UPPER BAD RIVER-RIVER BASIN STUDY

Project #5005

Prepared By:

UNITED STATES DEPARTMENT OF AGRICULTURE
Natural Resources Conservation Service
U.S. Forest Service

In Cooperation With:

American Creek Conservation District
Badlands Resource Conservation and Development Area Council, Inc.
East Pennington Conservation District
Haakon County Conservation District
Jackson County Conservation District
Jones County Conservation District
Stanley County Conservation District
South Dakota Cooperative Extension Service
South Dakota Department of Agriculture, Division of Resource Conservation and Forestry
South Dakota Department of Environment and Natural Resources

October 1998

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 Badlands near Wall, South Dakota, and flows to the east approximately 100 miles where it discharges into Lake Sharpe near the communities of Fort Pierre and Pierre. The Bad River Watershed encompasses 3,173 square miles of Haakon, Jackson, Jones, Lyman, Pennington, and Stanley Counties. The U.S. Army Corps of Engineers' (COE) gauge data from 1948 to 1986 estimates that the Bad River discharges an average annual sediment load of 3,250,000 tons of sediment into Lake Sharpe. Because of the large sediment load and size of the drainage area, two river basin studies have been conducted: the Lower Bad River-River Basin Study was completed in 1994, and the Upper Bad River-River Basin Study in 1998.

The Upper Bad River-River Basin Study is sponsored by the Badlands Resource Conservation and Development (BRCD) Area Council, Inc., and the conservation districts in East Pennington, Haakon, Jackson, Jones, Lyman, and Stanley Counties. The main objectives of the study are:

(1) to identify and quantify areas in the upper portion of the watershed needing treatment for sediment reduction and water quality improvement.

(2) to utilize a channel classification system to identify and quantify stable and unstable channel conditions for the entire watershed and determine sediment yields for these channels; and

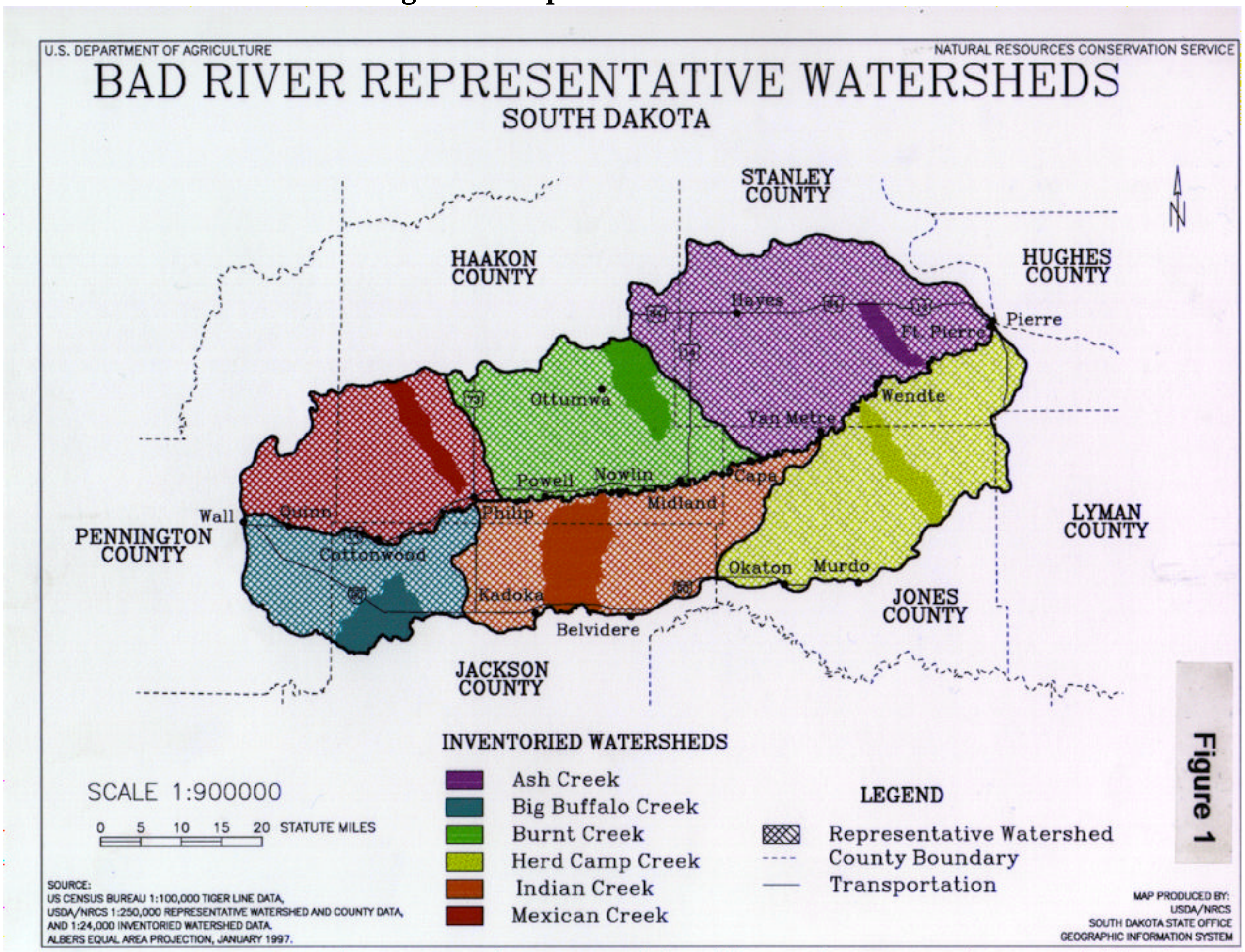
(3) to develop alternatives which will assist sponsors in setting priorities for implementation of agricultural nonpoint source water pollution management activities.

Six inventory subwatersheds were delineated in the Bad River Watershed drainage area (Figure 1). The channels in these subwatersheds were individually inventoried and classified using both the Rosgen stream classification system and Schumm's channel evolution model. This data was extrapolated and expanded to the portion of the Bad River Watershed that each inventoried subwatershed represents (representative subwatersheds). A geographic information system (GIS) was used to extrapolate the data from the six inventoried subwatersheds to the entire Bad River Watershed. The GIS layers included topography, soils, subwatershed boundaries, stream classification, landform, county boundaries, hydrography, and U.S. Census Bureau Topologically Integrated Geographic Encoding Referencing System (TIGER) data.

The Upper Bad River-River Basin Study determined relative percentages of sheet and rill, channel, streambank, and gully 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), the Direct Volume Method, and direct measurements were the methods used to determine gross erosion. Erosion rates were assigned to the types of channels in the inventoried watersheds and expanded to the whole Bad River Watershed. Gross erosion rates from the different sources within the study area were multiplied by an estimated sediment delivery ratio to calculate sediment loading.

Estimates of sediment transport are based on research data, historical records, gauging station measurements, and when appropriate, professional experience and judgment. This study utilized a descriptive research approach to generate survey data about several hydrologic parameters in the sampled subwatersheds through the use of inductive reasoning (specific to general).

Figure 1 - Representative Watersheds



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

1. The upper Bad River Watershed is relatively stable, and the overall condition of the upper watershed is good. The major source (63 percent) of sediment delivered to Lake Sharpe from the upper Bad River is due to geologic erosion. Channels are relatively stable and do not have major reaches with active bank erosion. There were no areas identified in the upper Bad River Basin where active channel or bank erosion is dominant, but there are instances where channel and bank erosion occur. In those areas where channel and bank erosion do occur, a landowner could use conventional or bio engineering or agronomic management practices to control this erosion and protect the resource.

2. Sheet and rill erosion on cropland is the second largest source of sediment delivered to Lake Sharpe (15 percent of total) from the upper Bad River. This is partly due to the fact

that 36 percent of the watershed is in cropland. Management practices that increase infiltration on cropland would not only reduce sheet and rill erosion, but would also have an indirect effect on reducing channel erosion by reducing runoff.

3. Sheet and rill erosion on rangeland in the upper Bad River Watershed is the third largest source of sediment delivered to Lake Sharpe (14 percent of total). Overall, rangeland in the watershed is in good to excellent condition with approximately 12 percent in fair to poor condition. Improving the condition of rangeland through management to increase taller grass species would have a positive impact on reducing runoff in the areas of poor, fair, and low good range condition classes.

4. The channels in the lower Bad River Watershed area were identified in a previous river basin study (Lower Bad River-River Basin Study, March 1994) as the major source of sediment. The high sediment yield is a result of the subwatersheds of the lower Bad River basin area being in an active downcutting phase. In the active downcutting phase, changes occur rapidly, and the downcutting channels are very unstable and susceptible to erosion (Rosgen F and G type channels). This is evident from the number of F and G type channels in the lower Bad River. The F and G type channels in this area contribute nearly 1.5 million tons of sediment yearly into Lake Sharpe. Practices which reduce the volume of runoff entering channels in the lower Bad River subwatersheds would make the biggest impact on sediment delivered to Lake Sharpe. Conservation practices that are installed to stop the advancement of the gullies would help stabilize the F and G channels and reduce the sediment load further.

5. The Badlands landform in the upper portion of the watershed comprises 10 percent of the upper Bad River Watershed area. This landform accounts for 11 percent of the total average annual sediment delivered from the Bad River Basin. These figures correlate with previous results of laboratory analyses of Lake Sharpe sediment. These sediment samples indicate the Badlands are not a major source of the sediment delivered to Lake Sharpe. Although the gross erosion rate in the Badlands landform is quite high, a large portion of this sediment is redeposited in the upper reaches of the watershed, and is not transported to Lake Sharpe.

PREFACE

Introduction

The present-day Missouri River took shape as the last ice sheets retreated from the continent about 14,000 years ago. The gradient of the Bad River adjusted to the new base level established by the Missouri River. The Bad River probably underwent periods of instability as climate changes occurred over the past 14,000 years. The Missouri River bottom rose and fell as sediment filled the valley during cool and moist periods and as sediment was removed from the valley by channel incision during hot and dry periods. Historical weather records only go back to the early 1800's in the Great Plains, but vegetation patterns indicate that the present-day climate is probably representative of the climate for a number of decades prior to the 1800's. It appears that the Bad River is not responding to any historical climatic disturbance. Present instabilities in the bed and banks of the Bad River and its tributaries appear to be due to historical land use management.

According to oral history accounts, early settlers in the watershed in the 1850's encountered little difficulty in traveling cross-country with wagons and horses. Streams draining the middle and upper reaches of watersheds were easily crossed. As more and more land was settled, livestock numbers increased exponentially from 1850 to 1890. The "white winter" of 1889-1890 almost wiped out the livestock industry on the plains. Even though the numbers of livestock are much reduced from those historical levels, livestock production remains the principal industry within the Bad River Watershed today.

Some adverse impacts of the great numbers of livestock in the watershed include reductions in the percent of ground cover and woody vegetation, native species of grasses being replaced with introduced species, and soil depth decreases due to sheet and rill erosion. These factors combined to change the runoff patterns in the Bad River Watershed. It appears that high runoff years following dry periods initiated downcutting in the Bad River. This process probably began sometime after 1890 and prior to the well-documented drought of the early 1930's. Today, streams in the middle and upper reaches of watersheds close to the mouth of the Bad River are still downcutting and widening in response to the historical downcutting in the Bad River.

Suspended sediment and runoff records for the Bad River begin in 1948 (U.S. Army Corps of Engineers, 1991). A major increase in suspended sediment was recorded during the flood years of 1952 and 1953. It appears that as streams higher in the watersheds and farther from the mouth of the watershed are eroding, not as much sediment reaches the mouth of the river as when the Bad River and its tributaries were first being incised. The flood of 1986 appears to corroborate this hypothesis. Even though the amount of runoff appears to be similar to that of the 1952-1953 floods, much less sediment discharge occurred.

Even though the sediment production from channel erosion may be decreasing as the channels evolve into more stable forms, high sediment loads are still occurring at the mouth of the Bad River. The high sediment loads will continue to occur for many more decades as these streams downcut and widen in an attempt to attain a state of dynamic equilibrium.

The Upper Bad River-River Basin Study is the result of a United States Department of Agriculture (USDA) cooperative study requested by the Badlands Resource Conservation and Development (BRCD) Area Council, Inc., and the local conservation districts in cooperation with the South Dakota Department of Environment and Natural Resources (DENR). The study authorization was received in September 1993. A plan of work (POW) was developed and served as the official document of agreement between the study participants. It provided a work outline and detailed items to be completed.

The purpose of the Upper Bad River-River Basin Study was to quantify and identify the source of sediment in the upper portion of the drainage area and integrate these findings with those of the Lower Bad River-River Basin Study. In this study, land treatment recommendations will focus on the upper Bad River, but recommendations will also be made for the entire Bad River Watershed. Other studies that have been completed or are in progress are listed in Table 1.

Table 1 - Existing Studies in the Bad River Watershed

STUDY	COMPLETION DATE	ACTIVITIES/CONCLUSION
Phase I and IB	1990	Badlands soils are not a major sediment source. Cropland is not a major sediment source. The lower one-third of the Bad River drainage area is the major source of sediment.
Lower Bad River- River Basin Study	March 1994	72 percent of sediment is from the lower third of the drainage area. Gully and channel erosion are the primary sources.
Phase II	September 1995	Identified cost-effective land treatment practices.
Phase III	September 1999	Initiated best management practices (BMP) implementation in the lower basin.
Demonstration Project	February 2000	Developed project and local ownership in the upper basin.
319 Monitoring	2008	Sediment will be monitored for paired watersheds.

Authority

Cooperative river basin studies are conducted through the authority of Section 6 of Public Law 83-566, the Watershed Protection and Flood Prevention Act, as amended. 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 to assist them in developing implementation strategies to solve problems and resolve conflicts.

PROJECT PARTICIPANTS

United States Department of Agriculture

The Natural Resources Conservation Service (NRCS) and the U.S. Forest Service (USFS), two agencies of USDA, participated in the river basin study under the terms of the Memorandum of Understanding (MOU) dated February 2, 1956, and revised April 15, 1968.

Natural Resources Conservation Service
NRCS 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. NRCS is responsible for developing the final report for the study.

U.S. Forest Service
The USFS is responsible for the aspects of planning related to federal grasslands and forested lands. The USFS funded a hydrologist through a cooperative agreement with the South Dakota Department of Environment and Natural Resources (DENR). The hydrologist reviewed United States Geological Survey (USGS) stream flow data for six gauged watersheds in the vicinity of the Bad River. The hydrologist also analyzed the storm events using Technical Release 20 (TR-20-Hydrology) software.

State of South Dakota

South Dakota Department of Environment and Natural
The DENR has the responsibility for protecting, assessing, and reporting the quality of surface and ground water resources in the state. DENR has also 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 Upper Bad River-River Basin Study by providing funding and technical assistance in all phases of the Bad River water quality studies.

South Dakota Department of Agriculture, Division of Resource Conservation and Forestry
The South Dakota Department of Agriculture, Division of Resource Conservation and Forestry (DRCF), has the responsibility for protecting the soil and water resources in the state. As a part of that responsibility, the DRCF cooperates with and provides assistance to federal, state, and local agencies for the purpose of achieving mutual objectives.

Sponsoring and Cooperating Agency Participation

A task force composed of landowners, city and county elected officials, sportsmen groups, and state and federal agencies was formed to coordinate all watershed efforts and provide local input. The task force approved a vision statement on February 6, 1996. The vision statement reads, "To promote voluntary and cost-effective land treatment in the Bad River Watershed which will result in reduction of sediment delivery into the Missouri River while sustaining the natural resources, agricultural and business economy, and landowner rights." Alternatives for the development of water and related land resource treatment were developed by the task force using this vision statement.

The Bad River Task Force includes:

- Badlands Resource Conservation and Development Area Council, Inc. (BRCD)
- North Central Resource Conservation and Development Association, Inc. (NCRC&D)
- City of Fort Pierre
- City of Kadoka
- City of Midland
- City of Murdo
- City of Philip
- City of Pierre
- City of Wall
- Pierre Chamber of Commerce
- American Creek Conservation District
- East Pennington Conservation District
- Haakon County Conservation District
- Jackson County Conservation District
- Jones County Conservation District
- Stanley County Conservation District
- South Dakota Department of Agriculture,
  Division of Resource Conservation & Forestry (DRCF)
- South Dakota Department of Environment and Natural Resources (DENR)
- South Dakota Department of Game, Fish and Parks (GF&P)
- South Dakota Great Lakes Association
- South Dakota State University (SDSU)
- USDA Cooperative Extension Service (CES)
- USDA Farm Service Agency (FSA)
- USDA Natural Resources Conservation Service (NRCS)
- U.S. Army Corps of Engineers (COE)
- U.S. Environmental Protection Agency (EPA)
- U.S. Fish and Wildlife Service (F&WS)
- U.S. Forest Service (USFS)
- U.S. Geological Survey (USGS)

Study Objectives

A river basin study provides a basis for the sustained use and management of water and related land resources. The study evaluated several alternatives that will make the best use of the resources to reduce sediment loads reaching Lake Sharpe and make the greatest long-term contribution to the economic growth and well-being of the people residing within the basin and the rest of the Nation.

The main objectives of the study were: (1) to identify and quantify areas in the upper Bad River Watershed that are contributing to sediment and water quality problems in Lake Sharpe; (2) to utilize a channel classification system to identify and quantify stable and unstable channel conditions for the entire watershed and develop sediment yields for these channels; (3) to develop alternatives which will assist sponsors in setting priorities for implementation of agricultural nonpoint pollution management activities. The task force vision statement guided the sponsors in selecting alternatives and setting priorities for the implementation of nonpoint management activities.

PROBLEMS AND CONCERNS

The large annual sediment load from the Bad River has adversely affected the water quality in a 30 mile stretch of Lake Sharpe from the mouth of the Bad River to the DeGrey area. The sediment has constricted the main channel causing a rise in water levels. This has created high water problems in the southeast area of Pierre and in the City of Fort Pierre, resulting in adverse economic impacts. Continued high water problems have impacted a large number of homes and have forced the Corps of Engineers into a buyout program. To prevent this flooding, flow rates from the Oahe Dam are reduced. Reduced flow rates affect power generation and cause more negative economic impacts.

The turbidity caused by the Bad River sediment has a negative impact on sport fishing, recreation, and tourism in the area. The South Dakota Department of Game, Fish and Parks stated that, "When the Bad River is discharging its normal spring silt loads, sport fishing and boating recreation decreased to near zero man-days of use." (Appendix A)

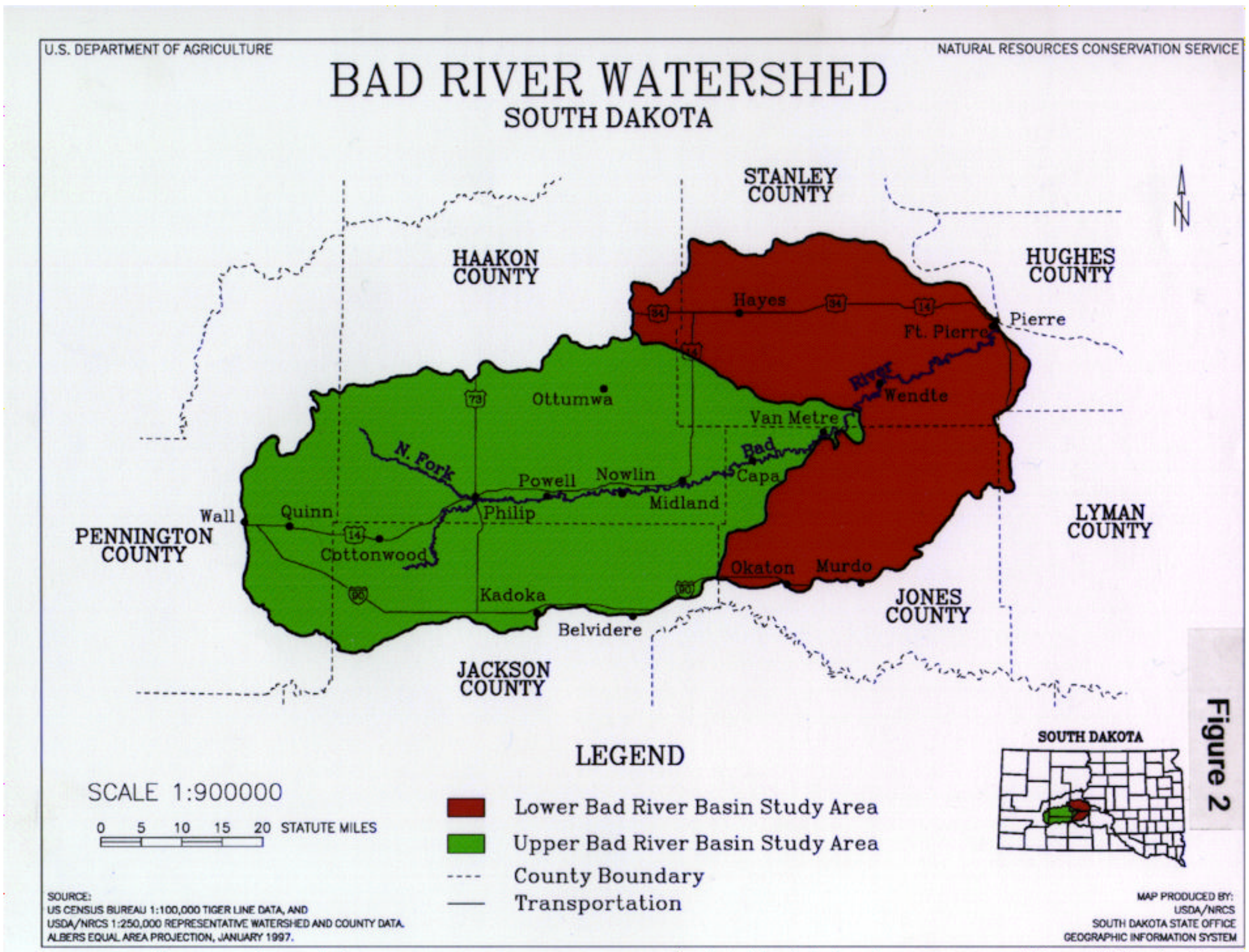
PHYSICAL DESCRIPTION OF THE UPPER BAD RIVER BASIN

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 Badlands near Wall, South Dakota, and flows to the east approximately 100 miles, where it discharges into Lake Sharpe near the communities of Fort Pierre and Pierre. The basin drains 3,173 square miles of Haakon, Jackson, Jones, Lyman, Pennington, and Stanley Counties (Figure 2). The Upper Bad River-River Basin Study encompasses the area above Van Metre, South Dakota, which drains an area of 1,936 square miles. The study area is located in the First Congressional District and makes up hydrologic unit (HU) number 10140102.

The South Dakota Water Quality Standards list the beneficial use classifications for the Bad River as warm water marginal fish life propagation, limited contact recreation, wildlife propagation, livestock watering, and irrigation.

Figure 2 - Bad River Watershed



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. Less frequent periods of short duration can yield higher than normal amounts of precipitation.

Climatological data for the area has been recorded since the late 1880's. The average annual precipitation for this region varies from 16 inches in the western half of the study area to 18 inches in the eastern 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 generally occurs as a result of brief, intense thunderstorms. Annual runoff varies widely from year to year. The average annual runoff ranges from about 0.5 to 0.7 inches. The Bad River, and most of its tributaries, will experience periods of no flow most years 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 degrees Fahrenheit 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 3,020 feet above mean sea level to 1,420 feet at the mouth of the Bad River.

The Cretaceous Pierre Shale Formation, primarily a clay 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 clay soils exposed along most of the primary and secondary streams in the study area. Soils formed from this formation typically have clay content exceeding 50 percent (textural Class III) of the mineral fraction of the soil. Some younger, lighter-colored silt, sand, and clay soils overlie this shale in the uplands area. These deposits are less consolidated and generally more erodible than the Pierre Shale.

