WATER QUALITY MONITORING

AT BELTZVILLE RESERVOIR

DURING 2002

Prepared for

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

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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 2002. 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 2002 monitoring program follows that in most recent years and includes the following major elements:

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

- Meteorological monitoring of air temperature, relative humidity, solar radiation, wind speed and direction every ½ hour at the Beltzville Reservoir discharge tower;

- Sediment priority pollutant monitoring of PCB's, pesticides, and volatile organic compounds 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 six times at Beltzville Reservoir between May and October 2002 (Table 2-1). Due to scheduling problems, the late July sampling was conducted in the first week of August and the late September was conducted the first week of October. 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 six times (approximately once a month) at Beltzville Reservoir between May and October 2002 (Table 2-1). Due to scheduling problems, the late September sampling was conducted in the first week of October. 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 phosphorus, dissolved phosphate total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), alkalinity, total organic carbon (TOC), total inorganic carbon (TIC), total carbon, 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).

Table 2-1. Beltzville Reservoir water quality monitoring schedule for 2002

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*
13 March						Sets A and B
22 May	X	X	X	X		
20 June	X	X	X	X		Sets A
8 August	X	X	X	X	X	
21 August	X	X	X	X		Sets A and B
2 October	X	X	X	X		
23 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

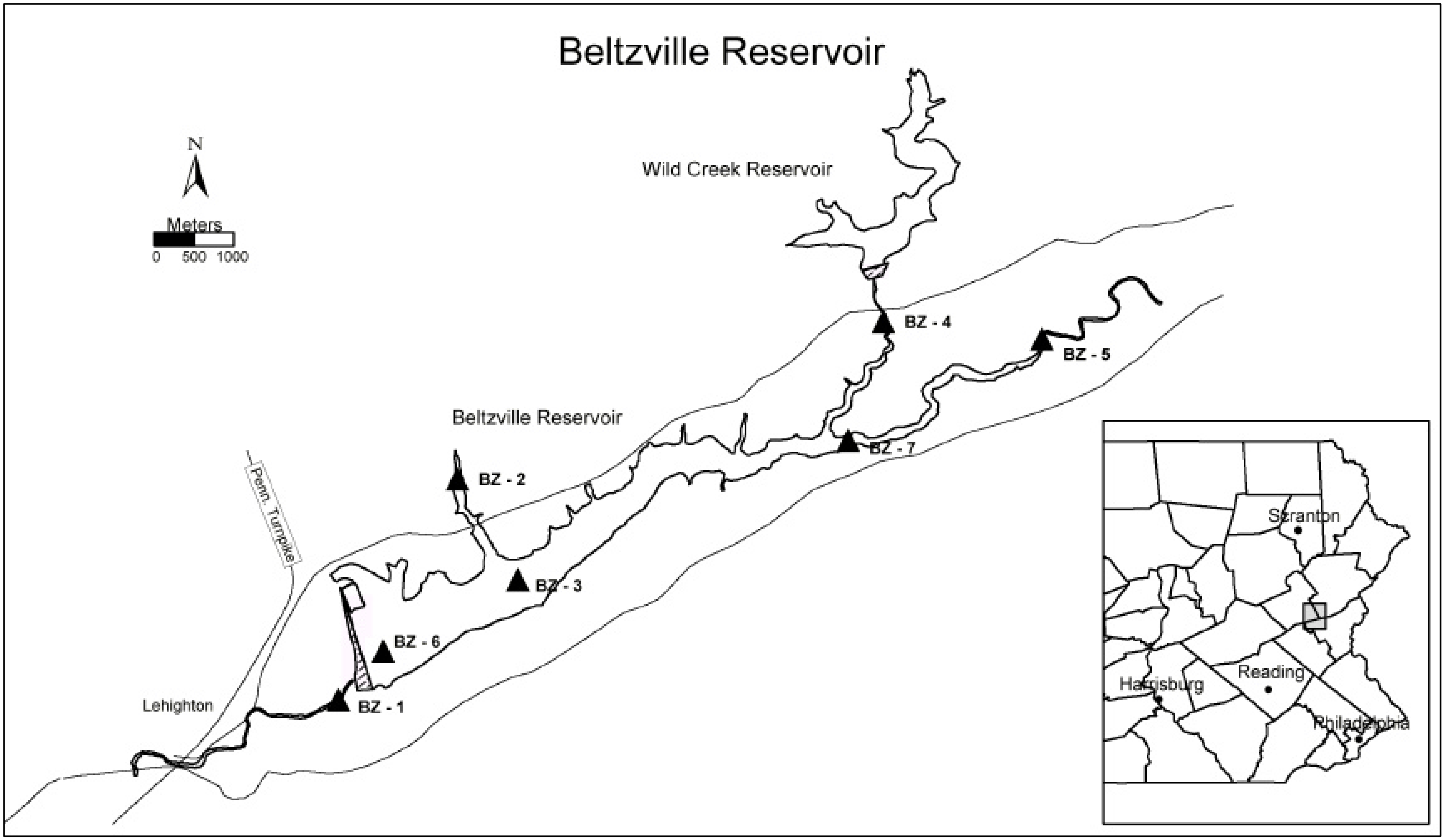

Figure 2-1. Beltzville Reservoir and the location of water quality monitoring stations in 2002.

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 2002 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 2002

Parameter	EPA Method	Detection Limit	PADEP Surface Water Quality Criteria	Allowable Hold Times (Days)	Maximum Hold Time Achieved (Days)
Alkalinity	310.1	1 mg/L	minimum 20 mg/L $CaCO_3$	14	13
Biochemical Oxygen Demand (BOD)	SM5210B	2 mg/L	None	2	2
Total Phosphorus	365.2	0.01 mg/L	None	28	9
Total Dissolved Phosphorus	365.2	0.01 mg/L	None	28	13
