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STREAM FLOW, SEDIMENT LOAD, AND WATER QUALITY STUDY OF HOSEANNA CREEK BASIN NEAR HEALY, ALASKA: 1992 PROGRESS REPORT

by

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INTRODUCTION

This report discusses sediment, stream flow, and water quality data collected during the 1992 summer field season by Alaska Division of Water (formerly the Hydrology Section of the Alaska Division of Geological and Geophysical Surveys) 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.

Previous studies in the basin have concentrated on Hoseanna Creek, with shorter duration studies on smaller tributaries. This report discusses the data collected at Hoseanna Creek (Bridge 3) during the summer of 1992. Table 1 shows the basins studied during each summer since studies began by DGGS and DOW in the Hoseanna basin.

Table 1. Basin *characteristics of sampling sites with reference to the report which contains the data from the sites.*

Site	Area'- (mi^2)	Percent of total basin area	Period of Record	Principle Lithology
Sanderson	5.1	11.6	1986-88	Schist
Clinker	1.7	3.9	1991	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	1986-92	Mixed
Runaway	0.9	mm--	1989-90	Coal Group, Schist
Two Bull	0.9	----	1988-90	Nenana Gravel, Coal Group

Table 1 (cont). Basin characteristics of sampling sites with reference to the report which contains *the data from the* sites.

Site	Report number	
Sanderson	1-4*	* Report
Clinker	6	
North Hoseanna	l-4	1 - Mack (1987)
Hoseanna @ Brd 6	3-5	2 - Mack (1988)
Popovitch	1-4	3 - Ray and Maurer (1989)
Louise	3,4	4 - Ray (1990)
Frances	l-4	5 - Ray et al. (1991)
Hoseanna @ Brd 3	1-7	6 - Ray and Vohden (1992)
Runaway	4,5	7 - This report
Two Bull	3-5	

METHODS

PRECIPITATION

The precipitation data for the basin was gathered in three locations during 1992. DOW operates a Wyoming gage with two data recording devices at Gold Run Pass (see Mack ,1988 for location and construction specifications). The first device is a tipping bucket rain gage which records hourly precipitation and temperature. The second rain gage is a canister type with a float. Readings are taken every 30 minutes, with changes as small as twelve one-hundredths of an inch recorded. DOW also operates a tipping-bucket rain gage located at Bridge 1. The other reporting station is operated by Usibelli Coal Mine personnel and is located at Poker Flat mine. The resolution of all the tipping-bucket gages is 0.01 inches. Neither tipping-bucket gage at Poker Flat or Bridge 1 is wind protected.

DISCHARGE

Discharge was measured at Bridge 1 by USGS personnel. DOW did supply flow measurements to the USGS for the rating curve. 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).

SEDIMENT RATING EQUATIONS

The sediment rating equation was calculated for Hoseanna Creek at Bridge 3 to estimate sediment concentrations from discharge data for periods when the automated sediment sampler was not functioning. 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 automated samples, the equation was developed as linear log-log plots ($\log TSS = a + b \log Q$). Using the actual and estimated sediment concentrations and the continuous discharge data, the daily sediment load was calculated. Whenever possible, the actual values (automated samples) were used in the calculation. The daily loads were then added to estimate the season load. The daily loads for the 1992 season from Bridge 3 were calculated from the daily composite samples and the sediment rating equation.

WATER QUALITY

To ensure consistency of data between the different field seasons, the same water quality sampling and analytical methods were used during the 1987-92 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 chum 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 lmhoff 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 fordetermining 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). 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

As in 1991, the precipitation during summer 1992 was also light. The season rainfall (not snow) was 7.96 inches at Gold Run Pass (Table 2). This is more than four inches below the 1987-92 average. However more precipitation fell during the May - September period than what was reported here. Unusually late snows fell in mid May and unusually early snows fell in September. Both of these storms were quite large. An additional three to four inches of water-equivalent snow could be added to the season total. This would bring the total much closer to the 1987-92 average. The June-August average (1987-92) at Gold Run Pass is 9.5 inches. The total for the same period in 1992 was 7.8 inches, 82 percent of the average.

The total precipitation at Poker Flat continues to be about 80 percent of the Gold Run Pass total. The total precipitation at Bridge 1 was about 60 percent of the total at Gold Run Pass.

Table 2. *Monthly precipitation for Go/d Run Pass (GRP), Poker F/at (PF)* and *Bridge 1 (Bl). **All** values in inches.*

Site	MAY	JUN	JUL	AUG	SEP	Total
GRP 1986			----	----	----	-----
PF 1986	1.82	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	2.18	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	-----
GRP 1991	0.36	1.44	3.00	2.16	0.72	7.88
PF 1991	0.53	0.89	3.05	1.39	1.13	6.99
B1 1991			2.06	----	1.05	-----
GRP 1992	0.12	2.75	3.61	1.43	0.05	7.96
PF 1992	0.33	1.77	2.64	1.56	0.46	6.76
B1 1992	0.20	1.64	1.60	0.84	0.34	4.62
Avg GRP (87-92)	0.78	3.05	3.30	3.20	1.93	12.26
Avg PF (87-92)	0.77	2.29	3.10	2.44	1.44	10.04
Avg PF (78-92)	0.85	2.61	3.06	2.82	1.83	11.17

DISCHARGE

Discharge was measured at Bridge 1 (USGS gaging station) by both the USGS and DOW. The daily average flow for the period of June-September was 45.3 cfs (Table 3). The average for the same months for **1985-92** was 56.1 cfs. The average flow for May 1992 was 166 cfs. This was the highest average monthly flow for any month since the gage was installed in 1985. The previous high was June 1989 at 145 cfs. The average flow for August 1992 was 27.2 cfs. This was the lowest August flow since the gage was installed. The previous low was 30.0 cfs in August 1987. The average flow for June 1992 (89.7 cfs) was slightly above average (82.1 cfs). All of the remaining months were well below the average. Figure 1 shows the hydrograph for **Hoseanna** Creek at Bridge 1 for field season.

*Table 3. Average monthly **flow** data for **Hoseanna** Creek at Bridge **1*** (USGS, 1993). *All* data *are in cfs.*

	May	Jun	Jul	Aug	Sep
1992	166	89.7	42.0	27.2	23.1
1985-92	95.5	82.1	51.5	45.8	45.9
Max	166	145	77.0	98.6	134
year	1992	1989	1986	1986	1990
Min	42.6	46.5	28.9	27.2	17.6
year	1987	1987	1989	1992	1987

SEDIMENT LOAD

The r^2 value for the regression equation was 0.62. This was the lowest r^2 value since the study began (Table 4). The “a” coefficient (0.56) was similar to value calculated in 1991, but lower than the previous years. The "b" coefficient (1.73) was within the range of previous years. The variability of the data in 1991 and 1992 is probably due to the type of sample being collected. In

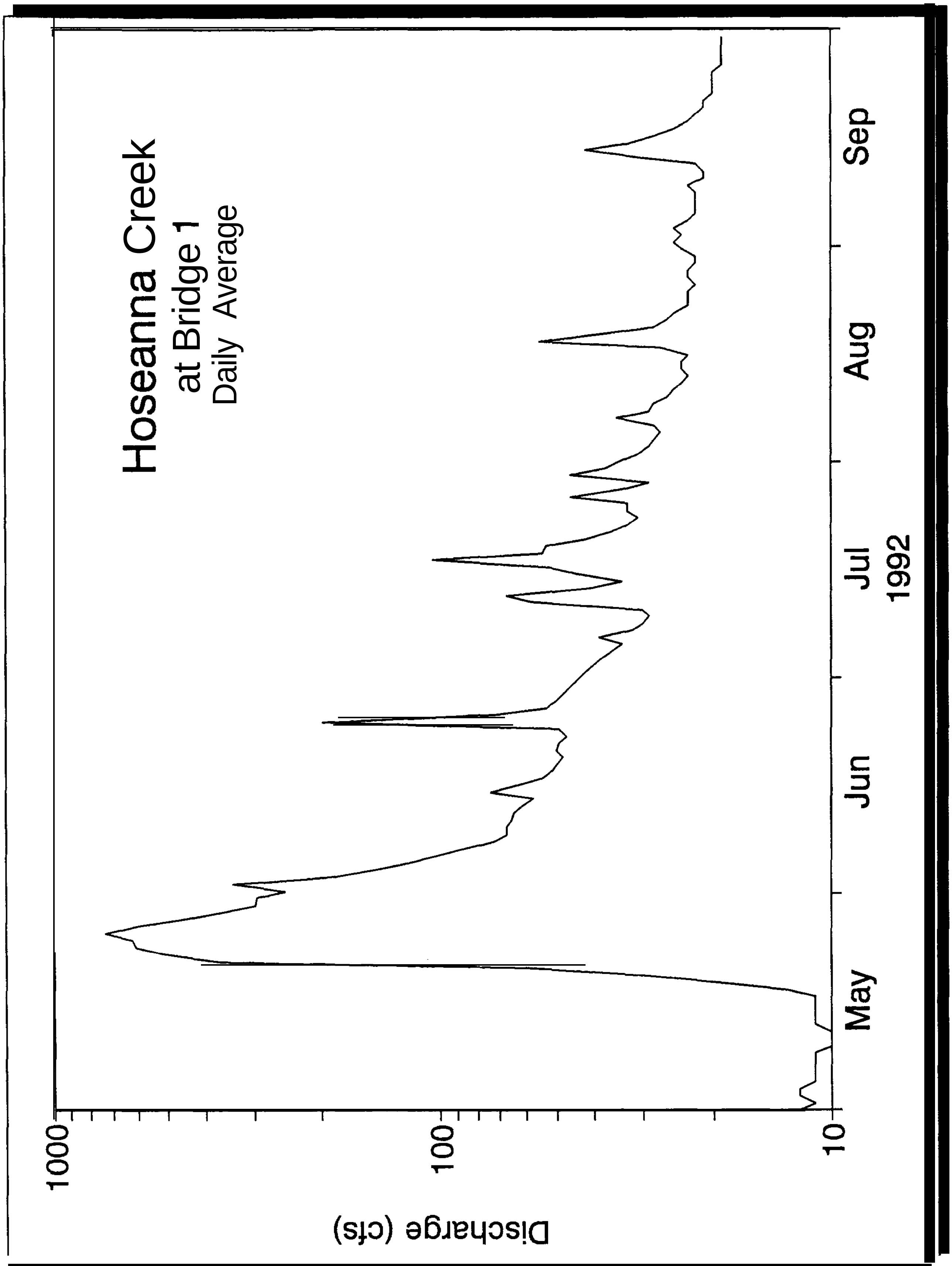


Figure 1. Hydrograph of Hoseanna Creek at bridge 1 (USGS, 1993).

