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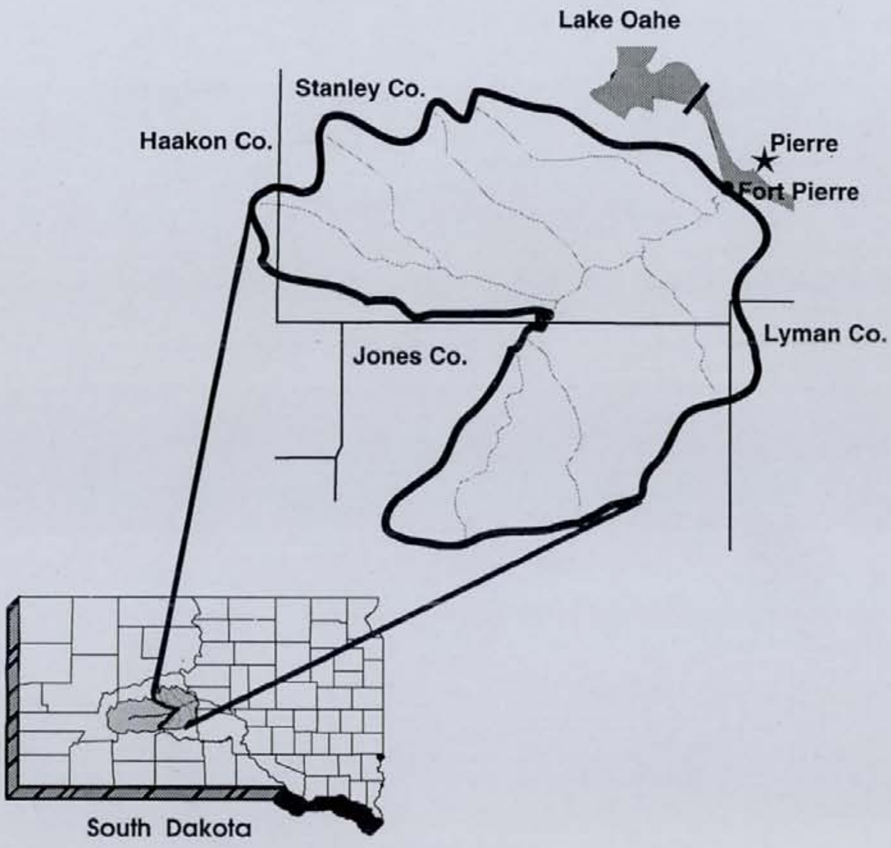
Lower Bad River River Basin Study *Final Report*



March 1994

LOWER BAD RIVER - RIVER BASIN STUDY

Project # 4380

Prepared By:

United States Department of Agriculture

SOIL CONSERVATION SERVICE

FOREST SERVICE

In Cooperation With:

South Dakota Department of
Environment and Natural Resources

South Dakota Department of Agriculture
Division of Conservation

Stanley County Conservation District

Jones County Conservation District

Haakon County Conservation District

American Creek Conservation District

South Dakota Cooperative Extension Service

As Revised
June 1994

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EXECUTIVE SUMMARY

The Bad River is the smallest of five major river basins in western South Dakota that drain into the Missouri River. It originates in the Big (White River) Badlands near Wall, South Dakota, and flows to the east approximately 100 miles where it discharges into Lake Sharpe near the towns of Fort Pierre and Pierre. The basin drains approximately 3,209 square miles of Stanley, Jones, Lyman, Haakon, Jackson, and Pennington Counties. Based on gage data from 1948-1986, the U.S. Army Corps of Engineers estimates that the Bad River discharges an average annual sediment load of approximately 3,250,000 tons/year of sediment into Lake Sharpe.

The Lower Bad River-River Basin Study was requested by the Stanley County Conservation District as the result of public concern about the adverse effects sediment deposition from the Bad River has on water quality, recreation, and fish and wildlife habitat in Lake Sharpe. The objective of the study was to identify major sediment sources, quantify sediment contributions, and develop sediment reduction strategies in the watershed.

The river basin study focuses on the lower one-third of the Bad River drainage, 792,000 acres. This region was identified in a previous study as the major source of sediment in the watershed. The Lower Bad River-River Basin Study has determined relative percentages of erosion and sediment yield from cropland, hayland, rangeland, channels, gullies, and streambanks in the study area.

The Universal Soil Loss Equation (USLE), Pacific Southwest Inter-Agency Committee (PSIAC) evaluation method for sediment yield, Ephemeral Gully Erosion Model (EGEM), Simulation of Production and Utilization of Rangeland (SPUR-91) computer model, and the Direct Volume Procedure were the methods used to determine gross erosion. Gross erosion from the different sources within the study area was multiplied by an estimated sediment delivery ratio to calculate sediment yield. Estimates of sediment transport are based on research data, historical records, gaging station measurements and when appropriate, professional experience and judgment.

Sheet and rill erosion from cropland and rangeland are the major sources of <u>erosion</u>. However, erosion originating from gullies, channels and streambanks is the major <u>sediment</u> source. Wind erosion, a significant form of erosion from cropland in the upper portion of the watershed, was not quantitatively evaluated due to the great distances between eroding areas and the point of sediment delivery at the mouth of the Bad River. As a result, wind erosion on cropland, although a significant resource concern, is a minor source of sediment to the Bad River.

The major conclusions of the Lower Bad River-River Basin Study are:

1. Channel and gully erosion in the River Breaks is the main source of sediment reaching the Bad River. These

areas contribute 80 percent of the total sediment load leaving the study area.

2. The present grass species composition of the rangeland has a significant impact on infiltration rates which affects the hydrologic condition of the rangeland and the amount of runoff from storm events. Runoff is directly related to the amount of channel and gully erosion occurring in the study area.

3. The deterioration of riparian areas along channels and streambanks, as a result of heavy livestock use, accelerates gully formation and reduces the sediment filtering effects of vegetation.

4. The amount of sediment from cropland that is delivered to the mouth of the Bad River is a relatively small amount. Erosion control practices on cropland will not significantly reduce downstream sediment loads but will increase infiltration and reduce runoff. Reducing the amount of runoff reaching the channels and gullies will reduce the amount of sediment delivered to Lake Sharpe.

PREFACE

Authority

Cooperative river basin studies are made under the authority of section 6 of Public Law 83-566, as amended, (the Watershed Protection and Flood Prevention Act). This authorizes the Secretary of the United States Department of Agriculture (USDA), in cooperation with other federal, state and local agencies to make investigations and surveys of the watersheds of rivers and other waterways. These studies are made to help local citizens identify land and water resource problems, concerns and opportunities and assist them in developing implementation strategies to solve problems and resolve conflicts.

The Lower Bad River-River Basin Study is the result of a USDA cooperative study requested by the Stanley County Conservation District, in cooperation with the South Dakota Department of Environment and Natural Resources (DENR). The study authorization was received in September 1991. A Plan Of Work (POW) was developed, detailing work items to be completed. It was the official document of agreement between the study participants and it also provided a work outline.

The purpose of the Lower Bad River-River Basin Study was to identify cost-effective alternatives for the development of water and related land resources that will: (1) identify and quantify areas needing treatment for sediment reduction; (2) enhance the water quality and aesthetics of Lake Sharpe through the reduction of sediment; (3) increase economic and environmental stability through improved conservation application, and (4) improve economic development of the area by enhancing wildlife and fisheries habitat, improving recreational use and increasing productivity of depleted agricultural lands.

USDA Responsibilities

SCS and the Forest Service (FS), two agencies of USDA, participated in the river basin study under the terms of the Memorandum of Understanding dated February 2, 1956, and revised April 15, 1968.

SCS is responsible for making physical appraisals of water and related land resource problems, resource development needs, and for defining them in terms of meeting regional economic needs for water-related goods and services. The Forest Service is responsible for the aspects of planning related to federal grasslands and forested lands.

The efforts of all study participants were coordinated by the State River Basin Coordinating Committee. The committee is composed of representatives from SCS, FS, and DENR. SCS has been designated as the lead agency.

South Dakota - DENR Responsibilities

The South Dakota DENR has the responsibility for protecting, assessing, and reporting the quality of surface and ground water resources in the state. DENR has been designated the lead agency for nonpoint source pollution control in South Dakota and administers all Environmental Protection Agency (EPA) Section 319, 604b, and South Dakota Consolidated Water Fund grants.

DENR has taken an active role in the Lower Bad River-River Basin Study, as well as providing funding and technical assistance in all phases of the Bad River water quality studies. In 1989, EPA 319 funds were allocated for the implementation of Phase I and IB of the Bad River Water Quality Project. This project monitored sediment along different reaches of the Bad River with the objective of identifying major sediment sources.

Phase II of the Bad River Water Quality Project was begun in 1990. The Plum Creek Watershed in Stanley County was selected as a demonstration project for erosion control and sediment reduction practices. Sediment monitoring stations are maintained below completed conservation practices to evaluate their effectiveness in reducing sediment. The major goal of Phase II is to identify cost-effective land treatment activities that provide long-lasting erosion control and sediment reduction.

A representative from DENR serves on the Bad River Task Force. This group coordinates water quality efforts and provides a forum for local input within the Bad River area.

Sponsoring and Cooperating Agency Participation

A task force composed of city and county elected officials, sportsmen groups, and state and federal agencies was formed to coordinate monitoring efforts and provide local input. In addition to the South Dakota DENR, key members of the Bad River Task Force include:

The Stanley County Conservation District is the original sponsor of the Lower Bad River-River Basin Study. The conservation district is an entity of state government composed of elected supervisors that are charged with the supervision of conservation activities in Stanley County.

The Jones, Haakon, Jackson and American Creek Conservation Districts have supported the Lower Bad River-River Basin Study with their cooperation and assistance.

The South Dakota Department of Agriculture, Division of Conservation, has the responsibility for protecting the soil and water resources in the state. The Division cooperates with and provides assistance to federal, state, and local agencies for the purpose of achieving mutual objectives.

Other members of the task force that have assisted with this study through their cooperation and/or providing data are:

North Central Resource Conservation and Development Council
South Dakota Department of Game, Fish & Parks
South Dakota State University

City of Pierre

City of Fort Pierre

Pierre Chamber of Commerce

South Dakota Great Lakes Association

USDA Agriculture Stabilization and Conservation Service

USDA Cooperative Extension Service

U.S. Fish and Wildlife Service

U.S. Army Corps of Engineers

U.S. Environmental Protection Agency

U.S. Geological Survey

Study Objectives

In 1990, sediment monitoring along the Bad River[1] and a sediment survey of Hayes Lake[2] in west central Stanley County were completed. These projects, called Phase I and IB, were completed using a combination of local, state, and federal resources and funding. Three main conclusions were made from these projects:

1. Badland soils of the upper reaches of the Bad River drainage area are not a major sediment source.

2. Cropland is not a major sediment source. However, it may be a major source of runoff causing offsite channel erosion.

3. The major sediment producing area is located in the lower one-third of the Bad River drainage.

Based on these conclusions, the objective of the Lower Bad River-River Basin Study was to further identify and quantify sediment sources in the lower one-third of the Bad River drainage. Land treatment alternatives which have the potential to treat these areas have been identified. These results will be used as a guide by potential water quality project sponsors to set priorities for implementing nonpoint source management activities.

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[1] Phase I - Bad River Water Quality Project, USDA - Soil Conservation Service, 1990.
[2] Phase IB - Bad River Water Quality Project. Appendix B. USDA - Soil Conservation Service, 1990.

PHYSICAL DESCRIPTION OF THE LOWER BAD RIVER BASIN

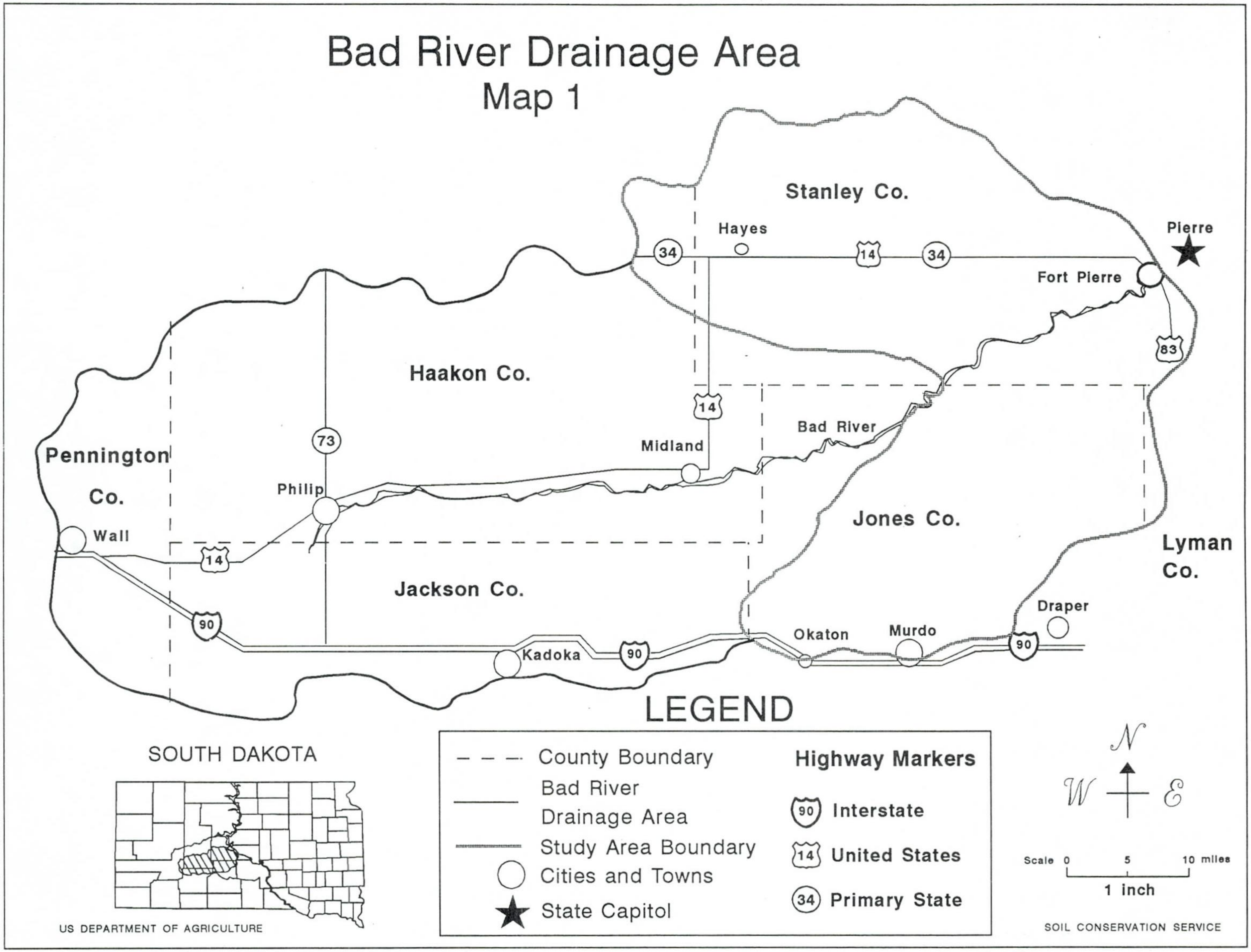
Location

The Bad River is the smallest of five major river basins in western South Dakota that drain into the Missouri River. It originates in the Big (White River) Badlands near Wall, South Dakota, and flows to the east approximately 100 miles where it discharges into Lake Sharpe near the towns of Fort Pierre and Pierre. The basin drains 3,209 square miles of Stanley, Jones, Lyman, Haakon, Jackson and Pennington Counties (Map 1).

This river basin study focuses on the lower one-third of the Bad River drainage, 792,000 acres in 7 sub-watersheds, (Map 2) in hydrologic unit No. 10140102, the west central part of the state between the Cheyenne and White River Basins. The study area is located in the first congressional district of South Dakota. This area has been identified as the major source of sediment reaching Lake Sharpe.

Climate

The climate in the study area is semiarid and continental, characterized by wide temperature ranges, low relative humidity, frequent high winds, small amounts of precipitation, long winters and warm summers. Recurring periods of drought and near-drought conditions are common.


Bad River Drainage Area
Map 1
Stanley Co.
Hayes
Pierre
Fort Pierre
34
14
83
Haakon Co.
73
Pennington
Co.
Philip
Midland
Bad River
Jones Co.
Lyman
Co.
Wall
Jackson Co.
90
Kadoka
Okaton
Murdo
Draper
LEGEND
County Boundary
Bad River
Drainage Area
Study Area Boundary
Cities and Towns
State Capitol
Highway Markers
Interstate
United States
Primary State
SOUTH DAKOTA
US DEPARTMENT OF AGRICULTURE
N
W
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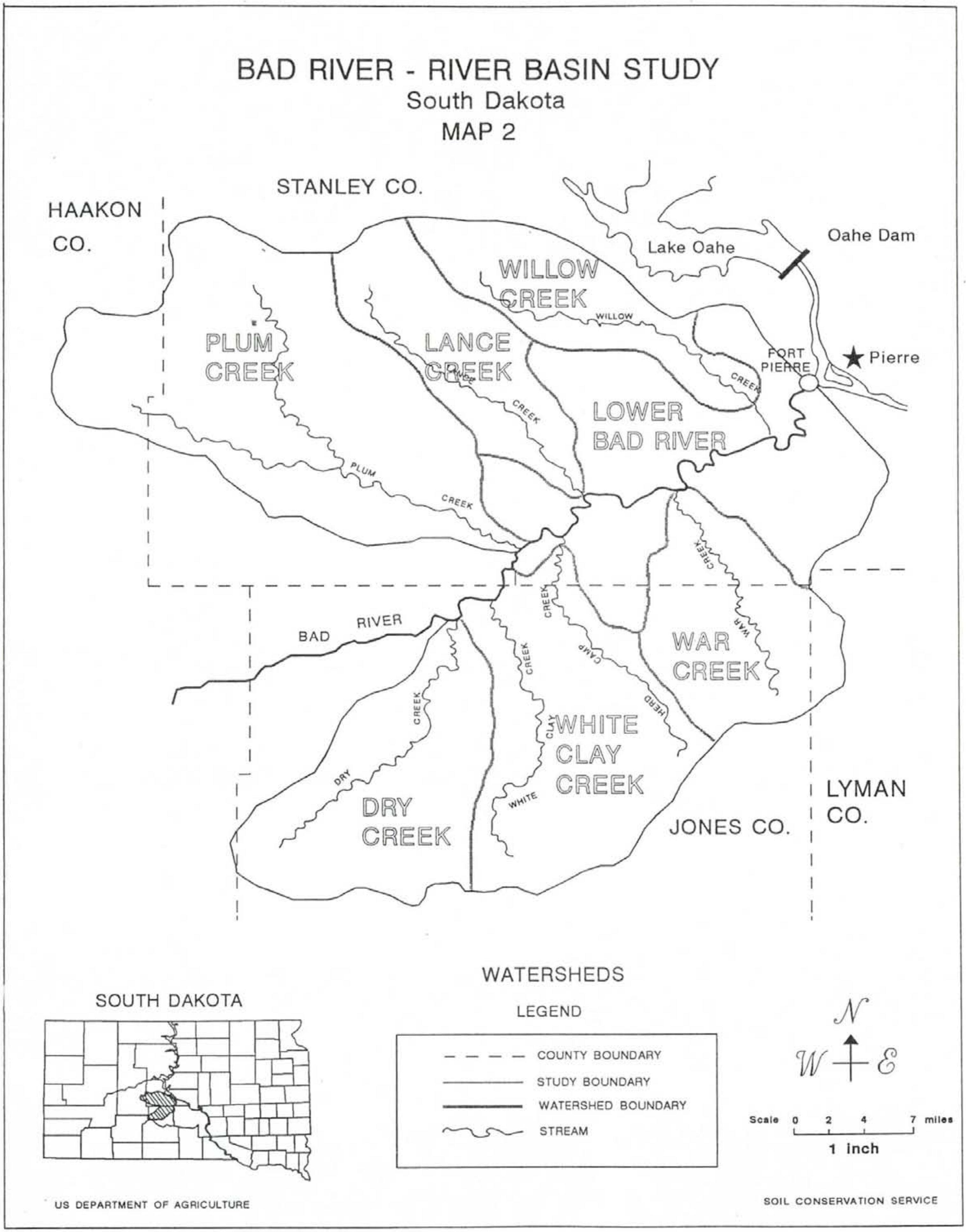
Scale 0 5 10 miles
1 inch
SOIL CONSERVATION SERVICE


BAD RIVER - RIVER BASIN STUDY
South Dakota
MAP 2
STANLEY CO.
HAAKON CO.
Lake Oahe
Oahe Dam
WILLOW CREEK
PLUM CREEK
LANCE CREEK
FORT PIERRE
Pierre
LOWER BAD RIVER
BAD RIVER
WAR CREEK
WHITE CLAY CREEK
DRY CREEK
JONES CO.
LYMAN CO.
WATERSHEDS
SOUTH DAKOTA
LEGEND
COUNTY BOUNDARY
STUDY BOUNDARY
WATERSHED BOUNDARY
STREAM
N
W
E
Scale 0 2 4 7 miles
1 inch
US DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

The average annual precipitation for this region varies from 16 inches in the northern half of the study area to 18 inches in the southern part. Normally 80 percent of this total occurs during the months of April through September, the growing season for most crops raised in this area. The growing season ranges from 115 days to 130 days with the average last killing frost in mid-May and the first killing frost in mid-September.

It is estimated that more than 75 percent of the annual runoff occurs during the four-month period of March through June. Runoff in March and April is usually caused by snowmelt while the runoff in May and June is from rainfall. June normally has the highest amounts of precipitation and runoff. Heavy runoff during summer months may occur as a result of brief, intense thunderstorms. Annual runoff varies widely from year to year, but the average annual runoff ranges from about 0.5 to 0.7 inches. The Bad River, and most of the tributaries, will experience periods of no flow almost every year during the fall and winter months.

Temperatures vary considerably throughout the year. The average winter temperature is 19 degrees Fahrenheit and the average summer temperature is 72 degrees Fahrenheit. Extreme temperatures for the year often range from below zero in the winter to an occasional 100 plus degree summer day.

Geology

The study area lies within the Pierre Hills section of the Missouri Plateau division of the Great Plains Physiographic Province. The landscape is characterized by long, smooth slopes on uplands with shorter, steeper slopes along well-defined drainageways. The elevation in the study area ranges from approximately 2,500 feet above mean sea level to 1,440 feet at the mouth of the Bad River.

The Cretaceous Pierre Shale Formation, primarily a silty shale, underlies the entire basin and is exposed in eroding streambanks, channels, and gullies. The Pierre Shale is found at the surface of the study area and its maximum thickness is about 1,100 feet. The Bad River has cut a 200-to 300-foot trench below the uplands through this region creating the shale bluffs typical of the "Missouri Breaks" topography.

The Pierre Shale is the parent material for the erodible, gray-black silt, and clay soils exposed along most of the primary and secondary streams in the study area. Some younger, lighter-colored silts, sands, and clay soils overlie this shale in the uplands area. These deposits are less consolidated and generally more erodible than the Pierre Shale.

