WATER QUALITY MONITORING

AT BELTZVILLE RESERVOIR

DURING 2001

Prepared for

U.S. Army Corps of Engineers
Philadelphia District
Philadelphia, PA 19107

Prepared by

Craig M. Bruce
Katherine Dillow
Versar, Inc.
9200 Rumsey Road
Columbia, MD 21045

Contract No. DACW61-00-D-0009
Delivery Order No. 01

Prepared Under the Supervision of

____
William H. Burton
Principal Investigator

February 2002

TABLE OF CONTENTS

Page

1.0 INTRODUCTION 1-1
1.1 PURPOSE OF THE MONITORING PROGRAM 1-1
1.2 DESCRIPTION OF BELTZVILLE RESERVOIR 1-1
1.3 ELEMENTS OF THE STUDY..1-1

2.0 METHODS 2-1
2.1 STRATIFICATION MONITORING 2-1
2.2 WATER COLUMN CHEMISTRY MONITORING....................................2-1
2.3 TROPHIC STATE DETERMINATION..2-4
2.4 RESERVOIR BACTERIA MONITORING..2-5
2.5 STREAMFLOW AND PRECIPITATION..2-6
2.6 SEDIMENT PRIORITY POLLUTANT MONITORING....................................2-6
2.7 TREND ANALYSIS METHODS 2-15
2.7.1 Regression Analysis 2-15
2.7.2 Mann-Kendall Analysis 2-16
2.8 DRINKING WATER MONITORING 2-16

3.0 RESULTS AND DISCUSSION 3-1
3.1 STRATIFICATION MONITORING 3-1
3.1.1 Temperature 3-1
3.1.2 Dissolved Oxygen..3-1
3.1.3 pH..3-9
3.1.4 Conductivity 3-12
3.2 WATER COLUMN CHEMISTRY MONITORING....................................3-12
3.2.1 Ammonia..3-12
3.2.2 Nitrite and Nitrate..3-22
3.2.3 Total Inorganic Nitrogen..3-22
3.2.4 Total Kjeldahl Nitrogen 3-27
3.2.5 Dissolved Phosphate..3-29
3.2.6 Total Phosphorus..3-29
3.2.7 Total Dissolved Solids 3-34
3.2.8 Total Suspended Solids..3-38
3.2.9 Biochemical Oxygen Demand..3-38
3.2.10 Alkalinity..3-41
3.2.11 Total Organic and Inorganic Carbon..3-44
3.2.12 Chlorophyll *a* 3-44
3.2.13 BTEX..3-44
3.3 TROPHIC STATE DETERMINATION..3-49
3.4 RESERVOIR BACTERIA MONITORING..3-52
3.5 SEDIMENT PRIORITY POLLUTANT MONITORING....................................3-62

TABLE OF CONTENTS (CONTINUED)

Page

3.6 DRINKING WATER MONITORING 3-63
3.6.1 Primary and Secondary Contaminants 3-64
3.6.2 Inorganic Nitrogen and Coliform Bacteria 3-65
3.6.3 Historical Drinking Water Quality 3-65

4.0 SUMMARY 4-1
4.1 WATER QUALITY MONITORING 4-1
4.2 SEDIMENT PRIORITY POLLUTANT MONITORING 4-2
4.3 MONITORING PROGRAM TRENDS 4-2
4.4 DRINKING WATER MONITORING 4-2

5.0 RECOMMENDATIONS 5-1

6.0 REFERENCES 6-1

APPENDICES

A STRATIFICATION MONITORING A-1

B WATER COLUMN CHEMISTRY MONITORING LABORATORY ANALYSIS CERTIFICATES B-1

C SEDIMENT PRIORITY POLLUTANT AND ARSENIC MONITORING LABORATORY ANALYSIS CERTIFICATES C-1

D DRINKING WATER MONITORING LABORATORY ANALYSIS CERTIFICATES D-1

E SCOPE OF WORK E-1

LIST OF TABLES

Table **Page**

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

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 2-4

2-3 Water quality test methods, detection limits, PADEP standards, and sample holding times for bacteria parameters monitored at Beltzville Reservoir in 2001 2-5

2-4 Analytical methods, detection limits, and sample hold times for sediment priority pollutant metals and semivolatiles monitored at Beltzville Reservoir in 2001 2-14

2-5 Analytical methods, method detection limits, and sample hold times for drinking water monitored at Beltzville Reservoir in 2001 2-17

3-1 Spring and summer season trends of dissolved oxygen concentration at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic 3-9

3-2 Summary of surface, middle, and bottom water quality monitoring data for Beltzville Reservoir in 2001 3-15

3-3 PADEP ammonia nitrogen criteria 3-21

3-4 Seasonal trends of ammonia concentration at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic 3-22

3-5 Seasonal trends of total nitrogen at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic 3-27

3-6 Seasonal trends of total phosphorus concentration at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic 3-34

3-7 Seasonal trends of total dissolved solids concentration at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic 3-38

3-8 Seasonal trends of total BOD concentration at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic 3-41

3-9 Concentrations of BTEX parameters measured in surface water at Beltzville Reservoir during 2001 3-49

LIST OF TABLES (CONTINUED)

Table		Page
3-10	EPA trophic classification criteria and average monthly measures for Beltzville Reservoir in 2001	3-51
3-11	Bacteria counts at Beltzville Reservoir during 2001	3-57
3-12	Summary statistics of fecal coliform counts among all stations of Beltzville Reservoir during 2001	3-58
3-13	Seasonal trends of fecal coliforms/100-ml at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic	3-61
3-14	Seasonal trends of fecal coliforms/100-ml at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic	3-61
3-15	Metals and semivolatiles concentrations measured in sediments of Beltzville Reservoir in 2001	3-62
3-16	Concentrations of primary and secondary contaminants in drinking water at Beltzville Reservoir in 2001	3-64
3-17	Concentrations of nitrate and nitrite, and results of coliform bacteria monitoring of drinking water sampled from the public water fountain located in the overlook building at Beltzville Reservoir during 2001	3-66
3-18	Results of coliform bacteria monitoring of drinking water sampled on 26 June at various places at the Beltzville Reservoir after the testing on 21 June	3-67

LIST OF FIGURES

Figure **Page**

2-1 Beltzville Reservoir and the location of water quality monitoring stations in 2001 2-3

2-2 April streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001 2-7

2-3 May streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001 2-8

2-4 June streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001 2-9

2-5 July sreamflow and precipitation in the vicinity of Beltzville Reservoir during 2001 2-10

2-6 August streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001 2-11

2-7 September streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001 2-12

2-8 October streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001 2-13

3-1 Surface water temperature measured at Beltzville Reservoir in 2001 3-2

3-2 Temperature stratification at station BZ-6 of Beltzville Reservoir in 2001 3-3

3-3 Dissolved oxygen concentrations measured in surface waters at Beltzville Reservoir in 2001 3-4

3-4 Dissolved oxygen stratification at station BZ-6 of Beltzville Reservoir in 2001 3-6

3-5 Spatial/temporal distribution of hypoxic reservoir water in Beltzville Reservoir measured at the “Tower” station in 2001 3-7

3-6 Trends in seasonal average hypoxia at the “Tower” station BZ-6 3-8

3-7 Surface water pH measured at Beltzville Reservoir in 2001 3-10

3-8 pH stratification at station BZ-6 of Beltzville Reservoir in 2001 3-11

LIST OF FIGURES (CONTINUED)

Figure		Page

3-9 Surface water conductivity measured at Beltzville Reservoir in 2001 3-13

3-10 Conductivity stratification at station BZ-6 of Beltzville Reservoir in 2001 3-14

3-11 Ammonia measured in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-20

3-12 Nitrite measured in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-23

3-13 Nitrate measured in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-24

3-14 Seasonal trends of total nitrogen in the spring at Beltzville Reservoir 3-25

3-15 Seasonal trends of total nitrogen in the summer at Beltzville Reservoir 3-26

3-16 Total Kjeldahl nitrogen measured in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-28

3-17 Dissolved phosphorus measured in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-30

3-18 Total phosphorus measured in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-31

3-19 Seasonal trends of total phosphorus in spring at Beltzville Reservoir 3-32

3-20 Seasonal trends of total phosphorus in summer at Beltzville Reservoir 3-33

3-21 Total dissolved solids in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-35

3-22 Seasonal trends of total dissolved solids in spring at Beltzville Reservoir 3-36

3-23 Seasonal trends of total dissolved solids in summer at Beltzville Reservoir....3-37

3-24 Total suspended solids in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-39

LIST OF FIGURES (CONTINUED)

Figure **Page**

3-25 Biochemical oxygen demand in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-40

3-26 Seasonal trends of five-day biochemical oxygen demand in spring at Beltzville Reservoir 3-42

3-27 Seasonal trends of five-day biochemical oxygen demand in summer at Beltzville Reservoir 3-43

3-28 Alkalinity in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-45

3-29 Total inorganic carbon in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-46

3-30 Total organic carbon in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-47

3-31 Total Chlorophyll *a* in surface, middle, and bottom waters of Beltzville Reservoir in 2001 3-48

3-32 Trophic state indices calculated from secchi disk depth and concentrations of total phosporus and chlorophyll *a* at Beltzville Reservoir in 2001 3-50

3-33 Total coliform counts in surface waters of Beltzville Reservoir in 2001 3-53

3-34 Fecal coliform counts in surface waters of Beltzville Reservoir in 2001 3-54

3-35 Fecal streptococcus counts in surface waters of Beltzville Reservoir in 2001 3-55

3-36 Maximum, average, and geometric mean of fecal coliform for all stations monitored at Beltzville Research in 2001 3-56

3-37 Seasonal trends of fecal coliform in spring at Beltzville Reservoir 3-59

3-38 Seasonal trends of fecal coliform in summer at Beltzville Reservoir 3-60

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

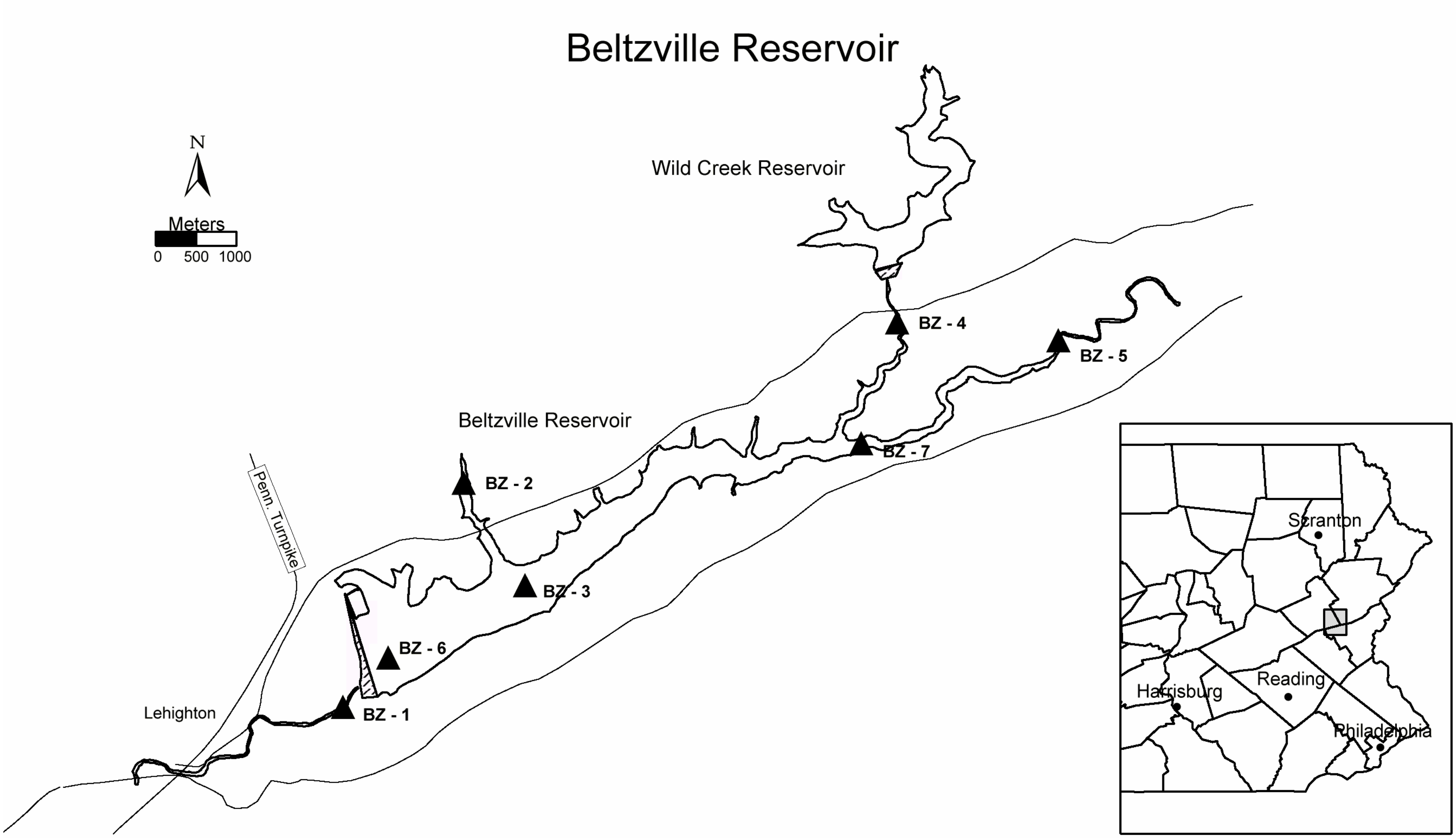

Figure 2-1. Beltzville Reservoir and the location of water quality monitoring stations in 2001.

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 2inches. 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:

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

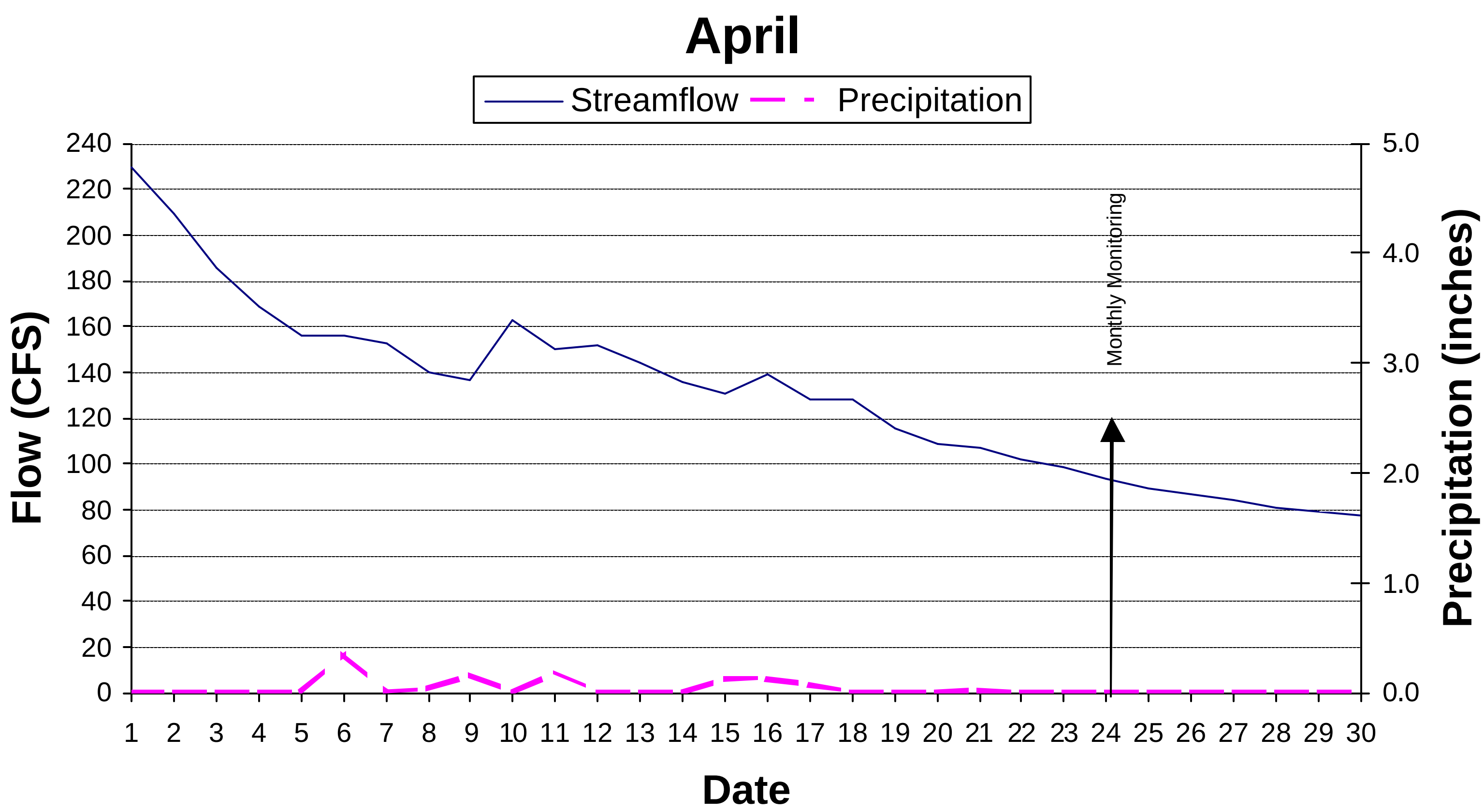

Figure 2-2. April streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

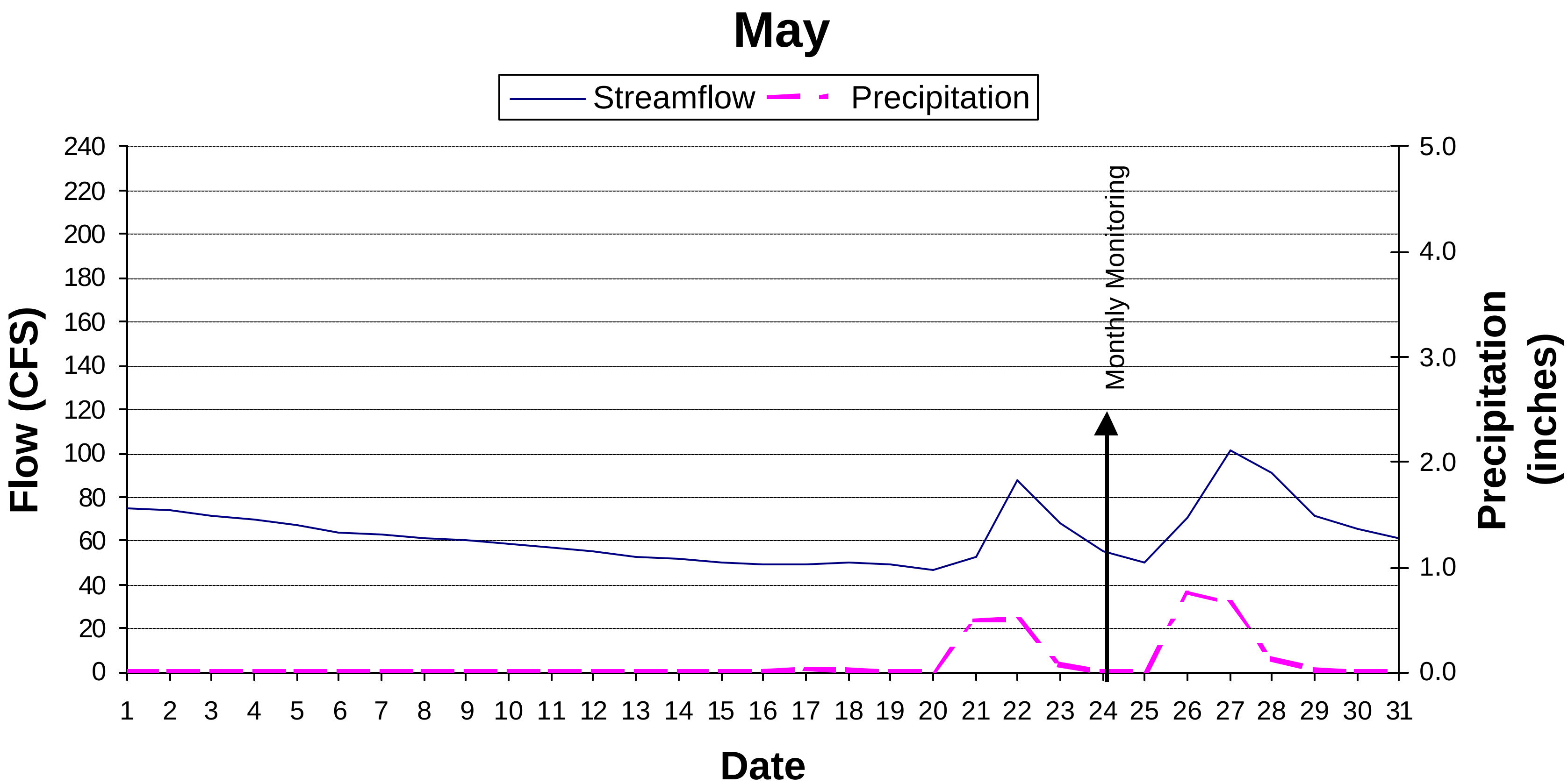

Figure 2-3. May streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

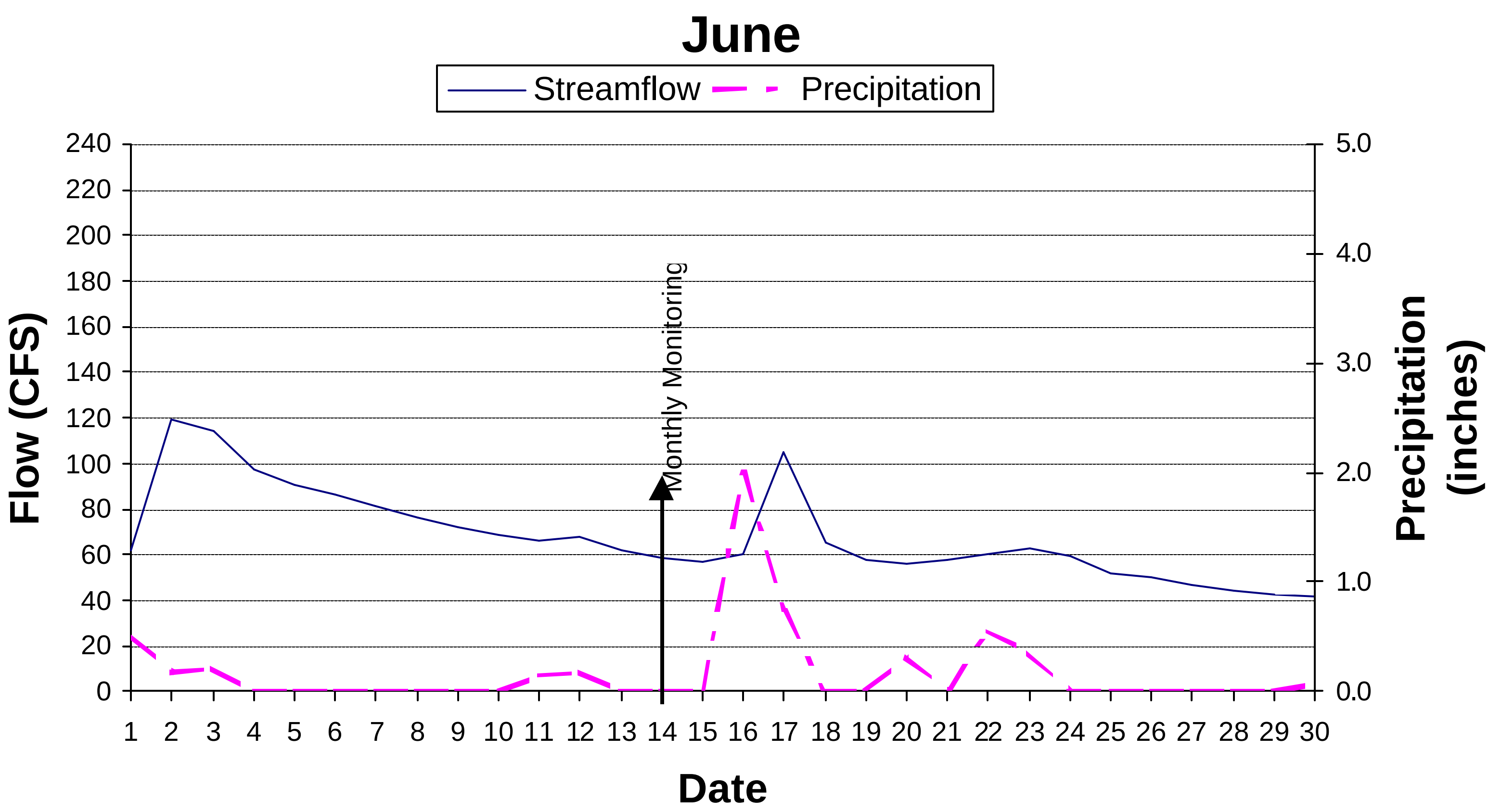

Figure 2-4. June streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

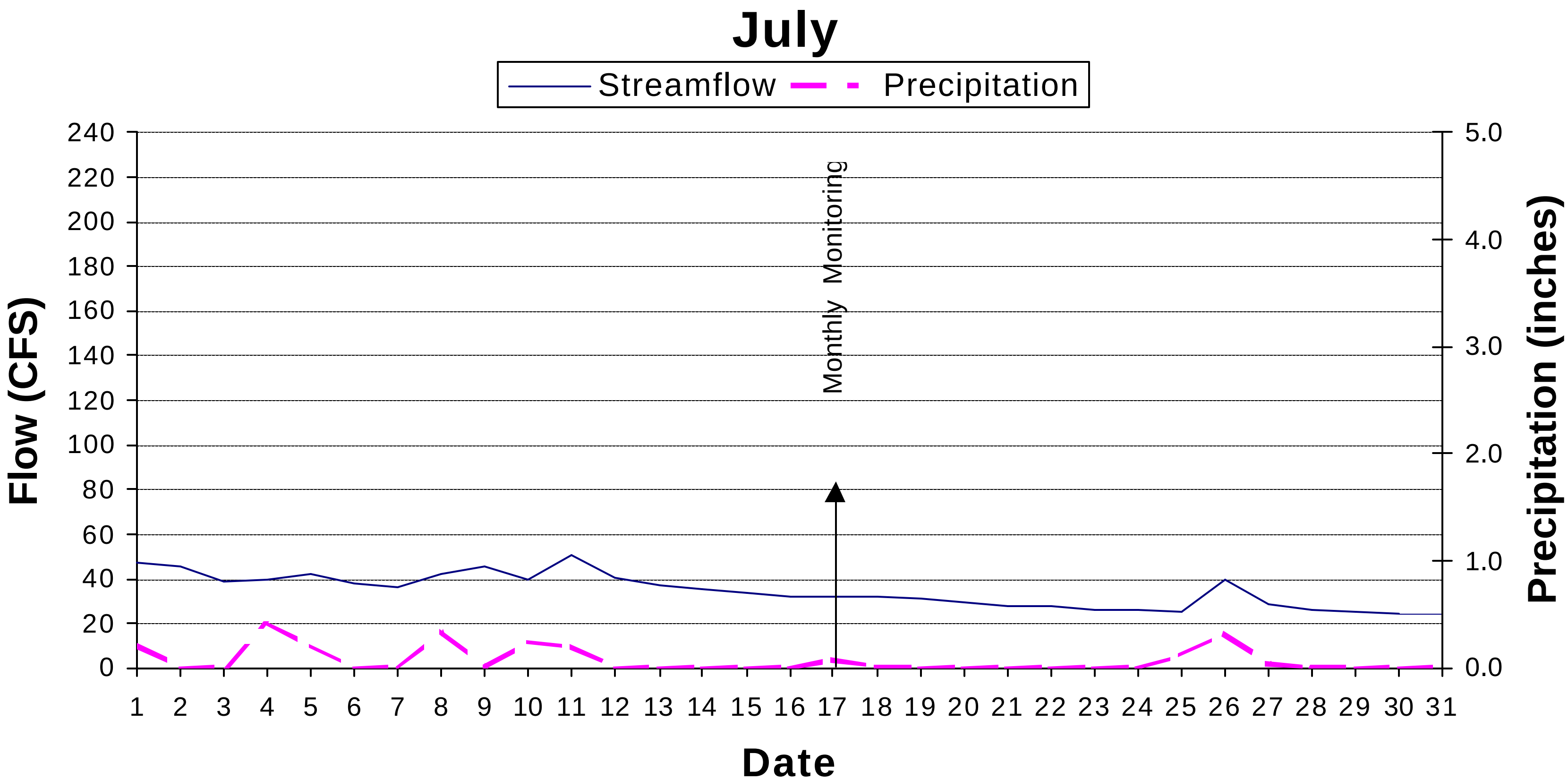

Figure 2-5. July streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

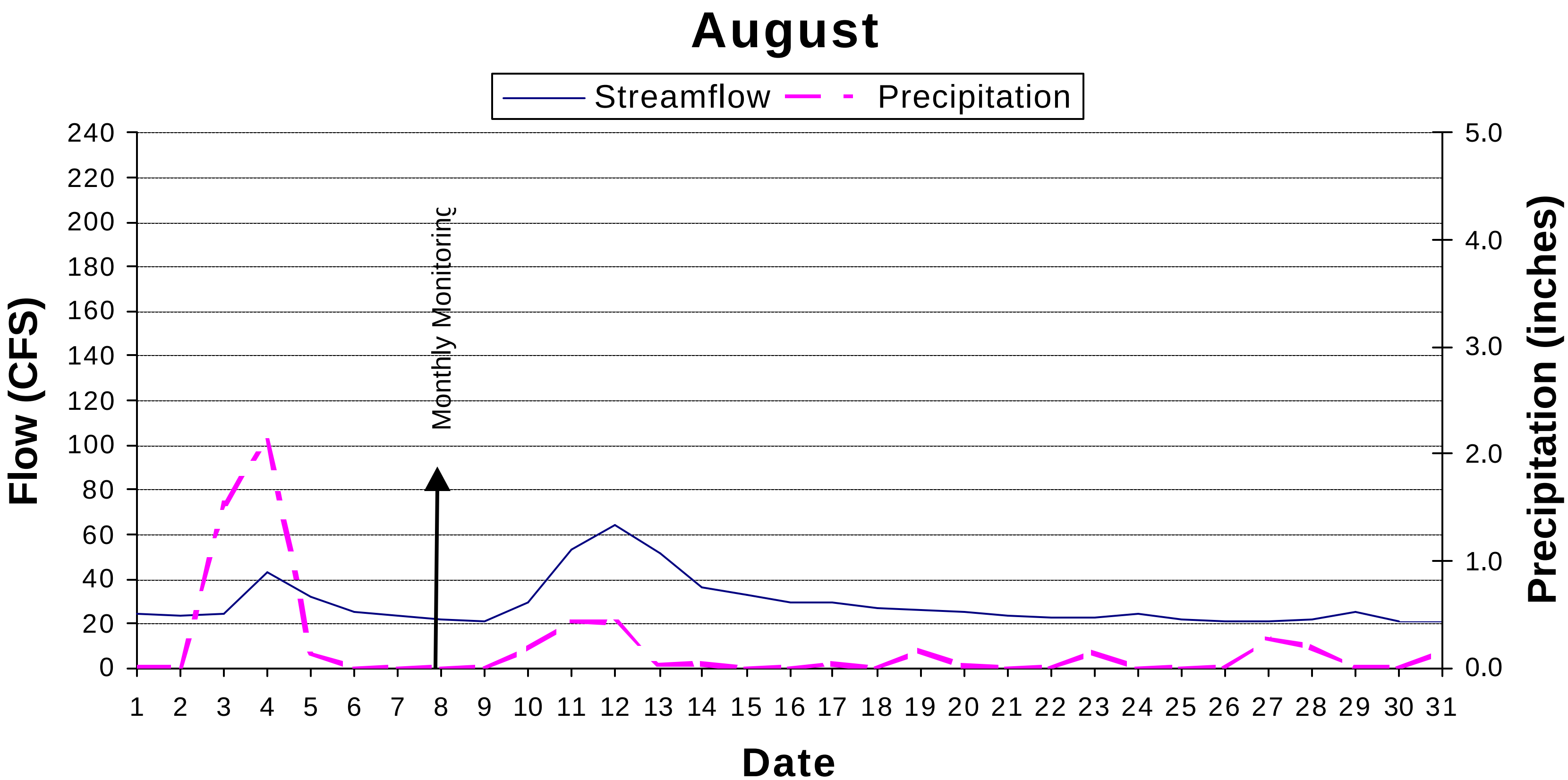

Figure 2-6. August streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

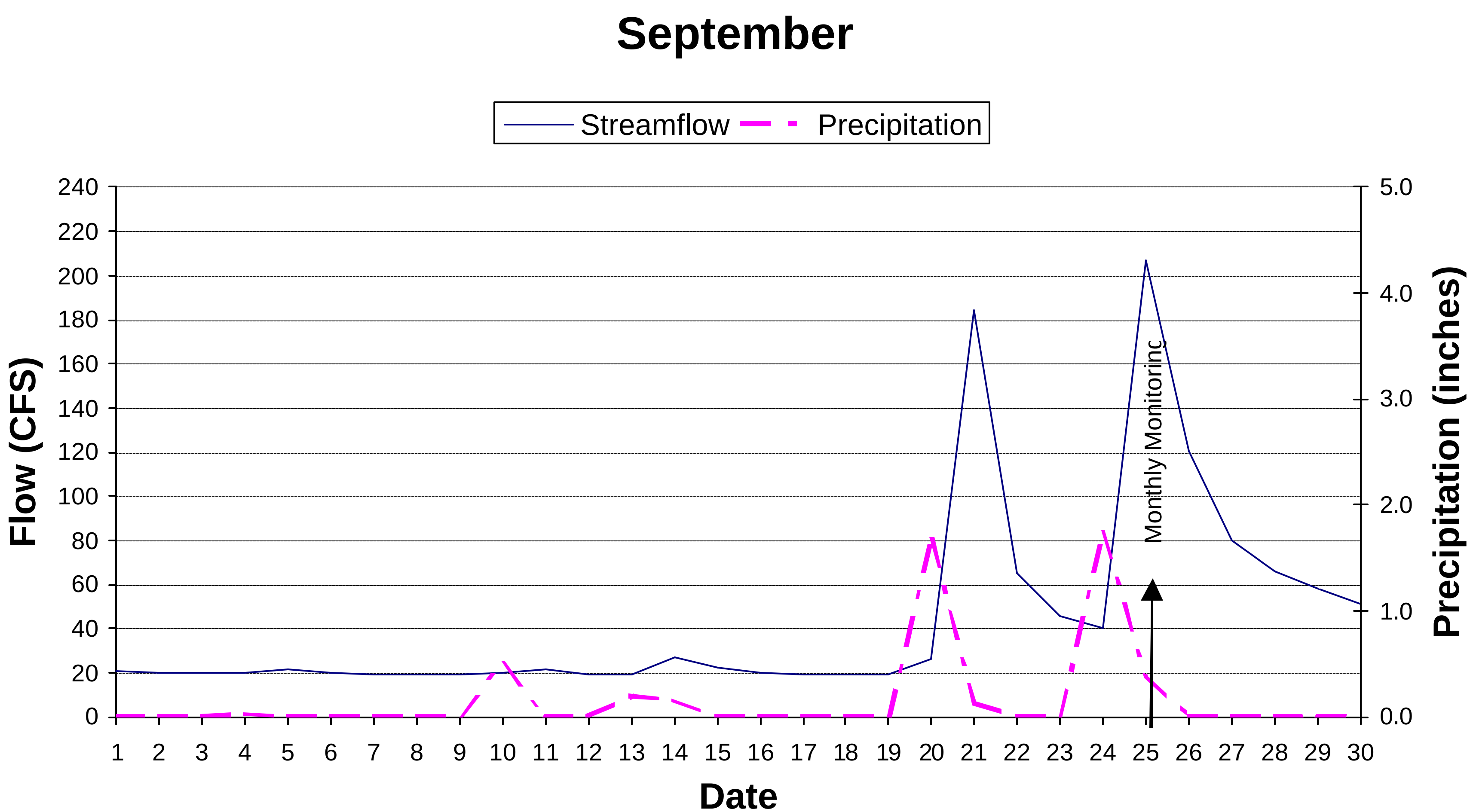

Figure 2-7. September streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

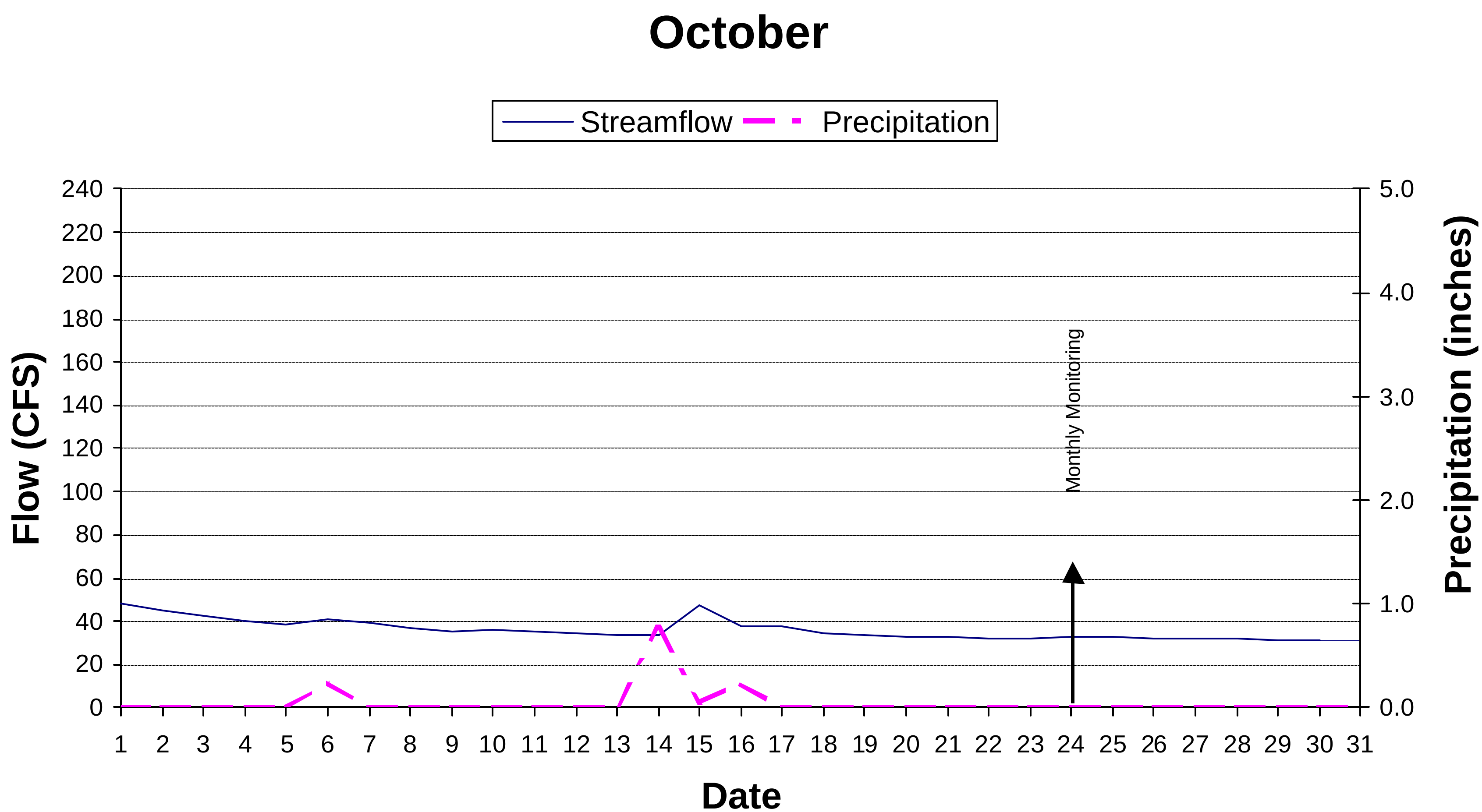

Figure 2-8. October streamflow and precipitation in the vicinity of Beltzville Reservoir during 2001

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 Tim 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

3.0 RESULTS AND DISCUSSION

3.1 STRATIFICATION MONITORING

The following sections summarize the water quality monitoring results of the physical and chemical parameters: temperature, dissolved oxygen, pH, and conductivity. For each parameter, we describe seasonal and spatial patterns of surface water quality measured throughout the reservoir watershed, and seasonal and depth related patterns of the stratified water column based on measures from the deepest portion of the reservoir (station BZ-6 or the "Tower"). We feel that it is appropriate to focus discussion of stratification at this station as water quality problems related to depth are generally most severe in deeper water habitats, thus our evaluation will be a conservative one. Finally, we analyze 2001 data along with the Beltzville Reservoir historical database for trends in dissolved oxygen concentrations over the past two decades. Versar personnel collected the physical and chemical water quality data discussed herein over the monitoring period from April to October 2001. All of the parameters were measured with a calibrated Hydrolab water quality meter and are presented in Appendix Table A.

