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Upper White River BMP Implementation Project (NPS Final Report)

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UPPER WHITE RIVER BMP IMPLEMENTATION PROJECT

NPS Final Report 95-800

Cooperating Agencies
Arkansas Water Resources Center
ARKANSAS SOIL & WATER CONSERVATION COMMISSION
WASHINGTON COUNTY SOIL AND WATER CONSERVATION DISTRICT
UNIVERSITY OF ARKANSAS

Federal Assistance Project No. C9996103

Project / Task No. 800

December 24, 2000

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PROJECT DESCRIPTION

The project objective was to monitor agricultural best management practices implemented to minimize sediment, nutrient, and bacterial impact on water quality of the Upper White River watershed. The project targeted the primary agricultural causes of non-point source nutrient and bacterial pollution in three sub-basins of the White River in the Beaver Lake Watershed. Areas with high animal densities targeted high source areas. High source areas were treated with best management practices (BMP) in an effort to reduce the impact to the White River and Beaver Lake. The predominant BMP implemented was waste management, a component of the farm nutrient management plan. Yearly totals of farm acres, acres of waste management and estimated tons of animal waste managed are listed in Tables 1, 2, and 3 for the entire Upper White River watershed, East Fork, and Middle Fork watersheds, respectively.

The Upper White River project was a cooperative project consisting of three sub-projects, development of a Geographic Information System (GIS) database, implementation of best management practices (BMP), and water quality monitoring. This report covers the water quality monitoring aspect of the project.

Monitoring of the Upper White River began in the December 1995 and continued until the June 1998. Sites selected for monitoring were the East Fork (EF) of the White River, the Middle Fork (MF) of the White River, Cannon Creek (CC) and Shumate (SC) Creek. Cannon Creek and SC are adjacent watersheds and tributaries of the EF. Shumate Creek was by all indications the most vulnerable due to the amount of animal manure used for pasture fertilization. Whereas, Cannon Creek is less impacted and useful for testing if the BMPs are effective when animal waste amendments are less intense.

OBJECTIVES

The objective of the water quality monitoring is to demonstrate the ability of BMPs to reduce nutrients, sediment, carbon, and microbes in the Upper White River.

MATERIALS AND METHODS

Watershed Description

Watershed monitoring points were the East Fork, Middle Fork, Shumate Creek, and Cannon Creek. All points were upstream of Lake Sequoyah, an impoundment of the White River that is fed by East Fork and Middle Fork. Shumate and Cannon Creeks are tributaries of the East Fork. For a detailed description of these sub-basins refer to the report by Scott and McKimmey (2000). In this report the specific locations of the monitoring points are represented by the downstream extent of the watershed areas and latitudes/longitudes for the monitoring sites are listed in Table 2.

To summarize parts of Scott and McKimmey's report (2000), the East Fork and Middle Fork watersheds are approximately 170,000 acres of which 81% is forested and 19% is pastureland. The monitored portion of the Shumate Creek watershed encompassed 1,455 acres of which 1,126 acres were forested and 326 acres in pastureland. Cannon Creek was a comparable size with 1,553 total acres, 1,328 acres forested, and 171 acres of pasture.

Water Quality Monitoring

Four water quality-monitoring sites were maintained for the collection of base flow and storm flow samples. These four sites are referred to as the East Fork (EF), Middle Fork (MF), Cannon Creek (CC), and Shumate Creek (SC). The specific locations of these monitoring sites are mapped in the report by Scott and McKimmey (2000) and are located as the downstream extent to each watershed. The EF and MF sampling points are related to easily identifiable landmarks, U.S. Highway 74 and Highway 16 bridges, respectively. The landmark that is associated with the CC site was the old-one-lane Highway 16 bridge over Cannon Creek. The landmark that best identifies the SC site is the point where electrical power transmission lines cross Shumate Creek.

Automated samplers and data-loggers were used at all sites to measure and record stream stage and collect flow-weighted composite or discrete water samples during storm flow events. Flow-weighted composite storm samples were collected at all sites following the development of discharge curves. Prior to having discharge curves, discrete time-weighted storm samples were collected that were later converted to loads. Base flow water samples were collected as grab samples on two week intervals or as needed at all sites.

Water samples collected at base flow or from a storm were analyzed for concentrations of *Escherichia coli* (EC), coliphage virus (CV), ammonium- nitrogen (NH_4), nitrate-nitrogen (NO_3), dissolved reactive phosphate (DP), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), total phosphorus (TP), and total suspended solids (TSS). Stream stage was monitored continuously and converted to discharge using a rating-curve. Mass transport of microbes, nutrients, carbon, and sediment were calculated by integrating, with respect to time, the product of the mean event concentration and stream discharge. Calculating monthly mean concentration and loads then summarized these data.

This project had intended to use chlorophyll concentrations at the EF and MF sites, terminal pools of these tributaries prior to entering the impoundment of Lake Sequoyah, to integrate the nutrient loads. However, all analyses for this parameter showed that the chlorophyll measured in the water column was predominantly pheophytin. Pheophytin is chlorophyll from dead algae and cannot be used to indicate algae growth in these terminal pools. Therefore, the chlorophyll measurements are not useful and will not be presented in this report.

Statistical Trend Analysis

The objective of the statistical analysis was to determine if the response variables exhibited a significant increasing or decreasing trend across time. The statistical approach was adapted from the methods used by Edwards et al. (1996 and 1997) and Vendrell et al. (1998). Each of the response variables was transformed by the natural logarithm for use as the dependent variable in the statistical analysis. The trend analysis was achieved by a linear regression on time, where time was represented by the number of months of the sample collection. The regression model included the sine and cosine functions of time in order to remove potential seasonal effects that would be consistent across years. A significant ($p<0.10$) model and regression coefficient, determined by a t test, indicated the presence of a trend with time, and the sign of the coefficient indicates whether the trend is increasing (positive) or decreasing (negative). The regression model used was:

$$\ln(y) = B0 + B1\,(\text{time}) + B2\sin(2\pi\,\text{time}/12) + B3\cos(2\pi\,\text{time}/12).$$

Another statistical method was used to compare Cannon and Shumate Creeks. After transforming the load and mean concentration data into natural logarithms, a paired t-test was performed to test for significant differences between the quality parameters for Cannon and Shumate Creeks.

RESULTS AND DISCUSSION

Trend Analysis

Discharge

Monthly-accumulated volumes of water discharged past the monitoring points from December 1995 through June 1998 are graphed for each monitoring site. Discharge volumes were separated into base, storm, and total flow conditions and these separated discharge types are presented in Figures 1, 20, and 39, respectively. Base flow is that volume of water that was discharged by the rivers and creeks during periods between storm-water runoff. Conversely, storm flow was the accumulated discharge over a month when storm water runoff occurred. Total discharge was then the sum of base and storm discharge.

As expected, the higher order rivers, EF and MF, had more discharge than the lower order creeks, CC and SC. For the purpose of characterizing the distribution of discharge at these sites, three individual months were selected that represent high, low, and medium discharge, Tables 5, 6, and 7, respectively. During the high discharge conditions in February 1997 (Table 5), the EF had by far the highest discharge, six times higher than the MF. This phenomenon can partially be explained by the relative sizes of these two watersheds, the EF is approximately 2.6 times larger than the MF. The distribution of discharge between base and storm types was approximately 30% base and 70% storm at the EF site. The MF site had a 10% higher percentage of the total discharge from base flow with approximately a 4:6 base to storm discharge ratio (B:S). The significance of this is that even though these are adjacent watersheds, they have different hydrology.

Cannon Creek and SC acted similarly in term of their B:S ratio even though SC discharged approximately 1.5 times more water compared to CC and the SC watershed acreage is slightly smaller that the CC watershed. Shumate Creek and CC discharged approximately 54 and 56%, respectively, of their total discharge during storm events in February 1997 (Table 5).

In July and September of that same year (Table 6 and 7), the base discharges were considerably lower at all sites except for SC in September, which was anomalously high due to an isolated thunderstorm. More importantly, the MF had the higher discharge compared to the EF in both July and September, which is opposite to the relationship observed in February. This relationship reiterates the concept that the hydrology differs between these two adjacent watersheds. The MF watershed appears to have less or slower in developing surface-runoff compared to the EF and in doing so should respond differently to BMP implementation.

When looking for water quality trends over a relatively short period, 2.5 years, that are to be attributed to BMP implementation, it is important to know if there were significant changes in discharge over this same period. Increasing or decreasing discharge could be the causative agent for significantly changing nutrient, sediment, carbon, or microbe loads. Traditionally, mean concentrations are used to buffer the effects of changing discharge. However, it is the contention of this author that the effects of significant trends in discharge carry beyond the mere mathematical treatment used to calculate mean concentrations. Years with higher discharge are due primarily to higher amounts of rainfall. Logically, more frequent or intense rainfall should cause more mass transport from surfaces and predispose these surfaces to produce lower concentrations in subsequent runoff events; therefore, making mean concentrations conceptually dependent on discharge.

Significant trends in discharge with time were observed at the EF, CC, and SC sites (Table 8). However, no discharge trends were observed at the MF site. Discharge significantly increases for base and total discharge at the EF. Contrary to this, discharge significantly decreases in CC and SC. Base and total discharge decreased over time in CC; however, all three flow types, base, storm, and total discharge decrease in SC. Plausible explanations for this disagreement, increasing discharge over time downstream and decreasing discharge upstream, are that rainfall was not distributed evenly over these watersheds or that complex karstic-groundwater interactions were involved.

Loads

Monthly loads are summarized for each water quality parameter, monitoring site, and flow type in temporal graphics. Base flow discharge loads are presented in Figures 2 through 10. Figures 21 through 30 contain monthly loads discharged during storm events and Figures 40 through 48 summarize total discharge loads. In summary, all loads fluctuated in a cyclic nature that was created by seasonal fluctuations in discharge and these fluctuating cycles are inherent in non-point source studies. This phenomenon is referred to as seasonality. The model used for the statistical trend analysis is designed to account for this seasonality.

It is realistic to expect that loads should increase when there is a significantly increasing trend in discharge, decrease when discharge decreases, and not change when discharge is constant. This relationship occurred on a general basis at all the sites monitored. There was a significant increase in total discharge at the EF site (Table 8) and there was a significantly increasing trend in load transport of NO_3 and TOC (Table 9). No discharge trends were observed at the MF site and there were no trends in load transport for any of the water quality parameters measured (Table 9). This relationship is further supported by the observations for specific flow types. No trends during storm discharge were observed at the EF site and no significant trends in loads of any of the water quality parameters were observed for the storm loads.

No increasing trends were observed at the EF site for EC, CV, NH_4, DP, TKN, TOC, TP, or TSS parameters. A possible explanation for the increasing NO_3 and TOC loads with total discharge could be that these two parameters are soluble and transported in the base flow discharge; whereas, the other parameters are transported in surface-runoff.

The smaller and selectively more vulnerable watersheds, CC and SC, showed significantly decreasing trends for all water quality parameters (Table 10 and 11). However, as discussed previously, discharge trends for both watersheds significantly decreased (Table 8). This again supports the concept that the decreasing trends in discharge caused a decrease in nutrient, sediment, carbon, and microbial loads. To make the assumption that decreasing trends in loads were due to BMP implementation, other causes such as decreasing discharge must be eliminated. It is obvious that decreasing trends in load transport are more likely due to decreasing discharge and difficult to attribute all of the load decreases to the effects of the BMPs. However, it was pointed out in the proposal for this project that the ability to observe the effects of BMPs would be limited by the short duration of monitoring, less than 5 years.

Mean Concentrations

In a style similar to the graphic presentation of the monthly loads, monthly mean concentrations of the base flow periods are given in Figures 11 through 19. Mean concentrations during storm discharges can be found in Figures 30 through 38 and mean concentrations for total flow in Figures 49 through 57. Mean concentrations exhibited seasonality similar to that for loads and this seasonality was also addressed in the statistical trend model.

Significant trends of either increasing or decreasing mean concentrations for the water quality parameters measured at the EF and MF sites are listed in Table 12. Unlike load trends, there were significant trends at the MF site. Coliphage virus and NO_3 significantly decreased and NH_4 increased at the MF site, but these significant trends occurred only for the total flow conditions. There is currently insufficient information to explain the cause for these anomalous MF trends.

The EF site had significantly decreasing trends in mean concentrations for EC, DP, TKN, TOC, TP, and TSS (Table 12). Both EC and TSS decreased at all three flow types (base, storm, and total flow). All other significantly decreasing parameters at the EF site decreased during base and total flow except for TOC that decreased only during total flow. These decreases may be attributable to the BMP implementation providing that mean concentrations are considered to be totally independent of discharge and that there were no factors other than the BMP implementation that could have affected these decreases.

The concept that waste management BMPs cause decreases in mean concentrations and not loads is consistent with the concept that these BMPs can slow the losses of nutrients and bacteria. Eventually the load will increase even with BMPs if the source continues to increase. Furthermore, it is generally accepted that watershed monitoring must continue for a minimum of five years before valid watershed changes can be documented. Therefore, the BMPs implemented here should not be considered as ineffective due to the results of this monitoring and trend analysis.

Significant trends for mean concentrations at the CC site are listed in Table 13. *Escherichia coli*, CV, NO3, TKN, TP, and TSS all showed significantly decreasing trends. The mean concentration of CV decreased only during total flow conditions. Nitrate decreased during base and total flow and all other significant parameters decreased during all three flow types. Similarly, the SC site showed significantly decreasing trends for EC, CV, TKN, TP, and TSS (Table 14). However, additional decreases were observed for the parameters DP and TOC. This is consistent with the information that SC was more vulnerable than CC with 1.9 times more pasture in the SC watershed which received 5.4 times more animal waste compared to pastures in the CC watershed (Table 15). More animal waste applied into the SC watershed predisposed this watershed with higher initial concentrations and increased the potential to observe decreasing trends as a result of animal waste management. As can be seen in Table 15, there was successively less animal manure applied to pastures in both CC and SC and this is the most probable cause for the significantly declining trends. This shows that nutrient management BMPs can be effective when the management decision is to apply less manure in vulnerable areas and utilize these manures outside the targeted watershed.

Cannon and Shumate Creek Comparison

Cannon and Shumate Creeks are small adjacent watersheds that were selected for monitoring because they satisfied a list of selective criteria given previously. Having a high vulnerability or potential to loose nutrients, sediment, carbon, and microbes into waterways made these smaller watersheds useful for detecting changes in water quality as a result of BMPs. Another advantage of monitoring these adjacent watersheds is to compare the CC and SC as paired-watersheds. Roggio et al. (1997) described these two watersheds as being similar in area, soils, relief, and geology. Therefore, the primary differences in contaminant transport should be from differing land use or management. As described previously, both land use and management was considerably different, SC had more pastureland and these pastures received considerably more animal waste. Roggio et al. (1997) described the nutrient transport differences between CC and SC but these descriptions were unsupported by statistical analysis. Therefore, a statistical comparison of CC to SC is given in Tables 16, 17, and 18.

Table 16 compares discharge under base, storm, and total flow conditions. Cannon Creek had lower discharge volumes under all three-flow conditions. However, only base and total discharges were significantly different from SC discharges. As discussed previously, significant changes in discharge cause significant changes in load.

Comparisons of loads for all parameters monitored are given in Table 17. For every parameter, base and total flow loads were significant higher in the SC watershed. Storm loads were only significantly higher in SC for the CV and NH_4 parameters.

Considerably fewer significant differences were observed among mean concentrations (Table 18). Shumate Creek exhibited significantly higher mean concentrations of CV, NO_3, DP, TKN, and TP only during base and total flow conditions. No mean concentration differences occurred between CC and SC during storm flow.

SUMMARY AND CONCLUSIONS

According to the statistical trend analysis performed on the data collected during the monitoring period from December 1995 through June 1998, there were both increasing and decreasing trends. Trends were for loads to increase when discharge increased and decrease when discharge decreased. However, practically all the mean concentration trends decreased. It is only possible to attribute these decreases to the BMPs providing the belief that mean concentrations are totally independent of changing discharge and that these implemented BMPs were the predominant land use changes in these watersheds.

The most defendable evidence that nutrient management was able to reduce nutrient, sediment, carbon, and microbial impact to the Upper White River is from the significantly decreasing trends in the small vulnerable watersheds, Cannon Creek and Shumate Creek. It is clearly evident that the mean concentrations were closely related to the amount of animal waste amended to pasturelands in these watersheds. Applying successively less manure from monitored-year to year created significant trends. Nutrient management BMPs can be effective when the management decision is to apply less manure in vulnerable areas and utilize these manures outside the targeted watershed. The effectiveness of any other components of nutrient management BMPs cannot be determined due to the short time period that monitoring was conducted.

REFERENCES

Edwards, D. R., T. C. Daniel, J. F. Murdock, P. F. Vendrell, and D. J. Nichols. The Moores Creek monitoring project. Final Report. Arkansas Water Resources Center, University of Arkansas, Fayetteville, Arkansas. Publication No. MSC-162, 1994.

Edwards, D. R., T. C. Daniel, H. D. Scott, P. A. Moore, Jr., J. F. Murdock, and P. F. Vendrell, Effect of BMP implementation on storm flow quality of two Northwest Arkansas streams, ASAE, 40(5):1311-1319, 1997.

Edwards, D. R., T. C. Daniel, H. D. Scott, J. F. Murdock, M. J. Habiger, and H. M. Burks, Stream quality impacts of best management practices in a Northwest Arkansas basin, Water Resources Bulletin, 32(3), 499-509, 1996.

Roggio, R. G., K. F. Steele, P. F. Vendrell, and M. A. Nelson. Effects of agricultural practices on nutrient concentrations and loads in two small watersheds, northwest Arkansas, Proceedings of the Arkansas Academy of Science, 1997.

Scott, H. D. and J. M. McKimmey. Spatial and temporal changes in land use and land cover from 1988 to 1992 in the Upper White River Watershed. Arkansas Water Resources Center. Publication No. MSC-281, 2000.

Vendrell, P. F., M. A. Nelson, W. Cash, K. F. Steele, R. W. McNew, D. R. Edwards, and J. F. Murdock. 1998. Continuation of the Illinois River water quality monitoring of Moores Creek. Non-Point Source Final Report. Submitted to: Arkansas Soil and Water Conservation Commission. Arkansas Water Resources Center, Publication No. MSC-0213, 1998.

APPENDIX A
Tables 1-18

Table 1. Acres of waste management implemented and the tons of animal waste managed in the Upper White River watershed.

Year	Total Farm Acres Enrolled	Acres of Waste Management Implemented	Tons of Animal Waste Managed*
1995	14,671	6,335	12,670
1996	13,265	6,289	12,578
1997	5,385	2,405	4,811
1998	4,237	2,188	4,376
Four Year Total	37,556	17,217	34,434

* These are estimates based on the acres of waste management receiving two tons of animal waste per acre per year.

Table 2. Acres of waste management implemented and the tons of animal waste managed in the East Fork watershed.

Year	Total Farm Acres Enrolled	Acres of Waste Management Implemented	Tons of Animal Waste Managed*
1995	2,587	1,219	2,438
1996	3,924	1,699	3,397
1997	1,034	584	1,168
1998	385	290	581
Four Year Total	7,929	3,792	7,584

- These are estimates based on the acres of waste management receiving two tons of animal waste per acre per year.

Table 3. Acres of waste management implemented and the tons of animal waste managed in the Middle Fork watershed.

Year	Total Farm Acres Enrolled	Acres of Waste Management Implemented	Tons of Animal Waste Managed*
1995	7,742	3,072	6,145
1996	4,408	2,044	4,088
1997	1,987	417	834
1998	2,054	915	1,830
Four Year Total	16,191	6,449	12,897

* These are estimates based on the acres of waste management receiving two tons of animal waste per acre per year.

Table 4. Upper White River monitoring site locations.

Site Name	Latitude	Longitude	Altitude (ft)
Cannon Creek	35°54'13.543148"N	93°57'01.467248"W	1300.83
Shumate Creek	35°55'26.722795"N	93°58'08.510362"W	1233.8
East Fork	36°01'49.448025"N	94°01'03.052001"W	1113.81
Middle Fork	36°02'27.373986"N	94°03'21.349416"W	1089.64

Table 5. Discharge characteristics for the East Fork (EF), Middle Fork (MF), Cannon Creek (CC), and Shumate Creek (SC) during a high flow month, February 1997.

Site	Flow Type	Discharge (1.0E+06 m^3)	% of Total Discharge
EF	base	25.011	29.6
	storm	59.351	70.4
	total	84.362	
MF	base	5.433	39.2
	storm	8.418	60.8
	total	13.851	
CC	base	0.472	44.3
	storm	0.593	55.7
	total	1.065	
SC	base	0.709	45.9
	storm	0.837	54.1
	total	1.546	

Table 6. Discharge characteristics for the East Fork (EF), Middle Fork (MF), Cannon Creek (CC), and Shumate Creek (SC) during a low flow month, July 1997.

Site	Flow Type	Discharge (1.0E+06 m^3)	% of Total Discharge
EF	base	1.32	100
	storm	0	
	total	1.32	
MF	base	3.444	100
	storm	0	
	total	3.444	
CC	base	0.104	100
	storm	0	
	total	0.104	
SC	base	0.275	100
	storm	0	
	total	0.275	

Table 7. Discharge characteristics for the East Fork (EF), Middle Fork (MF), Cannon Creek (CC), and Shumate Creek (SC) during a medium flow month, September 1997.

Site	**Flow Type**	**Discharge (1.0E+06 m^3)**	**% of Total Discharge**
EF	base	1.605	4.5
	storm	33.99	95.5
	total	35.595	
MF	base	4.407	47.4
	storm	4.891	52.6
	total	9.298	
CC	base	0.144	25.5
	storm	0.42	74.5
	total	0.564	
SC	base	1.478	41.1
	storm	2.122	58.9
	total	3.6	

Table 8. Significant trends in discharge for monitoring sites, East Fork (EF), Middle Fork (MF), Cannon Creek (CC), and Shumate Creek (SC). No significant trends were observed at the MF site.

Site	Flow Type	Model Probability*	Trend Coefficient**	Trend Probability*
EF	base	0.0006	0.08926	0.0063
	total	0.0001	0.08703	0.0079
CC	base	0.0002	-0.12968	0.0001
	total	0.0001	-0.13676	0.0001
SC	base	0.0006	-0.08754	0.0001
	storm	0.1038	-0.34513	0.0424
	total	0.0014	-0.09452	0.0002

* Probabilities less than 0.10 are considered to be significant.
** Positive coefficients represent significantly increasing discharge and negative values indicate significantly decreasing trends.

Table 9. Significant trends in loads of nitrate-N (NO_3) and total organic carbon (TOC) transported by the East Fork (EF). There were no significant trends observed at the Middle Fork (MF) site.

Parameter	Flow Type	Model Probability*	Trend Coefficient**	Trend Probability*
NO_3	base	0.0004	0.10675	0.0235
	total	0.0006	0.08136	0.0808
TOC	base	0.0204	0.06531	0.0675
	total	0.0038	0.05891	0.1013

* Probabilities less than 0.10 are considered to be significant.
** Positive coefficients represent significantly increasing discharge and negative values indicate significantly decreasing trends.

Table 10. Significant trends in loads of Escherichia coli (EC), coliphage virus (CV), ammonium-N (NH4), nitrate-N (NO3), dissolved reactive phosphate (DP), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), total phosphorus (TP) and total suspended solids (TSS) transported by Cannon Creek (CC) during base and total flow conditions. No trends were observed during storm flow.

Parameter	**Flow Type**	**Model Probability***	**Trend Coefficient****	**Trend Probability***
EC	base	0.0001	-0.27496	0.0001
	total	0.0001	-0.29321	0.0001
CV	base	0.0003	-0.15973	0.0005
	total	0.0001	-0.18849	0.0001
NH_4	base	0.0002	-0.13422	0.0002
	total	0.0001	-0.14293	0.0005
NO_3	base	0.0001	-0.18245	0.0001
	total	0.0001	-0.19453	0.0001
DP	base	0.0001	-0.15638	0.0001
	total	0.0001	-0.17341	0.0001
TKN	base	0.0001	-0.2122	0.0001
	total	0.0001	-0.22924	0.0001
TOC	base	0.0001	-0.19174	0.0001
	total	0.0001	-0.20404	0.0001
TP	base	0.0001	-0.2205	0.0001
	total	0.0001	-0.24244	0.0001
TSS	base	0.0001	-0.3336	0.0001
	total	0.0001	-0.34745	0.0001

* Probabilities less than 0.10 are considered to be significant.
** Positive coefficients represent significantly increasing load and negative values indicate significantly decreasing trends.

Table 11. Significant trends in loads of Escherichia coli (EC), coliphage virus (CV), ammonium-N (NH4), nitrate-N (NO3), dissolved reactive phosphate (DP), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), total phosphorus (TP) and total suspended solids (TSS) transported by Shumate Creek (SC) during base, storm, and total flow conditions.

Parameter	**Flow Type**	**Model Probability***	**Trend Coefficient****	**Trend Probability***
EC	base	0.0088	-0.21272	0.0015
	total	0.0064	-0.22445	0.0011
CV	base	0.0001	-0.22091	0.0001
	storm	0.0058	-0.64089	0.001
	total	0.0001	-0.24037	0.0001
NH_4	base	0.0219	-0.09355	0.0111
	storm	0.0724	-0.40002	0.0161
	total	0.0112	-0.12053	0.0053
NO_3	base	0.0073	-0.08177	0.0034
	total	0.004	-0.09583	0.0016
DP	base	0.0001	-0.13766	0.0001
	storm	0.031	-0.36739	0.0065
	total	0.0001	-0.15345	0.0001
TKN	base	0.0001	-0.16162	0.0001
	total	0.0001	-0.17496	0.0001
TOC	base	0.0003	-0.11908	0.0001
	total	0.0001	-0.13563	0.0001
TP	base	0.0001	-0.18978	0.0001
	storm	0.0142	-0.41912	0.003
	total	0.0001	-0.20322	0.0001
TSS	base	0.0001	-0.29735	0.0001
	total	0.0001	-0.31032	0.0001

* Probabilities less than 0.10 are considered to be significant.
** Positive coefficients represent significantly increasing load and negative values indicate significantly decreasing trends.

Table 12. Significant trends in mean concentrations of Escherichia coli (EC), coliphage virus (CV), ammonium-N (NH4), nitrate-N (NO3), dissolved reactive phosphate (DP), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), total phosphorus (TP) and total suspended solids (TSS) in the East Fork (EF) andMiddle Fork (MF) during base, storm, and total flow conditions.

Parameter	Site	Flow Type	Model Probability*	Trend Coefficient**	Trend Probability*
EC	EF	base	0.0001	-0.15339	0.0008
		storm	0.0564	-0.19453	0.0255
		total	0.0001	-0.18046	0.0003
CV	MF	total	0.0122	-0.08304	0.0055
NH_4	MF	total	0.0037	0.0235	0.0259
NO_3	MF	total	0.0221	-0.01897	0.0212
DP	EF	base	0.0147	-0.05509	0.1034
		total	0.0226	-0.06048	0.024
TKN	EF	base	0.0002	-0.0435	0.0135
		total	0.0005	-0.05245	0.0088
TOC	EF	total	0.0044	-0.03015	0.0966
TP	EF	base	0.0001	-0.08096	0.0013
		total	0.0001	-0.09072	0.0012
TSS	EF	base	0.0014	-0.08418	0.0107
		storm	0.1024	-0.12816	0.0305
		total	0.0009	-0.09375	0.007

*** Probabilities less than 0.10 are considered to be significant.**
**** Positive coefficients represent significantly increasing load and negative values indicate significantly decreasing trends.**

Table 13. Significant trends in mean concentrations of Escherichia coli (EC), coliphage virus (CV), nitrate-N (NO_3), total Kjeldahl nitrogen (TKN), total phosphorus (TP), and total suspended solids (TSS) in Cannon Creek (CC) during base, storm, and total flow conditions.

Parameter	Flow Type	Model Probability*	Trend Coefficient**	Trend Probability*
EC	base	0.0012	-0.14528	0.0006
	storm	0.0063	-0.20437	0.0015
	total	0.0019	-0.15321	0.0006
CV	total	0.0053	-0.05578	0.024
NO_3	base	0.0149	-0.05277	0.0774
	storm	0.0332	-0.0888	0.0202
TKN	base	0.0323	-0.08253	0.0081
	storm	0.0517	-0.14145	0.0105
	total	0.0218	-0.09019	0.0049
TP	base	0.0041	-0.09082	0.0019
	storm	0.0614	-0.14691	0.0145
	total	0.0029	-0.10229	0.0011
TSS	base	0.0021	-0.20393	0.0004
	storm	0.0382	-0.25284	0.0077
	total	0.0063	-0.2052	0.0008

*** Probabilities less than 0.10 are considered to be significant.**
** Positive coefficients represent significantly increasing load and negative values indicate significantly decreasing trends.

Table 14. Significant trends in mean concentrations of Escherichia coli (EC), coliphage virus (CV), nitrate-N (NO3), dissolved reactive phosphate (DP), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), total phosphorus (TP), and total suspended solids (TSS) in Shumate Creek (SC) during base, storm, and total flow conditions.

Parameter	**Flow Type**	**Model Probability***	**Trend Coefficient****	**Trend Probability***
EC	base	0.0433	-0.12518	0.0162
	total	0.0148	-0.12005	0.0028
CV	base	0.0002	-0.13338	0.0016
	storm	0.0004	-0.257	0.0004
	total	0.0001	-0.14174	0.0002
DP	base	0.0011	-0.05012	0.0006
	total	0.0001	-0.06091	0.0001
TKN	base	0.001	-0.07408	0.0003
	total	0.0001	-0.08025	0.0001
TOC	base	0.0135	-0.03154	0.0226
	total	0.0001	-0.0411	0.0001
TP	base	0.0001	-0.10224	0.0001
	total	0.0001	-0.10969	0.0001
TSS	base	0.0002	-0.20981	0.0001
	total	0.0001	-0.21579	0.0001

*** Probabilities less than 0.10 are considered to be significant.**
**** Positive coefficients represent significantly increasing load and negative values indicate significantly decreasing trends.**

Table 15. Animal manure applications to pasture acreages in the Cannon (CC) and Shumate Creek (SC) watersheds.

	Pasture Acreage (acres)	Manure (tons)	Nitrogen (tons-N)	Phosphorus (tons-P_2O_5)	Potassium (tons-K_2O)
Shumate Creek	326				
1995		3338	28.5	48.8	32.6
1996		1943	16.6	28.4	19.0
1997		1741	14.9	25.5	17.0
1998		305	2.6	4.5	3.0
Four year total		7328	62.6	107.2	71.5
Cannon Creek	171				
1995		521	4.4	7.6	5.1
1996		648	5.5	9.5	6.3
1997		178	1.5	2.6	1.7
1998		0	0	0	0
Four year total		1347	11.5	19.7	13.1
SC:CC Ratio	1.91				
1995		6.40			
1996		3.00			
1997		9.78			
1998					
Four year total		5.44			

Table 16. Comparison of Shumate to Cannon Creek water discharge during base, storm, and total flow conditions.

Flow Type	averages **Cannon** m^3/month	averages **Shumate** m^3/month	log averages **Cannon**	log averages **Shumate**	**P-value***
Base	573988.8	1412368.11	12.3856	13.5811	**0.00022**
Storm	507121.6	1351894.78	10.4154	10.1465	0.87937
Total	827549.1	2088315	12.5318	13.7283	**0.00026**

- Cannon Creek log means are considered to be significantly different from Shumate Creek log means when the P-value is less than 0.10 according to a paired t-test. Bolded P-values are greater than 0.10.

Table 17. Comparison of Shumate to Cannon Creek logarithmic load averages of Escherichia coli (EC), coliphage virus (CV), ammonium-N (NH4), nitrate-N (NO3), dissolved reactive phosphate (DP), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), total phosphorus (TP), total suspended solids (TSS) during base, storm, and total flow conditions.

