DEPARTMENT OF THE ARMY
US ARMY INSTALLATION MANAGEMENT COMMAND
HEADQUARTERS, US ARMY GARRISON, FORT STEWART / HUNTER ARMY AIRFIELD
DIRECTORATE OF PUBLIC WORKS
1587 FRANK COCHRAN DRIVE
FORT STEWART, GEORGIA 31314

REPLY TO
ATTENTION OF

Office of the Directorate AUG 31 2010 Certified Mail

NonPoint Source Program
Watershed Protection Branch
Environmental Protection Division
Attention: Ms. Lisa A. Perrett
4220 International Parkway, Suite 101
Atlanta, GA 30354

Dear Ms. Perrett:

Reference the Georgia Department of Natural Resources Environmental Protection Division's [GA EPD] Phase II National Pollutant Discharge Elimination Systems General Permit No. GAG480000 for Stormwater Discharges Associated with Small Municipal Separate Storm Sewer Systems (MS4) At Military Facilities, the permit condition IV.B.6, and the Fort Stewart/Hunter Army Airfield Notice of Intent/Stormwater Management Plan. Specifically, Appendix F titled; Pollution Prevention/Good Housekeeping for Municipal Operations Best Management Practice Number One (BMP #1) states Fort Stewart/Hunter Army Airfield will revise the existing Installation Stormwater Maintenance Standard Operating Procedures (SOP) with a submittal to GA EPD by August 2010 and implementation by September 2010.

The Revised Installation Stormwater Maintenance SOP is enclosed for your review. The revised SOP will be posted on the Fort Stewart/Hunter Army Airfield website for outreach and availability to Installation personnel and contractors by September 2010.

If additional information is required please contact Ms. Tressa Rutland, Mr. Brent Rabon, or Mr. Russell Moncrief, this directorate, at (912) 767-2010.

Sincerely,

Thomas C. Fry

Robert R. Baumgardt
Director, Public Works

Enclosures

FORT STEWART STORMWATER MAINTENANCE

RECOMMENDATIONS AND RESPONSIBILITIES

Revision OCT 2010

UNITED STATES ARMY GARRISON
HEADQUARTERS, FORT STEWART/HUNTER ARMY AIRFIELD
DIRECTORATE OF PUBLIC WORKS
ENVIRONMENTAL DIVISION
1550 FRANK COCHRAN DRIVE, Bldg. 1137
FORT STEWART, GEORGIA 31314-4927

STORMWATER MANAGEMENT PROGRAM STANDARD OPERATING PROCEDURES (SOP)

Table of Contents

1.0 Purpose

To enhance and support the Fort Stewart and Hunter Army Airfield Stormwater Management Program, and ensure compliance with the Municipal Separate Storm Sewer Systems (MS4) permitting compliance to establish standard operating procedures (SOP) and responsibilities for the administration, financing, planning, design and construction, management, operations and maintenance (O&M), inspection, quality surveillance of contractors, and environmental compliance for the Installation's.

2.0 Applicability

This SOP is applicable to the Directorate of Public Works (DPW) Environmental Division Stormwater Program Management Inspection Teams, and DPW Services Division O&M; and all Installation Civilian, Military and contractor personnel, responsible for the administration, management and compliance of the stormwater conveyance systems as a whole, tank trails, and dirt roads on Fort Stewart and Hunter Army Airfield.

3.0 General

The DPW Quality Assurance team, the DPW Services Division O&M personnel, the DPW Engineering and Master Planning Divisions, and the DPW Environmental Division play an essential role in the management of the Stormwater Compliance Management Program. These teams are responsible for ensuring the design, construction, operation and maintenance of the stormwater systems comply with all Department of Defense (DoD), Department of the Army (DA), United States Environmental Protection Agency (USEPA), and State Standards and Regulations.

By incorporating a step-by-step quality assurance and training program into the design, construction, and operation of the stormwater systems, the DPW quality assurance process will ensure compliance requirements are adhered too and ease the responsibilities of the engineer, maintenance and environmental teams when inspecting the O&M of the stormwater systems. Additionally, this program will improve support and compliance by providing direct interaction between the DPW Quality Assurance team, the Environmental Division Stormwater Management Program Inspection team, and the in-house or contract maintenance personnel. The quality assurance and inspection teams will close the loop in the "design to maintenance" initiative by ensuring that all stormwater systems operate in accordance to design standards and the stormwater discharges meet all DoD, DA, USEPA, and State regulatory requirements.

Environmental visits, quarterly inspections, and assisted visits will be scheduled to monitor compliance with established policies, stormwater management plans and guidance, best management practices (BMPs), and this SOP. The inspections and stormwater BMPs site visits are designed to provide the Commander and Civilian managers with an appraisal of the organization's management program regarding stormwater system design, construction, O&M, and status of compliance with the post-construction BMPs.

4.0 Proponent

The proponent of this SOP is the Planning and Engineering Services Division, the Environmental Division, and the Services Division O&M Branch, located within the DPW. Recommendations are encouraged and should be forward to the DPW Environmental Division, Stormwater Program Manager.

5.0 Responsibilities

5.1 The Directorate of Public Works (DPW), Planning & Engineering, and Services Division

The Director is responsible for the general administration of the Fort Stewart and Hunter Army Airfield stormwater systems. The DPW will ensure the management, capital improvements, BMPs, and regulatory requirements for the stormwater systems are addressed in the Installation Master Plan, DPW and environmental budgets, sustainable design and stormwater manuals, and SOPs. The DPW is also responsible for finance and billing for capital improvements and maintenance, record keeping, inspections, tracking of schedules, public relations, State and Federal Regulation compliance, and contract management for stormwater design, construction and maintenance, reference; the Fort Stewart/Hunter Army Airfield (FS/HAAF) Command Policy Memorandum-Stormwater Management Program, and the Fort Stewart/Hunter Army Airfield Stormwater Guidance for Construction Site Stormwater Runoff Controls and Post-Construction Stormwater Management in New Development and Redevelopment.

In order to maintain the stormwater systems' integrity and compliance, the DPW will ensure that the following steps are implemented for all contracted maintenance for the stormwater system:

- Provide stormwater system design criteria to the contractor for each specific site to be included in the maintenance contract.

- Provide location maps, maintenance schedules, Installation inspection sheets to the Contract office, O&M contract personnel, and DPW Environmental Division.

- Provide additional maintenance checklists and requirements to the Contract office and contractor. They must include maintenance requirements for each type of stormwater system design and maintenance procedures for vegetation planted in or near the stormwater systems (reference; the FS/HAAF Command Stormwater Management Policy).

- Track completed contractor maintenance performed by site and date.

- Inspect and track maintenance contractor performance and adherence to BMP installation requirements.

- Ensure contractor has access to stormwater system maintenance sites and POC for problems which may arise.

5.2 The Directorate of Contracting

The Director of Contracting will ensure that all stormwater system maintenance contracts contain a copy of this SOP, location maps of each stormwater system section to be maintained under the contract, maintenance specifications for vegetation and each type of stormwater system design, maintenance schedules, Installation inspection sheets, reporting and record keeping requirements, and POCs for access and emergencies.

5.3 DPW Services Division, Operations & Maintenance (O&M) Branch

The Director will ensure that DPW personnel in charge of O&M contracts for Fort Stewart and Hunter Army Airfield are available and provide detailed inspection sheets and maintenance procedures for each type of stormwater control to the Installation/Contractor inspectors as needed to ensure proper maintenance of current and new stormwater controls and techniques utilized. Appendix A contains a sample inspection sheet. The DPW inspection sheets can mirror the State of Georgia's *Technical Handbook, Appendix E Structural Control Maintenance Checklists,* which can be located at http://www.georgiastormwater.com/ vol2/E.pdf. The DPW will provide the inspection sheets to all stormwater system O&M contractors (Appendix A). As part of the stormwater control maintenance procedures and inspection sheets, the DPW will include a list of native plant species used for each stormwater control and their proper care to ensure the stormwater control meets its intended use and treatment capacity.

