INTERNATIONAL REFERENCE GROUP ON GREAT LAKES POLLUTION FROM LAND USE ACTIVITIES

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STREAMBANK EROSION IN THE UNITED STATES PORTION OF THE GREAT LAKES BASIN

STREAMBANK EROSION IN THE
U.S. PORTION OF THE GREAT LAKES BASIN

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The study was carried out as part of the Task C activities of the Pollution from Land Use Activities Reference Group, an organization of the International Joint Commission, established under the Canada-U.S. Great Lakes Water Quality Agreement of 1972. Findings and conclusions are those of the author and do not necessarily reflect the views of the Reference Group or its recommendations to the Commission.

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SUMMARY

Riverbank erosion studies were included in the Detailed Study Plan as an assignment of the Task C Work Group. These studies began in 1974 on the Maumee River Basin. The experience and knowledge gained from the study provided the confidence to do similar studies on the watersheds previously selected by the work group.

The concept used on the Maumee study was to examine a two percent sample of the watershed. Sample areas 160 acres in size selected on a random basis were examined and the data expanded to the watershed. The field crew worked 1,182 hours and traveled 12,630 miles to visit 597 sample sites.

A worksheet was designed to provide a record of items of interest regarding streambank erosion and arranged in a manner to facilitate keypunching operations. Since this was a streambank erosion study, items on eroding bank height, length, and average annual bank recession were obviously included. It was thought that adjacent land use and soil series might correlate with eroding banks so columns were included on the worksheet for this information. Since an important part of the study was to recommend a program of treatment, columns were included for present and needed treatment. It was also thought that there might be some correlation between the absence of fencing adjacent to the streambank and bank erosion so this item was also included on the worksheet.

Each individual of the field crew was given the necessary maps to locate the sample areas and to identify the soil series. They were also given instructions for completing the worksheet and definitions of the terms to be used in the study.

The field procedure was to walk along every stream in each sample area recording pertinent data on a worksheet. These worksheets were then sent to the Department of Statistics, Iowa State University, where the data was transferred to punch cards and processed by a computer.

During the summer of 1975, the five watersheds that had been selected for study by the Task C Work Group were examined. In addition two small watersheds being studied by the University of Wisconsin Water Resources Center were also examined.

The three largest watersheds, all of which were larger than 130 square miles, were studied using the sample technique used on the Maumee River Basin. The area the samples covered was from 16.7 to 25 percent of the watershed. The four smaller watersheds, which were less than 20 square miles in size, were sampled 100 percent. In other words, the entire watershed was divided into convenient sample plot sizes and each plot was field checked.

The soil series identified as major contributors to riverbank erosion were sampled and analyzed for the parameters selected by the Task C Technical Committee. No more than six soil series from each watershed contributed the majority of the volume of material lost by riverbank erosion. In the case of the smallest watershed one soil series contributed all the riverbank erosion material.

For these watersheds studied, an average of 10 percent of the streambanks are actively eroding. Cost for treatment of all these eroding banks would be $29.2 million.

For the entire basin it is estimated that the annual sediment yield to the Great Lakes from streambank erosion is slightly more than 617,000 tonnes (680,600 tons) or about 13 percent of the total sediment yield.

The cost of needed treatment for streambank protection in the U.S. portion of the Great Lakes Basin is nearly 213 million dollars.

Total phosphorus eroded from streambanks compared to that element in the stream, is the most important and largest chemical contributor. Slightly more than 344,000 kg/yr (756,800 lbs/yr) of phosphorus are delivered to the Great Lakes from streambank erosion. This represents less than four percent of that contributed by shoreline erosion from the U.S. side of the Great Lakes.

On a volume basis, riverbank erosion is a minor portion of the sediment yield and chemical contribution to the Great Lakes.

INTRODUCTION

This study was carried out as part of the effort of the Pollution from Land Use Activities Reference Group, an organization of the International Joint Commission, established under the Canada-United States Great Lakes Water Quality Agreement of 1972. Funding was provided by the U.S. Environmental Protection Agency through the Ohio Department of Natural Resources and the Great Lakes Basin Commission. Findings and conclusions are those of the author and do not necessarily reflect the views of the Reference Group or its recommendations to the Commission.

When this study was formulated neither funds nor time was available to accomplish a complete investigation on the entire basin. It was determined that only a small percentage of the basin could be studied and that examining a large number of randomly selected small areas was the best way to acquire accurate information on the various streambank conditions.

The Soil Conservation Service had previously done land inventory studies using this technique. The program called Conservation Needs Inventory (CNI) used, in most of the Great Lakes Basin, 160 acre sample areas selected on a random statistical basis that covered two percent of the total area (1). Soil surveys had been made on each of these sample areas and base maps showing their location were already available. It was decided to use these sample areas for the streambank erosion study.

When the concept for this study was first conceived its feasibility and cost was not known so a trial was conducted on the Maumee River Basin in 1974. After the concept was proved workable and the costs could be estimated more accurately it was decided that the major U.S. watersheds selected for study by Task C would be studied using techniques developed and used in the Maumee River Basin Riverbank Study.

STUDY OBJECTIVES

The objectives of the study are to evaluate the effect of material eroded from riverbanks on water quality of the Great Lakes, to determine measures for riverbank protection and the cost of such a program.

DATA COLLECTION METHODS

The field work on the pilot streambank erosion study began in the fall of 1974 on the Maumee River Basin where a two percent sample of the watershed was examined. Primary Sample Units (PSU's) of 160 acres in size from the CNI were examined for streambank erosion conditions.

The procedure was for an individual of the field crew to walk along every stream on each PSU recording pertinent data on a worksheet. These worksheets were then sent to the Statistical Department, Iowa State University where the data was transferred to punch cards and processed by a computer. The computer then expanded the data to the county, state, sub-basin and basin.

In order to maintain consistency it was necessary to define certain of the terms used in the study. These definitions included natural stream, modified stream, drainage ditch and the various land use and treatment categories (Appendix A).

Each individual of the field crew was given the necessary maps to locate the sample areas and to identify the soil series. They were also given instructions for completing the work sheet, and definitions of the terms used in the study (Appendix A).

The SCS from each state in the basin was asked to furnish an estimated weight for a cubic foot of soil from an eroding streambank. In order to compute the cost of existing treatment or treatment which was needed, the SCS from each state was asked to furnish a cost per mile for each treatment category.

Once the computer printout was available the soil series contributing to streambank erosion could be identified. Samples of the major horizons of the soil series were obtained and analyzed for the parameters selected by the Task C Technical Committee.

After it was determined that the Maumee Study yielded reasonable results and the cost figures were available it was decided that the major U.S. watersheds selected for study by Task C could be examined using similar techniques. In addition, two small watersheds in Wisconsin were included in the study at the request of the Wisconsin Department of Natural Resources. Figure 1 shows the location of the watersheds discussed in this report.

The field procedure was the same as in the Maumee River Basin study but the intensity of sampling was greater. Table 1 shows the sample intensity, the number of samples and the area of each of the watersheds studied.

