In cooperation with the Dane County Land Conservation Department
and the Wisconsin Department of Natural Resources

Hydrologic, Ecologic, and Geomorphic Responses of Brewery Creek to Construction of a Residential Subdivision, Dane County, Wisconsin, 1999–2002

Preconstruction

Land disturbance

Home construction

Scientific Investigations Report 2004–5156

U.S. Department of the Interior
U.S. Geological Survey

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Conversion Factors and Abbreviated Water-Quality Units

Multiply	By	To obtain
	Length	
inch (in)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	.4047	hectare (ha)
acre	.004047	square kilometer (km^2)
square ft (ft^2)	.09290	square meter (m^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
cubic foot (ft^3)	.02832	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	.06309	liter per second (L/s)
inch per hour (in/h)	.0254	meter per hour (m/h)
	Mass	
pound, avoirdupois (lb)	.4536	kilogram (kg)
ton, short (2,000 lb)	.9072	megagram (Mg)
foot squared per day (ft^2/d)	.09290	meter squared per day (m^2/d)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Hydrologic, Ecologic, and Geomorphic Responses of Brewery Creek to Construction of a Residential Subdivision, Dane County, Wisconsin, 1999–2002

By William R. Selbig, Peter L. Jopke[1], David W. Marshall[2], and Michael J. Sorge[2]

Abstract

The U.S. Geological Survey (USGS), in cooperation with the Dane County Land Conservation Department (LCD) and the Wisconsin Department of Natural Resources (DNR), investigated the instream effects from construction of a residential subdivision on Brewery Creek in Dane County, Wisconsin. The purpose of the investigation was to determine whether a variety of storm-runoff and erosion-control best-management practices (BMPs) would effectively control the overall sediment load, as well as minimize any hydrologic, ecologic, and geomorphic stresses to Brewery Creek.

Stormwater volumes decreased 60 percent from the preconstruction phase to the land-disturbance phase and slightly increased (9 percent) from the land-disturbance phase to the home-construction phase. The stormwater volumes were applied to total solids and total suspended solids concentrations to compute a solids load for each contaminant. Total and suspended solids load indicated a similar trend from preconstruction to land-disturbance phases with decreases of 52 and 72 percent, respectively. Both total and suspended solids load continued to decrease in the transition from land-disturbance to home-construction phases, by 22 and 37 percent, respectively. However, because of variability in the data, statistically there was no change in the magnitude of difference between the upstream and downstream solids load from one phase of construction to the next at the 90-percent confidence level.

Other physical, biological, and ecological surveys including macroinvertebrates, fish, habitat, and geomorphology were done on segments of Brewery Creek affected by the study area. Macroinvertebrate sampling results (Hilsenhoff Biotic Index value, or HBI), on Brewery Creek ranged from “very good” to “good” water-quality with no appreciable differences during any phase of construction activity. Results for fish-community composition, however, were within the “poor” range (Index of Biotic Integrity value, or IBI) during each year of testing. A general absence of intolerant species, with the exception of brown trout, reflects the low IBI values. Habitat values did not change significantly from preconstruction to postconstruction phases. Although installation of a double-celled culvert in Brewery Creek most likely altered the width-to-depth ratio in that reach, the overall habitat rating remained “fair”. Fluvial geomorphology classifications including channel cross sections, bed- and bank-erosion surveys, and pebble counts did not indicate that stream geomorphic characteristics were altered by home-construction activity in the study area. Increases in fine-grained sediment at various cross sections were attributed to instream erosion processes, such as bank slumping, rather than increases in sediment delivery from the nearby construction site.

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Introduction

Controlling nonpoint sources of water contamination has been a major focus of the regulatory community in recent years. Because of the past and current successes in controlling contamination from point sources, contamination from nonpoint sources (including sediment deposition, erosion, contaminated runoff, hydrologic modifications that degrade water quality, and other diffuse sources of contaminants) is now the largest cause of water-quality impairment in the United States (U.S. Environmental Protection Agency, 2001).

Conversion of rural and agricultural lands to developed urban areas is a leading contributor of nonpoint-source pollution. Urban development generates numerous contaminants that are associated with the activities of dense populations. Urban development also increases the amount of impervious surface in a watershed as farmland, forests, and meadowlands with generally high infiltration characteristics are converted into buildings with rooftops, driveways, sidewalks, roads, and parking lots with virtually no capacity to absorb stormwater. When stormwater and snowmelt runoff wash over these impervious areas, the runoff picks up contaminants along the way while gaining speed and volume, because it does not have the capacity to disperse and filter into the ground. The results are stormwater flows that are higher in volume, contaminant load, and temperature than the flows in less developed areas, which generally have more natural vegetation and soil to filter the runoff (U.S. Environmental Protection Agency, 1997).

Although water quality across the country has improved since passage of the Clean Water Act in 1972, various challenges still remain. In 2000, water-quality assessments conducted by States indicated that 39 percent of assessed stream miles, 45 percent of assessed acres of lakes, and 51 percent of assessed estuary areas failed to meet criteria for one or more designated uses. The top causes of impairment in assessed stream miles were siltation, nutrients, bacteria, metals (primarily mercury), and oxygen-depleting substances. Pollution from urban and agricultural land that is transported by precipitation and runoff was found to be the leading source of impairment (U.S. Environmental Protection Agency, 2002).

The U.S. Geological Survey (USGS), in cooperation with the Dane County Land Conservation Department (LCD) and the Wisconsin Department of Natural Resources (WDNR), investigated the instream water-quality effects from construction of a residential subdivision on Brewery Creek, Dane County, Wis. The purpose of the investigation was to determine whether storm-runoff and erosion-control best-management practices (BMPs) would effectively control the overall sediment load, as well as minimize any physical, biological, and ecological stresses to Brewery Creek.

Few previous studies have assessed the capacity of erosion and sediment controls and stormwater-management practices to prevent degradation of receiving waters in urbanizing areas. Even fewer studies have been multiparameter investigations, integrating water-quality observations with evaluations of stream physical habitat and biological quality. This investigation paired water-quality analyses with physical habitat, stream geomorphology, and biological indices to evaluate the capacity of selected management techniques to prevent degradation of a receiving stream.

This study has relevance at both national and local levels. At the national level, the investigation could provide necessary background data on water-quality impairments related to construction-site runoff. This, in turn, would help facilitate the implementation of Phase II of the USEPA National Pollution Discharge Elimination System (NPDES) standard for pollution control on construction sites of less than 5 acres. At the local level, county officials are mandating construction-site erosion-control standards throughout Dane County. The objective of this investigation was to provide evidence of the effects that construction has on hydrology, ecology, and morphology of receiving waters.

Purpose and Scope

This report describes the methods used in and the results from the Brewery Creek study. An upstream-downstream (above-and-below) experimental design was used to isolate the pollutant loads coming from the construction site. Automated, intensive stream-water sampling took place during storm-runoff periods in three different phases on the project: preconstruction (October 1999 to April 2001), land disturbance (May 2001 to March 2002), and home construction (April 2002 to September 2002). Concentrations of total solids and total suspended solids in stream-water samples were used to compute storm loads for each contaminant contributed to Brewery Creek during each phase. In addition to water quality and quantity, other physical and biological data were analyzed to determine the effectiveness of storm-runoff and erosion controls in protecting the integrity of Brewery Creek. Geomorphology classifications, including bed- and bank-material characterizations, were done at intervals throughout the study period. Stream temperatures were recorded at 15-minute intervals during each phase of the project. Annual fish surveys were done to determine species composition and density. Finally, macroinvertebrate and habitat data were collected at various intervals to assess the overall health of the stream.

Description of Study Area

Brewery Creek is in the Black Earth Creek watershed, in northwestern Dane County (fig. 1). The drainage area of 10.5 mi^2 at the downstream end of the study area includes 2.8 mi^2 of noncontributing area. The stream is 6.1 mi long from the downstream station to the stream headwaters; 0.5 mi is within the study area. The stream has been

Figure 1. Location of the Brewery Creek Watershed within the Black Earth Creek Watershed in Dane County, Wis.

channelized in places, with the upper reaches of the stream last being dredged in 1976. The stream bed material is mostly soft silt and clay. Brewery Creek flows through outwash and alluvium composed of sandstone with some shale; most of the bedrock in the watershed is dolomite (Graczyk and others, 2003). The soils of Brewery Creek Watershed are predominantly silt loams that are poorly drained in valley bottoms and highly erodible in the uplands (Glocker and Patzer, 1978). Brewery Creek is a warm-water stream that maintains a forage fish population (Wisconsin Department of Natural Resources, 1989). Although classified as a warm-water stream, the stream does support cold-water species and is a candidate to be reclassified as a cold-water stream by the WDNR (Wisconsin Department of Natural Resources, 1989). The largest land-use categories in the Brewery Creek Watershed are agriculture, at 57 percent, and woodland, at 22 percent (Graczyk and others, 2003).

The St. Francis residential subdivision includes single-family lot development over approximately 72 acres. It lies in the southernmost part of the Brewery Creek Watershed and represents approximately 4 percent of the basin area (fig. 2). The area had previously been used for corn and soybean production. An established vegetated stream buffer varies from 30 to 100 ft in width on either side of the stream.

Erosion Control and Stormwater Management at the Subdivision Site

Since August 22, 2002, all municipalities in Dane County, Wisconsin have been required to meet the requirements of the Dane County Erosion Control and Stormwater Management Ordinance. In Dane County, all developments disturbing more than 4,000 ft^2 are required to implement an erosion-control plan. Stormwater-management plans are required when 20,000 ft^2 or more of impervious surface is created. (Chapter 14, Dane County Code of Ordinances). During the general permitting of the St. Francis subdivision, these regulations were not applicable because the permit was issued in April 2001. However, the developer agreed to design and implement an erosion-control and stormwater-management plan that would meet or exceed requirements in the proposed Dane County Ordinance.

The St. Francis subdivision employed a variety of BMPs constructed for erosion control and stormwater management. The erosion-control practices were designed to meet the maximum allowable cumulative soil loss of 7.5 ton/acre/yr. Practices included installing silt fence reinforced with straw bales, maintaining vegetative buffers (fig. 3), sequencing construction, deep tilling to minimize compaction, temporary seeding of soil stockpiles, protecting inlets, emplacing stone tracking pads, and building temporary earthen berms.

Stormwater-management practices were designed and implemented in accordance with the water-quality and -quantity standards under development in the Dane County Erosion Control and Stormwater Management Ordinance. The applicable standards included the following:

- Maintaining the predevelopment peak-runoff rates for the 2-year and 10-year, 24-hour storms, and safely passing the 100-year flood.
- Discharging to a stable outlet carrying the designed flows at a nonerosive velocity.
- Retaining all soil particles greater than 5 microns.
- Directing runoff from downspouts, driveways, and other impervious areas to pervious areas.
- Including provisions and practices to reduce the temperature of runoff to the receiving waters.

Stormwater-management practices included grassed swales and boulevards for infiltration and storage of runoff, reduced street widths to minimize impervious cover, protection of present woodlands, two detention and infiltration basins with stone cribs for thermal protection, maintenance of stream buffers, and use of available parkland and open space for runoff storage and infiltration. Figure 4 highlights some of the BMPs used in the development of the study area.

The site was designed to maximize infiltration of runoff on the basis of predevelopment soil and permeability rates. Surface runoff is diverted from impervious surfaces to one or more BMPs for temporary storage and infiltration. Runoff first enters grassed swales in the street medians (fig. 4). The swales were designed to infiltrate stormwater over a period of 24 hours. During periods of intense runoff, excess water in the swale enters a conveyance system that directs runoff to a larger infiltration basin, where it is temporarily stored and allowed to infiltrate. Each system is designed to reduce water quantity and improve water quality before runoff enters Brewery Creek. Vegetated buffers were left intact during site grading and plot construction to provide additional water-quality benefit.

