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Sediment Detention Basin Feasibility Study of Horseshoe Lake, Alexander County, Illinois

by Ming T. Lee
Office of Spatial Data Analysis & Information

Prepared for the
Illinois Department of Conservation
and
U.S. Fish and Wildlife Service
Department of the Interior

October 1992

Illinois State Water Survey
Hydrology Division
Champaign, Illinois

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2204 Griffith Drive
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DISCLOSURE

Research project F-109-R-2, Horseshoe Lake Sedimentation and Detention Basin Project, was conducted with funding from the Federal Aid in Sport Fish Restoration Act (Dingell-Johnson Program) — a cooperative program between the states and the U.S. Fish and Wildlife Service. The project was sponsored by the Illinois Department of Conservation. The form, content, and interpretations of the data are the responsibility of the University of Illinois at Champaign-Urbana, and not of the Illinois Department of Conservation or other cooperating agencies/organizations.

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ABSTRACT

A feasibility study was conducted, which uses sediment detention basins to control lake sedimentation in the Horseshoe Lake (HSL) watershed. The study used the state-of-the-art Geographic Information System (GIS) to compile map data, which include soils, land use, streams, roads, and watersheds in the area. Sheet and streambed/bank erosion rates were assessed. Sheet erosion rates were determined by using the soil loss equation, which was developed by the U.S. Department of Agriculture (USDA). Streambank/bed erosion was assessed by field inspection and surveys. Sediment yield was estimated based on soil erosion rates, watershed characteristics, lake sediment survey data, and in-stream sediment measurements. Eight sub-watersheds were delineated for the Pigeon Roost and Black Creek watersheds, which are main tributaries to Horseshoe Lake. The capacities of the sediment detention basins were calculated based on the sediment yields at the selected sites.

Two alternative schemes were developed: 1) construction of one large sediment detention basin near the discharge point of Black Creek and Pigeon Roost Creek or 2) construction of two smaller sediment detention basins in upland watersheds. The results indicated the large sediment detention basin will detain about 5,455 tons of sediment per year versus 3,539 tons for the two smaller detention basins. The effectiveness and associated costs of these two approaches were compared with those of land treatment only.

INTRODUCTION

The Horseshoe Lake (HSL) watershed is located in Alexander County, Illinois, near the junction of the Mississppi and Cache Rivers. The HSL is an oxbow lake of the old Mississippi River as shown in figure 1. A recent lake sediment survey (Bogner et al., 1985) showed at the HSL is losing its capacity at the rate of about 0.5 inch per year. Major losses of fish habitat are a result of this sedimentation. To solve this problem, the Illinois Department of Conservation (IDOC) contracted with the Illinois

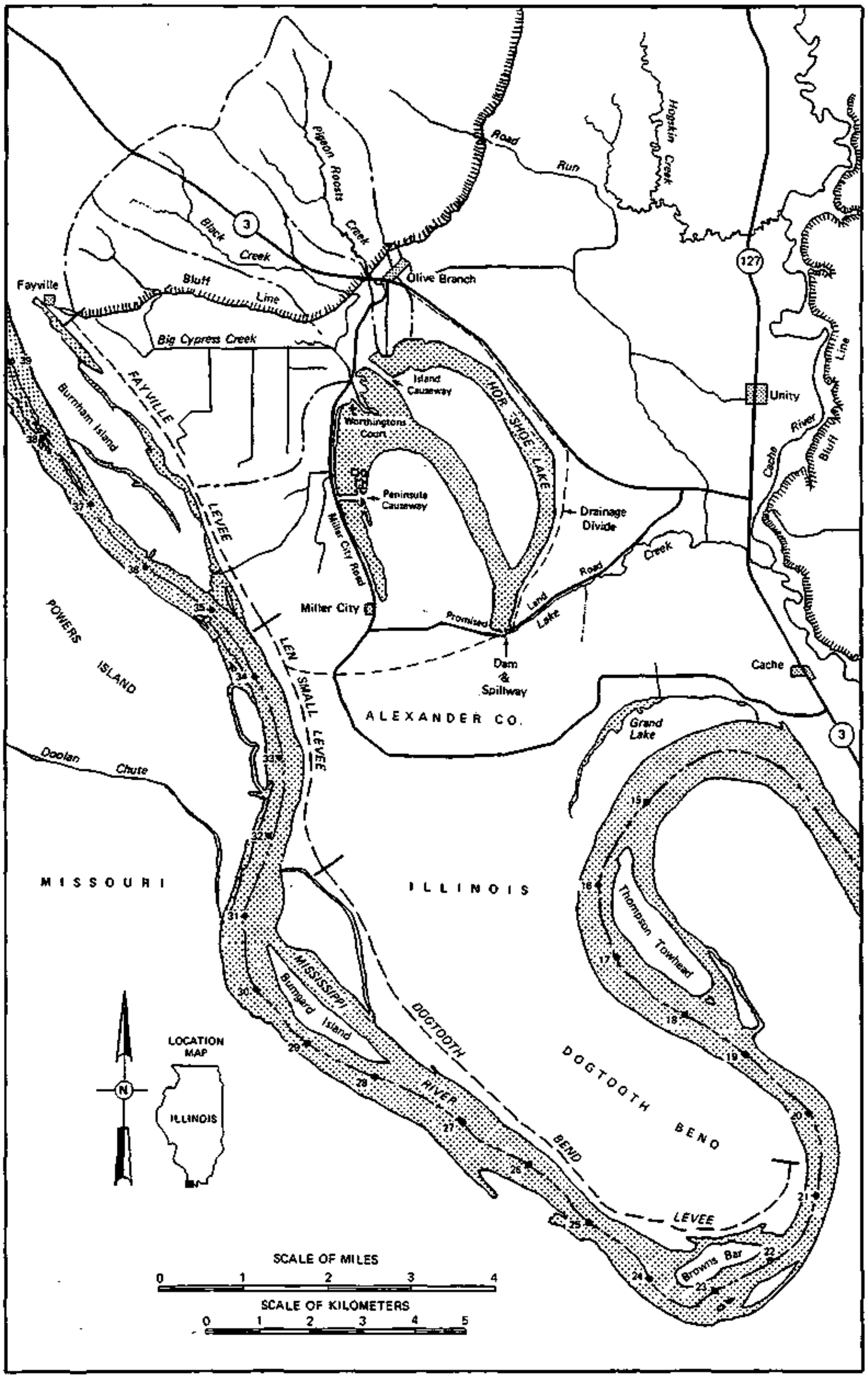

Figure 1. Location map for Horseshoe Lake, Alexander County, Illinois (After Lee et al., 1986)

State Water Survey (ISWS) to conduct a series of studies to identify feasible lake management alternatives: in-lake management, in-stream management, and watershed management (Lee et al., 1986; Blakley and Lee, 1987). Among the three alternatives, in-lake sediment management was first considered, and an earth dam rehabilitation plan is being implemented. The in-stream management plan, which includes numerous stream relocations, was considered too costly. The third alternative is the watershed management plan. This report focuses on determining the feasibility of sediment detention basins for lake sedimentation reduction or watershed management, the third alternative.

ACKNOWLEDGMENTS

This investigation, sponsored and financially supported by the Illinois Department of Conservation and the U.S. Fish and Wildlife Service, Department of Interior, was conducted under the general supervision and guidance of Richard Semonin (Chief Emeritus), Mark Peden (Acting Chief), John Shafer (Head of Hydrology Division) and Michael Terstriep (Director, Office of Spatial Data Analysis and Information), Illinois State Water Survey. Amelia Greene and Jack Drobisz digitized the soil map. John Brother and Linda Hascall provided the graphic service. Becky Howard formatted the camera-ready copy and Eva Kingston edited the report.

The Horseshoe Lake Task Force of the Illinois Department of Conservation provided general guidance for this investigation. Bill Boyd served as the project coordinator. Mike Sweet served as federal aid coordinator. The Soil Conservation Service provided technical assistance. Gary Barnett, Euley Simington, and Michael Harvell, District Conservationist and field technicians of Pulaski-Alexander Counties, and James Evans, Assistant State Conservation Engineer, assisted on field data collection and selection of the sediment detention sites.

DESCRIPTION OF STUDY AREA

The HSL watershed is a tributary of the Cache River basin which drains to the Mississippi River. The HSL drainage area, 14,969 acres, consists of the sub-watersheds of Pigeon Roost Creek, Black Creek, and floodplain direct drainage areas. The Pigeon Roost and Black Creek sub-watersheds, which have a combined drainage area of 5,129 acres, are being considered for sediment detention sites.

Detailed descriptions of HSL watershed soils, topography, geology, lake sedimentation, hydrology, and water quality are found in Lee et al. (1986).

OBJECTIVES

The purpose of this project was to determine the value of sediment detention basins to control HSL sedimentation for sport fishery. The specific objectives were:

1. To determine detailed soil erosion and sediment sources to HSL.

2. To determine the locations, sediment storage capacity, sediment trapping efficiency, and costs of sedimentation detention basins.

RELATED STUDIES

For many years, sediment detention basins have been used as watershed management tools for reducing the sediment discharge into lakes and reservoirs. But prior to siting the sediment detention basins, the soil erosion rates and the sediment yield of the watersheds have to be investigated by using methods developed by the USDA (Wischmeier and Smith, 1978). Estimates of sediment yield for small agricultural watersheds have been reported by Harm et al. (1982), Chow (1964), Beasley (1972), Vanoni (1975), and numerous other researchers.

