A REMOTE SENSING STUDY OF SEDIMENT IN THE CLARKS FORK YELLOWSTONE RIVER

Prepared For:

Bureau of Reclamation
Department of the Interior
Denver, Colorado

By

James F. Ruff

Morris M. Skinner

John W. Keys III

Dennis Waugaman

Civil Engineering Department
Colorado State University
Fort Collins, Colorado
November, 1972

ABSTRACT

Interpretation of remotely sensed data was used to locate and identify perennial and intermittent tributaries to the Clarks Fork Yellowstone River, Rock Creek and Red Lodge Creek located in southcentral Montana and northwestern Wyoming. Color infrared photography and thermal infrared imagery were obtained which covered the river and a strip of the flood plain approximately 1 1/2 to 2 1/2 miles wide. Inflows and contributing sources of sediment from tributaries, ditches, and gullies to the Clarks Fork Yellowstone River were located and identified. Results of the study indicate that aerial color infrared photography and thermal infrared imagery are practical tools for locating and identifying inflow of sediment laden water to a river system.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Purpose of Study

This report presents the results of a cooperative study of sediment problems in the Clarks Fork Yellowstone River by the Bureau of Reclamation and Colorado State University. The basic purposes of the study were: (1) to locate the points at which sediment loads are discharged into the river, (2) to estimate the relative magnitude of sediment concentrations in the river and tributary flows, and (3) to show the usefulness of aerial remote sensing techniques (color infrared photography and thermal imagery) in monitoring and studying sediment movements in a river system.

Background

Historically, the Clarks Fork Yellowstone River, located in south-central Montana and northwestern Wyoming, has discharged heavy loads of sediment annually into the Yellowstone River. The transport of this material from the basin has destroyed much of the potential of the river for trout fishing and recreation, represents a substantial loss of top-soil to the agriculturists, and has created numerous problems for public water supplies. The soils, topography, rainfall pattern, land use, and irrigation practices of the basin are the principal causes for sediment in the river and its deposition in the stream channel.

In an effort to define sediment and siltation problems and their causes in the Clarks Fork Yellowstone River, the 1971 Montana State Legislature established the Clarks Fork Siltation Study Committee and charged it with the preparation of a report on its findings for the 1973 legislative session (1971 House Resolution No. 24). Composed of representatives from several state agencies, federal agencies, and various county and local organizations, the Committee began its investigation of the basin during the summer of 1971. In early discussions of investigative procedures, the use of remote sensing techniques to aid in the study was considered, and the Bureau of Reclamation agreed to support such an investigation as part of its participation in the program. This report is a result of that support.

This study of sediment in the Clarks Fork Yellowstone River was conducted primarily by personnel of the Civil Engineering Department of Colorado State University under contract and with assistance from the Bureau of Reclamation. The Upper Missouri Regional Office of the Bureau in Billings, Montana, provided a portion of the financial support for the project, supplied personnel to conduct the reconnaissance and ground-truth data programs in the basin, and assisted in the interpretation of the imagery and preparation of the report. The Engineering and Research Center in Denver, Colorado provided the balance of the financial support for the study and supplied personnel and equipment to aid in the interpretation of the remote sensing data. This report is a combined effort of Colorado State University and Bureau of Reclamation personnel.

Scope of the Investigation

To accomplish the basic purposes of the study, inflows of surface water to the Clarks Fork Yellowstone River, Rock Creek and a portion of Red Lodge Creek were located and identified. The inflows involved both perennial and intermittent tributaries to these rivers and irrigation return flows including drainage from high water table areas and canal wasteway flows.

Remote sensing provides the most practical method of obtaining data to achieve the above objectives. The data can be easily obtained and coverage of the entire area is accomplished in a relatively short period of time. Stereoscopic viewing of overlapping photographs assists the interpretation by providing topographic relief to delineate the small drainage areas, catchments, and watersheds.

Color infrared photography with 60% endlap for stereoscopic viewing and thermal infrared imagery were obtained for the rivers and adjacent flood plains shown in Figure 1. The photographs provided coverage of a strip of the flood plain approximately 1-1/2 miles wide for Red Lodge Creek, Rock Creek and the lower section of the Clarks Fork Yellowstone River. The coverage of the upper 36 miles of the Clarks Fork Yellowstone River provided a strip approximately 2-1/2 miles wide. Interpretation of the data was based upon and limited to this coverage.

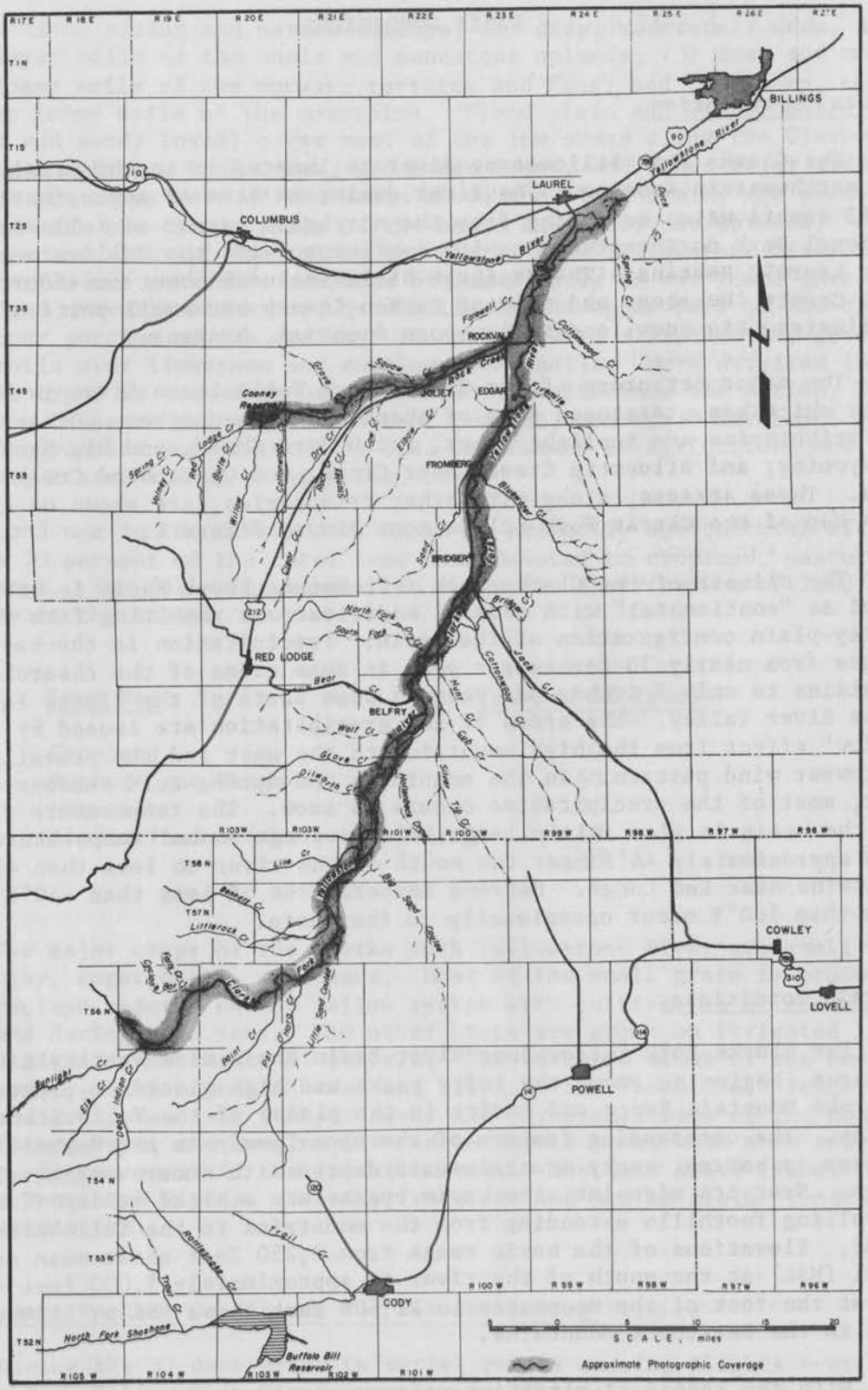

Figure 1 Location Map of the Clarks Fork Yellowstone River Remote Sensing Project

BASIN CONDITIONS

General Description

The Clarks Fork Yellowstone River is located in southcentral Montana and northwestern Wyoming. The river drains an area of approximately 2,783 square miles extending from the northeast corner of Yellowstone National Park northeastward to its confluence with the Yellowstone River near Laurel, Montana. The drainage basin includes about one-fourth of Park County, Wyoming, and most of Carbon County and small parts of Park, Stillwater, Big Horn, and Yellowstone Counties, Montana.

The major tributary of the Clarks Fork Yellowstone River is Rock Creek which has a drainage area of about 571 square miles. Other important tributaries are Sunlight Creek, Pat O'Hara Creek, and Big Sand Coulee in Wyoming, and Silvertip Creek, Bear Creek, and Cottonwood Creek in Montana. These streams, along with other tributaries, are shown on the Location Map of the Clarks Fork Yellowstone River, Figure 1.

The climate of the Clarks Fork Yellowstone River Basin is broadly classified as "continental" with several modifications resulting from the mountain-valley-plain configuration of the basin. Precipitation in the basin ranges from nearly 70 inches per year in some areas of the Absaroka Mountains to only 7 inches per year in some parts of the Clarks Fork Yellowstone River Valley. The areas of low precipitation are caused by a "rain shadow" effect from the high mountains to the west and the prevailing west to southwest wind pattern. In the mountains and during cold seasons of the year, most of the precipitation occurs as snow. The temperature range for the basin is also fairly large, with average annual temperatures varying from approximately 46°F near the mouth of the river to less than 40°F in the mountains near Red Lodge. Estreme temperatures of less than -40°F and more than 100°F occur occasionally in the basin.

Terrain Conditions

The Clarks Fork Yellowstone River Basin has a wide variety of physical features, beginning among the lofty peaks and high glaciated plateaus of the Absaroka Mountain Range and ending in the plains of the Yellowstone River Valley. The outstanding feature of the upper basin is the Beartooth Plateau, a barren, rocky mountain-mass dotted with numerous glacial lakes. Near its midpoint, the basin opens into a broad valley flanked by rolling foothills extending from the mountains to the Yellowstone River. Elevations of the basin range from 3,250 feet above mean sea level (MSL) at the mouth of the river to approximately 5,000 feet above MSL at the foot of the mountains to 12,600 feet above MSL at Silver Run Peak in the Beartooth Mountains.

With the ranges of elevation, topography, and precipitation present in the Clarks Fork Yellowstone River Basin, soil types are quite varied depending upon the location of sites in question. Generally, there are four main soil groups in the drainage area: (1) loamy well-drained soils

of the flood plains and narrow valleys; (2) deep, moderately deep, and shallow clayey soils of the shale and sandstone uplands; (3) deep and moderately deep loamy soils of the outwash terraces and fans; and (4) steep, shallow to deep loamy soils of the mountains. Flood plain and valley soils (loams and sandy loams) cover most of the low areas along the Clarks Fork Yellowstone River, Rock Creek, Red Lodge Creek, and other major tributaries. Land of the lower half of the basin above the flood plains are predominantly covered with the clayey soils of the shale and sandstone uplands. Outwash, terraces and alluvial fans along the Clarks Fork Yellowstone River and its tributaries are generally composed of loamy soils in the lower part of the basin and gravelly and stony, loam soils in the upper part of the basin. The upper portion of the drainage is covered with alpine soils, generally loam soils over limestone and shallow stony soils. More detailed information on soil types in the basin can be found in "Guidelines for Action, Beartooth Resource Conservation and Development Project, Montana," developed by Project Sponsors and assisted by U.S. Department of Agriculture and other Federal, State, and Local Agencies, 1970.

Land use in the Clarks Fork Basin is primarily agricultural with nearly 70 percent of the total land area devoted to cropland, pasture, and range. The following tabulation shows the distribution of land and its use in the basin:

Land Use	Percent of Total
Cropland	10
Pasture and Range	60
Forest	20
Alpine Tundra (above timberline)	10
	100

The major crops of the Clarks Fork Yellowstone River are small grains, corn, hay, sugar beets, and beans. Most of the small grain is produced on dry cropland under a summer fallow system with cultivation of about half of the land during each year. The other crops are grown on irrigated land along with a significant amount of pasture. The forested areas of the basin cover most of the mountain areas and parks of the foothills. Ponderosa pine and Rocky Mountain juniper cover the forested slopes of the mountains and drainageways, and Douglas fir and lodgepole pine, with some aspen in the low areas, occur in the foothill areas. The land above timberline in the Beartooth Plateau contains few trees and has an Alpine tundra-type vegetation.

Antecedent Weather Conditions for Remote Sensing Flights

During the 30 days prior to aerial remote sensing flights over the Clarks Fork Yellowstone River, weather conditions in the basin were generally cool and wet. Temperatures for the area were about five degrees below normal with an average of about 65°F. There were three significant rainstorms over most of the basin during the July 18 - August 18 period.

These storms and their precipitation were as follows:

Storm Period	Area of Basin	Precipitation
July 19-21	Entire basin with heaviest rainfall in western and northern portion of basin	1.3 inches
August 2-3	Entire basin with heaviest rainfall in northern portion of basin	1.0 inches
August 13-15	Light rain in eastern portion with heavy rainfall in western portion of basin	.5 inches

The August 13-15 storm deposited heavy amounts of rain in the southwestern portion of the basin on August 13 with some local flooding around Cooke City, Montana. It was estimated that flooding had subsided and runoff conditions were nearly normal at the time of the remote sensing flights which were made on August 18, 1972.

