# EVALUATION OF NONPOINT-SOURCE CONTAMINATION, WISCONSIN: SELECTED DATA FOR 1992 WATER YEAR

By D.J. Graczyk, J.F. Walker, S.R. Greb, S.R. Corsi, and D.W. Owens

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# EVALUATION OF NONPOINT-SOURCE CONTAMINATION, WISCONSIN: SELECTED DATA, FOR 1992 WATER YEAR

By D.J. Graczyk[1], J.F. Walker[1], S.R. Greb[2], S.R. Corsi[1], and D.W. Owens[1]

## INTRODUCTION

This report presents the annual results of the U.S. Geological Survey's (USGS) watershed-management evaluation monitoring program. The program is being conducted in cooperation with the Wisconsin Department of Natural Resources (WDNR). This report fulfills part of the contractual obligation between the USGS and WDNR.

The overall objective of each individual project in the program (fig. 1) is to determine if the water chemistry in the receiving stream has changed as a result of the implementation of land-management practices in the watershed. This is accomplished through monitoring of water chemistry and ancillary variables before best-management practices (BMP's) are installed, during installation, and after watershed-management plans have been completely implemented. The period before BMP implementation is termed "pre-BMP" conditions, the period during active installation is termed "transitional," and the period after complete implementation is termed "post-BMP" conditions.

This report is divided into nine sections and two appendixes. The following topics are addressed: (1) rainfall data, (2) water-quality data, (3) bedload data, (4) metals data, (5) dissolved-oxygen data, (6) comparison of total- and dissolved-hardness data, (7) single-stage sampler evaluation, (8) mapping BMP land use, and (9) quality-control and quality-assurance considerations. In each section, data collected during the 1992 water year (October 1991-September 1992) are presented, and implications for future data-collection efforts are discussed, if appropriate. The two appendixes present a listing of the storm-load data collected during 1985-92 water years, and the quality-assurance document developed during 1992 for all of the projects.

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## RAINFALL DATA

A network of rain gages in each watershed is used to account for the spatial variability of rainfall and adequately determine individual rainfall characteristics. A concern identified in 1991 was the failure of several individual rain gages to operate continuously. During the 1990 and 1991 water years, at least one rain gage in a watershed's rain-gage network failed to operate during a significant number of storms that produced at least 0.5 in. of rainfall (fig. 2). At the beginning of the 1992 water year, several modifications were made to improve the efficiency of rainfall data collection. First, a fine-mesh screen was installed on each rain gage to prevent debris from clogging the funnel because the coarse-mesh screen supplied with the rain gages was inadequate. Second, the data-logger program was modified to allow the field technician to test the operation of the gage with each visit. Third, more rigorous field notes were used to help identify problems. Finally, an effort was made to process the data immediately and compare the operation of each gage within a given watershed. As a result of these modifications, data-collection efficiency improved (fig. 2). All of the rain-gage networks performed satisfactorily during the 1992 water year, with the exception of Garfoot Creek. A faulty switch at one Garfoot Creek rain gage caused considerable missing record early in the 1992 water year; the switch was repaired, and the gage operated well thereafter. No further improvements in the rain-gage networks are anticipated for the 1993 water year.

## WATER-QUALITY DATA

### Storm Loads

Water-quality monitoring continued during the 1992 water year at the monitoring sites with sampling of both base-flow periods and storms. The water-quality data were used in conjunction

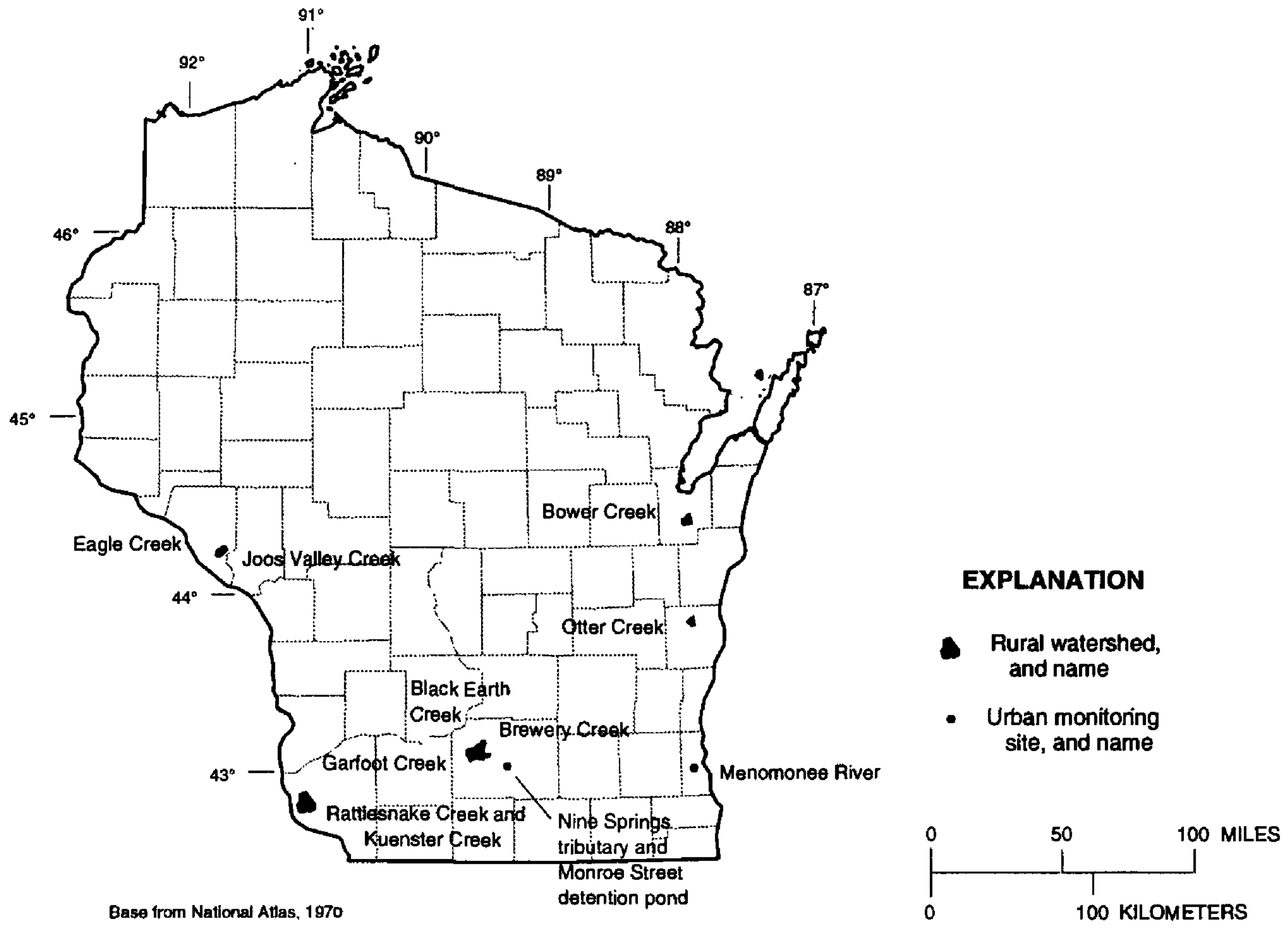


**Figure 1.** Location of rural watersheds and urban monitoring sites in watershed-management evaluation monitoring program.

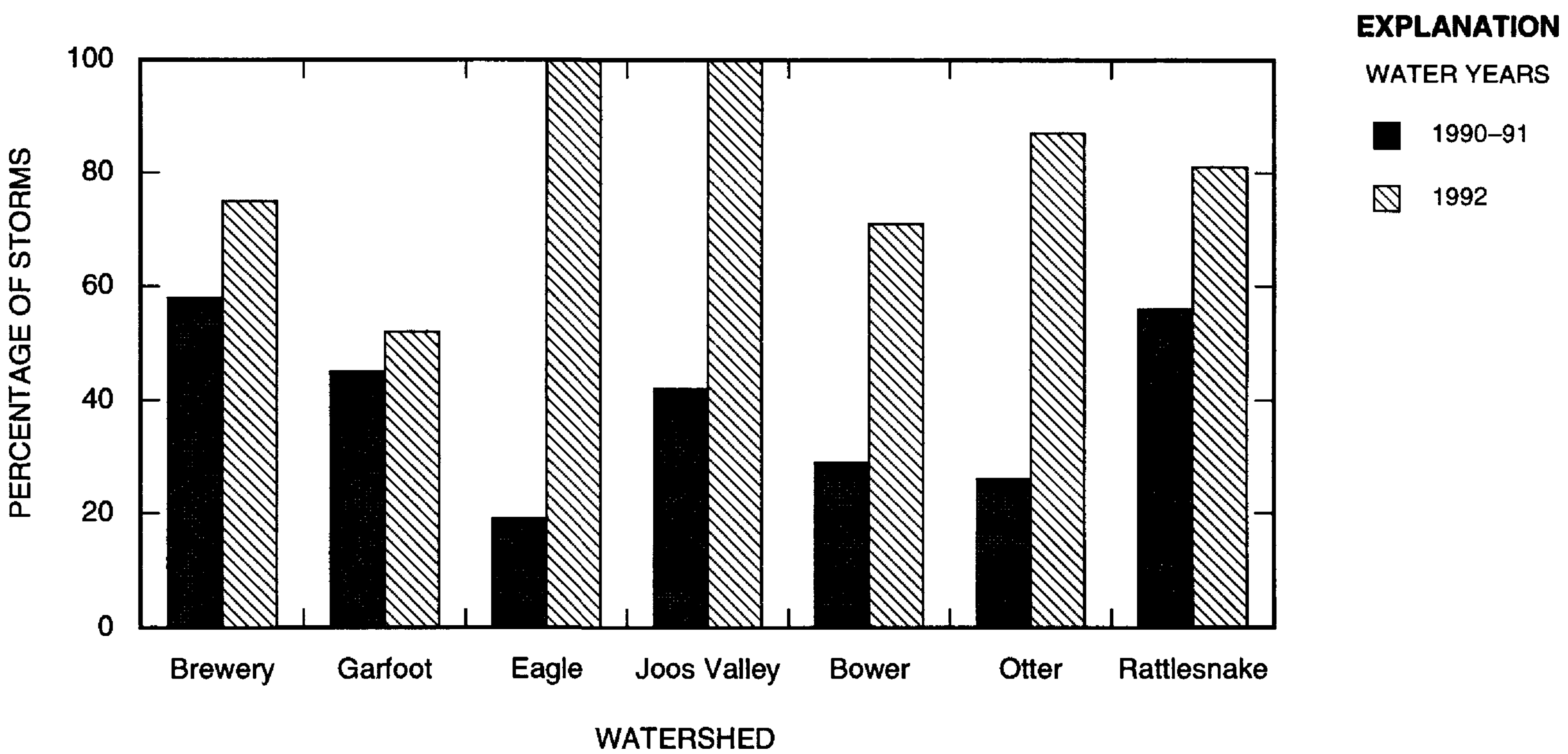


**Figure 2.** Percentage of storms in each rural watershed averaging at least 0.5 inch of total precipitation where all gages operated properly, 1990-92 water years.

with streamflow data to estimate total constituent loads for storms. The storm-load data will be used to evaluate the effect of BMP's on streamwater quality. In general, at least 20 pre-BMP and 20 post-BMP storms are needed to detect moderate differences in water quality that may be related to implementation of the BMP's (Walker, 1993). The total number of storms with complete sampling (enough samples collected during the storm to accurately determine a constituent load) for each monitoring site are presented in figure 3 for the 1992 water year and for all data collected from 1990 through the 1992 water year. With the exception of Rattlesnake Creek, all of the sites appear to have sampled a sufficient number of storms during the 1992 water year, and there should be enough pre-BMP information from the data collected to date for adequate evaluation. Brewery and Garfoot Creeks are currently in a transitional period, with BMP implementation beginning in 1989 and continuing through 1993. The transitional data were used in a preliminary evaluation of BMP effectiveness and are summarized by Walker and Graczyk (1993).

Suspended-solids and total-phosphorus storm loads for pre-BMP conditions are presented in figures 4-10 for each rural watershed monitoring site. Brewery and Garfoot Creek are not included because those data are summarized elsewhere (Walker and Graczyk, 1993). The storm loads are plotted versus total precipitation to demonstrate the range in storms covered and to give an indication of the relationship with climatic variables (total rainfall in this case). In evaluating the effect of BMP's, the relation of constituent load to climatic variables is used to reduce the natural variability in the data and isolate BMP effects (Walker, 1993). Although the plots indicate a fair amount of scatter, additional independent variables will be used to further describe the load-producing mechanisms and separate seasonal effects.

Although there was a sufficient number of storms sampled during the 1992 water year, additional analyses were performed to evaluate the effectiveness of the sampling procedures. For each site, the continuous streamflow record was inspected to identify all periods where a substantial hydrograph rise and subsequent fall occurred. For each hydrograph-rise period, the total runoff was computed, and each period was classified into one of four categories: (1) complete sampling, (2) equipment malfunction, (3) partial sampling, and (4) no sampling. The distinction between complete and partial sampling was determined individually by site based on the shape of the hydrograph and the number of samples collected. Results for each of the seven rural monitoring sites are presented in figures 11-17.

In general, the current sampling protocols (samples are collected whenever the stage increases by 0.2 ft on the rising limb of the hydrograph and whenever the stage decreases by 0.4 ft on the falling limb of the hydrograph) appear to be providing a representative set of storms, both in terms of the magnitude of the storm and the season of occurrence. Because the larger storms tend to carry the greatest loads, it is encouraging to note that a high percentage of the large storms were sampled completely. However, in a number of cases there are quite a few moderate-sized storms that were not sampled completely. With the exception of Bower and Otter Creeks, all of the sites may be missing storms that should have been sampled. In many cases, several hydrograph-rise periods in late winter and early spring were missed because the water-level sampling threshold was set artificially high to prevent the collection of unneeded samples triggered by increases in stream stage caused by ice effects. The hydrograph-rise periods missed were generally snowmelt periods, which can carry substantial loads and are potentially important.

It appears that adequate hydrograph-rise periods are being sampled; there may be room for improvement in future years. The data for the 1992 water year will be used to experiment with the sampling protocols in an effort to determine if some of the periods not sampled could be covered more completely. The obvious tradeoff involves sampling some of the smaller storms at the expense of missing the larger storms because of automatic-sampler capacity limitations. If additional storms can be sampled without missing the larger storms, the sampling protocols will be revised accordingly. Finally, closer attention will be paid to the sampling thresholds set during the winter period in an effort to sample the midwinter snowmelt periods.

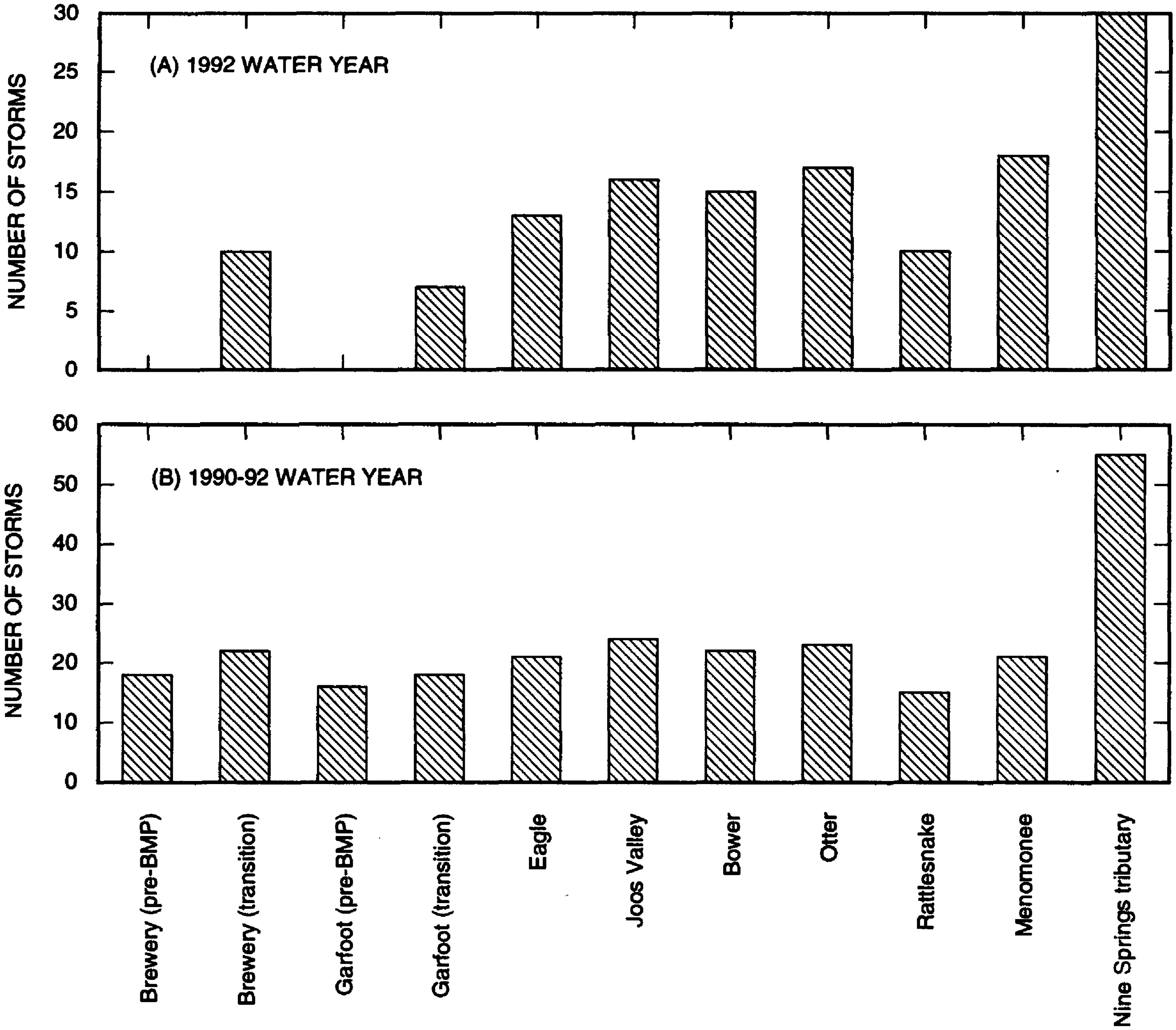


**Figure 3.** Total number of storms with complete sampling and computed storm loads for (A) 1992 water year and (B) total number of storms sampled during 1990-92 water years for evaluation of best-management practices (BMP).

## Bedload Transport in Eagle Creek

Data were collected for Eagle Creek at two monitoring sites (County Trunk G and Schaffner Farm) to determine if bedload was a significant portion of the total-sediment load. Bedload typically is composed of larger sediment particles, such as particles greater than 0.0625 mm (millimeters). These sediment particles usually move in contact with the bed by sliding, rolling, or bouncing and usually are not collected using suspended-sediment samplers. Bedload can be determined by direct (Helley-Smith sampler) or indirect (modified Einstein procedure) methods (Colby and Hembree, 1955).

A Helley-Smith bedload sampler was used to collect the bedload portion of the total-sediment load at Eagle Creek. This sampler has a 3 in. by 3 in.-square entrance with a mesh bag attached to the sampler. The mesh bag usually has an opening of 0.25 mm. The sampler is placed flat on the bottom at approximately 20 locations across the stream width (if the stream is wide enough) and is kept on the bottom for 30-60 seconds. Usually two traverses are made across the stream. It is USGS policy that samples for bedload be collected by the Helley-Smith sampler if physical conditions permit sample collection. The following physical conditions will permit sample collection:

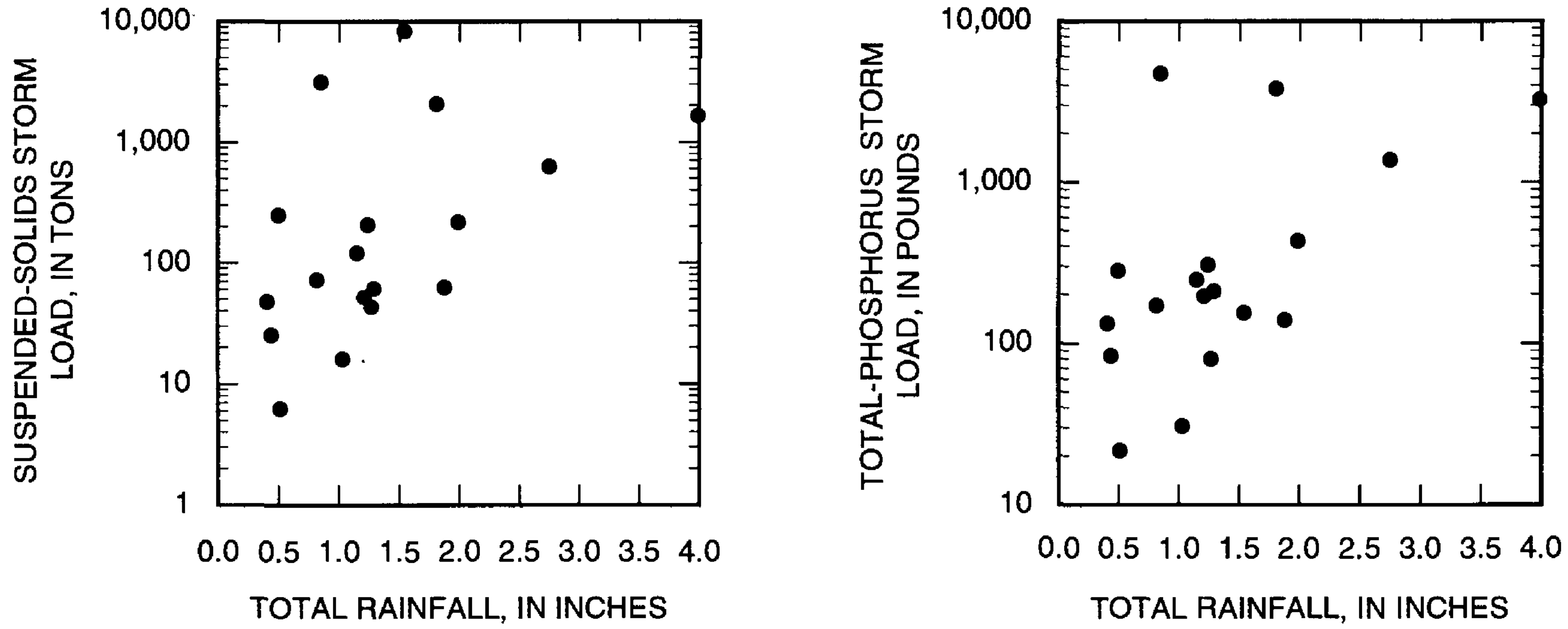


**Figure 4.** Relation of total storm loads of suspended solids and total phosphorus to total storm precipitation for the Eagle Creek rural watershed, 1992 water year.