Since the intent of this project was to assess sediment yield with the available data and the best field experience, the USDA's universal soil loss equation (USLE) was used. The sediment yield was estimated by using lake sedimentation data, watershed characteristics, and in-stream sediment survey measurements.

DATA COLLECTION

For the study, information on soil erosion, sediment yield of the selected sites, sediment trap efficiency, and topography was required to determine the capacity of the sediment detention basins. Since most of these data are spatial, and save time for various spatial data analyses, a GIS database was created.

Watersheds and Stream Networks

The stream data layer was obtained from the U.S. Geological Survey (USGS) 1:100,000 scale digital line graph (DLG) layer. The original DLG data were converted into ARC/INFO format and divided into county units. The watershed stream data were clipped from the county stream data by using the watershed boundary as a template as shown in figure 2.

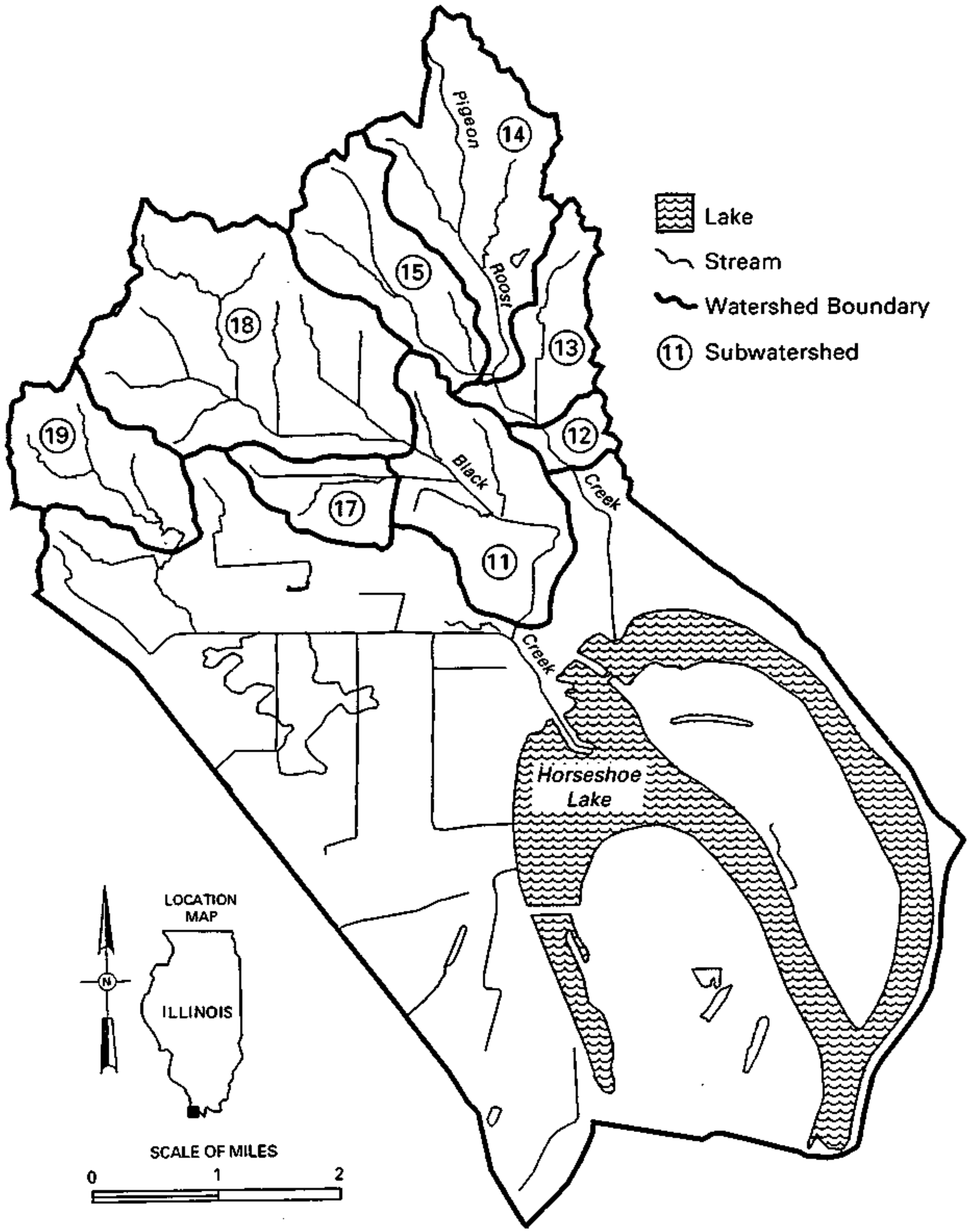

Figure 2. Watersheds of Horseshoe Lake

Soil Layer

The soil map for the HSL watershed was obtained from Soil Conservation Service (SCS, 1968).

The soil map with 1:15,840 scale was digitized using the ARC/INFO GIS (ESRI, 1991) system as shown in figure 3. For each soil mapping unit, the soil erodibility factor (K), slope, and slope length were assigned by using the tabular data provided by the SCS.

Land Use

A land use map was obtained from the Alexander County Soil and Water Conservation District. The 1:24,000 scale map was digitized as shown in figure 4. The cropping factor and conservation practice factors were entered for each field track as attribute data.

The land use breakdowns in the HSL watershed are listed in table 1. The largest acreage is used for cropland, which covers 7,542 acres or 50.4 percent. Forests cover 3,966 acres or 26.4 percent. Water and wetlands cover 2,208 acres or 14.8 percent. Smaller acreages are used for pasture, urban areas, and highway construction.

Table 1. Land Use in the Horseshoe Lake Watershed

Land use	*Acreage*	*Percent*
Cropland	7,542	50.4
Forest	3,966	26.4
Water and wetlands	2,208	14.8
Pasture	1,059	7.1
Urban	162	1.1
Highway construction	32	0.2
Total	14,969	100.0

Soil-Land Use Overlay

By using GIS operation, soil and land use layers were intersected electronically to create a composite layer. The soil and land use attribute data were transferred to the new coverage. This composite layer was useful in defining the relationship of soils and land use in the watershed. Further details of using this layer are explained in the analysis and summary sections.