On the day of the aerial remote sensing flights, streamflow at U.S. Geological Survey gaging stations in the Clarks Fork Yellowstone River basin was as follows:

Station No.	Stream and Station	Flow (c.f.s.)
6207500	Clarks Fork Yellowstone River near Belfry	2,100
6208800	Clarks Fork Yellowstone River near Silesia	1,150
6209500	Rock Creek near Red Lodge	370
6211000	Red Lodge Creek above Cooney Reservoir	25
6212500	Red Lodge Creek below Cooney Reservoir	125

These flows are higher than normal for the basin at that time of the year, but they reflect the above-normal precipitation in the area for the entire summer. Flows of the main stem of the Clarks Fork Yellowstone River are reduced between Belfry and Silesia by irrigation diversions.

With these background conditions on the Clarks Fork Yellowstone River basin, the aerial remote sensing study of sediment problems in the river was conducted. The following sections describe that study and its results.

PROCEDURE

The basic procedure for the investigation of sediment in the Clarks Fork Yellowstone River involved four main phases of operation: (1) a reconnaissance of the basin to outline the problems to be investigated and general conditions of the area, (2) the ground-truth data program to collect physical information from the study area to relate to the photographs and imagery, (3) aerial flights to obtain the necessary color infrared photographs and thermal imagery to adequately cover the areas in question, and (4) the interpretation and analysis of results from these three data collection programs.

Reconnaissance

The first step in the study of sediment in the Clarks Fork Yellowstone River was several reconnaissance surveys of the basin to review the area of study, determine the nature of sediment problems in the river, and outline a plan of study for the proposed investigation. These surveys were conducted during the Fall of 1971 and the Spring and Summer of 1972 and involved both aerial and ground surveilance.

Aerial reconnaissance of the Clarks Fork Yellowstone River Basin was conducted by the Clarks Fork Siltation Study Committee on September 13, 1972, and covered the main stem of the river and its tributaries in Montana. Results of that survey showed the river to be carrying a heavy sediment load at its mouth, but to be relatively clear at the Montana-Wyoming state line. There appeared to be two main reasons for this increase in sediment transport by the river: (1) sediment-laden inflows from tributary streams, and (2) irrigation return flows and wastes. Many subbasins of the Clarks Fork Yellowstone River drainage have highly erodible soils with only sparse vegetative cover. These conditions, along with rainfall patterns of the basin and current irrigation practices were observed over the eastern portion of the basin and appear to give the small drainages a high potential for contributing sediment to the river. At several different locations in the basin, irrigation facilities were observed to be discharging excess water into the Clarks Fork Yellowstone River and its tributaries. It appears that irrigation practices along these streams allow large volumes of water to be returned to the river which carry a heavy load of sediment. The aerial flights of this reconnaissance were most useful in observing sediment problems and conditions in the Clarks Fork Yellowstone River basin. To better define the relationship between these principles, several ground surveys were conducted.

Ground surveys of the Clarks Fork Yellowstone River basin, although limited, were directed toward observing soil and ground cover conditions in several subbasins of the drainage and observing irrigation practices in the flood plain of the river. Reconnaissance of several subbasins in the eastern portion of the basin (the area with least precipitation) revealed land whose soil was highly errosive, covered by only sparse vegetation, and cut by numerous gullies with severe vertical cutting. Observations of

irrigation practices in the basin showed a great deal of waste water being discharged into the river and its tributaries along with normal return flows. With the large area of the basin to be covered by this investigation and the amount of time involved with detailed ground surveys, an effort was made to find a suitable method for studying sediment problems in the whole Clarks Fork basin in a reasonable length of time.

From the information gained during the aerial and ground reconnaissance of the Clarks Fork basin and a review of present remote sensing technology, aerial infrared photography and thermal imagery were selected for this study of sediment problems in the river. A ground-truth data program was then established to gather the necessary information to adequately define relationships between physical conditions of the basin and the photographs and imagery.

Ground-Truth Data Program

The ground-truth data program for the aerial remote sensing study of sediment in the Clarks Fork Yellowstone River was designed to provide regularly spaced information on flow conditions of the river and its tributaries during the time when remote sensing flights were in progress. These data were obtained for the main stem of the river and its major tributaries from its confluence with the Yellowstone River near Laurel, Montana, to the mouth of Clarks Fork Yellowstone River Canyon in Wyoming. Figure 2 is a map of the basin showing the location of sampling stations for the program. Table 1 contains a detailed description of each sampling point and the data collected at that location.

The primary data collected during this ground-truth program were sediment samples, water temperatures, stream dimensions, and water depths at each sampling location. The sediment samples were analyzed for turbidity and sediment concentration. Results of the sampling program are shown in Tables 2 and 3.

In addition to these data, water temperature cross sections were also obtained for five locations along the main stem of the Clarks Fork Yellowstone River. These cross sections were used in the interpretation of thermal imagery obtained with the thermal infrared line scanner. The location of these cross sections are included in Figure 2 and Table 1 and the results of the temperature measurements are shown in Table 4.

The ground-truth data program was conducted simultaneously with the aerial flights to collect color infrared photographs and thermal imagery. The combination of these data are the nucleus of this study of sediment in the Clarks Fork Yellowstone River.

Airborne Data

The aerial photography for the Clarks Fork Yellowstone River, Red Lodge and Rock Creeks was obtained on August 18, 1972 between 10.24 am and 11:45 am Mountain Daylight Time. The weather over the sites was generally clear with a few localized scattered clouds in the vicinity

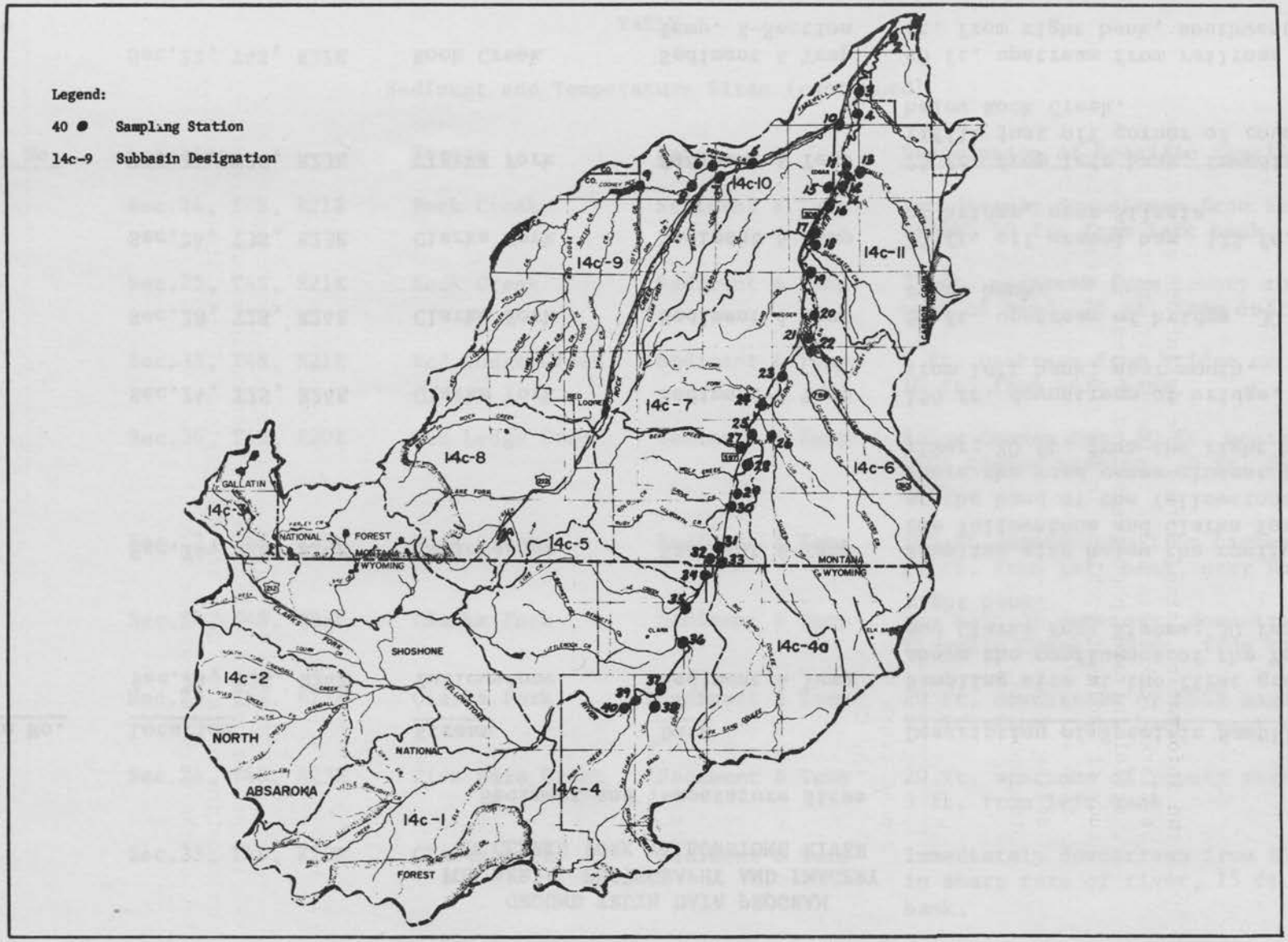

Figure 2 Drainage Area Map of the Clarks Fork Yellowstone River Showing Ground-Truth Collection Program for Aerial Remote Sensing Study

TABLE 1

GROUND TRUTH DATA PROGRAM
FOR AERIAL PHOTOGRAPHY AND IMAGERY
ON CLARKS FORK YELLOWSTONE RIVER

Sediment and Temperature Sites

Site No.	Location	Stream	Data	Description of Specific Sampling Site
YA	Sec.24, T2S, R24E	Yellowstone	Sediment & Temp	Sampling site at the first gravel bar above the confluence of the Yellowstone and Clarks Fork Rivers; 30 feet from the right bank.
YB	Sec.24, T2S, R24E	Yellowstone	Sediment & Temp	Sampling site below the confluence of the Yellowstone and Clarks Fork Rivers at the bend of the Yellowstone River where the road comes closest to the river; 20 ft. from the right bank.
1	Sec.24, T2S, R24E	Clarks Fork	Sediment & Temp	150 ft. downstream of bridge, 10 feet from left bank, near mouth.
2	Sec.28, T2S, R24E	Clarks Fork	Sediment & Temp	50 ft. upstream of bridge, 30 ft. from right bank.
3	Sec.24, T3S, R23E	Clarks Fork	Sediment & Temp	25 ft. off gravel bar, 125 ft. upstream of bridge, near Silesia.
4	Sec.25, T3S, R23E	Clarks Fork	Sediment & Temp	25 ft. from left bank, immediately below riffle just off corner of county road, below Rock Creek.
5	Sec.22, T4S, R22E	Rock Creek	Sediment & Temp Temp. X-Section	40 ft. upstream from railroad bridge, 40 ft. from right bank, southwest of Joliet.

TABLE 1

Sediment and Temperature Sites (continued)

Site No.	Location	Stream	Data	Description of Specific Sampling Site
6	Sec.24, T4S, R21E	Rock Creek	Sediment & Temp	Immediately downstream from Red Lodge Creek, 50 ft. from left bank.
7	Sec.25, T4S, R21E	Rock Creek	Sediment & Temp	75 ft. upstream from county road bridge west of Boyd, 10 ft. from left bank.
8	Sec.35, T4S, R21E	Red Lodge Creek	Sediment & Temp	5 ft. upstream from bridge on side road, 10 ft. from left bank.
9	Sec.36, T4S, R20E	Red Lodge Creek	Sediment & Temp	Below Cooney Dam, 50 ft. upstream from USGS gaging station, 10 ft. from right bank.
10	Sec. 2, T4S, R23E	Rock Creek	Sediment & Temp	100 ft. downstream from highway bridge, 25 ft. from left bank, near Rockvale.
11	Sec.14, T4S, R23E	Clarks Fork	Sediment & Temp	Due east of cemetery, downstream of Fivemile Creek, 30 ft. from right bank.
12	Sec.23, T4S, R23E	Clarks Fork	Sediment & Temp	20 ft. downstream of USGS gaging station, 25 ft. from right bank, east of Edgar.
13	Sec.24, T4S, R23E	Five Mile Creek	Sediment & Temp	20 ft. upstream of county road bridge, 3 ft. from left bank.
14	Sec.35, T4S, R23E	Clarks Fork	Sediment & Temp	Immediately downstream from Elbow Creek, in sharp turn of river, 15 ft. from left bank.
15	Sec.34, T4S, R23E	Elbow Creek	Sediment & Temp	5 ft. downstream from CMP, 8 ft. from left bank.

TABLE 1

Sediment and Temperature Sites (continued)

Site No.	Location	Stream	Data	Description of Specific Sampling Site
16	Sec. 3, T5S, R23E	Clarks Fork	Sediment & Temp	East of Highway, immediately downstream from 2 farm buildings and land leveler, 12 ft. from left bank.
17 T-1	Sec.16, T5S, R23E	Clarks Fork	Sediment & Temp Temp. X-Section	150 ft. upstream from bridge east of Fromberg, 165 ft. from right bank.
18	Sec.21, T5S, R23E	Bluewater Creek	Sediment & Temp	Taken from upstream side of county road bridge, south of Fromberg, 6 ft. from left bank.
19	Sec. 3, T6S, R23E	Clarks Fork	Sediment & Temp	50 ft. out (right) from downstream point of brushed island.
20 T-2	Sec.22, T6S, R23E	Clarks Fork	Sediment & Temp Temp. X-Section	100 ft. upstream from bridge east of Bridger, 20 ft. from right bank.
21	Sec.33, T6S, R23E	Clarks Fork	Sediment & Temp	125 ft. downstream from main highway 310 bridge, 35 ft. from right bank.
22	Sec. 4, T7S, R23E	Bridger Creek	Sediment & Temp	5 ft. downstream from county road bridge, 5 ft. from right bank.
23	Sec.18, T7S, R23E	Clarks Fork	Sediment & Temp	15 ft. downstream from county road bridge, 25 ft. from right bank.
24	Sec.25, T7S, R22E	Clarks Fork	Sediment & Temp	1/8 mile downstream from Dry Creek, 75 ft. upstream from main highway bridge, 15 ft. from left bank.