Parameter	**Flow Type**	averages **Cannon**	averages **Shumate**	log averages **Cannon**	log averages **Shumate**	**P-value***
		$1e^6$organisms/month	$1e^6$organisms/month			
EC	Base	1778.27	15824.41	5.19938	6.9102	**0.00198**
	Storm	1153.89	23931.01	4.76233	6.1302	0.18783
	Total	2354.71	27789.41	5.42357	7.0717	**0.00252**
		$1e^6$organisms/month	$1e^6$organisms/month			
CV	Base	29.68	547.53	1.87206	4.107	**0.00016**
	Storm	32.46	500.65	1.74633	3.7406	**0.04548**
	Total	45.41	797.35	2.124	4.317	**0.00009**
		kg/month	kg/month			
NH_3	Base	4.73	28.8	1.07922	2.2053	**0.00043**
	Storm	22.99	147.05	1.27582	2.471	**0.09850**
	Total	15.73	101.83	1.35276	2.4873	**0.00167**
		kg/month	kg/month			
NO_3	Base	226.05	1288.64	3.82725	6.261	**0.00000**
	Storm	235.45	1483.03	3.5429	4.3897	0.38023
	Total	343.28	2029.65	3.98392	6.4046	**0.00000**
		kg/month	kg/month			
DP	Base	21.73	132.41	2.25633	3.956	**0.00000**
	Storm	34.99	211.68	2.09579	3.0264	0.16276
	Total	38.72	237.75	2.47906	4.1331	**0.00000**
		kg/month	kg/month			
TKN	Base	402.51	1774.5	4.5091	6.2145	**0.00001**
	Storm	632.23	3034.02	4.14192	4.865	0.45662
	Total	718.13	3291.01	4.74376	6.3686	**0.00002**
		kg/month	kg/month			
TOC	Base	2833.71	7371.89	6.61708	7.9691	**0.00002**
	Storm	3731.49	10510.53	5.91966	5.9815	0.95374
	Total	4698.96	12626.66	6.84762	8.1487	**0.00006**
		kg/month	kg/month			
TP	Base	126.69	580.18	3.38048	4.8952	**0.00001**
	Storm	269.34	884.73	3.24556	4.1046	0.29319
	Total	260.86	1022.04	3.6617	5.0578	**0.00001**
		kg/month	kg/month			
TSS	Base	130283.85	236271.27	8.82141	9.9306	**0.00624**
	Storm	94634.98	525603.69	8.24407	8.7156	0.72578
	Total	177600.84	499072.61	9.0613	10.1092	**0.00538**

* Cannon Creek log means are considered to be significantly different from Shumate Creek log means when the P-value is less than 0.10 according to a paired t-test. Bolded P-values are greater than 0.10.

Table 18. Comparison of Shumate to Cannon Creek logarithmic mean concentration averages of Escherichia coli (EC), coliphage virus (CV), ammonium-N (NH4), nitrate-N (NO3), dissolved reactive phosphate (DP), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), total phosphorus (TP), total suspended solids (TSS) during base, storm, and total flow conditions.

Parameter	**Flow Type**	averages **Cannon** organisms/l	averages **Shumate** organisms/l	log averages **Cannon**	log averages **Shumate**	**P-value***
EC	Base	0.0027	0.0049	-7.1862	-6.6709	0.17567
	Storm	0.11407	0.12855	-5.653	-4.0991	0.14844
	Total	0.00276	0.00507	-7.1082	-6.6566	0.21110
		organisms/l	organisms/l			
CV	Base	0.00005	0.00031	-10.5135	-9.4741	**0.04225**
	Storm	0.11122	0.11753	-8.669	-6.4887	0.11099
	Total	0.00005	0.00032	-10.4078	-9.4113	**0.03369**
		mg/l	mg/l			
NH4	Base	0.00002	0.00001	-11.3064	-11.3759	0.77188
	Storm	0.11118	0.1171	-9.1395	-7.7584	0.35867
	Total	0.00002	0.00002	-11.179	-11.241	0.80954
		mg/l	mg/l			
NO3	Base	0.00027	0.00072	-8.5583	-7.3201	**0.00048**
	Storm	0.11153	0.11778	-6.8725	-5.8397	0.28742
	Total	0.00027	0.00072	-8.5479	-7.3237	**0.00052**
		mg/l	mg/l			
DP	Base	0.00005	0.00007	-10.1293	-9.6252	**0.03050**
	Storm	0.11123	0.11715	-8.3196	-7.2029	0.38136
	Total	0.00005	0.00008	-10.0527	-9.5952	**0.03839**
		mg/l	mg/l			
TKN	Base	0.0006	0.00084	-7.8765	-7.3667	**0.00245**
	Storm	0.112	0.11848	-6.2734	-5.3643	0.36759
	Total	0.00066	0.00085	-7.788	-7.3597	**0.00264**
		mg/l	mg/l			
TOC	Base	0.00447	0.00405	-5.7685	-5.612	0.32909
	Storm	0.11742	0.12315	-4.4957	-4.2478	0.73826
	Total	0.00484	0.00423	-5.6842	-5.5796	0.49944
		mg/l	mg/l			
TP	Base	0.00021	0.00028	-9.0051	-8.686	**0.06364**
	Storm	0.11147	0.11755	-7.1698	-6.1247	0.37740
	Total	0.00023	0.00029	-8.8701	-8.6705	**0.06967**
		mg/l	mg/l			
TSS	Base	0.14243	0.11408	-3.5642	-3.6505	0.69117
	Storm	0.22747	0.36671	-2.1713	-1.5138	0.33522
	Total	0.14454	0.12141	-3.4705	-3.6191	0.26856

* Cannon Creek log means are considered to be significantly different from Shumate Creek log means when the P-value is less than 0.10 according to a paired t-test. Bolded P-values are greater than 0.10.

APPENDIX B
Figures 1-57

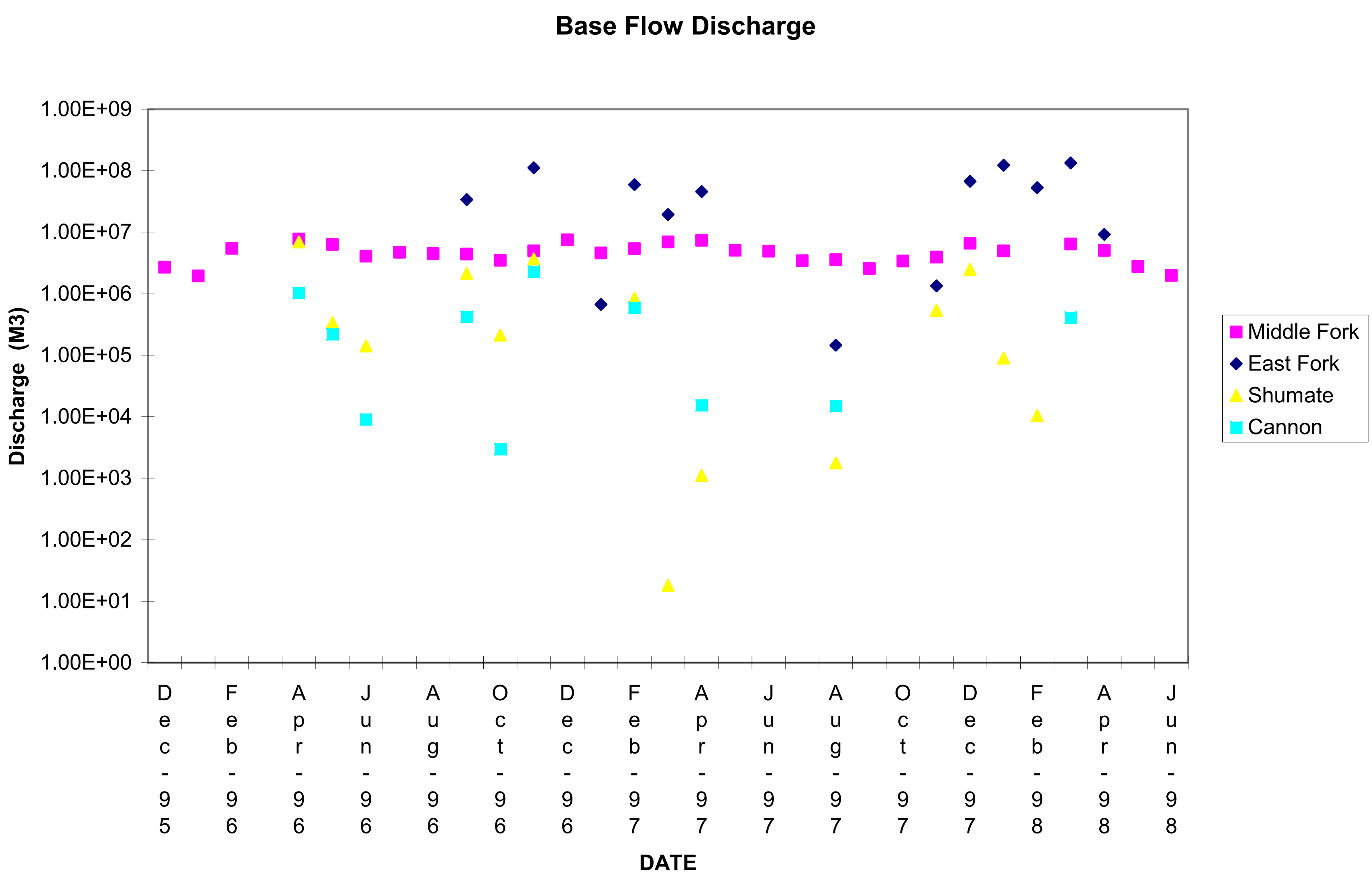

Figure 1. Monthly base flow discharge for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

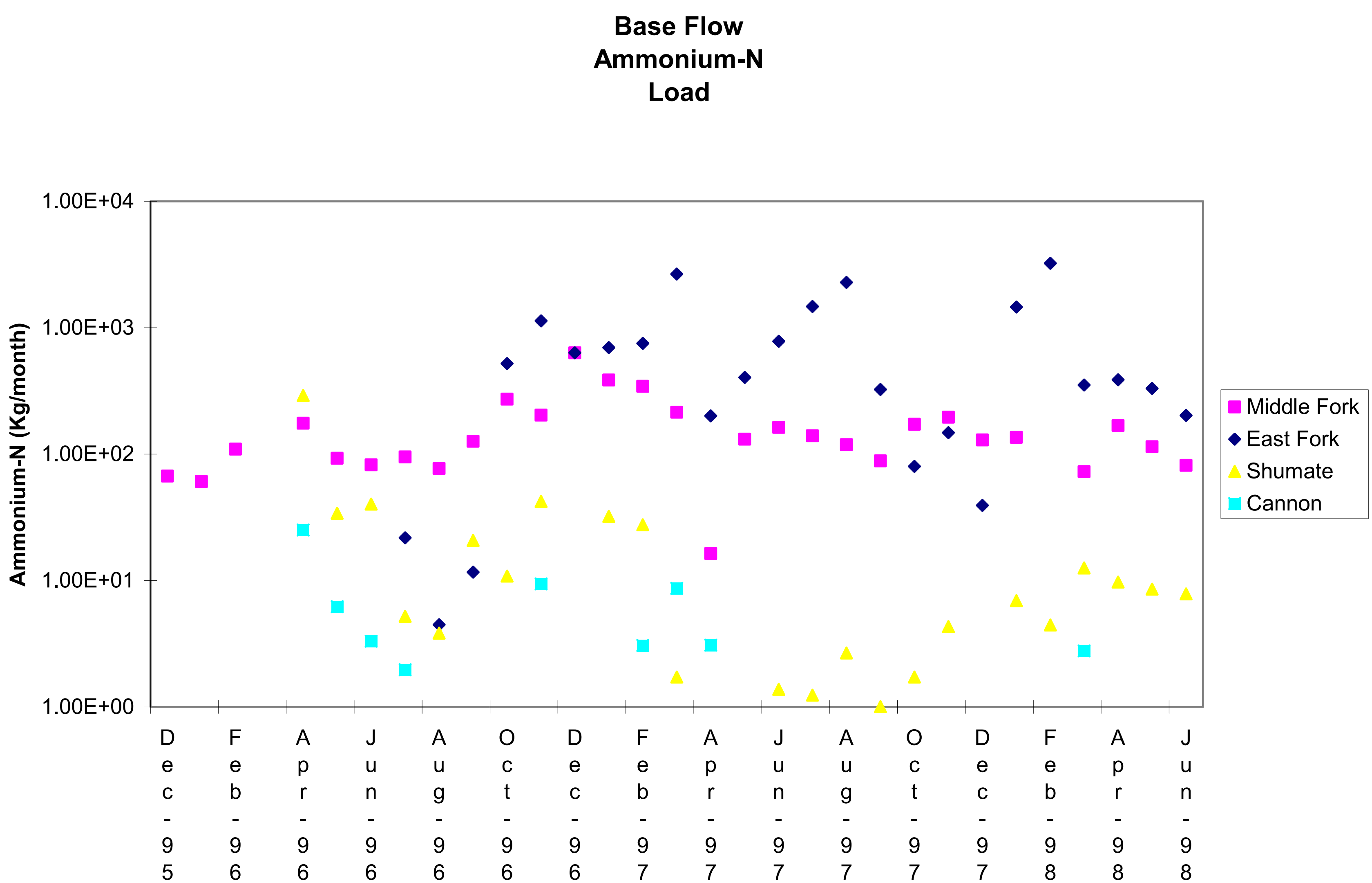

Figure 2. Monthly base flow ammonium-N loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

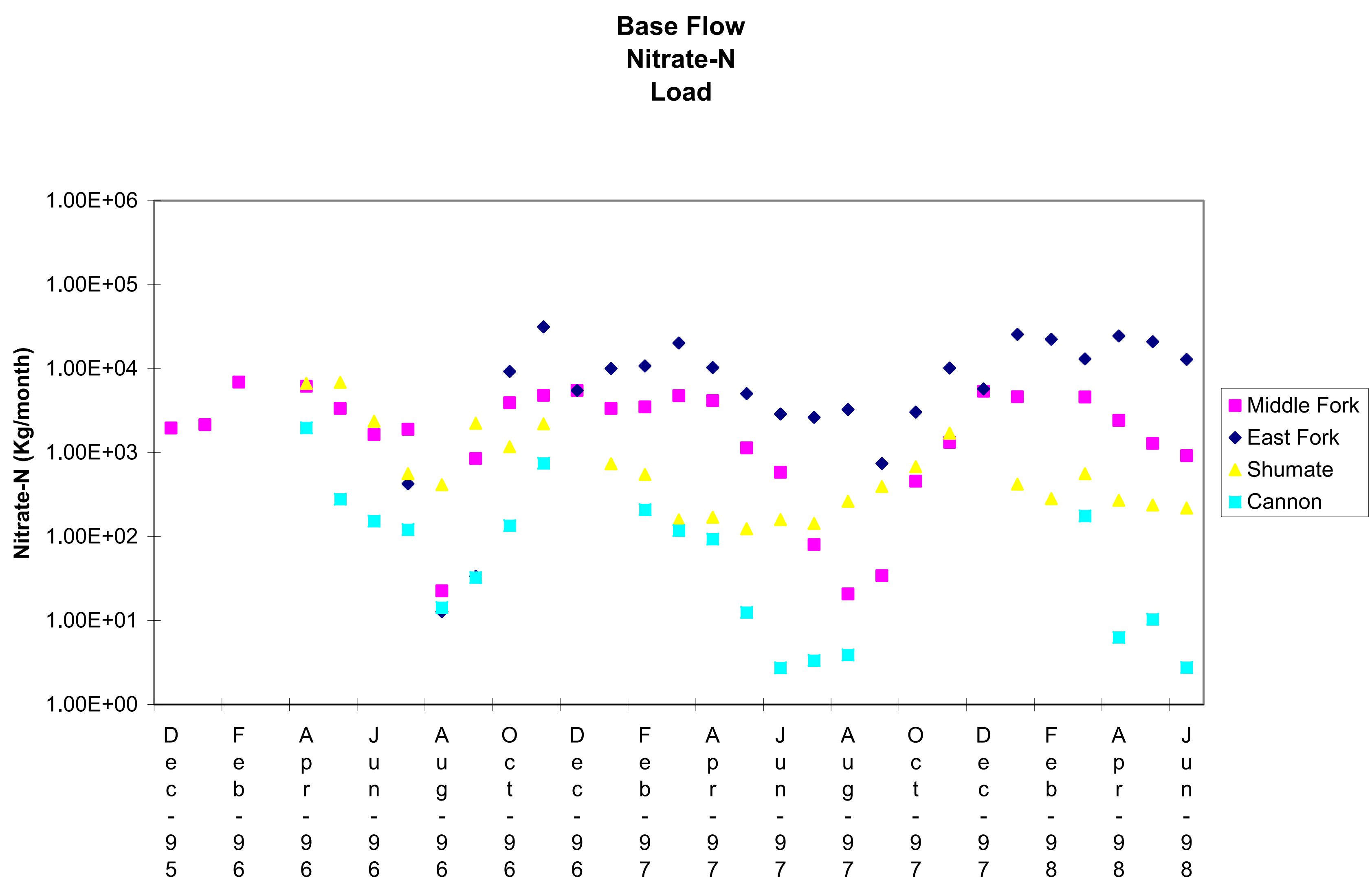

Figure 3. Monthly base flow nitrate-N loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

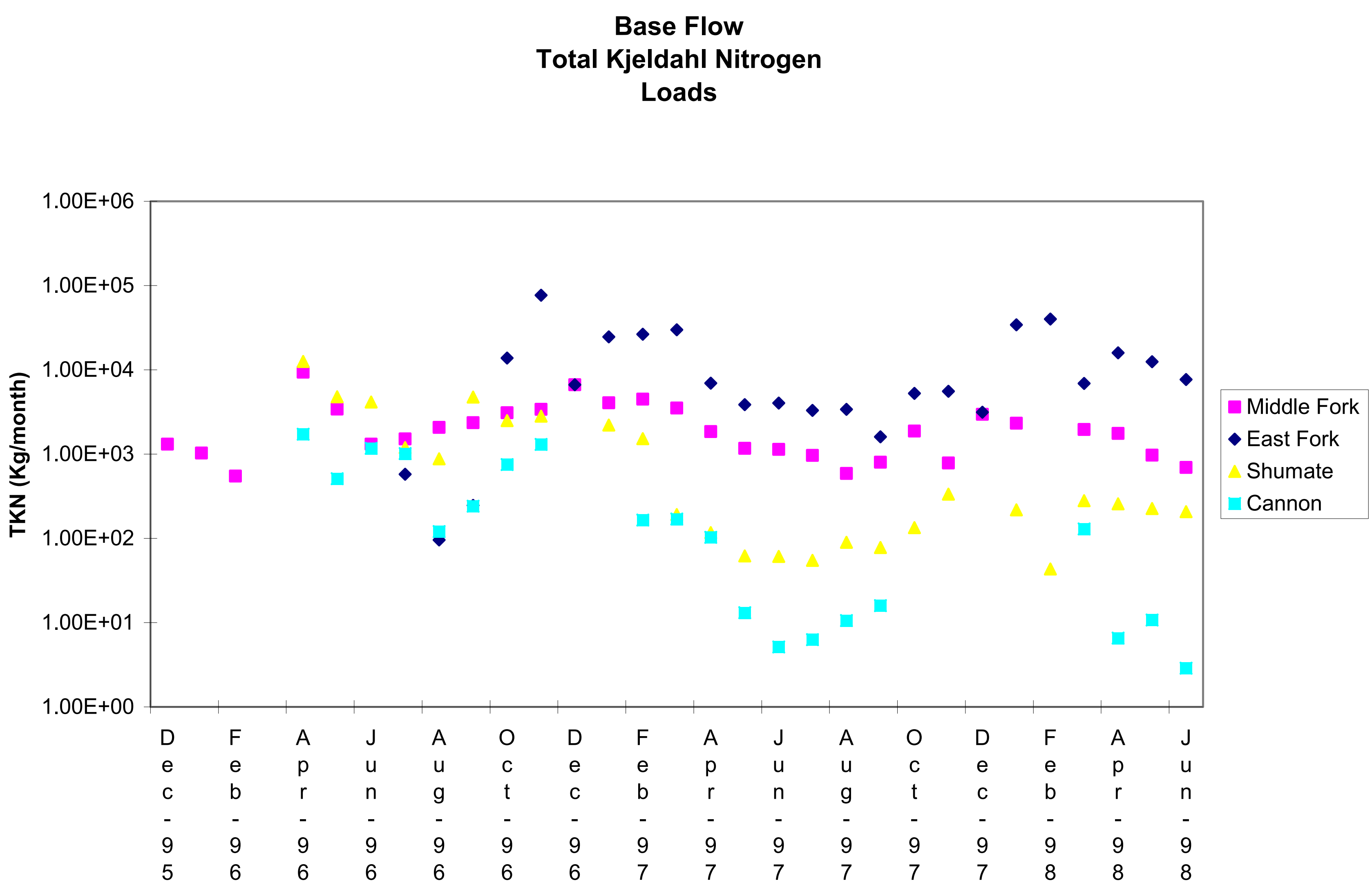

Figure 4. Monthly base flow total Kjelahl nitrogen loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

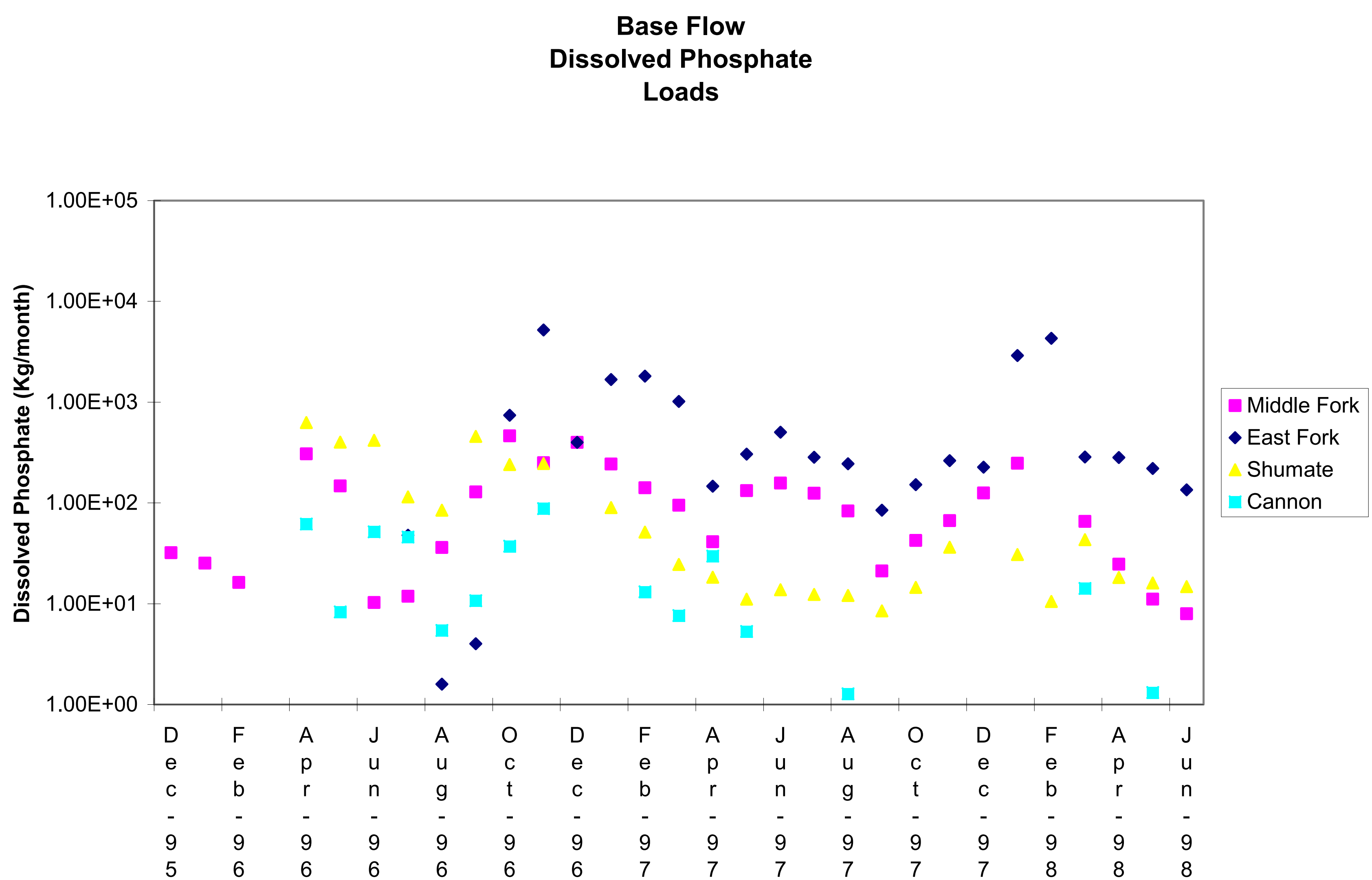

Figure 5. Monthly base flow dissolved phosphate loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

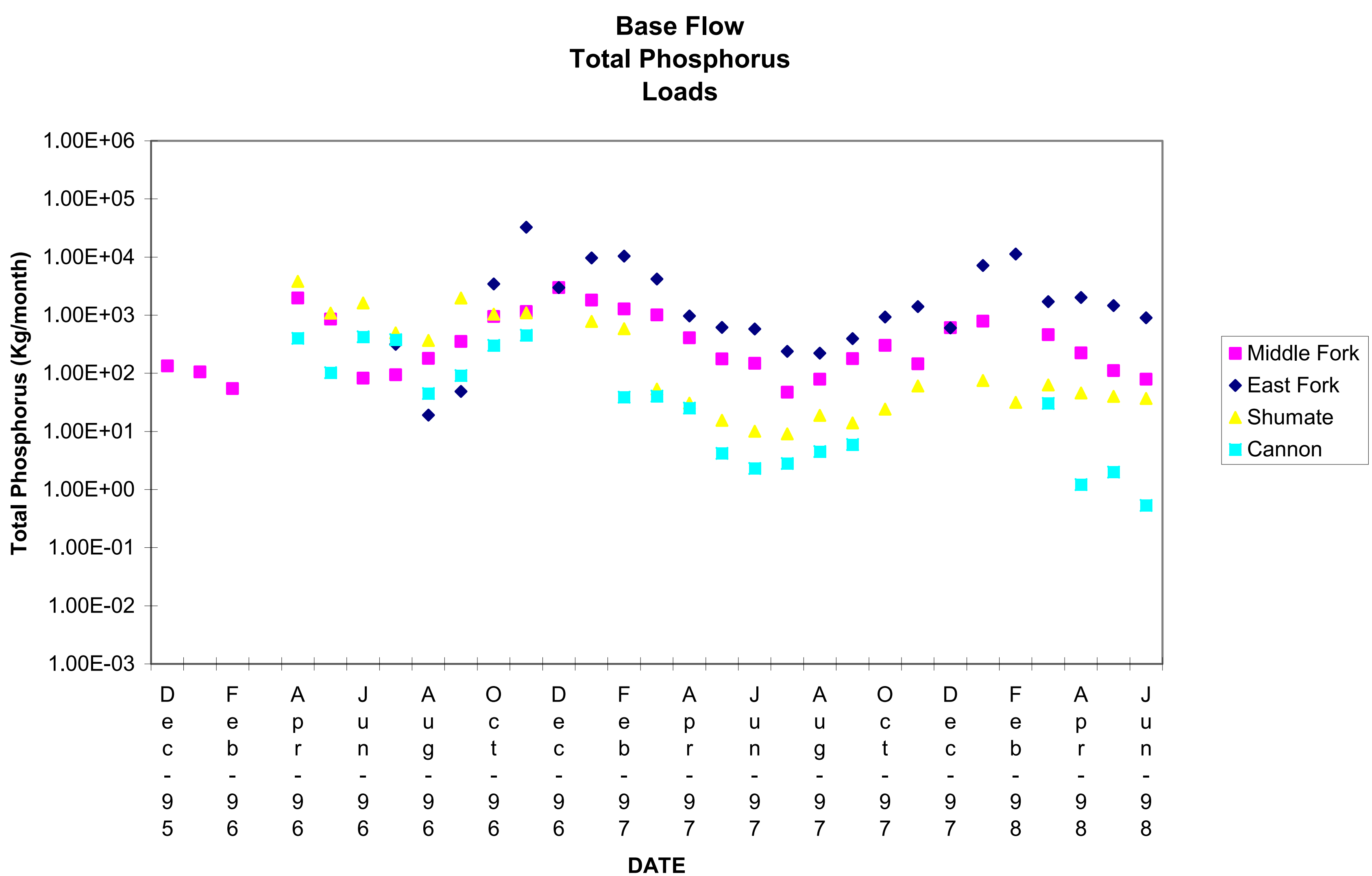

Figure 6. Monthly base flow total phosphorus loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

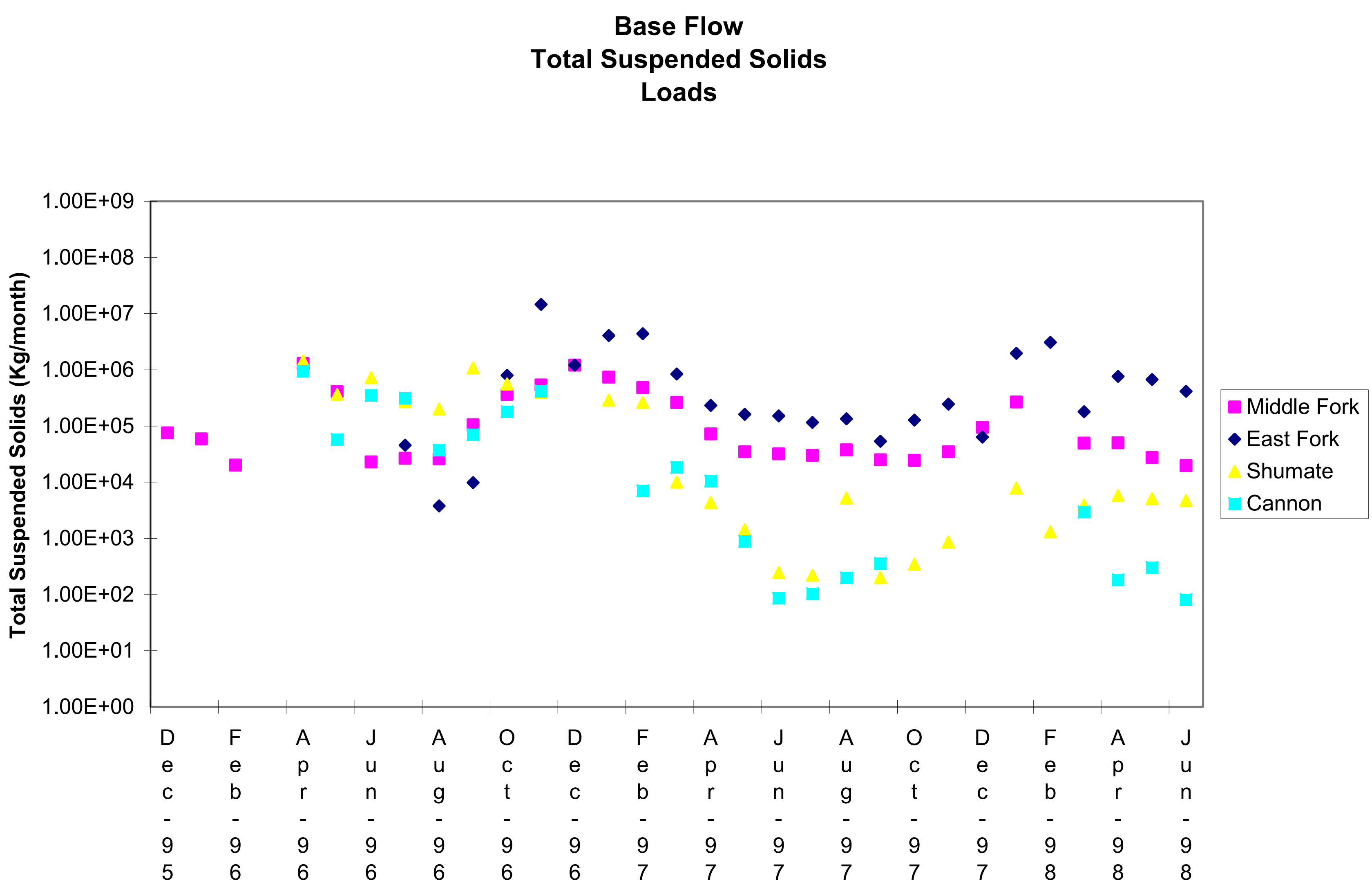

Figure 7. Monthly base flow total suspended solids loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

