PART III

ANALYSES AND CONCLUSIONS

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In this part of the report, it is the purpose of the Panel to present Area VIII Chloride Control project data, and to use these data to determine the effectiveness of the project in accomplishing project objectives to improve water quality, as presented in "Supplemental Data to Arkansas - Red River Basin Chloride Control, Red River Basin, Design Memorandum No. 25, General Design, Phase I - Plan Formulation," Volume I, Department of the Army, Tulsa District, Corps of Engineers, Tulsa, Oklahoma, November 1980. The flow and chloride concentration data of Memorandum No. 25 were taken from Design Memorandum No. 3, U.S. Army Corps of Engineers, Tulsa District, Oklahoma, August 1972.

ACHIEVEMENT OBJECTIVES

As presented and explained in Memorandum No. 25, it is estimated that in the case of Area VIII, the Chloride Control project will intercept and divert 85 percent of the estimated 195 tons of chlorides that are entering the South Wichita River on the average day, upstream of the Ross Ranch pumping station site, by way of spring flows and seeps[1]. It is specifically noted and emphasized by the Panel that in the economic reanalysis of 1980, no benefits were credited to the project until all project elements of the areas recommended for construction were completed. Following completion of project construction, which was estimated in the 1980 report to be 1990, the water quality benefits were phased in as Red River Water was used[2]. The benefits were then allowed to grow as the use of the Red River water increased. Thus, it is the observation of the Panel, that the economic reanalysis of 1980 was based upon appropriate concepts, insofaras the benefits to water quality are concerned. Therefore, the task of the Panel can best be accomplished by evaluating physical parameters.

In its consideration of the 1980 reanalysis, the Panel concluded that the data currently being collected by the U.S. Geological Survey at the Bateman gages located upstream and downstream of the Bateman Pump Station, and the Benjamin gage located on the South Wichita River, approximately 50 river miles downstream of Bateman, were all that could be effectively used. The Panel further concluded that these data should be sufficient to allow proper evaluation of the effects of Area VIII operation. The Panel also determined that it would be unnecessary and outside the charge of the Panel to review the benefit reanalysis to decide if project benefits are being realized, but that a qualitative analysis of water quality would be sufficient. Therefore, the remainder of the Panel's efforts were directed toward analysis of stream flows, pump diversions at the Bateman station, and water quality data in order to evaluate the effectiveness of the existing parts of Area VIII Chloride Control project in the accomplishment of the levels of water quality improvement that were forecast for these parts of the Chloride Control project[3]. The results of these analyses and comparison are presented below.

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[1] "Design Memorandum No. 25, General Design, Phase I - Plan Formulation, "Department of the Army, Tulsa District, Corps of Engineers, Tulsa, Oklahoma, November 1980; page II-16.

[2] Ibid pages III-97, III-105, and III-106.

[3] Panel meeting minutes of October 28, 1987.

PERFORMANCE AT BATEMAN

In the following discussion, data in the first full year of operation (from May 1, 1987 through April 30, 1988) of the Bateman Pump Station are presented and analyzed. Table 6 shows a summary of flows and chloride concentrations in the South Wichita River upstream from the pump station. Flows measured at the site averaged 12.5 cfs while loads were 222 tons/day for this period. The spilled portion averaged 5.3 cfs and 30.5 tons/day and an average of 7.2 cfs with a load of 192 tons/day was diverted (see Table 5). Figures 4 and 5 show graphical presentations of the flow and chloride data presented in Table 5.

A comparison of these records shows that diversions of the more saline low flows resulted in an 86-percent reduction (192 of 222 tons/day) of the chloride load in the flow passing downstream from the Bateman Pump Station. This occurred even though an average of more than 138 tons/day of chloride was spilled during the two shutdowns. (During the test period two pipeline breaks occurred reducing the effectiveness of the pumping effort. The first occurred January 11, 1988 necessitating 10 days of down-time. The second break was on April 22, 1988 necessitating 7 days of down-time. In both cases the breaks were quickly repaired and pumping resumed.)

The average degree of control was less than expected due to high flows in May 1987 (this was the wettest month of record). Flow in May averaged 58.7 cfs with a load of 313 tons/day. Pumping caught 5.7 cfs (about 10 percent of the flow) and 155 tons/day (about half of the load). In comparison, pumping diverted 89 percent (7.4 of the average flow of 8.3 cfs), and 91 percent (195 of the average load of 214 tons/day) for the period June 1987 through April 1988.

