SNY MAGILL
WATERSHED MONITORING PROJECT:
BASELINE DATA

Geological Survey Bureau
Technical Information Series 32

Iowa Department of Natural Resources
Larry J. Wilson, Director
December 1994

SNY MAGILL WATERSHED MONITORING PROJECT: BASELINE DATA

Geological Survey Bureau
Technical Information Series 32

Edited by
L.S. Seigley

Iowa Department of Natural Resources
Energy and Geological Resources Division
Geological Survey Bureau

Papers by (listed alphabetically)

E.A. Bettis III, M.W. Birmingham, M.R. Craig, D.A. Eash, J.D. Giglierano, G.R. Hallberg, M.C. Hausler, S.J. Kalkhoff, J.O. Kennedy, R.D. Libra, Z-J. Liu, K.O. Mann, K.D. Rex, R.D. Rowden, M.D. Schueller, L.S. Seigley, L. Stahl, T.F. Wilton, G. Wunder

Supported, in part, through grants from the
U.S. Environmental Protection Agency, Region VII, Nonpoint Source Program

December 1994

Iowa Department of Natural Resources
Larry J. Wilson, Director

PREFACE

The Sny Magill Nonpoint Source Pollution Monitoring Project, in northeast Clayton County, Iowa, is part of the U.S. Environmental Protection Agency's Section 319 National Monitoring Program, designed to support 20 to 30 watershed projects nationwide to document the effectiveness of nonpoint source (NPS) pollution controls in restoring water quality. Funding for the Sny Magill Project is provided, in part, through U.S. EPA Region VII, Section 319 of the Clean Water Act.

The Sny Magill Project began in October 1991 and is an interagency effort designed to monitor and assess improvements in the surface water quality of the Sny Magill Creek resulting from the implementation of two U.S. Department of Agriculture land treatment projects in the watershed (the Sny Magill Hydrologic Unit Area Project and the North Cedar Creek Water Quality Special Project). A paired watershed approach is being used to compare surface water quality of Sny Magill Creek (27.6 mi^2 watershed) to Bloody Run Creek (34.3 mi^2 watershed), the adjacent watershed to the north. There are five monitoring components to the project: (1) U.S. Geological Survey stream gages on Sny Magill and Bloody Run creeks, (2) an annual habitat assessment along the stream corridors, (3) biomonitoring of benthic macroinvertebrates, (4) an annual fisheries survey, and (5) weekly to monthly monitoring of nine sites on Sny Magill and Bloody Run creeks for chemical and physical water quality variables.

This report is a compendium of work done in the Sny Magill Watershed and surrounding areas, both prior to the beginning of the Sny Magill Project and during the first water year (October 1991 to September 1992) of activities. The report is intended to provide perspective for analysis of future data from the Sny Magill Project.

ACKNOWLEDGMENTS

The Sny Magill Nonpoint Source Pollution Monitoring Project is supported in part, by the U.S. Environmental Protection Agency, Region VII, Kansas City, through a 319-Nonpoint Source Program Grant to the Iowa Department of Natural Resources (IDNR). George Hallberg of the University of Iowa Hygienic Laboratory provided the vision for this compendium. A special thanks to Pat Lohmann of the IDNR-Geological Survey Bureau who oversaw the design and layout of this report. Thanks to Angie Bowman and Mary Skopec for proofreading this report. Mary Clare Jones and Angie Bowman assisted in the development of tables for this report.

TABLE OF CONTENTS

SNY MAGILL WATERSHED MONITORING PROJECT:
BASELINE DATA

Iowa Department of Natural Resources, Geological Survey Bureau
Technical Information Series 32, 1994

GEOLOGY, HYDROGEOLOGY AND LANDUSE OF SNY MAGILL AND BLOODY RUN WATERSHEDS

E.A. Bettis III[1], L.S. Seigley[1], G.R. Hallberg[2], and J.D. Giglierano[1]

[1] Iowa Department of Natural Resources, Geological Survey Bureau
109 Trowbridge Hall
Iowa City, IA 52242-1319

[2] University of Iowa Hygienic Laboratory
University of Iowa; Oakdale Campus
Iowa City, IA 52242

ABSTRACT

The Sny Magill and Bloody Run watersheds are located in the Paleozoic Plateau landform region in northeast Iowa. The area is dominated by Paleozoic age bedrock, including the sandstones and sandy dolostones of the Upper Cambrian-age Jordan Sandstone Formation, the oldest bedrock in the area, through the Upper Ordovician-age Maquoketa Formation. The sequence of bedrock exposed in these two watersheds includes sandstones, sandy dolostones, dolostones, shales, shaly carbonates, and limestones. The sandstones and limestones form important aquifers in the area, including the Galena aquifer and St. Peter aquifer. Water movement through the carbonate bedrock units is influenced by bedding planes and vertical fractures. Dissolution along bedding planes and fractures has caused some local karst development. Sinkholes occur in both watersheds. Most sinkholes occur near the top of the Galena carbonates, often at the contact between the Galena and the shaly carbonates of the overlying Elgin Member of the Maquoketa Formation.

The surficial deposits in the watersheds owe their origin to the direct or indirect effects of glacial advances. Upland deposits include loam-textured pre-Illinoian glacial till, Sangamon and Farmdale paleosols, and Peoria Loess. Wedges of colluvium are present along most steeply sloping valley walls. Valley fills include slack water deposits associated with the melting of glaciers during the late-Wisconsinan, and loamy, sandy and silty late-Wisconsin and Holocene alluvial deposits of the DeForest Formation.

Landuse for both watersheds was compiled for 1991. Five landuse classes were delineated from color infrared aerial photographs; those classes include row crop, cover crop/pasture, forest/forested pasture, farmstead/urban, and other. Most of Sny Magill Watershed is forest/forested pasture (49%), row crop (26%), and cover crop/pasture (24%). Bloody Run Watershed is dominated by row crop (39%), followed by forest/forested pasture (30%), and cover crop/pasture (29%).

INTRODUCTION

Northeast Iowa has been the site of extensive stratigraphic and groundwater studies by the Iowa Department of Natural Resources-Geological Survey Bureau (DNR-GSB) for the past decade. Extensive work in the Big Spring basin (Figure 1) has prompted the detailed stratigraphic work and development of some of the most extensive groundwater and surface water monitoring in the United States. This report summarizes the stratigraphic and hydrogeologic setting of the area, and summarizes the landuse information for 1991 for the Sny Magill and Bloody Run watersheds in particular.

Northeast Iowa is characterized by a midcontinental subhumid climate. Mean annual precipitation at the Elkader recording station, located approximately 20 miles (32 km) southwest of the Sny Magill watershed, is about 33 inches (84 cm) with 70 percent of that occurring during the growing season, between April and September. Mean annual temperature is 44° F (6.7° C). Winter average temperature is 22° F (-5.6° C) and the summer average is 72° F (22.2° C).

GEOLOGIC SETTING

The Sny Magill and Bloody Run watersheds are located in the Paleozoic Plateau landform region in northeast Iowa (Prior, 1991). The watersheds are marked by gently sloping uplands that break into steep slopes with common rock outcrops. Up to 550 feet (168 m) of relief occurs across the watersheds. The landscape is mantled with loess overlying thin remnants of glacial till on upland interfluves, which in turn overlie Paleozoic age bedrock formations. The bedrock strata in northeastern Iowa generally dip to the southwest at about 20 feet per mile (3.79 m/km).

Paleozoic Bedrock

A variety of bedrock units are exposed in northeastern Clayton County. The generalized stratigraphy is presented in Figure 2. More detailed analysis of the stratigraphy is provided in McKay (1993), Rowden and Libra (1990), Hoyer and others (1986), Hallberg and others (1984), and Hallberg and others (1983). The oldest rocks in the area are sandstones and sandy dolostones of the Upper Cambrian-age Jordan Sandstone Formation. These rocks are exposed only in the lowermost reaches of Bloody Run watershed and are present in the subsurface beneath Sny Magill watershed (Figure 3). The Jordan Sandstone is overlain by Lower Ordovician-age Prairie du Chien Group dolostones and sandstones (Oneota dolomite and the Shakopee Formation; the Shakopee Formation is primarily a dolostone but includes the New Richmond sandstone). These rocks crop out low in the valley wall in the middle and lower reaches of the watersheds. The Shakopee Formation is unconformably overlain by the St. Peter Sandstone which is quite variable in thickness, and forms an aquifer of local importance in northeast Iowa. The St. Peter Sandstone is overlain by shales, shaly carbonates, and carbonates (dolostones) of the Glenwood and Platteville formations. These rocks, together with the Decorah Formation, form an aquitard which separates the underlying St. Peter aquifer from the overlying Galena aquifer. The uppermost bedrock units in the area are limestones of the Galena Group. These form the resistant cliffs high along the valley walls in the lower and middle parts of these watersheds, and crop out low in the valley

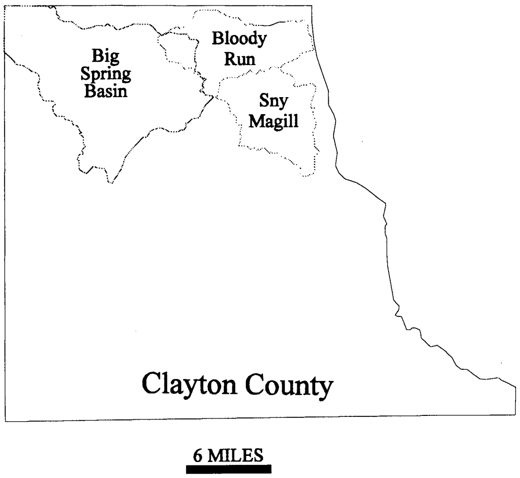
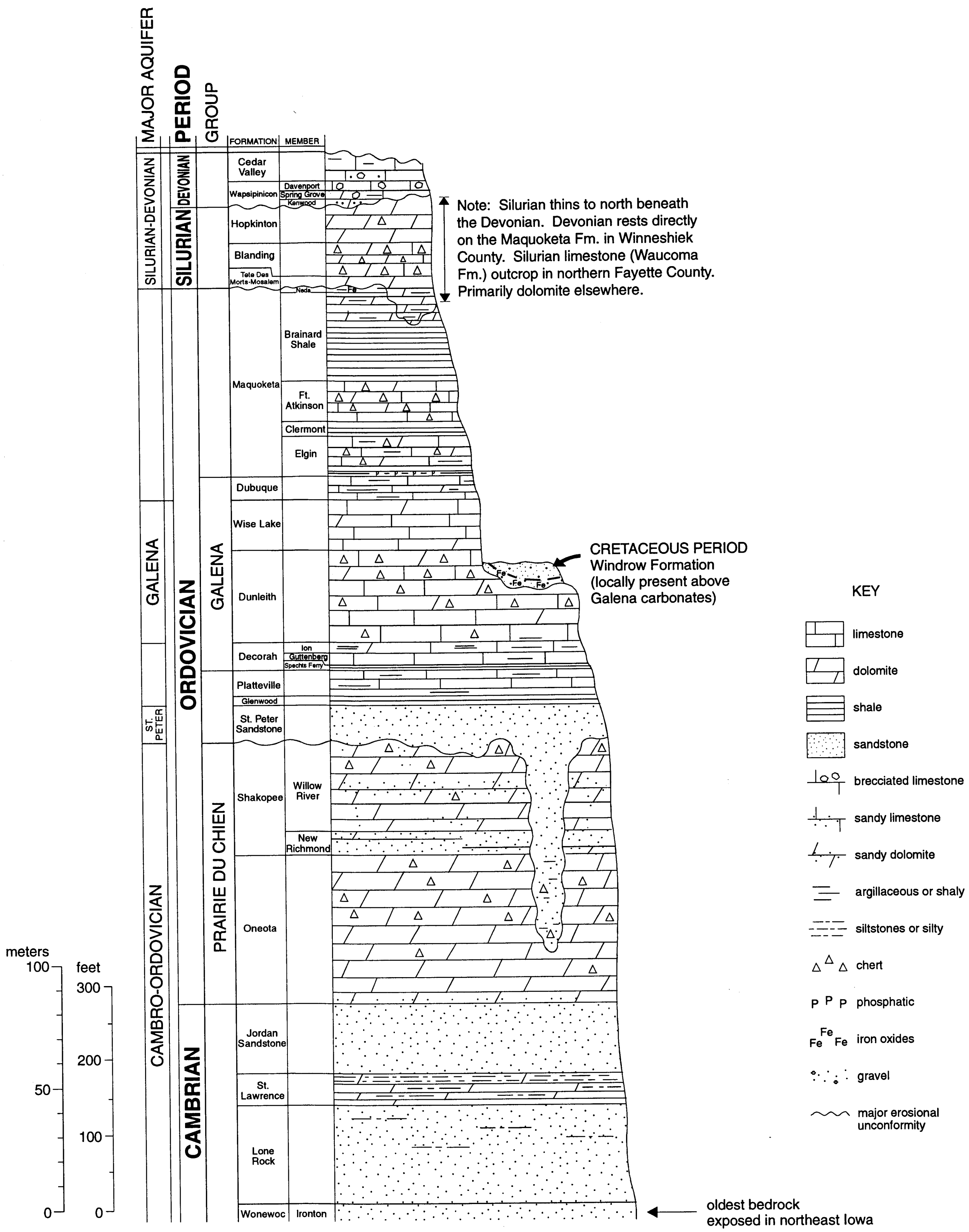


Figure 1. Location of the Big Spring groundwater basin, and the Sny Magill and Bloody Run surface water basins, Clayton County, Iowa.



Note: Silurian thins to north beneath the Devonian. Devonian rests directly on the Maquoketa Fm. in Winneshiek County. Silurian limestone (Waucoma Fm.) outcrop in northern Fayette County. Primarily dolomite elsewhere.

CRETACEOUS PERIOD
Windrow Formation
(locally present above Galena carbonates)

oldest bedrock exposed in northeast Iowa

Figure 2. General stratigraphic column for northeast Iowa (after Hallberg et al., 1983).

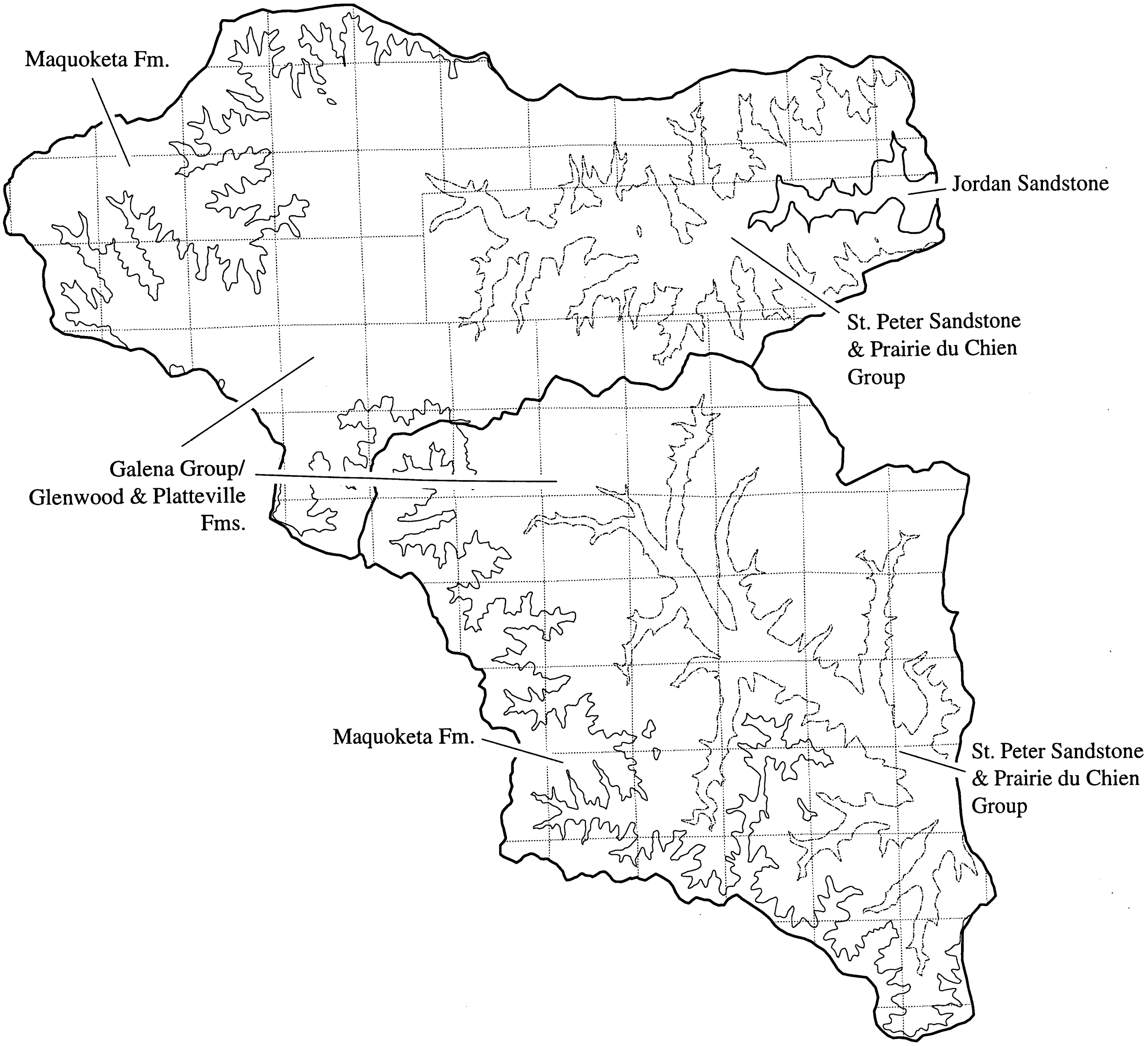


Figure 3. Bedrock geologic map of the Sny Magill and Bloody Run watersheds. Field mapping by G.A. Ludvigson, R.M. McKay, M.J. Bounk, and S.J. Lenker. Squares represent sections. Each section is one square mile. Area in eastern one-half of Bloody Run watershed is Giard Claim.

wall in the upper reaches of the watersheds. The Decorah, Dunleith, Wise Lake, and Dubuque formations form the Galena Group, with all but the Decorah forming the Galena aquifer. Figure 3 is the bedrock geologic map of the area. Contacts mapped include the contact of the Jordan Sandstone Formation with the Prairie du Chien Group/St. Peter Sandstone Formation, the contact of the Prairie du Chien Group/St. Peter Sandstone Formation with the overlying Glenwood and Platteville formations/ Galena Group, and the contact of the Glenwood and Platteville formations/Galena Group with the overlying Maquoketa Formation. The latter contact occurs in the upper reaches of both watersheds.

Water movement through all the carbonate bedrock units is strongly influenced by horizontal bedding planes and regional and local-scale patterns of secondary subvertical fractures or "joints." Bedding planes and fractures are often widened by dissolution of the adjacent carbonate rock. Bedding planes and fractures have widened and interconnected in the Galena Group limestones, and locally some karst features have evolved, allowing local connection of surface water and shallow groundwater within the bedrock aquifer. Solutional enlargement of the bedding planes and fractures has occurred, to a lesser extent, in the carbonate rocks of the Prairie du Chien Group. Detailed studies in the region, including hydrologic observations from monitoring wells have shown that the Platteville-Glenwood-Decorah sequence forms a very effective aquitard between the Galena and the lower St. Peter and Prairie du Chien aquifers (Rowden and Libra, 1990; Libra, 1993).

Quaternary Deposits

A variety of unlithified deposits comprise the surficial deposits in these watersheds (Figure 4; Table 1). The surficial geology was interpreted from the U.S. Department of Agriculture Soil Conservation Service Soil Survey for Clayton County along with field work conducted by the DNR-GSB. The information was transferred to 7.5' topographic maps. Most of these deposits owe their origin to the direct or indirect effects of glacial advances during the last two million years. Thin, reddish brown, cherty "residuum" is often present on the bedrock surface. These deposits are paleosols and transported paleosol-derived sediment. Most include exotic rock fragments derived from pre-Illinoian glacial deposits and clay mineral assemblages related to the glacial deposits and do not appear to represent material directly weathered from the underlying bedrock in large part. These deposits are variable in age and have very small outcrop areas. Where these deposits are buried only by Roxana Silt and Peoria Loess they are referred to as the Sangamon Soil.

Eroded patches of loam-textured pre-Illinoian glacial till are present in restricted areas of the upland. These do not crop out on the modern surface, are usually less than 13 feet (4 m) in thickness, tend to be oxidized and fractured throughout, and do not strongly affect surface topography. These deposits are the erosional remnants of once more extensive till plains that formed during several continental glaciations before 500,000 years ago (Hallberg, 1980). The present topography of the Paleozoic Plateau likely developed after these glaciations.

Peoria Loess is the dominant upland surficial deposit in the watersheds. This deposit is windblown silt that was blown from the major river valleys (such as the Mississippi Valley) between about 21,000 and 12,000 years ago. The Peoria Loess attains its maximum local thickness of about 16 feet (5 m) on broad upland areas, and thins toward the valleys. A thin (usually less than 3 feet (1 m) thick) older loess unit, the Roxana Silt, is sometimes present beneath the Peoria Loess on divides. The Farmdale Soil, marked by a brown organic-enriched zone, is developed in the upper part of the Roxana Silt.

Wedges of colluvium derived from loess, glacial till, and Paleozoic bedrock mantle most steeply sloping valley walls. The colluvium consists of blocky to sandy talus, sometimes supported by a silty and loamy loess- and till-derived matrix. The colluvial wedges tend to be less rocky in hollows at the upper end of the drainage network. Thickness of the colluvial wedges varies downslope and within the drainage basins, ranging from about 3 to 16 feet (1 to 5 m). Most of the colluvium originated

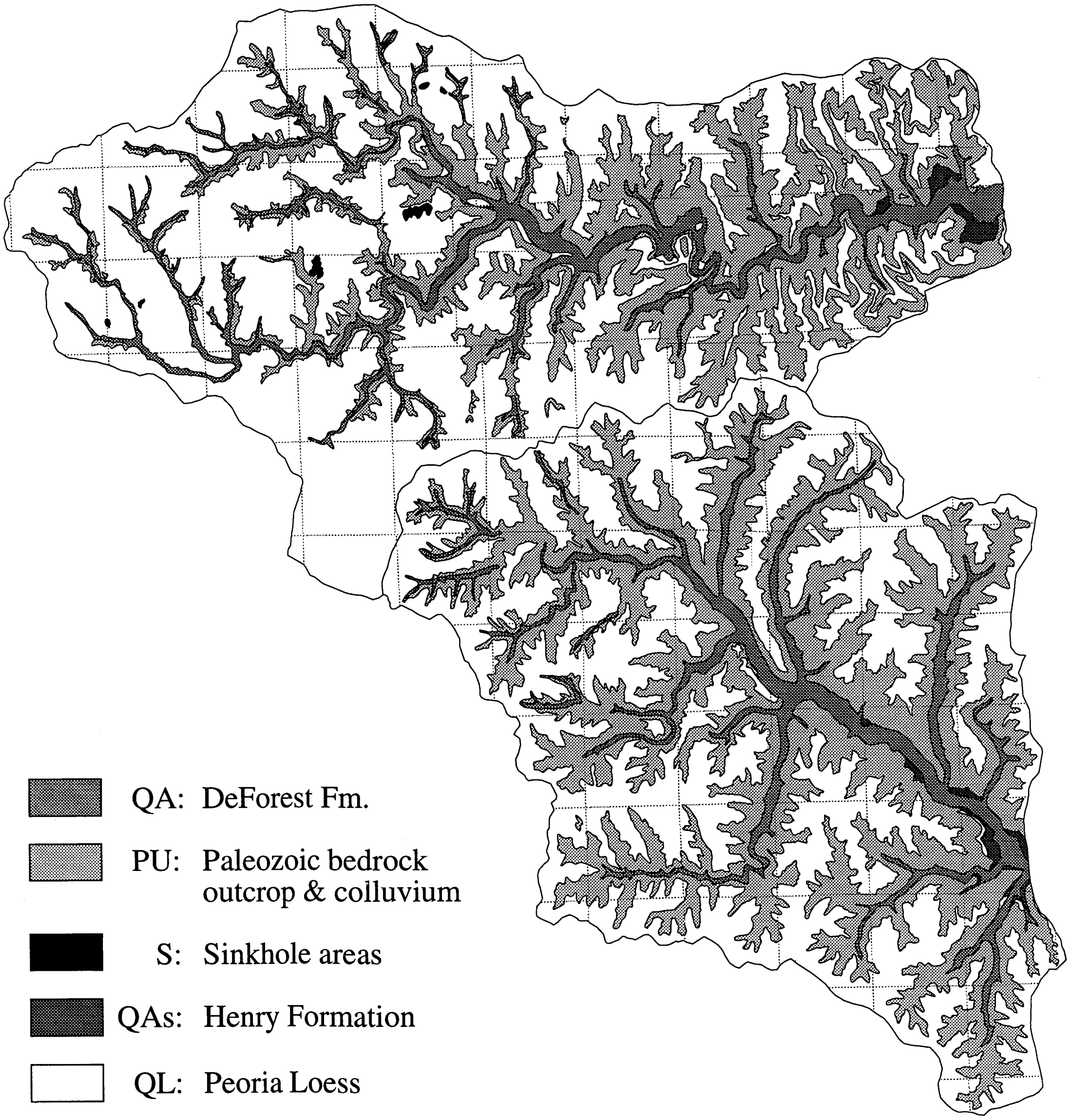


Figure 4. Surficial geologic map of the Sny Magill and Bloody Run watersheds. Squares represent sections. Each section is one square mile. Area in eastern one-half of Bloody Run watershed is Giard Claim.

Table 1. Description of units for surficial geologic map of Sny Magill and Bloody Run watersheds.

QA: Quaternary; Holocene and Late Wisconsinan DeForest Formation.

Alluvial and colluvial deposits underlying terraces, and floodplains, and colluvial slopes descending to low terraces. Dominantly silt loam to loam texture grading downward to basal sandy and gravelly channel deposits. Few areas with sandy loam grading downward to gravel. Colluvial deposits in this mapping unit lack the blocky talus associated with colluvial deposits in the QL and PU map units. Thickness of the alluvial deposits in this unit ranges from one to five meters. Surface soils are Alfisols, Mollisols, and Entisols.

QAs: Quaternary; Late Wisconsinan Henry Formation.

Slack water deposits and tributary valley alluvium underlying the Savanna Terrace. Terrace capped with reddish brown and gray clay and silty clay formed in slack water environments of flooded Mississippi River tributary valleys. Typically the fine-grained stratified clays and silty clays are five to seven meters thick and overlie stratified silt loam and fine to medium sand tributary valley alluvium. The valley-margin side of the terrace may be mantled with a meter or less of silt loam colluvium derived from the valley wall. Surface soils are Alfisols that have high shrink-swell capacity.

QL: Quaternary; Late Wisconsinan Peoria Loess.

Wind-blown eolian deposit, typically silt loam in texture, approximately 10-15 feet (3-4.6 m) thick on upland divides; thins downslope. On slopes includes local slopewash deposits and colluvium, and local outcrops of loam-textured, Pre-Illinoian till and clay-loam to clay textured Sangamon Paleosols. Colluvial areas may include blocks and fragments of bedrock units in a loam to silt loam matrix. Surface soils are dominantly Alfisols.

S: Sinkhole areas.

Areas shallow to carbonate bedrock with abundant closed depressions and small blind valleys; most are filled with slopewash deposits derived from loess and till; local bedrock blocks and bedrock outcrop; few have open conduit into the bedrock. Surface soils are Alfisols.

PU: Paleozoic bedrock outcrop and colluvium.

Local outcrop area of Paleozoic bedrock units; Middle Ordovician Galena Group (Dubuque, Wise Lake, Dunleith, and Decorah formations); Middle Ordovician Platteville, Glenwood, and St. Peter formations; Lower Ordovician Prairie du Chien Group (Shakopee and Oneota formations), and Upper Cambrian Jordan Formation. Often includes thin silty to loamy mantle of colluvial material derived from loess and till upslope. Also includes thick colluvial wedges along steep valley margins. These consist of blocky to sandy talus, sometimes with silty loess-derived inclusions. Surface soils are dominantly Alfisols with some Mollisols on south- and west-facing slopes developed on sandy bedrock units.

---

through mass-wasting processes when periglacial conditions were present in northeastern Iowa during the Wisconsinan glacial maximum between 21,000 and 16,500 years ago. The colluvial wedges have continued to develop since then, but the volume of accumulation has been significantly reduced. Today most activity on the colluvial slopes consists of local remobilization of colluvial deposits by rills, gullies, and shallow debris flows.

Valley Fills

Late-Wisconsinan slack water deposits of the Henry Formation are present in the lower few miles of Bloody Run and Sny Magill valleys (Figure 4). These deposits accumulated between 20,000 and 12,000 years ago as the Mississippi River and its tributaries aggraded in response to sediment and water input by glaciers in the upper part of the Mississippi River basin. The slack water deposits are present beneath a high terrace (the Savanna Terrace) that stands about 50 feet (15 m) above the Holocene floodplain. The gradient of the terrace is flat, and as the floodplain rises in elevation going upstream, the terrace and floodplain merge. The slack water deposits consist of a lower zone comprised of locally derived stratified sand, silt and loam alluvium. This zone gives way upward to a zone of planar bedded gray silt loam, silty clay, and reddish brown silty clay derived from both local and distant Mississippi River basin sources.

Loamy, sandy and silty late-Wisconsinan and Holocene alluvial deposits of the DeForest Formation (Bettis, 1990; Bettis et al., 1992) comprise the alluvial fill inset below the Savanna Terrace and colluvial wedges. The valley floor in these drainage basins exhibits a low terrace and floodplain along the mainstem, and typically just a floodplain along the lower order streams. DeForest Formation deposits are variable in thickness, texture, organic matter content, and degree of pedogenic modification. Studies in the nearby Roberts Creek basin in northwest Clayton County (Big Spring basin) suggest the following distribution pattern of DeForest Formation members. Oxidized Gunder Member alluvium, having surface soils with an A-Bt-BC profile, is found beneath footslopes, toeslopes, and the low terrace along the mainstem, and beneath the floodplain in low-order parts of the drainage network. Darker colored, organic-rich Roberts Creek Member with A-Bw profile surface soils is present beneath a narrow, slightly elevated part of the floodplain that usually parallels the modern channel. The Roberts Creek Member is also found in abandoned channel belts that diverge from the present channel in artificially straightened reaches. In many low-order valleys modern channel erosion has completely removed the Roberts Creek Member. Stratified sandy and loamy Camp Creek Member deposits (post-settlement alluvium) are present in the modern channel belt and beneath levees and splays adjacent to the present channel. Planar bedded to massive silty and loamy Camp Creek Member overbank deposits with A-C surface soil profiles form a veneer of variable thickness across the floodplain that is usually thicker where Roberts Creek Member deposits are subjacent than where the subjacent unit is the Gunder Member. Local, discontinuous Camp Creek Member deposits are present where small gullies and rills cut the lower part of colluvial slopes and Savanna Terraces.

Gravel derived primarily from the local Paleozoic bedrock is present beneath the fine-grained part of the alluvial fill. The gravel rests directly on Paleozoic bedrock. Total thickness of the DeForest Formation ranges from less than 6.6 to over 26 feet (2 to 8 m). The thickest sections are found in the lower reaches of Bloody Run and Sny Magill creeks.

Sinkhole Distribution

Sinkholes occur in both Sny Magill and Bloody Run watersheds. The distribution of sinkholes was transferred from the U.S. Department of Agriculture Soil Conservation Service Soil Survey for Clayton County (Kuehl, 1978). The sinkhole areas are shown in Figure 4. Only sinkhole complexes are mapped and this explains the absence of mapped sinkholes in Sny Magill. Sinkholes do exist in the Sny Magill watershed but not commonly as complexes. The major concentration of sinkholes occurs near the top of the Galena carbonates, often

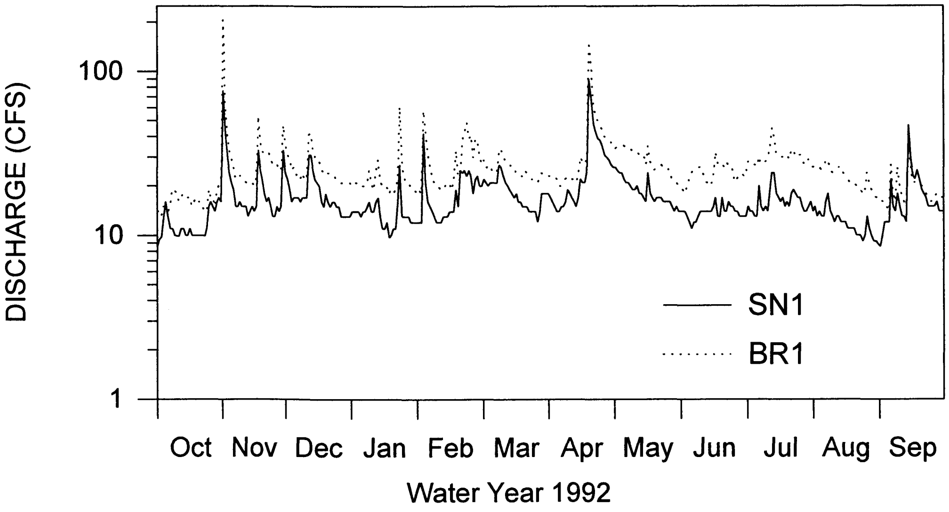


Figure 5. Hydrograph of discharge (in cubic feet per second) from water year 1992 for gage sites on Sny Magill (SN1) and Bloody Run (BR1).

developed at the contact between Galena and the shaly carbonates of the overlying Elgin Member of the Maquoketa Formation. In Bloody Run, the sinkhole complexes comprise less than 0.2% of the acreage in the watershed and are located in the western portion of the watershed.

HYDROGEOLOGIC SETTING

Hydrogeology

Both Sny Magill and Bloody Run creeks receive groundwater baseflow from the Ordovician Galena aquifer. Figure 5 shows a surface water hydrograph (discharge through time) for Sny Magill and Bloody Run for Water Year 1992. A hydrograph has two components: a direct surface runoff component and a groundwater or baseflow component. Analysis of the hydrographs suggests that 78% of the discharge for Sny Magill Creek is groundwater and 80% is groundwater for Bloody Run Creek (Institute of Hydrology, 1980). Streams in other parts of Iowa tend to have lower groundwater baseflow inputs and a greater surface runoff component.

Groundwater and surface water basins are not necessarily one and the same. Surface water basins represent an area drained by a stream and surface water divides are marked by topographic highs. The surface water basins for both Sny Magill and Bloody Run are well defined. The groundwater basin, however, is not as well defined in these two areas. The Big Spring basin, the area to the west of Sny Magill and Bloody Run, is a groundwater basin. Part of the Big Spring basin overlaps the western most part of the Bloody Run surface water basin (Figure 1).

Aquifer Availability

The Galena aquifer is extensively used by residents in Sny Magill and Bloody Run watersheds (see Seigley and Hallberg, this volume). Studies in the Big Spring basin (e.g., Hallberg et al., 1983) have lumped the shales, shaly carbonates, and carbonates of the Glenwood, Platteville, and Decorah formations together for mapping because these units form an aquiclude which separates the St. Peter Sandstone aquifer from the Galena aquifer. The carbonate rocks of the Dunleith, Wise Lake, and Dubuque formations are defined as the Galena aquifer. These three units are comprised of interbedded limestone and dolomites. The Dubuque Formation tends to be well bedded with shaly partings, while the Wise Lake is more massive. The Dunleith tends to be cherty. The average thickness of the rocks of the Galena aquifer in the Big Spring

Table 2. Surficial geology for Sny Magill and Bloody Run watersheds, and for subwatersheds.

	Geologic Units					
	QA: Quaternary DeForest Formation	PU: Paleozoic bedrock/ colluvium	QAs: Quaternary Henry Formation	QL: Quaternary Peoria Loess	S: Sinkhole area	Total
Sny Magill (lowermost) - acres	388	2,148	75	2,288	----	4,899
Sny Magill (lowermost)- % total	7.9	43.8	1.5	46.7	----	100
SN1 - acres	436	1,625	36	1235	----	3,332
SN1- % total	13.1	48.8	1.1	37.1	----	100
SN2 - acres	214	428	0	424	----	1,066
SN2 - % total	20.1	40.2	0	39.7	----	100
SN3 - acres	421	2,218	0	3,433	----	6,072
SN3 - % total	6.9	36.5	0	56.5	----	100
NCC - acres	160	1,227	0	1,881	----	3,268
NCC - % total	4.9	37.5	0	57.5	----	100
SNWF - acres	156	854	0	924	----	1,934
SNWF - % total	8.0	44.2	0	47.8	----	100
SNT - acres	134	896	0	978	----	2,008
SNT - % total	6.7	44.6	0	48.7	----	100
Bloody Run (lowermost) - acres	301	2,20	116	956	0	2,593
Bloody Run (lowermost) - % total	11.6	47.1	4.5	36.9	0	100
BR1 - acres	531	3,159	0	2,758	0	6,448
BR1 - % total	8.2	49.0	0	42.8	0	100
BR2 - acres	775	1,981	0	5,606	25	8,386
BR2 - % total	9.2	23.6	0	66.9	0.3	100
BRSC - acres	521	605	0	5,625	18	6,769
BRSC - % total	7.7	8.9	0	83.1	0.3	100

basin is 220 feet (67 m). The thickness of the Galena aquifer in Sny Magill and Bloody Run watersheds is less since erosion has removed the upper part of the Galena in these watersheds.

Bedrock wells in northeast Iowa often are open to several bedrock units. A well may be 265 feet (81 m) deep but cased down only 52 feet (16 m), and open to the Galena aquifer down through the St. Peter Sandstone. Of the private wells in Sny Magill and Bloody Run inventoried in October 1992, 50% of those wells were Galena wells and 13% were a combination Galena (open to the Galena and bedrock below the Galena; see Seigley and Hallberg, this volume).

The Galena wells had a mean NO_3-N concentration of 13.5 mg/L. The combination Galena wells had a mean NO_3-N concentration of 9.0 mg/L. Wells situated in bedrock other than the Galena aquifer had a mean NO_3-N concentration of 5.8 mg/L.

GEOGRAPHIC INFORMATION SYSTEM STATISTICS

Table 2 summarizes the surficial geology by each water-quality sampling location. These totals are for each subwatershed and are not cumulative (i.e., SN1 does not equal SN1 + SN2 + SN3 + SNT + SNWF + NCC). The drainage areas for most of the sampling locations have 30-50% bedrock (and colluvium) and 35-60% loam or Peoria Loess.

The 1991 landuse for Sny Magill and Bloody Run watersheds was compiled from 1:24,000 scale color infrared aerial photographs taken September 20, 1991. Eleven landuse classes were distinguished by color and pattern differences on the

Table 3. Landuse from 1991 for Sny Magill and Bloody Run watersheds, and for subwatersheds.

	Landuse Classes					
	Row Crop (for cropland)	Cover crop, pasture	Forest, forested pasture	Farmstead	Other	Total
Sny Magill (lowermost) - acres	5,842	5,400	11,034	263	28	22,567
Sny Magill (lowermost)- % total	25.9	23.9	48.9	1.2	0.1	100
SN1 - acres	4,871	4,538	8,022	207	28	17,666
SN1- % total	27.6	25.7	45.4	1.2	0.2	100
SN2 - acres	4,011	3,809	6,314	171	28	14,334
SN2 - % total	28.0	26.6	44.1	1.2	0.2	100
SN3 - acres	1,552	2,374	2,017	89	26	6,058
SN3 - % total	25.6	39.2	33.3	1.5	0.4	100
NCC - acres	1,093	387	1,764	25	0	3,269
NCC - % total	33.4	11.8	54.0	0.8	0.0	100
SNWF - acres	431	364	1,124	15	0	1,934
SNWF - % total	22.3	18.8	58.1	0.8	0.0	100
SNT - acres	795	426	752	34	2	2,009
SNT - % total	39.6	21.2	37.5	1.7	0.1	100
Bloody Run (lowermost) - acres	9,344	6,909	7,171	415	376	24,215
Bloody Run (lowermost) - % total	38.6	28.5	29.6	1.7	1.6	100
BR1 - acres	9,061	6,436	5,553	403	167	21,621
BR1 - % total	41.9	29.8	25.7	1.9	0.8	100
BR2 - acres	7,842	4,814	2,000	337	167	15,160
BR2 - % total	51.7	31.8	13.2	2.2	1.1	100
BRSC - acres	3,948	2,050	416	192	167	6,773
BRSC - % total	58.3	30.3	6.2	2.8	2.5	100

photography: 1) water, 2) cover crop, 3) farmstead, 4) forest, 5) row crop, 6) permanent pasture, 7) terraced cover crop, 8) terraced row crop, 9) terraced strip crop, 10) strip crop, and 11) urban. The landuse classes were originally delineated by hand on the color infrared aerial photographs and then transferred to 7.5' topographic base maps. The data was then digitized into the Department of Natural Resources' (Geological Survey Bureau) Geographic Information System. The data was then summarized by water-quality sampling locations (Table 3).

The landuse numbers represent cumulative totals for each site (i.e., SN1 = drainage from all subwatersheds above SN2 plus subwatershed between sites SN2 and SN1). The original eleven categories were consolidated into five categories: 1) row crop (for cropland), 2) cover crop, pasture, 3) forest, forested pasture, 4) farmstead, and 5) other. *Row crop* includes the original categories of row crop, terraced row crop, and 50% of the terraced strip crop and 50% of the strip crop areas. *Cover crop/pasture* includes cover crop, permanent pasture, terraced cover crop, and 50% of terraced strip crop and 50% of strip crop. The category *other* includes water and urban areas. *Water* represents ponds and does not include streams such as Sny Magill Creek. All areas designated as row crop were planted in corn. Figures 6 and 7 are the 1991 landuse maps for Sny Magill and Bloody Run watersheds.

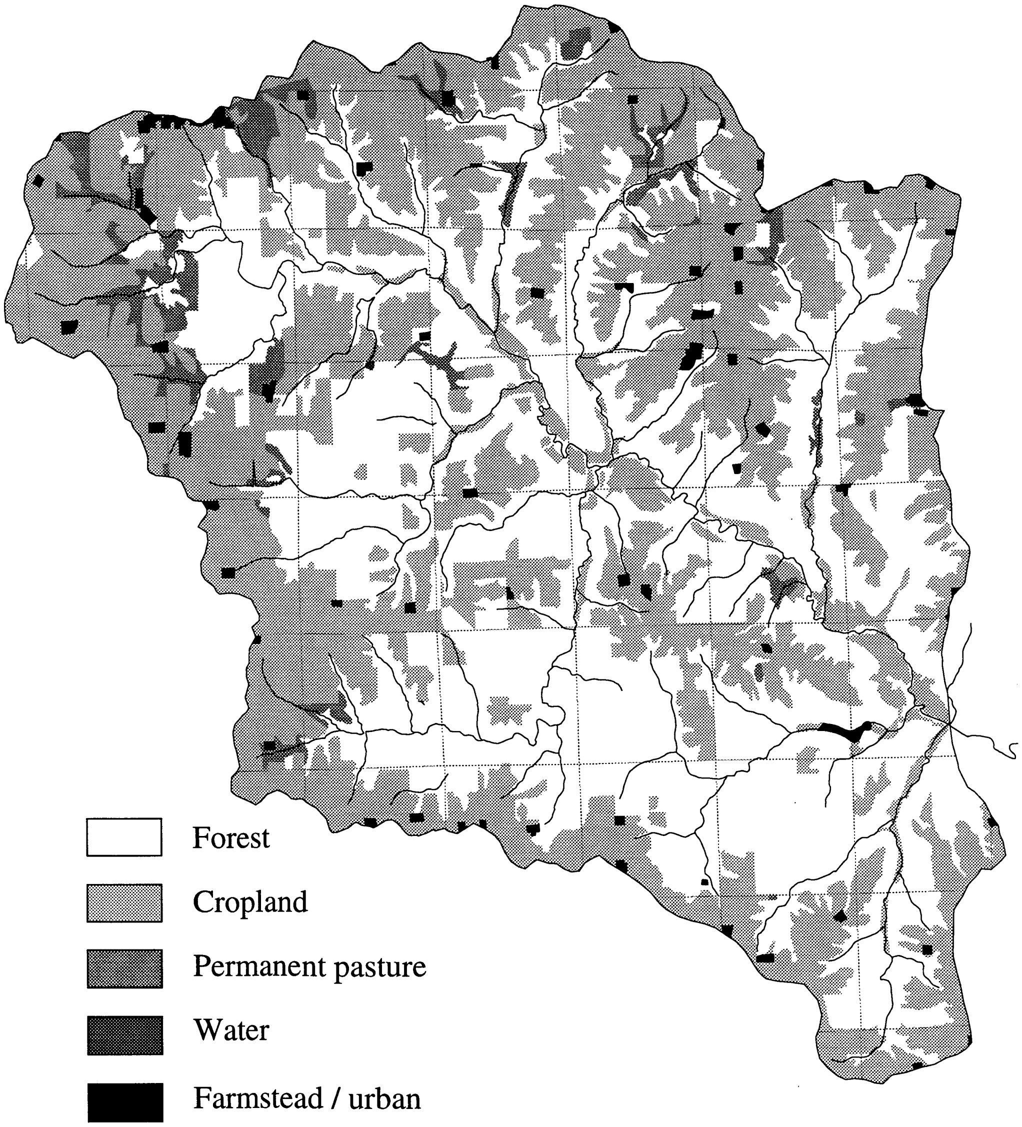


Figure 6. Landuse from 1991 for Sny Magill watershed. Squares represent sections. Each section is one square mile.

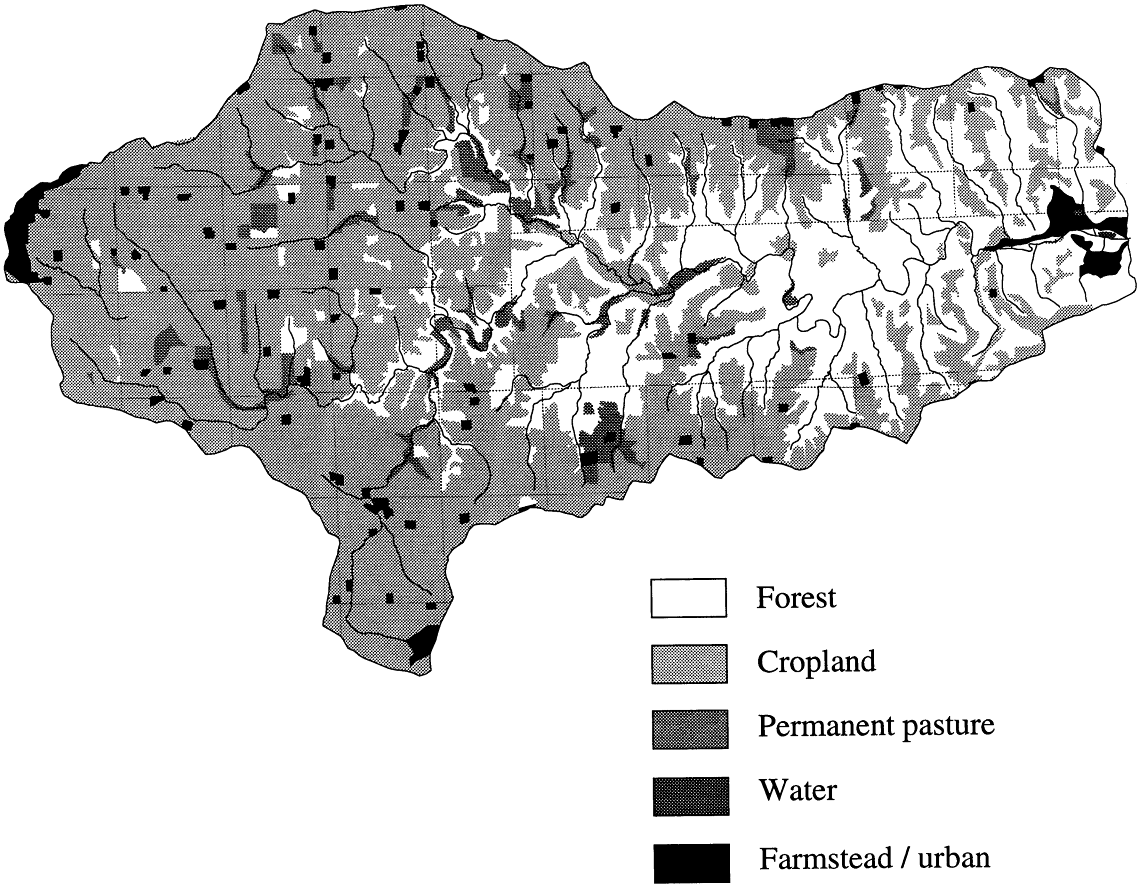


Figure 7. Landuse from 1991 for Bloody Run watershed. Squares represent sections. Each section is one square mile. Area in eastern one-half of Bloody Run watershed is Giard Claim.

Table 4. Livestock numbers for 1991 for Sny Magill and Big Spring watersheds based on initial questionnaires. n= number of farms.

		Sny Magill (a)	Mean per		Big Spring within NEIDP (a)	
	n	range	farm	n	range	mean
Swine (# marketed in 1991)						
farrow -to- finish	13	100 - 1,800	1,012	29	56 - 5,000	1,112
feeder -to -finish	3	20 - 800	357	20	120 - 5,000	1,008
feeder pigs	4	10 - 2,400	930	8	250 - 2,400	948
Beef						
stock cows	19	7 - 100	42	20	10 - 100	41
feedlot steers/ heifers	10	12 - 550	81	31	5 - 371	81
replacement heifers	10	1 - 20	9	8	5 - 40	15
Dairy						
milking herd	10	31 - 73	53	43	20 - 130	58
replacement heifers	10	5 - 60	30	41	10 - 112	42
Sheep						
ewe flock	2	7 - 17	12	3	7 - 40	23
lambs marketed at weaning	2	10	10	1	10	10
feeder lambs	1	18	18	2	16 - 35	26
Poultry						
egg layers	1	6	6	3	30 - 50,000	16,703
broilers	0	--	--	1	30	30
turkeys	0	--	--	0	--	--
Other	0	--	--	0	--	--

(a) Questionnaire for Sny Magill had 74% response rate and 64% response rate for Big Spring questionnaire.

Source: Iowa State University Extension (1992a and 1992b).

LIVESTOCK INFORMATION

Iowa State University Extension conducted a survey in March 1991 of Sny Magill watershed residents, and residents of the Big Spring basin who also are included in the Northeast Iowa Demonstration Project (NEIDP). The NEIDP is funded through the agencies of the U.S. Department of Agriculture as part of the Water Quality Initiative program. The NEIDP includes the northwest corner of Clayton County. The survey was to gather information on fertilizer rates and practices, tillage practices, record keeping, livestock inventory and manure management, and water issues and farmstead management. Table 4 summarizes the livestock numbers for 1991 for both Sny Magill and the Big Spring area in the NEIDP. Mean values for the number of animals within the two watersheds is fairly comparable. Only the category egg layers under poultry shows a large difference. Thirty-four residents responded to the Sny Magill survey. All of the respondents reported some livestock, 56% reported beef, 38% swine, and 29% reported dairy. Table 5 summarizes the livestock numbers for 1990 for Clayton County.

SUMMARY

The Sny Magill and Bloody Run watersheds are underlain by Paleozoic age bedrock, ranging in age from Upper Cambrian through Upper Ordovician. Lithologies include sandstones, sandy dolostones,

Table 5. Livestock numbers for 1990 for Clayton County.

All cattle & calves	115,000
Beef cows	20,500
Milk cows	32,000
Grain fed cattle marketed	13,500
Sows farrowed & marketings	(per 1000 head)
Hogs & pigs on farm	270
Total sows farrowed	64.2
Total pigs saved	510
Hogs marketed	452
All cows	52,500
All calves	50,000
All sheep & lambs inventory	1900
All sheep & lambs marketings	1000
Poultry	no information
Other	no information

Source: Skow and Holden (1990).

dolostones, shales, shaly carbonates, and limestones. Dissolution along bedding planes and fractures in some carbonate bedrock units has caused some karst development. Sinkhole areas comprise less than one percent of the acreage in both watersheds. Surficial deposits in the upland areas of the watersheds include glacial tills, paleosols, and loess deposits. Slack water and sandy and silty alluvial fills occur in the valleys. Five landuse classes were mapped on 1991 aerial photography for both watersheds. Sny Magill watershed was comprised of 26% row crop and 49% forest/forested pasture, and 39% of the Bloody Run watershed was in row crop and 30% in forest/forested pasture.

