

Division of Geological and Geophysical Surveys

Public-data File 92-17

**HYDROLOGIC AND WATER QUALITY INVESTIGATION OF THE  
GOLD RUN PASS AREA NEAR HEALY, ALASKA**

By

Scott R. Ray and Jim Vohden  
Alaska Division of Water

Released by  
Alaska Division of  
Geological and Geophysical Surveys

June 1992

**THIS REPORT HAS NOT BEEN REVIEWED FOR  
TECHNICAL CONTENT (EXCEPT AS NOTED IN TEXT) OR FOR  
CONFORMITY TO THE EDITORIAL STANDARDS OF DGGS.**

794 University Avenue, Suite 200  
Fairbanks, Alaska 99709-3645

## INTRODUCTION

This report describes the hydrology and water quality of the streams and groundwater associated with the Gold Run Pass area of the Hoseanna Basin. Coal mining has continued off and on in the area for the past twenty years. It is this activity which has compelled the Division of Water to undertake this study. This report will compare data collected for this study to previous studies conducted in the area by the Alaska Division of Geological and Geophysical Surveys and by the US Geological Survey.

### Location

Hoseanna Creek Basin is located in the Nenana Coal Field (Merritt and Hawley, 1986) on the north flank of the Alaska Range. Hoseanna Creek flows east to west into the Nenana River approximately five miles north of the old Healy townsite. Gold Run Pass, located 11 miles northeast of Healy, separates the middle Healy and upper Hoseanna basins (see Figure 1). The Hoseanna side of Gold Run Pass is drained by Sanderson Creek on the east and north, Hoseanna Creek on the west, and Clinker Creek on the south and west. Elevations in the study area range from 3,300 feet at the headwaters of Clinker Creek east of the pass, to 2,500 feet at the pass, and 1,870 feet at the confluence of Clinker and Hoseanna creeks.

### Geology

The Hoseanna Creek Basin is underlain by the highly-deformed Precambrian quartz-sericite Birch Creek Schist (Wahrhaftig, 1970). The schist is overlain by the mid-Tertiary Usibelli Group (Wahrhaftig, 1987), which is comprised of weakly consolidated sand, silt, clay and coal sequences. The late Tertiary Nenena Gravel tops the Usibelli Group (Wahrhaftig, 1987). This formation is composed of large cross-bedded coarse-grained sands and thick gravel sediments (Wilbur, 1989).

Both the Birch Creek Schist and the Usibelli Group are found in the Gold Run Pass area. The Birch Creek Schist is exposed in the southern portion of the area, while the Usibelli Group is exposed in the northern portion. Because of the north facing aspect of the schist terrain, much of the soils covering it are permafrost-rich and susceptible to solifluction, frost heaving and frost scarring (Wilbur, 1989). The Usibelli

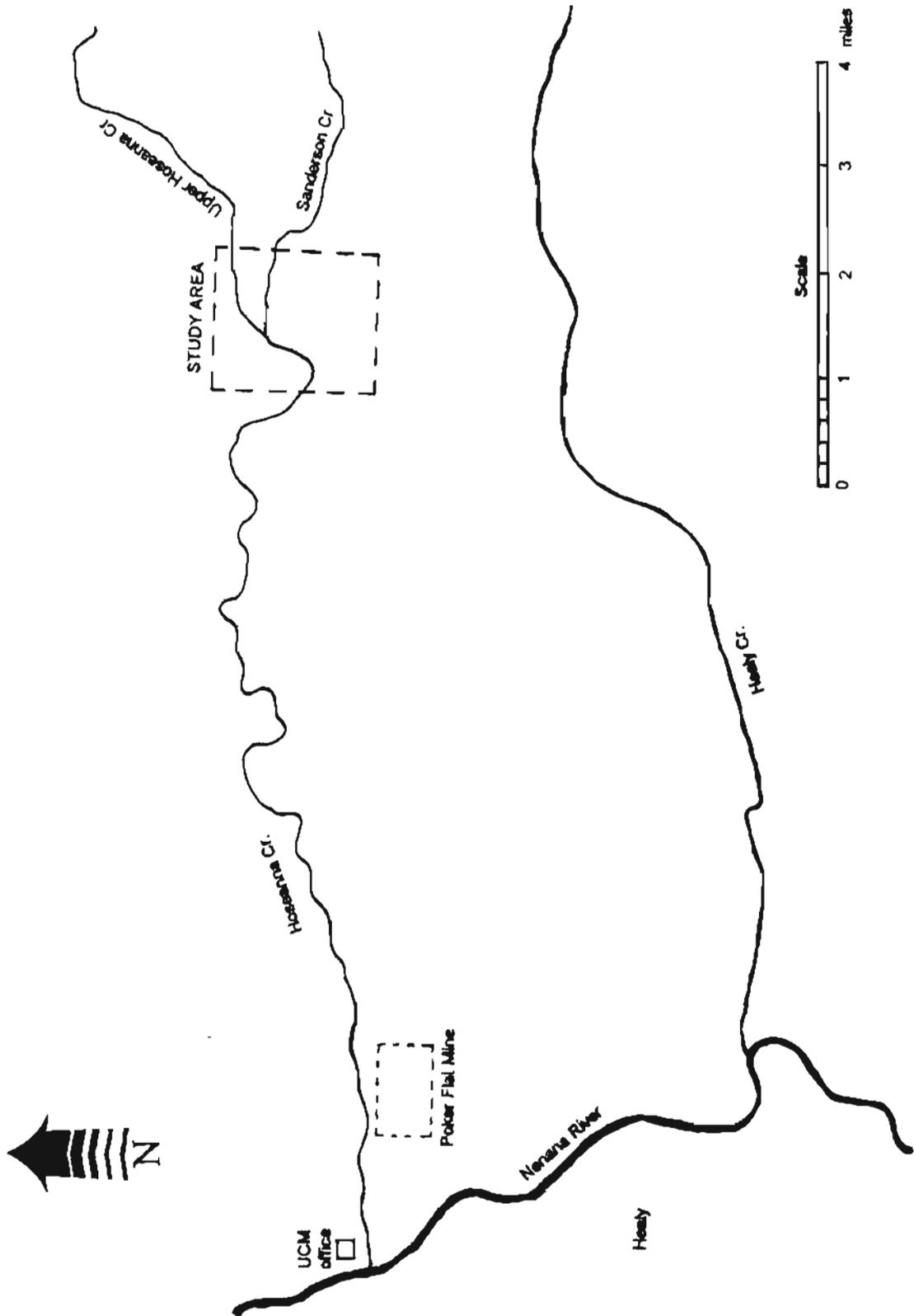


Figure 1. Map showing location of the Gold Run Pass study area.

Group is characterized by active landslides, soil creep and badlands topography (Wilbur and Beget, 1988).

Two landslides in the study area are located to the east and to the west of the mine pit. Wilbur and Renshaw (1987) estimated average horizontal displacement of slides in the valley ranging from 2 to 75 feet per year.

### **Climate**

Typical interior Alaskan summers are characterized as short and warm with average highs in July in the low 70s °F and lows in the lower 50s °F. Winters are long and cold with average January temperatures ranging from -20 °F to 0 °F. Precipitation generally falls as snow from October through April. Summer precipitation generally occurs as light showers with occasional heavier convective showers. The largest precipitation events are the result of large cyclonic storms from the Gulf of Alaska or Bering Sea. These moisture-laden storms are accompanied by low-level west-southwesterly winds which are capable of dropping more than two inches in 24 hours (Ray, 1990).

### **Mining History**

Coal mining in the region began in the 1920's in the Healy Creek basin. During the early years, underground methods were used, but the use of these methods ceased by 1963. Surface mining methods have been used exclusively since.

Mining in the Hoseanna Creek basin began in the mid 1950's at Lignite near Louise Creek. Mining moved up the basin with the discovery of the Gold Run Pass reserves in the early 1970's. Mining continued in the Gold Run Pass pit until the late 1970's when the Poker Flat mine began operation. Mining began again in 1988 (on a small scale) when the newly completed road up the Hoseanna valley provided easy access to the pit. The current pit is near the end of operation. A new mine is proposed west of the present pit.

## METHODS

### Sampling Sites

Data was collected at seven surface water sampling sites during the summer of 1991 and three wells were sampled in the fall of 1991. Table 1 summarizes the surface water sampling sites and Figure 2 (page 36) shows the sampling site locations. Previous types of data collected in the area are also summarized in Table 1. These data were reported by the following: Ray and Maurer (1989), Wilbur (1989), Mack (1988), Parks (1983), and Scully et al. (1981).

*Table 1. Surface water sites used in this study, the year the sites were sampled, and the type of data collected. Map number refers to the site number on Figure 2 (page 36).*

Map Number	Location	Year	Discharge	Continuous Discharge	Sediment	Chemistry
1	Sanderson Creek 1.6 miles above Hoseanna Creek basin area = 4.7 mi <sup>2</sup>	1991	Y	N	Y	Y
		1988	Y	Y	Y	N
		1987	Y	Y	Y	N
		1981	Y	N	Y	Y
2	Sanderson Creek 0.8 miles above Hoseanna Creek basin area = 5.1 mi <sup>2</sup>	1981	Y	N	Y	Y
		1980	Y	N	Y	Y
3	Sanderson Creek above Hoseanna Creek basin area = 5.3 mi <sup>2</sup>	1991	Y	N	Y	Y
		1988	Y	N	Y	N
		1987	Y	N	Y	N
		1986	Y	N	Y	N
4	Hoseanna Creek above Sanderson Creek basin area = 8.6 mi <sup>2</sup>	1991	Y	N	Y	Y
		1988	Y	N	Y	N
		1987	Y	N	Y	N
		1986	Y	N	Y	N
		1978	Y	N	Y	Y
5	Hoseanna Creek below Sanderson Creek basin area = 14.1 mi <sup>2</sup>	1991	N	N	Y	N
		1978	Y	N	Y	Y
		1977	Y	N	Y	Y
6	Clinker Creek above Hoseanna Creek basin area = 1.7 mi <sup>2</sup>	1991	Y	Y	Y	Y
		1988	Y	N	Y	N
		1987	Y	N	Y	N
		1986	Y	N	Y	N

*Table 1 (cont). Surface water sites used in this study, the year the sites were sampled, and the type of data collected. Map number refers to the site number on Figure 2 (page 36).*

Map Number	Location	Year	Discharge	Continuous Discharge	Sediment	Chemistry
7	North Clinker Creek above Clinker Creek basin area = 0.08 mi <sup>2</sup>	1991	Y	N	Y	Y
8	East seep	1991	Y	N	Y	Y
9	West seep	1991	Y	N	Y	Y

Three groundwater monitoring wells were installed at Gold Run Pass and sampled in 1991. The sites names (and Figure 2 labels) are as follows: 91GA-1 (#10), 91GA-3 (#11), and 91GA-5 (#12).