1991 and 1992, only daily composite samples were collected. In previous years, level-activated samples were collected, where 12 to 24 samples were collected in one day. Figure 2 shows the total suspended solids plotted versus the discharge for the data collected in 1992 and Figure 3 plots all the data collected since the study began.

*Table 4. Coefficients, r^2 value, and number of samples used (n) for the sediment rating equations for the **1986-1992** seasons. The equations are of the form: $TSS = aQ^b$.*

Site	a	b	r^2	n
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
1991	0.32	1.91	0.65	146
1992	0.56	1.73	0.62	95
1986-1992	2.56	**1.43**	0.71	**961**

WATER QUALITY

Surface Water

Samples have been collected at Hoseanna Creek at bridges 1 and 3 since 1987. The samples have been collected annually in September, with additional samples collected at various time of the year. Samples were again collected in late September 1992. The complete listing of the analytical results are found in Appendix F.

Table 5 lists the major ion percentages for Hoseanna Creek at Bridges 1 and 3. Magnesium continues to be the dominant cation (38 percent) at bridge 3, although only slightly higher than calcium (33 percent). Sodium continues to fluctuate, with the highest percentage recorded (26 percent) in 1992. Potassium has remained nearly constant at 1 to 3 percent. At Bridge 1, there was no dominant cation. Sodium was the highest (34 percent), with magnesium and calcium at 33 and

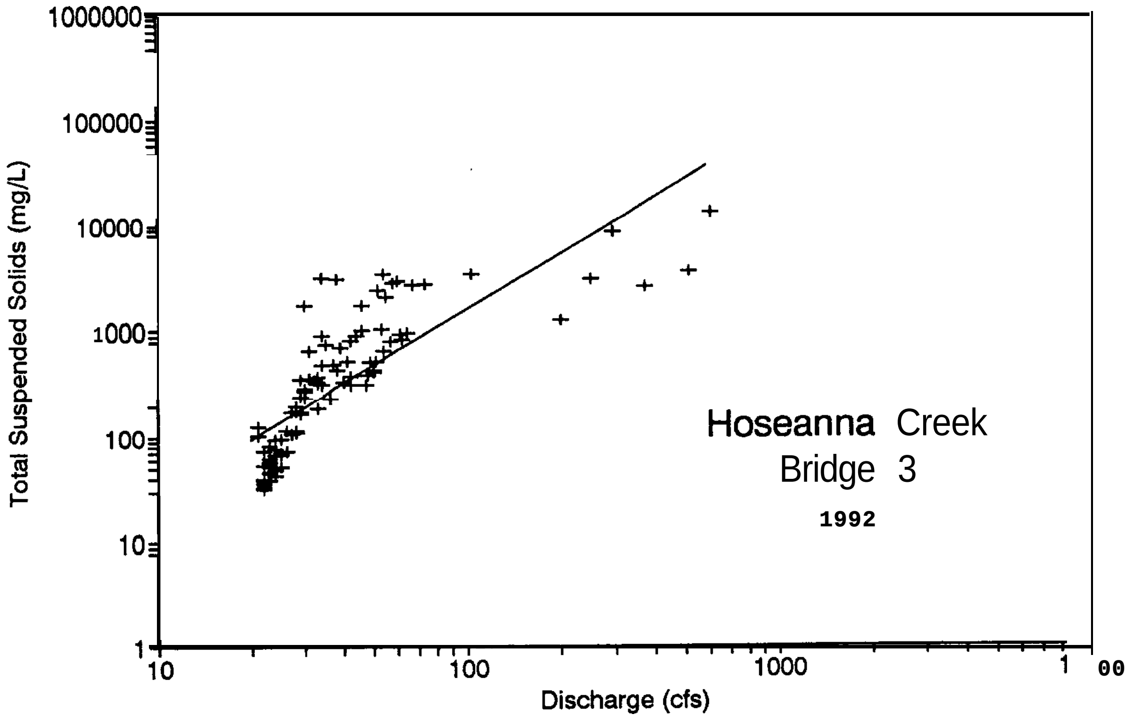


Figure 2. TSS versus discharge for Hoseanna Creek at bridge 3 (1992). r^2 value = 0.62, n = 95.

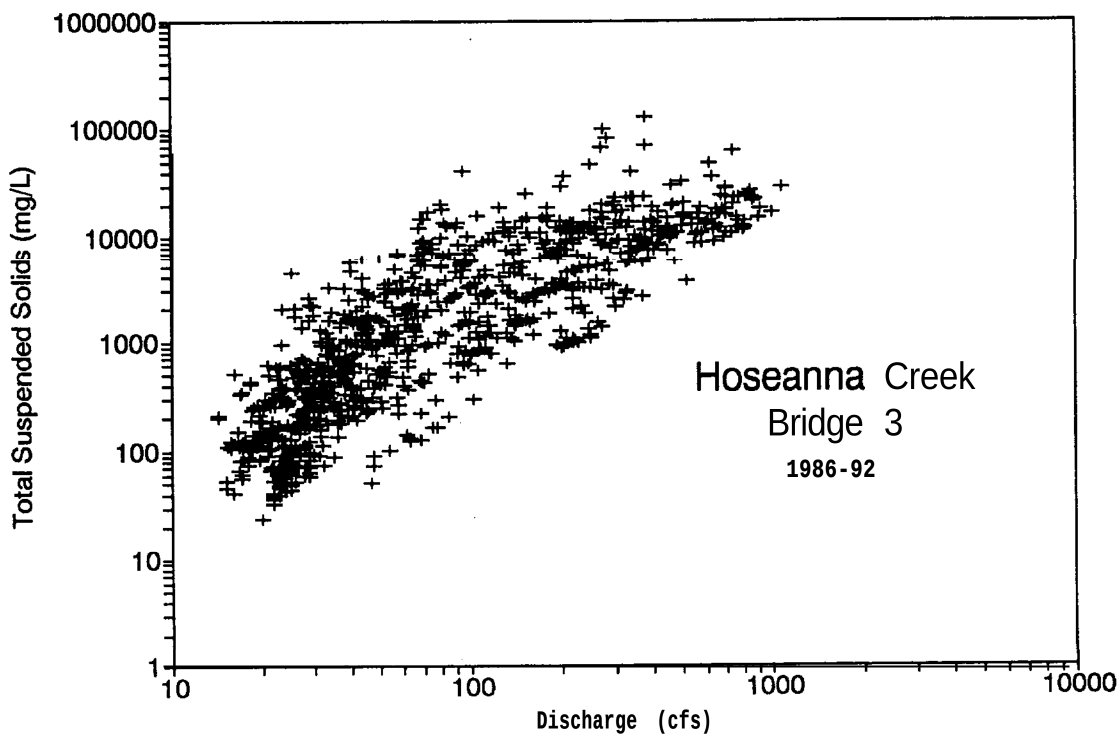


Figure 3. TSS versus discharge for Hoseanna Creek at bridge 3 (1986-92). r^2 value = 0.71, n = 961.

30 percent, respectively. Potassium remained nearly constant at 1 to 3 percent. Both the calcium and magnesium percentages were down from the previous years at bridge 3. This is due to the increase in the sodium concentration, thus reducing the percentages of the other constituents. This is even more evident at bridge 1.

The anion percentages were similar, with the chloride percentages rising both at bridges 1 and 3. Sulfate remained nearly constant, although dropping slightly. The bicarbonate ion dropped the most, about 4 percent at bridge 3 and about nine percent at bridge 1.

Table 6 lists the mean values (1987-92) for selected water-quality parameters. Most parameters are slightly higher at Bridge 1. Notable exceptions are dissolved oxygen, magnesium and sulfate.

Table 5. **Average *percentages of the major ion composition (in meq/l) at lioseanna Creek for 1987-1992.***

	Bridge 3						Bridge 1					
	1987	1988	1989	1990	1991	1992	1987	1988	1989	1990	1991	1992
Calcium	37	37	37	37	36	33	38	36	37	38	34	30
Magnesium	44	51	35	44	40	38	43	49	29	41	37	33
Sodium	16	11	26	17	22	26	16	14	32	19	27	34
Potassium	3	1	2	2	2	3	3	1	2	2	2	3
Bicarbonate	56	47	50	50	59	48	56	46	50	50	58	43
Sulfate	34	31	32	36	32	31	29	29	31	34	31	27
Chloride	10	22	18	14	9	21	12	25	19	16	11	30
Nitrate	<1	<1	<1	<1	<1	<1	3	<1	<1	<1	<1	<1

Table 6. *Mean values of selected* water *quality constituents from* **Hoseanna** *Creek sites (1987-1992). All values in* **mg/l** *unless otherwise noted.*

	Bridge 3	Bridge 1
Field Determination		
pH	7.27	7.30
Dissolved oxygen	13.0	11.6
Specific Conductance (umhos/cm)	514	551
Lab Determinations		
Color (pcu)	35	35
Total Suspended Sediment	547	636
Turbidity (NTU)	140	170
Total Dissolved Solids	274	290
Cations		
Calcium	36.2	37.4
Magnesium	26.5	25.7
Sodium	21.8	27.4
Potassium	4.0	4.5
Anions		
Alkalinity	127	131
Sulfate	77.5	74.9
Chloride	30.7	38.9
Nitrate	0.58	2.43

Ground Water

Three wells were sampled in 1992 and have been sampled since 1988. Detailed descriptions of the GAMW wells and installations are given by Golder Associates (1987) with the well locations given in Table 7. 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).

