MANUAL OF TEMPORARY EROSION CONTROL PRODUCTS FOR ROADSIDE DITCHES


Prepared by:

Hazem Elzarka
Ce Gao
John Matos
Debaditya Chakraborty

Department of Civil/Architectural Engineering and Construction Management
University of Cincinnati

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1. Introduction

Sediment continues to be the primary pollutant by volume in Ohio's streams and rivers. Unvegetated roadside ditches' side slopes and bottoms erode and contribute tons of sediment annually to local receiving streams. Pollutants attach themselves to sediments and are transported by the stormwater runoff throughout the watershed, degrading the water quality of receiving streams and rivers (CRWP 2012). Excessive erosion causes both "on-site" and "off-site" problems. Off-site effects include sedimentation of waterways and eutrophication of water bodies. On-site impacts include loss of the nutrient-rich upper soil layers.

Erosion and sedimentation control and storm water quality treatment in ditches typically relies on the vegetation in ditches. Temporary erosion control products in roadside ditches which are the focus of this manual, reduce soil erosion from the ditches' sides and bottoms by protecting bare soil surface from raindrop impact and sheet erosion until vegetation is established. Once vegetation is established, it filters sediment and pollutants attached to the sediment as the water flows through the plants. Vegetation also slows down the water, allowing a portion of it to infiltrate into the soil and allowing some of the debris and pollutants to settle out (Elfering and Biesboer, 2003).

Ditches that are stripped of the vegetative cover during ditch cleaning maintenance operations should be immediately seeded to control erosion and sedimentation and promote treatment of the storm runoff prior to discharge into the receiving waterbody. Vegetation is used to stabilize soil, reduce erosion, prevent sediment pollution, and reduce runoff by promoting infiltration. Healthy, dense vegetation promotes infiltration and reduces the amount of runoff. If ditches' slopes and bottoms are not protected immediately after cleaning, they will erode and begin a new cycle of sedimentation which will decrease the time between required cleaning operations and further stretches the already limited ODOT maintenance resources.

Soils within roadside ditches are often compacted, poorly drained and may be nutrient deficient. These characteristics along with seasonal fluctuations in weather patterns sometimes make it difficult to establish vegetative cover immediately following ditch maintenance operations (CRWP 2012). The establishment of quality vegetation requires careful seedbed preparation, temporary seed protection, and adequate maintenance. It is therefore important that after seeding, the soils and seed are temporary protected until vegetation is established.

Recent research completed has concluded that the practice of seeding ditches and providing temporary seed protection is not a standard practice in all of ODOT counties and in other state DOTs (Elzarka et al. 2016, CRWP 2012, Chesapeake 2016, IRVM 2013). The research has confirmed the importance of such a practice in reducing excessive erosion. The research has also reported that newer erosion control technologies products such as advanced hydraulic mulch products and straw wattles have potential use in ditches.

Elzarka et al. 2016 also concluded that ODOT counties that are currently seeding ditches after cleaning don't have standard procedures and in some cases there is a lack of information on what best temporary erosion control practice to use, what equipment to purchase and what application rates are effective. Hence it was important to develop this manual of temporary erosion control in ditches to familiarize highway maintenance personnel with best practices for installation, recommended application rates and selection methods of erosion control products.

2. Scope

This manual only applies to a “Non Jurisdictional” ditches. A jurisdictional ditch means it is regulated by Federal Law and is subject to Clean Water Act regulations (OES 2014). A “Non Jurisdictional Ditch” means it falls outside of federal regulations.

The majority of roadway ditches are “Non Jurisdictional” and their recommended temporary erosion control procedures are covered in this manual. If the ditch is jurisdictional, however, Highway Maintenance Managers have to consult with their District Environmental Coordinator (DEC), or their staff, to capture any necessary environmental permissions, permits, or coordination prior to performing the work.

A non-jurisdictional ditch’s function is to drain the landscape. However, it is not Relatively Permanent Waters (RPW) and does not possess an Ordinary High Water Mark OHWM. In addition, these ditches do not possess a captured stream and were not constructed in a hydric soil unit for the purpose of draining a wetland at the time of construction. Typical examples of these types of ditches range from grassy swales to ditches with sufficient hydrology to become fully vegetated with hydrophytes (fully vegetated ditches are considered to be lacking an OHWM). Any maintenance activity involving these non-jurisdictional ditches are exempt from 404 regulations (OES 2014).

To summarize, a ditch is most likely a Non-jurisdictional ditch if:

- It doesn’t have water in it for three months straight per year
- It doesn’t have an OHWM
- It is not a stream captured in the ditch line
- It is not draining a wetland

Sometimes it is not possible to establish vegetation in ditches. Examples include cases in which there is rocky substrate, high velocity flow conditions or heavy shade. In such instances, the ditch may need permanent protection with concrete, riprap, gabion baskets, geogrid, turf reinforcement matrices, retaining walls, or other approved products. Permanent erosion control product installation should be properly designed by an engineer and are outside the scope of this Manual.

3. Selection of Temporary Erosion Control Methods

A series of flowcharts have been developed to assist Highway Maintenance Managers with selecting appropriate temporary erosion control products for a ditch that has been cleaned and that need to be seeded and protected.

3.1. Required Information

Before using the flow charts the following information should be obtained:

Is a hydroseeder available?

Ditch longitudinal grade:

The ditch's longitudinal grade is measured as a % and can be determined as shown in Figure 1. Note that Figure 1 include 3 ditches with various grades.

Ditch Length in feet.

The ditch's length is measured in feet as shown in Figure 1.

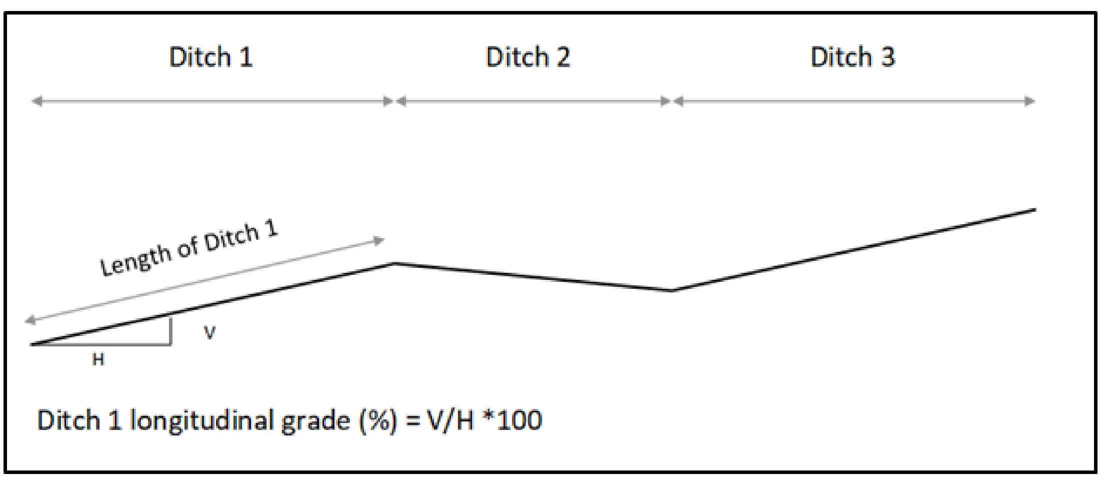


Figure 1. Determining ditch grade and length

Ditch Side slope (H:V):

The ditch side slope is represented as an H:V ratio and can be determined as shown in Figure 2

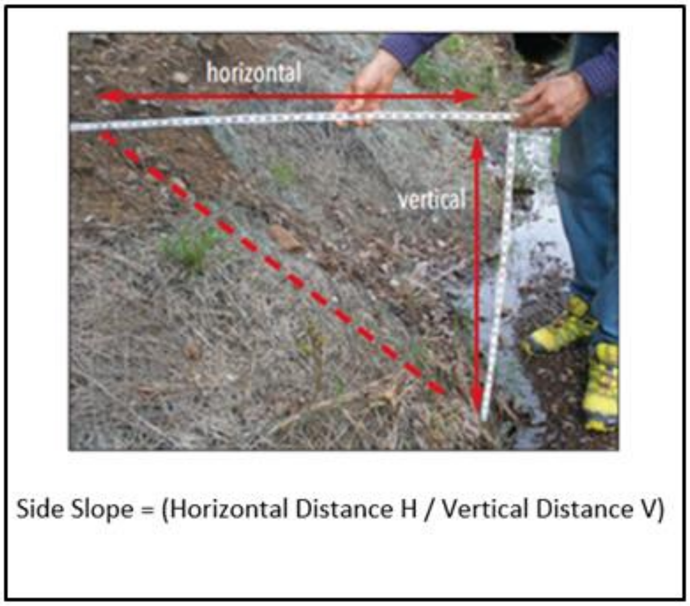


Figure 2. Determining ditch side slope (Brady et al. 2014)

Once you have measured the Horizontal Distance H and the Vertical Distance V as shown in Figure 2, convert your H and V measurements to the simplest ratio possible; for example, 45:15 reduces to 3:1.

% Wet Perimeter:

The estimated % of the ditch perimeter that will be subjected to water flow during the period of vegetation establishment (≈1 month if seeding takes place during the growing season from April 15 to October 15). The % wet perimeter can be determined as show in Figure 3.

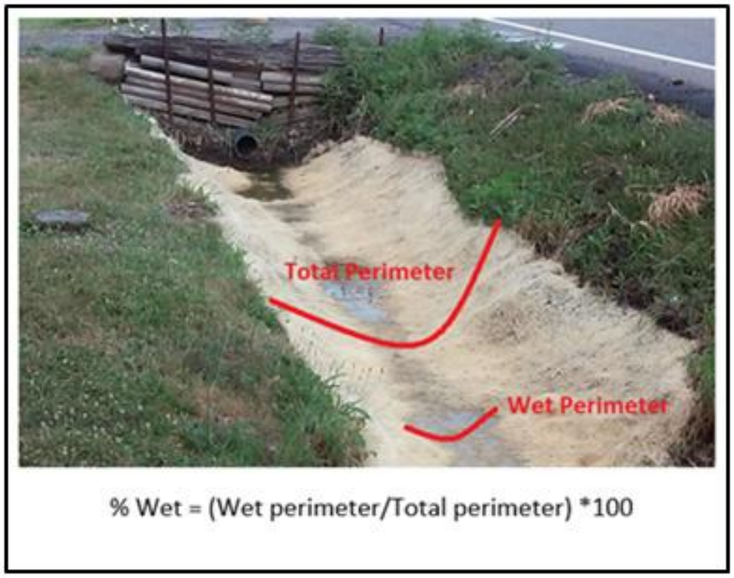


Figure 3. Determining ditch side slope (Brady et al. 2014)

Time before next rain storm

Time when ditch is cleaned

3.2. Importance of required information

This section discusses how the required information impact the selection process.

Is a hydroseeder available?

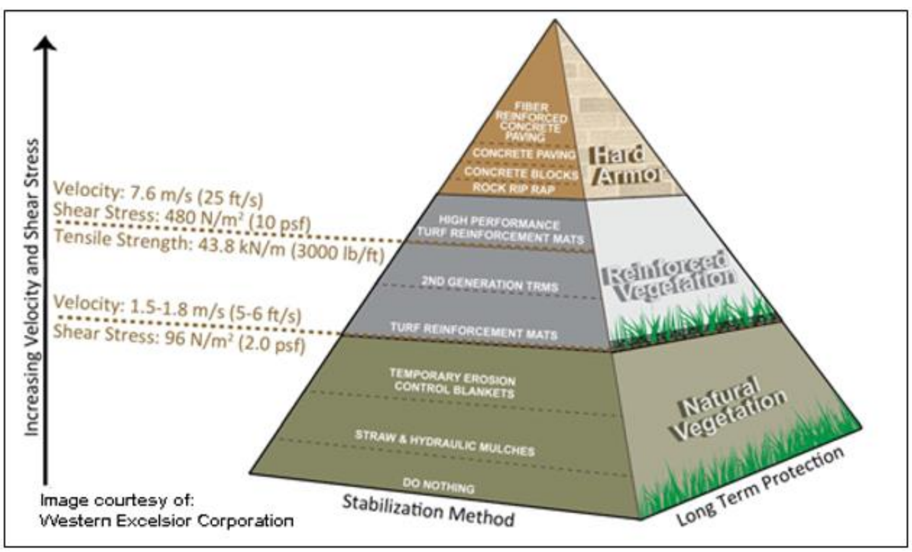
As discussed in the Introduction section, several recent research studies have concluded that advanced hydraulic mulch products can be an effective method to grow vegetation in ditches. (Elzarka et al. 2016, CRWP 2012, Chesapeake 2016, IRVM 2013). However, these products can only be used if a hydroseeder is available.

Giving the importance of temporarily protecting a seeded ditch in order to control erosion and sedimentation as discussed above, the unavailability of a hydroseeder should not be a deterrent to seed a recently cleaned ditch and in this case, products that do not require a hydroseeder should be utilized.

<u>Ditch longitudinal grade:</u>

The ditch longitudinal grade has a significant impact on the flow velocity in the ditch and the value of the shear stress on the ditch's boundary. The steeper the ditch longitudinal grade, the larger the shear stress and the larger the flow velocity.

The selection of temporary erosion control products (ECP)s should *ideally* be performed based on expected shear strength. Shear strength is a term describing the amount of shear stress and concentrated flow velocity that the BMP can withstand. Natural vegetation for example can withstand a concentrated flow velocity of 5-6 feet/sec and a sheer stress of 2 lbs/sf. Typically, hydraulically applied erosion control products (HECP)s initially have low shear strength and can only withstand concentrated flow velocities of up to 2 ft/sec. HECPs can be used in combination of Jute netting to increase their shear strength until vegetation is established. Another alternative is to use flow attenuation devices such as rock check dams or wattles with HECPs to reduce concentrated flow velocities and shear stress. Figure 4 shows acceptable shear stress for different erosion control solutions.



<u>Figure 4. Selection of ECP based on shear stress (Western Excelsior Corporation)</u>

It can be concluded from Figure 4 that if the expected shear stress on the ditch's boundary is greater than 2 psf. (lbs. per square foot), then temporary erosion control blankets are no longer feasible and a permanent turf reinforcement map is needed. Figure 4 also shows that once established, natural vegetation can withstand shear stresses up to 2 psf. Thus the main function of temporary erosion control products is to ensure that vegetation is established and they are no longer needed after that.

