1.0 INTRODUCTION

1.1 PURPOSE OF THE MONITORING PROGRAM

The U.S. Army Corps of Engineers (USACE) manages Beltzville Reservoir located in east-central Pennsylvania within the Delaware River Basin. Foremost, Beltzville Reservoir provides flood control and a dependable water supply to downstream communities along the Lehigh River. Additionally, the reservoir provides important habitat for fish, waterfowl, and other wildlife, and recreational opportunities through fishing, boating, and swimming. Due to the broad range of uses and demands that Beltzville Reservoir serves, the USACE monitors water quality to compare with state water quality standards and to diagnose other problems that commonly effect reservoir health such as nutrient enrichment and toxic loadings. This report summarizes the results of water quality monitoring at Beltzville Reservoir from April to October 2001. This report also discusses the relevance of the water quality measures to the ecology of the reservoir and makes recommendations toward future water quality monitoring.

1.2 DESCRIPTION OF BELTZVILLE RESERVOIR

Beltzville Reservoir was designed to provide flood control, water supply, and enhanced water quality to downstream communities along the Lehigh River. The damming of Pohopoco Creek approximately three miles upstream of its confluence with the Lehigh River formed the reservoir. The reservoir is located in Carbon County, 3 miles northeast of Lehighton and about 20 miles northwest of Allentown, Pennsylvania. The reservoir dams a drainage area of 96.3 square miles and can impound up to 13 billion gallons of water. The primary water source feeding into the lake is Pohopoco creek as it flows southwest to the Lehigh River. Secondary water sources include Pine Run and Wild Creek, both entering the reservoir from the north. The reservoir is approximately 7 miles long and, when full, covers an area of 947 acres. The maximum depth of the lake is 140 feet near the face of the dam. The average annual discharge is approximately 196 cubic feet per second (USGS 1993).

1.3 ELEMENTS OF THE STUDY

The USACE, Philadelphia District, has been monitoring the water quality of Beltzville Reservoir since 1975. Over this time, the yearly monitoring designs have evolved to address new concerns such as the health of public drinking water and contamination of

reservoir bottom sediments. The 2001 monitoring program follows that in most recent years and includes the following major elements:

- Monthly water quality monitoring from April through October of reservoir and upstream sources to evaluate compliance with Pennsylvania state water quality standards;

- In an effort to coordinate concurrent studies, additional parameters were collected and analyzed in conjunction with the Lehigh Water Quality Study. This included the addition of a meteorological station on the dam tower;

- Sediment priority pollutant monitoring of semivolatile organics and metals to evaluate sediment toxicity relative to USACE identified screening concentrations; and

- Drinking water monitoring to ensure public health and safety by comparing water from a public drinking water source to standards determined by the Safe Drinking Water Act (SDWA).

2.0 METHODS

2.1 STRATIFICATION MONITORING

Physical stratification monitoring of the water column was conducted 6 times at Beltzville Reservoir between April and October 2001 (Table 2-1). Physical stratification parameters included temperature, dissolved oxygen (DO), pH, and conductivity. Physical stratification was monitored at seven fixed stations throughout the reservoir watershed (Fig. 2-1). Three stations were located within the reservoir body (BZ-3, BZ-6, and BZ-7) for which water quality was measured from the surface to the bottom at 5-foot intervals. Surface water quality was measured at four stations, located on upstream source waters (BZ-2 on Pine Run, BZ-4 on Wild Creek, and BZ-5 on Pohopoco Creek) and downstream of the reservoir (BZ-1). The physical water quality parameters were measured with a calibrated Hydrolab water quality meter.

For this report, all of the stratification monitoring results were summarized and compared to water quality standards enacted by the Pennsylvania Department of Environmental Protection (PADEP). The water quality standard for DO is a minimum concentration of 5 mg/L and the criteria for pH is an acceptable range of 6 to 9.

2.2 WATER COLUMN CHEMISTRY MONITORING

Water column chemistry monitoring was conducted seven times at Beltzville Reservoir between April and October 2001 (Table 2-1). Water samples were collected at the seven fixed stations in the reservoir watershed (Fig. 2-1). Surface water samples were collected downstream of the reservoir (BZ-1) and on upstream sources Pine Run (BZ-2), Wild Creek (BZ-4), and Pohopoco Creek (BZ-5). Surface, middle, and bottom water samples were collected at three reservoir stations (BZ-3, BZ-6, and BZ-7). Surface water samples were collected by opening sample containers approximately 1 foot below the water's surface. Middle and bottom water samples were collected with a Van Dorn design horizontal water bottle.

Water samples from all depths were analyzed for ammonia, nitrite, nitrate, total Kjeldahl nitrogen (TKN), total phosphorus, total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), alkalinity, total organic carbon (TOC), total inorganic carbon (TIC) and chlorophyll *a*. Additionally, surface water samples collected at stations BZ-3, BZ-6, and BZ-7 were analyzed for purgeable aromatics (benzene, toluene, ethylbenzene, and xylenes, i.e., BTEX). BTEX was not analyzed during May monitoring because of a lab processing error.

Table 2-1. Beltzville Reservoir water quality monitoring schedule for 2001

Date of Sample Collection	Physical Stratification Monitoring (All Stations)	Water Column Chemistry Monitoring (All Stations)	Trophic State Assessment (BZ-3, -6, and -7)	Coliform Bacteria Monitoring (All Stations)	Sediment Priority Pollutant Monitoring (BZ-6)	Drinking Water Monitoring*
24 April	X	X	X	X		
24 May	X	X	X	X		
14 June	X	X	X	X		Sets A and B
21 June						Total Coliform/E. Coli
26 June						Total Coliform/ Fecal Coliform
5 July						Total Coliform/E. Coli
17 July	X	X	X	X	X	
7 August	X	X	X	X		Set A
25 September	X	X	X	X		
24 October	X	X	X	X		Set A

*Set A – comprised analyses for nitrate, nitrite, and coliform bacteria contaminants
Set B – comprised analyses for primary and secondary contaminants