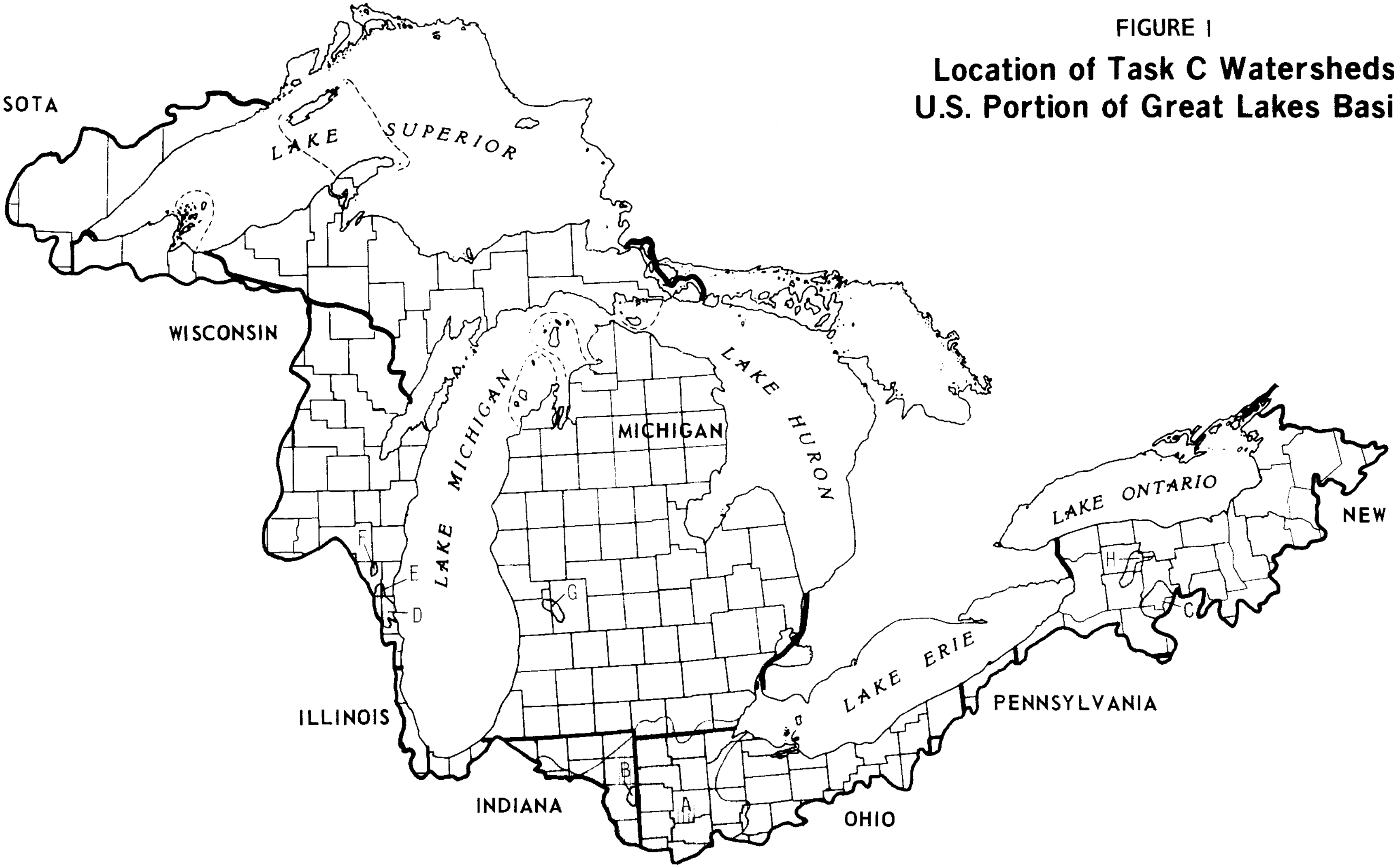


FIGURE I

Location of Task C Watersheds U.S. Portion of Great Lakes Basin

(A) Maumee River Basin
(B) Black Creek Watershed
(C) Canaseraga Creek Watershed
(D) Menomonee River Watershed
(E) Germantown Watershed
(F) Kewaskum Watershed
(G) Mill Creek Watershed
(H) Oatka Creek Watershed

TABLE 1 Sample Intensity, Number of Samples, & Size of Watersheds in the Great Lakes Basin Streambank Erosion Study

Watershed	Sample Intensity %	Number of Samples	Watershed Area (km^2)[a]
Maumee	2	597	17,920
Black Creek[b]	100	79	49
Canaseraga	16.7	260	865
Menomonee	25	134	352
Germantown[c]	100	19	12
Kewaskum	100	44	28
Mill Creek	100	87	53
Oatka Creek	16.7	157	559
Total		1,377	19,035

[a] To convert to square miles multiply by 0.3861

[b] Within the Maumee River Basin

[c] Within the Menomonee River Watershed

EXPERIMENTAL RESULTS

Maumee River Basin

The results of the Maumee River Basin streambank erosion study were reported in February 1975 (2). A summary of general data is shown in Table 2.

TABLE 2 General Data from the Maumee River Basin Streambank Erosion Study

	Natural Stream[a]	Modified Stream[a]	Drainage Ditch[a]	Total
Stream length (km)[b]	536	7,881	7,979	16,396
Bank kilometers of erosion	360	1,850	1,102	3,312
Bank erosion (tonnes/yr)[c]	6,152	50,791	40,969	97,912
Bank erosion (tonnes/km^2/yr)	0.34	2.83	2.29	5.46
Stream density (km/km^2)	0.03	0.44	0.45	0.92

[a] See Appendix A for definition

[b] To convert kilometers to miles multiply by 0.6214

[c] To convert tonnes to tons multiply by 1.103

Because there had been considerable publicity about and discussion of the natural streams in this area, it was interesting to find that natural streams represented only three percent of the total. There are slightly more drainage ditches than streams but the ditches erode slightly less than the streams.

One of the objectives of the study was to determine remedial measures for streambank protection and the cost of such a program. Table 3 shows the bank kilometers of treatment needs and the cost.

During the course of the field investigation a considerable amount of treatment was noted as having already been installed. It is not known when the treatment was installed or under what cost arrangements. Table 4 shows the existing treatment and the cost. It also shows that the majority of treatment needed and the required cost is for modified streams.

TABLE 3 Streambank Treatment Needs and Cost in the Maumee River Basin
(Bank kilometers and 1974 Dollars)

Treatment[a]	Natural Stream		Modified Stream		Drainage Ditch		Total	
	Bank km	cost	Bank km	cost	Bank km	cost	Bank km	cost
Management	0	0	72	288,582	8	34,909	80	323,491
Simple	245	1,980,125	1,405	10,629,445	1,057	5,440,839	2,707	18,050,409
Deflection	85	230,087	344	3,188,617	0	0	429	3,418,704
Armoring	13	1,109,024	27	2,462,396	35	241,588	75	3,813,008
Total	343	3,319,236	1,848	16,569,040	1,100	5,717,336	3,291	26,605,612

[a] See Appendix A for definitions of the various treatment categories

TABLE 4 Existing Streambank Treatment and Cost in the Maumee River Basin
(Bank kilometers and 1974 Dollars)

Treatment	Natural Stream		Modified Stream		Drainage Ditch		Total	
	Bank km	Cost	Bank km	Cost	Bank km	Cost	Bank km	Cost
Management	484	1,928,030	8,996	35,783,019	5,884	23,402,463	15,364	61,113,512
Simple	13	107,473	1,897	14,345,182	7,686	39,554,471	9,596	54,007,126
Deflection	0	0	23	27,634	0	0	23	27,634
Armoring	2	85,262	66	5,852,427	40	253,838	108	6,191,527
Total	499	2,120,765	10,982	56,008,262	13,610	63,210,772	25,091	121,339,799

Land owners in the Basin have already installed 25,091 bank kilometers (15,594 bank miles) of streambank treatment at a cost of $121,339,799. If this is compared to the 3,291 bank kilometers (2,046 bank miles) of treatment needed at a cost of $25,605,612 it can be seen that a large amount of treatment has already been installed.

The computer printout shows that 87 percent of the streambank erosion is contributed by eight soil series of the 65 identified during the study. Table 5 shows the calculated averate contribution of streambank erosion to chemical composition of the Maumee River at Waterville, Ohio.

TABLE 5 Calculated Chemical Contribution of Streambank Material for Maumee River Basin

Parameter		Chemical Contribution kg/yr
P	avail[a]	NA
	total	58,000
N	total	86,000
C	total	810,000
Ca	total N NH_4OAc	260,000
Mg	total N NH_4OAc	42,000
Na	total N NH_4OAc	4,000
K	total N NH_4OAc	5,900
Cu	total IN HNO_3	1,200
Pb	total IN HNO_3	870
Zn	total IN HNO_3	1,800
Cr	total IN HNO_3	130
Ni	total IN HNO_3	610
Cd	total IN HNO_3	40

[a] Soluble in 0.03N NH_4F, 0.025N HCl

BLACK CREEK WATERSHED

The results of the Black Creek Streambank Study were reported in January 1976(3). A summary of general data is shown in table 6.