Appendix A includes a methodology developed by the authors for calculating shear stresses using readily available data. However, since the methodology may be time consuming, the authors have developed the selection flow charts based on nationally acceptable rule of thumbs. The brief discussion of Figure 4 and the introduction to Appendix A were meant to alert the user that the ditch's longitudinal grade has a significant impact on the shear stress on the ditch's boundary and thus has a considerable effect on the selection of temporary erosion control products.

Ditches with gently sloping bottoms (less than 5%) can be stabilized with temporary erosion control products that protect seeds until vegetation is established. These temporary measures include various types of hydraulic mulches and erosion control blankets which will be later discussed in detail. If the ditch's longitudinal slope is between 3% and 5%, the temporary measures can be combined with check dams to improve results. The installation of check dams can help slow the flow of stormwater and help protect the plants. It will also provide areas for the short-term ponding of stormwater to facilitate infiltration.

Moderately sloping ditches (5%–10% slopes) will likely require turf reinforcement mats which are considered permanent erosion control installations. Steeply sloping ditches (greater than 10%) need permanent armoring with concrete, rock lining, gabion baskets, riprap, geogrid, retaining walls, or other approved products. Permanent erosion control product installation should be properly designed by an engineer and are outside the scope of this Manual.

Ditch Length in feet.

The ditch's length also has an impact on flow velocity and shear stresses. Water flowing in long ditches picks up kinetic energy as it flows downstream uninterrupted for long distances thereby increasing shear stresses on the ditch's boundary. It is therefore recommended to used check dams in combinations with Hydraulic mulches or temporary erosion control blankets for ditches longer than 600 ft.

Ditch Side slope (H:V):

Steep side slopes of ditches can experience sheet erosion when it rains and therefore need a resilient temporary erosion control product. In cases where a ditch's side slope is steeper than 2H:1V, a double net temporary erosion control blanket or a Flexible Growth Medium (FGM) hydraulic mulch product such as Flexterra should be used for adequate protection of seeding. South Carolina DOT has conducted some field tests on Flexterra and based on those tests has written Flexterra into its standard construction specifications as an equal to double-sided blankets for applications on slopes up to 2H:1V (Profile 2012).

% Wet Perimeter:

When developing the selection process, the authors considered new trends of using hydraulic mulch in special ditch configurations since they are easier to apply and since new hydraulic mulch products that can be used for steeper ditch side slopes currently exist. At the same time, the authors also considered the main limitation of hydraulic mulch which is its inability to resist concentrated flows before vegetation is established. For this reason, the authors suggest not using hydraulic mulches in cases where a relatively large percentage of the ditch's perimeter (>30%) would be subjected to concentrated flow during the period of vegetation establishment; in such cases temporary erosion control blankets are a better choice.

Time before next rain storm

The curing time of the temporary erosion control product should be less than the time when the next rain storm is expected. The curing time is the length of time that a product needs to dry out and gain its designed strength. If a major rainfall takes places within the curing time of an applied hydraulic mulch product, there will be significant product loss due to water flush. A temporary erosion control blanket has zero curing time whereas the curing time of hydraulic mulch products vary from 2 hours to 48 hours.

Time when ditch is cleaned

It is important to know when the ditch is cleaned because it will determine whether hydraulic mulches can be used or not. Per ODOT CMS 659.15, hydraulic mulch should be applied from March 1 to October 30.

3.3. Additional information considered in developing the selection flow charts

In addition to the information provided by the user, the flow charts consider other information that impact the selection process that was identified by the research team. These include:

Ease of installation

Erosion control blankets are more challenging to use compared to hydraulic mulch and it is recommended to use them in cases where hydraulic mulch won't work. In cases where terrain is rocky, rolled blankets might not be able to adapt to the contour of the land and hydraulically applied products become the better choice.

Schedule and resource requirements

Using hydraulic mulch is faster and requires less resources compared to blankets, as no fine grading is required to smooth the slopes before application.

Cost

In general, the purchase cost from least expensive to most expensive is: straw mulch, hydraulic mulch, erosion control blankets, and turf reinforcement mat. It should be noted that the purchase cost is only a part of the selection process since picking the product that will provide the best results is the most cost-effective solution as it will reduce future sedimentation and the need to re-clean the ditch.

Maintainability of the ditch

Using hydraulic mulches is more maintenance friendly compared to erosion control blankets. If the blanket is not fully decomposed at the time of the following cleaning, it may get tangled up in cleaning equipment and mowers.

Impact on wild life

The netting within most erosion control blankets can entrap wildlife and pause a danger to wildlife particularly if it takes several years to degrade. A net-free blanket, which is stitched together with a biodegradable thread, or hydraulic mulch is a better option for flatter areas that will be mowed or to prevent potential wildlife entrapment (Brady et al. 2014).

4. Selection Flow charts

Four flow charts have been developed to assist Highway Maintenance Managers with selecting an appropriate temporary erosion control product based on the information discussed in the previous sections. These flowcharts are shown in Figures 5-8 and are as follows:

1. FC1- Flowchart to be used if a hydroseeder is available. Based on the outcome of this flow chart, the user should continue the selection process using FC3 (in case a hydraulic mulch is recommended initially) or FC4 (in case an erosion control blanket is recommended initially)
2. FC2- Flowchart to be used if a hydroseeder is not available. Based on the outcome of this flow chart, the user should continue the selection process using FC4 (in case an erosion control blanket is recommended initially)
3. FC3- Flowchart to select adequate category of hydraulic mulch.
4. FC4- Flowchart to select adequate type of temporary erosion control blanket.