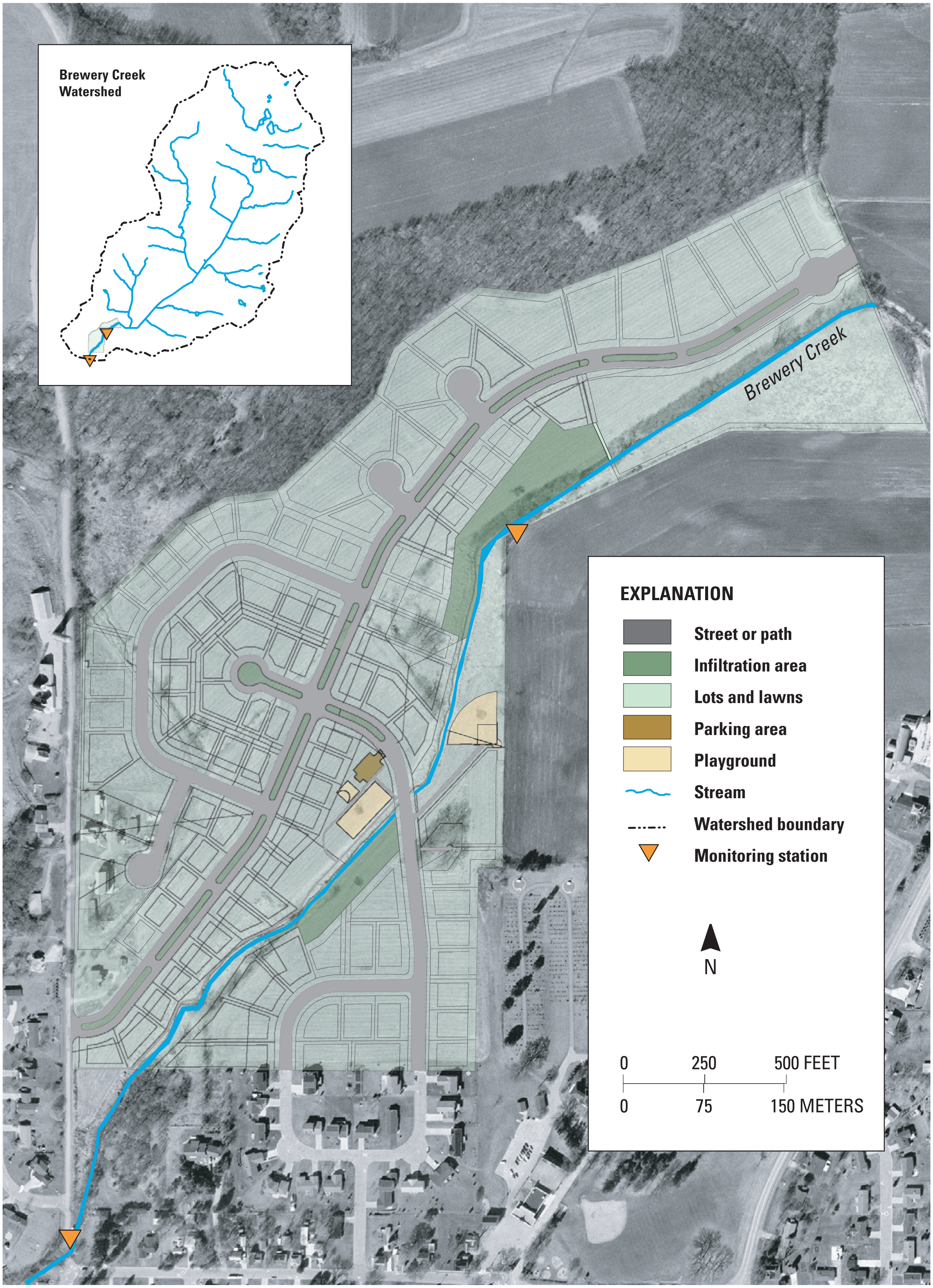

Figure 2. Location of the St. Francis residential subdivision in the Brewery Creek Watershed, Dane County, Wis.

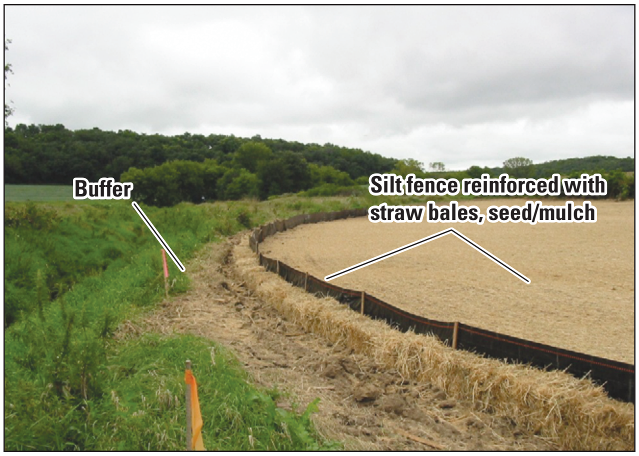

Figure 3. Example of erosion-control practices at the St. Francis residential subdivision, Dane County, Wis. (View looking upstream).

Figure 4. Example of stormwater-management practices at the St. Francis residential subdivision, Dane County, Wis.

Methods of Data Collection

Data collection in the study area involved water-quantity and sediment measurement at two monitoring stations and habitat, biologic, and geomorphic data near each station. Locations of the data-collection stations are shown in figure 5.

Water-Quantity, Precipitation, and Water-Quality Measurement

A stream-monitoring station had been established at the downstream site in 1984 and was active from 1984 to 1986; 1989 to 1998, and May 1999 to September 2002. The upstream monitoring station was established in October 1999. The location of each station in relation to the study area is shown in figure 5. Although the upstream station appears to be near the center of the study area, all construction activity was confined to the area between the upstream and downstream stations for the duration of the study. Future development has been planned beyond the upstream station. Each station continuously measured stream levels and water temperature, and event-based water samples also were collected. Water-level measurements were recorded in 15-minute increments during periods of base flow and 5-minute increments during storm events.

A storm event was defined as a period of precipitation bracketed by 6 hours or more of no precipitation. In some cases, storm events were defined as a period of precipitation bracketed by 12 hours or more of no precipitation; these events typically were the result of stormwater runoff continuing beyond a 6-hour period of no precipitation, followed by a second burst of rainfall causing additional runoff.

Water Quantity. Changes in stream levels were measured with a bubble-gage system and pressure transducer. Stream levels were then converted to a discharge rate by use of a field-verified rating table. A V-notch weir was added to the upstream station to gain added sensitivity of measured discharge for small fluctuations in water level, whereas the downstream channel cross section provided sufficient accuracy.

Precipitation. Precipitation was measured at the downstream station with a tipping-bucket raingage. Because of the close proximity to the upstream station, all precipitation data were collected at a single station. Precipitation depths, intensities, and erosivity indices were computed for all storm events except snowmelt. See tables A1 through A3 in the appendix for precipitation data. Intensities are reported in 5-, 10-, 15-, 30-, and 60-minute increments.

Water Quality. Stream temperature was measured with a Teflon-shielded thermocouple at a single point in the water column at each stream-monitoring station.

Automated water samplers at each station collected samples for water-quality analyses. Sample collection was activated by a rise in stream level during a storm event. Once a stream-level threshold was exceeded, typically a rise of 0.10 ft above base-flow level, the volume of water passing the station was measured and accumulated at 1-minute increments until a volumetric threshold was reached. At that point, the sampler collected a discrete water sample and the volumetric counter was reset. The process was repeated until the stream level receded below the threshold.

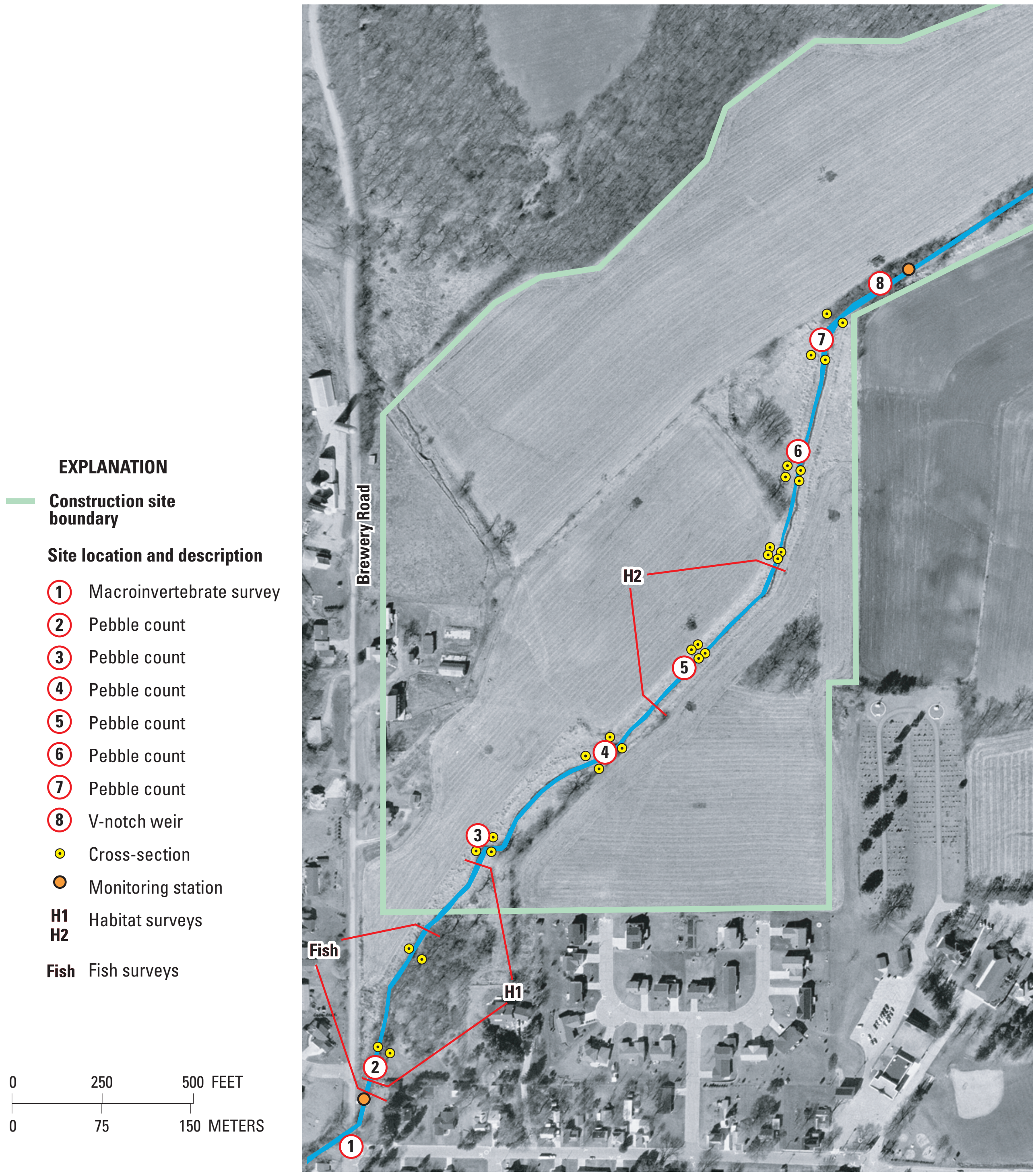

Figure 5. Locations of habitat, biologic, and geomorphic data acquisition on Brewery Creek, Cross Plains, Wis.

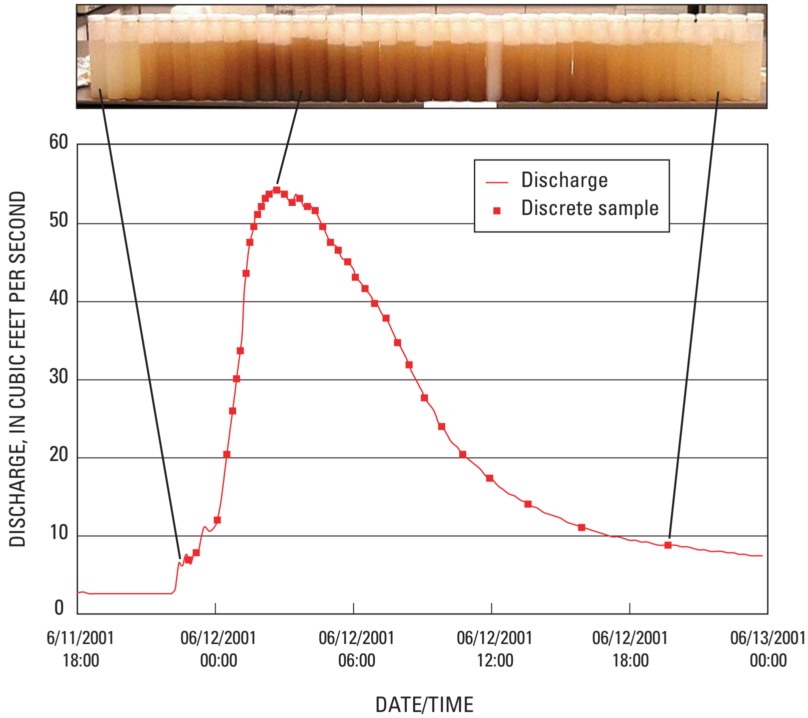

Figure 6. Discrete samples collected during a single storm event on Brewery Creek, Cross Plains, Wis. Note how samples change in color (change in sediment concentration) with respect to the rising and receding limb of the hydrograph.

These flow-weighted samples were collected and composited into a single water sample, then split and processed for analysis. A Teflon-coated, stainless-steel churn splitter was used to composite and split samples. Processed samples were placed on ice and taken to the Wisconsin State Laboratory of Hygiene (WSLH) within 48 hours after runoff cessation for determination of concentrations of total and suspended solids. Because each discrete sample was composited into a single event sample, the resulting concentration represents the event mean concentration (EMC). In some cases, individual discrete samples were submitted to the laboratory to gain a better understanding of concentration variations during a storm event. Figure 6 illustrates how discrete samples were acquired over a single storm event.

Solids loads were computed by multiplying the EMC by the total volume of the storm event and a constant for unit conversion. For those events in which discrete-sample concentrations were used rather than an EMC, continuous streamflow and instantaneous concentration data were used to estimate loads of total and suspended solids. In this case, loads were computed by summing the product of streamwater-sample concentration and streamflow rate for that storm-runoff period (Porterfield, 1972).

To ensure sample integrity, field and sample-processing equipment blanks were collected at the upstream and downstream stations. Blank samples were obtained by drawing deionized water through the suction line and sampler into a collection bottle. The Teflon sample line and automatic sampler were not cleaned before obtaining blank samples. Blank water collected in the sample bottle was then run through the Teflon-lined churn splitter into laboratory-prepared sample bottles. Samples were placed on ice and delivered to the WSLH for analysis. Deionized blank water was also used to isolate individual elements of the sampling process from source to delivery. These samples were not delivered to the WSLH unless erroneous concentrations were found in the original blank sample. Blank-sample results are detailed in table A4 in the appendix. A significant concentration of total and suspended solids was detected in the upstream blank sample collected in August 1999. This blank sample may have been compromised by stream water entering the sample tubing while the blank sample was being acquired. An additional blank sample was acquired as an added quality measure. The results of that sample fell within acceptable limits.

