist. of Columbia	Dewatering	Pumped Water Filter Bags
Georgia	Silt Fence	Silt Fence Type A, B, C
Georgia	Triangular Silt Barrier	Geotextile Filter Fabric
Hawaii	Geotextiles for Permanent Erosion Control Applications.	Woven Monofilament Geotextiles, all other geotextiles, and Silt Fence
Idaho	Riprap/Erosion Geotextile Criteria	Geotextile Type 1, 2
Idaho	Temporary Silt Fence	Temporary Silt Fence Geotextile
Illinois	Above grade inlet filters	Fitted Geotextile filter
Indiana	Silt Fence	Wire and Self supported Silt Fence Geotextile
Louisiana	Temporary Construction Entrance	Geotextile Class D
Maryland	Silt Fence	Woven Silt Fence Geotextile Class F
Michigan	Silt Fence	Silt Fence Geotextile
Michigan	Geotextile for filtration applications, including trench lining, ditch lining, streambed protection, pipe wrap, joint wrap, drain hole and weep hole filter, granular blanket separation, and filter bags	Non-Woven Geotextile
Michigan	Turbidity Curtain	Geotextile
Minnesota	Silt Fence	Woven and Non-Woven Silt Fence geotextile
Mississippi	Silt fence	Silt Fence Geotextile Type 1, 2
Montana	Permanent Erosion Control Geotextile	Moderate and High Survivability Woven and Non-Woven Geotextile Type A, B, C
Montana	Silt Fence	Stabilized and Unstabilized Silt Fence Geotextile
New Jersey	Geotextile	Geotextile for Sediment Control Bag
Oregon	Construction Entrance, Tire Wash Facility, Inlet protection, Temporary Energy Dissipater, Temporary Sediment Trap, Concrete Washout	Woven and Non-Woven Geotextile Type 1, 2
Oregon	Sediment Fence	Geotextile for Sediment Fence
Pennsylvania	Sediment Control, Silt Barrier Fence, Heavy Duty Silt Fence, Sediment Trap	Woven Geotextile Type A, B
Pennsylvania	Sediment Control, Rock Construction Entrance, Outlet protection, Temporary Slope Pipe, Pumped water filter bag, Sediment Trap and Sediment trap- riser, Sediment Basin	Needle punched non-woven Geotextile
Pennsylvania	Pumped water filter bag	Non-Woven Geotextile Bag
Pennsylvania	Inlet Filter Bag	Polypropylene Geotextile Bag

Table 3.16 Summary of Recommendations by SHAs for ASTM D4751 (States South Carolina through Wyoming)

State	Practice Type	Material / Component
South Carolina	Inlet Filters	Geotextile
South Carolina	Silt Fence	Silt Fence Geotextile
Texas	Temporary Sediment Control Fence	Woven Geotextile Fabric
Utah	Inlet Barrier	Geotextile Fabric
Vermont	Geotextile under stone	Woven or Non-Woven Geotextile
Vermont	Silt Fence	Woven Silt Fence Geotextile
Virginia	Dewatering bag	Non-woven Geotextile
Washington State	Silt Fence	Unsupported and Supported Silt Fence
Wisconsin	Silt Fence	Silt Fence Geotextile
Wyoming	Erosion Control	Geotextile, Silt Fence Geotextile, Non-Woven Separation and Stabilization Geotextile

3.12.16 Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products (ASTM D4833/D4833M)

ASTM D4833 is a test method to measure the index puncture resistance of geomembranes. This test method does not apply to geotextiles that have large openings. The equipment for the test method includes tensile/compression testing machine (CRE type), ring clamp attachment, and solid steel rod. This test method requires atmospheric conditions of 70 ± 4 °F (21 ± 2 °C) and 65 ± 5% relative humidity. The test specimen is fixed without tension between circular plates of a ring clamp attachment. Next, the ring clamp attachment is placed inside the tensile testing machine. The force is applied to the center of the unsupported area of the specimen by a solid steel rod that is attached to the load indicator until puncture. The method of clamping the specimen should be mentioned in the report. The recorded maximum force is considered as the value of puncture resistance of the specimen. Average puncture resistance, coefficient of variation, and standard deviation of specimens should be reported (ASTM D4833 2013b). Figure 3.91 shows Solid steel rod puncturing geomembrane during testing. Table 3.17 provides details of SHAs that recommend ASTM D4833 for testing E&SCPs.

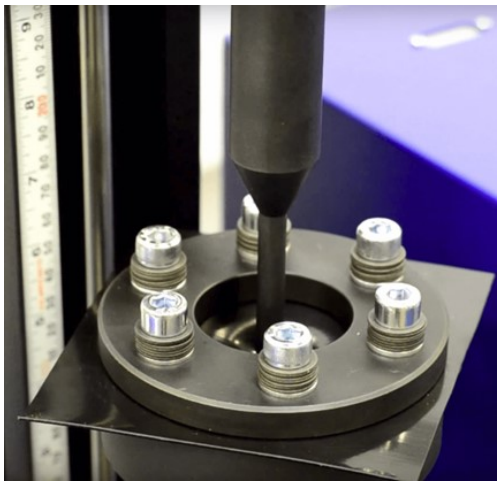


Figure 3.91 Puncture Test for a Geomembrane (ADMET Testing Systems 2013).

Table 3.17 Summary of Recommendations by SHAs for ASTM D4833

State	Practice Type	Material / Component
Dist. of Columbia	Sediment Barriers and Filters	Geotextile for Inlet Filter Bags
Dist. of Columbia	Dewatering	Geotextile for Pumped Water Filter Bags
Hawaii	Geotextiles for Permanent Erosion Control Applications.	Woven Monofilament Geotextiles, all other geotextiles, and Silt Fence
Illinois	Inlet filters	Geotextile_ Inner fabric bag
Illinois	Above grade inlet filters	Fitted Geotextile filter
Louisiana	Temporary Construction Entrance	Geotextile Class D
Michigan	Silt Fence	Silt Fence Geotextile
Michigan	Geotextile for filtration applications including trench lining, ditch lining, stream bed protection, pipe wrap, joint wrap, drain hole and weep hole filter, granular blanket separation, and filter bags	Non- Woven Geotextile
Michigan	Turbidity Curtain	Geotextile
Minnesota	Silt Fence	Silt Fence Geotextile
New Hampshire	Silt Fence	Silt Fence Geotextile
New Jersey	Sediment Control Bag	Geotextile for Sediment Control Bag
Pennsylvania	Pumped water filter bag	Non-Woven Geotextile Bag
Pennsylvania	Inlet Filter Bag	Polypropylene Geotextile Bag
South Carolina	Inlet Filters	Geotextile
Virginia	Dewatering bag	Non-woven Geotextile
Wisconsin	Turbidity Barriers	Geotextile Fabric
Wisconsin	Rock bags	High-density polyethylene or Geotextile
Wyoming	Erosion Control	Geotextile, Silt Fence Geotextile, Non-Woven Separation and Stabilization Geotextile

3.12.17 Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method) (ASTM D5035)

ASTM D5035 is a test method to determine breaking force and elongation of most textile fabrics by raveled strip and cut strip test procedures. The ravel strip test is appropriate for nonwoven fabrics, whereas the cut strip test is suitable for nonwoven fabrics, felted fabrics, and dipped or coated fabrics. This test method is not suitable for knitted fabrics or fabrics that have more than 11% stretch. The equipment, reagent, and materials include tensile testing machine (CRE, CRL or CRT type), clamps and jaw face, metal clamp, distilled water and nonionic wetting agent for wet testing, a container for wetting specimens, standard fabrics for verifying apparatus, and pins. A test specimen is fixed in a tensile testing machine, and a force is applied until the specimen breaks. The breaking force and elongation values of the test specimen are noted from machine scales, dials, autographic recording charts, or a computer that is connected to the testing machine. In conditional testing, if the samples have a higher moisture content compared to moisture content at equilibrium, then the moisture of the sample should be reduced to equilibrium moisture. The specimens to be tested in wet testing should be rigorously submerged into the water at room temperature before the testing. After taking the specimens out from water, the specimen testing is to be completed in two minutes. Average breaking force and average apparent elongation of acceptable specimens for each test condition and strip test should be reported (ASTM D5035 2015e). Figure 3.92 shows a woven textile fabric fixed to clamps for testing. Table 3.18 provides details of SHAs that recommend ASTM D5035 for testing E&SCPs.

Figure 3.92 Woven Textile Fabric during Testing (Instron 2017).

Table 3.18 Summary of Recommendations by SHAs for ASTM D5035

State	Practice Type	Material / Component
Arizona	Erosion Control Blankets	Short term and Long-term ECBs
California	Rolled Erosion Control Products	Jute Mesh Netting Type A, B, C ECB Type A, B, C TRM Type A, B, C
Florida	Erosion Control	TRM-Type 1, 2, 3
Missouri	Erosion control Blankets	Mulch Control Nets, Net less RECPs, ECBs, Light-Weight Double Net ECBs, Heavy Double-Net ECBs
New Jersey	ECB	Erosion Control Mulch Blanket
South Carolina	RECP	Excelsior Blankets, Coconut Blankets
Vermont	RECP	Mulch Control Nets, Net less RECPs, Single net ECBs, Double net ECBs

3.12.18 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics (ASTM D5199)

ASTM D5199 is a test method to measure the nominal thickness of geosynthetics except textured and some structured geomembranes. This test method cannot give thickness for geosynthetics that are under variable normal compressive stresses or determine minimal thickness. The equipment for this test method includes a thickness testing instrument. The nominal thickness in this test method can be obtained by

measuring the distance between two parallel surfaces keeping the specimen under a specified pressure for 5 seconds. Three test procedures are included: Procedure A is for geotextiles, planar geocomposite drainage materials, and geonets; Procedure B is for all kinds of geomembranes except textured or structured geomembranes; and Procedure C is for the materials that cannot be tested with procedures A and B. Description of thickness apparatus, specimen dimensions, procedure used, diameter of the presser foot, applied pressure, and average nominal thickness needs to be reported (ASTM D5199 2012a). Figure 3.93 depicts measuring the thickness of a geomembrane

Figure 3.93 Thickness Measuring Instrument and Geomembrane (Geosynthetic Institute 2018d)

Arizona DOT recommends this specification for testing short term and extended term ECBs.

3.12.19 Standard Test Method for Measuring Mass per Unit Area of Geotextiles (ASTM D5261)

ASTM D5261 is a test method for determining the mass per unit area of all geotextiles. The equipment includes a weighing balance with 176 oz. (5000g) capacity and an accuracy of 0.0003 oz. (0.01g). The specimens need to be cut from multiple locations of the geotextile sample. The dimensions of each specimen should be recorded. The mass per

unit area of the specimens is measured by weighing specimens on a balance (ASTM D5261 2018d). Table 3.19 provides details of SHAs that recommend ASTM D5261 for testing E&SCPs.

Table 3.19 Summary of Recommendations by SHAs for ASTM D5261

State	Practice Type	Material / Component
Alabama	ECB	Mulch Control Netting
Alabama	Flow Baffles	RECP
New Jersey	ECB	Erosion Control Mulch Blanket
Pennsylvania	Sediment Control, Silt Barrier Fence, Heavy Duty Silt Fence, Sediment Trap	Woven Geotextile
Pennsylvania	Sediment Control, Rock Construction Entrance, Outlet protection, Temporary Slope Pipe, Pumped water filter bag, Sediment Trap and Sediment trap- riser, Sediment Basin	Needle punched woven Geotextile

3.12.20 Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe (ASTM D6241)

ASTM D6241 is an index test method to determine the force required to puncture a geotextile and geotextile-related products. The use of a large-sized plunger to puncture gives a multidirectional force on the geotextile. This test method requires a CRE testing machine with an autographic recorder, plunger with flat diameter of 1.9685 ± 0.04 inches (50 ± 1 mm) with a radial edge of 0.98 ± 0.019 inches (2.5 ± 0.5 mm), and clamping apparatus with an internal diameter of 5.9 in. (150mm) and an external diameter of 9.8 in. (250 mm). This test method requires atmospheric conditions of 70 ± 4 °F (21 ± 2 °C) and 65 ± 5% relative humidity. The geotextile specimen is fixed without tension between circular plates and placed in the testing machine. A force is applied to the center of the unsupported area of the specimen by a steel plunger that is attached to a load indicator until rupture. The maximum force is considered as puncture strength. Method of holding the test specimen in the circular plates should be mentioned. Average puncture strength of tested specimens should be reported (ASTM D6241 2014a). Figure 3.94 shows a 1.9 inches

probe puncturing a geotextile during testing. Table 3.20 provides details of SHAs that recommend ASTM D6241 for testing E&SCPs.

Figure 3.94 Geotextile Under 1.9 Inches Probe in Testing (Geosynthetic Institute 2018e).

Table 3.20 Summary of Recommendations by SHAs for ASTM D6241

State	Practice Type	Material / Component
Idaho	Riprap/Erosion Geotextile Criteria	Geotextile Type 1,2
Maryland	Silt Fence	Woven Geotextile
Montana	Permanent Erosion Control Geotextile	Moderate Survivability, High Survivability Non-Woven Geotextile
North Carolina	Stilling Basin	Geotextile for Stilling basin
Oregon	Construction Entrance, Tire Wash Facility, Inlet protection, Temporary Energy Dissipater, Temporary Sediment Trap, Concrete Washout	Woven and Non-Woven Geotextile
Pennsylvania	Sediment Control, Silt Barrier Fence, Heavy Duty Silt Fence, Sediment Trap	Woven Geotextile Type A, B
Pennsylvania	Sediment Control, Rock Construction Entrance, Outlet protection, Temporary Slope Pipe, Pumped water filter bag, Sediment Trap and Sediment trap- riser, Sediment Basin	Needle punched woven Geotextile
Vermont	Geotextile under stone	Woven and Non-Woven Geotextile
Vermont	Silt Fence	Woven Silt Fence Geotextile

3.12.21 Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion (ASTM D6459)

ASTM D6459 is a test method that describes the guidelines, requirements and test procedures of RECPs to secure hillslopes from the erosion caused by rainfall. This test

method covers full-scale testing procedures and is designed for typical conditions observed at construction project sites during the ending period of earthwork activities and before applying vegetation. Therefore, this test method is confined to vegetated conditions and gives a relative assessment of an RECP application to bare soil conditions under controlled and documented environmental conditions. The equipment for this test method includes rainfall simulators, water source, runoff and sediment collection system, vegetative stand quantification equipment, and other miscellaneous items such as rain gauges (20), pie pans (3), sieve set (standard US sieves), evaporating dishes, a drying oven or microwave oven, meteorological equipment (wind speed, temperature, precipitation), a surveyor's rod, sample bottles and bags, cooler, and camera or video recorder. The performance of RECPs in reducing rainfall-induced erosion is deduced by exposing RECPs to rainfall simulation in controlled and documented conditions. The key components to be reported in this testing process are rainfall simulation equipment calibration, test slot preparation, RECP documentation and installation, test performance, runoff and related sediment yield data, and data analysis (ASTM D6459 2015f). Figure 3.95 shows an Overall setup for testing RECPs in protecting hill slopes form erosion Table 3.21 provides details of SHAs that recommend ASTM D6459 for testing E&SCPs.

Figure 3.95 Test Setup for Testing RECPs (TRI Erosion Test 2019).

Table 3.21 Summary of Recommendations by SHAs for ASTM D6459

State	Practice Type	Material / Component
Alabama	ECP for Slope applications	RECP
Alabama	Mulching	HECP
Colorado	ECB/RECP	Soil Retention Mat Type 1,2
Illinois	Mulching	Light and Heavy-duty Hydraulic mulch
Iowa	Bonded Fiber Matrix	Hydraulic Mulch
Iowa	Mechanically Bonded Fiber Matrix	Hydraulic Mulch
Maryland	Soil Stabilization Matting (SSM)	SSM Type A, B, E
Mississippi	ECB	ECB Type 1, 2, 3, 4
Missouri	Erosion control Blankets	Mulch Control Nets, Net less RECPs, Light-Weight Double-Net Heavy Double ECBs
Montana	RECPs	Temporary RECPs
Pennsylvania	RECP	Mulch Control Netting, Net less ECBs, Single net, Double Net ECBs, and Open weave textile
Utah	RECP	ECB, Flexible Channel Liner, TRM
Utah	HECP	HECP Type 1, 2, 3
Vermont	RECP	Mulch Control Nets, Net less RECPs, Single net ECBs, Double net ECBs
Virginia	HECP	HECP Type 1, 2, 3, 4
Virginia	RECP	RECP Type 1, 2, 3, 4
Washington State	Mulching	Long term, Moderate term, Short term Mulch
Washington State	ECBs	Biodegradable ECB

3.12.22 Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion (ASTM D6460)

ASTM D6460 is a test method that explains the guidelines, requirements and test procedures of RECPs to protect earthen channels from stormwater-induced erosion. This test method covers full-scale testing procedures and is designed for typical conditions observed at construction project sites during the ending period of earthwork activities and before applying vegetation. Therefore, this test method is confined to unvegetated conditions and gives a relative assessment of an RECP application to bare soil conditions under controlled and documented conditions. The equipment for this test method includes water delivery system, water source, survey apparatus, velocity probe, earthwork equipment, geotechnical testing equipment, vegetative stand qualification equipment, photographic equipment, and meteorological equipment (wind speed, temperature, precipitation). The performance of an RECP in decreasing stormwater water-induced erosion is calculated by testing the material in simulated stormwater flow in controlled and documented environmental conditions. The major components to be reported in this testing process are calibration of stormwater simulation, test channel preparation, documentation of RECP, installation of RECP, installation of vegetation stand, test execution, collection of hydraulic, topographical and relative data, and data analysis (ASTM D6460 2012b). Figure 3.96 depicts a full-scale test setup for RECPs in protecting earthen channels. Table 3.22 provides details of SHAs that recommend ASTM D6460 for testing E&SCPs.

Figure 3.96 Full Scale Test Setup for RECPs (TRI Erosion Test 2019).

Table 3.22 Summary of Recommendations by SHAs for ASTM D6460

State	Practice Type	Material / Component
Alabama	ECP	RECPs for Channel applications
California	Erosion Control Blanket	Jute Mesh; Netting Type A, B, C; TRM Type A, B, C
Colorado	ECB/RECP	TRM Type 1, 2, 3
Iowa	RECP	TRM Type 1, 2, 3, 4
Maryland	Soil Stabilization Matting	SSM Type A, B, E
Minnesota	RECP	Wood Cellulose fiber, RECPs, TRM 1, 2, 3, 4
Missouri	ECBs	TRM Type 1, 2, 3, 4
Montana	RECP	Temporary RECPs
New Jersey	ECB	Erosion Control Mulch Blanket, TRM
North Dakota	ECB	Straw, Wood, Coconut fiber ECBs
North Dakota	ECB	ECBs Type 1, 2, 3, 4; TRMs Type 1, 2
Pennsylvania	RECP	Mulch Control Netting, Nettles ECBs, Single net, Double net ECBs, and Open weave textiles
Pennsylvania	RECP	TRM Type 5A, 5B, 5C
Utah	RECP	TRM for Vegetated Channels
Vermont	RECP	Mulch Control Nets, Nettles RECPs, Single net ECBs, Double net ECBs, TRMs Type A, B, C
Virginia	RECP	RECP Type 1, 2, 3, 4
Virginia	TRM	TRM Type 1, 2, 3
Washington State	ECB	Biodegradable ECBs for Ditches

3.12.23 Standard Test Method for Measuring Mass per Unit Area of Erosion Control Blankets (ASTM D6475)

ASTM D6475 is an index test method to measure mass per unit area of all ECBs. The equipment for this test method includes weighing balance with a capacity of weighing to an

accuracy of 0.0035 oz. (0.1g), drying oven, corrosion resistant specimen trays, and container handling apparatus such as gloves, tongs, or suitable holder to handle hot trays after drying. The mass of the specimen tray (M_c) is recorded to the nearest 0.1g. The specimen is placed on the specimen tray, and it is placed in a drying oven with a temperature of 122 ± 41°F (50 ± 5°C). The time needed to get constant mass will vary according to the material type, specimen size, moisture content of specimen before the test, and other factors. After drying the specimen in the oven, the specimen tray is removed. The mass of the dried specimen along with the tray (M_t) is measured within 5 min after removing them from the oven. The mass of the specimen (M_s) is the difference between the mass of the dried specimen along with the tray and the mass of the specimen tray. The mass per unit area (m) is calculated with the area of the specimen(A) and mass of the specimen. Type of tested ECB used, sampling method used, size and size of the test specimen, number of tested specimens, average mass per unit area, and standard deviation are included in the report (ASTM D6475 2017e). Table 3.23 provides details of SHAs that recommend ASTM D6475 for testing E&SCPs.

Table 3.23 Summary of Recommendations by SHAs for ASTM D6475

State	Practice Type	Material / Component
Arizona	ECB	Short term and Long-term ECBs
Colorado	ECB/RECP	Soil Retention Mat Type 1,2
Iowa	Special Ditch Control	Wood Excelsior mat, Coconut Fiber mat
Iowa	Slope protection	Wood Excelsior mat, Coconut Fiber mat
Kentucky	Erosion control blankets	Curled Wood Fiber, Straw, Coconut Fiber ECBs
Maryland	Soil Stabilization Matting	SSM Type A, B, D, E
Minnesota	RECP- ECB	Wood Cellulose fiber, RECPs
North Dakota	ECB	TRM 1, 2
Pennsylvania	RECPs	Mulch Control Netting, Net less ECBs, Single net, Double net ECBs, and Open weave textiles
South Carolina	RECP	Temporary ECB; Excelsior Blankets; Coconut fiber Blankets; TRM Type 1, 2, 3 4
Washington State	ECBs	Biodegradable ECB for Ditches and Slopes

3.12.24 Standard Test Method for Measuring Nominal Thickness of Rolled Erosion Control Products (ASTM D6525/D6525M)

ASTM D6525 is a test method to measure the nominal thickness of RECPs. This test method cannot give thickness for RECPs that are under variable compressive stresses and determine minimal thickness. The equipment required includes thickness testing instrument, cutting dies and scissors. The measuring scale should be calibrated to zero before conducting the test. The specimen is placed on the base under the presser foot. After the presser foot contact the specimen, the pressure should be increased slowly to 0.029 psi (0.2 kPa) and applied for 5 seconds on the specimen. The thickness should be recorded to the nearest to 0.001 in. (0.0025mm). RECP type, sampling method used, description of thickness apparatus, the dimension of presser foot, number of tests conducted, loading time interval, average nominal thickness, and coefficient of variation should be included in the report (ASTM D6525 2018e). Figure 3.97 shows measuring the thickness of a TRM Table 3.24 provides details of SHAs that recommend ASTM D6525 for testing E&SCPs.

Figure 3.97 Thickness Measuring Equipment and a TRM (Geosynthetic Institute 2018f)

Table 3.24 Summary of Recommendations by SHAs for ASTM D6525

State	Practice Type	Material / Component
California	ECB	Nettings Type A, B, C; TRMs Type A, B, C
Colorado	ECB/RECP	Soil Retention Mat (SRM) Type 1,2; TRM 1, 2, 3
Iowa	Turf Reinforcement Mat	TRM 1, 2, 3, 4
Iowa	Matting	Transition Mat
Maryland	Soil Stabilization Matting	SSM Type A, B, D, E
New Jersey	RECP	TRM Type 1, 2; ECBs (Straw, Wood, Excelsior, Coconut Fibers)
South Carolina	RECP	Temporary ECB, Excelsior blankets, Coconut Blankets, TRM 1, 2, 3, 4
South Carolina	Bonding agents	Bonded Fiber Matrix (BFM), Flexible Growth Matrix (FGM)
Utah	RECP	TRM
Virginia	RECP	TRM Type1, 2, 3

3.12.25 Standard Test Method for Measuring Mass Per Unit Area of Turf Reinforcement Mats (ASTM D6566)

ASTM D6566 is an index test method to measure the mass per unit area of turf reinforcement mats (TRMs). The equipment required for this test method includes a balance that is calibrated to 0.0003 oz. (0.01g). The test should be conducted in standard atmospheric conditions of 70 ± 4 °F (21 ± 2 °C) and 65 ± 10 % relative humidity. The test specimens of known dimensions that are cut from equally spaced distances over the width of the TRM sample should weighed, and mass per unit area is calculated. Type of TRM tested, used sampling method, size of the test specimen, shape, number of specimens tested, average mass per unit area, and standard deviation to three significant figures should be included (ASTM D6566 2018f). Figure 3.98 shows measuring the mass of a TRM. Table 3.25 provides details of SHAs that recommend ASTM D6566 for testing E&SCPs.

Figure 3.98 Weight Scale and a TRM (Geosynthetic Institute 2018f).

Table 3.25 Summary of recommendations by SHAs for ASTM D6566

State	Practice Type	Material / Component
Iowa	Matting	Transition Mat
New Jersey	ECB	Matting with mechanically Bonded Fiber Matrix
Pennsylvania	RECP- TRM	TRM Type 5A, 5B, 5C
South Carolina	Bonding agents	Bonded Fiber Matrix (BFM), Flexible Growth Matrix (FGM)
Utah	HECP	HECP Type 1, 2, 3

3.12.26 Standard Test Method for Measuring the Light Penetration of a Rolled Erosion Control Product (RECP) (ASTM D6567)

ASTM D6567 is a test method that measures the amount of radiant light penetrating through an RECP. This test method does not give light penetration values under normal sunlight and soil conditions. The equipment includes light penetration box, adjustable rod with a light bulb, light meter, and cutting dies. This test method requires atmospheric conditions of 70 ± 4 °F (21 ± 2 °C) and 60 ± 10% relative humidity. The light penetration of RECPs is measured by a light meter in foot candles. The nominal light penetration in the box should be measured with and without placing the specimen at a specific location between the light source and light meter. Measured light meter readings before and after putting the specimen in the box can be used to calculate the percentage of light penetration.

Type of tested RECP, sampling, specimen size, number of tests, type of light source, average nominal light penetration percentage, and coefficient of variation should be reported (ASTM D6567 2018g). Table 3.26 provides details of SHAs that recommend ASTM D6567 for testing E&SCPs.

Table 3.26 Summary of Recommendations by SHAs for ASTM D6567

State	Practice Type	Material / Component
Iowa	Matting	Transition Mat
Maryland	Soil Stabilization Matting	SSM Type A, B, D, E
New Jersey	ECB	Matting with mechanically Bonded Fiber Matrix
South Carolina	Bonding agents	Bonded Fiber Matrix (BFM), Flexible Growth Matrix (FGM)
Utah	HECP	HECP Type 1, 2, 3

3.12.27 Standard Test Method for Determining Stiffness of Geosynthetics Used as Turf Reinforcement Mats (TRMs) (ASTM D6575/D6575M)

ASTM D6575 is a test method that measures flexural rigidity of TRMs. The equipment includes stiffness tester that contains a horizontal platform, indicator, metal bar weight, and a scale and pointer. This test method requires atmospheric conditions of 70 ± 4 °F (21 ± 2 °C) and 60 ± 10% relative humidity. The TRM test specimen is placed on the horizontal platform with weight on top it. By clasping the load on the horizontal plane, the specimen along with the weight is moved gradually until the front end of the specimen extends past the platform edge. The length of overhang is measured when the overhang makes an angle of 41.5°. The bending length is half of the overhang length. Flexural rigidity is obtained by multiplying the quantity and mass per unit area of the test specimen (D6575 2016c).

South Carolina DOT recommends this test method for finding flexural rigidity of Flexible Growth Matrix (FGM).

3.12.28 Standard Test Method for Ultimate Tensile Properties of Rolled Erosion Control Products (ASTM D6818)

ASTM D6818 is a test method to determine the tensile properties of RECPs by strip test procedures. The test method does not cover RECPs that are made of composite materials. The equipment includes a tensile testing machine of CRE type, and clamps and jaw faces. This test method requires atmospheric conditions of 70 ± 4 °F (21 ± 2 °C) and 60 ± 10% relative humidity. The test specimen is fixed in a tensile testing machine, and a force is exerted on the specimen until it breaks. Force at breaking point and elongation values of the test specimen are recorded. Average breaking unit force per unit width and average elongation of acceptable specimens, and the number of specimens should be reported (ASTM D6818 2018h). Figure 3.99 shows a TRM fixed to clamps in the tensile testing machine. Table 3.27 provides details of SHAs that recommend ASTM D6818 for testing E&SCPs.

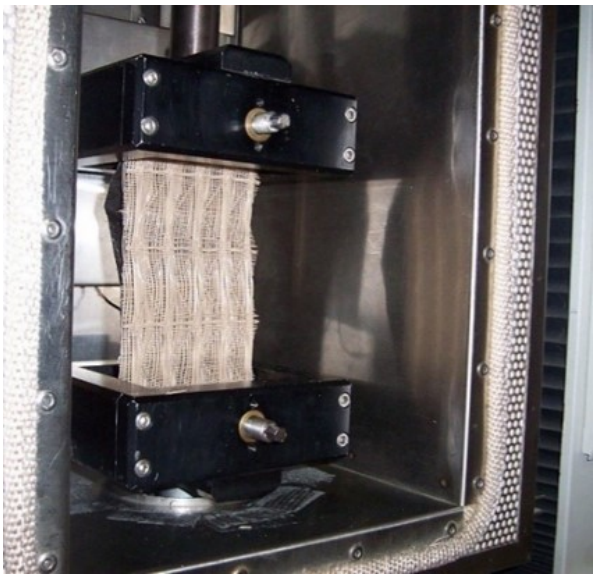


Figure 3.99 Tensile Strength Testing of a TRM (Geosynthetic Institute 2018f).

Table 3.27 Summary of Recommendations by SHAs for ASTM D6818

State	Practice Type	Material / Component
Colorado	ECB/RECP	SRM Type 1, 2
Colorado	ECB/RECP	TRM Type 1, 2, 3
Florida	Plastic erosion mat	TRM Type 1, 2, 3
Iowa	Turf Reinforcement Mat	TRM Type 1, 2, 3, 4
Iowa	Transition Mat	Matting
Maryland	Soil Stabilization Matting	SSM Type A, B, C, E
Minnesota	RECP- ECB	Netted Products (Straw, Wood Fiber, Coconut fibers), TRMs Type 1, 2, 3, 4
Minnesota	Sediment control log	Geotextile Rock logs
Mississippi	ECB	ECB Type 1, 2, 3, 4
New Jersey	ECB	TRM
North Dakota	RECBs/ ECBs	ECB Type 1, 2, 3, 4, TRM Type 1, 2
Pennsylvania	RECP	Mulch Control Netting, Net less ECBs, Single net, Double net ECBs, and Open weave textiles
Pennsylvania	RECP- TRM	TRM Type 5A, 5B, 5C
South Carolina	RECP	Temporary ECB, TRM Type 1, 2, 3, 4
Utah	RECP	ECB, Flexible Channel Liner
Vermont	RECP	TRM Type A, B, C
Washington State	ECB	Biodegradable ECB for ditches and slopes

3.12.29 Standard Index Test Method for Determination of Unvegetated Rolled Erosion Control Product (RECP) Ability to Protect Soil from Rain Splash and Associated Runoff Under Bench-Scale Conditions (ASTM D7101)

ASTM D7101 is an index test method which describes the guidelines, requirements and test procedures for determining the potential of unvegetated RECPs to preserve soils from simulated rainfall and minimal runoff-induced erosion. This index test method uses bench-scale testing procedures and does not imply unvegetated RECPs performance in the field. The equipment includes rainfall simulator, soil cores, incline structure, collection buckets, filters, sieve set (standard US service), evaporating dishes, drying oven, and balance. Both bare and unvegetated RECP-protected soil containers are subjected to a simulated rainfall. The amount of soil displaced by runoff from the containers is collected and weighed. The results can be used to discuss the difference between bare and unvegetated RECP-protected conditions. The major components are rainfall simulation equipment calibration; test core preparation; RECP documentation and installation; test

completion; and data analysis. Bench-scale index (BSCI) is reported by calculating the mean mass of soil loss from RECP protected cores (M_{RECP}) per mean mass of soil loss from unprotected control cores ($M_{CONTROL}$) (ASTM D7101 2013c). Table 3.28 provides details of SHAs that recommend ASTM D7101 for testing E&SCPs.