3.1.1 Temperature

Temperatures of surface water generally followed a similar pattern throughout the watershed of Beltzville Reservoir during 2001, however consistent differences were apparent between reservoir-body and upstream and downstream waters (Fig. 3-1). Stations located in the reservoir-body (BZ-3, -6, and -7) averaged 20 ?C throughout the monitoring period. Temperatures downstream of the reservoir (BZ-1) and at the upstream stations (BZ-2, -4, -5) were similar but averaged 6 ?C cooler than the reservoir.

Beltzville Reservoir was stratified with respect to temperature in 2001 (Fig. 3-2). In April stratification was already apparent with surface temperatures (10 ?C) approximately 4 ?C warmer than the lower water column (6 ?C). This difference was also observed in May, however the upper water column from the surface to about 50 feet had warmed to about 15 ?C. Throughout June and into September, the temperature pattern was very consistent with temperature at the surface averaging 22 ?C and decreasing to 6 ?C near the bottom.

3.1.2 Dissolved Oxygen

Dissolved oxygen (DO) in the surface water generally followed a similar pattern throughout the watershed of Beltzville Reservoir during 2001, however consistent differences were apparent between reservoir-body and upstream and downstream waters (Fig. 3-3). Stations located in the reservoir-body (BZ-3, -6, and –7) averaged 8 mg/L throughout the monitoring period. Dissolved Oxygen concentrations downstream of the reservoir

Temperature - Surface Water

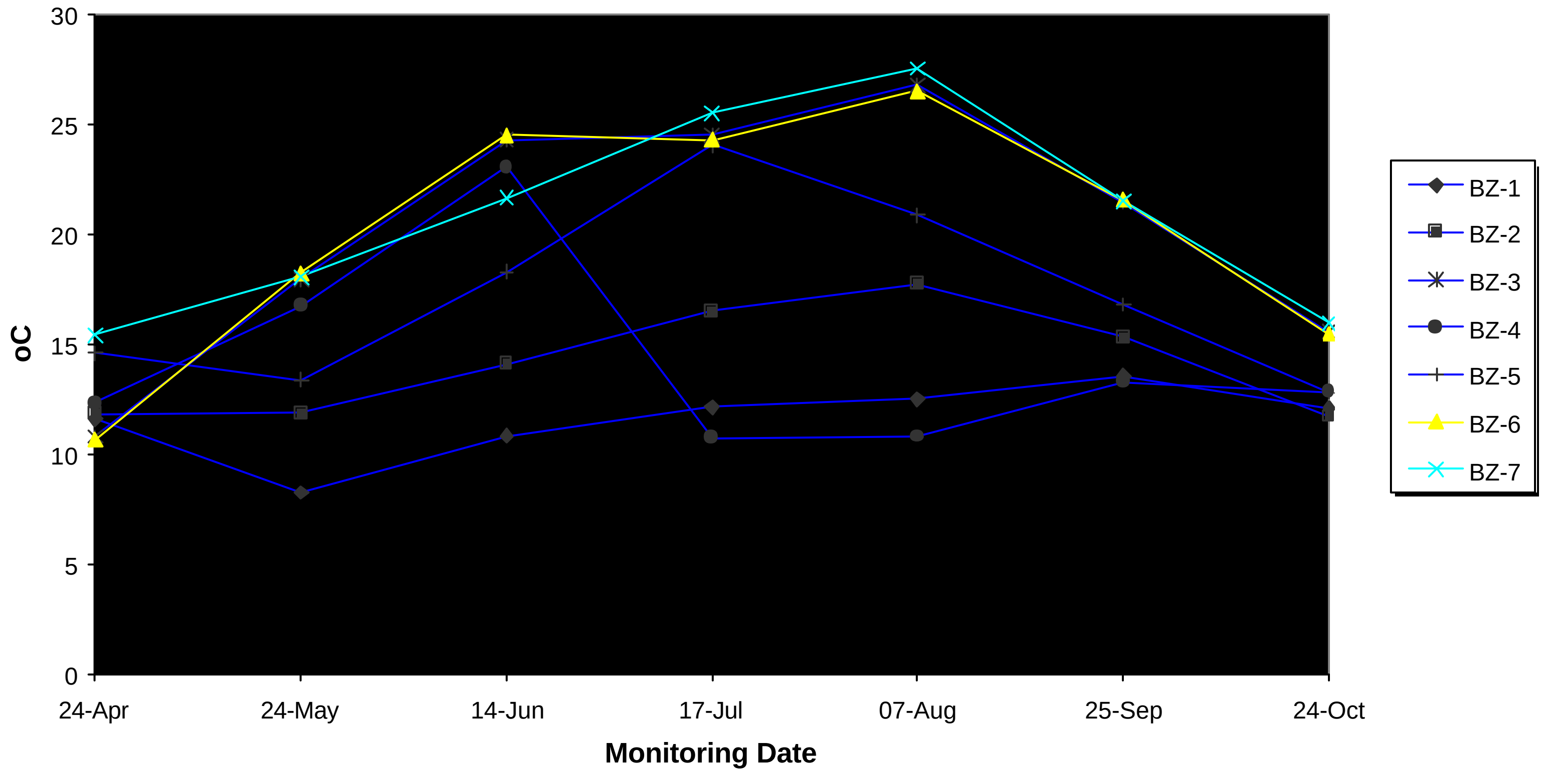

Figure 3-1. Surface water temperature (°C) measured at Beltzville Reservoir in 2001. See Appendix A for Summary of plotted values.

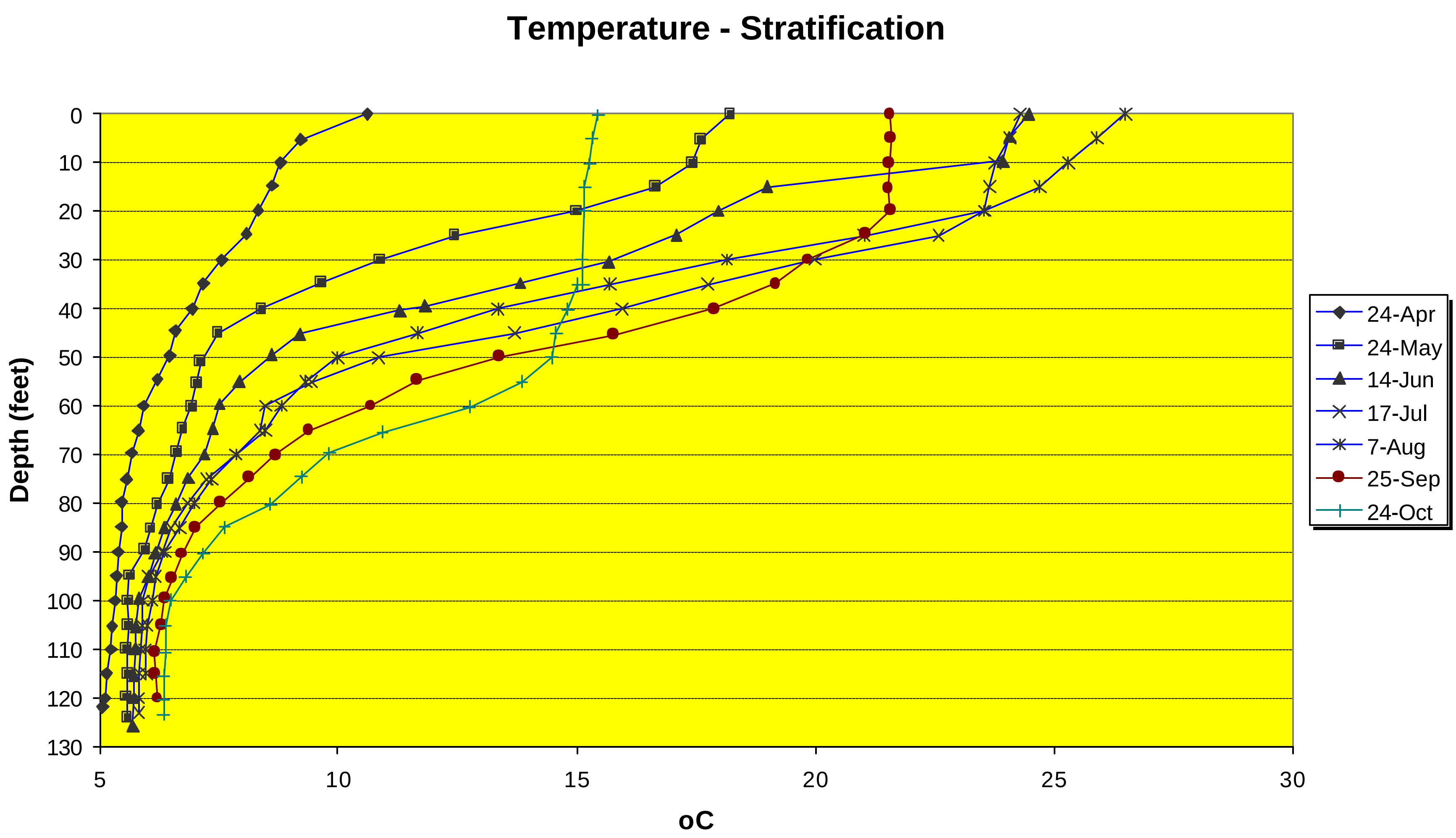

Figure 3-2. Temperature stratification at station BZ-6 of Beltzville Reservoir in 2001. See Appendix A for summary of plotted values.

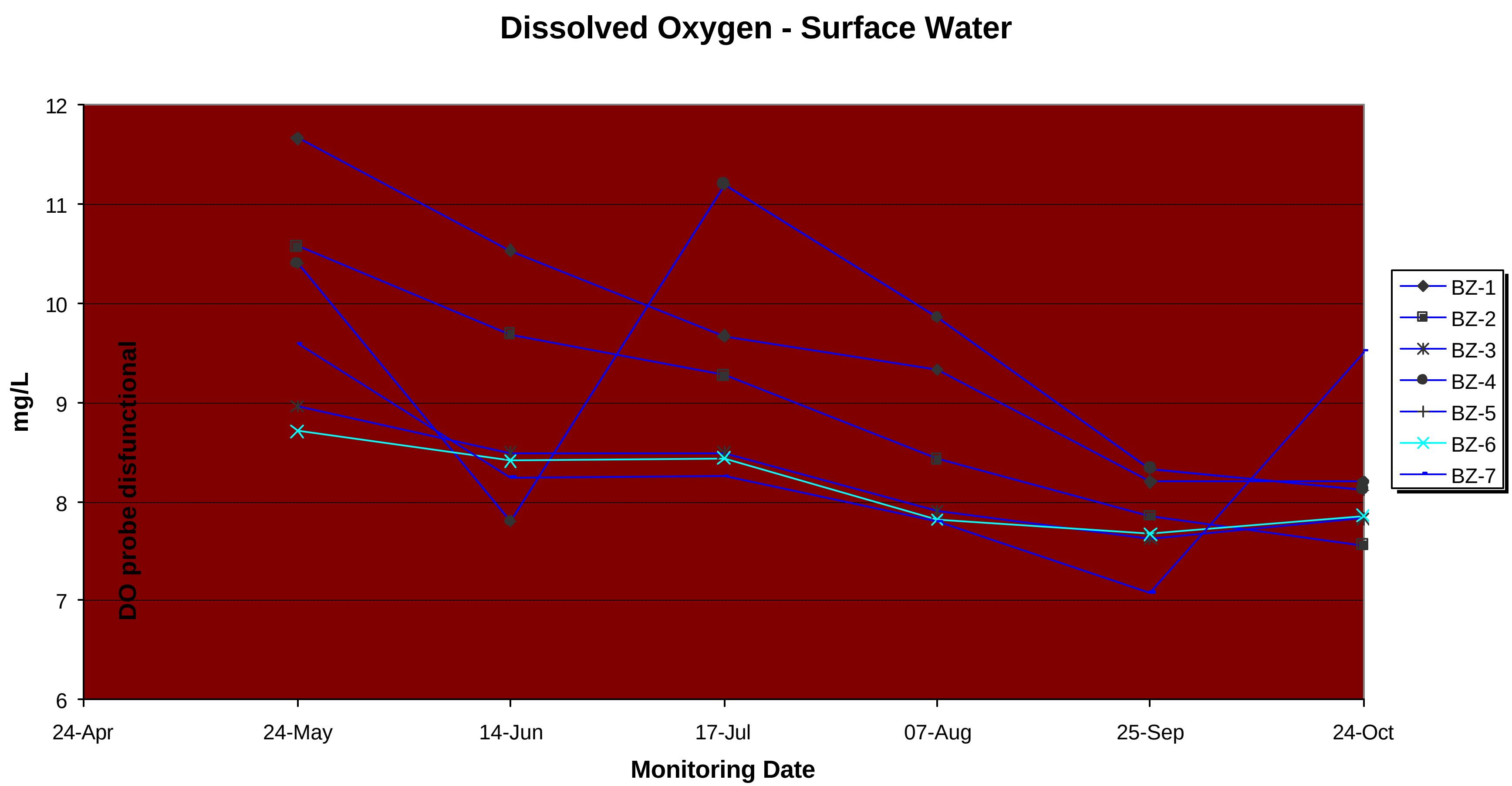

Figure 3-3. Dissolved oxygen concentrations measured in surface waters at Beltzville Reservoir in 2001. (The PADEP water quality standard for dissolved oxygen is a minimum concentration of 5 mg/L.) See Appendix A for summary of plotted values.

(BZ-1) and at the upstream stations (BZ-2, -4, -5) were consistently higher and averaged 9-mg/L.

DO in the water column of Beltzville Reservoir was stratified during September and October (Fig. 3-4). However, in most months DO concentrations were high throughout the water column. In September and October, DO concentrations were severely depleted throughout most of the water column. In these months, DO was less than 5-mg/L from 45-ft to the bottom, while concentrations nearer the surface were closer to 8-mg/L. Also during these months, DO exhibited a sinuous pattern with concentrations decreasing rapidly from the surface to approximately 50 feet, increasing to a depth of 90 feet, and decreasing again thereafter to the bottom. This pattern has been observed in previous years and may be due to a lens of oxygenated water passing through the reservoir from upstream sources or a result of portal operations at the reservoir tower.

DO concentrations in the water column of Beltzville Reservoir at times were not in compliance with PADEP water quality standards during 2001. The state water quality standard for DO is a minimum concentration of 5-mg/L. As stated above, concentrations falling below the standard were encountered during the September and October. In addition, the concentrations of DO fell to 4.6-mg/L during August (Fig 3-4). DO concentrations measured in all surface waters of the reservoir and upstream and downstream were in compliance with the standard.

The health of aquatic ecosystems is impaired by low DO concentrations in the water column. Hypoxia, or conditions of DO less than 2 mg/L, is generally accepted as the threshold at which the most severe effects on biota occur. In 2001, the deeper water column of Beltzville was affected by hypoxia (Fig. 3-5). Hypoxic water was encountered in September and October and occupied the lower two-thirds of the water column from around 45-ft to the bottom. Hypoxia in the lower water column is a symptom of eutrophication. Nutrients in the water column feed accelerating algal growth at the surface photic zone. Dead and decaying algae sink to lower levels of the water column and during the process of decay; oxygen is depleted from the water column. This phenomenon is not uncommon for lake systems.

Since 1988, DO concentrations have been measured in the water column at station BZ-6 near the “Tower”. Station BZ-6 is located in the deepest part of the reservoir (120-ft) at which DO has been measured at 5-foot intervals from the surface to the bottom. We analyzed this historical data along with this year’s data to determine if the depth at which hypoxia was initially encountered in the water column had significantly changed over the past 14 years. The trend analysis was conducted for the summer season (July to September) only as hypoxia was rarely observed in the spring (April to June). From the regression analysis, the level of hypoxia has not changed significantly ($P > 0.05$; $R^2 = 0.00003$) over the past 14 years (Fig. 3-6). In most years, the average depth at which hypoxia occurred was between 70 and 90 feet. In 2001, this average depth at which hypoxia occurred was 80 feet.

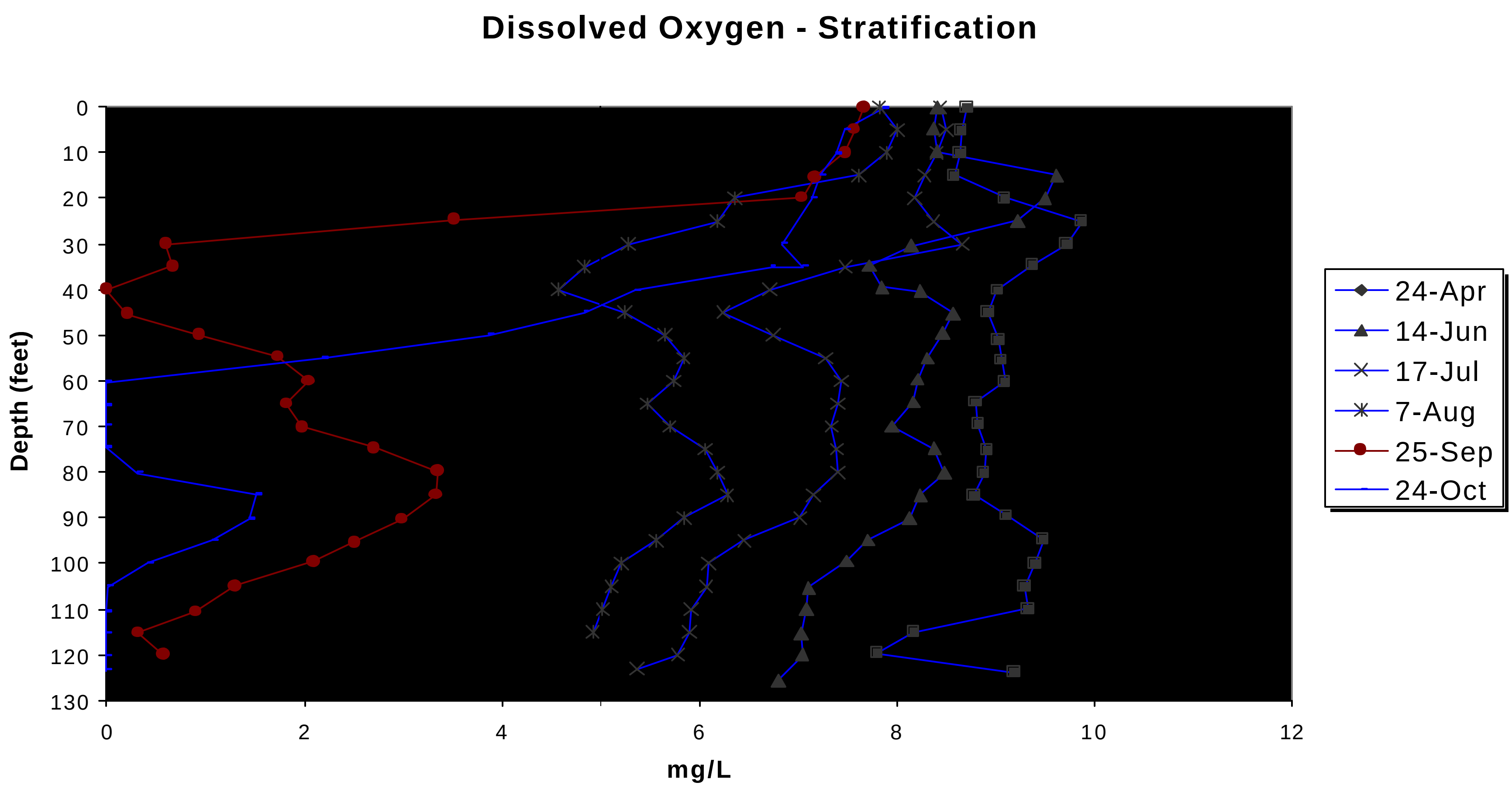

Figure 3-4. Dissolved oxygen stratification at station BZ-6 of Beltzville Reservoir in 2001. (The PADEP water quality standard for DO is a minimum concentration of 5 mg/L.) See Appendix A for summary of plotted values.

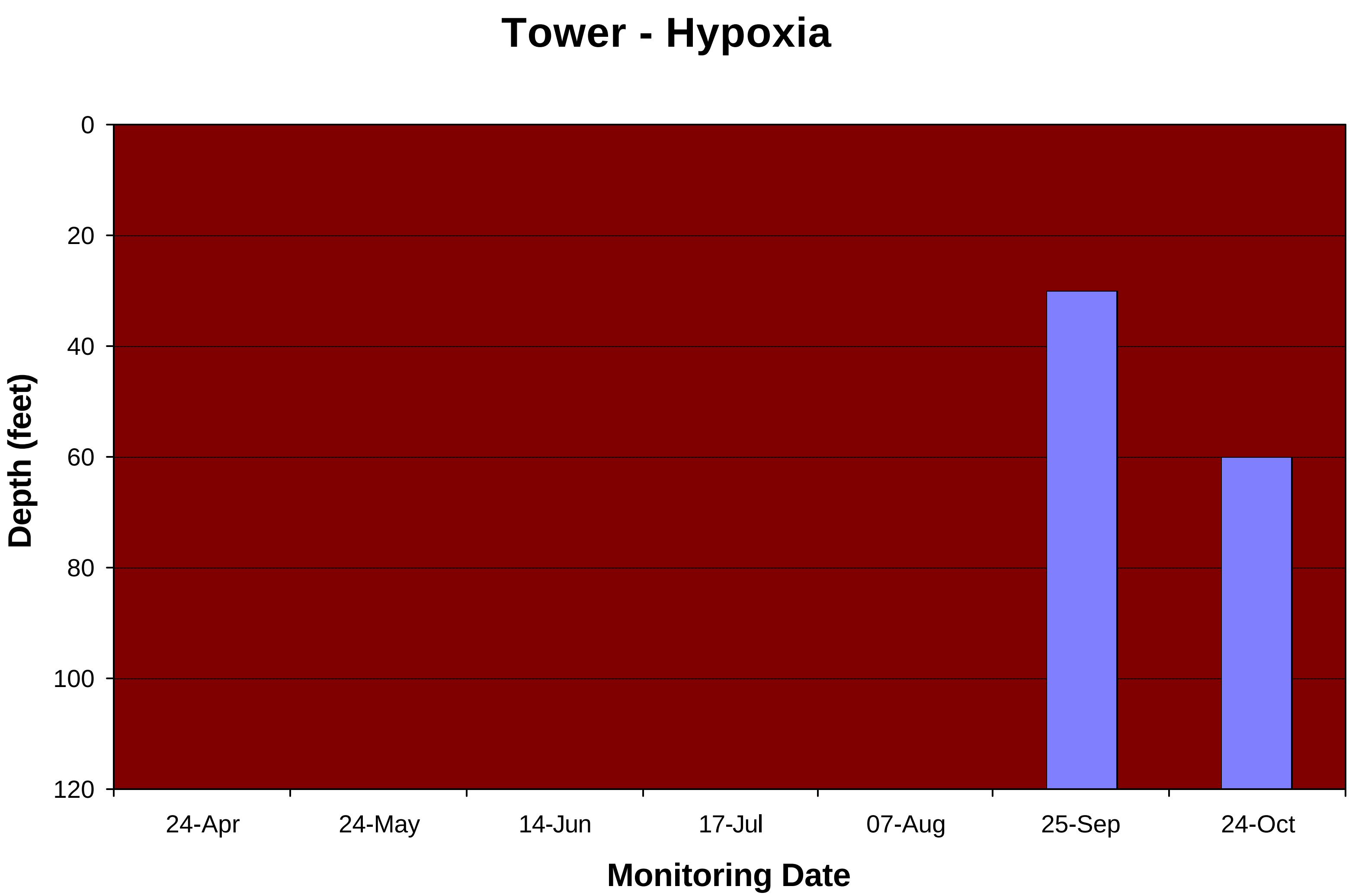

Figure 3-5. Spatial/temporal distribution of hypoxic reservoir water in Beltzville Reservoir measured at the “Tower” station in 2001. Histograms indicate dissolved oxygen concentrations in the water column below 2.0 mg/L.

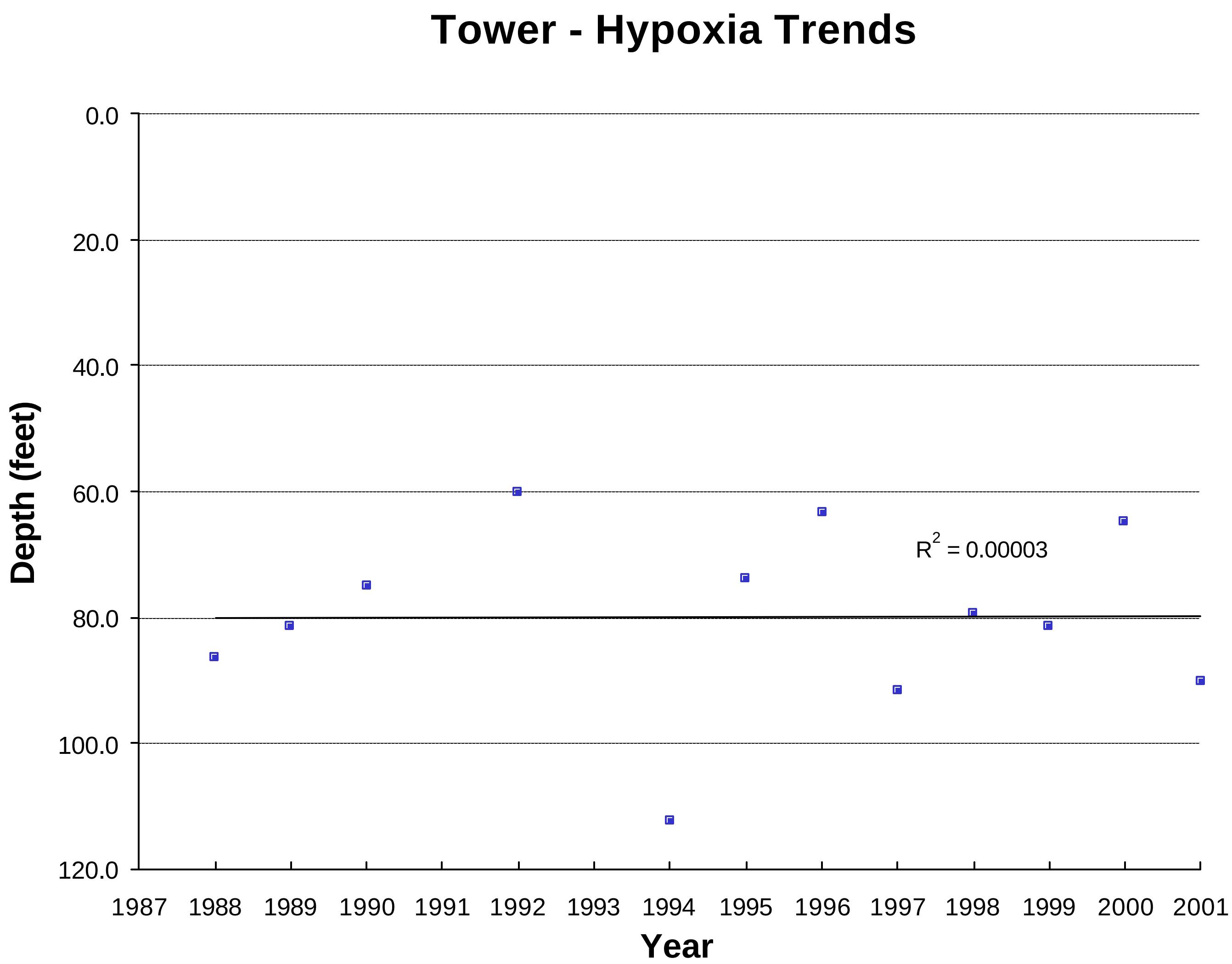

Figure 3-6. Trends in seasonal average hypoxia at the “Tower” station BZ-6. Measured as the depth at which hypoxia was observed in the water column.

In addition to the regression analysis, we also used the Mann-Kendall test to determine if DO concentrations had changed significantly at individual monitoring stations over the past 20 years or more. As before, the trend analysis was conducted separately for spring (April to June) and summer (July to September) seasons. Surface water concentrations were analyzed at upstream station BZ-5 and downstream station BZ-1. Surface and bottom water concentrations were averaged at the reservoir-body station BZ-3. Dissolved oxygen in surface waters of Beltzville Reservoir does not appear to have changed in concentration over the past two decades. However, a significant decreasing trend was determined from the analysis at station BZ-3 for the summer. The rate of decrease was 0.12 mg/L/year (Table 3-1).

Table 3-1. Spring and summer season trends of dissolved oxygen concentration at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic.

Station	# of Years spring/summer	Spring		Summer	
		P Level	Rate (mg/L/year)	P Level	Rate (mg/L/year)
Surface Water					
BZ-1	23	NS	0.02	NS	-0.02
BZ-2	21	NS	0.03	NS	0.01
BZ-3	25	NS	-0.02	<0.05	-0.12
BZ-4	23	NS	0.01	NS	0.01
BZ-5	24/25	NS	0.02	NS	0.01
BZ-6	6	NS	-0.24	NS	0.22
BZ-7	6	NS	-0.12	NS	0.17

3.1.3 pH

The concentrations of pH in surface water followed a similar pattern at Beltzville Reservoir during 2001 (Fig. 3-7). Throughout the reservoir and upstream and downstream stations the pH among stations remained consistent among stations. The overall average pH throughout the monitoring period was 7.1, with a maximum average of 7.3 at station BZ-7.

In 2001, pH in the water column of Beltzville Reservoir was broadly effected by stratification (Fig. 3-8). In general, the stratification pattern was marked by a rapidly decreasing pH from the surface to about 30 feet and thereafter remaining relatively consistent to the bottom. In April, pH at the surface was 7.2 while the lower water column was about 6.9. In early August, pH of the entire water column was lowest and ranged from 7.5 at the surface to about 5.6 in the lower water column.

