

Erosion and Sediment Control Manual

Ministry of Transportation and Infrastructure

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Acknowledgements

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In addition, the title of this manual was changed to "*Erosion and Sediment Control Manual*".

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Introduction

The Ministry of Transportation & Infrastructure (MoTI) has developed this manual, titled *"Erosion and Sediment Control Manual (2022)*", to help project managers, planners, consultants, contractors, and Appropriately Qualified Professionals (AQPs) provide services in an environmentally responsible manner.

The manual is divided into two parts:

Part A – Erosion and Sediment Control Theory contains a summary of the processes involved in runoff, erosion, sediment management, shallow slope movement (slumping) as well as guidance for creating Erosion and Sediment Control Plans (ESCPs).

Part B – Erosion and Sediment Control Implementation identifies control measures and descriptions of each technique, including Best Management Practice (BMP) guidance documents.

PART A – Erosion and Sediment Control Theory

PART A - EROSION AND SEDIMENT CONTROL THEORY

1.0 Erosion and Sediment Control Theory

Erosion is a naturally occurring process that constantly moulds and alters landforms, removing soil material from one place and depositing it downstream or downslope. However, the erosion of soil materials resulting from the disturbances of construction activity can have serious impacts on the environment, including:

- polluting surface water;
- degrading streams and aquatic habitat;
- impacting the succession of vegetation; and
- damaging adjacent land and downstream infrastructure.

Conditions that can result in erosion must be properly evaluated by an appropriately qualified professional (AQP) in both the design and construction phases of the project. Appropriate temporary and permanent runoff, erosion, and sediment control measures must be incorporated when and where required.

An AQP is an applied scientist or technologist specializing in a relevant applied science or technology including, but not necessarily limited to, archaeology, agrology, forestry, biology, engineering, erosion and sediment control, geomorphology, geology, hydrology, hydrogeology, or landscape architecture. An AQP must be recognized in B.C. with the appropriate professional organization, registered and in good standing, acting under that organization's Code of Ethics and subject to disciplinary action by that organization (2020 Standard Specifications for Highway Construction).

1.1 Erosion and Sediment Control Process

This manual will review five erosion processes:

- surface runoff;
- soil erosion;
- sediment;
- sedimentation; and
- shallow slope movement.

Understanding the difference between these processes is important when considering effective approaches for minimizing erosion and sediment issues resulting from disturbance. The five processes are explained below.

Surface runoff is the process of water mobilizing over the surface of the earth following a rain or thaw event.

Soil erosion involves the removal and transport of particles of soil by water and wind action. In BC, wind erosion is generally less significant on construction projects than water erosion; therefore, only water erosion is considered in this manual.

Sediment is fragmentary material that originates from weathering of rocks and soil particles that have been detached and mobilized by the soil erosion process.

Sedimentation is the gravitational deposition of transported material in flowing or standing water.

Shallow slope movement (slumping) is the mass movement of saturated soils along a slope, occurring within one or two metres of the surface.

1.2 Regulations

This section outlines a summary of the key Federal and Provincial statutes and regulations that address erosion and sedimentation issues from a construction perspective (Table 1). This list is not intended to be all-encompassing, and current versions of the most relevant statutes and regulations can be found at: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/laws-rules.

It is important to adhere to regulations and legislation as violations can result in significant fines.

Table 1: Federal and Provincial regulations

Federal	***Provincial***
Canadian Environmental Protection Act	*B.C. Oil and Gas Activities Act*
Canadian Navigable Water Act	*Environmental Management Act*
Federal Fisheries Act	*Water Sustainability Act*
Seeds Act	*Weed Control Act* and Regulations
Species at Risk Act	*Wildlife Act*

2.0 Runoff Management

Runoff management is considered the first line of defense against erosion. Effective surface runoff management often reduces erosion potential and minimizes the need for sediment management.

It is important to evaluate drainage patterns prior to construction. During the planning phase, the following questions should be asked and answered:

- where is the surface runoff coming from?
- where does it need to go?
- how is it going to get there?

2.1 Runoff Management Principals

Effective runoff management techniques should limit the concentration of water flowing through the site, decrease the velocity of surface runoff, and divert flows to less erodible areas. The high-level design principles described below will help achieve effective runoff management (TAC 2005):

- Divert off-site surface water around the construction site via perimeter ditching;
- Retain sediment-laden water on-site and do not discharge into the receiving environment until sediment is settled out of suspension and discharge is compliant with the appropriate approved B.C. Water Quality Guidelines;
- Keep overland flow areas and rates small by providing adequate drainage density to reduce rilling/gullying potential (see section 3.1);
- Keep channel slopes low (1 to 5%) to reduce velocities; and
- Reduce channel flow volumes to limit potential scour erosion.

2.2 Surface Runoff within the Watershed

During the design of erosion and sediment protection measures, the estimation of watershed runoff is a key consideration in determining appropriate ESC controls. Drainage and watershed runoff assessments should be completed by an AQP. For larger catchment areas (major watercourses), the individual drainage assessment is generally provided by a qualified hydrotechnical engineer or hydrologist. Estimates of peak runoff flow rates and flood frequency for returns of flood (Q10 and Q100) are commonly used for small catchment areas that are under 100 hectares.

2.3 Factors Affecting Runoff

The factors affecting runoff include:

- precipitation;
- time parameters and watershed areas;
- storage within the watershed area;
- soil permeability and antecedent moisture condition; and
- ground cover.

Precipitation

Precipitation is the amount of accumulated rainfall over a 24-hour period. Precipitation can be measured as the amount of rainfall over 24-hours and the intensity of the storm within that 24-hour period. Snow is another form of precipitation that may affect runoff and erosion on a site. This may be particularly problematic in spring when snow is thawing.

Time Parameters and Watershed Areas

The shape and steepness of the watershed are key elements in determining the length of time it takes runoff to travel from one location to another within a watershed. If the watershed is more uniformly round, then the time for the peak discharge to reach the site may be less than if the drainage area is long and narrow (see Figure 1: Round and Narrow Watershed Area for examples). Knowing this will help an AQP determine when the peak flow will reach the construction site following a storm event within that watershed (EnviroCert International, 2018).

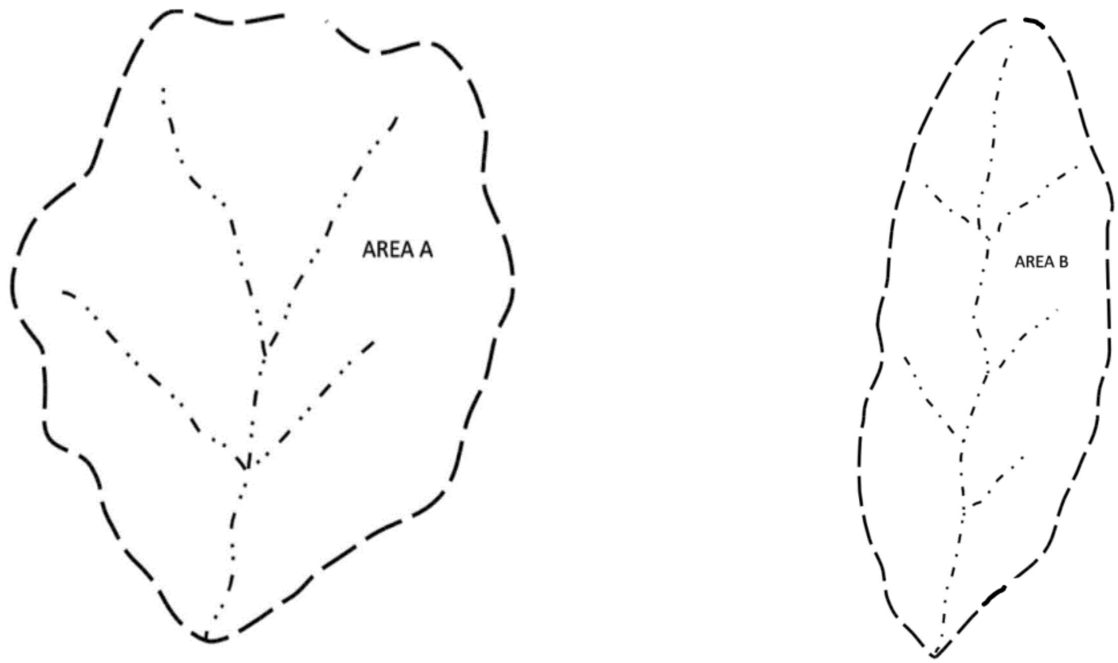

Figure 1: Round and Narrow Watershed Area

Storage Within the Watershed Area

Storage refers to any area within the watershed that will prevent or minimize surface runoff from continuing downslope or downstream. These areas are defined as lakes, ponds, wetlands, and/or groundwater infiltration.

Soil Permeability and Antecedent Moisture Conditions

Soil permeability refers to the rate at which surface runoff can infiltrate the soils when flowing over the surface of the ground. Finer soil textures do not infiltrate surface runoff as easily as course textured soils (e.g., surface runoff will infiltrate gravels much easier than clay textured soils).

Antecedent moisture conditions refer to how much water can be stored within the saturated soils. Once the soils are saturated, the rest of the surface runoff will continue moving downslope or pool on the surface.

Ground Cover

Ground cover refers to the vegetative cover on the landscape and is an important measure against erosion and sediment issues within a construction site. Cover allows for the interception of runoff from reaching the soils and moving downstream as well as allows for evaporation, transpiration, infiltration, and vegetative uptake (Figure 2).

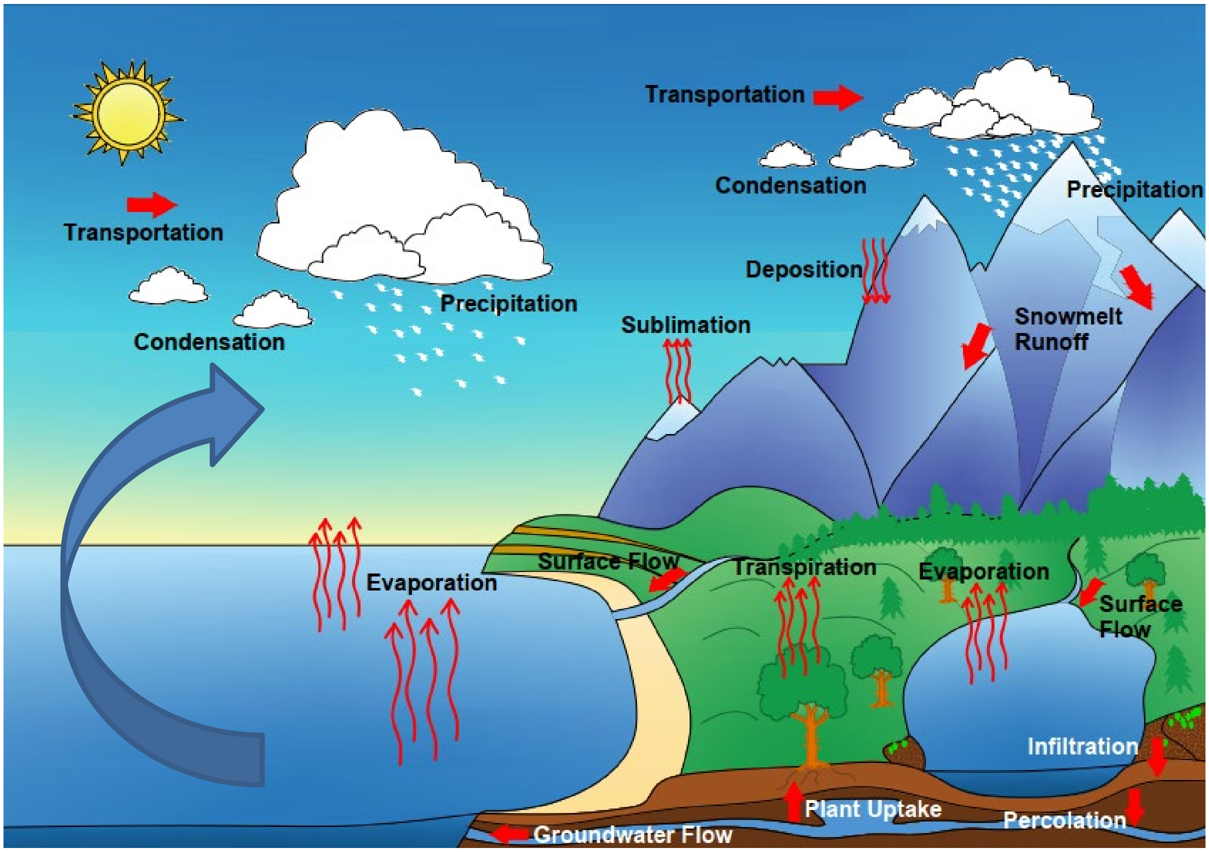

Figure 2: The Hydrologic Cycle

3.0 Erosion Management

This section describes the categories of erosion, factors in erosion, and explains the revised universal soil loss equation (RUSLE).

3.1 Erosion Categories

Water erosion can be divided into five different categories: raindrop, sheet, rill, gully, and stream channel erosion (Figure 3).

Raindrop erosion is the effect of dislodging soil particles by the impact of raindrops (Figure 4).

Sheet erosion results from shallow, broad, overland flow of surface runoff and is the initial mechanism for transporting soil dislodged by raindrop erosion.

Rill erosion begins when small variations in slope topography cause erosion from sheet flow to concentrate in defined channels. The higher water velocity and steeper slope results in shallow, well-defined channels, with removal of soil particles from the bottom and sides of those channels (Figure 5).

Gully erosion occurs when rills join to form larger, deeper channels. Rills can be more easily repaired by shallow grading of the soil; repairing gullies requires more effort and cost to restore.

Channel erosion results from water in a stream channel removing material from the banks and bed.

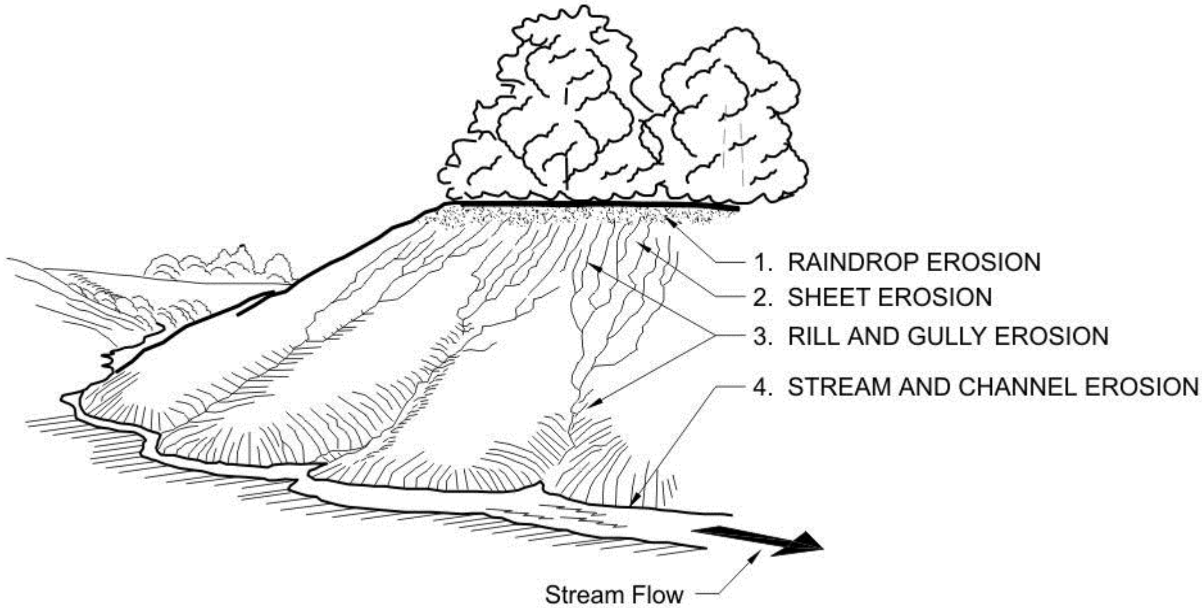

Figure 3: Types of erosion **Source: Calgary 2017**

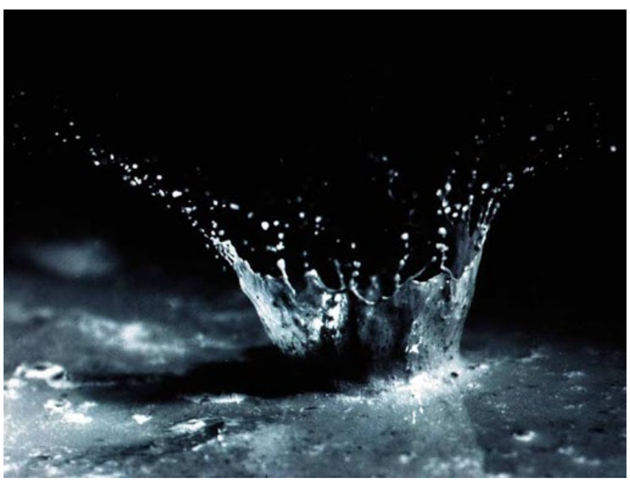

Figure 4: Example of raindrop erosion Source: (USDA 2021

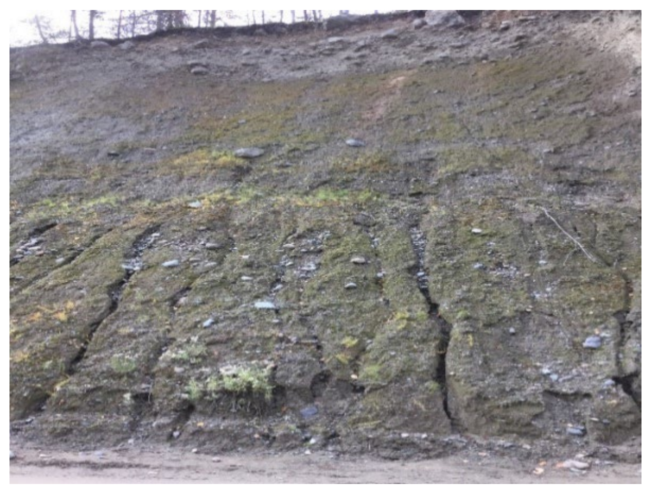

Figure 5: Example of sheet/rill erosion

3.2 Factors Affecting Erosion

Erosion potential is determined principally by the following factors:

- rainfall and runoff;
- topography;
- soil characteristics:
  - particle size
  - cohesiveness
  - porosity; and
- cover conditions.

Rainfall and Runoff

Surface runoff is a major factor in dislodging soil particles, with the degree of erosion proportionate to the amount and velocity of runoff flowing on the soil (Wall et al., 2002). Runoff can include off-site runoff flowing into the site and runoff generated within the site by rainfall and groundwater sources.

The key factors in producing surface runoff are intensity, frequency, and duration of rainfall. Local weather data can provide information to assess the probability of rain event occurring at a site; this is referred to as the return period. Shorter return periods indicate more frequent occurrences which will saturate the soils more quickly, causing erosion to occur more frequently (Alberta Transportation, 2011).

Intense heavy rainfall events dislodge particles more easily than lighter rainfall events. Heavy rainfall duration leads to greater surface flows and increases water content of the soils. This causes decreased stability of slopes due to:

- greater surface flows because of reduced infiltration; and
- easier soil particle dislodgement.

Topography

The shape, size, and slope characteristics of the upslope area influence the amount, rate, and energy of runoff to the construction area. Minor depressions intersected by a cut slope can allow concentration of runoff. Erosion from a smooth, compacted surface may be 50% more than that from a rough and loose surface with undulations of 0.3 m (Alberta Transportation, 2011).

Erosion potential is directly related to the length and steepness of the slope. For the same vertical height, reducing a slope angle is beneficial, but results in a longer slope. The net effect of slope flattening is, overall, slightly advantageous (TAC, 2005).

Surface texture and minor undulations on a slope affect the velocity of flow and infiltration of water into the soil. In a natural forest setting the surface is rough and loose with undulations due to the processes of trees falling and roots upturning. These undulations slow the flow of water and allow it to seep into the ground (Polster, 2019).

Soil Characteristics

Cohesionless soils are those that have little or no adhesion between the particles. Sometimes the particles form bonds by the presence of cementing agents or clay (Alberta Transportation, 2011).

The potential for erosion of cohesionless soils increases as particle size decreases. Silt and fine sand particles are the highly erodible, easily transported by water, and take the longest time to settle out of standing water. Figure 6 shows the soil texture triangle, which aids in determining soil characteristics (percent sand, silt, and clay) and soil erodibility rating (K) (TAC, 2005).

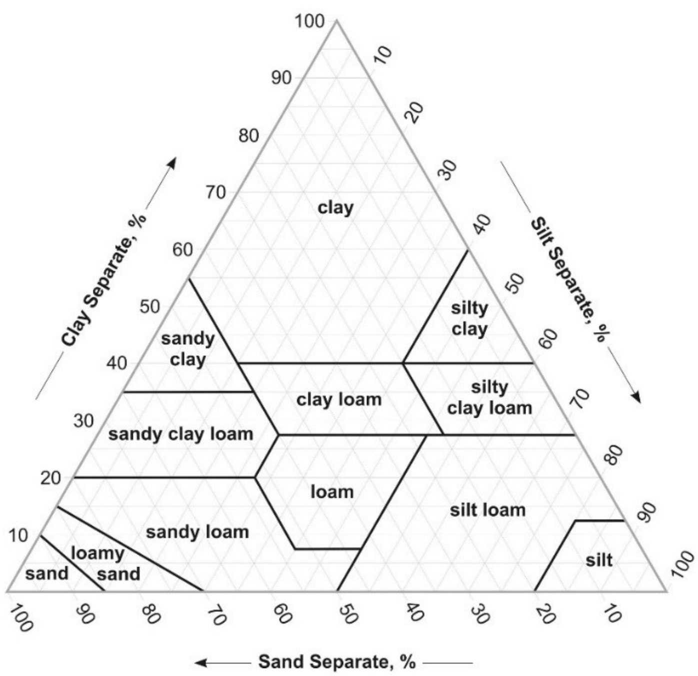

Figure 6 Soil Texture Triangle

Cover Condition

Cover condition refers to the amount of vegetation occurring on a site. The effect of removing vegetative cover is easily seen when construction starts. Figure 7 illustrates the linear relationship between removing vegetation and the increase in erosion potential. Vegetation controls erosion by:

- reducing raindrop impacts on the soil;
- slowing runoff velocity; and
- increasing water infiltration into the soil mass.

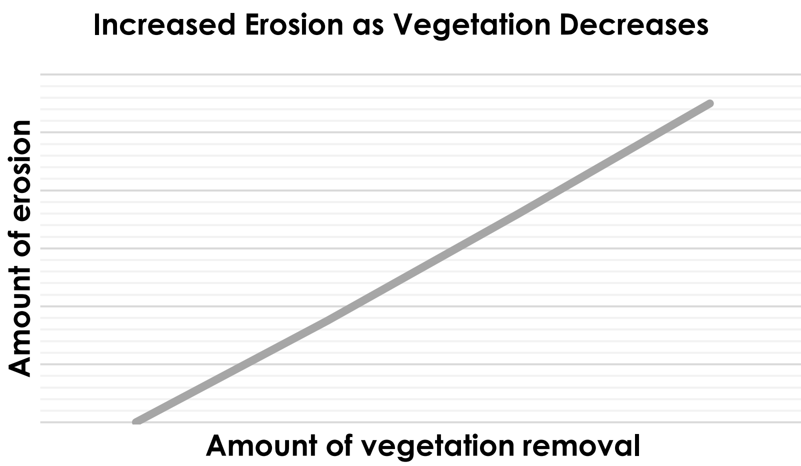

Figure 7: Increased erosion as vegetation decreases

Ways to mitigate erosion include staged clearing (not clearing an area until it is necessary) and leaving the rooting zone intact as roots provide fibres of high tensile strength within a material of lower strength (City of Calgary, 2017). The strength of the soil to root ratio increases in direct proportion to the strength, depth, and concentration of the roots. Other forms of cover protection for erodible soils include naturally occurring gravels, mulch, and bioengineered or engineered products that will be discussed in Part B of this manual.

3.3 Revised Universal Soil Loss Equation (RUSLE)

The Revised Universal Soil Loss Equation (RUSLE) was developed and is maintained principally by the USDA-Agricultural Research Service, the USDA-Natural Resources Conservation Service (NRCS), and the University of Tennessee (USDA, n.d.). It was developed as a tool to determine the erosion potential for a site and help an AQP make decisions regarding the ESC measures that should be put in place.

Assessing the amount of potential erosion for a site can be made by using the RUSLE equation. This was developed for agricultural purposes and has been modified for assessing construction conditions (Wall et al., 2002).

The equation shown below is for illustrative purposes only. The equation demonstrates how the amount of erosion is influenced by changes in the values of the individual factors listed above, and Table 2 describes the values in further detail. The values for each factor are determined for the site and used to estimate the total amount of soil loss. The equation is as follows (EnviroCert International, 2018):

$$\boxed{A = R * K * L * S * C * P}$$

Where:

A = Annual soil loss due to erosion (tonnes/hectare/year)

R = Rainfall runoff erosivity factor

K = Soil erodibility factor based on a specific soil's susceptibility to erosion

L = Slope length factor of the overland flow path (the ratio of soil loss from the field slope length to soil loss from a 22.1-metre length under identical conditions)

S = Slope steepness factor of the overland flow path (the ratio of soil loss from the field slope gradient to soil loss from a 9% slope under otherwise identical conditions)

C = Cover management factor

P = Erosion control practices factor

Table 2: Summary description of RUSLE variables

Factor and Description	***Category***	***Effect***	***Control Examples***
A = Average annual soil loss	A = R x K x L x S x C x P		
R = Rainfall-runoff erosivity	**Climate**	Climates with more frequent or intense rainfall events will have greater soil loss.	Can be controlled by pausing work during, or planning work outside of, storm events with heavy rainfall or periods with significant snowmelt.
K = Soil erodibility	**Soil Factor**	Soil erodibility is affected by particle size, texture, chemistry, water content, organic content, and permeability.	Relatively difficult to control; however, proper planning can help to avoid problem areas and appropriate mitigation will be dependent on soil characteristics.
L = Slope length	**Topographic Factor**	Longer slope lengths increase erosion potential because it collects larger quantities of water and offers more potential for flow concentration.	Site drainage density can be planned to introduce drainage diversions at regular intervals to reduce slope lengths. Earthwork designs and landscaping can be planned to avoid long, steep slopes and minimize the effect of slopes. This may affect earthworks quantities.
S = Slope steepness		Steeper slopes increase erosion potential because it allows water to flow faster.	
C = Cover management	**Cover Management**	Large values of C and P factors represent relatively erosive conditions, including no cover (C = 1) and no erosion control practice applied (P = 1).	Cover management and erosion control practice factors are the easiest and most cost-effective factors that can be manipulated to control erosion.
P = Erosion control practice			

Note: In general, erosion increases as the value of the individual factors increase.
Cite: (TAC 2005)

Computing the **Rainfall and Runoff Factor (R)** requires detailed statistical analysis of rainfall. Although rainfall is not controllable, rainfall and runoff should be considered when preparing the Erosion and Sediment Control Plan (ESCP). R values can be obtained from tables in RUSLEFAC 2002 Manual that give estimates for use in rough calculations.