ACKNOWLEDGMENTS

Wazir Khan assisted in the development of the surficial geologic map. Pat Lohmann helped prepare several of the graphics in this report.

REFERENCES

Bettis, E.A., III, 1990, Holocene alluvial stratigraphy of western Iowa, *in* Bettis, E.A., III (ed.), Holocene alluvial stratigraphy and selected aspects of the Quaternary history of western Iowa: Midwest Friends of the Pleistocene Field Trip Guidebook, p. 1-72.

Bettis, E.A., III, Baker, R.G., Green, W.R., Whelan, M.K., and Benn, D.W., 1992, Late Wisconsinan and Holocene alluvial stratigraphy, paleoecology, and archaeological geology of east-central Iowa: Iowa Department of Natural Resources, Geological Survey Bureau, Guidebook Series No. 12, 82 p.

Hallberg, G.R., 1980, Pleistocene stratigraphy in east-central Iowa: Iowa Geological Survey Technical Information Series no. 10, 168 p.

Hallberg, G.R., Hoyer, B.E., Bettis, E.A., III, and Libra, R.D., 1983, Hydrogeology, water quality, and land managment in the Big Spring basin, Clayton County, Iowa: Iowa Geological Survey Open File Report 83-3, 191 p.

Hallberg, G.R., Bettis, E.A., III, and Prior, J.C., 1984, Geologic overview of the Paleozoic Plateau Region of northeastern Iowa: Proceedings of the Iowa Academy of Science, v. 91, p. 5-11.

Hoyer, B.E., Bettis, E.A., III, and Witzke, B.J., 1986, Water quality and the Galena Group in the Big Spring area, Clayton County: Geological Society of Iowa Guidebook 45, 34 p.

Institute of Hydrology, 1980, Low flow studies: Report No. 3, England.

Iowa State University Extension, 1992^a, Sny Magill Project: baseline questionnaires: May 1992, 12 p.

Iowa State University Extension, 1992^b, Big Spring respondents withing Northeast Iowa Demo Project: baseline questionnaires: June 1992, 12 p.

Kuehl, R.J., 1978, Soil survey of Clayton County, Iowa: U.S. Department of Agriculture, Soil Conservation Service, 358 p.

Libra, R.D., 1993, A case of extremely low matrix permeability, or still waiting for the recovery: abstract from the 38th Annual Groundwater Conference, Champaign, IL, p. 17.

McKay, R.M., 1993, Selected aspects of Lower Ordovician and Upper Cambrian geology in Allamakee and northern Clayton counties: Geological Society of Iowa Guidebook 57, 61 p.

Prior, J.C., 1991, Landforms of Iowa: University of Iowa Press, Iowa City, 154 p.

Rowden, R.D., and Libra, R.D., 1990, Hydrogeologic observations from bedrock monitoring well nests in the Big Spring basin: Iowa Department of Natural Resources, Geological Survey Bureau, Open File Report 90-1, 27 p.

Seigley, L.S., and Hallberg, G.R., 1994, Water quality of private water supplies in Sny Magill and Bloody Run Watersheds: this volume.

Skow, D.M., and Holden, H.R., 1990, 1990 Agricultural statistics: Iowa agricultural statistics: Iowa Department of Agriculture and Land Stewardship, and the U.S. Department of Agriculture, 112 p.

Iowa Department of Natural Resources, Geological Survey Bureau
Technical Information Series 32, 1994

PALEOZOIC PLATEAU EROSION PERSPECTIVE

E.A. Bettis III

Iowa Department of Natural Resources, Geological Survey Bureau
109 Trowbridge Hall
Iowa City, IA 52242-1319

ABSTRACT

Geological and historical records provide a long-term perspective on the impact of agricultural landuse on soil erosion and sediment movement in the Paleozoic Plateau. Uplands were most affected by erosion in the late 1800s and early 1900s before the implementation of soil conservation measures, while streams continue to be adversely affected because of delayed movement of sediment through the drainage network. A drainage-system-wide perspective on the soil erosion and sedimentation issue provides a clearer view of the potential outcome of land-management practices across the entire landscape.

INTRODUCTION

The Upper Mississippi River basin is the agricultural "heart" of the nation. Most of the country's grain and livestock are produced in this region, and a large percentage of the total land area is in agricultural use. This pattern of intensive agricultural landuse began in the late nineteenth century and reached a peak around the turn of the century, with only slight changes in the total percentage of land in farms since then.

Conversion of the original mosaic of prairie, savanna, and forest to pasture and cropland brought about dramatic changes in soil properties, runoff relationships, erosion, sediment delivery, stream behavior, and water quality. The impacts of these landscape changes on the region's biota were profound- catastrophic in many cases.

This paper briefly summarizes the chronology and impacts of agricultural landuse in the Paleozoic Plateau region on the Upper Mississippi River basin. This paper focuses on soil erosion and its effects on stream behavior and water quality, and will provide an evaluation of the success of soil conservation programs on a landscape scale. By combining geological and historical perspectives we are able to better understand the routing of sediment through the drainage system, and its consequences with respect to long-term erosion and sediment control.

A PERSPECTIVE ON THE FLUVIAL SYSTEM

The fluvial system encompasses the surface and near surface pathways that water and associated sediment and solutes follow on their journey to lakes or the sea. Traditionally, these are grouped into surface water (flowing at the surface) and groundwater (flowing beneath the surface). All but a small percentage of the sediment moving through the fluvial system is associated with surface water, while groundwater can carry significant amounts of solutes. In the Paleozoic Plateau region of the Upper Mississippi River basin groundwater contributes significant baseflow to streams, resulting in the generally low suspended sediment and temperature conditions characteristic of the area's small streams.

Surface water passes across the soil surface and into a channel network. In doing so it transports variable amounts of solutes and sediment. Solutes tend to travel with the water, while sediment spends most of its time stored at various locations in valleys. The location(s) and duration of sediment storage are aspects of the fluvial system rarely considered when implementing and evaluating soil conservation measures, yet they have profound influences on the long-term effects of those measures in the riparian zone.

Systems consist of a group of units that form a whole. In the case of the fluvial system the various surface and subsurface water, solute, and sediment pathways combine to form a transfer network. Behavior of one part of the system influences the other parts through a number of feedback loops. The system constantly adjusts to changes in sediment and water supply produced by external forces such as rainfall and landuse, and internal factors such as sediment storage.

The ultimate driving force of the fluvial system is climate because precipitation is a prerequisite for both infiltration (recharge) and runoff. Climate change and weather patterns have resulted in changing runoff and erosion relationships through time over and above those produced by human activity. Even before the landscape was dramatically altered by Historic landuse changes, feedback loops involving climatic and weather variations, vegetation, runoff, erosion, sediment delivery, transport and storage kept the system from reaching a steady state where runoff, recharge, and sediment input were in adjustment and the fluvial system was unchanging. The fluvial system, then, is historical in nature. Its behavior at a point in time, especially with regard to sediment supply, channel pattern, and channel slope is conditioned by what has occurred in the past. Similarly, the response of the system to a change in any variable depends on preexisting conditions.

Another important aspect of the fluvial system is the scale-dependent nature of factors that influence the system's behavior. A classic paper on the topic concluded that the relative importance of fluvial system variables depends on the temporal and areal scales considered (Schumm and Lichty, 1965). As an example, consider soil erosion and its relationship to rainfall. When viewed on a daily scale soil erosion by runoff is completely dependent on rainfall. If no rainfall occurs soil erosion does not take place. If we are concerned with the relationship over the course of a year, however, we see that other factors such as the yearly change in vegetation cover, weather patterns, and antecedent moisture conditions also come into play. Relationships among rainfall, runoff, and soil erosion are not as straightforward at this larger scale and factors other than rainfall may control runoff and soil erosion.

THE PALEOZOIC PLATEAU

The Paleozoic Plateau region occupies the northeastern corner of Iowa and adjacent portions of Minnesota, Wisconsin, and Illinois. Much of this area was formerly referred to as the "Driftless Area," but recent studies have shown that all but a portion of southwestern Wisconsin and adjacent northwestern Illinois have been glaciated (Hallberg et al., 1984). The region is a dissected plateau with local relief ranging from 115 up to about 500 feet (35 to 150 meters), moderately sloping uplands, steep valley slopes, and narrow, deeply entrenched valleys. Relatively flat-lying sedimentary bedrock exerts a profound influence on the shape of the land in the area. In Iowa, Minnesota, and Illinois resistant carbonates (limestone and dolomite) and weak shales are dominant, while coherent to very friable sandstone and carbonates dominate the sequence in Wisconsin. Uplands and gentle to moderate slopes are mantled with a variable thickness of easily eroded loess underlain by weathered glacial deposits or rock. Thick wedges of blocky talus in a silty or sandy matrix occur on lower parts of steep valley slopes below rock outcrops. The valleys contain a series of alluvial terraces that record several periods of aggradation during the last 30,000 years.

At the time of Euroamerican settlement the area was occupied by a complex mosaic of vegetation (Davis, 1977). The vegetation mosaic was fostered by a wide array of edaphic conditions and differences in fire disturbance controlled by the geology (Chumbley, 1988). Broad upland areas harbored tall-grass prairie that gave way to oak savanna on narrower uplands and more sloping areas. Deciduous forests occupied valley slopes, except for steep, south and west facing slopes in large valleys, where "goat prairies" occurred. The narrow valleys were usually forested, but prairies were found on some sandy terraces in the larger valleys.

The picture of pre-agriculture water quality is not as clear as that of the vegetation. A few early explorers such as Lieutenant Zebulon Pike (1805-1806) and Major Stephen Long (1817) commented on the extreme clarity of the Mississippi River, and we can probably assume this reflected similar conditions in the tributary streams (Scarpino, 1985). By the 1890s habitat changes were observed that adversely affected fisheries in Iowa and northern Illinois (Meek, 1892), supporting the picture of low sediment content and less fluctuating flows prior to settlement. Insect remains collected from stream sediments deposited just prior to early Historic clearing and cultivation in the western part of the Paleozoic Plateau indicate that the stream had trout-stream water quality, with alternating rocky riffles and pools bordered by muddy banks and zones of marsh-associated plants (Baker et al., 1993).

IMPACTS OF EUROAMERICAN AGRICULTURAL SYSTEMS ON THE PALEOZOIC PLATEAU

Before 1850 the impact of agricultural landuse was slight in the Paleozoic Plateau. The population density was low and focused along the Mississippi Valley. The agricultural system was subsistence gardening and grazing, consisting of little more than Indian corn, potatoes, and small pastures for horses, sheep, cattle, and swine (Vogel, 1988). In the mid-1800s the pace of economic growth quickened as the transportation infrastructure, farming equipment, and methods improved. With these improvements the farm-based population expanded rapidly and a shift to cash crops occurred. By the 1850s and 60s most farmers were planting a large percentage of their acreage in spring wheat, with corn, oats, barley, sorghum, and rye serving as supplemental cash crops. At the turn of the century, depressed wheat prices pushed corn to prominence among the cash crops in the region. Livestock raising, originally confined largely to hogs, increased to an industry of major proportions after the Civil War. With this transformation much of the grain formerly sold as cash crops was fed to livestock and marketed as beef, pork, mutton, and dairy products. A dramatic increase in pasture acreage, both unimproved forest and prairie as well as timothy and alfalfa, accompanied the burgeoning livestock and dairy industry.

Erosion control was not on the agenda during the agricultural revolution of the nineteenth and early twentieth centuries. Characteristically fields were plowed up and down the slope, steep slopes were cultivated, crop rotations were few and poor, cover crops were nonexistent, and pastures were overgrazed. After a few decades of this landuse the fluvial system witnessed changes greater than those of the preceding 10,000 years.

The impact of nineteenth and early twentieth century agricultural landuse on soil erosion and stream behavior has been studied in several parts of the Paleozoic Plateau (Baker et al., 1993; Knox, 1977; 1987; Trimble, 1983; Trimble and Lund, 1982). During the 1850s and 1860s agriculture was in a developmental phase and effects on the fluvial system were local in nature, in line with the limited extent of agricultural landuse. Soils in the region had good tilth, relatively high organic matter content, and moderate to high infiltration capacity after the initial cultivation. These properties retarded runoff, and for a time, severe soil erosion was probably not widespread.

As the amount of land under cultivation increased, and wheat and corn became the dominant crops, fields of increasing size were exposed to the full force of spring rainfall and runoff. After a few years of these conditions erosion had usually removed the upper, humus rich parts of soils, less permeable subsoil was exposed, and a vicious cycle of increasing runoff, rilling, and soil erosion moved into full swing. This marked the beginning of a period of large-scale environmental degradation that continued through the 1940s.

Sheet and rill erosion removed massive amounts of material from upland margins and valley slopes. This sediment overwhelmed the system and most of it was stored as colluvium at the base of steep slopes, in small alluvial fans, and as overbank sediment on floodplains (Carman, 1909; Trowbridge and Shaw, 1916; Trimble, 1983; Beach, 1994). Valley-side rills expanded into gully networks that increased the volume of runoff entering the channel network and allowed sediment eroded from the uplands to directly enter the channel network during runoff events (Knox, 1987). Dramatic increases in flood frequency and peak flood height accompanied the increased runoff and floodplains and low terraces were rapidly buried with a mantle of post-settlement alluvium.

By the 1920s stream channels in small valleys began to adjust to the changed hydrologic conditions. Frequent overbank flooding progressively increased channel bank heights and as a result, the erosive energy within the channel increased. This promoted accelerated lateral channel erosion, and new floodplains began to develop at lower levels in the wake of the migrating channels (Knox, 1987; Baker et al., 1993). Early Historic floodplains thus became low terraces subject to less frequent flooding as their cross-sectional area increased to the point where they contained most floods.

Trimble and Lund (1982) concluded that most of the rapid floodplain sedimentation in the drainage system of Coon Creek (southwestern Wisconsin) occurred during the 1930s. Studies elsewhere in the Paleozoic Plateau, however, indicate that rapid aggradation affected upper parts of the drainage network much earlier (Carman, 1909; Trowbridge and Shaw, 1916). When hydrologic response (channel migration and construction of a new, lower floodplain) occurred in the upper part of the drainage system beginning about 1920, the sediment eroded during channel migration was added to that already entering the network from slope, rill, and renewed gully erosion (Knox, 1987). This increased the downstream transport of sediment and water and boosted flood frequency in lower parts of the drainage network. As a result, aggradation of floodplains (sediment storage) in larger valleys was delayed relative to that in small valleys.

Floodplain aggradation rates also varied from tributary to main valley. Knox (1987) found that sedimentation rates during the period 1860 to 1940 were significantly higher in the main stem than in tributaries of the Galena River basin. Observations in other basins of the Paleozoic Plateau confirm this overall observation; the thickness of post settlement alluvium tends to be significantly greater in main stem valleys than in tributaries (Bettis, 1984; Hudak, 1987; Beach, 1994). On the other hand, small valleys account for a much larger total area of the drainage network than do large valleys, and therefore large amounts of Historic sediment are stored in this part of the drainage network. Beach (1994) determined the historic sediment budget of two drainage basins in the Paleozoic Plateau of southeastern Minnesota and found that about 24% of the sediment eroded from upland sites during the Historic period is stored in valleys smaller than third-order. He also found that about 15% of the Historic sediment is stored as colluvium at the base of steep valley wall slopes and that storage in large tributary valleys is strongly influenced by valley width and location relative to the Mississippi Valley. Storage is greatest in tributaries closest to the Mississippi Valley where the gradient is low and backwater effects are greatest.

In the early 1930s, the Coon Creek basin in southwestern Wisconsin was designated as the nation's first Soil Erosion Control Demonstration Area. The demonstration project instituted widespread structural control and land treatment measures. Improved land management included contour tillage and strip cropping, various longer rotations with cover crops, and incorporation of manure and crop residues into the soil. By the late 1960s a large percentage of the basin's agricultural land was under some form of erosion control measure and conservation tillage was being introduced (Trimble and Lund, 1982). Aggregate landuse was about the same as during the period of intensive erosion in the 1920s and 1930s; the amount of land in row crops, cover crops, and pasture had changed little, but agricultural land management had improved.

Calculations by Trimble and Lund (1982) suggest that soil erosion decreased by about 80% between 1934 and 1975 as a result of improved land management in the Coon Creek basin. The extensive gully network was also nearly eliminated by the late 1970s (Fraczek, 1978). The combination of less soil and gully erosion dramatically decreased the amount of sediment reaching the drainage network. Comparing the periods 1936-45 with 1962-75, Trimble and Lund (1982) found dramatic decreases in sediment deposition rate in the basins behind small erosion control structures. Although changes in trap efficiency produced by sediment accumulation make the magnitude of the sedimentation rate changes suspect, the results still show that much less sediment was being delivered to the upper part of the drainage network after soil conservation measures were implemented.

Adoption of erosion control practices spread outward from the Coon Creek basin to a large portion of the Paleozoic Plateau. The scale of soil erosion reduction has probably been similar over much of the area, though the rates are still greater than before settlement and conversion to agricultural landuse (Knox, 1987; Baker et al., 1993). Changing land management has also had impacts on catchment-scale hydrology in the region. Analysis of gage records from the East Branch of the Pecatonica River in southwest Wisconsin (drainage area 221 m^2; 572 km^2) shows that since 1940 floods of all seasons have decreased, and rise times of all events and baseflow have increased (Potter, 1991). These changes indicate that runoff has decreased and infiltration increased. There are no major hydraulic structures in the catchment, no major change in landuse, and no significant trends in relevant climatic parameters over the period of record. Hence the hydrologic changes seem to be related to adoption of various soil and water conservation measures. Potter (1991) concludes that with respect to rise time and flood peaks, the treatment of gullies seems to be the critical factor, while the adoption of conservation tillage is the most important variable with respect to the decrease of winter/spring flood volumes and the observed baseflow increases.

DISCUSSION

It is clear that soil conservation programs have been successful in curtailing the large-scale environmental degradation caused by soil erosion and sedimentation effected by poor land treatment prior to the 1940s. What is not so clear are the effects that the vast amount of sediment stored in valleys during the period of severe soil erosion will have on the behavior of streams and the quality of their water in years to come. Field cases discussed above, laboratory simulations, and theoretical considerations all indicate that sediment is transported episodically through the drainage network. Presently, large volumes of post-settlement alluvium are in storage in the drainage system. The bulk of this sediment is stored in a two tier-fashion: on floodplains of large to moderate-size valleys and in upper parts of the drainage network, including colluvial slopes along valley margins. During the 1930s large-scale remobilization of sediment temporarily stored on floodplains and colluvial slopes of small tributary valleys resulted in gullying, active lateral channel erosion and widening in the tributaries, and increased flood frequency and aggradation of floodplains in lower parts of the drainage network (Happ, 1944; Trimble and Lund, 1982).

Although the rate of sediment remobilization and transport down the drainage system has been significantly reduced by the direct and indirect effects of improved land management on runoff, infiltration, and soil erosion, we cannot ignore the fact that the amount of historical sediment stored in the system represents a condition of instability (Knox, 1987; Trimble, 1983; Womack and Schumm, 1977). Beach (1994) concluded that in three southeastern Minnesota watersheds no less than 87, 56, and 63.5 percent of all sediment eroded from uplands during the Historic period still resided in the watersheds. This recent sediment is inherently more unstable than prehistoric sediment because it lacks the aggregate stability attained by the latter during centuries/millennia of pedogenesis. Evidence that significant amounts of sediment are still moving through the drainage network is provided by sedimentation occurring in the channel and backwater system of the Mississippi Valley and some of its tributaries.

Sedimentation studies in Pool 19 of the Mississippi River (between Keokuk, Iowa and Hamilton, Illinois) show typical relationships: a high initial rate of sedimentation followed by a decreasing rate (Bhowmik and Adams, 1989). The timing of the initial sedimentation period in Pool 19 (1913-1930) is probably a little earlier than in other Upper Mississippi River pools because the Keokuk dam was originally constructed for hydroelectric purposes about seventeen years before the rest of the lock-and-dam navigation system between Alton, Illinois and the Twin Cities was installed. From 1950 to 1979, Pool 19 lost 20 percent of its original volume as a result of sedimentation, with the loss of an additional 25 percent predicted by the year 2050 (Bhowmik and Adams, 1989). This sedimentation has caused successional change and loss of open water and submerged habitats, and is converting the original slough- and backwater-dominated Upper Mississippi Valley into a single channel system bordered by a low, moist floodplain.

The implications are clear: the large quantity of Historic sediment stored in the drainage network of the Paleozoic Plateau pose a great threat of remobilization during major landuse change, climate and vegetation change, or by a complex fluvial response. Though soil conservation efforts have been effective at mitigating erosion on uplands, our understanding of, and ability to predict sediment storage and flux in valleys is meager. This is an area of investigation that deserves immediate attention because off-site costs of erosion (sedimentation, water pollution, dredging, etc.) may be at least on a par with on-site costs (decreased fertility). A drainage-system-wide perspective is needed to determine the sources, sinks, and landscape linkages that control sediment flux in the Paleozoic Plateau. This perspective will allow for more reasoned approaches to controlling and/or allowing for sedimentation in various environments of the valley landscape.

REFERENCES

Baker, R.G., Schwert, D.P., Bettis, E.A., III, and Horton, D.G., 1993, Impact of Euro-American settlement on a riparian landscape in Midwestern USA: an integrated approach based on historical evidence, floodplain sediments, fossil pollen, plant macrofossils, and insects: The Holocene, v. 3, no. 4, p. 313-323.

Beach, T., 1994, The fate of eroded soil: sediment sinks and sediment budgets of agrarian landscapes in southern Minnesota, 1851-1988: Annals of the Association of American Geographers, v. 84, no. 1, p. 5-28.

Bettis, E.A., III, 1984, Preliminary investigations of the stratigraphy and chronology of northeast Iowa alluvium with special reference to the Turkey River basin: Report submitted to the Iowa State Historical Department, Division of Historic Preservation.

Bhowmik, N.G., and Adams, J.R., 1989, Successional changes in habitat caused by sedimentation in navigation pools: Hydrobiologica v. 176/177, p. 17-27.

Carman, J.E., 1909, The Mississippi Valley between Savanna and Davenport: Illinois State Geological Survey Bulletin 13, Urbana.

Chumbley, C.A., 1988, Late glacial and Holocene vegetation, *in,* Green, W. (ed.), Archeological and paleoenvironmental studies in the Turkey River Valley, northeastern Iowa,: Research Papers 13 (1), Office of the State Archeologist, Iowa City, p. 74-109.

Davis, A.M., 1977, The prairie-forest ecotone in the upper middle west: Annals of the Association of American Geographers, v. 67, p. 204-213.

Fraczek, W., 1978, Assessment of the effects of changes in agricultural practices on the magnitude of floods in Coon Creek watershed using hydrograph analysis and airphoto interpretation: M.S. thesis, University of Wisconsin, Madison.

Hallberg, G.R., Prior, J.C., and Bettis, E.A., III., 1984, Geologic overview of the Paleozoic Plateau region of northeast Iowa: Proceedings of the Iowa Academy of Science, v. 91, no. 1, p. 3-11.

Happ, S.C., 1944, Effect of sedimentation on floods in the Kickapoo Valley, Wisconsin: Journal of Geology, v. 52, p. 53-68.

Hudak, C.M., 1987, Quaternary landscape evolution of the Turkey River valley, Northeastern Iowa: PhD dissertation, University of Iowa, Iowa City.

Knox, J.C., 1977, Human impacts on Wisconsin stream channels: Annals of the Association of American Geographers, v. 67, p. 323-342.

Knox, J.C., 1987, Historical valley floor sedimentation in the Upper Mississippi Valley: Annals of the Association of American Geographers, v. 77, no. 2, p. 224-244.

Meek, S.E., 1892, A report upon the fishes of Iowa, based upon observations and collections made during 1889, 1890, and 1891: Bulletin of the United states Fish Commission for 1890, v. 10, p. 217-248. Washington, D.C.

Potter, K.W., 1991, Hydrological impacts of changing land management practices in a moderate-sized agricultural catchment: Water Resources Research, v. 27, no. 5, p. 845-855.

Scarpino, P.V., 1985, Great River: an environmental history of the Upper Mississippi, 1890-1950: University of Missouri Press, Columbia.

Schumm, S.A., and Lichty, R.W., 1965, Time, space and causality in geomorphology: American Journal of Science, v. 263, p. 110-119.

Trimble, S.W., 1983, A sediment budget for Coon Creek Basin in the Driftless Area, Wisconsin, 1853-1977: American Journal of Science, v. 283, p. 454-474.

Trimble, S.W., and Lund, S.W., 1982, Soil conservation and the reduction of erosion and sedimentation in the Coon Creek Basin, Wisconsin: U. S. Geological Survey Professional Paper 1234, Washington, D.C.

Trowbridge, A.C., and Shaw, E.W., 1916, Geology and geography of the Galena and Elizabeth Quadrangles: Illinois State Geological Survey Bulletin 26.

Vogel, R.C., 1988, Archival research, *in* Benn, D.W., Bettis, E.A. III, and Vogel, R.C, (eds.), Archaeology and geomorphology in pools 17& 18, Upper Mississippi River: Center for Archaeological Research Report CAR-714, Southwest Missouri State University, Springfield, p 228-315.

Womack, W.R., and Schumm, S.A., 1977, Terraces of Douglas Creek, north-western Colorado: an example of episodic erosion: Geology, v. 5, p. 72-76.

Iowa Department of Natural Resources, Geological Survey Bureau
Technical Information Series 32, 1994

WATER QUALITY MONITORING PERSPECTIVES FOR NORTHEAST IOWA

G.R. Hallberg[1], L.S. Seigley[2], R.D. Libra[2], Z-J. Liu[3], R.D. Rowden[2],
K.D. Rex[2], M. R. Craig[3], and K.O. Mann[4]

[1] University of Iowa Hygienic Laboratory
University of Iowa; Oakdale Campus
Iowa City, IA 52242

[2] Iowa Department of Natural Resources, Geological Survey Bureau
109 Trowbridge Hall
Iowa City, IA 52242-1319

[3] University of Iowa, Department of Geography
Jessup Hall
Iowa City, IA 52242

[4] Juniata College, Department of Geology
Huntingdon, PA 16652

ABSTRACT

Deducing improvements in water quality related to reductions in nonpoint source pollution (NPS) is a very difficult task. Water quality, at a watershed scale, is a complex integration of many factors upstream and many scales of spatial and temporal variability. Water-quality studies from the Roberts Creek watershed, in the Big Spring groundwater basin, and the Sny Magill and Bloody Run watersheds provide perspectives on this variability for the design of agricultural NPS monitoring. The three watersheds are contiguous and share a similar hydrogeologic framework which allows direct comparison with little confounding climatic/hydrogeologic variability.

The proportion of land in corn production is directly related to the nitrogen loading in these watersheds. For Water Year 1991, 53% of the Roberts Creek watershed was in corn, 3% in forest and/or pasture, and the stream had an annual mean NO_3-N concentration of 9 mg/L. In comparison, the Bloody Run watershed was 39% corn, 30% forest/pasture with mean NO_3-N of 4 mg/L; the Sny Magill watershed was 26% corn, 49% forest/pasture with a mean NO_3-N of 2 mg/L. In all three streams, NO_3-N concentrations decline downstream related to in-stream biological processing. The rate (and mass) of in-stream nitrate removal varies seasonally, reaching a maximum during summer low-flow periods. With the pronounced downstream depletion of nitrate, water quality from small headwater basins cannot be directly compared with larger aggregate watersheds.

Through the Big Spring Basin Demonstration Project significant improvements in nitrogen input efficiency have occurred; fertilizer-N rates for continuous corn have been reduced from 178 to 137 lbs/ac from 1981 to 1991. These reductions have yet to be definitively reflected in groundwater discharged at Big Spring because of extremes in rainfall, recharge, and overall water flux. NO_3-N concentrations declined to an all-time low in 1989, during a drought, followed by NO_3-N increases to record highs in 1990 and 1991. These trends were not unexpected: the dry conditions allowed the accumulation, or storage of residual NO_3-N in the soil-water system, which was subsequently mobilized by excessive precipitation and recharge.

With the length of record now available in the Big Spring basin, the changes in landuse and N-loading resulting from the Payment-In-Kind (PIK) set-aside program in 1983 can provide an overall model of results expected at the watershed scale. The reduction in corn acreage under PIK, coupled with the changes in nitrogen management, reduced basin N-loading about 27%. With an apparent two-year time lag, this reduction in loading was reflected by a significant change in groundwater quality. Nitrate-N concentrations in groundwater in Water Year 1985 declined about 28%, dropping from annual flow-weighted means of 10.2 mg/L in Water Year 1983 and 9.6 in Water Year 1984, to 6.9 mg/L in Water Year 1985; in Water Year 1986 NO_3-N increased back to 9.6 mg/L. However, groundwater discharge and NO_3-N concentrations are significantly related. Hence, because discharge also declined across this period a decline in NO_3-N could be expected, as well. Only with several years of data subsequent to Water Year 1985 has it been possible to accomplish analysis that provides statistical, as well as intuitive confidence that these water-quality improvements in Water Year 1985 are related to landuse and management changes. Even with over a decade of water-quality data, the Big Spring basin demonstrates the complexity of assessing water-quality improvements related to improved nitrogen management.

INTRODUCTION

The primary goal of reducing nonpoint source (NPS) pollution is to improve water quality. Many measures can be employed to evaluate progress in mitigating NPS, but the ultimate measure must be better water quality. Yet deducing improvements in water quality from monitoring data in relation to improved landuse and management is a very difficult task. With NPS we cannot simply measure effluent from a discharge pipe that is unambiguously related to some activity, as with some point-source monitoring. At a watershed scale, anywhere that we collect a water sample for nonpoint source effects we are dealing with a complex integration of many factors upstream from that point. Landuse and management varies spatially throughout a watershed and improvements in landuse and management typically take place incrementally in space and time. Many landuse and management activities that contribute to NPS vary seasonally (i.e., tillage, crop planting, fertilizer application). Climatic or meteorological events vary on daily, seasonal, and longer scales and these obviously have significant effects on runoff, recharge, and contaminant loading in the hydrogeologic system. Because we are dealing with complex watershed scale effects, the storage of various compounds or pollutants within the hydrogeologic system is also important as well as possible biologic and chemical transformations. These influences result not only in temporal variations that must be considered, but also spatial variations within a watershed system.

The general effects of these sources of variability are relatively well recognized for pollutants common to surface runoff. Temporal variability is well recognized for suspended sediment and total phosphorus, for example; it is critical to have adequate data during the major runoff events that actually mobilize and move these pollutants off the soil and land. Their concentrations during baseflow periods, between storm-runoff events, are often negligible. There are also spatial considerations, if multiple sites or watersheds are to be compared. The concentrations are much different at the edge of a field than one mile (1.6 km) downstream in the local waterbody. For comparison over the long term (e.g., years), changes may not be evident because considerable sediment, or sediment attached compounds may be stored in the system (see Bettis, this volume), and until the storage component is understood, or depleted, water quality improvements may not be evident or unequivocal. These same sources of variability also affect pollutants that may primarily be carried in the dissolved phase in groundwater and baseflow components, such as nitrate.

Nitrate has been a contaminant of major concern in the waters of Iowa. Considerable research over the last 15 years has shown that agriculture is the most extensive source of nitrate delivered to groundwater and surface waters (e.g., Hallberg, 1989; Follett et al., 1991). Various plot studies have shown direct relationships between nitrogen-fertilization rates, total-nitrogen loading, and nitrate in groundwater. In the nitrogen cycle (Hallberg and Keeney, 1993), nitrate is formed in the soil and is delivered to surface waters through groundwater discharge, both naturally and through artificial subsurface drainage (e.g., tile drainage lines). Areal studies have shown direct correlations between agricultural landuse and nitrate concentrations for both groundwater and surface water at various watershed scales (Hallberg, 1989; Omernik, 1977). However, various processes complicate analysis of water quality on spatial and temporal scales, with respect to landuse and management changes. Various studies in northeast Iowa provide perspective on these factors which help set a baseline for monitoring future changes and for developing additional, appropriate monitoring projects elsewhere.

Northeast Iowa Watersheds

Surface water and groundwater monitoring has been conducted in several agricultural watersheds in northeast Iowa to understand the relationships among landuse, management practices, and water quality (Figure 1). These studies are designed to assess changes in agricultural nonpoint-source (NPS) pollution with changing land management practices brought about by various voluntary demonstration programs. The longest-term project, the Big Spring Basin Demonstration Project, includes

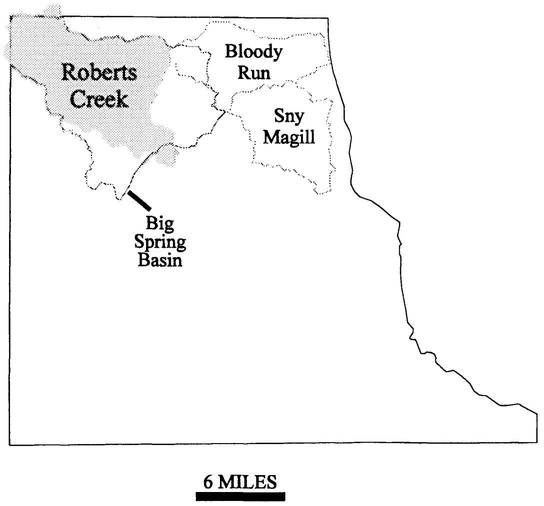


Figure 1. Location of the Big Spring groundwater basin, and the Sny Magill and Bloody Run surface water basins, Clayton County, Iowa. Shaded area represents Roberts Creek surface water basin.

data from various scales of surface water basins within the Roberts Creek watershed (69 mi^2; 179 km^2), the main surface water basin in the Big Spring groundwater basin. The Sny Magill watershed (28 mi^2; 72 km^2) and Bloody Run watershed (34 mi^2; 89 km^2) are included in a U.S. Environmental Protection Agency (Region VII) 319-NPS monitoring project to monitor water quality improvements associated with management practices implemented through the Sny Magill Hydrologic Unit Area project (Seigley et al., 1992). Both project areas are also included, in part, in the Northeast Iowa Demonstration Project. Analysis of baseline data from these watersheds, and historic observations from the Big Spring basin, provide perspectives that must be understood for monitoring and interpreting future changes in water quality in northeastern Iowa and other hydrologic systems.

These three watersheds are contiguous and share a similar hydrogeologic framework which allows direct comparison with little confounding climatic/hydrogeologic variability. The watersheds provide various insights on nitrogen cycling in the groundwater/surface water system as it relates to landuse differences, in-stream biological processing, seasonal variations, and size of watersheds sampled.

The record of water quality data available for the Big Spring basin also provides perspective on the length of record necessary to document improvements, especially when affected by climatic aberrations. Significant reductions have been made in nitrogen fertilizer applications in the basin, however, the effects of climatic extremes have overshadowed changes in loading and measurement of long-term improvements in the quality of groundwater discharged at Big Spring.

NITRATE CYCLING THROUGH THE WATERSHED

In the Big Spring basin, a nested network of monitoring sites provides a view of nitrate cycling from the root-zone of individual fields to the watershed scale, for both groundwater and surface water (Littke and Hallberg, 1991). The hydrologic and chemical responses of individual fields to seasonal recharge events can be tracked through the larger groundwater and surface-water systems.

Figure 2 shows NO_3-N concentrations for Water Year 1992 (a water year is a 12-month period, from October 1 through September 30, designated by the calendar year in which it ends). Site L22T discharges shallow groundwater through a tile line, from beneath a 30 acre (0.12 km^2) cornfield; site L23S is a surface water site on Silver Creek, a tributary to Roberts Creek, with a 4.4 mi^2 (11.4 km^2) drainage area; and BSP is Big Spring, the groundwater discharge point for the 103 mi^2 (270 km^2) groundwater basin. Even with these differences in scale of drainage area, similar seasonal trends and pronounced short-term changes are evident at all sites. Infiltrating recharge water delivers relatively high nitrate concentrations to the water table below row-cropped, fertilized fields (L22T). This shallow groundwater discharges laterally to streams (e.g., site L23S) and downward to the Galena aquifer (underlying the Big Spring basin), eventually discharging at Big Spring (BSP). These larger-scale sites integrate more landuse, including many areas that do not deliver any substantial nitrate, and hence the concentrations are lower than those from the corn field. The nitrate concentration

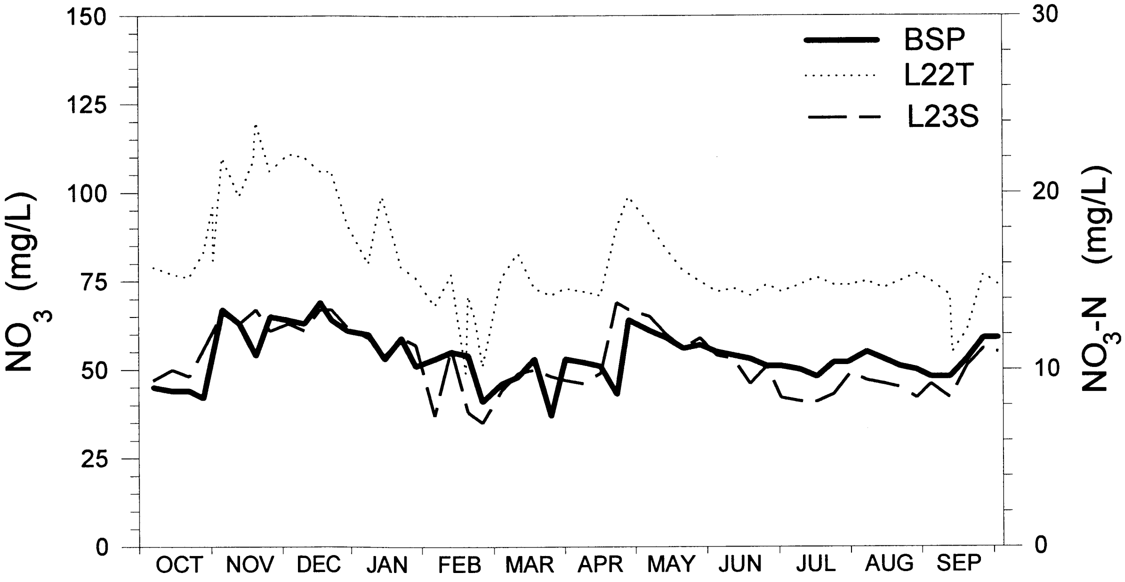


Figure 2. Nitrate-N concentrations for three sites in the Big Spring basin for Water Year 1992. L22T= groundwater/tile-line discharge from one cornfield, 30 acre; L23S= a stream site from a 4.4 mi^2 watershed; BSP= groundwater from Big Spring, 103 mi^2 basin.

changes that occur are not as great or immediate at larger scales, but are clearly evident as a recharge-induced pulse moving through the hydrogeologic system (Seigley et al., 1993). Studies from individual fields or plots clearly show that decreased nitrogen loading through improved management will lower the nitrate concentrations and mass losses from the field. While management improvements and decreased nitrogen loading at one individual site, such as L22T, would have no discernible effect at Big Spring, the understanding of the integration of the hydrogeologic system clearly supports the presumption that watershed water-quality improvements will result by improved management on a greater scale.

LANDUSE AND WATER QUALITY

Omernik (1977) demonstrated a relationship of increasing inorganic-N in surface waters throughout the U.S., with increases in the amount of landuse in row crop in their drainage areas. This trend occurs at a smaller scale in Roberts Creek, Sny Magill, and Bloody Run watersheds. These watersheds differ in landuse and this in turn affects nitrogen loading in the watersheds. There are no significant urban-industrial nitrogen sources in these three watersheds; the watersheds are dominated by agricultural activities. Corn is the dominant crop, accounting for over 95% of the row-cropped areas. About 50% is grown as continuous corn with the remainder in rotation with oats and alfalfa and a very minor acreage of soybean. Over 80% of the farms have livestock operations, involving dairy or beef cattle or swine. While there are many sources of nitrogen, the largest input is from fertilizer applied to corn (Hallberg, 1987). Hence, the proportion of land in corn is directly related to the nitrogen load for a particular watershed. This nitrogen loading to the land directly affects nitrate concentrations and loading in the streams. Data for Water Year 1991 are exemplary: 53% of the Roberts Creek watershed was in row-crop production and the stream had a mean NO_3-N concentration of 8-9 mg/L (Table 1). In comparison, Sny Magill had 26% of the watershed in row-crop production and an average NO_3-N concentration of 2 mg/L. Bloody Run was intermediate with 39% of the area in corn and a mean NO_3-N of 4 mg/L.

Table 1. Landuse and mean nitrate-N concentrations for Water Year 1991.

	Sny Magill Watershed	Bloody Run Watershed	Roberts Creek Subwatershed	Roberts Creek Watershed
Row crop	26%	39%	53%	53%
Cover crop/pasture	24%	29%	41%	38%
Forest/forested pasture	49%	30%	3%	6%
Urban/roads/other	1%	3%	3%	4%
Watershed size	28 sq. mi (72 sq. km)	34 sq. mi (89 sq. km)	30 sq. mi (78 sq. km)	69 sq. mi (179 sq. km)
Mean annual nitrate-N	2 mg/L	4 mg/L	9 mg/L	8 mg/L

IN-STREAM SPATIAL AND TEMPORAL VARIABILITY

Relating watershed-scale water quality to differences in management between watersheds or within a watershed over time can be confounded by many processes. In all three streams, Roberts Creek, Sny Magill, and Bloody Run, NO_3-N concentrations decline downstream. Analysis of landuse and loading factors show little change downstream and little relationship to water-quality changes. There are no significant changes in landuse sources that might dilute NO_3-N. Previous studies documented that moving downstream, Roberts Creek becomes a losing stream, i.e., the stream loses water through the stream bed to the groundwater and, without other influences, the NO_3-N should remain constant (Hallberg et al., 1983; Kalkhoff, 1993). The downstream decline in NO_3-N can be related to in-stream biological processing. Various lab and field studies suggest that the major mechanisms for the depletion of nitrate in these stream systems is bacterial denitrification in the anaerobic stream-sediment interface and algal assimilation of nitrate and ammonium (Bachmann et al., 1991; Isenhart and Crumpton, 1989). Data from Roberts Creek indicates the rate (and mass) of in-stream nitrate removal varies seasonally, reaching a maximum during summer low-flow periods (Figures 3 and 4), also a time when groundwater inputs are at a minimum. These seasonal variations are interrelated with seasonal discharge patterns that affect residence time of the water and NO_3-N, as well as temperature. With the pronounced downstream depletion of nitrate, water quality from small headwater basins cannot be directly compared with larger aggregate watersheds (Figure 4), particularly in relation to landuse and management differences.

Such in-stream processing contributes to significant variability in surface water NO_3-N; Roberts Creek varies from >20 to <1 mg/L during some years. Roberts Creek integrates groundwater baseflow and surface water drainage, as do all perennial streams. During cool seasons, NO_3-N in Roberts Creek closely parallels basin groundwater concentrations at Big Spring, as should be expected (Figure 5). During warm seasons the concentrations fall far below the integrated groundwater values because of the in-stream processing. For example, NO_3-N concentrations declined in groundwater (site BSP) during the drought years (water years 1988-1989), however, the decline in NO_3-N concentrations in surface water (sites RC-02, RC-11) was even greater because of in-stream processing. Towards winter, in-stream processing decreases in surface water, because of cooler temperatures and decreased biologic activity, and surface water nitrate concentrations reflect baseflow conditions, similar to groundwater being discharged at Big Spring (site BSP). This difference between the groundwater input and the surface water NO_3-N load can be used to estimate the magnitude of biological processing (Bachmann et al., 1991).

At watershed scales much greater than Roberts Creek (Table 1), an equilibrium pattern appears to be reached. Roberts Creek and the Big Spring basin discharge to the Turkey River. In similar monitoring along the Turkey River, with drainage areas ranging from 150 to over 1550 mi^2 (390 to over 4,015 km^2), little downstream difference in NO_3-N has been apparent, though similar seasonal trends in concentration occur. To assess trends or relationships to landuse and management practices at the scale of these master streams (e.g., Turkey River, Iowa River, Des Moines River), detailed baseflow analysis is required, with particular attention to seasonal patterns to overcome the complications of warm season, in-stream consumption and depletion of nitrate. Such spatial and temporal variability must be considered in the analysis and comparison of surface-water nitrate records and in defining the scale of comparisons that are feasible.

CLIMATIC ABERRATIONS

Water-quality studies in the Big Spring basin have been instrumental in defining agricultural impacts on water quality. Historic data illustrated that regional increases in NO_3-N in groundwater paralleled increasing fertilizer-N rates and corn acreage during the 1960s and 1970s (Figure 6). Through the Big Spring Basin Demonstration Project significant improvements in nitrogen input efficiency have occurred; fertilizer-N rates for continuous corn have declined from 178 pounds fertilizer-nitrogen per acre in 1981 to 131 pounds fertilizer-nitrogen per acre in 1991 (Table 2). These reductions in fertilizer-nitrogen have yet to be reflected in groundwater discharged at Big Spring because of extremes in rainfall, recharge, and overall water flux. Figure 7 illustrates the annual flow weighted mean nitrate concentrations, annual groundwater

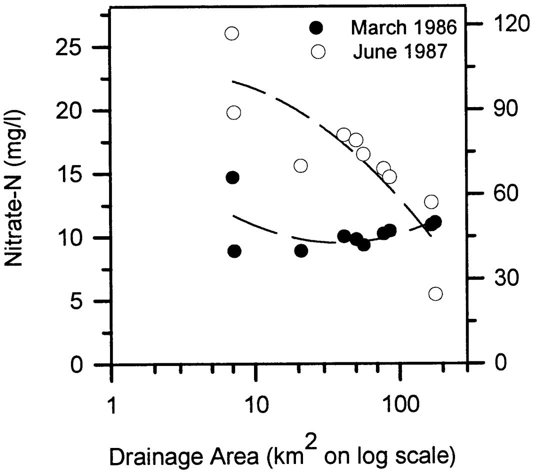


Figure 3. Nitrate-N concentrations at various sampling stations along Roberts Creek for March 1986 (cool season baseflow) and June 1987 (warm season low flow); dashed lines represent second order regression fit of data.

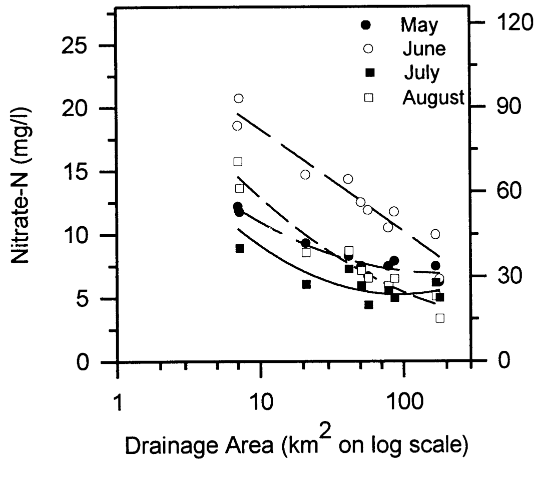


Figure 4. Monthly mean nitrate-N concentrations (for water years 1982-1991) at various sampling stations along Roberts Creek for warm-season months; dashed lines represent second order regression fit of data.

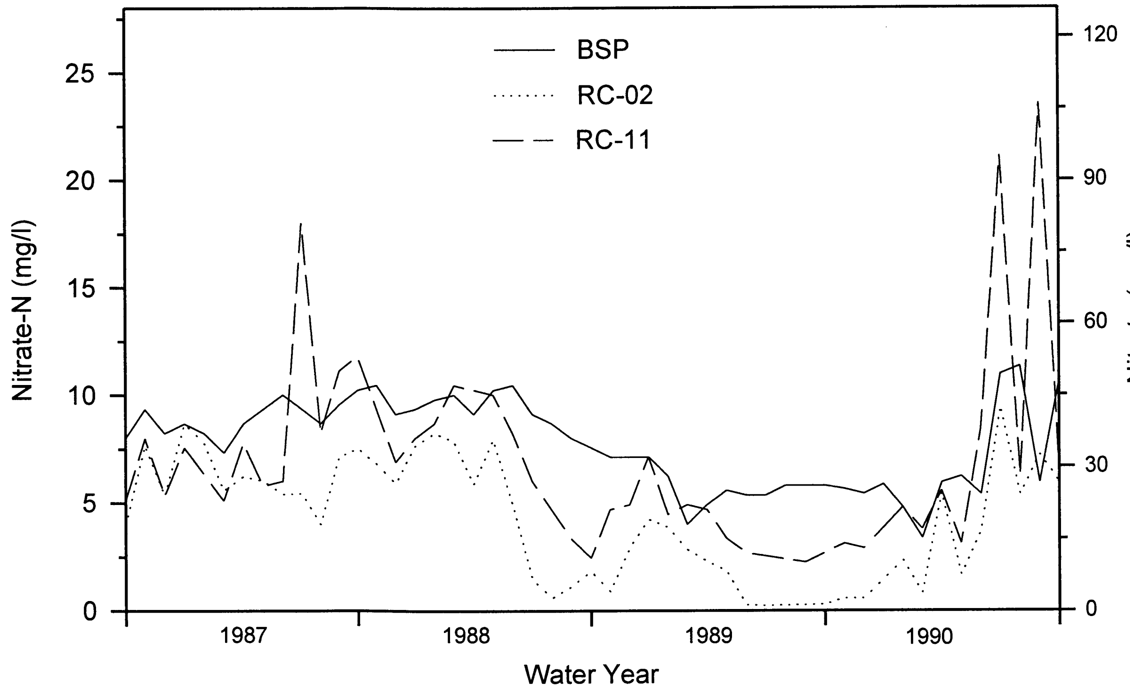


Figure 5. Nitrate-N concentrations for three sites in the Big Spring basin for water years 1987-1990.

discharge, and departure from normal rainfall at Big Spring. NO_3-N concentrations declined to an all-time low in 1989, during a drought, followed by increases in NO_3-N concentrations to record highs in 1990 and 1991. These trends were not unexpected considering the extremes in rainfall. The dry conditions allowed the accumulation, or storage of residual NO_3-N in the soil-water system, which was later mobilized by excessive precipitation and recharge during the subsequent years. This same trend was apparent in private well data collected in 1981, 1989, and 1992 in the Big Spring basin (Seigley and Hallberg, 1993), and groundwater and surface water projects elsewhere in Iowa (Quade, 1993; Lucey and Goolsby, 1993).

