United States Department of Agriculture

Natural Resources Conservation Service

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Attached is a copy of the Erosion, Sedimentation, and Sediment Yield Report that deals with the sedimentation problems in the Thief and Red Lake Rivers Basin in northwestern Minnesota. The study was conducted by the Water Resources Staff of the Natural Resources Conservation Service (formerly the Soil Conservation Service), in St. Paul, Minnesota, along with the agency's area and field office staffs. The Marshall-Beltrami and Pennington Soil and Water Conservation District and others cooperated in the study.

This study includes the development of a sediment budget that will assist the sponsors and others in solving the sedimentation problems in the basin.

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Sincerely,

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WILLIAM HUNT
State Conservationist

EROSION

SEDIMENTATION

SEDIMENT YIELD

REPORT

THIEF AND RED LAKE RIVERS BASIN, MINNESOTA

APRIL 1996

Prepared by the USDA Natural Resources Conservation Service,
in cooperation with the sponsors:
Marshall-Beltrami Soil and Water Conservation District
Pennington Soil and Water Conservation District
and other local, state, and federal agencies

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Thief and Red Lake Rivers Basin, Minnesota

ABSTRACT

This document describes the development of a sediment budget for the Thief and Red Lake Rivers Basin. The study includes a drainage area of 970,900 acres located upstream of the Thief River Falls Reservoir (reservoir) in the city of Thief River Falls in northwestern Minnesota. It does not include the drainage area upstream of the outlet of Lower Red Lake. The sediment budget contains all the soil erosion and sediment deposition processes that occur within the basin. About 9,500 tons of sediment are yielded annually to the pools of the public wildlife areas within the basin, of which about 98 percent is deposited in them. The reservoir receives about 19,800 tons of sediment annually, of which about 27 percent (5,330 tons) is deposited in it. The rest remains in suspension and is yielded downstream of the reservoir. The sediment budget was used to analyze various future options to predict the changes in the erosion-sedimentation processes in the basin.

INTRODUCTION

The Thief and Red Lake Rivers Basin Study was made under the authority of Section 6 of Public Law 83-566, the Watershed and Flood Prevention Act. This section authorizes studies for appraising water and related land resources and formulating alternative plans for the conservation, use, and development of these resources. The Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service, in the US Department of Agriculture (USDA) has been designated the role of providing leadership in conducting the study. The sponsors are the Pennington Soil and Water Conservation District and the Marshall-Beltrami Soil and Water Conservation District (SWCD). Also cooperating are other local, state, and federal agencies and groups. The objective of the sponsors is to qualitatively and quantitatively define the resource problems occurring within the watershed. In particular, the study identified and quantified sediment sources impacting the public wildlife areas and the reservoir from the 970,900-acre drainage area of the Thief River and the Red Lake River downstream of Lower Red Lake. This report does not contain any information about the basin upstream of the outlet of Lower Red Lake. Upper and Lower Red Lakes are large lakes that yield essentially no sediment. The study also outlines implementable solutions and identifies potential PL-566 Small Watershed Project areas.

Setting

The Thief and Red Lake Rivers are located in northwestern Minnesota. The study area encompasses approximately 970,900 acres in Pennington, Marshall, Beltrami, and Clearwater Counties. Approximately 175,000 acres are located in the Red Lake (Native American) Reservation (See Figure 1). The study area includes all of the U.S. Geological Survey (USGS) Hydrologic Unit 09020304 and the upper part of USGS Hydrologic Unit 09020302.

The watershed is comprised primarily of nearly level plains from Glacial Lake Agassiz. Most of the cultivated soils are sandy clay loams, fine sandy loams, or thin mucks overlying loam. Much of the eastern part of the basin is in bogs or depressions or on ground moraines, lake plains, and outwash plains. Poor or very poor drainage is common to most of the soils throughout the basin. The soils adjacent to Thief River and Red Lake River are primarily stratified silt, very fine sand, and loam (see Appendix A).

Because of the poor natural drainage, the basin contains a network of legal drainage ditches. These serve as outlets for private field ditches. The ditches generally have very low gradients and low velocities. However, observed velocities in ditches during storm events have been fast and significant.

The study area has a continental climate with very cold winters and relatively cool summers. Heavy summer rainstorms of short duration and local occurrence are common. The normal annual precipitation is 20 inches, and 75 percent occurs during the growing season from May through September. The normal annual snowfall is 30 inches. The average annual runoff is about 2.3 inches. The mean temperatures range from a maximum of 69 degrees F in July to a minimum of 4 degrees F in January. Temperature extremes have ranged from 104 degrees F to minus 40 degrees F. The average date of the last killing frost (32 degrees F) is May 16, and that of the first killing frost is September 22, resulting in an average frost-free period of 136 days.

Conservation Reserve Program (CRP) contracts currently exist on about 20 percent of the cropland in the basin (80,300 acres).

The municipal dam on the Red Lake River in Thief River Falls creates a reservoir with a surface area of 135 acres. The approximate reservoir volume, including water and sediment, is 1,133 acre-feet. This reservoir is used for water supply and hydro-power generation and is also used extensively for recreation.

Approximate land ownership patterns are as follows: (also see Appendix B)

ITEM	**ACREAGE**	**PERCENT**
Private and Tribal	672,500	69
County	700	<1
State	234,900	24
Federal	62,800	7
TOTAL	**970,900**	**100**

The basin includes the Agassiz National Wildlife Refuge (61,500 acres) and several Minnesota Department of Natural Resources (MN DNR) wildlife management areas, including Eckvoll (6,440 acres), Elm Lake (15,560 acres) and Thief Lake (54,860 acres). Total public wildlife areas make up approximately 138,360 acres, or 14 percent of the total basin area.

In 1990, the population of the study area was 12,340. Between 1980 and 1990, the population declined by 1,870, a reduction of 15 percent. Thief River Falls, the largest city in the basin, had a population of 8,010 in 1990 but the population had declined by 1,095 between 1980 and 1990. The Red Lake Reservation, part of which is included in the study area, had a population of 3,690, which represents an increase of 683 from 1980.

The ethnic makeup of the population in the four-county area, according to the 1990 U.S. Census, is approximately 89 percent Caucasian and 11 percent people of color. Ethnic makeup is shown below in more detail:

COUNTIES	AFRICAN AMERICAN	NATIVE AMERICAN	ASIAN	HISPANIC	WHITE
Beltrami	100	5,641	194	146	24,409
Marshall	2	50	14	113	10,889
Pennington	11	101	48	106	13,100
Clearwater	2	633	10	16	7,663
TOTAL	**115**	**6,425**	**266**	**381**	**56,061**
	<1%	10%	<1%	<1%	89%

The majority of the Native Americans in the four-county area live on reservations, including the Red Lake Reservation and two others.

In 1990, per capita income for the study area was about $10,600 and ranged from a high of $15,650 in Thief Lake Township to a low of $5,210 in Mayfield Township in Pennington County. Per capita income on the Red Lake Reservation was $4,280. Fifty-three percent of the persons living on the Reservation have income below the poverty level, as compared to 16 percent for Pennington County, 24 percent for Beltrami County, 23 percent for Clearwater County, and 14 percent for Marshall County. About 22 percent of the people over 65 years of age have income below the poverty level (U.S. Census data).

In 1990, the unemployment rate by counties was 9.6 percent for Pennington, 9.3 percent for Beltrami, 10.2 percent for Marshall and 14.5 percent for Clearwater County. For the Red Lake Reservation, the unemployment rate was 25.5 percent (1990 U.S. Census data).

Resource Problems

The local sponsors and other local organizations have identified a wide variety of problems, including erosion, sedimentation, flooding, loss of wetland habitat, excessive aquatic weed growth in the reservoir, loss of recreation, loss of property, and contamination of the Thief River Falls drinking water supply. There is concern about nutrient, bacterial, and pesticide contamination of surface water. Others have also expressed concern about drainage ditch erosion and streambank erosion. Local citizens are also concerned with the potential impacts of large acreages coming out of CRP contracts starting in 1996-97.

The sponsors have prioritized the erosion and sedimentation problems as the main focus of this study. A major concern is the accumulation of sediment in the reservoir and in the pools of the public waterfowl wetland management areas.

Sedimentation/Sediment Budget

Sediments are materials consisting of single grain and/or aggregates of soil particles which come to rest in some place after they are detached from their original location and transported for some distance. Detachment can be by raindrop impact, flowing water, wind action, ice, gravity and living material. Sediments will settle out of transporting water when the velocity becomes low enough for a period of time. In the case of wind action, sediments will be deposited when the wind velocity is reduced by barriers, vegetative cover, and/or rough surfaces or the wind subsides.

Sediments form in layers on the earth's surface in loose, unconsolidated forms which consist of sand, gravel, silt, clay, till, loess, alluvium and colluvium.

The sediment load transported in streams is an important component of stable conditions along with stream velocity, discharge and slope. Any changes in the hydrologic, climatic, or geologic characteristics of the drainage area can cause streams or parts of streams to lose equilibrium. Streams will adjust to any changes by eroding the streambed, depositing part of the sediment load, or changing the course of the stream to increase or decrease its length.

Developing a sediment budget is a technique used to identify and quantify all the soil erosion, sediment deposition, and yield processes that occur within the drainage area. Many types of erosion occur, including sheet and rill, wind, classic gully, ditchbank, and streambank erosion; likewise, the deposition processes vary widely within the drainage area. The development of a sediment budget is an essential first step in planning for the reduction of sediment yields. The same is true for the public wildlife areas and the reservoir. With a sediment budget, impacts on sediment yield from possible changes in soil erosion or sediment delivery can be easily predicted. Numerical values can be changed to reflect, for example, a particular treatment scenario and produce a new sediment yield value.

REVIEW OF LITERATURE AND CURRENT STUDIES

The city of Thief River Falls and Walter-Butler, Inc., surveyed cross-sections of the reservoir in 1965 and 1966. The report (Walter-Butler, 1967) stated that 374,300 cubic yards of sediment needed to be removed. Of this amount, approximately 279,000 cubic yards were removed between 1966 and 1969.

In 1991, the Red Lake Watershed District (RLWD) took cross-sections at approximately the same location as those taken in 1965 and 1966. From this study they determined that the volume of sediment deposition throughout the reservoir in 1991 was approximately 332,000 cubic yards or about 18 percent of the total volume of the reservoir. They concluded that 236,700 cubic yards had re-accumulated in the reservoir since 1969. For the 24-year period, this amounts to 9,862 cubic yards per year or 6.11 acre-feet per year. Four sediment samples were collected and analyzed for texture. The analysis showed that the four samples were an average of 10 percent clay, 36 percent silt, 52 percent sand (loam-sandy loam texture) and 2 percent gravel. The RLWD estimated that the total sediment yielded to the reservoir was 19,536 tons annually from a drainage area of 884 square miles, or 22.1 tons per square mile per year. Their studies showed that 5,330 tons are trapped annually in the reservoir. They calculated the sediment-trapping efficiency of the reservoir to be 27 percent (Thief River Falls Reservoir Study, RLWD, Project #63, March 1992).

The water level in the reservoir was lowered about 7 feet between August 15 and October 15, 1995, in order to accomplish the following:

1. Determine the extent that sediment would consolidate under aerated conditions.
2. Observe the sedimentation and weed growth patterns.
3. Use the lowered water level as an educational opportunity to inform local citizens of the sedimentation conditions.

Representatives from the RLWD, Pennington SWCD, the city of Thief River Falls, USGS, and the NRCS met during the reservoir drawdown condition to observe the sedimentation-weed growth patterns and to speculate on the success of the endeavor. The RLWD will conduct surveys and other studies to determine the full impact of the lower water level on sediment consolidation and weed growth in the reservoir.

A suspended sediment monitoring program is currently under way by USGS in cooperation with Pennington SWCD, RLWD, Marshall County, city of Thief River Falls, Thief Lake State Wildlife Management Area, and Agassiz National Wildlife Refuge on the Mud, Moose, Thief, and Red Lake Rivers. Completion of the effort in a few years will greatly add to the knowledge of sediment transport processes in these rivers.

METHODS

Preparation of the sediment budget involved the following steps:

A. Determine land use acreages.
B. Estimate total gross erosion.
C. Estimate amount of the gross erosion yielded to streams and ditches.
D. Estimate amount of sediment in streams and ditches yielded to the wildlife pools and to the reservoir. (The RLWD's values on sediment deposition and trap efficiency for the reservoir were used to determine the sediment yield.)

See Appendix C for supplemental data on study methods.

In order to better locate major problem areas and consider treatment scenarios, the study area was divided into eight evaluation units (EVAL). The area included in each is as follows:

EVAL 1	The drainage area of Thief Lake.
EVAL 2	The drainage area on the west side of Thief River.
EVAL 3	The drainage area of the Agassiz Wildlife Refuge and Mud River (also known as Judicial Ditch 11). The area in EVAL 1 is not included.
EVAL 4	The drainage area of Elm Lake and downstream areas to Thief River. This area is also known as Branch 200.
EVAL 5	The drainage area of County Ditch 20.
EVAL 6	The drainage area of Judicial Ditch 18.
EVAL 7	The western drainage area to Red Lake River within the study area.
EVAL 8	The eastern drainage area to Red Lake River within the study area.

As the first step in developing the gross erosion, the land use within the drainage area of each EVAL was established.

A. Land Use

A breakdown of the various land use acreages within each of the eight EVALs and in the total drainage area was obtained from the MN Board of Water and Soil Resources (BWSR), which utilized land use data from the Land Management Information Center (LMIC) of the MN Planning Agency. Verification of this data was done to eliminate possible errors.

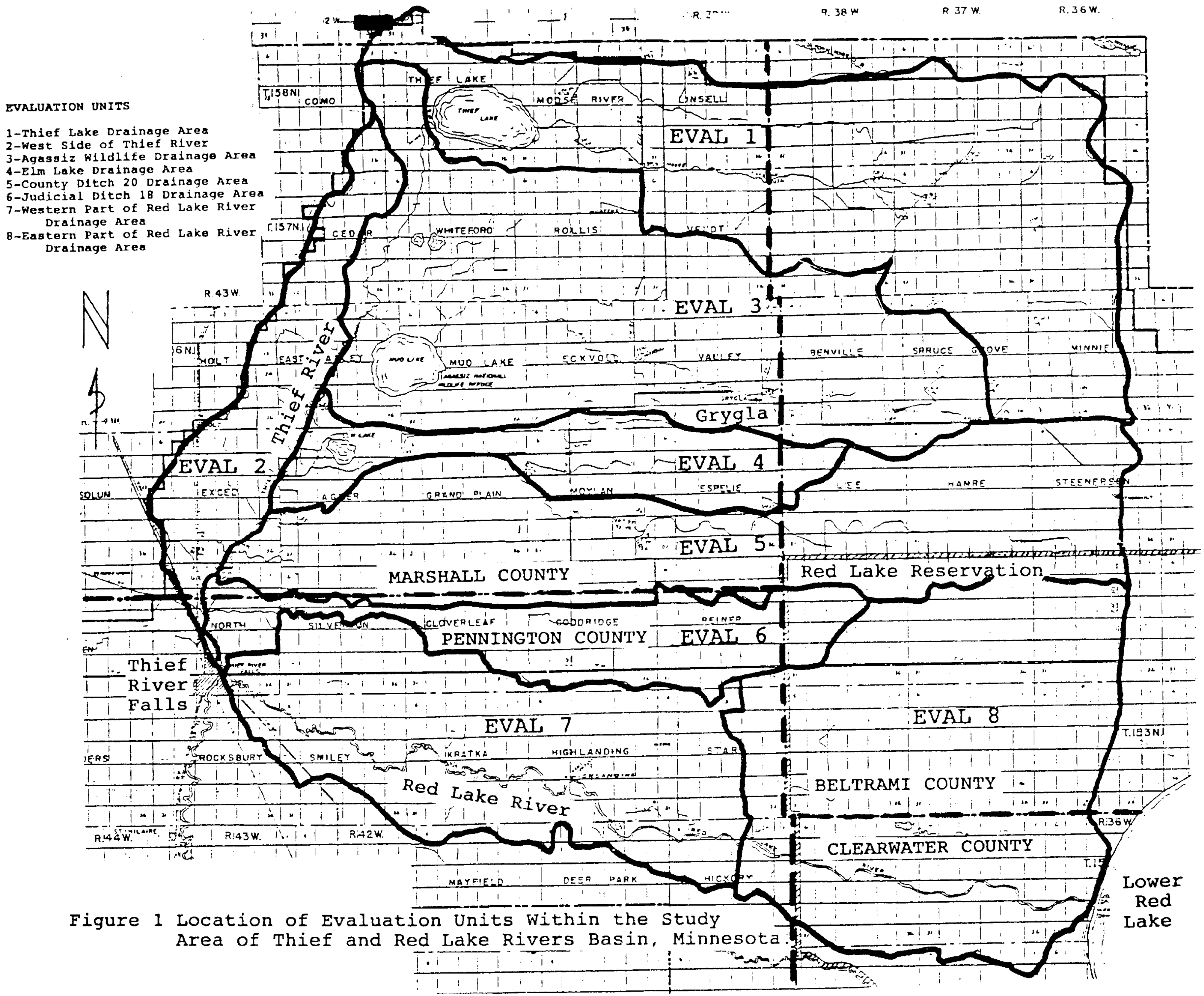


Figure 1 Location of Evaluation Units Within the Study Area of Thief and Red Lake Rivers Basin, Minnesota

The various LMIC land uses have been condensed into six groups as follows:

GROUP	LMIC LAND USE DESIGNATION
Cropland (including CRP)	Cultivated Land
Pastureland	Pasture and Hayland
Shrub-Grassland	Open shrub grassland Closed shrub grassland (deciduous) Closed shrub grassland (coniferous)
Forest Land	Deciduous forest Coniferous forest Forested (Clearwater County)
Wetlands and Lakes	Wetlands Water
Other Land	Urban and industrial Farmstead and rural residences Rural residential development complexes Other rural developments Feedlots (Clearwater County) Transitional or idle cultivated Gravel or sand pits and open mines Exposed soil, sand bars, and dunes

A land use map and LMIC descriptions of each land use appear in Appendix B.