The **Rainfall Runoff Factor (R)** can be minimized by controlling the amount of water entering the construction site (such as by diversion ditches and dikes). This can result in a proportional reduction in erosion potential and is therefore one of the most effective ways to minimize erosion.

The soil **Erodibility Factor (K)** ranges from 0.1 to 0.7, with values above 0.3 representing very erodible soil (EnviroCert International, 2018). If a table of K factors is not available for an area of interest, K-factor can be calculated using the Foster Nomograph[1] discussed in Section 3.3.1. Soil properties affecting erodibility include:

- Particle size and distribution, especially the percent silt and very fine sand (0.050 to 0.100 mm), and medium and fine sand (0.100 to 2.00 mm);
- Soil structure (very fine granular to blocky);
- Permeability (rapid to very slow); and
- Percentage of organic matter.

In very erodible soils (i.e., silt and very fine sand), incorporating a small number of organics (~2%) into the surface layer can result in a significant reduction (~20%) in the **Erodibility Factor (K)**.

The Topographic Factor (LS) increases as the slope angle increases; therefore, erosion can be decreased by slope flattening or shortening the length of slope by terracing it into more sections. The effect of changing slope angle on the topographic factor is shown in Figure 8.

While the **Topographic Factor (LS)** can be lowered by slope flattening, a relatively small reduction in the factor requires a significant change in slope angle.

[1] See section 3.3.1 for Determining K-Factor using a Nomograph.

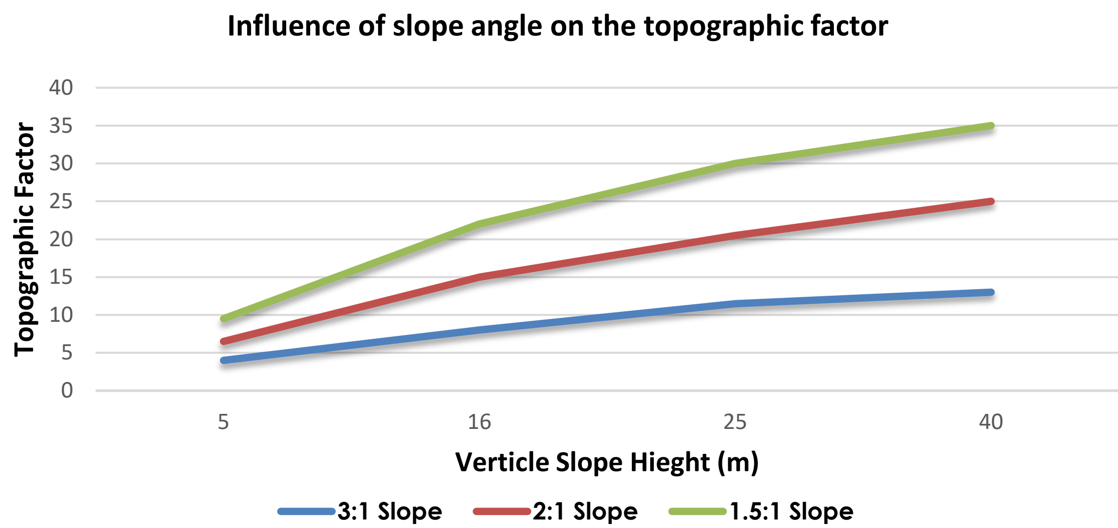

Figure 8: Influence of slope angle on the Topographic Factor

The benefits of slope flattening are offset to some extent by slope lengthening that increases the total area of exposed soil that may be eroded. The net benefit is shown in Figure 9, where the total amount of erosion for various slope angles is compared to that for a 1.5:1 slope (horizontal: vertical).

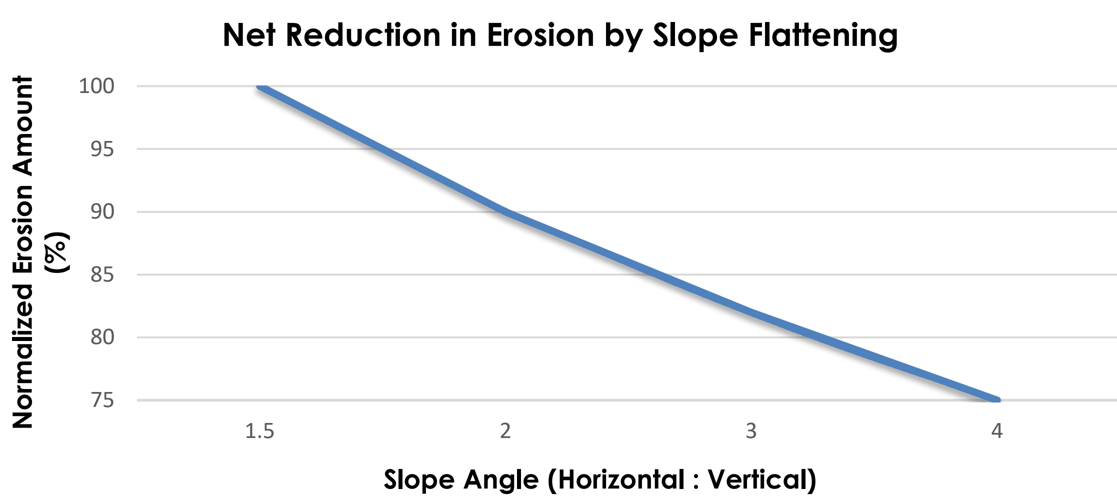

Figure 9: Net reduction in erosion by slope flattening

The Cover Factor (C) is a measure of erosion protection provided by a cover type on an erodible material (EnviroCert International, 2018). Cover is one of the most effective means of controlling erosion by shielding soil from rainfall impacts, reducing runoff velocities, dispersing surface flows, improving soil permeability, and physically binding soil particles together.

Temporary cover management can take the form of vegetative cover, mulches, wood chips, geotextile fabrics, rolled erosion control products (e.g., jute, wood fibres, coconut fibres, straw fibres) or rock. Forms of permanent cover management are not discussed in this document. The type of soil cover required depends on the site conditions. For instance, coarse granular material or rock cover may be necessary under situations where immediate protection is necessary (e.g., exposed, or anticipated ground water on a cut). For most sites, use of vegetation is the most cost-effective method for protecting the soil.

Most ESC BMPs focus on temporary cover management practices. Bare, exposed soil that has no cover would have a C-factor value of 1. Temporary seeding with annual ryegrass can reduce the C-factor to 0.1 (90% reduction). Covering exposed soil with straw mulch can reduce the C-factor to 0.02 to 0.25 (EnviroCert International, 2018), depending on the application rate.

Improving the Cover Factor (C) is one of the best ways to lower erosion potential. Figure 10 demonstrates the amount of rill erosion that can occur on a vegetated slope compared to a non-vegetated slope.

Figure 10: A comparison of a vegetated and non-vegetated slope

Table 3: Typical temporary cover factors

Type of Cover	*Application Rate (Ton/Ha)*	*Cover Factor (C)*	*Erosion Protection (%)*
None (fallow ground)		1.00	0.0
Temporary Seeding: (90% stand)			
Rye grass (perennial type)		0.05	95
Rye grass (annuals)		0.1	90
Small grain		0.05	95
Millet or Sudan grass		0.05	95
Field Bromegrass		0.03	97
Permanent Seeding: (90% stand)		0.01	99
Sod (laid immediately)		0.01	99
Mulch:			
Straw	1.24	0.25	75
Straw	2.47	0.13	87
Straw	3.71	0.07	93
Straw	4.94	0.02	98
Wood chips	14.82	0.06	94
Wood cellulose	4.32	0.10	90

Cite: (EnviroCert International 2018)

Erosion Control Practice (P) is the ratio of soil loss with a specific support practice, where the (P) accounts for the erosion control effectiveness of that support practice. These practices primarily affect erosion by modifying the flow pattern, grade, or direction of surface runoff and by reducing the amount and rate of runoff. Generally, (P) is most effective when erosion is limited and any eroded sediments are deposited further upslope, very close to the source (Wall et al., 2002).

Using a combination of runoff control, reducing slope length, and implementing appropriate cover and practice measures can effectively reduce the risk of erosion.

Table 4 explains various surface preparation methods and their effectiveness. A smooth, compacted landscape that is uniform on a slope will have a P-factor of 1.3 whereas a slope that is left rough and loose will have a P-factor of 0.8. With respect to the RUSLE equation, a site that has no surface preparation will have a P-factor of 1.0 (EnviroCert International, 2018).

Table 4: Practice Factor (P) – surface condition for construction sites

Surface Condition with No Cover	***Factor (P[1])***
Compact and smooth, scraped with bulldozer or scraper up- and downhill	1.3
Same condition, except raked with bulldozer root rake up- and downhill	1.2
Compact and smooth, scraped with bulldozer or scraper across the slope	1.2
Same condition, except raked with bulldozer root rake across the slope	0.9
Loose as a disked plow layer or **no support practice**	1.0
Rough, irregular surface equipment tracks in all directions	0.9
Loose with smooth surface greater than 0.3-m depth	0.9
Loose with rough surface greater than 0.3-m depth	0.8

[1] Values are based on estimates as there is limited data in Canada.

Note: "P" is the least accurate and most subject to error of the RUSLE factors, due to a deficient database, compared to that for other factors in the RUSLE (Wall et al. 2002).

3.3.1 Determining K-Factor using a Nomograph.

To determine the erodibility factor when there is no K-Factor table available, the following steps to use the Soil Erodibility Nomograph (see Figure 11 for an example) will help an AQP identify the K-Factor for a site (City of Calgary 2017):

- Determine the soil texture, (percent of sand, silt, and clay) by interpreting the soil texture triangle in Figure 6, then start at the left of the page, find the **PERCENT SILT AND VERY FINE SAND** (example 45%).
- Move horizontally right across the nomograph until you intersect the **PERCENT SAND** (example 25%). Interpolation between curves is allowed.
- Now move up vertically until you intersect the percent Organic Matter (example 0% in this case, as determined by analyzing a soil sample for organic matter).
- Move horizontally to the right until you intersect the **SOIL STRUCTURE** (example type 4, blocky, platy).
- Move directly down until you hit the **PERMEABILITY**, based on the RUSLEFAC (example 4, slow to moderate).
- Finally, move to the left horizontally to find the **SOIL ERODIBILITY FACTOR** (final K-value) (example = 0.49).

Note: If approximating K-Factor values, this may produce very different soils loss estimates. Wherever possible, use detailed information, especially when estimating soil losses for a specific site.

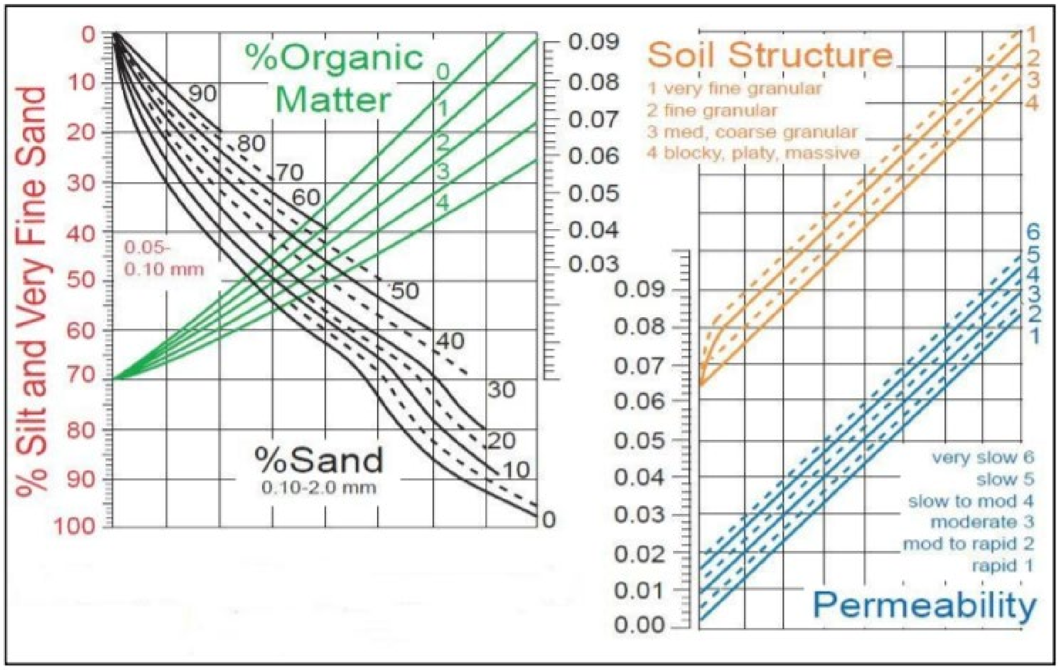

Figure 11: Soil Erodibility Nomograph

Source: City of Calgary 2017

4.0 Sediment Management

The best approach for sediment management is to limit the amount of sediment that is mobilized through effective runoff and erosion mitigation measures. However, runoff and erosion controls may not always be possible or may need to be supplemented by additional control measures. Conventional sediment controls are designed to pond small volumes of sediment-laden water for a period to allow coarse sediment to fall out of suspension. Conventional sediment controls can be effective for sands and large silts, but fine silts and clays are very difficult to settle out of suspension and require longer settling time and larger settling structures (TAC 2005) and may require flocculants, like chitosan, which helps smaller particles bind together, thus forming larger, heavier particles (Divikaran, Pillai, 2002).

4.1 Factors Affecting Sediment and Sedimentation

Sediment is fragmentary material that originates from weathering of rocks and soil particles that have been detached and mobilized by the soil erosion process, whereas sedimentation is the gravitational deposition of transported material in flowing or standing water (EnviroCert International 2018). Sedimentation is influenced by the following factors:

- soil characteristics;
- topography;
- velocity;
- climate;
- season; and
- sediment load.

Soil Characteristics: The main factor in sediment and sedimentation is the soil characteristics. The smaller or finer the soil particles are (e.g., clay), the more potential sediment load will be transported, as smaller particles are transported easier than medium to large size particles. Also, finer particle sizes will require longer time to settle out of suspension, require a larger sediment detainment area, or require treatment (e.g., chitosan).

Topography: Topography is a significant factor in sediment management; if slopes are too steep and too long (>70 m), they will be susceptible to erosion and subsequent sediment transport downslope (TAC, 2005).

Many BMPs for sediment control are only applicable to sheet flows and should not be used in channels with concentrated flows. The transition from sheet flow to concentrated flow is highly dependent on topography (TAC, 2005).

Velocity: Higher velocity water carries more energy and can therefore move more and larger material. Slower velocities allow for finer sediments to settle out of suspension. Implementing proper runoff and erosion BMPs will reduce surface water velocities and allow sediment to settle out of suspension when flows are directed into sediment control structures.

Climate: Climate is the long-term, general weather conditions of a given location. It should not be confused with weather, which refers to short term conditions of the course of days to weeks. Climate change is expected to contribute to more erosion and sedimentation potential through severe storms, droughts, wildfires and other extreme weather and environmental events which can adversely affect site conditions.

Selection of vegetative sediment control BMPs, such as sod or vegetated buffer strips, are highly dependent on local climate. The size of a sediment control structure depends on the anticipated quantity of runoff from rainfall or snowmelt. Coastal B.C. generally has more rain precipitation during the winter season, whereas Interior B.C. generally has more rain in the spring and fall seasons.

Season: Accounting for seasonal weather conditions that will be encountered during a project will guide the ESC design and help anticipate and prevent failures.

Sediment control BMPs that are intended to protect against high moisture events must be selected appropriately, even if they are installed in drier seasons (TAC, 2005). Spring freshet for most of the province is between May and July with peak flows in June. Having sediment controls in place prior to freshet will benefit the receiving environment.

Sediment load: Can be separated further in to two categories: bed load and suspended load. Bed load applies to sediment that moves by sliding, rolling, or skipping on or very near the bottom surface. Suspended load is soil particles held in a water column by the upward momentum in the flow. When very fine particles with a faster flow velocity are suspended in water, they can be held in suspension and may never settle out (TAC, 2005).

4.2 Risk of Sedimentation

Sediment control BMPs are intended for application where the risk assessment indicates the need to retain mobilized sediment. It is advisable to install sediment control measures within the construction site, close to the sediment source. This reduces the volume of water that must be managed and reduces the consequences of a failure of the control measure (TAC, 2005).

Sediment control can be accomplished by filtering or settling sediment-laden runoff water while preventing runoff from leaving the construction site. The various risks associated with sedimentation include the following:

- **Harmful Alteration, Disruption or Destruction (HADD)** refers to any activity that negatively affects the aquatic environment including fish and fish habitat (DFO, 2019). These effects can range from behavioural effects (e.g., avoidance behaviour, decreased foraging success) to outright mortality, depending upon the concentration and duration of exposure (TAC, 2005). Depositing fine sediment in spawning areas can smother eggs and/or make streambed substrate unusable for spawning via infilling the interstitial spaces.
- **Vegetation** can be adversely impacted when diverting sediment-laden surface runoff flows into vegetated areas for natural filtering. If there is too much sediment being introduced into the vegetation, the sediment will inundate the existing vegetation and may not allow further succession or growth of the native vegetation. Adjacent landownership must be considered to not discharge into areas where is it not permitted, for example a park or protected area.
- **Wildlife habitat** may be deemed environmentally sensitive because it is protected for the success of specific wildlife during all or part of its life cycle, and therefore a contractor would not be permitted to release sediment into that habitat. This includes any animals that are listed in the *Species at Risk Act* (e.g., amphibians).
- **Associated costs** relating to a sediment release in the environment can be significant. The contractor may have to hire more resources to effectively clean up excessive sediment. This will affect the project costs and schedule. Depending on the significance of the sediment release, the contractor may also be subject to legal consequences for a lack of due diligence.
- **Land damage** to neighbouring property caused by sediment leaving the site, can be costly to repair. In extreme cases, this can also affect project completion schedules, as the contractor will have to clean up neighbouring properties, at their expense, prior to project completion (TAC, 2005).

- **Legal consequences** can arise in relation to the release of sediment into the aquatic environment. Sediment is a deleterious substance under the *Fisheries Act*, which does not allow for sediment discharge at any concentration. Therefore, any sediment release could potentially result in charges laid under the *Fisheries Act*. In addition, stop-work orders may be issued by regulatory officials. These can require all work to cease until ESC measures are properly implemented and can affect project timelines (TAC, 2005). Under the B.C. *Environmental Management Act*, any person found in contravention of this Act (i.e., unauthorized sediment release into the environment) is subject to a monetary fine up to $1,000,000 and/or up to six months in jail (EMA, 2003). Water is also protected under other B.C. Acts, such as the *Water Sustainability Act* and the *Drinking Water Protection Act*, all of which carry their own associated penalties and legal consequences.

5.0 Shallow Slope Movement

The purpose of this section is to briefly outline shallow slope movement situations typically encountered during a construction project. Shallow slope movement may be a sign of more serious slope failure that could threaten public or worker safety, infrastructure integrity, or lead to significant environmental damage. For these reasons shallow slope movement should be referred to a geotechnical engineer for assessment. Regular inspections should occur until vegetation is re-established and the site is determined to be stable. Consult the Ministry's Project Manger and/or geotechnical engineer for further guidance.

5.1 Types of Movement

Shallow slope movement (slumping) is the mass movement of saturated soils that typically comes to rest a short distance from the source or at the base of the slope (MFLNRORD, 1994). The soil mass has the potential to block drainage courses and ditches (Figure 12).

Figure 12: Shallow slope movement infilling a ditch

5.2 Factors Affecting Slope Movement

Shallow slope movement, or slumping, is caused by soil having insufficient strength to stand at the constructed slope angle (MFLNRORD, 1994). The required slope angle to avoid failure conditions is a function of:

- soil type;
- moisture condition; and
- soil density.

For a particular soil type (i.e., gravel, sand, silt, clay, or mixed soils), stability decreases with a rise in moisture content and a fall in soil density. A geotechnical engineer should determine the appropriate slope angle for a cut or fill slope. Typical required slope angles for compacted soils are given in Table 5 (TAC, 2005).

Table 5: Typical slope angles for various soil types

Material		***Slope Angle* (horizontal: vertical)***
Gravel and sand		1:1 – 1.5:1
% silt & clay	<30%	1.5:1
	30-50%	2:1 - 2.25:1
Silt, sandy silt		2:1 - 2.5:1
Silty clay		2.25:1 - 3:1

* The higher values are for higher moisture contents.

Changes in Soil Strength

Soil strength varies with time, primarily because the soil moisture is not constant. For that reason, a slope that has been constructed during the drier season when moisture conditions are low, may be impacted during the wetter seasons as the material becomes saturated.

Groundwater

Groundwater may cause slope movement as the shear strength of soil is affected by water with the strength of a slope decreasing as water concentration rises (Latief & Zainal, 2019). A high-water table or very saturated soils may be encountered during excavation which may be obvious in a permeable material (sand or gravel) since the water will seep or flow out of the slope. In silt and clay soils, the effect is less obvious as it will take longer to permeate up through the soils to reach the surface. A high-water table may be noted by a sponginess of the soil (MFLNRORD, 1994).

5.3 Slope Movement Assessment

Predicting locations where slumping may occur is difficult. Such predictions are particularly difficult to make when observing construction during dry conditions.

A rise in groundwater after construction can lead to failure of excavated slopes below the water table, due to high hydrostatic and seepage forces (MFLNRORD, 1994). Slopes may be constructed during the low water level period without incident but fail as the groundwater level rises. Cut slopes that may be below the water table at any time of the year should be designed to prevent sloughing and erosion of the soil (Figure 13).

Figure 13: Failure in a sandy gravel stratum with high water table

6.0 Incorporating Climate Change Impacts Into ESC

6.1 Rain Events

Climate change is expected to lead to an increase in severe coastal storm surges and flooding events that could have significant impacts to infrastructure (MECCS, 2019), as was shown during the 2021 atmospheric river event which caused extensive damage to major highways around the province. Project managers should plan for storms and rainfall that are more severe than what has historically been experienced when planning and implementing ESC measures. More robust structures that can accept a higher volume of water and sediment may be required.

6.2 Wildfire

Increased frequency and severity of wildfire is the greatest overall risk caused by climate change in B.C. (MECCS, 2019). Based on area burned, the three worst fire seasons in the history of B.C. occurred from 2017-2022. Although wildfires generally have little direct impact to infrastructure, they destroy vegetation which would normally intercept rainfall and absorb excess water, significantly increasing erosion potential. Furthermore, post-fire soils are typically less able to absorb water which makes slopes much more prone to erosion and can quickly intensify into mudslides, debris flows, and even large-scale slope failure (Curran et al., 2006). Care should be taken when working in burned areas until vegetation has re-established. A geotechnical assessment may be required to ensure the site is safe for work.

In areas of low to moderate intensity burn, vegetation may quickly re-establish naturally. However, in areas of high intensity burn, seeding may be required. Note: however, that seeding alone will often not significantly reduce erosion potential if applied late in the season as it will not germinate until the following spring. Where seeding occurs late in the season, the site will be vulnerable to fall storms, snow melt, and spring freshet before the seed is able to germinate, establish roots, and contribute to erosion control. In this case combining seeding with a flexible growth medium (aka hydraulically applied mulch), which provides long-term erosion control (up to 18 months) may provide further protection. Additional, more robust ESC measures beyond what would normally be expected may also be needed to help reduce erosion. Always review seed certificates of analysis to confirm that seed mixes are not contaminated with invasive weeds.

7.0 Erosion and Sediment Control Plans (ESCP)

The 2020 MOTI Standard Specifications for Highway Construction, Section 165.04.01 states that "*the contractor is responsible for preparing and implementing an ESCP for the project and must be in accordance with the methodology of the National Guide to Erosion and Sediment Control on Roadway Projects* – Transportation Association of Canada 2005" (MOTI, 2020).

SS 165.04.01 further states, *"The contractor is required to incorporate all appropriate control measures for runoff, erosion, and sediment issues into the ESCP. The contractor is also responsible for daily inspections of the integrity of the ESC measures, especially during adverse weather conditions or when construction operations are proceeding in Environmentally Sensitive Areas (ESAs).*

Any inadequacies observed in ESC measures should be immediately corrected after observing such defect. Contingency materials should be on-site in case of an emergency so that emergency response times may be decreased greatly" (MOTI 2020).

7.1 Erosion and Sediment Control Plan (ESCP)

An ESCP must be prepared by an AQP prior to commencing construction activities. Runoff, erosion, and sediment control methods are detailed in the TAC 2005 Manual, *Designing and Reviewing Effective Sediment and Erosion Control Plans* (Fifield, 2011), *Standards and Best Practices for Instream Works* (MWLAP, 2004) guidance document, the *Standard Specifications for Highway Construction* (2020), and this manual (MOTI ESC, 2020).

The ESCP should focus on the details described in SS 165.04.01. A summary of ESCP requirement listed in section SS165.04.01 is provided here for information.

- The contractor must identify areas and major construction activities for which the contractor will be required to prepare one or more ESCP.
- The ESCP must be submitted to and approved by the Ministry prior to works commencing.
- The contractor is required to ensure work is carried out in accordance with the ESCP and may be required to update it at the direction of the Ministry.
- The ESCP must contain:
    - a schedule of the works as they pertain to the ESCP;
    - description of erosion and sediment control procedures;
    - site specific drainage and run-off management plans;

  - lists of all erosion and sediment control equipment and materials; and
  - plans for monitoring and inspection.

It is important to regularly compare the actual site conditions with those that were originally anticipated at the start of the project. The ESCP is a living document and must be revised to take account of changes that arise. These include changes in:

- sub-surface conditions;
- surface flows;
- construction approach or methodology; and
- project scheduling.