Sample-collection bottles were cleaned with a non-phosphate detergent, tapwater rinse, and hydrochloric acid rinse and then were air-dried. Clean bottles replaced soiled bottles upon collection of the samples and remained in the sampler housing until the next runoff event. A Teflon-lined churn splitter was rinsed with deionized water before sample processing.

Replicate samples were submitted to verify reproducibility with automatically collected samples. Replicate samples were checked for precision on the basis of a relative percent difference (RPD). Manual samples were collected periodically to verify reproducibility with corresponding stream equal-width-increment (EWI) samples (Ward and Harr, 1990). Manual samples were also checked for precision on the basis of a relative percent difference. Total and suspended solids RPD values fell below the 20-percent-precision criteria for both upstream and downstream replicate samples. However, RPD values exceeded the 20-percent criteria on suspended solids at the upstream station and downstream station in August 2002. Replicate and manual sample results are listed in table A4 in the appendix.

Macroinvertebrate- and Fish-Community Assessment

Macroinvertebrate communities were sampled in the spring and (or) fall beginning in October 1999. A D-frame net was used to sample riffle habitats in Brewery Creek at Brewery Road (fig. 5). An additional site located on Brewery Creek at Highway 14 (fig. 7) was also sampled because of its extensive historical macroinvertebrate data record for comparison. Samples were submitted to the Biomonitoring Laboratory at the University of Wisconsin at Stevens Point for processing and identification. The semi-quantitative methodology used in the study for sampling and biotic index calculation was the Hilsenhoff Biotic Index, or HBI (Hilsenhoff, 1987), which is based on sensitivity of various aquatic insects and crustaceans to organic contamination. The HBI water-quality scale ranges from 0 to 10, with 0 indicating best possible water quality and 10 the worst.

Fish communities were sampled at least once per year beginning in October 1999. A towed barge with two electrodes was used to sample 160 m of stream above Brewery Road (fig. 5). The sampling methodology and Coldwater Index of Biotic Integrity, or IBI, calculation used for assessing the environmental health of trout streams was developed by Lyons and others (1996). The Coldwater IBI is based on variable tolerances of different fish species to environmental degradation. Scores range from 0 (worst) to 100 (best). The presence of numerous trout, intolerant species, and numerous species adapted to cold temperatures score the highest and indicate favorable stream conditions.

Habitat Assessment

Physical characteristics of the stream at both sites were measured to document present conditions. Measurements included stream width, stream depth, depth of fines, bank erosion, substrate type and amount, and cover for fish; all were recorded at 48 transects at each “habitat station” (H1 and H2), a stream reach whose length is 36 times the mean stream width (fig. 5).

Surveys also were done during summer 2003 to determine whether construction had an effect on fish habitat. The surveys followed methods outlined in “Guidelines For Evaluating Fish Habitat in Wisconsin Streams,” (Simonson and others, 1994). Qualitative ratings have been established to characterize the physical habitat available for fish. The habitat scores range from 0 to 100, with 0 indicating the worst habitat for fish and 100 being optimal.

Geomorphic Assessment

The segment of Brewery Creek investigated for this study included both straightened channel and natural channel (pools, riffles, and runs). The upper reaches of the creek have been hydraulically manipulated by past dredging for agricultural purposes.

Various methods were used to determine physical stream characteristics and any subsequent changes resulting from construction activity. Stream classifications, channel cross sections, pebble counts, and bed- and bank-erosion surveys were done according to methods outlined in “Stream Channel Reference Sites: An Illustrated Guide to Field Technique” (Harrelson and others, 1994). Stream classifications were done in 2001 and 2003, whereas channel cross sections and bed- and bank-erosion surveys were completed during 2001 to 2003.

Fourteen cross sections were established with permanent monuments placed in representative locations (fig. 5). Monuments consisted of 4-ft sections of rebar anchored into the ground with 4-in diameter pvc tubes filled with concrete (fig. 8). Annual surveys were conducted by use of a surveyor’s level. Survey points included monuments, top of bank, bankfull, bank pins, and water levels.

Bank Pins. Bank pins consisting of 4-ft sections of 3/8-in. rebar were inserted horizontally into the streambank at most permanent cross sections at or slightly above bankfull in fall 2001. Bank pins were set flush with the bank and were intended to measure subtle changes in erosion and deposition to the banks. Measurements of the amount of material either deposited or the amounts of the bank pin exposed (erosion), in millimeters were made in

Figure 7. Locations of macroinvertebrate surveys on Brewery Creek, Cross Plains, Wis.

Figure 8. Example of permanent monument used in geomorphic assessment to mark cross sections along Brewery Creek, Cross Plains, Wis.

Figure 9. Measuring a streambed rock along the intermediate axis as part of a Wolman Pebble Count in Brewery Creek, Cross Plains, Wis.

September 2002 and October 2003 and noted differences as either deposition or erosion. If possible, pins were reset to “0” or flush with the bank. Because of severe slumping, this was not possible in most locations. Data were recorded and used for comparison at all cross sections where bank pins were installed.

Stream Classification. Two segments of Brewery Creek were classified using Rosgen’s Stream Classification System (Rosgen, 1996). Cross-sections 1 (the furthest upstream site in the channelized reach) and 9 (meandering reach) were classified in October 2001 and repeated in October 2003 to compare different reaches of stream. Stream variables used in the classification procedure include slope, sinuosity, width/depth ratio, entrenchment ratio, and dominant bed material.

Wolman Pebble Count. The Wolman Pebble Count Procedure was used to characterize the composition of the streambed at seven locations. Pebble counts were done in 2001, 2002, and 2003. Selected reaches were sampled (step-toe procedure) from bankfull to bankfull in a random fashion. A minimum of 100 samples were recorded per location. Particles were tallied according to the Wentworth size classes. Particles larger than sand (greater than 2 mm) were measured along the intermediate axis (fig. 9) and recorded under the appropriate size class. Data were plotted annually by size class and frequency.

Hydrologic Response

Data on runoff volume, solids load, and EMC for each storm event are listed in tables 1 and 2; a statistical summary of runoff volume and solids results for each phase of the study is given in table 3. Temperature data are listed in table 4.

Large differences in rainfall patterns between each phase could potentially bias the results of data analyses. To determine whether each construction phase differed with respect to rainfall depth and intensity (in the form of an erosivity index), the Kruskal-Wallis test was used. Precipitation depth and intensities indicated a nonnormal distribution. The Kruskal-Wallis test checks for a difference between the medians of independent samples for nonnormal datasets. No significant differences between the preconstruction and land-disturbance phases were detected at the 90-percent confidence level. Similarly, no significant differences were detected between the land-disturbance and home-construction phases. Therefore, any differences between the downstream and upstream stations between study phases are not likely because of differences in rainfall patterns.

On the whole, the downstream-upstream experimental design worked well at documenting the effects of the BMP systems from preconstruction through the home-construction phases. This design could continue to have merit in documenting further changes in water volume, solids load, and stream temperature after the residential development is completely built out.

Solids Load

Critical to obtaining useful conclusions for this study was the ability to document that downstream loads were significantly greater than upstream loads before any BMPs

Table 1. Description of runoff events at the upstream water-quality sampling station in Brewery Creek, Cross Plains, Wis.

[** - Discrete samples only; mg/L, milligrams per liter]

Brewery Creek upstream							
Sampled runoff event		Storm information		Average solids loads		Event mean concentration (EMC)	
Start date	Construction phase	Precip. depth (inches)	Runoff volume (cubic feet)	Total solids (tons)	Suspended solids (tons)	Total solids (mg/L)	Suspended solids (mg/L)
02/22/00	Preconstruction	snowmelt	3,574,500	72.5	36.9	650**	331**
04/19/00	Preconstruction	2.13	1,531,300	27.5	6.6	576**	138**
05/17/00	Preconstruction	5.04	6,116,800	307.4	263.5	1,610	1,380
05/30/00	Preconstruction	5.07	17,508,000	1,032.9	890.8	1,890	1,630
06/04/00	Preconstruction	.88	807,500	13.8	3.9	548	156
06/13/00	Preconstruction	2.70	4,491,300	171.0	136.0	1,220	970
07/02/00	Preconstruction	.99	661,900	19.8	13.7	960	664
07/10/00	Preconstruction	.73	322,200	4.4	.8	438	75
08/05/00	Preconstruction	1.81	422,100	5.8	.7	438	56
08/17/00	Preconstruction	.96	268,900	4.2	.2	496	17.5
09/11/00	Preconstruction	1.08	625,000	9.4	1.1	484	54
09/22/00	Preconstruction	.64	507,900	7.9	.6	496	35
04/11/01	Preconstruction	.73	392,100	7.5	2.9	546	136
05/10/01	Land-disturbance	.75	152,900	2.5	.7	596	157
05/21/01	Land-disturbance	2.02	1,334,800	29.2	14.8	662	298
05/23/01	Land-disturbance	.54	368,100	6.2	.9	518	68
06/05/01	Land-disturbance	.73	268,700	4.6	1.4	534	101
06/11/01	Land-disturbance	2.07	1,937,800	57.1	38.7	944	640
08/01/01	Land-disturbance	9.56	22,855,400	694.4	570.2	974**	800**
08/22/01	Land-disturbance	.20	119,300	1.9	.1	502	36
08/25/01	Land-disturbance	1.31	365,400	5.5	.9	494	57
09/17/01	Land-disturbance	.57	321,800	5.2	.5	522	48
09/19/01	Land-disturbance	1.06	662,900	10.0	3.1	498	114
09/23/01	Land-disturbance	1.73	1,424,500	27.0	15.5	584	262
10/22/01	Land-disturbance	1.17	462,700	7.6	1.7	520	90
11/24/01	Land-disturbance	.82	342,000	6.7	1.9	574	119
12/12/01	Land-disturbance	.58	291,900	5.9	1.9	586	141
02/18/02	Land-disturbance	1.68	1,878,600	37.0	14.3	600	199
03/08/02	Land-disturbance	.45	1,066,200	20.2	7.5	592	206
04/07/02	Home-construction	1.35	1,057,500	18.4	5.1	558	154
04/18/02	Home-construction	.66	220,400	4.1	1.1	602	153
04/24/02	Home-construction	.39	177,300	2.9	.6	530	103
04/27/02	Home-construction	.70	556,900	9.3	1.3	534	74
05/01/02	Home-construction	.56	271,600	4.5	.8	526	92
05/09/02	Home-construction	.78	461,800	11.5	6.4	796	442
05/11/02	Home-construction	.83	637,600	14.6	7.8	696	337
05/28/02	Home-construction	.30	134,000	2.2	.3	522	75
06/03/02	Home-construction	.24	517,400	23.1	18.7	1,430	1,160
06/04/02	Home-construction	.36	1,206,600	22.6	8.6	600	228
07/22/02	Home-construction	1.16	251,000	3.90	.4	498	47
08/11/02	Home-construction	1.74	431,300	6.1	1.5	460	94
08/21/02	Home-construction	.93	479,700	7.7	.6	516	38
09/02/02	Home-construction	1.05	312,400	5.3	.7	540	67

Table 2. Description of runoff events at the downstream water-quality sampling station in Brewery Creek, Cross Plains, Wis.

