City of Mankato Surface Water Management Manual

A publication of the
Engineering Division

Section 1 *Introduction*	Introduces the Surface Water Management Plan and discussion the goals of the implementation of the policy.
Section 2 *Vulnerable Locations*	Provides guidance for determining where effective improvements can be made and how location should be evaluated.
Section 3 *Management Strategies*	Details out the practices to be implemented and how they will be carried out.
Section 4 *Prescriptive BMPs*	Provides BMPs that property owners can install with minimum design or permitting
Section 5 *Maps*	Provides maps to assist in determining locations where the policy is applied.

Section 1: Introduction

Surface Water Management

1.1 The City of Mankato is committed to managing its water resources and protecting surface waterways now and into the future. In order achieve this goal though a comprehensive policy the city has developed the Surface Water Management Manual. This Manual details the policy for management and maintenance of surface water conveyances, drainage ways, streams, creeks, and ravines for both public and private property.

Who should use this manual?

This manual provides guidance suitable for use by a wide range of individuals.

- Developers, including their planners and engineers;
- Contractors, including their engineers, estimators, superintendents, foremen, tradesmen, and subcontractors;
- Municipal inspectors, building inspectors, code enforcement officers, and public works staff;
- Residents who live along a surface water conveyance;
- The general public with an interest in surface water management, and erosion control and prevention.
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"How should this manual be used with other City guidance?

This manual is for the operation and maintenance of surface waterways within the City of Mankato. This document is meant to guide city staff and property owners along waterways as to the best practices to minimize undesirable conditions of surface water ways. In conjunction with the City of Mankato's Grading Manual various improvements or Best Management Practices (BMPs) can be implemented to improve the flow of water and minimize the amount of erosion taking place along a surface waterway. The BMPs in this policy are designed to be installed under and Land Disturbance Permit, with minimal design requirements. The Grading Manual has been developed as a regulatory document to aid in maintaining compliance with the City of Mankato's MS4 permit. As such is provides more detailed design information and the target audience are those individuals that are undertaking improvements that require a MPCA Construction Stormwater Permit. BMPs and improvements designed under the guidance and requirements of the Grading Manual will require a more in-depth review and permitting process and are generally not recommended for individual property owners.

This Policy is also meant to guide city staff in the operation of surface waterways and to provide a uniform maintenance policy in responding to deficiencies discovered though regular inspections and calls for service. This policy will help aid in communicate the expected level of service provided by the City and allow various staff members from various departments provide uniform response to service needs.

Though this Policy this City will be able to establish regular inspection intervals and maintenance activities for waterways that drain publicly owned storm sewers that are located within public parcel or have drainage easements over them.

Reasons for the Surface Water Management

1.2 The City of Mankato is located adjacent to two major rivers within Southern Minnesota, the Blue Earth River and the Minnesota River. The city has three broad areas that are affected by drainage differently. These being the river valley and flood plain; bluff, hillside and ravine areas; and the hilltop or upland plain.



Natural channels are often used for stormwater conveyance resulting in increased flows through the system.

The flood plain of the Minnesota River is where much of the original development within Mankato occurred. This was followed by development of accessible and stable areas of the bluff and hillside. As the city continues to expand, much of the development is occurring on the upland plain or hilltop area.

For many years much to the drainage for the city was provided by utilizing natural waterways. These waterways received the stormwater either directly or through a stormwater system. Often times discharge to these natural waterways was done without a comprehensive understanding of the downstream impacts from the stormwater. The drainage principle applied was to convey as much water as quickly as possible.

The goals of this manual are to bring together the various policies and practices for drainage and erosion control of along surface waters the organization into a single location. This Policy is to prescribe BMPs that can be implemented by property owners and define the maintain activities carried out by the City. Design of capital improvements initiated by the City or as part of a development will be also need to meet the requirements of the Grading Manual. By bringing this information into a single location it allow those that live along surface waters to understand the maintenance activities that are available to them as well as the level of service that the City of Mankato provides. Examples of the types of projects and the level of review can be found later in the manual.

Overall the goal of this manual is to protect the stability of the surface water conveyances within the city and provide ways to perform the most effective maintenance of these natural waterways.

Surface Water Challenges

1.3 The use of natural waterways for conveying storm water runoff can present unique design and livability challenges. The goal is to have an attractive amenity that provides access to nature while conveying runoff and ensuring that the stream channel remains stable.

There are three main challenges managing surface waters through natural waterways: erosion, flooding and vegetation. The forces of erosion and flooding interact directly with each other to cause continual changes in the stream course. These changes that are caused by erosion and flooding will often adversely impact vegetation which can create an undesired influence on the stream.



Vegetation management is an important part of the operation of surface waters.

1.3.1 Erosion. Erosion is the loss of material along banks or bottom of a channel. This is often caused by a lack of stability in the channel material. Stability is often thought of in one of two ways. The channel is stable up to the point where material comprising the bank becomes mobile. This view point treats the channel boundary as rigid and static. The second view point is the channel is stable when the amount of sediment entering and leaving the stream are equal and the channel has reached a dynamic equilibrium. This view point treats the channel as a dynamic system that is always changing. This viewpoint is more closely aligned with the actual conditions in nature.

1.3.2 Bank Erosion. Streambank erosion due to lateral migration of the channel is referred to as meandering. This is a common characteristic of most surface waterways. In general, a combination of coarse alluvium in the channel bed and vegetated, cohesive banks are considered to be the necessary ingredients for the meandering process in natural streams. While bank erosion is very much a natural process, the rate at which it happens can be influenced if the flows in the stream change or use of the land draining to the stream is modified. This often resulted from development of the watershed in the form of urbanization or improvement of drainage through grading, channelization and tiling.

In general, urban development implies larger percentage of impervious surfaces and dense, efficient storm sewer network that results in higher, flashy discharge to the streams. Urban development and land use can have a detrimental effect on the characteristics of streams in more complex ways. For example, many streams have been straightened and often times the streambanks have been structurally reinforced in order to restrict lateral channel migration. Natural streams have also been segmented into short reaches by culverts and bridge crossings which also limit the overall ability of streams to migrate laterally and develop wide meander bends.



Dynamic stream in equilibrium and are harmonious with the surrounding land.

Generally speaking, the sinuosity and ability of engineered channel courses to meander in developed areas has been artificially reduced. At the same time, the land use conversion and increase in impervious surface has altered the hydrologic regime resulting in generally more flashy discharge with much larger peak flow rates. Other types

of hydromodificaions can take place that result in the duration of the discharges lasting longer at a higher rate that may be been previously present in a stream. In turn the change in the flow triggers bank erosion and causes the channel to widen in order to accommodate the increased flow. Channel widening and bank erosion due to increased flow rates affect modified stream and naturals streams alike. In addition higher peak flowrates can increase the rate of the lateral channel migration, independently from the widening aspect.

1.3.3 In-channel sediment. Adding to the general complexity of the bank erosion is the issue of the in-channel sediment. Bank erosion, caused in large part by the channel widening due to the increased flow rates, generates additional sediment material for the channel to transport. The finer fractions, silt and clay sized material, are typically transported along the channel with coarser sediment accumulating within the channel bed.

An increased amount of coarse sediment tends to increase the channel lateral mobility. The mechanism is related to the in-channel accumulation of the coarse sediment which cannot be effectively transported downstream. The coarse sediment forms channel bars, particularly adjacent to the convex, inner banks. These are referred to as point bars. The growing point bars deflect the flow towards the opposite bank, increasing the shear stress on the soil and implicitly the rates of erosion of the concave bank.



Sediment deposits create channel bars which may negatively direct the flows in the stream.

Vegetation Loss

1.3.5 As channel widening and meandering take place, the loss of bank material will often result in the supported vegetation falling. This vegetation will either fall into the channel or into the flood plain.

Vegetation that falls into the channel has an immediate impact on the flow characteristics of the stream. These can range from redirecting the flow, to creating turbulence within the stream, narrowing the flow channel and increasing velocity; or even fully blocking and impounding the flow. As the flow is altered it will often times begin to interact with a portion of the channel that may not readily accept the altered flow regime and will begin to erode to accommodate the new flow. The will result in additional erosion and repeat the cycle.



Vegetation management is an important part of the operation of surface waters.

Vegetation that falls within the floodplain can be problematic in its own fashion. This vegetation may have the opportunity to decompose for a time before the level of the stream may interact with this debris. The decomposition will reduce the weight and density of the debris but not the size. The resultant is that the debris is more easily transported during flood events and will

impact areas of the surface water and restrict flow. This then begins to cause erosion as well.

Flooding

1.4 Flooding is the result of the channel unable to pass the flows that it is receiving and causing flows to be passed outside the normal channel geometry. These excess flows utilize a floodplain to continue along the stream course. Depending on the location of development relative to the floodplain and the water surface elevation, damage to property can result.

Most healthy natural streams have some level of floodplain associated with them. The level at which the flooding becomes damaging is dependent on the make of the flood plain. In areas with little or no development, either urban or agriculture, flood events are typically of lesser consequence. In areas where development has occured floods can cause damage though erosion, deposition or inundation.

In order to minimize the amount of damage caused within an urban setting, municipalities will often work to define the floodplain for a given stream at a given precipitation event or storm and restrict the types of development that can occur within that area. Typically this floodplain is for a 100-year (or 1% recurrence) flood. This is the design event that the City of Mankato is using in its Grading Manual as the extreme event.

1.4.1 Causes of Flooding Flooding is generally caused by one of two mechanisms. The first is the flow entering a surface water conveyance exceeds the capacity of the conveyance channel and rises to a level until the necessary flow path is able to reach equilibrium with the flow.

The second method of flooding is loss of channel capacity. This may be due to natural or artificial restrictions. Such restrictions come in the forms of deposition of fill material, eroded material, eroded material that has suffered sudden slope failure, vegetation that has fallen in the flow channel, or culverts or bridges that are unable to pass the flow.

1.4.2 Flooding due to excess flow Flooding due to excess flow generally affects an entire stream course. The excess flow can be either seasonal such as spring melt, or from specific precipitation events.

The mechanism of flooding is caused by precipitation or snow melt within the watershed that contributes enough flow for the water level to exceed the normal bank elevations of a stream. When the flow within the stream is such that to be able to continue to convey the flow the elevation of the water must overtop the banks, flooding has occurred.

1.4.3 Recurrence intervals To better illustrate flood events a discussion on precipitation events is presented here. The intensity or amount of precipitation from a storm are often related to the probability of recurrence of the storm. Oftentimes, large events are referred to as a 25-year or a 100-year event. This nomenclature can lead to a misinterpretation of terminology and a misconception of what a 100-year storm really is.

Instead of using the term "100-year event" the preferred description would be that the extreme precipitation event has a one percent annual chance of occurrence. Instead of thinking that this is a storm that would take place once every 100 years, it actually means that it is a storm that has a 1% chance of occurring in any year.

The question that is often posed to engineers and hydrologist is how can there be two 100-year events in less than two years? Or as expressed by a resident "Based on the number of 100-year events we've had I must be 900 years old!"

This question points out the importance of proper terminology. The term "100-year flood" is used in an attempt to simplify the definition of a flood that statistically has a 1-percent chance of occurring in any given year. Likewise, the term "100-year storm" is used to define a rainfall event that statistically has this same 1-percent chance of occurring. In other words, over the course of 1 million years, these events would be expected to occur 10,000 times. But, just because it rained 6 inches in one day last year doesn't mean it can't rain 6 inches in one day again this year.

The second part of this issue is the fact that a 100-year rainfall event may not result in a 100-year flood. There are several factors that can independently influence the cause and effect relationship between rainfall and resulting runoff.

Extent of rainfall in the watershed: When rainfall data is collected at a point within a stream basin, it is highly unlikely that this same amount of rainfall occurred uniformly throughout the entire basin, especially for relatively large basins. During intensely localized storms, rainfall amounts throughout the basin can differ greatly from the rainfall amount measured at the location of the rain gage. Some parts of the basin may even remain dry, supplying no additional runoff to the streamflow and lessening the impact of the storm.

Soil saturation before the storm: Existing conditions prior to the storm can influence the amount of stormwater runoff into the stream system. Dry soil allows greater infiltration and retention of rainfall within the soil, and reduces the amount of runoff entering the stream. Conversely, soil that is already wet from previous rain has a lower capacity for infiltration and moisture retention within the soil, resulting in more runoff entering the stream.

Relation between the size of the watershed and duration of the storm: Another factor to consider is the relation between the duration of the storm and the size of the stream basin in which the storm occurs. For example, a 100-year storm of 30-minutes duration in a 1-square-mile (mi2) basin will have a more significant effect on streamflow than the same storm in a 50-mile square basin. Generally, streams with larger drainage areas require storms of longer duration for a significant increase in streamflow to occur. These and other factors determine whether or not a 100-year rainfall will produce a 100-year flood.

For further reading on this issue the United States Geological Service (USGS) has a more in-depth explanation on their website, excepts of which were presented here. The website can be found at: https://water.usgs.gov/edu/100yearflood.html

1.4.4 Flooding due to inadequate capacity Flooding can also be caused by a lack of capacity of the stream to pass a given flow. While the mechanism of flooding is the same as previously described, the difference here is that under normal flow conditions and channel geometry flooding wouldn't occur.

Typically the channel geometry is altered in some fashion that causes it to reduce its capacity to pass flows. This is usually caused by some obstruction that is placed or falls into the stream. Two major types of obstructions are vegetation and deposition of material.

These deposited materials will cause flooding and the flows will attempt to "find a new path" around the obstruction. This rerouting of the flow will often cause the channel to move and possibly erode areas that are not desirable to have erosion occur. In order to minimize damage caused by flooding due to the obstruction it is desirable to have generally stable banks and vegetation along the stream.

1.5 Stream response to flooding Under normal conditions a stable stream will achieve equilibrium. This can be seen as the amount of water entering and leaving a given location along the stream being equal. Also this means that the amount of sediment being transported from and depositing in a given location is equal as well. It can be said that the stream is in equilibrium.