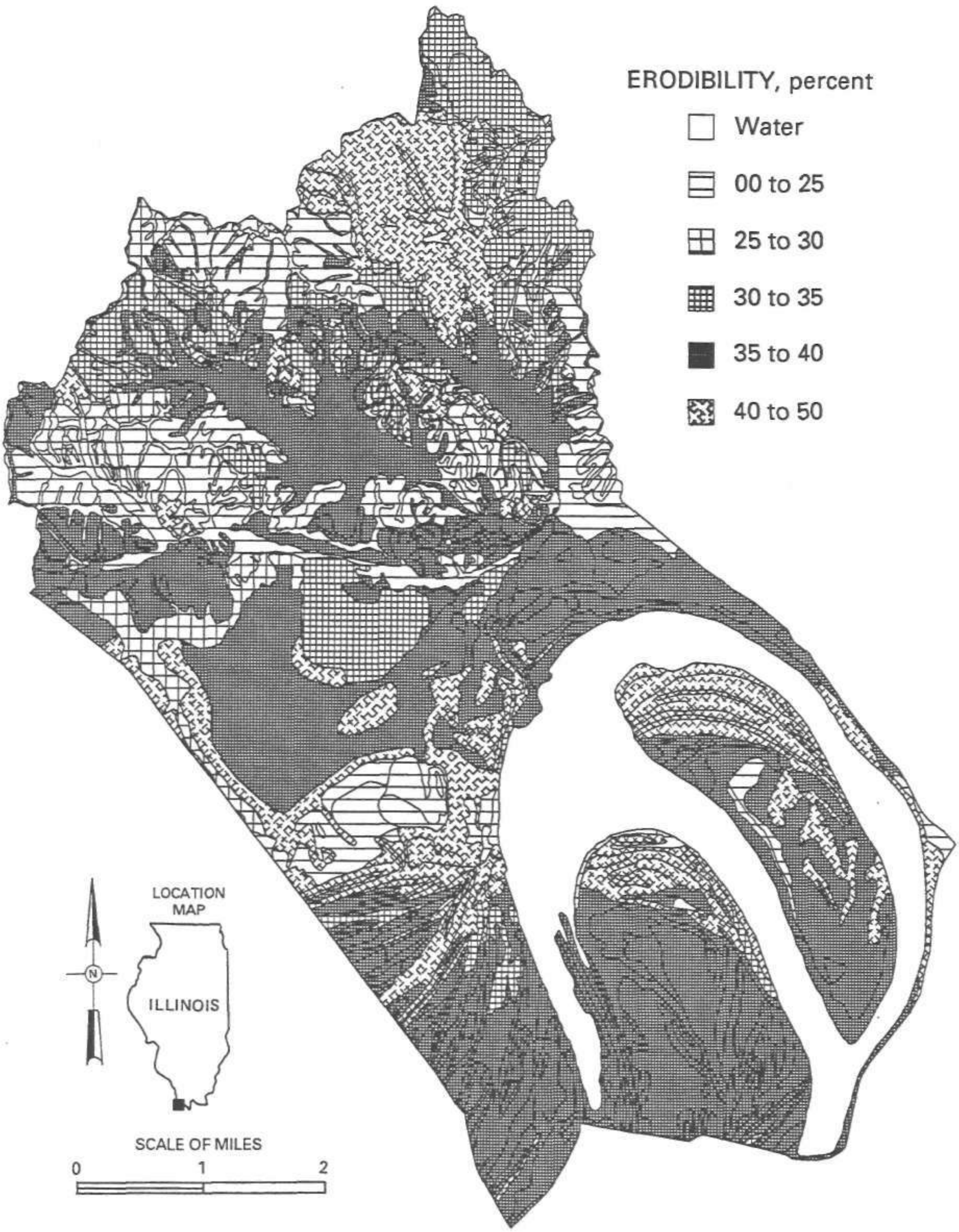

Figure 3. Soil map of Horsehoe Lake watershed

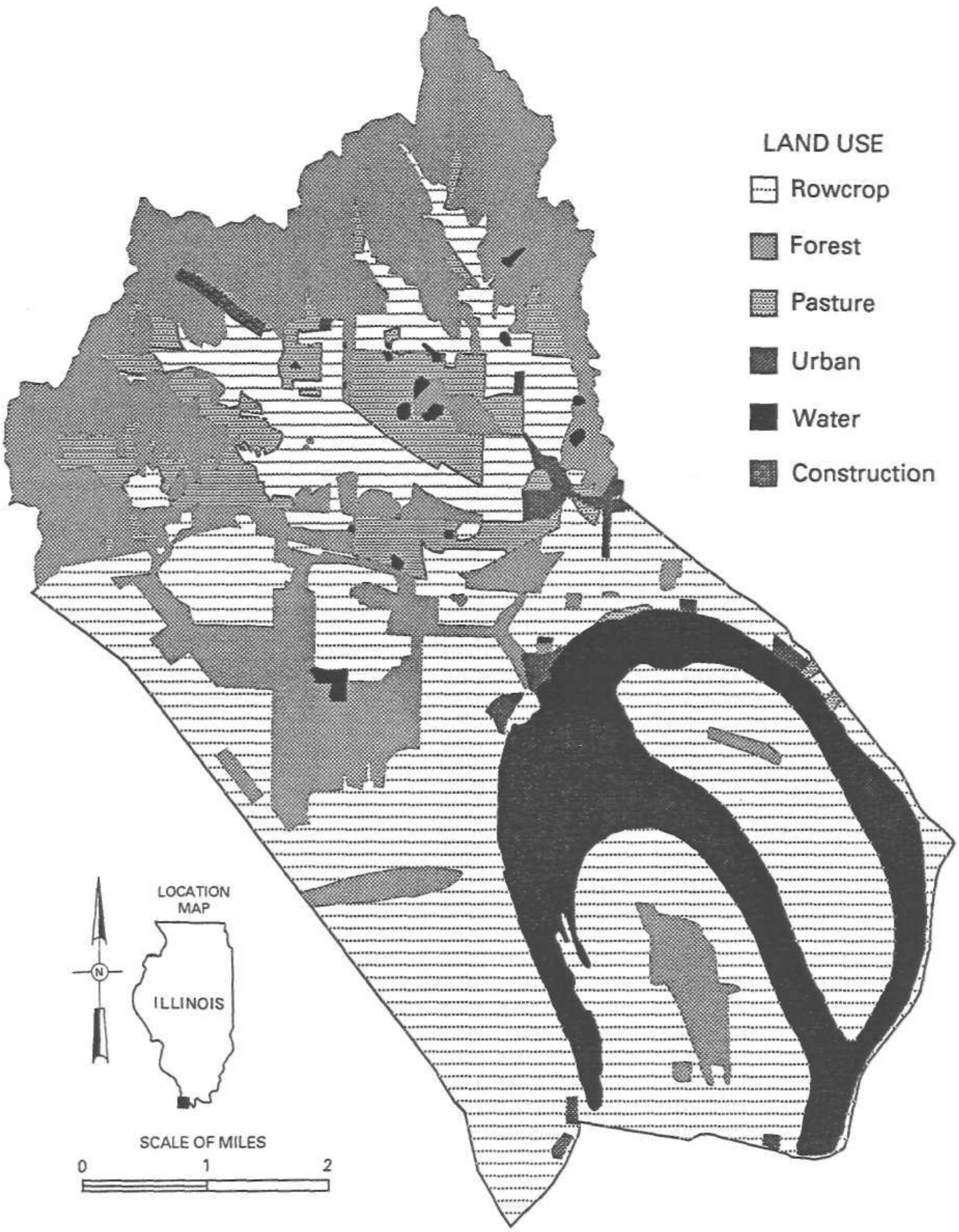

Figure 4. Land use map of Horseshoe Lake

Floodplain

The floodplains were obtained from the new digitized floodplain database at the ISWS. The source maps came from the Federal Emergency Management Agency's flood information rate maps. The present database is in county units, but using GIS operation, the county map was clipped to create the floodplain map within the watershed as shown in figure 5. About 70 percent of this watershed is in the 100-year flood hazardous zone.

ANALYSIS

Sheet Erosion Assessment

The USDA's USLE (Wischmeier and Smith, 1978) was used to assess sheet erosion. Streambank/bed erosion was assessed based on samples of about 25 percent of the stream segments in the watersheds. Sediment yield was determined by using existing data and an empirical formula.

For sheet erosion, the USLE requires inputs of factors such as soil erodibility, rainfall, cropping, conservation practices, slope, and slope length. Because attribute data of the GIS layers do not contain all parameters of the USLE, surrogate values have to be provided. The soil erodibility factor, K, was assigned for each soil mapping unit that was available from the SCS soil database. The rainfall factor, R, was assigned based on the project site's location in the state. This information can be found in Wischmeier and Smith (1978). The cropping factor, C-value, determined by land use and, more specifically, the crop rotation and tillage systems for cropland. The conservation practice factor, P, is determined by the conservation practices used on the lands. A P value was assigned by the District Conservationist based on the available records. The slope and slope length records were determined by the soil type and its slope class, and the average values were used for each soil-type/slope-class in a county. All these values were stored as attribute data in either the soil or land use layer.

The next step was to compute the soil erosion rate for each soil-type/slope-class using the USLE developed by Wischmeier and Smith:

$$A=RKLSCP$$

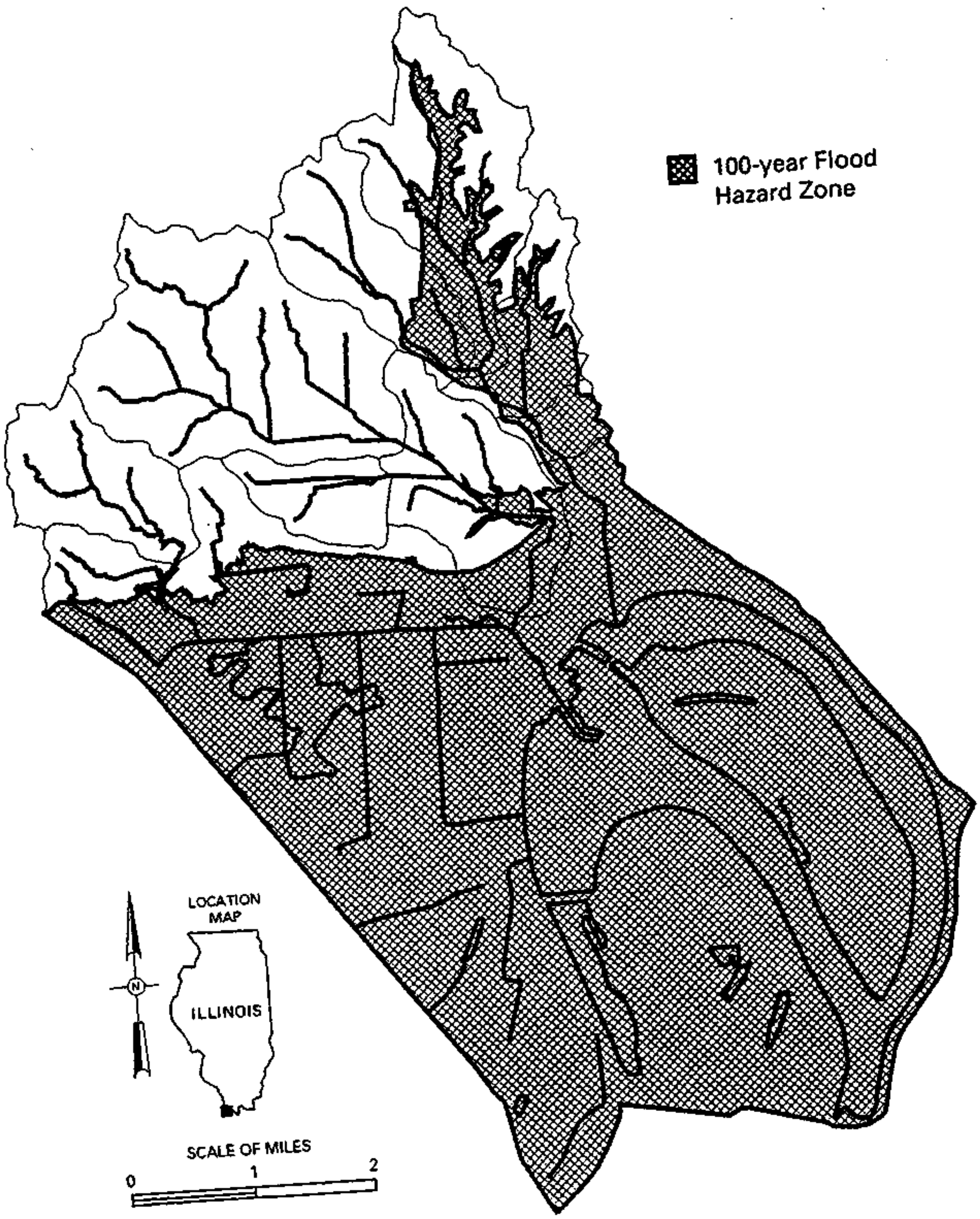

Figure 5. Floodplain map of Horseshoe Lake

where:

A = computed soil loss per unit area (expressed in units selected for K and period selected for R).