General Soils

Soils of the study area have been placed into 15 broad groups called soil associations and are described on the General Soil

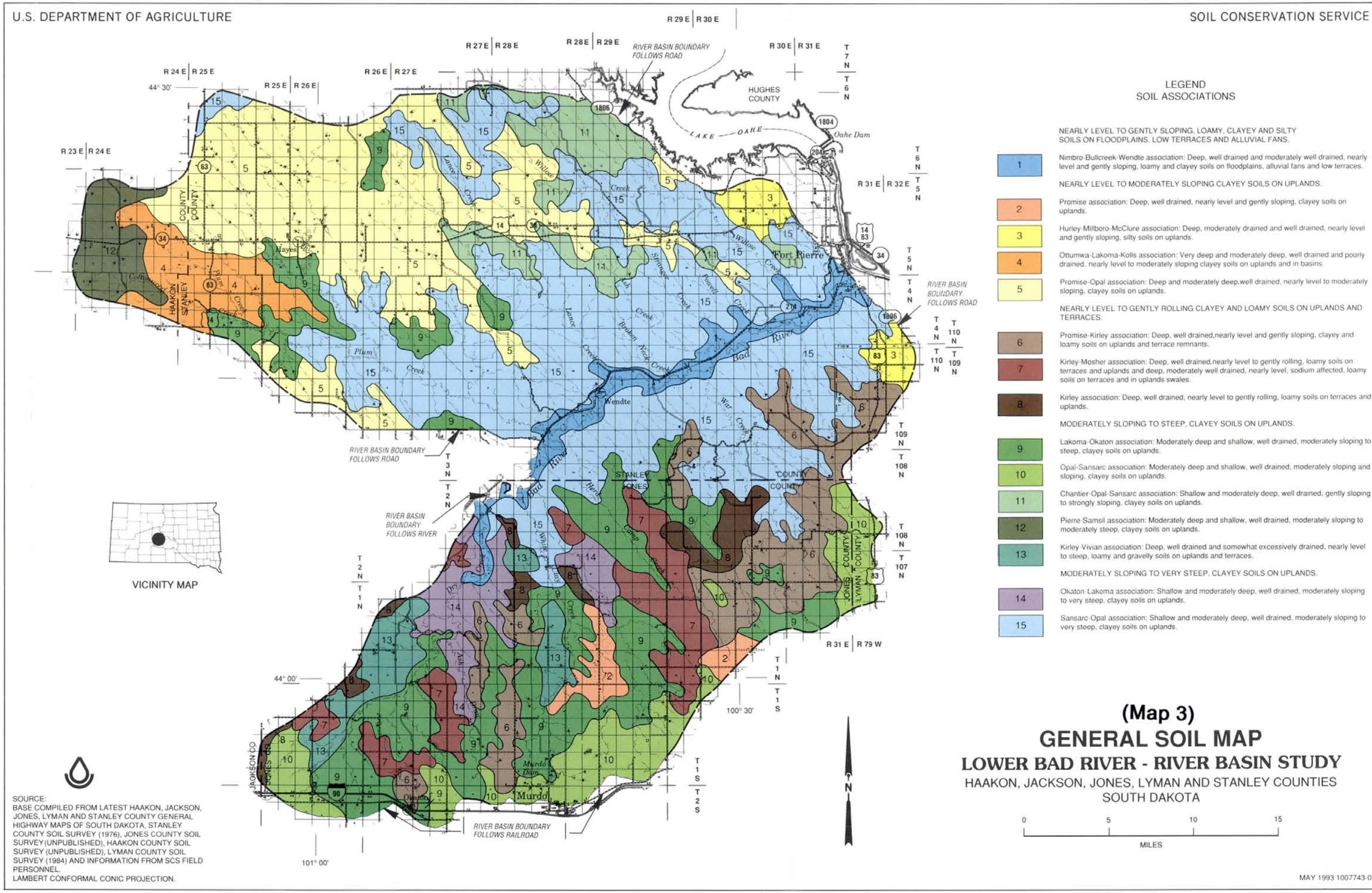
Map, (Map 3). Each soil association has a distinctive pattern of soils, relief, drainage, and natural landscape. The dominant soils within this area are residual clays on uplands and alluvial clays on floodplains and low terraces. More detailed information on individual soils is available in the published county soil survey reports. The accompanying map is of a general nature and is not intended for any type of intensive planning and management.

Topographical Areas

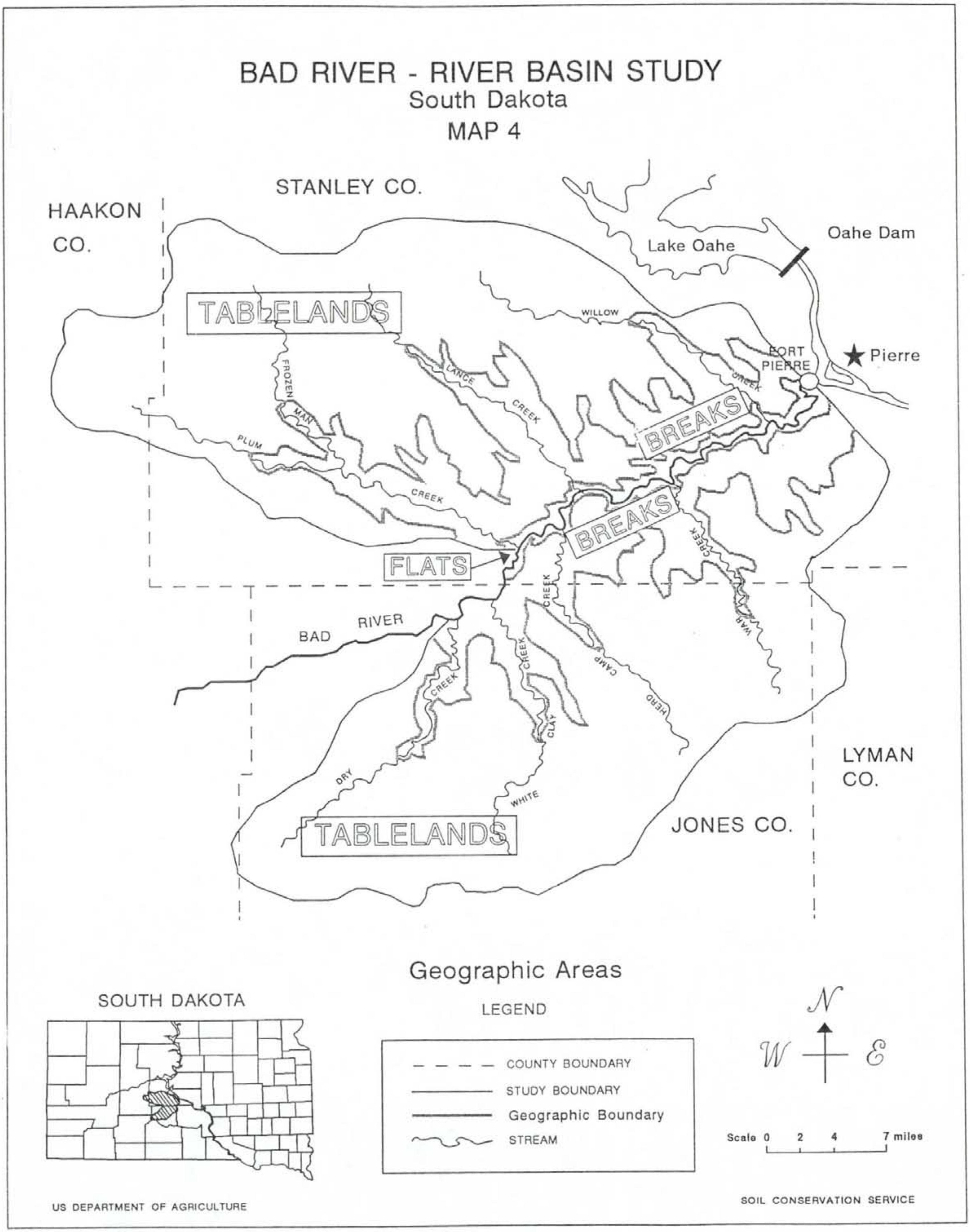
The shape of the natural landscape has been extensively influenced by long-term erosive processes. The Lower Bad River-River Basin Study area can be defined by three general topographic or landscape areas: Tablelands, River Breaks, and Bad River Flats. These areas differ in soil depth, slope, terrain, natural vegetative composition, erosive characteristics, and sediment contribution. As a result of these differences, effective land treatments will also vary. In order to identify the general boundary lines between these three areas, four criteria have been used: land use, soils, slope, and elevation. Map 4 identifies the location of these topographic areas within the Lower Bad River-River Basin Study area.

Tablelands

The Tablelands region makes up about 72 percent of the total study area, 570,000 acres. This landscape unit occupies the



U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
LEGEND
SOIL ASSOCIATIONS
NEARLY LEVEL TO GENTLY SLOPING, LOAMY, CLAYEY AND SILTY SOILS ON FLOODPLAINS, LOW TERRACES AND ALLUVIAL FANS.
1 Nimbro-Bullcreek-Wendte association: Deep, well drained and moderately well drained, nearly level and gently sloping, loamy and clayey soils on floodplains, alluvial fans and low terraces.
NEARLY LEVEL TO MODERATELY SLOPING CLAYEY SOILS ON UPLANDS.
2 Promise association: Deep, well drained, nearly level and gently sloping, clayey soils on uplands.
3 Hurley-Millboro-McClure association: Deep, moderately drained and well drained, nearly level and gently sloping, silty soils on uplands.
4 Ottumwa-Lakoma-Kolls association: Very deep and moderately deep, well drained and poorly drained, nearly level to moderately sloping clayey soils on uplands and in basins.
5 Promise-Opal association: Deep and moderately deep,well drained, nearly level to moderately sloping, clayey soils on uplands.
NEARLY LEVEL TO GENTLY ROLLING CLAYEY AND LOAMY SOILS ON UPLANDS AND TERRACES.
6 Promise-Kirley association: Deep, well drained,nearly level and gently sloping, clayey and loamy soils on uplands and terrace remnants.
7 Kirley-Mosher association: Deep, well drained,nearly level to gently rolling, loamy soils on terraces and uplands and deep, moderately well drained, nearly level, sodium affected, loamy soils on terraces and in uplands swales.
8 Kirley association: Deep, well drained, nearly level to gently rolling, loamy soils on terraces and uplands.
MODERATELY SLOPING TO STEEP, CLAYEY SOILS ON UPLANDS.
9 Lakoma-Okaton association: Moderately deep and shallow, well drained, moderately sloping to steep, clayey soils on uplands.
10 Opal-Sansarc association: Moderately deep and shallow, well drained, moderately sloping and sloping, clayey soils on uplands.
11 Chantier-Opal-Sansarc association: Shallow and moderately deep, well drained, gently sloping to strongly sloping, clayey soils on uplands.
12 Pierre-Samsil association: Moderately deep and shallow, well drained, moderately sloping to moderately steep, clayey soils on uplands.
13 Kirley-Vivian association: Deep, well drained and somewhat excessively drained, nearly level to steep, loamy and gravelly soils on uplands and terraces.
MODERATELY SLOPING TO VERY STEEP, CLAYEY SOILS ON UPLANDS.
14 Okaton-Lakoma association: Shallow and moderately deep, well drained, moderately sloping to very steep, clayey soils on uplands.
15 Sansarc-Opal association: Shallow and moderately deep, well drained, moderately sloping to very steep, clayey soils on uplands.
HUGHES COUNTY
LAKE OAHE
Oahe Dam
Fort Pierre
Hayes
Wendte
Murdo
Bad River
RIVER BASIN BOUNDARY FOLLOWS ROAD
RIVER BASIN BOUNDARY FOLLOWS RIVER
RIVER BASIN BOUNDARY FOLLOWS RAILROAD
HAAKON COUNTY
STANLEY COUNTY
JONES COUNTY
LYMAN COUNTY
VICINITY MAP
SOURCE:
BASE COMPILED FROM LATEST HAAKON, JACKSON, JONES, LYMAN AND STANLEY COUNTY GENERAL HIGHWAY MAPS OF SOUTH DAKOTA, STANLEY COUNTY SOIL SURVEY (1976), JONES COUNTY SOIL SURVEY (UNPUBLISHED), HAAKON COUNTY SOIL SURVEY (UNPUBLISHED), LYMAN COUNTY SOIL SURVEY (1984) AND INFORMATION FROM SCS FIELD PERSONNEL.
LAMBERT CONFORMAL CONIC PROJECTION.
(Map 3)
GENERAL SOIL MAP
LOWER BAD RIVER - RIVER BASIN STUDY
HAAKON, JACKSON, JONES, LYMAN AND STANLEY COUNTIES
SOUTH DAKOTA
0 5 10 15
MILES
MAY 1993 1007743-01
USDA, SCS, NATIONAL CARTOGRAPHY & GIS CENTER, FORT WORTH, TX, 1993


BAD RIVER - RIVER BASIN STUDY
South Dakota
MAP 4
STANLEY CO.
HAAKON CO.
Lake Oahe
Oahe Dam
Pierre
FORT PIERRE
TABLELANDS
WILLOW
FROZEN MAN
LANCE CREEK
PLUM CREEK
BREAKS
BREAKS
FLATS
BAD RIVER
CREEK
WAR CREEK
CAMP CREEK
HERD
DRY CREEK
CLAY CREEK
WHITE
TABLELANDS
LYMAN CO.
JONES CO.
Geographic Areas
SOUTH DAKOTA
LEGEND
COUNTY BOUNDARY
STUDY BOUNDARY
Geographic Boundary
STREAM
N
W
E
Scale 0 2 4 7 miles
US DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

highest elevations in the study area, generally above 1,950 feet. This area is nearly level to moderately sloping (0 to 15 percent). Promise, Opal, Lakoma, and Kirley are the dominant soils.

Land use is approximately 46 percent cropland and 54 percent rangeland. Much of the cropland was converted within the last 20 years.

River Breaks

The landscape of the River Breaks area is steep to excessively steep (16 to 45 percent) fragile rangeland positioned below the Tablelands and above the Bad River valley floor. Soils in this landscape unit are predominantly Sansarc and Okaton. These soils have low infiltration rates and are highly erosive. Land use has been and will likely remain grazing of native grassland. The River Breaks landscape includes 25 percent of the total study area, 200,000 acres.

Bad River Flats

The Flats region of the study area is composed of the Bad River, the associated floodplain, and the valley floor. Slopes in this area are nearly level to gently sloping (0 to 6 percent). The major soils are Swanboy, Wendte, Nimbro, Promise, and Chantier. Land use is predominantly livestock grazing with some hay and forage crop production. The Bad River flats area covers 22,000 acres or 3 percent of the study area.

Land Use

Livestock grazing is the dominant land use, occurring on 522,000 acres. The remaining area consists of cropland and tame hayland. Major crops that are raised include winter wheat, grain sorghum, and alfalfa. Other important crops are: oats, barley, millet, and forage sorghum.

Less than 10 percent of the operating units in the Tablelands consist of 100 percent cropland. Ranches in the River Breaks and Flats consist of native rangeland and hayland. The average operating unit in the Lower Bad River-River Basin Study area consists of 1,600 acres of cropland and 2,400 acres of rangeland or native hayland. Farm and ranch size varies considerably, however, ranging from approximately 3,000 to 35,000 acres.

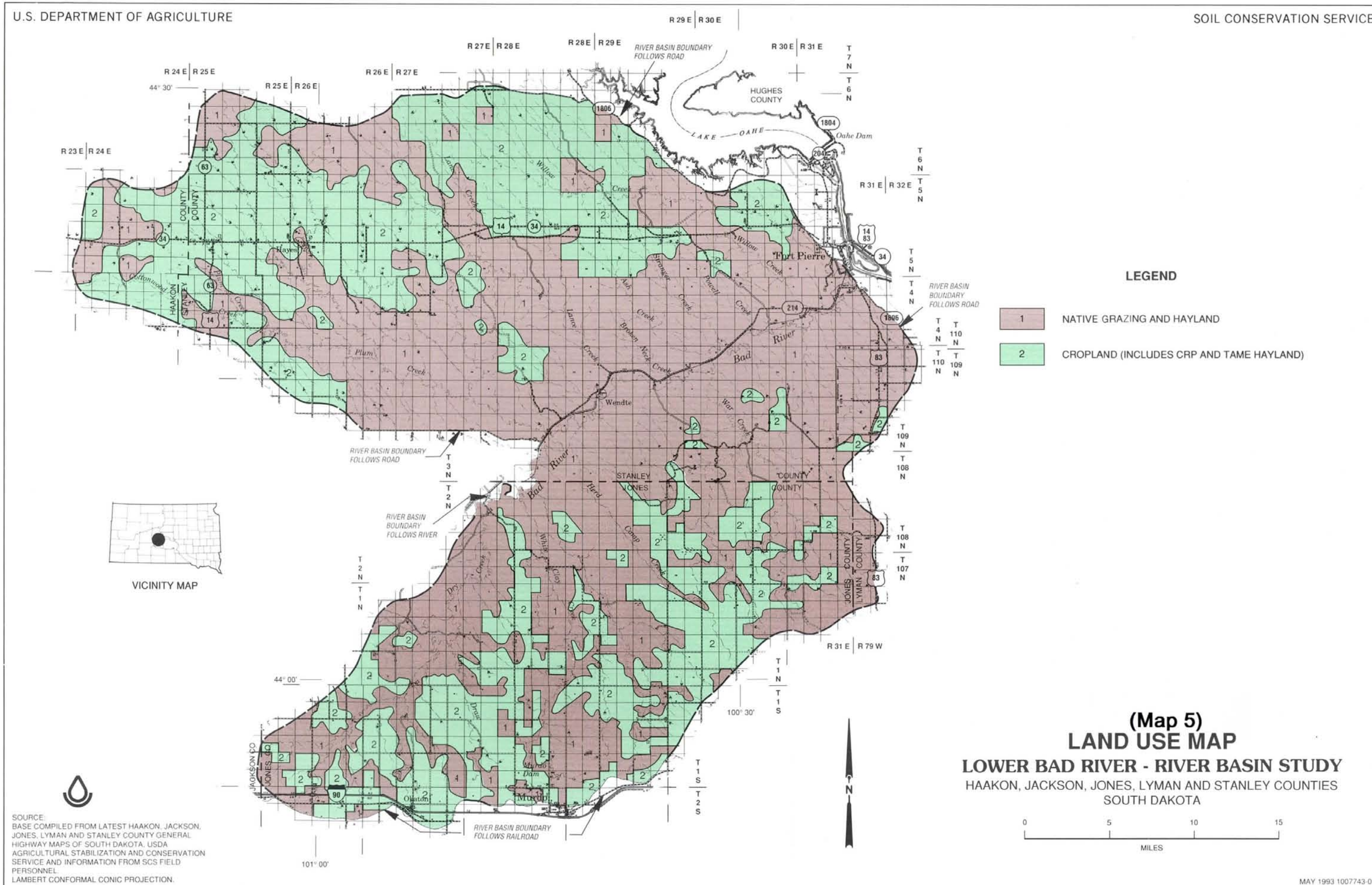
A summary of land use in the Bad River study area is shown in Table 1. Map 5 identifies land use by location.

Table 1 - Land Use

Lower Bad River-River Basin Study

Land Use	Acres	Percentage
Rangeland	522,000	66.0
Cropland	264,000	33.25
Water (less than 40 acres surface area)	4,000	.5
Other*	2,000	.25
TOTAL	792,000	100.0

*Other includes roads, railway right-of-way, farmsteads and urban areas.



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Land Ownership

In the study area, 95 percent of the land is privately owned and operated. Federally owned land consists of 31,000 acres of Fort Pierre National Grasslands managed by the U.S. FS and 4,000 acres managed by the Bureau of Land Management (BLM) . Both agencies lease rangeland to private individuals in the area. State land, excluding state and county highway or railroad right-of-ways, is managed by the School and Public Lands or the Department of Game, Fish and Parks.

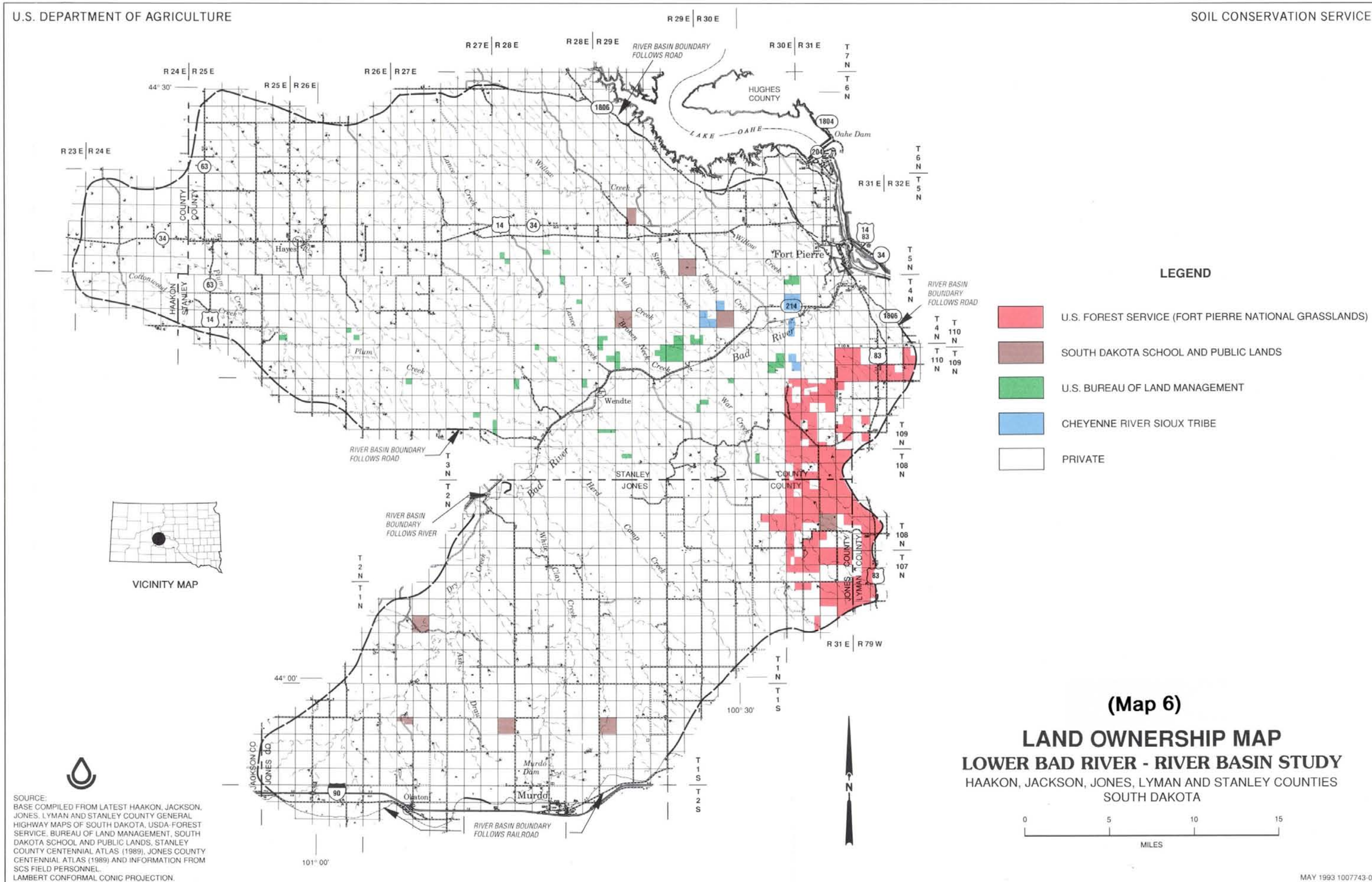
Land ownership by acreage and percent is identified in Table 2. Map 6 illustrates the location of land ownership by the different entities.

Table 2- Land Ownership

Lower Bad River-River Basin Study

Owner	Acres	Percentage
Private	749,080	94.7
Federal	36,000	4.5
State*	5,000	.6
Cheyenne River Sioux Tribe	1,920	.2
TOTAL	792,000	100.0

*Does not include state and county highway or railroad right-of-way property.



USDA, SCS, NATIONAL CARTOGRAPHY & GIS CENTER, FORT WORTH, TX, 1993

Population

Approximately 47 percent of the population in the entire Bad River Basin reside in the study area. Population figures from the 1990 U.S. Census Bureau indicate that the population is 2,300. Over half reside in the residential areas of Fort Pierre and Murdo, South Dakota. The remaining population is rural, living on farms or ranches. Women and minority groups living in this area include 41 percent females, 5 percent Native Americans, and 9 percent physically disabled.

Economic Profile

Economic characteristics for Jones County are typical of the entire rural watershed and are used in this analysis to represent the study area. Economically, Fort Pierre is characteristic of the Pierre/Fort Pierre, Missouri River and state capital economy and is not representative of the study area. Stanley County and Fort Pierre statistics have been combined in the 1990 Census figures, and therefore, are not representative of the rural population. Table 3 displays the economic analysis of Jones County, South Dakota, and the Nation (USA).

Table 3 - Economic Information

Lower Bad River-River Basin Study

ECONOMIC INFORMATION	USA	S Dak	Jones Co.
1990 Per Capita Income[3]	$ 18,696	$ 15,890	$ 19,923
Percent of US Average		85%	106%
Percent of SD Average	118%		125%
July 1993 Unemployment Rate[4]	7.0%	2.9%	1.0%
Median Home Value[5]	$ 79,100	$ 45,200	$ 23,400
Average size of farm/ranch(acres)[6]	461	1,214	2,790
1987 Value of Land and Building[7]			
Average per farm	$ 380,159	$ 326,333	$ 554,803
Percent of SD average	116%		170%
Average per acre	$ 548	$ 269	$ 241
1987 Average market value of Agricultural products sold[8]		$ 74,761	$ 83,379
1993 Cropland Value per acre (with wheat base)		$ 411	$ 197
1993 Hayland Value per acre		$ 223	$ 140
1993 Rangeland Value per acre		$ 127	$ 89

3 April 1992 Survey of Current Business, Bureau of Economic Analysis, U.S. Department of Commerce.
4 July 1993 South Dakota Labor Bulletin, South Dakota Department of Labor.
5 1990 US Census data furnished by the Census Data Center, Department of Rural Sociology, South Dakota State University.
6 1987 Census of Agriculture, Part 41, South Dakota, State and County Data.
7 ibid.
8 ibid.

The 1990 per capita income for Jones County was $19,923, the highest ever for the county due to good cattle and wheat production and prices. South Dakota per capita income for the same year was only $15,890, while the national per capita income was $18,696.

Employment is highly seasonal within Jones County. While only 6 residents were registered as unemployed in June of 1993, 12 percent or 64 residents were registered as unemployed in January. As a result, many of the youth leave the area to find permanent, higher paying jobs.

Table 4 shows employment by industry for Jones County, which represents the rural watershed, and Hughes County, which represents the Pierre/Fort Pierre area.