When flooding occurs due to one of the conditions that was previous discussed it will stress the equilibrium in the stream. This will cause the stream system to respond to the flood event and attempt to reach a new equilibrium under the conditions that are causing the flooding.

When the flooding is caused by a large inflow of water the stream will tend to have higher velocities which will result in increased erosion. This erosion will remove material along the channel bed and banks to deepen and widen the channel so that more of the flow will be conveyed within the channel. It can be thought of in a manner that the water will flow along the path of least resistance. This means that an improved channel is the preferred flow path rather than the overland flow through the flood plain.

However, these higher velocities and subsequent erosion may cause bank and vegetation materials to enter the stream and alter the flow. In this way the process of erosion, flooding and subsequent material loss continues.

With mitigation measures in place, either through protection of the bank and channel or reduction in flow and velocity, this cycle of erosion and flooding may be reduced.

1.6 Flood Levels Many of the management practices that are discussed in this policy are based on the a various water levels based on a flow event, such as a 10-year , or 100-year event. As projects are implemented and studies of various waterways are completed updated event elevations will be published on a map in the appendix.

Where an engineering determination of the 100-year water level does not exist, the 100-year elevation will be defined as 2 feet above the mean top of bank elevation.

Where an engineering determination of the 10-year water level does not exist the 10-year elevation will be defined at the 4 feet above the channel bottom.

These elevations will be determined by staff and placed on the Surface Waters Map found in the appendix.

Section 2: Vulnerable Locations

Vulnerable locations

2.1 The first step mitigating potential damage from surface water is to evaluate areas along the stream course that would be vulnerable to failure. Once areas that can potentially be damaged by the surface water flow, or have the potential to alter the course of the water are identified, a plan for addressing these areas can be developed.

While some areas are easily identified as areas that can be affected by the flooding and erosion, other areas are not as readily apparent. This goal of this guide is to provide a method for property owners and design professionals alike to identify areas that may need mitigation or need to be monitored for a future improvement.

This goal of this guide is to aid in determining areas of concern before issues arise.

Should the guidance provided in this document be inadequate in determining that a location is vulnerable to a property owner, residents are encouraged to contact City of Mankato Public Works personnel for an evaluation.

Contact Public Works Personnel for areas of concern.

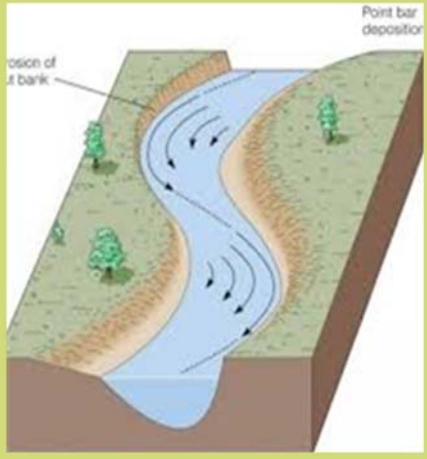
2.2 Determining vulnerable areas Locations can be determined to be vulnerable based on the discussion present in the prior section of this guide. Locations that should be evaluated include but are not limited to:

- areas where bank erosion is occurring or has a high potential to occur,
- areas where sensitive or erodible soils exist
- areas where large volumes of storm water are discharged
- areas of steep grades
- areas of dead and downed vegetation, especially trees
- areas where trees are out of plumb (later defined in the vegetation removal section of this manual)
- areas where trees are on or near the bank

Other areas that should be monitored are areas of active water ways at the base of a large hill or bank that is over 10 feet tall and areas near structures such as homes or sheds. .

2.2.1 Cut Banks One of the most noticeable areas for vulnerability is locations that are currently exhibiting signs of erosion. This can be at the base of the slope were the stream is actively removing material or an area that has fallen into the stream and experienced slope failure. If the material lost in these areas is frequently inundated with regular precipitation events or under steady state flow conditions, this is an area that would have high vulnerability.

These locations typically exist on cut banks, or the outside of a curve on a stream course.



Cut banks can be found on the outside of a bend or curve in a stream.

Other locations of concern would be where a storm sewer system discharges, or where two or more stream courses come together.

In certain locations within the City of Mankato, sensitive or highly erodible soils may exist. These soils are typically fine-grained sand or even silts or clays with a higher-than-normal sand content. Because these soils do not exhibit a high degree of cohesion they tend to erode easily. These areas may exhibit signs of groundwater moving through them which will also make them more vulnerable to failure.

2.2.2 Vegetation Other locations that should be monitored are areas where vegetation is growing within the stream channel or is overhanging the stream channel. This vegetation should be evaluated for removal if through erosion or saturated soil conditions the vegetation may fail and obstruct the flow of the stream.

Vegetation that has over 50% of its above ground mass over a waterway can be considered a vulnerable location.



Vegetation with over 50% of its mass over a waterway is a vulnerable location

Vegetation that is both alive and dead should be evaluated for its potential to negatively impact that stream.

Section 3: Managing Surface Waters

Best Management Practices

3.1 Management Strategies The City of Mankato's policy to managing surface water conveyance is to use a multi-faceted approach. The policy as presented by this document provides management strategies for personnel and property owners to protect property, prevent erosion and mitigate flooding.

Individually, each of these components of the management policy can make an effective improvement to a stream, but the best results will be realized when several of the strategies are combined to provide a sustainable surface water conveyance system.

BMPs

Best Management Practices (BMPs) are structural or non-structural devices and practices designed to protect streams and property to mitigate flooding, erosion, reduce pollution and provide other amenities.

3.1.1 Meander Corridor Meander Corridors will be established for surface waters within Mankato's jurisdiction. These will be a prescriptive practice for streams on public property. Streams that cross private property can voluntarily adopt this practice.

3.1.2 Vegetation Management Vegetation within the meander or other established corridors such as a drainage easement or defined floodplains will be managed in accordance with the policy on public property. Private property owners will be encouraged to adopt the same practice.

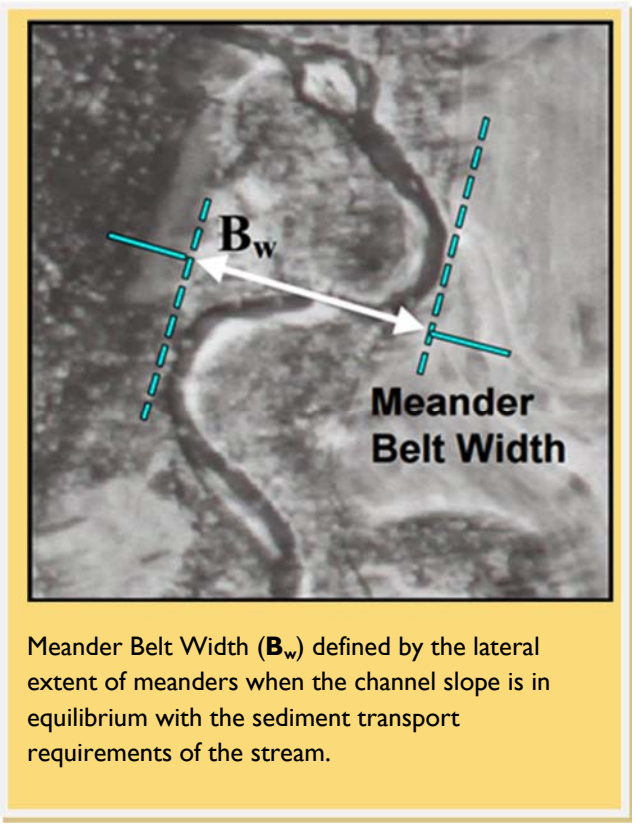
3.1.3 Reach and Watershed Improvements Capital improvement projects will be proposed that will address issues for a stream or ravine on a reach or watershed scale. These types of improvement will look at controlling surface waters on a larger scale. These will be individual projects that will be prioritized and included with the Community Investment Plan. Included in this section are improvements that are required or can be done as a part of a new or redevelopment project. The design requirements for these improvements are located in the Grading Manual and will provide the frame work for these types of projects.

3.1.4 Prescriptive Individual BMPs Prescribed activities or improvements that can be performed or installed at the individual property owner level and would require only minimum permitting and review. These prescribed activities allow property owners to make improvement to their desired level of service. These improvements can be done in conjunction with a City initiate project, or independently. Additionally cost sharing and financing options are available.

Meander Corridors

3.2 Meander Corridors The establishment of Meander Corridors for surface water would provide a defined area where the surface water would be allowed for nature to "take its course". This is the area that provides the physical space that the river needs to express its energy and meander without causing it to dig down.

The width of the corridor is defined by the lateral extent of the stream meanders, called the meander belt width, which is controlled by valley landforms, surficial geology, and the length and slope requirements of the stream channel.



Meander Belt Width ($\mathbf{B_w}$) defined by the lateral extent of meanders when the channel slope is in equilibrium with the sediment transport requirements of the stream.

Stable stream channels in equilibrium, erode and move in the landscape, but have the ability over time and in an unchanging climate, to transport the flow, sediment, and debris of their watersheds in such a manner that they generally maintain their channel geometry, meander pattern, and grade without deposition or erosion to the stream as a whole.

However, establishing channel equilibrium as a river management objective, demands a recognition that the geometry of certain stream channels, due to their location in the watershed, may be influenced by a net storage or net export of sediment in the reach.

Protecting river corridors as defined by the meander belt width of the equilibrium channel avoids conflicts with human land uses and minimizes investments and the need to conduct expensive channel management or stabilization activities. Failure to recognize the physical imperatives of stream systems and the land area that streams will occupy over time will require continual private and public investments to maintain this condition of dis-equilibrium. This is an unsustainable practice and will ultimately fail.

Some streams within Mankato are at or near balance. The power produced by flood flows and channel slope is not so great as to cause significant erosion of the stream bed, or so diminished as to cause a loss of sediment transport capacity and a deposition of sediment in the channel. In these cases, it is cost effective to simply prevent changes or allow improvements within the Meander corridor and avoid the eventual need to construct BMPs which become necessary to protect investments. These BMPs will ultimately change the streams length and slope, lead to channel adjustments, and increase erosion hazards.

For many of Mankato's ravines and streams, a combination of watershed, floodplain, and channel modifications over the past 100 years, has led to the major erosion concerns that are ongoing today. The initial stage of adjustment typically involved the bed scour and head-cutting associated with channel straightening and degradation. Steeper, straightened channels are now adjusting or "evolving" back into a gentler gradient, creating more sinuous channels through the erosion and depositions process. The narrower belt widths observed after straightening and excavation of the channel, which held for decades and encouraged human encroachment, have now begun to widen during recent floods as new sediments deposit and longer meanders develop putting human encroachments at risk.

The practice of dredging sediment to avoid flood hazards has typically worked until there is another flood. Berming and armoring may hold longer, but tend to cause the unbalanced condition to extend upstream and downstream. Such practices are unsustainable and will eventually unravel requiring extensive maintenance operations. A cost-effective, geomorphic approach would involve avoiding or minimizing encroachments and improvements in stream corridors.

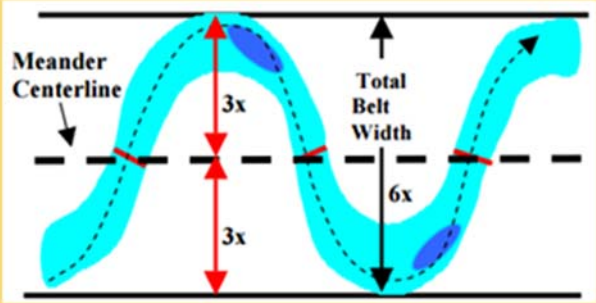
Corridors can be defined by applying fluvial geomorphic principles to calculate and predict the belt widths which

would accommodate the meanders and slope of equilibrium river channels.

3.2.1 Defining the Meander Corridor When streams are in dynamic equilibrium, sustainable meanders provide for the dissipation of the energy of moving water and the transportation of sediment. The fact that unconfined, single thread streams tend to follow a sinuous or meandering course is related to the characteristics of the channel. Laminar or turbulent flows can cause the selective erosion, transport, and deposition of bank and channel bed materials which produces a gradation of sediment sizes between areas of erosion and deposition. The combination and sequence of channel characteristics and flow types leads to the development of a sinuous channel with areas of change from laminar to turbulent flow causing the stream to change direction.

Researchers have developed meander geometry formulas that relate channel dimension with planform measurements. The work of G.P Williams in the paper *River Meanders and Channel Size* (Journal of Hydrology 88:147-164, 1986) is the basis for this formula. The relationship between channel width and the mender belt width is expressed by the formula $\mathbf{B=3.7W^{1.12}}$, where B is the meander belt width and W is the channel width in feet. This formula can be used for channels ranging in size from 4 to 13,000 feet in width.

This formula results in a meander width ratio approximately equal to six. Meander Corridors for streams with slopes in narrow to broad alluvial valleys (a majority of the streams in Mankato) should have corridors established that are six times the width of the stream channel.



Idealized representation of a Meander Corridor drawn to accommodate the meander belt width, measured out as parallel lines "3x channel width" either side a corridor centerline drawn through the centroid of the stream (dotted line)

Rarely does one find the idealized sinuosity shown in above. Streams in Mankato are usually less sinuous, many having been straightened to promote greater drainage capacity, efficiencies in agriculture practices or facilitate development. The Meander Corridor should still be established so it is 6 times the channel width, but may not be centered on the stream and it may need to be extended to one side of the stream or the other.

These corridors are not established with the expectation that river adjustments will occur and result in a perfect sine wave pattern which conforms to the calculated belt width. Rather, they provide an area within which channel adjustments may occur, in order to re-establish an equilibrium condition, and there can be a reasonable expectation that fluvial erosion hazards will be minimized.

The Meander Corridor may be adjusted beyond the guidance provided here to accommodate certain specific characteristics of a vulnerable location. This may include locations where there is existing private improvements or public infrastructure; areas with less erodible boundaries where the bank and channel material may not be as susceptible to erosion, or areas where the soils are extremely sensitive to erosion or slope failure.

3.2.2 Establishing Meander Corridors The establishment of Meander Corridors requires that all active surface water conveyances be mapped and an overall meander beltway be determined. Using the determined beltway width and shape the Meander Corridor can be established with respect of the constraints of the stream course.