[** - Discrete samples only; mg/L, milligrams per liter]

Brewery Creek downstream							
Sampled runoff event		Storm information		Average solids loads		Event mean concentration (EMC)	
Start date	Construction phase	Precip. depth (inches)	Runoff volume (cubic feet)	Total solids (tons)	Suspended solids (tons)	Total solids (mg/L)	Suspended solids (mg/L)
02/22/00	Preconstruction	snowmelt	3,862,800	87.0	50.5	722**	419**
04/19/00	Preconstruction	2.13	1,755,700	32.1	8.6	586**	157**
05/17/00	Preconstruction	5.04	7,077,700	291.6	229.8	1,320	1,040
05/30/00	Preconstruction	5.07	18,098,100	1,050.8	909.5	1,860	1,610
06/04/00	Preconstruction	.88	908,000	13.0	1.4	458	48
06/13/00	Preconstruction	2.70	4,838,800	179.7	149.5	1,190	990
07/02/00	Preconstruction	.99	662,600	20.7	15.2	1,000	736
07/10/00	Preconstruction	.73	343,200	5.1	.7	476	62
08/05/00	Preconstruction	1.81	521,300	8.0	2.1	490	130
08/17/00	Preconstruction	.96	308,800	4.7	.2	486	24
09/11/00	Preconstruction	1.08	766,900	11.9	2.0	498	82
09/22/00	Preconstruction	.64	580,600	9.2	.8	506	42
04/11/01	Preconstruction	.73	451,000	9.4	4.0	614	218
05/10/01	Land-disturbance	.75	150,400	1.9	.6	624	205
05/21/01	Land-disturbance	2.02	1,383,500	37.3	22.5	864	522
05/23/01	Land-disturbance	.54	415,800	6.6	1.1	512	84
06/05/01	Land-disturbance	.73	329,100	6.1	1.8	566	124
06/11/01	Land-disturbance	2.07	2,104,700	96.6	80.8	1,470	1,230
08/01/01	Land-disturbance	9.56	24,816,900	930.2	802.0	1,202**	1,036**
08/22/01	Land-disturbance	.20	147,300	1.8	.2	488	49
08/25/01	Land-disturbance	1.31	352,700	5.8	1.4	518	94
09/17/01	Land-disturbance	.57	342,400	5.7	.5	534	49
09/19/01	Land-disturbance	1.06	696,400	11.4	2.8	522	117
09/23/01	Land-disturbance	1.73	1,535,200	33.7	20.3	654	325
10/22/01	Land-disturbance	1.17	558,200	9.5	2.8	526	110
11/24/01	Land-disturbance	.82	341,600	6.4	1.7	576	136
12/12/01	Land-disturbance	.58	273,300	4.9	1.3	536	102
02/18/02	Land-disturbance	1.68	1,943,400	40.8	17.5	632	234
03/08/02	Land-disturbance	.45	1,070,500	19.9	6.8	582	188
04/07/02	Home-construction	1.35	1,096,300	18.3	4.2	536	123
04/18/02	Home-construction	.66	240,300	4.2	1.1	562	144
04/24/02	Home-construction	.39	189,200	3.0	.5	506	79
04/27/02	Home-construction	.70	568,300	8.8	1.0	496	57
05/01/02	Home-construction	.56	292,800	4.4	.6	484	70
05/09/02	Home-construction	.78	511,800	11.7	6.5	734	409
05/11/02	Home-construction	.83	727,500	16.7	8.9	688	332
05/28/02	Home-construction	.30	152,700	2.4	.4	512	76
06/03/02	Home-construction	.24	571,800	24.5	20.2	1,370	1,130
06/04/02	Home-construction	.36	1,398,600	25.9	11.0	594	251
07/22/02	Home-construction	1.16	281,800	4.4	.8	498	96
08/11/02	Home-construction	1.74	525,500	7.3	2.6	452	127
08/21/02	Home-construction	.93	558,000	8.6	.7	494	42
09/02/02	Home-construction	1.05	380,000	5.9	.7	490	50

Table 3. Statistics for measured storm events at the upstream and downstream water-quality gages, Brewery Creek, Cross Plains, Wis.

Statistic	Construction phase		
	Pre-construction	Land-disturbance	Home-construction
DOWNSTREAM SITE			
Volume (cubic feet x 106)			
Mean	3.09	2.28	.54
Median	.77	.49	.52
Maximum	18.10	24.82	1.40
Minimum	.31	.15	.15
Coeff. of variation	1.61	2.65	.66
Total solids (tons)			
Mean	132.5	76.2	10.4
Median	13	8	8
Maximum	1050.75	930.2	25.93
Minimum	4.69	1.81	2.44
Coeff. of variation	2.18	3.01	.75
Suspended solids (tons)			
Mean	105.71	60.25	4.22
Median	3.95	2.26	1.05
Maximum	909.52	802	20.17
Minimum	.23	.18	.36
Coeff. of variation	2.38	3.3	1.36
UPSTREAM SITE			
Volume (cubic feet x 106)			
Mean	2.86	2.12	.48
Median	.66	.42	.45
Maximum	17.51	22.86	1.21
Minimum	.27	.12	.13
Coeff. of variation	1.67	2.63	.66
Total solids (tons)			
Mean	129.54	57.57	9.73
Median	13.81	7.16	6.91
Maximum	1032.88	694.4	23.09
Minimum	4.16	1.87	2.18
Coeff. of variation	2.21	2.96	.74
Suspended solids (tons)			
Mean	104.43	42.12	3.83
Median	3.93	1.9	1.17
Maximum	890.79	570.2	18.73
Minimum	.15	.13	.31
Coeff. of variation	2.38	3.35	1.36

were in place. Results from the Wilcoxon signed ranks test, used to find differences between paired data sets, revealed that downstream loads were significantly greater than upstream loads at the 90-percent confidence level. Therefore, the study area was an important contributor of total and suspended solids to Brewery Creek. However, previous studies indicate that streambank slumping could be an additional input to the solids load of the stream in addition to inputs related to construction activities (Allen and Gray, 1984).

Summary statistics for solids load at the downstream and upstream gages during each phase of the study are listed in table 3. Mean volume, total solids load, and total suspended solids load are greater at the downstream site than the upstream site for each phase of construction. However, examination of downstream and upstream volumes and loads revealed a highly skewed distribution. Large rain events can skew the distribution of volume and solids load. One such event occurred in August 2001 when over 9.5 in of rain was recorded at the downstream station within 48 hours. This type of event is atypical and should be given less weight statistically. Median rather than mean values were used during statistical analyses because the median is a more appropriate representation of the population center in highly skewed data sets than the mean. (Ott and Longnecker, 2001).

The difference between downstream and upstream loads was computed for total and suspended solids for the preconstruction, land-disturbance, and home-construction phases. Changes in the magnitude of the differences are believed to be a result of activity in the study area. The erosion-control and stormwater BMPs used at the construction site were effective at limiting the amount of solids load entering Brewery Creek (fig. 10). Each bar represents the median of all differences between the downstream and upstream constituent loads for the preconstruction, land-disturbance, and home-construction storm-runoff periods. Differences in median total solids loads decreased by 52 percent between the preconstruction and land-disturbance phases and 22 percent between the land-disturbance and home-construction phases (fig. 10). Similarly, downstream-upstream differences in suspended-solids loads decreased 72 and 37 percent, respectively (fig. 10).

However, examination of the median value fails to explain the variability of the data. Most of the coefficients of variation in table 3 have a value greater than 1, indicating substantial variability in solids load. The Wilcoxon rank sum test (Ott and Longnecker, 2001) was used to describe the variability of the data and to ultimately

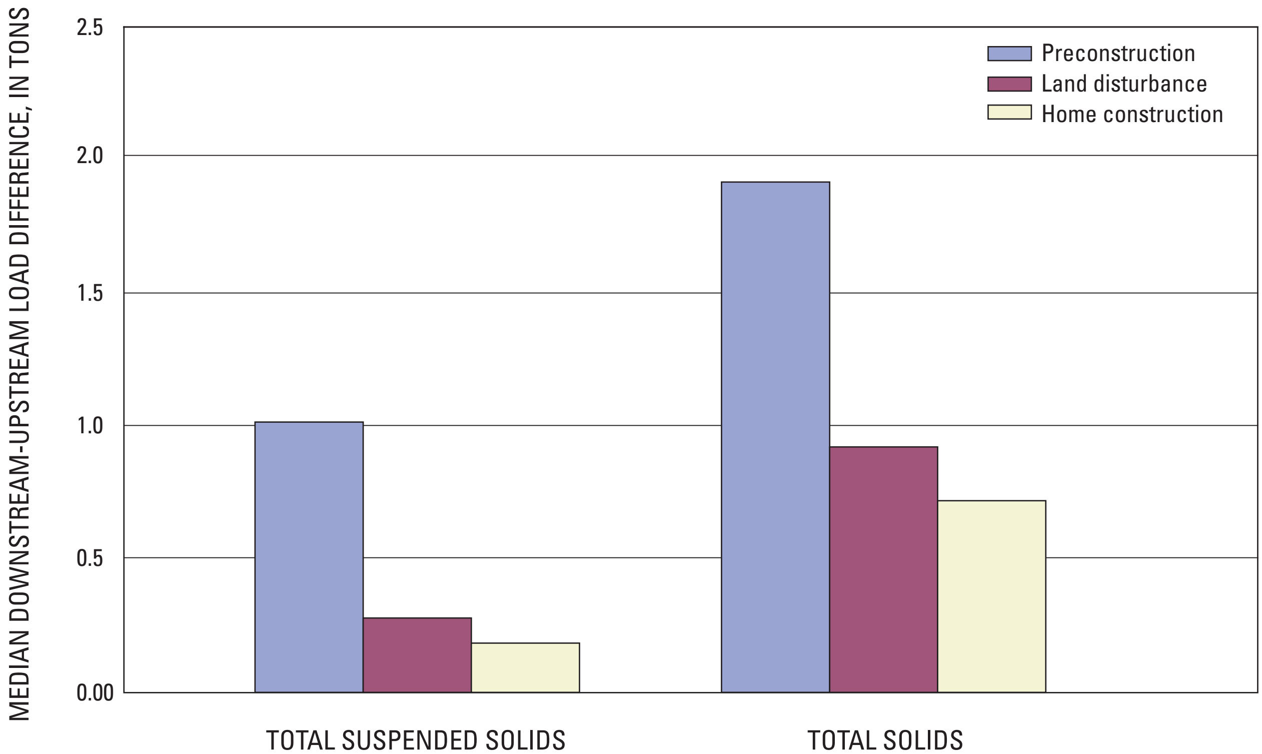

Figure 10. Median value of difference between downstream and upstream total solids and total suspended solids load in Brewery Creek during each phase of construction activity at the St. Francis residential subdivision, Cross Plains, Wis.

determine whether the contribution of loads significantly increased or decreased from one phase of construction to the next. The null hypothesis states there is no change in the magnitude of the difference between the upstream and downstream solids load from one phase of construction to the next. The alternative hypothesis suggests there is a significant change in the magnitude of the difference between the downstream and upstream solids load from one phase of construction to the next and this change is related to BMP effectiveness. Results from the test, at the 90-percent confidence level, failed to reject the null hypothesis. The data provide insufficient evidence to report an increase or decrease in solids load from preconstruction levels. Because the test did not indicate a significant increase in solids load, one could imply the BMP systems implemented before and during the land-disturbance and home-construction phases are at least somewhat effective at limiting the amount of solids entrained in runoff from reaching Brewery Creek. This limitation is supported by the reduction in the magnitude of differences between downstream and upstream total solids and total suspended solids load from one phase of construction to the next (fig. 10).

Runoff Volume

Summary statistics for event volumes are also detailed in table 3. Similar to solids loads, the median of all differences between the upstream and downstream volumes were determined for each phase of the study. A 60-percent reduction in median runoff volumes from the preconstruction to the land-disturbance phase is illustrated in figure 11; results from the Wilcoxon rank sum test shows this difference to be significant at the 90-percent confidence level.

Median runoff volumes appeared to increase slightly between the land-disturbance to the home-construction phases (fig. 11); however, statistical tests indicated no significant difference in runoff volume between these two phases. The apparent increase could be due, in part, to the failure of a runoff infiltration pond during the home-construction phase. Overall, the BMPs utilized within the study area were able to reduce the amount of stormwater runoff entering Brewery Creek.

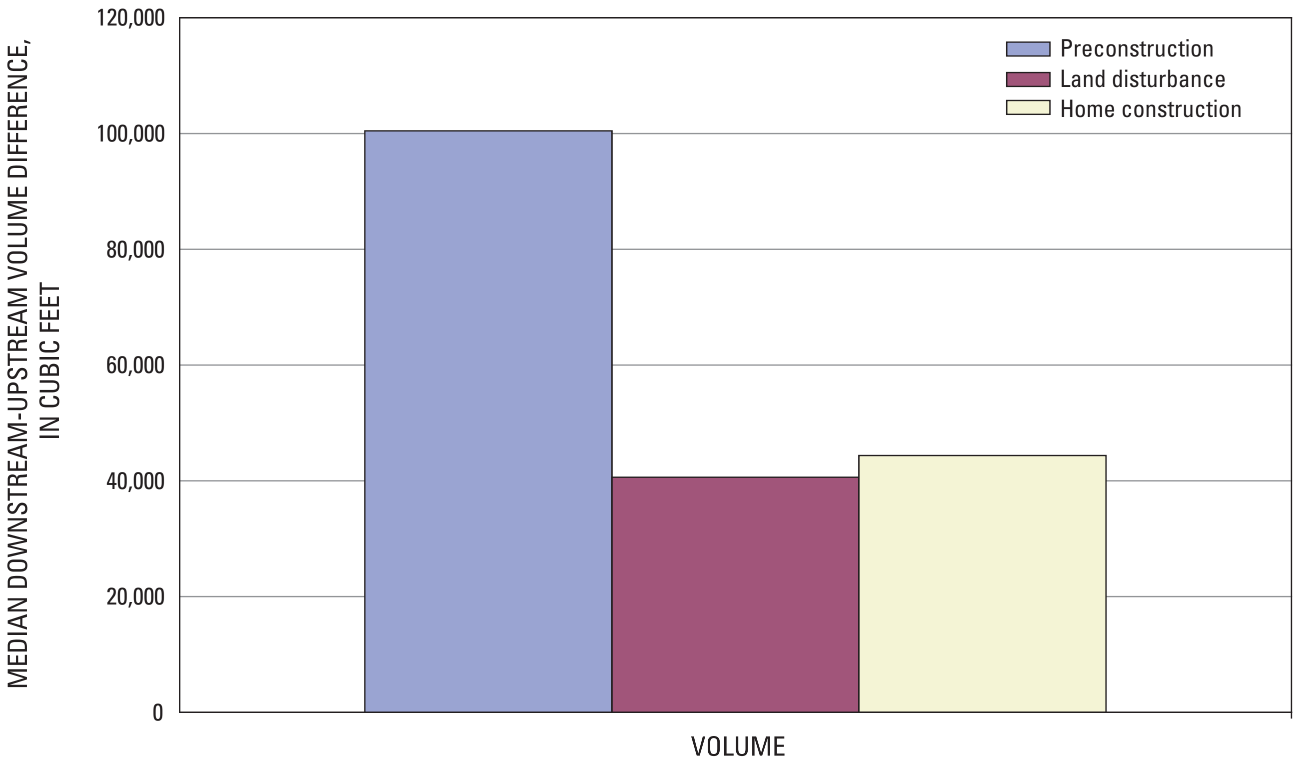

Figure 11. Median value of difference between downstream and upstream event volume in Brewery Creek during each phase of construction activity at the St. Francis residential subdivision, Cross Plains, Wis.

