Soil Erosion from Two Small Construction Sites, Dane County, Wisconsin

Introduction

Soil erosion from construction sites has long been identified as a significant source of sediment and other suspended solids in runoff in many parts of the United States (Hagman and others, 1980; Yorke and Herb, 1976; Becker and others, 1974). In some states, such as Wisconsin, sediment has been identified as the number one pollutant (by volume) of surface waters (Wisconsin Department of Natural Resources, 1994). Because numerous water-quality problems in streams are associated with excessive sedimentation, Federal and state regulations requiring erosion-control measures at construction sites larger than 5 acres have been developed and implemented from the 1970’s to the present. During the 1990’s, excessive erosion and sediment production associated with small residential and commercial sites of less than 5 acres has been increasingly recognized for its effects on streams— not only erosion from individual sites but also erosion from discontinuous groups of sites within a stream basin.

Currently, most Federal, state, and local construction regulations require some type of erosion control plan for sites disturbing more than 5 acres. On sites less than 5 acres, minimal erosion control measures are required. In most instances, only perimeter controls (silt fences and straw bails) and tracking pads (crushed stone or gravel at vehicle access points) are required as erosion control practices. In the U.S. Environmental Protection Agency Phase II Stormwater Rules, erosion control will be required on sites less than 5 acres (small construction sites) beginning in 2003. The purpose of the project was to evaluate the significance of erosion on construction sites less than 5 acres as a source of sediment to surface waters.

Overview

Numerous studies have shown that the amount of sediment transported by stormwater runoff from large construction sites (greater than 5 acres) with no erosion control practices in place is significantly greater than from sites with erosion controls (U.S. Environmental Protection Agency, 1999). This Fact Sheet evaluates water-quality data collected by the U.S. Geological Survey (USGS) and the Dane County Land Conservation Department from June 1998 to July 1999 from two small construction sites (less than 5 acres)—one residential and one commercial—in Dane County, Wisconsin (fig. 1). Study data characterizing the magnitude of erosion from these two typical small construction sites will be used in the formulation of U.S. Environmental Protection Agency's National Pollution Discharge Elimination System (NPDES), regulations requiring erosion control practices on construction sites that disturb less than 5 acres.

Results of this USGS/Dane County Land Conservation study indicated that small construction sites are potential sources of large amounts of sediment erosion. Sediment loads from the two monitored construction sites were 10 times larger than typical loads from rural and urban land uses in Wisconsin. Total and suspended solids concentrations data indicate the active construction phase produced concentrations that were orders of magnitude higher than pre- and post-construction periods. Furthermore, these concentrations were dramatically reduced when the site was seeded and mulched. These results support the need to design and implement erosion control plans.
and increases runoff volume. The tracked mud and debris is deposited on the roads, which are usually connected to the stormwater drainage system.

- Erosion rates caused by construction activities have the potential to be higher than erosion rates from plating because of the steep, uncovered high-slope soil piles that are created when topsoil is stripped and when basements or foundations are excavated.

**How and when were the Dane County sites studied?**

**Site selection**

Two small construction sites in Dane County, one residential and one commercial, were selected to represent typical construction activity on sites less than 5 acres in size (fig. 1). The residential lot was 0.34 acres with an average slope of 8 percent, and the commercial office development lot was approximately 1.72 acres with an average slope of 4 percent.

Sites were selected on the basis of five criteria:

1. The site had to be stabilized or without construction activity for a sufficient period to allow for pre-construction monitoring of water quantity and water quality.
2. The site had to accommodate small wing walls or other structures that would direct discharge from a significant area of the site to a single discharge point.
3. The site had to be smaller than 5 acres.
4. Construction on the site had to be completed by September 1998.*
5. The builder had to agree to the proposed monitoring plan.

*Note: Some changes in scheduling occurred after site selections were made.

**Site monitoring**

Because the objective of the study was to quantify the movement of soil during construction activity, erosion control practices were not evaluated as part of this study. At both the commercial site and the residential site, erosion controls were placed downstream from the monitoring equipment. The monitoring equipment installed at each site is shown and described in figure 2.