Sub-surface Conditions

Given the sometimes-limited amount of sub-surface information available before construction begins, variations in sub-surface conditions can generally be expected as construction proceeds. Soil materials may differ, and groundwater may be encountered in places or volumes that were not anticipated. Larger variations may require the ESCP to be updated.

Surface Flows

Drainage patterns both within and adjacent to the project area should be identified and captured during the design phase (and shown on design drawings). Excavations that intercept minor drainages may result in a significant increase in erosion potential. These drainages may need to be diverted during construction to ensure the protection of the work site and receiving environment.

Construction Scheduling

When the construction schedule changes, the erosion risk may be affected. For example, a delay in a project may affect the schedule for re-vegetation and the possible impacts of working in a wetter time of year (e.g., the project was not completed in the fall and therefore must be stabilized through the winter and spring freshet), thus must be evaluated and considered in an updated ESCP. Changes to weather or unanticipated storms may also affect the erosion risk throughout the life of the project.

7.2 Risk Assessment Flow Chart

The following ESC risk assessment process (Tables 6-8) is derived from the 2005 TAC Manual and will assist AQP's, contractors and their consultants in completing a site level risk assessment. Section 165 in the 2020 Standard Specifications for Highway Construction also outlines specific expectations surrounding an ESC risk assessment. Tables 7 to 9 provide a method to assess ESC risk and provide guidance on the selection of appropriate ESC BMPs to mitigate that risk (TAC 2005).

7.2.1 Step 1 - Soil Erodibility

Table 6 describes how soil erodibility is rated, given the different soil textures as described in Figure 6.

Table 6: Step 1 – Soil erodibility rating

Soil Texture	***Erodibility Classification***	***Soil Erodibility Rating***
Silt, Silty Loam, Loam, Silty Sand	Most Erodible ↓	High
Sandy Loam, Silty Clay Loam, Sandy Clay Loam, Silty Clay		Moderate
Sandy Clay, Clay, Clay Loam, Loamy Sand, Sand, Poorly graded Gravel, Well-graded Gravel	Least Erodible	Low

7.2.2 Step 2 - Erosion Potential

Slope length and gradient also plays a key role in determining the risk of erosion. For slopes with a run greater than 70 m, the risk of erosion increases. Any slope greater than 20% will also require more extensive ESC measures. Table 7 describes potential erosion associated with varying slope lengths and gradients.

Table 7: Step 2 – Determining erosion potential

Slope Gradient	***Soil Erodibility Rating (Step 1)***	***Erosion potential on slopes <70 m***	***Erosion potential on slopes >70 m***
0-10%	Low	Low	Low
	Moderate	Low	Moderate
	High	Moderate	High
10-20%	Low	Low	Moderate
	Moderate	Moderate	High
	High	High	High
>20%	Low	Moderate	Moderate
	Moderate	High	High
	High	High	High

Notes:

Slope gradient ratio to % gradient equivalency: 1:1 = 100%, 1.5:1 = 67%, 2:1 = 50%, 3:1 = 33%, 4:1 = 25%, 5:1 = 20% and 10:1 = 10%

Applicable to slopes less than 70 m in length; generally, increase a level in erosion protection for slopes longer than 70 m.

7.2.3 Step 3 - Determination of Consequence Rating

Step 3 illustrates potential project consequences of ESC failures:

- Ecological consequences. **LOW/HIGH**
  - Related to the introduction of sediment to the aquatic environment
- Project consequences. **LOW/HIGH**
  - Related to the need to respond to and repair erosion damage and the implications for project schedule and finances
- Regulatory consequences. **LOW/HIGH**
  - Associated with the deposition of sediment in receiving waterbodies.

For a project to have low consequences of erosion and sediment, there should be no ecologically sensitive areas that could be negatively affected, no project costs or schedules that would be affected by erosion or sediment issues, and no risk of legal consequences due to regulatory violations. If the level of risk in any category is significant, then the consequences should be rated as high (TAC, 2005).

7.2.4 Step 4 - Required Levels of ESC

Step 4 involves assessing the risk of erosion for a particular site to determine the level of ESC required (Table 8). This next step will assist in determining the types of BMPs that should be considered when developing the ESCP. Procedural BMPs and ESC Plans are administrative in nature, whereas runoff, erosion, and sediment control BMPs are physical structures that will require maintenance over time.

Table 8: Step 4 – Required levels of ESC

Erosion Potential (from Step 2)	***Level of Erosion and Sediment Control***			
	Procedural BMPs	**ESC Plan and Structural BMPs**	**Runoff Control BMPs**	**More Intensive Erosion & Sediment Control BMPs**
Low	Recommended	Required	-	-
Moderate	Required	Required	Recommended	Recommended
High	Required	Required	Required	Required

The extent of how detailed the ESCP should be is usually determined by the level of risk associated with the individual project (TAC, 2005). Sites with a high-risk rating will require the selection and implementation of a combination of runoff, erosion, and sediment control BMPs to reduce the potential for adverse project impacts during and following construction activities.

PART B - EROSION AND SEDIMENT CONTROL IMPLEMENTATION

8.0 Erosion and Sediment Control (ESC) BMP Selection Guide

The ESC BMP Selection guide has been developed to address specific conditions that are generally found with highway construction projects.

The following tables provide a summary of possible ESC BMPs and their appropriate application. In cases where a product is selected that has manufacturer-specific recommendations for installation that differ from this guide then the manufacturer recommendations shall apply.

The BMP Selection Guide is divided into the following sections:

- Procedural BMPs
- Runoff Control BMPs
- Erosion Control BMPs
- Sediment Control BMPs
- Shallow Slope Movement BMPs.

Procedural BMPs for Site Management and Scheduling are procedures that are non-structural in nature but are integral for identifying site-specific ESC issues and measures prior to construction. Table 9 and Table 10 below describes procedural BMPs in more detail.

Runoff Control BMPs are intended to control surface flows and reduce erosion potential including on-site and off-site measures. Table 11 below outlines the available runoff control BMPs.

Erosion Control BMPs are implemented to prevent or minimize the dislodgement of soil particles. Erosion can be controlled by protecting exposed surfaces from runoff or rain splash and by reducing the quantity and/or velocity of surface flows via runoff controls. It is important to select the most appropriate erosion controls for specific application areas. Table 12 outlines the available erosion control BMPs.

Sediment Control BMPs are adopted to capture water-borne particles in a controlled manner before undesirable damage is caused. It is advisable to install sediment control measures close to the sediment source. This reduces the quantity of water that must be managed and reduces the consequences of a failure inundating a specific control measure with too much sediment-laden water (TAC, 2005). Table 13 below outlines the available sediment control BMPs.

Shallow Slope Movement BMPs are intended to prevent or minimize the occurrence of shallow slope movement, or slumping. Table 14 below outlines the available shallow slope movement BMPs.

The tables below were obtained from the TAC 2005 Manual and modified to suit the purpose of this document and are intended to provide enough detail to assist with the selection of an appropriate mitigation measure. Additional information for each BMP can be found in Appendix 1 – BMP Guidance Documents.

Table 9: Procedural Best Management Practices for Site Management

Site Feature	***Design and Implement an ESCP***	***Minimize Exposed Soils***	***Perimeter Control***	***Site Access Management***	***Stockpile Management***	***Dust Management***	***Sensitive Area Signage***
Slopes	✓	✓	✓	✓		✓	✓
Natural Channels	✓	✓	✓				✓
Drainage Channel	✓	✓	✓				✓
Pipes and Culverts	✓	✓	✓				✓
Large Flat Surfaces	✓	✓	✓	✓		✓	✓
Borrow/Stockpiles	✓	✓	✓		✓	✓	✓
Adjacent Properties	✓		✓	✓		✓	✓
Comments	Design and implement a site-specific Erosion and Sediment Control Plan to reduce erosion and ensure that sediment is not released from the construction site. This includes monitoring, maintenance, and decommissioning.	By minimizing the total disturbed soil area and length of exposure, the erosion potential is reduced, and the quantity of sediment control measures is also reduced.	During clearing and grubbing activities, the limits of construction activity should be clearly marked. Limits should be established to the minimum area required to complete the work.	Temporary access roads should be paved or graveled to minimize the tracking of material off-site.	Stockpiles should not be located near environmentally sensitive areas. Stockpiles should be seeded, or a synthetic cover applied.	Re-vegetate areas that will not be traveled on. Reduce vehicle speeds on unpaved roads. Water dirt roads for dust control.	Areas that are sensitive to disturbance and areas that must not be disturbed should be clearly signed to convey that message. Areas that represent a safety hazard, such as deep ponds, should be signed as such and barricaded if necessary.

Table 10: Procedural Best Management Practices for Scheduling

Site Feature	Optimal Weather	Planned Shutdowns	Fish Windows	Optimize Schedules	Follow BMPs Early	Restore Early
Slopes	✓	✓		✓	✓	✓
Natural Channels	✓	✓	✓	✓	✓	✓
Drainage Channel	✓	✓	✓	✓	✓	✓
Pipes and Culverts	✓	✓	✓	✓	✓	✓
Large Flat Surfaces	✓	✓		✓	✓	✓
Borrow/ Stockpiles	✓	✓		✓	✓	
Adjacent Properties	✓	✓		✓	✓	
Temporary (T) or Permanent (P) Measure	P	T	T	T	T	T/P
Comments	Reduce erosion by working during the driest possible conditions. Avoid activities that cause significance disturbance, such as grading, during periods of heavy rain.	Be prepared for planned or unplanned work stoppages, including winter shutdowns.	Schedule work in or near fish bearing streams during the Provincial fish windows to reduce potential effects on fish and fish habitat.	The construction schedule should ideally be compatible with plans for progressive reclamation, instream works, etc.	Erosion potential can be minimized by installing ESC BMPs as soon as possible. Soil should never be exposed before developing an ESCP.	Erosion potential can be minimized by restoring or reclaiming constructed areas as soon as possible. Temporary works (e.g., retention ponds, sediment controls) should be removed as soon as they are no longer required.

Table 11: Runoff Control Best Management Practices

Site Feature	**Runoff Control BMPs**								
	Surface Texturing	***Slope Drains***	***Fibre Rolls & Wattles***	***Check Dams***	***Diversion Ditch***	***Energy Dissipator***	***Vegetated Soil Wrap***	***Ditch Blocks***	***Asphalt Berms***
Slopes	✓	✓	✓		✓	✓			
Natural Channels							✓	✓	
Drainage Channel			✓	✓	✓	✓		✓	
Pipes and Culverts		✓				✓		✓	
Large Flat Surfaces	✓				✓				✓
Borrow/Stockpiles	✓				✓				
Adjacent Properties	✓				✓				✓
BMP	1	2	3	4	5	6	7	8	9

Table 12: Erosion Control Best Management Practices

Site Feature	**Erosion Control BMPs**										
	Topsoil	*Seeding*	*Mulching*	*Sodding*	*Vegetated Riprap Armouring*	*Live Staking and Brush Layering*	*Riprap or Rock Cover*	*Stabilized Entrances*	*Rolled Erosion Control Products*	*Cellular Confinement System*	*Impermeable Sheeting*
Slopes	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Natural Channels					✓	✓	✓			✓	✓
Drainage Channel	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Pipes and Culverts				✓			✓				
Large Flat Surfaces	✓	✓	✓	✓	✓						✓
Borrow & Stockpiles	✓	✓	✓	✓	✓	✓			✓	✓	✓
Adjacent Properties	✓	✓	✓	✓	✓			✓			
BMP	10	11	12	13	14	15	16	17	18	19	20

Table 13: Sediment Control Best Management Practices

Site Feature	Sediment Control BMPs								
	Vegetated Buffer Strip	***Synthetic Permeable Barriers***	***Fibre Rolls or Wattles***	***Sediment Fence***	***Brush Berm/Earth Dyke***	***Drain Inlet Sediment Barrier***	***Check Dams***	***Sediment Control Pond***	***Pump Outlet Filter Bag***
Slopes	✓	✓	✓	✓	✓				
Natural Channels	✓				✓				
Drainage Channel	✓	✓	✓				✓	✓	✓
Pipes and Culverts	✓			✓		✓			
Large Flat Surfaces					✓				
Borrow and Stockpiles				✓					
Adjacent Properties	✓			✓	✓	✓			
BMP	21	22	3	23	24	25	4	26	27

Table 14: Shallow Slope Movement Best Management Practices

Site Feature	**Shallow Slope Movement BMPs**	
	Rock Cover	***Subsurface Drains***
Slopes	✓	✓
Natural Channels	✓	
Drainage Channel	✓	
Pipes and Culverts	✓	
Large Flat Surfaces		✓
Borrow/Stockpiles		
Adjacent Properties		
BMP	16	28

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Appendix 1 ESC BMP Guidelines

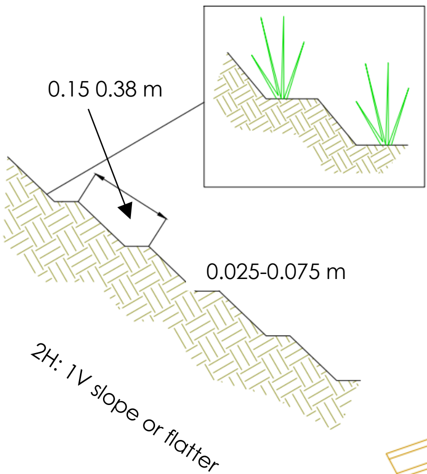
EROSION AND SEDIMENT CONTROL BEST MANAGEMENT PRACTICE GUIDELINES

Surface Texturing

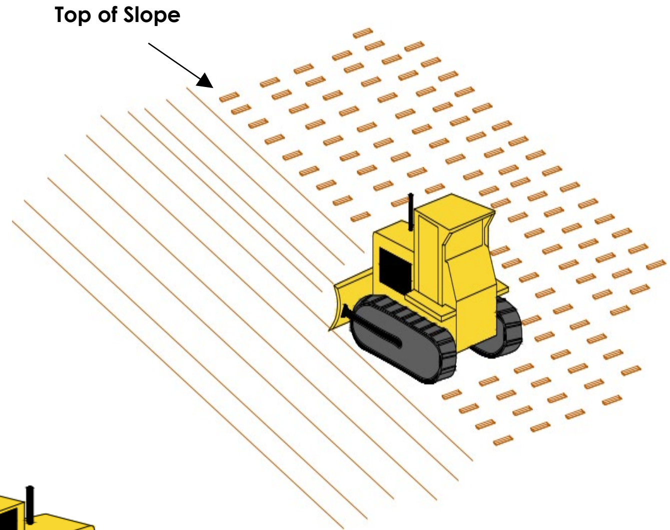
Runoff and Erosion Control BMP

BMP # 1

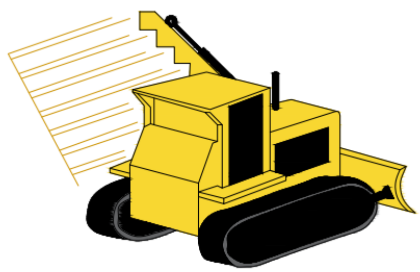
Temporary or Permanent BMP



Surface Roughening



Track Packing



Surface Grooves

Surface Roughening

Track Packing

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Refer to BC Ministry of Transportation & Infrastructure's document titled, *Standard Specifications for Highway Construction – Section 751* – Topsoil and Landscape Grading for more details.

British Columbia Ministry of Transportation and Infrastructure

# Surface Texturing	# BMP # 1
Runoff and Erosion Control BMP	**Temporary or Permanent BMP**

Description and Purpose:

- Build textured slopes by roughening the surface, track packing the surface, or installing serrated grooves (horizontal, not vertical which may increase rill and gully erosion).
- Texturing reduces the runoff velocity, traps sediment, and increases the water infiltration and is used in many applications to aid in slope stabilization and re-vegetation prescriptions.

Applications:

- Temporary or permanent slope treatment to allow for vegetation to initialize and reduce the surface runoff velocities.
- May be used to roughen exposed soils (of at least a 2:1 slope or flatter for finer textured soils and a 1.5:1 slope if using a gravel material) in the direction of surface flow to minimize erosion and trap sediment and soils nutrients.
- Application will be dependent on soil texture, environmental conditions (e.g., precipitation, runoff, snow melt), slope angle and length, fill slope (uncompacted soils), cut slope (untouched native soils may be more stable).
- May be used on graded soils with smooth surfaces to interrupt surface flows.
- Can be used on slopes that will not be immediately topsoiled, vegetated, or otherwise stabilized.
- May be applied to topsoiled slopes to provide track serration to further reduce erosion potential.

Construction:

- Surface Roughening (rough and loose):
    - Leave soil in rough grade condition; do not smooth grade soil, the large clods of soil will help slow runoff velocities, trap sediment, and increase infiltration of surface flows.
    - Can place large woody debris (LWD) on the slope surface to enhance recovery.
    - Can excavate holes (excavator bucket size) and mound soils for roughness. Excavating holes and mounding soils along the treatment area will achieve rough and loose.
- Track Packing:
    - Use tracked equipment to move up and down the slope, leaving small depressions on the surface. Limit over-compaction of the surface. Depressions will help with decreasing runoff velocities, trap sediment, and increase infiltration.
    - Track packing a slope will create micro-sites in the soil and promote vegetative growth.
- Surface Grooves:
    - Excavate shallow grooves perpendicularly across the width of the slope. Grooves should be approximately 0.1 to 0.2 m in depth and can be made by hand or via teeth on an excavator’s digging bucket.

Considerations:

- It is important to minimize the loosening of soil by turning equipment at the end of each pass.
- Keep tracking passes to 1 or 2-times to avoid over-compaction; over-compacted soils will impede infiltration and vegetation growth.

- Roughening of low height slopes may not be required as the erosion potential is lower for a slope of low vertical height (3H:1V).
- Re-vegetate the exposed soils as soon as practical.

Inspection and Maintenance:

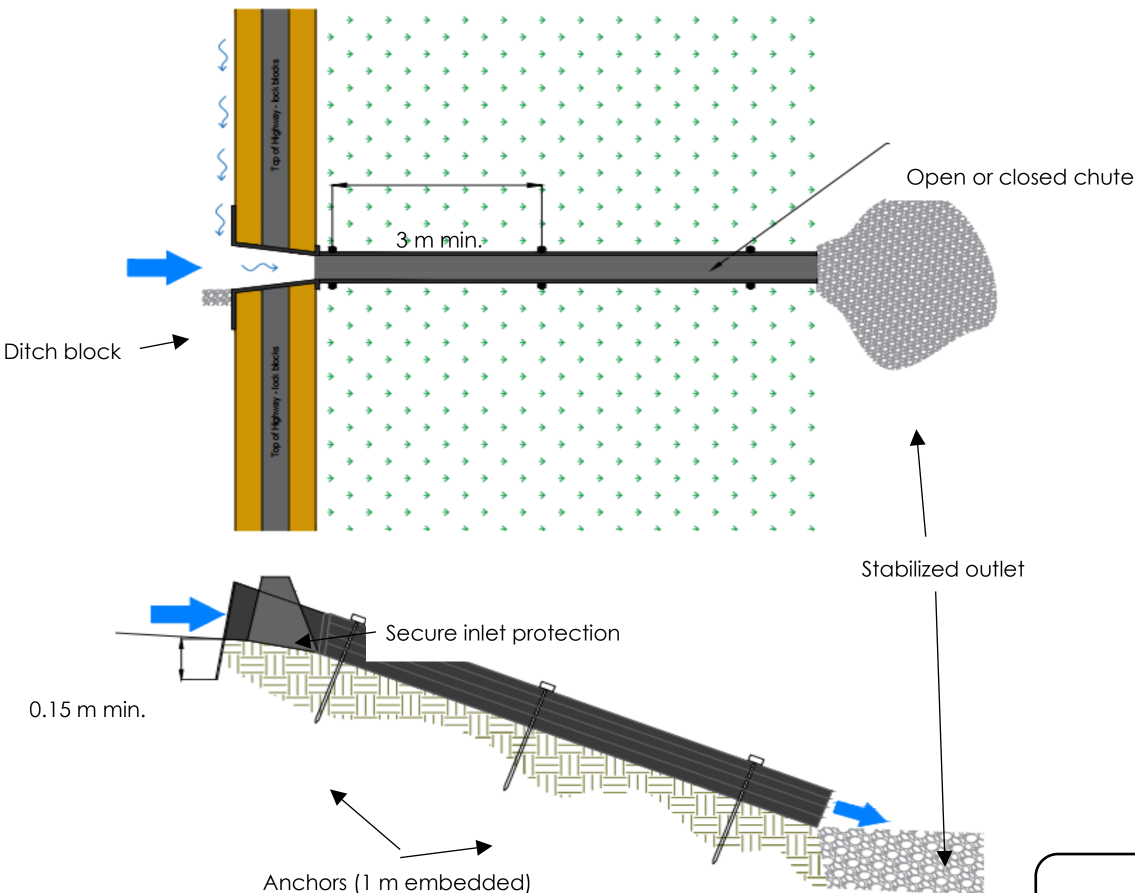
- Inspect slopes following rain events for signs of erosion and assess the effectiveness of vegetation following one growing season; the slope may require more surface preparation and re-vegetation efforts.

Slope Drains

Runoff and Erosion Control BMP

BMP # 2

Temporary or Permanent BMP



Slope Drains

Closed chute flexible drain

Open chute fixed drain

British Columbia
Ministry of Transportation and Infrastructure

Slope Drains

Runoff and Erosion Control BMP

BMP # 2

Temporary or Permanent BMP

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Description and Purpose:

- Slope drains are heavy duty (often flexible) pipe that convey runoff from the top of the slope to the bottom while preventing concentrated erosion on the face of the slope.

Applications:

- Temporary or permanent measure.
- Used on slopes where there is a high potential for erosion over the face of the slope.
- Used in conjunction with water containment or diversion structures, such as diversion channels, berms, or barriers to convey and direct runoff into slope drains.

Construction:

- Construct a diversion or intercept channel, ditch block, barrier, or other inflow apron structure at the crest of slope to channel the flow toward the slope drain inflow.
- Install the slope drain through an inlet berm or into the shoulder of the road with a minimum of 0.45 m of soil cover overtop of drainpipe, as to secure or key-in the inlet.
- Install scour inlet protection (such as riprap, sandbags, pavement, or asphalt curb).
- Install an energy dissipator (such as riprap, gravel, or concrete) at the outlet of the slope drain; the outlet must not discharge directly onto unprotected soil.
- Secure the pipe from movement by tying to steel anchor stakes, hold-down grommets, or other approved anchor methods.
- Space anchors on each side of the drainpipe at maximum 3 m intervals along the entire length of the drainpipe.

Considerations:

- Ensure drains are sized correctly to accommodate anticipated flow volumes (Q-10); install more drains if one drain will not carry anticipated flows.
- Armour and secure the drain inlet to ensure runoff will not go around the drain and erode the slope.
- If constructing a temporary inflow apron out of sandbags at the crest of slope, only fill each sandbag ¾ full; this will allow the sandbag to be flexible enough to mould around the drainpipe and remain in continuous contact with the ground.
- Construct an energy dissipator (see BMP#6) at the outlet of the drain to minimize erosion.
- The slope drain must be anchored securely to the face of the slope.

# Slope Drains	# BMP # 2
Runoff and Erosion Control BMP	**Temporary or Permanent BMP**

Inspection and Maintenance:

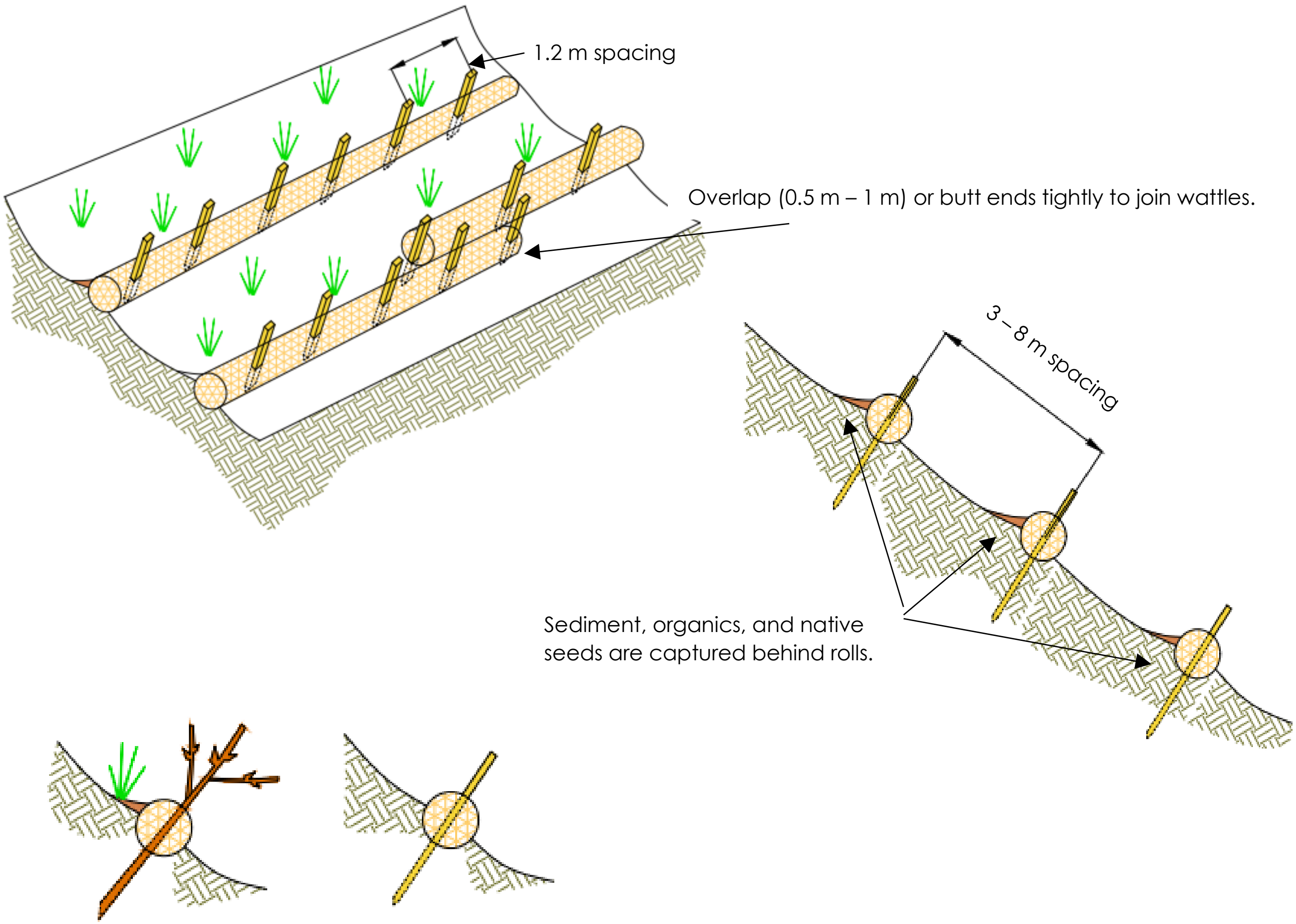
- Regularly inspect drains to ensure that the structures are still anchored and not eroding the face of the slope.
- Repair sections of pipe as soon as possible; install more anchors if the drain is moving.
- Check for signs of erosion at the outlet of the drainpipe.
- Regularly remove sediment from the drain inlet.