Importance of Long-Term Record

Changes in nitrogen management during the last decade in the Big Spring basin, while significant, have been gradual and incremental (Table 2). Even under the most normal of climatic conditions, assessment of possible water-quality improvements related to improved nitrogen management would take time. With the length of record now available in the Big Spring basin, the changes in landuse and nitrogen loading resulting from the PIK (Payment-In-Kind) set-aside program in 1983 can provide an overall model of results that can be expected at the watershed scale. Under PIK, the Big Spring basin area in corn production was reduced by about 33% (relative to 1982). Coupled with the changes in nitrogen management (Table 2; Figure 6), fertilizer nitrogen loading on corn was reduced about 39% and total nitrogen loading was reduced about 27% (accounting for all crops, rotation effects, manure, and soil nitrogen). With an apparent two-year time lag, this reduction in nitrogen loading was reflected by a significant reduction in NO_3-N in the groundwater in Water Year 1985. Nitrate-N concentrations in groundwater in Water Year 1985 declined about 28% (from water year 1984), dropping from

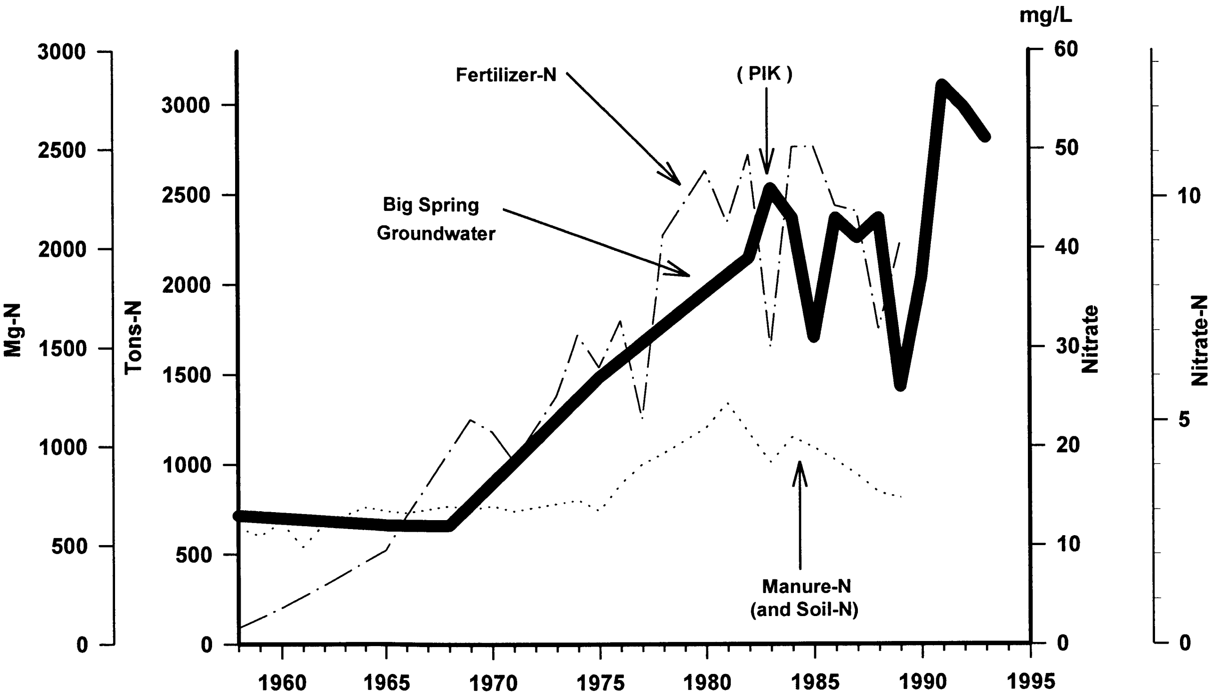


Figure 6. Fertilizer nitrogen and estimated-available manure (and soil) nitrogen applied in the Big Spring basin (left axis, Mg) and annual average nitrate-N concentrations (right axis, mg/L) in groundwater at Big Spring (Hallberg, 1986; Hallberg and Keeney, 1993; Hallberg et al., 1984).

annual flow-weighted means of 10.2 mg/L in Water Year 1983 and 9.6 in Water Year 1984, to 6.9 mg/L in Water Year 1985; in Water Year 1986 NO_3-N increased back to 9.6 mg/L (Figure 7; Table 3). On an annual or monthly basis groundwater discharge and NO_3-N concentrations are significantly related. Hence, because discharge also declined across this period a decline in NO_3-N could be expected, as well (Hallberg et al., 1993). Only with several more years of monitoring data, to establish an adequate period of record subsequent to Water Year 1985, has it been possible to accomplish analysis that provides statistical, as well as intuitive confidence that these water-quality improvements in Water Year 1985 are related to landuse and management changes.

Annual and monthly mean discharge and nitrate data for Water Year 1985 have been compared to the six years of record for water years 1982-1984 and water years 1986-1988 (avoiding the extreme dry and wet conditions of 1989-1991). The evaluations all indicate highly significant statistical differences for NO_3-N concentrations and loads in Water Year 1985. The statistical results and significance are most easily summarized and illustrated in Figure 8. While discharge (Q) declined in Water Year 1985, the decrease in monthly-Q was within normal bounds, with all but one month within 1.5 standard deviations. Decreases in NO_3-N, however, were often four to six standard deviations from long-term means. Water Year 1987 and Water Year 1988 showed discharge reductions similar to Water Year 1985, but no comparable reduction in nitrate, as summarized in Table 3.

CONCLUSIONS

The monitoring data from northeastern Iowa provide some important perspectives for the design of nonpoint source monitoring studies, and also set a baseline for comparison of future progress in mitigating NPS water-quality effects. The ex-

Table 2. Fertilizer-nitrogen (FN) rates used for corn and continuous corn yields, from surveys and farm census inventories in the Big Spring basin.

Rotation	Basin average fertilizer-N rates				Average Yield
	All corn	1st-yr corn after alfalfa	2nd-yr corn after alfalfa	Continuous corn	Continuous corn yields
Year	------	lbs-FN/acre		------	bu/acre
1981	174	123	160	178	128
1982	174	123	---	178	138
1984	158	115	155	169	130
1986	147	96	---	153	149
1987	149	84	121	157	141
1988	141	84	124	151	79
1989	138	82	125	148	147
1990	123	66	121	145	145
1991	117	59	112	131	138

Table 3. Comparison of annual discharge and mean nitrate-N concentrations from the Big Spring basin for water years 1985-1988.

Water-Year	Mean annual discharge		Total annual discharge		Annual flow-weighted mean nitrate-N (as nitrate)	
	cfs	(cms)	ac-ft	(mcm)	mg/L	(mg/L)
1985	35.2	(0.99)	25,100	(30.95)	7.0	(31)
1986	42.0	(1.19)	30,300	(37.36)	9.7	(43)
1987	35.4	(1.00)	25,500	(31.44)	9.1	(41)
1988	35.8	(1.01)	26,000	(32.06)	9.6	(43)

cfs=cubic feet per second; cms=cubic meters per second

ac-ft=acre-feet; mcm=millions of cubic meters amples presented for nitrate serve as examples of the scales of variation that must be considered. Nested spatial monitoring networks, such as established in the Big Spring basin, provide insights to nitrate cycling that must be considered in defining the appropriate scale of nonpoint source monitoring for different purposes and for different landuse conditions, and for evaluating water-quality data in relation to changing landuse and management practices. As water quality monitoring progresses to larger area watersheds, more landuse and management variables are integrated, responses are damped and complicated by climatic variation, storage effects, and biochemical processing, in surface waters and even in the groundwater system. Where watershed areas and hydrology are comparable, nitrate concentrations and loading can be compared among basins and related to landuse and management variables. At the watershed scale, storage of nitrate within the soil and hydrologic system and climatic variations complicate any short term assessment of gradual changes in management. Even with over a decade of water-quality data, the Big Spring basin demonstrates the complexity of assessing water-quality improvements related to improved nitrogen management.

ACKNOWLEDGMENTS

This work has been supported, in part, by grants from the U.S. Environmental Protection Agency, Region VII, Nonpoint Source and Pollution Prevention programs.

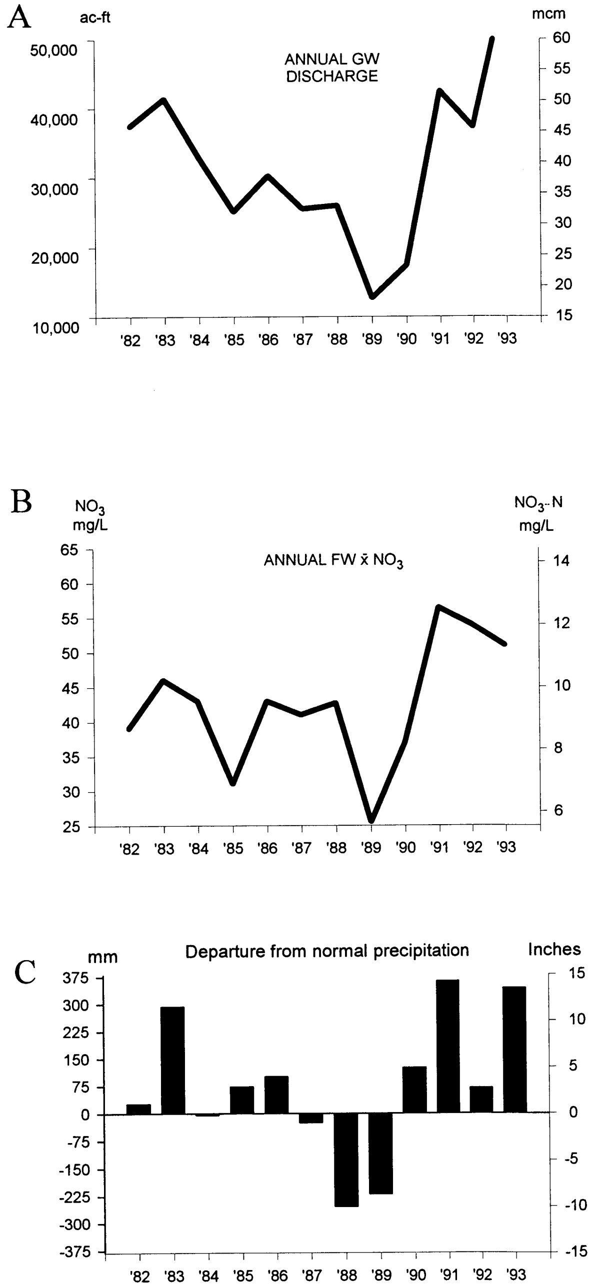


Figure 7. Annual groundwater discharge (A), annual mean flow-weighted nitrate (B), and departure from normal precipitation (C) for Big Spring, water years 1982-1993.

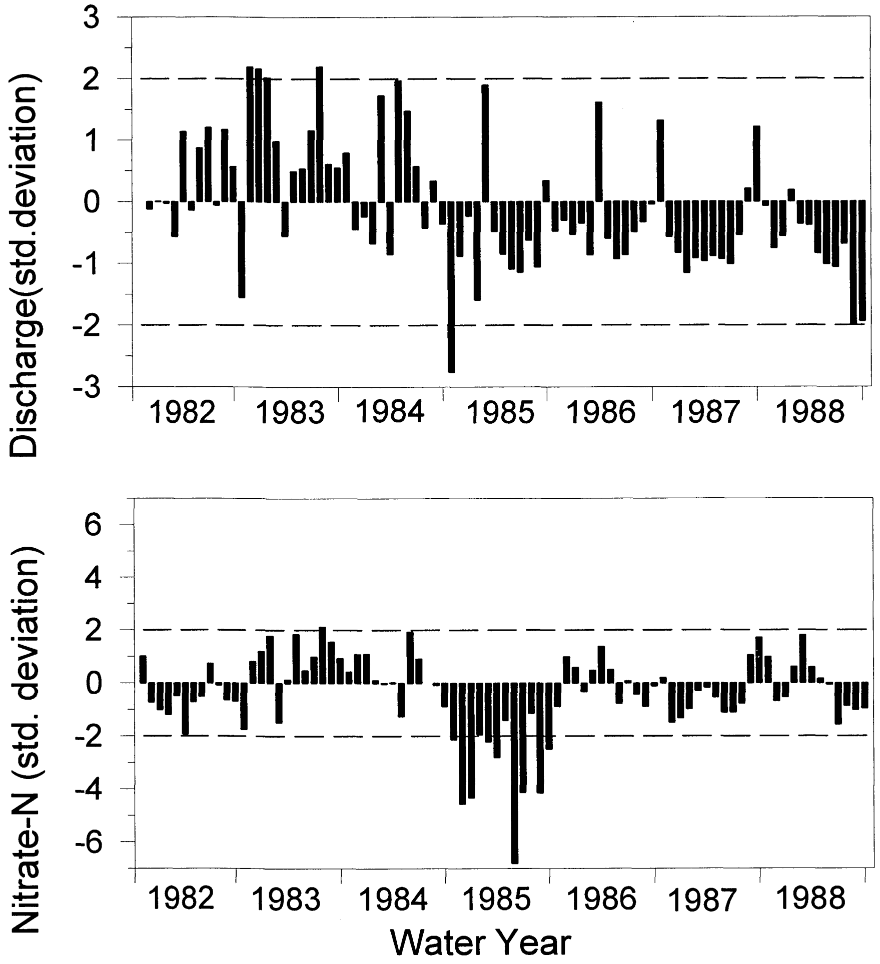


Figure 8. Monthly mean groundwater discharge and nitrate-N concentration, from Big Spring; plotted in units of standard deviation (+ or -) from the long-term monthly mean (for water years 1982-1988, exclusive of 1985).

REFERENCES

Bachmann, R.W., Crumpton, W.G., and Hallberg, G.R., 1991, Nitrogen losses in an agricultural stream: Verh. Internat. Verein. Limnol., v. 24, p. 1641-1643.

Bettis, E.A., III, 1994, Paleozoic Plateau erosion perspective: this volume.

Follett, R.F., Keeney, D.R., and Cruse, R.M. (eds.), 1991, Managing nitrogen for groundwater quality and farm profitability: Soil Science Society of America, Madison, WI.

Hallberg, G.R., 1986, From hoes to herbicides; agriculture and groundwater quality: Journal of Soil and Water Conservation, v. 41, no. 6, p. 357-364.

Hallberg, G.R., 1987, Nitrates in groundwater in Iowa, *in*, D'Itri, F.M. and Wolfson, L.G. (eds.), Rural Groundwater Contamination, Lewis Publish., Inc., Chelsea, Mich., Chapt. 3, p. 23-68.

Hallberg, G.R., 1989, Nitrate in ground water in the United States, *in* R.F. Follett (ed.), Nitrogen Management and Ground Water Protection, Developments in Agric. and Managed-Forest Ecology 21: Elsevier Science Publ., Amsterdam, p. 35-74.

Hallberg, G.R., Hoyer, B.E., Bettis, E.A., III, and Libra, R.D., 1983, Hydrogeology, water quality, and land management in the Big Spring basin, Clayton County, Iowa: Iowa Geological Survey, Open-File Report 83-3, 191 p.

Hallberg, G.R., Libra, R.D., Bettis, E.A., III, and Hoyer, B.E., 1984, Hydrogeologic and water-quality investigations in the Big Spring basin, Clayton County, Iowa: 1983 Water-Year: Iowa Geological Survey, Open-File Report 84-4, 231 p.

Hallberg, G.R., Libra, R.D., Liu, Z-J, Rowden, R.D, and Rex, K.D., 1993, Watershed-scale water-quality response to changes in landuse and nitrogen management: Proceedings, Agricultural Research to Protect Water Quality, Soil and Water Conservation Society, Ankeny, IA, p. 80-84.

Hallberg, G.R., and Keeney, D.R., 1993, Nitrate, *in* Alley, W.A., Regional Ground-Water Quality: Van Nostrand Reinhold, New York, NY, Chapter 2, p. 297-322:

Isenhart, T.M., and Crumpton, W.G., 1989, Transformation and loss of nitrate in an agricultural stream: J. Freshwater Ecol., v. 5, p. 123-129.

Kalkhoff, S.J., 1993, Using a geographic information system to determine the relation between stream quality and geology in the Roberts Creek watershed, Clayton County, Iowa: Water Resources Bull., v. 29, p. 989-996.

Littke, J.P., and Hallberg, G.R., 1991, Big Spring basin water-quality monitoring program: design and implementation: Iowa Department of Natural Resources, Geological Survey Bureau, Open-File Report 91-1, 19 p.

Lucey, K.J., and Goolsby, D.A., 1993, Effects of climatic variations over 11 years on nitrate-nitrogen concentrations in the Raccoon River, Iowa: Journal of Environmental Quality, v. 22, p. 28-46.

Omernik, J.M., 1977, Nonpoint source-stream nutrient level relationships: a nationwide study: EPA-600/3-77-105, U.S. Environmental Protection Agency. Corvallis, OR.

Quade, D.J., 1993, Temporal variability of groundwater quality in Floyd and Mitchell counties: *Iowa Groundwater Quarterly*, vol. 4, no. 2, p. 11.

Seigley, L.S., Hallberg, G.R., Wilton, T., Schueller, M.D., Hausler, M.C., Kennedy, J.O., Wunder, G., Link, R.V., and Brown, S.S., 1992, Sny Magill Watershed nonpoint source pollution monitoring project workplan: Iowa Department of Natural Resources, Geological Survey Bureau, Open File Report 92-1, 31 p.

Seigley, L.S., and Hallberg, G.R., 1993, Private well water quality in the Big Spring Basin: 1981-1992: *Water Watch*, February 1993, p. 1-2.

Seigley, L.S., Hallberg, G.R., Rowden, R.D., Libra, R.D., Giglierano, J.D., Quade, D.J., and Mann, K.O., 1993, Agricultural landuse and nitrate cycling in surface water in northeast Iowa: Proceedings, Agricultural Research to Protect Water Quality, Soil and Water Conservation Society, Ankeny, IA, p. 85-88.

Iowa Department of Natural Resources, Geological Survey Bureau
Technical Information Series 32, 1994

SUMMARY OF BASELINE WATER - QUALITY DATA FOR SNY MAGILL AND BLOODY RUN WATERSHEDS, AND SURROUNDING LOCATIONS

L.S. Seigley[1] and G.R. Hallberg[2]

[1]Iowa Department of Natural Resources, Geological Survey Bureau
109 Trowbridge Hall
Iowa City, IA 52242-1319

[2]University of Iowa Hygienic Laboratory
University of Iowa; Oakdale Campus
Iowa City, IA 52242

ABSTRACT

Historic water quality data was compiled for Sny Magill and Bloody Run creeks, for surrounding creeks and rivers, and for groundwater from the Big Spring basin to give perspective on past quality of surface water and groundwater in the northeastern Iowa area. The water-quality data illustrates an increase in nitrate concentrations with increases in agricultural landuse and management changes. Average nitrate-N concentrations from Sny Magill and Bloody Run have approximately doubled from 1976-78 to 1991. The studies illustrate both temporal and seasonal changes in water quality. The coldwater streams in the region generally have good water quality, especially during groundwater dominated baseflow periods. Data from across the region showed typical downstream declines in nitrate concentrations, related to in-stream nutrient consumption and denitrification. The historic water-quality data, especially from the Big Spring basin, illustrates the need for long-term monitoring to document improvements in water quality from land management changes and to account for extreme climatic conditions.

INTRODUCTION

The Sny Magill Watershed Nonpoint Source Pollution Monitoring Project (Seigley et al., 1992) is designed to monitor and assess improvements in water quality resulting from the implementation of two U.S. Department of Agriculture land treatment projects in the watershed: the Sny Magill Hydrologic Unit Area (HUA) Project and the North Cedar Creek Water Quality Special Project (WQSP).

This report summarizes historical water-quality data from the northeastern Iowa area around the Sny Magill watershed. Four sources of data are used: (1) an overview of the Big Spring basin monitoring by the Iowa Department of Natural Resources-Geological Survey Bureau (DNR-GSB) and by the U.S. Geological Survey; (2) historical water-quality data for surrounding surface-water sites available from STORET, conducted by various agencies; (3) water-quality data from intensive stream surveys by the University of Iowa Hygienic Laboratory; and (4) baseline data collected from February-September 1991 from nine sites on Sny Magill and Bloody Run creeks.

The majority of the water-quality analytical work for all these studies was performed at the University of Iowa Hygienic Laboratory (UHL), using standard, approved laboratory methods and procedures and rigorous quality assurance and control practices; the UHL is certified by EPA through the Contract Laboratory Program. Standard water analyses combine nitrite (NO_2) plus nitrate (NO_3) because nitrite concentrations are typically very low (generally below detection); hence, these data are reported and discussed as nitrate-nitrogen (NO_3-N).

BIG SPRING BASIN

The Big Spring basin is a 103 mi^2 (270 km^2) groundwater basin located west of the Sny Magill and Bloody Run watersheds. Precipitation, groundwater and surface water discharge, and the concentrations and loads of various chemicals have been monitored at a network of sites since 1981. Groundwater discharge from the Big Spring basin has been monitored at Big Spring since the fall of 1981. Several subwatersheds within the Big Spring groundwater basin are similar in size to the Sny Magill and Bloody Run watersheds and subwatersheds, and will be used in future comparative analysis. The data from this area are directly pertinent because the Big Spring basin is adjacent to the Sny Magill watershed, sharing a portion of its west divide. A portion of the northeasterly Big Spring groundwater basin overlaps into the surface watershed of Bloody Run (Figure 1).

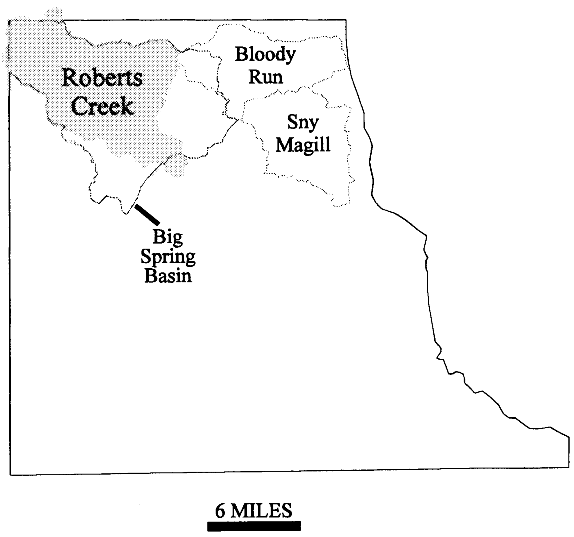


Figure 1. Location of the Big Spring groundwater basin, and the Sny Magill and Bloody Run surface water basins, Clayton County, Iowa. Shaded area represents Roberts Creek surface water basin.

Reviews of the hydrologic and water-quality monitoring in the Big Spring basin for water years (October 1 through September 30) 1982 through 1991 have been presented by Hallberg and others (1983, 1984, 1985, 1987, 1989), Libra and others (1986, 1987, 1991), and Rowden and others (1993). Data from several monitoring sites within the basin for water years 1988 through 1990 are summarized in Kalkhoff (1989), Rowden and Libra (1990), Kalkhoff and Kuzniar (1991), and Kalkhoff and others (1992). Reviews of rainfall monitoring for pesticides are discussed in Nations (1990), Nations and Hallberg (1992), Goolsby and others (1990), and Capel (1990). Kennedy and others (1988) and Kennedy and Miller (1990) have summarized background work on benthic macroinvertebrates and

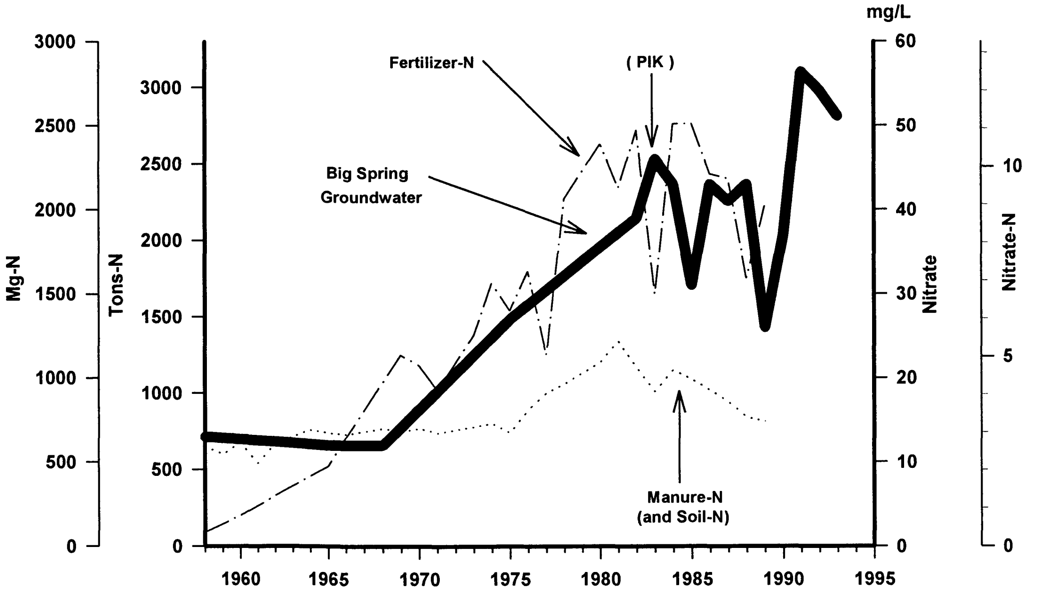


Figure 2. Mass of fertilizer-N and estimated-available manure (and soil-) nitrogen applied in the Big Spring basin (left axis), and annual average nitrate-N concentration (right axis) in groundwater at Big Spring through Water Year 1993.

fish in the Big Spring basin. The design and implementation of the network of monitoring stations used to quantify changes in water quality in the basin are described in Littke and Hallberg (1991).

Collaborative efforts to improve farm management, under the field leadership of the Iowa State University Cooperative Extension Service, have been underway since 1982. These efforts culminated in the Big Spring Basin Demonstration Project (BSBDP), which formally began in 1986. The project included development of an intensive, interactive farm demonstration and public education program to help farmers implement improved management practices. Through the BSBDP, significant improvements in nitrogen-input efficiency have occurred (Hallberg et al., 1991). During the 1980s, with implementation of the BSBDP, basin farmers reduced fertilizer-nitrogen rates for corn by about 30%, with no yield loss.

Figure 2 summarizes background data and water-quality observations from the Big Spring basin. These data illustrate that nitrate concentrations increased substantially since the late 1950s, paralleling the increase in nitrogen loading to the basin resulting from increasing land brought into corn production and increasing rates of fertilizer use on corn (e.g., Hallberg, 1989). Similar changes to more intensive management and landuse occurred in the Sny Magill and Bloody Run watersheds, though not to the same extent as in the Big Spring basin because the land and soils are not as conducive to, or as productive for row-crop production.

Figure 3 summarizes the hydrologic and water quality monitoring at Big Spring for water years 1982 through 1991 (Rowden et al., 1993). During the period, precipitation has varied from 22.9 inches (581.7 mm) in Water Year 1988 to 47.3 inches (1201.4 mm) in Water Year 1991. Normal rainfall is approximately 33 inches. Groundwater discharge has varied from 12,700 ac/ft in Water Year 1989 to 42,500 ac/ft in Water Year 1991. The highest annual flow-weighted mean nitrate-N concentration, 12.5 mg/L, and the greatest nitrate-nitrogen load, 1,446,000 pounds (656,000 kg), occurred in Water Year 1991. The lowest annual flow-weighted mean and nitrate-nitrogen load, 5.6 mg/L and 195,000 pounds (88,000 kg), occurred in

Water Year 1989. Annual mean nitrate concentrations tend to parallel annual groundwater discharge; higher nitrate concentrations occur during years with greater groundwater discharge.

The highest annual flow-weighted mean atrazine concentration, 1.17 µg/L, and the greatest atrazine load, 135 pounds, also occurred during Water Year 1991. During Water Year 1988, only 9 pounds of atrazine were discharged, at a flow-weighted mean concentration of 0.13 µg/L. Maximum atrazine concentrations analyzed ranged from 0.40 µg/L in Water Year 1988 to 16.00 µg/L in Water Year 1991. Annual flow-weighted mean atrazine concentrations, and the frequency and magnitude of detections of other herbicides, do not parallel annual discharge. The variability of these annual parameters over a short period of time underscores the need for long-term monitoring of nonpoint-source contamination.

In addition to the groundwater data, surface water quality has also been studied. Nitrate concentrations in Roberts Creek, the primary surface water drainage in the basin, show a decline in concentration downstream. The downstream decline has been related to in-stream biological processing (Bachmann et al., 1991; Isenhart and Crumpton, 1989). Depletion of nitrate is related to bacterial denitrification in the anaerobic stream-sediment interface and algal assimilation of nitrate and ammonium. The rate and mass of in-stream nitrate removal varies seasonally, reaching a maximum during summer low-flow periods, also a time when groundwater inputs are at a minimum (Seigley et al., 1993).

U.S. Geological Survey Water-Quality Data

The U.S. Geological Survey monitored water quality at three surface water sites in the Big Spring basin from 1988-1990. Table 1 is a summary of the water quality data from sites DC-5, Boog-D, and RC-2 (from Kalkhoff, 1989; Kalkhoff and Kuzniar, 1991; and Kalkhoff et al., 1992). During this period, total rainfall for the Big Spring basin was 22.94 inches (582.7 mm) in 1988, 24.32 inches (617.7 mm) in 1989, and 37.87 inches (961.9 mm)

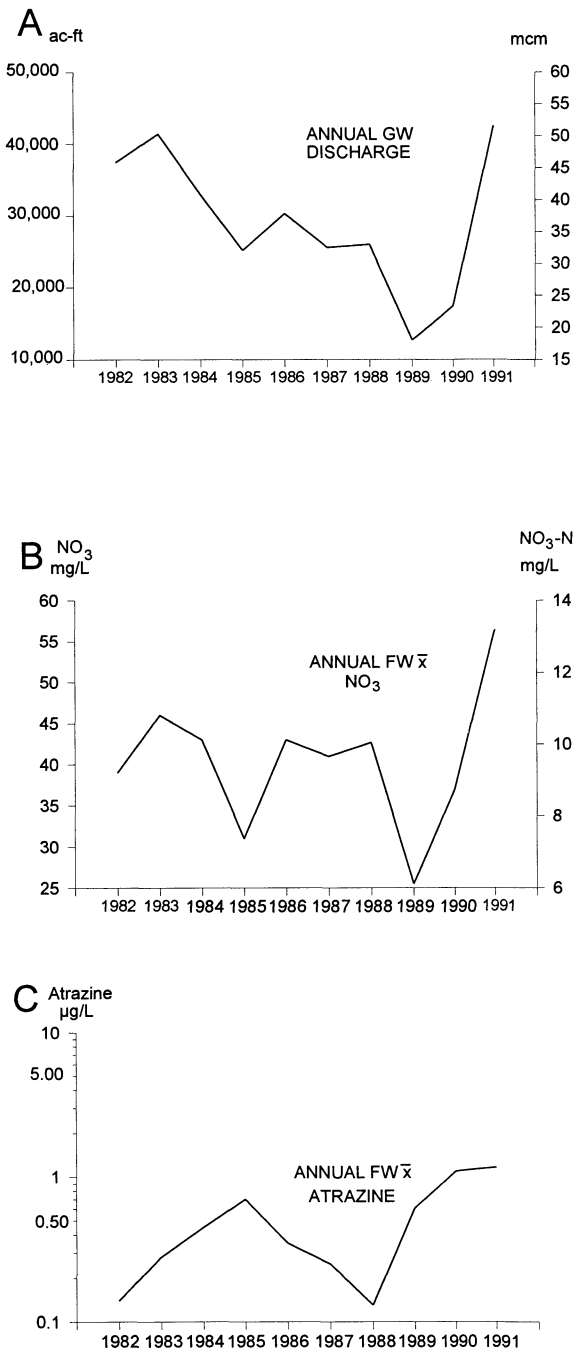


Figure 3. Summary of annual groundwater discharge (A), flow-weighted mean NO_3-N (B), and atrazine concentrations (C) from Big Spring groundwater for 1982-1991 (from Rowden et al., 1993).

Table 1. Historic water-quality data from three surface water sites in the Big Spring basin.

Parameter	1989	1990	1988	1989	1990
	DC-5	DC-5	Boog-D	Boog-D	Boog-D
Drainage Area (square miles)	1.1		1.15		
Temperature (°C)	-----	0 - 22	5 - 24	-----	0 - 30
Specific Conductance (uS/cm at 25 °C)	-----	231 - 680	410 - 819	-----	220 - 1100
pH	-----	7.1 - 8.2	7.31 - 8.31	-----	7.0 - 8.4
Dissolved Oxygen (mg/L)	-----	6.7 - 14.5	5.7 - 10.6	-----	4.0 - 13.3
NO2 + NO3-N (mg/L)	1.1 - 4.9	0.7 - 17.0	7.6 - 14.0	1.8 - 2.9	1.0 - 30.0
NH4-N (mg/L)	<0.1 - 4.9	<0.1 - 3.8	<0.1 - 0.5	2.0 - 3.4	<0.1 - 5.3
Organic-N (mg/L)	<0.1 - 11.0	0.2 - 9.9	0.1 - 0.8	3.9 - 5.8	0.8 - 14.0
Total Organic-Carbon (mg/L)	1.5 - 48.0	1.4 - 74.0	2.8 - 3.4	-----	4.0 - 48.0
Daily Mean Discharge (cubic feet/second)	0.14 - 4.2	-----	0.0 - 7.0	0.0 - 7.0	0.0 - 21.0
Suspended Sediment Concentration (mg/L)	-----	-----	22 - 1160	-----	9 - 1140
Suspended Sediment Load (tons/day)	-----	-----	-----	-----	0 - 9
Calcium (mg/L)	10 - 87	68 - 110	44 - 79	12	-----
Magnesium (mg/L)	3.3 - 28.0	23.0 - 30.0	19 .0- 33.0	4.0	-----
Potassium (mg/L)	<0.1 - 19.0	0.7 - 2.1	2.2 - 5.1	14	-----
Sodium (mg/L)	1.3 - 5.9	4.0 - 5.7	5.4 - 9.8	3.5	-----
Silica (mg/L)	8.2 - 26.0	18.0 - 25.0	10.0 - 18.0	7.0	-----
Chloride (mg/L)	8.5 - 16.0	9.5 - 12.0	12 .0- 26.0	12.0	-----
Sulfate (mg/L)	<0.1 - 43.0	3.0 - 34.0	22.0 - 32.0	<0.1	-----
Bicarbonate (mg/L)	54 - 415	330 - 380	182 - 366	-----	-----
Carbonate (mg/L)	0 - 12	0	0	-----	-----
Orthophosphorus (mg/L)	1.2 - 48.0	<0.1 - 2.0	<0.1 - 0.1	-----	0.1 - 1.7
Atrazine (ug/L)	<0.10 - 11.00	<0.10 - 55.00	0.16 - 0.34	1.50 - 3.50	0.46 - 19.00
Cyanazine (ug/L)	<0.10 - 0.30	<0.10 - 12.00	<0.10	<0.10 - 0.25	<0.10 - 7.20
Metolachlor (ug/L)	<0.10 - 3.40	<0.10 - 69.00	<0.10	<0.10 - 0.63	<0.10 - 3.80
Alachlor (ug/L)	<0.10 - 0.53	<0.10 - 0.35	<0.10 - 0.11	<0.10 - 0.14	<0.10 - 8.60
Metribuzin (ug/L)	<0.10	<0.10	<0.10	<0.10	<0.10
Butylate (ug/L)	<0.10	<0.10	<0.10	<0.10	<0.10
Trifluralin (ug/L)	<0.10	<0.10	<0.10	<0.10	<0.10

Data from Kalkhoff (1989), Kalkhoff and Kuzniar (1991), and Kalkhoff and others (1992).

in 1990 (Libra et al., 1991; Rowden et al., 1993). Additional data for nitrate and pesticides are available from these sites, collected by the DNR-GSB, and summary reports are in progress.

Site DC-5 was sampled in 1989 and 1990. The predominant ions were calcium, magnesium, and bicarbonate. Nitrate plus nitrite-nitrogen concentrations ranged from 0.70-17.00 mg/L. Atrazine concentrations varied from <0.10-55.00 μg/L; cyanazine from <0.10-12.00 μg/L; metolachlor from <0.10-69.00 μg/L; and alachlor from <0.10-0.53 μg/L.

At site RC-2, the predominant ions were calcium, magnesium, and bicarbonate. Nitrate plus nitrite-nitrogen concentrations ranged from <0.1-18.0 mg/L. Daily mean discharge varied from 0-

Table 1. (cont.)

Parameter	1988 RC-2	1989 RC-2	1990 RC-2
Drainage Area (square miles)	70.7		
Temperature (°C)	2 - 30	1 - 27	0 - 28
Specific Conductance (uS/cm at 25 °C)	365 - 700	344 - 740	255 - 797
pH	7.23 - 9.40	7.12 - 8.87	7.1 - 9.1
Dissolved Oxygen (mg/L)	7.5 - >20.0	-----	6 - 13.2
NO2 + NO3-N (mg/L)	0.2 - 15.0	0.3 - 6.2	<0.1 - 18.0
NH4-N (mg/L)	<0.1 - 0.4	<0.1 - 4.2	<0.1 - 4.0
Organic-N (mg/L)	<0.1 - 1.1	0.4 - 7.2	0.5 - 20.0
Total Organic-Carbon (mg/L)	1.7 - 4.2	2.8 - 45.0	17.0 - 93.0
Daily Mean Discharge (cubic feet/second)	0.02 - 190.0	0.0 - 290.0	0.0 - 426.0
Suspended Sediment Concentration (mg/L)	4.2 - 810	-----	6 - 730
Suspended Sediment Load (tons/day)	-----	0 - 220	0 - 2960
Calcium (mg/L)	51 - 85	25 - 92	33 - 110
Magnesium (mg/L)	22.0 - 36.0	9.8 - 37.0	12.0 - 40.0
Potassium (mg/L)	3.5 - 5.1	5.0 - 21.0	4.8 - 27.0
Sodium (mg/L)	7.2 - 10.0	5.4 - 68.0	4.6 - 16.0
Silica (mg/L)	7.5 - 15.0	3.1 - 14.0	4.1 - 12.0
Chloride (mg/L)	16.0 - 26.0	16.0 - 110.0	25.0 - 35.0
Sulfate (mg/L)	24.0 - 40.0	2.3 - 61.0	23.0 - 46.0
Bicarbonate (mg/L)	220 - 354	114 - 404	260 - 270
Carbonate (mg/L)	0 - 36	0 - 24	0 - 50
Orthophosphorus (mg/L)	<0.1 - 0.2	3.7 - 45.0	0.6 - 2.1
Atrazine (ug/L)	<0.10 - 0.72	0.11 - 4.40	0.16 - 12.00
Cyanazine (ug/L)	<0.10 - 0.72	<0.10 - 0.78	<0.10 - 8.50
Metolachlor (ug/L)	<0.10 - 0.11	<0.10 - 0.83	<0.10 - 7.40
Alachlor (ug/L)	<0.10 - 0.55	<0.10 - 0.77	<0.10 - 8.20
Metribuzin (ug/L)	<0.10	<0.10	<0.10 - 1.60
Butylate (ug/L)	<0.10	<0.10	<0.10
Trifluralin (ug/L)	<0.10	<0.10	<0.10

Data from Kalkhoff (1989), Kalkhoff and Kuzniar (1991), and Kalkhoff and others (1992).

426 ft^3/s. Suspended sediment concentrations ranged from 4.2-810 mg/L and suspended sediment load from 0-2,960 tons/day. Atrazine concentrations varied from <0.10-12.00 µg/L; cyanazine from <0.10-8.50 µg/L; metolachlor from <0.10-7.40 µg/L; alachlor from <0.10-8.20 µg/L; and metribuzin from <0.10-1.60 µg/L.

At site Boog-D, nitrate plus nitrite-nitrogen concentrations ranged from 1.0-30.0 mg/L. Daily mean discharge ranged from 0-21.0 ft^3/s. The suspended sediment concentrations ranged from 9-1,160 mg/L and suspended sediment load from 0-8.9 tons/day. Atrazine concentrations varied from 0.16-19.00 µg/L; cyanazine from <0.10-7.20 µg/L; metolachlor from <0.10-3.80 µg/L; and alachlor from <0.10-8.60 µg/L.

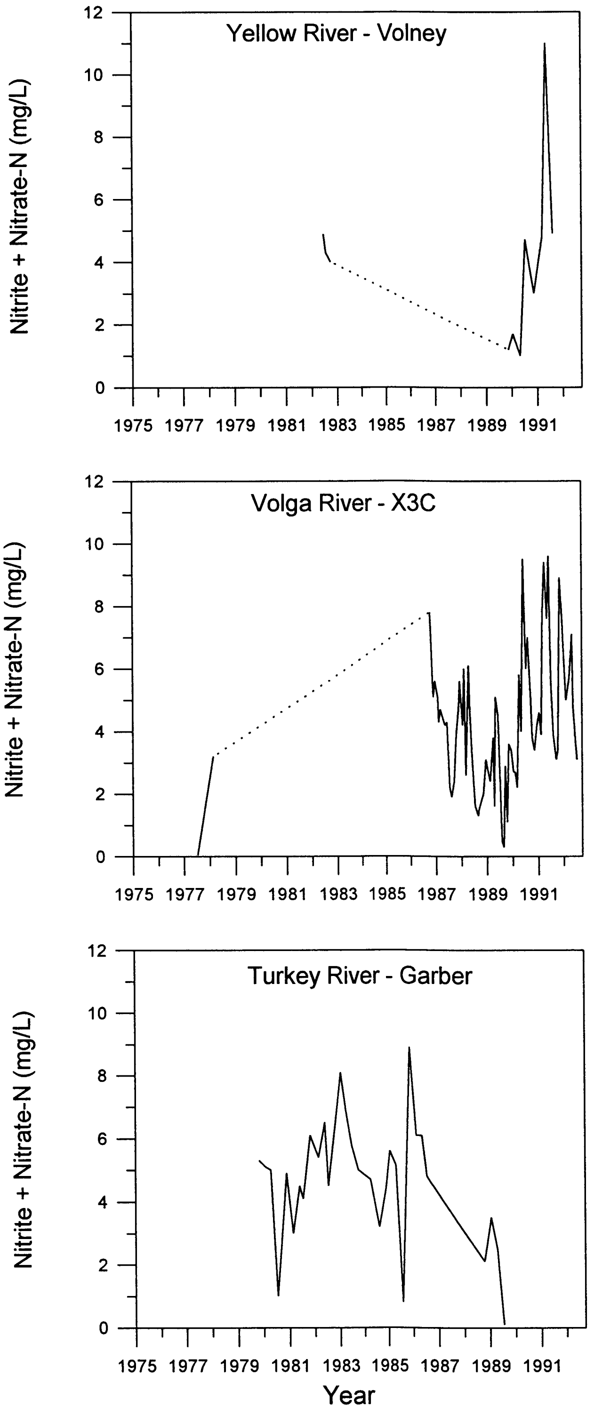


Figure 4. Historic nitrite+nitrate-N data for three surface water locations in northeast Iowa: Yellow River at Volney, Volga River at county road X3C, and the Turkey River at Garber.

HISTORIC SURFACE-WATER QUALITY DATA FROM STORET

STORET is a national computer database for water quality data. Historic water-quality data for creeks and rivers near Sny Magill and Bloody Run was downloaded from STORET and summarized by water quality parameter (Appendix I). Sixteen locations were identified and the most relevant parameters summarized. These watersheds are all in northeastern Iowa, within 30 to 40 miles (48 to 64 km) of the Sny Magill area, and provide further regional insight and historic background. These data were collected to gather background water-quality observations for various state and federal programs, for waste-load allocation studies, and as part of general monitoring for assessing and reporting of water-quality conditions in Iowa (e.g., for USEPA 305b reporting). Detections of various pesticides were recorded, including a wide range of concentrations, relating to wide variance in drainage area and flow/discharge conditions. Locally, problems are evident for high fecal bacteria and BOD. Other evaluations have noted that sedimentation is a problem in most areas. Because of the time span the data were collected over it is difficult to make many additional generalizations. Perhaps most pertinent to the current review are some observations from sites with longer temporal records.

Figure 4 shows the nitrite + nitrate-N concentrations for three sites with longer-term records: the Volga River (road X3C bridge), the Yellow River at Volney, and the Turkey River at Garber. The Volga River shows a general increase in concentrations during the 16-year period. Declines in concentrations occurred seasonally as well as a significant decline during the drought years of 1988-89. Concentrations increased during 1990-92 in association with increased rainfall, a trend similar to the groundwater at Big Spring (Figure 3).

UHL WATER QUALITY SURVEYS OF NORTHEASTERN IOWA STREAMS

During the late 1970s and 80s, the University of Iowa Hygienic Laboratory (UHL) conducted several, more detailed water-quality studies of small

Table 2. Summary of water-quality data from the University Hygienic Laboratory studies.

Analyte	# of Samples	Range	Mean	# of Samples	Range	Mean
Kennedy, 1978 (UHL Report 78-13);				Meierhoff and Prill, 1980 (UHL Report 80-19)		
		Volga River and tributaries			*Little Turkey River and tributaries: winter*	
Temperature (°C)	27	21 - 32	26	10	0 - 0	0
Fecal Coliform Bacteria (per 100 ml)	23	190 - 230,000	14,772	10	10 - 1,200	197
Ammonia-N (mg/L)	23	0.01 - 0.24	0.07	10	0.09 - 0.21	0.12
Organic-N (mg/L)	23	0.42 - 2.10	1.10	10	0.15 - 0.41	0.25
Nitrate-N (mg/L)	23	<0.1 - 1.4	0.5	10	3.8 - 6.2	5.2
Dissolved Oxygen (mg/L)	27	3.0 - 13.9	10.1	10	8.7 - 11.4	10.1
BOD (mg/L)	23	<1 - 13	4	10	1 - 2	2
TOC (mg/L)	23	6.8 - 24.2	14.1	10	3 - 7	4
Turbidity (NTU)	23	1.5 - 320.0	63.1	10	1.4 - 4.9	2.4
Conductance (umho)	23	350 - 520	417	10	440 - 600	511
Chloride (mg/L)	23	3 - 33	12	10	12 - 15	13
Prill and Meierhoff, 1978 (UHL Report 78-47);						
		Volga River and tributaries			*Little Turkey River and tributaries: summer*	
Temperature (°C)	30	0 - 3	0	10	19 - 24	22
Fecal Coliform Bacteria (per 100 ml)	30	<10 - 400,000	13,545	10	300 - 3,600	1329
Ammonia-N (mg/L)	30	0.01 - 2.60	0.25	10	0.02 - 0.08	0.05
Organic-N (mg/L)	30	<0.01 - 0.84	0.02	10	0.06 - 0.53	0.44
Nitrate-N (mg/L)	30	1.2 - 7.0	3.9	10	4.3 - 6.2	5.9
Dissolved Oxygen (mg/L)	30	10.6 - 15.3	13.1	10	9.0 - 13.6	12.2
BOD (mg/L)	30	<1 - 4	1	10	1 - 2	1
TOC (mg/L)	30	3.9 - 21	6.2	10	5 - 12	8
Turbidity (NTU)	30	<1.0 - 7.2	2.7	10	2.5 - 8.9	6.6
Conductance (umho)	30	480 - 650	580	10	470 - 540	497
Chloride (mg/L)	30	3 - 30	14	10	14 - 19	18
Kennedy and Meierhoff, 1979 (UHL Report 79-20)						
		Yellow River and tributaries				
Temperature (°C)	18	17 - 25.5	22			
Fecal Coliform Bacteria (per 100 ml)	18	80 - 15,000	2,213			
Ammonia-N (mg/L)	18	<0.01 - 0.10	0.04			
Organic-N (mg/L)	18	0.07 - 0.91	0.52			
Nitrate-N (mg/L)	18	1.6 - 5.9	3.7			
Dissolved Oxygen (mg/L)	18	6.8 - 13.0	10.3			
BOD (mg/L)	18	1 - 4	3			
TOC (mg/L)	18	3 - 12	7.4			
Conductance (umho)	18	460 - 690	577			
Chloride (mg/L)	18	3 - 20	11			

northeastern Iowa streams. The main purpose of the studies was to obtain background data where little water-quality data was available and, in part, to address possible source loading and waste-load allocation assessments. Tables 2 and 3 summarize the water-quality data from Geary (1977), Kennedy (1978), Kennedy and Meierhoff (1979), Meierhoff and Prill (1980), and Prill and Meierhoff (1978, 1979).

Twenty-seven sites on the Volga River and

Table 3. Summary of water-quality data from the University Hygienic Laboratory studies; Bloody Run and Sny Magill creeks.

Analyte	Number of Samples	Range	Mean	Number of Samples	Range	Mean
				Bloody Run Creek		
	Geary, 1977 (UHL Report 77-20)			Prill and Meierhoff, 1979 (UHL Report 79-14)		
Sample Period:	**August, 1976**			**August, 1978**		
Temperature (°C)	2	17.0 - 19.5	18.3	5	17.0 - 20.5	19.3
Fecal Coliform Bacteria (per 100 ml)	2	240 - 1,600	920	4	350 - 2,500	1,263
Ammonia-N (mg/L)	2	<0.01 - 0.02	0.01	5	<0.01 - 0.05	0.03
Organic-N (mg/L)	2	0.28 - 0.28	0.28	---	---	---
Nitrate-N (mg/L)	2	1.3 - 3.4	2.4	5	1.8 - 6.1	3.8
Dissolved Oxygen (mg/L)	2	13.9 - 14.1	14	5	7.3 - 10.7	8.9
BOD (mg/L)	2	1 - 1	1	5	<1 - 2	1
TOC (mg/L)	2	3.9 - 12.7	8.3	5	5.0 - 7.0	6.0
COD (mg/L)	2	6 - 12	8	5	5 - 18	12
Turbidity (NTU)	2	3.0 - 6.5	4.8	5	3.7 - 18	9.4
Chloride (mg/L)	2	5.0 - 5.5	5.3	5	4.0 - 13.0	8.0
				Sny Magill Creek		
Temperature (°C)	3	21.0 - 22.0	21.7	6	22.5 - 25.0	23.8
Fecal Coliform Bacteria (per 100 ml)	3	50 - 720	330	6	50 - 330,000	93,655
Ammonia-N (mg/L)	3	<0.01 - 0.01	0.01	6	<0.01 - 0.09	0.03
Organic-N (mg/L)	3	0.19 - 0.24	0.21	---	---	---
Nitrate-N (mg/L)	3	0.30 - 1.20	0.60	6	0.30 - 0.80	0.49
Dissolved Oxygen (mg/L)	3	12.4 - 14.1	13.4	6	10.0 - 13.6	11.7
BOD (mg/L)	3	1 - 1	1	6	<1 - 2	1
TOC (mg/L)	3	0 - 5.2	2.1	6	4.0 - 14.0	7.0
COD (mg/L)	3	6 - 12	8	6	6 - 26	12
Turbidity (NTU)	3	1.5 - 4.3	3.1	6	1.8 - 9.6	4.0
Chloride (mg/L)	3	1.5 - 4.5	2.8	6	2.0 - 3.0	3.0

several tributaries were monitored in July 1977 (Kennedy, 1978). Water quality was variable, probably the result of rainfall the day prior to sampling, followed by subsequent runoff. High fecal coliform bacteria counts were detected at several sites and the overall water quality was rated as fair (Table 2). These sites on the Volga River and tributaries were studied again February 20-22, 1978, under low-flow, ice-covered conditions (Prill and Meierhoff, 1978). Overall water quality was considered good, supporting the conclusion of Kennedy (1978) that the poor water quality during the July 1977 sampling was influenced by the rainfall and runoff.

The Yellow River and several of its tributaries were sampled in July and August 1978 (Kennedy and Meierhoff, 1979). Biological data was collected in addition to bacteriological, chemical, and physical data. Dissolved-oxygen concentrations were considered adequate for fish and aquatic life. Water temperatures were elevated at several locations as were fecal coliform bacteria counts. The high fecal coliform bacteria counts were thought related to pastureland runoff. Organic-N and ammonia-N concentrations were low. Nitrate-N concentrations were highest at the headwaters of the

Yellow River and its tributaries and then declined downstream. This trend was attributed to dilution and utilization of nitrate-N by in-stream plant life. Overall water quality of the Yellow River and its tributaries during average summer stream flows was rated good.

Meierhoff and Prill (1980) analyzed water samples from ten locations on the Little Turkey River in January and September 1979. Water quality was considered good and the benthic community was classified as healthy and diverse.

Water-quality data was collected for both Sny Magill and Bloody Run creeks in 1976 and 1978 (Geary, 1977; Prill and Meierhoff, 1979; Table 3). The study by Geary (1977) included several upper Mississippi River tributaries and was done in August 1976. Sampling of two sites on Bloody Run and three on Sny Magill occurred under low-flow conditions. Water-quality conditions generally were typical of northeastern Iowa's coldwater streams. Fecal coliform bacteria counts, COD, and TOC concentrations at the downstream Bloody Run site were higher than counts and concentrations at the upstream locations. Water quality on Sny Magill was considered excellent except for elevated summer temperatures.

Eleven sites on Sny Magill and Bloody Run were also sampled August 14-15, 1978 (Prill and Meierhoff, 1979). Bacteriological, chemical, physical, and biological data were collected. Overall, water quality was considered good, but at the Sny Magill sites water temperatures were elevated for a coldwater stream, and locally fecal bacteria were very high.