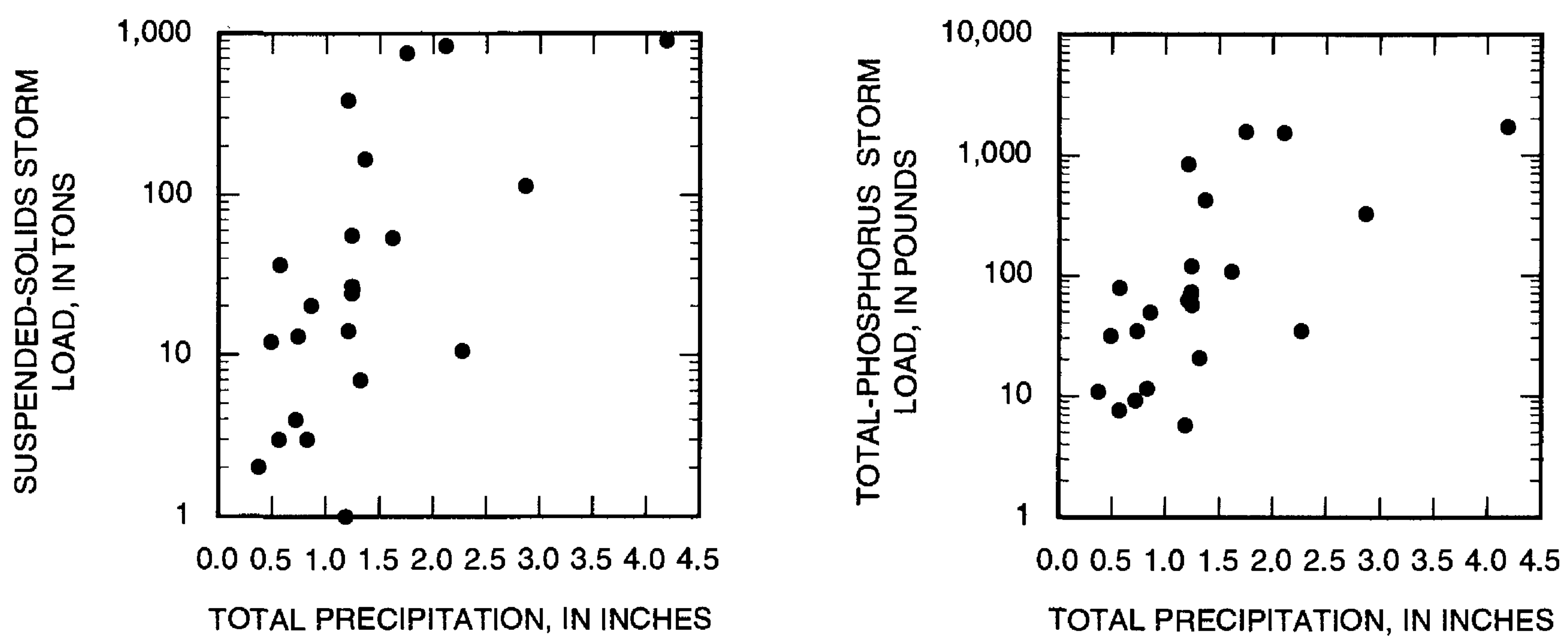


**Figure 5.** Relation of total storm loads of suspended solids and total phosphorus to total storm precipitation for the Joos Valley Creek rural watershed, 1992 water year.

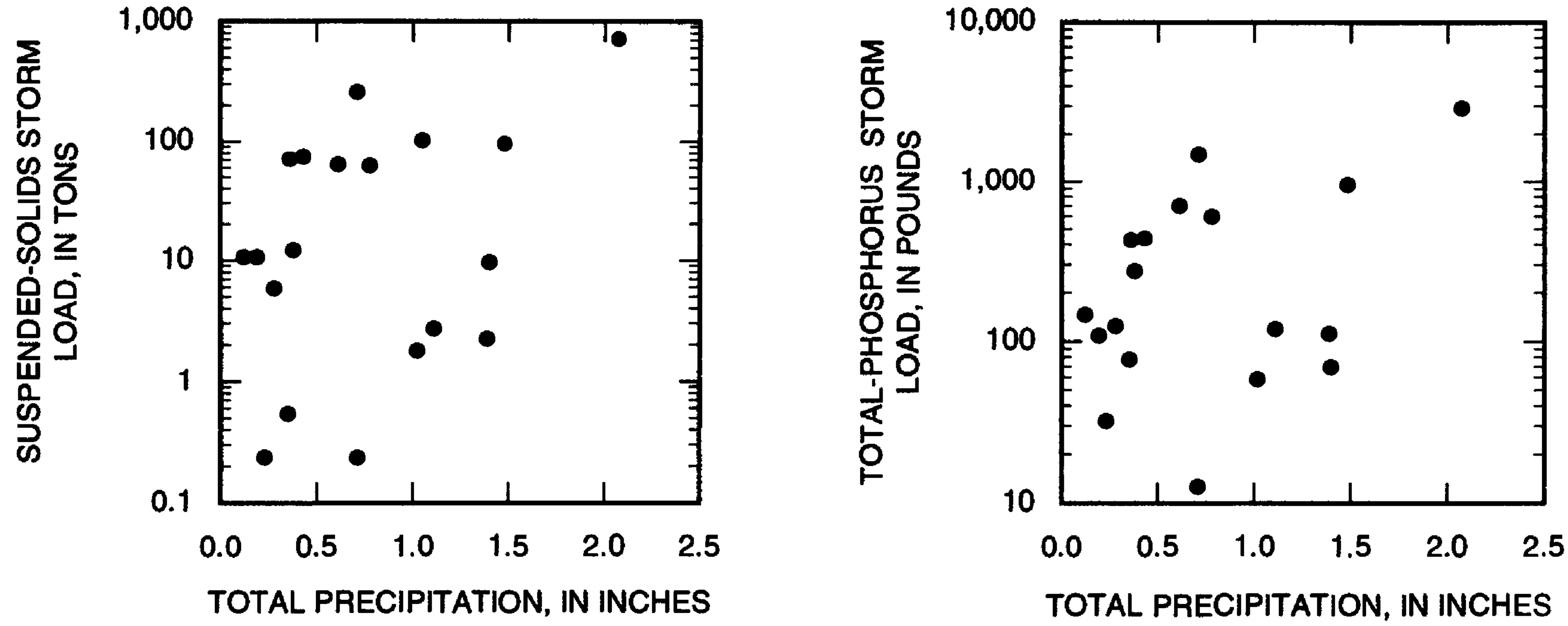


**Figure 6.** Relation of total storm loads of suspended solids and total phosphorus to total storm precipitation for the Bower Creek rural watershed, 1992 water year.

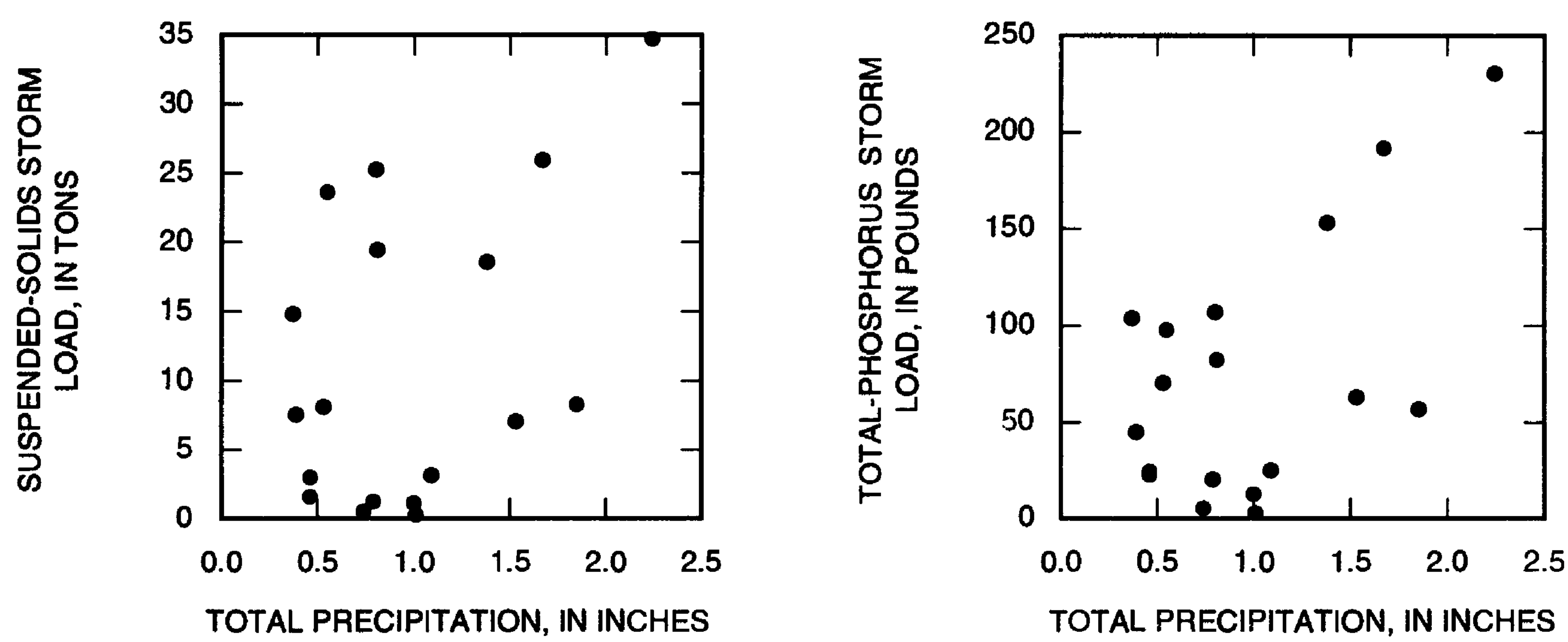


**Figure 7.** Relation of total storm loads of suspended solids and total phosphorus to total storm precipitation for the Otter Creek rural watershed, 1992 water year.

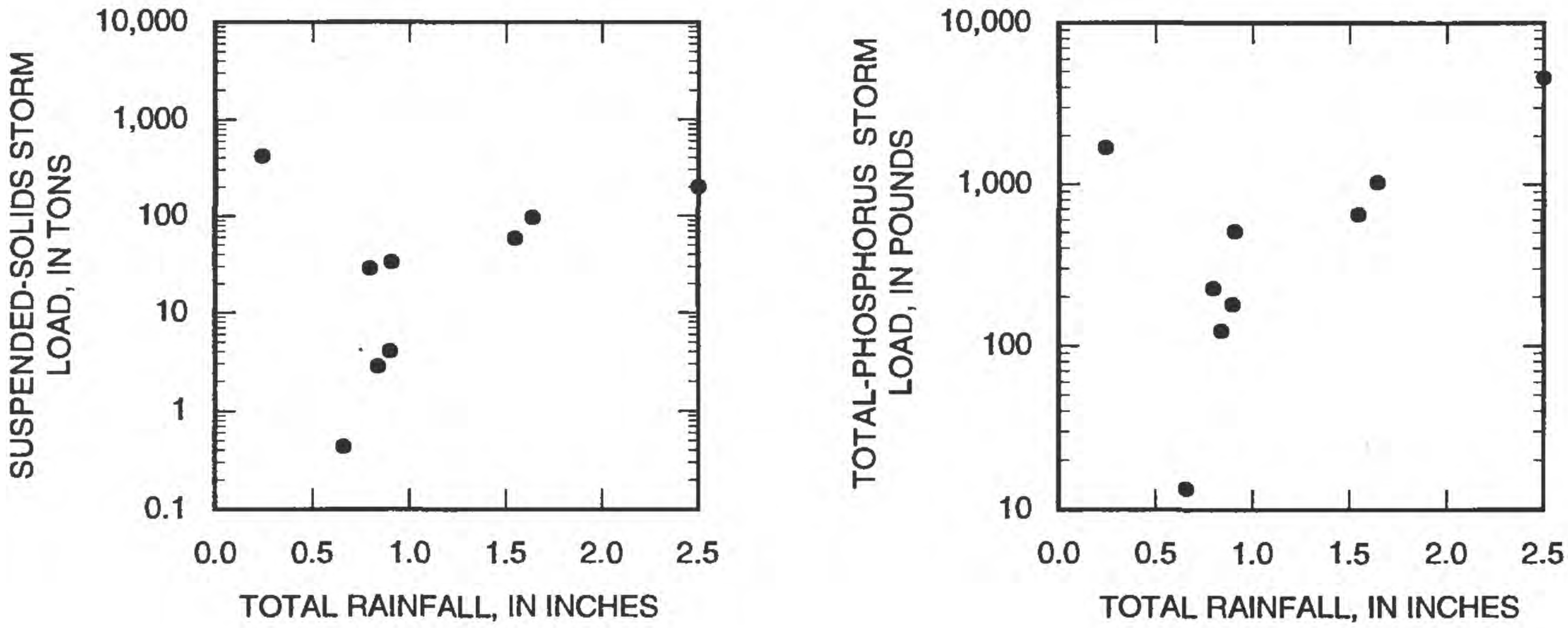


**Figure 8.** Relation of total storm loads of suspended solids and total phosphorus to total storm precipitation for the Rattlesnake Creek rural watershed, 1992 water year.

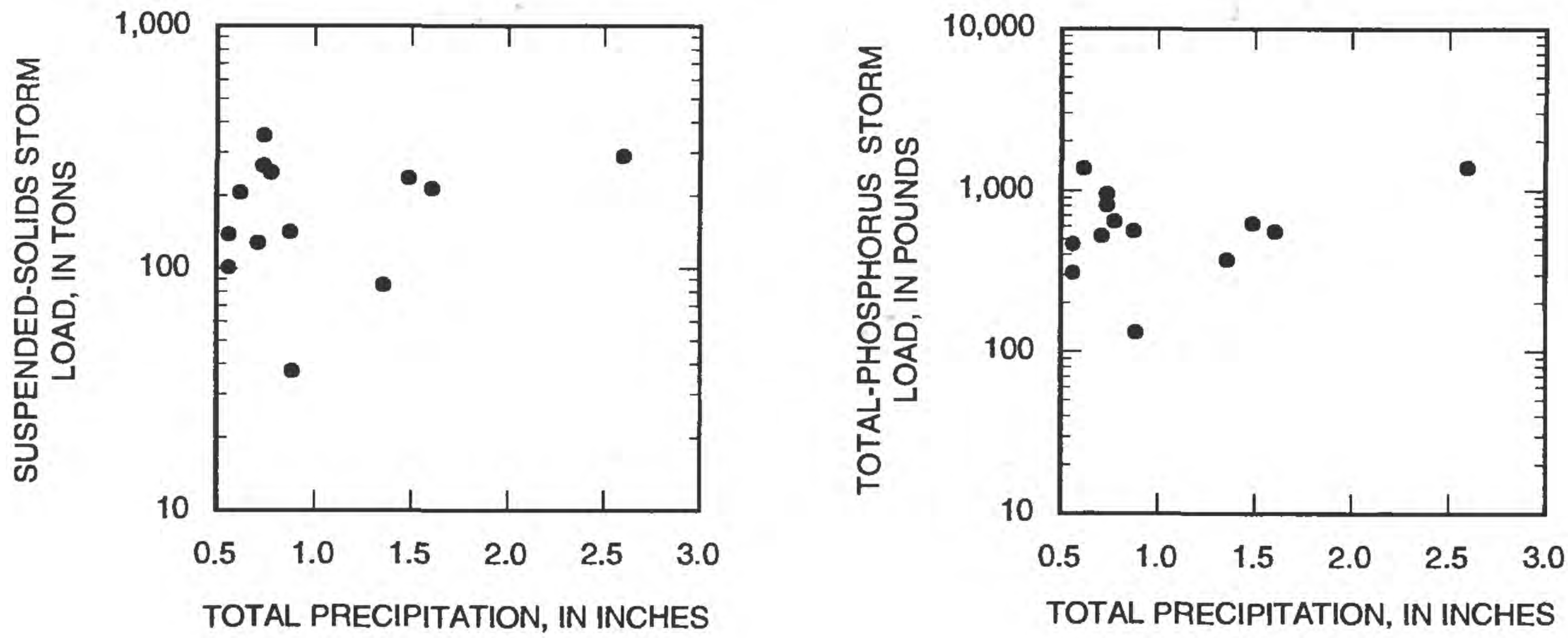


**Figure 9.** Relation of total storm loads of suspended solids and total phosphorus to total storm precipitation for the Menomonee River urban watershed, 1992 water year.

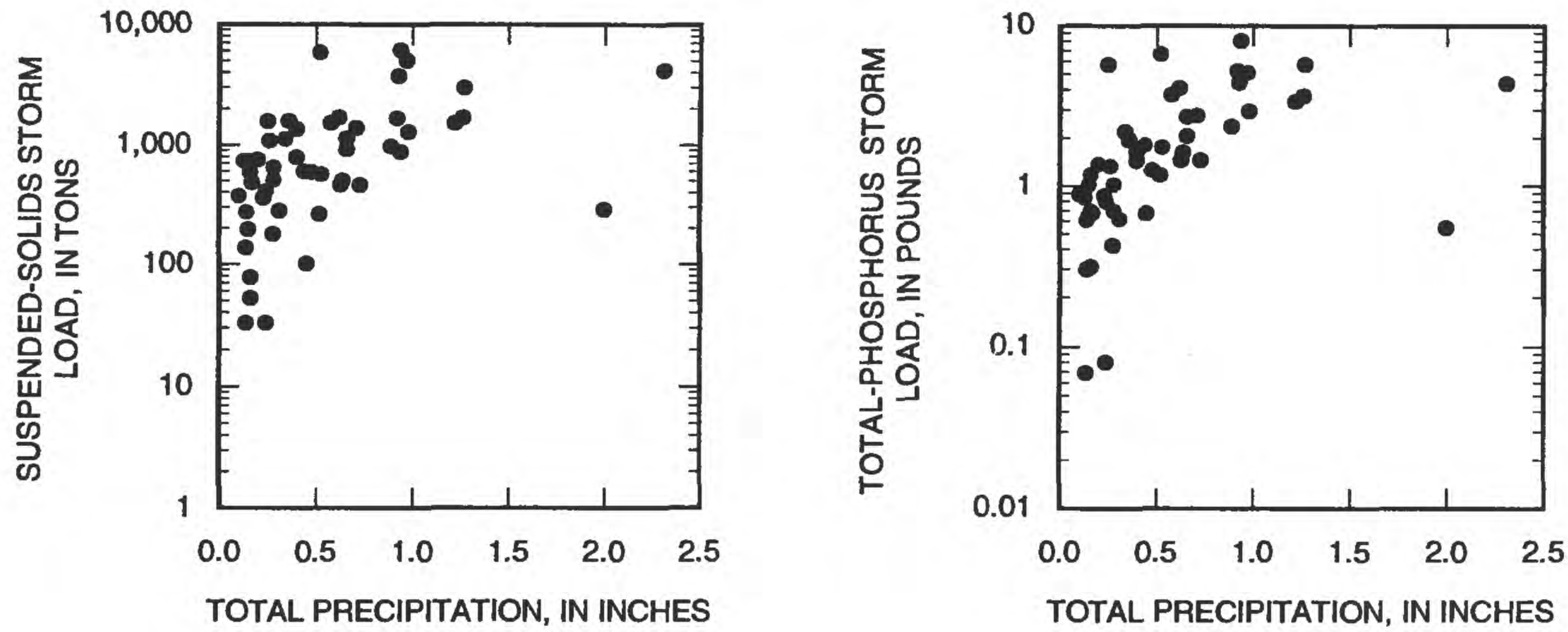


**Figure 10.** Relation of total storm loads of suspended solids and total phosphorus to total storm precipitation for the Nine Springs Creek tributary urban watershed, 1992 water year.

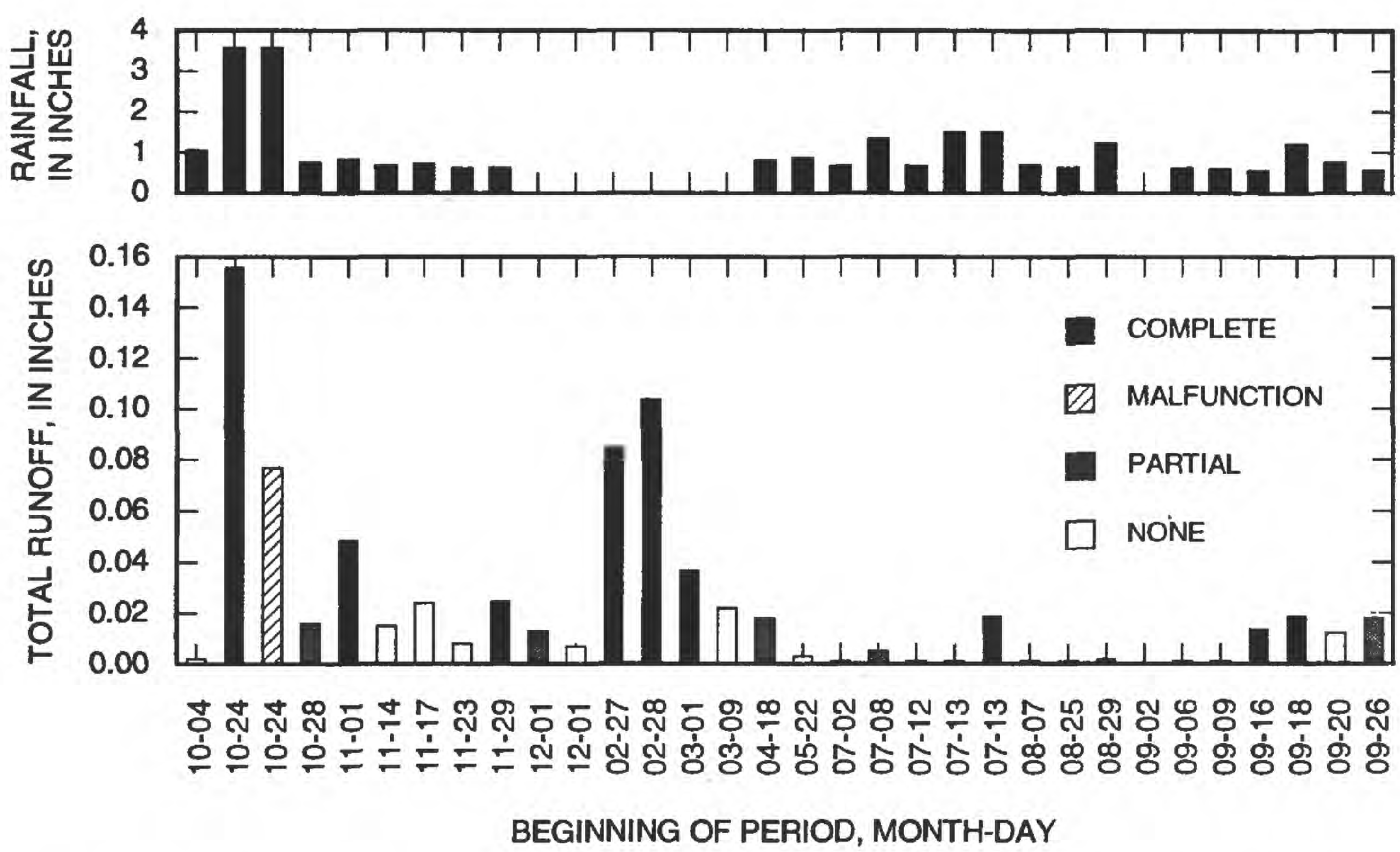


**Figure 11.** Total rainfall and runoff for selected hydrograph-rise periods at the Brewery Creek monitoring site, 1992 water year. Runoff periods are identified with the amount of sampling provided during the period--complete sampling, equipment malfunctions, partial sampling, and no sampling.

