Pennsylvania Stormwater Best Management Practices Manual

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Section 8
Special Stormwater Management for Highways and Roads

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Section 8 Special Stormwater Management for Highways and Roads

8.1 Introduction

8.2 Roadway Runoff Quality Issues

8.3 BMP Considerations for Roadways

8.4 Specific BMP Considerations:

8.4.1 Limited Access Highways, Interstates and Turnpikes (Principal Arterials)

8.4.2 New Streets and Residential Roads

8.5 Gravel Roads

Section 8 Special Stormwater Management for Highways and Roads

8.1 Introduction

The purpose of this Section is to consider the most suitable BMPs for management of runoff from roadways. Consideration of roadway design, construction, and maintenance must be included in the selection of BMPs that mitigate the quality, rate, and volume impacts of roadway runoff.

Mitigating the impacts of runoff from highways and roads is a concern for both highway managers (such as PennDOT and the PA Turnpike Commission) and for municipalities tasked with stormwater management and NPDES Phase II responsibilities. Highways and roads face specific challenges in managing stormwater, including:

- The need to manage stormwater while maintaining safe roadway conditions
- Limited available space and the need to locate BMPs within the right-of-way, if possible.
- Drainage area imperviousness greater than 50 percent, and sometimes 100%.
- Areas of extensive disturbance and compaction of soils (cut and fill).
- The potential for spills of hazardous materials.
- The use of deicing chemicals and salts, and the need to dispose of removed snow.
- Higher concentration of pollutants as compared to many other land uses.
- Thermal impacts to receiving streams in both summer and winter.

Pennsylvania is ranked eighth in the country in terms of “total road and street” miles (http://www.fhwa.dot.gov), with a total of over 120,000 road miles, including 20,000 miles of gravel roads. Since the state also leads the nation in stream miles, the intersection of these two surface networks warrants careful consideration by both stormwater managers and roadway designers in Pennsylvania.

Figure 8-1. Arterial Road in Radnor Township, Delaware County

8.2 Roadway Runoff Quality Issues

The runoff from highways and roadways has been identified as a significant source of stormwater pollutants (Bannerman, et al 1993), as well as a significant source of thermal pollution to receiving waterways (Bush, et al 1974). The chemical constituents of roadway runoff are highly variable. The Federal Highway Administration (FHWA, 1999, Ultra-urban) identifies a number of roadway runoff pollutants and possible sources (Table 8-1). The FHWA also summarizes the concentrations of typical constituents found in highway runoff as outlined in Table 8-2. In comparison to other land uses and impervious surfaces, roadway runoff tends to have higher levels of sediment and suspended solids, which must be taken into consideration when selecting BMPs. Roadway runoff may also contain salts, deicing materials, and metals that can affect both receiving waters and vegetation and must be considered in BMP selection.

In addition to the chemical water quality issues associated with roadway runoff, there may also be temperature impacts that affect water quality. Roadway systems may deliver large amounts of warm or cold water directly and rapidly to receiving streams and wetlands, resulting in significant temperature impacts for aquatic species. Studies have shown that the runoff from summer storm events may exceed 32 degrees C, and winter runoff may be 3-4 degrees C colder than the receiving stream ambient temperature (Galli, 1990, Pluhowski, 1970). These temperature impacts can have profound impacts on the aquatic systems of a receiving stream, and significantly alter and reduce the aquatic diversity. Stormwater collection/conveyance systems must be designed with consideration of the potential impacts on receiving waters due to the temperature of runoff from impervious road surfaces. Stormwater BMPs must also be designed with consideration of temperature impacts. Extended detention basins may increase temperature impacts, and should be designed to reduce this potential impact as discussed below.

*Table 8-1 Constituents and Sources in Highway Runoff **

Constituent	Source
Particulates	Pavement wear, vehicles, atmospheric deposition, maintenance activities
Nitrogen, Phosphorus	Atmospheric deposition and fertilizer application
Lead	Leaded gasoline from auto exhausts and tire wear
Zinc	Tire wear, motor oil and grease
Iron	Auto body rust, steel highway structures such as bridges and guardrails, and moving engine parts
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides
Cadmium	Tire wear and insecticide application
Chromium	Metal plating, moving engine parts, and brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, bushing wear, brake lining wear, and asphalt paving
Manganese	Moving engine parts
Cyanide	Anti-caking compounds used to keep deicing salts granular
Sodium, Calcium Chloride	Deicing salts
Sulphates	Roadway beds, fuel, and deicing salts