1991 BASELINE SAMPLING IN SNY MAGILL AND BLOODY RUN WATERSHEDS

Nine sites on Sny Magill and Bloody Run creeks were sampled by the Department of Natural Resources-Geological Survey Bureau for nitrogen-series (nitrate plus nitrite-nitrogen, ammonium-nitrogen, organic-nitrogen), and pesticides on a weekly to monthly basis from February through September 1991 (see Figure 5). Primary sites on Sny Magill and Bloody Run creeks were monitored weekly for nitrate and monthly for nitrogen-series (N-series), and common pesticides. The remaining sites were sampled monthly for N-series. As final plans were made for the Sny Magill Watershed Nonpoint Source Monitoring Project, during the spring and summer of 1991, sampling sites and sampling frequency were modified. During February and March 1991 six sites were sampled monthly for nitrate and N-series. From April through October, nine sites were monitored; five primary sites weekly and the other four sites monthly.

Water Quality Results

Table 4 summarizes the water-quality data for the nine sites. For parametric statistical summaries, values below the quantitation limit of 0.2 mg/L of NO_3-N were given a value of 0.1 mg/L (i.e., half the quantitation limit). Sampling for NO_3-N showed a general trend of higher NO_3-N concentrations at upstream sites with a decline in concentrations moving downstream for both Sny Magill and Bloody Run. A downstream decline in NO_3-N concentrations has been reported in surface water in other areas of Iowa, such as the adjacent Big Spring basin (Bachmann et al., 1991) and Bear Creek, a shallow stream in central Iowa (Isenhart and Crumpton, 1989).

For both Bloody Run and Sny Magill sites, higher mean NO_3-N concentrations occurred at the upstream sites (BR2, SN2) than at the downstream sites (SN1, BR1). Overall, higher concentrations were reported from Bloody Run sites than Sny Magill sites. The highest concentration of NO_3-N was 10.0 mg/L at site BR2. Concentrations of NO_3-N ranged from 0.7 - 10.0 mg/L. Overall mean concentration was 3.4 mg/L and overall median concentration was 2.7 mg/L.

Of the six different sites in the Sny Magill watershed, site NCC had the highest mean NO_3-N concentration, 2.8 mg/L. For both streams the overall concentrations for NO_3-N ranged from 0.7 to 10.0 mg/L.

For statistical summary of ammonium-N, and organic-N, values below the detection limit of 0.1 mg/L were given a value of 0.05 mg/L. Eighty-two percent of the samples reported no detection of

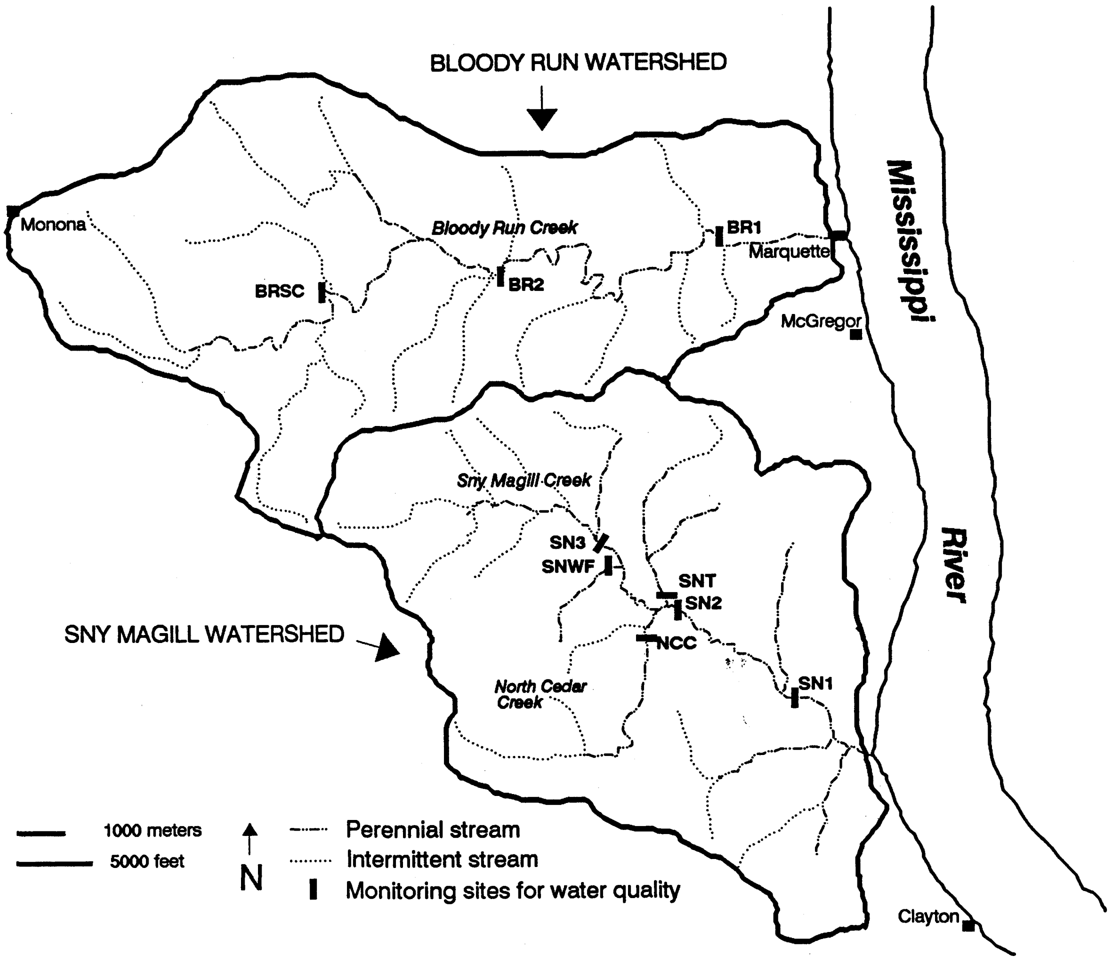


Figure 5. Sny Magill and Bloody Run water sampling locations for baseline monitoring conducted in 1991.

ammonium-N. The highest detection of ammonium-N was 0.2 mg/L at sites SN1 and SN2. Concentrations for ammonium-N ranged from <0.1 to 0.2 mg/L. Overall mean and median ammonium-N concentrations were <0.1 mg/L. Ammonium-N is toxic to fish in concentrations above 1.0 mg/L, but varies with water temperature and other factors. Results for organic-N showed higher concentrations at the upstream site than downstream site on Bloody Run, however, this was not true for Sny Magill. On Sny Magill there was not a consistent trend as with nitrate. Overall concentrations ranged from <0.1 to 0.8 mg/L. The highest concentration (0.8 mg/L) was detected at site BR2.

The primary sites on Sny Magill and Bloody Run (SN1 and BR1) were sampled monthly for 18 common pesticides. For statistical analysis, values below the detection limit of 0.1 µg/L were given a value of 0.05 µg/L. Three herbicides (atrazine, cyanazine, alachlor) were detected (Table 4). Detectable concentrations ranged from 0.13 to 1.40 µg/L. Atrazine was the most commonly detected herbicide, being detected in 81% of the samples. Atrazine was detected in all samples from site BR1. The highest concentration of atrazine occurred in May at site BR1 on Bloody Run (1.40 µg/L) and

Table 4. Summary of 1991 baseline water-quality data for Sny Magill and Bloody Run watersheds.

Parameter	Site	Drainage area (sq. mi.)	Number of samples	Range in Concentration	Mean Concentration	Median Concentration
Ammonium-N (mg/L)	SN1	27.6	8	<0.1 - 0.2	<0.1	<0.1
	SN2	22.5	8	<0.1 - 0.2	<0.1	<0.1
	SN3	7.3	1	<0.1	-----	-----
	SNWF	3.1	1	<0.1	-----	-----
	SNT	3.2	8	<0.1 - 0.1	<0.1	<0.1
	NCC	6.0	8	<0.1	-----	-----
	BR1	34.3	8	<0.1 - 0.1	<0.1	<0.1
	BR2	24.5	8	<0.1 - 0.1	<0.1	<0.1
	BRSC	10.5	1	<0.1	-----	-----
	Overall		51	<0.1 - 0.2	<0.1	<0.1
Nitrate-N (mg/L)	SN1	27.6	36	0.7 - 4.0	1.9	1.7
	SN2	22.5	16	1.2 - 4.1	2.4	2.1
	SN3	7.3	5	2.2 - 2.7	2.5	2.4
	SNWF	3.1	5	1.8 - 2.1	2.0	2.0
	SNT	3.2	16	0.9 - 3.3	1.9	1.7
	NCC	6.0	16	0.7 - 5.6	2.8	2.7
	BR1	34.3	36	2.4 - 7.6	3.9	3.7
	BR2	24.5	16	6.2 - 10.0	8.0	7.7
	BRSC	10.5	5	6.2 - 8.3	7.7	8.0
	Overall		151	0.7 - 10.0	3.4	2.7
Organic-N (mg/L)	SN1	27.6	8	0.1 - 0.7	0.3	0.3
	SN2	22.5	8	<0.1 - 0.5	0.2	0.2
	SN3	7.3	1	0.3	-----	-----
	SNWF	3.1	1	0.3	-----	-----
	SNT	3.2	8	<0.1 - 0.4	0.2	0.1
	NCC	6.0	8	<0.1 - 0.6	0.3	0.4
	BR1	34.3	8	<0.1 - 0.5	0.3	0.3
	BR2	24.5	8	<0.1 - 0.8	0.4	0.3
	BRSC	10.5	1	0.4	-----	-----
	Overall		51	<0.1 - 0.8	0.3	0.2
alachlor (µg/L)	SN1	27.6	8	<0.10 - 0.13	<0.10	<0.10
	BR1	34.3	8	<0.10 - 0.16	<0.10	<0.10
	Overall		16	<0.10 - 0.16	<0.10	<0.10
atrazine (µg/L)	SN1	27.6	8	<0.10 - 0.73	0.26	0.16
	BR1	34.3	8	0.16 - 1.40	0.44	0.24
	Overall		16	<0.10 - 1.40	0.35	0.23
cyanazine (µg/L)	SN1	27.6	8	<0.10	-----	-----
	BR1	34.3	8	<0.10 - 0.23	<0.10	<0.10
	Overall		16	<0.10 - 0.23	<0.10	<0.10

NOTE: The following 15 pesticides were analyzed for but not detected: butylate, metolachlor, metribuzin, pendimethalin, propachlor, trifluralin, chlorpyrifos, diazinon, dimethoate, ethoprop, fonofos, malathion, parathion, phorate, terbufos.

June at site SN1 on Sny Magill (0.73 μg/L).

The 1991 baseline data afford some comparisons with the prior water-quality data collected in 1976 and 1978 by the UHL. Though the sampling regimens were different some trends are apparent for nitrate, consistent with the other regional data discussed. With nitrate, minimum concentrations are always similar because of in-stream consumption and denitrification that takes place during summer low-flows, but medians, means, and maxima are useful for temporal comparison. During the 1976 and 1978 sampling nitrate-N concentrations on Bloody Run varied from 1.3 to a maximum of 6.1 mg/L, with an overall mean of 3.2 mg/L. In 1991, overall site means or medians on Bloody Run ranged from 4 to 8 mg/L, with a maximum of 10 mg/L. For Sny Magill the concentrations and, hence, increases were less. In 1976-1978, NO_3-N ranged from 0.3 to 1.2; in 1991 the medians for all sites were greater than even these maximum values, ranging from 1.7 to 2.7 mg/L, with a maximum >5.0 mg/L.

Ammonium and organic-N remained low and little change is apparent. Herbicides were not included in the 1976-78 analytes. As noted by Seigley and others (1992), high temperatures, sediment, and at times ammonium, and oxygen demand have become a problem for aquatic life over time.

SUMMARY

Historic water-quality data was compiled for Sny Magill and Bloody Run creeks, and for surrounding creeks and rivers, and groundwater from the Big Spring basin. All of the rivers and creeks in northeastern Iowa have a large groundwater flow component, particularly the coldwater streams such as Sny Magill and portions of Bloody Run.

Water-quality data from the Big Spring basin and area streams summarized from STORET and other special studies, illustrate many aspects of regional water quality. Over time, nitrate concentrations have risen, concurrent with increases in agricultural landuse and management changes, particularly increases in fertilizer-N use, that increased nitrogen loading. Comparative data from Sny Magill and Bloody Run suggest that average nitrate-N concentrations approximately doubled from 1976-78 to 1991, similar to regional trends.

The studies illustrate, as expected, that many water-quality parameters vary temporally with runoff and with seasonal changes. The coldwater streams in the region have generally good water quality, particularly during groundwater dominated baseflow periods, but during runoff sediment loads are high and fecal bacteria are a concern in many areas related to the area's livestock enterprises. Locally, and seasonally, problems are apparent with ammonium, BOD, or COD. In Sny Magill, fecal bacteria are a local problem, and summer temperatures had become a problem even by the late 1970s, for the coldwater fishery. Data from across the region showed typical downstream declines in nitrate concentrations, related to in-stream nutrient consumption and denitrification; samples from small headwater basins having greater nitrate-N concentrations than downstream sample locations that integrate larger watershed drainage areas.

Several commonly-used herbicides have been detected in area stream water in 1982 and 1991 sampling. Data are not available for any trend analysis, but some of the herbicides now detected were not in use 20 years ago.

The extensive monitoring of water quality and of farming practices in the Big Spring basin illustrates the need for such long-term monitoring and evaluation studies as the Sny Magill project. The Big Spring Basin Demonstration Project has effected substantial improvements in farm management that should be reflected in water-quality improvements. The project has documented improvements in nitrogen-input efficiency; but despite reductions in fertilizer-nitrogen rates for corn of about 30% by basin farmers, nitrate concentrations in groundwater have not shown a consistent decline. Extreme climatic conditions have affected the variability of nitrate and pesticides as shown by the correspondence of the highest annual mean nitrate concentrations to periods of greater groundwater discharge (1991). The lowest flow-weighted mean nitrate concentration occurred in 1989, a drought year. Annual flow-weighted mean atrazine concentrations do not parallel annual discharge. The extreme variability of these annual parameters over a short period of time underscores the need for long-term monitoring of nonpoint-source contamination.

ACKNOWLEDGMENTS

Tom Wilton of the IDNR, Water Quality Bureau downloaded the STORET data summarized in this report. Bob Rowden and Matt Culp did the baseline water sampling in Sny Magill and Bloody Run watersheds. Mary Skopec, Deb Quade, and Bob Rowden assisted with needed graphics.

REFERENCES

Bachmann, R.W., Crumpton, W.G., and Hallberg, G.R., 1991, Nitrogen losses in an agricultural stream: Vehr. Internat. Verein. Limnol., v. 24, p. 1641-1643.

Capel, P.D., 1990, Atmospheric deposition of herbicides in the mid-continental United States (abs): Eos, Trans. AGU, v. 71, no. 43, p. 1329.

Geary, D.M., 1977, Summer water quality of the Upper Mississippi River tributaries: UHL Report 77-20, University Hygienic Laboratory, Iowa City, IA.

Goolsby, D.A., Thurman, E.M., Pomes, M.L., and Majure, J.J., 1990, Herbicides in atmospheric wet deposition-preliminary results: National Atmospheric Deposition Program Technical Committee Meeting Abstracts of Papers, NADP/NTN Coordination Office, Colorado State University, Fort Collins, CO, p. 7.

Hallberg, G.R., 1989, Nitrate in groundwater in the United States, *in* R.F. Follett (ed.), Nitrogen Management and Groundwater Protection, Developments in Agric. and Managed-Forest Ecology 21: Elsevier Science Publ., Amsterdam, p. 35-74.

Hallberg, G.R., Hoyer, B.E., Bettis, E.A., III, and Libra, R.D., 1983, Hydrogeology, water quality, and land management in the Big Spring basin, Clayton County, Iowa: Iowa Geological Survey, Open-File Report 83-3, 191 p.

Hallberg, G.R., Libra, R.D., Bettis, E.A., III, and Hoyer, B.E., 1984, Hydrologic and water-quality investigations in the Big Spring basin, Clayton County, Iowa: 1983 Water-Year: Iowa Geological Survey Report 84-4, 231 p.

Hallberg, G.R., Libra, R.D., and Hoyer, B.E., 1985, Nonpoint source contamination of groundwater in karst-carbonate aquifers in Iowa, *in* Perspectives on Nonpoint Source Pollution: Washington, D.C., United States Environmental Protection Agency, Environmental Protection Agency 440/5 85-001, p. 109-114.

Hallberg, G.R., Libra, R.D., Long, K.R., and Splinter, R.C., 1987, Pesticides, groundwater, and rural drinking water quality in Iowa, *in* Pesticides and Groundwater: A Health Concern for the Midwest: Navarre, MN, The Freshwater Foundation and the United States Environmental Protection Agency, p. 83-104.

Hallberg, G.R., Libra, R.D., Quade, D.J., Littke, J., and Nations, B., 1989, Groundwater monitoring in the Big Spring basin 1984-1987: a summary review: Iowa Department of Natural Resources, Geological Survey Bureau, Technical Information Series 16, 68 p.

Hallberg, G.R., Contant, C.K., Chase, C.A., Miller, G.A., Duffy, M.D., Killorn, R.J., Voss, R.D., Blackmer, A.M., Padgitt, S.C., DeWitt, J.R., Gulliford, J.B., Lindquist, D.A., Asell, L.W., Keeney, D.R., Libra, R.D., and Rex, K.D., 1991, A progress review of Iowa's agricultural-energy-environmental initiatives: nitrogen management in Iowa: Iowa Department of Natural Resources, Geological Survey Bureau, Technical Information Series 22, 29 p.

Isenhart, T.M., and Crumpton, W.G., 1989, Transformation and loss of nitrate in an agricultural stream: Journal of Freshwater Ecology, v. 5, no. 2, p. 123-129.

Kalkhoff, S.J., 1989, Hydrologic data for the Big Spring basin, Clayton County, Iowa, Water Year 1988: U.S. Geological Survey Open File Report 879-230, 44p.

Kalkhoff, S.J., and Kuzniar, R.L., 1991, Hydrologic data for the Big Spring basin, Clayton County, Iowa, Water Year 1989: U.S. Geological Survey

Open File Report 91-63, 66 p.

Kalkhoff, S.J., Kuzniar, R.L., Kolpin, D.L., and Harvey, C.A., 1992, Hydrologic data for the Big Spring basin, Clayton County, Iowa, Water Year 1990: U.S. Geological Survey Open File Report 92-67, 80 p.

Kennedy, J.O., 1978, Water quality of the Volga River and tributaries: UHL Report 78-13, University Hygienic Laboratory, Iowa City, IA.

Kennedy, J.O., Ceilley, D.W., and Miller, J.G., III, 1988, A survey of the benthic macroinvertebrates and fishes of the Big Spring basin, Iowa: UHL Report 88-9, University Hygienic Laboratory, Iowa City, IA.

Kennedy, J.O., and Meierhoff, M.L., 1979, Water quality of the Yellow River: UHL Report 79-20, University Hygienic Laboratory, Iowa City, IA.

Kennedy, J.L., and Miller, J.G., III, 1990, A survey of the benthic macroinvertebrates of the Big Spring basin, Iowa: The Journal of the Iowa Academy of Science, v. 97, no. 2, p. 46-54.

Libra, R.D., Hallberg, G.R., Hoyer, B.E., and Johnson, L.G., 1986, Agricultural impacts on groundwater quality: the Big Spring basin study, *in* Agricultural Impacts on Ground Water, National Water Well Association, Worthington, OH, p. 253-273.

Libra, R.D., Hallberg, G.R., and Hoyer, B.E., 1987, Impacts of agricultural chemicals on groundwater quality in Iowa, *in* D.M. Fairchild (ed.), Ground Water Quality and Agricultural Practices: Chelsea, MI, Lewis Publ. Inc., p. 185-217.

Libra, R.D., Hallberg, G.R., Littke, J.P., Nations, B.K., Quade, D.J., and Rowden, R.D., 1991, Groundwater monitoring in the Big Spring basin 1988-1989: a summary review: Iowa Department of Natural Resources, Geological Survey Bureau, Technical Information Series 21, 29 p.

Littke, J.P., and Hallberg, G.R., 1991, Big Spring basin water-quality monitoring program: design and implementation: Iowa Department of Natural Resources, Geological Survey Bureau, Open File Report 91-1, 19 p.

Meierhoff, M.L., and Prill, S.D., 1980, Winter/summer water quality of the Little Turkey River: UHL Report 80-19, University Hygienic Laboratory, Iowa City, IA.

Nations, B.K., 1990, Pesticides in Iowa precipitation: National Atmospheric Deposition Program Technical Committee Meeting Abstracts of Papers, NADP/NTN Coordination Office, Colorado State Unviersity, Fourt Collins, CO, p. 7.

Nations, B.K., and Hallberg, G.R., 1992, Pesticides in Iowa precipitation: Journal of Environmental Quality, v. 21, no. 3, p. 486-492.

Prill, S.D., and Meierhoff, M.L., 1978, Water quality survey of the Volga River basin: UHL Report 78-47, University Hygienic Laboratory, Iowa City, IA.

Prill, S.D., and Meierhoff, M.L., 1979, Summer water quality survey of the Bloody Run Creek and Sny Magill Creek basins: UHL Report 79-14, University Hygienic Laboratory, Iowa City, IA.

Rowden, R.D., and Libra, R.D., 1990, Hydrogeologic observations from bedrock monitoring well nests in the Big Spring basin: Iowa Department of Natural Resources, Geological Survey Burea, Open File Report 90-1, 27 p.

Rowden, R.D., Libra, R.D., Hallberg, G.R., and Nations, B., 1993, Groundwater monitoring in the Big Spring basin 1990-1991: a summary review: Iowa Department of Natural Resources, Geological Survey Bureau, Technical Information Series 27, 36 p.

Seigley, L.S., Hallberg, G.R., Wilton, T., Schueller, M.D., Hausler, M.C., Kennedy, J.O., Wunder, G., Link, R.V., and Brown, S.S., 1992, Sny Magill Watershed nonpoint source pollution monitoring project workplan, Iowa Dept. of Natural Resources, Geological Survey Bureau, Open File Report 92-1, Iowa City, IA, 32 p.

Seigley, L.S., Hallberg, G.R., Rowden, R.D., Libra, R.D., Giglierano, J.D., Quade, D.J., and Mann, K.O., 1993, Agricultural landuse and nitrate cycling in surface water in northeast Iowa: Proceedings from Agricultural Research to Protect Water Quality, February 21-24, Minneapolis, MN, p. 85-88.

APPENDIX

Water quality data from STORET for surrounding locations.

Analysis (STORET code)	Site	Number of Samples	Sample Period	Range	Mean	Standard Deviation
Temperature (00010) - degrees Celcius						
	Elk Creek	15	4/20/78 - 10/9/78	6 - 24	13	6.6
	Little Turkey	4	10/29/75 - 9/11/79	0 - 22.5	12.6	10.9
	SCC	2	10/29/75 - 6/29/76	9 - 18.6	13.8	6.8
	SCC - Sec. 32	4	11/14/77 - 1/5/78	0 - 5.5	2.4	2.8
	SCC - TR15	15	4/20/78 - 10/9/78	6 - 24	12.8	6.6
	TR-Eldorado	4	10/29/75 - 9/11/79	0 - 24	12.8	11.6
	TR-near Garber	5	11/14/77 - 2/22/78	0 - 5	1.6	2.3
	TR - TR14	23	4/20/78 - 10/11/78	5.5 - 23	12.7	5.5
	TR - USGS Garber	32	10/30/79 - 7/11/89	0 - 29	12.5	9.7
	TR - W70 bridge	2	10/29/75 - 6/29/76	9 - 20.8	14.9	8.3
	VR - TR12	15	4/20/78 - 10/9/78	6 - 24	13.3	6.8
	VR - X3C bridge	70	10/29/75 - 3/17/92	0 - 29	11	9.6
	YR - Co. Rd. bridge	10	8/15/78 - 9/21/82	13 - 22	16.9	2.5
	YR - Rossville	16	8/15/78 - 9/21/82	13 - 21.5	18	2
	YR - Sec. 12	7	8/2/76 - 9/21/82	10.5 - 22.5	16.1	3.5
	YR - Volney	24	8/2/76 - 8/5/91	0.5 - 24	15.9	6.3
Conductivity (00095) - microohms/centimeter at 25°C						
	Elk Creek	1	8/17/78	480	-	-
	Little Turkey	4	10/29/75 - 9/11/79	430 - 530	475	48
	SCC	2	10/29/75 - 6/29/76	650 - 660	655	7.1
	SCC - TR15	11	4/20/78 - 10/7/78	383 - 680	588	75.9
	TR-Eldorado	4	10/29/75 - 9/11/79	490 - 530	513	20.6
	TR-near Garber	1	2/22/78	600	-	-
	TR - TR14	11	4/20/78 - 10/8/78	395 - 532	487	43.9
	TR - W70 bridge	2	10/29/75 - 6/29/76	480 - 510	495	21.2
	VR - TR12	12	4/20/78 - 10/9/78	430 - 540	509	32.4
	VR - X3C bridge	70	10/29/75 - 3/17/92	190 - 750	530	95.4
	YR - Co. Rd. bridge	10	8/15/78 - 9/21/82	460 - 650	540	67.2
	YR - Rossville	17	2/28/72 - 9/21/82	420 - 660	553	70.3
	YR - Sec. 12	7	8/2/76 - 9/21/82	470 - 700	574	81.2
	YR - Volney	24	8/2/76 - 8/5/91	300 - 650	558	72.8
Dissolved Oxygen (00300) - milligrams/liter						
	Little Turkey	4	10/29/75 - 9/11/79	8.1 - 11.9	10.1	1.6
	SCC	2	10/29/75 - 6/29/76	7.6 - 12.7	10.2	3.6
	SCC - Sec. 32	4	11/14/78 - 1/5/78	11.8 - 12.8	12.3	0.4
	SCC - TR15	14	4/20/78 - 10/9/78	4.2 - 11.0	8.6	1.8
	TR-Eldorado	4	10/29/75 - 9/11/79	8.9 - 12.7	10.4	1.7
	TR-near Garber	5	11/14/77 - 2/22/88	12.0 - 12.9	12.5	0.3
	TR - TR14	22	4/20/78 - 10/11/78	7.8 - 12.4	10.2	1.1
	TR - USGS Garber	28	10/30/79 - 7/11/89	7.7 - 20.0	11.7	2.5
	TR - W70 bridge	2	10/29/75 - 6/29/76	8.6 - 12.3	10.5	2.6
	VR - TR12	13	4/20/78 - 10/9/78	8.1 - 11.2	10.1	1.1
	VR - X3C bridge	70	10/29/75 - 3/17/92	7.6 - 18.8	11.4	2.3
	YR - Co. Rd. bridge	2	8/15/78 - 9/21/82	11.9 - 12.8	12.4	0.6

YR - Rossville	4	6/15/71 - 9/21/82	8.6 - 15.2	12.2	2.7
YR - Sec. 12	2	8/2/76 - 9/21/82	11.1 - 18.5	14.8	5.2
YR - Volney	11	8/2/76 - 8/5/91	8.0 - 17.3	12.7	2.7

BOD (00310) - milligrams/liter

Elk Creek					
Little Turkey	4	10/29/75 - 9/11/79	1 - 2	1.5	0.6
SCC	2	10/29/75 - 6/29/76	2 - 2	2	0
SCC - Sec. 32	4	11/14/77 - 1/5/78	1.0 - 2.0	1.8	0.5
SCC - TR15	15	4/20/78 - 10/9/78	1.0 - 2.3	1.5	0.5
TR-Eldorado	4	10/29/75 - 9/11/79	1 - 2	1.3	0.5
TR-near Garber	5	11/14/77 - 2/22/78	1 - 2	1.2	0.4
TR - TR14	13	4/20/78 - 10/9/78	0.2 - 3.2	1.6	0.7
TR - USGS Garber	28	10/30/79 - 7/15/86	1 - 12	3	2.8
TR - W70 bridge	2	10/29/75 - 6/29/76	1 - 2	1.5	0.7
VR - TR12	15	4/20/78 - 10/9/78	0.7 - 2.3	1.3	0.5
VR - X3C bridge	7	10/29/75 - 12/17/86	1 - 13	2.7	4.5
YR - Co. Rd. bridge	10	8/15/78 - 9/21/82	1 - 27	13.5	9
YR - Rossville	18	6/15/71 - 9/21/82	1 - 29	12.1	9.4
YR - Sec. 12	7	8/2/76 - 9/21/82	1 - 24	9.6	8.5
YR - Volney	16	8/2/76 - 9/21/82	1 - 27	8.1	6.9

Organic - N (00605) - milligrams/liter

Little Turkey	4	10/29/75 - 9/11/79	0.19 - 0.5	0.37	0.13
SCC	2	10/29/75 - 6/29/76	0.11 - 0.59	0.35	0.3
TR-Eldorado	4	10/29/75 - 9/11/79	0.06 - 0.41	0.3	0.16
TR-near Garber	1	2/22/78	0.01	-	-
TR - USGS Garber	28	10/30/79 - 7/15/86	0.11 - 7.6	1.19	1.67
TR - W70 bridge	2	10/29/75 - 6/29/76	0.36 - 0.56	0.46	0.1
VR - X3C bridge	4	10/29/75 - 2/22/78	0.01 - 1.8	0.62	0.8
YR - Co. Rd. bridge	10	8/15/78 - 9/21/82	0.1 - 11.0	4.08	3.67
YR - Rossville	18	6/15/71 - 9/21/82	0.17 - 10.0	3.4	3.19
YR - Sec. 12	7	8/2/76 - 9/21/82	0.46 - 5.9	2.74	2.03
YR - Volney	16	8/2/76 - 9/21/82	0.09 - 10.0	1.97	2.42

NH3 and NH4-N (00610) - milligrams/liter

Little Turkey	4	10/29/75 - 9/11/79	0.01 - 0.09	0.04	0.04
SCC	2	10/29/75 - 6/29/76	0.01 - 0.08	0.05	0.05
SCC - Sec. 32	4	11/14/77 - 1/5/78	0.03 - 0.04	0.04	0.01
SCC - TR15	15	4/20/78 - 10/9/78	0.04 - 0.40	0.17	0.2
TR-Eldorado	4	10/29/75 - 9/11/79	0.01 - 0.11	0.04	0.05
TR-near Garber	5	11/14/77 - 2/22/78	0.01 - 0.09	0.05	0.04
TR - TR14	13	4/20/78 - 10/9/78	0.04 - 0.40	0.19	0.2
TR - USGS Garber	25	10/30/79 - 7/15/86	0.01 - 1.60	0.18	0.37
TR - W70 bridge	2	10/29/75 - 6/29/76	0.01 - 0.02	0.02	0.1
VR - TR12	15	4/20/78 - 10/9/78	0.04 - 0.40	0.17	0.2
VR - X3C bridge	70	10/29/75 - 3/17/92	0.01 - 1.00	0.11	0.14
YR - Co. Rd. bridge	10	8/15/78 - 9/21/82	0.01 - 0.87	0.31	0.27
YR - Rossville	18	6/15/71 - 9/21/82	0.01 - 0.58	0.17	0.17
YR - Sec. 12	7	8/2/76 - 9/21/82	0.01 - 0.88	0.43	0.36
YR - Volney	24	8/2/76 - 8/5/91	0.01 - 0.68	0.13	0.15

Appendix. (cont.)

NO3 - N (00620) - milligrams/liter

Little Turkey	2	10/29/75 - 6/29/76	1.6 - 3.1	2.4	1.1
SCC	2	10/29/75 - 6/29/76	0.6 - 0.8	0.7	0.1
TR-Eldorado	2	10/29/75 - 6/29/76	1.8 - 2.6	2.2	0.6
TR - W70 bridge	2	10/29/75 - 6/29/76	1.3 - 2.5	1.9	0.8
VR - X3C bridge	2	10/29/75 - 6/29/76	1.1 - 1.4	1.3	0.2
YR - Rossville	2	6/15/1971 - 2/28/72	2.1 - 3.4	2.8	0.9
YR - Sec. 12	1	8/2/76	2.1	-	-
YR - Volney	1	8/2/76	0.8	-	-

NO2+NO3 - N (00630) - milligrams/liter

Little Turkey	2	1/17/79 - 9/11/79	5.5 - 5.6	5.55	0.1
SCC - TR15	15	4/20/78 - 10/9/78	1.18 - 7.31	3.18	2.6
TR-Eldorado	2	1/17/79 - 9/11/79	5.0 - 5.6	5.3	0.4
TR-near Garber	1	2/22/78	3.7	-	-
TR - TR14	13	4/20/78 - 10/9/78	2.82 - 8.63	4.58	2.4
TR - USGS Garber	32	10/30/79 - 7/11/89	0.10 - 8.9	4.69	1.9
VR - TR12	15	4/20/78 - 10/9/78	2.01 - 8.72	4.55	2.9
VR - X3C bridge	68	7/13/77 - 3/17/92	0.10 - 9.6	4.24	2.2
YR - Co. Rd. bridge	10	8/15/78 - 9/21/82	3.0 - 5.9	4.85	0.8
YR - Rossville	16	8/15/78 - 9/21/82	3.3 - 6.1	5.06	0.7
YR - Sec. 12	6	6/15/82 - 9/21/82	5.0 - 6.5	6.02	0.6
YR - Volney	23	8/15/78 - 8/5/91	1.0 - 11.0	4.24	1.91

NO2 - N (00615) - milligrams/liter

Little Turkey	2	10/29/75 - 6/29/76	0.01 - 0.02	0.01	0.01
SCC	2	10/29/75 - 6/29/76	0.01 - 0.02	0.015	0.01
TR-Eldorado	2	10/29/75 - 6/29/76	0.01 - 0.03	0.02	0.01
TR - W70 bridge	2	10/29/75 - 6/29/76	0.02 - 0.02	0.02	0
VR - X3C bridge	2	10/29/75 - 6/29/76	0.01 - 0.01	0.01	0
YR - Rossville	2	6/15/71 - 2/28/72	0.05 - 0.15	0.1	0.07

Total P (00665) - milligrams/liter

Little Turkey	2	1/17/79 - 9/11/79	0.06 - 0.09	0.08	0.02
SCC - TR15	15	4/20/78 - 10/9/78	0.10 - 0.41	0.21	0.1
TR-Eldorado	2	1/17/79 - 9/11/79	0.06 - 0.07	0.07	0.01
TR-near Garber	1	2/22/78	0.18	-	-
TR - TR14	13	4/20/78 - 10/9/78	0.08 - 0.57	0.2	0.2
TR - USGS Garber	31	10/30/79 - 7/11/89	0.04 - 4.00	0.41	0.8
VR - TR12	15	4/20/78 - 10/9/78	0.10 - 0.78	0.2	0.2
VR - X3C bridge	57	7/13/77 - 3/17/92	0.10 - 1.10	0.21	0.18
YR - Co. Rd. bridge	10	8/15/78 - 9/21/82	0.15 - 3.30	1.46	1.28
YR - Rossville	17	2/28/72 - 9/21/82	0.06 - 4.60	1.47	1.45
YR - Sec. 12	7	8/2/76 - 9/21/82	0 - 2.20	1.00	0.8
YR - Volney	23	8/15/78 - 8/5/91	0.07 - 2.80	0.53	0.63

Atrazine (39033) - micrograms/liter

YR - Co. Rd. bridge	2	6/15/82 - 9/21/82	0.19 - 18.0	9.1	12.6
YR - Rossville	3	6/15/82 - 9/21/82	0.17 - 26.0	9.72	14.2

Appendix. (cont.)

YR - Sec. 12	2	6/15/82 - 9/21/82	0.2 - 8.0	4.1	5.5
YR - Volney	1	6/15/82	0	-	-

Cyanazine (81757) - micrograms/liter

YR - Co. Rd. bridge	2	6/15/82 - 9/21/82	0.00 - 6.20	3.10	4.38
YR - Rossville	3	6/15/82 - 9/21/82	0.00 - 11.00	5.10	5.54
YR - Sec. 12	2	6/15/82 - 9/21/82	0.00 - 17.00	8.50	12.02

Dyfonate (81294) - micrograms/liter

YR - Co. Rd. bridge	2	6/15/82 - 9/21/82	0.00 - 0.22	0.11	0.16
YR - Rossville	3	6/15/82 - 9/21/82	0.00 - 0.30	0.10	0.17
YR - Sec. 12	2	6/15/82 - 9/21/82	0 - 0	-	-

Metolachlor (39356) - micrograms/liter

YR - Co. Rd. bridge	2	6/15/82 - 9/21/82	0 - 0.31	0.16	0.22
YR - Rossville	3	6/15/82 - 9/21/82	0 - 4.2	1.4	2.42
YR - Sec. 12	2	6/15/82 - 9/21/82	0 - 2.8	1.4	1.98
YR - Volney	3	6/15/82 - 9/21/82	0 - 0.41	0.14	0.24

Lasso (46317) - micrograms/liter

YR - Co. Rd. bridge	2	6/15/82 - 9/21/82	0.00 - 5.20	2.60	3.68
YR - Rossville	3	6/15/82 - 9/21/82	0.00 - 14.00	5.00	7.81
YR - Sec. 12	2	6/15/82 - 9/21/82	0.00 - 3.10	1.55	2.19

Fecal Coliform Bacteria (31616) - count/100 milliliters

Elk Creek	13	4/20/78 - 10/8/78	75 - 1200	480	349
Little Turkey	4	10/29/75 - 9/11/79	50 - 480	248	202
SCC	2	10/29/75 - 6/29/76	480 - 1000	740	368
SCC - TR15	13	4/20/78 - 10/8/78	100 - 9000	2364	3145
TR-Eldorado	4	10/29/75 - 9/11/79	20 - 550	273	232
TR-near Garber	1	2/22/78	720	-	-
TR - TR14	13	4/20/78 - 10/8/78	500 - 4800	2025	1355
TR - W70 bridge	2	10/29/1975 - 6/29/76	60 - 510	285	318
VR - TR12	14	4/20/78 - 10/9/78	120 - 1600	580	462
YR - Co. Rd. bridge	2	8/15/78 - 9/21/82	100 - 1100	600	707
YR - Rossville	4	6/15/71 - 9/21/82	10 - 4400	1245	2107
YR - Sec. 12	1	9/21/82	570	-	-

SCC = South Cedar Creek
TR = Turkey River
VR = Volga River
YR = Yellow River

SNY MAGILL WATERSHED MONITORING PROJECT:
BASELINE DATA

Iowa Department of Natural Resources, Geological Survey Bureau
Technical Information Series 32, 1994

WATER QUALITY OF PRIVATE WATER SUPPLIES IN SNY MAGILL AND BLOODY RUN WATERSHEDS

L. S. Seigley[1] and G. R. Hallberg[2]

[1]Iowa Department of Natural Resources, Geological Survey Bureau
109 Trowbridge Hall
Iowa City, IA 52242-1319

[2]University of Iowa Hygienic Laboratory
University of Iowa; Oakdale Campus
Iowa City, IA 52242

ABSTRACT

Private wells in the Sny Magill and Bloody Run watersheds in Clayton County were sampled in October 1992 to determine baseline well-water and groundwater quality for these two watersheds. A total of 151 wells were sampled for total coliform bacteria, fecal coliform bacteria, and nitrate-nitrogen. Eighteen selected wells were also sampled for common herbicides. Well depths ranged from 34 feet to 570 feet (10.4 to 173.7 m) in depth; two springs were also sampled. Average well depth was 221 feet (67.4 m); 42% of the samples tested positive for total coliform bacteria; 10% tested positive for fecal coliform bacteria; and 40% contained >10 mg/L for nitrate-nitrogen. The mean nitrate-nitrogen concentration was 10.8 mg/L with concentrations ranging from <0.2 to 47.8 mg/L. Wells identified as being located in the Galena aquifer had the highest mean NO_3-N concentration (13.5 mg/L), the greatest percentage of wells unsafe for NO_3-N (54%), the greatest percent positive for total coliform bacteria (57%), and percent positive for fecal coliform bacteria (12%). Atrazine was detected in seven samples (39%) at concentrations ranging from 0.10-0.61 μg/L; one sample detected deethylatrazine (an atrazine metabolite or breakdown product) at a concentration of 0.23 μg/L.

INTRODUCTION

An inventory of private wells in the Sny Magill and Bloody Run watersheds was conducted in October 1992 to assess baseline well-water and groundwater quality for these two watersheds (see Figure 1 for location). The sampling was done as part of the Sny Magill Watershed Nonpoint Source Pollution Monitoring Project (Seigley et al., 1992). A total of 151 wells were sampled for total coliform bacteria, fecal coliform bacteria, and nitrate-nitrogen (NO_3-N). A well questionnaire was completed for each well to determine well characteristics (depth, casing depth, age), well placement (topographic position, distance from septic system, feedlot, fuel tanks, chemical storage and handling), previous water quality problems, use of water treatment systems, and presence of sinkholes or abandoned wells near the active well. This report presents a summary of the well questionnaire information, and NO_3-N, total coliform bacteria, and fecal coliform bacteria results for the wells.

WATER QUALITY ANALYSES

Water-quality samples for this project were analyzed by the University of Iowa Hygienic Laboratory (UHL) in Iowa City, an U.S. Environmental Protection Agency certified laboratory. Total coliform bacteria was determined using the Most Probable Number (MPN) method and reported as safe (for zero coliforms) or unsafe (if coliforms were present). The total coliform bacteria data were reported as the statistical MPN of total coliform individuals per 100 milliliters of water (APHA, 1992). MPN categories include 0, 2.2, 5.1, 9.2, 16, and 16+. Fecal coliform bacteria, a subcategory of total coliform bacteria, were determined using the MPN method and reported as safe or unsafe. Fecal coliform bacteria were determined using the standard multiple tube fermentation method (MTF) (APHA, 1992).

NO_3-N results are in milligrams per liter (mg/L); one mg/L is equal to one part per million (ppm). NO_3-N was analyzed by cadmium reduction and colorimetric quantitation in an autoanalyzer (U.S. EPA Method 353.2; U.S. EPA, 1983). Analyses below the quantitation limit for NO_3-N were reported as <0.2 mg/L. For statistical summaries, values below the quantitation limit were given a value of 0.1 mg/L.

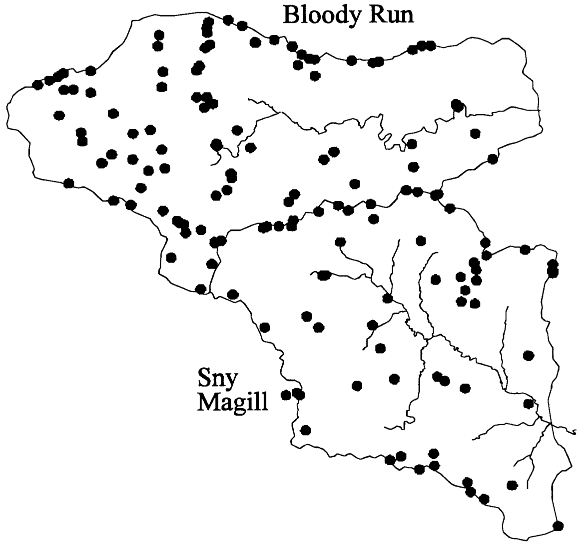


Figure 1. Location of private wells sampled in Sny Magill and Bloody Run watersheds.

Eighteen samples were analyzed for seven common herbicides using gas chromatography (after U.S. EPA, 1980) with dual-flame photometric and/or nitrogen-phosphorus detectors. The quantitation limit was 0.1 microgram per liter (µg/L). All detections were confirmed and quantified on two columns with periodic confirmations with electron-capture detectors and gas chromatography-mass spectrometry. More detailed information on the laboratory methods for the analytes can be found in Hallberg and others (1990).

RESULTS

Well Depth Information

Well depths ranged from 34 feet to 570 feet (10.4 to 173.7 m); two springs were also sampled. Average well depth was 221 feet (67.4 m). The greatest percentage of wells (29%) ranged between 100 and 199 feet deep (30.5 to 60.7 m). Well depth information was not available for twenty-six percent of the sampled wells (Table 1).

Table 1. Well-water quality of private wells in Sny Magill and Bloody Run watersheds by well depth categories.

Well depth range (feet)	# of wells	% of all wells	% of known well depth	Mean nitrate-N (mg/L)	Percent > 10 mg/L nitrate-N	Range in nitrate-N concentration (mg/L)	Percent positive total coliform bacteria	Percent positive fecal coliform bacteria
0 - 99	18	12%	16%	8.8	28%	<0.2 - 26.4	39%	0%
100 - 199	44	29%	40%	11.9	34%	<0.2 - 47.8	43%	11%
200 - 299	23	15%	21%	9.4	35%	<0.2 - 38.4	43%	4%
> 300	26	17%	23%	8.6	23%	<0.2 - 41.6	15%	0%
unknown	40	26%	----	11.3	30%	0.7 - 32.9	23%	3%
Sny Magill	60	40%	----	8.3	22%	<0.2 - 36.2	35%	12%
Bloody Run	91	60%	----	12.4	52%	<0.2 - 47.8	46%	6%
All wells	151	----	----	10.8	40%	<0.2 - 47.8	42%	10%

Total Coliform Bacteria Results

Forty-two percent of the samples tested positive for total coliform bacteria (Table 1). Only an MPN of 0 is considered a "safe" level of total coliform bacteria. Coliform bacteria are not a health hazard, but their presence suggests that disease-causing organisms may be able to enter the drinking-water supply. Total coliform positives imply that surface water or shallow groundwater that has recently interacted with the soil or soil water has entered the well. Coliforms are common constituents of soils and shallow groundwater and are present in surface water; their presence is also affected by the use of outside water storage (i.e., cisterns; Hallberg et al., 1983).

The percentage of samples testing positive for total coliform bacteria showed no significant trend relative to well depth range. However, of all the well depth ranges sampled, samples from wells greater than 300 feet deep (91.4 m) had the lowest percentage of positives (15%) for total coliform bacteria.

Fecal Coliform Bacteria Results

Ten percent of the samples tested positive for fecal coliform bacteria (Table 1). Fecal coliform bacteria are a subcategory of total coliform bacteria. Only an MPN of 0 is considered a "safe" level of fecal coliform bacteria. Fecal coliform bacteria represent a serious health concern, and water containing them should not be used for human consumption. Their presence indicates contamination from a relatively fresh waste source such as animal feedlot runoff, septic tank or cesspool leakage.

Of the samples positive for fecal coliform bacteria, 55% also were >10 mg/L NO_3-N. The fecal coliform bacteria results showed no significant trend related to depth of well for the water system. Wells less than 100 feet (30.5 m) deep and wells greater than 300 feet deep (91.4 m) had no detections of fecal coliform bacteria.

Nitrate-N Results

Forty percent of the samples contained more than 10 mg/L NO_3-N and were considered unsafe

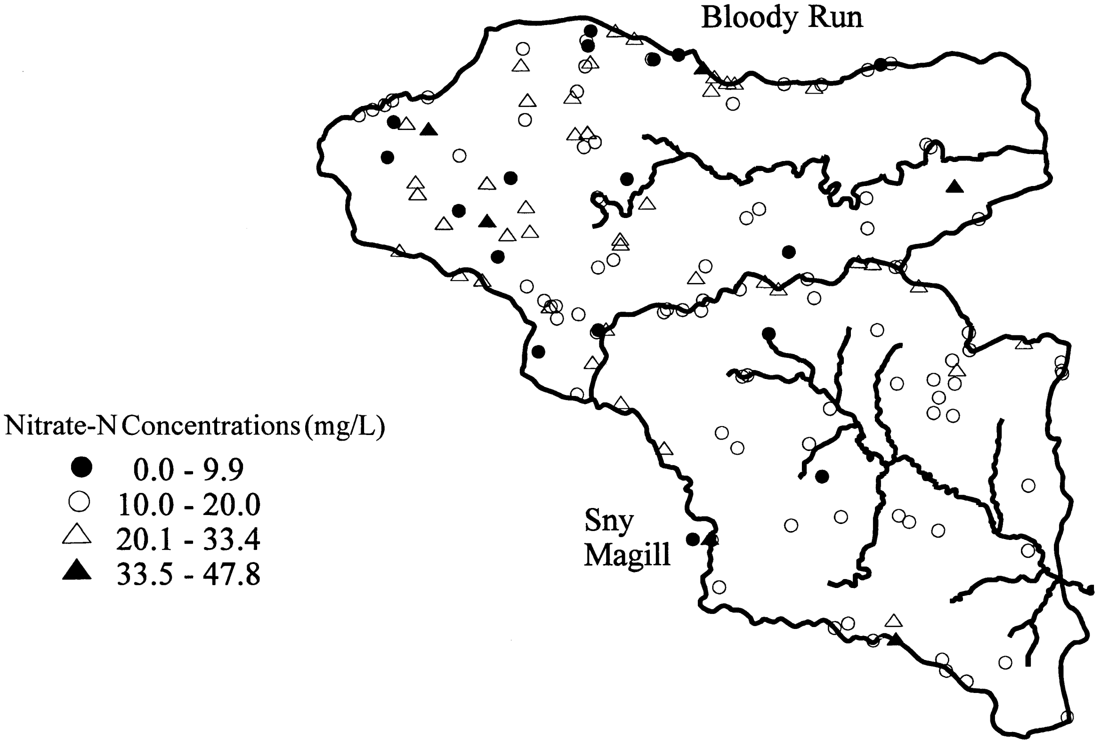
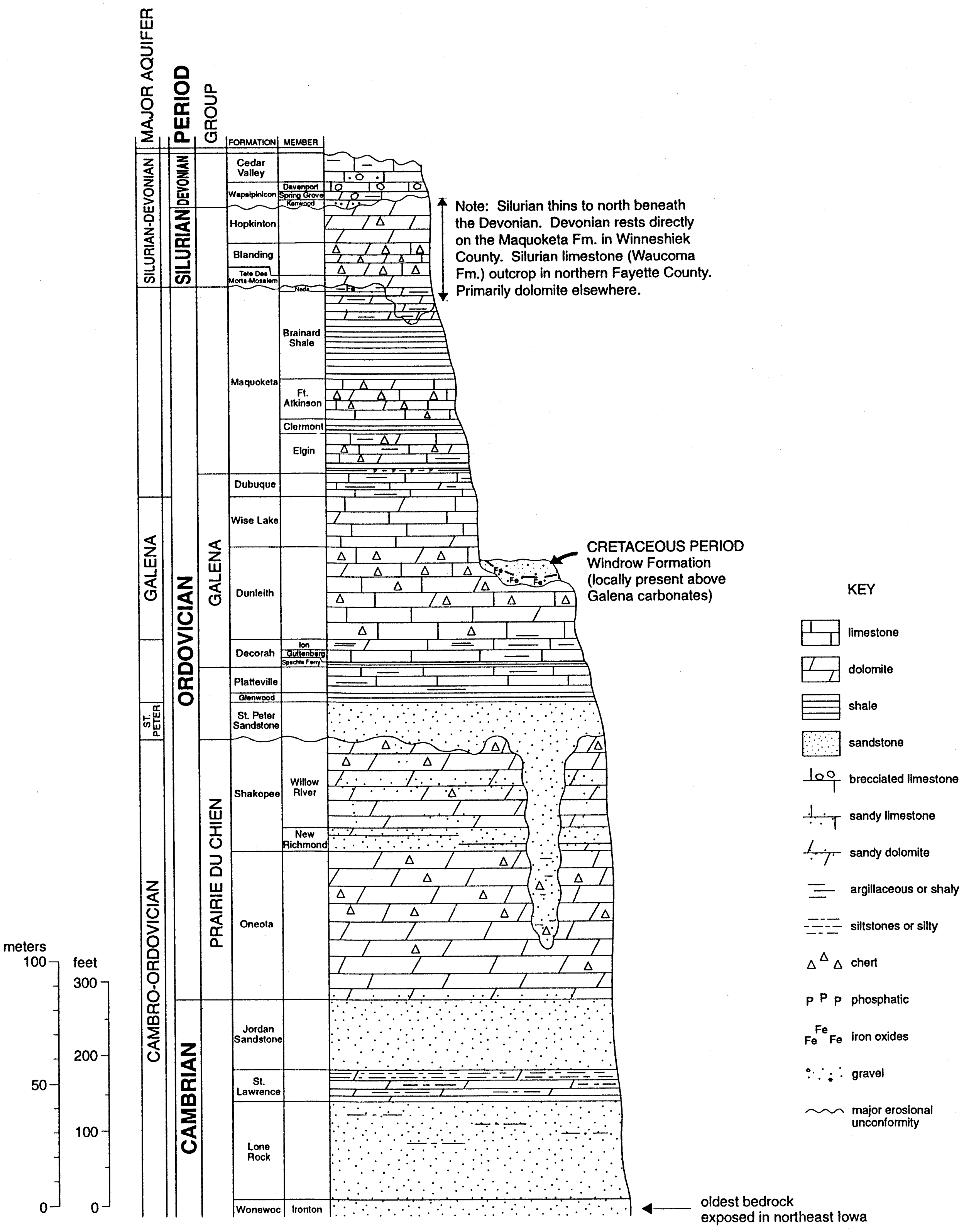


Figure 2. Distribution of nitrate-N concentrations in Sny Magill and Bloody Run watersheds.

for NO_3-N (Table 1). The U.S. EPA has set the drinking water standard for NO_3-N at 10 mg/L. Water containing greater than 10 mg/L should not be given to infants less than six months of age; consumption of water containing elevated NO_3-N concentrations may cause a temporary blood disorder that reduces the ability of an infant's bloodstream to carry oxygen through the body. The percentage of samples >10 mg/L NO_3-N showed no significant trend relative to depth. The overall mean NO_3-N concentration was 10.8 mg/L. Excluding the 0-99 well depth range (0.0 to 30.2 m), mean NO_3-N concentration declined with increasing well depth range, but the trend was not significant. Figure 2 shows the distribution of NO_3-N concentrations in the two watersheds.