Fibre Rolls and Wattles

Runoff, Erosion, and Sediment Control BMP

BMP # 3

Temporary BMP



Anchor using live stakes or wood stakes.

Fibre Rolls

Bio-engineered Wattles

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Fibre Rolls and Wattles

Runoff, Erosion, and Sediment Control BMP

BMP # 3

Temporary BMP

Description and Purpose:

- Fibre roll consists of bundled natural fibre wrapped in photo-degradable netting. It is staked into the soil along slope contours as a grade break to reduce potential erosion.
- Wattles can consist of bioengineered bundles of live fascine (i.e., willows) staked along the contours.
- Ideally, live stakes can be installed to anchor the fibre rolls and wattles to provide deep rooted vegetation with potential favourable moisture retention provided by the fibre roll.
- Fibre rolls and wattles also capture sediment, organic matter, and seeds carried by runoff.

Applications:

- Used on slopes stable enough to support vegetation (gradients steeper than 1H:1V may have low success); effective in controlling low sheet flow velocities.
- Generally used on long slopes as a grade break to shorten slope length between line of fibre rolls at different contour elevations.
- May be used as grade breaks, or where slopes transition from flatter to steeper slope gradients.
- Can be used on lake shores as wave break to assist in re-vegetation and stabilization of banks.
- Can be used in conjunction with live staking as bioengineering measure.
- Also used in ditches as a check dam structure; refer to BMP # 4 – Rock Check Dam

Construction:

- Prepare slope face and remove large rocks or other obstructive materials.
- Excavate small trenches a minimum of 0.15 m deep and 0.15 m wide across the width of the slope, perpendicular to slope direction, starting at the toe of the slope and working upward toward the crest of the slope.
- Space trenches 3 to 8 m apart along the slope incline, with steeper slopes having trench spacing closer together.
- Ensure continuous contact between fibre roll and soil surface; butt-joint adjacent fibre roll segments tightly against one another or overlap wattles (0.5 to 1.0 m) and stake them in place.
- Place wattles along slope contours and butt ends tightly together or overlap wattles.
- Spacing depends on slope steepness.
- Secure rolls to soil using wooden stakes or other appropriate anchors; live stakes may be used.
- Wattles can be installed in a slightly upslope curved manner (smile shape) instead of along the contour; this will also retain surface flows and capture sediment; see below photo.

Considerations:

- Place soil excavated from the trench on the upslope side of the fibre roll and compact the soil to minimize undermining of fibre roll by runoff.
- For steep slopes, additional anchors placed on the downslope side of the roll may be required.

Fibre Rolls and Wattles	BMP # 3
Runoff, Erosion, and Sediment Control BMP	Temporary BMP

Inspection and Maintenance:

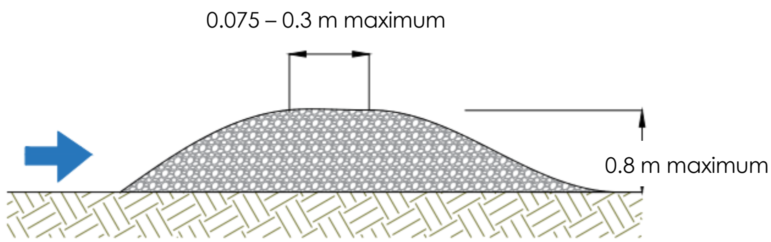
- Regularly inspect structures to ensure they remain anchored and there is no erosion occurring around the structures; eroded areas should be repaired immediately.

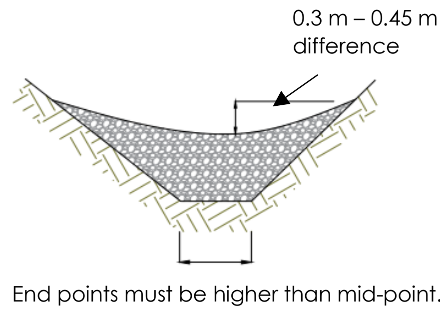
Check Dam

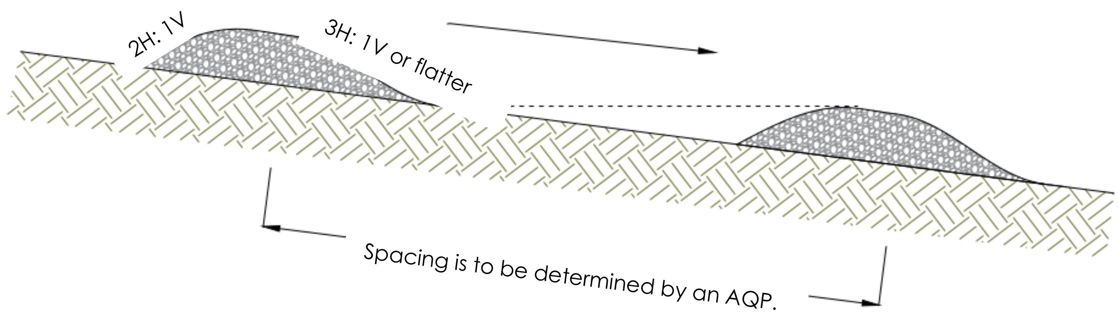
Erosion and Sediment Control BMP

BMP # 4

Temporary or Permanent BMP







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Description and Purpose:

- Small dam constructed of rocks placed across an unnatural roadside drainage course only.
- Decreases flow velocities caused by storm runoff to reduce potential erosion.
- Sediment-laden runoff is retained behind the structure, allowing sediment to settle out.

Applications:

- A permanent measure but can be used temporarily during construction.
- Reduces a long run into shorter intervals of gentle grades between structures.
- Reduces flow velocities and kinetic energy and will decrease erosion potential.
- Used in ditches where control runoff velocities are less than 1.5 m/s.

Construction:

- Key in the structure extending from one side of the ditch or channel to the other side.
- Place non-woven geotextile fabric over footprint area of the rock check dam.

- The structure should be constructed so that the centre of the crest is a minimum of 0.3 m lower than the outer edges.
- Height of structures should be less than 0.8 m to avoid impounding large volumes of runoff.

Considerations:

- Height and spacing between structures should be designed to reduce steeper slopes in ditches to intervals of flatter gradient.
- Structures should be constructed of free draining aggregate with limited fines.
- Aggregate used should have a mean diameter (D_{50}) of between 0.075 m and 0.15 m and must be large enough to remain in place during high velocity flow situations. Maximum rock diameter should not exceed 0.15 m if the structure is to be used as a sediment trap.
- If structures are placed in channels with ordinary high flows, they must be properly designed for stone size and structure spacings.
- Check dam not to be used in any fish-bearing watercourse as it will block fish passage.

Inspection and Maintenance:

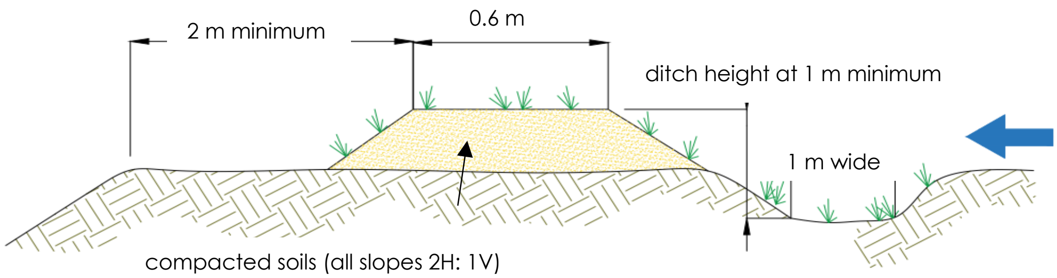
- Regularly inspect structures (i.e., weekly or after a heavy rain event) to ensure they are intact, and water has not eroded around them.
- Repairs should be made immediately.
- Remove sediment build-up before it reaches one half the structure height.
- Replace dislodged aggregate immediately with heavier aggregate.

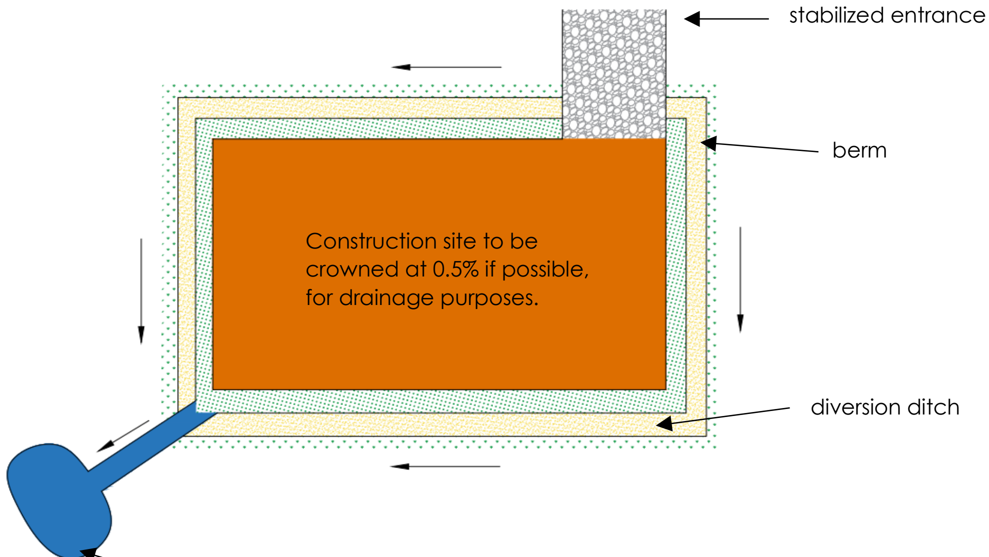
Diversion Ditch

Runoff Control BMP

BMP # 5

Temporary or Permanent BMP





Perimeter Ditch

Diversion Ditch

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Please refer to the *Standard Specifications for Highway Construction* Section 165.10.08 Channel Diversions for more information.

# Diversion Ditch	# BMP # 5
Runoff Control BMP	**Temporary or Permanent BMP**

Description and Purpose:

- Channels, or swales, excavated along the top of slopes to intercept and convey runoff away from exposed slopes and to minimize erosion.
- Also used to temporarily convey runoff around a site during the construction phase.
- Often carries water to slope drains or sediment basins which carry water further downslope.

Applications:

- Permanent and temporary measure.
- Effective method of intercepting runoff to avoid excessive sheet flow over a slope and reduce erosion in highly erodible soils.
- Can be used in conjunction with slope drains, sediment traps or sediment basins, check dam structures, or permeable synthetic barriers.
- Temporarily divert surface flows around a construction site on a poly-lined channel.
- The ditch should have positive grade to facilitate drainage.
- For sensitive high-risk areas, the ditch should be stabilized with an impermeable membrane, riprap, or vegetation.

Construction:

- Excavate the ditch a minimum offset distance of 2 m between the crest of the slope and the top of the diversion ditch side slope.
- Alternatively, place the diversion ditch outside of the construction activities but within the limits of construction (i.e., within the highway right-of-way).
- Place and compact excavated soil to form a berm between the crest of slope and the diversion ditch channel to provide adequate depth of the diversion ditch:
    - The consequence of failure of the berm will determine the level of compaction effort.
    - Side slopes of the diversion ditch should not be steeper than 2H:1V.
    - The depth of the diversion ditch (from base of ditch to top of embankment) should be a minimum of 1 m; the width of the ditch should also be 1 m minimum.
    - The ditch should be graded at a minimum of 1% to promote positive drainage and outfall.

Considerations:

- The ditch should be graded toward the nearest outfall or drainage pipe.
- A sediment basin or trap can be installed at the outfall, and the outflow of trap armoured with an energy dissipator.

Diversion Ditch **Runoff Control BMP**	BMP # 5 **Temporary or Permanent BMP**

Inspection and Maintenance:

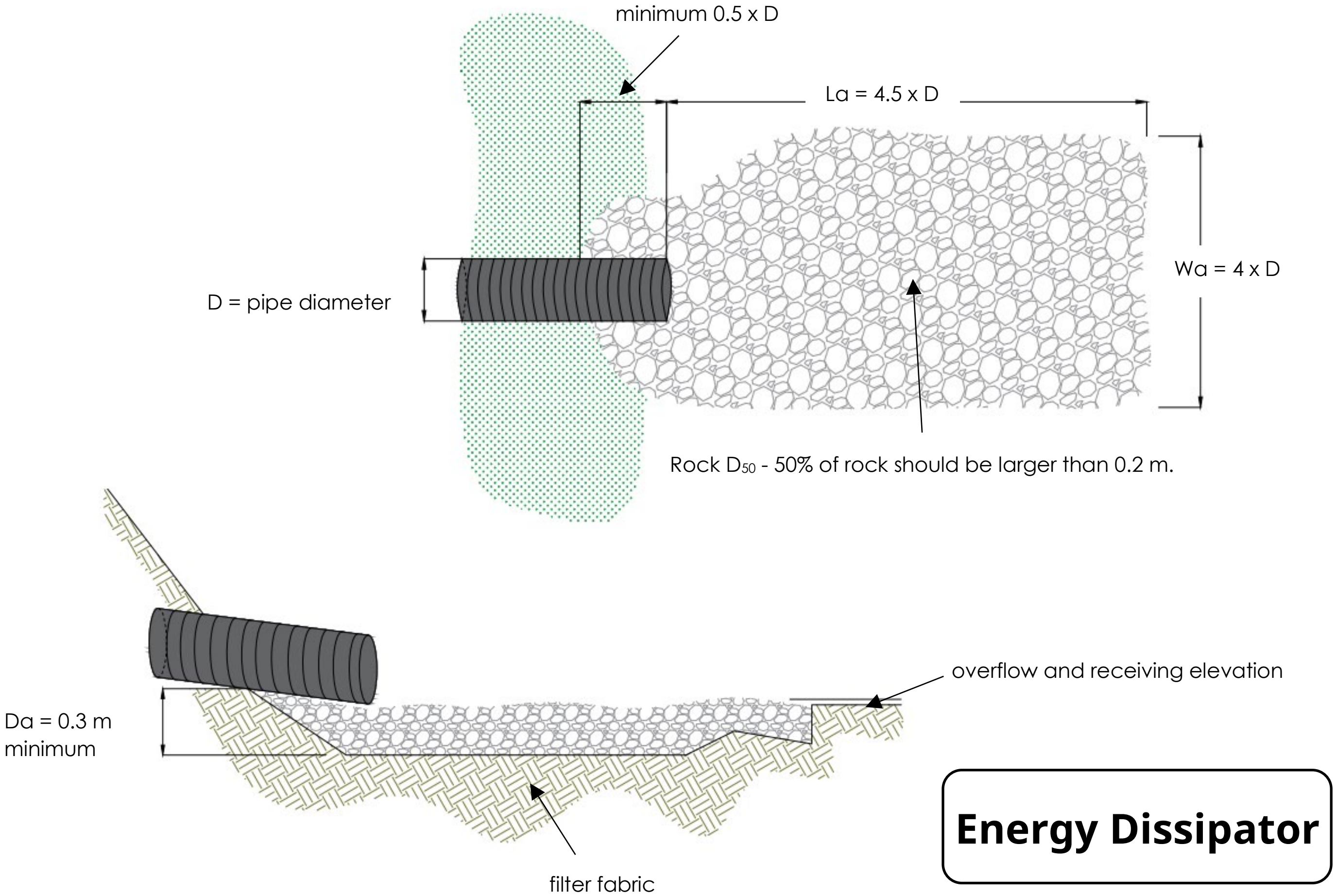
- Regularly inspect ditch (i.e., bi-weekly or after a heavy rain event) to ensure no damage has occurred.
- Repair any damage to the channel immediately.
- Remove any built-up sediment within the channel; sediment removal and ditch maintenance may be difficult due to limited access following construction.

Energy Dissipator

Runoff and Erosion Control BMP

BMP # 6

Temporary or Permanent BMP



Culvert Outlet Energy Dissipator

Ditch Energy Dissipator

# Energy Dissipator **Runoff and Erosion Control BMP**	# BMP # 6 **Temporary or Permanent BMP**

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Description and Purpose:

- Hard armour (riprap, cobble, cured and washed concrete) placed at pipe outlets, in channels, and at downstream side of check dam structures to reduce velocity and dissipate energy of concentrated flows to withstand a peak runoff event.
- Minimizes scour erosion at outflow.
- Geotextile cloth, plastic, sandbags, or woody debris can be used as a temporary measure.

Applications:

- Permanent and temporary measure.
- Used at outlets of pipes, slope drains, culverts, conduits, or channels with substantial flows.
- May be used where lined channels or pumping operations discharge into unlined channels.
- May be used as splash pad on downstream side of gabions, check dam structures, berms, barriers, and silt fences to prevent erosion caused by runoff overtopping these structures.

Construction:

- Grade the area to final design grades and elevations; sub-excavate energy dissipater location to thickness of energy dissipater. Outlet grade should be zero and aligned straight out of the pipe.
- Place filtration bedding material on base of excavation; bedding can be composed of well-graded sand and gravel or non-woven geotextile fabric. This acts as a separating filter between fine-grained subgrade and riprap size energy dissipating material.
- Filter material should be geotextile fabric or 0.15 m (minimum grade) gravel layer
- Place energy dissipating material (permanent or temporary) over filtration bedding material.
- The top of the energy dissipater should be flush with the surrounding grade.

Considerations:

- Length of energy dissipater (La) at outlets should be of sufficient length to dissipate energy (La = 4.5 x D; where D = diameter of pipe in m).
- Width (Wa) at outlets should be of sufficient width to contain and dissipate energy (Wa = 4 x D).
- Thickness of energy dissipater (da) at outlets should be a minimum thickness of 0.3 m.
- Energy dissipater should be constructed of well-graded riprap, minimum D_{50} = 0.2 m, (preferable D_{50} = 0.3 m).
- The energy dissipater should be constructed flush with the surrounding grade and should be directly in line with direction of outlet flow.

Inspection and Maintenance:

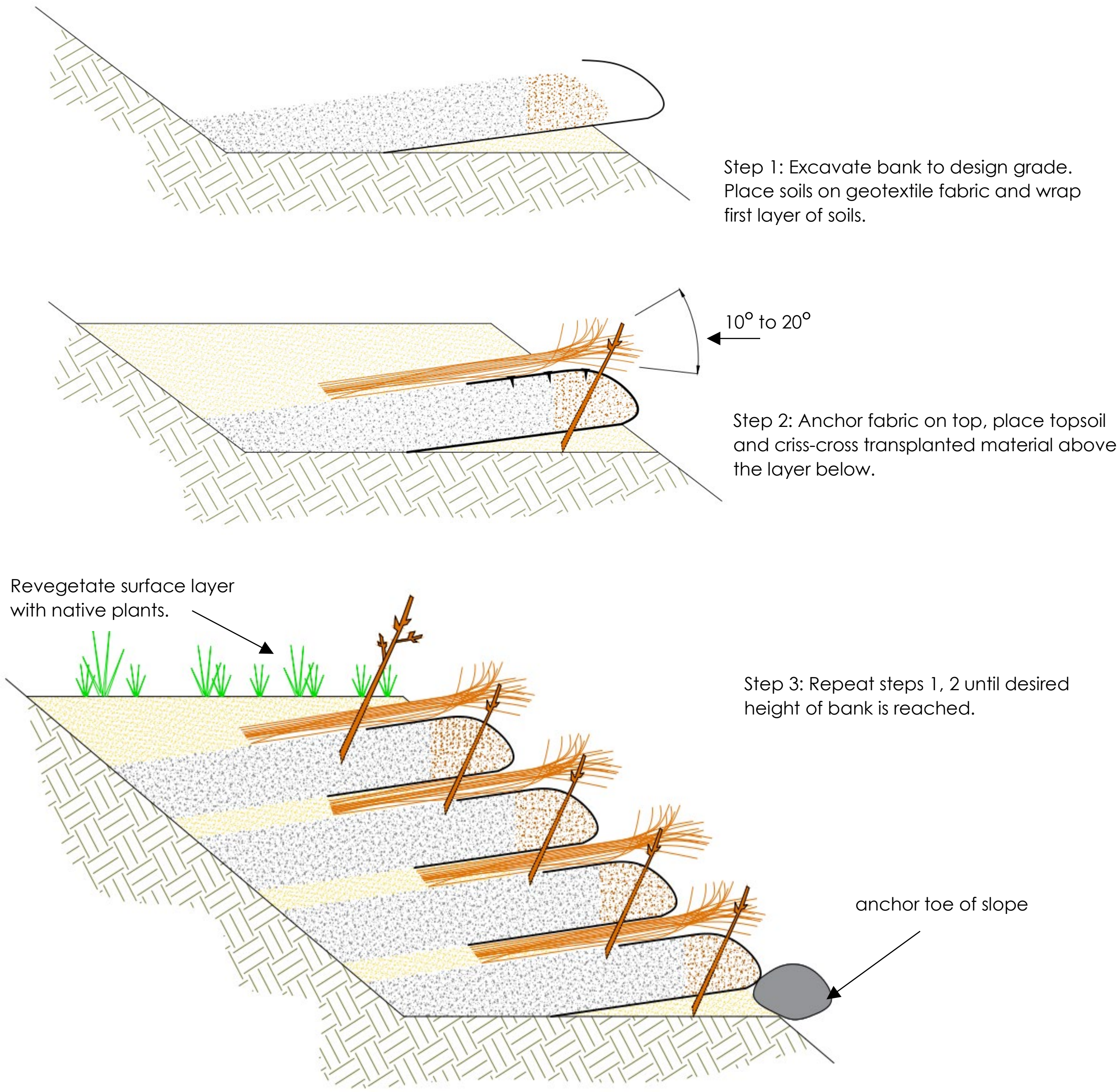
- Regularly inspect ditch (i.e., bi-weekly or after a heavy rain event) to ensure no damage has occurred.
- Repair any damage immediately.
- Remove any built-up sediment within the structure; sediment removal and ditch maintenance may be difficult due to limited access following construction.

Vegetated Soil Wraps

Erosion Control BMP

BMP # 7

Permanent BMP



Notes:

1. This structure must be designed by a geotechnical engineer.

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BRITISH COLUMBIA Ministry of Transportation and Infrastructure

Vegetated Soil Wraps

Erosion Control BMP

BMP # 7

Permanent BMP

Description and Purpose:

- Consists of live cut branches (brush layers) in between lifts of soil wrapped in a geotextile fabric.
- Brush is placed in a criss-cross or overlapping pattern over each wrapped soil lift.
- The fabric wrapping provides the primary reinforcement and the live cut branches eventually root and leaf out, providing vegetative cover and secondary reinforcement.

Applications:

- This permanent technique provides an alternative to vertical retaining structures.
- The use of synthetic geotextiles or geogrids provides greater long-term durability and security.
- The fabric or geotextile wrap also provides additional protection to upper portions of streambanks that are subject to periodic scour.
- The brush layers can act as a drainage layer or conduit that relieves internal pore water pressure and could favourably modify the groundwater flow regime within the slope and minimize slope stability problems.

Construction:

- Excavate bank to design grade. Lay geotextile fabric and place soils on fabric. Wrap first layer of soils with fabric.
- Anchor fabric, place topsoil over geotextile fabric, criss-cross layers of dormant cuttings or transplanted material, install live stake at front of soils wrap (optional).
- Begin at the base of the slope and work upward; the base should be supported on a solid foundation and inclined between 10° and 20° to laterally hold back the slope.
  - The following steps should be followed to construct a soil wrap retaining wall:
  - Excavate a trench to below the scour depth and backfill the base with rock at the desired batter angle for the rest of the structure.

- Place geogrid or geotextile fabric on the base layer and place selected fill material on the fabric, and compact in lifts to a thickness as specified by AQP. Use thinner lifts at the base of the structure where the shear stress is greatest.
- When geogrids are used, burlap strips at least 1.2 m wide can be inserted between the earthen fill and the geogrids at the front face, to contain the fines and prevent soil mobilization within the structure.
- Ensure there is a minimum of 0.9 m of extra fabric material on the face of the structure to allow for overlap when the material is pulled up and over the above lift and staked in place.
- Add layers of the brush criss-crossed overtop of the underlying wrapped soil lift, mixing 0.025 to 0.05 m of topsoil within the brush layers.
- Repeat the process with succeeding layers of earth fill, live brush, and geogrids (or fabric) until the specified height or elevation is reached.
- The maximum vertical spacing, and imbedded length of successive geogrid or reinforcement layers are determined (by a professional engineer) from the specified safety factor, slope angle, soil shear strength, allowable unit tensile strength, and interface friction properties of the reinforcement layer.

Considerations:

- Select long branches of native tree species. Willows are common because they generally root well from cuttings. Alder, cottonwood, and dogwood can also be used effectively, particularly when mixed in with willow.
- The length of the branches will vary depending upon the desired depth of reinforcement, but they should be long enough to reach the back of an earthen buttress placed against a streambank while protruding slightly beyond the face.
- The diameter of the live cuttings will also vary depending on their length, but typically should range from 0.02 to 0.05 m at their basal ends.
- Refer to BMP # 15 - Live Staking for further direction on plant specifications.

