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# Soil Erosion & Sediment Control Plans

by

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**Introduction:**
This course presents an overview of the specific features that go into the design of a Soil Erosion & Sediment Control Plan and also the maintenance required for many of the plan elements. When you complete this course you should be familiar with the most commonly used soil erosion and sediment control practices and know the main design features which will minimize off-site impacts of a construction or other land-disturbing project.
The main reference used in the preparation of this course is "The Standards for Soil Erosion and Sediment Control in New Jersey', 7$^{th}$ edition (2014) published by the NJ Department of Agriculture and the State Soil Conservation Committee. However, there are many state & county agencies that have published similar standards for areas under their jurisdiction.

Construction practices, mining operations, agricultural activities, and other land disturbing projects have the potential to significantly increase soil erosion and sedimentation. This, in turn, can have dire consequences on the quality of downstream waterways, wildlife communities, and human life and welfare

A well-developed plan that is maintained consistently throughout a construction project can virtually eliminate any soil erosion and sedimentation resulting from the project. It can reduce both short term and long term impacts associated with land disturbance including dust, erosion, degraded water quality, and damage to downstream properties.
However, if the plan is not well thought out, or if the erosion control features are not maintained both during and after construction, there can be significant detrimental effects on downstream properties.

As an example of this, the lined channel in the photograph below has not been properly maintained, is badly eroded and is in need of replacing.

The mud shown in the photograph below is due to erosion of the lined channel shown above. The channel must be replaced in order to prevent additional build up of sediment in this area.

The soil erosion & sediment control plan should be designed to prevent erosion and sedimentation problems like the ones pictured above.

**Factors to be Considered:**
As stated above, a soil erosion & sediment control plan is intended to minimize the impact of construction activities on downstream properties and waterways. The NJ Standards recognize the key planning objective as the ability to retain soil on the site and to minimize delivery of sediment off-site. In order to accomplish this goal it recommends that the following factors be considered by the design engineer:

1. Erodibility of the soils.
2. Existing drainage patterns.
3. The presence of steep slopes, stream corridors, & other critical site factors.

4. The quality of the existing vegetation to act as a buffer during construction.
5. The minimum area to be cleared.
6. The protection of roadway access points from tracking sediments.
7. The stabilization of excess excavated material which will eventually be deposited on or off site.

It is important to keep each of these factors in mind when designing and implementing the overall plan.

**Overview and Elements of the Plan:**

Essentially a soil erosion & sediment control consists of all of the design features that are intended to keep erosion to a minimum and to prevent sediment from leaving the site and affecting downstream areas. These can be divided into temporary measures (including topsoil stockpiles, silt fence, and stabilized construction entrances, for example) and permanent measures (including riprap at the outfall of drainage pipes, check dams along watercourses, and other, similar features). Alternatively, they could be divided into structural measures (e.g. grade stabilization structures, riprap, etc.) and non-structural measures (e.g. seeding, sodding, mulching, etc.). Regardless of how they are classified, all of the features have a common goal: preserving air and water quality by minimizing erosion and sedimentation. Soil erosion and sediment control plans should be prepared for all land disturbance projects. Their scope will naturally vary depending on the scope and type of land disturbance. Therefore, the development of a large industrial complex will require a more extensive plan than will the construction of a single dwelling. All of these plans will have some elements in common, though.

The New York State Water & Soil Conservation Committee recommends that the preparation of a soil erosion and sediment control plan is prepared using the following steps:

1. Plan the development to fit the site. This is accomplished by working with the topography instead of against it, by minimizing tree clearing wherever possible, and by avoid disturbance of steep slopes, wetlands, and other environmentally sensitive areas.
2. Determine the limits of clearing and grading. The areas to be disturbed should be exactly determined and staked in the field. In many cases, snow fencing or other barriers should be used to avoid encroachment of construction equipment into areas that are not slated for disturbance.
3. Divide the site into natural drainage areas. It is of critical importance to identify the existing drainage patterns and to design the plan so that erosion and sediment is avoided in each sub-drainage area. A properly designed stormwater conveyance system is actually a key part of the overall soil erosion control plan.

4. Design the actual soil erosion and sediment control plan. The plan should incorporate all of the necessary features to avoid sedimentation and erosion. Many of the most common practices are explained in the body of this course. The design engineer must decide which practices to employ on a given site and where and when to employ them.

A fifth step might also be included. This step would take place during the construction (or other land disturbing activity) and would include regular maintenance of the erosion control measures and a re-evaluation of the plan, as necessary, if inspections prove that the plan is not working as designed.

The New York State Water & Soil Conservation Committee has also prepared "Standards & Specifications for Erosion and Sediment Control" that includes a flow chart as well as a matrix of soil erosion and sediment control practices. The table below briefly describes many of the most commonly-employed erosion control practices and is based largely on this document. Note: Items marked * in the table below are discussed in more detail later in this course.

| **Practice** | **Primary Purpose** | **Site Characteristics** | **Estimated Design Life** | **Other Associated Practices** |
|---|---|---|---|---|
| Brush Matting | Stabilize soil & prevent erosion | Stream bank slopes | 5-10 years | Structural stream bank protection |
| Check Dam | Control runoff | Drainage area <2 acres | 1 year | Lined waterway, rock outlet protection |
| Construction Road Stabilization | Control sediment | All construction routes | 2 years | Dust control, temporary swales, temporary seeding |
| Diversion | Intercept & divert runoff | Where required to divert runoff | 10-25 years | Permanent seeding, level spreader, rock outlet protection |
| Dune Stabilization* | Stabilize sand dunes | Sand dune reinforcement or creation | 5-10 years | ------ |
| Dust Control* | Stabilize soil | Access points & construction roads | -------- | Stabilized construction entrance |
| Grade Stabilization Structure | Prevent erosion | Generally designed for a 10 year, 24 hour storm | >10 years | Permanent seeding, structural stream bank protection |