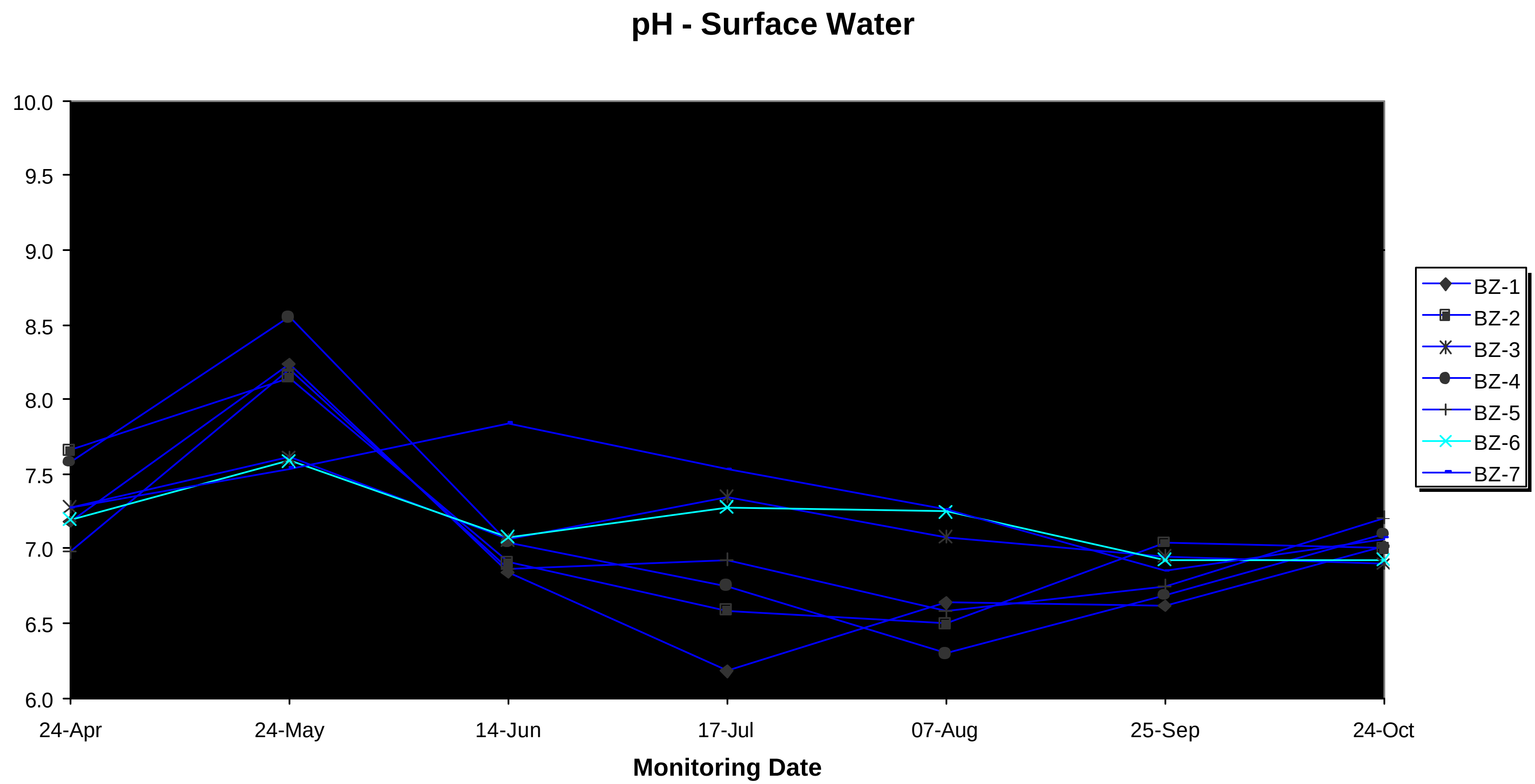

Figure 3-7. Surface water pH measured at Beltzville Reservoir in 2001. (The PADEP water quality standard for pH is from 6 to 9.) See Appendix A for summary of plotted values.

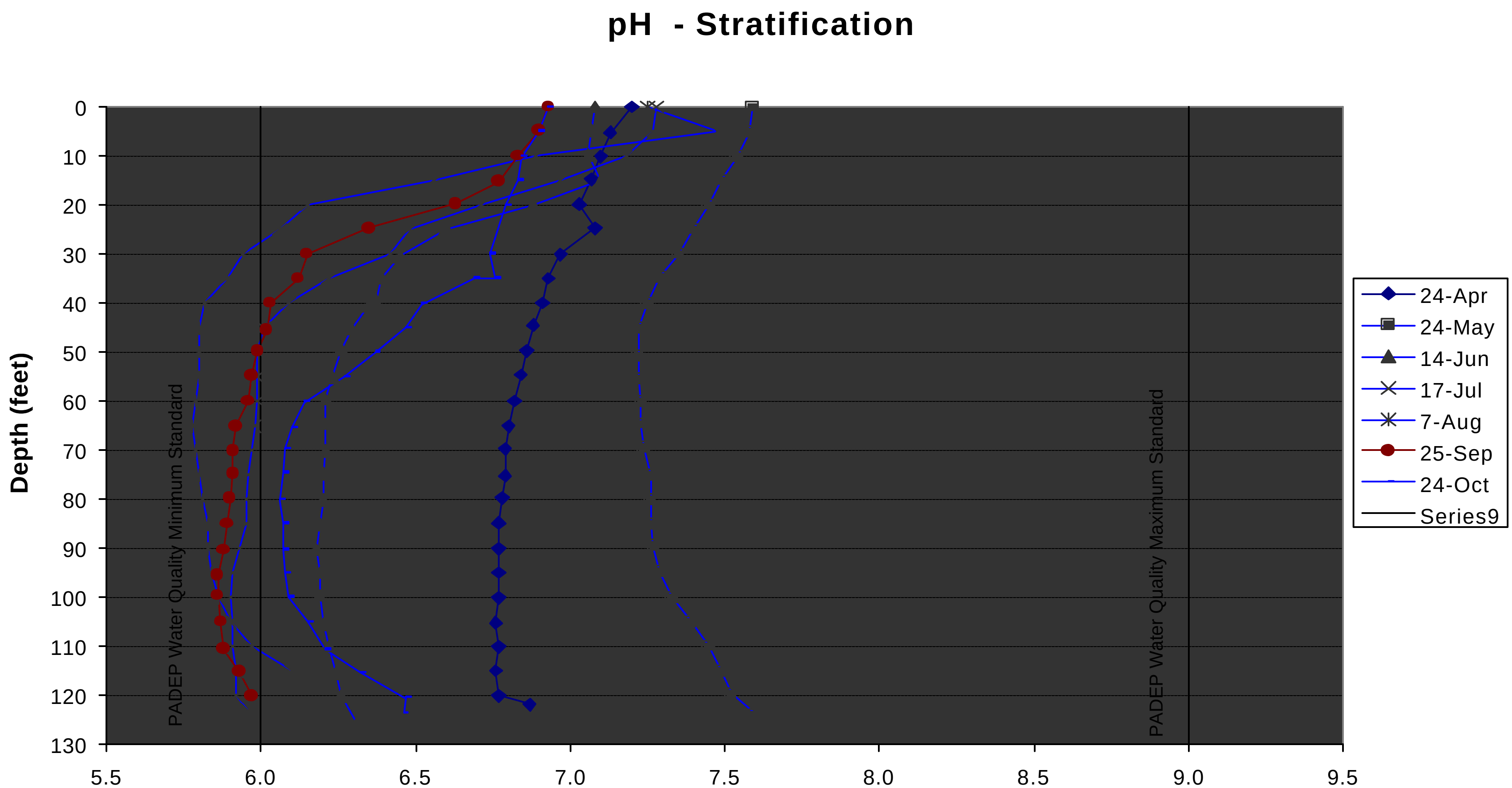

Figure 3-8. pH stratification at station BZ-6 of Beltzville Reservoir in 2001. (The PADEP water quality standard for pH is from 6 to 9.) See Appendix A for summary of plotted values.

The pH measures in the lower water column of Beltzville Reservoir were not in compliance with PADEP water quality standards from July to September. The standard for pH is a range of acceptable measures between 6 and 9. In July, August, and September, pH at station BZ-6 were below the minimum value of the standard. In those months, the average pH at station BZ-6 below 30 feet was 5.9. Additionally, the average pH at station BZ-7 below 25 feet in August was 5.9.

3.1.4 Conductivity

Conductivity measured in the surface waters of Beltzville Reservoir was generally consistent during 2001. Measures in the reservoir-body (stations BZ-3, BZ-6, and BZ-7), downstream of the reservoir (BZ-1), and upstream stations (BZ-2 and BZ-5) were most similar and averaged about 0.08-mS/cm throughout the monitoring period (Fig. 3-9). Conductivity measured at Wild Creek (BZ-4) was consistently the lowest, averaging 0.04-mS/cm and ranged from 0.07-mS/cm in May to 0.09-mS/cm in September.

Conductivity throughout the water column of Beltzville Reservoir was also fairly consistent during 2001 (Fig. 3-10). In May, measures were most consistent at about 0.074-mS/cm from surface to bottom. In the later months of August, September, and October, measures were lower at the surface than the bottom and overall ranged from 0.070-mS/cm to 0.089-mS/cm. The increasing conductivity in the lower water column during the summer months is and indication of eutrophic influences. As oxygen is depleted in the lower water column, a chemically reducing environment is formed. In this state, metals are mobilized into the water column, which results in an increase in conductivity. Conversely, at the surface, biological activity in the photic zone during the summer months effectively reduces conductivity as metabolizing algae remove dissolved constituents.

3.2 WATER COLUMN CHEMISTRY MONITORING

The following sections describe temporal, spatial, and patterns relating to depth for the water quality parameters measured in surface, middle, and bottom waters of Beltzville Reservoir during 2001 (Table 3-2). Where appropriate, long-term trends are discussed for surface water quality parameters incorporating 2001 data with the Beltzville Reservoir historical water quality database.

3.2.1 Ammonia

Ammonia concentrations were generally low in Beltzville Reservoir during 2001 (Fig. 3-11). Concentrations at most stations and depths were near or less than the method detection limit of 0.1 mg/L. The highest concentrations of ammonia (0.3-mg/L) were measured in the surface water at station BZ-1 during April and the middle water at station BZ-6 during August. Elevated ammonia in the lower water column of deep, stratified lakes and

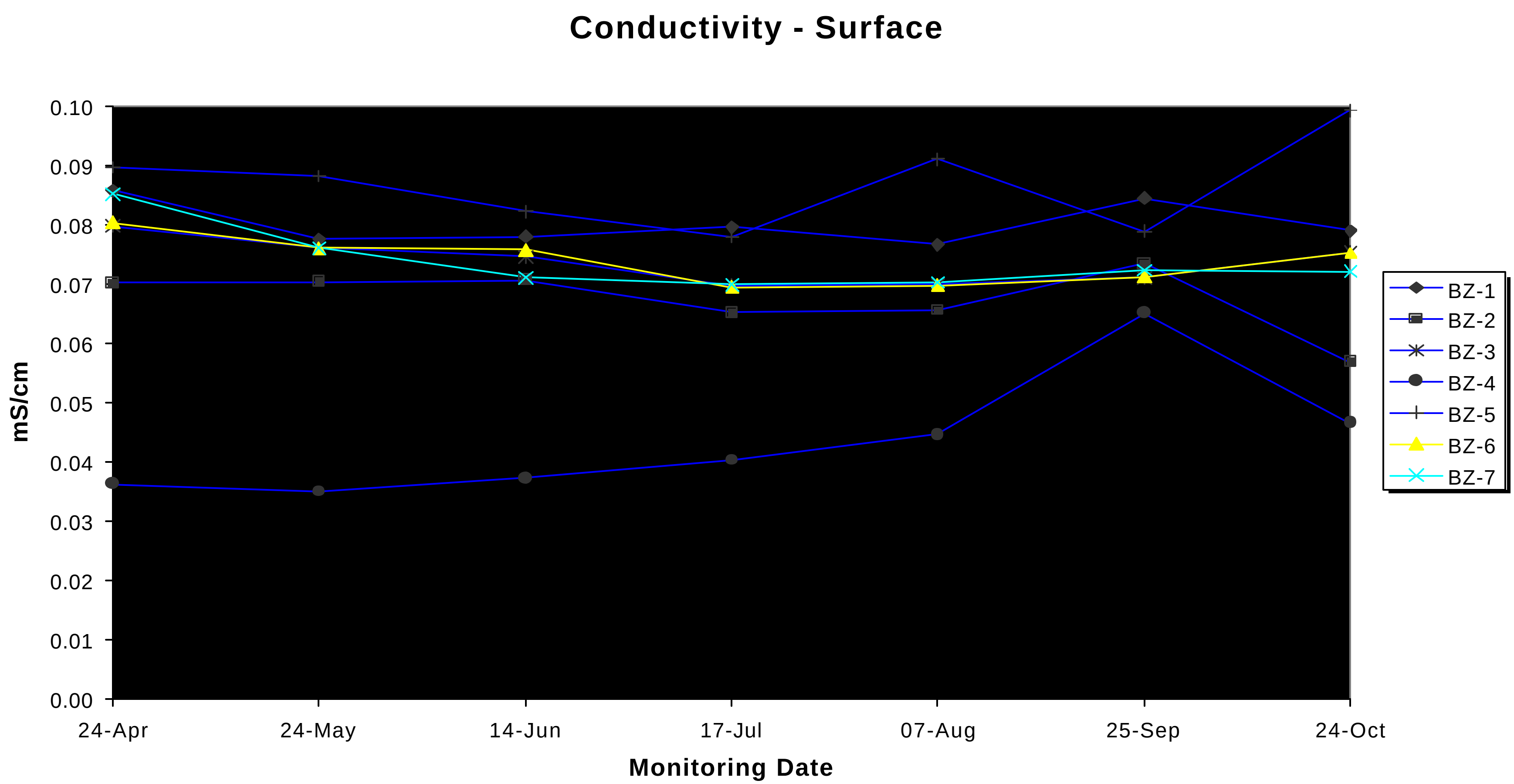

Figure 3-9. Surface water conductivity (mS/cm) measured at Beltzville Reservoir in 2001. See Appendix A for summary of plotted values.

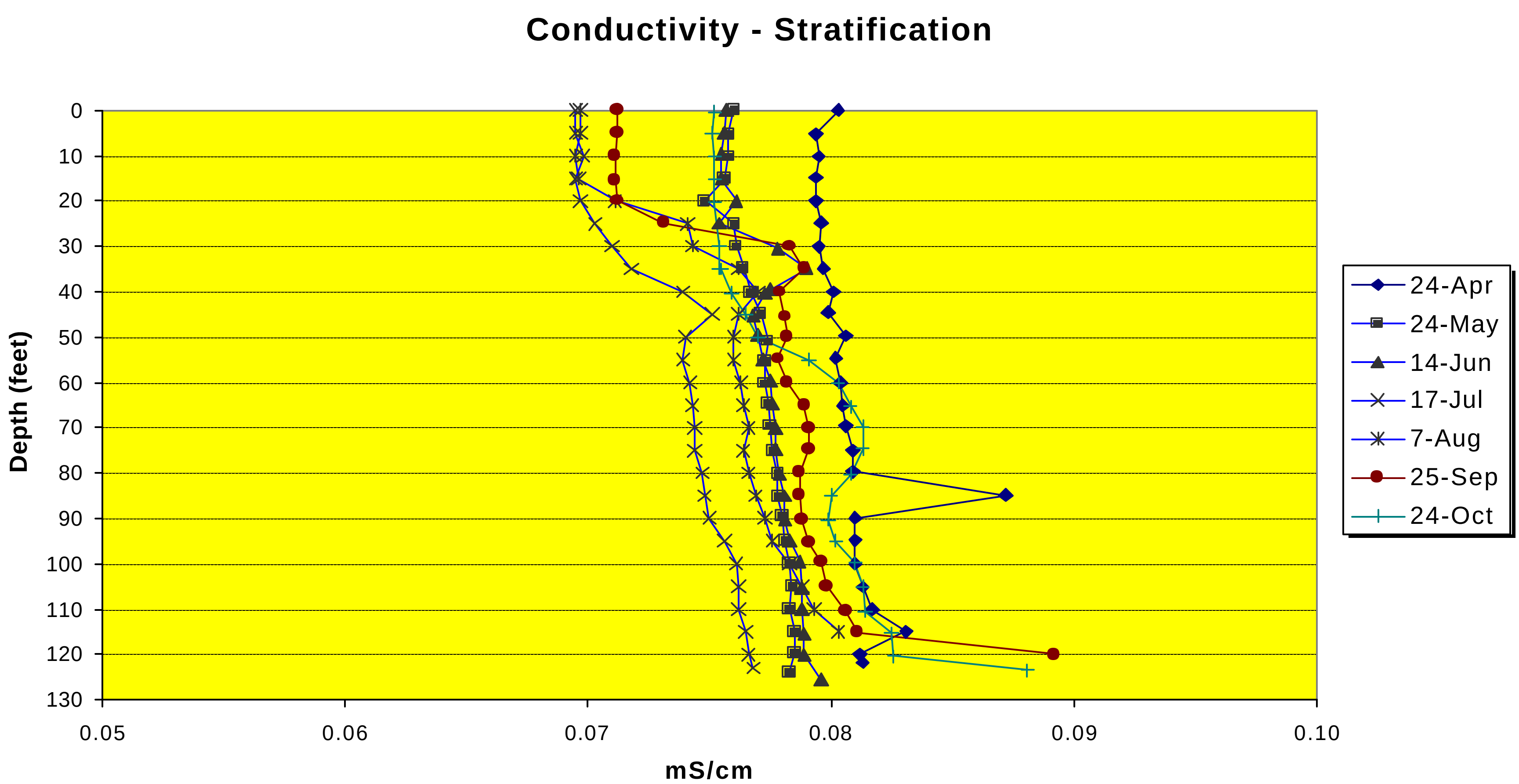

Figure 3-10. Conductivity stratification at station BZ-6 of Beltzville Reservoir in 2001. See Appendix A for summary of plotted values.

Table 3-2. Summary of surface, middle, and bottom water quality monitoring data for Beltzville Reservoir in 2001

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	CHL_A
BZ-1S	24-Apr	0.30	< 0.005	0.100	< 0.05	0.30	< 0.05	28	8.0	< 3.0	10.0	2.3
	24-May	< 0.10	< 0.005	0.700	< 0.05	< 0.10	< 0.05	96	2.0	< 3.0	8.0	1.5
	14-Jun	< 0.10	< 0.005	< 0.100	< 0.05	4.30	< 0.05	82	6.0	< 2.0	10.0	4.8
	17-Jul	< 0.10	0.008	0.400	< 0.05	0.23	< 0.05	80	2.0	< 1.0	10.0	3.2
	07-Aug	< 0.10	< 0.100	0.700	< 0.05	0.42	< 0.05	38	1.0	< 2.0	14.0	1.7
	25-Sep	< 0.10	< 0.100	0.500	< 0.05	< 0.20	< 0.05	105	4.0	2.0	16.0	0.9
	24-Oct	< 0.10	< 0.500	< 0.500	0.16	< 1.00	0.07	64	< 1.0	< 2.0	10.0	2.6
Mean		0.13	0.103	0.429	0.07	0.94	0.05	70	3.4	2.1	11.1	2.4
Maximum		0.30	0.500	0.700	0.16	4.30	0.07	105	8.0	3.0	16.0	4.8
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	28	1.0	1.0	8.0	0.9
Std. Dev		0.08	0.180	0.250	0.04	1.51	0.01	29	2.7	0.7	2.8	1.3
No. of D		1	1	5	1	4	1	7	6	1	7	7
BZ-2S	24-Apr	0.20	< 0.005	< 0.100	< 0.05	0.10	< 0.05	< 10	14.0	< 3.0	6.0	0.6
	24-May	0.10	< 0.005	0.400	< 0.05	< 0.10	< 0.05	72	< 1.0	< 3.0	6.0	0.2
	14-Jun	< 0.10	< 0.005	< 0.100	< 0.05	5.40	< 0.05	58	9.0	< 2.0	8.0	2.1
	17-Jul	0.10	< 0.005	0.300	< 0.05	0.45	< 0.05	84	3.0	< 1.0	10.0	0.2
	07-Aug	< 0.10	< 0.100	0.300	1.20	0.74	< 0.05	28	6.0	< 2.0	10.0	0.3
	25-Sep	0.10	< 0.100	0.200	0.07	< 0.20	< 0.05	66	4.0	1.0	10.0	0.8
	24-Oct	< 0.10	< 0.500	< 0.500	0.07	< 1.00	< 0.05	56	< 1.0	< 2.0	10.0	0.1
Mean		0.11	0.103	0.271	0.22	1.14	0.05	53	5.4	2.0	8.6	0.6
Maximum		0.20	0.500	0.500	1.20	5.40	0.05	84	14.0	3.0	10.0	2.1
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	10	1.0	1.0	6.0	0.1
Std. Dev		0.04	0.181	0.150	0.43	1.91	0.00	26	4.7	0.8	1.9	0.7
No. of D		4	0	4	3	4	0	6	5	1	7	7
BZ-3S	24-Apr	0.10	< 0.005	0.100	< 0.05	0.20	< 0.05	18	7.0	< 3.0	8.0	2.9
	24-May	0.10	0.005	0.600	< 0.05	< 0.10	< 0.05	70	3.0	< 3.0	6.0	1.1
	14-Jun	< 0.10	0.006	< 0.100	< 0.05	5.70	< 0.05	72	5.0	< 2.0	9.0	2.4
	17-Jul	< 0.10	< 0.005	0.400	< 0.05	0.58	< 0.05	92	9.0	< 1.0	11.0	3.2
	07-Aug	< 0.10	< 0.100	0.400	< 0.05	1.18	< 0.05	16	7.0	< 2.0	11.0	4.2
	25-Sep	< 0.10	< 0.100	0.200	< 0.05	< 0.20	< 0.05	52	1.0	3.0	12.0	12.3
	24-Oct	< 0.10	< 0.500	< 0.500	0.06	< 1.00	< 0.05	80	< 1.0	< 2.0	12.0	3.0
Mean		0.10	0.103	0.329	0.05	1.28	0.05	57	4.7	2.3	9.9	4.2
Maximum		0.10	0.500	0.600	0.06	5.70	0.05	92	9.0	3.0	12.0	12.3
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	16	1.0	1.0	6.0	1.1
Std. Dev		0.00	0.181	0.198	0.00	1.99	0.00	30	3.1	0.8	2.3	3.7
No. of D		2	2	5	1	4	0	7	6	1	7	7

Table 3-2. (Continued)												
STATION	**DATE**	**NH3**	**NO2**	**NO3**	**PO4**	**TKN**	**TP**	**TDS**	**TSS**	**BOD5**	**ALK**	**CHL_A**
BZ-3M	24-Apr	< 0.10	< 0.005	0.100	< 0.05	0.40	< 0.05	< 10	3.0	< 3.0	8.0	2.7
	24-May	< 0.10	< 0.005	0.600	< 0.05	< 0.10	< 0.05	76	7.0	< 3.0	6.0	1.0
	14-Jun	< 0.10	0.005	< 0.100	< 0.05	3.40	< 0.05	74	5.0	< 2.0	9.0	8.5
	17-Jul	< 0.10	0.005	0.500	< 0.05	0.53	< 0.05	104	5.0	< 1.0	12.0	1.2
	07-Aug	< 0.10	< 0.100	0.700	< 0.05	0.53	< 0.05	34	< 1.0	< 2.0	10.0	1.4
	25-Sep	< 0.10	< 0.100	0.500	0.06	< 0.20	< 0.05	61	4.0	1.0	12.0	0.8
	24-Oct	< 0.10	< 0.500	< 0.500	0.08	< 1.00	< 0.05	84	< 1.0	< 2.0	16.0	2.1
Mean		0.10	0.103	0.429	0.06	0.88	0.05	63	3.7	2.0	10.4	2.5
Maximum		0.10	0.500	0.700	0.08	3.40	0.05	104	7.0	3.0	16.0	8.5
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	10	1.0	1.0	6.0	0.8
Std. Dev		0.00	0.181	0.236	0.01	1.15	0.00	32	2.2	0.8	3.3	2.7
No. of D		0	2	5	2	4	0	6	5	1	7	7
BZ-3B	24-Apr	0.10	< 0.005	0.100	< 0.05	0.20	< 0.05	< 10	8.0	< 3.0	9.0	1.6
	24-May	< 0.10	0.005	0.600	< 0.05	< 0.10	< 0.05	76	8.0	< 3.0	12.0	0.5
	14-Jun	< 0.10	0.005	< 0.100	< 0.05	1.90	< 0.05	74	11.0	< 2.0	9.0	0.9
	17-Jul	< 0.10	0.008	0.300	< 0.05	0.37	< 0.05	90	8.0	< 1.0	11.0	0.8
	07-Aug	< 0.10	< 0.100	0.700	< 0.05	0.36	< 0.05	42	4.0	< 2.0	12.0	0.8
	25-Sep	< 0.10	< 0.100	0.500	0.05	< 0.20	< 0.05	65	11.0	1.0	14.0	0.8
	24-Oct	< 0.10	< 0.500	< 0.500	0.07	< 1.00	< 0.05	70	36.0	< 2.0	12.0	0.8
Mean		0.10	0.103	0.400	0.05	0.59	0.05	61	12.3	2.0	11.3	0.9
Maximum		0.10	0.500	0.700	0.07	1.90	0.05	90	36.0	3.0	14.0	1.6
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	10	4.0	1.0	9.0	0.5
Std. Dev		0.00	0.180	0.238	0.01	0.65	0.00	27	10.7	0.8	1.8	0.3
No. of D		10	3	5	2	4	0	6	7	1	7	7
BZ-4S	24-Apr	0.10	< 0.005	< 0.100	< 0.05	0.40	< 0.05	10	5.0	< 3.0	5.0	1.9
	24-May	< 0.10	< 0.005	0.300	< 0.05	0.10	< 0.05	54	4.0	< 3.0	10.0	11.7
	14-Jun	< 0.10	< 0.005	< 0.100	< 0.05	5.90	< 0.05	42	4.0	< 2.0	7.0	1.1
	17-Jul	< 0.10	0.005	0.400	< 0.05	0.43	< 0.05	80	1.0	< 2.0	8.0	0.8
	07-Aug	< 0.10	< 0.100	0.200	< 0.05	0.38	< 0.05	40	9.0	6.0	10.0	1.3
	25-Sep	< 0.10	< 0.100	0.500	< 0.05	< 0.20	< 0.05	52	7.0	5.0	18.0	0.7
	24-Oct	< 0.10	< 0.500	< 0.500	0.07	< 1.00	< 0.05	72	< 1.0	< 2.0	10.0	0.9
Mean		0.10	0.103	0.300	0.05	1.20	0.05	50	4.4	3.3	9.7	2.6
Maximum		0.10	0.500	0.500	0.07	5.90	0.05	80	9.0	6.0	18.0	11.7
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	10	1.0	2.0	5.0	0.7
Std. Dev		0.00	0.181	0.173	0.01	2.09	0.00	23	2.9	1.6	4.1	4.0
No. of D		1	1	4	1	5	0	7	6	2	7	7

Table 3-2. (Continued)												
STATION	**DATE**	**NH3**	**NO2**	**NO3**	**PO4**	**TKN**	**TP**	**TDS**	**TSS**	**BOD5**	**ALK**	**CHL_A**
BZ-5S	24-Apr	< 0.10	< 0.005	0.200	0.06	0.20	< 0.05	82	10.0	< 3.0	11.0	2.0
	24-May	0.10	0.025	1.000	< 0.05	< 0.10	< 0.05	82	6.0	< 3.0	10.0	1.2
	14-Jun	0.10	0.007	0.100	< 0.05	2.90	< 0.05	72	13.0	< 2.0	6.0	1.1
	17-Jul	< 0.10	0.011	0.500	0.11	0.40	< 0.05	86	6.0	< 2.0	13.0	14.8
	07-Aug	< 0.10	< 0.100	1.200	0.07	0.40	< 0.05	44	< 1.0	< 2.0	13.0	1.0
	25-Sep	< 0.10	< 0.100	0.800	0.28	< 0.20	0.10	89	73.0	1.0	20.0	3.1
	24-Oct	< 0.10	< 0.500	0.800	0.07	< 1.00	< 0.05	92	< 1.0	< 2.0	14.0	0.6
Mean		0.10	0.107	0.657	0.10	0.74	0.06	78	15.7	2.1	12.4	3.4
Maximum		0.10	0.500	1.200	0.28	2.90	0.10	92	73.0	3.0	20.0	14.8
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	44	1.0	1.0	6.0	0.6
Std. Dev		0.00	0.178	0.408	0.08	1.00	0.02	16	25.6	0.7	4.3	5.1
No. of D		2	3	7	5	4	1	7	5	1	7	7
BZ-6S	24-Apr	< 0.10	< 0.005	0.100	< 0.05	0.30	< 0.05	86	1.0	< 3.0	5.0	1.9
	24-May	< 0.10	0.006	0.600	< 0.05	< 0.10	< 0.05	90	6.0	< 3.0	12.0	2.0
	14-Jun	< 0.10	0.007	< 0.100	< 0.05	9.20	< 0.05	36	10.0	< 2.0	9.0	2.5
	17-Jul	< 0.10	0.006	0.400	< 0.05	0.43	< 0.05	92	1.0	< 2.0	10.0	5.4
	07-Aug	< 0.10	< 0.100	0.400	< 0.05	0.53	< 0.05	28	4.0	< 2.0	11.0	3.6
	25-Sep	< 0.10	< 0.100	0.200	< 0.05	< 0.20	< 0.05	53	2.0	< 1.0	10.0	8.8
	24-Oct	< 0.10	< 0.500	< 0.500	0.07	< 1.00	< 0.05	66	< 1.0	< 2.0	12.0	3.9
Mean		0.10	0.103	0.329	0.05	1.68	0.05	64	3.6	2.1	9.9	4.0
Maximum		0.10	0.500	0.600	0.07	9.20	0.05	92	10.0	3.0	12.0	8.8
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	28	1.0	1.0	5.0	1.9
Std. Dev		0.00	0.180	0.198	0.01	3.33	0.00	26	3.4	0.7	2.4	2.4
No. of D		0	3	5	1	4	0	7	6	0	7	7
BZ-6M	24-Apr	< 0.10	< 0.005	0.500	< 0.05	0.30	< 0.05	104	< 1.0	< 3.0	8.0	1.8
	24-May	< 0.10	< 0.005	0.700	< 0.05	< 0.10	< 0.05	92	3.0	< 3.0	10.0	0.8
	14-Jun	0.20	< 0.005	< 0.100	< 0.05	2.90	< 0.05	32	15.0	< 2.0	10.0	2.9
	17-Jul	< 0.10	0.008	0.600	< 0.05	0.34	< 0.05	110	6.0	< 2.0	10.0	2.0
	07-Aug	0.28	< 0.100	0.700	< 0.05	0.30	< 0.05	22	< 1.0	< 2.0	12.0	1.9
	25-Sep	< 0.10	< 0.100	0.600	< 0.05	< 0.20	< 0.05	51	3.0	< 1.0	12.0	9.2
	24-Oct	< 0.10	< 0.500	< 0.500	0.08	< 1.00	< 0.05	56	2.0	< 2.0	10.0	2.4
Mean		0.14	0.103	0.529	0.05	0.73	0.05	67	4.4	2.1	10.3	3.0
Maximum		0.28	0.500	0.700	0.08	2.90	0.05	110	15.0	3.0	12.0	9.2
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	22	1.0	1.0	8.0	0.8
Std. Dev		0.07	0.180	0.206	0.01	1.00	0.00	35	5.0	0.7	1.4	2.8
No. of D		2	1	5	1	4	0	7	5	0	7	7

Table 3-2. (Continued)

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	CHL_A
BZ-6B	24-Apr	< 0.10	< 0.005	0.200	< 0.05	0.30	< 0.05	80	3.0	< 3.0	10.0	1.3
	24-May	< 0.10	0.005	0.600	< 0.05	< 0.10	< 0.05	80	2.0	< 3.0	10.0	0.6
	14-Jun	0.10	< 0.005	< 0.100	< 0.05	4.10	< 0.05	44	20.0	< 2.0	9.0	1.1
	17-Jul	< 0.10	0.010	0.300	< 0.05	0.11	< 0.05	38	4.0	< 2.0	11.0	1.2
	07-Aug	0.12	< 0.100	0.700	0.06	0.28	< 0.05	22	1.0	< 2.0	12.0	1.0
	25-Sep	< 0.10	< 0.100	0.400	2.43	< 0.20	1.44	62	10.0	5.0	12.0	1.4
	24-Oct	< 0.10	< 0.500	< 0.500	0.07	< 1.00	< 0.05	78	< 1.0	< 2.0	12.0	0.5
Mean		0.10	0.104	0.400	0.39	0.87	0.25	58	5.9	2.7	10.9	1.0
Maximum		0.12	0.500	0.700	2.43	4.10	1.44	80	20.0	5.0	12.0	1.4
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	22	1.0	2.0	9.0	0.5
Std. Dev		0.01	0.180	0.216	0.90	1.46	0.53	23	7.0	1.1	1.2	0.3
No. of D		2	2	5	3	4	1	7	6	1	7	7
BZ-7S	24-Apr	< 0.10	< 0.005	0.100	0.06	0.20	< 0.05	74	8.0	< 3.0	5.0	1.4
	24-May	< 0.10	0.007	0.600	< 0.05	< 0.10	< 0.05	84	3.0	< 3.0	10.0	4.8
	14-Jun	0.20	0.006	< 0.100	< 0.05	5.00	< 0.05	40	8.0	< 2.0	9.0	3.3
	17-Jul	< 0.10	0.006	0.400	< 0.05	0.11	< 0.05	44	11.0	< 2.0	14.0	5.4
	07-Aug	< 0.10	< 0.100	0.300	0.05	0.41	< 0.05	18	12.0	< 2.0	14.0	5.6
	25-Sep	< 0.10	< 0.100	0.200	0.06	< 0.20	< 0.05	47	2.0	< 1.0	10.0	5.9
	24-Oct	< 0.10	< 0.500	< 0.500	0.06	< 1.00	< 0.05	46	< 1.0	< 2.0	10.0	4.0
Mean		0.11	0.103	0.314	0.05	1.00	0.05	50	6.4	2.1	10.3	4.3
Maximum		0.20	0.500	0.600	0.06	5.00	0.05	84	12.0	3.0	14.0	5.9
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	18	1.0	1.0	5.0	1.4
Std. Dev		0.04	0.180	0.195	0.01	1.79	0.00	22	4.4	0.7	3.1	1.6
No. of D		1	3	5	4	4	0	7	6	0	7	7
BZ-7M	24-Apr	0.20	< 0.005	0.100	< 0.05	0.30	< 0.05	92	3.0	< 3.0	8.0	3.4
	24-May	< 0.10	0.007	0.700	< 0.05	< 0.10	< 0.05	88	3.0	< 3.0	12.0	3.1
	14-Jun	< 0.10	0.006	< 0.100	0.06	4.10	< 0.05	34	6.0	< 2.0	10.0	6.0
	17-Jul	< 0.10	0.011	0.500	< 0.05	0.34	< 0.05	34	7.0	< 2.0	12.0	1.1
	07-Aug	< 0.10	< 0.100	0.500	0.08	0.47	< 0.05	32	11.0	< 2.0	16.0	3.5
	25-Sep	< 0.10	< 0.100	0.200	0.05	< 0.20	< 0.05	46	2.0	6.0	12.0	5.9
	24-Oct	< 0.10	< 0.500	< 0.500	0.09	< 1.00	< 0.05	58	1.0	< 2.0	12.0	3.9
Mean		0.11	0.104	0.371	0.06	0.93	0.05	55	4.7	2.9	11.7	3.8
Maximum		0.20	0.500	0.700	0.09	4.10	0.05	92	11.0	6.0	16.0	6.0
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	32	1.0	2.0	8.0	1.1
Std. Dev		0.04	0.180	0.236	0.02	1.43	0.00	26	3.5	1.5	2.4	1.7
No. of D		1	3	5	4	4	0	7	7	1	7	7

Table 3-2. (Continued)												
STATION	**DATE**	**NH3**	**NO2**	**NO3**	**PO4**	**TKN**	**TP**	**TDS**	**TSS**	**BOD5**	**ALK**	**CHL_A**
BZ-7B	24-Apr	< 0.10	< 0.005	0.100	0.06	0.20	< 0.05	84	8.0	< 3.0	10.0	1.2
	24-May	0.20	0.005	0.600	< 0.05	< 0.10	< 0.05	84	1.0	< 3.0	12.0	0.4
	14-Jun	< 0.10	0.005	< 0.100	0.07	4.60	< 0.05	34	11.0	< 2.0	10.0	1.5
	17-Jul	< 0.10	0.008	0.400	< 0.05	0.26	< 0.05	28	11.0	< 2.0	14.0	0.5
	07-Aug	0.11	< 0.100	0.600	0.09	0.36	< 0.05	46	5.0	< 2.0	14.0	1.0
	25-Sep	< 0.10	< 0.100	0.400	0.05	< 0.20	< 0.05	63	6.0	2.0	14.0	1.9
	24-Oct	< 0.10	< 0.500	< 0.500	0.08	< 1.00	< 0.05	68	6.0	< 2.0	12.0	4.2
Mean		0.12	0.103	0.386	0.06	0.96	0.05	58	6.9	2.3	12.3	1.5
Maximum		0.20	0.500	0.600	0.09	4.60	0.05	84	11.0	3.0	14.0	4.2
Minimum		0.10	0.005	0.100	0.05	0.10	0.05	28	1.0	2.0	10.0	0.4
Std. Dev		0.04	0.180	0.212	0.02	1.63	0.00	23	3.5	0.5	1.8	1.3
No. of D		2	3	5	5	4	0	7	7	1	7	7

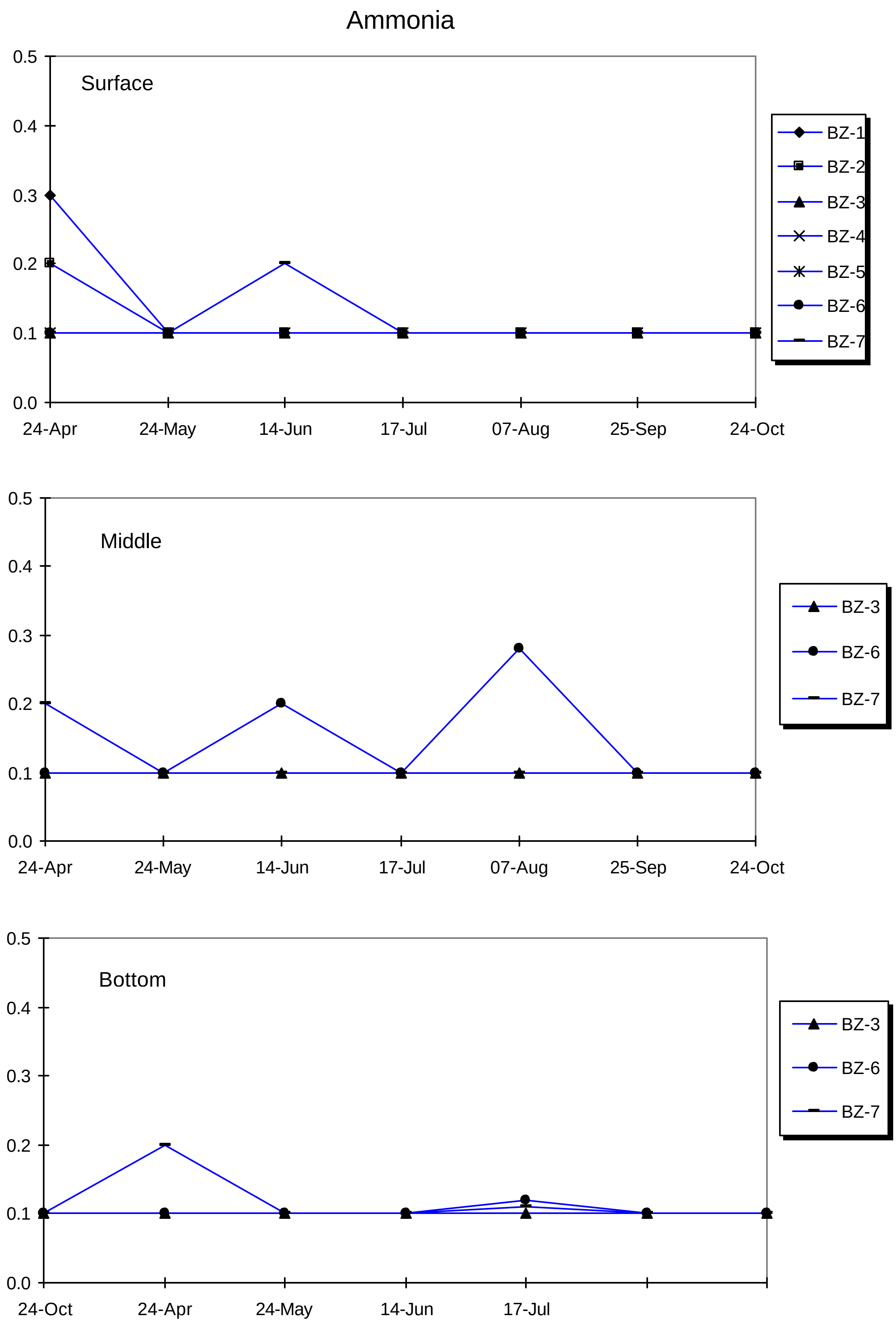

Figure 3-11. Ammonia measured in surface, middle, and bottom waters of Beltzville Reservoir in 2001.

reservoirs usually results in those that are affected by eutrophication. However, high concentrations of ammonia were not observed on later monitoring dates in September and October when hypoxia was present in the lower water column.