The MN BWSR 1989 data were verified by comparing the total cropland acreage with that obtained from the county assessors' files. The comparison showed a very close relationship. No adjustments of the land use acreages were made.

B. Gross Erosion

Quantification of the gross erosion included the following types of erosion:

1. **Sheet and rill**-removal of soil by flowing water on cultivated cropland.
2. **Wind**-removal of soil by wind on cultivated cropland.
3. **Classic gullies**-primarily at outlets of overland flow and field ditches into road ditches and legal drains.
4. **Ditchbanks**-primarily on the legal drains.
5. **Streambanks**-on Thief River and Red Lake River.

Sheet and Rill. Sheet and rill erosion rates by land use were developed by using the 1992 National Resource Inventory (NRI) rates for each hydrologic unit.

The 1992 NRI erosion data for sheet and rill erosion included the CRP acreage with zero erosion. This does not properly represent the conditions which produced the volume of sediment deposition in the reservoir between 1966 and 1990. Therefore, in order to be more consistent in developing the sediment budget, the NRI gross erosion values were increased by assuming the CRP acreage to be in crop production and possessing appropriate soil erosion conditions. Additional discussion of the role of CRP appears later in this report.

Wind Erosion. Adjusted NRI wind erosion rates by land use were used. The NRI wind erosion was reduced by a factor of 0.6 to convert it to a crop stage rate. The method of calculating wind erosion used in the NRI is excellent for determining extent of wind erosion based on conditions during the critical wind erosion period of the year. The crop staging method of calculating average annual wind erosion provides a composite rate representing various crop growth stages during the year. The NRI wind erosion data were further adjusted by assuming the CRP acreage to be in crop production and possessing appropriate soil erosion conditions similarly as was necessary for sheet and rill erosion determination.

Classic Gully Erosion. Classic gully erosion quantities were developed by expanding the tonnages obtained from local surveys of a sample area to the entire drainage area. The sample area included Eckvoll and Valley Townships and County Ditch 20 in Marshall County and Cloverleaf and Kratka Townships in Pennington County. An average of two tons per mile of legal drain was used. Total mileage of legal drains amounted to 810 miles. The gullies exist where overland flow or field ditches enter the main ditches.

Ditchbank Erosion. The erosion along the ditchbanks of the legal drains was quantified reflecting the following conditions:

The average cleanout is every 15 years, and 5 years are required before the ditchbank is completely revegetated.

The average recession rate is slight (0.01 ft/yr). See February 24, 1994, memo (Appendix C) on calculation of gully and streambank erosion rates.

An average channel depth of 6 feet and 2:1 side slopes for both banks of the 810 miles of legal drains was used.

Streambank Erosion. Streambank erosion along Thief and Red Lake Rivers was quantified by expanding the tonnage obtained from local surveys of the sampled reaches of the rivers. The length, height and depth were determined along 14.2 miles (38%) of Thief River and 22 miles (31%) of Red Lake River. A personal watercraft vehicle was used to observe the eroded conditions along the river while traveling on the river.

C. Sediment Yield to Streams and Ditches

The following factors were used to determine the total amount of gross erosion yielded as sediment to the Thief and Red Lake Rivers:

EROSION TYPE	SEDIMENT YIELD (%)
Sheet and Rill	10
Wind	0.3
Classic Gully	25
Ditchbank	25
Streambank	100

All of these factors are commonly used by sedimentation geologists for developing sediment budgets except the wind erosion factor. No data on sediment yield to streams from wind erosion were located.

As a result, a wind erosion factor was developed using the following steps: (see No. 6, Appendix C).

1. Determine the area of channels, field ditches and road ditches receiving accumulations of windblown soil.

2. Use a sediment delivery value for sheet and rill erosion to estimate sediment yield from erosion of windblown deposits in channels, field ditches, and road ditches. (Steffen, MNTC, 2-23-95, Appendix D)

D. Sediment Yield to Wildlife Areas and Reservoir

A factor of 54 percent of the sediment yielded to stream and ditches (see No. 5, Appendix C) was used to determine the quantity of sediment in the stream that is yielded to both the wildlife management areas and the reservoir. The remaining 46 percent is deposited on flood plains and in streams and ditches. Two EVALs and part of a third EVAL outlet into wildlife management areas. The remaining sediment not deposited in these EVALs is yielded to the reservoir along with the total from the remaining 5 EVALs.

RESULTS

A. Land Use

Land use in the Thief and Red Lake Rivers Basin study area consists of approximately 41 percent cropland, 2 percent pastureland, 7 percent shrub grassland, 23 percent forest land, 25 percent wetlands and lakes, and 2 percent other land. Table 1 shows the land use for each of the eight EVALs. About 20 percent of the cropland, or 80,300 acres, is in CRP (See Figure 2 for percentage values).

EVALs 2, 6, and 7 are predominantly cropland, while 1 and 8 are predominantly forest land and wetlands. About 40 percent of EVALs 3, 4, and 5 is cropland, and the rest is primarily forest land and wetlands.

B. Gross Erosion

Total gross erosion amounts to an average of 2,782,400 tons annually (pre-CRP).

Sheet and Rill Erosion. Sheet and rill erosion amounts to approximately 117,400 tons annually and accounts for about 4 percent of the total gross erosion (see Figure 3). Approximately 389,800 acres of cropland have sheet and rill erosion rates of less than one ton/acre/year, and 5,400 acres have rates of 1 to 3 tons/acre/year. The remaining land uses do not have measurable sheet and rill erosion. See Appendix D for values for each of the 8 EVALs.

Wind Erosion. Wind erosion on cropland amounts to 2,621,400 tons annually and accounts for 94 percent of the total gross erosion. Approximately 93,300 acres have wind erosion rates of 0 to 2 tons/acre/year, 77,200 acres have rates of 2 to 5 tons, 56,200 acres have rates of 5 to 10 tons/acre/year, and 88,200 acres have rates of 10 to 15 tons/acre/year. The CRP acreage of 80,300 acres is included at 10 tons/acre/year, which is the pre-CRP estimated wind erosion rate. See Appendix D for values for each of the 8 EVALs.

Classic Gully. Classic gully erosion, which occurs primarily at outlets of field ditches or overland flows outletting into main ditches and streams, amounts to 1,620 tons annually. It amounts to less than 1 percent of the total gross erosion.

TABLE 1- LAND USE ACREAGES
Thief and Red Lake Rivers Basin, Minnesota

LAND USE	EVAL 1	EVAL 2	EVAL 3	EVAL 4	EVAL 5	EVAL 6	EVAL 7	EVAL 8	TOTAL Acres	TOTAL Percent
					(THOUSANDS ACRES)					
Cropland	27.3	37.6	85.0	23.6	69.0	39.7	101.0	12.0	395.2	41
Pastureland	1.9	0.0	4.4	0.2	7.0	0.3	0.0	2.9	16.7	2
Shrub-grassland	11.9	2.7	25.3	8.5	9.6	2.5	6.9	4.4	71.8	7
Forest land	66.6	2.7	60.6	4.9	31.6	2.2	8.7	49.8	227.1	23
Wetlands & Lakes	35.0	0.6	64.3	8.3	31.2	3.9	1.0	98.1	242.4	25
Other	1.9	1.1	4.9	0.8	2.6	1.4	4.5	0.5	17.7	2
Total	144.6	44.7	244.5	46.3	151.0	50.0	122.1	167.7	970.9	100

APPENDICES

CONCLUSIONS

Many conclusions can be reached from this study. Some of them are as follows:

1. Even though 98 percent of the gross erosion occurs on cropland, this kind of erosion accounts for only 37 percent of the sediment yielded to ditches, streams, and the reservoir. Soil erosion on cropland, however, causes more damage on-site by reducing soil productivity, damaging growing crops, losing fertilizers and chemicals, and reducing net income.

2. Wind erosion accounts for 94 percent of the gross erosion but only 14 percent of the sediment yield to streams, ditches, and the reservoir.

3. The major source of sediment yielded to streams and ditches is from streambank and ditchbank erosion (63 percent).

4. Current sediment deposited in the reservoir accounts for about 18 percent of the total volume. Annual deposition over the past 24 years amounts to 5,330 tons (RLWD data). Future depositions are expected to be less, unless current sediment accumulations are removed and CRP acreage is returned to crop production.

5. Even though sediment yield values are considerably lower than in other parts of the state and nation, considerable local interest exists, especially among the recreationists and city officials in Thief River Falls, for reducing the sediment yield to the reservoir. Similar interest also exists for the wildlife management areas.

6. Opportunities exist for using the sediment budget to determine impacts of various treatment scenarios.

FUTURE STUDY NEEDS AND ISSUES NOT ADDRESSED

Filter Strips

There has been considerable discussion concerning the impacts that filter strips adjacent to drainage ditches have on sediment yield to ditch systems in northwestern Minnesota. It is generally believed by some that grass strips adjacent to ditches significantly reduce sediment yield caused by overland water erosion. However, for filter strips to be effective they need to be located where overland sheet flow occurs. In many cases, no overland water flow occurs adjacent to main drainage ditches; rather, most runoff is delivered to the ditches by smaller field ditches and waterways. Filter strips adjacent to drainage ditches may provide some benefit in trapping windblown soil; however, without additional practices, such as field windbreaks, stripcropping and crop residue management, the filter strips may not be capable of trapping all soil being transported by erosive winds and therefore provide limited benefits.

The types of vegetative cover (plant species) and management practices used to maintain the filter strips directly impact effectiveness. An uncertainty exists about the effectiveness of reducing sediment yield from adoption of filter strips adjacent to ditch systems as the principal conservation practice. Studies are needed to address the uncertainty regarding the effectiveness of establishing filter strips adjacent to ditches.

Revise Sediment Budget

Upon completion of the suspended sediment monitoring program currently underway, an opportunity exists to revise the sediment budget to incorporate findings from the monitoring efforts.

reservoir. The included drainage area in the latter case accounts for 60 percent of the sediment yield to the reservoir, or 11,800 tons out of a total 19,800 tons (sediment budget values). In either case more benefits would accrue than just to wildlife or the reservoir.

PL-566 requires full initiative and maximum responsibility for any undertaking by local people through their local organizations. It encourages close cooperation and assistance of state agencies and emphasizes the partnership of local, state, and federal agencies in achieving watershed goals.

An option is to request only USDA technical assistance without financial assistance to develop a watershed plan. Assistance under this arrangement would be easier and quicker to obtain. More information about PL-566 can be obtained from the NRCS.

Discussions have been conducted with personnel at the MN DNR state office regarding permits that are required for dredging. A watershed plan is not required for a permit to be approved, but oftentimes a plan can make the permit process simpler and less likely to be rejected. Local sponsors should follow the MN DNR permit process for dredging requests starting at the MN DNR area level.

2. Combining dredging with periodic drawdown will add to the reservoir life with a minimum of additional cost. Whether the loss of reservoir use during the drawdown is more than compensated for by the consolidation of the sediment needs to be determined. An opportunity has been provided with the drawdown in 1995 to determine the merits of the drawdown on sediment consolidation.

3. Combining dredging with land treatment measures would slightly increase the project life of the reservoir. The increased life may well not be justified economically unless substantial on-site benefits accrue to the landowners from reduced soil erosion.

The extent that future treatment options could be applied to benefit the wildlife areas was not studied. Land treatment would reduce sediment yield and be of benefit to the water bodies within the wildlife areas.

PL-566 Potential

Public Law 83-566, the Small Watershed Program, authorizes USDA to cooperate with state and local agencies and organizations providing technical and financial assistance in planning and carrying out works of improvement to protect, manage, improve, and develop the water and related land resources in applicable watersheds. Current emphasis is placed on watershed applications where projects can be formulated with the sponsoring local organization that will improve and/or protect water quality and other environmental concerns, reduce flood damage, and provide water conservation. Applicable watersheds are those with drainage areas up to 250,000 acres where the formulated corrective action significantly reduces off-site problems in a cost-effective manner.

The drainage area of this basin approximates 2.3 million acres, of which about one million acres are included in the study area. This is well above the 250,000-acre maximum for a PL-566 Project. However, the basin could be divided into a number of subwatersheds with each application not exceeding 250,000 acres and be planned together if the sponsoring local organization so desires. For example, the Thief River Basin could be divided as follows:

EVAL 1 (Thief Lake): 144,600 acres.
EVAL 3 (Agassiz Pool): 244,500 acres.
EVAL 2, 5, and 6 (TRF Reservoir): 245,700 acres.

Applications for EVAL 1 and/or 3 would be projects formulated primarily for wildlife purposes. These water bodies trap about 98 percent of the incoming sediment and release insignificant amounts downstream. An application including EVALs 2, 5, and 6 would be a project formulated primarily for the sediment yield caused by water erosion. This option would cost about $3.75 million, assuming a one-time incentive payment of $25 per acre.

3. Acceleration in the installation of grade stabilization structures (side water inlets) could be done at approximately 500 locations where classic gully erosion is occurring. This would reduce gross erosion by 1,600 tons and reduce sediment yield to streams and ditches by 400 tons, a yield reduction of 0.7 percent. This option would cost approximately $250,000, assuming an average cost of $500 per location.

4. Another possibility is to adequately revegetate legal drains after their cleanout to protect the ditchbanks from erosion. This would reduce ditchbank erosion by 10,800 tons annually (100 percent) and reduce sediment yield by 2,700 tons (100 percent). It would cost approximately $100,000 annually to revegetate about 160 acres at $600 per acre. Reshaping the ditchbanks to a flatter side slope and adequately revegetating them could well extend the life of the system and reduce the frequency of cleanouts.

Structural Measures. Structural measures are project works of improvement providing group benefits and requiring group action by means of a project sponsor for their installation, operation and maintenance.

1. Streambank stabilization measures could be installed to reduce streambank erosion along 33 miles of Thief and Red Lake Rivers. This would reduce gross erosion and sediment yield by 31,000 tons, or a 58 percent sediment yield reduction. Special effort would be required to avoid damaging the riparian wildlife habitat along the stream. Close coordination with the MN DNR would be needed (See MN DNR letter, Appendix E). The measures could cost up to $8.7 million, and could include shaping, seeding, placement of riprap, or using bioengineering techniques at an average cost of $50 per linear foot.

   Streambank erosion cannot be completely controlled. See discussion on sedimentation on page 4. Streambank stabilization measures in selective locations where severe erosion is threatening important on-site values may be more practical.

2. Another possibility consists of constructing in-stream structural measures in the Thief and Red Lake Rivers to trap the sediment before it is yielded to the reservoir. This approach includes excavation of materials in the bottom of the river channel along with stabilizing measures to prevent channel erosion. The sediment-holding capacity would be limited, and thus periodic cleanout would be necessary. A design of a similar structure in southern Minnesota had an estimated 1990 installation cost of $150,000 (See design in Appendix F).

Dredging. The RLWD has included various maintenance techniques for addressing the erosion, sedimentation, and aquatic plant growth problems of the reservoir. These include aquatic weed harvesting, use of herbicides, rototilling, shading, sediment covers, drawdown, and hydraulic dredging. A summary of each technique is provided in their report (Project #63).

1. The cost estimate of dredging to remove 90 percent of the reservoir sediment is over a million dollars based on a cost of $2.88 per cubic yard. Project life would be about 25 years.

and by 2,200 tons annually to the reservoir (54 percent of EVALs 2, parts of EVAL 4, 5, 6, 7, and 8). This is a 5 percent reduction to the wildlife pools and an 11 percent reduction to the reservoir. Deposition of sediment was reduced by about 500 tons in the wildlife pools and by 600 tons in the reservoir. Using trap efficiencies of 98 percent for wildlife pools and 27 percent for the reservoir, sediment deposition would be reduced by approximately 500 tons/year and 600 tons/year, respectively.

As CRP acreage is gradually returned to crop production, erosion rates and sediment yield quantities will increase. If the entire 80,300-acre amount is returned to crop production, the expected gross erosion and sediment yield would approximate that shown in Table 4.

Future Options for Reduced Sedimentation

Opportunities exist for changing the erosion-sedimentation processes in the Thief and Red Lake Rivers Basin. Some of them are discussed below as future options. These future options are not the only options; the possibilities are unlimited, but only some of them appear here.

Do Nothing. This option consists of forgoing implementation of any plan for reducing the erosion, sedimentation, and/or aquatic plant growth beyond that which is now occurring with existing programs and resources. Current conditions as described in this report would continue. Most of the cropland acreage currently in CRP would revert back to crop production in the next several years. Erosion rates on these areas would be greater than currently occurs with primarily grass cover. Increased application of fertilizers and herbicides will occur. There is a high potential that the water quality conditions, including sedimentation, in the wildlife areas and reservoir would gradually become worse.