TABLE 6 General Data from Black Creek Watershed Streambank Erosion Study

	Natural Stream[a]	Modified Stream[a]	Drainage Ditch[a]	Total
Stream length (km)[b]	0.0	41.7	3.6	45.3
Bank kilometers of erosion	0.0	6.0	1.6	7.6
Bank erosion (tonnes/yr)[c]	0.0	346.0	1.6	362.0
Bank erosion (tonnes/km^2/yr)	0.0	7.06	0.32	7.38
Stream density (km/km^2)	0.0	0.86	0.11	0.97

[a] Refer to Appendix A for definition

[b] To convert kilometers to miles multiply by 0.6214

[c] To convert tonnes to tons multiply by 1.103

In this watershed there are no natural streams, there are more kilometers of modified streams than drainage ditches and the modified streams erode more than drainage ditches.

The bank kilometers of needed treatment and the cost is shown in Table 7. A majority of treatment needed and the cost of such treatment is for modified streams.

During the field investigation a considerable amount of treatment was noted as having already been installed. It is not known when the treatment was installed or under what cost arrangements. Table 8 shows the bank kilometers of existing treatment and the cost.

Landowners in Black Creek Watershed have already installed 68.1 bank kilometers (42.3 bank miles) of streambank treatment at a cost of $265,151. If this is compared to the 11.7 bank kilometers (7.3 bank miles) of treatment needed at a cost of $72,420 it can be seen that a large amount of treatment has already been installed.

TABLE 7 Streambank Treatment Needs and Cost in Black Creek Watershed
(Bank kilometers and 1975 Dollars)

Treatment[a]	Natural Stream		Modified Stream		Drainage Ditch		Total	
	Bank km	Cost	Bank km	Cost	Bank km	Cost	Bank km	Cost
Management	0.0	0	0	0	0	0	0	0
Simple	0.0	0	7.6	31,896	2.6	7,342	10.2	39,238
Deflection	0.0	0	0	0	0	0	0	0
Armoring	0.0	0	1.5	33,182	0	0	1.5	33,182
Total	0.0	0	9.1	65,078	2.6	7,342	11.7	72,420

[a] Refer to Appendix A for definitions of treatment categories

TABLE 8 Existing Streambank Treatment and Cost in Black Creek Watershed
(Bank kilometers and 1975 Dollars)

Treatment	Natural Stream		Modified Stream		Drainage Ditch		Total	
	Bank km	Cost	Bank km	Cost	Bank km	Cost	Bank km	Cost
Management	0.0	0	25.7	33,580	8.2	10,755	33.9	44,335
Simple	0.0	0	29.4	123,763	0.2	517	29.6	124,280
Deflection	0.0	0	1.9	33,276	0	0	1.9	33,276
Armoring	0.0	0	2.7	63,270	0	0	2.7	63,260
Total	0.0	0	59.7	253,889	8.4	11,272	68.1	265,151

The computer printout shows that 95 percent of the streambank erosion is contributed by four soil series of the 12 identified during the study. Three of the soil series were sampled. Those three contribute 91 percent of the bank erosion. At the time this report was prepared chemical data of the stream discharge was not available to compare with data from the eroding banks so no evaluation was made.

CANASERAGA CREEK WATERSHED

The results of the Canaseraga Creek Watershed Streambank Erosion Study were reported in January 1976(4). A summary of general data is shown in Table 9.

TABLE 9 General Data from the Canaseraga Creek Watershed Streambank Erosion Study

	Natural Stream[a]	Modified Stream[a]	Drainage Ditch[a]	Total
Length of stream (km)[b]	69.0	512.6	110.2	691.8
Bank kilometers of erosion	0.2	59.4	14.3	73.9
Bank erosion (tonnes/yr)[c]	14	3,305.0	249.0	3,568.0
Bank erosion (tonnes/km^2/yr)	0.02	3.83	0.27	4.12
Stream density (km/km^2)	0.08	0.59	0.13	0.80

[a] See Appendix A for definition

[b] To convert kilometers to miles multiply by 0.6214

[c] To convert tonnes to tons multiply by 1.103

In this watershed where the concern about natural streams has not been very intense there is nearly ten percent natural streams. As in most watersheds studied, modified streams occur more frequently than any other and have more erosion.

The bank kilometers of needed treatment and the cost is shown in Table 10. This table also shows that the majority of treatment needed and the cost of the treatment is for modified streams.

During the field investigation a considerable amount of treatment was noted as having already been installed. It is not known when the treatment was installed or under what cost arrangements. Table 11 shows the bank kilometers of existing treatment and the cost.

Landowners in Canaseraga Creek Watershed have already installed 308 bank kilometers (192 bank miles) of streambank protection at a cost of $2,111,591. If this is compared to the nearly 74 kilometers (42 miles) of treatment needed at a cost of $2,111,591 it can be seen that a large amount of treatment has been installed.

TABLE 10 Streambank Treatment Needs and Cost in Canaseraga Creek Watershed
(Bank kilometers and 1975 Dollars)

Treatment[a]	Natural Stream		Modified Stream		Drainage Ditch		Total	
	Bank km	Cost	Bank km	Cost	Bank km	Cost	Bank km	Cost
Management	0.0	0	3.1	15,455	0.0	0	3.1	15,455
Simple	0.0	0	16.1	120,000	14.3	71,364	30.4	191,364
Deflection	0.0	0	26.4	302,727	0.0	0	26.4	302,727
Armoring	0.2	5,909	13.8	892,272	0.0	0	14.0	898,182
Total	0.2	5,909	59.4	1,330,454	14.3	71,364	74.9	1,407,728

[a] See Appendix A for definition of treatment categories

TABLE 11 Existing Streambank Treatment and Cost in Canaseraga Creek Watershed
(Bank kilometers and 1975 Dollars)

Treatment	Natural Stream		Modified Stream		Drainage Ditch		Total	
	Bank km	Cost	Bank km	Cost	Bank km	Cost	Bank km	Cost
Management	0.0	0	132.6	659,318	105.8	526,364	238.4	1,185,682
Simple	0.0	0	0.0	0	60.2	299,545	60.2	299,545
Deflection	0.0	0	0.0	0	0.0	0	0.0	0.0
Armoring	0.0	0	9.6	626,364	0.0	0	9.6	626,364
Total	0.0	0	142.2	1,285,682	166.0	825,909	308.2	2,111,591

The computer printout shows that 88 percent of the streambank erosion is contributed by six soil series of the 35 identified during the study. Table 12 shows the calculated average contribution of streambank erosion to chemical composition of Canaseraga Creek.

TABLE 12 Calculated Average Chemical Contribution of Streambank Erosion for Canaseraga Creek Watershed

Parameter		Streambank Erosion Contribution kg/yr
P	avail[a]	22
	total	1,500
N	total	4,300
C	total Org.	49,000
Ca	total 6N HCl	27,000
Mg	total 6N HCl	12,000
Na	total 6N HCl	140
K	total 6N HCl	NA
Cu	total 6N HCl	34
Pb	total 6N HCl	160
Zn	total 6N HCl	130[b]
Cr	total 6N HCl	34
Ni	total 6N HCl	82[b]
Cd	total 6N HCl	16[b]

[a] Soluble in 0.03N NH_4F, 0.025 N HCl

[b] Less than value given; none present in soil at detection limit of procedure used.

MENOMONEE RIVER WATERSHED

The results of the Menomonee River Watershed Streambank Erosion Study were reported in January 1976(5). A summary of general data is shown in Table 13.

TABLE 13 General Data from Menomonee River Watershed Streambank Erosion Study

	Natural Stream[a]	Modified Stream[a]	Drainage Ditch[a]	Total
Stream length (km[b])	0.0	175.4	49.4	224.8
Bank kilometers of erosion	0.0	36.0	5.8	41.8
Bank erosion (tonnes/yr)[c]	0.0	1,344.0	284.0	1,628.0
Bank erosion (tonnes/km^2/yr)	0.0	3.8	0.83	4.63
Stream density (km/km^2)	0.0	0.5	0.14	0.64

[a] Refer to Appendix A for definition

[b] To convert kilometers to miles multiply by 0.6214

[c] To convert tonnes to tons multiply by 1.103

In this largely urban watershed there were no natural streams. Modified streams again were the most important from the number of kilometers and amount of erosion standpoint.

The bank kilometers of needed treatment and the cost is shown in Table 14. A majority of the treatment needed and the cost is for modified streams.