Only one other period of record exists for the Bateman location other than the present period of record which began October 1, 1984. This was during the water years of 1971 through 1976 which appears to represent relatively "average" flow conditions based on observations of the 27 years of record available for the Benjamin gaging stations (see Table 7). Projected chloride diversions were simulated for the 1971-76 period by assuming the Bateman Pumping station and diversion were in operation, and the data are presented in Table 8. The simulated data is based on the assumption that the same operating strategy and similar breakdowns occurred during that period as during the actual period of operation between May 1, 1987 and April 30, 1988.

Important observations which can be made from reviewing the data in Table 8 are:

On averages approximately 87 percent or more of the chlorides occurring upstream of the Bateman Pump Stations can be removed. Average (and total) flow and chloride loads were considerably higher than average during the test period.

The efficiency of chloride removal in terms of percentages diverted is not very sensitive to the large variations in average annual flows and chloride loads.

TABLE 6

WATER FLOWS AND CHLORIDE CONCENTRATIONS AND LOADS FOR THE SOUTH WICHITA RIVER UPSTREAM FROM BATEMAN PUMP STATION

Period	Water discharge (cfs)	Dissolved chloride (Mg/L)	Dissolved chloride (tons)	Dissolved chloride (tons/day)
May 1987	58.7	1,960	9,700	313
June	14.0	5,890	6,700	220
July	10.8	7,870	7,200	232
August	7.86	10,000	6,740	218
September	7.86	10,000	6,546	218
October	6.96	11,000	6,242	201
November	7.35	11,000	6,436	214
December	7.96	10,000	6,810	220
January 1988	7.30	9,860	6,200	200
February	7.45	11,000	6,320	218
March	7.45	11,000	6,939	224
April	6.21	11,000	5,630	187
May 1987-April 1988	12.5	6,520	81,463	222
October 1970-September 1976	5.25	10,700		154

TABLE 7

BENJAMIN MONTHLY FLOWS (DSF)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1961										150	612	224	
1962	232	141	156	838	157	4,465	313	110	4,333	633	832	325	12,537
1963	211	192	183	227	1,309	1,044	252	0	1,183	42	412	170	5,225
1964	150	453	152	95	247	1,689	20	34	3,286	169	1,008	278	7,583
1965	206	137	147	1,033	327	57	0	5,935	8,133	7,575	501	345	24,396
1966	267	230	279	665	146	2,797	138	11,175	15,064	722	373	303	32,158
1967	273	195	162	4,195	3,523	9,352	2,060	293	514	119	177	204	21,069
1968	1,526	657	2,347	558	421	664	1,235	387	25	116	309	195	8,442
1969	166	176	225	157	2,235	467	20	821	7,515	4,545	1,323	547	18,199
1970	436	290	2,751	585	382	117	2	9	272	206	133	155	5,338
1971	162	129	108	116	4,306	788	142	2,271	832	2,478	581	662	12,575
1972	254	225	196	4,736	1,915	1,476	1,575	4,346	4,777	2,526	930	373	23,330
1973	585	677	1,972	1,613	439	180	470	167	1,905	229	607	184	9,028
1974	145	130	150	459	947	2,351	12	66	3,634	1,342	542	288	10,066
1975	301	762	313	509	7,012	2,277	3,859	1,296	2,252	318	1,412	285	20,597
1976	246	245	269	826	231	45	512	1,140	771	2,726	449	273	7,732
1977	232	237	231	1,244	4,258	537	96	176	65	237	193	163	7,668
1978	160	231	167	93	383	217	19	2,062	1,502	235	313	97	5,480
1979	190	156	538	252	1,044	944	450	1,083	30	5	300	157	5,149
1980	220	191	141	179	7,069	350	8	108	715	248	262	419	9,910
1981	215	243	485	560	1,280	3,066	11	1,242	299	881	241	235	8,759
1982	260	310	505	315	5,964	10,763	678	186	234	113	214	290	19,831
1983	481	383	338	538	721	1,056	76	2	1	20,347	1,331	664	25,938
1984	542	465	412	312	229	162	83	373	97	211	556	1,277	4,719
1985	545	322	1,584	1,413	166	2,386	301	116	326	5,747	643	367	13,918
1986	246	228	212	127	1,814	1,149	5,020	1,105	5,490	13,376	1,952	1,281	32,002
1987	974	1,651	1,770	486	7,708	3,226	979	659	247	42	34	110	17,887
1988	172	86	120	118									
Mean	348	339	589	824	2,086	1,986	705	1,352	2,442	2,420	602	366	14,213