Data were recorded hourly during dry periods. Rainfall and flume water levels were recorded every minute during periods of rainfall and runoff. Collection of individual water-quality samples was triggered by the datalogger during runoff by using time pacing (for example, 5 minutes between samples). This time pacing could be adjusted to ensure that the samples were representative of the entire storm, particularly the period of increasing runoff in the beginning.

Samples were split and processed for analysis. Processed samples were taken to the Wisconsin State Laboratory of Hygiene for determination of the concentrations of total and suspended solids (the measures used to represent sediment).

**Load computation**

Solids loads were computed by multiplying runoff volume, solids concentration, and a constant for unit conversion. The loads, rainfall, and runoff

![Photo 1. Water-quality samples from the commercial construction site.](image1)

![Photo 2. Residential construction site after monitoring equipment was installed in June 1998.](image2)

**Table 1. Summary table for the sampled runoff events for (A) the commercial construction site, and (B) the residential construction site [Precip., precipitation; lbs, pounds; mg/L, milligrams per liter]**

### A. Commercial construction site

<table>
<thead>
<tr>
<th>Sampled runoff event</th>
<th>Storm information</th>
<th>Average solids loads</th>
<th>Event mean concentration (EMC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Start date</td>
<td>Precip. depth (inches)</td>
<td>Runoff volume (cubic feet)</td>
</tr>
<tr>
<td>B-1 6/7/98 Pre</td>
<td>1.52</td>
<td>32</td>
<td>0.3</td>
</tr>
<tr>
<td>B-2 7/3/98 Active</td>
<td>0.72</td>
<td>689</td>
<td>901</td>
</tr>
<tr>
<td>B-3 7/16/98 Pre</td>
<td>0.26</td>
<td>26</td>
<td>25</td>
</tr>
<tr>
<td>B-4 7/19/98 Pre</td>
<td>0.55</td>
<td>529</td>
<td>529</td>
</tr>
<tr>
<td>B-5 7/19/98 Pre</td>
<td>0.80</td>
<td>736</td>
<td>325</td>
</tr>
<tr>
<td>B-6 7/20/98 Pre</td>
<td>0.61</td>
<td>219</td>
<td>342</td>
</tr>
<tr>
<td>B-7 6/19/98 Pre</td>
<td>0.50</td>
<td>863</td>
<td>136</td>
</tr>
<tr>
<td>B-8 6/23/98 Pre</td>
<td>0.46</td>
<td>1,601</td>
<td>1579</td>
</tr>
<tr>
<td>B-9 6/19/98 Pre</td>
<td>0.45</td>
<td>926</td>
<td>790</td>
</tr>
<tr>
<td>B-10 10/5/98 Pre</td>
<td>0.76</td>
<td>756</td>
<td>100</td>
</tr>
<tr>
<td>B-11 10/5/98 Pre</td>
<td>0.69</td>
<td>940</td>
<td>369</td>
</tr>
<tr>
<td>B-12 10/5/98 Pre</td>
<td>0.72</td>
<td>1,621</td>
<td>107</td>
</tr>
<tr>
<td>B-13 15/7/98 Pre</td>
<td>0.80</td>
<td>1,940</td>
<td>140</td>
</tr>
<tr>
<td>B-14 11/6/98 Pre</td>
<td>0.72</td>
<td>1,940</td>
<td>140</td>
</tr>
<tr>
<td>B-15 4/21/99 Pre</td>
<td>0.46</td>
<td>152</td>
<td>87</td>
</tr>
<tr>
<td>B-16 5/16/99 Pre</td>
<td>1.49</td>
<td>2,059</td>
<td>318</td>
</tr>
<tr>
<td>B-17 6/6/99 Pre</td>
<td>0.67</td>
<td>1,112</td>
<td>7.9</td>
</tr>
<tr>
<td>B-18 6/21/99 Post</td>
<td>0.27</td>
<td>455</td>
<td>3.5</td>
</tr>
<tr>
<td>B-19 6/21/99 Post</td>
<td>1.01</td>
<td>1,983</td>
<td>24</td>
</tr>
</tbody>
</table>