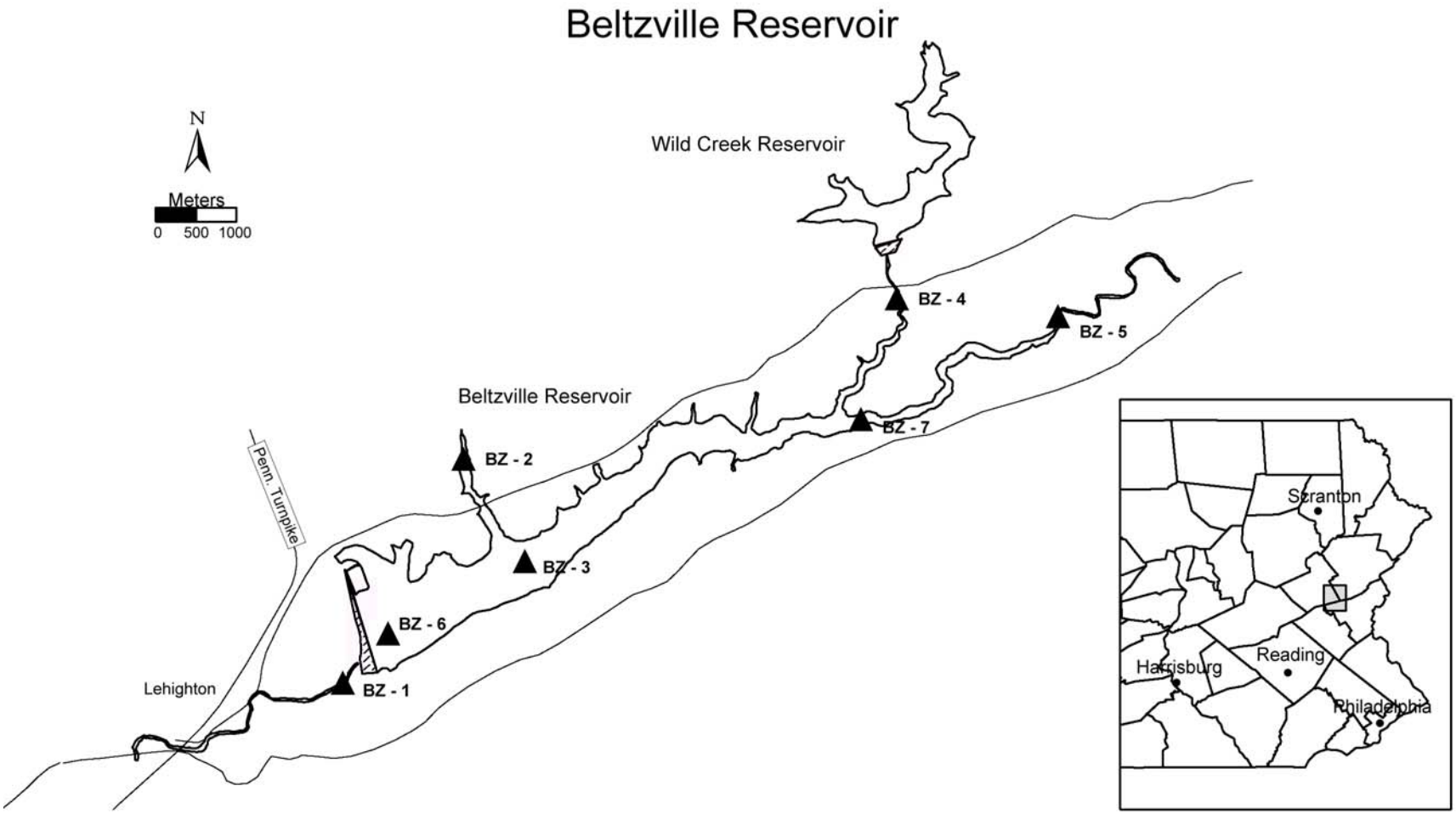

Figure 2-1. Beltzville Reservoir and the location of water quality monitoring stations in 2001.

Table 2-2 summarizes the laboratory methods; detection limits, state regulatory criteria, and sample hold times for each water quality parameter monitored. All of the water samples collected during the 2001 monitoring period were analyzed within their respective maximum allowable hold times.

Table 2-2. Water quality test methods, detection limits, state regulatory criteria, and sample holding times for water quality parameters monitored at Beltzville Reservoir in 2001

Parameter	EPA Method	Detection Limit	PADEP Surface Water Quality Criteria	Allowable Hold Times (Days)	Maximum Hold Time Achieved (Days)
Alkalinity	310.3	1 mg/L	minimum 20 mg/L $CaCO_3$	14	9
Biochemical Oxygen Demand (BOD)	SM5210B	3 mg/L	None	2	2
Total Phosphorus	365.2	0.05 mg/L	None	28	11
Dissolved Phosphorus	365.2	0.05 mg/L	None	28	11
Dissolved Phosphate	365.2	0.05 mg/L	None	28	11
Total Organic Carbon	415.1	5 mg/L	None	28	14
Total Inorganic Carbon	415.1	5 mg/L	None	28	14
* Chlorophyll *a*	445.0	0-mg/m^3	None	90	60
Total Kjeldahl Nitrogen	351.3	0.20 mg/L	None	28	16
Ammonia	350.3	0.1 mg/L	Temperature and pH dependent	28	13
Nitrate	300	0.5 mg/L	Maximum 10 mg/L (nitrate + nitrite)	2	2
Nitrite	300	0.5 mg/L		2	2
Total Dissolved Solids	160.1	10 mg/L	Maximum 500 mg/L	7	7
Total Suspended Solids	160.2	1 mg/L	None	7	7
Benzene	8021B	0.001 mg/L	None	14	12
Ethyl benzene	8021B	0.001 mg/L	None	14	12
Toluene	8021B	0.001 mg/L	None	14	12
Xylenes	8021B	0.001 mg/L	None	14	12

* Chlorophyll *a* samples were allowed this holding time when wrapped tightly in the dark at –20 °C

2.3 TROPHIC STATE DETERMINATION

The trophic state of Beltzville Reservoir was determined by methods outlined by Carlson (1977). In general, this method calculated trophic state indices (TSIs) independently for measures of total phosphorus, chlorophyll *a*, and secchi disk depth. Surface water measures of total phosphorus and chlorophyll *a* from chemistry monitoring were averaged in the calculation of monthly TSIs (Table 2-1). Secchi disk depth was measured monthly at stations BZ-3, BZ-6, and BZ-7 and similarly averaged for the TSI calculation. Trophic state determinations were made using criteria defined by Carlson and EPA (1983).