R = rainfall and runoff factor (number of rainfall erosion index units plus a factor for runoff from snowmelt or applied water where such runoff is significant).

K= soil erodibility factor (soil loss rate per erosion index unit for a specific soil as measured on a unit plot, which is defined as a 72.6-ft length of uniform 9-percent slope continuously in clean-tilled fallow land).

L = slope-length factor (ratio of soil loss from a field slope gradient to that from a 72.6-ft length under identical conditions).

S = slope steepness factor (ratio of soil loss from field slope gradient to that from a 9-percent slope under otherwise identical conditions).

C = cover and management factor (ratio of soil loss from an area with specific cover and management to that from an identical area in tilled continuous fallow land).

P = support practice factor (ratio of soil loss with a support practice like contouring, stripcropping, or terracing to that with straight-row farming up and down the slope).

The INFO (Henco, Inc., 1991) relational database management system was used to compute the gross erosion rate in annual tons. The amount of gross erosion was aggregated for each of the eight sub-watersheds as delineated in figure 2.

Streambank/Bed Erosion Assessment

The methods for assessing gully and streambank/bed erosion are being developed and therefore involve a great degree of uncertainty. The methods also require support by extensive field data. The ASCE *Sedimentation Engineering* (Vanoni, 1975) showed that the gully erosion process has been described for several regions of the United States, but the cause-effect interrelationships of gully formation have seldom been put into proper perspective. Methods are therefore not available for any given locality and under any set of existing or assumed conditions. However, some studies have produced quantitative information and some empirical prediction procedures. The erosion in streams, which includes streambank and bed erosion, can be very significant under some circumstances. Quantitative estimates of channel erosion or deposition rates are obtained from time sequence comparisons of surveyed cross sections, maps and aerial photographs, and historical records. Rough predictions of future channel changes are based on the sediment discharge formula (Lane and

Borland, 1951; Einstein, 1950; Colby and Hembree, 1953), use of the Regime theory (Blench, 1957), or other methods that consider the forces exerted on the stream boundaries (Lane, 1955).

For this project, the field survey method was used. The procedures are described as follows:

1. The stream network layer was obtained from the USGS 1:24,000 from the GIS database. The streams within Pigeon Roost Creek and Black Creek were clipped using the sub-watershed layer developed for this project. Eight sub-watersheds are delineated.
2. The stream networks were plotted on si: 15,840 scale. The streams were divided into 660 ft segments (equivalent to one inch on the plot). About 25 percent oh the samples of the stream segments were selected to represent the whole watershed as shown in figure 6.
3. The technical staff of the Soil Conservation District at Alexander County conducted field measurements on the width, depth, length, and durations of the gully, bed, and bank erosion within the selected samples. The depth and width were measured by tapes and the length by walk-steps. The duration was difficult to assess. Consultation with landowners and other local people provided some valuable time references. The data on erosion depth, width, length, and duration were recorded for all the samples, as shown in table 2.
4. The annual average volume of stream erosion was computed by multiplying depth, width, and length, and then dividing by duration in years. The weight of stream erosion in tons were computed by multiplying unit weight and volumes. The unit weight of 110 pounds per cubic foot was used based on the Alexander County Soil Survey report (SCS, 1968).

Using the USLE, sheet erosion of each soil mapping unit within the HSL was computed. Since the eight sub-watersheds in Pigeon Roost Creek and Black Creek were within the selected areas for siting the sediment detention basins, their sheet erosion rates are were summarized in figure 7.

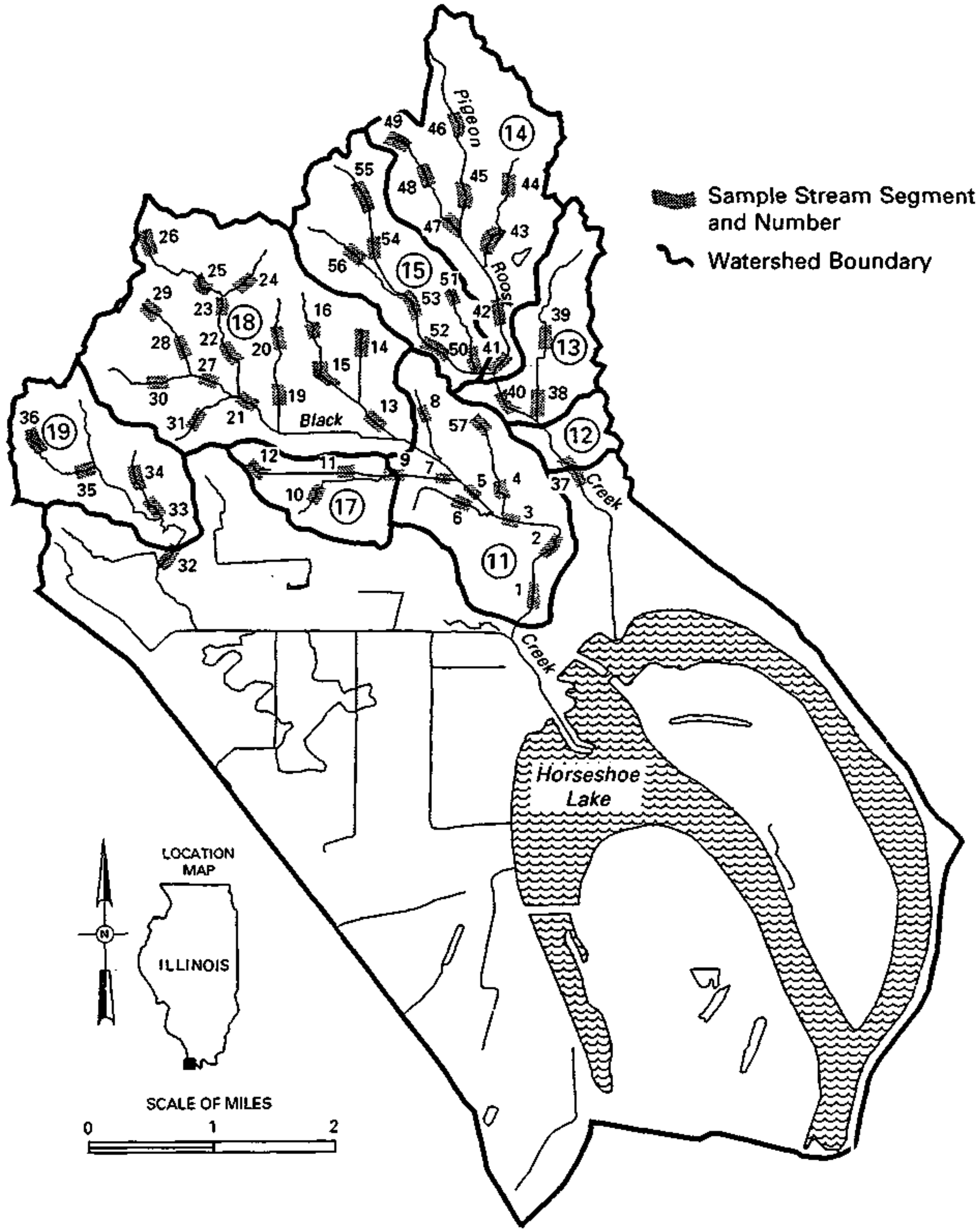

Figure 6. Streambank/bed sampled in Horseshoe Lake watershed

Table 2. Streambank/Bed Erosion Data

Sample no.	*Sub-basin*	*Width (ft)*	*Depth (ft)*	*Length (ft)*	*Years*	*Erosion* *Volume*	*Tons*
1	11	19	20	25	25	95	5.2
2	11	20	10	90	25	180	9.9
3	11	15	15	218	15	818	45.0
4	11	3	4	280	5	168	9.2
5	11	6	18	35	6	158	8.7
6	11	15	12	583	15	749	96.2
7	11	3	1	180	4	34	1.9
8	11	3	2	190	7	41	2.2
57	11	3	2	190	7	41	2.2
37	12	7	10	569	19	524	28.8
38	13	4	3	258	13	60	3.3
39	13	12	4	190	17	134	7.4
40	13	12	14	264	14	792	43.6
41	14	5	7	154	5	270	14.8
42	14	4	6	110	8	83	4.5
43	14	6	3	258	6	194	10.6
44	14	6	2	244	7	105	5.8
45	14	13	15	138	5	346	74.0
46	14	10	5	535	8	841	46.2
47	14	8	4	379	7	433	23.8
48	14	9	4	315	11	258	14.2
49	14	12	5	250	19	197	10.9
50	15	3	6	613	7	394	21.7
51	15	2	1	400	3	67	3.7
52	15	7	5	232	8	254	14.0
53	15	9	4	204	5	367	20.2
54	15	3	3	80	9	20	1.1
55	15	9	4	204	5	367	20.2
56	15	5	3	600	7	321	17.7
9	17	4	5	590	4	738	40.6
10	17	0	0	0	1	0	0.0
11	17	4	5	630	8	394	21.7
12	17	4	7	30	4	53	2.9
13	18	25	20	640	28	857	157.1
14	18	3	3	550	5	252	13.9
15	18	3	4	631	7	270	14.9
16	18	3	2	642	4	241	13.2
17	18	12	12	654	34	692	38.1
18	18	30	9	280	34	556	30.6
19	18	8	5	590	11	536	29.5
20	18	8	10	200	16	250	13.8
21	18	10	18	646	26	118	61.5
22	18	12	9	656	18	984	54.1

