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STREAMFLOW, SEDIMENT LOAD, AND WATER QUALITY STUDY OF HOSEANNA CREEK BASIN NEAR HEALY, ALASKA: 1990 PROGRESS REPORT

by

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EXECUTIVE SUMMARY

From 1986 through 1990, the Alaska Division of Geological and Geophysical Surveys investigators measured precipitation, measured discharge, and collected surface and ground water samples in the Hoseanna Creek basin near Healy, Alaska. The purpose of the study is two-fold. The first is to quantify the ambient water-quality and sediment transport conditions and establish baseline levels. The second is to measure, if any, the effects of the Poker Flat mine ground water on Hoseanna Creek. To this end, some 2100 water-quality and sediment samples have been collected.

The summer sediment load in 1990 for Hoseanna Creek was 64,000 tons at Bridge 3. This was approximately 40,000 tons less than in 1989, and was due to large storm events in 1990. Sediment rating curves were calculated at four sites, with number of samples used in the rating equations (n) ranging from 49 composite samples at Bridge 6 to 190 samples at Bridge 3.

Surface water samples for water quality analysis were collected once twice in 1990 at sites located on Hoseanna Creek at Bridge 3 (above mining) and at Bridge 1 (below mining). Generally, no appreciable difference was found in the field-determined parameters or between the ionic constituents.

Ground water samples for water quality analysis were collected from six wells in or nearby the Poker Flat mine. The major ion concentrations varied widely among the wells. Classification of the wells remained consistent with previously collected data.

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INTRODUCTION

This report discusses sediment, streamflow, and water quality data collected during the 1990 summer field season by Alaska Division of Geological and Geophysical Surveys (DGGS) investigators in Hoseanna Creek basin.

Hoseanna Creek flows west into the Nenana River approximately three miles north of Healy, Alaska. The total basin area is approximately 48 mi^2. Hoseanna Creek appears on USGS topographic maps as Lignite Creek, but is referred to as Hoseanna Creek by Usibelli Coal Mine and DGGS (see Ray and Maurer, 1989).

The lithologies of the basin (see Wahrhaftig, 1987; Wilbur and Clark, 1987; Wahrhaftig, et al., 1969) produce mass wasting, which contributes to high sediment loads in some of the streams in the basin. The purpose of this study is to estimate the discharge and quantify the sediment yield of selected basins above mining influence.

In 1986, five sites were chosen to represent different geologic aspects of the basin: Sanderson Creek (above mining), North Hoseanna Creek (unmined), Popovitch Creek (unmined), Frances Creek (future mining), and Hoseanna Creek at Bridge 3 (main channel, above mining)(Mack, 1987). Results of the 1986 season indicated that most of the sediment moves during high flow events, and that future field seasons should concentrate effort on measuring such events. Mack (1987) also concluded that the only way to obtain reliable data from the small sediment-laden streams was with a Parshall flume. The design of this flume prevents sediment from clogging the path of water flow, a problem which occurs with weirs or H-flumes. Parshall flumes were installed at Frances and Popovitch Creeks. Samples taken during high flow events by automated samplers were combined with grab samples taken at all flow stages to develop sediment rating equations. The equations were used to predict total suspended sediment (TSS) from discharge data in order to estimate daily and seasonal sediment loads for the various sites.

In an attempt to establish background data from the upper Hoseanna basin in 1987, a non-automated sampling site was added on Hoseanna Creek above its confluence with North Hoseanna Creek.

During the winter of 1988, Usibelli Coal Mine completed a haul road to Gold Run Pass, which now allows easy access to the upper basin sites. The site on Hoseanna Creek above North Hoseanna Creek was moved to the newly installed Bridge 6, which is about one-half mile downstream of North Hoseanna Creek. The bridge site is ideal for developing stage-discharge relationships. Automated equipment was placed at this site in late-July.

Two additional sites were added in 1988: Two Bull and Louise Creeks. Grab samples were collected and discharge measured throughout the season at these sites. Automated equipment began operation at these sites in August.

Additional changes were made during the 1989 sampling season. Sanderson, North Hoseanna, Popovitch, and Frances Creeks were all dropped from the study, while only one site was added to the study: Runaway Creek.

Louise Creek was dropped from the study in 1990 and the flume was moved to Runaway Creek. Another flume was purchased and installed on Two Bull Creek. The stage recorder was removed from Bridge 3 due to the numerous hydraulic problems which existed at this site. The flow at Bridge 3 was estimated from the USGS flow records at Bridge 1. Data from Bridge 6 were collected only during August and September.

Table 1 gives the basin characteristics of each sampling site, along with the period of record.

Surface water quality sampling has been conducted in the study since 1987. Two sampling sites on Hoseanna Creek, Bridge 3 (above mining) and Bridge 1 (below mining), are used to quantify the effect of the Poker Flat mine on water chemistry. The sites were sampled three times during the 1990 field season and analyzed for major ions. The samples were taken in September (prior to any freezing), November (just after freeze-up) and March, 1991 (prior to break-up).

Water quality samples were also collected during the 1990 summer season from three shallow wells (one upgradient of mine disturbance and two in the disturbed spoils). These wells were sampled at the same time as the surface water quality samples. The samples were analyzed for major ions, total and dissolved iron and manganese. Three additional wells on Runaway Ridge were sampled in June and September, and analyzed for major ions and trace metals.

Table 1. Basin characteristics of sampling sites (after Mack, 1988).

Site	Area (mi^2)	Percent of total basin area	Period of Record	Principle Lithology
Sanderson	5.1	11.6	1986-88	Schist
North Hoseanna	3.1	7.2	1986-88	Coal Group
Hoseanna @ Brd 6	20.8	47.5	1988-90	Mixed
Popovitch	4.1	9.3	1986-88	Nenana Gravel, Coal Group
Louise	1.6	3.6	1988-89	Nenana Gravel, Coal Group
Frances	1.7	3.9	1986-88	Nenana Gravel, Coal Group
Hoseanna @ Brd 3	43.8	100.0	1986-90	Mixed
Runaway	0.9	----	1989-90	Coal Group, Schist
Two Bull	0.9	----	1988-90	Nenana Gravel, Coal Group

METHODS

PRECIPITATION

The precipitation data for the basin was gathered in three locations during 1990. DGGS operates a Wyoming gage with a datapod recording device at Gold Run Pass (see Mack ,1988 for location and construction specifications). Readings are taken every 30 minutes, with changes as small as twelve one-hundredths of an inch recorded. DGGS also operates a tipping-bucket rain gage located at Bridge 1. This gage is connected to the USGS satellite system. It is possible to down-load the data in Fairbanks to obtain the current precipitation status. This gage was installed in August 1990. The other reporting station is operated by Usibelli Coal Mine personnel and is located at Poker Flat mine. The precipitation gage operated by UCM was moved approximately 2000 feet southwest of its original placement prior to the 1989 season. The gage has been replaced by a standard eight inch tipping-bucket gage connected to a datapod recording device. The resolution of both tipping-bucket gages is 0.01 inches. Neither tipping-bucket gage is wind protected.

DISCHARGE

Stream velocities used in the calculation of discharge were measured with a Price type AA meter for higher flows and a Price pygmy meter for lower flows. A bridge crane was used to measure the flows at the bridges during high-water events. Velocities were measured at six-tenths depth, with sufficient number of sections such that no one section contained over ten percent of the total flow. If the depth was greater than 2.5 feet, measurements were made at two-tenths and eight-tenths depth. The average of the two readings was interpreted as the mean velocity. Discharge was calculated using the standard midpoint method (US Dept. of Interior, 1981). At Two Bull and Runaway Creeks, discharge was estimated using the standard equations for Parshall flumes (US Dept. of Interior, 1981). The discharge at Bridge 3 was estimated from the flow at Bridge 1 (measured by USGS). A relationship for the two bridges was developed using the data collected from previous years.

A continuous stage record was recorded at each site using Omnidata DP320 stream stage recorders with pressure transducers. The small, battery operated device can measure water levels from 0 to 10 feet in intervals of one-hundredth of a foot. The data are stored on EPROM microchips, which are then read by a computer at the lab.

Discharge rating curves were calculated for each site using the discharge-stage data. High flow events which were not directly measured were estimated using the indirect slope-area method (Dalrymple and Benson, 1984). The rating equations were then used to convert the continuous stage record into a continuous discharge record.

SEDIMENT RATING EQUATIONS

Sediment rating equations were calculated at each site to estimate sediment concentrations from discharge data. Leopold and Maddock (1953) found that equations of the form:

$$TSS = aQ^b$$

where TSS = total suspended solids (mg/l)
Q = discharge (cfs)
a,b = numerical constants

adequately approximate the relationship. Using the TSS data from the grab and automated samples, these equations were developed as linear log-log plots ($\log TSS = a + b \log Q$). Using the actual and estimated sediment concentrations and the continuous discharge data, we calculated the daily sediment load. Whenever possible, the actual values (automated or grab) were used in the calculation. The daily loads were then added to estimate the season load. The daily loads for the 1990 season from Bridge 3 were calculated from the daily composite samples (except when TSS values were available from the level-actuated isco). Loads from Bridge 6 were calculated entirely from composite samples.

WATER QUALITY

To ensure consistency of data between the different field seasons, the same water quality sampling and analytical methods were used during the 1987-90 field seasons (see also

Mack, 1988). The following methods for surface water, ground water, and laboratory analysis are from Ray and Maurer (1989):

Surface Water

Surface water for chemical analyses was obtained and composited from Hoseanna Creek with a hand-held depth-integrating suspended-sediment sampler and a churn splitter, according to the methods of the U.S. Department of the Interior (1977). Samples collected from the splitter at each site were: filtered, for determining dissolved major anions; unfiltered, for determining suspended solids; and filtered and acidified, for determining dissolved trace metals and major cations. Water for major ion and dissolved trace-metal analyses was immediately pumped through 0.45 micron membrane filters. All acidified samples were collected in pre-acid-washed bottles, and acidified with Ultrex-grade nitric acid, to a concentration of 1.5 ml acid per liter sample.

Water temperature, dissolved oxygen, and specific conductance of surface water samples were measured in situ with a digital 4041 Hydrolab. A Beckman digital pH meter was used to measure pH on a composited sample. Alkalinity was measured electrometrically on a composited sample with an Beckman pH meter and a Hach digital titrator, according to the methods of the U.S. Environmental Protection Agency (1983). Settleable solids were determined in the field with Imhoff Cones according to the methods of the American Public Health Association, and others (1985).

Ground Water

Water levels in all wells were measured prior to pumping with a Johnson Watermark electric water-depth indicator. "Well Wizard" equipment was used to purge and sample all wells. The submersible bladder pump and tubing are composed of non-metallic materials. Water temperature, pH, and specific conductance were measured at regular intervals with a digital 4041 Hydrolab during well purging. After at least three well casing volume was removed from the well, sampling commenced when specific conductance fluctuated less than 10 percent. Water samples were obtained according to the methods of Scalf and others (1981). Water was collected in a churn splitter at the well head. Water temperature, pH, specific conductance and alkalinity were determined in the field using the same instrumentation and methods described for surface water samples. Samples for chemical constituent analysis were also treated and preserved in the same manner as surface water samples. Two additional samples were collected at each site: filtered, for determining nutrients, and unfiltered and acidified, for determining total iron. The sample for determining nutrients was kept on ice and placed in a freezer within one hour of collection.

Laboratory Analysis

Water quality analyses for surface water and ground water were conducted in the DGGS hydrology laboratory located in the Mineral Industry Research Laboratory (MIRL) on the University of Alaska Fairbanks (UAF) campus. Laboratory procedures used to analyze surface water are described in Mack (1988). Analytical methods and detection limits for surface water and ground water constituents are shown in Appendix E. The laboratory is a participant in EPA analytical quality assurance studies, and has participated in the USGS Standard Reference Water Sample Quality Assurance program since 1980. For all analyses, calibrations were performed using in-house analytical standards and blanks, and were monitored and verified by running previously analyzed USGS Standard Reference Water Samples along with the water samples collected for this study.

RESULTS

PRECIPITATION

The precipitation total for Gold Run Pass for May through September 1990 was 15.36 inches, with about eight inches falling after mid August. This is about an inch higher than the 1987-90 average (Table 2). The average precipitation total at Poker Flat for the period of May - September (1979-1989) is 12.44 inches (Wilbur, 1989). Using the 1990 precipitation of 13.09 inches, the 1979-90 average is now 12.50 inches. Both sites were less than 10 % above average. The August and September total at Bridge 1 was 6.81 inches. This was the least recorded for that time period of the three sites. The long-term trend of higher precipitation in the upper basin is supported by this data. Daily precipitation from each gage is found in Appendix A.

Table 2. Monthly precipitation for Gold Run Pass (GRP) and Poker Flat (PF). All values in inches.

Site	MAY	JUN	JUL	AUG	SEP	Total
GRP 1986	----	----	----	----	----	-----
PF 1986	1.62	2.43	4.30	3.37	1.79	13.51
GRP 1987	0.12	1.08	2.52	3.24	4.32	11.28
PF 1987	0.23	2.17	3.74	2.10	1.16	9.40
GRP 1988	2.16	5.88	4.92	2.52	1.56	17.04
PF 1988	2.15	4.25	4.20	1.87	1.43	13.90
GRP 1989	0.96	6.20	1.32	4.92	0.84	14.24
PF 1989	0.49	3.90	1.25	3.11	1.31	10.06
GRP 1990	0.96	0.96	4.44	4.92	4.08	15.36
PF 1990	0.90	0.74	3.72	4.59	3.14	13.09
B1 1990	----	----	----	3.96	2.85	-----
Avg GRP (87-90)	1.05	3.53	3.30	3.90	2.70	14.48
Avg PF (87-90)	0.94	2.77	3.23	2.76	1.76	11.46
Avg PF (79-90)	0.85	3.04	3.77	3.16	1.68	12.50

DISCHARGE

Continuous discharge records were made at Bridge 6, Runaway Creek, and Two Bull Creek (Appendix B). As stated in the introduction, continuous discharge was not recorded at Bridge 3. However, daily flows were estimated using the flow data from Bridge 1 (operated by USGS).

The flume on Louise Creek was removed on May 25 and installed on Runaway Creek. A new flume was purchased and installed on Two Bull Creek on June 7. The datapod was installed at Bridge 6 on August 8. The daily average flows from these sites are found in Appendix B. The estimated daily flows for Bridge 3 are also in Appendix B.

The average daily flow (June-September) for Bridge 3 was 70 cfs. This was the highest season average since the study began (Table 3). The peak flow at Bridge 3 was estimated at 1000 cfs on the morning of July 12. The average flows were higher at all locations with season averages of 48.3 cfs at Bridge 6 (August-September), 0.21 cfs at Runaway Creek, and 0.25 cfs at Two Bull Creek.

Table 3. Flow data for 1987-1990 field seasons. All values in cfs.

Site	Peak Flow				Season Average			
	87	88	89	90	87	88	89	90
Hoseanna Brd 6	----	150	550	326	----	18.9	25.9	48.3
Hoseanna Brd 3	449	740	1200	1000	35.9	42.6	52.6	70.0
Runaway	----	----	7.9	2.0	----	----	0.17	0.21
Two Bull	----	----	6.3	2.8	----	----	0.18	0.25

SEDIMENT LOAD

The quality of the regression were all similar, with r^2 values ranging from 0.75 at Bridge 3 to 0.79 at Bridge 6. The most significant increase in the r^2 values occurred at Two Bull and Runaway Creeks. These increases were a function of two factors. Flumes were installed on both creeks which improved the quality of the flow measurements. The other factor was the increase in the number of sediment samples which were collected (Usibelli employees assisted in the collection of grab samples from both sites). Table 4 gives the resulting regression equations, the r^2 value and the number of samples used in the regression calculation.

Table 4. Coefficients, r^2 value, and number of samples used (n) for the sediment rating equations. The equations are of the form: $TSS = aQ^b$.

Site	a	b	r^2	n
Hoseanna @ Brd 6	2.89	1.34	0.79	49
Hoseanna @ Brd 3	2.12	1.35	0.75	190
Runaway	13500	3.73	0.77	72
Two Bull	21900	2.30	0.76	61

Hoseanna Creek at Bridge 6

Figure 1 shows the plot of TSS versus discharge for this site. The r^2 value is 0.79. The data from this site is entirely of composite samples. This tends to smooth the data, resulting in the highest r^2 value this season. The spread of the data point about the regression equation is fairly uniform (the other sites are somewhat asymmetric, with greater spread at low flow than at high flow). This is also an effect of the composite samples.

Hoseanna Creek at Bridge 3

Figure 2 shows the plot of TSS versus discharge for this site. The r^2 value is 0.75. This is lower than the 1989 value of 0.85 (although similar to 1987 and 1988). This site had both composite and level-activated samples. There is little spread at the high flows (represented by two storms with level-activated samples). With the exception of a few samples, the low-flow end of the regression is fairly uniform.