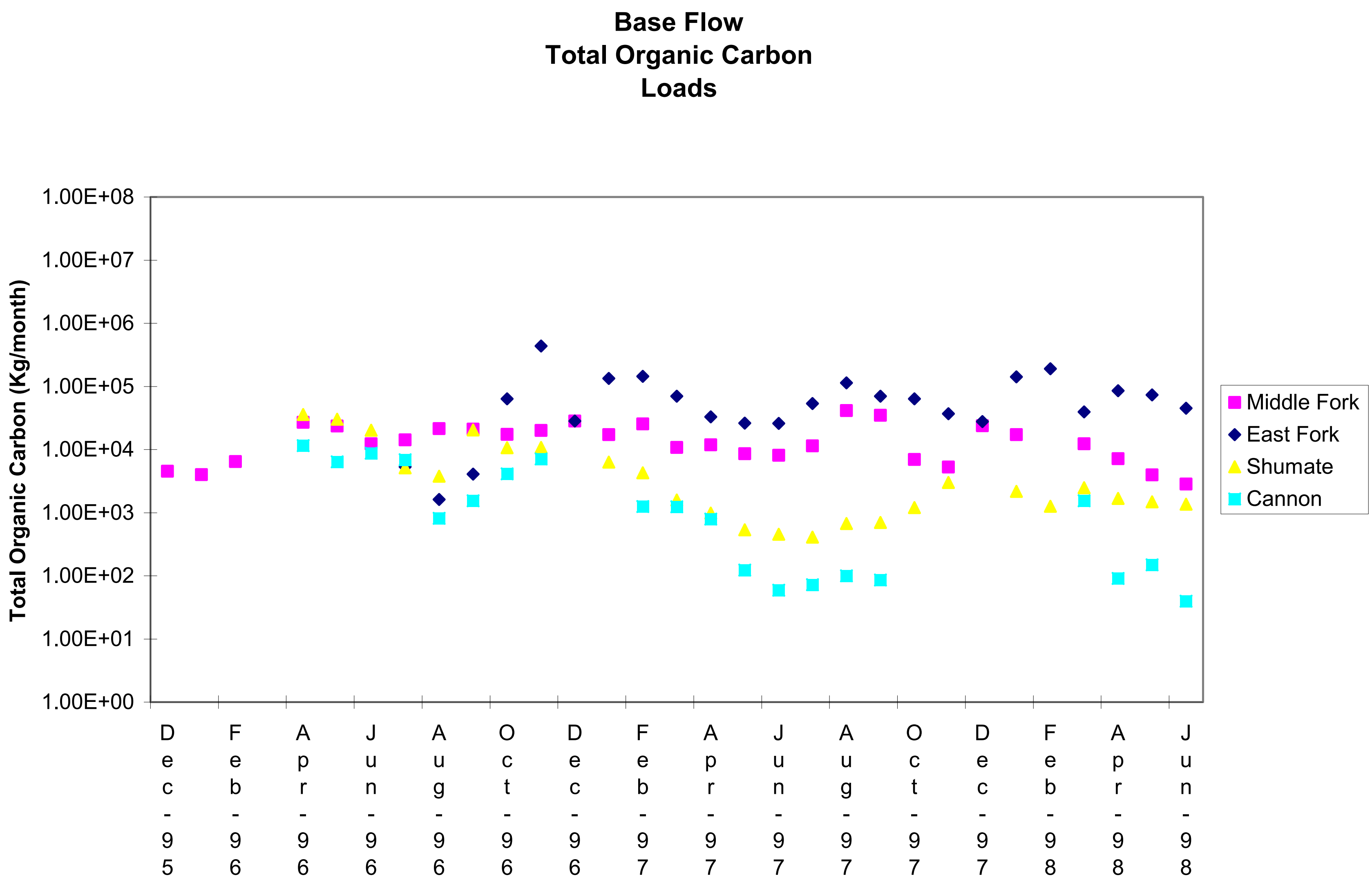

Figure 8. Monthly base flow total organic carbon loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

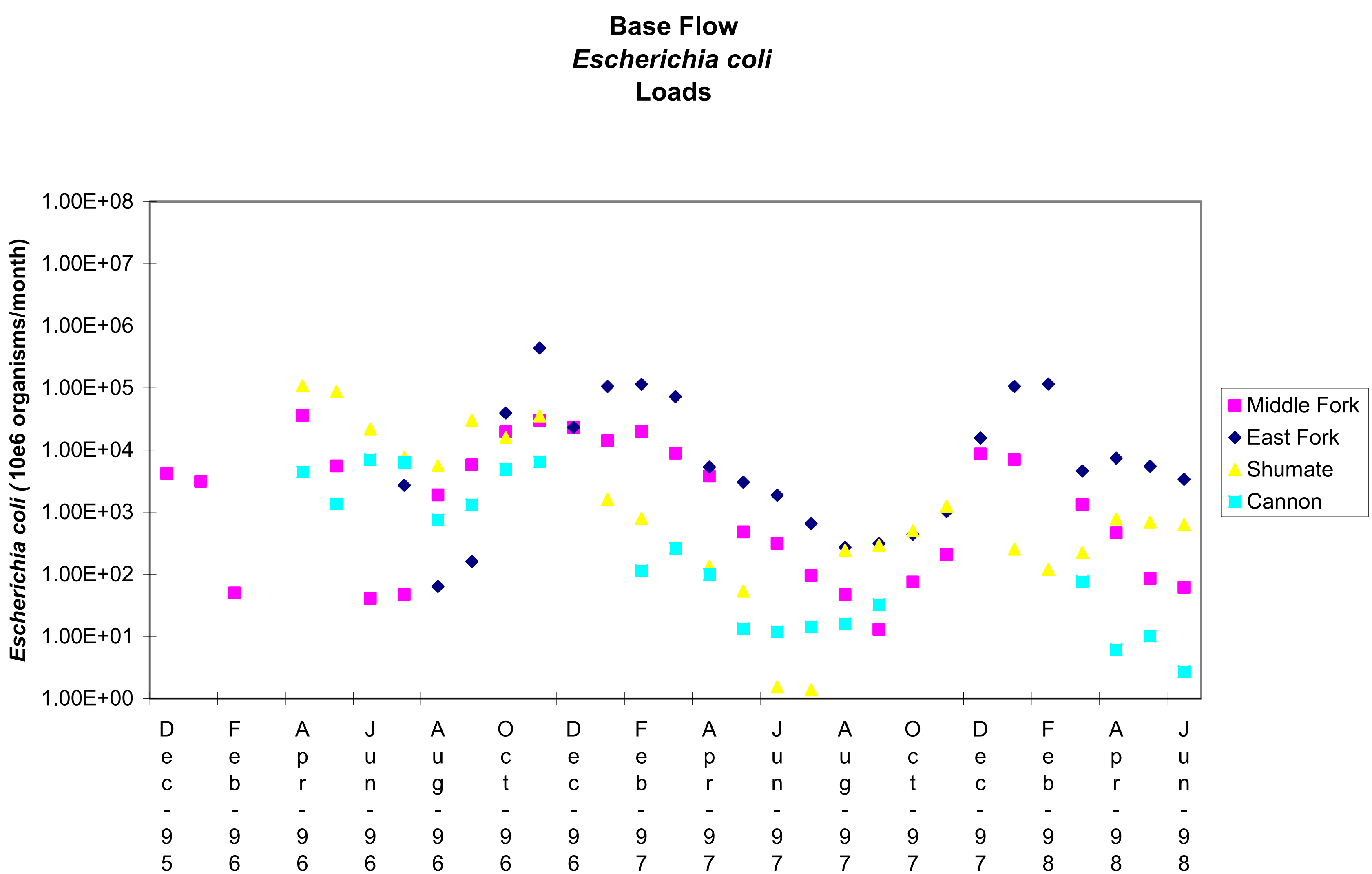

Figure 9. Monthly base flow *Escherichia coli* loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

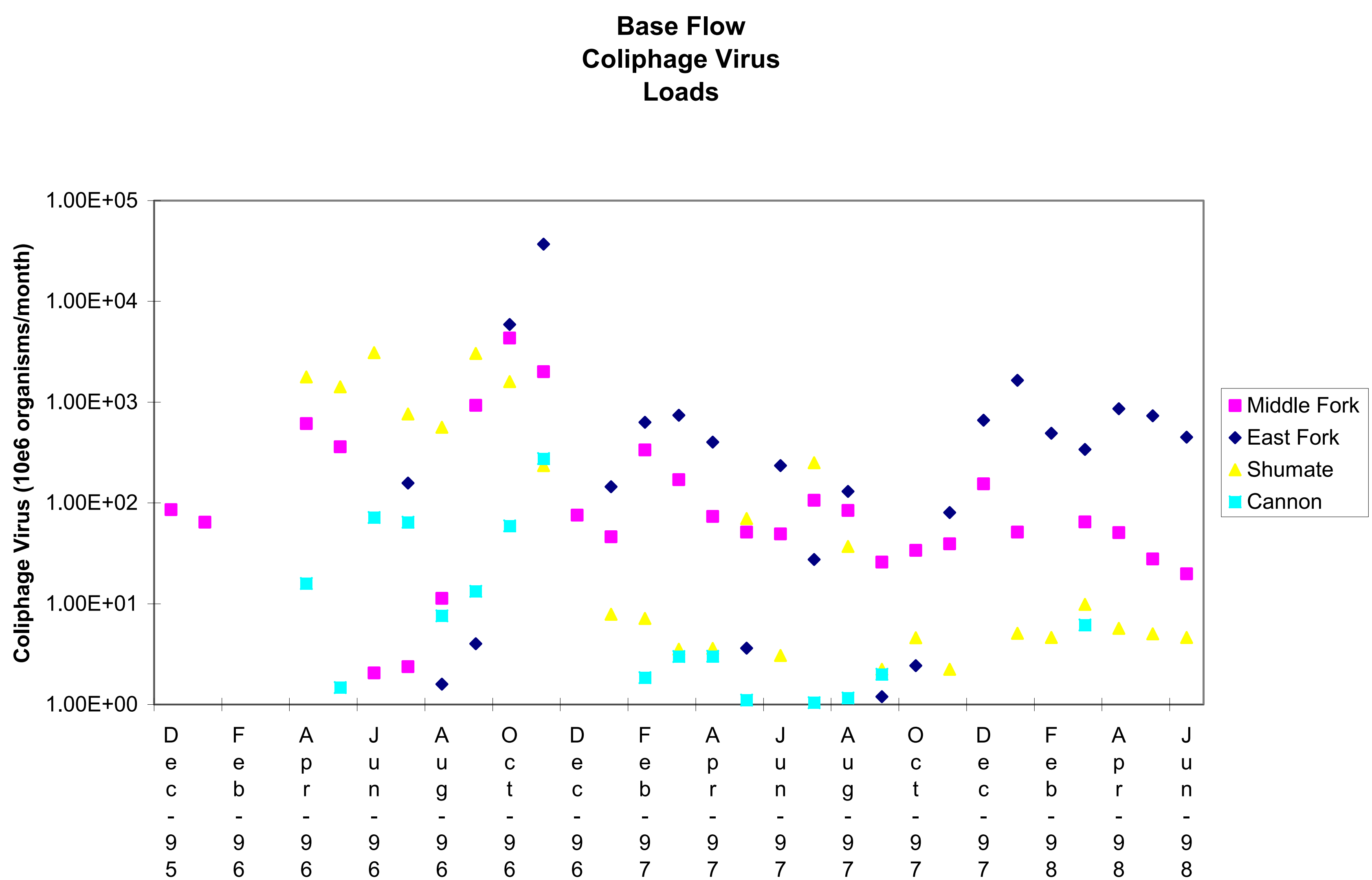

Figure 10. Monthly base flow coliphage virus loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

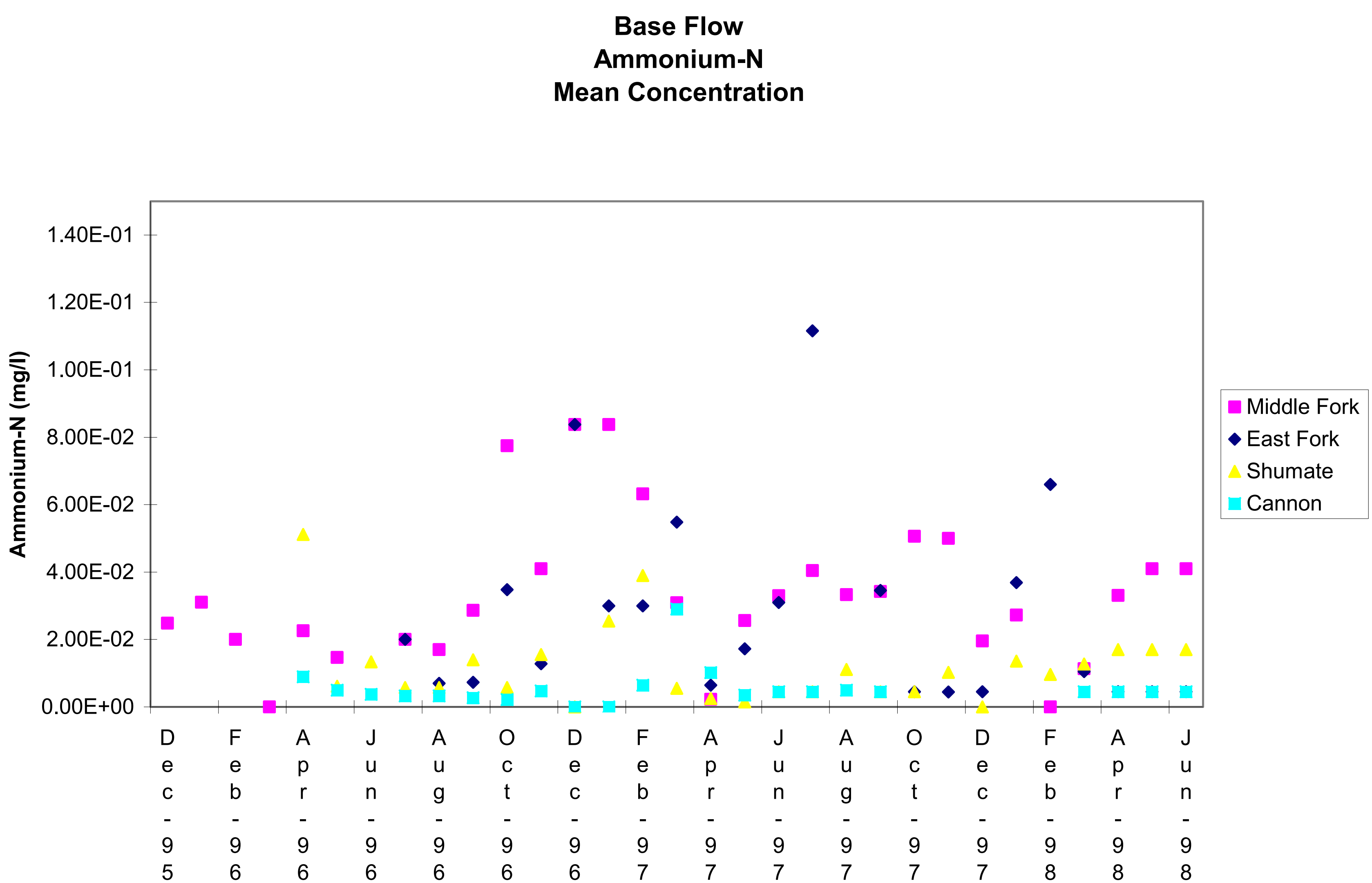

Figure 11. Monthly base flow ammonium-N mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

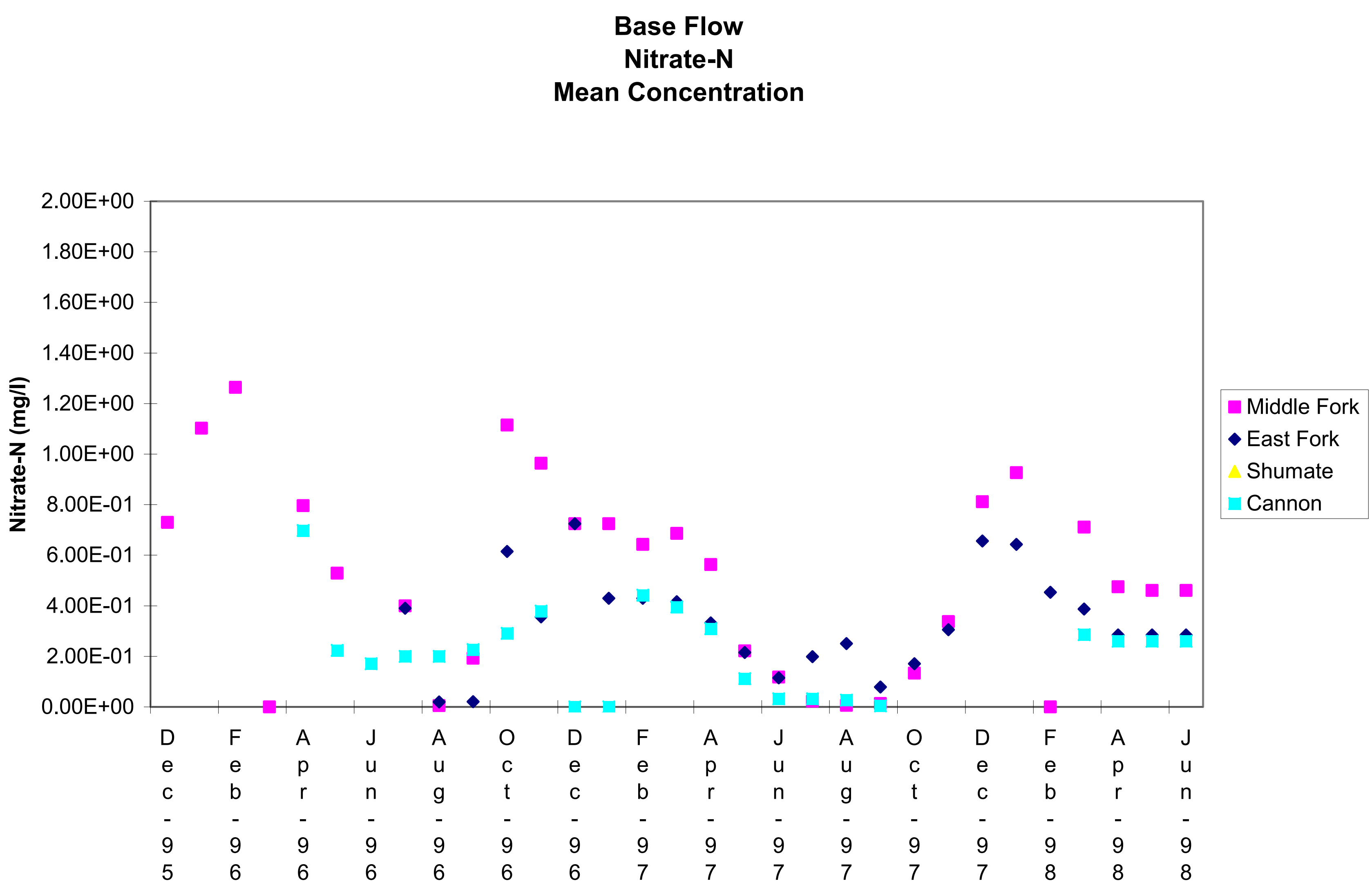

Figure 12. Monthly base flow nitrate-N mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

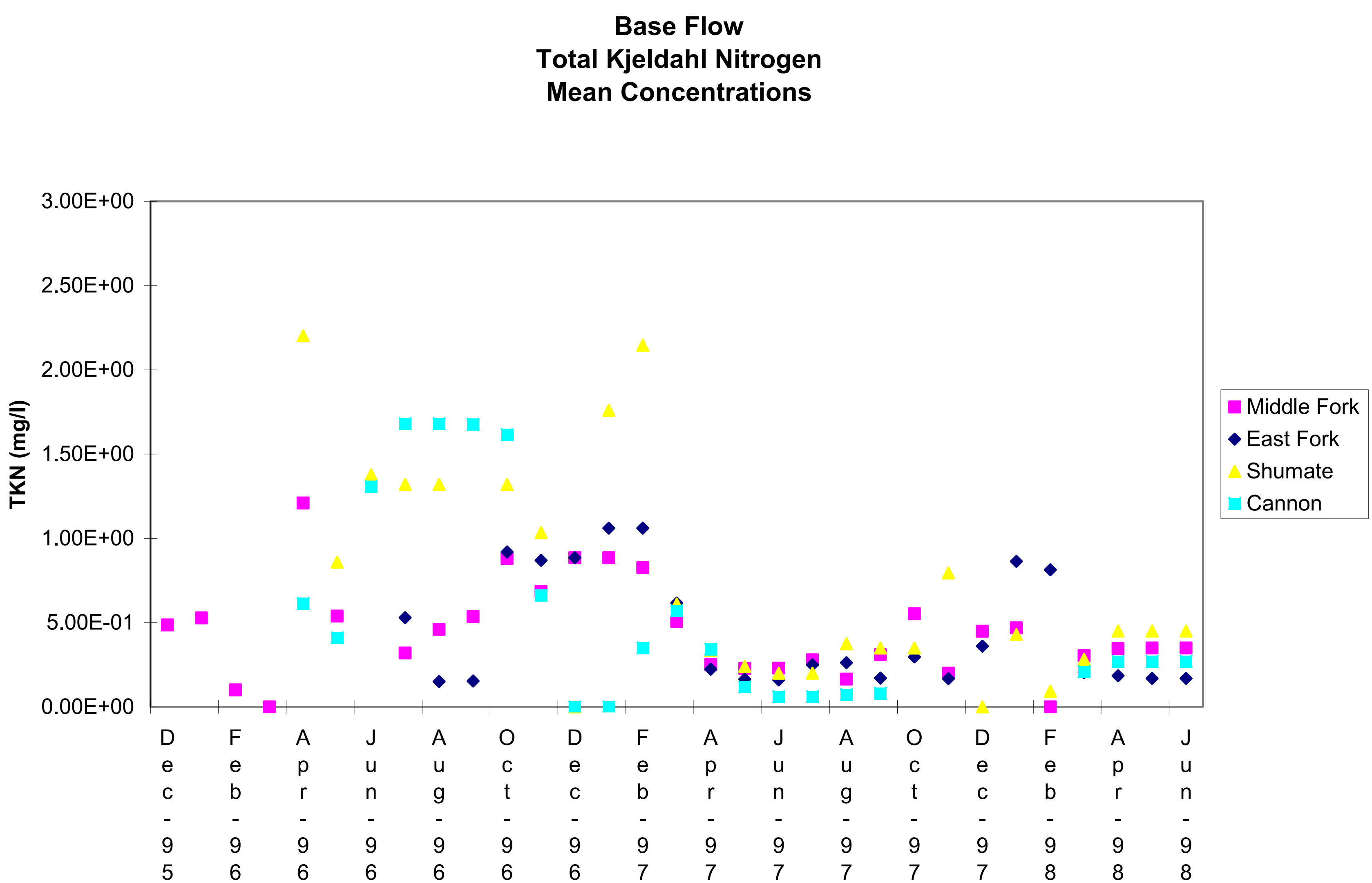

Figure 13. Monthly base flow total Kjeldahl nitrogen mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

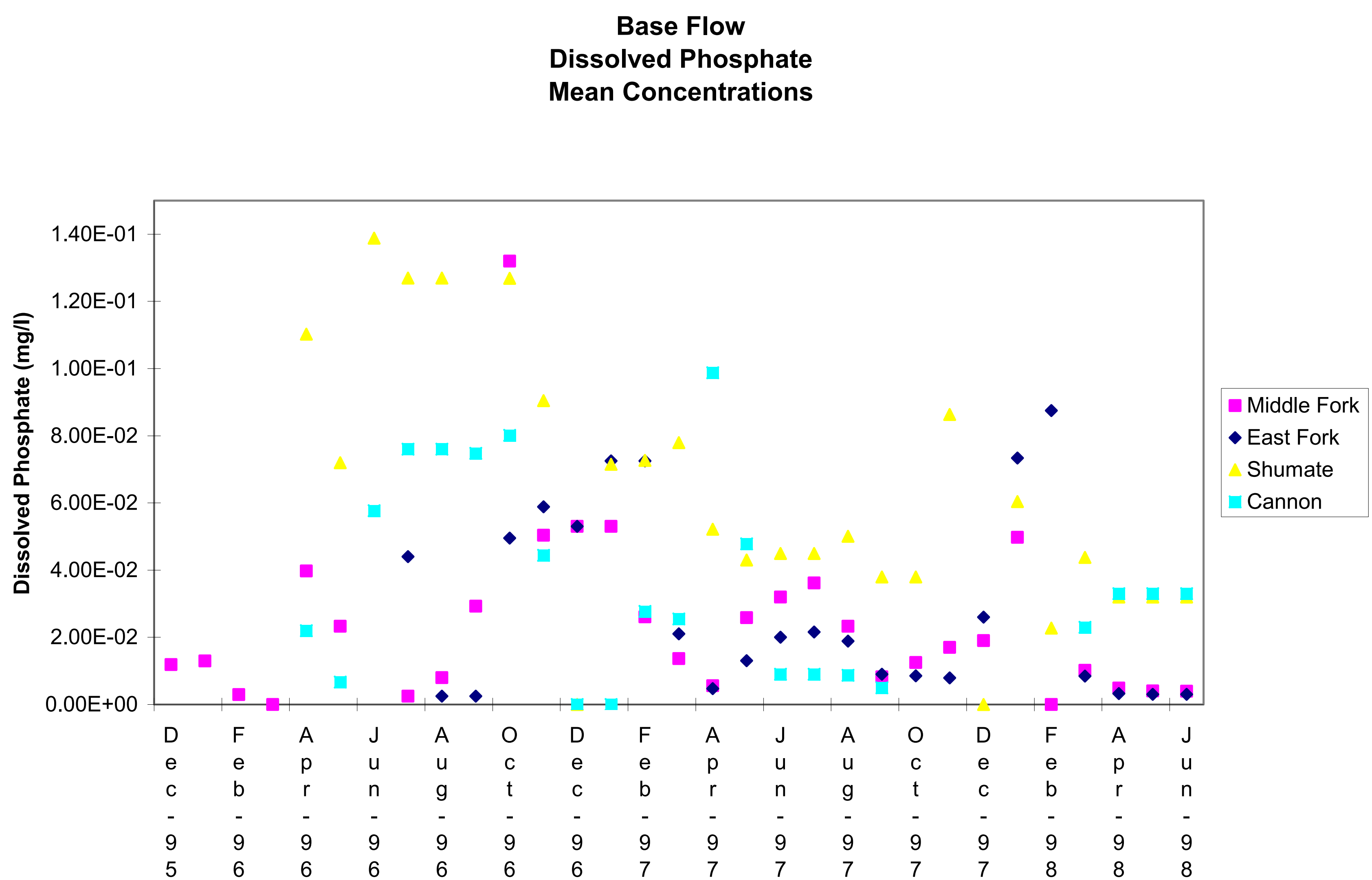

Figure 14. Monthly base flow dissolved phosphate mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

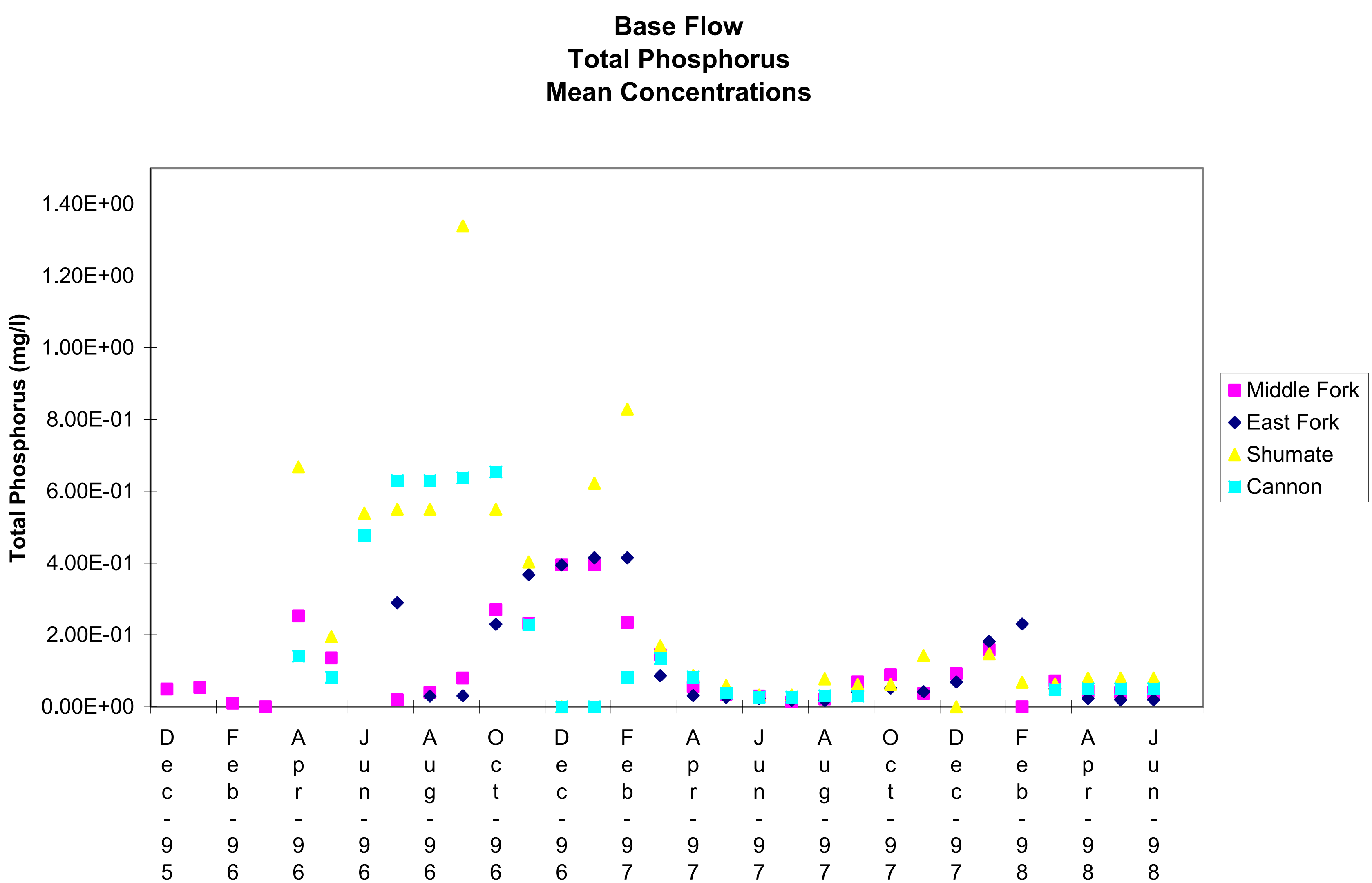

Figure 15. Monthly base flow total phosphorus mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

