City of Spearfish FERC Application – Proposed Bypass Flow Release
Provision for Suspension of Bypass Release under Low Flow Conditions

Background

On March 17, 2008, Devine, Tarbell & Associates on behalf of the city of Spearfish distributed a draft license application for the Spearfish Hydroelectric Project. The formal License Application for the initial licensing of the Spearfish Hydroelectric Project was submitted to the Federal Energy Regulatory Commission on September 10, 2008. This is the existing hydroelectric project constructed by Homestake Mining Company in the early 1900's in Spearfish Canyon and is currently owned and operated by the city of Spearfish. Water Right No. 43-1 for this diversion authorizes up to 120 cubic feet of water per second from Spearfish Creek for power generation. The diversion (intake) is located at an area known as Maurice. Due to the unique geologic setting the project's intake and aqueduct diverts water, some of which would otherwise be lost, as the creek passes over the Madison Limestone and Minnelusa Formation outcrops and associated loss zones. The city's application estimates the loss zone to be 20 – 33 cfs.

The city prepared an analysis of Spearfish Creek instream flows using the Delphi Team study approach to determine the impacts a bypass release will have on the aquatic resources both below Maurice Dam and below the powerhouse to the Redwater River. This study was a biologic evaluation that did not take into consideration impacts to the downstream beneficial uses. These established beneficial uses benefit from the aqueduct's conveyance of flow around the loss zone.

The Delphi team's final consensus is a two flow recommendation. A 6 cfs bypass flow is intended for normal and wet years at a frequency of 75 percent and a 4 cfs bypass flow is intended for dry years at a frequency of 25 percent. The team suggested using mean daily flow over a three year rolling average period with 75 percent exceedance as the cut off between dry and normal/wet years.

The city's FERC application proposes a bypass release at the Maurice intake of 3 cfs during the irrigation season and 6 cfs during the non-irrigation season, with a provision for suspending releases to the bypassed reach under extreme low flow conditions, to be defined by the South Dakota Department of Environment and Natural Resources.

This report investigates low flow conditions when the bypass release shall be suspended. This analysis includes review of historic USGS gaging station records.

USGS Gaging Station

The primary United States Geologic Survey (USGS) Gaging Station used is the Spearfish Creek Gage at Spearfish SD (USGS 06431500). The records from 1947 through 2007 were used in determining annual mean, exceedances, etc. This gage was chosen over the Spearfish Creek Gage above Spearfish (aka Maurice gage) because the gage at Spearfish best reflects the historic flow in the downstream reach.

There was also a Spearfish Creek Gage below Spearfish (USGS 06432020) active from 1988 through 1998. This gage proves valuable in analyzing the flow withdrawn from Spearfish Creek in the downstream reach during the summer season.

In conducting an analysis to determine when the flow bypass should be suspended, a review was conducted as follows:

- Flow exceedances for 75%, 80%, 90% and 95% for the 7- month irrigation season and the five months determined most critical.
- Comparison of annual mean flow records
- Flow records when gages "at" and "below" Spearfish were in operation
- Years when complaints were received

The analysis did not include the non-irrigation season when 6 – cfs would be bypassed at the intake near Maurice. Annual monthly mean flow records for the winter season do not indicate that this bypass release will pose a significant threat to the downstream beneficial uses during the non-irrigation season.

Flow Exceedances

Monthly flow exceedances for the Spearfish Creek @ Spearfish gaging station were downloaded from the USGS website for 75%, 80%, 90% and 95% exceedances. See Attachment 1. The exceedances for the irrigation season of April 1 through October 31 were averaged as shown on Table 1

Table 1 – Flow Exceedances for the Spearfish Creek Gage @ Spearfish Gaging Station (in cfs)

Exceedance	Apr	May	Jun	Jul	Aug	Sep	Oct	**Average**
75%	47.8	56.2	48.3	40.5	35.9	36.0	37.1	**43.1**
80%	45.1	52.2	46.4	35.8	34.2	34.2	35.8	**40.5**
90%	40.5	44.3	40.9	31.7	30.9	30.3	32.3	**35.8**
95%	36.6	40.5	36.7	28.0	27.6	25.6	29.0	**32.0**

Annual Mean Flow Records

Attachment 2 provides the annual mean flow from 1947 – 2007 for the Spearfish Creek gage at Spearfish. The data shows an annual mean of 55.5 cfs for this period of record. The high annual mean 105.8 cfs occurred in 1999 while the low was 27.1 cfs is 1961. The data shows the variability in annual mean flow which presumably can be attributed to climatic conditions. The data shows a maximum variation in annual mean between two consecutive years of 21.2 cfs decrease when going from a wet year to a dry year and a 42.8 cfs increase when going from a dry year to a wet year.

The annual mean was also determined for recent periods within the record. The 1988 – 1998 period of 51.6 cfs annual mean was calculated due to the fact this period is when the gage below Spearfish was operational. In addition, 1988 -1992 was calculated at 40.7 cfs because it was a dry period when known complaints were received on low flows in the creek downstream of Spearfish. Finally, the period 1993 – 2003 annual mean is 65.3 cfs and reflects a relatively wet period.

Flow Comparison for USGS gages "at" and "below" Spearfish from 1989 – 1998

The USGS gage at Spearfish reflects the creek's flow prior to withdrawals by irrigation ditches. The USGS gage below Spearfish is 1.4 miles upstream from Spearfish Creek's confluence with Redwater River and is located downstream of where the irrigation ditches withdraw water. The

Spearfish Creek gages at Spearfish and below Spearfish provide the ability to analyze flow losses or gains within this reach. This flow comparison is limited to ten irrigation seasons from 1989 through 1998 since the gage below Spearfish was only operational from October 1988 through September 1998. This provides records that include wet and dry periods in South Dakota. It also provides records from 1990 when a documented impairment to the downstream fishery occurred.

The creek below Spearfish can generally be characterized as a gaining stream between the two gages during periods when irrigation withdrawals are not occurring. This is based on records showing increase in flows during winter months. This can likely be attributed to inflow from Spring Branch, Higgins Gulch and other springs. Therefore, for the purpose of determining a low flow when the bypass release at Maurice is suspended during the winter months was not conducted.

The records were reviewed on a monthly and daily mean basis for the period of record when both gaging stations were operational.

Monthly Mean Analysis

Attachment 3 presents three tables which show the monthly mean flow for the gages Spearfish Creek at Spearfish and the Spearfish Creek below Spearfish and the difference between the gaging stations depicted as a flow gain or loss in the reach.

Based on the information for the 10 years of record, the irrigation months of April and October are not critical months when low flows are known to occur. This is likely a reflection that very limited irrigation withdrawals occur during these two months. The greatest loss based on monthly mean occurred in August of 1989 at 33.4 cfs which coincided with a monthly mean flow of 5.8 cfs at the gage below Spearfish and 39.2 cfs for the gage at Spearfish. The lowest monthly mean flow at the gage below Spearfish was 4.48 cfs during July of 1990 while the gage at Spearfish recorded 35.2 cfs mean flow for same month. This is the same month as a complaint and documented fish kill occurred in the stream reach. During the dry years of 1989 through 1991, the mean flow for the months of July and August for the gage below Spearfish did not exceed 10.0 cfs while the mean flows for the same period at Spearfish were between 33 and 41 cfs. Overall on a monthly mean basis, losses attributable to creek withdrawals commonly ranged about 30 cfs. During non-withdrawal periods this is a gaining reach so the actual withdrawals occurring are likely greater than 30 cfs. The year 1994 shows flow similar to the historic annual mean during June through August and the losses approached 30 cfs similar to the earlier dry years. The wetter years of the mid to late 1990's show higher flows when irrigation withdrawal would logically be lower.

Daily Mean Analysis

A possible criticism of analyzing monthly mean flow is that it does not represent day to day flow variations that have the potential for dramatic impacts on beneficial uses in the reach. Therefore, daily mean flows for the 10 year period of record were also reviewed. Attachment 4 provides tables of flow loss between the two gaging stations and the actual daily mean flows for each year when both gages were operational. In addition, the attachment includes a line graph representation of flow loss for the months May through September for the drier years of 1989, 1990, 1991, 1992 and 1994.

Table 2 below summarizes the data from Attachment 4 for the ten year period of record when both gages were active. The left half of the table provides the maximum loss that occurred each year and the associated flow at the USGS gaging station below Spearfish. The three columns on the right show the lowest daily mean flow for each year at the gage below Spearfish and the corresponding flow for the gage at Spearfish for the same day.

Table 2

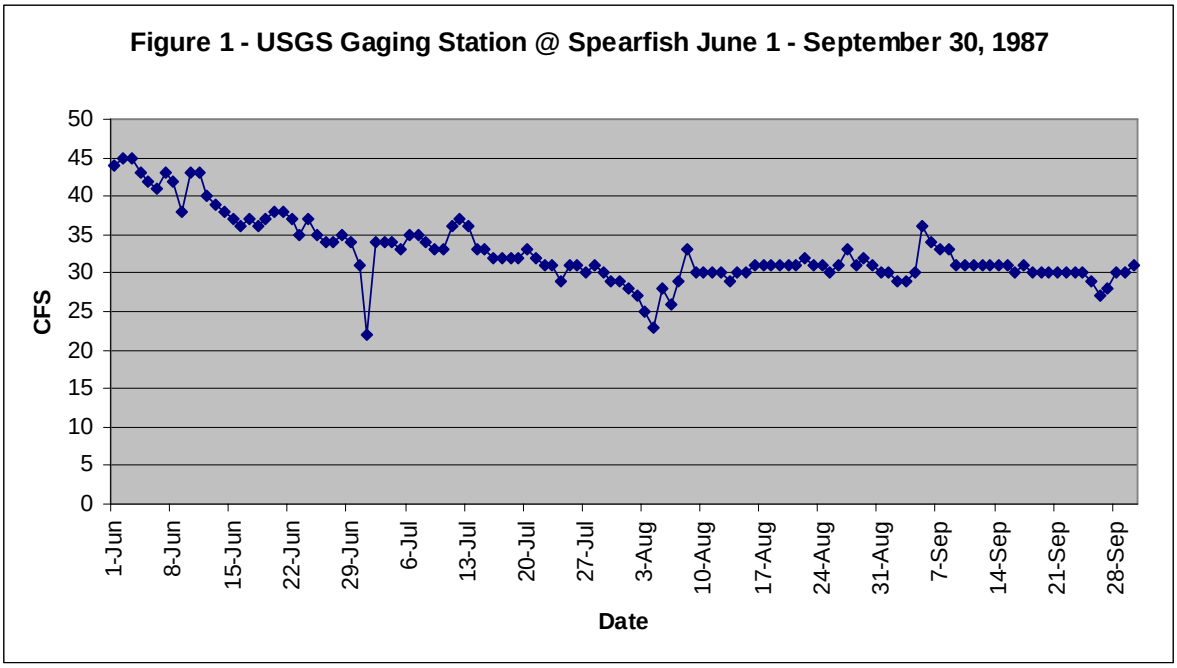
	Maximum Flow Loss				**Lowest Daily Mean Flow at Gaging Station below Spearfish**		
Year	Date	Maximum Loss (cfs)	Flow @ Gage below Spearfish (cfs)		Date	Lowest Flow below Spearfish (cfs)	Flow @ Spearfish (cfs)
1989	Aug. 20	39.7	5.3		July 9	1.7	36
1990	July 5	36.6	1.4		July 3	1.0	37
1991	July 29	39.1	1.9		July 30	1.6	40
1992	May 20	37.4	7.6		Aug. 16	5.1	32
1993	Aug. 25	13.0	29.0		Aug. 25	29.0	42
1994	June 28	46.6	7.4		July 1	6.3	50
1995	May 8	*379.0	825.0		Aug. 30	42.0	64
1996	Aug. 27	25.0	44.0		Aug.27	44.0	69
1997	May 7	36.0	244.0		July 18	72.0	93
1998	Aug. 31	52.0	40.0		Sept. 1	40.0	90