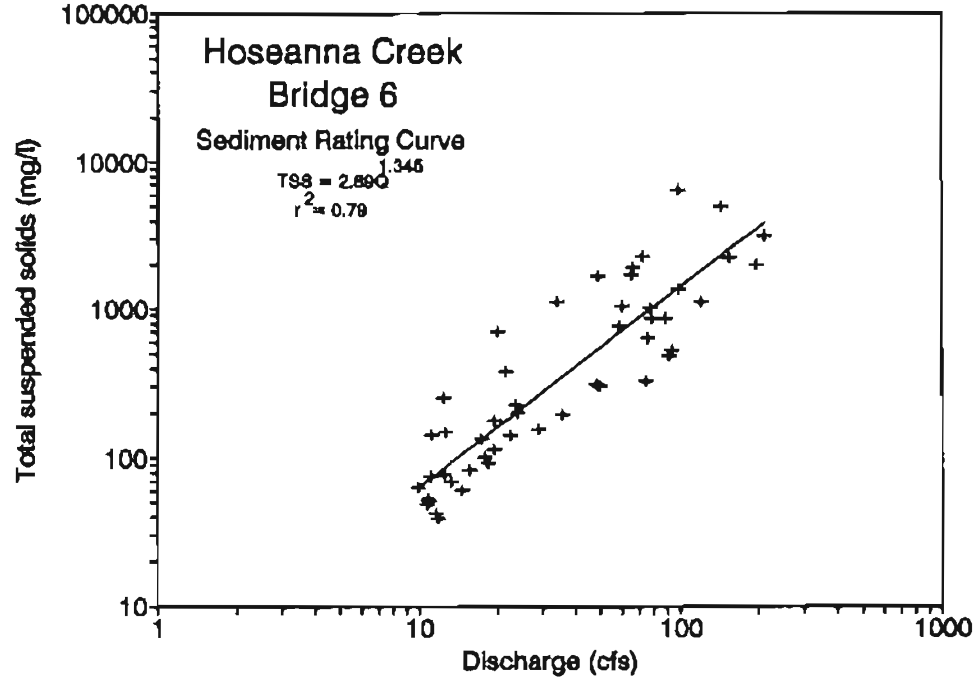

Figure 1. TSS versus discharge for Hoseanna Creek at Bridge 6 (1990 data). r^2 value equals 0.79.

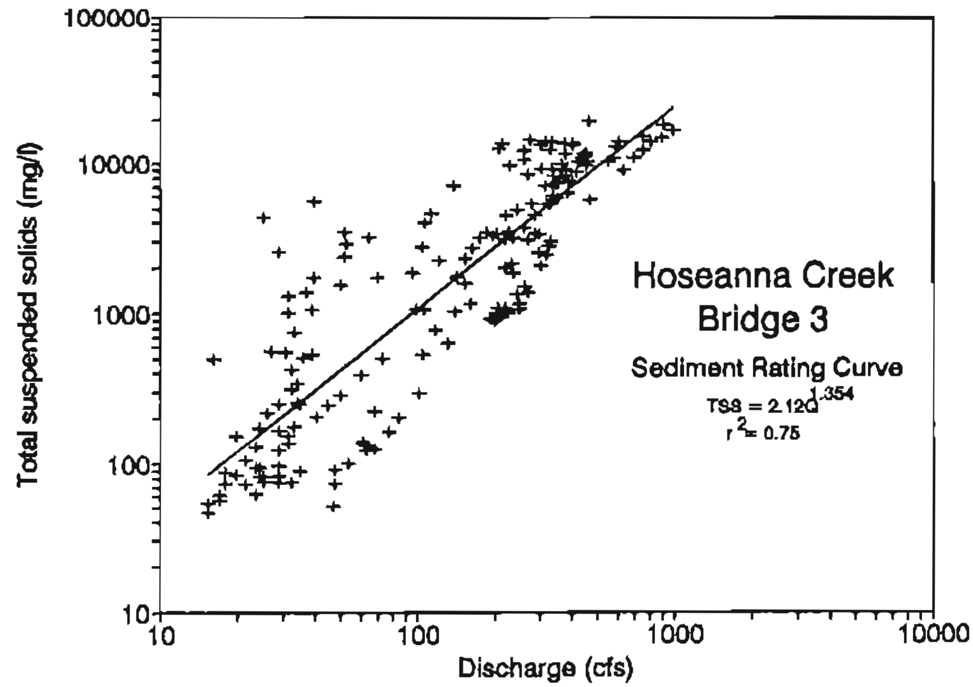

Figure 2. TSS versus discharge for Hoseanna Creek at Bridge 3 (1990 data). r^2 value equals 0.75.

Two Bull Creek

Figure 3 shows the plot of TSS versus discharge for this site. The r^2 value is 0.76. This is the highest r^2 value for this site since the study began (reasons previously cited). The spread at the lower flows at Two Bull Creek is common to many of the creeks in the basin. During a storm event, massive amounts of sediment are transported to or near the stream. After the high flow subsides, the sediment is still available for transport by the lower flow. It may take several days for the sediment to decrease.

Runaway Creek

Figure 4 shows the plot of TSS versus discharge for this site. The r^2 value is 0.77. The same explanation for Two Bull Creek also applies to Runaway Creek (see above).

Table 5 summarizes the results of the sediment regression equations for all available data for each site since the study began. Figures 5-8 are the plots of these data.

Table 5. Coefficients, r^2 value, and number of samples used (n) for the sediment rating equations for the 1986-1990 seasons. The equations are of the form: $TSS = aQ^b$.

Site	a	b	r^2	n
Hoseanna @ Brd 6 (1988)	1.41	1.83	0.72	50
1989	22.8	1.20	0.69	162
1990	2.89	1.34	0.79	49
1988-1990	**2.76**	**1.61**	**0.77**	**261**
Hoseanna @ Brd 3 (1987)	1.81	1.59	0.71	113
1988	2.82	1.56	0.74	127
1989	6.16	1.26	0.85	259
1990	2.12	1.35	0.75	190
1986-1990	**5.25**	**1.30**	**0.71**	**710**
Runaway (1989)	1630	1.34	0.56	22
1990	13450	3.73	0.77	72
1989-1990	**3750**	**2.47**	**0.60**	**94**
Two Bull (1988)	186000	3.37	0.74	13
1989	13700	1.24	0.53	41
1990	21900	2.30	0.76	61
1988-1990	**15300**	**1.75**	**0.66**	**115**

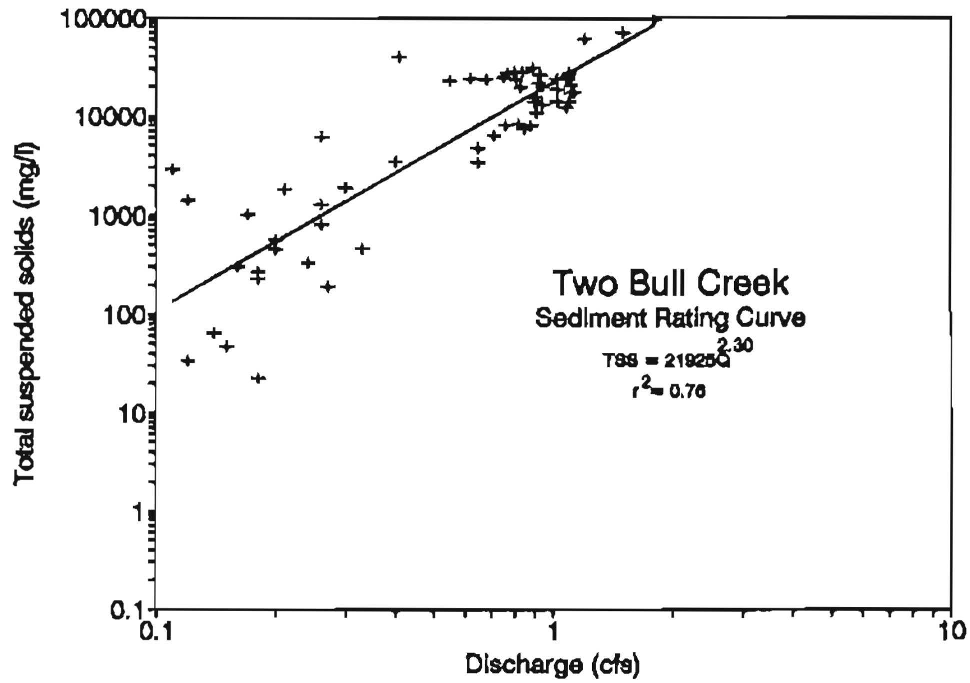

Figure 3. TSS versus discharge for Two Bull Creek (1990 data). r^2 value equals 0.76.

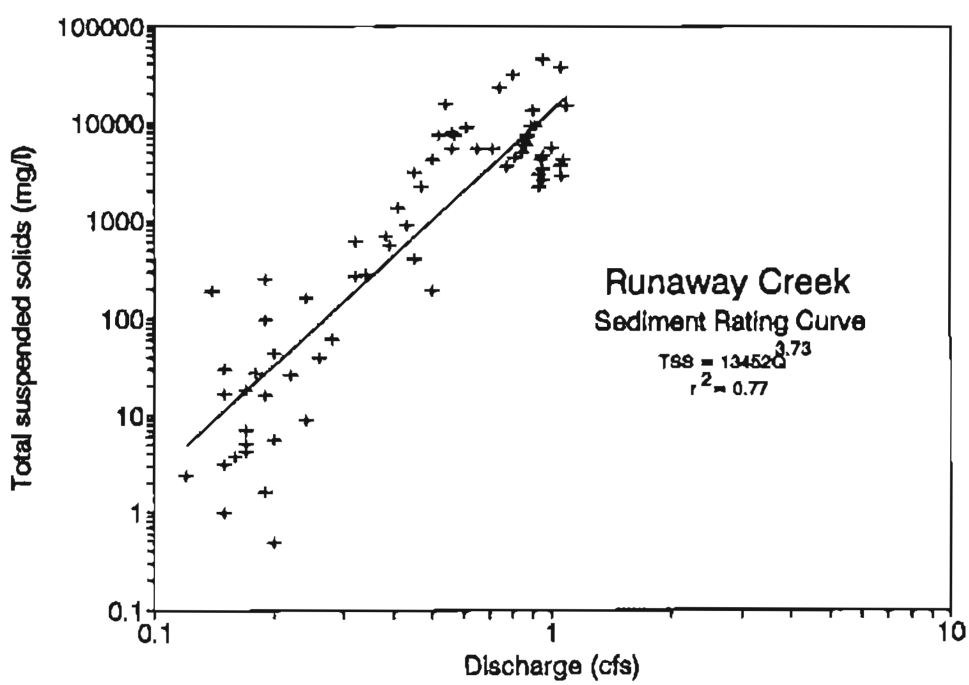

Figure 4. TSS versus discharge for Runaway Creek (1990 data). r^2 value equals 0.77.

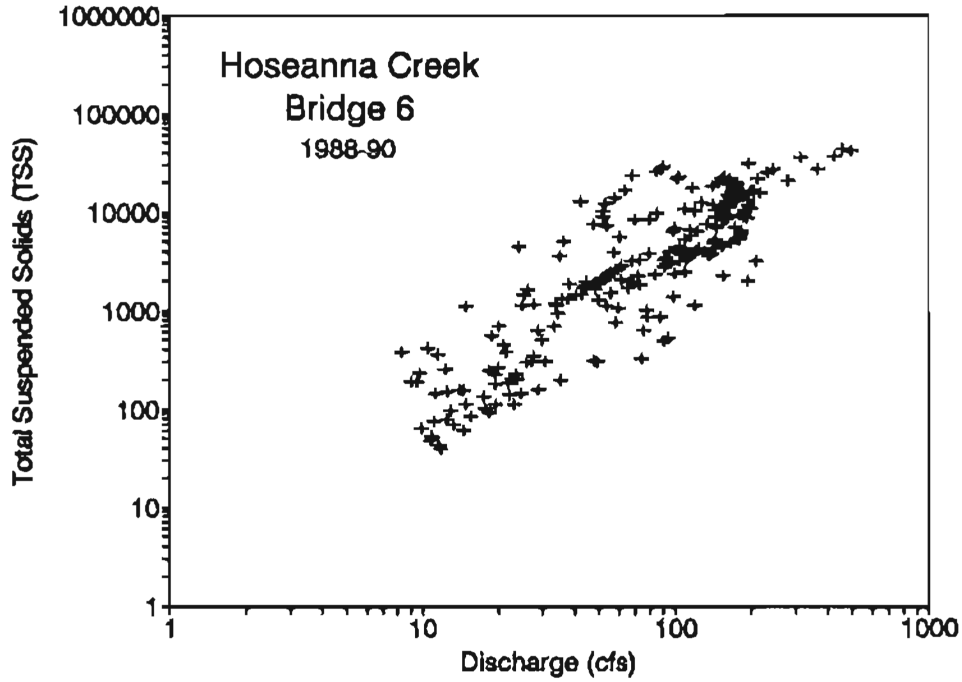

Figure 5. TSS versus discharge for Hoseanna Creek at Bridge 6 (1988-1990). r^2 value = 0.77, n = 261.

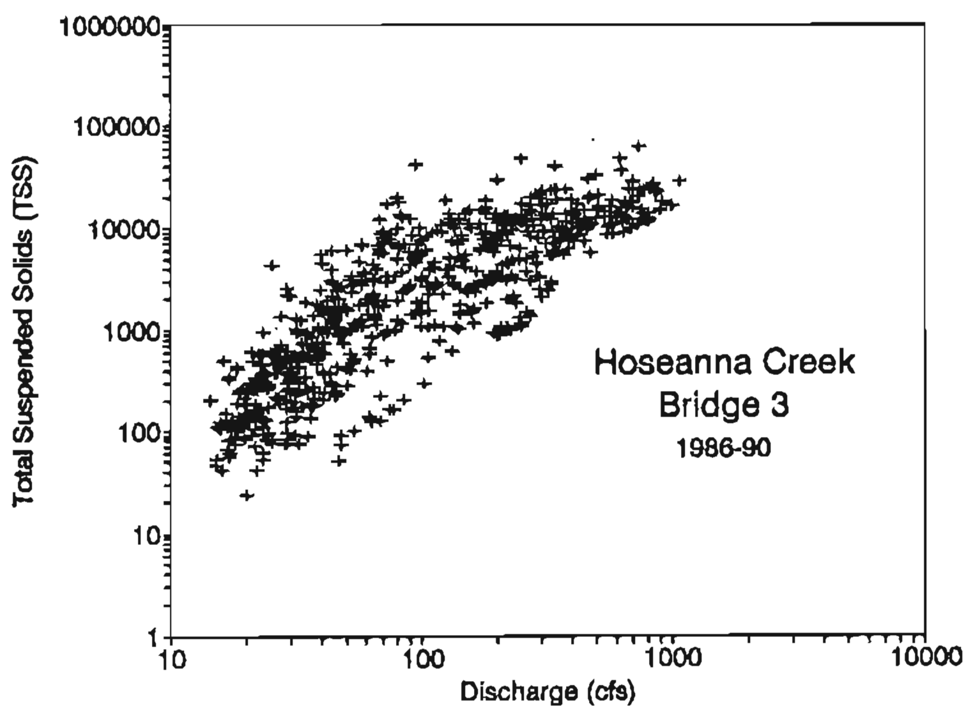

Figure 6. TSS versus discharge for Hoseanna Creek at Bridge 3 (1986-1990). r^2 value = 0.71, n = 710.

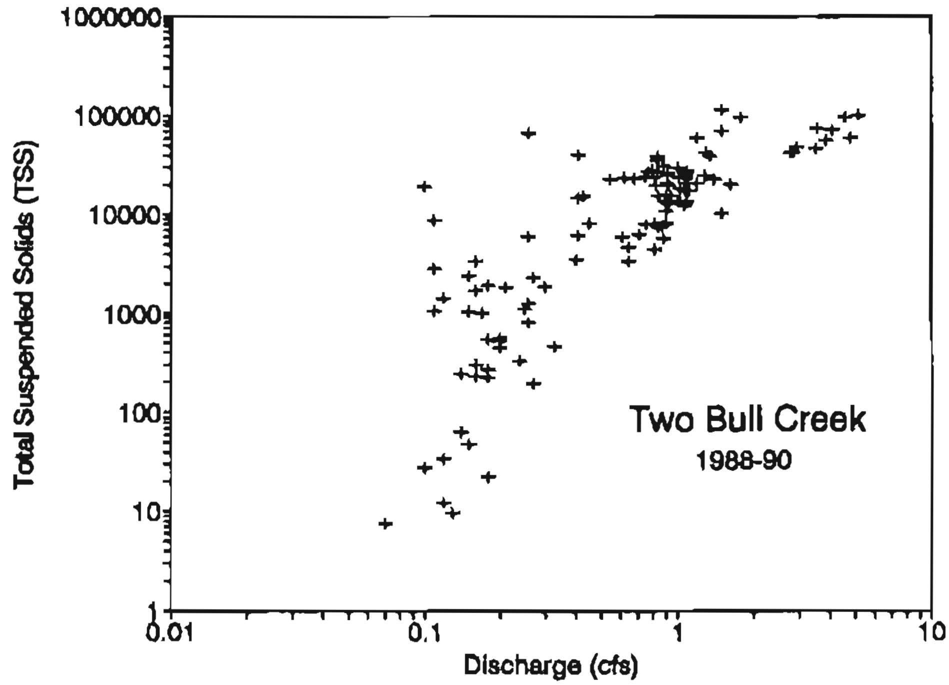

Figure 7. TSS versus discharge for Two Bull Creek (1988-1990). r^2 value = 0.66, n = 115.