5.4 Directorate of Public Works, Environmental Division

The DPW Environmental Division is responsible for ensuring the Installation's meet all Phase I & Phase II stormwater regulatory compliance requirements (e.g., permit compliance, stormwater management plan development/implementation, development/implementation of training, and compliance inspections) meets stormwater best management practices (BMPs) to the maximum extent technically feasible and addresses enforcement actions. Environmental Division personnel will inspect all stormwater systems located on Fort Stewart and Hunter Army Airfield. They will provide technical assistance as requested. The Environmental Division personnel will conduct quarterly environmental compliance inspections and assisted visits to all stormwater system structural BMP sites. They will prepare and submit reports of all regulator visits and inspections. The Environmental Division personnel will ensure this SOP is current and updated. They will work with the Director of Public Works to identify and eliminate any illicit discharges (reference; FS/HAAF Illicit Discharge Detection and Elimination Plan [IDDE Plan] by performing Dry Weather Screenings) to the stormwater system. The Environmental Division personnel will coordinate with DPW on the development of training and public awareness for contractors, Installation personnel (Military, Civilians, and tenant organizations) on stormwater system compliance, protection and maintenance. They will work with DPW to develop setbacks and management instructions to protect and maintain stormwater system compliance. The Environmental Division personnel will perform stormwater Quality Monitoring as required for Permits. In addition, the Environmental Division will perform inspections of the stormwater collection systems canals, ditches, swales, headwalls, catch basins, curb and drop inlets, ends of pipes, MS4 outfalls, and post construction stormwater structural BMPs, and report the findings of any deficiencies to the DPW Services O&M and/or Engineering Division's for corrective actions utilizing the inspection report in Appendix A. They will perform and track compliance inspections of the MS4 stormwater systems on a quarterly basis with a total of 20% of the overall MS4 systems and post construction stormwater structural BMPs inspected annually (see attached MS4 mapping and post construction stormwater structural BMPs listings). The Environmental Division personnel will provide updates on new environmental regulations that provide recommendations for compliance and maintenance.

5.5 Unit Commanders and Civilian Supervisors

Unit Commanders and Civilian Supervisors must ensure all personnel are aware of stormwater pollution prevention practices, safety procedures, and have knowledge of stormwater compliance requirements for illicit discharges and prevention of spills into stormwater collection systems, drains, and channels.

Commanders and Civilian Supervisors will adhere to all quality surveillance and technical programs (detailed elements of the program are outlined in Army Regulation (AR) 200-1, Chapter 4, Installation Stormwater Pollution Prevention Plan (SWP3) Master Plan, Installation Illicit Discharge, Detection, and Elimination Plan (IDDE Plan), and the Georgia Stormwater Management Manual). They will appoint representatives from the Unit or Civilian operation to ensure environmental compliance actions for stormwater systems as prescribed by AR 200-1, Chapter 4. Each appointed representative must attend the Stormwater Compliance and Management course (Environmental Compliance Officer Course) sponsored by the DPW, Environmental Division. A certificate must be kept on-hand to verify training.

Each Military and Civilian representative must ensure that any Installation personnel with access to or who have operations near stormwater systems also be provided stormwater pollution prevention training and be aware of their responsibilities to use proper prevention techniques and practices when performing their Installation duties.

Commanders and Supervisors must also ensure that all personnel are aware of their requirement to prevent illicit discharges from entering the stormwater systems. All Military and Civilian representatives will ensure that personnel maintain all Fort Stewart and Hunter Army Airfield Regulations and Army Regulations regarding stormwater compliance and management. These representatives should be acquainted with this Stormwater Management Program SOP.

5.6 Unit and Civilian Responsibilities

All Installation personnel will ensure that they meet requirements and responsibilities outlined in the stormwater training program. Personnel are responsible for implementing stormwater system pollution prevention techniques when performing their Installation duties and reporting illicit discharges and spills into the stormwater system to their Commanders and Civilian Supervisors.

Personnel must follow the Installation Spill Prevention, Control and Countermeasure Plan SOP when responding to spills associated with releases to the stormwater system. Spill response supplies will be on hand and identified with signs for easy access to personnel. For additional information regarding these supplies contact you're Unit's RCRA Inspector or:

Fort Stewart/HAAF Hazardous Materials Handling and Storage Facility:

Fort Stewart	(912) 767-3388/8012
Hunter Army Airfield	(912) 315-6287
DPW Environmental Division	(912) 767-2010

Spill response kits will consist at the minimum, of shovels, brooms; spill pads, dry sweep, protective gloves and protective eye guard. The Material Safety Data Sheets (MSDS) for the product that has been spilled must be present and be referred to in order to help prevent any further environmental or health problems.

5.7 Stormwater Maintenance Contractors

Stormwater Maintenance Contractor teams will:

- Notify DPW Environmental Division before maintenance begins for each stormwater site.
- Ensure employees are trained on proper maintenance by site design.
- Provide copies of site inspection reports and checklists to employees.
- Ensure all checklist and compliance information is kept on site for employee reference and use while performing maintenance duties.
- On a daily basis inspect maintenance work to ensure adherence to Installation requirements.
- Track performance on a daily basis and provide corrective action reports to DPW Environmental Division within 2 days of non-performance issues.
- Notify DPW Contracting Officer Technical Representative and the Environmental Division within 8 hours of environmental non-compliance.

For all stormwater ditches, canals, catch basins, curb inlets, and conveyances the Stormwater Maintenance Contractor teams will:

- Inspect ditches at least twice annually for erosion, damage to vegetation, for ditches and canals, and at least once annually for sediment and debris accumulation in catch basins, curb inlets and conveyances; preferably at the end of the wet season to schedule summer maintenance and before major fall runoff, to ensure the ditches are ready for winter. Additional inspection after periods of heavy rainfall runoff is desirable.

- Remove sediment that has accumulated near culverts, curb cuts and in channels when it builds up to 75 mm (3-4 in.) at any spot, or covers vegetation, so water flowing into ditches is unobstructed.

- Regularly inspect ditches for pools of standing water as they can become a nuisance due to mosquito breeding if obstructions develop (e.g. debris accumulation, invasive vegetation) and/or if proper drainage slopes are not implemented and maintained.

- For dirt roads, tank trails and conveyances adhere to USEPA Recommended Practices and Guidelines for Maintenance and Service of Unpaved Roads and Ditches (reference Appendix B).

- Develop an effective maintenance program that incorporates the entire system.[1]

[1] Atlanta Regional Commission, *Georgia Stormwater Management Manual*, Volume 1: Stormwater Policy Guidebook, Chapter 7, August 2001. See http://www.georgiastormwater.com/vol1/gsmmvol1.pdf. ; Coastal Stormwater Supplement-April 2009, Municipal Separate Storm Sewer Systems National Pollutant Discharge Elimination Permit GAG480000 and Command Stormwater Management Policy.

6.0References

AR 200-1, Chapter 4, 40 CFR, Part 122, Georgia Stormwater Management Manual, Installation Stormwater Management Pollution Prevention Plan (SWP3) Master Plan, Installation Spill Prevention, Control and Countermeasure (SPCC) Plan, Installation Master Plan, Installation Design Guide, Fort Stewart Watershed Impact Assessment 2004 Update, Georgia Stormwater Management Manual-Coastal Stormwater Supplement-April 2009, and the Georgia Municipal Separate Storm Sewer Systems-National Pollutant Discharge Elimination Systems Permit GAG480000 .