Table 2. Concluded

Sample no.	*Sub-basin*	*Width (ft)*	*Depth (ft)*	*Length (ft)*	*Years*	*Erosion*	
						Volume	*Tons*
23	18	15	4	400	17	353	19.4
24	18	5	2	649	8	203	11.2
25	18	15	3	628	17	416	22.9
26	18	6	4	638	9	425	23.4
27	18	8	6	654	26	302	16.6
28	18	3	3	643	7	207	11.4
29	18	3	4	208	7	89	4.9
30	18	3	3	609	13	105	5.8
31	18	3	1	190	4	36	2.0
32	19	16	6	633	16	950	52.2
33	19	4	6	629	16	236	13.0
34	19	3	1	646	7	69	3.8
35	19	20	4	656	19	691	38.0
36	19	3	3	644	7	207	11.4

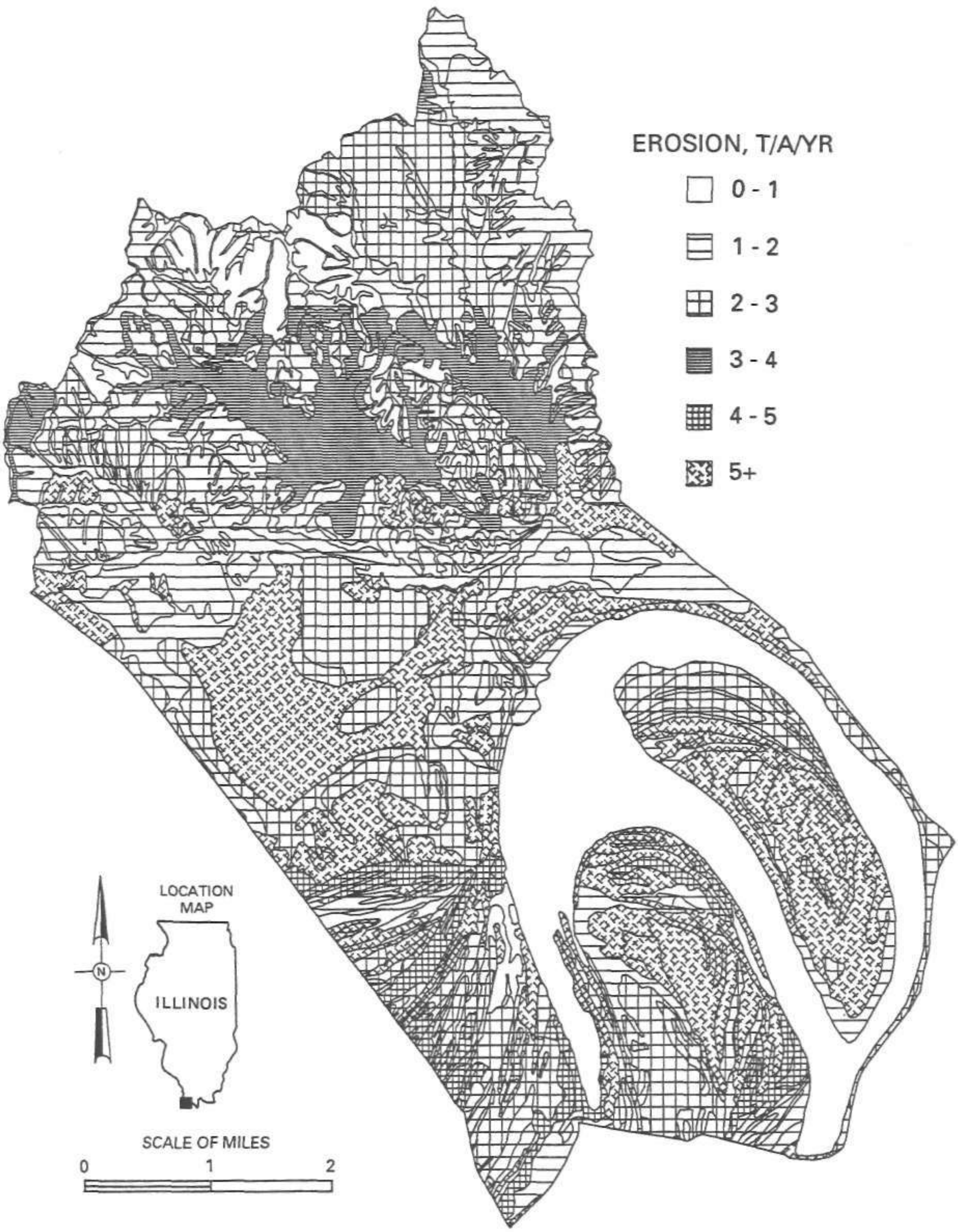

Figure 7. Soil map of Horseshoe Lake watershed

Table 3. Sheet and Streambank/Bed Erosion of the Pigeon Roost
and Black Creek Watersheds

(1)	*(2)*	*(3)*		*(4)*		*(5)*	*(6)*	
		Gross sheet erosion		*Stream erosion*		*Ratios of*	*Total gross erosion*	
Subbasin	*Acreage*	*(t/y)*	*(t/a/y)*	*(t/y)*	*(t/a/y)*	*(3)/(4)*	*(t/y)*	*(t/a/y)*
11	751	3,632	4.48	740	0.98	0.20	4,373	5.82
12	124	208	1.68	87	0.71	0.42	296	2.39
13	380	181	0.48	252	0.66	1.39	433	1.14
14	939	443	0.47	774	0.83	1.75	1,218	1.30
15	602	583	0.97	384	0.64	0.66	968	1.61
17*	288	432	1.50	228	0.80	0.53	661	2.30
18	1,520	1,068	0.70	1,964	1.29	1.84	3,032	1.99
19	525	1,040	1.98	496	0.95	0.48	1,537	2.93
Total	5,129	7,591	1.48	4,925	0.96	.65	12,516	2.44

* No sub-watershed #16

Table 3 shows that together the eight sub-watersheds generate 7,591 tons of sheet erosion annually. On a per-acre basis, sub-watersheds 11, 12, and 17 generate the most sheet erosion because of the high percentage of croplands. The low erosion rate of these watersheds is attributed to the high percentage of pasture and woodlands.

Table 3 also shows that together stream erosion of the eight sub-watersheds generates 4,925 tons which are about 65 percent of the sheet erosion. Sub-watersheds 13, 14, and 18 generate the highest ratios of streambed/bank erosion to sheet erosion.

The total amount of sheet and streambed/bank erosion for the eight sub-watersheds is 12,516 tons per year or 2.44 tons per acre per year.

Table 4. Sheet Erosion of the Horseshoe Lake Watershed
Breakdown Based on Land Use

Landuse	*Gross sheet erosion (tons/year)*	*Percent*
Cropland	4,613	60.8
Pasture	818	10.8
Urban	663	8.8
Forests	549	7.2
Water and wetlands	496	6.5
Highway construction	451	5.9
Total	7,591	100.0

Sediment Yield

The sediment yield is defined as "the total sediment outflow from a watershed or drainage basin, measurable at a cross section of references and in a specific period of time" (Vanoni, 1975). An assessment of sediment yield from erosion sources is sometime estimated by gross erosion and then multiplied by a delivery ratio to obtain sediment yield. Numerous regional regression equations were developed (Roehl, 1962; Maner, 1958; Ackermann and Corinth, 1962; Gottschalk and Brune, 1950; Maner and Barnes, 1953; Fleming, 1969; Glymph, 1951; Interagency Task Force, 1967; Glymph, 1954). For this project, a simple relationship of drainage area and sediment delivery ratio from the loess hills area of the Upper Mississippi River basin and Nebraska and Iowa was used (Vanoni, 1975). The sediment delivery ratios of all the sub-watersheds of Pigeon Roost Creek and Black Creek are given in Table 5.

The sediment delivery ratios of the eight sub-watersheds range from 26 to 40 percent. Note that this is a statistical average for the size of watersheds in the upper Mississippi River basin. The estimated sediment yields of the eight sub-watersheds vary from 0.34 to 1.57 tons per acre per year.