During the field investigation a considerable amount of treatment was noted as having already been installed. It is not known when the treatment was installed or under what cost arrangements. Table 15 shows the bank kilometers of existing treatment and the cost.

Landowners in the Menomonee River Watershed have already installed a large amount of treatment. If the 140 bank kilometers (87 bank miles) installed at a cost of nearly 15 million dollars is compared to that which is needed, 41.8 kilometers (26 miles) at slightly more than 1.5 million dollars it can be seen that most of the treatment has been installed.

TABLE 14 Streambank Treatment Needs and Cost in the Memomonee River Watershed
(Bank kilometers and 1975 Dollars)

Treatment[a]	Natural Stream		Modified Stream		Drainage Ditch		Total	
	Bank km	Cost	Bank km	Cost	Bank km	Cost	Bank km	Cost
Management	0.0	0	0.0	0	0.0	0	0.0	0
Simple	0.0	0	24.3	158,295	5.3	27,682	29.6	185,977
Deflection	0.0	0	8.2	81,697	0.0	0	8.2	81,697
Armoring	0.0	0	3.5	1,287,364	0.5	30,879	4.0	1,318,243
Total	0.0	0	36.0	1,527,356	5.8	58,561	41.8	1,585,917

[a] Refer to Appendix A for definitions of treatment categories

TABLE 15 Existing Streambank Treatment and Cost in Menomonee River Watershed
(Bank kilometers and 1975 Dollars)

Treatment	Natural Stream		Modified Stream		Drainage Ditch		Total	
	Bank km	Cost	Bank km	Cost	Bank km	Cost	Bank km	Cost
Management	0.0	0	41.8	174,251	57.8	240,363	99.6	414,614
Simple	0.0	0	0.0	0	0.0	0	0.0	0
Deflection	0.0	0	0.0	0	0.0	0	0.0	0
Armoring	0.0	0	40.4	14,493,788	0.0	0.0	40.4	14,493,788
Total	0.0	0	82.2	14,668,039	57.8	240,363	140.0	14,908,402

The computer printout shows that 93 percent of the streambank erosion is contributed by eight soil series of the 28 identified during the study. Table 16 shows the calculated average composition of streambank erosion to the chemical compositon of the Menomonee River.

TABLE 16 Calculated Average Chemical Contribution of Streambank Erosion for Menomonee River Watershed

Parameter		Streambank Erosion Contribution kg/yr
P	avail[a]	12
	total	1,200
N	total	5,500
C	total Org.	39,000
Ca	total 6N HCl	33,000
Mg	total 6N HCl	24,000
Na	total 6N HCl	250
K	total 6N HCl	NA
Cu	total 6N HCl	39
Pb	total 6N HCl	160[b]
Zn	total 6N HCl	160
Cr	total 6N HCl	60
Ni	total 6N HCl	81[b]
Cd	total 6N HCl	16[b]

[a] Soluble in 0.03N NH_4F, 0.025 N HCl

[b] Less than value given; none present in soil at detection limit of procedure used

GERMANTOWN WATERSHED

The results of the Germantown Watershed Streambank Erosion Study were reported in January 1976(6). At the request of the State of Wisconsin for a more intensive study, the minimum stream depth was reduced from one meter (three feet) to 0.6 meter (two feet). A summary of general data is shown on Table 17.

TABLE 17 General Data from Germantown Watershed Streambank Erosion Study

	Natural Stream[a]		Modified Stream[a]		Drainage Ditch[a]		Total	
	1.0m+	0.6m+	1.0m+	0.6m+	1.0m+	0.6m+	1.0m+	0.6m+
Stream length (km)[b]	0.0	0.0	0.6	7.2	3.1	3.1	3.7	10.3
Bank kilometers of erosion	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3
Bank erosion (tonnes/yr)[c]	0.0	0.0	0.0	0.0	8.2	8.2	8.2	8.2
Bank erosion (tonnes/km^2/yr)	0.0	0.0	0.0	0.0	0.68	0.68	0.68	0.68
Stream density (km/km^2)	0.0	0.0	0.04	0.58	0.25	0.25	0.29	0.83

[a] Refer to Appendix A for definition of stream

[b] To convert kilometers to miles by 0.6214

[c] To convert tonnes to tons multiply by 1.103

In this small watershed, on the fringe of an urban area, no natural streams were recognized. While there were more kilometers of modified streams than drainage ditches it was the drainage ditches which were eroding. Increasing the intensity of the study to a minimum 0.6 meter depth of stream increased the stream kilometers by 2.8 times but did not increase the bank kilometers of erosion or the tonnes of erosion per year.

The only treatment needed on this watershed was 0.3 of a bank kilometer (0.2 mile) of simple treatment on drainage ditches at a cost of $1,591.

Some existing treatment was also recognized. Table 18 shows the bank kilometers of existing treatment and Table 19 shows the cost.

TABLE 18 Existing Streambank Treatment in Germantown Watershed
(Bank kilometers)

Treatment	Natural Stream		Modified Stream		Drainage Ditch		Total	
	1.0m$^+$	0.6m$^+$	1.0m$^+$	0.6m$^+$	1.0m$^+$	0.6m$^+$	1.0m$^+$	0.6m$^+$
Management	0.0	0.0	0.3	1.3	1.1	1.1	1.4	2.4

TABLE 19 Existing Streambank Treatment Cost in Germantown Watershed
(1975 Dollars)

Treatment	Natural Stream		Modified Stream		Drainage Ditch		Total	
	1.0m$^+$	0.6m$^+$	1.0m$^+$	0.6m$^+$	1.0m$^+$	0.6m$^+$	1.0m$^+$	0.6m$^+$
Management	0.0	0.0	1,269	5,456	4,949	4,949	6,218	10,405

All the existing treatment recognized was defined as management. When treatment installed is compared to treatment needed it can be seen that landowners in Germantown Watershed have already installed a majority of the bank protection.

The computer printout shows that 100 percent of the streambank erosion is contributed by one soil series of the 15 identified during the study.

At the time this report was prepared chemical data of the stream discharge were not available to compare with data from the eroding banks so no evaluation was made.

KEWASKUM WATERSHED

The results of the Kewaskum Watershed Streambank Erosion Study were reported in January 1976(7). At the request of the State of Wisconsin for a more intensive study, the mimimum stream depth was reduced from one meter (three feet) to 0.6 meter (two feet). A summary of general data is shown on Table 20.

TABLE 20 General Data from Kewaskum Watershed Streambank Erosion Study

	Natural Stream[a]		Modified Stream[a]		Drainage Ditch[a]		Total	
	1.0m^{+}	0.6m^{+}	1.0m^{+}	0.6m^{+}	1.0m^{+}	0.6m^{+}	1.0m^{+}	0.6m^{+}
Stream length (km)[b]	0.0	0.0	10.8	17.9	4.5	4.5	15.3	22.4
Bank kilometers of erosion	0.0	0.0	4.3	4.3	0.0	0.0	4.3	4.3
Bank erosion (tonnes/yr)[c]	0.0	0.0	50.8	50.8	0.0	0.0	50.8	50.8
Bank erosion (tonnes/km^2)	0.0	0.0	1.81	1.81	0.0	0.0	1.81	1.81
Stream density (km/km^2)	0.0	0.0	0.39	0.64	0.16	0.16	0.55	0.80

[a] See Appendix A for definition

[b] To convert kilometers to miles multiply by 0.6214

[c] To convert tonnes to tons multiply by 1.103

No natural streams were recognized in this watershed. Modified streams have all the eroding banks. Increasing the intensity of the study to a minimum 0.6 meter (two feet) depth of streambank increased the modified streams by 1.7 times but did not increase the bank kilometers of erosion or the tonnes of erosion per year.

The only treatment needed on this watershed was 4.3 bank kilometers (2.7 bank miles) of simple treatment on modified streams at a cost of $22,750.

Some existing treatment was also recognized. Table 21 shows the bank kilometers of existing treatment and Table 22 shows the cost.