2.4 RESERVOIR BACTERIA MONITORING

Monitoring for coliform bacteria contaminants was conducted seven times at Beltzville Reservoir between April and October 2001 (Table 2-1). Surface water samples were collected at all seven stations and analyzed for total coliform, fecal coliform and fecal streptococcus. The samples were collected in the same manner as the chemistry samples or approximately 1-foot below the surface of the water. Table 2-3 presents the test methods, detection limits, PADEP standards, and sample holding times for the bacteria parameters monitored at Beltzville Reservoir in 2001. The bacteria analytical method was based on a membrane filtration technique. All of the samples were analyzed within their maximum allowable hold times. At the end of the monitoring period, streamflow data (CFS) were collected from a USGS gauging station in the region (Kresgeville) and precipitation data collected at Beltzville dam were used to correlate rainfall patterns with measured bacteria levels.

Monthly coliform bacteria counts were compared to the PADEP water quality standard for bacteria. The standard is defined as a maximum geometric mean of 200 colonies/100-ml based on 5 samples collected on different days. Given our logistical limitations (all monthly sampling conducted on one day), we calculated the geometric mean based on all of the surface reservoir samples collected for each month. Although our sampling design does not fully meet PADEP guidelines, we feel that this interpretation of the coliform data meets the intent of the PADEP water quality standard for evaluating Beltzville Reservoir bacteria levels.

Table 2-3. Water quality test methods, detection limits, PADEP standards, and sample holding times for bacteria parameters monitored at Beltzville Reservoir in 2001

Parameter	Total Coliform	Fecal Coliform	Fecal Streptococcus
Test method	SM 9222B	SM9222D	SM9230C
Detection limit	10 clns/100-mls	10 clns/100-mls	10 clns/100-mls
PADEP standard	-	Geometric mean < 200 clns/100-mls	-
Maximum allowable holding time	30 hours	30 hours	30 hours
Achieved holding time	< 30 hours	< 30 hours	< 30 hours

2.5 STREAMFLOW AND PRECIPITATION

Stream flow and precipitation data for the principal monitoring months of April to October were compiled from USACE records. Stream flow data was collected at the USGS

gauging station (measured in cubic feet per second; CFS) located in Kresgeville to reflect rainfall patterns throughout the watershed of Beltzville Reservoir. Precipitation data was collected by Beltzville Reservoir personnel and reflected more local conditions of rainfall pattern. Stream flow and precipitation records were largely in agreement throughout the monitoring period (Figs. 2-2 through 2-8).

In April through the middle of May, stream flow slowly decreased until two small precipitation events took place at the end of May (Fig. 2-2 and Fig. 2-8). These rain events increased the flow to 100-cfs. After the May rain events, stream flow began to decrease until the middle of June when there was another rain event that peaked at 2 inches. Monthly monitoring in all three months took place when stream flow ranged from 60 to 100-cfs. In the later part of the summer the stream flow decreased to approximately 35-cfs. Monthly monitoring was done at 35-cfs during July and August. Towards the end of September there were two storm events that each exceeded 1.5 inches of rain. These storm events caused the greatest stream flow to peak at approximately 200-cfs. Monthly monitoring was sampled during the highest stream flow on September 25.

2.6 SEDIMENT PRIORITY POLLUTANT MONITORING

Sediment from Beltzville Reservoir was monitored for priority pollutant contaminants, Group 2 – metals and semivolatile organic compounds. Sediment was collected 17 July at station BZ-6 with a petite ponar grab-sampler. Sediment from the grab-sampler was emptied into a stainless steel mixing bowl and homogenized with a stainless steel spoon. Sediments were contained in appropriately labeled sample jars and stored on ice until shipment to the analytical laboratory. All field equipment used during the handling of reservoir sediments was decontaminated prior to sampling. Decontamination procedures were as follows: detergent wash, first deionized water rinse, 10% nitric acid rinse, second deionized water rinse, hexane rinse, and third deionized water rinse. Table 2-4 summarizes the parameters monitored, method detection limits, sample hold times, and the laboratory methods used in the analyses. All of the sediment priority pollutant parameters were analyzed within their respective maximum allowable hold times. Laboratory analysis of sediments followed EPA methods 6010B and 8270C. Sediment contaminant concentrations were reported based on dry weight and are calculated as follows:

$$\text{Dry weight concentration (mg/kg)} = \frac{\text{Wet weight concentration (mg/kg)} \times 100}{\text{\% solids of sample}}$$