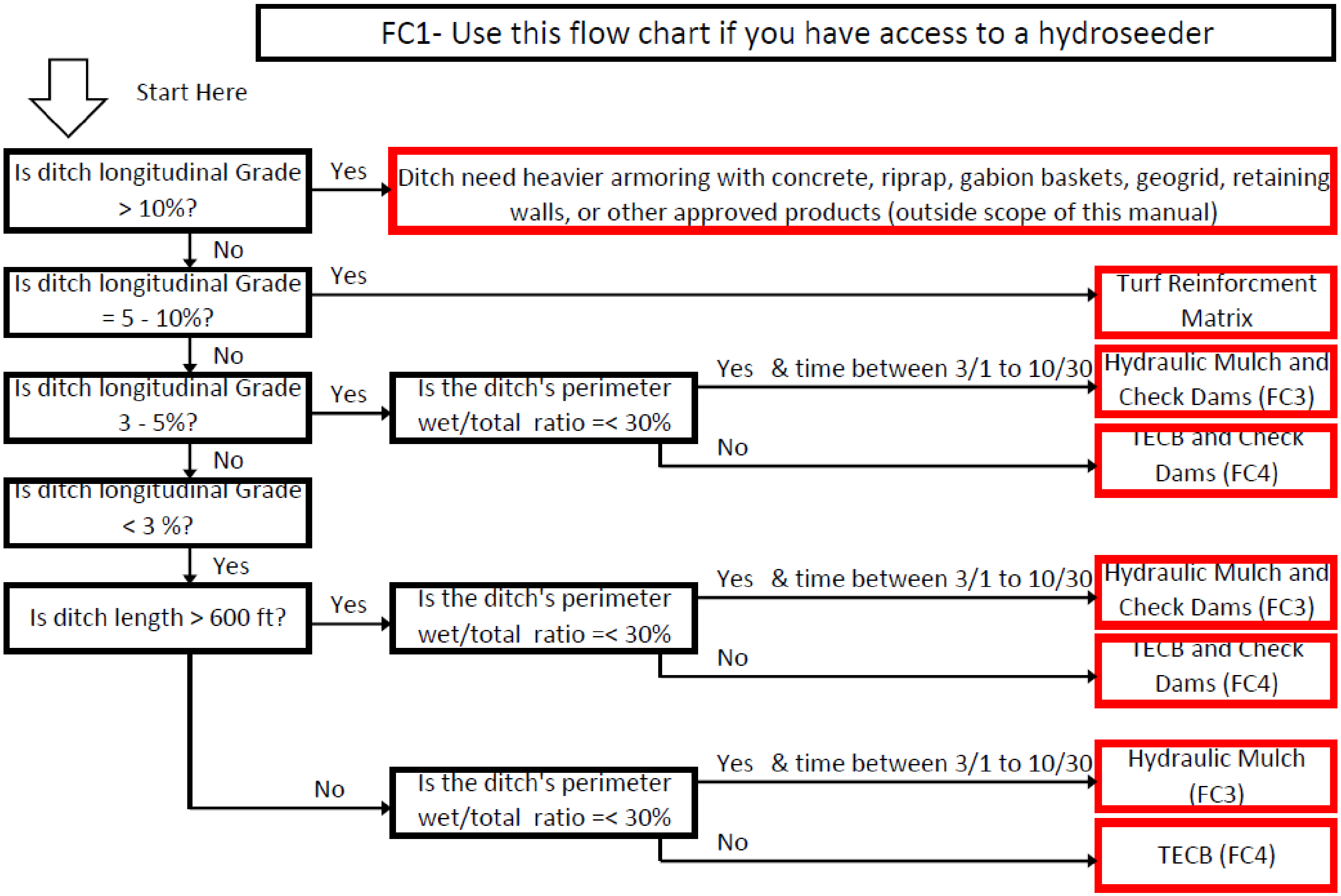


Figure 5. FC1- Flowchart to be used if a hydroseeder is available

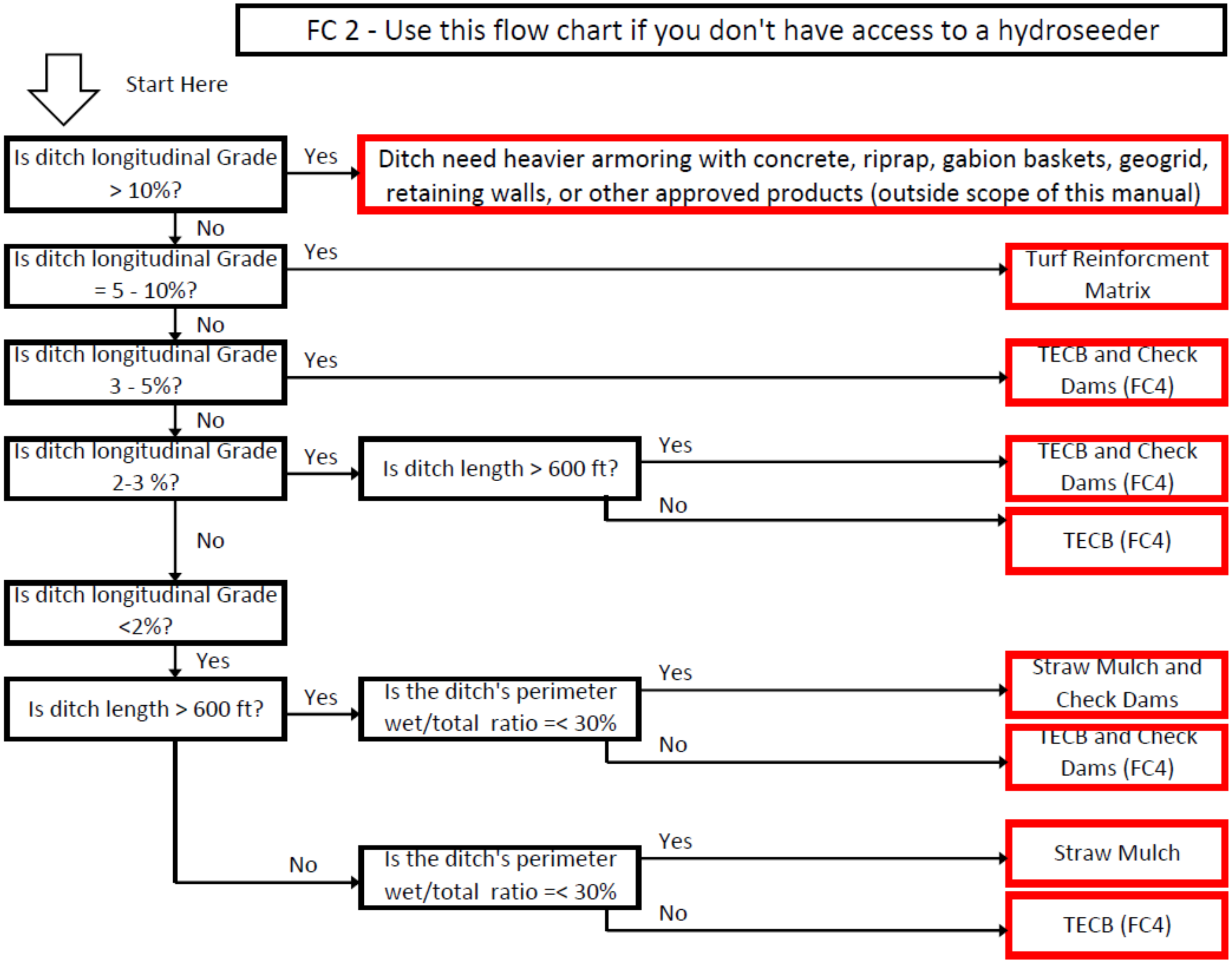


Figure 6. Flowchart to be used if a hydroseeder is not available

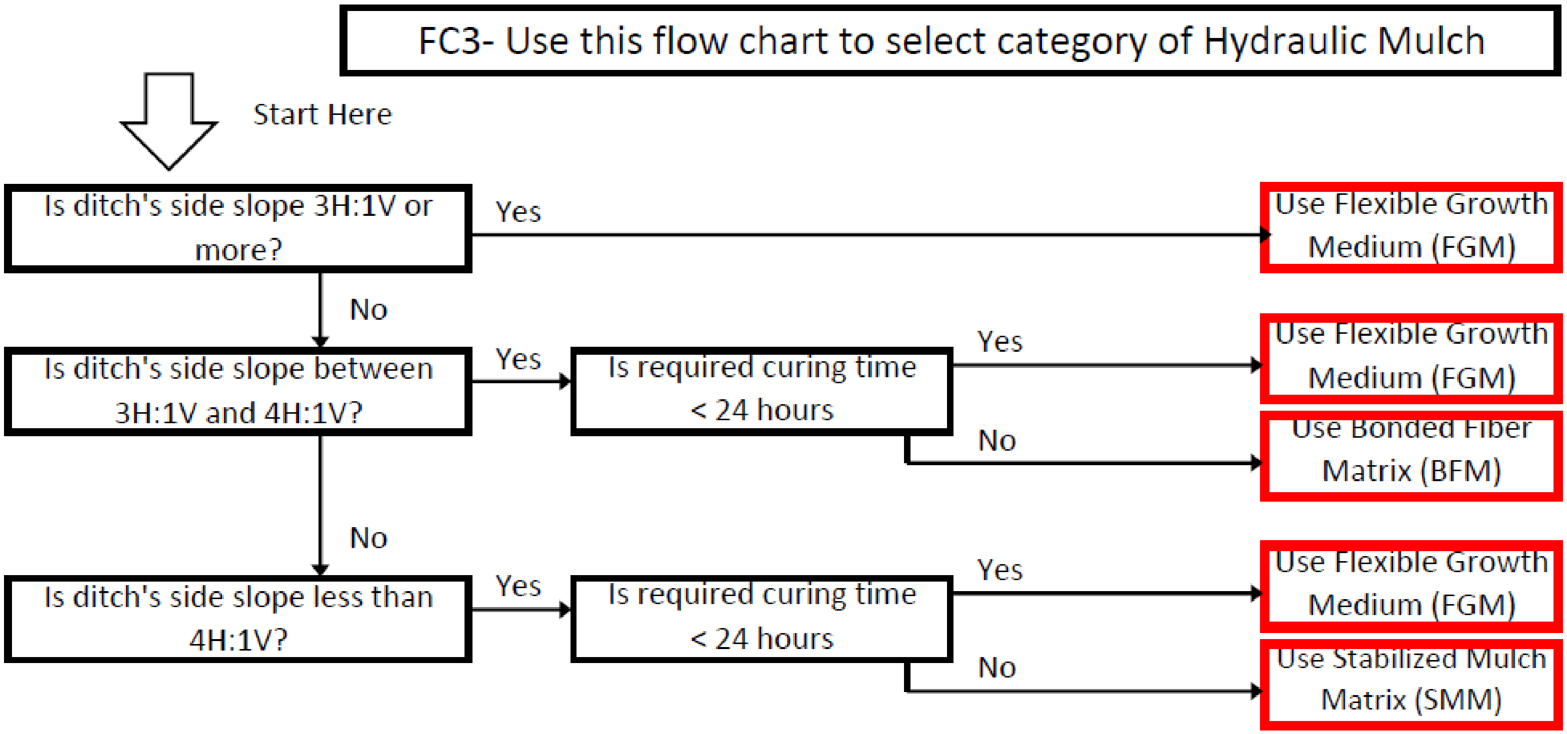


Figure 7. FC3- Flowchart to select adequate category of hydraulic mulch

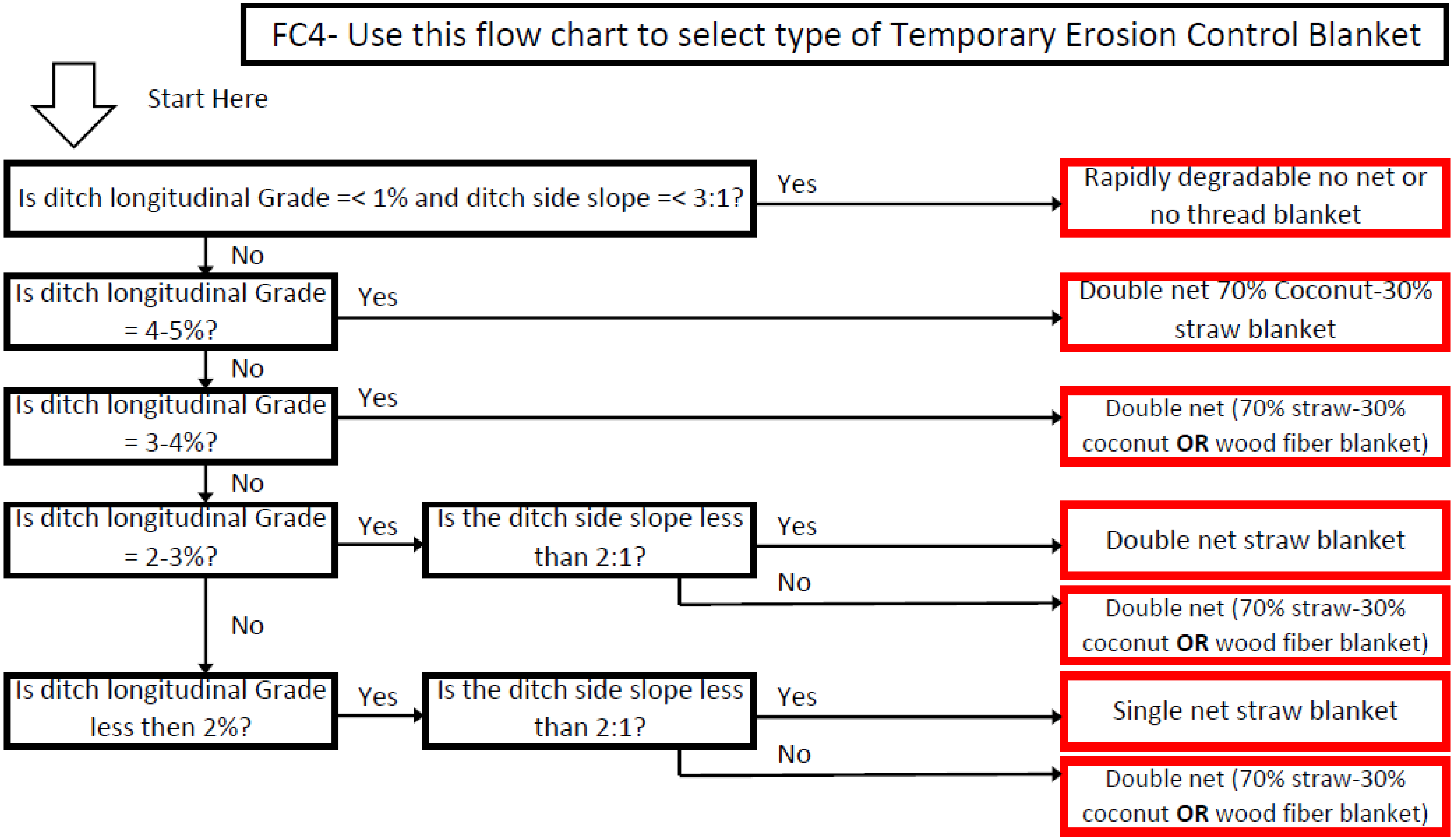


Figure 8. FC4- Flowchart to select adequate type of temporary erosion control blanket

To further assist Highway Maintenance Manager with selecting an appropriate temporary erosion control product, the research team developed an Excel spreadsheet "ODOT-FC" that incorporates all 4 flow charts. The user is asked a few questions and based on his/her answers, a recommended ECP is provided as shown in Figure 9.

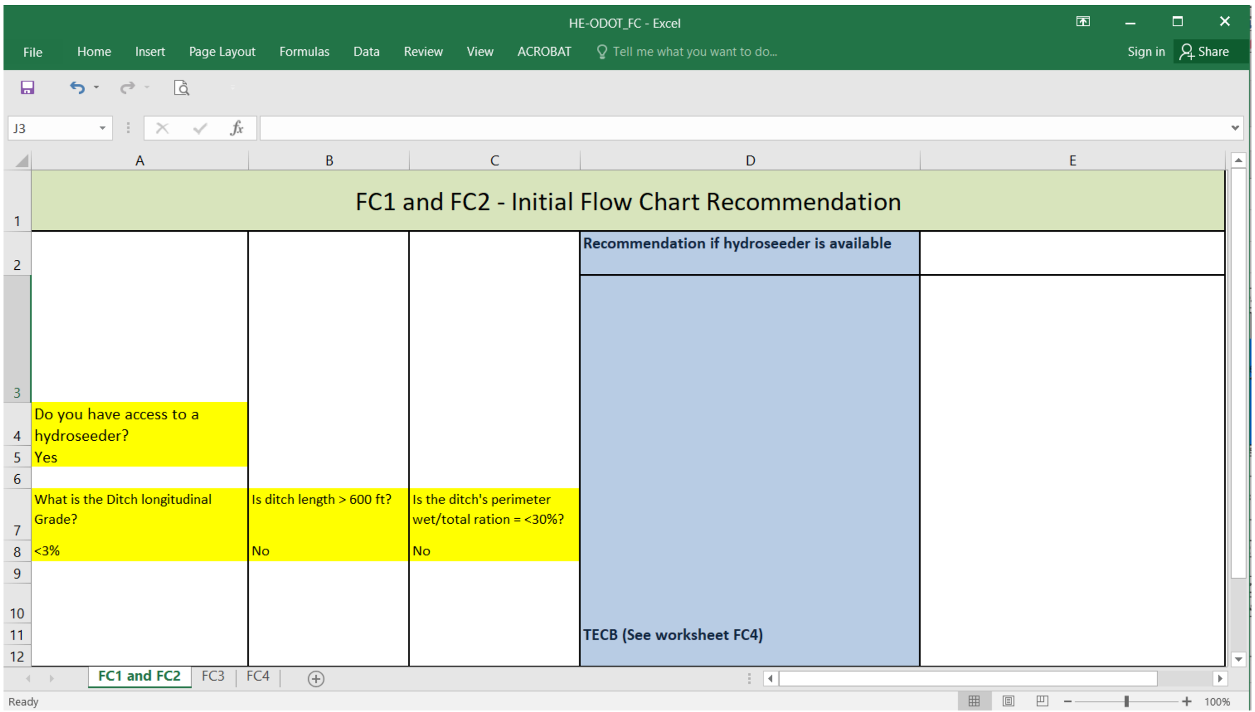


Figure 9- ECP Selection Spreadsheet "ODOT-FC".

The remainder of the manual include sections that describes in more detail the various procedures that may be used for providing temporary erosion control for ditches.

5. Permanent Seeding

5.1. Procedure Description

Permanent seeding includes seedbed preparation, planting seed, mulching, and maintenance. Figure 10 shows a ditch before and after permanent seeding. Permanent vegetation is used to stabilize soil, reduce erosion, prevent sediment pollution, reduce runoff by promoting infiltration, and provide stormwater quality benefits offered by dense grass cover. Permanent seeding should be done after completing all ditch cleaning work in the area and within 7 days.

Figure 10-Roadside Ditch before and after permanent seeding

5.2. Application rate and Seed mix

- Use approved O.D.O.T **Roadside Mix**
- 400lbs of O.D.O.T **Roadside Mix** seed /acre

of (50 lbs) seed bags = area of ditch (sf) * (8/43560)

5.3. Installation recommendations

Testing of soil and Liming

Per ODOT CMS 659.02 and 659.03, perform Standard Soil Analysis Test to measure the soil acidity or alkalinity (pH) if no topsoil is to be placed. This testing will determine the soil requirements for lime.

If liquid lime is used then use the following application table to achieve a pH of 6.5 or greater. Calculate the difference between the soil pH and 6.5 pH.

pH Difference	0.25	0.50	0.75	1.0
Application rate in gals/ac (L/ha)	2.5 (4)	5 (8)	10 (15)	20 (30)

Example: Soil Analysis Test pH=5.75 required pH=6.5 difference= 0.75 required application rate is 10 gals/ac (15L/ha)

Only use liquid lime on the Qualified Production list (QPL) list

- Incorporate lime into the top 3- to 6-inches of soil.
- Do not add lime if the pH is 7.0 or greater

Some Hydraulic Mulch manufacturers (e.g. Profile) provide free soil testing. The soil test determines 3 main things:

  - PH: recommended PH is from 6.3 to 7. This PH range maximizes plants' intake of micronutrients. If not in this range, plants will only be able to absorbs maximum 60% of nutrients; no matter how much fertilizer is used. This is not only wasting fertilizer but introduces more phosphates in the receiving water.
  - Organic matter: at least 3-5%
  - Salt level: determines amount of toxic salt that don't allow for vegetation

Planting Dates

- Traditional seeding for ODOT: April 15 to October 15

Fertilizer

- Per ODOT C&MS, obtain commercial fertilizer from a dealer or manufacturer whose brands are grades registered or licensed by the State of Ohio, Department of Agriculture.

- A fertilizer is typically denoted by 3 numbers (actual nitrogen-actual phosphorus- actual potassium). For example, fertilizer 10-24-18 has 10 percent of actual nitrogen – 24 percent of actual phosphorus and 18 percent of actual potassium within the fertilizer compound. If you had 100 pounds of a 10-24-18 blend you would have10 pounds of actual nitrogen, 24 pounds of actual phosphorus and 18 pounds of actual potassium within the bag.
    - Remember: Phosphorus helps roots grow and develop to get the grass plants established. Nitrogen will only be taken up after the seed has germinated and the vegetation is growing. It may wash down stream if applied heavily during seeding.
- A typical application rate of fertilizer for initial establishment of vegetation after seeding is approximately 1 pound of actual nitrogen per 1,000 square feet. With the 10-24-18 fertilizer this would require the application of approximately 435 pounds of this fertilizer mix per acre since there are 43,500 square feet in an acre. This fertilizer would also provide more than 2 pounds of phosphorus per acre.

of (50 lbs) fertilizer bags = area of ditch (sf) / (<u>Actual Nitrogen</u>*500)

- Incorporate lime and fertilizer to a depth of 3- to 6-inches
- Subsequent fertilization with an additional 2 pounds per 1,000 square feet of actual Nitrogen approximately one month after initial seeding will help grass growth after germination to achieve the density of vegetation to prevent or minimize erosion. A typical fertilizer for a second application once vegetation is established would be a 20-10-5 mix at 435 pounds of fertilizer per acre.

Seedbed Preparation

- Seedbed preparation is essential for the seed to germinate and grow.

- Loosen compacted, hard or crusted soil surfaces to a depth of approximately 3-inches with a disk, rake, ripper, chisel, harrow or other tillage equipment.
- Avoid preparing the seedbed under excessively wet conditions. Tillage for seedbed preparation should be done when the soil is dry enough to crumble and not form ribbons when compressed by hand

Seeding Method

Per ODOT CMS 659.12, evenly sow the seed over the prepared areas at the required rates. Seed can be broadcast using a cyclone seeder as shown in Figure 11. Do not sow seed during high winds. For slopes subject to windy conditions, seed using hydraulic methods only. Operate equipment in a manner to ensure complete coverage of the entire area to be seeded.