| | | | | |
|---|---|---|---|---|
| Grassed Waterway | Convey runoff | Generally designed for a 10 year storm | 10+ years | Rock outlet protection |
| Land Grading | Stabilize soil | Site specific | Permanent | Topsoiling, seeding |
| Level Spreader | Discharge runoff | Where the 10 year peak runoff <30CFS | 1 year | Note: Level spreaders are not allowed by all jurisdictions |
| Lined waterway (rock materials) | Convey runoff | Generally designed for a 10 year, 24 hour storm | 10+ years | Note: See photo of a lined channel at the end of this table. |
| Mulching* | Stabilize soil | Site specific | 1-2 years | Permanent seeding |
| Paved Channel or Flume | Convey Runoff | Generally designed for a 10 year, 24 hour storm | 10+ years | Rock outlet protection |
| Perimeter Dike/Swale | Divert runoff | Drainage area <5 acres | 1 year | Sediment trap, level spreader, temporary seeding |
| Protecting Trees and Other Vegetation | Preserve existing vegetation (which, in turn, can reduce erosion and transportation of sediment). | Site specific. | Up to 10 years. | -------- |
| Retaining Wall | Stabilize soil and minimize grading and associated vegetation removal and soil disturbance. | Site specific | 10+ years | Rock slope protection, land grading, permanent seeding. |
| Riprap Slope Protection | Stabilize soil and prevent erosion. | Maximum slopes of 1.5 horizontal to 1 vertical | 10 years | Lined waterway, rock outlet stabilization, structural stream bank stabilization |
| Rock Dam | Capture sediment | Drainage area<50 | 3 years | Sediment basin |

| | | | | |
|---|---|---|---|---|
| | | acres | | |
| Rock Outlet Protection | Prevent erosion | Rock size varies with pipe discharge | 10+ years | Diversion, grassed waterway, sediment basin |
| Sediment Traps | Trap sediment | Drainage area generally<5 acres | 1-2 years | Note: Sediment traps can be used at pipe outlets, grass outlets, storm inlets, swales, stone outlets, and riprap outlets. |
| Sediment Basin* | Capture & trap sediment. (Ad discussed on page 35, it also is used to control runoff). | Drainage area <100 acres | 3 years | Rock outlet protection, silt fence, seeding & other stabilization measures. |
| Seeding, Temporary* | Stabilize soil | Site specific | 1-2 years | Mulching, topsoiling, sodding |
| Seeding, Permanent* | Stabilize soil | Site specific | Permanent | Topsoiling, sodding |
| Silt Fence* | Control sediment | At bottom of slope of land disturbance | 1 year | Straw bale dike, wattles |
| Sodding | Stabilize soil | Can be used for aesthetics or when a quick stabilization is required. | Permanent | Topsoiling, permanent seeding |
| Stabilized Construction Entrance* | Control sediment | Construction access points | 2 years | Sediment traps |
| Storm Drain Inlet Protection | Prevent erosion | Drainage area <1 acre | Up to 1 year | Note: Storm drain inlet protection can consist of excavations, filter fabric, stone & block, or curb. |
| Surface | Stabilize soil | Construction | Permanent | Temporary seeding, |

| | | | | |
|---|---|---|---|---|
| Roughening | | slopes | | permanent seeding, mulching |
| Streambank Protection | Prevent erosion and maintain water quality | Generally designed for a 10 year storm | 10 years | Note: Can be either structural (if velocity>6FPS) or vegetated (if velocity>6FPS). |
| Temporary Storm Drain Diversion or Temporary Swale | Divert runoff | Draiange area<10 acres | 1 acre | Sediment trap or sediment basin |
| Turbidity Curtain | Control sediment | Calm water | Generally less than 1 month | Sediment trap or sediment basin |
| Vegetated Waterways | Stabilize soil | Site specific | Permanent | Grassed waterways, lined waterways |
| Wattles | Stabilize soil | Maximum slopes of 1.5 horizontal to 1 vertical | 10 years | Diversion, temporary swale |

A photograph of a rock-lined channel is shown below. This channel directs water around a commercial bank site and is stable despite being laid at a very steep slope. Channels like this one generally need minimal maintenance, but they should be inspected regularly for clogging or damage.

Determining exactly which of the soil erosion control measures listed in the table above to employ at a particular site naturally depends on a variety of factors. One of the most important of these considerations is the erosion potential of the soil, itself.

The table below indicates the erosion risk for different types of soils on a variety of land slopes:

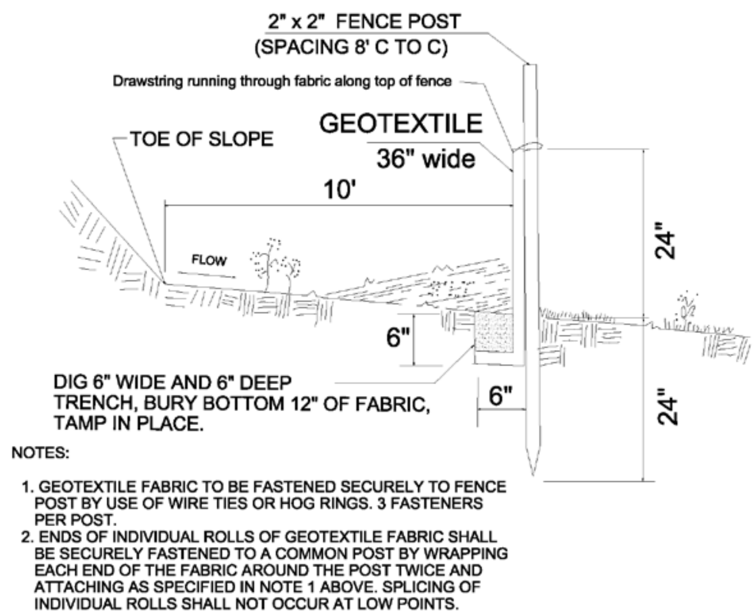
| **Soil Type** | **Slope 0-5%** | **Slope 5-15%** | **Slope>15%** |
|---|---|---|---|
| Gravelly, non-cohesive | Low | Low | Medium |
| Sandy | Medium | High | High |
| Silty | Medium | High | Very High |
| Clay, cohesive | Low | Medium | High |
| Dispersive Clay Soils | High | Very High | Extreme |

Information regarding the soils present on a particular site is best obtained by on-site soils investigation. However, a lot of good information can be obtained from the National Resource Conservation Service (NRCS) by accessing the NRCS web soil survey at http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx.

A number of the major soil erosion and control features used commonly on land-disturbing projects are discussed in detail below.

*Silt Fence:*

Silt fence is one of the most common measures employed to keep sediment on-site. It is generally used at the toe of slope of disturbance in order to keep sediments from travelling downhill and off-site. However, it is imperative that the silt fence be installed properly. Silt fence that is not properly buried is subject to failure and will allow significant erosion downstream. The detail below shows a properly installed silt fence. Note that the silt fence must be buried a minimum of 6” to prevent blow-outs during storms.