Table 3.28 Summary of Recommendations by SHAs for ASTM D7101

State	Practice Type	Material / Component
Iowa	Hydraulic Mulch	Bonded Fiber Matrix, Mechanically Bonded Fiber Matrix
Kentucky	Erosion control blankets	Curled Wood Fiber, Straw, Straw/ Coconut Fiber
Virginia	HECP	HECP Type 1, 2, 3, 4

3.12.30 Standard Test Method for Determination of Erosion Control Product (ECP) Ability to Encourage Seed Germination and Plant Growth Under Bench-Scale Conditions (ASTM D7322/D7322M)

ASTM D7322 is an index test method which describes the guidelines, requirements and test procedures for estimating the effect of Erosion Control Products (ECP) on seed germination and vegetation enhancement in a controlled environment. ECPs include RECPs and HECPs. This test method uses bench-scale testing procedures and does not imply performance on the field. The equipment comprises germination containers, controlled environmental chamber, photometer, thermometer, hygrometer, weighing balance, and drying oven. The seeds are planted on the soil containers, and then covered with ECPs. On the other hand, soil containers are just planted with seeds and left exposed. Light, temperature, and humidity at the testing place are recorded. The growth of vegetation on ECP covered soil containers, and uncovered containers are recorded at regular intervals. Seed germination and average plant height of each ECP (RECP) are calculated (ASTM D7322 2017f). Table 3.29 provides details of SHAs that recommend ASTM D7322 for testing E&SCPs.

Table 3.29 Summary of recommendations by SHAs for ASTM D7322

State	Practice Type	Material / Component
Alabama	RECP	RECPs for Slope and Channel applications
Alabama	Mulching	HECP
Illinois	Mulching	Light duty and Heavy-duty Hydraulic mulch
Iowa	Hydraulic Mulch	Bonded Fiber Matrix, Mechanically Bonded Fiber Matrix, Organic Fiber Matrix
Pennsylvania	RECP	Mulch Control Netting, Net less ECBs, Single net, Double net ECBs, and Open weave textiles
Pennsylvania	RECP- TRM	TRM Type 5A, 5B, 5C
Utah	HECP	HECP Type 1, 2, 3
Virginia	HECP	HECP Type 1, 2, 3, 4

3.12.31 Standard Test Method for Determining the (in-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic using a Constant Head (ASTM D4716/ D4716M)

ASTM D4716 is an index test method to find the flow rate per unit width of geosynthetics under differing normal compressive stress and a constant head. This test method can also be used as a performance test when the user chooses hydraulic gradients and specimen contact surfaces to design based on expected field conditions. The equipment for this test includes a constant head (in-plane) flow rate testing device that consists of a reservoir, loading mechanism, outflow weir, outflow collection, rubber substrate/ superstrate, thickness monitoring device, manometers, and thermometer calipers. Figure 3.100 show an in-plane water flow testing device. The flow rate per unit width is calculated by the quantity of water that flows through the test specimen in a specific time interval under specific normal stress and a hydraulic gradient (ASTM D4716 2014b).

$$q_w = R_t\,(Q_t/t*W)$$

q_w = flow rate per unit width, gpm/ft (m^3/s-m)
Q_t = Quantity of water collected during collection time, t
t = collection time, s.
W = Width of specimen.
R_t = temperature correction factor.

Hydraulic transmissivity of geotextiles can only be calculated if they show laminar flow (linear flow rate versus gradient relationship).

$$\Theta = (R_t * Q_t * L) / (W * H)$$

Θ = hydraulic transmissivity, ft^2/ sec (m^2/s)
R_t = temperature correction factor
Q_t = Quantity of water collected during collection time, t ft^3/ s (m^3/ s)
L = length of specimen that is under normal compressive stress
W = Width of specimen

Figure 3.100 In Plane Water Flow Testing Device (Fanyuan Instrument 2019).

3.12.32 Standard Practice for Determining the Specification Conformance of Geosynthetics (ASTM D4759)

ASTM D4759 is a practice that includes a procedure to find whether the properties of geosynthetics match standard specifications. This practice helps the purchaser to decide the legitimacy of geosynthetics' properties based on the specs (ASTM D4759 2018i).

3.12.33 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples (ASTM D4873/4873M)

ASTM D4873 is a standard guide that delivers guidelines for identifying and packaging rolled geosynthetics by the manufacturer and for the storing and handling of geosynthetics by the user. The geosynthetics that are discussed in this guide are geotextiles, geogrids, geomembrane rolls, geonets, geocomposites, RECPs, and sediment retention devices. The components for each geosynthetic mentioned are packaging and identification, receiving and storing at the job site, on-site handling, and sample identification (ASTM D4873 2017g).

3.12.34 Standard Test Method for Measuring the Resiliency of Turf Reinforcement Mats (TRMs) (ASTM D6524)

ASTM D6524 is a test method that includes resiliency of TRMs after three cycles of loading at 100 psi (689 kPa) for 1 min per cycle. This test method only describes to find nominal resiliency and does not give resiliency values under variable compressible stresses. The equipment includes a thickness testing instrument. Figure 3.101 shows the equipment used in measuring the resiliency of TRMs This test method requires atmospheric conditions of 70 ± 4 °F (21 ± 2 °C) and 60 ± 10% relative humidity. Before beginning the test, the measuring device should be zeroed. The thickness T_i (inches) of the specimen is measured after exerting full force onto the specimen for five seconds. The thickness is estimated to the nearest 7.88E-5inch (0.002 mm). After calculating T_i, an average compressive load of 100psi (689 kPa) is exerted evenly on the specimen for three cycles with one minute loaded and one minute unloaded. After three cycles, the specimen should set to recover for at least 30 min. After 30 min, the thickness T_f (inches) is

measured. The percentage of resiliency is calculated for each specimen (ASTM D6524 2016d)e.

$$\text{Resiliency} = (T_i / T_f) * 100$$

Average nominal resiliency and coefficient of variation are reported.

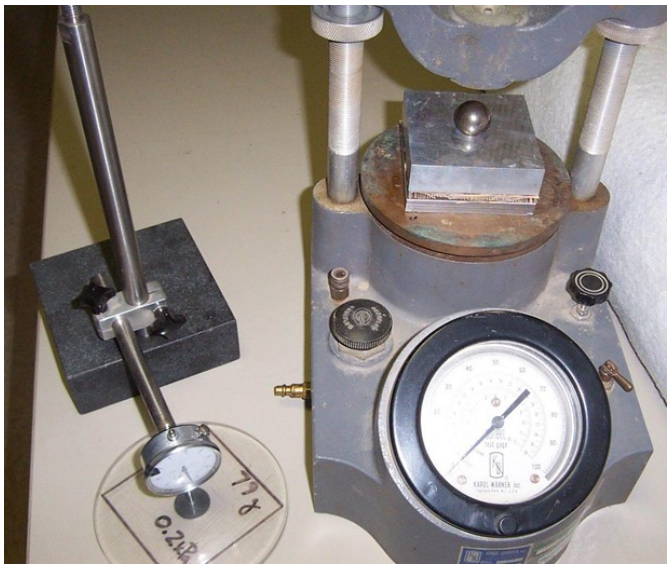


Figure 3.101 Thickness Scale (left), Compressing Machine (right) (Geosynthetic Institute 2018f).

3.12.35 Standard Test Method for Pore Size Characteristics of Geotextiles by Capillary Flow Test (ASTM D6767)

ASTM D6767 is a test method that describes finding the pore size distribution of geotextile filters. The pore sizes range from 3.28E-6 ft to 0.0032 ft (1 to 1000 μm). The equipment includes a clean gas pressure source, a pressure sensor, a closed filter holder, a metal punch, flow rate measurement sensors, an in-line fluid trap, appropriate fittings, a hose, connectors, piping, and a weighing balance. The pore size distribution of geotextile is calculated by analyzing gas flow rates of geotextiles by conducting dry and wet tests at identical pressures. The dry test is performed to find the resulting opening distribution of a geotextile, while the wet test is conducted after submerging the dry geotextile for one hour. Airflow rate versus pressure graph is plotted from the data obtained from the dry

test, and a fluid-wet filter gas flow rate versus pressure graph is plotted from the data collected from the wet test. Increasing the pressure in minimal intervals can help in finding the flow contribution of small size pores (ASTM D6767 2016e).

3.12.36 Standard Test Method for Determining the Flow Rate of Water and Suspended Solids from a Geotextile Bag (ASTM 7701)

ASTM D7701 is a test method for evaluating the water flow rate and solids suspended in the geosynthetic permeable bag that is used for blocking dredged material. This test method describes two testing procedures (A, B) for measuring the amount of dredged material. The equipment for test A includes a wooden frame, a geotextile container, three aluminum pans, an integrated water sampler, two large containers, a stopwatch, a stirrer, dredged material, a crucible, membrane filter apparatus, and a vacuum pump. The equipment and material for test B includes a geotextile container, two plastic pans, a beaker, a stirrer, dredged material, and sediment-free water. In both procedures, a specific amount of sediment-laden water with dredged material allowed though a geotextile bag that is fitted to the equipment. The quantity of water and sediment passed through the geotextile bag is collected and measured at regular time intervals. The amount of sediment passed through the geotextile bag is considered as total suspended solids (ASTM D7701 2011).

3.12.37 Standard Specification for Geosynthetic Specifications for Highway Applications (AASHTO M288)

AASHTO M288 is a standard specification for geosynthetic products used for highway applications. The requirements included for geosynthetic products used in subsurface drainage, separation, stabilization, erosion control, temporary silt fence, paving fabric and reinforcing soil (walls and slopes). The geosynthetics are required to meet the

physical, mechanical, and endurance properties included in the specification. This standard also specifies product certification process, sampling, testing, and acceptance; instructions for product identification, shipment, and storage (AASHTO M288 2018a). Table 3.30 provides details of SHAs that recommend AASHTO M288 for testing E&SCPs.

Table 3.30 Summary of Recommendations by SHAs for AASHTO M288

State	Practice Type	Material / Component
Alabama	Geotextile under Riprap, Silt Fence, Wattles, Brush Barrier	Geotextile
Alaska	Stabilization, Erosion Control, Temporary Silt Fence	Geotextile
Arkansas	Silt Fence for drop inlet, Triangular silt dike	Geotextile
Delaware	Silt fence, Reinforced Silt fence, Inlet sediment control, Riser pipe sediment trap, Sump pit, Sediment basin, Riprap ditch, Perimeter dike/swale, Earth dike, Temporary slope drain, Stilling Well, Geotextile, Lined Channel diversion, Dewatering basin, Stabilized construction entrance, Separation fabric, Stabilization fabric.	Geotextile
Illinois	Silt Fence	Geotextile
Kentucky	Temporary Silt Fence, Subsurface drainage, separation, stabilization, permanent erosion control, temporary silt fences, or paving fabric	Geotextile
Mississippi	Silt Fence	Geotextile
Missouri	Silt Fence	Geotextile
Missouri	Erosion control	Permanent Erosion control geotextile fabric
New Jersey	Temporary Silt Fence, Erosion Control Geotextile	Geotextile
New Mexico	Sediment control and Erosion Control	Geotextile
North Carolina	Silt Fence	Geotextile
North Carolina	Gravel Construction Entrance, Temporary Stream Crossing	Geotextile under the riprap
North Dakota	Silt Fence	Geotextile
Oklahoma	Silt Fence	Geotextile
Oklahoma	Temporary Sediment Filter	Geotextile
Utah	Silt Fence, Erosion Control	Geotextile
Utah	Stabilized Construction Entrance.	Separation geotextile Fabric
Virginia	Separation geotextile (under riprap)	Geotextile

3.13 Test Methods and Specifications for Hydraulic Erosion Control Products

ASTM, WSDOT develop the test methods and specifications mentioned in this section. Test procedures, equipment required for testing, standard testing conditions, and results to be reported after testing for each test method are discussed. The SHAs that recommend the test methods for testing HECPs used in erosion control and sediment control practices are tabulated.

3.13.1 Standard Test Method for Determining Water Holding Capacity of Fiber Mulches for Hydraulic Planting (ASTM D7367)

ASTM D7367 is a test method to determine water holding capacity of fiber mulches, including wood, paper, and agriculturally obtained and mixed fiber mulches used for hydraulic planting. The equipment includes a sieve pan with 8 inches (203.2 mm) diameter and 0.09 inch (2.36 mm) sieve size, large mixing bowl, electronic scale or balance scale with an accuracy of 0.0035 oz. (0.01g), baking pan or tray of 18 inches × 11 inches (457 mm × 279 mm) for draining, and mixer with dough kneader that has a capacity of 60 to 90 rpm. The test specimen should be weighed after conditioning and re-weighing, and after soaking in distilled water. The percentage of water holding capacity is calculated as the difference between the weight of the sieve, pan and saturated mulch (K), and sieve, pan and dry mulch (X) per difference between the weight of sieve and pan (X) and dry mulch, and sieve and pan (Y). Percentage of water holding capacity, average, and standard deviation are reported (ASTM D7367 2014c). Table 3.31 provides details of SHAs that recommend ASTM D7367 for testing E&SCPs.

Table 3.31 Summary of Recommendations by SHAs for ASTM F7367

State	Practice Type	Material / Component
Iowa	Hydraulic Mulch	Bonded Fiber Matrix, Mechanically Bonded Fiber Matrix, Organic Fiber Matrix
Minnesota	HECP	Organic Fiber Matrix
Utah	HECP	HECP Type 1, 2, 3
Virginia	HECP	HECP Type 1, 2, 3, 4

3.13.2 Standard Practice for Coagulation-Flocculation Jar Test of Water (ASTM D2035)

ASTM D2035 is a practice that describes a procedure for assessing the treatment to decrease dissolved, suspended, colloidal, and non-settling matter from water or wastewater by chemical coagulation-flocculation. The chemical coagulation-flocculation test is used to find the chemicals, dosages, and conditions needed to achieve ideal results. This practice can also be used for estimating color, turbidity, and hardness reduction. The equipment includes multiple stirrers, jars (or breaker), reagent racks, hand-held high-speed mixer, pipets, and pipet filler. The major components inspected using this practice are chemical additives, pH, temperature, order of addition and mixing conditions (ASTM D2035 2019).

3.13.3 Standard Practice for Performing Pressure In-Line Coagulation-Flocculation-Filtration Test in Water (D4188)

ASTM D4188 is a standard practice that describes a test procedure to execute pressure in-line coagulation-flocculation-filtration of water and wastewater. This practice helps in finding the efficiency of coagulants or flocculants or both and filter medium to in separating the suspended solids from wastewater. The coagulation-flocculation-filtration process is appropriate for water and wastewater with low suspended solids (0.004 oz./gal [30 mg/l]). This practice is suitable for any sized filter that is larger than 4 in. (100 mm) in diameter. The equipment includes a typical Pressure In-Line Coagulation-Flocculation-

Filtration System. A flocculant or coagulant, or both, is mixed with the pressurized water in the filtration system. Therefore, the formed floc can be separated and removed by using the filter medium. The efficiency of the filtration system can be calculated by observing the quality of the filter effluent. The percentage of raw water transformation to the clarified water can be calculated with the volume of water obtained from service run to the total amount of raw water (ASTM D4188 2017h).

3.13.4 Standard Test Method for Determination of Fiber Length Percentages in Hydraulic Erosion Control Products (HECPs) (ASTM D7560)

ASTM D7560 is a test method that describes the requirements and testing procedures to find the fiber length of hydraulic erosion control products (HECPs). The equipment for this test method includes a balance, sieve shaker, sieve frame, and a standard sieve set. A specific amount of fiber is weighed and placed on the top sieve screen of the sieve stack. The sieve stack is placed into the sieve shaker machine. After shaking for five minutes, the sieve stack is removed, and the amount of the fiber accumulated on each sieve screen is weighed. Therefore, the percentage of mass retained on each pan to the total mass is calculated (ASTM D7560 2016f).

3.13.5 Standard Practice for Preparing Specimens of Hydraulic Erosion Control Products for Index Property Testing (ASTM D7986)

ASTM D7986 is a standard practice that describes instructions for preparing samples of HECPs. The equipment and materials include a baking pan, a stand mixer, a drying oven, a balance, graduated cylinders, a timing device, test fluid, a metal pipe, a plastic spatula, scissors or cutting dies, zip top bags, and cooking spray. The dry HECPs are blended with water at a predetermined mixing rate. The HECP blend is spread across sheet

metal pan at an intended application rate. The mixture is dried and cut into sizes for index property tests (ASTM D7986 2017i).

3.13.6 Determination of Fiber Length Percentages in Wood Strand Mulch (WSDOT T125)

WSDOT T125 is a test method designed by the Washington State Department of Transportation to find the percentage by mass of fiber strands in a wood strand mulch sample. The equipment includes a weighing balance and a measuring device. Individual fiber strands are separated from the sample of wood strand mulch, and length, width and mass of each fiber strand are measured. After measuring, the strands are divided into two groups: strands satisfying the requirements (S) and strands not satisfying the requirements (N). The percentage of fiber stands satisfying the requirements (P) is calculated.

3.14 Test Methods and Specifications for Sediment Retention Devices

ASTM, AASHTO develop the test methods and specifications mentioned in this section. Test procedures, equipment required for testing, standard testing conditions, and results to be reported after testing for each test method are discussed. The SHAs that recommend the test methods for testing sediment retention devices used in sediment control practices are tabulated.

3.14.1 Standard Test Method for Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device (ASTM D5141)

ASTM D5141 is a test method to find the filtering efficiency and the flow rate of the filtration component of sediment retention devices (SRDs) such as silt fences, silt barriers, or inlet protectors. The filtering efficiency shows the percent of sediment separated from sediment-laden water. The flow rate is the average passage rate of the sediment-laden water through a sediment retention device. The soil used in the test can be site-specific or

should attribute the quality of target default gradation. The equipment for this test includes flume, inlet extension, sample cutter, integrated water sampler, two containers, stopwatch, stirrer, sediment-free water, Gooch crucible, membrane filter apparatus, vacuum pump, aluminum or stainless steel planchet, desiccator, and analytical balance. The specimen of SRD is fixed vertically across the flume while the sediment-laden water is discharged through the specimen. The time taken for water to pass and the amount of soil passed through the specimen should be measured. The amount of soil retained, filtering efficiency, and flow rate are determined from the measured values. The filtering efficiency is reported in percentage and flow rate units in gal/ft^2/min(m^3/m^2/min). The number of specimens used, type and physical properties of soil, the temperature of the water, time taken for the test, suspended solid contents, and filtering efficiencies should be reported (ASTM D5141 2018j). Figure 3.102 shows a bench scale test setup build for finding filtering efficiency and flow rate of SRDs. Table 3.32 provides details of SHAs that recommend ASTM D5141 for testing E&SCPs.

Figure 3.102 Bench Scale Test Setup (Sprague and Lacina 2010).

Table 3.32 Summary of Recommendations by SHAs for ASTM D5141

State	Practice Type	Material / Component
Dist. of Columbia	Sediment Barriers and Filters	Silt Fence geotextile/Super silt Fence geotextile
Florida	Silt Fence	Staked Silt Fence Geotextile
Virginia	Silt Fence	Silt Fence Geotextile

3.14.2 Standard Test Method for Determination of Temporary Ditch Check Performance in Protecting Earthen Channels from Stormwater-Induced Erosion (ASTM D7208)

ASTM D7208 is a test method that describes the guidelines, requirements, and testing procedures for assessing the potential of temporary ditch check systems used to safeguard earthen channels from stormwater erosion. The equipment includes a test channel, water delivery system, total station system, velocity probe, meteorological equipment, and camera or video recorders. The performance of temporary ditch checks in decreasing stormwater-induced erosion can be deduced by allowing the material to a simulated stormwater flow in controlled and documented conditions. The major components in the testing process are stormwater simulation equipment calculation; test channel preparation; temporary ditch checks documentation and installation; test performance; and hydraulic, topographical and relative data collection and data analysis (ASTM D7208 2014d). Figure 3.103 depicts a test setup built for testing ditch check performance in protecting earthen channels

Figure 3.103 Test Setup for Ditch Check performance Evaluations (TRI Erosion Test 2019)

3.14.3 Standard Test Method for Determination of Sediment Retention Device Effectiveness in Sheet Flow Applications (ASTM D7351)

ASTM D7351 is a test method that describes the guidelines, requirements, and testing procedure for assessing the potential of sediment retention devices (SRDs) that block the sediment that is left to sediment-laden sheet flow water. The equipment and material for this test method includes a combination mixing tank and scale, a clean water source and pumping equipment, a soil stockpile, a loader, a variable discharge apparatus, soil, water sampling equipment, excavating/ compacting machinery, a scaled collection system, retention area, and a collection tank. After setting up the equipment for the test method, the sediment-laden sheet flow water in the form of sheet flow is passed through SRD. The flow at the upstream and downstream size of the SRD is quantified. The efficiency of the SRD is calculated by comparing the amount of sediment that passed through the SRD to the sediment amount in the upstream flow (ASTM D7351 2013d). Figure 3.104 depicts a testing setup built for finding SRDs performance in sheet flow applications.

Figure 3.104 Testing Setup for SRDs Evaluation (TRI Erosion Test 2019)

3.14.4 Standard Practice for Compost for Erosion/ Sediment Control (Filter Berms and Filter Socks) (AASHTO R51)

AASHTO R51 is a standard specification for the compost used in filter berms and filter socks. This requirement is applicable for the filter and filter socks that are used on the slopes up to 2H:1V, level surfaces, and in the areas that have sheet flow drainage patterns. This specification includes chemical, physical and biological parameters for compost; field installation instructions for filter socks and filter berms; testing methods for compost; and instructions for sampling, inspection, packing, and marking of samples (AASHTO R51 2018b).

3.14.5 Standard Practice for Compost Erosion/ Sediment Control (Compost Blankets) (AASHTO R52)

AASHTO R52 is a standard specification for the compost used as a surface mulch on sloped areas. This requirement is suitable for the compost used on slopes up to 2H:1V, the areas that have sheet flow drainage patterns, and on the slopes up to 1H:1V with suitable slope length and compost application rates. This specification includes chemical, physical

and biological parameters for compost; field installation instructions for compost blankets on slopes; testing methods for compost; and instructions for sampling, inspection, packing, and marking of samples (AASHTO R52 2018c).

3.15 Summary

This chapter summarizes the implementation of NPDES stormwater program in all states across the United States. Various E&SC practices recommended by SHA's for construction site application are discussed. The QPL inclusion process for E&SCPs of all SHAs were discussed. Selected standard test practices and specifications for E&SCPs were summarized, and requirements of each SHA were tabulated.

CHAPTER 4 SURVEY AND DATA ANALYSIS

4.1 Introduction

In this chapter, data analysis for the conducted survey is presented. After the survey analysis section, the data collected from the unresponsive SHAs in the survey is mixed the survey data and overall analysis for QPL evaluation processes pertinent to E&SCPs of all 50 SHAs and DC DOT will be discussed. Following the analysis, the cost estimation analysis of equipment required in conducting standard tests will be discussed. Finally, an overall catalog of information related to the evaluation of E&SCPs will be presented.

4.2 Survey Questions, Responses, and Analysis

In this section, all the survey questions, their description, survey analysis of each question was discussed.

The questions included in this survey are:

Question: 1
Please state the agency you represent:

The first question in the survey is a general question to learn about the SHAs represented by the personnel.

Question: 2
Does your agency have a Qualified Products List for identifying erosion and/or sediment control products to be use on construction projects overseen or funded by your agency?
a. Yes, both erosion and sediment control products
b. Only erosion control products
c. Only sediment control products
d. No, neither erosion nor sediment control products
e. Not sure
f. Other, please explain:

The second question in this survey is to understand the SHAs maintenance of E&SCPs listed on the QPL.

Question: 3
How often is the Erosion and Sediment Control section updated on the Qualified Product List updated?
a. As needed
b. Monthly
c. Quarterly
d. Annually
e. Bi-Annually
f. Other, please explain:

The third question is designed to acquire the frequency of QPL updates pertinent to E&SCPs.

Question: 4
Does your agency use or allow for the use of erosion and/or sediment control products or materials from other federal, state, or local agency's qualified product list(s)?
a. Yes (please identify lists approved for use by your agency).
b. No
c. Not Sure
d. Only in special or rare cases, please explain

SHAs allow the use of erosion and/or sediment control products or materials listed on the QPLs of other SHAs. The fourth question was created to gather information about the SHAs that allow the usage of other SHAs' QPLs.

Question: 5
What qualification process does your agency follow to approve new erosion and/or sediment control products for inclusion in the Qualified Product List? Select all that pertain.
a. Application submission by product manufacturer
b. Fee submission by product manufacturer
c. Field testing
d. Large or full-scale performance-based laboratory testing
e. Bench-scale laboratory testing of material properties
f. Approval by other state highway agencies (please list)
g. Not Sure
h. Other, please explain:

The respondents may select more than one option in this question. The fifth question was designed to understand SHAs' inclusion process criteria for erosion and/or sediment control products.

If the respondents select "Field testing ", "Large or full-scale performance-based laboratory testing", or "Bench-scale laboratory testing of material properties" in the fifth question, then the sixth question is displayed.

Question: 6
What testing program does your agency use to evaluate products? Select all that apply.
a. In-house testing
b. University testing program (please list)
c. AASHTO National Transportation Product Evaluation Program (NTPEP)
d. ASTM testing
e. Other independent third-party agency (please list)
f. Other, please explain:
g. Not sure

In the sixth question, the respondent may again select one or more options. The main intention of this question is to learn about the SHAs' testing program policies during erosion and/or sediment control product evaluations.

Question: 7
Are erosion and sediment control products on the qualified product list periodically re-evaluated to ensure conformance to prescribed qualification standards?
a. Yes
b. No
c. Other, please explain:

The seventh question was created to understand whether SHAs' re-evaluate erosion and/or sediment control products on timely basis. If the respondents choose "Yes" in the seventh question, the following questions 7.1 and 7.2 are displayed.

Question: 7.1
How often are erosion and/or sediment control products re-evaluated?
a. 0-1 years
b. 1-2 years
c. 2-5 years
d. > 5 years

In Question 7.1, the respondents may choose more than one option. The question was designed to discover the SHAs' re-evaluation frequency of erosion and/or sediment control products listed on the QPL.

Question: 7.2
What does the product re-evaluation process include? select all that apply.
a. Previous performance records
b. Material based testing
c. Field testing on active construction sites
d. Performance-based testing
e. Submission of fee
f. Other, please explain:

In Question 7.2, the respondents may choose more than one option. The main idea in this question is to understand the SHAs' re-evaluation criteria pertinent to erosion and/or sediment control products.

Question: 8		
Please select all erosion and sediment control products listed in your agency's Qualified Product List.		
a. Anchoring devices	b. Flocculants	c. Soil stabilizers
d. Sediment basin baffles	e. Other geosynthetics	f. Soil sterilants
g. Bituminous treating roving	h. Inlet protection devices	i. Tackifiers
j. Erosion control blankets	k. Temporary mulch	l. Temporary and Permanent Seeding
m. Check dams	n. Hydraulic erosion control products	o. Turbidimeters
p. Dewatering devices	q. Silt fence	r. Turf reinforcement mats
s. Dust palliatives	t. Slope drains	u. Wattles or Sediment logs
v. Fertilizers	w. Soil binders	x. Other, please list

In the eighth question, the respondents may choose more than one option. This question is designed to learn about the E&SCPs listed on SHAs' QPL.

Question: 9
Does your agency maintain standard installation details for erosion and sediment control practices?
a. Yes, please provide link to installation details:
b. No

In the ninth question, respondents were asked about their SHAs' E&SCPs' standard installation details.

Question: 10
In your opinion, what changes could your agency employ to improve the product evaluation process for erosion and sediment control product inclusion in the qualified product list?
a. Please explain
b. None
c. Not sure

The final question was asked to respondents to learn of their views on improving the QPL inclusion process pertinent to E&SCPs.

The survey was sent to all SHA personnel in the country in September of 2018. 24 unique SHAs (47% response rate) have responded to the survey as shown in Figure 4.1.