TABLE 8

SUMMARY OF AVERAGE DAILY VALUES OF FLOW AND ACTUAL AND PROJECTED CHLORIDE DATA AND PERCENTAGES DIVERTED AT BATEMAN PUMPING STATION

Period	Diverted (tons/day)	Spilled (tons/day)	Total (tons/day)	Total (cfs)	Percentage Diverted (%)
Test Period	Actual				
May 87-Apr 88	192	30	222	12.5	86
Water Year	Projected*				
1985	105	5	110	3.6	95
1986	133	60	195	20.8	68
1971	107	17	124	6.3	86
1972	153	12	165	5.4	93
1973	165	16	181	5.4	91
1974	151	12	163	4.9	93
1975	132	18	150	5.5	89
1976	134	16	150	3.9	89
Avg. 71-76	140	13	153	5.25	92
Overall 9-yr. Average	141.3	20.9	162.2	7.6	87

*Assuming same operational program and two breakdowns totaling 17 days as during test period. The average concentrations which was assumed to be spilled during water year 1971-1976 was computed to be approximately:

$$\frac{138 \text{ tons/day} \times 17 \text{ days}}{365 \text{ days/year}} \times \frac{154 \text{ tons/day}}{222 \text{ tons/day}} \approx 5 \text{ tons/day}$$