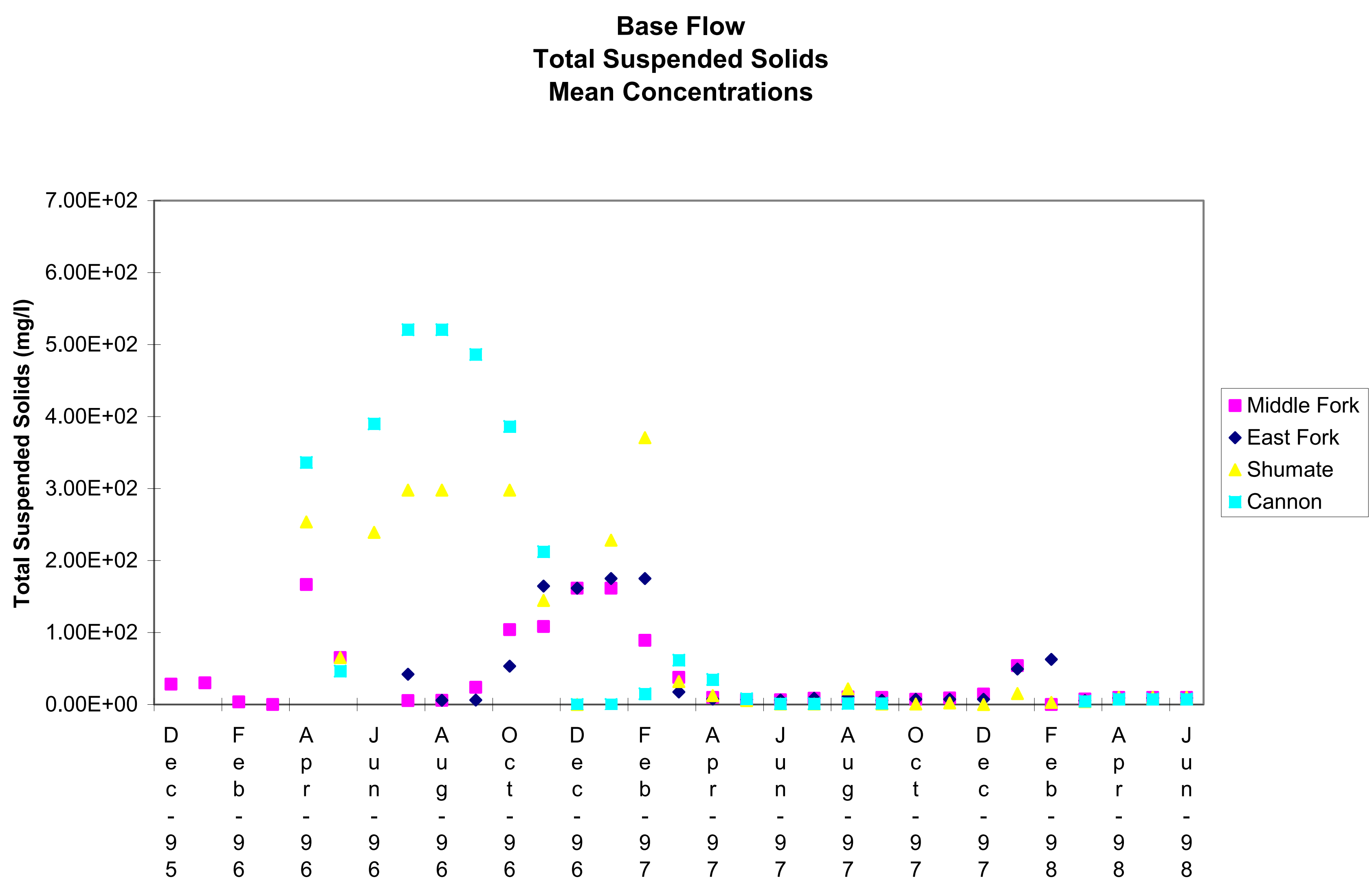

Figure 16. Monthly base flow total suspended solids mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

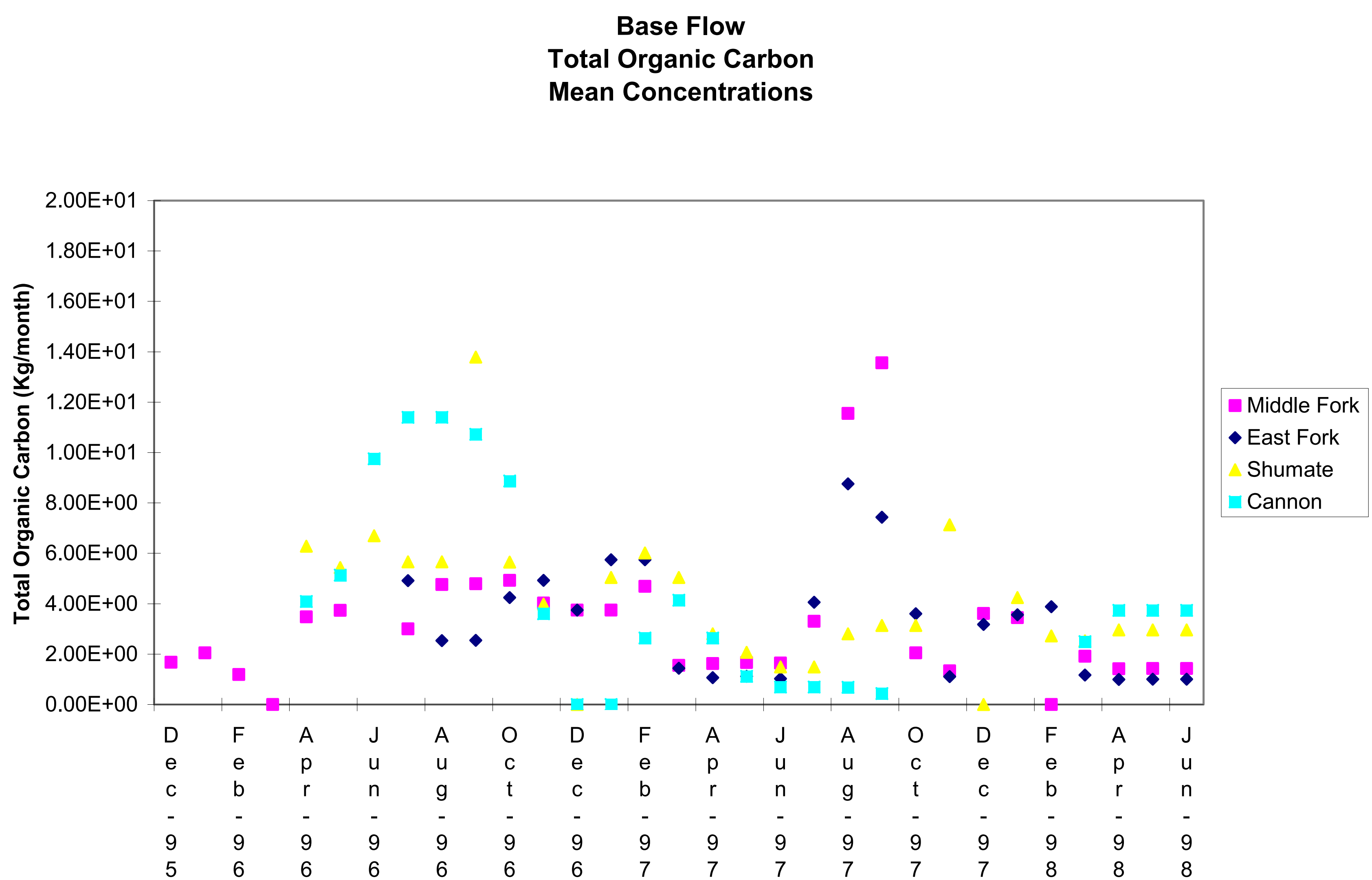

Figure 17. Monthly base flow total organic carbon mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

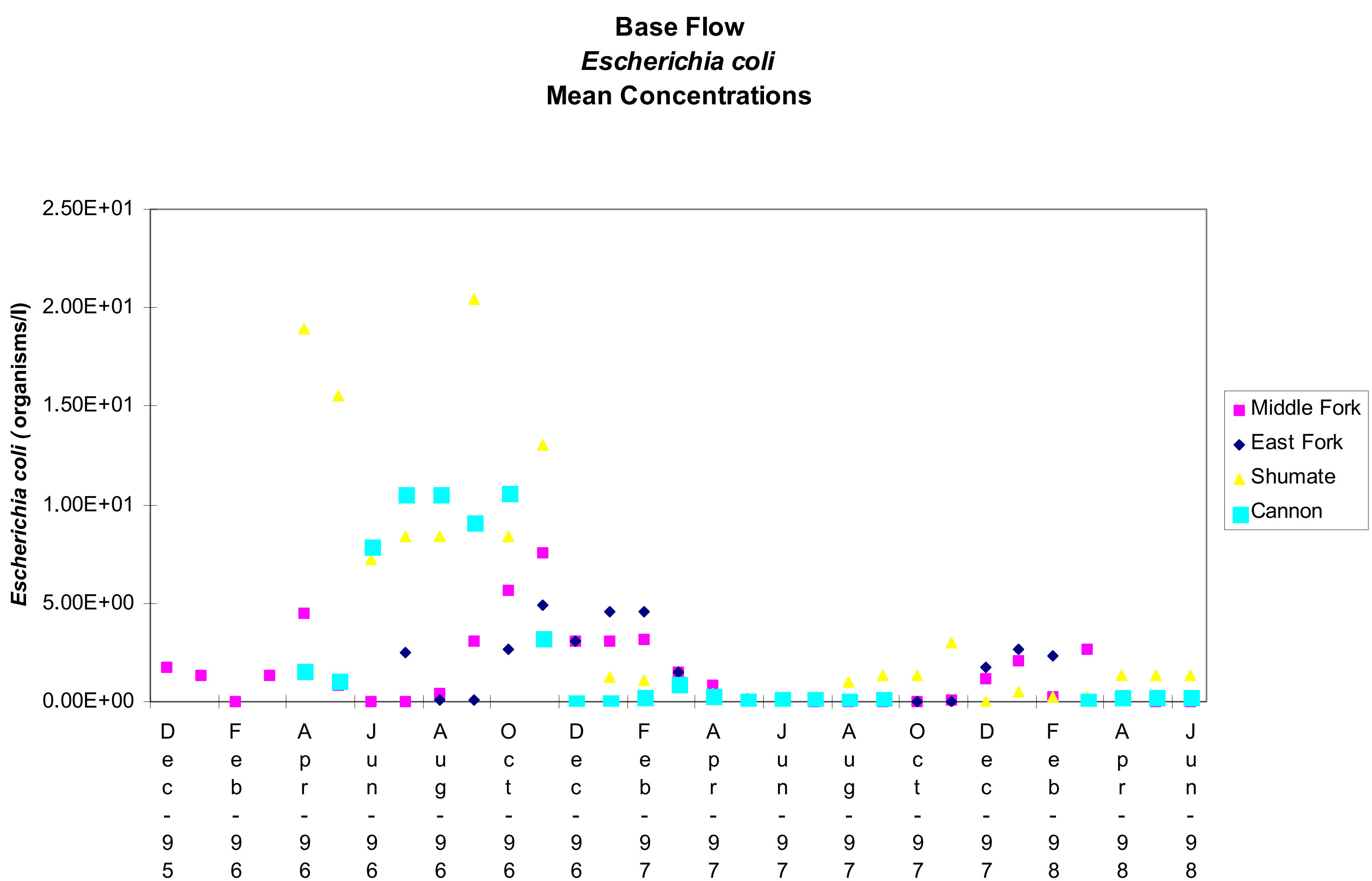

Figure 18. Monthly base flow *Escherichia coli* mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

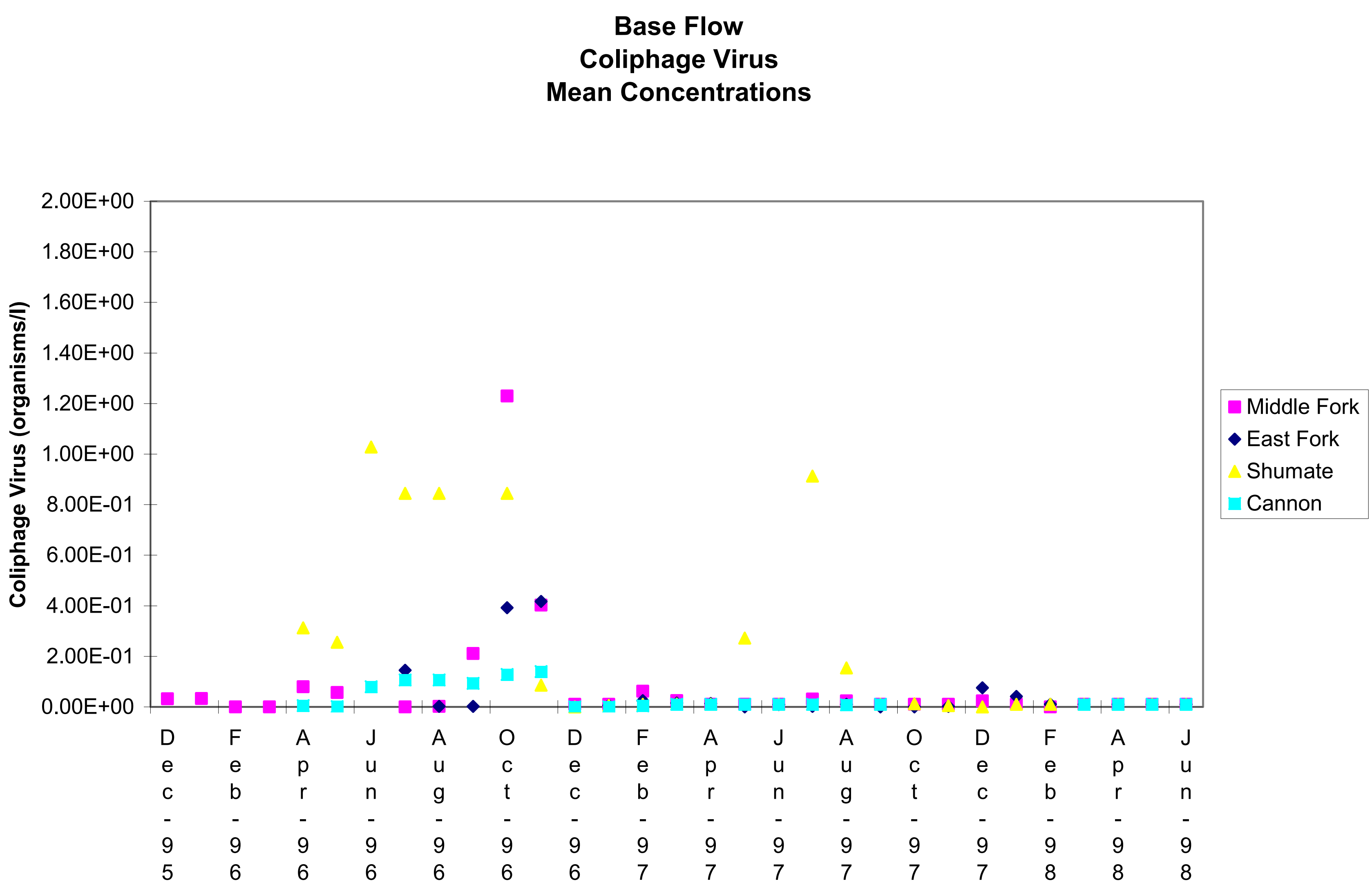

Figure 19. Monthly base flow coliphage virus mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

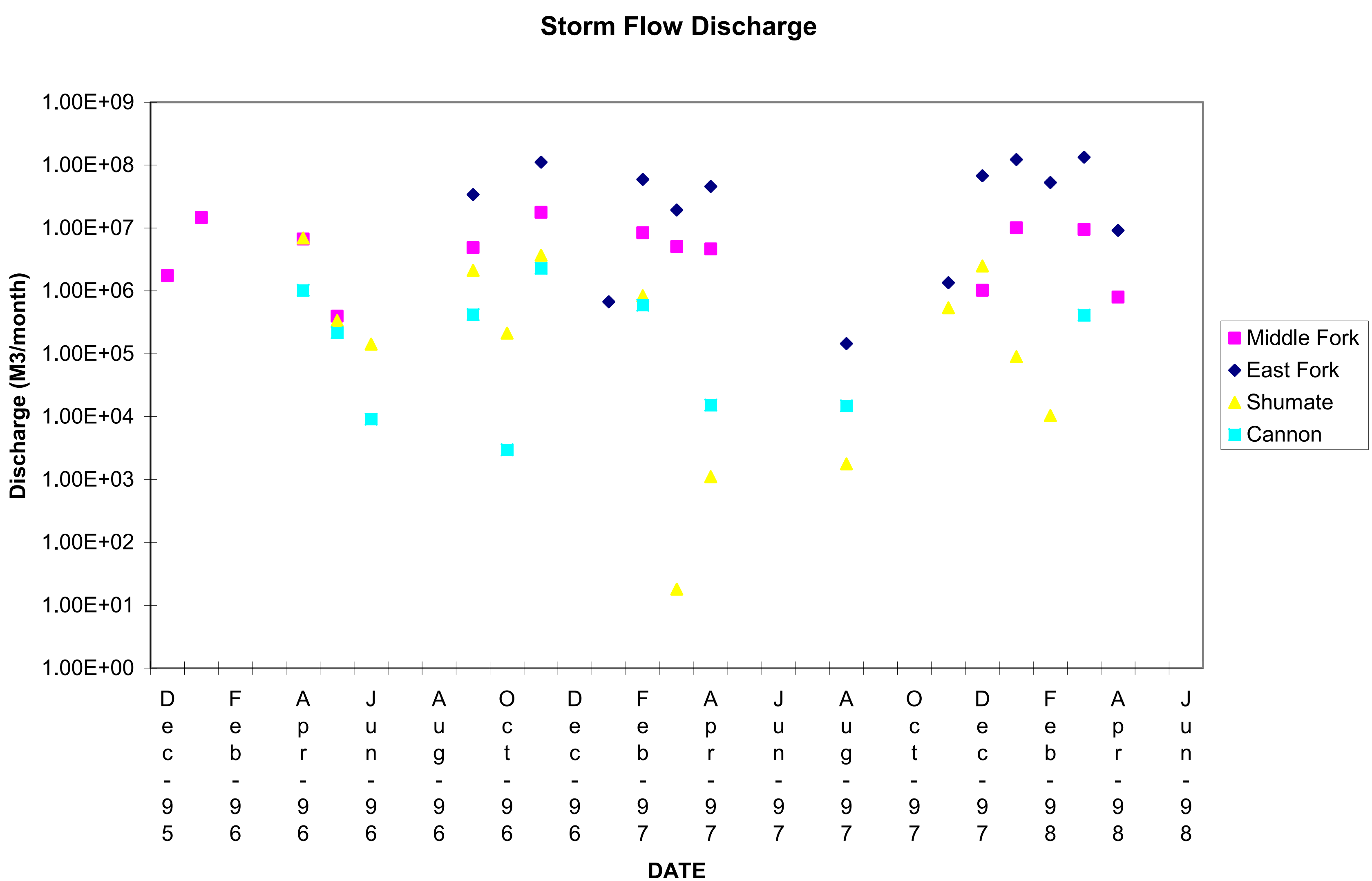

Figure 20. Monthly storm flow discharge for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

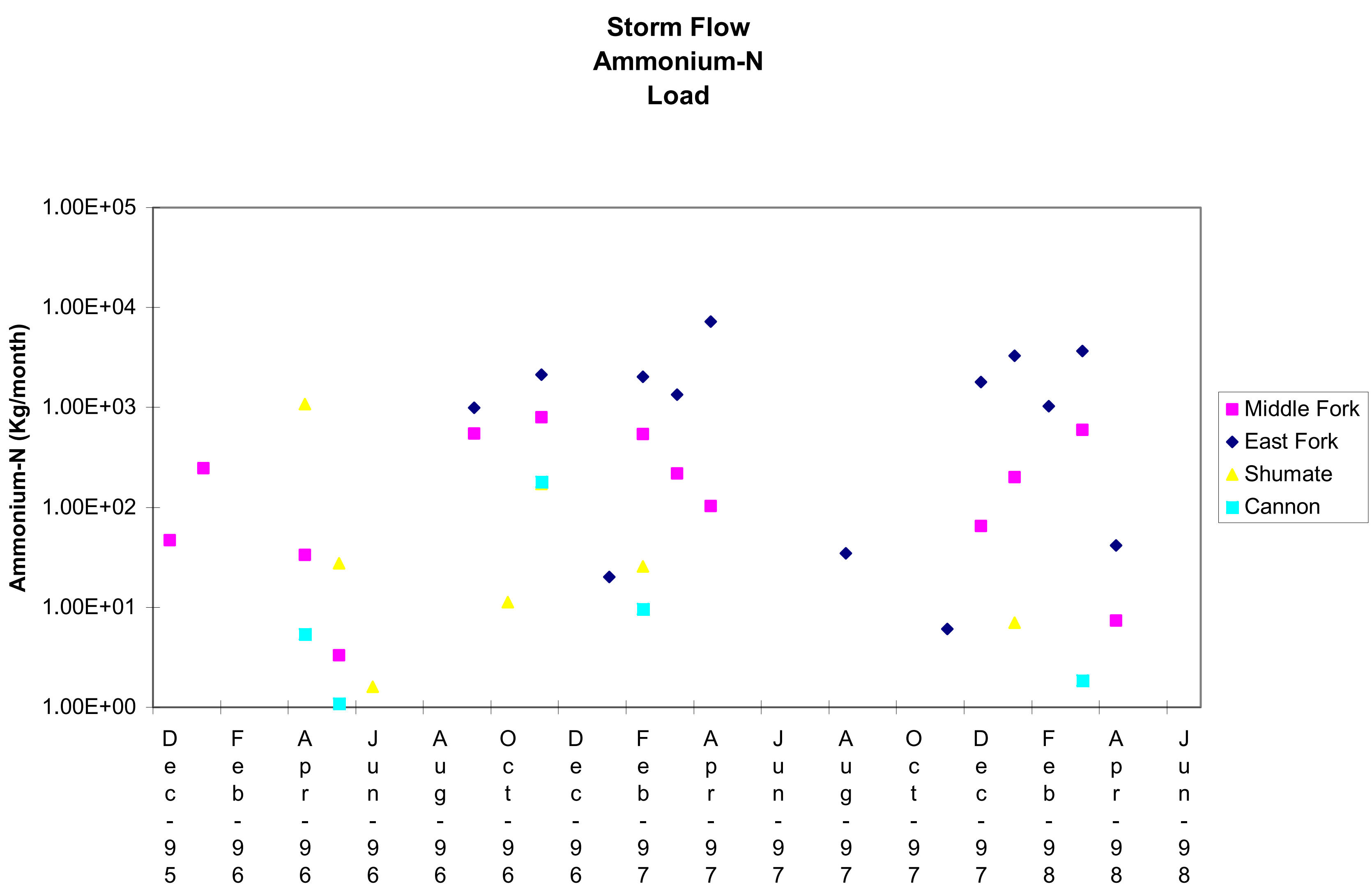

Figure 21. Monthly storm flow ammonium-N loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

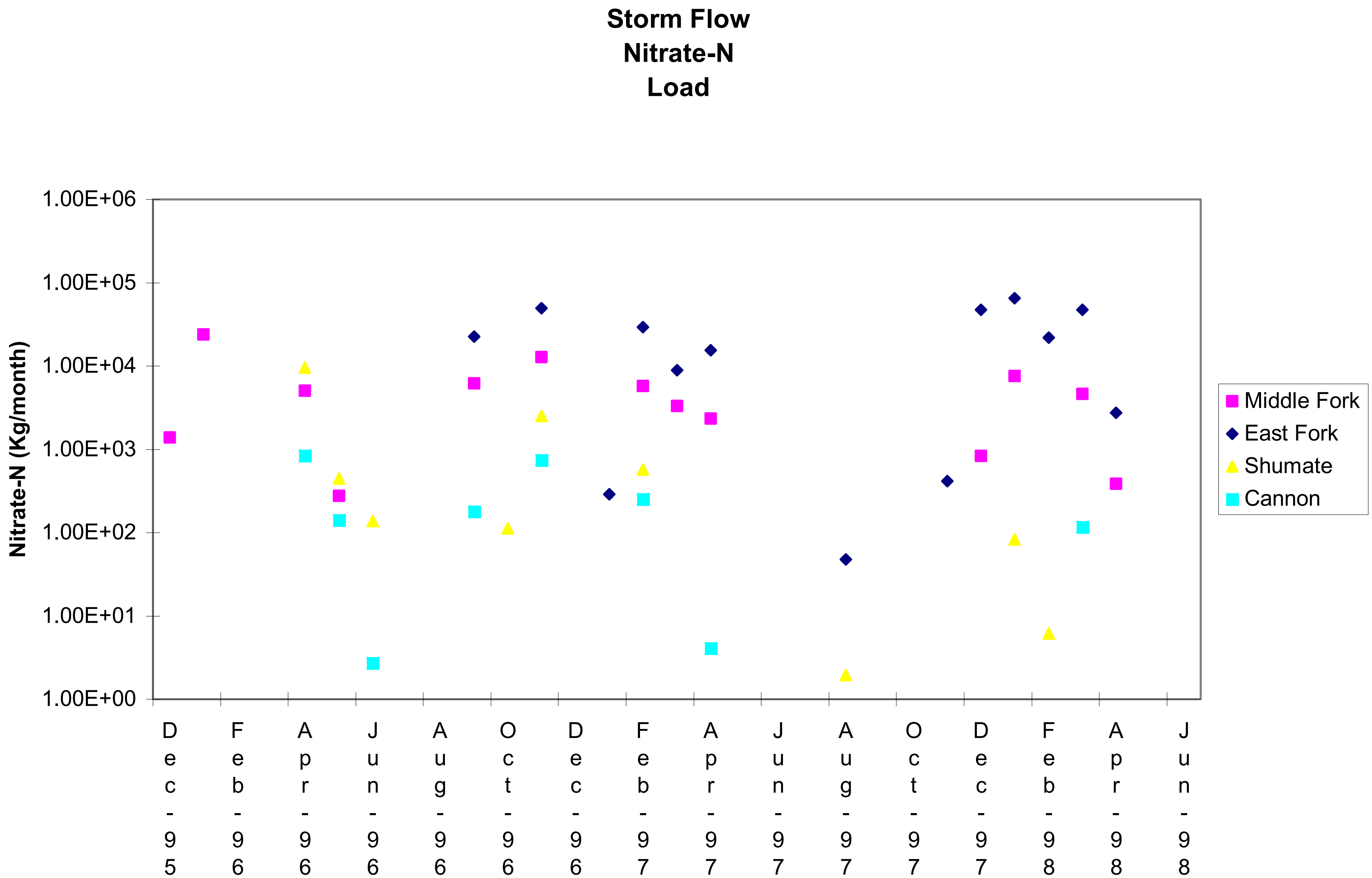

Figure 22. Monthly storm flow nitrate-N loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

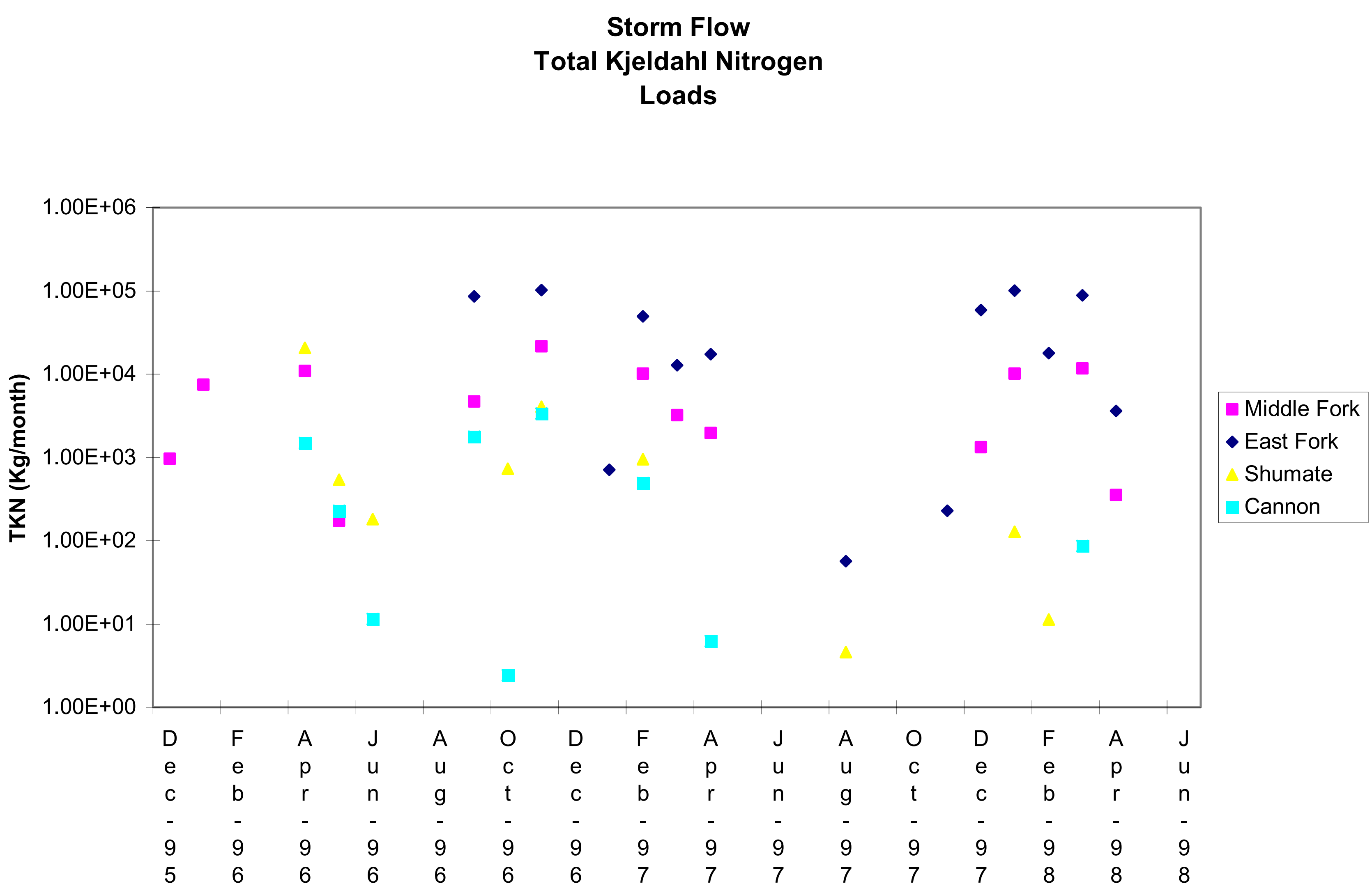

Figure 23. Monthly storm flow TKN loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

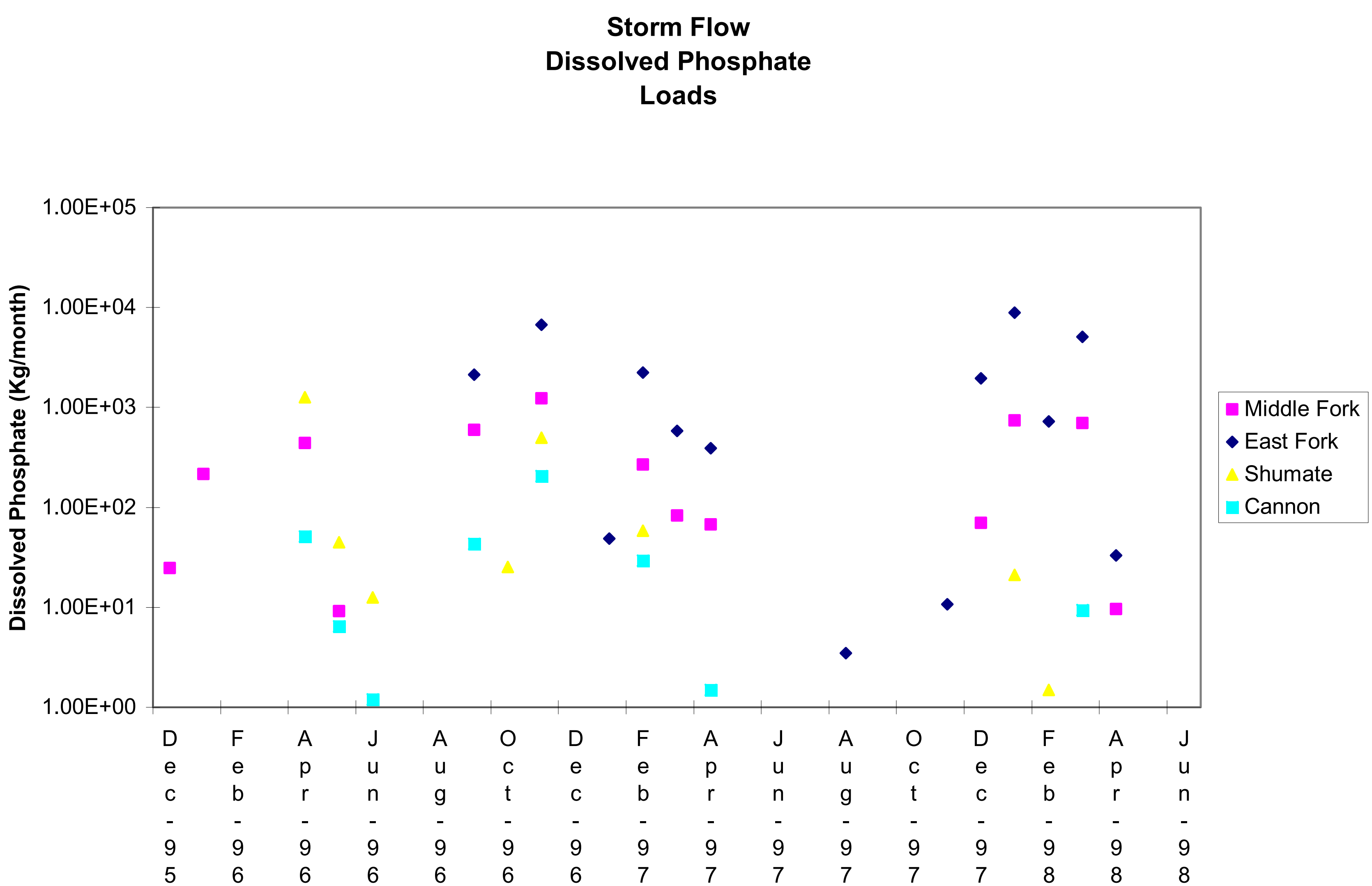

Figure 24. Monthly storm flow dissolved phosphate loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