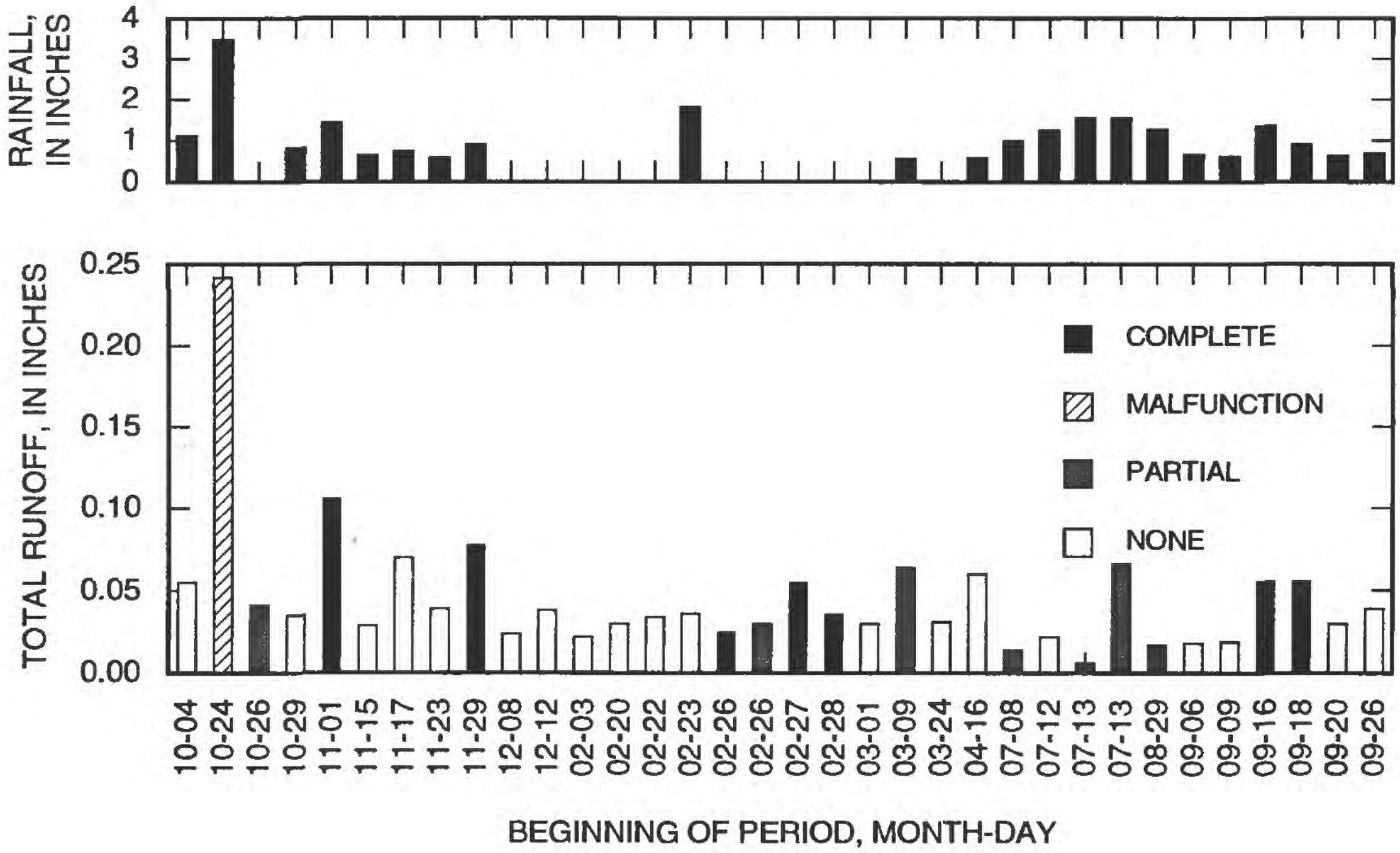


**Figure 12.** Total rainfall and runoff for selected hydrograph-rise periods at the Garfoot Creek monitoring site, 1992 water year. Runoff periods are identified with the amount of sampling provided during the period--complete sampling, equipment malfunctions, partial sampling, and no sampling.

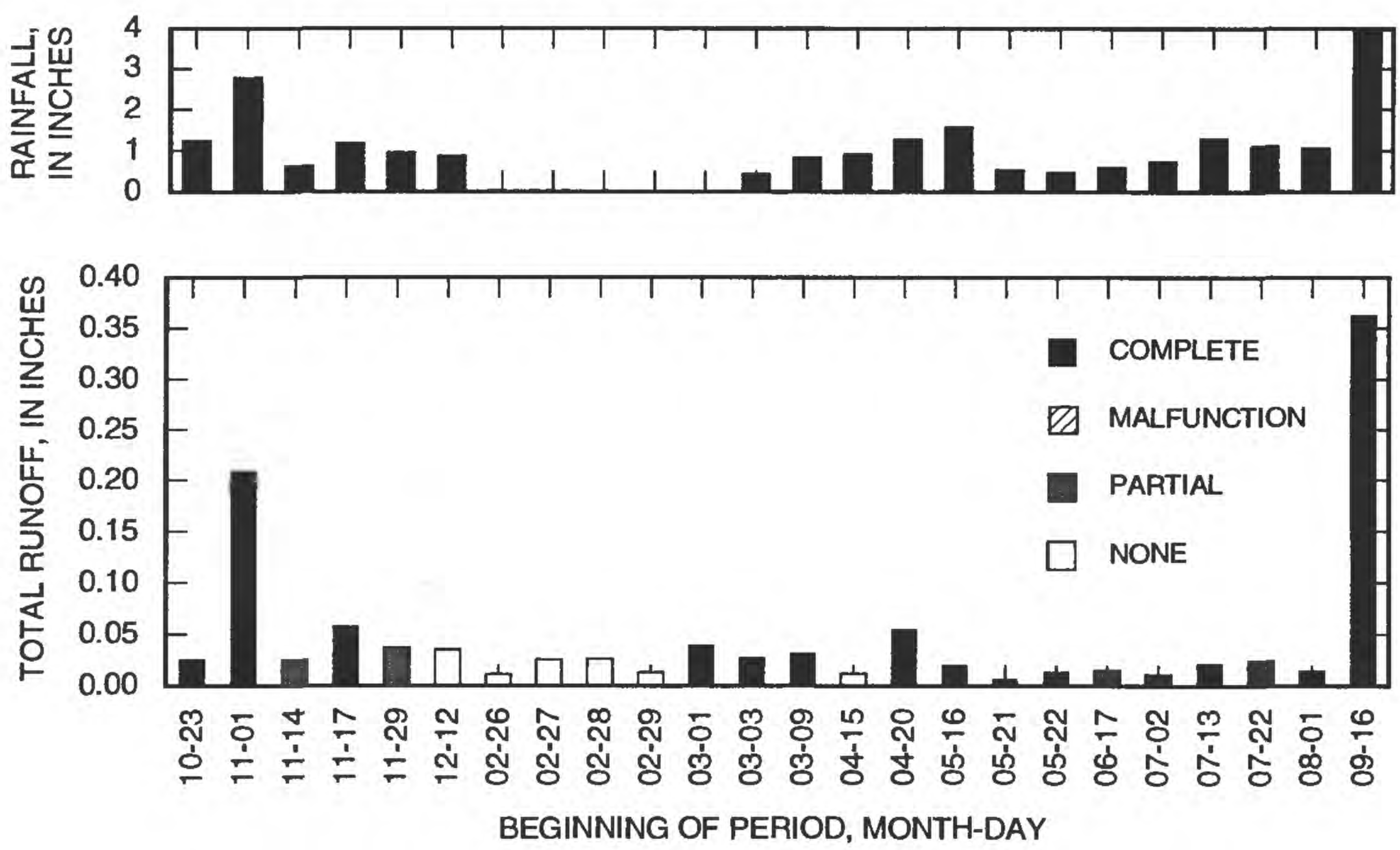


**Figure 13.** Total rainfall and runoff for selected hydrograph-rise periods at the Eagle Creek monitoring site, 1992 water year. Runoff periods are identified with the amount of sampling provided during the period--complete sampling, equipment malfunctions, partial sampling, and no sampling.

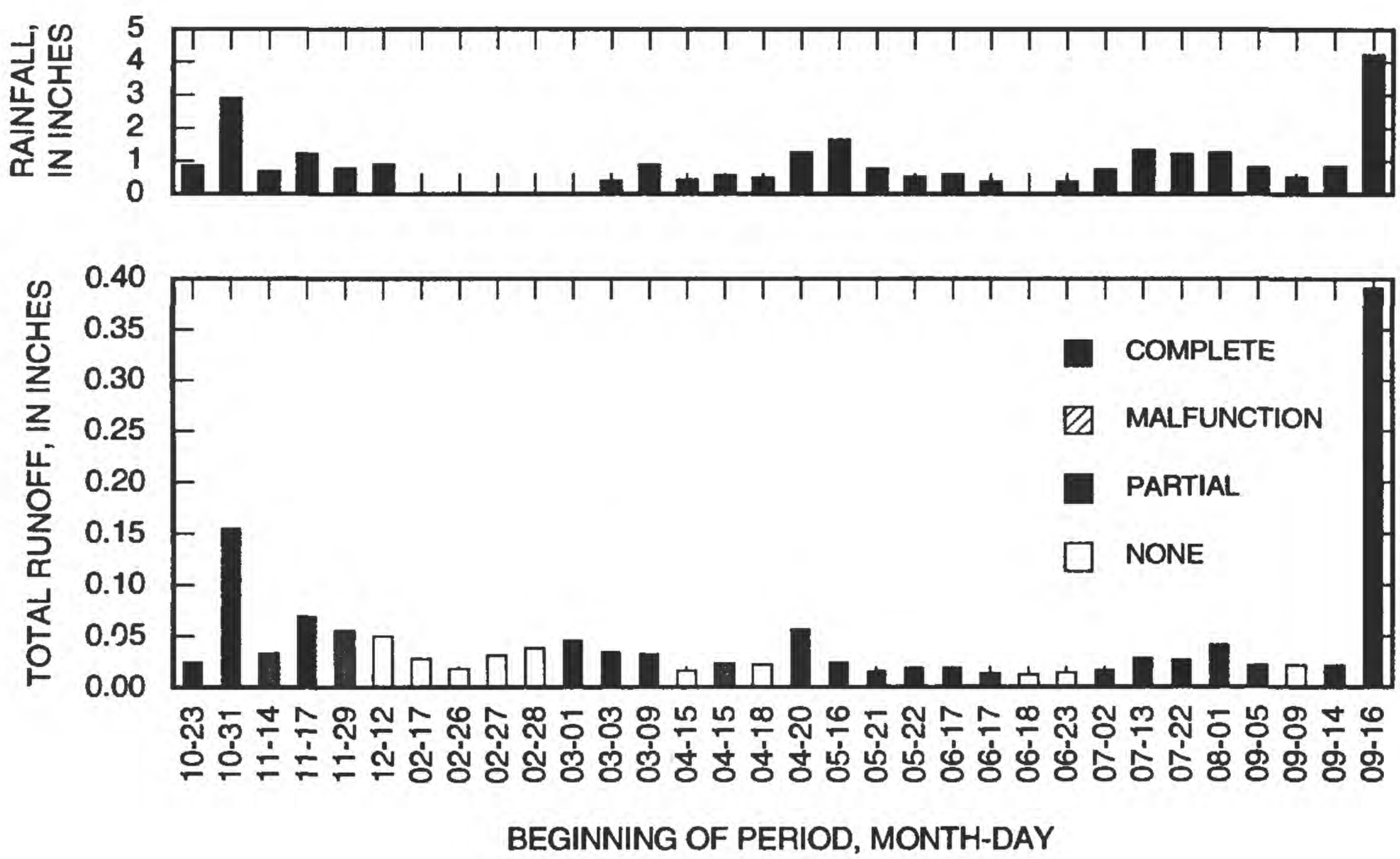


**Figure 14.** Total rainfall and runoff for selected hydrograph-rise periods at the Joos Valley Creek monitoring site, 1992 water year. Runoff periods are identified with the amount of sampling provided during the period--complete sampling, equipment malfunctions, partial sampling, and no sampling.

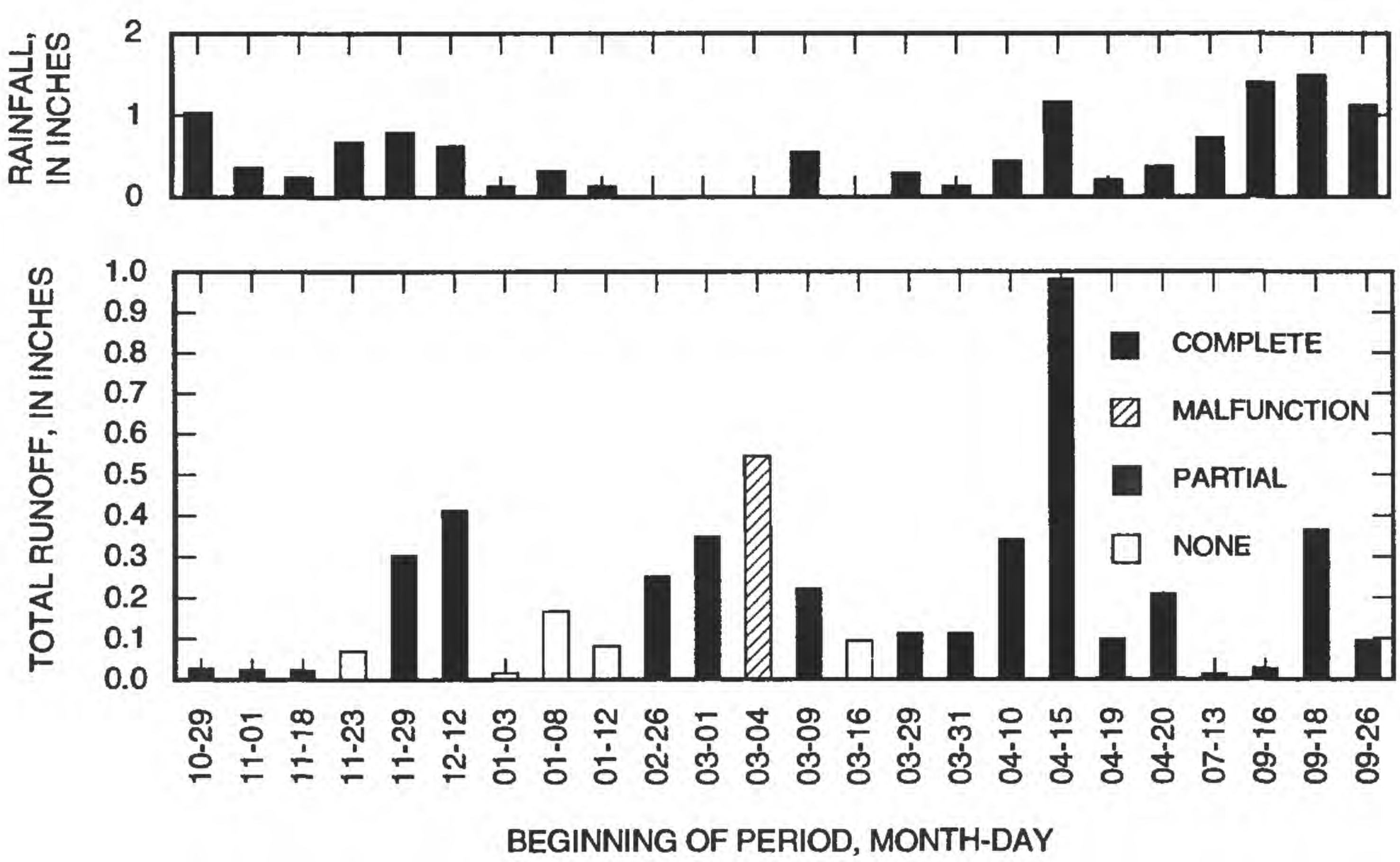


**Figure 15.** Total rainfall and runoff for selected hydrograph-rise periods at the Bower Creek monitoring site, 1992 water year. Runoff periods are identified with the amount of sampling provided during the period--complete sampling, equipment malfunctions, partial sampling, and no sampling.

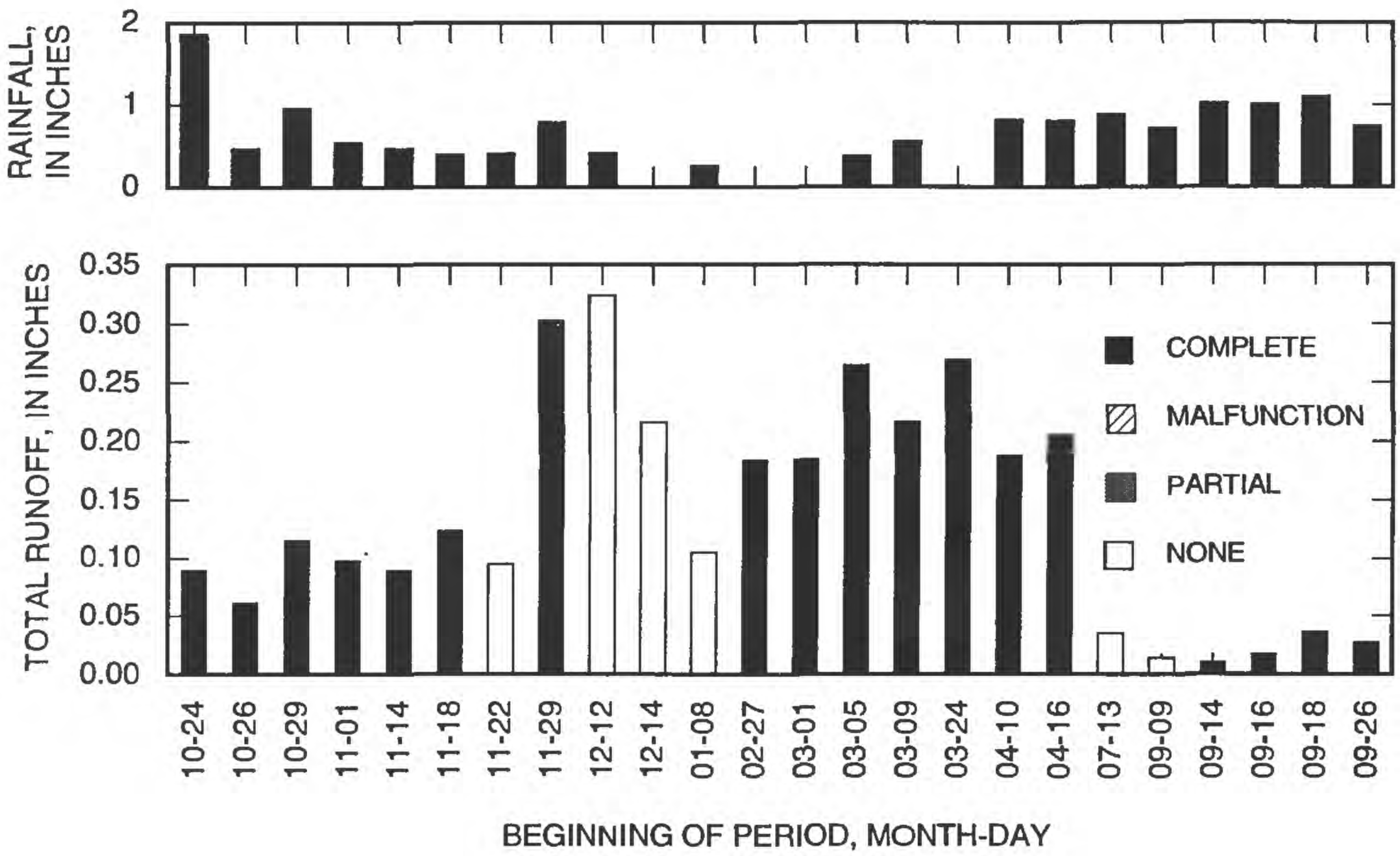


**Figure 16.** Total rainfall and runoff for selected hydrograph-rise periods at the Otter Creek monitoring site, 1992 water year. Runoff periods are identified with the amount of sampling provided during the period--complete sampling, equipment malfunctions, partial sampling, and no sampling.

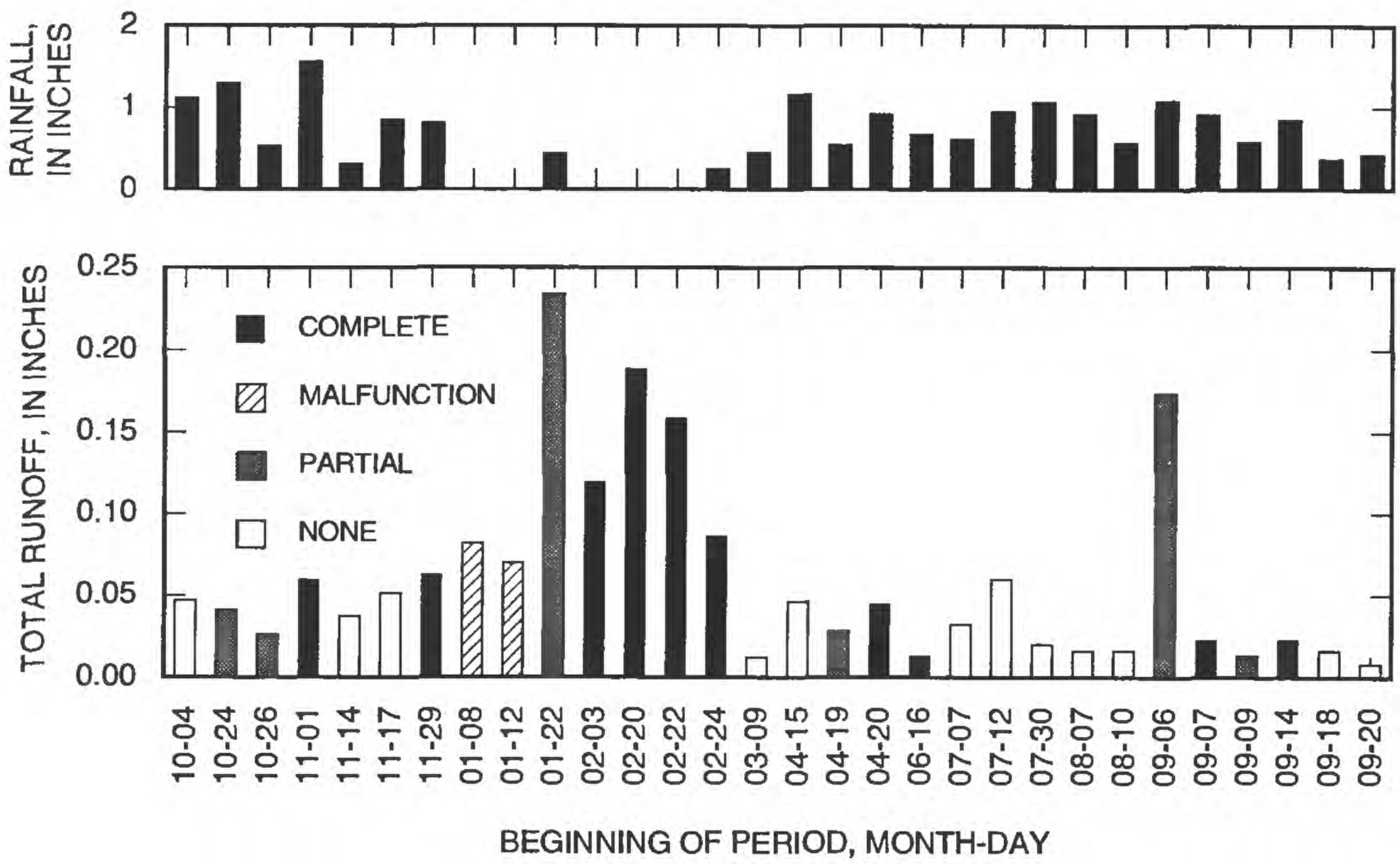


**Figure 17.** Total rainfall and runoff for selected hydrograph-rise periods at the Rattlesnake Creek monitoring site, 1992 water year. Runoff periods are identified with the amount of sampling provided during the period--complete sampling, equipment malfunctions, partial sampling, and no sampling.