* anomaly due extreme high flow conditions

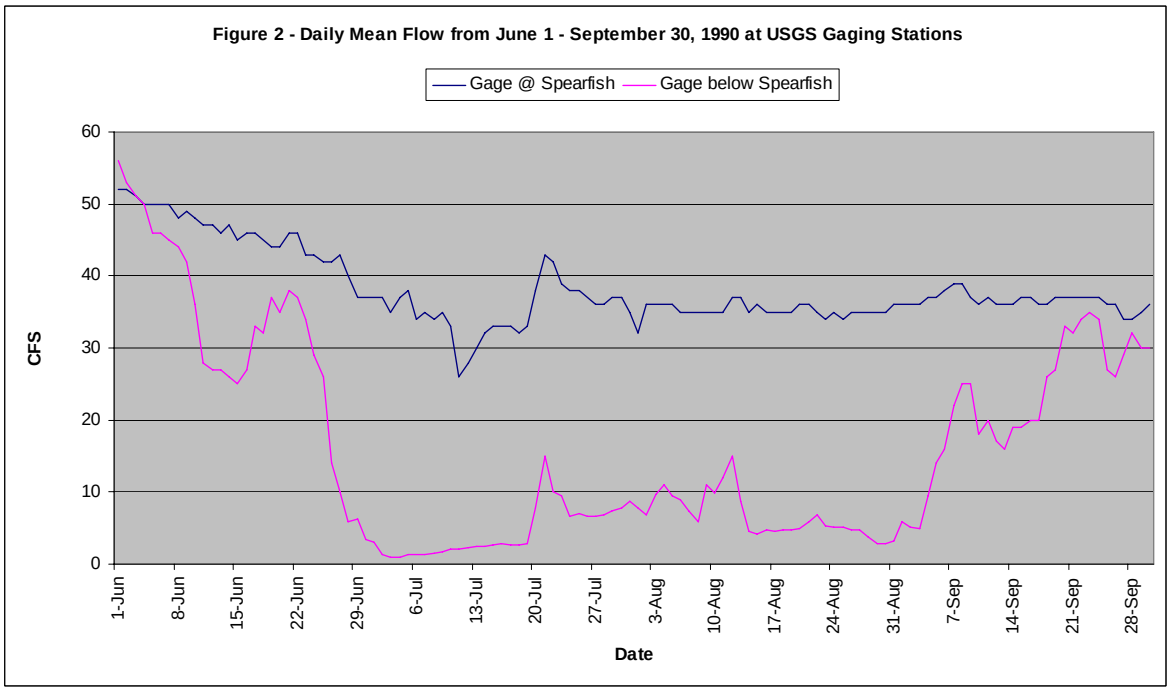
This table indicates that extreme low flow conditions are associated with drier climatic cycles. The dry years of 1989 through 1992 and 1994 provide relevant information to assist in determining flow conditions when the contemplated flow bypass should be suspended. During these years the daily mean flow loss between the two gages approaches 40.0 cfs and the gage below Spearfish nears 1.0 cfs. The columns to the right takes a different approach by finding the lowest mean daily value at the gage below Spearfish and associating it with the reading at the Spearfish gage. However, both reinforce a conclusion that critically low flows occur during the irrigation season when the creek flow at the Spearfish gage approaches 40 cfs.

Complaint and Period of Documented Mortality of Fish

July 1, 1987 -- The Water Rights Program received a call from the SD Department of Game, Fish and Parks personnel that irrigators where diverting the entire Spearfish Creek flow. A review of USGS gaging station records for the gage at Spearfish show the prior weeks daily mean flow was about 34 cfs. Then on July 1st the daily mean flow dropped to 22 cfs. Upon investigation it was found that Homestake Mining Company had a problem with the aqueduct requiring its temporary shutdown. Flow records show that daily mean flows rebounded to 34 cfs by July 2, 1987. Flows remained in the low 30 cfs range and on occasion dipped below 30 cfs until fall. Figure 1 provides the gaging station flow data for June through September of 1987. The USGS gaging station below Spearfish was not in operation at this time.

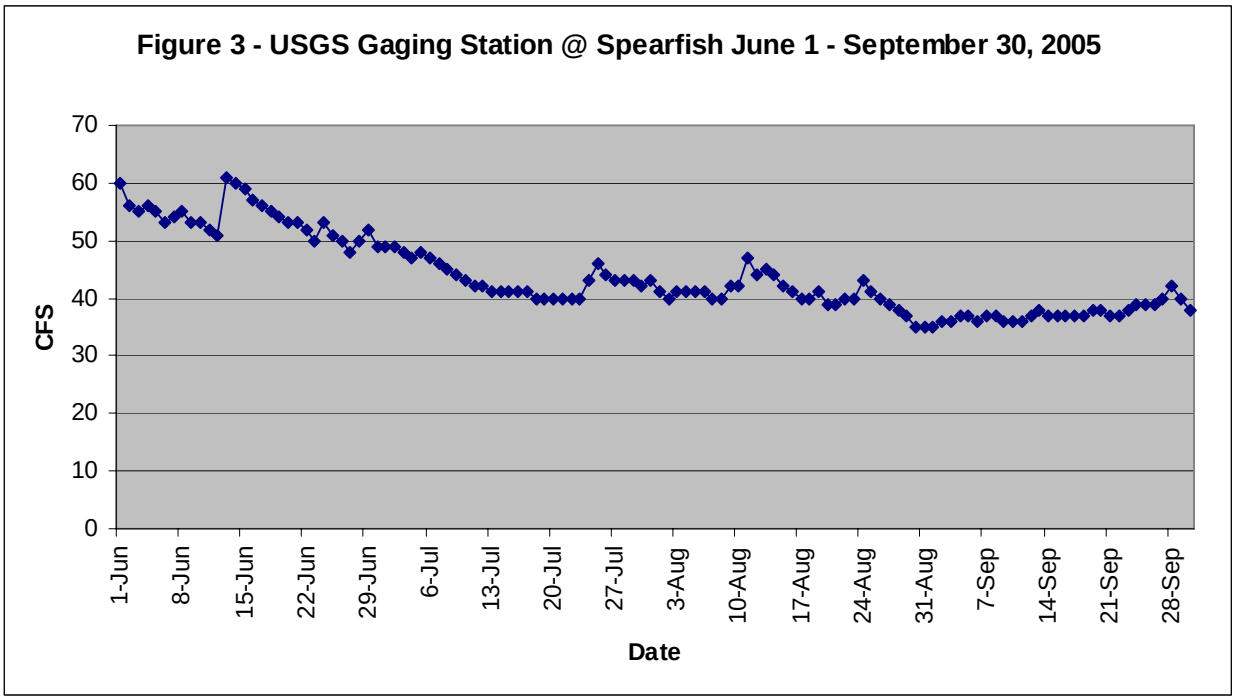


July 2, 1990 – G. Eugene Johnson contacted the Water Rights Program regarding a fish kill in Spearfish Creek near I-90. Game Fish and Parks personnel confirmed hundreds of dead fish in the reach. On that day the USGS gaging station at Spearfish recorded a daily mean flow of 37 cfs while the downstream gage was 1.3 cfs. The flow at the downstream gage remained below 2 cfs for nine days. Figure 2 depicts the flow at the two gaging stations from June through September of 1990.



2005 Irrigation season – The Delphi Study Team and draft application identified 2005 as a year of low flow summer conditions that resulted in thermal mortality of large adult trout north of I-90. The team's report states that "While not measurable, any decrease in tailwater flow could result in an increased, but not quantified, risk of thermal mortality of adult trout during summer

in this reach under present water use practices." Figure 3 provides the gaging station flow data for June through September of 2005.



Discussion

Ideally, the flow at which the bypass release is suspended should be prior to when the downstream beneficial uses are adversely impacted. However, there are many variables which simply can not be predicted that have the potential for impacting the downstream beneficial uses. These include the unpredictability in timing of withdrawals when dealing with nine ditch companies that hold long established and legal vested water rights for the Spearfish Creek. Also extreme air temperature conditions can increase the risk of thermal mortality to aquatic life. Therefore best engineering judgment needs to be exercised to determine the low flow condition that will trigger suspension of the bypass release.

The monthly mean, daily mean and other flow records when known impacts to downstream beneficial uses have occurred show flow at the USGS gaging station at Spearfish in the range of 35 – 40 cfs. The flow data from the 1990 water years provides the best representation since it was an event with a known impact on the downstream beneficial uses when both gaging stations were operational. In that instance flows at the Spearfish gage were 35 to 38 cfs when daily mean flows dropped to 1.0 cfs at the gage below Spearfish. Weighing all factors, a 40 cfs flow measured at the Spearfish gage when normal irrigation withdrawals are occurring is a reasonable flow to trigger suspension of the bypass release. However, implementation of this low flow condition does not mean that impacts to the resource will never occur. For example, in 2005 the flow at the Spearfish gage was 40 cfs when an event occurred resulting in thermal mortality of large adult trout north of I-90. At the same time, the daily mean flow at Spearfish Creek gaging station above Spearfish (Maurice) held consistently at 42 – 44 cfs from mid July through mid September.

There will have to be a greater flow at the Spearfish Creek gage above Spearfish (Maurice) in order to maintain a 40 cfs flow at the gaging station located below the project's outfall. First, the 3.0 cfs contemplated bypass release must be accounted for. Also, there is a loss associated with conveyance of water through the aqueduct. The USGS publication entitled "Streamflow Losses in the Black Hills of Western South Dakota (Water-Resources Investigations Report 98-4116) states the losses within the diversion aqueduct average about 2.0 cfs. In general, a flow of 45 cfs at the Maurice intake is necessary to have a 40 cfs flow at Spearfish.

The 40 cfs flow at the Spearfish gage or 45 cfs flow at the gage above Spearfish both equate very closely to the 80% exceedance of the daily mean flow average over the 7 month irrigation season. Attachment 5 is a table of the 80% exceedance for the gaging station above Spearfish. The 80% exceedance table for the Spearfish Creek gage at Spearfish is included in Attachment 1.

A 43 cfs flow at the Spearfish Creek gage at Spearfish is necessary to account for the proposed 3 cfs bypass release. This equates to 75% exceedance of the daily mean flow averaged over the 7 month irrigation season.

Conclusions

1. The USGS gaging station located at Spearfish (USGS 06431500) most accurately reflects flows in the downstream reach for use in assessing potential impacts to downstream beneficial uses.

2. Monthly flow exceedances for the Spearfish Creek @ Spearfish gage averaged over the 7 month irrigation season are: 75% exceedance - 43.1 cfs; 80% exceedance – 40.5 cfs; 90% exceedance – 35.8 cfs; 95% exceedance – 31.7 cfs.

3. The annual mean flow for the Spearfish Creek @ Spearfish gage during the period of record is 55.5 cfs.

4. The annual mean flow for the Spearfish Creek @ Spearfish gage for the dry period of 1988 -1992 is 40.7 cfs.

5. The months of April and October are not critical months when extreme low flows in the reach below Spearfish are known to occur.

6. The Spearfish Creek @ Spearfish gage and Spearfish Creek below Spearfish were both operational during the 1989 through 1998 irrigation seasons.

7. The average loss based on monthly mean flow records for the ten years when both gages were in operation commonly ranged around 30 cfs. This number is not a reflection of total irrigation withdrawal since the downstream reach is a gaining stream due to tributary inflow and return flows. Actual irrigation withdrawals are likely on average greater than 30 cfs.

8. An analysis of the daily mean flow loss between the two gages approaches 40 cfs during drier years of record.

9. Daily mean flow records for the gaging station below Spearfish have been reduced to 1.0 cfs.

10. Critical low flows in the downstream reach occur during the period May through September when the creek flow at the Spearfish gage approaches 40 cfs.

11. A complaint was been received on impairment to the downstream beneficial uses when the daily mean for gaging stations “at” and “below” Spearfish were 37 cfs and 1.3 cfs, respectively.

12. In 2005, the flow at Spearfish gage was approximately 40 cfs when an event occurred resulting in thermal mortality of large adult trout north of I-90.

13. Under normal conditions a flow of 45 cfs will be necessary at the gage above Spearfish (Maurice) to account for the bypass flow and conveyance loss in the aqueduct.