### Sampling Procedures

#### Precipitation

Precipitation data were collected at Gold Run Pass using a barrel-type gage with a Wyoming shield. The gage is located at an elevation of 2,490 feet (Figure 2). The gage uses an electronic data storage unit which takes a reading every 30 minutes. The resolution of the gage is 0.01 feet (0.12 inches).

#### Discharge

Stream velocities used in the discharge calculations were measured with a standard pygmy meter. Velocities were measured at six-tenths depth, with sufficient numbers of sections such that no one section contained over ten percent of the flow. Discharge was calculated using the standard midpoint method (USDI, 1981).

Discharge at Clinker Creek was determined with a nine inch Parshall flume, using the rating curves supplied with the flume. The discharge from the flume was also field checked to ensure the accuracy of the calibration. Continuous stage levels were recorded at the upper Sanderson Creek site in 1987 and 1988 and at

Clinker Creek in 1991 using Omnidata DP320 stream gage recorders with pressure transducers. The recorder is capable of measuring water depths up to ten feet in intervals of 0.01 feet.

Discharge rating curves were developed for the Sanderson Creek site using the stage-discharge data. High flow events which were not directly measured were estimated using the indirect slope-area method (Dalrymple and Benson, 1984).

On streams with insufficient flow to measure with the pygmy meter, the flow was channelled into a six-foot long, four-inch diameter PVC pipe. A suitable location was chosen such that a five gallon bucket could catch the discharge from the pipe. After the stream had reached equilibrium with the pipe, the time it took to fill the bucket was recorded. The average of five such measurements was reported (in gallons per minute).

## **Water Quality**

### **Surface Water**

Surface water samples for water-quality analysis were obtained using a hand-held depth-integrating sediment sampler and a churn splitter (USDI, 1977). Samples collected from the churn splitter were processed according to each parameter in compliance with approved methods (USEPA, 1982). Filtering was done with 0.45 micron membrane filters. Acidification was done with Ultrex-grade nitric acid.

Water temperature and dissolved oxygen were measured in situ using portable meters. Conductivity and pH were measured on the composited sample. Alkalinity was measured electrometrically on the composited sample with the pH meter and digital titrator, using the gran-plot method (Martin, 1972).

Automated sediment samplers were installed at the sites with continuous discharge measuring equipment. The sediment samplers were activated by high water levels during storm events. The samplers would then sample every hour until the sampler was full (24 samples). These samples were analyzed for total suspended solids and turbidity.

## Groundwater

Prior to pumping the wells, water levels were measured using an electric water-level indicator and the volume of water in the casing calculated. Wells were purged using a QED "Purge Master" pump. Water temperature, pH, and conductivity were measured at regular intervals during the well purging. After at least three well casing volumes were purged from the well, the pumping stopped when the conductivity fluctuated less than ten percent. The pump was removed from the well, and samples were collected using Teflon bailers. Water was bailed and collected in the churn splitter until sufficient water was obtained for all the analyses. Parameters and sample preparation were the same as for the surface water. The pump was cleaned prior to purging the next well.

## Laboratory Analysis

Water quality analyses for surface and ground waters were conducted in the Alaska Division of Water's Water-Quality Laboratory on the University of Alaska Fairbanks campus. The laboratory is a participant in the USEPA Performance Evaluation program as well as the USGS Standard Reference Water Sample Quality Assurance program. Analytical methods and detection limits are outlined in Table 2. For all parameters, calibrations were performed using NBS traceable standards where applicable. General data reduction procedures are described in Standard Methods (APHA, 1989).

Table 2. Analytical methods and detection limits for parameter determined in this study.

Parameter	EPA Method	Detection Limit
Alkalinity	310.1	0.1 mg/L as CaCO <sub>3</sub>
Aluminum	AES 0029	0.005 mg/L
Arsenic	206.2	0.001 mg/L
Barium	AES 0029	0.005 mg/L
Boron	AES 0029	0.01 mg/L
Cadmium	213.2	0.001 mg/L
Calcium	AES 0029	0.01 mg/L
Chloride	300.0	0.01 mg/L
Chromium	218.2	0.001 mg/L

Table 2 (cont). Analytical methods and detection limits for parameter determined in this study.

Parameter	EPA Method	Detection Limit
Cobalt	AES 0029	0.01 mg/L
Conductivity	120.1	0.1 uS/cm
Copper	220.2	0.001 mg/L
Dissolved Oxygen	360.1	0.1 mg/L
Fluoride	300.0	0.01 mg/L
Iron	AES 0029	0.03 mg/L
Lead	239.2	0.001 mg/L
Magnesium	AES 0029	0.01 mg/L
Manganese	AES 0029	0.005 mg/L
Molybdenum	AES 0029	0.01 mg/L
Nickel	AES 0029	0.01 mg/L
Nitrate	300.0	0.02 mg/L as N
pH	150.1	0.01 unit
Phosphate	300.0	0.1 mg/L as P
Potassium	258.1	0.01 mg/L
Silicon	AES 0029	0.01 mg/L
Sodium	273.1	0.1 mg/L
Sulfate	300.0	0.01 mg/L
Total Suspended Solids	160.2	0.1 mg/L
Turbidity	180.1	0.1 NTU
Zinc	AES 0029	0.005 mg/L

## HYDROLOGY

### Precipitation

The precipitation gage at Gold Run Pass has been operated by the Division of Water (formerly the Water Section of the Division of Geological and Geophysical Surveys) since 1987. The data from this gage is summarized in Table 3. The summer season totals range from 17 inches in 1988 to less than 8 inches in 1991. The average precipitation total at the Poker Flat Mine (seven miles to the west of Gold Run Pass) for the period of May through September 1979-89 was 12.44 inches (Wilbur, 1989). The average May through September precipitation at the Poker Flat mine gage (1987-91) was 10.48 inches. This compares to the average for the Gold Run Pass gage (1987-91) of 13.11 inches (Table 3). Ray (1991) attributes this difference in the precipitation amounts to the orographic effects of the upper basin.

Table 3. Monthly precipitation for Gold Run Pass. All values in inches.

Year	MAY	JUN	JUL	AUG	SEP	Total
1987	0.12	1.08	2.52	3.24	4.32	11.28
1988	2.16	5.88	4.92	2.52	1.56	17.04
1989	0.96	6.20	1.32	4.92	0.84	14.24
1990	0.96	0.96	4.44	4.92	4.08	15.36
1991	0.36	1.44	3.00	2.16	0.72	7.68
<b>Average</b>	<b>0.91</b>	<b>3.11</b>	<b>3.24</b>	<b>3.55</b>	<b>2.30</b>	<b>13.11</b>

### Surface Water

Continuous discharge data was collected in the Gold Run Pass area at two sites. Flow was recorded at Sanderson Creek (1.6 miles above Hoseanna Creek) from June to October 1987 (Mack, 1988) and from May through September 1988 (Ray and Maurer, 1989). Flow was also recorded at Clinker Creek above Hoseanna Creek from May to October 1991. The hydrographs of the streams are shown in Figures 3-5, with the average monthly and season discharge given in Table 4. The monthly averages are based on the amount of data available. For example, the May 1988 average for Sanderson Creek is based on five days of data.

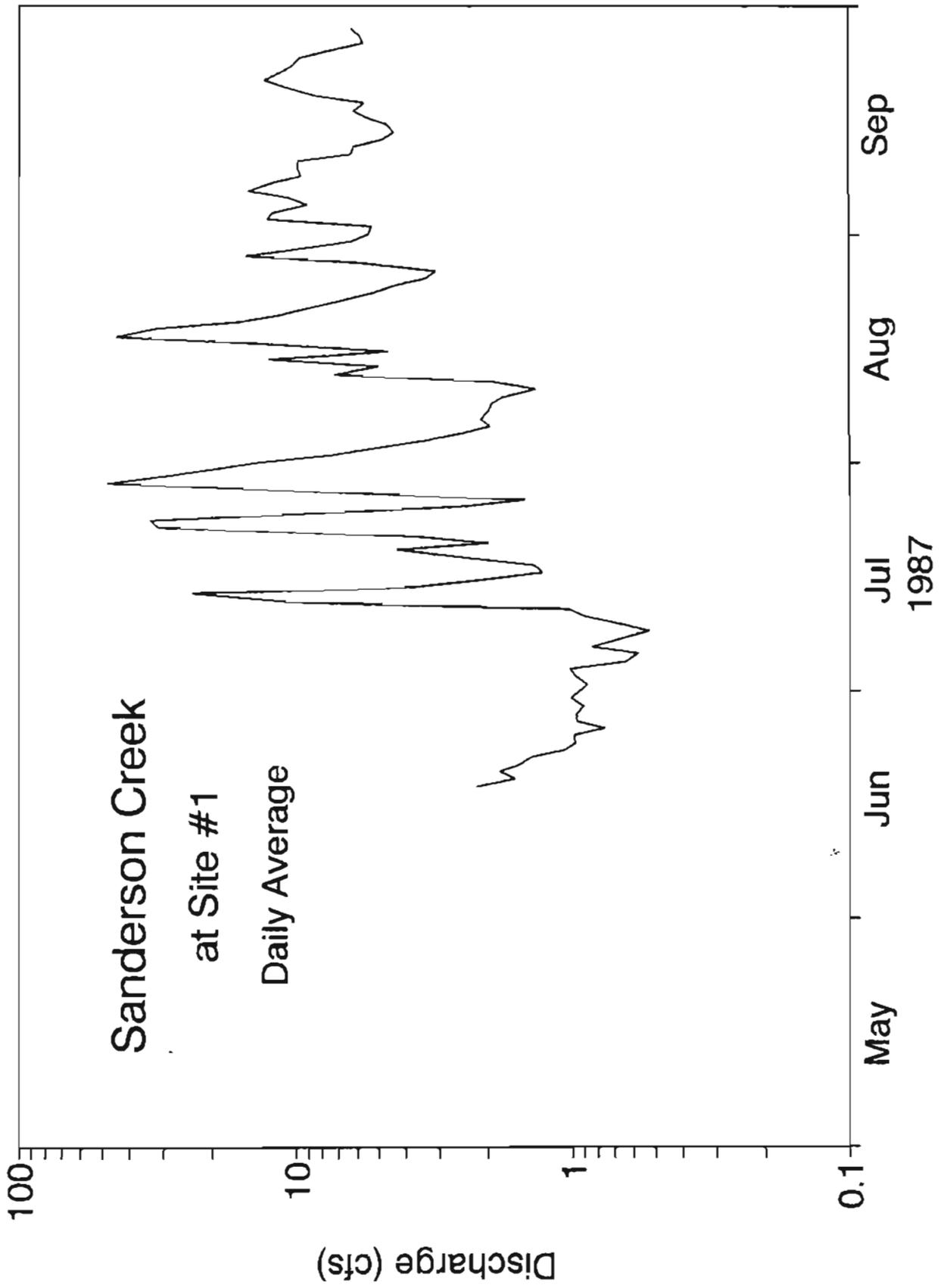


Figure 3. Hydrograph of Sanderson Creek at site #1, 1987.