Inspection and Maintenance:

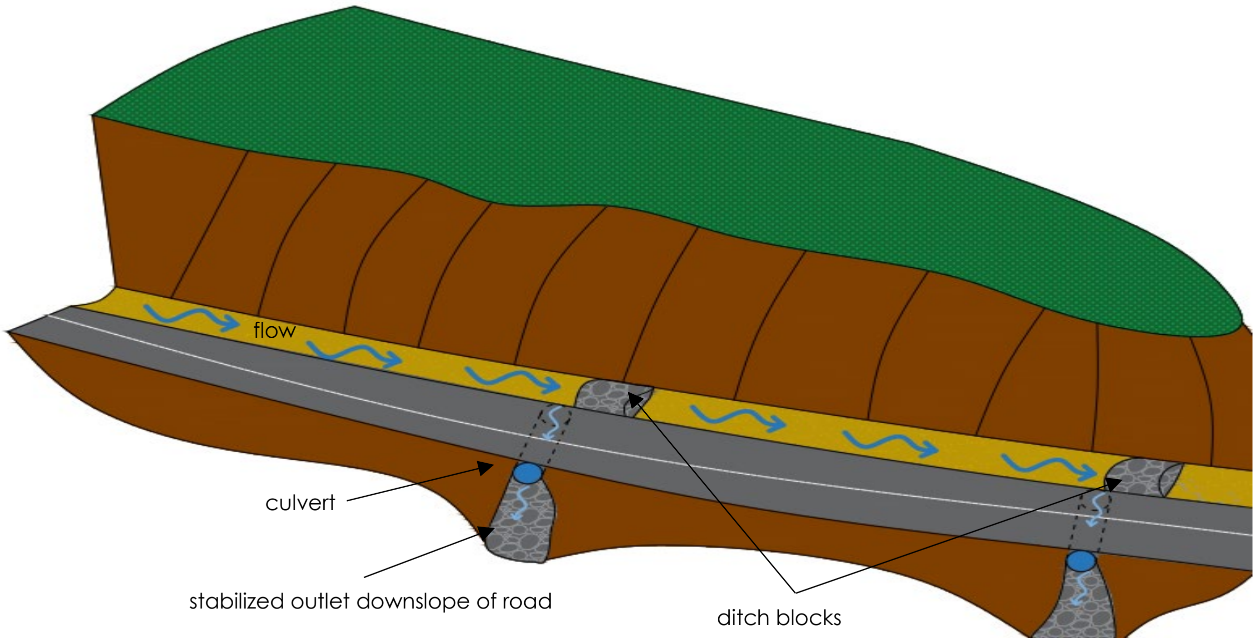
- Monitoring should consist of inspecting the geogrids (or fabric) for signs of breakage or tearing from erosion or possibly from excessive tensile stresses.
- Signs of uncontrolled seepages, such as weeping or wet spots in the structure should be noted.
- Common modes of failure:
  - Inadequate primary reinforcement from improper vertical spacing or lift thickness, insufficient allowable unit tensile resistance in the selected fabric or geotextile, or too short an embedment length.
  - Failure to properly consider seepage conditions and install adequate drainage measures.
  - Inadequate attention to construction procedures and details.

Ditch Blocks

Runoff Control BMP

BMP # 8

Temporary and Permanent BMP



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Description and Purpose:

- A ditch block is a barrier placed across a natural or man-made channel or drainage ditch to divert flows, typically into a cross-drain.
- Minimizes long runs of surface flows in the ditch, reduces flow velocities and allows localized runoff to stay in natural drainage areas.

Applications:

- Ditch blocks are generally installed in roadside ditches, near a natural drainage channel to divert runoff from the high-side of the road into a natural drainage area on the low-side of the road.

Construction:

- Ditch blocks should at a minimum be constructed with erosion-resistant material, such as gravel or crushed rock. A concrete precast structure can be used for more long-standing measures.
- If constructing a ditch block with finer textured soils, it should be armoured with riprap on both sides of the structure and if possible vegetated to minimize erosion.
- The crest of the structure should be approximately 0.3 m lower than the adjacent road surface.

- The face of the ditch block should be sloped a minimum of 7:1 and not more than 10:1 depending on space available (AB Transportation).
- The ditch block should be large enough to withstand anticipated flows (Q-10).

Considerations:

- Do not install ditch blocks where ditches converge.
- Keep surface runoff within its natural drainage.
- The ditch block height and the capacity of the cross-drain need to coincide to ensure that runoff is not forced onto the roadway or flows do not overtop the structure during a high-water event.
- If constructing the ditch block using soils, the structure should be vegetated during road re-vegetation activities; if using crushed rock, vegetation is not required.
- Erosion may result when vegetation does not establish or when a ditch block is overwhelmed during storm events.
- Barrier protection may be required.

Inspection and Maintenance:

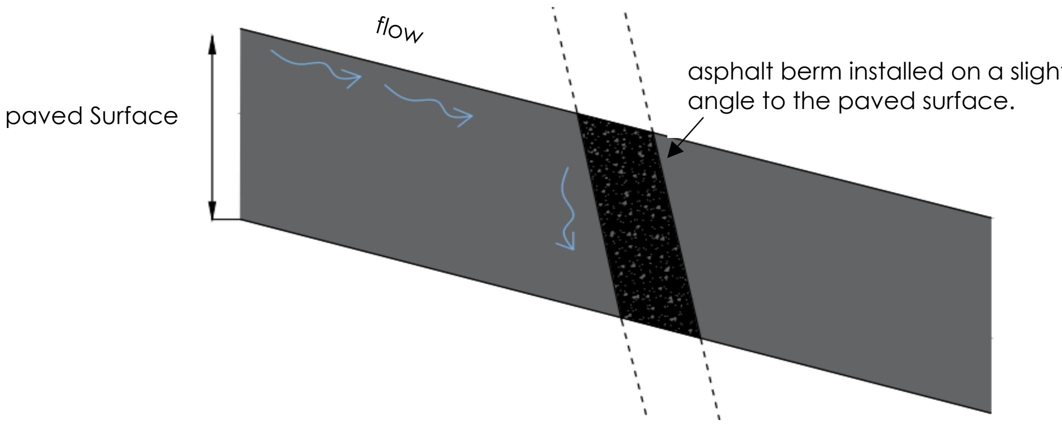
- Inspect ditch blocks after each major storm event (Q-10) or more regularly if being used as a temporary measure.
- Repair damage immediately.

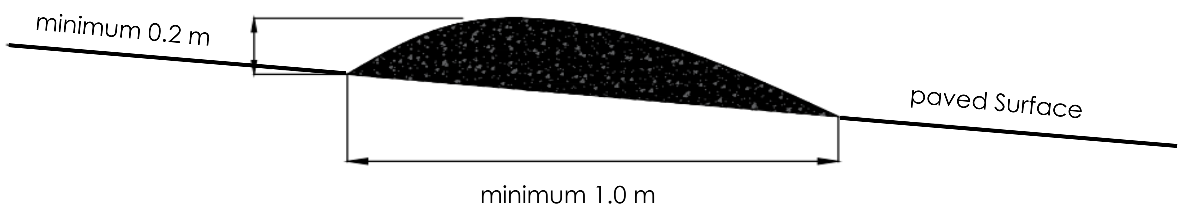
Asphalt Berms

Runoff Control BMP

BMP # 9

Temporary BMP





Asphalt berm with sediment barrier behind

Asphalt berm directing flow toward sump

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Asphalt Berms

Runoff Control BMP

BMP # 9

Temporary BMP

Description and Purpose:

- A temporary measure made of impermeable material mounded to intercept surface runoff, typically on asphalt and paved surfaces.
- Used to direct runoff off the road surface and into a sediment control measure.
- Designed for high-traffic areas to withstand being driven over.

Applications:

- Intercept sediment-laden runoff from a disturbed area within the construction site and direct runoff into a sediment control BMP.
- Intercept off-site stormwater runoff and divert away from the construction site.
- Segment drainage areas, within a construction site, into smaller more manageable areas (~ 0.5 ha).

Construction:

- Cross sectional dimension should be approximately 0.2 m high by 1.0 m wide, gently sloped and compacted (MOTI 2020).
- Berm slope angle should be sufficiently flat so vehicles may pass over it with ease (~6:1).
- Berms should be installed on roads sloped less than a 10% grade.
- Install berm on a slight angle, not perpendicular to the road. Alternatively, can construct the berm in a "V" configuration with the apex pointing upgrade. Both options should be able to convey runoff into a sediment control BMP, suitable for concentrated flows (Maryland 2011).

Considerations:

- Discharge from concentrated runoff must be directed to an undisturbed, non-erosive area, or into a sediment control BMP before releasing into the receiving environment.
- More costly than sandbags or wattles, but also more durable.
- May not be suitable for all regions of BC, as the berm can easily be damaged by graders or snow removal equipment. Consider alternate runoff management if the berm will be left over winter or ensure it is clearly marked. If the berm is not installed on a worksite entrance, the area behind the berm could be back filled and compacted with clean gravel, drain rock or stone.
- Remove asphalt berm while equipment is still on-site and only after the establishment of permanent ESC measures (i.e., vegetation).

Inspection and Maintenance:

- Periodic inspection should be conducted, and repair damaged asphalt as needed.
- Remove accumulated debris behind the berm regularly to maintain positive drainage.

Topsoiling Erosion Control BMP	BMP # 10 Permanent BMP

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Refer to BC Ministry of Transportation & Infrastructure's document titled, *Standard Specifications for Highway Construction* – [Section 751 – Topsoil and Landscape Grading] for more details

Ministry of Transportation and Infrastructure

Topsoiling

Erosion Control BMP

BMP # 10

Permanent BMP

Description and Purpose:

- Covering exposed mineral soil with soils of high organic content to establish vegetation more readily, which should minimize raindrop erosion once vegetation is established.
- Provides a medium for growing.

Applications:

- This BMP is a permanent measure.
- May be used to provide a bedding medium for seed germination and a cover to exposed soil that is not suitable to promote vegetative growth.
- Can be used on slopes with a maximum gradient of 2H:1V.
- Normally topsoil is placed first; then seeding, mulching, hydroseeding, or hydro mulching operations can occur; and finally, installation of rolled erosion control products (RECP) or planting of trees/shrubs will finish the job.

Installation:

- Prepare the ground to final grade by removing large rocks or other materials.
- Apply topsoil with dozer or light tracked equipment to design thickness.
- Track pack slope to provide roughness of topsoil and minimize erosion, being diligent not to over-compact the topsoil.
- Do not topsoil slopes greater than 2H:1V.

Considerations:

- Perform pre- and post-disturbance surveys of the soils stripping area to ensure sufficient topsoil is placed back on the subgrade following construction activities.
- Topsoil should be free of invasive plants and noxious weeds which may inhibit re-vegetation of desirable plants species (i.e., native plants).
- Topsoil shall be virtually free from subsoil, wood including woody plant parts, toxic materials, stones over 30 mm and foreign objects
- Water should be applied regularly during periods of hot dry weather to minimize wind erosion.
    - Hydroseeding or hydro mulching topsoil will minimize wind erosion of topsoil.

Inspection and Maintenance:

- Areas damaged by washout or rilling should be regraded and re-topsoiled immediately.

Seeding & Hydro Seeding | BMP # 11

Erosion Control BMP | **Permanent BMP**

Native seed mix along streambanks

Application of hydroseed

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Refer to BC Ministry of Transportation & Infrastructure's document titled, *Standard Specifications for Highway Construction* – Section 757 – Revegetation Seeding for more details.

Description and Purpose:

Seeding

- Planting seed after a layer of organic topsoil has been spread is optimal.
- Provides erosion protection through a shallow root structure from seed germination and plant growth.

Hydroseeding

- Spraying a slurry to a slope or channel surface to provide a layer of seed and growing medium.
- The slurry consists of seed, fertilizer, mulch, tackifiers, and water which are mixed in a tank.
- Hydroseeding enables quick re-vegetation of very steep or rocky/gravelly slopes where re-vegetation by any other method would be very difficult or unsafe.
- When sprayed on the soil, the slurry forms a continuous blanket with seeds, and protects the soil from wind and water erosion and raindrop impact by adhering them in place.
- The slurry conserves moisture, reduces soil moisture evaporation, and decreases soil surface crusting due to evaporation or drying of soil.

Applications:

Seeding

- Revegetation seeding with rapidly growing plants may be applied to exposed soil areas which will be exposed for more than 30 days.
- Revegetation seeding should be applied to exposed soil areas that have been graded to final contours as soon as possible.

Seeding & Hydro Seeding

Erosion Control BMP

BMP # 11

Permanent BMP

- Revegetation seeding may be applied to landscape corridors, slopes, and channels via broadcasting or hydraulically with mulch and tackifier.
- Erosion control can be enhanced with a protective layer of mulches or rolled erosion control products (RECPs) to improve the growth environment and provide protection for the soils.

Hydroseeding

- Slurry is held in suspension through consistent agitation and is sprayed onto disturbed areas using high pressure pumps.
- Can be used for spray-on seeding, covering large areas efficiently after placement of topsoil.
- Can be used to provide temporary or permanent erosion control before vegetation is established.
- May be used to provide soil stabilization for disturbed areas.
- Can also be used with higher efficiency and larger area coverage with advantages over conventional methods (broadcast seeders, drill seeders).
- Can be used in areas where little topsoil is available.

Installation:

- Prepare soil surface by removing large rocks or other deleterious materials.
- Apply topsoil if available.
- Spray on hydroseed as per supplier's recommendations.
- Apply seed as per the **BC MOTI Standard Specifications Section 757**
- Fertilizer should be applied after seeding, only to areas outside of the riparian zone.

Considerations:

- Selection of an appropriate seed mix depends on soil conditions, climate conditions, topography, land use, and regional location.
- Refer to the **BC MOTI Standard Specifications Section 757** for updated regional seed mixtures.
- Planting via hydro-seeding and mulching techniques should be considered for slopes steeper than 3H:1V where seedbed preparation may be difficult.
- Fertilizer use should be carefully controlled as this may increase nutrient loading to receiving environments (i.e., water bodies) if the runoff is not controlled properly.
- Seeding should occur during periods when germination of plants will have enough time to establish before the end of the growing season or periods of drought or frost.
- Mulch is required when broadcast seeding or if seeding is applied outside of the growing season.
- Consult a local seed supplier, Professional Agrologist, or Ministry Representative for specific needs of the local growth environment and specific planting design.
- Seed selection should be made in accordance with BC MOTI regionally approved seed mixes.

Seeding & Hydro Seeding **Erosion Control BMP**	BMP # 11 **Permanent BMP**

Inspection and Maintenance:

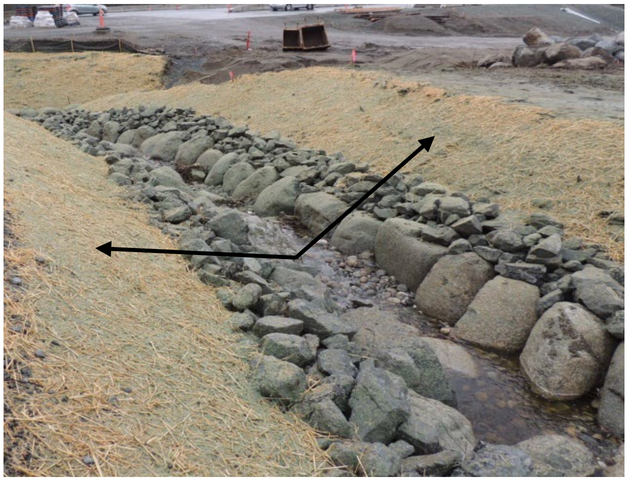
- Inspection frequency should be in accordance with the site-specific Erosion and Sediment control Plan (ESCP).
- Bare or damaged areas may need to be reseeded following initial application.
- Freshly seeded areas should be inspected frequently to ensure successful growth. Reseeding some areas may be required.

Mulching

Erosion and Sediment Control BMP

BMP # 12

Permanent BMP



Straw Mulch

Hydromulch after application

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Refer to BC Ministry of Transportation & Infrastructure's document titled, *Standard Specifications for Highway Construction* –Section 754 – Planting of Trees, Shrubs and Ground Covers and Section 757 – Revegetation Seeding for more details.

Description and Purpose:

Mulching

- Application of organic material or other biodegradable substances as a protection layer to the soil surface to: (a) minimize raindrop/runoff erosion and, (b) conserve a desirable soil moisture regime for plant growth and promote seed germination and plant growth.
- Mulch conserves soil moisture and reduces runoff velocities and surface erosion, as well as controls weeds, helps to establish plant cover, and protects seeds from predators.

Hydromulching

- Spraying a slurry to a slope or channel surface provides a layer of growing medium.
- The slurry consists of cellulose, wood fibre, or a bonded fibre-matrix that conserves moisture, reduces soil moisture evaporation, and decreases soil surface crusting due to evaporation or drying of soil.

Applications:

- Permanent measure.
- Used as an organic medium for seeds where topsoil is not readily available or sufficient.
- May be used with or without seeding in areas that are rough graded or final graded.
- Usually applied in conjunction with an approved seed mix to promote plant growth.

- Various organic mulches include straw, wood fibres, peat moss, wood chips, compost, or chemical mulches that are mixed with water.
- Chemical mulches are used to bind hydro-seeding or hydro-mulching applications together.
- Hydromulching can be used in areas where little topsoil is available.

Installation:

- Prepare soil surface by removing large debris and roughening up the soils so they are loosely compacted.
- Apply seed, and if necessary, topsoil to nutrient-deficient soils.
- Apply mulch as per supplier's or qualified professional's recommendations; mulch application should be stated in the ESCP, EMP, or design drawings for specific instructions.
- Spray on hydromulch as per the supplier's recommendations.
- Certain mulches may require additional anchoring to minimize loss of mulch due to wind or water erosion.

Considerations:

Types of mulches:

<u>Manual/dry applied erosion control products</u>

- Straw
  - Refers to stalks or stems of small grain (should be inspected by AQP to ensure it is free of seeds, weeds, and invasive plants).
  - Loose straw should be anchored as it is very susceptible to movement by wind and water.
  - When properly secured to surface, straw creates a suitable micro-climate for promoting grass cover; however, it may be a fire hazard in dry conditions.
  - Do not use hay bales as they are more likely to contain invasive species.
- Bark Mulch
  - Bark mulch shall be sized 25 mm or less, from Douglas Fir or Hemlock bark chips and fines, or a combination of both types, and of the quality used for decorative landscape mulching purposes.
  - It should be free of chunks and sticks, dark brown in colour and free of all soil, stones, roots, or other extraneous matter.

<u>Hydraulically applied erosion control products</u>

- Wood Fibre
  - Composed of whole wood chips and provides quick and uniform method and medium for re-vegetating large areas quickly and economically.
  - Longer fibre length will last longer and has better wet-dry characteristics than cellulose.
  - Provides limited erosion control even when sprayed on with tackifiers.

- Bonded Fibre Matrices (BFM)
    - Slurry composed of either cellulose mulch, wood fibre mulch, or a combination of the two.
    - Mulches are bound together using a chemical bond and/or a mechanical bond.
        - Chemical bond must be limited to periods with no rain during curing period (24-hours).
        - Mechanically bonded BFMs have no curing time and are effective immediately.
    - All fibres and binding agents are premixed by the manufacturer, certifying quality assurance.
    - Well-suited for sites where worker safety and minimal ground disturbance are desired.

Inspection and Maintenance:

- Inspect mulched areas regularly (i.e., once per year or after significant storm events) until the site has stabilized.
- Areas damaged by washout or rilling should be re-graded and re-covered with mulch.
- Additional stormwater control measures should be considered for areas of severe rilling erosion.
- Small bare spots may need to be re-seeded and re-covered with mulch.

Sodding

Erosion Control BMP

BMP # 13

Permanent BMP

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Description and Purpose:

- Use of grass sod to cover and stabilize disturbed areas of bare soil.
- Rapidly establishes vegetative cover in environmentally sensitive areas where hydroseeding and mulching may not be effective.
- Sod may be from a nursery or sourced from the field; sod is usually composed of one or more species of grasses but may contain invasive plants or weeds as well.

Applications:

- Permanent measure, requiring regular irrigation after placement.
- May be used to protect soil surface from water and wind erosion where adequate topsoil and fertilizer can be provided.
- Best used for areas that require immediate protection, or at locations where aesthetic appearance is a priority, or in areas that require a vegetative buffer.

Installation:

Refer to BC Ministry of Transportation & Infrastructure document, titled, *Standard Specifications for Highway Construction*, Section 754 - Planting of Trees, Shrubs and Ground Covers. A summary is provided below:

- Protect sod during transportation to prevent drying out so it arrives at the site in a fresh and healthy condition. Sod should be laid withing 24 hours after delivery unless proper storage is arranged.
- Remove any invasive plants, large debris from surface, apply design thickness of topsoil and fertilizer (if required). Fertilizer will be applied at the rates specified in the Special Provisions and worked well into the topsoil prior to laying the sod.
- Lay sod strips on prepared surface with long edge parallel to the top of slope with joints offset.
- Butt-joint ends of adjacent sod strips tightly together, do not overlap any pieces.
- Roll or tamp each sod strip to ensure continuous contact between topsoil and underside of sod.
- When working on a slope secure sod strips with stakes. See SS754.38 for further instructions.
- Rows of sod strips should have staggered joints.

Considerations:

- Sod should be nursery grown, true to type and conform to the British Columbia Standard for Turfgrass Sod, and the general requirements of the Canadian Nursery Stock Standard.
- Sod must not be placed on frozen ground or during hot and dry periods; topsoil should be cool and wetted by irrigation prior to placing sod strips.

Sodding
Erosion Control BMP

BMP # 13
Permanent BMP

- Freshly installed sod should be irrigated to moisten the topsoil to minimum depth of 0.1 m.
- Successful installation requires the use of freshly cut, healthy sod.
- Unless otherwise indicated, sodded areas shall be evenly watered within 12 hours of installation, and with enough water to saturate the grass and the upper portion of the topsoil.

Inspection and Maintenance:

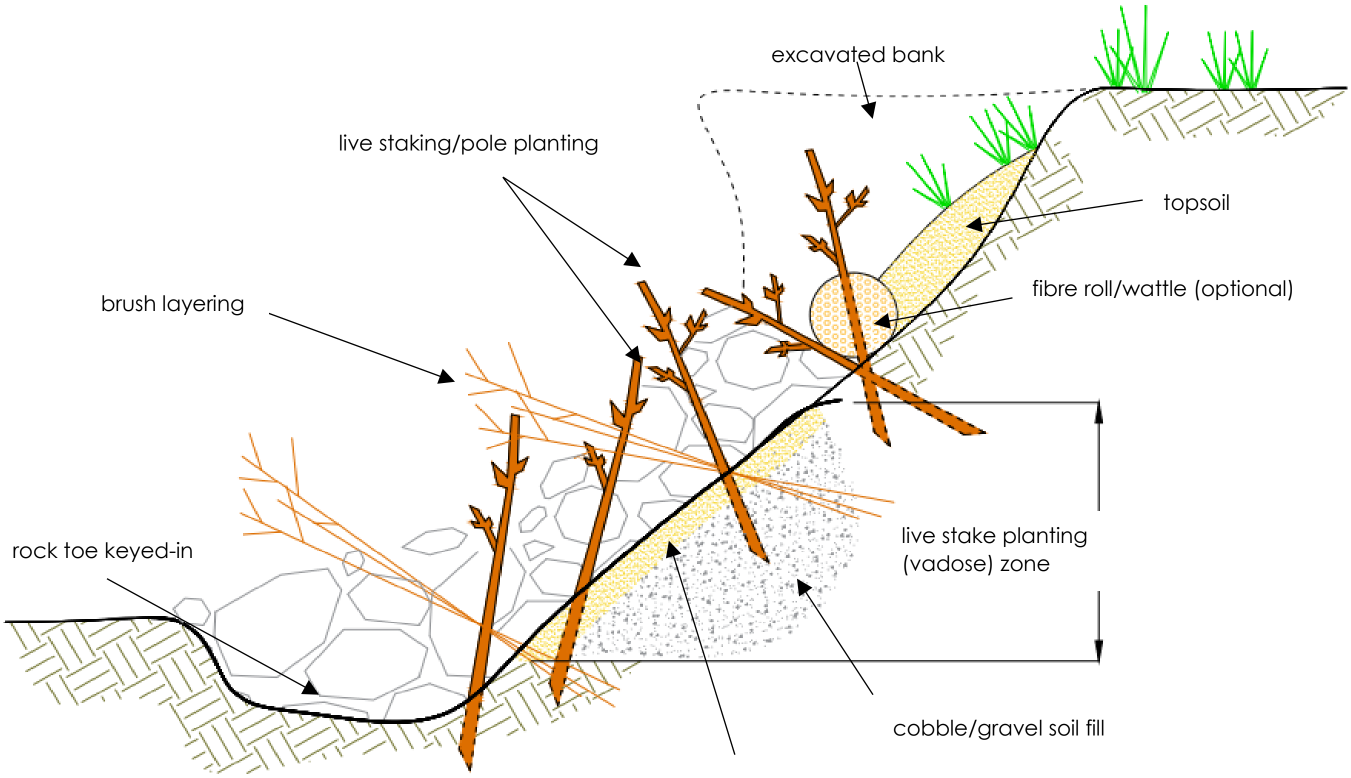
- Inspection frequency should be in accordance with the *Standard Specifications for Highway Construction* & the project specific Erosional and Sediment Control Plan (ESCP).
- Areas damaged by washout or rilling should be regraded and resodded immediately.
- Small bare spots may need to be resodded.
- Regular watering should continue as required for plant health until final acceptance of the work.
- Fertility levels in planted and grassed areas will be maintained in accordance with the requirements of the plant material. Excess grass clippings will be removed immediately after mowing and trimming.

Vegetated Riprap Armouring

Runoff and Erosion Control BMP

BMP # 14

Permanent BMP



Live stakes embedded in riprap

Topsoil pods with seeds embedded in riprap

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

Vegetated Riprap Armouring

Runoff and Erosion Control BMP

BMP # 14

Permanent BMP

Description and Purpose:

- Vegetative riprap armouring combines rock revetment techniques with vegetative techniques, such as brush layering and live staking.
- Vegetated riprap armouring is primarily used where the stream bank requires continuous protection.
- The riprap will resist the hydraulic forces, while roots and branches increase geotechnical stability and prevent soil loss from behind the structures (piping).
- The roots, stems, and shoots will anchor the rocks and resist movement by ice and debris forces.

Applications:

- Vegetated riprap is appropriate where infrastructure is at risk, and where bank protection measures have been rejected or deemed inappropriate.
- These techniques are also considered mitigation for some of the impacts caused by riprap.
- Incorporating plants & shrubs may be beneficial as they will cast shade and subsequently protect fish habitat.

Construction:

- There are two methods of constructing brush layered riprap; one involves building up a slope, and the other works with a pre-graded slope – do not use non-woven geotextile.

Method 1 (building up a slope):

- Excavate a key at the toe of slope and start placing rocks in the key. Pack soil behind these rocks, with filter gravel in between the soil and rocks.
- Continue installing riprap 0.9 to 1.2 m up the bank.
- Place a layer of live fascine cuttings on top of the soil, with the butt ends extending into the bank, and the tips of the branches sticking out 0.03 to 0.06 m.
- Place the next layer of stones on top of the initial rocks, but graded slightly back, and repeat the soil and brush layering process.
- When finished, trim the ends of the live fascine branches back to 0.03 m.
- Do not cut shorter than 0.03 m, as the plant will have difficulty sprouting.