### B. Residential construction site

<table>
<thead>
<tr>
<th>Sampled runoff event</th>
<th>Storm information</th>
<th>Average solids loads</th>
<th>Event mean concentration (EMC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Start date</td>
<td>Precip. depth (inches)</td>
<td>Runoff volume (cubic feet)</td>
</tr>
<tr>
<td>SH-1 6/27/98 Pre</td>
<td>0.81</td>
<td>256</td>
<td>314</td>
</tr>
<tr>
<td>SH-2 7/29/98 Pre</td>
<td>1.67</td>
<td>129</td>
<td>11.3</td>
</tr>
<tr>
<td>SH-3 8/1/98 Pre</td>
<td>0.69</td>
<td>76</td>
<td>4.07</td>
</tr>
<tr>
<td>SH-4 8/1/98 Pre</td>
<td>0.46</td>
<td>112</td>
<td>5.45</td>
</tr>
<tr>
<td>SH-5 8/4/98 Pre</td>
<td>0.29</td>
<td>244</td>
<td>24.2</td>
</tr>
<tr>
<td>SH-6 9/4/98 Pre</td>
<td>2.10</td>
<td>96</td>
<td>0.924</td>
</tr>
<tr>
<td>SH-7 9/15/98 Active</td>
<td>0.98</td>
<td>142</td>
<td>2.97</td>
</tr>
<tr>
<td>SH-8 10/5/98 Post</td>
<td>0.99</td>
<td>29</td>
<td>0.407</td>
</tr>
<tr>
<td>SH-9 10/17/98 Post</td>
<td>0.99</td>
<td>29</td>
<td>0.407</td>
</tr>
<tr>
<td>SH-10 11/1/98 Active</td>
<td>1.72</td>
<td>269</td>
<td>57.8</td>
</tr>
<tr>
<td>SH-11 4/19/99 Active</td>
<td>1.56</td>
<td>178</td>
<td>36.7</td>
</tr>
<tr>
<td>SH-12 4/19/99 Active</td>
<td>1.67</td>
<td>89</td>
<td>7.70</td>
</tr>
<tr>
<td>SH-13 7/17/99 Post</td>
<td>1.60</td>
<td>113</td>
<td>0.602</td>
</tr>
<tr>
<td>SH-14 7/17/99 Post</td>
<td>0.40</td>
<td>76</td>
<td>0.005</td>
</tr>
<tr>
<td>SH-15 7/20/99 Post</td>
<td>0.53</td>
<td>57</td>
<td>0.568</td>
</tr>
</tbody>
</table>
Post-construction monitoring resumed after the site was considered stable. Three events were monitored during July 1999; all sampling results indicated very low suspended-solids loads.

### What were the results?

#### Construction phase producing the most sediment

A summary of the data collected during runoff events at the two sites (tables 1A and 1B and fig. 3 show that during active construction, the average EMC of solids increased dramatically when compared to pre-construction and post-construction EMC’s. This finding indicates that the active construction phase is the most important phase to control.

#### Factors affecting sediment production

Several factors contributed to increased erosion during active construction. First, the vegetative cover is removed from the site. Vegetative cover reduces raindrop energy, and plant roots hold the soil in place. When vegetation is removed, the protective cover is removed. Seeding and site stabilization substantially reduce the concentration of solids in the runoff. A dramatic reduction in EMC for both sites after stabilization is depicted in figure 3. Second, heavy equipment compacts the soil, resulting in increased runoff volume. This is demonstrated by sampled events B-1 and B-2 (table 1A). A 1.92-inch, high-intensity rainfall on June 27, 1998, produced a runoff volume of 32 cubic feet, whereas a 0.72-inch rainfall on July 3, 1998, just after the soil was stripped produced 670 cubic feet of runoff.