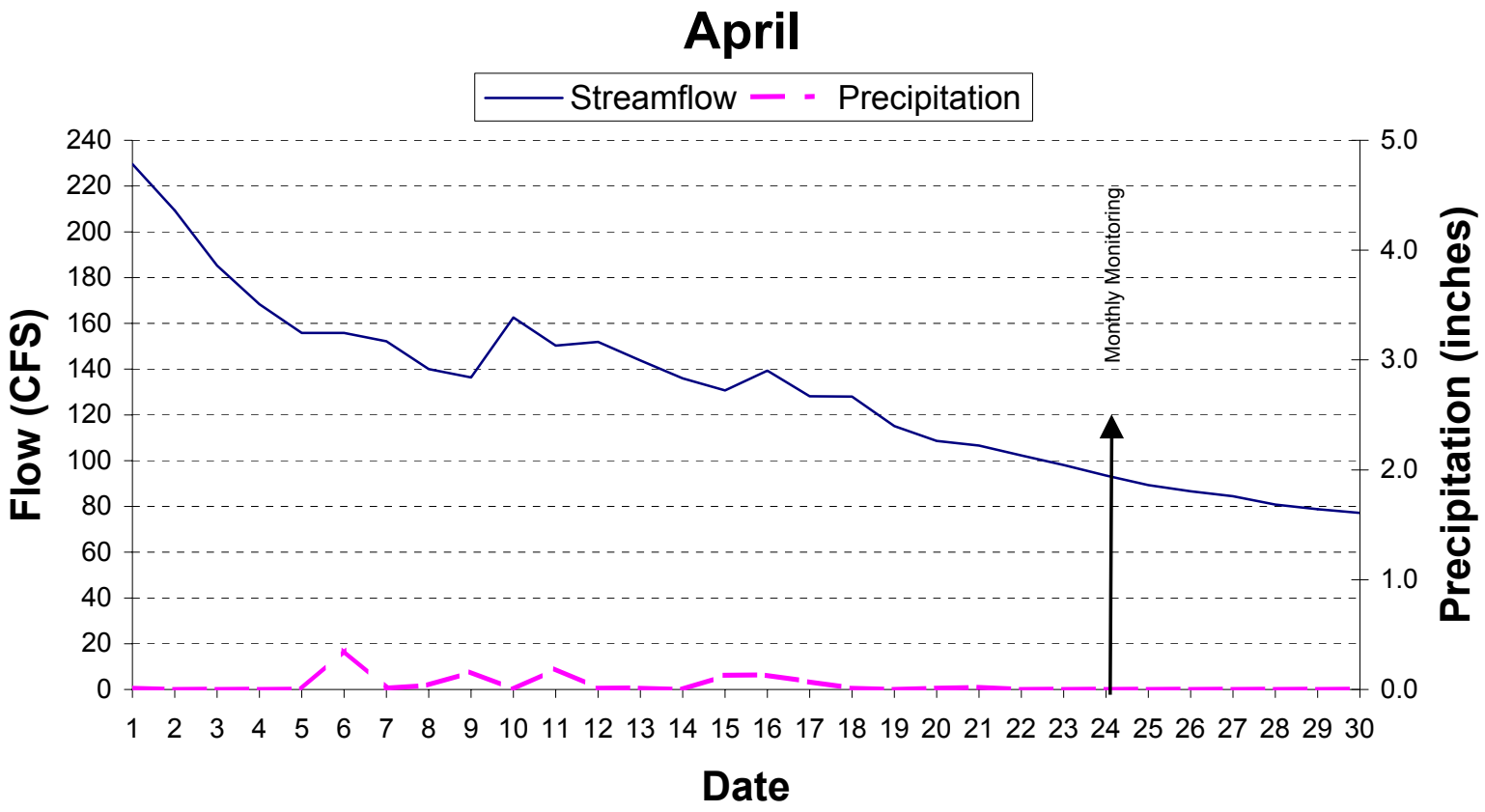

Figure 2-2. April streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

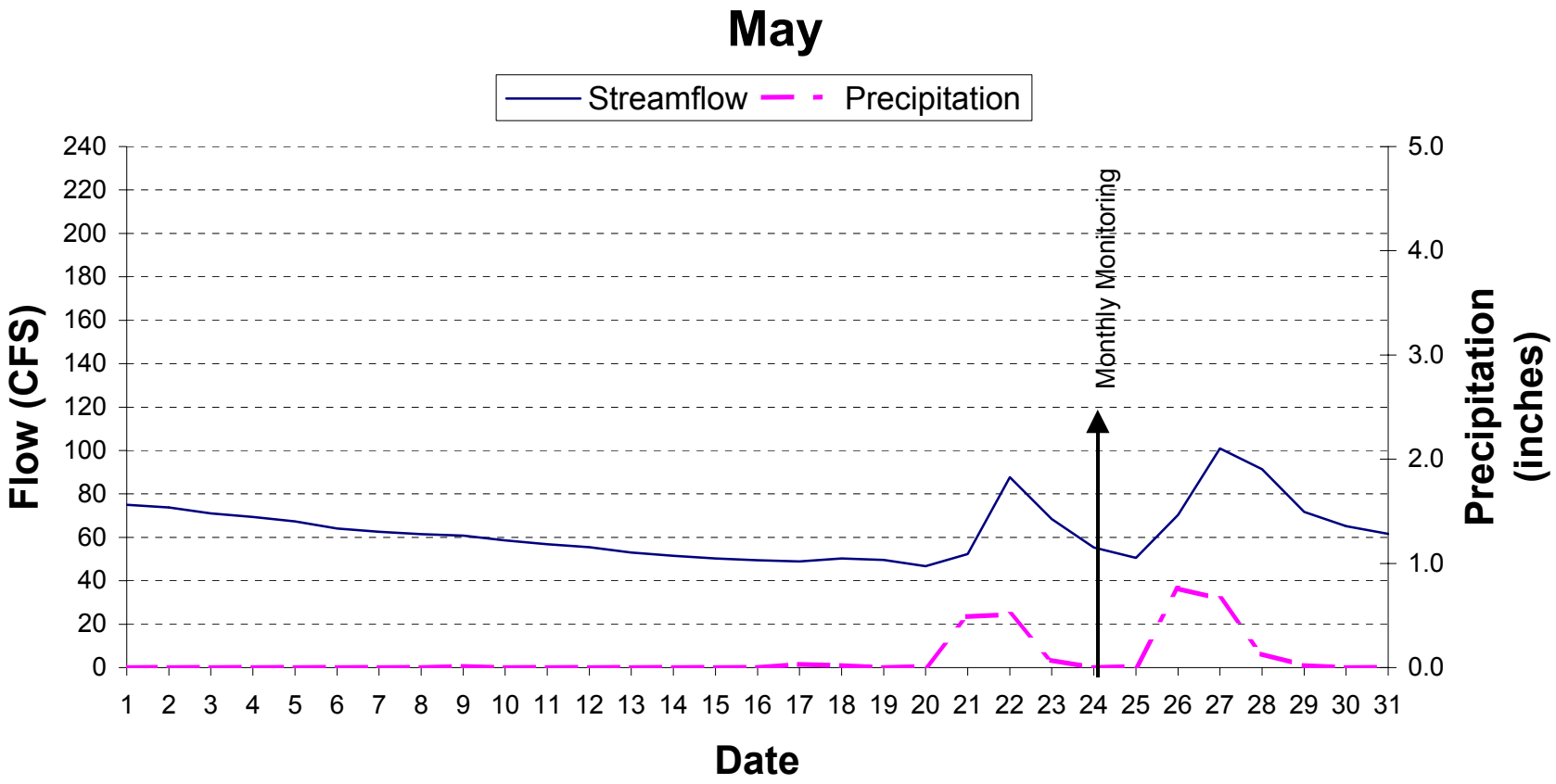

Figure 2-3. May streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

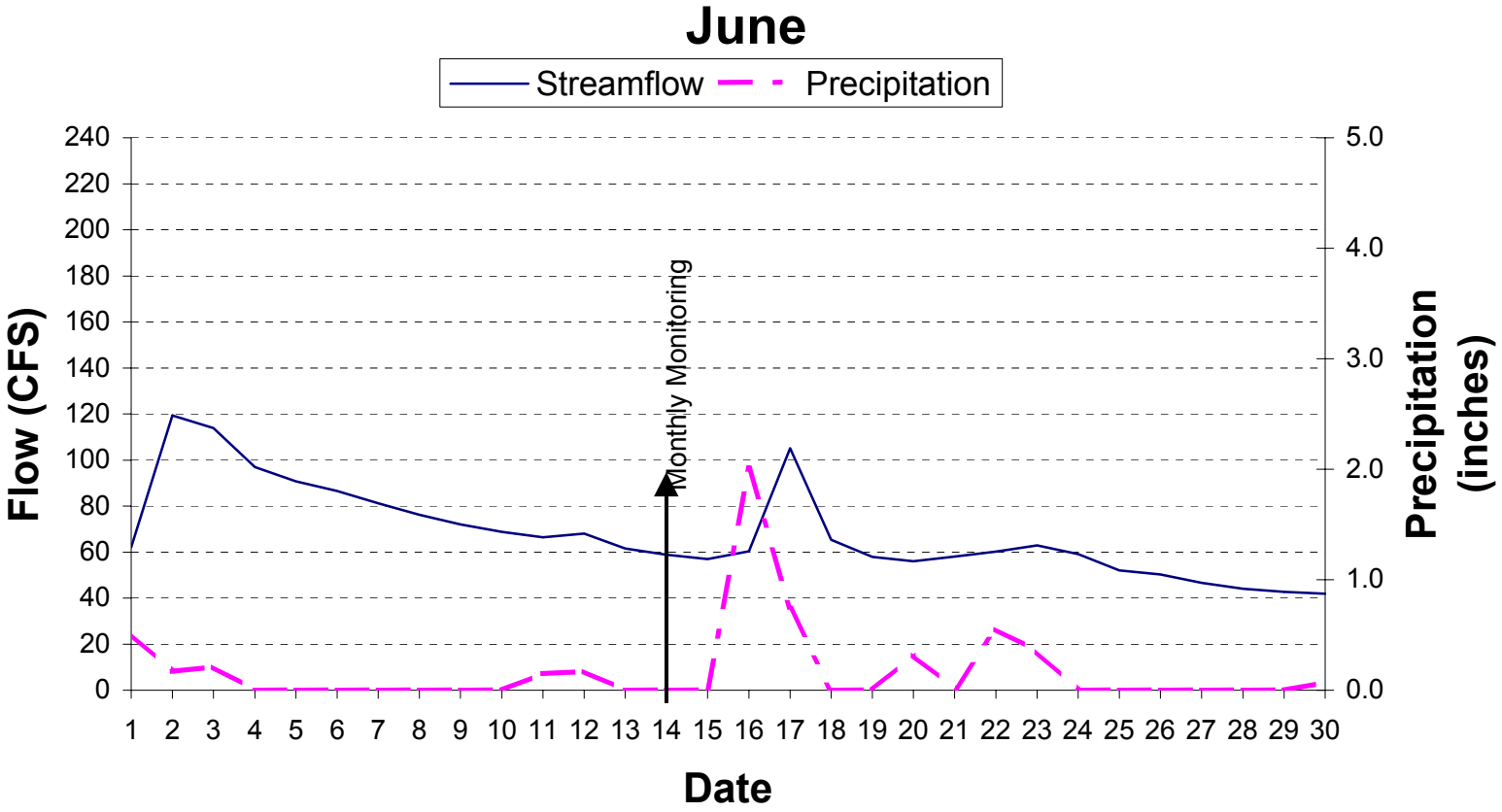