BATEMAN MONTHLY MEAN DISCHARGES
MAY 1987 - APRIL 1988

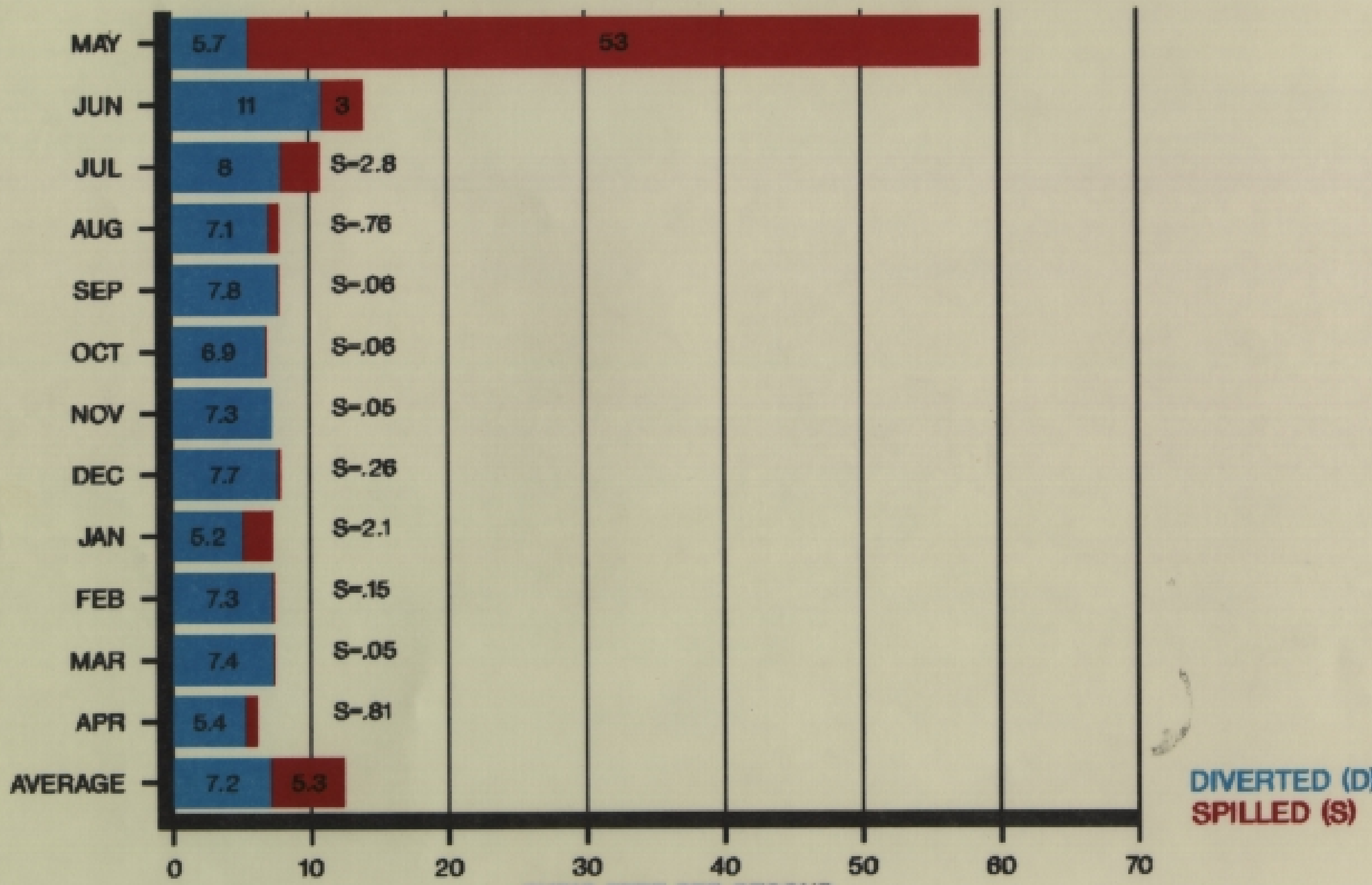

FIGURE 4

BATEMAN MONTHLY MEAN DISSOLVED-CHLORIDE LOADS
MAY 1987 - APRIL 1988

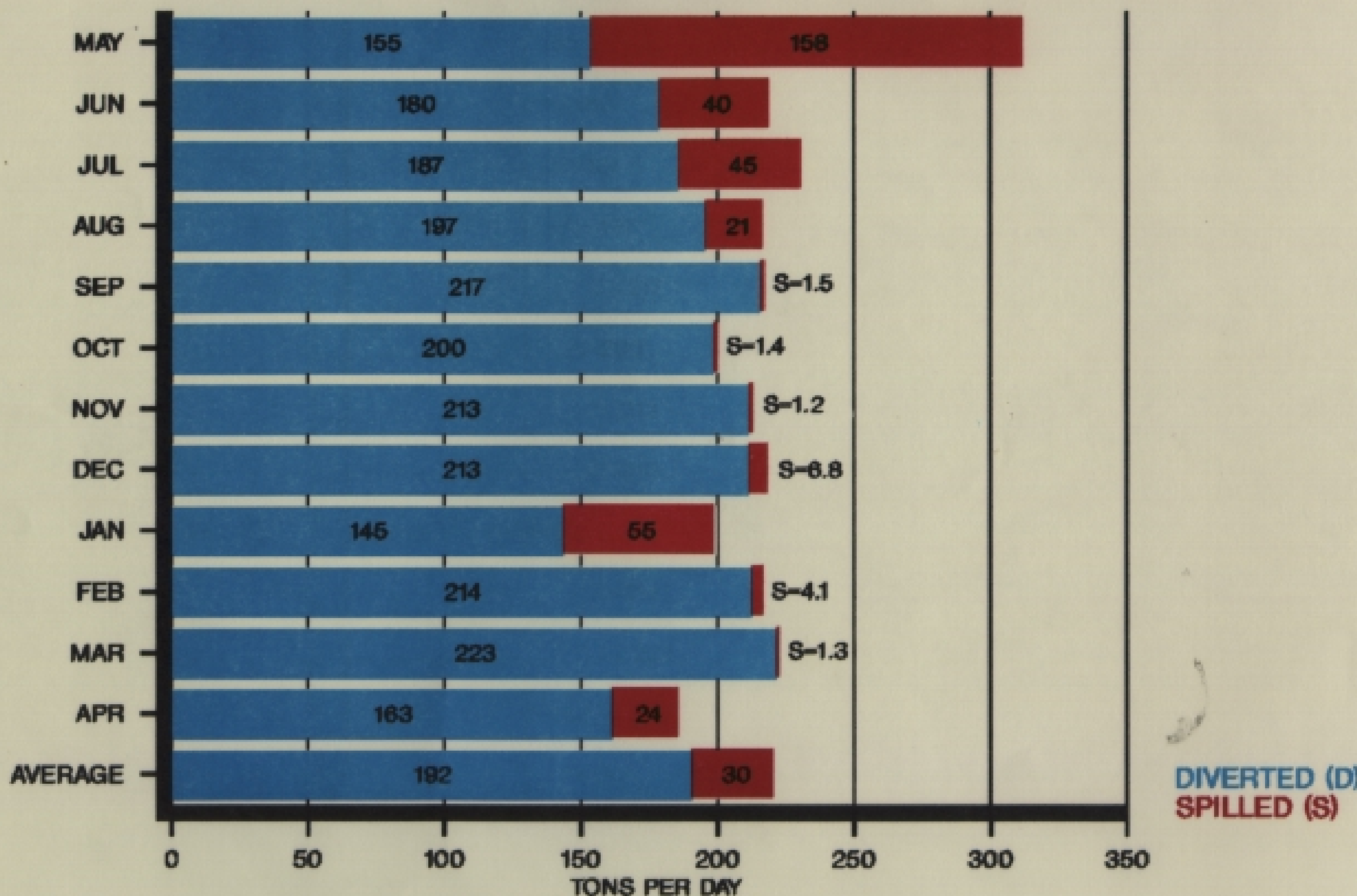

FIGURE 5

The two system breakdowns experienced during the test period (and assumed for each year in the simulation analysis) only caused an average 3- to 4-percent reduction in overall efficiency. The operational strategy used during the test period is an effective (suitable) strategy.

Both water year 1986 and the test period in 1987-88 were considerably wet and thus, flows were greater and carried more chlorides than normal although the concentrations were diluted by the high flows.

Examination of the quoted data confirms that the control system is operating better than predicted in design. The relative degree of control during the test period was somewhat reduced due to high flows in May of 1987 and by the two pipeline breaks. High flow periods will occur from time to time throughout the life of such a project but should not constitute a very large portion of the time as an average. Pipeline breaks will also occur during the operational phase, but the total down-time is not expected to rise in future years and may even drop as experience in repairs is accumulated. Considering these adjustments the expected level of control over the anticipated project life is estimated to be at least 87 percent as depicted in Table 8. This compares favorably to the forecast level of control used for design purposes (see Design Memorandum Nos. 3 and 25) which ranged from 83 to 85 percent.

PERFORMANCE AT BENJAMIN

Before measurable improvements of quality can be realized in impacted streams and lakes along the Red River, flushing of stored brines contained in alluvium waters must take place. A major concern addressed by the Chloride Control Feasibility Study was the estimated time required to flush these chloride loads. Significant flushing of brines was observed between the Bateman and Benjamin sites during the one-year operation indicating a much shorter time frame for this flushing action to occur than was originally envisioned.

The period of continuous concurrent streamflow and water-quality record for the South Wichita River at Bateman and near Benjamin is from October 1970 through September 1976. Flows near Benjamin averaged 36.2 cfs during this 6-year period and about 38.3 cfs during the 26-year period from October 1961 through September 1986. Distribution of flows for the two periods are very similar. Consequently, the water-quality records for both Bateman and Benjamin stations are considered to be representative of the long-term pre-pumping conditions.