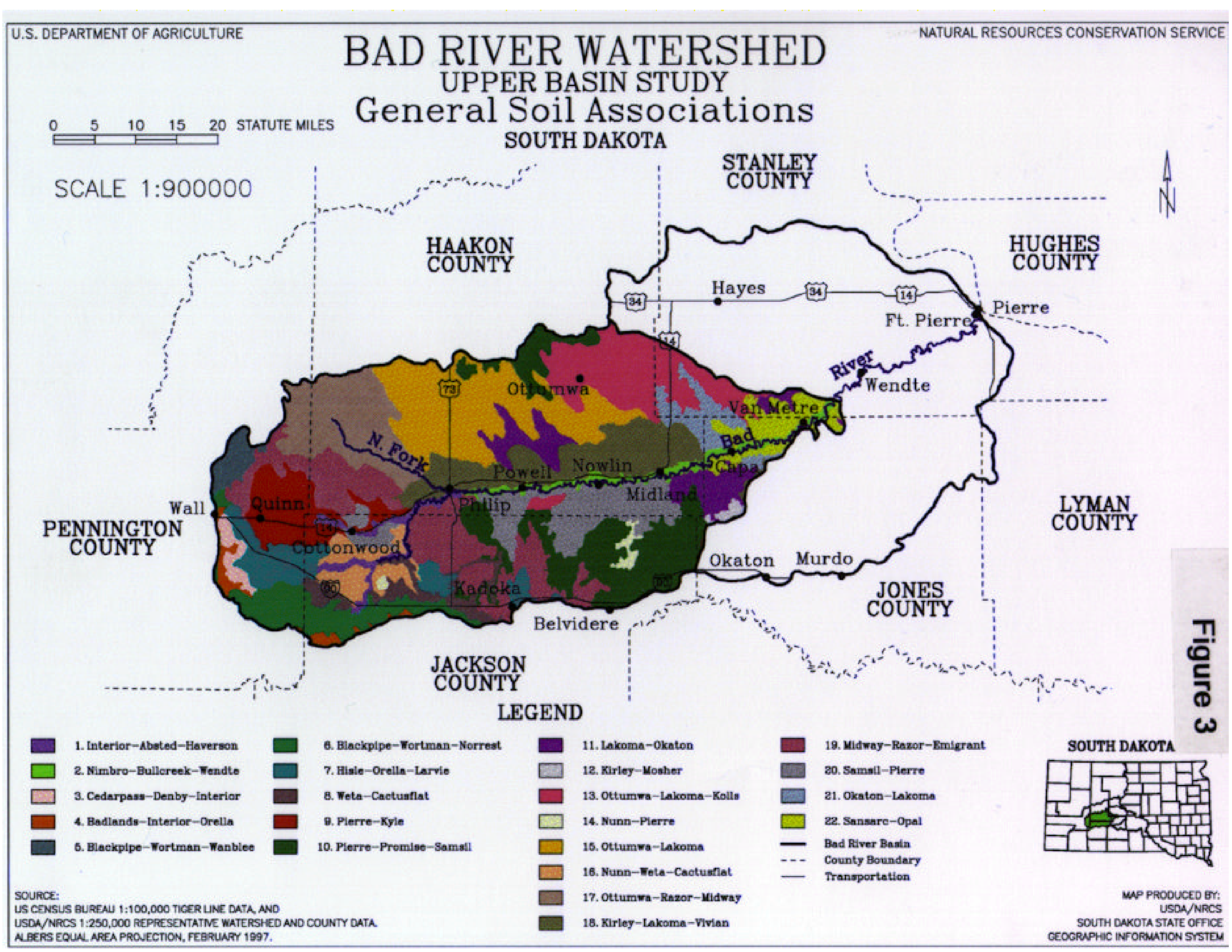
Geologic features of the Bad River Watershed have a major influence on the hydrology of the watershed. Relatively impermeable shale bedrock is near the surface on steeply sloping upland soils. Shrink-swell potentials are high due to the montmorillonite clay. The soils are highly susceptible to compaction when wet. Drainageways in the watershed are typically dense clay ecological (range) sites that support a near monoculture of western wheatgrass with no understory of shortgrasses, sedges, and forbs. With drought and/or heavy grazing pressure, these sites become nearly bare of vegetative cover and extremely susceptible to erosion.

Given the natural geology of the watershed, the greatest opportunity to positively influence hydrology in the watershed is through vegetation management (Appendix C).

General Soils

Soils of the study area have been placed into 15 broad groups called soil associations and are described on the General Soils Map (Figure 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 for the 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.

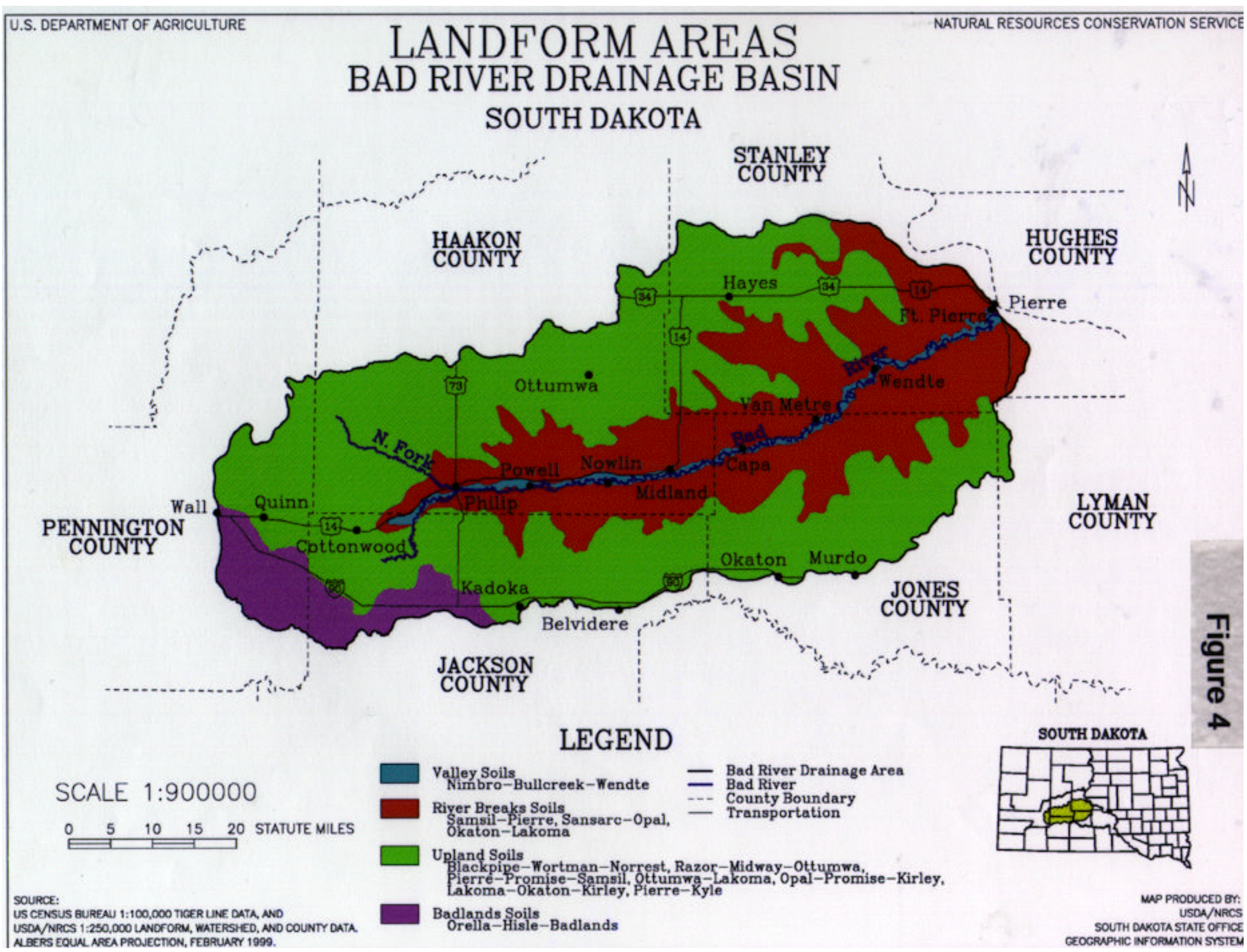
Figure 3 - General Soils Map



Landform Areas

The shape of the natural landscape has been extensively influenced by long-term erosive processes. The Upper Bad River-River Basin Study area can be defined by four general landform areas: uplands, river breaks, Badlands, and valley (Figure 4). 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 four areas, four criteria have been used: land use, soils, slope, and elevation. Figure 4 identifies the location of these landform areas within the Upper Bad River-River Basin Study area.

Figure 4 - Landform Areas



Uplands

The uplands area makes up about 53 percent (657,146 acres) of the Upper Bad River-River Basin Study area. This landform unit occupies the highest elevation in the study area, generally above 2,000 feet. This area is nearly level to moderately sloping (0 to 15 percent). The major soil associations of this area are Pierre-Promise-Samsil and the Lakoma-Okaton-Kirley associations.

Land use is approximately 36 percent cropland and 63 percent rangeland. Much of the cropland was converted from rangeland within the last 20 years.

River Breaks

The river breaks area is steep to excessively steep (16 to 45 percent) fragile rangeland positioned below the uplands and above the Bad River valley floor. Soil associations in this area are the Sansarc-Pierre and the Sansarc-Opal. 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 area includes 32 percent (399,374 acres) of the study area.

Badlands

The Badlands area is at the upper end of the Bad River drainage area. The slopes vary from gently rolling to vertical, and the elevation differences can vary as much as 250 feet. Much of the acreage supports native grasses but large areas exist that support no vegetation. The underlying material is light gray and white, calcareous, stratified silt loam, loam, and silty clay loam. The Badlands area covers 122,000 acres and makes up 10 percent of the upper Bad River Watershed.

Valley

The valley area includes 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 soil association is Nimbro-Bullcreek-Wendte in this area. Land use is predominantly livestock grazing with some hay and forage crop production. The Bad River valley area covers 60,200 acres or 5 percent of the study area.

Land Use

Livestock grazing is the dominant land use, utilizing 778,574 acres. The remaining area consists of cropland, water and other uses. Winter wheat is the major crop. The majority of cropland is located in the uplands. Ranches in the river breaks and valley consist of native rangeland and hayland. The average operating unit in the Upper Bad River-River Basin Study area consists of 1,600 acres of cropland and 2,400 acres of rangeland or hayland. Farm and ranch size varies considerably ranging from approximately 3,000 to 35,000 acres. Land use trends indicate an increase in cropland since 1970. A summary of land use in the upper Bad River study area is shown in Table 2.

Table 2 - Land Use

Land Use	Acres	Percentage
Rangeland/Hayland	778,574	62.9
Cropland/Conservation	452,046	36.5
Reserve Program Water (less than 40 acres surface area)	6,000	.5
Other*	2,100	.1
TOTAL	**1,238,720**	**100.0**

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

Land Ownership

In the study area, the majority of the land is privately owned and operated. Federally owned land consists of 149,000 acres of the Buffalo Gap National Grassland managed by the United States Forest Service (USFS), 3,600 acres managed by the Bureau of Land Management (BLM), and 14,090 acres in the Badlands National Park. State land, excluding state and county highway or railroad right-of-ways, is managed by the South Dakota Department of School and Public Lands or the South Dakota Department of Game, Fish and Parks. The USFS, BLM, and South Dakota Department School and Public Lands lease rangeland to private individuals in the area. Land ownership by acreage and percent is identified in Table 3.

Table 3 - Land Ownership

Owner	Acres	Percentage
UPPER BAD RIVER WATERSHED		
Private		
Federal	1,064,930	86.0
State*	166,690	13.5
	7,100	.5
TOTAL	**1,238,720**	**100.0**

*Excluding state and county highway or railroad right-of-ways

Population

Population figures from the 1990 U.S. Census Bureau indicate that the entire watershed area population is 6,500. Approximately 3,800 people, or 58 percent, reside in the Upper Bad River-River Basin Study area.

Economic Profile

Economic characteristics for the upper Bad River study are represented by Haakon, Jackson, Jones, Pennington, and Stanley Counties. Table 4 displays the economic analysis of the Bad River Watershed, the Upper Bad River-River Basin Study area, South Dakota, and the Nation (USA).

Employment in the upper Bad River Watershed is highly seasonal. In January 1996, 172 residents were registered as unemployed while in August of the same year, only 102 residents were unemployed. The work force for this same time frame rose from 3,406 in January to 3,741 in August. As a result, many of the youth leave the area to find permanent higher paying jobs.
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. These two enterprises directly employ 27 percent of the total work force and provide the support and enhancement of social and economic productivity for a major portion of the rest of the population in the watershed.

Table 4 - Economic Information

BAD RIVER WATERSHED ECONOMIC INFORMATION	UPPER BAD RIVER WATERSHED	BAD RIVER WATERSHED	SOUTH DAKOTA	USA
Per Capita Income [1]	$16,274	$16,740	$15,890	$18,696
Percent of US Average	87%	90%	85%	
Percent of SD Average	102%	105%		118%
Unemployment Rate [2]	2.9%	2.7%	2.8%	5.1%
Median Home Value [3]	$38,609	$40,740	$45,200	$79,100
Average Size of Farm/Ranch [4] (acres)	3,593	3,622	1,316	461
Value of Land and Buildings [5]				
Average per Farm	$619,064	$630,218	$360,111	$380,159
Percent of SD Average	172%	175%	100%	106%
Average per Acre	$171	$168	$274	$548
Average Market Value				
Agricultural Products Sold [6]	$89,878	$90,293	$95,239	NA
Cropland Value per Acre [7]	$221	$243	$456	NA
Pasture Value per Acre [8]	$114	$118	$256	NA

1. April 1992, Survey of Current Business, Bureau of Economic Analysis, U.S. Department of Commerce.
2. September 1996 South Dakota Labor Bulletin, South Dakota Department of Labor.
3. 1990 US census data furnished by the Census Data Center, Department of Rural Sociology, South Dakota State University.
4. 1992 Census of Agriculture, Part 41, South Dakota, State and County Data.
5. ibid.
6. ibid.
7. March 1996, South Dakota 1996 County Level Land Rents and Values, South Dakota Agricultural Statistics Service.
8. ibid.

Table 5 shows employment by industry for the upper Bad River Watershed as compared to South Dakota employment.

Table 5 - 1990 Employment by Industry

	UPPER BAD RIVER WATERSHED		SOUTH DAKOTA	
INDUSTRY	**EMPLOYED**	**PERCENT**	**EMPLOYED**	**PERCENT**
Farm	437	30%	41,876	10%
Agriculture/Forest/Fish	39	3%	4,097	1%
Mining	0	0%	2,998	1%
Construction	42	3%	18,335	5%
Manufacturing	110	7%	36,092	9%
Transportation	51	3%	17,052	4%
Wholesale	92	6%	20,062	5%
Retail	218	15%	71,578	17%
Finance/Insurance	57	4%	27,724	7%
Services	212	14%	97,014	24%
Government	221	15%	70,302	17%
TOTAL EMPLOYMENT	1,480	100%	407,130	100%

EXISTING RESOURCE CONDITIONS

WATER

Ground Water

The Bad River Watershed is characterized by poor quality ground water. Shallow aquifers are confined to low areas along the Bad River and its tributaries and perched water tables below stock dams or wetland areas. Shallow wells generally do not provide adequate amounts of water. Water quality is poor, a result of the influence of the soluble salts in the Pierre Shale.

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 Upper 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 milligrams per liter. An average hardness of 1,400 milligrams per liter is caused by high concentrations of dissolved calcium, magnesium, and sulfate. Excessive concentrations of manganese and iron (greater than 0.3 milligrams per liter) are 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).

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 is under construction. Development of this water system will ensure a dependable supply of high quality water in the Bad River study area. An adequate supply of livestock water is essential for producers to develop range management systems.

Surface Water

Surface water is all water whose surface is exposed to the atmosphere. The surface water resources of the upper Bad River Watershed are the natural stream flows and the water stored in dugouts, stock dams, or natural wetlands. A characteristic of the watershed is a general lack of surface water at least in the natural state.

Bad River and Tributaries

Low annual precipitation rates produce limited runoff, which means most of the streams are dry for a substantial portion of the year. Historically, the Bad River has had periods of no flow in the reach from Midland to the Missouri River. The upper portion of the Bad River receives water from several artesian wells in the Philip area, so water is present most of the year. Seasonal flow frequency at Midland and Fort Pierre typically has an initial peak at the end of March or early April from snowmelt and a second peak in mid-June representing rainfall runoff. A rapid decrease in runoff results in almost no flow by mid-August (South Dakota Water Plan, Resource Inventory of the Bad River Basin, 1975). There are an estimated 45 miles of main channel and 5,392 miles of tributary channel in the upper Bad River Watershed.

Wetlands

Approximately 0.5 percent of the total study area is surface water consisting of small ponds with 40 acres or less of surface area. There are an estimated 3,200 acres of wetlands and 1,600 acres of stock dams (artificial wetlands) in the Bad River basin (Table 6). The stock dams have a limited life span because of sedimentation and are highly dependent on annual precipitation and runoff.

Table 6 - Acres of Hydric Soils and Water/Stock Dams for Identified Subwatersheds

Watershed	Wetland *	Surface
Mexican Creek	188	107
Big Buffalo Creek	25	400
Indian Creek	240	655
Ash Creek	8	61
Herd Camp Creek	1,831	196
Burnt Creek	1,001	206
Total	**3,293**	**1,625**

*Derived from GIS 1:24,000 digitized soils and watershed information

WATER QUALITY

Bad River

The assigned beneficial uses of the Bad River are warm water marginal fish life propagation, limited contact recreation, wildlife propagation and stock watering, and irrigation (SD 74:03:04:05). Wildlife propagation and stock watering means the stream is satisfactory habitat for aquatic and semiaquatic wild animals and fowl, provides natural food chain maintenance, and is of suitable water quality for watering domestic and wild animals. Total dissolved solids (TDS) cannot exceed 2,500 milligrams per liter, and conductivity cannot exceed 4,000 micromhos/per centimeter at 25 degrees Celsius. Warm water marginal fish life propagation standards stipulate that suspended solids may not exceed 150 milligrams per liter in the Bad River.

The Bad River does not support its beneficial uses due to suspended solids concentration (SD DENR, 1994). Suspended solids are any suspended substance present in water in an undissolved state, usually contributing directly to turbidity. Suspended sediment, the very fine particles remaining in water for a considerable amount of time, are a component of suspended solids data. Suspended sediment concentration (milligrams per liter) for the lower Bad River has been recorded daily since 1971 by the United States Geological Survey in cooperation with the State of South Dakota at a gauging station. The station is located 4.3 miles downstream of Willow Creek and 6 miles upstream from the mouth of the Bad River. From 1990 through 1995, suspended sediment concentration in the lower Bad River exceeded the standard of 150 milligrams per liter from 62 days in 1991 to 225 days in 1995 (Table 7). Total suspended solids (TSS) concentrations exceed the established limit of 150 milligrams per liter during high river flows. During minimal flows, elevated fecal coliform concentration was a problem as identified in the South Dakota DENR 1994 Report to Congress for 305(b) Water Quality Assessment.

Table 7 - Number of days on the Bad River above Fort Pierre with sediment concentration greater than 150 milligrams per liter

	Water Year					
	95	**94**	**93**	**92**	**91**	**90**
Oct.	11	0	0	0	0	1
Nov.	2	4	0	0	0	3
Dec	30	12	0	0	0	5
Jan.	13	18	0	2	0	13
Feb.	28	28	13	19	0	9
Mar.	30	31	29	17	0	21
Apr.	30	3	30	0	8	6
May	31	16	19	0	21	20
June	30	18	29	14	24	18
July	19	23	31	31	9	12
Aug.	1	0	12	11	0	6
Sept.	0	0	2	4	0	0
Total	**225**	**153**	**165**	**98**	**62**	**114**

Suspended sediment concentration in the upper Bad River has been recorded daily in the south fork of the Bad River near Cottonwood since 1990. Suspended sediment concentration exceeded the standard annually, from 134 days in 1993 to 99 days in 1995 (Table 8).

Table 8 - Number of days by month where suspended sediment concentration exceeds 150 milligrams per liter in the south fork of the Bad River near Cottonwood, South Dakota

	Water Year					
	95	94	93	92	91	90
Oct.	19	22	0	10	0	7
Nov.	10	0	0	17	0	0
Dec.	1	0	0	0	0	0
Jan.	1	0	0	0	0	15
Feb.	4	17	0	5	3	5
Mar.	15	15	19	17	19	31
Apr.	2	22	20	0	18	1
May	6	28	16	8	30	20
June	10	25	18	25	21	27
July	13	0	30	31	9	9
Aug.	13	0	18	4	11	11
Sept.	5	0	13	3	13	6
Total	99	129	134	120	124	132

Lake Sharpe
The assigned beneficial uses of the Lake Sharpe portion of the Missouri River are domestic water supply, cold water permanent fish life propagation, immersion recreation, limited contact recreation, commerce and industry, irrigation, wildlife propagation, and livestock watering. Total dissolved solids may not exceed 1,000 milligrams per liter for domestic water supply or 2,000 milligrams per liter for commerce and industry. For cold water permanent fish life propagation, suspended solids must be less than 30 milligrams per liter in Lake Sharpe.

FISHERIES

Bad River
A total of 21 species of fish were identified in seine collections in 1996 at 20 stations in the Bad River from the mouth to the south fork (C. Milewski, South Dakota State University, Department of Wildlife and Fisheries, personal communication). Black bullhead, common carp, fathead minnow, green sunfish, plains minnow, red shiner, sand shiner, and white sucker were collected throughout the river. Channel catfish, flathead chub, and river carpsucker were collected in the mainstem but not in the south fork. Emerald shiner and orange-spotted sunfish were collected in the upper part of the watershed, while shorthead redhorse and yellow perch were found below Indian Creek. Goldeye were taken in the reach between Mexican and Burnt Creeks. Several other species collected in the upper Bad River were thought to have originated from farm pond overflow and included bluegill, golden shiner, hybrid sunfish, northern pike, and yellow perch.

Lake Sharpe
A total of 29 species of fish have been collected in gill nets and 14 species have been collected in seine collections in Lake Sharpe between 1990 and 1993 by the South Dakota Department of Game, Fish and Parks (GF&P). Bluegill, channel catfish, common carp, freshwater drum, gizzard shad, goldeye, largemouth bass, river carpsucker, smallmouth bass, spot-tail shiner, walleye, white bass, white crappie, white sucker, and yellow perch were collected with both methods. Bluntnose minnow, common shiner, creek chub, emerald shiner, fathead minnow, golden shiner, Johnny darter, and orange-spotted sunfish were collected only in seine collections. Bigmouth buffalo, black bullhead, blue sucker, flathead catfish, muskellunge, northern pike, rainbow smelt, rainbow trout, sauger, shorthead redhorse, shortnose gar, shovelnose sturgeon, smallmouth buffalo, and tiger muskie were collected only in gill nets. This survey is conducted to provide biological information (species composition, relative abundance, age, growth, condition, recruitment, survival and mortality rates, and population size structure) relative to management activities (regulations, stocking, sport fish harvest). Poor growth and recruitment of walleye were seen in both 1992 and 1993 compared to other years (SDGF&P, Annual Reservoir Fisheries Report, 1993).

Turbidity alone may not have a major effect on fish, with levels above 100,000 milligrams per liter being tolerated for short periods. Sustained high turbidity can reduce algal photosynthesis, reduce success of sight feeding fish, and possibly alter the food chain (Binkley and Brown, 1993). High sediment loads reduce porosity of gravel and promote anaerobic conditions unsuitable for spawning.

The accumulation of fine sediments can limit the benthic primary and secondary productivity (Cooper, 1993). Bedload sediments can abrade, bury, and/or dislocate benthic invertebrates as well as alter fish reproduction by suffocation, burial, and abrasion of eggs. Suspended sediments can reduce the amount of light available to aquatic plants, clog fish gills, and even smother fish spawning beds. The long-term effect of chronic suspended sediment is altered species composition.

Wildlife Habitat

In the upper Bad River Watershed, native vegetation is predominantly mixed grass prairie dominated by mid and short grasses and forbs with some tall grasses interspersed. Native grasses include western wheatgrass, green needlegrass, blue grama, sideoats grama, threadleaf sedge, little bluestem, and big bluestem. Common native forbs are American vetch, scarlet globemallow, black samson, scurfpeas, wild onion, and wild parsley.

It is important to remember that not all landscape is at its potential in terms of natural wildlife habitat, and that kinds and numbers of wildlife species using an area will be determined by current land use and land use management. The most conspicuous herbivores are the black-tailed prairie dog, mule deer, white-tailed deer, pronghorn antelope, white-tailed jackrabbit, eastern cottontail, and American bison in the Badlands National Park. Common carnivores include coyote, bobcat, red fox, badger, raccoon, and striped skunk. A small population of swift fox exists in the Badlands National Park. A highly diverse passerine and raptor avifauna is seasonally abundant. Primary raptors are the red-tailed hawk, ferruginous hawk, northern harrier, Swainson's hawk, American kestrel, prairie falcon, and golden eagle. Bald eagles can be seen in the spring and fall throughout the Bad River Watershed. Several species of owls can be found, primarily the great horned, long-eared, short-eared, and burrowing owl. Turkey vultures are also common in the region.

Three basic types of terrestrial wildlife habitat are present: openlands/grasslands, woodlands, and wetlands. Openland includes cropland, pastureland, rangeland, and Conservation Reserve Program (CRP) which produce grain, seed crops, grasses, legumes, and native herbaceous plants for food as well as cover. Woodlands have hardwoods, shrubs, grasses, legumes, and native herbaceous plants. The majority of habitat is rangeland/hayland (63 percent or 778,574 acres) and cropland (36 percent or 452,046 acres). Wetlands represent less than 0.5 percent of the project area.

Historically, woody species were common in many draws and the valley floor of major drainages. The creeks that empty into the upper Bad River generally drain areas high in clay content. Wendte clay, which is channeled, is the main soil along the drainageways. The main tree and shrub species in the lower riparian zone of tributary creeks of the upper Bad River are green ash, box elder, cottonwood, peachleaf willow, chokecherry, American plum, buffaloberry, skunkbush sumac, and wild rose.

American elm, American plum, bur oak, common chokecherry, common hackberry, false indigo, green ash, peachleaf willow, plains cottonwood, poison ivy, riverbank grape, sandbar willow, skunkbush sumac, Virginia creeper, western snowberry, and several species of wild rose are common in the Inavale, Munjor, Nimbro, and Wendte soils adjacent to the Bad River channel.

Native wildlife species include white-tailed deer, mule deer, pronghorn antelope, elk, bison, black-tailed prairie dogs, black-footed ferret, sharptail grouse, greater sage grouse, and prairie chicken.

Hunting and habitat loss have eliminated bison, elk, and black-footed ferrets from the Bad River Watershed.

Introduced wildlife species such as ring-necked pheasant, gray partridge, and wild turkey are also present, which may compete with native grassland species.