Table 8 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. However due to problems with the pump in GAMW-3, three casing volumes were not collected. There is some doubt about the ability to collect future samples from this well.

Table 7. 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"

Table *8.* **Initial** *water* **level readings and** *purging protocol for ground* **water** *monitoring wells at Usibelli Coal Mine.*

Well Name	Date	Initial Depth to Water (ft)	Calc Casing Volume (gal)	Volume Pumped (gal)	Pumping Rate (gal/hr)
GAMW-3	9-I 5-87	26.86	---	---	---
	5-23-88	25.97	1.5	1.4	---
	5-24-88	27.69	1.2	8.0	---
	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-l 2-90	26.68	1.4	4.2	5.0
	1 0-08-91	28.08	1.2	3.4	2.8
	9-23-92	27.31	1.3		
GAMW-4	9-I 5-87	7.68			
	5-24-88	7.96	3.6	6.8	---
	5-25-88	8.28	3.6	17.0	12.7
	7-18-88	8.74	3.5	14.7	9.8
	g-07-88	8.62	3.6	12.0	13.1
	9-20-89	9.26	3.4	10.5	13.7
	9-l 2-90	7.11	3.7	12.5	9.4
	g-24-91	9.29	3.4	12.0	13.8
	9-23-92	8.10	3.6		
GAMW-5	9-15-87	72.22	mm-	-	---
	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	mm-w-	---	--	1.1
	9-07-88	82.87	2.2	--	---
	9-21-89	81.95	2.4	22.0	1.0
	9-l 2-90	80.13	2.6	19.9	0.8
	g-25-91	82.74	2.3	16.5	0.8
	9-24-92	80.30	2.6		

The results of the ground water sample analyses are found in Appendix F. Well GAMW-4 continues to remain nearly constant since the 1989 sampling. All the parameters have remained nearly the same, with no trends detected in the data. However the results from the remaining two wells continue to show change from the previous samples. The total dissolved solids (TDS) continues to fall. TDS at well GAMW-3 has fallen to 457 mg/L in 1992 from the 800 mg/L range in 1988 and 1989. TDS at well GAMW-5 has fallen to 885 mg/L in 1992 from 3500 mg/L in 1988. Table 9 lists the percentage of the various major ions for 1992 and the average of previous samples (1988-91). Although the absolute concentrations of all the constituents have fallen, the relative sodium and chloride concentrations have dropped by a much larger percentage, resulting in a rise in the percentages of the other ions. Figure 4 illustrates the drop in sodium and chloride concentrations from samples collected from well GAMW-5.

Table 9. Average percentages of the major ion composition (in meq/l) of ground water monitoring wells at Usibelli Coal Mine (note GAMW-4 dates).

	GAMW-3		GAMW-4		GAMW-5	
	1988-91	1992	1989-91	1992	1988-91	1992
Calcium	17	28	9	8	28	39
Magnesium	13	18	6	5	14	22
Sodium	65	50	76	77	53	38
Potassium	5	4	9	10	5	1
Bicarbonate	55	76	86	88	31	55
Chloride	31	10	3	4	64	35
Sulfate	14	14	10	8	5	10
Fluoride	<1	<1	<1	<1	<1	<1

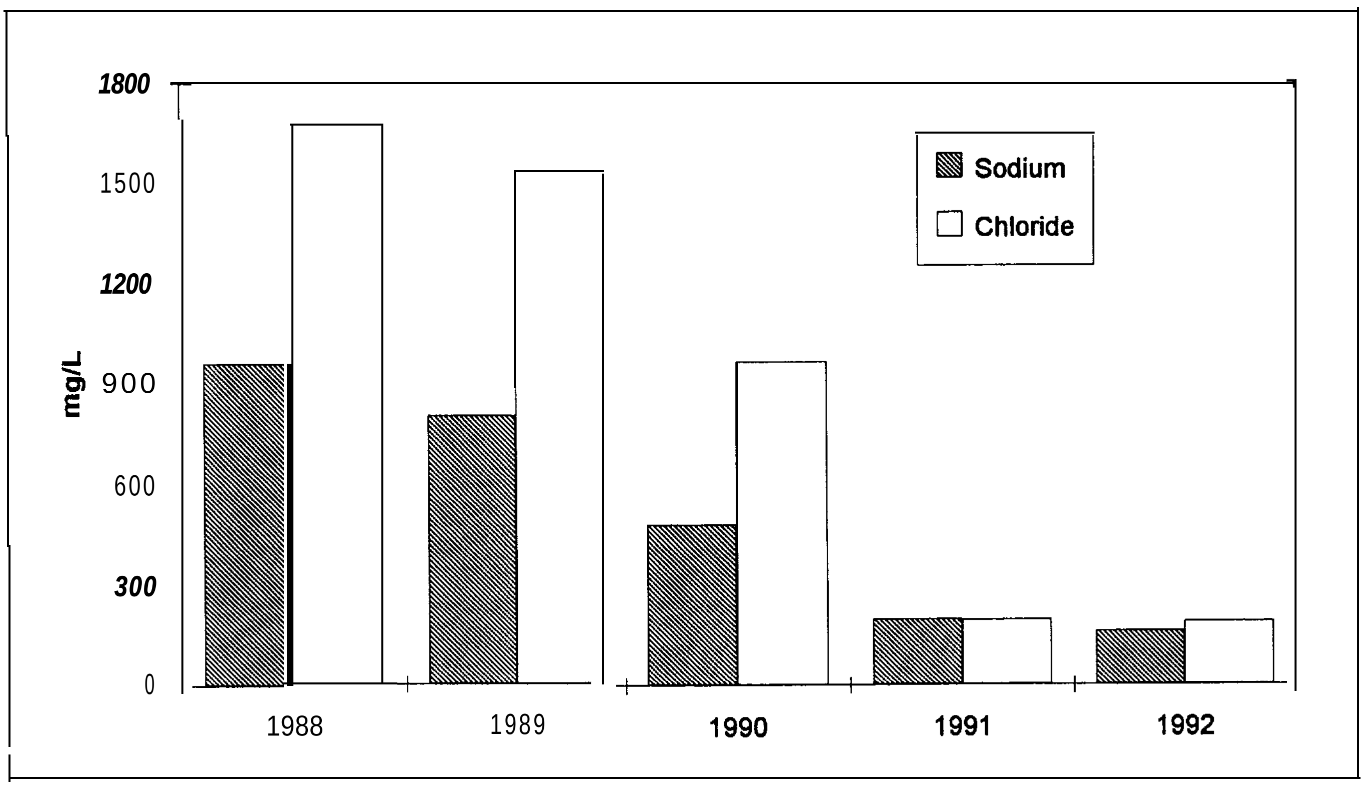


Figure 4. Sodium and *chloride values from samples collected* at *GAMW-5 since the* study *began.*

DISCUSSION

Previous reports have discussed precipitation, stream flow, sediment loading and water chemistry generally in greater detail than this report will discuss. This discussion will concentrate on three topics: 1) frequency distribution of total suspended solids; 2) changes in surface water chemistry; and 3) changes in ground water chemistry.

Sediment

In the previous reports, much of the discussion about sediment centered around the total load for the season and the relationship of discharge and flow. A brief discussion of the total load in 1992 is necessary. Table 10 lists the total seasonal load for Hoseanna Creek at Bridge 3 since the study began. The load in 1992 was the highest since the study began. This was the result of the late spring break-up and high flows. The record high flows in May generated most of the sediment load. Since the break-up was late, DOW was able to monitor most of the break-up flow and sediment. In previous years, total loads may not have included all of the break-up flows.

Table 10. Sediment load estimates (tons) for the period of* discharge *record.

Site-	1987	1988	1989	1.990	1991	1992
Hoseanna @ Brd 3	40,000	59,200	100,300	64,000	43,700	121,000

The total sediment load only tells part of the sediment story. Ray (1992) showed that most of the sediment is transported over a relatively short period of time. Figure 5 shows the frequency distribution of the daily-average total suspended sediment (mg/L) since the study began in 1987. Since composite samples were not collected until 1989, the daily average TSS value was calculated for samples collected in 1987 and 1988 from the daily average discharge and estimated daily sediment load (see Ray and Maurer, 1989). The total number of samples used in the frequency distribution analysis was 768. The mean value of the 768 values was 1241 mg/L. The median was