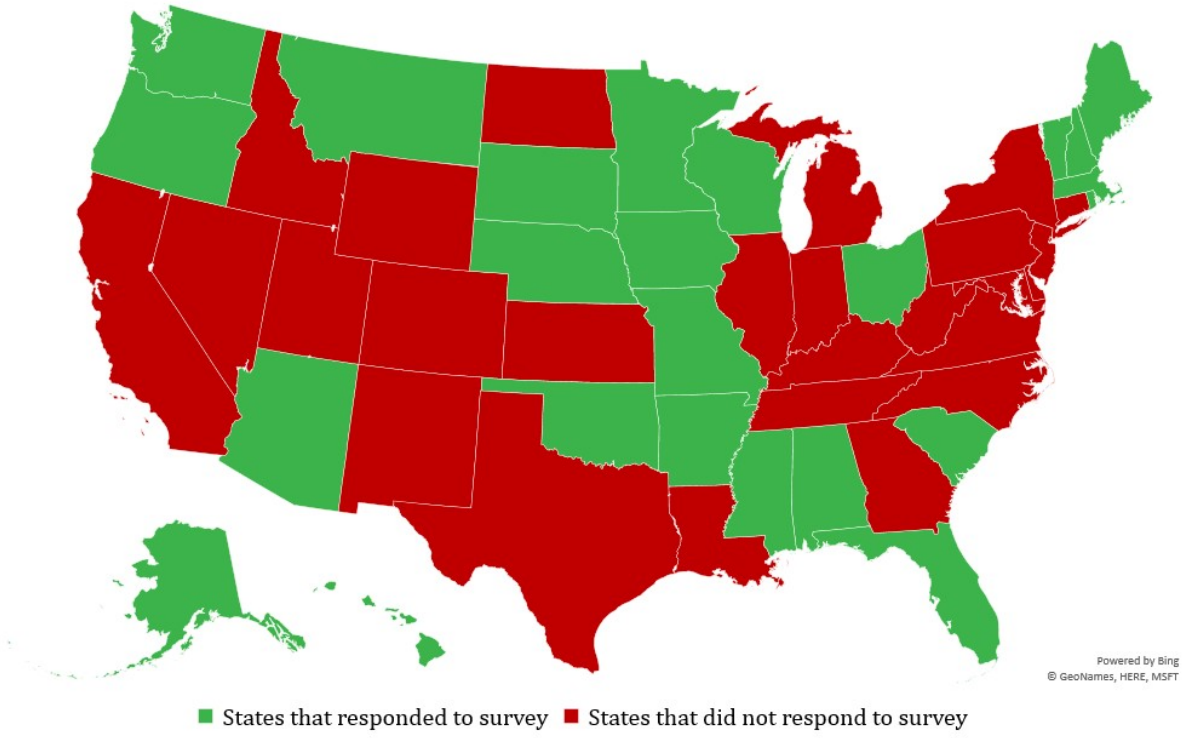
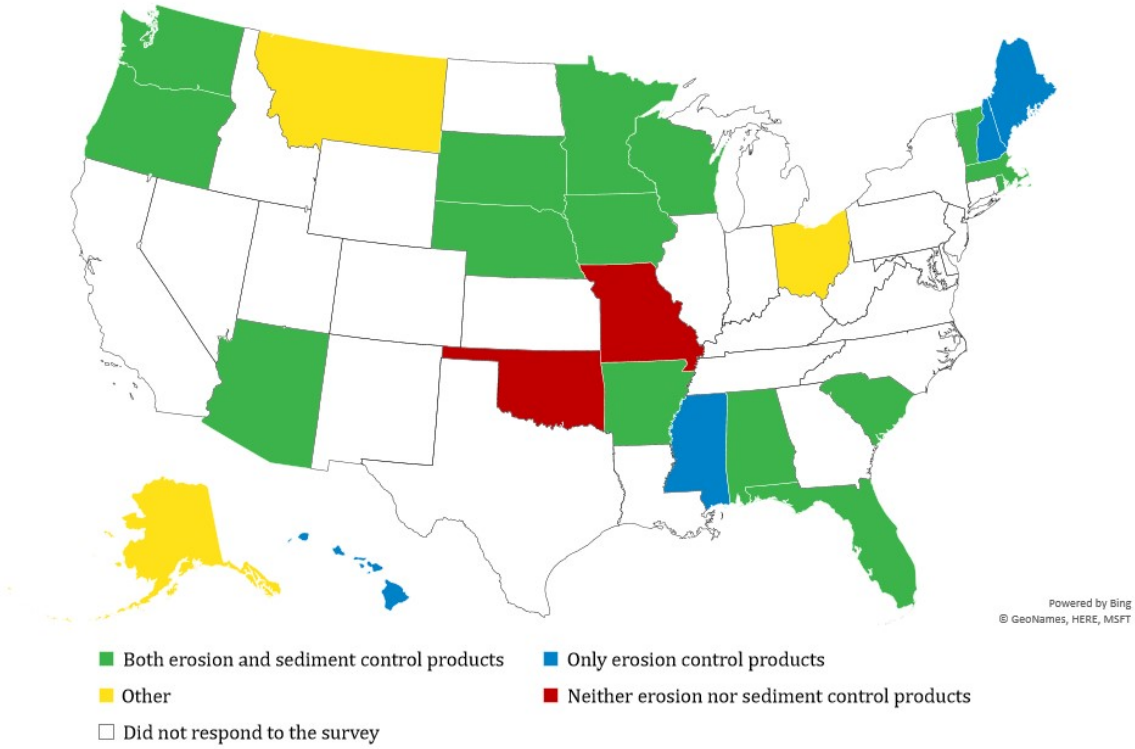
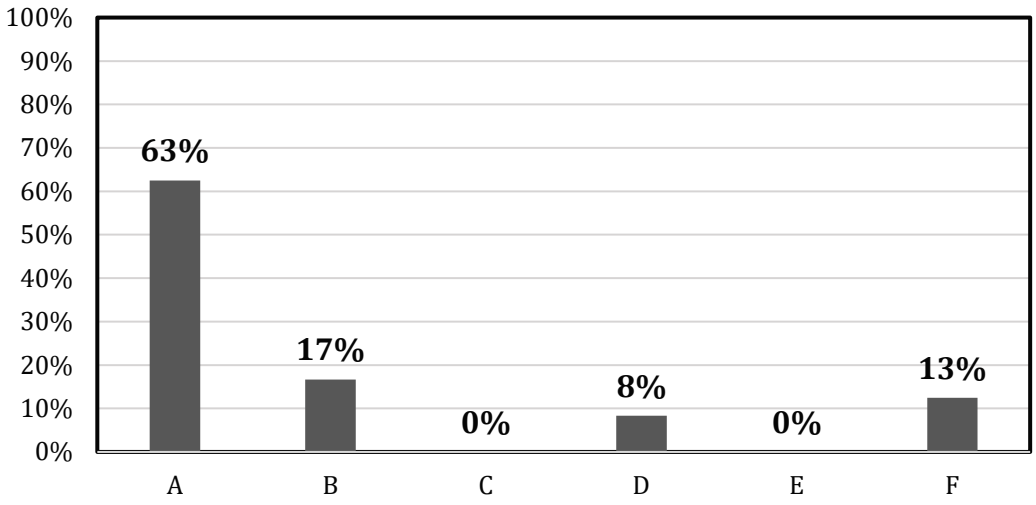


Figure 4.1Responded SHAs to the Survey

The second question in the survey is about the maintenance of E&SCPs on the QPL by SHAs. As shown in figure 4.2, of the 24 total SHA responses, 15 agencies (63%) answered that they maintain E&SCPs on their QPLs, four agencies (17%) maintain only erosion control products, two agencies (8%) do not maintain either erosion or sediment control products, and three agencies (13%) chose the 'Other, please explain' option. The four SHAs who selected this option explained their views. One of the four agencies expressed that they are required to list erosion control blankets on their QPLs but not sediment control devices such as straw wattles or silt fence, even though they can be accepted to the QPL but are not required to be listed on QPL. The second agency explained that they have QPL (can be used on projects without further approval) and they accept any product at project level if it meets their standard specifications. The third agency mentioned that they have standard specifications for E&SC devices and may specify job-specific items. Other SHA mentioned that they are in the process of developing criteria and processes for their QPL. The color-coded U.S map in the figure 4.2 shows the SHAs that list and maintain erosion and/or sediment control products on their QPLs.

Question 2: Does your agency have a Qualified Products List for identifying erosion and/or sediment control products to be use on construction projects overseen or funded by your agency?



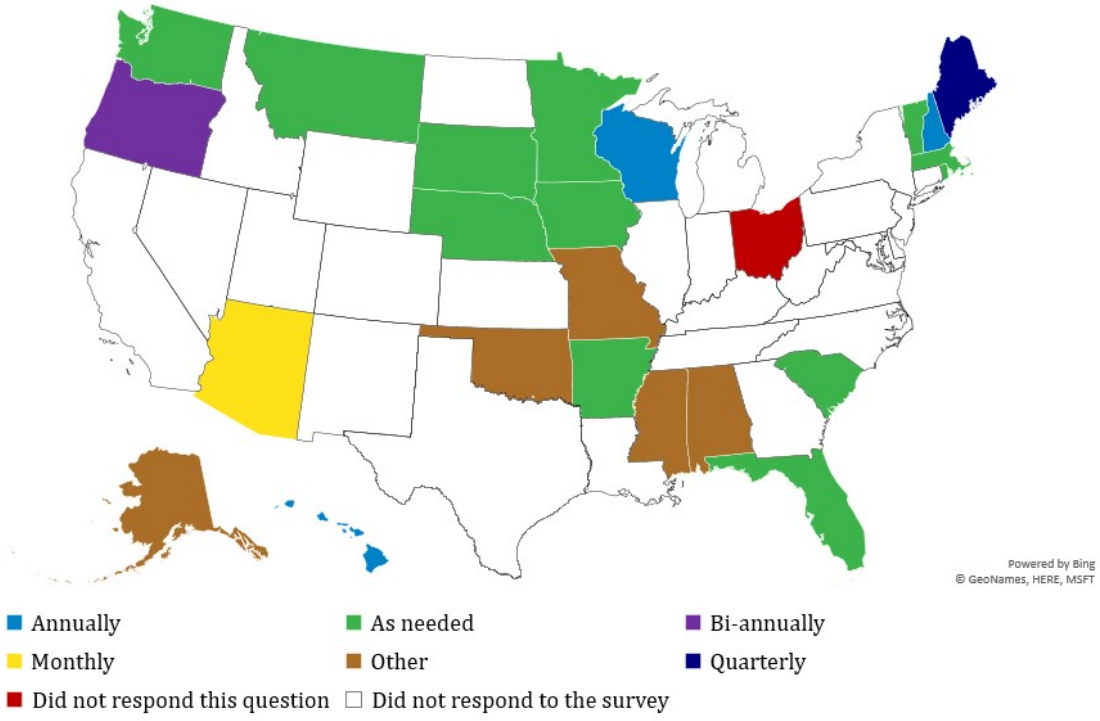


A-Both erosion and sediment control products
B- Only erosion control products
C-Only sediment control products
D-Neither erosion nor sediment control products
E-Not sure
F-Other

Figure 4.2 Mapping of SHAs Erosion and/or Sediment control Products Listed on SHAs' QPL

The third question is about the time frequency of E&SCPs section updates on the SHAs' QPL. As shown in Figure 4.3, out of 24 SHAs, one agency did not answer this question and 12 agencies (52%) responded that they update the erosion and control products section in their QPL when needed. Moreover, one agency upgrades monthly, another agency updates quarterly, three agencies (13%) update annually, and five agencies (22%) chose the 'Other, please explain' option and expressed their views. Additionally, one agency mentioned that they update once every four years, another SHA stated that they update RECPs bi-annually and other products when needed. Finally, another SHA expressed that they do not have a QPL list for E&SCPs, and yet another SHA mentioned that they do not solicit products unless applied by vendors or manufacturers. The color-coded U.S map in the Figure 4.3 shows the SHAs' updating frequency of E&SCPs section in their QPL.

Question:3 How often is the Erosion and Sediment Control section updated on the Qualified Product List updated?



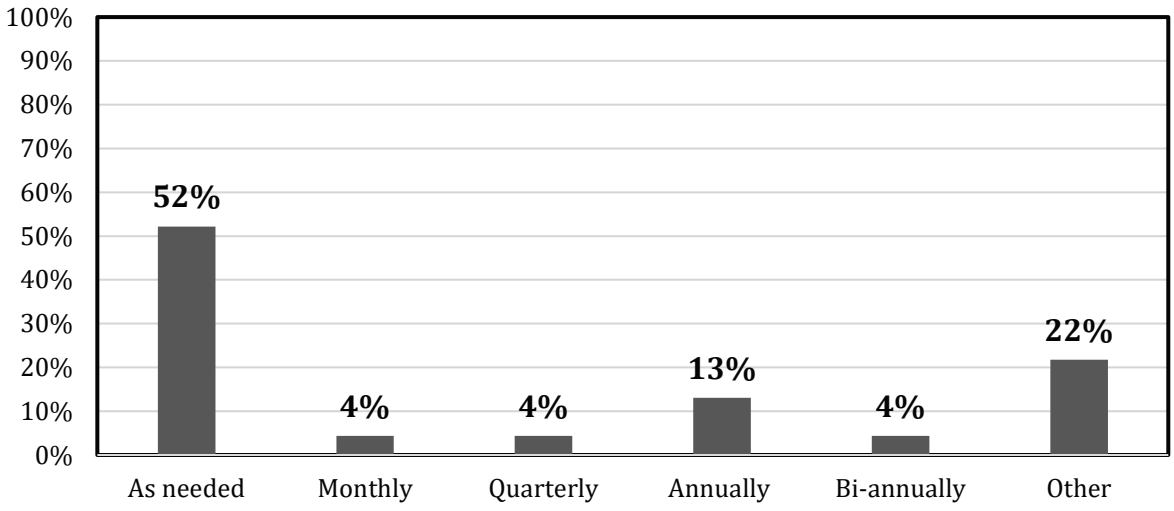
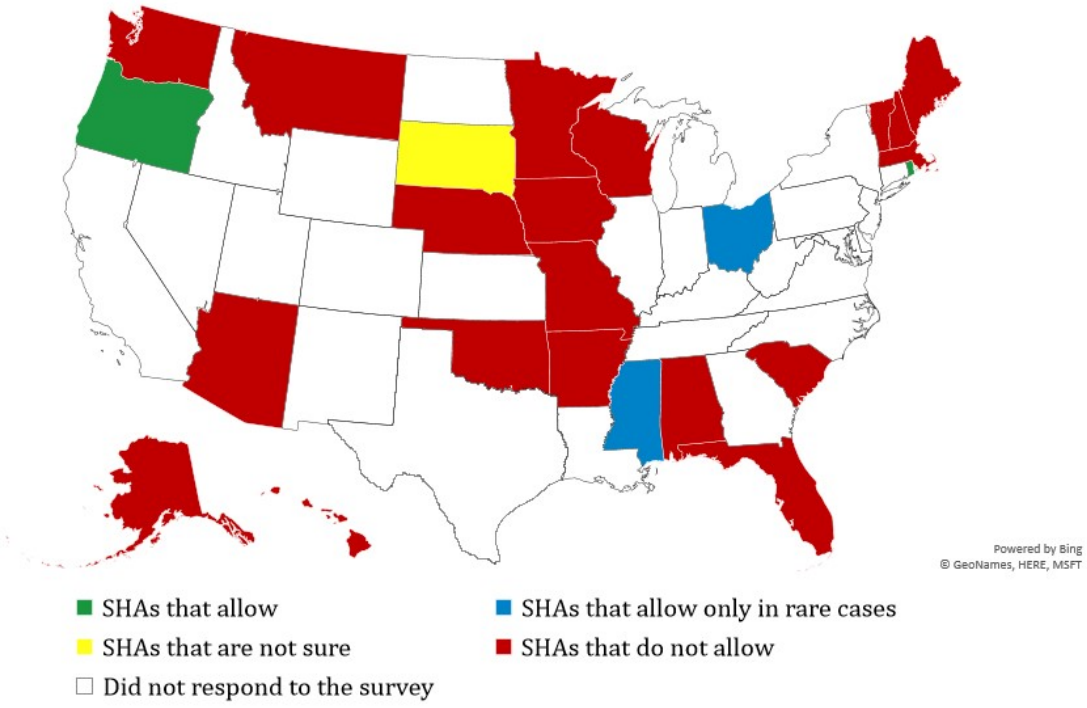


Figure 4.3 Mapping of SHAs QPL Updating Frequency for E&SCPs Section

In the fourth question, the participants were asked about the usage of E&SCPs from other federal, state or local agency QPLs. As shown in Figure 4.4, 19 agencies (79%) expressed that they would not use other agencies' QPLs. Two state agencies admitted that they use other agencies' QPLs, another two agencies were not certain, and two other agencies reported that they use other QPLs only in special cases. A special case mentioned included a contractor that can justify when the state's standard practices are inapplicable in a situation. Two SHAs expressed that they accept other agencies' QPLs; one agency mentioned that they use or allow the QPL list from the Texas DOT, and the other SHA stated that they accept the products mentioned on other agencies' QPLs if they conform to their standard specifications. Two SHAs chose "only in rare cases" option, and one of the respondents explained that their SHA adopts some portions of their QPL directly from other agencies' lists. The other SHA expressed that they allow alternative BMPs if the contractor can justify that their SHA standard practices cannot work in a certain situation, and they approve alternative BMPs on a case-by-case basis. The color-coded U.S map in the Figure 4.4 shows the status of SHAs related with usage of E&SCPs listed on other agency's QPL.

Question-4: Does your agency use or allow for the use of erosion and/or sediment control products or materials from other federal, state, or local agency's qualified product list(s)?



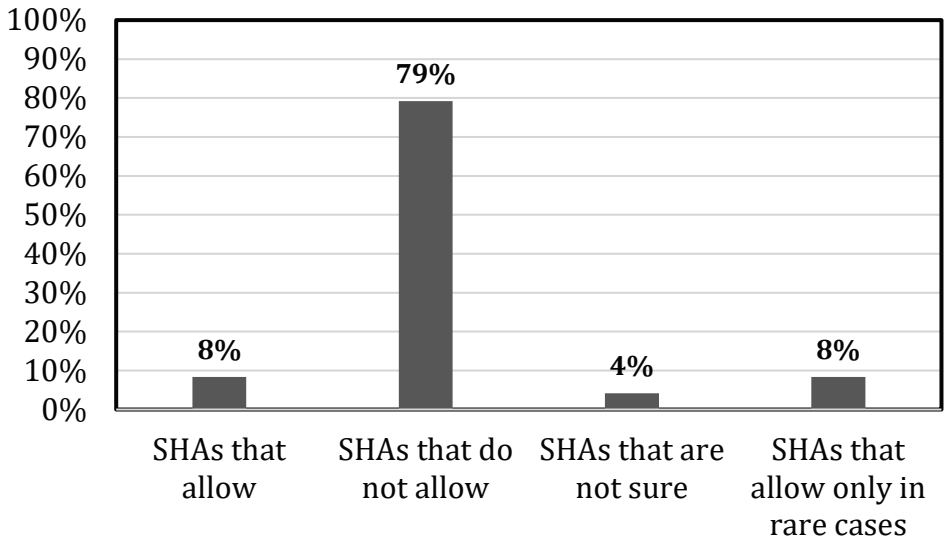
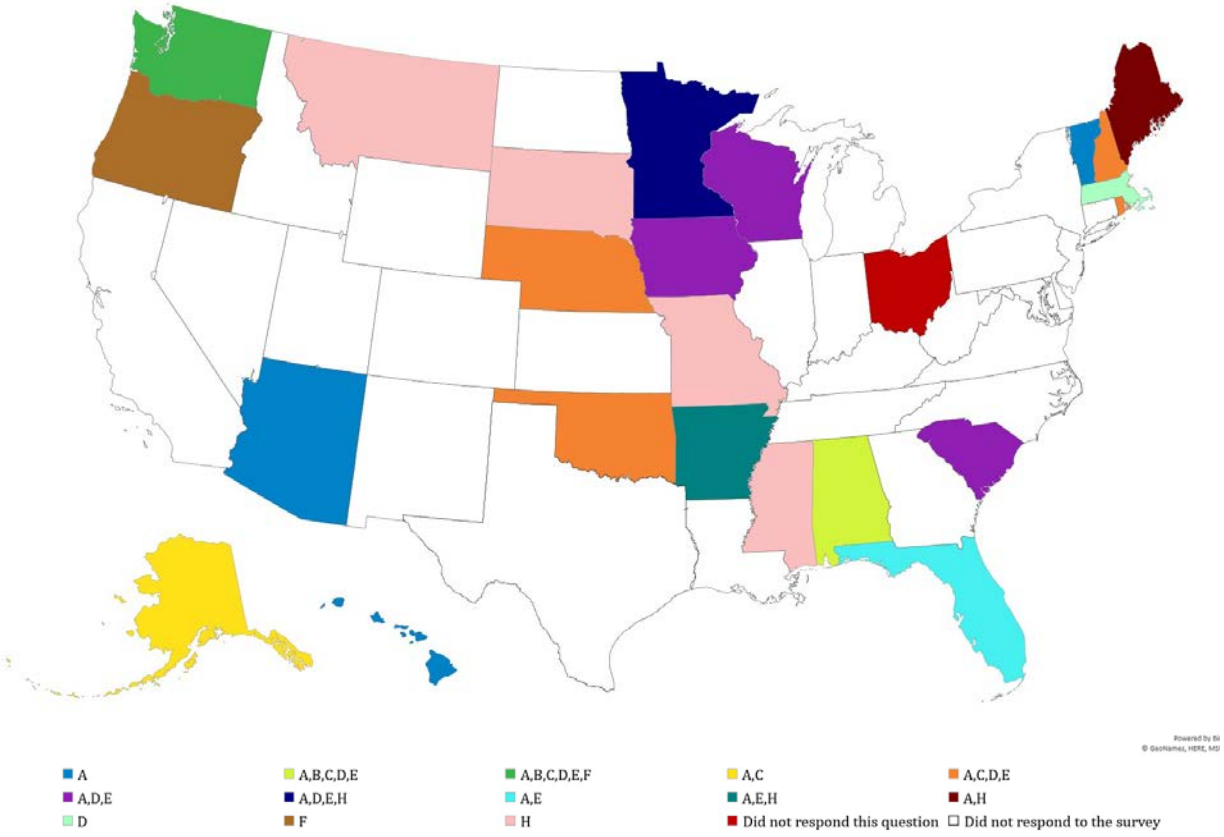
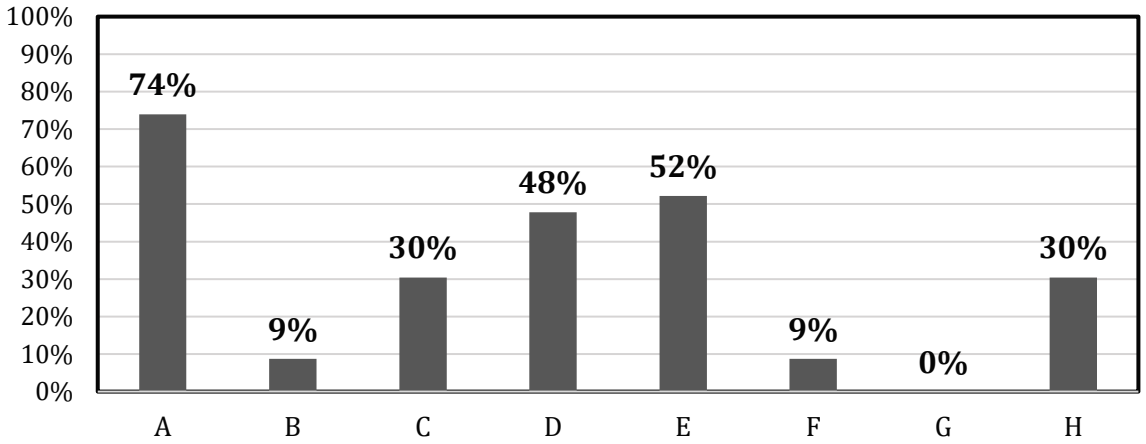


Figure 4.4 Mapping of SHAs that Allow E&SCPs Listed on other Federal/State or Local Agencies' QPL

The fifth question is about the QPL inclusion process preferred by SHAs to approve new erosion and/or sediment control products. Overall, 23 SHAs responded and one SHA did not respond to this question. As shown in the Figure 4.5, 17 agencies (74%) prefer the product inclusion process with the application submitted by the manufacturer, 12 agencies (52%) prefer bench scale laboratory testing of the material properties, 11 agencies (48%) prefer large or full scale performance based laboratory testing, seven agencies (30%) prefer field testing, two agencies (9%) accept the fee submission by the manufacturer, and two SHAs (9%) accept the products that were approved by other agencies. One of these final two agencies mentioned that they accept NTPEP evaluation, and the other accepts Texas DOT approval data during their product inclusion process. Seven agencies (30%) chose the 'Other, please explain' option. Two among the seven agencies mentioned that they accept NTPEP evaluation for geotextiles fabrics, one agency mentioned that they require NTPEP testing for ECPs and should be accepted by their qualified personnel, one of the seven agencies do 'Hazardous Evaluation' for HECPs and flocculants to protect their agency from pollution liability, one agency mentioned that they use Texas Transportation Institute (TTI) evaluations for ECBs acceptance, and another SHA stated that they do the inclusion process with the mixture of testing methods and adopting QPLs from other SHAs. The color-coded U.S map in the Figure 4.5 shows the QPL inclusion process preferred by SHAs.

Question:5 What qualification process does your agency follow to approve new erosion and/or sediment control products for inclusion in the Qualified Product List? Select all that pertain.



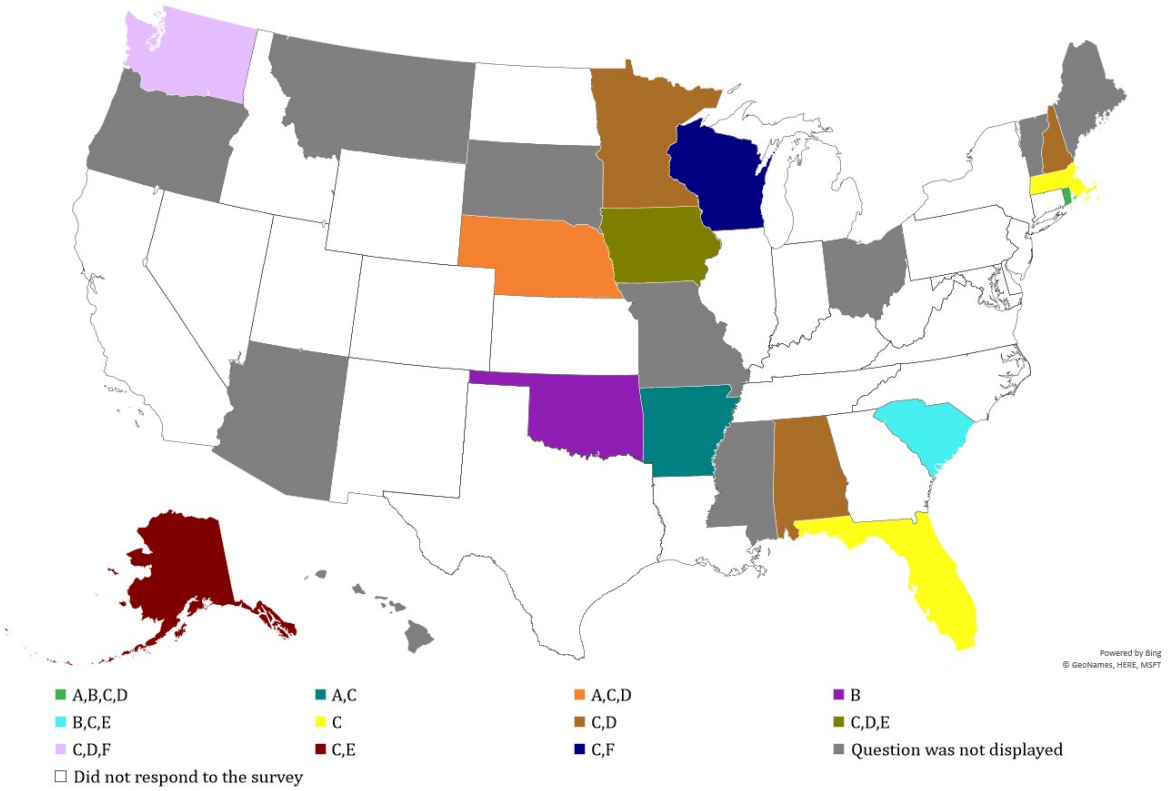


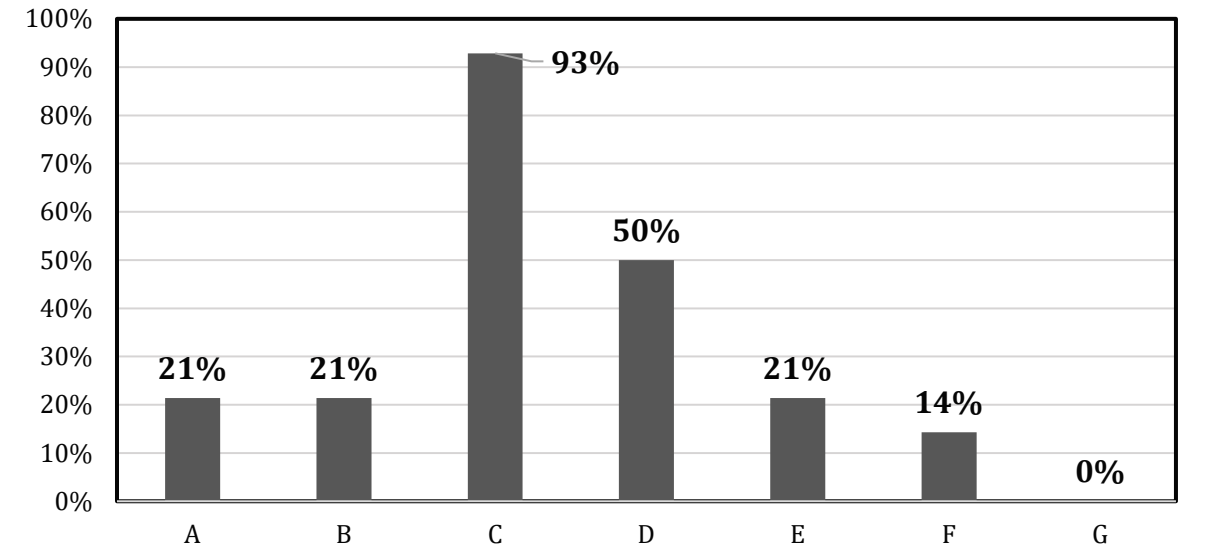
A-Application submission by product manufacturer
B-Fee submission by product manufacturer,
C-Field Testing
D-Large or full-scale performance based laboratory testing
E-Bench-scale laboratory testing of material properties
F-Approval by other state highway agencies
G-Not Sure
H-Other

Figure 4.5 Mapping of SHAs' New E&SCPs Evaluation Process

The sixth question is linked with the fifth question. An 'if logic' was used in this question. Based on the selection of choices in the sixth question, participants were directed to this question. Therefore, this question was not displayed to the 10 participants. This question is displayed to the respondents who selected 'field testing' or 'large or full scale performance based laboratory testing' or 'bench-scale laboratory testing of material properties' in the fifth question. The idea of this question is to understand about detailed testing program preferred by SHAs. As shown in Figure 4.6, Out of 14 responses from agencies, three (21%) prefer in-house testing, three (21%) prefer university testing program, 13 (93%) prefer AASHTO- NTPEP program, seven (50%) selected ASTM testing, three (21%) chose other independent third party agency, and two selected the "Other, please explain" option. One SHA stated that they accept test data from qualified independent labs when NTPEP test data is unavailable. SHAs mentioned that they accept testing data from Auburn University Erosion and Sediment Control testing facility, Colorado State University, University of Rhode Island, TTI, Utah State University, and other certified testing labs. The color-coded U.S map in Figure 4.6 shows the testing program preferred by SHAs.

Question-6: What testing program does your agency use to evaluate products? Select all that apply.



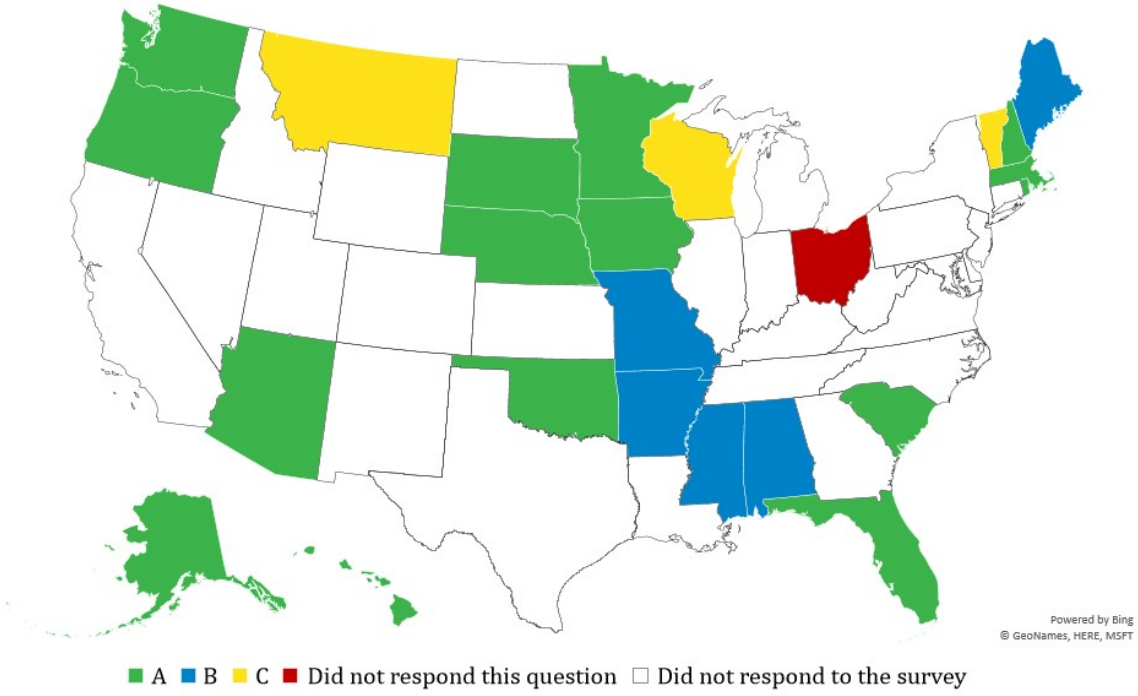


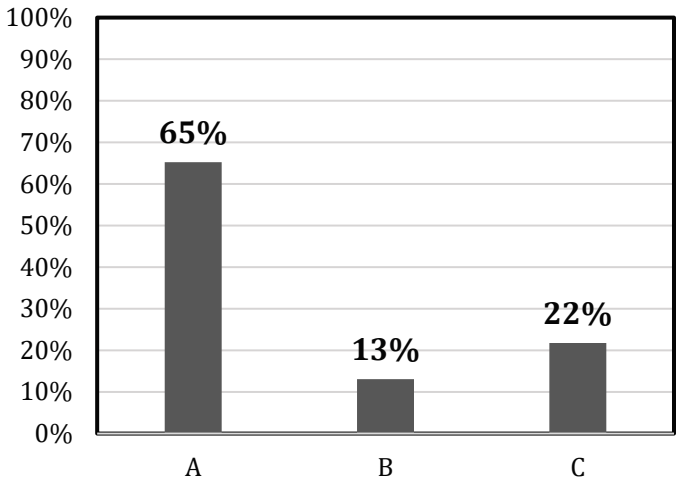
A-In house testing
B-University testing program
C-AASHTO NTPEP
D-ASTM testing
E-Other independent third-party agency
F- Other
G- Not sure

Figure 4.6 Mapping of SHAs based on Preferred Testing Programs

The main idea of the seventh question is to understand SHAs' policies on the re-evaluation processes of E&SCPs listed on their QPLs. Overall, 23 SHAs responded, and one SHA did not respond to this question. As shown in Figure 4.7, Out of 23 responses, 15 (65%) SHAs re-evaluate products periodically, three (13%) SHAs do not perform revaluation for the E&SC products listed on their QPLs, and five (22%) SHAs choose the 'Other, please explain' option. Various SHAs commented that they re-evaluate products only once in the tenure of their QPLs, monitor NTPEP audits of QPL listed geotextiles, and re-evaluate RECPs every three years. Finally, another SHA mentioned that they are currently developing a process to re-evaluate products at regular intervals. The color-coded U.S map in Figure 4.7 shows SHAs' reevaluation process pertained with E&SCPs section on QPL.