Water Quality Results by Aquifer

For each private well sampled, an attempt was made to determine total well depth and casing depth. Wells were assigned aquifers based on the structure contour map of the Galena aquifer created for the Big Spring basin (Hallberg et al., 1983) and available well logs from the area. Figure 3 is the general stratigraphic column for northeast Iowa. Table 2 lists the number of wells by aquifer type and the number of wells in each well depth category. The majority of the shallow wells were Galena wells. Table 3 lists the percentage of wells for each aquifer type and water quality. Fifty percent of the wells were Galena wells with a mean NO_3-N concentration of 13.5 mg/L. Over 50% of the Galena wells were unsafe for NO_3-N, 57% were positive for total coliform bacteria, and 12% were positive for fecal coliform bacteria. Private wells located in the Galena aquifer in the Big Spring basin showed similar trends of higher NO_3-N concentrations and greater percentages of bacteria detections than wells in other aquifers (unpublished data,



Note: Silurian thins to north beneath the Devonian. Devonian rests directly on the Maquoketa Fm. in Winneshiek County. Silurian limestone (Waucoma Fm.) outcrop in northern Fayette County. Primarily dolomite elsewhere.

CRETACEOUS PERIOD Windrow Formation (locally present above Galena carbonates)

oldest bedrock exposed in northeast Iowa

Figure 3. General stratigraphic column for northeast Iowa (Hallberg et al., 1983).

Table 2. The aquifer type and corresponding depth of the wells sampled.

	Aquifer Type				
	Galena	Combination Galena*	Unknown	Alluvium	Other Bedrock
Well Depth					
0 - 99	13	0	1	2	2
100 - 199	38	3	0	0	3
200 - 299	15	4	0	0	4
>300	2	12	0	0	12
unknown	8	1	29	1	1

* excludes wells identified as Galena only

Table 3. Well-water quality of private wells in Sny Magill and Bloody Run watersheds by aquifer type.

Aquifer	Count	% of All Wells	Mean nitrate-N (mg/L)	% > 10 mg/L nitrate-N	Range in nitrate-N (mg/L)	% Positive for Total Coliform Bacteria	% Positive for Fecal Coliform Bacteria
Galena	76	50.3	13.5	53.9	<0.2 - 47.8	56.6	11.8
Combination Galena	20	13.2	9.0	25.0	<0.2 - 37.3	35.0	5.0
Unknown	30	19.9	9.7	26.7	2.4 - 30.9	23.3	3.3
Alluvium	3	2.0	0.8	0.0	0.7 - 1.1	33.3	0.0
Other Bedrock	22	14.6	5.8	22.7	<0.2 - 34.4	22.7	9.1

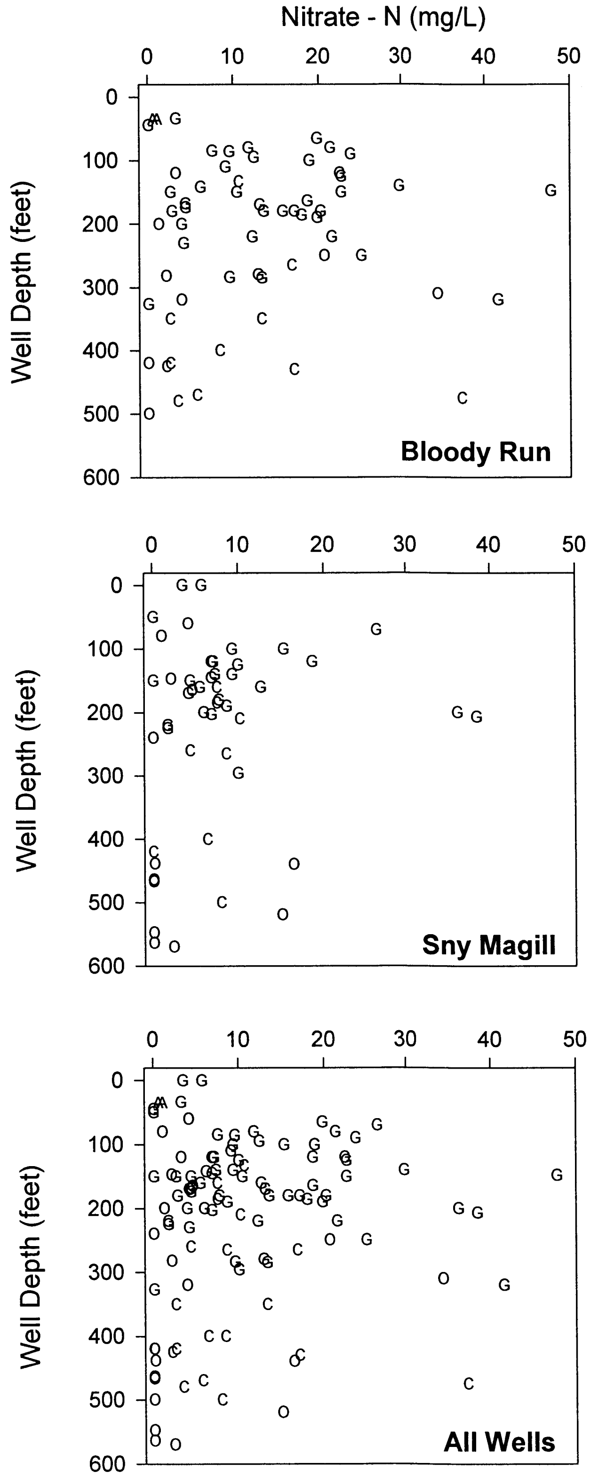


Figure 4. Well depth distribution of wells, aquifer identification, and corresponding nitrate-N concentrations (G=Galena; C=combination Galena; A=alluvium; O=other bedrock).

Department of Natural Resources, Geological Survey Bureau). Figure 4 shows the depth distribution of the wells and the corresponding aquifer type and nitrate-N concentration for wells only in Sny Magill, only in Bloody Run, and for all wells combined. Excluded are wells with no aquifer identification.

Pesticide Results

Water from 18 wells was analyzed for seven common herbicides (Table 4). Thirteen of the eighteen (72%) wells were Galena wells. These wells were selected by the field crews; shallow wells with the potential for contamination were preferentially sampled. Wells were selected from both watersheds. Seven samples (39%) had detections of atrazine at concentrations ranging from 0.10 to 0.61 µg/L with a mean detection value of 0.34 µg/L. All of the detections were below the health advisory of 3.00 µg/L for atrazine. Six of the seven samples were from Galena wells. Deethylatrazine, a metabolite or breakdown product of atrazine, was detected in one sample at a concentration of 0.23 µg/L. Of the seven wells with atrazine or deethylatrazine detected, five (71%) tested positive for total coliform bacteria, none tested positive for fecal coliform bacteria, and three (43%) had NO_3-N concentrations greater than 10 mg/L. Well depths for samples containing atrazine or deethylatrazine ranged from 80 to 160 feet (24.4 to 48.8 m) deep. The well depth for one well was unknown.

Well Questionnaire Information

A well questionnaire was completed for each well to determine possible point source problems. No one reported storing or mixing chemicals <100 feet from the well. No one reported any incident of backsiphoning of chemicals into the well. Eighty-seven percent of the wells were >100 feet from a feedlot and 97% were >50 feet from a septic system. Thirty people reported sinkholes nearby. The average nitrate concentration was greater for wells with sinkholes nearby, but few of these wells reported NO3-N concentrations >10 mg/L. Thirty-three people reported using cisterns. Wells with active cisterns had a greater percent unsafe for total

Table 4. Common herbicides analyzed.

Chemical Name	Typical product name	Number of detections (%)	Range of detected concentrations (μg/L)	Mean of detections (μg/L)
alachlor	Lasso	0%	-----	-----
atrazine	Aatrex	7 (39%)	0.10 - 0.61	0.34
butylate	Sutan	0%	-----	-----
cyanazine	Bladex	0%	-----	-----
metolachlor	Dual	0%	-----	-----
metribuzin	Sencor	0%	-----	-----
trifluralin	Treflan	0%	-----	-----

coliform bacteria. Wells that were positive for fecal coliform bacteria showed no correlation to distance of well from the septic system, feedlot, or abandoned wells.

SUMMARY

To assess baseline groundwater quality, a total of 151 private wells were sampled for total coliform bacteria, fecal coliform bacteria, and NO_3-N in Sny Magill and Bloody Run watersheds. Eighteen wells were also sampled for common herbicides. Well depths ranged from 34 feet to 570 feet (10.4 to 173.7 m) in depth; two springs were also sampled. Average well depth was 221 feet (67.4 m). Forty-two percent of the samples tested positive for total coliform bacteria. Ten percent of the samples tested positive for fecal coliform bacteria. Forty percent of the samples had NO_3-N concentrations >10 mg/L. The overall mean NO_3-N concentration was 10.8 mg/L. The percentage of wells testing positive for total coliform bacteria or fecal coliform bacteria, or the percentage of wells having greater than 10 mg/L NO_3-N showed no significant trend relative to well depth. Wells located in the Galena aquifer had the highest mean NO_3-N concentration, the greatest percentage of wells unsafe for NO_3-N, greatest percentage positive for total coliform bacteria and fecal coliform bacteria. Eighteen wells were analyzed for seven common herbicides. Atrazine was detected in seven samples (39%) at concentrations ranging from 0.10 to 0.61 μg/L; one sample detected deethylatrazine at a concentration of 0.23 μg/L.

In most hydrogeologic settings in Iowa, NO_3-N concentrations show a statistically significant decline with increasing well depth. Typically there is a significant difference between wells <50 and ≥50 feet (15.2 m) deep, with the most significant difference occurring between wells <100 feet and ≥100 feet (30.5 m) deep (Kross et al., 1990). In northeast Iowa, including the area of Sny Magill and Bloody Run watersheds, no significant trends with well depth are apparent. The lack of a trend of decreasing NO_3-N concentrations with increasing well depth is related to the great depth of groundwater circulation in this area of relatively high relief, that often exposes the full thickness of bedrock aquifers.

ACKNOWLEDGMENTS

Assistance with well questionnaires and field sampling was provided by Bob Rowden, Deb Quade, Bob Libra, K.D. Rex, Mary Skopec, and Karen Mumford of the Iowa Department of Natural Resources, Geological Survey Bureau.

REFERENCES

APHA, 1992, Standard methods for the examination of water and wastewater (17th edition): American Public Health Association, Water Works

Association, and Water Pollution Control Federation, Washington, D.C.

Hallberg, G.R., Hoyer, B.E., Bettis, E.A., III, and Libra, R.D., 1983, Hydrogeology, water quality, and land management in the Big Spring basin, Clayton County, Iowa: Iowa Geological Survey, Open File Report 83-3, 191 p.

Hallberg, G.R., Kross, B.C., Libra, R.D., Burmeister, L.F., Weih, L.M.B., Lynch, C.F., Bruner, D.R., Lewis, M.Q., Cherryholmes, K.L., Johnson, J.K., and Culp, M.A., 1990, The Iowa state-wide rural well-water survey design report: Iowa Department of Natural Resources, Technical Information Series 17, 135 p.

Kross, B.C., Hallberg, G.R., Bruner, D.R., Libra, R.D., Rex, K.D., Weih, L.M.B., Vermace, M.E., Burmeister, L.F., Hall, N.H., Cherryholmes, K.L., Johnson, J.K., Selim, M.I., Nations, B.K., Seigley, L.S., Quade, D.J., Dudler, A.G., Sesker, K.D., Culp, M.A., Lynch, C.F., Nicholson, H.F., and Hughes, J.P., 1990, The Iowa state-wide rural well-water survey water-quality data: initial analysis: Iowa Department of Natural Resources, Technical Information Series 19, 142 p.

Seigley, L.S., Hallberg, G.R., Wilton, T., Schueller, M.D., Hausler, M.C., Kennedy, J.O., Wunder, G., Link, R.V., and Brown, S.S., 1992, Sny Magill watershed nonpoint source water quality monitoring project: Iowa Department of Natural Resources, Open File Report 92-1, 31 p.

U.S. EPA, 1980, Manual of analytical methods for the analysis of pesticides in humans and environmental samples: U.S. Environmental Protection Agency, Office of Drinking Water, Washington, D.C.

U.S. EPA, 1983 (revised), Methods for chemical analysis of water and wastes: Cincinnati, OH, Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, EPA-600/4-79-020.

SNY MAGILL WATERSHED MONITORING PROJECT:
BASELINE DATA

Iowa Department of Natural Resources, Geological Survey Bureau
Technical Information Series 32, 1994

SUSPENDED SEDIMENT AND STREAM DISCHARGE IN BLOODY RUN AND SNY MAGILL WATERSHEDS: WATER YEAR 1992

S. J. Kalkhoff and D.A. Eash

U.S. Geological SurveyWater Resources Division
400 S. Clinton St.
Iowa City, Iowa 52244

ABSTRACT

Hydrologic data were collected in the Bloody Run and Sny Magill watersheds in Clayton County, Iowa during the 1992 Water Year (October 1, 1991 to September 30, 1992) to provide data on suspended sediment and stream discharge from these watersheds. Suspended-sediment samples were collected daily during normal flow and several times during rainstorms. Stream stage was recorded continuously and stream-discharge measurements were made monthly to develop a stage-discharge relation. Data on drainage-basin morphology and precipitation were quantified to help understand the variability in sediment and stream discharge. The total suspended-sediment discharge for Water Year 1992 was 2,720 tons at site BR1 on Bloody Run and 1,940 tons at site SN1 on Sny Magill Creek. The daily median suspended-sediment discharge was 1.1 tons at both sites BR1 and SN1. The maximum daily mean stream discharge (205 cubic feet per second) at site BR1 on Bloody Run occurred on November 1, 1991. The median daily discharge at site BR1 for the 1992 Water Year was 24 cubic feet per second or 0.70 cubic feet per second per square mile ($ft^3/s/mi^2$). The maximum daily mean stream discharge at site SN1 on Sny Magill Creek was 90 cubic feet per second which occurred on April 20, 1992. The median daily discharge at site SN1 for the 1992 Water Year was 15 cubic feet per second or 0.54 $ft^3/s/mi^2$.

INTRODUCTION

Suspended sediment originates principally from unconsolidated material that has formed by the chemical and physical weathering of rocks at the Earth's surface. The unconsolidated material is then transported to the stream by water and/or wind. The amount of sediment moving in a stream at a given location and time is a function of a complicated set of active and passive processes acting on the land surface of the drainage basin and throughout the channel system upstream from the location (Guy, 1970). Several factors that affect the amount of suspended sediment include the timing and intensity of precipitation and the volume and rate of runoff into the stream. The rate of runoff is influenced by the morphology and land use of the drainage basin (described later in this report).

Not all material eroded in a watershed is transported to the stream. The amount of eroded material discharged from the watershed in relation to the gross erosion (the sediment delivery ratio) depends on the areal distribution and intensity of runoff, and the size and morphology of the watershed. Suspended-sediment discharge is related directly to the amount and particle sizes of sediment delivered to the stream and the ability of the water in the stream to carry suspended material. Channel slope and sinuosity, physical factors that affect the velocity of water in the stream, indirectly affect sediment discharge.

The purpose of this chapter is to present the suspended-sediment and stream-discharge data collected during Water Year 1992 (October 1991 through September 1992) for the Bloody Run and Sny Magill Creek watersheds. These data include daily mean sediment concentrations and daily mean discharge at primary monitoring sites which are located near where the two streams discharge into the Mississippi River. Data on drainage-basin morphology and precipitation, two factors that affect suspended-sediment concentrations and stream discharge, also are presented. Additional stream-discharge data are reported for supplementary monitoring sites on tributaries of Bloody Run and Sny Magill creeks. Detailed analyses of these data will be presented in later reports.

METHODS

Suspended sediment was sampled and stream stage was monitored continually at site BR1 on Bloody Run and at site SN1 on Sny Magill Creek (Figure 1). These sites are located far enough upstream from the stream mouths to avoid backwater conditions from the Mississippi River. Data also were collected at supplemental sites BRSC, BR2, SN3, SNWF, NCC, SNT, and SN2.

Suspended Sediment

Suspended-sediment concentrations were determined from samples collected daily at site BR1 on Bloody Run and at site SN1 on Sny Magill Creek. Water samples for the determination of suspended-sediment concentrations were generally collected with a hand-held, depth-integrating sampler by field personnel and local observers. When the streams were too deep to wade, samples were collected from a bridge with a depth-integrating sampler attached to a handline. Because there were no major tributaries for several hundred feet upstream of the monitoring sites and because the streams were assumed to have stable cross sections and a rather uniform lateral suspended-sediment distribution, samples were collected in a single vertical profile. A sample was collected by lowering the sampler to the streambed and then raising the sampler to the surface at a constant transit rate. Occasionally, multiple verticals were sampled to determine lateral variability. Suspended-sediment sampled at the multiple verticals also were composited to determine the sand and silt-clay fractions.

An automatic sampler was installed at site BR1 on Bloody Run and site SN1 on Sny Magill Creek to sample the stream during rapidly changing stages when personnel were not present. Because the automatic sampler pumps water from a fixed point in the stream, sediment concentrations determined from these samples were correlated to manually collected samples to determine representative concentrations in the stream. Correlation was accomplished by manually collecting depth-integrated samples at three verticals in a cross section of the stream at the intake of the automatic sampler while

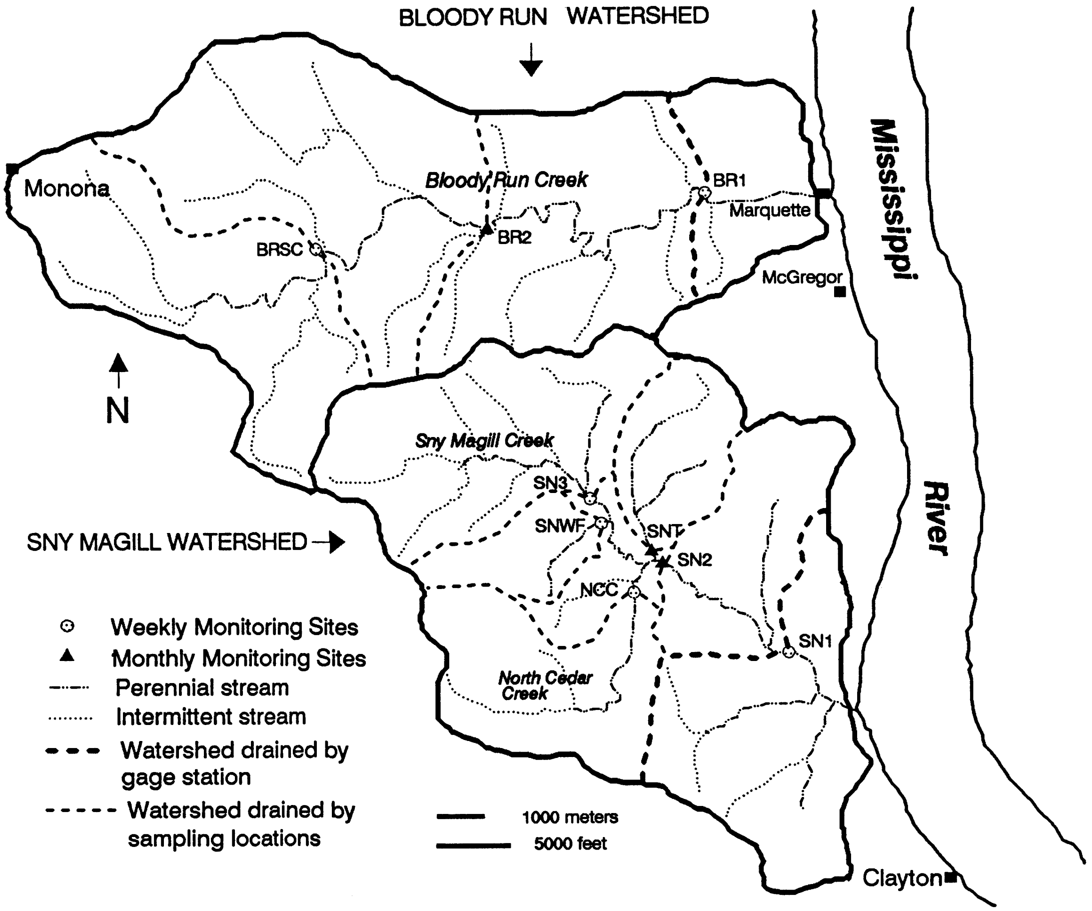


Figure 1. Location of monitoring sites on Sny Magill and Bloody Run creeks.

simultaneously sampling with the automatic sampler. The concentrations determined from the manually collected samples were related to the concentration in samples collected by the automatic samplers. Sediment concentrations in samples collected by the automatic samplers were adjusted on the basis of this relation.

Suspended-sediment concentrations were determined by the U.S. Geological Survey (USGS) sediment laboratory in Iowa City, Iowa using standard filtration and evaporation techniques (Guy, 1969). The wet-sieve method was used to determine the sand and silt-clay fractions (Guy, 1969; Matthes et al., 1992).

Suspended-sediment discharge was computed using the following equation: $Q_S = Q_W * C_S * k$

where Q_S is the daily suspended-sediment discharge in tons per day, Q_W is the mean daily stream discharge in cubic feet per second, C_S is the suspended-sediment concentration in milligrams per liter (mg/L), and k is a coefficient. The coefficient k is 0.0027 if the sediment concentration is less than 16,000 mg/L (Porterfield, 1972). If sediment concentrations are greater than 16,000 mg/L, k is calculated using techniques described by Porterfield (1972).

Stream Discharge

Current meter measurements of stream discharge were made monthly and during runoff events. Stream discharge was measured monthly at sites

BR1 and SN1 by measuring the stream velocity in about 20 sections across the channel. The velocity for each section was then multiplied by the cross-sectional area of the section to obtain the discharge in that section. Discharge for each section was summed to obtain the total stream discharge. Stream stages were measured continuously with a bubble-gage sensor and were recorded by data-collection platforms (DCP) and analog recorders. Stage data were referenced to direct water-surface readings with a staff plate placed in the streambed or to a type-A wire-weight gage attached to a nearby bridge. Stream stage and rainfall data were transmitted at 4-hour intervals from the DCP via satellite to the USGS office in Iowa City for computer storage.

To determine stream discharge for the two primary monitoring sites, stage-discharge curves (rating curves) were developed that relate current-meter, stream-discharge measurements to stream stage (Kennedy, 1984). Stream stage at the time of measurement was plotted on logarithmic graph paper as a function of the measured stream discharge. When sufficient measurements were made to cover the entire range of stream stage, a curve that best defined the points was drawn. Rating curves were recalculated as new discharge measurements became available to determine if shifts had occurred because of changing stream-channel conditions caused by erosional scour or sediment deposition.

Monthly stream discharge measurements also were made at seven supplemental sites on Bloody Run and Sny Magill creeks and their tributaries (Figure 1). Discharge measurements were made as previously described. Stream stages at these sites were measured with a steel tape as the distance from a permanent reference mark on a bridge to the water surface.

Drainage Basin Morphology

Drainage-basin characteristics, quantified using a Geographic Information System (GIS) procedure (Majure and Eash, 1991; Eash, 1993), were used to compare the morphology of the Bloody Run and Sny Magill watersheds. Morphologic characteristics that significantly influence the magnitude and frequency of surface-water runoff for streams in Iowa include contributing drainage area, relative relief, and drainage frequency (an indication of the spacing of streams in the drainage network). A detailed description of the GIS procedures used to calculate the drainage basin characteristics is given in Eash (1993), and a brief summary follows.

The GIS procedure included three main processing steps. In the first step, four GIS digital maps were created that represented selected aspects of the drainage basin. The drainage-divide digital map was created by delineating and digitizing the surface-water drainage-divide boundary from 1:250,000-scale U.S. Defense Mapping Agency (DMA) topographic maps. The drainage-network digital map was created by selecting the drainage network for the watershed from 1:100,000-scale USGS digital line graph data. The elevation-contour digital map was created from 1:250,000-scale DMA digital elevation model data. The basin-length digital map was created by delineating and digitizing the basin length from 1:250,000-scale DMA topographic maps. In the second processing step, attributes were assigned to specific polygon, line-segment, and point features in the first three digital maps. In the final step, 24 morphologic characteristics were quantified for a drainage watershed by using a set of programs that accessed the information automatically maintained by the GIS for each of the digital maps as well as the previously described attribute information. Selected basin characteristics that were quantified for Bloody Run and Sny Magill watersheds are listed in Table 1, and basin characteristics quantified for subbasins in the Bloody Run and Sny Magill watersheds are listed in Table 2. Many of the basin characteristics listed in Tables 1 and 2 are defined by Strahler (1964).

Precipitation

Rainfall was measured at sites BR1 and SN1 using standard tipping-bucket rain gages. Rainfall was recorded by the DCP and transmitted to the Iowa City office of the USGS by satellite for computer storage. Data collection began on March 12, 1992 at site BR1 and on April 5, 1992 at site SN1. To provide a complete year of rainfall data for

Table 1. Selected morphologic characteristics for the Bloody Run and Sny Magill watersheds.

Characteristic	Site BR1	 SN1
Total drainage area (square miles)	34.30	27.60
Contributing drainage area (square miles)	33.00	27.60
Basin length (mi)	12.00	7.80
Basin perimeter (mi)	29.00	25.00
Basin relief (ft)	570.00	496.00
Relative relief (ft/mi)	20.00	20.00
Main channel length (mi)	15.50	9.40
Total stream length (mi)	61.50	43.00
Main-channel slope (ft/mi)	28.00	50.00
Main-channel sinuosity ratio	1.30	1.20
Stream density (mi/miles squared)	1.90	1.60
Number of first order streams	25.00	17.00
Drainage frequency (fos/miles squared)	0.76	0.62

Water Year 1992, rainfall data from a climatic station located in Prairie du Chien, Wisconsin, was used. Rainfall at this site was 38.03 inches (966 mm) for Water Year 1992 (Harry Hillaker, personal communication). The maximum recorded daily rainfall at site BR1 was 1.92 inches (49 mm) on July 13, 1992. This rain was part of the maximum monthly rainfall (6.97 inches during July; 177 mm) recorded at site BR1 for the 1992 Water Year. The maximum recorded daily rainfall at site SN1 was 2.26 inches (57 mm) on September 14, 1992. The maximum recorded monthly precipitation at site SN1 was 5.57 inches (141 mm) during September 1992 (Table 3).

SUSPENDED SEDIMENT

Daily suspended-sediment concentrations and loads for monitoring sites BR1 and SN1 are listed in Tables 4 and 5. The daily suspended-sediment loads are plotted in relation to the daily mean discharge in Figure 2.

Bloody Run

The largest daily mean suspended sediment concentration at site BR1 was 1,110 mg/L on November 1, 1991. The maximum daily stream discharge was also measured on November 1. The variability in sediment concentrations is shown in Figure 3. At site BR1, the greatest monthly median sediment concentration was 25 mg/L in March 1992 and the smallest monthly median concentration was 12 mg/L in January 1992. The silt-clay sized fraction of the suspended sediment ranged from 14% on December 5, 1991 and April 10, 1992, when the instantaneous discharge was 26 and 23 ft^3/s (cubic feet per second), respectively, to 95% on September 14, 1992 when the instantaneous discharge was 73 ft^3/s (Table 6). The total suspended-sediment discharge at site BR1 for Water Year 1992 was about 2,720 tons. The greatest monthly discharge (1,250 tons) occurred in April 1992 and the smallest suspended-sediment discharge (20 tons) occurred in October 1991. The maximum daily suspended-sediment discharge was 916 tons on April 20, 1992. Mean daily suspended-sediment discharge exceeded 0.52 tons about 90% of the year; exceeded 1.1 tons about 50% of the year; and exceeded 3.2 tons about 10% of the year in Water Year 1992 (Figure 4).

Sny Magill Creek

The largest daily mean suspended-sediment concentration was 2,390 mg/L at site SN1 was recorded on April 20, 1992. At site SN1, the maximum-monthly median sediment concentration was 41 mg/L in May 1992 and the smallest monthly median concentration was 9 mg/L in January 1992

Table 2. Selected morphologic characteristics for subbasins in the Bloody Run and Sny Magill watersheds.

Characteristic	Supplemental sites						
	BRSC	BR2	SN3	SNWF	NCC	SNT	SN2
Total drainage area: square miles	10.50	24.50	7.20	3.10	6.00	3.20	22.50
Contributing drainage area: square miles	9.30	23.20	7.20	3.10	6.00	3.20	22.50
Basin length: mi	4.80	8.30	4.00	3.30	4.70	3.40	5.50
Basin perimeter: mile	16.50	22.20	11.40	8.10	11.10	7.40	21.90
Basin relief: feet	300.00	423.00	390.00	396.00	413.00	376.00	463.00
Relative relief: ft/mi	18.10	19.00	34.00	49.00	37.10	51.10	21.20
Main channel length: mile	5.90	9.10	4.50	3.40	5.30	3.60	6.50
Total stream length: mile	13.70	41.20	12.70	5.10	8.00	6.20	35.90
Main channel slope: ft/mi	37.50	35.60	88.40	121.00	83.40	100.00	72.50
Main channel sinuosity ratio	1.20	1.10	1.10	1.00	1.10	1.10	1.20
Stream density: mi/mile squared	1.50	1.80	1.80	1.60	1.30	1.90	1.60
Number of first order streams	4.00	16.00	6.00	2.00	3.00	3.00	15.00
Drainage frequency: first order streams/mile squared	0.43	0.69	0.83	0.64	0.50	0.93	0.67

(Figure 3). The silt-clay sized fraction of the suspended sediment ranged from 33% on December 6, 1991, when the instantaneous discharge was 16 ft^3/s, to 99% on September 14, 1992, when the instantaneous discharge was 55 ft^3/s.

The total suspended-sediment discharge at site SN1 during Water Year 1992 was about 1,940 tons. The greatest monthly discharge (1,320 tons) occurred in April 1992 and the smallest monthly discharge (17 tons) occurred in January 1992. The maximum daily suspended-sediment discharge was 1,190 tons on April 20, 1992. Mean daily suspended-sediment discharge exceeded 0.38 tons 90% of the year; exceeded 1.1 tons, 50% of the year; and exceeded 3.3 tons, 10% of the year in Water Year 1992 (Figure 4).

STREAM DISCHARGE

Bloody Run

Daily mean discharges for Bloody Run at site BR1 are listed in Table 7 and illustrated in Figure 2. The median discharge at site BR1 for the 1992 Water Year was 24 ft^3/s or 0.70 ft^3/s/mi^2. The maximum daily mean discharge (205 ft^3/s) occurred on November 1, 1991 and the minimum-daily mean discharge (13 ft^3/s) was recorded on October 3, 1991. The maximum recorded instantaneous discharge of 476 ft^3/s occurred at 10:00 am on November 1, 1991. Stream discharge duration is shown in Figure 4. Daily mean discharge exceeded 18 ft^3/s about 90% of the year and exceeded 36 ft^3/s about 10% of the year.

Sny Magill Creek

Daily mean discharges for Sny Magill Creek at site SN1 are listed in Table 5 and are illustrated in Figure 2. The median discharge at site SN1 for the 1992 Water Year was 15 ft^3/s or 0.54 ft^3/s/mi^2. The maximum-daily mean discharge (90 ft^3/s) occurred on April 20, 1992 and the minimum mean daily discharge (8.5 ft^3/s) occurred on October 1, 1991. The greatest recorded instantaneous discharge of 390 ft^3/s occurred at 6:00 pm on April 20, 1992. Flow duration is shown in Figure 4. Daily mean discharge exceeded 12 ft^3/s about 90% of the year and exceeded 24 ft^3/s about 10% of the year.

Supplemental Sites

Stream discharges were measured periodically at seven supplemental sites in the Bloody Run and Sny Magill Creek watersheds during Water Year 1992 (Table 8). The maximum measured discharge

(11.0 ft^3/s) at supplementary sites in the Bloody Run watershed occurred at site BR2 on June 4, 1992. At supplemental sites in the Sny Magill Creek watershed, the maximum stream discharge (15.8 ft^3/s) was measured at site SN2 on March 5, 1992 and on May 8, 1992.

ACKNOWLEDGMENTS

William Gruver and Joseph Kruse, the local observers, collected daily sediment samples. James Wellman, U.S. Geological Survey, measured streamflow, installed and maintained gages, and collected sediment samples. Josef Pohl, U.S. Geological Survey, computed the basin characteristics using the GIS procedure.

REFERENCES

Eash, D.A., 1993, A geographic information system procedure to quantify physical basin characteristics, *in* Harlin, J.M. and Lanfear, K.J. (eds.): Proceedings of the Symposium on Geographic Information Systems and Water Resources, American Water Resources Association, Bethesda, MD, p. 173-182.

Guy, H.P., 1969, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 5, Chapter C1, 58 p.

Guy, H.P., 1970, Fluvial sediment concepts: U.S. Geological Survey Techniques of Water-Resources Investigations Book 3, Chapter C1, 55 p.

Kennedy, E.J., 1984, Discharge ratings at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A10, 58 p.

Majure, J.J., and Eash, D.A., 1991, An automated method to quantify physical basin characteristics, *in* U.S. Geological Survey Toxic Substances Hydrology Program, Abstracts of the Technical Meeting, Montery, California, March 11-15, 1991: U.S. Geological Survey Open-File Report 91-88, p. 105.

Matthes, W.J., Sholar, C.J., and George, J.R., 1992, Quality-assurance plan for the analysis of fluvial sediment by laboratories of the U.S. Geological Survey: U.S. Geological Survey Open-File Report 91-467, 31 p.

Porterfield, G., 1972, Computation of fluvial-sediment discharge: U.S. Geological Survey Techniques of Water-Resources Investigations Book 3, Chapter C3, 66 p.

Strahler, A.N., 1964, Part II. Quantitative geomorphology of drainage basins and channel networks, *in* Ven Te Chow (ed.), Handbook of Applied Hydrology: McGraw-Hill, New York, p. 4-39.

Table 3. Daily precipitation (in inches) in the Bloody Run and Sny Magill watersheds; Water Year 1992.

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Site BR1												
1							0.00	0.00	0.00	0.00	0.00	0.00
2							0.00	0.00	0.00	0.22	0.11	0.43
3							0.00	0.00	0.00	0.00	0.06	0.01
4							0.00	0.02	0.00	0.08	0.01	0.00
5							0.00	0.00	0.00	0.00	0.00	0.82
6							0.16	0.00	0.00	0.00	0.00	0.24
7							0.01	0.00	0.00	0.51	0.81	0.04
8							0.44	0.00	0.00	0.10	0.00	0.00
9							0.01	0.00	0.00	0.16	0.00	0.80
10							0.12	0.00	0.00	0.27	0.18	0.00
11							0.00	0.10	0.00	0.48	0.00	0.00
12						0.00	0.00	0.01	0.00	0.74	0.31	0.00
13						0.00	0.00	0.00	0.00	1.92	0.00	0.00
14						0.40	0.00	0.00	0.00	0.00	0.00	1.65
15						0.00	0.91	0.05	0.00	0.07	0.01	0.00
16						0.10	0.23	0.55	0.55	0.18	0.00	0.54
17						0.00	0.00	0.52	0.68	0.24	0.08	0.02
18						0.00	0.21	0.00	0.00	0.01	0.00	0.27
19						0.00	0.85	0.00	0.32	0.26	0.01	0.00
20						0.10	1.03	0.00	0.00	0.00	0.00	0.00
21						0.00	0.05	0.16	0.00	0.00	0.00	0.00
22						0.16	0.02	0.34	0.13	0.88	0.00	0.00
23						0.00	0.08	0.00	0.06	0.01	0.00	0.00
24						0.00	0.03	0.00	0.01	0.00	0.00	0.00
25						0.20	0.00	0.00	0.00	0.48	0.07	0.00
26						0.00	0.00	0.00	0.00	0.01	0.01	0.43
27						0.00	0.01	0.00	0.00	0.00	0.00	0.00
28						0.45	0.00	0.00	0.00	0.00	0.00	0.00
29						0.25	0.00	0.00	0.00	0.00	0.00	0.01
30						0.01	0.00	0.00	0.01	0.34	0.00	0.00
31						0.00		0.00		0.01	0.00	
Total							4.16	1.75	1.76	6.97	1.66	5.26
Site SN1												
1								0.00		0.00	0.00	0.00
2								0.00	0.00	0.27	0.13	0.46
3								0.00	0.00	0.00	0.05	0.01
4								0.04	0.00	0.27	0.01	0.00
5							0.00	0.00	0.00	0.00	0.00	0.64
6							0.10	0.00	0.00	0.00	0.00	0.46
7							0.00	0.00	0.00	1.06	0.73	0.09
8							0.32	0.00	0.00	0.06	0.00	0.00
9							0.00	0.00	0.00	0.07	0.00	0.48
10							0.14	0.00	0.00	0.07	0.44	0.01
11							0.00	0.09	0.00	0.02	0.00	0.00
12							0.00	0.00	0.00	0.83	0.26	0.00
13							0.00	0.00	0.00	1.05	0.00	0.00
14							0.00	0.00	0.03	0.00	0.00	2.26
15							0.69	0.03	0.00	0.08	0.00	0.00
16							0.11	0.03	0.23	0.17	0.00	0.29
17							0.00	0.03	0.35	0.16	0.10	0.01
18							0.19	0.00	0.00	0.01	0.00	0.50
19							1.03	0.00	0.40	0.07	0.00	0.00
20							1.08	0.00	0.00	0.01	0.00	0.03
21							0.04	0.03	0.00	0.00	0.00	0.00
22							0.01	0.00	0.12	0.49	0.01	0.00
23							0.04	0.01	0.12	0.04	0.00	0.00
24							0.03	0.00	0.00	0.00	0.00	0.00
25							0.00	0.00	0.00	0.27	0.72	0.00
26							0.00	0.00	0.00	0.01	0.00	0.31
27							0.00	0.00	0.00	0.00	0.00	0.01
28							0.00	0.00	0.00	0.00	0.00	0.00
29							0.00	0.00	0.00	0.00	0.00	0.01
30							0.00	0.00	0.00	0.53	0.00	0.00
31								0.00		0.01	0.00	
Total							3.78	0.26	1.25	5.55	2.45	5.57

Table 4. Daily mean suspended sediment concentration and daily suspended-sediment load at site BR1 on Bloody Run; Water Year 1992.

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean daily suspended-sediment concentration, in milligrams per liter												
1	19.00	1110.00	22.00	11.00	11.00	16.00	13.00	30.00	23.00	27.0	16.00	15.00
2	22.00	185.00	20.00	12.00	8.00	20.00	7.00	29.00	24.00	21.0	17.00	10.00
3	20.00	39.00	20.00	12.00	103.00	17.00	5.00	22.00	24.00	15.0	18.00	21.00
4	17.00	27.00	21.00	12.00	107.00	22.00	5.00	10.00	24.00	14.0	10.00	30.00
5	15.00	17.00	17.00	12.00	42.00	20.00	7.00	16.00	23.00	18.0	13.00	21.00
6	14.00	19.00	17.00	12.00	26.00	25.00	9.00	18.00	20.00	14.0	13.00	27.00
7	16.00	12.00	17.00	13.00	14.00	25.00	8.00	25.00	17.00	17.0	15.00	27.00
8	17.00	18.00	17.00	11.00	10.00	26.00	13.00	24.00	16.00	18.0	16.00	9.00
9	17.00	16.00	17.00	12.00	11.00	40.00	13.00	12.00	14.00	16.0	13.00	18.00
10	15.00	13.00	18.00	4.00	10.00	25.00	12.00	20.00	16.00	14.0	10.00	19.00
11	16.00	18.00	18.00	12.00	10.00	46.00	16.00	27.00	17.00	13.0	17.00	16.00
12	16.00	16.00	122.00	26.00	12.00	51.00	12.00	23.00	19.00	22.0	17.00	9.00
13	13.00	16.00	43.00	14.00	23.00	47.00	13.00	30.00	38.00	34.0	12.00	11.00
14	12.00	17.00	27.00	3.00	15.00	42.00	12.00	17.00	39.00	30.0	12.00	41.00
15	12.00	24.00	13.00	13.00	8.00	40.00	22.00	27.00	34.00	22.0	15.00	30.00
16	11.00	13.00	11.00	9.00	17.00	27.00	19.00	22.00	24.00	19.0	15.00	24.00
17	13.00	20.00	11.00	5.00	12.00	22.00	15.00	33.00	50.00	14.0	11.00	24.00
18	9.00	220.00	13.00	2.00	18.00	31.00	15.00	20.00	39.00	17.0	11.00	16.00
19	11.00	73.00	14.00	3.00	17.00	18.00	24.00	12.00	16.00	19.0	12.00	12.00
20	11.00	36.00	14.00	12.00	43.00	26.00	1060.00	13.00	32.00	22.0	9.00	13.00
21	9.00	21.00	14.00	11.00	70.00	35.00	783.00	13.00	15.00	15.0	8.00	12.00
22	7.00	32.00	14.00	38.00	70.00	21.00	129.00	30.00	15.00	18.0	9.00	10.00
23	11.00	21.00	14.00	200.00	97.00	33.00	76.00	31.00	27.00	18.0	12.00	11.00
24	15.00	22.00	13.00	19.00	79.00	19.00	65.00	31.00	48.00	16.0	12.00	14.00
25	17.00	25.00	13.00	9.00	57.00	24.00	36.00	33.00	21.00	12.0	13.00	13.00
26	22.00	18.00	12.00	9.00	50.00	27.00	20.00	15.00	24.00	15.0	33.00	14.00
27	8.00	18.00	12.00	13.00	55.00	26.00	27.00	13.00	17.00	19.0	22.00	14.00
28	11.00	20.00	12.00	14.00	35.00	11.00	22.00	19.00	15.00	25.0	18.00	12.00
29	20.00	18.00	11.00	19.00	19.00	15.00	27.00	22.00	34.00	18.0	32.00	10.00
30	27.00	55.00	11.00	11.00		12.00	27.00	24.00	26.00	17.0	19.00	11.00
31	8.00		11.00	14.00		15.00		23.00		14.0	12.00	
Suspended-sediment load, in tons per day												
1	0.72	798.00	2.10	0.62	0.53	1.20	0.81	2.80	1.20	1.70	1.20	0.67
2	0.83	40.00	1.70	0.66	0.37	1.60	0.43	2.70	1.20	1.60	1.20	0.42
3	0.71	4.30	1.60	0.68	37.00	1.30	0.33	2.10	1.20	1.10	1.30	0.89
4	0.68	2.40	1.40	0.69	14.00	1.50	0.33	0.98	1.30	1.00	0.70	1.20
5	0.62	1.30	1.20	0.67	3.50	1.40	0.38	1.50	1.30	1.30	0.86	0.80
6	0.52	1.30	1.10	0.68	1.80	1.70	0.48	1.70	1.30	1.00	0.89	2.20
7	0.64	0.69	1.00	0.70	0.87	1.70	0.43	2.40	1.10	1.40	1.10	1.40
8	0.90	1.10	1.00	0.61	0.61	1.70	0.74	2.30	1.10	1.30	1.20	0.40
9	0.88	0.99	1.10	0.82	0.64	3.70	0.80	1.00	0.97	1.20	0.85	1.30
10	0.74	0.77	1.00	0.23	0.57	2.20	0.73	1.70	1.10	1.00	0.68	1.00
11	0.72	1.00	1.10	0.63	0.52	3.80	0.99	2.30	1.10	1.00	1.10	0.75
12	0.72	0.89	15.00	1.70	0.61	3.90	0.72	2.00	1.10	2.00	1.20	0.42
13	0.61	0.92	4.90	1.20	1.20	3.50	0.75	2.50	2.20	4.20	0.84	0.43
14	0.55	0.94	2.40	0.20	0.81	3.00	0.67	1.40	2.20	3.20	0.80	5.50
15	0.57	1.30	1.10	0.74	0.45	2.80	1.40	2.20	1.80	1.90	0.95	2.20
16	0.50	0.71	0.90	0.46	0.86	1.90	1.50	1.60	1.50	1.60	0.93	1.40
17	0.54	1.20	0.86	0.27	0.72	1.40	1.20	3.20	4.50	1.10	0.65	1.40
18	0.38	34.00	0.93	0.09	1.70	2.00	1.10	1.50	2.90	1.40	0.61	0.87
19	0.47	7.30	0.94	0.17	1.00	1.10	1.90	0.81	1.10	1.60	0.68	0.65
20	0.49	3.10	0.95	0.58	3.70	1.60	916.00	0.88	2.30	1.80	0.50	0.70
21	0.40	1.80	0.89	0.59	7.50	2.40	261.00	0.93	1.00	1.20	0.42	0.59
22	0.30	2.70	0.89	5.60	12.00	1.30	23.00	2.30	1.10	1.60	0.48	0.47
23	0.39	1.80	0.87	48.00	13.00	2.10	11.00	2.30	1.90	1.60	0.59	0.48
24	0.60	1.70	0.85	1.40	8.70	1.10	8.80	2.20	3.40	1.30	0.57	0.63
25	0.88	1.80	0.79	0.55	7.10	1.40	4.50	2.30	1.40	0.95	0.65	0.59
26	1.00	1.30	0.74	0.50	4.20	1.60	2.30	1.10	1.30	1.20	2.10	0.61
27	0.37	1.30	0.68	0.75	5.90	1.50	2.90	0.82	1.00	1.50	1.20	0.66
28	0.43	1.40	0.67	0.74	3.60	0.68	2.30	1.20	0.89	1.90	0.90	0.57
29	1.10	1.20	0.65	1.00	1.60	0.99	2.70	1.30	2.10	1.30	1.50	0.48
30	1.50	7.40	0.65	0.58		0.71	2.60	1.40	1.60	1.30	0.89	0.51
31	0.42		0.67	0.67		0.89		1.20		1.00	0.55	

Table 5. Daily mean suspended sediment concentration and daily suspended-sediment load at site SN1 on Sny Magill Creek; Water Year 1992.