In areas where the stream exists on public property, the entire parcel should be declared a part of the Meander Corridor and utilized to achieve a sustainable geometry for the stream to reach equilibrium. If through the development of the Meander Corridor the width of the corridor exceeds the public parcel width, the City should strive to establish drainage easements within the determined width of the calculated meander belt way. This ensures that a minimum of encroachments are present and a sustainable stream can be obtained.

Where streams exist on private property, the property owner should be made aware of the Meander Corridor and encouraged to voluntarily participate in establishing the corridor. This establishment would be accomplished by granting a drainage easement to the City of Mankato. As an incentive to property owners to grant an easement and operate the stream within a Meander Corridor, all maintenance activities as discussed in this policy will be

performed by the City of Mankato. If a property owner does not want to grant an easement for drainage and the establishment of a Meander Corridor for a stream course, then all maintenance activities, including emergency abatement of hazards, shall be the responsibility of the property owner. The City may correct any issues that are determined to be a nuisance condition within the stream and affecting public drainage, but that work will be assessed back to the property owner.

A map of areas where Meander Corridors will be established by this policy can be found as an appendix to this manual. The map provides the anticipated Meander Corridor, easement locations and property ownership type (public or private). As this policy is implemented this map will be amended as needed from time to time.

3.2.4 Corrective Actions If a stream course departs an established Meander Corridor, then an improvement should be performed to prevent any negative impact to adjacent property or infrastructure. If the departure is localized in nature then one of the prescriptive BMPs described in this policy should be used to mitigate further migration of the stream.

If the stream course departure from the Meander Corridor is taking place in multiple locations within a reach or, in the opinion of professional engineering personnel, cannot be corrected with a prescribed BMP, then a capital improvement project will need to be executed to correct the departure. These projects will be done on a watershed scale and are discussed more in the Reach and Watershed Improvements section of the policy.

Vegetation Management

3.3 Vegetation Management As a component of management of surface water conveyance systems, quality strategies for vegetation are critical. Management of vegetation is often one of the easier and more time sensitive activities that can take place along a stream to ensure proper function of the stream as well as mitigate and prevent negative impacts from the stream. By identifying desirable vegetation and maintaining it in vulnerable locations, a sustainable operation of the stream can be maintained.

The emphasis of this policy is to manage vegetation along surface ways that mimic native riparian wetland and upland buffer communities associated with streams. These communities include bottomland forests, marshes, oxbows and lowland prairies. Management of the vegetation within the floodplain of the stream requires an emphasis on management to promote the types of vegetation that are most beneficial for the overall health of the stream. Secondary uses and benefits for the vegetation should be considered, but should not be prioritized if the use or type of vegetation may negativity impact the stream.

3.3.1 Vegetation Management Goals The goal of the vegetation management is to prevent flooding, erosion and subsequent property damage due to vegetation failure and stream obstruction. To do this the types of vegetation that will be encouraged through maintenance and restoration practices along a stream will be native communities that are indigenous to floodplains and tolerate the flow regime of a particular waterway.

Vegetation management is necessary to eliminate potential floodplain, bank and channel erosion problems. This is done by providing graduated vegetation communities within the stream course. This includes grasses in the channel bottom and banks and deep rooted trees set back from top of bank but within the floodplain.

The function of the vegetation along the stream is to protect the stream from erosion of banks and channels, but also provide an area to filter any debris that may be entering the stream. This will reduce the chance that debris may restrict a culvert or passage within the system and cause flooding.

Vegetation also reduces flow velocities and mitigates erosion of the channel and the potential for channel growth and increased meanders.



Properly maintained vegetation provide many benefits along a stream course.

3.3.2 Vegetation Management Zone Vegetation management will take place within a designated

management zone. The recommended location for this management zone is within the 100 year floodplain. Ideally this zone will exist within the previously established Meander Corridor. Depending on channel geometry and peak flows the floodplain may exist outside the Meander Corridor. In these cases, the area managed for vegetation should be as close to the 100-year floodplain as possible. Depending on the available public ownership and access for vegetation management the minimum level management will take place within the 10-year event elevation.

3.3.3 Vegetation Removal Removal of certain types of vegetation is an importation part of maintaining a healthy plant community and functional stream system. As of part of this policy, several types of vegetation are recommended for removal in order to provide the highest level of sustainable operation of a stream as a surface water conveyance.

The first recommendation for removal of vegetation is to remove invasive, undesirable and weak species. Invasive plants can come in the form of trees, bushes or noxious weeds. The Minnesota Department of Natural Resources, the Minnesota Department of Transportation and Board of Soil and Water Resources provide literature as to the type of plants that fall into these categories.

In addition to invasive and noxious plants, other types of vegetation should be removed from the stream corridor as well. This would include soft wood trees such as silver maples, boxelder trees and cotton woods. These trees are often prone to limb loss and trunk failure. Such trees should not be promoted to grow along stream as they can shed woody debris into the stream and exacerbate flooding.

MnDOT provides an excellent resource on Noxious Weeds. It can be found at:

http://www.dot.state.mn.us/roadsides/vegetation/pdf/noxiousweeds.pdf

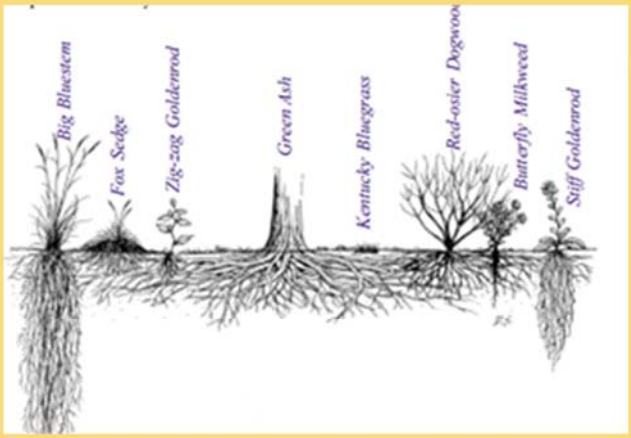
Other trees that should be removed included those that are out of plumb. These trees can be identified by more than half of the canopy or mass of the tree leans to one side of the base. These trees can be especially hazardous if they are between the top of the bank and the channel of a stream. When the root system or trunk fails, these trees will typically impede flow and negatively impact the stream resulting in erosion and flooding. These types of trees should be considered a priority for removal.

When possible, areas along the stream channel and banks should be afforded full sun or partial sun. This will allow for the greatest selection of grasses and native plants that will provide deep rooted soil stabilization within the active waterway. The width of this area should be the area that would be inundated by a 10-year event. The width of this area can be found on the Surface Waters Map found in the appendix. This also encourages removal of trees and other types of cover that do not provide dense ground coverage and soil reinforcement.

When trees or other woody vegetation is removed from a stream all of the debris created from the removal activities should be removed from the 100-year floodplain. This includes all branches, limbs and trunks. The stump however should be left in place in order to continue to reinforce the soil.

3.3.5 Vegetation Establishment When trees and other ground cover are removed from the channel area it allows adequate sunlight to encourage deep rooted grasses and sages to flourish and increase soil stability and minimize the disruption to the stream.

Determining the types of vegetation that should be maintained in this area, resources such as *Restoring & Managing Native Wetland & Upland Vegetation* (Jacobson, MN BSWR, MNDOT, 2006), or *Plants for Stormwater Design* (Shaw, Schmidt, MPCA, 2003) should be consulted.



Various species of plants have different root structures. Those that extend deep into the ground, and wide relative to the above ground mass are the most desirable.

The plant species provided in these resources and others like them are readily available in the area, were typically present in the Upper Midwest before European settlement, have desirable aesthetic properties, and will provide sustainable functionality with a stream.

These plants also do not contribute an appreciable amount of plant matter or debris to the waterway. This lessens the potential for blockage and subsequent flooding in the stream.

Since removal of some of the larger over grown vegetation may reduce the screening provided along a stream, additional plantings outside of the 100 year floodplain may be desired. Screening from evergreens, particularly Black Hills Spruce and hedges can be used to replace removed over growth.

3.3.6 Vegetation Maintenance In order to establish maintainable vegetation city personnel will need to initially inventory the vegetation within the various streams and creeks within Mankato. Once that inventory is complete projects to establish maintainable vegetation will be incorporated with the Community Investment Plan. These projects will work to address major reaches within the waterways. These vegetation projects may be recommended to be included with other type of improvements and repair projects to realize an economy of scale and minimize the disruption to the adjacent residents.

In areas where streams are on public property, or where easements have been provided, the City of Mankato will conduct regular inspections. These inspections will be on a three to five year basis depending on the vulnerability of certain vegetation, calls for service or where previous maintenance activities have occurred. Vegetation that is found to be deficient or non-beneficial to the operation of the surface water conveyance will be removed.

In areas where streams exist on private property, and no easement has been granted to the City to perform maintenance, it is encouraged that property owners follow the same guidelines in performing a project that brings the vegetation into a manageable condition and then begin regular maintenance to the vegetation. If no maintenance is performed and an obstruction occurs, the City may declare that obstruction a nuisance and abate it accordingly.

Once appropriate vegetation is established it will need to be maintained. The City will perform the required vegetation maintenance on public property and along streams that are within a public parcel or drainage easement. This maintenance will be part of the annual pond and stream maintenance program. This maintenance includes application of appropriate herbicides along with spot mowing and trimming to prevent weeds, invasive species and undesirable vegetation from establishing. This work will be performed on a regular basis with intervals ranging from three to five years, or as needed depending on evaluation by the engineering division.



Proper vegetation maintenance and management along a stream bank provides an effective way to manage surface water conveyances.

3.4 Reach and Watershed Improvements While establishment of Meander Corridors and proper vegetation management will minimize erosion and flooding within a surface waterway, some streams may have flows that are too great to be managed with these practices. To better manage these flows reach and watershed improvements are necessary. These types of projects are considered structural in natural, meaning that they attempt to control the flow or resist the erosive force of the water in the stream.

To provide an effective project that has high value, it is important that these types of the projects are performed on a larger scale. Such projects can include but are not limited to the construction of or improvement to stormwater ponds and wetlands; bank and channel armoring, storm sewer installation, and stream course or flow re-routing. Other improvements may be made as part of a development or redevelopment within a reach or watershed. Engineering division staff will determine if, as a part of development or redevelopment, a public improvement would complement of the proposed

project. If a project can be performed as a part of the development, then it will be included in the city's Community Investment Program.

These improvements are often large capital improvement projects that require substantial investment and have lead times that may span multiple months or even years. The development of these projects follow a multi-step process. Often time's areas of concern are identified by adjacent property owners. Once it is determined by city personnel that a large scale project is the best course of action a study will be conducted of the watershed or reach in question. Detailed hydraulic and hydrologic analysis of the waterway and soils evaluation will be performed as part of the study. The results will provide recommendations for projects that can be implemented to achieve the desired level of service for the waterway.

Once a project has been recommended it can be incorporated into the Community Investment Program for consideration with the budget. These projects often have a cost ranging from $500,000 to over $3 million. Funding for these projects typically is provided by the stormwater utility, but outside funding opportunities exist as well. The funds are provided by a variety of state agencies though the *Clean Water & Legacy Amendment and the Environment and Natural Resources Trust Fund.*

3.4.1 Potential Projects Public Works personnel have developed a list of example projects that have been evaluated at a planning level for cost and effectiveness and illustrate the type and magnitude of a reach or water shed project. These illustrative projects include:

1. Expansion of the Warren Street Pond
2. Wetland restoration and stormwater impoundment in the Rosewood Pond system
3. Channel cleaning and stabilization along Wilson Creek.
4. Culvert capacity improvements in Wilson Creek
5. Capacity improvements and bank stabilization in Premier Pond
6. Capacity improvements and bank stabilization in Thompson (Cloverleaf) Pond
7. Expansion of University Park Pond
8. Installation of pipe between Balcerzak Drive and Glenwood Avenue along Monks Avenue
9. Installation of pipe or channel stabilization along Barnes Creek
10. Channel cleaning and stabilization along Indian Creek.

Other projects will be identified and planned as necessary with an overall goal of minimizing the impact of urban drainage on natural waterways.

3.5 Prescriptive Individual BMPs In some instances property owners may want to take the opportunity to perform improvements in areas of concern or vulnerability on private property. In order to facilitate this investment, the City of Mankato has included approved Prescriptive Individual BMPs as well as a cost sharing program and financing options These BMPs can be installed by a property owner or their contractor to assist in stabilizing or restoring areas of vulnerability. These BMPs may be allowed to be installed within Meander Corridors with an appropriate level of engineering analysis, or elsewhere on private property. A land disturbance permit will be issued for all BMPs installed. The process for applying for a permit and installing prescriptive BMPs and the cost sharing program is located in Section 4 of this document.

City of Mankato
Best Management Practices

Engineering Division

Section 4: Best Management Practices

Best management practices presented in this manual are improvements that can be installed by property owners or their contractors to prevent erosion and flooding on private property. These improvements are prescriptive and will be permitted to be installed under a City of Mankato Land Disturbance Permit, which can be obtained on the city's website at www.mankatomn.gov. A site plan or sketch will be required to ensure that the installation does not negatively affect other property owners adjacent to the improvements.

The best management practices presented in this Manual may be implemented without engineering design .Other improvements are allowed by permit, but may require engineering design or other analysis to ensure that flows within the stream are not negatively impacted.

BMPs that are presented include:

- Check Dams
- Hydraulic Mulch
- Hydroseeding
- Wood mulch
- Velocity dissipation device
- Slope drain
- Geotextiles and mats
- Earth dikes and drainage swales
- Fiber rolls
- Gravel berm bags
- Rip rap
- Gabion baskets

Such items that may require additional engineering and review would include:

- Reinforced turf
- Engineered rip rap
- Bio-engineered or vegetation based solutions
- Changes in channel location, size or shape
- Storm sewer installation
- Weirs or other type of impoundment

Types of BMPs

4.1 Questions for Selecting BMPs

Question 1: **Land Use.** Which practices are best suited for the site? Should alternate uses be considered, or improvements relocated?