Table 4 - 1990 Employment by Industry[9]

	Jones County		Hughes County*	
	Employment	%	Employment	%
Farm	274	32%	308	3%
Agri/Forest/Fish	10	1%	49	1%
Mining	0	0%	16	0%
Construction	26	3%	339	3%
Manufacturing	10	1%	225	2%
Transportation/Utility	31	4%	271	3%
Wholesale	16	2%	251	2%
Retail	202	23%	1,896	19%
Finc./Ins./Real Estate	26	3%	588	6%
Services	144	17%	2,898	29%
Government	123	14%	3,213	32%
Total 1990 employment	862	100%	10,054	100%

*Jones County represents the rural economy, while Hughes County represents the Pierre/Fort Pierre area.

The natural resource base plays a significant role in the economic stability of the study area. The major source of income in the watershed is a mixture of cash grain and livestock production, directly employing 32 percent of the total work force and providing the support and enhancement of social and economic productivity for a major portion of the rest of the population in the county.

[9] 1991 South Dakota Community Abstracts, South Dakota State Data Center, Business Research Bureau, University of South Dakota.

Resource Inventory Evaluation

The average annual sediment discharge at the mouth of the Bad River since 1948, as estimated by the U.S. Army Corps of Engineers, is 3,250,000 tons.[10] This sediment is the result of geologic erosion and accelerated wind and water erosion from three major sources: rangeland, cropland, and the Bad River streambank. Water erosion makes the most significant contribution of sediment to the Bad River. Wind erosion, although a significant resource concern for cropland, is not a major source of sediment.

This section of the report summarizes the processes and results of erosion and sedimentation evaluations. Final results are organized into a sediment budget, which summarizes total erosion and sediment yield from each type of erosion by landscape unit. The sediment budget has been developed to identify and quantify the landscape areas having major contributions of sediment to the Bad River.

The types of water erosion which have been evaluated in this study include: sheet, rill, ephemeral gully, classic gully, channel, and streambank.

Sheet erosion occurs as water flows overland and moves layers of soil particles loosened by raindrop impact. Rill erosion is movement of soil particles as overland flow concentrates into

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[10] U.S. Army Corps of Engineers, Big Bend Aggradation Assessment April 1986.

small channels, or rills, 2 to 12 inches deep. Soil particles are loosened in rills by shear force exerted on the bottom and banks of the rill from the channelized water. Bank sloughing, or miniature landslides, occur as the bottom and lower banks are eroded.

An ephemeral gully is a temporary gully found only on cropland which is usually filled during normal tillage operations. Ephemeral gullies can be a major source of sediment in certain parts of the Bad River study area, depending on soils type, slope, and condition. The majority of ephemeral gully erosion occurs on fallow cropland during late spring and summer months. Crop residues, dormant crops, and the lack of heavy precipitation protects cropland from ephemeral gully erosion during the remainder of the year.

Classic gully erosion has been defined as any erosional channel so deep that it cannot be crossed with a wheeled vehicle or eliminated by tillage. Gullies in the study area form in the transitional area between the River Breaks and the Flats of the valley floor as the runoff after a storm event or snowmelt becomes concentrated flow.

Channel erosion is caused by the channelized flow of water in well-defined courses. Channels usually have a direct connection to the drainage network of a stream.

Streambank erosion is the mass wasting and scour in the stream channel and banks that occurs with the flow of water.

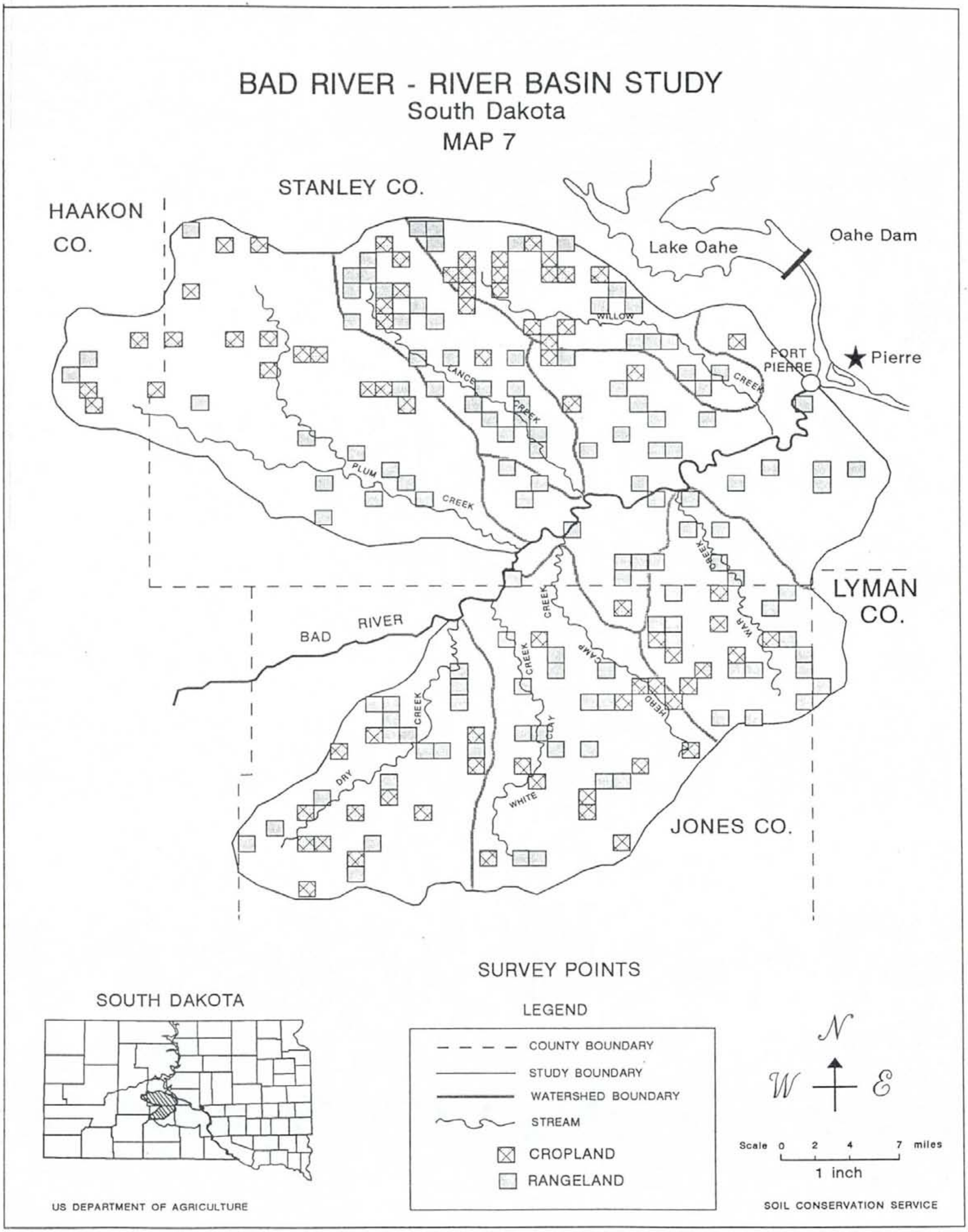
The evaluation of erosion in the study area is based on a resource survey completed in 1992. Twenty-nine quarter sections were randomly selected in each of the seven major sub-watersheds in the study area. Of the 203 total sites, 127 were rangeland and 76 sites were a combination of cropland and Conservation Reserve Program (CRP) land. Hydrologic conditions and erosion rates existing in these survey sites have been used to represent conditions existing in the entire watershed. Map 7 identifies the 7 major sub-watersheds and the 203 sites used to develop a representative data base for the Bad River study area.

Sediment contribution from each topographic area, and each source of erosion, is different. A sediment delivery ratio (SDR) has been estimated for each erosion source and each area to determine the percent of total erosion which is transported as sediment to the mouth of the Bad River. Estimates of sediment transport are based on research data, historical records, gaging station measurements, and when appropriate, professional experience and judgment.

Erosion and Sediment Yield by Topographic Area

Tablelands

Sheet, rill, ephemeral gully, and wind erosion are significant resource concerns on the cropland acres. Although erosion in the Tablelands is a significant problem, there is little sediment delivered to the Bad River from the Tablelands. Most of the



BAD RIVER - RIVER BASIN STUDY
South Dakota
MAP 7
STANLEY CO.
HAAKON CO.
Lake Oahe
Oahe Dam
Pierre
FORT PIERRE
WILLOW
CREEK
LANCE
CREEK
PLUM
CREEK
LYMAN CO.
BAD
RIVER
CREEK
CREEK
WAR
CAMP
CREEK
HERD
CREEK
CLAY
DRY
WHITE
JONES CO.
SURVEY POINTS
SOUTH DAKOTA
LEGEND
COUNTY BOUNDARY
STUDY BOUNDARY
WATERSHED BOUNDARY
STREAM
CROPLAND
RANGELAND
N
W
E
Scale 0 2 4 7 miles
1 inch
US DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

channels in the Tablelands are grassy swales that are an insignificant sediment source. The flat slopes and lack of intense grazing pressure on the rangeland result in a low erosion rate. There are pothole areas that act as closed basins and many of the drainages have a series of dams on them dating from the days when livestock production was the main land use. The potholes and dams in conjunction with the grass-covered drainageways act as excellent sediment traps and filters. Based on the Hayes Lake Sediment Survey (Appendix B), a maximum sediment delivery ratio of 10 percent is an accurate reflection of the total sediment contribution to the mouth of the Bad River from the Tablelands.

River Breaks

The principal source of sediment in the study area is channel and gully erosion in the River Breaks. The steep slopes are highly dissected by downcutting and widening channels which deliver sediment to livestock water ponds and to the channels and flats of the valley floor. The sediment delivery ratio to the Bad River for channel erosion has been determined to be 50 percent. Sheet and rill erosion on rangeland in the breaks has the next largest sediment contribution to the Bad River. Based on sheet and rill erosion studies done on rangeland in the Midwest and Canada, average sediment delivery ratios range from 5 to 30 percent. The delivery ratio used for sheet and rill erosion is 25 percent.

Many of the gullies in the watershed occur along the transition between the breaks and the valley floor. Gullies form on the steep slopes of the breaks but sediment delivery is relatively low when they empty onto the valley floor away from the established drainage network. Gullies that are physically connected to the drainage network will have a high delivery ratio. Considering the occurrence of both situations and the location of the gullies in the landscape, 30 percent of the sediment from gully erosion is estimated to reach the Bad River.

Bad River Flats

Sheet and rill erosion rates in the Flats are low since slopes are flat, but the sediment delivery ratio for sheet and rill erosion is close to 50 percent due to the close proximity of the river and valley floor channels. Channel and streambank erosion sediment delivery rates are high. Channel bottom slopes have increased due to historic downcutting of the Bad River channel. The steepened slopes have resulted in downcutting of the channel bottoms which leaves the channel banks high, steep, and unstable. The over-steepened slopes of the channel banks erode by mass wasting. Near vertical slabs of soil fall from the banks causing channel widening. Some of the channels actually outlet into abandoned meanders of the Bad River. These areas can trap sediment, so the overall delivery ratio used for channel erosion is 99 percent.

Bad River and the Floodplain

The Bad River with the floodplain occupy the lowest elevation in the landscape. The floodplain is fairly narrow, less than a quarter mile wide in most reaches, and lies 10 to 20 feet above the river. The Bad River has areas of high, nearly vertical, unstable banks. Where the river cuts into the higher ground at the edge of the valley floor, landslides occur. These sites can be up to 60 feet high and are a principal source of the streambank sediment load. The Direct Volume Procedure was used to estimate the tons of streambank erosion from the river. An average of 62,000 tons of bank erosion per year was calculated using this method. A sediment delivery ratio of 100 percent was used since the streambank erosion is deposited directly into the Bad River and is carried to Lake Sharpe.

Sheet and Rill Erosion on Cropland

Cropland includes tame hayland in rotation, CRP land, and the land annually tilled and planted. Sheet and rill erosion on these areas have been estimated separately.

Sheet and rill erosion on CRP and tame hayland was estimated using the Simulation of Production and Utilization of Rangeland (SPUR-91) computer model. The process of predicting erosion on CRP and tame hayland was the same as that for rangeland, and will be discussed in the <u>Rangeland Sheet and Rill Erosion</u> section.

Sheet and rill erosion was estimated on cropland with an annual cropping sequence using the Universal Soil Loss Equation (USLE). Erosion rates are based on information from crop years 1988 through 1992 supplied by the Jones County and Stanley County Agriculture Stabilization and Conservation Service (ASCS) offices. Field surveys of 62 quarter sections of cropland were inventoried for slope length and steepness on major soils, existence of ephemeral gullies, the vegetative condition, and signs of active erosion in waterways and channels.

Average annual erosion rates and sediment yield from acres of cropland are shown in Table 5. SCS personnel familiar with the study area used their field experience, the data collected from the survey sites, Section III of the South Dakota Technical Guide, and detailed soils maps to determine the values used in the USLE equation.

Table 5 - Tablelands Cropland Sheet, Rill Erosion and Sediment Yield to Lake Sharpe

Topographic Area	Area (acres)	Erosion (t/ac/yr)	Total Erosion (tons/year)	SDR	Delivered Sediment (tons/year)
Cropped Acres	189,000	4.7	890,000	10%	89,000
Tame Hayland	25,000	.52	13,000	10%	1,300
CRP Acreage	50,000	.14	7,000	10%	700
Total Sediment Contribution					91,000

Ephemeral Gully Erosion on Cropland

Ephemeral gully erosion has been modeled using the Ephemeral Gully Erosion Model (EGEM). EGEM has two major components: hydrology and erosion. The hydrology component estimates peak discharge and runoff volume based on values for runoff curve number, drainage area, watershed flow length, average watershed slope, 24-hour rainfall, and 1 of 4 standard rainfall distributions. These values were determined using standard procedures from the SCS Engineering Field Manual (EFM) for South Dakota, Chapter 2. Peak discharge and runoff volume estimates are then used to drive the erosion processes.

Ephemeral gully erosion has been modeled on the major cropland soils of Promise, Opal, Lakoma, and Kirley. Three general slope ranges were used for simulation: B slope (3-6 percent), C slope (6-9 percent), and D slope (9-15 percent). Variables for each soil and slope were estimated based on data collected from actual ephemeral gullies during the cropland inventory. Variables collected per gully included: drainage area, watershed length, concentrated flow length, concentrated flow slope, and maximum depth. Two basic types of cropping rotations have been simulated: winter wheat-fallow and winter wheat-milo-fallow.

Table 6 illustrates ephemeral gully erosion and its contribution to sediment from cropland. Since ephemeral gullies occur on cropland only, ephemeral gully erosion occurs only in the Tablelands area.

Table 6 - Tablelands - Cropland* Ephemeral Gully Erosion and Sediment Yield to Lake Sharpe

Topographic Area	Total Erosion (tons/year)	SDR	Delivered Sediment (tons/year)
Tablelands	80,000	10%	8,000

***Cropland acres from Table 5.**

Sheet and Rill Erosion on Rangeland

Overall, sheet and rill erosion is not a major contributor of sediment to the Bad River, except from the River Breaks area. However, sheet and rill erosion rates are often above tolerable limits and threaten resource sustainability. In addition, runoff is excessive where the sod-forming grass species such as buffalograss and blue grama are dominant. Small plot rainfall simulations on Promise clay soils (5 percent slope) show that stands of the tall and midgrass species are associated with an enhanced infiltration rate 82 percent higher than sites with the sod-forming species (Appendix E). The increased runoff serves to aggravate channel and gully erosion in the lower drainageways. By maintaining the existing tall and midgrass communities and improving rangeland dominated by the shortgrass species infiltration rates can be significantly increased and runoff and interrill erosion decreased.

Rangeland ecological condition rating and hydrologic condition are not always consistently correlated. Rangeland with a high percentage of blue grama and buffalograss may still rate in good ecological condition while hydrologic condition may be poor because the sod-forming shortgrass species are associated with higher runoff values. Sites dominated by the sod-forming species are associated with low infiltrability and relatively high runoff due to the highly compacted fine root system in the upper four inches of the soil surface. This highly compacted fibrous root system is essentially a "root pan" which inhibits infiltration.

Sheet and rill erosion on rangeland has been estimated using the computer model SPUR-91. SPUR-91 was developed by the USDA Agriculture Research Service as a physically based model and tool for use in range ecosystem simulation and planning. The model has five basic components: (1) Climate, (2) Hydrology, (3) Plants, (4) Animal, and (5) Economics. The animal and economics components had a minor effect on erosion and infiltration rate, and were not used in this simulation. Data for the animal component was represented in the plant component. Inputs to the climate, hydrology, and plant components were essential in the modeling of sheet and rill erosion on rangeland, and are discussed in the following section.

Climate

Climatological data from the Fort Pierre station was provided by the National Climatic Data Center monthly summary reports for the years 1982-1991.[11] Ten years of daily rainfall records were input into the climate component to simulate actual rainfall events within the Bad River area.

The hydrology component of SPUR-91 is based on information collected from the range survey completed on the 127 rangeland resource inventory sites in the study area. Measured variables relative to the hydrology file included range condition, vegetative height, density, weight and canopy cover, litter weight and ground cover, livestock grazing intensity and hoof action, soil condition and plant vigor.

A discriminant analysis was used to derive equations to predict group memberships from field observations (Appendix E). Six variables were determined to be significant in the determination of hydrologic condition; biomass weight, mulch weight, mulch cover, plant vigor, robel pole readings (used to measure vegetative height and density), and hydrologic curve number. Based on these variables, a plant protection index (PPI) was developed to describe the hydrologic condition of each survey site. This PPI was divided into four hydrologic conditions: high, protected, moderate, and low. Hydrologic data from each

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11 Climatological Data, Monthly Summary, South Dakota. National Climatic Data Center. January 1982 through December 1991.

condition was input into SPUR-91 to estimate sheet and rill erosion rates.

Plant

Data for the plant component of SPUR-91 was collected using a small plot rainfall simulator (Appendix C). Erosion and infiltration rates were measured on 16 sites representing Sansarc and Promise soils. The management treatments were light and heavy grazing. After each simulation, plots were clipped for vegetative analysis. Root samples were taken at 10 cm depths, canopy cover estimates of all species and soil characteristics for each plot were determined. The output from SPUR-91 was validated using the erosion and infiltration results from these simulations and extensive field data from the Cooperative Extension Service Research Station at Cottonwood, South Dakota. Additional plant inputs were supplied by the SPUR-91 Handbook.[12]

Results

Sheet and rill erosion rates were predicted for each of the four levels of hydrologic conditions. Infiltration models were developed from field rainfall simulation plots. Terminal cumulative infiltration (TCI) rate at one hour was correlated with grazing level and average height of vegetation and litter. Sediment was correlated with grass production, percent canopy

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12 SPUR-91: Workbook and User Guide, 1991 Upgrade of the Simulation of Production and Utilization of Rangelands Model, J. Charles Lee, Sept. 1992.

cover, average height of vegetation, litter and soil bulk density (Appendix E).

Yearly sheet and rill erosion rates will vary as the hydrologic condition class fluctuates with the effects of climatic variations and grazing levels. In 1992, a large portion of rangeland was in good to excellent hydrologic condition due to normal to above normal precipitation. There was adequate plant biomass, mulch, ground cover, and good plant vigor. This seems to coincide with the low sediment discharge of 781,000 tons at the mouth of the Bad River, 75 percent less than average.[13] The average annual rate of erosion for each topographic area is based on projections made from the 1992 survey results, the average annual Bad River sediment discharge from the study area (as measured by the USGS, 1982-1991) of 2,002,300 tons, and SPUR-91 sheet and rill erosion estimates using the climatological data for the same years. Tables 7 through 9 display average sheet and rill erosion rates by rangeland hydrologic condition for this 10-year period, as well as, sediment yield from each topographic area. In reference to the three rangeland areas, the River Breaks area contributes the majority of sediment followed by the Tablelands and Bad River Flats.

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[13] Water Resources Data. South Dakota. Water Year 1992. U.S. Geological Survey Water Data Report SD-92-1 P. 174.

Table 7 - Tablelands Rangeland
Sheet and Rill Erosion and
Sediment Yield to Lake Sharpe

Hydrologic Condition	Percent of Area	Total Acres	Erosion Rate (T/ac/yr)	Total Erosion (T/yr)	SDR	Sediment Yield (T/yr)
High	13%	39,000	.3	11,700	10%	1,170
Protected	31%	93,000	.7	65,100	10%	6,510
Moderate	40%	120,000	1.4	168,000	10%	16,800
Low	16%	48,000	2.9	139,200	10%	13,920
TOTAL		300,000	1.28	384,000		38,400

Table 8 - River Breaks
Sheet and Rill Erosion and
Sediment Yield to Lake Sharpe

Hydrologic Condition	Percent of Area	Total Acres	Erosion Rate (T/ac/yr)	Total Erosion (T/yr)	SDR	Sediment Yield (T/yr)
High	10%	20,000	1.0	20,000	25%	5,000
Protected	21%	42,000	1.8	75,600	25%	18,900
Moderate	46%	92,000	4.1	377,200	25%	94,300
Low	23%	46,000	8.3	382,800	25%	95,450
TOTAL		200,000	4.28	856,000		214,000

Table 9 - Bad River Flats
Sheet and Rill Erosion and
Sediment Yield to Lake Sharpe

Hydrologic Condition	Percent of Area	Total Acres	Erosion Rate (T/ac/yr)	Total Erosion (T/yr)	SDR	Sediment Yield (T/yr)
High	10%	2,200	.04	88	50%	44
Protected	21%	4,620	.10	462	50%	231
Moderate	45%	9,900	.21	2,079	50%	1,040
Low	24%	5,280	.44	2,323	50%	1,162
TOTAL		22,000	.22	5,000		2,500

Management implications and data collection from the rainfall simulation studies on the Promise and Sansarc range sites:

1. Grazing level, amount of litter or mulch and height of vegetation had the greatest influence on infiltration rates.

2. Grass production, percent canopy cover, height of vegetation, and soil bulk density had the greatest effect on sediment production.

3. Controlling utilization levels is one of the most important management options to maximize and maintain plant canopy cover, grass production, desired plant community composition (green needlegrass, western wheatgrass, and sideoats grama), and litter accumulation.

4. Season of use and degree of use are critical factors in reducing runoff and sediment production from upland range sites. In using actual climate data on a daily basis over a five year period, the SPUR-91 model showed that sediment peaks begin in April, continue throughout the summer months and subside in October (Carlson and Thurow, 1992). Comparisons of sediment peaks in the study area for April and July 1990 were 5.9 and 8.3 times greater, respectively, for the poor condition site compared to the good condition rangeland site (Appendix E).

5. Grazing management strategies must maximize accumulation of litter, plant height and promote growth of the taller non sod-forming species.

6. Critical erosion areas or pastures where gully erosion and headcuts are accelerating require year-round management to maintain adequate litter, plant height, grass residue, high midgrass composition levels, and lower soil compaction (lower soil bulk density).

7. Grass composition greatly affects the hydrology of the site. Certain grasses such as green needlegrass, sideoats grama, and little bluestem are associated with higher infiltration rates, lower runoff rates, and lower sediment yields.

8. The shorter sod-forming species such as buffalograss or blue grama are associated with high runoff rates which can cause gully formation and head cuts below the upland Promise sites.

Channel and Gully Erosion on Rangeland

An inventory of the number of miles of channels and gullies was done by using aerial photographs, topographic, soils, and general use maps. Local knowledge and a field evaluation of the area determined that the majority of active gullies and channels occur in the River Breaks and Flats areas. Two sample watersheds of 5-10 square miles were studied in the River Breaks and one in the Flats to determine channel and gully erosion characteristics. In the Breaks, one watershed had a history of heavy grazing while the other had a light or moderate grazing use.

Aerial photographs from 1976 and 1984 were compared to assess the length of actively eroding channels and gullies. The drainage network of channels and gullies was traced on mylar from the 1976 photos and the total length of each was measured. For this procedure, gullies were defined as those areas of concentrated flow not physically joined to the drainage network. Channels were defined as those waterways in the drainage network with a continuous link to the outlet.

The miles of channels and gullies per square mile of area is the drainage density. Actively eroding portions of the channels and gullies were marked, and the total length measured using the drainage network tracings. The length of eroding channels and gullies, divided by the total length of channels and gullies, equals the percent of actively eroding channels and gullies. The average drainage densities and the percent of eroding channels and gullies from the sample areas were applied to the rest of the watershed.

The average drainage density of gullies in the sample area was 4.7 mi/mi^2 in the River Breaks and .9 mi/mi^2 in the Flats. Approximately 35 percent of the gullies in the River Breaks are actively eroding while only 1 percent are active in the Flats.

The drainage density of channels in the River Breaks was determined to be 10.5 mi/mi^2 with 43 percent actively eroding. Channel drainage density in the Flats, not including the Bad

River channel, was measured at 1.75 mi/mi^2 with 27 percent actively eroding.

Some of the sediment from channel erosion in the River Breaks and Flats is deposited on floodplains. The sediment delivery ratio for channel erosion was estimated to be 50 percent in the River Breaks and 99 percent in the Flats.