Method 2 (pre-graded slope):

- Lay the bank slope back to the desired finished grade and excavate a key at the toe of the pre-graded slope.
- Place the largest rocks in the keyway, and fill in behind with filter gravel and soil, continuing to install riprap 0.9 to 1.2 m up the bank.
- Place the bucket of an excavator just above the layer of rocks at a 45° angle and pull the bucket down to the elevation at the bottom of the excavated key; this will provide a slot in the bank into which live fascine poles can be placed.

- Place live fascine poles (approx.18 poles per linear metre), ensuring that the butt ends face down.
- Place the next layer of rock on top of the branches, flush with the slope.
- Repeat the process, beginning again with pulling back a scoop of soil.

Considerations:

- Vegetation should be integrated into the design. Install topsoil pods with seed and live fascine poles to increase succession.
- Ensure filter material is installed as designed to reduce failures.
- Ensure stones are properly sized to reduce likelihood of being carried away by strong currents.
- Use irrigation for vegetation if planted in a non-dormant state, or in drought conditions.
- Two further considerations for vegetated riprap armouring include filter material and rock size, described below.

Filter Material:

- A filter material (woven geotextile fabric or graded filter gravel) is typically used to prevent piping of fine soils from below the riprap, if self-launching stone is not used.
- Filter gravel is the preferred filter media for vegetated riprap.
- Non-woven geotextile fabrics are not recommended for use in vegetated riprap, because roots have difficulty penetrating the fabric.

Rock Size:

- There are two options for rocks: self-launching/self-filtering rock or standard riprap.
- The advantage of self-launching/self-filtering rock is that the revetment will build its own toe, by self-launching, in any scour hole that forms.
- Different sizes of rock act as a filter medium, so no geotextile fabric or filter gravel is needed. This decreases cost and makes installation less labour-intensive.
- Self-launching stone is dependent on a source of graded rock, which is not always available.

Inspection and Maintenance:

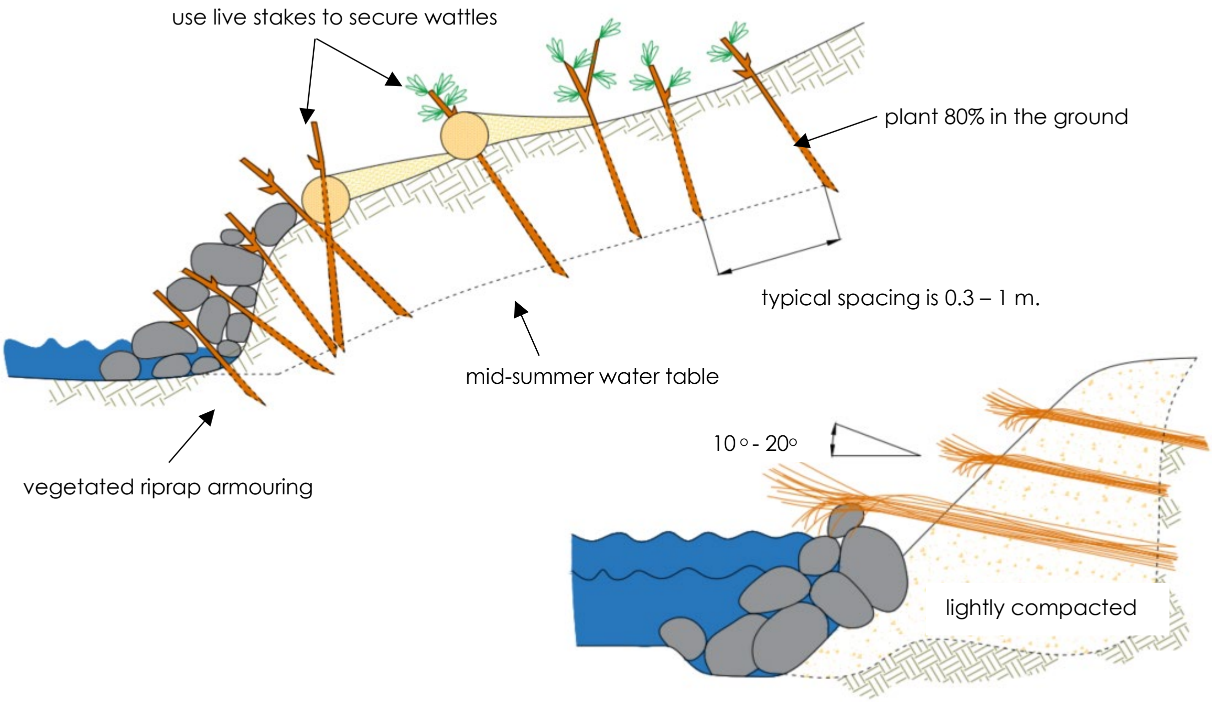
- Riprap should be visually inspected as frequently as outlined in the ESCP and with a focus on potential weak points, such as transitions between undisturbed areas.
- Soil above and behind the riprap may collapse or sink, or loss of rock may be observed.
- Inspect riprap during low flows (if possible), to ensure continued stability of the structure.
- Treat bank or replace rock, as necessary.

Live Staking and Brush Layering

Erosion Control BMP

BMP # 15

Permanent BMP



Live Staking

Brush Layering

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Description and Purpose:

- Consists of installing woody plants (trees and shrubs) to develop a root matrix within the soil, increasing subsurface soil strength and stabilizing slopes.
- Reduces erosion potential on slopes and channel banks.

Live Staking and Brush Layering

Erosion Control BMP

BMP # 15

Permanent BMP

Applications:

- Permanent measure.
- May be used on slopes stable enough to support vegetation; however, there is a low success rate for slopes greater than 1H:1V.
- May be used on slopes and channel banks with adequate sunlight, moisture, and wind protection to support vegetation.
- May be used as bio-engineering stabilization in cases where shallow slope instability has been documented, or where soil movement on eroded slopes and gullies has been identified.

Construction:

- Use on cut or fill slopes or in ditches and channels.
- Live cut stakes are inserted into the ground.
- Individual dormant stakes should be cut to a minimum length of 0.5 m using pruning shears and cut at a 45° angle, 5 cm below a leaf bud.
    - All branches should be trimmed to within 5 cm of the main stem.
- Install live stakes in a grid a minimum of 1 m by 1 (4/m^2), where 80% of the stem is underground.
- Make a pilot hole a minimum of 0.3 m in depth using an iron bar, rebar, drill, or other tool.
- Insert the live stake into the pilot hole and lightly tamp soil around live stake, leaving a minimum of two leaf buds above grade, and ensuring 80% of the stake is in the soil. If the top of the stake is damaged, cut off the end to a clean, shear edge.
- For brush layering, place a layer of willow cuttings on top of the soil, with the butt ends extending into the bank, and the tips of the branches sticking out 0.03 to 0.06 m.
- Criss-cross 15 to 25 branches per linear metre of random-aged stems when creating a brush layer.

Considerations:

- Successful installation requires the use of freshly cut branches.
    - Storage time of cut branches on-site prior to installation should be as short as possible (soak stakes in water for a minimum of 10 hours after cutting and prior to planting).
- Successful growth is dependant on soil moisture and rainfall conditions.

Inspection and Maintenance:

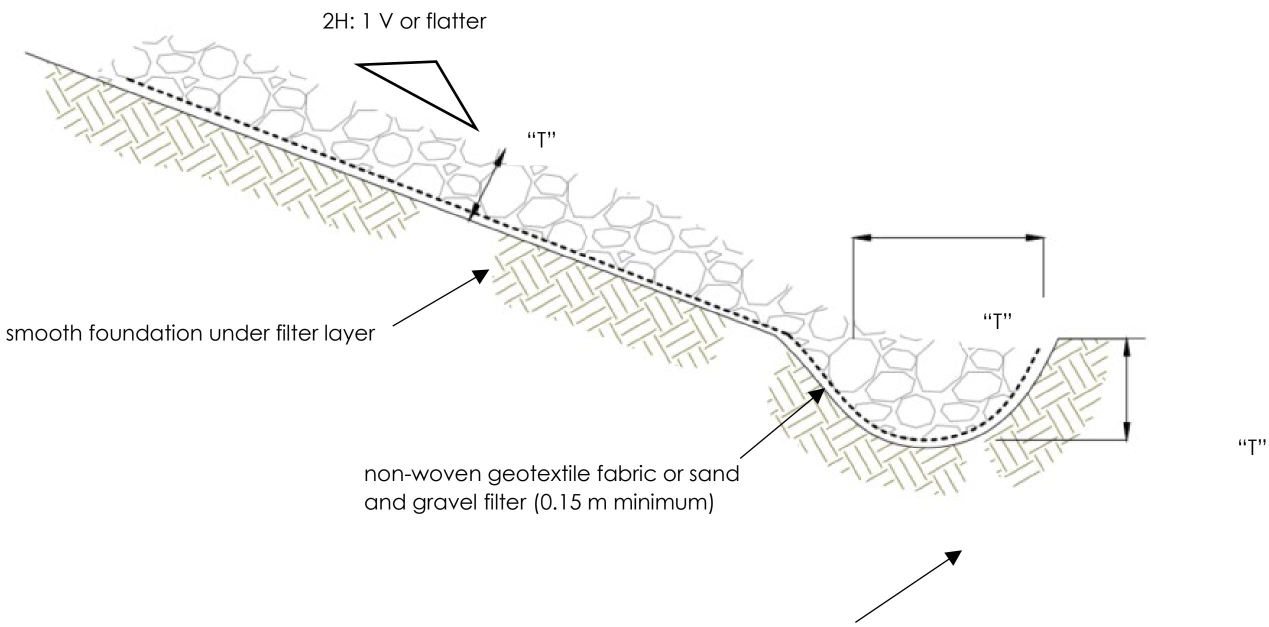
- Inspection frequency should be in accordance with the Erosion and Sediment Control Plan.
- Additional stormwater control measures should be considered for severely eroded areas damaged by runoff.

Riprap or Rock Cover

Erosion Control BMP

BMP # 16

Permanent BMP



Riprap cover under bridge

Rock cover on unstable soils

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Riprap or Rock Cover

Erosion Control BMP

BMP # 16

Permanent BMP

Description and Purpose:

- Large, loosely placed cobbles or ballast rock keyed-in along slopes to protect underlying soil from erosion.

Applications:

- Permanent measure for slope and channel protection.
- Often used to hold back slopes with ground water seepage that generally do not exceed 2H:1V
- Also used to protect stream banks from erosion around culverts or bridge structures.
- Other forms of soft armouring (Rolled Erosion Control Product, seeding) can be used to promote vegetation and protect soils at upper portion of slopes above the riprap.
- Should be used in conjunction with a non-woven geotextile underlay or a sand and gravel layer.

Construction:

- Shape the slope to specific design elevation.
- Anchor non-woven geotextile filter cloth on prepared slope before placing riprap.
- Filter layer can also consist of well-graded granular material, depending on seepage conditions; refer to a design engineer for more details regarding the filter layer.
- Riprap should consist of a graded mixture of sound, durable rock, as determined by an engineer.

Considerations:

- Riprap should be placed in a uniform thickness across the slope.
- Blasted rock is preferable (if available); test for acid rock drainage/metal leaching if unsure.
- Riprap layer should be 1.5 to 2 times the thickness of the largest rocks used and 1.5 to 3 times the thickness of the D_{50} material.
- Riprap should be sized according to engineering recommendations.

Inspection and Maintenance:

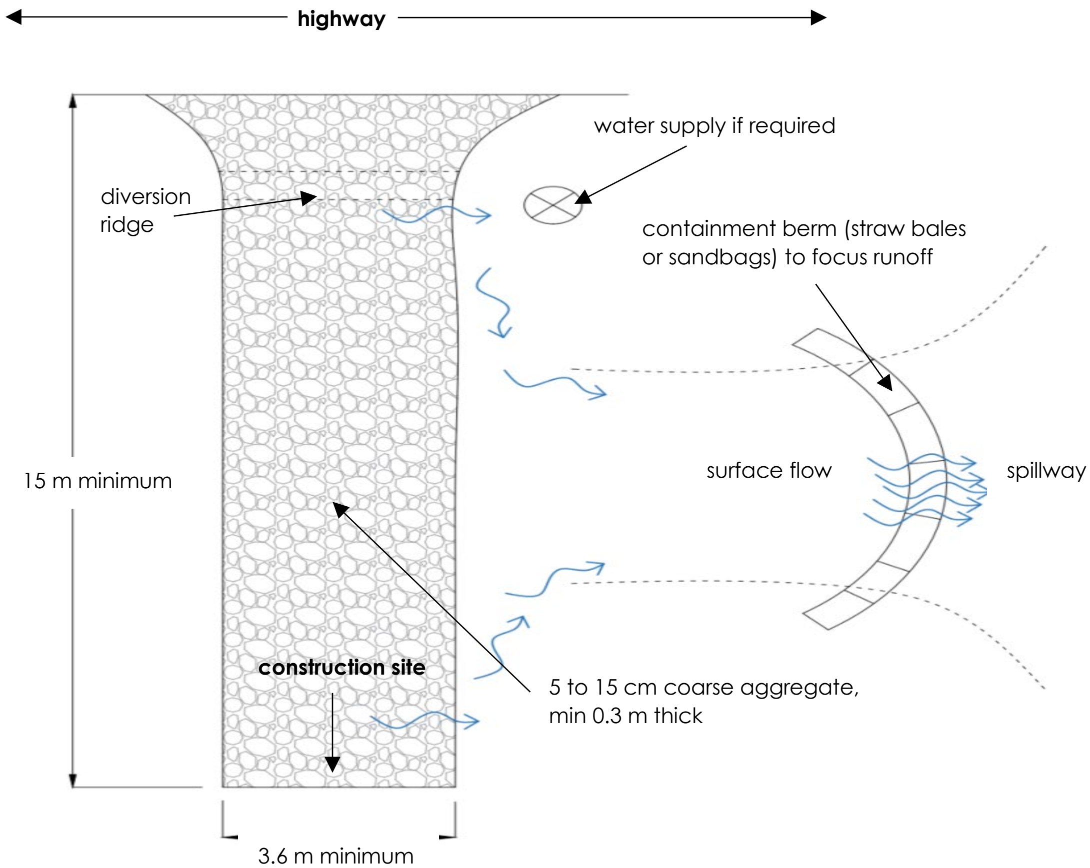
- Inspection frequency should be in accordance with the ESC Plans.
- Periodic inspections to check for erosion of protected material or movement of riprap is recommended.

Stabilized Entrance

Erosion and Sediment Control BMP

BMP # 17

Temporary BMP



Rock stabilized entrance

Synthetic mat stabilized entrance

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Stabilized Entrance

Erosion and Sediment Control BMP

BMP # 17

Temporary BMP

Description and Purpose:

- A gravel or synthetic pad located at site access points (entrances), used to reduce the amount of sediment carried off construction sites by vehicles.
- Collects sediment from vehicle washing and retains sediment on the construction site.
- May include water supply to wash off excess soil from vehicles prior to exiting the site.

Applications:

- Temporary measure.
- For use anywhere vehicles enter or exit a construction site onto a public right-of-way.

Construction:

- Install gravel pad at planned entrances to work site.
    - Gravel pad should be minimum 15 m long and 3.6 m wide, or of sufficient length and width to accommodate the biggest anticipated vehicle.
    - The thickness of the gravel pad should be a minimum of 0.3 m (preferred for highway projects) and should comprise 5 to 15 cm diameter coarse aggregate placed on top of woven geotextile filter fabric.
- Install temporary sediment control measures (such as straw bale barriers or sediment fence) downslope to collect washed off sediment from the gravel pad.

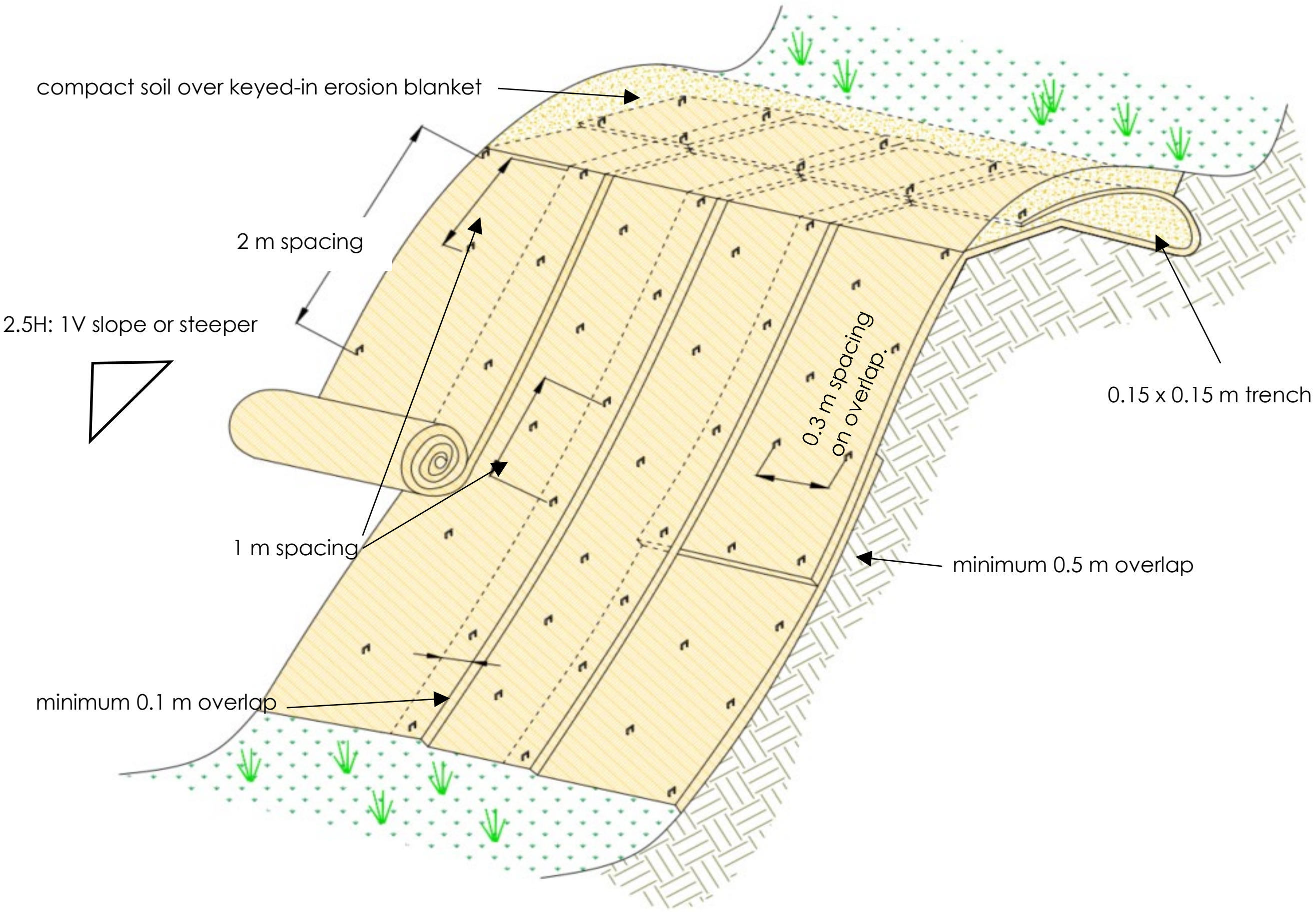
Considerations:

- A stabilized entrance should be constructed at all main vehicle access points to the construction site.
- Avoid entrances located with steep grades or at curves on public roads.
- Woven geotextile filter fabric should be used as underlay below the gravel pad to provide strength to the structure.
- Install a diversion ridge (water bar) adjacent to the road if the gravel pad is steeper than 2% and sloped toward a public roadway.
- If washing vehicles on the stabilized entrance, all drainage should be directed into a sediment basin or trap adjacent to the pad.

Inspection and Maintenance:

- Inspection frequency should be in accordance with the Erosion and Sediment Control Plans.
- Maintain the entrance in a condition that will not track sediment onto a public right-of-way.
- Granular material should be regraded when required.
- Inspect and clean out downslope sediment control measures regularly including after a heavy rain event. Material accidentally deposited onto public roads should be cleaned up immediately.

# Rolled Erosion Control Product	# BMP # 18
Erosion Control BMP	**Temporary or Permanent**



RECP installed on a slope

RECP installed on a stream bank

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Rolled Erosion Control Product

Erosion Control BMP

BMP # 18

Temporary or Permanent

Description and Purpose:

- Biodegradable or synthetic covering used for temporary or permanent protection of soils.
- Rolled Erosion Control Product (RECP) may be manufactured of organic material, synthetic material, or as a composite of organic and synthetic materials.
- Protects disturbed soils and seed from raindrop impact, runoff, and wind erosion, increases water infiltration into soil, retains soil moisture, decreases evaporation loss, stabilizes temperatures to promote seed germination, and protects seeds from wildlife predation.

Applications:

- Temporary or permanent measure on slopes 3H:1V or steeper where erosion potential is high.
- May be used on slopes where vegetation is likely to be slow to develop.
- May also be used to protect disturbed exposed soils in ditches and non-fish bearing channels.

Construction:

- RECP should be installed in accordance with the manufacturer's directions:
    - Prepare surface and place seed and topsoil (if required).
    - The surface should be smooth and free of large rocks and debris.
    - The blanket should be anchored at the top of slope in a minimum 0.15 m by 0.15 m trench for the entire width of the blanket and rolled downslope.
- The upslope portion of the blanket should overlap the downslope portion (shingle style), at least 0.5 m with staple anchors placed a maximum 0.3 m apart on the overlap.
- Adjacent rolls of blanket should overlap a minimum of 0.1 m side-to-side and 0.5 m end-to-end.
- Anchors should be placed along the central portion of blanket spaced at 4/m^2 minimum (0.5 m spacing) for slopes steeper than 2H:1V and 1/m^2 (1 m spacing) for slopes flatter than 2H:1V.
- Anchors along splices between adjacent rolls should be placed 0.9 m apart.

Considerations:

- Ensure the blanket is in close contact with the soil by properly grading soil and removing rocks or deleterious materials prior to placing the blanket.
- The blanket should be anchored by using wire staples, metal geotextile stake pins, or triangular wooden stakes, of sufficient length to hold the mat in place.
    - Anchors should be between 0.15 to 0.2 m in length; use longer anchors for looser soils.
- Blankets should be placed longitudinal to the direction of flow, with fabric not stretched but maintaining contact with underlying soil.
- Store product out of direct sunlight until ready to install.

Rolled Erosion Control Product

Erosion Control BMP

BMP # 18

Temporary or Permanent

Inspection and Maintenance:

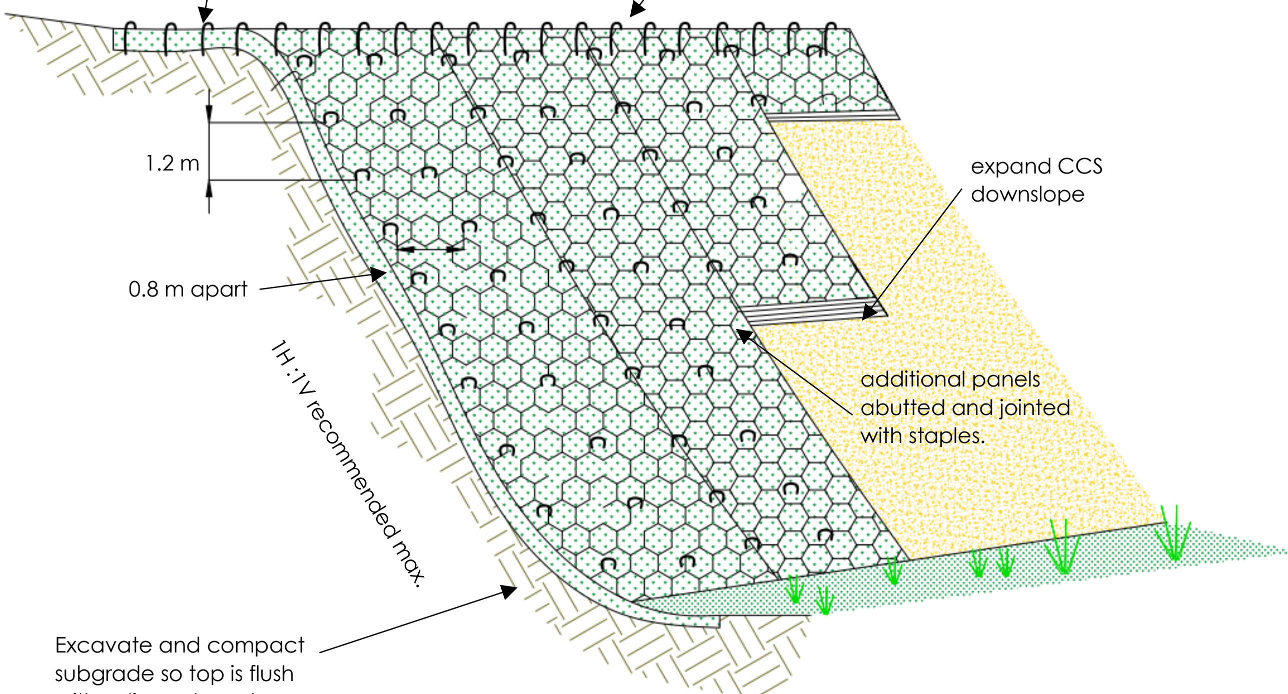
- Inspection and maintenance should continue until dense vegetation is established, especially in the spring and following a heavy rain event.
- In areas with low vegetation density, that section of RECP should be removed, the area reseeded and fertilized, and a new rolled erosion control blanket installed.
- Any damaged or poorly performing areas should be repaired/remediated immediately.

Cellular Confinement System

Erosion Control BMP

BMP # 19

Permanent BMP



CCS anchored at top of slope

CCS infilled with gravel material

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Cellular Confinement System

Erosion Control BMP

BMP # 19

Permanent BMP

Description and Purpose:

- Three-dimensional plastic matting with open cells to be filled with topsoil or aggregate, used to stabilize cut or fill slopes.
- Cells confine infilled topsoil or aggregate and protect rooting zone while allowing surface drainage.