Thomas C. Fry

ROBERT R. BAUMGARDT
Director, Public Works

APPENDIX A

Fort Stewart/Hunter Army Airfield
Stormwater System Maintenance-Inspection Checklist

Fort Stewart / Hunter Army Airfield
Stormwater System Maintenance-Inspection Checklist

Installation: Circle one **Fort Stewart / Hunter Army Airfield**

Collection System (MS4 sub basin) _____________ BMP ID# _____ Associated Building #(s) __________

Location/GPS: Latitude: _______ ° ______' _____" N Longitude: ______ °______' _____" W

Proponent Responsible For Maintenance: DPW Services Division Roads & Grounds

Contact: DPW Environmental Branch Stormwater Program 767-2010 / 0271

Evaluation Date:

Evaluation Completed by:

Circle type of system: Retention/Wetland Pond - Detention Basin - Bioretention Cell – Rain Garden - Open Channel*

***Open Channel Type: Stream, Ditch, Swale, Catch Basin, Curb Inlet, Headwalls or Open Pipe**

Findings	Yes	No	Maintenance Required?	Comments
1. Contributing Drainage Area. a. Excessive trash / debris				
b. Bare / Exposed soil				
c. Evidence of erosion				
2. Inlets and Outlets (headwalls, open pipes, outfall weirs, catch basins, curb inlets, etc…) a. Excessive sediment accumulation or debris	**Yes**	**No**		
b. Structural defects				
c. Evidence of clogging				
d. Evidence of erosion				
3. Facility Condition. a. Evidence of erosion	**Yes**	**No**		
b. Excessive sediment accumulation				
c. Exposed or bare soils				
d. Evidence of pollutants				
e. Presence of woody vegetation				
f. Evidence of dead vegetation				
g. Excessive trash/debris				
h. Evidence of standing water				

Fort Stewart / Hunter Army Airfield
Stormwater System Maintenance-Inspection Checklist

Site Description-Additional comments:
Sketch Facility

APPENDIX B
Recommended Practices
A Guideline for
Maintenance and Service of Unpaved Roads and Ditches

Chapter 1
ROAD SURFACE

Description

Unpaved roads carry local traffic between rural lands and communities, and provide connecting links between paved collector roads.

In the Cannoochee and Ogeechee River watershed's, most of the roadways consist of sandy to sandy clay loam soil material. These roadway surfaces and ditches are subject to erosion and degradation which lead to sedimentation within watercourses, streams, and rivers.

Importance to Maintenance & Water Quality

Disturbances to unpaved roadway surfaces and ditches, and poor road surface drainage always result in deterioration of the road surface. This deterioration is the erosion which accounts for a large percentage of unpaved road maintenance costs and stream sedimentation. Frequent, excessive, and unnecessary disturbances to the roadways are all too common because of political pressure from the public to continually blade roads, and the common practice of wholesale blading adopted by administrators and operators over the years. Proper and timely surface maintenance, selectively performed, will help reduce the amount of roadway being disturbed, and will reduce the amount and frequency of disturbance to the section of roadway requiring maintenance.

Proper, timely, and selective surface maintenance, which includes water disposal, prevents and minimizes erosion problems, thereby lengthening the life of the road surface which in turn lessens frequency and cost of maintenance. This will also decrease the amount of sediment carried into surface waters. Frequent and excessive disturbance of the roadway surface and ditches, and failure to direct surface water from the road surface to a drainage channel results in deterioration of the road surface, which leads to other roadway problems which may impair traffic flow and traffic safety, among other things.

Surface Profile, Grading, and Drainage Characteristics

General

Do not disturb roadway sections which *do not* need maintenance while repairing, blading, or grading those sections which do. When routine maintenance is being performed, limit the amount of disturbed areas to that which can be re-established to the desired final shape by the end of the work day. To minimize opportunity for degradation of the roadway, it is best not to blade, grade, or drag if rain or freezing temperatures are favorable within the 48 hour forecast. As much as possible, avoid non-essential or non-emergency work near streams or stream crossings during the “wet” months of the year. Save this work for drier seasons.

It is best to limit roadway blading to times when there is enough moisture content to allow for immediate re-compaction. Often, an optimum time for this is soon after a rain while the surface materials are still moist but not too wet. Blading with little moisture content in the soil is futile, and is often a causative factor in road surface degradation such as “washboarding” and other problems associated with loss of fines.

As shown in figure 1-1, crown roads 3/4 to 1 inch for each foot of road width, measured from the center of the roadway to the outside edge, to ensure good drainage. Roads in deep loose sands may be crowned 1/4 inch or less for each foot of road width from center of the roadway to the back of ditch. In this instance, there is no defined ditch front slope due to the excessively erosive nature of the sand. Rather, the extra road width provides drainage at the outer edges of the roadway. Proper crowning and compacting of the road surface quickens the removal of runoff, thus protecting the road surface from degradation.

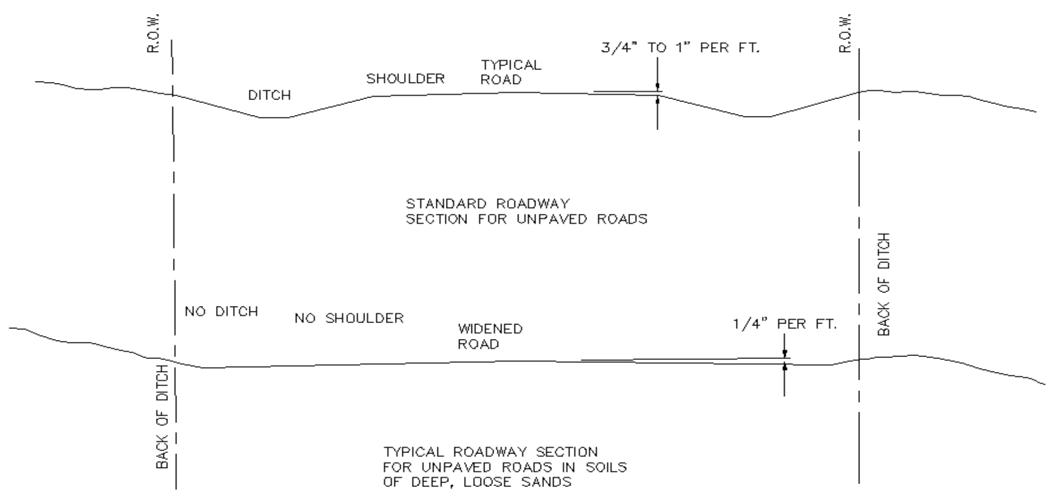


*Figure 1-1. Typical Sections - Unpaved Road*way

Exhibit 1.1a - Examples of 3/4" to 1' crown with road ditches in place. Water sheds readily off the crowned road surface and into the ditches. Proper drainage off the roadway surface helps to maintain a good "crust" which stabilizes the roadway and helps provide a good riding surface.

Exhibit 1.1b - Examples of 0" to 1/4" crown with no road ditches in place. Water infiltrates the soil of the sandy and flat road surface minimizing runoff from the roadway. The water that sheds from the roadway is readily removed from the road surface into the roadway edges allowing a passable lane in the center of the roadway.

Exhibit 1.1 - Typical Crowns and Sections Of Unpaved Roadways

Proper moldboard forward tilt for blading.

Proper blade angle and wheel lean.

Unnecessary Blading. Road is adequate.

Rutted, weathered, and rough surfaces require blading. Blading shaves high spots and fills low spots.

Exhibit 1.2 - Blading

Blading and Dragging

Blading and dragging is a smoothing operation which pulls loose material from the side of the road or spreads wind-rowed aggregate to fill surface irregularities and restore the road crown. It is performed with the moldboard tilted forward with light down pressure on the motor grader blade as shown in figure 1-2. The angle of the moldboard is adjusted to between 30 and 45 degrees, and in most cases, the front wheels are tilted slightly 10 to 15 degrees toward the direction the aggregate should roll.