14. A 40 cfs flow at the Spearfish Creek at Spearfish gage equates closely to the 80% exceedance of the daily mean flow average over the 7 month irrigation season. A 43 cfs flow is necessary to account for a 3 cfs bypass release equates closely to the 75% exceedance of the daily mean flow average at the Spearfish Creek at Spearfish gage.

Final Conclusion

Suspension of releases to the bypassed reach shall occur when the flow as measured at the USGS gaging station 06431500 (Spearfish Creek @ Spearfish) during the months May through September measure 40 cfs or less.

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ATTACHMENT 1

75% Exceedance (Spearfish Creek @ Spearfish - 61 years of record)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	33	32	35	41	56	53	43	36	35	36	36	35
2	34	33	35	41	57	53	43	37	36	37	36	36
3	33	33	35	41	58	51	43	39	36	37	38	37
4	32	34	34	41	57	51	43	37	36	37	38	36
5	34	33	35	42	56	51	46	36	36	37	39	36
6	34	34	36	44	54	50	43	36	37	36	38	36
7	34	34	35	45	53	51	43	36	36	38	38	35
8	34	33	35	43	55	49	41	38	35	38	38	34
9	35	34	35	43	56	49	41	36	35	35	37	34
10	34	33	36	43	56	49	41	35	36	37	38	36
11	35	34	35	47	56	48	41	35	36	37	38	35
12	34	34	35	48	56	48	41	35	36	37	37	35
13	34	34	35	49	58	47	41	36	35	36	37	34
14	34	34	34	47	57	49	41	37	36	38	38	34
15	34	33	35	49	58	51	39	36	35	38	37	34
16	34	34	36	51	58	47	39	36	35	37	37	34
17	34	34	36	50	58	49	39	36	35	39	38	34
18	34	34	36	48	58	48	40	36	35	38	38	34
19	34	34	37	49	59	50	39	37	37	38	38	34
20	33	34	36	48	56	47	40	38	36	37	38	33
21	33	34	36	50	56	48	40	36	36	38	36	33
22	33	35	36	50	57	47	40	35	37	37	36	33
23	34	34	36	52	58	47	39	35	36	37	36	33
24	34	34	36	52	56	45	39	35	35	37	35	33
25	32	34	36	53	55	46	38	36	36	37	38	34
26	34	35	37	52	55	46	38	36	36	37	38	34
27	34	35	40	53	54	45	38	35	36	37	36	34
28	34	35	40	55	55	45	40	34	38	36	38	34
29	33	37	39	53	54	45	39	34	37	36	36	34
30	32		39	53	55	45	39	34	38	37	35	34
31	33		40		55		38	35		37		34
	Average			47.8	56.2	48.3	40.5	35.9	36.0	37.1		
7- Month Irrigation Season Exceedance							43.1					
5 Critical Months (May - September)							**43.4**					

80% Exceedance (Spearfish Creek @ Spearfish - 61 years of record)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	32	32	34	38	51	52	43	35	34	34	36	33
2	32	32	34	39	54	50	41	35	33	36	35	36
3	32	32	34	40	54	51	42	36	34	34	36	36
4	31	32	33	40	53	50	41	36	34	36	36	35
5	32	32	33	42	53	49	41	34	35	35	36	34
6	32	33	34	42	52	48	41	34	34	34	37	34
7	33	33	34	43	51	48	41	34	34	35	36	34
8	32	32	34	41	49	47	40	34	33	36	37	34
9	32	32	34	42	51	49	40	34	33	35	36	32
10	31	32	34	42	53	48	37	34	33	36	36	34
11	32	33	32	44	51	47	37	34	33	36	36	34
12	32	33	33	43	51	46	38	34	34	36	36	33
13	33	34	33	42	53	46	38	35	34	36	36	33
14	33	33	33	46	54	47	39	33	35	36	35	32
15	32	32	34	47	52	47	37	34	34	36	36	33
16	33	31	36	47	51	46	37	35	34	36	35	33
17	33	32	35	47	49	48	37	35	33	36	36	32
18	32	33	34	48	53	45	38	35	34	36	36	32
19	32	32	35	48	52	47	36	34	35	36	36	32
20	31	32	35	46	53	46	39	34	35	36	36	31
21	32	33	35	47	53	46	38	34	34	36	35	32
22	32	34	36	47	53	45	38	33	35	36	35	33
23	33	33	36	49	53	44	38	35	34	36	35	30
24	31	33	36	49	53	43	37	34	34	36	35	32
25	32	33	36	48	52	43	37	35	34	36	36	31
26	32	34	36	48	53	44	37	34	35	37	35	33
27	33	34	37	50	51	43	36	34	35	36	35	33
28	31	34	40	49	51	42	38	34	35	36	36	31
29	31	36	37	50	52	43	37	33	35	36	35	32
30	31		38	50	53	42	38	33	36	36	34	32
31	32		39		53		36	33		37		34
		Average		45.1	52.2	46.4	35.8	34.2	34.2	35.8		
7- Month Irrigation Season Exceedance							40.5					
5 Critical Months (May - September)							**40.6**					

90% Exceedance (Spearfish Creek @ Spearfish - 61 years of record)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	29	29	29	36	46	47	37	31	29	29	33	31
2	30	29	30	37	46	45	36	32	29	29	33	31
3	28	28	30	37	46	45	36	32	30	29	32	33
4	28	28	30	36	46	44	37	33	30	29	31	33
5	29	30	30	36	46	43	38	32	31	30	32	28
6	28	29	32	40	45	42	37	32	31	31	33	29
7	29	29	32	38	44	43	35	31	31	31	33	29
8	30	30	32	39	46	42	36	33	31	31	33	28
9	30	29	30	38	46	41	35	32	30	32	33	29
10	30	29	31	36	47	43	33	32	31	33	33	30
11	28	29	30	36	45	41	32	30	31	33	33	28
12	29	31	28	36	44	40	34	31	31	34	33	31
13	30	31	28	38	43	39	35	30	31	34	31	31
14	31	30	28	39	43	41	33	30	30	32	31	28
15	29	29	30	39	44	41	33	30	30	32	31	29
16	30	30	31	42	42	41	33	31	30	33	32	29
17	30	29	30	41	42	39	32	31	29	33	32	28
18	29	29	32	42	44	43	32	30	30	33	33	29
19	30	30	32	43	43	39	32	29	29	33	33	26
20	28	29	32	41	44	38	33	30	30	34	33	26
21	25	29	31	44	43	39	31	31	30	34	32	27
22	25	31	32	43	44	39	31	31	30	33	30	25
23	27	30	33	44	44	38	33	31	30	34	30	24
24	26	31	33	44	44	38	30	31	30	34	31	25
25	28	30	34	44	43	39	30	30	31	33	32	26
26	27	31	34	44	43	40	31	31	31	34	29	28
27	26	31	34	46	42	40	31	30	32	33	27	28
28	29	30	34	44	41	39	31	31	30	34	27	25
29	27	30	35	46	43	38	30	31	31	33	30	26
30	28		35	46	46	39	32	30	31	32	29	26
31	30		36		49		32	30		32		29
			Average	40.5	44.3	40.9	31.7	30.9	30.3	32.3		
7- Month Irrigation Season Exceedance							35.8					
5 Critical Months (May - September)							35.6					

95% Exceedance (Spearfish Creek @ Spearfish)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	24	28	28	30	39	40	34	29	26	24	28	27
2	28	26	28	35	38	39	34	27	25	24	30	26
3	24	24	28	31	40	39	33	29	26	25	27	30
4	24	24	28	34	41	37	34	27	28	27	28	31
5	26	25	26	32	44	37	33	28	26	27	24	25
6	25	24	28	36	43	40	34	29	25	28	28	27
7	26	28	27	34	43	35	31	29	26	28	31	26
8	29	28	27	34	43	35	30	30	25	30	32	24
9	25	27	27	33	44	38	31	30	26	30	30	27
10	24	27	27	32	43	37	29	30	26	30	30	27
11	26	28	26	32	43	40	27	27	25	30	31	24
12	26	27	26	30	42	38	28	27	25	32	30	25
13	27	29	26	31	41	38	30	26	26	30	30	26
14	26	28	24	34	41	35	31	28	25	30	27	24
15	27	28	26	35	41	38	30	27	25	30	30	25
16	26	27	27	36	41	38	28	26	25	31	26	25
17	27	27	29	39	37	37	29	28	25	30	29	26
18	26	27	29	39	39	36	32	29	24	28	29	25
19	25	27	28	40	40	35	31	26	25	28	32	22
20	25	27	28	40	40	37	31	28	24	31	26	22
21	23	26	29	40	39	37	30	28	23	28	31	21
22	23	28	30	40	39	37	28	26	25	32	28	18
23	22	28	31	42	41	35	28	30	24	30	28	20
24	25	27	30	42	37	36	27	26	25	30	29	20
25	24	28	32	41	39	35	26	26	26	28	28	24
26	24	27	32	43	38	34	27	27	26	30	25	23
27	25	26	31	41	40	34	27	26	26	30	25	22
28	24	27	32	42	38	35	27	25	30	32	25	20
29	23		30	40	38	34	28	27	27	29	26	24
30	25		34	40	40	35	27	29	27	28	26	25
31	25		34		42		29	27		29		25
	Average			36.6	40.5	36.7	28.0	27.6	25.6	29.0		
7- Month Irrigation Season Exceedance							32.0					
5 Critical Months (May - September)							31.7					

Attachment 2

Annual Mean Flows from 1947 - 2007

Spearfish Gage at Spearfish

1947	56.8
1948	50.5
1949	47.3
1950	42.9
1951	37.5
1952	48.1
1953	46.2
1954	39.6
1955	45.5
1956	38.2
1957	40.8
1958	39.3
1959	34.6
1960	31.3
1961	27.1
1962	39.2
1963	53.7
1964	60.5
1965	79.5
1966	58.3
1967	56.3
1968	50.6
1969	52.4
1970	70.1
1971	63.1
1972	71.8
1973	74.6
1974	59.2
1975	54.8
1976	62.2
1977	57.3
1978	64.6
1979	55.4
1980	47.8
1981	41.7
1982	84.5
1983	65.1
1984	67.8
1985	46.6
1986	48.5
1987	39.6
1988	40.6
1989	41.6
1990	41.8
1991	40.7
1992	39

1993	44.2
1994	54.9
1995	82.1
1996	79.9
1997	97.2
1998	88.3
1999	105.8
2000	88.8
2001	70.8
2002	56.1
2003	59.7
2004	45.3
2005	46.6
2006	53.4
2007	59.1

55.5 cfs	Annual Mean from 1947 - 2007
51.6 cfs	Annual Mean from 1988 - 1998
40.7 cfs	Annual Mean from 1988 - 1992
65.3 cfs	Annual Mean from 1993 - 2003

Attachment 3, Monthly Mean for Gages at Spearfish & below Spearfish from 1988 - 1998

Spearfish Creek below Spearfish (in cfs)

	April	May	June	July	August	Sept	Oct
1988							49.5
1989	54.9	63	31.7	8.79	5.8	30.5	48.6
1990	55.7	68.6	32.3	4.48	6.65	22.4	36.8
1991	52.1	82.6	67.2	9.68	7.41	29.2	40.9
1992	47.2	21.4	16	18.3	14.2	30.7	38.9
1993	59.4	76	80.9	58.5	41.4	44.5	54.7
1994	87.8	92.5	27.1	26.1	26	40.8	87.9
1995	78.7	294	160.9	96.3	53.7	60.8	86.2
1996	116.3	138	134.2	69.2	58.5	81.9	104
1997	131.1	185	111.9	91.6	94.5	79.3	92.7
1998	105.7	78.6	127.2	84.3	94.1	58.9	

Spearfish Creek @ Spearfish (in cfs)

	April	May	June	July	August	Sept	Oct
1988							40
1989	43	72.5	44.6	38.4	39.2	39.3	37.2
1990	56.8	69.3	45.9	35.2	35.2	36.5	34.6
1991	43.6	70.8	63.3	41	33	34.3	39.1
1992	45.5	48.7	37.8	35.2	32.9	31.2	32.1
1993	52.1	71	74.7	50.1	42.9	43.8	46.8
1994	91.9	95.9	54.5	55.5	52.3	55.3	75.3
1995	60.7	269	110	81.9	63.9	65	71.3
1996	93.2	118	114.5	74.4	74.1	78.8	75.4
1997	138.8	189	107.4	96.6	86.5	83.1	86.2
1998	89	89.2	123.3	89.1	106	71.4	