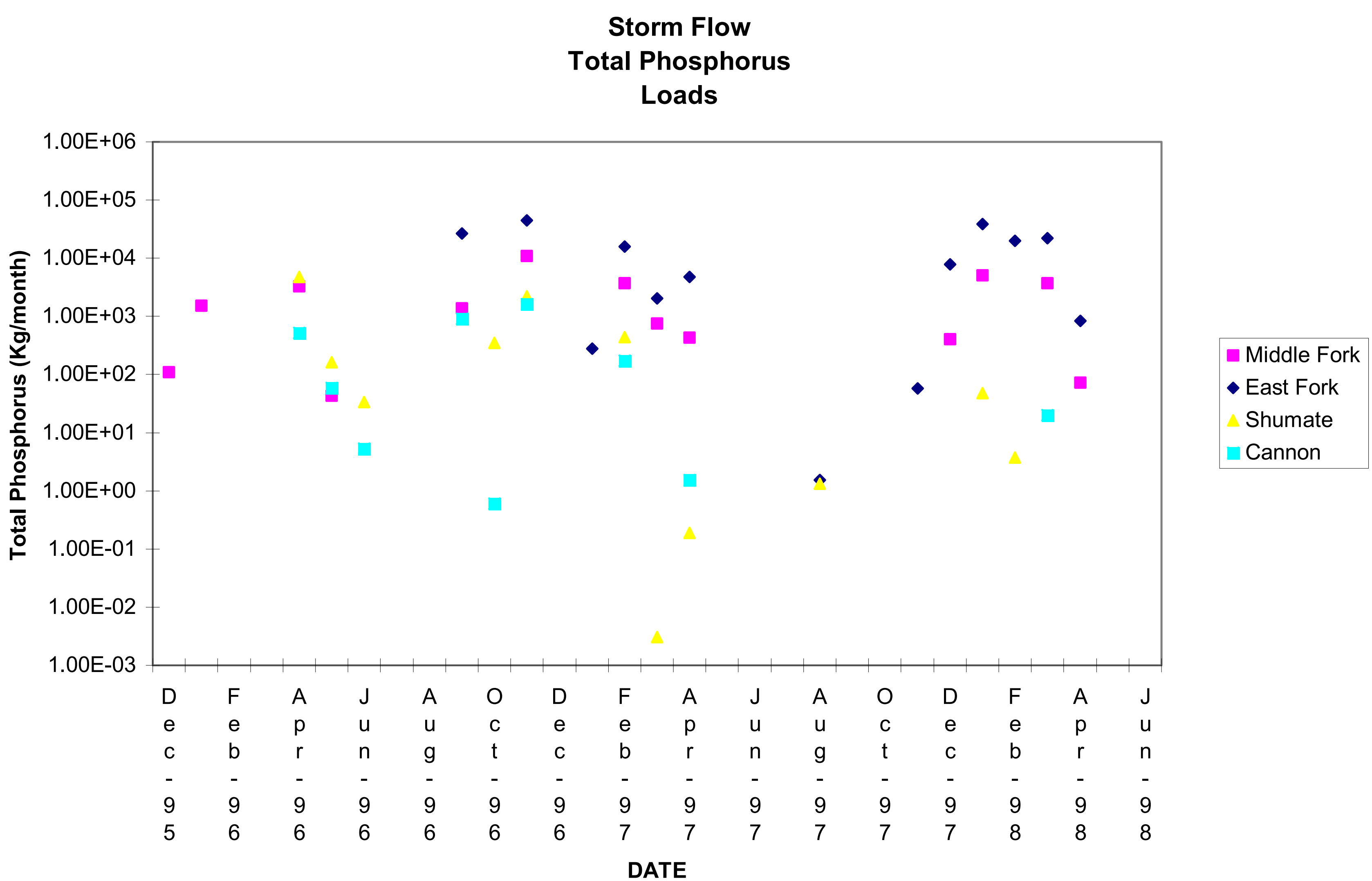

Figure 25. Monthly storm flow total phosphorus loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

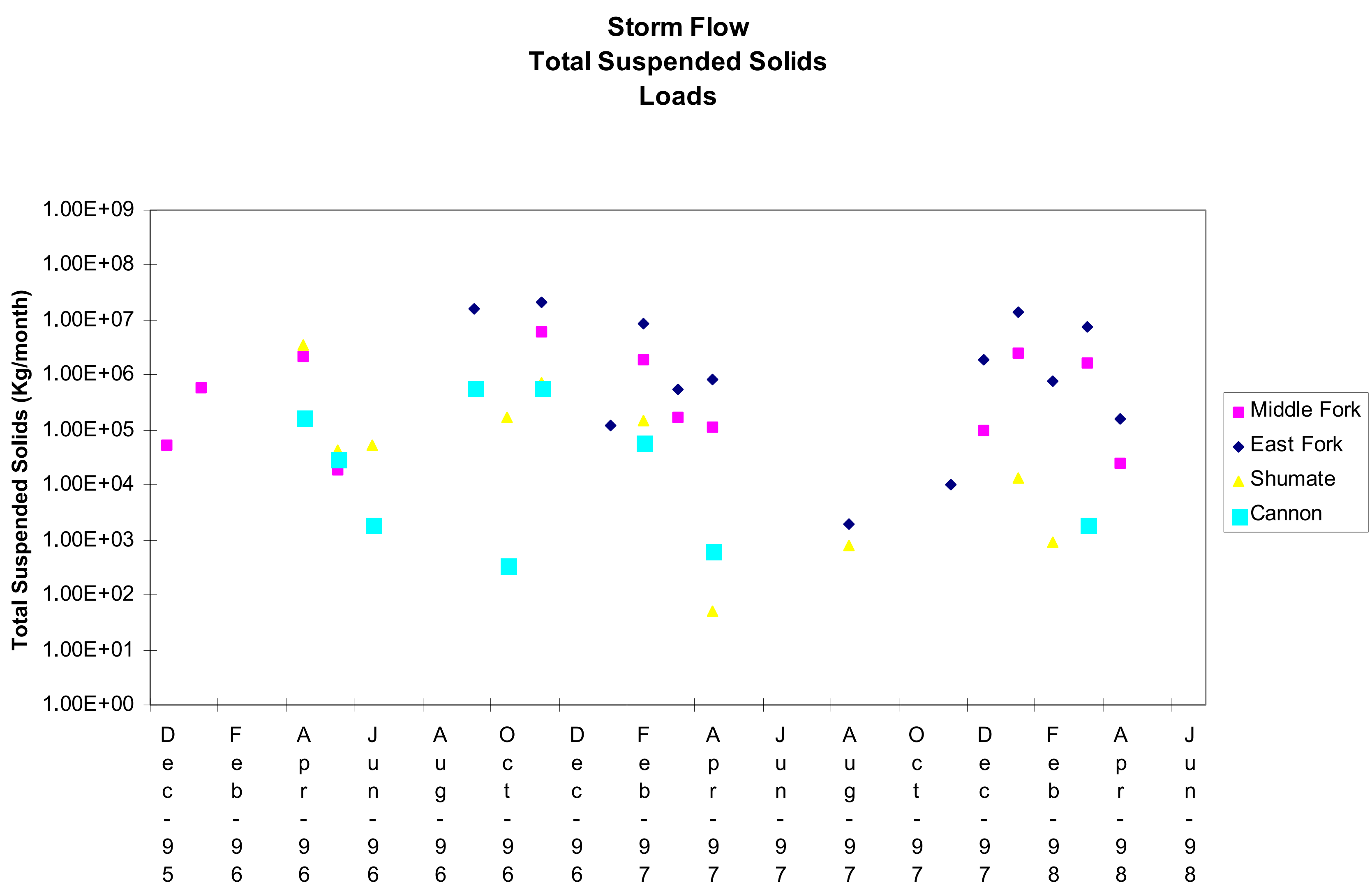

Figure 26. Monthly storm flow total suspended solids loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

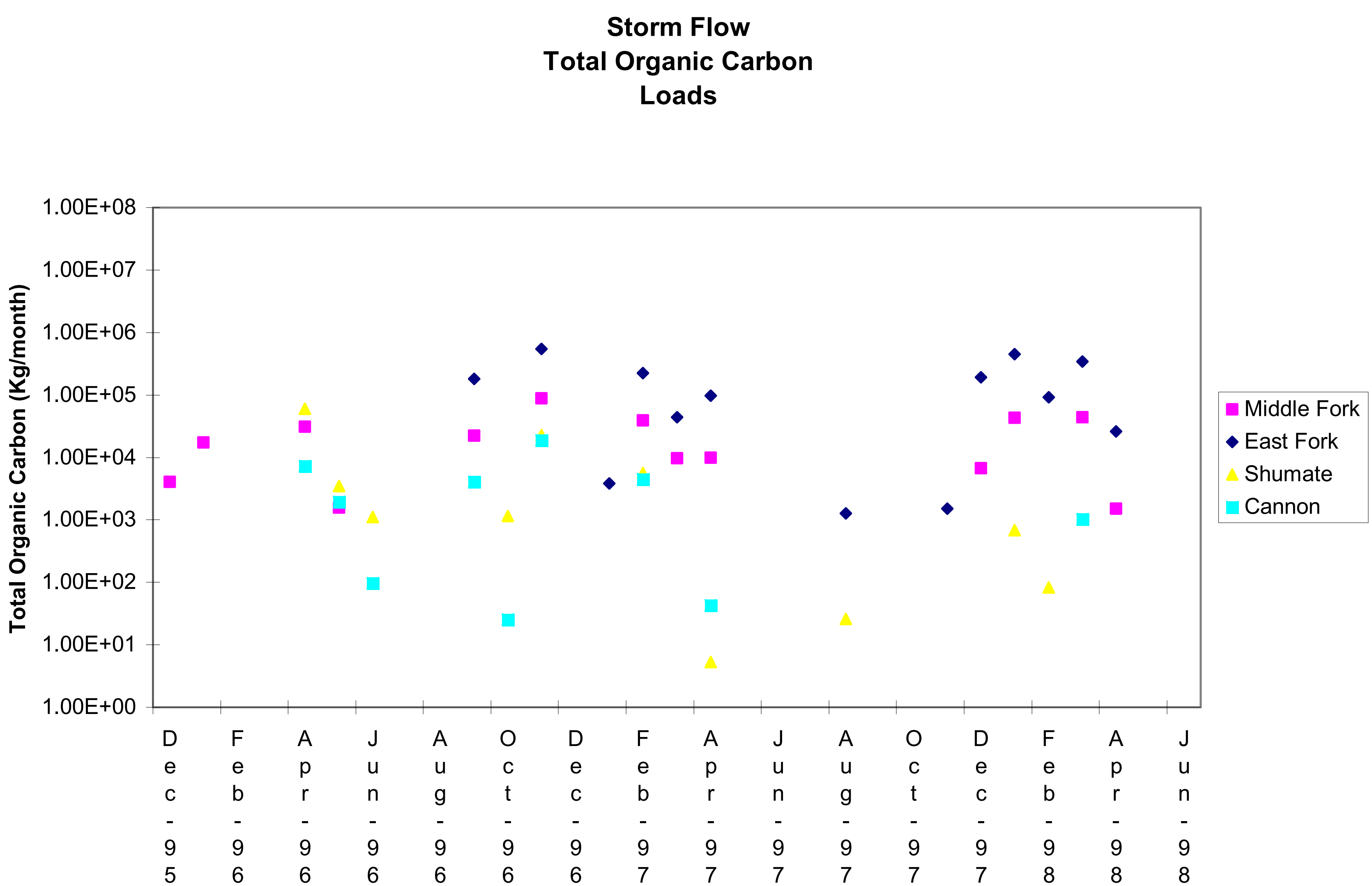

Figure 27. Monthly storm flow total organic carbon loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

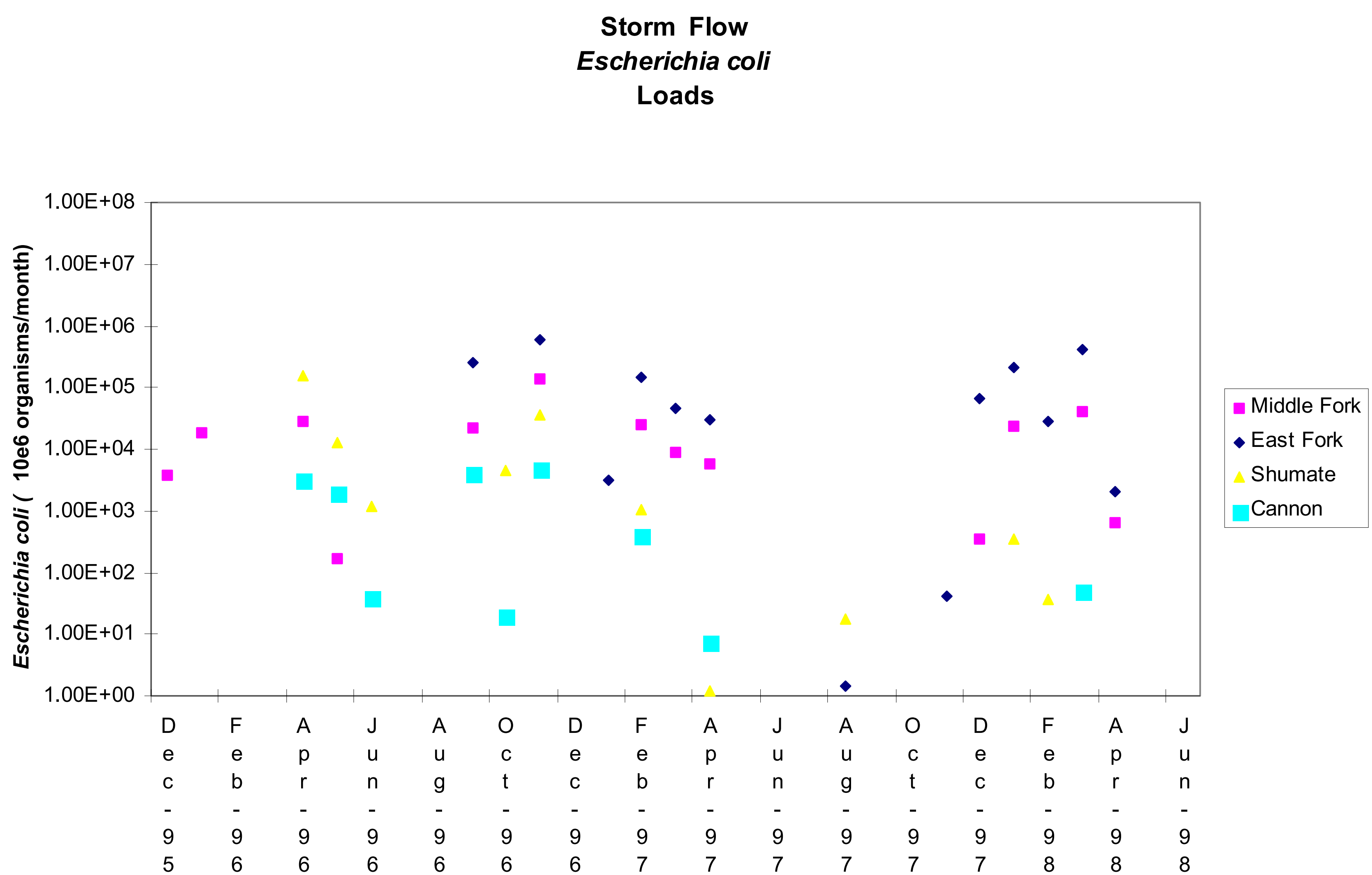

Figure 28. Monthly storm flow *E. coli* loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

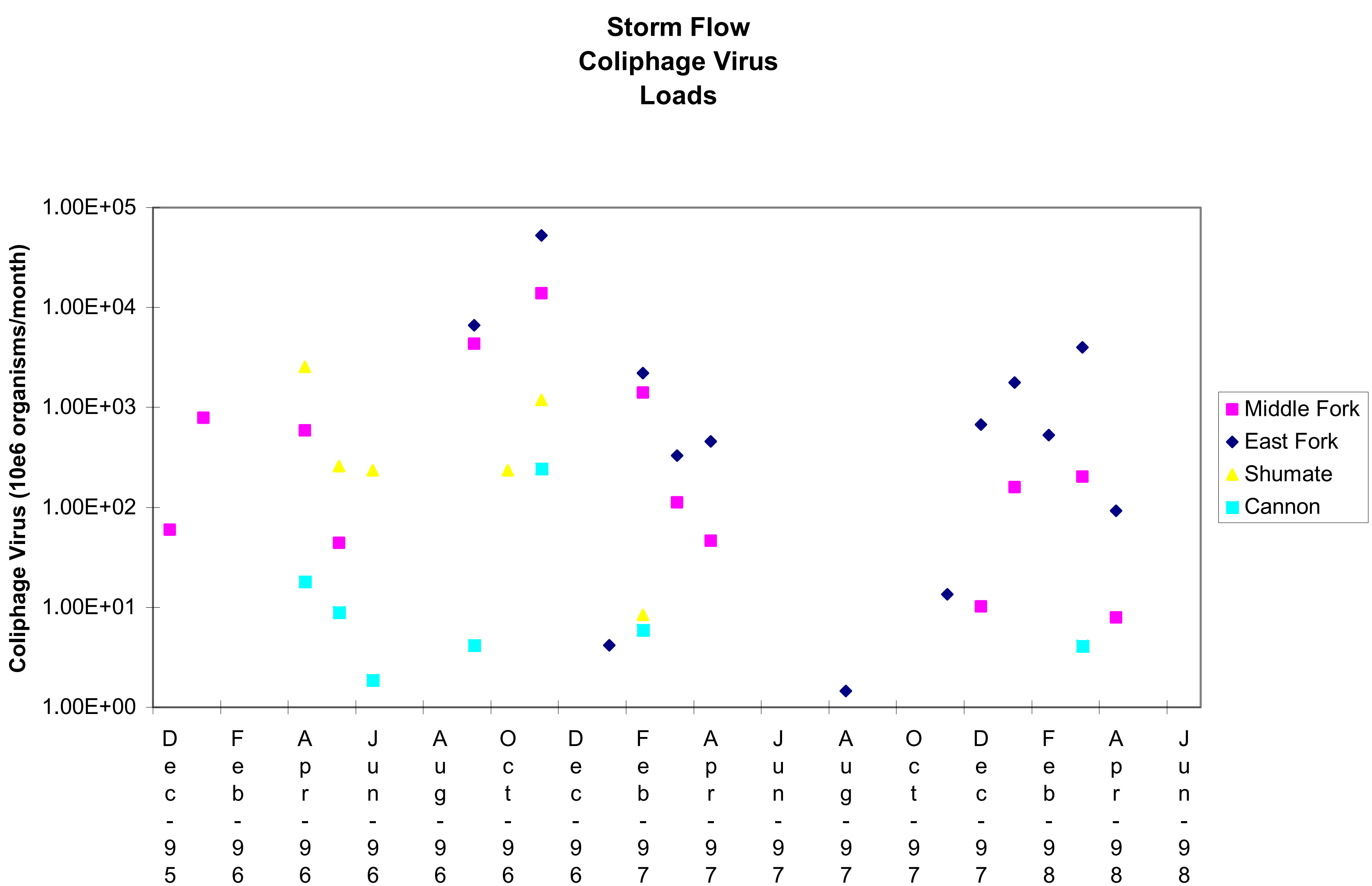

Figure 29. Monthly storm flow coliphage virus loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

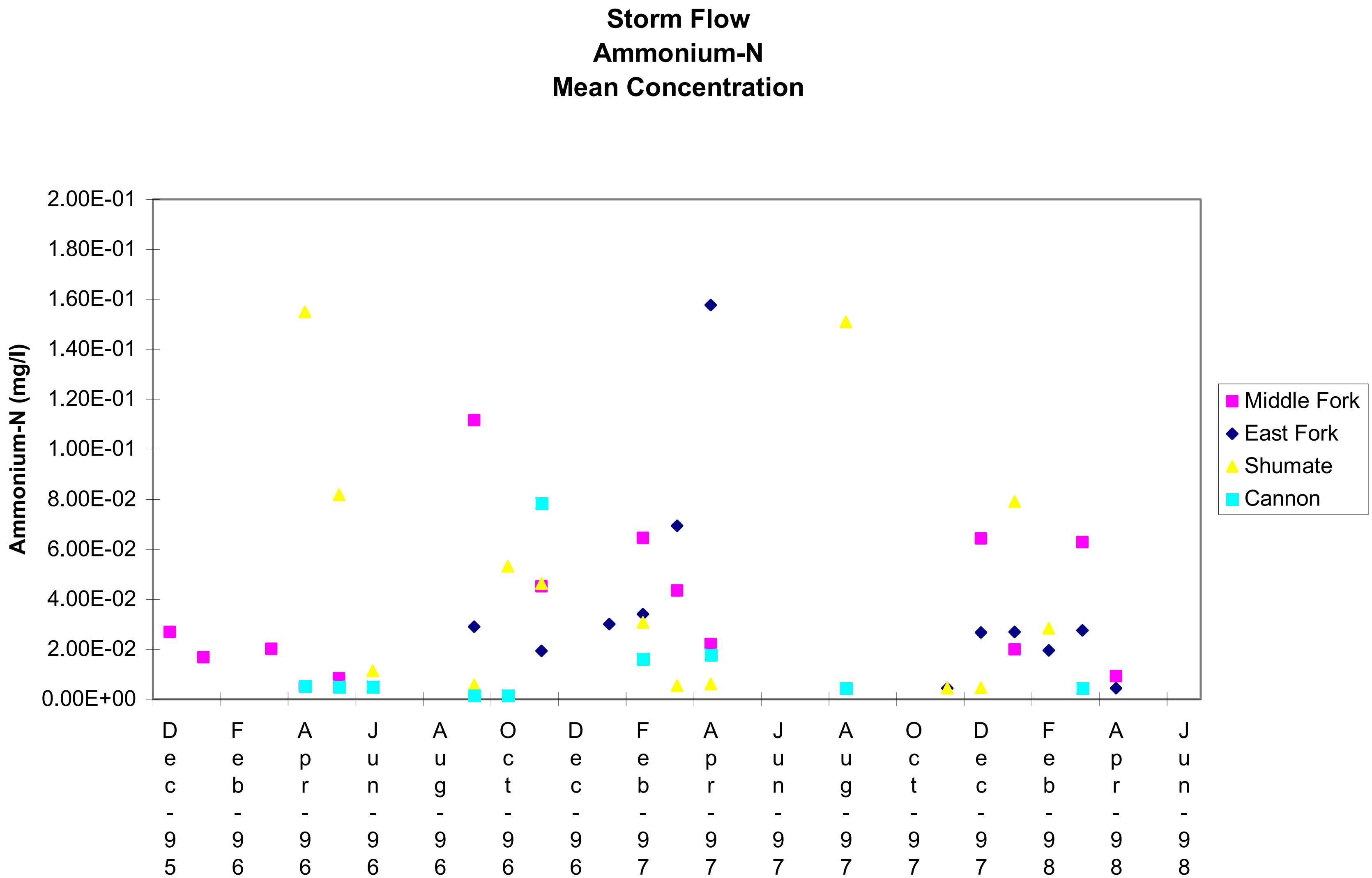

Figure 30. Monthly storm flow ammonium-N mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

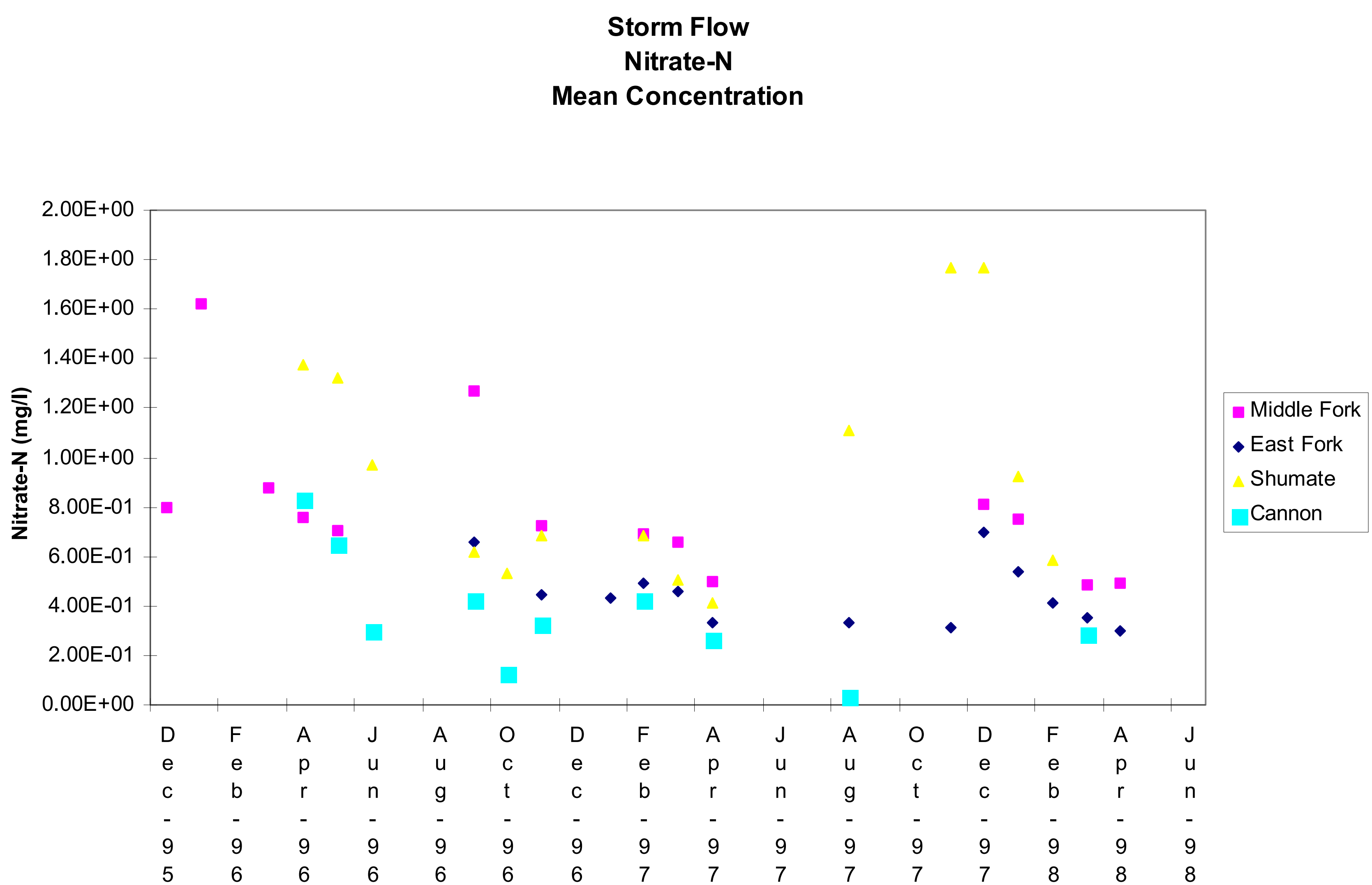

Figure 31. Monthly storm flow nitrate-N mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

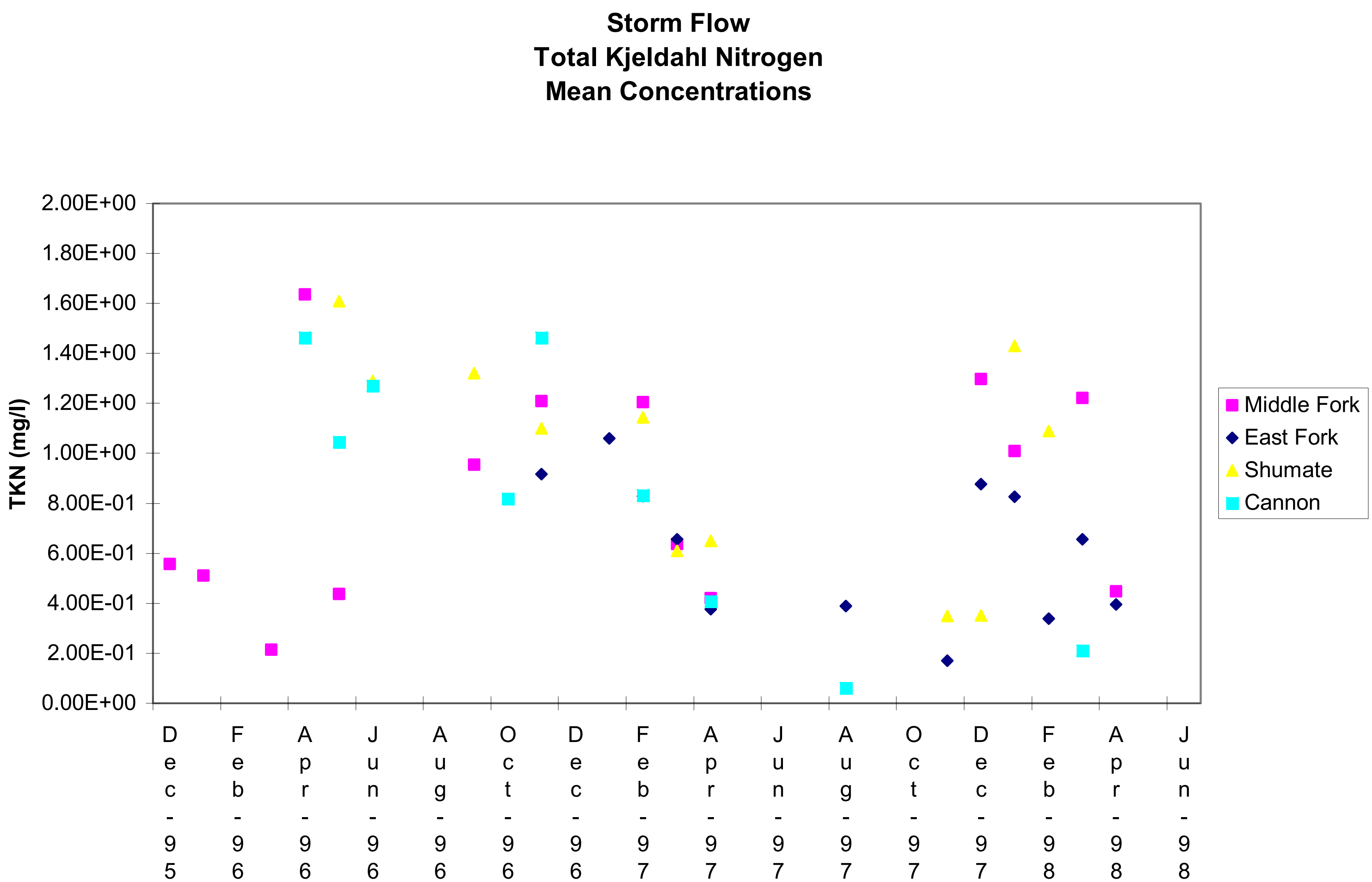

Figure 32. Monthly storm flow TKN mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