#### Differences between event mean concentrations of solids

The primary reason for between-site differences in EMC’s was the time of active construction. Construction at the commercial site was completed during the summer, when short, but high-intensity rainfalls are common; in contrast, the residential active construction was completed during the winter, when rain tends to fall at low intensity in protracted periods. Evidence indicates that the EMC’s at the residential site would be as high as those of the commercial site if the active construction period occurred during the summer months. The first sampled storm at the residential site was monitored when the site was similar to an active construction site. Much of the ground had little or no cover (photo 2). The EMC for that storm (SH-1) was 14,000 mg/L, which was similar to that for several storms monitored at the commercial site.

#### Application of Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) predicted a soil loss of 8.8 tons for the commercial site and 1.7 tons for the residential site over the construction period. As is evident from figure 4, agreement between predicted soil loss and actual sediment load is closer for the commercial site.

Several factors explain the difference between the sum of the monitored and estimated loads and the predicted loads at the residential site. The first is that...
active construction took place during the winter months, when the monitoring
equipment was deactivated. A second reason is that the USLE predicts soil
erosion, not sediment yield. Soil erosion is the process of soil particles being
detached from the soil surface. Sediment yield, on the other hand, is the process
detached soil being transported from a specific area. Not all soil that is eroded
will leave the site; therefore, the sediment yield should be lower than the amount
of soil that is eroded. The monitoring results indicate the amount of soil that is
leaving the construction site, which is sediment yield.

Comparison of unit-area loads

Comparisons of sediment yield from various land uses can be made if the
yields are expressed as unit-area loads, which are defined as the mass of a
particular constituent transported by a stream, divided by the drainage area of
the watershed (Corsi and others, 1997). For this study, the loads from the two
construction sites were converted to pounds per acre. Data from the
construction sites were based on one year of monitoring and represent the total load
estimated for that given year. The unit-area loads for other land-use categories
(fig. 5) reflect the median load from multiple years of data. The relative
significance of construction is evident in figure 5.

Rainfall during study period

The rainfall during the monitoring period was close to the 30-year long-term
average for Madison, Wis. (fig. 6). The exception was April 1999, when the
rainfall was nearly double the long-term average for that month.

First flush phenomenon

The data do not show a direct correlation between sediment yield and the first
rainfall (first flush) during the active construction phase. Discrete concentra­
tions of total and suspended solids were related more to rainfall intensity than
the first flush.

Application of results to other areas

The project results show the magnitude of the erosion problem for small
construction sites. Soil type, site slope, type of erosion control practices
installed, rainfall depth and intensity, and other factors play a large role in
erosion and transport of sediment off the site. This project serves as an indicator
that small construction sites are a significant contributor of sediment loading to
surface waters if proper erosion controls are not implemented.

Figure 5. Unit-area solids loads for residential and commercial construction
sites, compared with state summaries for urban and rural land uses.

Figure 6. Normal (30-year) monthly precipitation and monitored precipita­
tion at the commercial and residential construction sites.

References Cited

three EPA demonstration programs in erosion and sediment control: Washington,
D.C., U.S. Environmental Protection Agency Report EPA-660/2-74-073
Corsi, S.R., Graczyk, D.J., Owens, D.W., and Bannerman, R.T., 1997, Unit-area
loads of suspended sediment, suspended solids, and total phosphorus from small
erosion and sedimentation from residential construction activities, in National
Conference on Urban Erosion and Sediment Control—Institutions and Technol­
dy, October 10-12, 1979, St. Paul, Minnesota: U.S. Environmental Protection
Rosenberg, S., Madison Area Builders Association, March 30, 1999, personal
communication

U.S. Environmental Protection Agency, 1999, National Pollution Discharge Elimi­
nation System - Storm Water Phase II, Federal Register, Vol. 64, No. 235,
December 9, 1999, Rules and Regulations.
guide to conservation planning: Washington, D.C., U.S. Department of Agricul­
ture

Wisconsin Department of Natural Resources, 1994, The Wisconsin Water Quality
Assessment Report to Congress, PUBL-WR 254-94-REV, Wisconsin Depart­
ment of Natural Resources, Madison, Wis.

Yorke, T.H., and Herb, W.J., 1976, Urban area sediment yield effects of construc­
tion site conditions and sediment control methods, Proceedings of the Third
Federal Inter-Agency Sedimentation Conference, 1976, Denver, Colorado, March
through 2-64

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