Concentrations of ammonia measured at Beltzville Reservoir were in compliance with the PADEP water quality standards during 2001. The state water quality standard for ammonia is dependent on temperature and pH (Table 3-3). Throughout the monitoring period, the most conservative criterion for ammonia resulting from the highest measured pH (8.6) and temperature (30 ºC) was 0.6-mg/L.

Table 3-3. PADEP ammonia nitrogen criteria (Pennsylvania Code, Title 25, Chapter 93, 1996). Specific ammonia criteria dependent on temperature and pH.

pH	10°C	15°C	20°C	25°C	30°C
6.50	25.5	17.4	12.0	8.4	5.9
6.75	23.6	16.0	11.1	7.7	5.5
7.00	20.6	14.0	9.7	6.8	4.8
7.25	16.7	11.4	7.8	5.5	3.9
7.50	12.4	8.5	5.9	4.1	2.9
7.75	8.5	5.8	4.0	2.8	2.0
8.00	5.5	5.8	4.0	2.8	2.0
8.25	3.4	2.3	1.6	1.2	0.9
8.50	2.0	1.4	1.0	0.7	0.6
8.75	1.2	0.9	0.6	0.5	0.4
9.00	0.8	0.5	0.4	0.3	0.3
9.25	0.36	0.24	0.17	0.12	0.08
9.50	0.20	0.13	0.10	0.07	0.05

Seasonal trends for ammonia in surface water were determined for individual stations using the non-parametric Mann-Kendall statistic. The statistical analysis was conducted for stations with historical data (21 years or more), individually for spring (April through June) and summer (July through September) seasons. Data from seven stations were analyzed representing downstream (BZ-1), Pine Run (BZ-2), the reservoir-body (BZ-3, -6, and -7), Wild Creek (BZ-4), and upstream on Pohopoco Creek (BZ-5). Ammonia concentrations appear to be decreasing throughout the Beltzville Reservoir watershed (Table 3-4). From the analysis, stations BZ-1, -2, -3, -4, and -5 showed significant and decreasing trends. Rates of decrease were greater during the summer season and ranged from 0.001 to 0.004 mg/L/year. Stations BZ-1 and -5 also had significant decreasing spring season rates of 0.001 mg/L/year.

Table 3-4. Seasonal trends of ammonia concentration at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic. Shaded values are significant (at least P< 0.05).

Station	# of Years spring/summer	Spring		Summer	
		P Level	Rate (mg/)	P Level	Rate (mg/L)
Surface Water					
BZ-1	24/23	<0.05	-0.001	<0.001	-0.004
BZ-2	22	NS	-0.001	<0.05	-0.001
BZ-3	26/25	NS	-0.001	<0.01	-0.003
BZ-4	25/24	NS	-0.001	<0.01	-0.002
BZ-5	25	<0.001	-0.001	<0.001	-0.003
BZ-6	6	NS	0.009	NS	0.005
BZ-7	6	NS	0.005	NS	0.008

3.2.2 Nitrite and Nitrate

Nitrite concentrations in the water column of Beltzville Reservoir were very low during 2001 (Fig. 3-12). Concentrations measured at all stations and depths were less than the method detection limit of 0.5-mg/L throughout the monitoring period.

Nitrate was distributed uniformly in the water column of Beltzville Reservoir during 2001 (Fig. 3-13). At most stations and depths, concentrations ranged from less than the method detection limit (0.1-mg/L) to 0.8-mg/L. Concentrations in surface water from the reservoir-body stations (BZ-3, -6, and -7) were similar to those from middle and bottom depths. Overall, concentrations appeared to average 0.4-mg/L throughout the monitoring period. Concentrations of nitrate upstream of the reservoir on Pohopoco Creek (BZ-5) were usually highest and over the monitoring period ranged from 0.1 to 1.2-mg/L. Nitrate measured downstream of the reservoir (BZ-1) was consistent over the monitoring period at about 0.4-mg/L. This average was consistent with all other stations.

Beltzville Reservoir was in compliance with the PADEP water quality standard for nitrite and nitrate during 2001. The standard is a summed concentration of nitrite and nitrate of less than 10 mg/L. Throughout the monitoring period, the summed concentrations for all stations averaged 0.5-mg/L with maximum values of 1.3-mg/L in August and October at BZ-5

3.2.3 Total Inorganic Nitrogen

Concentrations of total inorganic nitrogen have not changed appreciably over the past 26 years in surface waters of Beltzville Reservoir or downstream of the reservoir in either spring or summer seasons (Figs. 3-14 and 3-15).

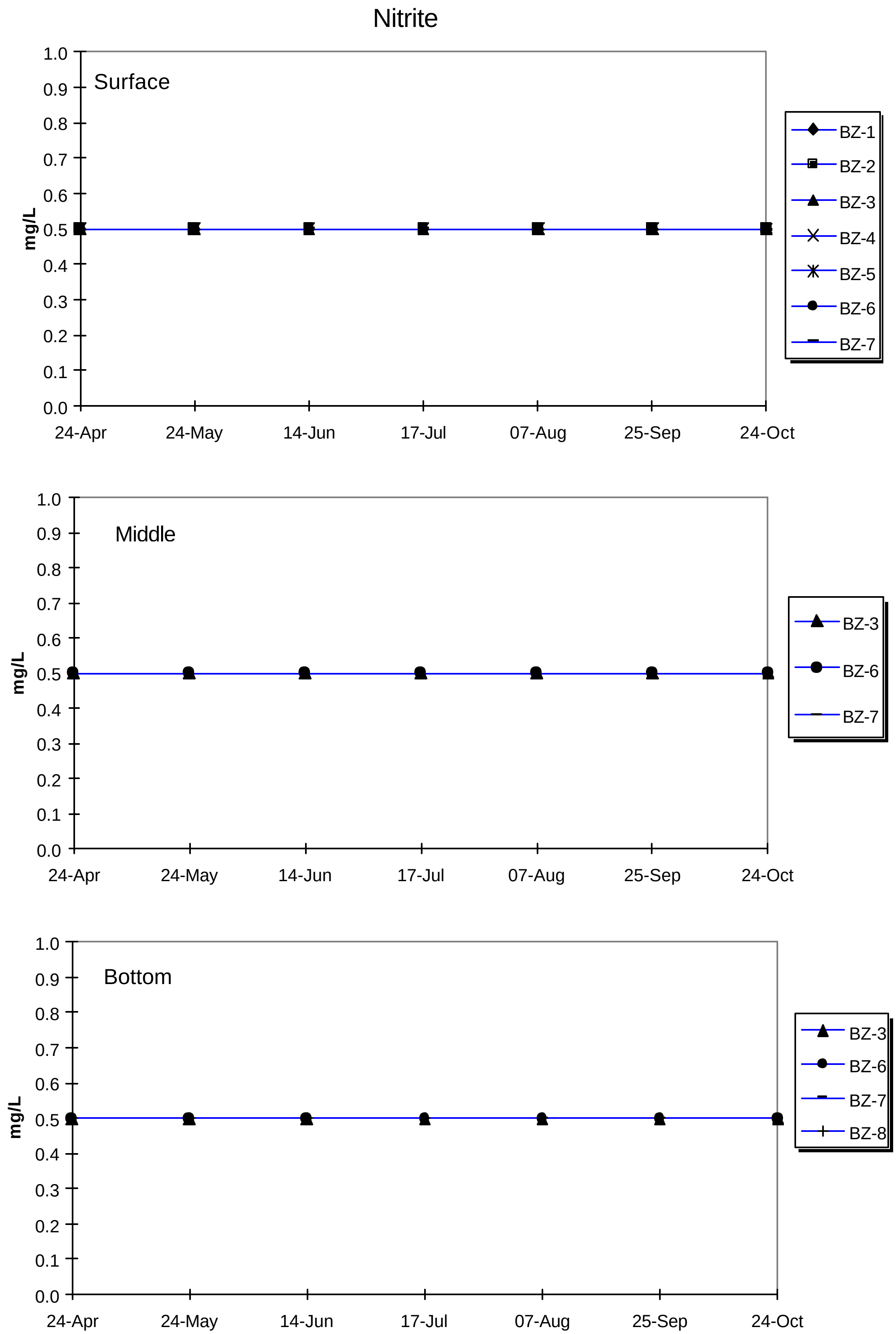

Figure 3-12. Nitrite measured in surface, middle, and bottom waters of Beltzville Reservoir in 2001.

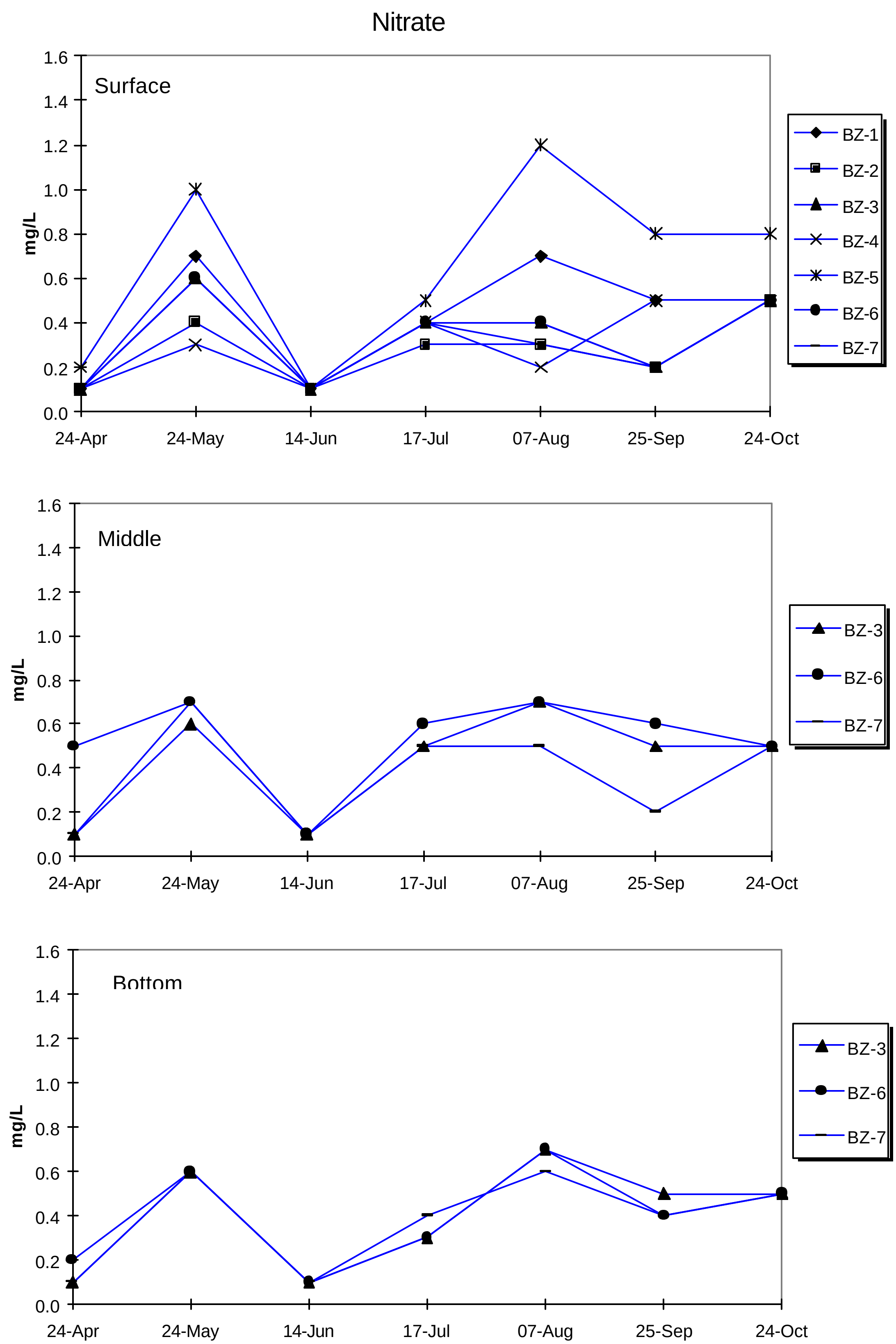

Figure 3-13. Nitrate measured in surface, middle, and bottom waters of Beltzville Reservoir in 2001.

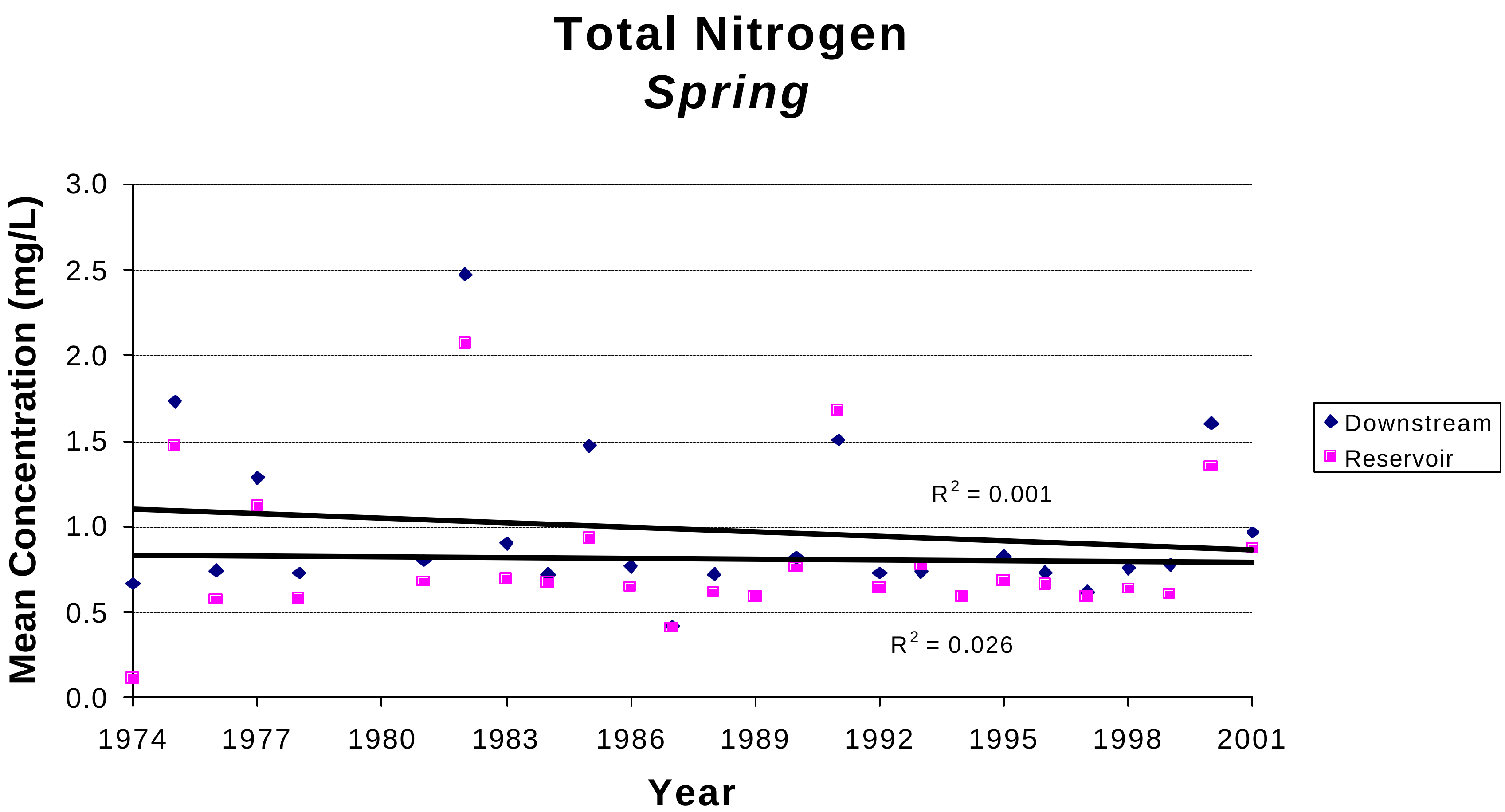

Figure 3-14. Seasonal trends of total nitrogen (ammonia + nitrite + nitrate) in the spring at Beltzville Reservoir.

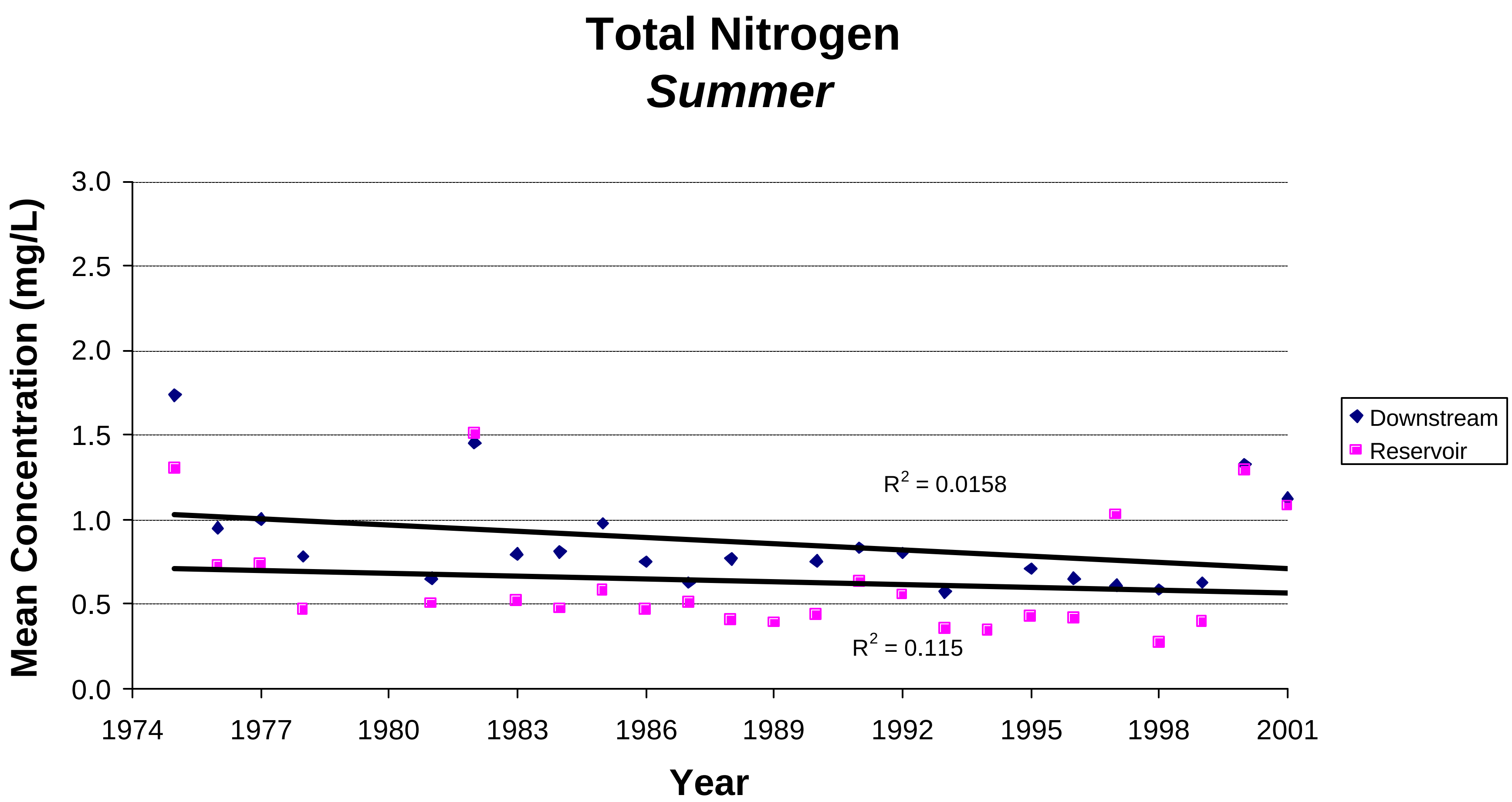

Figure 3-15. Seasonal trends of total nitrogen (ammonia + nitrite + nitrate) in the summer at Beltzville Reservoir.

Seasonal trends (spring and summer) for total nitrogen in surface water were also determined for individual stations using the non-parametric Mann-Kendall statistic. Total inorganic nitrogen, calculated as the summed concentration of ammonia, nitrite, and nitrate, was analyzed separately for reservoir and upstream stations (BZ-2, -3, -4, -5, -6, and -7) and downstream of the reservoir (station BZ-1). Regression analyses conducted on the average concentrations indicated significant decreasing trends for stations BZ-1, -3, and -4 during the summer period. Throughout the 26-year time series, total nitrogen concentrations generally averaged less than 0.8-mg/L; however, in 2001, concentrations were slightly higher at about 1.0-mg/L.

Table 3-5. Seasonal trends of total nitrogen at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic. Shaded values are significant at P – 0.05.

Station	# of Years Spring/Summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate
Surface Water					
BZ-1	24/23	NS	-0.004	< 0.01	-0.01
BZ-2	22	NS	-0.002	NS	0.002
BZ-3	26/25	NS	-0.002	< 0.05	-0.08
BZ-4	25/24	NS	-0.004	< 0.05	-0.01
BZ-5	25	NS	-0.007	NS	0.03
BZ-6	6	NS	-0.03	NS	0.02
BZ-7	6	NS	-0.05	NS	0.008

3.2.4 Total Kjeldahl Nitrogen

For the most part, total Kjeldahl nitrogen (TKN) was uniformly low in the water column of Beltzville Reservoir during 2001 (Fig. 3-16). Throughout the monitoring period, concentrations measured at all depths generally ranged less than 1.2-mg/L. In June; however, concentrations averaged 2.3-mg/L and ranged as high as 4.6-mg/L. Concentrations measured at upstream stations BM-2, -4, and –5 were 2.7, 2.95, and 1.45-mg/L, respectively. Concentrations were also elevated within the reservoir body at stations BZ-3, -6, and -7 and below the reservoir at station BZ-1. Concentrations at these stations measured 2.85, 4.6, 2.5, and 2.15-mg/L, respectively.

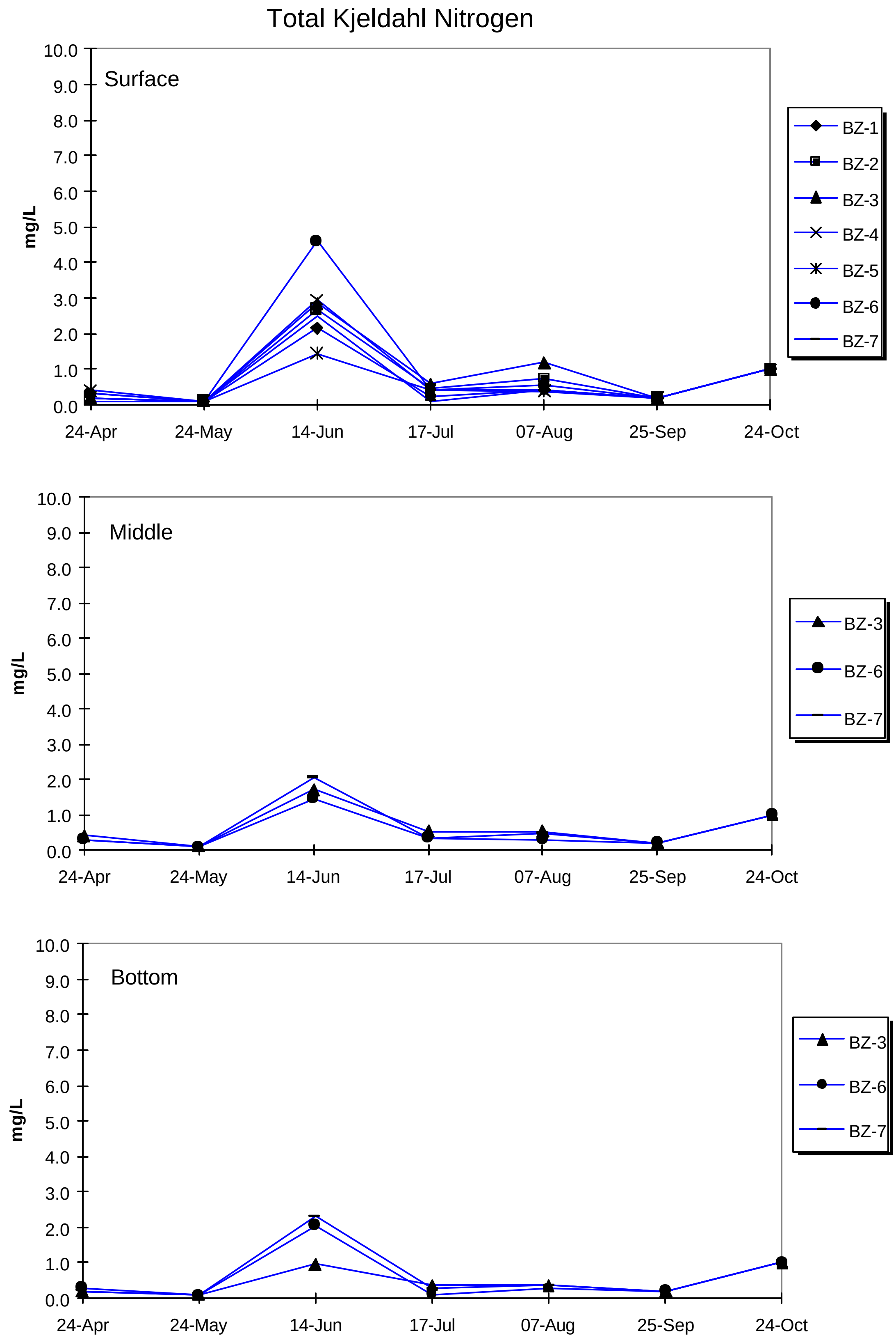

Figure 3-16. Total Kjeldahl nitrogen measured in surface, middle, and bottom waters of Beltzville Reservoir in 2001.

3.2.5 Dissolved Phosphate

Dissolved phosphate was not a significant nutrient parameter at Beltzville Reservoir in 2001 (Fig. 3-17). Concentrations of dissolved phosphate were generally at or below the detection limit of 0.05-mg/L. Two isolated instances of high values were recorded during August at BZ-2 in the surface water and in September at BZ-6 in the bottom water. These concentrations were 1.2 and 2.4-mg/L, respectively. In freshwater environments, dissolved phosphate is usually a limiting nutrient and is readily taken up by freshwater plants and algae.

3.2.6 Total Phosphorus

Total phosphorus in the water column of Beltzville Reservoir was consistently measured at low concentrations during 2001 (Fig. 3-18). EPA guidance for nutrient criteria in lakes and reservoirs suggests a minimum concentration for total phosphorus of 0.01-mg/L (EPA 2000). Lakes and reservoirs exceeding this concentration are more likely to experience algal bloom problems during the growing season. Overall, only three measures for total phosphorus with results greater than the detection limit from reservoir monitoring were greater than the EPA guideline. High measures of total phosphorus were recorded in the surface waters at station BZ-5 (0.1-mg/L) in September and BZ-1 (0.7-mg/L) in October. Additionally, a high concentration of total phosphorus was present in the bottom water at BZ-6 (1.4-mg/L) in September. All remaining results were less than the detection limit of 0.05-mg/L, which is a concentration 5 times greater than the guideline.

Total phosphorus concentrations measured during 2001 and historical data from the past 26 years were analyzed for seasonal trends. Regression analyses for spring and summer periods were conducted separately for stations of the reservoir and downstream. No trends were determined for either season at reservoir and downstream stations (Figs. 3-19 and 3-20). None of the regression lines were significant (P>0.05).

Trend analyses for total phosphorus were also conducted for individual monitoring stations of Beltzville Reservoir using the non-parametric Mann-Kendall statistic. As before, the trends were calculated separately for spring and summer seasons. Stations analyzed for the seasonal trends included BZ-1, -2, -3, -4, -5, -6, and -7. From these stations, historical data on total phosphorus spanned a maximum of 21 years. Only one significant trend resulted from the analysis. A significant decreasing trend in summer was determined for station BZ-4 on the Wild Creek tributary (Table 3-6). The estimated rate of decrease for this trend was 0.004-mg/L/year.

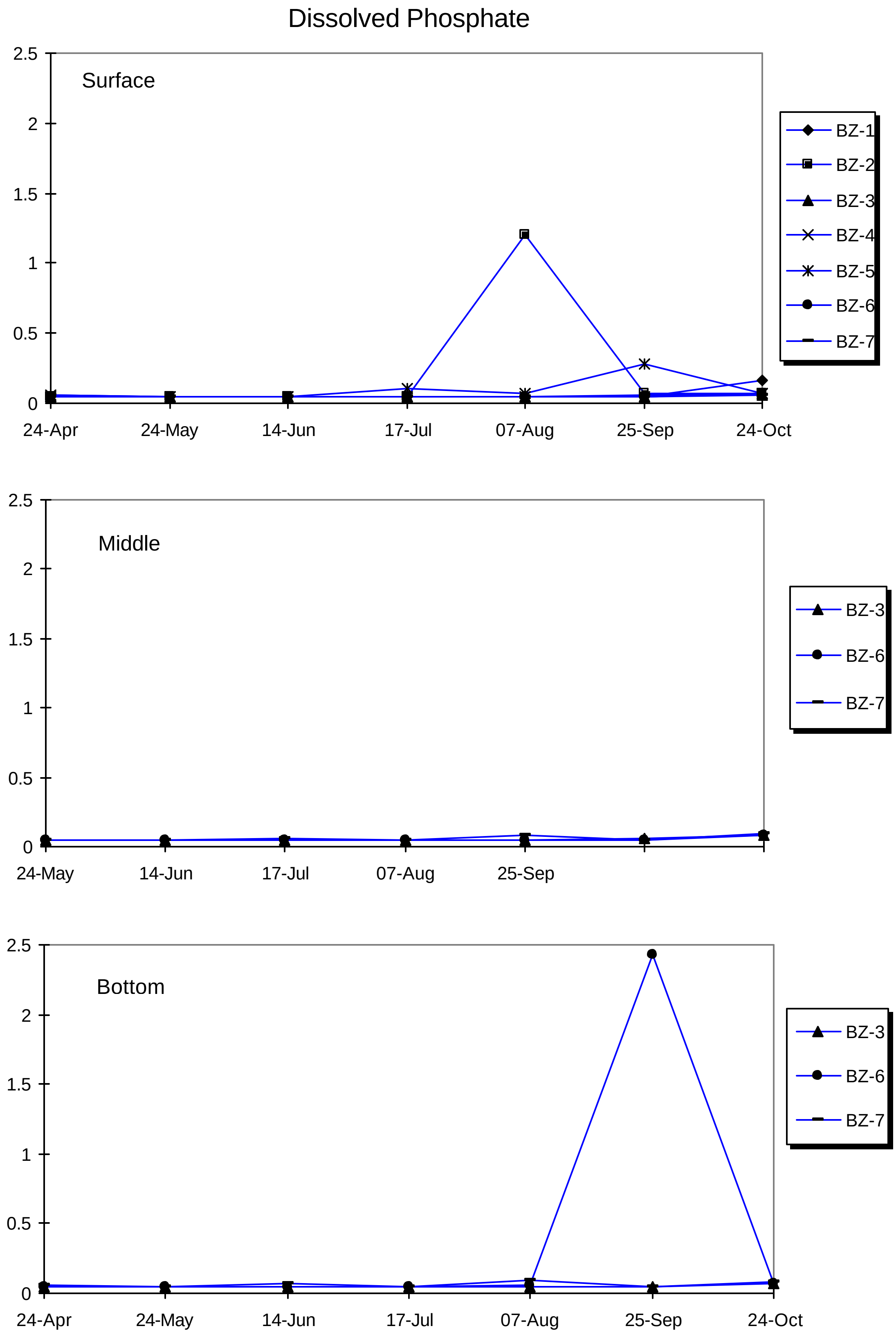

Figure 3-17. Dissolved phosphorus measured in surface, middle, and bottom waters of Beltzville Reservoir in 2001.