Dissolved Phosphate	365.2	0.01 mg/L	None	28	13
Total Organic Carbon	415.1	1 mg/L	None	14	2
Total Inorganic Carbon	415.1	1 mg/L	None	14	2
Total Carbon	415.1	1 mg/L	None	14	2
* Chlorophyll *a*			None		3
Total Kjeldahl Nitrogen	351.3	0.10 mg/L	None	28	13
Ammonia	350.3	0.05 mg/L	Temperature and pH dependent	28	9
Nitrate	353.2	0.1mg/L	Maximum 10 mg/L (nitrate + nitrite)	2	2
Nitrite	354.1	0.01 mg/L		2	2
Total Dissolved Solids	160.1	10 mg/L	Maximum 500 mg/L	7	6
Total Suspended Solids	160.2	1 mg/L	None	7	6
Benzene	8260B	0.001 mg/L	None	14	12
Ethyl benzene	8260B	0.001 mg/L	None	14	12
Toluene	8260B	0.001 mg/L	None	14	12
Xylenes	8260B	0.001 mg/L	None	14	12

* Chlorophyll *a* samples were calculated by averaging 10 readings per minute using a YSI 6600 with a chlorophyll sensor.

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 May and October 2002 (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 2002. 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.

Table 2-3. Water quality test methods, detection limits, PADEP standards, and sample holding times for bacteria parameters monitored at Beltzville Reservoir in 2002

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

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.

2.5 STREAMFLOW AND PRECIPITATION

Stream flow and precipitation data for the principal monitoring months of May 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 2-7).

In May, stream flow was elevated reaching a level as high as 285-cfs. There were few precipitation events that were near an inch or more which probably caused this high elevation (Fig. 2-2 and Fig. 2-7). After the May and early June rain events, stream flow began to decrease. Monthly monitoring in June took place when stream flow was 77-cfs (Fig. 2-3). In the later part of the summer the stream flow continued to decrease reflecting the drought conditions that occurred in 2002 (Fig 2-4). Monthly monitoring was completed at 24.5-cfs during 8 and 21 of August (Fig 2-5). There was an insignificant storm event that took place before 21 August monitoring. In the middle of September, stream flow began to slightly increase (Fig 2-6). On 2 October, monthly monitoring was conducted at a stream of 29-cfs. Two significant storm events on 11 October and 16 October that exceeded an inch of rain caused stream flow to increase (Fig 2-7). Monthly monitoring was conducted at the end of October when stream flows were at 94-cfs.

