Feasibility Study of an Erosion Control Laboratory in New England

R. P. Long and K. R. Demars

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16. Abstract

This study examines the need for a soil erosion control testing facility in New England to evaluate erosion protection products and techniques. The study includes a survey of the 6 New England Departments of Transportation to assess their current approach to erosion control and future erosion control needs. A literature review is performed to identify current erosion testing laboratories, to evaluate capabilities and to determine the economics of testing. Both large-scale and small-scale erosion testing facilities are considered and each testing facility/ method is evaluated considering current soil erosion theories. Several testing laboratories were contacted directly, including site visits, to obtain needed background information. A series of recommendations was prepared for the New England DOTs that considers the economics and quality of results of erosion testing.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	mililitres	mL
gal	gallons	3.785	Litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

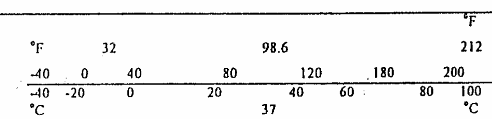
NOTE: Volumes greater than 1000 L shall be shown in m^3

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

* SI is the symbol for the International System of Measurement

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
		AREA		
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
		VOLUME		
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C+32	Fahrenheit temperature	°F



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1. Introduction

Erosion was probably the first environmental problem that affected humans. An early solution for the loss of topsoil was relocating to a different place and starting again. As the population increased this was no longer possible and humans became aware of the need to prevent erosion, first to save topsoil, then to prevent streams from silting up. The most common long-term solution to erosion is the establishment of appropriate vegetation to hold the soil in place.

On construction projects topsoil is often removed and stockpiled for use on the final configuration of the soil surface. The less fertile soil exposed during the construction process can erode and cause environmental problems. The soil that washes from the site can enter streams and effect aquatic life as well as silt up the channel and make it less attractive and less navigable. The soil particles must, therefore, either be held in place or contained on the site. Most states have a recommended list of Best Management Practices (BMPs) to achieve these goals.

To hold the soil particles in place, while the vegetation becomes established, requires a cover material. Many covers have been used to decrease the erosion from construction sites. Spreading hay has been a common method, facilitated in modern times with machinery that can blow the product into place. Wood waste products, such as pine bark, chipped stump or ground brush, have also been found effective in controlling erosion. Recently, rolled erosion control products (RECPs) have become available. RECPs are made of synthetic fibers and natural materials in many forms and styles. Soil solids are contained on the construction site with compost or wood waste filter berms, silt fences, or hay check bales. A list of BMPs appears in Appendix C. Although these were taken from the State of Connecticut (1988), they appear common to the other states. BMPs appear to be products or methods used to retain soil particles on a site. Most lists do not comment on the appropriateness for a given application.

Regardless which method is decided upon, the product used must be compatible with the soil on the site. A surface treatment must be able to dissipate the energy of the impacting raindrops and prevent the soil particles from being picked up by the moving surface-water and flowing downhill. In a sense the surface treatment must act like a soil filter. Similarly a berm/silt fence, which traps eroded particles before they can leave the site, must also be able to filter out the soil particles.

Today's dilemma for the Departments of Transportation is to determine which of the myriad of products on the market would be the best and the most economical for a given situation. New erosion control products enter the market each year and older products become modified as new methods of manufacture and new materials become available.

The question is, “How should new products be performance-tested?” Each of us would like to require that the manufacturer test the product at his/her expense at our site and on our soil. This is not a practical method since the manufacturer would never get done testing his or her product. A more economical and fair method is to have the product tested by some disinterested party concerned only with doing the test properly. That leaves one question:” What does doing the test properly mean?”

The work described in this report takes a look at this question of doing the test properly. The primary objective of any test is to yield results useful to anyone interested in using the product to determine if it will work on a specific site. Each site will have different characteristics, especially type of soil and slope. Soil types vary so much that it would be impossible to test a product against each type. Therefore, a rational, universal approach to erosion-prevention testing is needed.

This requires a review of the fundamentals of the erosion process to understand the mechanics of particle transport. Then the testing schemes are reviewed as to their adherence to these principles. Finally recommendations are made for solutions for the New England States that address an economical solution to product testing.

2. Literature Review

Erosion of soil from rainwater and wind has long been of importance in agricultural practice to preserve important topsoil and to improve runoff water quality (Ellison, 1944). Composts have been used successfully in agricultural applications to control erosion and aid in soil moisture retention when applied to the soil surface as a mulch (Banse, 1962). It has only been the last twenty five years or so (Israelson et al , 1980 a&b) that there has been a concern about controlling erosion on construction sites. Erosion control during construction has been achieved by the application of new geotextile products such as silt fence and erosion control blankets (Koerner, 1986) and more recently with organic mulches and source–separated composts (CONEG, 1996). A number of test standards have been developed (ASTM, 2002) to evaluate the properties and performance of geosynthetic and natural (compost) products for erosion control on construction sites.

Soil loss equations are used to estimate the quantity of soil eroded over a given area under specific conditions by the U.S. Department of Agriculture (USDA, 1951). There has been a series of developments in the last half-century or so related to the measurement and prediction of soil erodibility. In 1940, the first quantitative equation was developed in the Corn Belt region (Wischmeier and Smith, 1978). It is known as the slope practice method and it relates soil erodibility to the length and percentage of slope. This method served as the foundation for further soil loss equations and was the predominant method of soil loss estimation until 1946. Subsequently, Musgrave (1947) developed an equation which incorporates a rainfall factor into the soil loss estimation. That is to say, unlike the slope practice method, Musgrave accounts for the amount and intensity of rainfall events on erosion. While the Musgrave Equation was specifically used in flood abatement projects, it was quickly changed into a graphical rather than analytical analysis of soil erosion by 1952. This graphical analysis was primarily used in the northeastern states.

In 1954, the Universal Soil Loss Equation (USLE) was developed at Purdue University (Wischmeier and Smith, 1978). This was the first general (non-regional) analysis method of soil loss estimation on an annual basis. The USLE approach has three main parameters - a regional rainfall index, a soil erodibility factor, and a cropping and management component. The most recent advancement is a revision to the USLE and is known as the Revised Universal Soil Loss Equation (RUSLE). All of the aforementioned methodologies played a role in the development of the RUSLE. The RUSLE operates under the same variables as the USLE except that the RUSLE accounts for seasonal fluctuations in erodibility as well.

3. Traditional Erosion Quantification

3.1 The RUSLE

The first important approach to erosion control in the USA was that of the U.S. Department of Agriculture (USDA). The result of their research is called the RUSLE Equation, which accounts for the amount of soil eroded from an area of land depending on certain factors of soil, rainfall and land characteristics. The RUSLE method for predicting soil loss is widely considered the most accurate soil loss estimator. As a result, the USDA Natural Resources Conservation Service (NRCS) uses the RUSLE as its primary analysis method (USDA, 1997). The RUSLE estimates tons/acre of soil loss per annum. It predicts both long and short-term soil implications due to water erosion, but is not considered an accurate measure of erosion for periods less than a year because of climatic variations. These climate fluctuations are represented by the factor R, which considers the yearly rain characteristics. The RUSLE is used in many different ways by soil conservationists and geotechnical engineers to predict erosion and take steps to limit soil losses at agricultural, construction, and watershed sites.

The variables in the RUSLE were determined from an analysis of years of corresponding data (USDA, 1997). The RUSLE equation is written:

$$A = R * K * LS * C * P \qquad \text{(3.1)}$$

- ***A*** is the erosion loss given in terms of soil loss per unit area. The units of the R and K values define the units of the soil loss

- ***R*** is defined as the rainfall and runoff factor and was first used in the Musgrave Equation. The R factor is called the erosivity index and varies according to geographical location. The erosivity index is the annual summation of the energy supplied by all the rain drops in a given area times the maximum intensity over a 30-minute time interval. The energy supplied by a raindrop is dependent upon its size. Tables and maps for the entire United States have been created from compiled data of rainfall - the R values from these tables are used in the RUSLE.

- ***K*** is known as the soil erodibility factor and is one of the most important variables in the RUSLE. If all the variables that make up the RUSLE were held constant, some soils will tend to erode more than other soils. This disparity is the result of the inherent soil properties of a particular soil. Soil erodibility accounts for these soil properties. The K value can be evaluated graphically using a soil erodibility nomograh (USDA, 1978) or by using the K equation (Equation 3.3) shown below. The soil permeability, the percents of silt, clay and organic matter and the soil structure code are all incorporated in this equation (USDA 1978). The K factor can also be determined from experimental data on different soils while all other RUSLE variables are held constant.

- ***L and S*** are grouped together and referred to as the topographic factor. The L represents the length of the slope and S represents the incline of the slope. The velocity of water flow increases with the incline of the slope and the length of the area over which the water is flowing.

- ***C*** represents the cropping- management or cover factor. In agricultural land this factor generally accounts for the "tillage management crop, seasonal EI-index distribution, cropping history and crop yield level" (USDA, 1997). The C factor for bare soil is usually assumed to have a value of one. Obviously, there would be a difference in comparing an easily erodible soil such as silt with a less erodible clay. Both of these "bare" soils will erode different amounts during the same storm event.

- ***P*** is also related to the agricultural use of the RUSLE equation. The P factor takes into account methods of preventing erosion of tilled land by controlling the movement of water through such measures as proper drainage, blocking the flow of storm water with sod or other materials, etc. This factor is closely related to the C factor and overlaps its function.

This equation has limitations when applying it to the prediction of amount of erosion from a plot of land. The equation does, however, tie together the variables that affect the loss of soil from a site. Any site will have a certain slope and length. The steeper the slope or the longer it is, the more soil can be expected to erode. There is also no control over the precipitation that the area will receive, and we cannot change the soil readily. Therefore the only action that we can take to reduce the amount of erosion from the site is to change the effectiveness of the cover, represented in the equation by C. We do that by protecting the slope with some material while its vegetation is germinating and developing a root system to hold the soil.

When testing the effectiveness of a cover material in a large-scale test, the steepness and length of slope are constant and the same soil is used in the tests of bare and covered surfaces. Then if a storm of the same intensity and duration is applied to both areas, the ratio of the amounts eroded can be used to compute the cover factor thus:

$$\frac{A(\text{cov})}{A(bare)} = \frac{C(\text{cov})}{1} \quad \textbf{(3.2)}$$

It is important to note that the soil factor K has cancelled out of the calculation. How well any cover will protect an area will vary with the type of soil near the surface. Any testing of the effectiveness of a cover must also pay attention to the nature of the soil and its characteristics. Evaluation of an erosion control product requires attention be paid to both K and C.

The Equation 3.2 must be used with caution. Assuming that the C factor for bare soil always equals 1 has limitations. Various soils erode at different amounts and rates. The RUSLE Equation contains a term for the erodibility of soil in the term K. The assumption that the C factor for bare soil is always 1 carries the understanding that the K value predicts the erodibility of soil perfectly. There is limited experimental data that specifically looks at this question. The limited data available is shown in Figure 9.3 and indicates that the value of the product KC shows an increase as the K value decreases. This trend seems a little suspect and the difficulty is probably caused by the limitations of the RUSLE Equation.

Caution must be exercised when determining a value of C from the RUSLE. The use of Equation 3.2 may be somewhat appropriate for large-scale tests, when the applied intensity of rainfall approximates that received in a natural storm. Often erosion tests, especially small-scale tests do not test the system with enough artificial-raindrop energy to calculate a true C. It would be advisable to avoid the use of C when reporting results from tests whose rainfall impact energies do not approach natural field conditions.

3.2 Working with the Parameters

3.2.1 <u>The Erosivity Factor R</u>. As stated above the erosivity factor R in the equation depends on the energy of the rainfall reaching the ground and values have been worked out for various places in the USA. Data may also be available for other locations, but our interest is focused on North America.

There are also methods to calculate the erosivity of a given storm if the characteristics of the rainfall are known (Lal and Elliot, 1994;ASTM, 2000[i]). This can be used in testing erosion products, since the intensity, drop size and velocity are known or can be measured.

3.2.2 <u>The Soil Factor K</u>. The soil factor K indicates the erodibility of the soil. The easier the soil erodes, the greater its value of K. The soil factor K can be evaluated in two ways. One way is to estimate it directly from Equation 3.1, knowing R, and LS, and taking the bare soil as having a C*P = 1.0, the K can be calculated from the amount of soil eroded in a full-scale test, A in the equation. American Excelsior uses this method in its full-scale tests (Clopper, 2004). This approach does however yield some puzzling results, and should be used with caution when predicting amount of erosion.

A second method was worked out by USDA and is based on the sizes of the soil particles. In this method the K factor is computed from the equation:

$$\mathbf{100K = 2.1M^{1.14}(10^{-4})(12-a)+3.25(b-2)+2.5(c-3)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{(3.3)}$$

Where:

M is the particle size parameter = %(Silt+very fine sand)*(100-%Clay), when %Silt < 70%

a is the percent of organic matter

b is the "soil-structure code" that is used in soil classification. Table 1 of USDA (1993) lists different shapes and size classifications that can be attributed to b values of 1-4 as shown on the soil erodibility nomograph.

c is the classification of the soil permeability where a value of 1-6 is assigned to c.

The application of Equation 3.3 appears to be becoming a lost art. Most soils in the USA have already been classified by the USDA, and the classification includes a value of the soil factor K. Therefore there is little need for members of the Soil Conservation Service to be fluent with the terms in Equation 3.3.

The most troubling part of Equation 3.3 is the second term, which contains “b” the soil structure code. The value of K should be sensitive to the particle sizes in the soil. As reported by Lal and Elliot (1994) the values of b are as follows: very fine granular, 1; fine granular, 2; medium or coarse granular, 3; blocky, platy or massive, 4.

Very fine granular is the most erodible soil, but it is assigned a value of b=1. Substituting b=1 into Equation 3.3 yields a second term with a value of –3.25, which will reduce the value of K. Intuitively, this seems to be in the wrong direction. The presence of very fine granular soil will increase the amount of easily erodible particles, which would be indicated by a greater value of K.