Question-7: Are erosion and sediment control products on the qualified product list periodically re-evaluated to ensure conformance to prescribed qualification standards?





A-SHAs that re-evaluate E&SC products listed on QPL

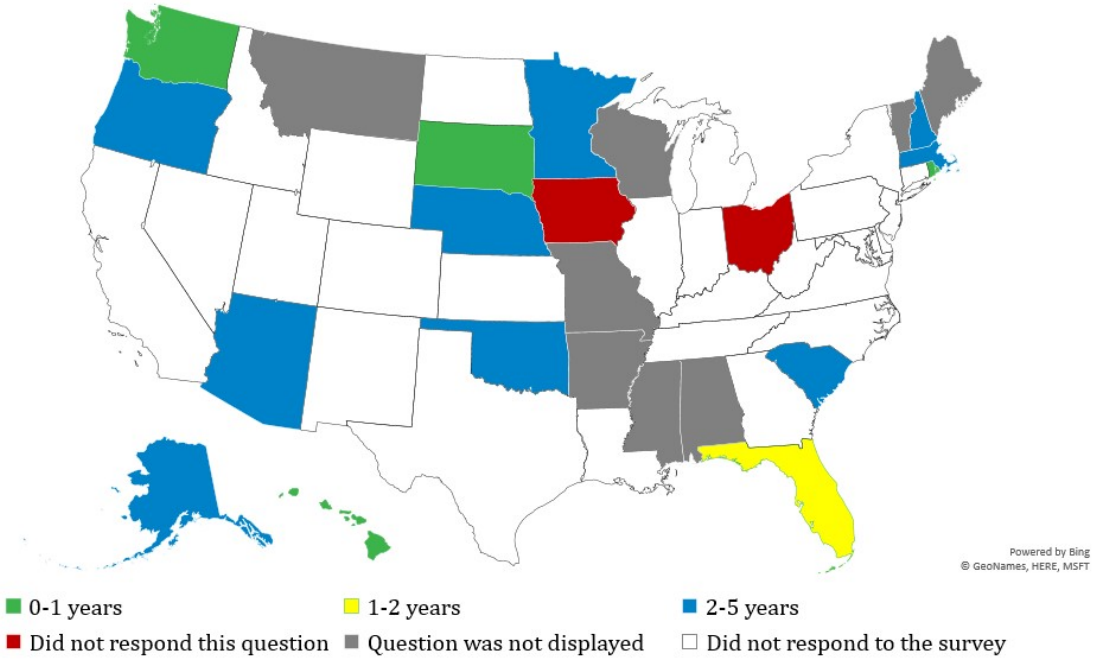
B-SHAs that do not re-evaluate E&SC products listed on QPL

C-SHAs that selected 'Other, please explain' option

Figure 4.7 Mapping of SHAs Based on Re-evaluation Criteria for E&SCP

The Question 7.1 is a sub question to the seventh question. The respondents were asked to choose the re-evaluation frequency of E&SC products listed on their QPLs. An 'if logic' was used in this question. This question is displayed to the respondents who chose 'Yes' option in the seventh question. Therefore, this question is displayed to 16 respondents that represent different SHAs out of 24 responded SHAs. As shown in Figure 4.8, Of these 16 SHAs, four (29%) perform re-evaluation every year, one (7%) does every 1 to 2 years, and nine (64%) SHAs perform re-evaluation every 2 to 5 years. Two SHAs did not answer this question. The color-coded U.S. map in Figure 4.8 shows the re-evaluation frequency of E&SCPs listed on QPL by SHAs.

Question-7.1: How often are erosion and/or sediment control products re-evaluated?



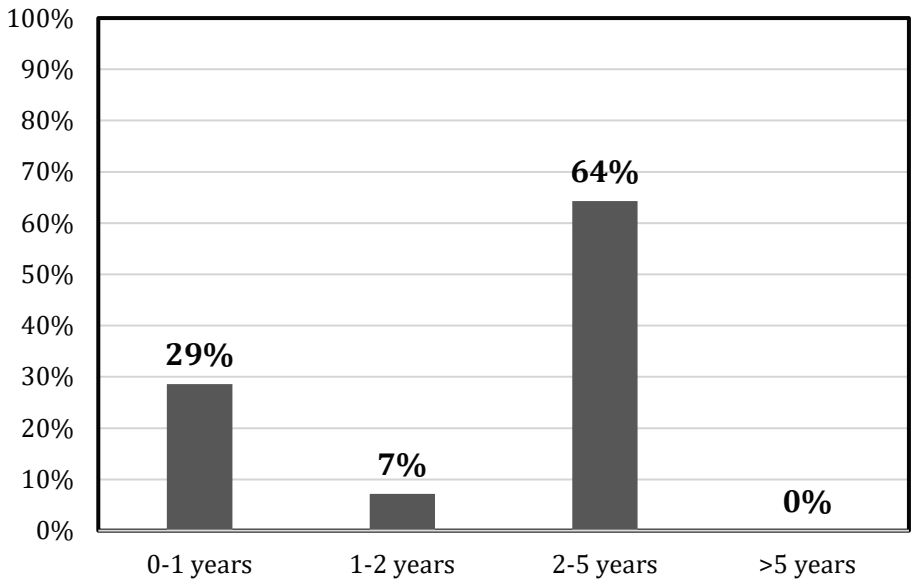
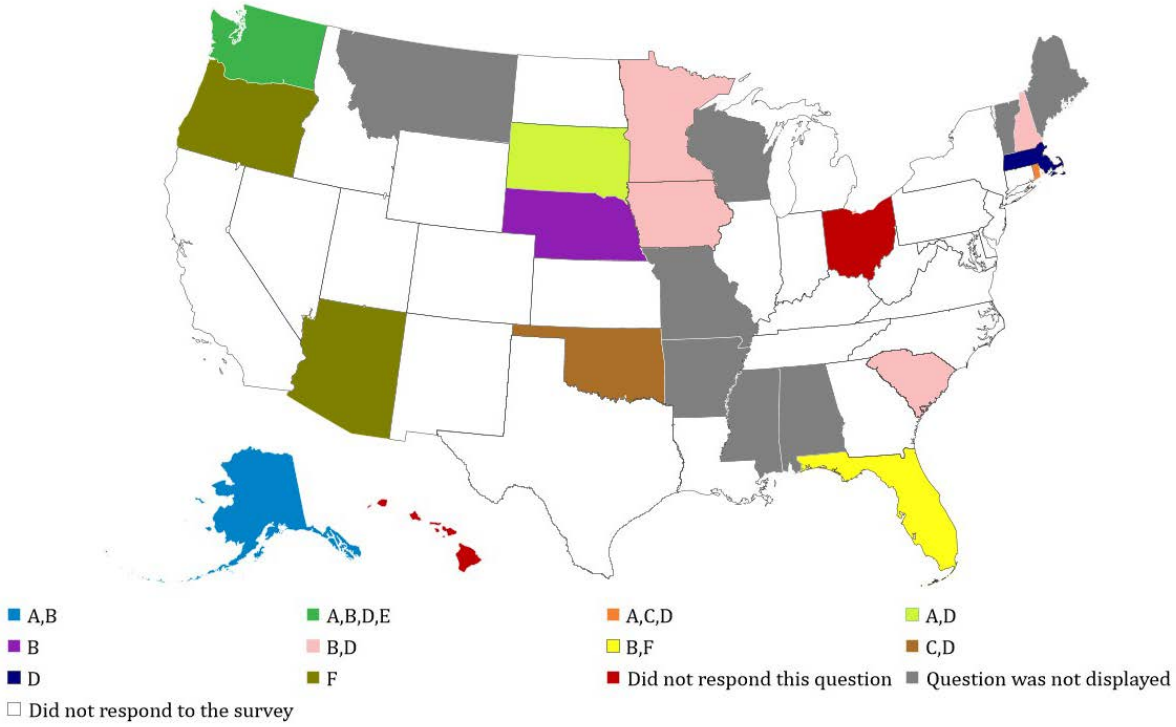
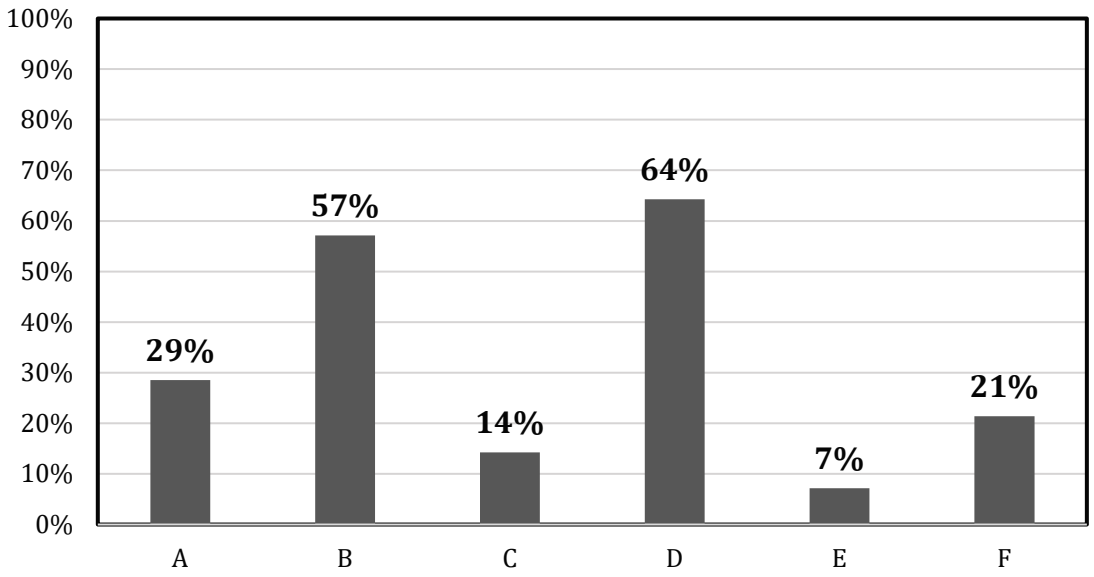


Figure 4.8 Mapping of SHAs based on reevaluation period for E&SCPs

Question 7.2 is also a sub question to the seventh question. This question is designed to understand the re-evaluation criteria for E&SCPs listed on QPL by SHAs. In this question, the respondent may choose one or more option if applicable. An 'if logic' was used in this question. This question was displayed to the respondents who chose 'Yes' in the seventh question. Therefore, this question is displayed to 16 respondents that represent different SHAs out of 24 responded SHAs. Of 16 SHAs, two SHAs did not answer this question. As shown in Figure 4.9 during re-evaluation process, four (29%) SHAs prefer the previous performance records, eight (57%) SHAs prefer material based testing, two (14%) SHAs prefer field testing on active construction sites, nine (64%) SHAs prefer performance based testing, one SHA requires fee submission for the re-evaluation process, and three (21%) chose the "Other, please explain" option to explain their re-evaluation criteria. One SHA mentioned that their re-evaluation process includes submission of statements by suppliers that no changes have been made to product since the approval. Another SHA stated that products should comply to latest changes in the specification requirements. Another SHA mentioned that products are required to meet requirements in the standard specifications and any applicable stored specifications. The color-coded U.S map in Figure 4.9 shows the re-evaluation criteria of E&SCPs listed on QPL by SHAs.

Question 7.2: What does the product re-evaluation process include? select all that apply.





A-Previous performance records
B-Material based testing
C-Field testing on active construction sites,
D- Performance-based testing
E- Submission of fee
F-Other

Figure 4.9 Mapping of SHAs Re-evaluation Criteria

The eighth question was created for respondents to choose the E&SC products that are listed on their SHAs' QPLs. Out of 24 SHAs, 23 SHAs have responded to this question. A bar chart in Figure 4.10 shows different types of E&SC products that are listed on the 23 SHAs' QPLs are shown in the figure below.

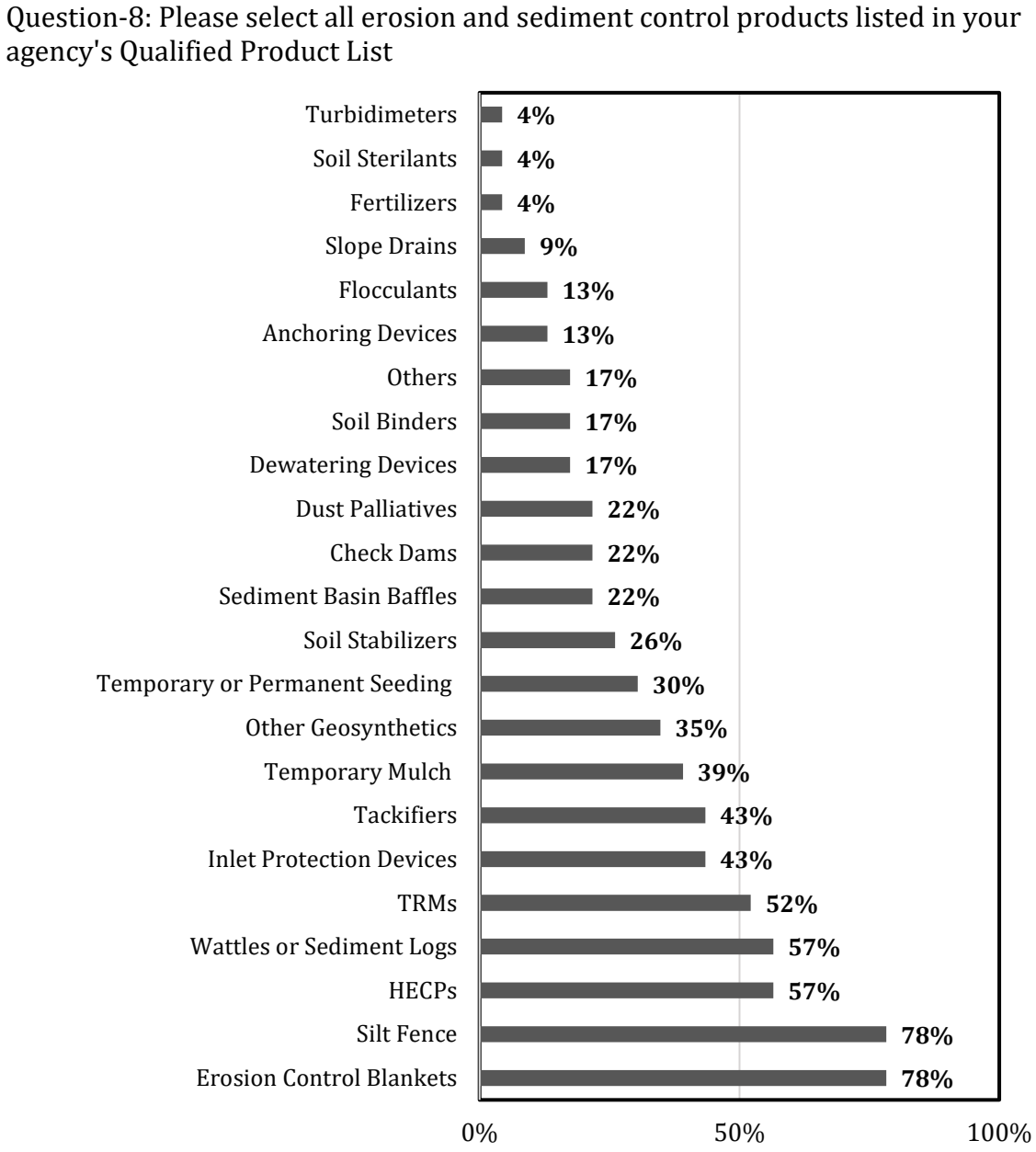
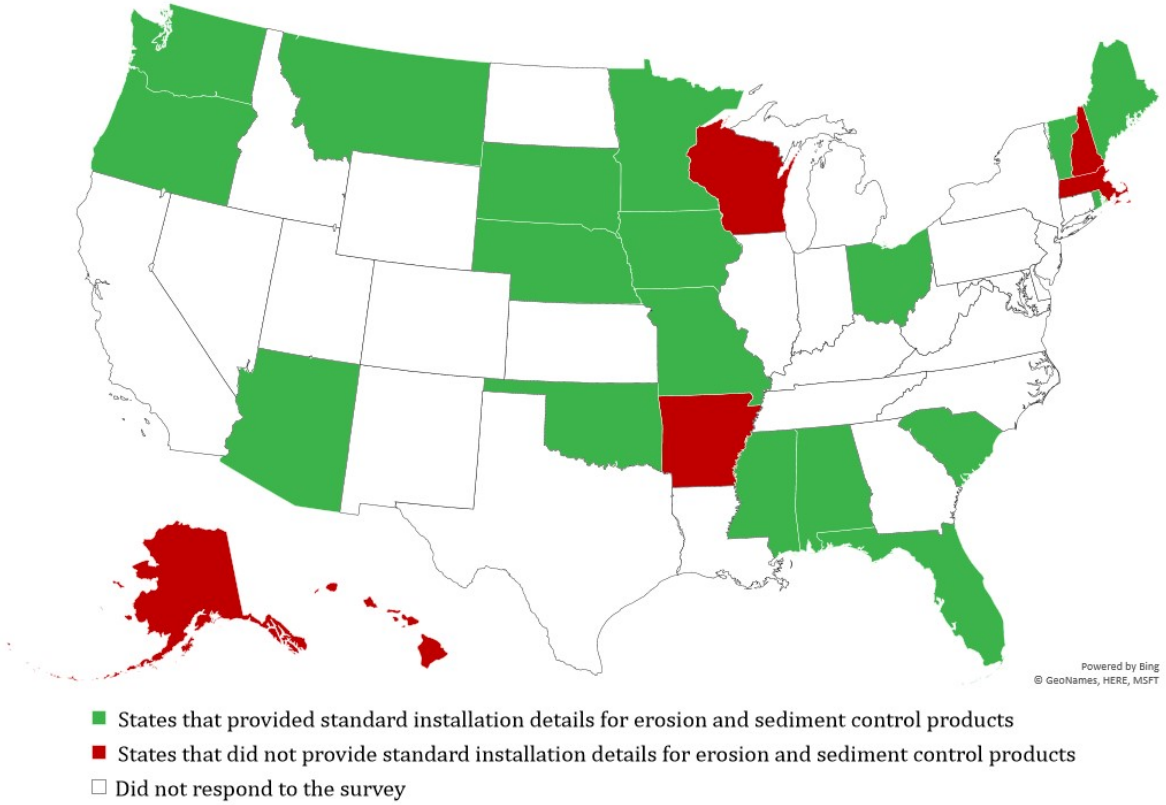
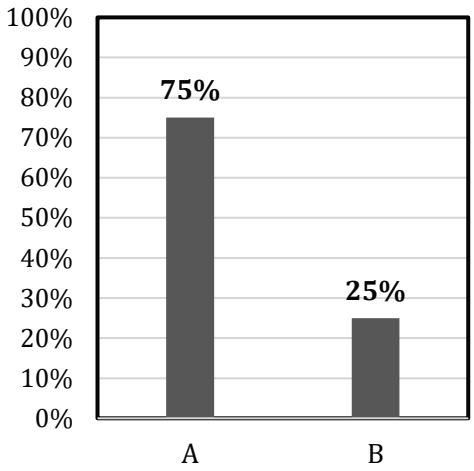


Figure 4.10 Common E&SCPs listed by SHAs

In the ninth question, the SHAs were asked to provide their standard installation details for E&SC practices. As shown in Figure 4.19, Out of 24 SHAs, 18 (75%) provided, and six (25%) did not provide standard installation details for E&SC practices. The color-coded U.S map in Figure 4.11 shows the SHAs that provided standard installation details for E&SCPs.

Question-9: Does your agency maintain standard installation details for erosion and sediment control practices?





A-SHAs that provided standard installation details for E&SCPs

B-SHAs that did not provide standard installation details for E&SCPs

Figure 4.11 Mapping of SHAs that Provided E&SCPs Installation Details

The intention of the tenth question is to understand the SHAs' views on improving the product evaluation process for E&SC product inclusion in the QPL. As shown in Figure 4.12 in overall, 11 (52.4%) SHAs chose "Please explain" option and explained their views, three (14.3%) SHAs chose "None," and seven (33.3%) SHAs chose "Not Sure." The color-coded U.S map in Figure 4.12 shows the SHAs that responded to this question

A respondent from one SHA explained that they focus on contractor performance rather than products and holding the contractor responsible for meeting E&SC standards on the job site. The respondent also stated that their SHA limits the type of products that show poor field performance and are required for pre-evaluation.

Comments of other SHAs include: improving definitions which could help evaluate products equally; requiring a product review and including each item listed on their QPL page; adding a formal evaluation process (which is not currently in place) and forming a committee for setting up a policy and process guidelines for E&SCPs; developing the QPL based on NTPEP testing; and improving communication between designers, construction contractors and internal project teams to identify successes and issues with products.

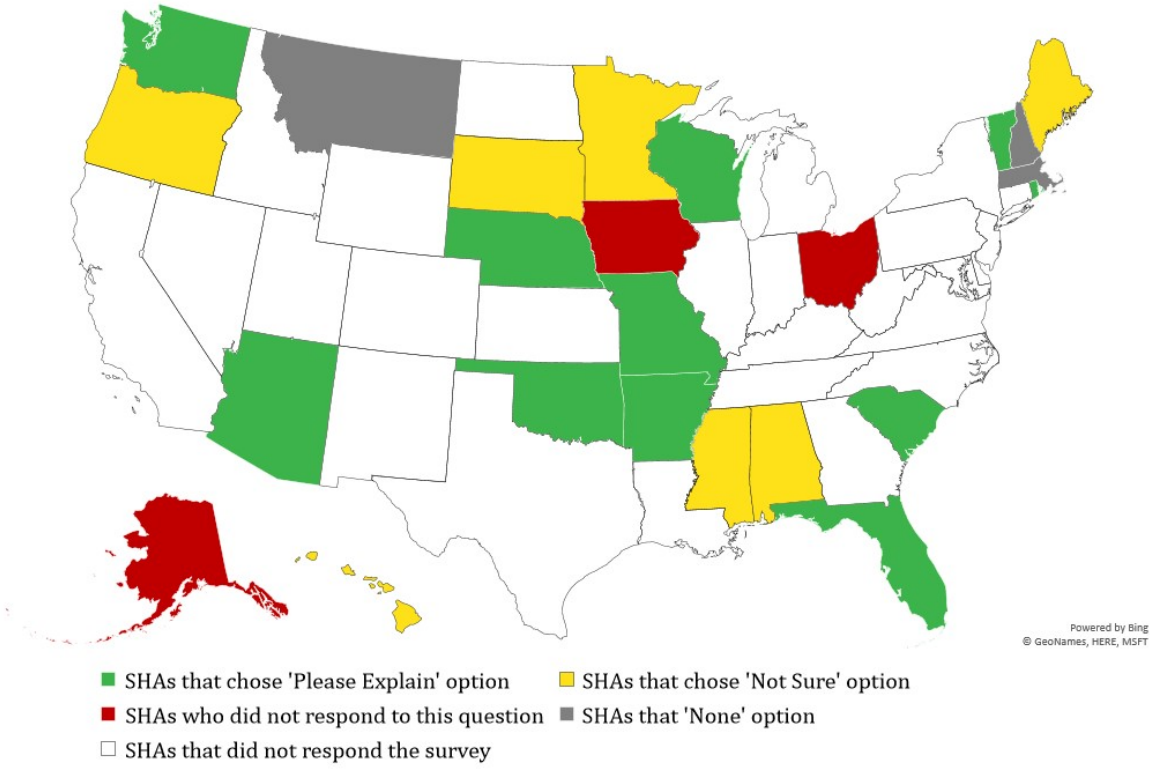
One SHA recommended creating a more streamlined process for maintaining QPL. The respondent stated that their QPL is maintained through their State Material Laboratory, and it is currently understaffed and behind on updating the QPL. The respondent stated that, due to such phenomena, their QPL includes products that haven't met their SHA's standard specifications. The respondent recommended to closely align the specification updates with QPL updates.

Another respondent noted that they are satisfied with their approval process. They noted that erosion control portion requires an improvement in field installation practices

and ensuring that appropriate decisions are made regarding what applications are appropriate to their intended locations and service conditions. Two more states have mentioned similar intentions in evaluating E&SCPs. One SHAs stated that they need to set requirements for the specific type of product, while another mentioned that they need detailed specifications for different erosion control products available in the market.

Finally, another SHA stated that the NTPEP program has been useful, but it does not cover all categories of products. The SHA recommended to evaluate such products nationally rather than each state evaluating individually, but it also stated that this evaluation may not be feasible due to different site conditions in different regions.

Question-10: In your opinion, what changes could your agency employ to improve the product evaluation process for erosion and sediment control product inclusion in the qualified product list?



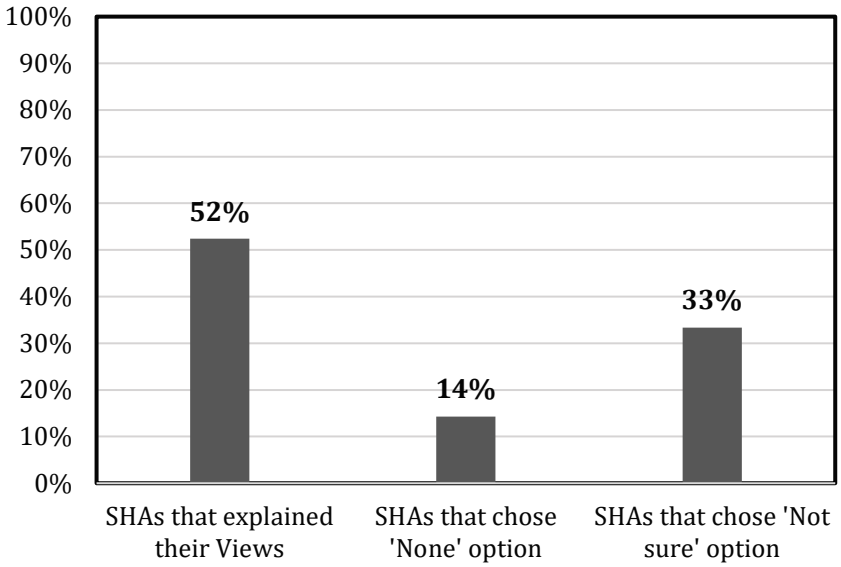
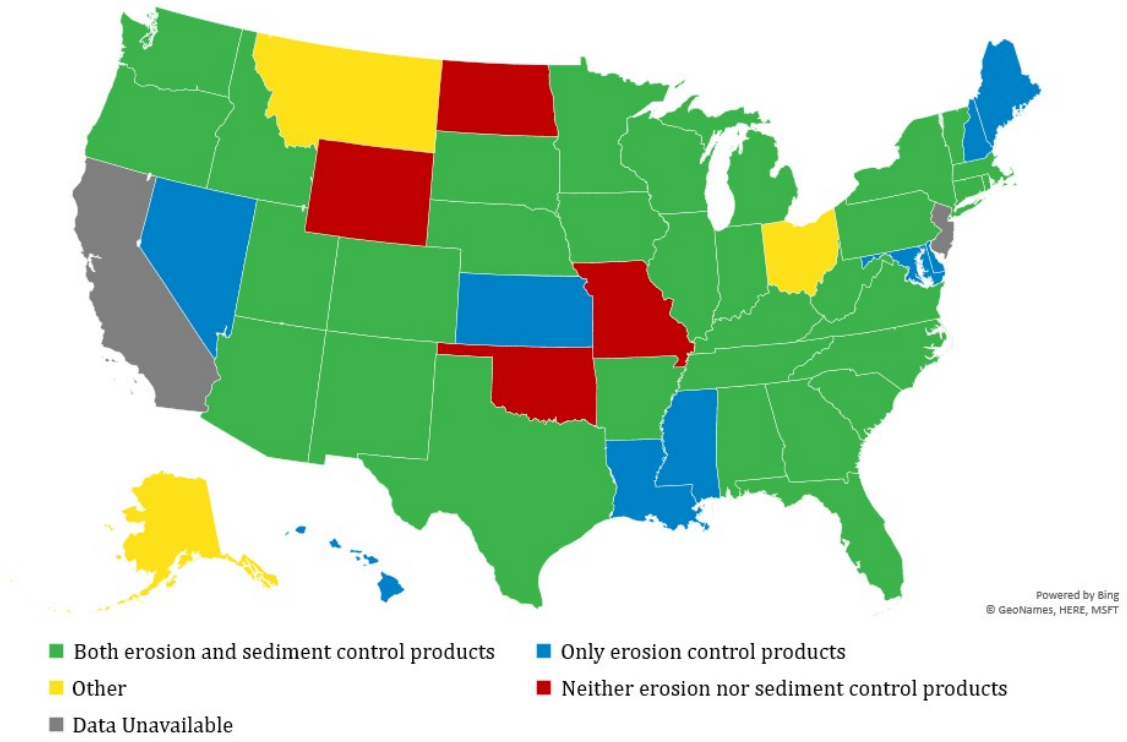


Figure 4.12 Mapping of SHAs that Expressed Views on Improving E&SCPs QPL Inclusion Process

4.3 Analysis for E&SCPs QPL Approval Process amongst SHAs

The main idea in this section is to provide the information about all SHAs' QPL evaluation processes. The overall data collected from the SHAs through surveys and individual SHA resources for those that did not respond to the survey are presented. Regarding the maintenance of E&SCPs in the QPL by the SHAs as shown in Figure 4.13, it was approximately found that 32 (63%) SHAs maintain both E&SCPs, nine (18%) SHAs maintain only erosion control products, four (8%) SHAs maintain neither erosion nor sediment control products, three (6%) SHAs have other criteria, and data is unavailable for the final three (6%) SHAs. The explanations for other criteria can be referred from the survey analysis discussion in Section 4.1. The color-coded U.S map in Figure 4.13 gives an approximate estimate on SHAs that list and maintain erosion and/or sediment control products on their QPLs.