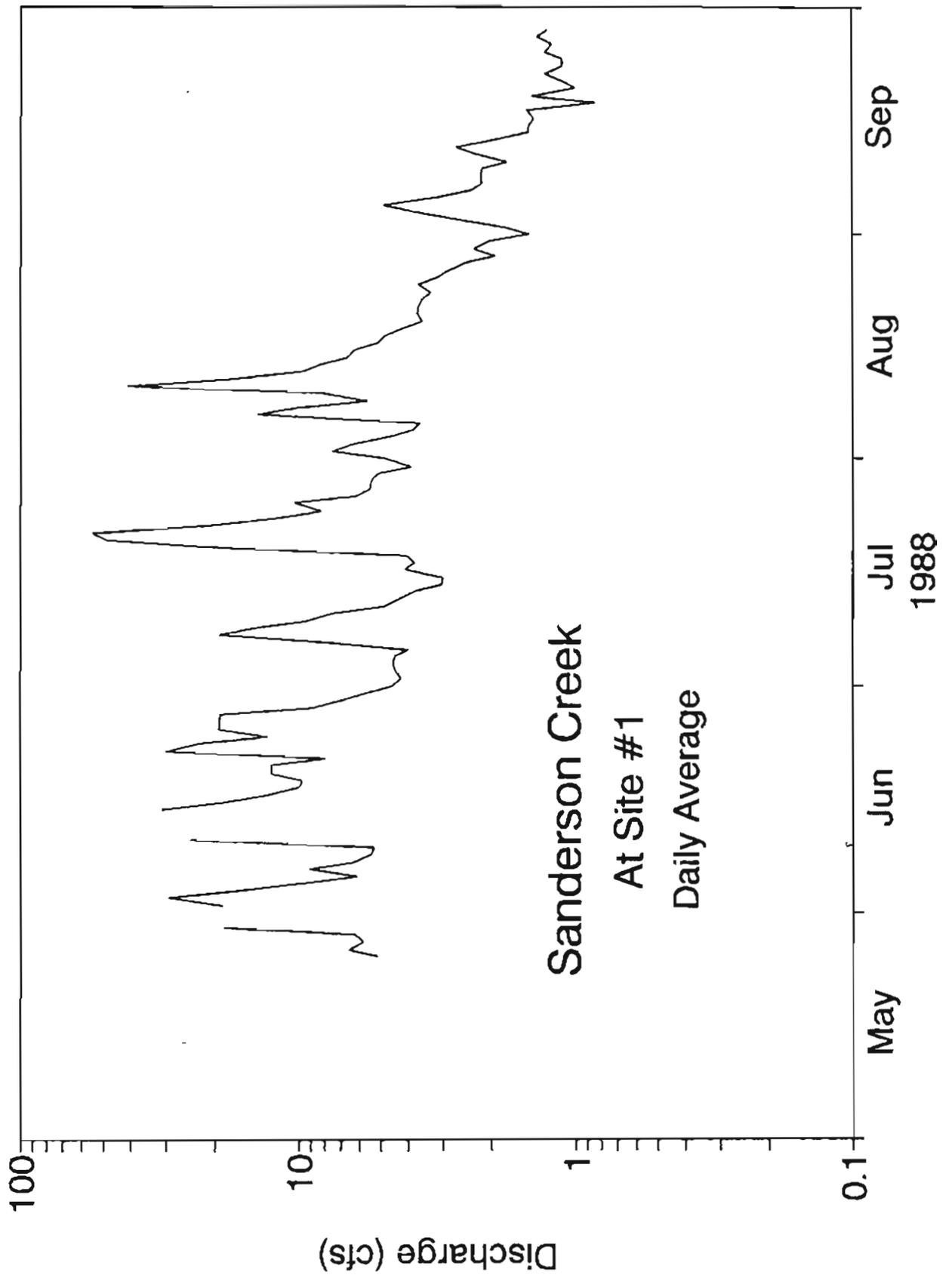


Figure 4. Hydrograph of Sanderson Creek at site #1, 1988

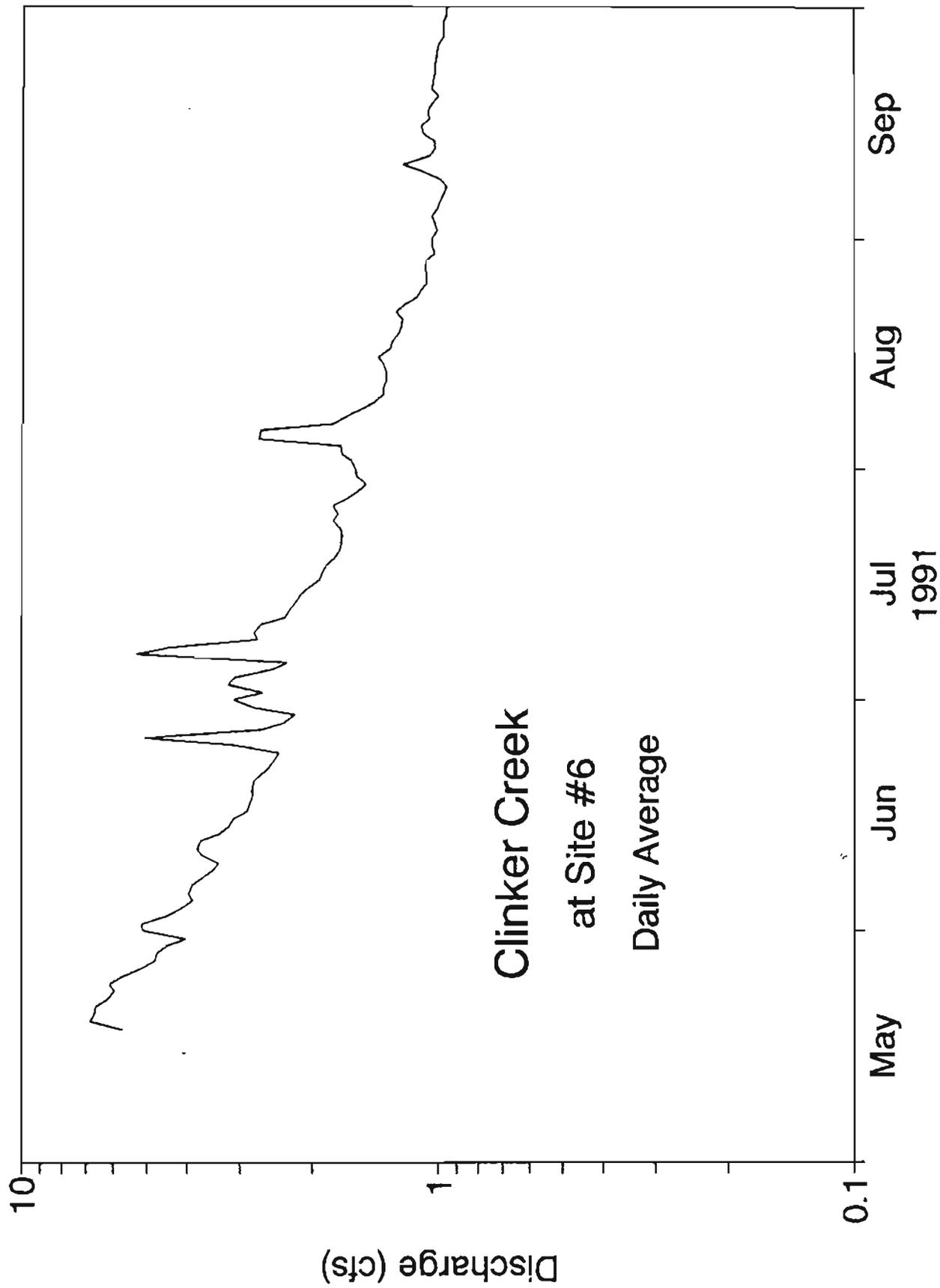


Figure 5. Hydrograph of Clinker Creek (site #6) above Hoseanna Creek, 1991.

*Table 4. Monthly and season discharge for Sanderson and Clinker creeks. All discharge values in cfs.*

	MAY	JUN	JUL	AUG	SEP	Average
<b>Sanderson Cr</b>						
1987	—	1.27	7.44	8.84	8.39	6.98
1988	8.42	14.8	10.3	6.75	1.87	8.23
<b>Clinker Cr</b>						
1991	5.61	3.39	2.35	1.43	1.03	2.39

The hydrographs should provide enough information as to the amount of data used in the monthly averages.

The season average is an average of all the data, not an average on the monthly data.

Peak flow at Sanderson Creek above mining (site #1) during the study period was 225 cfs in 1988 (Ray and Maurer, 1989). The peak flow at Clinker Creek (site #6) during the study period was 12.3 cfs in 1991.

The flow in Sanderson Creek is closely represented by the monthly precipitation at Gold Run Pass. In May and June of 1987, only 1.20 inches of rain fell at Gold Run Pass. Although no discharge measurements were made in May, the late June flows at Sanderson Creek were less than one cfs. However, the precipitation increased each month from July through September, as did the discharge at Sanderson Creek. In 1988, about 13 inches of rain fell in May, June and July. The average flow for this period was over ten cfs at Sanderson Creek. Less rain fell in August and even less in September, resulting in a slow regression of the baseflow. The average flow in September was under two cfs. In 1991, the stream flow at Clinker Creek is not representative of the precipitation which fell early in the summer (only 0.36 inches in May). The high baseflow discharge early in the summer was due to an usually heavy snowpack (many places in the interior set all-time snowfall records). The heavy snowpack recharged the aquifer, which slowly discharged to the streams. Storms during July and August slowed the baseflow recession, but flows still dropped below one cfs during September.

The total runoff per unit area (inches) for July, August and September for Sanderson Creek (1987), Sanderson Creek (1988), and Clinker Creek (1991) are 6.0 inches, 4.6 inches, and 3.2 inches, respectively. The ratio of runoff to precipitation for the sites is 0.59, 0.71, and 0.55, respectively. This means that during the period of July through September, 55 to 71 percent of the precipitation which fell in these basins ran off as stream flow. Both these basins are underlain by the Birch Creek Schist, with permafrost soils and a thin active layer with low infiltration capacity (Wilbur, 1989). As a result, the response of the creeks to storms tends to be rapid, with most of the water running off. In contrast, Two Bull Creek (seven miles to the west) is underlain by the Nenana Gravels and the Usibelli Group. In 1990 the runoff to precipitation ratio was 0.08. Only eight percent of the July through September precipitation ran off. This indicates a large groundwater storage capacity for that type of terrain.