2.6 SEDIMENT PRIORITY POLLUTANT MONITORING

Sediment from Beltzville Reservoir was monitored for priority pollutant contaminants, Group 1 – PCB's, pesticides, and volatile organic compounds. Sediment was collected 8 August 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:

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

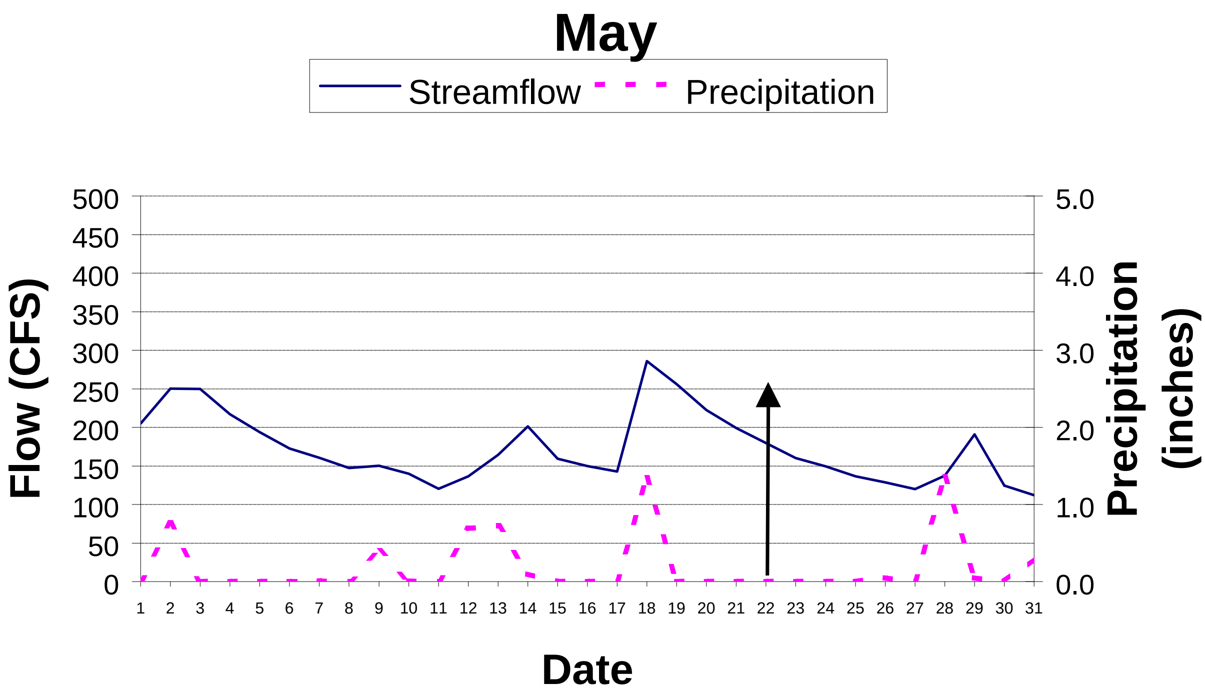

Figure 2-2. May streamflow and precipitation in the vicinity of Beltzville Reservoir during 2002