* From FHWA Stormwater Best Management Practices in an Ultra-Urban Setting

Table 8-2. Constituents of Highway Runoff

Parameter	Concentration (mg/L)
Total Suspended Solids (TSS)	45 - 798
Volatile Suspended Solids (VSS)	4.3 - 79
Total Organic Carbon (TOC)	24 - 77
Chemical Oxygen Demand (COD)	14.7 - 272
Biochemical Oxygen Demand (BOD)	12.7 37
Nitrate + Nitrite (NO_3 + NO_2)	0.15 - 1.636
Total Kjeldahl Nitrogen (TKN)	0.335 - 55.0
Total Phosphorus as P	0.113 - 0.998
Copper (Cu)	0.022 - 7.033
Lead (Pb)	0.073 - 1.78
Zinc (Zn)	0.056 - 0.929
Fecal coliform (organisms/100 ml)	50 - 590

8.3 BMP Considerations for Roadways

While many of the BMPs discussed in this manual are appropriate for use in managing roadway runoff, these BMPs should be designed and implemented with consideration of the nature of runoff from road surfaces. Specifically:

1. Roadway runoff has higher levels of Suspended Solids as compared to many other urban land uses. Roadway runoff should NOT be discharged directly to infiltration systems without measures to reduce sediment loads. Infiltration BMPs are appropriate for roadway systems but must be designed in conjunction with a measure (structural or non-structural) that reduces the amount of sediment in roadway runoff prior to infiltration. A variety of options exist to reduce sediment loads, including:

    a. Vegetated systems such as grassed swales, filter strips, and bioretention.
    b. Structural elements such as catch basin inserts, filters, and manufactured treatment units.
    c. Maintenance measures such as street sweeping and vacuuming.

    The use of these measures before discharge to an infiltration BMP will prevent the accumulation of sediment that may lead to failure of an infiltration BMP. All measures for sediment reduction require regular maintenance.

2. Vegetative BMPs such as grassed swales and filter strips can be highly effective in reducing pollutant loads from roadways but must be properly designed in terms of slope, flow velocity, flow length, and vegetative cover (Barrett, et al, 1997). Improperly designed or maintained systems may contribute to pollutant load, rather than reduce it.

3. The issue of spills must be considered. It is cost prohibitive to design for spill containment on all sections of roadway, but the designer should certainly consider the potential for spills and the necessary action should a spill occur. For subsurface systems, infiltration systems,

Figure 8-2. Bioretention incorporated in a highway median, (Photo courtesy of LIDC).

or vegetative systems, replacement of the system may be necessary should a spill occur. While this may seem to be a limiting factor in the use of such systems, many existing storm sewers from roadways discharge directly to receiving streams with no opportunity to contain or mitigate a spill before discharge to a receiving stream. Therefore, while BMP restoration may be required after a spill, a stream discharge of a spill may be prevented.

4. The use of deicing materials and salts may affect vegetation, soil conditions, and water quality. Consideration should be given to the types of vegetation used in vegetative BMPs, as chloride levels may adversely affect some vegetation as well as the soil microbial community. Proximity to water supply sources should also be considered when designing infiltration BMPs, and the potential for groundwater chloride levels to be impacted by roadway runoff should be considered. Consideration must also be given to the disposal of snow removed from roadways. This snow may ultimately be deposited in BMP areas and may contain higher concentrations of roadway salts and sediments. The potential impacts of this material on the BMP should be considered in the design process.

5. The temperature impacts of runoff from roadways can significantly affect receiving stream aquatic habitat. Roadways, especially asphalt roadways, tend to absorb heat and lack cooling vegetation. Many existing storm sewers from roads discharge directly and immediately to receiving waters. New discharges should provide mitigation for temperature impacts prior to discharge to the receiving water. This may involve:

    a. Vegetated systems and buffers to replace sections of concrete swales or pipes (that can impart heat to runoff), and disconnection of pipes that discharge directly to streams or natural wetlands. The use of multiple small drainage elements that use vegetated swales for conveyance will help to reduce the temperature impacts from roadway runoff.

    b. If extended detention systems, wet ponds, or constructed wetlands are used for peak rate mitigation, the discharge from these systems should be further mitigated by the use of vegetated swales or buffers, as these impoundments may also create adverse temperature impacts (SWRCB 2002; Oberts 1997). The discharge from an extended detention system should be conveyed via a vegetated swale, or dispersed through a level spreader. Discharges should not be piped directly into receiving streams or wetlands.

c. Extended detention systems should include design elements to reduce temperature impacts. Recommended techniques (FHW, Young, et al 1996) include:
    1. Design system with minimal permanent pool.
    2. Preserve existing shade trees, plant fast growing trees along shoreline.
    3. Align pond in a north-south direction.
    4. Avoid excessive rip-rapping and concrete channels that impart heat to runoff.