TABLE 1

Sediment and Temperature Sites (continued)

Site No.	Location	Stream	Data	Description of Specific Sampling Site
25 T-3	Sec.10, T8S, R22E	Clarks Fork	Sediment & Temp Temp. X-Section	Immediately upstream of main highway bridge, north of Belfry, 40 ft. from right bank.
26	Sec.12, T8S, R22E	Silver Tip Creek	Sediment & Temp	50 ft. upstream from USGS gaging station on Silver Tip Creek, 4 ft. from left bank.
27	Sec.11, T8S, R22E	Bear Creek	Sediment & Temp	Immediately upstream of highway bridge, north of Belfry, about 5 ft. from left bank.
28	Sec.27, T8S, R22E	Clarks Fork	Sediment & Temp	2.9 miles upstream from Belfry at main highway bridge, 30 ft. from right bank.
29	Sec.34, T8S, R22E	Clarks Fork	Sediment & Temp	3.9 miles upstream from Belfry at second main highway bridge, 15 ft. from right bank.
30	Sec. 4, T9S, R22E	Clarks Fork	Sediment & Temp	Immediately upstream from county road bridge, 15 ft. from right bank.
31 T-4	Sec.29, T9S, R22E	Clarks Fork	Sediment & Temp Temp. X-Section	150 ft. upstream from county road bridge, 20 ft. from left bank, below Sand Coulee.
32	Sec.32, T9S, R22E	Clarks Fork	Sediment & Temp	60 ft. downstream from county road bridge, above Big Sand Coulee, 12 ft. from right bank, above Wyoming line.
33	Sec.32, T9S, R22E	Big Sand Coulee	Sediment & Temp	1/4 mile upstream from confluence with Clarks Fork, at bridge near farm house, 10 ft. from right bank.

TABLE 1

Sediment and Temperature Sites (continued)

Site No.	Location	Stream	Data	Description of Specific Sampling Site
34	Sec.20, T58N, R101W	Clarks Fork	Sediment & Temp	Immediately downstream from county road bridge, 20 ft. from left bank, below Montana line.
35	Sec. 1, T57N, R102W	Clarks Fork	Sediment & Temp	Immediately downstream from bridge on paved road, 20 ft. from left bank, near F & WL HG.
36 T-5	Sec.30, T57N, R101W	Clarks Fork	Sediment & Temp Temp. X-Section	150 ft. downstream from main highway bridge, 40 ft. from right bank.
37	Sec. 8, T56N, R102W	Clarks Fork	Sediment & Temp	At old bridge location just downstream from Pat O'Hara Creek, 20 ft. from left bank.
38	Sec. 8, T56N, R102W	Pat O'Hara Creek	Sediment & Temp	Immediately downstream from small wooden bridge across Pat O'Hara Creek, 5 ft. from right bank.
39	Sec.12, T56N, R103W	Clarks Fork	Sediment & Temp	At foot bridge across Clarks Fork near farm houses, 50 ft. from left bank.
40	Sec.13, T56N, R103W	Clarks Fork	Sediment & Temp	About 1 mile downstream from river ford, 12 ft. from left bank, 4 miles east of Clarks Fork Canyon, last sample.

TABLE 1

(continued)

Soil Profiles

Site No.	Location	Data	Remarks
A-1	Sec.28 or 33, T7S, R23E	5'-Soil Profile	Near Cottonwood Creek
A-2	Sec.19 or 20, T8S, R23E	5'-Soil Profile	East of Belfry
A-3	Sec.33 or 34, T8S, R23E	5'-Soil Profile	On Cub Creek
A-4	Sec.21 or 22, T9S, R23E	5'-Soil Profile	Near Elk Basin, Oil Field
A-5	Sec.22 or 23, T9S, R22E	5'-Soil Profile	West of Silver Tip Creek
A-6	Sec. 9, T56N, R100W	5'-Soil Profile	In Wyoming, just off Cody Highway

TABLE 2

Clarks Fork Yellowstone River
Infrared Photography and Imagery Flights

Basic Data
October 18, 1972

Station No.	Stream	Time	Air Temp. (°F)	Water Temp. (°F)	Distance from Bank (ft)	Depth of water (ft)	Turbidity (JTU)
YA	Yellowstone	4:30 pm	71	71	30(R)	1.5	21
YB	Yellowstone	5:10 pm	-	72	20(R)	3.3	39
1	Clarks Fork	4:15 pm	71	72	10(L)	3.0	75
2	Clarks Fork	3:55 pm	72	70	30(R)	1.5	73
3	Clarks Fork	3:20 pm	72	70	25	2.0	69
4	Clarks Fork	3:35 pm	71	70	25(L)	2.2	65
5	Rock Creek	1:35 pm	74	68	40(R)	1.5	10
6	Rock Creek	1:55 pm	75	68	50(L)	1.8	9
7	Rock Creek	2:15 pm	75	68	10(L)	2.5	5
8	Red Lodge Cr.	2:30 pm	72	70	10(L)	2.5	11
9	Red Lodge Cr.	2:55 pm	72	66	10(R)	2.2	7
10	Rock Creek	1:15 pm	73	70	25(C)	2.3	11
11	Clarks Fork	12:55 pm	72	67	30(R)	1.5	70
12	Clarks Fork	12:15 pm	75	66	25(R)	3.2	66
13	Five Mile Cr.	12:10 pm	77	68	3(C)	1.0	89
14	Clarks Fork	12:05 pm	70	65	15(C)	2.5	65
15	Elbow Cr.	11:50 am	70	65	7(C)	2.0	95
16	Clarks Fork	11:40 am	68	64	12(R)	3.2	64
17	Clarks Fork	10:40 am	69	64	165(L)	2.5	62
18	Bluewater Cr.	10:18 am	72	64	6(C)	1.8	72
19	Clarks Fork	9:45 am	70	62	50(R)	2.3	54
20R	Clarks Fork	8:40 am	60	61	20(R)	2.3	53
20L	Clarks Fork	9:15 am	60	62	38(L)	2.0	57
21	Clarks Fork	7:25 am	60	60	35(R)	2.5	53
22	Bridger Cr.	7:10 am	62	60	5(C)	1.0	57
23	Clarks Fork	6:55 am	59	60	25(R)	2.0	57
24	Clarks Fork	6:35 am	56	62	15(L)	2.0	75
25	Clarks Fork	6:05 am	54	60	40(R)	2.8	45
26	Silver Tip Cr.	5:55 am	58	60	3.5(C)	0.25	295
27	Bear Cr.	6:25 am	54	59	5(C)	0.45	100
28	Clarks Fork	6:40 am	53	59	30(R)	2.3	42
29	Clarks Fork	6:50 am	55	59	15(R)	2.6	42
30	Clarks Fork	7:00 am	56	59	15(R)	2.2	40
31	Clarks Fork	7:30 am	56	57	20(L)	2.3	46
32	Clarks Fork	8:00 am	57	57	12(R)	4.0	51
33	Big Sand Coulee	7:15 am	58	58	10(C)	1.0	57
34	Clarks Fork	8:10 am	58	57	20(L)	2.5	53
35	Clarks Fork	8:30 am	58	55	20(L)	2.7	37
36	Clarks Fork	8:50 am	66	57	40(R)	2.0	44
37	Clarks Fork	9:45 am	66	59	20(L)	2.7	36
38	Pat O'Hara Cr.	9:30 am	68	60	5(C)	0.8	23
39	Clarks Fork	10:00 am	68	59	50(L)	2.6	32
40	Clarks Fork	10:15 am	72	59	12(L)	2.7	33

TABLE 3

Clarks Fork Yellowstone River
Infrared Photography and Thermal Imagery Flights

Suspended Sediment Data

October 18, 1972

Station No.	Suspended Sediment Concentration (ppm)	Station No.	Suspended Sediment Concentration (ppm)
YA	35	21	67
YB	85	22	109
1	145	23	130
2	162	24	158
3	152	25	98
4	140	26	676
5	11	27	252
6	11	28	84
7	77	29	87
8	15	30	74
9	4	31	114
10	7	32	80
11	142	33	116
12	113	34	124
13	206	35	80
14	173	36	98
15	879	37	52
16	129	38	24
17	119	39	7
18	180	40	71
19	129		
20R	249		
20L	124		

TABLE 4

Clarks Fork Yellowstone River
Infrared Photography and Imagery Flights

Temperature Cross Sections
October 18, 1972

Station No.	Time	Approx. Width (ft)	Air Temp. (°F)	Distance from Bank (ft)	Depth (ft)	Temp. at 6" (°F)
17, T-1	10:50 am	180	69	0(L)	0	-
				10(L)	0.5	63
				20(L)	1.0	64
				30(L)	1.6	64
				40(L)	2.2	64
				50(L)	2.5	64
				60(L)	2.0	64
				70(L)	1.6	64
				80(L)	1.4	64
				90(L)	1.5	64
				100(L)	2.3	64
				110(L)	2.6	64
				120(L)	2.8	64
				130(L)	2.5	64
				140(L)	1.5	64
				150(L)	2.3	64
				160(L)	2.5	64
				170(L)	2.4	64
				180(L)	0	-
20, T-2	9:00 am	240	60	0(R)	0	-
				10(R)	2.0	61
				20(R)	2.0	61
				30(R)	1.8	61
				40(R)	1.5	61
				50(R)	1.5	61
				60(R)	1.2	61
				70(R)	1.0	61
				80(R)	1.0	61
				90(R)	1.0	61
				100(R)	.9	61
				110(R)	1.1	61
				120(R)	1.4	61
				130(R)	1.6	61
				140(R)	1.6	61
				150(R)	1.0	61
				160(R)	1.5	61
				170(R)	2.0	61
				180(R)	2.5	61
				186(R)	2.2	61
				0(L)	0	-
				10(L)	1.5	62
				20(L)	2.0	62
				30(L)	2.0	62
				40(L)	2.0	62
				50(L)	2.6	61
				53(L)	2.2	62

TABLE 4 (continued)

Temperature Cross Sections (continued)

Station No.	Time	Approx. Width (ft)	Air Temp. (°F)	Distance from Bank (ft)	Depth (ft)	Temp. at 6" (°F)
25, T-3	11:45 am	200	85	0(L)	0	-
				20(L)	2.1	63
				40(L)	3.0	63
				60(L)	3.2	63
				70(L)	3.6	63
				90(R)	2.7	63
				80(R)	3.1	63
				60(R)	2.6	63
				40(R)	1.5	63
				20(R)	1.0	63
				0(R)	0	-
31, T-4	11:00 am	75	81	0(L)	0	-
				10(L)	1.7	61
				30(L)	3.0	60
				20(R)	2.9	61
				10(R)	1.6	61
				0(R)	0	-
36, T-5	9:15 am	205	66	0(R)	0	-
				15(R)	1.7	57
				35(R)	2.0	57
				55(R)	2.5	57
				75(R)	2.5	58
				100(R)	2.6	58
				120(R)	3.1	58
				140(R)	3.1	58
				160(R)	2.7	58
				180(R)	2.8	58
				200(R)	1.6	58
				205(R)	0	-

of the confluence of the Clarks Fork Yellowstone River and the Yellowstone River. Photographs of the Clarks Fork Yellowstone River from the confluence with the Yellowstone River to the mouth of the canyon were obtained at approximately 5,000 feet above the mean terrain providing a photograph scale of approximately 1:10,000. The Clarks Fork Yellowstone River above the mouth of the canyon were obtained at an altitude of approximately 8,500 feet above the mean terrain providing a photograph scale of approximately 1:17,000. Photographs of Rock Creek and Red Lodge Creek were also obtained at a scale of approximately 1:10,000.

The photography was obtained with a Wild RC-8 Precision Mapping Camera using a 6 inch Universal Aviogon Lens. The RC-8 system includes filters, a NF 1 navigation sight, and a PAV 2 Universal Mount. The camera system produces a 9 inch x 9 inch photograph with minimum distortion and high resolution.

Kodak Aerochrome Infrared Film 2443 was exposed in the Wild RC-8 camera. It was processed to a positive transparency for analysis on a light table. The color infrared film has three layers of emulsion which when exposed respond to wavelengths corresponding to the green, red and the photograph infrared portions of the electromagnetic spectrum. Through a subtractive color process this film produces a "false" color image of the scene in which green appears blue, red appears green, and photographic infrared appears red.

Thermal infrared imagery of the Clarks Fork Yellowstone River, Rock Creek and Red Lodge Creek were also obtained for this study. The U.S. Department of Agriculture, Forest Service, Missoula, Montana was subcontracted to fly these sections of the rivers to obtain the thermal infrared imagery. The imagery was obtained on August 18, 1972 between 6:20 am and 7:10 am Mountain Daylight Time using a modified Texas Instruments RS-7 Scanner flown in a Beechcraft King Air aircraft at an altitude of approximately 3,000 feet above the mean terrain. The imagery was recorded on a three and one half inch wide strip film format. A negative transparency is produced on which warmer temperatures appear dark and cool temperatures appear light; when the positive transparency or positive print is produced, warmer temperatures are lighter and cooler temperatures are darker.

Data Analysis

The primary data analysis was accomplished by viewing both the color infrared positive transparency film and the thermal infrared imagery (processed to a negative transparency) on a light table. A Bausch and Lomb Zoom 240 Stereoscope mounted on a Richards Corporation dual strand light table was used to provide a detailed view. This unit is designed so adjacent photographs in roll format can be viewed stereoscopically or a single photograph can be viewed through a mono-vision, zoom-magnification.