Miscellaneous discharge measurements were made at the remaining surface water sites. These data are found in the appendices with the chemistry and sediment data. There are two measurements of note. In 1991, measurements were made on Sanderson Creek during dry, baseflow runoff conditions. The flow at site #1 (upstream) was 4.07 cfs. A few hours later, the flow at site #3 (downstream) was 3.67 cfs. Based on the flow per square mile of the upstream site, the predicted flow at the lower site was 4.7 cfs. The flows could have been the same, with the variation in the flow data between the sites due to the error associated with each flow measurement. However, it appears that the downstream site was not greater than the upstream site or near the expected flow of 4.7 cfs.

## **Groundwater**

The two formations which occur in the Gold Run Pass area are the Birch Creek Schist and the Usibelli Group. No information is available from the area on the schist aquifer. In general, highly metamorphosed crystalline rock has little, if any, primary porosity. In order for groundwater to occur, the metamorphosed crystalline rock must have secondary porosity resulting from fractures and faults (Fetter, 1988). In the Fairbanks area, the groundwater aquifer in the hills is the Birch Creek Schist. The schist controls the nature of the aquifer through structural control of the groundwater movement. In particular, the spatial distribution of structural features such as fractures and joints which control the aquifer characteristics

are anisotropic and heterogeneous. The geologic system produces high spatial variability of hydrologic variables over relatively short distances (Weber, 1987). Domestic wells in the aquifer are generally 100 to 200 feet deep, although a few may range up to 500 feet (Pewe, 1982). Sustained yields are typically less than 10 gpm, although a well finished in a large fracture system on Ester Dome yields 300 gpm (Walther, 1987).

The Usibelli Group in the Gold Run Pass area is composed of layers of sandstone, siltstone, clay, and coal. Of particular interest to the study, are two mineable coal seams: the Caribou seam and the Moose seam. These seams are located in the northwest portion of Gold Run Pass. The uppermost seam is the Caribou seam. The seam ranges in thickness from 10 to 16 feet, strikes east-west and dips to the north from 3 to 18 degrees (UCM, personal communication). Depth to the top of the seam ranges from 5 feet in the west to 130 feet in the east. The Moose seam is the lowest coal seam of interest in the area. With thickness ranging from 13 to 30 feet, it also strikes east-west and dips to the north from 3 to 18 degrees. Maximum known interburden depths are 59 feet (UCM, personal communication).

In preparation for future mining, three monitoring wells and eight piezometers were installed by Usibelli Coal Mine in the coal seams to evaluate the aquifers associated with the Usibelli Group. Coal is commonly an aquifer, with secondary porosity developed by the bedding planes and cleats (Fetter, 1988). Throughout the Hoseanna Creek Basin, the coal seams tend to be the aquifers with the overlying siltstones acting as aquitards, and the underlying clays acting as aquicludes (UCM, personal communication).

The Caribou seam is generally dry, except in well 91GA-5. The well log (Golder Associates, 1991) reports the seam became wet near the bottom. Since the underlying layer is clay, any water which has "leaked" into the coal seam might form a perched aquifer. However, this was not seen in the other logs and does not appear laterally extensive. Some of the other minor coal seams exhibit similar characteristics.

The Moose seam is the major aquifer of concern in the Gold Run Pass area. The aquifer has both confined and unconfined areas, with the siltstone interburden acting as the confining layer. The source of the water in the aquifer is the north-south trending faults which border the Moose seam (UCM, personal communication). The hydraulic gradient is approximately 14 feet per 100 feet. This is considerably higher than the 3 feet per 100 feet in the seams at the Poker Flat Mine. If one assumes the same flow per unit area through the seams (similar recharge) then the hydraulic conductivity would be about five times higher at the

Poker Flat Mine. This concurs with the field observations by the Alaska Division of Water when the wells were sampled. Well 91GA-1 (site #10) did yield a constant rate of approximately 13 gph, however the other two wells (91GA-3 and 91GA-5) were much less (less than one gph). Once the well casings of these two wells were evacuated, these wells yielded little water. The depth to water in well 91GA-1 did recover quicker than the other wells. Four days after sampling, the depth to water was within one foot of the pre-sampling water level. Well 91GA-3 (site #11) did not recover as fast, and was within three feet of the pre-sampling level three days after sampling. Well 91GA-5 (site #12) was the worst, only recovering 70 percent (13 feet below the pre-sampling depth) after three days. It was still four feet below the pre-sampling level after nine days. A contributing factor of the slow recovery times was the well development (a considerable amount of sediment was pumped from all the wells). It is possible that the recovery was inhibited by the sediments in wells 91GA-3 and 91GA-5.

## WATER QUALITY

### Surface Water

#### Sediment

Automatic sediment samplers were installed at Sanderson Creek (site #1) in 1987 and 1988, and at Clinker Creek (site #6) in 1991. These samplers collected sediment data with the continuous discharge recorders. Grab samples were collected at the other sites for the sediment data. The samples were analyzed for total suspended sediment and turbidity. Using the sediment and discharge data, it is possible to develop sediment rating curves for the two sites. Figures 6 and 7 show the two rating curves developed for the sites using the sediment data collected. Table 5 summarizes the regression line coefficients and statistical-fit data.

Figure 6 plots the data collected (1986 through 1988) and the statistical regression line at Sanderson Creek (site #1) (Ray, 1990). Also plotted on Figure 6 is the statistical regression line for the data collected at Sanderson Creek (site #3) above Hoseanna Creek (Wilbur, 1989). Comparing the two regression lines shows that the upper site (#1) has much less sediment at low flows than the lower site (#3). Upper Sanderson Creek is underlain by the Birch Creek Schist, and has a limited supply of sediment available for transport at low flows. However, between the two sites the Usibelli Group is exposed. There are two landslides in this terrain

which slump into Sanderson Creek, supplying ample sediment for transport, even at low flows. At high flows, the regression lines merge, indicating that a limited amount of sediment may be available from both terrains.

*Table 5. Coefficients,  $r^2$  value, and number of samples used (n) for the sediment rating equations for Sanderson and Clinker creeks. The equations are of the form:  $TSS = aQ^b$ .*

Site	a	b	$r^2$	n
<b>Sanderson Creek (site #1)</b>				
1987	1.93	1.88	0.73	63
1988	<u>2.39</u>	<u>1.97</u>	<u>0.86</u>	<u>108</u>
1986-1988	2.25	1.93	0.80	173
<b>Sanderson Creek (site #3)</b>				
1986-1988	417	0.74	0.80	15
<b>Clinker Creek (site #6)</b>				
1991	14.6	2.16	0.65	112

Figure 7 shows the data collected from Clinker Creek and the statistical regression line. The regression line for Clinker Creek is similar to the regression line developed for Sanderson Creek site #1. The slope of the two lines are 2.16 and 1.93, respectively. The slope of the line for Sanderson Creek site #3 is 0.74. The equality of the slope of the two lines indicates that the two basins respond similarly with respect to sediment. Since both basins are underlain by schist, and both are hydrologically similar, it is not surprising that the stream-sediment characteristics are similar.

Calculated sediment loads for the three sites are given in Table 6. The loads for Sanderson Creek at site #1 and Clinker Creek (site #6) were calculated using the data collected from the automated sediment sampler and the average daily flow. When data from the automated equipment was not available, the predicted sediment value (based on the discharge) from the regression line was used. The load at Sanderson Creek at site #3 was estimated using the regression line developed by Wilbur (1989) and using the flow data from site #1 on Sanderson Creek. The load on Sanderson Creek is two to three times higher at site #3 than at site #1. The load at Clinker Creek is much less since the basin is smaller, schist-underlain, and because of the

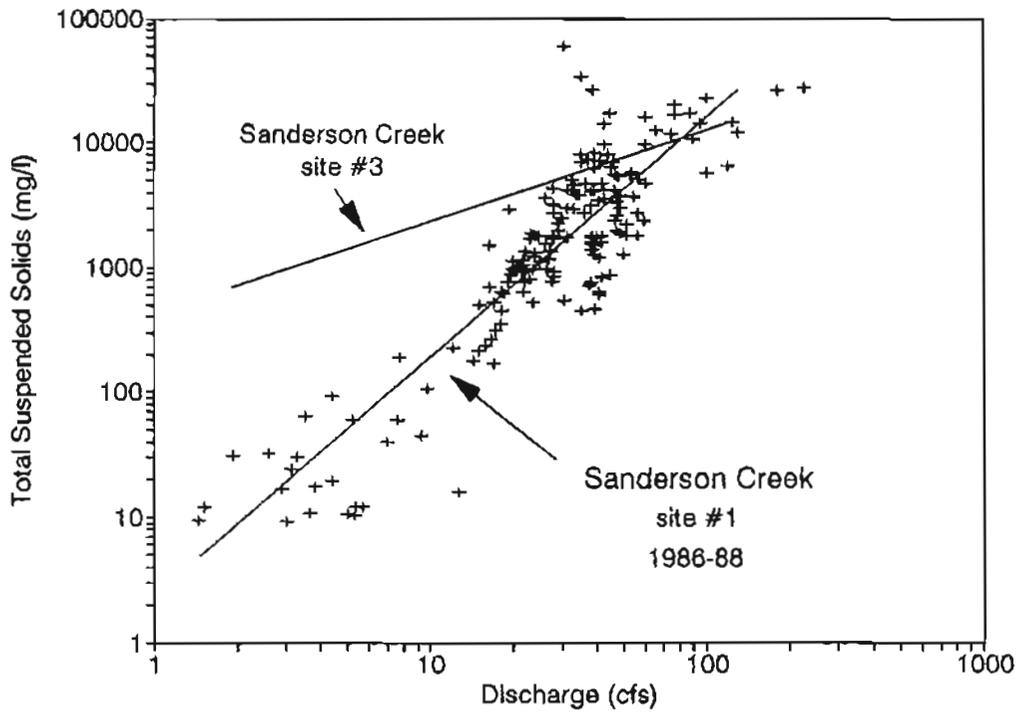


Figure 6. TSS versus discharge For Sanderson Creek (1986-88). Plotted data is from site #1. Regression lines from site #1 and site #3 (see text).