Figure 11. Manual Seeding using a Cyclone Seeder

Mulching

- Mulching or a rolled erosion control product is recommended to conserve moisture, reduce erosion and protect the seed.
- Crimp, tack or tie down straw mulch with netting. Mulching is extremely important for successful seeding (See Mulching and Hydromulching in this Manual).

Dormant Seeding

Per ODNR standards:

- Seeding should not be made from October 1 through November 20. During this period, the seeds are likely to germinate but probably will not be able to survive the winter.
- The following methods may be used for “Dormant Seeding”:
  - From October 1 through November 20, prepare the seedbed, add the required amounts of lime and fertilizer, then mulch and anchor. After November 20, and before March 15, broadcast the selected seed mixture. Increase the seeding rates by 50% for this type of seeding.
  - From November 20 through March 15, when soil conditions permit, prepare the seedbed, lime and fertilize, apply the selected seed mixture, mulch and anchor. Increase the seeding rates by 50% for this type of seeding.
  - Apply seed uniformly with a cyclone seeder, drill, cultipacker seeder, or hydro-seeder (slurry may include seed and fertilizer) on a firm, moist seedbed.
- Dormant seeding shall be mulched.

5.4. Maintenance and Inspection

- Inspect seeded areas weekly and after rain events. Check for erosion and seed wash out.
- Expect emergence of grasses within 28 days after seeding
- Check permanent seeding at each regular weekly inspection. Look for:
  - Germination.
  - Vigorous seedlings.
  - Uniform density with at least 70 percent of the ground surface covered.
  - Green, not yellow, leaves. Perennials should remain green throughout the summer, at least at the plant bases.

Mowing

- Consider mowing after plants reach a height of 6- to 8-inches.
- Mow grasses tall, at least 3-inches in height and minimize compaction during mowing process.

6. Straw Mulching

6.1. Procedure Description

As shown in Figure 12, a protective layer of mulch, usually of straw, is applied to bare soil to abate erosion by shielding it from raindrop impact. Mulch also helps establish vegetation by conserving moisture, holding fertilizer, seed, and topsoil in place, moderating soil temperatures and creating favorable conditions for seeds to germinate (ODNR 2006).

Figure 12- ODOT crew applying straw mulch to ditch after seeding it.

Straw mulch is readily available and inexpensive and is very effective in controlling erosion. It can be applied on large sites via blower. However, it may carry unwanted seeds and need tackifier or anchoring, especially on steep slopes or in windy conditions. If proper anchoring is not used, it is likely to be washed or blown away. Furthermore, it is labor intensive and time consuming and should be used if a hydroseeder is not available or on small ditches that don't justify the use of a hydroseeder.

Table 1- Advantages and Disadvantages of Straw Mulch

Advantages	Disadvantages
Provides rapid protection.	Thick mulches can delay germination.
Conserves moisture.	Can be blown or washed away if not adequately tackified.
Allows vegetation growth through the mulch.	May create road hazard if animals begin grazing on straw mulch applied to roadsides.
Protects seeding from heat, moisture loss, and transport due to runoff.	

Adopted from Oregon DOT Erosion Control Field Manual , 2006

6.2. Application Rate

Per ODOT CMS 659.14, evenly place straw mulch over all seeded areas at the following rates:

- From March 15 to October 30: 2 standard 45 lb. bales per 1000 sq. ft. of disturbed area.

of (45 lbs) straw mulch bales = area of ditch (sf) *2 / (1000)

- From October 31 to March 41: 3 standard 45 lb. bales per 1000 sq. ft. of disturbed area.

of (45 lbs) straw mulch bales = area of ditch (sf) *3 / (1000)

6.3. Installation Recommendations

Best Practices

- Apply seed first.
- Mulch material shall be applied immediately after seeding. 100% of the ground surface shall be covered with an approved material.
- Per ODOT CMS 659.13, mulch materials may consist of straw, compost, or wood fiber for 3:1 or flatter slopes. Use mulch that is reasonably free of weed seed, foreign materials, or other materials that would prohibit seed germination.
- Do not mulch during high winds. For slopes subject to windy conditions mulch using hydraulic methods only.

- Within 24 hours after seeding an area, evenly place mulch.
- Immediately replace mulch that becomes displaced.

Anchoring

- Crimp, tack or tie down mulch with netting.
- Per ODOT CMS 659.14, apply tackifiers according to the manufacturer's recommendations.
- Tackifiers assist in adhering the mulch to the ground. They also aid in maintaining a small quantity of moisture for seed germination.
- Different tackifiers are available including Polyacrylamide (PAM), Polysaccharides and natural gums such as Guar. Polysaccarides work well with straw mulch.

6.4. Maintenance and Inspection

- Inspect all mulched areas on a weekly basis and after rainstorms for erosion and damage to the mulch. Repair promptly and restore to original condition. Continue inspections until vegetation is well established.

7. Hydromulching

7.1. Procedure Description

Hydromulching (or hydroseeding) is a planting process that uses a slurry of seed and mulch. It is often used as an alternative to the traditional process of broadcasting or sowing dry seed. As shown in Figure 13, the hydroseeding slurry is transported in a tank, and sprayed over prepared ground. The slurry often has other ingredients including fertilizer, tackifying agents and biostimulants.

Figure 13- ODOT Crew applying hydraulic mulch to a ditch in Putnam County

Hydroseeding holds moisture and protect against soil loss from wind, rain, sun and pests and is very effective for hillsides and sloping lawns (Kitsap 2012). Hydroseeding will typically cost less than planting with sod, but more than broadcast seeding. Results are often quick with high germination rates producing grass growth in about a week. When fiber mulch is added to the hydroseed slurry, it accelerates the growing process by maintaining moisture around the seeds thereby increasing the rate of germination. If the seed mix is combined with a long term bonded fiber matrix (BFM), it will provide a quick erosion control measure until the seed emerges and grows into a healthy stand of groundcover.

Table 2- Advantages and Disadvantages of Hydromulching

Advantages	Disadvantages
Provides rapid installation.	Can be more expensive than broadcast or drilling seed applications.
Generally requires less seedbed preparation, surface soil may be left irregular with large clods, stones, or rock outcropping exposed.	Overly thick mulch applications can delay germination.
Less soil preparation, faster lay down and lower installed cost than rolled blankets	Can be blown or washed away if not adequately tackified.
Uniformly distributes seed and mulch material.	Required application rates can vary significantly depending on product.
Increases favorable conditions for quick germination and growth.	Will be washed away by concentrated flow
Can be used effectively on steep slopes and other areas where access is limited	

Adopted from Oregon DOT Erosion Control Field Manual , 2006

7.2. Application to ditches

Hydromulching is very effective in controlling erosion of a ditch's slopes and as such is an effective method of erosion control since soil particles on the slopes, if not protected will break down by rain and creates sheet erosion, which can lead to the formation of small rill channels and larger gullies as shown in Figure 14. Such erosion of ditch slopes will significantly increase sediment loading and buildup which will not only deteriorate water quality but will necessitate more frequent cleaning of ditches.

Figure 14. Rill erosion resulting from unprotected ditch slopes (CRWP, 2012)

Hydroseeding should particularly be used in ditches that have large, steep slopes as shown in Figure 15. Such slopes typically experience excessive sheet erosion and are more difficult to protect using erosion control blankets.

Figure 15. Ditch with a steep slope *(Schneider 2014)*

It should be noted however that hydromulch products are not designed to handle concentrated flows. As such, if it is expected that the ditch will experience concentrated flows before adequate vegetated cover is established, and to further reduce erosion from unvegetated ditch bottoms, additional BMPs such as flow attenuation devices (i.e. rock check dams, wattles) and/or erosion control blankets can be used in conjunction with hydromulching as shown in Figure 16. Such BMPs don't have to be installed along the entire length of the ditch and may only have to be installed in areas where concentrated flows exceeds 3.5 feet per second (e.g near culverts). More information about these BMPs is included later in this Manual. (See Temporary Erosion Control Blankets and Check dams).

Figure 16. Hydromulch used in conjunction with terra tube

7.3. Materials and Products

Per ODOT CMS 659.15 wood fiber mulch should consists of pure wood fibers manufactured expressly from clean wood chips. Ensure that the chips do not contain lead paint, varnish, printing ink, and petroleum based compounds. Do not use wood fiber mulch manufactured from recycled materials of unknown origin such as sawdust, paper, cardboard, or residue from chlorine-bleached pulp and paper mills. Ensure that the wood fiber mulch maintains uniform suspension in water under agitation and blends with grass seed, commercial fertilizer, and other additives to form a homogeneous slurry. Use manufacturer-approved tackifiers.

Several hydraulic mulching products exist in the market that meet ODOT CMS 659.15. Existing mulching products are typically classified in the following broad categories depending on their ability to bind to the soil which is partly affected by the amount of tackifiers they contain:

1. Stabilized Mulch Matrix (SMM) products which contain about 5% tackifiers. They are made of thermally refined wood fibers, tackifiers, and activators that anchor mixture to the soil surface. They can offer erosion control on flat surfaces to grades of 2.5H:1V. The SMM is phytosanitized, free from plastic netting, and when cured forms an intimate bond with the soil surface to create a continuous, porous, absorbent and flexible erosion resistant blanket that allows for rapid germination and accelerated plant growth.
2. Bonded Fiber Matrix (BFM) products which contain about 10% tackifiers. They consist of a matrix of defibrated fibers and cross-linked insoluble hydro-colloidal tackifiers that allow up to 1350 % water holding capacity. They dry to form a breathable, built-in-place blanket which contours with the surface to maintain intimate soil contact and offers erosion control on moderate to steep hills.
3. Flexible Growth Medium (FGM) products which combines both chemical and mechanical bonding techniques to lock the engineered medium in place and promote accelerated germination with minimal soil loss. FGM products are more expensive but are immediately effective upon application because they bond directly to soil. They are made of a matrix of thermally refined wood fibers, cross-linked biopolymers, and water absorbents that allow up to 1500% water holding capacity. They can immediately bond to the soil surface. Their flexible yet stable matrices retain > 99% of soil, vastly reducing turbidity of runoff for up to 18 months.

The above product categories vary greatly in longevity, strength, heaviness and the rate of water flow they can handle. As illustrated in Figure 17, the product categories are separated into tiers based on the recommended steepness of slope, flow velocities and shear stress that they can sustain.

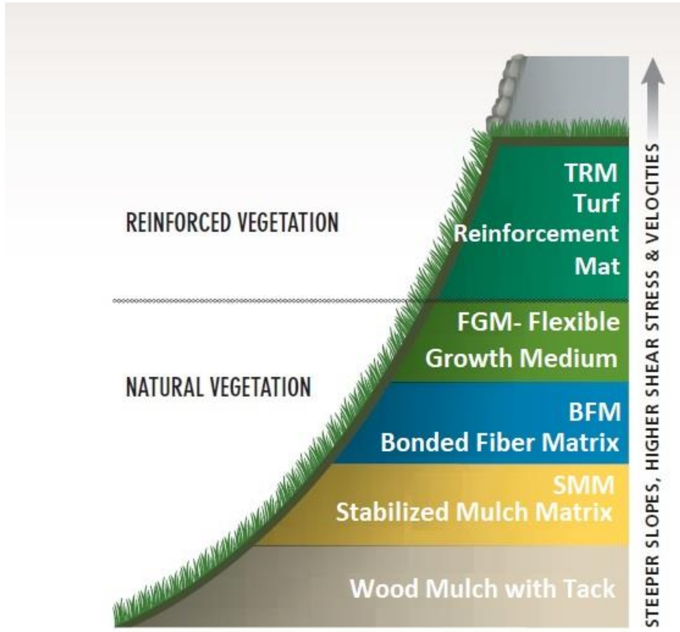


Figure 17 – Hierarchy of Hydraulic Mulch Categories

7.4. Selecting a Hydraulic Mulch Product

Factors affecting selection

Many factors should be considered when selecting among the various hydraulic mulch categories currently available in the market. These factors include functional longevity, maximum ditch side slope, curing time and cost. These factors are further described below. Table 3 include representative values of these factors for the different categories of hydraulic mulch.

Table 3- Typical attributes of hydraulic mulch categories

Hydraulic mulch Type	SMM	BFM	FGM
Maximum Ditch Side Slope	4H: 1V	3H:1V	1H:1V
Curing Time	24 hours	24 hours	2 hours
Functional Longevity	3 months	6 months	18 months
% tackifier	5%	10%	10% and other polymers
Example of available products	Terramatrix	Promatrix	Flexterra
Cost (product only, without installation) $/acre	$ 1,200.00	$ 1,520.00	$ 2,160.00

Maximum ditch side slope

As shown in Table 3, in cases where a ditch's side slope is steeper than 3H:1V, a Flexible Growth Medium (FGM) hydraulic mulch product such as Flexterra is the only category of hydraulic mulch that can provide adequate protection of seeding without causing sheet erosion of the slope. South Carolina DOT has conducted some field tests on Flexterra and based on those tests has written Flexterra into its standard construction specifications as an equal to double-sided blankets for applications on slopes up to 2H:1V (Profile 2012).

Curing time

The curing time of a hydraulic mulch should be less than the time when the next rain storm is expected. The curing time is the length of time that a product needs to dry out and gain its designed strength. If a major rainfall takes places within the curing time of an applied hydraulic mulch product, there will be significant product loss due to water flush. As shown in Table 3, a Flexible Growth Medium (FGM) hydraulic mulch product such as Flexterra has the shortest curing time of 2 hours, both the SMM and BFM products in Table 3 have 24 hours curing time. For other products not included in Table 3, the manufacturer's product information should be carefully reviewed to determine the curing time.

Functional longevity

Functional longevity is a term describing how long an erosion control material/BMP is predicted to provide desired performance attributes. The higher the functional longevity, the more storms the BMP can withstand; since paper mulch for example has a low functional longevity, it won't last very long (it will be gone after 1 or 2 rain events). As shown in Table 3, the functional longevity of the SMM product is 3 months, that of the BFM product is 6 months. a The FGM hydraulic mulch product Flexterra as shown in Table 3 has a functional longevity of 18 months.

Cost

As shown in Table 3, the cost of commercial hydraulic mulch vary significantly. In general, the purchase cost from least expensive to most expensive is: SMM, BFM and FGM. The most economical hydraulic mulch that meets the project requirements should be selected.