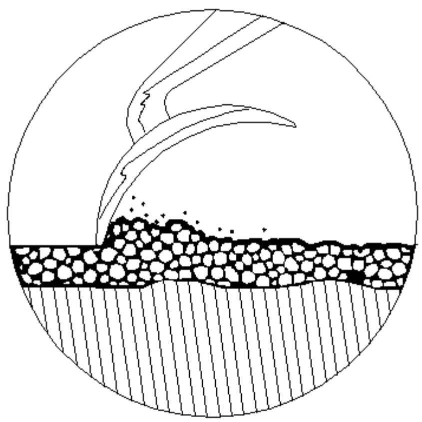


Figure 1-2. Blading

The following should be adhered to when blading:

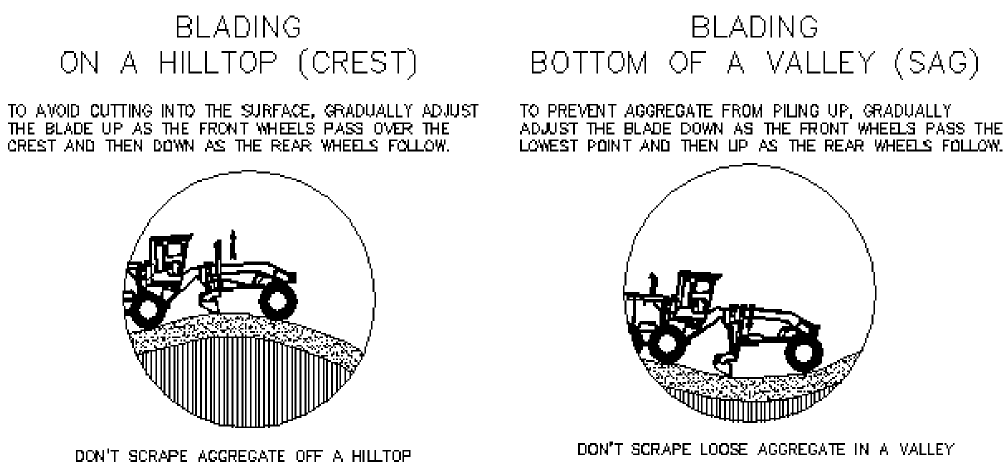
a. Avoid blading during extended dry periods to minimize the loss of fine aggregates and minimize "washboarding".

b. Blading/dragging speed depends on the operator's skill, type and condition of machine (grader), tire pressure, and road surface condition. Normally, **three miles per hour in second gear is advised**.

c. Periodically blade the road surface against traffic flow to prevent aggregate from drifting onto ends of bridges, culverts, intersections, and railroad crossings. This is commonly referred to as "back dragging".

d. On hill crests, avoid cutting into the road surface, gradually adjusting the blade up as the front wheels pass over the crest and then down as the rear wheels follow (figure 1-3a).

e. In valleys or swags, gradually adjust the blade down as the front wheels pass the lowest point and then adjust the blade up as the rear wheels follow. This will prevent loose, easily erodible materials from piling up where runoff and concentrated flows frequently occur, thus preventing loss of valuable road fill, and preventing massive sedimentation to local streams and waterways (figure 1-3b).



(a) (b)

Figure 1-3. Blading on Hill Crests and in Valleys or Swags

Reconstructive Grading

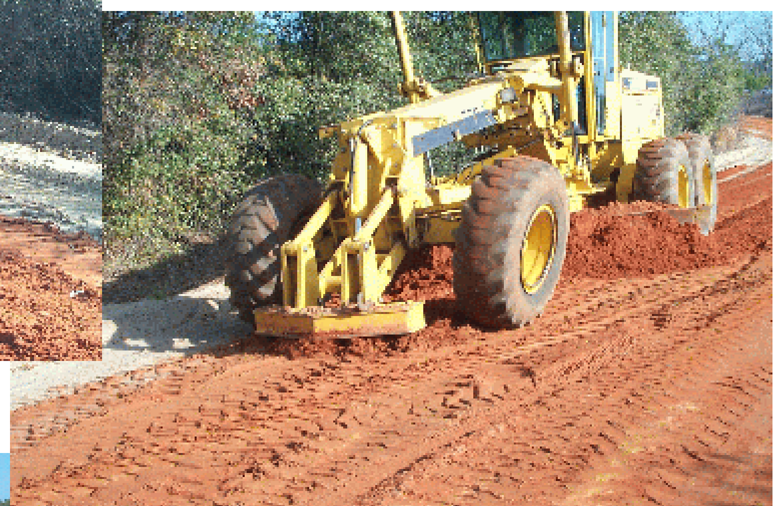
Reconstructive grading consists of cutting through, redistributing, and re-compacting the road surface crust, and/or adding new road fill material to obtain the desired roadway shape and profile. This method is used when reshaping the roadway or when the correction of major surface defects such as deep ruts, soft spots, severe erosion, etc. is necessary. Figure 1-4a shows motor grader cutting operations performed with the moldboard tilted backward with sufficient down pressure on the blade to produce a cutting action. Breaking the crust with a scarifying rake may be required before moldboard work can be performed (see figure 1-4b).

Deep rutting often requires grading work. Such ruts are frequently caused by heavy machinery such as farm equipment and feed trucks.

Exhibit 1.3 - Grading

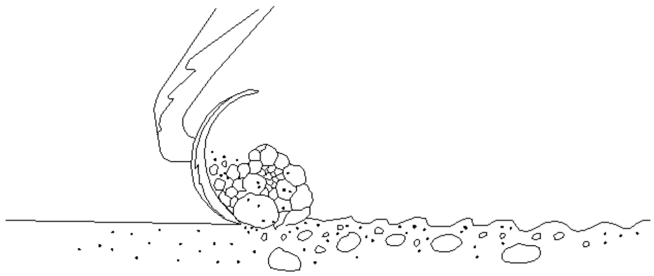
Clay surface layer placed over sandy roadway surface

Clay blended into roadway surface with scarifier and blade

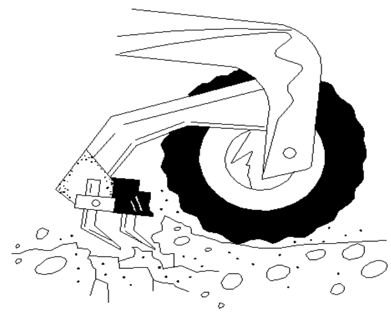


Aggregate blended into clay surface layer with scarifier

Exhibit 1.4 - Grading Using Scarifier and Blade



(a)



(b)

Figure 1-4. Grading Tools

The following should be adhered to when grading:

a. Perform grading cutting operations with the outer edge of the moldboard at the road surface's edge.

b. If the road ditch is not to be re-worked along with road grading operations, keep a minimum of one foot from the ditch line so that vegetation or rock stabilization is not disturbed. In this case, grading work <u>must</u> <u>always</u> bring the road surface back up to and slightly above the ditch line elevation to allow road surface runoff to flow into the ditch and not create a *false ditch* down the roadway (figure 1-5).

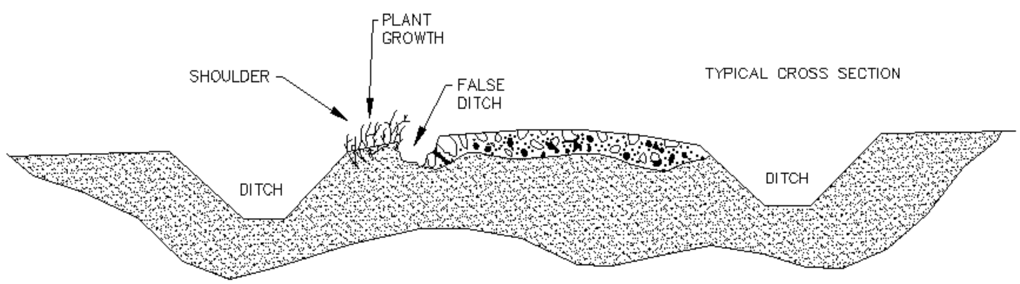


Figure 1-5. False Ditch

c. Lightly scarify the existing road surface before adding new material. This blends the soils and improves cohesion.

d. Adding new material should be done by running the dump truck down the center of the roadway and dumping as it travels. The new material should then be blended with the scarified old material using a grader, and compacted.

e. To reduce potential roadway degradation, the entire width of the of the roadway disturbed by grading should be compacted by the end of the day.

f. Positive drainage to road ditches or other outlets must be established throughout the entire finished road surface.