Table 8-3. Impacts and Mitigation Measures for use of extended detention basins (Young, et al. 1996)

Environmental Issue	Diligent Responses
Need to avoid an existing wetland	Perform wetland delineation before sitting pond.
	Select pond systems with minimal permanent pool.
	Adjust pond configuration.
	Install parallel pipe system to divert runoff around wetland to pond site sited further downstream.
	Construct ponds around the wetland.
Need to preserve mature forest or habitat area	Configure pond to minimize the removal of specimen trees.
	Limit the area of disturbance.
	Mandate tree protection measures during construction.
	Plant native trees and shrubs to replicate habitat functions lost due to pond.
Concern about the thermal impact of pond on downstream fishery	Select system with minimal permanent pool.
	Preserve existing shade trees, plant fast-growing shade trees along the shoreline.
	Align pond north-south direction.
	Avoid excessive rip-rapping and concrete channels that rapidly impart heat to runoff.
	Maximize detention and/or increase first flush amount to runoff greater than first 13 mm of rain.
Need to protect stream reach above pond from urban stormflows	Install parallel pipe system along the upstream reach to convey excessive stormflows.
	Install plunge-pools at terminus of storm drains to reduce runoff velocities.
	Use bioengineering techniques and checkdams to stabilize the stream reach.

PENNDOT Program and Recommendations

As the primary state agency charged with construction, operation and maintenance of the major roadways in the Commonwealth, the PA Dept. of Transportation has worked to develop a strategy to deal with two related issues. The immediate impact created by earthwork and disturbance during new construction, considered as Erosion and Sediment Control (E&S), is the subject of the recent Manual produced by the Department (PENNDOT E&S Manual, 2004). The long-term problems of stormwater runoff, discussed here, remains as a major issue. In discussions with PADEP, a set of strategies has been proposed for consideration, as follows:

- Utilize sod-forming grasses adjacent to the roadway shoulders and for Vegetated Swales to serve as Filters for suspended solids and metals.
- Utilize non-invasive native species vegetation (or plant species that are known to uptake and store certain contaminants) in lawn areas, on slopes and within wetland reconstruction/banking areas to enhance Water Uptake and the storage of certain pollutants in plant tissue.
- Limit the use of curb-gutter sections as much as practical for Filtering and Temperature considerations.
- Limit the use of storm sewers as much as practical for Filtering and Temperature considerations.
- Consider a Bioretention capability in the design of new detention basins (Dry Extended Detention Basin design).
- Monitor the effectiveness of existing Constructed Wetlands, updating the current design practices as necessary.
- Consider alternative methods of energy dissipation (in-lieu of rock pads) at culvert and storm sewer outfalls for Temperature considerations.
- Where practical, discharge storm sewers into wetland areas or vegetated swales instead of outfalling directly to streams for Filtering and Temperature considerations.
- Consider vegetated islands in-lieu of concrete islands (where practical for maintenance considerations) for Filtering and Temperature considerations.
- Consider the inclusion of Infiltration Berms and Retentive Grading in areas that are downslope of the roadway.
- Continue efforts to monitor and minimize the volume of winter maintenance materials utilized to Minimize Pollutant Loadings within the runoff and into the groundwater.
- Continue efforts to protect all salt storage and loading areas from weather influences in efforts to Minimize Pollutant Loadings.
- Consider practices to dilute flows where high concentrations of salts are anticipated to Minimize Pollutant Loadings.
- Consider Porous Pavement and other Subsurface Infiltration methodologies on Department park and ride sites and for Department building site parking areas.
- Consider Dry Wells and other Subsurface Infiltration methodologies for Department building roof drains.

8.4 Specific BMP Considerations

8.4.1 Limited Access Highways, Interstates and Turnpikes (Principal Arterials)

Highways are usually designed with shoulders and often include vegetated medians. These areas present the primary opportunities for BMP implementation on highways and interstates. Infiltration opportunities may be limited due to compaction and fill, as the right-of-way is often subject to significant grading changes to meet highway design standards. However, infiltration should not be precluded, and should be considered on a case-by-case basis.