TABLE 21 Existing Streambank Treatment in Kewaskum Watershed
(Bank Kilometers)

Treatment	Natural Stream		Modified Stream		Drainage Ditch		Total	
	$1.0m^+$	$0.6m^+$	$1.0m^+$	$0.6m^+$	$1.0m^+$	$0.6m^+$	$1.0m^+$	$0.6m^+$
Management	0.0	0.0	0.0	0.8	3.1	3.1	3.1	3.9
Simple	0.0	0.0	0.2	0.8	0.1	0.1	0.3	0.9
Total	0.0	0.0	0.2	1.6	3.2	3.2	3.4	4.8

TABLE 22 Existing Streambank Treatment Cost in Kewaskum Watershed
(1975 Dollars)

Treatment	Natural Stream		Modified Stream		Drainage Ditch		Total	
	1.0^+ft	0.6^+ft	1.0^+ft	0.6^+ft	1.0^+ft	0.6^+ft	1.0^+ft	0.6^+ft
Management	0.0	0.0	0.0	5,583	21,064	21,064	21,064	26,647
Simple	0.0	0.0	1,273	6,682	995	995	2,228	7,637
Total	0.0	0.0	1,273	12,265	22,059	22,059	23,292	34,284

When the treatment that had been applied is compared to that which is needed it can be seen that the landowners in Kewaskum Watershed have installed slightly over half.

The computer printout shows that 100 percent of the streambank erosion is contributed by two soil series of the ten identified during the study.

At the time this report was prepared chemical data of the stream discharge were not available to compare with data from the eroding banks so no evaluation was made.

MILL CREEK WATERSHED

The results of the Mill Creek Watershed Streambank Erosion Study were reported in January 1976(8). A summary of general data is shown in Table 23.

TABLE 23 General Data from Mill Creek Watershed Streambank Erosion Study

	Natural Stream[a]	Modified Stream[a]	Drainage Ditch[a]	Total
Stream length (km)[b]	0.0	38.1	9.5	47.6
Bank kilometers of erosion	0.0	2.7	2.4	5.1
Bank erosion (tonnes/yr)[c]	0.0	146	113	259
Bank erosion (tonnes/km^2/yr)	0.0	2.76	2.13	4.89
Stream density (km/km^2)	0.0	0.71	0.18	0.89

[a] Refer to the Appendix A for definition

[b] To convert kilometers to miles multiply by 0.6214

[c] To convert tonnes to tons multiply by 1.103

There were no natural streams recognized in this watershed. As in many of the watersheds studied, modified streams were in the majority, but in this case drainage ditches almost equaled them in bank kilometers of erosion and tonnes of erosion per year.

The bank kilometers of needed treatment and the cost is shown on Table 24.

As shown in the above table bank kilometers of treatment is about equally divided between modified streams and drainage ditches. The cost of treatment of modified streams is about 60 percent of the total. A cost was recorded for armoring under modified streams but no bank kilometers of treatment were needed. The reason for this is the computer program was designed to record bank miles to the nearest tenth of a mile and this figure was less than a half a tenth.

TABLE 24 Streambank Treatment Needs and Cost in Mill Creek Watershed
(Bank kilometers and 1975 Dollars)

Treatment[a]	Natural Stream		Modified Stream		Drainage Ditch		Total	
	Bank km	Cost	Bank km	Cost	Bank km	Cost	Bank km	Cost
Management	0.0	0	1.3	2,652	0.8	1,723	2.1	4,375
Simple	0.0	0	1.5	7,833	1.6	6,008	3.1	13,841
Deflection	0.0	0	0.0	0	0.0	0	0.0	0
Armorning	0.0	0	0.0	2,462	0.0	0	0.0	2,462
Total	0.0	0	2.8	12,947	2.4	7,731	5.2	20,678

[a] See Appendix A for definitions of treatment categories.

TABLE 25 Existing Streambank Treatment and Cost in Mill Creek Watershed
(Bank kilometers and 1975 Dollars)

Treatment	Natural Stream		Modified Stream		Drainage Ditch		Total	
	Bank km	Cost	Bank km	Cost	Bank km	Cost	Bank km	Cost
Management	0.0	0	5.5	11,866	13.7	29,697	19.2	41,563
Simple	0.0	0	0.5	2,667	1.5	5,777	2.0	8,444
Deflection	0.0	0	0.0	0	0.0	0	0.0	0
Armoring	0.0	0	1.3	49,858	0.0	0.0	1.3	49,858
Total	0.0	0	7.3	64,391	15.2	35,474	22.5	99,865

During the field investigation a considerable amount of treatment was noted as having already been installed. It is not known when the treatment was installed or under what cost arrangements. Table 25 shows the bank kilometers of existing treatment and the cost.

It is obvious that landholders in the Mill Creek Watershed have already installed much streambank treatment. If the 22.5 bank kilometers (13.9 bank miles) installed at a cost of $13,865 is compared to that which is needed, 5.2 kilometers (3.2 miles) at a cost of $20,678, it can be seen that most of the treatment has been installed.

The computer printout shows that 92 percent of the streambank erosion is contributed by eight soil series of the 20 identified during the study. Two of these series which contribute 83 percent of the erosion were sampled for chemical parameters. Table 26 shows the calculated average contribution of streambank erosion to the chemical composition of Mill Creek.

TABLE 26 Calculated Average Chemical Contribution of Streambank Erosion for Mill Creek Watershed

Parameter		Streambank Contribution kg/yr
P	avail[a]	4
	total	65
N	total	490
C	total org.	5,900
Ca	total 6N HCl	1,600
Mg	total 6N HCl	89
Na	total 6N HCl	910
K	total 6N HCl	NA
Cu	total 6N HCl	1.1
Pb	total 6N HCl	26
Zn	total 6N HCl	8.2[b]
Cr	total 6N HCl	3.9
Ni	total 6N HCl	13.0[b]
Cd	total 6N HCl	2.6[b]

[a] Soluble in 0.03N NH_4F, 0.025N HCl

[b] Less than value given; none present in soil at detection limit of procedure used

OATKA CREEK WATERSHED

The results of the Oatka Creek Watershed Streambank Erosion Study were reported in January 1976(9). A summary of general data is shown in Table 27.

TABLE 27 General Data From Oatka Creek Watershed Streambank Erosion Study

	Natural Stream[a]	Modified Stream[a]	Drainage Ditch[a]	Total
Stream length (km)[b]	29.5	245.5	66.0	341.0
Bank kilometers of erosion	0.0	31.7	8.2	39.9
Bank erosion (tonnes/yr)[c]	0.0	752	256	1.008
Bank erosion (tonnes/km^2/yr)	0.0	1.34	0.46	1.80
Stream density (km/km^2)	0.05	0.44	0.12	0.6

[a] Refer to Appendix A for definition

[b] To convert kilometers to miles multiply by 0.6214

[c] To convert tonnes to tons multiply 1.103

In this watershed where concern about natural streams has not been very intense there are nearly 12 percent natural streams. As in most watersheds studied modified streams occur more frequently than any other kind and have more erosion.

The bank kilometers of needed treatment and the cost is shown in Table 28, as well as the fact that the majority of the treatment needed and the cost of treatment is for modified streams.

During the investigation a considerable amount of treatment was noted as having already been installed. It is not known when the treatment was installed or under what cost arrangements. Table 29 shows the bank kilometers of existing treatment and the cost.

Landowners in Oatka Creek Watershed have already installed 73 bank kilometers (46 bank miles) of streambank treatment at a cost of $447,455. If this is compared to the 40 kilometers (238 miles) of treatment needed at a cost of $551,727 it can be seen that much treatment has been applied but the most expensive still remains to be done.

TABLE 28 Streambank Treatment Needs and Cost in Oatka Creek Watershed
(Bank kilometers and 1975 Dollars)

Treatment[a]	Natural Stream		Modified Stream		Drainage Ditch		Total	
	Bank km	Cost	Bank km	Cost	Bank km	Cost	Bank km	Cost
Management	0.0	0	1.8	9,091	0.0	0	1.8	9,091
Simple	0.0	0	19.0	141,545	6.1	30,000	25.1	171,545
Deflection	0.0	0	7.6	87,455	0.0	0	7.6	87,455
Armoring	0.0	0	3.2	212,727	2.3	70,909	5.5	283,636
Total	0.0	0	31.6	450,818	8.4	100,909	40.0	551,727

[a] See Appendix A for definitions of Treatment categories.