Distress Conditions

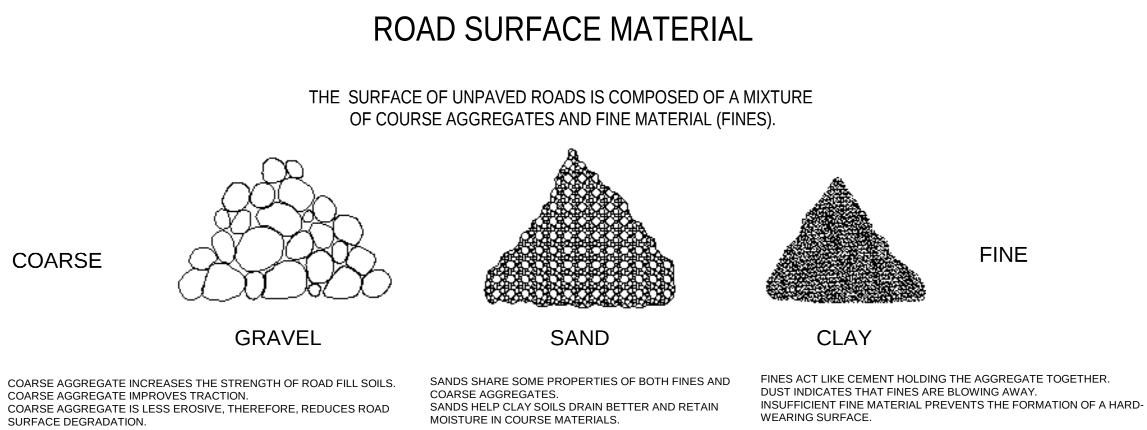


Figure 1-6. Aggregate Comparison

Surface Deteriorations

Dust

Dust in the air is a loss of fine, binder aggregates from road surfaces. Loss of these fines leads to other types of road distresses such as loss of cohesion and compaction of the road fill material, and reduced capacity to maintain moisture in the road fill. These deficiencies also tend to feed on themselves, compounding the problems - especially the lack of moisture within the road fill. Mechanically adding water to the road surface for dust control is a very short-term, expensive, and infeasible solution. In some cases, dust can be reduced by applying chemical additives which draw moisture from the air to improve fine aggregate cohesion, however, this also can be an expensive solution and may be feasible only in the most severe cases.

Ravelling

Ravelling is the loss of coarser aggregates. This is brought about when the coarser aggregates are worn away by traffic after fine, binder aggregates have been lost due to dust or erosion. Correct by grading or blading with the addition of fines or other binder to improve surface gradation and composition.

Slipperiness

Slipperiness is caused when the road surface contains excessive fine aggregates in proportion to coarser aggregates, especially within the crust. Traffic wear can reduce coarse aggregates to finer aggregates, thus dis-proportioning the original road fill aggregate mix. During wet weather, the road surface becomes slippery and may become impassible. This problem can be corrected by mixing the surface fines with coarser aggregate by grading and/or blading the road surface and compacting back in place. Occasionally, coarser aggregate will need to be hauled in and added to the roadway.

Surface Deformations

Surface deformation problems are almost solely the end result of excessive moisture in the road fill and thus can be reduced with proper road surface and road ditch maintenance.

Rutting

Ruts are longitudinal depressions in the wheel paths caused by high moisture content in the subsurface soil or base, inadequate surface course thickness, and /or heavy traffic loads. Rutting can be corrected by adding suitable material, grading, crowning, and rolling the road surface. Do not simply fill ruts with stone or soil. Filing ruts with stone can lead to new ruts being generated beside the original ones and thus would be an expensive and temporary “fix” which can also interfere with grading. The surface must be re-mixed and properly bladed or graded in more severe cases.

Areas of sustained and repeated rutting may require more severe measures. An elaborate drain system and/or geotextile fabric foundation with a crushed stone road fill may be used to correct severe rutting problems.

Corrugating/“Washboarding”

Corrugating/“washboarding” is a series of ridges and depressions across the road surface caused by the lack of surface cohesion. This lack of cohesion is a result of the loss of fines in the road surface which, in turn, is usually a result of very dry conditions within the road surface. These conditions are aggravated and enhanced by excessive vehicle speeds and high traffic volumes.

Where surface fines are segregated from coarser aggregates, blading with sufficient moisture content can repair the road surface. When the causative problem is of loss of fines, blading alone is not recommended. The problem will only recur shortly thereafter. The problem is best corrected by scarifying the road surface while damp, thereby re-mixing the road surface with a good percentage of fines, regrading, re-establishing the crown, and compacting the surface.

Depressions

Depressions are localized low areas one or more inches below the surrounding road surfaces caused by settlement, excessive moisture content, and improper drainage. These are larger areas not to be confused with potholes.

Depressions should be corrected by filling them with a well-graded aggregate, then grading the effected road surface, and compacting. Underdrains or cross drains may be necessary to improve drainage and prevent recurrence.

Potholes

Potholes are small depressions or voids in the road surface one or more inches deep which are caused by excessive moisture content, poor drainage, poorly graded aggregate, or a combination of these factors. Potholes may be corrected by patching with well-graded materials and compacting, and/or spot grading. Large areas of potholed road surface indicate a poor road fill condition over an extended section of roadway, and thus may require the re-grading, re-crowning, and re-compacting of the affected roadway section to mix aggregates into a well-graded road fill and improve road surface drainage. Underdrains may also be necessary in these areas to drain the sub-grade.

Softspots

Softspots are areas of the road surface and/or sub-grade made weak by poor drainage. These areas depress under vehicular weight and almost always develop one or more of the other types of surface deformations. These areas can be corrected by improving drainage conditions or

False ditch created by vegetal impediments

False ditch created by shoulder traffic and rutting

Washboarding

Slipperiness

Rutting

Exhibit 1.5 - Roadway Surface Problems

Soil stockpile
located on the
crest
of a hill where
runoff
is minimal

Soil stockpiles
located on
a well
vegetated
hillcrest and
away from
concentrated
flow channels

Exhibit 1.6 - Storing and Stockpiling Soil Materials

replacing the soft spot with more drainable materials. Depending on the cost effectiveness and feasibility of each, the following methods may be used to correct soft spots:

a. Improving the drainage of the road fill and/or sub-grade with underdrain. This method is outlet dependent.

b. Improving the drainage of the road fill and/or sub-grade by grading road ditches low enough to remove water from beneath the problem area. This may involve piping to move water from one side of the road to the other. This method is outlet dependent.

c. Patching the soft spot area with a suitable material such as well-graded stone or gravel.

d. A combination of the above.

Storing and Stockpiling Soil Materials

Improper storing or stockpiling of soil material can increase the amount of sediment that enters streams and damage sensitive areas, particularly wetlands. Soil materials should not be placed in or along wetlands, drainage ditches, swales, streambanks, areas within 50 feet of (and drain into) a waterway, and against slopes that are more than 2 horizontal to 1 vertical. Always ensure the area down slope of the storage area has an adequate vegetated filter strip to trap sediments, or use a properly installed and maintained silt fence or other barrier. Seed or vegetate any fill or spoil disposal areas as soon as possible.

Plan erosion-safe storage and stockpiling areas ahead of time, especially in the winter and early spring when rainfall can be high and vegetative cover minimal. Level to gently sloping, grassed areas usually provide good storage sites. Hilltops, ridges, and inactive or active borrow pits also often provide good sites. These planned storage areas will help reduce sedimentation and will also provide the opportunity to utilize these materials later when needed for roadway repairs. This can reduce overall maintenance costs by saving fill material and making it conveniently and readily available. Figure 1-7 illustrates proper stockpiling techniques of soil materials.

Disposal sites should drain well

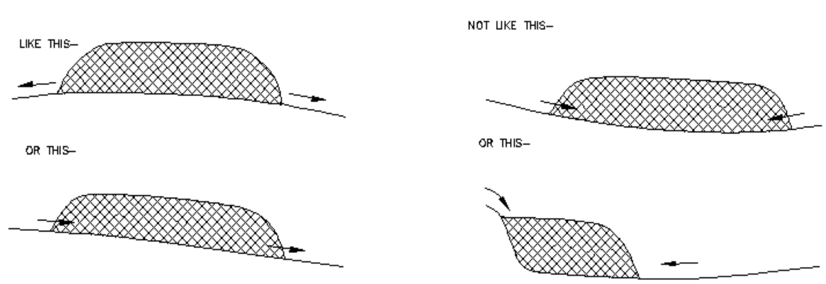


Figure 1-7. Soil Material Storage Site Configuration

Chapter 2
DITCHES

Description

Ditches are constructed to convey water from storm runoff to an adequate outlet. A good ditch is shaped and lined using the appropriate vegetative or structural material and does not cause flooding, erosion, or sedimentation. Energy dissipating structures to reduce velocity, dissipate turbulence, or to flatten flow grades in ditches are often necessary.