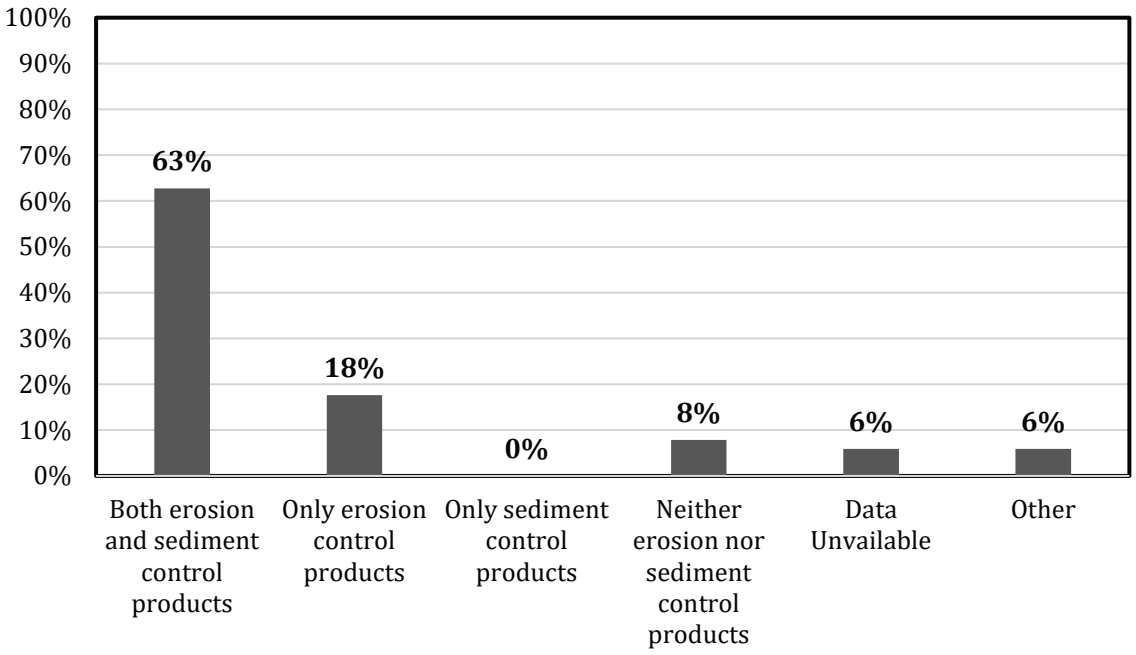
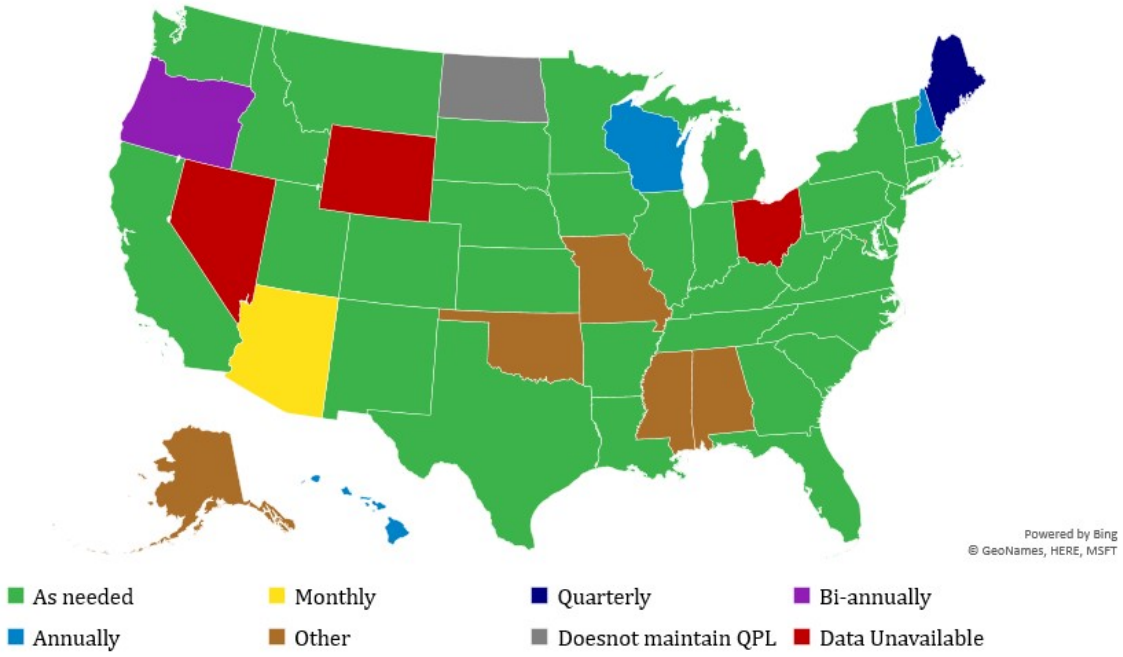


Figure 4.13 Overall estimate of SHAs' E&SCPs QPL Section Maintenance

The frequency of E&SCPs section updates in the QPL by the SHAs can be seen in Figure 4.14. It was approximately estimated that 35 (69%) SHAs update their QPLs as needed, one (2%) SHA updates monthly, one (2%) SHA updates quarterly, three (6%) SHAs update annually, one (2%) SHA updates bi-annually, five (10%) SHAs explained about their frequency of re-evaluation, one (2%) SHA does not maintain a QPL, and data is unavailable for the final four (8%) SHAs. Explanations for other criteria are found in survey analysis discussion in the Section 4.2. Evaluation frequency of each SHA is presented in Figure 4.14.



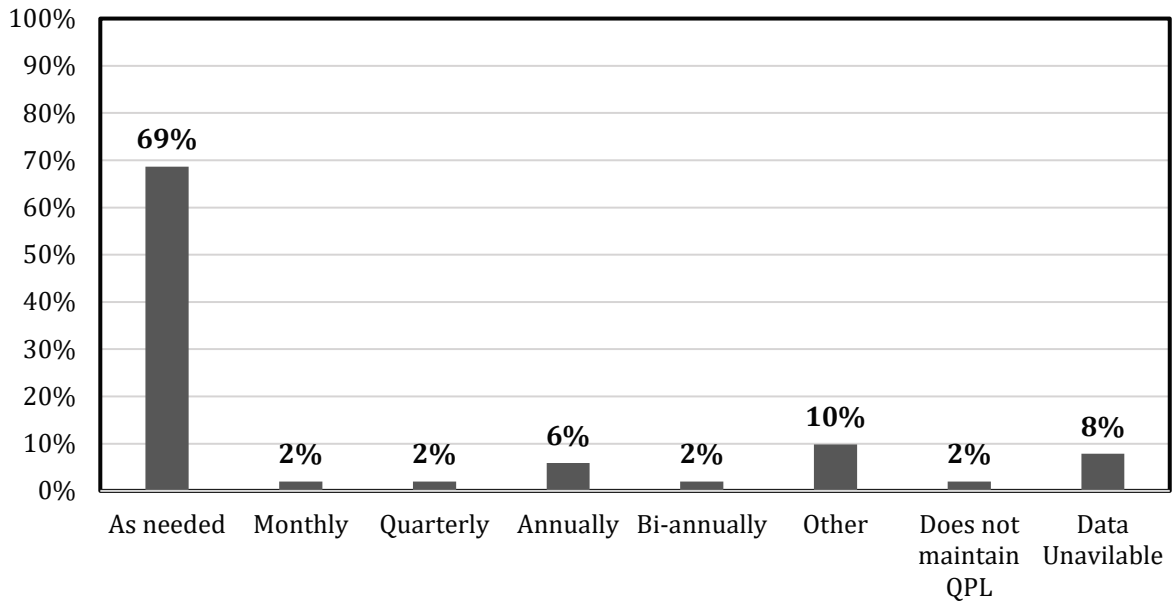


Figure 4.14 Overall estimate of SHAs' E&SCPs QPL Section Updating Frequency

The overall approximate of SHAs that use or allow for the use of erosion and/or sediment control products or materials from other federal, state, or local agency's qualified product lists can be seen in Figure 4.15. Two (4%) SHAs allow usage, 44 (86%) SHAs do not allow usage, two (4%) SHAs only allow usage in special cases, and three (6%) SHAs

were not sure about this topic. The status of each SHAs regarding usage of erosion and/or sediment control products from other agencies can be seen in Figure 4.15

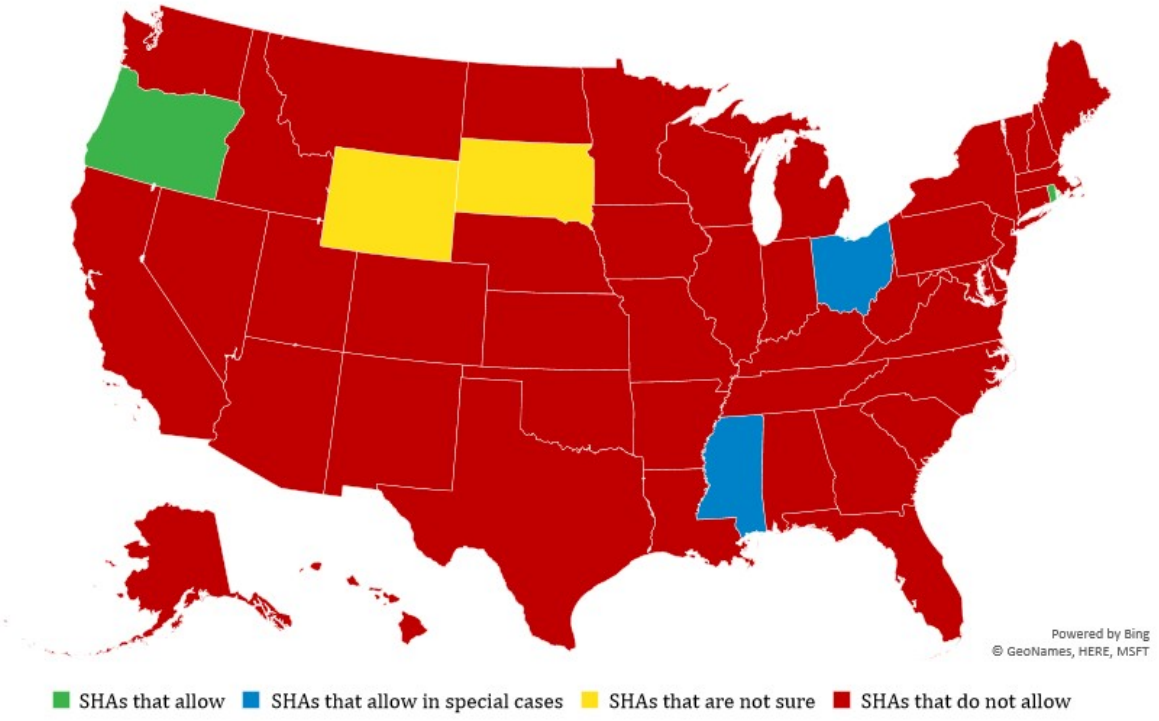
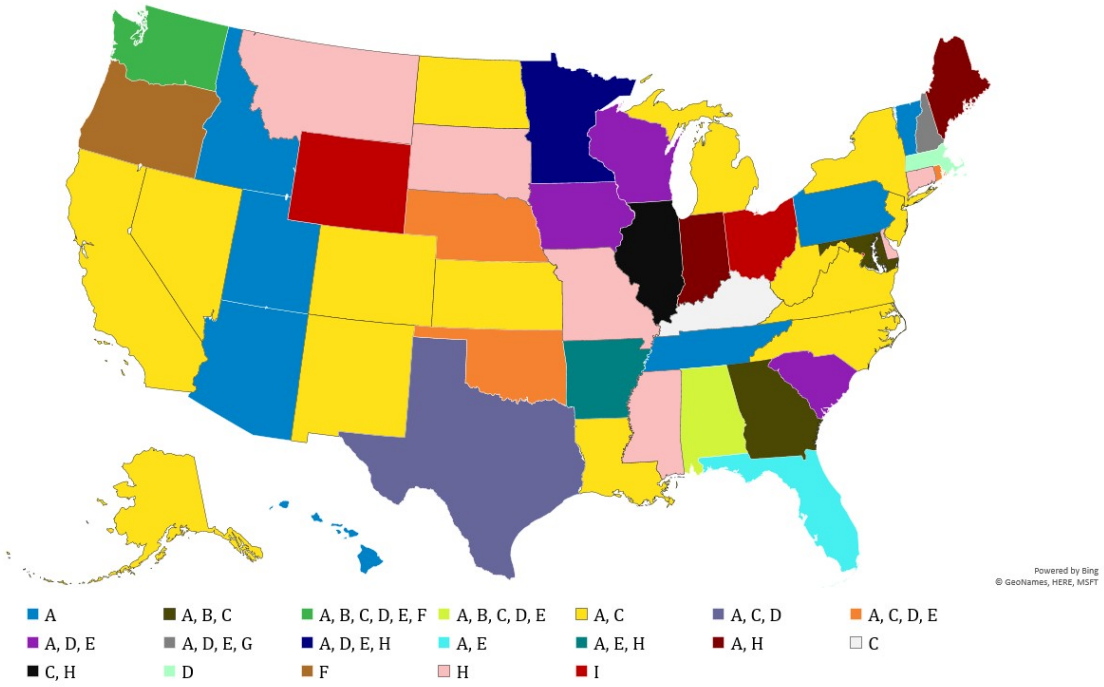
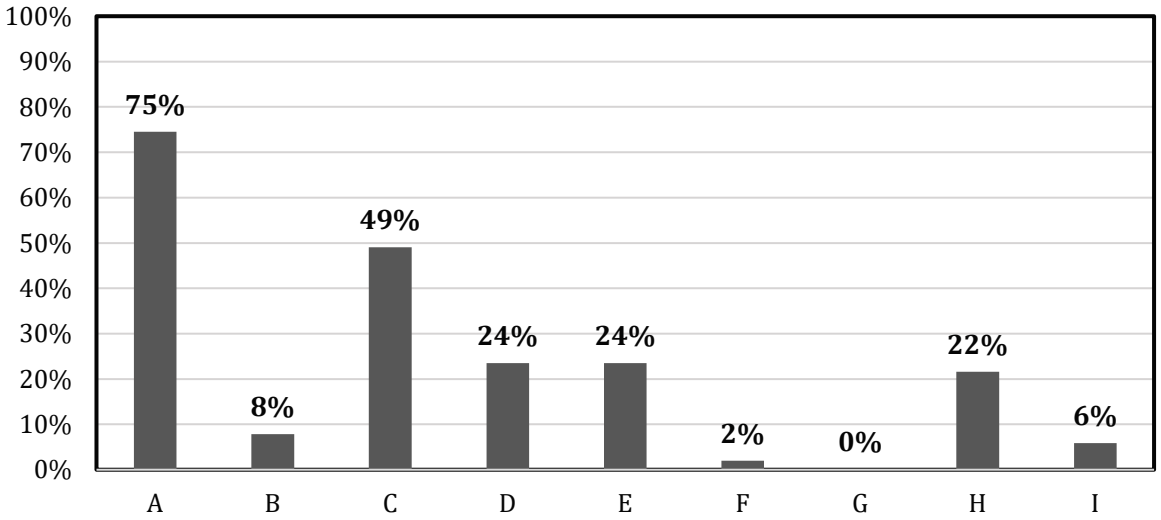


Figure 4.15 Overall estimate of SHAs' policy on Allowing Use of E&SCPs Other Agencies' QPL

Regarding the qualification process being followed by SHAs to approve erosion and/or sediment control products into the QPL, an approximate estimation can be seen in Figure 4.16. Thirty-eight (75%) SHAs accept application submission by the manufacturer, four (8%) SHAs require fee submission, 25 (49%) SHAs require field testing, 12 (24%) SHAs require large or full-scale performance-based laboratory testing, 12 (24%) SHAs require bench-scale laboratory testing, one SHA accepts the products approved by other SHAs, 11 (22%) SHAs have other criteria, and data is unavailable for the final three (6%) SHAs. The explanations for other criteria can be found in the survey analysis discussion in Section 4.2. Different criteria regarding qualification processes of each SHA can be seen in Figure 4.16.

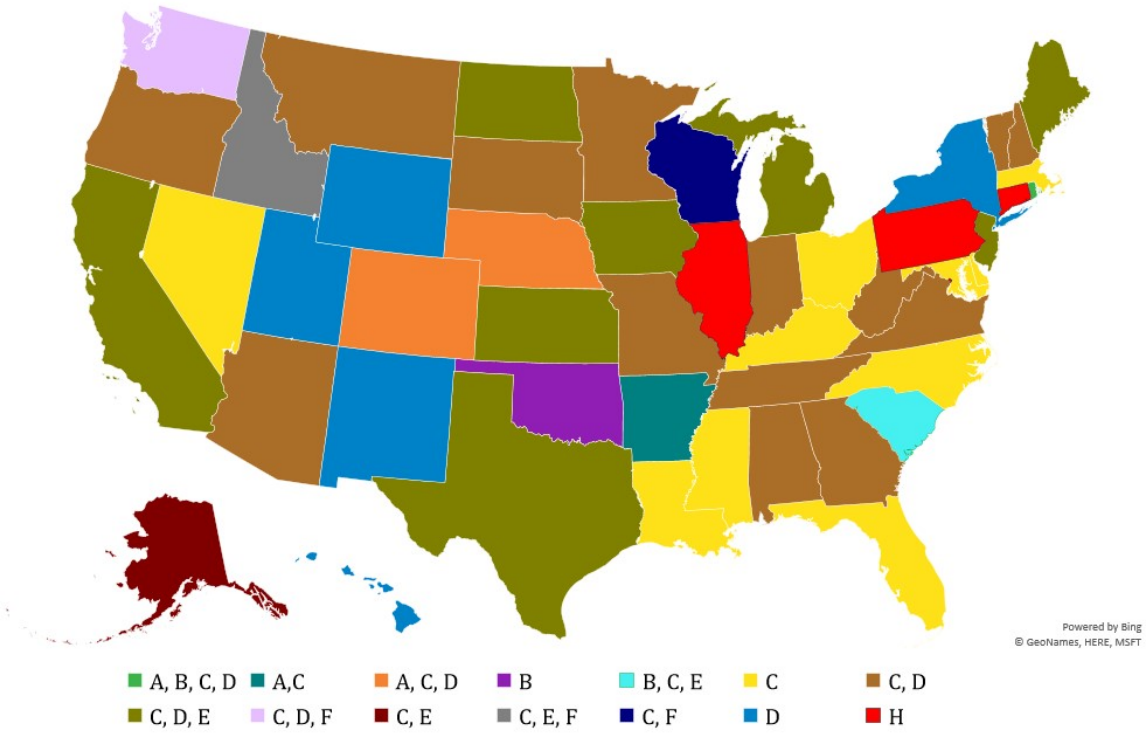


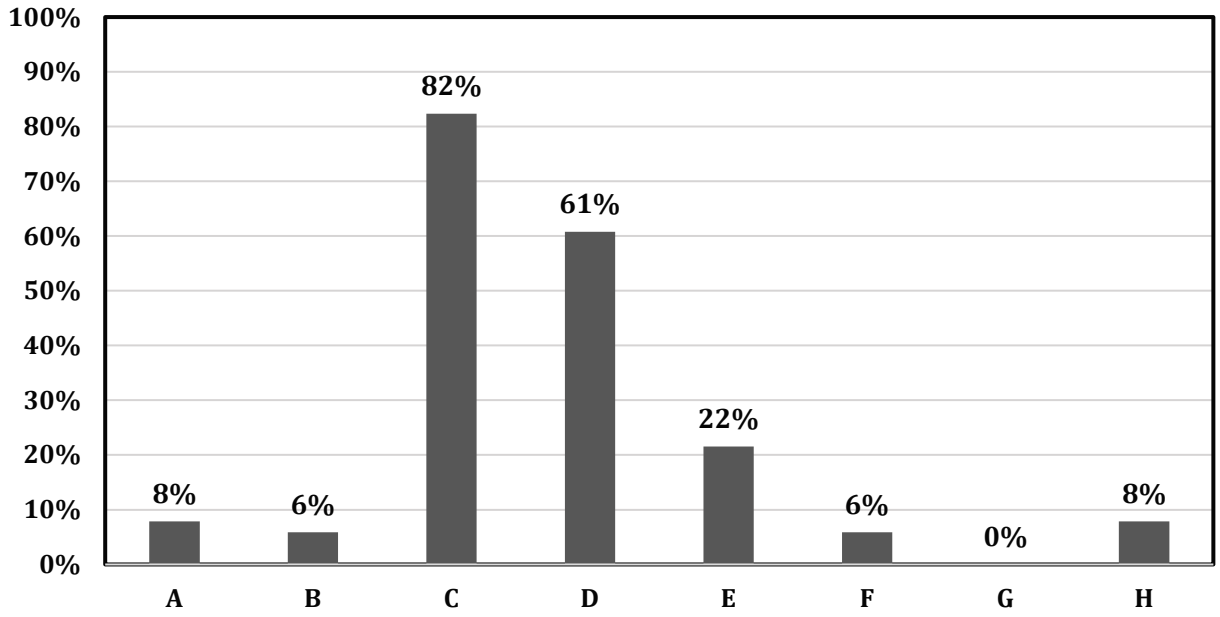


A-Application submission by product manufacturer.
B-Fee submission by product manufacturer.
C-Field Testing
D- Large or full-scale performance-based laboratory testing.
E- Bench-scale laboratory testing of material properties
F- Approval by other state highway agencies
G- Not sure
H-Other
I-Data unavailable

Figure 4.16 Overall Estimate on New E&SCPs Evaluation Process Preferred by SHAs

An overall approximation of testing programs preferred by SHAs to evaluate products can be seen in Figure 4.17. Four (8%) SHAs prefer in-house testing, three (6%) SHAs prefer university testing programs, 42 (82%) prefer AASHTO-NTPEP testing programs, 31 (61%) SHAs prefer ASTM testing, 11 (22%) SHAs accepts testing data from other independent third party agencies, three (6%) SHAs have other preferences, and data is unavailable for the final five (10%) SHAs. The explanations for other criteria can be found in the survey analysis discussion in Section 4.2. Different testing criteria of each SHA can be seen in the Figure 4.17.

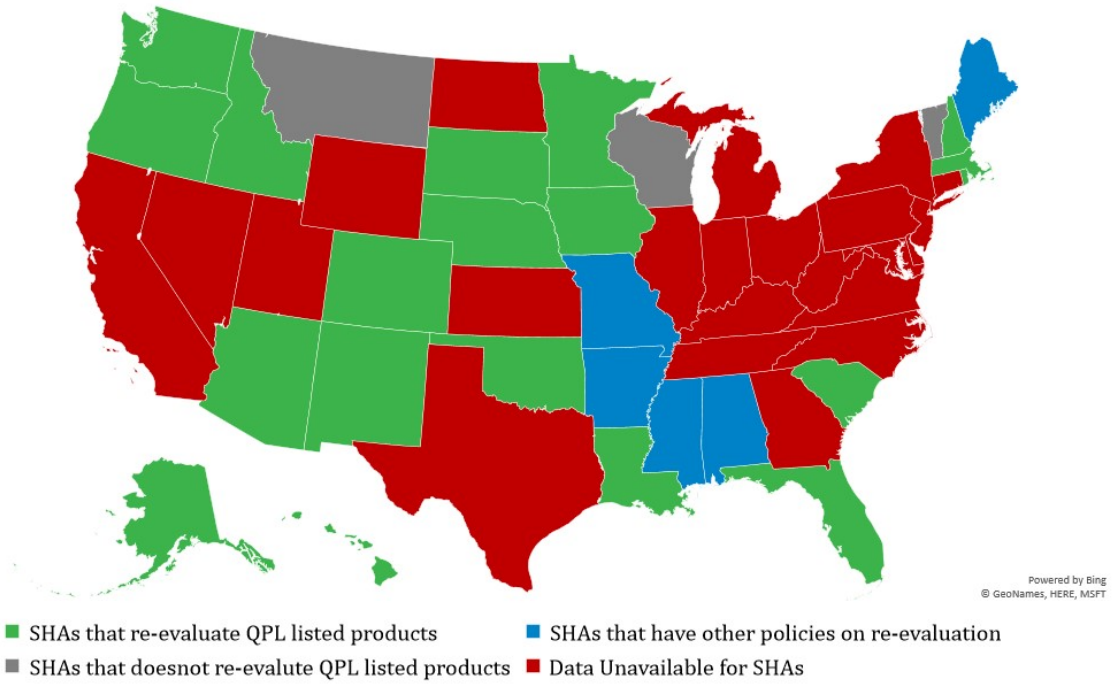




A-In house testing
B-University testing program
C-AASHTO NTPEP
D-ASTM testing
E-Other independent third-party agency
G- Not sure
H- Data Unavailable
F- Other

Figure 4.17 Overall Estimate on SHAs' Testing Program during QPL Inclusion Process

Overall re-evaluation criteria for E&SC listed on the QPL by SHAs is shown in Figure 4.18. Nineteen (37%) SHA re-evaluate QPL listed products, three (6%) SHAs do not re-evaluate QPL listed products, five (10%) SHAs have other policies on re-evaluating products, and data is not available for the final 24 (47%) SHAs. The commentary for other criteria can be found in the survey analysis discussion in section 4.2. Re-evaluation criteria of each SHA can be seen in Figure 4.18.



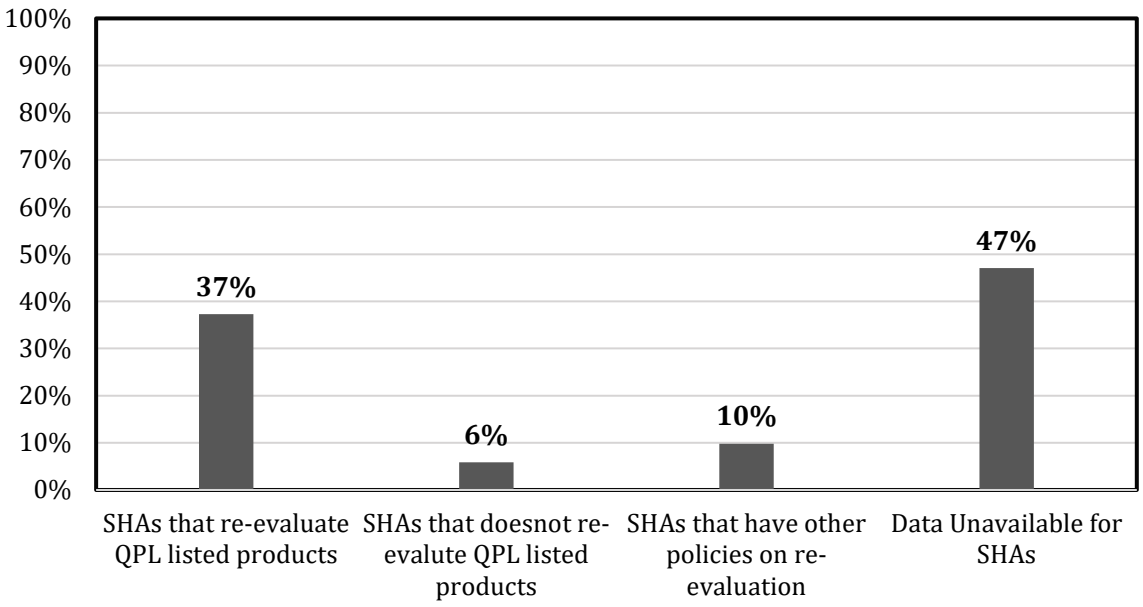


Figure 4.18 Overall Estimate on SHAs' E&SCPs QPL Re-evaluation Program

An overall estimation of E&SC listed on SHAs' QPL is shown in Figure 4.19. The data of 45 SHAs is collected from survey and SHAs website and the data of other 6 SHAs is not found.

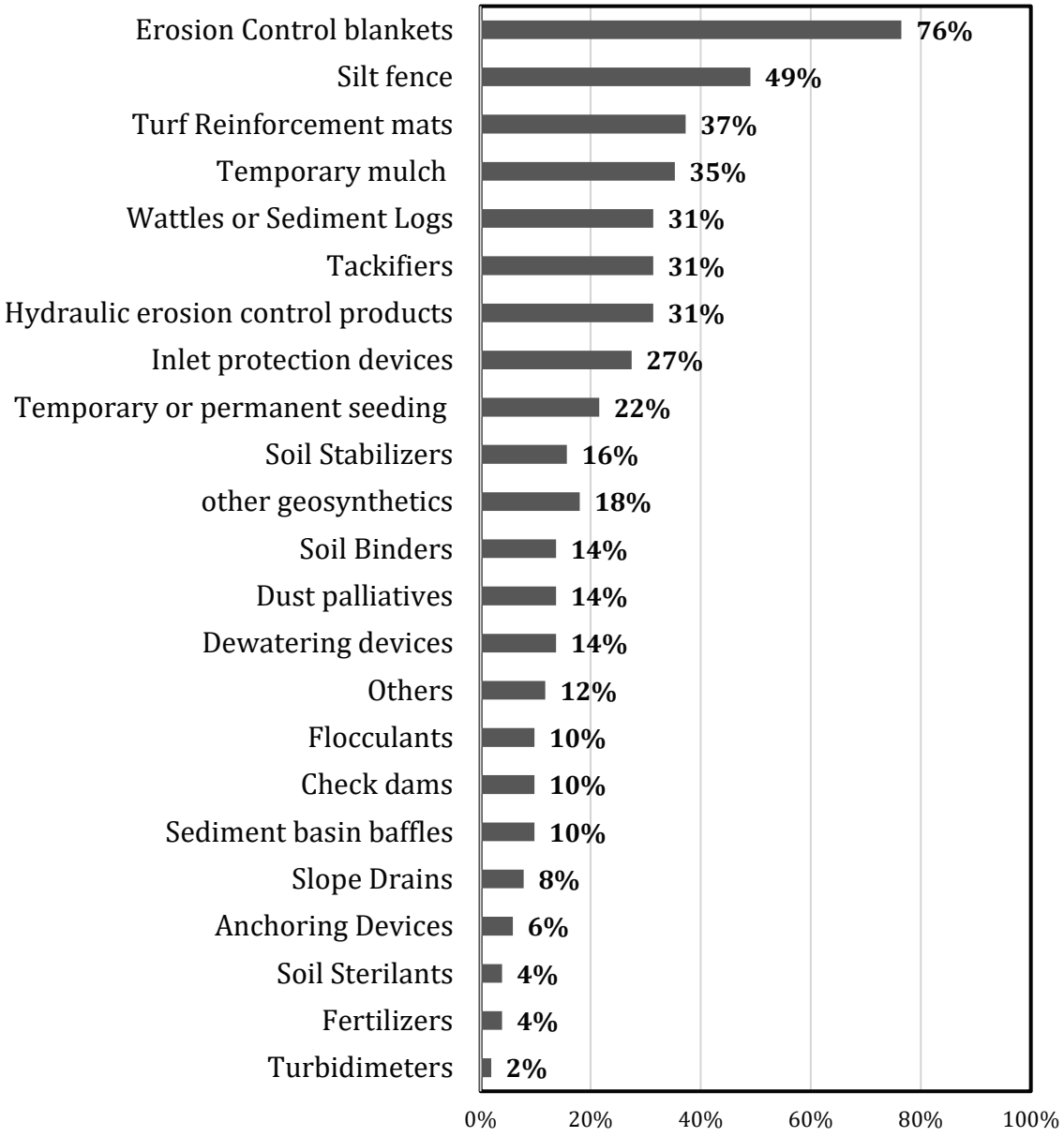


Figure 4.19 Overall Estimate on Frequent E&SCPs listed on SHAs' QPL

4.4 Cost Estimates and Analysis of Testing Equipment used for Standardized Tests

This section discusses cost estimates of testing equipment used in conducting standard ASTM tests for erosion and/or sediment control products. This section focuses on test methods that were discussed in the literature review. Estimates of some test methods were not included in this section as they do not require manufactured testing equipment.

ASTM D1777, D5199, and D6525 tests can be conducted at in-house testing facilities. Testing equipment required includes a thickness measuring gauge, spring force or dead weights, and cutting dies or templates. The prices of cutting dies and templates are negligible. The equipment's model names and prices from the checkline.com website are included in Table 4.1.

Table 4.1 Summary of Cost Estimates for Equipment Used in Conducting ASTM D1777, D5199, and D6525 Tests

Equipment	Model Name	Price
Digital Material Thickness Gauge	MTG-DX2	$ 1,295
Weight (273g less foot and spindle) & Footer (28.7mm) = test pressure of 4.14 kPa for ASTM D1777 Spec 1 (Woven, Knitted and Textured Fabrics)	MTG-D1777-1	$ 350
Weight (169g less foot and spindle) & Footer (9.5mm) = test pressure of 23.4 kPa for ASTM D1777 Spec 2 (Fabrics, Webbings, Tapes, Ribbons, Braids) & D751-06	MTG-D1777-2	$ 350
Weight (546g less foot and spindle) & Footer (6.3mm) = test pressure of 172 kPa for ASTM D1777 Spec 3 (Films, Glass Cloths, Glass Tapes)	MTG-D1777-3	$ 350
Weight (46g less foot & spindle) & Footer (28.7mm at 18g) = test pressure of 0.70 kPa and Weight (500g less foot & spindle) & Footer (28.7mm at 18g) = test pressure of 7.58 kPa for Blankets, Pile Fabrics & Napped Fabric	MTG-D1777-5	$ 485

ASTM D1907 tests can be conducted at in-house testing facilities. Testing equipment required are a Reel, weighing balance, and drying oven. The price of a weighing balance is not mentioned, as it is available in standard testing laboratories. The equipment's model names and prices are included in Table 4.2.