Threatened and Endangered Species

In an August 18, 1993, letter, the U.S. Fish and Wildlife Service provided a list of federally listed endangered (FE) and threatened (FT), as well as candidate species for listing in the lower Bad River project area. In a July 25, 1994, letter, the U.S. Fish and Wildlife Service responded to requests for information on the upper Bad River drainage. Funding limitations precluded their review of the proposed action as well as providing informal comments. Nell McPhillips, USFWS, (personal communication) felt that since there was no major earth moving activity planned, there would be no impact on the American burying beetle. A survey for the federally endangered American burying beetle was conducted during August 1996 along an eighty-mile transect adjacent to the Bad River from Fort Pierre to Philip, South Dakota. No specimens of the endangered species were collected (Gary M. Marrone, 1996).

The list provided for the Lower Bad River-River Basin Study will be considered valid unless notified otherwise. Recent changes, including downlisting of the bald eagle from endangered to threatened, as well as the elimination of Category 2 species, alters the list from the earlier study. State endangered (SE) and state threatened (ST) species are provided by the South Dakota Department of Game, Fish and Parks.

Name	**Status**
Bald eagle *Haliaeetus leucocephalus*	FT, SE
Whooping crane *(Grus americana)*	FE, SE
Peregrine falcon *(Falco peregrinus)*	FE, SE
Piping plover *(Charadrius melodus)*	FT, ST
Interior least tern *(Sterna antillarum)*	FE, SE
Black-footed ferret *(Mustela nigripes)*	FE, SE
American burying beetle *(Nicrophorus americanus)*	FE
Pallid sturgeon *(Scaphirhynchus albus)*	FE, SE

In the fall of 1994, black-footed ferrets were reintroduced into the Badlands National Park. The reintroduced black-footed ferrets and their progeny are classified as a non-essential experimental population which alleviates concerns of private landowners, Indian tribes, and other land managers by providing the flexibility to relocate black-footed ferrets. The experimental population area also acts as a buffer zone to help keep reintroduced black-footed ferrets from migrating beyond the boundaries of the experimental population area where they will be considered endangered. Should a black-footed ferret occur outside the experimental population area and the landowner request it, the animal will be relocated by designated persons. The ferrets could be captured to aid in the captive breeding program. Their capture and removal would remove the threat of land use restrictions associated with their endangered status.

Within the project area, only Haakon County has been block cleared for use of fumigants to control prairie dogs. If prairie dog control is desired for colonies of black-tailed prairie dogs that are less than 80 acres in size, a black-footed ferret survey is not required. Colonies less than the aforementioned sizes are inadequate to support a black-footed ferret population. Areas having 80 to 100 acres of black-tailed prairie dog colonies have importance for black-footed ferret recovery. Colonies of these sizes require black-footed ferret surveys. No black-footed ferrets have been sighted during recent years in the Buffalo Gap National Grassland (Bob Hodorff, USFS, personal communication).

RESOURCE INVENTORY

The processes, procedures, and results of erosion and sedimentation evaluations are presented in this section. A sediment budget summarizes total erosion and sediment yield from each type of erosion by landform unit. The sediment budget has been developed to identify and quantify the landform areas having major contributions of sediment to the Bad River.

The average annual sediment discharge at the mouth of the Bad River since 1948 to 1986, as estimated by the COE, is 3,250,000 tons. This sediment is the result of geologic erosion and accelerated wind and water erosion with water erosion making the most significant contribution of sediment to the Bad River. Channel erosion has been identified as the major sediment source in the Bad River basin (Lower Bad River-River Basin Study). This report evaluates the relationship between channel type and sediment production.

EROSION AND SEDIMENT YIELD

Channel Classification Procedure

The classification of channels within the Bad River Watershed was undertaken with the intent of providing a data base of channel conditions collected through field studies. The data base would be used as a basis to:

(1) provide an assessment of the existing evolutionary stages of incised channels within the subwatershed (geomorphic conditions),

(2) quantify the channels on the basis of stability and locate and quantify the sediment sources by subwatershed,

(3) develop a relationship between stream type and sediment yield,

(4) prioritize treatment areas, and

(5) develop alternatives for treatment based on stream type.

Two different stream classification methods (Schumm's and Rosgen's) were used on the Bad River Watershed. The Channel Evolution Model developed by Schumm (1963) is a delineation based on a subjective analysis of channel stability (stable, eroding, or deposition). The Rosgen Stream Classification System (1985) is a method to categorize stream channels based on measurable morphological features (entrenchment, width/depth ratio, sinuosity, slope, channel materials, and confinement). All of the channel reaches classified in the field study were classified using both methods. This was done primarily to evaluate each of these methods as a tool for watershed planning and evaluation of watershed health as well as studying the relationships between the two methods.

The Bad River Watershed was divided into six representative subwatershed areas based on similar landform features, soil associations, land use, management history, and subwatershed boundaries to collect the data necessary to evaluate the channel conditions in the watershed (Figure 1). Within each of these representative areas, a smaller subwatershed was selected in which to inventory field data and classify the channels. The inventoried subwatersheds were selected to be typical of the larger subwatershed area and yet be of a physical size which could be practically inventoried by the data collection team. The inventoried subwatershed acreages account for a total of 10 percent of the Bad River Watershed area.

Field data collection was carried out by NRCS personnel from the Kadoka, Philip, and Pierre Field Offices under the guidance of field support office staff members after consultation on the specific methodology with the NRCS's Midwest National Technical Center sedimentation geologist. The data was collected during the 1995 and 1996 field seasons.

USGS 7.5 minute topographic maps (1:24,000) were used to identify the channels to be classified which were the drainage patterns designated by USGS on the topographic map as intermittent streams and rivers (blue lines). The blue lines were also the basis for designating stream order and estimating sinuosity for each reach. Aerial photographs (1:20,000) were used to document the location and length of the individual channel reaches and the location of eroded banks.

The data collection team used changes in channel characteristics (geometry of channel cross-section, entrenchment, riparian vegetation, erosional features, and tributary confluence) to determine starting and ending points for each reach based on uniformity of features within the reach. Lengths of the individual reaches varied from approximately 500 feet to 4,500 feet with the typical reach length being approximately 2,000 feet.

Both stream classification methods use "bank full capacity" as a measure of that portion of the valley cross-section forming the channel to be classified. Flows above this capacity would be "overbank," or of a frequency associated with flooding. Identification of the bank full channel in the field was accomplished using curves developed to define the relationship between the drainage area and the cross-sectional area required to contain 1.5 year discharge (used as an approximation of bank full capacity). Using the cross-sectional area obtained from the curves as a guide to the approximate bank full level, field indicators (depositional features, point bars, vegetation, erosional features, and channel shape) were then used to select a field determined bank full stage. USGS Water Resources Investigation 80-80 was used to develop the drainage area versus discharge curve for the 1.5 year storm frequency. This technique used stream gauging data from numerous sites in South Dakota to develop discharge relationships with drainage area, soil infiltration parameters, and channel slope as equation variables.

The data collected for each reach included a typical cross-section, channel slope, channel bed material, approximate sinuosity, and bank erosion data (length, height, bank materials, and erosion potential). The cross-section portion of this data was used to calculate channel geometry relationships (entrenchment and width/depth ratio) necessary to classify the channel reach according to the Rosgen stream classification system.

Relationship Between Stream Types and Sediment Yield

The sediment erosion rates for the stream channels were estimated by the sediment geologist and engineers using the direct volume method as outlined in Amendment SD15 in Chapter 11 of the

South Dakota Engineering Field Manual. The soils, erosion and sediment transport characteristics for the landform areas were considered in determining the sediment yield from the different stream types (both eroding and non-eroding reaches with inventoried bank erosion) were then used to project the sediment yield attributable to channel erosion for the entire Bad River Watershed.

Rosgen Stream Classification Data

Stream Type A: entrenched confined channels, steep, cascading, step/pool morphology, low sinuosity, low width/depth ratios, high energy/debris transport, unstable in fine grained soils, very stable if bedrock or boulder dominated channel.

Stream Type B: narrow, gently sloping valleys, moderately entrenched, moderate gradient and width/depth ratio, moderate sinuosity, riffle dominated channel with infrequently spaced pools, stable banks, and stable profile.

Stream Type C: broad valleys with terraces in association with floodplains, alluvial soils, slightly entrenched with well-defined meandering channels, low gradient, moderate to high width/depth ratio and sinuosity, point-bar and riffle pool morphology.

Stream Type D: broad alluvial valleys, very wide braided channels with very high width/depth ratios, longitude and transverse depositional bars, active lateral adjustment with abundance of sediment, aggrading bed, high bedload, and bank erosion.

Stream Type E: broad valleys/meadows in association with floodplains, alluvial soils, slightly entrenched with well-defined highly sinuous, high meander width channels, low gradient, very low width/depth ratio, little deposition, riffle/pool morphology, well vegetated banks, very efficient, and stable.

Stream Type F: entrenched channels without floodplains, low gradient, high width/depth ratio, meandering, laterally unstable with high bank erosion rates, riffle/pool morphology.

Stream Type G: narrow valleys or deeply incised "gullies," entrenched channels without floodplains, moderate gradient with low width/depth ratios, step/pool morphology, unstable with grade control problems, and high bank erosion rates.

Results of the Rosgen stream types classified for each inventoried subwatershed are illustrated through the use of GIS generated watershed maps (Figures 5-10). Photographs of typical Rosgen stream types are displayed on Pages 62-64. Table 9 summarizes the length of each stream type and the landform areas in which they occur. Table 10 is a summary of the sediment yield by stream type in each of the topographic areas.