Question 2: **Physical Feasibility Factors.** Are there any physical constraints at the project site that may restrict or preclude the use of a particular BMP?

Question 3: **Climate/Regional Factors.** Are there any regional Characteristics that restrict or modify the use of certain BMPs?

Question 4: **Watershed Factors.** What watershed protection goals need to be met in the resource where my site drains?

Question 5: **Stormwater Management Capability.** Can one BMP meet all design criteria, or is a combination of practices needed?

Question 6: **Community and Environmental Factors.** Do BMPs have important community or environmental benefits or drawbacks that might influence the selection process?

In addition to the BMPs provided in this manual, the Minnesota Stormwater Manual provides an interactive guide to various BMPs as well. The stormwater manual is published by the Minnesota Pollution Control Agency and can be found at:

https://www.pca.state.mn.us/water/minnesotas-stormwater-manual

4.2 Installation process

To install a prescriptive BMP a property owner will need to create a basic site plan of the property where the improvement will be made. The best way to create a site plan is to find the property on the Blue Earth County's property information system at:

https://beacon.schneidercorp.com/

After finding the property a sketch of the improvement, either using the website tools or by hand on a printed sheet, should be made. With this site plan created an application to for a Land Disturbance Permit. A basic description of the permit can be found here:

https://www.mankatomn.gov/city-services-a-z/permits-and-licenses

The application can be downloaded here:

https://www.mankatomn.gov/home/showdocument?id=1546

Once the application is complete with the site plan it can be submitted to the City along with payment at the Intergovernmental Center, 10 Civic Center Plaza, Mankato MN 56001. Any questions regarding the permit

process can be directed to the 311 staff at 311 or 507-387-8600.

4.3 Cost sharing and financing

The city of Mankato recognizes that private investment in BMPs benefits not only the property owner making the investment, but the community as a whole. In order to foster the appropriate level of investment needed in many vulnerable locations a cost sharing and financing program has been developed. This program is to allow property owners to undertake an improvement that may not be addressed on within the time frame they desire or location that is out of the defined area of city maintenance.

4.3.1 Cost sharing

A cost sharing program is available to property owners who make improvements along surface waterways in conformance with this policy. This program will be dependent on the City Council appropriate funds as a part of the annual budget process. The funds will be available on a first come, first serve basis. This cost sharing program will provide funding for 25% of the cost of an improvement up to $5,000. In order to obtain the funds property owners should submit a cost sharing from for along with quotations for the work to be performed. Staff will review and approve the cost share application at the time of permit issuance. This is to ensure that adequate funds are available. Upon completion of the work to the property owner's satisfaction, a petition for private improvement will need to be submitted for work that is financed through an assessment. If the property owner is paying directly for the work, the cost sharing form will be updated with the final cost of the work and the cost share portion of the work will be remitted to the property owner.

4.3.1 Financing

Property owners may elect to have the cost of BMPs assessed and repay them as a part of their property taxes. Financing for The process to add one or all of these items to an assessment for a property is as follows:

1) Obtain a petition form from the engineering department.
2) Have the work completed by the contractor of the property owners choosing.
3) Submit the contractor bill and signed assessment form to the engineering department once the property owner is satisfied with the work.
4) The city will pay the bill and add the cost to the final assessment.
5) Property owners (not the contractor) need to complete and submit the petition forms.
6) Petition for extra work need to be submitted prior to adoption of the final assessment by the City Council.

CD: Check Dams



Description & Purpose

A check dam is a small barrier constructed of rock, gravel bags, sandbags, fiber rolls, or reusable products, placed across a constructed swale or drainage ditch. Check dams reduce the effective slope of the channel, thereby reducing the velocity of flowing water, allowing sediment to settle and reducing erosion.

Suitable Applications

Check dams may be appropriate in the following situations:

• To promote sedimentation behind the dam

• To prevent erosion by reducing the velocity of channel flow in small intermittent channels and temporary swales

• In small open channels that drain 10 acres or less

• In steep channels where stormwater runoff velocities exceed 5 feet per second

• During the establishment of grass linings in drainage ditches or channels

• In temporary ditches where the short length of service does not warrant establishment of erosion-resistant linings.

Limitations

• Not to be used in actively flowing streams or in channels with extended base flows

• Not appropriate in channels that drain areas greater than 10 acres

• Not appropriate in channels that are already grass-lined unless erosion is expected, as installation may damage vegetation

• Require extensive maintenance following high flows

• Promotes sediment trapping which can be re-suspended during subsequent storms or removal of the check dam.

Implementation

General

Check dams reduce the effective slope and create small pools in swales and ditches that drain 10 acres or less. Reduced slopes reduce the velocity of stormwater flows, thus reducing erosion of the swale or ditch and promoting sedimentation. Use of check dams for sedimentation will likely result in little net removal of sediment because of the small detention time and probable scour during larger storm events. Using a series of check dams will generally increase their effectiveness. A sediment trap (ST) may be placed immediately upstream of the check dam to increase sediment removal efficiency.

Design and Layout

Check dams work by decreasing the effective slope in ditches and swales. An important consequence of the reduced slope is a reduction in capacity of the ditch or swale. This reduction in capacity must be considered when using this BMP, as reduced capacity can result in overtopping of the ditch or swale and resultant consequences. In some cases, such as a "permanent " ditch or swale being constructed early and used as a "temporary" conveyance for construction flows, the ditch or swale may have sufficient capacity such that the temporary reduction in capacity due to check dams is acceptable. When check dams reduce capacities beyond acceptable limits, there are several options:

- Don't use check dams. Consider alternative BMPs
- Increase the size of the ditch or swale to restore capacity.

Maximum slope and velocity reduction is achieved when the toe of the upstream dam is at the same elevation as the top of the downstream dam. The center section of the dam should be lower than the edge sections so that the check dam will direct flows to the center of the ditch or swale.

Check dams are usually constructed of rock, gravel bags, sandbags, and fiber rolls. A number of products manufactured specifically for use as check dams are also being used, and some of these products can be removed and reused. Check dams can also be constructed of log or lumber, and have the advantage of a longer lifespan when compared to gravel bags, sandbags, and fiber rolls. Due to

their high failure rate, check dams should not be constructed from straw bales or silt fences, since concentrated flows quickly wash out these materials.

Rock check dams are usually constructed of 8 to 12 in. rock. The rock is placed either by hand or mechanically, but never just dumped into the channel. The dam must completely span the ditch or swale to prevent washout. The rock used must be large enough to stay in place given the expected design flow through the channel.

Log check dams are usually constructed of 4 to 6 in. diameter logs. The logs should be embedded into the soil at least 18 in. Logs can be bolted or wired to vertical support logs that have been driven or buried into the soil.

Gravel bag and sandbag check dams are constructed by stacking bags across the ditch or swale, shaped as shown in the drawing at the end of the BMP fact sheet.

Manufactured products should be installed in accordance with the manufacturer's instructions. If grass is planted to stabilize the ditch or swale, the check dam should be removed when the grass has matured (unless the slope of the swales is greater than 4%.

The following guidance should be followed for the design and layout of check dams:

- Install the first check dam approximately 16 feet from an outfall device and at regular intervals based on slope gradient and soil type.
- Check dams should be placed at a distance and height to allow small pools to form between each check dam.
- Backwater from a downstream check dam should reach the toes of the upstream check dam.
- A sediment trap provided immediately upstream of the check dam will help capture sediment. Due to the potential for this sediment to be re-suspended in subsequent storms, the sediment trap must be cleaned following each storm event.
- High flows (typically a 2-year storm or larger) should safely flow over the check dam without an increase in upstream flooding or damage to the check dam.
- Where grass is used to line ditches, check dams should be removed when grass has matured sufficiently to protect the ditch or swale.
- Gravel bags may be used as check dams with the following specifications:

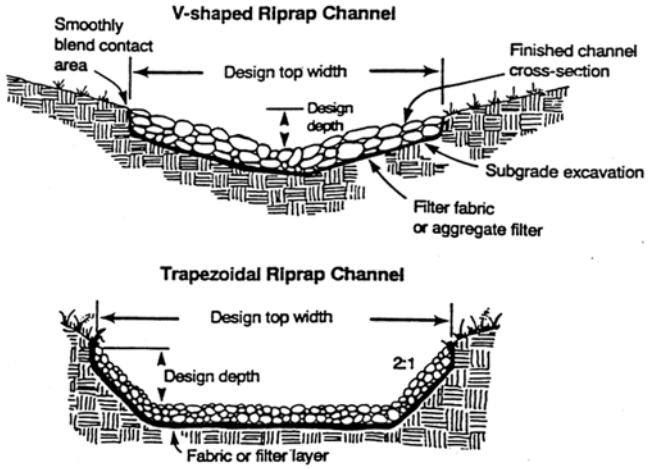
Materials
Gravel bags used for check dams should conform to the requirements of GB, Gravel Bag Berms. Sandbags used for check dams should conform to SB, Sandbag Barrier. Fiber rolls used for check dams should conform to FR, Fiber Rolls.

Installation

- Rock should be placed individually by hand or by mechanical methods (no dumping of rock) to achieve complete ditch or swale coverage.
- Tightly abut bags and stack according to detail shown in the figure at the end of this section.
- Gravel bags and sandbags should not be stacked any higher than 3 feet.
- Fiber rolls and straw bales must be trenched in and firmly staked in place.

Inspection and Maintenance

- Inspect BMPs prior to forecast rain, daily during extended rain events, after rain events, weekly during the rainy season, and at two-week intervals during the non-rainy season.
- Replace missing rock, bags, bales, etc. Replace bags or bales that have degraded or have become damaged.
- If the check dam is used as a sediment capture device, sediment that accumulates in the BMP must be periodically removed in order to maintain BMP effectiveness. Sediment should be removed when the sediment accumulation reaches one-third of the barrier height.
- Sediment removed during maintenance may be incorporated into earthwork on the site or disposed at an appropriate location.
- If the check dam is used as a grade control structure, sediment removal is not required as long as the system continues to control the grade.
- Remove accumulated sediment prior to permanent seeding or soil stabilization.
- Remove check dam and accumulated sediment after areas upstream of the check dam have been fully stabilized and no longer have the potential to erode.





Do. *Properly installed series of check dams creating settling ponds and slowing water velocity.*



Don't. *Straw or Hay bales should not be used as check dams. Even if "properly" installed, they have a high failure rate.*

Hydraulic Mulch

Description & Purpose

Hydraulic mulch consists of applying a mixture of shredded wood fiber of a hydraulic matrix, and a stabilizing emulsion of tackifier with hydro-mulching equipment, which temporarily protects exposed soil from erosion by raindrop impact or wind.

Suitable Applications

Hydraulic Mulching may be appropriate in the following situations:

- Disturbed areas requiring temporary protection until permanent stabilization is established
- Disturbed areas that will be re-disturbed following an extended period of time.

Limitations

- Hydraulic mulches are generally short lived
- A minimum of 24 hours is required for drying before effective
- May required more than one application to last a full rainy season

Implementation

General
Prior to application, roughen embankment and fill areas by rolling crimping or punching type roller or by track walking. Track walking shall only be used where other methods are impractical.

To be effective, hydraulic matrices require 24 hours to dry before rainfall occurs.

Avoid mulch spray onto roads, sidewalks, drainage channels, existing vegetation, etc.

Paper based hydraulic mulches alone shall not be used for erosion control.

Hydraulic Mulches

Wood fiber mulch can be applied alone or as a component of hydraulic matrices. Wood fiber applied alone is typically applied at the rate of 2,000 to 4,000 lb/acre. Wood fiber mulch is manufactured from wood or wood waste from lumber mills or from urban sources.

Hydraulic Matrices

Hydraulic matrices include a mixture of wood fiber and acrylic polymer or other tackifier as binder. Apply as a liquid slurry using a hydraulic application machine (i.e. hydro seeder) at the following minimum rates, or as specified by the manufacturer to achieve complete coverage of the target area: 2,000 to 4,000 lbs/acre wood fiber mulch, and 5 to 10% (by weight) of tackifier (acrylic copolymer, guar, psyllium, etc.)

Bonded Fiber Matrix
Bonded fiber matrix (BFM) is a hydraulically applied system of fibers and adhesives that upon drying forms an erosion resistant blanket that promotes vegetation, and prevents soil erosion. BFM's are typically applied at rates from 3,000 lb/acre to 4,000 lb/acre based on the manufacturer's recommendation. A biodegradable BFM is composed of materials that are 100% biodegradable. The binder in the BFM should also be biodegradable and should not dissolve or disperse upon re-wetting. Typically, biodegradable BFM's should not be applied immediately before, during or immediately after rainfall if the soil is saturated. Depending of the product, BFMs typically require 12 to 24 hours to dry and become effective.

Inspection and Maintenance

- Inspect BMP's prior to forecast rain, daily during extended rain events, after rain events, weekly during the rainy season, and at two-week intervals during the non-rainy season.
- Areas where erosion is evident shall be repaired and BMP's re-applied as soon as possible. Care should be exercised to minimize the damage to protected areas while making repairs, as any area damaged will require re-application of BMPs.
- Maintain an unbroken, temporary mulched ground cover throughout the period of construction.

HS: Hydroseeding



Description & Purpose

Hydroseeding typically consists of applying a mixture of wood fiber, seed fertilizer, and stabilizing emulsion with hydro-mulch equipment, to temporarily protect exposed soils from erosion by water and wind.

Suitable Applications

Hydroseeding may be appropriate in the following situations:

- Disturbed areas requiring temporary protection until permanent stabilization is established
- Disturbed areas that will be re-disturbed following an extended period of time.

Limitations

- May be used alone only when there is sufficient time in the season to ensure adequate vegetation establishment and coverage to provide adequate erosion control. Otherwise, hydroseeding must be used in conjunction with mulching (i.e. straw mulch).
- Steep slopes are difficult to protect with temporary seeding
- Temporary seeding may not be appropriate in dry periods without supplemental irrigation
- Temporary vegetation may have to be removed before permanent vegetation is applied
- Temporary vegetation is not appropriate for short term inactivity.