Streambank Erosion

Streambank erosion along the Bad River was estimated using the Direct Volume Procedure outlined in the SCS EFM for South Dakota, Amendment SD15. The total linear feet of eroding banks along the Bad River were inventoried using aerial photographs to measure the length of steep barren slopes adjacent to the river. Field observations and local knowledge were used to determine that the eroding banks have moderate to severe erosion rates. The actively eroding banks are characterized by the appearance of exposed tree roots, massive washouts, and large areas of slumping. Streambank erosion along the Bad River is estimated to contribute an average of 62,000 tons/year of sediment to Lake Sharpe. The SDR for streambank erosion is assumed to be 100 percent.

Sediment Contribution

In order to quantify the sediment yield from channel and gully erosion in the Bad River study area, the Pacific Southwest Inter-agency Committee (PSIAC) sediment yield method was used. The

PSIAC is a resource evaluation tool used to characterize sediment yield from various sized watersheds to a downstream delivery point. An interdisciplinary planning team evaluated the geology, soils, climate, topography, vegetation, land management, erosion, and sediment transport characteristics for the three topographic units to determine sediment yield from each area. Results from this evaluation are illustrated in Table 10.

Table 10 - Topographic Area Sediment Yield

to Lake Sharpe

River basin study area: 792,000 Ac.			
Topographic Area	acres	PSIAC* (t/ac/yr)	Sediment Yield (tons/year)
Breaks	200,000	9.0	1,800,000
Tablelands	570,000	.42	239,400
Flats	22,000	1.3	28,600
Total sediment yield from study area			2,068,000
Bad River Streambank Sediment			62,000
Study area plus Bad River Streambank average annual sediment yield			2,130,000
Study area sedimentation: 2,130,000 tons \ 792,000 Ac. = 2.7 t/ac/yr			

*Pacific Southwest Interagency Committee (PSIAC) Sediment Evaluation Method

Bad River Study Area Sediment Budget

The final step in the evaluation of erosion in the Bad River study area was to determine total channel and gully erosion. The PSIAC estimates of sediment yield from all types of water erosion totaled 2,068,000 tons per year from the study area. Subtracting sediment yield from sheet and rill erosion on cropland and rangeland, and ephemeral gully erosion from cropland from this total, leaves channel, and gully sediment yield as the remainder. Channel and gully erosion can be quantified by dividing the channel and gully sediment yield by the appropriate SDR.

Table 11 illustrates the Bad River sediment budget of sheet, rill, and ephemeral gully erosion from the various land uses and topographic areas. Table 12 displays the total sediment yield from channel and gully erosion.

Table 11* - Sheet, Rill and Ephemeral Gully Erosion

Sediment Yield to Lake Sharpe

TOPOGRAPHIC AREA	AREA (acres)	EROSION (t\ac\yr)	EROSION (tons/year)	SDR	DELIVERED SEDIMENT (tons/year)
TABLELANDS:					
Rangeland					
Sheet & Rill	300,000	1.3	384,000	10%	38,400
Cropland					
Sheet & Rill	189,000	4.7	890,000	10%	89,000
Ephemeral					
Gully	189,000	.42	80,000	10%	8,000
CRP					
Sheet & Rill	50,000	.14	7,000	10%	700
Hayland					
Sheet & Rill	25,000	.52	13,000	10%	1,300
Subtotals	**564,000**		**1,374,000**	**10%**	**137,400**
BREAKS:					
Rangeland					
Sheet & Rill	200,000	4.28	856,000	25%	214,000
FLATS:					
Rangeland					
Sheet & Rill	22,000	.22	5,000	50%	2,500
TOTAL EROSION AND SEDIMENT YIELD			2,235,000		353,900

***Table 11 does not include 6,000 acres of water and other land.**

Table 12 - Channel and Gully Erosion

Sediment Deliver to Lake Sharpe

	RIVER BREAKS (tons/year)	TABLELANDS (tons/year)	FLATS (tons/year)	TOTAL (tons/year)
PSIAC sedimentation est.	1,800,000	239,400	28,600	2,068,000
S & R, Ephemeral erosion	214,000	137,400	2,500	353,900
Delivered sediment from channel & gully erosion	1,586,000	102,000	26,100	1,714,100

These estimates are based on measured gage data for sediment discharge at the mouth of the Bad River (1982-1991), USLE erosion rates for sheet and rill erosion on cropland, SPUR-91 erosion rates for sheet and rill on rangeland, EGEM erosion amounts for ephemeral gullies, and PSIAC total sediment yield evaluations.

Tables 10, 11, and 12 identify channel and gully erosion as producing 80 percent of total sediment, while sheet, rill, and ephemeral gully erosion from all sources accounts for approximately 17 percent. Streambank erosion contributes 3 percent of the average annual sediment load to the mouth of the Bad River.

PROBLEMS AND CONCERNS

Erosion in the Lower Bad River Basin and the resulting sedimentation in Lake Sharpe have become significant resource concerns. The degradation of these soil and water resources impact water quality, agricultural productivity, fish, and wildlife habitat, power production constraints, and recreational uses. Improvement in water quality with the application of conservation practices to reduce erosion and runoff in the Bad River study area will benefit local landowners and operators, as well as, downstream water users.

Cropland

The long-term soil productivity of the Tablelands is being threatened by the high rates of erosion caused by wind and water. Sheet, rill, and ephemeral gully erosion are severe on cropland not protected with a conservation system. Wind erosion is also a significant problem on cropland.

Cropping sequences in the Bad River study area are conducive to high rates of erosion and runoff. Wheat fallow with occasional grain sorghum are the principal crop rotations used. Conventional tillage practices during fallow periods result in very little residue remaining on the soil surface to protect the soil from erosion. This cropping sequence is not favorable for good water infiltration and results in large amounts of runoff, especially during the summer fallow year.

The average sheet and rill erosion rate of all cropland soils in the study area is 4.7 tons/acre. This rate is based on a crop rotation consisting of primarily winter wheat/fallow, with an average slope of 5 percent and slope length of 150 feet. Some areas have greater slopes and lengths and consequently exhibit more erosion. An 8 percent slope with a length of 200 feet averages approximately 7.5 tons/acre of erosion, and a slope of 12 percent with a length of 100 feet, averages about 12 tons/acre.

Ephemeral gully erosion is a serious problem in certain areas of cropland. The average ephemeral gully erosion rate in the study area is approximately 80,000 tons/year. Cropland areas with ephemeral gullies can exhibit erosion rates ranging from 25 to 150 tons/acre.

Erosion from cropland is not a major contributor to the overall sedimentation in Lake Sharpe. Existing stockwater ponds and dugouts, wetland areas, road ditches, and grassed waterways serve as sediment traps which filter much of this sediment before it reaches the river. Many of the draws in the recently broken cropland acres were left in native range. These areas are in good to excellent condition and are trapping sediment from the surrounding cropland acres. Cropland erosion, however, is a resource concern that should be addressed. Conservation practices designed to decrease erosion will also increase infiltration and decrease runoff, as well as, protect the long-term productivity of the cropland soils. A reduction in runoff from cropland will help to reduce channel and gully erosion in the River Breaks.

Two USDA programs authorized by the 1985 Food Security Act (FSA) have affected erosion rates and will continue to reduce cropland erosion.

1. The Conservation Reserve Program (CRP) was established to remove highly erodible cropland acres from production. In return for an annual rental payment, landowners and operators agreed not to plant or harvest an annual crop, instead, a permanent or semi-permanent grass cover was established. Approximately 50,000 acres of CRP exists in the study area. Sheet and rill erosion has been reduced to .13 tons/acre/year and runoff from these acres has been reduced dramatically. However, starting in 1996 when existing contracts begin to expire, this land will again be eligible for cropping. It is estimated by SCS field office personnel that 80 percent of this land will be returned to production by the year 2003. Sheet and rill erosion on these 40,000 acres will increase substantially. It is estimated that sheet and rill erosion rates will rise to an average of 5.2 tons/acre/year. The increase in runoff from the CRP returned to cropland will significantly affect the channel and gully erosion in the River Breaks, increasing the sediment from this area.

2. The conservation provisions of the 1985 FSA established guidelines for farming soils which have the potential for high rates of erosion. These provisions require that a conservation

system be developed and implemented by landowners and operators to control erosion to acceptable levels on highly erodible soils. Benefits from all USDA farm subsidy programs can be denied if these conservation plans are not followed. A large portion of soils in the study area are considered highly erodible and have an approved conservation plan which must be fully implemented by January 1, 1995. It is estimated that nearly 95 percent of these conservation plans will be completely implemented. As a result, cropland erosion and runoff rates will be reduced significantly. Sheet rill and ephemeral gully erosion is expected to be reduced to approximately 3.9 tons/acre.

Rangeland

Sheet and rill erosion

In natural plant communities, the hydrologic condition of a site is the result of complex interactions of soil and vegetation factors. The kind and amount of vegetation influences many hydrologic processes including: interception, infiltration, evaporation, transpiration, percolation, surface runoff, soil water storage, soil erosion, and sediment yield.

For every watershed and site within the watershed there exists a critical point of deterioration due to surface erosion. Beyond this critical point, erosion continues at an accelerated rate which cannot be overcome by the natural vegetative and soil stabilizing forces.

The lack of a dependable source of well-distributed good quality water and overstocking are the major factors affecting livestock grazing management throughout the Bad River study area. During open range years of the early 1900's, cattle used the Bad River and its tributaries as a major water source. Years of intense grazing pressure along these river breaks established patterns which were detrimental to the fragile range ecosystems. The natural rangeland plant communities in the Bad River were diverse. The principal climax grass communities consisted of a mix of warm and cool season tall and midgrass species. In many of the areas of the watershed heavy grazing pressure has shifted the plant communities to the shortgrass species, annual weedy forbs, sedges, and bare ground which are hydrologically inferior to the tall and midgrass species.

Rangeland erosion in the Tablelands area, while still a concern, is not a major contributor of sediment to the Bad River. Small plot rainfall simulations[14] indicate that steady state infiltration rates decrease by as much as 98 percent on heavily grazed areas dominated by buffalograss and blue grama. Erosion was not excessive due to the excellent protection provided by these grasses, however, the increased runoff serves to aggravate channel and gully erosion in lower drainageways. Keeping the tall and midgrass communities healthy will improve water quality by increasing infiltration and decreasing runoff.

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14 Soil Conservation Service, Hydrologic Assessments within the Bad River Watershed of South Dakota, 1991.

Solutions to existing or potential problems involving the relationship between water and land uses can be either preventative or restorative. Preventing losses of soil, desirable vegetation, wildlife habitat, and losses of forage production are much less costly than trying to achieve the same benefits from a degraded situation with restoration. There is a variety of management practices which can be used to help restabilize the hydrologic and environmental balance of the rangeland ecosystems.

Grazing intensity and timing has a definite influence on erosion on native rangeland. Sheet and rill erosion rates in the River Breaks area are moderate to high and the second highest source of sediment. In addition, low infiltration rates increase runoff which causes the formation of incised channels and gullies in areas of concentrated flow. Rainfall simulation studies (4.0 inches/hour rate) on heavily grazed Sansarc shallow clay range sites showed that average interrill erosion was 1.2 tons/acre compared to 0.1 tons/acre for each storm event on the proper grazing use sites. Infiltration rates were 63 to 94 percent higher on the properly grazed sites compared to the heavily grazed sites. Species composition was significantly different between the proper use and heavily grazed Sansarc sites explaining much of the difference in infiltration rates (Appendix E).

Sheet, rill, and gully erosion are not critical in the Bad River Flats area due to the overall flat slopes. Sediment is predominantly from streambank erosion from the steep, high, and unstable banks of the Bad River and channel erosion from numerous tributaries cutting through the valley floor.

Channel and gully erosion

Channel and gully erosion produces the highest loads of sediment in the Bad River. Approximately 8,400 miles of channels and gullies exist in the 200,000 acres of River Breaks. Nearly 3,360 miles, 40 percent, of these are actively eroding. Sedimentation from channel and gully erosion accounts for nearly 80 percent of the total sediment contribution from the Bad River study area.

Water Resources

Approximately one-half percent of the total land area is surface water consisting of small ponds with 40 acres or less of surface area. These ponds have a limited life span because of sedimentation and are highly dependant on annual precipitation and runoff.

Deep wells provide additional supplies of water for livestock and domestic use, but are expensive and yield marginal quality water. Three artesian aquifers underlie the Lower Bad River-River Basin Study area: the Dakota at depths of 1,200 to 1,600 feet, Inyan Kara-Sundance from 1,600 to 2,500 feet, and the Minnelusa-Madison at depths in excess of 2,500 feet. Most deep wells in the study area are located in either the Dakota or Inyan Kara-Sundance aquifers. Costs for drilling new, deep wells range from $15,000 to $60,000 depending on depths and materials used.

Water from the bedrock aquifers is slightly saline due to concentrations of sodium chloride in the Dakota and calcium chloride in the Inyan Kara-Sundance and the Minnelusa-Madison. Concentrations of dissolved solids range from 1,500 to 3,490 mg/l. An average hardness of 1,400 mg/l is caused by high concentrations of dissolved calcium, magnesium, and sulfate. Excessive concentrations of manganese and iron (greater than 0.3 mg/l) is a problem found in each of the aquifers. All three of the bedrock aquifers are large geothermal reservoirs with temperatures that range from 23 to 49 degrees Celsius (73 to 120 degrees Fahrenheit).

Shallow aquifers are confined to low areas along the Bad River and its tributaries and perched water tables below stock dams or wetland areas. These wells generally do not provide adequate amounts of water. Water quality, although better than artesian, is still poor from the influence of the soluble salts in the Pierre shale.

Rural water development is being considered to service a large part of central and south central South Dakota, including the Bad River drainage area. The Mni Wiconi Water Project has been authorized for construction, however, congressional funding for the entire project is pending at this time. Development of this water system would ensure a dependable supply of high quality water in the Lower Bad River study area. An adequate supply of livestock water is essential for producers to develop range management systems. Grazing management systems can be implemented which would improve hydrologic conditions, reduce erosion, and increase infiltration rates.

Riparian Areas

Riparian areas are ecosystems that occur along watercourses or waterbodies. They are distinctly different from the surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by free or unbound water in the soil. These areas, if in good condition, can reduce stream and channel bank erosion, trap and store sediment, provide high quality forage for livestock and wildlife, regenerate subsurface water storage, and provide habitat for a large variety of wildlife.

Early homesteaders in the study area used much of the woody vegetation for fences, fuel, and building material. Livestock grazing and climatic patterns over the years have inhibited the regeneration of native woody species. Sandbar Willow, Cottonwood, Green Ash, American Plum, and Chokecherry are a few of the species native to some of the riparian areas associated with the Bad River and its major tributaries. Extended overgrazing during spring and summer months increases seeding mortality and severely damages or destroys existing tree cover. Heavy livestock use over long periods of time encourage gullies to form. This results in a lower water table and causes a change in vegetation. This has happened extensively in the River Breaks making the land difficult to manage and low in vegetative production.

Observations of riparian areas indicate that the gullies will continue to enlarge until a grazing management program addressing the vegetative needs of the site is implemented.

<u>**Lake Sharpe**</u>

Fishing

The South Dakota Department of Game, Fish and Parks (GF&P) conducts an angler survey of Lake Sharpe each year. The purpose of this creel survey is to measure and evaluate fishing in the area. Lake Sharpe is divided into three major areas for this survey: reach 1 extends from the Oahe Dam to La Frambois Island, reach 2 is from La Frambois Island to the De Grey Recreation area, and reach 3 is downstream from the De Grey Recreation area.

The sediment laden waters from the Bad River severely restrict fishing in reach 2 of Lake Sharpe. As an example, discharge from the Bad River was zero during May 1992. There were a total of 21,000 boat fishing hours in reach 2 of Lake Sharpe and a total of 57,000 hours in reaches 1 and 3 during that month. Beginning in June, the Bad River began discharging over 12,000 cubic feet per second (cfs) of water and 700,000 tons of sediment during the two months. Results from a creel survey completed for July found that there were a total of only 3,700 fishing hours in reach 2 and 65,000 hours in reaches 1 and 3. This was a decrease of over 16,000 fishing hours in July alone. In August, the GF&P survey found no fishing activity in the entire area of reach 2. Once discharge from the Bad River stopped in the middle of August, the fishing count in September increased to 23,000 hours.

Table 13 - Boat Fishing on Lake Sharpe

		Sediment	Hours		
Year	Month	Load	Reach 1	Reach 2	Reach 3
1992	April	4	13,332	8,064	5,346
1992	May	0	20,048	21,313	37,019
1992	June	24,638	22,011	10,389	80,182
1992	July	615,686	17,262	3,689	47,696
1992	August	96,850	7,302	0	10,690
1992	September	9,310	3,790	22,853	8,137
Total hours in 1992			83,745	66,308	189,070
Total Annual Value			$133,154	$105,429	$300,621
1993	April	86,896	11,381	2,187	11,583
1993	May	141,343	25,198	555	18,323
1993	June	209,490	27,544	1,622	55,975
1993	July	234,674	17,762	643	25,795
1993	August	3,100	4,387	472	23,391
1993	September	78	7,998	9,089	13,946
Total hours in 1993			94,270	14,568	149,013
Total Annual Value			$149,888	$23,163	$236,930

The U.S. Army Corps of Engineers (COE) has estimated the National Economic Development (NED) value of fishing in Lake Sharpe at $6.35 per visitor day.[15] This is an estimate of net benefits to the national economy received from expenditures by fishermen using Lake Sharpe. The average fishing trip on the lake lasts 4 hours, a NED value for an hour would be $1.59. Assuming that reach 2 would have maintained the May 1992 fishing hours of 22,000, total fishing hours for the months June, July, and August

15 U.S. Army Corps of Engineers, Masters Water Control Manual for the Missouri River, Volume 6C: Economic Studies, Recreational Economics, May 1993 draft, P. 21.

would total 66,000. Fishing would be valued at $105,000 in NED benefits. However, actual fishing hours for these months totaled only 14,000 hours. The National Economic Development benefits received from fishing during June through August are valued at only $22,000. For the summer of 1992, sediment from the Bad River cost the nation 52,000 fishing hours worth $83,000 in NED recreational benefits.

The regional impact of Lake Sharpe fishing expenditures has been estimated at $30 per day ($7.50 per hour).[16] A summer with 66,000 fishing hours, as projected, would generate $500,000 for the Pierre/Fort Pierre economy from reach 2 of Lake Sharp. That was cut to $105,000 in 1992, a loss of $395,000 in direct spending in the Pierre/Fort Pierre area.

The Bad River was running through most of the fishing season of 1993. Fishing hours in reach 2 were reduced to a total of 5,500 for April through August and 9,100 for September. Fishing in reaches 1 and 3 were about the same as in 1992. Total NED benefits were $23,200 out of a potential $209,900. The Bad River sediment caused a loss of 117,400 fishing hours worth $186,700 in NED benefits in 1993. This caused a loss of direct spending of $880,000 for the Pierre/Fort Pierre area economy in 1993.

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16 U.S. Army Corps of Engineers, Master Water Control Manual for the Missouri River, Volume 6C: Economic Studies, Recreational Economics, May 1993 draft, P. 33.

Flooding

Fort Pierre has a direct flooding problem when there are high flows in the Bad River. Damages were estimated by the COE to be $52,400 in average annual dollars in 1985. That is $68,000 in current dollars. Much of Fort Pierre is within the 100-year floodplain of the Bad River. The heavy sediment load intensifies this flooding problem. Measures that would reduce the sediment load would also reduce the flooding problem.[17]

Electric Power Generation

The Oahe Dam, located three miles upstream from the mouth of the Bad River, has a peak power production of 731 MW. Over the years, the accumulation of sediment from the Bad River has caused aggradation in the upper reaches of Lake Sharpe reducing the flow area below the dam which affects powerplant releases. During winter and spring months, ice accumulation on Lake Sharpe further restricts flow conditions creating flooding problems in the Pierre and Fort Pierre area which limits the power production of Oahe Dam to 350 MW. The combination of effects prevents Oahe Dam from generating enough power output to meet peak winter demand without flooding sections of Pierre and Fort Pierre. The COE has estimated that this power constraint has an annual cost of

17 U.S. Army Corps of Engineers, Western Dakota Region of South Dakota Water Resources Study, 1985.

$12,600,000, a result of the need for Western Area Power Administration to purchase replacement generating capacity.[18]

The COE Reconnaissance Report evaluated 10 alternatives to provide reliable, effective flood protection from ice-affected flows. Building levees along Pierre and Fort Pierre were the only alternative that would be economically feasible at an estimated cost between $7.4 million and $11.5 million dollars. The benefit cost ratio of building these levees ranges from 7.2:1 to 12.7:1.

If the current channel is deepened, reducing sediment from the Bad River would have a large economic benefit. However, dredging the current channel is not feasible on either economic or environmental grounds. Dredging would cost $3 per cubic yard and would require removal and disposal of 5 million to 51 million cubic yards of material.[19]

Gradual Filling of Lake Sharpe

Currently the Bad River is discharging an average annual sediment load of 3,250,000 tons of sediment into Lake Sharpe. This sediment is gradually filling the lake. However, Lake Sharpe is so large that even with the current sediment load, it will take 300 years to fill completely. The COE in 1985 estimated the

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18 U.S. Army Corps of Engineers, Reconnaissance Report, Constraints on Power Generation at Oahe Dam in the Vicinity of Pierre and Ft. Pierre, South Dakota, May 1992. The COE is currently proceeding on a more detail analysis of the constraints on power generators.
19 ibid.

economic loss from sediment filling the lake using an 8.625 percent discount rate at $4.00 per acre foot ($0.0025 per cubic yard or $0.003 per ton of sediment).[20] The estimated damage from a sediment load of 3,250,000 tons to the lake is $13,000 annually in current dollars.

Table 14 summarizes the known average annual NED damages in the Fort Pierre area related to the Bad River sediment load.

Table 14 - Downstream Average Annual NED Damages

Relating to the Bad River

1.	1992/1993 NED Recreational Damages[21]	$ 135,000
2.	Average Annual Fort Pierre Flood Damages	$ 68,000
3.	Loss of peak winter power generation	$12,600,000
4.	Long-term loss of storage in Lake Sharpe	$ 13,000
	Total downstream NED damages	$12,816,000

20 U.S. Army Corps of Engineers, Western Dakota Region of South Dakota Water Resource Study, 1985. Assumes 60 pounds per cubic foot of sediment.

21 This is an estimated average of 1992 and 1993 damages only. A study to determine longer term average damage is continuing.

RESOURCE INVENTORY

Wildlife Habitat

Suitable habitat for many species of wildlife exist in the Lower Bad River-River Basin study area. Habitat quality varies from year to year as agricultural activity and climatic conditions fluctuate.

Upland small game species include ring-necked pheasant, sharp-tailed grouse, prairie chicken, mourning dove, gray partridge, and rabbits.

Many waterfowl species are found in the study area and the adjacent Missouri River impoundments of Lake Sharpe and Lake Oahe. Large numbers of waterfowl often stop and rest during seasonal migrations. Numerous stock dams provide breeding habitat for ducks, primarily mallards and teal.

Big game species of wildlife include white-tailed and mule deer, antelope, and wild turkey. Mule deer prefer the rougher, steep country in the area adjacent to the Bad River. White-tailed deer and antelope prefer the open spaces of the upper portions of the watershed. Wild turkey habitat is limited to wooded areas along the Bad River.

Wildlife habitat quality was measured in this study by SCS Technical Guide Resource Management System (RMS) Quality Criteria

Guidelines.[22] Wildlife habitat quality is assessed by evaluating the average condition of the following habitats: streams, lakes and ponds, wetlands, native woody cover, windbreaks, cropland, rangeland, hayland, and pastureland. This method quantifies habitat quality using a system that places a rating from 0.0 to 1.0 on each habitat with 1.0 being optimal. Table 15 outlines the current ratings for each habitat type. The current overall wildlife habitat rating is 0.4. An acceptable rating for a RMS with SCS is 0.5.

Table 15 - Wildlife Habitat Quality

Lower Bad River-River Basin Study

Habitat Type	Total Acres	Final Rating
Cropland	184,000*	.37
Rangeland	442,000*	.31
Hayland, Pasture or CRP	75,000	.7
Windbreaks	1,000	.42
Native Woody Habitat	20,000	.3
Lakes & Ponds	4,000	.375
Wetlands	15,000	.4
Streams	50,000	.31
Average Wildlife Habitat Quality Rating		.4

*Cropland and Rangeland acres are included in lakes, ponds, wetlands and streams.

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22 SCS South Dakota Technical Guide, Section III - Conservation Management Systems. November 1992.

Threatened and Endangered Species

Habitat for several federal and state listed threatened and endangered species is found in the study area. Black-footed ferret, bald eagle, and peregrine falcon could potentially be permanent residents; the raptors are known to be seasonal migrants.

This information is summarized in Table 16. The implementation of any project for the treatment of identified resource concerns would serve to enhance this habitat.