Table 4.2 Summary of Cost Estimates for Equipment Used in Conducting ASTM D1907

Equipment	Website/ Source	Model Name	Price
Reel	alibaba.com	High quality ISO 2060 ASTM D1907 yarn linear density testing equipment	$ 1,100
Drying oven	toolots.com	Phaeton Scientific 2.5cf Drying Oven With 2 Shelves DO-9070A	$ 448

ASTM D3775 tests can be conducted at in-house testing facilities. Testing equipment required includes pick glass, a rule and pointer, and a microfilm reader or projection equipment. Testing with pick glass is considered economical over a microfilm reader or project equipment. The equipment's model names and prices are included in Table 4.3.

Table 4.3 Summary of Cost Estimates for Equipment Used in Conducting ASTM D3775

Equipment	Website/ Source	Model Name	Price
Pick glass	halcyonyarn.com	Magnifying Pick Counter Glass with Rule	$ 38

ASTM D3786 test can be conducted at in-house testing facilities. The only piece of testing equipment required for this is an inflated diaphragm bursting tester. The price range of the different machine models listed in Table 4.4.

Table 4.4 Summary of Cost Estimates for Equipment Used in Conducting ASTM D3786

Manufacturer Name	Product Name	Price
Testing Machines Inc.	Burst tester 13-60	$ 25,825
SDL Atlas Textile testing Solutions	Auto burst M229 Hydraulic Busting Tester	$ 35,263
SDL Atlas Textile testing Solutions	PnuBurst™ M229P Pneumatic Bursting Strength Tester	$ 32,972

ASTM D3787, D4533, D4595, D4632, D4833, D5035, D6241, and D6818 tests are conducted at in-house testing facilities. The equipment required only includes a Constant-Rate-of-Traverse (CRT) tensile testing machine. Some of these test methods require added accessories. The price range of the different machine models listed in Table 4.5. The added accessories required for different test methods are mentioned in Table 4.6

Table 4.5 Summary of Cost Estimates for Equipment Used in Conducting ASTM D3787, D4533, D4595, D4632, D4833, D5035, D6241, and D6818 tests

Manufacturer Name	Product Name	Price Range	
		Minimum	Maximum
Instron Company	3369	$ 50,000	$ 55,000
	5969	$ 65,000	$ 70,000

Table 4.6 Summary of Different Accessories Used in Conducting ASTM D3787, D4533, D4595, D4632, D4833, D5035, D6241, and D6818 tests

Manufacturer Name	Added Accessories	Price
Instron	Ball Burst Fixture for ASTM D3787	$ 5,500
	Puncture Fixture for ASTM D4833	$6,700
	Puncture fixture for ASTM D6241	$ 2,500
	Tensile grips (Manual Grips) for ASTM D 4533, D4595, D4632, D5035, D6818	$2,500
	Tensile grips (Pneumatic Grips) for ASTM D 4533, D4595, D4632, D5035, D6818	$8,000

ASTM D4329 tests are conducted at in-house testing facilities. The equipment required is a fluorescent UV apparatus. The prices of this apparatus from different manufacturers under different product names collected from alibaba.com are listed in Table 4.7.

Table 4.7 Summary of Cost Estimates for Equipment Used in Conducting ASTM D4329

Manufacturer name	Product Name	Price Range	
		Minimum	Maximum
Shenzhen Autostrong Instrument Co., Ltd	Accelerated Aging Testing Machine with UV Lamp	$ 4,500	$ 8,500
Dongguan Infinity Machine Inc.	ASTM D4329 & ASTM G53 UV Accelerated Weathering Tester	$ 7,000	$ 8,500
Dongguan Walter Technology Co., Ltd.	ASTM D4329 Accelerated Aging Test Oven/UV Weathering Test Chambers	$ 2,999	$ 5,288
Guangdong ASLi Test Instrument Co., Ltd.	ASTM D4329 Accelerated Aging Test Oven/UV Weathering Test Chambers	$ 7,500	$ 9,500
Dongguan Yaoke Instrument Equipment Co., Ltd.	ASTM D4329 Accelerated Aging Test Oven/UV Weathering Test Chamber with UV Lamp	$ 3,500	$ 3,500
Wuhan Bonnin Technology Ltd.	ASTM D4329 Trade Guarantee UV Plastic Aging Test Chamber	$ 3,000	$ 4,900
Xi'an HEB Biotechnology Co., Ltd.	ASTM D4329 UV aging test chamber	$6,000	$ 9,500

ASTM D4355 tests are conducted at in-house testing facilities. The equipment required is a Xenon arc apparatus. The price range of the different machine models listed in Table 4.8.

Table 4.8 Summary of Cost Estimates for Equipment Used in Conducting ASTM D4355

Manufacturer name	Product Name	Price range
Atlas Material Testing Technology LLC	Ci5000 Weather-Ometer	~ $ 160,000
	Ci4400 Weather-Ometer	~ $ 145,000
	Ci4400 Weather-Ometer	~ $ 80,000

ASTM D4491 tests are conducted at in-house testing facilities. The equipment required is a water flow apparatus. The prices of this apparatus from different manufacturers under different product names collected from alibaba.com are listed in Table 4.9.

Table 4.9 Summary of Cost Estimates for Equipment Used in Conducting ASTM D4491

Manufacturer name	Product Name	Price Range	
		Minimum	Maximum
Dongguan Zhongli Instrument Technology Co., Ltd.	Geotextile Water Permeability Test Equipment	$ 800	$ 1,500
Hefei Fanyuan Instrument Co., Ltd.	Geotextile Permeability Testing Equipment	$ 9,000	$ 10,000

ASTM D4751 tests are conducted at in-house testing facilities. The equipment required is a mechanical sieve shaker. The price of this shaker from its sole manufacturer collected from certifiedmtp.com is listed in Table 4.10.

Table 4.10 Summary of Cost Estimates for Equipment Used in Conducting ASTM D4751

Manufacturer name	Product Name	Price Range	
		Minimum	Maximum
RO-TAP	WS TYLER RX-29 8" ROTO TAP SIEVE SHAKER	$ 2,120	$ 2,120

ASTM D4716 tests are conducted at in-house testing facilities. The equipment includes a constant head (in-plane) flow rate testing device. The price of this device from its sole manufacturer collected from alibaba.com is listed in Table 4.11.

Table 4.11 Summary of Cost Estimates for Equipment Used in Conducting ASTM D4716

Manufacturer name	Product Name	Price Range	
		Minimum	Maximum
Hefei Fanyuan Instrument Co., Ltd	IN-plane water flow rate testing machine/apparatus DW1380	$ 10,000	$15,000

ASTM D6575 tests are conducted at in-house testing facilities. The equipment required is a stiffness tester. The price of this tester from its sole manufacturer collected from alibaba.com is listed in Table 4.12.

Table 4.12 Summary of Cost Estimates for Equipment Used in Conducting ASTM D6575

Manufacturer name	Product Name	Price
Dongguan Dongcheng Baifei Testing Instrument Product Factory	Manual fabric stiffness tester Taber	$ 550

4.5 Catalog- QPLs E&SCPs Evaluation Clearing House

The Catalog is created using WIX website builder and Caspio. The data stored in Caspio is linked with buttons that are added on the webpage. These buttons relate with SHAs' QPL evaluation program; SHAs' E&SCPs qualification process; SHAs' E&SCPs testing program; SHAs' erosion and sediment control plans, designs, product evaluation procedures, and applications; and SHAs' E&SCPs standard specifications. Each button on the web page will direct to a separate page that consists of a drop-down box. The relevant set of data can be viewed on a statewide basis.

4.6 Summary

This chapter provided survey analysis, overall data estimation of all SHAs inclusion processes, cost estimates of testing equipment required for conducting ASTM tests, and catalog information pertaining to E&SCPs.

CHAPTER 5 CONCLUSIONS AND FUTURE WORK

5.1 Introduction

Manufacturers are required to understand each SHAs' QPL inclusion processes and standard requirements before applying their products for evaluation. All SHAs in the U.S. have their own QPL inclusion process which differ from each other. This research focused on synthesizing all SHAs' QPL inclusion processes to provide for comparison and contrast of individual state standard processes..

The main objective is this research was to develop a catalog of all SHAs' QPL requirements involved from pre- to post-inclusion processes pertaining to E&SCPs. The overall literature review was conducted from the erosion and sediment control handbooks, SHAs' QPL evaluation applications and processes, and SHAs' standard specifications and requirements for E&SC products. This work will be useful for E&SCPs, erosion and sediment control industry personnel, and researchers. This objective was met by creating a web page that contains information pertained with SHAs' QPL inclusion process.

5.2 Literature Review

The primary objective of this project was to conduct a literature review of SHAs' QPL processes and all the standardized test methods associated with E&SCPs. To satisfy the objective, a literature review for all E&SC practices recommended by all SHAs was conducted initially to understand various practices and application of corresponding. In the second step, a literature review of SHAs' inclusion processes was completed. In the third step, standard test methods and requirements were identified through SHAs' standard specifications for highways and bridges. Within the literature review, 78 unique E&SC practices are identified, and discussed in Chapter 3 are 109 standardized test

methods and specifications related to E&SCPs. Of the 109 standard test methods, 48 have been selected and discussed in Chapter 3, and their corresponding SHAs requirements are mentioned.

5.3 State Highway Agencies Product Approval Survey and Analysis

The second objective of this project is to develop a survey related to QPL inclusion processes of all SHAs. The survey was sent to all SHAs in the United States, and 24 unique SHAs responded. During the analysis, it was found that 63% of responded SHAs maintain both E&SCPs on their QPLs; 52% of respondents update their QPL sections related to E&SCPs when needed; 79% of responded SHAs do not allow the use of E&SCPs listed on other agencies' QPLs; 74% of respondents begin evaluation processes with applications submitted by manufacturers; 93% of 14 responded SHAs accept AASHTO-NTPEP evaluation data; 65% of respondents have a re-evaluation program for the E&SCPs listed on their QPLs; Erosion control blankets, silt fence, wattles or sediment logs, and HECPs are most common E&SCPs on QPLs listed by most of the responded SHAs; and finally, 75% out of responded SHAs have provided their standard installation details for E&SCPs.

5.4 Data Estimation and Analysis for E&SCPs QPL Approval Process amongst SHAs

The third objective in this project was to analyze the E&SCPs approval processes among SHAs. The data of unanswered SHAs is collected from the literature related to SHAs' QPL inclusion processes. The data collected from the survey and unanswered states are mixed together to analyze all SHAs' inclusion processes overall. It is estimated that 63% of all SHAs list both E&SCP on their QPLs; 69% of SHAs update their QPL section related to E&SCPs when needed; 86% of SHAs do not allow the usage of other agency's QPLs; 75% of SHAs begin evaluation process with the applications submitted by

manufacturers; 82% of SHAs accept AASHTO-NTPEP evaluation data, and 67% of SHAs accept ASTM testing data; and re-evaluation program data of 47% of SHAs is not available. Moreover, it is estimated that 37% of SHAs re-evaluate QPL listed E&SCPs.

5.5 Catalog: SHAs' QPL inclusion process, Standards, and requirements

The fourth objective in this project was to create a catalog that consists of SHAs' QPL evaluation processes, standard test methods related to E&SCPs, and practices detailing procedures, equipment, and requirements. An online webpage was created that consists of multiple links that direct to data. The link for website is given below:

https://dcsrpavan.wixsite.com/shaqplesccatalog

5.6 Summary of the state-of-the-practice in SHA approval for ESC products

The standard practice in SHA approval for ESC products starts with the submission of applications by individual manufacturers, as 75% of SHAs begin the evaluation process with application submission. Manufacturers are required to include all information and relative testing in these applications. After receiving the applications, SHA personnel may review and forward them to competent evaluation personnel. The products may be approved by the SHA personnel if the submitted test data meets requirements. Otherwise, the evaluation personnel review the information and may forward the products for testing. If required, the personnel might ask manufacturers for extra information. After testing, the products may be approved for listing on QPLs if the results are satisfactory. Lastly, the manufacturers are notified.

5.7 Ease of conducting Standard tests

Based on selected test methods discussion in the Literature Review, the test methods were sorted based on the ease of performing tests. The test methods that are easy to conduct with basic technical understanding are ASTM D1777, ASTM D1907, D3775, D3776/D3776M, D4751, D5199, D5261, D6475, D6525/D6525M, D6566, D6524, D7367, and WSDOT T125. The test methods that require technical understanding of procedures and equipment operating knowledge are D3786/D3786M, D3787, D4329, D4355, D4491/4491M, D4595, D4632/D4632M, D4716, D4833/4833M, D5035, D6241, D6567/D6575M, D6767, and D6818. The test methods that require technical understanding of procedures, testing setup design, building, and operating knowledge are ASTM D6459 and D6460. The test methods that require technical understanding, testing setup design, and equipment operating knowledge are ASTM D5141, D7101, D7208, D7322, D7351, and D7701.

5.8 Cost Estimate of Testing Equipment

Cost estimates for testing equipment are provided in Table 5.1. The table presents the basic estimates for testing equipment, and the estimates may change over time.

Table 5.1Summary of Testing Equipment Price Range

Test method	Average estimated cost of testing equipment	
	Minimum	Maximum
ASTM D3775	$ 38	-
ASTM D6575	-	$ 550
ASTM D1907	$ 1,548	-
ASTM D4751	-	$ 2,120
ASTM D1777, D 5199, D6525	$ 2,830	-
ASTM D4491	$ 800	$ 10,000
ASTM D4329	$ 2,999	$ 9,500
ASTM D4355	$ 80,000	$ 160,000
ASTM D4716	$ 10,000	$ 15,000
ASTM D3786	$ 25,825	$ 35,263
ASTM D3787, D4533, D4595, D4632, D4833, D5035, D6241, and D6818	$ 77,700	$ 92,700

5.9 Recommendations on Approval Process

The results in this study show that 82% of SHAs accept AASHTO-NTPEP evaluation data. With this data, it is recommended to streamline SHAs E&SCPs' QPL approval processes into a single evaluation process. Streamlining the QPL approval process helps E&SCPs manufacturers to apply and evaluate their products for a single time rather than applying for several SHAs and anticipate for completion of each SHA evaluation process. Streamlining SHAs' QPL evaluation process pertained with E&SC products would help in decreasing the time of QPL evaluations. Moreover, it is recommended that manufacturers test their products using the AASHTO-NTPEP evaluation program so that their approval is easier and more immediate than when applying to SHAs.

It is recommended to develop a common QPL E&SC product evaluation process for all SHAs in the U.S., so that manufacturers do not need to go through all SHAs evaluation processes. This project has given the overall overview of all SHAs QPL evaluation process for E&SC products. Based on this study, it is recommended to research further on all SHAs QPL evaluation applications and communicate with all SHAs for their ideas and suggestions

to develop on a standard evaluation process. The common standard evaluation process requires to be streamlined with AASHTO-NTPEP evaluation as 82% of SHAs accept their test data. Currently, NTPEP has a designated lab (TRI, Environmental, Inc) for testing E&SCPs. Bias may occur during evaluations, as the products are being evaluated by a single testing lab. Therefore, more independent agencies are required to evaluate NTPEP tests to avoid bias.

Developing a standard evaluation process can be successful if a connection is established between all SHAs QPL evaluation process, the productivity of all SHAs QPL evaluation process, and the variance in each SHA's requirements based upon their geographical location.

The reevaluation period pertaining to E&SCPs differ between SHAs, so it is recommended to research and find the best reevaluation period based on product type.

In the survey, one SHA mentioned that "The NTPEP program has been a big help but it does not cover all categories of products. It would be helpful if some of these products could be evaluated nationally rather than each state having to evaluate them individually, but there are different conditions in different regions, so that may not be feasible." Therefore, it is recommended to find the relation between QPL evaluation processes and requirements of each SHA related with their E&SCP field applications, soil, and weather conditions. Further research on this subject would improve understanding of SHA E&SCP life-span expectations and would lead toward a more common evaluation process.

REFERENCES

1st Resource Solutions LLC. (n.d.). "Inlet Protection - Stormwater, Erosion, and Sediment Control." <http://www.1stresourcesolutions.com/erosion-control-inlet-protection.html#prettyPhoto> (Jun. 4, 2019).

Active Treatment Systems, I. (n.d.). "Stormwater - Active Treatment Systems." <https://www.ats-env.com/services/stormwater/> (Jun. 2, 2019).

ADMET Testing Systems. (2013). "ASTM D4833 Puncture Testing - YouTube." <https://www.youtube.com/watch?v=qOb3F7WWp0o> (Jun. 4, 2019).

Alabama Department of Transportation. (n.d.). "Procedure for Submitting New Products." <https://www.dot.state.al.us/rdweb/pdf/PROCEDUREFORSUBMITTINGNEWPRODUCTSFLOWCHART.pdf> (May 14, 2019).

Alabama Department of Transportation. (2017). *ALABAMA DEPARTMENT OF TRANSPORTATION New Product Evaluation Application Form*. Montgomery, Alabama.

Alabama Soil and Water Conservation Committee. (2009). *Erosion Control, Sediment Control Construction Sites and Urban Areas: Volume 1 Developing Plans and Designing Best Management Practices*. Montgomery, Alabama.

Alaska Department of Environmental Conservation. (2012). *Alaska Department of Environmental Conservation*. *Alaska Department of Environmental Conservation*, Anchorage, Alaska.

Alaska Department of Transportation and Public Facilities. (n.d.). "Alaska DOT&PF's QPL System." <http://www.dot.state.ak.us/stwddes/desmaterials/qpl_intro.shtml> (May 14, 2019).

American Association of State Highway and Transportation Officials. (2018a). "Standard Specification for Geosynthetic Specification for Highway Applications (AASHTO M288)." *Standard Specifications for Transportation Materials and Methods of Sampling and Testing and Provisional Standards (2018 Edition)*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C.

American Association of State Highway and Transportation Officials. (2018b). "Standard Practice for Compost for Erosion/Sediment Control (Filter Berms and Filter Socks) (AASHTO R 51)." *Standard Specifications for Transportation Materials and Methods of Sampling and Testing and Provisional Standards (2018 Edition)*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C.

American Association of State Highway and Transportation Officials. (2018c). "Standard Practice for Compost for Erosion / Sediment Control (Compost Blankets) (AASHTO R52)." *Standard Specifications for Transportation Materials and Methods of Sampling and Testing and Provisional Standards (2018 Edition)*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C.

American Society for Civil Engineers. (2017). *Management Practices for Control of Erosion and Sediment from Construction Activities*. *Management Practices for Control of Erosion and Sediment from Construction Activities*, ASCE, Reston, Virginia.

American Society for Testing and Materials. (2009). *Standard Practice for Sampling of Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing (D4354)*. *American Society for Testing and Materials*, West Conshohocken, PA.

American Society for Testing and Materials. (2011). *Standard Test Method for Determining the Flow Rate of Water and Suspended Solids from a Geotextile Bag (D7701)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2012a). *Standard Test Method for Measuring the Nominal Thickness of Geosynthetics (D5199)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2012b). *Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion (D6460)*. West Conshohocken, PA.

American Society for Testing and Materials. (2013a). *Standard Practice for Fluorescent Ultraviolet (UV) Lamp Apparatus Exposure of Plastics (D 4329)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2013b). *Standard Test Method for Index Puncture Resistance of Geomembranes and related products (D4833/D4833M)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2013c). *Standard Index Test Method for Determination of Unvegetated Rolled Erosion Control Product (RECP) Ability to Protect Soil from Rain Splash and Associated Runoff Under Bench-Scale Conditions (D7101)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2013d). *Standard Test Method for Determination of Sediment Retention Device Effectiveness in Sheet Flow Applications (D7351)*. West Conshohocken, PA.

American Society for Testing and Materials. (2014a). *Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile- Related Products Using a 50-mm Probe (D6241)*. West Conshohocken, PA.

American Society for Testing and Materials. (2014b). *Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head (D4716)*. West Conshohocken, PA.

American Society for Testing and Materials. (2014c). *Standard Test Method for Determining Water Holding Capacity of Fiber Mulches for*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2014d). *Standard Test Method for Determination of Temporary Ditch Check Performance in Protecting Earthen Channels from Stormwater-Induced Erosion (D7208)*. West Conshohocken, PA.

American Society for Testing and Materials. (2015a). *Standard Specification for Metallic-Coated, Steel-Woven Wire Fence Fabric (A 116)*. *American Society for Testing and Materials*, West Conshohocken, PA.

American Society for Testing and Materials. (2015b). *Standard Test Method for Thickness of Textile Materials (D1777)*. West Conshohocken, PA.

American Society for Testing and Materials. (2015c). *Standard Test Method for Trapezoid Tearing Strength of Geotextiles (D4533/4533M)*. *American Society for Testing and Materials*, West Conshohocken, PA.

American Society for Testing and Materials. (2015d). *Standard Test Method for Grab Breaking Load and Elongation of Geotextiles (D4632/4632M)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2015e). *Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Strip Method)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2015f). *Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion (D6459)*. West Conshohocken, PA.

American Society for Testing and Materials. (2016a). *Standard Test Method for Bursting Strength of Textiles Constant-Rate-of-Traverse (CRT) Ball Burst Test (D3787)*. West Conshohocken, PA.

American Society for Testing and Materials. (2016b). *Standard Test Methods for Determining Apparent Opening Size of a Geotextile (ASTM D4751)*. West Conshohocken, PA.

American Society for Testing and Materials. (2016c). *Standard Test Method for Determining Stiffness of Geosynthetics Used as Turf Reinforcement Mats (TRMs) (D6575/6575M)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2016d). *Standard Test Method for Measuring the Resiliency of Turf Reinforcement Mats (TRMs) (D6524/D6524M)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2016e). *Standard Test Method for Pore Size Characteristics of Geotextiles by Capillary Flow Test (D6767)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2016f). *Standard Test Method for Determination of Fiber Length Percentages in Hydraulic Erosion Control Products (HECPs) (D7560)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2017a). *Standard Test Method for Warp (End) and Filling (Pick) Count of Woven Fabrics (D3776)*. West Conshohocken, PA.

American Society for Testing and Materials. (2017b). *Standard Test Methods for Mass Per Unit Area (Weight) of Fabric (D3776/ D3776M)*. *American Society for Testing and Materials*, West Conshohocken, PA.

American Society for Testing and Materials. (2017c). *Standard Test Methods for Water Permeability of Geotextiles by Permittivity (D4491/D4491M)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2017d). *Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method (ASTM D4595)*. West Conshohocken, PA.

American Society for Testing and Materials. (2017e). *Standard Test Method for Measuring Mass per Unit Area of Erosion Control Blankets (D6475)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2017f). *Standard Test Method for Determination of Erosion Control Product (ECP) Ability to Encourage Seed Germination and Plant Growth Under Bench-Scale Conditions (D7322/D7322M)*. West Conshohocken, PA.

American Society for Testing and Materials. (2017g). *Standard Guide for Storage and Handling of Geosynthetic Clay Liners (D4873/D4873M)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2017h). *Standard Practice for Performing Pressure In-Line Coagulation-Flocculation- Filtration Test in Water (D4188)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2017i). *Standard Practice for Preparing Specimens of Hydraulic Erosion Control Products for Index Property Testing (D7986)*. West Conshohocken, PA.

American Society for Testing and Materials. (2018a). *Standard Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method (ASTM D1907)*. West Conshohocken, PA.

American Society for Testing and Materials. (2018b). *Standard Test Method for Hydraulic Bursting Strength of Textile Fabrics — Diaphragm Bursting Strength Tester Method (D3786/ 3786M)*. *American Society for Testing and Materials*, West Conshohocken, PA.

American Society for Testing and Materials. (2018c). *Standard Test Method for Deterioration of Geotextiles by Exposure to Light , Moisture and Heat in a Xenon Arc Type Apparatus (D4355)*. *American Society for Testing and Materials*, West Conshohocken, PA.

American Society for Testing and Materials. (2018d). *Standard Test Method for Measuring Mass per Unit Area of Geotextiles (D5261)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2018e). *Standard Test Method for Measuring Nominal Thickness of Rolled Erosion Control Products (D6525/6525M)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2018f). *Standard Test Method for Measuring Mass per Unit Area of Turf Reinforcement Mats (D6566)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2018g). *Standard Test Method for Measuring the Light Penetration of a Rolled Erosion Control Product (RECP) (D6567)*. West Conshohocken, PA.

American Society for Testing and Materials. (2018h). *Standard Test Method for Ultimate Tensile Properties of Rolled Erosion Control Products (D6818)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2018i). *Standard Practice for Determining the Specification Conformance of Geosynthetics (D4759)*. *ASTM International*, West Conshohocken, PA.

American Society for Testing and Materials. (2018j). *Standard Test Method for Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device (D5141)*. West Conshohocken, PA.

American Society for Testing and Materials. (2019). *Standard Practice for Coagulation/Flocculation Jar Test of Water (D2035)*. West Conshohocken, PA.

Arizona Department of Transportation. (2017). "Arizona Department of Transportation Product Evaluation Program." Arizona Department of Transportation, Phoenix, Arizona.

Arizona Department of Transportation. (2019). *Approved Product List*. Phoenix, Arizona.

Arizona Department of Transportation, and Wheat Scharf Associates. (2012). *Arizona Department of Transportation Erosion and Pollution Control Manual*. Phoenix, Arizona.

Arkansas State Highway and Transportation Department. (2016). *2016 Erosion and Sediment Control Design and Construction Manual*. Little Rock, Arkansas.

Arkansas State Highway and Transportation Department. (2018). "Arkansas Qualified Products List (QPL) Frequently Asked Questions." Arkansas State Highway and Transportation Department, Little Rock, Arkansas.

Bowman Construction Supply Inc. (n.d.). "Silt fence." <https://www.bowmanconstructionsupply.com/products/silt-fence/> (Jun. 4, 2019).

California Department of Transportation. (n.d.). "Caltrans New product evaluation process flow chart." <http://www.dot.ca.gov/pep/docs/new-product-evaluation-process-flowchart.pdf> (May 15, 2019).

California Department of Transportation. (2017). *Construction Site Best Management Practices (BMP) Manual*. Sacramento, California.

California Department of Transportation. (2018). "RECP (Turf Reinforcing Mat)." <http://www.dot.ca.gov/design/lap/landscape-design/erosion-control/recp/turf.html> (Jun. 2, 2019).

California Department of Transportation. (2019a). "Compost." <http://www.dot.ca.gov/design/lap/landscape-design/erosion-control/organics/compost.html> (Jun. 2, 2019).

California Department of Transportation. (2019b). "Brush Layering." <http://www.dot.ca.gov/design/lap/landscape-design/erosion-control/plants/brush_layering.html> (Jun. 2, 2019).

CALIFORNIA DEPARTMENT OF TRANSPORTATION. (2018). "NEW PRODUCT EVALUATION SUBMITTAL FORM." CALIFORNIA DEPARTMENT OF TRANSPORTATION, Sacramento, California.

Campco Engineering INC. (n.d.). "Erosion Control Inspections." <https://campcoengineering.com/services/construction-administration/erosion-control-inspections> (Jun. 3, 2019).

CCI SUPPLIES. (n.d.). "Using the Right Products for Sediment and Erosion Control - CCI SUPPLIES." <https://www.ccisupplies.com.au/construction-consumables/erosion-control/> (Jun. 4, 2019).

CFB Contracting LLC. (n.d.). "Level Spreaders / Plunge Pool." <http://cfbcontracting.com/Level_Spreader___Plunge_Pool.html> (Jun. 3, 2019).

Challenger Construction Corp. (2015). "Straw Bale Ditch Check Dam SWPPP Filtration Storm water compliance Silt Fence - Challenger Construction." <https://www.challengerhydroseeding.com/services/erosion-control-blanket-and-biodegradable-sediment-logs/straw-bale-ditch-check-dam-swppp-filtration-storm-water-compliance-silt-fence/> (Jun. 3, 2019).

Cirtex Civil. (n.d.). "Gabions - Double Twist Wire Mesh Baskets - Cirtex Civil." <https://cirtexcivil.co.nz/product/gabions/> (Jun. 2, 2019).

Colorado Department of Transportation. (2011). *Erosion Control and Stormwater Quality Field Guide*. Denver, Colorado.

Colorado Department of Transportation. (2019a). "Notice to Manufacturers." Colorado Department of Transportation, Denver, Colorado.

Colorado Department of Transportation. (2019b). "COLORADO DEPARTMENT OF TRANSPORTATION PRE-APPROVED PRODUCT EVALUATION REQUEST & SUMMARY." Colorado Department of Transportation, Denver, Colorado.

Connecticut Department of Transportation. (n.d.). "ConnDOT: Policy on New Product Evaluation at Connecticut DOT." <https://www.ct.gov/dot/cwp/view.asp?a=1387&q=259630> (May 16, 2019).

Delaware Department of Transportation. (n.d.). "Approved Product List - Delaware Department of Transportation." <https://deldot.gov/Business/prodlists/index.shtml> (May 16, 2019).

Department of Energy and Environment. (2017). *DISTRICT OF COLUMBIA EROSION AND SEDIMENT CONTROL MANUAL*. Washington, DC.

District of Columbia Department of Transportation. (2013). *Standards Specification for Highways and Structures*. Washington, D.C.

Division of Materials, K., Division of Highways, K., and Kentucky Transportation Cabinet. (2019). *LIST OF APPROVED MATERIALS*. Frankfort, KY.

Divison of Air Quality. (2012). "Photo Gallery: Applying Water or Palliatives in Alaska." Divison of Air Quality, Alaska, Juneau, Alaska.

DNREC Division. (2013). *Delaware Erosion & Sediment Control Handbook*. Dover, DE.

Donald, W. N. (2014). "Performance Evaluations on Ditch Check Practices and Products for Channelized Stormwater Runoff Control using Large-Scale Testing." Auburn University.

Eastcoast Site Work Inc. (n.d.). “Inlet Protection New Jersey.” <https://eastcoastsitework.com/inlet-protection/> (Jun. 3, 2019).

Encore Environmental LLC. (n.d.). “MALTBY TEMPORARY EROSION CONTROL INSTALLATION.” <https://www.encoreenvironmental.com/projects> (Jun. 2, 2019).

Environmental and Public Protection Cabinet. (2005). *Kentucky Best Management Practices for Construction Activities*. Frankfort, KY.

Fanyuan Instrument. (n.d.). “In-plane Water Flow Rate Test Apparatus for Sale - FYI Factory.” <https://fyitester.com/for-sale/in-plane-water-flow-rate-test-apparatus-dw1380/> (Jun. 4, 2019).

Federal Interagency Stream Restoration Working Group (FISRWG). (1998). “Stream Corridor Restoration: Principles, Processes, and Practices- Live Fascines.” <https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/restoration/?cid=nrcs143_026887> (Jun. 3, 2019).

Federal Register. (2014). *Effluent Limitations Guidelines and Standards for the Construction and Development Point Source Category*.

Federal Register. (2015). *Effluent Limitations Guidelines and Standards for the Construction and Development Point Source Category; Correcting Amendment*.

FLORIDA DEPARTMENT OF TRANSPORTATION. (n.d.). “Product Evaluation - Approved Products List (APL).” <https://www.fdot.gov/programmanagement/ProductEvaluation/APL/Default.shtm> (May 17, 2019).

FLORIDA DEPARTMENT OF TRANSPORTATION. (2003). “Florida DOT QPL Submittal Process FLowchart.” Florida Department of Transportation, Tallahassee, FL.

FLORIDA DEPARTMENT OF TRANSPORTATION. (2016a). “Florida DOT Product Evaluation Application.” Florida Department of Transportation, Tallahassee, FL.

FLORIDA DEPARTMENT OF TRANSPORTATION. (2016b). “Certification to Field Installation of Materials to the Department’s Test Deck.” Florida Department of Transportation, Tallahassee, FL.