TABLE 29 Existing Streambank Treatment and Cost in Oatka Creek Watershed
(Bank kilometers and 1975 Dollars)

Treatment	Natural Stream		Modified Stream		Drainage Ditch		Total	
	Bank km	Cost	Bank km	Cost	Bank km	Cost	Bank km	Cost
Management	0.0	0	0.0	0	29.5	146,727	29.5	146,727
Simple	0.0	0	4.8	35,455	37.7	187,273	42.5	222,728
Deflection	0.0	0	0.0	0	0.0	0	0.0	0
Armoring	0.0	0	1.3	78,000	0.0	0	1.3	78,000
Total	0.0	0	6.1	113,455	67.2	334,000	73.3	447,455

The computer printout shows that 80 percent of the streambank erosion is contributed by eight soil series of the 51 identified during the study. Table 30 shows the calculated average contribution of streambank erosion to the chemical composition of Oatka Creek.

TABLE 30 Calculated Average Chemical Contribution of Streambank Material for Oatka Creek Watershed

Parameter		Chemcial Contribution kg/yr
P	avail[a]	2.1
	total	390
N	total	990
C	total ORI.	8,400
Ca	total 6N HCl	19,000
Mg	total 6N HCl	8,700
Na	total 6N HCl	58
K	total 6N HCl	NA
Cu	total 6N HCl	13
Pb	total 6N HCl	68
Zn	total 6N HCl	57[b]
Cr	total 6N HCl	17
Ni	total 6N HCl	35[b]
Cd	total 6N HCl	7[b]

[a] Soluble in 0.03 N NH_4F, 0.025 N HCl

[b] Less than value given; none present in soil at detection limit of procedure used

DATA ANALYSIS AND INTERPRETATION

It is one thing to measure the amount of erosion occurring on streambanks in a watershed. It is yet another proposition to estimate or calculate the amount of this eroded streambank material which appears as sediment yield at the lower end of the watershed. Considerable judgment, evaluation of grain size distribution of material in the stream and comparison with computed sheet erosion are methods used to estimate the sediment yield of eroded streambank material.

Not all the sediment eroded from streambanks each year will be delivered to a downstream site. Some of the eroded material is coarser than the stream can transport, some is deposited as overbank deposition, some makes up a portion of point bar deposition downstream from the source of erosion, and some is dredged from the stream and used as fill or construction material. The selection of a sediment delivery ratio for streambank erosion takes into account many factors which require a great deal of judgment. Table 31 shows the streambank delivery ratios selected and their effect on sediment yield from that source.

As can be assumed from the above discussion, sediment yields from streambank erosion are not precise and absolute figures but they can be considered to be within an order of magnitude. Cost of streambank treatment is also not a precise figure but can be considered reasonable. It should be kept in mind that it is doubtful that treatment would be installed at every location where needed and in the proper manner under any program. Even if it were, streambank erosion would not be reduced to zero. But assuming that all needed treatment were installed and no more bank erosion occurred, the cost for eliminating streambank erosion is very high. Table 32 shows the sediment yield from streambank erosion and the streambank contribution to the total sediment yield of the watersheds studied.

Streambank contribution to the total sediment yield of each watershed varies from less than one percent to ten percent. The highest percentage, that of the Menomonee River, can be attributed to the fact that the watershed is urban and urbanizing. An urban watershed tends to have an increase in bank erosion and decrease in sheet erosion thus increasing the contribution of streambank erosion to the total. Strangely, Germantown Watershed with the least contribution from streambank erosion is within the Menomonee River Watershed. The reason for this small contribution is less clear. Possibly because it is very small and the topography is very flat is the reason.

The cost of treatment per assumed tonne of sediment yield controlled also varies widely. This can be explained simply by noting the highest cost is in an urban area with high land values and with expensive treatment required. The low value is because the treatment required was "simple" and not very expensive.

TABLE 31 Streambank Erosion, Delivery Ratio and Sediment Yield by Watershed

Watershed	Streambank erosion (tonnes/yr)	Delivery ratio (%)	Sediment yield from streambank erosion (tonnes/yr)
Maumee River	97,911	70	68,540
Black Creek[a]	362	58	210
Canaseraga Creek	3,568	62	2,210
Menomonee River	1,628	86	1,400
Germantown[b]	8.2	62	5
Kewaskum	50.8	68	35
Mill Creek	259	57	150
Oatka Creek	1,008	57	580

[a] Within Maumee River Basin

[b] Within Menomonee River Watershed

TABLE 32 Sediment Yield from Streambank Erosion and Streambank Contribution to Total sediment Yield for Each Watershed Studied

Watershed	Sediment Yield from Streambank Erosion	Streambank Contribution to Total Sediment Yield of Watershed
	Tonnes/year	%
Maumee River	68,540	7
Black Creek[a/]	210	6
Canaseraga Creek	2,210	1
Menomonee River	1,400	10
Germantown[b/]	5	1
Kewaskum	35	3
Mill Creek	150	5
Oatka Creek	580	4

[a/] Within Maumee River Basin

[b/] Within the Menomonee River Watershed

TABLE 33 Streambank Chemical Contribution as Percent of Chemicals in the River Waters

Parameter	Maumee River	Canaseraga Creek	Menomonee River	Mill Creek	Oatka Creek
P avail	NA	0.3	NA	NA	0.08
total	2.2	4.7	3.2	14	9.8
N total	0.35	2.7	2.0	2.2	1.6
C total org.	1.5	3.0	3.0	12	1.2
Ca total	0.09	0.2	0.6	0.2	0.1
Mg total	0.05	0.2	1.1	0.3	0.3
Na total	0.04	0.004	0.9	0.6	0.002
K total	0.03	NA	NA	NA	NA
Cu total	1.5	NA	0.9	0.1[b]	NA
Pb total	1.6	NA	1.6	0.7[b]	NA
Zn total	0.4	NA	1.7[a]	NA	NA
Cr total	0.3	NA	4.2	0.1[b]	NA
Ni total	NA	NA	5.0[a]	NA	NA
Cd total	0.9	NA	13.0[a]	NA	NA

[a] Less than value given; none present in soil at detection limit of procedure used

[b] Greater than value given; none present in soil at detection limit of procedure us

In any case the cost of treatment per tonne of sediment yield reduced ranges from $139 to $1,113. This cost would be to reduce material that now ranges from less than one percent to ten percent of the total sediment yield.

Table 32 indicated that sediment yield from streambank erosion is usually less than 10 percent of the total yield and Table 33 shows that the largest chemical contribution, total phosphorous, does not exceed 14 percent of the phosphorous in the stream. This would indicate that streambank erosion from these watersheds was not a large contributor to the pollution of the Great Lakes. Streambank erosion may even be an insignificant source of sediment and chemicals to the Great Lakes when it is considered that much of the streambank material chemical load is bound to sediment and may never dissolve in stream or lake waters. Also, the sediment delivery ratios discussed previously apply to the actual material eroded from streambanks. Many streams with actively eroding banks will maintain a constant width for years as bars build up opposite eroding banks. Streambank erosion in such cases is not a primary sediment source, but merely the natural reworking of floodplain alluvium.

The cost of streambank treatment for each tonne of sediment yield controlled is quite high. This cost is for controlling sediment yield of less than 10 percent of the total. The thought occurs that the same amount of money spent on land treatment to reduce sheet and rill erosion would reduce the sediment yield a much greater amount.

EXPANSION OF DATA TO U.S. PORTION OF GREAT LAKES BASIN

It is obvious that examination of 1,377 sample plots in watersheds totaling 19,035 square kilometers (7,350 square miles) provided meager data from which to expand to a basin of 305,900 aquare kilometers (118,100 square miles) less water areas. Particularly when the samples did not include all vegative types, geologic, physiographic and soils conditions.

A decision was made to use the Land Resource Regions (LRR) and Land Resource Areas (LRA) as a basis for expansion. There are four Land Resource Regions and 20 Land Resource Areas in the U.S. portion of the Great Lakes Basin (10,13). Figure 2 shows the location of the Land Resource Regions and Areas.