Importance to Maintenance & Water Quality

Efficient disposal of runoff from the road will help preserve the road bed and banks. Well vegetated ditches slow, control, and filter runoff providing an opportunity for sediments to be removed from the runoff water before it enters surface waters. In addition, a stable ditch will not become an erosion problem itself. Ideally, "turn-outs" (intermittent discharge points also called "tail ditches") will help maintain a stable velocity and the proper flow capacity within the road ditches by timely outleting water from them. This will help alleviate roadway flooding, reduce erosion, and thus reduce maintenance problems. In addition, properly placed "turn-outs" help distribute roadway runoff and sediments over a larger vegetative filtering area, helping to reduce the amount of road ditch maintenance required to remove caught-up sediment.

Ditch Profile and Grading

General

Roadway ditch location, profile, shape, lining and outlets effect how efficiently water will be removed from the roadway. Ideally ditches should resist erosion, be self cleaning, and discharge onto nearly level vegetated areas, thus maximizing the length of time between regrading, thereby reducing maintenance costs. As shown in figure 2-1, ditches should be located on the uphill side of the roadway to prevent runoff water from flowing onto and over the road surface.

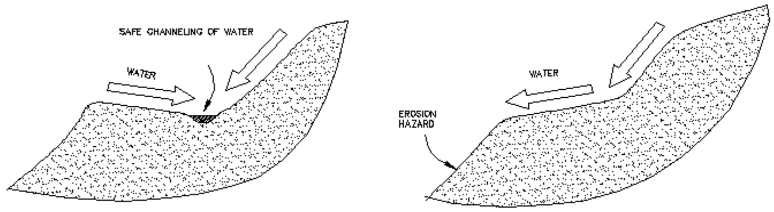


Figure 2-1. Hillside Pitch of Roadway and Proper Ditch Location

Excavate roadway ditches at a bottom elevation 1 to 2 feet below the road base. The ditch bottom should be rounded-V shaped (preferred), parabolic, or flat, as shown in figure 2-2, and at least 2 feet wide to disperse the flow and slow the velocity. Do not construct U-shaped ditches. U-shaped ditches actually have up to 30 percent less drainage capacity than other shapes and they tend to look messy. Their steep sides make maintenance difficult and the sides tend to cave in, compounding maintenance problems and adding to erosion and sedimentation.

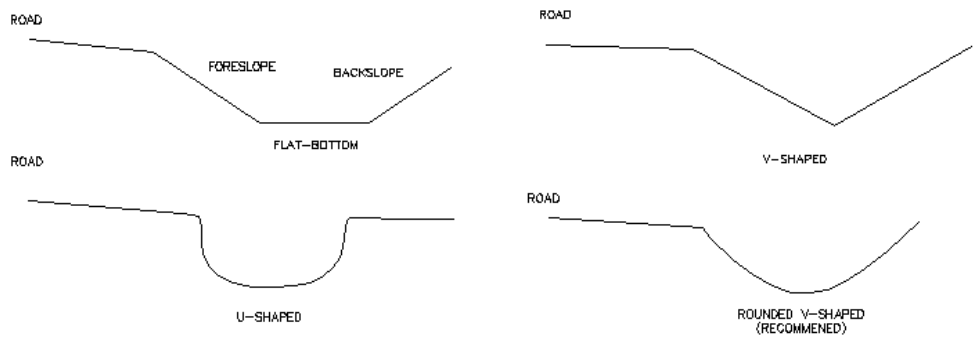


Figure 2-2. Common Ditch Shapes

Where possible, install "turn-outs" ("tail-ditches") to help maintain a stable velocity and the proper flow capacity within the road ditches by timely outleting water from them. See Figure 2-3 below. These structures are critical elements in establishing and maintaining a stable unpaved roadway drainage system. It is imperative that landowners adjacent to these roadways allow water to be discharged in this manner at crucial points. Correspondingly, these turn-out points must be stabilized to prevent creating worse erosion problems such as gullies. In many cases, the discharged runoff can be spread to reduce the erosive energy of concentrated flows.

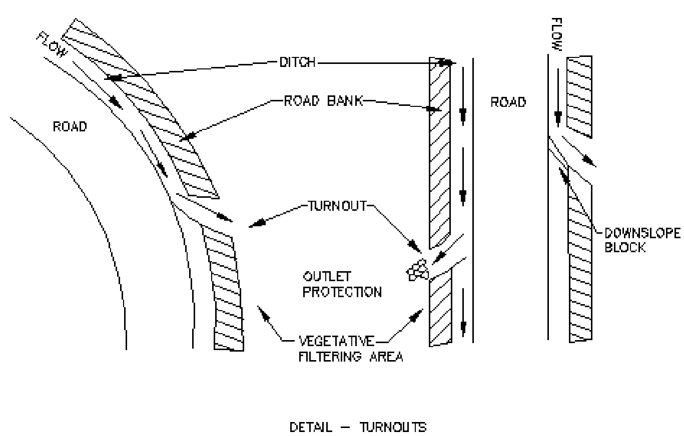


Figure 2-3. Typical Locations for "Turnouts" ("Tail Ditches")

No ditch on the uphill side of the roadway can allow runoff to overflow the roadway. This leads to surface erosion of the roadway, such as these corrugating rills, and often to complete washouts. Road surface overflow is a significant contributor to sedimentation, especially during high runoff events.

Exhibit 2.1 - Proper Ditch Location

Flat Bottom (Trapezoidal) Shaped Ditch

V-Shaped Ditch

U-Shaped Ditch

Rounded V-Shaped Ditch

Exhibit 2.2 - Common Ditch Shape Examples

Motor graders can be used to create and maintain tail ditches, however, backhoes and dozers can be more efficient and leave much less loose and disturbed soil which is easily and readily washed out.

Exhibit 2.3 - Tail Ditch/Turn-Out Construction with a Motor Grader

Turn-out to a drop inlet.

Turn-out at gradient changes.

Turn-out before bridges.

Turn-outs into filtering areas.

Turn-outs/Tail ditches outlet water from roadway ditches to maintain a stable flow volume and velocity within the ditches. They can be placed at specific and selected sites to protect down gradient structures such as bridges and culverts, or to utilize specific erosion control or storm water discharge facilities.

Exhibit 2.4 - Turn-outs/Tail Ditches

Line ditches which have a channel slope less than 5% with grass, and line those which have a 5% or greater channel slope with geo-fabric or aggregate filter underlain riprap or other material *(Concrete lining is not recommended on unpaved roads in the CPYRWMA area due to the highly erosive sandy soils and the potentially volatile nature of unpaved road degradation during intense storms common to this area).* Line ditches as soon as possible to prevent erosion and to maintain the ditch profile. Whenever possible, excavate ditch only as far as lining can catch up before the next expected or potential rainfall event.

All ditches should have appropriate outlets which allow water to completely drain from them. Standing water in ditches against road fill weakens the roadway. The preferred equipment for creating ditches is a rubber-tired excavator with an articulated bucket. A well designed and constructed road ditch can be cleaned with a grader or excavator making maintenance quicker, easier, and less costly.

Other Applications

Diversion ditches and berms may be used as structures to intercept, consolidate, and direct or redirect runoff at the top of a slope to prevent gullies and rills on slopes, or across the slope to break up the slope length or redirect water flow. These ditches and berms should be located where the outlet will empty onto a stable disposal area. Ditches and berms may be used in combination where runoff is significant and/or hard to control.

Cleaning & Maintenance

Check all ditches, including “tail-ditches” and “turn-outs”, after major storm events, as the storms may have caused obstructions, erosion, or bank collapse. Have a post-storm plan for checking for damage and determining maintenance needs.