1. The bed material is firm enough to physically support the sampler without sinking into the bottom;

2. The streambed is smooth enough for the nozzle to lay flat on the bottom;

3. The stream velocity is low enough to allow the sampler to properly sit on the streambed; and

4. Neither organic nor mineral deposits clog the bag to the extent that flow through the sampler is restricted (Edwards and Glysson, 1988).

The monitoring sites in the Eagle Creek watershed, for the most part, have acceptable sampling cross sections. For low- to medium-wadable flows at the County Trunk G site, the Helley-Smith section is a flat, firm sand bottom downstream from the County Trunk G bridge and upstream from the Eagle Creek gage. At the Shaffner Farm site, the cross section at low and medium flows is gravel and sand. At higher flows when wading is not possible, the cross sections are less than optimal, but the Helley-Smith sampler can be used with acceptable results.

Indirect methods can be used to calculate the bedload component of total discharge. The modified Einstein procedure is one such method (Colby and Hembree, 1955). The modified Einstein procedure requires determination of the particle size of the bed material and suspended-sediment and hydraulic properties obtained from a discharge measurement at the site during sample collection. The modified Einstein procedure was developed for alluvial streams, and is not applicable to Eagle Creek which is not a true alluvial stream (the sediment transported in suspension is not the same as the sediment of the streambed); therefore, the bedload discharge calculated by the indirect method may not be accurate.

### Bedload in Eagle Creek at County Trunk G

Bedload transport was calculated for the gaging station at County Trunk G on Eagle Creek for one storm in September 1992 . The Helley-Smith sampler collected 392 grams of material on the first traverse and 552 grams on the second traverse. This corresponds to 12 and 16 ton/d of bedload transport at the site, respectively, for a stream discharge of 90 $ft^3/s$. The instantaneous suspended-sediment discharge at the site at the same time the Helley-Smith sample was collected was approximately 550 ton/d; hence, the bedload portion of the total-sediment discharge was about 2 percent.

### Bedload in Eagle Creek at Shaffner Farm

Bedload transport was calculated for one storm in September 1992 for Eagle Creek at Shaffner Farm. The Shaffner Farm site is upstream from the continuous-streamflow and water-quality monitoring site at County Trunk G. A Helley-Smith sampler was used to collect one data set at the site. The first traverse yielded 87.6 grams of material, and the second traverse yielded 20.2 grams. The corresponding bedload transports are 4.2 and 1.0 ton/d for a stream discharge of 107 $ft^3/s$. The instantaneous suspended-sediment discharge at the site at the same time the Helley-Smith sample was collected was approximately 630 ton/d; hence, bedload discharge was less than 1 percent of the total-sediment discharge.

### Plans for 1993 Water Year

Additional data could be collected to further define the bedload transport for Eagle Creek. Data from the storm in September show that very little sediment load is being transported as bedload. The suspended load at the Eagle Creek sites transports the majority of the total-sediment load. Additional data would be able to define the relation between stream discharge and sediment discharge. If additional data indicate low bedload discharge at other stream discharges, then no additional bedload data need to be collected.

## Metals Data

Metals commonly are found in surface water. At increased concentrations, some metals may be toxic to fish and aquatic macroinvertebrates (Alabaster and Lloyd, 1982).

### Summary of Data

Water-sediment samples were collected and analyzed for total-recoverable copper and zinc (table 1). Hardness also was analyzed because both copper and zinc are more lethal to fish and aquatic macroinvertebrates in hard water as

**Table 1.** Concentrations of total-recoverable copper, zinc, and hardness in water-sediment samples collected at selected monitoring sites, November 1992

[y/m/d, year/month/day; µg/L, micrograms per liter; mg/L, milligrams per liter]

| Monitoring site (fig. 1) | Date (y/m/d) | Time (24-hour) | Total recoverable copper (µg/L) | Total recoverable zinc (µg/L) | Hardness (mg/L) |
|---|---|---|---|---|---|
| Brewery Creek | 92/11/20 | 2145 | 16 | 83 | 230 |
| | 92/11/21 | 0115 | 11 | 87 | 200 |
| | 92/11/21 | 1321 | 4 | 20 | 210 |
| Garfoot Creek | 92/11/20 | 2315 | 24 | 110 | 210 |
| | 92/11/21 | 0115 | 16 | 97 | 180 |
| | 92/11/21 | 0845 | 11 | 57 | 170 |
| Bower Creek | 92/11/09 | 1230 | 6 | 32 | 270 |
| | 92/11/09 | 2130 | 13 | 32 | 270 |
| | 92/11/10 | 0630 | 8 | 17 | 270 |
| | 92/11/12 | 2025 | 4 | 12 | 260 |
| | 92/11/12 | 1740 | 4 | 19 | 280 |
| Otter Creek | 92/11/12 | 1535 | 3 | 5 | 360 |
| | 92/11/12 | 2135 | 3 | 5 | 360 |
| | 92/11/13 | 0335 | 3 | 5 | 360 |
| Rattlesnake Creek | 92/11/20 | 1645 | 13 | 56 | 330 |
| | 92/11/21 | 0015 | 18 | 75 | 290 |
| | 92/11/21 | 0931 | 13 | 70 | 260 |
| Kuenster Creek | 92/11/20 | 2000 | 14 | 71 | 300 |
| | 92/11/20 | 2315 | 19 | 100 | 300 |
| | 92/11/21 | 1040 | 11 | 54 | 270 |

compared to soft water (Alabaster and Lloyd, 1982; EPA, 1986).

Total-recoverable copper is plotted versus hardness in figure 18. Also plotted in this figure is a line defining the acute toxicity and chronic toxicity for copper in both coldwater (maximum stream water temperature typically less than 24.0°C) and warmwater (maximum stream water temperature may be greater than 24.0°C) streams (Wisconsin Department of Natural Resources, 1973). Values above these lines indicate that the concentration of copper in that sample would be acutely and (or) chronically toxic to fish and other aquatic organisms. None of the samples analyzed had concentrations above the acute toxicity concentrations, but one sample (November 20 at 2315) from Garfoot Creek had a concentration (24 μg/L) above the chronic toxicity concentration (table 1, fig. 18).

Total-recoverable zinc is plotted versus hardness in figure 19. None of the samples had concentrations above the acute toxicity concentration. There were two samples that had concentrations above the chronic zinc concentration in coldwater and warmwater streams (fig. 19). These samples were collected from Garfoot Creek on November 20 at 2315 (110 μg/L) and November 21 at 115 (97 μg/L). None of the other samples had concentrations above the chronic toxicity concentrations.

### Plans for 1993 Water Year

Samples could be collected at the Eagle Creek and Joos Valley monitoring sites. These two sites are the only monitoring sites without samples for total-recoverable copper and zinc. These samples could be collected after July 1 during the 1993 water year. Samples also could be collected at the same time at the other monitoring sites to determine if copper and zinc concentrations vary with season.

## Dissolved-Oxygen Data

Continuous dissolved-oxygen concentration data (DO) were collected at nine monitoring sites: Garfoot Creek, Black Earth Creek at County Trunk P, Black Earth Creek at Mills Street, Black Earth Creek at South Valley Road, Eagle Creek, Joos Valley Creek, Otter Creek, Rattlesnake Creek, and Kuenster Creek (fig. 1). The dissolved-oxygen meters collected data during open-water periods, and all meters were removed during the winter.

### Summary of Data, 1990-92 Water Years

Maximum, minimum, and mean dissolved-oxygen concentrations for each of the monitoring sites for the 1990, 1991, and 1992 water years are found in table 2. The maximum dissolved-oxygen concentrations ranged from 12.0 mg/L in 1990 at Eagle Creek to 19.9 mg/L in 1992 at Kuenster Creek. The minimum dissolved-oxygen concentrations ranged from 0 mg/L at Rattlesnake Creek in 1991 to 5.2 mg/L from Joos Valley and Eagle Creeks in 1992.

The State of Wisconsin's water-quality standards require a minimum dissolved-oxygen concentration of 5.0 mg/L for warmwater streams and 6.0 mg/L for coldwater streams (Wisconsin Department of Natural Resources, 1973). The number of violations of these standards and the total number of days minimum dissolved-oxygen concentrations were not met during the 1991 and 1992 water years are listed in table 3. Eagle and Joos Valley Creeks had very few days when the minimum dissolved-oxygen concentrations were less than the State of Wisconsin standard of 6.0 mg/L. Kuenster and Rattlesnake Creeks had the most violations of the warmwater dissolved-oxygen standards (5.0 mg/L) with 31 and 22 percent of the days during the 1992 water year, respectively. For the coldwater streams, the three sites on Black Earth Creek had violations of the standard for 20 percent or more of the days during the 1991 water year. The dissolved-oxygen concentrations improved during the 1992 water year with only about 12 or 13 percent of the days in violation at the three Black Earth Creek monitoring sites.

Even though the minimum dissolved-oxygen concentrations violated the State of Wisconsin standards, the aquatic organisms in the streams may be able to tolerate those violations. The minimum dissolved-oxygen concentrations may have occurred for only short periods of time. A frequency analysis was done to determine the return period on days when the dissolved-oxygen concentrations were less than instantaneous dissolved-oxygen concentrations for 1 hour (figs. 20-21). In the warmwater streams (Rattlesnake and Kuenster Creeks), the dissolved-oxygen concentration decreased to less than 3.0 mg/L for

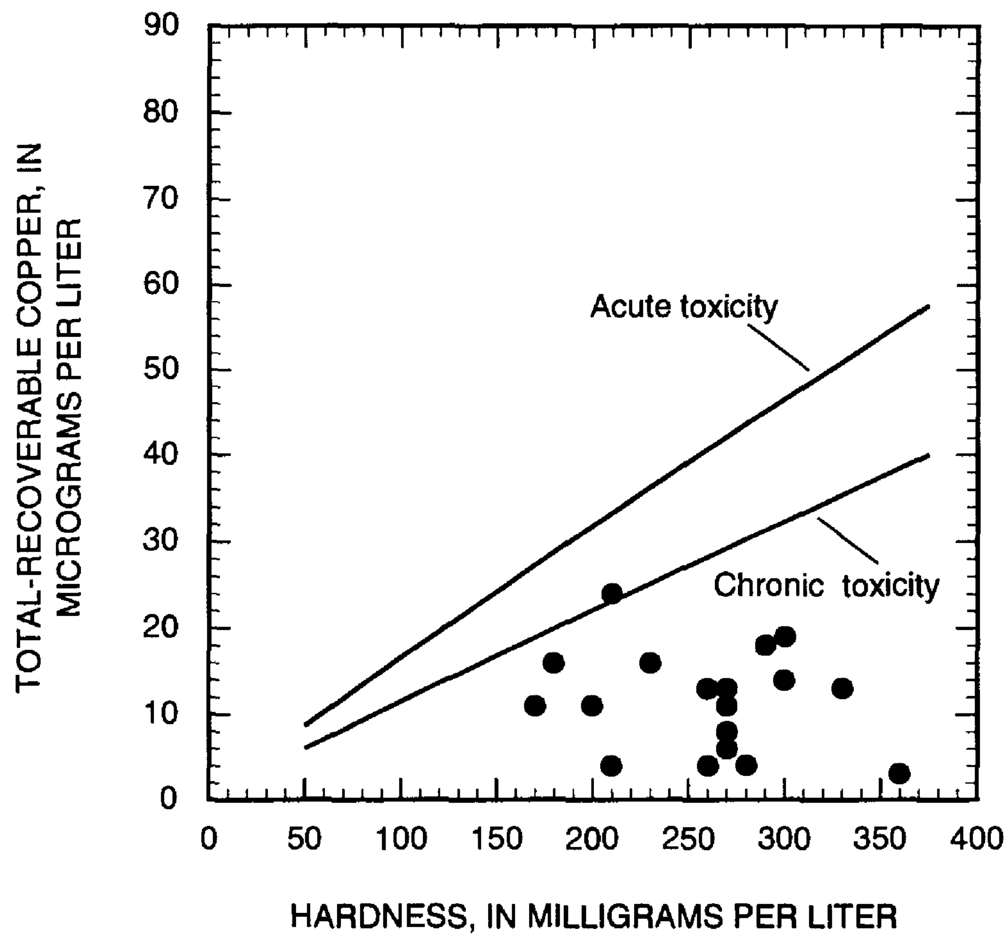


**Figure 18.** Relation of total-recoverable copper and hardness concentrations to acute and chronic toxicity for copper in cold and warmwater streams at selected monitoring sites, November 1992.

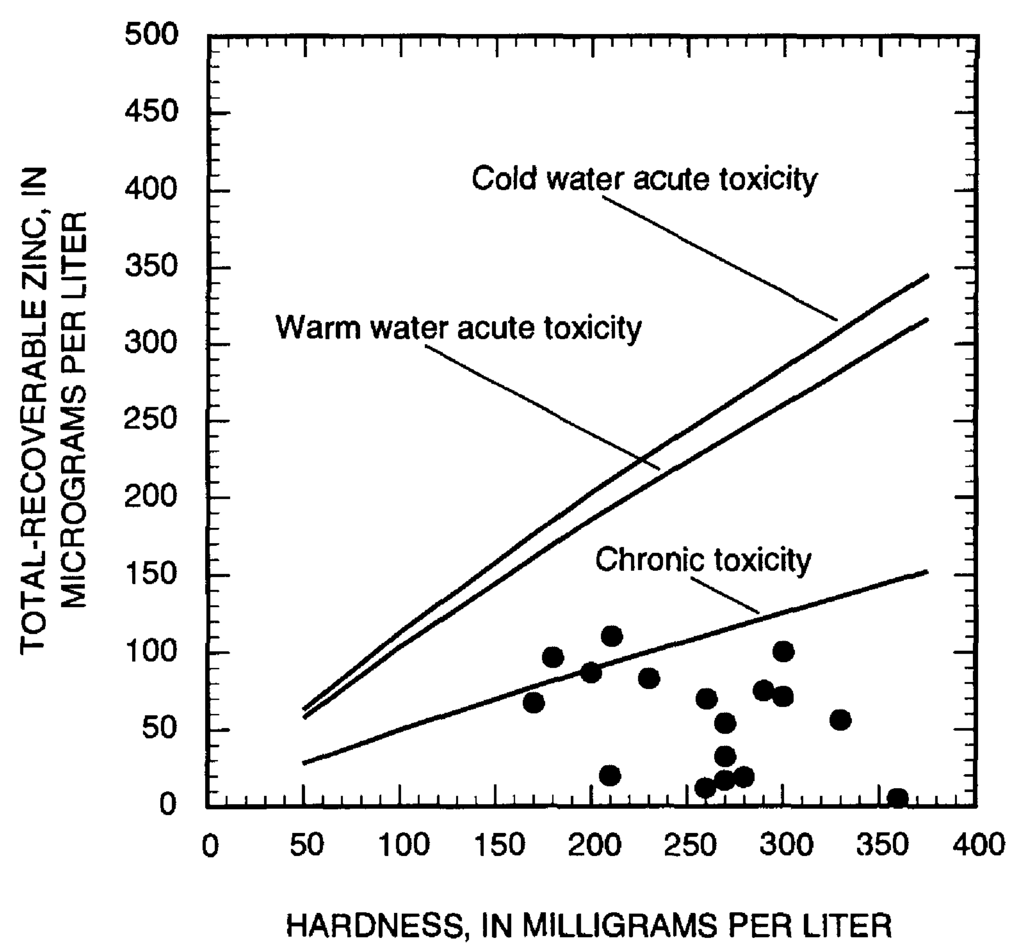


**Figure 19.** Relation of total-recoverable zinc and hardness concentrations to acute and chronic toxicity for zinc in cold and warmwater streams at selected monitoring sites, November 1992.

**Table 2.** Summary of dissolved-oxygen concentration data collected at watershed-management evaluation monitoring sites, 1990-92 water years

[Concentrations are in milligrams per liter (mg/L)]

| Water year | Maximum | Minimum | Mean | Maximum | Minimum | Mean | Maximum | Minimum | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | Garfoot Creek | | | Black Earth Creek at County Trunk P | | | Black Earth Creek at Mills Street | | |
| 1990 | 17.4 | 1.5 | 9.4 | 16.5 | 4.5 | 9.6 | 17.3 | 3.8 | 9.9 |
| 1991 | 14.6 | 4.7 | 9.5 | 15.5 | 3.6 | 9.1 | 16.3 | 3.7 | 9.4 |
| 1992 | 13.7 | 1.3 | 8.8 | 16.4 | 4.9 | 9.4 | 19.0 | 4.1 | 9.4 |
| | Black Earth Creek at South Valley Road | | | Joos Valley Creek | | | Eagle Creek | | |
| 1990 | 17.1 | 4.8 | 9.6 | 13.2 | 5.2 | 9.5 | 12.0 | 5.2 | 8.5 |
| 1991 | 18.3 | 3.9 | 9.9 | 15.8 | 4.3 | 10.0 | 13.7 | 4.3 | 9.5 |
| 1992 | 18.3 | 4.3 | 9.7 | 15.0 | 4.9 | 10.4 | 14.9 | 5.2 | 9.9 |
| | Otter Creek | | | Rattlesnake Creek | | | Kuenster Creek | | |
| 1990 | --- | --- | --- | 16.7 | 0.05 | 9.1 | -- | -- | -- |
| 1991 | 19.1 | 3.2 | 9.0 | 16.8 | 0.00 | 9.6 | -- | -- | -- |
| 1992 | 17.6 | 0.20 | 9.5 | 16.3 | 0.09 | 8.9 | 19.9 | 0.80 | 8.5 |

**Table 3.** Number of days State of Wisconsin dissolved-oxygen standard was violated during 1991 and 1992 water years

[Concentrations are in milligrams per liter (mg/L)]

| Water year | Number of days State of Wisconsin dissolved-oxygen standard was violated | Total number of days dissolved oxygen was monitored | Number of days State of Wisconsin dissolved-oxygen standard was violated | Total number of days dissolved oxygen was monitored | Number of days State of Wisconsin dissolved-oxygen standard was violated | Total number of days dissolved oxygen was monitored |
|---|---|---|---|---|---|---|
| | | | Coldwater streams[1] | | | |
| | Garfoot Creek | | Black Earth Creek at County Trunk P | | Black Earth Creek at Mills Street | |
| 1991 | 9 | 249 | 57 | 244 | 44 | 223 |
| 1992 | 22 | 169 | 18 | 155 | 26 | 188 |
| | Black Earth Creek at South Valley Road | | Eagle Creek | | Joos Valley Creek | |
| 1991 | 49 | 215 | 3 | 186 | 15 | 207 |
| 1992 | 21 | 158 | 3 | 198 | 8 | 189 |
| | | | Warmwater streams[2] | | | |
| | Otter Creek | | Rattlesnake Creek | | Kuenster Creek | |
| 1991 | 25 | 206 | 14 | 211 | --- | --- |
| 1992 | 23 | 206 | 35 | 161 | 53 | 171 |

[1] Coldwater streams typically have maximum stream water temperatures less than 24.0°C.
[2] Warmwater streams typically have maximum stream water temperatures greater than 24.0°C.

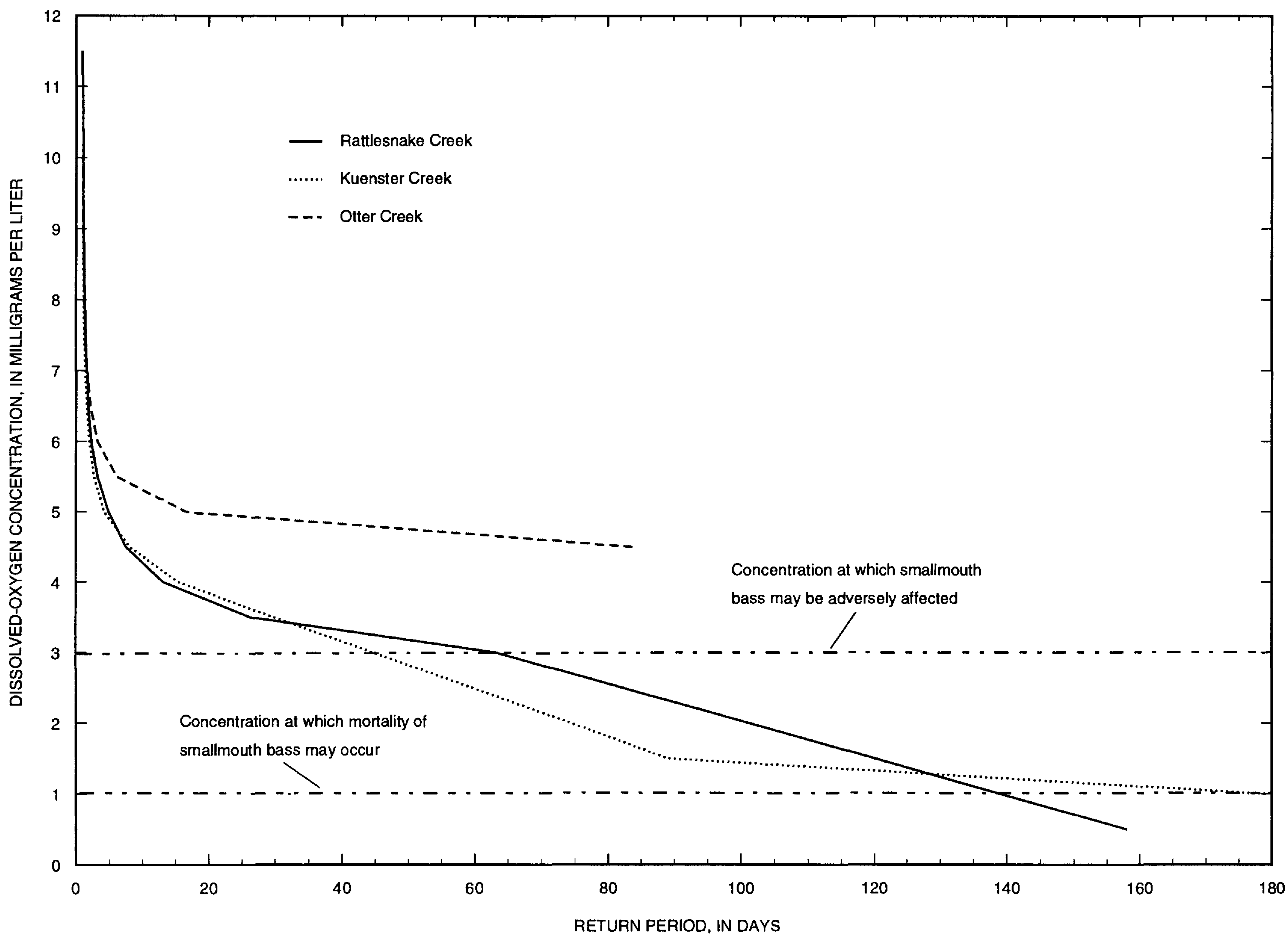


**Figure 20.** Return period in days that the dissolved-oxygen concentration was less than 3.0 milligrams per liter and 1.0 milligram per liter for one continuous hour in warmwater streams.