During this 6-year period, chloride loads in flows near Benjamin averaged 210 tons/day. During the one-year period from May 1987 through April 1988 with pumping underway at Bateman, flows at Benjamin averaged 37 cfs and chloride loads averaged 153 tons/day.

According to the Chloride Control Plan for Area VIII, pumpage of an average chloride load of 142 tons/day at Bateman would reduce the average chloride load at Benjamin to about 68 tons/day. However, pumpage of an average chloride load of 192 tons/day at Bateman during the one-year period reduced the average chloride load at Benjamin to only 153 tons/day. This discrepancy is readily explainable. According to estimates by the U.S. Army Corps of Engineers, "Between the Bateman gage and Benjamin gage, an estimate 250,000 tons of chloride are dissolved in the pore water in alluvial silt deposits. Flushing of the stored brine in the alluvium must take place for definable improvements of quality parameters at Benjamin. Considerable flushing could occur in one normally wet spring."

Available data indicate that the much greater-than-average flows in May and June 1987 (a large part of which originated from flood runoff downstream from Bateman) resulted in significant flushing of chloride from the alluvium in the intervening reach between Bateman and Benjamin (see Appendix B and Tables 5, 6, and 7 and Figure 6).

Monthly chloride loads contributed by the intervening area in May and June 1987 averaged 455 and 460 tons/day as indicated in Table 9. Corresponding flow contributions in May and June averaged 196 and 105 cfs. In July and August, as the flows receded to 29.2 and 20.2 cfs, the monthly chloride loads decreased to 194 and 121 tons/day, respectively. Throughout the remainder of the period from September 1987 through April 1988, the monthly flows contributed by the intervening area were significantly less than the long-term average. Monthly loads during this period ranged from 16 to 58 tons/day. This was the result of the flushing of the chlorides in the alluvium between Bateman and Benjamin. This flushing lowered the chloride concentration and improved the quality of the alluvium water. Future water coming out of the alluvium will contain less chlorides than before since the highly chloride concentrated base flows will be diverted at Bateman and no longer contribute to the alluvium's chloride concentration during low flow periods.