Table 16 - Listed and Endangered Species

Listed Species	Expected Occurrence
(E) Bald Eagle (Haliaeetus leucocephalus)	Migration, winter resident.
(E) Whooping Crane (Grus americana)	Migration.
(E) Peregrine falcon (Falco peregurinus)	Migration.
(T) Piping plover (Charadrius melodus)	Migration, summer breeding.
(E) Interior least tern (Sterna antillarum)	Migration, summer breeding.
(E) Black-footed ferret (Mustela nigripes)	Possible inhabitant of prairie dog towns.
(E) American burying beetle (Nicrophorus americanus)	Anywhere in SD with significant humus and topsoil suitable for the burying of carrion.
(E) Pallid sturgoen (Scaphirhynchus albus)	Missouri River.

(E) = Endangered species
(T) = Threatened species

Potential impacts on federal listed threatened and endangered species were assessed by the U.S. Fish and Wildlife Service. A summary of the comments, assessment, and recommendations is located in Appendix D.

Wetlands

There are approximately 15,000 acres of seasonal wetlands in the study area. Sixteen percent, or 2,400 acres are farmed. The remainder are located in rangeland areas of the Tablelands and in abandoned channels of the Bad River and its tributaries.

Wetlands existing presently in the study area will probably improve or remain in their present condition, both in hydrological and biological function.

Cultural Resources

Human activity in western South Dakota is documented for all major cultural periods. Woodland period sites and Plains Village occupations, as well as, Historic Indian presence can be found in the Bad River study area. Historic evidence of Euro-American presence is also well documented. There have been several significant historical, archaeological, and scientific sites identified.

A procedure has been implemented in cooperation with the South Dakota State Historic Preservation Officer (SDSHPO) to provide an inventory of all known archaeological and cultural resource sites. These sites are located on county maps which are maintained and used for reference by SCS personnel. The maps are updated annually. Should previously unknown cultural resources be found in the study area, appropriate federal and state procedures will be followed. Any federally assisted or funded projects proposed for implementation in the Bad River drainage will need to ensure that cultural resources will be protected and preserved.

Important and Prime Farmland

There is no prime farmland in the study area. There are 107,300 acres of land that are categorized as land of statewide importance.

Aesthetics

Visual resources and landscape settings are important resources. The wide open spaces of the prairie, the rugged grandeur of the Missouri Breaks, and the expanse of the Missouri River and Lake Sharpe are aesthetically pleasing.

Floodplains

The stream length of the Bad River within the Lower Bad River-River Basin study area is 51.5 miles. There are approximately 4,300 acres of floodplain located within the study area. Wendte and Nimbro soils are the dominant soils in the floodplains.

LAND TREATMENT ALTERNATIVES

Alternatives were developed and reviewed by an interdisciplinary planning team for the locally identified resource concerns of water quality (sedimentation), sheet, rill, channel, and gully erosion, wildlife and fisheries habitat and recreation. Land use practices which will protect or improve natural resources vary by landscape. For this reason, methodology was developed to evaluate the potential for erosion and sediment reduction within each of the three landscape units. Structural and management practices are identified that have the potential to reduce the erosion and associated sediment delivered to the mouth of the Bad River.

Each alternative was developed to quantify the range of plan elements needed for significant sediment reduction and the costs and impacts associated with each plan. A total on-and-offsite economic analysis of benefits for each alternative has not been done since insufficient data is available at this time. However, efforts will continue in this area. The U.S. Army Corps of Engineers has indicated that they will continue the study of power production constraints at the Oahe Dam and will look more closely at the effects of continued sedimentation in Lake Sharpe. The South Dakota Department of Game, Fish and Parks with the assistance of the U.S. Geological Survey and SCS is investigating the statistical correlation between the recreational use of Lake Sharpe and the amount of sediment discharged from the Bad River. Plans have been made for an economist from SCS to analyze the onsite economic benefits of the application of conservation practices in the Plum Creek Water Quality Project.

Alternative A.

This alternative assumes that no federally assisted or funded special project is implemented to address the resource concerns previously described in this report. The application of conservation practices will continue through the Great Plains Conservation Program (GPCP), Water Quality Incentive Program (WQIP), Agricultural Conservation Program, and the Highly Erodible Land (HEL) provisions of the 1985 Food Security Act (FSA) along with the 1990 Food, Agricultural, Conservation, and Trade Act (FACTA).

The reductions in erosion and runoff from FSA conservation plan implementation will be offset by the return of CRP acres to cropland production. Reductions in erosion and sedimentation due to ongoing conservation programs will not significantly affect the average annual sediment load from the watershed to Lake Sharpe.

Effects

The present resources allocated to ongoing programs are not sufficient to adequately address the resource concerns that have been identified. No significant reduction of erosion or sedimentation would occur in the next 5 to 10 years. The value of Lake Sharpe as a recreational and economic resource will continue to be impaired. No enhancement of wildlife habitat will occur within the watershed. The Habitat Quality Rating will decrease from 0.4 to 0.35, caused mainly by the return of CRP to crop production.

Cropland

Sheet, rill, and ephemeral gully erosion on cropland is projected to decrease to 4.0 tons/acre/year as FSA conservation plans are implemented. It is estimated approximately 80 percent of the land currently in CRP will be returned to crop production by the year 2003. Since these soils are generally steeper and more erodible, erosion rates are expected to increase to approximately 5.2 tons/acre/year. The decrease in cropland erosion and the increase in erosion on CRP acreage returned to production will offset each other, and the total erosion rate for cropland will remain close to current levels, 5 tons/acre/year.

Rangeland

With the exception of approximately 35,000 acres currently under a range improvement plan within the Plum Creek Water Quality Project, native rangeland conditions will have little or no change. As a result, average rangeland sheet and rill erosion rates will remain at approximately 2 tons/acre/year. No change is anticipated in channel and gully erosion and rates will remain at approximately 8 tons/acre/year of delivered sediment from the River Breaks area.

ALTERNATIVE A			
Bad River Sedimentation Projections:			
Year	1993	2003	2018
Sediment Yield (T/yr)	2,130,000	2,130,000	2,130,000

Alternative B. Cropland and Grazing Management

This alternative focuses on changing current land management techniques in the Bad River study area to reduce erosion and sedimentation rates and increase infiltration rates. This alternative is based on the development of cropland (14,300 acres) and rangeland (179,700 acres) resource management plans with local landowners.

Rangeland

Grazing management would focus on implementing practices designed to protect or improve water quality by reducing sheet, rill, channel, and gully erosion, increasing infiltration and improving production. These prescribed grazing techniques would use a combination of Planned Grazing Systems, Proper Grazing Use, and Deferred Grazing. Water development and cross-fencing would be needed to manage these systems. The management goal for prescribed grazing techniques is to change the species composition of the grass community from cool season, shortgrass, sod-forming species to a tall and midgrass, cool and warm season climax community of grasses. Improving the midgrass community will increase infiltration and reduce runoff providing a corresponding reduction in channel and gully erosion.

Cropland

Cropland management would target practices designed to increase infiltration and reduce runoff which will also reduce sheet, rill, and ephemeral gully erosion on cropland and subsequently channel and gully erosion in the River Breaks. Conservation tillage and crop residue management practices would be used to increase the percentage of ground cover. Conservation cropping sequences would be used to enhance productivity by improving water use efficiency and decrease weeds, disease, and insect pressure. Grassed waterways or critical area plantings would be used to control areas with concentrated flows from runoff or high rates of erosion.

Proposed application of conservation practices would be in addition to the implementation of conservation plans as required by the 1985 FSA.

Costs

The costs for implementing grazing management would be installation of fences for grazing distribution, construction of stock dams, wells, pipelines and tanks for livestock water development, and establishing prescription grazing systems. A sampling of actual costs from 10 Long-Term Agreements (LTA) and GPCP contracts from the Plum Creek Water Quality Project has given an estimate of costs per acre for structural development. See Table 17 for rangeland and cropland management practice costs.

Table 17 - Bad River - River Basin Study Projected Costs
Total Installation Cost and Average Annual Cost
Alternative B. Cropland and Grazing Management

PRACTICE	ACRES	TOTAL INSTALLATION COST $	AVERAGE ANNUAL COST $
BREAKS and FLATS			
Fencing	112,200	$88,200	$10,800
Pipeline	112,200	$448,400	$46,700
Wells	112,200	$720,200	$80,600
Water Tanks	112,200	$123,700	$19,700
Stockwater Ponds	112,200	$672,000	$85,200
Range Management			
Moderate to Protected	51,100	$350,900	$32,900
Low to Protected	26,400	$423,700	$39,700
Subtotal	112,200	$2,827,100	$315,600
$2.82 per acre		$25.20	$2.81
TABLELANDS			
Fencing	67,500	$53,100	$6,500
Pipeline	67,500	$269,800	$28,100
Wells	67,500	$433,300	$48,500
Water Tanks	67,500	$74,400	$11,800
Stockwater Ponds	67,500	$404,300	$51,300
Range Management			
Moderate to Protected	27,000	$218,800	$20,500
Low to Protected	10,800	$204,400	$19,100
Subtotal		$1,658,100	$185,800
$2.75 per acre	179,700	$24.56	$2.75
Crop Management	14,300	$131,300	$12,300
$0.86 per acre			
TOTAL TREATMENT COSTS	194,000	$4,616,500	$513,700
Technical Assistance	20%	$923,300	$86,500
Project Administration	5%	$230,800	$21,600
TOTAL COSTS	194,000	$5,770,600	$621,800

Notes on all Installation Costs Tables:

These costs are computed using a 25-year project life with an 8 percent discount rate. They assume a 60 percent participation rate on the rangeland in the River Breaks and Flats and 25 percent participation rate on rangeland in the Tablelands, along with 14,300 acres of cropland conservation treatment. 14,600 acres of riparian area management is included in the rangeland management practices in the River Breaks and Flats in alternatives C and D. Costs for cropland practices were estimated from the actual costs on a winter wheat/fallow rotation.

Effects

Sedimentation will decrease over an extended period of time as erosion is reduced, infiltration rates increase and cropland and rangeland productivity improve with the effects from implementation of management systems. Sheet, rill, and ephemeral gully erosion on cropland acres participating in the project would be reduced to approximately 3.3 tons/acre. Rangeland sheet, rill, channel, and gully sediment delivered from the River Breaks and Flats to Lake Sharpe has been estimated to change from an average of 9 tons/acre to approximately 5.3 tons/acre (PSIAC evaluation method). The channels and gullies in the River Breaks, the largest source of sediment, would still be vulnerable to the erosive effects of runoff without some type of riparian management efforts.

A hydrology evaluation of the relationship between the change in the runoff hydrograph and a reduction in sediment was not attempted in this study. It became apparent that such a relationship exists and it is very significant. A fourfold increase in infiltration was measured using rainfall simulations on properly managed grazing land with a corresponding reduction in erosion. In this study the evaluations of the reduction in erosion and the resulting sedimentation for each alternative were based on only the acres actually treated. The results of increased infiltration and reduced runoff from these acres and how that would affect the rest of the watershed was not considered in the analysis of the alternatives. Based on the data from the rainfall simulation results, a more significant reduction in sediment should be achieved with range management practices than what is indicated by evaluating only the actual acres that are treated. Increased infiltration and reduced runoff would impact the sediment production of "offsite" acres, however, no quantitative relationship has been established at this time.

Overall the wildlife habitat rating would not change and would remain at 0.4. Improved ecological condition of the rangeland would compensate for the return of an estimated 40,000 acres of CRP to production.

ALTERNATIVE B			
Bad River Sedimentation Projections:			
Year	1993	2003	2018
Sediment Yield (T/yr)	2,130,000	1,849,000	1,755,000

Alternative C. Management of Riparian Areas

This alternative is based on the rehabilitation of riparian areas in the River Breaks through grazing management practices. Areas of extensive channel and gully erosion will be fenced and managed as separate units. Deferred and/or prescribed grazing will be used to accelerate vegetative recovery and regrowth along active channels and gullies.

Costs

Table 18 - Bad River - River Basin Study Projected Costs
Total Installation Cost and Average Annual Cost
Alternative C. Management of Riparian Areas

PRACTICE	ACRES	TOTAL INSTALLATION COST $	AVERAGE ANNUAL COST $
BREAKS			
Channel fencing	14,600	$11,500	$1,400
Dormant Season Use	14,600	$368,400	$34,500
Fencing	14,600	$11,500	$1,400
Pipeline	14,600	$58,400	$6,100
Wells	14,600	$93,700	$10,500
Water Tanks	14,600	$16,400	$2,600
Stockwater Ponds	14,600	$87,400	$11,100
TOTAL TREATMENT COST	14,600	$647,000	$67,600
Technical Assistance	20%	$129,400	$12,100
Project Administration	5%	$32,400	$3,000
TOTAL COSTS	14,600	$808,800	$82,700

Effects

This alternative only addresses some of the resource concerns. Upland erosion processes, sheet, rill, and ephemeral gully erosion, would not be affected and infiltration rates would not be significantly increased. Overall range condition would not be greatly improved due to the small number of acres that would have improved grazing management. Channel and gully erosion would not be greatly affected without more extensive rangeland management to reduce the amount of runoff reaching the River Breaks and Flats. The benefits from this alternative would be a slight reduction in channel and gully erosion and delivered sediment from the treated acres. The sediment delivered from all sources on 14,600 acres of rangeland would decrease from 9 tons/acre to 5.3 tons/acre.

Wildlife habitat, overall, would not improve in the study area. Without treatment in the upland area, and with 40,000 acres of CRP returned to production, the wildlife rating would change slightly from 0.4 to 0.36.

ALTERNATIVE C			
Bad River Sedimentation Projections:			
Year	1993	2003	2018
Sediment Yield (T/yr)	2,130,000	2,090,000	2,077,000

Alternative D. Total Resource Management

This alternative consists of using management techniques and structural measures to reduce sediment from cropland, rangeland, and riparian areas. This alternative would encourage the development of resource management plans with local landowners.

Rangeland

Grazing management would focus on implementing practices designed to protect or improve water quality by reducing sheet, rill, channel and gully erosion, increasing infiltration, and improving production. These prescribed grazing techniques would use a combination of Planned Grazing Systems, Proper Grazing Use, and Deferred Grazing. Water development and cross-fencing would be needed to implement grazing management systems. The management goal for prescribed grazing techniques is to change the species composition of the grass community from cool season, short-grass, sod-forming species to a tall and midgrass, cool and warm season climax community of grasses. Improving the midgrass community will increase infiltration and reduce runoff providing a corresponding reduction in channel and gully erosion.

Cropland

Cropland management would target practices designed to reduce sheet, rill and ephemeral gully erosion and increase infiltration which will subsequently reduce channel and gully erosion in the River Breaks. Conservation tillage and crop residue management practices would be used to increase the percentage of ground cover.

Conservation cropping sequences would be used to enhance productivity by improving water use efficiency and decrease weeds, disease and insect pressure. Grassed waterways or critical area planting would be used to control areas with heavy runoff or erosion. Proposed application of conservation practices would be in addition to the implementation of conservation plans as required by the 1985 FSA.

Riparian Areas

Riparian area management would consist of rehabilitation of riparian areas using a combination of structures and grazing management. Small sediment retention structures would be installed in areas with deferred or dormant season grazing to accelerate vegetative recovery of actively eroding channels and gullies. These structures would store sediment and moisture providing suitable sites for the reestablishment of riparian vegetation. Livestock grazing will be controlled with fall and/or winter grazing and limited spring/summer use.

Costs

Table 19 - Bad River - River Basin Study Projected Costs
Total Installation Cost and Average Annual Cost
Alternative D. Total Resource Management

PRACTICE	ACRES	TOTAL INSTALLATION COST $	AVERAGE ANNUAL COST $
BREAKS and FLATS			
Fencing	112,200	$88,200	$10,800
Pipeline	112,200	$448,400	$46,700
Wells	112,200	$720,200	$80,600
Water Tanks	112,200	$123,700	$19,700
Stockwater Ponds	112,200	$672,000	$85,200
Range Management			
Moderate to Protected	51,100	$350,900	$32,900
Low to Protected	26,400	$423,700	$39,700
Channel Fencing	14,600	$11,500	$1,500
Riparian Structures	1,714	$1,714,000	$503,400
Dormant Season Use	14,600	$368,400	$34,500
Subtotal		$4,921,000	$855,000
per acre	112,200	$43.86	$7.62
TABLELANDS			
Fencing	67,500	$53,100	$6,500
Pipeline	67,500	$269,800	$28,100
Wells	67,500	$433,300	$48,500
Water Tanks	67,500	$74,400	$11,800
Stockwater Ponds	67,500	$404,300	$51,300
Range Management			
Moderate to Protected	27,000	$218,800	$20,500
Low to Protected	10,800	$204,400	$19,100
Subtotal		$1,658,100	$185,800
per acre	67,500	$24.56	$2.75
Crop Management	14,300	$131,300	$32,900
TOTAL LAND TREATMENT COSTS	194,000	$6,710,400	$1,073,700
Technical Assistance	20%	$1,342,100	$125,700
Project Administration	5%	$335,500	$31,400
TOTAL COSTS	194,000	$8,388,000	$1,230,800

Effects

This alternative will improve all resource concerns. Total delivered sediment would be reduced by 29 percent. Infiltration would increase and rangeland condition would improve as management systems take effect. Sheet, rill, and ephemeral gully erosion on cropland acres would be reduced to 3.3 tons/acre. The wildlife habitat rating would increase slightly from 0.4 to 0.41.

ALTERNATIVE D			
Bad River Sedimentation Projections:			
Year	1993	2003	2018
Sediment Yield (T/yr)	2,130,000	1,682,000	1,533,000

Effects of Alternatives on Resource Problems

Problem or Concern	Alternative A	B	C	D
EROSION: Sheet and Rill	0	++	0	++
EROSION: Ephemeral Gully	0	++	0	++
EROSION: Channel & Gully	0	++	+	++
SEDIMENT YIELD: Rangeland	0	++	+	++
SEDIMENT YIELD: Cropland	0	++	0	++
OFFSITE: Riparian	0	+	++	++
OFFSITE: Wildlife	0	++	+	++
OFFSITE: Recreation	0	+	+	++
OFFSITE: Power Production	0	0	0	+
Average Annual Costs	$0	$621,800	$82,700	$1,230,800
Sedimentation (in 1,000's tons)	2,130	1,755	2,036	1,533
Average Annual Sediment Reduction (in 1,000's tons)	0	375	94	597
Cost/Ton Reduction	n/a	$1.66	$0.88	$2.06

Effect	Definition
Negligible (O)	Little to no significant effect
Moderate (+)	Significant improvement
Significant (++)	Considerable positive effect

RECOMMENDATIONS

The major conclusion of the Lower Bad River-River Basin Study is that the most significant source of sediment in the study area comes from the channels and gullies in the River Breaks. This accounts for 80 percent of the total sediment load. Alternatives B and D provide the greatest reduction in sediment. Treatment of this type of problem requires treatment of the entire ecosystem using a combination of management and structural practices. Therefore, Alternative D is recommended as the most effective way of reducing sediment from the Bad River drainage.

The most effective way to treat channel and gully erosion is the application of conservation practices in the very early or the late stages of channel evolution. Channels and gullies in the study area are in all different stages of evolution. The types of cultural practices in the surrounding landscape greatly affect the formation and/or rate of degradation of channels and gullies. The scope of the Lower Bad River-River Basin Study did not include an assessment of the stages of channel evolution in the study area and how they correlate to the condition of the surrounding landforms. To ensure that the alternatives developed are feasible and provide adequate sediment reduction it is recommended that the entire Bad River drainage be studied to determine the relative percent of each stage of channel or gully evolution in relation to the surrounding watershed in order to select an appropriate erosion control strategy. Correlation of channel stage to condition of watershed can help planners prioritize channel types and select conservation practices that will be the most effective in treating channel and gully erosion.

A hydrology evaluation of the relationship between the change in the runoff hydrograph and a reduction in sediment was not attempted in this study. It became apparent that such a relationship exists and it is very significant. A fourfold increase in infiltration was measured using rainfall simulations on properly managed grazing land with a corresponding reduction in erosion. In this study the evaluations of the reduction in erosion and the resulting sedimentation for each alternative were based on only the acres actually treated. The results of increased infiltration and reduced runoff from these acres and how that would affect the rest of the watershed was not considered in the analysis of the alternatives. Based on the data from the rainfall simulation results, a more significant reduction in sediment should be achieved with range management practices than what is indicated by evaluating only the actual acres that are treated. Increased infiltration and reduced runoff would impact the sediment production of "offsite" acres, however, no quantitative relationship has been established at this time. An evaluation of the infiltration/runoff and erosion relationship would provide planners with another means of prioritizing and selecting management practices designed to meet resource concern goals.

APPENDIX

APPENDIX A - PRIOR AND ONGOING STUDIES

U.S. Army Corps of Engineers

In July 1984, the U.S. COE completed a study of potential sediment retention structures in western South Dakota.[23] The purpose of this study was to identify potential sites and evaluate costs of constructing sediment retention structures along the White, Cheyenne, and Bad Rivers.

Eight potential sites and six possible sediment retention systems were evaluated on the Bad River. These 6 systems consist of impoundments to retain either 20 percent or 50 percent of the average annual sediment yield with a design life of 25, 50, and 75 years. It was determined that 1 to 4 sites would be sufficient to meet sediment retention goals with costs ranging from $7.8 million to $32.8 million.

The initial study was intended only to identify sites or areas with favorable conditions which justified additional consideration. No recommendations for construction were included at this time. A benefit range was estimated to be $2.00 to $6.00 per acre-foot of sediment. An average benefit of $4.00 was assumed for calculating the amount of sediment retention benefit. Feasibility was not evaluated until 1986.

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[23] U.S. Army Corps of Engineers, Preliminary Investigation of Potential Sediment Retention Structures in the Western South Dakota Basin. July 1984.

The results of the analysis concluded that none of the selected sites were economically feasible using the present methods of benefit determination. The most likely solution is a combination of sediment retention structures, land treatment by all landowners along the river, and some dredging in the mainstem reservoirs.

U.S. Geological Survey

The U.S. Geological Survey (USGS) has been monitoring water discharge since 1928 and sediment discharge since 1971 at the mouth of the Bad River near Fort Pierre. They expanded their monitoring in 1989 to include sites at Plum Creek and Cottonwood, South Dakota.

In 1992, USGS completed a suspended sediment analyses of a sediment cloud which formed at the mouth of the Bad River.[24] The purpose of this study was to determine the relative contribution of sediment from Badlands type soils at the upper end of the watershed versus Pierre Shale soils. Representative suspended sediment samples were taken at the Cottonwood and Plum Creek gaging stations and compared to the sample taken at the mouth of the Bad River.

Results of this mineralogical survey support the conclusions drawn from the Phase I and IB monitoring project. Erosion from

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24 Particle Size and Aggregate Stability Analyses of SCS Soil Samples. Bad River Basin Study, Stanley County, South Dakota, Plant Science Dept., South Dakota State University, June 1993.

the Badlands Country is not principally responsible for the sediment cloud formed at Lake Sharpe. Approximately 22 percent of this sediment cloud originated from soils of the Badlands while 78 percent came from Pierre Shale soils.

Soil Conservation Service

SCS has been involved in several sedimentation projects in the Bad River area. In 1989, a sediment monitoring project was initiated that would monitor flows and suspended sediments at various points along the Bad River. USGS continued the automatic monitoring station at Fort Pierre and established another near Cottonwood, South Dakota. The North Central Resource Conservation and Development Area (NCRC&D), with EPA funds administered through the South Dakota DENR, established manual monitoring stations at the mouths of Willow Creek, Lance Creek, Plum Creek, and near Van Metre, Capa, Nowlin, and Powell on the Bad River. The object was to try and locate those segments in the Bad River drainage area that are the greatest source of sediment. The Phase I study results were inconclusive due to lack of runoff caused by drought conditions.

Beginning in 1990, a Phase I-B monitoring project was funded with monies from the DENR, the Stanley County Conservation District, SCS, USGS, and U.S. Army COE. This was an expansion of the Phase I monitoring project maintaining the automatic monitoring stations at Fort Pierre and Cottonwood and adding automatic monitoring stations at Willow Creek and Plum Creek.

A detailed sediment survey of Hayes Lake, near the town of Hayes, was made in January of 1990. The purpose of the survey was to accumulate sedimentation data for the improvement of planning and design of soil and water conservation projects, provide sediment yield information, and analyze the accuracy of erosion and sediment yield data using the USLE on a watershed basis.

Conclusions drawn from these three projects were:

1. Cropland is not a major sediment source.
2. Badland soils of the upper reaches of the Bad River drainage area are not a major sediment source.
3. The major sediment producing area appears to be in the lower portion of the Bad River.

The Plum Creek Watershed of western Stanley County was then selected as a demonstration project for erosion control practices. Designated Phase II, conservation practices are being applied and monitored to determine their effectiveness in sediment reduction. In order to evaluate the effectiveness of practice implementation, sediment monitoring stations are located below the installed practices and systems. Rain gauges have been placed throughout the drainage area to correlate the rainfall amounts. Cost-share from multiple state and federal programs has been available to help offset installation costs as an incentive for participation.