The interpreter scanned the photographs and imagery to locate points of inflow which were detectable as sediment plumes or temperature plumes in the river. Drainage patterns delineated by vegetation and/or

erosion areas identified other potential sources of sediment inflow. The most obvious locations were found and described by this scanning process. Stereo-pairs of photography then were viewed to identify drainage relief which was not obvious in the initial overview. Magnification of the image through the stereoscope assisted the interpreter to view characteristics at the bank line and in the gully and ditch bottoms necessary to determine if they contained water. Ditches, gullies, and tributaries were traced through their respective drainage basins to the limits of the photographic coverage. The color of the water was used to determine the amount of suspended sediment concentration of the inflow relative to the river.

Photography and Radiation Principles

Radiation is one of the three principle processes of energy transfer. Visible light, heat, radio waves, and X-rays are some of the energy forms transmitted by the radiation process. These forms of energy are similar and are grouped under a single classification of electromagnetic radiation. All forms of electromagnetic radiation travel in straight lines at the speed of light and obey similar laws of reflection, refraction, diffraction, and polarization. They can be focused to record images on sensitized paper or film or transduced to provide an electrical signal which may be recorded.

Three distinct portions of the electromagnetic spectrum are of interest in this remote sensing study. These three portions are:

1) The visible portion having wavelengths from 0.4 micrometers to 0.7 micrometers.

2) The photographic infrared portion from 0.7 micrometers to 0.9 micrometers.

3) The thermal infrared portion from 8 micrometers to 14 micrometers.

Color infrared film is sensitive to electromagnetic energy having wavelengths from 0.4 micrometers to 0.9 micrometers. It contains three layers of emulsion which are sensitized to respond to wavelength bands corresponding to green, red, and the photographic infrared. All three emulsions are sensitive to blue light and therefore a minus-blue filter is used to eliminate the wavelengths below 0.5 micrometers. Through a subtractive color process this film produces a "false" color image of the scene in which green appears blue, red appears green, and photographic infrared appears red. The infrared sensitive color film was originally designed for military applications of camouflage detection. It has been used extensively for forest surveys to identify diseased foliage. More recently the film has been used extensively by Colorado State University for river studies. The color infrared film has been found to be very effective for monitoring sediment transport processes in rivers. Small changes in suspended material concentrations in water change the reflectance characteristics singificantly in the wavelengths recorded on the color infrared film.

The longer wavelength portion of the electromagnetic spectrum from 8 to 14 micrometers is emitted or thermal radiation. To record this portion of the spectrum the emitted energy must be focused on a special detector and transduced to an electrical signal. The transduced signal is used to modulate a light source which in turn is used to expose a black and white film strip. The grey level of the resulting imagery is proportional to the emissivity and temperature of the object.

The grey tones, on the thermal imagery, between black and white, give a qualitative indication of water surface temperatures. The grey tones of other terrain scenes are recorded in accordance with the value of their corresponding emissivity as well as temperature. Water has an emissivity close to unity, but soil and vegetation may have a range of values less than unity.

INTERPRETATION

The following interpretive keys were used to identify the inflows, tributaries, and potential tributaries which would be sources of sediment for the river.

1) Color - Color is the primary key to identifying sources of inflow into the river. Clear water inflows appear dark blue (black in the cases of deep water) on color infrared film. Changes of concentrations of suspended material change the color of the water to a blue, blue grey or powder blue approaching a light blue with increased suspended sediment concentrations. Green vegetation which appears a bright red on color infrared film is also a key for identifying ditches or potential drainage ways.

2) Topographic Relief - Stereoscopic viewing of stereo-pairs of photographs provides the three-dimensional relief necessary to identify small catchments and erosion patterns and to judge the slope and topography related to agricultural lands.

3) Pattern, Shape, and Texture - Farmlands and row crops are readily identified by the patterns, alignments, colors and textures. Upland areas have color and erosion patterns and shapes which can be identified readily.

4) Temperature/Emissivity - The thermal infrared imagery is interpreted based upon a judgement of grey levels and the temperature/emissivity characteristics of the scene.

Color infrared photography effectively detects small changes in low concentrations of suspended particles in water and enhances the change by a color difference. Sufficient research has not been accomplished to identify if the cause of the color difference is due to the change in turbidity level or suspended solids concentrations. However, for this study it was found that the suspended solids concentration and the turbidity level appear to vary linearly within the normal scatter associated with field sampling procedures. The relationships between suspended solids concentration in parts per million (ppm) and turbidity levels in Jackson turbidity units (JTU) is shown in Figure 3. The data for Figure 3 was obtained from samples taken the day of the overflight.

Examples of the Clarks Fork Yellowstone River and several tributary inflows are given in the following illustrations:

Figure 4 - is the confluence of the Clarks Fork Yellowstone River and the Yellowstone River. Samples of suspended sediment indicated 35 ppm at Point YA upstream from the confluence on the Yellowstone; 85 ppm at Point YB downstream from the confluence, and 145 ppm at Point 1 on the Clarks Fork Yellowstone River upstream from the confluence. The higher sediment concentration is clearly delineated by the lighter,

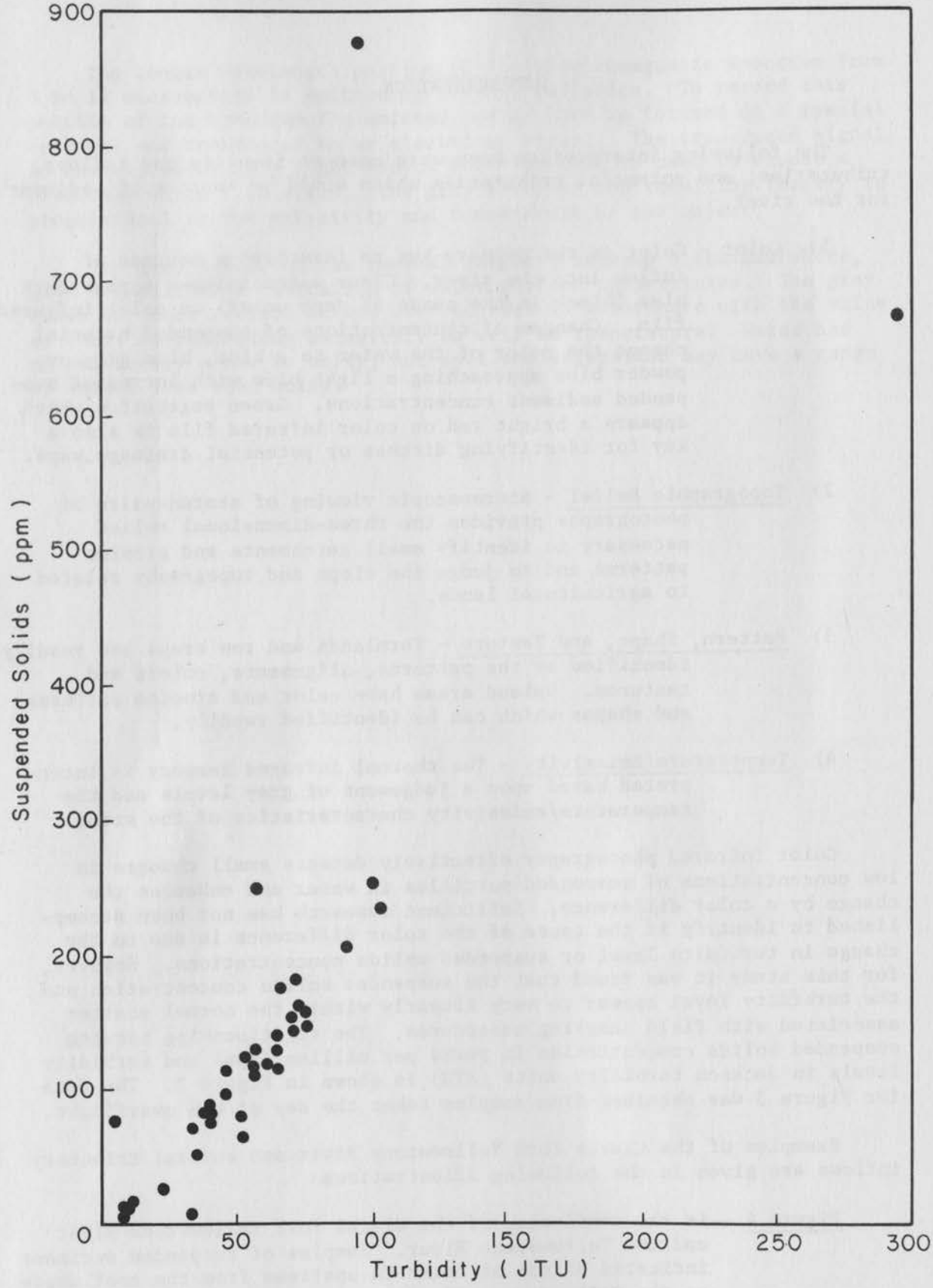

Figure 3 Relationship of Suspended Solids in Parts Per Million (ppm) and Turbidity in Jackson Turbidity Units (JTU)

Figure 4. Confluence of the Clarks Fork Yellowstone River and the Yellowstone River.

Sampling Site	Suspended Sediment Concentration (PPM)	Turbidity (JTU)
YA	35	21
YB	85	39
1	145	75

blue-grey color of the Clarks Fork Yellowstone River versus the darker blue of the Yellowstone River. Little mixing of the river waters occurs immediately downstream from the confluence as can be seen from the distinct plume. The suspended sediment sample obtained at Point YB was in the mixing zone or plume of the Clarks Fork Yellowstone River waters.

Figure 5 - shows the terrain in the vicinity of the confluence of Dry Creek and the Clarks Fork Yellowstone River. This area is typical of the terrain between the confluence of the Clarks Fork Yellowstone River and the Yellowstone River and mouth of the canyon. Depicted in the photograph are farmlands in the flood plain (A), the clayey-sandstone uplands (B), a highway (C), an irrigation diversion dam (D), the irrigation canal (E), and Dry Creek (F).

Figure 6 - is the confluence of Rock Creek and the Clarks Fork Yellowstone River. Rock Creek has a lower sediment concentration than the Clarks Fork Yellowstone River. The relatively clear water of Rock Creek stands out as a dark blue (black) color; the Clarks Fork Yellowstone River is a blue-grey color on this color infrared enlargement.

Figure 7 - shows a color infrared photograph of the confluence of Bennett Creek and the Clarks Fork Yellowstone River. The water in Bennett Creek has a lower sediment concentration than the Clarks Fork.

Figure 8 - is the thermal infrared imagery of the area that corresponds to the confluence shown on Figure 7. Bennett Creek is designated "BC", and the Clarks Fork Yellowstone River "CF" in Figure 8. The colder water of Bennett Creek, the plume and mixing zone, are clearly identified by the darker tone on the imagery. The plume can be observed on the imagery for approximately 1,500 feet downstream from the confluence. The temperature of the water in Bennett Creek was not measured, but the temperature of the Clarks Fork Yellowstone River approximately one third mile upstream from the confluence was 57°F and at a point approximately one half mile downstream was 55°F. The downstream measurement was obtained at a point 20 feet from the left bank and was probably in the cold water plume.

Figure 9 - shows the thermal infrared imagery obtained in the vicinity of Fromberg, Montana (FR). Bluewater Creek (BW) enters the Clarks Fork Yellowstone River (CF) near this town and shows up as the white line meandering through the irrigated fields on the right bank. The temperatures of the two streams are approximately equal (64°F) at their confluence and this is indicated by the same level of grey on the imagery. The imagery was obtained at approximately 6:50 am Mountain Daylight Time.

Figure 5. Confluence of Dry Creek and the Clarks Fork Yellowstone River and Environs.

Figure 6. Confluence of Rock Creek and Clarks Fork Yellowstone River.

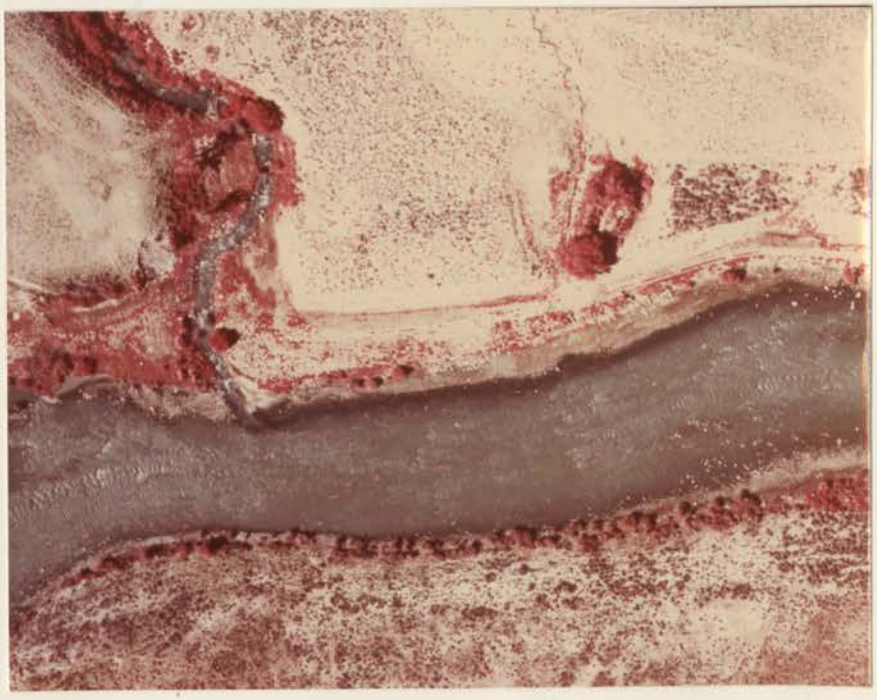

Figure 7. Confluence of Bennett Creek and Clarks Fork Yellowstone River.

Figure 8. Thermal Infrared Imagery of confluence of Bennett Creek and Clarks Fork Yellowstone River.

Figure 9. Thermal Infrared Imagery of the vicinity of Fromberg, Montana (showing Blue Water Creek and Clarks Fork Yellowstone River).