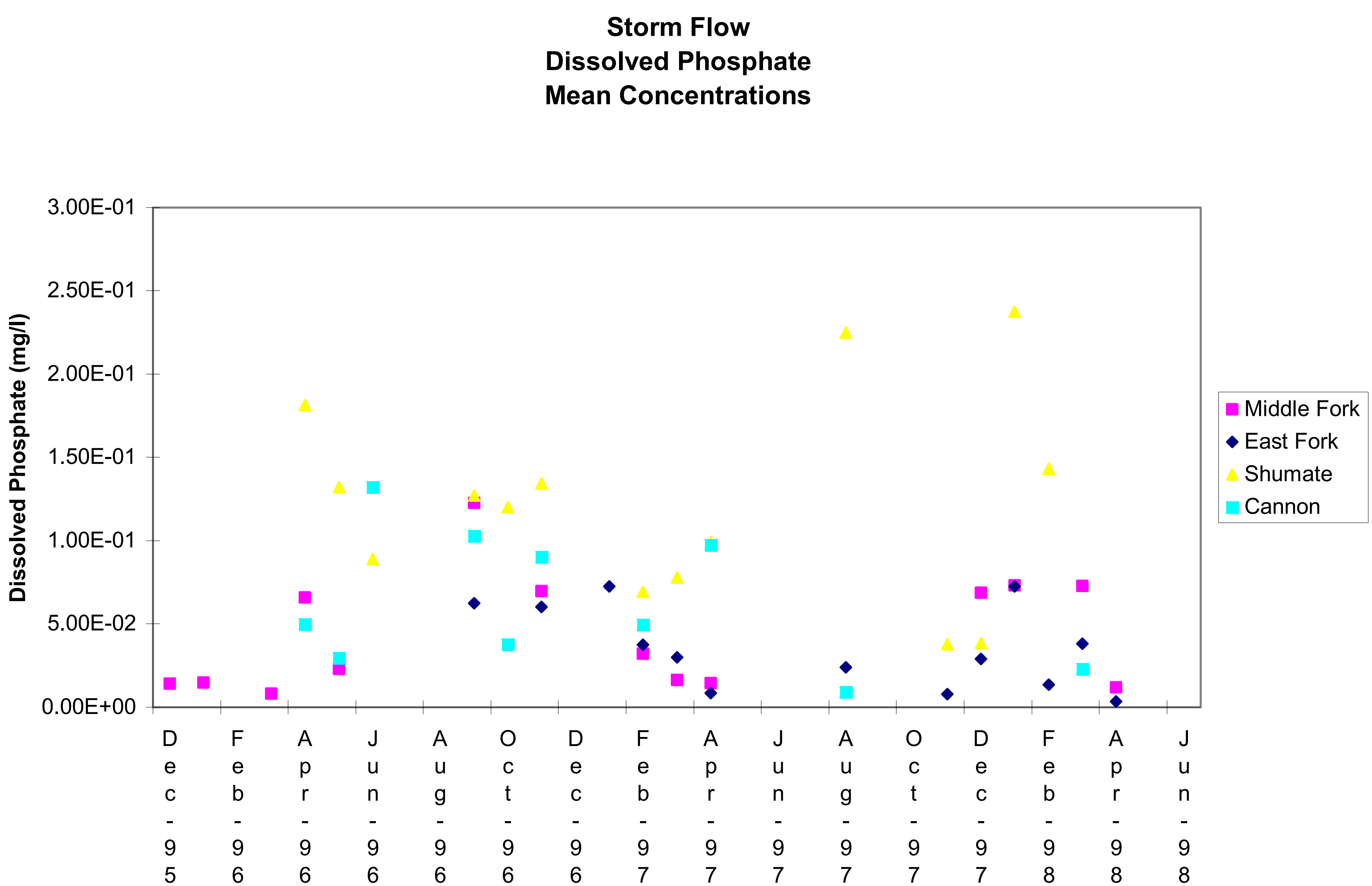

Figure 33. Monthly storm flow dissolved phosphate mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

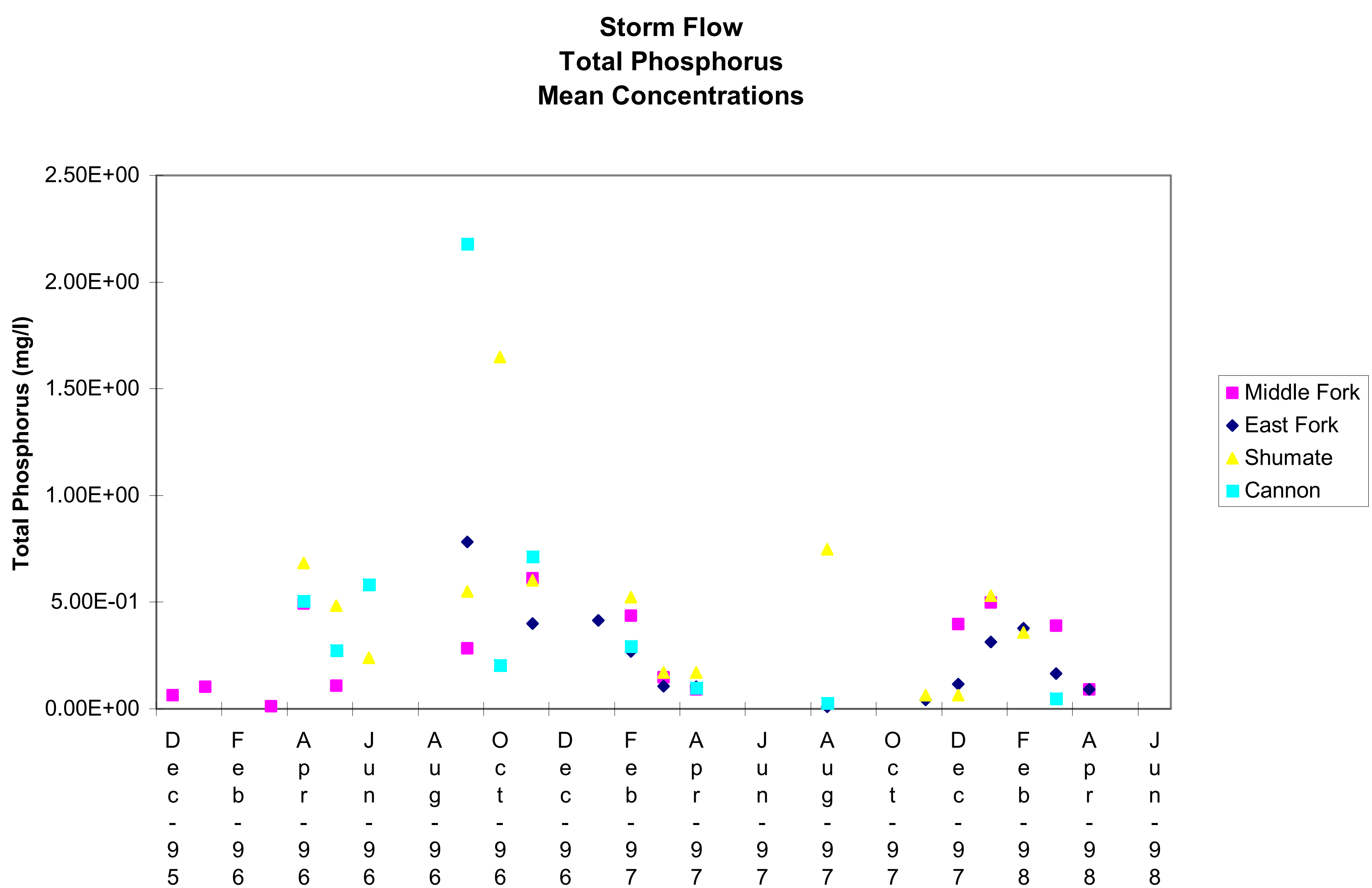

Figure 34. Monthly storm flow total phosphorus mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

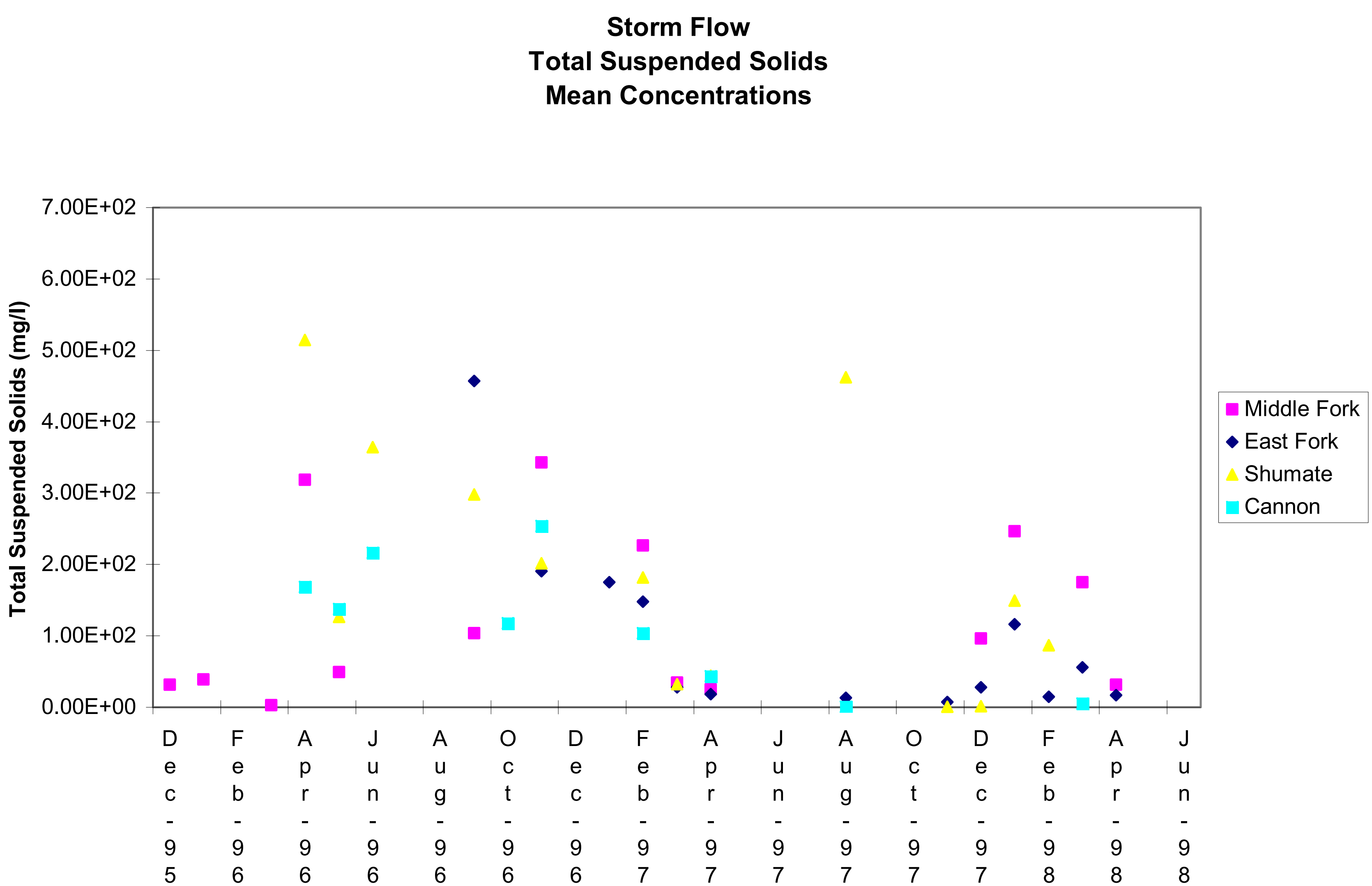

Figure 35. Monthly storm flow total suspended solids mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

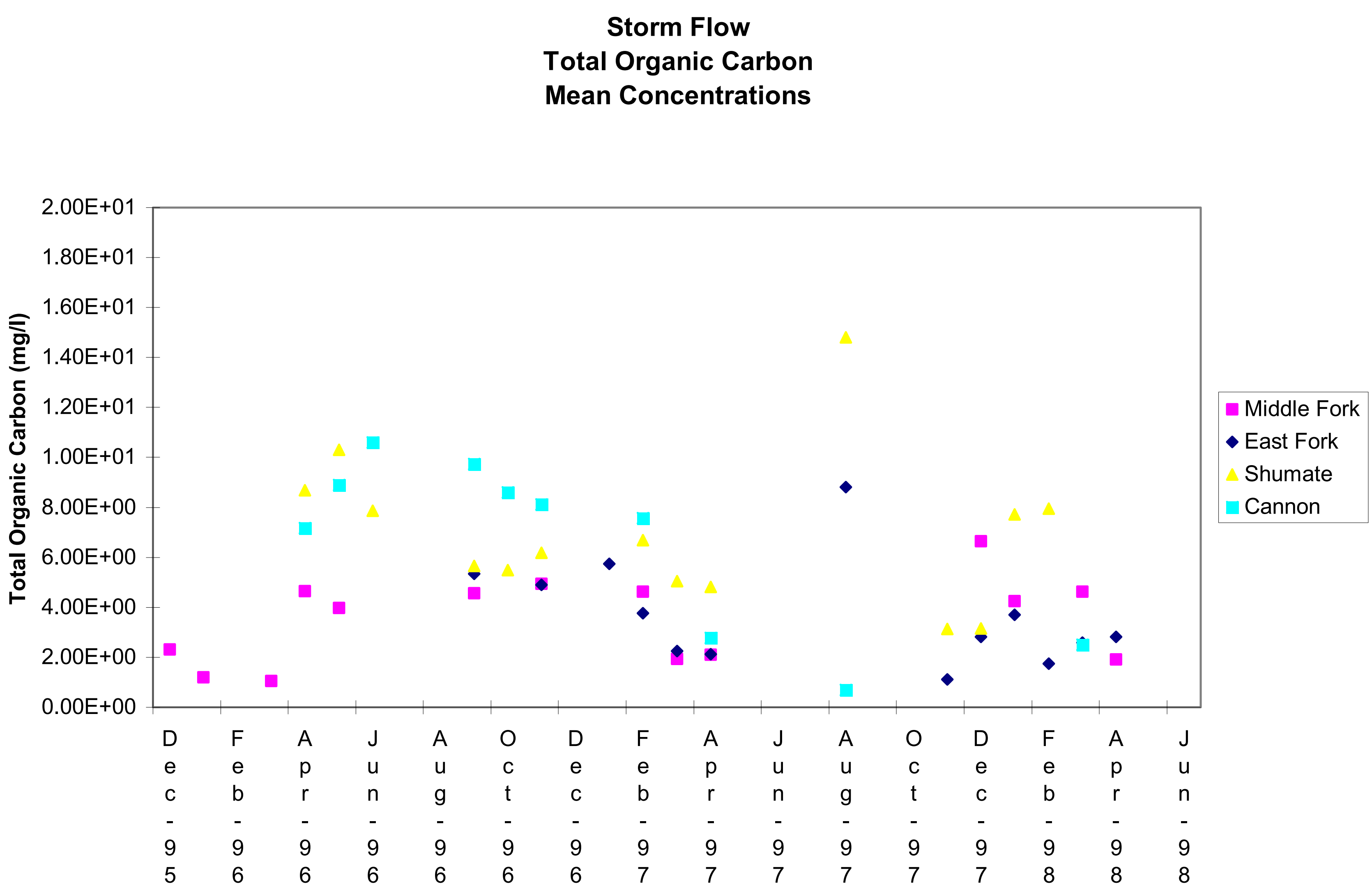

Figure 36. Monthly storm flow total organic carbon mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

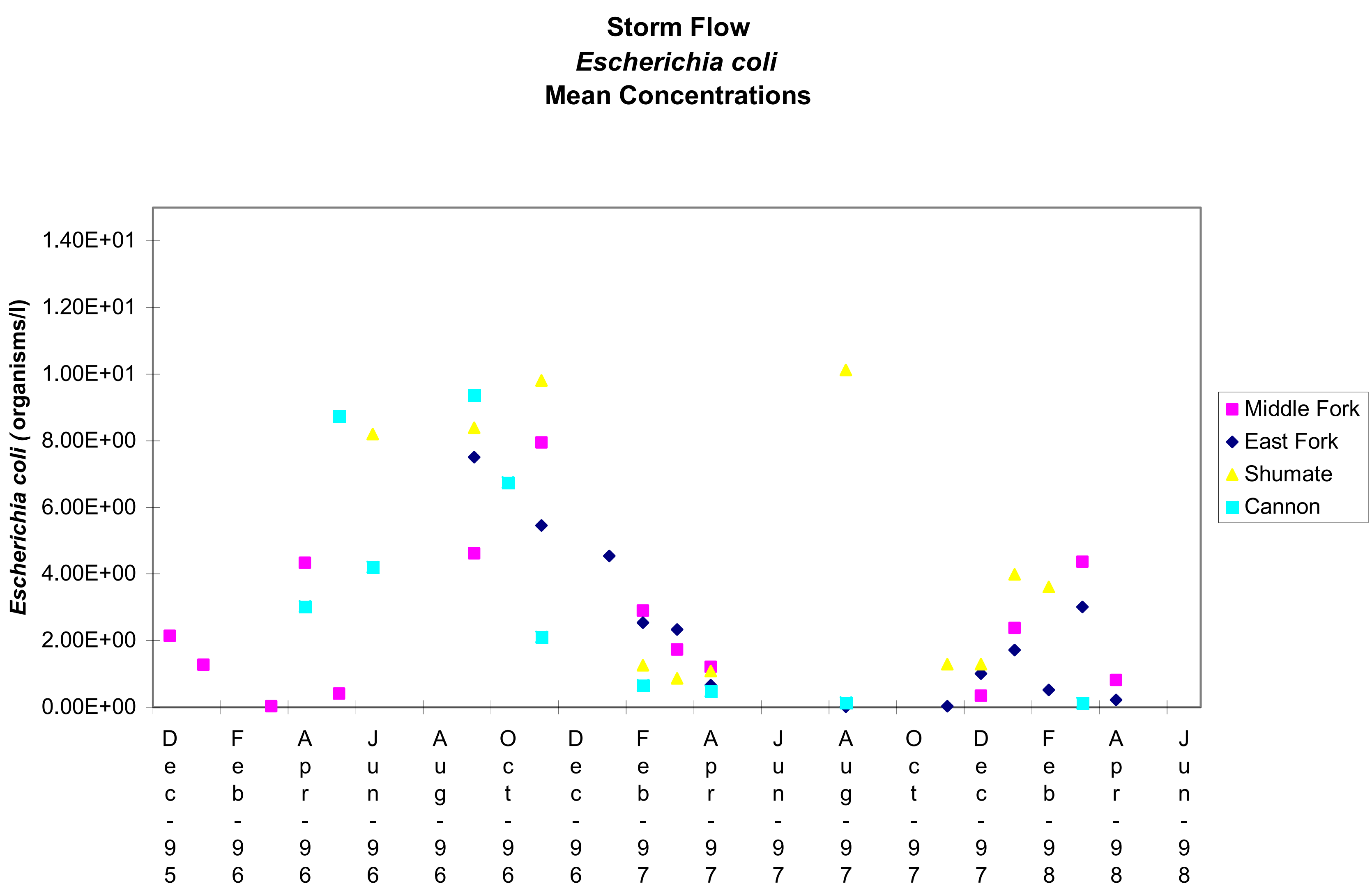

Figure 37. Monthly storm flow *E. coli* mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

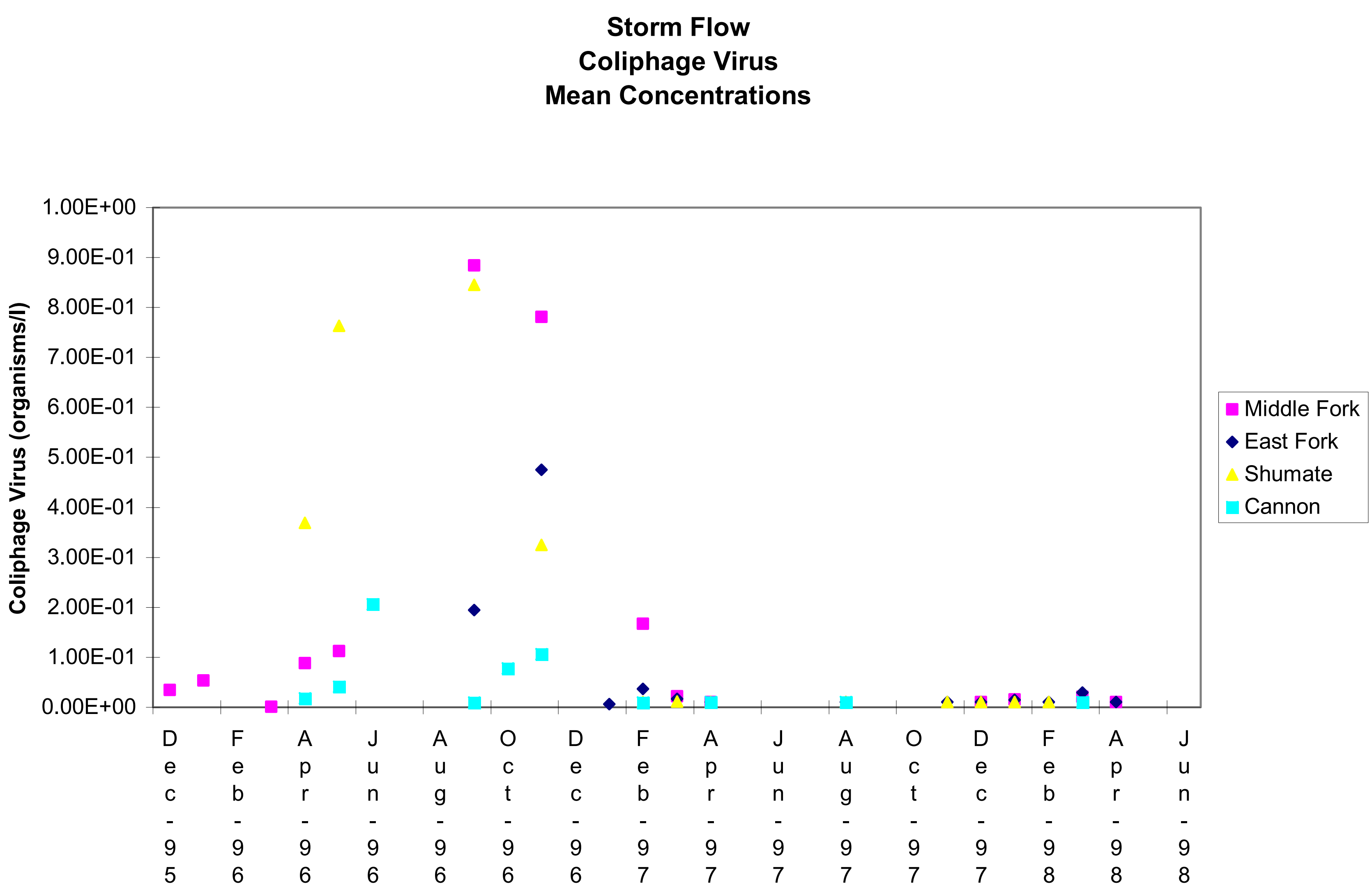

Figure 38. Monthly storm flow coliphage virus mean concentrations for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

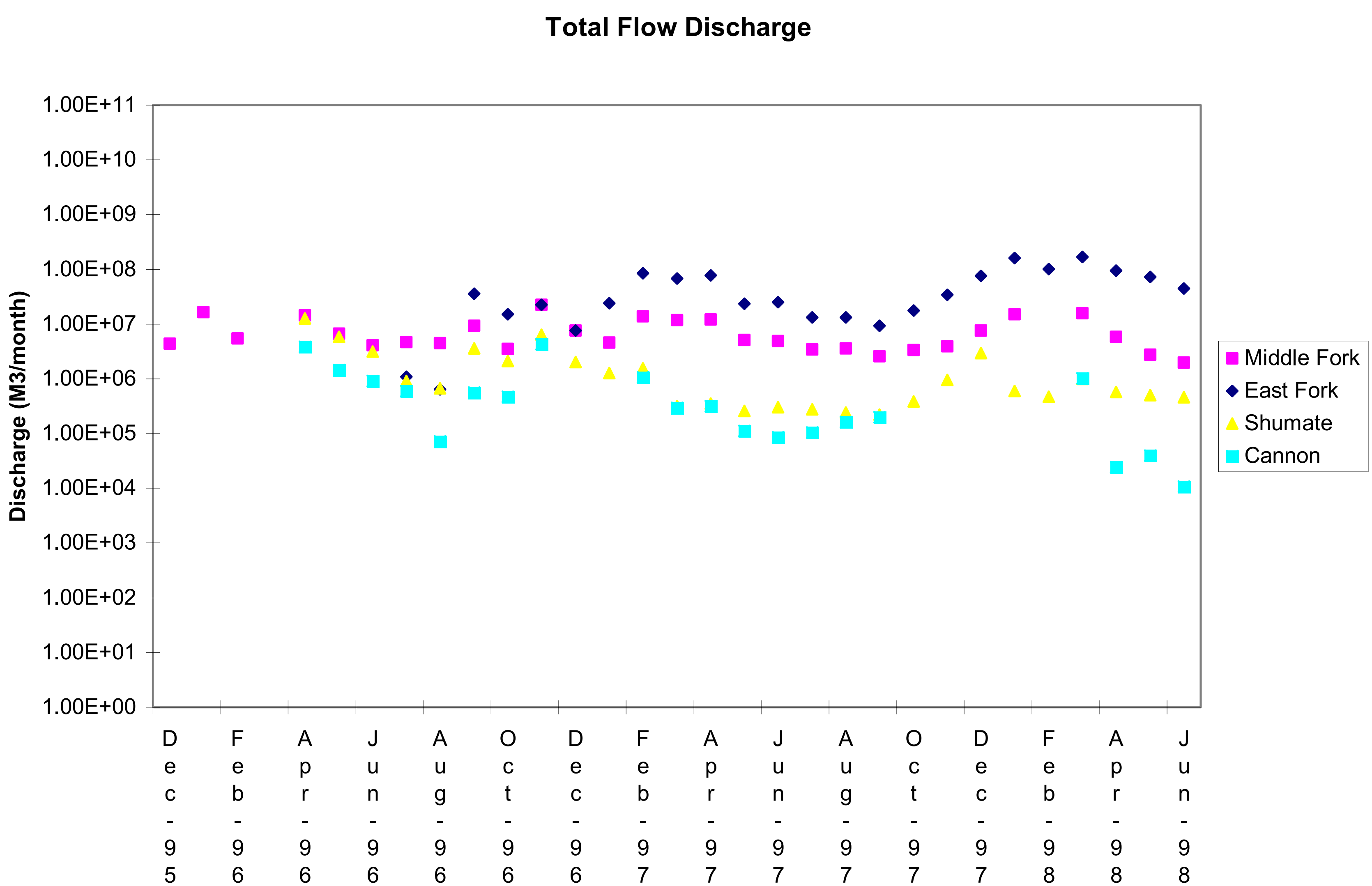

Figure 39. Monthly total flow discharge for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

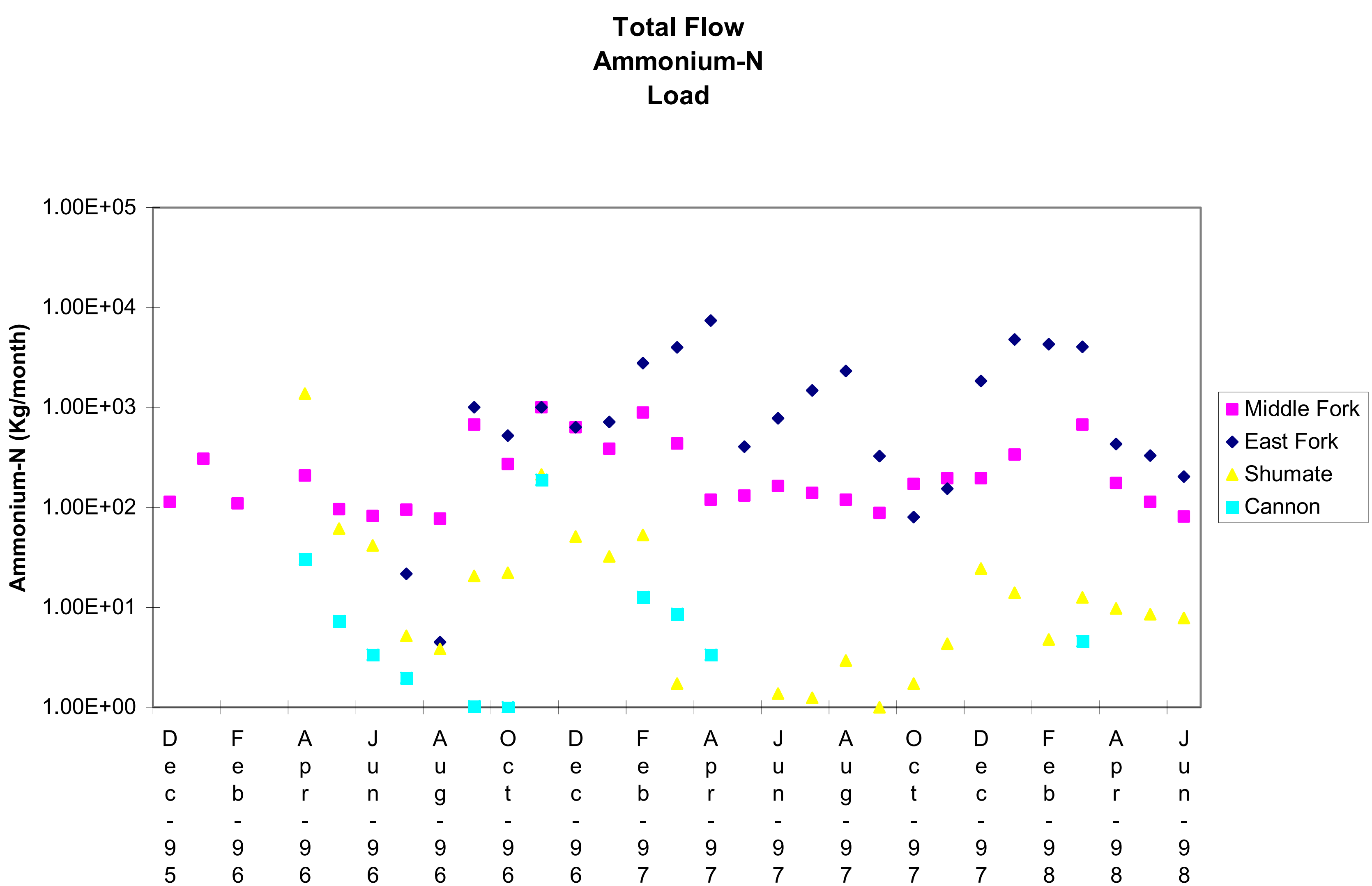

Figure 40. Monthly total flow ammonium-N loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