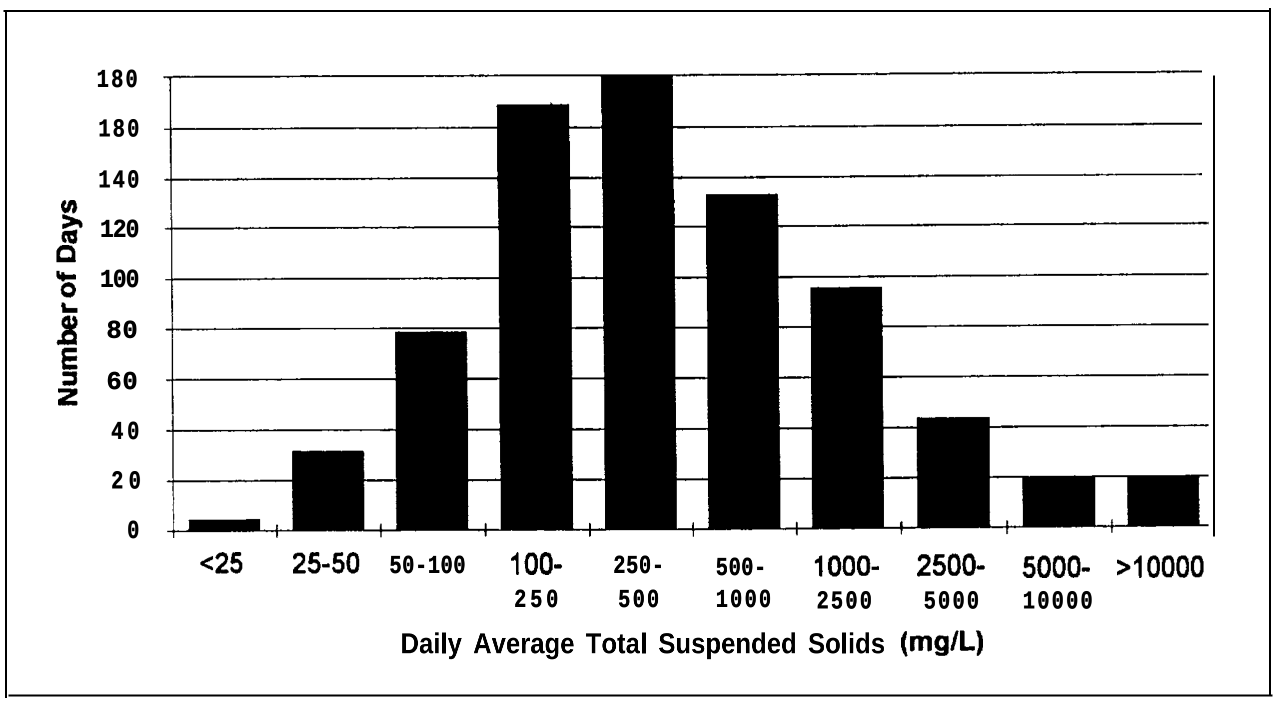


Figure 5. Frequency distribution for TSS samples collected (1987-92) from Hoseanna Creek at bridge 3. Total number of samples is 768. The mean value is 1241 mg/L. The median value is 363 mg/L.

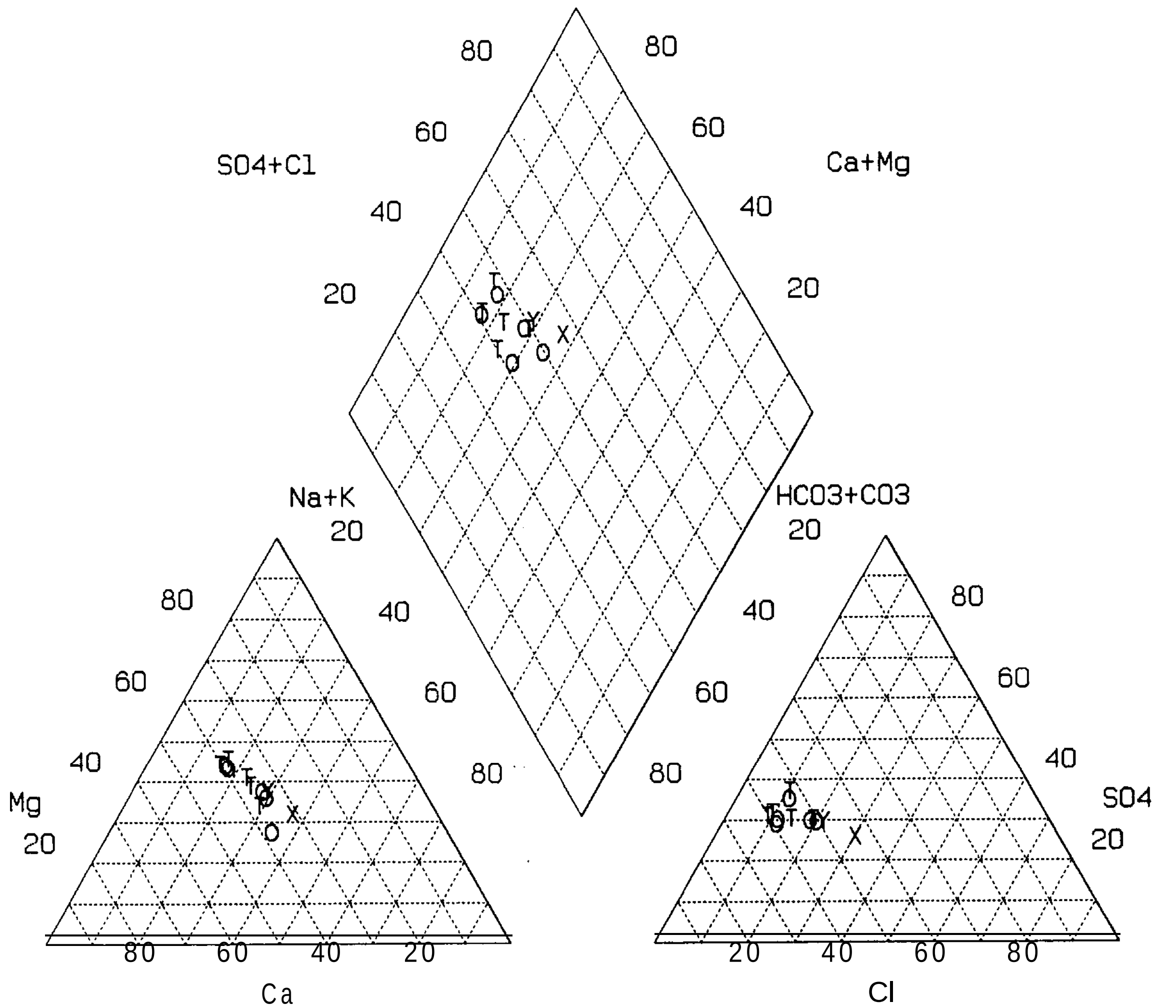
363 mg/L. There were only twelve days (1.6%) on which the average TSS was less than 35 mg/L and only 69 days (9.0%) where the TSS was less than 70 mg/L. Clearly there is a constant source of sediment in the basin available for transport during the summer months.

WATER QUALITY

Surface Water

Water quality samples collected at bridges 1 and 3 continue to have fairly constant total dissolved solids values. Although the samples collected in 1992 had the highest values since the study began (425 and 363 mg/L, respectively). This was probably caused in part by the early freeze-up. The cold weather decreased the amount of direct surface runoff, with most of the stream flow comprised of ground water.

Figure 6 plots the distribution of the major ions from the surface water data since the study began. As shown, the 1992 data is closer to the sodium and potassium end-member for the cations and closer to the chloride end-member for the anions. Figure 7 plots the 1992 data from the two surface water sites and the average values of the sites from the previous years. This clearly shows that the 1992 values have higher percentages of sodium and chloride. The sodium and chloride values have fluctuated over the years. This might be caused by hydrologic factors which influence the runoff from different streams in the basin. Some of the streams in the lower end of the basin (Pipe and Slime creeks) have relatively high concentrations of chloride and sodium. Since hydrologic factors vary across the basin and change in time (see Table 11), relative stream flow varies in the basin. For example, if Pipe and Slime creeks have a higher discharge than normal compared to Hoseanna Creek, then the percentages of chloride and sodium in Hoseanna creek below these creeks would probably be elevated. The converse is also true (this factor will be explored in more depth in a future study). The increase in these constituents between bridges 3 and 1 may be of similar cause, however the mine spoils probably contribute to the increase as the constituents are elevated in the ground water samples collected.



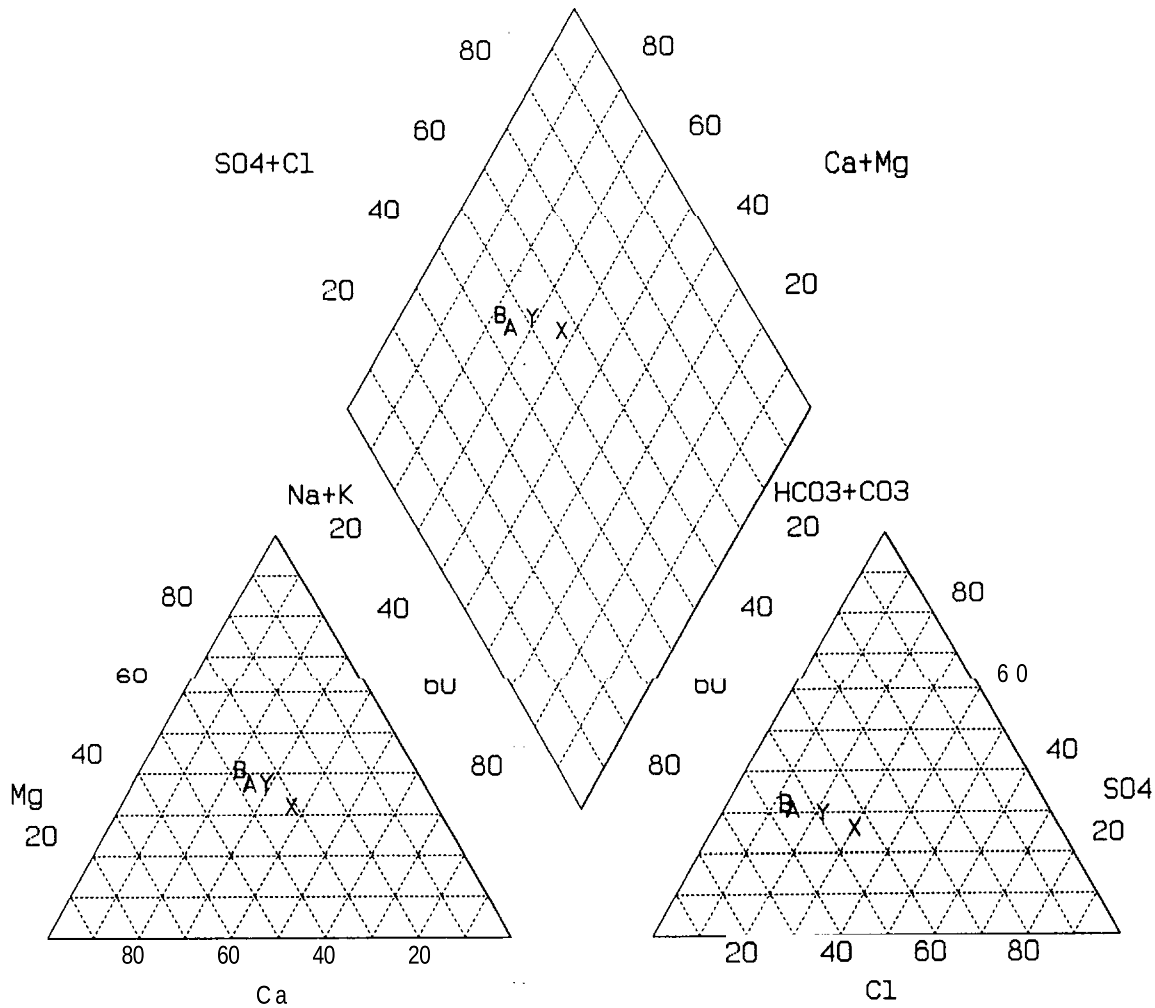
Hoseanna Creek

Svmbols

0 - Hoseanna Creek at Bridge 1 (September samples, 1987-91)
T - Hoseanna Creek at Bridge 3

X - Hoseanna Creek at Bridge 1 (September 1992)
Y - Hoseanna Creek at Bridge 3

Figure 6. Piper plot of surface water data collected since 1987. Diagram plotted by HC-Gram (McIntosh, 1987).