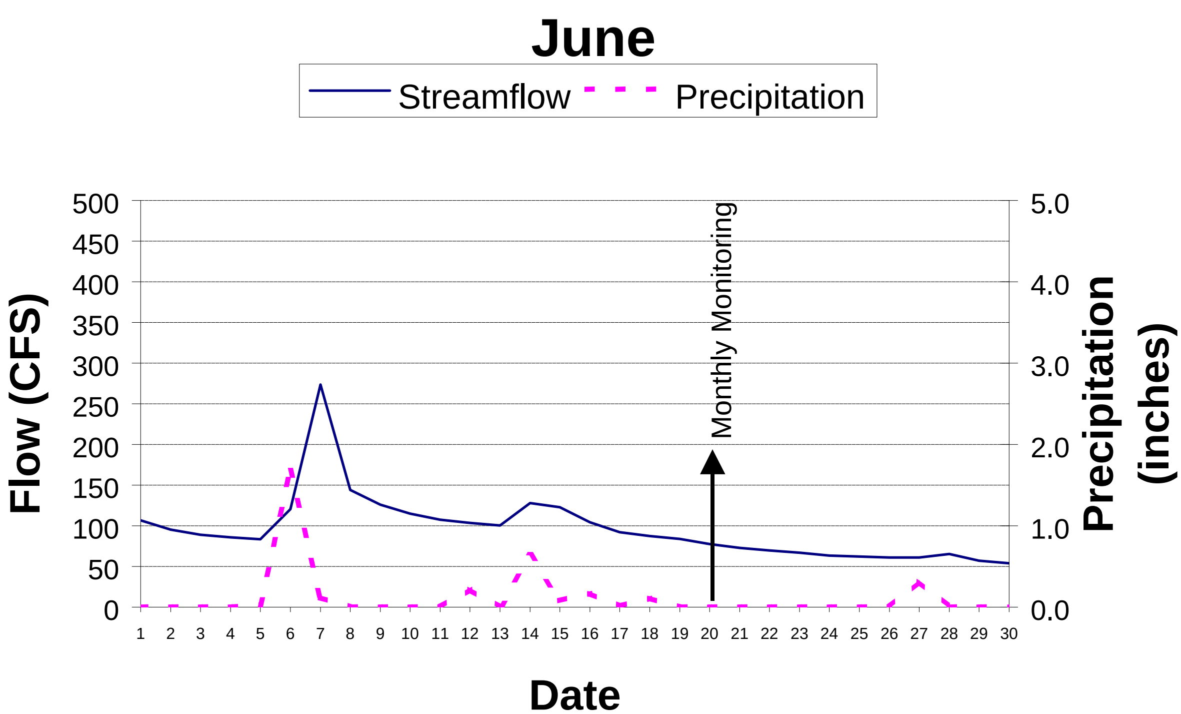

Figure 2-3. June streamflow and precipitation in the vicinity of Beltzville Reservoir during 2002