Applications:

- Permanent measure used with granular infill on cut or fill slopes up to 1H:1V.
- May be used with granular infill on slopes and in ditches where flow velocities are 3 m/s or less.
- Can be used as a flexible channel lining in temporary low-water stream crossings (stream ford).
- Matting is light, expandable, and easy to transport and place.
- Use of native fill materials reduces costs; local granular fill is preferred.

Construction:

- Slope should be graded to design elevations and rocks or other debris should be removed from the matting locations.
- Matting should be keyed in as deep as the matting is thick, extending 0.6 to 1.2 m beyond the crest of slope. Matting should be installed so that the top of the matting is flush with surrounding soil and anchored at every other cell with a "J" pin.
- When the blanket roll is not long enough to cover the entire length of the slope, the downslope section of matting should be butt-jointed to the upslope section and anchored securely.
- Anchors should be placed at a minimum of 1.2 m intervals down the slope and 0.8 m across the slope; use additional pins to ensure an intimate contact with the soils or on steeper slopes.
- Backfilling should start at the crest of the slope and proceed downslope:
  - For topsoil, overfill cells approximately 25 to 50 mm and lightly compact so that the top of the topsoil is flush with the matting.
  - For granular fill, overfill cells approximately 25 mm and tamp compact so that the top of the fill is flush with the matting.
- Seed should be applied after the fill is placed in the cells.

Considerations:

- Properly grade the matting location, removing rocks or other debris prior to placing matting, to ensure the matting has continuous contact with the soil.
- A single layer of matting should be placed in the direction of flow or downslope.
- Matting elevation should be excavated to the thickness of the matting so that the top of the matting is flush with the adjacent terrain; infill from top of slope and ensure placement height of fill into cellular mat is less than 1 m.

Cellular Confinement System

Erosion Control BMP

BMP # 19

Permanent BMP

Inspection and Maintenance:

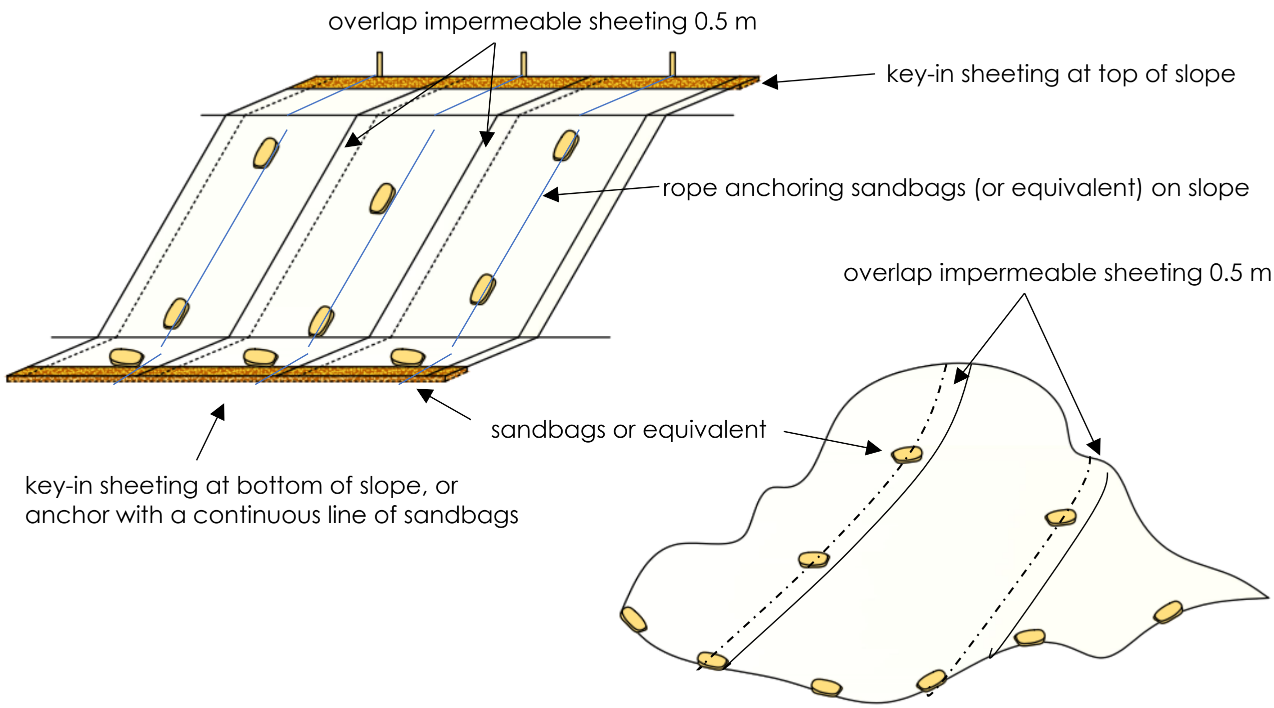
- The area covered with matting should be inspected regularly or in accordance with the ESC Plan. If matting is broken or damaged and washout of the underlying soil occurs, matting should be repaired or replaced after regrading the slope.
- Where vegetation fails to grow it should be reseeded immediately.

Impermeable Sheeting

Runoff and Erosion Control BMP

BMP # 20

Temporary BMP



Sheeting a slope and anchoring with rope sandbags

Stockpile covered and secured with

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Impermeable Sheeting

Runoff and Erosion Control BMP

BMP # 20

Temporary BMP

Description and Purpose:

- Impermeable material applied over exposed soils to prevent erosion and sedimentation by protecting the slope from rain and wind.
- Collects concentrated runoff, protects erodible soils, and directs flows into less erodible areas.
- Can use tarpaulin material or polyethylene material.

Applications:

- Used to cover exposed slopes, flat ground with exposed soils, and stockpiles.
- Used to protect exposed soils in ditches and line channels to divert water around site.

Construction:

- Grade and shape the area of disturbance relatively smooth and remove large rocks, clods and woody debris to ensure intimate contact with the soils.
- Anchors should not penetrate the impermeable sheeting (no nails, rebar, etc.). Instead use non-penetrating gravity anchors, such as sandbags or tires. Tie anchors lineally down the slope to avoid movement on sheeting.
- Can use rope to anchor sheeting on a stockpile; ensure rope is secured at bottom of pile.
- Excavate a 0.15 m x 0.15 m trench at the top of slope, place top edge of sheeting in the trench, then backfill to secure the sheeting in place. This also ensures water flows on top of the sheeting.
- Unroll sheeting starting from the top of slope to base of slope, ensuring there is sufficient sheeting at the bottom of the slope (~1 m) to securely anchor sheeting.
- Ensure sheeting is taunt and remove any creases and folds to ensure intimate contact with soils.
- Overlap sections of sheeting approximately 0.5 m and ensure sufficient anchors to keep sheeting in place.
- Continue placing additional sheeting in this manner until the slope area requiring protection is completely covered.
- Place a continuous line of sandbags at the top and bottom of the sheeting as well as along the terminal edges of the sheeting to secure in place.

Considerations:

- Sheeting must be tear-resistant and should be installed by hand to prevent tearing. Minimum thickness for sheeting should be $\geq$6 mm. If there is a risk of tearing, underlay a non-woven geotextile fabric.
- Not effective as a long-term mitigation, requires frequent inspection and maintenance to be effective as it is susceptible to displacement by wind and water.
- May be difficult to cover irregularly shaped stockpiles and steep slopes.
- Install sufficient gravity anchors to prevent displacement from wind or water.
- Fill sandbags with clean gravel that will not contribute to sediment loading or use tires.

- Do not walk on sheeting during or after installation.

Inspection and Maintenance:

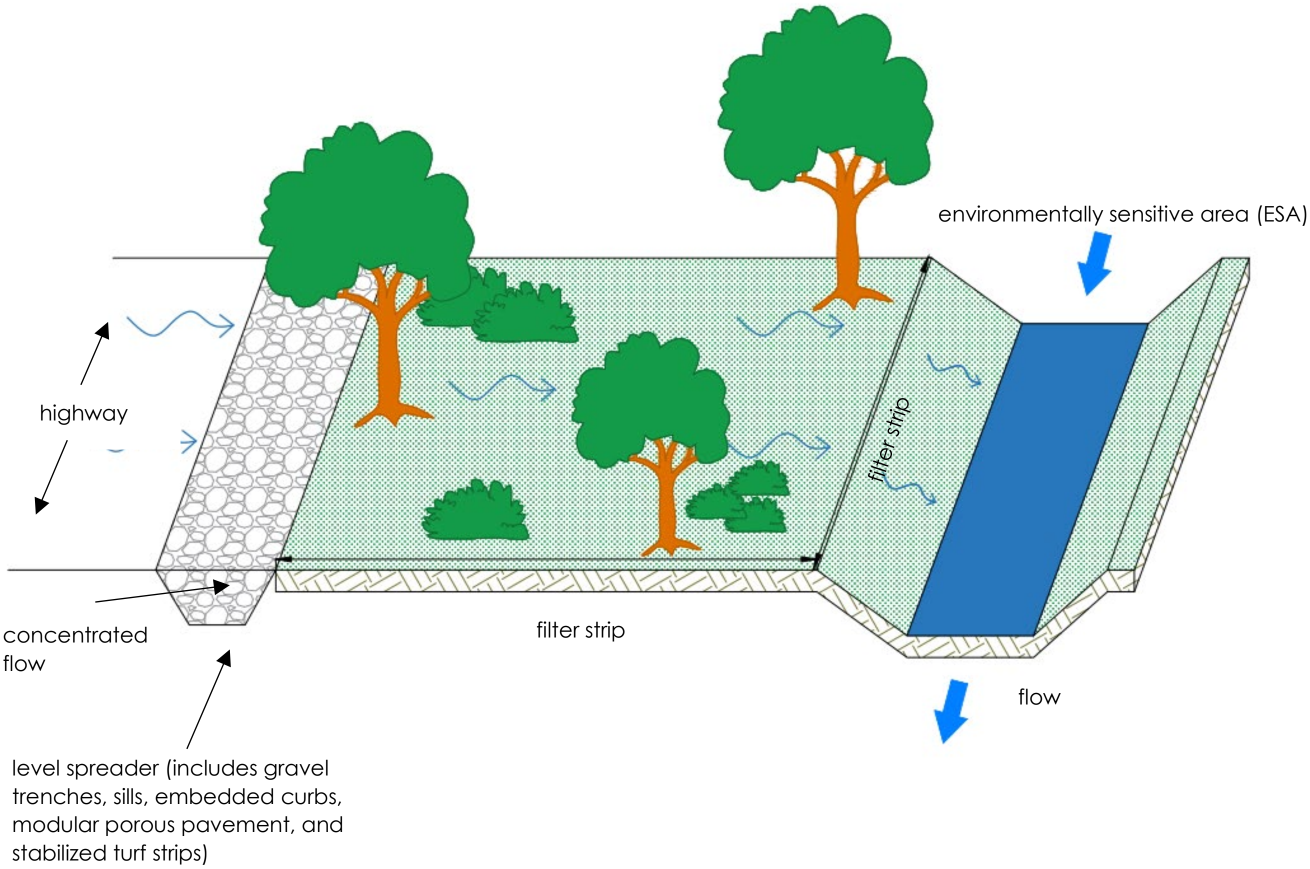
- Inspect sheeting at least once per week or following a rain (>25mm in 24 hours) or wind event.
- Check for soil erosion under and beside sheeting, which would result from water getting underneath the sheeting.
- Remove all sheeting upon completion of construction and stabilize soils using permanent ESC measures.

Vegetated Buffer Strip

Erosion and Sediment Control BMP

BMP # 21

Permanent BMP



Vegetated buffer above rock-lined ditch

Vegetated buffer next to ESA (not in photo)

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Vegetated Buffer Strip

Erosion and Sediment Control BMP

BMP # 21

Permanent BMP

Description and Purpose:

- Vegetated buffer strips are vegetated surfaces that are designed to suppress sheet flow from adjacent surfaces.
- They function by slowing the runoff velocities, allowing sediment to settle out and surface flows to infiltrate the soils.

Applications:

- If properly designed and installed, buffer strips can provide reliable water quality benefits and are aesthetically pleasing.
- Either grass or a diverse selection of other low-growing, drought-tolerant native vegetation should be specified. Consult a Professional Agrologist or the Ministry Representative for direction.
- Filter strips are best suited to treating runoff from roads and highways, small parking areas, and pervious surfaces.
- They are also ideal components of the riparian management area as a stream buffer or as a pre-treatment to a structural practice.

Construction:

- Apply to sites where the slope does not exceed 15%.
- Minimum slope distance should be 5 m to a maximum of 20 m (in the direction of flow).

Considerations:

- Install the strips at the time of the year when there is the greatest success of establishing vegetation without requiring irrigation (temporary irrigation may be required depending on the region).
- Where using seed to create a vegetated buffer strip, erosion controls will be necessary to protect the seeds for at least 75 days following the first rainfall after spreading seed.

Inspection and Maintenance:

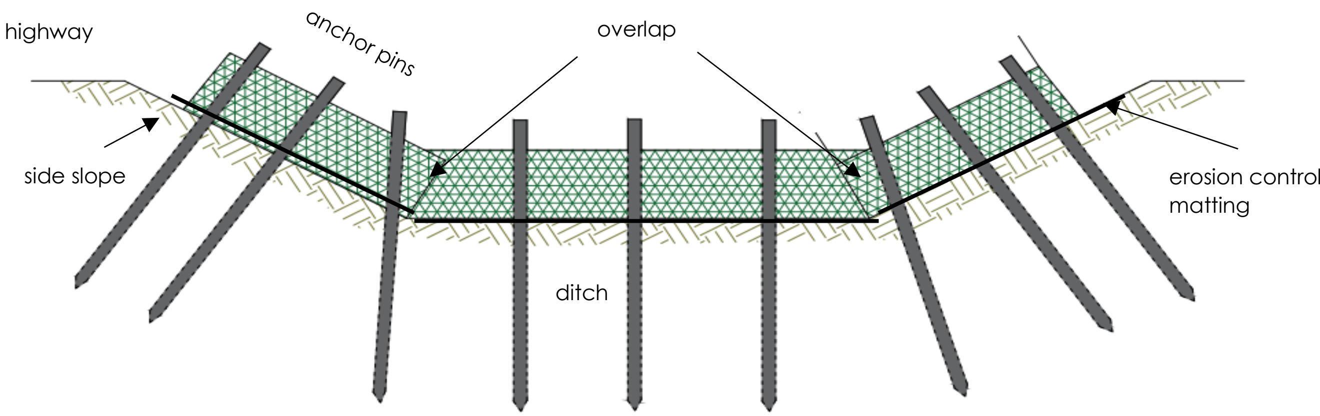
- Filter strips generally require low vegetative maintenance.
- Inspect strips at least twice per year for erosion and damage to vegetation (end of the spring and fall seasons).
- Inspect strips following a heavy rain event for damage and excessive debris, litter, and sediment accumulation.

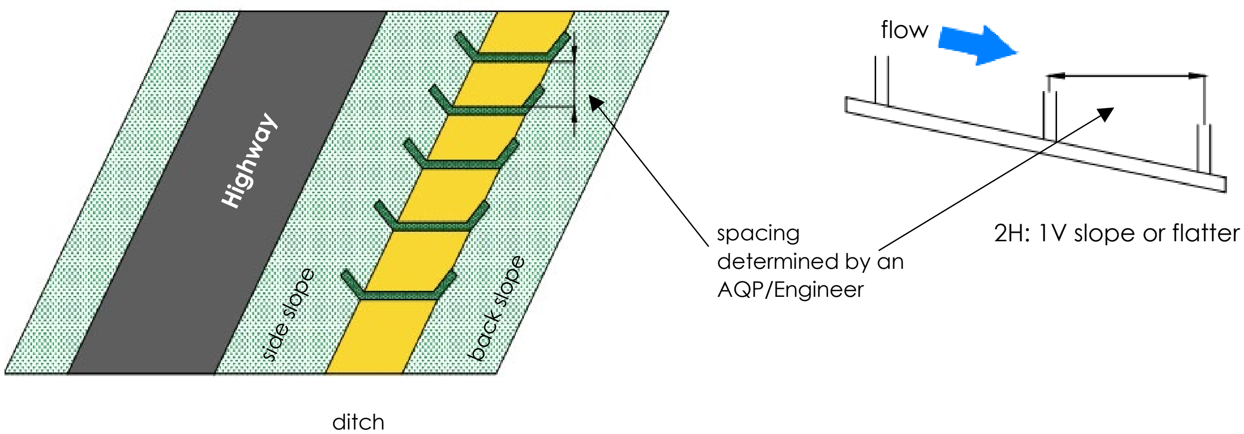
Synthetic Permeable Barrier

Runoff and Sediment Control BMP

BMP # 22

Temporary BMP





Spring berm in ditch

Spring berm slowing runoff velocities

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Synthetic Permeable Barrier

Runoff and Sediment Control BMP

BMP # 22

Temporary BMP

Description and Purpose:

- Double panel, low profile, porous synthetic barriers used to dissipate flow energy and reduce runoff velocities, such as a spring berm.
- Barriers of patented design constructed of lightweight and durable synthetic materials.
- Also used to create a grade break that reduces flow energy and velocities, allowing sediment to settle out of suspension at the upstream section of the barrier.
- Can be used to dissipate flow energy and trap sediment during the period of re-vegetation; should be removed following successful establishment of vegetation.

Applications:

- Primarily a grade break structure and flow energy dissipator; secondary use is for sediment control.
- Reusable design intended to be placed across a ditch to reduce flow velocities.
- Can be used to supplement as grade breaks along ditch interval between permanent drop structures along steep ditch grades.
- May be used as mid-slope grade breaks along mid-slope contours or at toe of disturbed slopes.
- Usually used as grade breaks along ditch (3 to 7% grade) in conjunction with erosion control matting or non-woven geotextile fabric as soil covering mattings.

Construction:

- Prepare soil surface so there are no rocks, large clumps of soil (clods), or other debris in the footprint of the structure.
- Install base of erosion mat or geotextile fabric; key-in base mat or fabric at upstream end.
- Place and anchor barrier panels with adequate pin anchors to basal soils, refer to the manufacturer's recommended installation instructions.

Considerations:

- Maintain continuous contact between base of barrier and soil.
- Ensure the side panel of the barrier is extended to the outer edges of the channel to a sufficient height that provides freeboard of channel flow.
- Requires a Rolled Erosion Control Product or geotextile fabric at base of ditch and keyed in at the upstream end

Inspection and Maintenance:

- Inspection frequency should be in accordance with the ESC Plan.
- Remove sediment build-up before it reaches one-half the check structure height, ensuring not to damage barrier panel during removal of sediment.
- Be mindful of water flow over-topping the barrier if not removing sediment from above structure.

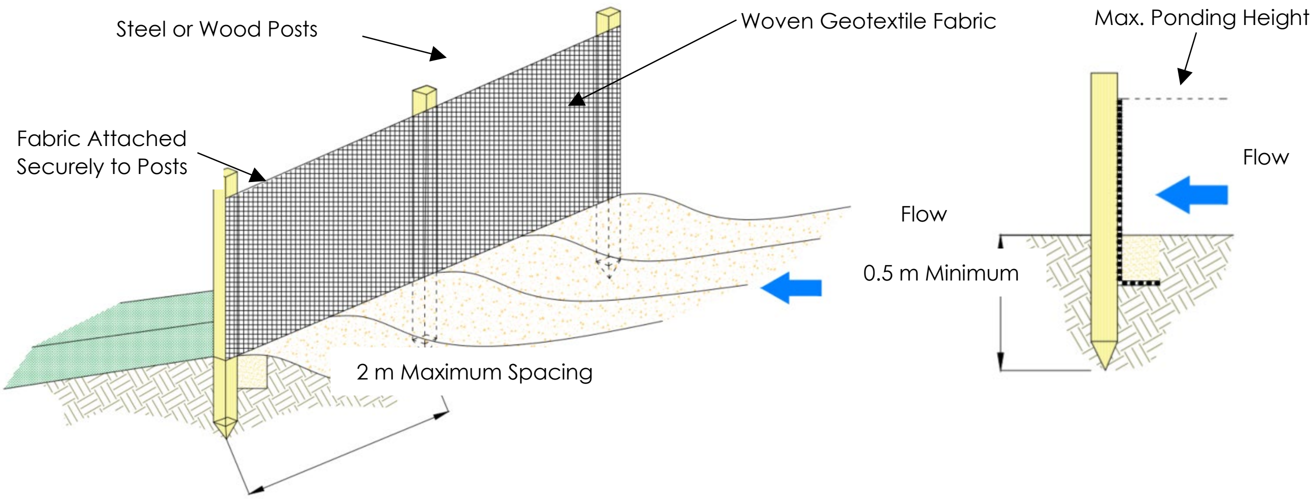
- The option of non-removal of sediments may be open to converting the sediment build-up into a "vegetated earth drop structure" along the ditch. This will require topsoil and seeding (or intensive mulch seeding) to promote vegetation growth.
- If erosion is noted at the toe or upslope edges of the structure, hand regrading or suitable repairs should be made immediately to prevent failure of the structure.
- Remove structure one year after vegetation is established.

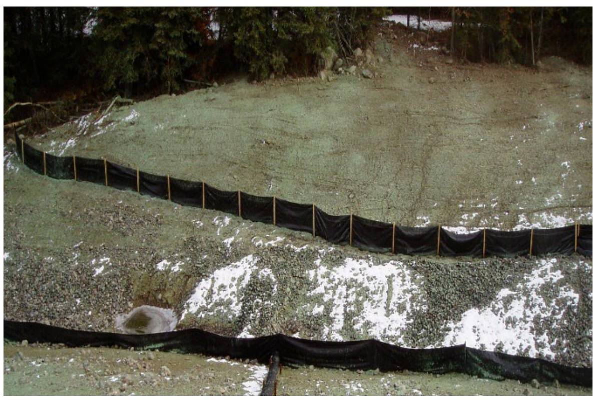
Sediment Fence

Sediment Control BMP

BMP # 23

Temporary BMP





Sediment fence installed along a contour

Sediment fence installed above riprap

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Description and Purpose:

- Permeable woven barrier installed on support posts along contours to collect and/or filter sediment-laden runoff from entering environmentally sensitive areas (i.e., streams).
- Allows coarse sediment to settle out as water filters through the fabric.
- Perimeter control for sediment transport and deposition.

Applications:

- Temporary measure, used at bottom of slopes, along stream banks or channels, and around stockpiles to collect sediment-laden runoff.
  Mid-slope grade break (using "J-hook" or "smile" pattern to effect ponding, filtering, and sedimentation).
- Low permeable sediment fences have high filtering capabilities for fine sand to coarse silt.

Sediment Fence

Sediment Control BMP

BMP # 23

Temporary BMP

Installation:

- Trench Method:
  - Select location of sediment fence (usually along a contour).
  - Excavate a trench approximately 0.15 m deep by 0.15 m wide for entire length of fence.
  - Drive support posts (approximately 0.5 m) into ground, spaced a maximum of 2 m apart.
  - Backfill and compact soil in the trench, being careful not to damage fence.
- Mechanical Installation Method:
  - Select location of sediment fence (usually along a contour).
  - Use mechanical installation machine to embed the fabric a minimum of 0.15 m into the ground. One mechanical installation method is by slicing the filter fabric to embed into the ground without excavation and backfill. There will be minor disturbance of the ground, if affected, and only tamping of ground is required for compaction.
  - Drive support posts (approximately 0.5 m) into ground, spaced a maximum of 2 m apart.

Considerations:

- Site Selection:
  - The drainage area should be no greater than 0.1 ha per 30 m length of sediment fence.
  - The maximum flow path length above the sediment fence should be no greater than 30 m.
  - The maximum slope gradient above the sediment fence should be no greater than 2H:1V.
- The fence should be placed far enough away from the toe of slope to provide adequate ponding area (minimum of 1.8 m away from toe of slope is recommended).
- Ends of the fence should be angled upslope to collect runoff.
- Posts can be wood or metal material; posts must be placed on the downslope side of the fence.
- The trench should be backfilled and compacted.
- Long runs of sediment fence are more prone to failure than short runs:
  - Maximum length of each section of sediment fence should be 40 m.
  - Sediment fence should be installed in 'J' hook or 'smile' configuration, with maximum length of 40 m, along contours allowing an escape path for ponded water (minimizing overtopping of sediment fence structure).

Inspection and Maintenance:

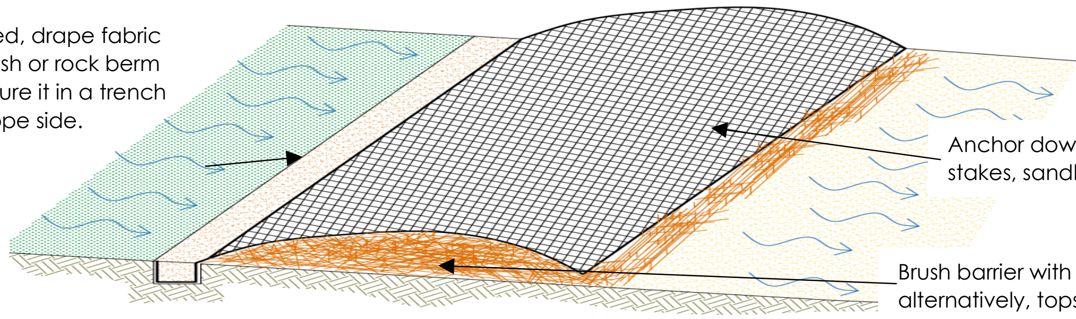
- Regularly inspect structures (as stated in the ESC Plan) to ensure they are intact, and water has not eroded around them.
- Repair undercut fences and repair or replace split, torn, slumping, or weathered fabric.
- Sediment build-up should be removed once it accumulates to a depth of half the height of the fence.
- Deactivate fabric by cutting off the top portion of fabric above ground; if possible, remove the entire fence including trenched-in fabric.