Primary interpretation of both the color infrared photography and the thermal infrared imagery was based on the interpreter's visual acuity. The inflows to the rivers were identified using the interpretative keys. The interpreter identified the inflow or potential inflow and described the relative suspended material concentration within the field of view provided by the photograph.

A description of the confluence of the Clarks Fork Yellowstone River and the Yellowstone River and the sampling sites above and below the confluence are given in Table 5. All tributaries and potential tributaries to the Clarks Fork Yellowstone River are identified in Table 6. Rock Creek, Red Lodge Creek and their tributaries are identified in Table 7.

The inflows are tabulated in an upstream order starting at the confluence of the Clarks Fork Yellowstone River and the Yellowstone River, the confluence of Rock Creek and the Clarks Fork Yellowstone River and the confluence of Red Lodge Creek with Rock Creek and proceeding to the confluence of Rock Creek. The points of inflow of the tributaries are located according to township, range, and section. A notation is made to indicate if the tributary had water in it or if it was dry at the time the photographs were taken. The photo number and quadrant number refers to the frame number of the 9 inch x 9 inch color infrared transparent photograph and the quadrant of the photograph the stream or tributary enters the river. The quadrants are assigned in a counter clockwise direction when the photograph is oriented with the clock and altimeter on the original film roll located on the observers right; quadrant 1 is upper right. A brief discription of the tributary inflow and, in some cases, the area it drains is provided. In cases where the discharge is small, no discription of the sediment concentration is given. Samples of water were collected at several locations on the day of the overflight. These samples were analysed for turbidity and suspended sediment concentrations (See Tables 2 & 3). Air and water temperature and water depth at sampling points also were recorded (See Tables 3 & 4). The results of the analysis of these samples are tabulated with the nearest tributary inflow.

TABLE 5 - Location and Discussion of Selected Areas near the Confluence of the Yellowstone River and the Clarks Fork Yellowstone River.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
Y1	2S	24E	24		CF2	W	71	71	1.5	35	21	YA	7801	Sampling Site YA at the first gravel bar above the confluence of the Yellowstone and Clarks Fork Rivers; 30 feet from the right bank. (See Figure 4)
Y2	2S	24E	24		CF2	W	-	72	3.3	.85	39	YB	7801	Sampling Site YB below the confluence of the Yellowstone and Clarks Fork River at the bend of the Yellowstone River, where the road comes closest to the river: 20 feet from the right bank. (See Figure 4)
Y3	2S	24E	24		CF2	W							7801	Yellowstone - Clarks Fork Confluence, The sediment laden water of the Clarks Fork can be easily delineated from the clearer water of the Yellowstone. This is indicated by the darker blue color of the Yellowstone as compared to the grey - blue color of the Clarks Fork. Thermal imagery shows no significant temperature difference between the two rivers. (See Figure 4)

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
1	2S	24E	24	R	CF2	W							7801 IV	There are deposits at the mouth of Spring Creek which is on the right side of the river opposite sampling site #1. The mouth of the creek is about 200 feet downstream from highway bridge. Flow rate is very small. The water is obscured partially by willow growth. Pooled water can be seen between essentially dry sections of the stream bed. (See Figure 4)
1A	2S	24E	24		CF2	W	71	72	30	145	75	1	7801	Sampling Site: 150 feet downstream of bridge, 10 feet from left bank. (See "C" in Figure 4)
2	2S	24E	21	R	CF3	D							7800 III	Drainage patterns converge and enter the flood plain from the right bank. These emanate from hay fields.
3	2S	24E	22	R	CF3	W							7799 Mid	A creek enters the river about 1 1/4 miles downstream of a bridge and appears to have about the same sediment concentration as the river. Its flow rate increases as it approaches the river due to a diversion canal discharging into the stream for return to the river. Algae is evident in some of the stagnant back waters.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
4	2S	24E	27	L	CF4-3	W							7798 I	A straight line ditch enters the river about 3/4 mile below the bridge. This ditch is the main drainage ditch for dewatering a high water table area. Relatively clear water is being discharged to the river.
5	2S	24E	27	L	CF4	W							7797 I	Relatively clear ground water return from the high water table is evident in the old river channel. There is some algae in the backwater.
5A	2S	24E	28		CF4	W	72	70	1.5	162	73	2	7796	Sampling Site; 50 feet upstream of bridge, 30 feet from right bank.
5B	2S	24E	33	L	CF5	D							7795 I	A ground water drainage ditch enters at the outside of bend of the river on the left bank.
6	2S	24E	33	L	CF5	W							7795 I-II	There is a groundwater drainage ditch next to road, near the farm house. The water is relatively clear.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
7	3S	24E	5	L	CF6	W							7793 I	This groundwater drainage ditch overlays the meander channel of the river. The return flow is relatively clear.
8	3S	24E	8	L	CF7	D							7792 IV	A dry ditch intersects the river above a sand bar.
9	3S	24E	8	R	CF7	W							7791 IV	The river divides in this area. The left channel is the larger of the two.
10	3S	24E	7	R	CF7	D							7790 IV	There are drainage patterns (dry) intersecting the right channel downstream from the storage bins and animal pens. A small dam has been constructed on the major drainage arm and a small pool of turbid water can be seen behind the dam.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
11	3S	R24E	7	L	CF7-8	W							7790 I	There is flow coming into the left channel from the old meander channel. At this time of the year, the flow would be primarily groundwater return. This flow appears to have about the same sediment concentration as the river.
12	3S	K23E	13	L	CF8	W							7788 I	Farewell Creek enters the river here. Irrigation water is diverted into and out of this creek. There is no appreciable difference in sediment concentration at the mouth from the creek.
13	3S	23E	24		CF9	W	72	70	2.0	152	69	3	7787	Sampling Site: 25 feet off gravel bar, 125 feet upstream of bridge.
14	3S	23E	24	R	CF9	W							7787 I	Cottonwood Creek enters river approximately 1100 feet upstream from sampling site #3. There is no evident sediment difference at the mouth. The creek drains primarily uncultivated land except for a small band of irrigated cropland near the river.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
15	3S	23E	25	L	CF9 10	W							7786 I	Groundwater return flow enters the river at 3 points on the outside of the bend of the river. The water is relatively clear. The return water passes through several cattle pens which were empty at the time of the photograph. Standing water between the creek and the river is evidence of the high water table in this area.
16	3S	23E	25		CF10	W	71	70	2.2	140	65	4	7786	Sampling Site: 25 feet from left bank immediately below riffle just off corner of county road.
17	3S	23E	25	L	CF10	W							7785 IV	Groundwater drainage ditches enter at two points on the straight portion of river. The upstream one is flowing clearer than the river. The downstream ditch does not appear to be contributing to the river at this time.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
18	3S	23E	25	L	CF10	W							7785 III	Vegetation and topography pattern indicate groundwater return entering at the large island. A small amount of return flow can be detected.
19	3S	23E	36	L	CF11	W							7784 IV	Groundwater return flow enters about 1400 feet downstream of the Rock Creek confluence with the Clarks Fork. This stream originates in the high water area between Rock Creek and the Clarks Fork. The water is relatively clear.
20	3S	23E	36	R	CF11	D							7784 IV	Dry drainage patterns on this bank. The drainage area is barren except for trees and brush in the bottom of the gullies.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
21	3S	23E	36	R	CF11	D							7595 II	Drainage patterns converge and intersect river, approximately 900 feet downstream from confluence of Rock Creek and Clarks Fork on the right bank.
22	3S	23E	36	L	CF11	W							7595 II	Rock Creek is very clear with a low sediment concentration. The plume boundary is clearly delineated by the nearly black color of Rock Creek and the very light blue color of the Clarks Fork. The thermal imagery shows Rock Creek to be the cooler of the two. (See Figure 6)
23	3S	23E	36	L	CF11	W							7595 I	Two ground water drainages enter the Clarks Fork near a small bar. One enters near the upstream end of the bar and the other enters approximately 500 feet below the bar. The return water is relatively clear. There is more flow in the upstream drainage.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
24	4S	23E	1	R	CF12	D							7596 I	A small dry creek enters the river from the right bank. There is also a dry ditch approximately 600 feet upstream from the creek.
25	4S	23E	12	R	CF12	W							7598 II	A ditch with heavy vegetation cover intersects the river on the outside of a very sharp bend to the left. This is irrigation waste water returned to the river. There is no flow at the time of the photograph.
26	4S	23E	12	L	CF12	W							7598 III	Clear water enters the river about 200 feet upstream of point where river runs parallel to and very near railroad track. This comes from across the tract from a very wet swamp and is probably the result of irrigation drainage.
27	4S	23E	12	R	CF13	W							7598 Mid	Flow comes out of old oxbow but there are no color differences in the river at the point of intersection. Irrigation is the source of this flow.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
28	4S	23E	14	L	CF13	W							7599 III	Ground water return flow enters from an old meander loop near the left bank. A drainage ditch also enters at approximately the same location. Both have clear water in them.
28A	4S	23E	14		CF13	W	72	67	1.5	142	70	11	7599	Sampling Site: Due east of cemetery downstream of Fivemile Creek, 30 feet from right bank.
29	4S	23E	14	L	CF13 14	W							7600 III-IV	Irrigation return is ponding and then returning to the river as two basic tributaries on left bank. The return water presently is relatively clear.
30	4S	23E	24	R	CF14	W	77	68	1.0	206	89	13	7601 II	Fivemile Creek intersects the river nearly tangentially on the right bank now the beginning of a bend to the left. It originates in the clayey soils of the shale and sandstone uplands and then flows through a broad band of cultivated farm land in the floodplain and irrigated terrace areas. This creek is carrying a higher sediment concentration than the river. The plume can be seen for nearly 400 feet downstream. Sampling Site: 20 feet upstream of county road bridge, 3 feet from left bank.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
31	4S	23E	24	L	CF14	W							7601 IV	Groundwater return flow enters just downstream of triangular shaped ponds. Return water is clearer than the river.
32	4S	23E	24	L	CF14	W							7602 III	Groundwater return flow enters the river about 800 feet downstream from the bridge. This return water is relatively clear.
33	4S	23E	24		CF15	W	75	66	3.2	113	66	12	7601	Sampling Site: 20 feet downstream of USGS gaging station which is at the bridge, 25 feet from right bank.
34	4S	23E	25	R	CF15	W							7603 II	A network of gullies on the right bank intersects the river on the outside of the bend. The two major inflow points are approximately 800 feet apart. The gullies originate on the clayey shale uplands. Excessive gully erosion is evident. Such areas produce large quantities of sediment during runoff periods. There is also groundwater return flowing through the point bar. The return flow is clearer than the river.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
35	4S	23E	25	R	CF15	W							7603 II	Flow from cut-off oxbow is clearer than the river. There is groundwater return flow entering this oxbow just upstream of Edgar, Montana.
36	4S	23E	35	L	CF16	W	70	65	2.5	173	65	14	7605	Sampling Site: immediately downstream from Elbow Creek, in sharp turn in river, 15 feet from left bank.