Land Resource Areas consist of geographically associated land resource units which are areas of land that are characterized by particular patterns of soil (including slope and erosion), climate, water resources, land use, and type of farming. Land Resource Regions consist of geographically associated major land resource areas.

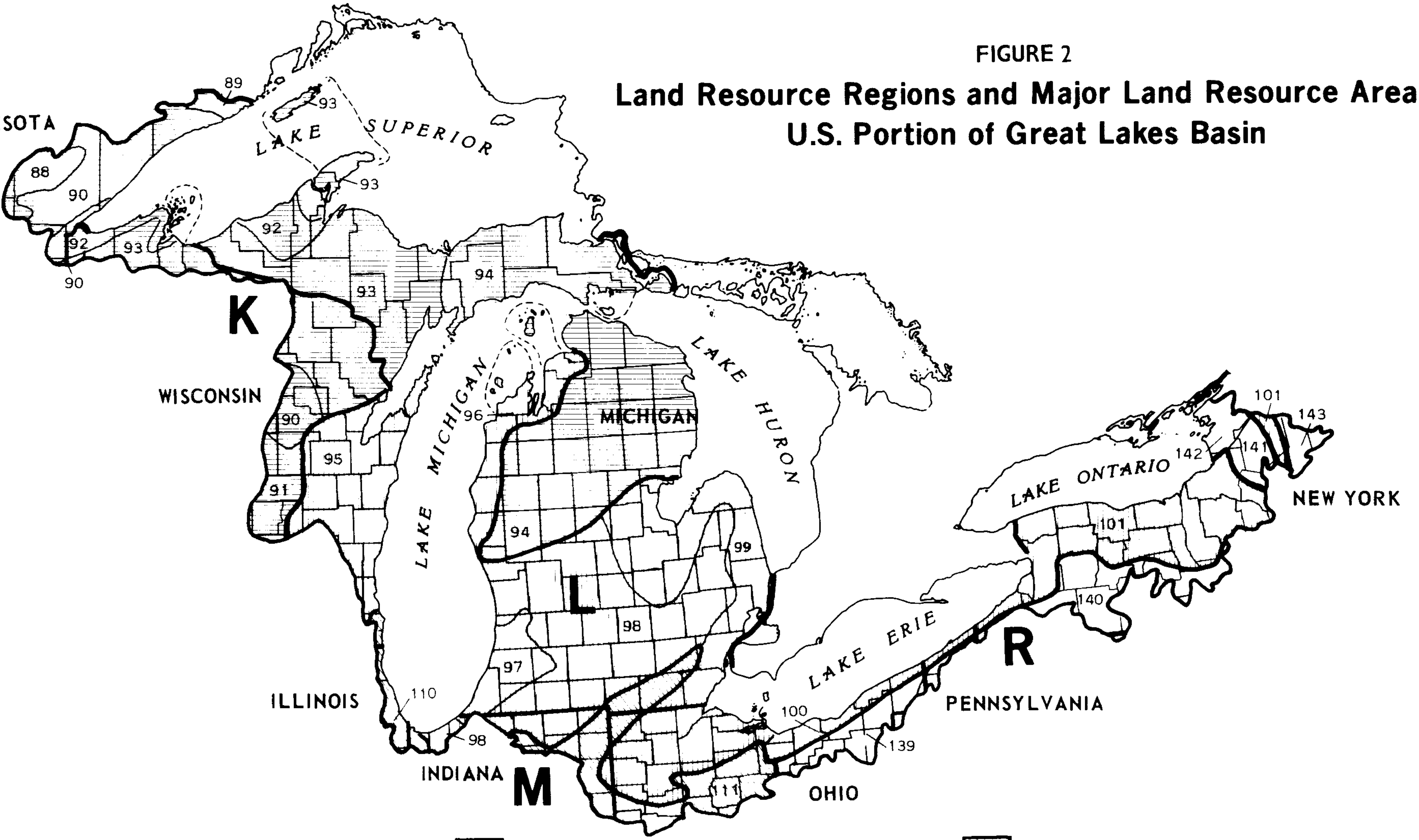
Each LRA was compared to each watershed studied and the watershed with the most factors in common was selected as the representative watershed for the LRA. Then parameters from the watershed such as streambank erosion rate, delivery ratio, stream density, percent of streambank kilometers needing treatment and average cost of treatment were used to develop tables which show sediment yield from bank erosion and the cost of needed treatment.

Table 34 shows that the annual sediment yield from streambanks to the Great Lakes is 617,110 tonnes (680,610 tons). Table 35 indicates the cost of streambank treatment needed is nearly 213 million 1975 dollars.

The estimated annual sediment yield from sheet and gully erosion to the Great Lakes is 4,316,200 tonnes (4,760,770 tons) (11). The estimated sediment yield from streambank erosion as shown on table 34 is 617,110 tonnes (680,670 tons) for a total sediment yield from the U.S. portion of the Great Lakes of 4,933,310 tonnes (5,441,440 tons) annually. This makes the contribution from streambank erosion about 13 percent of the total. This percentage is larger than for any watershed studied but it can probably be explained by noting that LRA 93 and 94 which are 30 percent of the Basin are 80 percent forest. Forested lands were not well represented by the watersheds studied but it can be assumed that sheet and rill erosion in these areas is low. Most of these areas are sandy which would tend to increase streambank erosion, at least in relation to that from sheet and rill.

FIGURE 2

Land Resource Regions and Major Land Resource Areas U.S. Portion of Great Lakes Basin



K NORTHERN LAKE STATES FOREST AND FORAGE REGION

- 88 *Northern Minnesota Swamps and Lakes*
- 89 *Minnesota Rockland Hills*
- 90 *Central Wisconsin and Minnesota Thin Loess and Till*
- 91 *Wisconsin and Minnesota Sandy Outwash*
- 92 *Superior Lake Plain*
- 93 *Northern Michigan and Wisconsin Stony, Sandy and Rocky Plains and Hills*
- 94 *Northern Michigan Sandy Drift*

L LAKE STATES FRUIT, TRUCK, AND DAIRY REGION

- 95 *Southeastern Wisconsin Drift Plain*
- 96 *Western Michigan Fruit Belt*
- 97 *Southwestern Michigan Fruit and Truck Belt*
- 98 *Southern Michigan Drift Plain*
- 99 *Erie - Huron Lake Plain*
- 100 *Erie Fruit and Truck Area*
- 101 *Ontario - Mohawk Plain*

M CENTRAL FEED GRAINS AND LIVESTOCK REGION

- 110 *Northern Illinois and Indiana Heavy Till Plain*
- 111 *Indiana and Ohio Till Plain*

R NORTHEASTERN FORAGE AND FOREST REGION

- 139 *Eastern Ohio Till Plain*
- 140 *Glaciated Allegheny Plateau and Catskill Mountains*
- 141 *Tughill Plateau*
- 142 *St. Lawrence - Champlain Plain*
- 143 *Northeastern Mountains*

The cost of treatment of sediment yield from streambank erosion is very high for the benefits which could accrue. If the total cost needed for streambank treatment were instead spent for land treatment to prevent sheet and rill erosion the resulting sediment yield decrease would be much larger. The benefits from a reduction of sheet and rill erosion would be greater still when it is considered that most contaminants from agricultural land are attached to the fine particles removed by sheet and rill erosion.

The confidence level for an expansion of chemical data from streambank erosion to the basin is less than for the procedure for determining sediment yield from streambank erosion or the cost of streambank treatment. This is because only five of the eight watersheds studied had chemical data of the stream discharge to compare with data from the eroding banks. Also, information on every parameter on each watershed was not available.

Total phosphorus eroded from streambanks compared to that element in the stream, is the most important and largest chemical contributor. Using phosphorus as a "worst case" example of the chemical parameters and expanding to the basin with the constraints listed above shows that slighly more than 344,000 kg/yr (756,800 lbs/yr) are delivered to the Great Lakes from streambank erosion. This represents less than four percent of that contributed by shoreline erosion on the U.S. side of the Great Lakes (12).