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean daily suspended-sediment concentration, in milligrams per liter												
1	28.00	236.00	21.00	16.00	3.00	31.00	38.00	31.00	32.00	14.00	39.00	18.00
2	26.00	88.00	12.00	11.00	10.00	37.00	28.00	29.00	18.00	35.00	44.00	20.00
3	20.00	35.00	9.00	12.00	115.00	31.00	16.00	29.00	32.00	36.00	31.00	16.00
4	29.00	30.00	22.00	16.00	41.00	35.00	20.00	30.00	40.00	43.00	22.00	15.00
5	47.00	28.00	30.00	15.00	13.00	42.00	11.00	31.00	36.00	32.00	33.00	15.00
6	45.00	27.00	21.00	11.00	12.00	58.00	16.00	46.00	39.00	44.00	21.00	27.00
7	42.00	22.00	14.00	10.00	10.00	67.00	29.00	44.00	42.00	86.00	23.00	29.00
8	28.00	31.00	11.00	10.00	6.00	67.00	22.00	40.00	34.00	45.00	40.00	29.00
9	29.00	24.00	14.00	11.00	4.00	68.00	17.00	40.00	20.00	24.00	24.00	31.00
10	36.00	14.00	14.00	6.00	4.00	61.00	21.00	37.00	19.00	32.00	21.00	13.00
11	35.00	16.00	15.00	6.00	3.00	56.00	19.00	27.00	29.00	77.00	21.00	12.00
12	35.00	27.00	31.00	11.00	2.00	55.00	33.00	28.00	28.00	99.00	23.00	23.00
13	37.00	32.00	24.00	12.00	5.00	65.00	17.00	45.00	16.00	42.00	23.00	28.00
14	23.00	48.00	9.00	3.00	6.00	64.00	17.00	41.00	8.00	39.00	15.00	320.00
15	16.00	26.00	5.00	1.00	4.00	53.00	20.00	30.00	39.00	15.00	18.00	212.00
16	27.00	17.00	11.00	5.00	40.00	44.00	26.00	41.00	32.00	19.00	24.00	26.00
17	46.00	16.00	19.00	3.00	58.00	34.00	17.00	80.00	47.00	20.00	25.00	22.00
18	61.00	115.00	18.00	15.00	67.00	20.00	11.00	46.00	73.00	22.00	19.00	21.00
19	67.00	58.00	18.00	7.00	39.00	29.00	29.00	40.00	55.00	32.00	31.00	8.00
20	34.00	49.00	14.00	1.00	41.00	38.00	2390.00	38.00	86.00	32.00	26.00	10.00
21	21.00	40.00	6.00	5.00	44.00	21.00	325.00	43.00	64.00	25.00	15.00	11.00
22	22.00	34.00	6.00	45.00	41.00	11.00	61.00	54.00	22.00	35.00	19.00	10.00
23	69.00	40.00	9.00	61.00	35.00	22.00	85.00	49.00	13.00	32.00	26.00	15.00
24	84.00	38.00	14.00	16.00	43.00	22.00	63.00	49.00	23.00	31.00	27.00	19.00
25	71.00	39.00	16.00	9.00	51.00	24.00	43.00	77.00	16.00	42.00	14.00	18.00
26	77.00	40.00	13.00	9.00	41.00	18.00	32.00	68.00	18.00	35.00	10.00	21.00
27	80.00	40.00	12.00	3.00	38.00	16.00	37.00	30.00	45.00	23.00	10.00	11.00
28	85.00	40.00	10.00	5.00	37.00	23.00	35.00	53.00	39.00	27.00	17.00	10.00
29	99.00	40.00	10.00	7.00	28.00	15.00	22.00	66.00	35.00	38.00	20.00	12.00
30	85.00	45.00	17.00	5.00		24.00	36.00	80.00	25.00	43.00	16.00	10.00
31	77.00		20.00	9.00		31.00		76.00		47.00	16.00	
Suspended-sediment load, in tons per day												
1	0.64	58.00	1.40	0.58	0.11	1.70	1.90	2.20	1.20	0.50	1.50	0.42
2	0.66	10.00	0.70	0.42	0.33	2.20	1.30	2.00	0.71	1.40	1.70	0.55
3	0.53	2.80	0.47	0.44	20.00	1.80	0.70	2.00	1.20	1.40	1.10	0.50
4	1.10	1.90	0.96	0.59	2.60	1.90	0.82	2.00	1.40	1.60	0.83	0.50
5	2.00	1.60	1.40	0.55	0.56	2.40	0.45	2.00	1.20	1.10	1.20	0.48
6	1.50	1.30	0.96	0.42	0.47	3.30	0.61	2.80	1.10	1.50	0.75	1.70
7	1.30	0.91	0.62	0.38	0.38	3.90	1.10	2.50	1.30	4.80	1.20	1.20
8	0.80	1.20	0.47	0.43	0.22	3.80	0.88	2.30	1.20	1.90	1.90	1.10
9	0.78	1.00	0.64	0.48	0.15	4.90	0.74	2.20	0.72	0.89	0.93	1.50
10	0.96	0.57	0.61	0.23	0.11	4.30	1.10	1.90	0.68	1.30	0.76	0.55
11	0.94	0.67	0.69	0.21	0.09	3.50	0.97	1.40	1.10	2.90	0.68	0.41
12	1.00	1.10	2.90	0.47	0.08	3.10	1.50	1.50	1.10	5.10	0.83	0.78
13	1.10	1.20	2.10	0.57	0.16	3.50	0.71	2.10	0.58	2.80	0.80	0.90
14	0.64	1.80	0.61	0.11	0.22	3.30	0.70	2.00	0.30	2.60	0.50	52.00
15	0.45	1.00	0.30	0.04	0.15	2.60	0.94	1.40	1.50	0.74	0.59	18.00
16	0.78	0.66	0.62	0.16	1.50	2.10	1.60	1.70	1.30	0.90	0.76	1.60
17	1.30	0.69	1.00	0.09	2.20	1.60	0.94	5.40	2.10	0.86	0.75	1.30
18	1.70	11.00	0.77	0.42	3.60	0.88	0.61	2.20	2.60	0.97	0.58	1.40
19	1.90	4.00	0.77	0.16	1.60	1.30	1.90	1.80	1.80	1.30	0.95	0.44
20	0.93	2.90	0.66	0.04	3.40	1.60	1190.00	1.60	4.00	1.40	0.75	0.50
21	0.58	2.00	0.28	0.15	2.90	0.84	71.00	2.00	2.40	0.99	0.42	0.54
22	0.62	1.50	0.25	2.60	2.60	0.44	7.90	2.50	0.84	1.70	0.53	0.47
23	1.80	1.90	0.38	5.30	2.20	0.86	9.80	2.30	0.54	1.60	0.71	0.63
24	2.40	1.60	0.61	0.53	3.00	0.82	6.70	2.10	0.95	1.50	0.67	0.75
25	2.90	1.40	0.65	0.32	3.20	0.92	4.40	3.30	0.66	1.90	0.39	0.71
26	3.30	1.50	0.53	0.30	2.00	0.66	3.00	3.00	0.68	1.60	0.35	0.85
27	3.30	1.60	0.41	0.11	2.30	0.52	3.20	1.30	1.70	0.93	0.27	0.49
28	3.30	1.50	0.34	0.16	2.20	0.90	2.90	2.20	1.40	1.00	0.46	0.37
29	4.40	1.60	0.36	0.22	1.50	0.72	1.70	2.50	1.20	1.50	0.50	0.46
30	4.00	4.20	0.57	0.17		1.10	2.60	3.30	0.86	1.80	0.39	0.37
31	3.30		0.74	0.29		1.50		2.90		2.10	0.38	

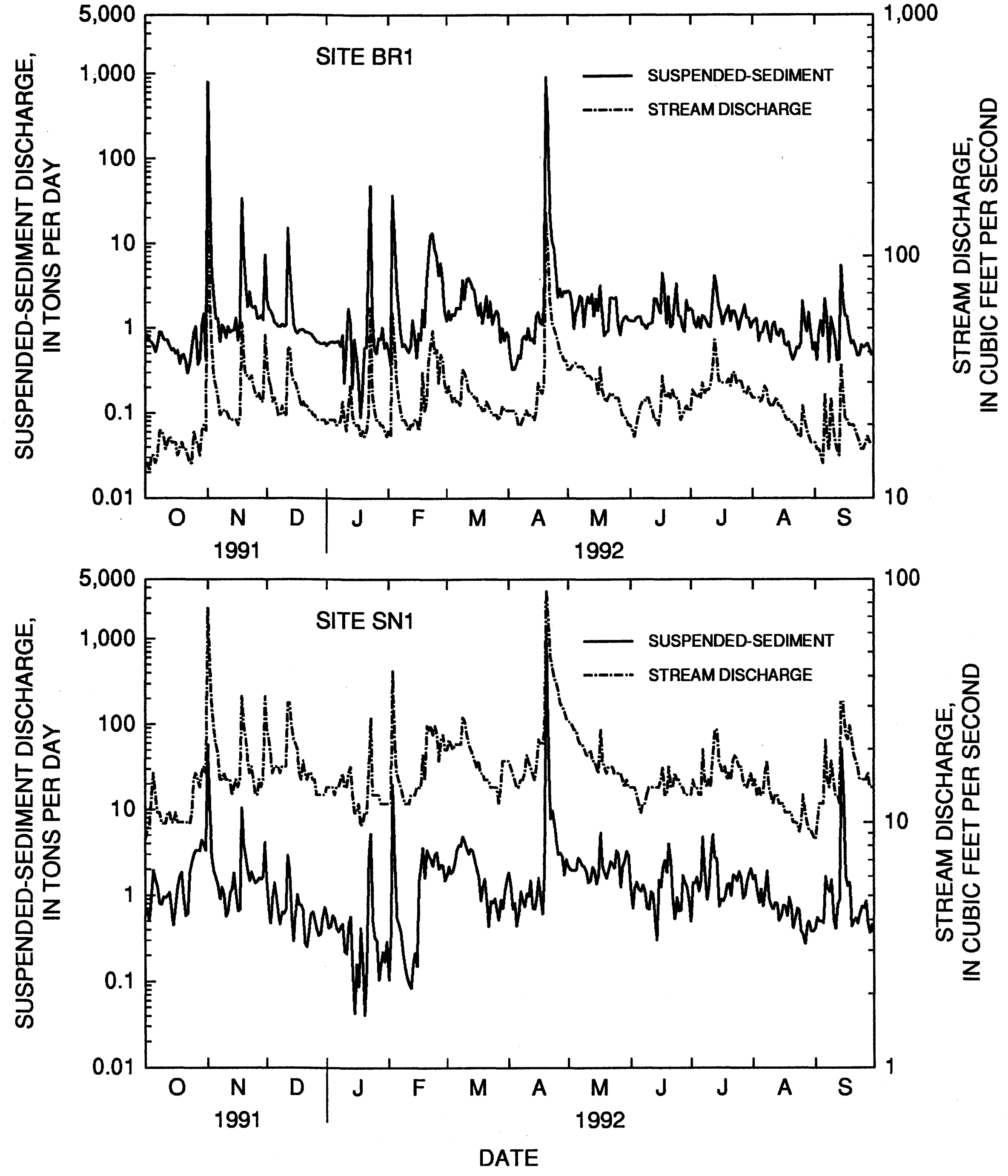


Figure 2. Suspended-sediment and stream discharge at the monitoring sites in Bloody Run and Sny Magill watersheds for Water Year 1992.

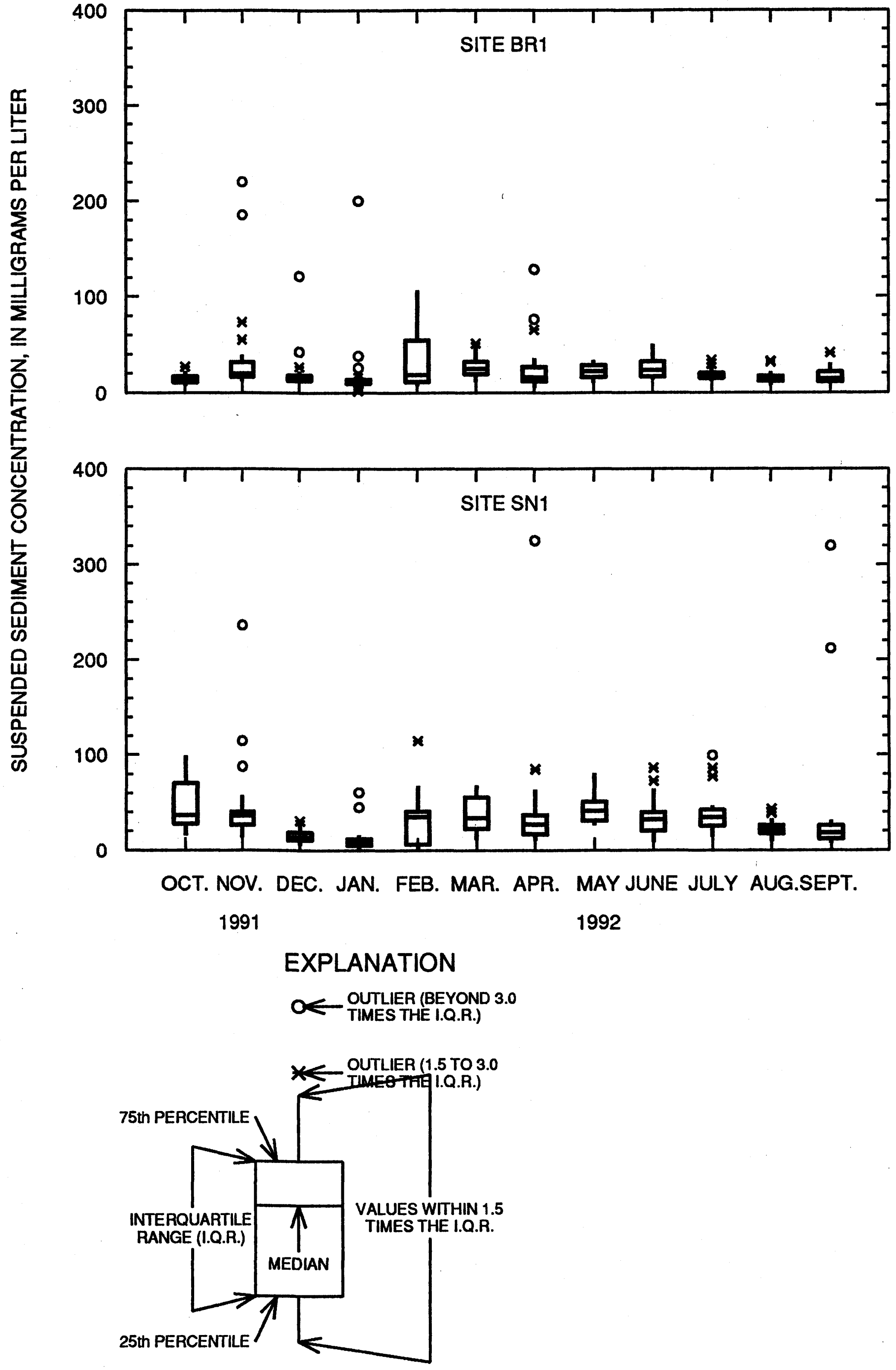


Figure 3. Summary of the monthly mean daily suspended-sediment concentrations at the monitoring sites in Bloody Run and Sny Magill watersheds for Water Year 1992.

Table 6. Particle size distribution of suspended sediment at the monitoring sites on Bloody Run and Sny Magill creeks.

Date	Time (24-hour)	Instantaneous discharge (cubic feet/sec)	Sediment Concentration (mg/L)	Silt-clay (percent <0.62 mm)	Sand (percent >0.62mm)
		Site BR1			
11/8/91	1530	27	22	55	45
12/5/91	1630	26	39	14	86
1/10/92	1015	21	18	25	75
2/13/92	1630	21	14	31	69
3/4/92	1630	25	13	76	24
4/9/92	1630	21	29	42	58
4/10/92	1230	23	28	14	86
4/24/92	1515	47	46	69	31
4/24/92	1800	49	48	66	34
5/7/92	1900	31	19	61	39
5/8/92	1210	35	39	59	41
6/4/92	1030	23	26	48	52
7/8/92	1045	27	59	53	47
7/8/92	1900	26	47	34	66
8/5/92	1930	23	10	39	61
9/2/92	1715	18	10	69	31
9/14/92	1445	73	104	95	5
		Site SN1			
11/7/91	930	14	22	58	42
12/6/91	930	16	30	33	67
1/9/92	1100	16	18	34	66
2/14/92	1000	13	9	54	46
3/5/92	1000	21	13	66	34
6/5/92	1000	14	40	49	51
8/6/92	1200	14	44	67	33
9/3/92	1515	11	48	88	12
9/14/92	1135	103	163	98	2
9/14/92	1735	55	488	99	1

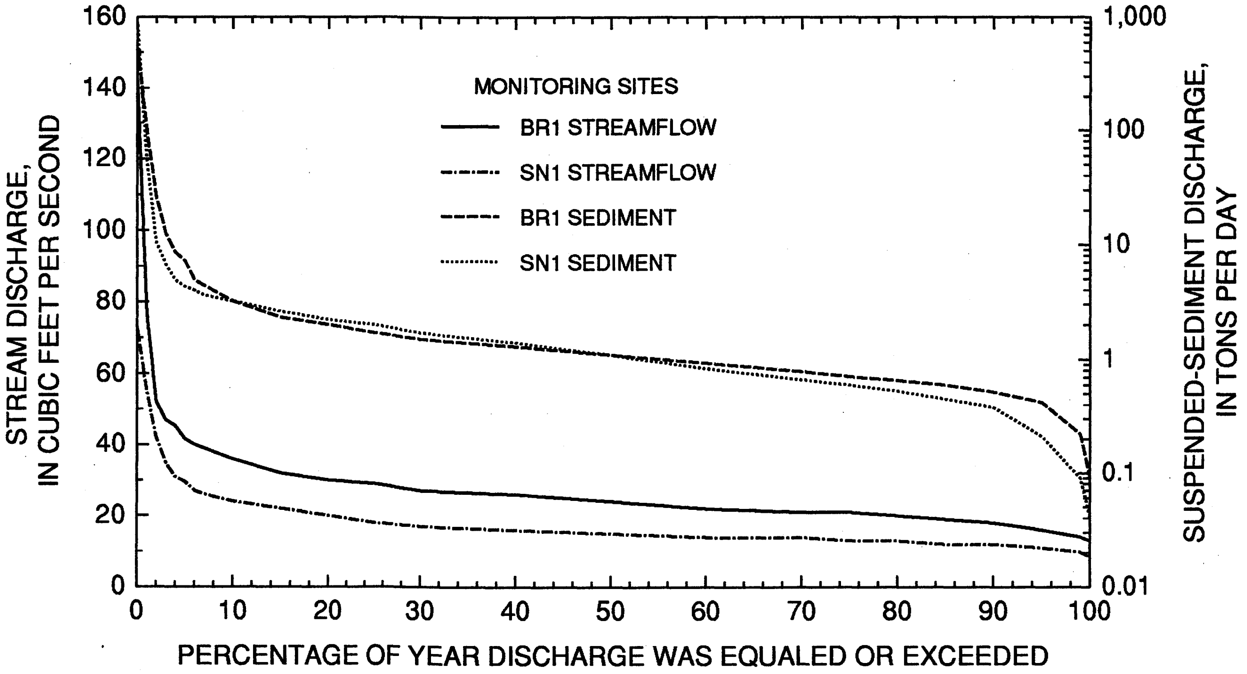


Figure 4. Percentage of year stream and suspended-sediment discharge was equaled or exceeded in Sny Magill and Bloody Run creeks for Water Year 1992.

Table 7. Daily mean discharge at the monitoring sites in the Bloody Run and Sny Magill watersheds; Water Year 1992. (Discharge in cubic feet per second).

(Discharge in cubic feet per second)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Site BR1												
1	14.0	205.0	36.0	20.0	19.0	27.0	23.0	34.0	20.0	23.0	26.0	17.0
2	14.0	64.0	31.0	21.0	18.0	29.0	23.0	34.0	19.0	28.0	26.0	16.0
3	13.0	41.0	29.0	21.0	58.0	27.0	23.0	35.0	18.0	27.0	26.0	16.0
4	15.0	32.0	25.0	21.0	43.0	25.0	23.0	36.0	20.0	26.0	26.0	15.0
5	15.0	29.0	26.0	21.0	31.0	26.0	22.0	36.0	22.0	27.0	25.0	14.0
6	14.0	26.0	24.0	20.0	26.0	25.0	20.0	35.0	24.0	26.0	26.0	27.0
7	15.0	22.0	22.0	20.0	23.0	25.0	20.0	35.0	25.0	30.0	29.0	18.0
8	19.0	23.0	22.0	21.0	21.0	24.0	21.0	35.0	25.0	27.0	28.0	16.0
9	19.0	23.0	24.0	25.0	21.0	34.0	22.0	34.0	26.0	28.0	25.0	26.0
10	18.0	23.0	22.0	21.0	20.0	33.0	23.0	32.0	26.0	28.0	24.0	20.0
11	16.0	22.0	22.0	19.0	19.0	31.0	22.0	32.0	24.0	29.0	24.0	17.0
12	17.0	21.0	41.0	24.0	20.0	28.0	22.0	32.0	23.0	34.0	25.0	16.0
13	18.0	21.0	42.0	29.0	20.0	27.0	22.0	31.0	21.0	45.0	26.0	15.0
14	17.0	21.0	33.0	22.0	21.0	27.0	21.0	31.0	21.0	39.0	24.0	36.0
15	17.0	21.0	30.0	20.0	21.0	26.0	23.0	31.0	20.0	31.0	24.0	27.0
16	17.0	20.0	30.0	20.0	19.0	26.0	30.0	27.0	23.0	30.0	23.0	21.0
17	15.0	22.0	28.0	20.0	22.0	24.0	28.0	35.0	32.0	30.0	22.0	21.0
18	16.0	53.0	26.0	18.0	33.0	24.0	27.0	28.0	27.0	30.0	21.0	20.0
19	17.0	37.0	24.0	19.0	23.0	23.0	30.0	26.0	26.0	30.0	21.0	20.0
20	16.0	32.0	25.0	18.0	25.0	23.0	152.0	25.0	27.0	31.0	21.0	20.0
21	16.0	32.0	24.0	19.0	38.0	25.0	105.0	26.0	26.0	29.0	20.0	19.0
22	15.0	31.0	24.0	22.0	43.0	24.0	65.0	27.0	28.0	33.0	20.0	18.0
23	14.0	32.0	23.0	61.0	49.0	23.0	53.0	27.0	26.0	33.0	19.0	17.0
24	14.0	29.0	23.0	27.0	39.0	22.0	50.0	26.0	26.0	30.0	18.0	16.0
25	19.0	27.0	22.0	23.0	41.0	22.0	47.0	26.0	25.0	30.0	18.0	16.0
26	17.0	26.0	22.0	21.0	30.0	22.0	44.0	26.0	21.0	31.0	24.0	17.0
27	17.0	27.0	21.0	21.0	39.0	21.0	40.0	24.0	22.0	29.0	21.0	18.0
28	15.0	25.0	21.0	20.0	37.0	22.0	39.0	22.0	23.0	27.0	19.0	17.0
29	19.0	25.0	21.0	20.0	30.0	24.0	37.0	22.0	24.0	27.0	18.0	17.0
30	20.0	47.0	21.0	19.0		23.0	37.0	21.0	23.0	29.0	17.0	17.0
31	19.0		21.0	18.0		23.0		20.0		27.0	17.0	
Site SN1												
1	8.5	76.0	24.0	14.0	12.0	20.0	18.0	26.0	14.0	13.0	14.0	8.5
2	9.4	42.0	22.0	14.0	12.0	22.0	17.0	26.0	14.0	15.0	15.0	10.0
3	9.8	30.0	19.0	14.0	42.0	21.0	16.0	25.0	14.0	14.0	13.0	12.0
4	13.0	24.0	16.0	14.0	21.0	20.0	15.0	24.0	13.0	14.0	14.0	12.0
5	16.0	21.0	17.0	13.0	16.0	21.0	14.0	24.0	12.0	13.0	13.0	12.0
6	13.0	19.0	17.0	14.0	15.0	21.0	14.0	22.0	11.0	13.0	13.0	22.0
7	11.0	15.0	17.0	14.0	14.0	21.0	15.0	21.0	12.0	20.0	16.0	15.0
8	11.0	15.0	16.0	15.0	13.0	21.0	15.0	21.0	12.0	15.0	18.0	14.0
9	10.0	16.0	17.0	16.0	12.0	27.0	16.0	20.0	13.0	14.0	14.0	18.0
10	9.9	15.0	17.0	14.0	12.0	26.0	19.0	19.0	14.0	15.0	13.0	15.0
11	9.9	15.0	17.0	14.0	12.0	23.0	18.0	19.0	14.0	14.0	12.0	13.0
12	11.0	15.0	31.0	16.0	13.0	21.0	17.0	20.0	14.0	19.0	13.0	13.0
13	11.0	13.0	31.0	17.0	13.0	20.0	16.0	18.0	14.0	24.0	13.0	12.0
14	10.0	14.0	25.0	13.0	13.0	19.0	15.0	18.0	14.0	24.0	12.0	47.0
15	10.0	15.0	22.0	11.0	14.0	18.0	17.0	17.0	14.0	18.0	12.0	29.0
16	11.0	14.0	21.0	11.0	14.0	17.0	22.0	16.0	15.0	17.0	12.0	23.0
17	10.0	15.0	20.0	12.0	14.0	18.0	21.0	24.0	17.0	16.0	11.0	22.0
18	10.0	33.0	16.0	9.7	19.0	16.0	21.0	18.0	13.0	17.0	11.0	25.0
19	10.0	25.0	15.0	10.0	15.0	16.0	24.0	17.0	13.0	15.0	11.0	22.0
20	10.0	22.0	18.0	11.0	25.0	15.0	90.0	16.0	17.0	16.0	11.0	19.0
21	10.0	18.0	16.0	11.0	24.0	15.0	69.0	17.0	14.0	15.0	10.0	18.0
22	10.0	16.0	15.0	16.0	25.0	15.0	48.0	17.0	14.0	18.0	10.0	17.0
23	9.9	17.0	16.0	27.0	23.0	14.0	43.0	17.0	16.0	19.0	9.9	15.0
24	11.0	15.0	16.0	13.0	25.0	14.0	39.0	16.0	15.0	18.0	9.2	15.0
25	15.0	13.0	15.0	13.0	23.0	14.0	38.0	16.0	15.0	17.0	10.0	15.0
26	16.0	13.0	15.0	13.0	18.0	14.0	35.0	16.0	14.0	17.0	13.0	15.0
27	15.0	15.0	13.0	13.0	22.0	12.0	31.0	16.0	14.0	15.0	11.0	16.0
28	14.0	14.0	13.0	12.0	23.0	14.0	30.0	15.0	13.0	14.0	9.9	14.0
29	16.0	15.0	13.0	12.0	20.0	18.0	29.0	14.0	13.0	14.0	9.2	14.0
30	17.0	33.0	13.0	12.0		18.0	27.0	15.0	13.0	15.0	9.2	14.0
31	16.0		13.0	12.0		18.0		14.0		16.0	8.8	

Table 8. Stage, mean velocity, and discharge measurements at supplemental sites in Bloody Run and Sny Magill watersheds.

Site	Date	Stage (Feet below reference mark)	Mean velocity (feet/sec)	Discharge (cubic feet/sec)
BRSC	10/10/91		0.23	2.95
	12/5/91	18.60	0.46	6.22
	1/10/92	18.70	0.40	5.14
	2/13/92	18.63	0.44	5.61
	3/4/92	18.67	0.44	5.98
	4/10/92	18.70	0.41	5.72
	5/7/92	18.49	0.41	5.83
	6/4/92	18.55	0.37	5.00
	7/9/92	18.54	0.36	4.72
	8/7/92	18.57	0.40	4.85
BR2	10/10/91	17.58	0.15	3.88
	6/4/92	17.48	0.60	11.00
	7/9/92	17.70	0.57	9.36
	8/7/92	17.57	0.34	7.72
SN3	10/10/91	18.93	0.48	1.40
	11/7/91	18.80	0.86	2.32
	12/6/91	18.57	0.97	2.70
	1/9/92	18.74	0.88	2.66
	2/14/92		0.96	2.10
	3/5/92	18.77	1.15	3.96
	4/9/92	18.76	0.78	2.81
	5/8/92	18.67	0.67	3.11
	6/5/92	18.73	0.77	2.76
	7/8/92	18.74	0.85	2.79
	8/6/92	18.77	0.43	2.20
SNWF	10/10/91	10.74	0.22	1.96
	11/7/91	10.79	0.38	2.01
	12/6/91	10.73	0.69	1.98
	1/9/92	10.82	1.12	2.99
	2/14/92	10.90	0.92	2.23
	3/5/92	10.82	0.98	3.86
	4/9/92	10.81	1.04	2.55
	5/8/92	10.62	0.91	2.66
	6/5/92	10.80	0.82	2.31
	7/8/92	10.77	0.81	2.12
	8/6/92	10.62	0.96	2.57
NCC	10/10/91	9.32	0.09	1.28
	11/7/91	9.91	0.98	2.48
	12/6/91	9.80	1.40	3.36
	1/9/91	9.90	1.30	2.59
	2/14/92	9.95	1.35	2.79
	3/5/92	9.88	1.15	2.28
	4/9/92	9.94	1.34	2.65
	5/8/92	9.73	1.44	3.54
	6/5/92	9.95	1.20	2.58
	7/8/92	9.96	1.15	2.32
	8/6/92	9.88	1.21	1.92
SNT	10/10/91	12.69	0.20	0.45
	11/7/91	12.69	0.47	0.87
	12/6/91	12.65	0.64	1.08
	1/9/91	12.70	0.92	1.46
	2/14/92	12.72	0.47	0.71
	3/5/92	12.70	0.74	1.28
	4/9/92	12.74	0.74	1.08
	5/8/92	12.51	0.91	1.49
	6/5/92	12.73	0.61	0.80
	7/8/92	12.74	0.85	0.82
	8/6/92	12.62	0.50	0.54
SN2	10/10/91	21.06	0.46	7.65
	11/7/91	21.06	0.94	13.40
	12/6/91	20.94	1.16	12.10
	1/9/91	21.05	0.94	12.70
	2/14/92	21.20	1.05	10.30
	3/5/92	21.00	1.38	15.80
	4/9/92	21.10	1.17	12.80
	5/8/92	20.79	1.35	15.80
	6/5/92	20.96	0.91	11.50
	7/8/92	20.94	1.02	12.30
	8/6/92	20.98	0.88	9.27

1991 HABITAT EVALUATION RESULTS - BASELINE INFORMATION

T. F. Wilton

Iowa Department of Natural Resources
Water Quality Bureau
Wallace State Office Building
Des Moines, IA 50319

ABSTRACT

A baseline habitat evaluation was conducted the fall of 1991 as part of the Sny Magill Watershed Nonpoint Source Pollution Monitoring Project. Habitat evaluations were completed at six locations in the Sny Magill and two in the Bloody Run watersheds. Instream and streamside habitat variables were measured and observed at all eight locations. The U.S. EPA Rapid Bioassessment Protocols habitat model was used to determine a qualitative habitat ranking for each site. Some sites reported better habitat quality than others, yet none of the differences among the sites were great enough to account for more than slight differences in biological integrity. The aquatic habitat characteristics were compared using a simple ranking process and habitat similarity index. Some of the habitat similarity shared among sites appears to be related to drainage basin size and channel slope.

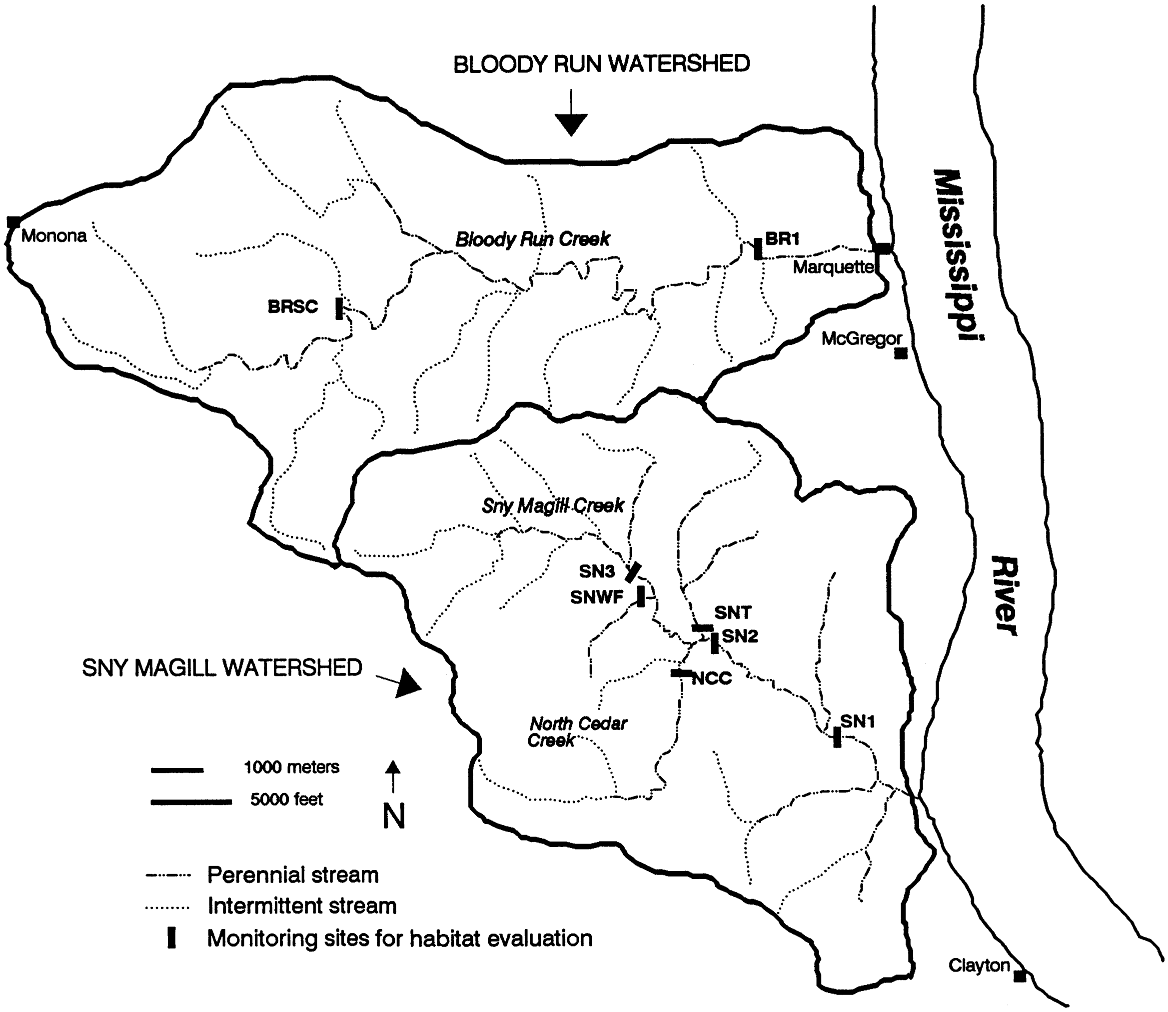


Figure 1. Location of sites in Sny Magill and Bloody Run watersheds where 1991 habitat evaluations were completed.

INTRODUCTION

This report summarizes aquatic habitat data collected during the fall of 1991 for the Sny Magill Watershed Nonpoint Source Pollution Monitoring Project. Habitat evaluations were completed at eight monitoring locations; six in the Sny Magill watershed and two in the Bloody Run watershed (Figure 1). The primary objective was to provide a baseline (pre-project) characterization of stream habitat conditions at sites selected for biological and chemical water quality monitoring. A secondary objective was to test standardized habitat evaluation methods developed for use in coldwater streams of Iowa.

PROCEDURES

Habitat evaluations were scheduled for September 1991 in an attempt to represent base-flow conditions at the end of the growing season. Ideally, all sites were to be evaluated within a few days of each other during stable stream flow conditions. Replicate habitat evaluations were planned for two sites to provide an estimate of observational variability.

Six of eight sites were evaluated on September 10-11. Because of rain and elevated stream flow on September 12, the remaining sites (SN3 and SNWF) were postponed until September 19. Habitat evaluations of SN3 and SNWF were repeated on October 7.

Habitat evaluations were completed by teams of two observers. One person was responsible for measuring and observing habitat variables and the other person recorded data. Site NCC was used as a training area where habitat evaluation procedures were reviewed and tested by all participants.

Habitat evaluation participants in 1991 were: Mark Hausler, Jack Kennedy, and Mike Schueller of The University of Iowa Hygienic Laboratory (UHL) Limnology Section, and John Olson and Tom Wilton of the Iowa Department of Natural Resources (IDNR) Water Quality Section. Assistance and procedural review were provided by Bob Clevenstine of the U.S. Fish and Wildlife Service, David Moeller and Gaige Wunder of the IDNR Fisheries Bureau, and John Vigna of The University of Iowa.

The procedures used are described in "Habitat Evaluation Data Collection Procedures" (Iowa DNR, 1991), a document prepared by the DNR Water Quality Section for standardization of coldwater stream data collection procedures in Iowa. Observational methods were patterned after those described by Hamilton and Bergersen (1984), Platts and others (1983), and several other sources (Lyons, 1990; OEPA, 1989; Pajak, 1987; Rankin, 1989; Simonson and Kaminski, 1990).

Generally, the procedures involve measuring and observing instream and streamside habitat variables at regularly-spaced, cross-sectional stream transects within a predefined reach. Data are recorded onto three field sheets (Appendix I) for later compilation and analysis. A wide variety of habitat variables from the following categories were evaluated: channel morphology, instream habitat, substrate composition, stream channel and reach dimensions, and streambank and riparian conditions.

RESULTS AND DISCUSSION

Aquatic habitat data from 1991 are summarized in Table 1, and habitat variables are defined in Table 2. The discussion of results is divided into three parts: (1) qualitative habitat assessment, (2) habitat similarity analysis, and (3) trout habitat modeling.

QUALITATIVE HABITAT ASSESSMENT

A qualitative habitat ranking of monitoring sites was accomplished using the U.S. EPA Rapid Bioassessment Protocols (RBP) habitat model (Plafkin et al., 1989). Information compiled from field sheets was used to assign scores for each of nine habitat variables in the RBP model (Appendix II). RBP habitat variables fall into three categories: primary - substrate and instream variables (44% of total possible score); secondary - channel morphology variables (33%); and tertiary - riparian and streambank variables (22%). Each variable was assigned a score based on the criteria provided in the RBP model. Individual variable scores were

Table 1. Summary of 1991 habitat evaluation data.

Site	BRSC	BR1	SN3	SN3	SNWF
Date	9/11/91	9/11/91	9/19/91	10/7/91	9/19/91
Reviewers	H:W	S:K	W:O	H:S	W:O
Reach area (square meters)	546.5	3327.9	329.7	348.1	166.3
Reach length (m)	132	350.5	95	97.5	72
Flow (CMS)	0.09	0.31	0.04	0.06	0.05
Average width (m)	4.6	8.8	3.5	3.6	2.3
Maximum depth (m)	1.04	1.83	0.64	0.67	0.43
Average maximum depth (m)	0.4	0.98	0.27	0.31	0.23
Average depth (m)	0.25	0.59	0.13	0.16	0.14
% instream cover	30	47	2	27	1
Dominant cover type	Pool	Pool	Undercut bank	Pool	Undercut bank
% pool area	27	50	29	32	14
Dominant pool class *	2	1	3	3	3
Dominant habitat type	Run	Pool	Run	Run	Run
Riffle repeat (X avg.width in meters)	9.5	13.2	6.8	5.5	5.2
Substrate composition					
% clay	0	4	0	2	8
% silt	6	34	0	0	4
% sand	0	8	4	2	6
% gravel	14	14	44	22	58
% cobble	48	34	44	64	20
% boulder	32	6	8	6	4
% other	0	0	0	2	0
% aquatic vegetation cover	55	14	12	68	6
Dominant aquatic vegetation type	Filamentous algae	Periphyton	Periphyton	Periphyton	Periphyton
Embeddedness rating **	3.1	1.8	3.9	3.6	2.2
% deposition	26	79	3	21	18
% scour	1	2	0	7	3
% stream shading	26	33	35	42	75
Streambank tree coverage rating ***	2.2	1.9	2.2	1.9	3.5
Streambank shrub coverage rating ***	1.3	1.0	2.2	1.0	1.2
Streambank herbaceous coverage rating ***	3.2	3.2	2.2	3.2	3.4
Streambank eroding rating ***	1.3	2.1	2.2	1.6	1.8
Average buffer width (m)	>14	>30	>23	>25	>26
Dominant buffer vegetation	Grass/Tree	Grass/Tree	Tree/ Herbaceous	Grass/Tree	Tree/ Herbaceous

* Pool class rating: 1= large and deep pools; 2= pools of moderate size and depth; 3= small and shallow pools.

**Embeddedness rating scale: 1= >75%; 2= 75-50%; 3= 50-25%; 4= 25-0%.

***Streambank variables rating scale: 1= 0-20%; 2=20-40%; 3= 40-60%; 4= 60-80%; 5= 80-100%.

Table 1. (cont.)

Site	SNWF	NCC	SNT	SN2	SN1
Date	10/7/91	9/10/91	9/11/91	9/11/91	9/11/91
Reviewers	S:H	W:K:S:H	S:K	W:H	W:H:S:K
Reach area (square meters)	181.5	304.9	90.7	834.9	3086.8
Reach length (m)	69.5	99	45.7	147	290
Flow (CMS)	0.05	0.03	0.01	0.23	0.31
Average width (m)	2.6	3.1	2.0	5.7	10.7
Maximum depth (m)	0.46	1.04	0.24	1.83	1.89
Average maximum depth (m)	0.24	0.24	0.14	0.51	0.93
Average depth (m)	0.16	0.14	0.08	0.31	0.65
% instream cover	5	19	0	31	72
Dominant cover type	Pool	Woody debris	-----	Pool	Pool
% pool area	6	16	2	30	60
Dominant pool class *	3	2	3	1	1
Dominant habitat type	Run	Run	Run	Run	Pool
Riffle repeat (X avg.width in meters)	-----	6.4	5.8	6.5	13.6
Substrate composition					
% clay	4	8	3	0	2
% silt	6	2	3	18	48
% sand	4	0	3	10	8
% gravel	40	56	17	36	10
% cobble	42	34	57	34	22
% boulder	4	0	17	0	10
% other	0	0	0	0	0
% aquatic vegetation cover	24	44	25	36	16
Dominant aquatic vegetation type	Periphyton	Periphyton	Periphyton	Periphyton	Periphyton
Embeddedness rating **	2.9	3.6	3.4	3.4	4.0
% deposition	35	16	24	30	63
% scour	8	4	28	0	8
% stream shading	79	32	58	42	13
Streambank tree coverage rating ***	1.0	1.8	2.5	2.1	1.9
Streambank shrub coverage rating ***	1.0	1.0	1.0	1.2	1.0
Streambank herbaceous coverage rating ***	4.6	3.6	4.9	4.2	4.3
Streambank eroding rating ***	1.8	1.2	1.0	1.3	1.2
Average buffer width (m)	>25	>27	>30	>28	>15
Dominant buffer vegetation	Grass/Tree	Tree/ Herbaceous	Tree/Grass	Tree/Shrub	Tree/Grass

Table 2. Definitions of habitat variables appearing in Table 1.

Site	See Figure 1
Date	Date that evaluation was completed.
Reviewers	H = Hausler; K = Kennedy; O = Olson; S = Schueller; W = Wilton.
Reach area	Surface area of stream reach evaluated (square meters).
Reach length	Length of stream reach evaluated (meters).
Flow	Stream flow in cubic meters per second.
Average width	Average stream width from 10 transect measurements (meters).
Maximum depth	Maximum depth in stream reach evaluated (meters).
Average maximum depth	Average maximum depth (thalweg depth) measured at 10 transects (meters).
Average depth	Average depth measured at 50 points along 10 transect lines (meters).
% instream cover	Percentage of reach area comprised of suitable cover for adult fish.
Dominant cover type	Predominant type of cover found (i.e., pool, undercut bank, woody debris).
% pool area	Percentage of reach area comprised of pool habitat.
Dominant pool class	Predominant pool class in reach (1=large and deep; 2=moderate size and depth; 3=small and shallow).
Dominant habitat type	Predominant type of habitat found in stream reach (i.e., pool, riffle, run).
Riffle repeat (X average width)	Frequency in which riffles repeat in stream reach (expressed as multiple of average stream width in meters).
SUBSTRATE COMPOSITION	
% clay	% of 50 substrate observations from 10 transects comprised of this type of substrate.
% silt	" " "
% sand	" " "
% gravel	" " "
% cobble	" " "
% boulder	" " "
% other	" " "
% aquatic vegetation cover	Percentage of stream bottom covered by aquatic vegetation.
Dominant aquatic vegetation type	Predominant type of aquatic vegetation (i.e., filamentous algae, periphyton).
Embeddedness rating	Average rating of percent large substrate (cobble and boulder) surface area that is embedded in fine substrate particles at riffle and run transects (embeddedness rating scale: 1 = >75%; 2 = 75-50%; 3 = 50-25%; 4 = 25-0%).
% deposition	Percentage of stream bottom affected by sediment deposition.
% scour	Percentage of stream bottom affected by scouring.
% stream shading	Percentage of stream reach surface area shaded between the hours of 10:30 and 14:30.
Streambank tree coverage rating	Average rating (20 observations) of % streambank area covered by tree canopy.
Streambank shrub coverage rating	Average raing (20 observations) of % streambank area covered by shrub canopy.
Streambank herbaceous coverage rating	Average rating (20 observations) of % streambank area covered by herbaceous vegetation.
Streambank eroding rating	Average rating (20 observations) of percentage streambank area that is eroding or unstable. Rating scale for streambank variables: 1 = 0-20%; 2 = 20-40%; 3 = 40-60%; 4 = 60-80%; 5 = 80-100%.
Average buffer width	Average width of buffer strip adjacent to stream on both sides (meters).
Dominant buffer vegetation	Predominant type of buffer strip vegetation (i.e., grass, herbaceous, shrub, tree).

summed to obtain an overall habitat ranking for each site.

RBP qualitative assessment results are summarized in Table 3. Monitoring site habitat scores ranged from 86 (SNWF) to 112 (SN2); the maximum possible score is 135. Based on the RBP scoring criteria, all eight monitoring sites received either a "good" or "good-to-excellent" habitat quality rating.

A theoretical curvilinear relationship between habitat quality and biological condition is presented in the RBP document (Chapter 8, p. 8-1). The curve can be used to predict the biological condition of a stream site based on the level of habitat comparability between the site and a reference site.

For example, suppose the Sny Magill project monitoring site with the best habitat score (i.e., SN2) is arbitrarily chosen as the reference site. As such, habitat scores for the other sites would range from 76-95% of the reference score. According to the habitat quality - biocondition curve, the habitat quality of nonreference sites is within the "supporting" or "comparable" range of the reference site. Consequently, in the absence of a water-quality impairment the biocondition of nonreference sites would be expected to be supporting or comparable to that of the reference site.

This example is strictly illustrative; the selection of a reference site(s) for analysis of biological monitoring data must be more carefully accomplished. However, these initial results suggest that habitat quality differences between the eight monitoring sites are not great enough to account for more than slight differences in biological integrity. More information is needed to determine whether this observation has merit.

HABITAT SIMILARITY ANALYSIS

The aquatic habitat characteristics of project monitoring sites were compared using a simple ranking process and habitat similarity index. The purpose of the comparison was to look for patterns in habitat characteristics among monitoring sites. An understanding of habitat differences and similarities among sites may potentially be useful for interpretation of biological and chemical monitoring results.

Twelve habitat variables were chosen for the comparative analysis. Six of the variables are related to instream habitat or channel morphology; four are substrate-related variables; two are streambank or riparian variables. Data were listed from highest to lowest site value for each habitat variable (Table 4). Average values were used for sites where replicate evaluations were completed (i.e., SN3 and SNWF).

The data for each of the twelve habitat variables were partitioned into high, medium, or low value categories using the following procedure:

(1) highest value was assigned to the high category.

(2) lowest value was assigned to the low category.

(3) both values bracketing the median were assigned to the medium category.

(4) remaining values were assigned to the high, medium, or low category depending on whether the value was closest to the high, median, or low value.

The results of the ranking process are listed in Table 5. The data were most heavily distributed around the median values; 28% of the values were assigned to the high category, 48% to the medium category, and 24% to the low category.

A simple index was used to quantify habitat similarity among sampling sites. The similarity index value for any given site combination is equal to the number of habitat variable data pairs that were assigned to the same category (high, medium, or low value) divided by the total number of habitat variables compared (twelve). Index values may range from 0.0 - 1.0. For example, if all twelve habitat variable data pairs were assigned to matching categories, the index value for that site comparison would be 1.0 (12/12). If half of the data pairs matched, the index value would be 0.50 (6/12).

Table 6 contains a matrix of the similarity index values and a summary of the best and worst (most

Table 3. Rapid Bioassessment Protocols (RBP) habitat assessment results for 1991.

	SITE									
Habitat variable (scoring range)	BRSC	BR1	SN3	SN3	SNWF	SNWF	NCC	SNT	SN2	SN1
Date:	9/11/91	9/11/91	9/19/91	10/7/91	9/19/91	10/7/91	9/10/91	9/11/91	9/11/91	9/11/91
Bottom substrate (0 - 20)	19	16	18	19	18	17	17	19	17	14
Embeddedness (0 - 20)	14	8	18	16	8	12	16	15	15	17
Stream flow (0 - 20)	18	20	12	15	14	14	11	5	20	20
Channel alteration (0 - 15)	13	10	11	13	13	13	14	14	14	13
Bottom scouring/ deposition (0 - 15)	9	4	14	8	9	5	10	4	8	4
Pool/riffle ratio (0 - 15)	9	11	12	12	12	7	13	12	14	10
Bank stability (0 - 10)	10	7	7	7	5	7	9	9	9	7
Bank vegetation stability (0 - 10)	9	7	7	8	8	7	9	10	10	9
Streamside cover (0 - 10)	5	5	5	5	7	4	5	5	5	5
Habitat quality score* (0 - 135)	106	88	104	103	94	86	104	93	112	99

* Habitat quality scoring guidelines: poor = <30; fair = 39-66; good = 75 - 102; excellent = 111-135.

Table 4. Ranking of habitat variable data from highest to lowest site value for habitat similarity analysis.

SITE	CBL	SITE	CVR	SITE	EMB	SITE	FIN	SITE	FLW	SITE	POL
SNT	57	SN1	72	BR1	4.0	SN1	58	BR1	0.31	SN1	60
SN3	54	BR1	47	SNWF	3.8	BR1	46	SN1	0.31	BR1	50
BRSC	48	SN2	31	BRSC	3.6	SN2	28	SN2	0.23	SN3	31
SN2	34	BRSC	30	SNT	3.4	SNWF	16	BRSC	0.09	SN2	30
NCC	34	NCC	19	SN2	3.4	SNT	10	SNWF	0.05	BRSC	27
BR1	34	SN3	15	NCC	3.1	NCC	10	SN3	0.05	NCC	16
SNWF	31	SNWF	3	SN3	2.5	BRSC	6	NCC	0.03	SNWF	10
SN1	22	SNT	0	SN1	1.8	SN3	4	SNT	0.01	SNT	2
median	34.00		24.80		3.40		13.00		0.07		28.50

SITE	RRT	SITE	SDP	SITE	SER	SITE	SHD	SITE	TWD	SITE	WDP
SN1	13.6	BR1	79	BR1	2.1	SNWF	77	BR1	0.98	SN3	27.1
BR1	13.2	SN1	63	SN3	1.9	SNT	58	SN1	0.93	SNT	24.8
BRSC	9.5	SN2	30	SNWF	1.8	SN2	42	SN2	0.51	NCC	22.1
SN2	6.5	SNWF	26	BRSC	1.3	SN3	39	BRSC	0.40	BRSC	18.4
NCC	6.4	BRSC	26	SN2	1.3	BR1	33	SN3	0.29	SN2	18.3
SN3	6.2	SNT	24	NCC	1.2	NCC	32	SNWF	0.24	SN1	16.4
SNT	5.8	NCC	16	SN1	1.2	BRSC	26	NCC	0.24	SNWF	16.4
SNWF	5.2	SN3	12	SNT	1.0	SN1	13	SNT	0.14	BR1	14.9
median	6.45		26.00		1.30		36.00		0.35		18.35

Habitat variable codes:

CBL: % Stream bottom area consisting of cobble substrate.

CVR: % Stream reach area providing instream cover.

EMB: Average rating of coarse substrate embeddedness in riffles and runs.

FIN: % Stream bottom area consisting of fine particle (sand, silt, clay) substrates.

FLW: Stream flow (cubic meters per second).

POL: % Stream reach area consisting of pool habitat.

RRT: Riffle repeat frequency (expressed as a multiple of average stream width).

SDP: % Stream bottom area affected by silt deposition.

SER: Average rating of eroding/unstable streambank area.

SHD: % Stream reach surface area shaded between the hours of 10:30 and 14:30.

TWD: Thalweg depth (average maximum depth in meters).

WDP: Ratio of average stream width to average stream depth.

Table 5. Results of habitat variable rankings (high, medium, or low value) by sampling site for habitat similarity analysis.

Site	High	Medium	Low
BRSC	CBL	CVR EMB FLW POL RRT SDP SER SHD TWD WDP	FIN
BR1	CVR FIN FLW RRT POL SDP SER TWD	CBL SHD	EMB WDP
SN3	CBL EMB SER WDP	CVR FLW RRT POL SHD TWD	FIN SDP
SNWF	SER SHD	CBL FIN FLW SDP	CVR EMB POL RRT TWD WDP
NCC		CBL CVR EMB FIN POL RRT SER SHD WDP	FLW SDP TWD
SNT	CBL SHD WDP	EMB FIN SDP	CVR FLW POL RRT SER TWD
SN2	FLW	CBL CVR EMB FIN RRT POL SDP SER SHD TWD WDP	
SN1	CVR EMB FIN FLW RRT POL SDP TWD	SER	CBL SHD WDP

Habitat variable codes:

CBL: % Stream bottom area consisting of cobble substrate.

CVR: % Stream reach area that provides instream cover.

EMB: Average rating of coarse substrate embeddedness in riffles and runs.

FIN: % Stream bottom area consisting of fine particle (sand, silt, clay) substrates.

FLW: Stream flow (cubic feet per second).

POL: % Stream reach area consisting of pool habitat.

RRT: Riffle repeat frequency (expressed as a multiple of average stream width).

SDP: % Stream bottom area affected by silt deposition.

SER: Average rating of eroding/unstable streambank area.

SHD: % Stream reach surface area shaded between the hours of 10:00 and 14:00.

TWD: Thalweg depth (average maximum depth in meters).

WDP: Ratio of average stream width to average stream depth

Table 6. Matrix of habitat similarity indices* (sites are arranged in order from largest to smallest drainage area) and summary of best and worst (most and least similar) site matches.

Site	BR1 (85.7**)							
SN1	0.67	SN1 (71.5)						
SN2	0.25	0.17	SN2 (58.3)					
BRSC	0.08	0.08	0.75	BRSC (24.1)				
SN3	0.17	0.08	0.42	0.67	SN3 (18.6)			
NCC	0.17	0.08	0.75	0.58	0.42	NCC (15.5)		
SNT	0.00	0.00	0.25	0.25	0.17	0.25	SNT (8.3)	
SNWF	0.33	0.08	0.25	0.17	0.17	0.25	0.58	SNWF (8.0)

* Similarity index=total number of habitat variable rankings (high, medium, or low value) in common (from Table 5) divided by the total number of variables (12). Index values may range from 0.0 - 1.0.

** Estimated drainage area above monitoring site (square kilometers).

Summary

Site	Best match	Similarity index	Common variables	Worst match	Similarity index
BRSC	SN2	0.75	CVR,EMB,POL,RRT,SDP,SER,SHD,TWD,WDP	BR1	0.08
BR1	SN1	0.67	CVR,FIN,FLW,POL,RRT,SDP,TWD,WDP	SN1	0.08
SN3	BRSC	0.67	CBL,CVR,FIN, FLW, POL, RRT, SHD, TWD	SNT	0.00
SNWF	SNT	0.58	CVR,FIN,POL,RRT,SDP,SHD,TWD	SN1	0.08
NCC	SN2	0.75	CBL,CVR,EMB,FIN,POL,RRT,SER,SHD,WDP	SN1	0.08
SNT	SNWF	0.58	CVR,FIN,POL,RRT,SDP,SHD,TWD	BR1 SN1	0.00 0.00
SN2	BRSC NCC	0.75 0.75	CVR,EMB,POL,RRT,SDP,SER,SHD,TWD,WDP CBL,CVR,EMB,FIN,POL,RRT,SER,SHD,WDP	SN1	0.17
SN1	BR1	0.67	CVR,FIN,FLW,POL,RRT,SDP,TWD,WDP	SNT	0.00

Table 7. Surface drainage and main channel slope estimates for 1991 habitat monitoring sites.

Site	Drainage area (square kilometers)	Main channel slope (meters/kilometer)
Sny Magill drainage basin		
SN1	71.5	9.6
SN2	58.3	13.7
SN3	18.6	16.7
NCC	15.5	15.8
SNT	8.3	18.9
SNWF	8.0	22.9
Bloody Run drainage basin		
BR1	85.7	5.4
BRSC	24.1	7.1

and least similar) site matches. Index values ≥ 0.42 may indicate relatively good habitat similarity, while smaller values indicate poorer habitat similarity. Three distinct groupings emerge when the monitoring sites in the matrix are arranged from largest to smallest surface drainage area and index values ≥ 0.42 are selected (groupings are highlighted in the table).