Difference between Spearfish Creek @ Spearfish & Spearfish Creek below Spearfish

	April	May	June	July	August	Sept	Oct
1988							9.5
1989	11.9	-9.5	-12.9	-29.6	-33.4	-8.8	11.4
1990	-1.1	-0.7	-13.6	-30.7	-28.6	-14.1	2.2
1991	8.5	11.8	3.9	-31.3	-25.6	-5.1	1.8
1992	1.7	-27.3	-21.8	-16.9	-18.7	-0.5	6.8
1993	7.3	5.0	6.2	8.4	-1.5	0.7	7.9
1994	-4.1	-3.4	-27.4	-29.4	-26.3	-14.5	12.6
1995	18.0	24.9	50.9	14.4	-10.2	-4.2	14.9
1996	23.1	20.7	19.7	-5.2	-15.6	3.1	28.2
1997	-7.7	-3.5	4.5	-5.0	8.0	-3.8	6.5
1998	16.7	-10.6	3.9	-4.8	-11.9	-12.5	

A positive number represents a gain in the stream flow as you progress downstream

A negative number (in yellow) represents a loss in the stream likely attributable to irrigation withdrawals

ATTACHMENT

4

Flow loss between Spearfish Creek @ Spearfish and Spearfish Creek Below Spearfish for 4/1/1989 thru 10/31/1989

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT			
1			10	28	36.1	27				
2		2	9	31.4	37.3	28				
3		2	4	33.5	35.6	26				
4		4	4	33.8	33.5	24				
5			9	34.6	31.5	19				
6			9	34.8	30.4	17				
7		1	11	34.2	29.7	21				
8		2	8	34.8	32.8	21				
9		3	7	34.3	34.4	15				
10		2	7	34.3	32.4	10				
11		1	5	33.4	29	10				
12		4	5	33.2	28	8				
13		0	7	34	28.5	5				
14		2	7	36.6	31.8	7				
15		5	15	36.5	33.5	8				
16		6	18	36.7	33	9				
17		7	15	30.4	35.9	9				
18		9	19	24	34.7	10				
19		13	22	13	36.6	14				
20		14	21	15	39.7	5				
21		10	20	15	36.8					
22		15	22	18	38.1	1				
23		18	24	17	36.7					
24	4	19	14	23	36.5					
25	7	17	9	26	37					
26		19	14	27.1	35.9					
27		26	11	29.6	32.7					
28	1	32	15	34.1	32.5					
29		25	18	35.9	29.9					
30		24	26	30	29.8					
31		16		36.2	26					

Mean Daily Flow for Spearfish Creek Gage below Spearfish for April 1, 1989 through October 31, 1989

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1	62	59	38	11	3.9	11	47
2	63	60	37	8.6	3.7	11	47
3	61	71	46	4.5	3.4	12	45
4	60	78	46	3.2	6.5	15	47
5	54	92	43	3.4	6.5	19	48
6	60	92	35	2.2	7.6	20	47
7	58	94	34	2.8	7.3	16	45
8	56	98	36	2.2	5.2	18	47
9	57	97	37	1.7	4.6	24	46
10	51	87	39	1.7	7.6	28	49
11	55	81	39	2.6	9	29	50
12	54	77	40	1.8	10	31	49
13	53	81	39	2	9.5	33	52
14	50	77	36	5.4	7.2	31	53
15	49	70	29	6.5	5.5	30	51
16	54	67	25	4.3	6	28	51
17	55	69	28	7.6	4.1	29	47
18	54	64	24	15	3.3	29	48
19	51	58	25	26	3.4	23	49
20	50	57	19	20	5.3	37	46
21	51	57	19	21	5.2	51	49
22	52	50	18	22	3.9	41	47
23	51	46	19	21	3.3	41	45
24	40	42	39	16	3.5	45	44
25	37	42	40	12	4	45	44
26	49	38	32	9.9	4.1	43	47
27	72	28	32	8.4	5.3	45	51
28	69	23	24	5.9	6.5	43	56
29	61	28	20	6.1	7.1	43	60
30	58	33	14	11	6.2	43	51
31		38		6.8	11		50

Mean Daily Flow for Spearfish Creek Gage @ Spearfish for April 1, 1989 through October 31, 1989

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1	38	57	48	39	40	38	41
2	38	62	46	40	41	39	40
3	39	73	50	38	39	38	36
4	36	82	50	37	40	39	39
5	34	90	52	38	38	38	39
6	41	92	44	37	38	37	38
7	38	95	45	37	37	37	38
8	37	100	44	37	38	39	39
9	39	100	44	36	39	39	37
10	34	89	46	36	40	38	38
11	36	82	44	36	38	39	37
12	37	81	45	35	38	39	36
13	36	81	46	36	38	38	35
14	38	79	43	42	39	38	37
15	39	75	44	43	39	38	37
16	43	73	43	41	39	37	35
17	41	76	43	38	40	38	36
18	43	73	43	39	38	39	36
19	40	71	47	39	40	37	37
20	40	71	40	35	45	42	35
21	46	67	39	36	42	49	37
22	46	65	40	40	42	42	38
23	47	64	43	38	40	40	36
24	44	61	53	39	40	39	35
25	44	59	49	38	41	41	36
26	47	57	46	37	40	40	37
27	66	54	43	38	38	42	37
28	70	55	39	40	39	38	38
29	59	53	38	42	37	40	39
30	55	57	40	41	36	40	38
31		54		43	37		36

Flow loss between Spearfish Creek @ Spearfish and Spearfish Creek Below Spearfish for 4/1/1990 thru 10/31/1990

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1	3			33.9	24.3	30.2	4
2	2			35.7	29.1	30.9	5
3	7			34	26.4	31	5
4	7			36	25	27.6	8
5	1		4	36.6	26.5	23	9
6			4	32.6	26.1	22	5
7		1	5	33.7	27.6	17	1
8			4	32.5	29.2	14	1
9	6		7	33.2	24	12	1
10	13	3	12	30.9	25.2	18	
11	5	3	19	24	23	17	
12		4	20	25.8	22	19	
13	4	3	19	27.6	28.2	20	
14	7	7	21	29.6	30.5	17	
15	4	9	20	30.3	31.9	18	
16	3	9	19	30.1	30.3	17	
17		3	13	30.3	30.5	16	
18		4	13	29.3	30.3	10	
19	1	3	7	30.2	30.3	10	
20	1	1	9	30.3	31	4	
21	3	3	8	28	30.2	5	
22		3	9	32	28.2	3	
23		2	9	29.5	28.6	2	
24			14	31.3	29.8	3	
25			16	31	28.9	9	
26	1		28	30.3	30.3	10	
27			33	29.4	30.2	5	
28	1		34.2	29.1	31.2	2	
29			30.8	29.6	32.2	5	
30			33.6	29.2	32.1	6	
31				26.2	32.7		

Mean Daily Flow for Spearfish Gage below Spearfish for April 1, 1990 through October 31, 1990

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	45	65	56	3.1	7.7	5.8	30
2	45	66	53	1.3	6.9	5.1	29
3	44	67	51	1	9.6	5	29
4	49	71	50	1	11	9.4	26
5	49	80	46	1.4	9.5	14	25
6	47	82	46	1.4	8.9	16	29
7	49	81	45	1.3	7.4	22	32
8	51	80	44	1.5	5.8	25	33
9	49	76	42	1.8	11	25	34
10	41	71	36	2.1	9.8	18	37
11	46	68	28	2	12	20	37
12	54	67	27	2.2	15	17	38
13	47	68	27	2.4	8.8	16	38
14	45	72	26	2.4	4.5	19	41
15	50	70	25	2.7	4.1	19	40
16	53	70	27	2.9	4.7	20	39
17	54	74	33	2.7	4.5	20	44
18	56	69	32	2.7	4.7	26	41
19	58	68	37	2.8	4.7	27	40
20	60	70	35	7.7	5	33	40
21	62	68	38	15	5.8	32	40
22	68	64	37	10	6.8	34	39
23	72	65	34	9.5	5.4	35	36
24	69	66	29	6.7	5.2	34	36
25	69	65	26	7	5.1	27	37
26	66	63	14	6.7	4.7	26	38
27	69	61	10	6.6	4.8	29	37
28	66	61	5.8	6.9	3.8	32	43
29	70	60	6.2	7.4	2.8	30	45
30	67	60	3.4	7.8	2.9	30	45
31		58		8.8	3.3		44

Mean Daily Flow for Spearfish Creek Gage @ Spearfish for April 1, 1990 through October 31, 1990

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	48	57	52	37	32	36	34
2	47	61	52	37	36	36	34
3	51	64	51	35	36	36	34
4	56	70	50	37	36	37	34
5	50	79	50	38	36	37	34
6	47	82	50	34	35	38	34
7	47	82	50	35	35	39	33
8	48	79	48	34	35	39	34
9	55	76	49	35	35	37	35
10	54	74	48	33	35	36	35
11	51	71	47	26	35	37	35
12	51	71	47	28	37	36	35
13	51	71	46	30	37	36	35
14	52	79	47	32	35	36	35
15	54	79	45	33	36	37	35
16	56	79	46	33	35	37	35
17	54	77	46	33	35	36	36
18	54	73	45	32	35	36	35
19	59	71	44	33	35	37	35
20	61	71	44	38	36	37	35
21	65	71	46	43	36	37	35
22	66	67	46	42	35	37	35
23	67	67	43	39	34	37	35
24	67	65	43	38	35	37	35
25	67	65	42	38	34	36	35
26	67	61	42	37	35	36	35
27	67	60	43	36	35	34	33
28	67	57	40	36	35	34	34
29	66	56	37	37	35	35	34
30	60	57	37	37	35	36	34
31		55		35	36		35

Flow loss between Spearfish Creek @ Spearfish and Spearfish Creek Below Spearfish for 4/1/1991 thru 10/31/1991

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1				25	30.8	22.9	2
2				24	32.6	23.2	8
3				25	32.4	23.4	5
4				25	32.2	22.9	
5				30	32.1	22	
6				30	27.4	17	
7				29	25.7	17	
8				14	22	16	
9				27	23.6	11	
10				29	23.7	10	
11				27	25	10	4
12				30	23	8	2
13				32	26	5	4
14				32	27.4	4	1
15				31.5	27	3	
16				31.6	27.1		
17				32.7	29.7		
18				32	28.8		
19				31.1	22.2		
20				36.8	21.5		
21				35.6	23		
22				35.6	23.4		
23			8	35.5	23.7		
24			4	34.6	25.4		
25			6	35	24		
26			13	34.8	23.9		
27			19	34.5	22.3		
28			22	38.2	22	1	
29			24	39.1	21	1	
30			27	38.4	22.7	3	4
31				36	22.8		10

Mean Daily Flow for Spearfish Creek Gage below Spearfish for April 1, 1991 through October 31, 1991

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1	47	56	87	20	2.2	9.1	34
2	46	54	81	19	2.4	8.8	29
3	48	56	87	19	2.6	8.6	32
4	48	55	103	18	2.8	9.1	41
5	49	54	95	17	2.9	10	41
6	51	51	101	14	6.6	15	36
7	51	50	110	15	7.3	16	42
8	53	53	102	25	12	17	40
9	53	58	99	14	9.4	21	40
10	50	66	95	16	9.3	22	38
11	52	65	89	22	11	23	36
12	55	70	82	14	12	25	37
13	52	65	77	12	10	28	37
14	49	64	83	11	5.6	29	40
15	50	82	77	9.5	5	31	42
16	49	95	72	7.4	4.9	36	44
17	48	102	69	7.3	3.3	37	43
18	49	104	65	6	5.2	36	44
19	50	96	62	3.9	9.8	40	46
20	49	96	57	2.2	9.5	38	49
21	49	90	49	2.4	8	40	51
22	51	99	44	2.4	7.6	47	51
23	51	122	37	2.5	8.3	45	50
24	52	118	37	2.4	7.6	49	44
25	56	115	33	3	8	45	45
26	63	107	32	3.2	8.1	43	45
27	67	110	25	3.5	9.7	42	46
28	61	110	24	2.8	11	35	52
29	58	102	23	1.9	10	35	31
30	56	102	19	1.6	9.3	35	30
31		94		2	8.2		32