Figure 5 - Rosgen Classification - ASH CREEK

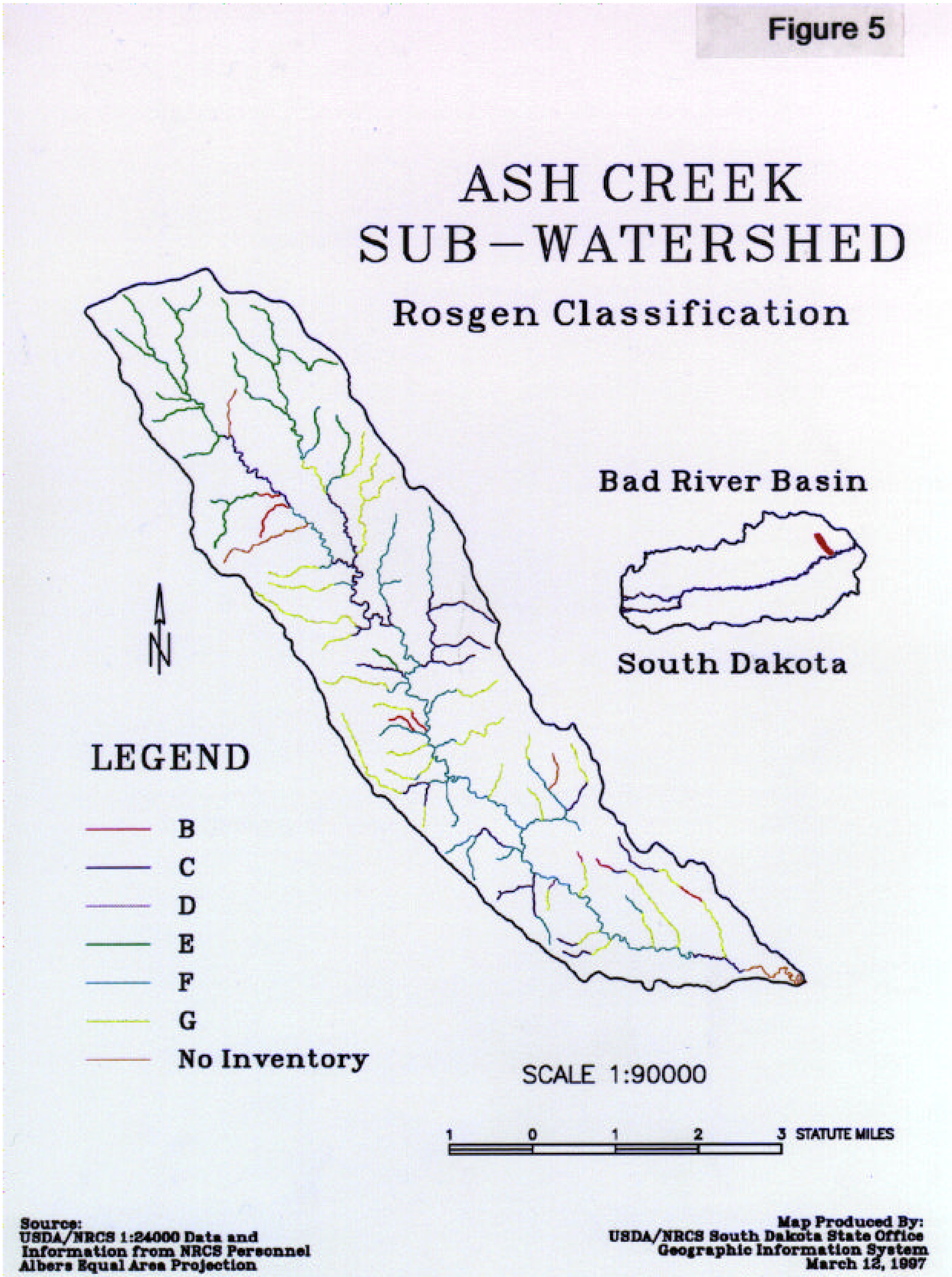


Figure 6 - Rosgen Classification - BIG BUFFALO CREEK

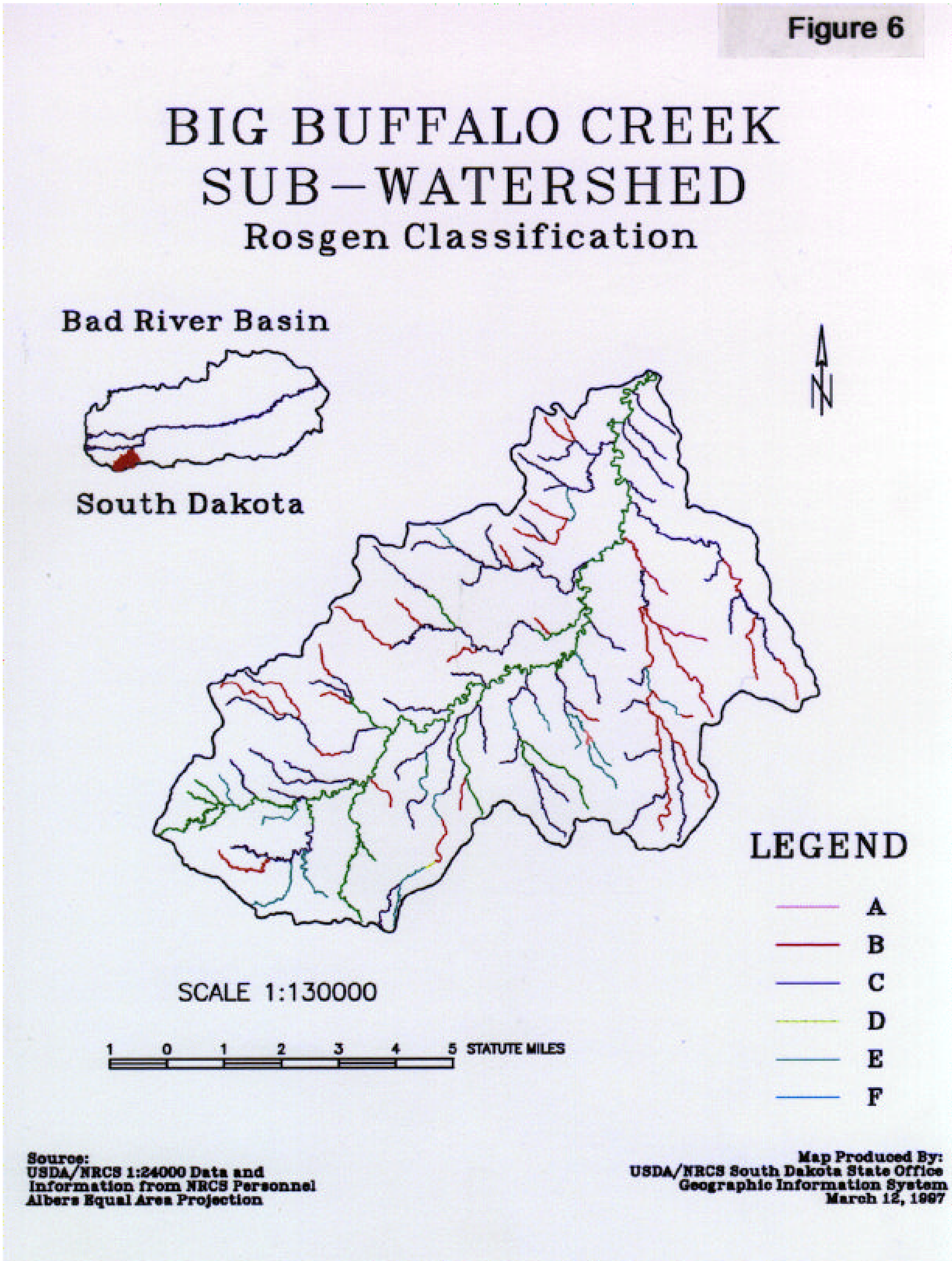


Figure 7 - Rosgen Classification - BURNT CREEK

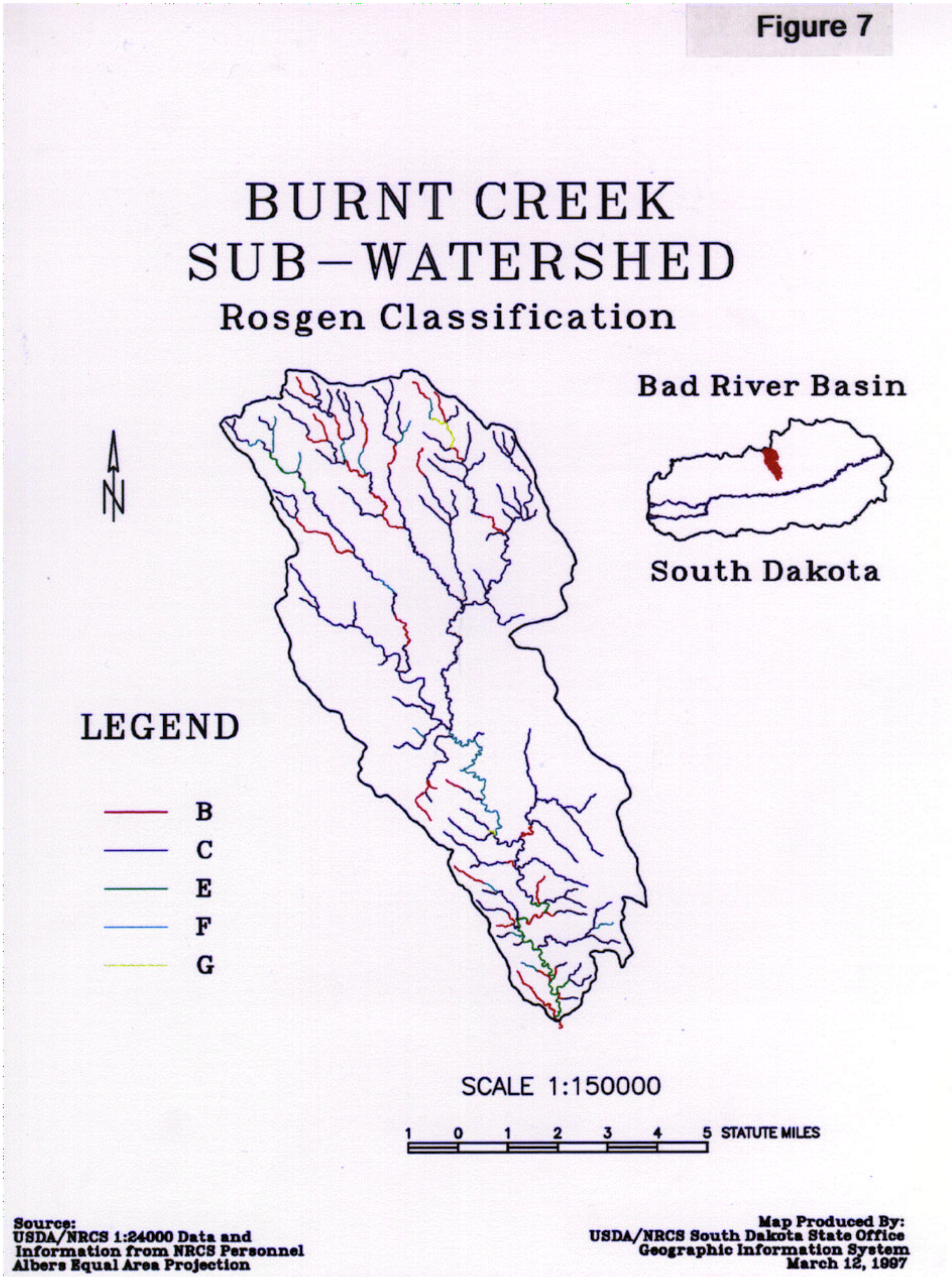


Figure 8 - Rosgen Classification - HERD CAMP CREEK

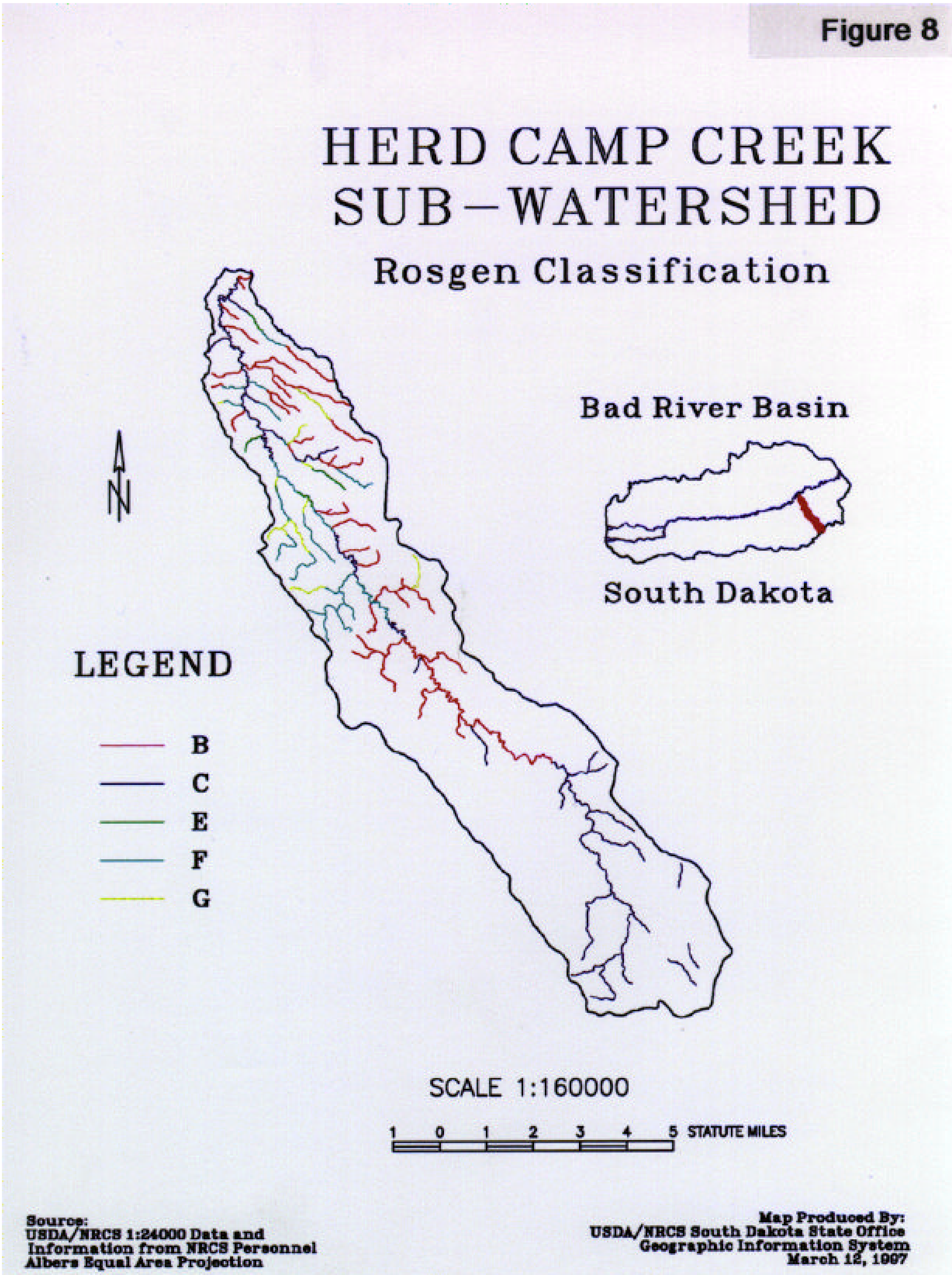


Figure 9 - Rosgen Classification - INDIAN CREEK

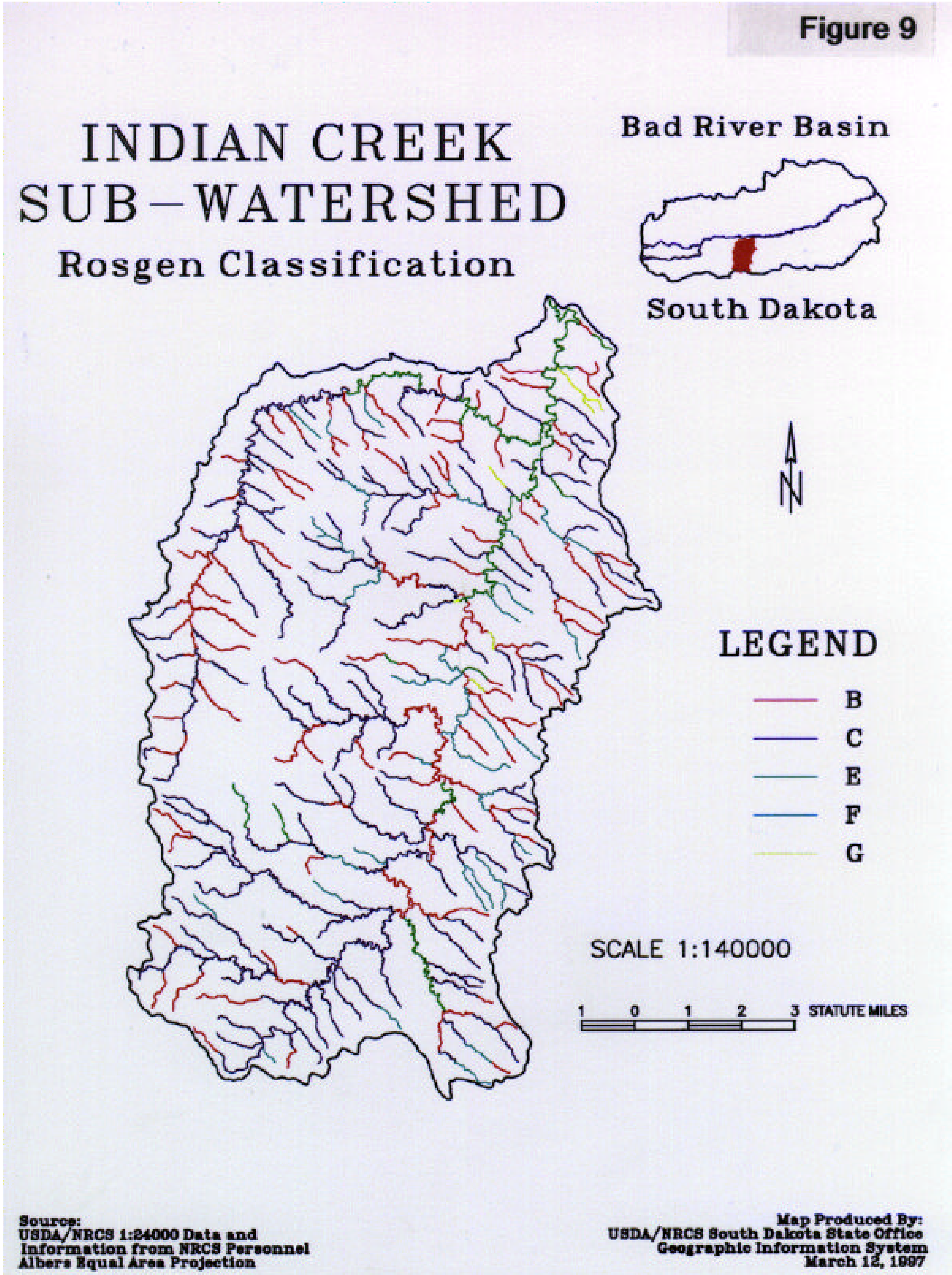


Figure 10 - Rosgen Classification - MEXICAN CREEK

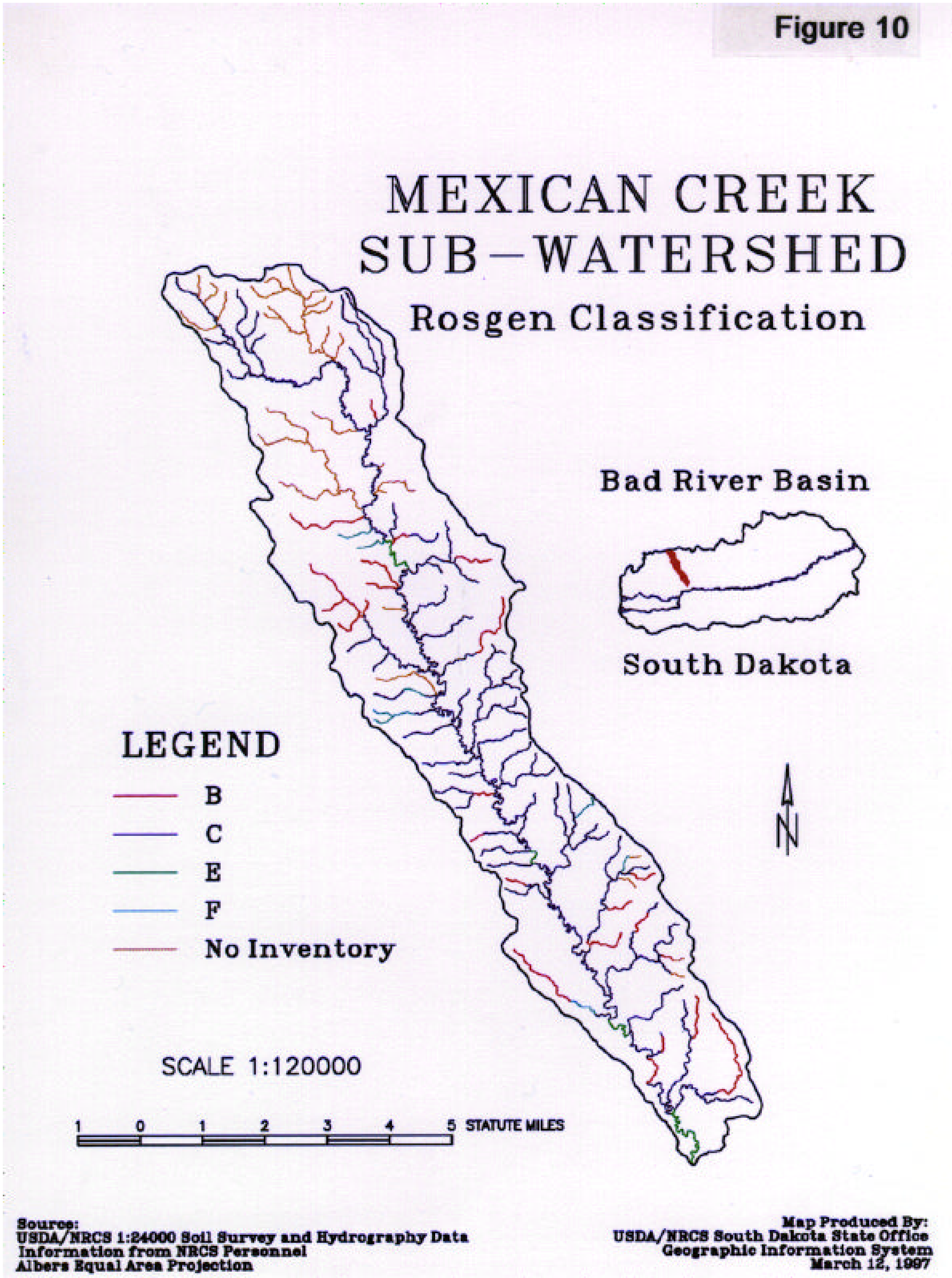


Table 9 - Rosgen Classification

values and uninventoried amounts are expanded to area represented by subwatershed

Stream Type	A		B		C		D		E		F		G		TOTALS	
	miles	tons	miles	tons	miles	tons	miles	Tons	miles	tons	miles	tons	miles	tons	Miles	Tons
SUBWATERSHEDS																
ASH																
-uplands			52.2	11,118	300.9	52,676			739.5	36,986	238.3	158,998	450	295,934	1780.9	555,712
-breaks			36.5	11,021	235.3	52,923	4.95	1,324	11.2	902	555.8	437,000	401	369,564	1244.75	872,734
BIG BUFFALO																
-uplands			57.28	5,838	206.4	25,168			169.6	8,515	1.5	478			434.78	39,999
-Badlands	2	160	113.7	12,259	186	23,449			116.2	6,475	70.3	40,145			488.2	82,488
BURNT																
-uplands			100.53	10,434	476.5	59,711			11.04	571	68.47	21,674	9.2	4,155	665.74	96,545
-breaks			162.2	16,632	280.4	37,023			231.2	12,745	53.9	16,884			727.7	83,284
HERD CAMP																
-uplands			12.1	1,201	365	43,807									377.1	45,008
-breaks			372.4	43,387	154.9	23,240			31.01	1,902	210.3	125,846	90.5	55,909	859.11	250,284
INDIAN																
-uplands			204.3	20,918	551.2	66,955			42.9	2,148	72.1	23,086			870.5	113,107
-breaks			230.9	24,997	253.8	32,161			119.8	6,058	109.5	36,712	15.8	8,111	729.8	108,039
-Badlands			12	1,200	18.69	2,243									30.69	3,443
MEXICAN																
-uplands			183.3	18,883	1109.1	134,613			31.7	1,585	64.7	21,428			1388.8	176,509
-breaks			16.4	1,723	29.3	3,527			9.84	493					55.54	5,743
TOTALS	2	160	1,553.81	179,611	4,167.49	557,496	4.95	1,324	1,513.99	78,380	1,444.87	882,251	966.5	733,673	9,653.61	2,432,895

Table 10 - Rosgen Channel Sediment Yield

UPPER AND LOWER WATERSHED BY ROSGEN CHANNEL TYPE

Topographic Landform	Channel Type	Miles	Sediment Delivered (Tons)
27			
Uplands			
Channel & Gully	B	545	56,073
	C	2343	286,447
	E	256	12,819
	F	208	86,394
	G	9	5,442
	Subtotal	3,361	447,175
Breaks			
Channel & Gully	B	409	43,352
	C	563	72,711
	E	361	19,296
	F	164	69,362
	G	16	10,280
	Subtotal	1,513	215,001
Badlands			
Channel & Gully	A	2	160
	B	126	13,459
	C	205	25,692
	E	116	6,475
	F	70	40,145
	Subtotal	519	85,931
Valley			
Main Channel		45	69,000
	TOTAL	5,438	817,107
LOWER			
Uplands			
Channel & Gully	B	64	12,319
	C	666	96,483
	E	740	36,986
	F	248	139,270
	G	450	322,602
	Subtotal	2,168	607,660
Breaks			
Channel & Gully	B	409	54,408
	C	390	76,163
	D	5	1,324
	E	42	2,804
	F	766	547,081
	G	482	395,350
	Subtotal	2,094	1,077,130
Valley			
Main Channel		20	62,000
	TOTAL	4,282	1,746,790

Schumm Channel Evolution Model

Stage I: a stable channel consisting of a small cross-sectional area. The average size of bank full channel is close to 1.5 year flow (Q), adjacent floodplain, low well-vegetated banks, minimal bank erosion and lateral migration. Stage I channels correlate to the Rosgen's stream types C and E.

Stage II: an unstable channel with downcutting bottom, lack of sediment deposits, high banks, and increased width of channel immediately downstream of nickpoints or headcuts. Stage II channels compare to Rosgen's stream type G.

Stage III: an unstable channel with failing banks that cause channel widening, high vertical banks, longitude extension cracks in the soil at the top of banks, bank slabs lying at the base of the bank, exposed tree roots, fence posts, and vegetative overhang at the top of the bank. Stage III channels compare to a Rosgen's stream type F.

Stage IV: an unstable channel due to widening and aggradation, increased top and bottom width compared with stage II or III channels, decreased frequency, and severity of slope failures in banks, reestablishment of riparian vegetation on some sloughed materials at the base of banks, some sediment accumulations in the channel bottom. This is also a Rosgen's stream type F.

Stage V: a stable channel consisting of a bank full channel and an adjacent floodplain that have been cut down into an existing valley floor, one or more terraces located on the adjacent floodplain. Stage V channels correlate with Rosgen's stream types B and C.

A description and typical cross-section of the channel types delineated in the Schumm Channel Evolution Model is illustrated in Figure 11.

Figure 11 - Channel Evolution Model

The Schumm Evolution Model data compiled for each inventoried subwatershed and illustrated through the use of GIS generated watershed maps are represented by the following pages (Figures 12-17). Tables 11 and 12 are a summary of the length of the different channels by subwatersheds and sediment yield based on the Schumm Evolution Model. The Rosgen's stream types that correlate with the Schumm Channel Evolution Model stages are pictorially represented on Pages 62-64.