The site groupings appear to identify a relationship between drainage area size and habitat. Based on a simple comparison of index values, the two monitoring sites with the largest drainage area above them (BR1, SN1) appear to share greater habitat similarity to each other than to sites of smaller drainage area. Likewise, monitoring sites located in the smallest drainage basins (SNT, SNWF) appear to have more in common with each other than with any of the other sites. The pattern also holds true for monitoring sites of intermediate-size drainage area (SN2, BRSC, SN3, NCC).

The relationship between drainage area size and habitat may be partially related to stream gradient. Main stream channel slope estimates for each of the monitoring sites are listed in Table 7. Channel slope and other basin morphometric statistics were estimated (Kalkoff and Eash, this volume) using Geographic Information System (GIS) adapted software (Eash, 1991). The channel slope estimates reported here are based on the change in elevation between points at 85% and 10% of the main channel segment length from the monitoring site (downstream endpoint) to the drainage divide (upstream endpoint).

As Table 7 indicates, there is an inverse relationship between main channel slope and drainage area for monitoring sites in the Sny Magill watershed. The steepest channel slopes occur in smaller subbasins of the watershed (SNT, 18.9 m/km; SNWF, 22.9 m/km). The main channel slope of Sny Magill Creek increases substantially from 9.6 m/km for the downstream site (SN1) to 16.7 m/km for the upstream site (SN3). In contrast, the main channel slope of Bloody Run Creek is smaller than that of Sny Magill Creek and there is less difference in slope between downstream and upstream sites (BR1, 5.4 m/km; BRSC, 7.1 m/km).

In general, sites located in stream segments of comparatively steep channel slope (i.e., SNT, SNWF, NCC, SN3) tend to have lower values for the following habitat variables compared to sites of more moderate gradient: (a) average depth; (b) distance between riffles; (c) fine-size substrate; (d) instream cover; (e) pool habitat; (f) silt deposition. The apparent interrelatedness of habitat, drainage area size, and channel slope suggests that physiography and stream morphological processes such as channel erosion and sediment deposition are important determinants of monitoring site habitat character.

TROUT HABITAT MODELING

U.S. Fish and Wildlife Service Habitat Suitability Index (HSI) models (Raleigh et al., 1984; Raleigh et al., 1986) were used to evaluate the quality of brown trout and rainbow trout habitat at project monitoring sites. Several instream and streamside habitat variables important to the adult and juvenile life stages of trout were evaluated. The models provide numerical ratings for individual habitat variables and overall habitat suitability for specific life stages of trout. The ratings are based on a linear scale ranging from 0.0 (unsuitable) to 1.0 (optimum).

Suitability Index (SI) values are summarized in Table 8. The data were not sufficient to analyze the suitability of water quality variables (i.e., dissolved oxygen, pH, water temperature) or physical vari-

Table 8. Suitability Index (SI) values for selected variables from the U.S. Fish and Wildlife Service brown trout and rainbow trout Habitat Suitability Index (HSI) models.

Habitat variable		BRSC	BR1	SN3	SNWF	NCC	SNT	SN2	SN1
Average Thalweg Depth (m)	(value)	(0.40)	(0.98)	(0.29)	(0.24)	(0.24)	(0.14)	(0.51)	(0.91)
	* BRW SI	---	---	---	---	---	---	---	---
	* RBW SI	1.00	1.00	0.99	0.90	0.90	0.43	1.00	1.00
Percent area - instream cover	(value)	(30)	(47)	(15)	(3)	(19)	(0)	(31)	(72)
	BRW SI	0.86	1.00	0.41	0.09	0.55	0.00	0.89	1.00
	RBW SI	1.00	1.00	0.82	0.36	0.92	0.20	1.00	1.00
Percent area - pools	(value)	(27)	(50)	(31)	(10)	(16)	(2)	(30)	(60)
	BRW SI	0.63	1.00	0.69	0.30	0.42	0.14	0.68	1.00
	RBW SI	0.87	1.00	0.92	0.53	0.67	0.35	0.91	1.00
Poor quality	(rating)	(C)	(A)	(C)	(C)	(C)	(C)	(B)	(A)
	BRW SI	0.30	1.00	0.30	0.30	0.30	0.30	0.60	1.00
	RBW SI	0.30	1.00	0.30	0.30	0.30	0.30	0.60	1.00
Predominant substrate type	(rating)	(A)	(B)	(B)	(B)	(B)	(A)	(B)	(B)
(riffle/run)	BRW SI	1.00	0.60	0.60	0.60	0.60	1.00	0.60	0.60
	RBW SI	1.00	0.60	0.60	0.60	0.60	1.00	0.60	0.60
Percentage area - fines	(value)	(5.0)	(30.0)	(0.0)	(16.0)	(11.1)	(11.1)	(15.0)	(15.0)
(riffle/run)	BRW SI	1.00	0.47	1.00	0.84	0.97	0.97	0.87	0.87
	RBW SI	1.00	0.71	1.00	0.94	0.99	0.99	0.95	0.95
Percent shaded stream surface	(value)	(26)	(33)	(39)	(77)	(32)	(58)	(42)	(13)
(between 10:00-14:00 hours)	BRW SI	0.66	0.76	0.85	0.98	0.75	1.00	0.89	0.48
	RBW SI	0.66	0.76	0.85	0.97	0.75	1.00	0.89	0.48
Percent stable streambank area	(value)	(84)	(68)	(72)	(73)	(86)	(90)	(85)	(87)
	BRW SI	1.00	0.97	0.99	0.99	1.00	1.00	1.00	1.00
	RBW SI	1.00	0.95	0.98	0.99	1.00	1.00	1.00	1.00
Streambank vegetation index	(index)	(144)	(127)	(141)	(164)	(139)	(192)	(167)	(161)
	BRW SI	1.00	0.95	1.00	1.00	1.00	1.00	1.00	1.00
	RBW SI	0.98	0.89	0.97	1.00	0.96	1.00	1.00	1.00
Overall adult life stage	BROWN	0.30	1.00	0.30	0.09	0.30	0.00	0.60	1.00
Habitat suitability index	RAINBOW	0.80	1.00	0.75	0.60	0.72	0.37	0.90	1.00

* BRW SI = brown trout suitability index (adult life stage); RBW SI = rainbow trout suitability index (adult life stage).
Suitability index values may range from 0.0 (unsuitable) to 1.0 (optimum).

ables important to trout embryo or fry life stages. As such, the modeling results indicate the suitability of physical habitat to support nonreproducing, stocked populations of trout. The results should not be extrapolated beyond the stream areas evaluated.

Site Differences

Differences in trout habitat suitability between project monitoring sites are primarily related to the amount of instream cover and the quantity and quality of pool habitat existing at each site. Instream cover and pool habitat are important determinants of trout habitat quality. Trout species exhibit a strong tendency to seek areas where visibility is obscured by such features as aquatic vegetation, deep or turbulent water, large boulders, overhanging streambank vegetation, undercut banks, or woody debris.

The HSI modeling results indicate that downstream sites in Bloody Run Creek (BR1) and Sny Magill Creek (SN1) have better habitat for adult brown trout and rainbow trout than other stream monitoring locations. Sites BR1 and SN1 received optimum HSI ratings (1.0) primarily because of optimum levels of instream cover and pool quality and quantity (Table 8). Sites located in the smaller sub-basins of Sny Magill Creek, SNT and SNWF, received poor HSI ratings (ranging from 0.00 to 0.60) because of the lack of instream cover and pool habitat. Monitoring locations of more intermediate-size drainage area (i.e., SN2, BRSC, SN3, NCC) received suboptimum HSI ratings ranging from 0.30 to 0.90.

Trout Species

A site-by-site examination of HSI ratings in Table 8 indicates a substantial difference between brown trout and rainbow trout habitat suitability levels at all sites where instream cover and pool habitat quality are suboptimum. The difference is attributable to the type of equation used to calculate the adult life stage HSI ratings for each species. A limiting variable equation is used in the brown trout model in which the overall HSI rating is set equal to the lowest habitat variable SI value. In contrast, the rainbow trout model uses a compensatory variable equation in which lower SI values for some variables can be compensated by higher SI values for other variables. Because the adult brown trout HSI ratings are governed by the lowest habitat variable SI value they tend to be lower than corresponding adult rainbow trout HSI ratings.

The difference between the models is based on the assumption that brown trout have a greater need for instream cover than rainbow trout and more strongly prefer to inhabit large, deep pools (Raleigh et al., 1986). The lack of quality pool habitat (pools large and deep enough to provide cover and space for numerous adult trout) was a limiting variable for brown trout habitat at all monitoring locations except BR1 and SN1. Instream cover was nearly devoid at SNWF and SNT, making it the primary limiting habitat variable at those sites.

The SI values for other instream and streamside habitat variables evaluated were not considered limiting to adult trout habitat suitability although several monitoring sites received suboptimum ratings for one or more of these variables (Table 8).

SUMMARY

Habitat evaluations completed during 1991 suggest that baseline habitat conditions are generally good at monitoring locations in the Sny Magill and Bloody Run watersheds. The RBP habitat assessment results suggest that while some sites appear to have somewhat better habitat quality than others, none of the sites appear to be physically limited or degraded to the point where dramatic differences in biological integrity would be expected between sites. However, these findings are based on a single evaluation and therefore require more substantiation. Further, the RBP habitat assessment is a generalized methodology that does not specifically address habitat requirements for any one species or type of biological community (e.g., fish, macroinvertebrates). Consequently, the methodology may not be sensitive to all forms of habitat degradation or limitation that may result in detectable biological impairment.

A habitat similarity index was used to identify patterns in habitat characteristics among project monitoring locations. Some of the habitat similarity shared among sites appears to be related to drainage basin size and channel slope. The information from this analysis may potentially aid the interpretation of biological and chemical monitoring data.

The results of habitat suitability modeling for adult brown trout and rainbow trout varied among monitoring locations from very poor to excellent depending on the amount of instream cover and the quality and quantity of pool habitat existing at each site. The results are based strictly on the conditions of selected physical habitat variables and do not account for possible water quality limitations.

REFERENCES

Eash, D., 1991, Unpublished morphometric basin characteristics of Sny Magill Creek sub-basins: Water Resources Division, U.S. Department of the Interior Geological Survey, Iowa City, IA.

Hamilton, K., and Bergersen, E.P., 1984, Methods to estimate aquatic habitat variables: Colorado Cooperative Fishery Research Unit, Colorado State University, Fort Collins, CO.

Iowa DNR, 1991, Habitat evaluation data collection procedures, Water Quality Section: Environmental Protection Division, Iowa Department of Natural Resources, Des Moines, IA.

Kalkoff, S.J., and Eash, D.A., 1994, Suspended sediment and stream discharge in Bloody Run and Sny Magill watersheds: Water Year 1992: this volume.

Lyons, J., 1990, Appraisal-phase stream habitat sampling protocol - WDNR Priority Watershed Projects, draft report, June 1990: Fisheries Section, Bureau of Research, Wisconsin Department of Natural Resources, Madison, WI.

OEPA, 1989, Biological criteria for the protection of aquatic life: Volume III: standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities: Ecological Assessment Section, Division of Water Quality Planning and Assessment, Ohio Environmental Protection Agency, Columbus, OH, 43 p.

Pajak, P., 1987, Stream habitat surveys, unpublished methods documentation: Wisconsin Department of Natural Resources, Madison, WI.

Plafkin J.L., Barbour, M.T., Porter, K.D., Gross, S.K., and Hughes, R.M., 1989, Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish: Assessment and Watershed Protection Division, Office of Water, U.S. Environmental Protection Agency, Washington, D.C., EPA/444/4-89-001.

Platts, W.S., Megahan, W.F., and Minshall, G.W., 1983, Methods for evaluating stream, riparian, and biotic conditions: USDA Forest Service, General Technical Report INT-138, 70 p.

Raleigh, R.F., Hickman, T., Soloman, R.C., and Nelson, P.C., 1984, Habitat suitability information: rainbow trout: U.S. Fish and Wildlife Service, FWS/OBS-82/10.60, 64 p.

Raleigh, R.F., Zuckerman, L.D., and, Nelson, P.C., 1986, Habitat suitability index models and instream flow suitability curves: brown trout (revised): U.S. Fish and Wildlife Service, Biological Report 82(10.124), 65 p.

Rankin, E.T., 1989, The qualitative habitat evaluation index (QHEI): rationale, methods, and application: Division of Water Quality Planning and Assessment, Ohio Environmental Protection Agency, Columbus, OH.

Simonson T. D., and Kaminski, M.T., 1990, Priority watershed evaluation - fish and fish habitat transect analysis - sample size determination, draft report, July 1991: Fisheries Section, Bureau of Research, Wisconsin Department of Natural Resources.

APPENDIX I

Example of the 1991 habitat evaluation field sheets.

FORM A: STREAM TRANSECT POINT OBSERVATIONS.

STREAM______________________ REACH LOCATION______________________ DATE____________

ESTIMATED STREAM WIDTH (ft/m)____________ TRANSECT SPACING (3X stream width)________(ft/m)

TRANSECT NUMBER	TOTAL WIDTH (ft/m)	MAX. DEPTH (ft/m)	DISTANCE FROM LEFT SHORE (ft/m)	DEPTH (ft/m)	DOM. SUBSTR.

substrate codes

clay (cl)
silt (st)
sand (sd)
gravel (gv)
cobble (cb)
boulder (bd)
wood (wd)
other (specify)

substrate size criteria

boulder > 10 "
cobble 10 - 2.5"
gravel 2.5 - 0.10"
sand 2.0 - 0.062 mm
silt 0.062 - 0.004 mm
clay < 0.004 mm

FLOW DETERMINATION

Distance from shore (ft/m)	Depth (ft/m)	Current Velocity (ft/s) (m/s)

Total Width (ft/m)_______

Appendix I. (cont.)

FORM B: STREAM TRANSECT LINE OBSERVATIONS.

Stream________________________ Reach Location _______________ Date__________ Time___________

Flow Level (high/ normal/low) Water Clarity (turbid/slightly turbid/clear) Water Temp_____(C/F)

TRANSECT

INSTREAM VARIABLES	1	2	3	4	5	6	7	8	9	10
dom. habitat type (a)										
% instream cover (>=0.5' and <0.5'/s)										
dom. cover type (b)										
% aquatic veg. coverage										
dom. aq. veg. type (c)										
embedd. rating(d)										
% deposition / % scour										
% stream shading (1000-1400 hrs)										

STREAMSIDE VARIABLES (e)	1	2	3	4	5	6	7	8	9	10
streambank coverage rating (tree) (f)										
streambank coverage rating (shrub)										
streambank coverage rating (herbs)										
streambank erosion rating										
buffer strip width (f/m)										
dom. buffer veg. (g)										

COMMENTS:____

(a) Indicate the dominant stream habitat type intercepted by the transect line: pool(pl); riffle (rf); run (rn).

(b) Instream cover codes: aquatic veg. (av); boulder (bd); overhanging veg. (ov); pool (pl); undercut bank (ub); woody debris (wd); other (specify).

(c) Aquatic vegetation codes: emergent macrophytes (em); floating macrophytes (fm); submergent macrophytes (sm); filamentous algae (fa); periphyton (pp).

(d) Embeddedness rating: 4=0-25%; 3=25-50%; 2=50-75%; 1=>75%. Measured in riffle areas containing large gravel, cobble, or small boulder size substrates.

(e) Streamside variables are recorded in divided boxes according to left side and right side (facing upstream) respectivley (i.e., L\R).

(f) Streambank coverage and streambank erosion ratings are coded as follows: (1) 0-20%; (2) 20-40%; (3) 40-60%; (4) 60-80%; (5) 80-100%.

(g) Buffer strip vegetation codes: grasses (gs); herbaceous (nonwoody) plants (hb); shrubs (sb); trees (tr).

Appendix I. (cont.)

FORM C: POOL SIZE AND CLASS OBSERVATIONS.

STREAM__________________ REACH LOCATION_________________ DATE________

POOL CELL NUMBER (a)	POOL CLASS RATING (b)	MAXIMUM DEPTH (f/m)	DIMENSIONS (c) length (f/m)	width (f/m)	POOL CELL AREA (ft2/m2)	POOL TYPE (d)

NUMBER OF RIFFLES IN EVALUATED REACH_______________________________

CHANNEL ALTERATIONS (e): little or none / some / moderate / extensive

STREAMBANK STABILITY (f): stable / moderately stable / moderately unstable / unstable

COMMENTS:____

(a) Indicate pool cell number (1,2,3, etc.)

(b) Class 1: large and deep pools. >30% of pool bottom obscured because of depth, surface turbulence, structures, overhanging banks, or vegetation. Depth is >=5 ' (1.5 m).
Class 2: pools of moderate size and depth. 5-30% of bottom obscured from view. Examples are large eddies behind boulders, low velocity moderately deep areas associated with undercut banks and overhanging vegetation.
Class 3: small and shallow pools. Virtually all of the stream bottom is visible. Examples are wide shallow areas in streams, small eddies behind boulders.

(c) Visualize pool as a rectangular cell and indicate length and width dimensions of each pool cell. Take more than one length and width measurement and average for large or irregularly-shaped pools.

(d) Indicate the dominant pool feature or cause of pool formation. For example: boulder eddy, undercut bank, channel bend, channel constriction, riffle, debris jam, plunge pool, beaver dam, other (specify).

(e) Rank the degrees of stream channel alteration due to point bar enlargement, island formation, pool siltation, or channelization.

(f) Rank the degree of streambank stability based on steepness of streambank slopes and the amount of slumping observed.

APPENDIX II

Habitat assessment field sheet.

	Category			
Habitat Parameter	Excellent	Good	Fair	Poor
1. Bottom substrate/ available cover (a)	Greater than 50% rubble, gravel, submerged logs, undercut banks, or other stable habitat. 16 - 20	30-50% rubble, gravel, or other stable habitat. Adequate habitat. 11 - 15	10-30% rubble, gravel, or other stable habitat. Habitat availability less than desirable. 6 - 10	Less than 10% rubble gravel or other stable habitat. Lack of habitat is obvious. 0 - 5
2. Embeddedness (b)	Gravel, cobble, and boulder particles are between 0 and 25 % surrounded by fine sediment. 16 - 20	Gravel, cobble, and boulder particles are between 25 and 50% surrounded by fine sediment. 11 - 15	Gravel, cobble, and boulder particles are between 50 and 75% surrounded by fine sediment. 6 - 10	Gravel, cobble, and boulder particles are over 75% surrounded by fine sediment. 0 - 5
3. <=0.15 cms (5 cfs) *Flow at rep. low flow (a)	Cold >0.05 cms (2 cfs) Warm >0.15 cms (5 cfs) 10 - 20	0.03-0.05 cms(1-2 cfs) 0.05-0.15 cms (2-5 cfs) 11 - 15	0.01-0.03 cms (.5-1 cfs) 0.03-0.05 cms (1-2 cfs) 6 - 10	<0.01 cms(.5 cfs) <0.03 cms (1 cfs) 0 - 5
OR				
>0.15 cms (5 cfs) Velocity/depth	Slow (<0.3 m/s), deep (>0.5 m); slow, shallow (<0.5 m); fast (>0.3m/s), deep; fast shallow habitat all present. 16 - 20	Only 3 of the 4 habitat categories present (missing riffles or runs receive lower score than missing pools). 11 - 15	Only 2 of the 4 habitat categories present (missing riffles/runs receive lower score). 6 - 10	Dominated by one velocity/depth category (usually pool). 0 - 5
4. Channel alteration (a)	Little or no enlargement of islands or point bars, and/ or no channelization. 12 - 15	Some new increase in bar formation, mostly from coarse gravel; and/or some channelization present. 8 - 11	Moderate deposition of new gravel, coarse sand on old and new bars; pools partially filled w/silt; and/or embankments on both banks. 4 - 7	Heavy deposits of fine material, increased bar developement; most pools filled w/silt; and/ or extensive channelization. 0 - 3
5. Bottom scouring and deposition (a)	Less than 5% of the bottom affected by scouring and depostion. 12 - 15	5-30% affected. Scour at constrictions and where grades steepen. Some depostion in pools. 8 - 11	30-50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling with pools. 4 - 7	More than 50% of the bottom changing nearly year long. Pools almost absent due to depostion. Only large rocks in riffle exposed. 0 - 3

Appendix II. (cont.)

	Category			
Habitat Parameter	Excellent	Good	Fair	Poor
6. Pool/riffle, run/bend ratio (a) (distance between riffles divided by stream width)	5-7. Variety of habitat. Deep riffles and pools. 12 - 15	7-15. Adequate depth in pools and riffles. Bends provide habitat. 8 - 11	15-25. Occasional riffle or bend. Bottom contours provide some habitat. 4 - 7	>25. Essentially a straight stream. Generally all flat water or shallow riffle. Poor habitat. 0 - 3
7. Bank stability (a)	Stable. No evidence of erosion or bank failure. Side slopes generally <30%. Little potential for future problems. 9 - 10	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes up to 40% on one bank. Slight potential in extreme floods. 6 - 8	Moderately unstable. Moderate frequency and size of erosional areas. Side slopes up to 60% on some banks. High erosion potential during extreme high flow. 3 - 5	Unstable. Many eroded areas. Side slopes >60% common. "Raw" areas frequent along straight sections and bends. 0 - 2
8. Bank Vegetative Stability (b)	Over 80% of the streambank surfaces covered by vegetation or boulders and cobble. 9 - 10	50-79% of the streambank surfaces covered by vegetation gravel or larger material. 6 - 8	25-49% of the streambank surfaces covered by vegetation, gravel, or larger material. 3 - 5	Less than 25% of the streambank surfaces covered by vegetation, gravel, or larger material. 0 - 2
9. Streamside cover (b)	Dominant vegetation is shrub. 9 - 10	Dominant vegetation is of tree form. 6 - 8	Dominant vegetation is grass or forbes. 3 - 5	Over 50% of the streambank has no vegetation and dominant material is soil, rock, bridge material, culverts, or mine tailings. 0 - 2
Column Totals	☐			
Total Score	☐			

(a) From Ball 1982.

(b) From Platts et al. 1983.

Note: * = Habitat parameters not currently incorporated into BIOS.

1991 BENTHIC BIOMONITORING PILOT STUDY RESULTS

M. D. Schueller[1], M. C. Hausler[2], and J. O. Kennedy[3]

[1]University of Iowa Hygienic Laboratory
University of Iowa; Oakdale Campus
Iowa City, IA 52242

[2]University of Wisconsin-LaCrosse, Department of Biology
LaCrosse, WI 54602

[3]University of Iowa Hygienic Laboratory
Wallace State Office Building
Des Moines, IA 50319

ABSTRACT

The Sny Magill watershed, Clayton County, Iowa was selected for conducting a comprehensive, long-term, Nonpoint Source (NPS) pollution monitoring project. A pilot study was conducted in September and October 1991 to determine a baseline list of benthic macroinvertebrate taxa inhabiting the Sny Magill and Bloody Run creeks, and also to determine which method(s) of benthic macroinvertebrate collection would be most appropriate for future monitoring. A total of 52 taxa were identified from collections made at six sites on Sny Magill Creek and two sites on Bloody Run Creek. These 52 taxa will serve as a preliminary baseline list for the two watersheds and will be used for comparison with future macroinvertebrate collections for the NPS Monitoring Project.

A total of three sampling methods were tested during this pilot study. After careful analysis of the data collected from all three methods, the Modified Hess bottom sampler was determined to be the preferred sampling method rather than kicknets or Hester-Dendy artificial substrates. Parametric statistical tests indicated no significant difference ($P<=0.05$) for species richness and HBI sample means between Hess and artificial substrate samples. Coefficients of variation for replicated Hess and artificial substrate samples indicated less variability among the Hess samples. Modified Hess sampling also has practical advantages in that it is not susceptible to human disturbances and does not require a colonization period before collections.

A general evaluation of the metric data calculated from the modified Hess samples indicates that the stream reaches sampled have water quality ranging from "good" to "excellent." A similarity index was utilized to determine the degree of similarity among the eight sampling sites in the two watersheds. A definite spatial pattern of similarity among the sampling sites did not manifest itself. However, those sites which had the highest degree of similarity also possessed comparable physical and biological characteristics such as stream discharge rate, nature of substrate, and visible density of periphyton.

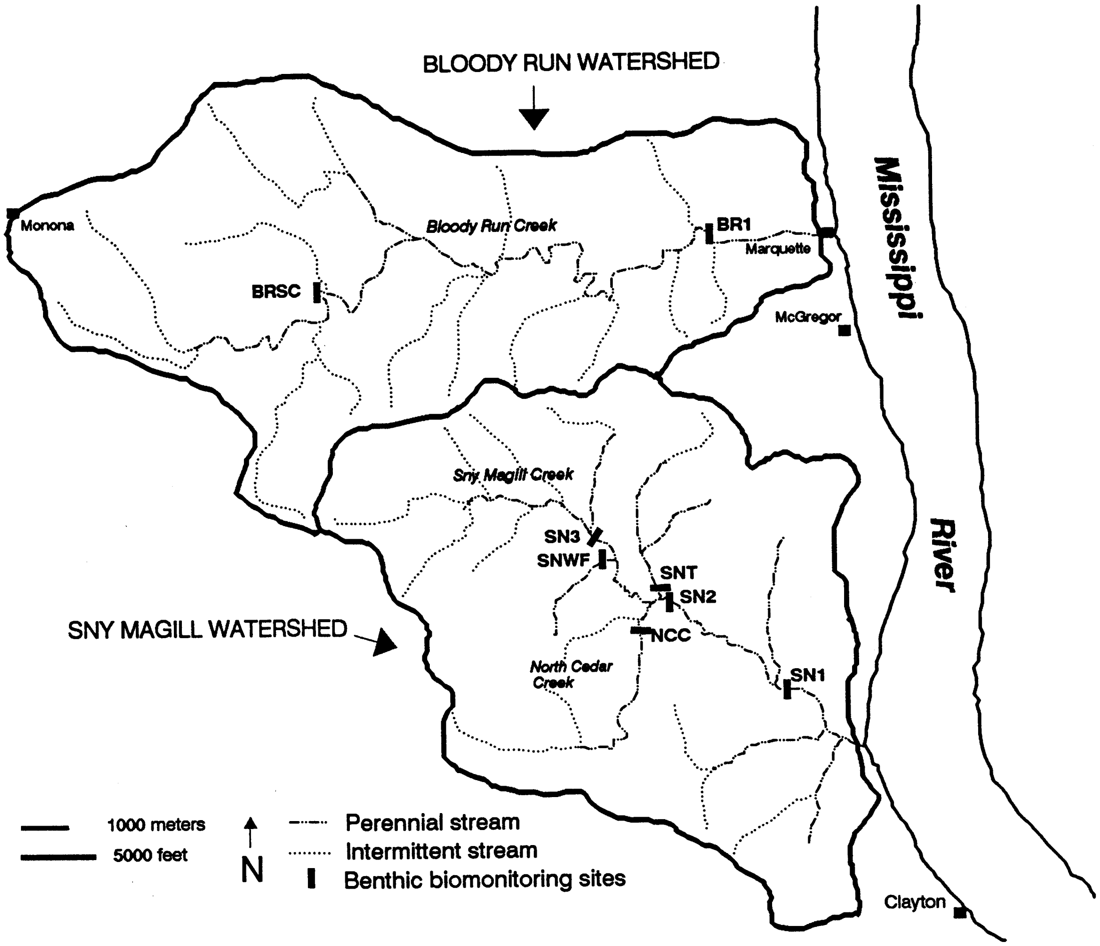


Figure 1. Location of benthic biomonitoring sites for fall 1991.

INTRODUCTION

Sny Magill Creek originates in northeastern Clayton County, Iowa, and flows in a southeasterly direction for approximately eight miles to its mouth where it empties into the upper Mississippi River at river mile (RM) 627.0. Sny Magill Creek, according to the Iowa Environmental Protection Commission (1990), is classified as a Class B, coldwater, high quality stream. Waters of this classification are described as those in which the temperature, flow, and other habitat characteristics are suitable for the maintenance of a wide variety of coldwater species, including non-reproducing populations of trout and associated aquatic communities. Additionally, special protection is warranted to maintain the unusual, unique, or outstanding physical, chemical, and biological characteristics which these waters possess.

Sny Magill lies entirely in a rural watershed and is subject to several nonpoint source (NPS) stress factors such as sediment, animal-waste runoff, fertilizers, and pesticides (Seigley et al., 1992). The creek drains a 35.6 square mile area (22,780 acres) of agricultural land (Seigley et al., 1992). Currently, through the USDA Water Quality Initiative, two special, nonpoint source, water-quality mitigation projects are being implemented in the Sny Magill watershed. In addition, a comprehensive, long-term, NPS Protocol Monitoring Project is in its early stages. This benthic macroinvertebrate study is a part of the NPS Monitoring Project. Biological data, in conjunction with water quality data, can be effectively used in evaluating recent and long-term trends in water quality of a stream (Plafkin et al., 1989).

SCOPE

The Nonpoint Source Monitoring Project implemented on the Sny Magill watershed has been designed to use a paired watershed comparison to evaluate the progress of the Best Management Practice (BMP) projects currently underway. The paired watershed for this project is the Bloody Run Creek watershed which lies north of Sny Magill. It is also located in Clayton County and drains into the upper Mississippi River at Marquette, Iowa (Figure 1). Water quality samples are currently being collected from six sites in the Sny Magill watershed and three sites in the Bloody Run watershed. The initial phase of this benthic study entails the use of different sampling techniques to collect benthic macroinvertebrates at eight of the nine water quality sites to: 1) determine a preliminary baseline list of species inhabiting the Sny Magill and Bloody Run creeks, and 2) evaluate which technique(s) will be the most appropriate for collecting an accurate and representative subsample of the macroinvertebrate population of each creek. Based on the pilot study, a technique will be selected and routine sampling will commence in the spring of 1992. This report summarizes the results of the pilot study conducted in 1991 for the benthic macroinvertebrate biomonitoring effort of the Sny Magill Creek NPS Pollution Monitoring Project. The raw data can be found in Schueller and others (1992).

This project is supported, in part, by the Iowa Department of Natural Resources, and the U.S. Environmental Protection Agency, Nonpoint Source Pollution Program (Region VII).

METHODS AND MATERIALS

Three methods of collection - kicknets, Hester-Dendy artificial substrates and a Modified Hess bottom sampler (APHA, 1989; Greeson et al., 1977) - were utilized during the pilot study. One kicknet sample was collected at each sampling site in early September 1991, at which time three artificial substrates were placed in the stream at each site. In mid-October 1991, the substrates, as well as three Modified Hess samples, were collected at each sampling site. Riffle/run habitats were sampled by each method at all sites in an attempt to collect from the most productive areas of each stream. The three sampling methods were all designed to achieve the same result, but each has inherent sampling biases, which may produce different results. Standardization of each sampling method among the sites was very important for proper evaluation of their effectiveness in collecting a representative sample.

All benthic macroinvertebrate samples collected were fixed in a 10% formalin solution and returned to the laboratory for processing. Laboratory processing consisted of selecting a 100-organism random subsample as outlined in the EPA Rapid Bioassessment Protocol III (Plafkin et al., 1989). All organisms in the subsample were identified to the lowest possible taxon and recorded. An audit, by a taxonomist who was not the original identifier, was performed on 15% of the subsamples to verify the original identification. One specimen of each species of arthropod collected has been sent to a benthic taxonomic expert for verification of its identity. A taxonomic expert is currently being sought for verification of the non-arthropod species. The benthic macroinvertebrate data were then analyzed by using the appropriate metrics (RBP III) as outlined in the EPA Rapid Bioassessment Protocol III (Plafkin et al., 1989). A total of six metrics were used with this method of evaluation. A description of each metric can be found in Table 1. Parametric statistical procedures were also used for data analysis.

RESULTS AND DISCUSSION

The pilot study was successful in accomplishing the objectives as outlined in the work plan for this study. A preferred method for sampling the benthic macroinvertebrate populations of the two streams was determined, and a preliminary list of the taxa inhabiting the streams was compiled.

Preliminary Taxa List

The preliminary list is comprised of 52 taxa (Table 2). All taxa are reported to the lowest verifiable taxonomic level. The goal for this study is to identify all organisms collected to the species level. As this goal is accomplished, these 52 taxa will be reviewed, with as many being identified to the species level as possible.

This list of taxa is considered preliminary because the pilot study was only conducted over a one- to two-month sampling period in late 1991. This leaves the possibility that some species that utilize these streams during other periods of the year may not have been collected during this sampling effort. A full year of sampling will take place in 1992. When that sampling is complete, the original list of taxa will be reviewed and updated if necessary. That list can then be considered a baseline list for the remainder of the long-term study.

Sampling Method Evaluation

The methods of collection were evaluated using the results of selected metrics analysis of the 100-count subsamples from each sample collected. Two metrics from EPA's RBP III (Rapid Bioassessment Protocols; Plafkin et al., 1989) were selected for parametric statistical analysis. These metrics were species richness and the modified Hilsenhoff Biotic Index (HBI). These two metrics were selected because 1) they include all taxa collected when they are calculated, and 2) they are the metrics most commonly used to assess the biological conditions of a stream or watershed. The results of these two metrics, as well as the other metrics used, can be found in Table 3.

The value for species richness and the HBI for both artificial substrates and the modified Hess samples were used for the statistical analyses. The kicknet samples were eliminated from the analysis because 1) only one sample was collected at each site versus the replicated samples of the other two methods, 2) kicknet sampling is qualitative sampling which does not allow for calculating total number collected per unit effort and relative abundances, and 3) it is a difficult method to standardize from site to site.

The results of the statistical analysis, as well as some practical sampling logistics, indicate that the Modified Hess sampler was the most appropriate method for collecting an accurate and representative sample of the macroinvertebrate populations of Sny Magill and Bloody Run creeks. Based upon analysis of variance (ANOVA) there is no significant difference ($P<=0.05$) in HBI and species richness sample means as calculated from substrate and Hess subsamples on a site by site basis. Student's t-test comparisons between Hess and substrate samples (where three substrates were collected) indicate no significant difference ($P<=0.05$) among

Table 1. Explanations of the metrics used for analysis of the benthic macroinvertebrate samples collected from the Sny Magill and Bloody Run watersheds.

Species Richness

The total number of taxa (genera and/or species) present in a community is a measure of benthic community health. The number of taxa generally increases with increasing habitat diversity, habitat suitability and improving water quality.

Hilsenhoff Biotic Index (HBI)

The HBI measures the overall pollution tolerance of a benthic community, and detects organic pollution in communities inhabiting rock or gravel riffles. Tolerance values are assigned to each taxa collected and range from zero to five. A zero value is given to species collected in unaltered streams of very high water quality, and a value of five is given to species known to inhabit severely polluted or disturbed streams. The number of individuals in each species is multiplied by the tolerance value assigned to that species and divided by the total number of individuals in the sample. The species values are added and the sum is the HBI. The HBI value increases as water quality decreases.

Ratio of Scraper and Filtering Collector Functional Feeding Groups

The Scraper/Filtering Collector ratio reflects the community foodbase and community balance in terms of function. The number of scrapers present increases with increased abundance of diatoms and decreases as filamentous algae increases. Filtering and Collector feeding groups increase as filamentous algae and aquatic mosses increase. A balanced community exhibits ratios for this metric near a value of one.

EPT Index

The EPT taxa metric is the number of distinct taxa within the generally pollution-sensitive insect orders of Ephemeroptera, Plecoptera, and Trichoptera (mayfly, stonefly, and caddisfly). An increasing value indicates a higher number of EPT taxa and improved water quality.

Ratio of EPT and Chironomidae Abundances

This metric is a ratio of the number of specimens collected from the orders of Ephemeroptera, Plecoptera, and Trichoptera to the abundance of Chironomidae at each site. Populations having a high number of pollution tolerant Chironomidae relative to the more sensitive groups will have a lower EPT/Chironomidae value and may indicate environmental stress. An increasing numerical value indicates a greater abundance of the more sensitive EPT taxa.

Percent Contribution of Dominant Taxa

This metric is a measure of the percent contribution of the numerically dominant taxon to the total number of organisms sampled and is a reflection of community evenness and redundancy. A high degree of community redundancy, as reflected in a high proportion of the dominant taxa (>40%), may be indicative of impairment.

Table 2. Benthic macroinvertebrates collected from Sny Magill and Bloody Run watersheds, September 4-5, and October 21-22, 1991.

	Sampling Sites							
	BR1	BRSC	SN1	SN2	SN3	SNT	SNWF	NCC
Annelida								
Hirudinea								
Pharyngobdellida								
Erpobdellidae						X		
Rhynchobdellida								
Glossiphoniidae	X							X
Nematoda (Roundworms)	X	X	X	X	X	X	X	X
Platyhelminthes								
Turbellaria (Flatworms)								
Planariidae	X							X
Molluska (Snails and Clams)								
Gastropoda								
Physidae								
Physa sp.		X		X	X		X	X
Pelecypoda								
Heterodonta								
Sphaeriidae								
Pisidium sp.					X			
Arthropoda								
Crustacea								
Amphipoda								
Gammaridae								
Gammarus pseudolimnaeus	X			X		X	X	
Decapoda								
Astacidae		X					X	
Insecta								
Coleoptera (Beetles)								
Dryopidae								
Helicus striatus	X			X		X	X	
Elmidae								
Optioservus fastiditus	X	X	X	X	X	X	X	X
Stenelmis crenata		X	X	X	X		X	X
Stenelmis sp. (larvae)	X		X		X			
Diptera								
Athericidae								
Atherix variegata				X				X
Chironomidae	X	X	X	X	X	X	X	X
Empididae								
Hemerodromia sp.					X			
Simuliidae	X	X			X			X
Simulium sp.	X					X		
S. vittatum			X					
Tabanidae							X	
Chrysops sp.							X	
Tipulidae							X	X
Antocha sp.			X	X	X	X	X	X
Dicranota sp.			X			X	X	
Tipula sp.			X		X	X	X	X

Table 2. (cont.)

	Sampling Sites							
	BR1	BRSC	SN1	SN2	SN3	SNT	SNWF	NCC
Ephemeroptera (Mayflies)								
Baetidae								
Baetis brunneicolor	X	X			X	X	X	
B. flavistriga	X	X	X	X	X	X	X	X
B. macdunnoughi					X			
B. tricaudatus	X	X	X	X	X	X	X	
Baetis sp.	X	X			X			X
Caenidae								
Caenis latipennis		X			X			
Ephemerellidae								
Serratella sp.	X							X
Heptageniidae							X	
Stenacron sp.		X	X	X	X	X	X	X
Stenonema mediopunctatum	X							
Stenonema vicarium	X	X	X	X	X		X	X
Leptophlebiidae								
Leptophlebia sp.					X		X	
Paraleptophlebia sp.					X		X	
Hemiptera (True Bugs)								
Belostomatidae								
Belostoma flumineum						X		
Gerridae								
Gerris remigis						X		
Odonata (Zygoptera) (Damselflies)								
Calopterygidae								
Hetaerina sp.							X	
Plecoptera (Stoneflies)								
Perlodidae								
Isoperla marlynia	X				X		X	X
Trichoptera (Caddisflies)								
Brachycentridae								
Brachycentrus occidentalis	X				X		X	
Glossosomatidae								
Glossosoma sp.			X	X		X	X	
Helicopsyhcidae								
Helicopsyche borealis			X		X			
Hydropsychidae								
Cheumatopsyche sp.	X	X	X	X	X	X	X	X
Ceratopsyhce alhedra	X	X	X	X	X			X
C. bronta	X	X	X	X				X
C. slossonae	X	X	X	X	X	X	X	X
Hydropsyche betteni				X				
Hydroptilidae								
Hydroptila sp.	X	X		X				
Leptoceridae								
Oecetis sp.		X					X	
Lemniphilidae								
Hesperophylax designatus						X		
Pycnopsyche sp.		X					X	
Philoptamidae								
Chimarra aterrima	X	X	X	X	X	X	X	X
Phryganeidae								
Ptilostimis sp.						X		

Table 3. Mean (n=3) metric values for artificial substrate and Hess samples collected from the Sny Magill and Bloody Run creeks, October 21-22, 1991.

	HESS SAMPLES LOCATION							
METRICS	**BR1**	**BRSC**	**SN1**	**SN2**	**SN3**	**SNWF**	**SNT**	**NCC**
Species Richness	12.00	11.00	9.33	10.33	12.00	12.33	8.67	12.33
HBI	2.20	2.20	2.23	2.23	2.62	2.34	1.73	2.40
EPT Index	7.67	6.33	5.33	5.33	8.33	7.33	3.67	6.33
% Dominant Taxa	48.73	43.30	49.47	57.57	64.03	29.03	54.57	41.93
EPT/Chironomidae	21.47	16.80	9.53	7.07	0.50	9.07	23.00	10.93
Scrapers/Filterers & Collectors	0.06	0.11	0.08	0.16	0.16	0.72	27.16	0.35

	ARTIFICIAL SUBSTRATES LOCATION							
METRICS	**BR1****	**BRSC**	**SN1***	**SN2***	**SN3****	**SNWF**	**SNT****	**NCC**
Species Richness	11.50	12.00	9.00	6.00	10.50	13.67	9.50	7.00
HBI	2.11	3.16	2.38	2.12	2.62	2.83	2.04	2.19
EPT Index	8.00	8.00	6.00	4.00	6.50	6.67	5.00	3.67
% Dominant Taxa	43.55	49.63	38.50	71.40	58.50	35.10	40.90	46.37
EPT/Chironomidae	59.50	20.30	5.70	11.10	0.65	1.27	0.30	4.17
Scrapers/Filterers&Collectors	0.05	0.64	0.01	0.05	0.21	0.49	1.40	1.98

* Only one artificial substrate retrieved.

** Only two artificial substrates retrieved.

Evaluation of water quality using Hilsenhoff Biotic Index values (Hilsenhoff, 1982)

Biotic Index Value	Water Quality Rating	Degree of Organic Pollution
0.00-1.75	Excellent	No organic pollution
1.76-2.25	Very Good	Possible slight organic pollution
2.26-2.75	Good	Some organic pollution
2.76-3.50	Fair	Significant organic pollution
3.51-4.25	Poor	Very significant organic pollution
4.26-5.00	Very Poor	Severe organic pollution

HBI sample means. Results of coefficients of variation (CV) calculations showed less variability existed among replicated Hess samples than replicated substrate samples.

The practical reasons for using the modified Hess sampler focus on the very important need to collect a complete data set for analysis. First, and most importantly, using the Modified Hess sampler guarantees collecting a complete data set (a total of three samples per sampling site). For artificial substrates, there is always a possibility of losing substrates during the period of colonization because of environmental and human factors. A total of 24 artificial substrates were deployed at eight sampling sites during the pilot study, but only 17 (70.8%) were recovered six weeks later. Only one of three substrates was recovered at two of the sites, most likely because they had been removed by someone or something moving in the stream. Secondly, the Hess sampler allows more flexibility in scheduling the macroinvertebrate sampling. The artificial substrates require a six- to eight-week colonization period before a sample can be collected. The Modified Hess samples can be collected almost any time during the designated bimonthly sampling periods. Lastly, sampling the natural substrates with the Modified Hess sampler will eliminate some of the sampling bias that could be introduced if artificial substrates were used as the preferred method. No extra variables will be introduced into the system by sampling the natural substrate.

Baseline Metrics

Mean baseline values for six of the metrics listed in RBP III (pages 6-13 to 6-15 in Plafkin et al., 1989) were established from Modified Hess sampling at each site during the pilot study (Table 3). A general evaluation of these data, based on the HBI values indicates that the stream reaches sampled range from "good" to "excellent." The eight sites sampled comprise five stream reaches (Figure 1) - Bloody Run Creek (BR1, BRSC), Sny Magill Creek (SN1, SN2, SN3), the West Fork of Sny Magill Creek (SNWF), one unnamed tributary to Sny Magill Creek (SNT), and North Cedar Creek (NCC). Three of the five - West Fork of Sny Magill (2.34), Sny Magill Creek (2.36; mean of sites SN1, SN2, and SN3), and North Cedar Creek (2.40) - had an HBI value from the Hess samples in the "good" range, indicating some organic pollution was present at these sites. Bloody Run Creek (2.20; mean of sites BR1 and BRSC) had an HBI value in the "very good" range, suggesting very little organic pollution was present in that stream reach. Site SNT (1.73) had an HBI in the "excellent" range, inferring no organic pollution present in this first order stream. Categorical ranges for stream condition based on the HBI metric can be found with Table 3.

The water quality of the two streams, as indicated by the HBI values, showed relatively little impairment at any of the sampling sites. Again, this is a preliminary assessment of the streams and should be treated as such. The relatively low HBI values are supported by other metric data. The EPT Index is a measure of the number of taxa collected from the pollution sensitive orders of Ephemeroptera, Plecoptera, and Trichoptera (mayfly, stonefly, caddisfly). The greater the EPT value, the better the relative water quality. The mean EPT Index at each sampling site was greater than half the mean species richness (number of taxa) value with the exception of site SNT. This means that over half the taxa collected at those sites were comprised of taxa from the EPT group. The relatively high EPT values are also reflected in the EPT:Chironomidae ratios. Seven of the eight sites have a ratio that is several times greater than one, the exception being SN3. Site SN3 does possess the greatest EPT Index (8.33) but the greater relative abundance of the pollution tolerant dipteran family of Chironomidae drops the EPT:Chironomidae ratio to 0.50.

Two of the metrics used in the data analysis do indicate that the benthic communities at the sampling sites are not well balanced. The percent dominant taxa metric demonstrates that all of the sites, with the exception of SNWF, were dominated (>40% of the composition of the sample) by one particular taxa. The collections from site SNWF showed evenness, with the dominant taxa representing only 29% of the overall specimens from that site. Evidence of the communities being somewhat unbalanced is also substantiated by the ratio of scrapers: filterers/collectors. A balanced community exhibits ratios for this metric near a value of one. Site SNWF, with a value of 0.72, has the most balanced benthic community. All of the other sampling sites have values much less than one (0.06-0.35), or in the case of site SNT (27.16), much greater than one. Hydropsychidae was the predominant macroinvertebrate family found at most of the sites throughout the watershed. Taxa from this family accounted for much of the percent dominant taxa values at each site. Also most of the taxa from that family are filter feeders, which is the major reason for the low scraper to filterer and collector functional feeding group ratios. The abundance of filamentous algae covering the rock substrate at the time of sampling provided an excellent habitat for the filter feeding species. The high functional feeding group ratio at SNT is related to the abundance of the scraper feeding amphipod *Gammarus pseudolimnaeus* and the caddisfly *Glossosoma sp.* The rock/riffle substrate at site SNT lacked the dense filamentous algal growth but did present enough periphyton growth to provide the needed food for the scraper feeding group.

The metrics, used individually though, do not clearly characterize each sampling site. For example, based on HBI, site SNT clearly has the best water quality, but based on species richness and

Table 4. Overall and individual site metric value rank for Modified Hess sample benthic macroinvertebrates collected from the Sny Magill and Bloody Run watersheds, October 21-22, 1991.

SITE	Overall Rank	Average Rank	Species Richness	HBI	EPT Index	% Dom. Taxa	EPT/ Chiron.	Scrapers/Filt. & Collect.
SNWF	1.0	3.1	1.5	6.0	3.0	1.0	6.0	1.0
BR1	2.5	3.5	3.5	2.5	2.0	4.0	2.0	7.0
NCC	2.5	3.5	1.5	7.0	4.5	2.0	4.0	2.0
BRSC	4.0	3.8	5.0	2.5	4.5	3.0	3.0	5.0
SN3	5.5	5.3	3.5	8.0	1.0	8.0	8.0	3.5
SNT	5.5	5.3	8.0	1.0	8.0	6.0	1.0	8.0
SN1	7.0	5.7	7.0	4.5	6.5	5.0	5.0	6.0
SN2	8.0	5.8	6.0	4.5	6.5	7.0	7.0	3.5

EPT Index, this site has the worst water quality. This same situation exists for nearly all of the sites. Thus, a ranking system, which incorporates all of the metrics used in the analysis, was devised to get an overall picture of the water quality at each site relative to all of the other sites. Sites were ranked from one to eight for each of the six metrics. Then the average rank was determined for each site by summing the ranks for each metric, at each site, and dividing by six. This ranking method provides a very good characterization of the sites relative to one another (Table 4).

The overall ranking indicates that the least impaired stream sites were in the upper end of the Sny Magill watershed and on Bloody Run Creek. Site SNWF ranked as the best of all sites sampled. Both sampling sites on Bloody Run Creek ranked in the upper 50% of the sites sampled, also. Site SN2 ranked in the lower 50% of all sites sampled for each individual metric analysis, and consequently received the lowest overall ranking. The important factors to consider in this analysis are that the sites with the better relative water quality have balanced communities with several taxa (species richness) utilizing each site, including adequate numbers of the EPT group (EPT Index), and were not comprised of predominantly one taxa (low % dominant taxa value). Site SNT is an example of a site with an "excellent" HBI (1.73) but an overall low rank. The low rank can be attributed to its ranking last among the eight sites in species richness, EPT Index, and the ratio of scrapers to filterers and collectors. It is evident, then, that the ranking method provides the investigator(s) with a more holistic characterization of the two streams.

Community Similarity

A similarity index was used to determine the similarity of benthic macroinvertebrate populations among the eight sampling sites. Van Horn's (1950) equation was used to calculate a coefficient of similarity between any two given sampling sites. The equation is as follows: $c=2w/(a+b)$ where c=coefficient of similarity, a=the number of taxa collected at one station, b=the number of taxa collected at another station, and w=the number of taxa common to both stations. The coefficient of similarity (c) can range from 0-1.0, with values closer to 1.0 indicating greater similarity between the two sites being compared. A matrix of the index values comparing each site to all of the others can be found in Table 5.

The range of values for c (0.44-0.77) generally indicates a moderate amount of similarity among most of the sampling sites. A definite pattern of similarity among the sites does not manifest itself. The two sites most similar were SN1 and SN2, with an index value of 0.77. Sampling site BR1 provided the worst match for six of the other seven sites, with index values for those matches ranging from 0.44 with sites SNWF and SNT to 0.59 with site NCC. Generally, the most similar sites (matches >0.60) were those located in the upper reaches of each watershed, with the exception of the SN1-SN2 match. The least similar comparisons occurred (matches <0.50), primarily when BR1 was compared with sites in the Sny Magill watershed. Sites most similar usually had comparable substrates and stream discharge levels.

Table 5. Similarity index of Modified Hess sampler benthic macroinvertebrate collections from the Sny Magill and Bloody Run watersheds, October 21-22, 1991.

		Number of Similar Taxa						
SITE	**Number of Taxa**	**BR1**	**BRSC**	**SN1**	**SN2**	**SN3**	**SNWF**	**SNT**
BR1	21							
BRSC	15	9						
SN1	13	9	9					
SN2	18	9	10	12				
SN3	20	10	10	9	10			
SNWF	24	10	12	10	12	14		
SNT	15	8	8	8	9	8	12	
NCC	20	12	11	9	10	13	14	9

	Similarity Index						
SITE	**BR1**	**BRSC**	**SN1**	**SN2**	**SN3**	**SNWF**	**SNT**
BRSC	0.50						
SN1	0.53	0.64					
SN2	0.46	0.61	0.77				
SN3	0.49	0.57	0.55	0.53			
SNWF	0.44	0.62	0.54	0.57	0.64		
SNT	0.44	0.53	0.57	0.55	0.46	0.62	
NCC	0.59	0.63	0.55	0.53	0.65	0.64	0.51

Benthic Biomonitoring for 1993

The UHL-Limnology Section began collecting benthic macroinvertebrate samples on a bimonthly schedule in April 1992. Sampling was scheduled to begin the third week in April. Samples were collected in triplicate at six sites in the Sny Magill watershed and two sites on Bloody Run Creek using the Modified Hess bottom sampler. Sampling continued through October 1992. A summary of the 1992 data is found in Schueller and others (1993).

Laboratory processing of samples and data analysis generally was performed as described in Rapid Bioassessment Protocols for Use in Streams and Rivers (Plafkin et al., 1989). Parametric statistical analyses were performed in certain situations to assess the variability among the triplicate samples collected at each site.