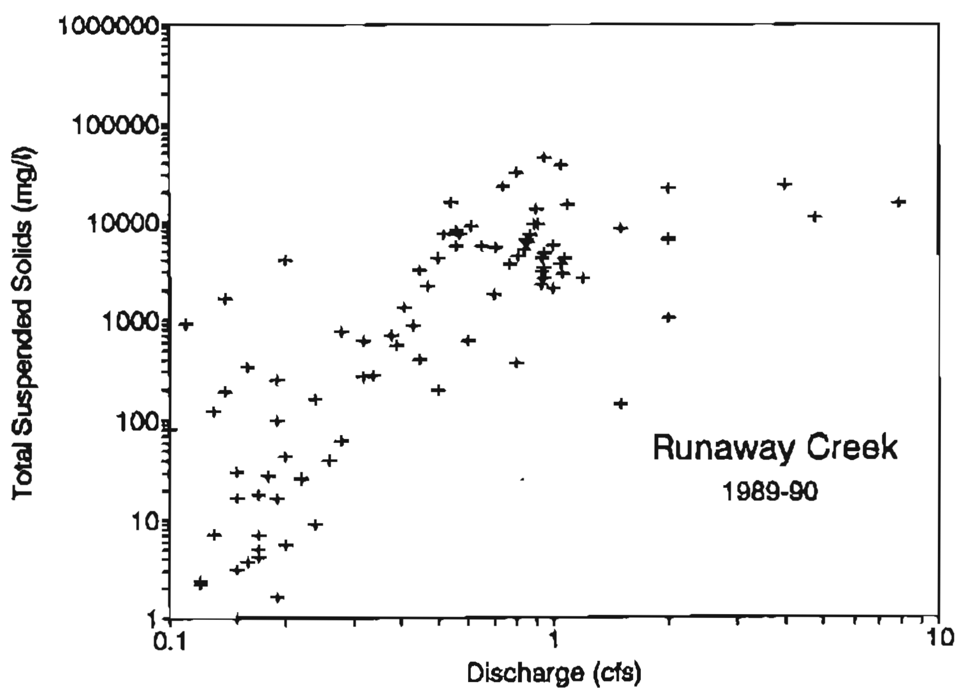

Figure 8. TSS versus discharge for Runaway Creek (1989-1990). r^2 value = 0.60, n = 94.

WATER QUALITY

Surface Water

Surface water-quality samples have been collected at two sites on Hoseanna Creek since 1987 (Bridges 1 and 3). During the 1990 field season, three samples were taken from each site (September, November and March). Since the March sample represents an entirely different regime (composed exclusively of baseflow just prior to break-up) than previous samples, its results will not be discussed or compared to previous data. However, it is anticipated that we will collect samples of this type for future comparisons. The high flow conditions at Bridge 3 and Bridge 1 during the September sampling trip (114 and 115 cfs, respectively) required the collection of addition samples prior to winter. The flow conditions during the November sampling trip (24 cfs at Bridge 1 and 21 cfs at Bridge 3) were similar to previous trips. Field-determined parameters compared well between the two sites, with only slight differences in temperature, pH, and conductivity. The results of the analyses of theses samples are found in Appendix F. The major ion data is summarized in Table 6. The results of the 1990 analyses are similar to those of previous years. The percentage of both potassium and calcium ions has remained very steady through the study period at 2 percent and 37 percent, respectively. Although there has been some fluctuations, magnesium and sodium have also remained steady. Bicarbonate has also remained constant and has always been the dominant anion. Sulfate percentages has remained steady at about 30%. Chloride percentages have shown the greatest fluctuations, but are generally 20%. Nitrate generally remains less than one percent for both sites.

Figure 9 is a Piper diagram showing all the samples collected for Bridge 1 and Bridge 3 (including the March, 1991 sample). The Piper diagram was plotted using HC-Gram (McIntosh, 1987). The cation portion of the diagram shows that calcium percentages have remained constant (linear trend of symbols), while the anion portion of the diagram shows that the sulfate percentages have remained nearly constant. The plot shows the natural variation of the system and how the composition is influenced by the flow. Table 7 shows the mean values of selected water quality constituents from the Hoseanna Creek sites (1987-1990).

Table 6. Average percentages of the major ion compostion (in meq/l) at Hoseanna Creek for 1987-1990.

	Bridge 3				Bridge 1			
	1987	1988	1989	1990	1987	1988	1989	1990
Calcium	37	37	37	37	38	36	37	38
Magnesium	44	51	35	44	43	49	29	41
Sodium	16	11	26	17	16	14	32	19
Potassium	3	1	2	2	3	1	2	2
Bicarbonate	56	47	50	50	56	46	50	50
Sulfate	34	31	32	36	29	29	31	34
Chloride	10	22	18	14	12	25	19	16
Nitrate	<1	<1	<1	<1	3	<1	<1	<1

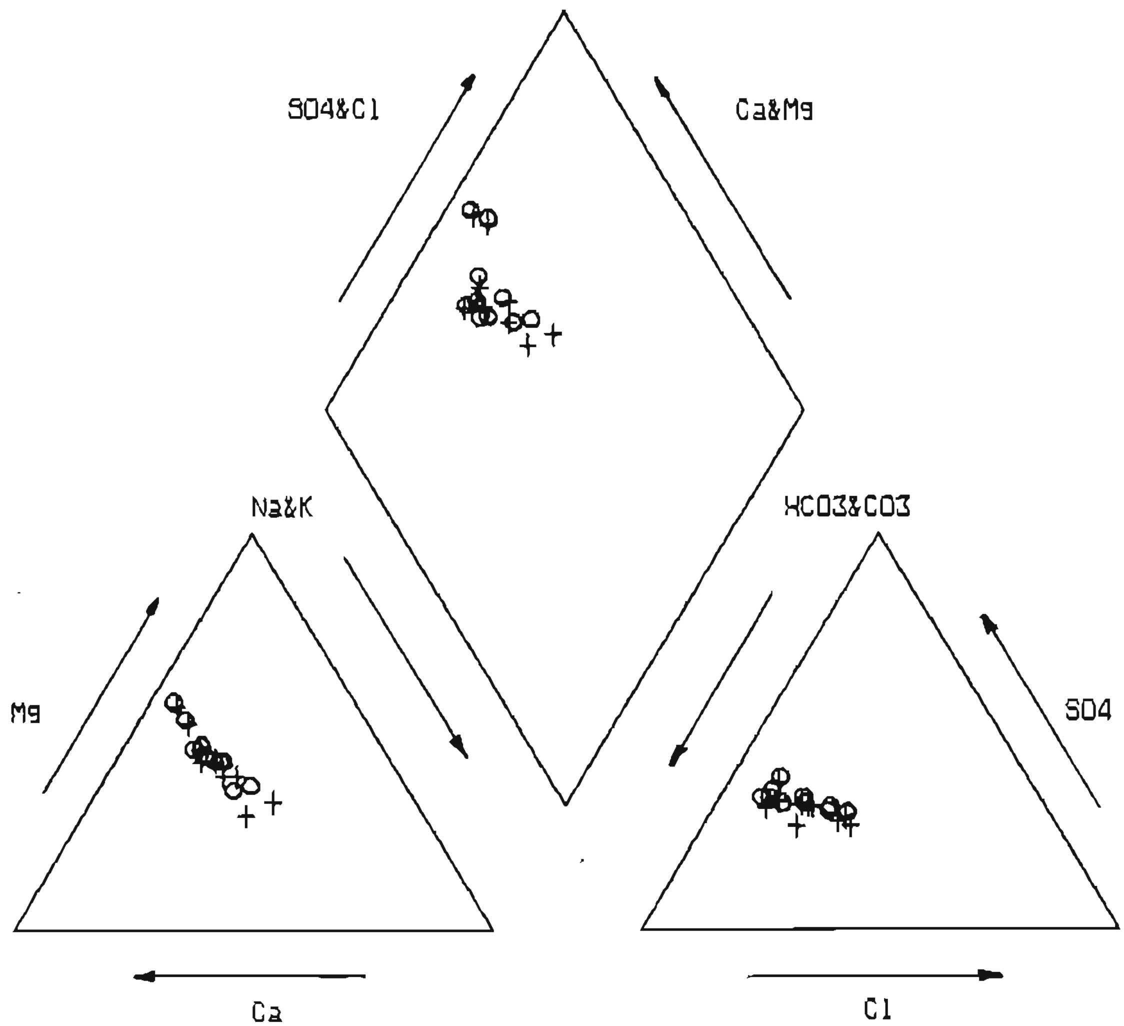

Figure 9. Piper diagram for the surface water sites. The + (plus) indicates samples collected at Bridge 1. The o (circle) indicates samples collected at Bridge 3.

Table 7. Mean values of selected water quality constituents from Hoseanna Creek sites (1987-1990). All values in mg/l unless otherwise noted.

	Bridge 3	Bridge 1
Field Determination		
pH	7.30	7.29
Dissolved oxygen	13.0	11.2
Specific Conductance (umhos/cm)	501	531
Cations		
Calcium	35.0	36.3
Magnesium	26.1	25.3
Sodium	17.2	19.1
Potassium	3.7	3.9
Anions		
Alkalinity	137	141
Sulfate	73.9	70.6
Chloride	27.6	32.2
Nitrate	0.58	3.03
Lab Determinations		
Color (pcu)	35	35
Total Suspended Sediment	580	670
Turbidity (NTU)	170	200
Total Dissolved Solids	274	283

Ground Water

The location of the six ground water monitoring wells sampled during 1990 are given in Table 8. Detailed descriptions of the GAMW wells and installations are given by Golder Associates (1987). Description and installation of the MW wells are given by Shannon and Wilson Inc. (1990). GAMW-4 and GAMW-5 are located in the Poker Flat spoils near Hoseanna Creek. GAMW-3 is parallel to the flow gradient of the spoils, however it is in unmined terrain (Golder Associates, 1987). MW-1A, MW-1C and MW-2 are located east of the Poker Flat mine on Runaway Ridge. MW-1A and MW-1C are located about mid basin and penetrate coal seams #3 and #2, respectively. MW-2 is near the top of the basin and is finished in coal seam #3 (Shannon and Wilson Inc., 1990).

Table 9 gives the initial depth-to-water, volume and pumping rates for the ground water monitoring wells. Samples for analyses are not collected until at least three well casings have been purged and the conductivity has stabilized.

Table 8. Coordinates for ground water monitoring wells at Usibelli Coal Mine.

Well Name	Longitude	Latitude
GAMW-3	148° - 54' - 42.5"	63° - 54' - 26.6"
GAMW-4	148° - 55' - 33.9"	63° - 54' - 26.9"
GAMW-5	148° - 56' - 57.2"	63° - 54' - 18.9"
MW-1A,C	148° - 54' - 46.3"	63° - 54' - 02.3"
MW-2	148° - 54' - 47.1"	63° - 53' - 54.1"

Table 9. Initial water level readings and purging protocol for ground water monitoring wells at Usibelli Coal Mine.

Well Name	Date	Initial[1] Depth to Water (ft)	Calc Casing Volume (gal)	Volume Pumped (gal)	Pumping Rate (gal/hr)	Comments
GAMW-3	9-15-87	26.86	---	---	---	
	5-23-88	25.97	1.5	1.4	---	2
	5-24-88	27.69	1.2	8.0	---	3
	7-18-88	27.59	1.3	4.1	5.0	
	9-07-88	28.04	1.2	8.0	6.4	
	9-20-89	27.82	1.2	5.5	5.7	
	9-12-90	26.68	1.4	4.2	5.0	
GAMW-4	9-15-87	7.68	---	---	---	
	5-24-88	7.96	3.6	6.8	---	4
	5-25-88	8.28	3.6	17.0	12.7	
	7-18-88	8.74	3.5	14.7	9.8	
	9-07-88	8.62	3.6	12.0	13.1	
	9-20-89	9.26	3.4	10.5	13.7	
	9-12-90	7.11	3.7	12.5	9.4	
GAMW-5	9-15-87	72.22	---	---	---	
	5-25-88	71.84	3.9	7.0	2.3	
	7-18-88	82.70	2.3	5.3	1.3	
	7-19-88	-----	---	---	1.1	5
	9-07-88	82.87	2.2	---	---	6
	9-21-89	81.95	2.4	22.0	1.0	7
	9-12-90	80.13	2.6	19.9	0.8	8

Table 9 (cont). Initial water level readings and purging protocol for ground water monitoring wells at Usibelli Coal Mine.

Well Name	Date	Initial[1] Depth to Water (ft)	Calc Casing Volume (gal)	Volume Pumped (gal)	Pumping Rate (gal/hr)	Comments
MW-1A	11-07-89	44.80	54.8	180	79	
	6-21-90	45.45	54.4	165	56	
	9-10-90	44.50	54.9	170	58	
MW-1C	6-21-90	61.76	20.4	80	95	
	9-11-90	61.49	20.5	65	75	
MW-2	6-22-90	109.2	4.1	16	12	
	9-11-90	104.8	4.8	24	24	

Comments:

1. All measurements are from top of PVC casing.
2. Irregular pumping rate due to low water yield and pump failure.
3. Irregular pumping rate due to low water yield.
4. Irregular pumping rate due to ice in well.
5. Pumped well from 2330 hrs, 7-18-88 to 1040 hrs, 7-19-88 due to very low water yield.
6. Pumped well from 1755 hrs, 9-7-88 to 1053 hrs, 9-8-88 due to very low water yield.
7. Pumped well from 1022 hrs, 9-21-89 to 0845 hrs, 9-22-89 due to very low water yield.
8. Pumped well from 1610 hrs, 9-12-90 to 1730 hrs, 9-13-90 due to very low water yield.

The results of the ground water sample analyses are found in Appendix F. The results from the analyses varied considerably among the sites, with little variance between dates. The specific conductance range from 246 umhos/cm at MW-2 in June to 4030 umhos/cm at GAMW-5 in September. The alkalinity (average, as $CaCO_3$) was 134 mg/l at MW-1A, 140 mg/l at MW-2, 151 mg/l at GAMW-4, 175 mg/l at MW-1C, 324 mg/l at GAMW-3, and 501 mg/l at GAMW-5. The pH for all the wells were below 7.0 (except MW-1C), ranging from 5.83 at GAMW-5 to 7.19 at MW-1C. The water temperatures were generally less than 4°C.

Table 10 gives the major ion average percentages (based on meq/l) for the ground water samples. As indicated by the variation in the specific conductance, the composition also varies widely among the sites. The waters were classified following the 1988 sampling as sodium bicarbonate-chloride (GAMW-3), calcium-potassium bicarbonate (GAMW-4), and sodium chloride (GAMW-5).

After the 1989 and 1990 sampling, GAMW-3 and GAMW-5 remain in their respective classifications. However GAMW-4 has changed from calcium-potassium bicarbonate to sodium bicarbonate. Wells MW-1A and MW-2 are classified as calcium bicarbonate. Well MW-1C is classified as sodium-calcium bicarbonate. Figure 10 is a Piper diagram showing the distribution of ground water samples collected.

Table 10. Average percentages of the major ion composition (in meq/l) of ground water monitoring wells at Usibelli Coal Mine (1988-1990).