37	4S	23E	34	L	CF16	W	70	65	2.0	879	95	15	7605 III	Elbow Creek enters the river from the left bank. It has a higher sediment concentration than the river. It originates in the uplands and passes through the broad belt of irrigated farm land near the river. Sampling Site: 5 feet downstream from corregated metal pipe, 8 feet from left bank.
38	4S	23E	35	L	CF16	W							7605 IV	A creek enters the river approximately 1700 feet upstream from the mouth of Elbow Creek. It appears to carry a higher sediment concentration than either Elbow Creek or the Clarks Fork Yellowstone River.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
39	4S	23E	35	L	CF16	W							7606 III	A ditch carrying irrigation return flow enters at the neck of horse head. It carries a higher sediment concentration than the river.
40	4S	23E	35	R	CF16	W							7606 II	A ditch transporting irrigation tailwater enters from the right bank immediately below the small point bar. The return water is relatively clear.
41	4S	23E	35	R	CF17	W							7606 I	Waste water from canal enters the river from the right bank. It contains a higher sediment concentration. The return channel has excessive gully erosion.
42	5S	23E	3	R	CF17	W							7607 II	Irrigation return flow enters on the outside of the bend. There is a very small amount of flow.
42A	5S	23E	3		CF17	W	68	64	3.2	129	64	16	7608 III	Sampling Site: east of highway, immediately downstream from 2 farm buildings and land leveler, 12 feet from left bank.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
43	5S	23E	3	L	CF18	W							7608 IV	Groundwater return flow enters from under the highway from the old river channel. The return flow is relatively clear.
44	5S	23E	3	R	CF18	W							7608 I	A groundwater drainage ditch on the right bank enters the outside of the bend. The bend is partially obscured by tree shadows. The return water is relatively clear.
45	5S	23E	10	L	CF18	W							7609 III	Drainage from an oxbow area across the highway enters on the left bank. Irrigation return flows contribute to the oxbow.
46	5S	23E	10	R	CF18	W							7609 I	Irrigation return flow enters from the right bank near the farmstead. Considerable erosion is evident on the outside of the river bend downstream from the point of entry. The thermal imagery indicates a cooler inflowing water. The photograph shows a higher sediment concentration in the return water but the plume can be traced for only a short distance. Cooler, more dense water would sink.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
47	5S	23E	10	R	CF18	W							7610 I	Irrigation tailwater returns through a small group of trees. The water is relatively clear.
48	5S	23E	16	L	CF19	W							7610 I-IV	Return flow from a high water table enters from the left bank. The water is relatively clear.
49	5S	23E	16	R	CF20	W							7612 III	A small gully has been eroded on inside of the bend near several stock pens. The water observed in the gully is relatively clear at the upstream end but the turbidity increases from pool to pool downstream. The gully would be the interceptor for the stock pen drainage and this may account for the increased turbidity level. The point of inflow into the river is at the downstream tip of the sand bar and is obscured slightly by the shadows.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
50	5S	23E	16	L	CF20	W							7612 III	Groundwater return flow enters the river from a small ditch on the left bank. The ditch provides drainage for the high water table. The water is relatively clear.
51	5S	23E	16	R	CF20	W	69	64	2.5	119	62	17	7612 I	Sampling Site: 150 feet upstream from bridge east of Fromberg, 165 feet from right bank.
52	5S	23E	16	R	CF20	W							7612 I	Bluewater Creek enters the river from the right bank. It has a higher sediment concentration than the river. The plume boundary can be traced for 100 feet downstream. Some caving of the banks of Bluewater Creek can be seen in the vicinity of the irrigated fields. (See Figure 9)
52A	5S	23E	21		CF20	W	72	64	1.8	180	72	18	7612	Sampling Site on Bluewater Creek: Taken from upstream side of county road bridge, south of Fromberg, Montana, 6 feet from left bank.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
53	5S	23E	21	L	CF20	W							7613 II	Some ponded water in the old meander loop drains to the river in a small gully from the left bank. Erosion is occuring on the outside of the bend at this location. A new point bar is forming on the inside of the bend indicating bank erosion from the bend immediately upstream.
54	5S	23E	21	L	CF21	W							7613 IV	There is irrigation return flow entering from the left bank under the highway and railroad next to a farm road. This has a higher sediment concentration than the river and the plume boundary can be seen for at least 300 feet downstream.
55	5S	23E	29	R	CF21	W							7614 I	Flow enters from the right bank at the outside of the bend. Two sources contribute to this flow. One is a high water table area in an old meander loop. The second is a irrigation return flow from across the road. The irrigation return flow has a high sediment concentration.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
56	5S	23E	29	L	CF21	W							7615 Mid	Irrigation return flow enters the river from the left bank at the sandbar. The water is relatively clear.
57	5S	23E	29	R	CF21	W							7615 I	Irrigation return flow enters from the right bank at a slightly higher concentration than the river.
58	5S	23E	32	R	CF22	W							7616 I	There is a large irrigation return flow at a higher sediment concentration than the river entering from the right bank at the outside of a large bend. The plume can be traced downstream for about 1000 feet.
59	6S	23E	3	R	CF23	W							7618 II	An inflow with a high sediment concentration can be seen entering from the right bank adjacent to a farm house in line with a section line road. The source of this discharge can not be identified.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
60	6S	23E	3	R	CF23	W							7618 I	A creek enters the river from the right bank near a farmstead. It has approximately the same sediment concentration as the river. The mouth of the creek is about 300 feet downstream from sampling site #19.
60A	6S	23E	3	L	CF23	W	70	62	2.3	129	54	19	7618	Sampling Site: 50 feet out (right) from downstream point of brushed island.
61	6S	23E	3	L	CF23	W							7618 I	High water table drainage ditch enters from the right bank about 800 feet downstream from railroad bridge. The water is relatively clear.
62	6S	23E	3	L	CF23	W							7618 I-IV	Sand Creek enters the river from the left bank about 1000 feet upstream from railroad crossing. It has a higher sediment concentration than the river.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
63	6S	23E	3	R	CF23	D							7619 III	Irrigation waste water return ditch enters the river on the right bank approximately 800 feet downstream from farm.
64	6S	23E	9	L	CF24	W							7619 IV	Irrigation return flow enters the river from the left bank from the fields across the highway. The return water has a higher sediment concentration than the river.
65	6S	23E	9	L	CF24	W							7619 IV	Irrigation drainage enters the river on the left bank through the trees near a farmhouse. The water is relatively clear.
66	6S	23E	15	R	CF25	D							7621 I	A drainage ditch intersects the river from the right bank at a bend midway between two large islands. There is no flow at present.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
67	6S	23E	15	L	CF25	W							7622 I-II	Groundwater return flow from an old meander loop enters from the left bank. The water is relatively clear.
68	6S	23E	22	R	CF25	W							7623 II	Groundwater return flow from a high water table area enters on the right bank. The return water has a slightly higher sediment concentration than the river. There is very little flow here. This is about 2/3 mile below the Bridger bridge.
69	6S	23E	22	R	CF25 26	W							7623 I	Groundwater return flow enters the river from the right bank about 1000 feet downstream from Bridger Bridge. The discharge is relatively clear and small.
70	6S	23E	22	L	CF26	W							7624 I	Groundwater return flow enters the river from the left bank approximately 700 feet downstream from the Bridger Bridge. The water is relativ-ely clear.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
70A	6S	23E	22	R	CF26	W	60	61	2.3	249	53	20R	7624	Sampling Site: 100 feet upstream from bridge east of Bridger, 20 feet from right channel.
70B	6S	23E	22	L	CF26	W	60	62	2.0	124	57	20L	7624	Sampling Site: 100 feet upstream from bridge east of Bridger, 38 feet from left bank. The color of the water at the sampling sites is relatively uniform and does not indicate a difference in sediment concentration of the magnitude obtained from the samples.
71	6S	23E	22	L	CF26	W							7624 Mid	A groundwater return flow drainage ditch enters the river upstream of the sewage lagoon. The water is relatively clear.
72	6S	23E	27	L	CF26 27	W							7625 Mid	Groundwater return flow enters the river from the left bank. The water is relatively clear.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
73	6S	23E	27	L	CF27	W							7625 I	Irrigation return flow enters the river from the left bank near the farmstead below the middle bar. The return flow has a higher sediment concentration than the river.
74	6S	23E	27	R	CF27	W							7625 I	A creek located at the upstream end of a large island is carrying a higher sediment concentration than the river. The inflow can be traced for approximately 1000 feet downstream. The creek has a deeply incised meandering channel that passes through irrigated farm land.
75	6S	23E	33		CF28	W	60	60	2.5	67	53	21	7627	Sampling Site: 125 feet downstream from main highway bridge, 35 feet from right bank.
76	7S	23E	4	R	CF28	W	62	60	1.0	109	57	22	7628 II	Bridger Creek enters the river from the right bank approximately 1500 feet upstream from the highway bridge. It has a slightly higher sediment concentration. Sampling Site on Bridger Creek: 5 feet downstream from county road bridge, 5 feet from right bank.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
77	7S	23E	4	L	CF28	W							7628 II	Return flow from a ponded area is an old meander channel which enters the river from the left bank approximately 800 feet downstream from Bridger Creek.
78	7S	23E	8	R	CF29	W							7630 Mid	Cottonwood Creek enters from the right bank. It has a higher sediment concentration than the river. The plume is visible for about 800 feet downstream of the confluence.
79	7S	23E	8	R	CF29 30	W							7631 IV	Groundwater irrigation return flow runs past the farm and drains into river on the right bank. The inflow is relatively clear.
80	7S	23E	8	L	CF30	W							7631 IV	Two drainage ditches combine and flow under the highway and enters the river on the left bank, on the upstream side of a farmhouse. The return water has a higher sediment concentration than the river and the inflow is visible for about 600 feet downstream.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
81	7S	23E	8	R	CF30	W							7631 IV	Groundwater return from the ponded area in the old meander loop enters from the left bank. The water is relatively clear.
82	7S	23E	18	L	CF30 31	W							7633 II	Return flow enters the river from the left bank upstream of the farmstead. The water is relatively clear.
83	7S	23E	18		CF31	W	59	60	2.0	130	57	23	7633	Sampling Site: 15 feet downstream from county road bridge, 25 feet from right bank.
84	7S	23E	18	L	CF31	W							7634 II-III	Return flow enters the river from the left bank immediately upstream of bridge. This inflow is clearer than the river.
85	7S	23E	30	R	CF32	D							7636 II	Drainage patterns delineated by vegetation, enter from the right bank. They are dry at this time of year.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
86	7S	23E	30	R	CF32	W							7636 I-II	Return flow ditch enters the river from the right bank about 1300 feet downstream from Hunt Creek. The water in the bottom of the ditch is relatively clear.
87	7S	22E	25	R	CF32 33	W							7636 I	Hunt Creek is carrying a high sediment load and can be seen for at least 1200 feet downstream.
88	7S	22E	25	R	CF33	W							7638 II	Irrigation drainage goes under a road immediately downstream of a corral. The point of intersection with the river is hidden in the trees but it does not appear to have a higher sediment concentration than the river. (See Figure 5)
89	7S	22E	25		CF33	W	56	62	2.0	158	75	24	7638	Sampling Site: 1/8 mile downstream from Dry Creek, 75 feet upstream from main highway bridge, 15 feet from left bank. (See Figure 5)