It should be noted that the values given in Table 3 are only representative values of the products listed in the table. In cases other products are used, the manufacturer's specifications should be reviewed.

7.5. Application Rates

To calculate the hydraulic mulch mix, you should determine the following:

1. Amount of mulch product needed in lbs.

of (50 lbs) mulch bales = area of ditch (sf) * (Application rate (lbs/acre) / (43560*50))

2. Amount of water needed in gallons.

   See below

3. Amount of fertilizers needed in 50 lbs bags. (as previously discussed)

of (50 lbs) fertilizer bags = area of ditch (sf) / (Actual Nitrogen*500)

4. Amount of seeds needed in 50 lbs bags. (as previously discussed)

of (50 lbs) seed bags = area of ditch (sf) * (8/43560)

Chapter 5 described how to determine amounts of fertilizers and seeds. The amount of mulch and water vary significantly depending on the product. It is thus very important to review manufacturer information such as that shown in Figure 18. As shown in Figure 18, the application rate depends on the steepness of the slope. Assuming a slope of < 3H: 1V, the application rate of is 3000lbs/acre.

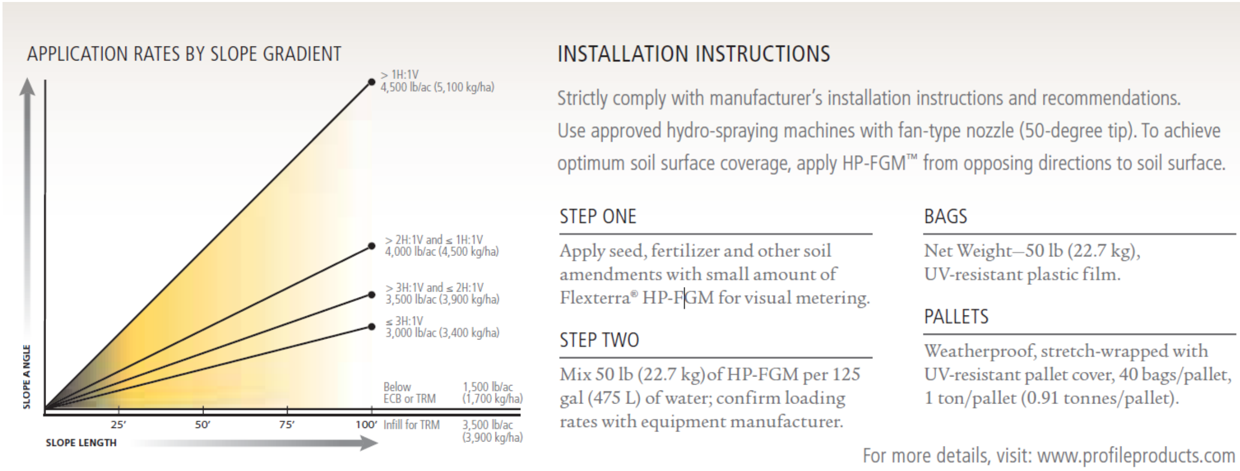


Figure 18- Application rates of Flexterra FGM (http://www.profileevs.com)

It should be noted that water mixing rate not only varies from one product to another but also can be provided by the manufacturer in different formats including:

1. Lbs. of mulch products that need to be mixed with 100 gallons of water
2. Gallons of water to be mixed with each 50 lbs. bale

This can be confusing and care should be taken to determine the correct amount of water. You can use the following equation to convert (1) to (2) or (2) to (1)

(2) = 5000/(1)

(1) = 5000/(2)

For example, a product that requires mixing 60 lbs. of mulch with 100 gallons of water (1) will require (5000/60= 83.3 ≈ 85 gallons to be added to each 50 lbs. bale (2).

Make sure you use the right equation from the 2 provided below based on the information provided.

Calculation of water needed if manufacturer data provide gallons of water to be mixed with each 50 lbs. bale

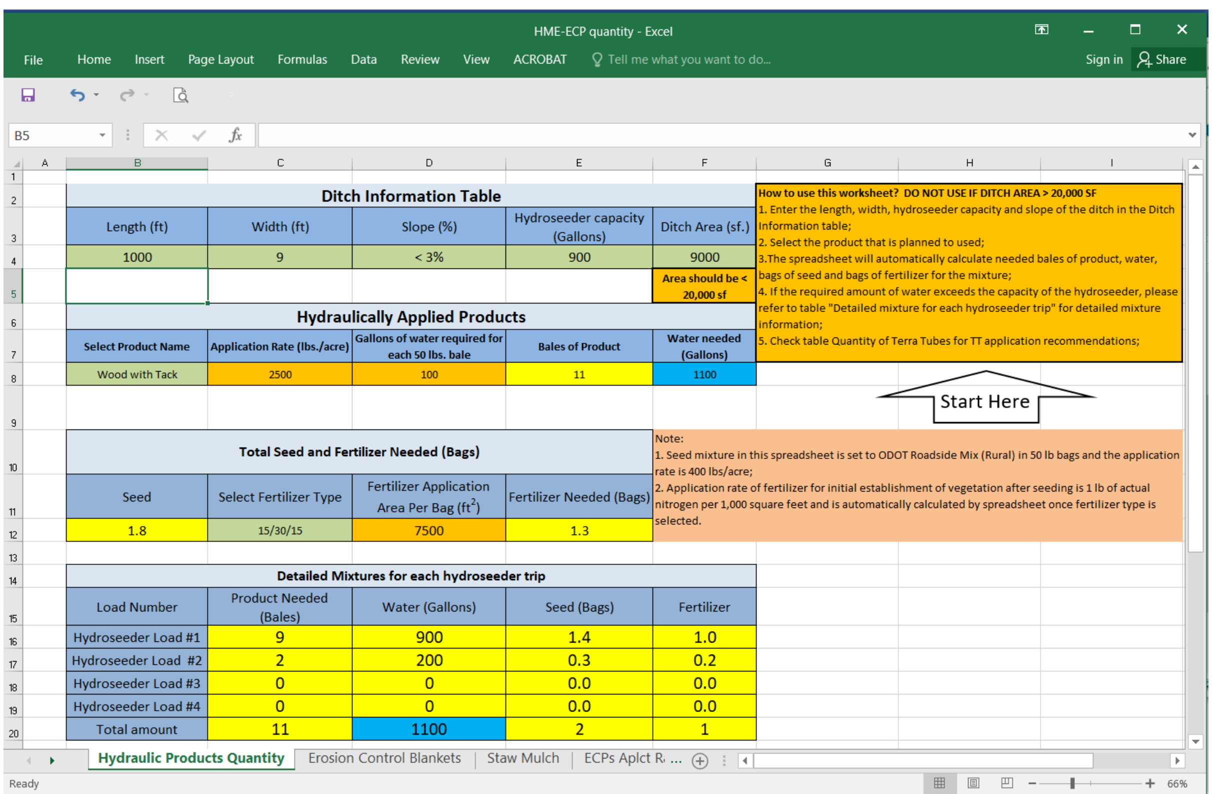
Gallons of water = # of 50 lbs mulch bales * gallons of water to be mixed with each 50 lbs bale

Calculation of water needed if manufacturer data provide lbs of mulch products to be mixed with 100 gallons. of water

Gallons of water = # of 50 lbs mulch bales * (5000 / lbs of mulch products to be mixed with 100 gallons. of water)

To simplify the process of determining the quantities of the hydraulic mulch mix, a spreadsheet "ECP quantity" was developed as shown in Figure 19. In the spreadsheet, the user enters the size of the ditch, the size of the hydroseeder and both the mulch application rate and water mixing rate. The spreadsheet calculates the required number of hydraulic mulch bales, the amounts of seeds and fertilizers and the volume of water in gallons needed for the mix.

In case of large ditches that need more water than the size of the available hydroseeder, the spreadsheet will divide the application into different "trips" and will provide the # of bales, the amount of seeds and fertilizers and the volume of water required for each "trip". The spreadsheet has already been populated with information corresponding to several mulching products that were tested during the research project. Information on additional mulching products can be easily added. Furthermore, in ditches where it is recommended to use wattle products such as terra tubes, the spreadsheet will calculate the number of wattles needed based on the ditch's slope. A screen shot of the spreadsheet is shown in Figure



Ditch Information Table

Length (ft)	Width (ft)	Slope (%)	Hydroseeder capacity (Gallons)	Ditch Area (sf.)
1000	9	< 3%	900	9000

Hydraulically Applied Products

Select Product Name	Application Rate (lbs./acre)	Gallons of water required for each 50 lbs. bale	Bales of Product	Water needed (Gallons)
Wood with Tack	2500	100	11	1100

Total Seed and Fertilizer Needed (Bags)

Seed	Select Fertilizer Type	Fertilizer Application Area Per Bag (ft^2)	Fertilizer Needed (Bags)
1.8	15/30/15	7500	1.3

Detailed Mixtures for each hydroseeder trip

Load Number	Product Needed (Bales)	Water (Gallons)	Seed (Bags)	Fertilizer
Hydroseeder Load #1	9	900	1.4	1.0
Hydroseeder Load #2	2	200	0.3	0.2
Hydroseeder Load #3	0	0	0.0	0.0
Hydroseeder Load #4	0	0	0.0	0.0
Total amount	11	1100	2	1

Figure 19- Spreadsheet "ECP quantity" to calculate quantities for the hydraulic mulch mix

7.6. Installation Recommendations

Soil testing

Some hydraulic mulch manufacturers provide free soil testing. To perform the test, a form should be submitted to the manufacturer together with soil samples. An example of this form is shown in Figure 20. The sampling procedures are straightforward and are described in detail on the form. The soil sample should be taken from *under* the soil in the ditch that is going to removed/dredged. Thus the soil that will be dredged should be removed before taking the sample.

Three samples are typically needed. The volume of soil required for each sample is roughly one 8-ounce cup (or approximately one pound). Each sample should be inserted into a Ziploc bag and clearly mark the sample number (should be 01, 02 or 03) on each bag along with the matching input form report number "3050-0003-1" using a permanent marker. A "sample description" and "location of sample" for each sample should be provided as shown below:

- Sample Description Example: loamy sand soil with organic matter
- Location of Sample Example: south facing 2H:1V slope above pond

Testing typically take 48 hours once received by the lab.

Profile — Solutions for your Environment	Profile Soil Analysis Laboratory 300 Speedway Circle, Suite 2 Lincoln, NE 68502 800-508-8681	Master Account No. 2861310 Report Type: Soil Test Input Report No. 0391-0032-1

Project Name:	ODOT District #1 Testing - Dr.Elzarka
Project City:	Canfield
Project State:	Ohio, United States
Date Samples Shipped:	

Sample No.	Sample Description	Location of Sample	Lab Use Only
1			
2			
3			

Instructions / Guidance

Proper Sampling Equipment:
Equipment should be such, that sampling depth can be monitored and controlled. A stainless steel sampling probe works the best, but is not required. Composite samples should be collected in a plastic bucket for thorough mixing. Metal buckets can contain traces of some micro-nutrients (particularly zinc), which can contaminate samples. Soil sample bags should be either plastic or plastic lined.

Sampling Procedures:
Determine which areas are to be sampled. Review the site, note significant changes in soil, such as color or texture. Each sample should consist of a composite of many sub-samples from like soils. Try to composite 10 to 15 sub-samples to create one representative sample. The volume of soil needed is roughly one 8 ounce cup (or approximately one pound). It is most important to "keep the sampling depth consistent". Erosion Control projects should be sampled to a depth of 3 inches. If organic matter is on the surface, scrape away prior to sampling, usually no more than ¼" to ½" surface layer. Insert each composite sample into a Ziploc bag and clearly mark the sample identification number (should be 01, 02 or 03) on each bag along with the matching input form report number using a permanent marker. Then place this bag inside another Ziploc bag and label the second bag identical to the first.

Paperwork and Shipping Instructions
Please be sure all information is completed on the soil testing input form. Be sure to make a copy of the input form for your records. Prior to closing up the box, make sure that the soil sample bags are properly labeled, double bagged and correspond with the input sheet. Pack samples very tightly in a strong shipping box. Use packing material so the bag(s) will not shift in the box. Tape the box completely and affix a shipping label. If possible, collect and ship samples the same day.

For more than 3 samples on a project call Profile using the number provided above.
Sample Description Example: loamy sand soil with organic matter
Location of Sample Example: south facing 2H:1V slope above pond
Make a copy of the form for your records and then ship this form and samples to address shown on top of the form.
Do not use this form more than once as each form has a tracking number!

Testing Packages:	
	Diagnostic + Soluble Nutrients + Particle Size Analysis (Erosion Control)
	Particle Size Analysis (Sportsfields only) email:

Figure 20- Soil Testing Form

Timing

Per ODOT CMS 659.15, hydromulch should be applied from March 1 to October 30.

Planning

- To ensure proper application rates, measure and stake ditch area by measuring the width of ditch and its length. Use the calculated area to determine mulch quantity and water needed for mixing.

Installation Procedures

- Strictly comply with equipment Manufacturer's installation instructions and recommendations. Use approved hydro-spraying machines with fan-type nozzle (50-degree tip) whenever possible to achieve best soil coverage. Apply from opposing directions to assure 100% soil surface coverage.
- Fill 1/3 of mechanically agitated hydroseeder with water. Turn pump on for 15 seconds and purge and pre-wet lines. Turn pump off;
- Turn agitator on, open recirculation valve and load low density materials first (i.e. seed);
- Continue slowly filling tank with water while loading mulch product into tank;
- Consult "Application Rates" above to determine the number of bags to be added for desired area and application rate;
- Hydraulic mulch product should be completely loaded before water level reaches 75% of the top of tank;
- Add fertilizer as water level approaches the top of the tank;
- Top off with water and mix until all fiber is fully broken apart and hydrated (minimum of 10 minutes—increase mixing time when applying in cold conditions). This is very important to fully activate the bonding additives and to obtain proper viscosity;
- Shut off recirculation valve to minimize potential for air entrainment within the slurry;
- Slow down agitator and start applying with a 50-degree fan tip nozzle;
- Spray in opposing directions for maximum soil coverage.

7.7. Maintenance and Inspection

Hydraulic mulches and tackifiers must provide the necessary erosion protection until permanent erosion-resistant vegetative cover is established. Inspect all mulched areas on a weekly basis and after rainstorms for erosion and damage to the mulch.