SILT FENCE
N.T.S.

The photograph below shows a properly installed silt fence. Note that the silt fence has been placed right at the toe of the slope of the fill material and, consequently, there is no transport of sediment below the fence.

Staked hay bales and soil retention blankets can be used as substitutes for silt fencing. Soil retention blankets are biodegradable materials that can be used to protect disturbed areas or channels from erosion. The blankets consist of natural materials such as wood, straw, or coconut or else they are made from geotextile synthetic woven materials. Some typical specifications for each type of blanket are included below:

Wood Excelsior Fiber Mat:

- The mat should consist of a machine-produced mat of cured wood excelsior in which 80% of the fibers are at least 6" long.
- The fiber should have a consistent thickness evenly distributed over the entire area.
- The top of the mat should be covered with a photo-degradable extruded plastic mesh with maximum opening of 1" X 3".
- It should be treated to be smolder resistant without using chemical additives.
- The mat should have a minimum width of 36" and minimum weight of 0.7 pounds per square yard.

Straw Mat:

- The straw mat should be machine-produced of clean straw and sewn together with cotton or nylon thread.
- The top should be covered with a biodegradable plastic mesh with maximum opening of 5/8" x 5/8".
- The mat should have a minimum width of 48" and a minimum weight of 0.5 pounds per square yard.

Straw-Coconut Fiber Mat:

- This type of mat should be the same as described for straw mats, above, except that it should consist of 70% straw and 30% coconut fibers.

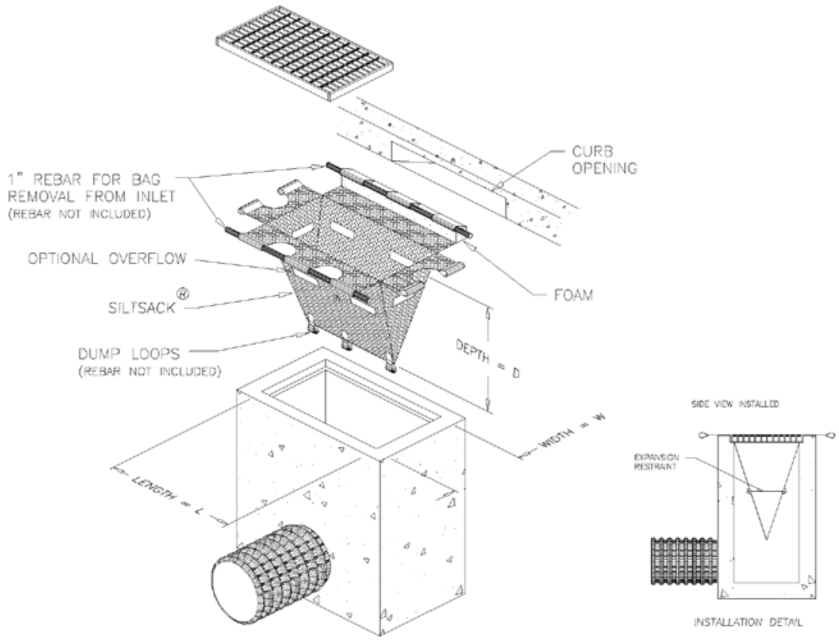
Coconut Fiber Mat:

- Material should be the same as described for straw mats except that it should be furnished with mesh or netting on the top and bottom of the mat. In addition, it should be composed of 100% coconut fiber and should be sewn together with biodegradable nylon thread.
- One side should be heavy duty mesh with a minimum weight of 2.5 pounds per 100 square feet.
- Maximum mesh size openings should be 5/8" x 5/8".

*Inlet Filter Barriers*:
All existing and proposed inlets that could be affected by sedimentation during construction should be protected to keep sediment from clogging the drainage system or affecting downstream areas. There are several different ways of providing inlet filter barriers. One of the more common methods involves using a barrier made up of concrete blocks and gravel to filter the stormwater entering the inlet. A simpler method is to use a manufactured product (commonly know as a "silt sack") to catch the sediment as it enters the inlet. A typical detail of

an inlet sediment barrier is shown below. Note that any inlets treated in this way should be inspected regularly, especially after any heavy rain, to ensure that they are functioning properly.




DETAIL OF INLET SEDIMENT CONTROL DEVICE
WITH CURB DEFLECTOR

The photograph below shows an actual "silt sack" installed in an existing drainage inlet.

*Stabilized Construction Access Points:*
All points of egress from an active land disturbance project must be provided with a stabilized construction entrance (also known as a wheel-cleaning blanket). This is simply a length of clean, crushed stone (with a minimum depth of 6") and of sufficient length to ensure that mud and debris are not tracked onto public roads. It is important that all access points be maintained on a daily basis to ensure that they continue to function properly.

The photograph on the following page shows a stabilized construction entrance for a new single family dwelling. The edge of pavement of the public road is visible in the foreground and the excavation for the proposed building can be seen in the background.

*Construction barriers:*
An effective means of reducing soil erosion is to keep construction equipment out of areas that are not to be disturbed. Snow fence is often used for this purpose. Snow fence placed at the drip line of trees will protect trees that are to be preserved. However, snow fence can be used in a variety of other ways to act as a construction barrier. In the photograph on the following page, the snow fence has been installed at the limit of disturbance of a public roadway project at the top of the bank. This snow fence is required to prevent any damage to the homes lining the road.

*Mulching:*

The establishment of a thriving vegetative cover is one of the surest ways to stabilize a construction site and minimize erosion. Mulching is often performed in conjunction with the establishment of vegetative cover. However, in many cases (due to the season, climate, or other factors), stabilization must be done by mulch alone. Where this is the case, the following procedures should be used:

1. Site Preparation:
    A. The grade should be prepared for mulching and/or topsoilling & seeding operations.
    B. All erosion control measures that will protect the area to be mulched (e.g. diversions, sediment basins, etc.) should be installed prior to mulching.