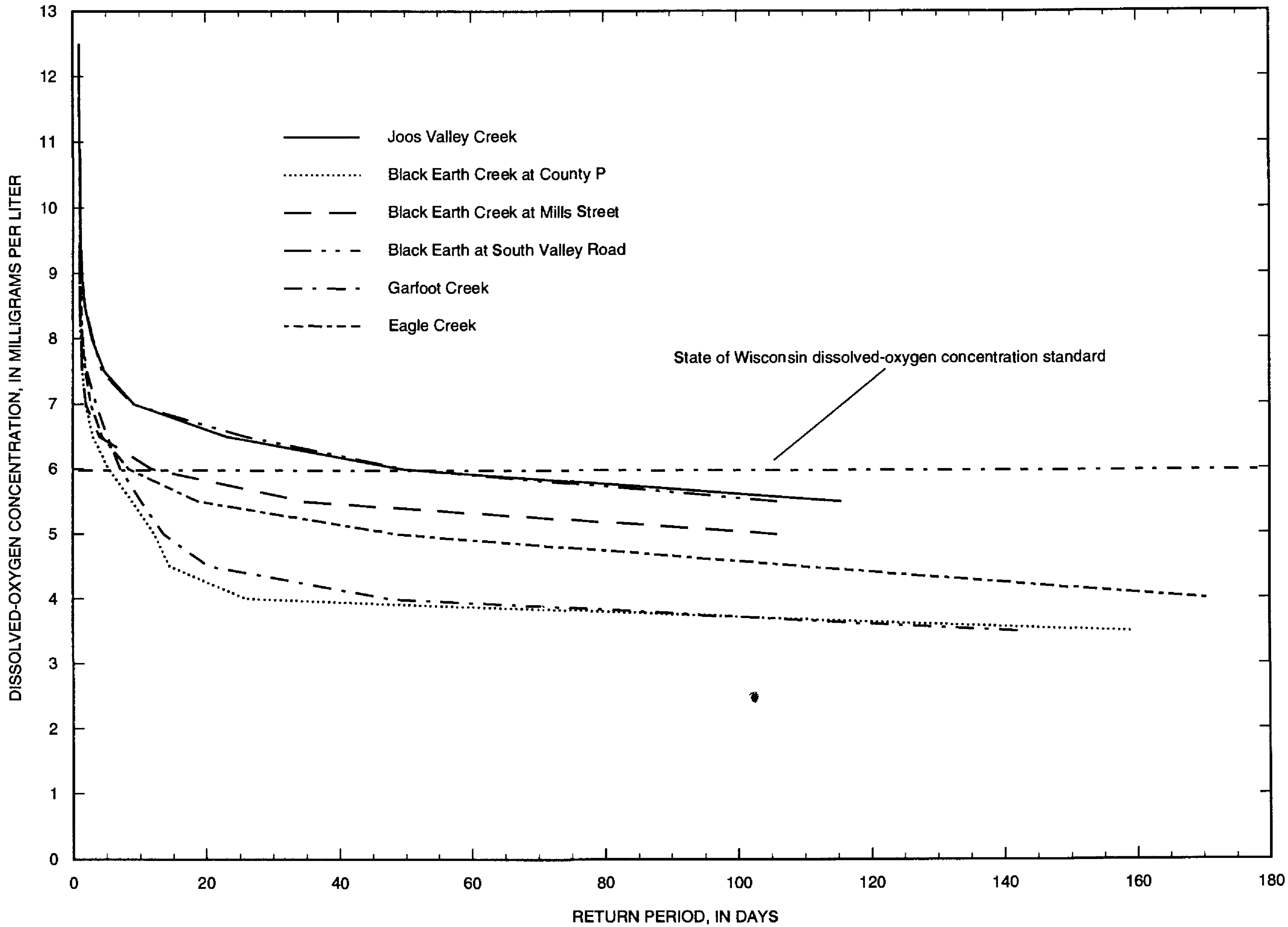


**Figure 21.** Return period in days that the dissolved-oxygen concentration was less than 6.0 milligrams per liter for one continuous hour in coldwater streams.

1 hour once every 45 to 65 days and decreased to less than 1.0 mg/L for 1 hour once every 140 to 180 days (fig. 20). Rattlesnake and Kuenster Creeks are smallmouth bass streams. Smallmouth bass may be adversely affected when dissolved-oxygen concentrations are less than 3 mg/L, and there may be mortality at concentrations less than 1.0 mg/L.

In the coldwater streams, the dissolved-oxygen concentrations were not less than 3.0 mg/L for 1 hour during the 1992 water year (fig. 21). All of the monitoring sites had dissolved-oxygen concentrations less than 6.0 mg/L (State of Wisconsin dissolved-oxygen concentration standard) for 1 hour once every 55-60 days. Concentrations of dissolved-oxygen do not appear to be adversely affecting aquatic organisms, especially fish in the coldwater streams that were monitored.

#### Plans for 1993 Water Year

Dissolved-oxygen monitoring should continue at the warmwater monitoring sites because of the possibility of severe dissolved-oxygen reductions (minimum dissolved-oxygen concentrations less than 1.0 mg/L). Dissolved-oxygen monitoring also should continue at the Black Earth Creek sites and Garfoot Creek monitoring sites. One of the overall objectives of the Black Earth Creek project was to determine if BMP's will improve the dissolved-oxygen regime of the streams and hence be an indicator of improving water quality. At Eagle and Joos Valley Creeks, the dissolved-oxygen monitoring may be discontinued. It is believed that enough pre-BMP data have been collected, and dissolved oxygen could be remonitored once the BMP is completely in place.

### Total-Recoverable Versus Dissolved-Hardness Data

#### Summary of Data

Beginning in November 1992, water-quality samples collected at three urban sites (Nine Springs tributary storm sewer, Monroe Street detention pond, and Menomonee River at Wauwatosa) were analyzed for total-recoverable hardness on whole-water samples with a mild digestion and for dissolved hardness on filtered-water samples. Eight analyses for the Nine Springs tributary storm sewer were available for this report, one for the Monroe Street detention pond, and nine for the Menomonee River at Wauwatosa.

Preliminary results for the two Madison urban monitoring sites (Nine Springs tributary storm sewer and Monroe Street detention pond) show that the dissolved-hardness concentrations were less than the total recoverable hardness concentrations (fig. 22A). These results indicate that calcium and magnesium are contained in the total solids being dissolved by the mild acid digestion. Results for Menomonee River at Wauwatosa, however, show that dissolved hardness is similar to total-recoverable hardness, but the hardness magnitude is generally greater than that at the other two sites (fig. 22B). The total solids, therefore, do not contain a significant amount of calcium and magnesium.

#### Plans for 1993 Water Year

Plans for the 1993 water year are to continue analysis of both total recoverable and dissolved hardness at the urban monitoring sites because sample filtration is being completed for dissolved metals. Further analyses of the hardness values are needed to determine whether the results displayed in figure 22 occur during other seasons. A more detailed analysis of the results will be conducted for the 1993 water year.

## EVALUATION OF SINGLE-STAGE SAMPLERS

Single-stage samplers US-U-59 were installed during the 1992 water year at the Eagle Creek, Joos Valley Creek, Rattlesnake Creek, and Kuenster Creek monitoring sites. The US-U-59 sampler consists of a 725-mL (milliliter) plastic bottle, a 3/16-in. inside-diameter air exhaust, and a 3/16-in. inside-diameter intake nozzle. The purpose of the sampler is to determine if a single-stage sampler would collect a representative water-quality sample. These samplers could be installed at other watershed-management evaluation sites that do not have continuous streamflow-gaging stations and automatic water-quality samplers. These samplers could be a low-cost alternative to installing continuous gaging stations and automatic water-quality samplers. A more detailed description of the sampler and how the sampler operates can be found in Edwards and Glysson (1988).

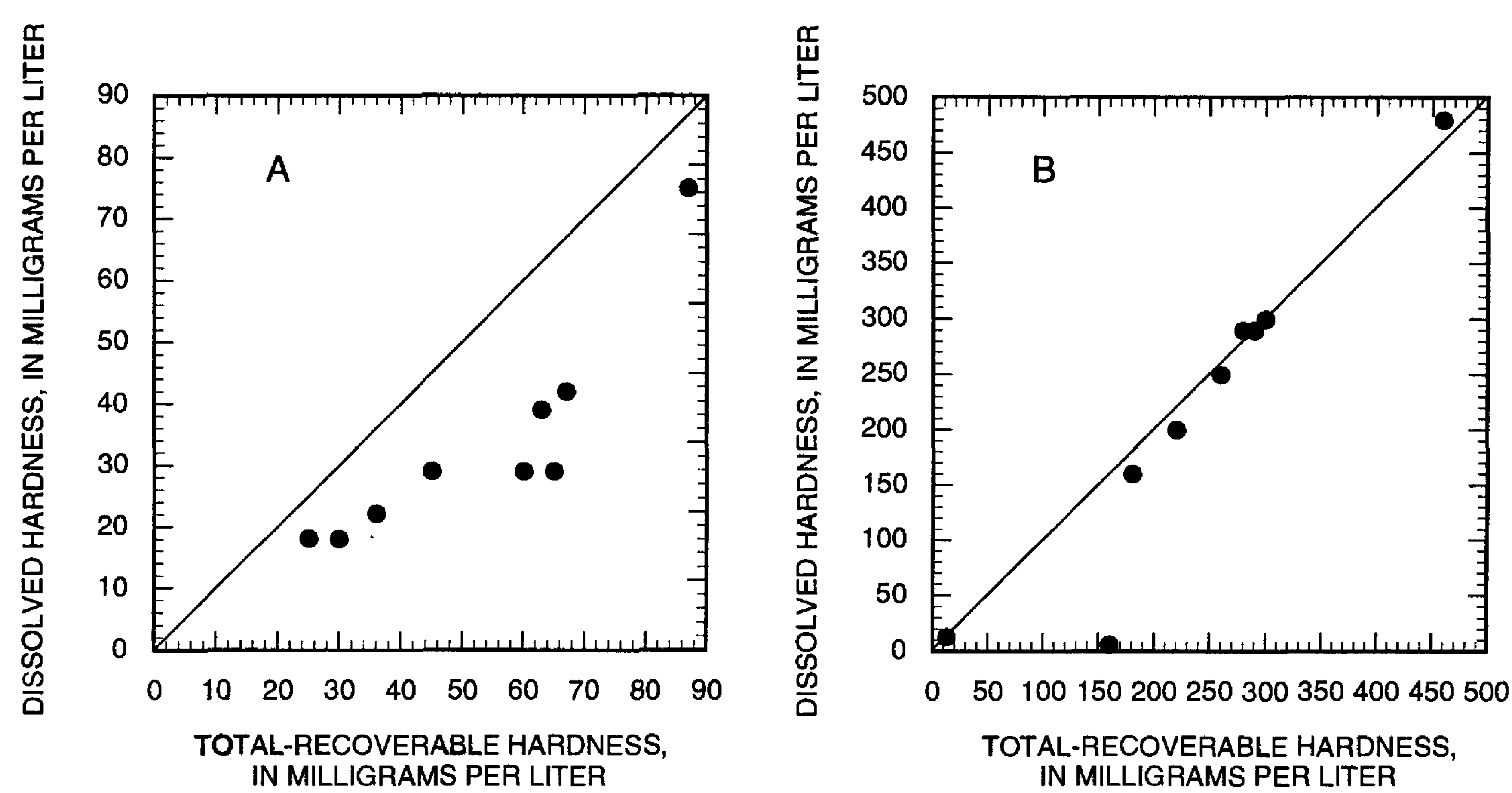


**Figure 22.** Relation of total-recoverable hardness to dissolved hardness for water-quality samples from (A) Nine Springs tributary storm sewer and Monroe Street detention pond and (B) Menomonee River at Wauwatosa urban monitoring sites, 1992 water year.

## Summary of Data

Two single-stage samplers with two sample bottles each sampled two different stream stages at the four monitoring sites. The water-surface stages that the single-stage samplers sampled were set so that the samples collected could be compared to the samples collected by the automatic samplers at the four sites.

One storm in September 1992 at the Eagle Creek and Joos Valley Creek monitoring sites was used to evaluate the single-stage samplers (tables 4-5). The samples from the single-stage samplers at both of the sites had greater concentrations than the concentrations from the samples collected by the automatic samplers. Some of the concentrations in samples from the single-stage samplers were one or two orders of magnitude greater than concentrations in samples collected by the automatic samplers. Some of the differences may be attributable to different sample-collection times and different water-surface stages, resulting in different flow rates and rapidly changing concentrations. The main difference in the concentrations may be attributable to faulty operation of the single-stage samplers. If the sample bottle and sampler have an air leak (for example, the rubber stopper becomes loose), water can continue to enter the sample bottle, and the sampler becomes a sediment trap, resulting in large suspended-solids and total-phosphorus concentrations.

The basis of the analysis is that the automatic sampler collects a representative sample compared with the concentrations of suspended solids and total phosphorus for the full cross-section at a monitoring site. Samples collected by the equal-width-increment (EWI) method (Edwards and Glysson, 1988) were compared with samples collected by the automatic samplers at the same time and water stages. The ratio of the automatic-sampler concentrations and the EWI sample concentrations from the Eagle Creek monitoring site ranged from 0.82 to 1.4; the mean for the 1992 water year was 1.1 for both suspended solids and total phosphorus. The same comparison of samples from the Joos Valley Creek monitoring site was done, and the ratios of concentrations ranged from 0.82 to 1.3, with a mean of 0.97 for the 1992 water year for suspended solids and 1.0 for total phosphorus. Thus, the automatic sampler provided samples representative of the full cross section of conditions at both of these sites.

**Table 4.** Comparison of samples collected by automatic and single-stage samplers at the Eagle Creek monitoring site on September 16, 1992

[Concentrations are in milligrams per liter (mg/L); ---, no data]

| Type of sample | Time of sample (24-hour) | Gage height of sample above an arbitrary datum (feet) | Suspended-solids concentration | Total-phosphorus concentration |
|---|---|---|---|---|
| Automatic sampler | 0330 | 2.94 | 1,240 | 1.5 |
| Single-stage sampler | 0425 | 3.52 | 935 | 1.5 |
| Automatic sampler | 0440 | 4.21 | 2,710 | 2.2 |
| Single-stage sampler | 0450 | 4.52 | 74,700 | 4.3 |
| Automatic sampler | 0455 | 4.92 | 3,170 | 3.2 |
| Single-stage sampler | 0505 | 5.43 | --- | 2.5 |
| Automatic sampler | 0510 | 5.74 | 4,280 | 3.9 |
| Single-stage sampler | 0525 | 6.48 | 3,900 | 28 |

**Table 5.** Comparison of samples collected by automatic and single-stage samplers at the Joos Valley Creek monitoring site on September 16, 1992

[Concentrations are in milligrams per liter (mg/L)]

| Type of sample | Time of sample (24-hour) | Gage height of sample above an arbitrary datum (feet) | Suspended-solids concentration | Total-phosphorus concentration |
|---|---|---|---|---|
| Automatic sampler | 0235 | 2.20 | 332 | 1.0 |
| Single-stage sampler | 0405 | 3.03 | 14,000 | 3.8 |
| Automatic sampler | 0415 | 3.32 | 3,070 | 3.3 |
| Single-stage sampler | 0425 | 4.03 | 10,200 | 220 |
| Automatic sampler | 0430 | 4.33 | 6,110 | 5.3 |

## Plans for 1993 Water Year

The single-stage samplers need more evaluation before they can be installed at more sites with any certainty of collecting representative samples. Samples will continue to be collected at the four selected monitoring sites and analyzed for suspended solids and total phosphorus. The samplers will be modified to minimize any problems caused by air leaks and flow through. More samples will be collected, and the data will be analyzed before the single-stage samplers are placed at additional sites.

# MAPPING BEST-MANAGEMENT PLAN LAND USE

Eligible and installed BMP's along with land use and any other changing watershed characteristics, need to be mapped for each watershed throughout the course of water-quality sampling. Mapping this information, along with results from water-quality sampling, will help to determine the cause of changes in water quality and the extent of implemented BMP's needed to achieve specified levels of water-quality improvement.

## Development of Geographic-Information-System Data Base

Mapping material for each project is being developed for test (priority watersheds) and reference sites (basins outside priority watersheds) as follows:

A. Base-map data are entered into ARC/INFO[3] software using available geographic-information-system (GIS) data from other sources or by digitizing the mapped data directly from U.S. Geological Survey 7.5-minute quadrangles. The base maps include a basin outline, the drainage system, major roads, and location of stream and rain gages.

B. Information for locating and identifying eligible and installed BMP's, land uses, and other changing watershed characteristics is obtained from the county Land Conservation Department (LCD) for each individual site.

C. The eligible and installed BMP's, land uses, and other changing watershed characteristics then are digitized onto the base maps.

D. The maps are updated each year to incorporate any changes in any of the mapped information.

Currently, the base maps and a preliminary account of eligible and installed BMP's have been compiled in ARC/INFO format for the eight rural-watershed monitoring sites. Land-use and gully information are still needed for these sites, and all information will be needed for any new monitoring sites. No information currently is compiled for the urban sites.

## Plans for 1993 Water Year

A meeting will be arranged with personnel at each appropriate LCD to accurately determine locations and types of BMP's, land-use information, gully locations and sizes, and other changing watershed characteristics in the basin. Complete maps will be constructed for the rural reference sites and all urban sites. The rural test sites will be updated to include land-use and gully information (if gully information is available).

# QUALITY CONTROL AND QUALITY ASSURANCE

## Data Collection

Field- and splitter-blank samples were collected to determine possible sources of contamination in samples collected during storms. The procedures used to collect field- and splitter-blank samples closely resembled the procedures used to collect and split storm samples for analysis by the Wisconsin State Laboratory of Hygiene (WSLOH).

Field-blank samples were collected by a standard protocol at each site. Milli-Q water was

[3]The use of ARC/INFO and other trade names is for identification puposes only and does not constitute endorsement by the U.S. Geological Survey.

pumped through the automatic sampler's intake line and pumping mechanism into sample bottles. Then the water was subsampled into additional bottles by using a small-volume sample splitter for rural sites and a churn splitter for urban sites. The samples were sent to the WSLOH for analysis. The splitter-blank samples followed essentially the same protocol, with Milli-Q water processed directly through the sample splitter. Complete procedures of collection of field- and splitter-blank samples can be found in Appendix 2.

The blank samples for rural monitoring sites were analyzed for the following constituents: biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia nitrogen ($NH_3$-N), nitrite plus nitrate as nitrogen ($NO_2$+$NO_3$-N), total phosphorus (TP), total solids (TS), total volatile solids (TVS), suspended solids (SS), volatile suspended solids (VSS), and the metals calcium (Ca), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), sodium (Na), and zinc (Zn).

The frequency of contamination of the blank samples is defined as the number of samples at or above the limit of quantification (LOQ) divided by the total number of samples and is a measure of contamination. The limit of quantification is the concentration of a substance above which quantitative results may be obtained with a specific degree of confidence (usually the 99-percent confidence interval).

### Splitter-Blank Samples

Five splitter-blank samples were collected during the 1992 water year. Two of the samples analyzed had concentrations at or near the LOQ for $NO_2$ + $NO_3$-N, and VSS (table 6). One of the samples had concentrations at or near the LOQ for BOD, $NH_3$-N, and SS (table 6).

### Field-Blank Samples

A total of 50 field-blank samples from rural sites were analyzed for non-metal constituents during the 1992 water year. All constituents except COD had concentrations greater than the LOQ (table 7). BOD, $NO_2$+$NO_3$-N, SS, and VSS had measurable concentrations at or greater than the LOQ more than 50 percent of the time. These are the same constituents that had concentrations above the LOQ in the splitter-blank samples and therefore, may indicate contamination in the splitter procedure. The concentrations in the field-blank samples were generally greater than the concentrations in the splitter-blank samples, although this would suggest that a part of the contamination was contributed from both the field sampling and splitter procedures (table 8). Maximum concentrations for all constituents that exhibited at least one contaminated sample are listed in table 8. Only five splitter-blank samples were collected, and more should be collected to determine whether contamination originates in either the field-blank samples, splitter-blank samples, or both. Iron was the only metal constituent that had blank concentrations greater than the LOQ for nearly 50 percent of the field-blank samples (table 9). Because no splitter-blank samples were analyzed for metals, it is difficult to determine where in the sample processing the contamination of the metal samples occurred.

## Relative Importance of Contamination

It is important to note whether the observed field-blank contamination is indeed significant when compared to storm samples. Concentration ranges of field-blank samples are compared with the maximum stream concentrations from all rural monitoring sites in figure 23. Stream-sample concentrations generally ranged more than two orders of magnitude greater than the field-blank samples, although it may be more meaningful to compare the sample concentrations collected only during high flows with the field-blank samples. Plotted in figure 24 is the relation of suspended-solids concentration and streamflow at Brewery Creek. Also plotted in figure 24 is the range of concentrations of the field-blank samples. The range of suspended-solids concentrations overlaps the concentration range of the field-blank samples for only three samples, and this occurs during low flows.

Whether the current frequency of contamination could be lowered is dependent on the source of the contamination. If the source of contamination is simply sample handling, this could be corrected. If the sample contamination is a result of systematic contamination inherent to the sam-

**Table 6.** Number of splitter-blank samples at or near the limit of quantification (LOQ), 1992 water year

| Constituent | Number of splitter-blank samples at or near the limit of quantification |
|---|---|
| Biochemical oxygen demand (BOD) | 1 |
| Chemical oxygen demand (COD) | 0 |
| Ammonia nitrogen ($NH_3$-N) | 1 |
| Nitrite plus nitrate nitrogen ($NO_2$+$NO_3$-N) | 2 |
| Total phosphorus | 0 |
| Total solids | 0 |
| Total volatile solids | 0 |
| Suspended solids | 1 |
| Volatile suspended solids | 2 |

pling protocol (for example, sediment in sample line), then the contamination must be handled as a correction term.

## Plans for 1993 Water Year

Some degree of contamination was found in both splitter- and field-blank samples. The degree of contamination appears to be tolerable with respect to storm sampling. If field-blank samples continue to be systematically contaminated, a correction may be applied. If the concentrations of low-flow samples are critical to this study, then a companion blank method could be developed and used in conjunction with the low-flow-sampling program.

Additional blank samples need to be collected during the 1993 water year and should include splitter-blank samples analyzed for metal constituents. Duplicate stream samples collected during both high and low flows need to be considered.

## Effects of Holding Time on Bacteria Samples

The effects of holding time on survival of fecal-coliform (FC) colonies were studied because field personnel sometimes found it difficult to get samples to the Wisconsin State Laboratory of Hygiene within the required 24-hour holding time.

### Data Collection

Samples were collected at Brewery, Garfoot, Bower, and Otter Creeks during storms in November and December of 1992. All samples (a total of 15) were received at the WSLOH within 24 hours of collection. Sample plates were set up for four different holding times: 0, 24, 48, and 72 hours, with 0 hours as the time the sample is received in the laboratory. Samples were set up in either duplicate or triplicate. Sample bottles were refrigerated between setup times. Each plate count was actually obtained by establishing a three-to-four serial dilution sequence and choosing the plate with the optimal colony count (20-60 colonies per plate).