The ASTM Standard Tests (2000[i], 2000[ii]), in addition to requiring a value of K for a soil used in a test, also call for classification of the soil according to the Unified Soil Classification System including Atterberg limits and measurement of the particle sizes passing the No. 200 sieve, and by the USDA classification system. These classifications should always be included so that a potential user can judge how his/her soil will perform.

4. Erosion Control Products

There are many natural and synthetic materials that have been used to control erosion. As part of this study, the New England DOT's were surveyed to assess their erosion control practices and needs. The survey questionnaire is presented in Appendix A and an item by item summary of responses to the 12 questions is presented in Appendix B. In general, the DOT's have used many of the available products to control erosion but with varying levels of success. The following traditional and manufactured products are frequently used by DOTs along with the characteristics that make them desirable.

4.1 Traditional Methods

Traditional erosion control methods use natural products, such as hay, to cover the soil until vegetation could be established. These products have been both effective and economical in many situations. Their lack of certain qualities such as strength make them unsuitable in demanding situations, such as steep slopes and channels.

a. Loose Mulches- usually hay or straw between 10 and 20 cm long. Good on flat to gently sloping land. Sometimes anchored into the soil.

b. Tackifiers – oversprays of viscous materials to anchor the loose mulch elements to themselves and to the ground. Tackifiers are often used when the slope angle becomes steeper.

c. Hydraulic Mulches – Primarily a method of applying mulches. Hydraulic mulches are usually a bit shorter than dry mulches. Have ability to absorb water allowing the hydraulic mulches to adhere to steeper slopes.

d. Wood Waste Products – A series of products resulting from various steps in turning timber into lumber. Have been shown very effective when applied in thicknesses of 0.75 inches or more.

4.2 Manufactured Products

Manufactured Products usually include materials known as geosynthetics. This group has come to be known as rolled erosion-control products (RECPs). These materials are capable of supplying tensile strength, which allows the product to be used on steeper slopes and to line channels. The products are designed to last only so long as needed. Some are stable for a few months, some for a few years and others are permanent. These products include:

a. Erosion-Control Nettings – two dimensional woven natural or geosynthetic nettings used for anchoring loose fiber mulches. Often used with hay or straw mulches.

b. Open-Weave Geotextile Meshes – usually woven or processed polyolefin yarns, having higher tensile strength than most nettings. Used on steeper slopes.

c. Erosion-Control Blankets – usually made of degradable organic or synthetic fibers bound to geosynthetic nettings. Typical blankets are made with straw, wood excelsior, coconut, polypropylene or a combination of these materials.

d. Geosynthetic Mattings – designed to be permanent or for drainage channels. Synthetic fibers and filaments stabilized against UV light in a 3 dimensional matrix. Usually in locations where the flow conditions exceed the velocities and shear stresses that natural vegetation can resist.

4.3 Desirable Characteristics of Erosion Control Products

There are several features of erosion control products that make them desirable to justify their use and extra cost. These include:

a. Holding the soil in place during the typical design storm. Flexible to conform to the soil surface and prevent some dislodged particles from moving away.

b. Retaining water so that it can infiltrate into the soil.

c. Allowing the sun to reach the soil so that vegetation will grow. Need a certain amount of open area.

d. Degrading as vegetation is established in cases where it is no longer needed, or

e. Permanently assisting the vegetation to contain the soil in cases of channel flow.

5. The Mechanics of Erosion

5.1 General

To analyze the applicability of a given test method, it is important to understand the principles underlying the processes taking place. Erosion is no exception. It is the action of water over the surface of the soil that causes the problem and there are two areas of hydraulics that deal in these mechanics: open channel flow and fluvial hydraulics.

5.2. Erosion Process Fundamentals/ Sediment Transport

Two mechanisms function in the erosion process on slopes: the impact of raindrops and the forces developed by flowing water. For channels the most important aspect is the flow of water. The impact of raindrops on the soil on a slope loosens the particles at the top of the soil making it easier for these particles to be picked up by flowing water. As the water flows over the soil the shear stress at the surface of the soil due to the water's velocity tends to lift the soil particles into the stream of water where they are carried along so long as the flow remains above the critical velocity to carry a particle of that size. When the velocity falls below the critical value, the particle becomes sediment.

The critical velocity and tractive forces have been subjects of investigation in Fluvial Hydraulics for a long time, because it is important to the understanding of the form and function of rivers. The tractive force is the shear stress necessary to start the particle moving along the surface of the soil. The critical velocity is defined as the velocity at which a particle of a certain size is carried by the water without being deposited or picked up. The pick up velocity must be somewhat larger than this and the particle will tend to deposit whenever the velocity falls below this value. The value changes of course with size and specific gravity of the particle, assuming the particle is surrounded by water.

Leliavsky (1966) shows that medium sand has a critical velocity between 1.0 and 1.5 ft/s, a velocity that appears obtainable under field conditions and in large-scale testing. The same reference (p. 45) shows that particles can be started in motion at small values of shear stress i.e. less than 0.5 lb/sq.ft. Investigations have also shown that the velocity of flow and tractive forces to move particles become greater for particles in denser, i.e. more compact, soil (Leliavsky).

5.3 Insight to the Problem from Open Channel Flow

Both sheet flow on slopes and flow in channels can be analyzed with the Equation known as Manning's Formula (Daugherty and Ingersoll, 1954). This will be demonstrated with the formulas for uniform flow in open channels. The Manning's Equation relating the velocity of the water flow to the characteristics of the channel shape and surface, as well as the slope, can be written:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2} \quad \text{……………………………………..(5.1)}$$

where:

V= velocity of flow in ft/s
n = roughness factor
R= hydraulic radius in ft (area of flow/wetted perimeter)
S= the soil slope

Equation 5.1 can be used directly for flow in channels. To use it for sheet flow on slopes, the hydraulic radius becomes the depth of flow, that is the height of water over the soil. The equation then becomes:

$$V = \frac{1.486}{n} H^{2/3} S^{1/2} \quad \text{……………………………………….(5.2)}$$

where: H = the height of the water in ft.

The shear stress on the soil surface due to uniform water flow in a channel is given by the equation (Daugherty and Ingersoll, 1954):

$$\tau_o = \gamma_w R S \text{……………………………………………………….(5.3)}$$

where : τ_o = shear stress
γ_w = unit weight of water
Other symbols as before

For sheet flow the equation for shear stress becomes:

$$\tau_o = \gamma_w H S \text{……………………………………………………….(5.4)}$$

Equations 5.1 through 5.4 can be used to estimate the flow and stress conditions that can occur during various storm events. For instance using Equation 5.2 one can estimate the flow on the surface of a slope and obtain the velocity of the water as it proceeds down the slope and Equation 5.4 allows us to estimate the amount of shear stress being developed. Equations 5.1 and 5.3 allow these calculations for channels. These equations show that while the critical flow values can be obtained in large-scale tests one must be more creative in the small-scale tests.

5.4 Erosion and Soil Properties

The soil properties that affect erosion are: particle size and distribution of sizes, compaction, permeability, water content and cohesion or plasticity. At a given velocity of flow, the smaller particles are more likely to be picked up and transported. Also a given size raindrop is more likely to dislodge a small particle that a larger particle. The greater the spread of particle sizes the more opportunity for interlocking and the less likely the chance for erosion. Compacting the soil makes the interlocking more effective and reduces erosion.

Permeability and water content are important parameters in that a high permeability will allow the water to infiltrate the soil and reduces the amount left to flow over the surface. Only the water that runs off can cause erosion. As the test or the rainfall continues, the water content increases and the rate of infiltration may decrease. Therefore it is important to know the water content and percent saturation of a soil being tested.

The most erodible soil particles are silts and very fine sands, because they are small and have only the force of gravity to hold them in place. Clay particles are smaller than silt particles but demonstrate an attraction for each other called cohesion. This attraction is best evaluated for erosion purposes through the property called plasticity measured by the Atterberg limits.

For an erosion-testing program to be effective it has to address each of these properties. For instance, if larger particles are eroded through a covering, one can conclude that smaller non-plastic particles will also be carried away. On the other hand testing with only silty soils would disqualify some products that could contain soil having only larger particles. This is the dilemma of trying to develop a test that satisfies everyone's needs. One way to surmount the size problem is to measure the particle sizes of the original soil as placed in the test bed and the particle sizes of the soil eroded during the test. The potential user can then compare both particle size distributions to their soil and make a reasonable estimate of the products potential effectiveness at their site. The particle sizes of the eroded soil may have to be measured by some electronic means.

5.5 Communicating Important Parameters

Additional items in a report on product performance should include:

a. Detailed test results, including maximum runoff, permeability etc
b. Particle size distribution of the eroded particles.
c. Small-scale tests should include shear stress testing at low values, about 0.5 lb./sq.ft.

This type of detailed information is needed to improve the understanding of erosion prevention and erosion control product performance.

6. Methods of Testing

6.1 Large-Scale Testing

Research has shown that the best test is the one that occurs in the field. Nature however does not always cooperate in producing the proper storms at the desired time to test these products. To overcome these shortcomings test facilities have been developed using rainfall simulators, but all test techniques reviewed have limitations.

The American Society for Testing and Materials has developed two standards for testing erosion Control products. The Standard Test Method for Determination of Erosion Control Blankets (ECB) Performance in Protecting Hillslopes from Rainfall-Induced Erosion is designated ASTM D6459-99. This standard includes a diagram of the rainfall simulator, cross sections of the slopes used in testing, and two grain size curves. The standard also calls for the soil used in the tests to be classified by several methods including the K factor. ASTM D 6460-99 presents a Standard Test Method for Determination of Erosion Control Blanket (ECB) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion.

The “test” soils contained in the ASTM specifications are shown in Figures 6.1 and 6.2. The size distribution of the loam is shown in Figure 6.1. As can be seen from the Figure there is more than 30 % passing the No. 200 sieve (0.075mm). The size distribution of the sand is shown in Figure 6.2. As can be seen in Figure 6.2, the sand contains more than 15% passing the No. 200 sieve. Of course the soil used in any one test will not have a particle size distribution exactly like these but the curves in the Figures show approximately what they should be.

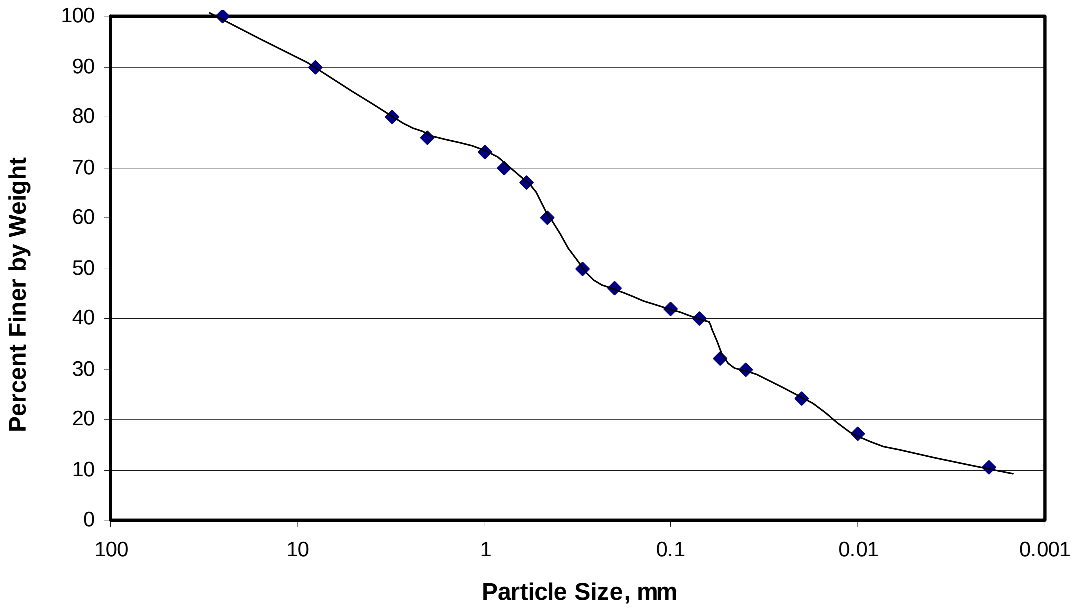

Figure 6.1 Particle Size Distribution for the ASTM Test Loam

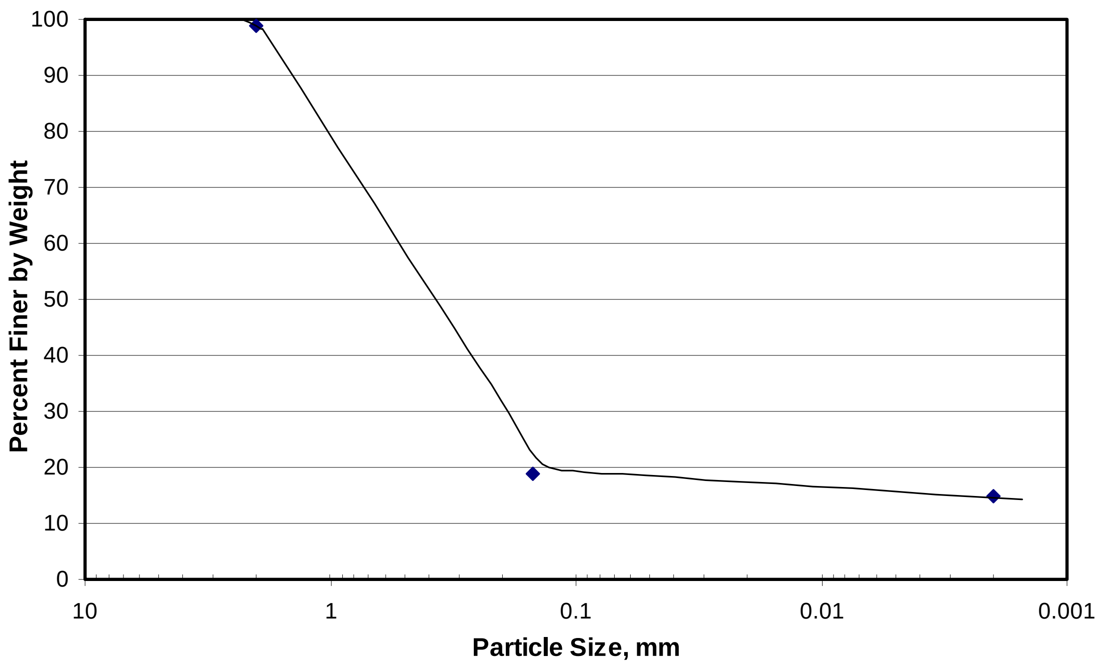

Figure 6.2 Particle Size Distribution for the ASTM Test Sand

6.1.1 Testing Hillside Slopes. Standard Test Method for Determination of Erosion Control Blanket (EBC) Performance in Protecting Hillslopes from Rainfall-Induced Erosion (ASTM D 6459-99)

6.1.1.a The soil used in the test

1. Defines test soils as Sand, Loam, and Clay. Gives particle size distributions for sand and loam shown in Figures 6.1 and 6.2. Includes Atterberg's plasticity index ranges for all soils. Calls for classification of the soils according to USCS, USDA, and "K" factor methods.
2. Specifies initial compaction of the soil at 90 to 95% of standard Proctor dry density, followed by tilling the surface of the soil to a depth of 100mm, raking it smooth, and compacting lightly before placing the blanket.
3. The top 150mm of soil must be replaced before each test run to insure that the same amount of erodible soil is present.
4. Must be at optimum water content +/- 4% at the time of testing. Water content must be sampled within one hour of the test. Plot must be wetted to achieve this moisture content.
5. Collect soil samples to determine total sediment.