Mean Daily Flow for Spearfish Creek Gage @ Spearfish for April 1, 1991 through October 31, 1991

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1	39	46	76	45	33	32	36
2	39	46	74	43	35	32	37
3	42	46	73	44	35	32	37
4	42	46	91	43	35	32	39
5	42	45	83	47	35	32	38
6	45	43	84	44	34	32	34
7	45	43	93	44	33	33	38
8	44	46	91	39	34	33	39
9	43	55	87	41	33	32	38
10	44	60	84	45	33	32	38
11	43	60	79	49	36	33	40
12	42	66	72	44	35	33	39
13	42	60	68	44	36	33	41
14	41	61	66	43	33	33	41
15	41	75	65	41	32	34	41
16	41	86	61	39	32	34	41
17	41	91	59	40	33	34	41
18	41	92	52	38	34	36	40
19	41	85	50	35	32	37	41
20	41	83	48	39	31	35	41
21	43	78	46	38	31	35	42
22	45	80	44	38	31	38	41
23	45	101	45	38	32	35	40
24	45	103	41	37	33	35	41
25	49	99	39	38	32	38	42
26	48	89	45	38	32	37	42
27	50	86	44	38	32	36	42
28	49	87	46	41	33	36	36
29	48	82	47	41	31	36	29
30	46	79	46	40	32	38	34
31		77		38	31		42

Flow loss between Spearfish Creek @ Spearfish and Spearfish Creek Below Spearfish for 4/1/1992 thru 10/31/1992

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1		15	26	18	16	6	6
2		12	26	21	20	4	6
3		15	29.9	24	18	7	4
4		19	28.9	14	20	6	3
5	1	25	27	16	17	4	1
6		28	22	16	18	3	
7	2	30	17	16	18		
8	1	30	18	20	19		
9	2	26	23	17	21		
10	1	17	24	16	19		
11		20	22	14	21		
12		24	24	14	25.4		
13		27	27	9	24.6		
14		30	23	13	24.5		
15	1	30	19	17	25.8	1	
16	1	29	16	20	26.9	1	
17	1	31	21	17	26.9	3	
18		35	22	20	23.5	5	
19		34.9	21	21	23.3	2	
20		37.4	19	22	24.2	6	
21		35.4	18	24	23.6	7	
22		32	19	21	23	4	
23		30	24	21	19	4	
24		30	22	19	21	4	
25		29	20	13	15	4	
26		30	21	14	14	2	
27		29	22	14	10	1	
28		27	14	12	5		
29	3	30	16	13	4		
30	11	31.2	22	14	7	3	
31		28		15	6		

Mean Daily Flow for Spearfish Creek Gage below Spearfish for April 1, 1992 through October 31, 1992

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	47	49	14	18	16	29	23
2	45	49	13	15	15	30	23
3	40	43	9.1	14	15	27	26
4	41	38	8.1	25	15	27	26
5	41	32	12	23	16	29	27
6	42	25	19	21	15	30	28
7	40	22	22	18	15	42	38
8	40	23	20	17	15	40	34
9	40	26	16	17	14	42	34
10	40	40	14	19	13	40	40
11	46	34	12	20	9	41	40
12	45	28	12	23	5.6	39	40
13	45	26	11	28	5.4	38	40
14	42	20	11	23	5.5	36	40
15	42	19	19	18	5.2	29	45
16	42	18	22	14	5.1	28	45
17	42	17	17	17	6.1	26	44
18	47	11	16	15	5.5	24	41
19	62	9.1	17	15	5.7	27	41
20	54	7.6	18	14	5.8	25	41
21	50	7.6	19	13	8.4	24	41
22	49	15	21	14	10	26	42
23	51	13	14	16	20	26	43
24	50	13	15	17	17	25	44
25	51	13	15	20	21	24	46
26	53	12	15	20	22	27	45
27	56	13	17	20	23	31	46
28	59	11	24	21	29	32	43
29	61	8	23	17	29	29	45
30	53	7.8	14	17	26	27	48
31		14		18	28		48

Mean Daily Flow for Spearfish Creek Gage @ Spearfish for April 1, 1992 through October 31, 1992

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	38	64	40	36	32	35	29
2	38	61	39	36	35	34	29
3	38	58	39	38	33	34	30
4	41	57	37	39	35	33	29
5	42	57	39	39	33	33	28
6	42	53	41	37	33	33	28
7	42	52	39	34	33	34	29
8	41	53	38	37	34	32	31
9	42	52	39	34	35	33	34
10	41	57	38	35	32	32	37
11	43	54	34	34	30	32	36
12	43	52	36	37	31	32	36
13	42	53	38	37	30	32	34
14	42	50	34	36	30	32	32
15	43	49	38	35	31	30	32
16	43	47	38	34	32	29	33
17	43	48	38	34	33	29	33
18	45	46	38	35	29	29	33
19	51	44	38	36	29	29	32
20	45	45	37	36	30	31	32
21	44	43	37	37	32	31	34
22	45	47	40	35	33	30	32
23	48	43	38	37	39	30	32
24	47	43	37	36	38	29	33
25	48	42	35	33	36	28	33
26	49	42	36	34	36	29	33
27	52	42	39	34	33	32	33
28	59	38	38	33	34	30	33
29	64	38	39	30	33	29	31
30	64	39	36	31	33	30	32
31		42		33	34		32

Flow loss between Spearfish Creek @ Spearfish and Spearfish Creek Below Spearfish for 4/1/1993 thru 10/31/1993

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1						4	1
2							
3							
4							
5							1
6							
7							
8							
9			1				
10		2	2		7	1	
11		2	4		6		
12		3	1		6		
13			3		5		
14							
15					3		
16					2		
17					6		
18					5		
19					6		
20					1		
21					2		
22							
23						1	
24					3	3	
25					13	5	
26					12	4	
27					9	5	
28					12	6	
29					11	5	
30					9	3	
31					8		

Mean Daily Flow for Spearfish Creek Gage below Spearfish for April 1, 1993 through October 31, 1993

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	50	77	57	69	52	37	48
2	47	76	58	69	52	44	52
3	47	72	57	67	52	42	50
4	48	72	59	63	53	40	50
5	51	77	58	64	53	47	48
6	53	92	56	63	47	49	52
7	55	93	80	71	52	48	52
8	53	103	102	62	50	45	56
9	54	97	99	60	43	42	54
10	56	96	98	59	35	38	58
11	56	96	96	57	34	38	56
12	56	91	99	59	33	42	59
13	56	89	90	57	40	42	60
14	56	85	86	56	46	42	53
15	56	83	82	55	42	42	55
16	56	82	86	55	41	46	59
17	56	77	91	55	36	42	57
18	57	73	86	59	40	46	53
19	59	69	89	54	39	51	54
20	60	67	87	53	50	51	54
21	59	66	88	57	45	49	54
22	60	71	92	54	45	48	55
23	61	66	91	55	45	47	56
24	69	64	83	57	38	46	58
25	70	63	81	54	29	46	56
26	73	62	80	56	31	46	56
27	76	60	79	56	34	44	57
28	77	58	71	53	31	46	57
29	74	62	76	53	31	45	56
30	80	58	71	53	32	45	54
31		58		59	32		57

Mean Daily Flow for Spearfish Creek Gage @ Spearfish for April 1, 1993 through October 31, 1993

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	39	71	54	62	42	41	49
2	41	68	48	60	42	44	48
3	41	68	49	57	42	39	47
4	42	65	49	56	42	40	49
5	42	74	48	55	42	39	49
6	44	83	48	53	39	43	47
7	44	87	58	54	45	40	49
8	45	94	94	51	42	40	50
9	47	96	100	48	43	39	52
10	53	98	100	48	42	39	48
11	55	98	100	49	40	38	50
12	53	94	100	50	39	38	49
13	51	87	93	51	45	40	47
14	50	85	85	50	46	40	47
15	49	80	82	50	45	41	50
16	46	77	79	50	43	43	52
17	45	69	81	50	42	42	48
18	48	64	80	49	45	43	47
19	50	61	82	46	45	48	47
20	51	57	84	45	51	48	47
21	50	55	84	50	47	47	45
22	50	59	82	48	45	46	45
23	53	61	79	46	42	48	43
24	64	58	75	45	41	49	45
25	64	57	75	46	42	51	43
26	64	56	71	49	43	50	41
27	70	55	67	49	43	49	45
28	70	57	64	47	43	52	45
29	69	57	65	46	42	50	43
30	72	56	65	46	41	48	40
31		53		46	40		43

Flow loss between Spearfish Creek @ Spearfish and Spearfish Creek Below Spearfish for 4/1/1994 thru 10/31/1994

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1			17	43.7	27	11	
2			24	41.8	36	17	
3		5	26	41.3	33	26	1
4		7	33	40.8	31	25	
5		15	33	40.4	30	27	
6		13	34	31	31	26	
7		8	28	27	34	27	
8		10	25	31	33	28	
9		12	26	38	33	28	
10		7	19	39	27	30	
11		8	21	41	20	28	
12		2	22	37	21	27	
13		2	21	27	22	28	
14		2	23	25	23	28	
15		12	24	25	23	25	
16			16	23	24	19	
17			16	23	17	10	
18	5		15	27	16	5	
19	19		22	28	21	6	9
20	16		21	32	21	12	23
21	18	2	23	30	23	6	20
22	25		26	27	25		5
23	50		29	25	27		
24	45		33	25	31	1	
25	46	1	34	25	32	1	
26	37	3	36.2	24	32	3	
27	22		38.6	22	30	2	
28	16	2	46.6	13	25	2	
29	5	11	47.8	16	24		
30		13	41.8	21	25		
31		12	0	21	16		

Mean Daily Flow for Spearfish Creek Gage below Spearfish for April 1, 1994 through October 31, 1994

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	61	112	43	6.3	28	42	63
2	62	109	36	9.2	17	38	57
3	65	112	34	7.7	20	30	57
4	68	116	32	9.2	20	28	63
5	68	113	32	9.6	21	29	62
6	66	116	31	22	20	30	114
7	66	118	32	30	21	29	131
8	67	115	35	27	24	28	115
9	66	110	34	17	25	26	104
10	69	108	36	16	28	25	98
11	70	105	34	15	29	25	96
12	72	104	33	15	30	26	90
13	73	105	34	32	30	27	86
14	76	104	32	33	30	27	82
15	78	102	31	34	28	31	79
16	79	101	39	34	29	38	87
17	85	98	36	35	34	42	91
18	88	94	35	32	30	48	101
19	96	89	28	31	28	48	99
20	101	89	25	28	28	44	96
21	101	83	25	27	27	52	94
22	103	80	24	30	26	58	93
23	113	75	21	32	24	57	90
24	118	77	15	32	22	55	88
25	125	74	12	33	21	54	87
26	132	72	9.8	33	21	54	86
27	124	71	9.4	35	23	55	84
28	115	63	7.4	41	26	54	83
29	113	54	8.2	37	28	60	84
30	113	52	8.2	33	29	63	83
31		48		32	40		81

Mean Daily Flow for Spearfish Creek Gage @ Spearfish for April 1, 1994 through October 31, 1994