- If sheet or rill erosion is evident, then prompt reapplication of treatments will be necessary.
- Areas that fail to establish adequate vegetative cover to prevent erosion should be re-mulched as soon as such areas are identified.
- If mulched areas are damaged by concentrated runoff, implement additional BMPs promptly as necessary to remedy the problem.
- Re-mulch and protect with a net or blanket any areas that experience erosion. If the erosion problem is drainage related, fix the drainage problem and re-mulch the eroded area.

8. Temporary Erosion Control Blankets

8.1. Procedure Description

A Temporary Erosion Control Blanket (TECB) as shown in Figure 20, is a degradable manufactured material used to stabilize easily eroded areas while vegetation becomes established. TECBs are composed of biologically, photo chemically or otherwise degradable materials. They degrade within 6 to 24 months, depending on their makeup. They usually consist of a layer of straw, coconut fiber, or wood fiber sandwiched between layers of plastic or fiber mesh. They reduce soil erosion and assist vegetative growth by providing temporary cover for the seed and soil until germination. Permanent non-degradable rolled erosion control products (turf reinforcement mats) are beyond the scope of this practice, but may be useful where design discharges or runoff exert velocities and shear stresses exceeding the ability of mature vegetation to withstand.

Figure 20. ODOT Crew installing a TECB in a ditch in Mahoning County

Table 4- Advantages and Disadvantages of Temporary Erosion Control Blankets

Advantages	Disadvantages
Immediate cushioning against splash erosion from raindrop impact.	Correct installation is critical to the product effectiveness. Good ground contact during installation prevents runoff concentrating under the blanket and causing significant erosion
Captures a great deal of sediment due to its open, porous structure.	Soil surface must be graded smooth with no surface irregularities.
Usually easy to install.	If blanket is not fully decomposed at the time of the following cleaning, it may get tangled up in cleaning equipment.

Adopted from Oregon DOT Erosion Control Field Manual , 2006

8.2. Application

Erosion-control blankets are used to help limit erosion and establish vegetation in ditches where conventional seeding would be inadequate. By reducing the negative effects of rainfall impact and runoff, erosion-control blankets provide ditches with a temporary, stable environment for seed to germinate. Most are designed to provide temporary stabilization until vegetation is established. As much as possible during establishment of vegetation, soil stabilization blankets should not be subjected to concentrated flows moving at greater than 3.5 feet/second.

8.3. Materials and products

Erosion control blankets can be made of wood fiber, straw, jute, coconut or a combination of these, typically with either 1 or 2 layers of plastic or jute netting which holds the material together. ODOT CMS 712.11 specifies different types of TECBs as shown in Table 5. The table also shows the allowable shear stress for each type as specified in ODOT Location and Design Manual (ODOT 2016).

Table 5- TECB types and allowable shear stress (ODOT 2016)

TECB	Description	Allowable Shear Stress (lbs./ft^2)
ECB Type A	Single net straw blanket	1.25
ECB Type B	Double net straw blanket	1.5
ECB Type C	Double net (70% straw 30% coconut) blanket	2
ECB Type E	Double net coconut blanket	2.25
ECB Type F	Single Jute yarn	0.45
ECB Type G	Double net wood excelsior blanket	1.75

Appendix A includes a methodology developed by the authors for calculating shear stresses using readily available data. The calculated shear stress can be compared to allowable shear stress values in Table 5 for proper TECB selection. However, since the methodology may be time consuming, the authors have developed FC4 "Selection Flow Chart for TECBs" based on nationally acceptable rule of thumbs and published manufacturers' data.

Factors affecting selection

Many factors should be considered when selecting among the various types of TECB currently available in the market. These factors include ditch longitudinal grade, maximum ditch side slope, and cost. Table 6 include representative values of these factors for the different types of TECBs.

According to Table 6, a net free blanket, which is stitched together with a biodegradable thread, is a better option for flat ditches with longitudinal grade less than 1% that will be mowed or to prevent potential wildlife entrapment.

Ditches with gently sloping bottoms (less than 2%) can be stabilized with a single net straw blanket if the ditch's side slope is less than 2H: 1V. For those ditches, if the side slope is steeper than 2H:1V, a double net (70% straw-30% coconut) or wood fiber blanket should be used.

<u>Table 6- Typical attributes of TECB types</u>

TECB type	ODOT SPEC	Mowed	Ditch Longitudinal grade	Ditch sides' slope	Service Life	Bio-degradability	Wildlife Friendly	Price
1 side no thread/stitching rapidly degradable wood cellulose blanket		Yes	1%	less than 3:1	6-8 wks	Fast	More Friendly	$
Rapidly degradable no net stitch only wood fiber blanket		Yes	1%	less than 3:1	6-8 wks	Fast	More Friendly	$
Rapidly degradable one side wood fiber blanket		Yes	1%	less than 3:1	1-3 mo	Fast	More Friendly	$$
Single net straw blanket	ECB Type A	No	up to 2%	from 3:1 to 2:1 and less than 50 ft long	6-9 mo	Medium	Friendly	$$
Double net straw blanket	ECB Type B	No	up to 3%	from 3:1 to 2:1 and greater than 50 ft long	6-9 mo	Medium	Friendly	$$
Double net 70% straw-30% Coconut blanket	ECB Type C	No	up to 4%	2:1 & steeper	24-36 mo	Slow	Less friendly	$$$
Double net wood fiber blanket	ECB Type G	No	up to 4%	2:1 & steeper	24-36 mo	Slow	Less friendly	$$$
Double net 70% Coconut-30% straw blanket		No	up to 5%		24-36 mo	Slow	Less friendly	$$$$$
Triple net 70% straw-30% Coconut or wood Fiber		No	up to 6%		> 36 mo	Very Slow	Unfriendly	$$$
Triple net coconut or wood fiber		No	up to 7%		> 36 mo	Very Slow	Unfriendly	$$$$

Ditches that have a longitudinal grade between 2% and 3% should use a double net straw blanket if the ditch's side slope is less than 2H: 1V and a double net (70% straw-30% coconut) or wood fiber blanket if the ditch's slope is steeper than 2H:1V.

Ditches that have a longitudinal grade between 3% and 4% should use a double net (70% straw-30% coconut) or wood fiber blanket and ditches that have a longitudinal grade between 4% and 5% should use a double net (70% coconut and 30% straw) blanket.

As shown in Table 6, the cost of TECBs vary significantly. In general, the purchase cost from least expensive to most expensive is: net free and rapidly degradable blanket, single net straw blanket, double net straw blanket, double net 70% straw -30% blanket, double net wood fiber blanket, double net 70% coconut and 30% straw blanket and triple net blankets. The most economical TECB that meets the project requirements should be selected.

It should be noted that the values given in Table 6 are only representative values of the products listed in the table. In cases other products are used, the manufacturer's specifications should be reviewed.

It should also be noted that in general, wood fiber blankets work better than straw blankets because, when wetted, they swell and the barbed fibers bind together to stay in place more effectively (Figure 21). The wood fibers also absorb water, helping seeds to germinate. Straw tends to float and doesn't absorb water or bind to the ditch or its slopes. Wood fiber blanket costs more, but typically works better for ditch maintenance projects (Brady et al. 2014).

Figure 21. Wood Fiber Blankets (Brady et al. 2014)

Staples

Per ODOT supplemental specification 832, the staples used to anchor the TECB to the ground should consist of 12-inch (0.3 m) No. 11 gage steel wire bent into narrow U-shape with the ends of the staples approximately 1 inch (25 mm) apart producing a 6-inch staple.

8.3. Application Rate

TECB can be applied to ditches in two ways:

1. As the only erosion control BMP in a ditch as shown in Figure 14. In this case, the required area of the blanket can be calculated by multiplying the ditch's width by the ditch's length **and adding 10% to account for overlap and anchor trenches as explained below**.

# of Blankets = 1.1 * (area of ditch (sf) / (length of blanket (ft) * width of blanket (ft)))

2. Used in combination with hydraulic mulch to only cover the area of the ditch from the high flow line to ditch's bottom. In this case, the required area of the blanket can be calculated by multiplying the ditch's wetted perimeter by the ditch's length.

# of Blankets = 1.1 * (wetted area of ditch (sf) / (length of blanket (ft) * width of blanket (ft)))

8.4. Installation Recommendations

Site Preparation and Seeding

- Prepare the surface to be protected by the erosion control blanket. Remove large stones;
- Add any soil amendments before you install the erosion control blanket. For example, you may need to amend the soil with lime.
- Make sure seed bed is firm yet friable.
- Seed and fertilize: apply seed and fertilizer to soil surface prior to installation. Refer to the Permanent seeding section for seeding recommendations.
- The TECB is then installed over the seed.
- All check slots, anchor trenches, and other disturbed areas must be reseeded as discussed below.

Blanket Installation

With the abundance of TECB products available, it is impossible to cover the installation procedures of all products. Therefore, as with many erosion control-type products, there is no substitute for a thorough understanding of the manufacturer's instructions, specifications and recommendations. Failure to do the above could result in soil erosion, which would require regrading and reseeding.

The following guidelines are general in nature and applies to most products. Manufacturer's selection and installation recommendations should supersede the general guidelines.

- TECB comes in different widths. If the blanket's width is larger than the width required for installation, it is easier to cut the blanket to the required width before unrolling it.

- It is difficult to roll the blanket out within the ditch. Instead, roll it out on the shoulder of the road and drag it into place.
- Start at the bottom of the ditch (downstream end) as shown in Figure 22. The TECB shall be installed parallel to the flow of water with the mat contacting the ground at all points
- At the starting point (downstream of the ditch), dig a small anchor trench (shown in green in Figure 22) across the area of the ditch where you will install the rolls of erosion control blanket (shown in pink in Figure 22). The trench acts as an anchor for the blanket. Dig the trench approximately 10" wide by 8" deep.

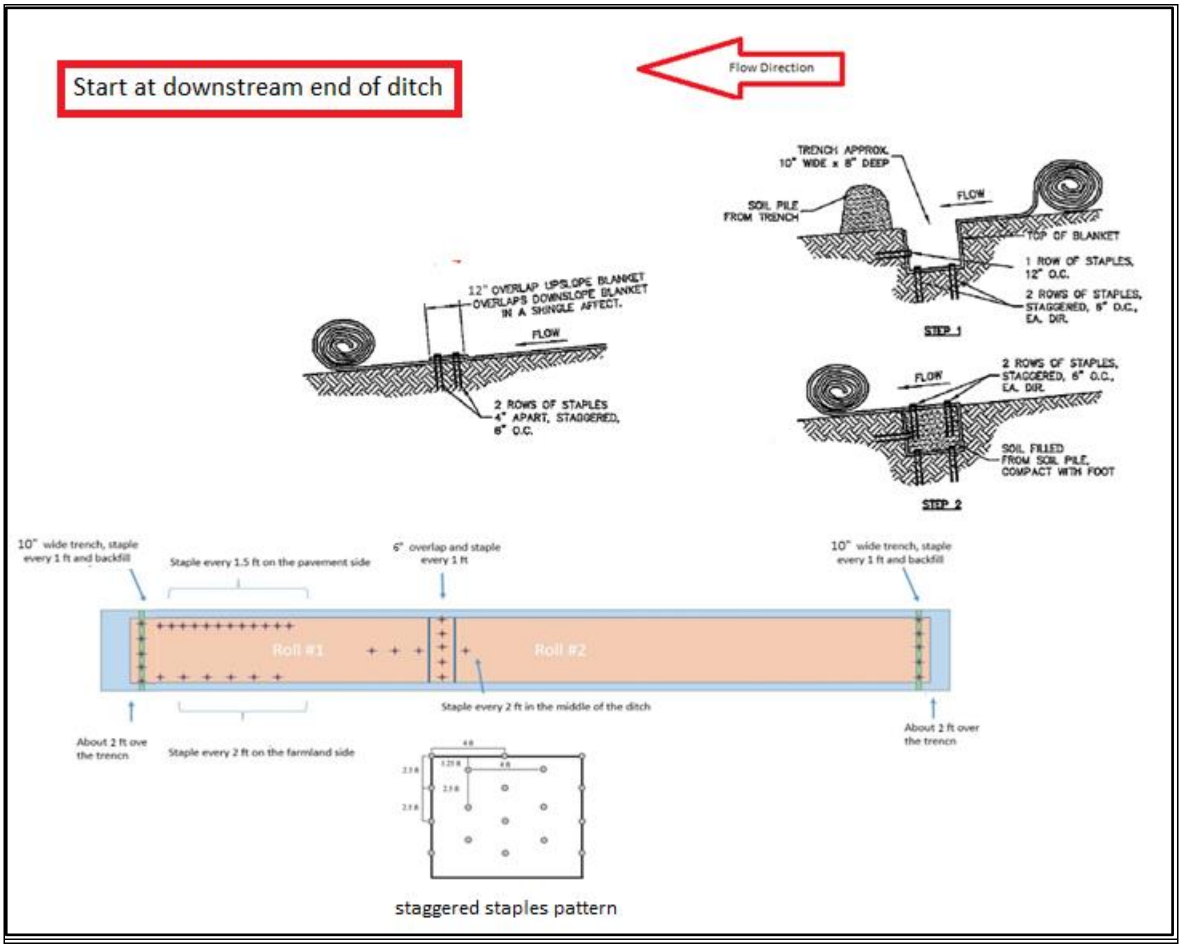


Figure 22. Temporary Erosion Control Blanket Installation

- Install the roll of erosion control blanket in the trench you've just dug. Place at least 2ft of the blanket above the trench, extending back of the beginning of the ditch (see Figure 23). Install anchoring staples through the blanket and into the bottom of the trench. The staples should be placed no more than a foot apart in the trench. The anchors or staples are usually sold with the erosion control blanket. If the soil is loose or sandy, make sure the anchors are long enough to install deeper in the trench.

- Backfill the trench with dirt and make sure it's compacted to help hold the TECB in place (See Figure 23). After the soil in the trench has been compacted, seed the dirt covering the trench. Bring the 2ft of blanket down over the backfilled trench and install more stakes or staples, one foot apart, across the width of the blanket.