Hoseanna Creek

Svmbols

A - **Hoseanna** Creek at Bridge 1 (Average September samples, 1987-91)
B - **Hoseanna** Creek at Bridge 3

X - **Hoseanna** Creek at Bridge 1 (September 1992)
Y - **Hoseanna** Creek at Bridge 3

*Figure 7. Piper plot of surface water data collected since 1987. Diagram plotted by HC-Gram (**McIntosh**, 1987).*

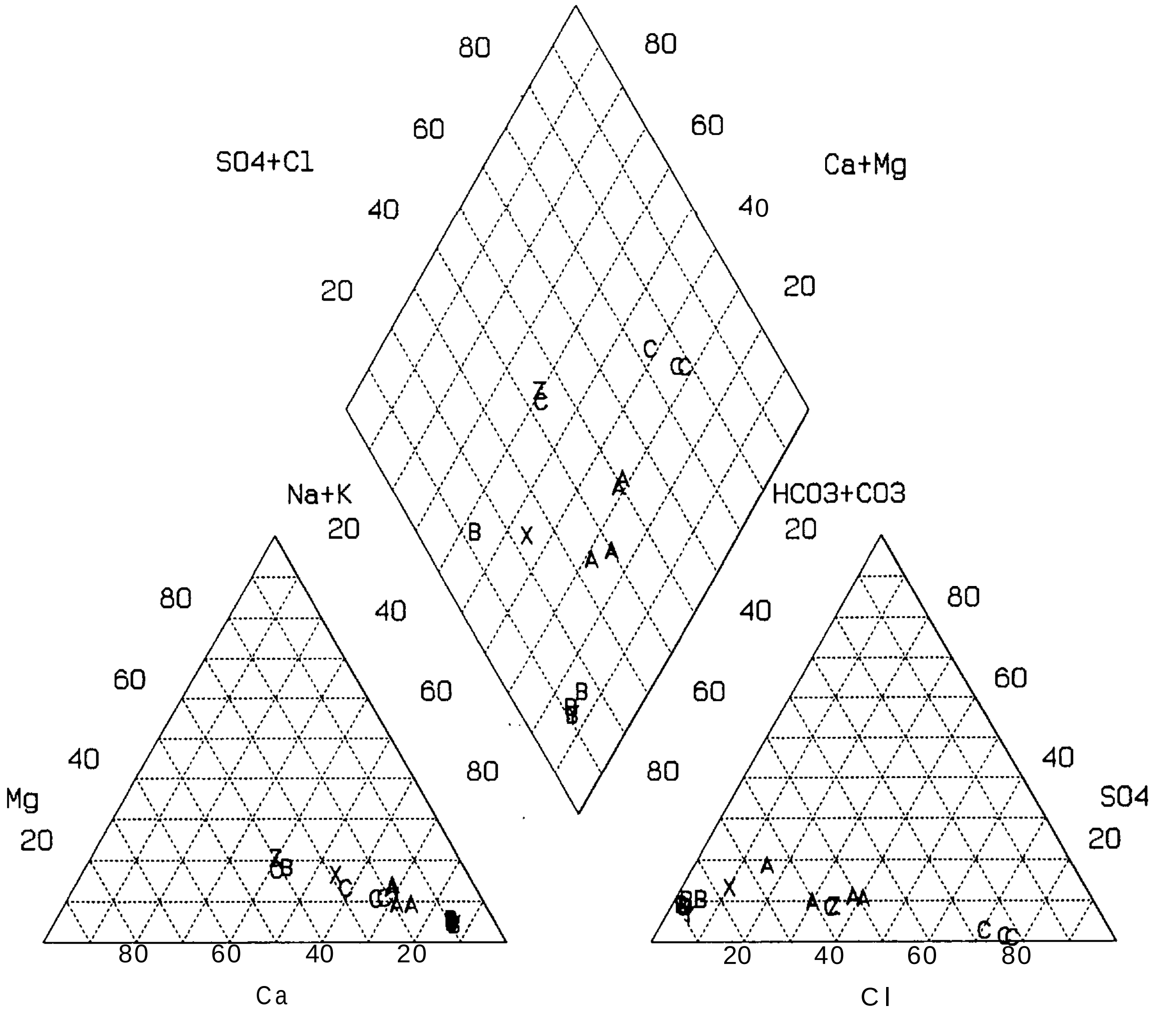
*Table 77. Average **flow** (cfs), total **runoff** (inches), total precipitation at Gold Run Pass (inches), and runoff to precipitation ratio for **Hoseanna** Creek at Bridge **1** for June through September.*

Site	Average Flow	Runoff	Precipitation	Ratio
1987	31.9	3.01	11.16	**.270**
1988	44.5	4.20	14.88	**.282**
1989	59.0	5.57	13.28	,419
1990	77.2	7.28	14.40	**.506**
1991	45.6	4.30	7.32	**.587**
1992	45.3	4.27	7.96	**.536**

Ground Water

There are two significant points to discuss about the ground water data collected. In Figure 8 the cation portion of the Piper diagram shows a linear trend for the ground water samples. The trend is a function of residence time and cation exchange. From left to right, the first cluster is GAMW-4 (1988 samples). These samples had an unusual chemical composition and appear to be a mixture of surface and ground waters (Ray and Maurer, 1989). The next two clusters are GAMW-5 and GAMW-3. 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.

The second point discusses the decrease of dissolved constituents in GAMW-5. The decrease is primarily sodium and chloride. Van Voast and Reiten (1988) reported that post-mining ground water in most cases contains substantially higher concentrations of dissolved solids than does the ground water of undisturbed aquifers. At mines where the spoils-water quality was monitored, trends of decreasing dissolved-solids concentrations are indications that soluble salts are being leached from the system and that long-term ground water quality will not be compromised. This is probably what has occurred at the spoils around GAMW-5. The trend of decreasing TDS, sodium and chloride are indications that the leaching of the soluble salts is decreasing.



Poker Flat Ground Water

Symbols

A - GAMW-3 (1988-91)
X - GAMW-3 (1992)

B - GAMW-4 (1989-91)
Y - GAMW-4 (1992)

C - GAMW-5 (1988-91)
Z - GAMW-5 (1992)

*Figure 8. Piper **plot** of ground water* data *collected since 7987. Diagram plotted by **HC-Gram** (McIntosh, 1987).*

SUMMARY

1. Hoseanna Creek above the Poker Fiat Mine (Bridge 3) continually carries a considerable amount of sediment during the summer months. Total suspended solids (TSS) samples collected since 1987 indicate only a small percentage of time that the streams carries less than 35 mg/L (1.6% of the samples). The median TSS value for the samples collected was 383 mg/L.

2. The composition (major ions) of Hoseanna Creek at Bridges 1 and 3 has fluctuated since the study began. This variation is probably caused by varying hydrologic conditions in the smaller basins. Since each basin has a chemical signature, changes in the flow from the smaller basins changes the overall chemical signature in Hoseanna Creek. The increase in the constituents in Hoseanna Creek from Bridge 3 to 1 is probably from ground water from the lower basin area and the Poker Flat Spoils.

3. The ground-water quality of the Poker Flat spoils (GAMW-5) continues to improve with the TDS falling from 3500 mg/L in 1988 to less than 900 mg/L in 1992. The decrease is primarily due to decreasing sodium and chloride values. This trend in decreasing TDS indicates that the leaching of the soluble salts is decreasing. Similar observations have been made at other coal mines in the lower 48.