Figure 2-4. June streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

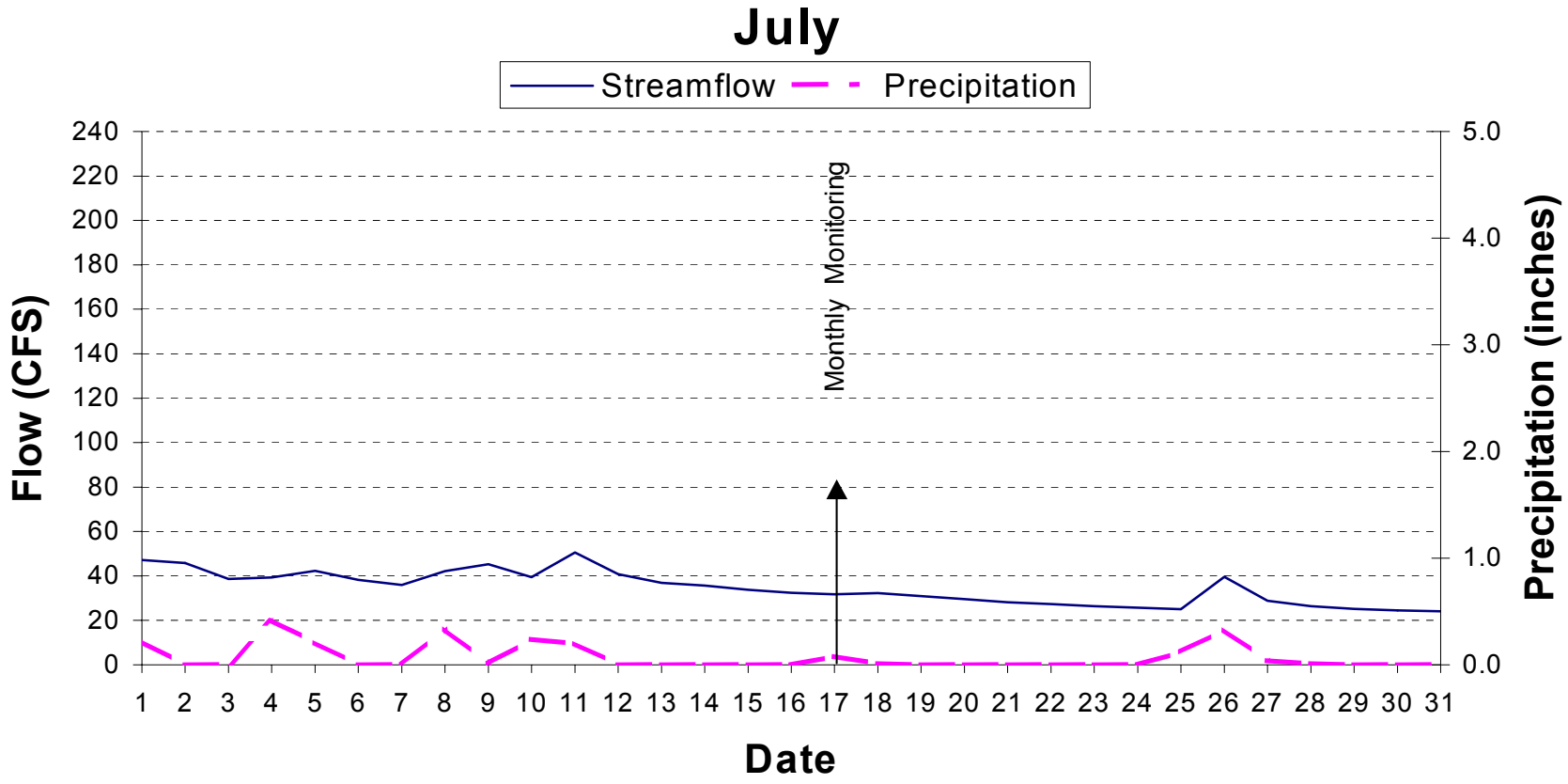

Figure 2-5. July streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

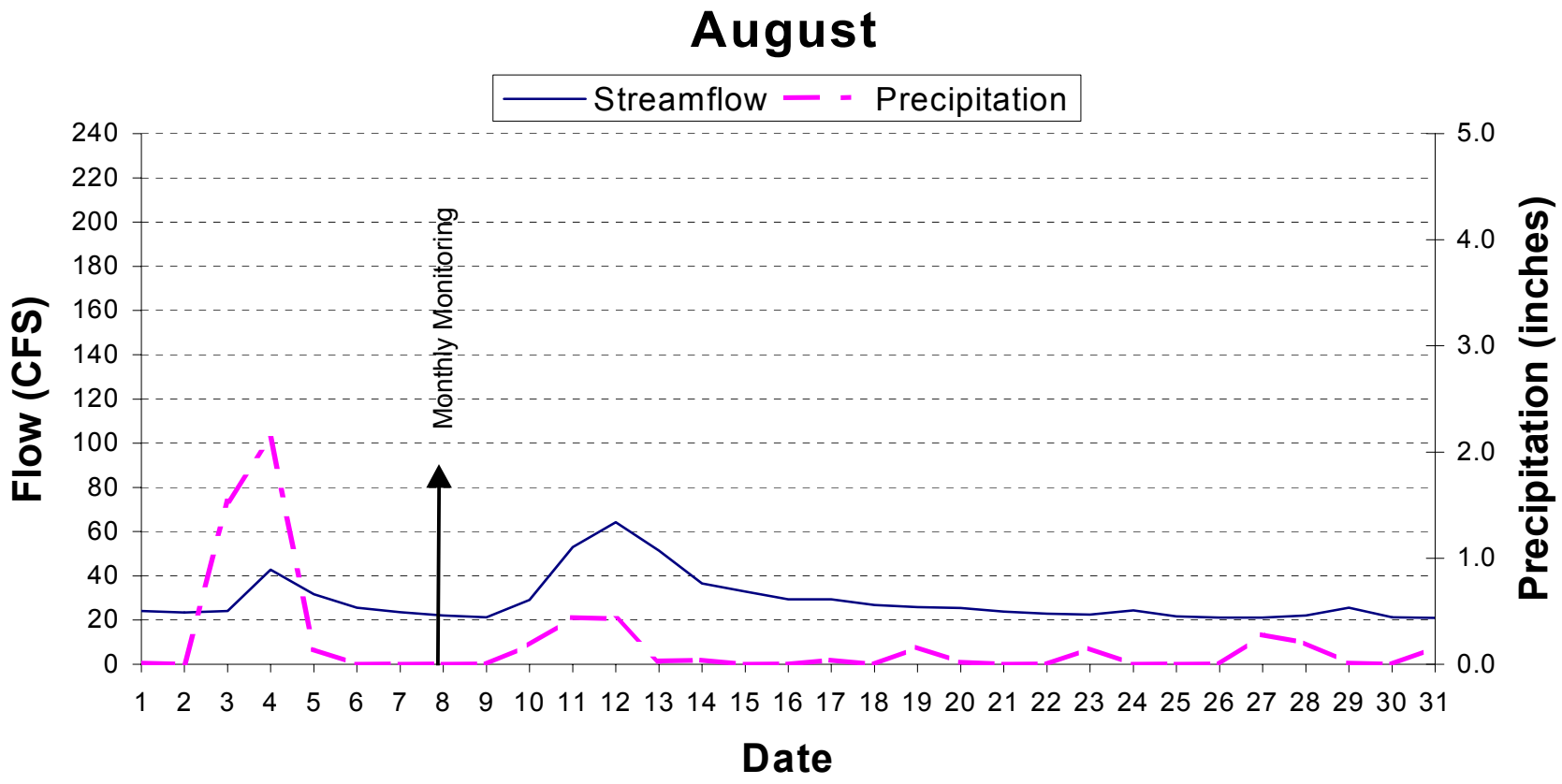

Figure 2-6. August streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