Stream Temperature

The temperature of urban streams is often affected directly by urban runoff. For example, Galli (1990) demonstrated an increase in base flow water temperature of 0.14°C for every 1-percent increase in watershed imperviousness. Although the Brewery Creek Watershed contains only 3 percent urban land, the stream flows through an urban environment for approximately 0.5 mi before its confluence with Black Earth Creek, a Class I trout stream. Certain species of fish, such as trout, require relatively low daily mean temperatures of less than 22°C (Lyons, 1996) for survival and are particularly sensitive to temperature fluctuations. As urbanization continues to spread throughout the basin, mitigation of thermal impacts caused by increases in impervious surfaces will be increasingly important.

A summary of daily mean stream temperatures measured during sampled events in each phase of construction is given in table 4. Downstream temperatures were statistically higher than upstream temperatures, most likely because lack of overhead tree canopy in the area between the upstream and downstream stations subjects the stream to direct solar heating. To determine whether the downstream temperatures increased as a result of activity within the study area, a one-way analysis of variance (ANOVA) (Ott and Longnecker, 2001) test was used to identify differences between the means of independent samples. Test results showed no significant increases in stream temperature as a result of activity within the study area (at the 90-percent confidence level).

Ecologic Response

Ecologic response in terms of macroinvertebrate communities, fish communities, and habitat to construction of the residential subdivision is discussed in the following sections below.

Macroinvertebrate and Fish Communities

A total of 10 macroinvertebrate samples were collected for this study from October 1999 to October 2002. HBI values (fig. 12) ranged from 4.19 (very good water quality) to 4.76 (good water quality). No significant differences (P=0.05) were detected either between sampling sites or before and after development. Results indicate

Table 4. Event mean temperature of Brewery Creek at the upstream and downstream monitoring stations during three phases of construction, Cross Plains, Wis.

[°C, degrees Celsius; Std Dev, standard deviation]

Temperature °C								
Preconstruction			Land disturbance			Home construction		
Event date	Upstream	Downstream	Event date	Upstream	Downstream	Event date	Upstream	Downstream
02/22/00	4.1	4.3	05/10/01	14.4	15.1	04/07/02	6.3	6.4
04/19/00	9.0	9.5	05/21/01	13.4	13.7	04/18/02	12.0	13.1
05/17/00	11.4	11.7	05/23/01	11.3	11.5	04/24/02	9.2	9.9
05/30/00	16.0	16.2	06/05/01	10.8	10.8	04/27/02	7.0	7.1
06/04/00	13.0	13.3	06/11/01	16.8	17.5	05/01/02	9.1	9.4
06/13/00	15.8	16.1	08/01/01	21.0	21.9	05/09/02	11.8	12.5
07/02/00	17.1	17.7	08/22/01	15.2	16.4	05/11/02	8.6	8.9
07/10/00	18.0	18.8	09/17/01	13.3	13.7	05/28/02	15.5	15.7
08/05/00	16.1	16.6	09/19/01	14.1	14.3	06/03/02	11.8	12.0
08/17/00	14.6	15.1	09/23/01	13.1	13.3	06/04/02	13.0	13.2
09/11/00	16.1	16.5	10/22/01	9.8	10.0	07/22/02	16.8	18.0
09/22/00	11.8	12.0	11/24/01	9.8	9.9	08/11/02	16.8	18.0
04/11/01	8.8	9.1	12/12/01	6.0	6.0	08/21/02	15.6	16.4
			02/18/02	3.8	4.0	09/02/02	15.7	16.4
			03/08/02	3.5	3.7			
Mean	13.2	13.6	**Mean**	11.7	12.1	**Mean**	12.1	12.6
Median	14.6	15.1	**Median**	13.1	13.3	**Median**	11.9	12.8
Std Dev	4.0	4.1	**Std Dev**	4.8	5.0	**Std Dev**	3.6	3.9
Maximum	18.0	18.8	**Maximum**	21.0	21.9	**Maximum**	16.8	18.0
Minimum	4.1	4.3	**Minimum**	3.5	3.7	**Minimum**	6.3	6.4

that dissolved-oxygen concentrations were consistently sufficient to support a diverse macroinvertebrate community and that organic contamination was not appreciable throughout the 3-year study period. Interpretation of the empirical results, relative to Hilsenhoff's scale, was that the degree of organic pollution ranged from "possible slight to some" during the study period.

Fish communities were sampled six times for this study. A total of 10 species were collected and identified at least once. The list includes brown trout, **creekchub**, **fathead minnow**, **golden shiner**, **white sucker**, **yellow bullhead**, black bullhead, brook stickleback, **green sunfish**, and bluegill. The species in bold are considered tolerant to environmental degradation. No intolerant species were found. The proportion of tolerant individuals ranged from 54 percent to 78 percent (fig. 13) and was the primary reason IBI scores remained low throughout the entire study. IBI scores of 10 or 20 (fig. 13) were both within the "poor" range. Brown trout were relatively abundant in Brewery Creek with numbers ranging from 22 to 46 (fig. 14) and percentages ranging from 16 percent to 46 percent (fig. 13). Brown trout size structure was variable during the study, with greater numbers of juvenile individuals from 1999 through 2001 and greater numbers of adults in 2002 and 2003. Trout of legal keeping size (greater than 9 in. long) ranged from 1 out of 37 in 2001 to 15 out of 26 in 2002 and 15 out of 44 in 2003 (fig. 14). The largest brown trout was 15.75 in. long.

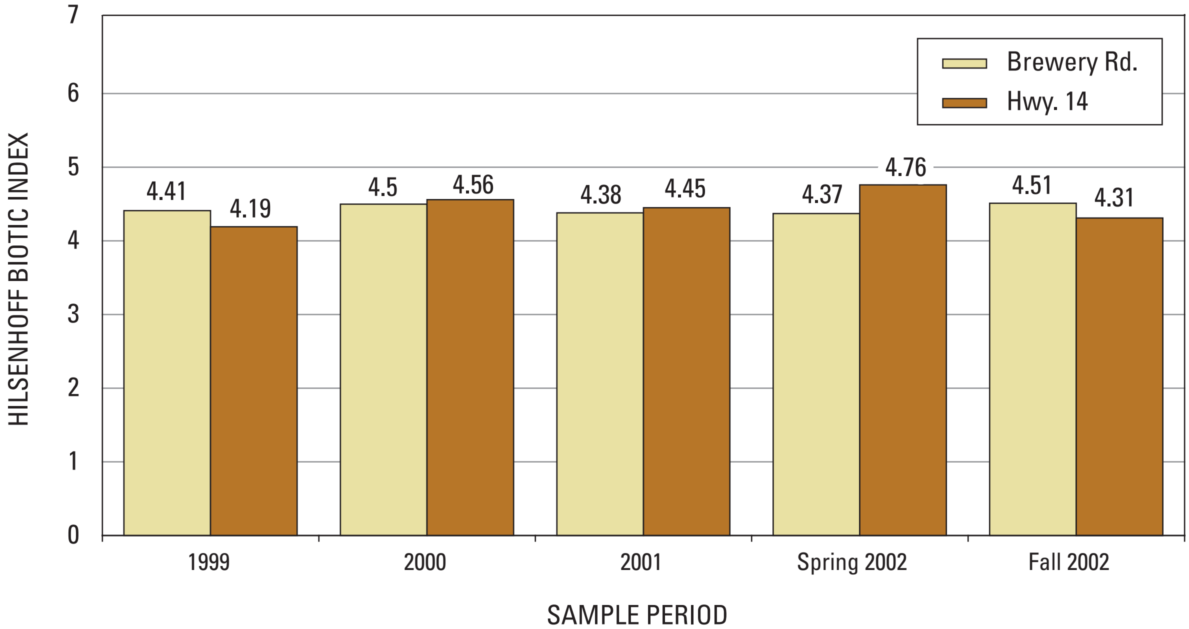

Figure 12. Hilsenhoff Biotic Index scores at two locations on Brewery Creek, Cross Plains, Wis.

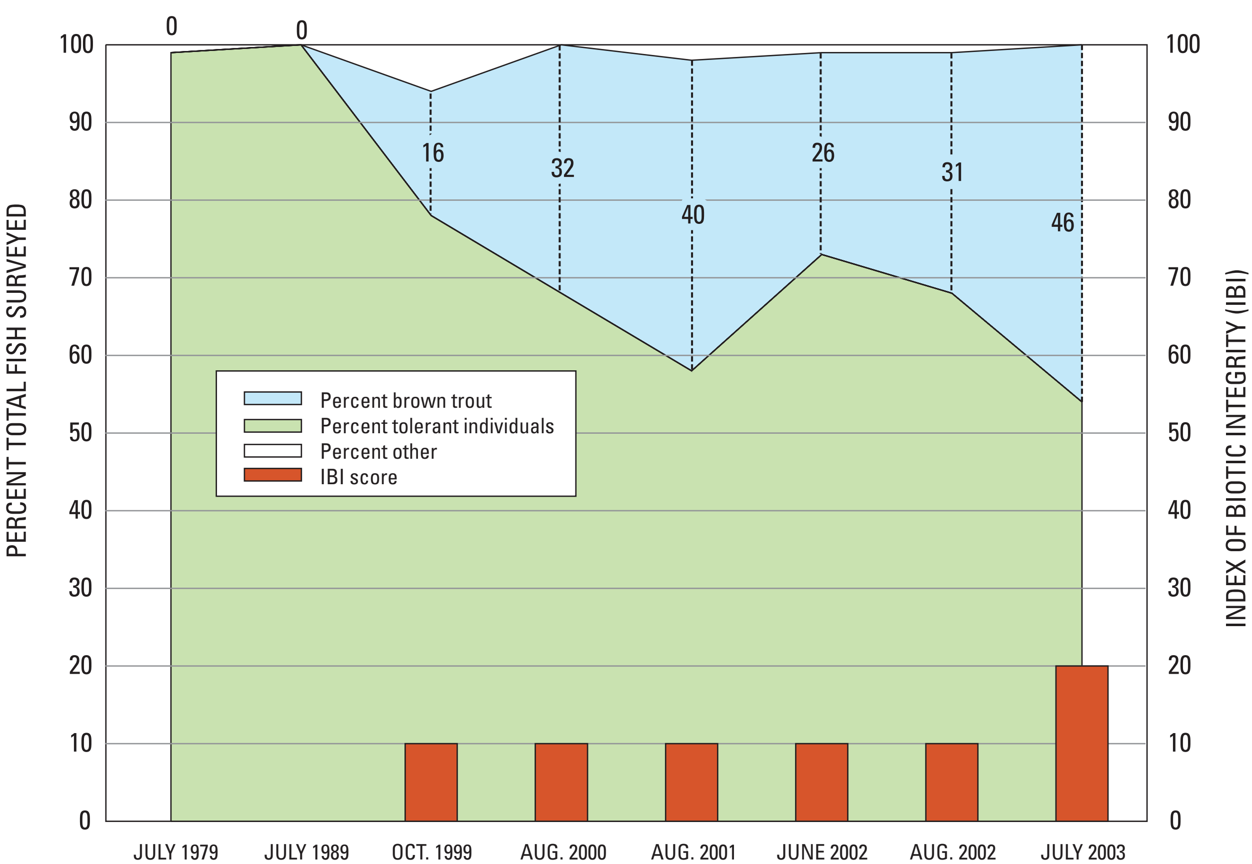

Figure 13. Results of fish-shocking surveys and subsequent Index of Biotic Integrity in Brewery Creek, Cross Plains, Wis. (1999–2003). [Pre-1999 data from Fago, 1979; and Wisconsin Department of Natural Resources, 1989].