The overall objective of Phase II is to determine the best combinations of land treatment activities that will help reduce sedimentation. Major goals include identification of principal sediment sources, determination of cost-effective land treatments that provide long lasting erosion control, and reduction of the sediment load.

In 1990, a small plot portable rainfall simulator was utilized on 16 clay and shallow clay range sites within the Bad River Basin. Runoff and sediment were measured from various range conditions and vegetative cover amounts. Grazing management strategies will be analyzed using data collected from this study.[25]

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[25] Hydrologic Assessments Within the Bad River Watershed of South Dakota, USDA-Soil Conservation Service, 1992.

HAYES LAKE SEDIMENTATION STUDY

Soil Conservation Service
U.S. Department of Agriculture
Huron, South Dakota

September 1990

Introduction and Acknowledgments

A detailed sediment survey of Hayes Lake, near the town of Hayes in Stanley County, South Dakota, was made by the Soil Conservation Service (SCS) during January 1990. See figure 1. The purpose of the survey was twofold:

1. Accumulate sedimentation data for planning and designing works of improvement for soil and water conservation.

2. Provide sediment yield information for use in the Bad River Water Quality Project.

Dave Konechne, Bob Strait, Carol Reed, Kevin Paulsen, and Kendel Newling of the U.S. Soil Conservation Service performed the sediment survey through the ice using the range lines located from the previous (1978) survey. Carol Reed, Geologist, SCS, analyzed the data and prepared this report.

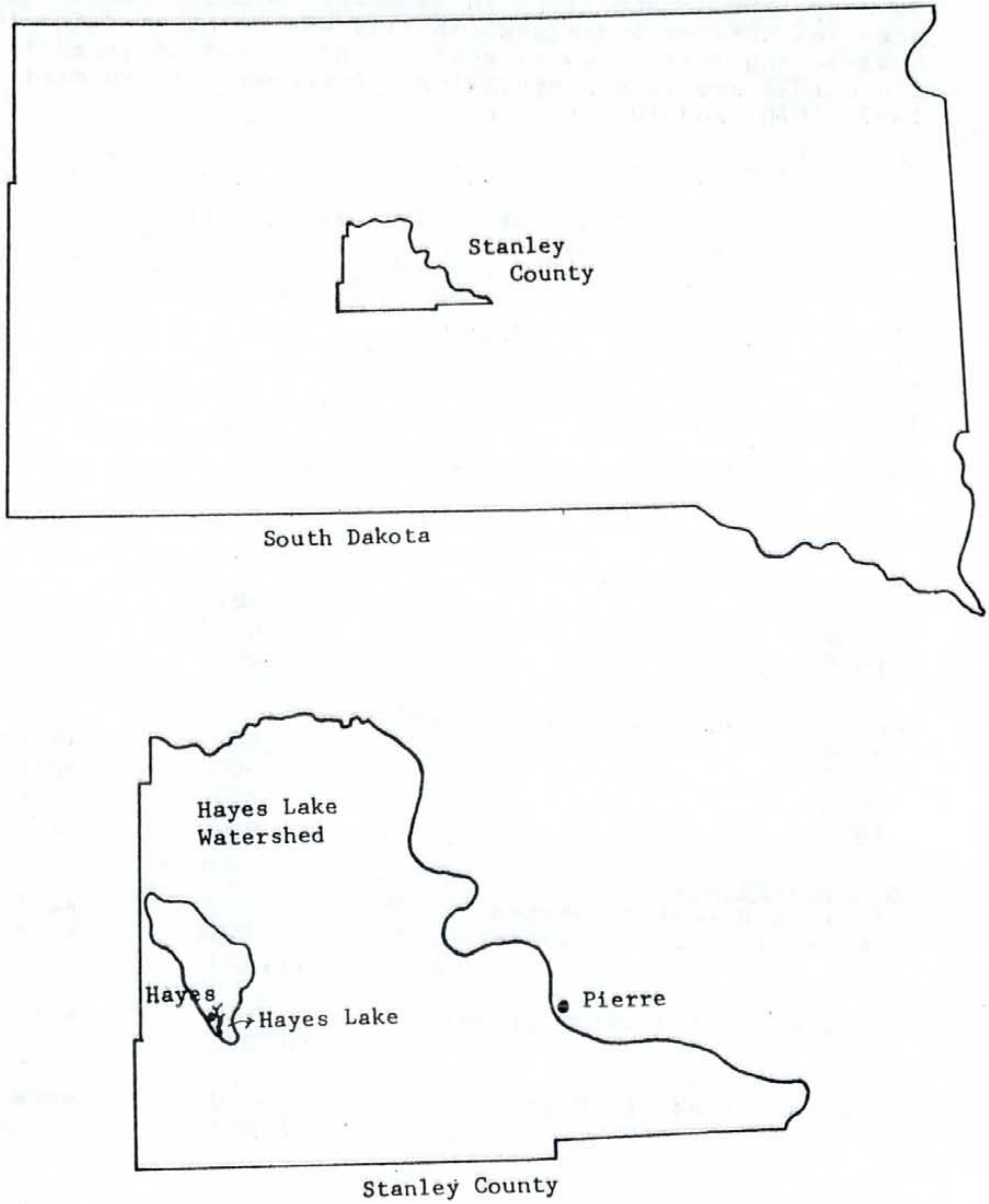


Figure 1 - Location Map of Hayes Lake and Hayes Lake Watershed

Summary

A detailed range sediment survey was made of Hayes Lake in January 1990. Capacities in 1937 and 1978 were obtained from previous surveys and a new capacity was calculated for 1990. Subtracting these figures gave 272 acre-feet of capacity loss since 1933 due to sedimentation. A summary of sediment data from 1937, 1978, and 1990 follows.

Sediment Survey Data Summary

Storage began in March 1933.
First survey was made in June 1937
Second survey was made in June 1978.
Third survey was made in January 1990.

Contributing drainage area is 43.29 $mi.^2$

Reservoir:	Quantity	Unit
Area at crest stage:		
Original	88.1	acres
1937	88.1	acres
1978 and 1990*	95.2	acres
Water storage capacity at crest stage		
Original	629	acre-feet
1937	580	acre-feet
1978*	756	acre-feet
1990	696	acre-feet
Sedimentation:		
Total sediment deposited:		
First period (4.2 years)	49	acre-feet
	41,490	tons
Second period (41.0 years)	163	acre-feet
	251,856	tons
Third period (11.5 years)	60	acre-feet
	112,610	tons

*Spillway was raised from 1,944.7 to 1,946.7 feet sometime in the 1950's.

Average annual accumulation per square mile of contributing drainage area:

First period (4.2 years)	0.27 228	acre-feet tons
Second period (41.0 years)	0.10 142	acre-feet tons
Third period (11.5 years)	0.12 167	acre-feet tons

Estimated average annual sediment yield to the mouth of the watershed in 1978 was 149 tons per square mile of contributing drainage area. No sediment estimates from gross erosion were made in 1990. Considering trap efficiency of Hayes Lake, along with the 1990 measured sediment volume, 180 tons per square mile of contributing drainage area currently is yielded to the mouth of the watershed annually.

Previous Surveys

Hayes Lake was first surveyed June 8 to 15, 1937, by Mark P. Connaughton, et al. 1/ This was a detailed range survey and iron pipes set in concrete permanently mark the range ends. 2/ Twenty-one ranges were established, sounded, and spudded; four sediment samples were collected and analyzed for volume weights. Data from that survey was recorded and compared to data from the survey done by SCS in 1978 in a comprehensive report by Lyle Steffen. 3/ Some data from the 1978 survey is included again in this report.

Location and Description

Hayes Lake watershed (28,237 acres) is in southeastern Stanley County, South Dakota. See figure 1. The watershed is longer than it is wide (12.2 miles by 3.6 miles) and is oriented along a northwest-southeast line. Hayes Lake (section 29, T. 5 N., R. 26 E.) is 1 mile southeast of Hayes which is 34 miles west of Pierre, South Dakota, on U.S. Highway 14.

1/ Connaughton, M.P., "Advance Report on the Sedimentation Survey of Hayes Lake,, Hayes, South Dakota, June 8-15, 1937", USDA-SCS, Sedimentation Studies, Division of Research, SCS-SS-20, 28 pages.

2/ Eakin, Henry M., "Silting of Reservoirs", USDA Technical Bulletin 524, pages 129-135.

3/ Steffen, Lyle, "Hayes Lake Sedimentation Studies", USDA-SCS, November 1978, 16 pages.

The lake (see figure 2) is formed behind a gravity-type, earth-fill dam on Frozenman Creek, a tributary to the Bad River. The dam was built through the Works Progress Administration program in 1933, and it was 28 feet high. (Top of dam elevation was 1,947.7.) Its principal spillway, 20 feet wide, was excavated 6 feet below the top of the dam and was located on the dam's east abutment. An emergency spillway, 90 feet wide, was located about 200 feet west of the west abutment. It is assumed that this spillway was also excavated. It was 3 feet below the top of the dam.

The main spillway could not carry the occasional flood flows so sometime after construction (in the 1940's?) a concrete spillway, of the same dimensions as the original, replaced the emergency spillway. Later, (in the 1950's), the dam was raised 9 feet, the main spillway was essentially filled in, and a 2-feet high lip was added to the concrete spillway. Records are inaccurate on exact dates the changes were made. The top of the dam is now at elevation 1,956.7 feet and the concrete spillway elevation is 1,946.7 feet.

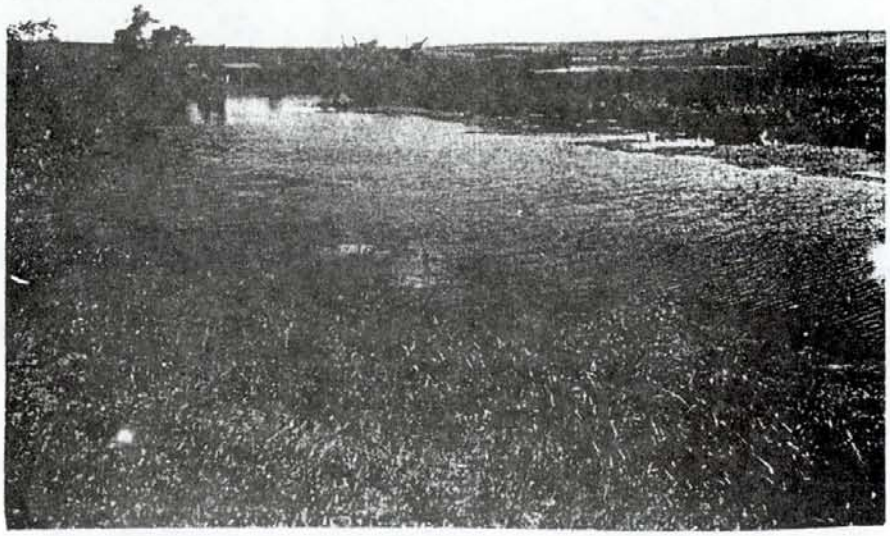
The lake was originally 88.1 surface acres in area and 629 acre-feet in volume. No new volume was recorded for the 2 feet higher spillway but the new surface area is 95.2 acres. A stage-storage water capacity curve was constructed after the 1937 sediment survey (contours were based on survey data). This curve was adjusted for compaction of the 49 acre-feet (at 38.8 pounds per cubic foot) of sediment deposited up to 1937, to 29 acre-feet (at 65.8 pounds per cubic foot) of sediment at the time the spillway was raised 2 feet. The adjusted curve was extended 2 feet and the new volume of water available after the spillway was raised was 756 acre-feet, or 784 acre-feet total volume. Some error is introduced here because it is known that sediment was deposited after 1937 but prior to the date the spillway was raised. The volume of this sediment is not accounted for in the above discussion so it is assumed that the water capacity of the lake in 1937 and at the time the spillway was raised (1950's) is the same - 756 acre-feet.

Climate, Physiography, Topography, Soils, and Geology

The climate of the Hayes Lake watershed is semiarid to subhumid based on the mixture of short and tall species of grasses found in the watershed. Average yearly precipitation in the Hayes Area is about 15 inches with a mean annual runoff of 0.45 inches.

Rain storms occur most frequently from April through July or August. These storms are of high intensity and short duration which contribute to flash-flooding.

The mean annual temperature in the area is about 47.5 degrees Fahrenheit; a maximum of 113 degrees and a low of -38 degrees Fahrenheit have been recorded.



Looking south, downstream, from near range marker R-16.

Looking northwest, upstream, from near range marker R-16. Town of Hayes is on hill in background.

Figure 2 - Hayes Lake at its widest point, segments 10 and 11. This wide, flat-bottomed portion of the lake acts as a sediment trap. Note the wide extent of marshy vegetation indicating significant sediment accumulations across the submerged flood plain.

The watershed lies within the Pierre Hills physiographic province in the Great Plains. Hayes Lake is just above the deeply dissected Bad River valley wall. The upper border of the watershed is the divide of the Cheyenne and Bad Rivers. This divide is about 2,200 feet above sea level and the lake elevation if 1,946.7 feet. the main branch of Frozenman Creek has a gradient of 0.0026 foot per foot. The landscape is characterized by long, smooth slopes on uplands with shorter, steeper slopes along well-defined drainageways. Local relief is generally about 30 feet, or less, and the drainage density is 1.9 miles of stream per square mile of drainage area.

Promise-Opal soils cover 86 percent of the watershed. These are deep and moderately deep, well drained, nearly level to moderately sloping, clayey soils formed in materials weathered from shale on uplands. Opal soils make up 25 percent of the unit and are underlain by shale at depths less than 40 inches. Promise soils are deeper to shale and both soils have medium fertility and low or moderate available water capacity. Permeability is very slow or slow and shrink-swell potential is high.

The Cretaceous Pierre Formation, primarily a silty shale, underlies the entire basin and is exposed in eroding streambanks, gullies, and the lakeshore. Some scattered Tertiary sands and gravels - remnants of ancient terraces or stream deposits - are found in the divide area at the top of the watershed.

Land Use History

The Hayes Lake watershed land use was estimated in 1937 (by the SCS sediment survey staff) to be 85 percent rangeland (including 15 percent abandoned homesteads) and 15 percent cropland (10 percent wheat, oats, and flax, and 5 percent corn and cane). Cover was generally thick weeds in June 1937, due to drought of the previous year. The weeds were primarily wild sunflowers, pepper grass, and alkali grass. In normal years the range consisted of short grasses (buffalo and grama) and the tall western wheatgrass.

Land use in May 1973, was compiled by the South Dakota State Planning Bureau, using computer processed LANDSAT imagery. 1/ Little change is noted since 1937 (36 years). There was 72 percent rangeland, 27 percent cropland (10 percent black fallow

1/ A map of Hayes Lake watershed land use, May 15, 1973, is published in Volume II of the "The South Dakota Statewide 208 Water Quality Management Plan," Office of Water Quality, South Dakota Department of Environmental Protection, Pierre, South Dakota, September 1978.

and 17 percent small grains), and 1 percent water in 1973. The range consisted of the tall western wheatgrass and green needlegrass species with an understory of short grasses, buffalo, and blue grama, along with some sedges.

Land use since 1975 showed a drastic increase in cropland acreage - probably due to high grain prices in 1974. From 1976 Agricultural Stabilization and Conservation Service (ASCS) photographs, field samples, and interviews, the watershed land use was found to be 30 percent rangeland, 68 percent cropland (23 percent winter wheat, 10 percent small grains, 10 percent rowcrops, 23 percent fallow - generally with more than 500 pounds residue, and 2 percent alfalfa), and 2 percent water. By 1990, land use was estimated to be about 71% cropland (mostly wheat and fallow), 27% rangeland, and 2% water.

Hayes is the only town in the watershed. There are 73 small dams and ponds throughout the watershed (1976 ASCS photographs).

Erosion

Sheet and rill erosion from cropland was estimated in 1978 to be 60 percent of the total water erosion in the watershed. Channelbank erosion from gullies and streambanks was and still is (in 1990) the second greatest contributor with about 27 percent of the total erosion. Based on aerial photos and sample studies in the field in 1978, there are about 150 active gullies and 50 miles of eroding streambanks in the watershed. The 1990 figures should be similar to 1978, based on similar land uses. Total tons of erosion per square mile of contributing drainage area per year is 1,350 or 2.1 tons per acre per year.

Based on field observations from 1978, sheet and rill erosion is most severe in the watershed on summer fallow fields with inadequate crop residue for cover. Erosion from rowcrop fields is secondary but probably is more severe than erosion from the small grain and alfalfa fields. The rangeland is only slightly eroding and reduces runoff considerably. Runoff from cropland may be aggravating the natural channelbank erosion in gullies and streams.

Lakeshore erosion may be more significant than estimated (1,200 feet, 15 feet high, recession rate of 0.2 foot per year). Connaughton's report mentions the fact that waves or ice constantly attack the lakeshores while other erosion only occurs during infrequent rainfall events.

Wind erosion is an important type of erosion that has not been quantitatively evaluated to date primarily because the mode of transport between the eroding areas and points of sediment yield are poorly understood. The lack of windbreaks and good vegetative cover on the cropland at critical periods of the year definitely contribute to severe wind erosion in the watershed.

Sediment Yields

Sediment Volume and Density

The volume of sediment in Hayes Lake was measured using the range method which is outlined in Chapter 7, Section 3, Sedimentation, of the Soil Conservation Service National Engineering Handbook, 1983. Soundings were made on 21 ranges and the sediment accumulation in the lake from 1978 to 1990 was calculated using Formula 7-4. This volume, 60 acre-feet, was subtracted from the water storage available in the lake in 1978, 756 acre-feet. Thus, 696 acre-feet of available water storage remains in the lake and a total of 272 acre-feet of sediment are stored in Hayes Lake today.

In order to convert volume or acre-feet of sediment to tons, the density or volume-weight of the sediment must be known. 1/ Fourteen sediment cores were collected in 1978 on seven ranges and the cores were divided into 33 samples to reflect the variable consolidation of the sediment. Volume weights for each of the 33 samples were determined in the SCS soils laboratory in Huron. For the 1990 study, the average density found for the 1978 samples was used because it was assumed that there would be little change.

A discussion of the study done on the 1978 sediment samples is included in the Appendix of this report.

Sediment Distribution

In 1990, a comparison of 1978 lake bottom elevations along each range and 1990 lake bottom elevations on the same ranges was made. The observations on sediment distribution made by Connaughton in the 1937 survey and Steffen in the 1978 survey appear to be generally true in the 1990 also. Following is a listing of Hayes Lake sediment characteristics.

1. Sediment thicknesses in the channel become greater downstream.

2. Sediment thicknesses on the flood plain become less downstream.

3. "New" sediment (since 1978) was found to be over 4 feet thick on the east half of R16-15.

4. "New" sediment on the flood plain on ranges near the dam averages 1.0 foot thick.

1/ Dry weight of sample divided by volume of wet sample = density. (pounds per cubic foot-pcf)

5. Bottom scouring occurs in the channel below lake surface during high flows even as close to the dam as R3-4. The channel has changed location and shifted 30 to 120 feet from its 1978 location at several ranges. (R3-4, R3-5, R6-7, R10-11)

6. Flood plain scour occurs above and below U.S. high 14 bridge. Several ranges showed little sediment accumulation from 1978 to 1990 due to scour in the channel.

7. Coarse particles of shale bedrock in the "new" sediment layer were found in the sample collected on the flood plain along R13-14.

8. Lakeshore erosion is continuing.

Lake bottom elevation comparisons between 1978 and 1990 provided information for most of the above observations.

As discussed in Connaughton's report, the 4 years following construction of the Hayes Lake dam were abnormally dry (10.98 inches average annual precipitation from 1933 to 1936). Any rain that fell in this period was particularly erosive because of the high runoff potential in the watershed (heavy clay soils and weedy cover). The sediment yield at the time of the first survey (June 1937) was 228 tons/mi^2/yr. This rate is much greater than the annual rate for the latter 41.0 years and it is considered to be abnormal for the above mentioned reasons.

Estimated Sediment Yield

Sediment yield to the mouth of Hayes Lake watershed was estimated to be 6,442 tons per year in 1978. This was based on the following relationship:

Gross Erosion x Sediment Delivery Ratio = Total Sediment Yield

Based on a contributing drainage area of 43.29 square miles, the sediment yield to the mouth of the watershed was estimated in 1978 to be 149 tons per square mile per year (tons/mi^2/yr). The measured sediment trapped in Hayes Lake (from 1937 to present) is 167 tons/mi^2/yr. Generally, not all the suspended sediment reaching the lake is trapped - some exits through the spillway during high flows. Using procedures outlined in USDA-SCS Technical Release 12 (1975), the trap efficiency of Hayes Lake is 93 percent. Based on this trap efficiency, and the 1990 sediment survey results, the actual sediment yield at the mouth of the watershed is currently about 180 tons/mi^2/yr.

See Appendix for more discussion on the Sediment Delivery Ratio and Sediment Yield Estimates.

APPENDIX

Sediment Volume and Density

Sediment deposits become denser in two ways - compaction due to weight of overlying sediment, and dessication, or drying. Density if also dependent on the texture of the sediment. A dry sandy clay may be 100 pounds per cubic foot (pcf) while the density of a dry silt may be 70 pcf.

In general, sediment shows a gradual increase in density with depth. However, an influx of sandy material over partially consolidated silts and clays may show a high density material grading to a lower density with depth. An abrupt increase in density with depth may indicate scouring of fence material during a rapid filling of a reservoir followed by deposition of new lighter weight sediment. The same density difference could be detected if a silt was deposited over sand, though.

When a lake dries, the uppermost sediments will become denser as they desiccate and may seal the surface so underlying deposits retain their water. Subsequent density measurements after the lake has filled, and more sediment deposited, may show low density sediment over high density sediments grading back to lighter sediments with depth. This particular situation may have occurred in samples S-24 and S-26 in Hayes Lake, since the lake was approximately 5 feet below spillway level in 1976.

The above paragraphs indicate that, generally, volume weights of sediment deposits vary laterally as well as vertically in a reservoir. The sediment samples collected in this survey corroborate that observation. The following section shows how sediment deposits are distributed in Hayes Lake and their volume converted to tons.

Sediment Description and Distribution (1978)

Sediment samples showed definite changes in consolidation of the sediment deposits vertically. The top layer, generally 0.2 foot thick, consisted of a suspended mixture of individually recognizable shale bedrock particles of various sizes. It is interesting to note that the grain sizes of the "new" sediment, "old" sediment, and Pierre shale samples were nearly identical.

The top layer of "new" sediment also had recognizable organic matter in it as well as Gastropod (snail) and Pelecypod (clam) shells. This layer had volume weights ranging from 8 to 60 pcf and was generally confined to segments above range R13-R14. Samples collected on range R3-R5 showed similar texture and density but this upper layer was thinner than that above R13-R14 and contained no recognizable shale particles.

Sediment Yield Estimates

Gully, streambank, lakeshore, road, and roadbank erosion were estimated in 1978 using direct volume methods (multiplying eroding areas by estimated erosion rates). These estimates were based on watershed samples (field and aerial photos) and other studies in the area made in the past (Western South Dakota River Basins and Sixth District Council of Local Governments Soil Erosion and Sediment Yield Study). The sample data and other information were expanded over the entire watershed using aerial photos and county highway maps.

Sediment Delivery Ratios

Sediment yield from sheet and rill erosion was estimated by multiplying the erosion by a sediment delivery ratio. From an SCS delivery ratio versus drainage area curve, a 12 percent delivery ratio could be used for Hayes Lake Watershed. An actual delivery ratio of 6 percent was used to account for the generally low slopes, rangeland along channels, and the 73 ponds and dams (many on the main creek) in the watershed. A 3 percent ratio was used for roadbank erosion because of the good grass condition in the road ditches. Weighted values of delivery ratios for gully and streambank erosion were used since erosion occurring near the lake had a much higher chance of actually becoming sediment yield to the lake. Ratios of 20 percent and 39 percent were used for gullies and streambanks, respectively. All lakeshore erosion reached the lake so a 100 percent delivery ratio was used.

USDA-Soil Conservation Service Technical Note
Rangeland Hydrology

Erosion Prediction in the Bad River Basin, South Dakota, using SPUR-91

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Introduction:

In natural plant communities, the hydrologic condition of a site is the result of complex interactions of soil and vegetation factors. The kind and amount of vegetation influences many hydrologic processes including interception, infiltration, evaporation, transpiration, percolation, surface runoff, soil water storage, soil erosion, and deposition of sediment. Spatial and temporal variability of soil and vegetation characteristics also strongly influence grazingland hydrology and erosion.

The complexity of biological, ecological, and physical properties makes it necessary to use models as potentially valuable tools for anticipating responses from land management decisions. All too often, important management decisions are made with little or no data, especially on a watershed scale. It is technically and politically necessary to substantiate planning activities with technologies that extend beyond professional intuitiveness and subjectivity.