Implementation

General

In order to select appropriate hydroseeding mixtures, an evaluation of site conditions shall be performed with respect to:

- Soil Condition
- Site Topography
- Season and climate
- Vegetation types
- Maintenance requirements
- Sensitive adjacent areas
- Water availability
- Plans for permanent vegetation

The local office of the U.S.D.A. Natural Resource Conservation Service (NRCS) is an excellent source of information on appropriate seed mixes.

The following steps shall be followed for implementation:

- Avoid use of hydroseeding in areas where the BMP would be incompatible with future earthwork activities and would have to be removed.
- Hydroseeding can be accomplished using a multiple step or one step process. The multiple step process ensures maximum direct contact of the seeds to soil. When the one step process is used to apply the mixture of fiber, seed, etc, the seed rate shall be increased to compensate for all seeds not having direct contact with the soil.
- Prior to application, roughen the area to be seeded with the furrows trending along the contours.
- Apply a straw mulch to keep seeds in place and to moderate soil moisture and temperature until the seeds germinate and grow.
- Commercial fertilizer shall conform to the current rules. Fertilizers shall be pelleted or granular form.
- Follow up applications shall be made as needed to cover weak spots and to maintain adequate soil protection.
- Avoid over spray onto roads, sidewalks, drainage channels, existing vegetation, etc.

Inspection and Maintenance

- Inspect BMP's prior to forecast rain, daily during extended rain events, after rain events, weekly during the rainy season, and at two-week intervals during the non-rainy season.
- Areas where erosion is evident shall be repaired and BMP's re-applied as soon as possible. Care should be exercised to minimize the damage to protected areas while making repairs, as any area damaged will require re-application of BMPs.
- When seeds fail to germinate, or where they germinate and then die, the area must be re-seeded, fertilized, and mulched within the planting season, using not less than half the original application rates.
- Irrigation systems, if applicable, should be inspected daily while in use to identify system malfunctions and line breaks. When line breaks are detected, the system must be shut down immediately and breaks repaired before the system is put back into operation.
- Irrigation systems shall be inspected for complete coverage and adjusted as needed to maintain complete coverage.

WM: Wood Mulch



Description & Purpose

Wood mulching consists of applying a mixture of shredded wood mulch, bark or compost to disturbed soils. The primary Function of wood mulching is to reduce erosion by protecting bare soil from rainfall impact, increasing infiltration, and reducing runoff.

Suitable Applications

Wood Mulching may be appropriate in the following situations:

- A disturbed area requiring temporary protection until permanent stabilization is established.

Limitations

- Not suitable for use on slopes steeper than 3:1 (H:V). Best suited to flat areas or gentle slopes or 5:1(H:V) or flatter
- Wood much and compost may introduce unwanted species.
- Not suitable for areas exposed to concentrated flows.
- May need to be removed prior to additional earthwork.

Implementation

Mulch Section

There are many types of mulches. Selection of the appropriate types of mulch should be based on the type of application, site condition, and compatibility with planned or future uses. It is recommended that that material used be free of mold, dirt, sawdust or other foreign material or decomposing. Also muclsh should not be made from manufactured boards, such as plywood, or chemically treated wood.

Application Procedure

Prior to application, existing vegetation has been removed, roughen embankment and fill areas by rolling with a device such as a punching type roller or by track walking. The construction application procedures for mulches vary significantly depending upon the type of mulching method specified. Two methods are highlighted here:

- Green Material – This type of mulch is produced by the recycling of vegetation trimmings such as grass, shredded shrubs, and trees. Methods of application are generally by hand although pneumatic methods are available.
    - Green material can be used as a temporary ground cover with or without seeding.
    - The green material should be evenly distributed on site to a depth not more than 2 in.
- Shredded Wood – Suitable for ground cover in ornamental or revegetated plantings.
    - Shredded wood/bark is conditionally suitable. See note under limitations.
    - Distribute by hand or use pneumatic methods.
    - Evenly distribute the mulch across the soil surface to a depth of 2 to 3 in.
- Avoid mulch placement onto roads, sidewalks, drainage channels, existing vegetation, etc.

Inspection and Maintenance

- Inspect BMP's prior to the forecast of rain, daily during extended rain events, after rain events, weekly during the rainy season, and at two-week intervals during the non-rainy season.
- Areas where erosion is evident shall be repaired and BMP's re-applied as soon as possible. Care should be exercised to minimize the damage to protected areas while making repairs, as any area damaged will require re-application of BMPs.
- Regardless of the mulching technique selected, the key consideration in inspection and maintenance is that the mulch needs to last long enough to achieve erosion control objectives. If the mulch is applied as a standalone erosion method over disturbed areas (without seed), it should last the length of time the site will remain barren or until final re-grading and revegetation.
- Where vegetation is not the ultimate cover, such as ornamental and landscape application of mulch or wood chips, inspection and maintenance should focus on longevity and integrity of the mulch
- Reapply mulch when bare earth becomes visible.

VD: Velocity Dissipation Devices



Description & Purpose

Outlet protection is a physical device composed of rock or grouted riprap, which is placed at the outlet of a pipe or channel to prevent scour of the soil caused by concentrated, high velocity flows.

Suitable Applications

Velocity dissipation devices are required in the following situations:

- Whenever discharge velocities and energies at the outlets of culverts, conduits, or channels are sufficient to erode the next downstream reach.

Velocity dissipation devices may be used at the following locations:

- Outlets of pipes, drains, culverts, slope drains, diversion ditches, swales, and conduits into channels.
- Outlets located at the bottom of mild to steep slopes.
- Tile line discharged into channels or ravines.
- Discharge outlets that carry continuous flows of water.
- Outlets subject to short, intense flows of water, such as flash floods.
- Points where lined conveyances discharge into unlined conveyances.

Limitations

- Large storms or high flows may wash away the rock outlet protection and leave the area susceptible to erosion.
- Sediment captured by the rock outlet protection may be difficult to remove without removing the rock.
- Outlet protection may negatively impact the channel habitat.
- Grouted riprap may break up in areas of freeze thaw.
- If there is not adequate drainage, and water builds up behind grouted riprap, it may cause the grouted riprap to break up due to the resulting hydrostatic pressure

Implementation

General

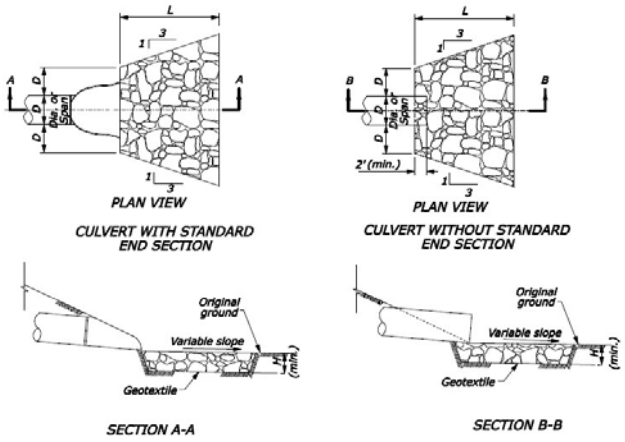
Outlet protection is needed where discharged velocities and energies at the outlets of culverts, conduits, or channels are sufficient to erode the immediate downstream reach. This practice protects the outlet from developing small eroded pools (plunge pools), and protects against gully erosion resulting from scouring at a culvert mouth.

Design and Layout

As with most channel design projects, depth of flow, roughness, gradient, side slopes, discharge rate, and velocity should be considered in the outlet design. Compliance to local and state regulations should also be considered while working in environmentally sensitive streambeds. General recommendations for rock size and length of outlet protection mat are shown in the rock outlet protection figure in this BMP and should be considered minimums. The apron length and rock size gradation are determined using a combination of the discharge pipe diameter and estimated discharge rate: Select the longest apron length and largest rock size suggested by the pipe size and discharge rate. Where flows are conveyed in open channels such as ditches and swales, use the estimated discharge rate for selecting the apron length and rock size. Flows should be same as the culvert or channel design flow but never less than the peak 5-year flow for temporary structures planned for one rainy season, or the 10-year peak flow for temporary structures planned for two or three rainy seasons.

- There are many types of energy dissipaters, with rock being the one that is represented in the attached figure.
- Best results are obtained when sound, durable, and angular rock is used.
- Install riprap, grouted riprap, or concrete apron at selected outlet. Riprap aprons are best suited for temporary use during construction. Grouted or wired tied rock riprap can minimize maintenance requirements.
- Rock outlet protection is usually less expensive and easier to install than concrete aprons or energy dissipaters. It also serves to trap sediment and reduce flow velocities.
- Excavate and grade outlet area as necessary

- Place filter fabric.
- Carefully place riprap to avoid damaging filter fabric.
    - Stone 4 in. to 6 in. may be carefully dumped onto filter fabric from a height not to exceed 12 in.
    - Stone 8 in. to 12 in. must be hand placed onto filter fabric, or the filter fabric may be covered with 4 in. of gravel and the 8 in. to 12 in. rock may be dumped from a height not to exceed 16 in.
    - Stone greater than 12 in. shall only be dumped onto filter fabric protected with a layer of gravel with a thickness equal to one half the D50 rock size, and the dump height limited to twice the depth of the gravel protection layer thickness.
- For proper operation of apron: Align apron with receiving stream and keep straight throughout its length. If a curve is needed to fit site conditions, place it in the upper section of the apron.
- Outlets on slopes steeper than 10 percent should have additional protection.



Insert something like: Details showing the recommended riprap placement at pipe outlets are included at the end of this section. Dimensions for length and depth of riprap apron are provided in the MPCA's Stormwater Manual. Main Page > Sediment control practices - Outlet energy dissipation

Inspection and Maintenance

- Inspect BMPs prior to the forecast of rain, daily during extended rain events, after rain events, weekly during the rainy season, and at two-week intervals during the non-rainy season.
- Inspect BMPs subjected to non-stormwater discharges daily while non-stormwater discharge occurs.
- Inspect aprons for displacement of the riprap and damage to the underlying fabric. Repair fabric and replace riprap that has washed away. If riprap continues to wash away, consider using larger material.
- Inspect for scour beneath the riprap and around the outlet. Repair damage to slopes or underlying filter fabric immediately.
- Temporary devices should be completely removed as soon as the surrounding drainage area has been stabilized or at the completion of construction.

SD: Slope Drain



Description & Purpose

A channel that is graded on a slope to intercept surface flows and direct them to a single point of discharge. The channel is graded at an angle to the face of the slope. This channel should be lined with mattings of natural materials that are used to cover the soil surface to reduce erosion from rainfall impact, hold soil in place, and absorb and retain moisture near the soil surface. Additionally, matting may be used to stabilize soils until vegetation is established.

A pipe slope drain can also be installed. This is similar to the channel method, but uses a perforated pipe in drain rock rather than a graded channel. This can be used in locations where the appearance or landscaping of the slope should not be interrupted.

Suitable Applications

Slope drain may be appropriate where:

- Concentrated flow of surface runoff must be conveyed down a slope in order to prevent erosion.
- Drainage for top of slope diversion dikes or swales.
- Drainage for top of cut and fill slopes where water can accumulate.
- Emergency spillway for a sediment basin.

Limitations

Installation is critical for effective use of the pipe slope drain to minimize potential gully erosion.

- Maximum drainage area per slope drain is 10 acres. (For large areas use a paved chute, rock lined channel, or additional pipes.)
- Severe erosion may result when slope drains fail by overtopping, piping, or pipe separation.
    - During large storms, pipe slope drains may become clogged or over charged, forcing water around the pipe and causing extreme slope erosion.
    - If the cross-section of the slope drain is not sized correctly, the runoff can spill over the drain sides causing gully erosion and potential failure of the structure.
- Dissipation of high flow velocities at the pipe outlet is required to avoid downstream erosion.

Implementation

General

The slope drain is applicable for any construction site where concentrated surface runoff can accumulate and must be conveyed down the slope in order to prevent erosion. The slope drain is effective because it prevents the stormwater from flowing directly down the slope by confining all the runoff into an enclosed pipe or channel.

Due to the time lag between grading slopes and installation of permanent stormwater collection systems and slope stabilization measures, temporary provisions to intercept runoff are sometimes necessary. Particularly in steep terrain, slope drains can protect unstabilized areas from erosion.

Design and Layout

The capacity for temporary drains should be sufficient to convey at least the peak runoff from a 10-year rainfall event. The pipe or channel size may be computed using the Rational Method.. Higher flows must be safely stored or routed to prevent any offsite concentration of flow and any erosion of the slope. The design storm is purposely conservative due to the potential impacts associated with system failures.

As a guide, temporary pipe slope drains should not be sized smaller than shown in the following table:

Minimum Pipe Diameter (inches)	Maximum Drainage Area (Acres)
4	1.0
6	3.0
8	5.0
10	7.0
12	10.0

Larger drainage areas can be treated if the area can be subdivided into areas of 10 acres or less and each area is treated as a separate drainage.

Materials

Soil type, rainfall patterns, construction schedule, local requirements, and available supply are some of the factors to be considered when selecting materials. The following types of slope drains are commonly used:

- Rigid Pipe – This type of slope drain is also known as a pipe drop. The pipe usually consists of corrugated metal pipe or rigid plastic pipe. The pipe is placed on undisturbed or compacted soil and secured onto the slope surface or buried in a trench. Concrete thrust bocks must be used when warranted by the calculated thrust forces. Collars should be properly installed and secured with metal strapping or watertight collars.
- Flexible Pipe – The flexible pipe slope drain consists of a flexible tube of heavy-duty plastic, rubber, or composite material. The tube material is securely anchored onto the slope surface. The tube should be securely fastened to the metal inlet and outlet conduit sections with metal strappings or watertight collars.
- Section Downdrains – The section downdrain consists of pre-fabricated, section conduit or half round or third round material. The sectional downdrain performs similar to a flume or chute. The pipe must be placed on undisturbed or compacted soil and secured into the slope.
- Concrete-lined Terrace Drain – This is a concrete channel for draining water from a terrace on a slope to the next level. These drains are typically specified as permanent structures and, if installed early, can serve as slope drains during construction, which should be designed according to local drainage design criteria.