Comparison of Erosion and Sediment Yield Assessment with Existing Field Observation Data

Erosion and sediment yield studies are always subject to errors. Even by using various ways to measure and assess erosion and sediment yield potentials, making an unbiased assessment is always difficult. One approach to understanding the potential bias is to compare the results to various data sources. The weak and strong points of each data set can then be explained.

Table 5. Sediment Yield of the Pigeon Roost Creek and Black Creek Watersheds

Sub-watershed	*Drainage Area* (sq. mi)	(acres)	*Sediment delivery ratio* (percent)	*Yield* (tons/yr)	(tons/ac/yr)
11	1.17	751	27	1,181	1.57
12	0.19	124	40	118	0.95
13	0.59	380	35	152	0.40
14	1.47	939	26	317	0.34
15	0.94	602	30	290	0.48
17*	0.45	288	33	218	0.75
18	2.38	1520	24	728	0.48
19	0.82	525	31	477	0.91

*No sub-watershed 16.

The data sources of existing field observations of the HSL watershed are: (1) lake sediment survey conducted in 1984 (Bogner et al., 1985), (2) in-stream sediment monitoring conducted from April 1984 to April 1985 (Lee et al., 1986), and (3) a 1984 erosion assessment (Lee et al., 1986).

According to the 1984 lake sediment survey, the lake sedimentation rate in HSL was 34,970 tons per year. This amount was contributed from the whole lake watershed, which has drainage area of 13,170 acres. After prorate for the sub-watersheds of the Pigeon Roost and Black Creek tributaries based on the drainage areas, the amount of sedimentation was calculated to be 13,618 tons per year.

The 1985-1986 in-stream suspended sediment measurement for HSL showed that the sediment yield for this 13-month period was 15,217 tons if the average 12-month period is calculated to be 13,952 tons. For the Pigeon Roost Creek and Black Creek sub-watersheds, the sediment yield was calculated to be 5,433 tons.

The third data source is the 1986 erosion assessment which was conducted by Soil Conservation Service and reported by Lee et al. (1986). This study was based on a 20-percent sample area. At the time, there were no detailed land use and soil map data, so representative soil erosion rates for cropland, pasture, and woodland were assigned. The total sediment yield of the HSL watershed was calculated to be 36,697 tons per year. The total sediment yield for the Black Creek and Pigeon Roost Creek watersheds was calculated to be 27,964 tons per year.

When comparing all the data sources, the present assessment, 12,516 tons per year (table 3), is close to the lake sediment survey results, 13,168 tons per year (Bogner et al., 1985). It is worthwhile to note here that not all the sediment from the sheet and streambed/bank erosion will be delivered to the lake. The in-stream sediment survey showed the least amount of sedimentation that was delivered to the lake. This may be attributed to problems with the in-stream sediment sampling: the samples did not reflect all major storms that carried high sediment concentrations. The 1986 SCS erosion assessment was based on preliminary land use data and the assignment of soil loss input parameters is highly dependent upon the land use maps. The present assessment, however, was based on the most accurate land use and soil maps. It should thus approximate the best technical assessment that is feasible for the erosion and sediment yield in the watershed.

Siting of Sediment Detention Basins

Installation of sediment detention basins is intended to prevent the sediment from discharging downstream. Consequently, designers of these basins need to determine the sediment storage capacity required to store the sediment yield at the sites. Based on the information from the erosion rate and sediment yield assessment, field reconnaissance was conducted. Three alternatives were selected:

Alternative 1: One Large Detention Basin

The site is located between the Pigeon Roost Creek and Black Creek as shown in figure 8.

This site was designed to catch sediment from sub-watersheds 11, 17, 18, 12, 13, 14, and 15. Because there is no suitable site at the channel, levee embankments will have to be built to create the detention basin in the bottomland areas.

The sediment yields are estimated as follows. From Pigeon Roost Creek (sub-watersheds 11, 17, and 18), the annual sheet erosion rates are:

Sub-watershed no.	*Tons*
11	3,632
17	432
18	1,068
Total	5,133

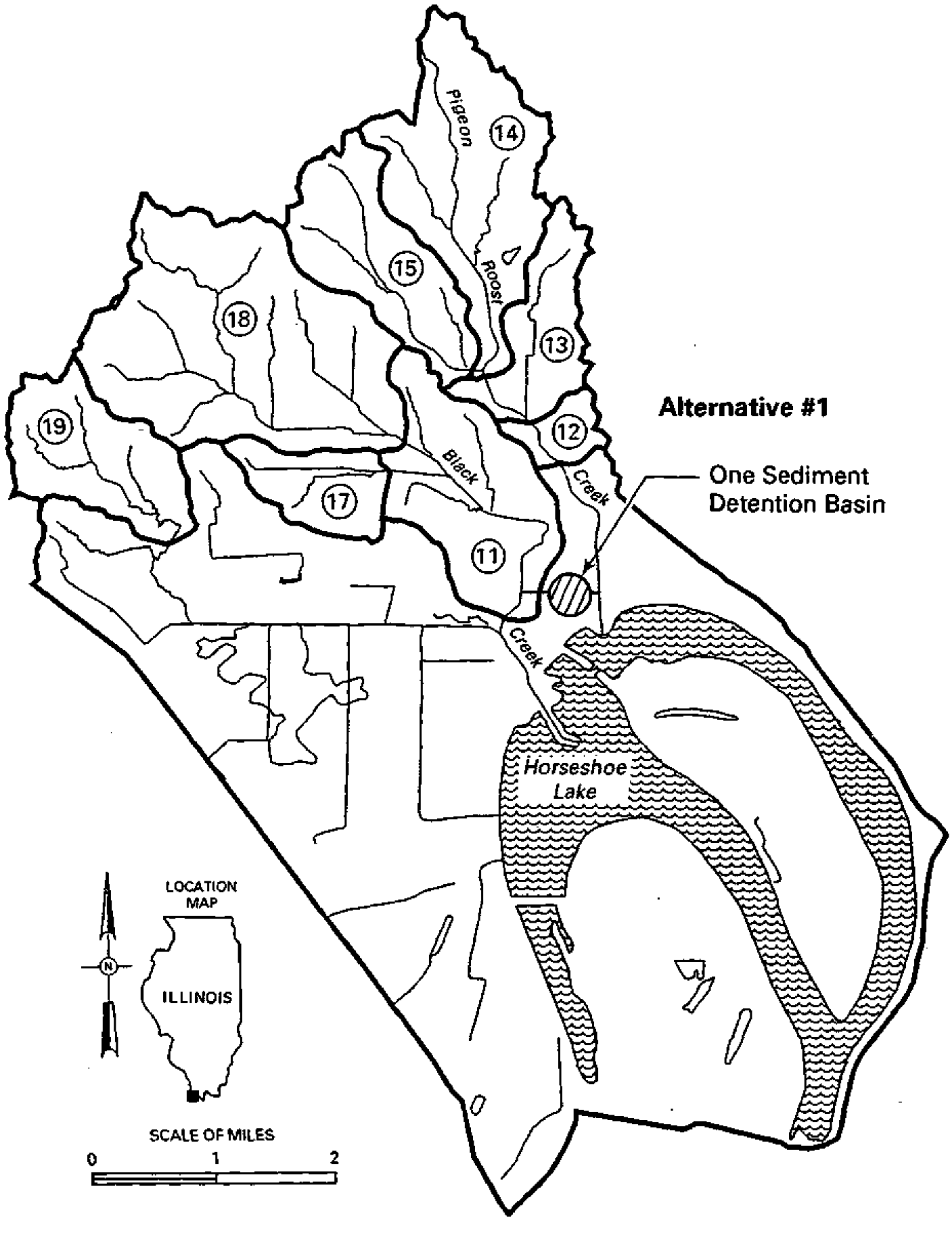

Figure 8. Alternative 1: one large sediment detention basin

The channel bank/bed erosion rates are:

Sub-watershed no.	*Tons*
11	740
17	228
18	1,964
Total	2,932

Similarly, from Black Creek (sub-watersheds 12, 13, 14, and 15), the sheet erosion rates are:

Subwatershed no.	*Tons*
12	208
13	181
14	444
15	583
Total	1,416

The channel bank/bed erosion rates are:

Subwatershed no.	*Tons*
12	87
13	252
14	774
15	384
Total	1,497

To estimate sediment yield for the detention basin, sediment delivery ratios for sheet and channel bank/bed erosion have to be selected. Sheet erosion is based on the empirical relationship (Gottschalk and Brune, 1950). Total drainage area of sub-watersheds 11, 17, and 18 is 3.99 square miles and that of sub-watersheds 12, 13, 14, and 15 is 3.00 square miles. Consequently, the delivery ratios are 22 percent and 24 percent, respectively. For channel erosion, the delivery ratios are considered to be higher. Due to the short runoff time lag, and relatively steep slope, 90 percent of the channel delivery ratio is used for the HSL watershed.

The sediment yields from sub-watershed 11, 17 and 18 are :

5,133 x 022 + 2,932 x.90 = 3,768 tons /yr.

The sediment yields from sub-watersheds 12, 13, 14, and 15 are:

1,416 x 0.24 + 1,497 x 0.90 = 1,687 tons /yr.

The sediment yields are within the ranges of the comparable watersheds reported by the U. S. Department of Agriculture (Vanoni, 1975).