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
90	7S	22E	25	L	CF33	W							7638 III	Dry Creek enters the river about 700 feet upstream of the bridge and is carrying a very high sediment load. This plume can be seen for a distance well past the bridge and around the bend (about 1700 feet). (See Figure 5)
90A													7638 IV	On left bank irrigation canal waste way approximately 500 feet upstream from diversion dam. (See Figure 5)
91	7S	22E	35	R	CF34	W							7639 I-IV	Silver Tip Creek is carrying a high sediment load which generates a plume that can be seen for about 1/2 mile downstream.
91A	8S	22E	12			W	58	60	0.25	676	295	26		Sampling Site on Silvertip Creek: 50 feet upstream from USGS gaging station, 4 feet from left bank.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
92	8S	22E	2	R	CF34	W							7640 II	There is irrigation return flow on the right bank coming from under the highway at a farm about 1700 feet upstream of Silver Tip Creek. This also is carrying a higher sediment concentration than the river.
93	8S	22E	3	L	CF35	D							7642 I-IV	There is a dry creek bed that enters river from under a dirt road bridge between highway bridge and diversion dam on left bank.
94	8S	22E	3	L	CF35	D							7642 I	There is a dry ditch about 800 feet upstream from the aforementioned dry creek bed.
95	8S	22E	11	L	CF35	W							7643 Mid	There are two small drainages from the left approximately 800 feet on the left bank. The contribution to the total load of the river at this flow rate would be very small.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
96	8S	22E	10	R	CF35	W	54	60	2.8	98	45	25	7643	Sampling Site: immediately upstream of main highway bridge, north of Belfry, 40 feet from right bank.
97	8S	22E	11	L	CF36	W	54	59	.45	252	100	27	7644 I-II	Bear Creek has a high sediment concentration. This plume can be discerned for nearly 1/4 mile downstream. Sampling Site on Bear Creek: immediately upstream of highway bridge, north of Belfry, Montana about 5 feet from left bank.
98	8S	22E	13	R	CF36	W							7647 I	Irrigation canal wasteway. The resulting plume in the river indicates a slightly higher turbidity than the river.
99	8S	22E	13	L	CF36	W							7648 I	Return flow from irrigation on the left bank. The inflow has a slightly higher turbidity than the river.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
100	8S	22E	13	L	CF36 37	W							7649 III	Irrigation return flow at the left bank with high turbidity near what appear to be bee hives, upstream of farm structures at a bend to the right.
101	8S	22E	27	R	CF38	W	53	59	2.3	84	42	28	7651	Sampling Site: 2.9 miles upstream from Belfry at main highway bridge, 30 feet from right bank.
102	8S	22E	28	R	CF38	W							7652 II	There is a gate for either letting water in or out from the irrigation channel. This is about 2200 feet upstream of the bridge.
103	8S	22E	28	L	CF38 39	W							7653 III	Wolf Creek is carrying a higher turbidity than the river but the flow is entirely the result of irrigation return flow. Wolf Creek channel is completely dry about 2000 feet from the river.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
104	8S	22E	34	L	CF39	W							7654 III	There is irrigation return flow coming into the left bank from under the highway at a very straight portion of the river. This is upstream of a farmhouse about 900 feet. This flow has a very high turbidity.
105	8S	22E	34	R	CF39	D							7654 II	There is a drainage ditch (dry) entering on the right bank at the peak of a bend to the left.
106	8S	22E	34	L	CF39 40	D							7654 I	A drainage ditch immediately upstream of a farm on the left bank and not contributing any flow at this time.
107	9S	22E	3	L	CF40	W							7655 I-II	Network of small irrigation return channels entering at left bank in the vicinity of the sand bar.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
108	9S	22E	3	R	CF40	D							7656 II	A complex of gullies discharging into a culvert and drainage ways on the right bank approximately 1500 feet downstream from bridge under irrigation canal. It is not contributing much flow at this time.
109	9S	22E	3	R	CF40	W							7656 II	Hallenbeck Draw enters on the right bank. It is dry but it intersects with a flowing ditch about 300 feet above the river. This ditch flows into the river about 500 feet downstream from the highway bridge. Inflow has about same sediment concentration as the river.
110	8S	22E	34		CF40	W	55	59	7.6	87	42	29	7656	Sampling Site: 3.9 miles upstream from Belfry at second main highway bridge, 15 feet from right bank.
111	9S	22E	3	R	CF40	W							7656	A creek runs parallel to highway and enters the river about 300 feet upstream of the bridge. This appears to have the same sediment concentration as the river.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
112	9S	22E	3	L	CF40	D							7656 I-IV	A vague pattern through the cultivated fields shows remnants of Grove Creek. No water is flowing and the channel has been obliterated by the reclamation to farmland in the flood plain.
113	9S	22E	3	L	CF40 41	W							7656 I	There is irrigation near the farm about 1/2 mile upstream from the bridge. The confluence with the river is obscured by trees but there is no indication of high sediment inflow.
114	9S	22E	18	L	CF42	D							7659 IV	A gully enters the river from the left bank opposite a feed lot operation. Gully is dry.
115	9S	22E	18	R	CF42	D							7660 III	Gully intersects river from right bank, no flow at this time.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
116	9S	22E	18	L	CF42	W							7660 IV	Another gully intersects the left bank, no visable flow in gully. Seepage into the gully from irrigation can be detected.
117	9S	22E	4	R		W	56	59	2.2	74	40	30		Sampling Site: immediately upstream from county road bridge. 15 feet from right bank. This has not been located on the photograph.
118	9S	22E	18	L	CF42	W							7660 IV	Dilworth Creek enters from the left bank. Inflowing water appears to have same sediment concentration as the river.
119	9S	22E	19	R	CF43	W							7661 III	Irrigation waste water from irrigation channel enters river from right bank. The diversion point is located approximately 1 mile from county road bridge.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
120	9S	22E	19	L	CF43	W							7661 III	There is irrigation return flow entering on left bank, next to a farm. It has a higher sediment concentration than the river and can be traced approximately 1000 feet downstream.
121	9S	22E	19	L	CF43	W							7661 IV	There are irrigation return channels entering the river on the left along the straight reach of the river. No water can be detected in the channel because of the heavy vegetation.
122	9S	22E	20	L	CF43	W							7662 Mid	There are two irrigation return channels into the river from the left bank, one approximately 800 feet from bridge and the other 400 feet downstream from bridge. The downstream ditch appears to be dry. Water in upstream ditch has sediment concentration higher than the river.
123	9S	22E	20	L	CF43	W							7662 I	There is irrigation return flow 1200 feet upstream of the bridge. The flow rate appears very small and there are no indications of high sediment concentration.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
124	9S	22E	29		CF43	W	56	57	2.3	114	46	31	7663	Sampling Site: 150 feet upstream from county road bridge, 20 feet from left bank.
125	9S	22E	29	L	CF44	W D							7663 I	Irrigation return flow enters on left bank, approximately 1000 feet upstream from county road bridge. Inflowing water has slightly higher sediment concentration than the river.
126	9S	22E	29	L	CF43 44	D							7663 I-II	Two groundwater return ditches draining a high water table area enter the river from the left bank, approximately 400 feet downstream from irrigation canal siphon. No flow can be detected in these at the present time.
127	9S	22E	29		CF44	D							7663 I	Drainage patterns converge on the right side of the highway and the resulting gullies intersect the river from the right bank approximately 100 feet upstream from the siphon. The gully is dry at this time.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
128	9S	22E	32	R	CF44	D							7664 II	A gully enters the river approximately 100 feet from the right bank and approximately 1700 feet downstream of the Big Sand Coulee. It is dry except from same backwater at the mouth.
129	9S	22E	32	R	CF44	W							7664 I-II	The Big Sand Coulee enters the river about 400 feet downstream from the bridge. The inflow has a higher sediment concentration than the river and it can be traced for about 700 feet downstream.
129 A	9S	22E	32		CF44	W	58	58	1.0	116	57	33	7664	Sampling Site on the Big Sand Coulee: 1/4 mile upstream from confluence with Clark's Fork at bridge near farm house, 10 feet from right bank.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
130	9S	22E	32		CF44	W	57	57	4.0	80	51	32	7664	Sampling Site: 60 feet downstream from county road bridge, above Big Sand Coulee, 12 feet from right bank.
131	9S	22E	32	R	CF44	W							7664 I	An irrigation return drainage ditch enters the river about 1200 feet upstream from the bridge. The return water has a higher sediment concentration than the river.
132	58N	101W	20	L	CF45	D							7666 IV	An irrigation return drainage ditch enters from the left bank approximately 3000 feet downstream from the bridge. There is some ponded water in the ditch but it does not appear to be flowing into the river at this time.
133	58N	101 W	20	R	CF46	W							7666 I	An irrigation return ditch appears to enter the river from the right bank immediately downstream from a large feed lot. The point of entry is hidden by the trees and shadows of the bank. The water in the ditch has approximately the same sediment concentration as the river. The thermal imagery indicates the ditch enters the river.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
134	58N	101W	20		CF46	W	58	57	2.5	124	53	34	7667	Sampling Site: Immediately downstream from county road bridge, 20 feet from left bank.
135	58N	101 W	29	R	CF46	W							7667 I	An irrigation drainage ditch enters the river just upstream of a feedlot and about 1100 feet upstream of a bridge. The sediment concentration is about the same as the river.
136	58N	101 W	32	R	CF46	D							7668 I	An irrigation drainage ditch enters from the right bank downstream of a sprinkler irrigated field. The ditch is dry at present.
137	58N	101 W	32	L	CF46	W							7668 I	A head gate structure returns some of the water diverted for irrigation from the river. The structure is located approximately 1500 feet from the point of diversion.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
138	58N	101 W	32	L	CF46	D							7668 I-IV	The main gully from the uplands enters from the left bank approximately 500 feet downstream from the irrigation diversion. A flume over the irrigation canal allows any runoff to reach the river. It is dry at this time.
139	58N	101 W	32	R	CF46 47	W							7669 Mid	An irrigation return drainage ditch enters from the right bank from the sprinkler system. The flow is very small.
140	58N	101 W	31	L	CF48	D							7670 III	A gully enters the river from the left bank. Deposits at the mouth indicate the flow from this gully contributes large sediment during runoff. The gully is dry presently.
141	57N	102 W	1	L	CF47 48	D							7671 III IV	Several drainage patterns and major gullies enter the river from the uplands on the left bank. These are dry at this time.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
142	57N	102 W	1	L	CF48	W							7672 III	A small creek (Line Creek ?) enters the river near a middle bar. There is a cultivated field upstream and barren ground downstream. The inflow is clearer water than the river.
143	57N	102 W	1	L	CF48	W							7672 IV	Irrigation return flow enters the river from the left bank in a gully. Water in the gully can be seen approximately half the length of the field. Upstream from that point the gully is dry.
144	57N	102 W	1	L	CF48	W							7672 IV	Seepage from an irrigation ditch enters the river from the left bank in a small gully system The return flow has about the same sediment concentration as the river.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
145	57N	102 W	1	L	CF49	D							7673 I-IV	Small drainage patterns (dry) converge at the peak of a small bend to the left. This is about 1 mile upstream from Line Creek.
146	57N	102 W	1		CF49	W	58	55	2.7	80	37	35	7674	Sampling Site: Immediately downstream from bridge on paved road, 20 feet from left bank.
147	57N	102 W	12	L	CF50	D							7675 I	A gully enters the river just upstream from the fish hatchery. The gully is dry but a fan shaped deposit at the mouth indicates considerable sediment input at times.
148	57N	102 W	13	L	CF51	D							7676 I	An irrigation return ditch enters from the left bank about midway between two middle bars. The ditch is dry at present.
149	57N	102 W	13	L	CF51	W							7677 II	An irrigation return flow enters from the left bank in a gully. The return flow is relatively clear water.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
150	57N	102 W	13	L	CF51	W							7678 II	Bennett Creek enters from the left bank. It has a lower sediment concentration than the river. The thermal imagery indicates Bennett Creek is colder than the river. The inflowing water can be traced on the color infrared photo about 800 feet and on the thermal imagery for about 1500 feet. (See Figures 7 and 8)
151	57N	102 W	13	L	CF51	W							7678 II	Irrigation return flow enters the river from the left bank in a tree covered ditch upstream from Bennett Creek. There is some flow. The discharge is very small and is obscured by the vegetation near the mouth,
152	57N	102 W	13	L	CF51 52	W							7678 I	Irrigation return drainage ditch enters from the left bank near the farmstead. The discharge is very small.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
153	57N	101 W	19	L	CF52	W							7679 I	Tailwater from an irrigation channel enters just downstream of the pipe that crosses the river. The return flow has about the same sediment concentration as the river.
154	57N	101 W	19	R	CF52	D							7680 I-II	Numerous gullies intersect the river between the pipe carrying the irrigation water and the first highway bridge upstream. This is in an area where the vegetation is very sparce and there is much erosion. The gullies are dry at this time.
155	57N	101 W	30	R	CF52	D							7681 I-IV	A gully enters the river about 1100 feet below the highway brdige. The erosion pattern is deeply incised and indicates high sediment concentrations are possible from this area. The gully is dry at this time.
156	57N	101 W	30		CF52	W	66	57	2.0	98	44	36	7681	Sampling Site: 150 feet downstream from main highway bridge, 40 feet from right bank.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
157	57N	101 W	30	R	CF52	D							7681 I	Little Sand Coulee enters from the right bank between the two highway bridges. The alluvial fan at the mouth indicates large sediment transport during runoff occurs in this gully. The gully is dry presently.
158	56N	102 W	4	R	CF54	D							7685 I-II	Several gullies enter the river from incised erosion patterns on the right bank. These gullies were dry at the time.
159	56N	102 W	4	R	CF54	D							7686 II	Two gullies intersect the river at the upstream end of a bend. They are dry at the time.
160	56N	102 W	5	R	CF55	D							7687 II	A dry creek bed emanates from a draw on the right bank and enters at a straight reach of the river. Deposits at the confluence are evident for about 200 feet along the bank and indicate considerable sediment has been transported in this creek during the runoff. No flow was evident at this time.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
161	56N	102 W	8	L	CF55 56	W							7688 II-III	Part of the irrigation channel flow is diverted back to the river about 1/2 mile downstream from the old bridge location. This has about the same sediment concentration as the river; this would be expected since the channel originated less than a mile up the river.
162	56N	102 W	8	R	CF56	D							7688 I-II	There are rainfall drainage patterns (dry) along the bend to the left just downstream of the old bridge location. Several gullies enter the river from incised erosion patterns on the right bank, downstream of the old bridge location. These were dry at the time.
163	56N	102 W	8		CF56	W	66	59	2.7	52	36	37	7688	Sampling Site: at old bridge location just downstream from Pat O'Hara Creek, 20 feet from left bank.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
164	56N	102 W	8	R	CF56	W	68	60	0.8	24	23	38	7688 I	Pat O'Hara Creek joins the river immediately upstream of the old bridge location. The gully is covered with vegetation and there is a cultivated field on the upstream side of the creek; other than that the surrounding area is barren. The color of the creek is a much lighter blue than the river, which would normally indicate a higher sediment concentration. However, there was very little flow at this time so the color is likely due to the reflection from its bed. This is further substantiated by the low turbidity measurement of 23 JTU taken on the creek. The deposits at the mouth indicate high sediment loads were carried by the creek at some time. Sampling Site on Pat O'Hara Creek: Immediately downstream from small wooden bridge, 5 feet from right bank.
165	56N	102 W	8	R	CF56	W							7689 I-II	Irrigation return flow enters from a small ditch at the diversion dam, from the right bank. The discharge is very small and the water is obscured by vegetation.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
166	56N	103 W	12	L	CF57	W							7691 III IV	A ditch intersects the river at a 45° bend to the right. This is covered by vegetation and its water appears to be al least as clear as the river. Irrigation return flow enters from the left bank. This water is relatively clear.
167	56N	103 W	12	L	CF57	D							7692 II III	Incised channel in the sand on the left bank about 1100 feet downstream of the footbridge indicates inflow to the river. Its origin cannot be determined but it is suspected that the source is irrigation return flow from adjacent fields.
168	56N	103 W	12	L	CF57	W	68	59	2.6	7	32	39	7692 II	Sampling Site: at footbridge across Clarks Fork near farm houses, 50 feet from left bank.
169	56N	103 W	13	L		W	72	59	2.7	71	33	40	7692	Sampling Site: about 1 mile downstream from river ford, 12 feet from left bank. The exact location in relation to Paint Creek has not been established.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
170	56N	103 W	13	R	CF58	W							7692 I	Paint Creek joins the river upstream of the footbridge. It has a higher sediment concentration than the river. A bar has formed immediately downstream of the mouth from sediment carried during periods of high run-off.
171	56N	103 W	14	R	CF58	D							7693 I-II	Vegetation pattern delineates irrigation return flow paths (dry) which enter the river at 3 locations upstream from Paint Creek about 1/2 mile.
172	56N	103 W	22	R	CF59	D							7695 I	A gully enters the river from the right bank. A small bar has formed at the mouth of the gully It was dry at the time.
173	56N	103 W	15	R	CF59	D							7697 I-II	Two draws (dry) drain upstream of aforementioned creek about 1700 feet. There is almost no vegetation around them except for trees and brush at the mouths. Numerous gullies enter from the upland on the right bank. All were dry at the time.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
174	56N	103 W	16	R	CF60	D							7698 I-II	Several gullies provide drainage from the sulphur colored (on color infrared photograph) deposits near the mouth of the canyon. These were dry at the time.
175	56N	103 W	16	R	CF60 61	D							7699 II III	A drainage path enters the river from the rocky hills on the right bank. It is dry at this time.
176	56N	103 W	16	R	CF61	W							7699 IV	A drainage ditch from a high water table area enters the river from the right bank. The water is relatively clear.
177	56N	103 W	7	L	CF62	W							7702 Mid	A creek enters from the left bank, from under the highway near the end of the pavement. Vegetation delineates the channel path. The water is relatively clear.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
178	56N	103 W	7	L	CF62	D							7702 IV	Two ditches (dry) located about 2300 feet and 3100 feet upstream of the pavement end enter from the left bank.
179	56N	103 W	7	L	CF62 63	W							7703 IV	Another ditch about 1200 feet upstream from the preceding site is carrying fairly clear water and there is vegetation along its banks. A creek enters the river from the left bank. The water is relatively clear.
180	56N	103 W	7	R	CF63	D							7703 I-IV	There are drainage patterns (dry) emanating from steep, rock cliffs upstream about 900 feet from the preceding site. They were dry at the time.
181	56N	104 W	13	L	CF63	W							7705 III	There is a braided creek joining the river about 1200 feet upstream from the preceding site. There is almost no vegetation along its banks. The water has a lower sediment concentration than the river.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
182	56N	104 W	14	L-R	CF64	D							7706 II III	There are drainage patterns, draws and gullies (all dry) incised into the canyon walls for about the next 1 1/2 miles along both banks.
183	56N	104 N	26	L	CF66	W							7707 IV	Very heavy vegetation follows a creek and obscures the view such that is is even difficult to determine whether it is flowing or not. There appears to be a slight trickle of water at the mouth but its sediment concentration cannot be compared to the river's from the photo.
184	56N	104 W	35	L-R	CF66	D							7708 II III	There are many drainage patterns (dry) for about the next 1/2 mile upstream of the preceding site.
185	56N	104 W	33	R	CF67	W							7717 I-II	Dead Indian Creek enters from the right bank. The cascading water makes it difficult to distinguish its color. However, it appears to be nearly the same sediment concentration as the river.