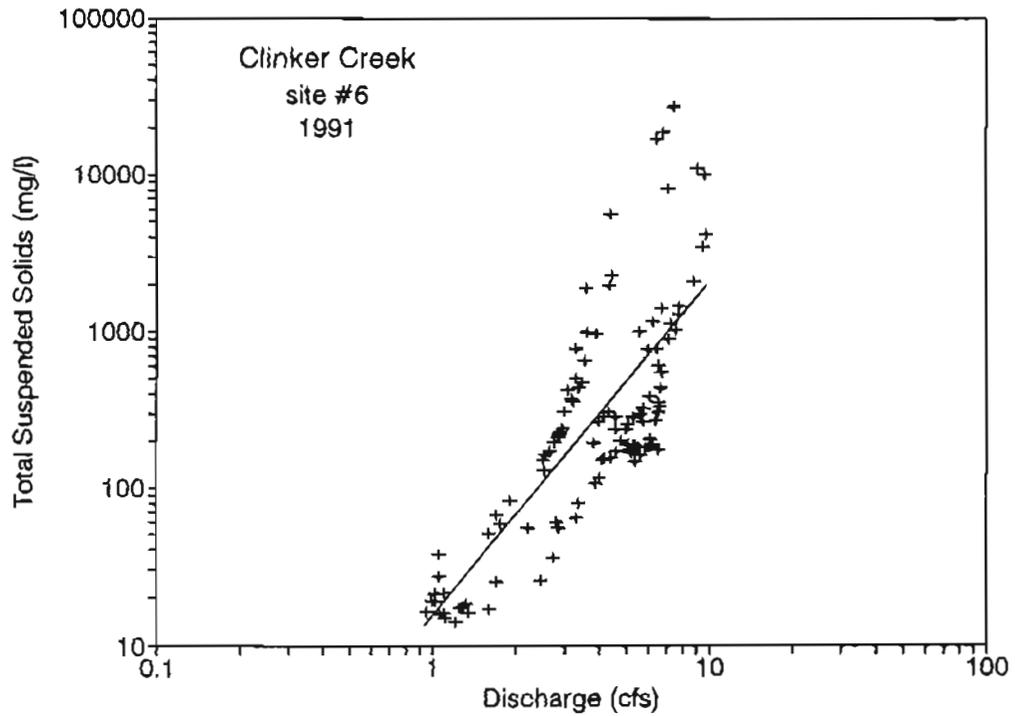


Figure 7. TSS versus discharge For Clinker Creek (1991 data).

lack of large storms during 1991. The average high flow at Clinker Creek in 1991 was due to the high baseflow from the spring recharge. This type of high flow does not contribute as much sediment to the stream as runoff from large precipitation events.

*Table 6. Monthly and season sediment load for Sanderson (site #1 and #3) and Clinker (site #6) creeks. All load values are in tons per day.*

	MAY	JUN	JUL	AUG	SEP	Total
<b>Sanderson Cr (site #1)</b>						
1987	---	1.16	1120	980	600	2700
1988	2040	1490	3030	1010	2.24	7570
<b>Sanderson Cr (site #3)</b>						
1987	---	22.0	2870	2530	1470	6890
1988	2500	4500	3540	1550	113	12200
<b>Clinker Cr</b>						
1991	108	105	30.2	25.5	1.26	268

One other site has a sufficient quantity of sediment data to discuss. Grab samples were collected twice a week by Usibelli personnel from Hoseanna Creek below Sanderson Creek (site #5) during 1991. Additional samples were collected by Alaska Division of Water investigators when on site. A total of 44 samples were collected. However, no flow data was collected. The mean TSS was 952 mg/l; median TSS was 300 mg/l; while the range was from 10,600 to 24.1 mg/l. These data are reported in Ray (1992). Other miscellaneous sediment samples were collected at the remaining surface water sites. These data are reported in the appendices with the flow and chemistry data.

## Chemical Quality

### Major Ions

Data used in this section are a compilation of data collected by the Alaska Division of Water in 1991 and from two USGS studies. Parks (1983) collected samples in the Gold Run Pass area in 1980 and 1981.

Scully et al., (1981) collected samples in 1977 and 1978. The data from these studies are found in the Appendices A, B, and C.

The chemical quality of water is similar at all sampling sites on Sanderson Creek. These waters are characterized by calcium and magnesium as the dominant cations and sulfate and bicarbonate as the dominant anions. Site #1 was sampled in 1981 and 1991, with the results of the analyses very similar. During the 1991 sampling, the dissolved-solids concentration (TDS) in Sanderson Creek drops from site #1 (550 mg/L) to site #3 (509 mg/L). The contribution of groundwater to stream flow must be low, if any, between the two sites since the flow dropped from site #1 (4.07 cfs) to site #3 (3.67 cfs). The TDS concentration of the groundwater must be lower than the TDS concentration at site #1 since the concentration dropped at site #3. Any groundwater contribution would be from the Usibelli Group. The hydraulic conductivity in sandstone and fractured-coal seams is generally higher than in a schist aquifer (Freeze and Cherry, 1979). If similar gradients are present then the residence time in the aquifer would be lower in the sandstone and fractured-coal seams. This results in lower dissolved-solid concentrations. Hoseanna Creek above Sanderson Creek (site #4) had a much lower dissolved-solids concentration (82.4 mg/L). The Upper Hoseanna basin is comprised of a larger percentage of the Usibelli Group (83 percent) than the Sanderson Creek basin (16 percent). This results in the lower dissolved-solids concentrations found in Upper Hoseanna Creek.

The percentage of constituents (based on milliequivalents) is different among the twelve sites sampled in 1991 (including the three groundwater sites). Figure 8 is a Piper diagram (Piper, 1944) which plots the average value of the twelve sites sampled during the study. The diagram shows that the waters at all sites dominated by sulfate and bicarbonate (right triangular plot), with almost no chloride. The cations (left triangular plot) have a fairly constant calcium percentage, with magnesium and sodium present in different percentages. The surface waters have more magnesium than sodium, however the groundwaters have higher sodium than magnesium. This forms a linear trend on the plot, with water from Sanderson Creek on the left, then water from Hoseanna and Clinker creeks, then the groundwater on the right. The Piper diagram can be used to differentiate the origin of the waters. Figure 9 shows a Piper diagram with the generalized characteristics of the waters shown. The Sanderson Creek samples plot in the area on top of the diamond. The waters are from a schist-dominated basin. The area on the lower-left side of the diamond are waters from

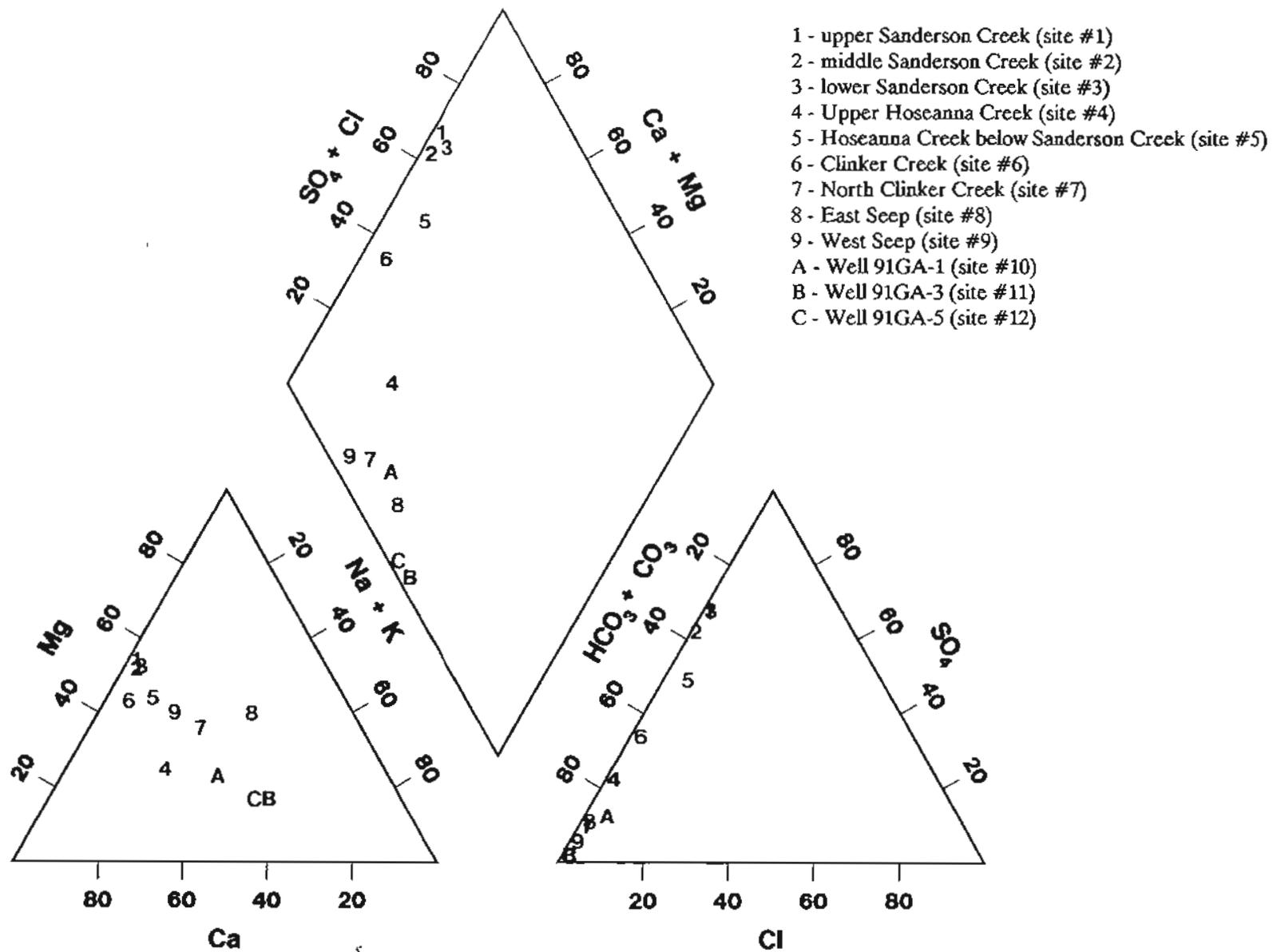


Figure 8. Piper diagram plotting the average value from each of the twelve sites sampled.