2. Protective Materials to be used:

| **Material** | **Rate** | **Notes** |
|---|---|---|
| Unrotted small-grain hay or straw | 2 to 2.5 tons /acre (90-115 lbs/1000 square feet) | Must be anchored with a mulch anchoring tool, liquid mulch binder, or netting tie down. |
| Asphalt emulsion | 600 to 1200 gallons per acre | Limited for use only where travel by people, animals, or machines is not anticipated. |
| Synthetic or organic stabilizers. | As recommended by the manufacturer | ---------- |
| Wood-fiber or paper-fiber mulch | 1500 lbs per acre | May be applied by a hydroseeder. |
| Mulch netting | As required to cover the area | Paper jute, excelsior, cotton, or plastic may be used |
| Wood chips | Spread uniformly to a minimum depth of 2” | Not to be used in areas where flowing water could wash the wood chips into an inlet and clog it. |
| Gravel, crushed stone, or slag | 9 cubic yards per 1000 square feet applied uniformly to a minimum depth of 3”. | Size 2 or 3 stone (ASTM C-33) should be used. |

3. Mulch Anchoring: This should be accomplished immediately after placement of hay or straw mulch to minimize loss due to wind or water. Any of the following methods of mulch anchoring can be used. The actual method employed should be decided upon based on the size of the treated area and the steepness of the slope.
   - A. Peg & twine: 8 to 10 inch wooden pegs should be driven to within 2 to 3 inches of the soil surface every 4 feet in all directions. Secure the mulch to the soil surface by stretching twine between pegs in a criss-cross and square pattern.
   - B. Mulch nettings: Paper, cotton, or plastic netting should be stapled over the mulch. These nettings are usually available in 4 foot wide rolls up to 300 feet long.
   - C. Crimper Mulch Anchoring Coulter Tool: This is a tractor-drawn implement designed to punch and anchor mulch into the soil surface. It is a very effective method but cannot be used on slopes that are too steep for a tractor to negotiate safely. The soil penetration should be between 3 and 4 inches. The operation should be with the contours on sloping land.

D. Liquid Mulch Binders: These should be uniformly placed except at edges, in valleys, ridges, and other areas where wind catches the mulch. In these areas the application should be heavier. The following table indicates the main types of liquid mulch binders:

| **Material** | **Specification** | **Rate** | **Notes** |
|---|---|---|---|
| Emulsified asphalt | SS-1, CSS-1, CMS-2, MS-2, RS-1, RS-2, CRS-1, and CRS-2 | 0.04 gallons per square yard or 194 gallons per acre on slopes less than 8%. On steeper slopes, use 0.075 gallons per square yard or 363 gallons per acre. | These materials can be difficult to apply uniformly and will discolor the surface. |
| Organic & vegetable based binders | Naturally occurring, powder based, hydrophilic materials that, mixed with water will form a gel, and, applied to mulch under satisfactory curing conditions, will form membraned networks of insoluble polymers. | See manufacturer's recommendations. | These should only be applied under ideal weather conditions. (See individual manufacturer's recommendations for specific limitations). The vegetable gel should be harmless and not result in a phytotoxic effect or impede growth of the turf grass. |
| Synthetic binders | High polymer synthetic emulsion, soluble with water when diluted and following application to mulch, drying and curing, no longer soluble or dispersible in water. | See manufacturer's recommendations. | These should only be applied under ideal weather conditions. (See individual manufacturer's recommendations for specific limitations). |

Hydromulching may also be used.

*Temporary Seeding & Permanent Seeding:*

Seeding is often the most effective way to stabilize a disturbed area. Establishing a vegetative cover prevents erosion from water and wind by reducing sedimentation transport and dust. A permanent seeding is generally done after the land disturbance is completely finished and the area is ready to be landscaped. Temporary seeding, on the other hand, is used as a stop-gap measure to stabilize soil stockpiles or other disturbed areas that will be left untouched for a period of more than 30 days. If the season does not allow for the establishment of a vegetative cover, other means, including mulching (see above) should be employed.

The exact grasses and other plants to be used in both permanent and temporary seeding will naturally vary from region to region. Generally, faster growing species are employed during a temporary seeding, while hardier, more drought and disease resistant plants are suitable for a permanent vegetative cover. Several soil conservation agencies around the country have detailed list of plants to be used for either a temporary or permanent seeding. These lists should be consulted by the design engineer when specifying a planting schedule.

In establishing a temporary or permanent seeding the following general procedures should be followed. (Note that some of these steps can be eliminated if a temporary seeding is being established and the conditions appear suitable to establishing a suitable cover).

The photograph below shows a scalped area that would benefit from a temporary seeding. If seeding is not applied, significant erosion can result from an area like this.

1. Site Preparation:
    A. The area should be graded as needed to be feasible for the use of conventional equipment in the preparation of the seedbed and mulching operation.
    B. Any associated erosion control practices (diversions, grade stabilization structures, channel stabilization measures, etc.) should be installed.
    C. If the soil has been compacted during the land disturbing operation, then prior to seeding the soil surface should be scarified to a depth of 6” to 12”. (Note: The contractor must be aware of the location and depth of any underground utilities and should omit this step if any conflicts are suspected.
2. Seedbed Preparation:

A. Ground limestone and fertilizer should be applied to the area to be seeded. The exact amount of soil amendments to be added should be based on soil testing or on locally-promulgated guidelines. In New Jersey, the following rates of limestone are recommended:

| Soil Texture | Limestone to be applied (tons/acre) | Limestone to be applied (Lbs./1000 Square feet) |
|---|---|---|
| Clay, clay loam, & highly organic soils | 3 | 135 |
| Sandy loam, loam, & silt loam | 2 | 90 |
| Loamy sand & sand | 1 | 45 |

B. The lime and fertilizer should be worked into the ground a depth of 4”, using suitable equipment.

C. If the soils has a pH of 4 or less or if it contains iron sulfide, it should be covered with at least 12 inches of soil having a pH of 5.5 or greater prior to initiating seedbed preparation.

3. Seeding:
   A. Be sure to select a seed mixture that is known to thrive in the local area at a rate recommended by the seed supplier or a local expert.
   B. Conventional seeding is performed by applying seed uniformly by hand, centrifugal seeder, drop seeder, drill or cultipacker seeder. Ordinarily the seed should be applied within 24 hours of the seedbed preparation. Seed should be planted at a depth of between ¼” and ½”.
   C. Hydroseeding is often a used to spread grass seed over difficult areas such as steep slopes or areas obstructed with rocks or other debris that makes conventional seeding difficult or impossible. It is a broadcast seeding method that usually involves a truck or trailer-mounted tank with agitation system and hydraulic pump for mixing seed, water, and fertilizer. Hydroseeding is not a preferred method because the seed and fertilizer are broadcast and not incorporated into the soil. This causes a relatively poor seed-soil contact and reduces seed germination rates. However, as stated above, it is often the only way

to seed hard to reach area. A typical piece of hydroseeding equipment is shown below:

D. After the seed is applied, firming the soil with a corrugated roller will improve the growth by assuring good seed to soil contact, restoring capillarity, and by improving seedling emergence.