TABLE 6 - Location and Discussion of Tributaries to the Clarks Fork Yellowstone River and Accompanying Sample Sites, con't.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
186	56N	104 W	33	R	CF67	W							7717 I	Sunshine Creek enters the river approximately 1200 feet upstream from Dead Indian Creek from the right bank. The cascading water makes it difficult to distinguish its color.
187	56N	104 W	29	L-R	CF68	?							7719	There is heavy vegetation in the draws on both sides of the river. No water is seen flowing into the river at this time.

TABLE 7 - Location and Discussion of Tributaries to Rock Creek and Red Lodge Creek and Accompanying Sample Sites.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
R1	4S	23E	1	R	RC1	W							7776 IV	Groundwater drainage ditch enters Rock Creek about 900 feet above the confluence with the Clarks Fork. The sediment concentration appears to be the same as Rock Creek. There is some algae on a section of ponded water in the ditch.
R2	4S	23E	2		RC2	W	73	70	2.3	7	11	10	7774	Sampling Site: 100 feet downstream from highway bridge, 25 feet from left bank.
R3	4S	23E	3	L	RC3	W							7774 II III	Water originally diverted for irrigation is drained back about 2000 feet upstream of the highway bridge. The flow is a mere trickle with approximately the same sediment concentration as Rock Creek.
R4	4S	23E	9	R	RC4	W							7772 IV	Irrigation return ditch enters from right bank. It originates on the irrigated bench above the floodplain. It has a slightly higher sediment concentration than Rock Creek.

TABLE 7 - Location and Discussion of Tributaries to Rock Creek and Red Lodge Creek and Accompanying Sample Sites.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
R5	4S	22E	13	L	RC6	W							7767 I	Groundwater return ditch follows the old river channel and enters the river about 900 feet upstream of farm buildings. The sediment concentration is about the same as Rock Creek. The thermal imagery indicates the temperature to be slightly cooler than Rock Creek.
R6	4S	22E	21	L	RC7	W							7766 I-II	Irrigation return flows in through a straight line ditch about 3300 feet below the Joliet Bridge. This is relatively clear water.
R7	4S	22E	21	L	RC8	W							7764 II	A straight line irrigation return ditch enters Rock Creek from the left bank just upstream of Joilet. The water is relatively clear. The temperature, however, is slightly less than Rock Creeks.
R8	4S	22E	32	L	RC8-9	W							7762 I	Flow that is diverted between the railroad and highway bridge reenters about 2300 feet downstream.

TABLE 7 - Location and Discussion of Tributaries to Rock Creek and Red Lodge Creek and Accompanying Sample Sites.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
R9	4S	22E	22		RC9	W	74	68	1.5	11	10	5	7762 I	Sampling Site: 40 feet upstream from railroad bridge, 40 feet from right bank.
R10	4S	22E	32	L	RC9	W							7762 II	Return flow from a main irrigation channel enters 500 feet upstream of the railroad bridge. This is relatively clear water.
R11	4S	22E	20	R	RC10	W							7759 I	Drainage from a highwater table area in the flood plain immediately below an irrigation diversion structure. There is irrigation drainage entering this are, some of which has a high sediment concentration. The ponds in the area act as settling basins so the sediment never reaches the river.
R12	4S	22E	20	L	RC10	D							7759 I	There is a vegetation pattern on the left bank, which indicates a gully joins Rock Creek just downstream of the farm house. It is dry.

TABLE 7 - Location and Discussion of Tributaries to Rock Creek and Red Lodge Creek and Accompanying Sample Sites.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
R13	4S	22E	20	L	RC10	D								A straight line irrigation return ditch enters Rock Creek on the left bank. It is dry.
R14	4S	21E	24		RC12	W	75	68	1.8	11	9	6	7755	Sampling Site: Immediately downstream from Red Lodge Creek-Rock Creek Confluence, 50 feet from left bank.
R15	4S	21E	21	R	RC12	W							7755 I	Rock Creek-Red Lodge Creek Confluence, the rivers appear to have about the same sediment concentration.
R16	4S	21E	25		RC13	W	75	68	2.5	77	5	7	7753 IV	Sampling Site: on Rock Creek, 75 feet upstream from county road bridge. West on Boyd, 10 feet from left bank.
R17	4S	21E	24	R	RC13	W							7753 II	A small creek enters from the right bank. There is some water in the creek but it becomes dry before it reaches the river.

TABLE 7 - Location and Discussion of Tributaries to Rock Creek and Red Lodge Creek and Accompanying Sample Sites.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
R18	4S	21E	26	L	RC14	W							7753 II	Grove Creek enters a cutoff from the left bank. It has a higher sediment concentration than Red Lodge Creek.
R19	4S	21E	35	R	RC14	D							7752 III	An irrigation return joins the river immediately downstream of a bridge at a sharp bend to the left. It is dry at this time.
R20	4S	21E	35		RC14	W	72	70	2.5	.15	11	8	7752	Sampling Site: 5 feet upstream from bridge on side road, 10 feet from left bank.
R21	4S	21E	34	L	RC14 15	D							7750 I-II	Several gullies intersect the river from the left bank. They drain primarily barren, plowed fields
R22	4S	21E	34	R	RC15	D							7748 IV	Several drainage patterns, on the uplands of the right bank, converge and cross the road and enter the river. They are dry at this time.

TABLE 7 - Location and Discussion of Tributaries to Rock Creek and Red Lodge Creek and Accompanying Sample Sites.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
R23	4S	21E	34	L	RC15 16	D							7748 I-II	Three gullies enter the river, upstream of a farmhouse, from the drainage patterns in the uplands on the left bank. They are dry at this time.
R24	4S	21E	34	L	RC16	D							7746 I-II	Two dry gullies converge and enter the river between two cultivated fields at a cut-off but flowing oxbow. These draws contrast well with the surrounding area on the thermal imagery. They are cooler than both the river and the surrounding area except for the cultivated fields near the river.
R25	4S	21E	34	R	RC16	D							7746 I-II	Two dry gullies converge on the right bank and enter the river.
R26	4S	21E	34	L	RC16	W							7745 I-II	A gully draining the highland of the left bank enters Red Lodge Creek approximately 1200 feet downstream from a farmstead.

TABLE 7 - Location and Discussion of Tributaries to Rock Creek and Red Lodge Creek and Accompanying Sample Sites.

Location No.	Township	Range	Section	Bank	Thermal Imagery Location	Wet or Dry	Air Temp. (°F)	Water Temp (°F)	Water Depth (Ft.)	Suspended Solids (ppm)	Turbidity (JTU)	Sample Site No.	Photo No. Quadrant No.	Description
R27	4S	21E	30	R	RC17	W							7743 I	Cottonwood Creek enters Red Lodge Creek about one mile below Cooney Dam. The sediment concentration is higher than Red Lodge Creek's. Cottonwood is slightly cooler than Red Lodge Creek. There are some irrigation drainage patterns that join Cottonwood Creek but nothing in the photograph is flowing.
R28	4S	21E	30	L	RC17	D							7743 I-II	Small gully enters the river about 3000 feet below the dam from the left bank. It is dry.
R29	4S	20E	36		RC18	W	72	66	2.2	4	7	9	7742	Sampling Site: below Cooney Dam, 50 feet upstream from USGS gaging station, 10 feet from right bank.

CONCLUSIONS

Inflows from tributaries, ditches, and gullies to the Clarks Fork Yellowstone River have been identified. Table 8 summarizes the contributing sources, real and potential, of sediment to the Clarks Fork Yellowstone River. Thirty seven (37) inflows to the Clarks Fork Yellowstone River and four (4) inflows to Rock Creek - Red Lodge Creek have a higher turbidity than the receiving water at their respective points of entry. Sixteen (16) inflows to the Clarks Fork Yellowstone River and four (4) inflows to Rock Creek - Red Lodge Creek have approximately the same turbidity. Forty two (42) inflows to the Clarks Fork Yellowstone River and three (3) inflows to Rock Creek - Red Lodge Creek have lower turbidity. Forty six (46) dry sites are tabulated as entering the Clarks Fork and nine (9) are entering, Rock Creek - Red Lodge Creek. More sites are represented than the actual number itemized since several drainage patterns may be included in a single dry site description.

All streams transport sediment to some degree (either as bed load, suspended load, or wash load) based upon the type of areas they drain, the stream velocities, and bed and bank materials. During the spring run-off, higher sediment concentrations are normally encountered. As the run-off decreases, the sediment concentration decreases until a minimum generally occurs sometime during the winter months. Thus the main stream reflects the sediment input from tributaries plus the amount of sediment entrained by its own flowing water.

The tributary flows into the Clarks Fork Yellowstone River, Rock Creek and Red Lodge Creek derive their sediment from numerous sources. Tributaries commonly pass through relatively barren land supporting only sage brush, through irrigated crop lands and pasture lands, through feed lots, and through small towns. In areas where small catchments exist on the side slopes of the canyon, the exact catchment area can be delineated and sediment sources readily identified. Tables 5, 6, and 7 identify the inflowing sources of sediment and describe some of the catchment areas which drain into the tributaries of the Clarks Fork Yellowstone River. However, since most photographs cover only the portion of the drainage basin adjacent to the river a complete description is not possible for each drainage area. It can be assumed that the adjacent fields contribute some sediment and in certain cases a change in the color of the water as it passes through a given field or the location of water in the stream or gully bed is a clue to the identification of the contributing source at the time of the photographs.

In general the following observations held for most cases. Groundwater return flow had a lower turbidity than the river. In one case the groundwater return flow traveled a sufficient distance through erodible material to entrain some suspended sediment. (See location number 68). Irrigation return flows had sediment concentrations equal to or greater than the river. Red Lodge Creek and Rock Creek were relatively clear water streams. This is to be expected since Red Lodge Creek derives its water from the discharge from Cooney Reservoir. Several smaller creeks such as Bennett Creek derive their water from sources in the Absaroka Range east of Yellowstone Park and are relatively clear and cold.

TABLE 8 - Summary of Inflows with Relative Turbidity Classifications

Location Number	Higher * Turbidity Than The River	Approximately * The Same Turbidity As The River	Lower * Turbidity Than The River	Name Of Tributary
3		X		
4			X	
5			X	
6			X	
7			X	
11		X		
12		X		Farewell Creek
14		X		Cottonwood Creek
15			X	
17			X	
19			X	
22			X	Rock Creek
23			X	
26			X	
27		X		
28			X	
29			X	
30	X			Five Mile Creek
31			X	
32			X	
35			X	
37	X			Elbow Creek
38	X			
39	X			
40			X	
41	X			
43			X	
44			X	
46	X			
47			X	
48			X	
49	X			
50			X	
52	X			Bluewater Creek
54	X			
55	X			
56			X	
57	X			
58	X			
59	X			
60		X		
61			X	
62	X			Sand Creek

TABLE 8 - Summary of Inflows with Relative Turbidity Classifications, con't.

Location Number	Higher * Turbidity Than The River	Approximately * The Same Turbidity As The River	Lower * Turbidity Than The River	Name Of Tributary
64	X			
65			X	
67			X	
68	X			
69			X	
70			X	
71			X	
72			X	
73	X			
74	X			
76	X			Bridger Creek
78	X			Cottonwood Creek
79			X	
80	X			
81			X	
82			X	
84			X	
86			X	
87	X			Hunt Creek
88		X		
90	X			Dry Creek
91	X			Silver Tip Creek
92	X			
97	X			Bear Creek
98	X			
99	X			
100	X			
103	X			Wolf Creek
104	X			
109		X		
111		X		
118		X		
120	X			
122	X			
125	X			
129	X			Big Sand Coulee
131	X			
133		X		
135		X		
142			X	Line Creek
144		X		
149			X	
150			X	Bennett Creek

TABLE 8 - Summary of Inflows with Relative Turbidity Classifications, con't.

Location Number	Higher * Turbidity Than The River	Approximately * The Same Turbidity As The River	Lower * Turbidity Than The River	Name Of Tributary
153		X		
161		X		
166			X	
170	X			Paint Creek
176			X	
177			X	
179			X	
181			X	
185		X		Dead Indian Creek
R1		X		
R3		X		
R4	X			
R5		X		
R6			X	
R7			X	
R10			X	
R11	X			
R15		X		Rock Creek-Red Lodge Creek Confluence.
R18	X			Grove Creek
R27	X			Cottonwood Creek
Total on Clarks Fork	37	16	42	TOTALS 95
Total on Rock Creek	4	4	3	11
Total	41	20	45	106

* Turbidity levels are based upon color differences of the water in the vicinity of the confluence of the tributary and the river. The tabulated tribtaries include only those with water visible in them.

Results of this study indicate that aerial color infrared photography and thermal infrared imagery are practical tools for locating and identifying existing and potential inflows of sediment laden water to a river system. Data can be obtained rapidly and accurately.

Color infrared photography effectively detects small changes in low concentrations of suspended particles in water and enhances the change by a color difference. Interpretation of the color infrared photography provides a means of qualitatively assessing the suspended material concentration of the river system. An interpreter can evaluate the ground truth information more accurately and can locate ground sampling sites that are representative of the phenomenon of interest. Field survey work can be performed with greater efficiency and at less cost because of prior knowledge about drainage locations, terrain and accessibility.

Thermal infrared imagery provides an indication of temperature differences of the river and tributaries. In this case, tributaries entering at approximately the same or at colder temperatures were observed. Tributaries entering at a higher temperature than the river were not detected.

Each of the above two systems provide information relative to the river system. Color infrared photography is best for identifying sediment concentration differences. Thermal infrared imagery provides an indication of the relative temperature of the scene. Together they provide a unique, quasi-synoptic view of the sediment transport process in a river system.