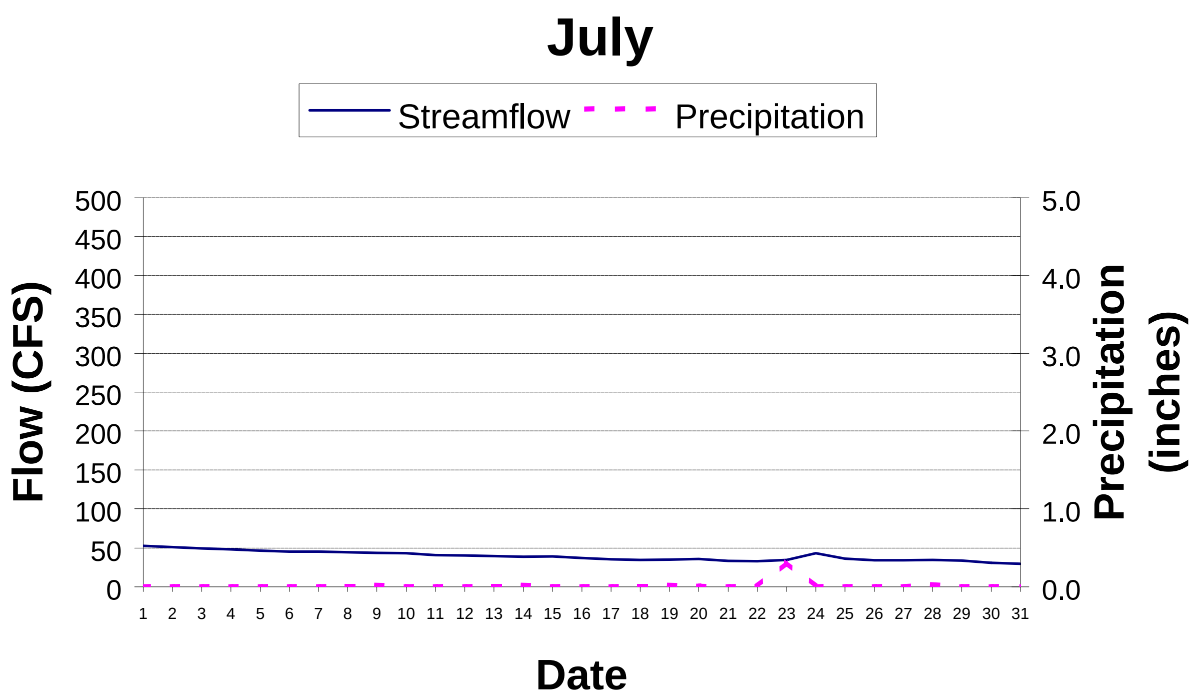

Figure 2-4. July streamflow and precipitation in the vicinity of Beltzville Reservoir during 2002

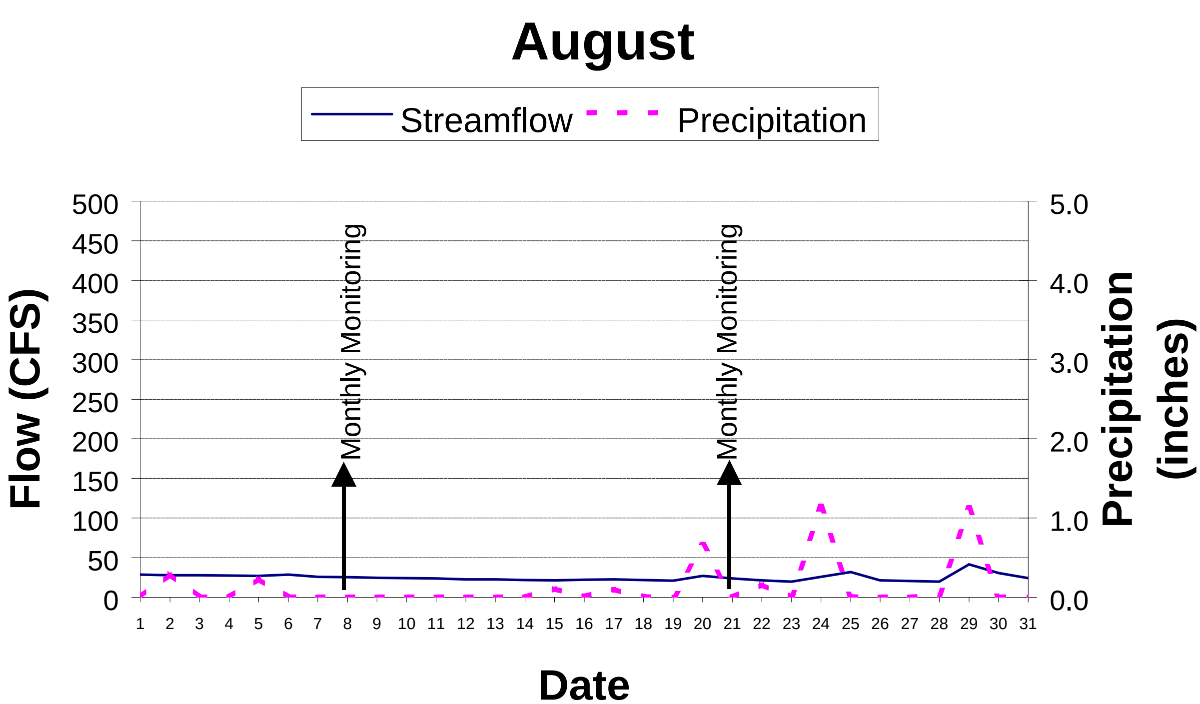

Figure 2-5. August streamflow and precipitation in the vicinity of Beltzville Reservoir during 2002