Figure 23. ODOT backfilling anchor trench with dirt

- Unroll the remaining TECB over the ditch you've seeded. Follow proper stapling guidelines. If not followed, TECB will likely move and be displaced. Unless otherwise indicated in manufacturer's installation recommendation, staple every 2 ft. in the middle of the ditch using a staggered staple pattern, every 1.5 feet along the pavement side of the ditch and every 2 ft. along the back slope side of the ditch as shown in Figure 22. Staple below the flow level every 12". Drive staples until the staple is flush with the ground surface.
- It is important to dig a small trench (approximately 6 inches deep) along the full length of each side of the ditch, and bury and staple the blanket within these trenches as shown in Figure 24. Otherwise, water will flow under the blanket and erode the soils.

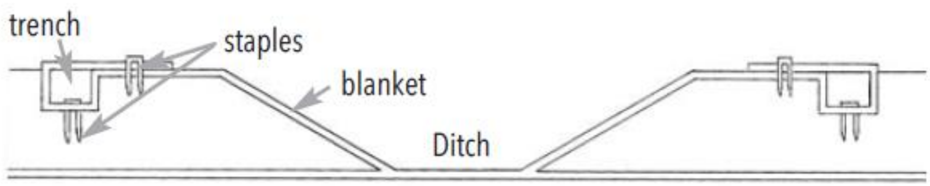


Figure 24. Blanket is trenched and stapled at the top of the slope (Brady et al. 2014)

- If you are not covering the entire side of a slope, place the blanket at least one foot higher up on the slopes than the normal high water level.
- As you are unrolling the blanket and applying the staples, ensure good contact between soil and the TECB. Poor contact results in erosion below the TECB and lower seed germination rates, causing failure.
- If you need more than one roll of blanket, install them as you would roof shingles, with an overlap of at least 12 inches as shown in Figure 25. Start at the lowest part of the ditch, then work your way up. Uphill pieces lap over downhill sections as shown in Figure 26. Staple through both layers around edges. Trench, tuck, and tampdown ends at the top of the slope. Do not stretch blankets or mats.

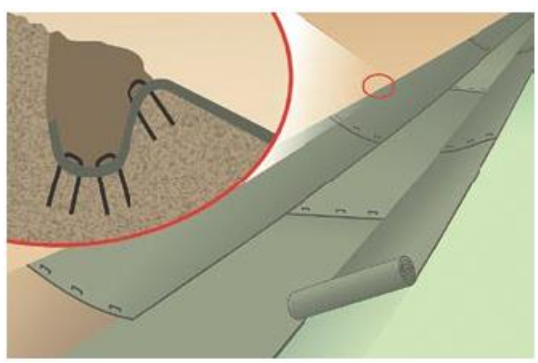


Figure 25. Laying out blankets in a ditch (Kentucky 2015)

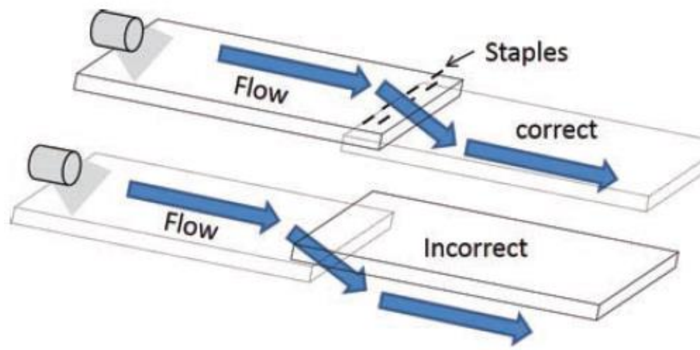


Figure 26. How to "shingle" and staple blanket layers in ditch bottom (Brady et al. 2014)

- Overlap by at least 12 inches wherever the erosion control blanket ends and another begins.
- Install upstream end in a terminal anchor trench (10”x8”) in a similar manner to downstream anchor trench explained above, staple every 12”, backfill, compact and seed.

Installation best practices

- Uphill layers overlap bottom layers.
- Staple below the flow level every 12".
- Staple every 1.5 feet along the pavement side of the ditch
- Walk blankets down to ensure good contact with the soil.
- The blankets should be securely trenched in at both ends.
- Use plenty of staples to keep blankets flat.
- Overlap blankets at 12 inches on sides, tops, and bottoms.
- Do not stretch blankets, and do not exceed manufacturer’s directions on maximum slope angle for the product.
- For ditches with steep longitudinal grades, consider installing check dams on top of blankets at various locations to reduce the length of slope that receives high-speed flows as shown in Figure 27.

Figure 27. Use of wattle check dams in combination with wood fiber blanket (Brady et al. 2014)

8.5. Maintenance and Inspection

- Inspect weekly and after storm events, until vegetation is established, for erosion or undermining beneath the blankets. If any area shows erosion, pull back that portion of the blanket, add tamped soil and reseed; then resecure the blankets.
- Repair any damaged areas of the blanket and staple any areas not in close contact with the ground surface into the ground.
- If erosion occurs, repair and protect the eroded area. Consider if BMP needs to be added or changed to prevent continuing problem.
- Undercutting. If the water is going under the blanket, it may have been installed without trenching the upper ends, or be improperly shingled and stapled. When such undercutting is occurring, the area should be reshaped and blanket re-installed properly. If it was installed properly the first time, the slope or velocity may be too much for the method used and the site may require a different type of blanket or erosion control method such as riprap.
    - Additional protection can come from adding check slots to prevent water from flowing under the blanket. This can be done by digging a small trench, placing the blanket over the channel and down in the trench, and covering the blanket with rock so it is flush with the channel bottom. A less effective but easier method is to add lines of double stapling along the blanket in the areas prone to undercutting (Brady et al. 2014).

9. Check dams

9.1. Procedure Description

Check dams are constructed across a swale or ditch to reduce velocities of concentrated flows, thereby reducing erosion in the swale or ditch. Check dams should be used in conjunction with straw mulch, hydraulic mulch or temporary erosion control blankets to provide periodic steps to lower the water's velocity (NCHRP, 2012). Check dams not only prevent gully erosion from occurring before vegetation is established, but also allow some suspended sediment to settle out.

Check dams can be made of rock, or straw wattles. They are placed intermittently over the length of a ditch, essentially dividing it into smaller sections. Figure 28 demonstrates a series of rock check dams inside a roadside ditch.

Figure 28. Picture of rock check dam placed inside roadside ditch (Tonning, 2007)

Straw wattles, as pictured in Figure 19, are tube-shaped devices filled with straw, flax, wood or coconut fibers and wrapped in netting. Straw wattles, though similar to rock check dams in function, can serve as a cost effective alternative due to their light weight, ease of transportation, and ease of installation. A single wattle can be installed in approximately 5 minutes. They are recommended for use in longitudinal slopes that are less than 10% (CRWP, 2012). Each wattle is wrapped with ultra-violet degradable polypropylene netting or 100% biodegradable materials like burlap or jute.

Figure 19. Picture of straw wattle placed inside a roadside ditch (Kitsap 2012)

There are many options for straw wattles. Some products such as Terra-Tubes (Figure 30) are made up of an engineered mixture of wood fibers, man-made fibers and performance-enhancing polymers that is encased in a cylindrical tube. In addition to reducing the flow velocity, they also capture and degrade chemical pollutants through filtration and flocculation. Tera Tubes are designed to effectively trap, filter and treat sediment-laden runoff while reducing hydraulic energy. Water passes through the engineered matrix, allowing soil particles to become trapped throughout the three-dimensional tube profile. Impregnated flocculants are slowly dissolved and released by the kinetic energy of water flowing through the tubes. This flow through process provides a superior polymer delivery system to treat sediment-laden water. The flocculants react with suspended soil particles initiating coagulation and aggregation. The tube's matrix entrains the majority of these coagulated particles.

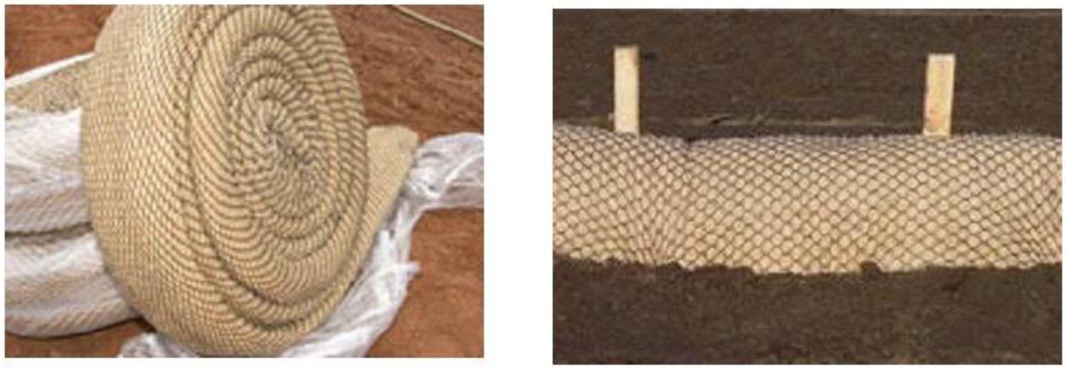


Figure 30. Terra Tubes

9.2. Application

Check dams will slow water velocity and trap sediment to prevent it from washing away. Check dams are placed across a drainage ditch perpendicular to the direction of the water flow. They reduce scour and channel erosion by reducing the velocity of concentrated storm water flows to non-erosive flow velocities and by encouraging sediment dropout. A series of check dams functions as a large sediment filter that gradually improves water quality as the sediment load is removed from the runoff. Check dams are generally considered temporary sediment control and should be removed after the ditch is stabilized and vegetation is established.

The primary use of check dams is to reduce flow velocities. To control ditch erosion, check dams should be used in conjunction with straw mulch, hydraulic mulch or temporary erosion control blankets. While a rock check dam may trap sediment, its trapping efficiency is extremely poor, therefore it should not be used as the primary sediment-trapping practice. While wattles have improved sediment removal, particularly if they contain polymers added to the fiber, they should also be used in combination with mulch or blankets.

9.3. Application Rate

Rock check dams

Spacing of check dams shall be in a manner such that the toe of the upstream dam is at the same elevation as the top of the downstream dam as shown in Figure 31.

Figure 31. Proper spacing of check dams (Brady et al. 2014)

Spacing can be determined using the following equation:

$$D = \frac{\text{Check Dam Height (feet)}}{\text{\% Channel Slope}} * 100$$

For example, if the ditch slope is 3% and the rock check dam height is 3 feet, then check dams should be placed 100 ft apart.

Wattles

Spacing of wattles should follow manufacturer's recommendations. For example, for Terra tubes, the manufacturer suggests that for channel gradients of 2%, the Terra tubes should be spaced by 25 ft. and that spacing be decreased with steeper channel gradients or more highly erosive soils.

9.4. Installation Recommendations

Rock Check Dams

- The check dam shall be constructed of 4" to 8" diameter stone, placed so that it completely covers the width of the channel. ODOT Type D stone is acceptable, but should be underlain with a gravel filter consisting of ODOT No. 3 or 4 or suitable filter fabric (ODNR 2006).
- Maximum height of check dam shall not exceed 3.0 feet.
- Rock ditch checks should be perpendicular to the flow line of the ditch.

- Rock ditch checks must be placed so that water can flow over them, not around them (Figure 32). The ditch check should extend far enough so that the ground level at the ends of the check is higher than the low point on the crest of the check. The midpoint of the rock check dam shall be a minimum of 6 inches lower than the sides in order to direct across the center and away from the channel sides.

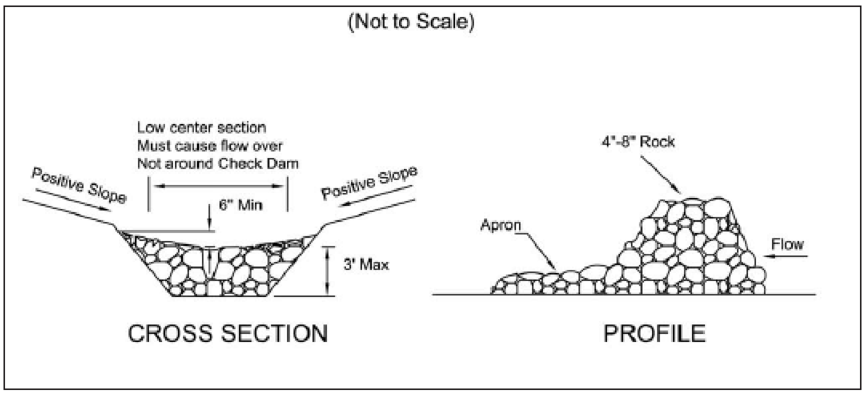


Figure 32. Rock check dam specifications (ODNR 2006)

Wattle Check dams

Installation of wattle check dams should follow manufacturer's recommendations.

9.5. Best practices

- Silt fencing and straw bales are not approved for use as check dams, and must not be used in drainage ditches that carry flowing water.
- Do not place silt checks in creeks or streams. Sediment must be intercepted before it reaches streams, lakes, rivers, or wetlands.
- Do not use in already vegetated areas unless erosion is expected, as installation may damage vegetation.
- Construct check dams wide enough to reach from bank to bank of the ditch or swale
- Follow prescribed ditch check spacing guidelines. If spacing guidelines are exceeded, erosion will occur between the ditch checks.

- Do not allow water to flow around the ditch check. Make sure that the ditch check is long enough so that the ground level at the ends of the check is higher than the low point on the crest of the check.
- Remove temporary silt checks after the site is stabilized and vegetation is established.
- Placing filter fabric under the ditch check during installation will make removal much easier.

9.6. Maintenance and Inspection

- Ditch check dams should be inspected every seven days and within 24 hours of a rainfall of 0.5 inches or more. Inspection should continue until 70% permanent vegetative cover is established.
- Sediment accumulated behind the ditch check should be removed when it reaches one-half of the original exposed height of the rock ditch check. Allowing too much sediment to accumulate behind a ditch check drastically reduces its effectiveness. Because one high-intensity rainfall can dislodge enough sediment from surrounding slopes to completely fill the space behind the ditch check, it is extremely important to inspect ditch checks within 24 hours of a heavy rainfall.
- Dispose of removed sediment in areas where it will not wash into waterways. Seed or mulch bare soil areas as soon as possible.
- Inspect for erosion along the edges, washouts, undermining, and clogging; repair any damage if occurred; and clean out sediment from upstream side
- Remove check dams and accumulated sediment when no longer needed. The area beneath the check dams should be seeded and mulched immediately after the check dams are removed.

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Appendix A- ECP selection using shear stress calculations.