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APPENDIX A

Gold Run Pass

Daily Precipitation - 1992 (inches)

Date	May	Jun	Jul	Aug	Sep
1		0.74		----	0.03
2		0.15		----	0.02
3			0.12	----	----
4					
5		----	----	0.01	----
6		----	0.02	0.11	----
7			0.05	0.14	----
8			----	----	----
9		----		0.02	Freeze up
10		----	----		
11		----	0.33		
12		----	0.46		
13		----	0.10		
14		----	----	0.02	
15		0.43	0.14		
16		0.07	0.09		
17			1.14	0.37	
18			0.07	0.53	
19			0.06		
20	Install Gage	0.11	0.04		
21	----	0.07			
22	----	0.01			
23	----	0.02			
24		0.36			
25	----	0.72	0.12	0.03	
26			0.13	----	
27			0.24	0.04	
28			---		
29	----	----	0.01		
30	----	0.07	0.47		
31	0.12		0.02	0.16	
Total	0.12	2.75	3.61	1.43	0.05

Season Total = 7.96 inches

APPENDIX A (cont)

Poker Fiat

Daily Precipitation - 1992 (inches)

Date	May	Jun	Jul	Aug	Sep
1		0.11	----	0.18	0.03
2		0.01	----	----	----
3		----	0.12	----	0.40
4		----	----	- -	----
5		----	----	0.05	----
6		----	----	0.56	----
7		----	0.23	----	----
8		----	0.02	0.06	----
9		----	----	----	0.03
10		----	----	----	Freeze up
11		----	----	----	
12		----	----	----	
13		----	0.70	----	
14		----	---	0.04	
15		0.42	0.14	----	
16		0.06	----	----	
17		----	0.07	0.08	
18		----	----	0.43	
19		----	0.52	----	
20	0.05	----	0.04	----	
21	----	0.18	----	----	
22	----	----	----	----	
23	----	----	----	----	
24	----	0.02	----	----	
25	----	0.95	----	----	
26	----	----	0.13	----	
27	----	----	0.24	0.08	
28	----	----	----	- -	
29	----	----	0.07	---	
30	----	0.02	0.44	---	
31	0.28		----	0.08	
Total	0.33	1.77	2.64	1.56	0.46

Season Total = 6.76 inches

APPENDIX A (cont)

Bridge 1

Daily Precipitation - 1992 (inches)

Date	May	Jun	Jul	Aug	Sep
1		D	----	----	0.05
2		a	----	----	----
3		i	----	0.01	0.25
4		l	0.01	----	----
5		y	----	- -	----
6			----	0.09	----
7		v	0.17	0.16	0.01
8		a	----	----	----
9		l	----	0.01	0.03
10		u	----	----	Freeze up
11		e	----	----	
12		s	0.29	----	
13			0.05	----	
14		n	----	0.01	
15		o	0.03	----	
16		t	0.02	----	
17			0.09	0.05	
18		a	0.11	0.36	
19		v	0.04	0.01	
20	Install Gage	a	0.10	----	
21	----	i	----	0.02	
22	----	l	----	----	
23	----	a	----	----	
24	----	b	0.01	----	
25	----	l	----	----	
26	----	e	----	----	
27	----		0.32	0.04	
28	----		----	0.02	
29	----		----	----	
30	----		0.36	----	
31	0.20		----	0.06	
Total	0.20	1.64	1.60	0.84	0.34

Season Total = 4.62 inches

APPENDIX B

Gold Run Pass

Daily Average Temperature - 1991-92 (°C)

Date	Oct	Nov	Dec	Jan	Feb	Mar
1	5.0	1.5	-15.5	-3.5	-28.0	-27.0
2	5.1	-6.0	-20.0	-5.5	-27.5	-27.0
3	5.7	-9.0	-23.5	-9.5	-28.5	-27.0
4	4.5	-9.0	-22.0	-17.5	-19.5	-30.5
5		-7.5	-20.5	-7.5	-20.0	-29.5
6		-5.0	-20.0	-2.0	-25.5	-26.5
7		-14.0	-20.0	-0.5	-19.5	-6.0
8		-16.0	-20.5	-3.0	-7.0	-1.0
9	-8.0	-17.5	-20.5	-3.0	-6.5	-1.0
10	-10.0	-17.0	-15.0	-8.0	-8.0	0.5
11	-11.5	-16.0	-12.0	-12.0	-14.5	1.0
12	-6.0	-18.5	-14.5	-10.0	-13.5	-6.0
13	-6.0	-23.0	-12.0	-2.5	-15.5	-9.5
14	-10.0	-14.5	-6.0	-2.5	-18.0	-6.0
15	-9.5	-24.5	-5.0	-6.5	-23.5	-2.0
16	-8.0	-24.5	-9.0	-1.0	-27.0	-2.0
17	-2.0	-24.0	-16.0	1.0	-28.5	-4.0
18	0.5	-24.0	-21.0	-5.5	-26.0	-4.0
19	-0.5	-23.5	-26.0	-12.5	-25.0	-1.5
20	-9.5	-19.0	-28.0	-18.0	-25.5	-2.0
21	-4.5	-20.0	-28.0	-20.0	-30.0	-4.0
22	-3.5	-25.0	-9.5	-22.0	-26.0	-3.5
23	-4.0	-23.0	-3.0	-27.5	-15.5	-2.5
24	-7.0	-21.5	-2.5	-24.0	-9.5	-1.5
25	-5.0	-21.5	-8.0	-23.5	-7.5	-1.0
26	-8.0	-22.5	-11.0	-26.5	-15.0	-3.0
27	-3.0	-13.0	-5.5	-28.0	-8.0	-11.0
28	-3.0	-5.0	-15.5	-27.0	-10.5	-11.5
29	-0.5	-3.0	-16.0	-26.0		-10.5
30	-6.0	-9.0	-5.0	-29.5		-10.5
31	1.0		-2.5	-29.0		-7.5
Average	-3.8	-15.8	-14.6	-13.3	-18.9	-9.0
Maximum	8.5	5.0	0	5.5	2.5	5.5
Day	1	5	30	13	27	17
Minimum	-16.5	-28.5	-32.0	-32.0	-34.0	-35.5
Day	16	22	21	30	21	5

Season Average = -3.9 °C

APPENDIX B (cont)

Gold Run Pass

Daily Average Temperature - 1992 (°C)

Date	Apr	May	Jun	Jul	Aug	Sep
1	-8.0	-5.0	9.0	13.3	14.7	6.1
2	-11.5	-8.5	8.9	18.6	13.2	3.7
3	-14.0	-10.4	11.4	18.8	12.9	5.1
4	-11.5	-10.8	11.1	17.1	14.7	6.8
5	-9.0	-6.8	10.2	17.3	17.0	7.3
6	-5.5	-3.2	12.5	13.3	13.1	7.0
7	-6.0	0.9	9.1	11.3	9.8	5.0
8	-6.0	-2.7	11.1	14.4	10.0	5.7
9	-5.5	-2.8	13.9	14.6	9.2	-2.0
10	-10.0	-3.9	15.4	14.8	13.8	-6.3
11	-19.5	-2.0	18.1	13.0	12.8	-4.2
12	-19.0		18.2	12.5	12.6	-2.9
13	-11.0		16.2	13.4	10.9	-0.4
14	-2.9		17.3	14.9	10.0	-1.8
15	3.5		9.2	11.7	10.1	-8.1
16	4.6		8.1	13.7	9.4	-7.2
17	1.4		10.4	12.9	4.9	-1.8
18	0.6			14.6	5.5	-3.6
19	-0.8			11.9	10.4	-7.9
20	0.4			12.1	12.7	-7.9
21	0.5	7.1	10.7	13.7	12.3	-8.8
22	-0.9	8.1	10.5	12.9	12.7	-10.4
23	-0.2	8.5	9.4	14.1	12.1	-13.1
24	-0.4	11.9	9.9	14.0	13.0	-15.1
25	-1.3	11.2	9.9	13.2	8.4	-13.5
26	-1.8	10.1	11.1	12.5	7.6	-11 .0
27	-2.5	11.0	12.9	12.7	6.8	-5.5
28	-5.3	11.6	19.1	13.6	8.5	-11.5
29	-3.3	10.8	21.1	14.0	8.0	-12.0
30	-3.3	11.1	10.6	11.0	8.1	-5.5
31		10.2		12.5	5.7	
Average	-4.9	2.6	12.4	13.8	10.7	-3.8
Maximum	11.5	18.5	27.0	28.5	21.5	15.0
Day	15	24	29	2	1	8
Minimum	-23.5	-17.0	1.5	8.0	2.5	-19.0
Day	12	4	8	25	17	30

Season Average = -3.9 °C

APPENDIX C

Hoseanna Creek at Bridge1 (USGS, 1993)

Daily Average Discharge - 1992 (cfs)

Date	May	Jun	Jul	Aug	Sep
1	e12	250	e44	34	25
2	e11	338	e42	31	24
3	e12	190	e40	29	25
4	e12	147	e38	28	23
5	e11	122	e36	27	22
6	e11	101	e34	28	22
7	e11	87	e39	35	22
8	e11	72	32	29	22
9	e11	67	30	28	23
10	e10	67	29	26	21
11	e10	65	30	25	21
12	e10	64	58	24	22
13	e11	61	67	23	30
14	e11	57	41	24	42
15	e11	74	34	24	33
16	e11	62	44	23	28
17	e11	54	52	27	e25
18	e13	51	104	55	e23
19	e20	50	54	38	e22
20	e30	48	53	28	e21
21	e60	50	42	26	e21
22	370	49	36	25	e20
23	516	e47	33	23	e20
24	603	49	31	23	e20
25	617	199	33	23	e20
26	732	72	33	22	e19
27	597	53	46	23	e19
28	458	50	34	23	e19
29	357	48	29	22	e19
30	296	e46	46	22	e19
31	294		37	24	
Average	166	69.7	42.0	27.2	23.1

Season average = 69.8 **cfs**

e Estimated

APPENDIX D

HoseannaCreekatBridge3

Daily Sediment Load - 1992 (tons)

Date	May	Jun	Jul	Aug	Sep
1		2100	94.9	296	3.56
2		5470	91.9	54.8	2.80
3		2360'	35.0	12.9	4.76
4		1670	324	15.1	2.88
5		1150	150	7.80	2.39
6		809'	84.6	13.3	2.14
7		587	73.4	70.5	1.93
8		388	29.5	27.4	1.97
9		325	21.7	8.68	2.44
10		325	19.1	8.05	7.20
11		298	19.4	6.54	5.86
12		165	447	3.17	4.36
13		154	497	5.14	22.9
14		124	58.2	5.00	35.0
15		563	44.0	6.07	29.2
16		140	109	3.90	
17		95.4	341	12.7	
18		70.9.	990	310	
19		55.3	514	43.3	
20	143	49.4	150	8.42	
21	484	57.0	41.7	5.23	
22	2650	67.2	22.8	4.65	
23	5140	39.2	17.0	3.49	
24	22100	132	29.7	2.91	
25	12300	682	32.7	2.90	
26	16200	388	28.3	2.24	
27	12100	157	128	3.70	
28	8400	142	28.5	3.24	
29	5780	129	13.7	3.20	
30	4550	112	218	2.31	
31	6950		48.6	4.37	
Total	96,600	16,600	4,700	957	129