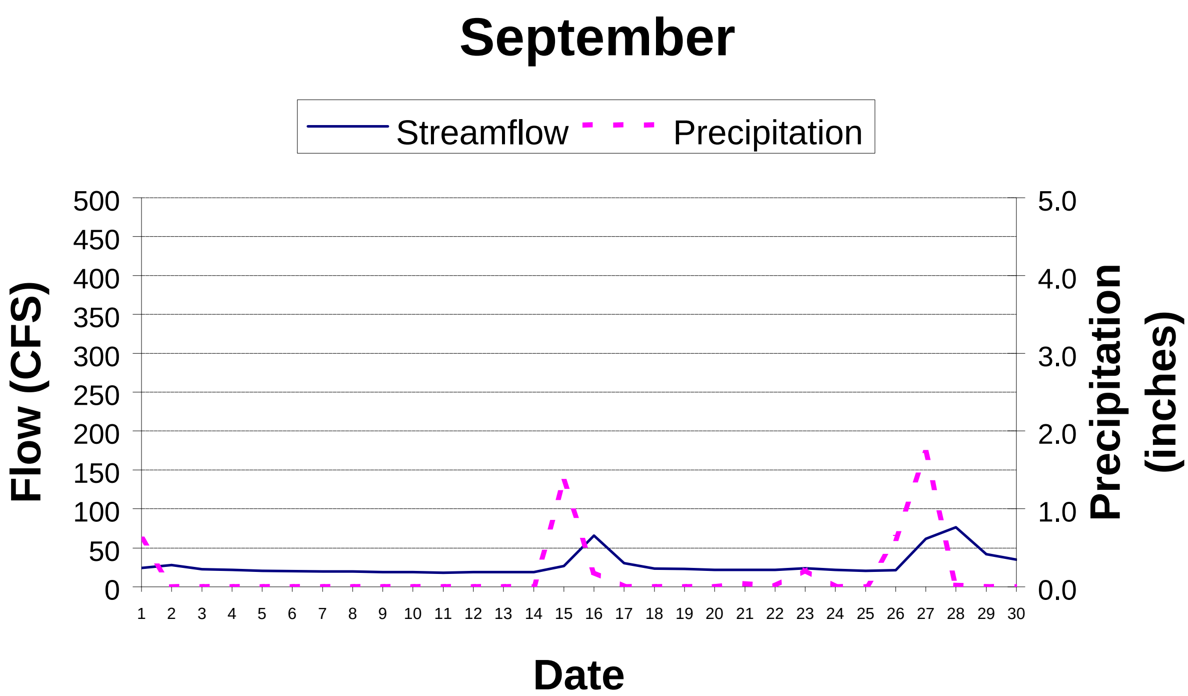

Figure 2-6. September streamflow and precipitation in the vicinity of Beltzville Reservoir during 2002