Clean out ditches, when they become clogged with sediments or debris, to prevent ponding, bank overflows, and road washouts. Re-grade ditches only when absolutely necessary and line with vegetation or stone as necessary. Re-grading of ditches should be limited to late spring or summer, after spring rains have diminished and drier weather has set in, and when vegetation can re-establish itself. Other times may be suitable depending on weather patterns, work to be performed, and exigency of work to be done. The main concern is to limit disturbance to the ditches during times of high erosion potential.

United States Environmental Protection Agency
Office of Water Washington, D.C.
832-F-99-006
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Storm Water Technology Fact Sheet
Vegetated Swales

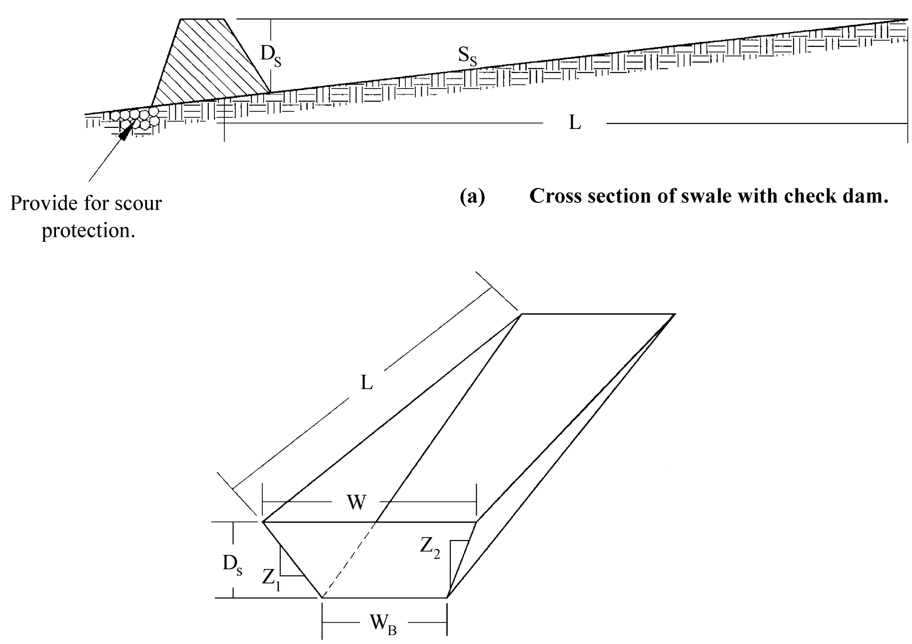
DESCRIPTION

A vegetated swale is a broad, shallow channel with a dense stand of vegetation covering the side slopes and bottom. Swales can be natural or manmade, and are designed to trap particulate pollutants (suspended solids and trace metals), promote infiltration, and reduce the flow velocity of storm water runoff. A typical design is shown in Figure1.

Vegetated swales can serve as part of a storm water drainage system and can replace curbs, gutters and storm sewer systems. Therefore, swales are best suited for residential, industrial, and commercial areas with low flow and smaller populations.

APPLICABILITY

Vegetated swales can be used wherever the local climate and soils permit the establishment and maintenance of a dense vegetative cover. The feasibility of installing a vegetated swale at a



(a) Cross section of swale with check dam.

(b) Dimensional view of swale impoundment area.

Notation:
- L = Length of swale impoundment area per check dam (ft)
- D_S = Depth of check dam (ft)
- S_S = Bottom slpe of swale (ft/ft)
- W = Top width of check dam (ft)
- W_B = Bottom width of check dam (ft)
- $Z_{1\&2}$ = Ratio of horizontal to vertical change in swale side slope (ft/ft)

Source: NVPDC, 1996.

FIGURE 1 EXAMPLE OF A VEGETATED SWALE

particular site depends on the area, slope, and perviousness of the contributing watershed, as well as the dimensions, slope, and vegetative covering employed in the swale system.

Vegetated swales are easy to design and can be incorporated into a site drainage plan. While swales are generally used as a stand-alone storm water Best Management Practice (BMP), they are most effective when used in conjunction with other BMPs, such as wet ponds, infiltration strips, wetlands, etc.

While vegetated swales have been widely used as storm water BMPs, there are also certain aspects of vegetated swales that have yet to be quantified. Some of the issues being investigated are whether their pollutant removal rates decline with age, what effect the slope has on the filtration capacity of vegetation, the benefits of check dams, and the degree to which design factors can enhance the effectiveness of pollutant removal.

ADVANTAGES AND DISADVANTAGES

Swales typically have several advantages over conventional storm water management practice, such as storm sewer systems, including the reduction of peak flows; the removal of pollutants, the promotion of runoff infiltration, and lower capital costs. However, vegetated swales are typically ineffective in, and vulnerable to, large storms, because high-velocity flows can erode the vegetated cover.

Limitations of vegetated swales include the following:

- They are impractical in areas with very flat grades, steep topography, or wet or poorly drained soils.
- They are not effective and may even erode when flow volumes and/or velocities are high.
- They can become drowning hazards, mosquito breeding areas, and may emit odors.
- Land may not be available for them.
- In some places, their use is restricted by law: many local municipalities prohibit vegetated swales if peak discharges exceed 140 liters per second (five cubic feet per second) or if flow velocities are greater than 1 meter per second (three feet per second).
- They are impractical in areas with erosive soils or where a dense vegetative cover is difficult to maintain.

Negative environmental impacts of vegetated swales may include:

- Leaching from swale vegetation may increase the presence of trace metals and nutrients in the runoff.
- Infiltration through the swale may carry pollutants into local groundwater.
- Standing water in vegetated swales can result in potential safety, odor, and mosquito problems.

DESIGN CRITERIA

Design criteria for implementation of the vegetated swales are as follows:

Location

Vegetated swales are typically located along property boundaries along a natural grade, although they can be used effectively wherever the site provides adequate space. Swales can be used in place of curbs and gutters along parking lots.

Soil Requirements

Vegetated swales should not be constructed in gravelly and coarse sandy soils that cannot easily support dense vegetation. If available, alkaline soils and subsoils should be used to promote the removal and retention of metals. Soil infiltration rates should be greater than 0.2 millimeters per second (one-half inch per hour); therefore, care must be taken to avoid compacting the soil during construction.

Vegetation

A fine, close-growing, water-resistant grass should be selected for use in vegetated swales, because increasing the surface area of the vegetation exposed to the runoff improves the effectiveness of the swale system. Pollutant removal efficiencies vary greatly depending on the specific plants involved, so the vegetation should be selected with pollution control objectives in mind. In addition, care should be taken to choose plants that will be able to thrive at the site. Examples of vegetation appropriate for swales include reed canary grass, grass-legume mixtures, and red fescue.

General Channel Configuration

A parabolic or trapezoidal cross-section with side slopes no steeper than 1:3 is recommended to maximize the wetted channel perimeter of the swale. Recommendations for longitudinal channel slopes vary within the existing literature. For example, Schueler (1987) recommends a vegetated swale slope as close to zero as drainage permits. The Minnesota Pollution Control Agency (1991) recommends that the channel slope be less than 2 percent. The Storm Water Management Manual for the Puget Sound Basin (1992) specifies channel slopes between 2 and 4 percent. This manual indicates that slopes of less than 2 percent can be used if drain tile is incorporated into the design, while slopes greater than 4 percent can be used if check dams are placed in the channel to reduce flow velocity.

Flows

A typical design storm used for sizing swales is a six-month frequency, 24-hour storm event. The exact intensity of this storm must be determined for your location and is generally available from the U.S. Geological Survey. Swales are generally not used where the maximum flow rate exceeds 140 liters/second (5 cubic feet per second).

Sizing Procedures

The width of the swale can be calculated using various forms of the Manning equation. However, this methodology can be simplified to the following rule of thumb: the total surface area of the swale should be one percent of the area (500 square feet for each acre) that drains to the swale.

Unless a bypass is provided, the swale must be sized both to treat the design flows and to pass the peak hydraulic flows. However, for the swale to treat runoff most effectively, the depth of the storm water should not exceed the height of the grass.

Construction

The subsurface of the swale should be carefully constructed to avoid compaction of the soil. Compacted soil reduces infiltration and inhibits growth of the grass. Damaged areas should be restored immediately to ensure that the desired level of treatment is maintained and to prevent further damage from erosion of exposed soil.