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	48	106	60	50	55	53	57
2	51	106	60	51	53	55	57
3	51	117	60	49	53	56	58
4	55	123	65	50	51	53	59
5	53	128	65	50	51	56	60
6	53	129	65	53	51	56	81
7	54	126	60	57	55	56	105
8	58	125	60	58	57	56	80
9	57	122	60	55	58	54	71
10	60	115	55	55	55	55	65
11	57	113	55	56	49	53	64
12	59	106	55	52	51	53	60
13	64	107	55	59	52	55	60
14	73	106	55	58	53	55	57
15	69	114	55	59	51	56	56
16	75	95	55	57	53	57	57
17	78	90	52	58	51	52	57
18	93	85	50	59	46	53	74
19	115	85	50	59	49	54	108
20	117	85	46	60	49	56	119
21	119	85	48	57	50	58	114
22	128	80	50	57	51	58	98
23	163	75	50	57	51	57	89
24	163	75	48	57	53	56	87
25	171	75	46	58	53	55	84
26	169	75	46	57	53	57	84
27	146	70	48	57	53	57	79
28	131	65	54	54	51	56	77
29	118	65	56	53	52	55	77
30	109	65	50	54	54	56	75
31		60		53	56		65

Flow loss between Spearfish Creek @ Spearfish and Spearfish Creek Below Spearfish for 4/1/1995 thru 10/31/1995

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1						20	
2						19	
3					3	21	
4					10	20	
5					5	21	
6					3	21	
7					5	16	
8		379			1	16	
9		80			4	16	
10					4	7	
11					4	14	
12		15			8	17	
13					6	17	
14					6	23	
15					12	21	
16					9	18	
17					11	20	
18					15	20	
19					17	13	
20					18	8	
21					17	12	
22					17		
23					18		
24					24		
25					22		
26					7		
27					10		
28					14		
29					16		
30					22		
31					19		

Mean Daily Flow for Spearfish Creek Gage below Spearfish for April 1, 1995 through October 31, 1995

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	69	109	181	117	75	44	93
2	69	106	177	116	71	45	93
3	70	104	177	109	64	43	95
4	71	108	171	110	56	44	124
5	71	102	171	109	60	43	132
6	71	107	166	98	61	43	105
7	72	118	160	107	58	45	93
8	72	446	155	100	61	49	93
9	74	1,310	165	98	58	53	91
10	74	890	164	99	56	58	88
11	74	612	155	98	58	50	82
12	74	445	155	93	56	47	78
13	75	530	157	94	59	46	77
14	77	413	160	98	59	40	78
15	78	341	156	95	51	43	78
16	78	296	154	111	53	46	78
17	79	261	150	102	51	44	74
18	79	236	148	98	47	45	76
19	81	224	145	95	48	54	75
20	81	215	142	94	47	58	74
21	80	205	237	96	46	54	76
22	78	193	209	97	46	82	87
23	80	190	190	86	44	100	85
24	83	190	169	84	39	96	80
25	84	178	151	89	41	94	80
26	88	174	143	90	59	91	82
27	91	178	137	85	54	91	84
28	93	216	133	82	51	93	83
29	95	213	129	81	49	91	84
30	99	203	120	76	42	91	78
31		191		78	45		76

Mean Daily Flow for Spearfish Creek Gage @ Spearfish for April 1, 1995 through October 31, 1995

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	58	64	129	98	66	64	65
2	58	64	120	96	68	64	65
3	58	64	119	94	67	64	66
4	58	66	114	92	66	64	74
5	58	75	107	92	65	64	82
6	57	89	104	90	64	64	75
7	57	88	98	90	63	61	74
8	57	825	100	88	62	65	73
9	57	1,390	106	85	62	69	73
10	56	787	111	84	60	65	73
11	55	530	108	83	62	64	72
12	56	460	107	80	64	64	75
13	58	485	103	78	65	63	74
14	58	387	105	80	65	63	75
15	61	318	103	85	63	64	74
16	64	277	102	100	62	64	73
17	64	231	102	90	62	64	71
18	64	203	100	85	62	65	71
19	64	181	94	82	65	67	74
20	64	167	92	80	65	66	72
21	64	155	119	78	63	66	71
22	64	142	122	76	63	65	73
23	64	137	149	74	62	66	70
24	64	131	128	72	63	66	68
25	64	122	119	70	63	67	68
26	64	115	113	69	66	66	68
27	64	124	113	70	64	66	72
28	64	184	108	70	65	66	70
29	64	174	105	70	65	67	70
30	64	156	100	70	64	67	69
31		141		68	64		59

Flow loss between Spearfish Creek @ Spearfish and Spearfish Creek Below Spearfish for 4/1/1996 thru 10/31/1996

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1				3	3	3	
2				7	4		
3				8	8		
4				12	9		
5				16	8		
6					15		
7					15	1	
8				4	17	2	
9				2	18	3	
10					11		
11					14		
12					16		
13					13		
14				8	15		
15				8	11	1	
16				3	17		
17				6	22		
18				14	20		
19				14	13		
20				14	17		
21				17	20		
22				16	22		
23				15	24		
24				15	22		
25				16	21		
26				2	21		
27			6		25		
28			4		25		
29			4		21		
30			2		13		
31				1	2		

Mean Daily Flow for Spearfish Creek Gage below Spearfish for April 1, 1996 through October 31, 1996

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	71	127	230	78	72	71	90
2	77	129	214	74	70	83	91
3	92	122	188	73	67	81	89
4	87	123	175	67	66	78	91
5	86	125	167	64	67	76	91
6	90	124	155	95	60	80	89
7	103	122	157	81	60	76	92
8	115	122	144	72	58	73	87
9	117	136	138	74	56	72	90
10	120	121	134	77	64	77	92
11	127	120	133	78	61	77	92
12	127	120	133	76	59	76	91
13	126	124	130	74	61	76	85
14	127	127	135	65	57	76	92
15	129	125	135	65	63	81	87
16	128	125	133	66	58	81	93
17	132	125	132	64	53	81	105
18	135	124	127	57	55	96	106
19	125	121	130	56	62	89	110
20	125	118	121	56	57	88	124
21	125	115	124	55	54	86	117
22	124	115	125	55	53	86	114
23	127	123	130	55	51	85	110
24	126	141	111	56	53	82	107
25	125	136	100	56	50	86	110
26	125	132	98	73	43	88	152
27	125	164	83	80	44	90	125
28	122	192	82	80	45	92	124
29	125	207	82	77	54	87	127
30	127	229	81	72	69	87	122
31		250		75	73		116

Mean Daily Flow for Spearfish Creek Gage @ Spearfish for April 1, 1996 through October 31, 1996

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	67	95	174	81	75	74	79
2	75	100	158	81	74	77	79
3	83	105	143	81	75	81	79
4	77	105	135	79	75	78	78
5	76	105	127	80	75	76	79
6	80	105	126	86	75	78	79
7	91	105	126	81	75	77	80
8	96	110	121	76	75	75	80
9	97	110	117	76	74	75	77
10	97	110	117	75	75	75	73
11	98	110	119	74	75	76	71
12	98	110	119	73	75	76	72
13	97	110	118	73	74	76	65
14	98	115	118	73	72	75	69
15	98	115	118	73	74	82	65
16	98	115	115	69	75	76	71
17	100	115	112	70	75	76	73
18	100	115	110	71	75	80	70
19	99	110	110	70	75	84	72
20	98	110	109	70	74	85	76
21	99	110	105	72	74	83	75
22	98	110	100	71	75	83	73
23	97	110	105	70	75	81	73
24	96	110	99	71	75	79	71
25	97	110	98	72	71	80	70
26	97	110	92	75	64	80	80
27	101	127	89	72	69	82	85
28	98	150	86	72	70	83	82
29	95	164	86	72	75	83	82
30	95	182	83	71	82	79	80
31		185		76	75		79

Flow loss between Spearfish Creek @ Spearfish and Spearfish Creek Below Spearfish for 4/1/1997 thru 10/31/1997

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1		4		2		4	
2				6		6	
3		1		5		8	
4		9		3		2	
5	5	23				3	
6		22				4	
7	12	36				4	
8	12	24	3	3		6	
9	13	2	3	1		1	
10	17		4	4		4	
11	17	10		7		7	
12	16			3		10	
13	18			5		7	
14	13	1		3		7	
15	8	3		15		6	
16	10			17		5	
17	9	2		22		10	
18	4			21	2	19	
19				17	1	16	
20				10		8	
21	29					8	
22		5		4		3	
23		2		8			
24				12			
25	5	4		16			
26	10			7			
27	12						
28	27		1				
29	21						
30	3	3					
31							

Mean Daily Flow for Spearfish Creek Gage below Spearfish for April 1, 1997 through October 31, 1997

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	112	195	125	104	98	75	82
2	110	210	122	99	94	75	79
3	107	172	123	96	96	73	81
4	111	165	121	97	97	76	83
5	115	186	114	99	101	74	84
6	113	219	109	100	105	74	87
7	107	244	105	94	103	74	90
8	103	264	100	89	102	74	101
9	100	255	100	89	98	79	101
10	94	245	102	85	94	76	97
11	89	247	115	83	97	74	100
12	87	235	114	94	97	73	99
13	85	221	109	88	99	74	98
14	90	208	111	87	96	76	97
15	97	195	123	76	95	77	98
16	93	189	111	73	98	81	96
17	102	187	112	69	96	76	93
18	113	194	111	72	92	68	91
19	116	181	111	83	92	75	90
20	117	160	116	87	94	80	91
21	190	154	113	102	94	80	92
22	232	151	108	92	95	90	91
23	210	143	112	89	93	92	89
24	185	142	114	86	91	89	95
25	167	138	109	93	87	90	93
26	156	151	105	94	94	89	94
27	159	152	107	107	89	87	100
28	174	145	109	101	85	86	96
29	201	138	114	105	85	86	96
30	199	131	111	101	87	86	95
31		129		107	85		95

Mean Daily Flow for Spearfish Creek Gage @ Spearfish for April 1, 1997 through October 31, 1997

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	108	199	121	106	95	79	81
2	108	199	119	105	92	81	80
3	109	173	121	101	90	81	84
4	110	174	113	100	88	78	82
5	120	209	108	97	92	77	82
6	110	241	108	96	90	78	83
7	119	280	105	94	91	78	85
8	115	288	103	92	91	80	89
9	113	257	103	90	89	80	88
10	111	245	106	89	88	80	87
11	106	257	110	90	87	81	87
12	103	235	103	97	84	83	90
13	103	219	105	93	88	81	91
14	103	209	104	90	92	83	90
15	105	198	102	91	91	83	90
16	103	189	105	90	91	86	89
17	111	189	105	91	93	86	86
18	117	188	105	93	94	87	87
19	116	174	107	100	93	91	85
20	117	158	110	97	80	88	88
21	219	148	107	101	79	88	87
22	222	156	107	96	78	93	87
23	199	145	106	97	77	87	85
24	182	141	105	98	75	89	87
25	172	142	105	109	82	85	87
26	166	148	105	101	82	84	85
27	171	151	105	100	81	81	86
28	201	145	110	100	81	83	85
29	222	137	105	98	83	82	86
30	202	134	105	95	83	79	85
31		129		98	81		87

Flow loss between Spearfish Creek @ Spearfish and Spearfish Creek Below Spearfish for 4/1/1998 thru 9/30/1998

in cubic feet of water per second

	APR	MAY	JUN	JUL	AUG	SEP	OCT
1			22	13		50	
2			28			39	
3			31			38	
4			26			34	
5		7	23			36	
6		10	19	14		39	
7		17	9	27		42	
8		17		33		30	
9		9	1	23		26	
10		3		23	2	28	
11		4	4	18		27	
12		2	1	17	4	13	
13				7	7		
14				2	14	11	
15			3		16	13	
16		1	5	6	25	11	
17		9	5	22	28	9	
18		14		25	19	4	
19		12		22	2		
20		10		14	7		
21		9		12	8	6	
22		6			9	9	
23		21			14	11	
24		31			20	6	
25		29			33		
26		26			38		
27		23	5		44		
28		22	10		29		
29		40	5		34		
30		26	12		47		
31		23			52		