Figure 12 - Schumm Stage Classification - ASH CREEK

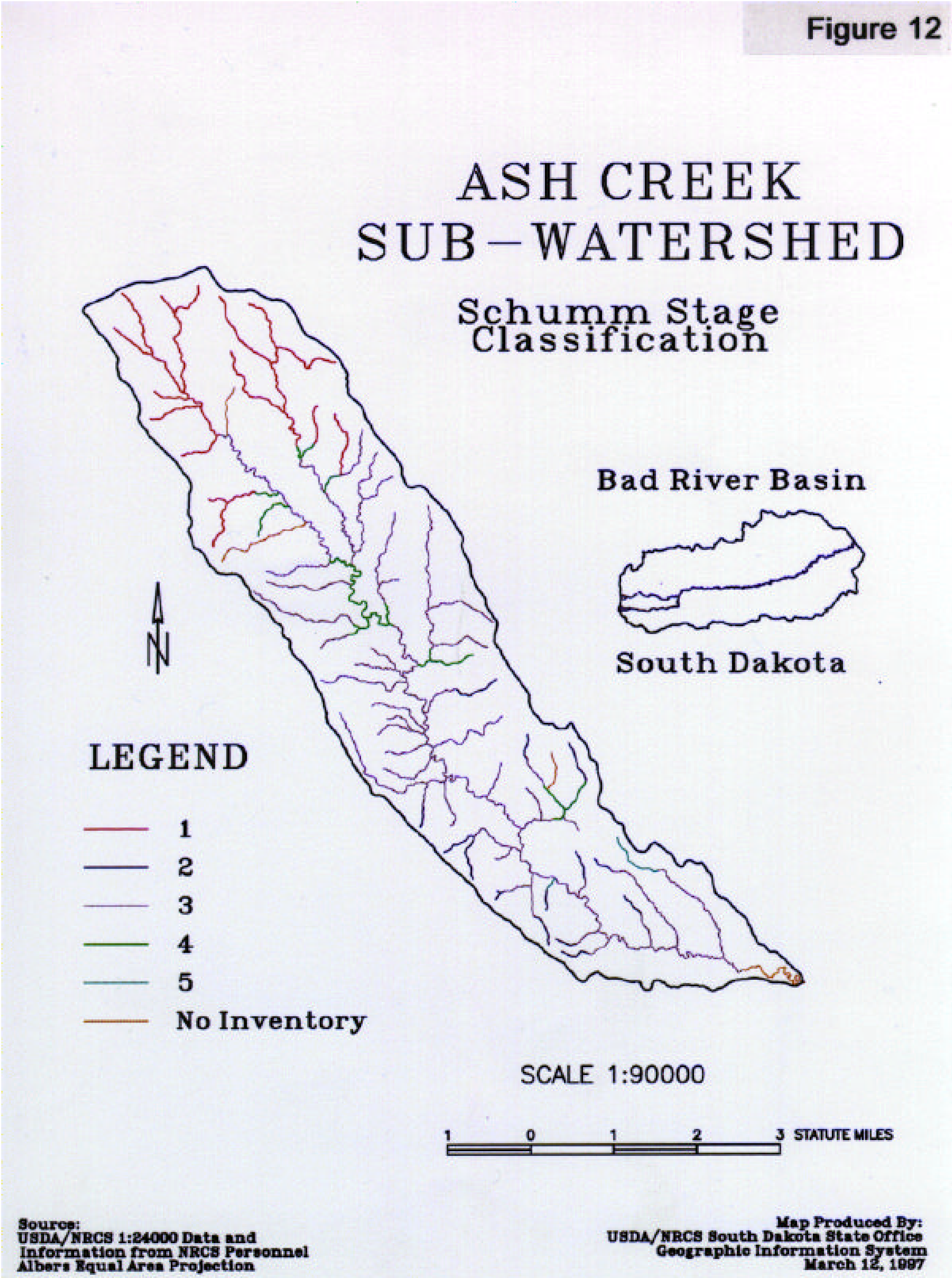


Figure 13 - Schumm Stage Classification - BIG BUFFALO CREEK

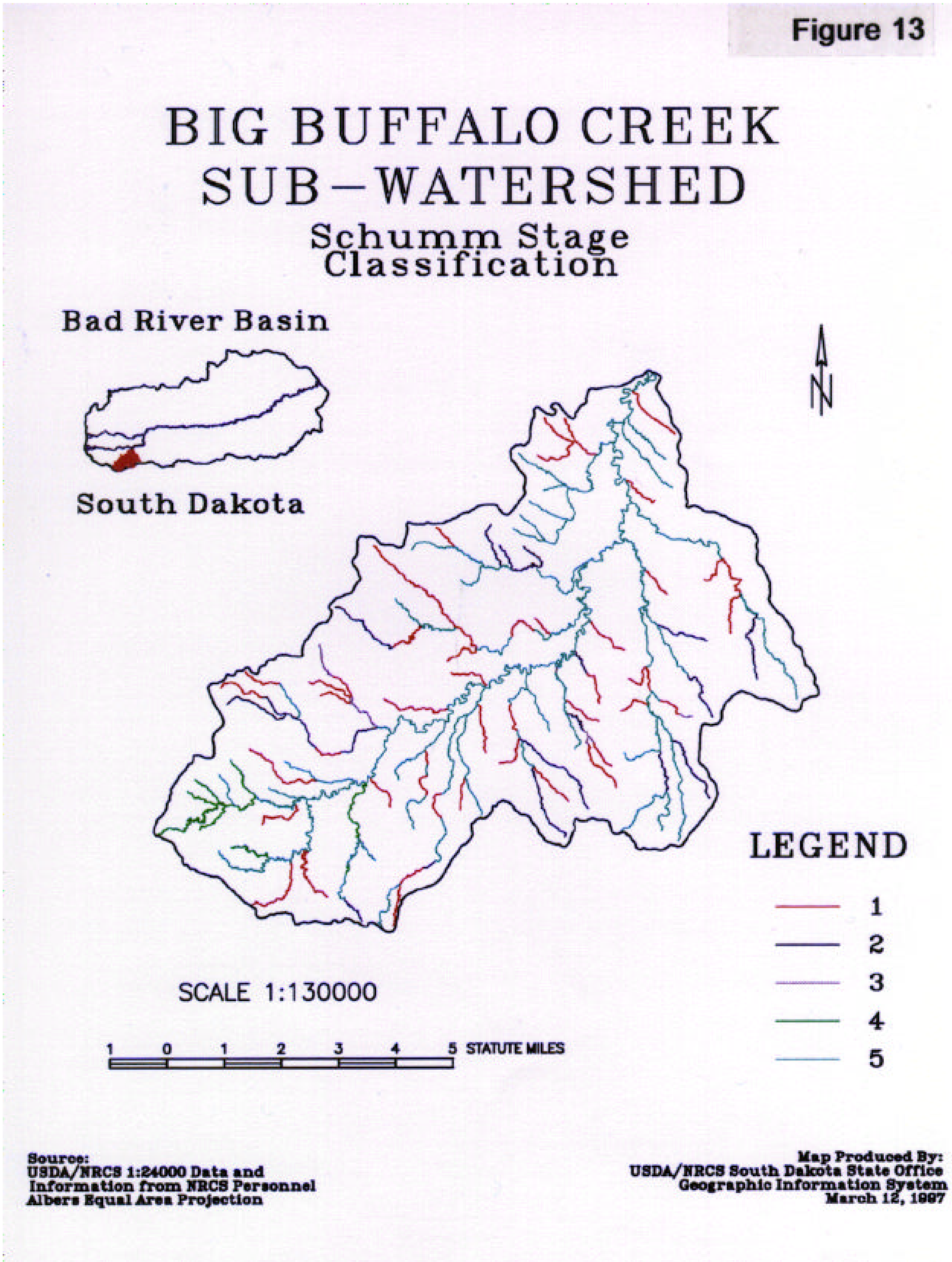


Figure 14 - Schumm Stage Classification - HERD CAMP CREEK

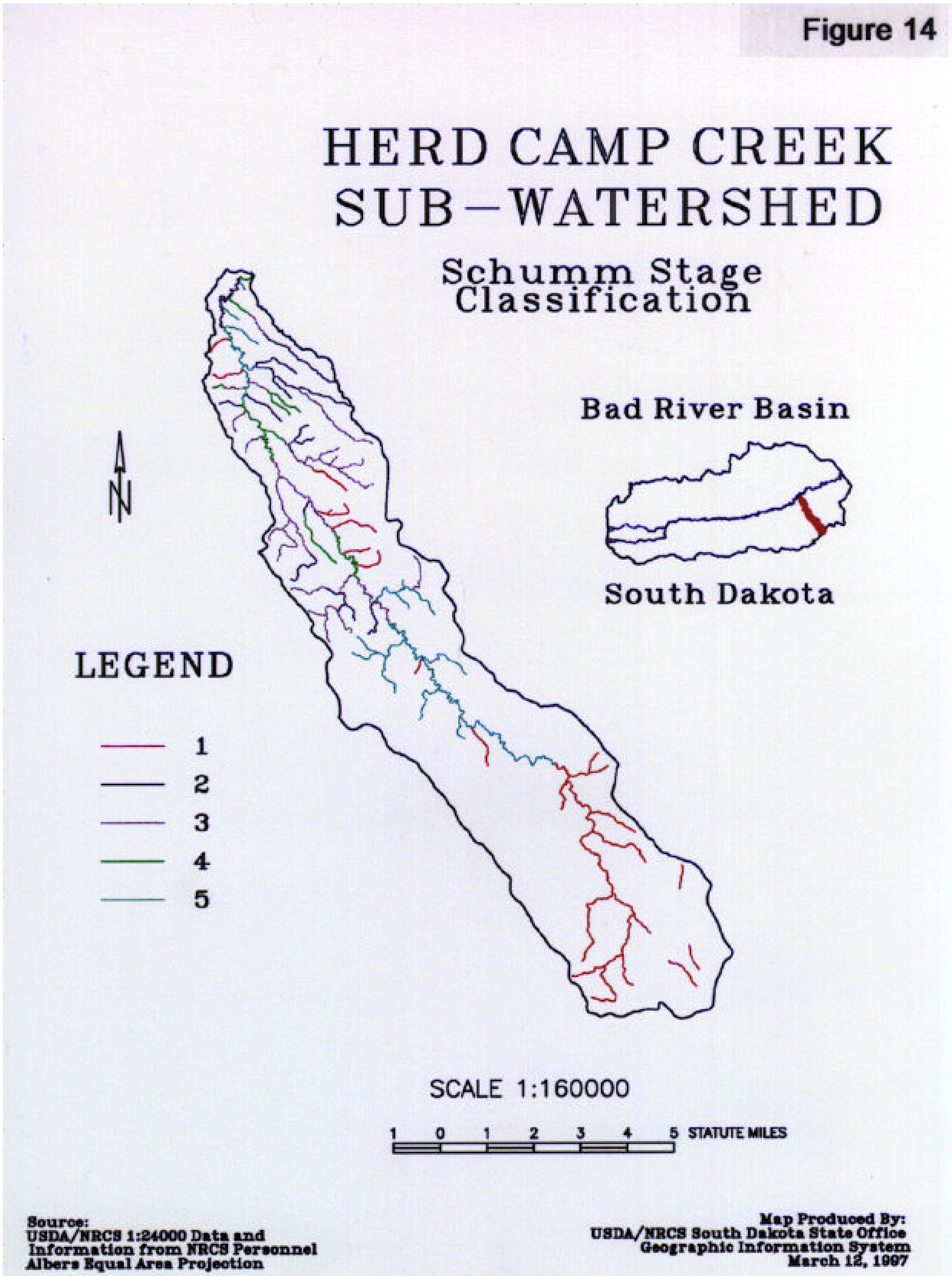


Figure 15 - Schumm Stage Classification - BURNT CREEK

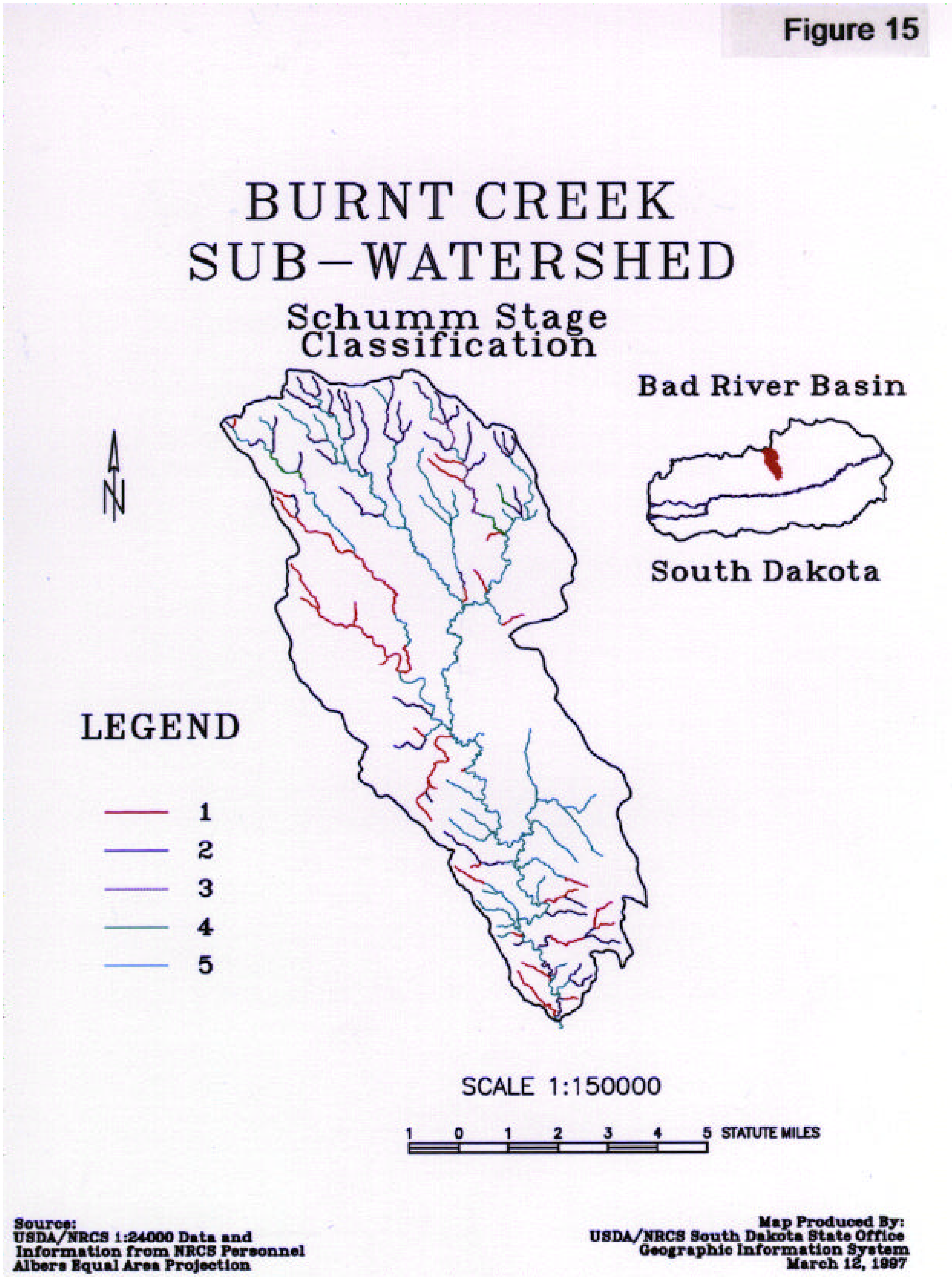


Figure 16 - Schumm Stage Classification - INDIAN CREEK

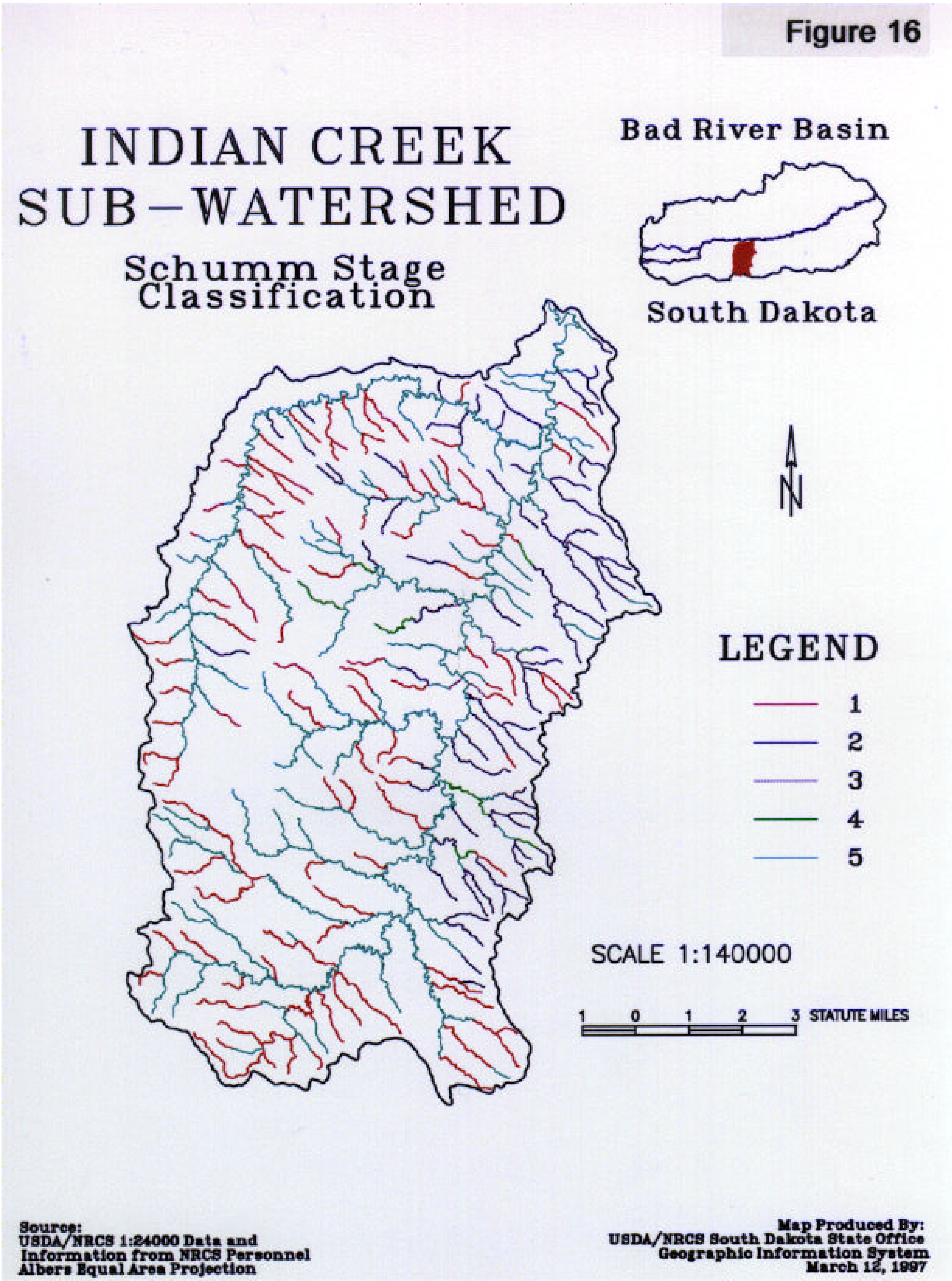


Figure 17 - Schumm Stage Classification - MEXICAN CREEK

Table 11 - Schumm Classification Channel and Gully Erosion

values are expanded to area represented by subwatershed

Stream Type	I		II		III		IV		V		TOTALS	
	miles	tons	miles	tons	miles	tons	miles	tons	miles	tons	MILES	TONS
SUB-WATERSHEDS												
ASH												
-uplands	740	36,986			747	453,712	239	67,299			1726	557,997
-breaks			232	161,975	910	631,620	49	13,731	23	4,937	1214	812,263
BIG BUFFALO												
-uplands	76	8,354	25	5,932					343	28,197	444	42,483
-Badlands	151	30,564	73	13,186	11	973	39	3,263	214	22,893	488	70,879
BURNT												
-uplands	122	16,051	148	29,759	18	5,101	16	1,415	349	49,219	653	101,545
-breaks	217	35,833	248	35,506	11	1,359			245	16,580	721	89,278
HERD CAMP												
-uplands	365	43,796							12	1,222	377	45,018
-breaks	65	7,168	260	56,073	333	169,920	96	16,813	236	26,619	990	276,593
INDIAN												
-uplands	304	40,606	81	22,504	2	224	21	2,935	451	51,838	859	118,107
-breaks	138	20,431	195	52,384	8	4,731	12	1,436	359	44,056	712	123,038
-Badlands	16	1,551							17	1,892	33	3,443
MEXICAN												
-uplands	415	49,483	137	38,391					827	98,635	1379	186,509
-breaks	37	3,843	4	448					18	1,451	59	5,742
TOTALS	2,646	294,666	1,403	416,158	2,040	1,267,640	472	106,892	3,094	347,539	9,655	2,432,895

Table 12 - Schumm Channel Sediment Yield

UPPER AND LOWER WATERSHED BY SCHUMM CHANNEL TYPE

Topographic Area	Channel Type	Miles	Sediment Delivered (Tons)
UPPER			
Uplands			
Channel & Gully	1	937	114,494
	2	391	96,586
	3	20	5,325
	4	37	4,350
	5	1976	226,420
	Subtotal	3,361	447,175
Breaks			
Channel & Gully	1	392	60,107
	2	457	88,338
	3	19	6,090
	4	12	1,436
	5	633	59,030
	Subtotal	1,513	215,001
Badlands			
Channel & Gully	1	167	36,115
	2	73	16,186
	3	11	1,273
	4	39	3,572
	5	229	28,785
	Subtotal	519	85,931
Valley			
Main Channel		45	69,000
	TOTAL	5,438	817,107
LOWER			
Uplands			
Channel & Gully	1	1105	80,782
	2		
	3	777	453,712
	4	274	71,944
	5	12	1,222
	Subtotal	2,168	607,660
Breaks			
Channel & Gully	1	65	7,168
	2	492	213,322
	3	1178	794,540
	4	145	30,544
	5	214	31,556
	Subtotal	2,094	1,077,130
Valley			
Main Channel		20	62,000
	TOTAL	4,282	1,746,790

Channel Bank Erosion

Data for channel bank erosion was collected for each of the representative subwatersheds during the field inventory. Critical erosion areas (channel banks) were identified and field measurements of length, height, and recession rates were used to calculate erosion using the Direct Volume Method (SD Amendment 15 of the Engineering Field Manual). The following pages illustrate the bank erosion for each of the inventoried subwatersheds (Figures 18-23). The data was compiled through the use of GIS watershed maps.