6.1.1.b The test plot and setup

1. The test plot is to be 8m x 12m on a slope of 3H to 1V.
2. Edges of the plot are to be isolated so that no additional water enters the plot besides that supplied by the rainfall simulator.
3. A diagram of the simulator is shown.
4. Calibration of the simulator for both drop size distribution and intensity is described. Calibration of drop size and intensity are related.
5. Installation of the EBC and cautions about not disturbing the plot.

6.1.1.c Testing Process

1. Documentation of the site by video and still photos, before and after testing.
2. Apply the desired intensity of rainfall for 20 min.
3. Collection and processing of the samples of soil and water.
4. Report preparation.

6.1.1.d Commentary

This testing standard covers most of the important aspects of the erosion process in that it accounts for the soil type and plasticity, intensity of rain, etc. The test plot is long enough to allow the flowing water to attain velocities and shear stresses able to cause erosion. The soil surface is tilled which sets up conditions often present at the construction site.

There will be concern if the results are applicable to a soil that has a different particle size distribution from the soil used in the test. This is a concern primarily when the soil to be protected has more fine particles than that used in the test, since larger particle soils should perform better. A possible solution is to measure the particle size distribution of the eroded soil. This could be done electronically. Knowing the size of the particles eroded and the amount of those particle sizes in the soil of interest would allow one to estimate the protection properties for the soil of interest.

6.1.2 Channel Testing. Standard Test Method for Determination of Erosion Control Blanket (EBC) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion. (ASTM D 6460-99)

6.1.2.a The Soil Used in the Test

1. Defines test soils as Sand, Loam, and Clay. Gives particle size distributions for sand and loam as shown in Figures 6.1 and 6.2. Includes Atterberg's plasticity index ranges for all soils. Calls for classification of the soils according to USCS, USDA, and "K" factor methods.
2. Specifies initial compaction of the soil at 90 to 95% of standard Proctor dry density, followed by tilling the surface of the soil to a depth of 100mm, and raking it smooth before placing the blanket. Soil must be loosened along the reach and 1.5m above and below.
3. The top 450mm of soil must be replaced before each test run to insure that the same amount of erodible soil is present.
4. Cross-section the soil surface before and after the test.

6.1.2.b Test Area

1. Trapezoidal cross-section 2H to 1V side slopes, 0.61m bottom width, bed slope 5 to 10%.
2. Minimum length 24.4m. Test reach is 12.2m beginning 6.1m from the inlet pipe.
3. Calibrate the water delivery system. Use three-point measurement of the water velocity.

6.1.2.c Testing Process

1. Documentation of the site by video and still photos, before and after testing.
2. Apply the target shear stress for a minimum of 30min. to a maximum of 2 hr or to the time of a catastrophic failure.
3. Careful removal of the EBC and measurement of the soil surface.
4. Report preparation.

6.1.2.d Commentary

(Same as under 6.1.1.d in previous section under slopes)

6.1.3 Summary on Large-Scale Testing. The ASTM specifications appear to be a good guide for large-scale testing. However, our investigation haas not found a test facility that follows these specifications. The soils should follow as closely as possible the typical ASTM test soils. The sands should contain non-plastic fines. The soils used in the test should be classified by all of the methods listed in the ASTM specifications.

Reports should contain at least the particle size distribution and Atterberg limits of the soils used in testing. It should list the classifications for the soil as stated in the ASTM specifications. The amount of compaction should be stated or the dry density of the soil as tested. The water content or the percent saturation at the beginning and at the end of the test should be stated. The report should show how much water was actually applied and for what time and the amount of runoff that occurred. The amount of soil eroded from the site as well as the particle size distribution of the eroded material should be included in the report.

Departments of Transportation should require the manufacturers to submit large-scale test data when approving a product for use. The test data should include all of the information discussed above. Small-test data might also be required so that the product could be verified in the future by small-scale testing. If a manufacturer is not willing to submit such data, that product or products should not appear on the approved product list. Such test data should be available to all who request it, at least in the executive summary form.

6.2 Small-Scale Testing

6.2.1 General. The cost and difficulty of running large-scale tests has led to the desire for small-scale, less expensive testing, sometimes called bench-scale testing by the Erosion Control Technology Council (ECTC). There are other small-scale tests that have been used in studying erosion (U.Georgia), but ECTC is a manufacturer's organization and will probably influence the small-scale approach significantly. At present there are two ECTC testing protocols: one attempts to index RECPs on their ability to prevent rainsplash-induced erosion, the other attempts to index RECPs on their ability to prevent channel erosion caused by the shear stress of flowing water. There is as yet no correlation showing that these tests index the RECPs the same as large-scale tests.

6.2.2 Rainsplash Test. The rainsplash test is run by spraying water onto three samples of soil contained in 8-inch diameter plastic-molds on a sloping surface as shown in Figure 6.3. The soil samples in the molds are compacted to about 90+/-3% of maximum dry density at optimum moisture content of +/- 2%. Although it is not clear from Figure 6.3, and is not covered in the protocol, Texas Transportation Institute isolated the erosion to rainsplash-only by insuring that the top of each mold is about ½ inch above the sloped surface. This can be seen in Figure 7.5. In this way the water running down the slope does not flow over the surface of the soil or RECP. In the test setup shown in Figure 6.3 there will be considerable water running over the soil or covered surface in addition to that falling directly on the sample.

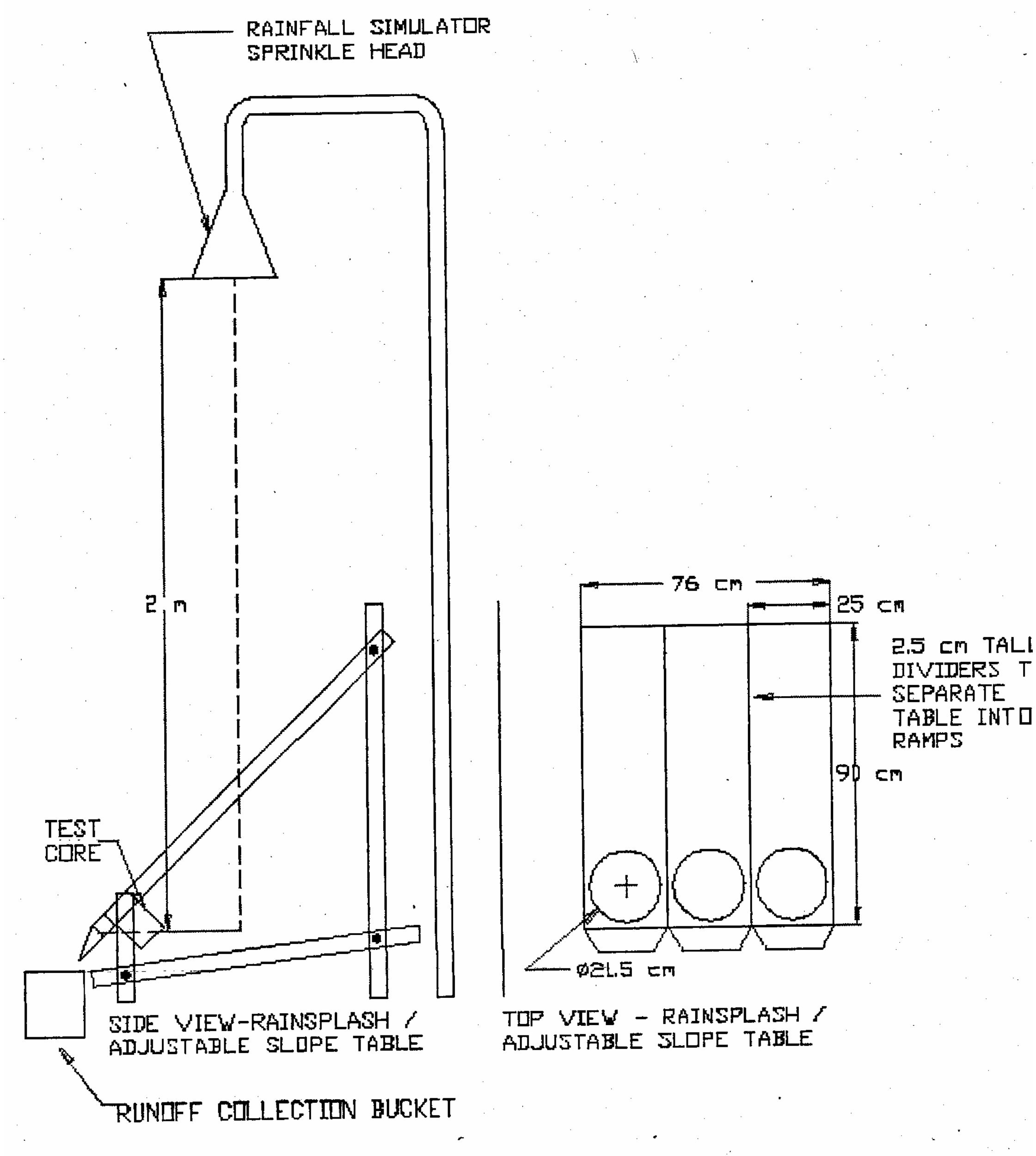

Figure 6.3 Rainsplash Test Apparatus from the Specifications of ECTC

When testing with RECPs the entire surface of the slope is covered with the product being tested. The test is conducted by placing a waterproof canopy or lid over the entire surface until the rainfall simulator is producing rain at the predetermined rate. The collection buckets are positioned at the bottom of the slope as shown in Figure 6.3 and the rainfall is allowed to impact the samples for 5 minutes. The water and eroded soil collected in each bucket is filtered through Whatman #3 filter paper. This procedure is repeated six times to produce 30 minutes of testing time. The same procedure is used for bare soil. The filtered samples are dried at 105 ^{o}C for 24 hrs and then weighed.

The test is conducted with both bare and RECP covered soil samples. The runoff is collected separately from each soil sample and the amount of eroded soil measured. The results are compared by the equation (ECTC, 2004):

$$SplashCoverFactor, SCF = \frac{M(RECP)}{M(Control)} \text{ ……………………………………}(6.1)$$

Where: M is the mean mass of soil. The splash cover factor should be calculated only for the summed 30-minute results

The rainfall simulator, as shown in Figure 6.3, is 2.0 m above the lowest point of the incline structure and must be capable of producing uniform drops 3.0 to 3.5 mm in diameter. The simulator must be capable of producing 130 +/-5mm/hr (about 5 in/hr). The method specified to measure the size of the drops is similar to the method presented in ASTM 2000[i]. There is nothing in this specification that addresses the velocity of the droplets at impact which is important when investigating rainsplash.

Another weakness of this procedure is the compaction of the soils. The soils in this procedure are relatively dense at the specified 90% of maximum dry density. Research in fluvial hydraulics has shown an inverse relation between compaction and movement of soil particles by water (Leliavsky, 1996). ASTM (2000[i]) has addressed this issue by tilling the top 100mm of soil after compaction but before testing for erosion.

The soil shown in the ECTC protocol is called ASTM sand, and the particle size shown is similar. The protocol allows for the use of other soils when the parties to testing are agreed. The protocol is mute on such important classification characteristics as Atterberg limits or K factor, and does not call for specific classification procedures.

This test is considered an index of the protection a manufactured product provides against raindrop impact. ECTC's definition of an index is to compare one product to another not to how any product might perform in the field.

6.2.3 <u>Channel Test.</u> Shear stresses produced by flowing water have been shown to initiate particle movement (Leliavsky, 1996). This is true for both channel and sheet flow. The second small-scale test applies a shear stress through water to the top of soil samples having the same size as in the rainsplash test i.e. 21.5 cm in diameter (about 8 in.). This test is designed to test the ability of the product to help the soil resist the shear stresses that accompany the flow of water over soil. This test is considered an index test of how a product may perform when used as protection for a channel.