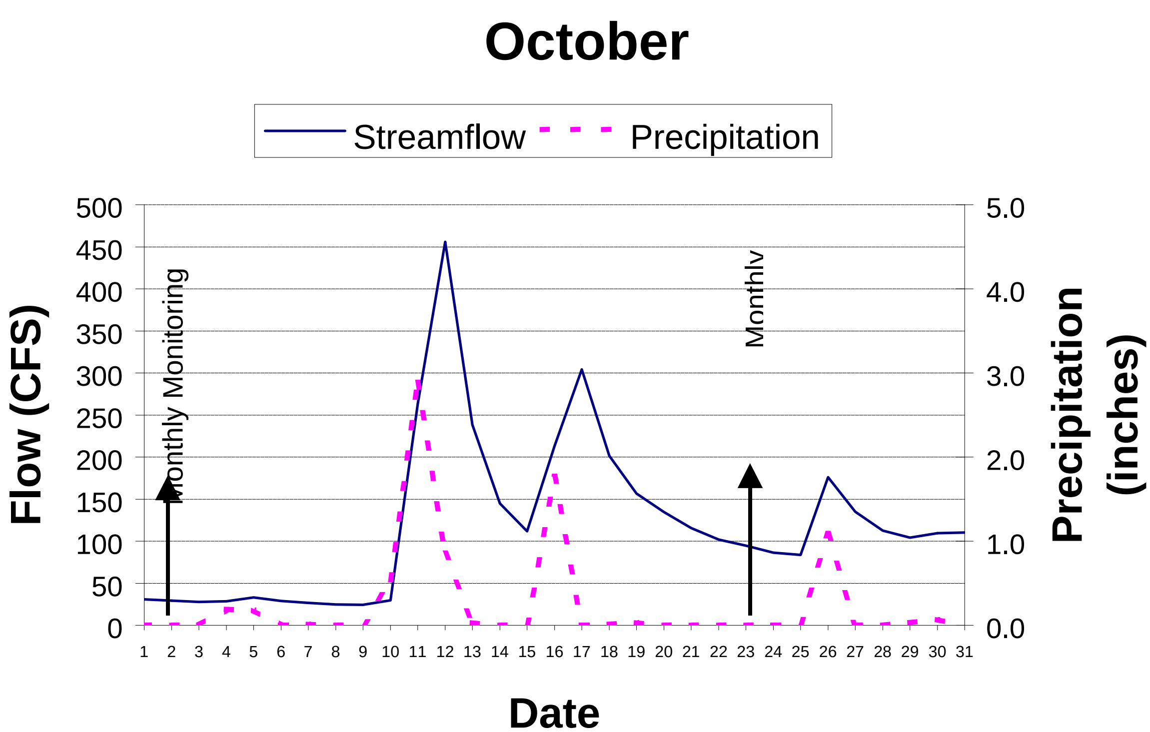

Figure 2-7. October streamflow and precipitation in the vicinity of Beltzville Reservoir during 2002

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. Sediment priority pollutants, Group 1 – volatile organic compounds, PCB's, and pesticides monitored at Beltzville Reservoir during 2002.

Parameter	Units	Method Detection Limit BM-6
PCBs - Method 8082		
Aroclor-1016	ppb	100
Aroclor-1221	ppb	100
Aroclor-1232	ppb	100
Aroclor-1242	ppb	100
Aroclor-1248	ppb	100
Aroclor-1254	ppb	100
Aroclor-1260	ppb	100
Pesticides - Method 8081A		
4,4'-DDD	ppb	5
4,4'-DDE	ppb	5
4,4'-DDT	ppb	5
alpha-BHC	ppb	5
a-Chlordane	ppb	5
Aldrin	ppb	5
beta-BHC	ppb	5
Chlordane, technical	ppb	25
delta-BHC	ppb	5
Dieldrin	ppb	5
Endosulfan I	ppb	5
Endosulfan II	ppb	5
Endrin	ppb	5
Endrin aldehyde	ppb	5
Endrin ketone	ppb	5
Endosulfan Sulfate	ppb	5
gamma-BHC (Lindane)	ppb	5
g-Chlordane	ppb	5
Heptachlor	ppb	5
Heptachlor epoxide	ppb	5
Methoxychlor	ppb	25
Toxaphene	ppb	25
Volatile Organic Compounds - Method 8260B		
1,1,1,2-Tetrachloroethane	ppb	1
1,1,1-Trichloroethane	ppb	1
1,1,2,2-Tetrachloroethane	ppb	1
1,1,2-Trichloroethane	ppb	1

Table 2-4. (Continued)		
Parameter	**Units**	**Method Detection Limit BM-6**
Volatile Organic Compounds - Method 8260B (Continued)		
1,1-Dichloroethane	ppb	1
1,1-Dichloroethene	ppb	1
1,1-Dichloropropene	ppb	1
1,2,3-Trichlorobenzene	ppb	1
1,2,3-Trichloropropane	ppb	1
1,2,4-Trichlorobenzene	ppb	1
1,2,4-Trimethylbenzene	ppb	1
1,2-Dibromo-3-chloropropane	ppb	1
1,2-Dichloroethane	ppb	1
1,2-Dichlorobenzene	ppb	1
1,2-Dichloropropane	ppb	1
1,2-Dibromoethane	ppb	1
1,3,5-Trimethylbenzene	ppb	1
1,3-Dichlorobenzene	ppb	1
1,3-Dichloropropane	ppb	1
1,4-Dichlorobenzene	ppb	1
2,2-Dichloropropane	ppb	1
2-Chlorotoluene	ppb	1
2-Hexanone	ppb	10
4-Chlorotoluene	ppb	1
Acetone	ppb	10
Benzene	ppb	1
Bromochloromethane	ppb	1
Bromodichloromethane	ppb	1
Bromobenzene	ppb	1
Bromoform	ppb	1
Bromomethane	ppb	1
c-1,2-Dichloroethene	ppb	1
c-1,3-Dichloropropene	ppb	1
Carbon Tetrachloride	ppb	1
Chlorobenzene	ppb	1
Chloroethane	ppb	1
Chloroform	ppb	1
Chloromethane	ppb	1
Methylene Chloride (DCM)	ppb	1
Dibromochloromethane	ppb	1
Dibromomethane	ppb	1
Dichlorofluoromethane	ppb	1
Ethylbenzene	ppb	1