Based on the soil survey report (SCS, 1968), dry sediment volume weight is assumed to be 90 pounds per cubic foot. Consequently, one acre-foot of sediment is equivalent to 1,960 tons. Combining the sediment yields from two sub-watersheds, the total volume will be 2.78 acre-feet per year. If a ten-year design period is selected, the total sediment storage will require 27.8 acre-feet.

To detain the maximum sediment yields (about 4,794 tons) from Black Creek and Pigeon Roost Creek, 90 percent trap efficiency is assumed.

According to the 1984 HSL sediment survey, the annual sediment deposition was estimated to be 30,500 tons. Consequently, the detention basin alone will reduce the lake sediment basin by about 15.7 percent.

Since the proposed sediment detention basin is envisioned to be built as an off-channel facility, the runoffs during high storm events have to be bypassed. The spillway and outlet structures have to constructed to accommodate this operation.

In order to implement this alternative, 4,000 feet of levee, a spillway and diversion works are needed. The $570,000 estimated construction costs include the levee ($120,000), spillway ($200,000), diversion structure ($100,000) and land ($150,000).

Alternative 2: Two Detention Basins

The sites of two detention basins are located at mouths of sub-watershed 12 and 18 as shown in figure 9. These two sites will have in-stream sediment detention facilities.

The sediment yields were estimated as follows. From sub-watersheds 13, 14, and 15, the annual sheet erosion is:

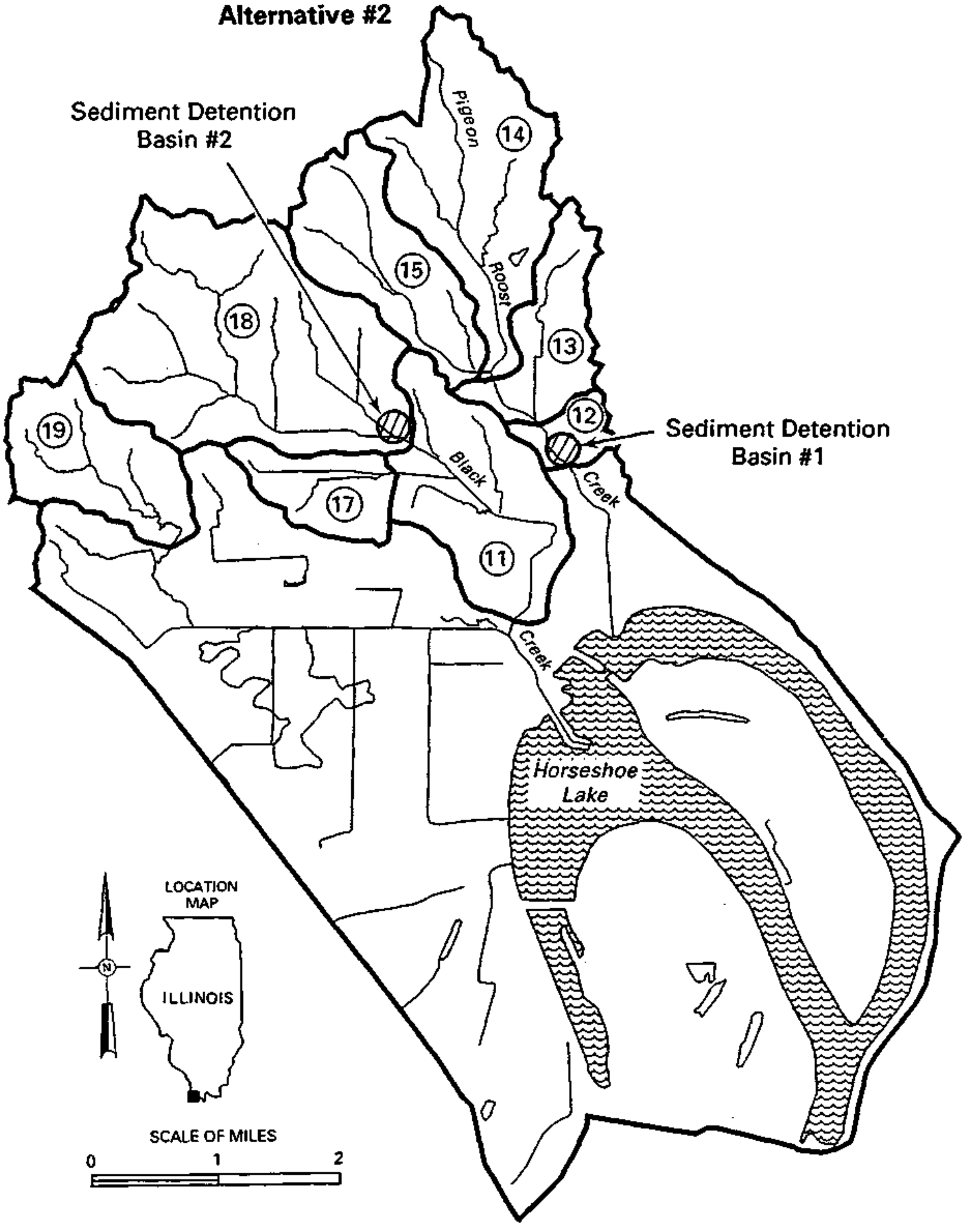

Figure 9. Alternative 2: two sediment detention basins

Sub-watershed no.	*Tons*
13	181
14	444
15	583
Total	1,208

The channel bank/bed erosion is:

Subwatershed no.	*Tons*
13	252
14	774
15	385
Total	1,410

Similarly, the annual sheet erosion is:

Subwatershed no.	*Tons*
18	1,068

and annual stream bank/bed erosion is:

Subwatershed no.	*Tons*
18	1,964

To estimate sediment yield, the sheet erosion sediment delivery ratios based on the Gottschalk empirical relationship were calculated to be 0.21 and 0.24 for sub-watersheds 13 and 18, respectively. The channel bank/bed erosion is estimated to be 90 percent.

Total sediment yield from sub-watersheds 13, 14, and 15 is:

$$1208 \times .21 + 1410 \times .90 = 2{,}523 \text{ tons}$$

Similarly, sediment yield from sub-watershed 18 is:

1,068 x .24 + 1964 x .90 = 2,024 tons

The equivalent dry volume of the sediment yields is 1.05 and 0.85 acre-feet per year. If a ten-year design period is selected, the total sediment storage will require 10.5 and 8.5 acre-feet for sub-watersheds 13 and 18, respectively.

In order to implement this alternative, the structure costs are estimated based on the capacity of the sediment detention basins as $300,000. The land cost is estimated as $50,000 (50 acres at $1,000 per acre). Additional costs of operations and maintenance are not included. The total cost of the project will exceed $350,000.

To detain the maximum sediment yields from the Black Creek and Pigeon Roost Creek (about 3,539 tons), 90 percent of trap efficiency is assumed.

According to the 1984 HSL sediment survey, the annual sediment deposition was estimated to be 30,500 tons. Consequently, the two detention basins alternative will reduce the lake sediment basin by about 11.6 percent.

Since the proposed sediment detention basin is envisioned to be built as an in-channel facility, the runoffs during high storm events have to be bypassed. The spillway and outlet structures have to constructed to accommodate this operation.

Alternative 3: Land Treatment in the Watershed

For this alternative, based on the SCS field experience, a reasonable goal for sheet and rill erosion reduction rates can be set at 10 percent and gully erosion at 30 percent. This will reduce the sediment deposition to the lake to 2,250 tons per year. Consequently, this alternative will reduce lake sediment on Pigeon Roost Creek and Black Creek to about 7.4 percent.

The cost of this alternative is estimated to be $250 per acre of cropland. Operation and maintenance costs will be insignificant. The total cost of this alternative will approximate $375,000.

SUMMARY

In summary, two alternative sediment detention basins were investigated. A single detention basin will provide the largest sediment reduction. Two detention basins reduce sediment yield to about 65 percent of that for a single detention basin. When compared with land treatment only (alternative 3), the detention basin alternatives are 1.5 to 2 times more effective in reducing the sediment yield as shown in table 6.

It is worthwhile to notice that the lake sediment survey and the sediment yield analysis were calculated by different data sources. A comparison of these two values is subject to potential bias.

The estimated costs of implementing one detention basin, two detention basins, or land treatment only are $570,000, $350,000, and $375,000, respectively. The unit costs of reducing sediment yield were estimated at about $105 (one detention basin) $99 (two detention basins), and $116 (and treatment alone). These results show that a sediment detention basin can achieve about the same or higher levels of sediment yield reduction as land treatment alone at about the same or lower costs.