The test apparatus is shown in Figure 6.4. The test apparatus includes a shear tank, false floor with test wells, transition cover plate, and motor-driven impeller. As can be seen from Figure 6.4 an impeller rotates over three soil samples developing a shear stress. The test is run over bare soil and soil covered with RECPs. The amount of soil that erodes at each of three stress levels is determined.

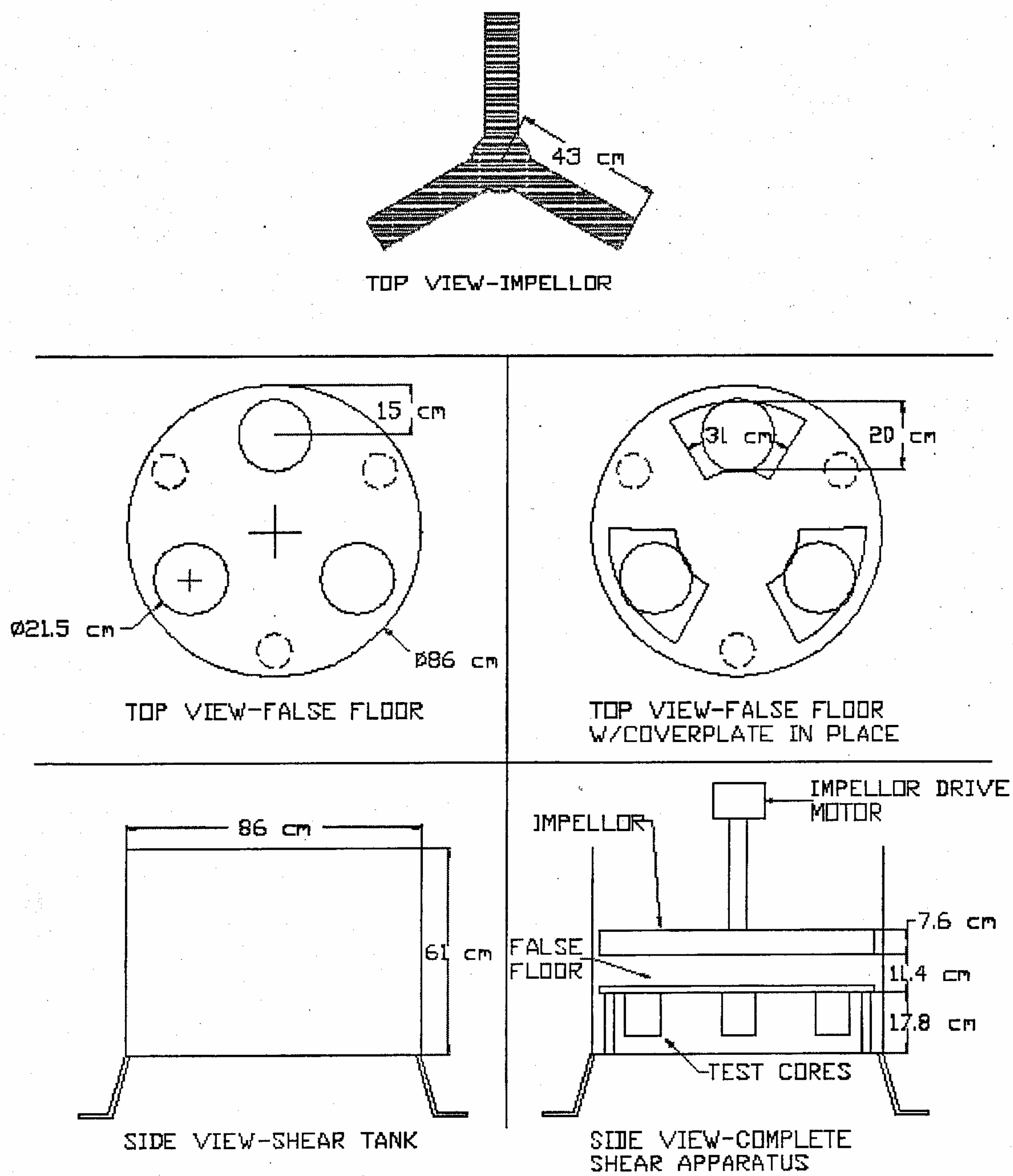

Figure 6.4 Schematic Diagram of the Shear Stress Test Apparatus

Due to differences in the surface roughness of various RECPs, the apparatus must be calibrated for each different type tested. The calibration involves gluing a sample to the surface of a plastic calibration disk, which is attached to an instrumented aluminum column. The calibration apparatus is placed in one of the plastic test core holders. The impeller is rotated through the water and readings of the force on the test platform recorded at various speeds to calibrate the device. During the test on soils, the shear stress is read from the calibration curve made with the load cell.

For this test the cores of soil are compacted and submerged for 24 hours to insure complete saturation. Each core is weighed in its submerged state and the submerged weight per unit length calculated. The amount of soil lost from each phase of testing is determined by measuring the submerged weight of the core and calculating the depth of soil loss from the equation:

$$SLc = \frac{SMi - SMf}{Cd} \quad \text{...(6.2)}$$

Where: SLc = average depth of soil loss
SMi = Initial submerged mass of core
SMf = Final submerged mass of core
Cd = Core linear density

The test is run at three different stress levels. At each level the samples are covered with a cover plate as shown in Figure 6.4, until the impeller reaches the speed to impart the desired average stress level to the surface of the sample. The cover plate is then rotated exposing the samples and the test is continued for 30 minutes. The cores are weighed then replaced for the next stress level test. It is recommended that the test be run in three stages-- first at the manufacturer's stress rating, then at one stress level above it and at one below it. Each stage of the test is to last 30 minutes.

A shortcoming of this test set up is the range of velocity over the various parts of the soil samples. Based on the standard dimensions of the apparatus and recognizing that the velocity of flow that causes the shear stress at the soil surface, the velocity of the rotor at the outermost point is 2.2 times the velocity at the innermost point of the soil sample. Analysis on an area basis shows that the ½ area on the outside experiences an average velocity that is 1.3 times the velocity experienced by the inside ½ area of the soil sample.

6.2.4 NTPEP. Small-scale tests have recently been used in an AASHTO project as part of its National Transportation Product Evaluation Program (NTPEP). A limited number of products have been tested under this program. The NTPEP tests were conducted by TRI Environmental, Inc. of Austin, Texas. They used a series of tests in the program to evaluate products on a national basis. The tests were conducted according to the ECTC protocols.

The AASHTO NTPEP tests yielded the results shown in Table 6.1. Unfortunately it is difficult to find large-scale results for some of these products. The index therefore relates only to small-scale testing. The values of soil loss from the columns 50, 100, and 150 mm are from the rainsplash test. The values represent the rate of rainfall in mm/hr. The values in the column "psf at 0.5" soil loss are from the channel test. When viewing Table 6.1 keep in mind that the soil loss factor is the reciprocal of the RUSLE "C".

The Soil Loss Factor shown is:

$$SLF = \frac{Loss(baresoil)}{Loss(coveredsoil)} \quad \text{..(6.3)}$$

Hence the soil loss values are all greater than 1.0. For several of the products the soil loss from the rainsplash test correlates with the loss from the channel test as shown in Figure 6.5. The values of soil loss ratio in the rainsplash test are plotted against the shear stress at a soil loss of 0.5” in 30 minutes for the North American Green test data for their products.

A plot of all the data at 150 mm/hr. is shown in Figure 6.6. The correlation in Figure 6.5 is better than that in Figure 6.6. The proper interpretation of these plots is open to discussion.

		Soil Loss Factor as 1/C			
Manufacturer's Name	**Product Name**	**50mm/hr**	**100mm/hr**	**150mm/hr**	**psf at 0.5" soil loss**
Erosion Control Systems	Duraguard C-1	22.2	18.5	16.7	3.5
Green & Biotech, Inc.	Sure Turf 1000	292.1	52.9	19.5	1.1
North American Green, Inc.	S75	8.8	8.16	7.81	1.8
North American Green, Inc.	DS75	9.72	8.8	8.31	1.8
North American Green, Inc.	S150	6.43	8.54	10.08	2.0
North American Green, Inc.	P300	11.92	10.79	10.17	3.3
North American Green, Inc.	C350	18.32	19.65	20.48	7.5
SI Geosolutions	Landlok S2	5.36	5.89	6.21	1.5
Western Excelsior	XCEL SS-2	6.7	8.87	10.45	2.1
Western Excelsior	XCEL CS-3	8.13	10.17	11.59	2.3
Western Excelsior	XCEL CC-4	7.52	8.18	8.6	3.1
SI Geosolutions	Landlok TRM 450	Withdrawn	Withdrawn	Withdrawn	Withdrawn

Table 6.1 Summary of Results from the NTPEP Tests. North American Green had 5 products tested.

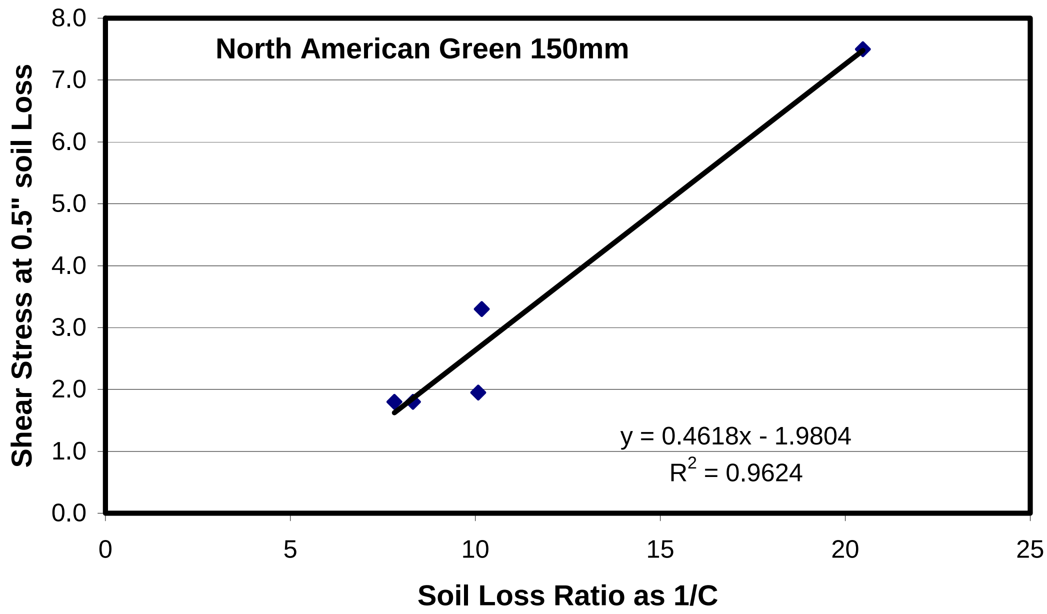

Figure 6.5 Comparison of Rainsplash Results at 150mm/hr with the Shear Stress Results for North American Green Products tested in the NTPEP Series

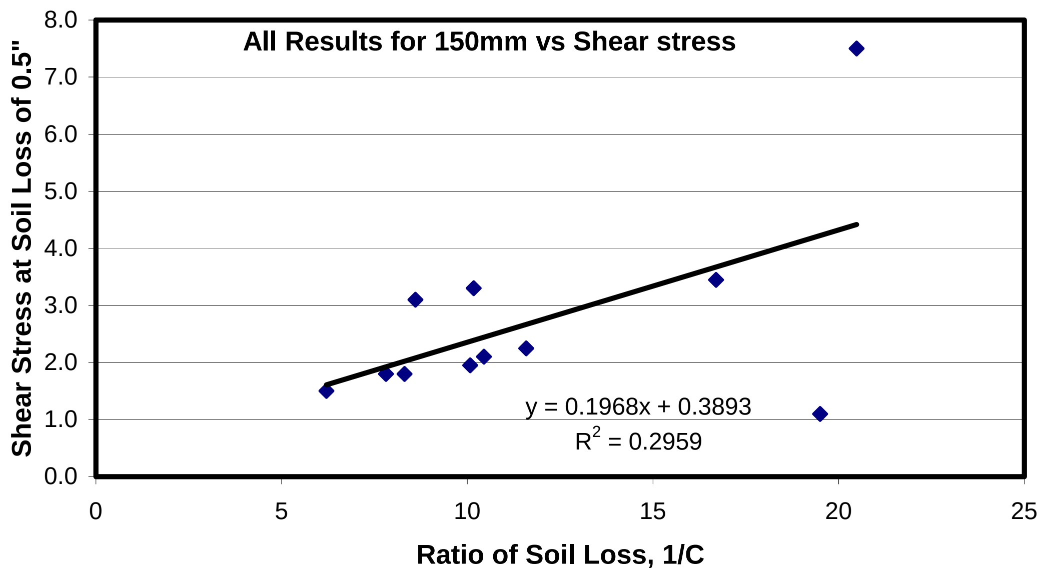

Figure 6.6 Comparison of Rainsplash to Shear Stress Results for all data in the NTPEP Series at 150mm/hr

6.2.5 Commentary on Small-Scale Testing. Exactly what small-scale testing attempts to index should be stated clearly. As this test is carried out at present, there is not enough water across the sample in the slope test for the flow to erode the particles. This coupled with the fact that the soil in this test is compacted to 90% of standard Proctor, biases the amount of soil removed to the low side. There may be some value in the test as now conducted to indicate how much soil would be loosened from the energy of the raindrops, but the compaction would also affect this by reducing the amount eroded. This is indicated by the low values of "C" factor from this test as seen in the recent NTPEP tests (NTPEP). The shear stress testing leaves much to be desired. Based on the results from the AASHTO –NTPEP tests, the shear stress testing is not carried at sufficient number of shear stress levels to draw a complete curve. The curves are very loosely fitted to the three values applied in the test and the origin. In some tests it appears that there may be a threshold value of the shear stress, i.e. a value below which the amount eroded is negligible. This would be valuable piece of information. At any rate the curves that appear in the report are not very useful. A fifty percent slope under a 3-inch per hour storm for 30 minutes may experience a shear stress of about 0.5 lb/sq.ft. It would be valuable if the test could be modified to include this amount of shear stress. The present shear stress load cells may not be accurate at these low stress levels, but an appropriate one could be developed.