4. Mulching: Mulch should be provided on all seeded areas to protect against erosion before the grass is established and to promote faster & earlier growth.

After a permanent seeding is established, the following maintenance activities should be employed:

1. Routine mowing is required for lawn areas. (Note: the use of native wild flowers and other native herbaceous species in lieu of lawn can reduce the mowing requirement significantly).
2. Fertilizer and lime should be applied regularly or as needed to maintain a dense stand of desirable species.

3. Because fertilization increases the need for lime, the soil should be tested periodically (e.g. every 2 years or so) to determine the need for lime.
4. The area should be weeded regularly. If maintenance has not bee performed for some years, brush may have accumulated and this also needs to be removed.
5. Pest and disease controls should be applied as needed.
6. In areas subject to fires, the vegetation must be maintained in such a way that it will not be a fire hazard.
7. Woody vegetation should be pruned regularly to enhance growth.

*Conduit Outlet Protection:*
Conduit outlet protection should be provided at the outlet of all storm drains, unless hydraulic analysis proves that the velocities are not erosive. To determine if riprap is required, the engineer should determine the exit velocity of the flow. The allowable velocities (without riprap) are given in the table below. Velocities below those shown are considered to be non-erosive and generally do not need outlet protection.

| **Soil Texture** | **Allowable Velocity** |
|---|---|
| Sand | 1.8 feet per second |
| Sandy loam | 2.5 feet per second |
| Silt loam or loam | 3.0 feet per second |
| Sandy clay loam | 3.5 feet per second |
| Clay loam | 4.0 feet per second |
| Clay, fine gravel, or graded loam to gravel | 5.0 feet per second |
| Cobbles | 5.5 feet per second |
| Non-weathered shale | 6.0 feet per second |

The actual design of the riprap aprons is based on several factors as discussed below. Depending on whether there is a watercourse at the end of the outlet pipe, the conduit outlet protection can take the form of a riprap apron or a scour hole. Details for each of these are shown below.

For a riprap stone apron, the stone size is calculated by the following equation:
$D_{50} = (0.016 / T_w) q^{1.33}$, where:
$D_{50}$ is the median stone diameter in feet.
$T_w$ is the tailwater depth in feet. (If the tailwater depth cannot be determined it should be assumed to be equal to 1/5 of the pipe diameter).

q is the is the unit discharge in cfs per foot of the outlet pipe and is calculated as: $q = Q / W_0$, where Q is the peak 25 year flow through the culvert (in cfs), $W_0$ is the culvert width (in feet), and $D_0$ is culvert height , or depth (in feet).

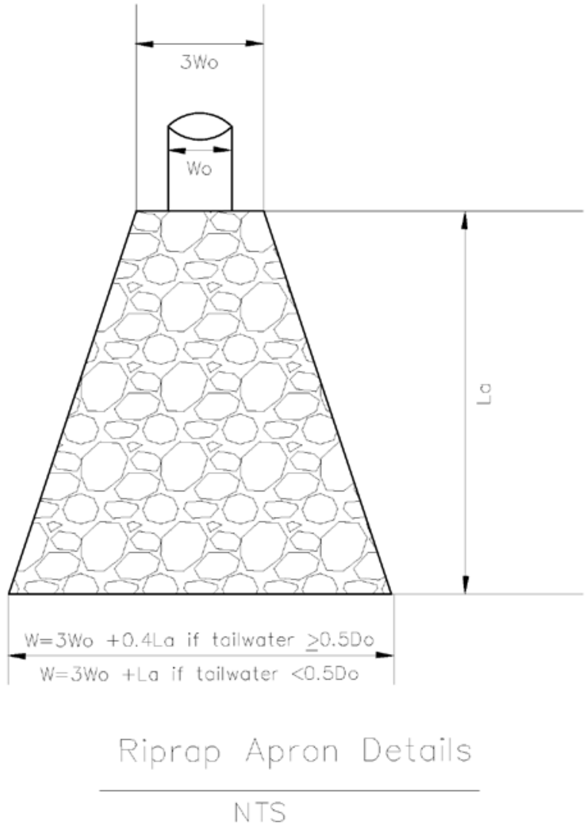
The apron dimensions are calculated by one of the following equations:
$L_a = (1.8q / D_0^{1/2}) + 7D_0$ if the Tailwater depth is less than ½ the diameter of the pipe, or
$L_a = 3q / D_0^{1/2}$ if the Tailwater depth is greater than or equal to ½ the diameter of the pipe, where:
$L_a$ is the length of the riprap apron in feet.
q is the is the unit discharge ($Q/W_0$) in cubic feet per second (CFS) for a 25 year storm.
$W_0$ is the maximum inside culvert width in feet.
$D_o$ is the maximum inside culvert height in feet.

The following example will illustrate the determination of required stone size for a riprap apron. Riprap Apron design example: A riprap must be designed at an inlet of a proposed detention basin for a new office complex in Morris County, New Jersey. The pipe leading to the basin is a 30" plastic pipe and the peak 25 year discharge has been calculated to be 55 CFS. Hydraulic analysis of the detention basin has indicated that the tailwater depth in the basin will approximately 2 feet. Determine the required stone size and the dimensions of the proposed riprap apron.
Solution: The following steps will be used to determine the required stone size:

1. Step 1: Calculate the unit discharge (q) using the peak 25 year Q of 55 CFS and the pipe diameter (2.5 feet). $q = Q / W_o = 55 / 2.5 = 22.0$
2. Step 2: Calculate the required stone size using the values for tailwater and q: $D_{50} = (0.016 / 2)(22)^{1.33} = 0.48\ feet$. Therefore, the stone size used in the apron should be 0.48 feet or 6 inches.
3. Step 3: Calculate the apron dimensions. The tailwater depth of 2 feet is more than half of the pipe diameter. Therefore, the following equation must be used: $L_a = 3q / D_0^{1/2}$. Inserting the variables described in the problem statement yields the following: $L_a = 3(22) / 2.5^{1/2} = 42\ feet$. Therefore, the apron will be 42 feet long. Based on the detail shown below, the width of the apron would vary linearly from three times the pipe diameter (7.5 feet) to 3 times the pipe diameter plus 40% of the length (24.3) feet at the downstream end. This is quite a large riprap apron and the design engineer should probably consider using a scour hole instead to save on material and labor costs.