Check Dams

Check dams can be installed in swales to promote additional infiltration, to increase storage, and to reduce flow velocities. Earthen check dams are not recommended because of their potential to erode. Check dams should be installed every 17 meters (50 feet) if the longitudinal slope exceeds 4 percent.

PERFORMANCE

The literature suggests that vegetated swales represent a practical and potentially effective technique for controlling urban runoff quality. While limited quantitative performance data exists for vegetated swales, it is known that check dams, slight slopes, permeable soils, dense grass cover, increased contact time, and small storm events all contribute to successful pollutant removal by the swale system. Factors decreasing the effectiveness of swales include compacted soils, short runoff contact time, large storm events, frozen ground, short grass heights, steep slopes, and high runoff velocities and discharge rates.

Conventional vegetated swale designs have achieved mixed results in removing particulate pollutants. A study performed by the Nationwide Urban Runoff Program (NURP) monitored three grass swales in the Washington, D.C., area and found no significant improvement in urban runoff quality for the pollutants analyzed. However, the weak performance of these swales was attributed to the high flow velocities in the swales, soil compaction, steep slopes, and short grass height. Another project in Durham, NC, monitored the performance of a carefully designed artificial swale that received runoff from a commercial parking lot. The project tracked 11 storms and concluded that particulate concentrations of heavy metals (Cu, Pb, Zn, and Cd) were reduced by approximately 50 percent. However, the swale proved largely ineffective for removing soluble nutrients. A conservative estimate would say that a properly designed vegetated swale may achieve a 25 to 50 percent reduction in particulate pollutants, including sediment and sediment-attached phosphorus, metals, and bacteria. Lower removal rates (less than 10 percent) can be expected for dissolved pollutants, such as soluble phosphorus, nitrate, and chloride. Table 1 summarizes some pollutant removal efficiencies for vegetated swales.

TABLE 1 EFFECTIVENESS OF DESIGN SWALES

Pollutant	Median % Removal
Total Suspended Solids	81
Oxygen Demanding Substances	67
Nitrate	38
Total Phosphorus	9
Hydrocarbons	62
Cadmium	42
Copper	51
Lead	67
Zinc	71

The effectiveness of vegetated swales can be enhanced by adding check dams at approximately 17 meter (50 foot) increments along their length (See Figure 1). These dams maximize the retention time within the swale, decrease flow velocities, and promote particulate settling. Structures to skim off floating debris may also be added to the swales. Finally, the incorporation of vegetated filter strips parallel to the top of the channel banks can help to treat sheet flows entering the swale.

OPERATION AND MAINTENANCE

The useful life of a vegetated swale system is directly proportional to its maintenance frequency. If properly designed and regularly maintained, vegetated swales can last indefinitely.

The maintenance objectives for vegetated swale systems include keeping up the hydraulic and removal efficiency of the channel and maintaining a dense, healthy grass cover. Maintenance activities should include periodic mowing (with grass never cut shorter than the design flow depth), weed control, watering during drought conditions, reseeding of bare areas, and clearing of debris and blockages. Cuttings should be removed from the channel and disposed in a local composting facility. Accumulated sediment should also be removed manually to avoid the transport of resuspended sediments in periods of low flow and to prevent a damming effect from sand bars. The application of fertilizers and pesticides should be minimal.

Another aspect of a good maintenance plan is repairing damaged areas within a channel. For example, if the channel develops ruts or holes, it should be repaired utilizing a suitable soil that is properly tamped and seeded. The grass cover should be thick; if it is not, reseed as necessary.

Any standing water removed during the maintenance operation must be disposed to a sanitary sewer at an approved discharge location. Residuals (e.g., silt, grass cuttings) must be disposed in accordance with local or State requirements.

COSTS

Vegetated swales typically cost less to construct than curbs and gutters or underground storm sewers. Schueler (1987) reported that costs may vary from $16-$30 per linear meter ($4.90 to $9.00 per linear foot) for a 4.5 meter (15-foot) wide channel (top width).

The Southeastern Wisconsin Regional Planning Commission (SEWRPC, 1991) reported that costs may vary from $28 to $164 per linear meter ($8.50 to $50.00 per linear foot) depending upon swale depth and bottom width. These cost estimates are higher than other published estimates because they include the cost of activities (such as clearing, grubbing, leveling, filling, and sodding) that may not be included in other published estimates. Construction costs depend on specific site considerations and local costs for labor and materials. Table 2 shows the estimated capital costs of a vegetated swale.

Annual costs for maintaining vegetated swales are approximately $1.90 per linear meter ($0.58 per linear foot) for a 0.5 meter (1.5-foot) deep channel, according to SEWRPC (1991). Average annual operating and maintenance costs of vegetated swales can be estimated using Table 3.

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TABLE 2 ESTIMATED CAPITAL COST OF A 1.5- FOOT DEEP, 10-FOOT-WIDE GRASSED SWALES[a]

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization / Demobilization-Light	Swale	1	$107	$274	$441	$107	$274	$441
Site Preparation								
Clearing[b]................	Acre	0.5	$2,200	$3,800	$5,400	$1,100	$1,900	$2,700
Grubbing[c].............	Acre	0.25	$3,800	$5,200	$6,600	$950	$1,300	$1,650
General Excavation[d]...........	Yd^3	372	$2.10	$3.70	$5.30	$781	$1,376	$1,972
Level and Till[e]........	Yd^2	1,210	$0.20	$0.35	$0.50	$242	$424	$605
Sites Development								
Salvaged Topsoil Seed, and Mulch[f]..	Yd^2	1,210	$0.40	$1.00	$1.60	$484	$1,210	$1,936
Sod[g].....................	Yd^2	1,210	$1.20	$2.40	$3.60	$1,452	$2,904	$4,356
Subtotal	--	--	--	--	--	$5,116	$9,388	$13,660
Contingencies	Swale	1	25%	25%	25%	$1,279	$2,347	$3,415
Total	--	--	--	--	--	$6,395	$11,735	$17,075

Source: (SEWRPC, 1991)

Note: Mobilization/demobilization refers to the organization and planning involved in establishing a vegetative swale.

[a] Swale has a bottom width of 1.0 foot, a top width of 10 feet with 1:3 side slopes, and a 1,000-foot length.

[b] Area cleared = (top width + 10 feet) x swale length.

[c] Area grubbed = (top width x swale length).

[d] Volume excavated = (0.67 x top width x swale depth) x swale length (parabolic cross-section).

[e] Area tilled = $\left(\text{top width} + \frac{8(\text{swale depth}^2)}{3(\text{top width})}\right)$ x swale length (parabolic cross-section).

[f] Area seeded = area cleared x 0.5.

[g] Area sodded = area cleared x 0.5.

TABLE 3 ESTIMATED OPERATION AND MAINTENANCE COSTS

Component	Unit Cost	Swale Size (Depth and Top Width)		Comment
		1.5 Foot Depth, One-Foot Bottom Width, 10-Foot Top Width	3-Foot Depth, 3-Foot Bottom Width, 21-Foot Top Width	
Lawn Mowing	$0.85 / 1,000 ft^2/ mowing	$0.14 / linear foot	$0.21 / linear foot	Lawn maintenance area=(top width + 10 feet) x length. Mow eight times per year
General Lawn Care	$9.00 / 1,000 ft^2/ year	$0.18 / linear foot	$0.28 / linear foot	Lawn maintenance area = (top width + 10 feet) x length
Swale Debris and Litter Removal	$0.10 / linear foot / year	$0.10 / linear foot	$0.10 / linear foot	--
Grass Reseeding with Mulch and Fertilizer	$0.30 / yd^2	$0.01 / linear foot	$0.01 / linear foot	Area revegetated equals 1% of lawn maintenance area per year
Program Administration and Swale Inspection	$0.15 / linear foot / year, plus $25 / inspection	$0.15 / linear foot	$0.15 / linear foot	Inspect four times per year
Total	**--**	**$0.58 / linear foot**	**$ 0.75 / linear foot**	**--**

Source: SEWPRC, 1991.

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