The six-year flow for this area and the one-year flow after the onset of pumping agree remarkably well -- 31.4 and 31.6 cfs. However, the average chloride load contributed by this area after the onset of pumping was much larger than the six-year pre-pumping average -- 123 and 71 tons/day, respectively. The increasing load with no additional source is another indication of significant flushing of brine from the alluvium downstream from Bateman. After initial flushout, chloride loads at Benjamin during the period from September 1, 1987, to April 30, 1988, ranged from 18 to 71 tons/day and averaged 42 tons/day, about 26 tons less than the anticipated long-term value.

Figure 6 shows an estimate of the leaching progress between Bateman and Benjamin and is a plot of the data on Table 10. Flows during this eight-month period averaged less than 4 cfs. After the initial flushing by high flows, the observed daily chloride loads at Benjamin were smaller for equivalent flows (see Figure 7).

The chloride control system effectiveness at Benjamin was demonstrated by the significant flushing action that was observed during the one-year operation. As the chloride load flushed from the alluvium continues to decline through the project life, a progressively greater degree of effectiveness of the Bateman Pump Station Operation will be prevalent.

TABLE 9

AVERAGE WATER DISCHARGES AND CHLORIDE CONCENTRATIONS AND LOADS CONTRIBUTED BY INTERVENING AREA BETWEEN BATEMAN AND BENJAMIN

Period	Water discharge (cfs)	Dissolved chloride (Mg/L)	(tons)	(tons/day)
May 1987	196	870	14,100	455
June	105	1,600	13,800	460
July	29.2	2,510	6,010	194
August	20.2	2,120	3,750	121
September	8.14	2,550	1,740	58
October	1.24	5,020	530	17
November	1.05	5,730	510	17
December	3.34	5,070	1,400	45
January 1988	3.50	1,820	500	16
February	2.85	5,420	1,190	41
March	3.85	4,020	1,279	41
April	3.19	1,970	480	16
May 1987–April 1988	31.6	1,450	45,280	123
October 1970–September 1976	31.4	910		71