Forestry Suppliers Inc. (n.d.). “Excel Straw Wattle.” <https://www.forestry-suppliers.com/product_pages/products.php?mi=83131&itemnum=43458&redir=Y> (Jun. 4, 2019).

Franklin, Hampden, H. C. D. (1997). *Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas*. Boston, MA.

Gabion Supply. (n.d.). “Check Dams | Gabion Supply.” <https://gabionsupply.com/check-dams/> (Jun. 3, 2019).

Georgia Department of Transportation. (2017a). “New Product Evaluation (NPE) Form Georgia DOT.” Georgia DOT, Forest Park, GA.

Georgia Department of Transportation. (2017b). “GEORGIA DEPARTMENT OF TRANSPORTATION NEW PRODUCTS EVALUATION COMMITTEE GUIDELINES AND PROCEDURES.” Georgia DOT, Forest Park, GA.

Georgia Soil and Water Conservation Commission. (2016). *MANUAL FOR EROSION AND SEDIMENT CONTROL IN GEORGIA*. Athens, GA.

Geosynthetic Institute. (2018a). “GRI ASTM D4533 Trapezoidal Tearing Strength of Geotextiles (GT12, GT13, AASHTO M288) - YouTube.” <https://www.youtube.com/watch?v=unxgNNLAI0Y> (Jun. 4, 2019).

Geosynthetic Institute. (2018b). “GRI ASTM D4632 Grab Tensile for Geotextiles (GT12, GT13, AASHTO M288) - YouTube.” <https://www.youtube.com/watch?v=6SzjeH1Cx2A> (Jun. 4, 2019).

Geosynthetic Institute. (2018c). “GRI ASTM D4751 Apparent Opening Size for Geotextiles (GT12, GT13, AASHTO M288) - YouTube.” <https://www.youtube.com/watch?v=PA_mH5ko9f8> (Jun. 4, 2019).

Geosynthetic Institute. (2018d). “GRI GM13 ASTM D5199 Thickness of HDPE Geomembranes - YouTube.” <https://www.youtube.com/watch?v=8jh5Y3iRYY8> (Jun. 4, 2019).

Geosynthetic Institute. (2018e). “GRI ASTM D6241 CBR Puncture Strength of Geotextiles (GT12, GT13, AASHTO M288) - YouTube.” <https://www.youtube.com/watch?v=j-7dM0iuGc8> (Jun. 4, 2019).

Geosynthetic Institute. (2018f). “GRI-GC14 Specification for Polymeric Turf Reinforcement Mats (TRMs).” Geosynthetic Institute, Folsom, PA.

Great Escape Farms. (n.d.). “Great Escape Farms Swales A Permaculture Practice - How to build a Swale.” <https://greatescapefarms.com/swales-a-permaculture-practice/#prettyPhoto> (Jun. 3, 2019).

Hanes Geo Components. (n.d.). “Inlet Pro® Sediment Bags - Hanes Geo - Leggett & Platt.” <https://hanesgeo.com/Catalog/Product?id=2994> (Jun. 4, 2019).

Hawaii Department of Transportation. (n.d.). “Highways | Approved Products List Procedures.” <http://hidot.hawaii.gov/highways/other/materials-testing-and-research-branch/approved-products-list-procedures/> (May 17, 2019).

Hawaii Department of Transportation. (2017). "APPROVED PRODUCTS LIST PRODUCT EVALUATION REQUEST FORM." Honolulu, Hawaii.

Helms, D. (2010). "Hugh Hammond Bennett and the creation of the Soil Conservation Service." *Journal of Soil and Water Conservation*, 65(2), 37A-47A.

Idaho Department of Environmental Quality. (2005a). *Catalog of Stormwater Best Management Practices for Idaho Cities and Counties*. Boise, ID.

Idaho Department of Environmental Quality. (2005b). "Catalog of Stormwater Best Management Practices." (September), 373–502.

Idaho Department of Transportation. (n.d.). "ITD QPL." <https://apps.itd.idaho.gov/apps/materials/QPL.aspx> (May 18, 2019a).

Idaho Department of Transportation. (n.d.). "ITD PRODUCT REVIEW AND EVALUATION." <https://apps.itd.idaho.gov/apps/materials/QPLReview.aspx> (May 18, 2019b).

Idaho Department of Transportation. (n.d.). "Idaho Department of Transportation QPL Frequent Asked Questions." <https://apps.itd.idaho.gov/apps/materials/QPLFAQ.aspx> (May 18, 2019c).

Idaho Department of Transportation. (2006). "Idaho Transportation Department Product Review Application." Idaho Department of Transportation, Boise, ID.

IECA. (n.d.). "History of IECA." <https://www.ieca.org/IECA/About_IECA/History_of_IECA/IECA/About_IECA/History_of_IECA.aspx?hkey=abcc683b-178d-455c-9270-02fa7b4db6ac> (Oct. 23, 2018).

Illinois Department of Transportation. (n.d.). "Illinois DOT Producer and Supplier Approval." <https://idot.illinois.gov/doing-business/material-approvals/producer-and-supplier-approval/index> (May 18, 2019).

Illinois Department of Transportation. (2010). *CONSTRUCTION SITE STORM WATER POLLUTION CONTROL*. Springfield, Illinois.

Indiana Department of Environmental Management. (2007). *CONSTRUCTION SITE STORM WATER POLLUTION CONTROL*. Indianapolis, IN.

Indiana Department of Transportation. (2019). *Approved List Requirements*. Indianapolis, IN.

Instron. (2017). "Instron® | ASTM D5035 Breaking Force and Elongation of Textile Fabrics (Strip Method) - YouTube." <https://www.youtube.com/watch?v=qFodrJlGpBM> (Jun. 4, 2019).

Iowa Department Of Transportation. (n.d.). "Erosion Control Products Approval Process." <http://www.iowadot.gov/erl/current/IM/content/469.10.htm> (May 20, 2019).

Iowa Department Of Transportation. (2017). *Erosion and Sediment Control Guide*. Ames, Iowa.

St. John Tradewinds. (n.d.). "Water Bars Help Direct and Stem Stormwater Runoff." <https://www.stjohntradewinds.com/water-bars-help-direct-and-stem-stormwater-runoff/> (Jun. 3, 2019).

Kansas Department of Transportation. (n.d.). "PREQUALIFIED MATERIALS AND NEW PRODUCT APPROVALS." <https://www.ksdot.org/1190ltr.asp> (May 20, 2019).

Kansas Department of Transportation. (2007). *KDOT TEMPORARY EROSION - CONTROL MANUAL*. Topeka, KS.

Louisiana Department of Natural Resources. (2008). *BEST MANAGEMENT PRACTICES (BMPS) FOR COASTAL LOUISIANA NONPOINT SOURCE POLLUTION*. Baton Rouge, Louisiana.

Louisiana Department of Transportaion. (2017a). "LA DOT Approved Materials Evaluation Form." Louisiana Department of Transporation, Baton Rouge, Louisiana.

Louisiana Department of Transportaion. (2017b). "Materials and Testing Section Approved Materials Procedure for Geotextile Fabrics." Louisiana Department of Transporation, Baton Rouge, Louisiana.

Louisiana Department of Transportaion. (2017c). "Materials and Testing Section Qualification Procedure for Erosion Control Products, Slope Protection and Felxible Channel Liners." Louisiana Department of Transporation, Baton Rouge, Louisiana.

Maine Department of Environmental Protection. (2016). *MAINE EROSION AND SEDIMENT CONTROL Best Management Practices (BMPs)*. Augusta, Maine.

Maine Department of Transportation. (2008). "MaineDOT Product Evaluation Flow Chart." Maine Department of Transportation., Augusta, Maine.

Maine Department of Transportation. (2018). "Maine DOT New product submittal Form." Maine Department of Transportation., Augusta, Maine.

Maryland Department of the Environment, Water Management Administration, Natural Resources Conservation Service, and Maryland Association of Soil Conservation Districts. (2011). *2011 Maryland Standards and Specifications for Soil Erosion and Sediment Control*. Baltimore, Maryland.

Maryland Department of Transportation. (2016). "Maryland State Highway Administration New Products Committee." Maryland Department of Transportation, Hanover, MD.

Maryland Department of Transportation. (2018). "Procedure for the Qualification of Geotextiles." Maryland Department of Transportation, Hanover, MD.

Massachusetts Department of Environmental Protection. (n.d.). “Temporary Slope Drain.” <http://prj.geosyntec.com/npsmanual/slopedraintemporary.aspx> (Jun. 2, 2019a).

Massachusetts Department of Environmental Protection. (n.d.). “Water Quality Swale.” <http://prj.geosyntec.com/npsmanual/waterqualityswales.aspx> (Jun. 3, 2019b).

Massachusetts Department of Environmental Protection. (n.d.). “Straw or Hay Bale Barrier.” <http://prj.geosyntec.com/npsmanual/straworhaybalebarrier.aspx> (Jun. 4, 2019c).

Massachusetts Department of Transportation. (2018). “MassDOT Highway Division QCML Product Evaluation Application.” Hopkinton, MA.

Michigan Department of Transporatation. (2017). “Qualifed Product Evaluation Request Form 1022 Q.” Michigan Department of Transportation, Lansing, MI.

Michigan Department of Transporatation. (2018). “Michigan DOT New Materials and New Products Evaluation Requests Procedures.” Michigan Department of Transportation, Lansing, MI.

Midwest Construction Products. (n.d.). “Dewatering Bag Midwest Construction Products.” <http://midwestconstruct.com/portfolio/dewatering-bag> (Jun. 4, 2019).

Minnesota Department of Transportation. (2015a). “Mn DOT Policies Approved/Qualified Products Process.” Minnesota Department of Transportation, Saint Paul, MN.

Minnesota Department of Transportation. (2015b). “MN DOT New Product Preliminary Information Form (Erosion and Landscape products).” Minnesota Department of Transportation, Saint Paul, MN.

Minnesota Department of Transportation, and Bonestroo Rosene Anderlik & Associates. (2006). *Erosion Control Handbook II*. Saint Paul, MN.

Minnesota Pollution Control Agency. (2016a). “File:Example of riprap outlet protection.jpg - Minnesota Stormwater Manual.” <https://stormwater.pca.state.mn.us/index.php?title=File:Example_of_riprap_outlet_protection.jpg> (May 28, 2019).

Minnesota Pollution Control Agency. (2016b). “File:Example riprap stilling basin plunge pool installation.jpg - Minnesota Stormwater Manual.” <https://stormwater.pca.state.mn.us/index.php?title=File:Example_riprap_stilling_basin_plunge_pool_installation.jpg> (Jun. 3, 2019).

Minnesota Pollution Control Agency. (2019a). “File:Example of a compacted soil berm.jpg - Minnesota Stormwater Manual.” <https://stormwater.pca.state.mn.us/index.php?title=File:Example_of_a_compacted_soil_berm.jpg> (Oct. 6, 2019).

Minnesota Pollution Control Agency. (2019b). "File:Schematic of a berm.png - Minnesota Stormwater Manual." <https://stormwater.pca.state.mn.us/index.php?title=File:Schematic_of_a_berm.png> (Jun. 3, 2019).

Minnesota Pollution Control Agency. (2019c). "File:Small Sediment Trap.jpg - Minnesota Stormwater Manual." <https://stormwater.pca.state.mn.us/index.php?title=File:Small_Sediment_Trap.jpg> (May 28, 2019).

Mississippi Department of Environmental Quality. (2011). *Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas*. Jackson, MS.

Mississippi Department of Transportation. (2018). "MS DOT Product Evaluation Form ADM- 361." Mississippi Department of Transportation, Jackson, MS.

Missouri Department of Transportation. (2014). "Missouri DOT Qualified Erosion Control Blankets." Missouri Department of Transportation, Jefferson City, MO.

Missouri Department of Transportation. (2016). "Missouri Department of Transportation New Product Evaluation Form Instructions Missouri Department of Transportation." Missouri Department of Transportation, Jefferson City, MO.

Missouri Department of Transportation. (2018). *Missouri Standard Specifications for Highway Construction*. Jefferson City, MO.

Montana Department of Transporation. (n.d.). "MT DOT Qualified Products Producer Requirements." <https://www.mdt.mt.gov/business/contracting/qpl-prod-requirements.shtml> (May 21, 2019).

Montana Department of Transporation. (2019). "MT DOT Request Form." Montana Department of Transportation, Helena, MT.

Natural Resources Conservation Service. (n.d.). "More Than 80 Years Helping People Help the Land: A Brief History of NRCS | NRCS." <https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/about/history/?cid=nrcs143_021392> (Oct. 23, 2018).

Natural Resources Conservation Service. (2010). "Natural Resources Conservation Service Conservation Practice Standard: Stormwater Runoff Control." (May), 1–3.

Natural Resources Conservation Service. (2014). "EQIP - General 2014 | NRCS Illinois." <https://www.nrcs.usda.gov/wps/portal/nrcs/detail/il/newsroom/factsheets/?cid=nrcs141p2_031327> (Jun. 3, 2019).

Nebraska Department of Roads. (2004). "APPROVED PRODUCTS LIST Removal and Reinstatement Policy." Lincoln, NE.

Nebraska Department of Roads. (2007a). *Erosion and Sediment Control Approved Products List Approval Procedures*. Lincoln, NE.

Nebraska Department of Roads. (2007b). "NDOR Approved Products Process." <https://dot.nebraska.gov/media/6967/npeflowchart.pdf>.

Nebraska Department of Transportation. (2006). *NDOT – Drainage Design and Erosion Control Manual*. Lincoln, NE.

Nebraska Department of Transportation. (2018). "Nebraska Department of Transportation New Products Evaluation Form." Nebraska Department of Transportation, Lincoln, NE.

Nevada Department of Transportation. (2017). *Stormwater Quality Manuals Construction Site Best Management Practices (BMPs) Manual*. Carson City, Nevada.

New Hampshire Department of Transportation. (2015). "QPL PRODUCT SUBMITTAL FORM." New Hamphsire DOT, Concord, New Hampshire.

New Hampshire Department of Transportation. (2018). *Product Evaluation Process*. Concord, New Hampshire.

New Hampshire Departmetn of Environmental Services. (2011). *New Hampshire Stormwater Manual*. Concord, New Hampshire.

New Jersey Department of Transportation. (n.d.). "NJDOT New Technologies Evaluations-Products FAQ." <https://www.state.nj.us/transportation/eng/technology/faq.shtm#NTP_EvaluationForm> (May 23, 2019).

New Jersey Department of Transportation. (2011). "NJDOT - New Technology and Products Evaluation Process Flowchart." <https://www.state.nj.us/transportation/eng/technology/NTPEvaluation.shtm> (May 23, 2019).

New Jersey Department of Transportation. (2018). "New Technologies and Product Evaluation Form." New Jersey Department of Transportation, Trenton, NJ.

New Mexico Department of Transportation. (2014). "Product Evaluation Application Instructions." New Mexico DOT, Santa Fe, New Mexico.

New Mexico Department of Transportation. (2016). "New Mexico Department of Transportation Application for Product Evaluation." New Mexico DOT, Santa Fe, New Mexico.

New Mexico Department of Transportation, City of Albuquerque Department of Municipal Development, Albuquerque Metropolitan Arroyo Flood Control Authority, The University of New Mexico Environmental Health, Southern Sandoval County Arroyo Flood Control Authority, New Mexico Environment Department Surface Water Quality Bureau, Rancho, C. of R., and Works, B. C. P. (2012). *National Pollutant Discharge Elimination System Manual Storm Water Management Guidelines for Construction and Industrial Activities*. Santa Fe, New Mexico.

New York Department of Conservation. (2016). *New York State Standards and Specifications for Erosion and Sediment Control*. Albany, NY.

New York State Department of Transportation. (2014). "NYSDOT New Product Evaluation Application." New York State DOT, Albany, NY.

North Carolina Department of Tranpsortation. (2018). *NCDOT Value Management Office External Guidelines*. Raleigh, NC.

North Carolina Department of Transportation. (2017). "NCDOT PEP Geotextiles Checklist." North Carolina DOT, Raleigh, NC.

North Carolina Sedimentation Control Commission, North Carolina Department of Environment and Natural Resources, and North Carolina Agricultural Extentsion Service. (2013). *Erosion and Sediment Control Planning and Design Manual*. Raleigh, NC.

North Dakota Department of Transportation. (2004). *North Dakota Department of Transportation (NDDOT) Erosion and Sediment Control Handbook*. Bismarck, ND.

North Dakota Department of Transportation. (2014). *Standard specifications for road and bridge construction*. Bismarck, ND.

North Dakota Department of Transportation. (2018a). "NEW PRODUCT SUBMITTAL." North Dakota DOT, Bismarck, ND.

North Dakota Department of Transportation. (2018b). "NDDOT New Product Evaluation." North Dakota DOT, Bismarck, ND, <https://www.dot.nd.gov/divisions/environmental/docs/NewProductProcedure.pdf > (May 25, 2019).

"NPDES Stormwater Program." (n.d.). <https://www.epa.gov/npdes/npdes-stormwater-program> (Nov. 17, 2018).

Ohio Department of Natural Resources. (2016). "Chapter 4 Permanent Runoff Control." Ohio DNR, Columbus, Ohio.

OHIO DEPARTMENT OF TRANSPORTATION. (n.d.). "Ohio DOT Qualified Products List." <http://www.dot.state.oh.us/Divisions/ConstructionMgt/Materials/Pages/QPL.aspx> (May 26, 2019).

OHIO DEPARTMENT OF TRANSPORTATION. (2014). *Ohio DOT Prodcedure for QPL*. Columbus, Ohio.

Oklahoma Department of Transportation. (2017). "Oklahoma DOT New or Equal Product Evaluation Request." Oklahoma DOT, Oklahoma City, OK.

Oregon Department of Transportation. (2004). "Oregon DOT Product Evaluation Administrative Flow Chart." <https://www.oregon.gov/ODOT/Construction/Documents/productevalflowchart.pdf> (May 26, 2019).

Oregon Department of Transportation. (2006). *Erosion Control Field Manual*. Salem, OR.

Oregon Department of Transportation. (2018). "Oregon DOT Preliminary Information for Product Evaluation." Oregon DOT, Salem, OR.

"Our History | Soil and Water Conservation Society." (n.d.). <https://www.swcs.org/about-us/our-history/> (Oct. 23, 2018).

Pennsylvania Department Of Transporation. (2012). *Design Manual Part 2 Highway Design*. Harrisburg, PA.

Pennsylvania Department Of Transporation. (2019). *Bulletin 15 (Publication 35) QPL for Construction*. Harrisburg, PA.

Pitt, R., Clark, S. E., and Lake, D. (2007). *Construction Site Erosion and Sediment Controls: Planning, Design and Performance*. DEStech Publications, Inc.

Rachel Calabro. (2012). "Mill River Restoration: Dewatering and Diversion Continue." <http://millriver.blogspot.com/2012/09/dewatering-and-diversion-continue.html> (Jun. 3, 2019).

Rhode Island Department of Transportation. (2014). "RHODE ISLAND DOT New Product, Material, Equipment or Process Form." Rhode Island DOT, Providence, RI.

Rhode Island State Conservation Committee (Rhode Island Department of Environmental Management, Rhode Island Coastal Resources Management Council, Rhode Island Department of Transportation, and The University of Rhode Island). (2014). *RHODE ISLAND SOIL EROSION AND SEDIMENT CONTROL HANDBOOK*. Providence, RI.

Scott, K., and Rich, M. (2015). "Fiber Check Dams and Polyacrylamide for Water Quality Improvement | NC State Extension Publications." *North Carolina State Extension Publications*, <https://content.ces.ncsu.edu/fiber-check-dams-and-polyacrylamide-for-water-quality-improvement> (Jun. 3, 2019).

South Carolina Department of Tranpsortation. (2007). "Qualified Products policy for Geotextile for Slope protection." South Carolina DOT, Columbia, SC.

South Carolina Department of Tranpsortation. (2014). "Qualified Products Policy for Temporary ECBs." South Carolina DOT, Columbia, SC.

South Carolina DHEC. (2005). *South Carolina DHEC StormWater Management BMP Feild Manual*. Columbia, SC.

South Dakota Depatment of Transportation. (2004). *Construction Field Manual*. Pierre, SD.

South Dakota Depatment of Transportation. (2009). "South Dakota DOT Product Evaluation Request." South Dakota DOT, Pierre, SD.

South Dakota Depatment of Transportation. (2016). *Product Evaluation Procedure*. Pierre, SD.

Sprague, J., and Lacina, B. (2010). "PERFORMANCE TESTING OF SEDIMENT RETENTION DEVICES."

Superior Hydroseeding Inc. (n.d.). "Wattles/Fiber Rolls." <http://www.superiorhydroseeding.net/services/wattlesfiber_rolls> (Jun. 4, 2019).

Tennessee Department of Transportation. (n.d.). "Research & Product Evaluation and Qualified Products List." <https://www.tn.gov/tdot/materials-and-tests/research---product-evaluation-and-qualified-products-list.html> (May 26, 2019).

Tennessee Department of Transportation. (2012a). "NEW PRODUCT, MATERIAL, EQUIPMENT OR PROCESS EVALUATION." Tennessee DOT, Nashville, TN.

Tennessee Department of Transportation. (2012b). *Tennesse DOT Drainage Manual*. Nashville, TN.

Texas Department of Transportation. (n.d.). "Research Manual: Product Evaluation Process." <http://onlinemanuals.txdot.gov/txdotmanuals/rtt/evaluation_process.htm> (May 26, 2019).

Texas Department of Transportation. (2004). *Storm Water Field Inspector's Guide*. Austin, TX.

Texas Department of Transportation. (2018a). "RTI Product Evaluation Request." Texas DOT, Austin, TX.

Texas Department of Transportation. (2018b). *The Texas Department of Transportation - Texas A&M Transportation Institute Sedimentation and Erosion Control (SEC) Laboratory*. Austin, TX.

The Connecticut Council on Soil and Water Conservation, and Connecticut Department of Environmental Protection. (2002). *2002 Connecticut Guidelines For Soil Erosion and Sediment Control*. Hartford, Connecticut.

The Universal Grip Company. (2015). "ASTM D4595 - Wide-Width Geotextiles - YouTube." <https://www.youtube.com/watch?v=CyAHRGrZwHs> (Jun. 4, 2019).

TRI Erosion Test. (n.d.). "Tests and Capabilities | Erosiontest." <http://erosiontest.com/tests-and-capabilities/> (Jun. 4, 2019).

U.S. Environmental Protection Agency. (2017). *NPDES compliance inspection manual*. Washington, D.C.

U.S. Senate. (2002). *Federal water pollution control act*. Washington, D.C.

United States Department of Agriculture. (2014). "USDA Researchers Study Hydromulches with Guar Gum Substitutes | USDA." <https://www.usda.gov/media/blog/2014/01/14/usda-researchers-study-hydromulches-guar-gum-substitutes> (Jun. 2, 2019).

United States Department of Agriculture. (2017). *Riparian Forest Buffers: An Agroforestry Practice*. Washington, D.C.

United states environmental protection Agency. (2007). "Developing Your Stormwater Pollution Prevention Plan A Guide for Construction Sites." *Construction*, (May).

US DOT Federal Highway Administration. (2019). "Construction Program Guide- Erosion Control Guide." <https://www.fhwa.dot.gov/construction/cqit/erosion.cfm> (Oct. 31, 2019).

US EPA. (n.d.). "About NPDES." <https://www.epa.gov/npdes/about-npdes> (Nov. 17, 2018a).

US EPA. (n.d.). "NPDES State Program Information." <https://www.epa.gov/npdes/npdes-state-program-information> (Nov. 17, 2018b).

US EPA. (2005). "Stormwater Phase II Final Rule Construction Site Runoff Control Minimum Control Measure." 4–7.

US EPA, O. (n.d.). "The Origins of EPA." <https://www.epa.gov/history/origins-epa> (Nov. 6, 2018c).

Utah Department of Transportation. (n.d.). "Utah Department of Transportation- Approved Product List." <https://www.udot.utah.gov/main/f?p=100:pg:0:::1:T,V:239,> (May 27, 2019).

UTAH DEPARTMENT OF TRANSPORTATION. (2004). *UTAH DEPARTMENT OF TRANSPORTATION MANUAL OF INSTRUCTION ROADWAY DRAINAGE*. Taylorsville, UT.

UTAH DEPARTMENT OF TRANSPORTATION. (2016). "Utah DOT APL- Application." Utah DOT, Taylorsville, UT.

Vermont Department of Transportation. (2018). "Approved Product List – Product Submittal Form." Vermont DOT, Montpelier, VT.

Vermont Environmental Conservation. (2006). *THE VERMONT STANDARDS & SPECIFICATIONS FOR EROSION PREVENTION & SEDIMENT CONTROL*. *Erosion Control*, Montpelier, VT.

Virginia Department of Environmental Quality. (1992). *Virginia Erosion and Sediment Control Handbook*. Richmond, VA.

Virginia Department of Tranpsoration. (2017). "Virginia DOT Preliminary Information for Product Evaluation." Virginia DOT, Richmond, VA.

Washington State Department of Transportation. (n.d.). "WSDOT - Materials Laboratory Qualified Products List (QPL)." <http://www.wsdot.wa.gov/Business/MaterialsLab/QPL.htm> (May 27, 2019).

Washington State Department of Transportation. (2014). *WSDOT Temporary Erosion and Sediment Control Manual*. Olympia, WA.

Washington State Department of Transportation. (2018). "Washington State Department of Transpartion QPL -Submittal Application Form." WA DOT, Tumwater, WA.

West Virginia Department of Transportation. (2016a). "PROCEDURE FOR EVALUATING PRODUCTS / PROCESSES FOR USE IN HIGHWAY CONSTRUCTION." West Virginia DOT, Charleston, West Virginia.

West Virginia Department of Transportation. (2016b). "PRELIMINARY INFORMATION FOR TECHNOLOGY/PRODUCT EVALUATION." West Virginia DOT, Charleston, West Virginia.

Wisconsin Department of Transportation. (2013). *WI DOT Facilities Development Manual*.

Wisconsin Department of Transportation. (2019). *Erosion Control and Storm Water Product Acceptability Lists User Guide and Submittal Procedures*. Madison, Wisconsin.

Wyoming Department of Transportation. (2010). *Standard Specifications for Road and Bridge Construction*. Cheyenne, WY.

Wyoming Department of Transportation. (2012). "Certification of Materials." Wyoming DOT, Cheyenne, WY.

WYOMING DEPARTMENT OF TRANSPORTATION. (2011). *Pollution Controls and Best Management Practices for Storm Water During Construction FIELD GUIDE*. Cheyenne, WY.

APPENDIX-A INSTITUTION REVIEW BOARD-IOWA STATE UNIVERSITY MEMO

IOWA STATE UNIVERSITY

Study

Study:	18-324	**Sponsor(s):**	
Committee:	IRB #1	**Sponsor Id:**	
Category:		**Grants:**	
Department:	Civil, Construction and Environmental Engineering		
Agent Types:	SBER	**CRO:**	
Title:	COMPARISON OF EROSION AND SEDIMENT CONTROL PRODUCT APPROVAL REQUIREMENTS FOR STATE HIGHWAY AGENCY INCLUSION ON QUALIFIED PRODUCT LISTS	**Year:**	2018
HIPAA:		**Exempt Categories:**	2: Research involving use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observations of public behavior, unless (i) Information obtained is recorded in such a manner that human subjects can be identified, and (ii) Any disclosure of the human subjects' responses outside the research could reasonably place the subject at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation., 4: Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, (i) if these sources are publicly available, or (ii) if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or indirectly through identifiers linked to the subjects.
FDA Study:	No		

Comments:

- Conduct a literature review of SHA QPL (State Highway Agency Qualified Product List)inclusion processes and all associated standard test methods;
- Develop and conduct an SHA (State Highway Agency) survey to gather information on the QPL (Qualified Product List) approval process;
- Compile a catalog of standard test methods pertinent to erosion and sediment control products and practices detailing procedures, equipment, and requirements.
- The catalog doesn't contain any agency-specific identifying information.

Study-Site

Site(s):	**00 - Unspecified**	**PI:**	**Perez, Michael**
Status:	Active	**Additional:**	N
Approval:	August 20, 2018	**Expiration:**	**Exempt**

Initial Approval:	August 20, 2018	**Other Expirations:**	Exempt Determination Expiration - 08/18/2020
Tags:	Exempt		
Comments:			

Study-Site Contacts (1)

Name	Role
Dokala, Chaitanya	Research Staff

Events (1)

Event	Att	FE	Instance/UDF	Start	Complete	Last Mtg
Initial Submission	3			08/15/2018	09/04/2018	09/04/2018

APPENDIX-B SURVEY DATA

Question 2

Does your agency have a Qualified Products List for identifying erosion and/or sediment control products to be use on construction projects overseen or funded by your agency?

Total Responses	**24**	**100%**
Yes, both erosion and sediment control products	15	63%
Only erosion control products	4	17%
Only sediment control products	0	0%
No, nether erosion nor sediment control products	2	8%
Not sure	0	0%
Other	3	13%

Other, please explain:

Ohio DOT: No, but we are in the process of developing criteria and process for a QPL right now

Montana DOT: We only require erosion control blankets to be listed on our QPL. Other sediment control devices like straw waddles or silt fence can be accepted of the QPL but are not required to be listed on the QPL.

Alaska DOT &PF: We have Qualified products, which can be used without further approval, but any product that meets our specification can be approved at the project level.

Question 3

How often is the Erosion and Sediment Control section updated on the Qualified Product List updated?

Total Responses	**23**	**100%**
As needed	12	52%
Monthly	1	4%
Quarterly	1	4%
Annually	3	13%
Bi-annually	1	4%
Other	5	22%

Other, Please Explain:

Mississippi DOT: Once per four years

Alabama DOT: Rolled and Hydraulic Erosion Control Products are updated Biannually, and all other products are updated as needed

Oklahoma DOT: We do not have a QPL list, so this does not pertain to us Oklahoma DOT

Alaska DOT &PF: As vendors or manufacturers apply or if requested by Maintenance We do not solicit products

Missouri DOT: Not applicable

Question 4

Does your agency use or allow for the use of erosion and/or sediment control products or materials from other federal, state, or local agency's qualified product list(s)?

Total Responses	**24**	**100%**
Yes	2	8%
No	19	79%
Not Sure	1	4%
Only in special or rare cases	2	8%

Yes (Please identify lists approved by your agency)

Oregon DOT: Texas DOT has a well-researched list
Rhode Island DOT: If they conform to the RIDOT specification

Only in Special or rare cases, please explain:
Mississippi DOT: Portions of our list are pulled directly from another agency's list
Ohio DOT: Alternative BMPs are allowed if the contractor can justify that our standard practices cannot work in a certain situation. Alternatives must be approved on a case by case basis

Question 5
What qualification process does your agency follow to approve new erosion and/or sediment control products for inclusion in the Qualified Product List? Select all that pertain.

Total Responses (More than one answer)	23	100%
Application submission by product manufacturer	17	74%
Fee submission by product manufacturer	2	9%
Field Testing	7	30%
Large or full-scale performance-based laboratory testing	11	48%
Bench-scale laboratory testing of material properties	12	52%
Approval by other state highway agencies (please list)	2	9%
Not sure		0%
Other, please explain	7	30%

Approval by other state highway agencies (please list)
Washington State DOT: NTPEP evaluation are used
Oregon DOT: TXDOT
Other, please explain
Mississippi DOT: It's a mixture of testing methods and pulling products from other DOT's lists
Arkansas DOT: NTPEP for geotextile fabrics.
South Dakota DOT Materials & Surfacing Program: Approval can be made by several of the processes above
Montana DOT: MDT requires geotextile manufacturers be audited and listed by the National Transportation Product Evaluation Program (NTPEP). Provide MDT with the manufacturer's name and facility location as listed by the NTPEP. MDT will review the NTPEP audit results for conformance with the Department's criteria. Materials found not to meet the Department's criteria from review of NTPEP audit results or MDT performed random testing and auditing will be rejected. Items meeting MDT's criteria will be placed on the QPL.
Minnesota DOT: Hazardous Evaluation Process to protect MNDOT from potential pollution liability. i.e. Hydraulic products, flocculants…
Missouri DOT: We use TTI for ECB acceptance as well as certifications by the manufacturer for ECB and all other produces on our projects.
Maine DOT: Maine DOT requires NTPEP testing, for ECPs, they must be okay-ed by committee of qualified persons and meet our specifications.