Land Treatment. Land treatment practices applied to individual farms and ranches can reduce identified soil- and water-related problems associated with erosion, sediment and disposal of water. Commonly used practices include conservation tillage, crop residue management, stripcropping and grade stabilization structures. Other applicable practices include filter strips, livestock exclusion, tree planting, and streambank protection.

1. One option is to keep or return about 40,000 acres of erosive cropland to permanent grass cover. This represents about 50 percent of the current CRP acreage. Annual gross erosion would be reduced by about 415,000 tons (15 percent). If 60 percent of the 40,000 acreage were within the direct drainage area of the reservoir, sediment yield to it would be reduced by 1,600 tons (8 percent) and sediment deposition in it would be reduced by 400 tons (8 percent). This would cost approximately $10 million, assuming a cost-share and/or one-time incentive payment of $250 per acre. The county could reduce property taxes on the 40,000 acres converted to permanent grass.

2. Another option is to accelerate the application of conservation tillage, crop residue use, field shelterbelts and filter strips on two-thirds of the cropland (150,000 acres), assuming no CRP eroding in excess of 5 tons per acre from wind erosion. This would not only increase net income to landowners but also reduce gross wind erosion by 760,000 tons (29 percent) and reduce sediment yield to ditches and streams by 2,300 tons (4 percent). This treatment would also reduce gross erosion and

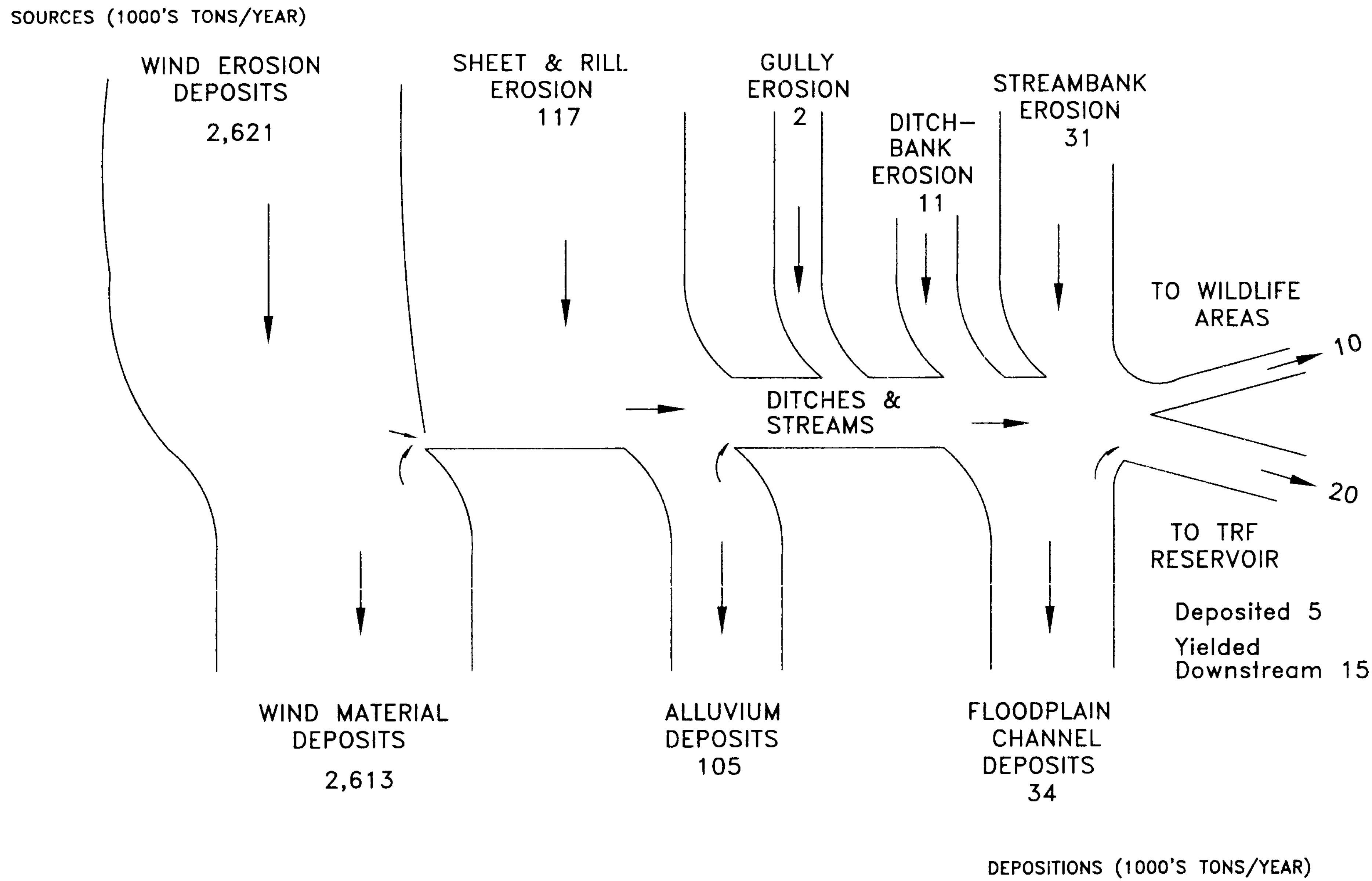


Figure 8

EROSION – SEDIMENTATION – YIELD PROCESSES
Thief & Red Lake Rivers Basin, Minnesota

DISCUSSION

Use of Sediment Budget

Table 4 contains the total gross erosion by type, sediment yields to ditches and streams, and sediment yield/deposition to the wildlife pools and the reservoir in total and for each EVAL.

The following example involving EVAL 5 provides an explanation on the calculations and use of the sediment budget. EVAL 5 has a drainage area of 151,000 acres (236 square miles). Total annual gross erosion in the EVAL includes sheet and rill, 14,800 tons; wind, 418,600 tons; classic gully, 400 tons; ditchbank, 2,500 tons; and streambank, 2,600 tons. The gross total is 438,900 average annual tons. The sediment yield to streams and ditches is determined by multiplying each gross erosion value by its sediment delivery ratio (SDR). The SDR's are sheet and rill, 0.10; wind, 0.003; classic gully and ditchbanks, 0.25; and streambank, 1.00. The total annual sediment yielded to streams and ditches is 6,100 tons for EVAL 5. See Figure 8.

Of the 6,100 tons, 54 percent, or 3,300 tons, is yielded to the reservoir. The rest is deposited on flood plains and in channel bottoms. Twenty-seven percent of the sediment yielded to the reservoir is deposited in it (900 tons), and the remainder (2,400 tons) stays in suspension and is yielded to the Red Lake River downstream of the reservoir.

Figure 8 illustrates the total erosion-sedimentation-sediment yield processes occurring in the basin.

Impacts of CRP

Gross erosion quantities discussed to this point do not include the impacts of CRP. These impacts are described in this section. The CRP removed 80,300 acres from crop production in the late 1980's and reduced soil erosion on these acres to unmeasurable quantities (0). Using the Sediment Budget (Table 4) to simulate the impacts of the reduced erosion, gross erosion quantities for both water erosion and wind erosion on 80,300 acres were developed and subtracted from the Sediment Budget quantities.

The decreased tonnage of soil erosion and expected sediment yield reduction to ditches and streams for each EVAL are as follows:

EVAL UNIT	CRP ACRES	WATER EROSION	WIND EROSION	SEDIMENT YIELD
1	3,020	900	30,200	180
2	14,090	4,400	140,900	860
3	10,040	2,200	100,400	520
4	4,780	1,500	47,800	300
5	10,750	2,300	107,500	550
6	12,760	4,000	127,600	780
7	23,700	9,500	237,000	1,660
8	1,160	400	11,600	80
TOTAL	**80,300**	**25,200**	**803,000**	**4,930**

Using the above soil erosion quantities and the sediment yield factors as discussed earlier in this report, the decreased soil erosion from wind and water amounts to 828,200 tons, or a decrease of 30 percent. Sediment yield to the wildlife pools was reduced by 500 tons annually (54 percent of the sediment yielded to ditches and streams in EVALs 1, 3, and part of 4)

Figure 7. QUANTITY OF SEDIMENT YIELDED TO THIEF RIVER FALLS RESERVOIR

Thief and Red Lake Rivers Basin, Minnesota

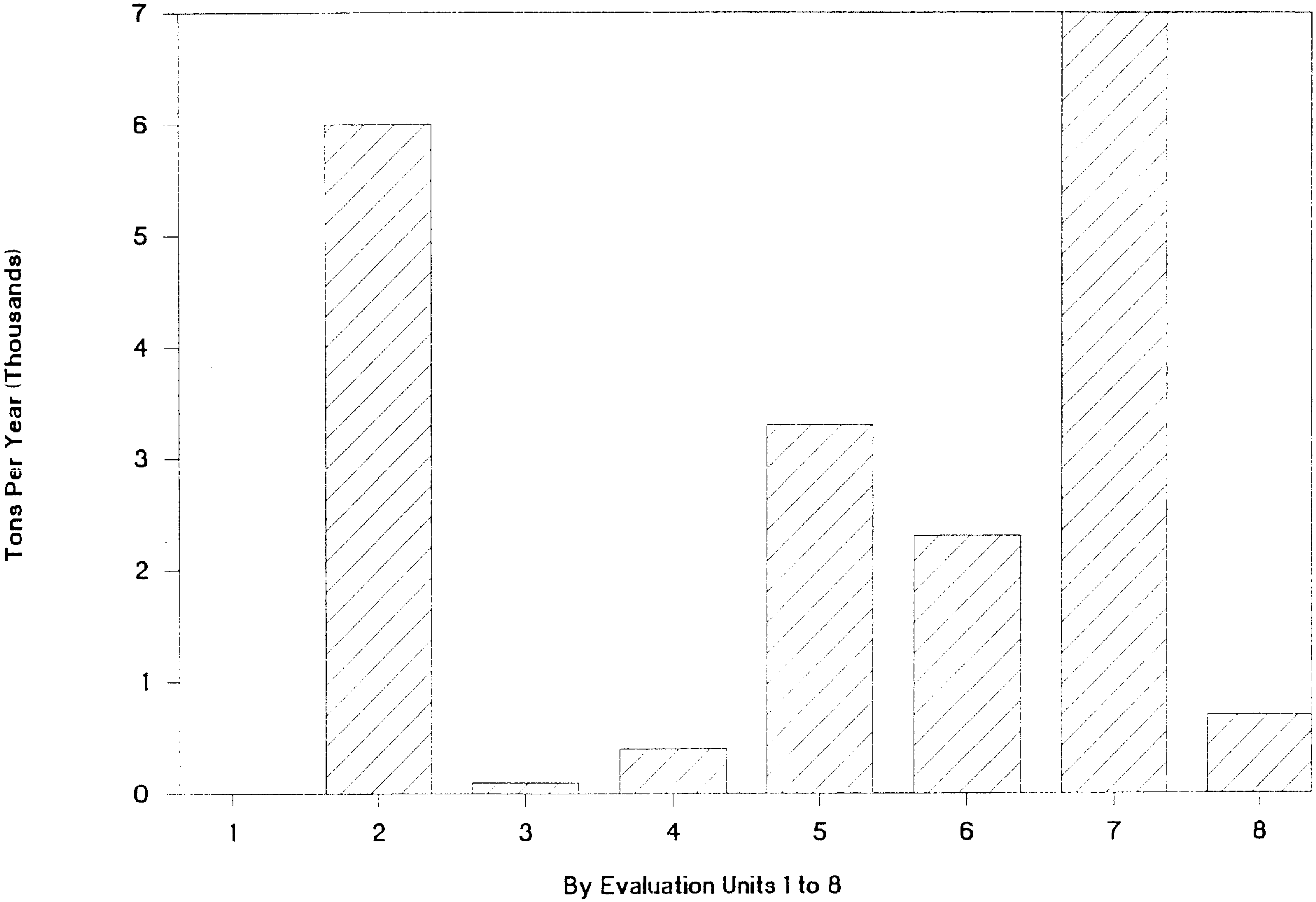


Figure 6. QUANTITY OF SEDIMENT YIELDED TO WILDLIFE AREAS
Thief and Red Lake Rivers Basin, Minnesota

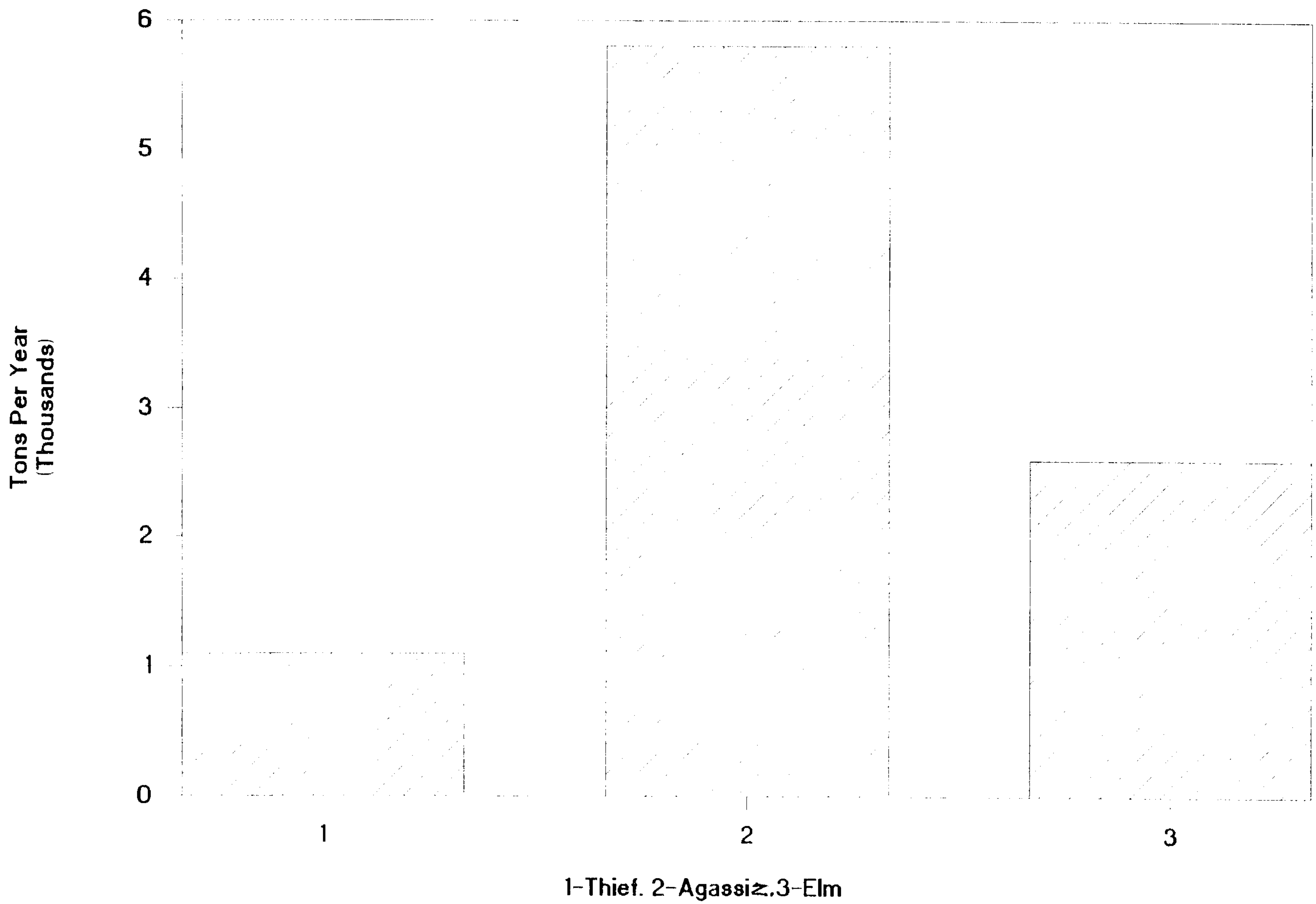


Figure 5. QUANTITY OF SEDIMENT YIELDED TO DITCHES AND STREAMS
Thief and Red Lake Rivers Basin, Minnesota