Installation

The slope drain may be a rigid pipe, such as corrugated metal, a flexible conduit, or a lined terrace drain with the inlet placed on the top of the slope and outlet at the bottom of the slope. This BMP typically is used in combination with a diversion control, such as an earth dike or drainage swale at the top of the slope.

The following criteria must be considered when sighting slope drains:

- Permanent structures included in the project plans can often serve as construction BMPs if implemented early. However, the permanent structures must meet or exceed the criteria for the temporary structure.
- Inlet structures must be securely entrenched and compacted to avoid severe gully erosion.
- Slope drains must be securely anchored to the slope and must be adequately sized to carry the capacity of the design storm and associated forces.
- Outlets must be stabilized with riprap, concrete or other type of energy dissipater, or directed into a stable sediment trap or basin. See VD, Velocity Dissipation Devices.
- Debris racks are recommended at the inlet, Debris rack located several feet upstream of the inlet can usually be larger than racks at the inlet, and thus provide enhanced debris protection and less plugging.
- Safety racks are also recommended at the inlet and outlet of pipes where children and animals could become entrapped.



Do. Properly installed slope drain to ensure erosion of the slope will not occur

- Secure inlet and surround with dikes to prevent gully erosion and anchor pipe slope.
- When using slope drains, limit drainage area to less than 10 acres per pipe. For larger areas, use a rock lined channel or a series of pipes.
- Size to convey at least the peak flow of a 10-year storm. The design storm is conservative due to the potential impact of system failures.
- Maximum slope generally limited to 2:1 (H:V) as energy dissipation below steeper slopes is difficult.
- Direct surface runoff to slope drains with interceptor dikes. See BMP ED, Earth Dikes and Drainage Swales. Top of interceptor dikes should be 12 in. higher than the top of the slope drain.
- Slope drains can be placed on or buried underneath the slope surface.
- Recommended materials include both metal and plastic pipe, either corrugated or smooth wall. Concrete pipe can also be used.
- When installing slope drains:
    - Install slope drains perpendicular to slope contours.
    - Compact soil around and under entrance, outlet, and along length of pipe.
    - Securely anchor and stabilize pipe and appurtenances into soil.

- Check to ensure that pipe connections are watertight.
- Protect area around inlet with filter fabric cloth. Protect outlet with riprap or other energy dissipation device. For high energy discharges, reinforce riprap with concrete or use reinforced concrete device. See BMP VD Velocity Dissipation Devices.
- Protect outlet of slope drains using a flared end section when outlet discharges to a flexible energy dissipation device.
- A flared end section installed at the inlet will improve flow into the slope drain and prevent erosion at the pipe entrance. Use a flared end section with a 6 in. minimum toe plate to help prevent undercutting. The flared section should slope towards the pipe inlet.

Inspection and Maintenance

- Inspect BMPs prior to the forecast of rain, daily during extended rain events, after rain events, weekly during the rainy season, and at two-week intervals during the non-rainy season.
- Inspect BMPs subjected to non-stormwater discharges daily while non-stormwater discharge occurs.
- Inspect outlet for erosion and downstream scour. If eroded, repair damage and install additional energy dissipation measures. If downstream scour is occurring, it may be necessary to reduce flows being discharged into the channel unless preventative measures are implemented.
- Inspect inlet for clogging or undercutting. Remove debris from inlet to maintain flows. Repair undercutting at inlet and if needed, install flared section or riprap around the inlet to prevent further undercutting.
- Inspect pipes for leakage. Repair leaks and restore damaged slopes.
- Inspect slope drainage for accumulations of debris and sediment.
- Remove built up sediment from entrances and outlets as required. Flush drains if necessary; capture and settle out sediment from discharge.
- Make sure water is not ponding onto inappropriate areas (e.g., active traffic lanes, material storage areas, etc.)
- Pipe anchors must be checked to ensure that the pipe remains anchored to the slope. Install additional anchors if pipe movement is detected.

GM: Geotextiles and Mats



Description & Purpose

Mattings of natural or synthetic materials are used to cover the soil surface to reduce erosion from rainfall impact, hold soil in place, and absorb and hold moisture near the soil surface. Additionally, matting may be used to stabilize soils until vegetation is established. These mats allow for the establishment of vegetation in areas that do not have constant flow and vegetation establishment and maintenance is desired.

Suitable Applications

Geotextiles and Mats may be suitable in the following situations:

- Short, steep slopes where erosion hazard is high and vegetation will be slow to establish.
- Stream banks where moving water at velocities between 3 fps and 6 fps are likely to wash out new vegetation.
- In areas where the soil surface is disturbed and where existing vegetation has been removed.
- When seeding cannot occur (e.g., late season construction and/or the arrival of an early rain season).
- When the soils are fine grained and potentially erosive. These measures should be considered in the following situations:
    - Steep slopes, generally steeper than 3:1 (H:V).
    - Slopes where the erosion potential is high.
    - Slopes and disturbed soils where mulch must be anchored
    - Disturbed areas where plants are slow to develop.
    - Channels with flows exceeding 3.3 fps.
    - Channels to be vegetated.
    - Stockpiles.
    - Slopes adjacent to water bodies of Environmentally Sensitive Areas (ESAs).

Limitations

- Properly installed mattings provide excellent erosion control but do so at relatively high cost. This high cost typically limits the use of mattings to areas of concentrated channel flow and steep slopes.
- Mattings are more costly that other BMP practices, limiting their use to areas where other BMPs are ineffective (e.g., channel, steep slopes).
- Installation is critical and requires experienced contractors. The contractor should install the matting material in such a manner that continuous contact between the material and the soil occurs.
- Geotextiles and Mats may delay seed germination, due to reduction in soil temperature.
- Blankets and mats are generally not suitable for excessively rocky sites or areas where the final vegetation will be mowed (since staples and netting can catch in mowers).
- Blankets and mats may need to be removed and disposed of prior to application of permanent soil stabilization measures depending on the manufacture's recommendations.
- Plastic sheeting is easily vandalized, easily torn, photodegradable, and must be disposed of at a landfill.
- Plastic results in 100% runoff, which may cause serious erosion problems in the areas receiving the increased flow.
- The use of plastic should be limited to covering stockpiles or very small graded areas for short periods of time (such as through on imminent storm event) until alternative measures, such as seeding and mulching, may be installed
- Geotextiles, mats plastic covers, and erosion control covers have maximum flow rate limitations; consult the manufacturer for proper selection.
- Not suitable for areas that have heavy foot traffic (tripping hazard) – e.g., pad areas around buildings under const.

Implementation

Material Selection

Organic matting materials have been found to be effective where re-vegetation will be provided by re-seeding. The choice of matting should be based on the size of area, side slopes, surface conditions such as hardness, moisture weed growth, and availability of materials. The following natural and synthetic mattings are commonly used:

Geotextiles

- Material should be a woven polypropylene fabric with minimum thickness of 0.06 in., minimum width of 12 ft and should have minimum tensile strength of 150 lbs (warp), 80 lbs (fill) in conformance with the requirements in ASTM Designation: D4355. Geotextile blankets must be secured in place with wire staples or sandbags and be keying into tope of slopes to prevent infiltration of surface waters under geotextile. Staples should be made of minimum 11 gauge steel wire and should be U-shaped with 8 in. legs and 2 in. crown.
- Geotextiles may be reused if they are suitable for the use intended.

Plastic Covers

- Plastic sheeting should have a minimum thickness of 6 mils, and must be keyed in at the top of slope and firmly held in place with sandbags or other weights placed no more than 10 ft apart. Seams are typically taped or weighted down their entire length, and there should be at least a 12 in. to 24 in. overlap of all seams. Edges should be embedded a minimum of 6 in. in the soil.
- All sheeting must be inspected periodically after installation and after significant rainstorms to check for erosion, undermining, and anchorage failure. Any failures must be repaired immediately. If washout or breakage occurs, the material should be re-installed after repairing the damage to the slope.

Erosion Control Blankets/Mats

- Biodegradable rolled erosion control products (RECPs) are typically composed of jute fibers, curled wood fibers, straw, coconut fiber, or a combination of these materials.
    - Jute – a natural fiber that is made into a yarn that is loosely woven into a biodegradable mesh. It is designed to be used in conjunction with vegetation and has longevity of approximately one year. The material is supplied in rolled strips, which should be secured to the solid ground with u-shaped staples or stakes in accordance with manufacturer's recommendations.
    - Excelsior – (curled wood fiber) blanket material should consist of machine produced mats of curled wood excelsior with 80% of the fiber 6 in. or longer. The excelsior blanket should be of consistent thickness. The wood fiber must be evenly distributed over the entire area of the blanket. The top surface of the blanket should be covered with a photodegradable extruded plastic mesh. The blanket should be smolder resistant without the use of chemical additives and should be non-toxic and non-injurious to plant and animal life. Excelsior blankets should be furnished in rolled strips, a minimum of 48 in. wide and should have an average weight of 0.8 lb/yd2, ±10%, at the time of manufacture. Excelsior blankets must be secured in place with wire staples. Staples should be made of minimum 11 gauge steel wire and should be U-shaped with 8 in. legs and 2 in. crown.
    - Straw Blanket – Should be machine produced mats of straw with lightweight biodegradable netting top layer. The straw should be attached to the netting with biodegradable thread or glue strips. The straw blanket should be of consistent thickness. The straw should be evenly distributed over the entire area of the blanket. Straw blanket should be furnished in rolled strips a minimum of 6 ft wide, a minimum of 80 ft long and a minimum of 0.5 lb/yd2. Straw blankets must be secured in place with wire staples. Staples should be made of minimum 11 gauge steel wire and should be U-shaped with 8 in. legs and 2 in. crown.
    - Wood Fiber Blanket – Composed of biodegradable fiber mulch with extruded plastic netting held together with adhesives. The material is designed to enhance re-vegetation. The material is furnished in rolled strips, which must be secured to the ground with U-shaped staples or stakes in accordance with manufactures' recommendation.
    - Coconut Fiber Blanket – Should be machine produced, 100% coconut fiber with biodegradable netting on the top and bottom. The coconut fiber should be attached to the netting with biodegradable thread or glue strips. The coconut fiber blanket should be of consistent thickness. The coconut fiber should be furnished in rolled strips with a minimum of 6. ft wide, a minimum of 80 ft long and a minimum of 0.5 lb/yd2. Coconut fiber blankets must be secured in place with wire staples. Staples should be made of minimum 11 gauge steel wire and should be U-shaped with 8 in. legs and 2 in. crown.
    - Coconut Fiber Mesh – A thin permeable membrane made from coconut or coir? fiber that is spun into a yarn and woven into a biodegradable mat. It is designed to be used in conjunction with vegetation and typically

has a longevity of several years. The material is supplied in rolled strips, which must be secured to the soil with U-shaped staple of stakes in accordance with manufacturers' recommendations.

- Straw Coconut Fiber Blanket – Should be machine produced mats of 70% straw and 30% coconut fiber with a biodegradable netting top layer and a biodegradable bottom net. The straw and coconut fiber should be attached to the netting with biodegradable thread or glue strips. The straw coconut fiber blanket should be of consistent thickness. The straw and coconut fiber blanket should be evenly distributed over the entire area of the blanket. Straw coconut fiber blanket should be furnished in rolled strips a minimum of 6.5 ft wide, a minimum of 80 ft long and a minimum of 0.5 lbs/yd2. Straw coconut fiber blankets must be secured in place with wire staples. Staples should be made of minimum 11 gauge steel wire and should be U-shaped with 8 in. legs and 2 in. crown.

- Non-biodegradable rolled erosion control products (RECPs) are typically composed of polypropylene, polyethylene, nylon or other synthetic fibers. In some cases, a combination of bio degradable and synthetic fibers is used to construct the RECP. Netting used to hold these fibers together is typically non-biodegradable as well.
  - Plastic Netting – Is a lightweight biaxially oriented netting designed for securing loose mulches like straw or paper to soil surfaces to establish vegetation. The netting is photodegradable. The netting supplied in rolled strips, which must be secure with U-shaped staples or stake in accordance with the manufactures' recommendations.
  - Plastic Mesh – An open weave geotextile that is composed of an extruded synthetic fiber woven into a mesh with an opening size of less than ¼ in. It is used with re-vegetation or may be used to secure loose fiber such as straw to the ground. The material supplied in rolled strips, which must be secure with U-shaped staples or stake in accordance with the manufactures' recommendations.
  - Synthetic Fiber w/Netting – A mat that is composed of durable synthetic fibers treated to resist chemicals and ultraviolet light. The mat is a dense three dimensional mesh of synthetic (typically polyolefin) fibers stitched between two polypropylene nets. The mats are designed to be re-vegetated and provide a permanent composite system of soil, roots, and geomatrix. The material is furnished in rolled strips, which must be secured with U-shaped staples or stake in accordance with the manufactures' recommendations.
  - Bonded Synthetic Fibers – A three dimensional geomatrix nylon (or other synthetic) matting. Typically it has more than 90% open area, which facilitates root growth. It's tough root reinforcing system anchors vegetation and protects against hydraulic lift and shear forces created by high volume discharges. It can be installed over prepared soil, followed by seeding into the mat. Once vegetated, it becomes an invisible composite system of soil, roots, and geomatrix. The material is furnished in rolled strips, which must be secure with U-shaped staples or stake in accordance with the manufactures' recommendations.
  - Combination Synthetic and Biodegradable RECPs – Biodegradable fibers, such as wood fiber or coconut fiber, with a heavy polypropylene net stitched tot eh top and a high strength continuous filament geomatrix or net stitched to the bottom. The material is designed to enhance re-vegetation. The material is furnished in rolled strips, which must be secured with U-shaped staples or stake in accordance with the manufactures' recommendations.

Site Preparation

- Proper site preparation is essential to ensure complete contact of the blanket or matting with the soil.
- Grade and shape the area of installation
- Remove all rocks, clods, vegetation or other obstructions so that the installed blankets or mats will have complete, direct contact with the soil.
- Prepared seedbed by loosening 2 to 3 in. of topsoil.