**Table 7.** Number of field-blank samples with concentrations greater than the limit of quantification (LOQ) and number of field-blank samples collected, 1992 water year

| Constituent | Brewery Creek | Garfoot Creek | Eagle Creek | Joos Valley Creek | Bower Creek | Otter Creek | Rattlesnake Creek | Kuenster Creek |
|---|---|---|---|---|---|---|---|---|
| Biochemical oxygen demand (BOD) | 4/6 | 4/7 | 1/4 | 0/4 | 1/2[1] | 4/8 | 5/6 | 4/5 |
| Chemical oxygen demand (COD) | 0/3 | 0/3 | 0/3 | 0/3 | 0/0 | 0/3 | 0/3 | 0/3 |
| Ammonia nitrogen ($NH_3$-N) | 2/7 | 5/8 | 1/5 | 2/5 | 2/3 | 3/9 | 4/7 | 0/6 |
| Nitrite plus nitrate nitrogen ($NO_2$+$NO_3$-N) | 6/7 | 7/8 | 1/5 | 1/5 | 1/3 | 6/9 | 7/7 | 5/6 |
| Total phosphorus | 0/7 | 1/8 | 1/5 | 0/5 | 0/3 | 0/9 | 4/7 | 3/6 |
| Total solids | 4/7 | 2/8 | 1/5 | 1/5 | 0/3 | 3/9 | 2/7 | 5/6 |
| Total volatile solids | 1/7 | 0/8 | 0/5 | 0/5 | 0/3 | 3/9 | 2/7 | 0/6 |
| Suspended solids | 5/7 | 5/8 | 2/5 | 4/5 | 1/3 | 1/9 | 4/7 | 6/6 |
| Volatile suspended solids | 6/7 | 6/8 | 2/5 | 4/5 | 0/3 | 4/9 | 2/7 | 3/6 |

[1] a/b, where a=number of blank samples with concentration exceeding LOQ, and b=number of field-blank samples collected.

**Table 8.** Limits of quantification for selected constituents and maximum concentrations of all splitter-blank and field-blank samples, 1992 water year

[Concentrations are in milligrams per liter (mg/L); ND, not detected; ---, no samples analyzed]

| Constituent | Limit of quantification for each constituent | Maximum concentration of all splitter-blank samples | Maximum concentration of all field-blank samples |
|---|---|---|---|
| Biochemical oxygen demand (BOD) | 1 | 1 | 2.5 |
| Ammonia nitrogen ($NH_3$-N) | 0.005 | 0.007 | 0.04 |
| Nitrite plus nitrate nitrogen ($NO_2$+$NO_3$) | .007 | .009 | .062 |
| Total phosphorus | .02 | ND | .09 |
| Total solids | 10 | ND | 36 |
| Total volatile solids | 10 | ND | 30 |
| Suspended solids | 2 | 4 | 19 |
| Volatile suspended solids | 2 | 2 | 5 |
| Calcium | 1 | --- | 1.1 |
| Copper | .02 | --- | .034 |
| Iron | .05 | --- | .24 |
| Zinc | .010 | --- | .075 |

**Table 9.** Number of field-blank samples with concentrations greater than the limit of quantification (LOQ) for selected metals and number of field-blank samples collected, 1992 water year

| Constituent | Brewery Creek | Garfoot Creek | Eagle Creek | Joos Valley Creek | Bower Creek | Otter Creek | Rattlesnake Creek | Kuenster Creek |
|---|---|---|---|---|---|---|---|---|
| Barium | 0/2 | 0/2 | 0/2 | 0/2 | 0/0[1] | 0/2 | 0/2 | 0/2 |
| Calcium | 0/2 | 0/2 | 0/2 | 0/0 | 0/0 | 1/2 | 1/3 | 1/2 |
| Copper | 1/2 | 0/2 | 0/2 | 0/2 | 0/0 | 0/2 | 0/3 | 0/2 |
| Iron | 1/2 | 2/2 | 0/2 | 0/2 | 0/0 | 0/2 | 3/3 | 2/2 |
| Magnesium | 0/2 | 0/2 | 0/2 | 0/2 | 0/0 | 0/2 | 0/3 | 0/2 |
| Manganese | 0/2 | 0/2 | 0/2 | 0/2 | 0/0 | 0/2 | 0/3 | 0/2 |
| Sodium | 0/2 | 0/2 | 0/2 | 0/2 | 0/0 | 0/2 | 0/3 | 0/2 |
| Zinc | 1/2 | 0/2 | 0/2 | 0/2 | 0/0 | 1/2 | 0/3 | 0/2 |

[1] a/b, where a=number of blank samples with concentration exceeding LOQ, and b=number of field-blank samples collected.

## Summary of Data

Fecal-coliform counts ranged between 10 and 310,000 per 100 ml (milliliters). Examples of sample counts are illustrated in figure 25 where the maximum, minimum, and mean counts are plotted. A large range of values occurred within duplicate and triplicate samples as well as over time. The median percentage difference between duplicate and triplicate samples was 17 percent although 4 out of the total 60 duplicate and triplicate samples had differences greater than 100 percent.

A decrease in FC counts generally occurred over the duration of the 4-day analyses. Plotted in figure 26 are the duplicate and triplicate colony counts mean over time for all samples. Linear regression models of the log-concentration values (dependant variable) with respect to time (independent variable) were calculated for all samples. Negative slopes were found for 14 of the 15 samples. Slopes varied from +0.5 to -38.4 percent gain/loss per day, with a median slope of -8.5 percent per day.

A t-test was applied to the data to examine whether or not significant differences in FC counts exist with respect to holding times. Because the t-test only compares two treatments, the test was conducted three times (0 versus 24-hour holding time, 0 versus 48-hour holding time, and 0 versus 72-hour holding time). Setting the level of significance at $p < 0.05$ and assuming equal variances, 27 percent (all from Bower and Otter Creeks) of the samples demonstrated a significant difference in colony count over the first 24 hours, 40 percent over 48 hours, and 47 percent over 72 hours. All samples that exhibited a significant change in colony count were because of a decrease in colony count of the sample.

The t-test was more robust at detecting significant effects of holding time for the longer holding periods. More importantly, the fact that 27 percent of the samples exhibited a significant decrease over the first 24-hour period would suggest some merit for samples being transported to the laboratory within 24 hours of collection.

## Plans for 1993 Water Year

A review of the fecal-coliform data in the context of its intended use will be made during the 1993 water year. If the data are used for monitoring water-quality violations, then those results generally exceed the State of Wisconsin's recommendation of the geometric mean of five samples

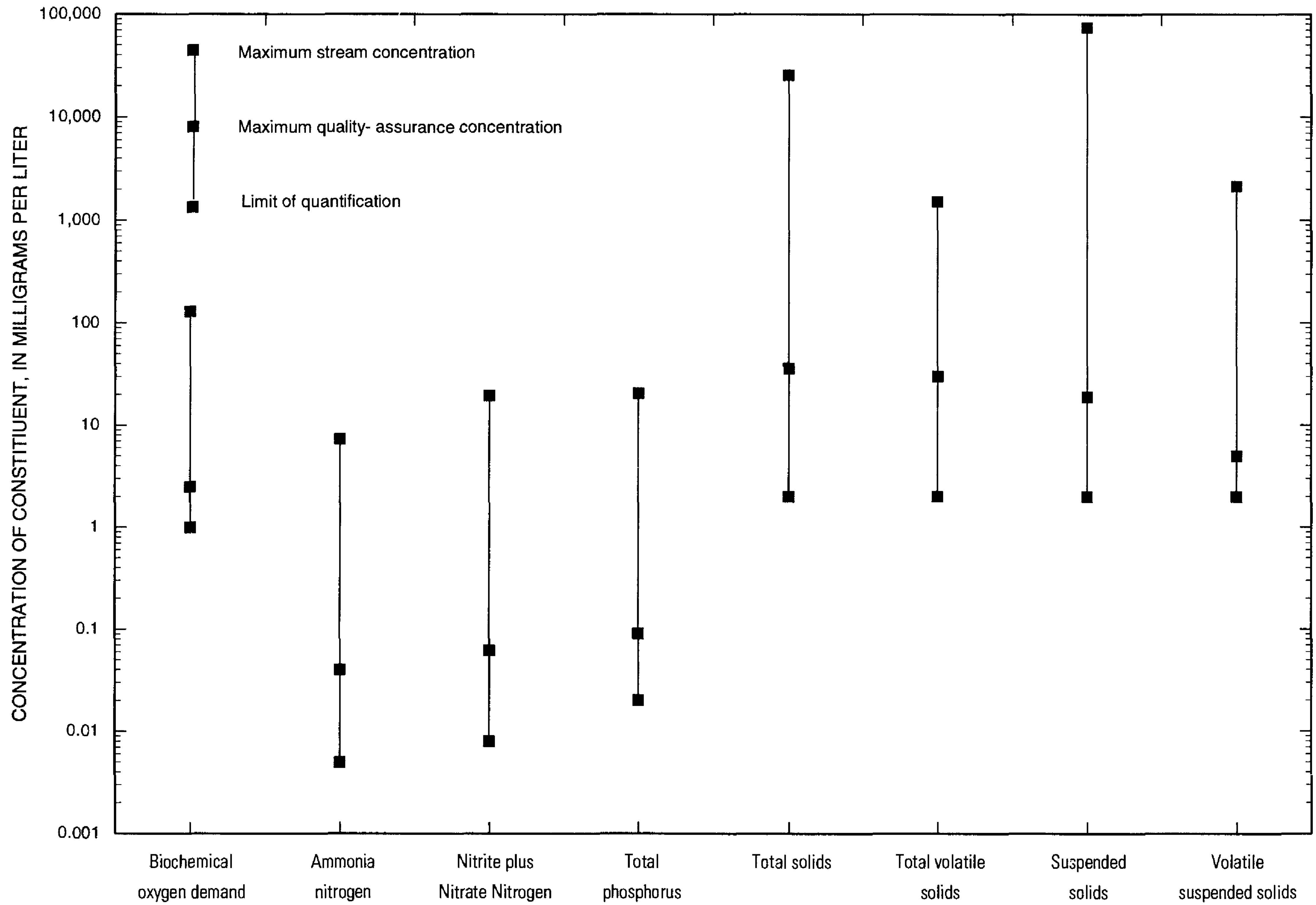


**Figure 23.** Ranges of concentration of field-blank samples, maximum stream concentrations, and concentrations of the limit of quantification.

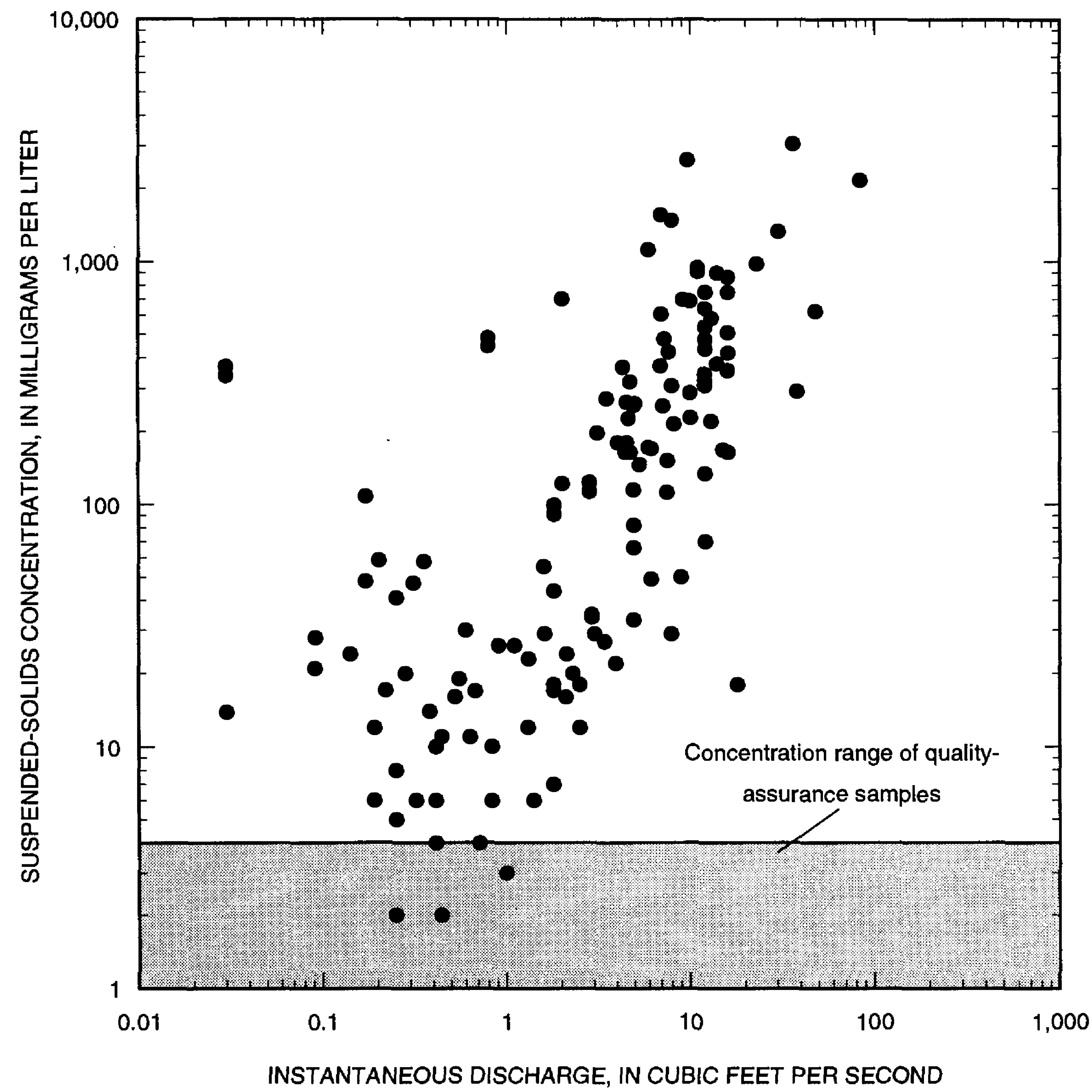


**Figure 24.** Suspended-solids concentrations and streamflow at Brewery Creek for the 1992 water year.

not to exceed 200 colonies per 100 mL or no single sample exceeding 1,000 colonies per 100 mL. For example, during the 1992 water year, 13 of the 15 samples were in violation of the State standard, with most of the samples exceeding the standard by orders of magnitude. Therefore, from a statistical standpoint, even though there is a significant loss of FC bacteria when holding-time limits are exceeded, from a public-health standpoint, this loss may not be an issue.

If the ultimate goal of the collection of these bacteria samples is to demonstrate an improvement or the detection of trends in bacteria counts of the pre-BMP data versus the post-BMP data, then the colony-count loss of 8 percent per day must be viewed in the context of the method or algorithm used for trend detection. To date, no method has been chosen for the trend analysis. Depending on the method used, the holding-time error will only be one of a number of error terms (for example, analytical, sampling, or flow-measurement errors), in addition to the natural variability, that may contribute to the total variability found in the data. For example, if the total variability requires that a 100-percent decrease in colony counts be needed to detect a significant change, then the 8-percent holding-time loss may be tolerable.

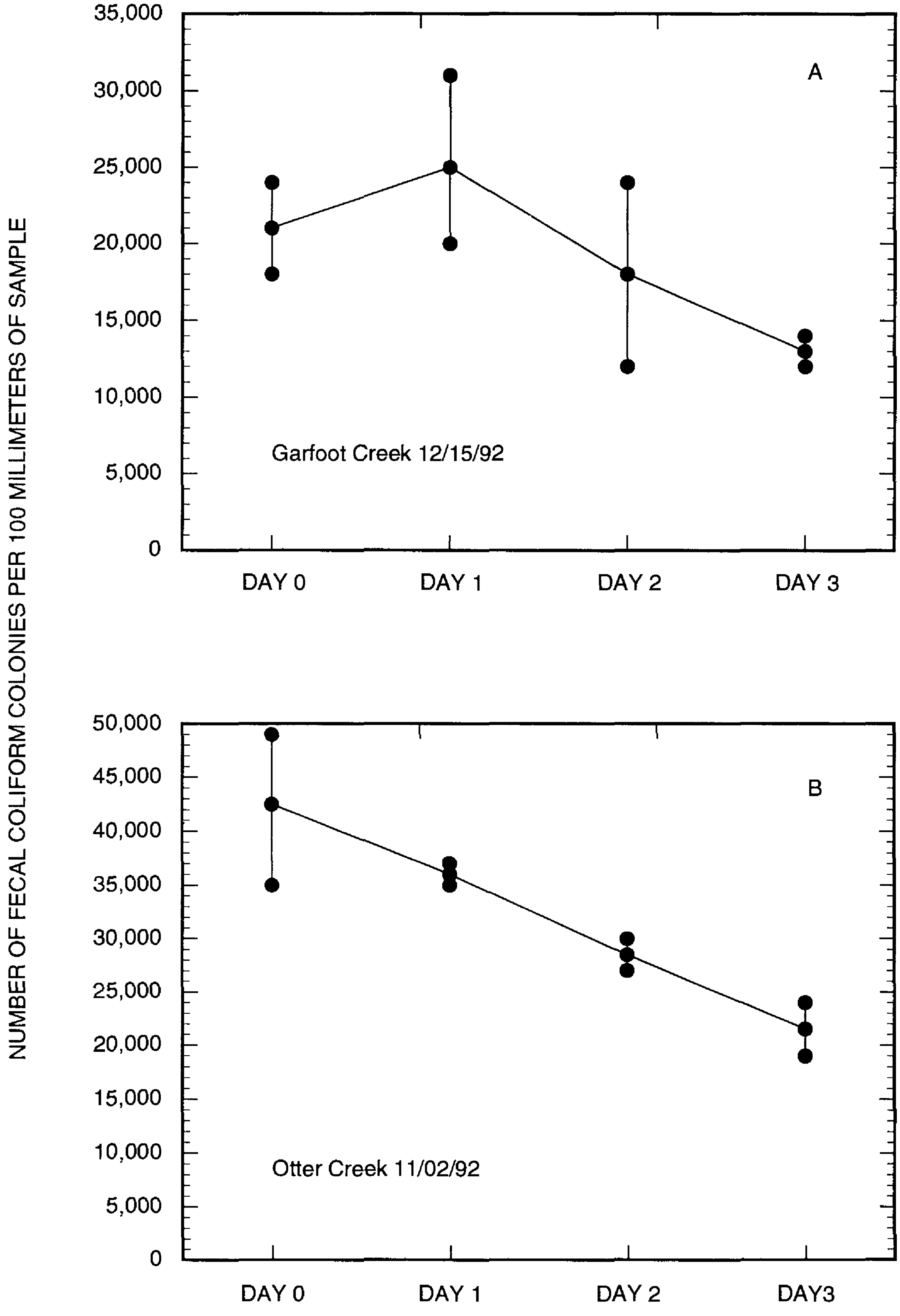


**Figure 25.** Number of fecal-coliform colonies in samples from (A) Garfoot and (B) Otter Creeks, November and December 1992.

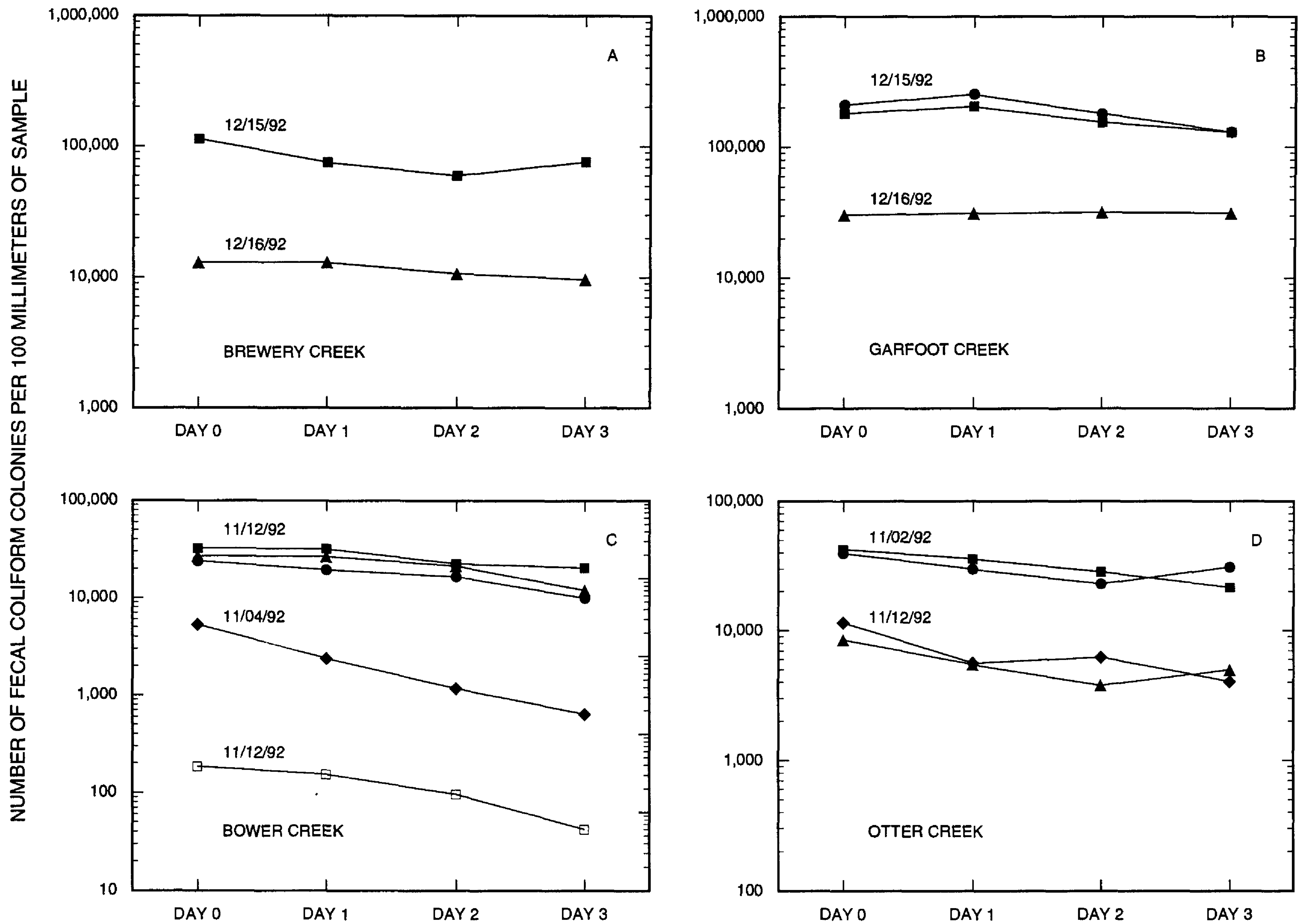


**Figure 26.** Replicate mean fecal-coliform colony counts for different holding times of samples from (A) Brewery Creek, (B) Garfoot Creek, (C) Bower Creek and (D) Otter Creek, November and December 1992.