A typical detail of a riprap apron is shown below:



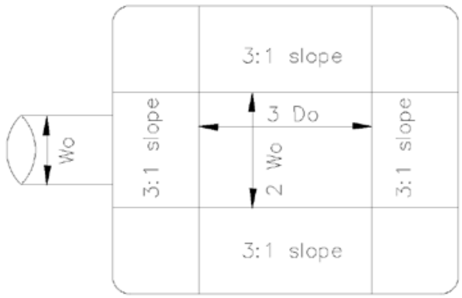

For a scour hole, the stone size ($D_{50}$) is calculated by one of the following equations:

$D_{50} = (0.0125 / T_w) q^{1.33}$ if the depth of the scour hole below the culvert invert is ½ of $D_0$.

$D_{50} = (0.0082 / T_w) q^{1.33}$ if the depth of the scour hole below the culvert invert is equal to $D_0$.

Typical details of a scour hole are shown below:




Scour Hole Plan View

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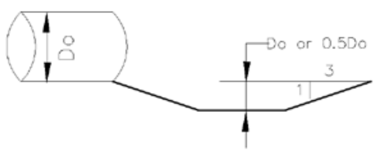



Scour Hole Profile

NTS

The following example will illustrate the calculation of stone size for a scour hole.

Scour Hole Example: A scour hole must be designed for a proposed outlet of a street drainage system for a local road in Somerset County, New Jersey. The pipe leading to the outlet is a 15" RCP laid at a slope of 3% and the peak 25 year discharge has been calculated to be 7.5CFS. There is no information on the tailwater depth at the end of the scour hole. It has been decided that the scour hole depth will be equal to $D_0$. Determine the stone size required for the scour hole.

Solution: The following steps will be used to determine the required stone size:

4. Step 1: Determine the tailwater depth. Because the tailwater depth is unknown it is assumed to be equal to one fifth of the pipe diameter (3" or 0.25 feet).
5. Step 2: Calculate the unit discharge (q) using the peak 25 year Q of 7.5 CFS and the pipe diameter (1.25 feet). $q = Q / W_o = 7.5 / 1.35 = 6.0$

6. Step 3 Calculate the required stone size:

$$D_{50} = (0.0082 / T_w) q^{1.33} = (0.0082 / 0.25)(6)1.33 = 0.36\ feet$$

Therefore, the required stone size is 0.36 feet or slightly greater than 4 inches. As a rule of thumb, however, stone less than 6" should not be used because it will tend to wash away. The final design should specify 6" stone.

The photograph below shows conduit outlet protection in the form of a riprap apron downstream of the flared end section visible in the background.

*Dune Stabilization:*

Engineers working in shoreline areas need to be aware of dune stabilization procedures. Essentially, these consist of controlling surface movement of sand dunes or drifting sand and can be accomplished by vegetative or mechanical means. Three main types of dune stabilization are discussed below:

1. Vegetation:
   - The foliage of most sand dune species filters sand from the wind. The reduction of wind velocity near the dune's surface allows sand to be deposited, growing the dune. The root mass of the plant species should typically be deep and extensive, anchoring the dunes to their foundation. Some species suitable for New Jersey and other Mid-Atlantic are listed below: (The engineer working in another geographic region should consult with a horticulturist regarding appropriate species to use).

   a. 'Cape' American Beachgrass (*Ammophila breiligulata*).
   b. 'Atlantic' Coastal Panicgrass (*Panicum amarum var. amaulum*).
   c. 'Avalon' Saltmeadow Cordgrass (*Spartina patens*).
   d. 'Wildwood' Bayberry (*Myrica pensylvanica*).
   e. 'Ocean View' Beach Plum (*Prunus maritima*).
   f. "Sandy' Rugosa Rose (*Rosa rugosa*).

   - Whenever foot or vehicular traffic is anticipated over the dunes a designated dune crossing area (consisting of a curvilinear path to direct traffic) should be established. This path can be constructed of boards or gravel and must be bordered by snow fence to funnel traffic over the path.
   - It is important that the appropriate plant species are used and that they are well established in order to get the dune off to a good start. Periodic maintenance of the vegetation is generally required, especially as dunes are often subjected to gale force winds and overwash.
2. Sandfencing: Utilizing sandfencing (standard snow fence) can be a quick and effective way to build temporary sand dunes. The fence line should be oriented parallel to the beach and should generally be placed approximately 140 feet above high tide. Some additional specifications for sandfencing are as follows:
   a. Materials:
   - Standard 4' high slatted wood snow fencing is often used, but polyvinyl fencing material with 50% porosity can be used as an alternative. Fence must be securely tied to the posts.
   - Posts should generally be made of wood, be spaced 10 feet apart, be 7 to 8 feet long and buried to a depth of greater than 3 feet.

   b. Techniques:
   - The orientation of the fence line should be parallel with the waterline of the beach and should be at least 140 feet from the mean high tide. The fencing

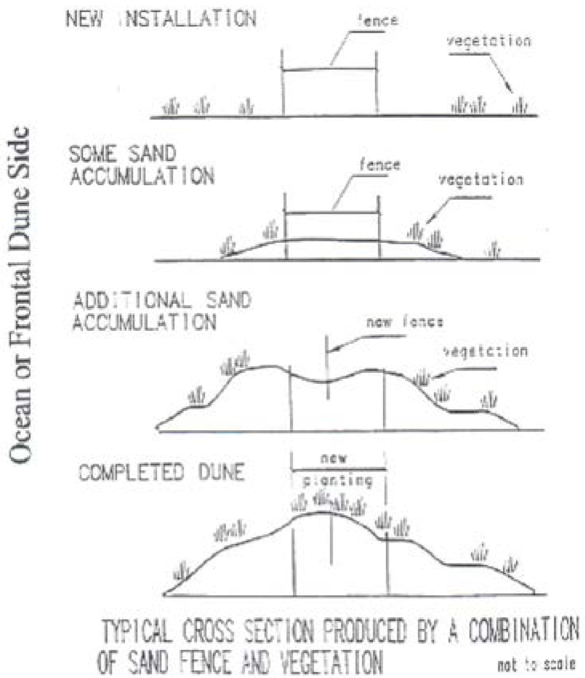
should weave in front of and behind alternating posts to attain maximum strength.