Figure 18 - Bank Erosion - ASH CREEK

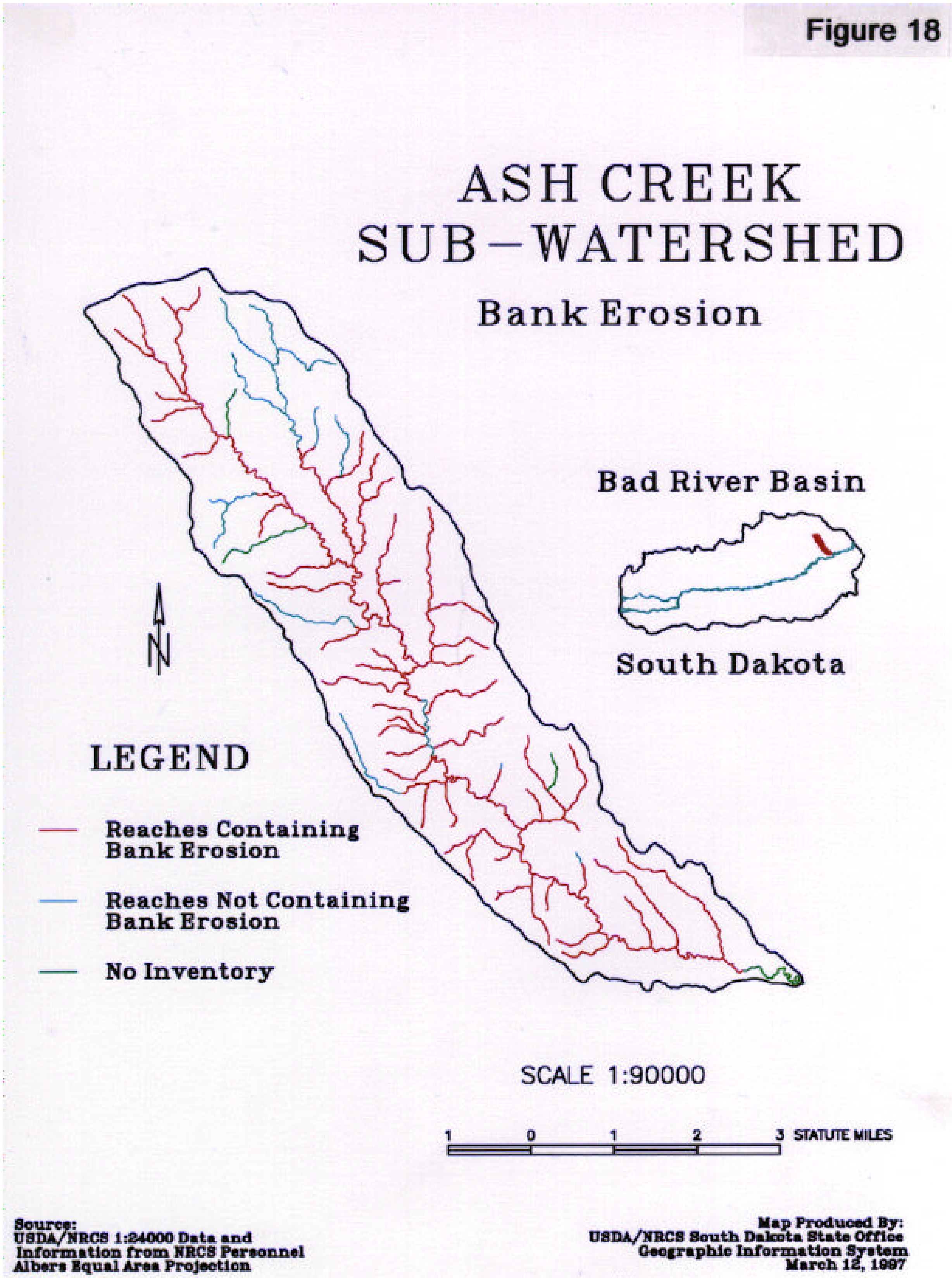


Figure 19 - Bank Erosion - BIG BUFFALO CREEK

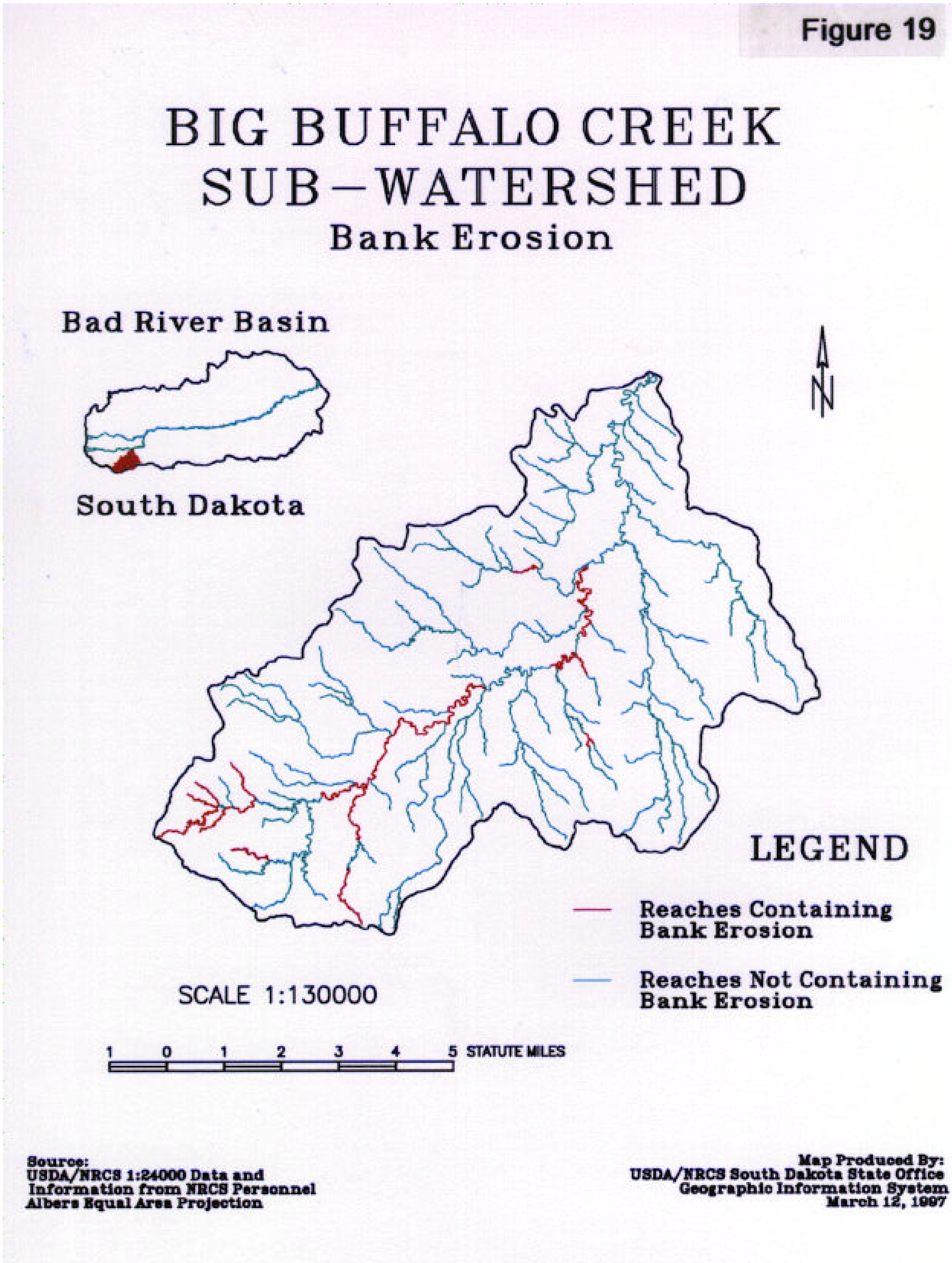


Figure 20 - Bank Erosion - BURNT CREEK

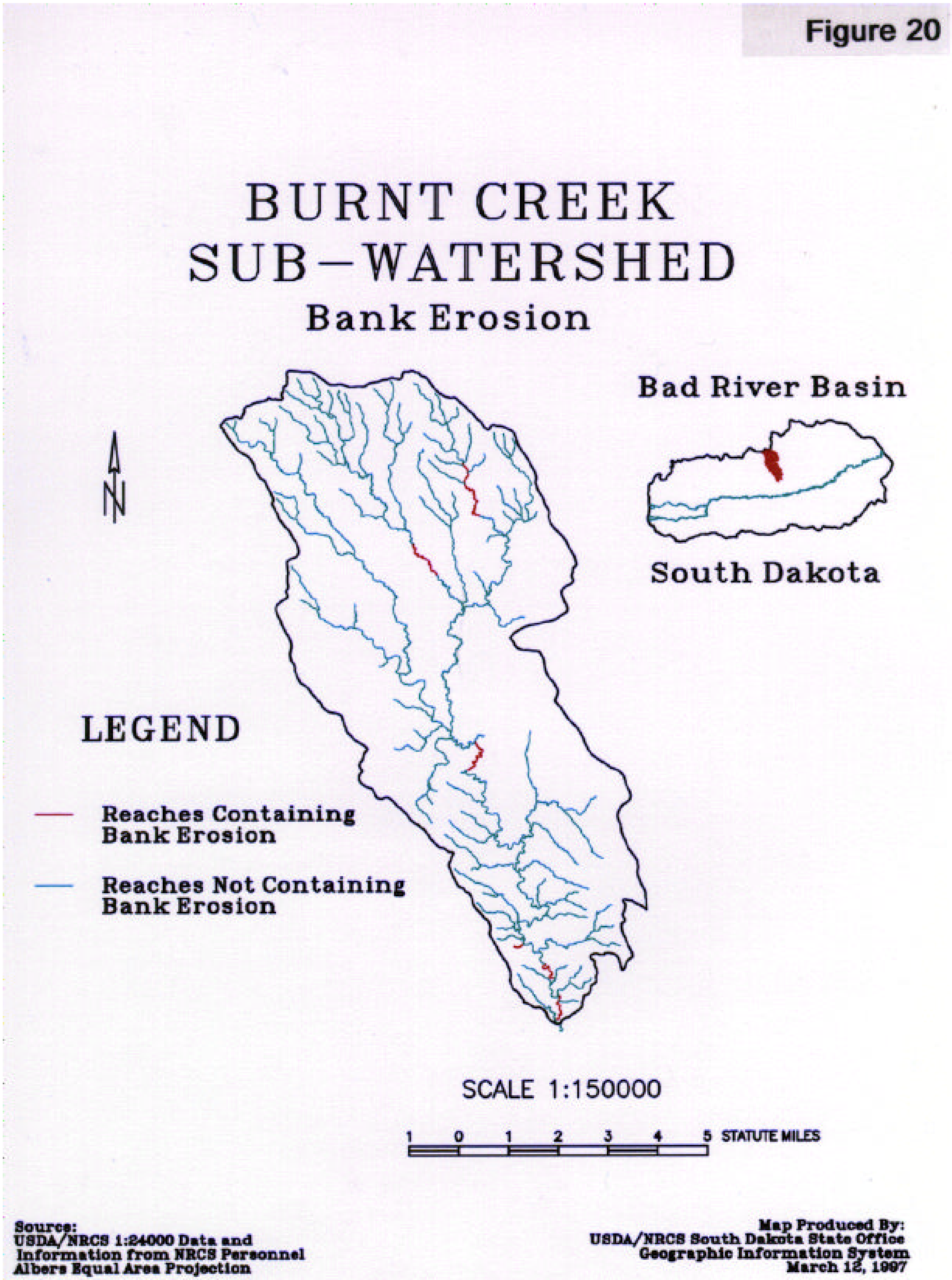


Figure 21 - Bank Erosion - HERD CAMP CREEK

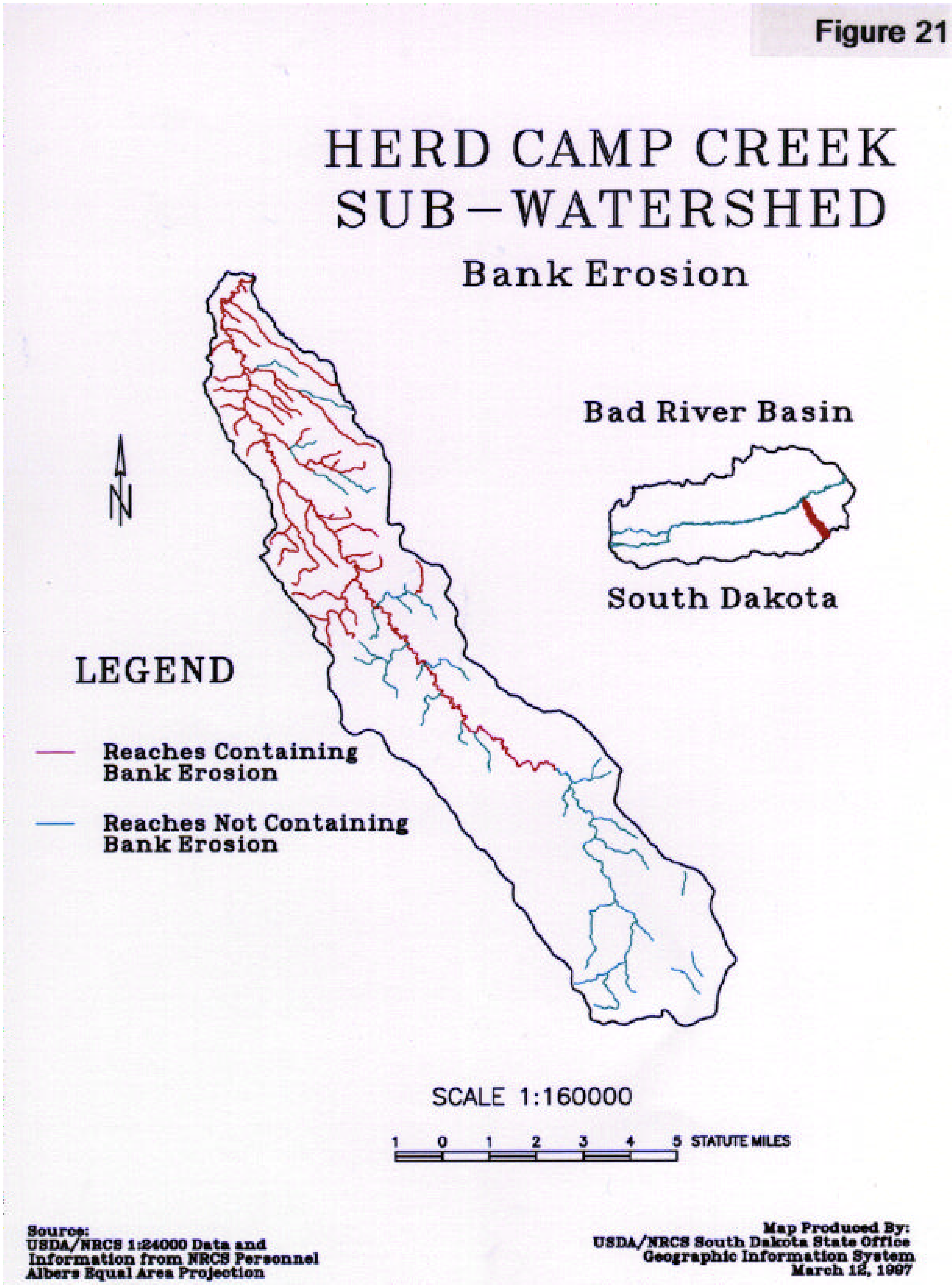


Figure 22 - Bank Erosion - INDIAN CREEK

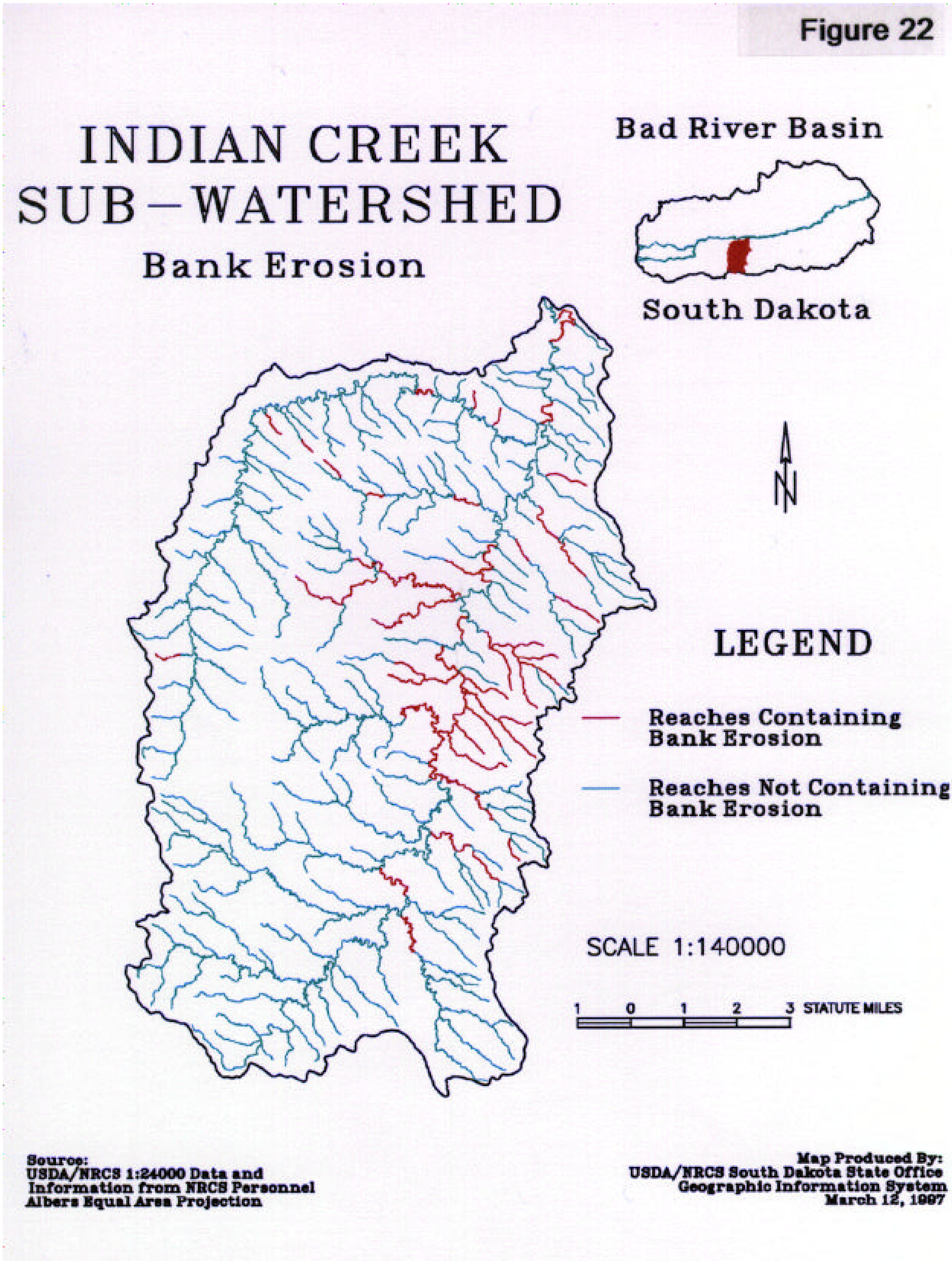
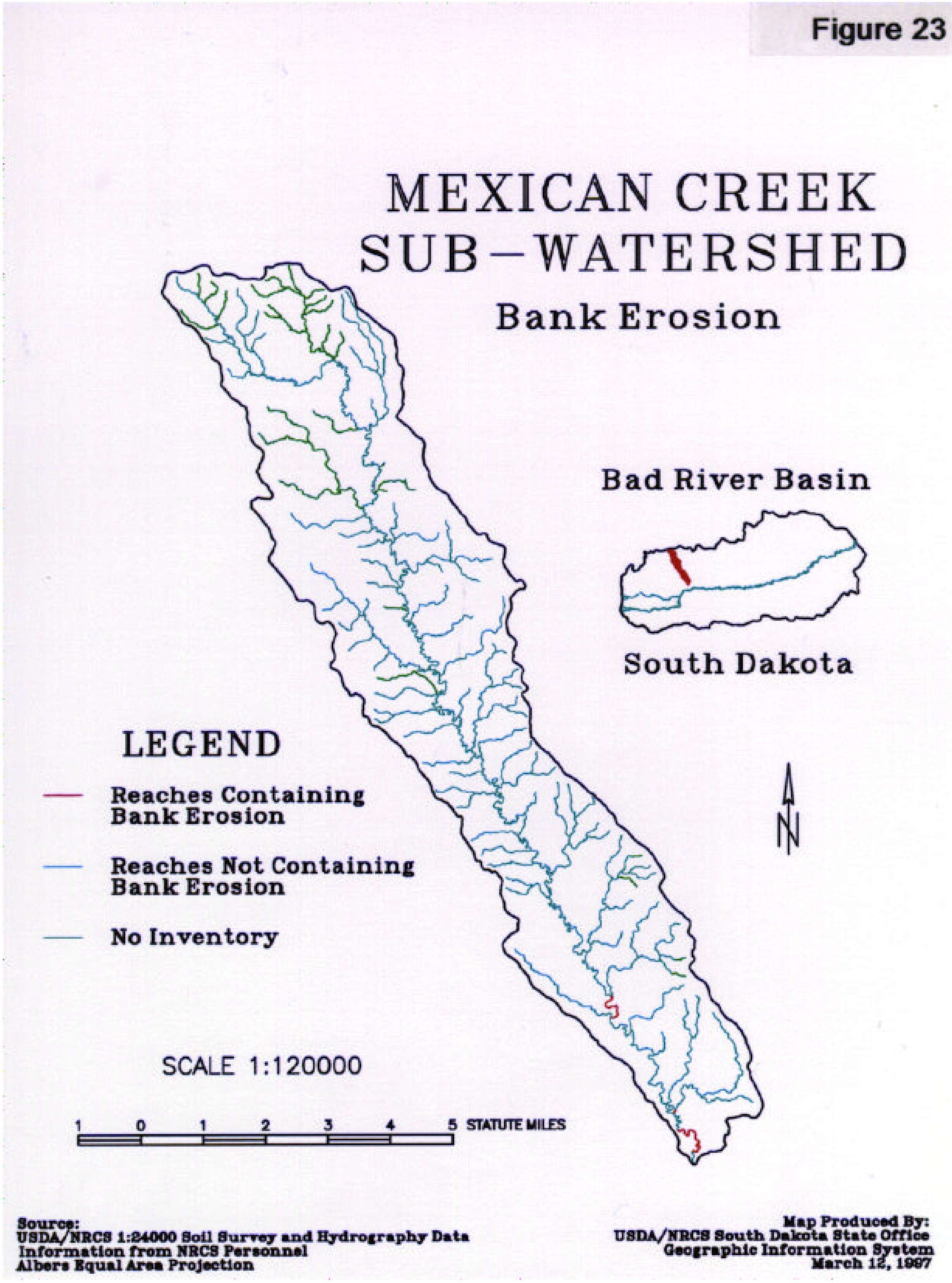


Figure 23 - Bank Erosion - MEXICAN CREEK



Data Extrapolation Procedure

The data collected from stream classification was entered as a layer in a geographic information system (GIS). Using GIS, the number of miles in each stream type was generated for each inventoried subwatershed, and the drainage density (channel miles per square mile) for each landform area within each inventoried subwatershed was calculated. Channels used in the drainage density calculations were the blue line channels on the 7.5 minute USGS topographic maps. Since the inventoried subwatersheds are considered to be typical of the larger representative watersheds, the total miles of each stream type, stage, and associated bank erosion were then extrapolated to each of the representative subwatershed.

Analysis of Relationships

The stream classification and bank erosion data collected in each of the six inventoried subwatersheds was used to determine the relationship between the degree of stability in the subwatershed and stream types, landform, soils, land use, stream order, or evolutionary stage. Any relationship between subwatershed instability and other factors within the subwatershed would be of inherent value in understanding the causes of such instability and in determining a course of action for treatment within the subwatershed. The approach examined trends in observed relationships common to all of the inventoried subwatersheds rather than a statistical analysis. The physical location of unstable channel types was compared with other subwatershed features using GIS generated maps. Channel reaches with bank erosion present were considered unstable areas and accounted for localized areas of high sediment yield.

Relationships Between Soils and Unstable Areas

The general soils map defines soil associations within the subwatershed. Soil depth, which is a measure of the thickness of weathered material over bedrock, varies within these associations from shallow to very deep. Generally as soil depth decreases, organic matter and root density in the upper root zone decreases, ground cover of the dominant species decreases, rooting depth decreases, and the soils are more prone to erosion, resulting in a less stable landscape within the Bad River Watershed. Watersheds in the lower portion of the Bad River (Ash Creek and Herd Camp Creek) had the highest percentage of unstable channels and a higher percentage of shallow soils. By comparison, the two subwatersheds at the upper end of the Bad River (Mexican and Big Buffalo Creeks) had the lowest percentage of unstable channels and have a low percentage of shallow soils.

This indicates that a relationship between soil depth and the degree of stability in a subwatershed may exist. Soil depth is most likely a contributing factor rather than the underlying basis for the condition of the channels. When each of the inventoried subwatersheds are analyzed individually, there appears to be little relationship between soils and the physical location of the unstable channels. Unstable channels were just as likely to occur within associations of predominantly moderately deep to deep soils as they were likely to occur where the soils are shallow. Channels erode in response to changes in watershed runoff and sediment yield which is directly related to management. Soils play a major role in watershed runoff and sediment yield so soils in the watershed above an eroding channel should be compared to channel stability as opposed to looking at soils immediately adjacent to the channel. Typically, the bank erosion process is tied to channel evolution in response to watershed changes in runoff and sediment yield and not to the soil properties in the banks of the channel. Soil properties in the bank dictate what slope failure mechanism will occur in the eroding banks and, to some extent, the rate of the bank erosion.

An analysis of the occurrence of bank erosion relative to the soil depth indicates a relationship similar to what was found for unstable stream types. Ash Creek and Herd Camp Creek had the highest percentage of bank miles containing active bank erosion (26 percent and 8 percent, respectively) and the soils in these subwatersheds are generally more shallow. By comparison, bank erosion as a percent of total stream miles was .04 percent for Mexican Creek, 1.5 percent for Big Buffalo Creek, 0.3 percent for Indian Creek, and .06 percent for Burnt Creek. However, when each of the subwatersheds is analyzed individually, the occurrence of bank erosion showed no relationship to soil depth. Bank erosion was as likely to occur in deep or moderately deep soils as it was in the shallow soils. While soil depth may be a contributing factor to the bank erosion occurring in the Bad River, it does not appear to be the underlying factor contributing to stability.

Relationship Between Landform and Unstable Areas

The landform or topographic areas (uplands, river breaks, valleys, and Badlands) are defined using multiple criteria of soils, slope, and elevation. The valley landform, which is made up of the Bad River and its associated floodplain, was not a part of any of the inventoried watersheds. The other landforms were analyzed for any relationship pertaining to stream stability. A comparison of the unstable stream types present by landform area is shown below for each subwatershed (Table 13).

Table 13 - Percent Of Total Stream Miles Unstable

	Uplands		Breaks		Badlands	
Subwatersheds	**Rosgen**	**Schumm**	**Rosgen**	**Schumm**	**Rosgen**	**Schumm**
Ash Creek	33	54	71	98	-	-
Big Buffalo Creek	1	6	-	-	14	25
Burnt Creek	10	28	7	36	-	-
Herd Camp Creek	0	0	30	62	-	-
Indian Creek	7	12	15	30	0	0
Mexican Creek	4	10	0	7	-	-

--Ash, Herd Camp and Indian Creeks have the most instability in the breaks versus Mexican and Burnt Creeks, which have the most instability in the uplands.

--Big Buffalo has the most instability in the Badlands versus Indian Creek, which is 100 percent stable in the Badlands.

--Comparing one subwatershed against another, there are large differences in the amount of unstable channels occurring by landform area.

If a watershed has a high incidence of unstable channels, then the instability may be less prevalent in the uplands than in the other landform areas, but landform area is not the underlying factor determining the relative stability in a watershed.

The Rosgen and Schumm classification systems are based upon different criteria. Therefore, any attempt to cross-reference the two systems can provide considerable variance as evidenced by the difference in percentages of unstable stream miles between the systems in the above table.

The Rosgen types B (stable) and F (unstable) show the most variation under the Schumm classification. It is common for each of these stream types to be classified as either stable or unstable types under Schumm. Much of the variation in the percentages of stability between the two systems can be attributed to these classification differences.

An analysis of the relationship between landform and the occurrence of bank erosion was made using a visual comparison of the respective GIS maps. The amount of bank erosion inventoried on Mexican Creek was extremely low (.04 percent), all of which occurred on the main channel, with some of these banks eroding as a direct result of flow being directed into the bank by fallen trees and accumulated flood debris. Burnt Creek also had little bank erosion (.06 percent). On Indian Creek, the bank erosion (0.3 percent) occurs in the river breaks or in upland areas adjacent to the river breaks. On Big Buffalo Creek, the erosion (1.5 percent) occurs primarily in the Badlands landform; and in Herd Camp Creek, the bank erosion (8 percent) is located entirely in the river breaks. Ash Creek had the highest percentage of actively eroding banks (26 percent), primarily located in the river breaks, but upland areas adjacent to the river breaks also had a large amount of bank erosion.

These relationships indicate the river breaks area and upland areas adjoining the river breaks landform are more susceptible to bank erosion than the uplands. The river breaks landform would have steeper slopes and larger drainage areas with higher volume, more erosive flows, shallower less stable soils, and therefore, the analogy of susceptibility to bank erosion would be logical. A similar relationship occurs in Big Buffalo Creek, which contains only Badlands and uplands landforms; the bank erosion is primarily in the Badlands.

Evolutionary Stage Relationships

The pattern of stream types within a watershed can give a view of general watershed health or stability. This pattern or blueprint of evolutionary stage can give insight into changes occurring within the watershed. It can also provide a sense of whether there is a general state of equilibrium, where adjustments occur gradually in a somewhat naturally stable manner, or whether there are rapid changes occurring within the watershed, leading to a general state of instability.

Rosgen Stream Types

The pattern of Rosgen stream types on Ash Creek indicate the entire subwatershed is presently undergoing a downcutting phase, which most likely originated at the mouth of Ash Creek on the Bad River. This observation is based on the pattern of progression of stream types beginning at the mouth of Ash Creek and proceeding through the subwatershed to the upper end.

Rosgen describes evolutionary stages of channel adjustment where progressive channel adjustments result in the evolution of a stream from G to F, from F to C, and from C to E. This process is one of progressive adjustments where a stream, after some disturbance in the watershed (a change in base level caused by headcutting, for example), proceeds through a natural evolutionary sequence of changing stream type leading towards a state of natural stability. A disturbance resulting in channel downcutting would also result in the headward advancement of the entrenched gully through the drainage network.

Evidence of this process is illustrated by the plot of Rosgen stream types on Ash Creek. The main channel near the mouth of Ash Creek is C stream type, above which lies a long segment of F. The C, due to its position at the mouth of Ash Creek, would have been the site of earliest downcutting, assuming an adjustment of the Bad River base grade. Moving upward through the watershed to the extremities would represent changes which have occurred more recently. The C was once a gully (G) which has since widened, reestablished a floodplain, and restabilized into the current C type stream. Above this point, the F type, being more recent, is still in the widening phase and has evolved from the former G type to the current F type stream. Many of the tributaries to the main channel in the lower portion of the subwatershed are type G. These tributaries have downcut after the main channel lowered in elevation and advanced up the tributary. These channels have not yet evolved to the later stages of adjustment, occurring after the initial downcutting phase. At the uppermost end of Ash Creek are a number of small drainage basins compromised entirely of E stream types. This area represents streams which are in a relatively stable state. They are located above the area of headward advancement of the gullies and have not yet downcut.

Instability in Ash Creek (F and G type streams and bank erosion) is a direct result of the current evolutionary stage of the entire subwatershed. It is in an actively downcutting phase. The large amount of bank erosion occurring results from the loss of the natural floodplain after the downcutting process, which then results in accelerated bank erosion and lateral extension or widening of the channels. Once this downcutting process begins, the rate at which the bank erosion and lateral widening process proceeds is often quite rapid due to the soils and landform present in Ash Creek. The shallow, quite fragile soils present in the river breaks landform would be very unstable after the initial disturbance. The steeper slopes occurring in the river breaks compound the inherent instability, thereby accelerating the erosional process.

The pattern of bank erosion occurring on Ash Creek follows quite closely with the F and G stream types. These stream types are going through the lateral adjustment stage and have high bank erosion rates. Bank erosion is also quite prevalent on most of the C stream types and also on some E types. Those C type streams which have reestablished a floodplain would still be subject to meander adjustments and would have many areas of quite fragile streambanks still subject to bank erosion. The E type streams which have not yet downcut are subject to minor lateral adjustments with accompanying bank erosion of lesser magnitude than those streams which have downcut.

The pattern of stream types on Herd Camp Creek indicates a pattern similar to that on Ash Creek from the aspect of evolutionary stage. The lower half of the subwatershed, which contains all of the unstable stream types and a high percentage of eroding banks, exhibits a pattern of progression of stream types indicating that a downcutting process has already occurred. The lower quarter of the main channel has reached a state of natural stability after downcutting. The main channel and side tributaries immediately above the lower quarter are presently in the widening phase with active lateral adjustment and bank erosion. There seems to be a greater tendency towards stability in Herd Camp Creek than in Ash Creek. This tendency is indicated by the lesser distance the downcutting has progressed up the drainage network and a corresponding more rapid restabilization (evolution back to C type) occurring at the mouth of Herd Camp Creek. The fairly rapid evolutionary sequence in Herd Camp Creek differs from that of Ash Creek. The difference is due to numerous variables (possibly soils, slopes, etc.) within the river breaks landform, which are more favorable to restabilization than those present in Ash Creek.

Burnt, Indian, Big Buffalo, and Mexican Creeks exhibit patterns of stream types tending more towards a general condition of equilibrium and inherent stability. The unstable stream types, which are mostly type F, tend to be in the upper portion of the landscape. The main channels of all of these subwatersheds are type E (most stable stream type) at the mouth of the watershed. They progress to type C in the upper reaches, except for Big Buffalo Creek, which is type E the entire length of the main channel. These patterns indicate a more mature evolutionary stage, where the most recent downcutting occurred during an earlier period in geologic time, compared to Ash Creek and Herd Camp Creek. The natural evolution of these watersheds has progressed to a state tending towards overall stability in the entire subwatershed. Bank erosion on Burnt, Big Buffalo, and Mexican Creeks occurred primarily on the type C and E streams. These stream types, although inherently stable, are very sensitive to any disturbance and dependent on the controlling influence of vegetation. The disturbance on Mexican Creek, in a number of instances, was flood debris blocking the main channel. On Big Buffalo Creek, the eroding banks were typically high hazard; therefore, they would tend to be even more sensitive. Factors affecting a bank's erodibility hazard include bank height and angle, rooting depth and density, soil stratification, and particle size.

Land Use Relationships

No relationship was evident between the instability in the subwatersheds and a particular land use. All of the subwatersheds inventoried contained both cropland and rangeland except for Big Buffalo Creek, which is entirely rangeland. The cropland areas were usually within the uplands landform. The uplands tended to contain a higher percentage of stable stream types and were less susceptible to bank erosion compared to the breaks landform which would typically be rangeland. This is contrary to what would be expected if land use were a primary factor affecting stability. Cropland generally would produce higher volume, higher intensity runoff events compared to rangeland. This is not to say that conversion from rangeland to cropland in modern times has had no effect on some of the watersheds; but an analysis of such a scenario is beyond the scope of these observations.

Stream Order Relationships

The relationship between stream order and unstable stream types was quite consistent in Burnt, Indian, Mexican, and Big Buffalo subwatersheds. These watersheds appear to be in a general state of equilibrium, where the type F and G streams occurred almost exclusively on stream order 1 and 2 in the very upper portion of the landscape. In contrast, Ash and Herd Camp Creeks are subwatersheds which appear to be in a state of rapid change. In these two subwatersheds, the F and G type channels occurred on all stream orders 1, 2, 3, and 4. These conditions would correspond with the observations made concerning evolutionary stage. Bank erosion is occurring irrespective of stream order in all of the subwatersheds (stream orders 1, 2, 3, and 4).

Rangeland Relationship

In natural plant communities, the hydrologic condition of a site is the result of complex interactions between soil and vegetation factors. The interaction of these factors determines how water is partitioned into the hydrologic cycle. Research has shown correlations between kinds of vegetation, amount of plant cover, and soils to erosion, infiltration, and runoff. This section summarizes available data on vegetative conditions within the Bad River watershed as well as range sites (soils) within the sampled subwatersheds. Determining the range site is the first step in determining range condition because the soils determine what the climax plant community potential is within a given climatic area.

Soils information was collected from NRCS soils surveys for the sampled watersheds. Table 14 summarizes the range sites (soils) within the six subwatersheds. A range site is an area of rangeland which has the potential to produce and sustain distinctive kinds and amounts of vegetation to result in a characteristic plant community under its particular combination of environmental factors, particularly climate, soils and associated native plants and animals (SRM, 1974).

The most dominant range site is clayey, making up over 42 percent of the subwatersheds, varying from a low of 14 percent in Big Buffalo Creek to a high of 58 percent in Mexican Creek. The climax plant community of clayey sites is chiefly a mixture of western wheatgrass and green needlegrass.

Silty range sites are the second most dominant making up over 12 percent of the subwatersheds, however three of the subwatersheds had 2 percent or less. The amount of Silty sites ranged from a low of 0 percent in Ash Creek to a high of 35 percent in Big Buffalo Creek. The climax plant community of silty sites is chiefly western wheatgrass, green needlegrass, and needleandthread. Big and little bluestem and sideoats grama occur in minor amounts. Both silty and clayey sites occur on flat to moderately steep slopes.

Table 14 - Summary of Range Sites for Sampled Subwatersheds

Ecological Site	Mexican Creek	Big Buffalo Creek	Indian Creek	Ash Creek	Herd Camp Creek	Burnt Creek	TOTAL ACRES	TOTAL PERCENT
Badlands Overflow	0.0	13.0	0.0	0.0	0.0	0.0	3396	2.5%
Clayey	58.0	14.0	46.0	36.0	49.0	56.0	58000	42.5%
Claypan	trace	12.0	5.0	0.0	5.0	trace	6443	4.7%
Clayey Overflow	1.0	trace	2.0	trace	1.0	3.0	1897	1.4%
Closed Depression	1.0	trace	trace	0.0	4.0	3.0	1544	1.1%
Dense Clay	0.0	trace	trace	16.0	6.0	3.0	3149	2.3%
Loamy Overflow	5.0	0.0	3.0	0.0	0.0	trace	2155	1.6%
Shallow	6.0	trace	3.0	trace	4.0	2.0	3493	2.6%
Shallow Clay	trace	3.0	11.0	40.0	11.0	trace	11478	8.4%
Shallow Marsh	0.0	0.0	0.0	0.0	1.0	0.0	194	0.1%
Silty	13.0	35.0	11.0	0.0	2.0	trace	16629	12.2%
Thin Claypan	3.0	10.0	11.0	trace	1.0	2.0	8812	6.5%
Thin Upland	11.0	2.0	5.0	trace	14.0	28.0	12997	9.5%
Rock Outcrop	0.0	6.0	0.0	4.0	trace	trace	1909	1.4%
Other Minor Sites	2.0	5.0	3.0	4.0	2.0	3.0	4358	3.2%
RANGELAND	15,040	26,123	46,754	8,542	19,396	20,599	136,454	100.0%

Range sites that occur on the steeper slopes are the shallow, shallow clay, and thin upland range sites. These sites are more susceptible to runoff and erosion. The combined amount of these sites totaled a significant 20.5 percent of the subwatersheds. Ash Creek has a total of 40 percent shallow clay sites. Burnt Creek has the highest amount of thin upland sites with 28 percent. The climax vegetation for these sites differs significantly from clayey and silty sites, in that warm season grasses, big and little bluestems plus sideoats grama, make up 50 percent or more of the plant community. The cool season grasses, porcupine grass, green needlegrass, needleandthread, and western wheatgrass are important. Forbs and shrubs are also more prevalent.

Dense clay range sites occurred in 5 of the subwatersheds, but only one, Ash Creek, had significant amounts with 16 percent. Dense clay sites occur in and along drainageways and are particularly vulnerable to erosion because they have very slow permeabilities and no understory of shortgrasses under the primary grass specie western wheatgrass.

The following table shows a comparison of the amounts of unstable F and G channels, shallow erosive soils, less erosive silty soils, fair and poor range condition, and cropland in the six sampled subwatersheds.

Table 15 - Comparison of Subwatersheds Sampled

	Ash Creek	Big Buffalo Creek	Burnt Creek	Herd Camp Creek	Indian Creek	Mexican Creek
Percent of Unstable Channels	54.0	8.0	9.0	24.0	12.0	5.0
Percent of Shallow Soils	40.0	5.0	30.0	29.0	19.0	17.0
Percent of Silty/Clayey Soils	0.0	35.0	0.0	2.0	11.0	13.0
Percent of Fair and Poor Range Condition	10.0	20.0	17.0	5.0	9.0	22.0
Percent of Cropland	38.0	6.0	33.0	36.0	21.0	28.0
Percent of Rangeland	62.0	94.0	67.0	64.0	79.0	72.0

It is interesting to note that Big Buffalo and Mexican Creeks have the fewest miles of F and G channels but the highest amount of rangeland in fair and poor range condition. These subwatersheds have the fewest acres of shallow soils susceptible to runoff and erosion and the highest percentages of the less vulnerable silty soils. This reinforces the importance of soils to hydrology.