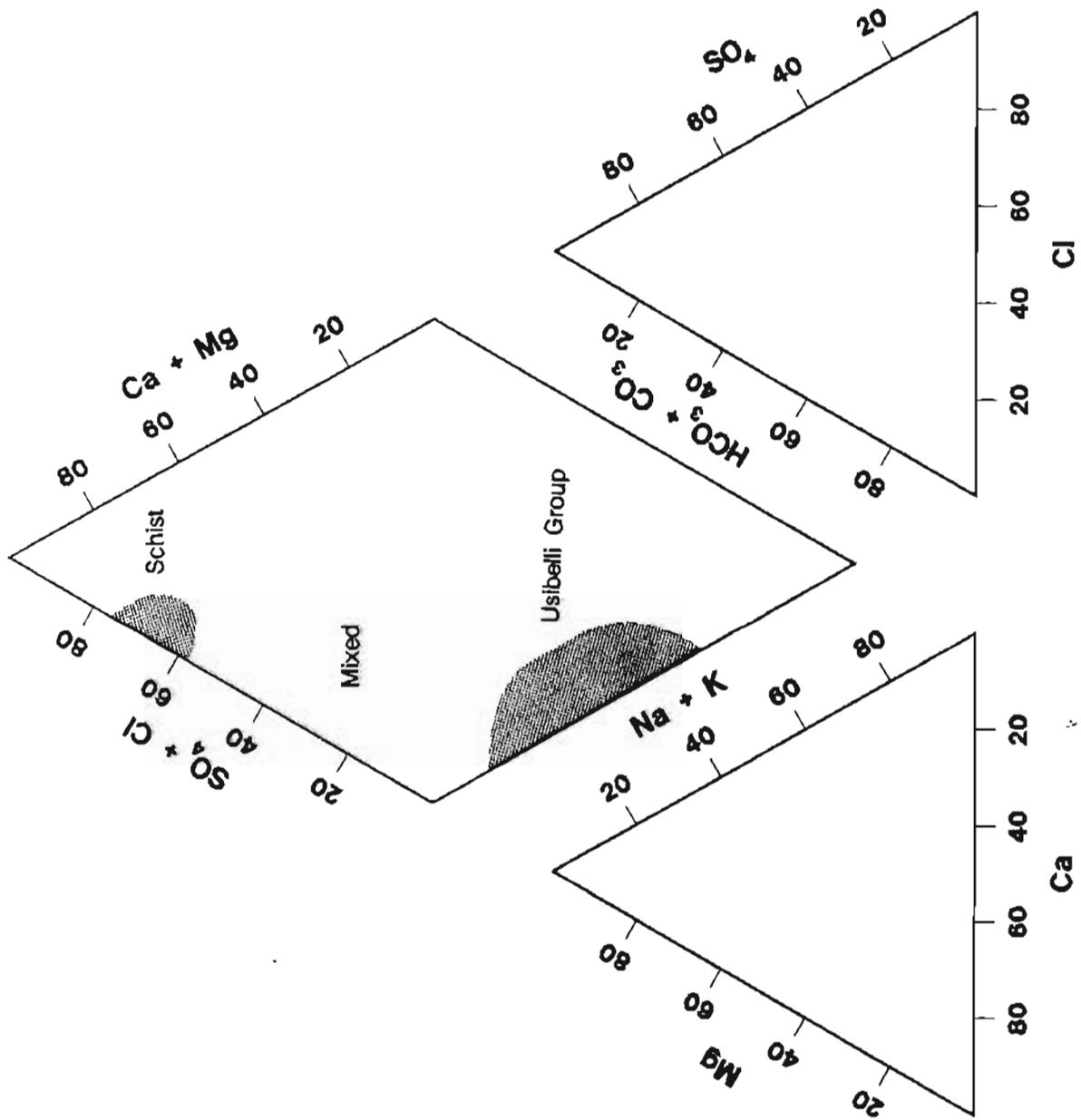


Figure 9. Piper diagram showing separation of basin types based on the water chemistry.

the Usibelli Group terrain. These include the groundwater samples from the Caribou coal seam (sites #10, #11 and #12), east and west seeps (sites #8 and #9), and North Clinker Creek (site #7). The sites which plot between these areas are streams which are made up of waters from both basin types.

Although the groundwater sample results plot with the surface waters with Usibelli Group origins, the concentrations of the groundwater is much higher. Site #10 (well 91GA-1) is the exception. The dissolved-solids concentration is very similar to the seeps. The well is at the top of the pass and is fairly shallow (depth to top of Moose seam is 42 feet). This water has not been in place very long, resulting in low dissolved solids. The other two wells (sites #11 and #12) are down-gradient of the pass, with the depths to the top of the Moose seam as 102 and 139 feet, respectively. These wells had dissolved-solids concentration six to seven times higher than site #10. These waters have a much longer residence time, resulting in the higher dissolved-solid concentrations. The results of the analyses from these wells are found in Appendix D.

#### Trace Metals

Samples for trace metal analysis were collected in this study and by Parks (1983). Most fresh waters in Alaska are regulated under drinking water-quality standards. The Alaska Department of Environmental Conservation (ADEC) has recently made changes in these criteria. Many factors determine whether a trace metal exceeds the water quality criteria. Factors such as: hardness of the water; type of sample (dissolved, total, or total-recoverable, length of average-time (instantaneous, 24-hour average, or 4-day average) (ADEC, 1991). Table 7 gives the criteria for the seven priority pollutants analyzed in the two studies. Since only grab samples were collected, it is not possible to calculate 24-hour and 4-day averages. All comparisons made are based only on instantaneous values. At no time was arsenic, cadmium, chromium, or nickel above the water-quality criteria for the surface waters at any of the sites. At Hoseanna Creek above Sanderson Creek (site #4) on July 30, 1991, the dissolved lead concentration was 2 ug/l. The water-quality criteria for lead (at a hardness of 64 mg/l) is 1.8 ug/l. The measured amount was only slightly over. On May 23, 1980, the lead concentration at Sanderson Creek (site #2) was reported at 51 ug/l. This certainly exceeded the water-quality criteria, however no hardness data was collected. However, the integrity of the sample is in question. At no other time or place in the study (Parks, 1983) did lead concentrations come close to that value, and most were

less than 5 ug/l. However, every sample collected on May 23, 1980 had dissolved lead concentrations ranging from 34 to 51 ug/l. It appears that the samples were contaminated, possibly from the acid used to preserve the samples. The total-recoverable zinc values exceeded the water-quality criteria of 47 ug/l on every date sampled by Parks (1983) on both sites on Sanderson Creek (sites #1 and #2). The total-recoverable zinc values also exceeded the water-quality criteria on the Sanderson Creek sites in the samples collected during 1991 by the Alaska Division of Water.

In the groundwater samples, arsenic, cadmium, and copper were all below the water quality criteria. Dissolved lead in well 91GA-1 was 8 ug/l. The water quality criterion for lead at the hardness of the water (77.1 mg/l) is 2.3 ug/l. Chromium values also exceeded the water quality criteria in wells 91GA-3 and 91GA-5, with values of 14 and 38 ug/l, respectively. The water quality criterion for chromium is 11 ug/l and is not hardness dependent. The total-recoverable zinc value at well 91GA-3 was 690 ug/l. The water quality criterion is 47 ug/l and is not hardness dependent. The high total iron values at wells 91GA-3 and 91GA-5 are probably elevated due to the large amounts of sediment in the samples collected. Table 8 summarizes the samples which exceeded the water quality criteria.

*Table 7. Water-quality standards for the priority pollutants at various hardness values for metals collected in this study. All values in micrograms per liter.*

Metal	Sample Type	Hardness			Time Period
		50 mg/l	200 mg/l	400 mg/l	
Arsenic	Total	50 ug/l - not hardness dependent			Instantaneous
Cadmium	Dissolved	0.66	2.0	5.6	4-day Average
Chromium	Dissolved	11 ug/l - not hardness dependent			4-day Average
Copper	Dissolved	6.5	21	39	4-day Average
Lead	Dissolved	1.3	7.7	19	4-day Average
Nickel	Total Recoverable	56	160	274	24-hour Average
Zinc	Total Recoverable	47 ug/l - not hardness dependent			24-hour Average

Table 8. Sample which exceeded the water quality criteria. All water quality criteria for the metals except arsenic are based on averages. Therefore the samples for the other metals may not exceed the criteria, but are shown only for comparison.

Metal	Site #	Date	Concentration (ug/L)	WQ Criteria (ug/L)
Arsenic	none			
Cadmium	none			
Chromium	#11	26 Sep 91	14	11
	#12	26 Sep 91	38	11
Copper	#6	22 Apr 91	25	17.6
Lead	#4	30 Jul 91	2	1.8
	#10	25 Sep 91	8	2.3
Nickel	none			
Zinc	#1	All	>47	47
	#2	All	>47	47
	#3	30 Jul 91	220	47
	#11	26 Sep 91	690	47

## CONCLUSIONS

1. Sanderson and Clinker creeks have high runoff to precipitation ratios (0.55 to 0.71) as a result of the schist-underlain basins and permafrost-rich soils.
2. The high sediment load in Sanderson Creek is due to the landslides in the Usibelli Group supplying ample amounts of sediment to the stream.
3. The Moose coal seam is the main aquifer in the Gold Run Pass area. The sources of recharge appears to be the faults which deliniate the seam on the south and west sides, and downward vertical percolation.
4. The hydraulic conductivity of the Moose seam is lower than other coal seams in the basin.
5. The water chemistry data can be used to differentiate between waters of schist origin from waters of Usibelli Group origin.
6. Although the seeps were similar in composition as the wells, they were much more dilute than the deep wells. The residence time of the water in the deeper wells is longer than in the seeps and the shallow well, resulting in more dissolution of the aquifer material (including trace metals).
7. Since the water quality criteria is based on time averages for most of the metals, it is not possible to compare the collected samples with the criteria (except arsenic). However, every sample collected for zinc in Sanderson Creek exceeded the water quality criterion of 47 ug/L. Zinc is probably the only metal which exceeds the criterion, and is probably a result of the high sediment load in the creek.
8. Although the dissolved-solids concentrations were much higher in the wells, only a few metals exceeded the water-quality standards.

## REFERENCES CITED

- Alaska Department of Environmental Conservation, 1991. Alaska water-quality standards workbook. 51 pp.
- American Public Health Association, American Water Works Association, Water Pollution Control Federation, 1989, Standard Methods for the Examination of Water and Wastewater, 17th edition: APHA, AWWA, WPCF, Washington D.C.
- Dalrymple, T., and Benson, M.A., 1984. Measurement of peak discharge by the slope-area method. Techniques of Water-Resources Investigations of the US Geological Survey, Book 3, Chapter A2, US Government Printing Office, 12 pp.
- Fetter, C.W., 1988. Applied Hydrogeology. Merrill Publishing Co., Columbus, Ohio, 592 pp.
- Freeze, R.A., and Cherry, J.A., 1979. Groundwater. Prentice-Hall, Inc. Englewood Cliffs, New Jersey, 604 pp.
- Golder Associates, 1991. Well logs of the Phase 5 Project. Unpublished report for Usibelli Coal Mine, Inc.
- Martin, D.F., 1972. Marine Chemistry. Volume 1. Marcel Dekker Inc., New York. 389 pp.
- Merritt, R.D. and Hawley, C.C., 1986. Alaska's coal resources. Alaska Division of Geological and Geophysical Surveys. Public-data File 88-9, 57 pp.
- Mack, S.F., 1988. Streamflow and sediment study of Hoseanna Creek near Healy, Alaska: 1987 progress report. Alaska Division of Geological and Geophysical Surveys. Public-data File 88-9, 58 pp.
- Parks, B., 1983. Trace metals in surface waters and stream sediments of Healy and Lignite Basins, Alaska. US Geological Survey Water-Resources Investigations 83-4173, 26 pp.