	GAMW-3	GAMW-4	GAMW-5	MW-1A	MW-1C	MW-2
Calcium	19	29	22	56	34	62
Magnesium	15	15	16	23	16	29
Sodium	61	34	61	20	48	8
Potassium	5	22	1	1	2	1
Bicarbonate	49	87	21	98	98	99
Chloride	39	3	76	1	1	1
Sulfate	12	9	3	1	1	<1
Fluoride	<1	1	<1	<1	<1	<1

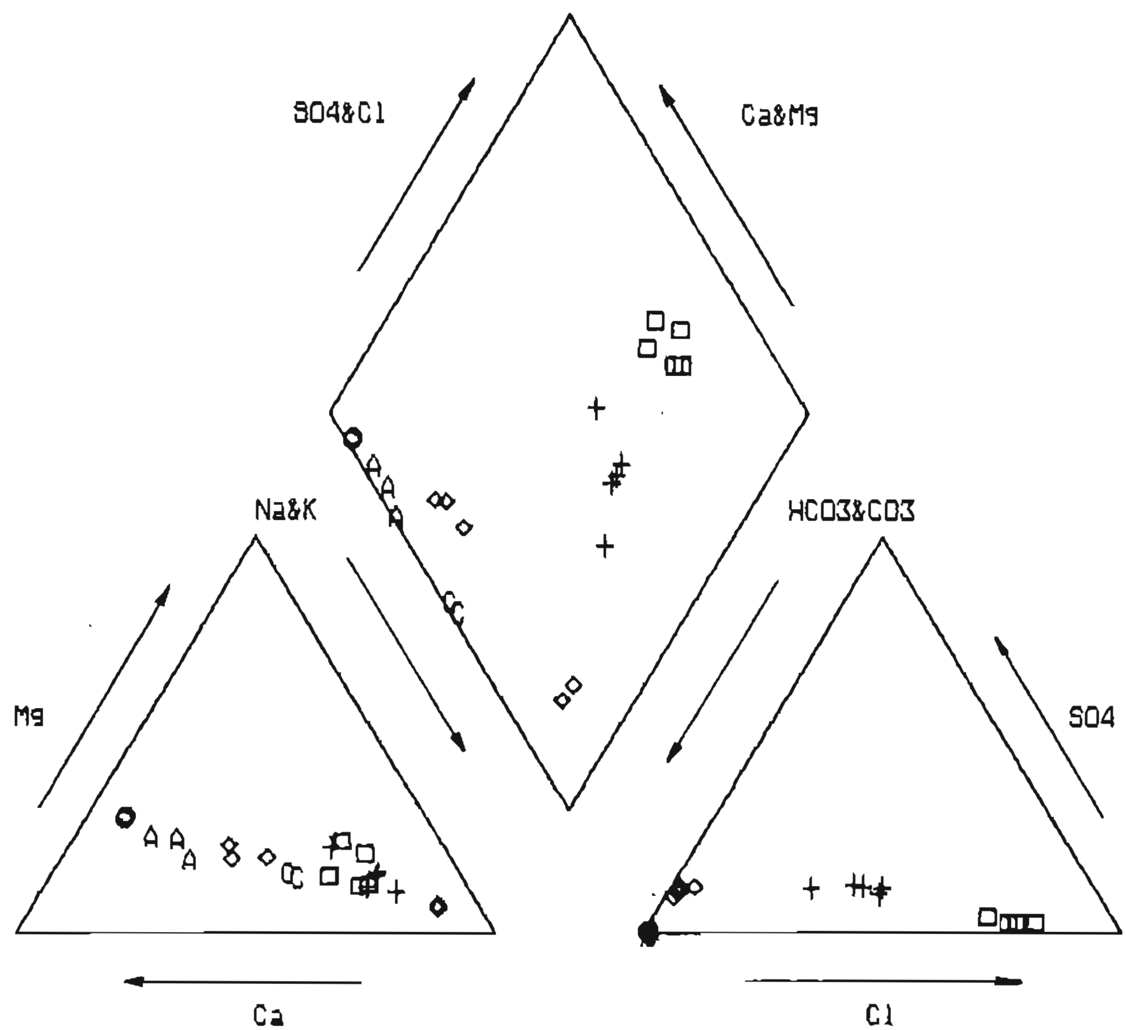

Figure 10. Piper diagram for the ground water sites. The sites are represented as follows: GAMW-3 (+), GAMW-4 (diamond), GAMW-5 (square), MW-1A (A), MW-1C (C), and MW-2 (circle).

DISCUSSION

The precipitation at Gold Run Pass was greater than Poker Flat again in 1990, as it has been in every year of the study. The 1987-90 record shows that the Gold Run Pass gage averages three inches more than the gage at Poker Flat (about 26%). Certainly some of this discrepancy is real, resulting from heavier showers further in the basin due to orographic effects. However, some may be due to the inability of the Poker Flat gage to accurately measure the rainfall because of wind. The Gold Run Pass gage has a "Wyoming" wind shield around it to protect the gage orifice from the wind. The Poker Flat gage does not have such a device. The previous Poker Flat gage site was better protected from the wind than the present site. If this is true, than the present site may not be recording the actual rainfall due to the wind blowing across the opening of the gage (Ray, 1990). The same condition now exists for the gage at Bridge 1.

The data continues to show that the events which produce the large flow events (resulting in high sediment loads) are the large cyclonic storms from the Gulf of Alaska or Bering Sea (Ray and Maurer, 1989). These moisture-laden storms are accompanied by low-level west-southwesterly winds and are capable of dropping more than two inches of rain in 24 hours to 48 hours (Ray, 1990).

The average seasonal runoff at Bridge 3 has increased each year. Table 11 shows the average flow (cfs), total runoff (inches), total precipitation (inches), and the runoff to precipitation ratio for Bridge 3 for June through September.

Table 11. Average flow (cfs), total runoff (inches), total precipitation at Gold Run Pass (inches), and runoff to precipitation ratio for Bridge 3 for June through September.

Site	Average Flow	Runoff	Precipitation	Ratio
1987	37.1	3.84	11.16	.344
1988	40.7	4.22	14.88	.284
1989	53.6	5.55	13.28	.418
1990	70.0	7.25	14.40	.504

The average runoff-to-precipitation ratio for the three years is approximately 0.39. The variance among the values is due to variation in temperature, wind, and the frequency of the rainfall events (Ray, 1990). Although 1990 season had the highest runoff ratio, it did not have the greatest total precipitation. Over half of the summers precipitation fell after mid August (7.8 inches). Most of this precipitation fell when the factors which increase evapotranspiration had lowered (temperature, plant growth). With lower evapotranspiration, more water is available for ground water recharge and runoff.

Table 12 shows the load for each site sampled from 1987-1990. The loads are for the period of discharge record.

Table 12. Sediment load estimates (tons) for the period of discharge record.

Site	1987	1988	1989	1990
Hoseanna @ Brd 6	----	2606	41900	11000
Hoseanna @ Brd 3	40000	59200	100300	64000
Runaway	----	----	----	51.2
Two Bull	----	----	554	315

Ray (1990) discussed the importance of the magnitude and number of the storm events in determining the season sediment load at Bridge 3. Although 1990 had the highest average season flow (70 cfs), it did not have the highest sediment load. The 1989 season had the highest sediment load, with a season average discharge of 52.6 cfs. Table 13 show the correlation of storm events and season sediment load.

As discussed by Ray and Maurer (1989) and Ray (1990) most of sediment transported during a season occurs over a relatively short period of time. Table 14 shows the percentage of sediment transported in discrete, short periods of time. For most sites, over 50 percent of the seasonal sediment load was transported in two to three days.

Table 13. Number of flow events over 500 and 1000 cfs and the corresponding season sediment load (tons).

Peak Storm Flow	1987	1988	1989	1990
# greater than 500 cfs	0	2	3	2
# greater than 1000 cfs	0	0	1	1
Season Sediment Load (tons)	40000	59200	103000	64000

Table 14. The percentage of seasonal sediment load in short durations.

			D A Y S		
Site	1	2	3	5	10
Hoseanna @ Brd 6 (1988)	55	62	68	71	82
1989	37	49	59	74	87
1990	17	33	48	66	82
Hoseanna @ Brd 3 (1988)	44	55	65	78	87
1989	42	56	63	78	91
1990	29	40	50	62	73
Runaway (1990)	36	56	74	78	84
Two Bull (1989)	58	64	69	77	87
1990	45	58	67	75	82
AVERAGE	40	53	63	73	84

WATER QUALITY

Surface Water

The surface water-quality sampling of Hoseanna Creek has been conducted since 1987. Samples were generally taken during non-storm periods, which represent average to low-flow conditions. However, the September samples were taken on the receding limb of a storm hydrograph (115 cfs). The purpose of the surface water quality study is to measure the general water-quality conditions above and below the Poker Flat mine and determine the effect of Poker Flat mine on the water quality of Hoseanna Creek. The most likely influence of the Poker Flat mine is from ground water input from the spoils. If samples were taken during storm runoff, any effects of the mine would probably be diluted by the large volume of surface runoff. To measure the maximum influence from the mine, samples should be taken at low-flow conditions when surface runoff is low and the ground water contribution is high. That is why samples were collected in March prior to break-up.

Figure 11 shows the cation portion of a Piper diagram of all surface and ground water samples collected since to beginning of the study. Both water types show a linear trend. The ground water trend will be discussed in the next section. The surface water trend shows the natural variations of the water chemistry over the last four years at different hydrologic setting. Many factors influence the chemical composition of the stream. But the underlying factor here is the ratio of surface runoff to ground water input. Samples which plot on the left side of the chart are either surface runoff dominated or short residence time ground water. As the ground water contribution or residence time increases, the composition moves toward the right (toward the ground water composition). It is expected as the ground water contribution becomes dominant, the composition of the surface water would become similar to the ground water.

Ground Water

As discussed in the previous section, the cation portion of the Piper diagram (Figure 11) shows a linear trend for the ground water samples. The trend is a function of residence time and cation exchange. The samples at the far left are MW-2. This well is at the top of the basin in coal seam #3. These samples represent low-residence time waters. The next cluster is MW-1A. This is also in coal seam #3, but further down in the basin. More ionic exchange has occurred. The next cluster is GAMW-4 (1987-88 samples). The samples have had an unusual chemical composition and appear to be a mixture of surface and ground waters (Ray and Maurer, 1989). The next cluster is MW-1C. This well is in the same location in the basin as MW-1A, but is in coal seam #2 (deeper stratigraphically than seam #3). These waters have a longer residence time than those of MW-1A. The next two clusters are GAMW-3 and GAMW-5. These wells are located low in the basin where long residence time and significant ion exchange has occurred. Although the two wells have similar composition, well GAMW-5 has a much higher concentration due to resaturation of material not previously in contact with the ground water (Ray and Maurer, 1989). The last cluster is GAMW-4. It is also low in the basin and has similar characteristics of GAMW-3 and GAMW-5.

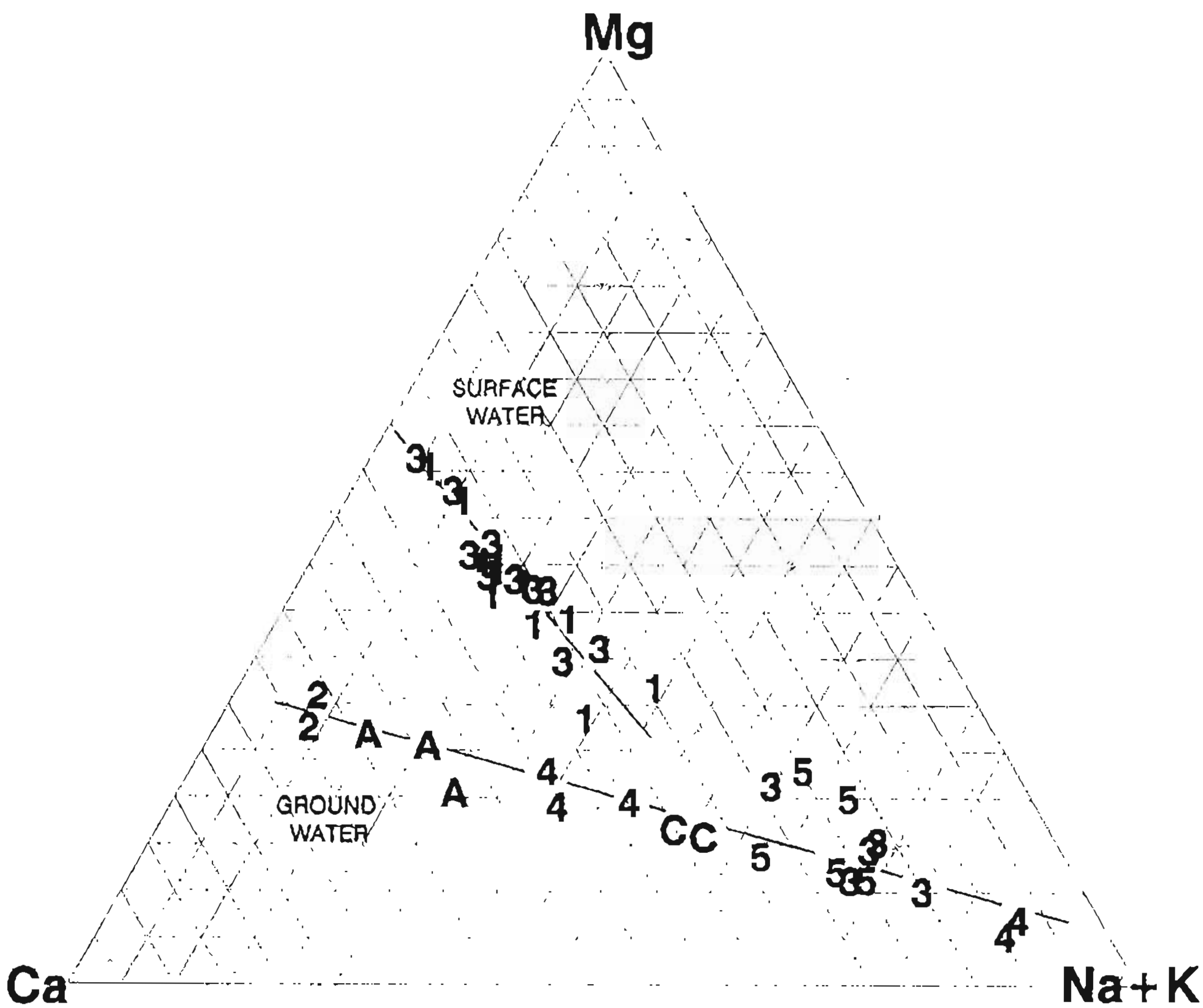

Figure 11. Triangular diagram (cations) for the surface and ground water sites. The sites are represented as follows: Hoseanna Creek - Bridge 1 (1), Hoseanna Creek - Bridge 3 (3), GAMW-3 (3), GAMW-4 (4), GAMW-5 (5), MW-1A (A), MW-1C (C), and MW-2 (2).

CONCLUSIONS

Most of the conclusions listed below are from Ray (1990). Some of the conclusion topics may not have been discussed in this report.

1. Large cyclonic storms are responsible for most of the sediment transport, while the isolated convective storms result in minor sediment production.

2. A large portion of the seasonal sediment load occurs during the first major flood event of the season (may coincide with break-up).

3. The runoff prior to break-up carries a significant sediment load which is important factor in the annual sediment load.

4. Most of the seasonal sediment load is transported over a relative few days during high-flow events.

5. Rating equations have a limited accuracy, in that they are power functions.

6. Good sediment rating equations (high r^2 values) are difficult to obtain for small creeks due to mass wasting events.

7. Some streams are better suited for the establishment of good rating equations (also noted by Wilbur, 1989).

8. Hysteresis results in additional variance in the calculation of the sediment rating equations.

9. The available sediment for transport decreases through the summer, resulting in additional variance in the calculation of the sediment rating equations.

10. The best time to sample the surface water is during the late-fall or even late-winter when the surface runoff is at a minimum.

11. The water type classification for the five ground water monitoring wells is significantly different.

12. Little change in the water chemistry has occurred in GAMW-3 and GAMW-5. What changes have taken place may be due to fertilization the of the spoils.

13. The water chemistry of GAMW-4 in 1988 may have been influenced by surface water runoff down the well casing.

14. Major surface-water cations show a linear trend on a Piper diagram. Future samples should plot on this line which represents the natural variations in the stream.