Seeding

Seed the area before blanket installation for erosion control and revegetation. Seeding after mat installation is often specified for turf reinforcement application. When seeding prior to blanket installation, all check slots and other areas disturbed during installation must be re-seeded. Where soil filling is specified, seed the matting and the entire disturbed area after installation and prior to filling the mat with soil.

Fertilize and seed in accordance with seeding specifications or other types of landscaping plans. When

using jute matting on a seeded area, apply approximately half the seed before laying the mat and the remainder after laying the mat. The protective matting can be laid over areas in which ground covers are to be planted, lay the protective matting first and then plant through matting according to design of planting and recommendation of the manufacture.

Check Slots
Check slots are made of glass fiber strips, excelsior matting strips or tight folded jute matting blanket or strips for use on steep, highly erodible watercourses. The check slots are placed in narrow trenches 6 to 12 in. deep across the channel and left flush with the soil surface. They are to cover the full cross section of designed flow.

Layering and Securing Matting
- Before laying the matting, all check slots should be installed and the friable seedbed mat free from clods, rocks, and roots. The surface should be compacted and finished according to the requirements of the of the manufacturer's recommendations.
- Mechanical or manual lay down equipment should be capable of handling full rolls of fabric and laying the fabric smoothly without wrinkles or folds. The equipment should meet fabric manufacturer's recommendations.

Anchoring
- U-shaped wire staple, metal geotextile stake pins, or triangular wooden stakes can be used to anchor mats and blankets to the ground surface.
- Wire staples should be made of minimum 11 gauge steel wire and should be u-shaped with 8 in legs and 2 in. crown.
- Metal stake pins should be 0.188 in. diameter steel with a 1.5 in. steel washer at the head of the pin, and 8 in. in length.
- Wire staples and metal stakes should be driven flush with the soil surface.

Installation on Slopes
Installation should be in accordance with the manufacturer's recommendations. In general, these will be as follows:

- Begin at the top of the slope and anchor the blanket in a 6 in. deep by 6 in. wide trench. Backfill trench and tamp earth firmly.
- Unroll blanket down slope in the direction of water flow.
- Overlap the edges of adjacent parallel rolls 2 to 3 in. and staple every 3 ft.
- When blankets must be spliced place blanket end over end (shingle style) with 6 in. overlap. Staple through overlapping area, approximately 12 in. apart.
- Lay blankets loosely and maintain direct contact with the soil. Do not stretch.
- Staple blankets sufficiently to anchor blankets and maintain contact with the soil. Staples should be placed down the center and staggered with the staples placed along the edges. Steep slopes, 1:1 (H:V) to 2:1 (H:V), require a minimum of 2 staples/yd2. Moderate slopes, 2:1 (H:V) to 3:1 (H:V), require a minimum of 11/2 staples/yd2.

Installation in Channels

Installation should be in accordance with the manufacturer's recommendations. In general, these will be as follows:

- Dig initial anchor trench 12 in. deep and 6 in. wide across the channel at the lower end of the project area.
- Excavate intermittent check slots, 6 in. deep and 6 in. wide across the channel at 25 to 30 ft intervals along the channels.
- Cut longitudinal channel anchor trenches 4 in. deep and 4 in. wide along each side of the installation to bury edges of matting, whenever possible extend matting 2 to 3 in. above the crest of the channel side slopes.
- Beginning at the downstream end and in the center of the channel, place the initial end of the first roll in the anchor trench and secure with fasting devices at 12 in. intervals. Note: matting will initially be upside down in anchor trench.
- In the same manner, position adjacent rolls in anchor trench, overlapping the preceding roll a minimum of 3 in.
- Secure these initial ends of mats with anchors at 12 in. intervals, backfill and compact soil.
- Unroll center strip of matting upstream. Stop at next check slot or terminal anchor trench. Unroll adjacent mats upstream in similar fashion, maintaining a 3 in. overlap.
- Fold and secure all rolls of matting snugly into all transverse check slots. Lay mat in the bottom of the slot then fold back against itself. Anchor through both layers of mat at 12 in. intervals, then backfill and compact soil. Continue rolling all mat widths upstream to the next check slot or terminal anchor trench.
- Alternate method for non-critical installations: Place two rows of anchors on 6 in. centers at 25 to 30 ft. intervals in lieu of excavated check slots.
- Staple shingled lap spliced ends a minimum of 12 in. apart on 12 in. intervals.
- Place edges of outside mats in previously excavated longitudinal slots; anchor using prescribed staple pattern, backfill, and compact soil.

- Anchor, fill, and compact upstream end of mat in a 12 in. by 6 in. terminal trench.
- Secure mat to ground surface using U-shaped wire staples, geotextile pins, or wooden stakes.
- Seed and fill turf reinforcement matting with soil, if specified.

Soil Filling (if specified for turf reinforcement)

- Always consult the manufacturer's recommendations for installation.
- Do not drive tracked or heavy equipment over mat.
- Avoid any traffic over matting if loose or wet soil conditions exist.
- Use shovels, rakes, or brooms for fine grading and touch up.
- Smooth out soil filling just exposing top netting of mat.

Temporary Soil Stabilization Removal

- Temporary soil stabilization removed from the site of the work must be disposed of if necessary.

Inspection and Maintenance

- Inspect BMPs prior to the forecast of rain, daily during extended rain events, after rain events, weekly during the rainy season, and at two-week intervals during the non-rainy season, and at two-week intervals during the non-rainy season.
- Inspect BMPs subject to non-stormwater discharges daily while non-stormwater discharges occur.
- Areas where erosion is evident shall be repaired and BMPs reapplied as soon as possible. Care should be exercised to minimize the damage to protected areas while making repairs, as any area damaged will require reapplication of BMPs.
- If washout or breakage occurs, re-install the material after repairing the damage to the slope or channel.
- Make sure matting is uniformly in contact with the soil.
- Check that all the lap joints are secure.
- Check that staples are flush with the ground.
- Check that disturbed areas are seeded.

ED: Earth Dikes and Drainage Swales



Description & Purpose

An earth dike is a temporary berm or ridge of compacted soil used to divert runoff or channel water to a desired location. A drainage swale is a shaped and sloped depression in the soil surface used to convey runoff to a desired location. Earth dikes and drainage swales are used to divert off site runoff around the construction site; divert runoff from stabilized areas and disturbed areas, and direct runoff into sediment basins or traps.

Suitable Applications

Earth Dikes and Drainage Swales may be suitable in the following situations:

- Where runoff needs to be diverted from one area and conveyed to another.
- To convey surface runoff down sloping terrain.
- To intercept and divert runoff to avoid sheet flow over steep sloped surfaces.
- To divert and direct runoff toward a stabilized watercourse, drainage pipe or channel.
- To intercept runoff from paved surfaces
- Below steep grades where runoff begins to concentrate.
- Along roadways and facility improvements subject to flood drainage.
- At the top of slopes to divert run-on from adjacent or undisturbed slopes.
- At bottom and mid slope location to intercept sheet flow and convey concentrated flows.
- Divert sediment laden runoff into sediment basins or traps.

Limitations

Dikes should not be used for drainage areas greater than 10 acres or along slopes greater than 10%. For larger areas more permanent drainage structures should be built. All drainage structures should be built in compliance with local and municipal requirements.

• Earth dikes may create more disturbed area on site and become barriers to construction equipment.

• Earth dikes must be stabilized immediately, which adds cost and maintenance concerns.

• Diverted stormwater may cause downstream flood damage. Dikes should not be constructed of soils that may be easily eroded.

- Re-grading the site to remove the dike may add additional cost.
- Temporary drains and swales or any other diversion of runoff should not adversely impact upstream or downstream properties.
- Temporary drains and swales must conform to local floodplain management requirements.
- Earth dikes/drainage swales are not suitable as sediment trapping devices
- It may be necessary to use other soil stabilization and sediment controls such as check dams, plastics, and blankets to prevent scour and erosion in newly graded dikes, swales, and ditches.

Implementation

The temporary earth dike is a berm or ridge of compacted soil, located in such a manner as to divert stormwater to sediment trapping device or a stabilized outlet, thereby reducing the potential for erosion and offsite sedimentation. Earth dikes can also be used to divert runoff from off site and from undisturbed areas away from disturbed areas and to divert sheet flows away from unprotected slopes.

An earth dike does not itself control erosion or remove sediment from runoff. A dike prevents erosion by directing runoff to an erosion control device such as a sediment trap or directing runoff away from erodible areas. Temporary diversion dikes should not adversely impact adjacent properties and must conform to local floodplain management regulations, and should not be used in areas with slopes greater than 10%.

Slopes that are formed during cut and fill operations should be protected from erosion by runoff. A combination of a temporary drainage swale and an earth dike at the top of a slope can divert runoff to a location where it can be brought to the bottom of the slope (se SD, Slope Drain). A combination dike and swale is easily constructed be a single pass of a bulldozer of grader and

compacted be a second pass of the tracks or wheels over the ridge. Diversion structures should be installed when the site is initially graded and remain in place until post construction BMPs are installed and the slopes are stabilized.

Diversion practices concentrate surface runoff, increasing its velocity and erosive force. Thus, the flow out of the drain or swale must be directed onto a stabilized area or into a grade stabilization structure. If significant erosion will occur, a swale should be stabilized using vegetation, chemical treatment, rock riprap, matting, or other physical means of stabilization. Any drain or swale that conveys sediment laden runoff must be diverted into a sediment basin or trap before it is discharged from the site.

General

- Care must be applied to correctly size and locate earth dikes, drainage swales. Excessively steep, unlined dikes and swales are subject to erosion and gully formation.
- Conveyances should be stabilized.
- Use a lined ditch for high flow velocities.
- Select flow velocity based on careful evaluation of the risks due to erosion of the measure, soil types, overtopping, flow backups, washout, and drainage flow patterns for each project site.
- Compact any fills to prevent unequal settlement.
- Do not divert runoff onto other property without securing written authorization from the property owner.
- When possible, install and utilize permanent dikes, swales, and ditches early in the construction process.
- Provide stabilized outlets.

Earth Dikes

Temporary earth dikes are a practical, inexpensive BMP used to divert stormwater runoff. Temporary diversion dikes should be installed in the following manner.

- All dikes should be compacted by earth moving equipment.
- All dikes should have positive drainage to an outlet.
- All dikes should have 2:1 or flatter side slopes, 18 in. minimum height, and a minimum top width of 24 in.
- Wide top widths and flat slopes are usually needed at crossings for construction traffic.
- The outlet from the earth dike must function with a minimum of erosion. Runoff should be conveyed to a sediment trapping device such as a Sediment Trap (ST) or Sediment Basin (SB) when either the dike, channel or the drainage area above the dike are not adequately stabilized.
- Temporary stabilization may be achieved using seed and mulching for slopes less than 5% and either riprap or sod for slopes in excess of 5%. In either case stabilization of the earth dike should be completed immediately after construction or prior to the first rain.
- If riprap is used to stabilize the channel formed along the toe of the dike, the following specifications apply:

Channel Grade	Riprap Stabilization
0.5 – 1.0%	4 in. Rock
1.1 – 2.0%	6 in. Rock
2.1 – 4.0%	8 in. Rock
4.1 – 5.0%	8 in. – 12 in. Riprap

- The stone riprap used for stabilization should be pressed into the soil with construction equipment.
- Filter cloth may be used to cover dikes in use for long periods.
- Construction activity on the earth dike should be kept to a minimum.

Drainage Swales

Drainage swales are only effective if they are properly installed. Swales are more effective than dikes because they tend to be more stable. The combination of a swale with a dike on the downhill side is the most cost effective diversion. Standard engineering design criteria for small open channel systems should be used. Unless local drainage design criteria state otherwise, drainage swales should be designed as follows:

- No more than 5 acres may drain to a temporary drainage swale.
- Place drainage swales above or below, not on, a cut or fill slope.
- Swale bottom width should be at least 2 ft.
- Depth of the swale should be at least 18 in.
- Side slopes should be 2:1 or flatter.
- Drainage swales should be laid at a grade of at least 1%, but not more than 15%.
- The swale must not be overtopped by the peak discharge from a 10-year storm, irrespective of the design criteria stated above.
- Remove all trees, stumps, obstructions, and other objectionable material from the swale when it is built.
- Compact any fillmaterial along the path of the swale.
- Stabilize all swales immediately. Seed and mulch swales at a slope of less than 5%, and use riprap or sod for swales with a slope between 5 and 15%. For temporary swales, geotextiles and mats may provide immediate stabilization.
- Irrigation may be required to establish sufficient vegetation to prevent erosion.

- Do not operate construction vehicles across a swale unless a stabilized crossing is provided.
- Permanent drainage facilities must be designed by a professional engineer.
- At a minimum, the drainage swale with a positive grade to a stabilized outlet.
- Provide erosion protection or energy dissipation measures if the flow out of the drainage swale can reach an erosive velocity.

Inspection and Maintenance

- Inspect BMPs prior to forecast rain, daily during extended rain events, after rain events, weekly during the rainy season, and at two-week intervals during the non-rainy season.
- Inspect BMPs subjected to non-stormwater discharges daily while non-stormwater discharge occurs.
- Inspect drainage swales and dikes for washouts. Replace lost riprap, damaged linings or soil stabilizers as needed.
- Inspect channel linings, embankments, and beds of ditches and berms for erosion and accumulation of debris and sediment. Remove debris and sediment and repair linings and embankments as needed.
- Temporary conveyances should be completely removed as soon as the surrounding drainage area has been stabilized or at the completion of construction.



Do. Line the channel when highly erodible soils may be encountered.



Don't. Wait until the runoff has already created severe erosion areas.

FR: Fiber Rolls



Description & Purpose

A fiber roll consists of straw, flax, or other similar materials bound into a tight tubular roll. When fiber rolls are placed at the toe and on the face of slopes, they intercept runoff, reduce its velocity, release the runoff as sheet flow, and provide removal of sediment from the runoff. By interrupting the length of the slope, fiber rolls can also reduce erosion. This can aid in establishing vegetation on bare soils or aid in redirecting flow for a temporary time period to aid in establishing new flow patterns.