Mean Daily Flow for Spearfish Creek Gage below Spearfish for April 1, 1998 through September 30, 1998

in cubic feet of water per second

	Apr	May	Jun	Jul	Aug	Sep	Oct
1	101	109	58	94	102	40	
2	99	106	50	97	108	41	
3	98	102	49	98	122	46	
4	102	95	56	95	140	48	
5	110	92	57	90	120	49	
6	112	88	60	75	117	48	
7	109	79	68	60	112	44	
8	105	79	88	53	113	54	
9	104	87	81	59	109	53	
10	103	94	78	61	105	50	
11	106	91	74	71	106	51	
12	117	98	76	70	106	58	
13	116	100	79	75	107	69	
14	111	96	81	82	99	59	
15	111	94	78	77	95	48	
16	107	89	77	72	88	46	
17	107	78	84	57	84	47	
18	105	71	392	68	91	51	
19	102	70	485	68	99	57	
20	100	73	320	73	98	70	
21	97	75	233	73	105	77	
22	97	75	186	82	95	69	
23	100	62	174	139	90	66	
24	105	51	151	105	84	69	
25	108	52	140	105	77	71	
26	108	54	125	101	70	72	
27	109	53	111	99	67	76	
28	107	53	105	97	62	76	
29	108	54	102	109	57	76	
30	108	55	98	107	49	87	
31		61		102	40		

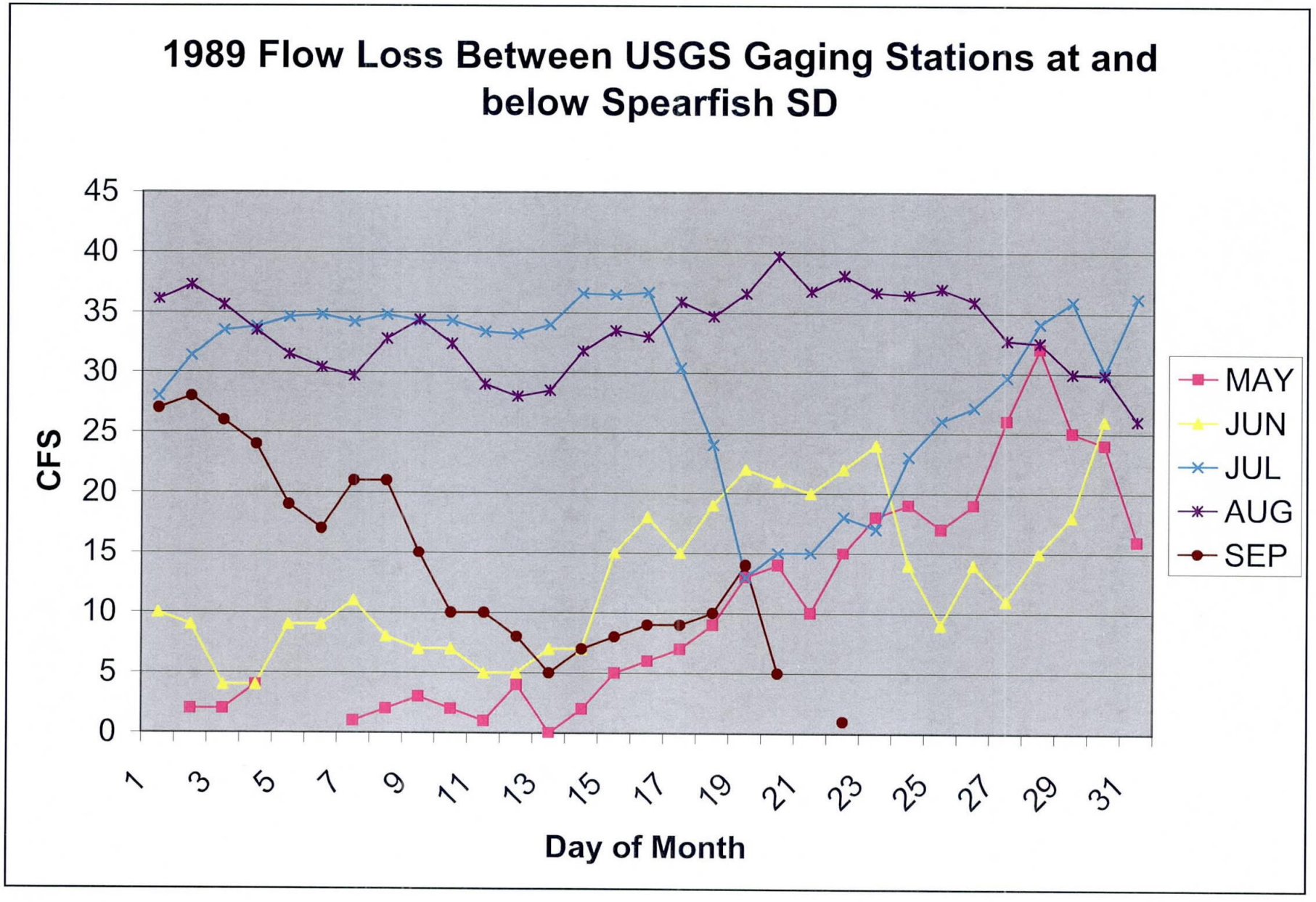
Mean Daily Flow for Spearfish Creek Gage @ Spearfish for April 1, 1998 through September 30, 1998

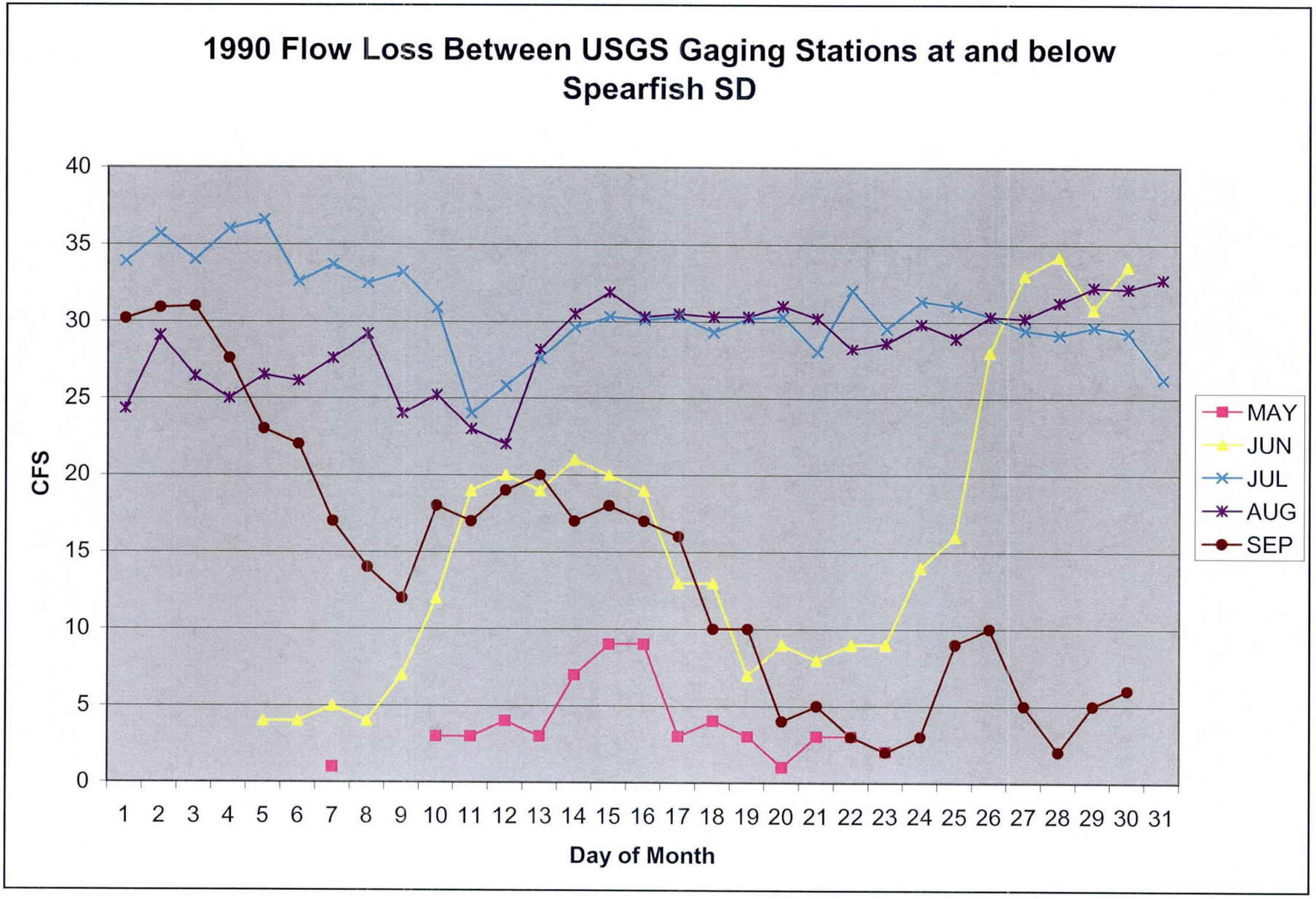
in cubic feet of water per second

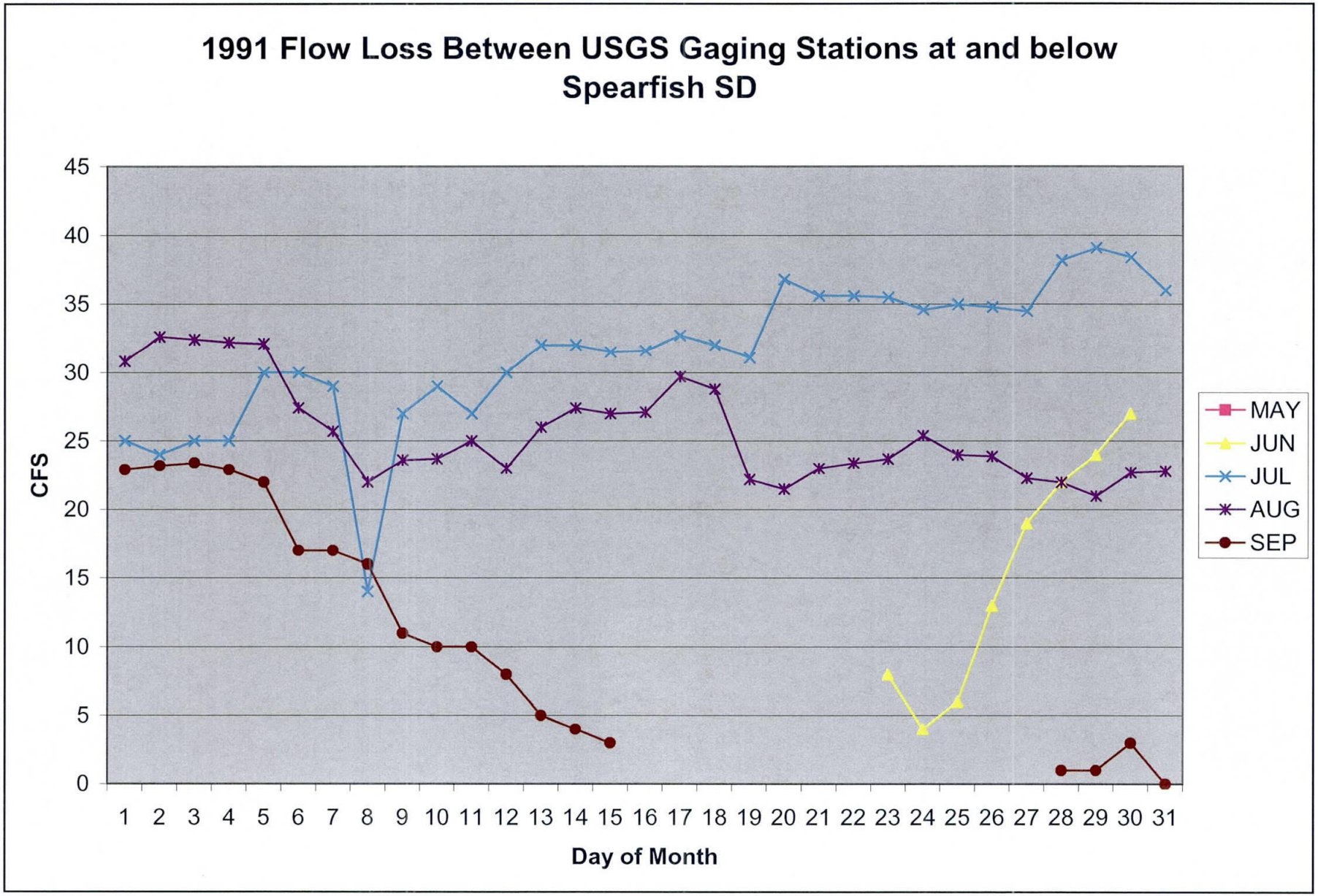
	Apr	May	Jun	Jul	Aug	Sep	Oct
1	93	96	80	107	94	90	
2	93	95	78	97	98	80	
3	93	96	80	95	104	84	
4	91	94	82	98	113	82	
5	81	99	80	90	119	85	
6	83	98	79	89	110	87	
7	82	96	77	87	108	86	
8	81	96	88	86	106	84	
9	81	96	82	82	107	79	
10	79	97	78	84	107	78	
11	83	95	78	89	106	78	
12	93	100	77	87	110	71	
13	96	94	77	82	114	65	
14	92	94	81	84	113	70	
15	90	92	81	75	111	61	
16	87	90	82	78	113	57	
17	85	87	89	79	112	56	
18	84	85	390	93	110	55	
19	84	82	340	90	101	54	
20	82	83	233	87	105	66	
21	82	84	184	85	113	83	
22	83	81	167	82	104	78	
23	86	83	159	86	104	77	
24	95	82	148	84	104	75	
25	103	81	139	94	110	64	
26	103	80	123	92	108	53	
27	100	76	116	92	111	52	
28	96	75	115	94	91	55	
29	94	94	107	108	91	69	
30	94	81	110	96	96	69	
31		84		91	92		