Question-6

What testing program does your agency use to evaluate products? Select all that apply.

Total Responses (More than one answer)	**14**	**100%**
In-house testing	3	21%
University testing program (please list)	3	21%
AASHTO National Transportation Product Evaluation Program (NTPEP)	13	93%
ASTM Testing	7	50%
Other independent third-party agency (please list)	3	21%
Other, please explain	2	14%
Not sure	0	0%

Other independent third-party agency (please list)

Alaska DOT &PF: Manufacturer choice of certified lab

Iowa DOT: Texas Transportation Institute, Colorado State University, Utah State University, or other approved testing facility.

University testing program (please list)

Oklahoma DOT: Auburn University Erosion and Sediment Control Testing

South Carolina DOT: Colorado state has been used sometimes

Rhode Island DOT: University of Rhode Island, UNH

Other, please explain

Washington State DOT: EPA for Acute Toxicity Solvents and Heavy Metals

Wisconsin DOT: Tests not available through NTPEP are allowed from qualified independent labs

South Carolina DOT: TRI, TTI are the most commonly used

Question 7

Are erosion and sediment control products on the qualified product list periodically re-evaluated to ensure conformance to prescribed qualification standards?

Total Responses	**23**	**100%**
Yes	15	65%
No	3	13%
Other, Please Explain	5	22%

Other, please explain

Mississippi DOT: They have been re-evaluated only once in their tenure on our lists

Washington State DOT: In the last 6 years, not periodically. Although we are currently scrubbing the HECP category (short, moderate and long-term mulch)

Arkansas DOT: We do not typically pull field samples, nor do we require additional sample submittals by the supplier/manufacturer. We do monitor NTPEP audits for geotextiles listed.

Alabama DOT: Only rolled and hydraulic erosion control products are reevaluated every three years

Missouri DOT: Not applicable

Maine DOT: Currently working on a process to do this at regular intervals. Currently the list is managed by the Qualified Products Coordinator

Question 7.1

How often are erosion and/or sediment control products re-evaluated?

Total Responses	14	100%
0-1 years	4	29%
1-2 years	1	7%
2-5 years	9	64%
>5 years	0	0%

Question 7.2

What does the product re-evaluation process include? select all that apply.

Total Responses	14	100%
Previous performance records	4	29%
Material based testing	8	57%
Field testing on active construction sites	2	14%
Performance- based testing	9	64%
Submission of fee	1	7%
Other, please explain	3	21%

Other, please explain

Florida DOT: Statement from supplier that no changes have been made to product since the approval.
Oregon DOT: Specification requirements change, so conformance with requirements is the criteria (E.G. biodegradable material)
Arizona DOT: Products must meet the requirements in the ADOT Standard Specifications for Road and Bridge Construction and any applicable Stored Specifications. The Stored Specifications are up-dates to the Standard Specifications.

Question 8

Please Select all erosion and sediment control products listed in your agency's Qualified Product List.

Total Responses	23	100%
Anchoring Devices	3	13%
Sediment basin baffles	5	22%
Erosion Control blankets	18	78%
Check dams	5	22%
Dewatering devices	4	17%
Dust palliatives	5	22%
Fertilizers	1	4%
Flocculants	3	13%
other geosynthetics	8	35%
Inlet protection devices	10	43%
Temporary mulch	9	39%
HECP	13	57%
Silt fence	18	78%
Slope Drains	2	9%
Soil Binders	4	17%
Soil Stabilizers	6	26%
Soil Sterilants	1	4%
Tackifiers	10	43%
Temporary or permanent seeding	7	30%
Turbidimeters	1	4%
TRM's	12	52%
Wattles or Sediment Logs	13	57%
Others, please list	4	17%

Others, please list

Mississippi DOT: Soil reinforcing mats, turbidity barriers, and silt dikes
Arizona DOT: Sediment Logs, Wattles, and Fiber Rolls. Also Filters & Filter material, for Gravel Bags, Storm Drain Inlets, Curb Inlets, Drop Inlets, Weep Holes, Dewatering Bags, Fabric Bags, Fabric Bags, Inlet Grates, etc.
Minnesota DOT: salt tolerant sod, compost suppliers, weed free mulch suppliers, seed vendors
Missouri DOT: not applicable
Iowa DOT: Transition mat, silt curtains

Question 9

Does your agency maintain standard installation details for erosion and sediment control practices?

Total Responses	24	100%
Provided	18	75%
Not Provided	6	25%

SHAs	Comments
Florida DOT	http://www.fdot.gov/roadway/Drainage/files/Erosion-Sediment-Control.pdf
Mississippi DOT	http://sp.mdot.ms.gov/Construction/Standard%20Specifications/2017%20Standard%20Specifications.pdf
Nebraska DOT	Installation details are not available online but can be provided upon request.
Washington State DOT	http://www.wsdot.wa.gov/Design/Standards/#SectionH
Ohio DOT	http://www.dot.state.oh.us/Divisions/Engineering/Hydraulics/Standard%20Drawings/DM/PDF/DM-4.3_2016-01-15.pdf http://www.dot.state.oh.us/Divisions/Engineering/Hydraulics/Standard%20Drawings/DM/PDF/DM-4.4_2016-01-15.pdf http://www.dot.state.oh.us/Divisions/Engineering/Hydraulics/Standard%20Drawings/DM/PDF/DM-4.2_2012-07-20.pdf http://www.dot.state.oh.us/Divisions/Engineering/Hydraulics/Standard%20Drawings/DM/PDF/DM-4.1_2018-07-20.pdf
Alabama DOT	https://alletting.dot.state.al.us/Docs/Standard_Drawings/2017%20English/STDUS17_1100.pdf#page=15
South Dakota DOT Materials & Surfacing Program	This is Standard Specification Section 734 & contract specific plan & detail
Wisconsin DOT	https://wisconsindot.gov/rdwy/sdd/sd-08-00toc.pdf
Oregon DOT	https://www.oregon.gov/ODOT/Engineering/Pages/Drawings-Roadway.aspx
Vermont Agency of Transportation	https://vtrans.vermont.gov/cadd/downloads/standard-drawings
Oklahoma DOT	http://www.okladot.state.ok.us/roadway/roadway2009/IndexStandards2009.htm
Arizona DOT	See the ADOT Standard Specifications and the "ADOT Erosion and Pollution Control Manual for Highway Design and Construction. " This is a "Best Management Practice Manual" used in the field.
Montana DOT	http://mdtinfo.mdt.mt.gov/environmental/docs/2016-BMP-MANUAL.pdf
Minnesota DOT	https://standardplans.dot.state.mn.us/
Missouri DOT	https://www.modot.org/media/16577 select standard plan 806.10j
South Carolina DOT	SCDOT Standard Drawings Section 815 https://www.scdot.org/business/standard-drawings.aspx
Maine DOT	https://www.maine.gov/mdot/env/documents/bmp/BMP2008full.pdf

Rhode Island DOT	http://www.dot.ri.gov/business/bluebook.php http://www.dot.ri.gov/documents/doingbusiness/RIDOT_Std_Details.pdf
Iowa DOT	https://iowadot.gov/erl/current/RS/Navigation/ec.htm

Question 10

In your opinion, what changes could your agency employ to improve the product evaluation process for erosion and sediment control product inclusion in the qualified product list?

Total Responses	21	100%
SHAs that explained their Views	11	52%
SHAs that chose 'None' option	3	14%
SHAs that chose 'Not sure' option	7	33%

Please Explain

Florida DOT: The FDOT has focused on contractor performance rather than products. FDOT holds the contractor responsible for meeting the erosion and sediment control on the job site. FDOT limits the type of products on our APL to those products that have demonstrated poor field performance and therefore have to pre-evaluated to use.

Nebraska DOT: Improved definitions by industry or third parties would greatly help in evaluating products for equality.

Washington State DOT: WSDOT has delegated the approval process of erosion and sediment control materials to the Project Engineer level. HQ State Laboratory review is no longer required; Resources: Hire qualified FTE's as subject matter experts dedicated to manage and track ESC products and product lists. Currently, WSDOT ESC SME's have other job responsibilities and are unable to dedicate more time to ESC SME duties; Create a more streamlined process for QPL maintenance. The QPL is maintained through the State Materials Laboratory and is currently understaffed and behind on updating the QPL. Therefore, we currently have products listed that do not meet the requirements of our Standard Specifications. Recommendation for others is to more closely align the Specification updates with QPL product list updates.

Arkansas DOT: Maybe a detailed list on our QPL page of each item required for product review and inclusion.

Wisconsin DOT: WisDOT is satisfied with its product approval process. The primary needs for improvement of the erosion control portion of transportation development practice are to field enforcement of installation practice and making sure that appropriate decisions are made regarding what applications are appropriate to their intended locations and service conditions.

Vermont Agency of Transportation: Define set requirements for the specific type of product.

Oklahoma DOT: Because we do not have a formal process, we want to start one for Erosion and Sediment Control products. Get a committee together, set of meeting schedules, set up a policy and process guidelines

Arizona DOT: More detailed Specifications for the different Erosion Control Products that are in the market.

Missouri DOT: Development of a qualified list based on NTPEP testing would be optimal.

South Carolina DOT: Not sure. The NTPEP program has been a big help but it does not cover all categories of products. It would be helpful if some of these products could be evaluated nationally rather than each state having to evaluate them individually, but there are different conditions in different regions, so that may not be feasible.

Rhode Island DOT: Better communication between designers, construction contractors and internal project team to identify successes and issues with products.

APPENDIX-C TESTING EQUIPMENT INFORMATION AND QUOTES

TMI

Burst Tester

13-60 Series

FEATURES

- Three (3) models to choose from to measure Paper and film, Board and Corrugated, and Textiles
- Pneumatic sample clamping pressure is measured with a transducer and displayed in bar/PSI
- Compatible with GraphMaster™ PC based data collection and curve analysis software
- Date of last calibration stored in memory (clamp pressure, bursting pressure, and height gauge)
- Menus allow programming to meet pre-defined test methods and international standards
- Number of test performed with diaphragm stored in memory

BURST TESTING

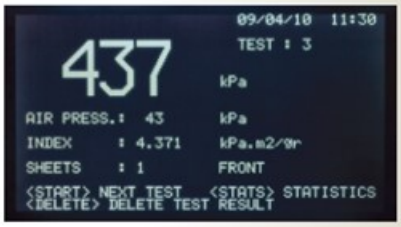
Burst Testers are used as a multi-directional tensile test to identify failure in the direction of least resistance for evaluating physical strength and fiber bond. Models are available to test a variety of materials. These models can also be fitted with a device to measure the deflection of the sample prior to burst.

The Burst tester is designed to meet international standards for tests on paper, foils, paper boards, corrugated board, textiles etc.

OPERATION

The Burst Tester is designed for measuring the bursting strength of fabric materials subjected to an increasing hydrostatic pressure. This pressure is applied to a circular region of the specimen via an elastic diaphragm. The specimen is firmly held round the edge of this circular region by a pneumatic clamping device. When the pressure is applied, the specimen deforms together with the diaphragm. The bursting strength corresponds to the maximum pressure supported by the specimen before failure. Identical, in the principle to the multi-directional tensile test, Ball Burst Method for Fabrics, this measurement is independent from the cutting direction of the sample (machine or cross) since the failure naturally occurs in the least resistance direction.

The rubber diaphragms with specific thickness and shore hardness must have a bulge versus pressure pattern within the tolerance of the standards related to the type of material tested.



APPLICATIONS

- Textiles, Fibers, Non-woven's, Polyester, Fabrics and Felts etc.
- Strength, stiffness, dye ability, resilience, fatigue elasticity, orientation and crystallinity.

MEETS STANDARDS

- ISO 2758, ISO 2759, , ISO 1328-2:1999, ISO 2960, ASTM D 3786 , ASTM D-774, BS 4768, TAPPI T403, TAPPI T807, TAPPI T810

Burst Tester

13-60 Series

Pressure system:
The hydrostatic pressure is transmitted to the diaphragm by a hydraulic jack associated with a frictionless ball-screw driven by a precision DC motor. The rotational speed and the position of the motor are servo-controlled by means of an optical encoder ensuring a perfect control of the fluid flow rate together with the determination of the displaced volume of fluid.

Note: This measurement may be used to determine the profile of the resistance pressure of the rubber diaphragm itself versus the displaced volume of fluid. The corresponding values may then be subtracted from the values actually measured during a test in order to take into account the sample resistance only. (Applications to textiles for instance).

Sample tightening system:
- A large pneumatic jack enables an accurate and reproducible tightening.
- The tightening surfaces have an adequate profile to minimize the slippage even for difficult materials like textiles for high volume bags.
- The tightening pressure is measured with a precision manometer and may be displayed in metric or imperial units.
- The gripping strength is recalculated according to the geometry of the tightening surfaces.

Bursting pressure measurement:
- The pressure is measure by a metallic gages pressure transducer (0 to 100 bars)
- Accuracy: +/-1% of read value +/-1 digit between 5% and 100% of the FSD.
- Resolution: 2 mbars (50,000 points)

Specifications			
Model	13-60-00 EC35	13-61-00 EC36	13-62 EC37
	Paper and Foils	Paper boards and Corrugated Board	Textiles
Measuring Range	40 - 2000 kPa	0 - 725 psig (0-5000 kPa)	0 - 1015 psig
Dimensions W x D x H	517 mm x 565 mm x 495 mm (20.35 in x 22.25 in x 19.5 in)		
Weight	65 kg (143.3 lbs)		
Electrical	110V/60Hz or 220V/50Hz		
Air	Instrument Quality 600 kPa (6 Bars)		
Safety	One start button when safety hood covers the test area and two start buttons, which has to be pushed simultaneously when cover is up to have a better view on the test area.		
Option	Height gauge to measure the height of the Burst.		
Option	Printer, small sized and handy roll printer delivers 40 column tickets.		

Standards	
ISO 2758	Paper. Determination of bursting strength
ISO 2759	Board. Determination of bursting strength
ASTM D 3786	Standard Test Method for Bursting Strength of Textile Fabrics- Diaphragm Burst Method
ISO 1328-2:1999	Bursting properties of Fabrics
ISO 2960	Test method for Bursting Strength
BS 4768	Determination of Bursting Strength and Bursting Distension
TAPPI	TAPPI T403 Bursting Strength of Paper TAPPI T807 Bursting Strength of Paperboard and Linerboard TAPPI T810 Bursting Strength of Corrugated and Solid Fiberboard

The TMI Group of Companies
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FIBRO System AB Stockholm, Sweden
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QUOTATION

SDL ATLAS
TEXTILE TESTING SOLUTIONS

Iowa State University
Attn: Chaitanya Dokala
Email: dcsrpk@iastate.edu
Phone: (515) 708-3537
Address: 4300 Westbrook Dr. Unit 30, Ames, IA 50014

Date: 8/5/2019
Quote #: MD 1317
Quotation Valid for 30 Days
Payment Terms: 100% Pre-Pay
Incoterms: Ex-works Rock Hill, SC

Dear Chaitanya,

Thank you for your interest in SDL Atlas. Your **requested pricing can be found below.**

Item code	Product Code	Description	Price
108555 (110V,50/60Hz)	M229	AUTOBURST BURSTING STRENGTH TESTER - The Autoburst is a hydraulic bursting tester with advanced testing controls. The instrument has automatic flow control allowing bursts to be achieved within the specified time of the standard. The advanced software provides diaphragm correction calculations for consistent results. These features, along with a maximum capacity of 6000 kPa (871 psi), make the Autoburst the most versatile burst tester on the market. Laboratory standard compressed air supply are not included. • Use for textile, nonwovens, paper, corrugated, plastic film, packaging • Hydraulic pressure to 6000 kPa (871 psi) • Quick change bells • Diaphragm correction • Automatic flow rate adjustment • Software analysis for full results • Distension measurement up to 70 mm • Two button clamping for safety • Integrated safety shield	$33,505
108421	M229/7	31 mm ASTM TEST KIT (7.55cm²), DESIGN 2018	$1,280
101266		RUBBER DIAPHRAGMS (Pack of 10) - For M229 Autoburst	$296
200135		BURSTING STRENGTH TESTER UKAS CALIBRATION CERTIFICATE	$182

QUOTATION

SDL ATLAS®
TEXTILE TESTING SOLUTIONS

Item code	Product Code	Description	Price
107828	M229P	PnuBurst Pneumatic Bursting Strength Tester - The PnuBurst provides unparalleled capabilities in a pneumatic bursting tester. Automatic flow control ensures bursts are achieved within the proper time according to standards. The instrument also provides diaphragm correction calculations to give accurate bursting pressures. A laser measurement system is used for distension height. The full-color touch screen controller is very easy to use and provides full test controls including clamping pressure and Marks &Spencer controls. Included software captures all of the data from standard burst tests for analysis. An optional software allows users to program special sequences such as cyclic testing or stretch and hold testing. Stretch and hold can be set to hold a given distension or a given pressure. With a maximum capacity of 1500 kPa (200 psi), the PnuBurst is the most powerful pneumatic burst tester on the market. • Maximum pneumatic pressure 1500 kPa (200psi) • Touch screen controller (English, Spanish, Chinese, Turkish) • Most common standards are preprogrammed • Quick change bells • Diaphragm correction • Automatic flow rate adjustment • Laser distension measurement • Distension measurement up to 70mm • Two button clamping for safety • Integrated safety shield • M&S approved There will be an additional software for advanced options such as cyclic and hold tests. This will be sold separately.	$22,353
107712		Advanced Software (for running special test sequences)	$1,969
101441		DIAPHRAGMS - For M229P Burst Tester, pack of 10	$138
108341		31 mm Test Kit (7.55 cm²)	$1,160
200135		BURSTING STRENGTH TESTER UKAS CALIBRATION CERTIFICATE	$182
104646		BOOSTER/REGULATOR AND AIR STORAGE TANK - To boost incoming air supply to allow M229P to utilize maximum test pressure at burst of 1500 kPa (200 psi) (15 bar)	$2,571

3934 Airway Drive Rock Hill, SC 29732 - +1 803 329 2110 - Fax: +1 803 329 2133
Email: info@sdlatlas.com - Web: www.sdlatlas.com

QUOTATION

SDL ATLAS
TEXTILE TESTING SOLUTIONS

Item code	Product Code	Description	Price
401956 (120V/60Hz)	G265	SILENT LABORATORY COMPRESSOR - Suitable for the provision of instrument quality compressed air with silent operation. Maximum pressure 8 bars (120psi) tank size 25L (6.6 U.S. gallons) maximum displacement 32 liters/minute (1.13 cubic feet/minute). Noise level 45dB(A) at 1 meter. Supplied complete with intake air filter, outlet air/oil filter/regulator and fittings. Larger capacities available, details on application.	$4,599

All of our products are subject to a one-year warranty.

Packing and Shipping costs are not included

If total purchase value is greater than $20,000 a 30% down payment is required.

Please Note: Next to our instruments, we also offer a wide range of test materials including Multifiber, Crocking Squares, and Ballast.

SDL Atlas is recognized by UKAS, a global accreditation agency, to perform ISO 17025 calibrations on your instruments and we are not limited to SDL Atlas equipment. Please contact us for a quote.

Kind regards,

Megan Davidson
Sales Manager
mdavidson@sdlatlas.com
(o): +1 803-329-2110 ext. 31
(c): +1 803-389-9034

INSTRON

Budgetary Proposal for Iowa State University
August 9th, 2019

Dear Chaitanya,

Thank you for taking the time to contact Instron. I have attached some brief information and budgetary pricing for two test instruments at the end of this document.

All Instron electromechanical instruments are made in the United States at our factory near Boston-MA by local Instron employees. Housing manufacturing, quality control, service and engineering functions under one roof helps us to ensure we deliver the highest quality test instruments available.

Below is some brief information regarding the Instron Models 3369 & 5969.

Models 3369 & 5969

Standard features include:

- Digital crosshead drive system with fully variable speed control.
- Integrated digital closed-loop control and data acquisition electronics.
- Crosshead extension and load measurement channels
- Automatic recognition and calibration of transducers.

The Series 3300 digital signal processing (DSP) electronics and linear load cells offer load accuracies better than +/-0.5% of reading down to 0.5% of the load cell capacity.

The Series 5900 digital signal processing (DSP) electronics and linear load cells offer load accuracies better than +/-0.5% of reading down to 0.1% of the load cell capacity.

Please visit our website for more information:

http://www.instron.us/en-us/products/testing-systems/universal-testing-systems/electromechanical/3300

http://www.instron.us/en-us/products/testing-systems/universal-testing-systems/electromechanical/5900

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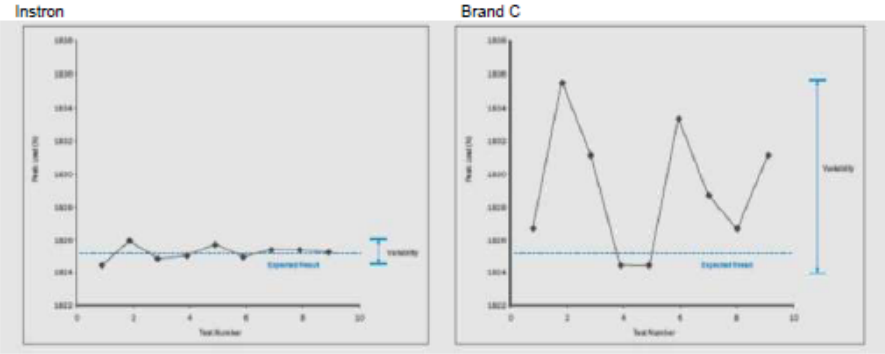
Data Integrity/Ease of Operation

- All Instron load cells and extensometers include an identification resistor that identifies its capacity and calibration values to the electronics. This allows operators to calibrate by simply pressing the clearly labeled icon or calibration key. Operators cannot mis-calibrate a load cell.
- All Instron test systems include state of the art electronic controllers with bandwidth optimized for low noise while maintaining rapid response to short lived events.
- Superior GR&R Results



Safety

- The self-identifying load cells described above allow the controller to automatically set the maximum load limit for a test to the capacity of the load cell. This will automatically stop a test that will damage a load cell even if the operator forgets to set any limits.
- All Instron test instruments have large digital displays that will allow operators to quickly see the current status of a test. The digital displays are located on the top portion of the computer screen and are designed specifically for safety reasons so that they cannot be covered with other window screens.

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- All Instron test systems include installation and on-site training in the safe operation of the test system.
- Optional test space enclosures are available.

Long Term Protection of Investment

- All Instron frames are designed with the highest quality materials and electronics. The ball screw design will provide many years of testing. Similar Instron instruments have been in use for over 25 years.
- Instron designs its' instruments with an upgrade path in mind. As technology changes the instrument can be upgraded to the latest computer and software.
- Instron test systems are supported by the largest worldwide service organizations in the materials testing industry. Most service can be handled over the phone from our Customer Service Center.

Customer Satisfaction

- Operating under ISO 9001 quality standards, all Instron electromechanical products are made in the USA by Instron. Instron employs a philosophy where customer satisfaction is paramount.
- Third-party post installation customer satisfaction surveys show that year after year, Instron exceeds our customers' expectations in regards to product quality, customer service, installation, applications expertise and training.

Please let me know if I can be of any further assistance.

Sincerely,

Anne E. Radville
Application & Sales Engineer
(781)234-4972
Anne_Radville@Instron.com

INSTRON STATIC MODELS	3369	5969
Factory Location	United States Boston-MA	United States Boston-MA
Load Capacity	50-kN (11,250-lbf)	50-kN (11,250-lbf)
Standard Vertical Test Space	47-in	47-in
Distance Between Columns	16-in	16-in
One Full Capacity Self-identifying Load Cell - 300% overload protection before mechanical failure. - Instrument automatically stops if the load exceeds 105% of capacity. - Reduce or eliminate downtime and costly repairs due to operator error. http://www.instron.us/en-us/products/testing-accessories/load-cells/static/2580-series-static/2580-301	Included	Included
Bluehill Universal Software - Insert photos of the test setup and work instructions. - Setup test prompts to walk an operator through the test process. - Automatic transfer results to files or database, no data entry required. - Integrated 22-in touch panel. http://www.instron.us/en-us/products/materials-testing-software/bluehill-universal	Included	Included
On-site installation and 1-1/2 Day training.	Included	Included
On-site ASTM / ISO Load, Speed & Displacement Calibration - Meets or exceeds ASTM requirements.	Included	Included
One Year Warranty	Included	Included
Budgetary Price for Frame (Educational Discount Included)	$50,000 - $55,000	$65,000 - $70,000

Fixtures Required

Ball Burst Fixture, **$5,500**

- ASTM D3787 Bursting Strength of Textiles

Puncture Fixture, **$6,700**

- ASTM D4833 Index Puncture Resistance of Geomembranes and Related Products

Puncture Fixture, **$8,750**

- ASTM D6241 Puncture Strength of Geotextiles and Related Products Using 50 mm Probe

Tensile Grips, **$2,500** (Manual Grips) - **$8,000** (Pneumatic Grips)

- ASTM D4595 – Wide-Width Geotextiles
- ASTM **D4632** – Geotextile Grab Test
- ASTM D5035 – Breaking Strength and Elongation Strip Length
- ASTM D6818 – Tensile Test of Turf Reinforcement Mats Tensile Grips
- ASTM D4533 - Trapezoidal Tearing Strength of a Geotextile

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LEAD TIME
4 to 6 Weeks from receipt of order, subject to prior orders.

PAYMENT TERMS
Net 30 days from Invoice Date, subject to credit approval.

DELIVERY TERMS
Please choose best option upon placing your order:

- Ex-Works (Collect, FOB Origin - title passes to buyer when goods leave the seller's dock) - please provide your collect account information.
- FOB Origin (title passes to buyer when goods leave the seller's dock), Instron to prepay and add shipping charges to invoice

TAX STATUS

If exempt, or partially exempt from taxes, please provide your tax exemption certificate with your purchase order.

Please Note: If any of the above fields are left blank on your purchase order, Instron reserves the right to default to the above preferred terms, and to ship FOB Origin via the most economical way and to add shipping charges to your invoice.

*** PRICES FIRM FOR 60 DAYS ***

WARRANTY: All Instron testing instruments are warranted against defects in material and workmanship for a period of one (1) year from the date of delivery, unless mutually agreed otherwise in the purchase documents. All equipment purchased from Instron but not installed by Instron Service Personnel or Instron authorized representative shall be warranted against defects in material and workmanship for a period of one (1) year from the date of delivery.

INSTRON HEREBY REJECTS ANY ADDITIONAL OR DIFFERENT TERMS OR CONDITIONS PROPOSED BY BUYER, WHETHER OR NOT CONTAINED IN ANY OF BUYER'S BUSINESS FORMS OR IN BUYER'S WEBSITE, AND SUCH ADDITIONAL OR DIFFERENT TERMS AND CONDITIONS SHALL BE VOID AND SHALL HAVE NO EFFECT UNLESS SPECIFICALLY AGREED TO IN WRITING BY INSTRON.

All Purchase Orders may be mailed to:
Instron, a division of ITW, Inc.
825 University Avenue
Norwood, MA 02062-2643

Or e-mailed to: info@instron.com

Or e-fax: (781) 634-0521, ATTN: Order Admin.

We accept Visa, MasterCard, and American Express
Prices above are for U.S. destination. Warranty and service commitments only apply to instrumentation installed in the U.S.

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5900 System Advantages Over the 3300 System

1. The 5900 System has a User Control Panel.

   The User Control Panel has the following features:

   a. It allows the user to run tests at the User Control Panel or from the computer keyboard.

   b. Along with jog buttons, it has a *fine position knob* that allows the user to finely position the crosshead easily.

   c. It has up to 4 programmable keys (such as Balance Load or Reset Gauge Length) and 4 programmable displays.

2. The 5900 System's Load Conditioning Circuitry provides a wider range of use of load cells than on 3300 Systems. The verified range of load cells when used on a 3300 System is down to 1% of the capacity of the load cell. On a 5900 System it is between 0.1 to 0.4% of the capacity of the load cell (depending on the load cell used & Standard or Advanced Option).

   Example: A 5000 N load cell on a 3300 System has a verified range down to 50 N. The same load cell could have a verified range on a 5900 System down to 5-20 N.

3. The 5900 System has the following machine specifications which exceed the 3300 System:

   a. Higher maximum test speeds, some as much as 3 times that of the 3300 equivalent system.

   b. Higher return speeds, some 2-3 times that of the 3300 equivalent system.

   c. Higher vertical test space (This is the maximum amount of grip distance with the crosshead fully extended. A higher vertical test space means the ability to test specimens with higher elongations.)

   d. Higher data collection rates available:

      (1) 5900: 1000 Hz [Standard Option] or 2500 Hz [Advanced Option]
      (2) 3300: 500 Hz (Bluehill 3) or 100 Hz (Bluehill Lite)

   e. Higher frame stiffness

4. The 5900 System has a Specimen Protect feature. This feature when enabled will protect the specimen from excessive tensile or compressive forces when clamping the specimen in the grips. If the load exceeds a specified value, then the crosshead will move to keep the initial force (prior to starting the test) below the threshold value.

5. The 5900 System is optimized for creep & relaxation testing. The 5900 System allows the user to collect data based on the change of up to 3 channels (such as time, load, extension, etc.). The 3300 System only has the ability to collect data based on time (example: 10 times per second).

   Example: The user wants to run a test where a load value is quickly approached (within 10 seconds) and then the extension is held for 10 hours while continuing to collect data.

   3300: If the user sets the data collection rate to 10 times per second, then the test for that specimen will include approximately 360,000 data points. This will result in extremely large data files. If the user sets the data collection rate to 1 time per minute, then the test for that specimen will include approximately 600 data points. The problem is that no data would be collected during the initial part of the test when the hold value is being approached.

   5900: The user could set data collection rates for 1 time per minute OR if the load changes by 1 N. In this scenario, the user will be able collect a sufficient number of data points without creating extremely large data files.

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6. The 5900 System has the following expansion capabilities:

a. Digital inputs, digital outputs, and analog outputs.

Examples:

(1) Output digital signal when a specified measurement is reached to command a temperature chamber to commence a temperature ramp
(2) Input a digital signal to end a hold during a test
(3) Output an analog signal for transducer measurements to a separate data logging device

b. Expansion Box allowing up to 8 additional transducers, such as an input from a thermocouple (for measuring temperature). Transducers plugged into the expansion box are treated as real measurements.

7. The 5900 System has an adjustable bandwidth filter. Data bandwidth defines the responsiveness of the system when converting data into an electrical signal that can be captured as digital data. Low bandwidth is less responsive but reduces noise in the test data. High bandwidth is very responsive but allows more noise which can result in scattered data and jumpy displays as shown below. Determining the appropriate bandwidth involves a compromise between the responsiveness of the system and the level of noise in the data.

8. Although the 3300 & 5900 Systems allow for identification of load cells based on capacity, the 5900 System also allows for identification of specific load cells (for load cells with Serial IDs). This means that the 5900 System can differentiate between two or more load cells even if they have identical capacities.

9. The 5900 Systems offer dual space, extra height, and extra width options. The 3300 Systems only offers an extra height option.

10. Additional gain adjustments to optimize system response when operating in Load or Strain Control. Both the 3300 & 5900 Systems allow for adjusting Proportional Gain for Loop Tuning to compensate for specimen stiffness differences. The 5900 System has additional adjustments beside Proportional Gain – such as Integral Gain & Lag Factor.

11. Most of the Top-Hat 2518-Series & 2525-Series load cells will mount (without additional hardware) to 5960-Series Systems but not to 3360-Series Systems. Most of the Top-Hat 2518-Series & 2525-Series load cells will mount (without additional hardware) to both 5980-Series Systems and 3380-Series Systems (This may not apply to the 5988 & 5989 Systems).

12. The alignment tolerances for the 5900 System typically exceed the alignment tolerances for the 3300 Equivalent System.