- With an adequate sand source, dune elevation can be increased annually by at least 4 feet. (This height can be increased if vegetation is used in conjunction with the fence.) The maximum dune height to be achieved by this method is ordinarily 12 to 15 feet but this varies greatly with prevailing wind conditions and sand particle size.
- Two or more parallel rows spaced 30 or 40 feet works best, but a single row of fence with 30 foot perpendicular spurs spaced 40 feet apart are also acceptable if space is limited. A zigzag fence pattern is sometimes used. If there is less than about 100 feet available above the mean high tide line, then it may not be appropriate to build dunes.
- Sand will typically fill the fencing to about ¾ of the fence height. When this maximum height is reached, additional fencing can be added until the maximum planned dune height is achieved. Fencing and posts damaged by storms should be replaced within one month of the damaging storm to maintain a continuous dune line.

c. Comments:

- This method can be more expensive (per linear foot of dune established) than creating dunes with vegetation alone but it is somewhat less expensive than using mechanical excavation.
- Dune height is limited by the height of the fence as described above.
- Planting vegetation on both sides of the fence generally makes this type of establishment more effective than establishment of dunes by vegetation or fencing alone. The vegetation should be planted no closer than 10 feet and no further than 15 feet from the fence and the planting strip should be about 20 feet wide. A schematic detail of this is shown below and shows graphically how the dune takes shape with time:




3. Mechanical Excavation: Earth moving equipment can be used to quickly create temporary sand dunes. The dunes created in this manner are often of short duration and provide relatively minimal protection to the public and private resources located above them. However, this method is often used to repair storm damage of dunes during fall and winter months. Sometimes, the earthwork equipment is used in conjunction with sand pumped from off-shore dredging operations.

*Dust Control:*
There are a variety of ways that dust can be controlled on a construction site. The simplest way, of course, is to sprinkle water on any scalped areas. The table below shows some additional ways to control dust:

| Material | Water Dilution | Type of Nozzle | Amount to be Applied (Gallons per acre) |
|---|---|---|---|
| Anionic asphalt emulsion | 7:1 | Coarse spray | 1200 |
| Latex emulsion | 12.5:1 | Fine spray | 235 |
| Resin in water | 4:1 | Fine spray | 300 |
| Polyacrylamide – spray on<br>Polyacrylamide – dry sread | --------- | -------- | Apply according to manufacturer's recommendations. |
| Acidulated Soy Bean Soap Stock | None | Coarse spray | 1200 |

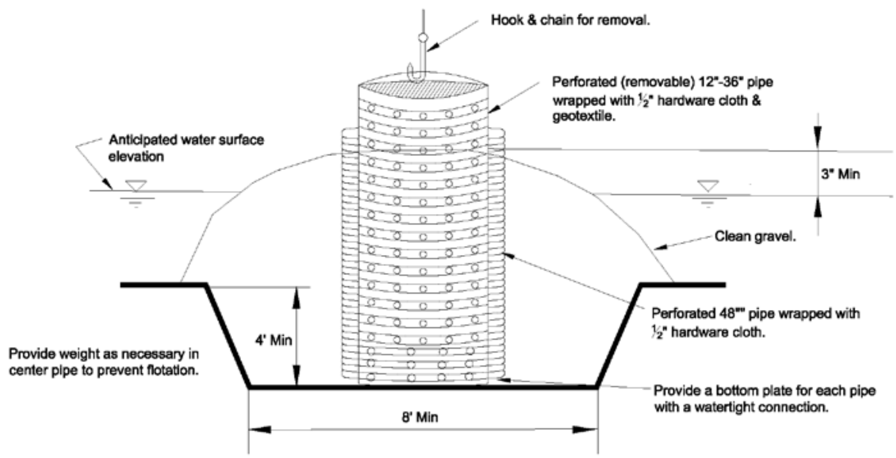
Other measures to control dust include solid board fences or snow fencing to control air currents, treating the area with calcium chloride, and covering the surface with crushed stone.

*Dewatering Operations:*
Many construction projects require temporary dewatering operations. The water to be removed will generally contain sediments that must be removed prior to being sent to receiving waters. Ordinarily either the water is pumped or containment berms are breached as part of the construction project. The practices described below will address virtually any dewatering operation.

1. Removable pumping stations: These are used when long durations of pumping are required. Water pumped from a pumping station should be discharged into a sediment

basin or other suitable filtering area. A typical detail of a portable pumping station is shown below:




Removable Pumping Station
Elevation (Cut–Away View)

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A. The suction hose from the pump must be placed inside the inner pipe to begin dewatering. The discharge hose should be placed in a stabilized area.
B. The inner pipe can be removed to facilitate changing the geotextile when it becomes clogged. Maintenance must be performed whenever the pump runs dry and backed up water remains.

2. Sump pits: are temporary pits designed to remove excess water while minimizing sedimentation. The detail of a sump pit is somewhat similar to the removable pumping station shown above. Generally, a perforated vertical standpipe is wrapped with ½" hardware cloth and geotextile fabric, then placed in the center of an excavated pit which is backfilled with filter material (usually clean gravel with minimum fines or 1 ½" clean, crushed stone (ASTM C-33)). Water is then pumped from the center of the standpipe into a suitable discharge area.
3. Sediment tank/silt control bags: These are containers through which sediment laden water is pumped to trap and retain the sediment. These features can be used on sites requiring deep excavations, where space is limited, and where direct discharge into a

stream or other water body should be avoided. The following specifications should be used:

A. Containers should be located for ease of clean-out of the trapped sediment and to minimize disturbance to construction activities and to pedestrian and vehicular traffic. Bags must never be placed adjacent to streams.
B. The size of the tank should be determined using a cubic foot of storage for each gallon per minute of pump discharge capacity.
C. Tanks consist of two concentric circular CMP pipes attached to a watertight baseplate. The inner pipe should be perforated with 1" holes and wrapped with geotextile and hardware cloth. Pumped water is discharged into the inner pipe and flows through the geotextile into the space between the two pipes. A discharge line is attached to the outer pipe and draws filter water out of the tank. Depending on the sediment load, this filtered water may need to be pumped into one or more additional sediment tank for additional treatment before it is finally discharged into the receiving stream.
D. Sediment control bags must be located away from waterways and must be disposed of according to the manufacturer's instructions. The bag should not be re-used after it has been filled once.