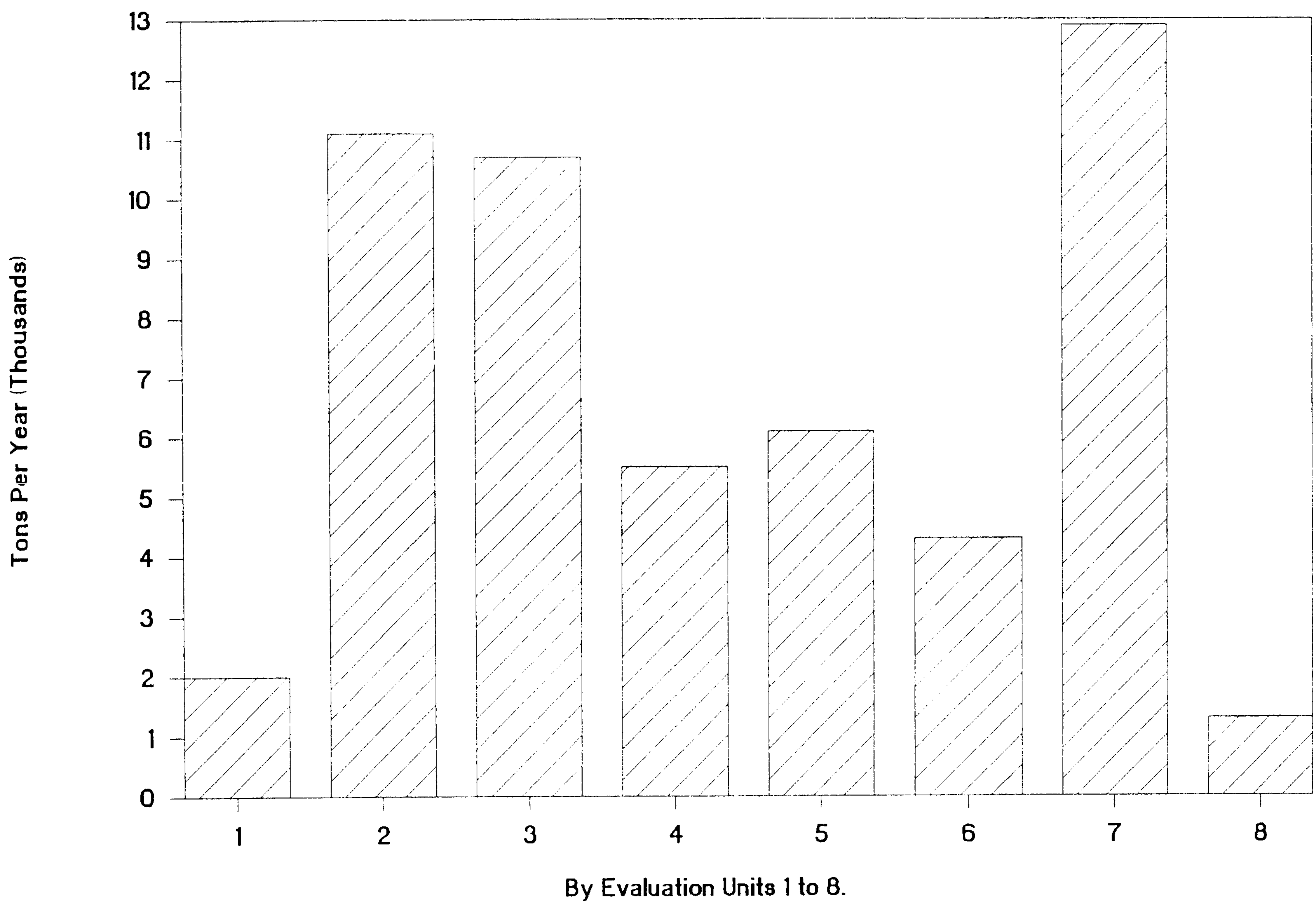


Figure 4. SOURCES OF SEDIMENT YIELD TO DITCHES AND STREAMS

Thief and Red Lake Rivers Basin, Minnesota

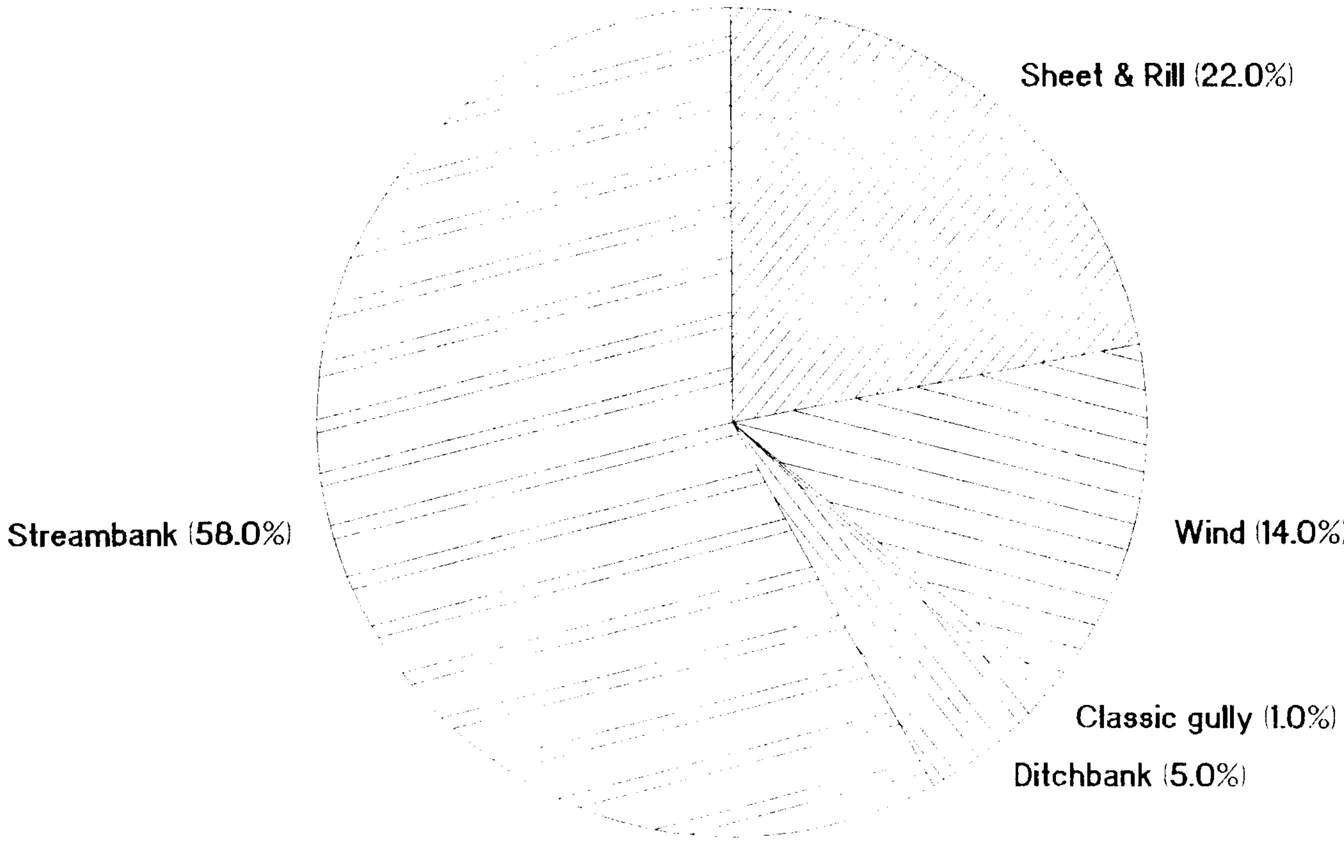


TABLE 4- SEDIMENT BUDGET

(Without CRP)

Thief and Red Lake Rivers Basin, Minnesota

ITEM	EVAL #1	EVAL #2	EVAL #3	EVAL #4	EVAL #5	EVAL #6	EVAL #7	EVAL #8	TOTAL	PERCENT
Drainage Area- Thousand Ac.	144.6	44.7	244.5	46.3	151.0	50.0	122.1	167.7	970.9	
Drainage Area- Sq. Miles	226.0	70.0	382.0	72.0	236.0	78.0	191.0	262.0	1517.0	
Gross Erosion Thou.T/Yr.										
Sheet and Rill	8.5	11.9	18.3	7.4	14.8	12.5	40.4	3.6	117.4	4.0
Wind	159.0	317.8	500.0	159.0	418.6	307.5	693.3	66.2	2621.4	94.0
Gully, Classic	0.3	0.1	0.4	0.1	0.4	0.1	0.2	0.0	1.6	<1.0
Ditchbank	1.8	0.8	2.4	0.7	2.5	0.9	1.6	0.1	10.8	<1.0
Streambank		8.8	6.7	4.1	2.6	2.0	6.3	0.7	31.2	1.0
Total Gross	169.6	339.4	527.8	171.3	438.9	323.0	741.8	70.6	2782.4	100.0
Sediment Yield-Thou.T/Yr.										
Sheet & Rill- (.1)_1/	0.9	1.2	1.8	0.7	1.5	1.2	4.0	0.4	11.7	19.0
Wind- (.003)	0.5	0.9	1.5	0.5	1.3	0.9	2.1	0.2	7.9	11.0
Ephem/Classic Gully-(.25)	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.4	1.0
Ditchbank (.25)	0.5	0.2	0.6	0.2	0.6	0.2	0.4	0.0	2.7	6.0
Streambank (1.0)		8.8	6.7	4.1	2.6	2.0	6.3	0.7	31.2	63.0
TOTAL YIELD TO STREAMS/DITCHES	2.0	11.1	10.7	5.5	6.1	4.3	12.9	1.3	53.9	100.0
Sediment Yield-Wildlife-Thou. T/Yr.										
Sediment to Streams/Ditches	2.0		10.7	4.8_3/					17.5	
Yielced to Wildlife Pools (.54)_2/	1.1		5.8	2.6					9.5	
Deposited-Wildlife Area	1.1		5.7	2.5					9.3	
Percent_4/	98.0		98.0	98.0						
Sediment Yield-Reservoir-Thou. T/Yr.										
Sediment to streams/Ditches	0.0	11.1	0.1	0.8	6.1	4.3	12.9	1.3	36.6	
Yielded Reservoir (.54)_5/	0.0	6.0	0.1	0.4	3.3	2.3	7.0	0.7	19.8	
Deposited-Reservoir										
(.27)	0.0	1.6	0.0	0.1	0.9	0.6	1.9	0.2	5.3 _6/	
Sediment Yield Below Reservoir										
(.73)	0.0	4.4	0.1	0.3	2.4	1.7	5.1	0.5	14.5	

_1/ Amount of gross erosion yielded to streams and ditches (SDR).

_2/ Amount of sediment in stream yielded to wildlife pool.

_3/ Eighty-eight percent of Eval 4 drains into Elm Lake Wildlife Management Area.

_4/ Trap Efficiency- Figure 8-2 NEH Chapter 8 Section 3.

_5/ Amount of sediment in stream yielded to reservoir.

_6/ Surveyed 1991 by Watershed District.

The amount of sediment deposited in the reservoir annually (5,330 tons) used in the sediment budget represents the average annual amount over 24 years (1966-1990). This time span covers the sediment removal of the 1960's to the surveyed conditions of 1991. The assumption used for the sediment budget is that future average deposition will be the same annual rate. This may well not be the case. Deposition is generally the highest immediately after sediment removal and decreases as sediment starts to accumulate in a reservoir. Even now, as evident in the reservoir drawdown condition, current deposition appears more limited. The more limited deposition could also reflect the impact of CRP. Since most of the CRP acreage was established in the latter 1980's, the average annual deposition over the 24-year period (5,330 tons) was not greatly influenced by CRP. However, the annual deposition value would be valid if the current sediment accumulations were to be removed and CRP acreage is returned to crop production.

The distribution of the streambank erosion by EVALs is as follows:

EVAL	STREAMBANK TONNAGE
1	0
2	8,800
3	6,700
4	4,100
5	2,600
6	2,000
7	6,300
8	700
TOTAL	31,200

Streambank erosion accounts for less than 2 percent of the total gross erosion. See Figure 3.

C. Sediment Yield to Streams and Ditches

Of the total annual gross erosion of approximately 2.8 million tons, only about 53,900 tons of sediment is yielded to the ditches and streams annually. The rest is deposited on land before the water runoff flows reach the ditches and streams or is blown beyond the drainage area in the case of wind erosion. Wind erosion materials deposited in the study area originating from other areas are probably offset by materials originating within the study area and transported beyond the boundaries of the study area. Of the 53,900 tons, 11,700 tons (22 percent) is from sheet and rill erosion, 7,900 tons (14 percent) is from wind erosion, 400 tons (1 percent) is from classic gully erosion, 2,700 tons (5 percent) is from ditchbank erosion, and 31,200 tons (58 percent) is from streambank erosion. See Table 4 and Figures 4 and 5 for the sediment yield for each of the eight EVALs.

D. Sediment Yield to Wildlife Areas and Reservoir

Additional deposition occurs in the ditches and streams and on the flood plain during flooding events before the rivers outlet into the wildlife areas and/or the reservoir. They receive the balance, or about 54 percent, of the sediment yielded to the ditches and streams. About 9,500 tons of sediment is yielded to the wildlife areas (EVALs 1, 3, and part of 4), of which nearly 98 percent is deposited in them. About 19,800 tons is yielded to the reservoir (EVALs 2, part of 4, 5, 6, 7, and 8). See Figures 6 and 7. About 27 percent (5,330 tons) of the incoming sediment is deposited in the reservoir, and the remainder stays in suspension and is carried downstream beyond the reservoir.

The 19,800 ton value is approximately the same value (19,536 tons) that the RLWD developed in their 1992 study (Project #63). A review of their calculations was done in consultation with the USGS. The conclusion reached was that the RLWD value is adequate for this study. The existence now of more USGS records and the development of specific values for the reservoir rather than extrapolating data from the Crookston Reservoir would provide opportunities to develop a better yield value. However, in light of the suspended sediment monitoring program currently underway, which will provide more applicable data in a few years, further analysis of the additional USGS records without the monitored results was considered not to be prudent at this time (See Appendix E).

TABLE 3- STREAMBANK EROSION
Thief and Red Lake Rivers Basin, Minnesota

EROSION CATEGORY	LATERAL RECESSION-FT. ANNUAL	AFTER 25 YRS.	AFTER 100 YRS.	LENGTH MILES	%	ANNUAL TONS TONS	%
			THIEF RIVER				
Slight	0.03	0.75	3	2.1	9	100	1
Moderate	0.13	3.25	13	7.1	29	2,500	10
Severe	0.40	10.00	40	12.3	51	16,000	66
Very Sev.	0.50	12.50	50	2.6	11	5,600	23
Total				24.1	100	24,200	100
			RED LAKE RIVER				
Slight	0.03	0.75	3	0.8	9	100	1
Moderate	0.13	3.25	13	3.6	41	1,500	22
Severe	0.40	10.00	40	4.4	50	5,400	77
Total				8.8	100	7,000	100
GRAND TOTAL				32.9		31,200	

The distribution of the classic gully erosion by EVALs is shown in the table below:

**Table 2 - Classic Gully and Ditchbank Erosion Quantities
Thief and Red Lake Rivers Basin, Minnesota**

EVAL	MILES OF LEGAL DRAIN	CLASSIC GULLY EROSION AVER/ANNL TONNAGE	DITCHBANK EROSION AVER/ANNL TONNAGE
1	130	260	1,790
2	60	120	810
3	180	360	2,430
4	50	100	690
5	190	380	2,550
6	70	140	930
7	120	240	1,620
8	10	20	120
TOTAL	**810**	**1,620**	**10,940**

Ditchbank Erosion. Ditchbank erosion, which occurs primarily on cleanout of legal drains that are not adequately vegetated, amounts to approximately 10,900 tons annually. This amounts to less than 1 percent of the total gross erosion. Approximately one-third of the legal drains lack adequate vegetation for erosion control. Cleanouts occur about every 15 years. On the average, five years are required to establish adequate vegetative cover to protect the banks from erosion. The distribution of the erosion by EVALs is also shown in Table 2.

Streambank Erosion. Sixty-five percent (approximately 24 river miles or 48 streambank miles) of the streambanks are eroding on the Thief River. Over 60 percent of this erosion is considered to be severe or very severe, accounting for about 90 percent of the total streambank erosion on the Thief River. On the Red Lake River only 15 percent (approximately 9 river miles or 18 streambank miles) of the streambanks are eroding. About half of this erosion is considered severe, accounting for about three-fourths of the streambank erosion on the Red Lake River. See Table 3 for more details on streambank erosion.

The more extensive streambank erosion on Thief River may be explained in part by the greater water level fluctuations that occur on it. The channel is not as wide as the Red Lake River, yet it has a larger uncontrolled drainage area. The drainage area of Thief River (EVALs 1-6) is 681,100 acres, while that on the Red Lake River below the outlet of Lower Red Lake (EVALs 7 and 8) is 289,800 acres.

The Thief River currently varies from 75 to 150 feet in width. The width variation of the Red Lake River is from 100 to 200 feet. If severe streambank erosion continues for the next 100 years, the lateral bank recession can amount to 40 feet. If streambank erosion is only slight, the lateral recession in the next 100 years will be only 3 feet.