Suitable Applications

Fiber rolls may be suitable in the following situations:

- Along the toe, top, face, and at grade breaks of exposed and erodible slopes to shorten slope length and spread runoff as sheet flow
- At the end of a downward slope where it transitions to a steeper slope.
- Along the perimeter of a project.
- As check dams in unlined ditches
- Down-slope of exposed soil areas
- Around temporary stockpiles.

Limitations

- Fiber rolls are not effective unless trenched.
- Fiber rolls at the toe of slopes greater than 5:1 (H:V) should be a minimum of 20 in. diameter or installations achieving the same protection (i.e. stacked smaller diameter fiber rolls, etc.).
- Difficult to move once saturated.
- If not properly staked and trenched in, fiber rolls could be transported by high flows.
- Fiber rolls have a very limited sediment capture zone
- Fiber rolls should not be used on slopes subject to creep, slumping, or landslides.

Implementation

Fiber Roll Material

- Fiber rolls should be either prefabricated rolls or rolled tubes of erosion control blanket.

Assembly of Field Rolled Fiber Roll

- Roll length of erosion control blanket into a tube of minimum 8 in. diameter.
- Bind roll at each end and every 4 ft long length of roll with jute-type twine.

Installation

- Locate fiber rolls on level contours spaced as follows:
  - Slope inclination of 4:1 (H:V) of flatter: Fiber rolls should be placed at a maximum interval of 20 ft.
  - Slope inclination between 4:1 and 2:1 (H:V): Fiber rolls should be placed at a maximum interval of 15 ft. (a closer spacing is more effective)
  - Slope inclination 2:1 (H:V) or greater: Fiber rolls should be placed at a maximum interval of 10 ft. (a closer spacing is more effective)
- Turn the ends of the fiber roll up slope to prevent runoff from going around the roll.
- Stake fiber rolls into a 2 to 4 in. deep trench with a width equal to the diameter of the fiber roll.
  - Drive stakes at the end of each fiber roll and spaced 4 ft maximum of center.
  - Use wood stakes with a nominal classification of 0.75 by 0.75 in. and minimum length of 24 in.
- If more than one fiber roll is placed in a row, the roll should be overlapped, not abutted.

Removal

- Fiber rolls are typically left in place.
- If fiber rolls are removed, collect and dispose of sediment accumulation, and fill and compact holes, trenches, depressions or any other ground disturbance to blend with adjacent ground.

Inspection and Maintenance

- Inspect BMPs prior to forecast rain, daily during extended rain events, after rain events, weekly during the rainy season, and at two-week intervals during the non-rainy season.
- Repair and replace split, torn, unraveled or slumping fiber rolls.
- If the fiber roll is used as a sediment capture device, or as an erosion control device to maintain sheet flows, sediment that accumulates in the BMP should

be removed when sediment accumulation reaches one-half the designated sediment storage depth, usually one-half the distance between the top of the fiber roll and the adjacent ground surface. Sediment removed during maintenance may be incorporated into earthwork on the site or disposed of at an appropriate location.

- If fiber rolls are used for erosion control, such as in a mini check dam, sediment removal should not be required as long as the system continues to control the grade. Sediment control BMPs will likely be required in conjunction with this type of application.

GBB: Gravel Bag Berm



Description & Purpose

A gravel bag berm is a series of gravel-filled bags placed on a level contour to intercept sheet flows. Gravel bags pond sheet flow runoff, allowing sediment to settle out, and release runoff slowly as sheet flow, preventing erosion. These provide similar benefits as fiber rolls but may be longer lasting, but will not aid in establishing vegetation.

Suitable Applications

Gravel bag berm may be suitable in the following situations:

- As linear sediment control measure:
  - Below the toe of slopes and erodible slopes.
  - As sediment traps at culvert/pipe outlets.
  - Below other small cleared areas
  - Along the perimeter of the site.
  - Down slope of exposed soil areas.
  - Around temporary stockpiles and spoil areas.
  - Parallel to a roadway to keep sediment off paved areas.
  - Along streams and channels.
- As linear erosion control measure:
  - Along the face and at grade breaks of exposed and erodible slopes to shorten slope length and spread runoff as sheet flow.
  - At the top of slopes to divert runoff away from disturbed slopes.
  - As check dams across mildly sloped construction roads.

Limitations

- Gravel berms may be difficult to remove.
- Removal problems limit their usefulness in landscaped areas.
- Gravel bag berms may not be appropriate for drainage areas greater than 5 acres.
- Runoff will pond upstream of the filter, possibly causing flooding if sufficient space does not exist.
- Degraded gravel bags may rupture when removed, spilling contents.
- Installation can be labor intensive.
- Berms may have limited durability for long-term projects.
- When used to detain concentrated flows, maintenance requirements increase.

Implementation

General

A gravel bag berm consists of a row of open graded gravel filled bags placed on a level contour. When appropriately placed, a gravel bag berm intercepts and slows sheet flow runoff, causing temporary ponding. The temporary ponding provides latent conditions allowing sediment to settle. The open graded gravel in the bags is porous, which allows the ponded runoff to flow slowly through the bags, releasing the runoff as sheet flows. Gravel bag berms also interrupt the slope length and thereby reduce erosion by reducing the tendency of sheet flows to concentrate into rivulets, which erode rills, and ultimately gullies, into disturbed, sloped soils. Gravel bag berms are similar to sand bag barriers, but more porous.

Design and Layout

- Locate gravel bag berms on level contours.
  - Slopes between 20:1 and 2:1 (H:V): Gravel bags should be placed at a maximum interval of 50 ft (a closer spacing is more effective), with the first row near the slope toe.
  - Slopes 2:1 (H:V) of steeper: Gravel bags should be placed at a maximum interval of 25 ft (a closer spacing is more effective), with the first row placed at the toe of the slope.
- Turn the ends of the gravel bag barriers up slope to prevent runoff from going around the berm.

- Allow sufficient space up slope from the gravel bag berm to allow ponding, and to provide room for sediment storage.
- For installation near the toe of the slope, consider moving the gravel bag barriers away from the slope toe to facilitate cleaning. To prevent flows behind the barrier, bags can be placed perpendicular to a berm to serve as a cross barrier.
- Drainage area should not exceed 5 acres.
- In Non-Traffic Areas:
  - Height = 18 in. maximum.
  - Top width = 24 in. minimum for three or more layer construction.
  - Top width = 12 in. minimum for one or two layer construction.
  - Side slopes = 2:1 of flatter.
- In Construction Traffic Areas:
  - Height = 12 in. maximum.
  - Top width = 24 in. minimum for three or more layer construction.
  - Top width = 12 in. minimum for one or two layer construction.
  - Side slopes = 2:1 of flatter.
- Butt ends of bags tightly.
- On multiple rows, or multiple layer construction, overlap butt joints of adjacent row and row beneath.
- Use a pyramid approach when stacking bags.

Materials

- Bag Material – Bags should be woven polypropylene, polyethylene or polyamide fabric or burlap, minimum unit weight of 4 ounces/yd^2, Mullen burst strength exceeding 300 lb/in^2 in conformance with the requirements in ASTM designation D_{3786}, and ultraviolet stability exceeding 70% in conformance with the requirements in ASTM designation D_{4355}.
- Bag Size – Each gravel-filled bag should have a length of 18 in., width of 12 in., thickness of 3 in., and mass of approximately 33 lbs. Bag dimensions are nominal, and may vary based on locally available materials.
- Fill Material – Fill material should be 0.5 to 1 in. Class 2 aggregate base, clean and free from clay, organic matter, and other objectionable material, or other suitable open graded, non-cohesive, porous gravel.

Inspection and Maintenance

• Inspect BMPs prior to forecast rain, daily during extended rain events, after rain events, weekly during the rainy season, and at two-week intervals during the non-rainy season.

• Gravel bags exposed to sunlight will need to be replaced every two of three months due to degrading of the bags.

• Reshape or replace gravel bags as needed.

• Repair washouts or other damage as needed.

• Sediment that accumulates in the BMP must be removed in order to maintain BMP effectiveness. Sediment should be removed when sediment accumulation reaches one-half the designated sediment storage volume. Sediment removed during maintenance may be incorporated into earthwork on the site or disposed of at an appropriate location.

• Remove gravel bag berms when no longer needed. Remove sediment accumulation and clean, re-grade, and stabilize area. Removed sediment should be incorporated in the project or disposed of.

RR: Rip Rap



Description & Purpose

An arranged layer of rock placed over the soil surface on slopes and at or below storm drain outfalls or temporary dikes. Rip rap used as slope protection against erosion and dissipates the energy of runoff or surface water flow.

Suitable Applications

Rip Rap may be suitable in the following situations:

- Use rip rap on slope greater than 4:1 (H:V)
- Along banks where the velocity and water surface elevation occurring during the 10-year storm event has the possibility of damaging the channel banks and/or flowline.
- In areas where riprap will be placed within the above the 10-year storm event elevations or in the channel of the stream an professional engineer will need to perform the design for approval by the City of Mankato.
- Around structures that require protection during storm events (i.e, Bridges, Culvert inlets)

Limitations

- The minimum particle size of the rock must be sized for the maximum expected velocity of flow of the outlet and the soil conditions where the outlet will be located.

Implementation

Design
Riprap should be installed as follows:

• Grade the bank to a maximum slope of two feet of horizontal distance for one foot of vertical rise.

The area should also be graded to allow room for the gravel and riprap to be placed without restricting the flow. The top of riprap will need to match natural or prefailure elevation and shape.

• Place a highly permeable and appropriately sized geotextile filter fabric are recommended by the MnDOT on the prepared slope following the manufacturer's recommendations. Take care not to tear the filter fabric during installation.

• Place a layer (six inch minimum) of gravel or small rock on the geotextile filter fabric. The underlayer stone needs to be sized appropriately so it will not wash through any gaps between the riprap stones.

• Place the layer of riprap, 1.5 times the thickness of the largest stone, on top of the gravel. The heaviest rocks should be placed along the bottom of the bank. Riprap should be placed into position with a bottom-up approach, not dumped over the bank edge.

• Entrench the bottom row of stone into the stream bed to prevent undercutting.

• Extend the revetment beyond the area of erosion to prevent erosion behind the ends of the structure.

• The rip rap should be sized according to the following table:

Velocity of Flow	Size Range Largest Diameter of Rock
2-6 feet/second	4"-12"; average 6"
6-8 feet/second	6"-18"; average 12"
8-10 feet/second	12"-24"; average 18"
10-12 feet/second	18"-30"; average 24"
12-15 feet/second	24"-42"; average 36"

- There are different types of rip rap available. The most common type in the Mankato area is limestone. This will often be the easiest to access and have the lowest initial cost. However, limestone can determined rapidly due to weather and freeze thaw. It may need to be replaced on a regular basis to ensure that the protection form the rip rap is maintained. The other type of rip rap that is quartzite or red stone. This material is much more durable and will last a long time

Inspection and Maintenance

- Rip rap must be inspected every two weeks during the construction phase of the project.
- Rip rap must be inspected quarterly after the construction phase of the project is finished.
- Rip Rap must be inspected after all storm events producing a significant amount of runoff.
- Any rocks displaced during storm events must be replaced immediately after the storm event has ended.



Do. Install rip rap lined channels where erodible channels are constructed or altered.



Don't. *Use concrete rubble or other non-natural products as rip rap material.*

GB: Gabion Basket



Description & Purpose

Gabion Baskets are similar to rip rap in use but are constructed in a different way. These baskets can make use of smaller stones and can be installed in areas where rip rap is not effectively transported or placed. These baskets can then be attached together providing a mechanical connection that increases the overall mass of the system and resistive force. Gabion Baskets can also be staked to for a retaining wall to provide protection to very steep slopes and areas with limited space.

Suitable Applications

- Gabion Baskets may be suitable in all location where rip rap can be used. Additional Gabion Baskets may be used in areas:Where slopes slope greater than 4:1 (H:V) included vertical installation location
- In channels where the velocity and water surface elevation occurring during the 100-year storm event has the possibility of damaging the channel banks and/or flowline.
- Around structures that require protection during storm events (i.e, Bridges, Culvert inlets)
- In areas that have limited access to heavy equipment, gabion baskets can be hand built if necessary
- In areas of high flows and high velocities. Gabions can be tied together to increase the effectiveness of the system.
- In locations where groundwater may be present behind the baskets, or flow through the system should be maintained.

Limitations

- The labor necessary to construct gabion baskets may make them cost prohibitive in certain instances.
- Gabion baskets should not exceed 30-inch in height. Any wall created with baskets that exceed 30-inches will require a Professional Engineer to submit a design to the City of Mankato for review and approval.

Implementation

Design

Gabion Baskets should be installed as follows:

• Grade the bank as practical to allow for the baskets to be installed and anchored into the bank if necessary.

• Place a highly permeable and appropriately sized geotextile filter fabric on the prepared slope following the manufacturer's recommendations. Take care not to tear the filter fabric during installation.

• Assemble the baskets per the manufacturer's instruction and place them in the final location.

• Place rock material in the baskets, ensuring that the rock against the basket are large in all dimensions than the openings of the baskets.

• Entrench the bottom row of baskets a minimum of 1/3 the height of the basket into the stream bed to prevent undercutting.

• Extend the revetment beyond the area of erosion to prevent erosion behind the ends of the structure.

Detailed design information regarding gabions, especially for design professionals can be found at:

Gabions.net9

Inspection and Maintenance

- Gabion Baskets must be inspected every lift of baskets during the construction phase of the project
- Gabion Baskets must be inspected quarterly after the construction phase of the project is finished during the establishment of any vegetation and to ensure there are no negative impact to the stream flow from the baskets. This inspection should take place after every precipitation event of 1-inch or more for one growing season.
- Gabion Baskets must be inspected after all storm events producing a significant amount of runoff.
- Any baskets displaced during storm events must be replaced or repaired immediately after the storm event has ended.