6.3 Jet Index Method of Testing.

There is one test method that was developed to test the erodibility of soils. It is called the Jet Index Method, and is described in an ASTM Standard D 5852 (ASTM, 1995). This test was developed as a standard procedure for characterizing the erosion resistance of soils (Hanson, 1991). It attempts to address the erosion occurring in channels and uses river scour as a model. The test has the following objectives:

1. To provide a common method of expressing erosion resistance.
2. To assist in measuring erosion resistance of various soils for design purposes.
3. To provide a common system for characterizing soil properties for developing performance and prediction relationships.

This test can be run in the field or in the laboratory. It was designed to run on unprotected soil, but it appears that it might supply some information on the suitability of various products to protect soils. Some modification will no doubt be required. The field apparatus is shown in Figure 6.7. The laboratory set-up is shown in Figure 6.8.

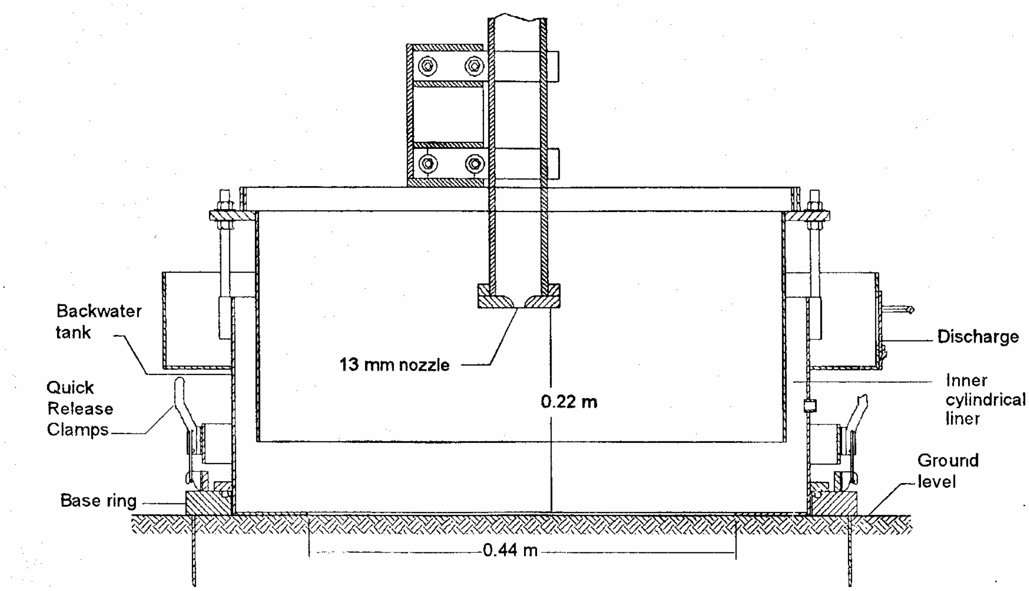

Figure 6.7 The Jet Index Test Apparatus for Field Testing

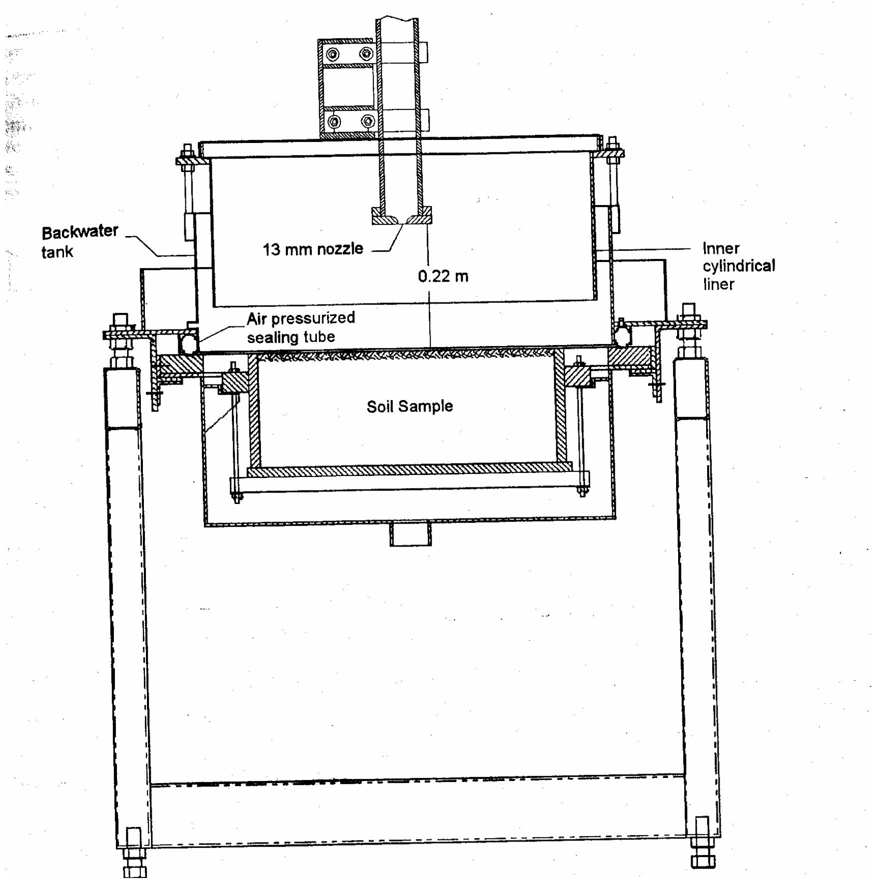

Figure 6.8 The Jet Index Test Apparatus for Laboratory Testing

A large mold for retrieving samples from the field is needed to bring large samples into the laboratory for testing. A submerged water jet is applied to the soil sample at a given jet velocity for a given period of time from 10 minutes to 1 hour. A differential pressure transducer is used to determine the mean velocity at the jet nozzle. The scour surface resulting from this procedure is measured with a pin profiler. The primary data from this test is the maximum erosion depth. Several jet velocities are used to complete the test. A log-log plot of the data yields a straight line.

The theoretical relationships of this test are developed through dimensional analysis. The theoretical development yields the equation (Hanson, 1991):

$$\frac{D_s}{t} = J_i U_o \left(\frac{t}{t_1}\right)^{-0.931} \quad \text{...(6.4)}$$

Where :

D_s= Maximum Scour Depth
t = Time
J_i= Non-dimensional Coefficient (Jet Index)
U_o=Velocity of Jet
t_1=1 second or the time equivalent of 1s.

The test results reported by Hanson show good agreement with his development.

6.4 Field Testing

Field studies investigated the ability of source-separated compost and wood waste to protect a typical New England soil on a construction site from excessive erosion (Demars et al, 2000; Demars and Long, 1998). These projects made field observations over several months at sites where construction was in progress. Fortunately during the time of testing there were sufficient rainfall events to produce meaningful results. A permanent test facility should include rainfall simulation. The detail design of such a facility is beyond the scope of this project.

A field test facility might be developed in New England, although it would only be functional for about 6 to 8 months of the year. If commercial products are to be tested, the tests will have to be run on a regular basis and not be dependent on natural rainfall. The rainfall-simulator standard should be similar to that shown in the ASTM Standard (ASTM 2000[i]). Rainfall simulation was not available at the Willington,CT site (Demars et al 2000). For planning purposes it would be appropriate to test two adjacent cells simultaneously with a rainfall of about 3.5 to 4.0 in/hr for about 30 minutes. To accomplish this requires a pumping system that can deliver 10 gal/min at 35psi.

An appropriate site would include a soil slope of about 3:1 next to a pond of water, with a borrow pit close by. The borrow pit would have to contain an appropriate soil for use in the test and the pond would have to contain enough water so that several tests could be conducted in a given day. The water could be pumped from the far side of the pond for the test and the water used in the testing could be replaced from the bank closest to the test location. The borrow pit would supply the soil to replenish the soil in the test area.

Testing would require about three or four of the simulators. They can be moved and placed to test other cells. It is recommended that the cells be tested serially, because after testing the cells must have the top 6" of soil replaced for the next test. Were there a series of cells, some cells could be under testing while others are being prepared for testing.

There of course needs to be means of collecting the soil and water that flow from the slope and an appropriate facility to test how much has been eroded. The testing should also include the amount of vegetation that will flourish under the protective cover. This can be accomplished in a small greenhouse.

The estimated items for this facility are as follows:

1. Water supply equipment
2. Earth moving and dressing equipment
    a. Front end loader
    b. Bulldozer
    c. Tiller
3. Three technicians
4. Laboratory

The most expensive items on this list are the technicians. The yearly expenses for three technicians are estimated to be between $240,000 and $300,000. The cost of item 1. including the pump and simulator fabrication is about $10,000. The Laboratory will be about $ 12,000.

6.5 Correlation of Large-Scale and Small-Scale Test Results

There is no information to date on the relation between the large-scale and small-scale test methods discussed above but there is agreement that large-scale tests tend to be a better predictor of field performance. The cost of large-scale tests is high which is justification to develop small-scale test methods if a correlation to field erosion prediction can be established.

The Federal Highway Administration (FHWA) has recently funded a study at Colorado State University to determine if correlations exist between small-scale and large-scale test results and if small-scale tests are relevant to the erosion control testing process. The results of this study should be available in early 2005 (Thornton, 2004).

7. Proving a Product

7.1 General

Potential users want to know how well the product will perform protecting their soils. The evidence they seek is usually supplied by some sort of test, in which storm and soil conditions are approximately what the product will experience in their area of the world. The end users need to be able to interpret these results and judge their applicability to their needs.

7.2 Large-Scale Test Facilities

Of the four large-scale test facilities, three are located at state universities: Texas Transportation Institute at Texas A. & M, Utah State University and San Diego State University. There is also a test facility located in Rice Lake, Wisconsin that is owned by American Excelsior, who hires an independent consultant to oversee the tests and analyze the results. The TTI facility at Texas A&M seems to be the most active. The available data from American Excelsior's consultant, Ayers Associates, appears most complete, but is limited to products from one company.

The Texas Department of Transportation (TxDOT) has worked with and supported the Texas Transportation Institute (TTI) since 1989. In this partnership, an Approved Product List (APL) of erosion control products has been developed and continually updated. The results since 2000 are not included in the APL published at the website. These have only been distributed to the States in a 'pooled fund study.

In 2000, TxDOT/TTI built a new multi-million dollar addition to their facility in order to incorporate weather related variables into their testing procedures (tti.tamu.edu). TTI claims that the new testing facilities will allow for "maximum control of critical variables to ensure that data is reproducible and regionally consistent (tti.tamu.edu)." This, of course, is the aim of this NETC project - to determine if the data these facilities are producing is regionally consistent and applicable to the Northeastern states.

TTI's test beds are shown in Figure 7.1. The closer bed contains clay and the farther bed contains sand. The rainfall simulator is shown in Figure 7.2. This simulator is capable of delivering 3.5 to 4 inches/hour of artificial rainfall to the beds shown in Figure 7.1.

TTI has also a greenhouse, which is used to determine the ability of vegetation to grow while covered by the erosion products. A test channel facility is beside the building that houses the sloped channel test beds as shown in Figure 7.4.

In addition to testing products in the erosion beds and channels, the products are also subjected to a number of specific property tests. These tests include for degradable products:

1. Tensile Properties
2. Material Properties

3. Resiliency
4. Mass per Unit Area
5. Water Absorption
6. Swell
7. Light Penetration
8. Stiffness
9. Smolder Resistance

For Non-degradable products the properties include:

1. Tensile Strength
2. Thickness
3. Resiliency
4. Mass per Unit Area
5. Specific Gravity
6. Porosity
7. Open Volume/ Unit Area
8. Stiffness
9. Light Penetration

Figure 7.1 Sheet Erosion Test Beds at TTI College Station, Texas

Figure 7.2 Rainfall Simulator at TTI

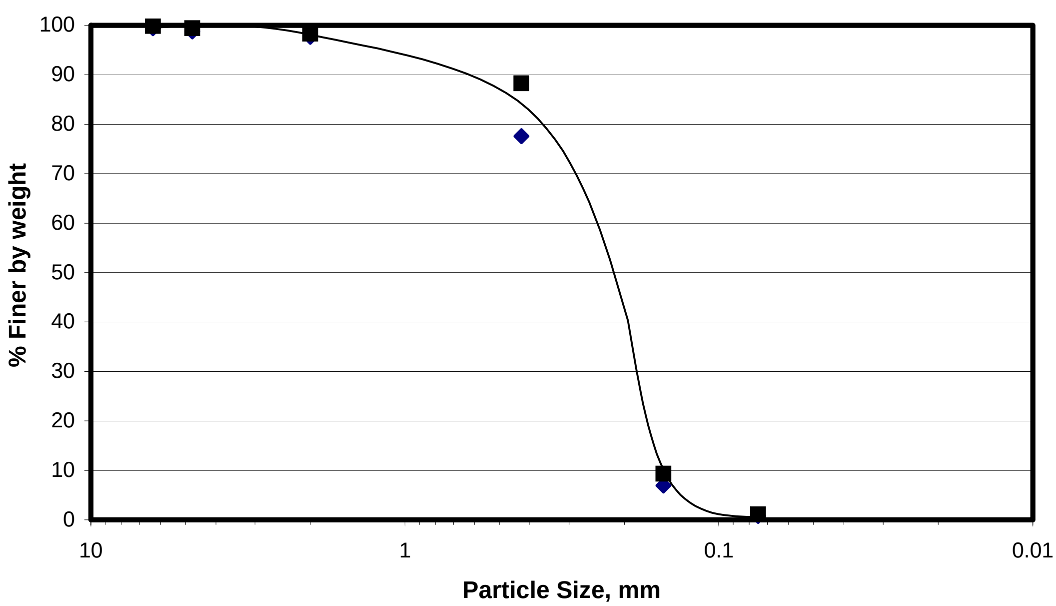

Figure 7.3 Particle Size Distribution of Sand used in TTI Tests

Figure 7.4 The Channel Erosion Test Facility at TTI

Some mention must be made about the soils used in the large-scale testing at TTI. The sand has a particle size distribution as shown in Figure 7.3 As can be seen from Figure 7.3 the test sand has no fines (<#200 sieve). It can be classified as a uniform medium to fine sand.