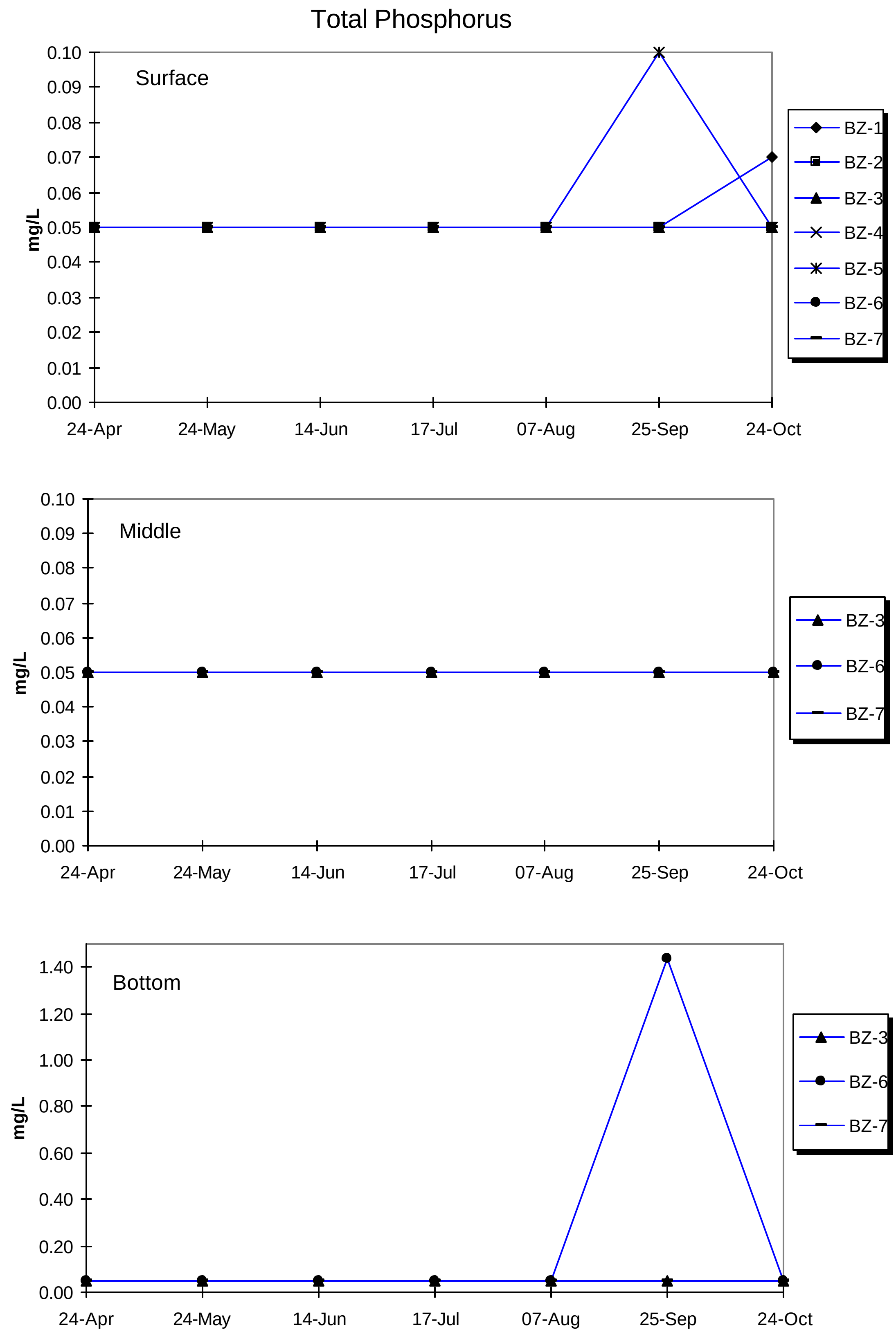

Figure 3-18. Total phosphorus measured in surface, middle, and bottom waters of Beltzville Reservoir in 2001.

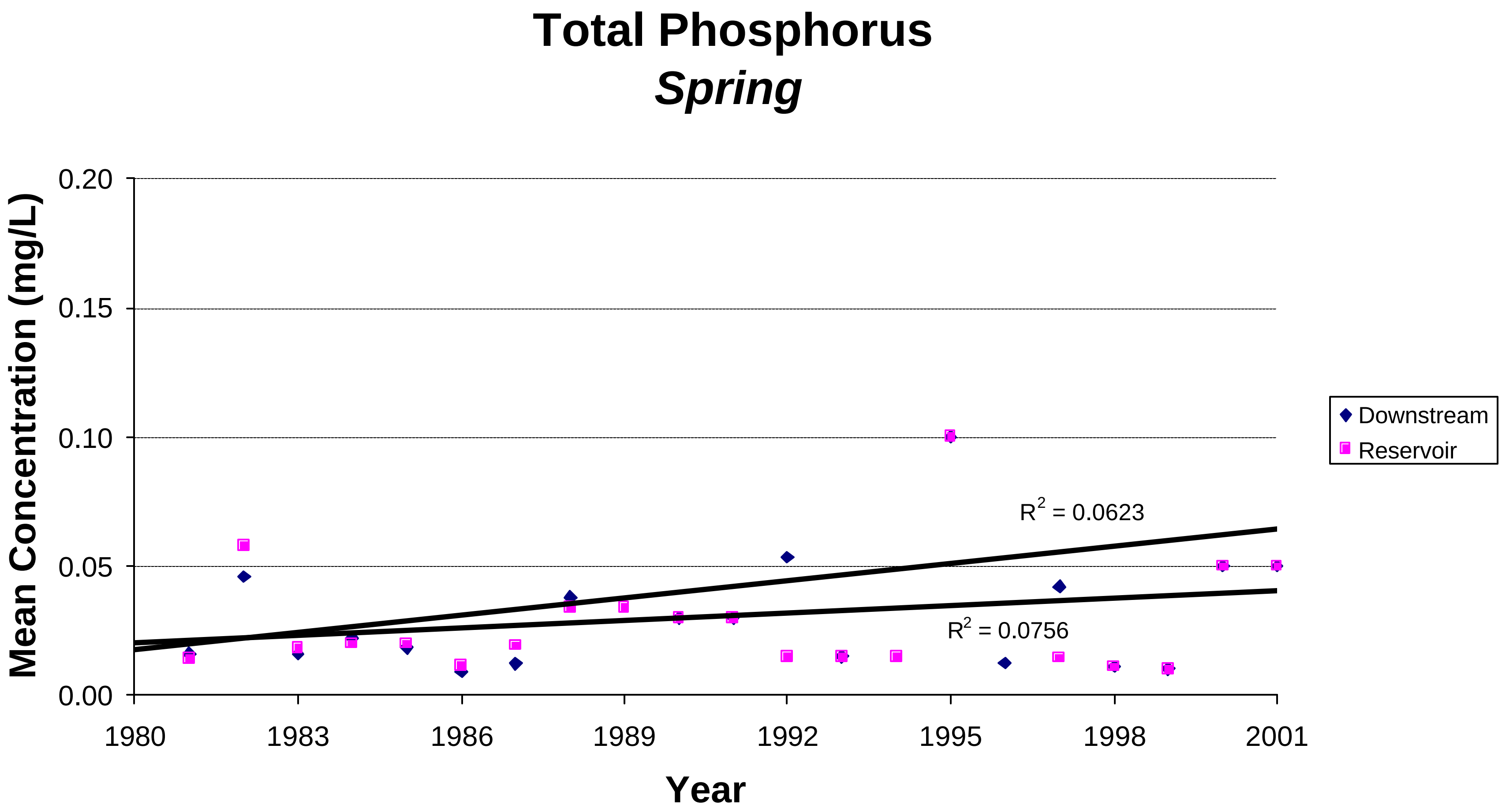

Figure 3-19. Seasonal trends of total phosphorus in spring at Beltzville Reservoir.

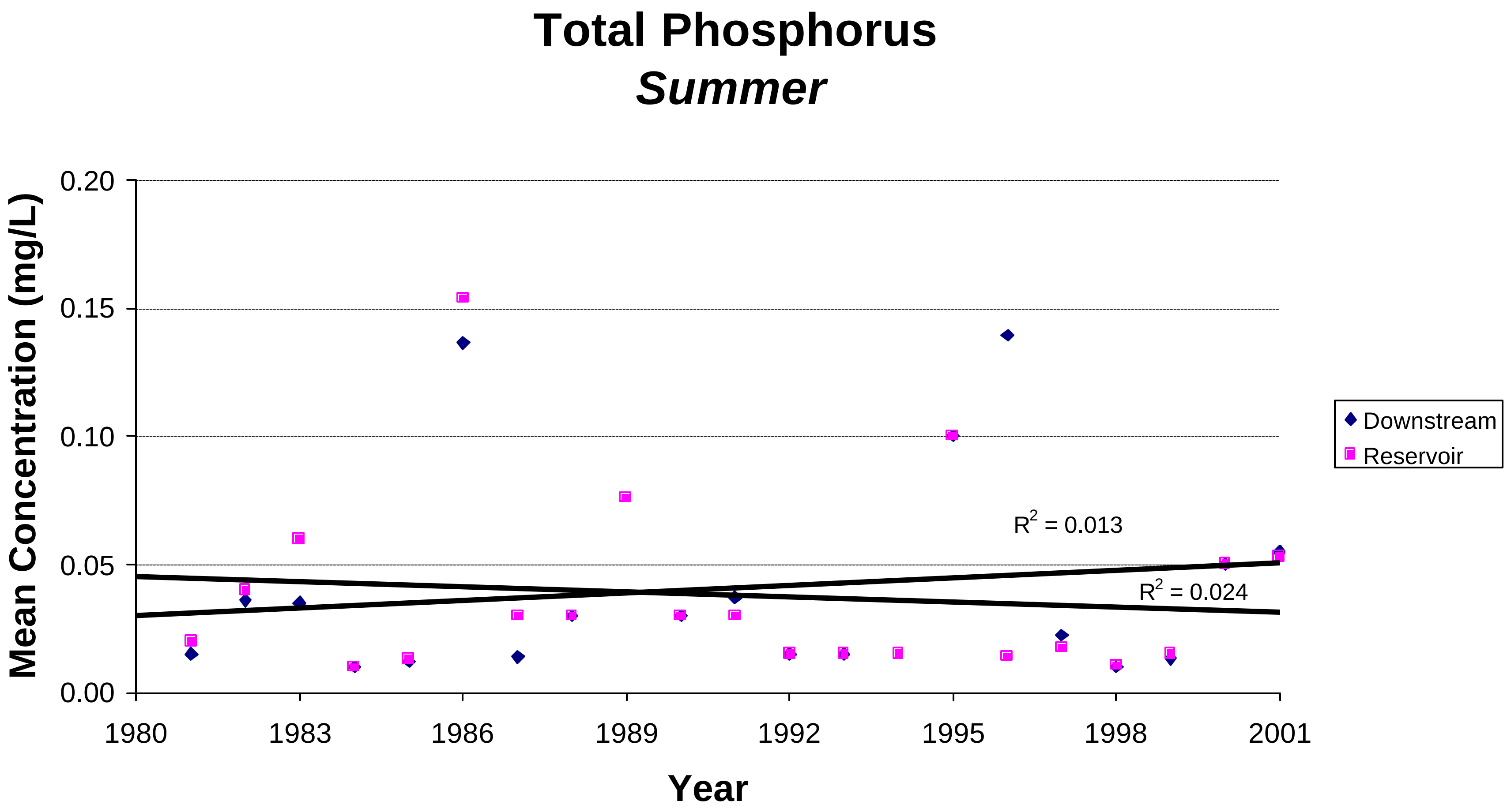

Figure 3-20. Seasonal trends of total phosphorus in summer at Beltzville Reservoir.

Table 3-6. Seasonal trends of total phosphorus concentration at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic. Shaded values are significant (at least P<0.05).

Station	# of Years spring/summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate (mg/L)
Surface Water					
BZ-1	19	NS	0.0	NS	0.0003
BZ-2	21	NS	0.09	NS	-0.0004
BZ-3	22/21	NS	-0.13	NS	-0.0003
BZ-4	21/20	NS	0.28	<0.05	-0.004
BZ-5	21	NS	-0.09	NS	-0.00001
BZ-6	5	NS	5.75	NS	0.007
BZ-7	5	NS	6.44	NS	0.006

3.2.7 Total Dissolved Solids

Concentrations of total dissolved solids (TDS) in the water column of Beltzville Reservoir were variable during 2001 (Fig. 3-21). The variability among measures was different on each monitoring date, and patterns of consistency for individual stations were not easily discernible. Concentrations among all stations and depths ranged from 10 to 104-mg/L. Overall, measures of TDS at all stations and depths averaged 60-mg/L.

TDS concentrations measured at Beltzville Reservoir in 2001 were in compliance with PADEP water quality standards. The state water quality standard for TDS is a maximum concentration of 500 mg/L. Throughout the monitoring period, all measures of TDS were at least 5 times less than the standard (Fig. 3-21).

Total dissolved solids concentrations have exhibited no discernible pattern over the past 26 years of water quality monitoring at Beltzville Reservoir. Regression analyses conducted separately by season for upstream and downstream data did not result in any significant trends (Figs. 3-22 and 3-23). Average TDS concentrations calculated this year were slightly higher than recent years.

Seasonal trends (spring and summer) for total dissolved solids in surface water were also determined for individual stations using the non-parametric Mann-Kendall statistic. Overall, seven stations were tested representing downstream (BZ-1), Pine Run (BZ-2), mid-reservoir (BZ-3, -6, and -7), Wild Creek (BZ-4), and upstream on Pohopoco Creek (BZ-5). Concentrations of total dissolved solids appear to have decreased in many of the surface waters of Beltzville Reservoir over the past two decades (Table 3-7). Significant

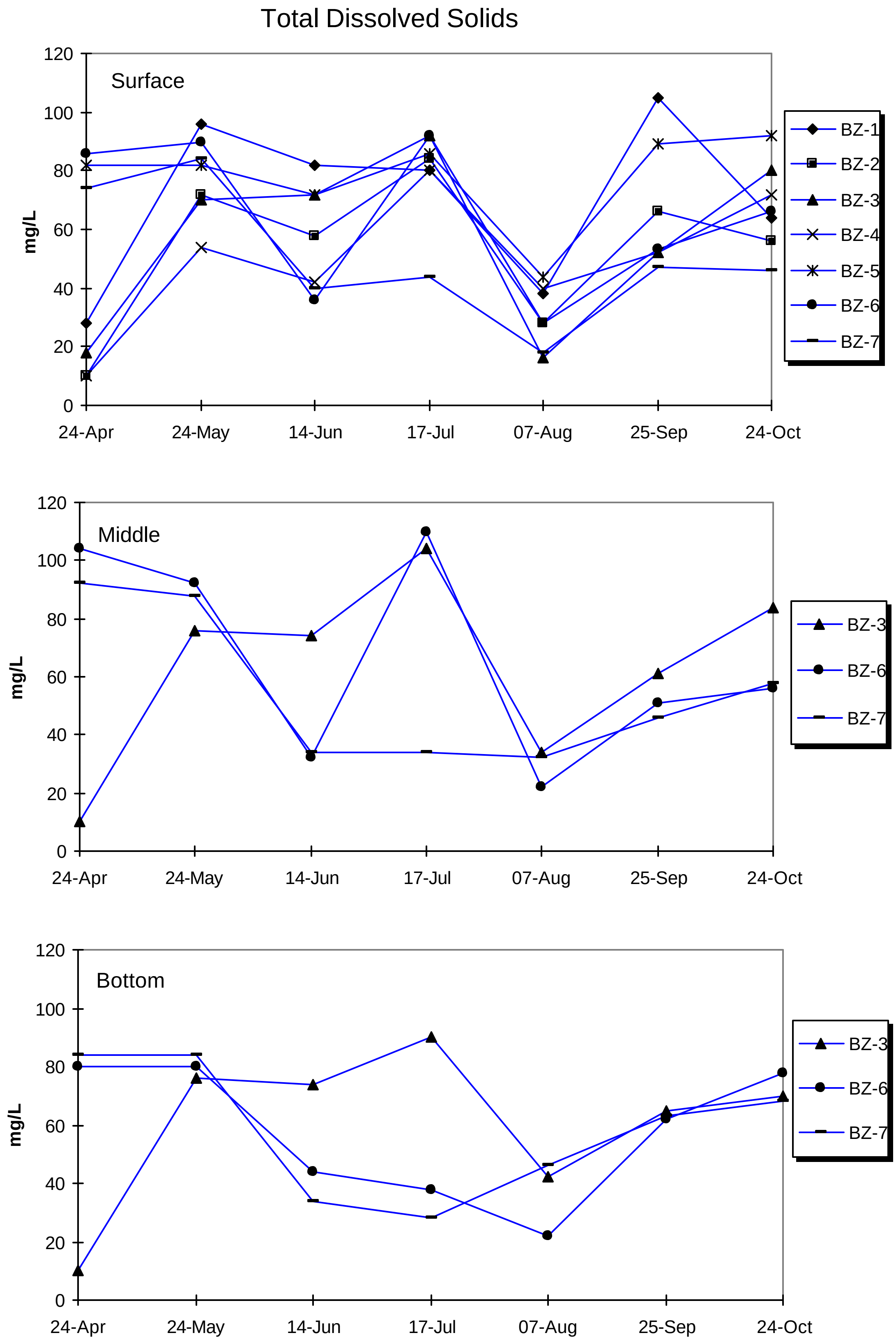

Figure 3-21. Total dissolved solids in surface, middle, and bottom waters of Beltzville Reservoir in 2001. (The PADEP water quality standard for TDS is a maximum concentration of 500 mg/l.)

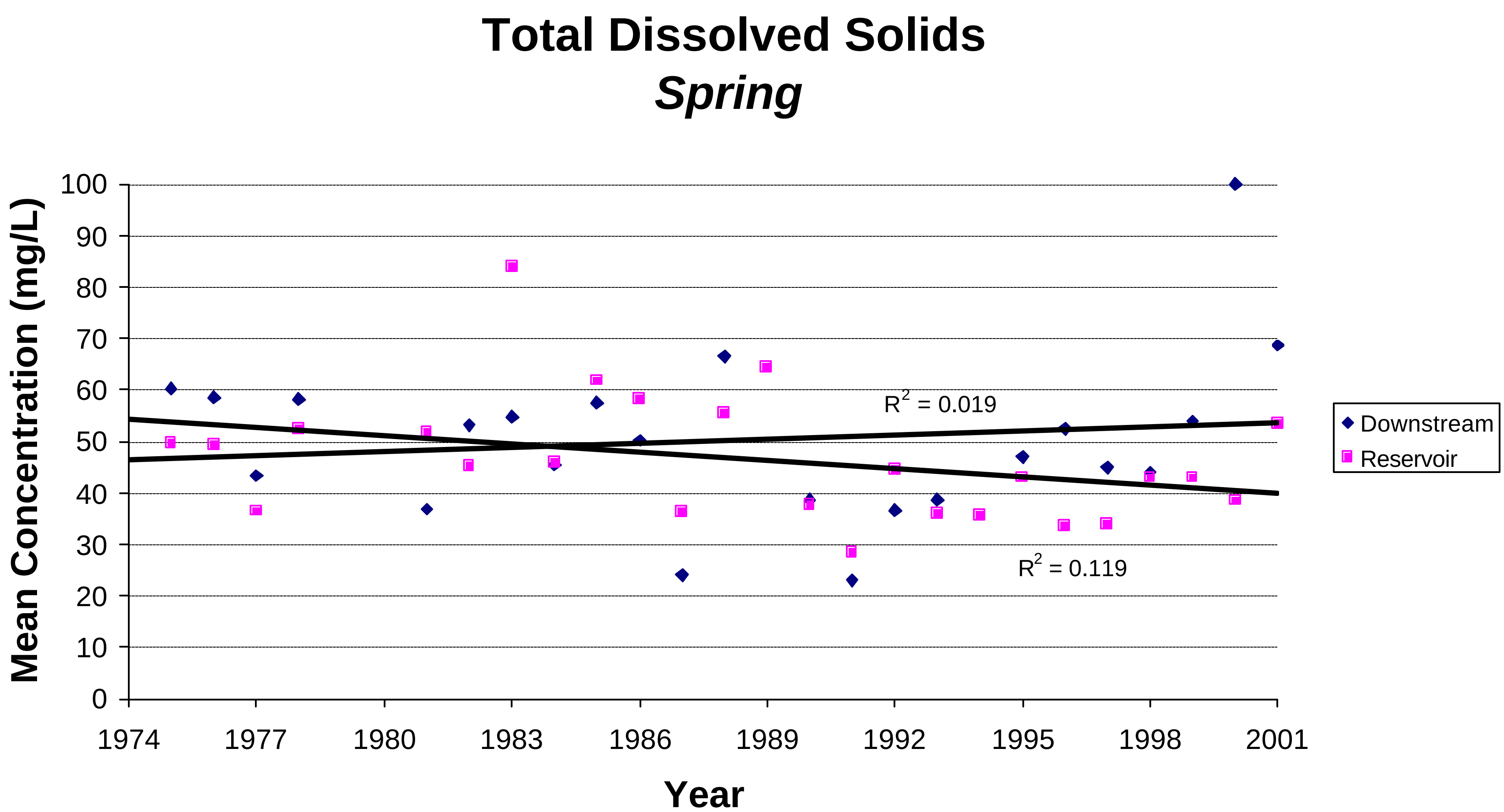

Figure 3-22. Seasonal trends of total dissolved solids in spring at Beltzville Reservoir.

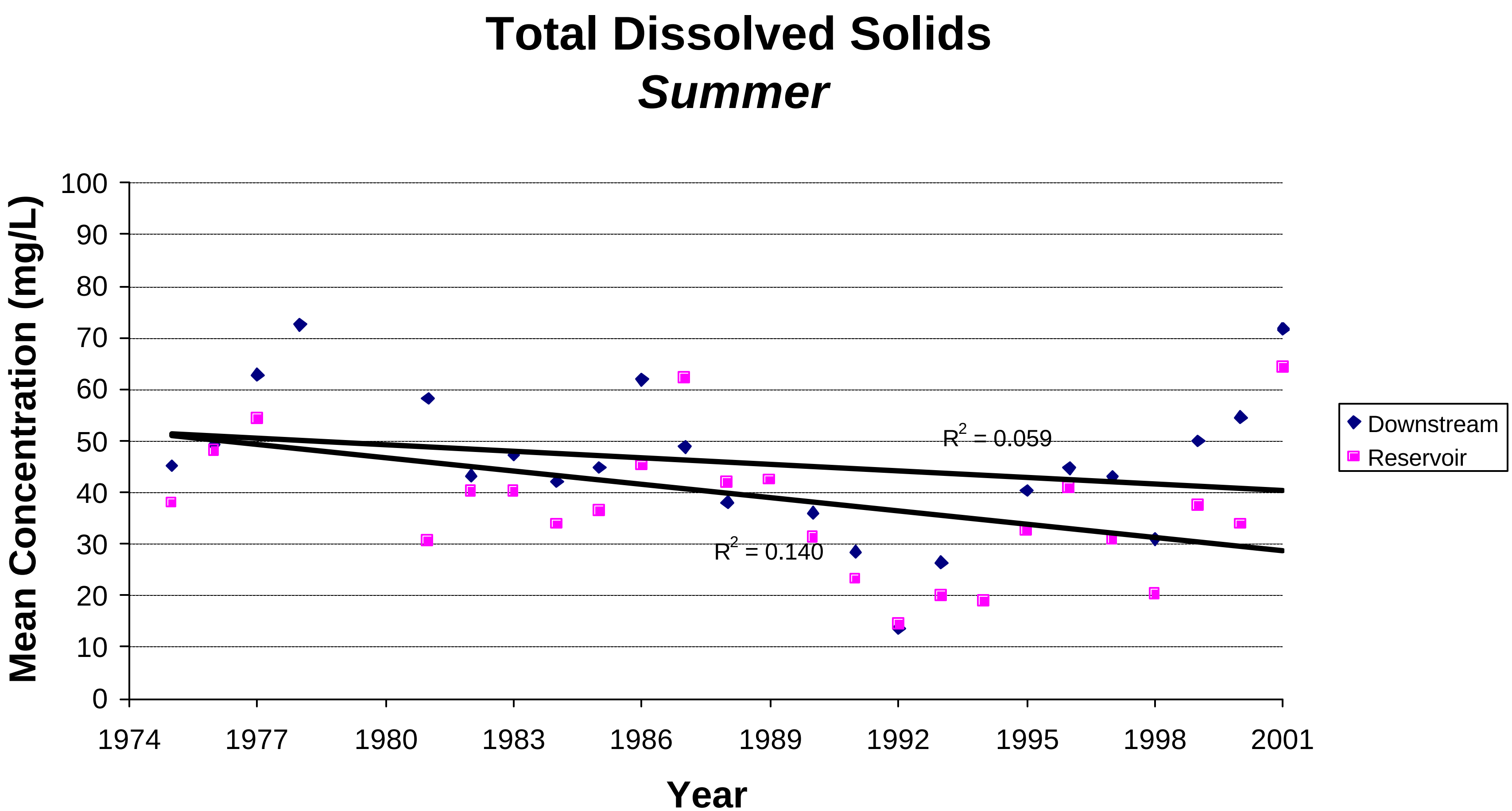

Figure 3-23. Seasonal trends of total dissolved solids in summer at Beltzville Reservoir.

decreasing trends were observed in the mid-reservoir (station BZ-3) during both seasons as well as for Pine Creek and Wild Creek tributaries (stations BZ-2 and BZ–4) in the summer. The estimated rates of decrease among all trends were similar at about 0.8-mg/L/year. A significant increasing trend was seen at station BZ-6 during the spring period. The rate of increase was 11.5-mg/L/yr.

Table 3-7. Seasonal trends of total dissolved solids concentration at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic. Shaded values are significant (at least P<0.05).

Station	# of Years spring/summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate (mg/L)
Surface Water					
BZ-1	23	NS	-0.047	NS	-0.527
BZ-2	22	NS	-0.583	<0.05	-1.02
BZ-3	25	<0.05	-0.579	<0.05	-0.742
BZ-4	24	NS	-0.342	<0.05	-0.922
BZ-5	25	NS	0.105	NS	-0.487
BZ-6	6	<0.05	11.5	NS	5
BZ-7	6	NS	5.5	NS	-2.33

3.2.8 Total Suspended Solids

Total suspended solids (TSS) concentrations in the water column of Beltzville Reservoir were generally low during 2001 (Fig. 3-24). In general, concentrations measured at most stations and depths ranged less than 20 mg/L. Higher concentrations were measured in September at the surface of station BZ-5 and in the bottom waters of station BZ-3 in October. The concentration of TSS at BZ-5 was 73-mg/L and 36-mg/L at BZ-3.

3.2.9 Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is a measure of the oxygen-depleting burden imposed by organic material present in water. BOD concentrations in the water column of Beltzville Reservoir were relatively low in 2001 (Fig. 3-25). Throughout the monitoring period, concentrations measured at 91% of all stations and depths were typically less than the method detection limit (1 to 3-mg/L). BOD was detected at all stations and throughout the water column in September and only once in August on Wild Creek (BZ-4). Concentrations at all stations and depths in the water column averaged 2.3-mg/L throughout the monitoring period.

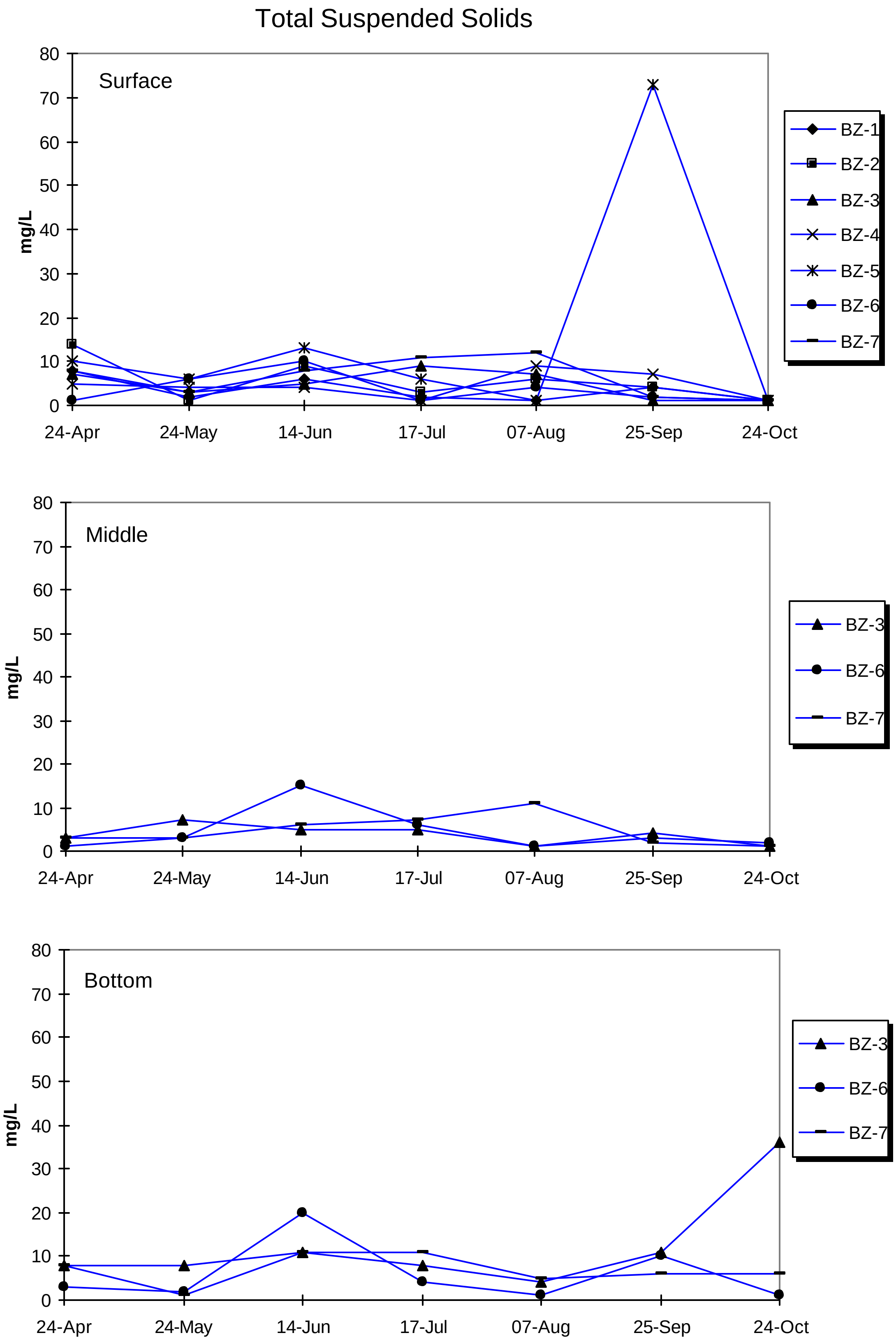

Figure 3-24. Total suspended solids in surface, middle, and bottom waters of Beltzville Reservoir in 2001.

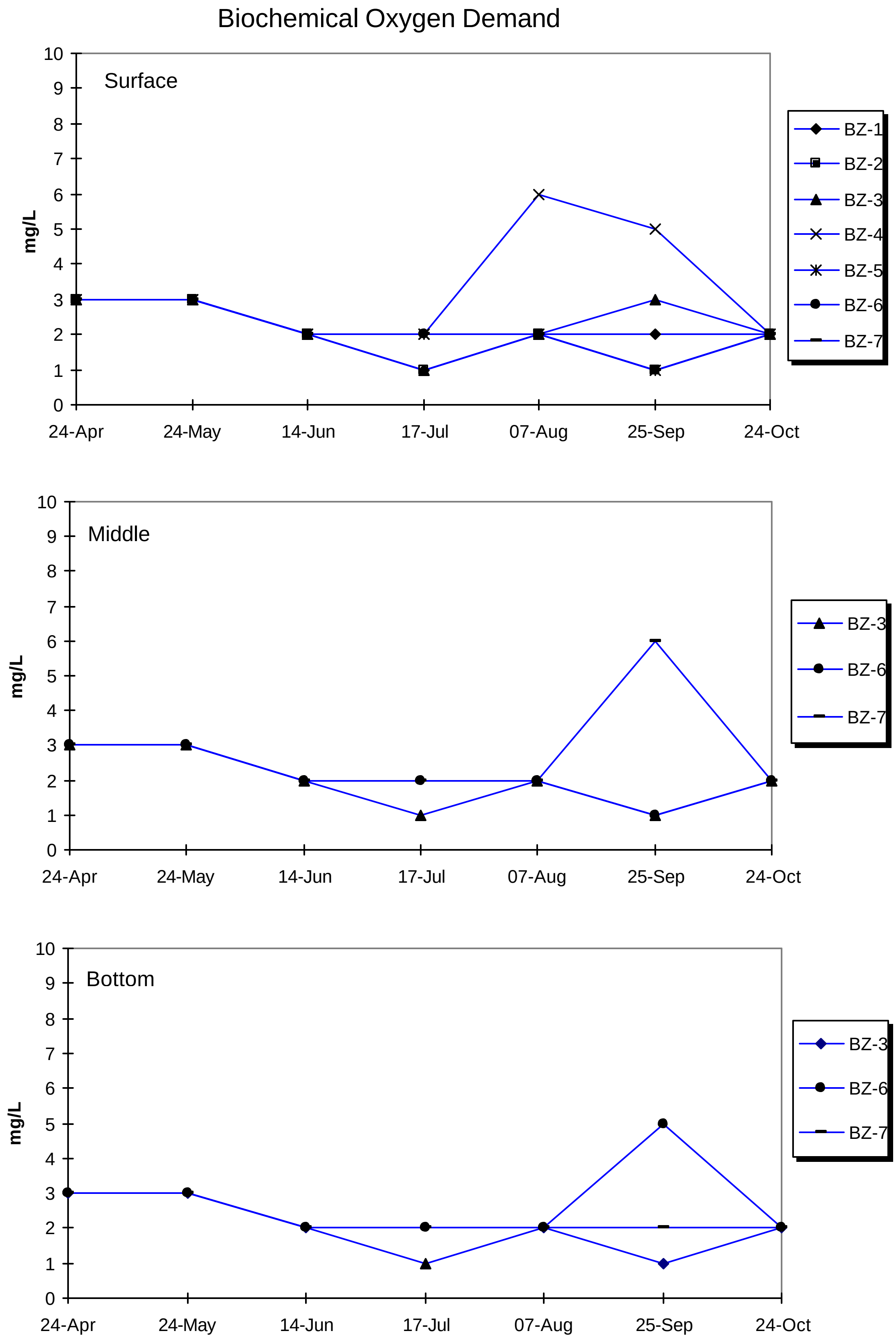

Figure 3-25. Biochemical oxygen demand in surface, middle, and bottom waters of Beltzville Reservoir in 2001.

Based on trend analyses using 2001 and historical data, BOD does not appear to have changed significantly in the reservoir or downstream (Figs. 3-26 and 3-27). Although the regression lines for both spring and summer seasons suggested a slight reduction in BOD concentrations, none of the trends were significant (P > 0.05).

A trend analysis for BOD was also conducted on individual monitoring stations of Beltzville Reservoir using the non-parametric Mann-Kendall statistic (Table 3-8). Based on this analysis, a significant decreasing summer trend was determined for station BZ-1, downstream of the reservoir. The estimated rate of decrease ranged was 0.03-mg/L/year.

Table 3-8. Seasonal trends of total BOD concentration at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic. Shaded values are significant (at least P<0.05).

Station	# of Years spring/summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate (mg/L)
Surface Water					
BZ-1	19	NS	-0.003	<0.01	-0.03
BZ-2	21	NS	0.0	NS	-0.004
BZ-3	21	NS	-0.02	NS	-0.009
BZ-4	20	NS	0.0	NS	0.0
BZ-5	21	NS	0.0	NS	-0.04
BZ-6	6	NS	0.13	NS	0.0
BZ-7	6	NS	0.13	NS	0.0

3.2.10 Alkalinity

Alkalinity is a measure of the acid-neutralizing capacity of water. Alkalinity in the water column of Beltzville Reservoir was relatively low during 2001 (Fig. 3-28). Throughout the monitoring period, concentrations measured at all stations and depths ranged between 5 and 20-mg/L.