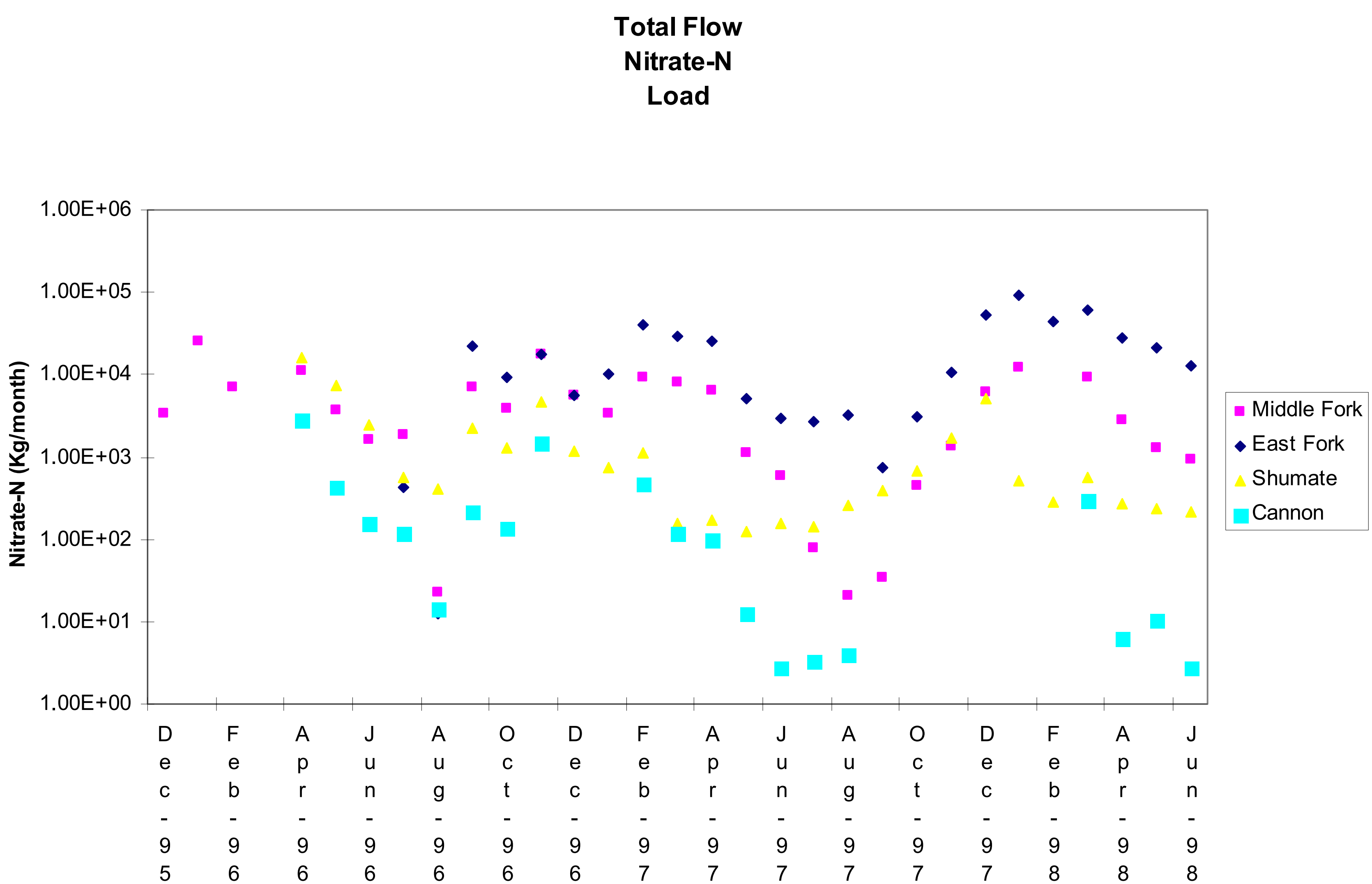

Figure 41. Monthly total flow nitrate-N loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

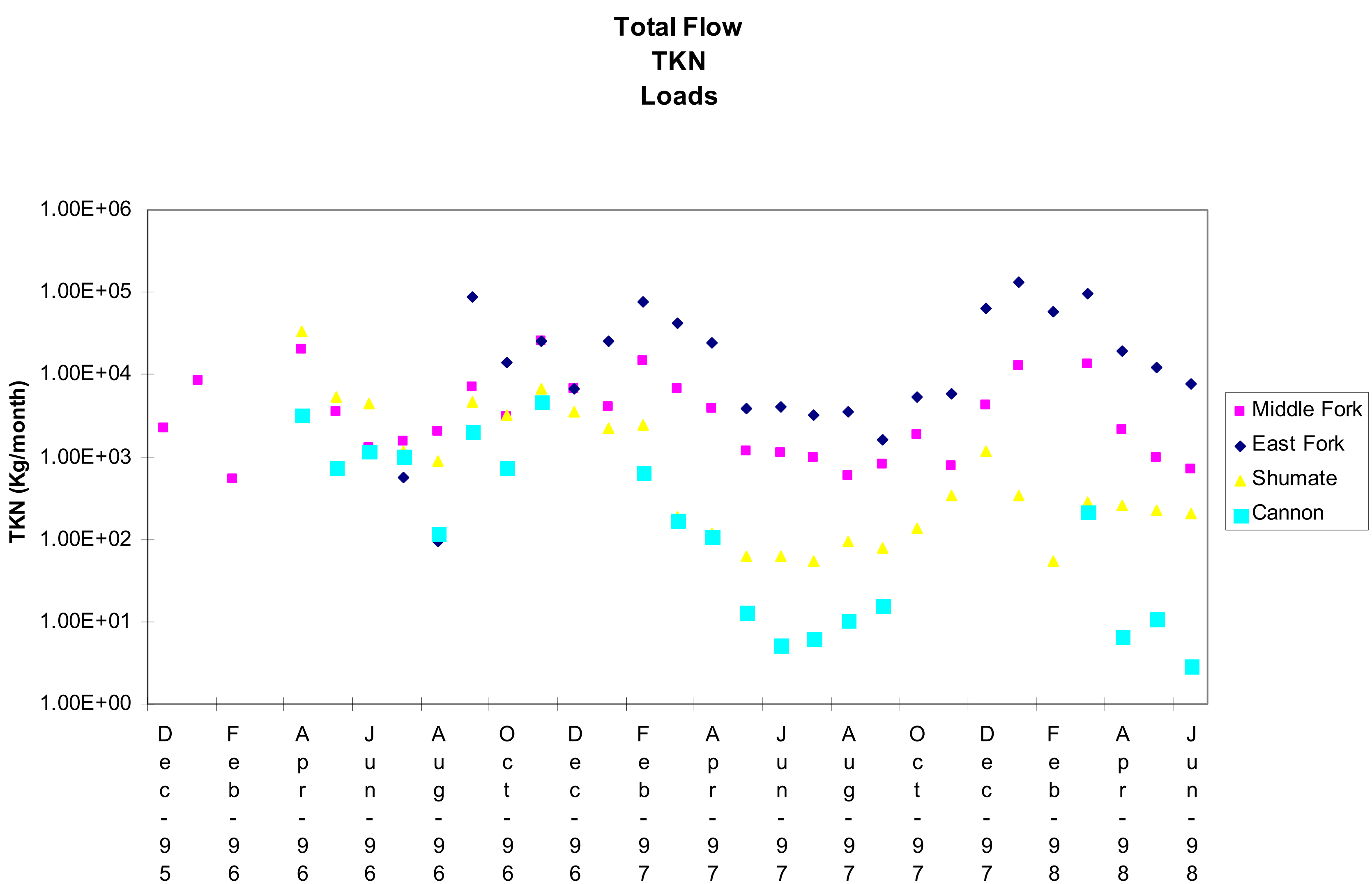

Figure 42. Monthly total flow TKN loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

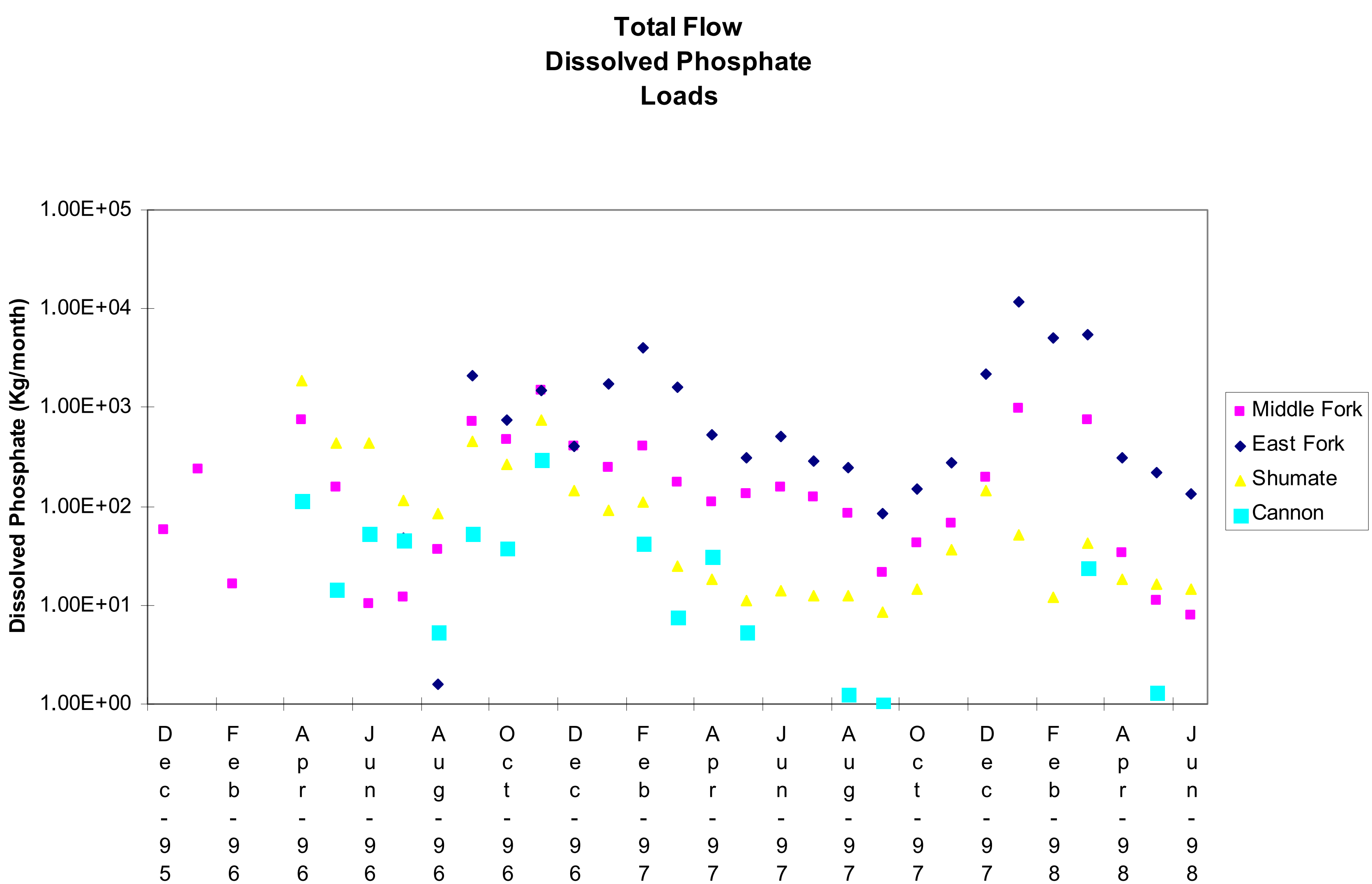

Figure 43. Monthly total flow dissolved phosphate loads for the East fork, Middle fork, Cannon Creek, and Shumate Creek.

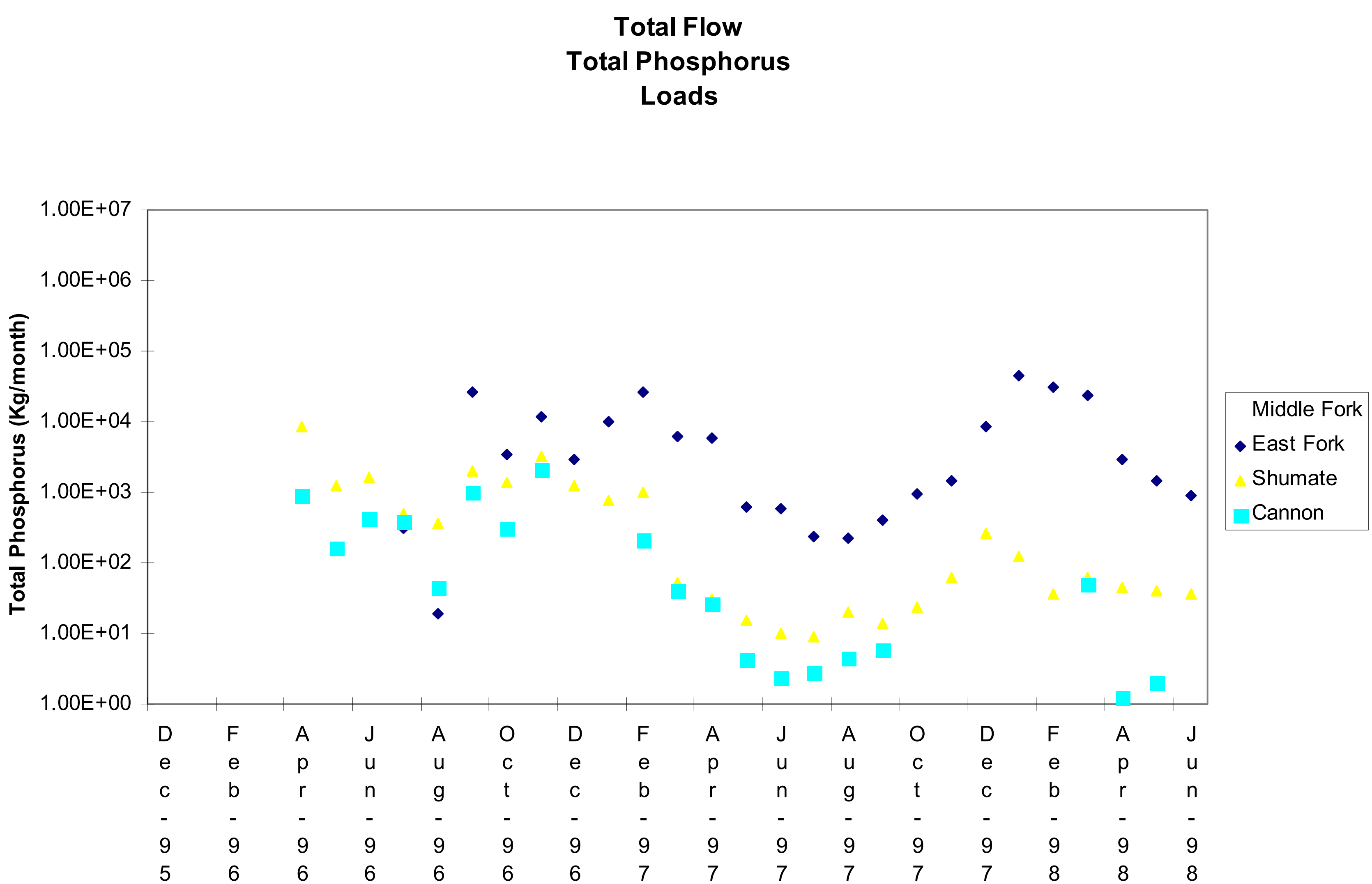

Figure 44. Monthly total flow total phosphorus loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

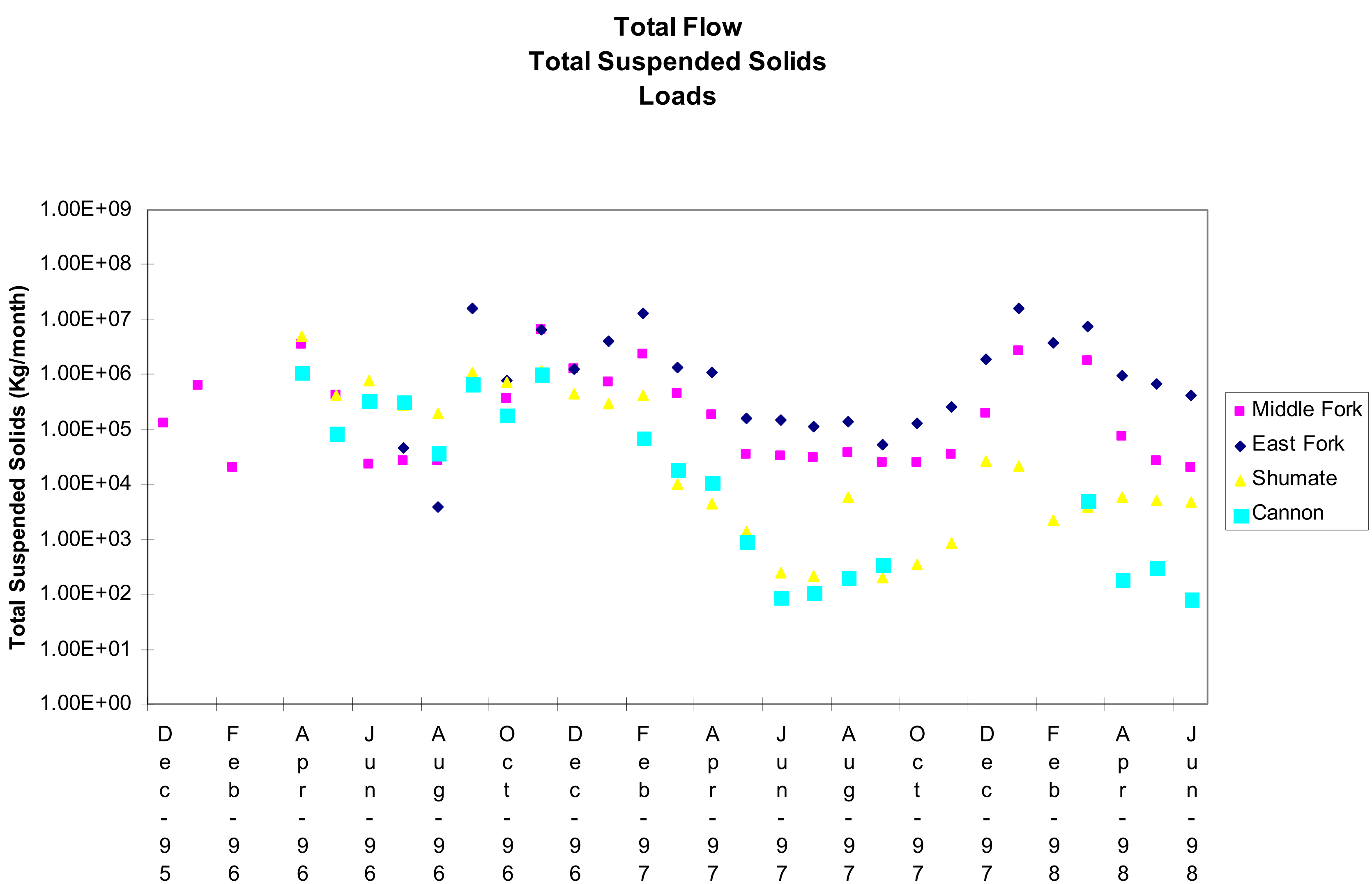

Figure 45. Monthly total flow total suspended solids loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

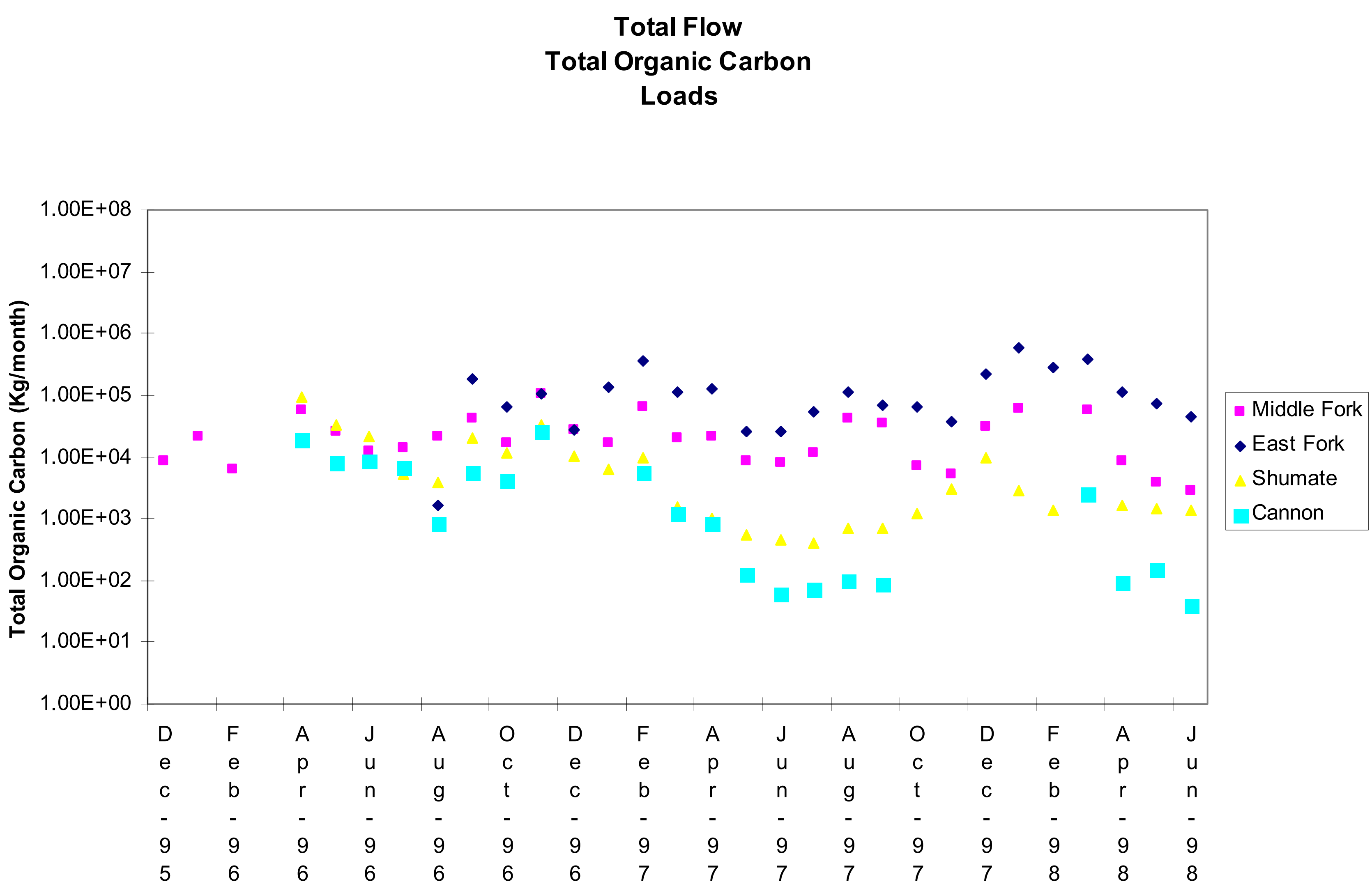

Figure 46. Monthly total flow total organic carbon loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

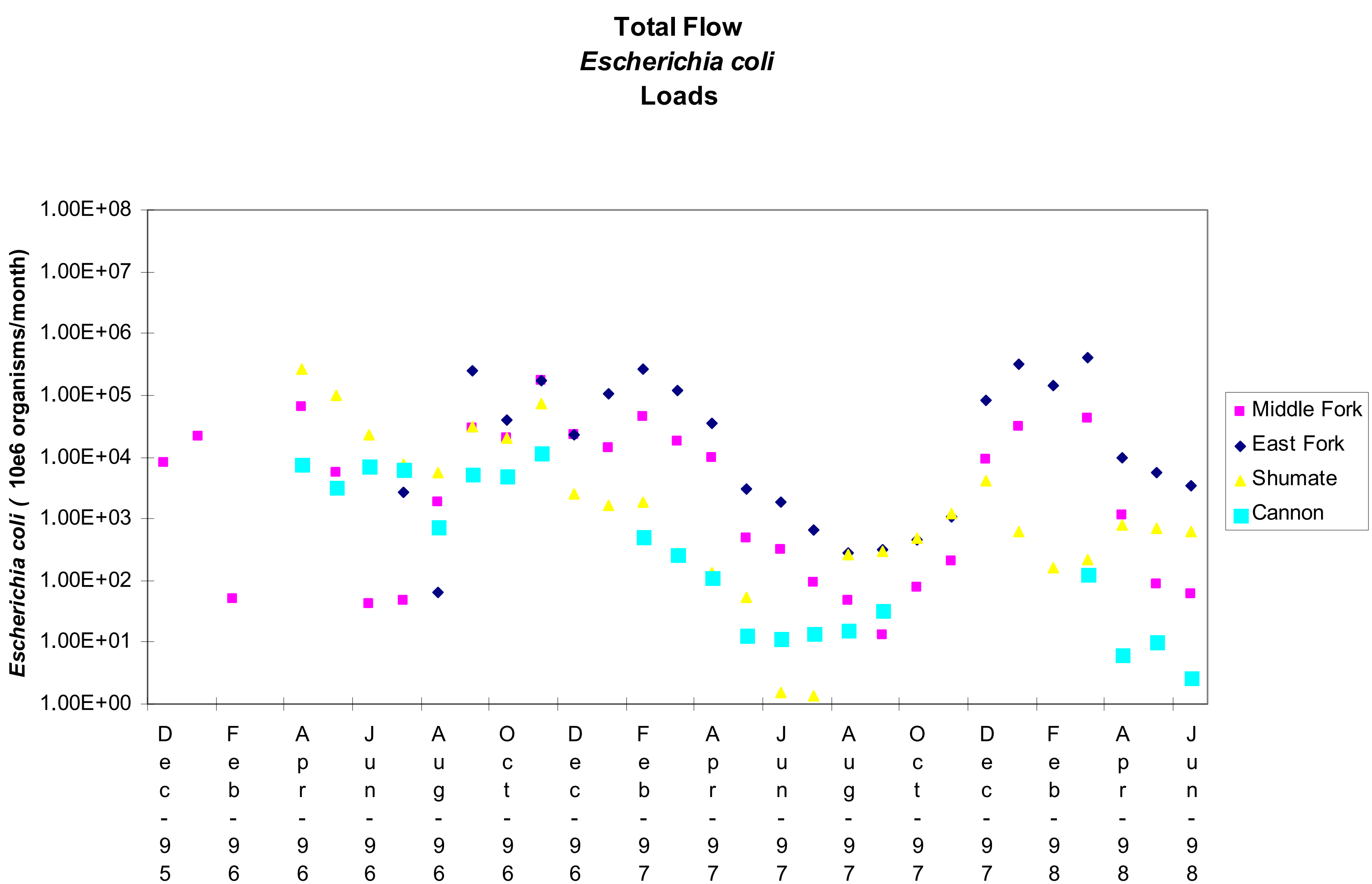

Figure 47. Monthly total flow *E. coli* loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

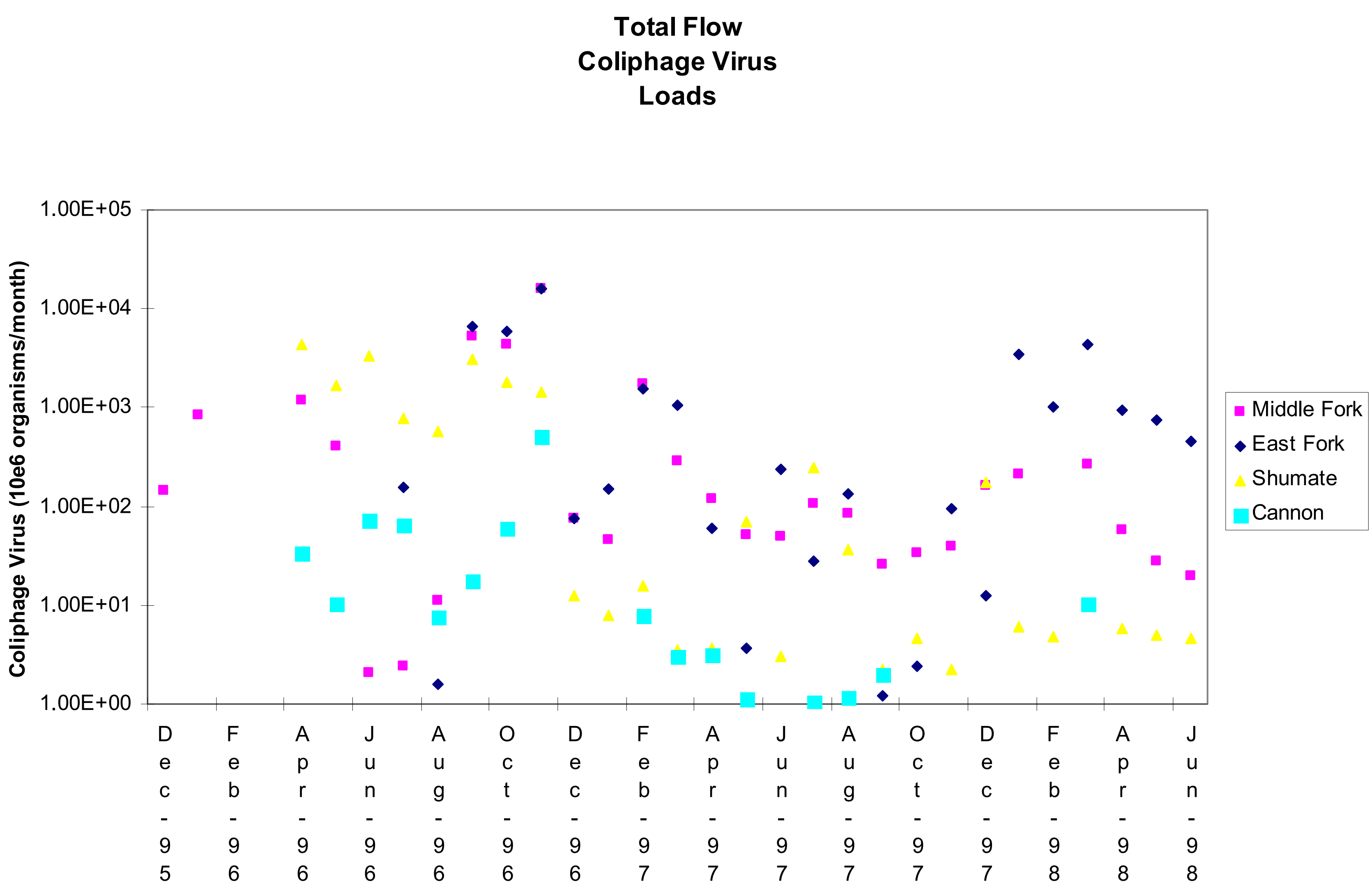

Figure 48. Monthly total flow coliphage virus loads for the East Fork, Middle Fork, Cannon Creek, and Shumate Creek.

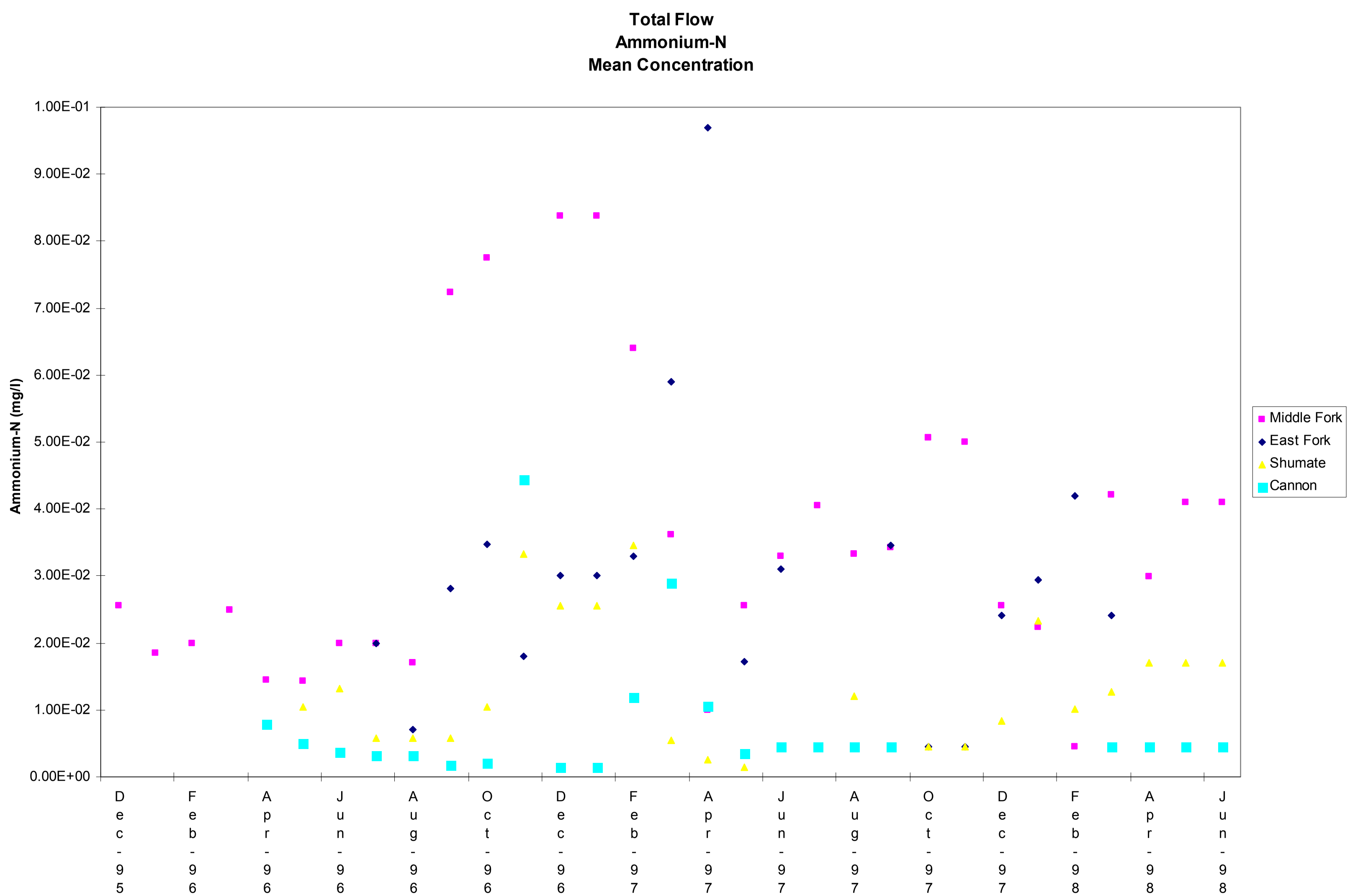

Figure 49. Monthly total flow ammonium-N mean concentrations for the East Fork, Middle Fork, Cannon Creek and Shumate Creek.