- Pewe, T.L., 1982. Geologic hazards of the Fairbanks area, Alaska. Alaska Division of Geological and Geophysical Surveys Special Report 15, 109 pp.
- Piper, A.M., 1944. A graphic procedure in the geochemical interpretation of water-analyses. American Geophysical Union Transactions 25:914-923.
- Ray, S.R., 1992. Streamflow, sediment load, and water-quality study of Hoseanna Creek Basin near Healy, Alaska: 1991 progress report. Alaska Division of Geological and Geophysical Surveys. In Press.
- Ray, S.R., 1991. Streamflow, sediment load, and water-quality study of Hoseanna Creek Basin near Healy, Alaska: 1990 progress report. Alaska Division of Geological and Geophysical Surveys. Public-data File 91-20, 65 pp.
- Ray, S.R., 1990. Streamflow, sediment load, and water-quality study of Hoseanna Creek Basin near Healy, Alaska: 1989 progress report and 1986-89 data summary. Alaska Division of Geological and Geophysical Surveys. Public-data File 90-15, 99 pp.
- Ray, S.R. and Maurer, M., 1989. Streamflow, sediment load, and water-quality study of Hoseanna Creek Basin near Healy, Alaska: 1988 progress report. Alaska Division of Geological and Geophysical Surveys. Public-data File 89-10, 62 pp.
- Scully, D.R., Krumhardt, A.P. and Kernodle, D.R., 1981. Hydrologic reconnaissance of the Beluga, Peters Creek, and Healy Coal areas, Alaska. US Geological Survey Water-Resources Investigations 81-56, 71 pp.
- USDC, National Weather Service, 1991. Annual summary of local climatologic data with comparative data for Fairbanks, Alaska. National Climatic Data Center. Asheville, NC. 8 pp.
- US Department of the Interior, 1977. National handbook of recommended methods for water-data acquisition., US Geological Survey Office of Water Data Coordination. 3 volumes.

- US Department of the Interior, 1981. Water measurement manual, US Bureau of Reclamation, US Government Printing Office. 329 pp.
- US Environmental Protection Agency, Handbook for sampling and sample preservation of water and wastewater. EPA-600/4-82-029, September 1982.
- Usibelli Coal Mine, Inc., 1992. Personal communication from Dan Graham to Scott Ray.
- Wahrhaftig, C., 1970. Geologic map of the Healy D-4 quadrangle. US Geological Survey maps GQ-806, 807.
- Wahrhaftig, C., 1987. The Cenozoic section at Suntrana, Alaska. Contribution for the Geological Society of America. DNAG Centennial Guide, Cordilleran Section. Volume 1.
- Walther, M.D., 1987. A drawdown model for groundwater appropriations in the Fairbanks uplands. Unpublished Master Degree Project Report. University of Alaska Fairbanks. 83 pp.
- Weber, E.F., 1987. A stochastic model and risk analysis of arsenic, well depth, and well yield in the Fairbanks area, Alaska. Unpublished Master's Thesis. University of Alaska Fairbanks. 196 pp.
- Wilbur, S., 1989. Predicting sediment concentrations for small subarctic creeks in the Hoseanna Creek Basin, In Proceedings: International Conference on Mining in the Arctic. University of Alaska Fairbanks. July 1989.
- Wilbur, S. and Beget, J., 1988. Landslide motion in discontinuous permafrost. In Proceedings: Fifth International Conference on Permafrost. Volume 1, pp. 897-902.
- Wilbur, S. and Renshaw, D., 1987. Geologic and climate controls governing high erosion rates in the Hoseanna Creek Coal Basin of central Alaska. In: Focus on Alaska's Coal, 1986. University of Alaska Fairbanks. Mineral Industry Research Laboratory Report 72, pp. 106-115.

Appendix A. 1991 data collected by Alaska Division of Water.

All values in mg/L unless otherwise specified.

All metals as dissolved unless otherwise specified.

Map #	Location	Date	Discharge		Air Temp	Water Temp	Diss Oxy	% Sat	pH	Cond ( $\mu\text{S/cm}$ )	Alkalinity ( $\text{mg CaCO}_3/\text{L}$ )
			(CFS)	(GPM)	( $^{\circ}\text{C}$ )	( $^{\circ}\text{C}$ )	( $\text{mg/L}$ )				
1	Sanderson Creek 1.6 mi ab Hoseanna	30-Jul-91	4.07	-	15.4	14.0	8.5	86.3	7.75	697	133
3	Sanderson Creek ab Hoseanna	30-Jul-91	3.67	-	12.7	11.1	9.2	89.6	8.14	688	147
4	Hoseanna Creek above Sanderson	30-Jul-91	10.6	-	12.6	9.7	9.6	88.5	6.90	163	58.9
6	Clinker Creek	22-Apr-91	1.25	-	7.4	0.0	12.8	88.9	6.70	384	103
6	Clinker Creek	30-Jul-91	1.55	-	14.9	9.2	9.5	86.6	8.11	355	119
7	North Clinker Creek	30-Jul-91	-	9.7	16.4	11.1	8.9	84.8	8.04	422	217
8	East Seep	30-Jul-91	-	1.9	16.6	14.6	6.6	67.9	7.44	395	202
9	West Seep	30-Jul-91	-	5.6	15.1	8.5	7.9	70.8	7.83	217	101

Map #	Location	Date	Hardness*	Turb	TSS	TDS*	F	Cl	NO <sub>3</sub>	PO <sub>4</sub>	SO <sub>4</sub>
			( $\text{mg/L CaCO}_3$ )	(NTU)	( $\text{mg/L}$ )	( $\text{mg/L}$ )			(as N)	(as P)	
1	Sanderson Creek 1.6 mi ab Hoseanna	30-Jul-91	429	32	38.8	550	1.36	0.71	0.06	<DL	330
3	Sanderson Creek ab Hoseanna	30-Jul-91	404	65	158	509	1.25	0.27	0.06	<DL	285
4	Hoseanna Creek above Sanderson	30-Jul-91	64.0	85	331	82.4	0.21	0.83	0.23	<DL	17.2
6	Clinker Creek	22-Apr-91	159	130	88.4	228	0.61	5.77	0.19	<DL	102
6	Clinker Creek	30-Jul-91	174	29	27.3	195	0.43	2.26	0.12	<DL	59.6
7	North Clinker Creek	30-Jul-91	185	14	24.7	242	0.54	0.71	0.03	<DL	23.1
8	East Seep	30-Jul-91	131	40	79.1	235	0.53	0.47	0.07	<DL	24.2
9	West Seep	30-Jul-91	94.2	11	9.77	108	0.29	0.10	0.15	<DL	5.71

\* by calculation: Hardness =  $2.497[\text{Ca}] + 4.116[\text{Mg}]$

Total Dissolved Solids =  $[\text{Ca}] + [\text{Mg}] + [\text{Na}] + [\text{K}] + [\text{Alkalinity}] + [\text{Cl}] + [\text{SO}_4]$

Appendix A (continued).

All values in mg/L unless otherwise specified.

All metals as dissolved unless otherwise specified.

Map #	Location	Date	Ca	Mg	Na	K	Al	As (total)	Ba	Cd	Cr
1	Sanderson Creek 1.6 mi ab Hoseanna	30-Jul-91	73.6	59.7	4.37	1.90	0.25	0.002	0.02	0.002	0.006
3	Sanderson Creek ab Hoseanna	30-Jul-91	69.6	56.0	7.66	2.39	0.16	<DL	0.03	0.002	0.002
4	Hoseanna Creek ab Sanderson	30-Jul-91	14.7	6.64	6.62	1.07	0.06	0.014	0.06	<DL	<DL
6	Clinker Creek	22-Apr-91	28.5	21.4	6.90	1.93	0.06	0.011	0.05	<DL	<DL
6	Clinker Creek	30-Jul-91	36.2	20.4	3.65	1.33	0.70	<DL	0.04	<DL	<DL
7	North Clinker Creek	30-Jul-91	35.1	23.6	25.1	4.31	0.06	0.010	0.16	<DL	0.004
8	East Seep	30-Jul-91	19.8	19.9	42.2	7.78	0.12	0.007	0.16	<DL	0.002
9	West Seep	30-Jul-91	17.5	12.3	9.13	2.53	0.10	0.021	0.13	<DL	<DL

Map #	Location	Date	Cu	Fe	Fe (total)	Pb	Mn	Mn (total)	Ni	Zn (total recoverable)
1	Sanderson Creek 1.6 mi ab Hoseanna	30-Jul-91	0.005	0.03	7.17	0.004	0.03	0.63	0.06	0.34
3	Sanderson Creek ab Hoseanna	30-Jul-91	0.002	<DL	6.70	<DL	0.59	0.61	0.03	0.22
4	Hoseanna Creek ab Sanderson	30-Jul-91	0.001	0.17	4.77	0.002	0.08	0.23	<DL	<DL
6	Clinker Creek	22-Apr-91	0.025	0.26	14.6	<DL	0.17	0.24	<DL	0.02
6	Clinker Creek	30-Jul-91	0.003	<DL	5.63	0.003	0.03	0.05	<DL	<DL
7	North Clinker Creek	30-Jul-91	0.005	0.02	0.63	0.001	<DL	<DL	<DL	<DL
8	East Seep	30-Jul-91	0.011	<DL	<DL	0.001	<DL	<DL	0.02	<DL
9	West Seep	30-Jul-91	0.008	0.43	0.84	<DL	0.03	0.04	<DL	<DL

Appendix B. Data collected by Parks (1983).

All values in mg/L unless otherwise specified.

All metals as dissolved unless otherwise specified.

Map #	Location	Date	Discharge (CFS)	Water Temp (°C)	pH	TSS (mg/L)	TDS (mg/L)	Hardness (noncarbonate)	Hardness	Ca	Mg
1	Sanderson Creek 1.6 mi ab Hoseanna	11-Jun-81	3.1	9.0	8.1	9	513*	420	260	71	58
		30-Jul-81	4.2	8.5	7.8	15	571*	480	—	78	70
		12-Sep-81	4.2	5.0	7.8	11	559*	480	290	81	68
2	Sanderson Creek 0.8 mi ab Hoseanna	23-May-80	4.4	4.0	7.9	1270	—	—	—	—	—
		09-Jul-80	3.3	10.0	7.5	136	485	—	—	—	—
		28-Aug-80	12	8.5	8.3	343	464	380	210	62	54
		22-Sep-80	13	2.5	8.0	215	442	350	200	62	48
		03-Apr-81	0.24	0.0	7.5	3	1130	800	550	140	110
		11-Jun-81	3.7	7.5	8.0	119	499*	410	260	72	56
		30-Jul-81	4.5	9.0	7.5	132	545*	430	—	76	59
12-Sep-81	5.1	5.5	7.5	108	533*	450	250	76	62		

Map #	Location	Date	Na	K	Alkalinity (mg CaCO <sub>3</sub> /L)	SO <sub>4</sub>	Cl	F	NO <sub>3</sub> +NO <sub>2</sub> (as N)	Fe dissolved	Fe suspended
1	Sanderson Creek 1.6 mi ab Hoseanna	11-Jun-81	6.7	—	160	300	1.5	—	—	0.010	1.90
		30-Jul-81	5.9	—	—	300	0.8	—	—	0.010	4.60
		12-Sep-81	4.7	—	190	300	1.1	—	—	0.010	6.30
2	Sanderson Creek 0.8 mi ab Hoseanna	23-May-80	—	—	110	—	—	—	—	0.020	32.0
		09-Jul-80	—	—	140	—	—	—	—	0.040	5.10
		28-Aug-80	4.9	1.9	170	210	0.1	0.5	0.10	0.070	13.0
		22-Sep-80	4.3	1.6	150	210	0.7	0.6	0.26	0.040	8.50
		03-Apr-81	34	5.6	310	560	6.5	0.7	—	0.260	0.330
		11-Jun-81	8.3	—	150	280	1.4	—	—	0.020	4.50
		30-Jul-81	8.0	—	—	270	0.7	—	—	0.028	7.00
12-Sep-81	7.0	—	200	280	0.7	—	—	0.010	8.20		

\* by calculation: Total dissolved solids based on specific conductance value

Appendix B (continued).