The use of vegetated swales and buffer strips is highly recommended to reduce sediment loads from highways, but the possible impact on sight distances and roadway visibility must be considered, with planting design sensitive to this height issue. Vegetated swales and buffer strips can be combined with subsurface infiltration trenches or small infiltration/bioretention basins for volume reduction and temperature mitigation. For example, strips of vegetated swales that are underlain by infiltration trenches can provide both quality treatment and volume reduction, and replace concrete channels and pipe systems. Numerous small bioretention systems can provide peak rate mitigation and be incorporated into the right-of-way.

Figure 8-3. Pennsylvania Turnpike (AH)

8.4.2 New Streets and Residential Roads

New streets and roads in residential and commercial developments provide the greatest opportunity to incorporate both non-structural and structural BMPs to address road runoff. Non-structural BMPs include:

- Reduced street widths
- Reduction or elimination of curbs and gutters
- Reduction of storm sewer infrastructure

Structural residential road systems include:

- Vegetated swales and infiltration trenches along right-of-way
- Bioretention areas along roadway
- Bioretention or bio-infiltration in cul-de-sacs
- Porous pavement
- Infiltration trenches along the contour that are perpendicular to the road
- Catch basin inserts or treatment devices

In new development, the roads and driveways often comprise the greatest amount of impervious area, sometimes as much as 70% of the total impervious area. Techniques that seek to manage the roadway runoff where it is generated and reduce piping and conveyance of stormwater should be implemented to the greatest extent possible.

Figure 8-4. Residential Road in West Vincent Township, Chester County (AH)

8.5 Gravel Roads

A significant portion of the state is served by unpaved roadways constructed of various types of gravel base, constructed over time and with locally available materials. While not constructed with AC impervious pavement, theses roadways serve as stormwater conveyance pathways, creating significant erosion in the process and requiring constant maintenance to restore shoulders.

Pennsylvania has over 20,000 miles of gravel roads. These roads consist of dirt and/or gravel and have historically remained un-maintained compared to paved roads. These roads can be a source of pollution to streams and rivers in a drainage area, especially for sediment. This pollution occurs as precipitation carries sediment eroded from these roads and adjacent banks along the road surface and into open water. Statewide, runoff from these roads is not the major source of pollution in streams, but close proximity of rural roads to high quality streams is common, and these roads sometimes parallel streams and discharge directly into them. Others have culverts that convey large amounts of water before discharging at high rates, following long downhill grades to a stream crossing.

Adequate drainage is essential to the longevity of these roads, but the discharge of this drainage must consider the health of the surrounding environment.

The Pennsylvania Conservation District's Pennsylvania's Dirt & Gravel Road Pollution Prevention Program was formed in 1997 to "fund environmentally sound maintenance of unpaved roadways that have been identified as sources of dust and sediment pollution." This program strives to reduce erosion, sediment, and dust pollution by using improved maintenance techniques that benefit both dirt and gravel roads and the environment. This program is centered on using local control as a method of stopping pollution. At least 500 projects have been completed under this program, and over 1,800 people have participated in their training course, "Environmentally Sensitive Maintenance." Generally, areas that are eligible for review are those that have sediment from the road reaching a stream.

Figure 8-5. Pennsylvania Dirt Road (Penn State Center for Dirt and Gravel Road Studies)

Program initiatives include identifying and replacing pipes running beneath unpaved roads that are undersized and contribute to "ponding" on the road. The program also has developed a GIS (Geographical Information Systems) database, which tracks the location and status of all the dirt and gravel roads in PA, and allows the local entities to submit electronic reports directly to the State Conservation Commission. In 2000, data from over 17,000 miles of unpaved roads was compiled and resulted in over 11,000 verified pollution sites found. In addition to this, the program is undergoing an aggregate study in Center County, PA to determine the most economical and durable stone for gravel roads.

Local Municipalities and state agencies have jurisdiction of over 90% of dirt and gravel roads, and while the cost of paving these roads is high, there are some measures that can be taken to maintain an unpaved road. Recommendations are:

- Work with the natural landscape in the design of roads (minimize cut and fill)
- Identify existing drainage patterns and design to minimize disturbance
- Crown the road to drain the water away from the center
- Tractors or trucks with blades can be used to reshape a road
- Roadside ditches should be sized appropriately and perhaps incorporated with an infiltration design
- Aggregate mix should be angular on the surface with fines to provide stability (stone quality matters)
- Vegetate roadside cutbanks to prevent erosion
- Reshape road after snow season
- Preserve any vegetation in ditches and trees alongside road
- Limit driving speeds

Reduced road maintenance costs (blading, regrading, & regraveling) and reduced sedimentation in water affecting aquatic life and drinking water reservoirs should result form the implementation of these measures, and are consistent with the various BMPs discussed in this Manual.

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