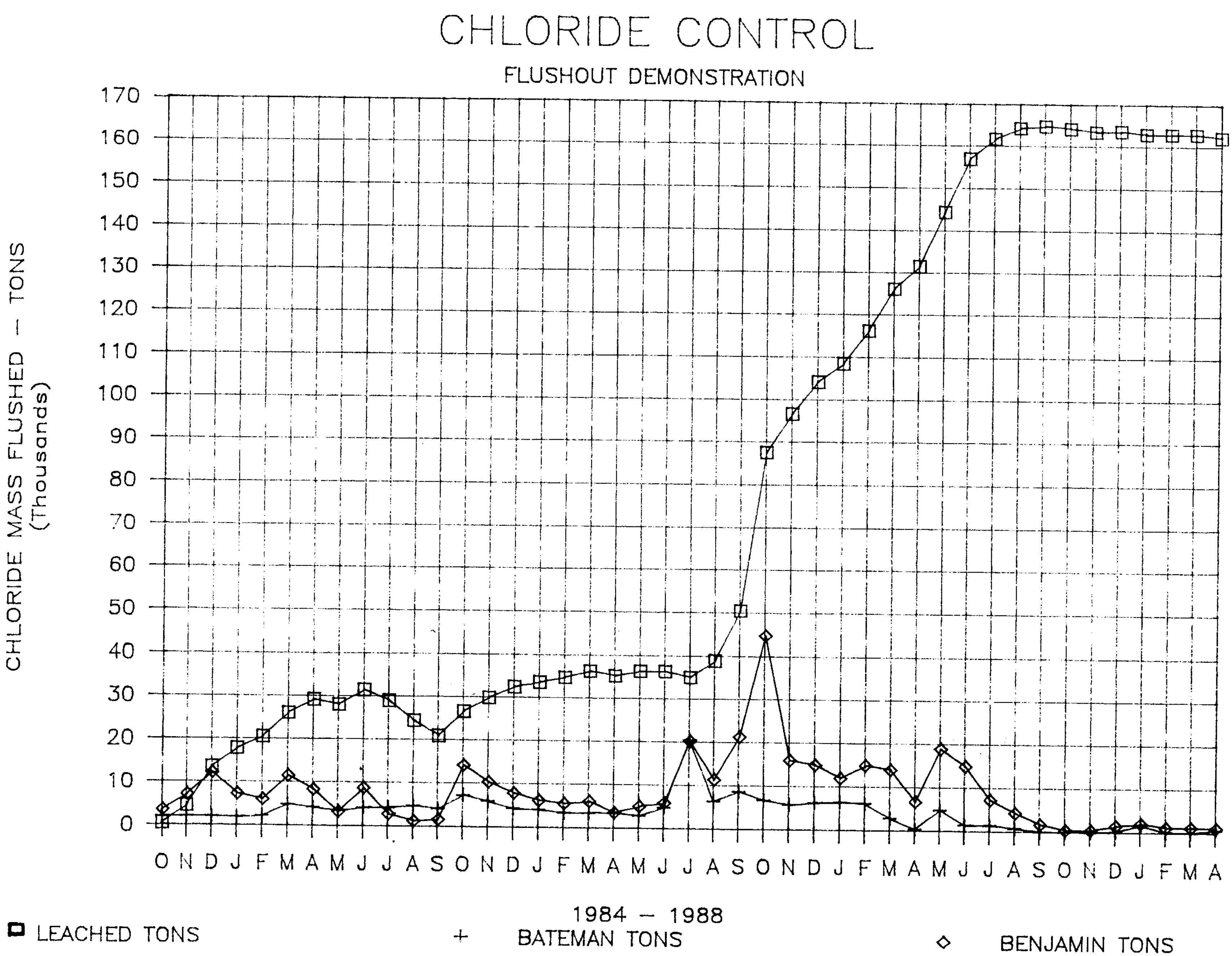

FIGURE 6 Estimate of the Leaching Progress Between Bateman and Benjamin

TABLE 10

ESTIMATE OF LEACHING BETWEEN BATEMAN AND BENJAMIN

	Tons Passing Bateman	Tons Passing Benjamin	Intervening Load Tons	Estimated Leached Tonnage	Accum Leached Load
Oct 84	1,900	3,640	1,200	540	540
Nov 84	1,990	7,240	1,200	4,050	4,590
Dec 84	2,040	12,200	1,200	8,960	13,550
Jan 85	1,810	7,330	1,200	4,320	17,870
Feb 85	2,210	6,130	1,200	2,720	20,590
Mar 85	4,830	11,600	1,200	5,570	26,160
Apr 85	4,060	8,420	1,200	3,160	29,320
May 85	3,320	3,390	1,200	-1,130	28,190
Jun 85	4,160	8,810	1,200	3,450	31,640
Jul 85	4,250	2,900	1,200	-2,550	29,090
Aug 85	4,760	1,340	1,200	-4,620	24,470
Sep 85	4,020	1,720	1,200	-3,500	20,970
Oct 85	7,270	14,200	1,200	5,730	26,700
Nov 85	5,870	10,400	1,200	3,330	30,030
Dec 85	4,160	7,910	1,200	2,550	32,580
Jan 86	3,970	6,290	1,200	1,120	33,700
Feb 86	3,320	5,670	1,200	1,150	34,850
Mar 86	3,470	6,200	1,200	1,530	36,380
Apr 86	3,430	3,600	1,200	-1,030	35,350
May 86	2,810	5,170	1,200	1,160	36,510
Jun 86	4,860	6,030	1,200	-30	36,480
Jul 86	20,400	20,300	1,200	-1,300	35,180
Aug 86	6,390	11,500	1,200	3,910	39,090
Sep 86	8,710	21,400	1,200	11,490	50,580
Oct 86	6,700	45,000	1,200	37,100	87,680
Nov 86	5,700	16,000	1,200	9,100	96,780
Dec 86	6,300	15,000	1,200	7,500	104,280
Jan 87	6,500	12,000	1,200	4,300	108,580
Feb 87	6,100	15,000	1,200	7,700	116,280
Mar 87	2,800	14,000	1,200	10,000	126,280
Apr 87	310	6,800	1,200	5,290	131,570
May 87	4,900	19,000	1,200	12,900	144,470
Jun 87	1,300	15,000	1,200	12,500	156,970
Jul 87	1,400	7,400	1,200	4,800	161,770
Aug 87	640	4,400	1,200	2,560	164,330
Sep 87	46	1,800	1,200	554	164,884
Oct 87	42	590	1,200	-652	164,232
Nov 87	36	540	1,200	-696	163,536
Dec 87	210	1,600	1,200	190	163,726
Jan 88	1,700	2,200	1,200	-700	163,026
Feb 88	120	1,300	1,200	-20	163,006
Mar 88	39	1,300	1,200	61	163,067
Apr 88	730	1,200	1,200	-730	162,337