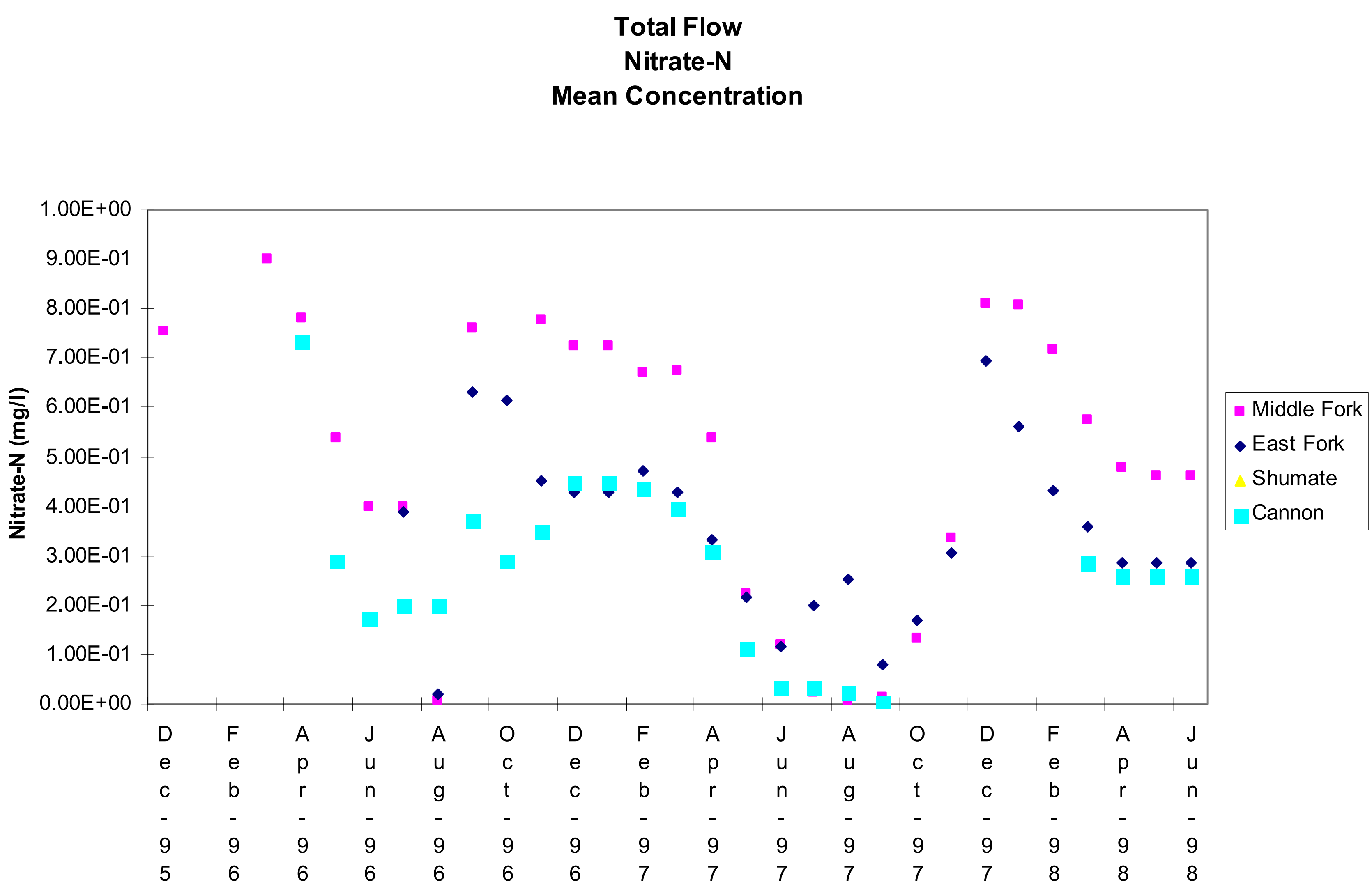

Figure 50. Monthly total flow nitrate-N mean concentrations for the East fork, Middle Fork, Cannon Creek and Shumate Creek.

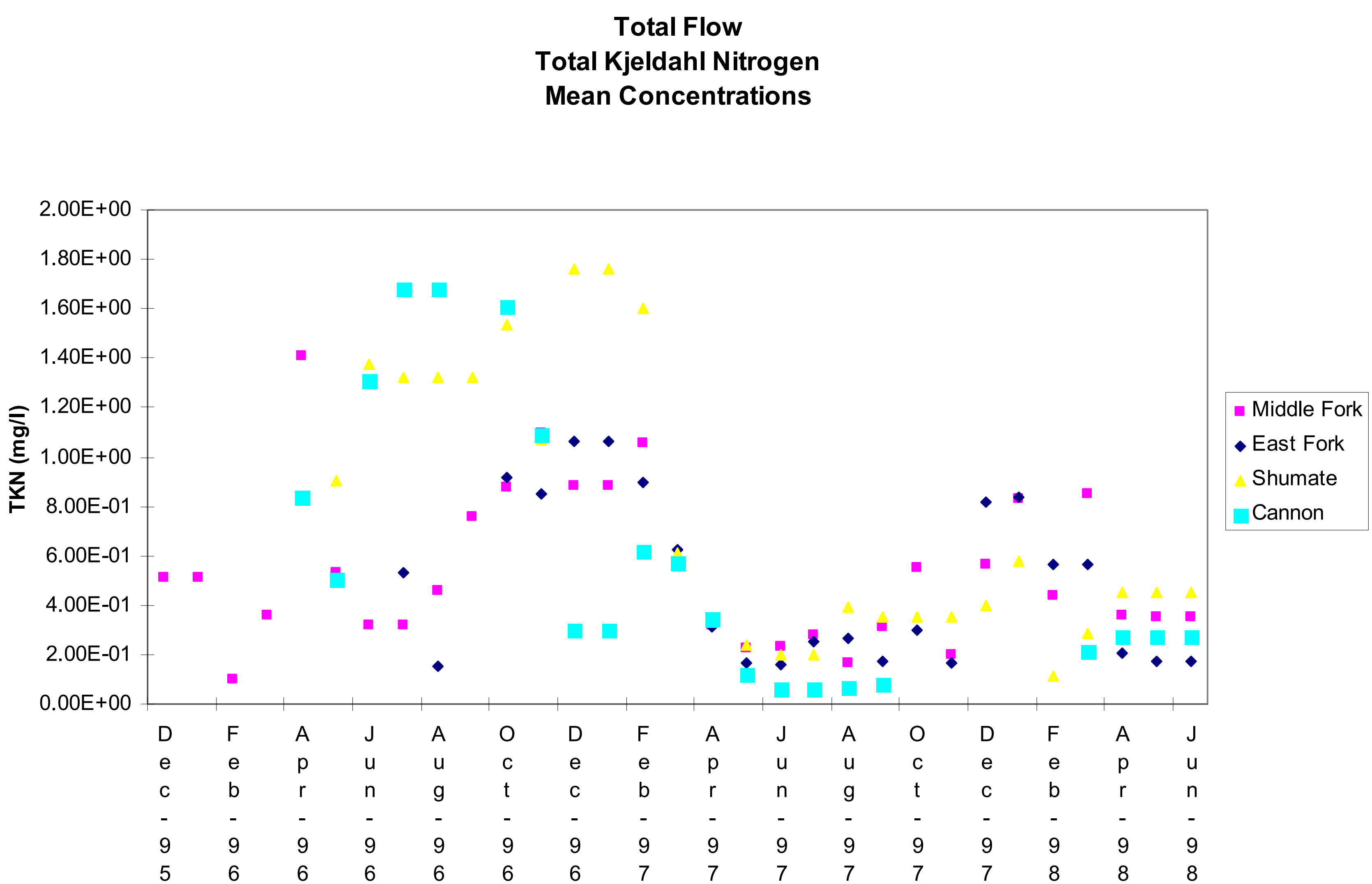

Figure 51. Monthly total flow TKN mean concentrations for the East Fork, Middle Fork, Cannon Creek and Shumate Creek.

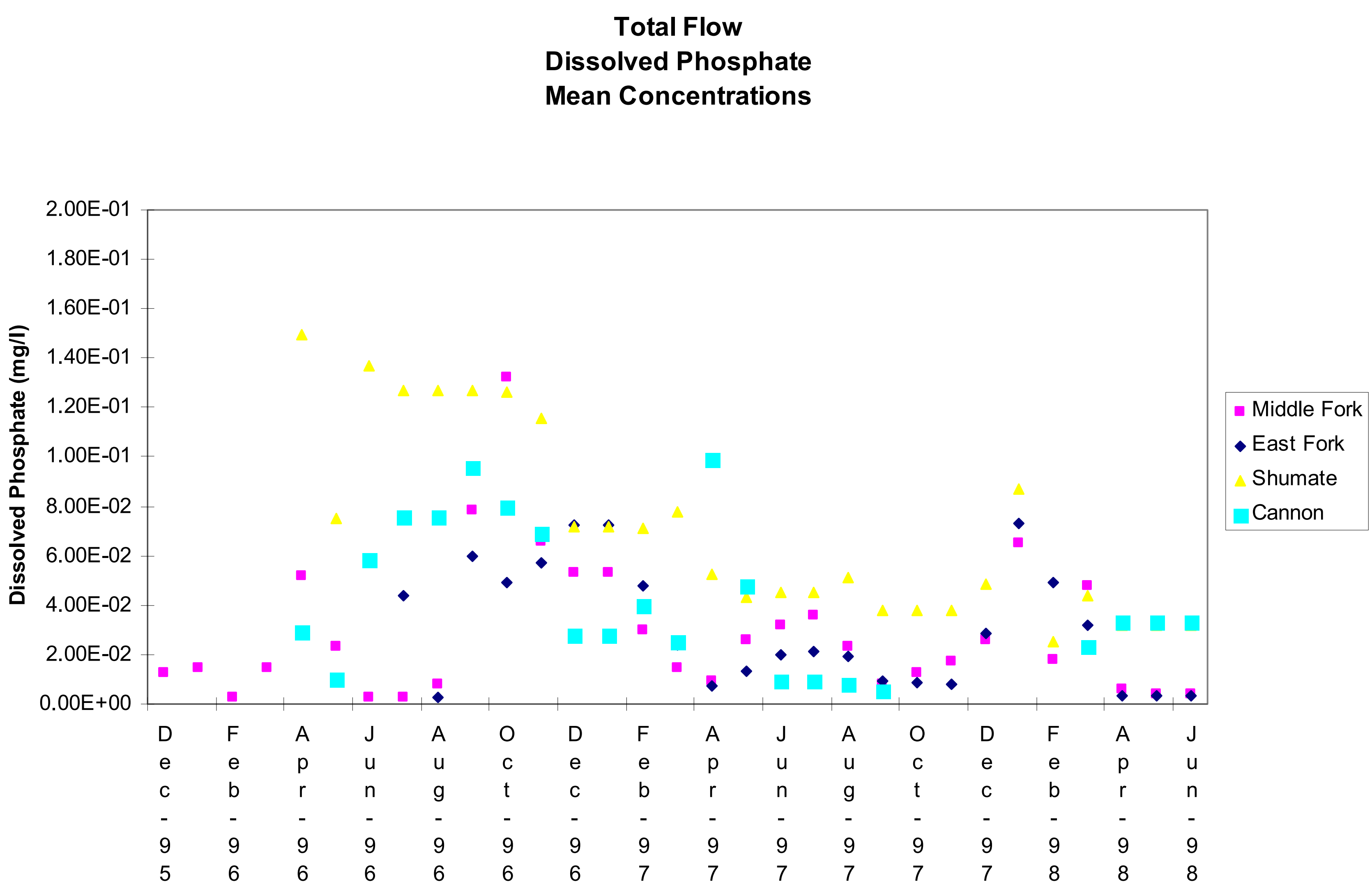

Figure 52. Monthly total flow dissolved phosphate mean concentrations for the East Fork, Middle Fork, Cannon Creek and Shumate Creek.

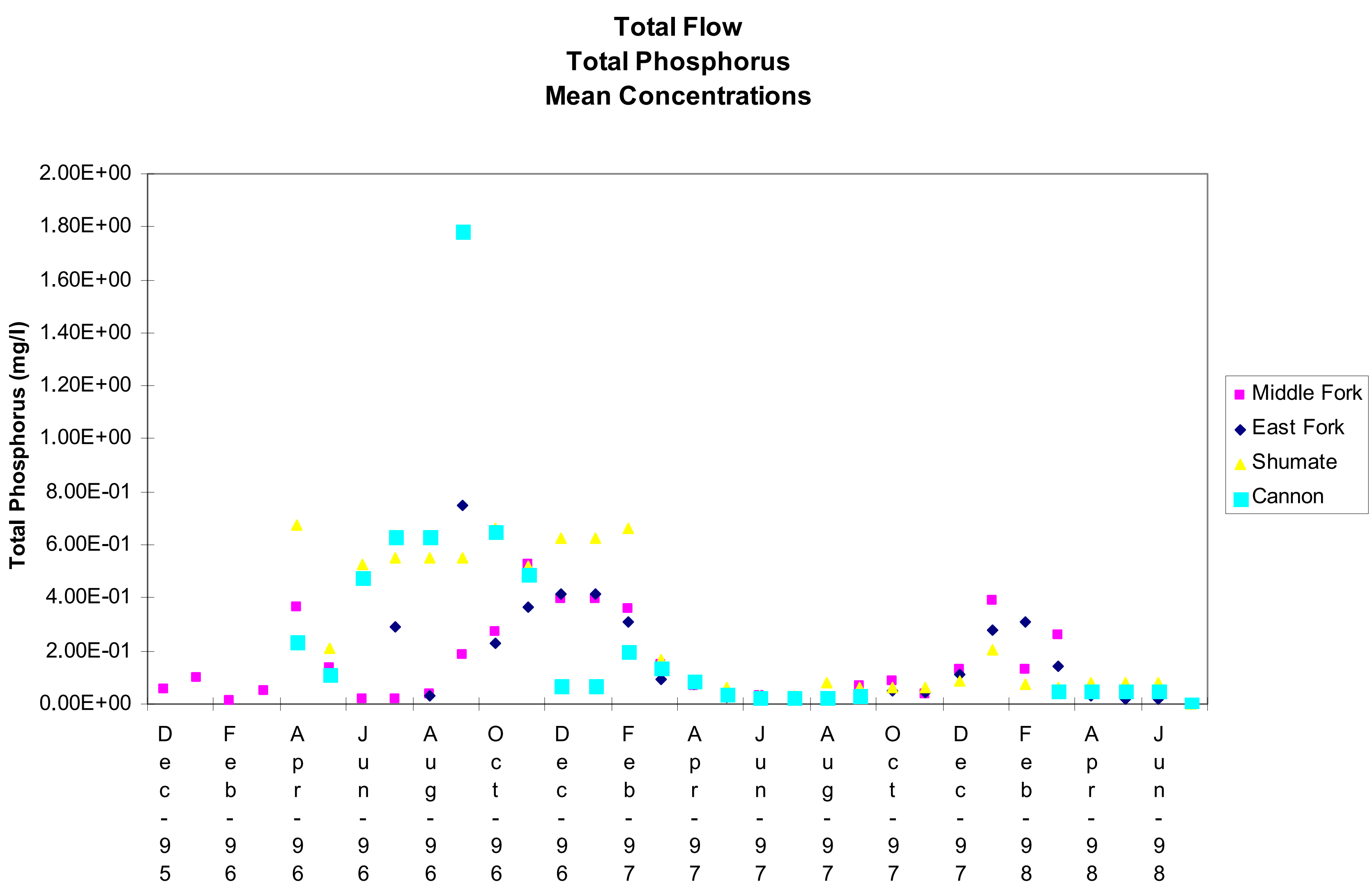

Figure 53. Monthly total flow total phosphorus mean concentrations for the East Fork, Middle Fork, Cannon Creek and Shumate Creek.

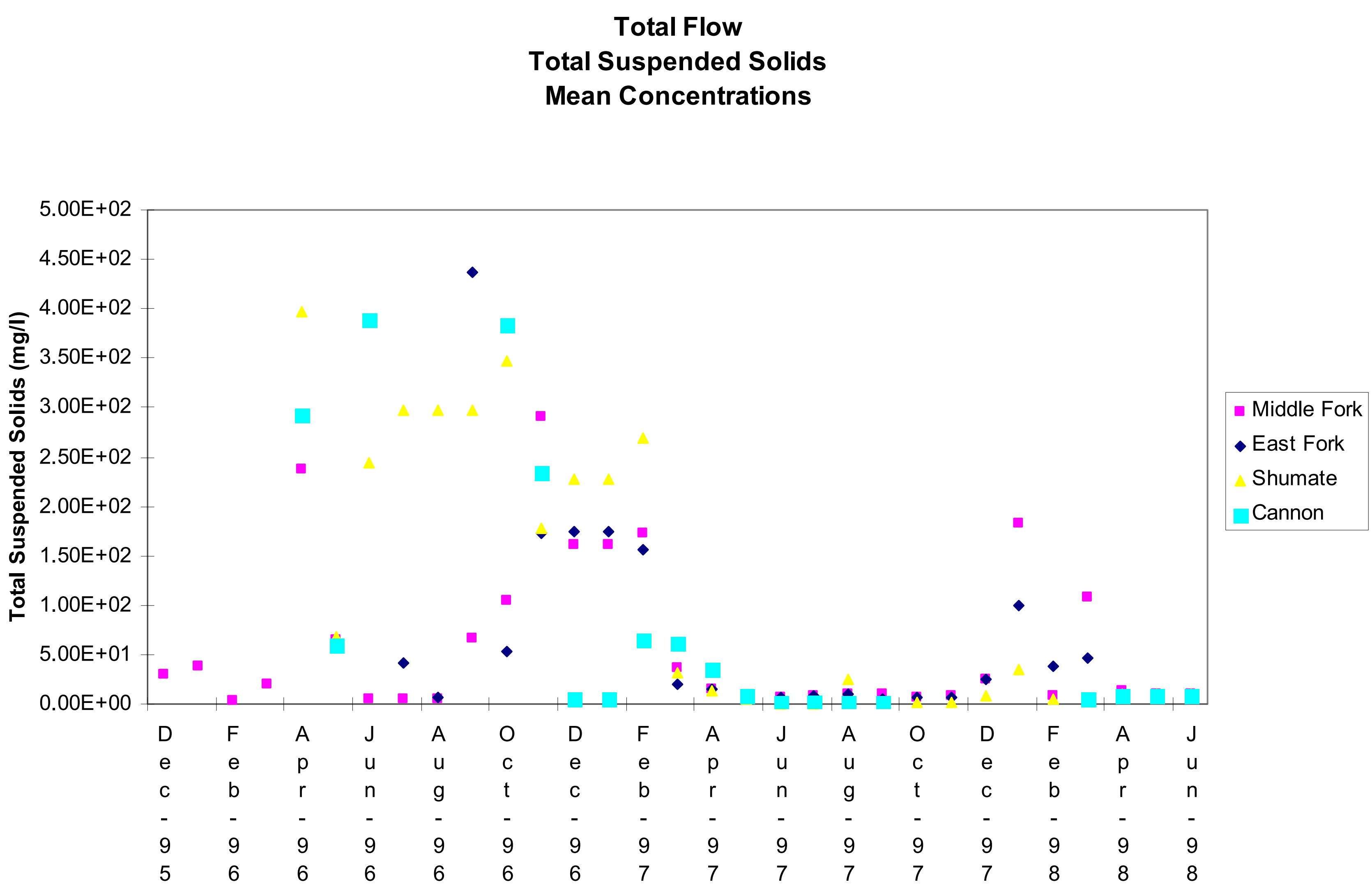

Figure 54. Monthly total flow total suspended solids mean concentrations for the East Fork, Middle Fork, Cannon Creek and Shumate Creek.

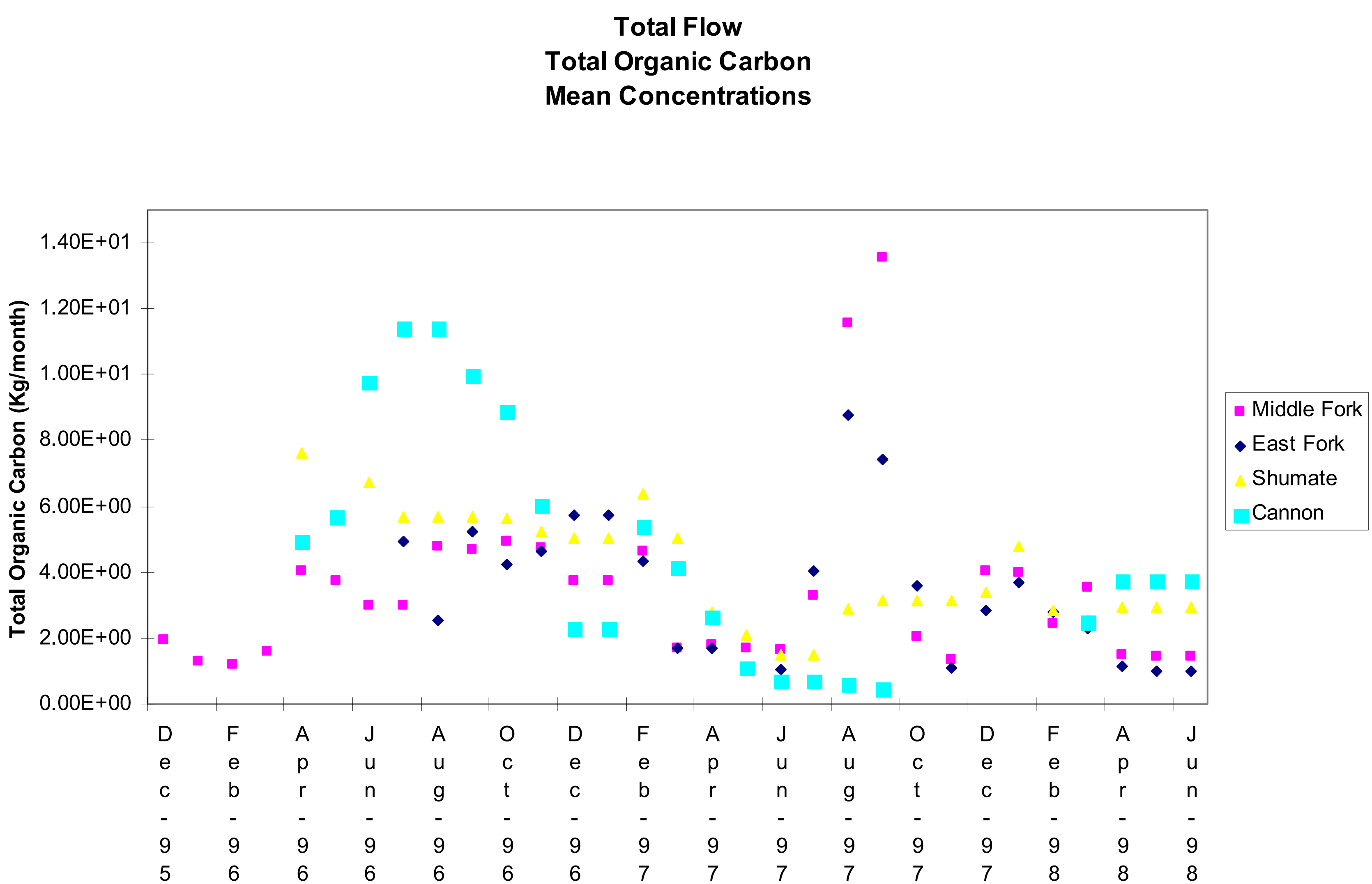

Figure 55. Monthly total flow total organic carbon mean concentrations for the East Fork, Middle Fork, Cannon Creek and Shumate Creek.

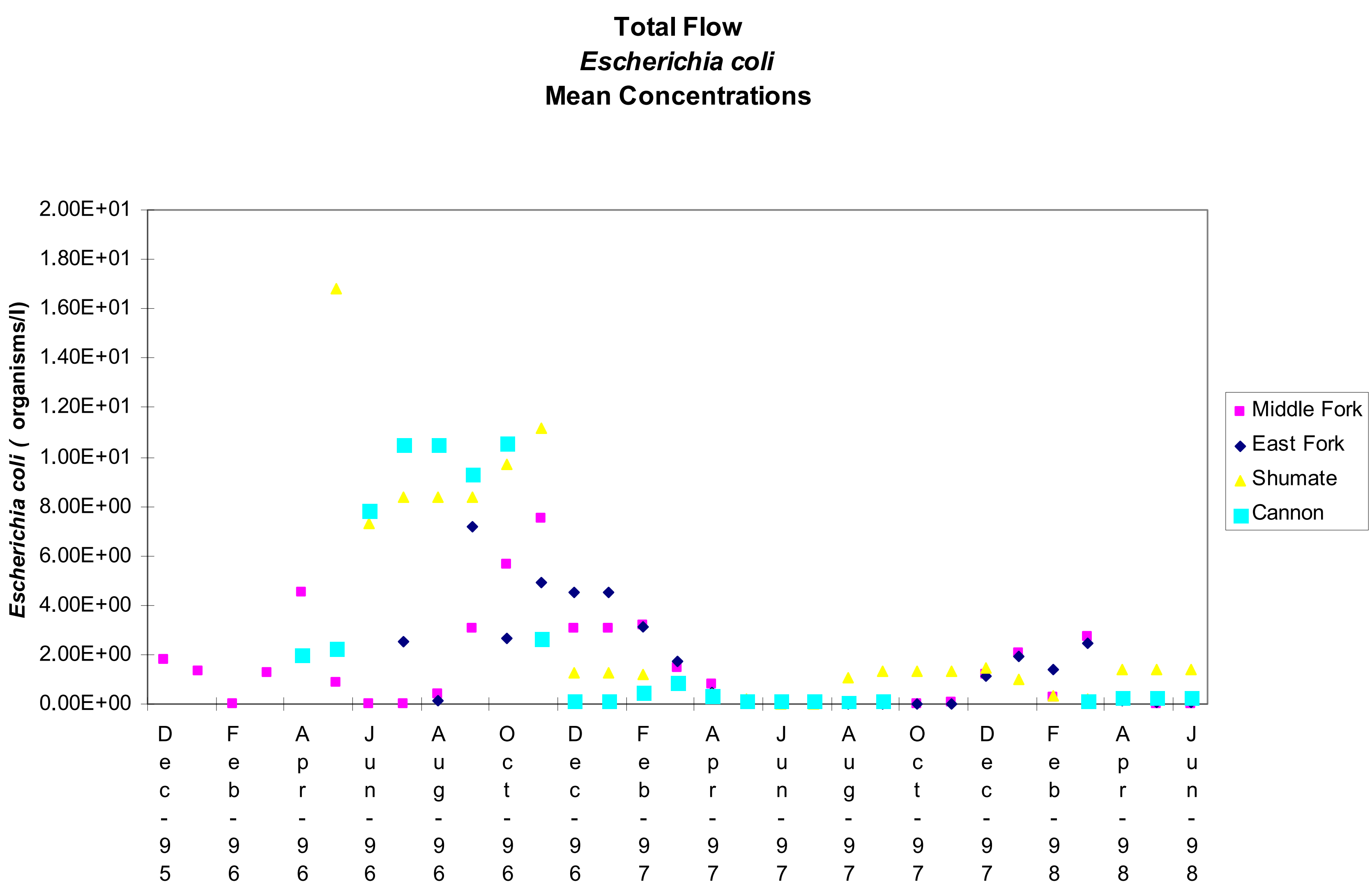

Figure 56. Monthly total flow *Escherichia coli* mean concentrations for the East Fork, Middle Fork, Cannon Creek and Shumate Creek.

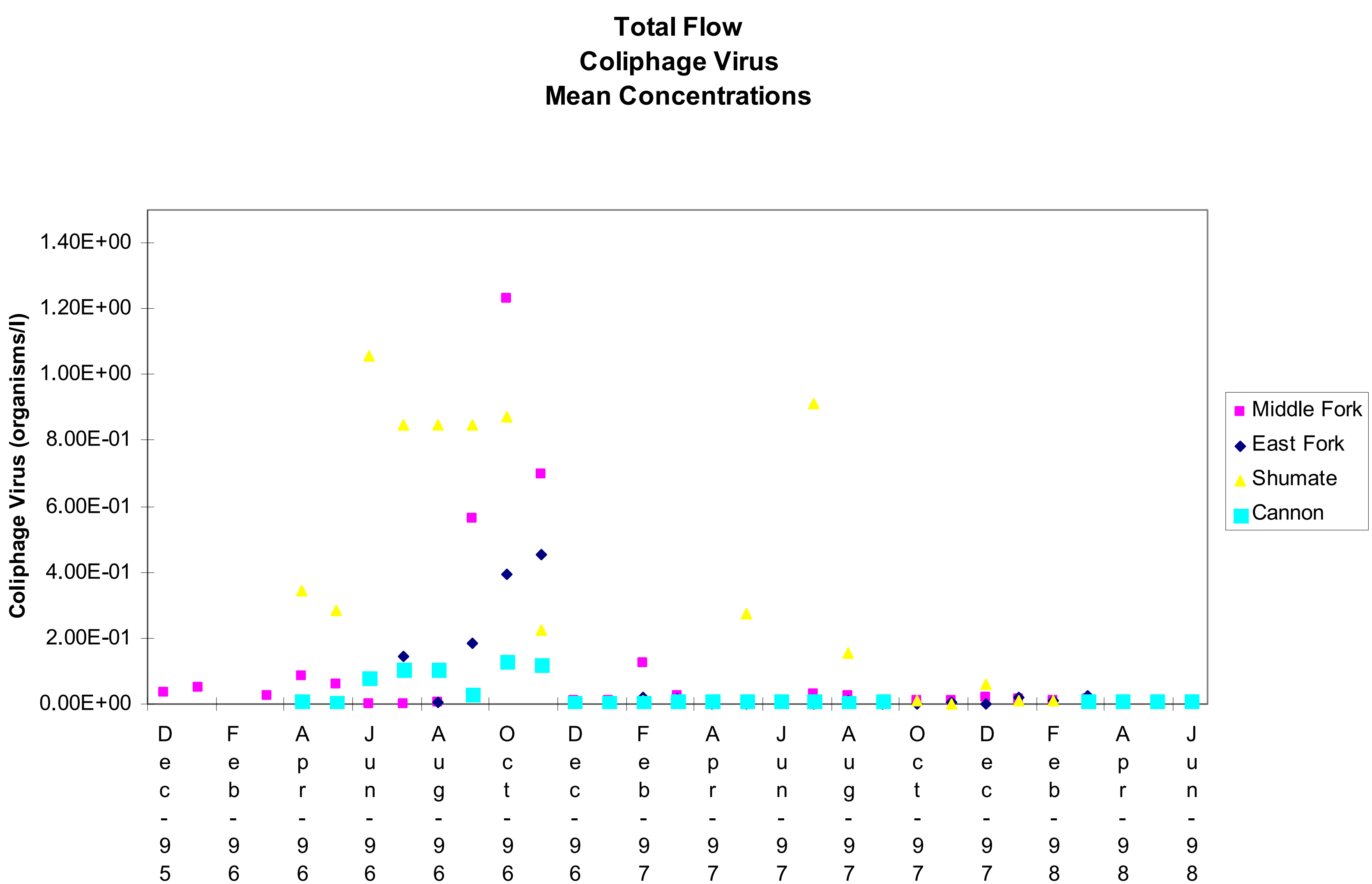

Figure 57. Monthly total flow mean concentrations for coliphage virus for the East Fork, Middle Fork, Cannon Creek and Shumate Creek.