Figure 3. GROSS EROSION DISTRIBUTION
Thief and Red Lake Rivers Basin, Minnesota

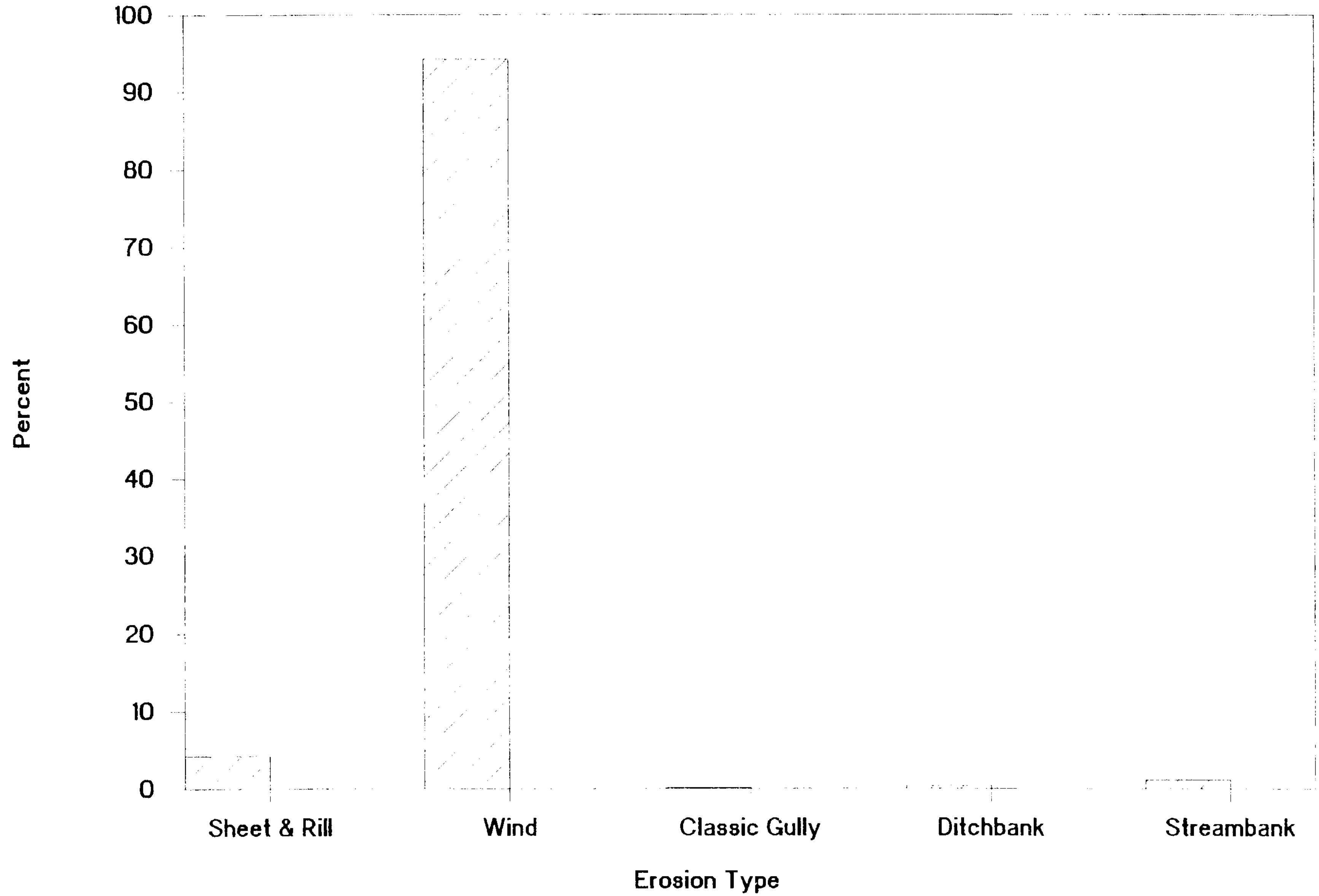
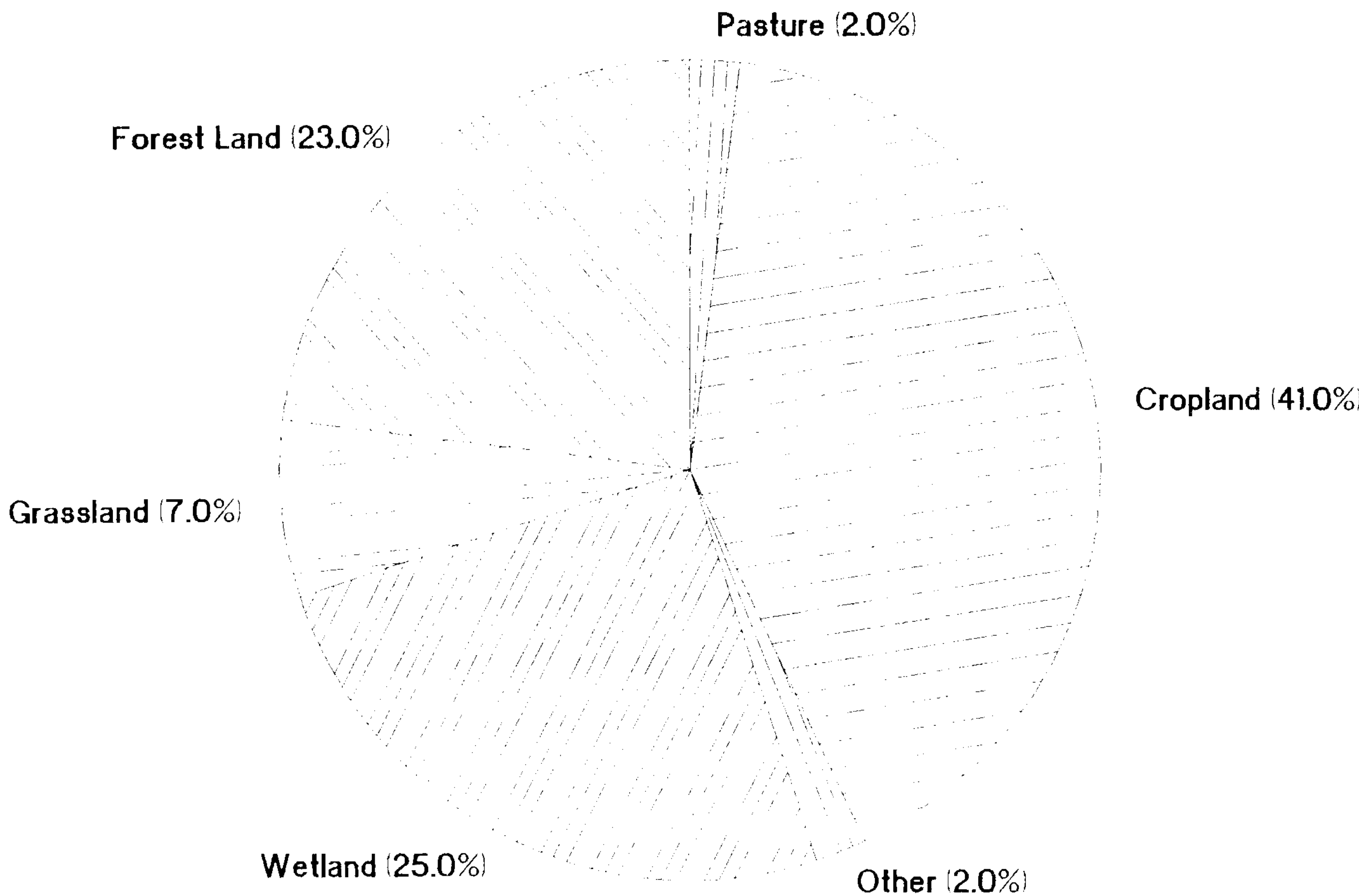


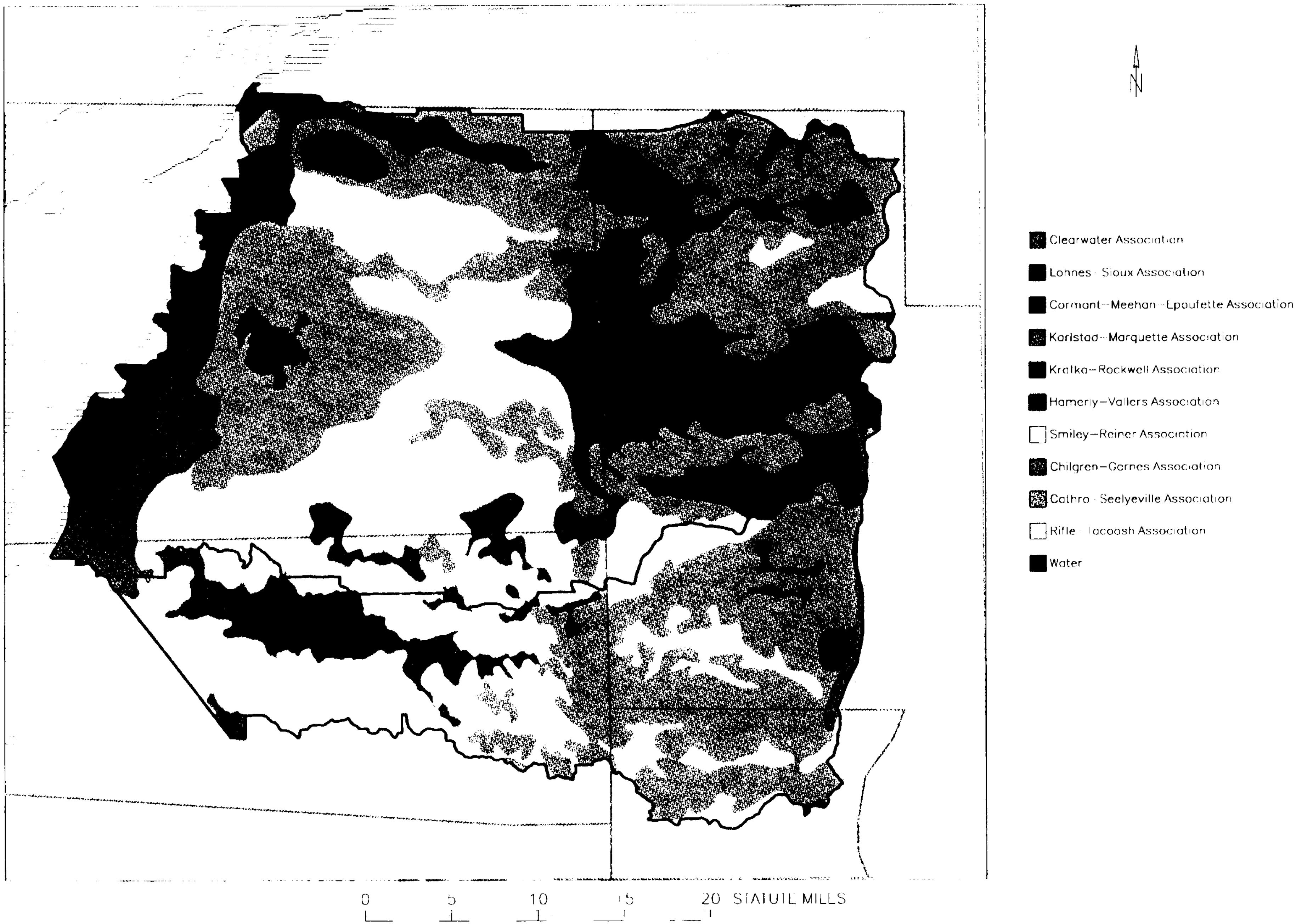
Figure 2. LAND USE IN PERCENT
Thief and Red Lake Rivers Basin, Minnesota



APPENDIX A

SOILS

Soil Association Map of Thief River—Red Lake River Basin



Land Management Information Center

LAND USE / LAND COVER CLASS DESCRIPTIONS 1989

1. URBAN OR BUILT-UP

11 **Urban and Industrial** - This category includes cities, towns and villages with place names. Small residential areas without USGS topographic map place names are classified as rural residential developments (see category 13 below). The urban and industrial category also includes commercial, industrial or urban developments that are included within, or are directly associated with, an urban area. Examples include; manufacturing and processing plants, power plants, urban airports and waste treatment plants

12 **Farmsteads and Rural Residences**

Farmsteads - Include the farmhouse and adjoining farmyard areas. Farmsteads also include buildings such as machinery storage areas, grain storage facilities, and corrals and livestock holding and feeding areas directly associated with the farmyard area.

Rural Residences - Are non-urban residences other than farmsteads. Rural residences include the residence, associated structures such as garages and sheds, and the associated landscaped area. This category includes from one to four residences in close proximity, with no distinguishable, intervening, non-residential features.

13. **Rural Residential Development Complexes** - This category includesrural residences, as defined above, in a complex that includes five or more residences in close enough proximity to be mapped as a single unit.

14. **Other Rural Developments** - This category includes commercial and industrial, cultural and recreational, and agricultural developments not directly associated with urban areas.

Commercial and Industrial - developments include substations, communications facilities, power plants, small private airstrips, junkyards, landfills, storage maintenance yards, businesses, factories, lumber mills, commercial livestock and poultry operations, and grain operations.

Cultural and Recreational - developments include built-up factories and service areas associated with parks and rest areas, camp ground and golf courses. It also includes churches, cemeteries, community halls, and rural schools.

Agriculture - developments include those agricultural facilities not directly associated with farmsteads. It includes machine storage areas, grain storage areas, barns and corrals, and isolated buildings. It also includes isolated farmsteads that no longer have apparent road access.

2. AGRICULTURAL LAND

21 Cultivated Land - Cultivated land includes those areas under intensivecropping or rotation, including periods when a parcel may be fallow. It represents land planted to forage or cover crop. The units exhibit linear or other patterns associated with current or relatively recent tillage.

22 Pasture Land - Land in active pasture use. This class was discontinued and combined into 23.

23 Transitional Agricultural Land - This category includes areas that show evidence of past tillage but do not now appear to be continuously cropped or in a crop rotation. Parcels in this unit include fields that are idle or abandoned and may or may not have been planted to a cover crop. In addition to displaying some evidence of past tillage, they usually are relatively uniform in vegetation.

3. GRASSLANDS AND GRASSLAND SHRUB TREED COMPLEX

31 Grassland - This unit includes grasslands and herbaceous plants. It may contain up to one-third shrubs and/or tree cover. Areas may be small to extensive, and range from regular to very irregular in shape. They are often found between agricultural land and more heavily wooded areas, and along right-of-ways and drainages. These areas may be mowed or grazed, and range in appearance from very smooth to quite mottled.

32 Grassland Shrub Treed Complex - This classification includes a combination of grass, shrubs, and trees, in which the deciduous treed cover comprises from one-third to two thirds of the area, and/or the shrub cover comprises more than one-third of the area. This complex is often found adjacent to grassland or forested areas, but may be found alone. These areas are often irregular in shape and vary greatly in extent.

33 Grassland Shrub Treed Complex (coniferous) - This classification treed cover comprises from one-third to two thirds of the area, and/or the shrub cover comprises more than one-third of the area. This complex is often found adjacent to grassland or forested areas, but may be found alone. These areas are often irregular in shape and vary greatly in extent.

4. FOREST

41 Upland Deciduous Forest - This classification includes areas with at least two thirds of the total canopy cover composed predominately woody deciduous species. It may contain coniferous species but it is dominated by deciduous species. It includes woodlots, shelterbelts, and plantations.

42 Upland Coniferous Forest - This classification includes areas with at least two-thirds of the total canopy cover composed of predominantly woody coniferous species. It may contain deciduous species but it is dominated by coniferous species. It includes woodlots, shelterbelts, and other planted areas.

Sioux. The Sioux series, loamy, consists of excessively drained, very shallow over sand and gravel soils formed in gravelly outwash on outwash plains, terraces, terrace escarpments and knolls and ridgetops on glacial moraines. The surface layer is dark gray loam 5 inches thick. The next layer is grayish brown gravelly loam transitional layer 3 inches thick. The substratum is light brownish gray and pale brown gravelly sand. Slopes range from 0 to 40 percent. Most areas are used for rangeland.

Smiley. The Smiley series consists of very deep poorly drained soils formed in calcareous loamy glacial till on till floored glacial lake plains and on till plains. The surface layer is black loam 12 inches thick. The subsoil is olive gray clay loam and loam 30 inches thick. The substratum is olive gray loam. Slopes are 0 to 2 percent. Areas are used for cropland and pastureland.

Tacoosh. The Tacoosh series consists of very deep, very poorly drained soils formed in deposits of herbaceous organic material over loamy materials in depressions. The surface layer is black muck 8 inches thick. The subsurface layer is black, very dark brown and very dark grayish brown hemic material 32 inches thick. The substratum is brown very fine sandy loam and light grayish brown sandy loam. Slopes are 0 to 2 percent. Most areas are used for woodland.

Vallers. The Vallers series consists of very deep, poorly drained soils formed in calcareous glacial till under tall grass prairie on glacial ground moraines and till floored glacial lake plains. The surface layer is black silty clay loam 12 inches thick. The substratum is 9 inches of dark gray and gray clay loam over olive gray loam. Slopes range from 0 to 3 percent. Most areas are used for cropland.

APPENDIX B

LAND OWNERSHIP,

LAND USE

GENERAL SOIL DESCRIPTIONS

Cathro. The Cathro series consist of very deep, poorly drained soils formed in deposits of herbaceous organic material over loamy sediments in depressions. The surface soil is black muck 23 inches thick. The substratum is grayish brown sandy loam. Slopes are 0 to 2 percent. Most areas are used for woodland.

Chilgren. The Chilgren series consists of deep poorly drained soils formed in glacial till under forest vegetation in concave areas on glacial lake plains. The surface layer is very dark gray loam 4 inches thick. The subsurface layer is grayish brown mottled fine sandy loam 6 inches thick. The subsoil is dark grayish brown mottled clay loam 8 inches thick. The substratum is olive gray mottled loam. Slopes are 0 to 2 percent. Areas are used for woodland, hayland, pastureland and cropland.

Clearwater. The Clearwater series consists of very deep, poorly drained soils formed in clayey, calcareous till or lacustrine sediments on glacial lake plains under tall grass prairies or aspen and oak savannahs. The surface layer is black clay 8 inches thick. The subsoil is dark grayish brown clay 7 inches thick. The substratum is olive gray and grayish brown clay. Slopes are 0 to 2 percent. Most areas are used for cropland, hayland and pasture.