In an article on the TTI's website titled "Erosion control lab makes rain" details of TTI's new facility, the TxDOT Hydraulics, Sedimentation and Erosion Control Laboratory (HSECL), are listed (tti.tamu.edu). TTI claims to have the ability to accept and test soil from anywhere in the world or create specific soil profiles on command. TTI has a program in which any state can contribute to a pooled-fund research project in exchange for erosion control testing. These soils are tested in an indoor facility to control variables such as wind and rain. A massive rainfall simulator drops rain from 14 feet above the soil beds as shown in Figure 7.2. This allows the raindrops to achieve terminal velocity and the greatest impact force on the soil. A 30-foot long soil bed allows for testing at any desired slope up to 2:1 (tti.tamu.edu).

TTI is also capable of doing small-scale tests. Their equipment is used to discuss small-scale testing below.

The Utah State University (USU) hydraulics laboratory contains a 400 square foot rainfall simulator. It is typically run for a 1-hour period at up to approximately 20 inches per hour. The wooden erosion testing flume is 4 ft by 4 ft by 500 ft long and has a hydraulic lift that can tilt the testing flume (www.engineering.usu.edu). USU's testing facility is used more for educational purposes than the TTI facility, which is used mainly for commercial purposes. Blake Tullis, Assistant Professor at USU, estimates each test would cost about $5000 plus the costs of shipping large quantities of soil (B. Tullis, email communication, October 22, 2003). The USU laboratory is unable to create New England-type soil properties and, therefore, samples from the area would have to be shipped to the Utah facility. Professor Tullis estimates that the turn around time from the commencement of testing to the receipt of test results and analysis would be about 1 to 2 weeks.

The San Diego State University (SDSU) Soil Erosion Research Laboratory (SERL) is headed by director, Michael Harding. Harding was part of the construction of the SERL and estimates the construction costs to have been about $3.2 million. He states that the laboratory is seldom used and only to test erosion control products for private manufacturers. The laboratory at SDSU seems to be more versatile than the laboratory at USU. Harding makes it clear that any soil profile of interest could be created and tested on site. The cost for such a test is $2000 every time the rainfall simulator is activated. For redundancy purposes 3 tests are usually performed on each sample, bringing the total value to around $6000 per soil sample. The rainfall simulator usually conducts a Type II, 10-year storm event for the Los Angeles area. This storm event can be varied to correspond to a New England storm pattern. The time frame to receive a completed analysis on a given soil ranges from 3 to 4 weeks (M. Harding, email communication, November 1, 2003).

7.3 Large-Scale Testing

The typical test cell is from 6 to 8 feet wide and about 30 feet long. Some tests are conducted outside with the water being applied by a rainfall simulator. The intensity on the rainfall in inches/hour and size distribution of the raindrops are measured periodically.

To control the rainfall and the characteristics of the soil and the slope of the surface, large-scale facilities have been constructed indoors. Examples of these facilities are the Texas Transportation Institute’s (TTI) facility at College Station, Texas and the facility a San Diego State University in California. At these facilities, the surface of the soil can be sloped at various angles, usually up to 2 to 1 so that the effectiveness of the cover can be tested at the conditions found at a typical construction site. The cost of constructing such a facility is about $5 Million, and requires a substantial yearly operating budget. TTI is trying to solve some of its budget problems with the pooled fund study.

At a typical facility the rainfall is applied for a given period of time, usually 30 minutes, to a test cell with bare soil and to the same soil prepared the same way having an erosion protection covering. The covering is normally applied in accordance with the manufacturer’s instructions. In the two tests the length and the slope are the same so the LS term is the same. The soils are the same so the K is the same. The applied rainfall makes the R values the same for each cell and P does not really apply. One determines the ‘C’ value for the covering by comparing the amount eroded from the covered cell to the amount eroded from the bare-soil cell.

The difficulty with large-scale tests is that the tests are expensive. Cost per test can run as high as $3400 or more.

7.4 Small-Scale Test Facilities

As stated previously there is much interest in small-scale or bench top testing, because of the lower costs involved. There are as yet no test results to show how small-scale testing correlates with large-scale testing. The Erosion Control Testing Council (ECTC), a manufacturers’ organization has developed the protocols in use today. These facilities can be more widespread since they require much less space and can be accomplished in most laboratory settings. There is a FHWA study underway at Colorado State University to compare large-scale to small-scale test results in hopes of finding some correlation. In the meantime ECTC is pushing the bench top tests as “Index” tests, but is not sure what they are indexing.

TTI’s equipment for the rainsplash test is shown in Figure 7.5. As can be seen in Figure 7.5 TTI sets the soil cylinders about ¼ to ½ inch above the surface of the inclined plane. This insures that all the erosion is due to the impact of the raindrops, but this arrangement is not called for in the ECTC Specifications.

Figure 7.5 Rainsplash Testing at TTI

The tank in which the shear stress testing is accomplished is shown in Figure 7.6. The rotator blades are not visible because of the turbidity of the water. The shear stress load cell in shown in Figure 7.7. This device is placed in one of the locations for a soil sample and the system is calibrated as rpm vs. shear stress. The load cell must be calibrated for each product.

Figure 7.6 Shear Stress Test Tank

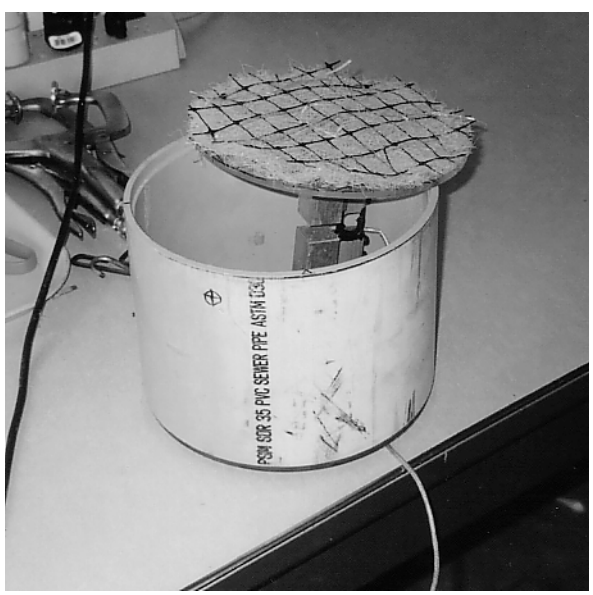

Figure 7.7 Shear Stress Load Cell

8. Approved Products List

Some states have posted Approved Products Lists (APL) on their websites. Usually there is little or no explanation as to the bases for these selections. The concept of the APL is good in that both the designer and the contractor know what is acceptable. Most states that post a list of products, do not list the criteria or any rationale by which these products were selected.

TxDOT has an extensive APL for the years from about 1995-2000. After this the data has only been supplied to the participants in their pooled fund study. The website for TTI show the criteria by which the products are approved by the TxDOT. The maximum soil loss from slopes is reported in kilograms of sediment per 10 square meters of test area. For channel liner products the criteria is cm of soil lost. The particle size distribution of the sand used in these tests is shown in Figure 7.3. Figure 7.3 shows that the sand is a uniform medium to fine sand with little fines.

Wisconsin DOT states on their website that the manufacturers must submit results from large-scale testing for the product to be approved with subsequent periodical submittals of ECTC type test results to insure that the quality of the product is constant. The rules do not require that small-scale tests results be submitted originally, so it is not clear as to how one will keep track of the quality if the performance of the original material in small-scale tests is unkown. The specific criteria for product acceptance are not listed on the website, only the test results that must be submitted.

Other sites do not list their acceptance criteria and, as a result, acceptance of a product for the APL appears to be very subjective.

9. Manufacturer Test Data

9.1 General

No agency will accept a product without some sort of performance verification, from a field demonstration to a very detailed controlled test. The problem with a field test for erosion control products is that a storm of critical intensity and duration may not occur during the field trial. Therefore the field trial may not give information for the critical case. To insure that the critical storm will be applied to the product, a testing situation is needed in which a storm duration and intensity can be simulated.

Controlling the application of rainfall is only one phase of the test procedure. The other important variable is the soil that is being protected by the product. The properties of the soil include both the properties of the individual particles and the compaction used in placing it. Both of these properties affect the amount of soil that can be eroded and will therefore affect the amount of soil displaced during the test. Small non-plastic silt particles can be most readily displaced by both the impact of the raindrops as well as being carried away by a lower velocity of water. Soil compaction affects these values directly because a more compact soil will require greater water energy to remove the particles both by impact and velocity of flow. Although these principles are well known in fluvial hydraulics, they do not seem to be applied in any rational manner in erosion testing.

Another soil property that affects the amount of soil eroded, but gets little attention is the permeability of the soil being tested. This is important for higher permeability soils that allow infiltration of water at the beginning of storms with lower intensities. Water that percolates into the soil cannot erode soil. The permeability of soil varies with time and water content during testing.

9.2 Difficulties

A preliminary review of websites containing approved products lists led to a request for test data from companies who had prepared reports for submission for product approval. Two States that have procedures for acceptance on their website are Texas DOT and Wisconsin DOT. Texas has an extensive list of products tested by the Texas Transportation Institute. This list shows all test results including those that pass and those that did not. The criteria include both the amount soil eroded and the generation of vegetation. The Texas website does not mention the availability of test reports. The Wisconsin DOT website lists its approval procedure but not its criteria. The manufacturer must submit results from large-scale testing for inclusion on the approved list and periodically submit results from small-scale testing to keep the product on the approved list.

Each product on Wisconsin DOT's approved product has had a report submitted to the State. An email request for a copy of the report submitted to Wisconsin DOT was sent to manufacturers on the list who had not been previously contacted. This request, although asking for a report that had already been prepared, caused a reaction that seems a little peculiar. Our request, emailed directly to companies, resulted in a letter from a

Laura Honnigford of the Erosion Control Testing Council (ECTC) stating that this information, “was available, but not readily available”. It is obvious that some companies do not want to give out test data. The reason is not obvious, since this data has already been submitted to at least one state DOT.

9.3 Cooperating Companies

Two companies have been very cooperative: American Excelsior and North American Green. Both of these have provided information in answer to our simple request. American Excelsior provided Executive Summaries of their test results. These tests were overseen at their facility by an independent consultant, Ayres Associates. Paul Clopper one of Ayres Associates who oversaw the tests was very cooperative in discussing their approach. These results pointed out the importance of permeability to the test results. Although they did not measure permeability, they measured the amount and rate of runoff during the tests, which showed how infiltration reduces the amount of soil erosion. Their test results are shown in Figure 9.1

Figure 9.1 shows the data for the sand and loam are nearly linear. The data from the clay is a bit scattered, but the trend with amount of runoff and erosion is clear.

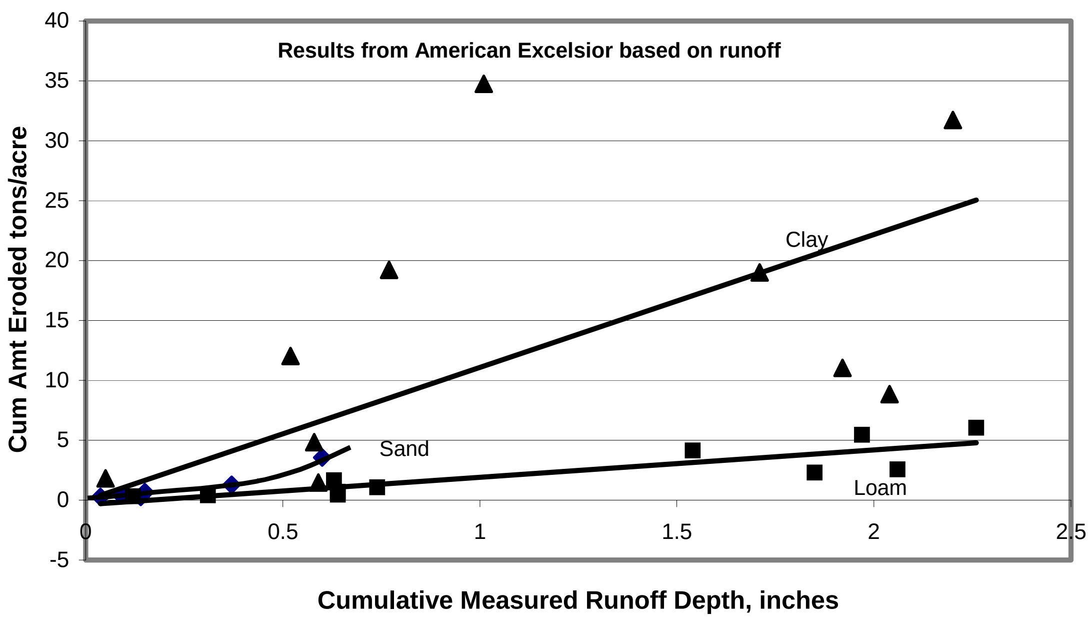

Figure 9.1 Data from American Excelsior Tests Showing Cumulative Runoff Depth versus the Cumulative Amount Eroded

North American Green also supplied data on the soil used in the tests, including particle size distribution and Atterberg limits. North American Green has some interesting software that can be downloaded from their website (www.nagreen.com). This software allows the user to select North American Green Erosion Control Products according to USDA classification system. In using this software, one can set parameters such as slope, length, “C” factor, etc. Although this software selects only NAG products, indexing may allow a wider use.