Season total = 121,000 tons

Season average = 1,020 tons/day

APPENDIX E

Sediment samples collected

Type: g -grab sample
i - automated Isco sample
c - composited Isco sample

Location	Date	Time	Turbidity (NTU)	TSS (mg/L)	Q (cfs)	Type
Hoseanna Cr at Bridge 3	20-May-92		340	1770	30	c
Hoseanna Cr at Bridge 3	21-May-92		800	2990	60	c
Hoseanna Cr at Bridge 3	22-May-92		750	2650	370	c
Hoseanna Cr at Bridge 3	23-May-92		850	3690	516	c
Hoseanna Cr at Bridge 3	24-May-92		850	13600	603	c
Hoseanna Cr at Bridge 3	25-May-92				617	
Hoseanna Cr at Bridge 3	26-May-92				732	
Hoseanna Cr at Bridge 3	27-May-92				597	
Hoseanna Cr at Bridge 3	28-May-92				458	
Hoseanna Cr at Bridge 3	29-May-92				357	
Hoseanna Cr at Bridge 3	30-May-92				296	
Hoseanna Cr at Bridge 3	31-May-92		850	8760	294	c
Hoseanna Cr at Bridge 3	01-Jun-92		800	3120	250	c
Hoseanna Cr at Bridge 3	02-Jun-92				338	
Hoseanna Cr at Bridge 3	03-Jun-92				190	
Hoseanna Cr at Bridge 3	04-Jun-92				147	
Hoseanna Cr at Bridge 3	05-Jun-92				122	
Hoseanna Cr at Bridge 3	06-Jun-92				101	
Hoseanna Cr at Bridge 3	07-Jun-92				87	
Hoseanna Cr at Bridge 3	08-Jun-92				72	
Hoseanna Cr at Bridge 3	09-Jun-92				67	
Hoseanna Cr at Bridge 3	10-Jun-92				67	
Hoseanna Cr at Bridge 3	11-Jun-92				65	
Hoseanna Cr at Bridge 3	12-Jun-92		400	954	64	c
Hoseanna Cr at Bridge 3	13-Jun-92		370	938	61	c
Hoseanna Cr at Bridge 3	14-Jun-92		350	807	57	c
Hoseanna Cr at Bridge 3	15-Jun-92		1000	2820	74	c
Hoseanna Cr at Bridge 3	16-Jun-92		500	836	62	c
Hoseanna Cr at Bridge 3	17-Jun-92		290	655	54	c
Hoseanna Cr at Bridge 3	18-Jun-92		220	516	51	c
Hoseanna Cr at Bridge 3	19-Jun-92		180	410	50	c
Hoseanna Cr at Bridge 3	20-Jun-92		170	382	48	c
Hoseanna Cr at Bridge 3	21-Jun-92		180	423	50	c
Hoseanna Cr at Bridge 3	22-Jun-92		210	509	49	c
Hoseanna Cr at Bridge 3	23-Jun-92		150	309	47	c
Hoseanna Cr at Bridge 3	24-Jun-92				49	
Hoseanna Cr at Bridge 3	25-Jun-92		650	1270	199	c
Hoseanna Cr at Bridge 3	26-Jun-92				72	
Hoseanna Cr at Bridge 3	27-Jun-92				53	
Hoseanna Cr at Bridge 3	28-Jun-92				50	
Hoseanna Cr at Bridge 3	29-Jun-92				48	
Hoseanna Cr at Bridge 3	30-Jun-92				46	

APPENDIX E (cont)

Location	Date	Time	Turbidity (NTU)	TSS (mg/L)	Q (cfs)	Type
Hoseanna Cr at Bridge 3	01-Jul-92				44	
Hoseanna Cr at Bridge 3	02-Jul-92		160	811	42	c
Hoseanna Cr at Bridge 3	03-Jul-92		140	325	40	c
Hoseanna Cr at Bridge 3	04-Jul-92		1400	3160	38	c
Hoseanna Cr at Bridge 3	05-Jul-92				36	
Hoseanna Cr at Bridge 3	06-Jul-92		350	922	34	c
Hoseanna Cr at Bridge 3	07-Jul-92		250	698	39	c
Hoseanna Cr at Bridge 3	08-Jul-92		130	342	32	c
Hoseanna Cr at Bridge 3	09-Jul-92		110	269	30	c
Hoseanna Cr at Bridge 3	10-Jul-92		95	244	29	c
Hoseanna Cr at Bridge 3	1 l-Jul-92		80	240	30	c
Hoseanna Cr at Bridge 3	12-Jul-92		1000	2860	58	c
Hoseanna Cr at Bridge 3	13-Jul-92		900	2750	67	c
Hoseanna Cr at Bridge 3	14-Jul-92		220	526	41	c
Hoseanna Cr at Bridge 3	15-Jul-92		200	479	34	c
Hoseanna Cr at Bridge 3	16-Jul-92		330	920	44	c
Hoseanna Cr at Bridge 3	17-Jul-92		900	2430	52	c
Hoseanna Cr at Bridge 3	18-Jul-92		1400	3530	104	c
Hoseanna Cr at Bridge 3	19-Jul-92		380	3530	54	c
Hoseanna Cr at Bridge 3	20-Jul-92		450	1050	53	c
Hoseanna Cr at Bridge 3	21-Jul-92		190	368	42	c
Hoseanna Cr at Bridge 3	22-Jul-92		120	235	36	c
Hoseanna Cr at Bridge 3	23-Jul-92		110	191	33	c
Hoseanna Cr at Bridge 3	24-Jul-92		170	355	31	c
Hoseanna Cr at Bridge 3	25-Jul-92		110	368	33	c
Hoseanna Cr at Bridge 3	26-Jul-92		130	318	33	c
Hoseanna Cr at Bridge 3	27-Jul-92		400	1030	46	c
Hoseanna Cr at Bridge 3	28-Jul-92		140	311	34	c
Hoseanna Cr at Bridge 3	29-Jul-92		85	175	29	c
Hoseanna Cr at Bridge 3	30-Jul-92		700	1760	46	c
Hoseanna Cr at Bridge 3	31-Jul-92		210	486	37	c
Hoseanna Cr at Bridge 3	01-Aug-92		1500	3230	34	c
Hoseanna Cr at Bridge 3	02-Aug-92		260	655	31	c
Hoseanna Cr at Bridge 3	03-Aug-92		65	184	29	c
Hoseanna Cr at Bridge 3	04-Aug-92		120	199	28	c
Hoseanna Cr at Bridge 3	OS-Aug-92’		110	107	27	c
Hoseanna Cr at Bridge 3	06-Aug-92		70	176	28	c
Hoseanna Cr at Bridge 3	07-Aug-92		650	746	35	c
Hoseanna Cr at Bridge 3	08-Aug-92		70	351	29	c
Hoseanna Cr at Bridge 3	09-Aug-92		60	115	28	c
Hoseanna Cr at Bridge 3	10-Aug-92		60	115	26	c
Hoseanna Cr at Bridge 3	11-Aug-92		45	97.0	25	c
Hoseanna Cr at Bridge 3	12-Aug-92		38	49.0	24	c
Hoseanna Cr at Bridge 3	13-Aug-92		40	82.8	23	c
Hoseanna Cr at Bridge 3	14-Aug-92		50	77.3	24	c
Hoseanna Cr at Bridge 3	15-Aug-92		70	93.8	24	c
Hoseanna Cr at Bridge 3	16-Aug-92		50	62.9	23	c
Hoseanna Cr at Bridge 3	17-Aug-92		90	174	27	c

APPENDIX E (cont)

Location	Date	Time	Turbidity (NTU)	TSS (mg/L)	Q (cfs)	Type
Hoseanna Cr at Bridge 3	18-Aug-92		700	2090	55	c
Hoseanna Cr at Bridge 3	19-Aug-92		170	423	38	c
Hoseanna Cr at Bridge 3	20-Aug-92		50	112	28	c
Hoseanna Cr at Bridge 3	21 -Aug-92,		39	74.5	26	c
Hoseanna Cr at Bridge 3	22-Aug-92		39	68.9	25	c
Hoseanna Cr at Bridge 3	23-Aug-92		29	56.3	23	c
Hoseanna Cr at Bridge 3	24-Aug-92		25	46.8	23	c
Hoseanna Cr at Bridge 3	25-Aug-92		25	46.7	23	c
Hoseanna Cr at Bridge 3	26-Aug-92		22	37.7	22	c
Hoseanna Cr at Bridge 3	27-Aug-92		34	59.6	23	c
Hoseanna Cr at Bridge 3	28-Aug-92		5.2	52.2	23	c
Hoseanna Cr at Bridge 3	29-Aug-92		15	53.9	22	c
Hoseanna Cr at Bridge 3	30-Aug-92		21	39.0	22	c
Hoseanna Cr at Bridge 3	31 -Aug-92		33	67.5	24	c
Hoseanna Cr at Bridge 3	01-Sep-92		28	52.8	25	c
Hoseanna Cr at Bridge 3	02-Sep92		27	43.2	24	c
Hoseanna Cr at Bridge 3	03-Sep-92		45	70.6	25	c
Hoseanna Cr at Bridge 3	04-Sep-92		28	46.5	23	c
Hoseanna Cr at Bridge 3	05-Sep-92		26	40.3	22	c
Hoseanna Cr at Bridge 3	06-Sep-92		22	36.1	22	c
Hoseanna Cr at Bridge 3	07-Sep-92		21	32.5	22	c
Hoseanna Cr at Bridge 3	08-Sep-92		20	33.3	22	c
Hoseanna Cr at Bridge 3	09-Sep-92		25	39.4	23	c
Hoseanna Cr at Bridge 3	10-Sep-92		90	127	21	c
Hoseanna Cr at Bridge 3	11-Sep-92		55	104	21	c
Hoseanna Cr at Bridge 3	12-Sep-92		36	73.5	22	c
Hoseanna Cr at Bridge 3	13-Sep-92		120	283	30	c
Hoseanna Cr at Bridge 3	14-Sep-92		120	309	42	c
Hoseanna Cr at Bridge 3	15-Sep-92		90	328	33	c

