2016-15TS
Published August 2016

RESEARCH SERVICES & LIBRARY

OFFICE OF TRANSPORTATION SYSTEM MANAGEMENT

IMPLEMENTATION SUMMARY

Technical Liaison:
Barbara Loida, MnDOT
Barbara.Loida@state.mn.us

Project Coordinator:
Bruce Holdhusen, MnDOT
Bruce.Holdhusen@state.mn.us

Principal Investigator:
John Gulliver, University of Minnesota

PROJECT COST:
$190,082

Measurements were taken via tube infiltrometers at Minnesota Highway 51 to validate the model developed in this study.

Putting Research into Practice: Calculating the Effectiveness of Swales in Handling Stormwater

What Was the Need?

The use of grassed swales, including roadside drainage ditches, is an inexpensive and effective stormwater management practice. These vegetated roadside surfaces capture and infiltrate stormwater close to its source, reducing the quantity of pollutants and volume of stormwater carried off-site to receiving waters.

The stormwater permit issued by the Minnesota Pollution Control Agency (MPCA) requires new developments that disturb more than 1 acre of land to provide for infiltration of the first 1.1 inches of runoff. (The permits are issued pursuant to the Environmental Protection Agency's National Pollutant Discharge Elimination System.) Swales are one of the stormwater management mechanisms included in the MPCA's Minimal Impact Design Standards. However, the amount of water that a swale can infiltrate, particularly on its side slope, has not been precisely characterized. Existing models of water infiltration in swales focus primarily on infiltration that occurs in the swale's bottom channel.

A simplified calculator for estimating the stormwater infiltration capacity of swales was developed from a series of lab and field measurements. By giving more complete credit for the infiltration provided by the side slopes of grass swales, this calculator will reduce the need for more costly stormwater management programs.

A more accurate calculation of the volume of water captured through infiltration would encourage more widespread use of swales as a pollution prevention practice and reduce the need for solutions such as stormwater infiltration and filtration basins that are more expensive and difficult to build and maintain.

In addition, current practice involves the construction of check dams on the ditch bottom to slow stormwater flow and provide ponding. However, these structures require maintenance as well and are prone to blowouts. More accurate infiltration calculations are needed to verify the true need for check dams.

What Was Our Goal?

The goal of this project was to quantify how much infiltration occurs in the side slopes of swales and to develop a simple but accurate tool to estimate the infiltration capacity of swales.

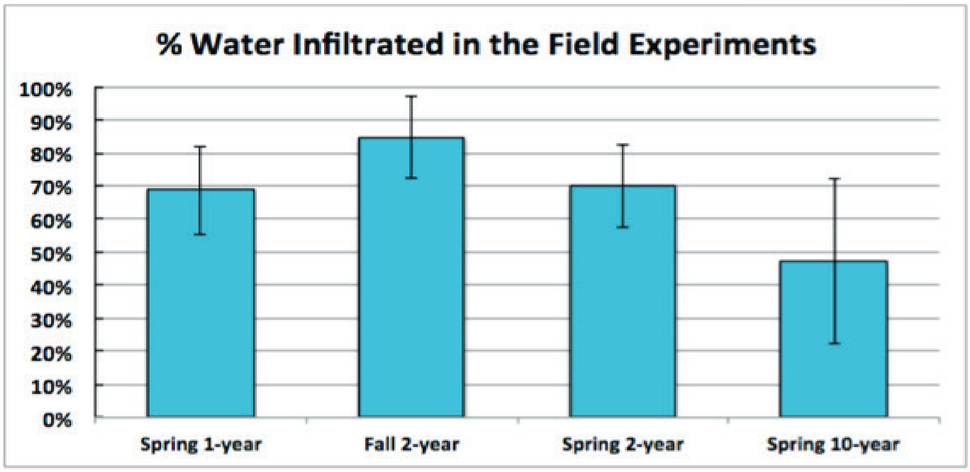
What Did We Implement?

This project implements the Local Road Research Board (LRRB) produced project "Assessing and Improving Pollution Prevention by Swales" (2014-30), which demonstrated that grassed swales in Minnesota were better than expected at infiltrating water.

How Did We Do It?

To better understand the infiltration behavior of a swale's side slope, investigators conducted laboratory tests in a full-scale physical model of a road shoulder and side slope at the St. Anthony Falls Laboratory. They used this model to measure the amount of infiltration in smooth soil and a soil surface with three or five parallel channels.

continued



Average percentage of stormwater infiltrated in the field experiments. Two sites were tested for each of four highways. Three rainfall intensities were applied: 1-, 2- and 10-year storms. The error bars represent the standard deviations.

Investigators conducted field tests at four Twin Cities roadside swales, each 30 to 50 years old and of different soil types, during both spring and fall. At each site, investigators applied water at three different rates (1.1 inches per hour, 1.1 inches per half-hour and 1.1 inches per quarter-hour), and monitored flow patterns and volume of water that did not infiltrate. Investigators also used the Modified Philip Dunne infiltrometer method demonstrated in project 2014-30 to estimate the saturated hydraulic conductivity of the soil (a measure of how easily fluid moves through a saturated soil).

Using all the data collected, as well as previously developed models for water infiltration in the bottom channel of a swale, investigators developed and verified a model that characterized stormwater infiltration in both sections of a swale. They also conducted a sensitivity analysis to identify which input parameters had the most impact on the model's results so it could be simplified without sacrificing accuracy. The product is the Minnesota Dry Swale Calculator.

What Was the Impact?

While they identified nearly a dozen factors that affect swale infiltration, investigators were able to develop and verify a simplified dry swale calculator for Minnesota that accurately estimates volume reduction based on only four factors: saturated hydraulic conductivity of the soil, width of the swale, width of the road and the location's rainfall volume percentile as a function of rainfall depth. This calculator accounts for infiltration of both the side slope and the bottom channel of the swale.

Laboratory tests showed that surfaces with channels (simulating erosion) infiltrated water less effectively than smooth surfaces. Erosion in a drainage ditch is a worst-case scenario, however, as vegetation typically stabilizes the surface.

Field tests showed that water flows down the side slope of a swale as a series of small rills rather than as a sheet, which is what current design practices assume. The soil's saturated hydraulic conductivity was the most important factor in a swale's infiltration performance.

What's Next?

The research illustrates that more infiltration occurs in a swale's side slopes than originally thought and that a more consistent and accurate calculator can be achieved.

MnDOT plans to share study findings with the Stormwater Working Group of the American Association of State Highway and Transportation Officials Subcommittee on the Environment so other states and municipalities can benefit from this research.

This Implementation Summary pertains to Report 2016-15, "Enhancement and Application of the Minnesota Dry Swale Calculator," published April 2016. The full report can be accessed at mndot.gov/research/TS/2016/201615.pdf.

"The research team developed a simplified tool and we think there is a lot of value to this tool. We are very excited by this data."

—Barbara Loida,
MS4 Coordinator Engineer, MnDOT Metro District

"The study verified that there is much more infiltration in the side slopes than previously thought. This is a significant shift from current theory."

—John Gulliver,
Professor, University of Minnesota Department of Civil, Environmental, and Geo-Engineering

Produced by CTC & Associates for:
Minnesota Department of Transportation
Research Services & Library
MS 330, First Floor
395 John Ireland Blvd.
St. Paul, MN 55155-1899
651-366-3780
www.mndot.gov/research