TABLE 34 Estimated Annual Sediment Yield from Streambank Erosion, U.S. Portion of Great Lakes Basin

Land Resource Region and Area	Area (km^2)	Representative Watershed	Streambank Erosion Rate (tonnes/km^2)	Streambank Erosion (tonnes)	Streambank Delivery Ratio %	Sediment Yield From Bank Erosion(tonnes)
K 88	3,800	Germantown	0.64	2,430	62	1,510
K 89	1,500	Germantown	0.64	960	62	600
K 90	4,200	Germantown	0.64	2,690	62	1,670
K 91	2,600	Kewaskum	1.83	4,760	68	3,240
K 92	7,800	Black Creek	7.43	57,950	58	33,610
K 93	38,300	Germantown	0.64	24,510	62	15,200
K 94	52,800	Germantown	0.64	33,790	62	20,950
Subtotal	111,000			127,090		76,780
L 95	23,400	Kewaskum	1.83	42,820	68	29,120
L 96	6,500	Kewaskum	1.83	11,900	68	8,090
L 97	4,400	Mill Creek	4.88	21,470	57	12,240
L 98	41,100	Mill Creek	4.88	200,570	57	114,320
L 99	36,100	Maumee	5.46	197,110	70	137,980
L 100	7,000	Maumee	5.46	38,220	70	26,750
L 101	20,900	Oatka	1.80	37,620	57	21,440
Subtotal	139,400			549,710		349,940
M 110	3,100	Menomonee	4.62	14,320	86	12,320
M 111	18,900	Black Creek	7.43	140,430	58	81,450
Subtotal	22,000			154,750		93,770
R 139	8,300	Black Creek	7.43	61,670	58	35,770
R 140	15,900	Canaseraga	4.12	65,510	62	40,610
R 141	3,900	Canaseraga	4.12	16,070	62	9,960
R 142	2,300	Oatka	1.80	4,140	57	2,360
R 143	3,100	Canaseraga	4.12	12,770	62	7,920
Subtotal	33,500			160,160		96,620
Total	305,900			991,710		617,110

TABLE 35 Cost of Needed Streambank Protection U.S. Portion of Great Lakes Basin

Land Resource Region and Area	Area (km^2)	Representative Watershed	Stream Density (km/km^2)	Percent of Stream Needing Treatment	Treatment cost Per Bank Kilometer	Cost (Dollars)
K 88	3,800	Germantown	0.29	1.5	4,940	163,300
K 89	1,500	Germantown	0.29	1.5	4,940	64,500
K 90	4,200	Germantown	0.29	1.5	4,940	180,500
K 91	2,600	Kewaskum	0.55	9.6	5,290	1,452,400
K 92	7,800	Black Creek	0.97	8.4	6,250	7,944,300
K 93	38,300	Germantown	0.29	1.5	4,940	1,646,100
K 94	52,800	Germantown	0.29	1.5	4,940	2,269,200
Subtotal	111,000					13,558,300
L 95	23,400	Kewaskum	0.55	9.6	5,290	13,071,800
L 96	6,500	Kewaskum	0.55	9.6	5,290	3,631,100
L 97	4,400	Mill Creek	0.89	5.4	4,020	1,700,200
L 98	41,400	Mill Creek	0.89	5.4	4,020	15,997,100
L 99	36,100	Maumee	0.92	10.1	7,770	52,127,600
L 100	7,000	Maumee	0.92	10.1	7,770	10,107,800
L 101	20,900	Oatka	0.61	5.9	15,820	23,799,300
Subtotal	139,400					120,434,900
M 110	3,100	Menomonee	0.64	9.3	37,900	13,986,100
M 111	18,900	Black Creek	0.97	8.4	6,250	19,249,700
Subtotal	22,000					33,235,800
R 139	8,300	Black Creek	0.97	8.4	6,250	8,453,600
R 140	15,900	Canaseraga	0.80	5.3	19,060	25,699,000
R 141	3,900	Canaseraga	0.80	5.3	19,060	6,303,500
R 142	2,300	Oatka	0.61	5.9	13,820	2.288,000
R 143	3,100	Canaseraga	0.80	5.3	19,060	5,010,500
Subtotal	33,500					45,754,600
Total	305,900					212,983,600

APPENDIX A

Definitions and Land Use Categories

DEFINITION OF STREAM

For the purpose of this study there are three types of streams. They are natural streams, modified streams, and drainage ditches.

Natural streams - a body of running water which flows a major portion of the year and has a clearly defined channel with a bank height of three feet or more. This stream cannot have been modified by man by straightening, bank shaping, etc.

Modified streams - same as above except they have been altered by man.

Drainage ditches - a channel dug by man. It can be either perennial, intermittent or ephemeral but the bank height shall be four feet or more.

LAND USE CATEGORIES

U - Urban and Built-up areas: Areas that include (a) cities, villages and built-up areas of more than 10 acres; (b) industrial sites (except strip mines, barrow and gravel pits), railroad yards, cemeteries, airports, golf courses, shooting ranges, and so forth; (c) institutional and public administrative sites and similar types of areas.

P - Pasture: Land in grass or other long-term forage growth used primarily for grazing. The land may contain shade or timber trees if the canopy is less than 10 percent, but the principal plant cover must be such as to identify its use as permanent grazing land.

F - Forest: Land at least 10 percent stocked by forest trees of any size that is capable of:

1) Producing timber or other forest products or
2) Influencing a water regime

Land formerly having had at least 10 percent stocking by forest trees of any size and not currently developed for a non forest use.

C - Cropland: Land in row and close grown field crops, pasture which is part of the crop rotation, rotation hay, idle cropland, orchards vineyards, and bush fruits and open land formerly cropped.

O - Other: Farmsteads, roads and built up areas of less than 10 acres.

TREATMENT CATEGORIES

The following categories are listed in order of increasing complexity, cost of installation, and intensity of treatment. Management is normally most effective on the smaller streams while armoring is usually installed on larger streams or in areas of high value land. The category was selected which in the judgement of the investigator, would provide adequate treatment for the least expenditure of effort and cost.

Management - Includes the following or similar measures. Buffer strip, deferred grazing, fencing, livestock exclusion and proper grazing use.

Simple Treatment - Includes the following or similar measures. Vegetation alone, fertilizing, planting or any of the preceding in combination with limited smoothing, grading or shaping, or clearing and snagging the channel.

Deflection or Deposition - Includes the following or similar measures - Groins, in-stream fences, jetties, revetments, jacks and living fences such as willow poles.

Armoring - Includes the following or similar measures. Coverings of concrete or other material, bulkheads, matting and riprap.

DEFINITIONS

Groins - a protective structure (usually built perpendicular to the shoreline) to deflect currents, trap sediment or retard erosion of the shore.

In stream fences - fences built in the stream channel to retard velocity and induce deposition.

Jack - a device built of three poles crossed and fastened together at their midpoints and used to retard the velocity, prevent scour, and induce deposition. Wire is strung between the legs to further reduce velocities and catch floating debris. A series of jacks may be strung along a cable which is anchored to a deadman.

Jetty - a structure extending into a stream from the bank and so placed as to induce scouring, bank building or to protect against erosion.

Livestock exclusion - excluding livestock from an area where grazing is not wanted.

Living fences - fences constructed in the stream with posts which will take root and grow.

Matting - an interweaving of brush and wire used to retard streambank erosion.

Planting - establishing and re-establishing long-term stands of adapted species of perennial, biennial, or reseeding of forage plants.

Proper grazing use - grazing at an intensity which will maintain enough cover to protect the soil and maintain or improve the quantity and quality of desirable vegetation.

Buffer strip - a strip of vegetation between a stream and an area of more intensive land use.

Bulkhead - a structure of wood, stone or concrete erected along shores of water bodies to arrest wave action or along steep embankments to control erosion.

Clearing & Snagging - removing snags, drifts or other obstructions within the channel.

Coverings of concrete - lining the bank or channel with concrete.

Deferred grazing - postponing grazing or resting grazing land for a prescribed period.

Fencing - enclosing or dividing an area of land with a suitable permanent structure that acts as a barrier to livestock, big game or people.

Grading or shaping - to form or create a more desirable streambank for the purpose of allowing vegetation of establish itself or to minimize the effect of the stream on the bank.

Revetment - a facing of stone, concrete, brush, etc., built to protect a bank against erosion by currents.

Riprap - a layer, facing, or protective mound of stones randomly placed to prevent erosion, scour, or sloughing of a structure or embankment.

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