15. Major ground-water cations show a linear trend which represents the residence time and ion exchange.

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APPENDIX A

GOLD RUN PASS

DAILY PRECIPITATION - 1990 (in)

	MAY	JUN	JUL	AUG	SEP
1					
2		0.36	0.24	0.12	
3			0.12	0.24	
4	0.72				0.36
5					0.24
6					0.12
7				0.84	0.36
8			0.12		
9					0.72
10			0.72		0.84
11			0.84		
12			1.92		
13					
14					0.72
15				0.12	
16					
17					
18					
19				0.24	
20				0.48	
21	0.24	0.12		0.72	
22					
23		0.36		0.36	
24					0.36
25			0.24		
26		0.12		0.84	
27				0.12	
28			0.24		0.36
29				0.24	
30					
31				0.60	
Total	0.96	0.96	4.44	4.92	4.08

Season Total = 15.60

APPENDIX A (cont)

POKER FLAT

DAILY PRECIPITATION - 1990 (in)

	MAY	JUN	JUL	AUG	SEP
1					
2		0.27	0.19	0.10	
3	0.05		0.08	0.15	
4	0.65	0.02			0.26
5	0.02				0.22
6					0.05
7				0.94	0.25
8			0.04		
9					0.42
10			0.65		0.54
11			0.73		0.33
12			1.74		
13					
14					0.60
15				0.06	
16					
17					
18		0.03			
19				0.25	
20				0.45	
21	0.18	0.05		0.68	
22					
23		0.31		0.33	
24					0.23
25			0.10		
26		0.05		0.84	
27		0.01		0.06	
28			0.19	0.02	0.24
29				0.22	
30					
31				0.49	
Total	0.90	0.74	3.72	4.59	3.14

Season Total = 12.19

APPENDIX A (cont)

BRIDGE 1

DAILY PRECIPITATION - 1990 (in)

	MAY	JUN	JUL	AUG	SEP
1					0.22
2				Installed	0.01
3					
4					0.15
5					0.30
6					0.02
7				0.95	0.31
8					0.01
9					0.55
10					0.63
11					0.04
12					
13					
14					0.16
15				0.04	0.27
16					
17					
18					
19				0.30	
20				0.45	
21				0.25	
22					0.09
23				0.18	0.01
24					0.01
25					0.01
26				1.35	
27				0.04	
28				0.02	
29				0.17	
30				0.04	0.06
31				0.17	
Total				3.96	2.85

APPENDIX B

Hoseanna Creek at Bridge 3

Daily Average Discharge - 1990 (cfs)

	MAY	JUN	JUL	AUG	SEP
1		104	29	23	302
2		113	34	23	111
3		107	50	25	75
4		70	39	24	115
5		52	48	23	139
6		65	19	23	142
7		40	18	42	154
8		32	18	35	140
9		53	16	24	264
10		40	25	22	325
11		33	209	20	233
12		32	582	18	161
13		31	228	17	105
14		37	99	17	118
15		122	73	20	220
16		58	60	18	131
17	149	41	50	15	102
18	175	35	45	15	85
19	143	32	41	20	77
20	144	30	36	32	68
21	136	31	34	52	63
22	122	29	33	32	63
23	128	29	32	27	68
24	113	26	29	39	61
25	114	24	29	32	54
26	113	23	29	239	48
27	115	35	25	116	48
28	117	32	24	77	47
29	111	29	24	168	45
30	106	32	22	123	44
31	95		23	110	
AVE	125	47	65	48	120

Season Average = 70.0 cfs

APPENDIX B (cont)

Hoseanna Creek at Bridge 6

Daily Average Discharge - 1990 (cfs)

	JUN	JUL	AUG	SEP
1				211
2				75.6
3				48.4
4				77.9
5				88.0
6				78.4
7				99.6
8			12.5	94
9			11.2	156
10			11.1	195
11			9.94	121
12			10.8	91.3
13			10.9	74.2
14			10.8	58.7
15			12.6	60.1
16			13.3	49.4
17			11.6	35.6
18			11.8	28.9
19			12.5	22.3
20			21.6	19.6
21			34.1	18.4
22			23.9	17.9
23			19.5	17.5
24			20.1	15.6
25			23.6	14.6
26			144	13.7
27			65.8	13.8
28			48.7	13.2
29			98.4	11.7
30			72.1	11.3
31			66.4	
AVE			32.4	61.1

Season Average = 48.3 cfs

APPENDIX B (cont)

Runaway Creek

Daily Average Discharge - 1990 (cfs)

	MAY	JUN	JUL	AUG	SEP
1		0.13	0.17	0.14	0.22
2		0.19	0.15	0.17	0.20
3		0.12	0.17	0.17	0.20
4		0.15	0.16	0.11	0.26
5		0.26	0.17	0.14	0.38
6		0.29	0.15	0.14	0.16
7		0.15	0.15	0.28	0.19
8		0.18	0.15	0.14	0.17
9		0.17	0.15	0.15	0.35
10		0.17	0.20	0.12	0.41
11		0.14	0.62	0.14	0.30
12		0.15	1.25	0.12	0.30
13		0.15	0.35	0.15	0.25
14		0.19	0.34	0.15	0.33
15		0.34	0.28	0.14	0.51
16		0.14	0.25	0.14	0.21
17		0.17	0.24	0.12	0.26
18		0.15	0.24	0.11	0.24
19		0.15	0.22	0.14	0.26
20		0.17	0.22	0.18	0.24
21		0.15	0.22	0.24	0.22
22		0.17	0.22	0.16	0.27
23		0.17	0.20	0.15	0.29
24		0.15	0.20	0.11	0.28
25	0.12	0.19	0.25	0.14	0.26
26	0.11	0.18	0.13	0.66	0.24
27	0.14	0.15	0.17	0.24	0.26
28	0.17	0.17	0.15	0.20	0.24
29	0.14	0.15	0.16	0.24	0.24
30	0.14	0.18	0.15	0.22	0.20
31	0.17		0.14	0.25	
AVE	0.14	0.17	0.25	0.18	0.27

Season Average = 0.21 cfs

APPENDIX B (cont)

Two Bull Creek

Daily Average Discharge - 1990 (cfs)

	JUN	JUL	AUG	SEP
1		0.16	0.14	0.36
2		0.19	0.15	0.25
3		0.26	0.15	0.24
4		0.26	0.17	0.33
5		0.22	0.17	0.36
6		0.19	0.15	0.29
7	0.25	0.16	0.27	0.31
8	0.26	0.16	0.18	0.26
9	0.24	0.14	0.18	0.42
10	0.21	0.26	0.14	0.54
11	0.20	0.64	0.18	0.45
12	0.20	1.80	0.16	0.37
13	0.17	0.72	0.16	0.33
14	0.21	0.41	0.18	0.40
15	0.41	0.35	0.15	0.48
16	0.22	0.27	0.15	0.33
17	0.21	0.24	0.12	0.30
18	0.18	0.24	0.12	0.26
19	0.16	0.22	0.17	0.24
20	0.16	0.21	0.25	0.21
21	0.18	0.20	0.34	0.22
22	0.18	0.21	0.20	0.26
23	0.18	0.20	0.21	0.31
24	0.17	0.19	0.19	0.21
25	0.15	0.19	0.16	0.17
26	0.19	0.17	0.54	0.14
27	0.16	0.17	0.42	0.19
28	0.16	0.17	0.26	0.19
29	0.15	0.18	0.29	0.19
30	0.14	0.15	0.26	0.16
31		0.14	0.25	
AVE	0.20	0.29	0.21	0.29

Season Average = 0.25 cfs

APPENDIX C

Hoseanna Creek at Bridge 3

Daily Sediment Load - 1990 (tons)

	MAY	JUN	JUL	AUG	SEP
1		754	6.30	3.83	6630
2		1370	31.0	3.77	361
3		1130	207	5.03	143
4		319	55.2	10.2	397
5		473	49.8	8.49	2600
6		545	5.63	8.49	661
7		181	5.02	37.5	643
8		84.4	5.02	23.3	380
9		402	21.4	11.3	1050
10		581	289	6.04	1320
11		65.9	5190	4.39	495
12		108	18300	3.51	150
13		44.8	2110	2.78	243
14		135	281	2.55	880
15		715	98.0	8.00	1100
16		77.6	62.8	4.21	220
17		35.7	38.0	2.18	79.7
18		24.2	29.6	1.86	45.3
19		18.7	22.2	4.42	33.9
20		16.3	49.2	20.0	22.7
21		17.5	23.3	326	20.6
22		194	15.5	26.8	21.9
23		19.2	12.9	40.1	40.5
24		15.0	9.44	108	22.5
25		11.1	7.32	36.3	14.3
26		8.07	12.6	7010	11.4
27		8.27	5.50	840	9.28
28		11.5	5.20	156	6.35
29		5.70	6.07	968	6.15
30	296	6.41	4.10	465	5.45
31	471		5.78	1150	
Total	767	7380	27000	11300	17600

Season Total = 64,000 tons

APPENDIX C (cont)

Hoseanna Creek at Bridge 6

Daily Sediment Load - 1990 (tons)

	MAY	JUN	JUL	AUG	SEP
1					1740
2					126
3					40.1
4					209
5					201
6					176
7					361
8				8.36	131
9				4.25	916
10				2.22	1020
11				1.67	359
12				1.52	117
13				1.49	64.3
14				1.38	120
15				4.98	166
16				2.45	39.8
17				1.30	18.5
18				1.23	12.0
19				2.59	8.35
20				21.8	5.89
21				101	4.49
22				12.8	4.80
23				9.25	6.20
24				37.3	3.45
25				14.2	2.35
26				1900	2.10
27				295	2.20
28				215	2.00
29				1680	1.90
30				432	1.80
31				338	
Total				5090	5860

Season Average = 11,000 tons

APPENDIX C (cont)

Runaway Creek

Daily Sediment Load - 1990 (tons)

	MAY	JUN	JUL	AUG	SEP
1		0.020	0.008	0.003	0.026
2		0.030	0.004	0.008	0.020
3		0.040	0.001	0.023	0.020
4		0.025	0.005	0.001	0.537
5		0.070	0.003	0.003	0.377
6		0.150	0.003	0.003	0.351
7		0.040	0.002	0.090	0.310
8		0.121	0.002	0.003	0.285
9		0.040	0.001	0.005	0.260
10		0.020	0.017	0.002	0.536
11		0.010	9.05	0.003	0.119
12		0.007	10.6	0.002	0.122
13		0.005	0.263	0.005	0.256
14		0.040	0.120	0.005	0.183
15		0.367	0.080	0.003	1.49
16		0.080	0.030	0.003	0.423
17		0.050	0.006	0.001	0.201
18		0.020	0.008	0.001	0.104
19		0.013	0.011	0.003	0.063
20		0.008	0.015	0.010	0.044
21		0.005	0.010	0.041	0.030
22		0.002	0.005	0.754	0.078
23		0.002	0.002	0.712	0.104
24		0.003	0.001	0.619	0.090
25	0.060	0.002	0.055	0.644	0.028
26	0.055	0.002	0.010	18.2	0.044
27	0.070	0.005	0.008	0.650	0.063
28	0.080	0.008	0.005	0.448	0.044
29	0.070	0.008	0.003	0.330	0.044
30	0.072	0.007	0.001	0.232	0.020
31	0.080		0.000	0.047	
Total	0.487	1.20	20.3	22.9	6.27

Season Total = 51.2 tons

Two Bull Creek

Daily Sediment Load - 1990 (tons)

	MAY	JUN	JUL	AUG	SEP
1			0.15	0.09	1.94
2			0.23	0.10	0.62
3			0.66	0.24	0.54
4			0.67	0.15	1.55
5			0.37	0.16	1.95
6			0.26	0.10	0.94
7		4.10	0.13	1.47	1.19
8		0.66	0.14	0.11	0.71
9		0.53	0.09	0.19	3.17
10		0.36	0.69	0.02	7.61
11		0.28	42.1	0.19	4.18
12		0.28	141	0.12	2.14
13		0.18	19.7	0.14	0.40
14		0.36	3.12	0.01	2.91
15		2.94	1.72	0.10	5.01
16		0.39	0.14	0.11	1.41
17		0.35	0.54	0.01	1.13
18		0.20	0.51	0.05	0.87
19		0.14	0.41	0.15	0.54
20		0.14	0.36	0.56	0.31
21		0.20	0.30	3.62	0.42
22		0.13	0.32	0.29	0.66
23		0.20	0.31	0.30	1.18
24		0.16	0.24	1.00	0.32
25		0.12	0.25	0.13	0.45
26		0.22	0.18	26.5	0.09
27		0.14	0.18	5.74	0.23
28		0.12	0.16	0.66	0.23
29		0.11	0.19	0.96	0.23
30		0.09	0.11	0.55	0.14
31			0.02	0.21	
Total		12.41	215	44.1	43.1

Season Total = 315 tons

APPENDIX D

Units: Turb (Turbidity) - NTU
TSS (Total Suspended Solids) - mg/l
Q (Discharge) - cfs

Type: g - grab sample
i - automated isco sample
c - automated composite sample

Location	Date	Time	Turb	TSS	Q	T
HOS BRD 1	26-Aug-90	642	2400	5400	195	i
HOS BRD 1	26-Aug-90	742	3600	11000	260	i
HOS BRD 1	26-Aug-90	842	4600	9950	295	i
HOS BRD 1	26-Aug-90	942	5300	10300	312	i
HOS BRD 1	26-Aug-90	1042	3700	9280	325	i
HOS BRD 1	26-Aug-90	1142	2900	8080	334	i
HOS BRD 1	26-Aug-90	1242	3000	7900	357	i
HOS BRD 1	26-Aug-90	1342	3700	8230	381	i
HOS BRD 1	26-Aug-90	1442	2800	7450	384	i
HOS BRD 1	26-Aug-90	1542	2800	7200	381	i
HOS BRD 1	26-Aug-90	1642	2300	6620	402	i
HOS BRD 1	26-Aug-90	1742	3300	10800	408	i
HOS BRD 1	26-Aug-90	1842	3400	9080	377	i
HOS BRD 1	26-Aug-90	1942	3000	7150	348	i
HOS BRD 1	26-Aug-90	2042	2400	6580	340	i
HOS BRD 1	26-Aug-90	2142	2200	5460	324	i
HOS BRD 1	26-Aug-90	2242	2100	4910	291	i
HOS BRD 1	26-Aug-90	2342	1800	3970	257	i
HOS BRD 1	27-Aug-90	42	1500	3230	230	i
HOS BRD 1	27-Aug-90	142	1300	2790	210	i
HOS BRD 1	27-Aug-90	242	1000	2260	193	i
HOS BRD 1	27-Aug-90	342	1300	2180	179	i
HOS BRD 1	27-Aug-90	442	1200	2010	168	i
HOS BRD 1	27-Aug-90	542	1100	1670	157	i
HOS BRD 1	31-Aug-90	2200	1500	2890	197	i
HOS BRD 1	31-Aug-90	2300	2500	6820	262	i
HOS BRD 1	01-Sep-90	0	4000	8980	335	i
HOS BRD 1	01-Sep-90	100	3600	9310	381	i
HOS BRD 1	01-Sep-90	200	3700	9410	381	i
HOS BRD 1	01-Sep-90	300	2700	7660	345	i
HOS BRD 1	01-Sep-90	400	2000	6470	335	i
HOS BRD 1	01-Sep-90	500	2000	4880	335	i
HOS BRD 1	01-Sep-90	600	1900	5440	330	i
HOS BRD 1	01-Sep-90	700	1700	4120	335	i
HOS BRD 1	01-Sep-90	800	1600	5160	355	i
HOS BRD 1	01-Sep-90	900	2100	5840	360	i
HOS BRD 1	01-Sep-90	1000	2400	6110	402	i
HOS BRD 1	01-Sep-90	1100	2700	10400	451	i
HOS BRD 1	01-Sep-90	1200	3200	9040	456	i
HOS BRD 1	01-Sep-90	1300	3000	8490	446	i

APPENDIX D (cont)

Location	Date	Time	Turb	TSS	Q	T
HOS BRD 1	01-Sep-90	1400	2600	7480	440	i
HOS BRD 1	01-Sep-90	1500	2100	6190	386	i
HOS BRD 1	01-Sep-90	1600	1800	4610	350	i
HOS BRD 1	01-Sep-90	1700	1600	3940	325	i
HOS BRD 1	01-Sep-90	1800	1300	3370	288	i
HOS BRD 1	01-Sep-90	1900	1400	2880	262	i
HOS BRD 1	01-Sep-90	2000	1300	2520	238	i
HOS BRD 1	01-Sep-90	2100	1300	2370	219	i
HOS BRD 1	07-Sep-90	1100	180	719	183	i
HOS BRD 1	07-Sep-90	1200	370	1210	193	i
HOS BRD 1	07-Sep-90	1300	850	1860	215	i
HOS BRD 1	07-Sep-90	1400	1000	1900	207	i
HOS BRD 1	07-Sep-90	1500	1400	3330	215	i
HOS BRD 1	07-Sep-90	1600	1600	3720	215	i
HOS BRD 1	07-Sep-90	1700	1300	3420	207	i
HOS BRD 1	07-Sep-90	1800	1300	3090	207	i
HOS BRD 1	07-Sep-90	1900	1100	2710	211	i
HOS BRD 1	07-Sep-90	2000	1100	2710	215	i
HOS BRD 1	07-Sep-90	2100	950	2410	207	i
HOS BRD 1	07-Sep-90	2200	900	2060	207	i
HOS BRD 1	07-Sep-90	2300	750	1780	204	i
HOS BRD 1	08-Sep-90	0	650	1430	197	i
HOS BRD 1	08-Sep-90	100	650	1600	193	i
HOS BRD 1	08-Sep-90	200	550	1260	190	i
HOS BRD 1	08-Sep-90	300	550	1130	183	i
HOS BRD 1	08-Sep-90	400	550	1140	176	i
HOS BRD 1	08-Sep-90	500	450	970	170	i
HOS BRD 1	08-Sep-90	600	450	937	170	i
HOS BRD 1	08-Sep-90	700	500	861	157	i
HOS BRD 1	08-Sep-90	800	400	775	160	i
HOS BRD 1	08-Sep-90	900	650	1000	157	i
HOS BRD 1	08-Sep-90	1000	650	947	157	i
HOS BRD 1	13-Sep-90	1200	230	427	115	g
HOS BRD 1	02-Nov-90	1150	15	17.2	24.2	g
HOS BRD 3	30-May-90		300	1060	106	c
HOS BRD 3	31-May-90		550	1880	95	c
HOS BRD 3	01-Jun-90		650	2750	104	c
HOS BRD 3	02-Jun-90		1100	4620	113	c
HOS BRD 3	03-Jun-90		1400	4000	107	c
HOS BRD 3	04-Jun-90		650	1730	70	c
HOS BRD 3	05-Jun-90		2200	3450	52	c
HOS BRD 3	06-Jun-90		2000	3200	65	c
HOS BRD 3	07-Jun-90		950	1740	40	c
HOS BRD 3	08-Jun-90		800	1020	32	c
HOS BRD 3	09-Jun-90		1600	2880	53	c
HOS BRD 3	10-Jun-90		2200	5590	40	c
HOS BRD 3	11-Jun-90		650	753	33	c

APPENDIX D (cont)