Although the method for bacteria trend detection has yet to be determined, a first approach might simply be to examine the change in mean colony counts before and after implementation of BMP's. By using a t-test, one can determine the change in mean colony counts required to detect a significant change. These mean colony counts have been calculated for the four selected monitoring sites discussed previously with all existing FC data to date (table 10). Note that all four sites would require a substantial decrease (more than 50 percent) in colony counts to detect a significant change given the natural variability currently observed at these sites. This analysis would suggest that an 8-percent holding-time error would not be of primary importance when examining trends using this method.

Nonetheless, there was significant die off in samples collected and analyzed for fecal coliform if the samples were held for more than 24 hours. Twenty-seven percent (4/15) showed a significant loss after 24 hours, with greater losses observed after 48 and 72 hours. The median daily loss was 8.5 percent. Whether the magnitude of this loss makes the results less useful from an interpretive standpoint (trends analysis) has yet to be determined. Additional analyses need to be performed on samples from other sites and at different seasons to determine what effect these factors have on colony die off. If precise enumeration of FC colonies is critical to this study, alternative methods that allow for a 72-hour holding period are available (American Public Health Association, 1989), and should be considered. Until these issues are resolved, it is suggested that field personnel continue to transport FC samples within 24 hours.

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**Table 10.** Required decline in geometric mean fecal-coliform concentrations in samples collected from four monitoring sites during November and December 1992 determined by a t-test

[mL, milliliters; $p< 0.05$]

| Site name (fig. 1) | Number of observations | Geometric mean of fecal-coliform counts per 100 mL | Required change of fecal-coliform counts per 100 mL | Percent change |
|---|---|---|---|---|
| Brewery Creek | 20 | 6,198 | 4,453 | 72 |
| Garfoot Creek | 19 | 12,870 | 8,746 | 68 |
| Bower Creek | 13 | 328 | 247 | 81 |
| Otter Creek | 25 | 736 | 419 | 57 |

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# APPENDIXES 1-2

**Appendix 1.** Storm-load data, 1985-92 water years

[lb, pound; Mcf, million cubic feet; in., inch; s/m, smowmelt; --, no data]

| Start date (year/month/day) | Start time (24-hour) | End date (year/month/day) | End time (24-hour) | Suspended-solids load (tons) | Total-phosphorus load (lb) | Streamflow volume (Mcf) | Precipitation (in.) |
|---|---|---|---|---|---|---|---|
| | | | Brewery Creek | | | | |
| 84/10/18 | 1745 | 84/10/19 | 1700 | 35 | 140 | 1.5 | 2.78 |
| 84/11/01 | 0015 | 84/11/01 | 2245 | 7.4 | 28 | 0.48 | 0.93 |
| 84/12/28 | 0045 | 84/12/28 | 2145 | 22 | 180 | 1.3 | s/m |
| 85/02/21 | 0430 | 85/02/25 | 0700 | 120 | 1,500 | 9.6 | s/m |
| 85/07/24 | 1930 | 85/07/26 | 2230 | 500 | 2,000 | 14 | 6.85 |
| 85/08/12 | 2145 | 85/08/13 | 1800 | 1.2 | 13 | .25 | .94 |
| 85/08/25 | 0200 | 85/08/26 | 1000 | 2.6 | -- | .53 | 1.70 |
| 85/09/04 | 2330 | 85/09/05 | 2115 | 2.3 | 38 | .56 | 1.53 |
| 85/09/09 | 0015 | 85/09/09 | 2345 | 25 | 130 | 1.3 | 1.40 |
| 85/10/12 | 0315 | 85/10/13 | 0200 | 3.3 | -- | .76 | .80 |
| 85/10/23 | 1515 | 85/10/24 | 1400 | 2.3 | 20 | .39 | .59 |
| 85/10/31 | 1800 | 85/11/02 | 1100 | 20 | 190 | 2.4 | 2.77 |
| 85/11/17 | 2245 | 85/11/19 | 0800 | 3.5 | 55 | .85 | .63 |
| 86/03/09 | 2200 | 86/03/10 | 2300 | 8.1 | -- | .67 | s/m |
| 86/03/17 | 1200 | 86/03/20 | 0100 | 60 | 330 | 3.1 | s/m |
| 86/05/15 | 1500 | 86/05/16 | 0200 | 1.2 | 18 | .28 | .58 |
| 86/05/17 | 0100 | 86/05/18 | 0600 | 8.1 | 78 | .96 | 1.09 |
| 86/06/22 | 0100 | 86/06/22 | 2300 | 1.1 | 24 | .77 | 1.16 |
| 89/10/05 | 0745 | 89/10/05 | 1500 | .040 | 1.1 | .020 | -- |
| 90/03/08 | 0930 | 90/03/09 | 0500 | 590 | 750 | 1.8 | .67 |
| 90/03/11 | 0600 | 90/03/12 | 0200 | 160 | 820 | 2.5 | .50 |
| 90/03/13 | 1815 | 90/03/14 | 0600 | 48 | 250 | .89 | .84 |
| 90/06/02 | 1315 | 90/06/03 | 1000 | 35 | 140 | .59 | 1.54 |
| 90/06/28 | 2330 | 90/06/29 | 1900 | 250 | 1,100 | 4.1 | 2.14 |
| 91/04/12 | 1230 | 91/04/13 | 1230 | 8.3 | 85 | .75 | 1.17 |
| 91/04/14 | 0600 | 91/04/14 | 2400 | 4.1 | 54 | .61 | .80 |
| 91/04/28 | 2045 | 91/04/29 | 1100 | 7.1 | 47 | .29 | 1.24 |
| 91/05/05 | 0900 | 91/05/05 | 2400 | 3.4 | 25 | .24 | 1.08 |
| 91/07/01 | 1415 | 91/07/02 | 1500 | 1.7 | 27 | .34 | 1.29 |

**Appendix 1.** Storm-load data, 1985-92 water years--Continued

| Start date (year/month/day) | Start time (24-hour) | End date (year/month/day) | End time (24-hour) | Suspended-solids load (tons) | Total-phosphorus load (lb) | Streamflow volume (Mcf) | Precipitation (in.) |
|---|---|---|---|---|---|---|---|
| | | | Brewery Creek--Continued | | | | |
| 91/07/07 | 1430 | 91/07/08 | 1315 | 3.1 | 56 | .52 | 1.11 |
| 91/08/08 | 0130 | 91/08/08 | 0900 | .97 | 9.9 | .14 | 2.24 |
| 91/10/24 | 2000 | 91/10/26 | 0100 | 120 | 740 | 2.9 | 3.55 |
| 91/11/01 | 0030 | 91/11/02 | 1330 | 5.4 | 90 | .88 | .81 |
| 91/11/29 | 1900 | 91/11/30 | 1800 | 2.3 | 32 | .44 | .61 |
| 92/02/27 | 1030 | 92/02/28 | 0500 | 6.7 | 130 | .87 | s/m |
| 92/02/28 | 0845 | 92/02/29 | 0300 | 14 | 160 | .98 | s/m |
| 92/03/01 | 1200 | 92/03/02 | 0700 | 20 | 120 | .66 | s/m |
| 92/07/13 | 1500 | 92/07/15 | 0300 | -- | 36 | .34 | 1.49 |
| 92/08/29 | 0330 | 92/08/29 | 1100 | .13 | .78 | .037 | 1.21 |
| 92/09/16 | 1100 | 92/09/17 | 1800 | .51 | 27 | .25 | 1.19 |
| 92/09/18 | 0330 | 92/09/19 | 1700 | .47 | 18 | .33 | .73 |
| | | | Garfoot Creek | | | | |
| 84/10/18 | 1200 | 84/10/19 | 2200 | 37 | 210 | 3.1 | 2.64 |
| 84/10/31 | 2400 | 84/11/01 | 1800 | 16 | 76 | 1.1 | 1.13 |
| 84/12/27 | 2200 | 84/12/29 | 0900 | 45 | 140 | 2.4 | s/m |
| 85/02/21 | 0200 | 85/02/25 | 0100 | 62 | 470 | 6.3 | s/m |
| 85/07/24 | 1915 | 85/07/26 | 0500 | 65 | 710 | 7.5 | 6.56 |
| 85/09/04 | 2400 | 85/09/05 | 1300 | 1.7 | 22 | .49 | 1.38 |
| 85/09/09 | 0015 | 85/09/09 | 2100 | 17 | 130 | 2.2 | 1.63 |
| 85/09/23 | 0300 | 85/09/24 | 0300 | 1.9 | -- | .57 | 1.20 |
| 85/10/11 | 2345 | 85/10/12 | 2100 | 14 | -- | 1.1 | .85 |
| 85/10/23 | 1600 | 85/10/24 | 0700 | 9.8 | 46 | .62 | .70 |
| 85/10/31 | 1626 | 85/11/02 | 1400 | 34 | 370 | 5.3 | 2.79 |
| 85/11/18 | 0300 | 85/11/19 | 0900 | 17 | 98 | 1.6 | .73 |
| 86/03/09 | 1600 | 86/03/11 | 0600 | 26 | 110 | 1.7 | s/m |
| 86/03/16 | 1200 | 86/03/20 | 0200 | 59 | 610 | 7.7 | s/m |
| 86/05/15 | 1400 | 86/05/16 | 0500 | 14 | 27 | 0.53 | 0.72 |
| 86/05/17 | 0100 | 86/05/18 | 0400 | 15 | 75 | 1.2 | 1.15 |
| 89/10/05 | 0930 | 89/10/06 | 0600 | .27 | 6.4 | .21 | -- |

**Appendix 1.** Storm-load data, 1985-92 water years--Continued

| Start date (year/month/day) | Start time (24-hour) | End date (year/month/day) | End time (24-hour) | Suspended-solids load (tons) | Total-phosphorus load (lb) | Streamflow volume (Mcf) | Precipitation (in.) |
|---|---|---|---|---|---|---|---|
| | | | Garfoot Creek--Continued | | | | |
| 90/01/16 | 1845 | 90/01/17 | 2200 | 13 | 190 | 1.4 | s/m |
| 90/03/11 | 0600 | 90/03/12 | 0400 | 53 | 330 | 2.9 | .48 |
| 90/03/13 | 0600 | 90/03/14 | 1300 | 30 | 160 | 1.3 | .76 |
| 90/03/14 | 1600 | 90/03/15 | 1500 | 31 | 230 | 2.0 | 1.12 |
| 90/06/02 | 1300 | 90/06/03 | 0100 | 23 | 100 | .42 | 1.48 |
| 90/06/28 | 2330 | 90/06/29 | 2300 | 77 | 530 | 3.0 | 2.45 |
| 90/08/19 | 1630 | 90/08/20 | 1200 | 4.6 | 61 | .81 | -- |
| 91/03/01 | 0945 | 91/03/02 | 2200 | 53 | 370 | 3.2 | 1.51 |
| 91/03/22 | 2130 | 91/03/23 | 0700 | 4.2 | 28 | .33 | .74 |
| 91/04/12 | 1500 | 91/04/13 | 1400 | 74 | 210 | 2.2 | 1.74 |
| 91/04/14 | 0600 | 91/04/14 | 2400 | 58 | 200 | 1.9 | .99 |
| 91/08/08 | 0200 | 91/08/08 | 1500 | - | 12 | .30 | 2.34 |
| 91/11/01 | 0900 | 91/11/02 | 0100 | 15 | 150 | 1.3 | 1.40 |
| 91/11/29 | 2000 | 91/11/30 | 1300 | 13 | 76 | .98 | .87 |
| 92/02/26 | 1400 | 92/02/27 | 0100 | - | 11 | .30 | s/m |
| 92/02/27 | 1044 | 92/02/28 | 0100 | 9.0 | 54 | .68 | s/m |
| 92/02/28 | 1130 | 92/02/28 | 2400 | 1.5 | 21 | .44 | s/m |
| 92/09/16 | 1200 | 92/09/17 | 0330 | 7.4 | 46 | .69 | 1.34 |
| 92/09/18 | 0330 | 92/09/18 | 1800 | 5.2 | 48 | .70 | .89 |
| | | | Eagle Creek | | | | |
| 91/04/29 | 0200 | 91/04/29 | 2200 | 2,100 | 3,800 | 5.1 | 1.81 |
| 91/05/05 | 0800 | 91/05/05 | 2230 | 61 | 210 | 1.7 | 1.29 |
| 91/05/15 | 2130 | 91/05/17 | 0200 | 3,200 | 4,700 | 6.9 | .85 |
| 91/05/31 | 0900 | 91/05/31 | 2000 | 250 | 280 | 1.2 | .50 |
| 91/07/21 | 1715 | 91/07/21 | 2400 | 220 | 430 | 1.6 | 1.99 |
| 91/08/07 | 1540 | 91/08/08 | 1500 | 62 | 140 | 1.6 | 1.88 |
| 91/10/23 | 2325 | 91/10/24 | 1200 | 52 | 200 | .88 | 1.21 |
| 91/11/01 | 0050 | 91/11/01 | 2300 | 620 | 1,400 | 7.0 | 2.75 |
| 91/11/17 | 1900 | 91/11/18 | 1200 | 120 | 250 | 1.9 | 1.15 |
| 92/03/01 | 1100 | 92/03/02 | 0400 | 140 | 220 | 1.3 | s/m |

**Appendix 1.** Storm-load data, 1985-92 water years--Continued

| Start date (year/month/day) | Start time (24-hour) | End date (year/month/day) | End time (24-hour) | Suspended-solids load (tons) | Total-phosphorus load (lb) | Streamflow volume (Mcf) | Precipitation (in.) |
|---|---|---|---|---|---|---|---|
| | | | Eagle Creek--Continued | | | | |
| 92/03/03 | 2000 | 92/03/04 | 0900 | 48 | 130 | .92 | .41 |
| 92/03/09 | 0100 | 92/03/09 | 1300 | 72 | 170 | 1.1 | .82 |
| 92/04/20 | 1500 | 92/04/21 | 0900 | 210 | 300 | 1.8 | 1.24 |
| 92/05/16 | 1645 | 92/05/16 | 2400 | 8,300 | 160 | .66 | 1.54 |
| 92/05/21 | 1730 | 92/05/21 | 2200 | 6.3 | 22 | .24 | .51 |
| 92/05/22 | 1815 | 92/05/23 | 0300 | 26 | 84 | .47 | .44 |
| 92/07/13 | 1400 | 92/07/13 | 2400 | 43 | 80 | .73 | 1.27 |
| 92/08/01 | 1900 | 92/08/02 | 0200 | 16 | 31 | .49 | 1.03 |
| 92/09/16 | 0200 | 92/09/16 | 2400 | 1,700 | 3,300 | 1.2 | 3.99 |
| | | | Joos Valley Creek | | | | |
| 90/08/17 | 1850 | 90/08/18 | 0200 | 170 | 420 | .96 | 1.37 |
| 90/08/26 | 0545 | 90/08/26 | 1500 | 750 | 1,600 | 2.8 | 1.75 |
| 91/04/29 | 0200 | 91/04/29 | 1600 | 840 | 1,500 | 1.7 | 2.11 |
| 91/05/05 | 0730 | 91/05/05 | 2000 | 26 | 57 | .64 | 1.25 |
| 91/05/15 | 2000 | 91/05/17 | 0200 | 390 | 850 | 1.8 | 1.21 |
| 91/05/31 | 0850 | 91/05/31 | 1900 | 36 | 78 | .40 | .57 |
| 91/07/21 | 1710 | 91/07/22 | 1100 | 27 | 70 | .68 | 1.24 |
| 91/08/07 | 1500 | 91/08/08 | 1100 | 11 | 34 | .63 | 2.27 |
| 91/10/23 | 2250 | 91/10/24 | 1300 | 3.4 | 12 | .34 | .83 |
| 91/10/31 | 2200 | 91/11/01 | 2200 | 110 | 330 | 2.1 | 2.87 |
| 91/11/17 | 1800 | 91/11/18 | 1400 | 14 | 62 | .96 | 1.21 |
| 92/03/01 | 1000 | 92/03/02 | 0400 | 16 | 68 | .63 | s/m |
| 92/03/03 | 1400 | 92/03/04 | 0800 | 1.5 | 11 | .47 | .37 |
| 92/03/08 | 2400 | 92/03/09 | 1100 | 20 | 49 | .45 | .86 |
| 92/04/20 | 1300 | 92/04/21 | 0700 | 56 | 120 | .77 | 1.24 |
| 92/05/16 | 1500 | 92/05/16 | 2200 | 54 | 110 | .34 | 1.62 |
| 92/05/21 | 1700 | 92/05/21 | 2400 | 13 | 35 | .22 | .74 |
| 92/05/22 | 1800 | 92/05/23 | 0300 | 12 | 31 | .27 | .49 |
| 92/06/17 | 0400 | 92/06/17 | 1800 | 2.8 | 7.7 | .25 | .57 |
| 92/07/02 | 0500 | 92/07/02 | 1500 | 4.2 | 9.2 | .23 | .72 |

**Appendix 1.** Storm-load data, 1985-92 water years--Continued

| Start date (year/month/day) | Start time (24-hour) | End date (year/month/day) | End time (24-hour) | Suspended-solids load (tons) | Total-phosphorus load (lb) | Streamflow volume (Mcf) | Precipitation (in.) |
|---|---|---|---|---|---|---|---|
| | | | Joos Valley Creek--Continued | | | | |
| 92/07/13 | 1300 | 92/07/14 | 0200 | 7.1 | 21 | .40 | 1.32 |
| 92/07/22 | 1000 | 92/07/23 | 0300 | 1.4 | 5.7 | .37 | 1.19 |
| 92/08/01 | 1800 | 92/08/02 | 1300 | 24 | 73 | .57 | 1.24 |
| 92/09/16 | 0100 | 92/09/16 | 2200 | 910 | 1,700 | 5.4 | 4.19 |
| | | | Bower Creek | | | | |
| 90/10/17 | 2040 | 90/10/20 | 0925 | 12 | 280 | 3.6 | .38 |
| 91/03/01 | 1500 | 91/03/04 | 1100 | 100 | -- | 28 | 1.05 |
| 91/03/05 | 1700 | 91/03/08 | 1500 | 12 | 520 | 11 | s/m |
| 91/03/18 | 1300 | 91/03/25 | 0900 | 160 | 1,800 | 43 | s/m |
| 91/04/09 | 1100 | 91/04/12 | 2000 | 48 | 460 | 11 | s/m |
| 91/04/12 | 2400 | 91/04/17 | 2400 | 260 | 1,500 | 29 | .71 |
| 91/06/14 | 0500 | 91/06/15 | 1545 | 9.7 | 70 | 1.2 | 1.40 |
| 91/10/29 | 1000 | 91/10/31 | 1400 | 1.8 | 58 | 12 | 1.02 |
| 91/11/01 | 1325 | 91/11/04 | 0600 | .55 | 77 | 11 | .35 |
| 91/11/18 | 0700 | 91/11/20 | 0905 | .24 | 32 | 10 | .23 |
| 91/11/29 | 1805 | 91/12/02 | 1610 | 64 | 590 | 120 | .78 |
| 91/12/12 | 0825 | 91/12/14 | 0700 | 64 | 700 | 170 | .61 |
| 92/03/29 | 1500 | 92/03/31 | 0940 | 5.9 | 120 | 45 | .28 |
| 92/03/31 | 1200 | 92/04/02 | 1100 | 11 | 150 | 45 | .12 |
| 92/04/10 | 1700 | 92/04/13 | 1535 | 75 | 440 | 140 | .43 |
| 92/04/15 | 1200 | 92/04/18 | 0935 | 710 | 2,900 | 390 | 2.07 |
| 92/04/19 | 1355 | 92/04/20 | 1815 | 11 | 110 | 40 | .19 |
| 92/04/20 | 1945 | 92/04/22 | 0910 | 72 | 430 | 84 | .36 |
| 92/07/13 | 1820 | 92/07/16 | 0500 | .24 | 13 | 5.6 | .71 |
| 92/09/16 | 0725 | 92/09/17 | 0520 | 2.3 | 110 | 11 | 1.39 |
| 92/09/18 | 0240 | 92/09/20 | 0800 | 97 | 950 | 150 | 1.48 |
| 92/09/26 | 1000 | 92/09/30 | 0510 | 2.7 | 120 | 39 | 1.11 |
| | | | Otter Creek | | | | |
| 90/09/06 | 1940 | 90/09/08 | 1845 | 7.1 | 63 | 1.5 | 1.53 |
| 90/09/14 | 0540 | 90/09/18 | 2335 | 26 | 190 | 6.5 | 1.67 |

**Appendix 1.** Storm-load data, 1985-92 water years--Continued

| Start date (year/month/day) | Start time (24-hour) | End date (year/month/day) | End time (24-hour) | Suspended-solids load (tons) | Total-phosphorus load (lb) | Streamflow volume (Mcf) | Precipitation (in.) |
|---|---|---|---|---|---|---|---|
| | | | Otter Creek--Continued | | | | |
| 90/11/05 | 0610 | 90/11/06 | 1030 | 1.2 | 20 | 1.2 | .79 |
| 91/02/03 | 0300 | 91/02/08 | 1400 | 11 | 180 | 10 | s/m |
| 91/03/01 | 1100 | 91/03/04 | 1600 | 27 | - | 5.3 | s/m |
| 91/06/14 | 1735 | 91/06/18 | 0300 | 35 | 230 | 5.2 | 2.24 |
| 91/10/24 | 1200 | 91/10/26 | 1245 | 8.3 | 57 | 23 | 1.85 |
| 91/10/26 | 1245 | 91/10/27 | 2300 | 1.6 | 23 | 16 | .46 |
| 91/10/29 | 0225 | 91/10/30 | 1910 | 11 | 83 | 30 | - |
| 91/11/01 | 1200 | 91/11/03 | 0005 | 8.1 | 70 | 25 | .53 |
| 91/11/14 | 1535 | 91/11/17 | 0155 | 3.0 | 24 | 23 | .46 |
| 91/11/18 | 0140 | 91/11/20 | 1810 | 7.6 | 45 | 32 | .39 |
| 91/11/29 | 2015 | 91/12/02 | 2235 | 19 | 150 | 77 | 1.38 |
| 92/02/27 | 1200 | 92/03/01 | 0900 | 12 | 110 | 47 | s/m |
| 92/03/01 | 0900 | 92/03/03 | 0900 | 14 | 130 | 47 | s/m |
| 92/03/05 | 2100 | 92/03/08 | 1100 | 15 | 100 | 68 | .37 |
| 92/03/09 | 0335 | 92/03/10 | 1930 | 24 | 98 | 55 | .55 |
| 92/03/24 | 1200 | 92/03/28 | 0700 | 8.3 | 82 | 69 | s/m |
| 92/04/10 | 1800 | 92/04/13 | 0500 | 19 | 82 | 48 | .81 |
| 92/04/16 | 0500 | 92/04/18 | 0540 | 25 | 110 | 53 | .80 |
| 92/09/14 | 1230 | 92/09/15 | 0600 | .27 | 2.8 | 2.7 | 1.01 |
| 92/09/16 | 0950 | 92/09/17 | 0640 | 1.1 | 13 | 4.7 | 1.00 |
| 92/09/18 | 0440 | 92/09/19 | 0735 | 3.1 | 25 | 9.5 | 1.09 |
| 92/09/26 | 2110 | 92/09/28 | 1700 | .52 | 5.2 | 7.3 | .74 |
| | | | Rattlesnake Creek | | | | |
| 90/01/16 | 1700 | 90/01/18 | 0800 | 150 | 1,600 | 9.4 | s/m |
| 90/03/08 | 0600 | 90/03/08 | 1200 | 1,300 | 3,600 | 16 | s/m |
| 90/03/11 | 0500 | 90/03/12 | 0200 | 57 | 480 | 4.1 | s/m |
| 90/05/09 | 0115 | 90/05/10 | 0100 | 170 | 360 | 3.2 | -- |
| 90/05/19 | 0500 | 90/05/20 | 2100 | 83 | 530 | 5.8 | -- |
| 90/06/22 | 0315 | 90/06/22 | 1800 | 55 | 180 | 3.3 | -- |
| 90/08/24 | 2000 | 90/08/25 | 2300 | 230 | 1,600 | 7.9 | -- |