Cormant. The Cormant series consists of very deep, poorly drained soils formed in sandy glacial lacustrine or outwash sediments under mixed prairie and forest on glacial lake plans, deltas and outwash plains. The surface layer is black loamy fine sand 6 inches thick. The substratum is light brownish gray and grayish brown fine sand. Slopes range from 0 to 3 percent. Most areas are used for woodland.

Epoufette. The Epoufette series consists of very deep, very poorly drained soils formed in glaciofluvial sediments on uplands. The surface layer is very dark gray loamy sand 8 inches thick. The subsurface layer is grayish brown mottled loamy sand 18 inches thick. The subsoil is grayish brown mottled gravelly sand loam. The substratum is grayish brown gravelly sand. Slopes range from 0 to 2 percent. Most areas are used for woodland.

Garnes. The Garnes series consists of very deep, moderately well drained soils formed in glacial till under forest vegetation on glacial lake plains. These soils have 2 inches of forest litter over a dark grayish brown loam subsurface layer 6 inches thick. The subsoil is dark brown sandy clay loam 4 inches thick. The substratum is grayish brown loam and fine sandy loam. Slopes range from 0 to 8 percent. Areas are used for woodland and cropland.

Hamerly. The Hamerly series consists of very deep, somewhat poorly drained soils formed in loamy glacial till on uplands. The surface layer is very dark gray loam 8 inches thick. The substratum is 17 inches of light brownish gray and light olive brown loam with high calcium carbonate over light olive brown and olive brown loam. Slopes range from 0 to 6 percent. Most areas are used for cropland.

Karlstad. The Karlstad series consists of moderately well drained soils formed in a loamy to sandy mantle over outwash sediments under mixed tall grasses and deciduous forest. The surface layer is very dark brown sandy loam 3 inches thick. The subsurface layer is grayish brown loamy sand 6 inches thick. The subsoil is dark brown sandy loam and gravelly sandy loam 10 inches thick. The substratum is multicolored sand and gravelly coarse sand. Slopes are 0 to 3 percent. Areas are used for cropland, pastureland and woodland.

Kratka. The Kratka series consists of very deep, poorly drained soils formed in sandy lacustrine sediments over loamy till under prairie grasses on glacial lake plains and moraines. The surface layer is black fine sandy loam 11 inches thick. The subsoil is dark grayish brown mottled loamy fine sand 7 inches thick. The substratum is 7 inches of grayish brown mottled sand over olive gray mottled loam. Slopes are 0 to 2 percent. Most areas are used for hayland, pastureland and cropland, but some areas are idle.

Lohnes. The Lohnes series consist of deep, well drained soils formed in sandy sediments on glacial lake and outwash plains. The surface layer is very dark gray loamy coarse sand 16 inches thick. The next layer is very dark grayish brown loamy coarse sand 14 inches thick. The substratum is brown and grayish brown coarse sand. Slopes range from 0 to 15 percent. Areas are used for hayland, rangeland and cropland.

Marquette. The Marquette series consists of very deep excessively drained soils formed in gravelly deposits under forest on beach ridge outwash areas or gravelly moraines. The surface layer is very dark-brown loamy sand 6 inches thick. The subsurface layer is brown gravelly loamy fine sand 3 inches thick. The subsoil is dark yellowish brown very gravelly fine sandy loam 5 inches thick. The substratum is brown very gravelly loamy coarse sand. Slopes range from 0 to 30 percent. Most areas are used for woodland.

Meehan. The Meehan series consists of somewhat poorly drained soils formed in sandy alluvial deposits on outwash plains, stream terraces and glacial lake basins. The surface layer is very dark grayish brown sand 4 inches thick. The subsoil is brown and dark yellowish brown mottled sand 25 inches thick. The substratum is light yellowish brown mottled sand. Most areas are used for woodland or cropland. Some areas are pastured.

Reiner. The Reiner series consists of very deep moderately well drained soils formed in calcareous loamy glacial till on glacial lake plains. The surface layer is black fine sandy loam 7 inches thick. The subsoil is olive brown clay loam 10 inches thick. The substratum is brown, grayish brown and light olive brown mottled loam. Slopes range from 0 to 3 percent. Most areas are used for cropland.

Rifle. The Rifle series consists of very deep, very poorly drained soils formed in herbaceous organic deposits in bogs and depressional areas within till floored glacial outwash and till plains. The surface soil is yellowish brown and black peat 4 inches thick. The underlying material is black and dark reddish brown mucky peat. Slopes are 0 to 2 percent. Most areas are used for woodland.

Rockwell. The Rockwell series consists of very deep, poorly drained soils formed in moderately coarse textured lacustrine sediments over medium textured glacial till or lacustrine sediments on glacial lake plains. The surface layer is black sandy clay loam 9 inches thick. The substratum is 10 inches of dark gray and gray fine sandy loam over 8 inches of light olive gray and pale olive fine sand over light gray silt loam. Slopes are less than 1 percent. Cropland is the main use.

Seelyeville. The Seelyeville series consists of very deep, very poorly drained soils formed in organic material undermarsh vegetation on flood plains. These soils are black and very dark brown (mostly sapric material). Most areas are idle.

43 **Lowland Deciduous Forest** Primarily forest types in wetland areas. Upland definitions of forest cover were followed.

44 **Lowland Coniferous Forest-** Primarily forest types in wetland areas. Upland definitior of forest cover were followed.

50. WATER

This category includes permanent water bodies; including lakes (U.S. Fish & Wildlife Service Lacustrine System "L"), rivers, reservoirs, stock ponds and permanent palustrine open water (U.S. Fish & Wildlife Service POWH). Intermittently exposed palustrine open water areas (U.S. Fish & Wildlife Service POWG, POWJ, POWZ) are included in this open water category when the photo evidence indicates that the areas is covered by water the majority of time.

61. WETLANDS

This category includes wetlands visible on the photography with an area of at least 2 acres. Wetlands boundaries are delineated from U.S. Fish & Wildlife Service National Wetland Inventory data. In cases where these boundaries have changed (such as for drained wetlands), the boundaries are determined from the current photography.

U.S. Fish & Wildlife Service National Wetland Inventory types included in this category a semi-permanent palustrine emergent wetlands (PEMF and PEMY categories) and areas of semi-permanent palustrine open water (POWF) associated with PEM-F through PEM-Y wetlands, as defined in the U.S. Fish & Wildlife Service National Wetland Inventory. These categories represent basins with deep-water emergents (primarily cattail, bulrush, and whitetop) and open water inclusions. Where U.S. Fish & Wildlife Service data are not available, wetland classification will be based on the distribution of visible deep-water emergents and open water inclusions.

Temporary, saturated, seasonal and intermittently exposed palustrine wetlands will, in most cases, be mapped according to dominant cover type visible on the photography (e.g., open grassland, cultivated, grass-shrub-tree complex, etc.) rather than as wetlands.

7 **Miscellaneous**

71 **Gravel pits and open mines** - These category includes areas stripped of top soil with exposed substrate. Gravel pit areas that have been reclaimed either naturally of artificially are classified as the current cover type.

72 **Bare Rock** - This category includes areas of rock outcrops that lack appreciable soil development or vegetative cover.

73. **Exposed soil, sandbars and sand dunes** - This category includes areas lacking appreciable plant cover that are not gravel pits or bare rock.

8 **Unclassified** - This category includes areas that could not be classified into any of the other categories.

APPENDIX C

STUDY METHODS

APPENDIX C

STUDY METHODS

1. Procedures followed to determine sheet and rill erosion and wind erosion rates.

   a. The National Resource Inventory (NRI) Data Base for Minnesota located at the NRCS State Office as queried for 1982, 1987, and 1992 conditions. NRI is a multi-resource inventory containing data collected every five years at selected random sample sites throughout the nation, including the Thief and Red Lake Rivers Basin. The sample data are analyzed by the Statistical Lab at Iowa State University before they are released for use.

   b. NRI data queried were by Water Resources Subbasin (8-digit hydrologic unit) as follows:

      H.U. 09020302 - Red Lakes - Total area
      H.U. 09020303 - Red Lake River - Beltrami County
      " " - Clearwater County
      " " - Pennington County
      H.U. 09020304 - Thief River - Total Area.

   c. NRI data included land ownership, land use, sheet and rill erosion rates, and wind erosion rates.

2. Procedures for calculating gully erosion.

   a. Selected representative townships for sampling (a representative township would include a majority of agriculture lands with the interspersion of public owned land with an extensive ditch system).

   b. All navigable roads in the townships were traveled by truck and surveyed by visual observation.

   c. Location of gully erosion was determined and plotted on plat maps.

   d. Pictures were taken.

   e. Length, height, and width were measured using a tape measure in order to calculate volume.

   f. The type of erosion was determined to be ephemeral or classic.

   g. Calculated volume of material displaced according to procedure supplied by NRCS geologist.

3. Procedures for locating streambank erosion.

   a. With the aid of Tigersharks provided by Artco, 22 river miles on the Red Lake River, and 15 river miles on the Thief River were traveled.

   b. Erosion sites were mapped on aerial photos.

   c. Length, heights, and width measurements were taken.

   d. Severity of erosion was classified.

e. Photographs were taken. (Available at the Pennington SWCD).

f. Calculated volume of material displaced according to procedure supplied by NRCS geologist.

g. Erosion sites were resurveyed one year later at low flow to check accuracy of original data.

4. Procedures for calculating streambank erosion volume.

   a. See geologist's recommended procedure in the February 24, 1994 memo (See Appendix C).

5. Procedure for calculating sediment yield factor.

   a. Tonnage per year of sediment deposition in reservoir equals 5,330 tons (Red Lake Watershed District Report, Project #63, March 1992).

   b. Trap efficiency of Thief River Falls Reservoir is 27 percent (ibid).

   c. Sediment yield to the reservoir is 5,330 tons divided by 0.27 or 19,800 tons annually.

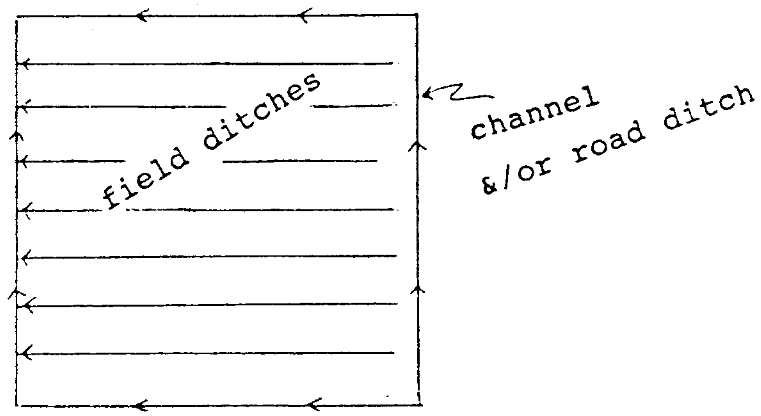
   d. Tonnage per year of sediment in streams and ditches equals 36,600 tons (See Sediment Budget).

   e. Percent of sediment tonnage in streams and ditches yielded to the reservoir is 19,800 tons divided by 36,600 tons times 100, or 54 percent.

6. Procedure for determining wind erosion sediment yield factor.

   a. Determine the area of channels, field ditches and road ditches receiving accumulations of wind blown sediments. The typical section contains 7 miles of channels and/or field ditches, and 4 miles of road ditches. The average width of the channels and ditches is one rod (16.5 feet) for a total of 22 acres per section, or 3 percent of the area in the section.

$$\frac{[7+4\text{miles}]\ \left[\frac{5{,}280\text{ ft}}{1\text{ mile}}\right]\ [16.5\text{ ft}]}{\frac{43{,}560\text{ sq ft}}{1\text{ acre}}} = 22\text{ acres}$$



Typical Section of Land

b. Use the same sediment delivery factor as for sheet and rill erosion (0.1).

c. Factor is equal to 0.3 percent (3 x 0.1).

From tak Thu Feb 23 14:21 CST 1995
>From tak Thu Feb 23 14:21:37 1995
Date: Thu, 23 Feb 95 14:21:37 CST
From: Timothy A. Koehler <tak>
To: @mn600g.UUCP:sll, @mn600g.UUCP:vjr
Subject: sed yield from wind erosion

Tim:

I did receive your VoiceMail message about the wind erosion sediment yield problem. There are no easy answers to that one!

Two suggestions:

1. estimate the area of channels (including road ditches) that receive accumulations of wind blown soil. Take that percentage of area times the total amount of wind erosion and assume that has a 100 % SDR to your watershed outlet (unless you are routing sediment after it gets into your stream system, which would require dropping some sediment onto floodplains).

2. Work with soil scientists & agronomist to develop K and C factors for deposits of wind blown soil. Estimate a USLE rate for deposits of wind blown soil and multiply the rate by the area of deposits to estimate tons/yr. Use a SDR for sheet and rill erosion to estimate sediment yield from erosion of wind blown deposits. SDR's of 25% or less are typical for sheet and rill erosion.

Maybe these ideas will generate some discussion. You are really on your own here; even I have never really tried to account for sediment yield from wind eroded soil.

Lyle Steffen, MNTC Sedimentation Specialist, Lincoln, Nebraska

United States Department of Agriculture
Soil Conservation Service
375 Jackson Street, Suite 600
St. Paul, MN 55101-1854

February 24, 1994

Gary Lane, Manager
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USDA-Soil Conservation Service
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Cheryl Sistad
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Grygla, MN 56727-0016

Here are methods for calculating both gully and streambank erosion rates and volumes. Hopefully you will find this process self-explanatory and straight forward in its approach.

Questions can be answered by Steve Lacy at the state office at (612) 290-3672.

We would suggest that photos be taken (with scale) of the representative sites used for review purposes.

Please note that when measuring bank height, the measurement follows the slope of the bank, not just vertical height.

Sincerely,

Tim Koehler

TIMOTHY A. KOEHLER
Water Resources Staff Leader

cc:
Glen Kajewski, AC, SCS, Thief River Falls, MN
Maggie Leach, Pennington SWCD, Thief River Falls, MN
Mike Majeski, FS, St. Paul, MN
Vic Ruhland, SCS, St. Paul, MN
Robert Bird, SCS, St. Paul, MN

Gully Erosion

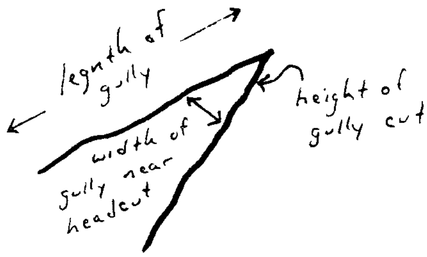
1. Determine the size of the drainage area in square miles. Example 10 mi^2

2. Select representative section(s) for sampling.

3. Observe gullies and determine if these are ephemeral or classic.

4. Determine an "average" size for the representative gullies.

5. Calculate the volumes for the selected average gullies.



Example: gully #1 - concentrated flow from field.

	(ft) Length	(ft) Height	Lateral (ft) Width	Recession Rate (ft/yr)	Density (pcf)	=	Erosion rate tons/gully
Headcut		5	5	.8	95		.95
Left bank	150	5		.2	95		7.1
Right bank	150	5		.2	95		7.1
Total tons/gully							15.2

6. Add the tons/gully from the representative gullies and divide by the number of gullies used to get average tons/gully.

   Example: 78 tons/yr/4 gullies = 19.6 tons per gully.

7. Multiply average number of gullies per section with the watershed size.

   Example: 4 gullies/section x 10 mi^2 = 40 gullies in watershed.

8. Multiply number of total gullies x tons/gully for total ton amount.

   Example: 40 gullies x 19.6 tons/gully = 784 tons/yr gully erosion.

Streambank Erosion (for ditches or streams)

1. Determine the size of the drainage area in square miles.

2. Calculate the total number of miles of streambank and ditch banks in the watershed.

3. Select representative sampling location (5-25%) of streambanks and ditch banks for field data collection.

4. Conduct field work to determine representative erosion rates and volume on the banks. (see below)

<u>Average Annual Lateral Recession Rate</u>

The average annual lateral recession rate is the thickness of soil eroded from a bank surface (perpendicular to the face) in an average year. Recession rates are measured in feet per year. Channel erosion often occurs as "chunk" or "blowout" type erosion. A channel bank may not erode for a period of years when no major runoff events occur. When a major storm does occur, the bank may be cut back tens of feet for short distances. It is necessary to assign recession rates to banks with such a process in mind. When a bank is observed after a flood and ten feet of bank has been eroded, that ten feet must be averaged with the years when no erosion occurred. This will result in a much lower average annual lateral recession rate than a recession rate for one storm.

Selecting the average annual lateral recession rate is the most critical step in estimating channel erosion using the direct volume method. A historical perspective is required in many instances. Old photographs, old survey records, and any other information that tells you what a bank looked like at known times in the past are very useful data. In most instances, such information is lacking and field observations and judgment are needed to estimate recession rates.

Exposed bridge piers, suspended outfalls or culverts, suspended fence lines, and exposes tree roots are all good indications of lateral recession. Discoloration on the bridge piers may show the original channel bottom elevation. Given the date of bridge installation, a recession rate can be calculated for that reach of stream. Culverts are generally installed flush with a bank surface. The amount of culvert exposed and age of the culvert will allow you to calculate a recession rate.

Exposed tree roots are probably the most common field evidence of lateral recession. Consult references to familiarize yourself with tree height and appearance as related to tree age. Roots will not grow towards a well drained, exposed, eroding channel bank. The amount of root exposed should be increased by at least a factor of 2x to account for soil that was in the bank and that the root was growing in. By dividing the length of root exposed and the thickness of soil around the root by the age of the tree, an estimated recession rate can be obtained.