Location	Date	Time	Turb	TSS	Q	T
HOS BRD 3	12-Jun-90		700	1300	32	c
HOS BRD 3	13-Jun-90		450	557	31	c
HOS BRD 3	14-Jun-90		1100	1390	37	c
HOS BRD 3	15-Jun-90		1600	2240	122	c
HOS BRD 3	22-Jun-90		500	2570	29	c
HOS BRD 3	23-Jun-90		150	254	29	c
HOS BRD 3	24-Jun-90		110	219	26	c
HOS BRD 3	25-Jun-90		100	174	24	c
HOS BRD 3	26-Jun-90		80	131	23	c
HOS BRD 3	27-Jun-90		70	89.7	35	c
HOS BRD 3	28-Jun-90		95	139	32	c
HOS BRD 3	29-Jun-90		50	75.4	29	c
HOS BRD 3	30-Jun-90		55	75.3	32	c
HOS BRD 3	01-Jul-90		55	83.3	29	c
HOS BRD 3	02-Jul-90		180	345	34	c
HOS BRD 3	03-Jul-90		800	1560	50	c
HOS BRD 3	04-Jul-90		500	543	39	c
HOS BRD 3	09-Jul-90		180	503	16	c
HOS BRD 3	10-Jul-90		950	4370	25	c
HOS BRD 3	11-Jul-90		3400	12700	209	c
HOS BRD 3	11-Jul-90	1230	3200	9790	230	i
HOS BRD 3	11-Jul-90	1330	3600	9300	306	i
HOS BRD 3	11-Jul-90	1430	4300	13900	375	i
HOS BRD 3	11-Jul-90	1530	3800	14000	408	i
HOS BRD 3	11-Jul-90	1630	5000	19800	467	i
HOS BRD 3	11-Jul-90	1830	1400	5740	472	i
HOS BRD 3	11-Jul-90	2130	3600	10500	435	i
HOS BRD 3	11-Jul-90	2230	2800	10300	424	i
HOS BRD 3	11-Jul-90	2330	3000	9890	456	i
HOS BRD 3	12-Jul-90		4000	10900	582	c
HOS BRD 3	12-Jul-90	30	2900	10500	461	i
HOS BRD 3	12-Jul-90	130	3800	10500	555	i
HOS BRD 3	12-Jul-90	230	4200	13100	596	i
HOS BRD 3	12-Jul-90	330	4300	14400	612	i
HOS BRD 3	12-Jul-90	430	5500	15500	759	i
HOS BRD 3	12-Jul-90	530	4500	14300	810	i
HOS BRD 3	12-Jul-90	630	5000	18500	913	i
HOS BRD 3	12-Jul-90	730	6100	17000	995	i
HOS BRD 3	12-Jul-90	830	5000	15300	895	i
HOS BRD 3	12-Jul-90	930	4300	12600	759	i
HOS BRD 3	12-Jul-90	1030	4100	11200	700	i
HOS BRD 3	12-Jul-90	1130	3200	9210	639	i
HOS BRD 3	13-Jul-90		1800	3530	228	c
HOS BRD 3	14-Jul-90		600	1080	99	c
HOS BRD 3	15-Jul-90		380	512	73	c
HOS BRD 3	16-Jul-90		240	396	60	c
HOS BRD 3	17-Jul-90		150	287	50	c
HOS BRD 3	18-Jul-90		120	250	45	c

APPENDIX D (cont)

Location	Date	Time	Turb	TSS	Q	T
HOS BRD 3	19-Jul-90		110	209	41	c
HOS BRD 3	20-Jul-90		290	520	36	c
HOS BRD 3	21-Jul-90		150	260	34	c
HOS BRD 3	22-Jul-90		80	177	33	c
HOS BRD 3	23-Jul-90		90	156	32	c
HOS BRD 3	24-Jul-90		70	125	29	c
HOS BRD 3	25-Jul-90		50	96.8	29	c
HOS BRD 3	26-Jul-90		110	167	29	c
HOS BRD 3	27-Jul-90		50	83.0	25	c
HOS BRD 3	28-Jul-90		36	81.5	24	c
HOS BRD 3	29-Jul-90		45	95.1	24	c
HOS BRD 3	30-Jul-90		34	72.2	22	c
HOS BRD 3	31-Jul-90		40	94.0	23	c
HOS BRD 3	01-Aug-90		32	62.3	23	c
HOS BRD 3	02-Aug-90		32	61.3	23	c
HOS BRD 3	03-Aug-90		25	76.0	25	c
HOS BRD 3	08-Aug-90		120	253	35	c
HOS BRD 3	09-Aug-90		100	177	24	c
HOS BRD 3	10-Aug-90		60	106	22	c
HOS BRD 3	11-Aug-90		45	84.5	20	c
HOS BRD 3	12-Aug-90		38	74.3	18	c
HOS BRD 3	13-Aug-90		33	61.9	17	c
HOS BRD 3	14-Aug-90		34	56.7	17	c
HOS BRD 3	15-Aug-90		70	154	20	c
HOS BRD 3	16-Aug-90		55	89.0	18	c
HOS BRD 3	17-Aug-90		31	54.2	15	c
HOS BRD 3	18-Aug-90		21	46.2	15	c
HOS BRD 3	19-Aug-90		40	85.0	20	c
HOS BRD 3	21-Aug-90		1400	2380	52	c
HOS BRD 3	22-Aug-90		180	315	32	c
HOS BRD 3	23-Aug-90		250	566	27	c
HOS BRD 3	24-Aug-90		600	1060	39	c
HOS BRD 3	25-Aug-90		220	426	32	c
HOS BRD 3	26-Aug-90		500	1850	239	c
HOS BRD 3	26-Aug-90	636	4600	13800	215	i
HOS BRD 3	26-Aug-90	736	5300	14700	275	i
HOS BRD 3	26-Aug-90	836	4700	13500	302	i
HOS BRD 3	26-Aug-90	936	3800	14300	316	i
HOS BRD 3	26-Aug-90	1036	4400	12500	330	i
HOS BRD 3	26-Aug-90	1136	3300	9370	335	i
HOS BRD 3	26-Aug-90	1236	3300	9980	365	i
HOS BRD 3	26-Aug-90	1336	4000	7660	391	i
HOS BRD 3	26-Aug-90	1436	2600	8390	381	i
HOS BRD 3	26-Aug-90	1536	2900	9020	381	i
HOS BRD 3	26-Aug-90	1636	2900	8880	419	i
HOS BRD 3	26-Aug-90	1736	4200	13600	402	i
HOS BRD 3	26-Aug-90	1836	2900	9190	365	i
HOS BRD 3	26-Aug-90	1936	3000	8250	340	i

APPENDIX D (cont)

Location	Date	Time	Turb	TSS	Q	T
HOS BRD 3	26-Aug-90	2036	3000	6090	340	i
HOS BRD 3	26-Aug-90	2136	3200	7100	316	i
HOS BRD 3	26-Aug-90	2236	2200	5360	279	i
HOS BRD 3	26-Aug-90	2336	1800	4880	246	i
HOS BRD 3	27-Aug-90	36	1500	4470	222	i
HOS BRD 3	27-Aug-90	136	1200	3390	204	i
HOS BRD 3	27-Aug-90	236	1400	3490	186	i
HOS BRD 3	27-Aug-90	336	1400	3160	176	i
HOS BRD 3	27-Aug-90	436	1200	2730	164	i
HOS BRD 3	27-Aug-90	536	1100	2330	154	i
HOS BRD 3	31-Aug-90	2230	5400	10700	262	i
HOS BRD 3	31-Aug-90	2330	4200	14100	335	i
HOS BRD 3	01-Sep-90	30	4200	9380	381	i
HOS BRD 3	01-Sep-90	130	4500	11600	381	i
HOS BRD 3	01-Sep-90	230	3500	7450	345	i
HOS BRD 3	01-Sep-90	330	3000	7180	335	i
HOS BRD 3	01-Sep-90	430	2200	6100	335	i
HOS BRD 3	01-Sep-90	530	2400	5430	330	i
HOS BRD 3	01-Sep-90	630	2300	5730	335	i
HOS BRD 3	01-Sep-90	730	2600	7470	355	i
HOS BRD 3	01-Sep-90	830	2400	7970	360	i
HOS BRD 3	01-Sep-90	930	2700	7570	402	i
HOS BRD 3	01-Sep-90	1030	3700	11400	451	i
HOS BRD 3	01-Sep-90	1130	3100	12000	456	i
HOS BRD 3	01-Sep-90	1230	3300	11900	446	i
HOS BRD 3	01-Sep-90	1330	2800	10900	440	i
HOS BRD 3	01-Sep-90	1430	2000	6360	386	i
HOS BRD 3	01-Sep-90	1530	1900	5970	350	i
HOS BRD 3	01-Sep-90	1630	1600	5380	325	i
HOS BRD 3	01-Sep-90	1730	1500	4520	288	i
HOS BRD 3	01-Sep-90	1830	1400	3730	262	i
HOS BRD 3	01-Sep-90	1930	1200	3170	238	i
HOS BRD 3	01-Sep-90	2030	1100	3110	219	i
HOS BRD 3	01-Sep-90	2130	1100	3300	197	i
HOS BRD 3	05-Sep-90		1800	7130	139	c
HOS BRD 3	06-Sep-90		650	1770	142	c
HOS BRD 3	07-Sep-90		750	1590	154	c
HOS BRD 3	08-Sep-90		500	1030	140	c
HOS BRD 3	09-Sep-90		750	1510	264	c
HOS BRD 3	11-Sep-90		750	2160	233	c
HOS BRD 3	12-Sep-90		390	1170	161	c
HOS BRD 3	13-Sep-90		260	541	105	c
HOS BRD 3	14-Sep-90		350	785	118	c
HOS BRD 3	14-Sep-90	2130	2000	12400	262	i
HOS BRD 3	14-Sep-90	2230	1600	8460	271	i
HOS BRD 3	14-Sep-90	2330	1600	3410	288	i
HOS BRD 3	15-Sep-90		700	2020	220	c
HOS BRD 3	15-Sep-90	30	1500	3360	297	i

APPENDIX D (cont)

Location	Date	Time	Turb	TSS	Q	T
HOS BRD 3	15-Sep-90	130	1500	3030	330	i
HOS BRD 3	15-Sep-90	230	1200	2820	325	i
HOS BRD 3	15-Sep-90	330	1300	2450	320	i
HOS BRD 3	15-Sep-90	430	900	2090	302	i
HOS BRD 3	15-Sep-90	530	800	2530	297	i
HOS BRD 3	15-Sep-90	630	700	3060	271	i
HOS BRD 3	15-Sep-90	730	600	1380	271	i
HOS BRD 3	15-Sep-90	830	600	1340	246	i
HOS BRD 3	15-Sep-90	930	500	1160	250	i
HOS BRD 3	15-Sep-90	1030	500	1080	250	i
HOS BRD 3	15-Sep-90	1130	500	1040	222	i
HOS BRD 3	15-Sep-90	1230	450	1010	219	i
HOS BRD 3	15-Sep-90	1330	400	1010	226	i
HOS BRD 3	15-Sep-90	1430	600	976	211	i
HOS BRD 3	15-Sep-90	1530	650	1090	219	i
HOS BRD 3	15-Sep-90	1630	650	1090	207	i
HOS BRD 3	15-Sep-90	1730	650	1000	204	i
HOS BRD 3	15-Sep-90	1830	550	923	204	i
HOS BRD 3	15-Sep-90	1930	600	895	200	i
HOS BRD 3	15-Sep-90	2030	500	930	193	i
HOS BRD 3	16-Sep-90		270	636	131	c
HOS BRD 3	17-Sep-90		130	298	102	c
HOS BRD 3	18-Sep-90		90	204	85	c
HOS BRD 3	19-Sep-90		80	167	77	c
HOS BRD 3	20-Sep-90		70	126	68	c
HOS BRD 3	21-Sep-90		65	124	63	c
HOS BRD 3	22-Sep-90		65	132	63	c
HOS BRD 3	23-Sep-90		110	225	68	c
HOS BRD 3	24-Sep-90		75	140	61	c
HOS BRD 3	25-Sep-90		60	101	54	c
HOS BRD 3	26-Sep-90		50	90.6	48	c
HOS BRD 3	27-Sep-90		45	74.1	48	c
HOS BRD 3	28-Sep-90		45	51.7	47	c
HOS BRD 3	10-Oct-90		45	2030		g
HOS BRD 3	02-Nov-90	1350	35	66.9		g
HOS BRD 6	08-Aug-90		120	256	12.5	c
HOS BRD 6	09-Aug-90		100	144	11.2	c
HOS BRD 6	10-Aug-90		37	75.7	11.1	c
HOS BRD 6	11-Aug-90		32	63.9	9.94	c
HOS BRD 6	12-Aug-90		25	53.3	10.8	c
HOS BRD 6	13-Aug-90		25	52.1	10.9	c
HOS BRD 6	14-Aug-90		21	48.6	10.8	c
HOS BRD 6	15-Aug-90		70	150	12.6	c
HOS BRD 6	16-Aug-90		50	70.0	13.3	c
HOS BRD 6	17-Aug-90		25	42.7	11.6	c
HOS BRD 6	18-Aug-90		28	39.4	11.8	c
HOS BRD 6	19-Aug-90		37	78.8	12.5	c

APPENDIX D (cont)

Location	Date	Time	Turb	TSS	Q	T
HOS BRD 6	20-Aug-90		240	385	21.6	c
HOS BRD 6	21-Aug-90		750	1130	34.1	c
HOS BRD 6	22-Aug-90		130	203	23.9	c
HOS BRD 6	23-Aug-90		65	181	19.5	c
HOS BRD 6	24-Aug-90		340	706	20.1	c
HOS BRD 6	25-Aug-90		120	229	23.6	c
HOS BRD 6	26-Aug-90		2600	5010	144	c
HOS BRD 6	27-Aug-90		1400	1710	65.8	c
HOS BRD 6	28-Aug-90		700	1680	48.7	c
HOS BRD 6	29-Aug-90		1300	6490	98.4	c
HOS BRD 6	30-Aug-90		550	2280	72.1	c
HOS BRD 6	31-Aug-90		950	1940	66.4	c
HOS BRD 6	01-Sep-90		1400	3140	211	c
HOS BRD 6	02-Sep-90		380	634	75.6	c
HOS BRD 6	03-Sep-90		3700	316	48.4	c
HOS BRD 6	04-Sep-90		550	1020	77.9	c
HOS BRD 6	05-Sep-90		450	868	88.0	c
HOS BRD 6	06-Sep-90		600	855	78.4	c
HOS BRD 6	07-Sep-90		700	1380	99.6	c
HOS BRD 6	08-Sep-90		300	529	94.3	c
HOS BRD 6	09-Sep-90		1100	2240	156	c
HOS BRD 6	10-Sep-90		1100	1990	195	c
HOS BRD 6	11-Sep-90		650	1130	121	c
HOS BRD 6	12-Sep-90		280	490	91.3	c
HOS BRD 6	13-Sep-90		170	330	74.2	c
HOS BRD 6	14-Sep-90		400	777	58.7	c
HOS BRD 6	15-Sep-90		600	1050	60.1	c
HOS BRD 6	16-Sep-90		170	307	49.4	c
HOS BRD 6	17-Sep-90		130	197	35.6	c
HOS BRD 6	18-Sep-90		90	157	28.9	c
HOS BRD 6	19-Sep-90		85	143	22.3	c
HOS BRD 6	20-Sep-90		70	114	19.6	c
HOS BRD 6	21-Sep-90		60	93.0	18.4	c
HOS BRD 6	22-Sep-90		50	102	17.9	c
HOS BRD 6	23-Sep-90		75	135	17.5	c
HOS BRD 6	24-Sep-90		55	84.2	15.6	c
HOS BRD 6	25-Sep-90		45	61.1	14.6	c
HOS BRD 6	08-Aug-90		120	256	12.5	c
HOS BRD 6	09-Aug-90		100	144	11.2	c
HOS BRD 6	10-Aug-90		37	75.7	11.1	c
HOS BRD 6	11-Aug-90		32	63.9	9.94	c
HOS BRD 6	12-Aug-90		25	53.3	10.8	c
HOS BRD 6	13-Aug-90		25	52.1	10.9	c
HOS BRD 6	14-Aug-90		21	48.6	10.8	c
HOS BRD 6	15-Aug-90		70	150	12.6	c
HOS BRD 6	16-Aug-90		50	70.0	13.3	c
HOS BRD 6	17-Aug-90		25	42.7	11.6	c
HOS BRD 6	18-Aug-90		28	39.4	11.8	c

APPENDIX D (cont)