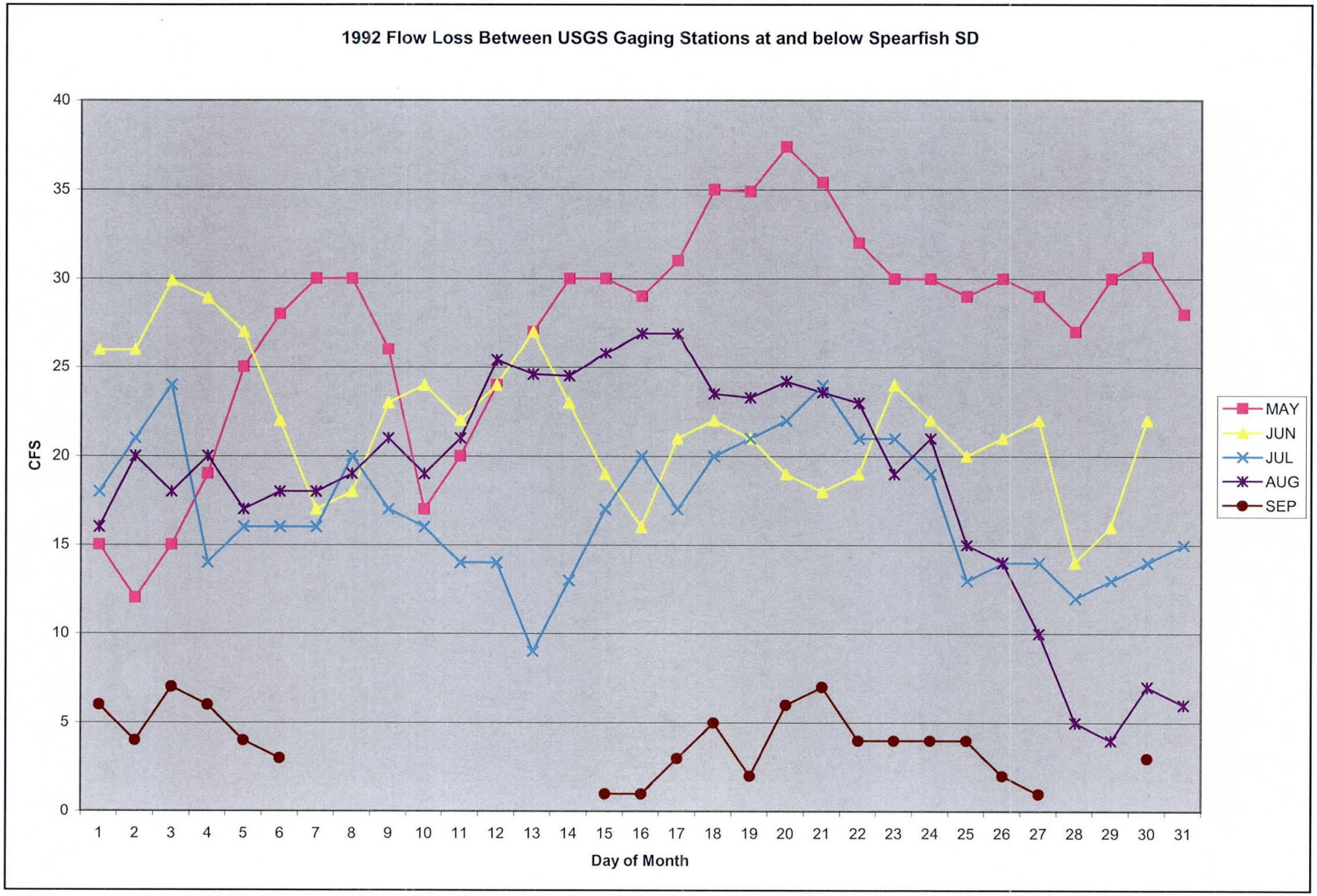
ATTACHMENT 5 80% Exceedance for USGS Gaging Station (06430900) Spearfish Creek above Spearfish (Maurice)

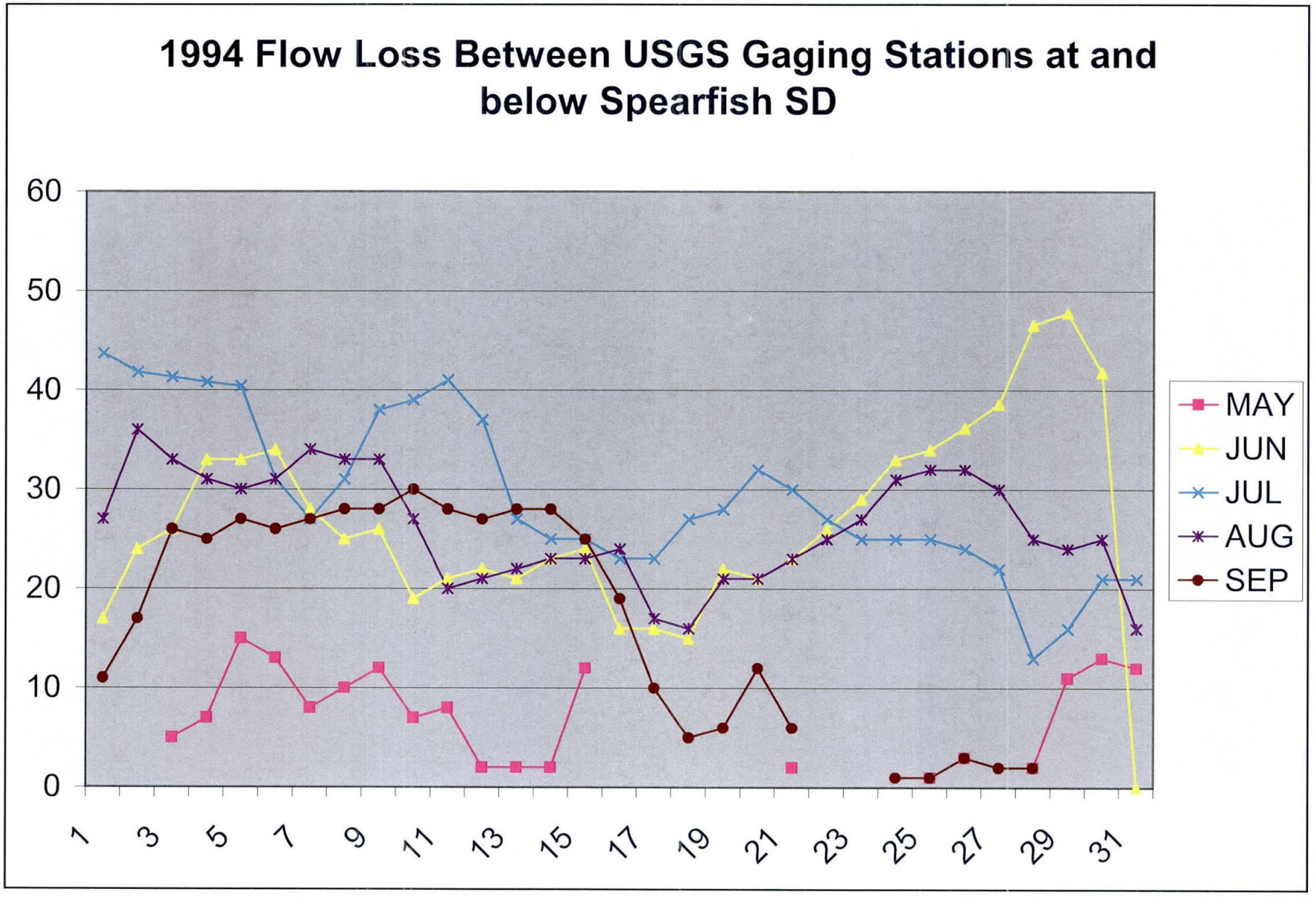
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	38	36	39	44	58	53	43	39	38	36	36	36
2	38	36	38	45	57	52	44	39	37	37	37	36
3	37	35	39	46	54	52	43	39	37	38	39	36
4	36	36	38	45	53	51	42	40	37	39	40	37
5	40	37	40	46	53	53	44	40	38	39	41	35
6	34	37	39	49	52	52	42	40	38	40	40	37
7	34	38	40	49	54	52	41	39	40	38	40	37
8	39	36	40	49	58	51	43	39	39	38	39	36
9	39	37	39	49	66	51	42	38	39	39	40	37
10	38	38	41	47	68	51	42	39	37	37	41	37
11	39	37	42	47	70	51	42	39	37	38	39	34
12	37	37	42	47	68	51	43	40	37	37	40	35
13	37	36	41	46	69	50	44	39	36	38	39	36
14	36	36	42	48	68	50	43	37	37	39	39	34
15	39	34	40	49	69	48	43	36	36	39	38	34
16	39	33	40	51	68	50	42	37	36	37	37	34
17	38	36	41	51	67	49	42	38	35	39	39	34
18	35	36	40	51	66	49	42	37	36	37	38	33
19	38	36	40	51	63	49	41	37	37	38	40	32
20	38	39	40	52	61	49	43	40	39	39	39	32
21	41	38	41	53	60	47	42	38	37	39	39	34
22	39	39	40	54	62	47	42	37	38	39	39	35
23	37	38	39	56	60	48	42	38	37	38	38	38
24	39	38	41	55	57	49	41	37	39	37	38	41
25	37	38	43	54	55	49	41	37	39	37	39	40
26	38	39	43	57	54	48	40	36	36	38	37	39
27	38	40	43	58	53	47	40	36	37	38	38	39
28	38	39	44	59	54	45	42	37	37	37	38	38
29	40		43	58	54	44	41	35	36	37	38	39
30	37		44	58	55	44	41	36	37	37	38	36
31	37		43		54		39	37		36		38
Average	38	37	41	51	60	49	42	38	37	38	39	36
7 - Month Irrigation Season Exceedance					**45**							
5 Critical Months (May - September)					45							


1989 Flow Loss Between USGS Gaging Stations at and below Spearfish SD
CFS
45
40
35
30
25
20
15
10
5
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
Day of Month
MAY
JUN
JUL
AUG
SEP


1990 Flow Loss Between USGS Gaging Stations at and below Spearfish SD
CFS
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Day of Month
MAY
JUN
JUL
AUG
SEP


1991 Flow Loss Between USGS Gaging Stations at and below Spearfish SD
CFS
45
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Day of Month
MAY
JUN
JUL
AUG
SEP


1992 Flow Loss Between USGS Gaging Stations at and below Spearfish SD
CFS
Day of Month
MAY
JUN
JUL
AUG
SEP


1994 Flow Loss Between USGS Gaging Stations at and below Spearfish SD
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
MAY
JUN
JUL
AUG
SEP