Textbooks on photogrammetry should be consulted to review techniques for estimating bank erosion from aerial photos. There are techniques available to measure bank height from a stereo pair of air photos.

As can be seen in the discussion above, there are few instances where you will be able to measure recession rates in the field. Much experience and judgment are generally required to estimate recession rates for channel erosion. Because of this, a table has been compiled for your use which relates recession rates to narrative descriptions of banks eroding at different rates.

Slight, Moderate, and Severe Erosion and Corresponding Lateral Recession Rates

The following page lists lateral recession rates, categories of erosion severity, and corresponding narrative descriptions for each category. Roadbank erosion is separate because flows in road ditches are not as severe as in streams and gullies. The placement of road cuts across slopes generally invites erosion problems, however, either due to mass movements or changes in drainage.

When using the direct volume method for gullies, different lateral recession rates may be required for the eroding walls than for the eroding headcut or nick point area. If there is field evidence that the bed of the channel is being eroded, the direct volume method can be used to estimate that erosion. A recession rate for the downcutting would be required.

To estimate channel erosion, first determine the slope height and length of the eroding banks. By field observation, match the appearance of the eroding areas with the narratives shown to identify what category the erosion is in. Once you have categorized the erosion, note whether all the symptoms discussed in the narrative are present or if only a few symptoms occur. If only a few of the symptoms in the narrative characterize the eroding area, you may want to use the low end of the range of recession rates shown for that category.

When you are actually observing sample areas in the field, you will probably note that eroding areas are mixed in severity and in frequency of occurrence. As an example, a 500 foot long streambank may generally be in the moderate erosion category (0.06 feet/year). A few 50 foot reaches within that 500 foot reach may be eroding very severely (0.5+ feet/year). If you are only interested in the total tons of erosion, you could increase the recession rate to 0.1 feet/year and use that for the entire 500 foot reach. This simplifies data collection and decreases time in the field, without jeopardizing the level of accuracy of your study.

Continuing the example above: if you wish to locate erosion problems on a map and give recommendations for treating the problems, it is then necessary to record each and every segment of bank where changes in the category of erosion occur. This allows you to recommend how many miles of rock rip-rap or vegetative stabilization will be required to remedy the severely and very severely eroding banks.

Volume-Weight Conversions

By multiplying eroding areas by a lateral recession rate, cubic feet of eroded material is obtained. To convert this volume of erosion to a weight, the dry density of the soil must be known. Table 1 lists soils by texture with corresponding volume weights. These can be used or soil samples can be collected in the field. The samples must be undisturbed, moist, and of known volume. Dry weights are measured and the volume of the sample is used to determine the dry density of the sample. The samples must be moist because that will probably be their condition at the time of erosion.

Streambank and Gully Erosion

Lateral Recession Rate (ft/yr)	Category	Description
0.01-0.05	Slight	Moderate bare bank but active erosion not readily apparent. Some rills but no vegetative overhang. No exposed tree roots.
0.06-0.2	Moderate	Bank is predominantly bare with some rills and vegetative overhang. Some exposed tree roots but no slumps or slips.
0.3-0.5	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads and trails. Channel cross-section becomes more U-shaped as opposed to V-shaped.
0.5+	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross-section is U-shaped and stream course or gully may be meandering.

Table 1. Volume-Weights of Soils

Soil Texture	Volume-Weight
Clay	60-70 pcf
Silt	75-90
Sand	90-110
Gravel	110-120
Loam	80-100
Sandy loam	90-110
Gravelly loam	110-120

NOTE: For soil density values in Thief/Red Lake River Project area use 65 pcf.

Sample Calculations

1. There are 12 miles of first order streams in the Doodad Watershed. You go out to sample one mile of a first order stream. One bank is grassed and noneroding. The other bank is a sandy loam soil and three spots are bare. Two of the spots are 600 and 800 feet long. The banks are bare with a few roots exposed and some rills. There is no grass overhang above the two spots and the bare areas are about 10 feet high. The

third spot is on the outside edge of a curve in the stream. It is 1,200 feet long and the bare banks are 12 feet high. Two fence posts are lying at the base of the bare bank and two trees have fallen into the channel. Most of the bank has rills and about 2 inches of grass overhang is at the top of the bank. Based on your sample, how much streambank erosion is occurring on 1st order streams in the Doodad Watershed?

Use direct volume method:

Spots 1 and 2
(600 + 800') (10' high) (moderate rate = .06'/yr) (100 pcf)

$$\frac{\text{(eroding area) (lateral recession rate) (density)}}{\text{2000 pounds/ton}} = \text{erosion}$$

$$\frac{\text{1400 ft x 10 ft x 0.06 ft/yr x 100 pcf}}{\text{2000 pounds/ton}} = \text{42 tons/yr/sample}$$

Spot 3

$$\frac{\text{1200 ft x 12 ft x 0.4 ft/yr x 100 pcf}}{\text{2000 pounds/ton}} = \underline{288}\ \text{ton/yr erosion}$$

Total for all spots = 330 tons/yr/erosion

$$\frac{\text{2600 ft eroding}}{\text{2 bank miles sampled}} = \text{25\% of sample was eroding}$$

$$\frac{\text{330 tons/yr erosion}}{\text{1/2 mile eroding}} = \text{660 tons/yr/bank mile is erosion rate}$$

12 miles of 1st order streams x 25% = 3 total miles eroding

3 miles x 2 banks/mile = 6 total bank miles eroding

6 bank miles eroding x 660 tons/yr/bank mile - 3960 tons/yr bank erosion per watershed or selected grouping.

2. Air photos of the Doodad Watershed show that 22 large and 40 small gullies occur in the watershed. You randomly select one large and two small gullies to examine in the field. The large gully is 900 feet long and eight feet deep. It is cut on a rangeland hillside. The soil exposed in the banks of the gully is a loam. The nick point is 10 feet wide with clumps of soil at the base that still have grass on their surfaces. Deep rills cut the face of the nick point and about three inches of grass overhang the edge. The banks of the gully are bare with some grass overhanging the top edge. Only a few rills are observed. Two small gullies are observed a few hundred feet away on each side of the large gully. Both of these gullies are similar. One is 220 feet long and one is 300 feet long. Both are three feet deep and four feet wide. The nick point and the banks are bare with some rills. About one inch of vegetation hangs over their edge. What is the total amount of gully erosion in the Doodad Watershed?

Use direct volume method:

$$\frac{\text{(eroding area) (lateral recession rate) (density)}}{\text{2000 pounds/ton}} = \text{erosion}$$

$$\frac{\text{10 ft x 8 ft x 0.4 ft/yr x 90 pcf}}{\text{2000 pounds/ton}} =$$

1.4 or 1 tons/yr erosion
(head cut portion)

$$\frac{\text{1800 ft x 8 ft x 0.06 ft/yr x 90 pcf}}{\text{2000 pounds/ton}} =$$

39 tons/yr erosion
40 tons/yr erosion from one large gully
(one side bank)

$$\frac{\text{1048 ft x 3 ft x 0.06 ft/yr x 90 pcf}}{\text{2000 pounds/ton}} =$$

8.5 tons/yr erosion
(other side bank)

8.5 tons/yr/2 gullies = 4 tons/yr erosion from one small gully.

22 large gullies x 40 tons/yr = 880 tons/yr erosion.

40 small gullies x 4 tons/yr = 160 tons/yr erosion.
1040 tons/yr gully erosion.

APPENDIX D

SHEET AND RILL EROSION TABLES

WIND EROSION TABLES

TABLE D1-AVERAGE ANNUAL SHEET AND RILL EROSION - 1992 CONDITIONS

BY EVALUATION UNITS FOR THIEF LAKE HYDROLOGIC UNIT _1/

Thief and Red Lake Rivers Basin, Minnesota

LAND USE	EVAL 1			EVAL 2			EVAL 3			EVAL 4			EVAL 5			EVAL 6			SUBTOTAL	
/RANGE	Acres	Rate	Tons	Acres	Rate	Tons	Acres	Rate	Tons	Acres	Rate	Tons	Acres	Rate	Tons	Acres	Rate	Tons	Acres	Tons
Cropland_2/																				
0-1	23.9	0.3	7.2	22.9	0.3	6.9	73.6	0.2	14.7	18.4	0.3	5.5	57.2	0.2	11.4	26.3	0.3	7.9	222.3	53.6
1-3	0.4	1.0	0.4	0.6	1.0	0.6	1.4	1.0	1.4	0.4	1.0	0.4	1.1	1.0	1.1	0.6	1.0	0.6	4.5	4.5
CRP_3/																				
0-1	3.0	0.3	0.9	13.9	0.3	4.2	9.8	0.2	2.0	4.7	0.3	1.4	10.5	0.2	2.1	12.6	0.3	3.8	54.5	14.4
1-3	0.0	0.0	0.0	0.2	1.0	0.2	0.2	1.0	0.2	0.1	1.0	0.1	0.2	1.0	0.2	0.2	1.0	0.2	0.9	0.9
Cropland Total	27.3		8.5	37.6		11.9	85.0		18.3	23.6		7.4	69.0		14.8	39.7		12.5	282.2	73.4
Pastureland	1.9	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.2	0.0	0.0	7.0	0.0	0.0	0.3	0.0	0.0	13.8	0.0
Shrub-grasslan	11.9	0.0	0.0	2.7	0.0	0.0	25.3	0.0	0.0	8.5	0.0	0.0	9.6	0.0	0.0	2.5	0.0	0.0	60.5	0.0
Forest land	66.6	0.0	0.0	2.7	0.0	0.0	60.6	0.0	0.0	4.9	0.0	0.0	31.6	0.0	0.0	2.2	0.0	0.0	168.6	0.0
Wetland	27.7	0.0	0.0	0.5	0.0	0.0	60.8	0.0	0.0	8.1	0.0	0.0	31.0	0.0	0.0	3.8	0.0	0.0	131.9	0.0
Lakes	7.3	0.0	0.0	0.1	0.0	0.0	3.5	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0	11.4	0.0
Other	1.9	0.0	0.0	1.1	0.0	0.0	4.9	0.0	0.0	0.8	0.0	0.0	2.6	0.0	0.0	1.4	0.0	0.0	12.7	0.0
Total	144.6		8.47	44.7		11.9	244.5		18.3	46.3		7.4	151.0		14.8	50.0		12.5	681.1	73.4

_1/ Acres and tons in thousands.

_2/ Rates from 1992 NRI- 98.4% at 0-1 T/Ac. & 1.6% at 1-3 T/Ac. (includes CRP).

_3/ CRP acreage in the 1992 NRI are considered as cropland with zero erosion. However, this does not properly represent the conditions which produced the volume of sediment deposited in the reservoir between 1966-1990. In order to have conditions more consistant for developing a sediment budget, the CRP acreages were assumed to be in crop production and possessing soil erosion conditions.

TABLE D1 (cont.)-AVERAGE ANNUAL SHEET AND RILL EROSION - 1992 CONDITIONS
BY EVALUATION UNITS FOR RED LAKE RIVER HYDROLOGIC UNITS_1/
Thief and Red Lake River Basin, Minnesota

LAND USE /RANGE	EVAL 7			EVAL 8			SUBTOTAL		TOTAL	
	Acres	Rate	Tons	Acres	Rate	Tons	Acres	Tons	Acres	Tons
Cropland_2/										
0-1	77.3	0.4	30.9	10.8	0.3	3.2	88.1	34.1	310.4	87.7
1-3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	4.5
CRP_3/										
0-1	23.7	0.4	9.5	1.2	0.3	0.4	24.9	9.9	79.4	24.3
1-3			0.0			0.0	0.0	0.0	0.9	0.9
Cropland Total	101.0		40.4	12.0		3.6	113.0	44.0	395.2	117.4
Pastureland	0.0	0.0	0.0	2.9	0.0	0.0	2.9	0.0	16.7	0.0
Shrub-grassland	6.9	0.0	0.0	4.4	0.0	0.0	11.3	0.0	71.8	0.0
Forest land	8.7	0.0	0.0	49.8	0.0	0.0	58.5	0.0	227.1	0.0
Wetlands	0.2	0.0	0.0	97.1	0.0	0.0	97.3	0.0	229.2	0.0
Lakes	0.8	0.0	0.0	1.0	0.0	0.0	1.8	0.0	13.2	0.0
Other	4.5	0.0	0.0	0.5	0.0	0.0	5.0	0.0	17.7	0.0
Total	122.1		40.4	167.7		3.6	289.8	44	970.9	117.4

_1/ Acres and tons in thousands.

_2/ Rates from 1992 NRI-98.4% at 0-1 T/Ac. & 1.6% at 1-3 T/Ac. (includes CRP).

_3/ CRP acreage in the 1992 NRI are considered as cropland with zero erosion. However, this does not properly represent the conditions which produced the volume of sediment deposited in the reservoir between 1966-1990. In order to have conditions more constistant for developing a sediment budget, the CRP acreages were assumed to be in crop production and possessing soil erosion conditions.

TABLE D2-AVERAGE ANNUAL WIND EROSION - 1992 CONDITIONS_1/

Thief and Red Lake Rivers Basin, Minnesota

LAND USE /RANGE	EVAL 1 Acres	EVAL 1 Rate	EVAL 1 Tons	EVAL 2 Acres	EVAL 2 Rate	EVAL 2 Tons	EVAL 3 Acres	EVAL 3 Rate	EVAL 3 Tons	EVAL 4 Acres	EVAL 4 Rate	EVAL 4 Tons	EVAL 5 Acres	EVAL 5 Rate	EVAL 5 Tons	EVAL 6 Acres	EVAL 6 Rate	EVAL 6 Tons	SUBTOTAL Acres	SUBTOTAL Tons
Cropland_2/																				
0-2	10.7	0.0	0.0	4.9	0.0	0.0	32.8	0.0	0.0	7.1	0.0	0.0	16.1	0.3	4.8	2.6	1.2	3.1	74.2	7.9
2-5	3.3	4.4	14.5	4.5	4.4	19.8	10.3	4.4	45.3	2.9	4.4	12.8	17.5	4.4	77.0	10.1	4.4	44.4	48.6	213.8
5-10	2.3	7.0	16.1	3.1	7.0	21.7	7.1	7.0	49.7	1.9	7.0	13.3	13.0	7.6	98.8	7.5	7.6	57.0	34.9	256.6
10-15	8.0	12.3	98.4	11.0	12.3	135.3	24.8	12.3	305.0	6.9	12.3	84.9	11.7	11.2	131.0	6.7	11.2	75.0	69.1	829.6
CRP_3/	3.0	10.0	30.0	14.1	10.0	141.0	10.0	10.0	100.0	4.8	10.0	48.0	10.7	10.0	107.0	12.8	10.0	128.0	55.4	554.0
Cropland Total	27.3		159.0	37.6		317.8	85.0		500.0	23.6		159.0	69.0		418.6	39.7		307.5	282.2	1861.9
Pastureland	1.9	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.2	0.0	0.0	7.0	0.0	0.0	0.3	0.0	0.0	13.8	0.0
Shrub-grasslan	11.9	0.0	0.0	2.7	0.0	0.0	25.3	0.0	0.0	8.5	0.0	0.0	9.6	0.0	0.0	2.5	0.0	0.0	60.5	0.0
Forestland	66.6	0.0	0.0	2.7	0.0	0.0	60.6	0.0	0.0	4.9	0.0	0.0	31.6	0.0	0.0	2.2	0.0	0.0	168.6	0.0
Wetland	27.7	0.0	0.0	0.5	0.0	0.0	60.8	0.0	0.0	8.1	0.0	0.0	31.0	0.0	0.0	3.8	0.0	0.0	131.9	0.0
Lakes	7.3	0.0	0.0	0.1	0.0	0.0	3.5	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0	11.4	0.0
Other	1.9	0.0	0.0	1.1	0.0	0.0	4.9	0.0	0.0	0.8	0.0	0.0	2.6	0.0	0.0	1.4	0.0	0.0	12.7	0.0
Total	144.6		159.0	44.7		317.8	244.5		500.0	46.3		159.0	151.0		418.6	50.0		307.5	681.1	1861.9

_1/ Acres and tons in thousands.

_2/ Erosion rates are 60 percent of the 1992 NRI erosion rates for each hydrologic unit. The adjustment more nearly represents the crop stage method of calculating average annual wind erosion rates. Erosion rates of the Red Lake River Hydrologic Unit were used in Evaluation Units 5 and 6 (better data).

_3/ CRP acreage in the 1992 NRI are considered as cropland with zero erosion. However, this does not properly represent the conditions which produced the volume of sediment deposited in the reservoir between 1966-1990. In order to have conditions more consistant for developing a sediment budget, the CRP acreages were assumed to be in crop production and possessing soil erosion conditions.