Location	Date	Time	Turb	TSS	Q	T
HOS BRD 6	19-Aug-90		37	78.8	12.5	c
HOS BRD 6	20-Aug-90		240	385	21.6	c
HOS BRD 6	21-Aug-90		750	1130	34.1	c
HOS BRD 6	22-Aug-90		130	203	23.9	c
HOS BRD 6	23-Aug-90		65	181	19.5	c
HOS BRD 6	24-Aug-90		340	706	20.1	c
HOS BRD 6	25-Aug-90		120	229	23.6	c
HOS BRD 6	26-Aug-90		2600	5010	144	c
HOS BRD 6	27-Aug-90		1400	1710	65.8	c
HOS BRD 6	28-Aug-90		700	1680	48.7	c
HOS BRD 6	29-Aug-90		1300	6490	98.4	c
HOS BRD 6	30-Aug-90		550	2280	72.1	c
HOS BRD 6	31-Aug-90		950	1940	66.4	c
HOS BRD 6	01-Sep-90		1400	3140	211	c
HOS BRD 6	02-Sep-90		380	634	75.6	c
HOS BRD 6	03-Sep-90		3700	316	48.4	c
HOS BRD 6	04-Sep-90		550	1020	77.9	c
HOS BRD 6	05-Sep-90		450	868	88.0	c
HOS BRD 6	06-Sep-90		600	855	78.4	c
HOS BRD 6	07-Sep-90		700	1380	99.6	c
HOS BRD 6	08-Sep-90		300	529	94	c
HOS BRD 6	09-Sep-90		1100	2240	156	c
HOS BRD 6	10-Sep-90		1100	1990	195	c
HOS BRD 6	11-Sep-90		650	1130	121	c
HOS BRD 6	12-Sep-90		280	490	91.3	c
HOS BRD 6	13-Sep-90		170	330	74.2	c
HOS BRD 6	14-Sep-90		400	777	58.7	c
HOS BRD 6	15-Sep-90		600	1050	60.1	c
HOS BRD 6	16-Sep-90		170	307	49.4	c
HOS BRD 6	17-Sep-90		130	197	35.6	c
HOS BRD 6	18-Sep-90		90	157	28.9	c
HOS BRD 6	19-Sep-90		85	143	22.3	c
HOS BRD 6	20-Sep-90		70	114	19.6	c
HOS BRD 6	21-Sep-90		60	93.0	18.4	c
HOS BRD 6	22-Sep-90		50	102	17.9	c
HOS BRD 6	23-Sep-90		75	135	17.5	c
HOS BRD 6	24-Sep-90		55	84.2	15.6	c
HOS BRD 6	25-Sep-90		45	61.1	14.6	c
Runaway	30-May-90	1100	16	191	0.14	g
Runaway	07-Jun-90	1030	15	98.7	0.19	g
Runaway	08-Jun-90	1425	16	252	0.19	g
Runaway	12-Jun-90	830	3.4	16.7	0.15	g
Runaway	15-Jun-90	905	390	407	0.45	g
Runaway	19-Jun-90	1000	3.6	30.5	0.15	g
Runaway	22-Jun-90	955	55	4.18	0.17	g
Runaway	22-Jun-90	1520	2.5	5.04	0.17	g
Runaway	26-Jun-90	815	4.6	3.77	0.16	g

APPENDIX D (cont)

Location	Date	Time	Turb	TSS	Q	T
Runaway	29-Jun-90	1430	5.3	18.1	0.17	g
Runaway	03-Jul-90	905	4.6	1.63	0.19	g
Runaway	05-Jul-90	1547	5.8	7.08	0.17	g
Runaway	09-Jul-90	954	4.1	3.10	0.15	g
Runaway	09-Jul-90	1205	3.9	0.99	0.15	g
Runaway	11-Jul-90	1440	950	5450	0.71	i
Runaway	11-Jul-90	1510	700	3640	0.77	i
Runaway	11-Jul-90	1540	900	4460	0.81	i
Runaway	11-Jul-90	1610	860	6530	0.85	i
Runaway	11-Jul-90	1640	1000	7330	0.87	i
Runaway	11-Jul-90	1710	1200	9320	0.89	i
Runaway	11-Jul-90	1740	1200	7510	0.87	i
Runaway	11-Jul-90	1810	700	5020	0.84	i
Runaway	11-Jul-90	1840	700	6020	0.86	i
Runaway	11-Jul-90	1910	1100	13400	0.90	i
Runaway	11-Jul-90	2010	800	9280	0.91	i
Runaway	11-Jul-90	2110	700	15100	1.09	i
Runaway	11-Jul-90	2140	450	4230	1.07	i
Runaway	11-Jul-90	2210	550	3710	1.05	i
Runaway	11-Jul-90	2240	1000	5630	1.00	i
Runaway	11-Jul-90	2310	550	4700	0.95	i
Runaway	11-Jul-90	2340	400	4260	0.94	i
Runaway	12-Jul-90	10	450	3380	0.95	i
Runaway	12-Jul-90	40	550	3010	0.93	i
Runaway	12-Jul-90	110	400	2610	0.95	i
Runaway	12-Jul-90	140	330	2230	0.93	i
Runaway	12-Jul-90	210	450	2880	1.06	i
Runaway	13-Jul-90	1045	22	197	0.50	g
Runaway	17-Jul-90	830	2.9	8.91	0.24	g
Runaway	20-Jul-90	1040	2.7	25.7	0.22	g
Runaway	24-Jul-90	909	2.6	0.48	0.20	g
Runaway	31-Jul-90	1150	2.9	0.00	0.14	g
Runaway	03-Aug-90	1422	3.3	43.5	0.20	g
Runaway	07-Aug-90	1038	13	27.8	0.18	g
Runaway	08-Aug-90	1350	1.9	5.64	0.20	g
Runaway	17-Aug-90	1337	2.8	2.39	0.12	g
Runaway	24-Aug-90	940	30	1638	0.14	g
Runaway	26-Aug-90	1452	3200	44900	0.95	i
Runaway	26-Aug-90	1522	1800	23000	0.74	i
Runaway	26-Aug-90	1552	1700	31600	0.80	i
Runaway	26-Aug-90	1652	1300	37700	1.05	i
Runaway	26-Aug-90	1822	1600	5520	0.65	i
Runaway	26-Aug-90	1952	1500	8970	0.61	i
Runaway	26-Aug-90	2020	1600	7490	0.57	g
Runaway	26-Aug-90	2022	900	5500	0.56	i
Runaway	26-Aug-90	2052	1200	8100	0.56	i
Runaway	26-Aug-90	2122	2600	15800	0.54	i
Runaway	26-Aug-90	2152	1000	7510	0.52	i

APPENDIX D (cont)

Location	Date	Time	Turb	TSS	Q	T
Runaway	26-Aug-90	2222	550	4240	0.50	i
Runaway	26-Aug-90	2252	400	2210	0.47	i
Runaway	26-Aug-90	2322	310	3180	0.45	i
Runaway	26-Aug-90	2352	230	882	0.43	i
Runaway	27-Aug-90	22	170	1350	0.41	i
Runaway	27-Aug-90	52	150	560	0.39	i
Runaway	27-Aug-90	122	120	697	0.38	i
Runaway	27-Aug-90	152	160		0.36	i
Runaway	30-Aug-90	1215	9.0	269	0.32	g
Runaway	31-Aug-90	1042	6.8	62.1	0.28	g
Runaway	04-Sep-90	1005	29	622	0.32	g
Runaway	13-Sep-90	1430	85	279	0.34	g
Runaway	18-Sep-90	930	15	161	0.24	g
Runaway	25-Sep-90	830	4.6	40.3	0.26	g
Runaway	02-Oct-90	830	9.4	26.5	0.22	g
Runaway	10-Oct-90	1430	4.4	16.4	0.19	g
Two Bull	30-May-90	1330	1900	9260		g
Two Bull	07-Jun-90	1500	750	6000	0.26	g
Two Bull	22-Jun-90	1500	25	267	0.18	g
Two Bull	03-Jul-90	1600	9000	39800	0.41	i
Two Bull	03-Jul-90	1630	17900	70100	1.51	i
Two Bull	07-Jul-90	1130	17	300	0.16	g
Two Bull	11-Jul-90	730	4900	22700	0.55	i
Two Bull	11-Jul-90	800	5200	23800	0.62	i
Two Bull	11-Jul-90	830	5500	23100	0.68	i
Two Bull	11-Jul-90	900	6100	24200	0.75	i
Two Bull	11-Jul-90	930	5800	27100	0.77	i
Two Bull	11-Jul-90	1000	5500	28200	0.80	i
Two Bull	11-Jul-90	1030	4400	23400	0.81	i
Two Bull	11-Jul-90	1100	3700	19500	0.83	i
Two Bull	11-Jul-90	1130	4700	27900	0.84	i
Two Bull	11-Jul-90	1200	4700	30800	0.89	i
Two Bull	11-Jul-90	1230	4000	25300	0.93	i
Two Bull	11-Jul-90	1300	3600	26200	0.93	i
Two Bull	11-Jul-90	1330	3400	21200	0.92	i
Two Bull	11-Jul-90	1400	2900	15700	0.91	i
Two Bull	11-Jul-90	1430	2700	13800	0.90	i
Two Bull	11-Jul-90	1500	3300	19800	0.94	i
Two Bull	11-Jul-90	1530	4100	23700	1.02	i
Two Bull	11-Jul-90	1600	4900	27500	1.10	i
Two Bull	11-Jul-90	1630	4200	20400	1.11	i
Two Bull	11-Jul-90	1700	3400	17300	1.13	i
Two Bull	11-Jul-90	1730	2400	13800	1.10	i
Two Bull	11-Jul-90	1800	2700	23200	1.09	i
Two Bull	11-Jul-90	1830	2300	12200	1.08	i
Two Bull	11-Jul-90	1900	2400	13800	1.03	i
Two Bull	16-Jul-90	1205	240	192	0.27	g

APPENDIX D (cont)

Location	Date	Time	Turb	TSS	Q	T
Two Bull	31-Jul-90	1326	13	47.4	0.15	g
Two Bull	03-Aug-90	1610	33	451	0.20	g
Two Bull	07-Aug-90	1054	800	1870	0.30	g
Two Bull	08-Aug-90	1620	100	226	0.18	g
Two Bull	10-Aug-90	1345	5.6	64.1	0.14	g
Two Bull	14-Aug-90	850	5.1	22.5	0.18	g
Two Bull	17-Aug-90	1330	9.3	33.8	0.12	g
Two Bull	21-Aug-90	1045	750	3450	0.40	g
Two Bull	23-Aug-90	1550	45	567	0.20	g
Two Bull	24-Aug-90	930	55	1810	0.21	g
Two Bull	26-Aug-90	1630	3700	18600	1.03	i
Two Bull	26-Aug-90	1700	19800	94400	1.80	i
Two Bull	26-Aug-90	1730	10600	59900	1.20	i
Two Bull	26-Aug-90	1800	5200	25200	1.09	i
Two Bull	26-Aug-90	1830	2600	17100	1.11	i
Two Bull	26-Aug-90	1900	2000	13100	0.94	i
Two Bull	26-Aug-90	1930	1400	10700	0.91	i
Two Bull	26-Aug-90	2000	1400	7830	0.88	i
Two Bull	26-Aug-90	2030	1400	7420	0.85	i
Two Bull	26-Aug-90	2100	1400	8250	0.82	i
Two Bull	26-Aug-90	2130	1900	7980	0.76	i
Two Bull	26-Aug-90	2200	1400	6300	0.71	i
Two Bull	26-Aug-90	2230	1400	4720	0.65	i
Two Bull	26-Aug-90	2300	1400			i
Two Bull	26-Aug-90	2330	700		0.65	i
Two Bull	27-Aug-90	0	180	3360	0.65	i
Two Bull	27-Aug-90	30	1300			i
Two Bull	30-Aug-90	1235	24	805	0.26	g
Two Bull	31-Aug-90	1105	40	328	0.24	g
Two Bull	13-Sep-90	1415	19	461	0.33	g
Two Bull	18-Sep-90	830	23	1280	0.26	g
Two Bull	25-Sep-90	830	39	1000	0.17	g
Two Bull	02-Oct-90	830	23	1410	0.12	g
Two Bull	10-Oct-90	1400	50	2860	0.11	g

APPENDIX E

GROUNDWATER

Constituents	Instrument	Method	Detection limit (ppm)
Major ions			
Alkalinity	Electrometric titration (in field)	310.1	0.6
F	DIONEX ion chromatography	300.0	0.01
Cl	DIONEX ion chromatography	300.0	0.01
NO_3	DIONEX ion chromatography	300.0	0.02
PO_4	DIONEX ion chromatography	300.0	0.1
SO_4	DIONEX ion chromatography	300.0	0.01
Na	Flame atomic absorption spectrophotometry	273.1	0.1
K	Flame atomic absorption spectrophotometry	258.1	0.01
Ca	Direct current plasma emission spectrophotometry	AES 0029	0.01
Mg	Direct current plasma emission spectrophotometry	AES 0029	0.01
Trace metals			
As	AA, hydride	206.3	0.004
Al	DCP	AES 0029	0.002
Ba	DCP	AES 0029	0.001
Be	DCP	AES 0029	1.0
Cd	DCP	AES 0029	0.001
Cu	DCP	AES 0029	0.01
Cr	DCP	AES 0029	0.001
Fe dissolved	0.45um filter, DCP	AES 0029	0.03
Fe total	unfiltered, HCl digestion, DCP	AES 0029	0.03
Mn	DCP	AES 0029	0.005
Ni	DCP	AES 0029	0.05
Pb	DCP	AES 0029	0.03
Zn	DCP	AES 0029	0.02
Other determinations			
Total dissolved solids	calculated from analytical data		
pH	pH meter (field)	150.1	
Specific conductance	conductivity meter (field)	120.1	
Acidity	Electrometric titration (field)	305.1	

APPENDIX E (cont)

SURFACE WATER

Constituents	Instument	Method	Detection limit (ppm)
Major ions			
Alkalinity	Electrometric titration (in field)	310.1	0.6
F	DIONEX ion chromatography	300.0	0.01
Cl	DIONEX ion chromatography	300.0	0.01
NO_3	DIONEX ion chromatography	300.0	0.02
SO_4	DIONEX ion chromatography	300.0	0.01
Na	Flame atomic absorption spectrophotometry	273.1	0.1
K	Flame AA	258.1	0.01
Ca	DCP	AES 0029	0.001
Mg	DCP	AES 0029	0.001
Trace metals			
As	AA, hydride	206.3	0.004
Ba	DCP	AES 0029	0.001
Cd	DCP	AES 0029	0.001
Cu	DCP	AES 0029	0.01
Cr	DCP	AES 0029	0.001
Fe	DCP	AES 0029	0.03
Mn	DCP	AES 0029	0.005
Pb	DCP	AES 0029	0.03
Zn	DCP	AES 0029	0.02
Other determinations			
Total dissolved solids	calculated for analytical data		
pH	pH meter (field)	150.1	
Specific conductance	conductivity meter (field)	120.1	
Acidity	Electrometric titration (field)	305.1	
Temperature	Meter (field)	170.1	
Dissolved oxygen	Meter (field)	360.1	
Color	spectrophotometer (lab)	110.3	1 PCU
Settleable solids	Imhoff cone (field)	160.5	0.1 ml/l
Total suspended solids	Filtration (lab)	160.2	1 mg/l
Turbidity	Turner turbidimeter	180.1	0.1 NTU

APPENDIX F

Surface Water

SITE	DATE	TIME	Tw	pH	Acidity	DO	% SAT	Color	TSS	TURB	SS	Q
HOSEANNA B1	08 JUN 87	1708	13.3	6.70	3.50	10.5	100	20	1850	700	1.4	36.4
	03 AUG 87	1630	16.5	6.79	4.60	9.5	100	25	198	100	0.1	31.7
	14 SEP 87	1540	4.1	7.56	7.90	14.4	100	30	625	180	0.5	35.5
	23 MAY 88	1840	9.2	7.24	4.25	10.6	96	80	2360	444	1.3	46.2
	19 JUL 88	1500	20.1	7.32	2.19	8.3	95	30	253	38	0.1	23.0
	08 SEP 88	1230	5.9	7.84	2.50	12.9	100	30	78.6	36	Tr	26.4
	21 SEP 89	1110	4.0	7.65	2.72	14.0	100	45	234	54	Tr	22.9
	13 SEP 90	1100	6.2	7.39		12.5	100	30	427	230	0.7	115
	02 NOV 90	1530	0.6	7.12				30	17.2	15	Tr	24.2
	14 MAR 91	1400	0.4	6.87				20	21.0	22	Tr	14.1
HOSEANNA B3	08 JUN 87	1510	13.1	6.68	6.10	10.7	100	15	1970	600	2.0	41.8
	03 AUG 87	1515	15.6	6.85	5.70	10.0	100	40	275	95	Tr	36.9
	14 SEP 87	1400	2.0	7.36	8.10	15.4	100	25	378	120	Tr	26.4
	23 MAY 88	1620	8.6	7.19	5.90	12.4	100	70	1440	342	0.8	42.4
	19 JUL 88	1010	12.2	7.76	2.75	14.1	100	30	292	45	0.8	24.7
	08 SEP 88	1000	3.0	7.92	2.32	14.0	100	20	84.2	30	Tr	24.0
	21 SEP 89	0825	2.8	7.65	4.08	14.5	100	55	113	55	Tr	19.7
	13 SEP 90	0915	5.5	7.10		12.6	100	30	578	210	0.6	114
	02 NOV 90	1235	0.6	7.18				35	66.9	35	Tr	21.4
	14 MAR 91	1610	0.5	6.84				25	16.9	29	Tr	12.0

All units are mg/l except:

Water Temp (Tw) - ^{o}C
pH - pH units

Color - PCU
Turbidity - NTU
Settleable Solids (SS) - ml/l
Discharge (Q) - cfs

Conductivity - umhos/cm at 25 ^{o}C
Alkalinity - mg/l as $CaCO_3$

APPENDIX F (cont)