Information on the status of range vegetation was gathered from three sources including the 1994 Lower Bad River-River Basin Study, the 1992 National Resources Inventory, and estimates from the Natural Resources Conservation Service personnel in Stanley, Jones, Haakon, Jackson and Pennington Counties. The following sections summarizes each of those sources.

I. LOWER BAD RIVER - RIVER BASIN STUDY

A total of 248 sample sites were evaluated from randomly selected quarter sections within the lower one-third (792,000 acres) of the Bad River Watershed to characterize vegetative and soil conditions influencing hydrology. The quarters were selected using a random numbers table.

The vegetative and soil parameters that were evaluated included:

(1) Dominant plant species by canopy cover
(2) Plant height
(3) Canopy cover percent and number of layers
(4) Ecological site and status (range site and condition)
(5) Utilization (grazing intensity)
(6) Mulch cover percent and weight
(7) Total biomass weight
(8) Plant vigor
(9) Total cover percent
(10) Hoof action (trampling)

Values for vigor, hoof action, and grazing intensity were determined subjectively using a rating system of low, medium, and high. Mulch and biomass weights are in air-dry pounds per acre. The percent mulch cover was determined using either visual estimates or 3 ten pin point-frame readings (30 pins total per site).

Table 16 identifies the range conditions that were determined for the Lower Bad River-River Basin Study.

Table 16 - Range Condition

Topographic Area	Excellent	Good	Fair	Poor
River Breaks	39%	59%	2%	0%
Uplands	25%	66%	9%	0%

Range condition (the kind and amount of plant species on a site in relation to natural potential for the site) is not always a reliable indicator of hydrologic conditions. Other variables that influence hydrology such as vigor and ground cover, also need to be considered when assessing the hydrologic condition of the watershed.

II. 1992 National Resource Inventory

Data from the 1992 National Resources Inventory (NRI) for Major Land Resource Area (MLRA) 63A, within which the entire Bad River Watershed is located, shows range conditions to be:

30% Excellent	**57% Good**	**13% Fair**	**0% Poor**

This data is statistically reliable for the MLRA but not at the county or watershed level. Determinations of the hydrologic condition were not a part of the 1992 NRI sampling procedures nor were they possible using the estimating procedures employed in the Upper Bad River - River Basin Study.

III. Natural Resources Conservation Service Estimates

Range condition estimates by the Natural Resources Conservation Service personnel located in the Bad River Watershed are shown in Chart 4 (Appendix C) by county and subwatershed. A summary of these estimates show the following range conditions:

26% Excellent	**59% Good**	**12% Fair**	**3% Poor**

Based on the range condition estimates for the subwatersheds of the Bad River, the 1992 NRI data for MLRA 63A, and the data from the Lower Bad River - River Basin Study, 85 percent or more of the rangeland is in good and excellent range condition (ecological status). The plant communities on these sites are dominated by midgrasses, which inherently contribute to higher infiltration rates due to the characteristics of their root systems.

Approximately 15 percent of the rangeland acres in the watershed are in fair and poor range condition. The plant communities on these acres are dominated by shortgrasses that have been shown to contribute to higher runoff amounts.

Range condition is an indicator of hydrologic condition. In general the better the range condition the better the hydrologic condition. In some cases, however, range condition is not a good indicator of hydrologic conditions. Rangelands in excellent range condition (ecological status) can be exposed to high amounts of runoff and erosion by the removal of protective mulch and grass cover and by soil surface compaction. In a discussion of ecological dynamics and management effects on rangeland hydrology, Spaeth et al (1996) states:

Rangeland managers need to be wary of relating range condition to hydrologic health. They may or may not be correlated depending upon the characteristics of the plant community. A site where a loss of vegetation or a shift in species composition causes less water to infiltrate into the soil, increases runoff, and subsequently increases soil movement is indicative of low hydrologic condition.

In Stanley County, South Dakota, Spaeth (1994) found that good condition rangeland dominated by the shorter climax sod forming grasses, such as buffalograss and blue grama, were associated with high runoff, which is believed to exacerbate gully erosion, headcutting, and riparian area degradation downstream. Infiltration experiments in Nebraska, Kansas, and Wyoming have also confirmed lower infiltration rates in buffalograss stands.

In Texas, Spaeth (1990) found the relatively low erosion rates between fair condition buffalograss stands similar to excellent condition sites dominated by blue grama, even though runoff was significantly higher from buffalograss stands.

Research by McCalla and Blackburn (1984) showed that infiltration rates in the midgrass (bunchgrass) communities averaged 40 percent greater than in the shortgrass (sodgrass) community. They found that a decline in midgrasses, regardless of the cause, will eventually result in lower infiltration rates and soil water for plant growth. Their study showed that the greatest infiltration rates for both communities were maintained in the moderately stocked continuous grazing system compared to double stocked short duration grazing and heavily stocked continuous grazing.

Infiltration rates on several of the major soils in the watershed were studied by Ken Spaeth, NRCS Rangeland Hydrologist, and Robert Self, South Dakota State University, in combination with various vegetative cover amounts and plant communities.

Spaeth (1990) found that cumulative infiltration rates were 236 to 367 percent higher for lightly to moderately grazed sites compared to heavily grazed sites on Promise clayey and Sansarc shallow clay sites (Chart 4, Appendix C). Erosion rates were reduced 62 to 95 percent.

Robert Self (1996) recorded these certain patterns in the way variables affected runoff and soil erosion on Lakoma and Pierre soils. Lakoma is a Thin Upland range site. Pierre is considered a Clayey range site.

* An increase in the height of western wheatgrass was always correlated with lower amounts of runoff.
* On the Lakoma soils, an increase in western wheatgrass cover or shortgrass cover resulted in an increase in runoff.
* An increase in the biomass of bluestem or the percent litter cover always reduced runoff on the Lakoma sites.
* On Pierre soils an increase in soil moisture was always positively correlated with runoff and an increase in percent bare ground resulted in an increase in the amount of runoff in all but one case.
* For both Lakoma and Pierre soils, increases in the amount of runoff, the percent western wheatgrass cover, or the biomass of western wheatgrass always increased the amount of soil loss, while an increase in percent litter cover was always negatively correlated with soil loss.
* On Lakoma soils, an increase in shortgrass cover resulted in an increase in soil loss, while an increase in percent litter cover resulted in a decrease in soil loss.
* On Pierre soils an increase in soil moisture or an increase in bare ground resulted in an increase in soil loss in all but one case.
* Sediment production was very low (under 138 lbs./acre) for these two soils.

Based on Self's findings, the hydrologic health of thin upland sites (Lakoma soils) can be improved by managing grazing to reduce the amount of western wheatgrass and shortgrasses in favor of the bluestems and maintaining litter cover. On the clayey sites (Pierre soils), hydrologic health can be improved by increasing the height of western wheatgrass, reducing shortgrass cover, and reducing the percent bare ground.

Hanson et al (1973) studied reservoir sedimentation between 1958-1969 on stock water ponds to determine sediment yields from rangeland watersheds on two soil textural groups of western South Dakota. Data from 15 experimental watersheds indicate that the mean annual sediment yields are related to the soil textural groups. Watersheds having fine textured soils show a mean annual sediment yield of 3.47 tons per acre, while watersheds with medium textured soils had a mean annual sediment yield of 1.03 tons per acre.

Hanson et al. (1978) studied the effects of grazing intensity and range condition on the hydrology of western South Dakota from 1963 to 1972. Hanson reported that mean annual runoff was 0.91, 0.77, and 0.59 inches from the low, medium, and high range condition watersheds with average standing crops of vegetation and mulch of 1,844, 2,008, and 3,338 lbs per acre respectively.

Gifford (1985) in a review of cover allocation in rangeland watershed management generalized that 50 to 60 percent plant cover is most likely sufficient to minimize sheet and interrill erosion and maximize infiltration. Osborn (1952) reported that water losses exceeded 50 percent of the applied amount whenever the cover was less than 50 percent effective in controlling raindrop splash. After simulating rainfall on over 300 plots on a wide range of soil textures, Osborn reported that regardless of soil texture, all soils studied were capable in their optimum condition of holding with little or no runoff the first 2 inches of water applied at intensities of up to a 50-year frequency.

The vegetative inventory indicates that all of the major range sites in the watershed have the ability to produce over 50 percent plant cover. Grazing intensities that maintain adequate vegetative cover throughout the growing season and minimize soil compaction will help maintain hydrologic conditions by increasing infiltration, thereby reducing and slowing runoff.

Vegetative production varies widely depending on precipitation. In dry years when forage demand is high in relation to production, there is a high risk of reducing plant cover below the amount needed for site protection. Flexible stocking is recommended to match consumption with production. Numerous studies published between 1964 and 1990 concluded that heavy grazing has a negative impact on infiltration. Hydrologic condition can be improved by restoring plant communities dominated by midgrasses. Improving range condition on these acres would have a significant onsite impact on hydrologic health.

Conclusions

Channel form is a function of many complex and interrelated variables present within a watershed. The following interpretations are based entirely on relationships observed between the stream stability, data collected as part of the stream classification, and other general facts concerning the Bad River Watershed.

The pattern of stream types, as classified on Ash Creek and Herd Camp Creek, indicates the present instability may be due to the current evolutionary stage of these subwatersheds. Stream adjustments are occurring quite rapidly. This leads to a general state of instability in response to changes which may have occurred in these subwatersheds at their confluence with the Bad River. This observation is based on a pattern of progression of Rosgen stream types indicating these subwatersheds are currently in a downcutting phase.

On Ash Creek, this downcutting has advanced through the river breaks and into the uplands. The headward advancement and lowering of the base grade of the main channel has resulted in a corresponding unraveling of the tributaries joining the main channel, many of which are now entrenched gullies. Once this downcutting process starts, the bank erosion and lateral extension or widening of the channels are part of the natural process of streams trying to readjust to a more stable form, which causes erosion rates and sediment loads to be very high. The shallow and quite fragile soils present in the river breaks, with steeper slopes and low permeability, compound this inherent instability, thereby further accelerating a process of rapid geologic change.

On Herd Camp Creek, the lower quarter of the main channel has reached a state of natural stability after downcutting, while the main channel and side tributaries immediately above the lower quarter are presently in the widening phase with active lateral adjustment and bank erosion. There seems to be a greater tendency towards stability in Herd Camp Creek than in Ash Creek as evidenced by the shorter distance the downcutting has progressed up the drainage network and a corresponding rapid restabilization occurring at the mouth of Herd Camp Creek. This rapid evolutionary sequence in Herd Camp Creek may be due to numerous variables (soils, slopes, etc.) within the river breaks landform, which are more favorable to restabilization than those present in Ash Creek. As long as the vegetative conditions in the watersheds with stable stream types remain the same or improve, the channels will remain in equibrium, and therefore, stable.

Burnt, Indian, Big Buffalo, and Mexican Creeks exhibit patterns of stream types that have a general condition of equilibrium and inherent stability. The presence of deeper soils, flatter slopes and smaller drainage areas in these watersheds contributes to a greater degree of stability and general state of equilibrium. Bank erosion is occurring at locations in these watersheds where conditions such as localized disturbances, high bank erosion hazard, or vegetation sensitivity is the driving force for localized adjustment, as compared to Ash and Herd Camp Creeks, where the change is being driven by geologic downcutting in the watershed.

Conclusions for Classification Systems

Rosgen and Schumm classification systems use a 1.5 year bank full capacity as the basis for the channel to be classified. Intermittent channels in the inventoried watersheds made it difficult to determine bank full conditions based on visual observations. Regional curves developed from stream flow gauge data are normally used as an initial estimate of the bank full/drainage area relationship to aid in the identification of the bank full condition. Regional curves for the Bad River were based on USGS gauges in the area and were developed using gauge data from USGS Water Resources Investigation Manual 80-80. The 1.5 year bank full conditions were verified by a hydrologist using NRCS Technical Release 20 water surface profile software on randomly selected reaches.[1] Using the NRCS Technical Release 20, it was found that the water surface profiles calculated using antecedent moisture condition II (moist condition prior to storm event) exceeded the field determined bank full condition. Use of antecedent moisture condition I (dry condition prior to storm event) produced flow rates and water surface stages consistent with the field determined bank full stage.

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1. Flow characteristics for Watersheds in Central South Dakota, Mark Rath, Hydrologist, DENR, 3-28-96.

Channel classification provides a valuable tool for use in studies in which channel erosion is identified as a major resource concern in the watershed. Rosgen's method appears to give a more definitive classification with specific parameters governing each stream type. Guidelines have been developed based on design parameters governing restoration as well as management interpretations for specific Rosgen stream types. The Rosgen system is based on morphological features obtained from actual measurement rather than features observed by the classifier.

The Schumm method is not based on actual measurements but is an observation of channel conditions. The Schumm method would have an advantage in planning situations, where personnel not proficient in Rosgen's stream classification techniques could use Schumm's subjective descriptions of stage descriptions to classify the channel.

Sheet, Rill, and Ephemeral Gully Erosion

The sediment yield for sheet, rill, and ephemeral gully erosion from cropland and rangeland in the upper Bad River river basin was based on the same rates used in the Lower Bad River-River Basin Study (Table 17). Sheet and rill erosion from cropland was determined using the Universal Soil Loss Equation (USLE). The ephemeral gully erosion rates were calculated using the Ephemeral Gully Erosion Model (EGEM). The sheet and rill erosion on rangeland is based on the erosion rates determined in the Lower Bad River-River Basin Study using the SPUR-91 (Simulation of Production and Utilization of Rangelands) model. These methods are outlined in further detail in the Lower Bad River-River Basin Study Final Report.

Table 17 - Upper Bad River Sheet and Rill Erosion

Topographic Area	Area (Acres)	Erosion Tons/Acre/Year	Total Erosion Tons/Year	Sediment Delivery Ratio	Delivered Sediment Tons/Year
Uplands					
Cropland	452,046	3.8	1,717,775	0.1	171,777
Rangeland	114,100	0.5	57,050	0.1	5,705
Hayland	91,000	0.5	45,500	0.1	4,550
Breaks					
Rangeland	399,374	1.7	678,935	0.17	113,531
Badlands					
Rangeland	122,000	8	976,000	0.05	48,800
Valley					
Rangeland	60,200	0.2	12,040	0.2	2,408
SUBTOTAL	**1,238,720**				**346,771**

Upper Bad River Sediment Budget

The sediment budget for the upper Bad River is shown in Table 18. The channel classification system was used to identify sediment yield from channels and gullies. Sheet, rill and emphemeral gully erosion was calculated for each of the landform areas. Table 18 identifies the specific sources and amounts of sediment contributing to the previously measured sediment load of 1,182,060 tons delivered to Lake Sharpe from the Upper Bad River Watershed.

Table 18 - Upper Bad River Sediment Budget

Topographic Area	Area (acres)	Erosion t/ac/yr	Total Erosion Tons/year	Sediment Delivery Ratio	Delivered Sediment tons/year	Channel and Gully Type	Miles
UPLANDS							
Sheet and Rill							
Cropland	452,046	3.8	1,717,775	0.1	171,777		
Rangeland	114,100	0.5	57,050	0.1	5,705		
Hayland	91,000	0.5	45,500	0.1	4,550		
Ephemeral Gullies		0.4	181,218	0.1	18,122		
Channel & Gully					56,073	B	545
					286,447	C	2343
					12,819	E	256
					86,394	F	208
					5,442	G	9
BREAKS							
Sheet and Rill							
Rangeland	399,374	1.7	678,936	0.17	113,591		
Channel & Gully					43,352	B	409
					72,711	C	563
					19,296	E	361
					69,362	F	164
					10,280	G	16
BADLANDS							
Sheet and Rill							
Rangeland	122,000	8	976,000	0.05	48,800		
Channel & Gully					160	A	2
					13,459	B	126
					25,692	C	205
					6,475	E	116
					40,145	F	70
VALLEY							
Sheet and Rill							
Rangeland	60,200	0.2	12,040	0.2	2,408		
BAD RIVER CHANNEL BANK					69,000		
TOTALS	**1,238,720**				**1,182,060**		

CONCLUSIONS - UPPER BAD RIVER WATERSHED

The upper Bad River Watershed is relatively stable, and the overall condition of the watershed is good. Bank erosion is occurring at locations where conditions such as localized disturbances, high bank erosion hazard, or lack of vegetation are the cause for bank erosion. The inventory of channels found no areas, however, where bank erosion is a dominant feature. The stream types tend to be generally stable. The vegetative evaluation showed 85 percent of the rangeland to be in good and excellent condition and 15 percent to be in fair and poor condition.

Channel erosion is the largest source of sediment, accounting for 69 percent of the total sediment budget, and is comprised of the erosion from the following channel sources:

- channel and gully erosion along the main channel of the Bad River (6 percent)

- channel and gully erosion from areas identified during the field inventory as having active bank erosion and totaling approximately 27 miles of bank length, 0.7 percent of total channel erosion.

- geologic erosion from those channels identified during the field inventory as having stable banks, but which are still producing sediment, although at rates much lower than the channel sections with active bank erosion (62.3 percent).

Cropland erosion accounts for 16.5 percent of the total sediment budget, which is comprised of sheet and rill erosion (15 percent) and ephemeral gullies (1.5 percent), which form in cropland but are normally filled during tillage operations. Rangeland sheet and rill erosion accounts for 14.5 percent of the sediment budget.

The channels located in the Badlands landform are predominantly stable types with no areas where bank erosion is a predominant feature. Although the gross erosion rate for sheet and rill erosion is quite high, a large portion of this sediment does not reach Lake Sharpe. The Badlands landform comprises 10 percent of the upper basin land area and accounts for 11 percent of the annual sediment budget. These figures correlate with previous results of laboratory analyses of Lake Sharpe sediment samples, which determined the Badlands were not a major source of sediment.

Conservation practices considered applicable for controlling each type of erosion occurring in the watershed were evaluated on cost versus sediment reduction to Lake Sharpe. The estimated installation costs for each practice were amortized and then compared to estimated sediment reduction rates to calculate the cost per ton sediment reduction in Lake Sharpe. Those practices which had the lowest sediment reduction costs were primarily range management practices (deferment, grazing land mechanical treatment, prescribed grazing, farm ponds, critical area planting, stream barbs).

Improvements in the vegetative cover resulting from range management practices reduce sheet and rill erosion onsite and reduce channel erosion in riparian areas. Improved vegetative cover also improves hydrologic condition, reducing runoff volume and peak flows, which results in reduced channel erosion downstream. Ponds provide a sediment trap and a reduction in volume of flow and peak rates which also benefits downstream channels. The critical area plantings and stream barbs provide site specific erosion control for eroding banks. Those practices which increase vegetative cover and improve hydrologic condition have the greatest potential for affecting sediment reduction in the upper Bad River.

CONCLUSIONS - LOWER BAD RIVER WATERSHED

The study inventoried the channels in two watersheds in the lower basin as part of the upper Bad River river basin study. The inventory showed a large percentage of channels in the lower basin are of an unstable type (F and G), have characteristics similar to gullies and are producing 70 percent of the sediment attributed to the lower basin (1,443,251 tons). Bank erosion is a predominant feature on these unstable channels. The pattern of stream types indicates these unstable channels are the result of the watersheds being in an active downcutting phase which began at the mouth of the watersheds and has progressed upstream.

Channel erosion is the largest source of sediment, accounting for 85 percent of the total sediment budget in the lower basin, and is comprised of erosion from the following channel sources:

- streambank erosion along the main channel of the Bad River (3 percent)
- streambank erosion from areas identified in the field inventory as having active bank erosion and comprising 18.5 percent of the total bank length (36 percent).
- geologic erosion from those channels identified during the field inventory as having stable banks, but which are still producing sediment, although at rates much lower than the channel sections with active bank erosion (46 percent).

Those practices which had the best cost versus sediment reduction benefits in the lower Bad River study area were primarily range management practices, as also noted for the upper river basin study area. However, the practices which increased vegetative cover and improved hydrologic condition showed the greatest benefit on the F and G channel types, which are very prevalent in the lower river basin, and, therefore, would have the largest effect on sediment reduction to Lake Sharpe.

ALTERNATIVES

There are numerous combinations of conservation practices that can be used to reduce sediment delivery. A data base was established that considered conservation practices that would treat the erosion problem. The data base for the practices considered: (1) percent of sediment reduction of the practice, (2) average annual cost, (3) installation cost, and (4) units installed per mile or acre. Conservation practices used considered sediment reduction in the four different landforms, with the different land uses, and their effect on all types of erosion. The conservation practices were amortized at 8 percent interest for 30 years.

The following practices were considered in the data base:

CROPLAND SHEET AND RILL EROSION PRACTICES:

Pasture and Hayland Planting: Establishing long-term stands of adapted species of perennial, biennial, or reseeding forage plants.

Conservation Tillage System: Managing the amount, orientation, and distribution of crop and other plant residues on the soil surface year round, while growing crops in narrow slots or tilled strips in previously untilled soil residue. This includes practices such as no-till, strip-till, ridge-till and mulch-till.

Crop Residue Use: Managing the amount, orientation, and distribution of crop and other plant residues on the soil surface during part of the year while growing crops in a clean tilled seedbed.

RANGELAND SHEET AND RILL EROSION CONTROL:
Deferment 1: Delay of livestock grazing on an area for one growing season to provide for plant reproduction, establishment of new plants, or restoration of vigor of existing plants.

Deferment 2: Delay of livestock grazing on an area for one growing season to provide for plant reproduction, establishment of new plants, or restoration of vigor of existing plants. In addition, water development and fencing would be needed to the extent of 1 pond for each 640 acres, and 1,120 feet of cross-fence for every 640 acres.

Prescribed Grazing 1: Managing pastures so that not more than 50 percent of the annual production, by weight, is removed. Not more than 60 percent will be removed during the dormant season. Pastures will not be grazed during the same season in consecutive years.

Prescribed Grazing 2: Managing pastures so that not more than 50 percent of the annual production, by weight, is removed. Not more than 60 percent will be removed during the dormant season. Water development and fences will be included, and pastures will not be grazed during the same season in consecutive years.

Grazing Land Mechanical Treatment (Furrowing): Constructing three inch wide by four I inch deep furrows on the contour spaced two to five feet apart.

Grazing Land Mechanical Treatment (Subsoiling): Constructing six inch wide by eight inch deep furrows spaced three to four feet apart.

Farm Pond: A water development made by constructing a dam or embankment, or by excavating a pit or "dugout."

EPHEMERAL GULLY TREATMENTS
Waterway: A natural or constructed waterway or outlet, shaped or graded, and established to suitable vegetation for the safe disposal of runoff.

Crop Residue Use: Managing the amount, orientation, and distribution of crop and other plant residues on the soil surface during part of the year while growing crops in a clean-tilled seedbed.

Conservation Tillage System: Managing the amount, orientation, and distribution of crop and other plant residues on the soil surface year-round while growing crops in narrow slots or tilled strips in previously untilled soil residue.

CHANNEL AND GULLY TREATMENTS:

Critical Area Planting: Shaping eroding banks, seeding to erosion resistant grasses, and planting willow or other woody species in the channel and on the channel banks.

Streambank Protection: Protecting channel banks by using trees, rocks, and other bioengineering techniques to stabilize the bank. This would include such practices as rock toes, stream barbs, rock vortex weirs, and riparian exclusion.

Grade Stabilization (Traditional): A structure to stabilize the grade or to control head cutting in natural or artificial channels.

Grade Stabilization (Non-Traditional): Using willow brush boxes, willow packing, rock weirs, or other bioengineering methods to stabilize channels.

Diversion: A channel with a supporting ridge on the lower side constructed across the slope to divert runoff away from eroding areas.

ALTERNATIVE 1

This alternative implements no change in the existing conservation program. Presently in the upper Bad River Watershed, 22 percent of the rangeland is under some type of range management, and 15 percent of the cropland is under minimum tillage. 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.

The Bad River Watershed has been designated a high priority area under the Environmental Quality Incentives Program (EQIP) and will be in a position for additional funding to be used for the implementation of conservation practices.

Alternative 1 Continue with Present Conservation Efforts Upper Bad River Sedimentation Projections			
Year	1997	2002	2007
Sediment Yield (tons per year)	1,182,000	1,182,000	1,182,000

ALTERNATIVE 2

Alternative 2 includes conservation practices to reduce sheet and rill erosion on the cropland in the upper Bad River Watershed. This alternative focuses on applying the most cost-effective practices to treat sheet and rill erosion on cropland in the upper Bad River Watershed. Conservation practices considered are: (1) pasture and hayland planting, (2) conservation tillage system, and (3) crop residue use. Field personnel feel that 5 percent of the cropland would be seeded to pasture or range, 5 percent of the cropland would have conservation tillage applied, and 20 percent of the cropland would have crop residue use. This could be accomplished over a five year period.

Effects

This alternative would achieve a 3-percent sediment reduction in the upper Bad River by the year 2002 at a cost of $28.17 per ton of delivered sediment. Secondary benefits downstream would be gained by increasing infiltration and decreasing runoff (Table 19).

Alternative 2 Reduction of Sheet and Rill Erosion on Cropland Upper Bad River Sedimentation Projections			
Year	1997	2002	2007
Sediment Yield (tons per year)	1,182,000	1,144,500	1,107,000

Table 19 - Alternative 2

UPPER BAD RIVER WATERSHED - ALTERNATIVE 2 Effects of Practices on Sheet and Rill Erosion from Cropland				
Practice	Acres	Sediment Reduced Tons/Year *	Installation Cost $	Avg Annual Cost $
Pasture & Range Planting	22,600	8,100	1,550,000	140,000
Crop Residue Management	90,400	15,400		501,000
Conservation Tillage	22,600	4,700		204,000
Secondary Benefits Channels and Ephemeral Gullies		9,300		
TOTALS	135,600	37,500	$1,550,000	$845,000
Technical Assistance 20%			310,000	169,000
Project Administration 5%			77,500	42,250
TOTAL COSTS			$1,937,500	$1,056,250

*Projected sediment reductions by 2002

ALTERNATIVE 3

This alternative focuses on applying practices to treat sheet and rill erosion on rangeland in the upper Bad River Watershed.