This paper addresses the effect of differences in plant community composition on erosion and hydrology in a typical sub-watershed. The Simulation of Production and Utilization of Rangelands (SPUR1) was developed by USDA-ARS and updated by [1]Carlson and Thurow (1991, SPUR-91) to be used as a decision support tool for land managers to anticipate plant growth and hydrologic responses associated with various management scenarios. SPUR can evaluate the impact of management and research decisions. SPUR is robust because of the complexity of the biological, ecological, and physical processes in rangeland ecosystems.

Bad River Basin:

The Bad River basin has a drainage area of about 3,209 square miles. The headwaters of the Bad River begin in the badlands of western South Dakota and empties into Lake Sharpe, an impoundment on the Missouri River. About 75 percent of the watershed is rangeland and the remaining 25 percent is mostly cropland. Sediment produced from fragile clayey soils on rangeland has been identified as a major water quality problem in the state.

Plant community compositional differences on specific range sites are the result of past livestock management practices. During the open range years of the early 1900's, cattle used the Bad River and its tributaries as a major water source. Years of intense grazing pressure along these river breaks caused substantial deterioration of an already fragile ecosystem. Many of the desirable climax species such as big and little bluestem, sideoats grama, green needlegrass, and western wheatgrass were replaced by shortgrass species such as buffalograss and blue grama.

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[1] Carlson, D.H., and T.L. Thurow. 1991. SPUR-91: Workbook and User Guide. 1991 Upgrade of the Simulation of Production and Utilization of Rangelands Model. The Texas Agricultural Experiment Station. MP-1743, September 1992.

Methods: Study Area

The example watershed (52 ac) was selected from the Sansarc-Opal association (Table 1) and is characterized by shallow and moderately deep, well drained, moderately sloping to steep, clayey soils on uplands. The association is dissected by many small draws and prominent drainageways. The shallow Sansarc soils are positioned on the convex parts of the landscape while the moderately deep Opal soils are on the smoother parts of the landscape (Fig 1.).

Table 1. Description of 52 acre watershed, Sansarc-Opal association, Bad River Basin South Dakota.

Soil	Slope	Acres	Range Site	Vegetation
Opal	12	20	Clayey	Agsm/Stvi/Bocu
Sansarc	29	12	Shallow Clay	Scsc/Agsm/Bocu/Stvi
Sansarc	16	20	Shallow Clay	Scsc/Agsm/Bocu/Stvi

Agsm, *Agropyron smithii*, Western wheatgrass
Stvi, *Stipa viridula*, Green needlegrass
Bocu, *Bouteloua curtipendula*, Sideoats grama
Scsc, *Schizachyrium scoparium*, Little bluestem

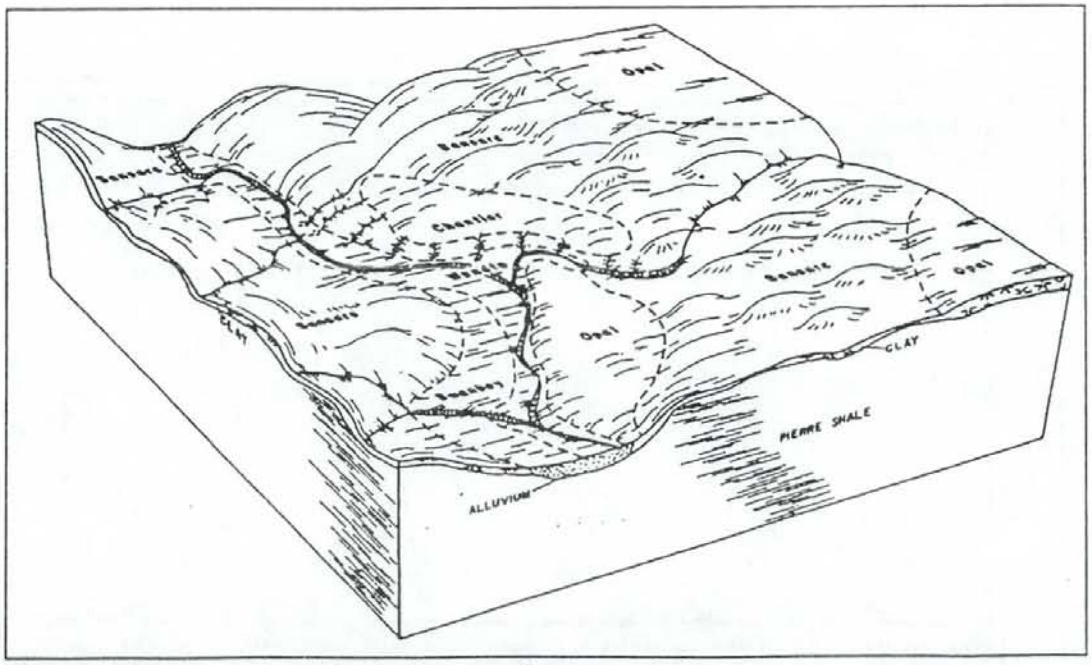

Figure 1. Patterns of soils in the Sansarc-Opal association.

Model: SPUR-91

SPUR-91 was used to simulate plant growth and hydrologic differences between range condition classes. The SPUR-91 model has five basic components: (1) Climate; (2) Hydrology; (3) Plants; (4) Animal; and (5) Economics. The hydrology component uses inputs form the climate component as a starting point for daily water balance computations. Actual daily temperature and precipitation data was used from the area. The curve number technique is used to compute runoff. Erosion is calculated using the Modified Universal Soil Loss Equation (MUSLE). The upland hydrology portion of SPUR-91 is a modification of the Simulation for Water Resources in Rural Basins (SWRRB) model.

Results:

Predicted sediment peaks spiked in April and July for 1990 through 1991 (Fig 2.). During July of 1990, the SPUR-91 model showed that the poor site had 6.4 times more interrill erosion than the good condition site. Predicted interrill erosion during April and July (1991) for the poor condition site were 5.9 and 8.3 times greater, respectively, than the good condition site. Predicted total sediment loss on an annual basis for the five year period (1987-1991) is given in Fig 3. Model predicted interrill erosion rates were highly variable during the five year and were over 5 tons/ac on the poor condition site, except for year 4, and peaked in year 5 at over 20 tons/ac. On the fair condition sites, predicted erosion rates were under 5 tons/ac for three out of the five years. Model predicted erosion exceeded an annual total of 10 tons/acre during the fifth year. On the good and excellent condition sites, predicted interrill erosion rates were consistently at tolerable limits (T = 3 tons/ac).

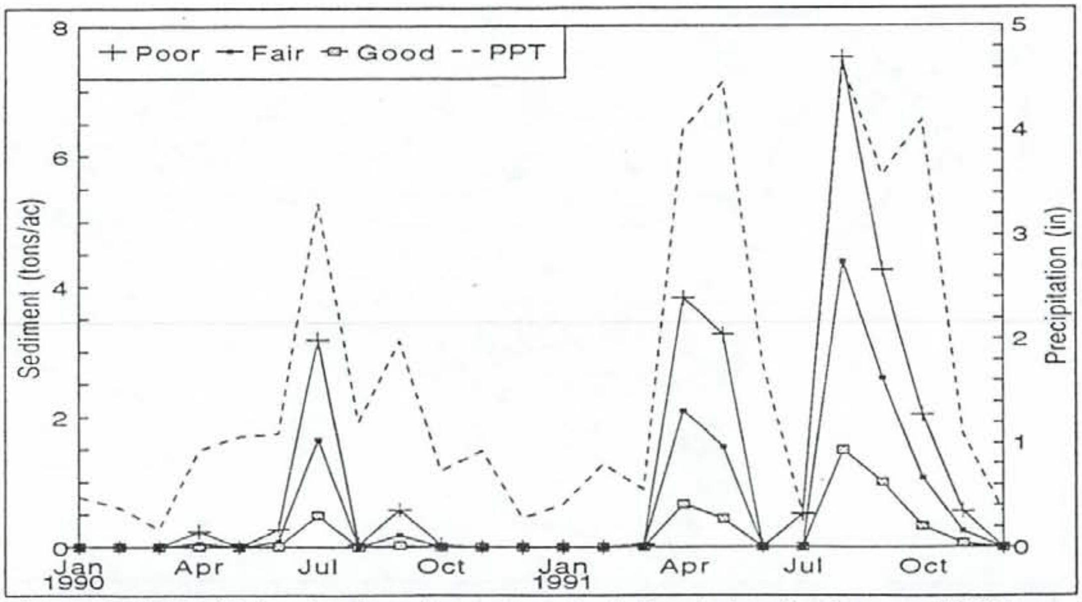

Figure 2. SPUR-91 simulated erosion using actual climate data for January 1990 through December 1991.

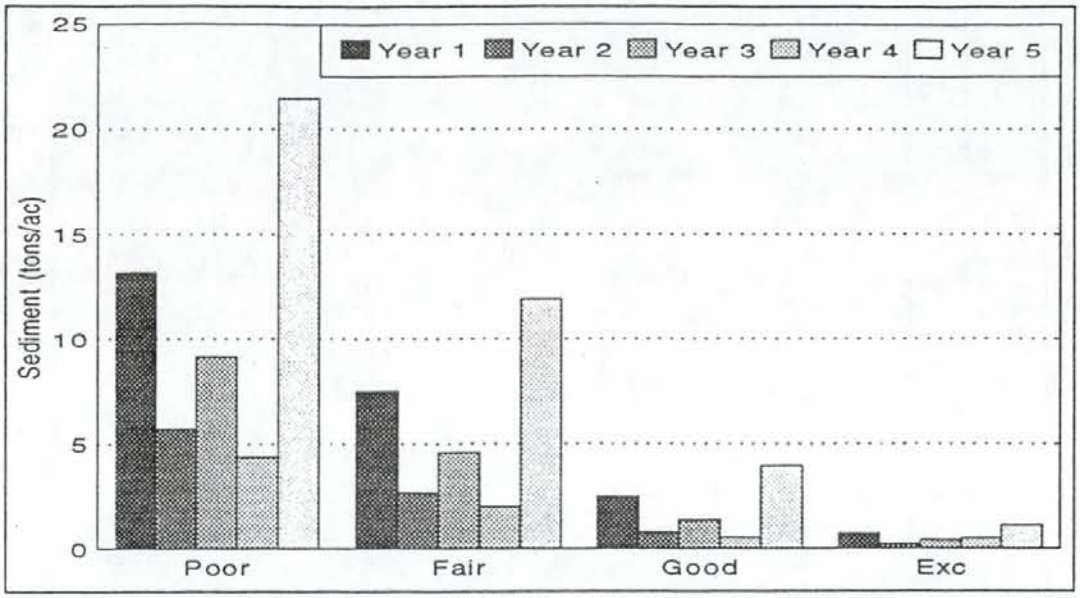

Figure 3. Predicted SPUR-91 annual totals for interrill erosion for various range condition classes.

Rainfall simulation experiments on a Sansarc Shallow Clay (5% slope) site during 1991 showed that erosion rates for an hour simulation at 4 in/hr were 1.4 tons/ac on a heavily grazed site compared to 0.07 tons/ac on a lightly grazed site. On a Sansarc Shallow Clay range site (25% slope), rainfall simulated a 4 in/hr for one hour produced 1.06 tons/ac on a heavily grazed site compared to 0.13 tons/ac on a lightly grazed site. High interrill erosion rates produced during the rainfall simulations on heavily grazed sites in low hydrologic condition substantiate the high rates for poor and fair condition sites predicted by SPUR-91. Although the rainfall simulation experiments exceeded the length of most convective storms in the area, it is important to note the relative interrill erosion rates between the two grazing treatments.

Rainfall simulation studies have shown that average steady state infiltration rates on Sansarc Shallow Clay sites (5% slope, proper grazing use) dominated by green needlegrass and western wheatgrass was 0.5 in/hr. This rate was 67% higher than identical nearby sites with a history of heavy grazing use and dominated by buffalograss and western wheatgrass. On Sansarc Shallow Clay sites (25% slope) with big and little bluestem, average steady state infiltration was 1.42 in/hr, 94% higher than identical heavily grazed sites (0.08 in/hr) with higher percentages of western wheatgrass.

The SPUR-91 simulation of biomass production reflects the natural phenology of the watershed (Fig 4.). Cool season grass production peaked in late June through July. Warm season grasses matured in July and August. In 1991, a bimodal response of the cool season grasses (June and late August-early September) was evident. This condition occurs naturally when late summer and fall rains initiate new growth of western wheatgrass.

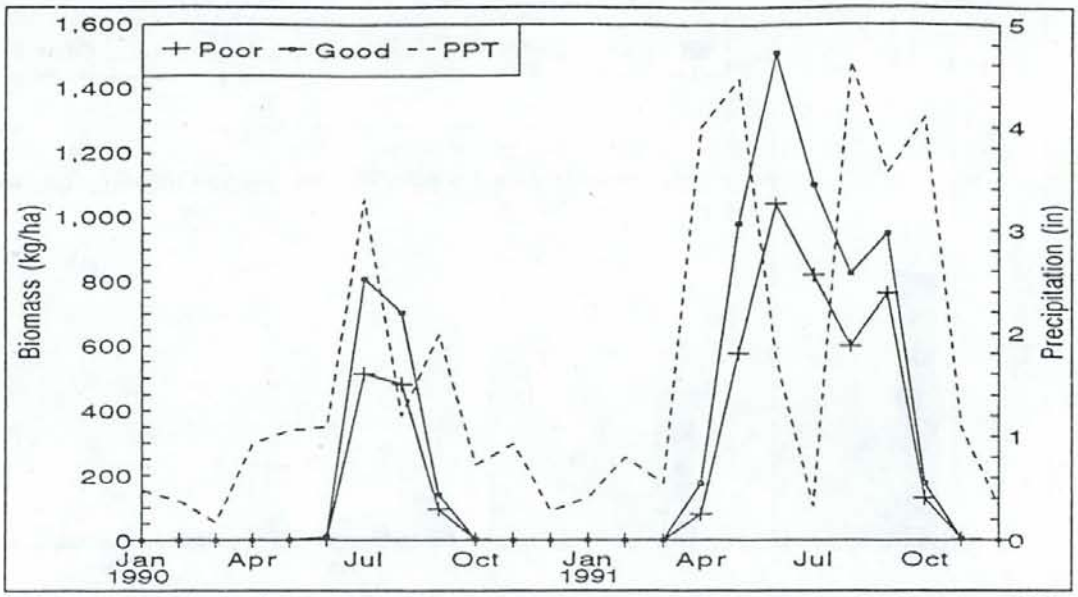

Figure 4. SPUR-91 simulation of live-green above ground production for January 1990 through December 1991.

One advantage of using the SPUR-91 model in planning scenarios is that data outputs can be set to many different temporal scales (daily-weekly-monthly-yearly). Precipitation, infiltration, potential evapotranspiration, soil evaporation, plant transpiration, deep percolation, plant-available water, sediment, and monthend live phytomass can be evaluated on any of these scales. SPUR-91 also has two scales of resolution: a field scale version (up to 9 sites) and a basin level version (up to 27 fields).

Individual plant species can have a profound effect on the hydrology of the site. When subjected to heavy livestock use, some range sites in the Bad River Basin (Promise soils) become dominated by native short grass species such as buffalograss and blue grama. Although cover and biomass production may be high, runoff may be excessive. Accelerated runoff from these sites accentuates erosion on contiguous sites in the watershed. Plant species, by the intrinsic characteristics that they have (above and below ground morphology, spatial and temporal growth patterns etc.) are unique in their effect on hydrology. Species such as buffalograss, smooth bromegrass, and Kentucky bluegrass can provide almost complete soil cover and have high site potential for protecting the site; however, runoff and erosion rates may be accelerated because of very low infiltration rates associated with these species. These species modify soil surface characteristics and are associated with root bound conditions (root pan).

CONCLUSIONS

- SPUR-91 is a valuable tool in range planning. Various management scenarios can be evaluated. It is recommended that SPUR-91 outputs be validated with some actual data from the sample area.

- In comparison with actual field rainfall simulation data, the SPUR-91 erosion and plant production changes were correlated.

- Grazing management strategies which maintain mid to tall grass composition, adequate plant height and cover, promote litter accumulation, and reduce soil compaction (bulk density) are critical factors for reducing runoff and erosion in the Bad River watershed. These values were highly correlated with sediment production and infiltration in an earlier rainfall simulation study (see Tech note: Hydrologic Assessments within the Bad River Watershed of South Dakota).

- SPUR-91 was sensitive to changes in management (i.e., hydrologic curve number, cover factors, plant composition).

APPENDIX D - THREATENED AND ENDANGERED SPECIES

Several federal and state listed threatened and endangered species are found in the study area. The following is a summary of comments and assessment made by the U.S. Fish and Wildlife Service (USFWS), Pierre, South Dakota, in accordance with Section 7(c) of the Endangered Species Act (ESA) of 1973.

Bald eagles will utilize mature riparian timber near streams and lakes. Wintering populations are found on the Missouri River with the major population being found on Lake Sharpe. Bald eagles have been documented using the Bad River during the migration and wintering periods. Projects aimed at restoring riparian areas with native vegetation, particularly the cottonwood tree (Populus deltoides), would be beneficial to bald eagles.

Peregrine falcons are attracted to open areas such as wetlands and grasslands. Peregrine falcons can be relatively abundant during the migration period and are often seen in grasslands in the study area. Management actions aimed at restoring grassland ecosystems and their adjacent riparian areas would be beneficial to prey species of the peregrine falcon.

Whooping cranes are often found in South Dakota during spring and fall migration. Whooping cranes will use cropland, pasture, wet meadows, shallow marshes, and shallow portions of rivers, reservoirs, and stock ponds for feeding and loafing. Overnight roosting occurs in shallow water in which they stand and rest.

Whooping cranes are often sighted on stock dams and associated grasslands in South Dakota. Thus, potential project actions that may include the creation of stock dams would provide for some shallow water habitat in association with those dams.

The interior least tern and piping plover nest on sparsely vegetated sandbars or shoreline areas of South Dakota rivers. The interior least tern is known to nest on the Cheyenne and Missouri Rivers, while the piping plover nests on the Missouri River and possibly alkali wetlands and reservoirs. If dredging is ever proposed as an option to resolve sedimentation problems on Lake Sharpe, consideration should be given to using the dredged sediment to create least tern and piping plover nesting areas. Least terns and piping plovers once nested on Lake Sharpe as late as the 1980's, but lack of suitable habitat in recent years has eliminated any reproduction of these birds on Lake Sharpe.

Very little is known about the American burying beetle in South Dakota. Historic locations for the beetle include an area in the Bad River basin at Nowlin in Haakon County. Current information suggests this species occurs in grassland habitat. The beetle is attracted to carrion, on which it is dependent for food, and buries the carrion below ground. The beetle is one of the largest of its kind enabling it to fly great distances in search of food. Surveys for this species are lacking. The species may still be found in South Dakota since a population was found recently near Valentine, Nebraska.

All prairie dog towns are considered to be potential habitat for the black-footed ferret. Prairie dog complexes greater than or equal to 1,000 acres that will be affected by federally proposed actions must be considered by USFWS as "essential" to the recovery and survival of the ferret until such areas have been specifically evaluated and determined not to be essential. Federal actions that will affect the biological integrity of existing prairie dog towns will be considered by the Service as actions that will be "likely to adversely affect" the ferret.

Ferret surveys will be required prior to projects involving a prairie dog town or complex greater than 80 acres. A complex consists of two or more neighboring towns within seven kilometers of each other. Surveys must be conducted in accordance with the U.S. Fish and Wildlife Service Black-Footed Ferret Survey Guidelines (April 1989). A copy of these guidelines can be obtained from the U.S. Fish and Wildlife Service.

The pallid sturgeon is a large river fish known only to occur in the Missouri River, the lower Yellowstone River in Montana, and the Mississippi River downstream of it's juncture with the Missouri River. Pallid sturgeon require large, turbid, free flowing, riverine habitat with rocky or sandy substrate. This species is still known to exist in Lake Sharpe.

Candidate species have no legal status and receive no protection under the ESA. However, during the life of a project, the potential of a status change exists. The protection of these species should be considered in order to aid in their recovery or avoid their future listing. Several species that may occur in the Bad River study area and may be affected by any project activities are listed in Table 21.

If it is determined that any agency program or project "is likely to adversely affect" any listed species, formal consultation should be initiated with USFWS. If it is concluded that the project "is not likely to adversely affect" listed species, they should be asked to review the assessment and concur with the determination of no adverse effect.

Table 20- Candidate Species

Category	Common Name	Scientific Name	Status
2	Plains spotted skunk	Spilogale putorius interrupta	Unknown
2	Swift fox	Vulpes velox	Unknown
2	Ferruginous hawk	Buteo regalis	Declining
2	Mountain plover	Charadrius montanus	Unknown
2	Black tern	Chlidonias niger	Declining
2	Loggerhead shrike	Lanius ludovicianus	Unknown
3c	Long-billed curlew	Numenius americanus	Declining
2	White-faced ibis	Plegadis chihi	Unknown
2	Lake sturgeon	Acipenser fulvescens	Unknown
2	Blue sucker	Cycleptus elongatus	Stable
2	Sturgeon chub	Hybopsis gelida	Declining
2	Sicklefin chub	Hybopsis meeki	Declining
2	Paddlefish	Polydon spathula	Unknown
2	Plains topminnow	Fundulus sciadicus	Declining
2	Scaleshell	Leptodea leptodon	Unknown
2	Belfragi's chlorochroan bug	Chlorochroa belfragi	Declining
2	Regal fritillary butterfly	Speyeria idalia	Declining

USDA-Soil Conservation Service Technical Note
Rangeland Hydrology

Hydrologic Assessments within the Bad River Watershed of South Dakota

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Abstract:

Rainfall simulation studies can provide valuable information for SCS planning efforts (i.e., River Basin studies, Special projects, State Water Quality programs, PL-566 programs, etc). In the past, the Soil Conservation Service has relied almost entirely on the Universal Soil Loss Equation to estimate erosion. With increasing concern over quality of surface and ground water, erosion and sedimentation, it is imperative that the Soil Conservation Service utilize other existing technologies to better understand the hydrologic cycle and key factors that affect it.

This study provides an example of how small plot rainfall simulations can provide information on infiltration and erosion rates on rangeland, pastureland, forestland, or cropland. The primary advantage for using small plot rainfall simulations is to obtain field data which can be used to compare relative hydrologic differences for 1) vegetation types; 2) management (i.e., grazing intensity, range improvement practices, etc.); and 3) compositional and species changes in ecological sites.

Introduction:

By having knowledge of hydrologic principles and processes and how these processes are affected by vegetation, vegetation management practices, and structural practices (engineering activities), the conservationist or land manager can more easily conceptualize how various activities in a given area effect the water cycle.

Solutions to existing or potential problems involving the relationship between water and land uses can be physical, economic, or regulatory. Conservation strategies on grazingland watersheds can be classified as preventive or restorative. Usually, most situations are a combination of the two. Preventive strategies and sound management plans are equally as important as the more dramatic and sometimes more politically visible restorative actions. For every watershed and site within the watershed, there exists a critical point of deterioration due to surface erosion. Beyond this critical point, erosion continues at an accelerated rate which cannot be overcome by the natural vegetation and soil stabilizing forces until a new equilibrium is achieved. Areas that have deteriorated beyond this critical point continue to erode even when man-caused disturbance is removed (Satterlund 1972).

Preventing losses of soil, desirable vegetation, wildlife habitat, and losses of forage production are much less costly than achieving the same benefit from a degraded situation by restoration. Depending on the severity of resource and watershed degradation (which includes water, soil, plant, animal, air, and human resources), restoration may not be feasible from an ecological and/or economic perspective. The results of grazingland watershed degradation can be serious and irreversible.

Infiltration, one of the most important processes in the hydrologic cycle is regulated by the kind and amount of vegetation, edaphic, climatic, and topographic influences (Wood and Blackburn 1981, Spaeth 1990). The kind and amount of vegetation influences many hydrologic processes including: interception, infiltration, evaporation, transpiration, percolation, surface runoff, soil water storage, soil erosion, and deposition of sediment. Every plant-soil complex exhibits a characteristic infiltration pattern (Gifford 1989). Hydrologic processes are affected by more than plant cover: Many plant and soil factors affect infiltration, runoff, and interrill erosion.

The purpose of this study was to 1) study the effects of grazing levels, plant composition on hydrologic assessments (infiltration, runoff, and erosion); and 2) identify important vegetative and soil variables which could be used to predict erosion and infiltration on dominant range sites in the Bad River Basin.

Methods:

Study Area:

The Bad River basin has a drainage area of about 3,209 square miles. The headwaters of the Bad River begin in the badlands of western South Dakota and empties into Lake Sharpe, an impoundment on the Missouri River. About 75 percent of the watershed is rangeland and the remaining 25 percent is mostly cropland. Sediment produced from fragile clayey soils on rangeland has been identified as a major water quality problem in the state. The average annual Bad River sediment discharge (as measured by USGS, 1982-1991) was 1,816,082 Mg tonnes (2,002,295 tons). Previous studies within the river basin concluded that a substantial amount of sediment comes from gullies and sheet and rill erosion on rangelands.