North American Green also supplied information about the soil used in their testing. The particle size distribution of their soil is shown in Figure 9.2.

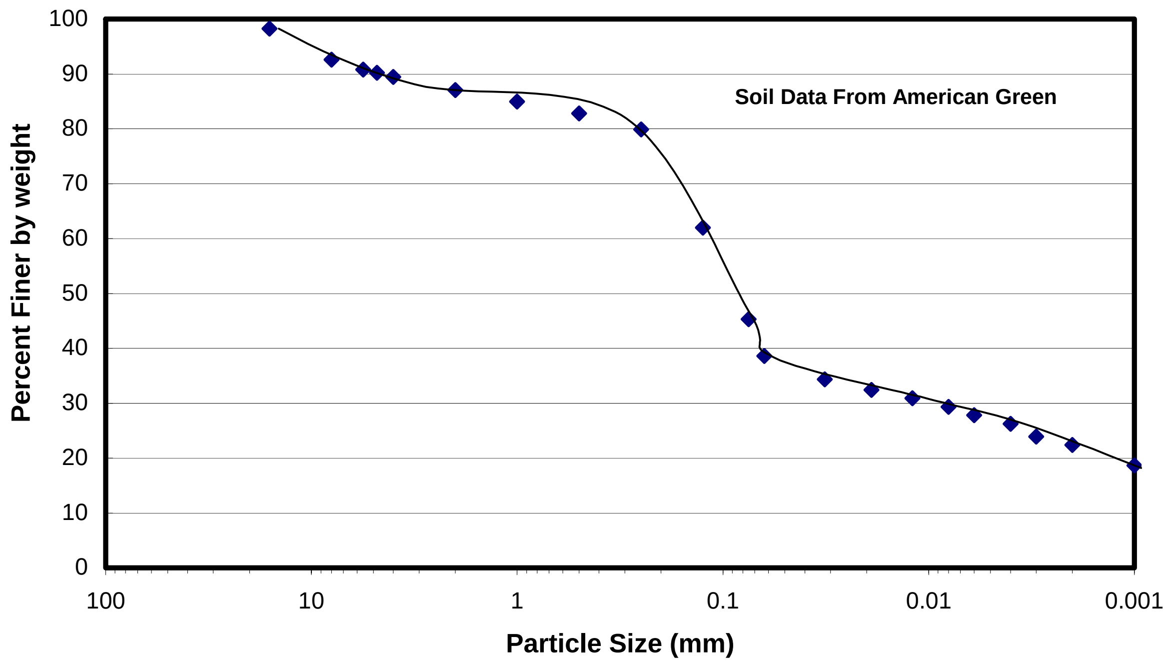

Figure 9.2 Particle Size Distribution of Soil used by North American Green

Figure 9.2 shows that this soil contains a high amount of fines. Atterberg limits for the soil are LL=31.6, PL= 26.2 and PI=5.4. This soil appears to be highly erodible.

The tests reported by American Excelsior measured the K values of the test soils directly from the runoff from the bare soil. They used soils with three different Ks: a sand, a loam, and a clay. Their results showed some interesting trends in the calculated C values for the various cover products. The loam had the greatest K, the sand was intermediate and the clay the least. The calculated Cs varied with the soil: smallest for the loam, intermediate for the sand and greatest for the clay.

This indicates that, as the K decreases, the C may increase. In these tests although there was less soil coming through the cover, the calculated C increased, because the C factor is a ratio between the amount coming from the bare soil, which is lower for a lower K soil, to the amount coming through the cover. In the few cases that we have so far been able to analyze, as the K factor increases, the product CxK as it appears in the equation tends to decrease. This phenomenon requires more study, since it indicates that the less erodible a soil is, the more protection it needs. Perhaps this shows one of the limitations of the RUSLE Equation to analyze the test results.

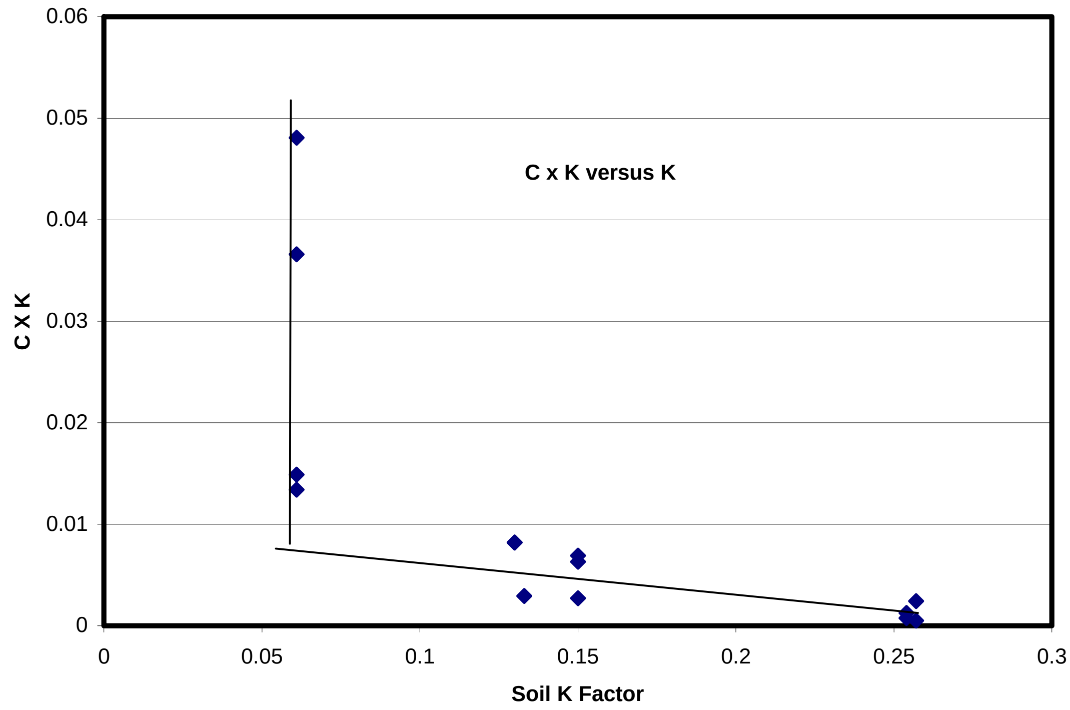

Figure 9.3 Plot of the Product CxK as it appears in the RUSLE Equation versus the Soil Factor K

10. Summary, Conclusions and Recommendations

10.1 Summary

This study examines the need for a soil erosion control testing facility in New England to evaluate erosion protection products and techniques. The study includes a survey of the 6 New England Departments of Transportation to assess their current approach to erosion control and future erosion control needs. A literature review was performed to identify current erosion testing laboratories, to evaluate capabilities and to determine the economics of testing. Both large-scale and small-scale erosion testing facilities are considered and each testing facility/ method is evaluated considering current soil erosion theories. Several testing laboratories were contacted directly, including site visits, to obtain needed background information. A series of recommendations was prepared for the New England DOTs that considers the economics and quality of results of erosion testing.

10.2 Identify Testing Needed at a New England Laboratory

New England States need to know the ability of erosion control products to protect their soil. There are two considerations: the soil characteristics and climatic conditions. New England has glaciated soils, that is, soils that have been caused by the formation and movement of the glaciers during the last ice age. This has resulted in soils that have fine non-plastic particles such as occur in glacial tills.

These needs can be satisfied without physically running the tests in the North East. The test soils must have an adequate component of fine grained non-plastic soil particles so that the test will show how well the product will protect this size particle against movement under the influence of raindrops and flowing water. There is no reason to believe that a 0.050mm particle that is non-plastic found in some other part of the country is any different in behavior under erosive forces as a similar particle in New England.

The climactic conditions present in New England insure that each winter the ground freezes to a certain depth depending on location and severity of the winter. The freezing process tends to accumulate ice in the pores between soil particles increasing the size of the pores and decreasing the bulk density of the soil.

It would be uneconomical to have a test installation in New England that had to wait for the frost season to test the products ability to protect the soil against erosion under thaw conditions. The solution to the problem is to understand the mechanism of the process so that a good simulation can be attained. The simulation for the effects of frost on the erosion of a soil is to control the density of the soil near the surface so that the erosion forces can act as they would on a soil that has been frozen and thawed. This can be done in a number of ways, also allowing the appropriate test to be done in a number of locations, so long as the mechanics and processes are understood and incorporated into testing.

Of the three large-scale testing facilities available to various manufacturers, the test facility at the Texas Transportation Institute appears to be the most utilized. The income from charges for testing of products falls short of the annual cost of operating the facility. The facilities at San Diego State University and Utah State University appear to have intermittent testing of erosion control products.

The Texas Transportation Institute is at present hosting an FHWA pooled fund study to evaluate erosion control products. This is outlined in a promotional video that states:

a. Each participating state may have a representative on the Pooled Fund Study Committee.
b. The Committee is responsible for setting direction of the Laboratory testing program.
c. Future direction includes providing performance data for:
    1.)Rolled and non-rolled erosion control products
    2.)Mulches and Channel Liners\
    3.)Turf Reinforcing Mats
d. Future Direction includes:
    1.) Developing a better understanding of erosion control processes.
    2.) Development of reliable low cost test methods.

10.3 Feasibility Analysis of a New England Test Facility

10.3.1 Economic Considerations. Large scale testing is the only type testing shown to simulate field conditions. A test facility could probably be sited in many places in the North Eastern United States. What is required is a soil slope whose soil can be regenerated, a supply of water to apply to do the testing and means of measuring the resulting erosion.

Large scale testing is very expensive. It is expensive for both the manufacturers as well as the laboratory itself. At the present time it does not appear to be a self-sustaining operation. Consider the following:

- A full scale test facility such as the one at Texas Transportation Institute would cost an estimated $3M to $5M to construct. The yearly budget is approximately $375,000 and the income from testing is approximately $110,000. This means that there must be much thought given attracting additional funds. TTI has used the pooled fund study to supplement these funds and there may be a couple of research projects supplying overhead funds. The short fall must be made up with DOT funds.

- The companies must pay to have their product tested. It will be very expensive to test each product against each soil using a variety of climatic conditions.

- The test facility at San Diego State University is not in constant use.

- The required nationwide testing, if handled correctly, could be accomplished most efficiently at one large-scale test facility.

- The Federal Highway Administration indicated to us that they would not support another large-scale test facility at this time.

10.3.2 State of the Art Considerations. AASHTO is developing a National Transportation Product Evaluation Program (NTPEP). This approach is focusing on the bench top test approach using the testing protocols developed the Erosion Control Technology Council (ECTC). As of this writing there is no correlation between large scale and bench top testing. Bench top testing is considered "Index Testing," which means each product is compared to the others.

10.3.3 Considerations Endemic to New England. New England regional factors include soil type and climate- especially frost action. Both of these factors are related. The soil used in testing a product for its capacity to protect against erosion must have a sufficient amount of granular particles finer than 0.075mm to insure that the test will show how well the product retains them.

The climactic feature of importance in the North East is frost and the subsequent thaw. The action of frost is to make the soil less dense, and therefore more erodible. The density of the soil near the surface is the most critical and can be controlled by tilling as outlined by ASTM (ASTM, 2000[i]; ASTM, 2000[ii]).

10.3.4 Solution. It is not feasible for the New England States to build a test facility at this time. The necessary information can be obtained in less costly ways. The two considerations that are critical to New England can be addressed through testing with specifications similar to those of ASTM (ASTM, 2000[i], ASTM,2000[ii]).

1. For instance, the ASTM Sand shown in Figure 6.2 has about 16% of its particles by weight passing the No. 200 sieve (0.075mm). The plasticity index (PI) as determined by the Atterberg limit tests in the Unified Soil Classification System is limited to 4.5 to 5.0, which insures that the soil particles will be erodible. A test soil that will yield meaningful results for New England will have similar properties perhaps a bit more soil particles in the fines region.

2. There must be one additional measurement of the soil particle size distribution that should be included to insure that the results can be interpreted for any soil of interest. The size of the soil particles that are eroded are collected at the base of the slope, dried and weighed, should also have their sizes measured and reported. The additional step is: That the particle size distribution be measured of the soil particles eroded and collected at the bottom of the slope.

In this way the particle sizes that erode through the protection system can be compared to the amount of those same size particles in the soil of interest that must be protected. Then the product must not be tested against an infinite number of soils.

3. The other concern for New England is frost action. There is a provision in the ASTM Specifications that provides for loosening the top 100mm of the soil by tilling and lightly compacting it before testing. The critical issue is what amount of "light compaction" is appropriate to simulate frost action, but this is not a big impediment. The density of typical New England soils can be measured after frost has been experienced and the soil thawed. This will give a value of the soil density to which the soil in the test should be compacted before the simulated rainfall is applied.

4. Testing of special products, such as wood waste, can be handled is several ways. The product could be sent to a test facility for evaluation. Or a research project could be awarded to one of the state universities. In either case, ASTM Specifications should be followed.

10.4 Identify Additional Study Tasks

1. Each New England State should become ***an extremely active partner*** in the pooled fund study at the TTI. An extremely active partner must insist on the best approach to erosion-control-product testing. If each of the New England States became a member of the pooled fund study and voted as a block to direct the testing so that the tests would be most useful to the transportation and construction areas in general, a win-win situation would develop. The NETC States would get the information they need and the testing at TTI would be more valuable to more States and their pooled fund study group would increase.
2. The New England states must insist that the soils and testing conditions follow guidelines similar to the ASTM Standards.
3. They must also insist that the particle size distribution of the eroded soil be measured and reported for each test.
4. The progress of small-scale testing should be monitored. It may be possible to get the necessary information from these tests, with the proper correlation.
5. If these steps are pursued and do not yield the necessary information, a good case can be made to federal agencies as well as state government for constructing a test facility in New England.