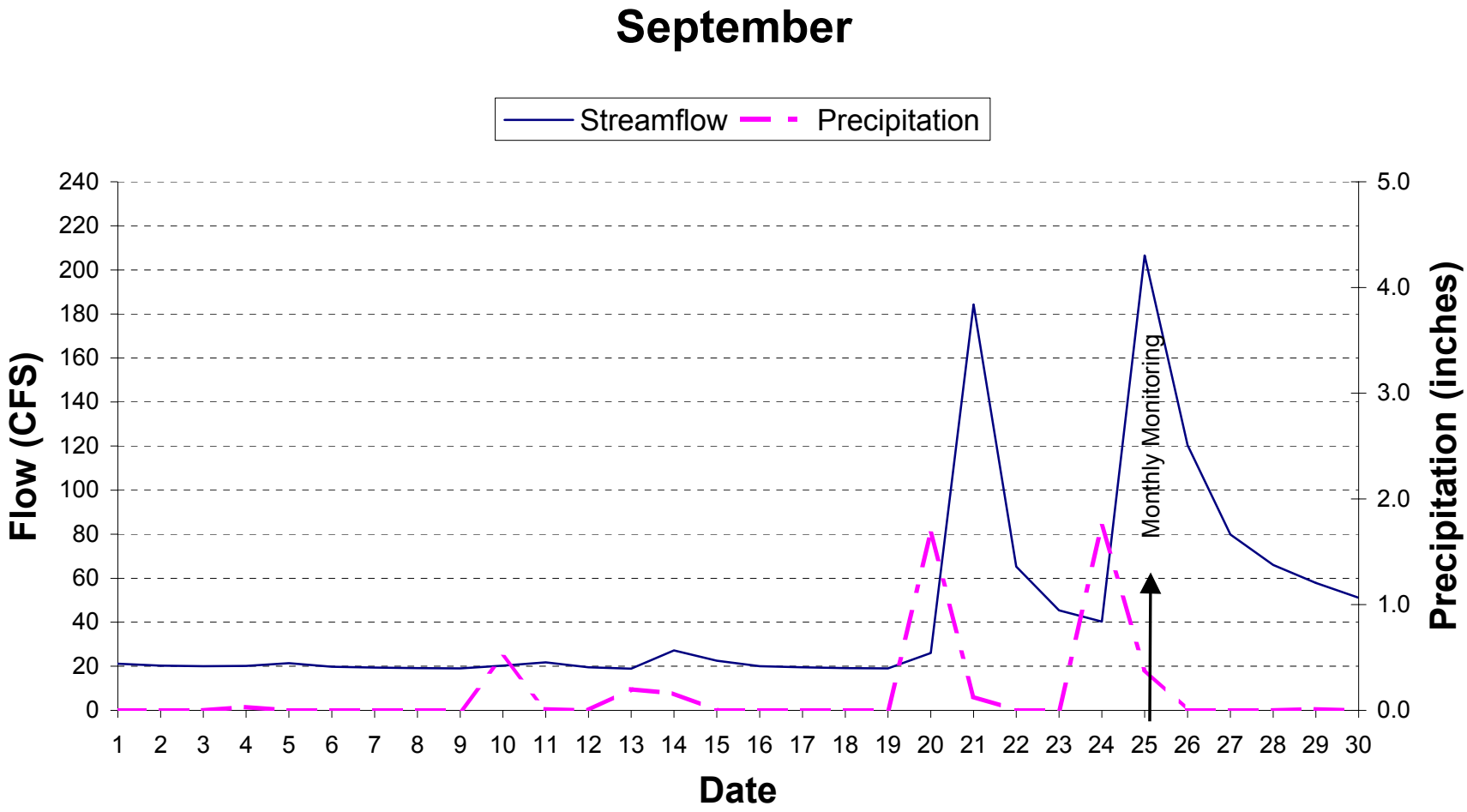

Figure 2-7. September streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

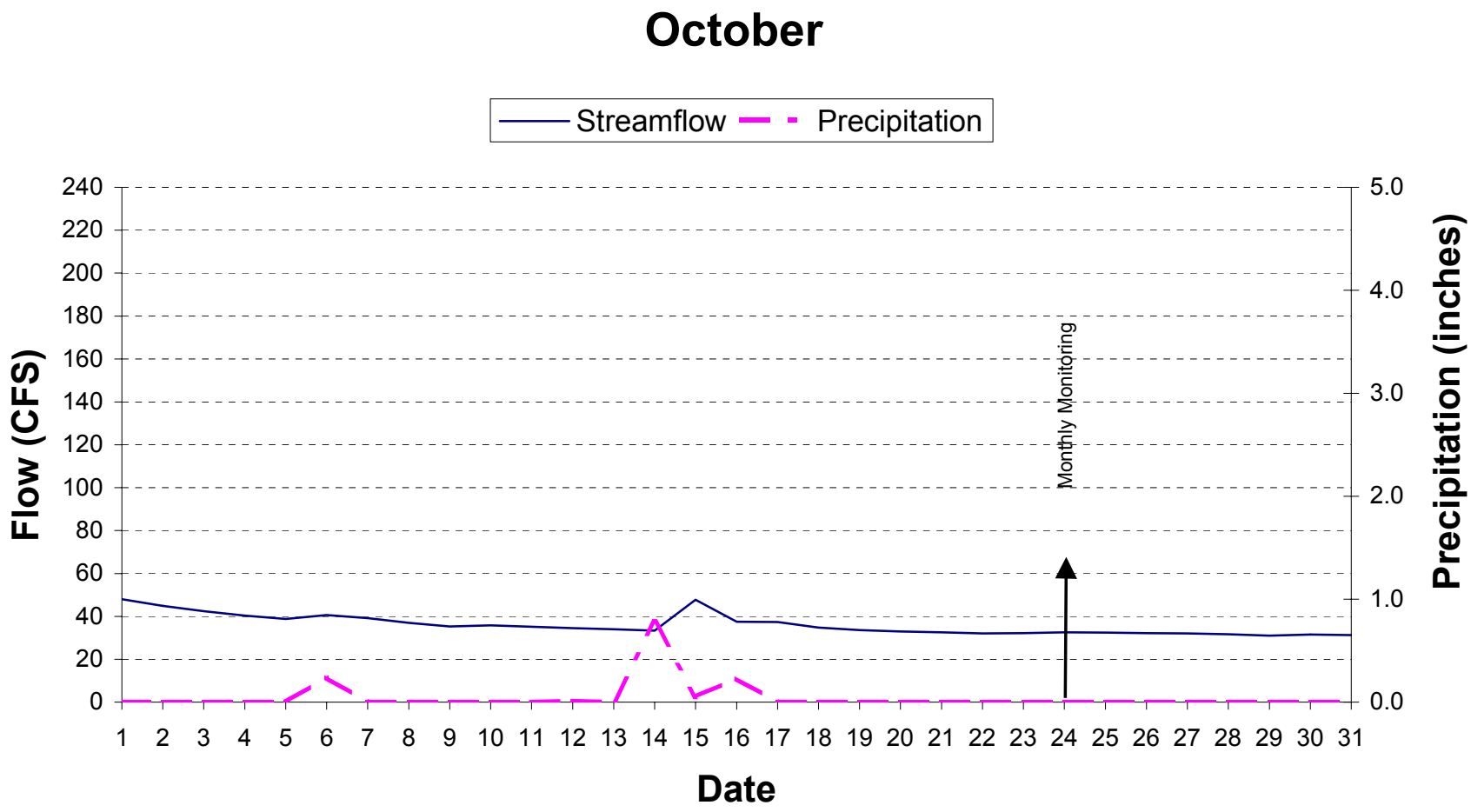

Figure 2-8. October streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

Sample-specific detection limits were calculated for the sediment tests because of matrix interference and the conversion from wet weight to dry weight.

Table 2-4. Analytical methods, detection limits, and sample hold times for sediment priority pollutant metals and semivolatiles (SVOCs) monitored at Beltzville Reservoir in 2001.