Concentrations of alkalinity measured at Beltzville Reservoir were in compliance with PADEP water quality standards during 2001. The state water quality standard for alkalinity is a minimum concentration of 20 mg/L $CaCO_3$, except where natural conditions are less. The natural alkalinity of water is largely dependent on the underlying geology and soils within the surrounding watershed. The low alkalinity measured at Beltzville Reservoir probably results from the regional geology, which is primarily sandstone and shale (Van Diver 1990).

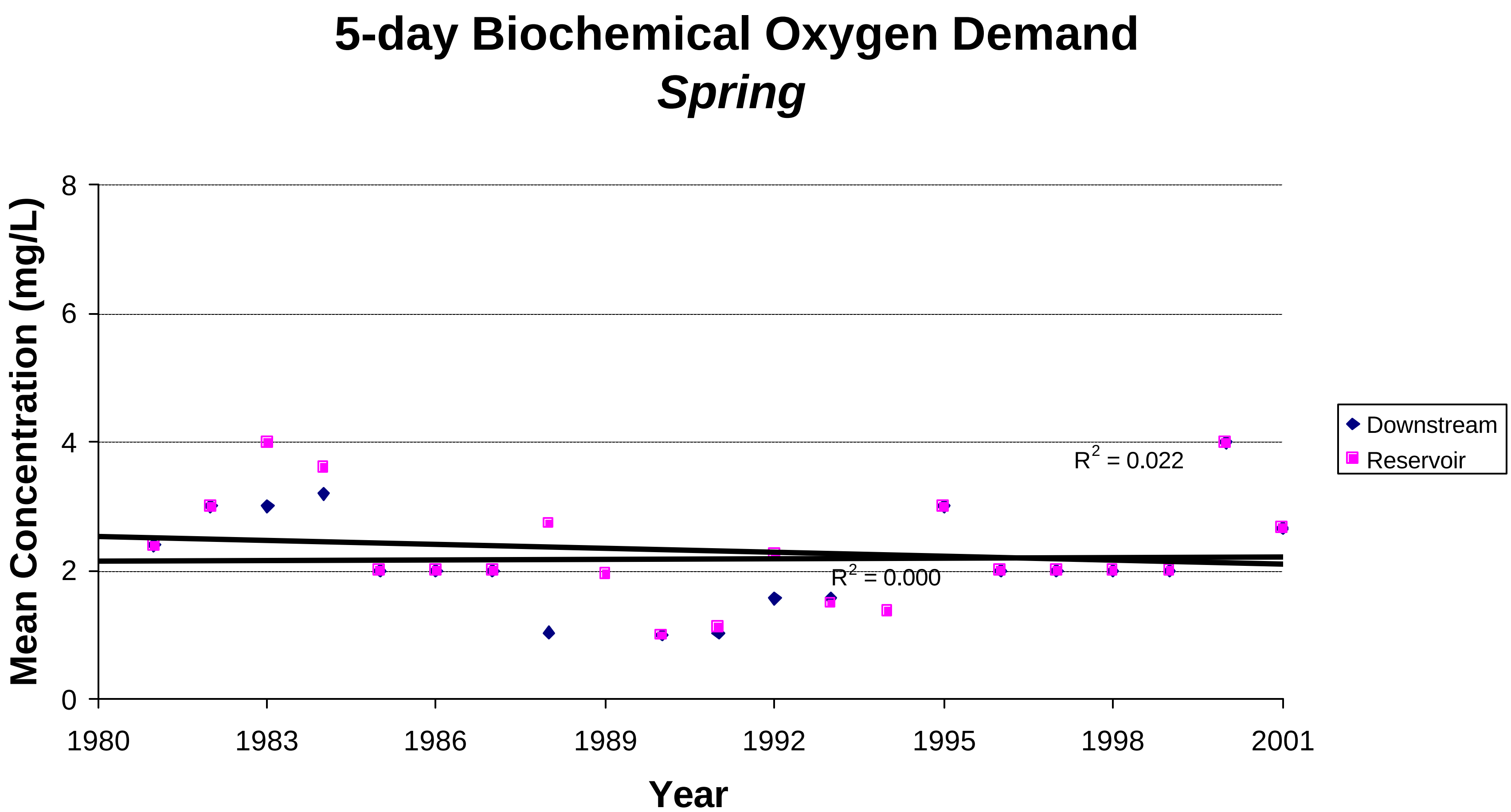

Figure 3-26. Seasonal trends of five-day biochemical oxygen demand in spring at Beltzville Reservoir.

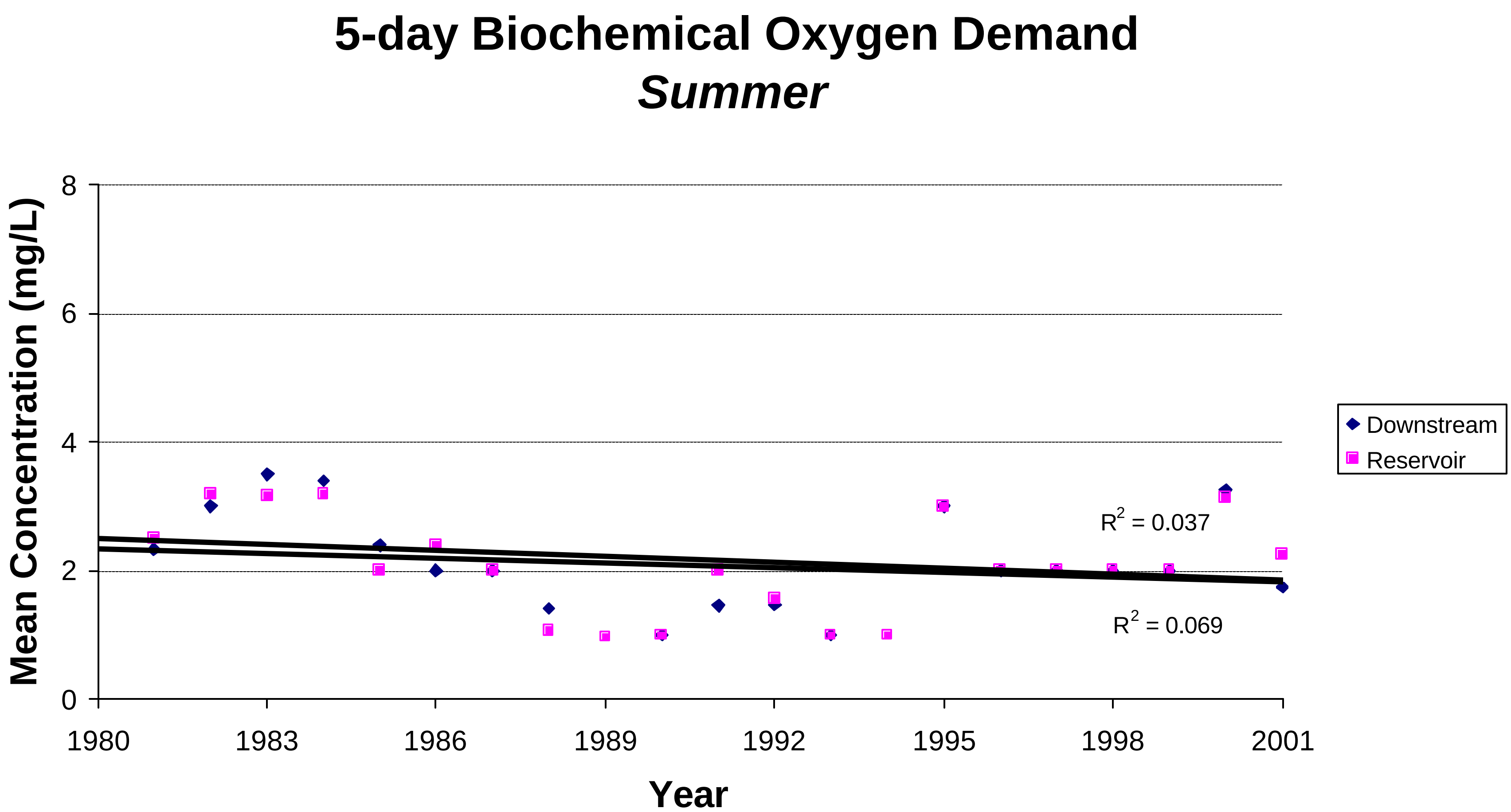

Figure 3-27. Seasonal trends of five-day biochemical oxygen demand in summer at Beltzville Reservoir.

3.2.11 Total Organic and Inorganic Carbon

Total inorganic carbon and total organic carbon in the water column of Beltzville Reservoir were not present in measurable concentrations during 2001(Fig. 3-29 and Fig. 3-30). All concentrations measured were less than the method detection limit of 5-mg/L

3.2.12 Chlorophyll *a*

Chlorophyll *a* is a measure of algal biomass. For the most part, chlorophyll *a* concentrations in the water column of Beltzville Reservoir were relatively low during 2001 (Fig. 3-31). Concentrations measured at all stations and depths ranged between 0.1 and 14.8-mg/m^3. Concentrations were highly variable throughout the reservoir and its tributaries and averaged 2.6- mg/m^3.

3.2.13 BTEX

Concentrations of benzene, toluene, ethylbenzene, o-xylene and m,p-xylenes (BTEX) in surface waters of Beltzville Reservoir were consistently low during 2001 (Table 3-9). Benzene and Ethylbenzene concentrations were always less than method detection limits of 1.0 µg/L. Toluene was detected in April, June, and August with values ranging from 1 to 4 µg/L. o-Xylene concentrations were only detected one time in August with a low value of 1 µg/L. m,p-Xylene was detected in August at all three stations (BZ-3, -6, and -7) with values of 2 and 4 µg/L.

Beltzville Reservoir was in compliance with PADEP water quality standard for BTEX parameters during 2001. All of the concentrations measured were more than an order of magnitude less than PADEP water quality criteria for toxic substances. PADEP fish and aquatic criteria continuous concentrations (CCCs) for the 4 parameters are as follows: benzene, 128µg/L ; ethylbenzene, 580 µg/L; toluene, 330 µg/L; and xylene, 211 µg/L (Pa. Code, Title 25, Chapter 16).

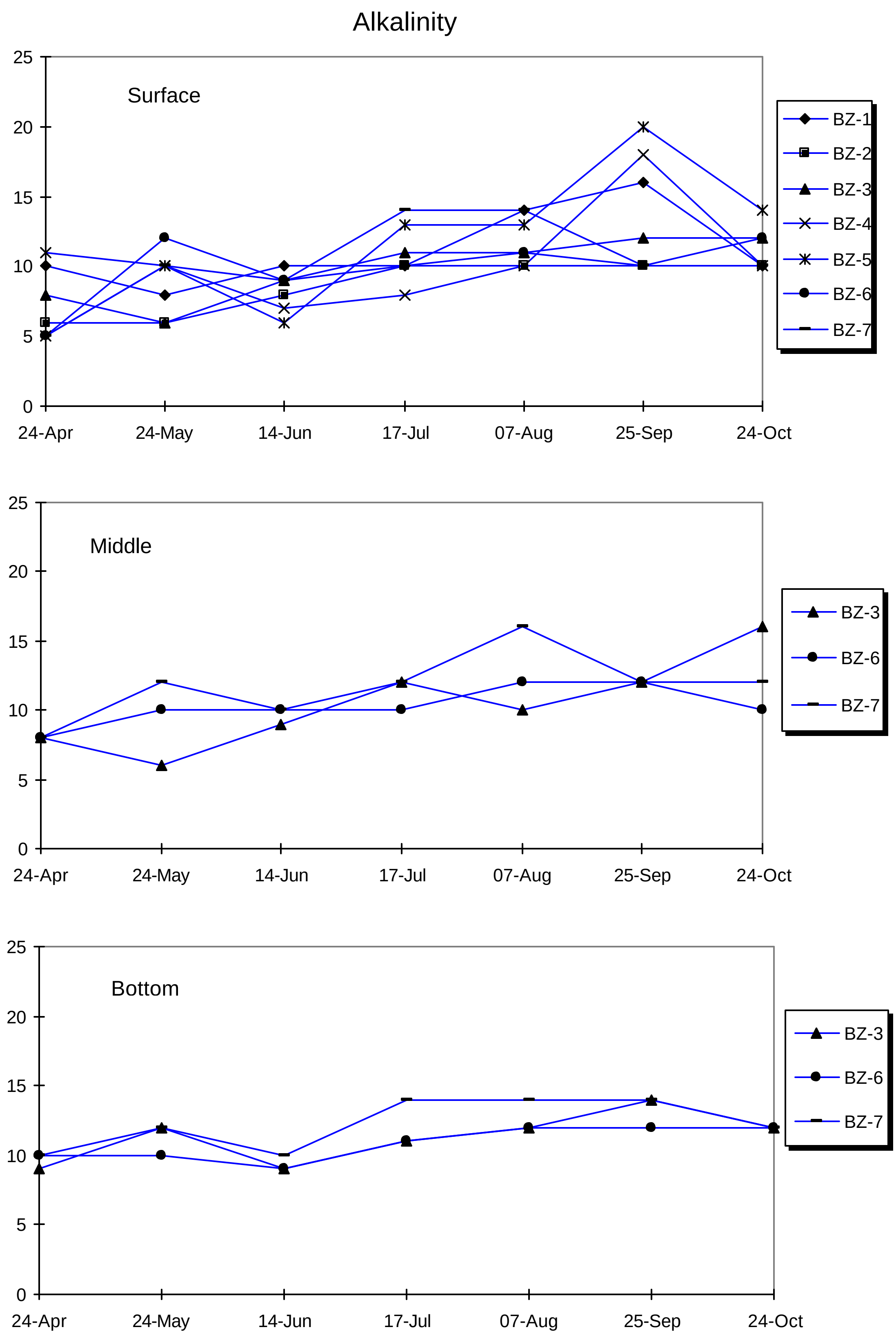

Figure 3-28. Alkalinity in surface, middle, and bottom waters of Beltzville Reservoir in 2001. (The PADEP water quality standard for alkalinity is a minimum concentration of 20 mg/L, except where natural conditions are less.)

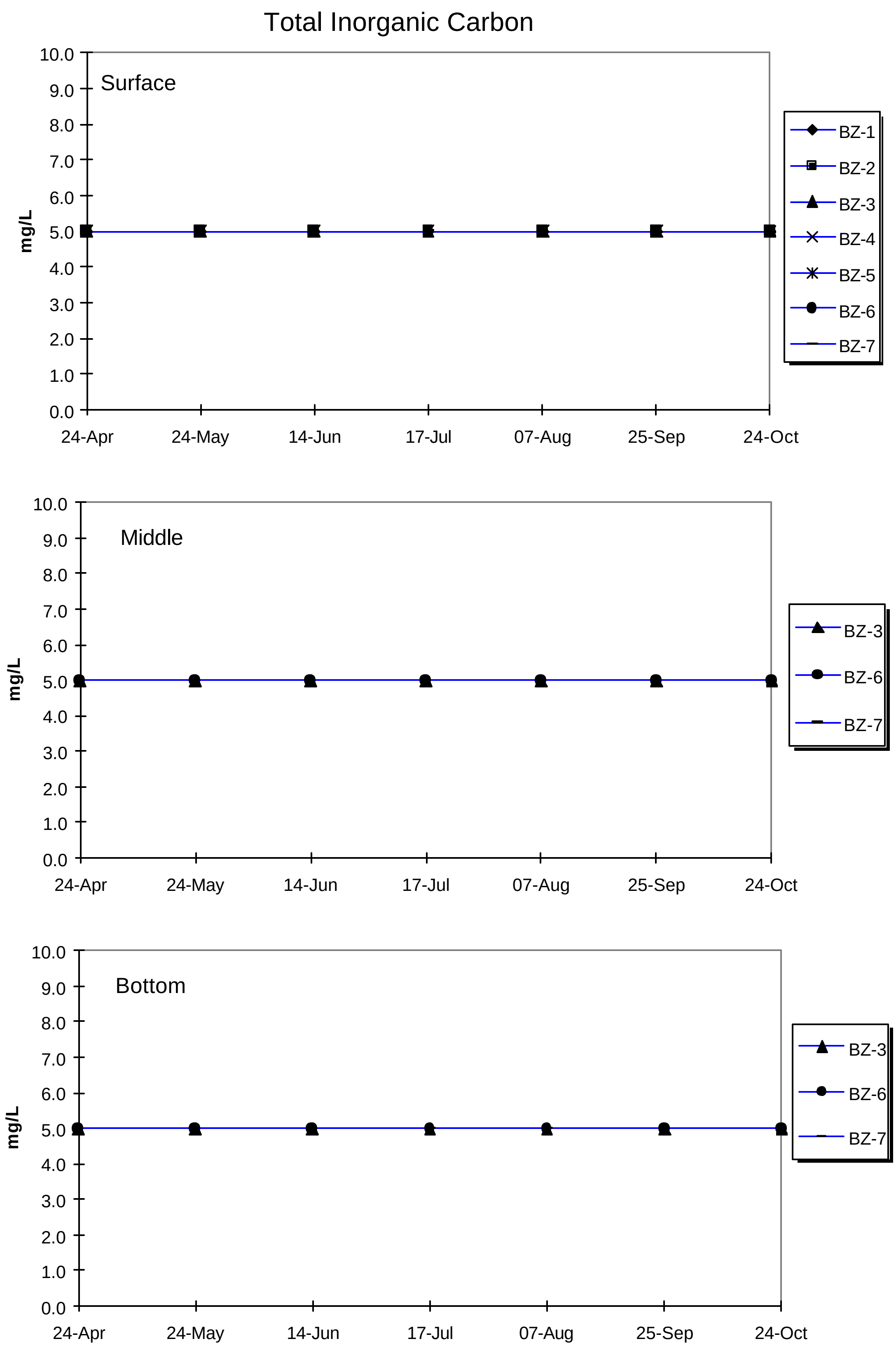

Figure 3-29. Total inorganic carbon in surface, middle, and bottom waters of Beltzville Reservoir in 2001.

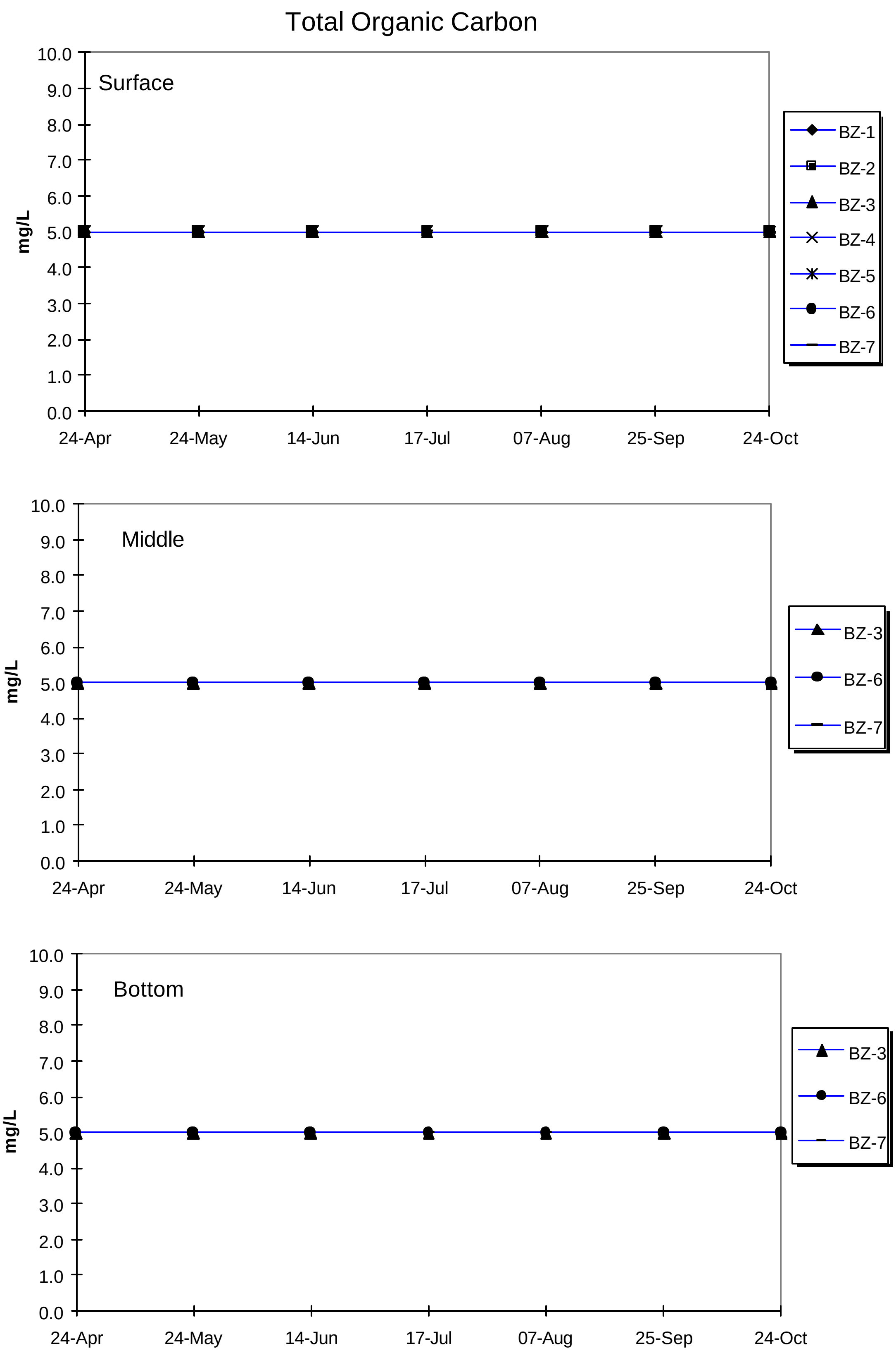

Figure 3-30. Total organic carbon in surface, middle, and bottom waters of Beltzville Reservoir in 2001.

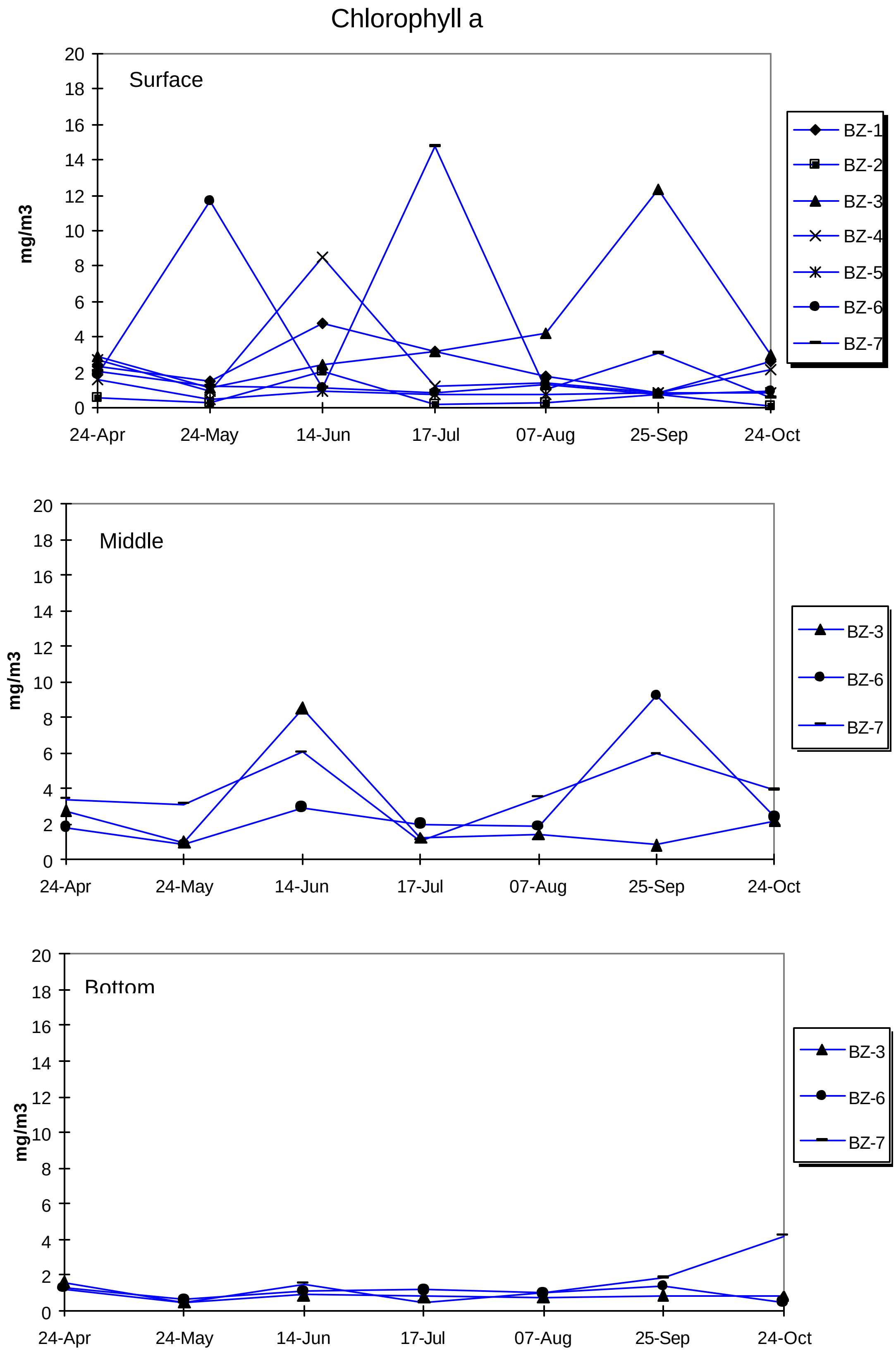

Figure 3-31. Total Chlorophyll *a* in surface, middle, and bottom waters of Beltzville Reservoir in 2001.

Table 3-9. Concentrations of BTEX parameters (?g/l) measured in surface water at Beltzville Reservoir during 2001.*

Station	Date	Benzene	Ethylbenzene	Toluene	o-Xylene	m,p-Xylene
BZ-3S	24-Apr	<1	<1	1	<1	<1
	24-May					
	14-June	<1	<1	2	<1	1
	17-July	<1	<1	<1	<1	<1
	7-Aug	<1	<1	3	1	4
	25-Sept	<1	<1	<1	<1	<1
	24-Oct	<1	<1	<1	<1	<1
BZ-6S	24-Apr	<1	<1	<1	<1	<1
	24-May					
	14-June	<1	<1	4	<1	<1
	17-July	<1	<1	<1	<1	<1
	7-Aug	<1	<1	2	<1	2
	25-Sept	<1	<1	<1	<1	<1
	24-Oct	<1	<1	<1	<1	<1
BZ-7S	24-Apr	<1	<1	1	<1	<1
	24-May					
	14-June	<1	<1	<1	<1	<1
	17-July	<1	<1	<1	<1	<1
	7-Aug	<1	<1	2	<1	2
	25-Sept	<1	<1	<1	<1	<1
	24-Oct	<1	<1	<1	<1	<1

* BTEX was not analyzed during May monitoring because of laboratory sample processing error

3.3 TROPHIC STATE DETERMINATION

Carlson's (1977) trophic state index (TSI) is a method of quantitatively expressing the magnitude of eutrophication for a lake. The trophic state analysis calculates separate indices for eutrophication based on measures of total phosphorus, chlorophyll *a*, and secchi disk. Index values for each parameter range on the same scale from 0 (least enriched) to 100 (most enriched). The resulting indices can also be compared to qualitative threshold values that correspond to levels of eutrophication: mesotrophic (TSI < 40), mesoeutrophic (TSIs from 50 to 60), and eutrophic (TSI > 60).

TSIs calculated for measures of secchi disk depth classified Beltzville Reservoir as both oligotrophic and mesotrophic during 2001 (Fig. 3-32). The TSI values ranged from 28 to 36 when it was oligotrophic and from 40 to 47 during the mesotrophic period.

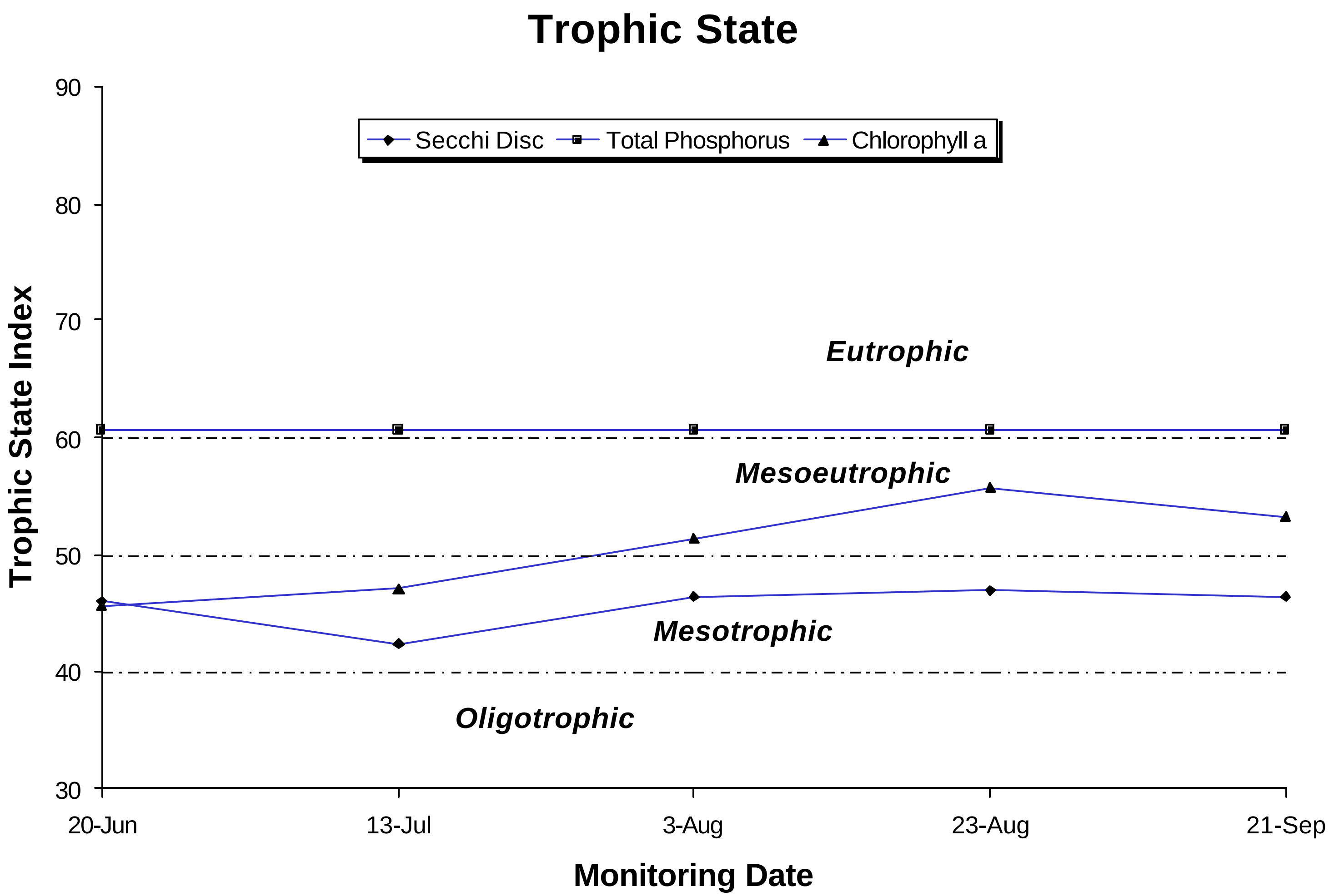

Figure 3-32. Trophic state indices calculated from secchi disk depth and concentrations of total phosphorus and chlorophyll *a* at Beltzville Reservoir in 2001

The TSI classification based on measures of total phosphorus was not feasible because of the high method detection limit for the parameter (Fig. 3-32). All concentrations measured at Beltzville Reservoir were less than the method detection limit of 0.05-mg/L. However, at this concentration, the TSI result of 60 is already bordering on eutrophic.

TSIs calculated for measures of chlorophyll *a* classified Beltzville Reservoir as mesotrophic (Fig. 3-32). Most of the TSI values ranged from 40 to 45. There were two monitoring dates that were not in that range. On 24 April, the TSI value was 37.67, which is in the oligotrophic level and on 25 September the TSI value was 52.13, which is in the mesoeutrophic level.

Carlson (1977) warned against averaging TSI values estimated for different parameters, and instead suggested giving priority to chlorophyll *a* in the summer and to phosphorus in the spring, fall, and winter. With this in mind, our estimation of the trophic state of the reservoir based on TSI's was mesotrophic during 2001.

The EPA (1983) also provides criteria for defining the trophic conditions of lakes of the north-temperate zone based on concentrations of total phosphorus, chlorophyll *a*, and secchi depth (Table 3-10). As related above, total phosphorus was not measured with enough precision to permit a substantive interpretation of trophic condition. The concentration of the method detection limit used for total phosphorus was eutrophic. Concentrations of chlorophyll *a* and secchi disk depth ranged from oligotrophic (April to June and October) to mesotrophic (July to September). Taking into account the general agreement between the EPA classifications with that of the TSIs, the trophic condition of Beltzville Reservoir was borderline oligotrophic-mesotrophic.

Table 3-10. EPA trophic classification criteria and average monthly measures for Beltzville Reservoir in 2001

Water Quality Variable	Oligo-trophic	Meso-trophic	Eutrophic	Apr	May	Jun	Jul	Aug	Sep	Oct
Total phos. (µg/l)	<10	10-20	>20	50	50	50	50	50	50	50
Chlorophyll (mg/m^3)	<4	4-10	>10	2.06	2.65	2.74	4.67	4.45	9.00	3.60
Secchi depth (m)	>3.7	2-4	<2	3.83	4.99	4.95	8.86	2.45	2.82	3.40

3.4 RESERVOIR BACTERIA MONITORING

Three forms of coliform bacteria contamination were monitored at Beltzville Reservoir during 2001 including total coliform, fecal coliform, and fecal streptococcus (Table 3-11). Total coliform includes *Escherica coli (E. coli)* and related bacteria that are associated with fecal discharges. Fecal coliform bacteria are a subgroup of the total coliform and are normally associated with waste derived from human and other warm-blooded animals. Fecal streptococcus refers to a group of bacteria that are common to warm-blooded animals other than humans. Because of the relative differences between fecal coliform and fecal streptococcus, their ratio can be used as a qualitative indicator of the source of fecal contamination.

Total coliform contamination of Beltzville Reservoir was generally low during 2001 monitoring period (Fig. 3-33). No station appeared to have consistently higher counts over the monitoring period. However, all stations during the autumn season (September and October), had higher total coliform counts that ranged from 60 to 560-clns/100ml. The highest counts of 560-clns/100-ml were found at station BZ-1, on 25 September.

Fecal coliform counts were generally lower counts than total coliform except for station BZ-4 (Fig. 3-34). On 24 October monitoring, BZ-4 had the highest count of 850-clns/100-mls. Counts within the reservoir (stations BZ-3, BZ-6, and BZ-7) were low throughout the monitoring period.

Fecal streptococcus contamination at Beltzville Reservoir had low counts below 200-clns/100-mls except for one station BZ-2 (Fig. 3-35). On 7 August station BZ-2 had the highest count of 330-clns/100-mls observed during monitoring period. Counts within the reservoir (stations BZ-3, BZ-6, and BZ-7) and downstream (station BZ-1) were low generally ranging less than 120-clns/100-ml.

With respect to PADEP water quality standards, coliform bacteria contamination was low at Beltzville Reservoir during 2001 (Table 3-12; Fig. 3-36). The PADEP standard for bacteria during the swimming season (from 1 May to 30 September) is a geometric mean not greater than 200 colonies/100-ml calculated for fecal coliform samples collected on consecutive days. Given that our regular monitoring was completed on one day, we calculated the geometric mean based on all the surface water samples collected on that day. Throughout the monitoring period, the geometric mean, calculated for each monitoring day, was less than the PADEP criteria.