Ground Water

SITE	DATE	TIME	Tw	pH	Acidity	DO	% SAT	Color	TSS	TURB	SS	Q
GAMW 1C	20 JUL 88	1805	3.8	6.71	71.4							
GAMW 3	24 MAY 88	1650	2.4	6.40	66.6							
	18 JUL 88	1450	3.9	6.15	147							
	07 SEP 88	1415	1.5	5.96	278							
	20 SEP 89	1432	1.1	6.15	163							
	12 SEP 90	1447	2.3	6.11	121							
GAMW 4	25 MAY 88	1000	1.2	6.70	32.5							
	18 JUL 88	1700	1.9	6.95	56.3							
	07 SEP 88	1650	1.9	6.35	83.3							
	20 SEP 89	1802	1.8	6.10	95.3							
	12 SEP 90	1305	1.9	6.15	55.4							
GAMW 5	25 MAY 88	1710	4.9	6.30	129							
	19 JUL 88	1200	3.7	6.24	224							
	08 SEP 88	1100	2.3	6.36	302							
	21 SEP 89	1840	3.9	6.02	332							
	22 SEP 89	0925	3.4	6.04	381							
	13 SEP 90	1730	3.0	5.83	284							
MW-1A	07 NOV 89	1337	3.3	6.95	43.6							
	21 JUN 90	1600	3.9	7.15	34.5							
	10 SEP 90	1830	2.6	6.84	38.7							
MW-1C	21 JUN 90	1745	3.9	7.19	32.5							
	11 SEP 90	1112	3.0	7.12	34.1							
MW-2	22 JUN 90	1025	3.8	6.83	28.4							
	11 SEP 90	1810	3.5	6.52	29.1							

All units are mg/l except:

Water Temp (Tw) - °C
pH - pH units

Color - PCU
Turbidity - NTU
Settleable Solids (SS) - ml/l
Discharge (Q) - cfs

Conductivity - umhos/cm at 25 °C
Alkalinity - mg/l as $CaCO_3$

APPENDIX F (cont)

Surface Water

SITE	DATE	Cond	TDS	Ca	Mg	Na	K	ALK	F	Cl	NO3	SO4	PO4
HOSEANNA B1	08 JUN 87	456	207	25.3	17.8	14.6	3.99	103	0.16	14.1	21.6	47.2	<DL
	03 AUG 87	583	236	33.9	22.1	15.1	5.08	120	0.20	20.6	0.26	67.2	<DL
	14 SEP 87	631	254	36.0	25.5	14.7	5.14	140	0.20	19.1	0.20	69.5	<DL
	23 MAY 88	459	250	36.3	32.6	6.78	1.03	106	0.63	47.0	0.21	61.6	<DL
	19 JUL 88	571	322	45.9	38.5	13.4	3.45	129	0.80	62.3	0.27	79.7	<DL
	08 SEP 88	570	285	36.2	24.9	30.9	4.58	130	0.81	32.2	1.41	76.2	<DL
	21 SEP 89	638	325	46.0	21.6	45.9	5.50	139	0.78	38.6	0.85	82.4	<DL
	13 SEP 90	352	214	28.9	20.2	13.7	2.34	105	0.45	15.2	0.66	70.0	<DL
	02 NOV 90	522	299	38.4	24.5	27.3	4.70	134	0.55	39.8	1.82	81.5	<DL
	14 MAR 91	705	380	38.8	25.8	55.1	5.92	150	0.72	75.9	1.46	86.7	<DL
HOSEANNA B3	08 JUN 87	441	184	25.6	18.2	14.6	3.80	94	0.09	12.2	0.23	53.0	<DL
	03 AUG 87	554	230	31.6	22.3	14.7	4.68	116	0.17	15.3	0.09	71.4	<DL
	14 SEP 87	582	248	34.7	26.5	14.7	4.70	133	0.16	14.9	0.05	72.8	<DL
	23 MAY 88	433	242	36.7	33.7	5.63	0.97	100	0.56	38.5	0.26	65.9	<DL
	19 JUL 88	516	318	44.8	38.4	11.8	3.22	125	0.75	60.6	0.26	82.9	<DL
	08 SEP 88	532	275	35.4	25.6	23.2	3.99	139	0.79	24.5	1.16	77.4	<DL
	21 SEP 89	580	316	42.5	24.9	35.3	4.90	141	0.76	36.8	0.82	85.4	<DL
	13 SEP 90	357	209	28.7	20.1	11.2	2.55	100	0.45	13.7	0.62	71.4	<DL
	02 NOV 90	508	286	34.9	25.8	24.1	4.15	130	0.53	32.0	1.69	84.4	<DL
	14 MAR 91	640	349	40.0	27.2	42.0	5.36	146	0.69	55.0	1.42	90.2	<DL

APPENDIX F (cont)

Ground Water

SITE	DATE	Cond	TDS	Ca	Mg	Na	K	ALK	F	CL	NO3	SO4	PO4
GAMW 1C	20 JUL 88	3318	2038	52.2	57.1	661	64.4	1680	0.59	171	<0.02	24.1	5.35
GAMW 3	24 MAY 88	1562	826	64.8	35.9	164	19.3	346	0.80	248	<0.02	85.4	<DL
	18 JUL 88	1538	820	55.6	18.6	195	20.5	354	0.81	245	<0.02	71.7	<DL
	07 SEP 88	1645	795	45.9	22.4	187	27.6	373	0.84	201	<0.02	86.9	<DL
	20 SEP 89	1400	831	49.8	26.7	208	34.4	358	0.17	212	1.46	83.4	<DL
	12 SEP 90	1030	602	32.1	13.2	165	24.1	324	0.91	115	0.18	57.6	<DL
GAMW 4	25 MAY 88	415	233	35.8	9.06	5.62	45.1	186	1.01	3.85	0.06	21.3	<DL
	18 JUL 88	504	277	42.8	12.9	8.56	47.9	230	1.43	3.84	<0.02	21.8	<DL
	07 SEP 88	445	256	30.6	9.51	6.73	55.8	204	1.18	3.54	<0.02	25.9	<DL
	20 SEP 89	425	246	7.30	3.52	75.3	13.4	199	0.93	3.89	0.42	21.5	<DL
	12 SEP 90	410	207	6.55	2.78	64.8	15.2	151	0.67	6.58	<DL	20.2	<DL
GAMW 5	25 MAY 88	4013	3034	190	133	792	10.5	454	4.39	1570	<0.02	61.7	<DL
	19 JUL 88	7841	3580	283	193	893	15.6	645	6.23	1730	<0.02	72.0	<DL
	08 SEP 88	6905	3440	251	89.6	956	11.2	638	6.10	1680	<0.02	63.1	<DL
	21 SEP 89	3193	1716	182	58.9	360	29.7	532	2.84	680	2.12	81.0	<DL
	22 SEP 89	5945	3184	245	78.6	806	52.1	646	3.37	1540	2.36	68.8	<DL
	13 SEP 90	4030	2112	204	64.0	480	26.3	501	1.97	962	1.78	71.3	<DL
MW-1A	07 NOV 89	315	180	39.1	8.57	20.7	1.90	180	0.49	0.38	0.30	0.87	<DL
	21 JUN 90	257	104	24.3	6.37	6.60	1.10	104	0.34	0.63	0.13	1.83	<DL
	10 SEP 90	295	118	25.4	7.20	10.6	1.36	117	0.28	0.75	<DL	2.40	<DL
MW-1C	21 JUN 90	319	171	22.7	6.24	38.6	2.38	163	0.57	1.28	0.49	0.58	<DL
	11 SEP 90	343	191	26.0	7.31	39.6	2.79	187	0.40	1.16	<DL	1.36	<DL
MW-2	22 JUN 90	246	139	36.8	10.3	4.87	1.25	138	0.49	0.83	0.93	0.44	<DL
	11 SEP 90	247	138	34.6	10.1	4.77	1.08	143	0.32	0.84	<DL	0.33	<DL

APPENDIX F (cont)

Surface Water

All units are mg/l

SITE	DATE	Al	As	B	Ba	Be	Cd	Co	Cr
HOSEANNA B1	08 JUN 87	0.057	<0.004	0.14	0.098	<1.0	<0.001	<0.01	<0.002
	03 AUG 87	0.057	<0.004	0.19	0.117	<1.0	<0.001	<0.01	<0.002
	14 SEP 87	0.050	<0.004	0.19	0.116	<1.0	<0.001	<0.01	<0.002
	23 MAY 88	0.058	<0.004	0.13	0.110	<1.0	<0.001	0.009	<0.002
	19 JUL 88	0.061	<0.004	0.15	0.107	<1.0	<0.001	0.010	0.003
	08 SEP 88	0.057	<0.004	0.17	0.099	<1.0	<0.001	0.011	0.002
	20 SEP 89	0.054	<0.004	0.16	0.087	<1.0	<0.001	0.005	<0.002
	13 SEP 90								
	02 NOV 90								
	14 MAR 91								
HOSEANNA B3	08 JUN 87	0.055	<0.004	0.13	0.089	<1.0	<0.001	<0.01	<0.002
	03 AUG 87	0.066	<0.004	0.17	0.096	<1.0	<0.001	<0.01	<0.002
	14 SEP 87	0.055	<0.004	0.19	0.094	<1.0	<0.001	<0.01	<0.002
	23 MAY 88	0.057	<0.004	0.12	0.091	<1.0	<0.001	0.012	<0.001
	19 JUL 88	0.059	<0.004	0.14	0.076	<1.0	<0.001	0.011	0.002
	08 SEP 88	0.059	<0.004	0.16	0.064	<1.0	<0.001	0.012	0.005
	20 SEP 89	0.059	<0.004	0.15	0.067	<1.0	<0.001	0.007	<0.002
	13 SEP 90								
	02 NOV 90								
	14 MAR 91								

APPENDIX F (cont)

Ground Water

All units are mg/l

SITE	DATE	Al	As	B	Ba	Be	Cd	Co	Cr
GAMW 1C	20 JUL 88	0.294	<0.004	<0.01	0.245	<1.0	<0.001	0.023	0.002
GAMW 3	24 MAY 88	0.287	<0.004	1.71	0.404	<1.0	<0.001	0.027	0.004
	18 JUL 88	0.276	0.004	1.53	0.398	<1.0	<0.001	0.041	0.003
	07 SEP 88	0.290	<0.004	2.82	0.242	<1.0	0.002	0.040	0.003
	20 SEP 89	0.260	<0.004	2.26	0.121	<1.0	<0.001	0.024	<0.001
	12 SEP 90								
GAMW 4	25 MAY 88	0.175	0.009	0.45	0.420	<1.0	0.017	0.009	<0.001
	18 JUL 88	0.211	<0.004	0.50	0.355	<1.0	<0.001	<0.001	<0.001
	07 SEP 88	0.191	0.016	0.29	0.135	<1.0	0.042	0.002	<0.001
	20 SEP 89	0.154	<0.004	0.38	0.114	<1.0	0.003	<0.001	<0.001
	12 SEP 90								
GAMW 5	25 MAY 88	0.271	0.010	1.53	1.37	<1.0	<0.001	0.412	0.004
	19 JUL 88	0.252	0.005	1.41	1.13	<1.0	<0.001	0.267	0.005
	08 SEP 88	0.261	0.013	2.90	1.32	<1.0	0.005	0.345	0.001
	21 SEP 89	0.226	0.007	1.29	0.571	<1.0	<0.001	0.254	0.003
	22 SEP 89	0.278	0.006	2.60	0.943	<1.0	<0.001	0.326	0.006
	13 SEP 90								
MW-1A	07 NOV 89	0.049	<0.004	0.05	0.317	<1.0	<0.001	<0.001	<0.001
	21 JUN 90	0.015	0.009	0.08	0.627		<DL	<DL	<DL
	10 SEP 90	0.012	0.006	0.09	0.495		<DL	<DL	<DL
MW-1C	21 JUN 90	0.024	<DL	0.09	0.600		<DL	<DL	<DL
	11 SEP 90	0.028	<DL	0.09	0.517		<DL	<DL	<DL
MW-2	22 JUN 90	0.005	<DL	0.10	0.600		<DL	<DL	<DL
	11 SEP 90	0.013	0.004	0.09	0.660		<DL	<DL	<DL

APPENDIX F (cont)

Surface Water

SITE	DATE	Cu	Fe (T)	Fe (D)	Mn (T)	Mn (D)	Mo	Ni	Pb	Si	Zn
HOSEANNA B1	08 JUN 87	<0.01		0.09		0.20	0.021		<0.03	1.92	<0.02
	03 AUG 87	<0.01		<0.03		0.24	0.022		<0.03	2.31	<0.02
	14 SEP 87	<0.01		<0.03		0.32	0.023		<0.03	2.24	<0.02
	23 MAY 88	<0.01		0.08		0.47	0.019		<0.03	5.52	<0.02
	19 JUL 88	<0.01		0.04		0.41	0.020		<0.03	6.12	<0.02
	08 SEP 88	<0.01		<0.03		0.36	0.022		<0.03	5.43	<0.02
	20 SEP 89	<0.01		<0.03		0.40	0.029		<0.03	6.28	<0.02
	13 SEP 90		12.1	0.19	0.32	0.14					
	02 NOV 90		0.77	0.25	0.30	0.28					
	14 MAR 91		4.01	0.32	0.43	0.40					
HOSEANNA B3	08 JUN 87	<0.01		0.08		0.23	0.018		<0.03	1.91	<0.02
	03 AUG 87	<0.01		0.07		0.26	0.018		<0.03	2.29	0.03
	14 SEP 87	<0.01		<0.03		0.33	0.023		<0.03	1.72	0.04
	23 MAY 88	<0.01		0.07		0.41	0.019		<0.03	5.54	<0.02
	19 JUL 88	<0.01		<0.03		0.39	0.022		<0.03	6.24	<0.02
	08 SEP 88	<0.01		<0.03		0.38	0.020		<0.03	5.43	<0.02
	20 SEP 89	<0.01		<0.03		0.39	0.025		<0.03	6.06	<0.02
	13 SEP 90		14.2	0.22	0.38	0.14					
	02 NOV 90		4.23	0.52	0.37	0.36					
	14 MAR 91		3.98	0.45	0.01	0.01					

NOTE:
(T) = Total
(D) = Dissolved

APPENDIX F (cont)

Ground Water

SITE	DATE	Cu	Fe (T)	Fe (D)	Mn (T)	Mn (D)	Mo	Ni	Pb	Si	Zn
GAMW 1C	20 JUL 88	<0.01	0.35	0.28		0.12	0.032	<DL	0.05	6.79	<0.02
GAMW 3	24 MAY 88	0.13	47.2	39.2		1.23	0.026	<DL	0.109	8.98	0.21
	18 JUL 88	0.15	43.4	31.9		1.19	0.041	<DL	0.111	5.34	0.23
	07 SEP 88	<0.01	36.1	18.0		1.26	0.028	<DL	0.108	7.89	0.10
	20 SEP 89	<0.01	29.5	25.1		1.01	0.028	<DL	0.085	8.07	<0.02
	12 SEP 90		27.5	26.0	1.17	1.11					
GAMW 4	25 MAY 88	0.01	12.7	8.45		0.66	0.012	<DL	<0.03	9.34	<0.02
	18 JUL 88	0.02	12.1	7.12		0.78	0.017	<DL	<0.03	11.2	<0.02
	07 SEP 88	0.81	7.75	3.78		0.58	0.013	<DL	<0.03	8.57	<0.02
	20 SEP 89	<0.01	14.8	12.0		0.47	<0.01	<DL	<0.03	7.65	<0.02
	12 SEP 90		12.3	11.4	0.59	0.57					
GAMW 5	25 MAY 88	0.13	57.7	45.8		10.9	0.143	<DL	0.175	10.4	0.30
	19 JUL 88	0.02	59.2	46.1		7.32	0.124	<DL	0.168	12.4	0.34
	08 SEP 88	<0.01	42.8	22.7		8.30	0.112	<DL	0.209	10.2	0.20
	21 SEP 89	<0.01	41.2	34.0		3.91	0.121	<DL	0.198	8.95	0.04
	22 SEP 89	<0.01	56.9	50.0		6.39	0.142	<DL	0.213	9.08	0.13
	13 SEP 90		43.0	41.3	4.66	4.55					
MW-1A	07 NOV 89	<0.01	4.70	4.16		1.24	0.022	<DL	<0.03	11.4	0.03
	21 JUN 90	<DL	6.54	5.88	1.84	1.57	<DL	<DL	<DL	15.0	0.03
	10 SEP 90	<DL	4.54	1.58	1.66	1.28	<DL	<DL	<DL	10.3	0.04
MW-1C	21 JUN 90	<DL	2.86	1.05	0.13	0.13	<DL	<DL	<DL	10.5	<DL
	11 SEP 90	<DL	4.91	0.74	0.18	0.15	<DL	<DL	<DL	14.5	0.02
MW-2	22 JUN 90	<DL	57.7	0.33	0.97	0.14	<DL	<DL	<DL	12.3	0.02
	11 SEP 90	0.02	30.3	1.17	0.50	0.08	<DL	<DL	<DL	11.4	0.02

NOTE:
(T) = Total
(D) = Dissolved