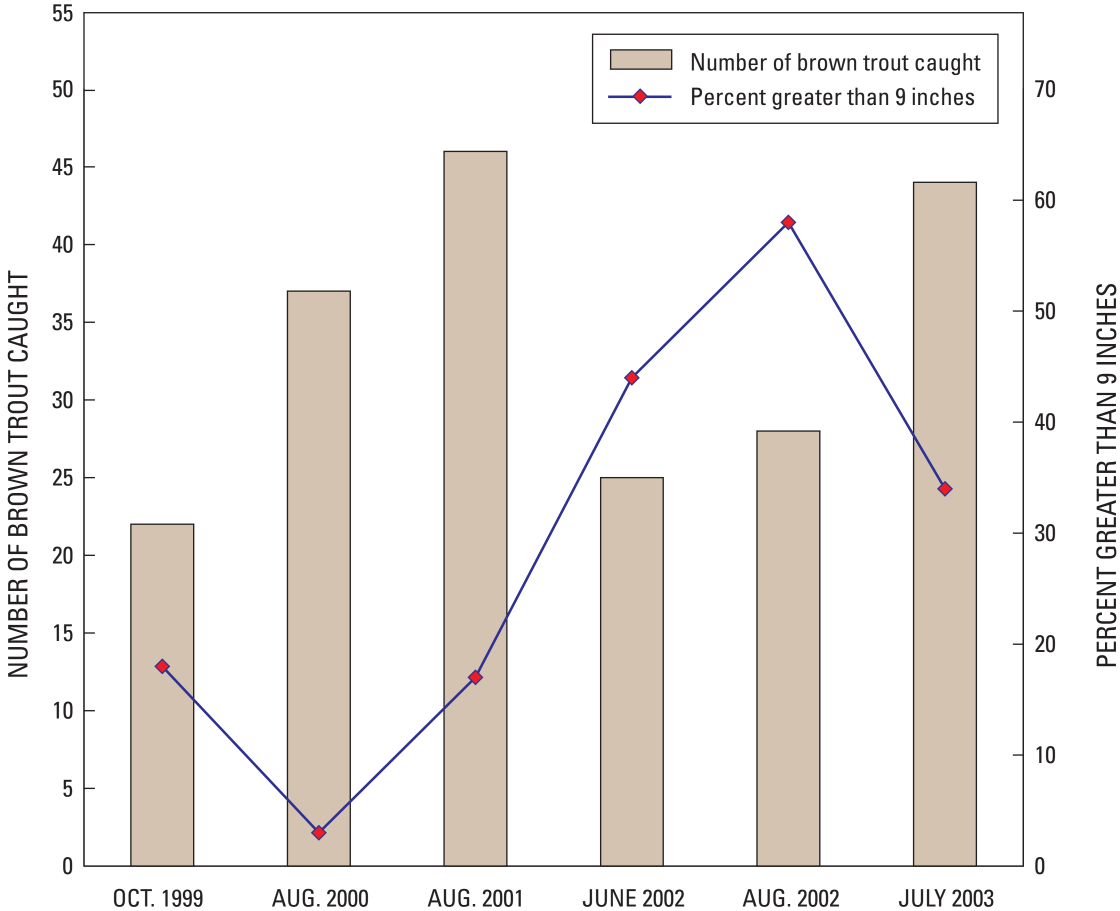

Figure 14. Number of brown trout measured during fish-shocking surveys in Brewery Creek, Cross Plains, Wis. (1999–2003).

Low IBI scores reflected a combined absence of intolerant species and a general lack of coldwater indicators (with the exception of brown trout) and presence of numerous tolerant species. Although brown trout size structure did change during the study, the overall fish-community structure remained the same.

Differences in the macroinvertebrate and fish sample results are related to different metric objectives. The HBI is based on macroinvertebrate tolerances to organic pollution, whereas the coldwater IBI is based on fish tolerances to a wide variety of environmental factors including temperature and physical habitat. The combination of these results indicate that organic-contaminant loading is not a limiting factor in Brewery Creek but that overall habitat is in poor condition.

Beginning in the mid-1980s, Brewery Creek became the focus of water-quality evaluation as part of the Black Earth Creek Priority Watershed Project. Historical water-quality, macroinvertebrate, and fish-community data indicated that Brewery Creek was appreciably impaired. Best management practices implemented as part of the Black Earth Creek Priority Watershed Project did not affect total-phosphorus or suspended-sediment concentrations over time, but ammonia concentrations did decline (Graczyk and others, 2003). This result suggests that organic loading declined. Such a decline is also reflected by a trend (R^2 = 0.58) of improved HBI scores (fig. 15). Although fish-community data from Brewery Creek are limited, surveys done before 1990 indicate that the stream was degraded (fig. 13). No trout were found during surveys in 1979 or 1989, and IBI scores were 0 or "very poor". Beginning in 1999, substantial brown trout numbers were found in every survey, and coldwater IBI scores improved slightly. Although the overall fish community is still considered unbalanced, the recent fish-shocking surveys are consistent with macroinvertebrate collections and indicate improved water quality and habitat conditions in Brewery Creek.

The improved water-quality and habitat conditions in Brewery Creek are beneficial for managing Black Earth Creek trout fisheries. Not only have organic loads declined in Brewery Creek, the small tributary also provides habitat for migrating brown trout and forage populations. During the 3-year study, fisheries in Brewery Creek were not affected as a result of the new subdivision development.

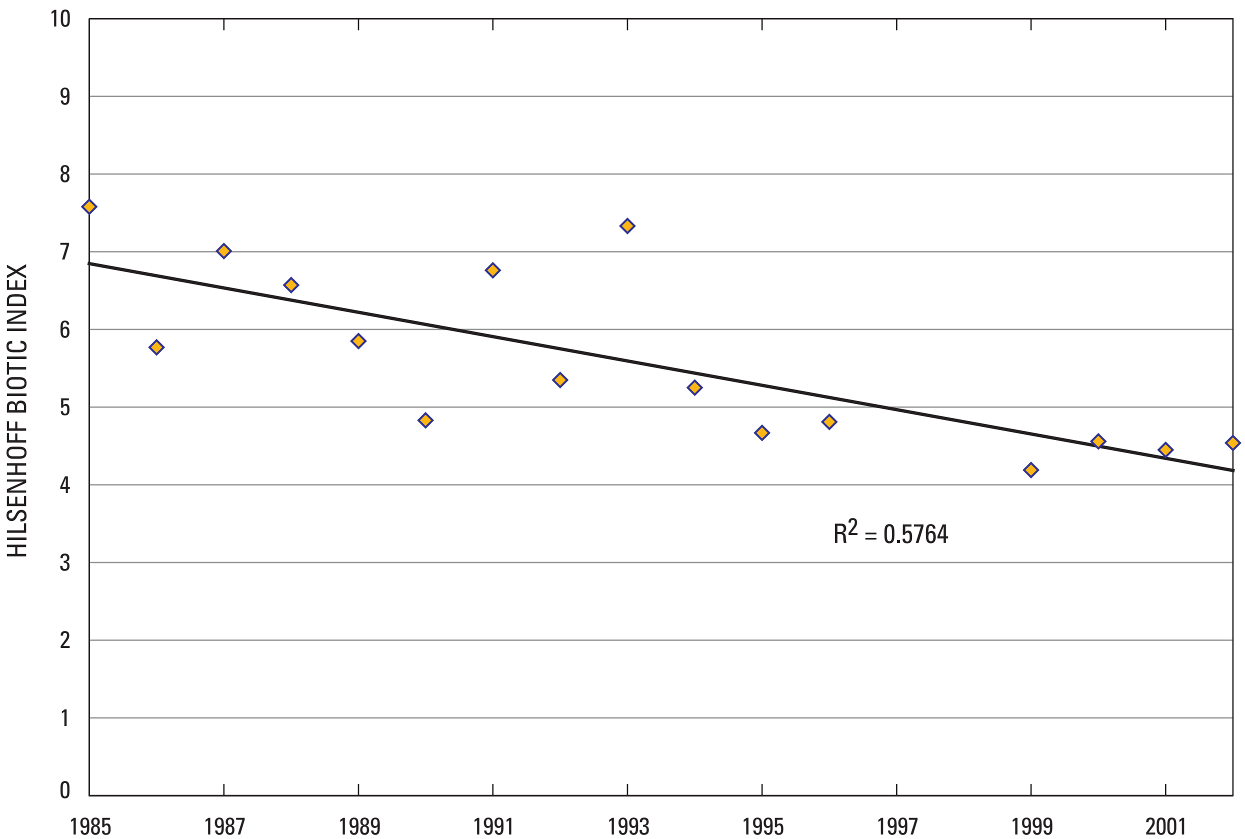

Figure 15. Trend in Hilsenhoff Biotic Index scores in Brewery Creek at Highway 14, Cross Plains, Wis. (1985–2002).

Habitat

Preconstruction results from sampling locations H1 and H2 yielded Habitat Index Scores of 40 and 45, respectively (table 5), which correspond to "fair" in the qualitative assessment. Scores from the postconstruction evaluation were 40 and 35 at H1 and H2, respectively, but the rating for H2 was still "fair." The 10-point change at H2 was due to 5-point changes in two of the assessment metrics, width-to-depth ratio and riffle-to-riffle ratio. The change in width-to-depth ratio resulted from placement of a large double-celled culvert within the habitat station (fig. 16).

Mean stream width and depth also were computed for each habitat station (table 5). The preconstruction mean stream widths indicate a second-order stream (Strahler, 1957). Postconstruction mean stream widths indicate a substantial increase for both stations. The change was greater at H2, where the difference of 3.3 feet amounted to a 53-percent increase. Changes in mean stream depth from preconstruction to postconstruction were, in contrast, insubstantial and opposite for the two stations, H1 deepening by 0.13 feet and H2 becoming shallower by 0.13 feet. The changes at H2 were, again, attributable to the placement of the large culvert.

The mean depth of fines over the coarse sand and silt substrate at both stations ranged from 0.26 to 0.35 feet (table 6). At H1, a slight postconstruction increase in mean depth of fines was noted. At H2, however, the depth of 4.86 feet was nearly double the preconstruction value.

The exact cause for the increase is difficult to determine. Sediment influx as a result of construction activity of the St. Francis development is one possible scenario; however, results of water-quality sampling during storm events did not substantiate this scenario. Other activities or occurrences within the study area may have contributed to an increase in the depth of fines, including removal of the weir structure during spring 2003, contribution of fines from upstream sources, and failing streambanks. Data from additional habitat sites would be needed to identify other potential sources of sediment to Brewery Creek.

Table 5. Physical habitat data for Brewery Creek, St. Francis residential subdivision, Cross Plains, Wis.

[ft, feet]

Site	Mean stream width (ft)	Mean stream depth (ft)	Width/depth ratio	Habitat score
H1 Preconstruction	9.3	0.9	10.3	40/FAIR
H2 Preconstruction	6.3	1.0	6.3	45/FAIR
H1 Preconstruction	10.2	1.0	10.2	40/FAIR
H2 Preconstruction	9.6	0.9	10.7	35/FAIR

Table 6. Depth of fines data analysis for Brewery Creek, St. Francis residential subdivision, Cross Plains, Wis.

[all depths in feet]

Site	Mean	Maximum	Median
Preconstruction H1	0.35	1.18	0.33
Preconstruction H2	0.26	0.92	0.23
Preconstruction H1	0.44	1.18	0.43
Preconstruction H2	0.49	1.18	0.39
Difference H1	0.09	0	0.10
Difference H2	0.23	0.26	0.16

Geomorphic Response

Results of the bank-pin surveys indicated failing banks at most sites. Bank pins in cross sections 1–8 (straightened reach) averaged 43.6 mm of deposition, whereas bank pins at cross sections 9–14 (meandering reach) averaged 26.4 mm of deposition at the conclusion of the study period. Bank material on Brewery Creek is primarily cohesive alluvial silt loam, making exposed banks susceptible to erosion. Although measurements indicated deposition, this was due to bank failure rather than sediment deposition on the banks. Streambank erosion processes are classified into two basic groups: gravitational or mechanical failures and tractive-force failures (O'Neill and Kuhns, 1994). The failing banks on Brewery Creek were indicative of gravitational failure, given low flows and the fine-grained cohesive soils. An example of streambank failure on Brewery Creek is shown in figure 17.

Results of the Rosgen Stream Classification showed only minor variations from 2001 and 2003 classifications (table 7). Bankfull widths and average depths decreased, whereas the width depth (w/d) ratios and entrenchment ratios increased. These changes were due in part to the placement of two large culverts (fig. 16) directly upstream from cross-section 8 and lower annual average precipitation in 2003. At cross section 1, the stream type went from a "G" to an "F" (Rosgen, 1996) with the dominant bed material changing from gravel to silt-clay. This difference can be attributed to removal of the V-notch weir at the upstream water-quality station in May 2003. During removal of the weir, soft sediment that had been deposited upstream from the structure was flushed and allowed to travel downstream. Cross section 9, in the uppermost part of the meandering section, did not change in stream type, but an increase in size of bed material from silt-clay to more gravel was noted.

Results of the Wolman Pebble Count Procedure indicated an increase in the cumulative percentage of fine-grained sediment at all transect survey locations. For example, differences in size-class distribution at cross section 13 can be seen in figure 18.

In summary, results of the fluvial geomorphology classifications and analyses do not indicate that the St. Francis Development on Brewery Creek contributed to changes in stream characteristics. Stream hydrology may have been altered slightly by removal of the weir and placement of the culverts as part of the road construction, but it is difficult to quantify the effects of these actions, if they can be quantified at all. No significant changes were detected after analyzing yearly stream-survey data.

Erosion of the streambanks was the primary source of increased fine-grained sediment noted during annual

Figure 16. Culverts placed in Brewery Creek for road crossing (view looking upstream), Cross Plains, Wis. Note difference between the culverts and the channel width directly downstream.

Figure 17. Example of gravitational streambank erosion in Brewery Creek, Cross Plains, Wis. Wedge failure leads to mass wasting of bank.