Brush Berm or Earth Dyke

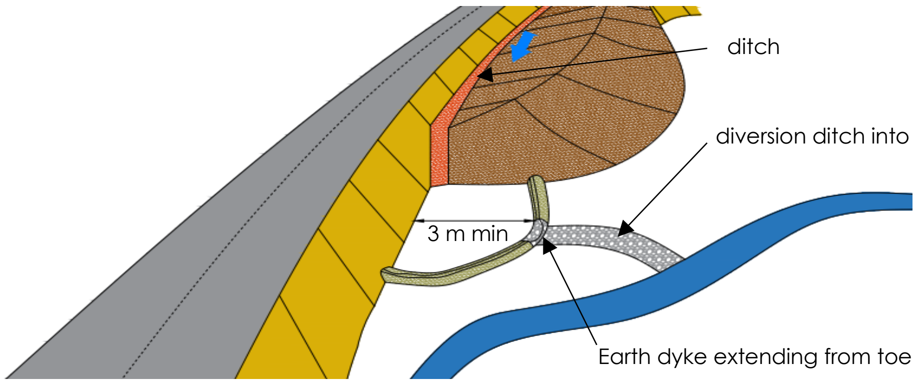
Runoff and Sediment Control BMP

BMP # 24

Temporary or Permanent BMP



Brush Berm



Earth Dyke

Brush and topsoil berm

Earth dyke retaining runoff on the field

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

# Brush Berm or Earth Dyke	# BMP # 24
Runoff and Sediment Control BMP	**Temporary or Permanent BMP**

Description and Purpose:

- Temporary or permanent barrier composed of brush or rock that is secured in geotextile fabric.
- Designed to intercept and divert runoff away from environmentally sensitive areas (ESAs).

Applications:

- Temporary or permanent perimeter control measure.
- Constructed near the toe of slopes, along the crest or tops streams and channels, or around drain inlets that are subjected to sheet flow and rill erosion.
- Maximum drainage area of 250 m^2 per 25 m length of barrier.

Construction:

- The size of the brush berm or earth dyke depends on the condition of the site.
- The height of the berm should be at least 1 m and the width should be a minimum of 1.5 m.
- Brush, roots, stumps, and/or stones are piled into a mounded row along contours.
- During clearing and grubbing, equipment can push the material into windrows along toes of slopes or other areas prone to erosion.
- Lay woven geotextile across the berm with edges overlapping, secured in a trench upslope of the berm. The trench should be 0.15 m wide and 0.15 m deep and run the entire berm length.
- The geotextile in the trench should be staked down approximately 1 m apart, then backfilled and compacted over the staked fabric.
- A rock berm should be constructed by replacing brush with rock (D_{50} = 7.5 cm to 15 cm).
- Rock berms should consist of hard, durable, clean aggregate, free of organic matter, clods, soft particles, or other substances that might interfere with drainage and filtering properties.
- An earth dyke barrier should be constructed from the bottom up by placing and compacting subsequent lifts of soil material in a trapezoidal shape.
- The degree of compaction of each lift is to be determined by the design engineer based on consequences of failure.

Considerations:

- Use rock or brush material up to 0.15 m diameter; there is no predetermined shape for berms.
- Water must be forced to pond behind the berm to encourage sediment to settle out.
- Brush barriers can generally be constructed of clean organic material from clearing and grubbing operations that is normally burned or discarded.
- Rock and brush berms are temporary measures and should be removed upon completion of service life, after vegetation is established.

Inspection and Maintenance:

- Inspect berms regularly and after a significant rainfall events or as specified in the ESC Plan.

- Reshape berms as needed and replace lost or dislodged rock, brush, and/or geotextile fabric.
- Inspect for sediment accumulation and remove sediment when depths reach approximately one-third the berm height or 0.3 m.
- Inspect for undercutting, defective fabric, end runs, and erosion of the berm, and repair.

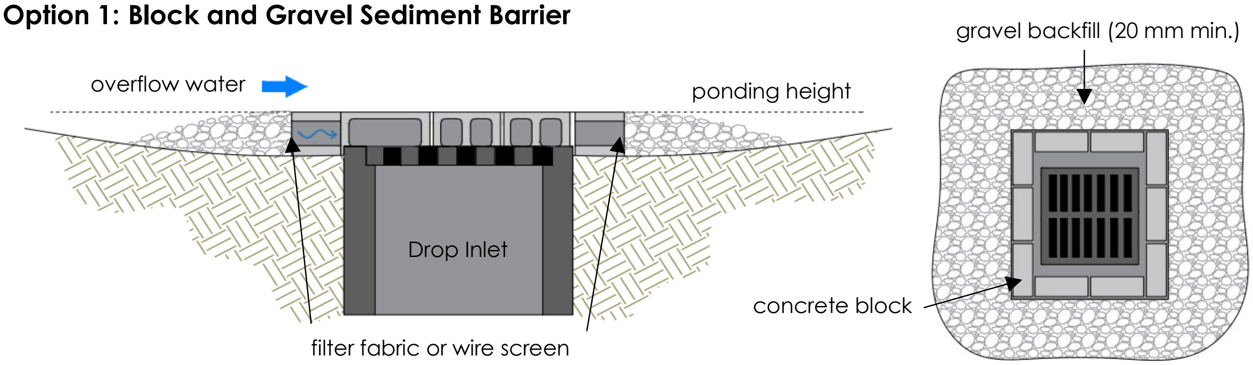
Drain Inlet Sediment Barrier

Sediment Control BMP

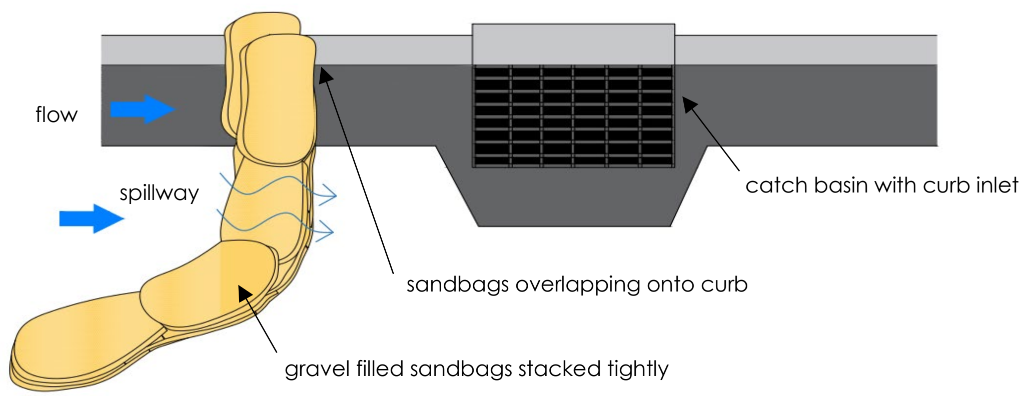
BMP # 25

Temporary BMP

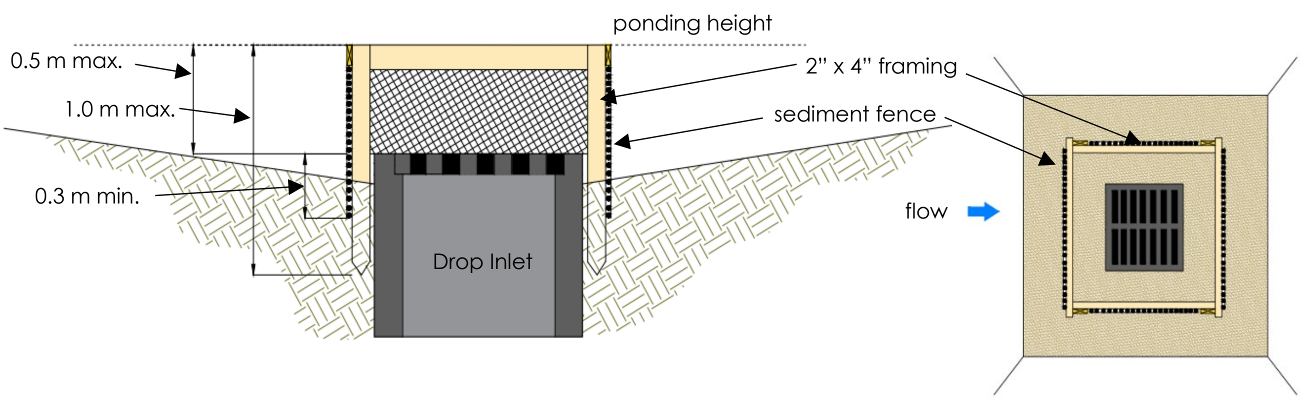
Option 1: Block and Gravel Sediment Barrier



Option 2: Sandbag Curb and Gutter Sediment Barrier



Option 3: Sediment Fence Barrier



# Drain Inlet Sediment Barrier **Sediment Control BMP**	# BMP # 25 **Temporary BMP**

Option 1- Block and Gravel Sediment Barrier

Option 2 - Sandbag Curb and Gutter

Option 3 - Sediment Fence Barrier

<u>Alternate inlet protection techniques:</u>

Aggregate filled filter sock cover.

Geotextile fabric under manhole

Drain Inlet Sediment Barrier

Sediment Control BMP

BMP # 25

Temporary BMP

Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Description and Purpose:

- Temporary devices constructed to minimize the amount of sediment entering a catch basin by ponding sediment-laden runoff at the inlet.
- Storm drain inlet protection can consist of the following measures:
  - Block and Gravel Sediment Barrier – Option 1.
  - Sandbag Curb and Gutter Sediment Barrier – Option 2.
  - Sediment Fence Sediment Barrier – Option 3.

Applications:

- Temporary measure around catch basins prior to establishment of vegetation or pavement.
- Effective on construction sites where drainage enters municipal sewers or watercourses.
- Used as curb inlet barriers in gently sloping ditches where drainage area is 0.4 ha or less.
- Used where areas are subjected to sheet and concentrated flows (less than 0.014 m^3/s).

Construction:

- Place inlet sediment barrier around the entrance to drain/pipe (with option chosen based on site conditions).
- A sediment fence barrier is to be used for soil surfaces.
- Block and gravel or aggregate-filled sandbags can be used for asphalt or concrete surfaces.

Considerations:

- Ensure drop height is below ground level to ensure runoff does not bypass structure.
- Allow water to filter through the structure, allowing sediment to settle out of suspension.
- Block and gravel filter sediment barrier:
  - Slope gravel toward the inlet at a maximum slope of 2H:1V.
  - Maintain a 0.3 m spacing between the toe of gravel and the inlet to minimize gravel entry.
  - 25 mm wire mesh may be placed over the inlet to prevent gravel from entering the inlet.
  - Can incorporate straw bales into barrier structure for extra filtration.
- Sandbag curb and gutter sediment barrier:
  - Sandbags should be filled with pea gravel, drain rock, or other free draining material.
  - Sandbags should be filled only 3/4 full to allow sandbag to be flexible to maintain contact.
  - Use aggregate sandbags filled with 25 mm diameter rock in place of concrete blocks.
  - Barrier should be placed at least 0.1 m from the drain inlet.
  - Several layers of sandbags should be overlapped and tightly packed against one another.
  - A sandbag gap should be left at the lowest point of the upper layer as emergency spillway.
- Sediment fence barrier:

    - Key-in sediment fence 0.3 m away from inlet structure. See BMP # 22 - Sediment Fence.
    - For a sediment fence barrier, install a 2’x4’ wood top frame to ensure stability.
- For drainage areas larger than 0.4 ha, runoff should be directed toward a sediment retention device designed for larger flows before allowing water to reach the inlet protection structure.
- See photos of alternate sediment barrier techniques below for more for inlet protection options.

Inspection and Maintenance:

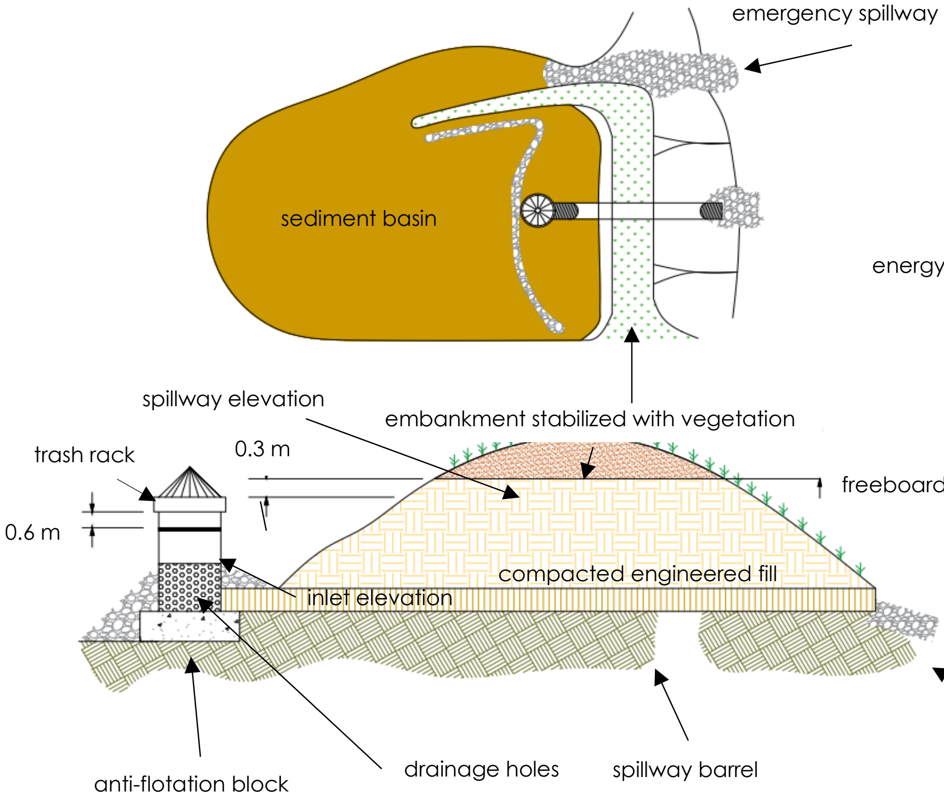
- Inspection frequency should be in accordance with the ESC Plan and after major storm events.
- Remove sediment build-up after each storm event if necessary.
- Sediment and gravel should not be allowed to accumulate on roads; replace gravel if needed.

Sediment Control Pond

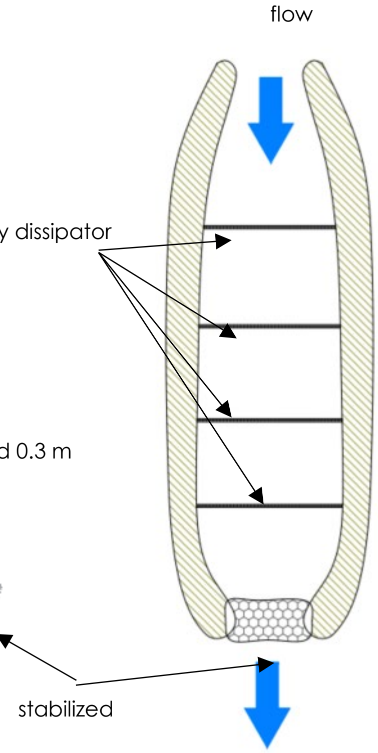
Sediment Control BMP

BMP # 26

Temporary or Permanent BMP



Typical Sediment Pond with Riser and Outlet



Alternate Design

Large sediment pond with riser outlet

Small sediment retention area in ditch

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Sediment Control Pond

Sediment Control BMP

BMP # 26

Temporary or Permanent BMP

Refer to BC Ministry of Transportation & Infrastructure's document titled, *Standard Specifications for Highway Construction* – 165.04.03 – Sediment Control Ponds for more details.

Description and Purpose:

- Low height dam enclosure to impound sediment-laden storm water.
- Used to trap storm water and promote sediment to settle out prior to releasing to environment.
- Excavated pit and berm embankment above ground, lined pond if necessary.

Applications:

- Generally, a permanent measure, although it can be used as a temporary measure on longer projects until vegetation is established and the sediment source has stabilized.
- Usually at the end of a ditch with concentrated flows to impound sediment-laden water prior to release further downstream.
- Also used as a sedimentation control measure surrounding construction sites where sediment-laden water may enter a watercourse, storm drain, or other sensitive area.
- Used where there is a need to impound a large amount of sediment from significant areas of land disturbance.
- Where practical, contributing drainage areas should be subdivided into smaller areas and multiple sedimentation impoundments installed.

Construction:

- A qualified professional must design the structure appropriately for anticipated flows (Q-10).
- The sediment pond footprint should be stripped of vegetation, topsoil, and roots to exposed mineral subgrade soils for maximum infiltration.
- Berm fill material should be clean mineral soil and compacted.
- The main outlet structure should be installed at the furthest point from the inflow. Proper inlet and outlet protection should be installed to protect from erosion.
- Build an emergency spillway to accommodate any unexpected storm events (Q-100).

Considerations:

- Strip the mineral soil along the footprint area required to construct the berm of the pond.
- Construct sediment ponds at the site perimeter and around environmentally sensitive areas prior to the wet season and/or construction activities.
- Riser pipe or sediment curtains can be installed at the inflow to aid in settling out the sediment.
- The sediment pond/pond bottom should be flat or gently sloping toward the outlet.
- Berm slopes of the sediment pond should not be steeper than 2H:1V and should be compacted and vegetated; berm height should be a minimum of 1 m.

Sediment Control Pond

Sediment Control BMP

BMP # 26

Temporary or Permanent BMP

Inspection and Maintenance:

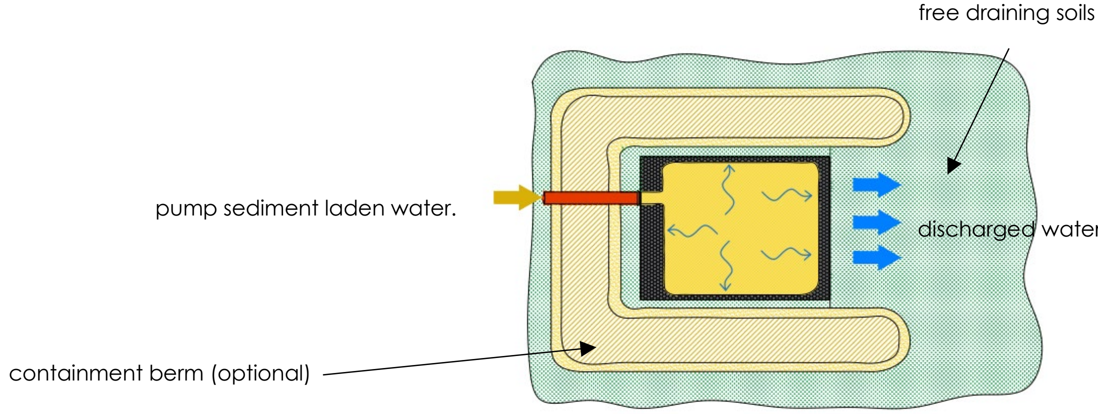
- Regularly inspect structure for seepage, structural soundness, outlet damage, debris accumulation, and amount of sediment load, especially after a heavy rain event.
- Sediment should be removed once it has reached half the height of the berm.
- Sediment traps can be deactivated or removed after vegetation of previously disturbed upstream areas has been established and sedimentation is no longer an issue.

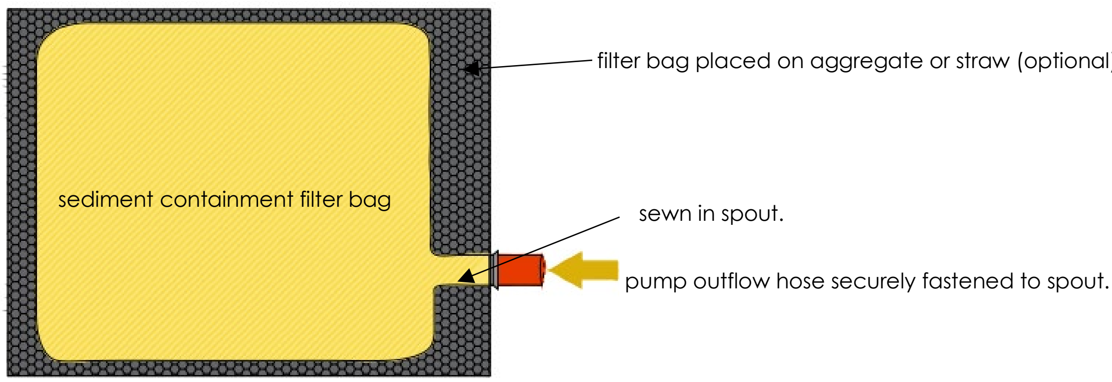
Pump Outlet Filter Bag

Sediment Control BMP

BMP # 27

Temporary BMP





Disclaimer: The guidance provided is for information purposes only. An Erosion and Sediment Control Plan (ESCP) created by an appropriately qualified professional (AQP) may be required for site-specific requirements.

Description and Purpose:

- Sediment-laden runoff is separated through a manufactured bag made of a permeable geotextile.
- Runoff filters through while coarse sediment is retained within the filter bag.

Pump Outlet Filter Bag

Sediment Control BMP

BMP # 27

Temporary BMP

Applications:

- Can be used in environmentally sensitive areas to supplement containment pond systems.
- An example area is where containment pond space is limited on a construction site and an appropriately sized containment pond cannot be constructed adjacent to high-risk areas.
- Useful for additional extraction of sediment-laden dewatering sumps, sediment ponds, or other retention facilities with accumulations of sediment-laden runoff.

Installation:

- Place filter bag on free-draining soils or straw bales and ensure bag is on a slight slope with opening of filter bag facing upslope.
- Optionally, build up a slight berm using dirt fill or straw bales to direct flows from the filter bag away from environmentally sensitive areas.
- Attach outflow hose to opening of filter bag inlet and ensure a tight seal to prevent discharge of sediment-laden runoff outside of bag (hose clamps are effective to seal).
- Attach hose to pump and insert suction hose into retention facility to be dewatered.
- Turn on pump and remove sediment-laden water until the filter bag is full of sediment.
- Disengage pump once the filter bag is full, tightly close the filter bag opening to prevent spilling of sediment and remove the bag.
- Repeat the process (using new filter bags) until the retention facility is dewatered to acceptable levels.

Considerations:

- Full filter bags can be removed from site or cut open and contents buried in designated locations on-site.
- Care should be taken to ensure the filter bag is not overfilled, which may cause it to tear and spill sediment.
- Ensure a piece of equipment can access the filter bag for removal purposes.
- Care should be taken when transporting full filter bags to prevent tearing.
- Discharge water into a vegetated swale or into secondary containment.
- Discharged water must flow away from the construction site.
- Sediment from the filter bag must be removed and stabilized.

Inspection and Maintenance:

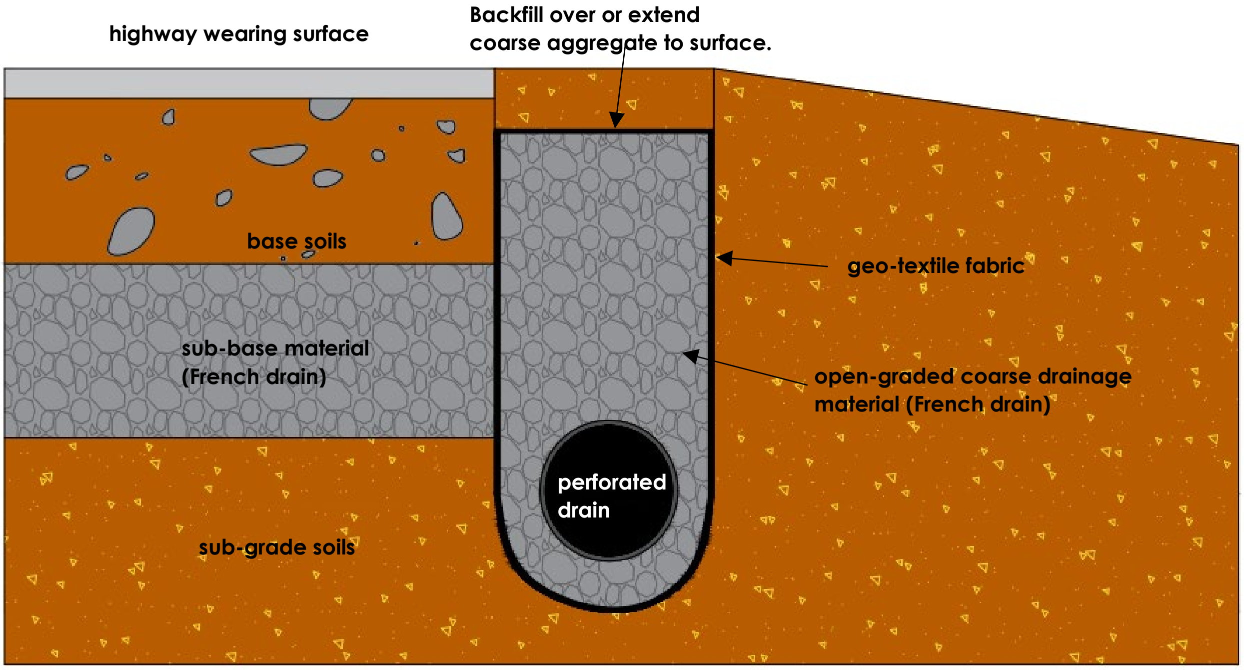
- Inspect all hoses and connections before and during pumping operations to minimize leaks, and fix or replace equipment, as necessary.
- Take precautions to ensure sediment accumulation does not enter an environmentally sensitive area when replacing/removing filter bags.

Subsurface Drains

Runoff and Erosion Control BMP

BMP # 28

Permanent BMP



French drain

Sub-surface drain with surface grate

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Refer to BC Ministry of Transportation & Infrastructure's document titled, *Standard Specifications for Highway Construction* – [Section 318 PVC Plastic Drainage Pipe] for more details.

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

Subsurface Drains

Runoff and Erosion Control BMP

BMP # 28

Permanent BMP

Description and Purpose:

- Drains that intercept and collect subsurface groundwater and divert it from a slope, focusing groundwater seepage, reducing subsurface flows, and increasing soil stability.
- Relief drains (perforated finger-drains or French drains) to mitigate high groundwater table to minimize piping erosion.

Applications:

- Permanent measure.
- Used on cut slopes or areas where groundwater seepage exits.

Construction:

- Excavate trench at subsurface drain location.
- Install perforated drainpipe or place rock wrapped in geo-textile cloth in trench.
- Backfill with clean, coarse drainage gravel and/or non-woven geotextile fabric to provide filtration separation with adjacent soils.

Considerations:

- When signs of seepage and unstable excavations are encountered, it is advisable to install trench protection measures for safety (e.g., trench box).
- Carry out work as soon as possible to mitigate seepage damage, soil loss, and deterioration of unstable soils.
- Excavate and install drains to the grade and spacings according to design and recommendations made by the geotechnical engineer.
- Protect drainage outlets with sturdy pipe to ensure free-draining condition.
- Drains and pipes should be designed with frost penetration and the freezing of pipes in mind.

Inspection and Maintenance:

- Drains installed below grade will require manholes at frequent intervals (100 m maximum) to facilitate inspection and maintenance.
- Flushing and maintenance clean-out of drains can be carried out through manhole locations.