4. Temporary filters for small impoundments: For small quantities of ponded water such as may be found in shallow excavations a sediment filter may be constructed using a combination of hay bales, small clean stone, and filter fabric. This method should only be used for small amounts of water and non colloidal sediments.

*Sediment Basins:*

On many construction projects a sediment basin represents the main barrier to downstream transportation of sediment. A sediment basin is simply a barrier, dam, or excavated pit placed at a suitable location to intercept and temporarily store sediment. In order for the sediment basin to be effective over the life of the construction project, it is generally necessary to remove the trapped sediment as necessary. The sediment basin should be designed both to control floodwaters and to intercept sediment. However, a full discussion of the design features of sediment basins is beyond the scope of this course.

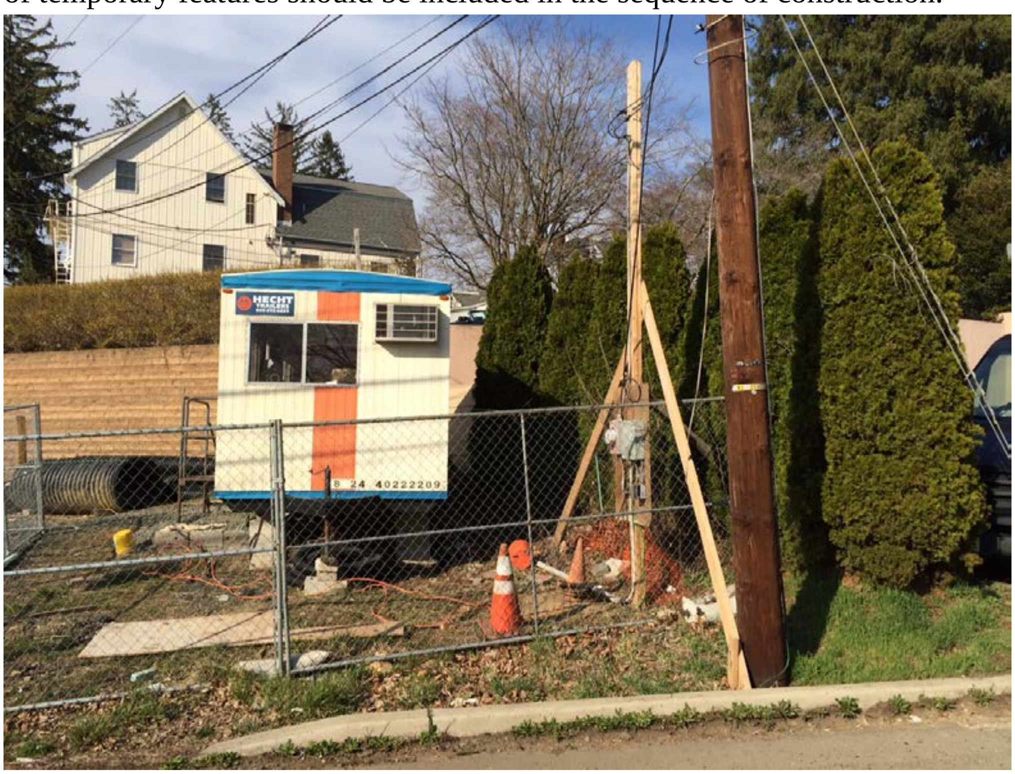
*Construction schedule:*

Although it may not seem necessary, a well-conceived construction schedule is an integral part of a complete soil erosion and sediment control plan. The construction sequence should outline the overall scope of the land disturbance and should describe when the various soil erosion control devices should be installed and removed. A typical construction sequence for the construction of a single dwelling might look something like the following:

1. Install silt fence and stabilized construction access point.
2. Clear trees.
3. Strip topsoil and temporarily stockpile and seed same.
4. Rough grade the site.
5. Install building foundation and begin driveway installation.
6. Install underground utilities.
7. Restore all disturbed areas with a permanent seeding and remove all soil erosion control measures as the final item.

Of course, this schedule is conceptual only and will need to be modified to fit any particular situation. For example, if the dwelling will be serviced by a septic system, installation of the system is generally one of the first tasks to be performed. If, however, the area of the septic field is required for construction access to other areas, then the septic system should be installed after the area is not longer required for access. Also, if there is any demolition involved in the project (if, for example an existing dwelling is to be razed to make room for a new structure) then this should be added to the sequence of construction.

The photograph below shows a construction trailer and temporary electric service. These types of temporary features should be included in the sequence of construction.



**Final Considerations:**

A well designed soil erosion & sediment control plan can eliminate many of the detrimental effects of construction or other land disturbing activities. It can prevent sedimentation of downstream waterways, mitigate against property downstream to downstream owners, and avoid dust and debris on local roads. The practices described in this course include many of the most widely used methods. However, many other methods are used and many of the methods described herein can be used for other applications. It is up to the design engineer to familiarize himself with the methods generally employed in his or her region and to fir the design to the specific design parameters of any particular job.

Continued maintenance of any soil erosion and sediment control feature is a required part of the overall design. Given the nature of construction sites (scalped areas, heavy, sediment-laden runoff, etc) features such as silt fence, inlet filter barriers, sediment basins, or others can quickly become overwhelmed and cease functioning properly. Even the most simple of features, such as stabilized construction entrances, should be inspected and maintained regularly. Dune construction and stabilization projects can be particularly challenging in this regard. Repeated storms and high tides can undo months worth of progress in a single day.

On larger projects, the soil erosion and sediment control plan might need to be re-evaluated periodically. It is sometimes found that the sediment load is greater than anticipated. In this case, silt fence rows may need to be doubled (especially in steeply sloping terrain) or sediment basins may need to be enlarged.

On all projects, stabilization should be provided as quickly as possible. This can be done temporarily by mulching or temporary seeding or permanently by a permanent seeding or other methods described in this course. Whatever methods are used, the overall goal is to provide a stable, safe environment both during and after the land disturbance.

The photograph above shows a well-seeded new lawn. Once established, this lawn will minimize the potential for erosion from this site. In order to preserve its usefulness, however, a lawn like this one (as is true for most soil erosion control features) will need to be maintained on a regular basis.