Table 6. Comparison of Alternatives Effectiveness and Costs

	Land treatment	*One detention basin*	*Two detention basins*
Sediment yield reduction (tons)	2,250	5,455	3,539
Percent of lake sediment reduction	7.4	15.7	11.7
Total cost	$375,000	$570,000	$350,000
Unit costs of reducing one ton of sediment	$226	$105	$99

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APPENDIX 1

Sheet erosion of sub-watershedbreakdown by soil types

SUB-BASIN	Soil Series	Acreage	Gross Erosion (tons/yr)
11	131A	26.78	13.15
	131B	7.83	32.03
	131C2	3.51	23.52
	131D2	4.50	1.60
	162A	27.86	22.30
	162B	31.05	19.02
	175A	15.09	11.98
	175B	21.49	16.47
	178	3.11	19.79
	180	1.04	0.01
	184A	111.17	32.42
	214D2	33.12	352.00
	214D3	125.32	507.96
	214E3	54.09	27.41
	214F3	3.33	0.00
	216E3	4.90	0.00
	216F	29.80	228.30
	216F3	18.32	7.42
	216G	150.03	310.31
	219	9.62	5.37
	221C1	1.74	1.21
	241C2	6.20	36.40
	284A	5.83	22.17
	304B	15.99	2.58
	308C	91.10	221.65
	308C2	141.85	1.76
	308D	209.00	1,178.15
	308D2	263.62	27.25

308E	1.70	2.05
308E3	4.80	5.10
308F	21.76	92.72
308F2	0.11	2.81
333	411.70	144.31
334	3.35	1.23
338A	9.08	56.47
338B	0.50	8.36
344	0.08	0.09
382	15.99	26.79
401	4.76	49.90
420	6.35	2.91
422	9.73	4.52
422+	8.87	2.39
426	24.57	0.26
460	0.10	1.74
4611	25.58	8.45
463A	20.11	0.02
84	64.05	53.13
990G	0.37	35.41
W426	25.47	0.06
W71	219.68	11.00
WATER	1,981.65	0.58
	--------	--------
	4,277.64	3,632.56
	========	========

SUB-BSN	S/S	AC	GERO
12	131C2	2.01	0.20
	178	1.89	0.03
	214E3	34.43	2.69
	216F	5.21	8.80

216F3	1.89	0.30
216G	12.50	45.11
308C2	2.54	0.21
308D	6.88	0.75
308D2	6.07	0.93
308F	3.85	3.84
333	68.10	45.53
382	10.78	2.05
420	4.11	1.10
422	45.57	4.71
422+	9.55	0.04
460	12.30	8.73
4611	1.11	0.08
461B	2.32	0.01
72	4.26	40.18
84	19.44	41.52
WATER	1,990.70	1.68
	--------	--------
	2,245.50	208.50
	========	========

SUB-BSN	S/S	AC	GERO
13	131A	54.61	0.30
	131B	22.87	1.23
	131C2	2.01	0.01
	175A	1.29	0.09
	175C	35.08	0.07
	178	71.11	1.50
	180	9.35	15.82
	184A	10.90	0.10
	214C	10.13	22.94
	214E3	3.01	0.97

216F	32.31	24.26
216F3	9.92	1.83
216G	40.09	44.71
219	23.22	0.14
266	11.73	0.11
288	0.46	0.29
304B	0.00	0.01
308C	504.88	0.94
308C2	13.16	0.05
308D	9.51	5.42
308F	3.85	24.07
331	2.84	5.19
333	27.04	30.12
382	2.06	0.01
420	0.10	0.00
422	0.00	0.01
422+	9.55	0.17
426	1.28	0.04
460	13.56	0.09
4611	51.10	0.01
461B	2.32	0.21
475	7.93	0.02
525	1.64	0.02
53B	1.00	0.07
84	30.46	0.49
W71	42.67	0.10
	--------	--------
	1,063.03	181.41

SUB-BSN	S/S	AC	GERO
		-1.5E+04	0.00
14	109	7.33	0.03
	131A	11.19	0.05
	131B	7.25	0.22

131C	2.02	18.67
162A	17.34	1.48
162B	0.06	0.12
175A	4.99	3.33
175B	2.72	2.16
175C	18.20	50.57
178	6.82	7.04
180	11.32	9.20
184A	23.61	1.83
214B	6.26	5.70
214C	15.96	40.08
216G	27.58	0.44
219	1.29	5.31
266	10.40	0.69
288	3.23	0.71
308D	10.70	45.29
308E	2.96	4.04
331	1.15	10.93
333	37.02	158.77
334	3.23	31.04
338A	15.60	0.69
338B	5.41	29.23
344	0.48	0.57
382	0.00	0.82
420	0.05	6.31
422	1.38	0.15
422+	1.90	0.00
460	0.20	2.99
4611	1.81	1.02
475	17.88	0.01
70	83.79	0.05
72	0.11	0.08
84	39.48	0.64
85	3.24	3.34
WATER	2.16	0.00
	--------	--------

443.60

SUB-BSN	S/S	AC	GERO
15	108	6.50	0.13
	131A	77.55	0.49
	131B	1.15	0.22
	131C	3.33	0.10
	175A	1.01	0.08
	175C	3.19	256.95
	180	9.30	0.06
	184A	76.89	0.66
	184B	20.82	2.11
	214C	4.61	2.44
	216F	3.94	9.39
	219	14.06	32.77
	288	19.08	129.56
	308C	60.49	0.13
	308D	2.42	2.80
	331	0.76	1.95
	333	9.80	33.17
	334	2.63	61.39
	338A	0.93	3.10
	344	13.39	0.19
	422+	1.90	0.25
	460	0.00	0.02
	461B	0.02	0.02
	475	53.47	43.26
	72	394.42	0.04
	84	52.54	1.44
	85	6.92	0.55
	W422	0.06	0.15
	W71	0.55	0.05
	WATER	8.60	0.00
		--------	--------

		850.34	583.46
		========	========
		850.34	583.46

SUB-BSN	S/S	AC	GERO
17	109	1.98	0.89
	131A	15.32	18.19
	131B	7.25	44.93
	162A	29.62	10.03
	162B	18.45	10.77
	175A	6.94	5.24
	175B	11.48	4.95
	178	3.07	1.73
	184A	20.10	21.28
	216F	2.27	7.01
	216G	255.12	137.90
	219	3.91	0.18
	266	4.06	24.70
	288	2.11	0.60
	308C	102.97	67.30
	308D	8.27	3.60
	308D2	14.82	0.16
	308E	22.47	1.20
	308F	15.42	8.49
	331	0.27	0.63
	333	38.77	14.63
	334	7.29	3.48
	422	7.45	17.51
	426	5.50	0.13
	460	3.02	20.33
	84	1.90	6.63
	WATER	2.36	0.16
		--------	--------
		612.18	432.64

		========	========
		612.18	432.64

SUB-BSN	S/S	AC	GERO
18	108	18.26	1.89
	109	1.06	0.10
	131A	68.21	8.56
	131B	44.59	3.34
	131C	14.83	334.32
	131C2	1.64	0.08
	162A	10.63	0.07
	162B	0.41	0.03
	175A	69.41	0.50
	175B	23.28	0.71
	175C	38.22	4.82
	178	90.81	2.92
	180	2.78	2.88
	184A	88.13	0.93
	184B	2.19	1.12
	214B	1.31	42.78
	214C	2.09	65.32
	214D3	0.35	3.73
	214E3	1.11	0.13
	214F2	6.97	0.42
	216F	53.83	127.45
	216F3	4.66	3.89
	216G	109.43	62.90
	219	184.64	159.11
	221C1	2.75	0.01
	266	55.17	0.52
	284A	13.25	0.01
	288	36.44	16.31
	304B	14.69	0.44
	308C	9.98	1.23

308C2	33.23	2.56
308D	12.12	25.11
308D2	7.69	11.16
308D3	1.04	0.87
308E	1.56	2.63
308F	13.01	47.75
331	19.18	4.85
333	78.34	65.42
334	2.49	0.04
338A	32.84	34.06
338B	0.22	2.21
344	8.91	2.47
382	2.34	0.28
401	1.25	0.01
420	0.06	0.05
422	8.33	0.08
422+	47.74	0.06
426	40.71	0.16
460	29.16	0.48
4611	5.92	1.95
461B	0.02	3.09
462B	0.35	0.00
463A	19.10	0.25
475	2.56	0.05
70	1.23	0.08
71A	43.93	0.23
72	3.99	1.04
84	496.57	9.28
85	55.34	0.27
W422	1.38	3.65
W426	1.50	0.02
W71	3.62	0.21
WATER	20.39	1.37
	---------	---------
	1,967.24	1,068.26

SUB-BSN	S/S	AC	GERO
19	131A	1.35	20.95
	131B	16.46	9.27
	175A	0.52	4.44
	175B	1.53	6.92
	178	5.96	4.75
	184A	11.72	6.79
	214E3	4.40	5.61
	214F2	6.97	4.50
	216F	55.99	175.73
	216F3	3.68	9.41
	216G	98.42	148.55
	219	4.60	17.44
	288	7.51	0.12
	308C	206.38	32.94
	308C2	0.36	1.17
	308D	30.21	39.21
	308D3	0.13	4.51
	308F	25.94	13.15
	331	1.74	17.16
	333	81.16	186.79
	334	3.66	0.92
	338A	1.47	0.04
	344	15.39	92.44
	382	4.68	27.21
	420	1.13	4.50
	422	4.19	60.41
	426	2.40	0.42
	460	1.31	3.76
	4611	248.41	7.90
	463A	0.71	0.25
	525	2.11	0.44
	71A	0.21	2.39
	72	13.40	54.70

84	28.86	76.17
WATER	108.93	0.00
	--------	--------
	1,001.88	1,040.99

APPENDIX 2

Summary of sheet erosion by sub-watersheds

SUB#	AC	GERO
11	751	3,632.56
12	124	208.50
13	380	181.41
14	939	443.60
15	602	583.46
17	288	432.64
18	1,520	1,068.26
19	525	1,040.99
	========	========
	5,129	7,591.42