A concern that arose during the pilot study pertains to the Bloody Run Creek sampling site near Spook Cave (BRSC). It is perceived that this site could easily be disturbed because of the volume of recreational use this area receives during the biomonitoring sampling season. A more acceptable site on Bloody Run Creek would be in proximity to the bridge that crosses the creek on an undesignated Clayton County Road (T95N, R4W, Sec.24, NW1/4). This site has an excellent riffle/run area that is likely to be biologically productive and provide an adequate sampling site. It is also likely that there will be less of a human impact on this area than the Spook Cave area. Thus, site BR2 replaced the Bloody Run-Spook Cave (BRSC) sampling site beginning with the April 1992 sampling period.

SUMMARY

A pilot study was conducted in September and October 1991 to determine a baseline list of benthic macroinvertebrate taxa inhabiting the Sny Magill and Bloody Run creeks, and also to determine which method(s) of benthic macroinvertebrate collection would be most appropriate. A total of 52 taxa were identified from collections made at six sites on Sny Magill Creek and two sites on Bloody Run Creek. These 52 taxa will serve as a preliminary baseline list for the two watersheds and will be used for comparison with future macroinvertebrate collections for the Sny Magill NPS Monitoring Project.

A total of three sampling methods were tested during this pilot study. After careful analysis of the data collected from all three methods, the Modified Hess bottom sampler was determined to be the preferred sampling method to be utilized rather than kicknets or Hester-Dendy artificial substrates. Parametric statistical tests indicated no significant difference ($P<=0.05$) for species richness and HBI sample means between Hess and substrate samples. Coefficients of variation for replicated Hess and artificial substrate samples indicated less variability among the Hess samples. Modified Hess sampling also has practical advantages in that it is not susceptible to human disturbances and does not require a colonization period before collections can take place.

A general evaluation of the macroinvertebrate metric data calculated from the modified Hess samples indicates that the stream reaches sampled have water quality ranging from "good" to "excellent." Site SNWF was found to have the best overall water quality. This site had the most balanced community of macroinvertebrates with several taxa (species richness) utilizing the area, including adequate numbers of the EPT group. The ratio of scrapers to filterers and collectors (0.72) along with the low percent dominant taxa (29%) further substantiated the balance in the community at this site.

A similarity index was utilized to determine the degree of similarity among the eight sampling sites in the two watersheds. A clear spatial pattern of similarity among the sampling sites did not manifest itself. However, those sites which had the highest degree of similarity, sites SN1:SN2 (0.77), NCC:SN3 (0.65), and SN1:BRSC (0.64), also possessed comparable physical and biological characteristics such as stream discharge rate, nature of substrate, and visible density of periphyton. A comparison of the sites in the two watersheds indicates a moderate similarity between BRSC and the six sites in the Sny Magill watershed and a lower degree of similarity between BR1 and the Sny Magill sites. This may be attributable to the spatial and habitat differences between the watersheds. As the NPS Monitoring Project continues, further comparative analysis between the watersheds and among the individual sampling sites will be conducted.

REFERENCES

APHA, 1989, Standard methods for the examination of water and wastewater, 17th edition: American Public Health Association, Water Works Associations, and Water Pollution Control Federation, Washington D.C.

Greeson, P.E., Ehlkey, T.A., Irwin, G.A., Lium, B.W., and Slack, K.V. (eds.), 1977, Methods for collection and analysis of aquatic biological and microbiological samples, *in* Techniques of Water Resources Investigations of the United States Geological Survey, Chapter 5, Book 4.

Iowa Environmental Protection Commission, 1990, 1990 Water quality standards: Iowa Administrative Code, Chapter 61.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., and Hughes, R.M., 1989, Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish: Assessment and Watershed Protection Division, Office of Water, Washington D.C., U.S. Environmental Protection Agency, EPA/444/4-89-001, Washington, D.C.

Schueller, M.D., Hausler, M.C., and Kennedy, J.O., 1992, Sny Magill Creek nonpoint source pollution monitoring project: 1991 benthic biomonitoring pilot study results: UHL Report Number 92-5, University Hygienic Laboratory, Iowa City, IA, 78 p.

Schueller, M.D., Birmingham, M.W., and Kennedy, J.O., 1993, Sny Magill Creek nonpoint source pollution monitoring project: 1992 benthic biomonitoring results: UHL Report Number 93-2, University Hygienic Laboratory, Iowa City, IA, 124 p.

Seigley, L.S., Hallberg G.R., Wilton, T., Schueller, M.D., Hausler, M.C., Kennedy, J.O., Wunder, G., Link, R.V., and Brown, S.S., 1992, Sny Magill watershed nonpoint source water quality monitoring project: Iowa Department of Natural Resources, Geological Survey Bureau, Open File Report No. 92-1, 31 p.

Van Horn, W.M., 1950, The biological indices of stream quality: Proceedings 5th Indiana Waste Conference, Purdue University, Est. Ser. 72:215.

Taxonomic Keys

Hilsenhoff, W.L., 1981, Aquatic insects of Wisconsin: keys to Wisconsin genera and notes on biology, distribution and species: Natural History Council, University of Wisconsin No. 2. 60 p.

Hilsenhoff, W.L., 1982, Using a biotic index to evaluate water quality in streams: Wisconsin Department of Natural Resources, Technical Bulletin 132, 22 p.

Holsinger, J.R., 1976, The freshwater amphipod crustaceans (Gammaridae) of North America: Water Pollution Control Research Series 18050 ELD04/72, U.S. Environmental Protection Agency.

Merritt, R.W., and Cummins, K.W. (editors) (second edition), 1984, An introduction to the aquatic insects of North America: Kendall/Hunt Publishing Company, Dubuque, IA.

Nebraska Stream Classification Study, 1991, Surface Water Section, Water Quality Division, Department of Environmental Control, State of Nebraska.

Schmude, K.L. and Hilsenhoff, W.L., 1986, Biology, ecology, larval taxonomy, and distribution of Hydropsychidae (Trichoptera) in Wisconsin: Great Lakes Entomologist v. 19, p. 123-145.

SNY MAGILL WATERSHED MONITORING PROJECT:
BASELINE DATA

Iowa Department of Natural Resources, Geological Survey Bureau
Technical Information Series 32, 1994

HISTORICAL BIOLOGICAL WATER QUALITY DATA FOR SNY MAGILL AND BLOODY RUN CREEKS

M.W. Birmingham[1] and J. O. Kennedy[2]

[1]University of Iowa Hygienic Laboratory
University of Iowa; Oakdale Campus
Iowa City, IA 52242

[2]University of Iowa Hygienic Laboratory
Wallace State Office Building
Des Moines, IA 50319

ABSTRACT

Historical and recent biological data from the Bloody Run and Sny Magill watersheds in northeastern Iowa were reviewed. Data were evaluated to determine if the findings from a 1991 study were similar to results of a study completed in 1978. Although sampling sites, collection methods, and ambient conditions varied between studies, the taxa encountered in the current and the 1978 study were very similar, while the relative abundance and dominant taxa were generally different.

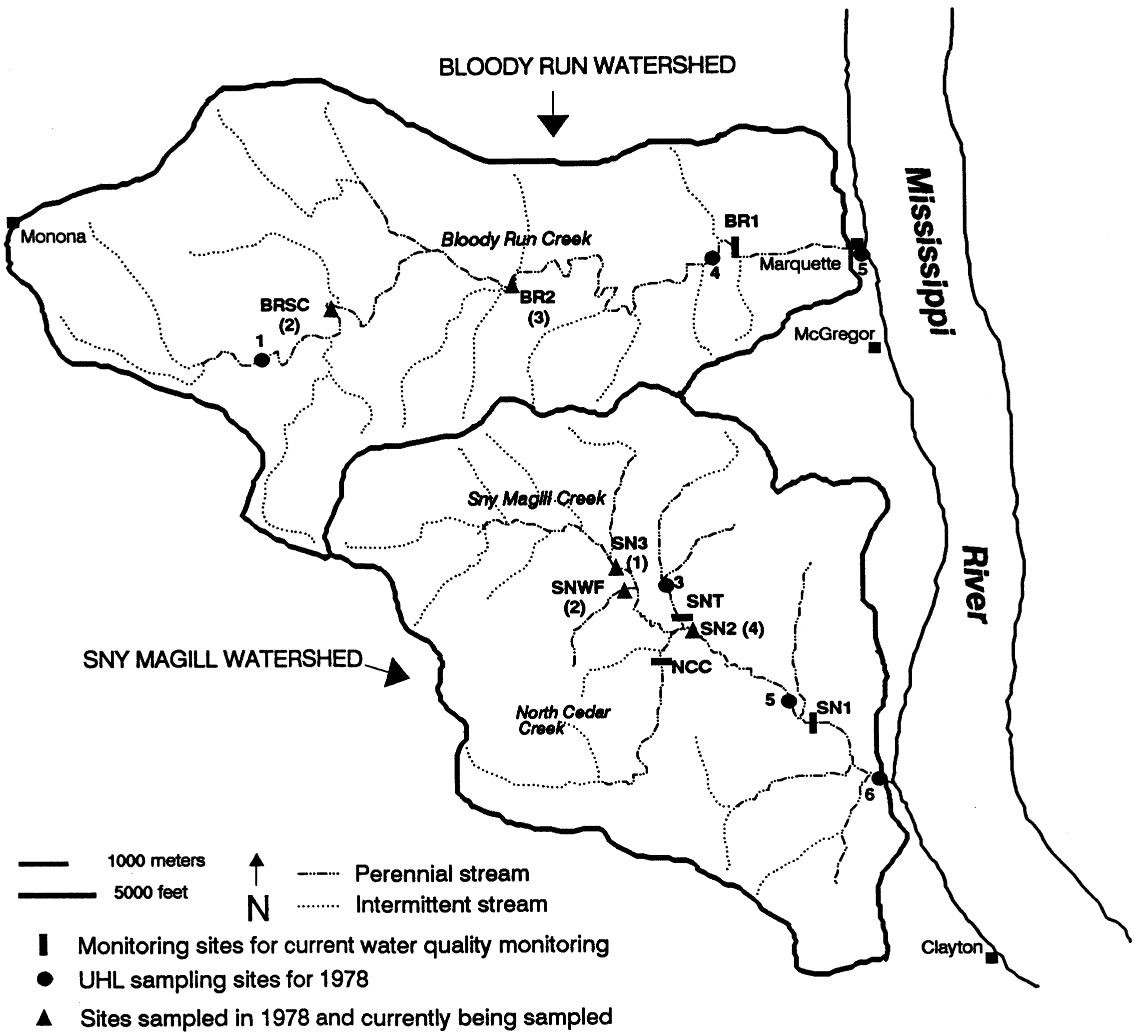


Figure 1. Sampling locations on Sny Magill and Bloody Run creeks for current water quality monitoring and University Hygienic Laboratory biological monitoring in 1978 (Prill and Meierhoff, 1979).

INTRODUCTION

To evaluate changes in water quality over time, it is necessary to know the water quality at two different points in time. The extensive monitoring currently being conducted for the Sny Magill Watershed Nonpoint Source Pollution Monitoring Project (Seigley et al., 1992) will provide a very good data base for future comparison. To determine what existing data were available for Sny Magill and Bloody Run creeks, a data review was conducted. Historical water quality and biological data for the Bloody Run and Sny Magill watersheds are limited.

PREVIOUS WATER CHEMISTRY STUDIES

In August 1976, the water quality of six upper Mississippi River tributaries was evaluated by chemical analyses (Geary, 1977). Both Bloody Run and Sny Magill creeks were included in that study. The main purpose of the study was "to obtain background water quality data" (Geary, 1977). Results of the 1976 study indicated that although several streams had water temperatures exceeding the recommended 20° C, "the overall water quality of all the streams studied was very good" (Geary, 1977).

PREVIOUS BIOMONITORING STUDIES

During the summer of 1978, the University Hygienic Laboratory performed a water quality survey of Bloody Run and Sny Magill creeks (Prill and Meierhoff, 1979). The purpose of this survey was to "obtain more information on the water quality of these two relatively unstudied but important natural resources." The 1978 study also incorporated sampling the aquatic macrobenthic organisms by Surber sampler and kick-net. Biological sampling was performed at four locations on Bloody Run, three locations on Sny Magill Creek, and one site on each of two Sny Magill tributaries (Figure 1). Results of the 1978 study indicated "with the exception of decreased numbers and types of organisms at Station 4, the results of the biological sampling reflected good water quality on Bloody Run Creek as concluded from the bacteriological, chemical, and physical data analyses. The community structure (types of organisms present) was similar throughout Bloody Run Creek indicating a healthy, non-degraded environment. Caddisfly (Trichoptera) larvae (3 genera) and mayfly (Ephemeroptera) nymphs (6 genera) generally were the predominant forms collected in Bloody Run Creek. Certain species of mayflies such as *Ephemerella sp.* and *Paraleptophlebia sp.* found at one station are indicators of good water quality (Hart and Fuller, 1974). The presence of the chironomids throughout the creek and *Limnodrilus sp.* at Stations 1, 2 and 3 was noteworthy. Frequently these organisms are used as indicators of an organically polluted environment. Their occurrence in Bloody Run Creek, though, was more probably due to "natural" organic enrichment from leaves and other rotting material (detritus) entering into the creek (Hart and Fuller, 1974) rather than from point source dischargers" (Prill and Meierhoff, 1979).

"The results of the biological sampling from Sny Magill Creek demonstrated a healthy environment that was reflecting good water quality. The good water quality exhibited by the macroinvertebrate communities in Sny Magill Creek corresponded with the similar conclusion reached from the biological collections of Bloody Run Creek. When comparing the two creeks, the Sny Magill Creek basin was the more productive of the two creeks" (Prill and Meierhoff, 1979). The maximum total taxa from Bloody Run was 17 as compared to 23 taxa for Sny Magill. In addition, more taxa of mayflies, stoneflies, and caddisflies (Ephemeroptera, Plecoptera and Trichoptera Group) were found in Sny Magill than Bloody Run. "The average number of benthic organisms taken from the five stations in the Sny Magill Creek basin (1,223.6 organisms per square meter) was almost three times the average collected from the four locations on Bloody Run Creek (437.8 organisms per square meter)" (Prill and Meierhoff, 1979).

"The biological sampling at the West Fork Sny Magill site (Station 2) yielded some interesting

Table 1. Comparison of metric values for the 1991 pilot study and UHL Report 79-14 Sny Magill and Bloody Run creeks.

1991 Pilot Study Metric Values (*indicates mean)-Hess Samples

Metrics	BR1	BRSC	SN3	SNWF	SNT
Number of Taxa	19	15	19	25	16
EPT Index	9	7	9	12	5
% Dominant Taxa*	38.5	43.3	64	29	54.6
EPT/Chironomidae*	21.5	16.8	0.5	9.1	23
Scrapers/Filters & Collectors*	0.06	0.11	0.16	0.72	27.2
Total # of Organisms	297	301	303	235	226

UHL Report 79-14 Metric Values-Surber and Kicknet Samples

Metrics	BR1(1)	BRSC(2)	SN3(3)	SNWF	SNT
Number of Taxa	10	14	23	27	18
EPT Index	4	5	8	6	5
% Dominant Taxa	7.2	41.7	45	55.9	53.3
EPT/Chironomidae	0.4	5.5	5.1	6.3	4.5
Scrapers/Filters & Collectors	0.35	0.06	0.07	1.65	0.02
Total # of Organisms	43	228	387	381	548

(1) Near BR1; Station #4 on Bloody Run in 1978 Study

(2) Station #2 on Bloody Run in 1978 Study

(3) Station #1 on Sny Magill in 1978 Study

NOTE: For comparison, metrics for the NPS study presented here were calculated with organisms keyed to the same taxonomic levels as used in the 1978 study.

results. Of the total density of 1,367.0 organisms per square meter determined from this location, greater than fifty percent (764.3 organisms per square meter) were the beetle, *Optioservus fastiditus sp.* These beetles are vegetative feeders, feeding on plant tissue, roots, algae and moss (Hart and Fuller, 1974). The cause for such a dense population of this beetle, other than perhaps sampling biases, is not known at this time. Also, at Station 2 a stonefly nymph was collected. These pollution intolerant aquatic macroinvertebrates are generally used as indicators of clean water" (Prill and Meierhoff, 1979).

COMPARISON WITH CURRENT STUDIES

In September and October of 1991, benthic macroinvertebrates were collected in Bloody Run and Sny Magill creeks (Schueller et al., 1992;

Schueller et al., this volume) as part of the initial biomonitoring effort for the Sny Magill Watershed Nonpoint Source Pollution Monitoring Project Workplan (Seigley et al., 1992). The objectives of this "pilot" study were to: 1) compile a baseline list of species inhabiting the two creeks; and 2) evaluate which method(s) of collection would be most appropriate for obtaining a representative sample of benthic macroinvertebrate populations in each creek. Two of the sites on Bloody Run and three sites in the Sny Magill watershed which were sampled in 1978 were also sampled for the current nonpoint source (NPS) pilot study (Figure 1). The bioassessment metrics applied in the current (NPS) study were also calculated (where practical) for the 1978 biological data. The metrics for the sites common to both studies are presented in Table 1. The number of taxa, EPT index, and EPT/Chironomidae ratio values are generally higher for the NPS pilot study (Table 1), which might suggest an improvement in water quality. However, it is difficult to base such a conclusion solely on two sampling dates separated by many years. Differences in sampling methods and time of collection (season) also need to be considered. Interestingly, the West Fork Sny Magill site (SNWF) in 1991 continued to have a relatively high population of the beetle *Optioservus fastiditus sp.,* as was observed in the 1978 study. Overall, the taxa encountered in the current and the 1978 study are very similar, but the relative abundances and "dominant" taxa are generally different.

The water quality studies by Geary (1977) and Prill and Meierhoff (1979) are the only known water quality studies to have been completed on Bloody Run or Sny Magill creeks prior to the current NPS Monitoring Project. Benthic macroinvertebrate data have been collected for several other northeastern Iowa streams; i.e., Yellow River (Kennedy and Meierhoff, 1979; Prill et al., 1982), Little Turkey River (Meierhoff and Prill, 1980), Upper Iowa (Meierhoff et al., 1981), and the Big Spring basin (Kennedy et al., 1988). Because of the variations in sample collection methodology (i.e., Surber sampler, kicknet, artificial substrates, Hess sampler and hand-picking from natural substrates) and time of collection and stream types, comparison between these studies can only be general in nature. Taken together, these studies provide an extensive list of the cool and coldwater taxa typically found in northeastern Iowa. Studies on the larger streams, i.e., Upper Iowa, Little Turkey, and Yellow Rivers revealed a somewhat more diverse benthic community than was found on smaller streams such as Sny Magill and Bloody Run. The rivers usually contained most of the taxa found in the smaller streams plus several additional mayfly, stonefly, and caddisfly taxa. Likewise, several taxa such as *Gammarus psuedolimnaeus sp.* (amphipod or scud) and *Ceratopsyche slossonae sp.* (caddisfly) were generally absent from the rivers but were often dominant in smaller streams. Overall, the macroinvertebrate taxa found in the 1991 and 1978 Bloody Run and Sny Magill studies are very similar to the taxa present in the tributaries to the Upper Iowa River (Meierhoff et al., 1981) and Yellow River (Kennedy and Meierhoff, 1979). The studies on the Upper Iowa and Yellow rivers also indicated seasonal shifts in the invertebrate community composition. In reference to the April and July collections on the Upper Iowa, it was noted that "the spring and summer collections yielded quite different organisms" (Meierhoff et al., 1981). Impressive differences in the relative abundances of taxa were also found between July 1978 and May 1981 collections from identical sites on the Yellow River (Prill et al., 1982).

Distinguishing water quality related changes in the macroinvertebrate community from "natural" spatial and/or temporal variations is difficult. Factors such as variations in sampling techniques and seasonal considerations make it impossible or impractical to calculate and directly compare bioassessment metrics in most of these previous northeastern Iowa studies. As a result of the 1991 pilot study many of these concerns have been addressed. Maintaining regular sampling intervals and consistency in sampling methods over the project's multi-year duration should provide the best possible comparable data for evaluating the effects of water quality improvements in the Sny Magill Watershed Monitoring Project.

REFERENCES

Geary, D.M., 1977, Summer water quality of the upper Mississippi River tributaries: UHL Report Number 77-20, University Hygienic Laboratory, Iowa City, IA.

Hart, C.W., and Fuller, S.L.H. (editors), 1974, Pollution Ecology of Freshwater Invertebrates, Academic Press, New York, NY.

Kennedy, J.O., and Meierhoff, M., 1979, Water quality survey of the Yellow River: UHL Report Number 79-20, University Hygienic Laboratory, Iowa City, IA, 33 p.

Kennedy, J.O., Ceilley, D.W., and Miller, J.G., III, 1988, A survey of the benthic macroinvertebrates and fishes of the Big Spring basin, Iowa: UHL Report Number 88-9, University Hygienic Laboratory, Iowa City, IA, 100 p.

Meierhoff, M., and Prill, S.D., 1980, Winter/summer water quality survey of the Little Turkey River: UHL Report Number 80-19, University Hygienic Laboratory, Iowa City, IA, 32 p.

Meierhoff, M., Prill, S.D., and Splinter, R.C., 1981, Benthic macroinvertebrates of the upper Iowa River basin: UHL Report Number 81-32, University Hygienic Laboratory, Iowa City, Iowa, 46 p.

Prill, S.D., and Meierhoff, M., 1979, Summer water quality of the Bloody Run Creek and Sny Magill Creek basins: UHL Report Number 79-14, University Hygienic Laboratory, Iowa City, IA, 31 p.

Prill, S.D., Splinter, R.C., and Kennedy, J.O., 1982, A survey of the benthic macroinvertebrates of the Yellow River: UHL Report Number 82-8, University Hygienic Laboratory, Iowa City, IA, 20 p.

Schueller, M.D., Hausler, M.C., and Kennedy, J.O., 1992, Sny Magill Watershed Nonpoint Source Pollution Monitoring Project: 1991 benthic biomonitoring pilot study: UHL Report Number 92-5, University Hygienic Laboratory, Iowa City, IA, 78 p.

Schueller, M.D., Hausler, M.C., and Kennedy, J.O., 1994: Sny Magill watershed nonpoint source pollution monitoring project: 1991 benthic biomonitoring pilot study results: this volume.

Seigley, L.S., Hallberg, G.R., Wilton, T., Schueller, M.D., Hausler, M.C., Kennedy, J.O., Wunder, G., Link, R.V., and Brown, S.S., 1992, Sny Magill Watershed Nonpoint Source Pollution Monitoring Project workplan: Iowa Department of Natural Resources Open File Report 92-1, 31 p.

1991 FISH ASSESSMENT FOR SNY MAGILL CREEK

G. Wunder and L. Stahl

Iowa Department of Natural Resources
Fish and Wildlife Division; Fisheries Bureau
RR #1; State Fish Hatchery
Decorah, IA 52101

ABSTRACT

A water quality improvement project has been initiated by several state and federal agencies via pollution prevention activities in the Sny Magill Creek watershed in northeast Iowa. The U.S. Fish and Wildlife Service, U.S. Geological Survey, U.S. National Park Service, the University of Iowa Hygienic Laboratory, and Iowa Department of Natural Resources (Iowa DNR) are cooperating to conduct a comprehensive, long-term water quality monitoring program designed to identify and document project benefits. The Iowa DNR-Fisheries Bureau's primary role is to monitor and assess responses in the fisheries population in Sny Magill Creek. Fish population sampling conducted in 1991 will serve as the pre-project baseline data set for future annual fisheries surveys. The initial fish population samples from Sny Magill contained species typically found in Iowa coldwater streams. The population was made up of eight fish species and was dominated by fantail darters, blacknose dace, redbelly dace, and johnny darters.

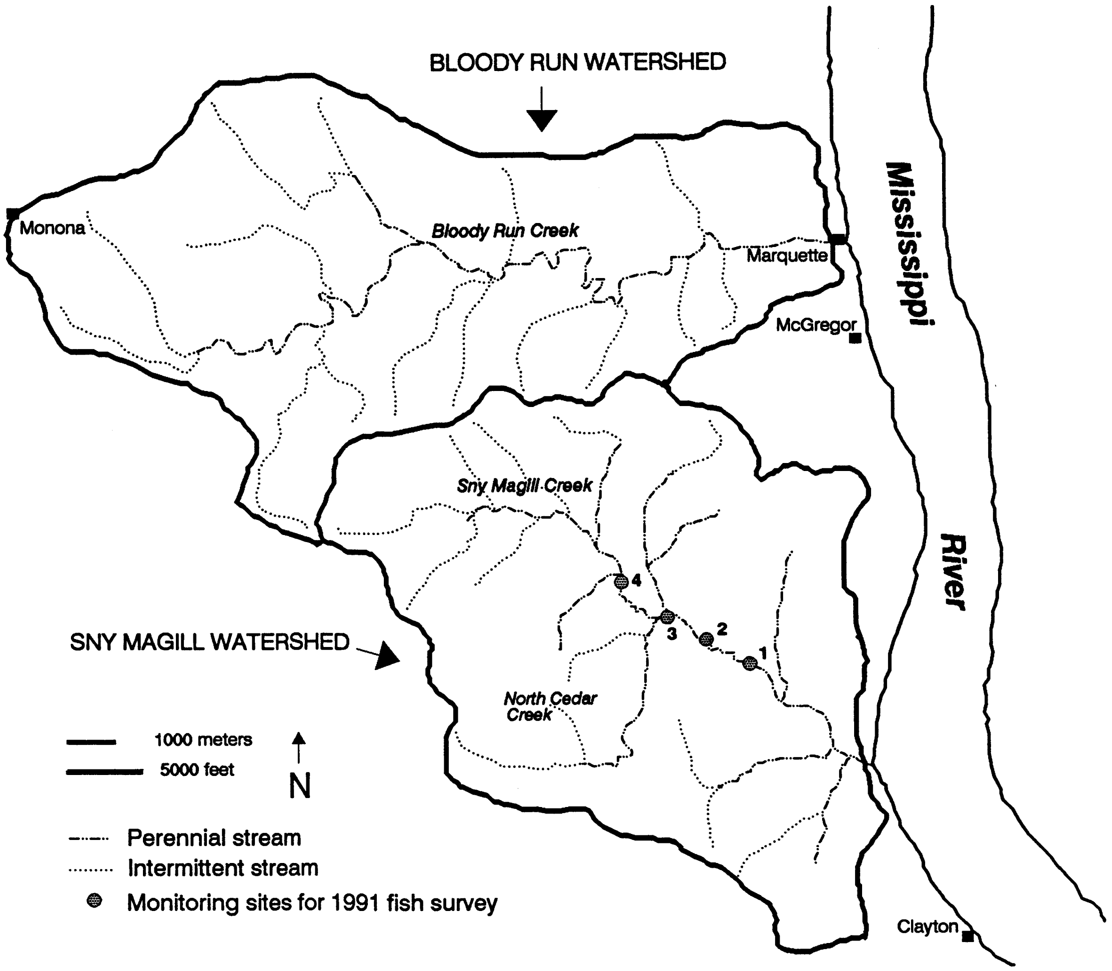


Figure 1. Sampling locations for fish assessment conducted September 23, 1991.

INTRODUCTION

Interest by federal and state agencies in initiating water quality improvement projects on Iowa trout stream watersheds has been very high in recent years. The Sny Magill Hydrologic Unit Area Project will provide benefits to the public using lands and waters in the watershed, including improved recreational opportunities and a healthier, cleaner environment. Fish and wildlife species in the watershed are expected to respond with higher population levels and better condition of individual organisms and hopefully greater species diversity as a result of improved water quality and associated habitat conditions.

Long-term monitoring and assessment of the fish populations in Sny Magill Creek may provide important information and documentation of biotic responses to changes in water quality resulting from the watershed project. Documentation of significant improvements in the overall stream fish community would be highly beneficial in the furtherance and expansion of other comprehensive watershed projects.

STUDY AREA

Sny Magill Creek is a Class B coldwater stream in east-central Clayton County near McGregor, Iowa (Figure 1). It flows approximately 6.2 miles (10.0 km) in an easterly direction where it empties into the Mississippi River. About 5.5 miles (8.9 km) of stream corridor and adjacent lands (approximately 700 acres) were purchased by the Iowa DNR between 1972 and 1974 for trout fishing, recreation, and to provide public access to the length of the stream. The watershed outside of the state-owned stream corridor is privately-owned and is primarily in cropland, pasture, and forestland. Considerable livestock production also occurs in the watershed. On state lands, there is no livestock grazing and crop production is managed per U.S. Soil Conservation Service recommendations to minimize soil loss. The local climate is temperate with snow cover possible from late October through early April. The stream receives groundwater baseflow from the Ordovician Galena aquifer and is ice-free during all but extremely cold weather. The stream bottom is primarily rock and gravel with some sand and silt.

Instream habitat favorable for fish populations consists primarily of rock and natural brush piles, vascular plants, and over-hanging bank vegetation. Siltation from previous farming activities along the stream corridor has been reduced by improved land management cropping techniques and bank stabilization projects. Soil erosion, nutrient loading, chemical runoff, and associated poor water quality from sources in the watershed above the state-owned property remain serious detriments to the stream habitat and fish populations.

Angler access to the stream is excellent via a county gravel road which generally lies parallel to the entire stream length. Six parking lots are distributed along the road to provide vehicle parking and walk-in access for recreationists. Trout do not successfully reproduce in Sny Magill, thus the stream is stocked with catchable-size rainbow and brown trout from April through November. Approximately 14,000 rainbow and brown trout are stocked and there are approximately 16,000 angler trips to Sny Magill annually.

The Iowa DNR has also purchased 4.5 miles (7.2 km; approximately 900 acres) of a tributary stream, North Cedar Creek, and its adjacent lands for fishing recreation. North Cedar Creek is managed as a walk-in, brown trout catchable fishery. It is stocked annually with approximately 1,000 catchable brown trout and receives around 3,000 angler trips annually. Brook trout were introduced in North Cedar Creek in 1977 and 1978 in an attempt to establish a naturally reproducing brook trout population. The project was largely unsuccessful; however, a small brook trout population has survived via natural reproduction on the very upper reaches of North Cedar Creek. Since 1988, there has been an approved Agricultural Conservation Program water quality improvement project on the North Cedar Creek watershed.

MATERIALS AND METHODS

Fish species were collected from four permanently-established sample sites on Sny Magill

Creek on September 23, 1991 (see Figure 1) with the assistance of Lester Stahl. Sites consisted of approximately 100-yard (91.4 m) stream segments located near an old oxbow (Site 1), a small parking "area" for fishery access (Site 2), a small spring run (Site 3), and the mouth of the West Fork of Sny Magill (Site 4). The sample date was selected just prior to a scheduled trout stocking to minimize the numbers of stocked trout in the sample and the potential interference of the work crews with trout anglers. The sites selected for sampling were not necessarily areas with the best habitat for trout since it was mainly the subordinate species which were of interest. Sampling gear consisted of two, backpack-mounted stream electrofishing units operated at 100 volts DC and 100 pulses per second. Electrofishing unit operators generally fished side-by-side and sampled in an upstream direction through the sample sites. Small-mesh seines (1/4-inch bar) were used to block the upper and lower boundaries of each sample site to prevent fish movement in and out of the sample sites. All captured fish were identified to species, enumerated, and later released. Sampled trout species were enumerated but not considered part of the baseline data due to the fact that their presence was due solely to put-and-take stocking. All electrofishing runs were made upstream through approximately 100 yards of mixed, pool-riffle habitat.

RESULTS

A total of eight species representing three families (excluding salmonids) were collected at Sny Magill Creek. Fish species collected in order of abundance at all four sample sites (combined) were fantail darter, southern redbelly dace, blacknose dace, johnny darter, bluntnose minnow, white sucker, longnose dace and creek chub (Table 1). Fantail darters were the most abundant fish species making up 65.4 percent of the sample, followed by southern redbelly dace at 11.5 percent and blacknose dace at 10.3 percent.

Species diversity was slightly higher at the two downstream sample sites, Sites 1 and 2, with seven and eight species represented, respectively (Table 2). Creek chubs were collected at the two downstream sites but not at the upper sites. The relative abundance of fantail darters as well as the total catch was greatest at the midstream sites, Sites 2 and 3. Even though Sny Magill is stocked with both rainbow and brown trout, only two rainbow trout were sampled (one each at Sites 2 and 3).

Of the fish species sampled, longnose dace are the most intolerant of poor water-quality conditions. Fantail darters, white sucker, and creek chub represent species which are tolerant to poor water quality.

DISCUSSION / CONCLUSIONS

Species diversity and the relative abundances of each species have been determined on four representative sample sites on Sny Magill Creek. All species collected are typical of those found in Iowa coldwater streams. The level of species diversity was not particularly high. Fantail darters represented 65.4% of the sample population.

Implementation of pollution limiting/prevention measures via the Sny Magill Hydrologic Unit Area Project will undoubtedly result in improved water quality in this coldwater stream. Responses in fisheries population can potentially be reflected by changes in: (1) species diversity, possibly by a decline in the percentage of the sample population represented by fantail darters resulting from an increase in the other species such as southern redbelly dace, blacknose dace, and longnose dace, (2) increases in the abundance of pollution-sensitive species, and (3) improvements in the overall health/condition of individuals in the resident populations. Baseline data collected in this study will allow for determinations of changes in species diversity and relative abundance. Recently developed field procedures for assessing fish health will be thoroughly investigated in 1992 to determine the feasibility and practicability of assessing changes in health of Sny Magill fish populations and the potential correlation with changes in water quality.

For 1992 a site will be added on North Cedar Creek and another will be added near the lower reach of Bloody Run.

Table 1. Relative abundance of non-salmonid fish samples in Sny Magill Creek, September 1991.

Species	Common Name	Number	Percent of Total Sample
Etheostoma flabellare	Fantail Darter	369	65.4%
Phoxinus erythrogaster	Southern Redbelly Dace	65	11.5%
Rhinichthys atratulus	Blacknose Dace	58	10.3%
Etheostoma nigrum	Johnny Darter	47	8.3%
Pimephales notatus	Bluntnose Minnow	8	1.4%
Catostomus commersoni	White Sucker	7	1.3%
Rhinichthys cataractae	Longnose Dace	6	1.1%
Semotilus atromaculatus	Creek Chub	4	0.7%

Table 2. Species diversity and relative abundance of non-salmonid fish collected at the Sny Magill Creek sample sites, September 1991.

	Sites				
Species	1	2	3	4	Total
Fantail Darter	46	116	150	57	369
Southern Redbelly Dace	0	33	7	25	65
Blacknose Dace	24	26	2	6	58
Johnny Darter	5	33	5	4	47
Bluntnose Minnow	5	2	0	1	8
White Sucker	1	5	1	0	7
Longnose Dace	3	1	1	1	6
Creek Chub	2	2	0	0	4
Total N Collected	86	218	166	94	564
N Species Represented	7	8	6	6	8
N Families Represented	3	3	3	2	3

SNY MAGILL WATERSHED MONITORING PROJECT: BASELINE DATA

Iowa Department of Natural Resources, Geological Survey Bureau
Technical Information Series 32, 1994

1992 FISH ASSESSMENT FOR SNY MAGILL AND BLOODY RUN WATERSHEDS

G. Wunder and L. Stahl

Iowa Department of Natural Resources
Fish and Wildlife Divisions; Fisheries Bureau
RR #1; State Fish Hatchery
Decorah, IA 52101

ABSTRACT

Water quality improvement projects have been implemented by various state and federal agencies on the combined North Cedar/Sny Magill Creek watershed in northeast Iowa. This report summarizes the second year of involvement of the Fisheries Bureau in this long-term monitoring project. It provides additional baseline data and ongoing evaluation of changes in water quality through use of a stream forage fish survey and subsequent identification of suitable indicator species.

Samples from Sny Magill in 1991 contained forage fish species typically found in middle to high quality Iowa trout streams. The population consisted of eight fish species and was dominated by fantail darter followed by redbelly dace and blacknose dace in relative abundance. Samples from 1992 contained nine fish species also dominated by fantail darter and blacknose dace. Only small numbers of redbelly dace were collected in 1992. Fish samples taken on North Cedar and Bloody Run creeks were dominated by fantail darters and slimy sculpin, respectively. Autopsies of creek chubs from Sny Magill Creek indicated that population to be in a normal, healthy condition.

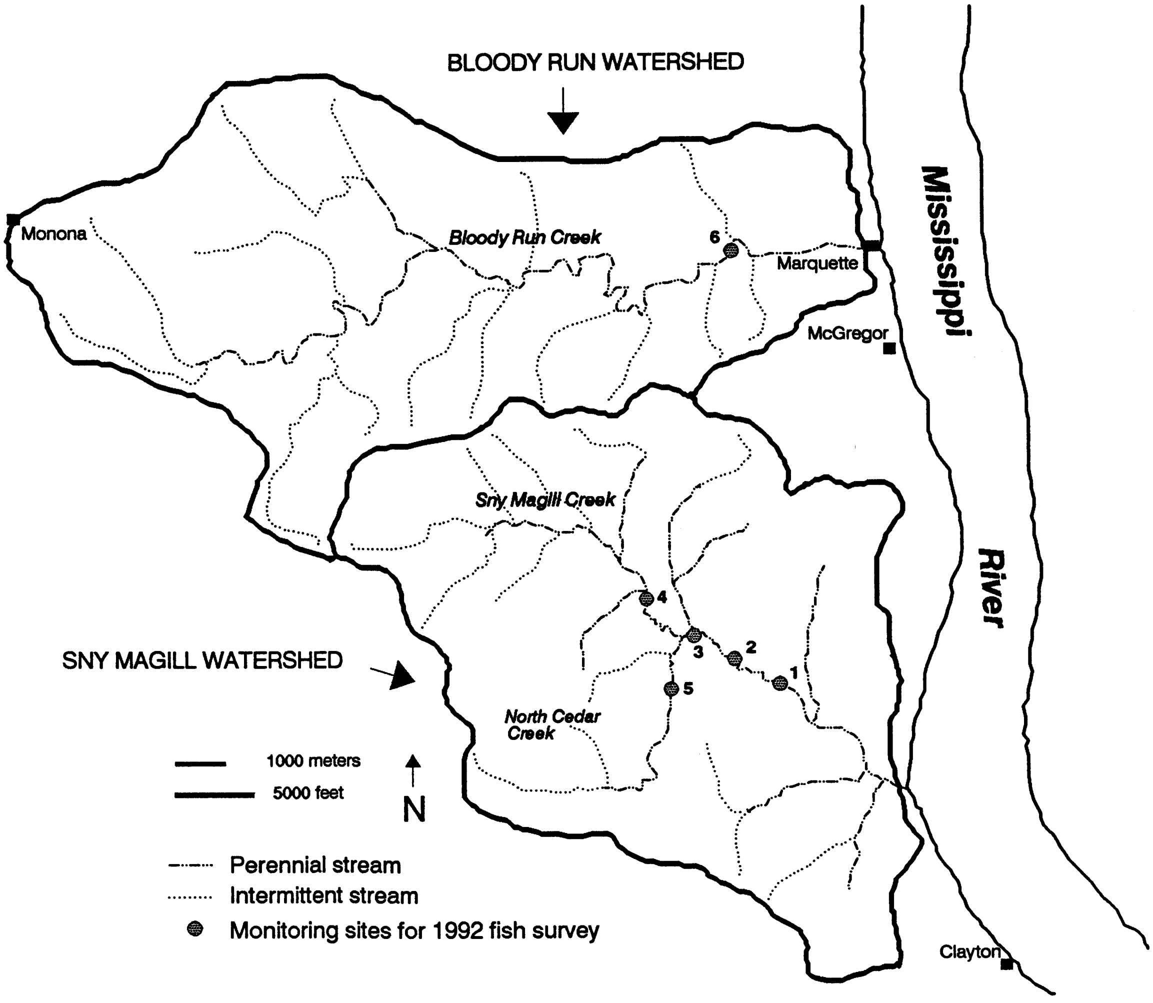


Figure 1. Fish assessment sampling locations for 1992 on Sny Magill, Bloody Run, and North Cedar creeks.

INTRODUCTION

The Sny Magill Hydrologic Unit Area Project and the North Cedar Creek Agricultural Conservation Program Water-Quality Special Project will provide several benefits to recreationists using the resources in these watersheds. These benefits include improved recreational opportunities for many outdoor activities and a healthier, cleaner stream environment. As a result of the projects' improved water quality and associated habitat conditions, it is anticipated that fish and wildlife populations in the watershed will exhibit greater species diversity, higher population levels, and better physical condition among individual organisms. These two projects will provide for land management changes designed to reduce sediment and nutrient input into Sny Magill and North Cedar creeks. Information from Sny Magill watershed will be compared to Bloody Run watershed, which is serving as the control watershed. No program is in place in the Bloody Run watershed to encourage adoption of farm practices to reduce soil and nutrient loss.

The establishment and response of the forage fish population in Sny Magill Creek over several years may provide important information and documentation for the anticipated changes in water quality in this stream. Establishment of the stream forage fish population as an indicator of improvements in water quality would be extremely useful in verifying the success of this and similar projects. Comparative sampling in two adjacent streams, North Cedar and Bloody Run, was added in 1992 to support any conclusions from the Sny Magill data.

STUDY AREA

Sny Magill Creek is a Class B coldwater stream in east-central Clayton County near McGregor, Iowa (Figure 1). The stream runs approximately 5.5 miles (8.9 m) through the state-owned Sny Magill/North Cedar Wildlife Management Area which provides public access for the entire coldwater segment. The stream corridor and adjacent uplands were purchased between 1972 and 1974 and are managed as an easy-access, catchable brown and rainbow trout fishery. The watershed above the state-owned stream corridor is privately-owned and is intensively farmed. Grazing is restricted on the state-owned lands and other cropping practices are managed through rental agreements subject to strict Soil Conservation Service guidelines. The local climate is temperate with snow cover possible from late October through early April. The stream is ice free during all but extremely cold weather. Stream bottom types vary from limestone rubble to sand to heavy silt.

North Cedar Creek is a tributary stream to Sny Magill and lies within the same wildlife management unit. It flows from the south and west for approximately three miles and joins Sny Magill midway through the state-owned segment. It is managed as a limited-access, catchable brown trout fishery. Bloody Run is a tributary to the Mississippi River near the town of Marquette about eight miles north of Sny Magill. Stream length is similar to Sny Magill. Bloody Run is managed as a catchable rainbow and brown trout fishery in the area of the fish sampling site. Physical features of both North Cedar and Bloody Run are similar to those on Sny Magill.

Instream habitat of all streams in the study area consisted of rock and natural brush piles, vascular plants, and over-hanging bank vegetation. Riparian vegetation varied from native grasses and brushy plants to tree species. Deep water habitat was most prevalent in Bloody Run while North Cedar was the shallowest of the three streams. Siltation from farming activities along the stream banks of Sny Magill and North Cedar has been reduced by better crop management techniques and bank stabilization projects. Bloody Run is privately owned except for one public-owned segment and has areas of severe bank erosion. Soil erosion, nutrient loading, chemical runoff, and associated poor water quality from sources in the watershed above the public-owned property on all three streams remain as serious detriments to the stream fisheries.

Angler access to Sny Magill is via a county gravel road which lies parallel to the entire stream length. Six gravel lots are distributed along the road to provide parking and walk-in access for anglers.

Materials and Methods

Forage fish species were collected from four sites on Sny Magill and one site each on North Cedar and on Bloody Run creeks during one day of sample collection in September 1992 (Figure 1). The collection date was selected to minimize stocked trout numbers and associated angler interaction with work crews. Sampling gear consisted of two backpack-mounted stream electrofishing units operated at 100 volts DC and 100 pulses per second. Small seines (1/4-inch bar measure) were used to block the upper and lower sample site boundaries and prohibit inter-site fish movement. All fish captured were identified to species, numerated, and immediately released downstream. All sample runs were made through approximately 100 yards (91.4 m) of mixed pool-riffle habitat. A small subsample of creek chubs was collected from Site 1 on Sny Magill and autopsied to provide fish health/ condition data.

Sample sites on Sny Magill were listed by number and in distance by road from the main crossroads access lot (Figure 1). Site 1 ran from the mouth of the old stream channel upstream for 100 yards (91.4 m). Site 2 was located about 0.65 miles (1.05 km) below the main lot and ran from a point 200 yards (183 m) below the access lot to a point 100 yards (91.4 m) upstream. Site 3 ran 100 yards (91.4 m) upstream from the downstream side of the main access lot bridge. Site 4 ran upstream 100 yards (91.4 m) from the second trail crossing below the access lot on the West Fork Sny Magill. The single site on North Cedar (site 5) was a 100-yard (91.4 m) segment located immediately below the first trail crossing above the mouth of the creek. The single site on Bloody Run (site 6) was a 100-yard (91.4 m) segment located immediately below the third upstream trail crossing in the Clayton County Conservation Board campground.

RESULTS

Forage fish species collected in order of abundance from Sny Magill include fantail darter, blacknose dace, brook stickleback, bluntnose minnow, johnny darter, longnose dace, creek chub, central stoneroller, and redbelly dace (Table 1). Rainbow and brown trout were collected but made up less than one percent of the fish sampled. Fantail darters were the most abundant forage fish, making up 63 percent of the sample, followed by blacknose dace which constituted 25 percent of the sample. Other species contributed less than three percent each to the sample.

The fish sampled from the single North Cedar Creek site were dominated by fantail darter (50%) and blacknose dace (45%) (Table 2). When combined, creek chub, bluntnose minnow, central stoneroller, and burbot contributed less than five percent to the sample. A single sample from Bloody Run Creek contained slimy sculpin (52%), blacknose dace (23%), and fantail darter, (20%) (Table 3). Longnose dace accounted for the remaining five percent of the sample.

Results of the Sny Magill creek chub autopsies are shown in Table 4. The procedure was based on Goede (1991). Mean condition factor was 1.0. The chubs deviated from normal in only two of the ten categories: fat storage and kidney condition. No terminal deviations were noted.

DISCUSSION / CONCLUSIONS

A second year of baseline data on forage fish populations in Sny Magill Creek has been established. One year of comparative data from two adjoining trout streams, North Cedar Creek and Bloody Run Creek, has also been collected. A majority of the fish species noted were similar to those sampled in 1991 (Wunder and Stahl, 1994). Exceptions included the addition of brook stickleback and central stoneroller in the Sny Magill sample, burbot in the North Cedar sample and slimy sculpin in the Bloody Run sample. White suckers were sampled in Sny Magill in 1991 but were not collected in 1992. All species collected were common to this type of stream habitat and were indicative of typical, Iowa coldwater streams.

As in 1991, a majority of the stream forage fish population was dominated by a single species - the fantail darter in Sny Magill and the slimy sculpin in Bloody Run. The fantail darter was also the major species in North Cedar; blacknose dace ran a close second. The redbelly dace went from second to ninth position in relative abundance in Sny Magill

Table 1. Relative abundance of forage fish species sampled from four sites in Sny Magill Creek, September 1992.

	Species*	Common Name	Number	Percent
Site 1				
	Rhinicthys atratulus	Blacknose dace	122	54
	Etheostoma flabellare	Fantail darter	91	41
	Pimephales notatus	Bluntnose minnow	6	3
	Semotilus atromaculatus	Creek chub	2	<1
	Culaea inconstans	Brook stickleback	2	<1
	Phoxinus erythrogaster	Redbelly dace	1	<1
Site 2				
	Etheostoma flabellare	Fantail darter	401	66
	Rhinicthys atratulus	Blacknose dace	114	19
	Culaea inconstans	Brook stickleback	36	6
	Pimephales notatus	Bluntnose minnow	35	6
	Etheostoma nigrum	Johnny darter	16	3
	Semotilus atromaculatus	Creek chub	2	<1
	Phoxinus erythrogaster	Redbelly dace	1	<1
Site 3				
	Etheostoma flabellare	Fantail darter	307	79
	Rhinicthys atratulus	Blacknose dace	62	16
	Rhinicthys cataractae	Longnose dace	11	3
	Etheostoma nigrum	Johnny darter	6	2
	Culaea inconstans	Brook stickleback	1	<1
	Pimephales notatus	Bluntnose minnow	1	<1
Site 4				
	Rhinicthys atratulus	Blacknose dace	44	40
	Etheostoma flabellare	Fantail darter	41	38
	Etheostoma nigrum	Johnny darter	16	15
	Campostoma anomalum	Central stoneroller	3	3
	Culaea inconstans	Brook stickleback	3	3
	Rhinicthys cataractae	Longnose dace	2	2
Overall				
	Etheostoma flabellare	Fantail darter	840	63
	Rhinicthys atratulus	Blacknose dace	342	25
	Culaea inconstans	Brook stickleback	42	3
	Pimephales notatus	Bluntnose minnow	42	3
	Etheostoma nigrum	Johnny darter	38	2
	Rhinicthys cataractae	Longnose dace	13	<1
	Semotilus atromaculatus	Creek chub	4	<1
	Campostoma anomalum	Central stoneroller	3	<1
	Phoxinus erythrogaster	Redbelly dace	2	<1

* Stocked rainbow and brown trout were also sampled but made up <1 percent of the total sampled.

Table 2. Species and relative abundance of forage fish species sampled in North Cedar Creek, September 1992.

Species*	Common Name	Number	Percent
Etheostoma flabellare	Fantail darter	60	50
Rhinicthys atratulus	Blacknose dace	53	45
Semotilus atromaculatus	Creek chub	3	3
Pimephales notatus	Bluntnose minnow	1	<1
Campostoma anomalum	Central stoneroller	1	<1
Lota lota	Burbot	1	<1

* Five stocked brook trout were also sampled.

Table 3. Relative abundance of forage fish species sampled in Bloody Run Creek, September 1992.

Species	Common Name	Number	Percent
Cottus cognatus	Slimy sculpin	64	52
Rhinicthys atratulus	Blacknose dace	29	23
Etheostoma flabellare	Fantail darter	25	20
Rhinicthys cataractae	Longnose dace	6	5

in 1992. The severe reduction of redbelly dace in Sny Magill Creek was unexpected and needs to be monitored in future surveys. These small fish may be vulnerable to subtle changes in water or habitat quality that can cause considerable fluctuations in population numbers. The sensitivity of these fish make them valuable as indicators of overall water quality.

Autopsy data on ten creek chubs revealed no gross irregularities or problems. All of the rated fish were in normal condition and in good health.

REFERENCES

Goede, R.W., 1991, Fish health/condition assessment procedures: Utah Division of Wildlife Resources.

Wunder, G., and Stahl, L., 1994, 1991 fish assessment for Sny Magill Creek: this volume.

Table 4. Fish autopsy results from creek chubs sampled in Sny Magill Creek, September 1992.

Sample	1	2	3	4	5	6	7	8	9	10	Mean	% Dev*
Length (mm)	112	132	130	147	127	104	114	119	109	102		
Weight (gm)	24	21	20	29	24	17	13	14	11	9		
Condition	1.7	0.9	0.9	0.9	1.2	1.5	0.9	0.8	0.8	0.8	1.0	
Eye	N	N	N	N	N	N	N	N	N	N		0
Gill	N	N	N	N	N	N	N	N	N	N		0
Pseudobranch	N	N	N	N	N	N	N	N	N	N		0
Thyroid	N	N	N	N	N	N	N	N	N	N		0
Fat	1	1	2	1	1	2	1	1	2	1		30
Spleen	R	R	R	R	R	R	R	R	R	R		0
Gut	0	0	0	0	0	0	0	0	0	0		0
Kidney	NG	S	NG	NG	NG	NG	NG	OT	NG	NG		20
Liver	R	R	R	R	R	R	R	R	R	R		0
Bile	0	0	0	0	0	0	0	0	0	0		0
Sex	F	M	F	M	M	F	F	F	F	F		

*Percent deviation from normal observations.

N=normal; R=red; NG=not granular; S=swollen; OT=other

Bile = 0 (yellow or straw color, normal)

Gut = 0 (no inflammation)

Fat : 0 (no fat covering cecal area); 1 (slight coverage); 2 (approximately 50% coverage); 3 (greater than 50% coverage); 4 (complete coverage)

Iowa Department of Natural Resources
Energy and Geological Resources Division
Geological Survey Bureau
109 Trowbridge Hall
Iowa City, Iowa 52242-1319
(319) 335-1575