Conservation practices for treating sheet and rill erosion on rangeland in the upper Bad River Watershed are: (1) deferment 1, (2) deferment 2, (3) grazingland mechanical treatment (subsoiling), (4) grazingland mechanical treatment (furrowing), (5) prescribed grazing 1, and (6) prescribed grazing 2.

This alternative assumes that 20 percent of the rangeland would be treated by prescribed grazing 1, 28 percent of the rangeland would be treated by prescribed grazing 2, 1 percent of the fair and poor rangeland would be treated with pasture furrows, and 1.5 percent of the rangeland would be treated by deferment 1. There would also be eight miles of critical area planting on the E type channels. These practices could be applied over two, five year periods.

Effects

Benefits would apply to the channels where conservation practices were applied by reducing runoff and increasing infiltration. Riparian benefits on the E type channels would increase wildlife habitat as well as provide a seed source for channels downstream. There would be a 4-percent reduction in sediment by the year 2002 at a cost of $5.55 per ton of delivered sediment (Table 20).

Alternative 3 Sheet and Rill Erosion Treatment for Rangeland Upper Bad River Sedimentation Projections			
Year	1997	2002	2007
Sediment Yield (tons per year)	1,182,000	1,132,000	1,082,000

Table 20 - Alternative 3

UPPER BAD RIVER WATERSHED - ALTERNATIVE 3 Effects of Practices on Sheet and Rill Erosion from Rangeland				
Practice	Acres	Sediment Reduced Tons/Year *	Installation Cost $	Avg Annual Cost $
Prescribed Grazing 1	140,000	18,000	201,000	39,000
Prescribed Grazing 2	196,000	25,000	1,350,000	175,000
Mechanical Treatment (furrows)	850	550	10,000	1,000
Deferment 1	10,500	500	75,000	7,000
Critical Area Planting 8 miles "E" channels		1,200	11,000	1,000
Secondary Benefits to channels		5,000		
TOTALS	347,350	50,250	$1,647,000	$223,000
Technical Assistance 20%			329,400	44,600
Project Administration 5%			82,350	11,150
TOTAL COSTS			$2,058,750	$278,750

*Projected sediment reductions by 2002

ALTERNATIVE 4
Alternative 4 is a combination of Alternative 2 and Alternative 3 for treating sheet and rill erosion on the cropland and rangeland in the upper Bad River Watershed. This combination of practices would treat 40 percent of the upper Bad River Watershed.

Effects
There would a 7 percent reduction in sediment by the year 2002.

The secondary benefits to the channels, gained from applying the conservation practices to the rangeland and cropland, would be a 1.2 percent reduction in delivered sediment to Lake Sharpe.

The cost of applying Alternative 4 by the year 2002 would be $15.21 per ton of delivered sediment (Table 21).

Alternative 4 Sheet and Rill Erosion Treatment for Rangeland Upper Bad River Sedimentation Projections			
Year	1997	2002	2007
Sediment Yield (tons per year)	1,182,000	1,094,000	1,006,500

Table 21 - Alternative 4

UPPER BAD RIVER WATERSHED - ALTERNATIVE 4 Effects of Practices on Sheet & Rill Erosion from Rangeland & Cropland				
Practice	Acres	Sediment Reduced Tons/Year	Installation Cost $	Avg Annual Cost $
Prescribed Grazing 1	140,000	18,000	201,000	39,000
Prescribed Grazing 2	196,000	25,000	1,350,000	175,000
Mechanical Treatment (furrows)	850	550	10,000	1,000
Deferment 1	10,500	500	75,000	7,000
Critical Area Planting 8 miles "E" Channels		1,200	11,000	1,000
Pasture and Range Planting	22,600	8,100	1,550,000	140,000
Crop Residue Mgt	90,400	15,400		501,000
Conservation Tillage	22,600	4,700		204,000
Secondary Benefits channels and ephemeral Gullies		14,300		
TOTALS	482,950	87,750	$3,197,000	$1,068,000
Technical Assistance 20%			639,400	213,600
Project Administration 5%			159,850	53,400
TOTAL COSTS			$3,996,250	$1,335,000

Table 22 shows a comparison of the alternatives for their effects on erosion, sediment yield, offsite conditions and the costs involved.

Table 22 - Effects of Alternatives

Problems of Concern	**ALTERNATIVES**						
	1	2	3	4	5	6	7
EROSION: sheet & rill	0	*	*	*	* *	*	* *
EROSION: ephemeral gullies	0	*	0	*	0	*	* *
EROSION: channel & gully	0	*	0	*	*	0	* *
EROSION: Bad River channel banks	0	0	0	0	0	0	0
SEDIMENT YIELD: rangeland	0	0	*	*	* *	0	* *
SEDIMENT YIELD: cropland	0	*	0	*	0	*	* *
OFFSITE: riparian	0	*	*	*	*	*	* *
OFFSITE: wildlife	0	*	*	*	*	*	*
OFFSITE: recreation	0	0	0	0	0	0	0
OFFSITE: power generation	0	0	0	0	0	0	0
Average annual costs		$2,222,500	$213,475	$2,436,600	$637,831	$1,620.00	$2,257,831
Installation costs		$5,375,000	$2,106,125	$7,481,125	$6,905,438	$3,000,000	$9,905,438
Average annual Sed reduction Tons/year		37,500	50,810	88,310	187,607	59,600	193,607
Cost/Ton sed reduction		$205	$46	$112	$40	$78	$63

Effect	Definition
Negligible (0)	Little to no significant effect
Moderate (*)	Significant improvement
Significant (* *)	Considerable positive effect

GLOSSARY

BADLANDS: A landscape which is intricately dissected and characterized by a very fine drainage network with high drainage densities and short, steep slopes with narrow interfluves.

BREAKS: The area of rough land dissected by draws, ravines or gullies. The sudden change in topography as from a plain to hilly country.

BIOMASS: The total amount of living plants and animals above ground in an area at a given time.

CHANNEL: The deepest or central part of the bed of a stream, containing the main current and occupied more or less continuously by water.

DRAW: A small stream channel, generally more open and with a broader floor than a ravine or gully.

EPHEMERAL GULLY: A temporary gully found only on cropland, which is usually filled during normal tillage operations.

EROSION: The wearing away of the land surface by running water, wind, or by such process as mass wasting.

EROSION (GEOLOGIC): Erosion caused by geologic processes and resulting in the wearing away of mountains and the building up of such landscape features as floodplains and coastal plains.

FLOOD PLAIN: The nearly level plain that borders a stream and is subject to inundation under flood stage conditions.

FRAGILE: A soil that is easily damaged by use or disturbance.

GROUND COVER: The percentage of material, other than bare ground, covering the land surface.

GULLY: A very small channel with steep sides cut by running water and through which water ordinarily runs only after a rain or snowmelt. The distinction between a gully and a rill is one of depth.

INTERFLUVE: The relatively undissected upland or ridge between two adjacent valleys containing streams flowing in the same general direction. Any elevated area between two drainageways that sheds water to those drainageways.

MULCH: A layer of dead plant material on the soil surface.

POINT BAR: One of a series of low, arcuate ridges of sand and gravel developed on the inside of a growing meander by the slow addition of individual accretions accompanying migration of the channel toward the outer bank.

PROPER GRAZING USE: Grazing at an intensity that maintains enough cover to protect the soil and maintain or improve the quantity and quality of the desirable vegetation.

RANGE CONDITION: The present composition of the plant community on a range site in relation to the potential natural plant community for that site. Range condition is expressed as excellent, good, fair, and poor on the basis of how much the present plant community has departed from the potential.

RANGE CONDITION CLASS: One of a series of arbitrary categories used to classify ecological status of a specific range site in relation to its potential.

Range Condition Class	Percent of Climax for the Range Site
Excellent	76-100
Good	51-75
Fair	26-50
Poor	0-25

UNUSED: No livestock use.

SLIGHT: Appears practically undisturbed when viewed obliquely. Only favored areas near water, trails, or shade, and choice plants are grazed.

MODERATE: Most all accessible range shows grazing. Little or no use of poor forage. Little evidence of trailing to grazing.

FULL: All fully accessible areas are grazed. The major sites have key forage species properly utilized (about 1/2 taken and 1/2 left). Areas of concentration with overuse are limited to between 5 and 10 percent.

CLOSE: All accessible range plainly shows use, and major sections are closely cropped. Livestock are forced to use much poor, dry, and stemmy forage, considering seasonal preference.

SEVERE: Key forage species almost completely used. Low value forage carrying grazing load. Trampling damage is widespread in accessible areas.

EXTREME: Range appears stripped of vegetation. Key forage species are weak from continual grazing of regrowth. Poor quality forage closely grazed. Livestock trail great distances for forage.

RANGELAND: Land on which the potential natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs suitable for grazing or browsing.

RILL: A steep-sided channel resulting from accelerated erosion. A rill generally is a few inches deep and not wide enough to be an obstacle to farm machinery.

RIPARIAN: The areas in ecosystems that occur along water courses or water bodies. 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.

SHEET EROSION: Occurs as water flows over land and moves particles loosened by raindrop impact.

UPLAND: A general term for the higher ground of a region, in contrast with a valley, plain, or low area.

VALLEY: A floodplain landform. A general term for broad, nearly level floodplain surfaces adjacent to the main stream channel.

VIGOR: Relates to the relative robustness of a plant in comparison to other individuals ofthe same species. It is reflected primarily by the size of a plant and its parts in relation to its age and the environment in which it is growing.

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APPENDICES

APPENDIX A - AVERAGE ANNUAL NATIONAL ECONOMIC DEVELOPMENT (NED) DAMAGES

Fishing

The South Dakota Department of Game, Fish and Parks (GF&P) has conducted an angler survey of Lake Sharpe each year since 1991. The purpose of this creel survey is to measure and evaluate fishing pressure in the area. Lake Sharpe is divided into three major areas for this survey: reach 1 extends from the tailwaters of Lake Oahe to LaFrambois Island, reach 2 is from LaFrambois Island to the DeGrey Recreation area, and reach 3 is downstream from the DeGrey Recreation Area. The South Dakota Department of Game, Fish and Parks has estimated that the sport fishing on Lake Sharpe from the Bad River to DeGrey is valued from $1,087,000 to $2,556,000 annually.

The sediment laden waters from the Bad River severely restrict fishing in reach 2 of Lake Sharpe. The average Bad River sediment discharge for the years 1991 through 1996 for the months April through September has been 1.6 million tons. Creel surveys for this same time period indicate fishing pressure to have averaged about 49,000 hours. By selecting the maximum fishing pressure for each corresponding month of this 6 year period, the potential fishing pressure is estimated to have been 125,000 hours, nearly 60 percent greater than actual use. Sediment discharged from the Bad River only during these months was 25,000 tons, 99 percent less than the actual average discharge. Although other factors may have a significant impact on fishing pressure, e.g., weather, the economy, personal preferences, etc., sediment is assumed to be the major factor in this analysis. See Chart 1 for comparisons.

Chart 1 - Fishing on Lake Sharpe [1]

Actual Average Sediment and Fishing Hours					
Year	Month	Sediment Load	Zone 1	Fishing Hours Zone 2	Zone 3
91-96	April	253,116	16,263	4,308	7,295
91-96	May	792,093	39,170	14,707	40,068
91-96	June	433,367	25,922	5,645	67,187
91-96	July	183,914	20,373	4,030	49,340
91-96	August	16,718	12,976	6,142	16,167
91-96	September	4,334	22,831	14,534	11,800
	TOTALS	1,693,542	127,830	49,365	191,855
Zone 2 NED Average Annual Value				$109,099	
Zone 2 RED Average Annual Value				$806,938	
Potential Fishing Pressure Using 5 Year Low Sediment Load					
Year	Month	Sediment Load	Zone 1	Fishing Hours Zone 2	Zone 3
1992	April	4	15,411	12,204	7,245
1992	May	0	28,225	29,845	42,791
1992	June	24,638	28,555	15,640	84,642
1995	July	934	34,616	5,850	64,223
1991	August	1	11,124	23,559	14,275
1994	September	0	7,612	38,489	22,304
	TOTALS	25,577	125,543	125,587	235,480
NED Potential Annual Value				$277,553	
RED Potential Annual Value				$1,329,549	
NED Average Annual Loss				$168,454	
RED Average Annual Loss				$806,938	

1. 1990 - 95 Angler and Sport Fishing Harvest Survey on Lake Sharpe, South Dakota Department of Game, Fish and Parks

In 1994, the U.S. Army Corps of Engineers (COE) estimated the National Economic Development (NED) value of fishing in Lake Sharpe at $8.35 per visitor day[1]. This is an estimate of net benefits to the national economy received from expenditures by anglers using Lake Sharpe. The average fishing trip on the lake lasts 4 hours, a NED value for an hour of fishing would be $2.09. Indexed to current dollars, this would amount to $2.21 per hour. Assuming that losses are attributable to sediment produced by the Bad River, the NED average annual recreation loss is $168,454.

In 1993, the regional impact of Lake Sharpe fishing expenditures was estimated at $39 per day ($9.75 per hour) [2]. In current dollars, this increases to $10.63 per hour. The RED average annual recreational loss based on the 1991-1996 creel survey data is $806,938.

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 $76,504 in current dollars. Much of Fort Pierre is within the 100-year floodplain of the Bad River. Measures that would reduce the sediment load would also reduce the flooding problem. [3]

Electric Power Generation

The Oahe Dam, located three miles upstream from the mouth of the Bad River, has a peak power production of 731 metawatts. 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 power plant 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 megawatts. The combination of effects prevents the 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 $12,600,000, a result of the need for Western Area Power Administration to purchase replacement generating capacity [4]. Indexed to current dollars, this amounts to $13,860,000 annually.

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1. 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.
2. U.S. Army Corps of Engineers, Masters Water Control Manual for the Missouri River, Volume 6C: Economic Studies, Recreational Economics, May 1993 draft, p. 33.
3. U.S. Army Corps of Engineers, Western Dakota Region of South Dakota Water Resources Study, 1985
4. 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.

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. In 1985, the COE estimated the economic loss from sediment filling the lake by using an 8.625 percent discount rate at $4 per acre foot ($0.0025 per cubic yard or $0.003 per ton of sediment) [5]. The estimated damage from a sediment load of 3,250,000 tons to the lake is $14,000 annually in current dollars.

Chart 2 summarizes the known average annual NED damages in the Pierre and Fort Pierre areas related to the Bad River sediment load.

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

Chart 2 - Downstream Average Annual NED Damages
Relating to the Bad River

1.	1991-1995 NED Recreational Damages	$168,454
2.	Average Annual Fort Pierre Flood Damages	$76,504
3.	Loss of peak winter power generation	$13,860,000
4.	Long-term loss of storage in Lake Sharpe	$14,000
Total downstream NED damages		$14,109,965

APPENDIX B - WILDLIFE HABITAT RATING

In the Natural Resources Conservation Service, wildlife habitat quality is evaluated by looking at the existing and potential value of the landscape for wildlife. Grain and seed crops are domestic grain and seed producing plants such as corn, wheat, oats, and barley. Grasses and legumes are domestic perennial grasses and herbaceous legumes, such as intermediate wheatgrass, smooth bromegrass, sweet clover, and alfalfa. Hardwood trees are planted trees and shrubs that produce nuts or other fruit, buds, catkins, twigs, bark, and foliage. Examples include bur oak, cottonwood, currant, chokecherry, American plum, hackberry, green ash, box elder, and silver buffaloberry.

Wildlife habitat quality is quantified by evaluating the average condition of the potential habitat type (stream, lake and pond, wetland, native woody cover, windbreaks, cropland, rangeland, hayland, and pastureland) and assigning a habitat rating ranging from 0.0 (poorest) to 1.0 (optimal) for each habitat type (NRCS Technical Guide, Section III-Conservation Management Systems, November 1992).

The Bad River river basin project area encompasses portions of 6 counties: Haakon County (602,967 acres); Jackson County (361,560 acres); Jones County (357,735 acres); Lyman County (6,289 acres); Pennington County (167,317 acres); and Stanley County (534,760 acres). To facilitate assessment of wildlife habitat quality within each county, one or two representative subwatersheds were examined. It is assumed that the general trends are similar within the other subwatersheds of that county.

Wildlife Habitat Quality Rating [1]

Upper Bad River-River Basin Study

Jackson County

(Big Buffalo Creek subwatershed is 36,181 acres; Indian Creek subwatershed is 65,555 acres)

	Big Buffalo Creek			**Indian Creek**		
Habitat Type	**Existing**	**Without**	**With**	**Existing**	**Without**	**With**
Wetlands						
Stream	.55	.55	.58	.59	.59	.61
Lake and Pond	.45	.45	.45	.45	.45	.45
Wetland	.37	.37	.47	.42	.42	.42
Woodlands						
Native Woody	.41	.41	.42	.42	.42	.42
Windbreaks	.46	.46	.48	.41	.41	.44
Openland						
Hayland, Pasture or CRP	.52	.35	.51	.69	.35	.58
Rangeland	.45	.45	.47	.46	.46	.50
Cropland	.35	.33	.48	.34	.32	.53
Average	.55	.52	.58	.57	.53	.60

Haakon County

(Mitchell Creek subwatershed is 105,725 acres; Mexican Creek subwatershed is 23,139 acres)

	Mitchell Creek			**Mexican Creek**		
Habitat Type	**Existing**	**Without**	**With**	**Existing**	**Without**	**With**
Wetlands						
Stream	.30	.27	.39	.38	.27	.39
Lake and Pond	.36	.34	.48	.34	.34	.47
Wetland	.34	.34	.53	.36	.36	.47
Woodlands						
Native Woody	.41	.40	.46	.41	.40	.46
Windbreaks	.46	.46	.46	.46	.46	.47
Openland						
Hayland, Pasture or CRP	.49	.33	.34	.63	.40	.47
Rangeland	.37	.37	.38	.37	.37	.43
Cropland	.36	.36	.41	.35	.35	.41
Average	.49	.36	.53	.51	.37	.55

Haakon, Jackson, and East Pennington Counties
(Lake Creek subwatershed includes 18,330 acres in Haakon County;
11,478 acres in Jackson County; 58,191 acres in East Pennington County)

	Lake Creek		
Habitat Type	**Existing**	**Without**	**With**
Wetlands			
Stream	.53	.46	.57
Lake and Pond	.47	.47	.56
Wetland	.42	.42	.47
Woodlands			
Native Woody	.39	.42	.50
Windbreaks	.45	.44	.45
Openland			
Hayland, Pasture or CRP	.47	.34	.36
Rangeland	.37	.37	.45
Cropland	.34	.34	.37
Average	.53	.50	.57

Jones and Stanley Counties
(Herd Camp Creek subwatershed includes
26,154 acres in Jones County; and 4,618 acres in Stanley County)

	Herd Camp Creek Jones County			Herd Camp Creek Stanley County		
Habitat Type	**Existing**	**Without**	**With**	**Existing**	**Without**	**With**
Wetlands						
Stream	.20	.19	.27	.20	.50	.30
Lake and Pond	.27	.23	.42	.22	.22	.22
Wetland	.21	.21	.32	.55	.55	.55
Woodlands						
Native Woody	NA	NA	NA	.51	.50	.54
Windbreaks	.45	.50	.50	.50	.50	.50
Openland						
Hayland, Pasture or CRP	.73	.76	73	NA	NA	NA
Rangeland	.50	.47	.52	.56	.53	.58
Cropland	.47	.50	.57	NA	NA	NA
Average	.40	.41	.48			

Stanley County
(Willow Creek subwatershed includes 40,812 acres)

	Willow Creek		
Habitat Type	**Existing**	**Without**	**With**
Wetlands			
Stream	.24	.24	.44
Lake and Pond	.38	.38	.47
Wetland	.38	.38	.38
Woodlands			
Native Woody	.65	.64	.67
Windbreaks	.38	.35	.46
Openland			
Hayland, Pasture or CRP	.86	.86	.86
Rangeland	.49	.49	.54
Cropland	.38	.38	.49
Average	.47	.47	.64

1. Reference: South Dakota Technical Guide
   Section III - Quality Criteria Rating System for Habitat for Wild Animals, Tables 1 through 6, dated November 1992 (Notice SD-1).

APPENDIX C - VEGETATIVE SAMPLING DATA

Chart 3 - Summary of Bulk Density

Chart 4 - Range Condition by County

	Total		**C O N D I T I O N**		
Stanley County	**Rangeland**	**Exc.**	**Good**	**Fair**	**Poor**
Ash	8,542	25%	65%	8%	2%
Big Prairie Dog	26,112	35%	62%	2%	1%
Broken Neck	8,184	24%	70%	3%	3%
Cotton/Plum	87,257	32%	60%	7%	1%
Crow Eagle	19,032	40%	55%	3%	2%
Dry Run	8,170	25%	63%	10%	2%
Gray Blanket	15,007	37%	50%	10%	3%
Herd Camp	4,618	55%	45%		
Lance	28,097	25%	65%	7%	3%
Little Prairie Dog	7,084	35%	58%	5%	2%
Lone Tree	82		100%		
Porcupine	14,196	40%	55%	3%	2%
Powell	10,921	22%	72%	5%	1%
Stranger	8,100	30%	55%	5%	10%
Tomahawk	8,352	30%	67%	2%	1%
War	22,900	40%	53%	5%	2%
White Clay	2,921	40%	55%	4%	1%
Willow	43,710	45%	52%	2%	1%
Yellow Shoulder	12,139	40%	55%	3%	2%

	Total		**C O N D I T I O N**		
Jones County	**Rangeland**	**Exc.**	**Good**	**Fair**	**Poor**
Ash Creek	1,005	55%	35%	8%	2%
Big Prairie Dog	18,912	45%	49%	5%	1%
Crow Eagle Creek	2,257	27%	65%	6%	2%
Dry Creek	59,993	37%	50%	10%	3%
Herd Camp	14,778	40%	53%	5%	2%
Little Prairie Dog	6,679	35%	59%	5%	1%
Lone Tree	10	10%	90%	0%	0%
Porcupine	180	50%	47%	3%	0%
South Creek	35,321	25%	62%	8%	5%
War Creek	37,161	65%	30%	3%	2%
White Clay	63,366	40%	49%	8%	3%

Jackson County	Total Rangeland	Exc.	CONDITION Good	Fair	Poor
Ash Creek	7,329	25%	60%	10%	5%
Big Buffalo	26,123	25%	55%	17%	3%
White Willow	61,160	25%	60%	10%	5%
Brave Bull	51,601	25%	60%	10%	5%
Dry Creek	1,608	20%	60%	15%	5%
Hay Draw Creek	1,310	25%	60%	10%	5%
Indian Creek	37,000	25%	65%	9%	1%
Lake	10,481	20%	55%	20%	5%
South Fork	75,830	15%	65%	15%	5%
South Creek	460	20%	60%	15%	5%
Upper Cottonwood	1,935	20%	65%	10%	5%

Haakon County	Total Rangeland	Exc.	CONDITION Good	Fair	Poor
Ash Creek	13,706	29%	65%	5%	1%
Big Prairie Dog	2,129	25%	65%	8%	2%
White Willow	11,018	24%	65%	8%	3%
Brave Bull	10,193	29%	65%	5%	1%
Buzzard Creek	23,234	20%	62%	15%	3%
Cottonwood/Plum	12,941	25%	65%	8%	2%
North Fork Bad	45,291	15%	58%	25%	2%
Dry Creek	19,713	20%	62%	15%	3%
Grindstone	27,397	15%	52%	30%	3%
Hay Draw Creek	7,697	29%	65%	5%	1%
Indian Creek	9,754	29%	65%	5%	1%
Little Prairie Dog	6,482	28%	65%	5%	2%
Lone Tree	6,204	26%	65%	8%	1%
Lake Creek	9,532	15%	58%	25%	2%
Medicine Creek	26,287	18%	65%	15%	2%
Mexican Creek	15,040	18%	60%	20%	2%
Mitchell Creek	62,378	20%	65%	13%	2%
Squaw Creek	40,047	20%	65%	13%	2%
Philip East	3,238	15%	57%	25%	3%
South Creek	3,821	24%	65%	10%	1%
South Fork Bad	3,602	20%	65%	13%	2%
Wilburn Creek	11,360	20%	68%	10%	2%

Pennington County	Total Rangeland	Exc.	CONDITION Good	Fair	Poor
North Fork Bad River	10,906	15%	58%	25%	2%
Lake Creek	32,604	15%	58%	25%	2%
South Fork Bad River	54,790	20%	58%	20%	2%
Upper Cottonwood	22,129	15%	58%	25%	2%

1. South Dakota Agricultural Statistics Service.
2. April 1992, Survey of Current Business, Bureau of Economic Analysis, U.S. Department of Commerce.
3. September 1996 South Dakota Labor Bulletin, South Dakota Department of Labor.
4. 1990 US census data furnished by the Census Data Center, Department of Rural Sociology, South Dakota State University.
5. 1992 Census of Agriculture, Part 41, South Dakota, State and County Data.
6. ibid.
7. ibid.
8. March 1996, South Dakota 1996 County Level Land Rents and Values, South Dakota Agricultural Statistics Service.
9. ibid.
10. Flow characteristics for Watersheds in Central South Dakota, Mark Rath, Hydrologist, DENR, 3-28-96