**Appendix 1.** Storm-load data, 1985-92 water years--Continued

| Start date (year/month/day) | Start time (24-hour) | End date (year/month/day) | End time (24-hour) | Suspended-solids load (tons) | Total-phosphorus load (lb) | Streamflow volume (Mcf) | Precipitation (in.) |
|---|---|---|---|---|---|---|---|
| 90/08/26 | 0900 | 90/08/27 | 0400 | 190 | 940 | 5.6 | -- |
| 91/04/12 | 1100 | 91/04/13 | 1900 | 98 | 1,000 | 14 | 1.64 |
| 91/08/07 | 2000 | 91/08/08 | 2300 | 200 | 4,600 | 8.3 | 2.50 |
| 91/11/01 | 0045 | 91/11/02 | 0330 | 59 | 650 | 5.9 | 1.55 |
| 91/11/29 | 1100 | 91/11/30 | 1700 | 29 | 230 | 6.2 | .80 |
| 92/02/03 | 1300 | 92/02/04 | 0900 | 69 | 290 | 3.7 | s/m |
| 92/02/20 | 1445 | 92/02/21 | 0800 | 2,800 | 7,600 | 19 | s/m |
| 92/02/22 | 1400 | 92/02/23 | 1633 | 1,600 | 4,400 | 14 | s/m |
| 92/02/24 | 1500 | 92/02/25 | 0900 | 420 | 1,700 | 8.6 | .24 |
| 92/04/20 | 1300 | 92/04/21 | 0900 | 34 | 520 | 4.4 | .91 |
| 92/06/16 | 1000 | 92/06/17 | 0300 | .44 | 14 | 1.3 | .66 |
| 92/09/07 | 2230 | 92/09/08 | 1800 | 4.1 | 180 | 2.3 | .90 |
| 92/09/14 | 1400 | 92/09/15 | 1800 | 2.9 | 130 | 2.3 | .84 |
| | | | Menomonee River | | | | |
| 91/06/14 | 1500 | 91/06/15 | 0550 | 240 | 630 | 23 | 1.49 |
| 91/06/22 | 0300 | 91/06/22 | 2000 | 13 | 62 | 5.5 | -- |
| 91/07/01 | 1600 | 91/07/01 | 1840 | 240 | 530 | 11 | -- |
| 91/0707 | 1615 | 91/07/07 | 2300 | 74 | 190 | 8.8 | -- |
| 91/07/12 | 0730 | 91/07/12 | 1320 | 240 | 630 | 20 | -- |
| 91/07/18 | 1720 | 91/07/18 | 2055 | 9.4 | 45 | 2.0 | -- |
| 91/07/21 | 0520 | 91/07/21 | 1920 | 100 | 310 | 18 | .56 |
| 91/07/29 | 0500 | 91/07/29 | 1200 | 1.7 | 14 | 2.4 | -- |
| 91/08/08 | 0550 | 91/08/08 | 1420 | 210 | 560 | 24 | 1.61 |
| 91/09/09 | 1830 | 91/09/10 | 0500 | 57 | 210 | 9.7 | -- |
| 91/10/04 | 0215 | 91/10/07 | 0430 | 290 | 1,400 | 93 | 2.60 |
| 91/10/14 | 0030 | 91/10/14 | 1515 | 1.7 | 20 | 4.5 | -- |
| 91/10/28 | 2010 | 91/11/06 | 1145 | 210 | 1,400 | 170 | .62 |
| 92/03/16 | 1910 | 92/03/20 | 1400 | 66 | 310 | 71 | s/m |
| 92/03/23 | 1330 | 92/03/25 | 0955 | 18 | 100 | 33 | s/m |
| 92/03/25 | 0955 | 92/03/27 | 0900 | 8.4 | 110 | 45 | s/m |
| 92/03/27 | 0900 | 92/03/29 | 2105 | 1.4 | 55 | 44 | s/m |
| 92/03/30 | 0930 | 92/04/02 | 0420 | 3.8 | 50 | 40 | s/m |

**Appendix 1.** Storm-load data, 1985-92 water years--Continued

| Start date (year/month/day) | Start time (24-hour) | End date (year/month/day) | End time (24-hour) | Suspended-solids load (tons) | Total-phosphorus load (lb) | Streamflow volume (Mcf) | Precipitation (in.) |
|---|---|---|---|---|---|---|---|
| | | | Menomonee River--Continued | | | | |
| 92/04/15 | 0720 | 92/04/16 | 1500 | 250 | 650 | 42 | .78 |
| 92/04/16 | 1500 | 92/04/17 | 1330 | 120 | 380 | 43 | s/m |
| 92/04/17 | 1330 | 92/04/18 | 1445 | 17 | 100 | 28 | s/m |
| 92/04/18 | 1445 | 92/04/21 | 0015 | 11 | 110 | 43 | s/m |
| 92/05/11 | 2115 | 92/05/13 | 1000 | 16 | 100 | 15 | -- |
| 92/06/14 | 0300 | 92/06/14 | 1515 | 12 | 80 | 3.8 | -- |
| 92/06/17 | 1350 | 92/06/18 | 1230 | 270 | 810 | 25 | .74 |
| 92/07/08 | 0935 | 92/07/09 | 1235 | 140 | 540 | 18 | -- |
| 92/07/12 | 1140 | 92/07/13 | 2230 | 350 | 950 | 46 | .74 |
| 92/07/13 | 2230 | 92/07/16 | 0830 | 86 | 380 | 38 | 1.36 |
| 92/08/12 | 1000 | 92/08/13 | 0745 | 38 | 130 | 11 | .89 |
| 92/08/25 | 2210 | 92/08/27 | 1030 | 130 | 530 | 26 | .71 |
| 92/08/27 | 1030 | 92/08/30 | 0405 | 25 | 150 | 22 | -- |
| 92/09/09 | 0725 | 92/09/10 | 0925 | 140 | 570 | 22 | .88 |
| 92/09/14 | 1320 | 92/09/16 | 1355 | 140 | 470 | 23 | .56 |
| 92/09/16 | 1355 | 92/09/18 | 1235 | 210 | 610 | 45 | -- |
| | | | Nine Springs tributary | | | | |
| 90/11/21 | 0306 | 90/11/21 | 0349 | .02 | .082 | .0049 | .24 |
| 90/11/27 | 0523 | 90/11/27 | 0630 | .33 | .70 | .018 | .28 |
| 90/11/27 | 1550 | 90/11/27 | 1639 | .02 | .071 | .0031 | .14 |
| 90/12/12 | 1315 | 90/12/12 | 1501 | .002 | .012 | .0006 | -- |
| 91/02/04 | 1402 | 91/02/04 | 1553 | .02 | .094 | .0026 | -- |
| 91/03/01 | 1001 | 91/03/02 | 0918 | 1.1 | 6.5 | .23 | -- |
| 91/03/17 | 1435 | 91/03/18 | 0157 | .18 | 1.3 | .086 | -- |
| 91/03/22 | 1849 | 91/03/22 | 2251 | 3.0 | 6.6 | .100 | .52 |
| 91/03/26 | 0345 | 91/03/26 | 0650 | .07 | .30 | .025 | .14 |
| 91/03/26 | 2332 | 91/03/27 | 1523 | 3.0 | 8.0 | .30 | .94 |
| 91/04/08 | 1710 | 91/04/09 | 1500 | .75 | 3.4 | .32 | 1.22 |
| 91/04/12 | 0933 | 91/04/12 | 2253 | 1.5 | 5.7 | .48 | 1.27 |
| 91/04/13 | 1840 | 91/04/14 | 1159 | .49 | 2.4 | .32 | .89 |

**Appendix 1.** Storm-load data, 1985-92 water years--Continued

| Start date (year/month/day) | Start time (24-hour) | End date (year/month/day) | End time (24-hour) | Suspended-solids load (tons) | Total-phosphorus load (lb) | Streamflow volume (Mcf) | Precipitation (in.) |
|---|---|---|---|---|---|---|---|
| | | | Nine Springs tributary--Continued | | | | |
| 91/05/05 | 0717 | 91/05/05 | 1333 | .23 | 1.4 | .15 | .73 |
| 91/05/17 | 1909 | 91/05/17 | 2000 | .03 | .36 | .0077 | -- |
| 91/05/18 | 1051 | 91/05/18 | 1518 | .70 | 2.8 | .19 | .71 |
| 91/05/21 | 1608 | 91/05/21 | 1723 | .37 | 1.00 | .039 | .15 |
| 91/05/25 | 1529 | 91/05/25 | 1538 | .003 | .021 | .0011 | -- |
| 91/06/10 | 1541 | 91/06/10 | 1739 | .55 | 2.2 | .064 | .34 |
| 91/06/12 | 0253 | 91/06/12 | 0450 | .40 | 1.4 | .082 | .40 |
| 91/06/13 | 2257 | 91/06/14 | 0128 | .26 | 1.00 | .063 | .28 |
| 91/07/01 | 1702 | 91/07/01 | 1738 | .24 | .68 | .023 | .17 |
| 91/07/21 | 0503 | 91/07/21 | 0625 | 2.1 | 4.4 | .21 | 2.31 |
| 91/08/07 | 0621 | 91/08/07 | 0651 | .14 | .55 | .013 | 2.00 |
| 91/08/16 | 2234 | 91/08/17 | 0021 | .10 | .65 | .028 | .15 |
| 91/09/03 | 0947 | 91/09/03 | 1101 | .19 | .89 | .022 | .10 |
| 91/09/09 | 2303 | 91/09/10 | 0027 | .05 | .68 | .039 | .45 |
| 91/10/03 | 2241 | 91/10/04 | 0015 | .14 | .61 | .021 | .14 |
| 91/10/04 | 0923 | 91/10/05 | 0941 | .85 | 5.3 | .34 | .92 |
| 91/10/13 | 1925 | 91/10/13 | 2128 | .04 | .70 | .024 | .16 |
| 91/10/28 | 1549 | 91/10/29 | 1146 | .28 | 1.8 | .20 | .53 |
| 91/10/31 | 1335 | 91/11/01 | 1432 | .80 | 5.8 | .42 | .25 |
| 91/11/14 | 1252 | 91/11/15 | 0308 | .46 | 2.7 | .19 | .66 |
| 91/11/17 | 1940 | 91/11/18 | 0349 | .24 | 1.5 | .18 | .63 |
| 91/12/12 | 0235 | 91/12/12 | 1620 | .75 | 3.7 | .19 | .58 |
| 92/01/08 | 2131 | 92/01/09 | 0102 | .38 | 1.4 | .056 | .20 |
| 92/03/09 | 0147 | 92/03/09 | 0805 | .55 | 1.3 | .040 | .26 |
| 92/03/28 | 2217 | 92/03/29 | 0404 | .09 | .42 | .042 | .28 |
| 92/04/08 | 1945 | 92/04/09 | 0104 | .14 | .62 | .058 | .31 |
| 92/04/15 | 0456 | 92/04/15 | 0651 | .70 | 1.7 | .068 | .40 |
| 92/04/15 | 2046 | 92/04/15 | 2154 | .37 | .85 | .030 | .13 |
| 92/04/16 | 0621 | 92/04/16 | 1044 | .18 | .87 | .066 | .23 |
| 92/04/18 | 2317 | 92/04/19 | 0325 | 1.9 | 4.4 | .15 | .93 |

**Appendix 1.** Storm-load data, 1985-92 water years--Continued

| Start date (year/month/day) | Start time (24-hour) | End date (year/month/day) | End time (24-hour) | Suspended-solids load (tons) | Total-phosphorus load (lb) | Streamflow volume (Mcf) | Precipitation (in.) |
|---|---|---|---|---|---|---|---|
| | | | Nine Springs tributary--Continued | | | | |
| 92/04/23 | 1216 | 92/04/23 | 1702 | .20 | .80 | .058 | .24 |
| 92/05/11 | 1644 | 92/05/11 | 1730 | .30 | 1.2 | .022 | .16 |
| 92/06/17 | 1200 | 92/06/17 | 1248 | .80 | 2.0 | .049 | .36 |
| 92/06/24 | 0644 | 92/06/24 | 0730 | .16 | .45 | .015 | -- |
| 92/07/02 | 0810 | 92/07/02 | 1545 | .55 | 2.1 | .12 | .66 |
| 92/07/08 | 0757 | 92/07/08 | 1054 | 2.5 | 5.1 | .22 | .97 |
| 92/07/13 | 0709 | 92/07/13 | 2158 | .85 | 3.7 | .40 | 1.26 |
| 92/07/16 | 0221 | 92/07/16 | 0415 | .03 | .31 | .029 | .16 |
| 92/08/29 | 0400 | 92/08/29 | 0825 | .65 | 2.9 | .26 | .98 |
| 92/09/06 | 0213 | 92/09/06 | 0730 | .26 | 1.6 | .15 | .64 |
| 92/09/09 | 0531 | 92/09/09 | 0910 | .30 | 1.3 | .11 | .48 |
| 92/09/16 | 1221 | 92/09/16 | 1656 | .44 | 8.0 | .27 | .94 |
| 92/09/17 | 0419 | 92/09/17 | 0906 | .85 | 4.1 | .23 | .62 |
| 92/09/18 | 0332 | 92/09/18 | 0803 | .30 | 1.8 | .13 | .44 |

**Appendix 2.** Quality-control and quality-assurance plan for watershed-management evaluation monitoring program

## INTRODUCTION

Following are quality-control (QC) and quality-assurance (QA) procedures that apply to all of the U.S. Geological Survey (USGS) watershed-management-evaluation data-collection projects (WI17201-17209). The purpose of this document is to provide consistent procedures to be used by all field personnel collecting data for the projects.

## QC PROCEDURES

The quality-control procedures are divided into field procedures and laboratory procedures. All samples are processed in a consistent manner as described in the following sections. All chemical analysis are by the Wisconsin State Laboratory of Hygiene (WSLOH). Samples for suspended-sediment concentration are analyzed at the USGS laboratory in Iowa City, Iowa. These two laboratories have their own internal quality-control procedures, which will not be discussed here. The USGS conducts an interlaboratory evaluation program semiannually. The WSLOH participates in this program. This program provides a variety of reference samples to accomplish quality-assurance testing of laboratories and to provide an adequate supply of samples that contribute to quality-control programs of participating laboratories. Reports of the results of the standard-reference sample program and a more detailed description of the program are on file at the USGS office in Madison, Wisconsin.

### Field Procedures

Water samples are collected from streams during low-flow and high-flow periods. Low-flow samples are collected every 2 weeks from April through November. Samples are collected monthly from December through March.

Low-flow samples are collected with a DH-81 sampler. The DH-81 sampler is constructed of polypropylene plastic; the nozzle, head, and collar are all autoclavable. The DH-81 can be used with 1/8-, 3/16-, or 1/4-in. nozzles and is suspended from a rod. Any bottle having standard mason-jar threads can be used with this sampler. The 1/4-in. nozzle typically is used during the low-flow sampling. The sampler is washed periodically with nonphosphate soap, rinsed with tap water, and with a final rinse of deionized water. The sampler bottle is plastic or glass. These bottles are prewashed in nonphosphate soap, rinsed with tap water, and a final rinse of deionized water and let air dry before being capped. Before sample collection, the sampler and sample bottles are rinsed twice with native water. An equal-width-increment (EWI) sample is collected (5-10 verticals depending on the stream width), and this sample is split into the bottles that are sent to the WSLOH and USGS sediment laboratories for analysis. If there is insufficient depth or volume of water in the stream, a sample will be obtained by dipping the sample bottles in the center of the flow. Bacteria samples are collected by dipping a pre-sterilized bacteria bottle obtained from the WSLOH into the stream at the center of the flow.

Samples are collected manually during highflows to determine coefficients to be applied to the automatic water-quality samplers at the evaluation-monitoring sites. An EWI sample is collected at the normal wading section or from the bridge near the gaging station. When the EWI sample is being collected, a concurrent sample or a maximum of 5 minutes before or after the EWI sample, a sample is collected by the automatic water-quality sampler for comparison. If wading is possible, the sampling procedures are the same as for low-flow samples; if the stage is high enough that wading is not possible, a suspended DH-59 is used. The DH-59 is a 25-lb handline sampler for use in shallow (depths less than 9 ft), unwadable streams with flow velocities up to 5 ft/s. This sampler is made of bronze and has intake nozzles of 1/8-, 3/16- and 1/4-in. diameter, and the nozzles can be changed when flow conditions vary.

All sample bottles are labeled with preprinted labels with site name and number. Date, time, and sample number are transcribed on the labels before the samples are placed in a cooler with ice.

## Record Keeping

All samples collected by the automatic water-quality sampler are capped and transcribed with a unique consecutive number before the sample is removed from the sampler. A log sheet of the unique consecutive numbers is kept in the gage house. On the log sheets, the date, time, gage height, and consecutive number of the sample is transcribed. The log sheets are kept with the samples and are used to determine which samples will be sent to the WSLOH. A log of when low-flow samples are kept as a record when low-flow samples were collected.

## Sample Processing

Low-flow samples are processed in the field. After the EWI sample is collected, the sample is agitated by hand to suspend all the particles in the sample and poured into the bottles provided by the WSLOH. Usually two EWI samples are collected to provide a sufficient volume of water to fill the WSLOH bottles. The first EWI sample is used to fill the 250-mL bottle for nutrient analysis (total phosphorus, ammonia nitrogen, nitrite plus nitrate- nitrogen) and is acidified with 2.0 mL of 12.5 percent sulfuric acid. The second EWI sample is used to fill the 735-mL bottle for analysis of biochemical oxygen demand, pH, suspended solids, total solids, total volatile solids, and suspended volatile solids and is untreated. The two EWI samples are collected as close as possible in time so that the flow conditions and concentrations of the constituents that are being analyzed for have not changed.

The high-flow samples collected by the EWI method and samples from the automatic water-quality samplers are processed at the USGS field office. The samples to be sent to the WSLOH for analysis are split with a 10-port, plastic, small-volume sample splitter. Before the sample splitter is used, it is disassembled, washed with nonphosphate soap and rinsed with tap water. The sample splitter is rinsed thoroughly with tap water. Then three approximate 250-mL volumes of deionized water (tap water passed through an ionic exchange resin column) are used to rinse the sample splitter. The sample splitter then is rinsed with an approximately 100-mL volume of Milli-Q water (deionized water passed through a carbon filter and membrane filter) that is obtained from the WSLOH. Between individual samples at each station, the sample splitter is rinsed with one rinse each of deionized water and Milli-Q water. The 250-mL bottle for nutrient analysis is acidified with 2.0-mL of 12.5-percent sulfuric acid. The 735-mL bottle for total solids, suspended solids, total volatile solids, suspended volatile solids, pH, and biochemical oxygen demand is sent as raw sample. A 250-mL bacteria bottle is filled from the sample splitter and sent to the WSLOH for bacteria analysis. The sample splitter is not sterilized for the bacteria samples. After all samples have been processed, the sample splitter is rinsed once with tap water and deionized water. A clean plastic bag is placed over the splitter to keep airborne contamination to a minimum.

# QUALITY ASSURANCE

Quality-assurance procedures include the regular analysis of blank samples to check for sampler and sample-splitter contamination. No spiked, replicate, or blind samples are collected or sent to the WSLOH for analysis. Once a year the automatic sampler lines are cleaned. A stiff bottle brush is used to clean the sampler line. Deionized water then is pumped through the sampling line and through the sampler. The Manning sampler's collection chamber is disassembled and cleaned with nonphosphate soap and rinsed with deionized water.

## Blank-Sample Processing

Two types of blank samples are used to investigate possible sources of contamination in the sample-collection and processing procedures. Sample-collection and processing (SCAP) blanks are used to evaluate contamination for the entire sampling process, including collection of the sample by the automatic sampler and processing with the sample splitter. Separate splitter-blank samples are used to evaluate contamination caused by processing through the sample splitter. SCAP blanks are processed every 2 months, whereas splitter- blank samples are processed three times a year during the field season (April through November). If both SCAP and splitter-blank samples are processed on the same day, the splitter-blank sample is processed first.

The following procedures were used to collect the blank samples. Procedures for collecting a SCAP blank sample at a water-quality monitoring site with a ISCO sampler follow: (1) Wash a glass bottle with nonphosphate soap and rinse with tap water. Rinse this glass bottle with Milli-Q water and discard this water; (2) Fill the glass bottle with Milli-Q water and connect one end of a Teflon hose to the sampling line and place the other end into the glass bottle; (3) Set sampler to pump forward and pump 1,000 mL of Milli-Q water through the sampler line and fill one bottle. This approximates the normal purge cycle. Discard this water; (4) Set the sampler to pump forward and pump 1,000 mL to fill a sample bottle. Use this sample for the blank sample. Place this sample in a cooler with ice; (5) Process this sample through the sample splitter as you would process a runoff sample collected by the sampler. The sample splitter should be cleaned just as you would clean the splitter for processing of runoff samples; and (6) Analyze the sample for the same constituents that would be analyzed for runoff samples, including nutrients, suspended solids, total solids, total volatile solids, suspended volatile solids, biochemical oxygen demand, and bacteria but not including suspended-sediment particle size or suspended-sediment concentration.

Procedures for collecting a SCAP blank sample at a water-quality monitoring site with a Manning sampler follow: (1) Wash a glass bottle with nonphosphate soap and rinse with tap water. Rinse this glass bottle with Milli-Q water, discard this water, and rinse the Manning sampler line used to collect blank sample with Milli-Q water; (2) Fill the glass bottle with Milli-Q water, connect Manning sampling line to the sampler, and place sampling line in the glass bottle. Sample used for analysis is collected from this bottle. This blank sample only checks the sample-collection chamber and purge chamber for contamination and not if the sample line from the stream is contaminated; (3) Set the sampler to manual sample, pump 1,000 mL of Milli-Q water through the sampler line, and fill one bottle; (4) Use this sample for the blank sample. Place this sample in a cooler with ice; (5) Process the SCAP blank sample through the sample splitter as you would process a runoff sample collected by the sampler. The sample splitter should be cleaned just as you would clean the splitter for processing of runoff samples; (6) Analyze the sample for the same constituents that would be analyzed for runoff samples, including nutrients, suspended solids, total solids, total volatile solids, suspended volatile solids, biochemical oxygen demand, and bacteria but not including suspended-sediment particle size or suspended- sediment concentration.

Procedures for collecting a splitter-blank sample from a 10-port, plastic sample splitter include: (1) Clean the sample splitter as you would normally clean it before processing runoff samples; (2) Process about 1,000 mL of Milli-Q water through the sample splitter; (3) Analyze the sample for the same constituents that would be analyzed for runoff samples, including nutrients, suspended solids, total solids, total volatile solids, suspended volatile solids, biochemical oxygen demand, and bacteria but not including suspended-sediment particle size or suspended-sediment concentration.

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