10.5 Conclusions

Based on the results of this study, we conclude:

1. At present large-scale testing is needed to predict with reasonable accuracy the performance of erosion control products. Large-Scale testing should be the main source of information until the results from the bench top tests are shown to produce information that can be used by designers to predict performance.

2. Large-scale testing is expensive.

3. Even at the TTI facility, income from product testing falls short of budget.

4. The characteristics of soils used in erosion control testing should be similar to those recommended in ASTM Standards D6459-99 and D 6460-99.

5. Testing should be based on the fundamental principles of open channel flow and fluvial hydraulics.

6. The desire to reduce costs has led to the development of small-scale (bench top) tests.
7. At present the results from large-scale and small-scale tests have not been correlated.
8. Indexing of erosion control products with small-scale tests has not been well established to date.

10.6 Recommendations

1. The most economical way to get needed information about erosion control products is to become *an extremely active partner* in the pooled fund study at the TTI.

The testing features that must be requested as a pooled-fund participant are:

a.) Follow ASTM Standards for type of soil used, or use a soil with a larger component of non-plastic fines.

b.) Handle the compaction properly especially the part about tilling to a depth of 100mm.

c.) Measure the particle size distribution of the eroded particles.

2. The NETC States would have to convince the Committee and TTI to use soil of low plasticity (i.e. high K value) whose particle size distribution is more in line with that of the ASTM Standards. The ASTM Standard Tests (2000[i], 2000[ii]), in addition to requiring a value of K for a soil used in a test, also call for classification of the soil according to the Unified Soil Classification System including Atterberg limits and measurement of the particle sizes passing the No. 200 sieve, and by the USDA classification system. These classifications should always be included so that a potential user can judge how his/her soil will perform.

3. It is recommended that the large-scale testing include measurement of the particle size distribution of the soil that is eroded. The size of the soil particles that pass through the system will give a good indication which other soils the product will protect.

4. The progress of small-scale testing should be monitored and correlated with the experiences of the NETC States. Successful correlation will produce the most economical solution.

5. Special erosion control methods, such as the use of wood waste, can be most economically tested by a large-scale facility that uses a soil with characteristics similar to those in ASTM Standards.

6. A regional field-testing facility as discussed in Section 6.3 could function effectively for 6 to 8 months of the year, but at a significant cost. This type of facility with a rainfall simulator could provide needed regional information.

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Appropriate DOT Website Addresses -examples of Approved Products Lists

CalTrans: //www.dot.ca.gov/ (access Erosion Control Products List)

FLDOT: //www.dot.state.fl.us/ (access Doing Business with State, Qualified Products List, Erosion Control Items, Erosion Control)

GDOT: //www.dot.state.ga.us/ (access Business Opportunities, Approved Materials, Quality Products List, Erosion Control)

PennDOT: //www.dot.state.pa.us/ (access Doing Business with PennDOT, New Products Evaluation, Mulch and Erosion Control)

TXDOT: //www.dot.state.tx.us/mnt/erosion/contents.htm (access eBusiness, Specifications, Erosion Control Products)

WIDOT: //www.dot.state.wi.us/business/engrserv/pal.htm (access Product Acceptance List-PAL)

12. Appendices

Appendix A Questionnaire

The following questionnaire on erosion control practice and needs in New England was submitted to representatives of each New England Department of Transportation for their input to this study. This survey has been compressed from its original form to save space in this report. A summary of responses to the 12 questions in the survey is presented in Appendix B.

Survey Form
Erosion Control
Practice and Needs in New England

(This survey is part of a study for the New England Transportation Consortium)

Agency____
Person completing this questionnaire ___________________________
Address____
City____________________State________-Zip_________
Phone No.___________________ Fax No.________________
Email address__________________

Please answer the following questions. More than one answer may apply.

1. For what length of time does your agency use erosion control measures? (Check all that apply.)

- ❑ Temporary construction measure - 0 to 3 months
- ❑ Semi- permanent measure – up to 2 years
- ❑ Permanent Installation- over 2 years

2. Indicate all of the types of erosion control protection that your agency uses or has used. (See definitions in Appendix)

a. Natural Products — Comments

- ❑ Loose mulches ____________________________
- ❑ Tackifiers ____________________________
- ❑ Hydraulic mulches ____________________________
- ❑ Wood waste ____________________________
- ❑ Source separated compost ____________________________
- ❑ Other (state type) ____________________________

b. Manufactured Products — **Comments**

- ❑ Erosion-control blankets ____________________________
- ❑ Erosion-control nettings ____________________________
- ❑ Erosion Control Re-vegetation Matrix____________________________
- ❑ Geosynthetic mattings ____________________________
- ❑ Open-weave geotextile meshes ____________________________

- ❑ Combination(s) of the above (state)____
- ❑ Other (state)____

3. Does your agency have a pre-approved product list? Yes________ No__________

If yes please attach a copy of your pre-approved list.

4. How does your agency obtain the information necessary to approve a product either for your pre-approved list or for a specific erosion protection application? Check all that apply.

- ❑ Tests by this agency
- ❑ Tests by other DOTs
- ❑ Demonstrations by the manufacturer
- ❑ Demonstrations by Federal Highway Administration
- ❑ Tests conducted by an independent center for erosion testing.
- ❑ Research conducted on various products and methods

5. Have the available products and methods produced satisfactory results?

a. Natural Products — Advantages/ Problems Encountered

- ❑ Loose mulches ____
- ❑ Tackifiers ____
- ❑ Hydraulic mulches ____
- ❑ Wood waste ____
- ❑ Source separated compost ____
- ❑ Other ____

b. Manufactured Products — Advantages/Problems Encountered

- ❑ Erosion-control blankets ____
- ❑ Erosion-control nettings ____
- ❑ Erosion Control Revegetation Matrix_______________________________________
- ❑ Geosynthetic mattings ____
- ❑ Open-weave geotextile meshes ____
- ❑ Combination(s) of the above (state)____
- ❑ Other (state)____

6. What criteria does your agency use to determine the success or failure of an erosion control installation?

- ❑ Overall water quality near the installation
- ❑ Turbidity of runoff
- ❑ Soil loss from the site
- ❑ Vegetation establishment
- ❑ Other ____

7. What kind of soil has your agency found to be most difficult to protect from erosion?

Soil Description___________________________________

According to the ______________________________Classification System

Please provide a 2lb sample of the troublesome soil(s), if possible.

If your agency is having difficulty with more than one soil, add sheet(s) with the information asked for under 7 for each additional soil, and provide a sample.

8. Has your agency had difficulty trying to protect slopes steeper than 3 horizontal to 1 vertical? Yes______ No________

9.When selecting materials to prevent soil erosion, what information would you like to have and from which sources? Include the influence of cost in your decision.

____

____

10. Comment about your agency's problems in using products to prevent soil erosion. Include methods of comparing products. (use additional sheets if necessary)

____

11. Does your agency feel the need for a New England Erosion Control Testing Facility at the present time? Why?

____

12. If you would rather talk to us about your experiences and /or problems with erosion treatments you can contact us at: (860) 486-2074 or (860) 486-2339.

Appendix B <u>**Questionnaire Summary**</u>

The following agencies and individuals responded to this survey:

Connecticut DOT (CT)	Andrew J. Mroczkowski
Maine DOT (ME)	Robert LaRoche Peter Newkirk
Massachusetts Highway Department (MA)	George Batchelor Patricia Trombly
New Hampshire DOT (NH)	Guy J. Giunta Jr.
Vermont Agency of Transportation (VT)	David Wiley Jonathan Armstrong

Question

1) *What length of time does your agency need erosion control measures?*
   Each agency has a need for temporary construction measures (0-3 months), semi-permanent measures (up to 2 years) and permanent installations (over 2 years).

2) *Types of erosion control protection your agency uses or has used?*
   a) <u>*Natural Products*</u>
      - Loose Mulches- All report use of these materials
      - Tackifiers- MA/ ME use these to anchor hay in wind
      - Hydraulic Mulches- All states use these materials
      - Wood Waste- All states use these materials
      - Source-Separated Compost- All but VT use these
      - Other- MA lists hay bales

   b) <u>*Manufactured Products*</u>
      - Erosion Control Blankets- All use these (ME requires 100% org.)
      - Erosion Control Nettings- Seldom used- concern for wildlife
      - Erosion Control Re-vegetation Matrix- minor useage
      - Geosynthetic Mattings- All use/ rip-rap replacement
      - Open Weave Geotextile Meshes- All use except ME
      - Combinations of Above- Minor use of combinations
      - Other- MA has used "soil sement" for dust control

3) *Does your agency have a pre-approved product list?*
   CT, ME and NH have a pre-approved product list

4) *How does your agency approve a product for a specific application?*
   - Tests by this agency- CT, ME and NH use this method
   - Tests by other DOTs- All but VT use this method

- Demonstrations by the manufacturer- Some use with caution
- Demonstrations by FHWA- Very little FHWA information
- Tests by an independent center such as T.T.I. and NTPEP-CT, ME, NH and VT use this info
  - Research on various products and methods- MA/ NH use this

5) Types of erosion control protection your agency uses or has used?

a) <u>Natural Products   Advantages/ Problems</u>

- Loose Mulches—inexpensive, works well, east to apply, promotes vegetation/ moves from wind or water
- Tackifiers—holds mulch together to prevent movement
- Hydraulic Mulches—quick, inexpensive, can add seed and moisture/ dry in summer, adds moisture
- Wood Waste—works well, available (often on site), good on tough sites/ poor revegetation, cost increasing
- Source Separated Compost-- good soil amendment, good fertilizer/ cost increasing
- Other- NA

c) <u>Manufactured Products   Advantages/ Problems</u>

- Erosion Control Blankets—works well when installed correctly, good for steep slopes and ditch liner, good re-vegetation/ costly, difficult to install on steep slope
- Erosion Control Nettings- good to hold hay and loose mulch in wind, good growth/ polynet banned, poor degradation
- Erosion Control Re-vegetation Matrix- no comments
- Geosynthetic Mattings- replacement for rip-rap, worked well/ costly, affects seed growth
- Open Weave Geotextile Meshes- no comments
- Combinations of Above- no comments
- Other- no comments

6. What criteria does your agency use to determine the success or failure of an erosion control installation?

- Overall water quality near the installation- most are concerned
- Turbidity of runoff- all use this criteria
- Soil loss from the site- all are concerned
- Vegetation establishment- all are concerned
- Other- No comments

7. What kind of soil has your agency found to be most difficult to protect from erosion*?* Soil Description *<u>Silt, sandy loam, clay/ ML, CL, ML-CL</u>*

According to the <u>USDA/ Unified</u> *Classification System*

Please provide a 2lb sample of the troublesome soil(s), if possible.

No samples provided

8. Has your agency had difficulty trying to protect slopes steeper than 3 horizontal to 1 vertical? Yes __**X**____ *No*________

All agencies had troubles depending on rainfall, soil, erosion protection, etc

9.When selecting materials to prevent soil erosion, what information would you like to have and from which sources? Include the influence of cost in your decision.

All agencies desire information from an independent or government testing laboratory. They prefer field test performance data that defines site and soil limitations, construction problems, material specifications, effect on re-vegetation and product availability. Cost is a factor used to compare alternative products for a specific job.

10. Comment about your agency's problems in using products to prevent soil erosion. Include methods of comparing products. (use additional sheets if necessary)

- No quantitative way to compare products- comparison is visual and selection is often based on professional judgement.
- Difficult to evaluate product except thru field use at several sites.
- Most products do not consider soil type or unique (weather/site) conditions in New England.
- Products often difficult to install because of rocks, roots, wet spots, soft soil, steep slopes, etc.
- DOT specifications may be too loose allowing contractors to select an inappropriate product—many designers are unfamiliar with available products and limitations.
- More information on natural products such as composts and mulches are needed to increase their use including empirical data on performance and test methods for comparison of different mulch products.

11. Does your agency feel the need for a New England Erosion Control Testing Facility at the present time? Why?

- Seven of the eight responses supported the need for a New England Erosion Control Testing Facility of some form to deal with unique regional conditions.
- One response was that a regional facility is not needed because the Texas Transportation Institute provides very good data on products and AASHTO's NTPEP is starting to look at rolled erosion control products.

12. If you would rather talk to us about your experiences and /or problems with erosion treatments you can contact us at: (860) 486-2074 or (860) 486-2339.

Appendix C **<u>Best Management Practices for Soil Erosion Control</u>**

Construction projects under federal, state or local control are required by law to use best management practices (BPMs) to control soil erosion. While the ultimate goal is to establish a permanent vegetative cover, this may take several months unless a costly sodding is used as the final vegetative cover. Thus, there exists a need for soil erosion control methods to prevent soil particles from moving to a water course until a vegetative cover can be established. There are many soil erosion control methods and the objective of this report is not to recommend any specific method or to define how a particular method is specified and implemented but to list some of the best management practices for erosion control.

The Connecticut Guidelines for Soil Erosion and Sediment Control (1988) lists the following BMPs as:

<u>STRUCTURAL MEASURES</u>

a. Grassed Waterway
b. Diversion
c. Permanent Lined Waterway
d. Sediment Basin
e. Detention Basin
f. Construction Entrance
g. Outlet Protection
h. Subsurface Drain
i. Riprap
j. Gabions
k. Reinforced Concrete Retaining Wall
l. Precast Cellular Blocks
m. Prefabricated Retaining Wall
n. Grade Stabilization Structure
o. Temporary Stream Crossing
p. Temporary Channel Lining, and as

<u>NONSTRUCTURAL MEASURES</u>

b. Temporary Mulching
c. Permanent Mulching
d. Dust Control
e. Topsoiling
f. Land Grading
g. Sediment Barriers
h. Silt Curtain

The focus of this study is to examine the type of test facility that is needed in New England to measure the performance of non-structural measures including natural products, such as composts and mulches, and manufactured products such as geosynthetic nettings, silt fence and erosion control blankets.