Years of intense grazing pressure along these river breaks caused substantial deterioration of an already fragile ecosystem. Many of the desirable climax species such as big and little bluestem, sideoats grama, green needlegrass, and western wheatgrass were replaced by shortgrass species such as buffalograss and blue grama. Although adequate cover may exist in stands of buffalograss and blue grama, runoff may be excessive. Accelerated runoff from these sites exaccerbates erosion in rills and drainage ways within a field and ultimately on the watershed.

Rainfall Simulation:

Rainfall simulation studies were conducted on 16 sites representing Sansarc and Promise soils, Shallow Clay and Clayey range sites, respectively. These two soils are prominent range soils in the Bad River Drainage area. Two grazing levels were evaluated: light to moderate grazing and heavy grazing. Table 1 lists the variables that were measured on each plot.

Table 1. Summary of variables collected on each rainfall simulation plot.

Symbol	Dependent Variables	Units
TCI	Terminal cumulative infiltration	in/hr
5IN	5-minute infiltration	in/5 min
10IN	10-minute infiltration	in/5 min
15IN	15-minute infiltration	in/5 min
20IN	20-minute infiltration	in/5 min
5-10SED	5-10 minute sediment	lbs/ac
15-20SED	15-20 minute sediment	lbs/ac
TSED	Total sediment at 1 hr	lbs/ac
Ksat	Saturated Hydraulic Conductivity	in/hr

Table 1. cont.

Symbol	Independent Variables	Units
BIO	Biomass (standing green)	lbs/ac
PHY	Phytomass (BIO+LIT)	lbs/ac
GRASS	Total Grass Component	lbs/ac
LIT	Litter or Mulch	lbs/ac
ROOT	Root biomass (at 4 in depth)	lbs/ac
Pb1	Bulk Density (0 to 1.5 in depth)	Mg/m^3
Pb2	Bulk Density (1.5 to 3.0 in depth)	Mg/m^3
COV	Canopy Cover	%
SLOPE	Slope	%
HT	Average Height of Vegetation	in

Simulation plots were pre-wet by applying 100 l/m^2 (26 gal/10 ft^2) of water. Depth of wetting was approximately 15 cm (6 in). The pre-wetted area was covered with plastic and rainfall simulation commenced about 24 hours later. A portable single nozzle rainfall simulator was used on 0.5 m^2 (5.4 ft^2) plots in June 1991. Water was applied 2.0 m (6.5 ft) above the plot at 20 Kpa (3 psi) pressure which produces an average droplet size 2.4 mm in diameter.

Plot simulation was replicated 2-4 times on each treatment. Simulated rainfall was applied at the rate of 10 cm/hr (4 in/hr) for 60 minutes. Runoff was measured at 5-minute intervals and mean infiltrability was calculated by determining the difference between applied rainfall and the quantity of water running off the plot. Sediment samples were obtained at 5-10 and 15-20 minutes (depending on when runoff started). A cumulative sediment sample was also collected after the one hour run.

Each plot was clipped (grasses, forbs, half shrubs, and litter). Root samples were taken in each plot [26 cm (10.2 in) diameter x 10-cm (4.0 in) depth]. Cover measurements of each species and bare ground was made by ocular estimates to the nearest percent. Soil bulk density was determined by the core method at 0- to 4-cm and 1.5- to 8.0-cm depths. A 375 m^2 (0.1 ac) circular macroplot was established with the 0.5 m^2 plot in the center, and all plant species were recorded to the nearest percent. The macroplot was used to further verify (quantify and identify) that the 0.5 m^2 microplots were actual representations of the respective community types. The soil in each plot was verified by an SCS Soil Scientist.

Treatments:

Sansarc Shallow Clay Range site, heavily grazed, 5% slope
Sansarc Shallow Clay Range site, light to moderate grazing, 5% slope
Sansarc Shallow Clay Range site, heavily grazed, 25% slope
Sansarc Shallow Clay Range site, light to moderate grazing, 25% slope
Promise Clayey Range site, heavily grazed, 5 % slope
Promise Clayey Range site, light to moderate grazing, 5 % slope

Statistical Analysis:

Multiple regression analysis was used to determine the amount of variation in infiltration attributable to selected independent and dependent variables. Diagnostic procedures, and practical considerations of the equations were also considered: the magnitude of the regression coefficients and their signs with respect to realistic expectations; significance of the calculated F* value of the analysis of variance (ANOVA); significance of t* tests for individual variables; residual plots for independent variables and their respective error variances, and the coefficient of determination (R^2).

Results:

Infiltration Curves:
5-Minutes

Five minute infiltrability was approximately 30% higher on the light to moderate grazed (LMG) Sansarc (5% slope, Fig. 1) and Promise (5% slope, Fig. 2) sites. On the heavily grazed (HG) treatments of these soils, buffalograss was a predominant species. On the LMG treatment, western wheatgrass and green needlegrass were the major components.

There was no difference in 5-minute infiltration rates on the Sansarc (25% slope, Fig. 3) treatments. Both the LMG and HG treatments contained tall grass components, however difference in height of vegetation was significant: 9.9 cm (3.9 in) for (HG) and 54.9 cm (21.6 in) for (LMG).

15-Minutes:

At 15 minutes, infiltrability was about 2/3 higher on the LMG treatments for the Sansarc (5% slope), Promise (5% slope), and Sansarc (25% slope) sites (See Figs. 1,2, and 3).

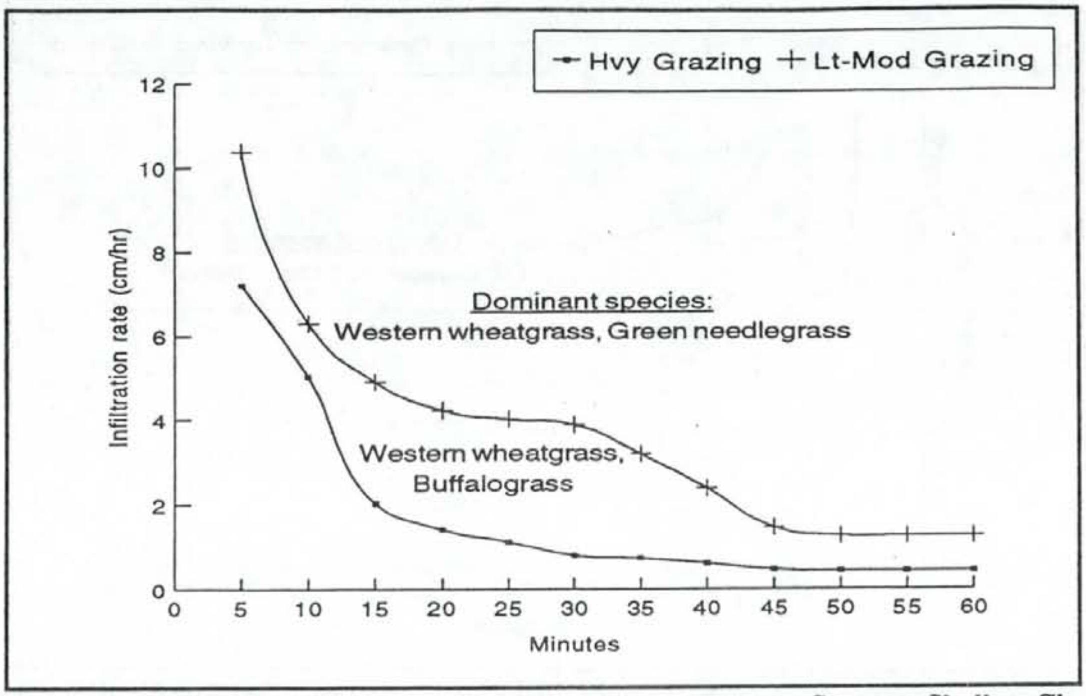

Figure 1. Infiltration of heavy vs. light-moderate grazing on a Sansarc, Shallow Clay range site (5% slope).

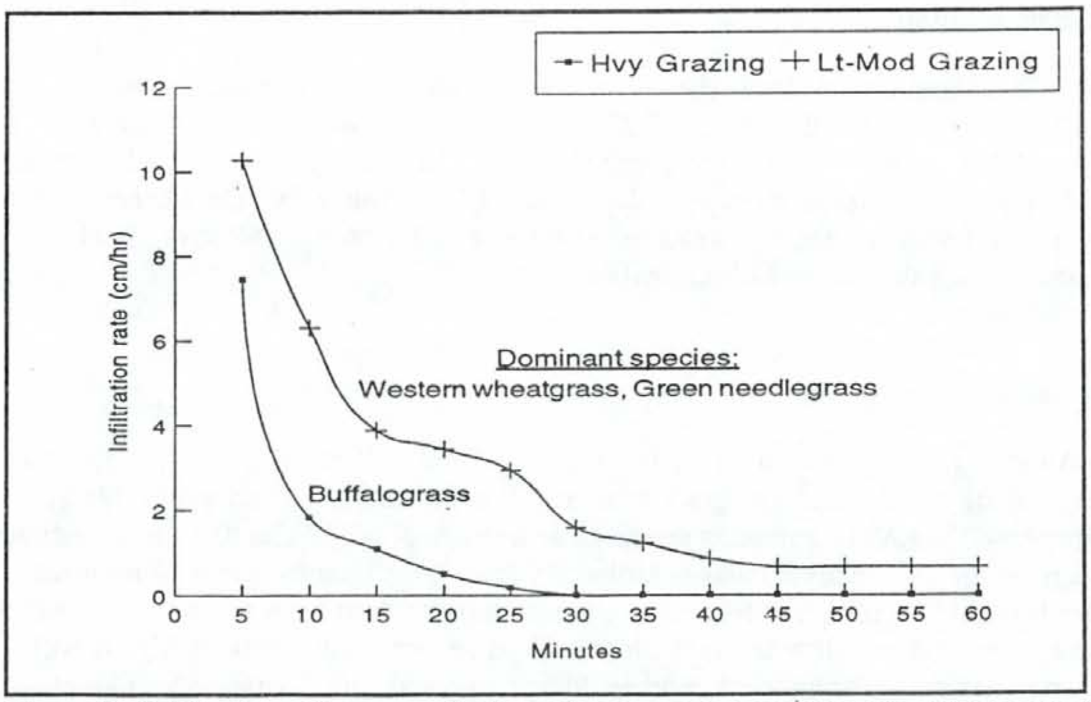

Figure 2. Infiltration of heavy vs. light-moderate grazing on a Promise, Clayey range site (5% slope).

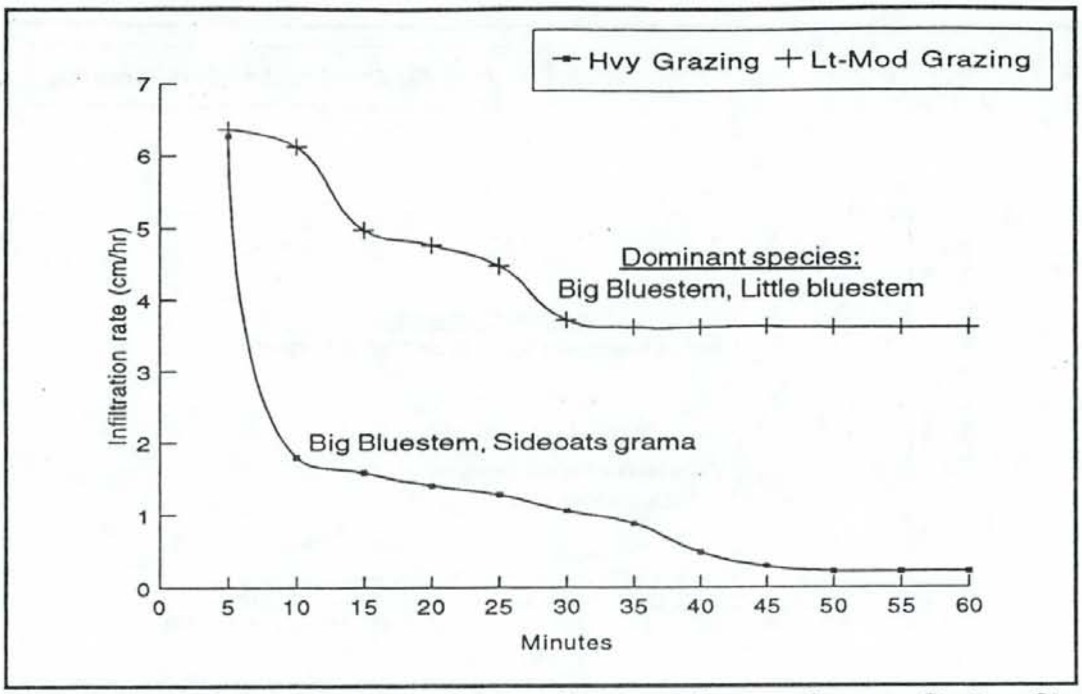

Figure 3. Infiltration of heavy vs. light-moderate grazing on a Sansarc, Shallow Clay range site (25% slope).

Steady State Infiltration:

On the Sansarc (5% slope) site, average steady state infiltration (SSI) was 0.41 cm/hr (0.16 in/hr) for the HG and 1.27 cm/hr (0.50 in/hr) for the LMG treatments. The comparative SSI on the Promise (5% slope) site was 0.13 cm/hr (0.05 in/hr) and 0.66 cm/hr (0.26 in/hr), an 82% difference between the HG and LMG treatments. The steeper Sansarc site (25% slope) SSI values were 0.03 cm/hr (0.01 in/hr) and 3.6 cm/hr (1.42 in/hr), a 94% difference between the HG and LMG treatments.

Interrill Erosion:

Average interrill erosion on the HG Sansarc, 5 and 25% slope phases, produced about 2.7 Mg/ha (1.2 t/ac) of sediment during a 10 cm/hr (4.0 in/hr) rainfall simulation (Table 2). Comparatively, the LMG treatments produced an average of 0.2 Mg/ha (0.1 t/ac). Sediment production on the HG treatment was considerably less on the Promise site because it was dominated by buffalograss, a sod-forming grazing resistant short grass species. The buffalograss sites were correlated with low sediment, low infiltration rates, and relatively high runoff. This phenomenon has been documented in other studies (Mazarak and Conrad 1959, Dee et al. 1966, and Spaeth 1990). Buffalograss is associated with a highly compacted fine root mass in the upper 10 cm (4.0 in) of soil.

Table 2. Summary of bulk density, infiltration, and sediment yields for a Promise Clayey site and Sansarc Shallow Clay site. A portable rainfall simulator was used with an application rate of 4.0 inches/hr.

	Promise Clayey Site (5% slope)			Sansarc Shallow Clay (5% slope)			Sansarc Shallow Clay (25% slope)		
Variable	Heavy Grazing Use	Light to Moderate Grazing Use	Percent Difference	Heavy Grazing Use	Light to Moderate Grazing Use	Percent Difference	Heavy Grazing Use	Light to Moderate Grazing Use	Percent Difference
Bulk Density 0-1.5" Depth Mg/M3	1.28	1.01	- 21%	1.37	1.13	- 18%	1.32	1.24	- 6%
Bulk Density 0-3" Depth Mg/M3	1.55	1.24	- 20%	1.38	1.34	- 3%	1.33	1.11	- 17%
Infiltration Rate in/hr	0.047	0.26	+ 82%	0.16	0.50	+ 63%	0.085	1.42	+ 94%
Cumulative Infiltration Rate in/hr	0.35	1.08	+ 68%	0.61	1.44	+ 58%	0.51	1.87	+ 73%
Erosion Rate lbs/ac	425	163	- 62%	2732	144	- 95%	2120	265	- 88%
Canopy Cover %	88	84	- 4%	28	87	+ 68%	21	94	+ 78%
Biomass lbs/ac	1401	2308	+ 39%	644	1362	+ 53%	514	1101	+ 53%
Litter lbs/ac	258	157	- 39%	1481	1792	+ 21%	109	130	+ 16%
Grass Production lbs/ac	1277	2112	+ 40%	326	1024	+ 68%	492	897	+ 45%
Root Biomass 0-4" Depth lbs/ac	7100	3824	- 46%	1779	1449	- 19%	8670	12,432	+ 30%
Avg. Plant Height inches	3.9	21.6	+ 82%	9.05	21.7	+ 58%	3.9	21.6	+ 82%
Range Condition %	29	77	+ 48%	24	43	+ 19%	59	78	+ 19%

Infiltration and Runoff Characteristics: Sansarc 5% slope

Thunderstorms occur on about 40 days each year, most of which occur during the summer. Average storm intensities are: 2-year, 24 hr, is about 5.3 cm (2.1 in); 5-year, 24 hr, is about 7.4 cm (2.9 in); and 25-year, 24 hr, is about 10.4 cm (4.1 in).

As an example, comparisons of infiltration and runoff on the Sansarc (5% slope) sites, HG and LMG treatments, showed that heavily grazed sites will produce considerable more runoff than light to moderately grazed sites. Under antecedent conditions, average runoff was about 2/3 higher on the HG treatment at 10 minutes with 1.68 cm (0.66 in) of water applied (Fig. 4). Average cumulative rainfall at 15 minutes (2.54 cm, 1.0 in of rain), produced 48% more runoff on the HG treatment. Average cumulative infiltration was 56% higher on the LMG treatment.

Infiltration Models:

The following infiltration models were developed from field data from the rainfall simulation plots. Terminal cumulative infiltration (TCI) rate at 1 hr was correlated with 3 variables: grazing level, average height of vegetation, and litter. The best single variable equation was

Model 1:

TCI = 1.18 - 0.715(Grazing Level)

$r^2 = 0.85$

where:

heavily grazed = 1
lightly to moderately grazed = 0

example TCI= 1.18 - 0.715(1) for heavy grazing, TCI = 0.465 in/hr. For light to moderate grazing, TCI = 1.18 in/hr.

This model accounted for 85% of the variation in terminal cumulative infiltration rate at 1 hour. At a 95% confidence level, heavy grazing tends to reduce cumulative infiltration on Promise Clayey and Sansarc Shallow range sites somewhere between 0.93 and 0.49 in/hr compared to light grazing.

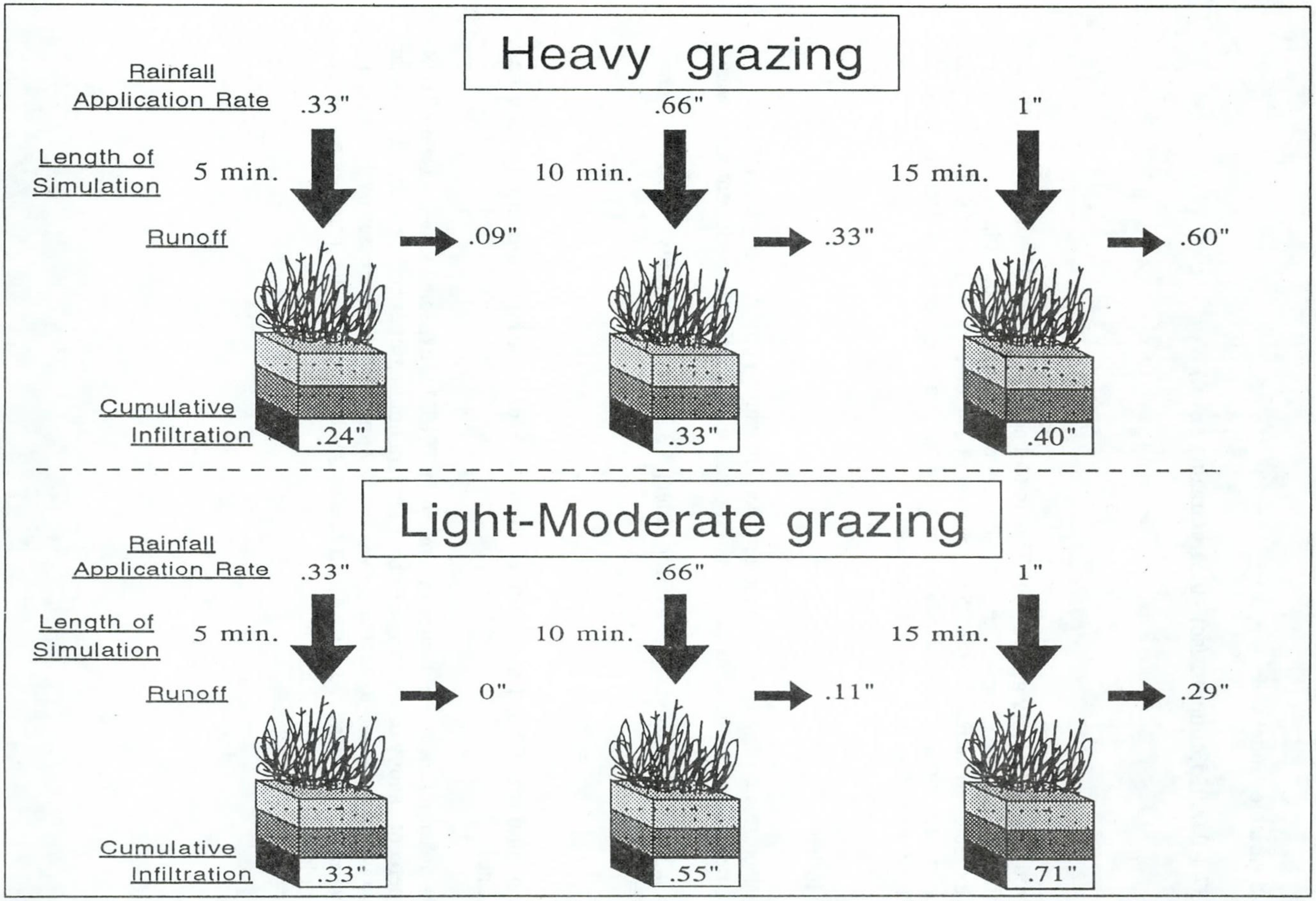

Figure 4. Diagramatic representation of average rainfall simulation results on a Sansarc Shallow Clay range site (5% slope), in the Bad River Basin, South Dakota. Rainfall application rates, length of simulation (5-15 minutes), runoff, and cumulative infiltration are represented for Heavily grazed and Light to Moderately grazed sites.

Model 2:

The best two variable model was

TCI = 1.0137 + 0.000253(litter,lbs/ac) - 0.615(Grazing Level)

$R^2 = 0.93$

where:

heavily grazed = 1, and lightly grazed = 0. This model accounted for 93% of the variation in terminal infiltration rate at 1 hour. The above equation indicates that cumulative infiltration rate at 1 hour is expected to increase 0.00025 in/hr when litter increases by 1.0 lb/ac, holding grazing influence constant. Cumulative infiltration rate at 1 hour is also expected to decrease by 0.615 in/hr under heavy grazing, holding litter constant.

Sediment Models:

Sediment was correlated with grass production, percent canopy cover, average height of vegetation, litter, and soil bulk density. The best predictive equation for sediment yield was

ln(TSED) = 4.33 - 0.0286(Cover) - 0.000389(Litter) + 3.3306(Bulk density of soil 0-3 inch depth), $R^2 = 0.92$

where:

ln(TSED) = natural log of Total Sediment Yield (lbs/ac) for a one hour simulation at 4 inches/hr application rate.

The above regression function indicates that mean ln(TSED) is expected to decrease by 0.028 units when percent canopy cover increases by 1 percent holding litter and bulk density constant. The lnTSED is also expected to decrease by 0.000389 units as litter increases by 1 lb/ac holding the other 2 variables constant. As bulk density increases by 1 Mg/m^3, the lntsed increases by 3.306 units holding cover and litter constant.

Conclusions:

The following conclusions are specific to the Sansarc and Promise range sites in the Bad River Drainage.

Management Implications:

1. Grazing level, amount of litter or mulch, and height of vegetation had the greatest influence on infiltration rates.

2. Grass production, percent canopy cover, height of vegetation, and soil bulk density had the greatest effect on sediment production.

3. Controlling utilization levels is one of the most important management options to maximize plant canopy cover, continued optimum grass production, desired plant composition (mid grass species i.e., green needlegrass, western wheatgrass, and sideoats grama), and litter accumulation.

4. Season of use and degree of use are critical factors in reducing runoff and sediment production from upland range sites. In using actual climate data on a daily basis over a 5-year period, the Simulation, Production, and Utilization of Rangelands (SPUR-91, Carlson and Thurow 1992) model showed that sediment peaks begin in April, continue throughout the summer months and subside in October. Comparisons of sediment peaks for April and July (1990) were 5.9 and 8.3 times greater, respectively, for the poor condition site compared to the good condition rangeland site.

5. Grazing management strategies must maximize accumulation of litter, plant height, and promote growth of the taller non-sod forming species.

6. Critical erosion areas or pastures where gully erosion and headcuts are accelerating, require year round management to maintain adequate litter, plant height, grass residue, high mid grass composition levels, and lower soil compaction (lower soil bulk density). Excessive runoff from contiguous sites because of changes in species composition from midgrasses to shortgrasses accellerates existing gully erosion and new headcuts.

7. Grass composition greatly affects the hydrology of the site. Certain grasses such as green needlegrass, sideoats grama, little bluestem are associated with higher infiltration rates, lower runoff, and lower sediment yields.

8. The shorter sod-forming species such as buffalograss and blue grama are associated with high runoff and this accentuates gully formation and headcuts.

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