Flow data from a USGS gauging station within the Beltzville Reservoir watershed (Kresgeville) were analyzed to qualitatively correlate precipitation patterns with coliform bacteria contamination (Fig. 2-2 through 2-6). Overall, coliform contamination did not appear to be strongly correlated with precipitation and streamflow. The only time that precipitation may have effected coliform bacteria contamination is during the monitoring on

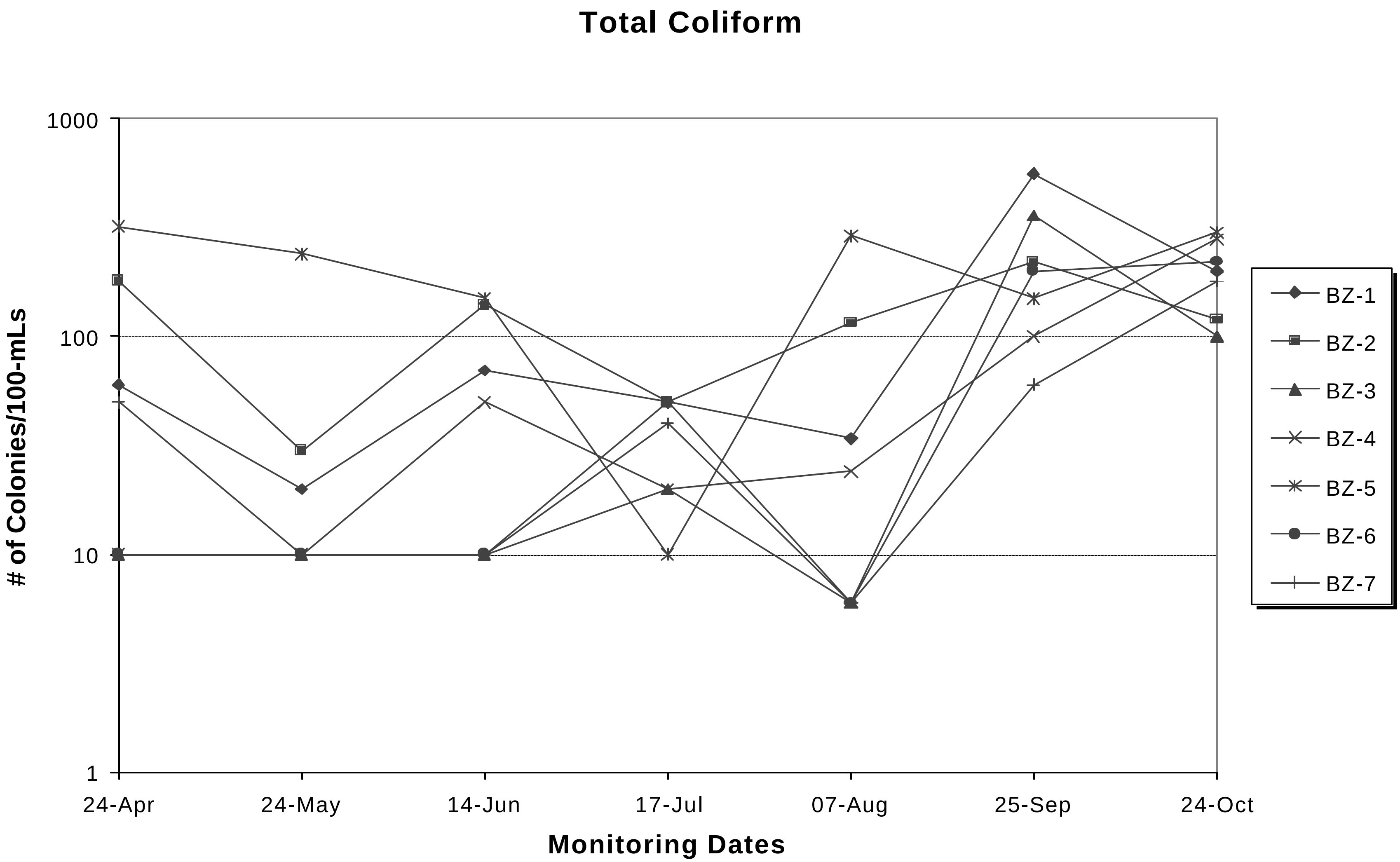

Figure 3-33. Total coliform counts in surface waters of Beltzville Reservoir in 2001

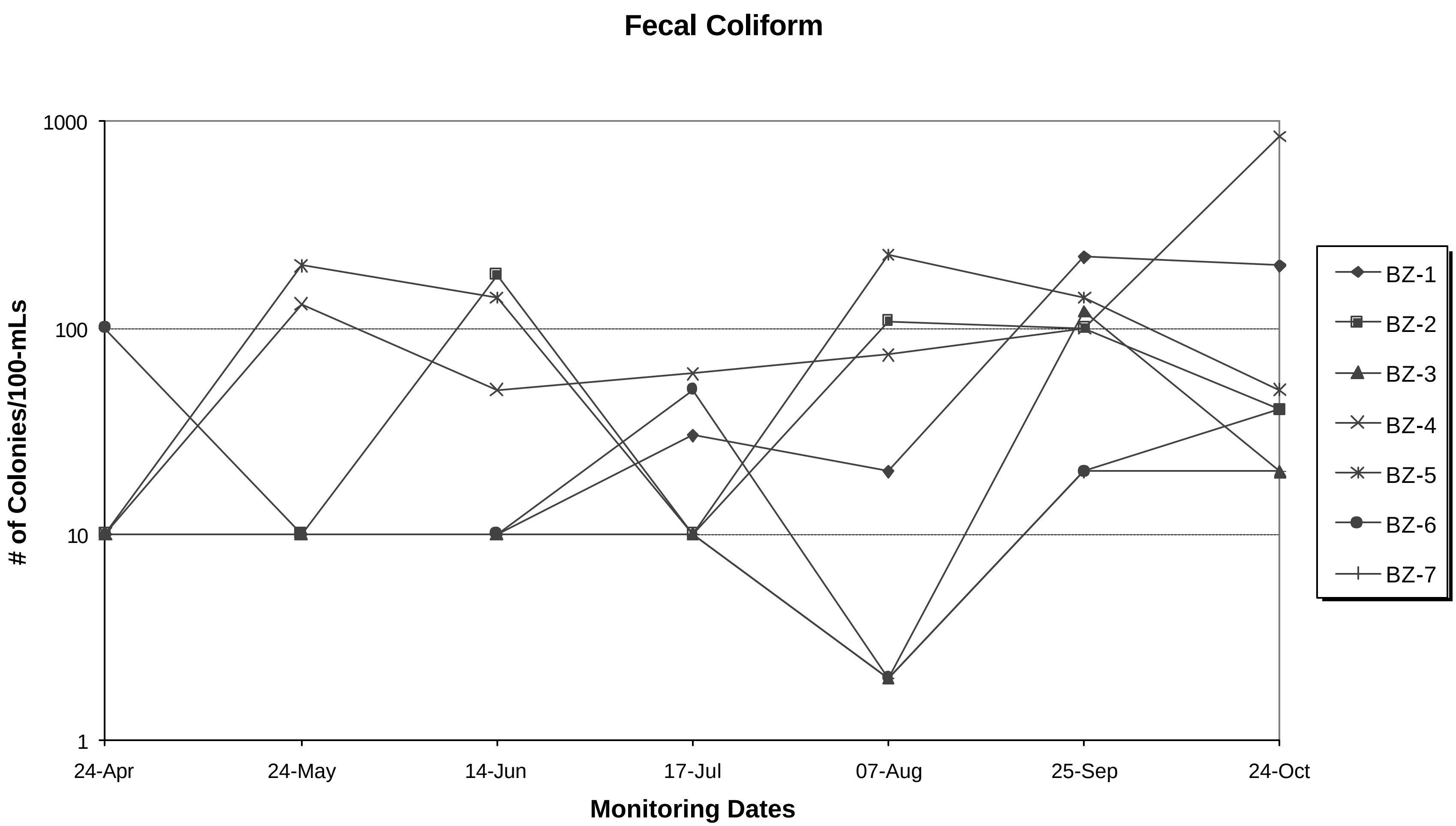

Figure 3-34. Fecal coliform counts in surface waters of Beltzville Reservoir in 2001. (PADEP water quality standard for fecal coliform is less than 200 colonies/100 mls.)

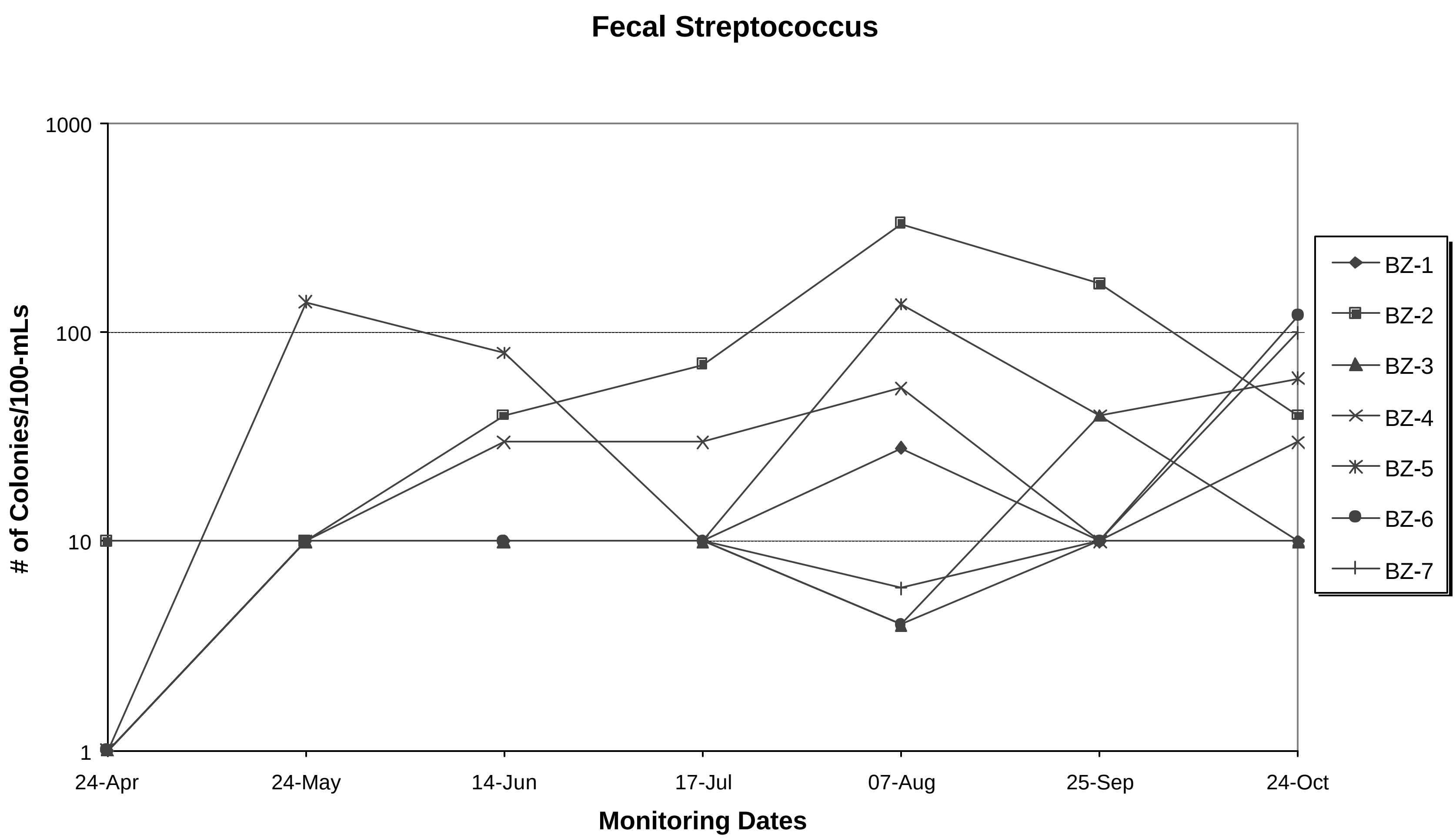

Figure 3-35. Fecal streptococcus counts in surface waters of Beltzville Reservoir in 2001

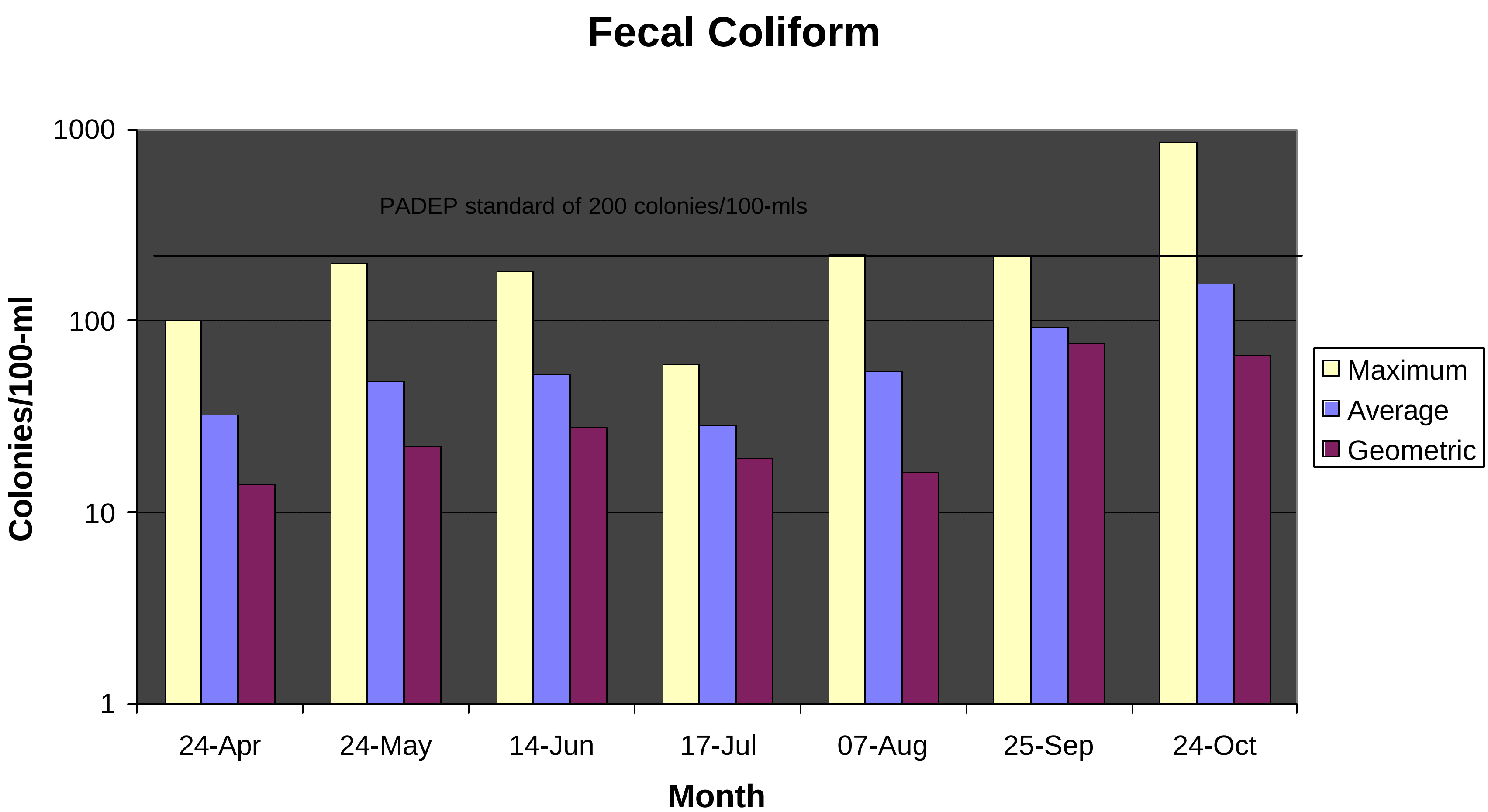

Figure 3-36. Maximum, average, and geometric mean of fecal coliform counts (colonies/100-ml) for all stations monitored at Beltzville Reservoir in 2001

25 September. This rain event exceeded four inches of rain and the total coliform counts are high ranging from 60 to 560-clns/100-mls.

Table 3-11. Bacteria counts (colonies/100 ml) at Beltzville Reservoir during 2001.

STATION	DATE	Total Coliform (TC)	Fecal Coliform (FC)	Fecal Strep (FS)	FC/FS
BZ-1S	24-Apr	60	< 10	1	NC
	24-May	20	< 10	< 10	NC
	14-Jun	70	< 10	10	NC
	17-Jul	50	30	10	3.00
	07-Aug	34	20	28	0.71
	25-Sep	560	220	< 10	NC
	24-Oct	200	200	< 10	NC
BZ-2S	24-Apr	180	< 10	10	NC
	24-May	30	10	< 10	NC
	14-Jun	140	180	40	4.50
	17-Jul	50	< 10	70	NC
	07-Aug	116	108	330	0.33
	25-Sep	220	100	170	0.59
	24-Oct	120	40	40	1.00
BZ-3S	24-Apr	10	10	< 1	NC
	24-May	< 10	< 10	< 10	NC
	14-Jun	< 10	< 10	< 10	NC
	17-Jul	20	< 10	< 10	NC
	07-Aug	6	< 2	4	NC
	25-Sep	360	120	40	3.00
	24-Oct	100	20	< 10	NC
BZ-4S	24-Apr	10	10	< 1	NC
	24-May	10	130	10	13.00
	14-Jun	50	50	30	1.67
	17-Jul	20	60	30	2.00
	07-Aug	24	74	54	1.37
	25-Sep	100	100	< 10	NC
	24-Oct	280	850	30	28.33
BZ-5S	24-Apr	320	< 10	1	NC
	24-May	240	200	140	1.43
	14-Jun	150	140	80	1.75
	17-Jul	10	< 10	10	NC
	07-Aug	290	226	136	1.66
	25-Sep	150	140	40	3.50
	24-Oct	300	50	60	0.83
	24-Oct	220	40	120	0.33

Table 3-11. (Continued)					
STATION	**DATE**	**Total Coliform (TC)**	**Fecal Coliform (FC)**	**Fecal Strep (FS)**	**FC/FS**
BZ-6S	24-Apr	< 10	100	< 1	NC
	24-May	10	< 10	< 10	NC
	14-Jun	< 10	< 10	< 10	NC
	17-Jul	50	50	< 10	NC
	07-Aug	6	2	4	0.50
	25-Sep	200	20	< 10	NC
BZ-7S	24-Apr	50	< 10	< 1	NC
	24-May	< 10	< 10	< 10	NC
	14-Jun	< 10	10	< 10	NC
	17-Jul	40	< 10	< 10	NC
	07-Aug	6	2	6	0.33
	25-Sep	60	20	< 10	NC
	24-Oct	180	20	100	0.20

Table 3-12. Summary statistics of fecal coliform counts (colonies/100-ml) among all stations of Beltzville Reservoir during 2001. (PADEP water quality standard for fecal coliforms is a geometric mean not greater than 200 colonies/100-ml.)			
	Geometric Mean	**Arithmetic Mean**	**Maximum Count**
24-Apr	13.9	32.5	100.0
24-May	22.1	48.8	200.0
14-Jun	27.7	52.5	180.0
17-Jul	19.0	28.8	60.0
07-Aug	16.2	54.5	226.0
25-Sep	76.1	92.5	220.0
24-Oct	66.0	157.5	850.0

An analysis for trends was conducted on fecal coliform data collected during 2001 and historical data collected over the past 21 years. Average counts at reservoir and downstream stations were analyzed separately, for trends occurring in spring and summer sessions. None of the regression lines were significant for either location in either season (Figs. 3-37 and 3-38). However, the plotted averages for both reservoir and downstream sites over the past 21-year time frame reflect consistently low fecal coliform contamination.

Seasonal trend analyses for total and fecal coliform contamination in surface water were also calculated for individual stations using the Mann-Kendall Statistic (Tables 3-13 and 3-14). The tests were conducted for spring (April through June) and summer (July through September) seasons for seven stations with extensive historical data. No trends were observed for total coliforms (Table 3-13). For fecal coliforms there were two trends that were

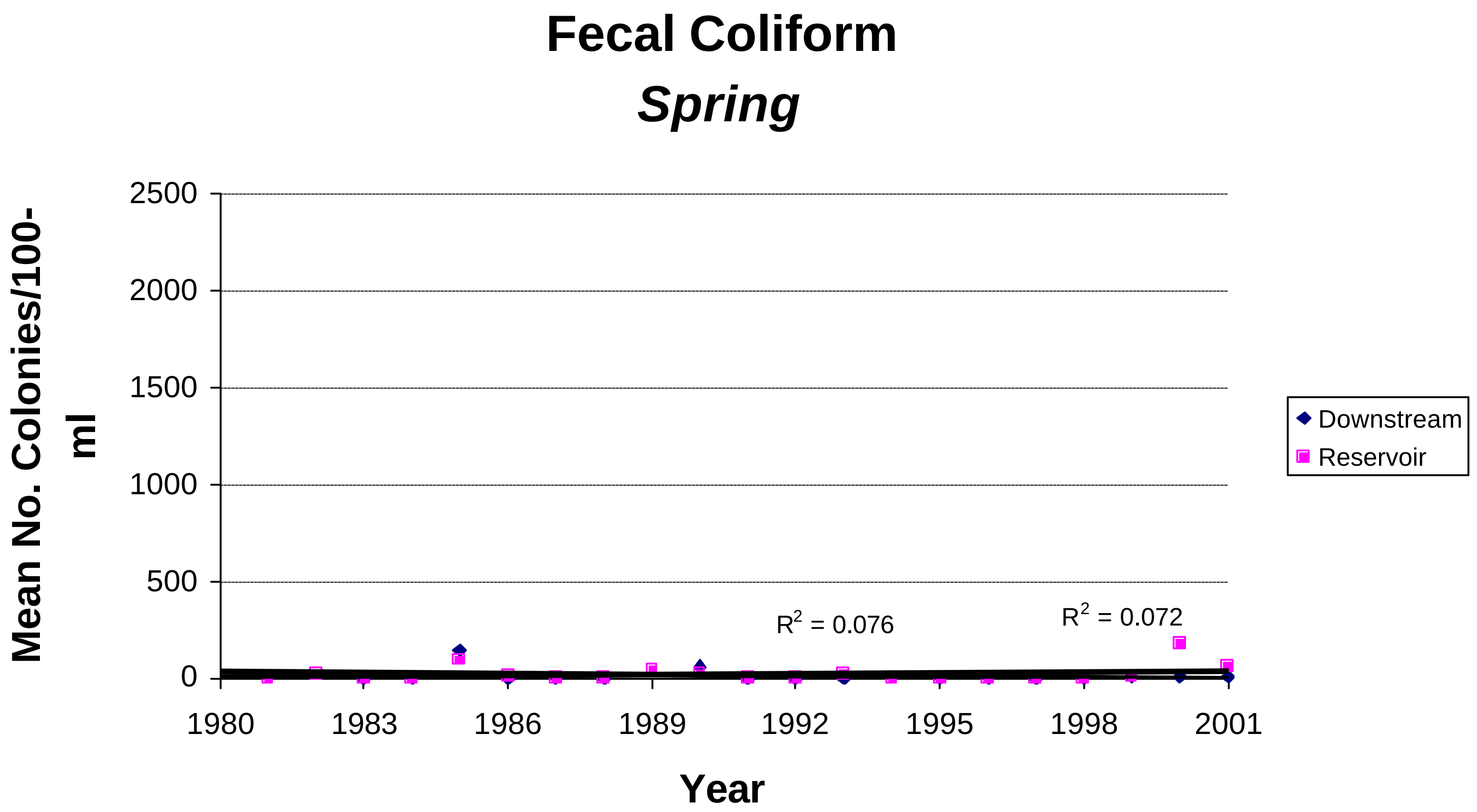

Figure 3-37. Seasonal trends of fecal coliform in spring at Beltzville Reservoir

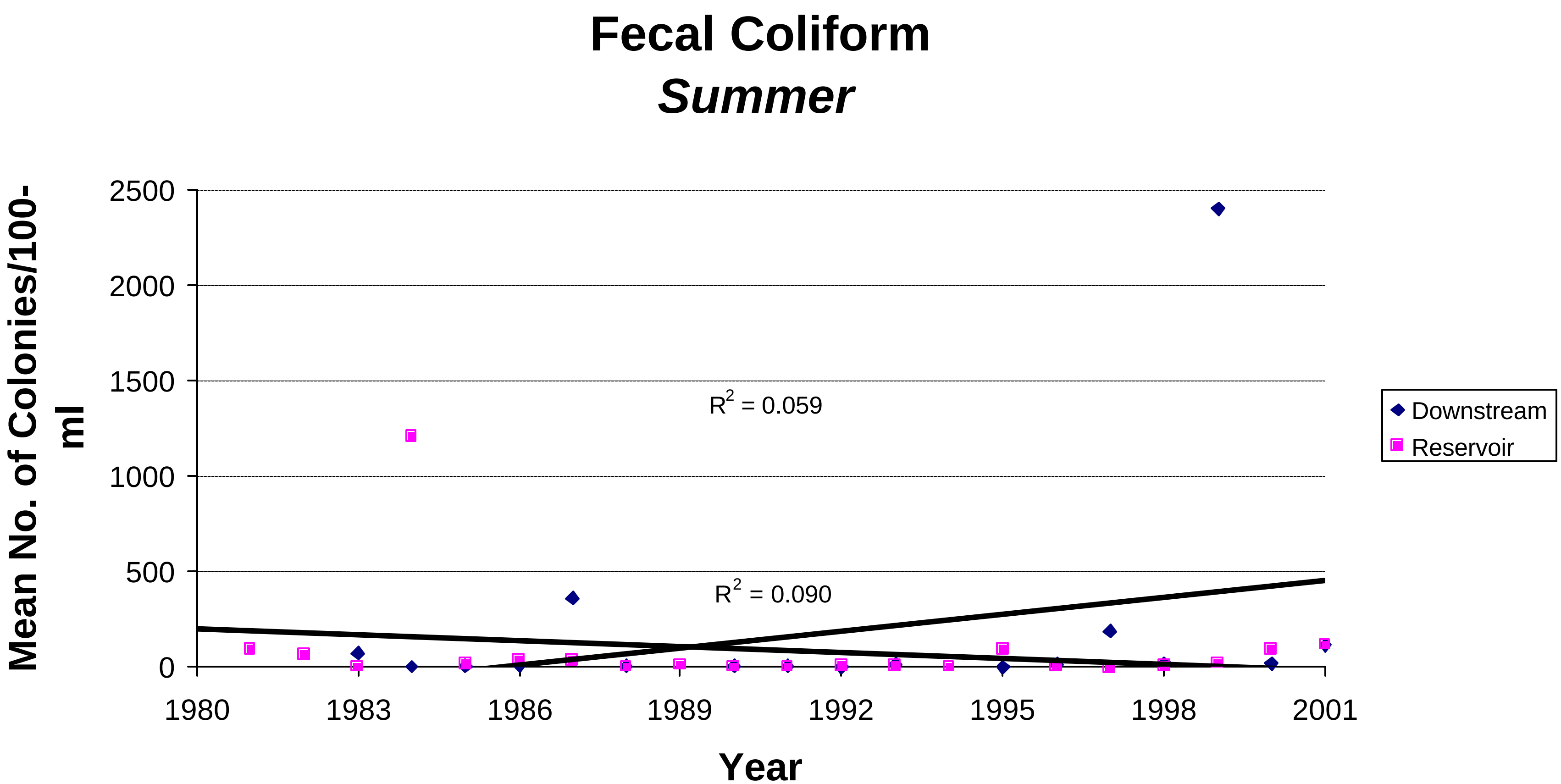

Figure 3-38. Seasonal trends of fecal coliform in summer at Beltzville Reservoir

determined to be significant; station BZ-5 and BZ-6 for fecal coliform contaminants in the spring (Table 3-13). The rate of increase estimated for the trend was 8.58 and 3.0 colonies/100-ml/year.

Table 3-13. Seasonal trends of fecal coliforms/100-ml at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic.

Station	# of Years spring/summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate
Surface Water					
BZ-1	17/16	NS	-0.06	NS	8.06
BZ-2	21	NS	-4.75	NS	6.11
BZ-3	21/20	NS	-2.78	NS	-1.14
BZ-4	21/20	NS	-6.75	NS	-3.54
BZ-5	21	NS	-18.61	NS	3.64
BZ-6	6	NS	0.5	NS	3.67
BZ-7	6	NS	-2	NS	-72.33

Table 3-14. Seasonal trends of fecal coliforms/100-ml at individual stations of Beltzville Reservoir calculated with the Mann-Kendall Statistic.

Station	# of Years spring/summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate
Surface Water					
BZ-1	17	NS	0.12	NS	1.07
BZ-2	21	NS	0.82	NS	3.35
BZ-3	21	NS	-0.13	NS	-1.07
BZ-4	21	NS	-0.42	NS	0.82
BZ-5	21	< 0.05	8.58	NS	6.37
BZ-6	6	< 0.05	3.0	NS	3.25
BZ-7	6	NS	0.75	NS	-104

The ratio of fecal coliform to fecal streptococcus counts can be used to qualitatively identify sources of bacteria contamination (McComas 1993). The ratio is characteristic for several animal species and certain waste disposal practices; for human waste, the ratio is 4 to 1. Use of the ratio was limited to the extent that counts at most stations were at or less than method detection limits for one or both coliform parameters. Out of a total of 49 perspective ratios, only 21 were calculated. Of these, ratios ranged from 0.2 to 28.33, and only 10 fell within the range one would expect for human waste sources (Table 3-12).

3.5 SEDIMENT PRIORITY POLLUTANT MONITORING

Sediment samples were collected at station BZ-6 and analyzed for priority pollutant contaminants, Group 2 – semivolatile organic compounds and metals. Resulting concentrations were compared to New Jersey Soil Cleanup Criteria (NJDEP 1999; Table 3-15). The NJDEP criteria are human health based with categories addressing residential and non-residential settings, and impacts to groundwater. For our comparison, we reported the most conservative of the three criteria.

Table 3-15. Metals and semivolatiles (Group II) concentrations measured in sediments of Beltzville Reservoir in 2001.

Parameter	Units	Method Detection Limit	BZ-6	USACE Screening Level	References
CONVENTIONALS					
Percent Solids	%	0.1	20.4		
METALS					
Aluminum	mg/kg	97.6	17,674.40		
Antimony	mg/kg	2	ND	14	NJDEP 1999
Arsenic	mg/kg	4.9	ND	20	NJDEP 1999
Barium	mg/kg	0.5	161.1	700	NJDEP 1996
Beryllium	mg/kg	0.5	1.1	2	NJDEP 1999
Cadmium	mg/kg	0.5	12.3	39	NJDEP 1999
Calcium	mg/kg	2	1513.6		
Chromium	mg/kg	0.5	26.1	33	MacDonald 1992
Cobalt	mg/kg	2	26.9		
Copper	mg/kg	0.5	32.8	600	NJDEP 1999
Iron	mg/kg	24.4	35,251.20		
Lead	mg/kg	2	105.5	400	NJDEP 1999
Magnesium	mg/kg	2	2,216.60		
Manganese	mg/kg	0.5	907.2		
Mercury	mg/kg	0.1	0.14	14	NJDEP 1999
Nickel	mg/kg	0.5	35.1	250	NJDEP 1999
Potassium	mg/kg	2	1152.3		
Selenium	mg/kg	4.9	ND	63	NJDEP 1999
Sodium	mg/kg	2	130.8		
Vanadium	mg/kg	2	45.7	370	NJDEP 1999
Zinc	mg/kg	0.5	682.6	1500	NJDEP 1999

Table 3-15. (Continued)					
Parameter	**Units**	**Method Detection Limit**	**BZ-6**	**USACE Screening Level**	**References**
SVOC (mg/kg)					
2,4,5-Trichlorophenol	mg/kg	0.490	ND	5,600	NJDEP 1999
2,4,6-Trichlorophenol	mg/kg	0.490	ND	62	NJDEP 1999
2,4-Dichlorophenol	mg/kg	0.490	ND	170	NJDEP 1999
2,4-Dimethylphenol	mg/kg	0.490	ND	10	NJDEP 1999
2,4-Dinitrophenol	mg/kg	0.490	ND	10	NJDEP 1999
2-Chlorophenol	mg/kg	0.490	ND	280	NJDEP 1999
2-Methylphenol	mg/kg	0.490	ND	2,800	NJDEP 1999
2-Nitrophenol	mg/kg	0.490	ND		
3-Methylphenol	mg/kg	0.490	ND		
4,6-Dinitro-2-methylphenol	mg/kg	0.490	ND		
4-Chloro-3-methylphenol	mg/kg	0.490	ND	10,000	NJDEP 1999
4-Methylphenol	mg/kg	0.490	ND	2,800	NJDEP 1999
4-Nitrophenol	mg/kg	0.490	ND		
Benzoic acid	mg/kg	0.490	ND		
Benzyl alcohol	mg/kg	0.490	ND	10,000	NJDEP 1999
Pentachlorophenol	mg/kg	0.490	ND	6	NJDEP 1999
Phenol	mg/kg	0.490	ND	10,000	NJDEP 1999

A total of 21 metals were analyzed in Beltzville Reservoir sediments (Table 3-15). None of compounds analyzed exceeded the screening level.

A total of 17 semivolatile organics (SVOC) were analyzed in Beltzville Reservoir sediments (Table 3-15). None of the compounds were detected in the sediment sample from station BZ-6 (Table 3-15).

3.6 DRINKING WATER

Drinking water from the public water fountain located in the overlook building of Beltzville Reservoir was monitored for compliance with PADEP water quality standards for primary and secondary contaminants, and quarterly monitored inorganic nitrogen (nitrate and nitrite) and coliform bacteria contaminants during 2001. Drinking water samples were analyzed in duplicate, comprising initial and confirmation samples. For matters of reporting, only if the result of the initial sample was not in compliance with water quality standards, the result of the confirmation sample was also reported.

3.6.1 Primary and Secondary Contaminants

Beltzville Reservoir drinking water was in compliance with PADEP water quality standards for all the primary and secondary contaminants (Table 3-16). As part of drinking water compliance monitoring, Safe Drinking Water Act (SDWA) form 4 for the reporting of results of primary and secondary drinking water contaminants were submitted to appropriate state environmental agencies.

Table 3-16. Concentrations of primary and secondary contaminants in drinking water at Beltzville Reservoir in 2001. Shaded values indicate results that exceeded Pennsylvania State drinking water standards; in these instances the result of a second sample is also reported.

Parameter	Sampling Date 14 June	PADEP Regulatory Level	Detection Limits	EPA Method
Aluminum	ND	0.2	0.02	200.7
Antimony	ND	0.006	0.05	200.7
Arsenic	ND	0.05	0.05	200.7
Barium	ND	2.0	0.005	200.7
Cadmium	ND	0.005	0.005	200.7
Chromium	ND	0.1	0.005	200.7
Copper	0.589	1.3	0.005	200.7
Iron	0.143	0.3	0.005	200.7
Lead	0.004	0.015	0.001	200.8
Magnesium	2.02	NL	0.02	200.7
Manganese	0.042	0.05	0.005	200.7
Mercury	ND	0.002	0.0002	245.1
Nickel	0.006	0.1	0.005	200.7
Selenium	ND	0.05	0.05	200.7
Silver	ND	0.1	0.005	200.7
Sodium	3.49	NL	0.02	200.7
Thallium	ND	0.002	0.05	200.7
Zinc	2.476	5.0	0.005	200.7
Chloride	2	250	1	325.3
Cyanide	ND	0.2	0.007	SM 4500CN-C&E
Fluoride	ND	2.0	0.1	SM 4500F-C
Foaming Agents	ND	0.5	0.05	SM 5540C
PH	7.14	6.5-8.5	+/-0.01	150.1
Sulfate	11	250.0	5	375.4
Total Dissolved Solids	34	500.0	10	SM 2540C

All results, criteria and detection limits are expressed in mg/L except pH which is expressed in positive/negative
ND – Not Detected

3.6.2 Inorganic Nitrogen and Coliform bacteria

Beltzville Reservoir drinking water was in compliance with PADEP criteria for nitrate and nitrite (Table 3-17). Concentrations of nitrate and nitrite were not detected throughout the monitoring period. On 14 June during a scheduled sampling event, total coliform was present in the drinking water sample. A test collected on 21 June also detected coliform bacteria. To further investigate the source of bacteria four additional samples were collected on 26 June (Table 3-18). Water was collected from the observation fountain, the office fountain, the office sink, and the ranger's house faucet and tested for total coliform and fecal coliform. Coliform was present in the samples collected from the office sink. An additional sample collected on 5 July indicated that total coliform present. Subsequently, in late July, the USACE personnel at the Beltzville Reservoir office added a chlorine system to the water supply. On 7 August and there was no coliform bacteria contamination present. Additionally, coliform was absent on the scheduled 24 October sampling event. Following laboratory testing, drinking water monitoring results were recorded on Safe Drinking Water Act (SDWA-S and SDWA-4) forms and submitted to the appropriate state environmental agencies.