Parameter	EPA Method	Method Detection Limit (mg/kg)	Allowable Hold Time (days)	Max. Hold Time Achieved (days)
CONVENTIONALS				
Percent Solids	STM D2974	0.1		1
METALS				
Aluminum	6010B	97.6	180	13
Antimony	6010B	2	180	13
Arsenic	6010B	3/ 4	180	13
Barium	6010B	0.5	180	13
Beryllium	6010B	0.5	180	13
Cadmium	6010B	0.5	180	13
Calcium	6010B	2	180	13
Chromium	6010B	0.5	180	13
Cobalt	6010B	2	180	13
Copper	6010B	0.5	180	13
Iron	6010B	24.4	180	13
Lead	6010B	2	180	13
Magnesium	6010B	2	180	13
Manganese	6010B	0.5	180	13
Mercury	6010B	0.1	28	2
Nickel	6010B	0.5	180	13
Potassium	6010B	2	180	9
Selenium	6010B	4.9	180	13
Sodium	6010B	2	180	8
Vanadium	6010B	2	180	13
Zinc	6010B	0.5	180	13

Table 2-4. (Continued)

Parameter	EPA Method	Method Detection Limit (mg/kg)	Allowable Hold Time (days)	Max. Hold Time Achieved (days)
SVOC (mg/kg)				
2,4,5-Trichlorophenol	8270C	490	40	2
2,4,6-Trichlorophenol	8270C	490	40	2
2,4-Dichlorophenol	8270C	490	40	2
2,4-Dimethylphenol	8270C	490	40	2
2,4-Dinitrophenol	8270C	490	40	2
2-Chlorophenol	8270C	490	40	2
2-Methylphenol	8270C	490	40	2
2-Nitrophenol	8270C	490	40	2
3-Methylphenol	8270C	490	40	2
4,6-Dinitro-2-methylphenol	8270C	490	40	2
4-Chloro-3-methylphenol	8270C	490	40	2
4-Methylphenol	8270C	490	40	2
4-Nitrophenol	8270C	490	40	2
Benzoic acid	8270C	490	40	2
Benzyl alcohol	8270C	490	40	2
Pentachlorophenol	8270C	490	40	2
Phenol	8270C	490	40	2

2.7 TREND ANALYSIS METHODS

Annual water quality, sediment contaminant, and drinking water monitoring have been conducted at Beltzville Reservoir since 1974. Data collected over these years were compiled into an electronic database by the USACE (Versar 1996). Similarly, water column stratification monitoring of temperature, dissolved oxygen, pH, and conductivity has been conducted by USACE personnel bi-monthly during spring and summer seasons since 1988. Electronic copies of these data were also compiled into a separate database. The compilation of historical data enables the use of statistical trend analysis, an important step toward understanding how the water quality of Beltzville Reservoir is changing. A number of trend analysis methods are available, some more complicated than others. For the purposes of this report, we employed two general methods, regression and the Mann-Kendall, or Seasonal Kendall, test.

2.7.1 Regression Analysis

The spatial and temporal distributions of the historical data were examined to determine for which stations and parameters had sufficient time series to warrant meaningful trend analysis. For the major water quality parameters (e.g., nutrients, dissolved oxygen, total dissolved solids) downstream station BZ-1 and reservoir station BZ-2, BZ-3, BZ-4, BZ-5, BZ-6, and BZ-7 were consistently sampled over the time series. Water

quality trend analyses was limited to the spring (April through June) and summer (July through 15 October) periods. The "spring season" analyses were conceptualized as representing long-term trends associated with inputs to the reservoir system during snow melt periods. The "summer season" analyses depicted conditions during periods of maximum productivity and greatest low DO stress. Trends at station BZ-1 were analyzed separately to evaluate conditions downstream of the dam. Water quality trends within the reservoir were evaluated with concentrations observed at station BZ-2, BZ-3, BZ-4, BZ-5, BZ-6, and BZ-7. Regressions analyses were used to determine if significant increases or decreases in parameter concentrations occurred during the time series. The slope of the regression line was used to estimate the yearly rate of change. For this report, regression analysis was applied to the following water quality parameters: dissolved oxygen, ammonia, total nitrogen, total phosphorus, total dissolved solids, biochemical oxygen demand, and fecal coliform.

2.7.2 Mann-Kendall Analysis

In addition to the regression analysis, the non-parametric Mann-Kendall test was used to determine trends for individual stations over the time span of historical monitoring at Beltzville Reservoir. The Mann-Kendall test (or Seasonal Kendall test) scores all combinations of yearly changes for the tested parameter with a $+1$ or -1 depending on whether parameter concentrations increased or decreased over the time interval. All of the scores are then summed and compared to the Chi-Square distribution to determine if the parameter has a significant trend (increasing or decreasing) over the time series. For this report, the Mann-Kendall test was applied to the following water quality parameters: dissolved oxygen, ammonia, total nitrogen, total phosphorus, total dissolved solids, biochemical oxygen demand, and total and fecal coliform.

2.8 DRINKING WATER MONITORING

Drinking water was monitored at the public water fountain in the overlook building of Beltzville Reservoir (Table 2-1). Drinking water parameters were divided into two sets, A and B. Set A comprised bacteria parameters, total and fecal coliform (for analytical methods, see section 2.4), and nitrate and nitrite. Set A samples were collected 14 June, 7 August, and 24 October. Set B samples were analyzed for primary and secondary contaminants and were collected on 14 June. Addition coliform samples were collected on the following dates 21 June, 26 June, and 5 July. Table 2-5 summarizes the analytical method, detection limits, and sample hold times for each Set B parameter. All of the drinking water quality parameters were analyzed within their respective maximum allowable hold times.

Table 2-5. Analytical methods, method detection limits, and sample hold times for drinking water monitored at Beltzville Reservoir in 2001

Parameter	Detection Limits (mg/L)	Method	Allowable Hold Times (Days)	Maximum Hold Time Achieved (Days)
Aluminum	0.020	200.7	180	12
Antimony	0.050	200.8	180	12
Arsenic	0.050	200.7	180	12
Barium	0.005	200.7	180	12
Beryllium	0.005	200.7	183	15
Cadmium	0.005	200.7	180	12
Chromium	0.005	200.7	180	12
Copper	0.005	200.7	180	12
Iron	0.005	200.7	180	12
Lead	0.001	200.8	N/A	6
Magnesium	0.02	200.7	180	12
Manganese	0.005	200.7	180	12
Mercury	0.0002	245.1	28	12
Nickel	0.005	200.7	180	12
Selenium	0.050	200.8	180	12
Silver	0.005	200.7	180	12
Sodium	0.020	200.7	180	12
Thallium	0.05	200.8	180	12
Zinc	0.005	200.7	180	12
Chloride	1	300.0	28	12
Cyanide, total	0.007	SM4500CN-C&E	14	12
Fluoride	0.100	SM4500F-C	28	1
Foaming Agents	0.05	SM5540C	2	1
Nitrate	0.1	SM4500	2	2
Nitrite	0.5	SM4500	2	2
pH	0.010	150.1	N/A	1
Sulfate	5.000	300.0	28	7
Total Dissolved Solids @ 180C	10	SM2540C	7	5