All values in mg/L unless otherwise specified.

All metals as dissolved unless otherwise specified.

Map #	Location	Date	Pb dissolved	Pb suspended	Mn dissolved	Mn suspended	Ni dissolved	Ni suspended	Silica	Zn dissolved	Zn suspended
1	Sanderson Creek 1.6 mi ab Hoseanna	11-Jun-81	0.001	0.007	0.300	0.020	0.048	0.002	--	0.050	0.140
		30-Jul-81	0.000	0.002	0.380	0.000	0.042	0.015	--	0.058	0.300
		12-Sep-81	0.000	0.009	0.550	0.020	0.070	0.024	--	0.072	0.420
2	Sanderson Creek 0.8 mi ab Hoseanna	23-May-80	0.051	0.008	0.500	0.500	0.027	0.073	--	0.030	0.310
		09-Jul-80	0.004	0.009	0.580	0.030	0.033	0.009	--	0.040	0.150
		28-Aug-80	0.000	0.013	0.310	0.190	0.022	0.038	2.1	0.170	0.210
		22-Sep 80	0.003	0.006	0.410	0.080	0.038	0.016	3.5	0.130	0.300
		03-Apr-81	0.002	0.002	2.20	0.100	0.065	0.001	9.0	0.190	0.010
		11-Jun 81	0.001	0.008	0.510	0.040	0.042	0.007	--	0.060	0.110
		30-Jul-81	0.002	0.013	0.540	0.060	0.034	0.024	--	0.082	0.260
		12-Sep-81	0.000	0.001	0.680	0.050	0.052	0.027	--	0.068	0.330

Appendix C. Data collected by Scully et. al. (1980).

All values in mg/L unless otherwise specified.

All metals as dissolved unless otherwise specified.

Map #	Location	Date	Discharge (CFS)	Water Temp (°C)	pH	TDS (mg/L)	Silica	Hardness (mg/L as CaCO <sub>3</sub> )	Bicarbonate (mg/L as HCO <sub>3</sub> )	Ca
4	Hoseanna Creek ab Sanderson	04-Aug-77	5.4	17.0	7.6	125	19	81	91	20
		01-Nov 77	5.4	0.0	6.7	141	21	90	130	21
		07-Sep-78	6.5	7.0	7.5	111	16	70	84	16
5	Hoseanna Creek below Sanderson	04-Aug-77	8.3	18.0	7.8	237	14	180	124	36
		01-Nov 77	6.7	0.0	6.9	311	18	180	140	36
		12-May-78	29	0.0	7.6	162	6.2	130	80	24
		07-Sep-78	12	8.0	7.8	262	11	190	128	35

Map #	Location	Date	Mg	Na	K	SO <sub>4</sub>	Cl	F	Fe	Mn	TSS (mg/L)
4	Hoseanna Creek ab Sanderson	04-Aug-77	7.5	9.3	1.4	22	2.2	0.1	0.400	0.210	212
		01-Nov 77	9.1	10	1.3	23	2.1	0.1	0.190	0.240	373
		07-Sep-78	7.4	8.9	1.2	15	1.7	0.1	0.350	0.140	128
5	Hoseanna Creek below Sanderson	04-Aug-77	21	13	2.0	85	9.2	0.3	0.020	0.270	114
		01-Nov 77	23	14	1.7	100	9.2	0.3	0.090	0.340	216
		12-May-78	16	7.4	2.1	63	4.6	0.2	0.270	0.150	3400
		07-Sep-78	26	10	1.8	100	6.0	0.3	0.110	0.280	153

Appendix D. 1991 groundwater data collected by DNR/DOW.

All values in mg/L unless otherwise specified.

All metals as dissolved unless otherwise specified.

Well ID	Map #	Date	Depth to H <sub>2</sub> O (feet)	Casing Vol (gallons)	Vol Purged (gallons)	pH	Conductivity (uS/cm)	Alkalinity (mg CaCO <sub>3</sub> /L)	TDS* (mg/L)	Hardness* (mg/L CaCO <sub>3</sub> )
91GA-1	10	25-Sep-91	58.52	1.9	15	6.17	182	189	208	77.1
91GA-3	11	26-Sep-91	115.3	6.5	11	7.91	808	719	1210	408
91GA-5	12	26-Sep-91	78.75	9.0	9.0	7.47	615	827	1360	462

Well ID	Map #	Date	F	Cl	NO <sub>3</sub> (as N)	PO <sub>4</sub> (as P)	SO <sub>4</sub>	Ca	Mg	Na
91GA-1	10	25-Sep-91	0.52	3.28	0.23	<DL	16.9	16.2	8.93	13.9
91GA-3	11	26-Sep-91	2.80	1.26	<DL	<DL	11.7	82.7	49.0	190
91GA-5	12	26-Sep-91	3.19	0.96	0.05	<DL	7.54	100	51.7	187

Well ID	Map #	Date	K	Al	As (total)	Ba	B	Cd	Cr	Co
91GA-1	10	25-Sep-91	5.26	0.85	<DL	0.35	0.22	<DL	0.004	<DL
91GA-3	11	26-Sep-91	811	5.24	<DL	0.21	0.52	<DL	0.014	0.02
91GA-5	12	26-Sep-91	18.6	6.53	0.007	<DL	0.22	0.003	0.038	<DL

Well ID	Map #	Date	Cu	Fe	Fe (total)	Pb	Mn	Mo	Silica	Zn
91GA-1	10	25-Sep-91	0.006	0.50	41.5	0.008	0.92	<DL	28.0	<DL
91GA-3	11	26-Sep-91	0.014	1.41	335	0.017	12.4	<DL	37.6	0.69
91GA-5	12	26-Sep-91	0.013	48.0	234	0.015	11.6	<DL	23.7	<DL

\* by calculation: Hardness = 2.497[Ca] + 4.116[Mg]

Total Dissolved Solids = [Ca] + [Mg] + [Na] + [K] + [Alkalinity] + [Cl] + [SO<sub>4</sub>]

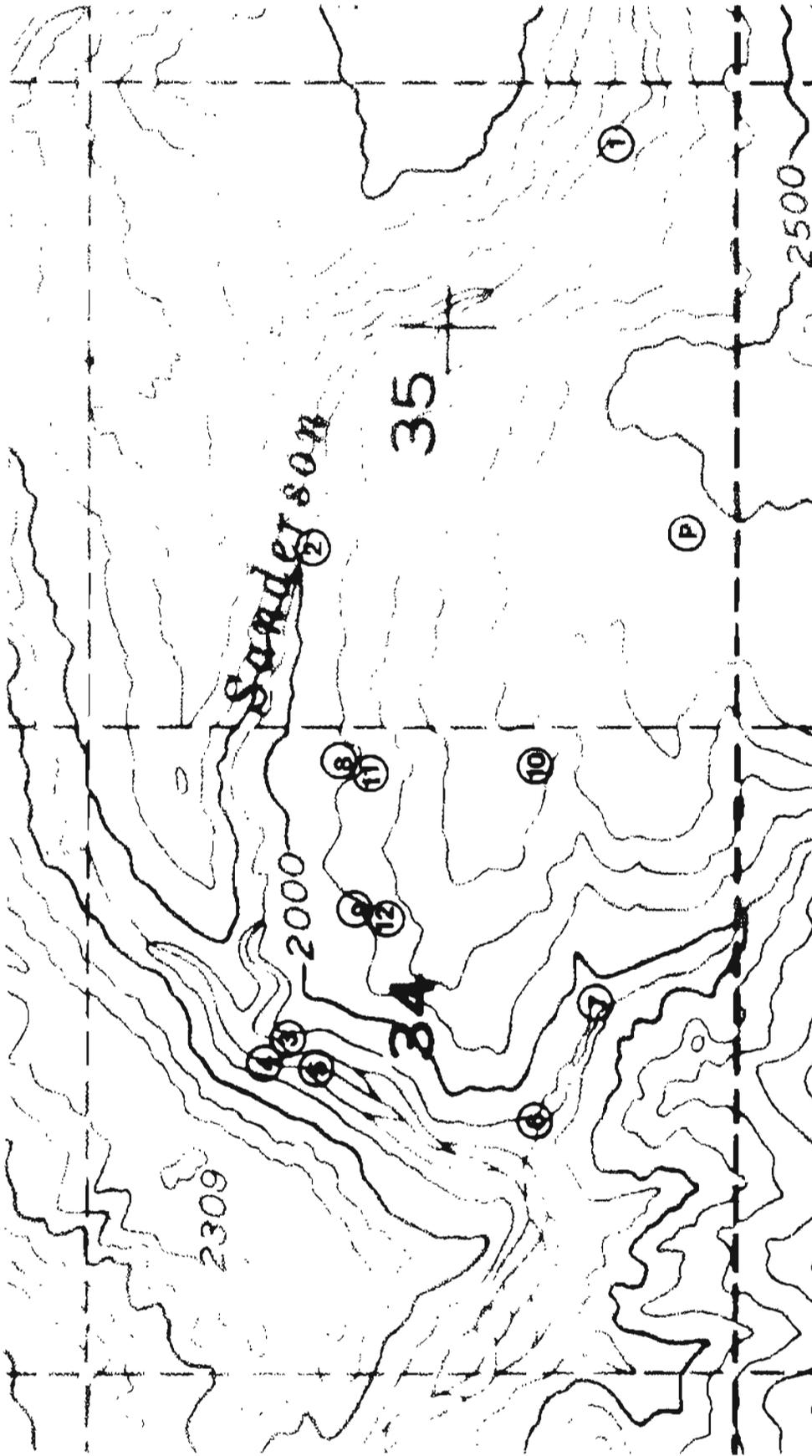


Figure 2. Map showing location of sampling sites. Numbers 1-12 correspond to sites in Table 1. Site P is the precipitation gage. One inch equals one-quarter mile.