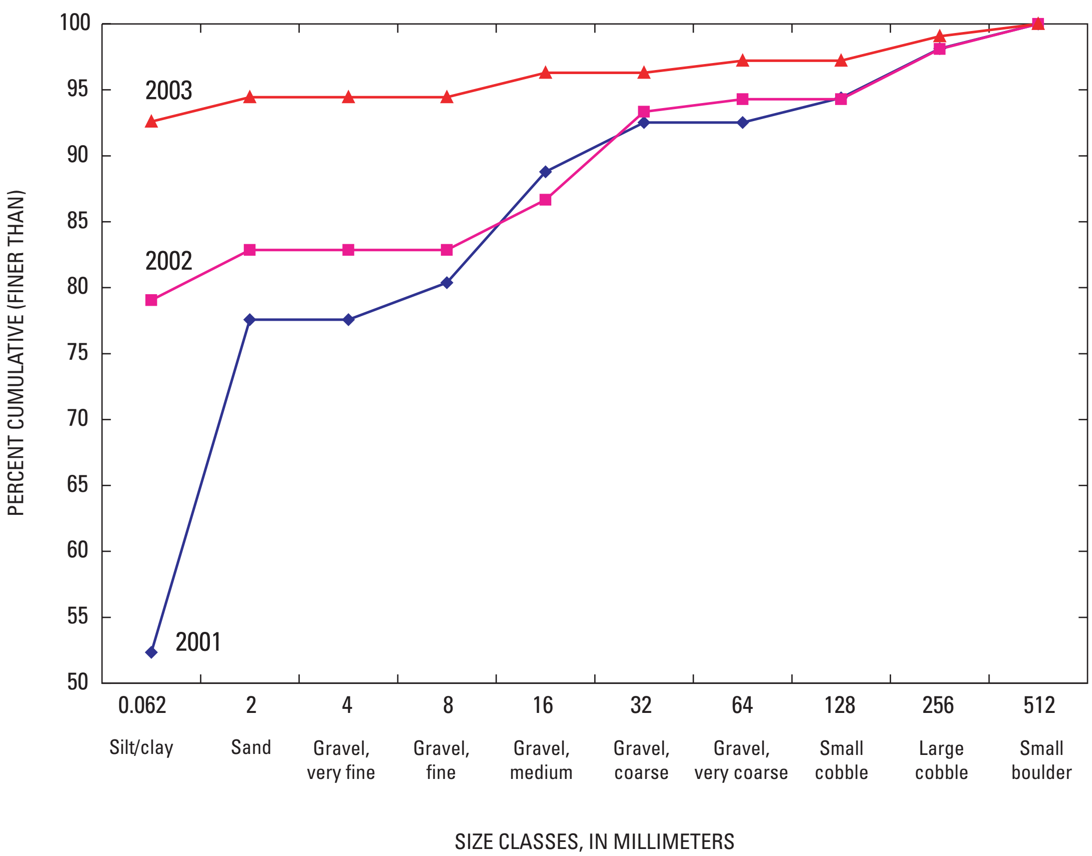

Figure 18. Results of Wolman Pebble Count at cross section 13 in Brewery Creek, Cross Plains, Wis. (2001–03).

pebble counts. Based on flow regimes and overall decreases in sediment yield from the construction site, the percentage of fine-grained sediment should have decreased corresponding to flows and constituent loading. In the loess area of the midwestern United States, however, bank material has been reported to contribute as much as 80 percent of the total sediment eroded from incised channels (Simon and others,1996). Analysis with Rosgen's stream classification indicated that channels were entrenched to slightly entrenched, making them more susceptible to erosion processes.

In addition to bank erosion, removal of the V-notch at the upstream water-quality station in the spring of 2003 likely contributed to an increase in fine-grained sediments. The weir was in the upstream segment of the study area (channelized reach) and released sediment downstream when it was removed. Data collected in 2001 and 2002 were very similar in results, whereas 2003 data indicated a significant increase in fines at all measured cross sections.

Summary and Conclusions

The U.S. Geological Survey (USGS), in cooperation with the Dane County Land Conservation Department (LCD) and the Wisconsin Department of Natural Resources (WDNR), conducted a multidisciplinary study incorporating streamflow, water-quality sampling, and physical, ecological, and geomorphic metrics to assess instream effects from construction of a residential subdivision on Brewery Creek, Dane County, Wis. An upstream/downstream (above and below) approach was used to isolate any changes caused by the study area over a period of 3 years (2001–03).

Collectively, the stormwater-management and erosion-control BMPs used at the St. Francis residential subdivision provided sufficient protection against degradation to Brewery Creek. Additionally, proper implementation and maintenance of the erosion-control and stormwater-management plan were critical components to reducing stormwater runoff. Results from this project will serve as an example for Dane County developers and builders of how to meet stormwater standards detailed in the Dane County Ordinance.

Erosion and stormwater-management controls implemented within the study area were effective at controlling runoff and solids transport during construction activity. Downstream event volumes, loads, and temperature were significantly greater than upstream volumes, loads, and temperature during three phases of construction: preconstruction, land disturbance, and home construction. The effectiveness of stormwater-management and erosion-control BMP systems was measured by evaluating the change in magnitude of differences between the downstream and upstream stations from one phase of construction activity to the next. The median difference between downstream and upstream storm volumes decreased (60 percent) from the preconstruction phase to the land-disturbance phase and slightly increased (9 percent) from the land-disturbance phase to the home-construction phase. The median differences for total and suspended solids load indicated a similar trend from preconstruction to land-disturbance phases with decreases of 52 and 72 percent, respectively. Both total and suspended solids load continued to decrease in the transition, from land-disturbance to home-construction phases; by 22 and 37 percent, respectively. Extreme data variability hampered statistical interpretation. Additional storm volume and load data could reduce variability and improve the statistical significance when determining an increase or decrease in volume or load from the study area.

Although daily mean stream temperature at the downstream monitoring station was consistently higher than at the upstream monitoring station during each phase, there was no statistical evidence to suggest an increase in stream temperature as a result of activity within the study area. Stream temperatures were most likely affected by direct solar heating because of a lack of overhead tree canopy between the downstream and upstream stations on Brewery Creek. Tree canopy was not altered during construction activity in the study area and was not considered part of the storm-runoff BMP system.

Ecologic indices for macroinvertebrate and fish communities indicate there were no negative effects to water quality and fisheries in Brewery Creek as a result of activity within the St. Francis subdivision. Macroinvertebrate sampling results (HBI value) on Brewery Creek ranged from "very good" to "good" water quality with no significant differences during any phase of construction activity. Results for fish-community composition, however, fell within the "poor" range (IBI value) during each year of testing. A general absence of intolerant species, with the exception of brown trout, reflects the low IBI values. The combination of these results suggests that organic loading is not a limiting factor in Brewery Creek but that overall fish habitat is in poor condition.

Habitat measurements did not change significantly from preconstruction to postconstruction phases. Although installation of a double-celled culvert in Brewery Creek most likely altered the width-to-depth ratio in that reach, the overall habitat rating remained “fair”. Installation of the culvert may also have caused changes in mean stream width and depth. These changes were a result of modifications to the stream itself and do not reflect changes caused by surface runoff because of activities in the study area.

Fluvial geomorphology classifications, including channel cross sections, bed- and bank-erosion surveys, and pebble counts did not indicate that stream geomorphic characteristics were altered by home-construction activity in the study area. Increases in fine-grained sediment at various cross sections were attributed to instream erosion processes, such as bank slumping, rather than increases in sediment delivery from the nearby construction site. This result was further substantiated by the reduction of storm runoff from the construction site during each phase of the study. Additional sediment was introduced to the stream by way of removal of the V-notch weir at the upstream monitoring station in spring 2003.

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Appendix

Table A1. Preconstruction-phase precipitation data, Brewery Creek, Cross Plains, Wis.

[-, storm duration does not allow for intensity computation; in/hr, inches per hour]

Start date/time	End date/time	Total rain (inches)	5-minute intensity (in/hr)	10-minute intensity (in/hr)	15-minute intensity (in/hr)	30-minute intensity (in/hr)	60-minute intensity (in/hr)	Erosivity index
10/01/99 21:05	10/02/99 04:30	.36	.24	.18	.16	.12	.10	.27
10/03/99 12:15	10/03/99 18:00	.21	.12	.12	.12	.10	.09	.13
10/16/99 01:20	10/16/99 07:10	.25	.48	.42	.36	.26	.18	.44
11/10/99 14:45	11/10/99 18:30	.80	1.92	1.86	1.84	1.10	.72	7.83
11/23/99 01:45	11/23/99 12:40	.99	.84	.66	.52	.36	.21	2.52
12/03/99 10:55	12/03/99 18:40	.31	.12	.12	.12	.12	.09	.23
12/04/99 15:00	12/04/99 23:30	.12	.12	.06	.08	.06	.05	.04
12/09/99 11:00	12/09/99 16:40	.15	.12	.12	.08	.08	.06	.07
01/09/00 20:30	01/10/00 07:55	.13	.12	.06	.08	.06	.04	.05
02/15/00 12:35	02/15/00 13:50	.16	.24	.24	.20	.18	.14	.19
02/24/00 02:40	02/24/00 10:30	.31	.12	.12	.12	.10	.08	.19
02/25/00 18:10	02/26/00 01:25	.66	1.32	.96	.72	.42	.27	1.94
03/08/00 10:40	03/08/00 17:50	.20	.72	.60	.52	.30	.16	.46
03/09/00 03:25	03/09/00 08:45	.13	.12	.12	.12	.10	.07	.08
03/15/00 12:35	03/15/00 15:30	.13	.12	.12	.12	.08	.06	.06
03/19/00 13:05	03/20/00 05:35	.34	.12	.12	.08	.08	.06	.17
03/26/00 16:15	03/26/00 18:35	.11	.24	.24	.20	.14	.08	.10
04/08/00 13:20	04/08/00 15:15	.28	.36	.36	.36	.32	.25	.64
04/19/00 07:35	04/21/00 00:40	1.67	.96	.72	.64	.42	.38	5.03
04/23/00 00:15	04/23/00 09:30	.46	.24	.18	.16	.14	.14	.41
05/08/00 08:25	05/08/00 10:20	.13	.48	.42	.36	.24	.12	.23
05/11/00 22:35	05/12/00 09:20	.14	.24	.24	.20	.10	.07	.09
05/17/00 12:50	05/20/00 07:35	5.04	4.68	4.38	3.80	2.42	1.24	101.33
05/26/00 22:30	06/01/00 23:30	5.07[1]	11.52	6.60	4.44	2.24	1.36	103.42
06/04/00 06:25	06/05/00 06:55	.88	.36	.24	.20	.20	.19	1.13
06/12/00 06:00	06/12/00 11:10	.20	.36	.36	.32	.26	.15	.36
06/13/00 15:15	06/14/00 02:40	2.71	3.00	2.88	2.44	1.52	.87	37.54
06/16/00 03:20	06/16/00 05:40	.11	.12	.12	.12	.10	.06	.07
06/20/00 04:35	06/20/00 16:00	.70	.96	.90	.76	.50	.31	2.58
06/24/00 14:00	06/24/00 18:50	.29	.24	.18	.16	.14	.13	.25
06/26/00 08:50	06/26/00 10:00	.11	.36	.30	.20	.12	.10	.09
06/28/00 06:20	06/28/00 10:35	.18	.24	.18	.16	.12	.09	.13
07/02/00 19:35	07/02/00 21:15	.99	3.48	3.12	2.68	1.64	.90	15.65
07/09/00 06:20	07/09/00 10:15	.42	.48	.36	.32	.24	.22	.69
07/10/00 03:40	07/10/00 08:45	.73	.84	.72	.68	.44	.30	2.34
07/20/00 17:00	07/20/00 17:15	.14	.96	.78	.56	-	-	-
07/28/00 17:35	07/28/00 22:50	.20	.60	.48	.40	.30	.18	.44
07/30/00 16:05	07/30/00 16:20	.14	.96	.78	.56	-	-	-
08/05/00 11:15	08/05/00 22:10	1.81	3.12	3.00	2.80	2.06	1.39	34.29

Table A1. Preconstruction-phase precipitation data, Brewery Creek, Cross Plains, Wis.—Continued

[-, storm duration does not allow for intensity computation; in/hr, inches per hour]

Start date/time	End date/time	Total rain (inches)	5-minute intensity (in/hr)	10-minute intensity (in/hr)	15-minute intensity (in/hr)	30-minute intensity (in/hr)	60-minute intensity (in/hr)	Erosivity index
08/12/00 19:50	08/12/00 21:15	.13	.12	.12	.12	.12	.11	.10
08/13/00 06:30	08/13/00 09:35	.14	.36	.30	.28	.18	.11	.17
08/16/00 20:20	08/17/00 09:05	1.00	1.20	1.02	.96	.72	.50	5.48
08/26/00 07:30	08/26/00 10:05	1.14	2.88	2.34	1.84	1.28	.91	12.99
09/03/00 07:05	09/03/00 08:30	.28	1.08	.72	.56	.36	.24	.76
09/11/00 07:40	09/11/00 22:05	1.08[1]	2.04	1.80	1.48	.90	.77	8.59
09/14/00 00:45	09/14/00 06:40	.22	.36	.30	.28	.20	.10	.29
09/19/00 17:00	09/19/00 23:55	.54	.84	.54	.40	.28	.22	1.04
09/22/00 09:20	09/22/00 23:30	.64	.36	.30	.28	.18	.17	.75
10/03/00 19:30	10/03/00 23:45	.17	.24	.18	.16	.12	.10	.13
10/05/00 16:10	10/05/00 20:00	.16	.24	.18	.16	.12	.07	.12
10/23/00 08:20	10/23/00 14:25	.29	.24	.18	.16	.12	.10	.22
11/06/00 13:00	11/07/00 00:30	.89	.48	.36	.32	.24	.18	1.41
11/09/00 09:50	11/09/00 16:30	.15	.48	.24	.16	.08	.06	.08
11/24/00 11:25	11/24/00 14:15	.25	.24	.18	.16	.14	.11	.22
12/15/00 20:10	12/16/00 06:45	.35	.24	.18	.16	.12	.08	.26
12/18/00 09:25	12/18/00 22:20	.29	.12	.12	.08	.06	.06	.11
12/28/00 19:45	12/29/00 19:05	.22	.12	.06	.08	.04	.03	.05
01/14/01 01:45	01/14/01 09:55	.24	.12	.12	.12	.12	.09	.18
01/29/01 11:30	01/29/01 23:05	.86	.36	.30	.28	.22	.18	1.21
02/07/01 21:30	02/08/01 04:15	.24	.36	.36	.28	.26	.18	.43
02/08/01 15:25	02/09/01 17:55	1.34	.48	.42	.36	.32	.29	2.89
02/24/01 06:20	02/24/01 20:10	.23	.12	.12	.08	.08	.07	.11
03/12/01 07:45	03/12/01 11:30	.14	.12	.12	.08	.08	.07	.07
03/31/01 14:15	03/31/01 17:15	.27	.24	.18	.16	.14	.13	.24
04/05/01 13:15	04/05/01 17:35	.31	.72	.42	.36	.28	.15	.64
04/08/01 23:20	04/09/01 04:35	.76	.36	.36	.32	.28	.24	1.46
04/10/01 22:50	04/11/01 15:20	.73	1.20	.78	.68	.50	.31	2.82
04/20/01 02:15	04/20/01 06:10	.48	.36	.30	.28	.24	.20	.77
04/21/01 00:10	04/21/01 04:55	.44	1.44	.72	.56	.38	.23	1.37

[1] storm defined using 12-hour interval

Table A2. Land-disturbance-phase precipitation data, Brewery Creek, Cross Plains, Wis.