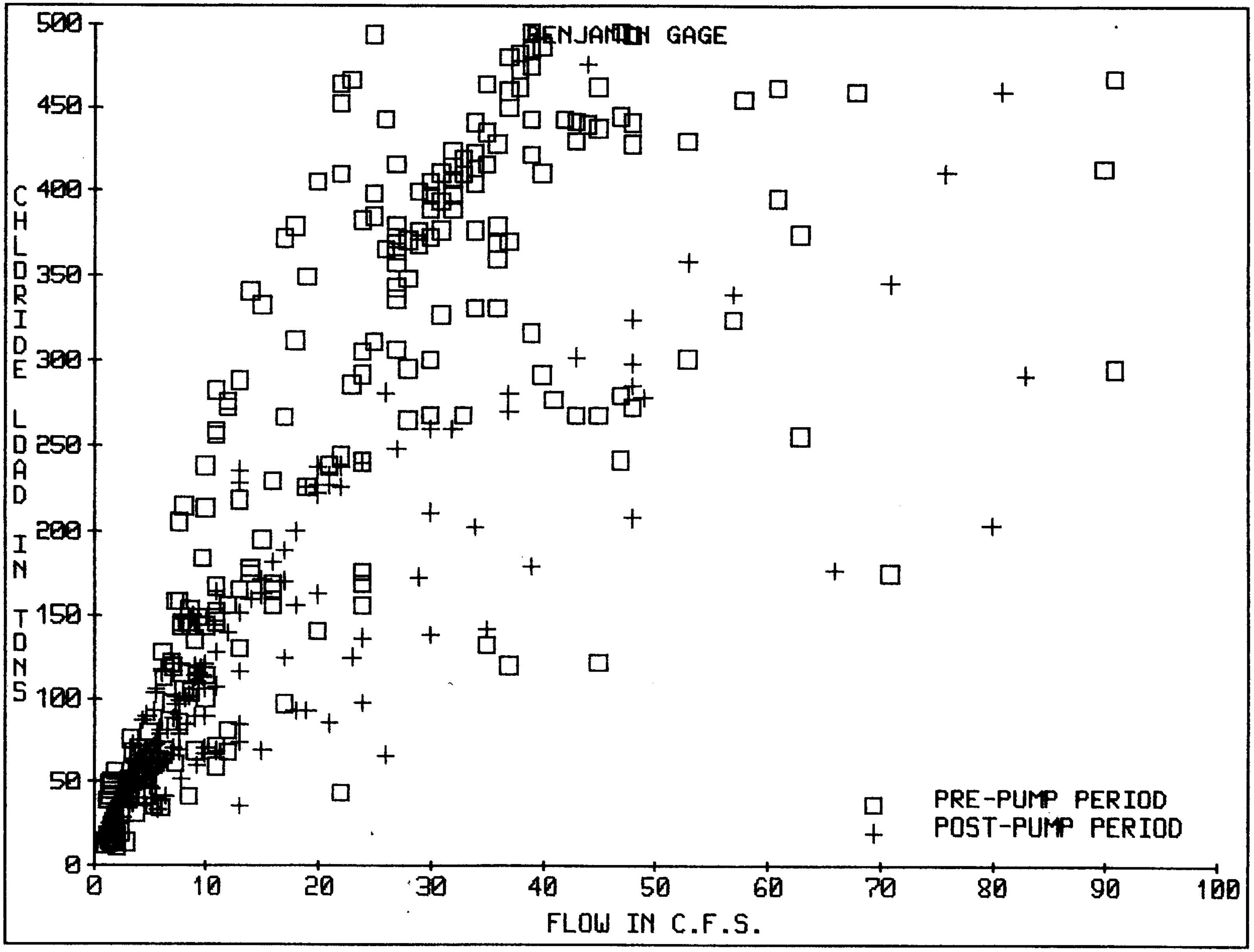

FIGURE 7
Comparison Between Chloride Loads During
Pre and Post Pump Periods at Benjamin