3.6.3 Historical Drinking Water Quality

Drinking water quality has been monitored at Blue Marsh Reservoir over the past 20 years. Versar (1996) compiled the results from all of the previous years into a single database to facilitate water quality comparisons. Historical data from drinking water quality parameters were compared to their respective PADEP standards. Of 26 parameters summarized, 7 had incidences of noncompliance with drinking water standards from 1983 to present (Table 3-18. Lead, pH, and corrosivity were most often not in compliance with PADEP criteria.

Table 3-17. Concentrations of nitrate and nitrite, and results of coliform bacteria monitoring of drinking water sampled from the public water fountain located in the overlook building at Beltzville Reservoir during 2001

Parameter	**Sampling Dates**					**PADEP Regulatory Level**	**Detection Limits**	**Method**
	14 June	**21 June**	**5 July**	**7 August**	**24 October**			
Nitrate as N (mg/L)	ND			ND	ND	10.0	0.5	SM4500
Nitrite as N (mg/L)	ND			ND	ND	1.0	0.5	SM4500
E. coli (CFU)	Absence	Absence	Absence	Absence	Absence	Presence	1	SM 9223
Total Coliform (CFU)	Presence	Presence	Presence	Absence	Absence	Presence	1	SM 9223

CFU – colony forming units
ND – Not Detected

Table 3-18. Results of coliform bacteria monitoring of drinking water sampled on 26 June at various places at the Beltzville Reservoir after the testing on 21 June. (Detection limit 10-clns/100-mls)

	Observation Fountain	**Office Fountain**	**Office Sink**	**Rangers House Faucet**
Total Coliform (10-clns/100-mls)	ND	ND	40	ND
Fecal Coliform (10-clns/100-mls)	ND	ND	10	ND

ND – Not Detected

4.0 SUMMARY

The USACE implements an annual monitoring program at Beltzville Reservoir to evaluate lake water quality and potential public health concerns. In general, the monitoring programs emphasize measuring water quality and sediment contamination. Monitoring results are compared to state and federal criteria to evaluate the condition of Beltzville Reservoir. The 2001 monitoring program of Beltzville Reservoir comprised four major elements:

- water quality of physical/chemical parameters at fixed stations from April through October;
- monthly water quality monitoring of nutrient parameter concentrations and bacteria contamination from April to October;
- sediment priority pollutant monitoring for semivolatile organic compounds and metals at a fixed station in the deepest part of the reservoir; and
- drinking water monitoring of the public water fountain in the overlook building.

4.1 WATER QUALITY MONITORING

Surface and downstream water quality were in compliance with state standards for dissolved oxygen concentrations (minimum of 5 mg/L). Dissolved oxygen in the lower water column of the deeper portions of the reservoir was below standards during September and October. Measures of pH throughout the water column of the reservoir met the conditions of the water quality standard. Beltzville Reservoir contained acceptable levels of nutrients during 2001. Ammonia, nitrate + nitrite, TDS, and alkalinity were in compliance with state water quality standards throughout the reservoir watershed. Organic contamination in the reservoir was relatively low during 2001. Concentrations of toluene, o-xylene and m,p-xylenes were rarely measured above detection limits throughout the monitoring period.

The trophic status of Beltzville Reservoir was defined, independently, Carlson's trophic state indices and EPA criteria. Carlson's trophic state indices indicated the reservoir to be in mesotrophic condition during 2001. EPA criteria indicated the reservoir to be in oligotrophic/mesotrophic condition during 2001.

Beltzville Reservoir was in compliance with the PADEP water quality standard for bacteria contamination during 2001. The geometric means among samples collected each month were always less than 200 colonies/100-ml. Ratios of fecal coliform to fecal streptococcus counts were ambiguous and did not appear to identify a source of bacteria contamination.

4.2 SEDIMENT PRIORITY POLLUTANT MONITORING

Beltzville Reservoir was in compliance with NJDEP soil guidelines in 2001. Concentrations of metals and semivolatile organic compounds were less than screening guidelines.

4.3 MONITORING PROGRAM TRENDS

Analysis of long-term downstream and reservoir trends suggested that few water quality changes have occurred in Beltzville Reservoir over the past 26 years.

Trends computed for individual stations using the Mann-Kendall test indicated significant water quality changes at several locations in the Beltzville Reservoir watershed. Ammonia appears to be decreasing at most stations throughout the reservoir and downstream in both seasons. Total phosphorus was decreasing only at station BZ-4 in summer. TDS was decreasing at station BZ-3 in both seasons, and at stations BZ-4 and BZ-5 in the summer. Additionally, TDS was increasing at station BZ-6 in the spring. BOD was decreasing in the summer at station BZ-1, downstream of the reservoir. Fecal coliform was increasing at stations BZ-5, -6, and –7 in the spring and decreasing at BZ-3 in the summer.

4.4 DRINKING WATER MONITORING

Drinking water from the public fountain located in the overlook building of Beltzville Reservoir was in compliance with most water quality standards in 2001. Repeated tests for Coliform presence in the drinking water was out of compliance in the early half of the summer; however, upon installation of a chlorination system into the water supply, coliform was absent in subsequent drinking water monitoring tests.

5.0 RECOMMENDATIONS

The USACE intends to continue monitoring of the Beltzville Reservoir in future years to evaluate trends and to identify potential environmental problems related to human development within the watershed. The USACE is continually seeking to improve the quality and cost-effectiveness of the information gathered as part of this effort. Below, we present several recommendations for improving the monitoring program:

Recommendation 1: Add a monitoring component to assess relative loadings of nutrients, toxic chemicals, and sediment from each of the major watersheds draining into the Beltzville reservoir.

The Beltzville Reservoir contains several feeder streams which drain different watersheds. Each of these watersheds has different land use characteristics (e.g., residential, agricultural, forested ecosystems) each of which may contribute a different suite of chemical loadings to the reservoir. Management of water quality problems in the reservoir will require an understanding of the relative loadings of nutrients, toxics, and sediment from each watershed, and in which watersheds these loadings are changing most rapidly. Developing this information could be accomplished by deploying automatic samplers into the major feeder streams to obtain composite samples over randomly selected 24-hour periods, stratified by season, and by conducting special sampling during storm events.

Recommendation 2: Conduct a watershed modeling effort.

A survey of all nutrient and pollutant sources (point source and non-point source) within the Beltzville Reservoir watershed could be conducted and presented in a GIS format. Using predicted loadings from the various pollutant sources identified within the watershed, a simple nutrient/DO prediction model could be constructed and verified with the long-term data set. This model could be used to predict the degree of improvement in reservoir water quality that could be obtained through various nutrient control measures such as sewage treatment upgrades and reduced fertilizer application to farmlands.

6.0 REFERENCES

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography 22:361-369.

EPA. 1983. Technical Guidance Manual for Performing Waste Load Allocations. Book 4 Lakes and Impoundments. Chapter 2 Nutrient/Eutrophication Impacts. U.S. Environmental Protection Agency Washington, DC.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management, 19: 881-97.

MacDonald, D.D., S.L. Smith, M.P. Wong, and P. Mudrock. 1992. The development of Canadian marine environmental quality guidelines. Ecosystem Sciences and Evaluation Directorate, Conservation and Protection, Environmental Canada, Ottawa, Ontario.

McComas, Steve. 1993. Lake Smarts, the First Lake Maintenance Handbook. Terrene Institute.

New Jersey Department of Environmental Protection. 1984. Cleanup standards for contaminated sites, N.J.H.C. 7: 260. May 12, 1999. Trenton, NJ.

Pennsylvania Code, Title 25. Environmental Resources, Chapter 93 Water Quality Standards. Department of Environmental Resources, Bureau of Water Quality Management, Division of Assessment and Standards. 1992. Harrisburg, Pennsylvania.

American Public Health Association (APHA). 1992. Standard Methods for the Examination of Water and Wastewater, 18th Edition. Prepared by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation. Washington DC.

USGS. 1993. Water resources data Pennsylvania 1993. Volume 1 Delaware Basin. U.S. Geological survey water-data report PA-93-1. Lemoyne, PA.

Versar. 1995. Blue Marsh historical database and trend analysis. Prepared for U.S. Army Corps of Engineers, Philadelphia District by Versar, Inc., Columbia, MD.

Versar. 1996. Historical database appendices for Blue Marsh, Beltzville, F.E. Walter, and Prompton Reservoirs.

Van Diver, B.B. 1990. Roadside geology of Pennsylvania. Mountain Press Publishing Co., Missoula, MT.

APPENDIX A

STRATIFICATION MONITORING

Table A-1. Summary of stratification monitoring at Betzville Reservoir in 2001

Station	DATE	Depth (F)	Temp ?C	pH	DO (mg/L)	DO (%)	Cond (mS/cm)
BZ1	24-Apr	0	11.57	7.18	*	*	0.086
	24-May	0	8.25	8.24	11.66	99.10	0.078
	14-Jun	0	10.81	6.84	10.53	95.10	0.078
	17-Jul	0	12.15	6.18	9.67	90.06	0.080
	07-Aug	0	12.49	6.64	9.33	87.56	0.077
	25-Sep	0	13.54	6.62	8.20	78.78	0.085
	24-Oct	0	12.09	7.02	8.20	76.30	0.079
BZ2	24-Apr	0	11.83	7.66	*	*	0.070
	24-May	0	11.87	8.15	10.57	97.81	0.070
	14-Jun	0	14.10	6.91	9.69	94.25	0.071
	17-Jul	0	16.49	6.59	9.27	94.91	0.065
	07-Aug	0	17.72	6.50	8.43	88.55	0.066
	25-Sep	0	15.31	7.04	7.85	78.38	0.073
	24-Oct	0	11.70	7.00	7.56	69.70	0.057
BZ3	24-Apr	100	5.18	6.88	*	*	0.082
		95	5.19	6.87	*	*	0.082
		90	5.20	6.86	*	*	0.082
		85	5.24	6.86	*	*	0.082
		80	5.27	6.85	*	*	0.082
		75	5.27	6.86	*	*	0.082
		70	5.32	6.86	*	*	0.082
		65	5.60	6.87	*	*	0.081
		60	5.74	6.89	*	*	0.081
		55	5.83	6.89	*	*	0.081
		50	6.01	6.91	*	*	0.081
		45	6.38	6.94	*	*	0.080
		40	6.66	6.96	*	*	0.080
		35	6.99	6.98	*	*	0.080
		30	7.30	7.02	*	*	0.080
		25	7.61	7.04	*	*	0.080
		20	8.72	7.11	*	*	0.079
		15	10.14	7.21	*	*	0.079
		10	10.38	7.23	*	*	0.080
		5	10.49	7.26	*	*	0.080
		0	10.78	7.28	*	*	0.080

Table A-1. (Continued)							
Station	**DATE**	**Depth (F)**	**Temp ?C**	**pH**	**DO (mg/L)**	**DO (%)**	**Cond (mS/cm)**
BZ3 (Con't)	24-May	95	5.75	7.98	8.51	67.97	0.079
		90	5.73	7.80	10.06	80.31	0.078
		85	5.85	7.72	8.38	67.10	0.078
		80	6.12	7.60	8.62	69.50	0.078
		75	6.23	7.57	8.70	70.34	0.078
		70	6.39	7.44	8.56	69.49	0.078
		65	6.64	7.42	8.48	69.27	0.078
		60	6.85	7.39	8.43	69.23	0.078
		55	7.13	7.38	8.43	69.71	0.077
		51	7.28	7.36	8.77	72.79	0.077
		50	7.33	7.30	8.34	69.31	0.077
		45	7.62	7.29	8.42	70.47	0.077
		40	8.45	7.30	8.68	74.13	0.077
		35	9.27	7.33	9.04	78.74	0.077
		30	11.36	7.37	8.77	80.22	0.076
		25	15.84	7.45	8.37	84.52	0.076
		20	15.89	7.47	8.34	84.31	0.076
		15	16.84	7.53	8.52	87.87	0.076
		10	17.28	7.57	8.37	87.12	0.076
		5	17.50	7.60	8.65	90.45	0.076
		0	17.95	7.61	8.96	94.56	0.076
	14-Jun	90	6.30	6.43	7.72	62.53	0.079
		85	6.49	6.40	7.85	63.88	0.078
		80	6.71	6.39	8.06	65.96	0.078
		75	7.03	6.37	8.07	66.57	0.078
		70	7.19	6.35	7.76	64.26	0.078
		65	7.36	6.34	7.67	63.79	0.078
		60	7.68	6.31	7.35	61.61	0.078
		55	7.95	6.30	7.24	61.09	0.078
		50	8.30	6.31	7.63	64.93	0.078
		45	9.50	6.34	7.76	67.96	0.077
		40	12.10	6.40	7.45	69.30	0.078
		35	14.20	6.46	7.43	72.43	0.079
		30	15.60	6.51	7.89	79.27	0.078
		25	16.96	6.60	8.88	91.82	0.076
		20	17.60	6.71	9.24	96.82	0.076
		15	19.34	6.98	9.34	101.40	0.076
		10	21.47	7.04	8.88	100.55	0.076
		5	23.74	7.05	8.51	100.63	0.074
		0	24.27	7.06	8.49	101.39	0.075

Table A-1. (Continued)							
Station	**DATE**	**Depth (F)**	**Temp ?C**	**pH**	**DO (mg/L)**	**DO (%)**	**Cond (mS/cm)**
BZ3 (Con't)	17-Jul	97	6.13	6.19	6.02	48.55	0.076
		95	6.19	6.01	6.67	53.87	0.076
		90	6.41	5.98	6.69	54.33	0.076
		85	6.70	5.98	6.99	57.19	0.075
		80	6.93	5.99	7.06	58.09	0.075
		75	7.28	5.98	7.09	58.85	0.075
		70	7.90	5.97	6.88	57.98	0.075
		65	8.19	5.96	6.62	56.18	0.075
		60	8.41	5.94	6.18	52.73	0.075
		55	8.80	5.91	5.43	46.77	0.076
		50	9.75	5.93	5.40	47.58	0.075
		45	10.95	5.95	5.78	52.37	0.075
		40	13.62	6.01	5.79	55.72	0.076
		35	15.82	6.08	6.23	62.89	0.075
		30	17.89	6.20	7.11	74.94	0.073
		25	19.74	6.28	7.81	85.47	0.073
		20	22.37	6.45	8.25	95.05	0.071
		15	23.78	6.84	8.39	99.28	0.070
		10	24.18	7.22	8.44	100.63	0.070
		5	24.36	7.33	8.40	100.49	0.070
		0	24.48	7.35	8.49	101.79	0.070
	07-Aug	100	6.44	5.95	5.45	44.30	0.078
		95	6.57	5.87	5.33	43.46	0.078
		90	6.71	5.83	5.43	44.43	0.078
		85	6.72	5.81	5.43	44.45	0.078
		80	7.07	5.79	5.61	46.32	0.077
		75	7.50	5.77	5.22	43.56	0.078
		70	7.79	5.75	5.07	42.61	0.077
		65	8.38	5.73	4.59	39.14	0.078
		60	8.88	5.72	3.86	33.31	0.078
		55	9.29	5.70	3.36	29.28	0.078
		50	10.01	5.69	3.32	29.43	0.078
		45	11.59	5.73	3.98	36.60	0.077
		40	13.84	5.77	3.89	37.62	0.077
		35	16.39	5.83	3.98	40.66	0.077
		30	19.07	5.91	4.82	52.04	0.075
		25	21.11	6.00	5.50	61.84	0.075
		20	23.50	6.18	6.65	78.28	0.072
		15	24.76	6.56	7.75	93.40	0.070
		10	25.45	7.31	8.19	99.97	0.070
		5	26.59	7.10	7.80	97.20	0.070
		0	26.76	7.08	7.90	98.75	0.070
Table A-1. (Continued)							

Station	DATE	Depth (F)	Temp ?C	pH	DO (mg/L)	DO (%)	Cond (mS/cm)
BZ3 (Con't)	25-Sep	100	6.45	6.07	1.86	15.12	0.082
		95	6.52	5.99	1.74	14.17	0.081
		90	6.85	5.94	1.63	13.39	0.080
		85	7.25	5.93	1.87	15.51	0.080
		80	7.84	5.94	2.13	17.92	0.080
		75	8.35	5.93	1.97	16.78	0.080
		70	8.91	5.93	1.11	9.59	0.080
		65	9.61	5.93	0.70	6.15	0.080
		60	10.13	5.94	0.51	4.53	0.080
		55	11.17	5.96	1.16	10.56	0.079
		50	13.18	6.00	0.98	9.34	0.079
		45	14.80	6.03	0.87	8.59	0.078
		40	17.25	6.07	0.04	0.42	0.079
		35	19.13	6.27	4.17	45.08	0.081
		30	21.20	6.49	5.98	67.36	0.072
		25	21.46	6.71	7.31	82.75	0.071
		20	21.48	6.79	7.49	84.82	0.071
		15	21.48	6.86	7.55	85.50	0.071
		10	21.48	6.89	7.58	85.84	0.071
		5	21.46	6.93	7.68	86.94	0.071
		0	21.46	6.95	7.63	86.38	0.071
	24-Oct	95	7.28	6.14	0.13	1.10	0.083
		90	7.47	6.07	0.00	0.00	0.082
		85	7.81	6.04	0.00	0.00	0.082
		80	8.28	6.03	0.00	0.00	0.083
		75	8.96	6.05	0.00	0.00	0.084
		70	9.63	6.07	0.00	0.00	0.083
		65	10.86	6.09	0.00	0.00	0.082
		60	12.46	6.26	2.31	21.60	0.082
		55	13.35	6.48	5.53	52.90	0.080
		50	14.68	6.56	5.57	54.80	0.076
		45	14.86	6.60	6.07	60.00	0.076
		40	14.97	6.64	6.30	62.40	0.076
		35	14.98	6.67	6.41	63.50	0.076
		30	15.01	6.73	6.53	64.70	0.076
		25	15.06	6.74	6.61	65.70	0.076
		20	15.11	6.77	6.91	68.70	0.075
		15	15.16	6.81	7.12	70.90	0.075
		10	15.32	6.84	7.15	71.40	0.075
		5	15.40	6.89	7.50	75.00	0.075
		0	12.79	7.21	9.03	85.30	0.099
		0	15.53	6.90	7.83	78.60	0.075

Table A-1. (Continued)

Station	DATE	Depth (F)	Temp ?C	pH	DO (mg/L)	DO (%)	Cond (mS/cm)

BZ4	24-Apr	0	12.32	7.58	*	*	0.036
	24-May	0	16.72	8.55	10.40	106.98	0.035
	14-Jun	0	23.04	7.04	7.80	91.01	0.037
	17-Jul	0	10.74	6.75	11.20	100.98	0.040
	07-Aug	0	10.80	6.30	9.86	89.02	0.045
	25-Sep	0	13.29	6.69	8.33	79.58	0.065
	24-Oct	0	12.81	7.10	8.12	76.70	0.047
BZ5	24-Apr	0	14.60	6.98	*	*	0.090
	24-May	0	13.35	8.20	9.63	92.13	0.088
	14-Jun	0	18.27	6.86	8.10	86.05	0.082
	17-Jul	0	24.04	6.93	7.14	84.91	0.078
	07-Aug	0	20.87	6.58	7.08	79.24	0.091
	25-Sep	0	16.79	6.75	7.82	80.57	0.079
	24-Oct	0	12.79	7.21	9.03	85.30	0.099
BZ6	24-Apr	122	5.07	6.87	*	*	0.081
		120	5.11	6.77	*	*	0.081
		115	5.14	6.76	*	*	0.083
		110	5.24	6.77	*	*	0.082
		105	5.26	6.76	*	*	0.081
		100	5.32	6.77	*	*	0.081
		95	5.36	6.77	*	*	0.081
		90	5.39	6.77	*	*	0.081
		85	5.46	6.77	*	*	0.087
		80	5.47	6.78	*	*	0.081
		75	5.57	6.79	*	*	0.081
		70	5.67	6.79	*	*	0.081
		65	5.81	6.80	*	*	0.081
		60	5.92	6.82	*	*	0.080
		55	6.21	6.84	*	*	0.080
		50	6.47	6.86	*	*	0.081
		45	6.59	6.88	*	*	0.080
		40	6.94	6.91	*	*	0.080
		35	7.17	6.93	*	*	0.080
		30	7.56	6.97	*	*	0.080
		25	8.08	7.08	*	*	0.080
		20	8.33	7.03	*	*	0.079
		15	8.62	7.07	*	*	0.079
		10	8.79	7.10	*	*	0.080
		5	9.22	7.13	*	*	0.079
		0	10.62	7.20	*	*	0.080

Table A-1. (Continued)							
Station	**DATE**	**Depth (F)**	**Temp ?C**	**pH**	**DO (mg/L)**	**DO (%)**	**Cond (mS/cm)**
BZ6 (Con't)	24-May	124	5.58	7.60	9.19	73.09	0.078
		120	5.57	7.52	7.80	62.02	0.079
		115	5.59	7.49	8.17	64.99	0.079
		110	5.57	7.45	9.33	74.18	0.078
		105	5.61	7.39	9.29	73.94	0.078
		100	5.60	7.33	9.40	74.80	0.078
		95	5.63	7.29	9.48	75.49	0.078
		90	5.94	7.27	9.11	73.12	0.078
		85	6.07	7.26	8.78	70.70	0.078
		80	6.21	7.26	8.88	71.76	0.078
		75	6.45	7.26	8.91	72.44	0.078
		70	6.61	7.24	8.82	72.00	0.078
		65	6.74	7.23	8.80	72.07	0.077
		60	6.93	7.23	9.09	74.79	0.077
		55	7.04	7.22	9.06	74.75	0.077
		51	7.12	7.22	9.03	74.65	0.077
		45	7.48	7.22	8.92	74.40	0.077
		40	8.39	7.25	9.02	76.93	0.077
		35	9.64	7.29	9.37	82.34	0.076
		30	10.88	7.35	9.72	87.93	0.076
		25	12.45	7.40	9.87	92.54	0.076
		20	14.99	7.45	9.09	90.14	0.075
		15	16.64	7.49	8.58	88.12	0.076
		10	17.42	7.54	8.64	90.19	0.076
		5	17.61	7.58	8.65	90.65	0.076
		0	18.22	7.59	8.71	92.43	0.076
	14-Jun	126	5.70	6.31	6.80	54.25	0.080
		120	5.71	6.26	7.04	56.17	0.079
		115	5.72	6.24	7.03	56.11	0.079
		110	5.75	6.22	7.08	56.55	0.079
		105	5.76	6.20	7.11	56.81	0.079
		100	5.82	6.19	7.49	59.93	0.079
		95	6.03	6.19	7.71	62.02	0.078
		90	6.17	6.18	8.13	65.63	0.078
		85	6.36	6.19	8.24	66.84	0.078
		80	6.60	6.20	8.48	69.20	0.078
		75	6.86	6.20	8.38	68.83	0.078
		70	7.20	6.21	7.95	65.85	0.078
		65	7.37	6.21	8.17	67.96	0.078
		60	7.52	6.21	8.21	68.55	0.078
		55	7.93	6.23	8.31	70.08	0.077

Table A-1. (Continued)							
Station	**DATE**	**Depth (F)**	**Temp ?C**	**pH**	**DO (mg/L)**	**DO (%)**	**Cond (mS/cm)**
BZ6 (Con't)	14-Jun (Con't)	50	8.61	6.26	8.46	72.53	0.077
		45	9.20	6.29	8.57	74.52	0.077
		40	11.30	6.35	8.24	75.27	0.077
		40	11.82	6.37	7.85	72.56	0.078
		35	13.82	6.39	7.72	74.63	0.079
		30	15.68	6.45	8.14	81.92	0.078
		25	17.09	6.60	9.22	95.59	0.075
		20	17.97	6.88	9.50	100.30	0.076
		15	18.99	7.10	9.62	103.70	0.076
		10	23.93	7.06	8.40	99.68	0.076
		5	24.08	7.07	8.37	99.61	0.076
		0	24.48	7.08	8.41	100.83	0.076
	17-Jul	123	5.83	5.96	5.37	42.98	0.077
		120	5.83	5.92	5.78	46.26	0.077
		115	5.84	5.92	5.90	47.23	0.077
		110	5.86	5.91	5.92	47.42	0.076
		105	5.88	5.91	6.07	48.64	0.076
		100	5.91	5.90	6.09	48.84	0.076
		95	6.02	5.91	6.45	51.87	0.076
		90	6.32	5.93	7.02	56.89	0.075
		85	6.50	5.95	7.15	58.20	0.075
		80	6.85	5.95	7.40	60.77	0.075
		75	7.24	5.96	7.39	61.27	0.074
		70	7.85	5.97	7.34	61.78	0.074
		65	8.36	5.98	7.40	63.06	0.074
		60	8.48	5.99	7.44	63.59	0.074
		55	9.44	5.99	7.28	63.67	0.074
		50	10.85	5.99	6.75	61.02	0.074
		45	13.70	6.01	6.24	60.16	0.075
		40	15.95	6.09	6.71	67.92	0.074
		35	17.75	6.22	7.48	78.62	0.072
		30	19.99	6.42	8.66	95.24	0.071
		25	22.58	6.48	8.37	96.82	0.070
		20	23.54	6.71	8.18	96.36	0.070
		15	23.65	6.97	8.28	97.74	0.070
		10	23.76	7.18	8.40	99.36	0.070
		5	24.07	7.27	8.50	101.13	0.070
		0	24.29	7.28	8.44	100.83	0.070

Table A-1. (Continued)

Station	DATE	Depth (F)	Temp ?C	pH	DO (mg/L)	DO (%)	Cond (mS/cm)
BZ6 (Con't)	07-Aug	115	5.98	6.10	4.92	39.53	0.080
		110	5.96	5.97	5.02	40.31	0.079
		105	6.00	5.90	5.11	41.08	0.079
		100	6.11	5.86	5.21	42.00	0.078
		95	6.18	5.84	5.56	44.90	0.078
		90	6.37	5.83	5.85	47.47	0.077
		85	6.68	5.83	6.28	51.35	0.077
		80	6.99	5.81	6.18	50.93	0.077
		75	7.35	5.80	6.06	50.38	0.076
		70	7.86	5.79	5.70	47.99	0.077
		65	8.48	5.78	5.47	46.75	0.076
		60	8.81	5.79	5.74	49.45	0.076
		55	9.33	5.80	5.84	50.94	0.076
		50	10.00	5.80	5.65	50.07	0.076
		45	11.66	5.80	5.24	48.26	0.076
		40	13.35	5.82	4.57	43.72	0.077
		35	15.70	5.89	4.83	48.63	0.076
		30	18.15	5.94	5.28	55.95	0.074
		25	21.02	6.06	6.18	69.36	0.074
		20	23.55	6.15	6.36	74.94	0.071
		15	24.71	6.56	7.61	91.63	0.070
		10	25.30	6.89	7.89	96.04	0.070
		5	25.90	7.48	8.00	98.45	0.070
		0	26.50	7.25	7.82	97.29	0.070
	25-Sep	120	6.21	5.97	0.58	4.69	0.089
		115	6.17	5.93	0.32	2.58	0.081
		111	6.15	5.88	0.90	7.26	0.081
		105	6.29	5.87	1.30	10.53	0.080
		100	6.37	5.86	2.10	17.04	0.080
		95	6.52	5.86	2.51	20.44	0.079
		90	6.73	5.88	2.99	24.48	0.079
		85	7.01	5.89	3.34	27.54	0.079
		80	7.54	5.90	3.35	27.98	0.079
		75	8.13	5.91	2.71	22.97	0.079
		70	8.69	5.91	1.98	17.01	0.079
		65	9.38	5.92	1.82	15.89	0.079
		60	10.68	5.96	2.04	18.37	0.078
		55	11.66	5.97	1.73	15.93	0.078
		50	13.38	5.99	0.94	9.00	0.078
		45	15.78	6.02	0.21	2.12	0.078
		40	17.88	6.03	0.00	0.00	0.078
		35	19.17	6.12	0.67	7.25	0.079

Table A-1. (Continued)

Station	DATE	Depth (F)	Temp ?C	pH	DO (mg/L)	DO (%)	Cond (mS/cm)
BZ6 (Con't)	25-Sep (Con't)	30	19.84	6.15	0.60	6.58	0.078
		25	21.04	6.35	3.52	39.52	0.073
		20	21.57	6.63	7.04	79.87	0.071
		15	21.53	6.77	7.17	81.28	0.071
		10	21.55	6.83	7.48	84.83	0.071
		5	21.58	6.90	7.57	85.90	0.071
		0	21.56	6.93	7.67	87.00	0.071
	24-Oct	124	6.34	6.46	0.00	0.00	0.088
		120	6.34	6.47	0.00	0.00	0.083
		115	6.34	6.32	0.00	0.00	0.083
		111	6.38	6.21	0.00	0.00	0.081
		105	6.38	6.15	0.02	0.20	0.081
		100	6.48	6.09	0.41	3.30	0.081
		95	6.80	6.08	1.07	8.70	0.080
		90	7.18	6.07	1.45	12.00	0.080
		85	7.62	6.07	1.52	12.70	0.080
		80	8.58	6.06	0.31	2.60	0.081
		75	9.23	6.07	0.00	0.00	0.081
		70	9.81	6.08	0.00	0.00	0.081
		65	10.93	6.10	0.00	0.00	0.081
		60	12.75	6.14	0.00	0.00	0.080
		55	13.85	6.27	2.19	21.20	0.079
		50	14.47	6.37	3.87	38.00	0.077
		45	14.57	6.47	4.83	47.50	0.077
		40	14.81	6.52	5.35	52.90	0.076
		35	15.03	6.69	6.72	66.70	0.076
		35	15.13	6.76	7.05	70.20	0.075
		30	15.11	6.74	6.84	68.00	0.075
		20	15.17	6.79	7.14	71.10	0.075
		15	15.17	6.83	7.23	72.00	0.075
		10	15.27	6.84	7.38	73.60	0.075
		5	15.32	6.90	7.47	74.60	0.075
		0	15.45	6.93	7.86	78.70	0.075

Table A-1. (Continued)							
Station	**DATE**	**Depth (F)**	**Temp ?C**	**pH**	**DO (mg/L)**	**DO (%)**	**Cond (mS/cm)**
BZ7	24-Apr	50	6.94	6.84	*	*	0.080
		45	7.05	6.84	*	*	0.080
		40	7.27	6.84	*	*	0.080
		35	8.42	6.89	*	*	0.084
		30	9.91	6.97	*	*	0.084
		25	10.87	7.06	*	*	0.078
		20	12.01	7.15	*	*	0.076
		15	12.60	7.18	*	*	0.077
		10	12.99	7.21	*	*	0.076
		5	13.45	7.24	*	*	0.077
		0	15.40	7.27	*	*	0.085
	24-May	50	7.90	7.38	9.57	80.65	0.078
		45	8.10	7.31	9.34	79.10	0.078
		40	8.59	7.28	9.16	78.50	0.078
		35	11.18	7.28	8.71	79.34	0.081
		30	13.50	7.29	8.75	83.99	0.084
		25	15.13	7.34	8.93	88.82	0.079
		20	16.00	7.38	9.44	95.65	0.076
		15	16.57	7.45	9.75	99.99	0.076
		10	17.00	7.47	9.83	101.72	0.076
		5	17.38	7.51	9.70	101.18	0.076
		0	18.03	7.54	9.59	101.38	0.076
	14-Jun	50	8.41	6.56	6.19	52.82	0.080
		45	8.42	6.42	6.27	53.51	0.079
		40	8.55	6.33	6.42	54.96	0.079
		35	9.32	6.29	6.27	54.68	0.079
		30	11.82	6.27	5.96	55.09	0.081
		25	15.31	6.34	6.17	61.61	0.083
		20	17.03	6.46	6.66	68.96	0.082
		15	17.96	6.66	7.68	81.07	0.077
		10	19.74	7.34	7.99	87.44	0.074
		5	20.88	7.92	8.40	94.02	0.073
		0	21.62	7.84	8.24	93.57	0.071

Table A-1. (Continued)							
Station	**DATE**	**Depth (F)**	**Temp ?C**	**pH**	**DO (mg/L)**	**DO (%)**	**Cond (mS/cm)**
BZ7 (Con't)	17-Jul	50	11.24	6.06	3.62	33.02	0.078
		45	12.81	6.06	3.45	32.61	0.078
		40	15.04	6.09	3.47	34.45	0.078
		35	16.26	6.05	4.12	41.98	0.076
		30	17.40	6.09	4.51	47.06	0.076
		25	20.19	6.39	6.91	76.30	0.081
		20	21.51	6.47	7.17	81.25	0.078
		15	24.44	6.65	7.56	90.57	0.071
		10	25.07	7.07	7.95	96.36	0.070
		5	25.35	7.43	8.17	99.54	0.070
		0	25.49	7.53	8.25	100.77	0.070
	07-Aug	50	11.66	5.80	1.41	12.99	0.082
		45	14.66	5.80	1.31	12.90	0.081
		40	16.42	5.81	1.80	18.40	0.080
		35	17.98	5.83	2.60	27.46	0.079
		30	18.76	5.87	3.09	33.16	0.078
		25	20.70	5.99	4.22	47.07	0.079
		20	22.79	6.21	5.78	67.13	0.082
		15	24.84	6.45	6.82	82.32	0.073
		10	27.37	7.02	7.49	94.65	0.070
		5	27.48	7.16	7.45	94.33	0.070
		0	27.52	7.26	7.79	98.71	0.070
	25-Sep	50	14.17	6.27	0.03	0.29	0.088
		45	17.88	6.42	4.59	48.38	0.091
		40	19.34	6.60	6.61	71.76	0.089
		35	20.21	6.67	6.82	75.34	0.084
		30	20.65	6.68	6.55	72.99	0.080
		25	21.21	6.63	6.03	67.93	0.074
		20	21.49	6.72	6.81	77.14	0.071
		15	21.53	6.77	6.87	77.88	0.071
		10	21.52	6.80	7.03	79.68	0.071
		5	21.52	6.84	6.94	78.66	0.071
		0	21.50	6.85	7.08	80.21	0.072

Table A-1. (Continued)							
Station	**DATE**	**Depth (F)**	**Temp ?C**	**pH**	**DO (mg/L)**	**DO (%)**	**Cond (mS/cm)**
BZ-7 (Con't)	24-Oct	50	13.83	6.86	8.58	83.00	0.087
		45	14.26	6.87	8.77	85.60	0.082
		40	14.67	6.88	8.54	84.10	0.078
		35	14.80	6.86	8.39	82.80	0.076
		30	14.86	6.85	8.37	82.80	0.076
		25	14.94	6.85	8.37	82.90	0.076
		20	15.04	6.87	8.47	84.10	0.076
		15	15.14	6.89	8.38	83.40	0.075
		10	15.39	6.92	8.94	89.40	0.075
		5	15.64	7.00	9.39	94.50	0.075
		0	15.94	7.07	9.51	96.20	0.072
* Dissolved Oxygen was not sampled in April due to a probe malfunction							

APPENDIX B

WATER COLUMN CHEMISTRY MONITORING LABORATORY ANALYSIS CERTIFICATES

APPENDIX C

SEDIMENT PRIORITY POLLUTANT AND ARSENIC MONITORING LABORATORY ANALYSIS CERTIFICATES

APPENDIX D

DRINKING WATER MONITORING LABORATORY ANALYSIS CERTIFICATES

APPENDIX E

SCOPE OF WORK