TABLE D2 (cont.)-AVERAGE ANNUAL WIND EROSION - 1992 CONDITIONS_1/

Thief and Red Lake Rivers Basin, Minnesota

LAND USE /RANGE	EVAL 7			EVAL 8			SUBTOTAL		TOTAL	
	Acres	Rate	Tons	Acres	Rate	Tons	Acres	Tons	Acres	Tons
Cropland_2/										
0-2	15.6	0.5	7.8	3.5	0.3	1.1	19.1	8.9	93.3	16.8
2-5	25.6	4.4	112.6	3.0	4.4	13.2	28.6	125.8	77.2	339.6
5-10	19.0	7.6	144.4	2.3	7.6	17.5	21.3	161.9	56.2	418.5
10-15	17.1	11.2	191.5	2.0	11.2	22.4	19.1	213.9	88.2	1043.5
CRP_3/	23.7	10.0	237.0	1.2	10.0	12.0	24.9	249.0	80.3	803.0
Cropland Total	101.0		693.3	12.0		66.2	113.0	759.5	395.2	2621.4
Pastureland	0.0	0.0	0.0	2.9	0.0	0.0	2.9	0.0	16.7	0.0
Shrub-grassland	6.9	0.0	0.0	4.4	0.0	0.0	11.3	0.0	71.8	0.0
Forest land	8.7	0.0	0.0	49.8	0.0	0.0	58.5	0.0	227.1	0.0
Wetland	0.2	0.0	0.0	97.1	0.0	0.0	97.3	0.0	229.2	0.0
Lakes	0.8	0.0	0.0	1.0	0.0	0.0	1.8	0.0	13.2	0.0
Other	4.5	0.0	0.0	0.5	0.0	0.0	5.0	0.0	17.7	0.0
Total	122.1		693.3	167.7		66.2	289.8	759.5	970.9	2621.4

_1/ Acres and tons in thousands.

_2/ Erosion rates are 60 percent of the 1992 NRI erosion rates for each hydrologic unit. The adjustment more nearly represents the crop stage method of calculating average annual wind erosion rates. Erosion rate of the Red Lake River Hydrologic Unit were used in Evaluation Units 5 and 6 (better data).

_3/ CRP acreage in the 1992 NRI are considered as cropland with zero erosion. However, this does not properly represent the conditions which produced the volume of sediment deposited in the reservoir between 1966-1990. In order to have conditions more consistant for developing a sediment budget, the CRP acreages were assumed to be in crop production and possessing soil erosion conditions.

APPENDIX E

CORRESPONDENCES

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
2280 Woodale Drive
Mounds View, Minnesota 55112

November 9, 1995

Mr. Vic Ruhland
Natural Resources Conservation Service
FCS Building, Suite 600
375 Jackson Street
St. Paul, MN 55101

Dear Vic,

Attached is a write-up discussing the work I did evaluating the sediment transport curve for the Red Lake River at Crookston. If you need more information about what was done, please call me at (612) 783-3272.

Respectfully,

Lan H. Tornes
Hydrologist

Page 14 paragraph 4: This has the potential to be both a blessing or curse in terms of wildlife habitat and we would want to be involved in development of this option.

Page 14 paragraph 6: It would be more favorable to treat the problem upstream rather than to dredge.

Page 15 paragraph 4: Recommend that this needs to be looked at. Applications which reduce sediments right away is a good start.

Page 16 paragraph 1: These would have more benefit that just the wildlife areas and these alone are significant.

Page 16 Paragraph 2: We should pursue the PL-566 or similar projects.

Page 16 Paragraph 4: While wind erosion is number 1, overland water erosion is also significant. Both deserve attention and efforts to curtail them.

Please call if you have questions.

Sincerely -

John Williams

John Williams - Asst. Mgr.
Thief Lake WMA

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES

PHONE NO (218) 222-3747

FILE NO.

Thief Lake Wildlife Management Area
HCR 3 Box 17
Middle River, MN 56737

Post-it™ Fax Note 7671	Date 1/9/96 # of pages ▸ 2
To Vic Ruhland	From John Williams
Co./Dept. NRCS	Co. Thief Lake WMA
Phone #	Phone # (218) 222 3747
Fax #	Fax # (218) 222-3746

January 9, 1995

Vic Ruhland
Natural Resources Conservation Service
375 Jackson St..
St. Paul, Mn. 5501-1854

Mr. Ruhland:

Below are comments which Paul Telander (Manager - Thief Lake WMA) and myself have regarding the draft of the "Erosion and Sediment Data - Thief and Red Lake River Basin Study". These were faxed to Mike Ratzloff and he requested they be faxed directly to you. We discussed these comments over the phone after he had contacted you for further details. The following are comments by page and paragraph revised since I've talked to Mike:

Page 2 paragraph 1: During storm events the velocities observed in our local ditches can be quite fast and significant.

Page 9 under section titled " Gross Erosion": Five paragraphs follow - each paragraph references a type of erosion. It would be helpful if the statistics discussed would be consistent between all five paragraphs. For example under "Sheet and Rill Erosion" it is stated that 19% of the sediment yielded to streams is of this type while in classic Gully, Ditchbank, and Streambank no percentage is mentioned and needs to be.

Page 11 paragraph 1: It mentions that of 2 million tons of gross erosion only 49,200 tons are yielded to the ditches and streams...the remainder being deposited or blown beyond the study area. Has any calculation been determined what tonnage is being deposited from other areas into the study area? (Wind deposits primarily) As this may be considered a wash it should be stated as such.

Page 14 paragraph 2: Mention the % reduction that 400 less tons yielded to the streams would result in.

Page 14 paragraph 3: Would this practice also extend the clean out interval? If so this is also an added benefit. We need to recommend this!

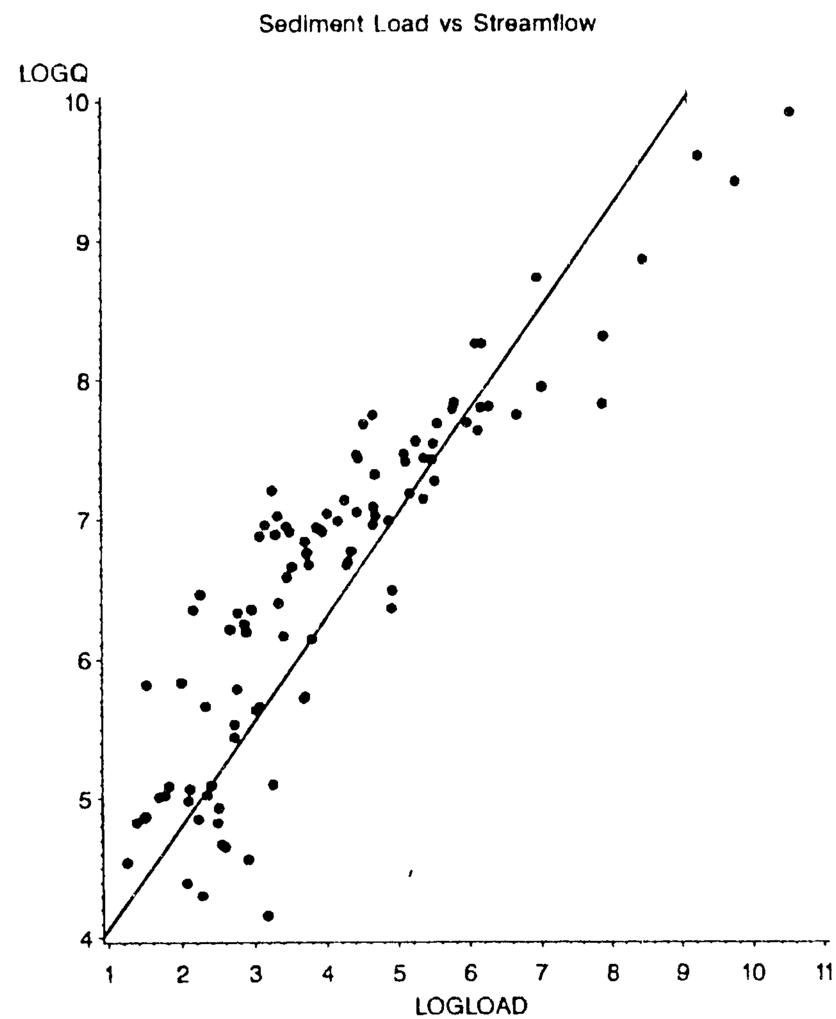


Figure 1

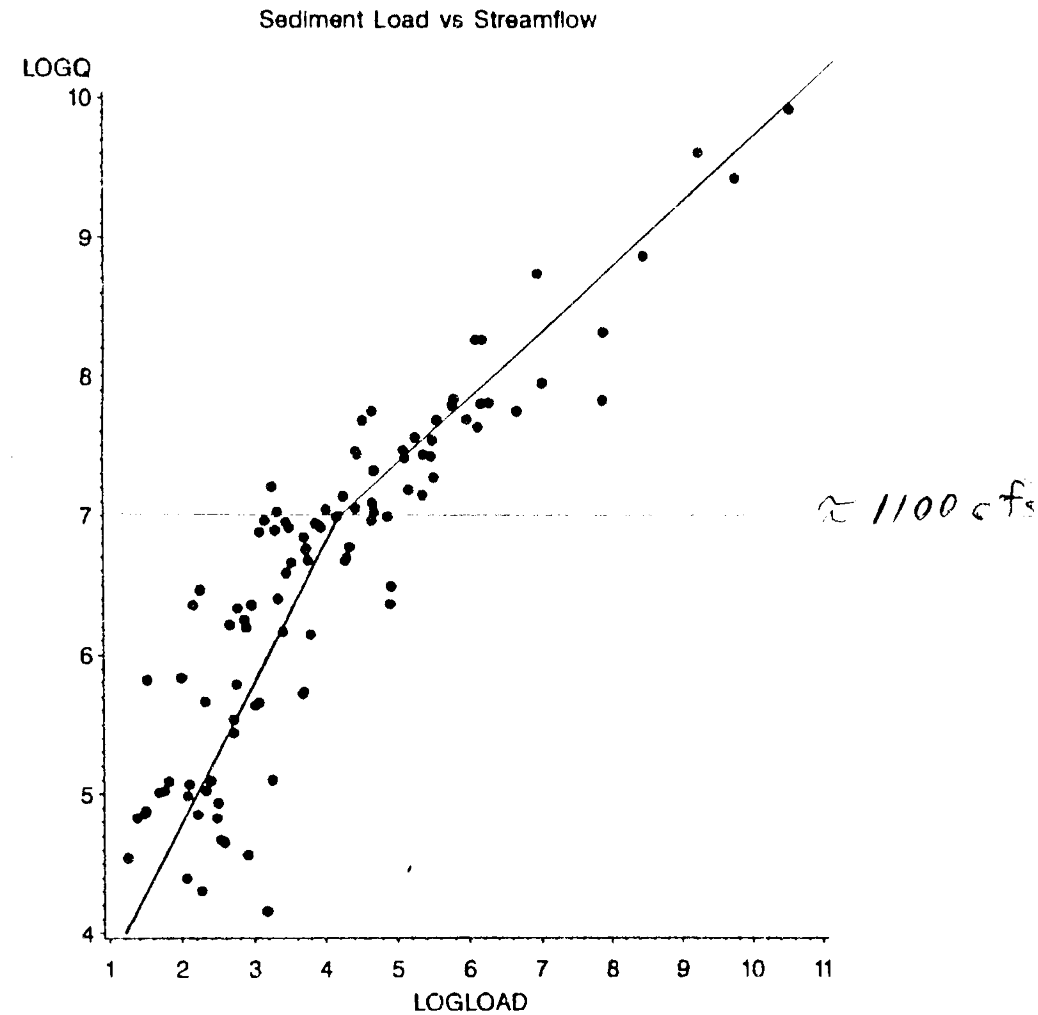


Figure 2

A sediment-transport curve (the relation between sediment load and streamflow) was developed by the U.S. Geological Survey (USGS) from instantaneous samples of suspended sediment collected by the USGS at the Red Lake River at Crookston, MN. This curve incorporated data available through August 1994 from ongoing (National Stream Quality Accounting Network) and newly-initiated (National Water Quality Assessment) data collection programs. This curve is an update to one developed by the Red Lake River Watershed District (RLRWD). The RLRWD used 68 samples to develop their curve. Additional data provided a total of 102 samples, and many of the newer samples were collected during moderate to high-flow conditions. Higher-flow samples are needed to better define the upper portion of the sediment-transport curve.

Summary statistics of sediment data for the Red Lake River at Crookston (rounded to 3 significant figures):

Period of record: January, 1979 - August 1994

	Flow (cubic feet/second)	Load (Tons/day)
Minimum	63.0	2.51
Maximum	20200	37900
Mean	1560	857
Standard dev.	2810	4250

Correlation coefficient between flow and load: 0.896, statistically significant at 0.0001.

The highly-skewed streamflow and load data were transformed by taking the natural logarithm. Least squares linear regression was used on the transformed data to determine the equation (model) to compute the sediment load from values of streamflow. When this method is used it is important to compensate for bias introduced when transforming the log-based equation back to real numbers; this was done by adding one-half of the mean square error of the model (MSE/2). The resulting equation is:

$$S=0.0118Q^{1.35}$$

where S = Suspended sediment load in tons per day (T/day)
Q = Streamflow in cubic feet per second (cfs)
** = Exponent (raised to the power)

Comparison of this model with the data (figure 1) suggests that a more precise model should be broken into two parts with one equation fit to the data at and below 1100 cfs (LOGQ=7) and another fit to the data above 1100 cfs (figure 2). That was not done because the RLRWD used only one equation for their model. Computation of sediment load using the updated equation and selected flow values from the table in Annex E of the Thief River Falls Reservoir Study, Project #63 (RLRWD, March 1992) show that sediment load in that table is underestimated by more than 100 percent at the lowest streamflow to about 27 percent at the highest streamflow.

Although the previously published values may be low, it probably is not worth continuing evaluation of the sediment-transport curve for the Red Lake River at Crookston. It is uncertain whether the curve developed for Crookston is applicable at Thief River Falls, and instantaneous sediment concentrations generally should not be used for determining long-term sediment loads and yields.

The data collection program ongoing at stream sites near Thief River Falls should provide much better results because they are collected at the sites of concern and they will be used to develop at relatively long-term, almost daily record of suspended sediment concentration and load. These data will be more appropriate for developing sediment-transport curves for each of the stream sites that are of concern to the local officials.

APPENDIX F

SEDIMENT BASIN DESIGN

Sediment Basin 3 - Sediment Basin No. 3 is located on the Upper North Branch of the Root River approximately 2,000' upstream of Lake Florence. It has a drainage area of 97.3 square miles.

The sediment basin will consist of an excavation in the bottom of the river channel. Approximately 9,800 cubic yards will be excavated by extending the channel side slopes down at a 2:1 slope five feet below the existing channel bottom. The excavation will be 750 feet in length and will be done using a dragline. A sheet pile weir will be placed upstream of the excavated reach at the channel bottom elevation. This is to insure that a headcut will not migrate upstream from the excavated area. Sediment storage capacity is six acre-feet.

This structure is designed as full flow structure and has no floodwater retention. The purpose of the structure is to trap the bedload sediment, preventing it from being deposited in Lake Florence. In order to maintain its trapping efficiency, the trapped sediment will have to be removed when conditions necessitate. This will be done by a dragline operating along the south side of the river.

A 100 foot strip on the south side of the sediment basin will be cleared of trees to provide a raceway for the dragline to operate for the basin excavation and sediment removal. A corridor planted to trees will be reestablished adjacent to the raceway. See Figures 10 and 11. The sediment basin will require land rights consisting of term easements on about four acres.

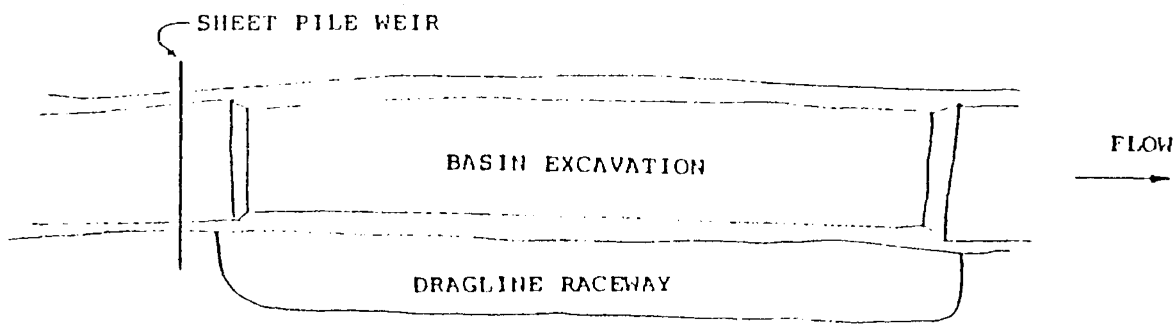


Figure 10. Plan View of Sediment Basin 3

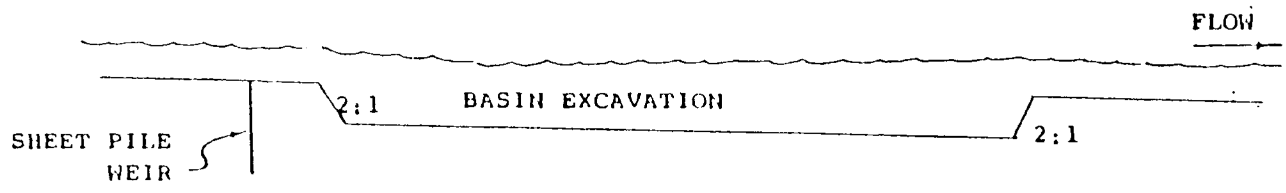


Figure 11. Profile, Sediment Basin 3.

From: Draft Watershed Plan - Environmental Assessment, Upper North Branch Root River Watershed, Minnesota, 9-1992.