A.1. Erosion Control Product Selection

Due to the fact that maintenance personnel are not tasked with the design of roadside channels, they lack the parameters necessary to properly select erosion control products for the ditches that they are tasked with maintaining. A framework was developed for usage by ODOT maintenance personnel in order to select proper erosion control products after having performed ditch maintenance. This framework proposes the use of already available tools, such as ADOT's Rational Method Tool (ADOT, 2013) and the NRCS' Web Soil Survey (http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm), as well as the use of a spreadsheet for shear stress calculations, developed specifically for this project. Combining the outcome of these calculations with permissible shear stress values provided by manufacturers, maintenance personnel should be able to properly select a channel lining that resists the erosive forces of the flow of water in their ditch. This framework is summarized in Figure A.1.

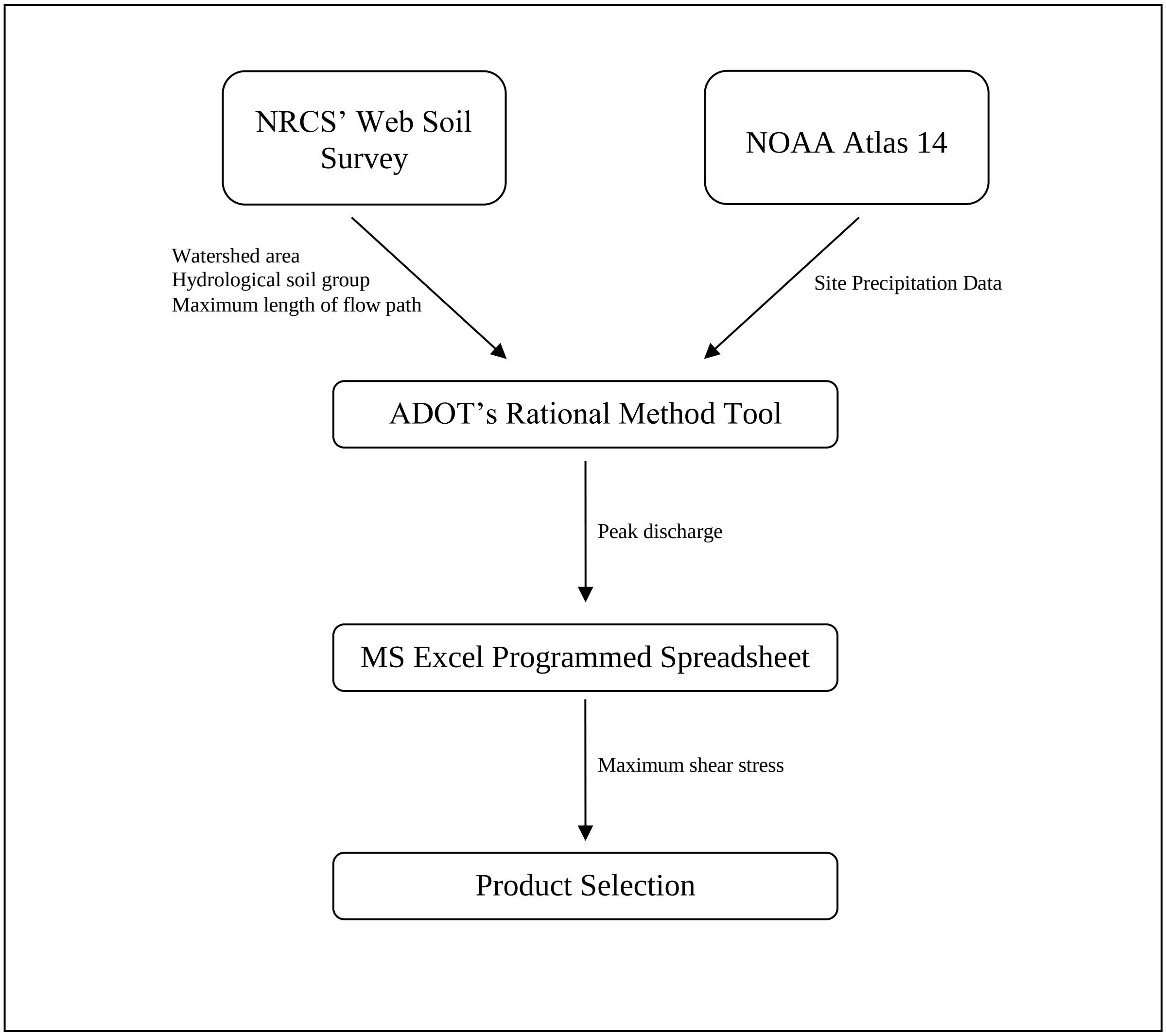

Figure A.1. Flowchart for channel lining selection procedure

A.1.1. Estimating Peak Runoff

In order to estimate peak runoff, this proposed framework makes use of the ADOT's Rational Method Tool. This tool allows for the input of subbasin information and rainfall information for calculations of peak discharges. Calculations performed are for watersheds of a maximum area of 160 acres (ADOT, 2014). The first data entered is related to the runoff coefficient, C. Input includes:

- Drainage areas in acres
- Hydrologic soil group classification

- Estimates of imperviousness and vegetation cover

The second data to be entered is related to the watershed slope. Input includes:

- Length of the longest flow path inside the watershed, in miles
- Total change in elevation along the abovementioned path

The third data to be entered is related to the resistance coefficient of overland flow. Input only includes:

- Selection of predominant landform type

Final data to be entered is rainfall data. Input includes:

- Rainfall depth acquired from NOAA Atlas 14: http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html

After entering all required input data, the program generates a table for the user that displays the peak discharge, in cfs, for 2, 5, 10, 25, 50, and 100 year storm events.

A.1.2. Calculating Shear Stresses

Using the peak discharge calculated in the previous step, the HEC-15's procedure for channel lining design is used to select a proper ECP. This procedure is summarized in Figure . In the case of Ohio, a 5 year storm and 2 year storm are used for flow depth and shear stress computations, respectively (ODOT, 2016).

A spreadsheet has been designed specifically for this task. The spreadsheet requires inputs of channel dimensions, depth of flow, longitudinal slope of the channel, Manning's roughness coefficient, and design discharge. The spreadsheets provide suggested values for Manning's roughness coefficient in accordance to ODOT's drainage manual. Some of these suggested values have been listed in Table 11.

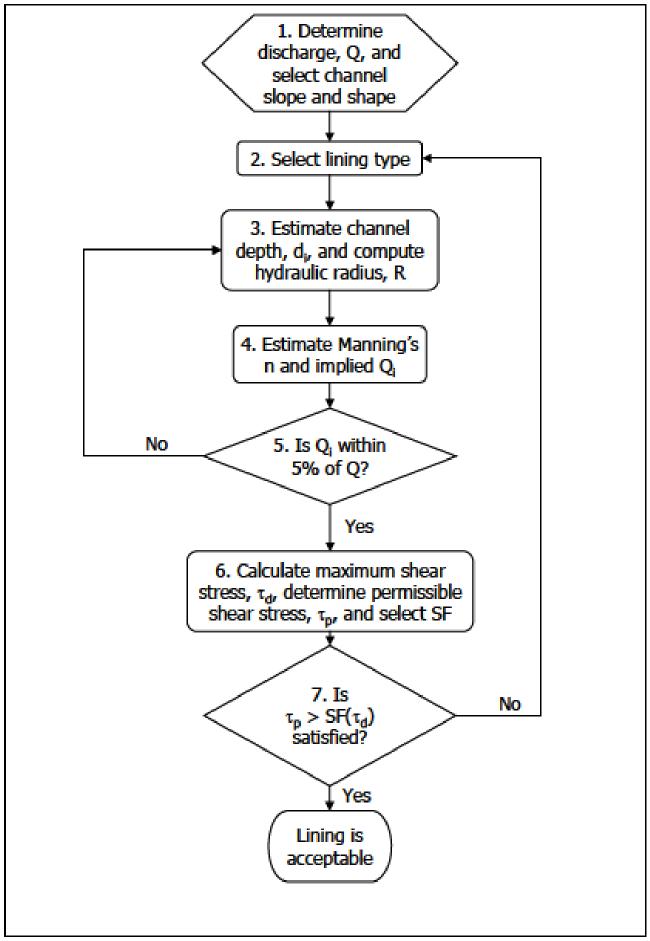

Figure A.2. Flowchart of HEC-15 design procedure (Kilgore & Cotton, 2005)

Table 1. ODOT's suggested Manning's roughness coefficient (ODOT, 2016)

Type of Lining	n
Bare Earth	0.02
Seeded	0.03
Sod	0.04
Item 670 (Erosion Control)	0.04

With these values, the spreadsheet then calculates wetted perimeter, area of flow, hydraulic radius, and discharge. The discharge value obtained is then compared to the design discharge and the user is notified if it is within 5% of this value. In cases where the values are not within 5% of each other, the user changes the initial depth of flow estimate, essentially performing the iterations specified by HEC-15. Once the design discharge and calculated discharge are within 5% of each other, the depth of flow is used to calculate maximum shear stress at the bottom of the channel. The spreadsheet can be used to calculate maximum shear stress for ditches that are semi-circular, V-shaped, and trapezoidal in shape. Maximum shear stress values can then be compared to permissible shear stress values for proper ECP selection. Permissible shear stress values for various linings, as provided by ODOT, are shown in Table A.2.

Table A.2. ODOT's allowable shear stresses for channel linings (ODOT, 2016)

Protective Lining	Allowable Shear Stress (lb/ft^2)
Seed	0.40
Sod	1.00
ECB Type A	1.25
ECB Type B	1.50
ECB Type C	2.00
ECB Type E	2.25
ECB Type F	0.45
ECB Type G	1.75
TRM Type 1	2.00
TRM Type 2	3.00
TRM Type 3	5.00

According to ODOT specifications (ODOT, 2013):

- ECB Type A refers to single net straw blankets
- ECB Type B refers to double net straw blankets
- ECB Type C refers to double net straw/coconut blankets
- ECB Type E refers to double net coconut blankets
- ECB Type F refers to jute netting
- ECB Type G refers to single net excelsior blankets

A.2. Case Study: Mahoning County, OH

A roadside ditch in Mahoning County was selected for maintenance and erosion control protection by Mahoning County transportation officials. As seen in Figure , the area identified was a stretch of SR 165 that is located between intersections with R 95 and R 107. The stretch of road between these intersections was estimated at approximately 5,111'.

Figure A.3. Satellite imagery of site acquired from Google; ditch highlighted in yellow

As the road contained ditches on both sides, two watersheds were delineated for the northern and southern ditches respectively. Their respective delineations using NRCS' Web Soil Survey can be seen in Figure A.4. The northern watershed was calculated to be 158.1 acres in area, containing soils belonging to the hydrological groups C and D. From visual observations, impervious area was estimated to be 1% of the total area. This resulted in vegetated areas of 156.52 acres and impervious areas of 1.581 acres. The longest traveling path of water in this watershed was measured to be 4,640', or 0.8787 mi. The change of elevation along this path was determined to be 50'. The southern watershed was calculated to be 114 acres in area, containing soils primarily belonging to the hydrological groups C and D. Similarly to the northern area, impervious areas were estimated at 1% of the total area, resulting in 1.14 acres. Vegetated surfaces then resulted in 112.86 acres. The longest traveling path of water in this watershed was measured to be 3,827', or 0.7248 mi. The change in elevation along this path was measured to be 20’. Precipitation data from NOAA Atlas 14 was acquired from the weather station located in Canfield, Ohio at coordinates 41.0167°, -80.7667°. The predominant landform type for time of concentration calculation was determined to be tilled agricultural fields for both watersheds.

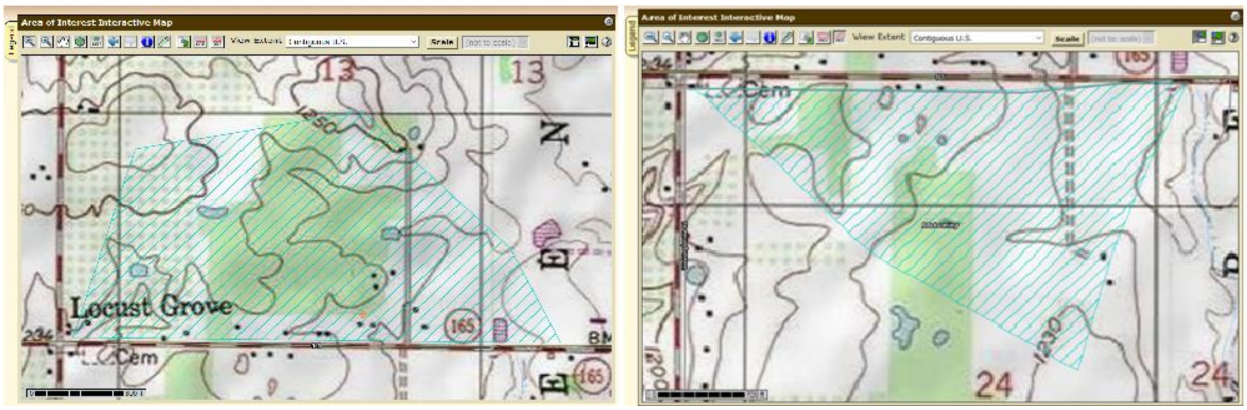

Figure A.4. Watershed delineations using NRCA's Web Soil Survey

Input of this information into ADOT’s Rational Method Tool yielded discharge values of 54.6 cfs and 34.7 cfs, for the 2 year storm in the northern and southern ditches respectively. Design discharge values were then input into the programmed spreadsheet along with values for longitudinal channel slope and Manning’s roughness coefficient. In this case, longitudinal channel slope was determined to be 0.01 and Manning’s roughness coefficient was 0.4, in accordance to ODOT’s provided value for ECBs. The worksheets with the input data for all three channel shapes can be found in the Excel Spreadsheet. However, as the machinery used to clean out the ditches produces a nearly semi-circular shape, only the values obtained from this shape will be presented in this section. Calculations for the northern ditch along this road resulted in a maximum shear stress of 1.622 lb/ft^2. On the other hand, calculations for the southern ditch along the same road resulted in a maximum shear stress of 1.273 lb/ft^2. Consulting the table provided with ODOT’s allowable shear stresses, ECBs of type B, C, and G would be suitable for the channel bottom. According to ODOT specifications, these would be equivalent to double net straw blankets, double net straw/coconut blankets, and single net excelsior blankets.