[-, storm duration does not allow for intensity computation; in/hr, inches per hour]

Start date/time	End date/time	Total rain (inches)	5-minute intensity (in/hr)	10-minute intensity (in/hr)	15-minute intensity (in/hr)	30-minute intensity (in/hr)	60-minute intensity (in/hr)	Erosivity index
05/01/01 04:05	05/01/01 07:10	.15	.36	.30	.28	.22	.13	.23
05/03/01 18:30	05/04/01 08:35	.37	.36	.30	.28	.18	.12	.43
05/06/01 19:35	05/07/01 10:50	.46	.48	.36	.36	.26	.21	.83
05/10/01 00:55	05/10/01 03:05	.15	.36	.30	.28	.20	.13	.21
05/10/01 19:45	05/11/01 05:15	.60	1.68	1.50	1.16	.70	.41	3.44
05/20/01 23:55	05/21/01 12:20	2.02	1.92	1.74	1.52	1.04	.71	17.33
05/22/01 11:20	05/23/01 16:30	.54	.48	.48	.32	.18	.11	.65
05/31/01 15:20	06/01/01 07:30	.42	.24	.18	.12	.10	.08	.26
06/01/01 16:55	06/01/01 20:20	.45	1.32	.78	.60	.40	.29	1.36
06/05/01 01:30	06/05/01 13:00	.73	1.32	1.02	.80	.54	.41	2.97
06/09/01 21:35	06/10/01 05:30	.28	.72	.54	.44	.26	.13	.56
06/11/01 22:00	06/12/01 05:30	2.07	2.40	2.22	2.04	1.74	1.31	33.12
06/14/01 11:40	06/14/01 22:55	.14	.72	.48	.32	.16	.08	.17
06/15/01 05:40	06/15/01 10:45	.16	.24	.18	.16	.08	.08	.08
06/18/01 03:00	06/18/01 11:55	.46	.48	.42	.36	.22	.19	.69
06/21/01 18:50	06/22/01 00:15	.33	.48	.42	.44	.34	.26	.81
07/17/01 08:20	07/17/01 13:45	.55	3.00	1.86	1.40	.80	.52	3.94
07/18/01 07:15	07/18/01 08:30	.98	3.72	3.24	2.76	1.74	.96	16.70
07/24/01 20:25	07/25/01 02:00	.24	.72	.48	.32	.16	.09	.26
08/01/01 18:00	08/02/01 08:00	9.56	5.40	5.10	4.76	3.84	2.74	235.11
08/09/01 17:10	08/09/01 17:25	.11	1.08	.60	.44	-	-	-
08/15/01 15:25	08/16/01 07:30	.50	.24	.24	.20	.14	.09	.43
08/22/01 06:40	08/22/01 13:05	.20	.24	.18	.20	.16	.08	.21
08/24/01 19:10	08/26/01 01:40	1.31	2.28	1.98	1.44	1.08	.84	12.09
08/27/01 04:20	08/27/01 06:30	.16	.48	.30	.24	.14	.09	.15
09/06/01 14:15	09/07/01 03:30	.14	.72	.42	.28	.14	.07	.14
09/07/01 12:20	09/07/01 12:40	.46	2.52	2.34	1.76	-	-	-
09/07/01 19:05	09/08/01 03:00	1.28	2.52	2.22	2.04	1.48	.81	17.45
09/09/01 09:00	09/09/01 19:50	.71	.36	.24	.24	.18	.16	.82
09/17/01 04:45	09/17/01 12:15	.57	.36	.30	.28	.24	.22	.90
09/18/01 23:45	09/19/01 14:35	1.06	.36	.30	.28	.22	.22	1.52
09/20/01 19:50	09/21/01 00:30	.24	.24	.24	.24	.24	.21	.40
09/22/01 22:30	09/23/01 16:40	1.73	1.08	.96	.88	.84	.63	10.80
10/09/01 23:35	10/10/01 12:55	.23	.24	.18	.16	.14	.08	.21
10/13/01 09:15	10/13/01 20:40	.20	.36	.24	.16	.08	.07	.10
10/22/01 14:40	10/22/01 22:05	1.17	.96	.84	.76	.60	.41	5.06
10/24/01 07:25	10/24/01 18:35	.25	.24	.24	.20	.18	.14	.29
11/13/01 02:50	11/13/01 10:05	.24	.36	.24	.20	.14	.12	.22
11/18/01 18:20	11/19/01 02:15	.25	.24	.12	.12	.10	.07	.16

Table A2. Land-disturbance-phase precipitation data, Brewery Creek, Cross Plains, Wis.—Continued

[-, storm duration does not allow for intensity computation; in/hr, inches per hour]

Start date/time	End date/time	Total rain (inches)	5-minute intensity (in/hr)	10-minute intensity (in/hr)	15-minute intensity (in/hr)	30-minute intensity (in/hr)	60-minute intensity (in/hr)	Erosivity index
11/23/01 18:00	11/24/01 11:00	.82	.60	.54	.48	.30	.19	1.62
11/26/01 17:20	11/27/01 02:45	.25	.36	.24	.20	.12	.08	.19
11/30/01 02:10	11/30/01 07:05	.25	.24	.18	.16	.14	.10	.22
12/05/01 03:05	12/05/01 07:55	.17	.24	.18	.20	.12	.10	.13
12/12/01 17:30	12/13/01 04:05	.58	.48	.42	.36	.28	.23	1.10
12/22/01 07:55	12/22/01 18:00	.23	.36	.30	.24	.18	.10	.27
02/01/02 10:05	02/01/02 13:20	.31	.24	.18	.16	.16	.13	.31
02/09/02 22:45	02/10/02 13:20	.50	.12	.12	.12	.12	.09	.37
02/18/02 22:10	02/20/02 19:55	1.68	.24	.24	.20	.18	.16	1.89
03/05/02 12:15	03/05/02 15:20	.20	.24	.18	.20	.16	.13	.20
03/07/02 22:00	03/09/02 09:45	.46[1]	.84	.54	.44	.24	.14	.80
03/19/02 13:50	03/19/02 22:10	.20	.12	.12	.12	.10	.08	.12

[1] storm defined using 12-hour interval

Table A3. Home-construction-phase precipitation data, Brewery Creek, Cross Plains, Wis.

[-, storm duration does not allow for intensity computation; in/hr, inches per hour]

Start date/time	End date/time	Total rain (inches)	5-minute intensity (in/hr)	10-minute intensity (in/hr)	15-minute intensity (in/hr)	30-minute intensity (in/hr)	60-minute intensity (in/hr)	Erosivity index
04/02/02 08:25	04/02/02 18:30	.25	.12	.12	.12	.10	.09	.15
04/07/02 03:40	04/09/02 06:40	1.36[1]	.36	.36	.32	.28	.14	2.40
04/12/02 00:25	04/12/02 02:20	.16	.24	.24	.20	.18	.11	.19
04/14/02 18:10	04/14/02 19:10	.19	1.08	.84	.64	.32	.19	.51
04/18/02 16:00	04/18/02 22:25	.66	1.44	1.32	1.08	.84	.46	4.74
04/21/02 03:15	04/22/02 03:00	.32	.36	.24	.24	.16	.08	.32
04/24/02 12:55	04/24/02 15:30	.39	.72	.66	.64	.58	.36	1.79
04/27/02 11:05	04/28/02 06:15	.70	.36	.30	.28	.18	.12	.79
05/01/02 12:20	05/02/02 00:20	.56	.36	.30	.28	.22	.15	.79
05/06/02 22:15	05/06/02 23:15	.31	1.32	1.14	1.00	.60	.31	1.67
05/08/02 22:20	05/09/02 07:45	.78	1.44	.90	.64	.64	.50	3.90
05/11/02 10:50	05/12/02 10:30	.83	.84	.42	.32	.28	.22	1.60
05/25/02 05:05	05/25/02 13:55	.76	.36	.36	.32	.30	.24	1.50
05/28/02 20:25	05/29/02 05:35	.30	.60	.54	.44	.36	.24	.79
06/02/02 16:30	06/03/02 10:15	.24	.24	.18	.16	.12	.09	.18
06/03/02 22:45	06/04/02 11:30	.36	.36	.36	.32	.24	.16	.56
06/10/02 18:55	06/10/02 20:50	.14	.24	.24	.24	.16	.11	.15
06/26/02 04:05	06/26/02 10:10	.39	1.20	.84	.68	.38	.21	1.10
07/08/02 12:05	07/08/02 12:45	.56	1.56	1.50	1.48	1.06	-	5.56
07/08/02 20:35	07/08/02 20:50	.10	.60	.54	.40	-	-	-
07/20/02 15:20	07/20/02 15:55	.55	2.28	2.16	1.68	1.08	-	5.75
07/22/02 00:35	07/22/02 07:25	1.16	3.48	2.46	2.12	1.28	.70	13.21
07/27/02 05:30	07/27/02 10:30	.21	.24	.18	.16	.10	.08	.13
07/27/02 23:05	07/27/02 23:15	.12	1.20	.72	-	-	-	-
08/04/02 02:25	08/04/02 10:35	.73	2.28	2.04	1.76	.98	.50	6.34
08/11/02 16:35	08/11/02 17:55	1.74	3.96	3.30	2.96	2.02	1.53	35.90
08/12/02 20:15	08/13/02 05:10	.43	.60	.42	.36	0.26	.16	.76
08/17/02 06:50	08/17/02 07:10	.32	1.56	1.44	1.12	-	-	-
08/21/02 18:00	08/22/02 13:05	.93[1]	2.28	2.10	1.60	.88	.45	6.62
09/02/02 03:45	09/02/02 08:15	1.05	1.56	1.38	1.20	.90	.57	7.73
09/10/02 12:15	09/10/02 13:25	.16	.24	.24	.20	.18	.14	.19
09/19/02 00:55	09/19/02 05:05	.35	.72	.42	.36	.22	.17	.54
09/19/02 12:45	09/19/02 20:35	.17	.72	.48	.48	.26	.14	.34
09/20/02 04:00	09/20/02 18:15	.28	.96	.72	.52	.28	.14	.57
09/28/02 21:45	0 9/29/02 05:35	.70	1.45	1.17	.93	.71	.36	3.99

[1] storm defined using 12-hour interval

Table A4. Quality-control results for water sampling at Brewery Creek, Cross Plains, Wis.

[mg/L, milligrams per liter; RPD, relative percent difference; NA, not applicable; <, less than; %, percent]

Date/time	Sample type	Total solids (mg/L)	Total solids (RPD)	Suspended solids (mg/L)	Suspended solids (RPD)
			UPSTREAM		
08/17/99 16:45	Blank	66	NA	48	NA
08/17/99 17:00	Blank	<7	NA	<5	NA
04/17/01 09:40	Blank	<20	NA	<2	NA
07/09/02 09:20	Blank	<50	NA	<2	NA
08/21/02 13:05	Replicate	454	4%	18	0%
08/21/02 13:06	EWI	438		18	
11/07/01 12:00	Manual	506	0%	52	10%
11/07/01 12:01	EWI	504		47	
08/21/02 13:00	Manual	494	12%	45	86%
08/21/02 13:06	EWI	438		18	
			DOWNSTREAM		
08/17/99 16:30	Blank	22	NA	<5	NA
04/19/01 09:00	Blank	<50	NA	<2	NA
07/09/02 09:00	Blank	<50	NA	<2	NA
12/12/01 19:40	Replicate	554	3%	110	8%
12/12/01 19:41	EWI	536		102	
08/21/02 12:55	Replicate	454	0%	17	11%
08/21/02 12:56	EWI	452		19	
03/06/00 09:25	Manual	482	0%	23	4%
03/06/00 09:20	EWI	482		22	
11/07/01 11:50	Manual	512	1%	52	2%
11/07/01 11:51	EWI	508		51	
08/21/02 12:48	Manual	462	2%	32	51%
08/21/02 12:56	EWI	452		19	

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