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	440	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	55	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
	25 SEP 91	0910	3.0	8.09	3.15	9.8	73	30	131	60	Tr	26.2
	23 SEP 92	1830	0.0	7.07		13.5		20	258	170	Tr	
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	340	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
	25 SEP 91	1000	2.8	7.63	3.84	12.4	91	30	80.9	55	Tr	24.8
	23 SEP 92	1740	0.0	7.05		14.0		20	182	37	Tr	

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	s s	Q
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							
	08 OCT 91	1300	2.5	6.05	154							
	23 SEP 92	1530		6.60								
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							
	24 SEP 91	1415	3.8	6.23	74.1							
	23 SEP 92	1710		6.22								
GAMW 5	25 MAY 88	1710	4.9	6.30								
	19 JUL 88	1200	3.7	6.24	2::							
	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:o	5.83	284							
	25 SEP 91	1150	3.2	5.80	314							
	24 SEP 92	2015		5.73								

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 CaC03

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
	25 SEP 91	533	284	39.0	25.9	35.8	4.42	142	0.67	19.3	0.16	73.9	<DL
	23 SEP 92	595	425	44.1	29.2	56.5	8.08	169	0.36	82.9	0.23	102	<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	ii.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
	25 SEP 91	491	274	38.3	26.0	27.4	3.93	145	0.65	14.8	0.16	76.0	<DL
	23 SEP 92	535	363	41.6	29.4	37.7	6.29	161	0.35	50.6	0.24	100	<DL

APPENDIX F (cont)

Ground Water

SITE	DATE	Cond	TDS	Ca	Mg	Na	K	ALK	F	Cl	NO3	so4	PO4
GAMW 3	24 MAY 88	1562	826	64.8	35.9	164	19.3	346	0.80	248	co.02	85.4	<DL
	18 JUL 88	I 538	a20	55.6	18.6	195	20.5	354	0.81	245	co.02	71.7	<DL
	07 SEP 88	1645	795	45.9	22.4	187	27.6	373	0.84	201	co.02	86.9	<DL
	20 SEP a9	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
	08 OCT 91	653	479	31.9	11.0	132	16.2	270	0.80	45.7	0.08	79.4	<DL
	23 SEP 92	556	457	39.8	15.1	81.0	12.7	352	0.24	32.6	0.26	63.8	<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	co.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 a9	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
	24 SEP 91	439	273	7.83	3.10	83.3	15.4	225	0.81	2.85	<DL	25.0	<DL
	23 SEP 92	421	249	6.91	2.77	73.5	15.5	208	0.58	7.60	<DL	17.4	<DL
GAMW 5	25 MAY 88	4013	3034	190	133	792	10.5	454	4.39	1570	co.02	61.7	<DL
	19 JUL 88	7841	3580	283	193	a93	15.6	645	6.23	1730	co.02	72.0	<DL
	08 SEP 88	6905	3440	251	89.6	956	11.2	638	6.10	1680	<0.02	63.1	<DL
	22 SEP a9	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
	25 SEP 91	1230	975	174	49.5	198	10.1	452	2.30	197	0.40	72.9	<DL
	24 SEP 92	813	885	146	49.0	162	11.3	423	0.12	191	<0.02	72.0	<DL

APPENDIX F (cont)

Surface Water

SITE	DATE	Al	As	B	Ba	Be	Cd	co	Cr	All units are mg/l
HOSEANNA B1	08 JUN 87	0.057	co.004	0.14	0.098	<1.0	<0.001	<0.01	co.002	
	03 AUG 87	0.057	co.004	0.19	0.117	<1.0	<0.001	co.01	co.002	
	14 SEP 87	0.050	co.004	0.19	0.116	<1.0	~0.001	co.01	co.002	
	23 MAY 88	0.058	co.004	0.13	0.110	4.0	<0.001	0.009	co.002	
	19 JUL 88	0.061	co.004	0.15	0.107	<1.0	~0.001	0.010	0.003	
	08 SEP 88	0.057	co.004	0.17	0.099	4.0	<0.001	0.011	0.002	
	20 SEP 89	0.054	co.004	0.16	0.087	<1.0	~0.001	0.005	co.002	
	13 SEP 90									
	02 NOV 90									
	14 MAR 91									
	25 SEP 91									
	23 SEP 92									
HOSEANNA B3	08 JUN 87	0.055	co.004	0.13	0.089	<1.0	<0.001	co.01	co.002	
	03 AUG 87	0.066	co.004	0.17	0.096	<1.0	<0.001	co.01	<0.002	
	14 SEP 87	0.055	<0.004	0.19	0.094	4.0	<0.001	co.01	co.002	
	23 MAY 88	0.057	co.004	0.12	0.091	4.0	<0.001	0.012	<0.001	
	19 JUL88	0.059	co.004	0.14	0.076	4.0	<0.001	0.011	0.002	
	08 SEP 88	0.059	co.004	0.16	0.064	<1.0	~0.001	0.012	0.005	
	20 SEP 89	0.059	co.004	0.15	0.067	<1.0	~0.001	0.007	co.002	
	13 SEP 90									
	02 NOV 90									
	14 MAR 91									
	25 SEP 91									
	23 SEP 92									

APPENDIX F (cont)

Ground Water

SITE	DATE	Al	AS	B	Ba	Be	Cd	co	Cr	All units are mg/l
GAMW3	24 MAY 88	0.287	co.004	1.71	0.404	4 . 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									
	08 OCT 91									
	23 SEP 92									
GAMW 4	25 MAY 88	0.175	0.009	0.45	0.420	a . 0	0.017	0.009	<0.001	
	18 JUL 88	0.211	<0. 004	0.50	0.355	4 . 0	<0.001	<0.001	~0.001	
	07 SEP 88	0.191	0.016	0.29	0.135	4 . 0	0.042	0.002	<0.001	
	20 SEP.89	0.154	co.004	0.38	0.114	<1.0	0.003	<0.001	~0.001.	
	12 SEP 90									
	24 SEP 91									
	23 SEP 92									
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	4 . 0	<0.001	0.267	0.005	
	08 SEP 88	0.261	0.013	2.90	1.32	4 . 0	0.005	0.345	0.001	
	21 SEP 89	0.226	0.007	1.29	0.571	4 . 0	<0.001	0.254	0.003	
	22 SEP 89	0.278	0.006	2.60	0.943	4 . 0	~0.001	0.326	0.006	
	13 SEP 90									
	25 SEP 91									
	24 SEP 92									

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	co.03				1.92	co.02
	03 AUG 87	co.01	co.03	0.24	0.022	co.03				2.31	co.02
	14 SEP 87	co.01	co.03	0.32	0.023	co.03				2.24	co.02
	23 MAY 88	co.01	0.08	0.47	0.019	co.03				5.52	co.02
	19 JUL 88	co.01	0.04	0.41	0.020	co.03				6.12	co.02
	08 SEP 88	co.01	co.03	0.36	0.022	co.03				5.43	co.02
	20 SEP 89	co.01	co.03	0.40	0.029	co.03				6.28	co.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					
	25 SEP 91		2.74	co.03	0.33	0.19					
	23 SEP 92		8.80	0.26	0.53	0.35					
HOSEANNA B3	08 JUN 87	co.01	0.08	0.23	0.018	<0.03				1.91	co.02
	03 AUG 87	<0.01	0.07	0.26	0.018	co.03				2.29	0.03
	14 SEP 87	co.01	co.03	0.33	0.023	co.03				1.72	0.04
	23 MAY 88	co.01	0.07	0.41	0.019	<0.03				5.54	co.02
	19 JUL 88	co.01	co.03	0.39	0.022	<0.03				6.24	<0.02
	08 SEP 88	co.01	co.03	0.38	0.020	<0.03				5.43	<0. 02
	20 SEP 89	co.01	co.03	0.39	0.025	co.03				6.06	co.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					
	25 SEP 91		2.56	co.03	0.33	0.18					
	23 SEP 92		8.92	0.14	0.41	0.22					

APPENDIX F (cont)

Ground Water

SITE	DATE	Cu	Fe (T)	Fe (D)	Mn (T)	Mn (D)	Mo	Ni	Pb	Si	Zn
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	co.01	36.1	18.0	1.26	0.028	<DL		0.108	7.89	0.10
	20 SEP 89	co.01	29.5	25.1	1.01	0.028	<DL		0.085	8.07	co.02
	12 SEP 90		27.5	26.0	1.17	1.11					
	08 OCT 91		124	24.8	2.40	0.92					
	23 SEP 92		155	4.95	2.67	0.84					
GAMW 4	25 MAY 88	0.01	12.7	8.45	0.66	0.012	<DL		co.03	9.34	co.02
	18 JUL 88	0.02	12.1	7.12	0.78	0.017	<DL		co.03	11.2	co.02
	07 SEP 88	0.81	7.75	3.78	0.58	0.013	<DL		co.03	8.57	co.02
	20 SEP 89	co.01	14.8	12.0	0.47	<0.01	<DL		co.03	7.65	co.02
	12 SEP 90		12.3	11.4	0.59	0.57					
	24 SEP 91		15.5	12.6	0.66	0.56					
	23 SEP 92		14.6	11.4	0.55	0.48					
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	co.01	42.8	22.7	8.30	0.112	<DL		0.209	10.2	0.20
	21 SEP 89	co.01	41.2	34.0	3.91	0.121	<DL		0.198	8.95	0.04
	22 SEP 89	co.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					
	25 SEP 91		34.0	20.4	3.46	2.05					
	24 SEP 92		29.6	28.2	3.68	3.64					