Article 114

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Performance of Grassed Swales Along East Coast Highways

Highways are a unique form of development in that their impervious lanes span over many miles, frequently crossing both large and small drainage divides. For many highway engineers, the preferred option for runoff treatment involves the use of long grassed swales, located in a narrow right-of-way parallel to the highway or within the median strip. Grassed swales are cheap to construct, easy to maintain, and are often needed anyway to convey excess stormwater runoff off the road. How effective are they in removing the many pollutants that wash off road surfaces?

To address this question, Dorman and his colleagues (1989) evaluated the performance of three highway swale systems in Florida, Maryland and Virginia. They measured flows and pollutant concentrations through three different swales that were each about 200 feet in length. The three swales that were selected spanned a wide range of conditions encountered along highways: slopes (one to 5%), soil types (sandy to silt loam), vegetative cover (good to poor) and age (five to 20 years-see Table 1). In addition, they monitored the concentration of metals and nutrients within swale soils to determine if pollutants were accumulating over time. In another related study, a research team lead by Shaw Yu (1993) has been monitoring the pollutant removal capability of a 300- foot-long highway swale in Virginia.

Despite the fact that the swales were of equal length, their reported removal rates were quite different (Table 2). As might be expected, the Florida swale exhibited the best overall removal capability. High removal rates for sediment (98%) organic carbon (64%) and nitrogen (45 to 48%) are often expected at sites with low slope, sandy soils, and dense grass cover. Monitored phosphorus removal (18%) was on the low range reported for grassed swales and biofilter systems, but metal removal usually exceeded 50 to 70%.

The Maryland swale occupied the other end of the performance spectrum. The swale had a moderate slope (3.2%), but had poor grass cover and was prone to erosion. Although the sampling was limited (four storm events), the swale was found to export sediment and nitrate and demonstrated little capability to remove organic nitrogen, organic carbon, or total phosphorus. Metal removal rates were mixed, with high rates reported for cadmium, and low rates for copper, lead and zinc.

While the Virginia swale had the highest average slope (4.7%), it had better vegetative cover and experienced only minor erosion. Consequently, it exhibited moderate performance in removing highway pollutants. Removal of sediment and organic carbon exceeded 65%, and total phosphorus was reduced by 41% (the highest total phosphorus removal of any swale monitored by Dorman). On the other hand, removals of organic nitrogen, nitrate and metals were on the low end of the range reported for other swale systems.

Dorman and colleagues also found that trace metals accumulated over time in each of the three swale soils, which corroborates that these pollutants are being removed. Nutrients, on the other hand, showed a mixed pattern, with roughly half of the samples showing evidence of nutrient accumulation in swale sediments, and the remainder showing either no change or a decrease in sediment concentration. The analysis could not determine if the lack of nutrient accumulation in some of the test sites was due to re-suspension and "spiralling" out of the swale. Another interesting finding relates to the longevity of highway swales. Two out of the three swale systems were eventually eliminated as a result of construction to add more highway lanes.

Yu's monitoring of another Virginia highway swale is not yet complete, but a preliminary assessment after four storms showed that the swale removed 68% of sediment and 60% of total phosphorus. The higher removal rate could be due to the greater length of the swale, and the presence of a checkdam. Yu indicates that many swales tend to exhibit a curious hydraulic behavior. During small storm events, much less flow was recorded at the bottom of the swale than at the top of the swale (presumably reflecting the infiltration of runoff as it passes along the swale soils). In some small storms, no measurable flow was detected at the swale outlet.

In contrast, during large and intense storms, more runoff was measured at the bottom of the swale than at the top (probably because of additional runoff inputs that come down the side-slopes of the swale). This finding suggests that swale removal rates may be underestimated during smaller storms because some fraction of the incoming runoff infiltrates into swale soils.

Each of the four monitored swale systems described here were originally intended merely to convey stormwater runoff. Their dimensions and capacity were designed solely to accommodate the peak discharge of the 10-year, 24-hour storm event in a non-erosive manner (about six to eight inches of rain, depending on the location of the study site). Unlike the biofilter, the standard highway swale is not explicitly designed for the smaller storm events (0.2 to 1.2 inches of rain) that produce the majority of annual runoff that passes through the swale.

In summary, the studies show that the length of a highway swale alone is not a reliable measure of its future performance. Other factors, such as slope, soil type, and grass density appear to be very important. Since many of these variables cannot be controlled or assured over the long term, the highway designer should consider a more "structural" swale design. In this approach, a series of water quality design elements are incorporated along the length of swale systems, such as underdrains, checkdams, sand layers, diversions to off-line swales or pocket wetlands. These elements should result in improvement in both the rate and reliability of a swale's long term pollutant removal capability.

—TRS

Table 1: Summary of Site Characteristics of the Three Highway Swale Systems Studied by Dorman *et al.*, 1989

Variables	Virginia	Maryland	Florida
Length	185 ft	193 ft	185 ft
Area served	1.27 ac	1.27 ac	0.56 ac
Impervious	67%	64%	63%
Slope	4.7%	3.2%	1%
Cover	Poor	Poor	Good
Erosion	Moderate	Severe	None
Soil type	Silt loam	Silt loam	Sandy
Age	20 years	ND	5 years

Table 2: Monitored Pollutant Removal Performance of Three Highway Swale Systems (Dorman *et al*, 1989)

Swale site	Virginia	Maryland	Florida
Storms sampled	9	4	8
Sediment	65	(-85)	98
Organic carbon	76	23	64
TKN	17	9	48
Nitrate	11	(-143)	45
Total P	41	12	18
Cadmium	12-98	85-91	29-45
Chromium	12-16	22-72	51-61
Copper	28	14	62-67
Lead	41-55	18-92	67-94
Zinc	49	47	81

Removal rates computed as % long term mass reduction, based on the assumption that inflow and outflow runoff volumes were equivalent. Range in metal removal rates reflect uncertainty in concentration due to detection limit problems.

References

Dorman, M., J. Hartigan, J. Steg and T. Quaserbarth. 1989. *Retention/Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff. Vol. I. Research Report.* Federal Highway Administration. FHWA/RD-89/202. 202 pp.

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