Table 2-4. (Continued)		
Parameter	**Units**	**Method Detection Limit BM-6**
Volatile Organic Compounds - Method 8260B (Continued)		
Hexachloro1,3-butadiene	ppb	1
Isopropylbenzene (cumene)	ppb	1
m,p-Xylene	ppb	1
2-Butanone(MEK)	ppb	10
4-Methyl-2-pentanone (MIBK)	ppb	10
Methyl-tert-butylether (MTBE)	ppb	1
n-ButylBenzene	ppb	1
n-Propylbenzene	ppb	1
Naphthalene	ppb	1
o-Xylene	ppb	1
p-Isopropyltoluene	ppb	1
Tetrachloroethene	ppb	1
sec-Butylbenzene	ppb	1
Styrene	ppb	1
t-1,2-Dichloroethene	ppb	1
t-1,3-Dichloropropene	ppb	1
t-Butylalcohol	ppb	10
Trichloroethene	ppb	1
Toluene	ppb	1
Trichlorofluoromethane	ppb	1
Vinyl chloride	ppb	1

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 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 woman's restroom in the office 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 13 March, 20 June, 21 August, and 23 October. Set B samples were analyzed for primary and secondary contaminants and were collected on 13 March and 21 August. 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 2002

Parameter	Detection Limits (mg/L)	Method	Allowable Hold Times (Days)	Maximum Hold Time Achieved (Days)
Aluminum	0.025	200.7	183	5
Antimony	0.024	200.7	183	5
Arsenic	0.018	200.7	183	5
Barium	0.005	200.7	183	5
Cadmium	0.001	200.7	183	5
Chromium	0.006	200.7	183	5
Copper	0.002	200.7	183	5
Iron	0.005	200.7	183	5
Lead	0.01	200.7	183	5
Magnesium	0.02	200.7	183	5
Manganese	0.002	200.7	183	5
Mercury	0.0002	245.1	28	7
Nickel	0.003	200.7	183	5
Selenium	0.02	200.7	183	5
Silver	0.003	200.7	183	5
Sodium	0.02	200.7	183	8
Thallium	0.063	200.7	183	5
Zinc	0.003	200.7	183	5
Chloride	0.5	300	28	2
Cyanide, free	0.009	SM4500CN-I	14	5
Fluoride	0.1	300	28	2
Foaming Agents	0.01	SM5540C	2	1
Nitrate	0.5	300	2	2
Nitrite	0.5	300	2	2
PH	0.01	150.1	N/A	0
Sulfate	5	300	28	2
Total Dissolved Solids @ 180 °C	10	SM2540C	7	2

2.9 METEORLOGICAL MONITORING

Air temperature, relative humidity, solar radiation, wind speed and direction were monitored every ½hour with a YSI 6200 meteorological station installed and maintained at the Beltzville Reservoir discharge tower. Local weather conditions were recorded with these units from May through October 2002 (Appendix E).

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 2002 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 May to October 2002. 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 2002, 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 21 °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 about 7 °C cooler than the reservoir body stations.

Beltzville Reservoir was stratified with respect to temperature in 2002 (Fig. 3-2). In May stratification was already apparent with surface temperatures (14 °C) approximately 8 °C warmer than the lower water column (6 °C). Throughout June and into early October, the temperature pattern was very consistent with temperature at the surface averaging 25 °C and decreasing to 8 °C near the bottom. By late October, the entire water column was fairly uniform, averaging 13.9 °C.

3.1.2 Dissolved Oxygen

Dissolved oxygen (DO) in the surface water generally followed a similar pattern throughout the watershed of Beltzville Reservoir during 2002; however, consistent differences were apparent between reservoir-body and upstream and downstream waters (Fig.

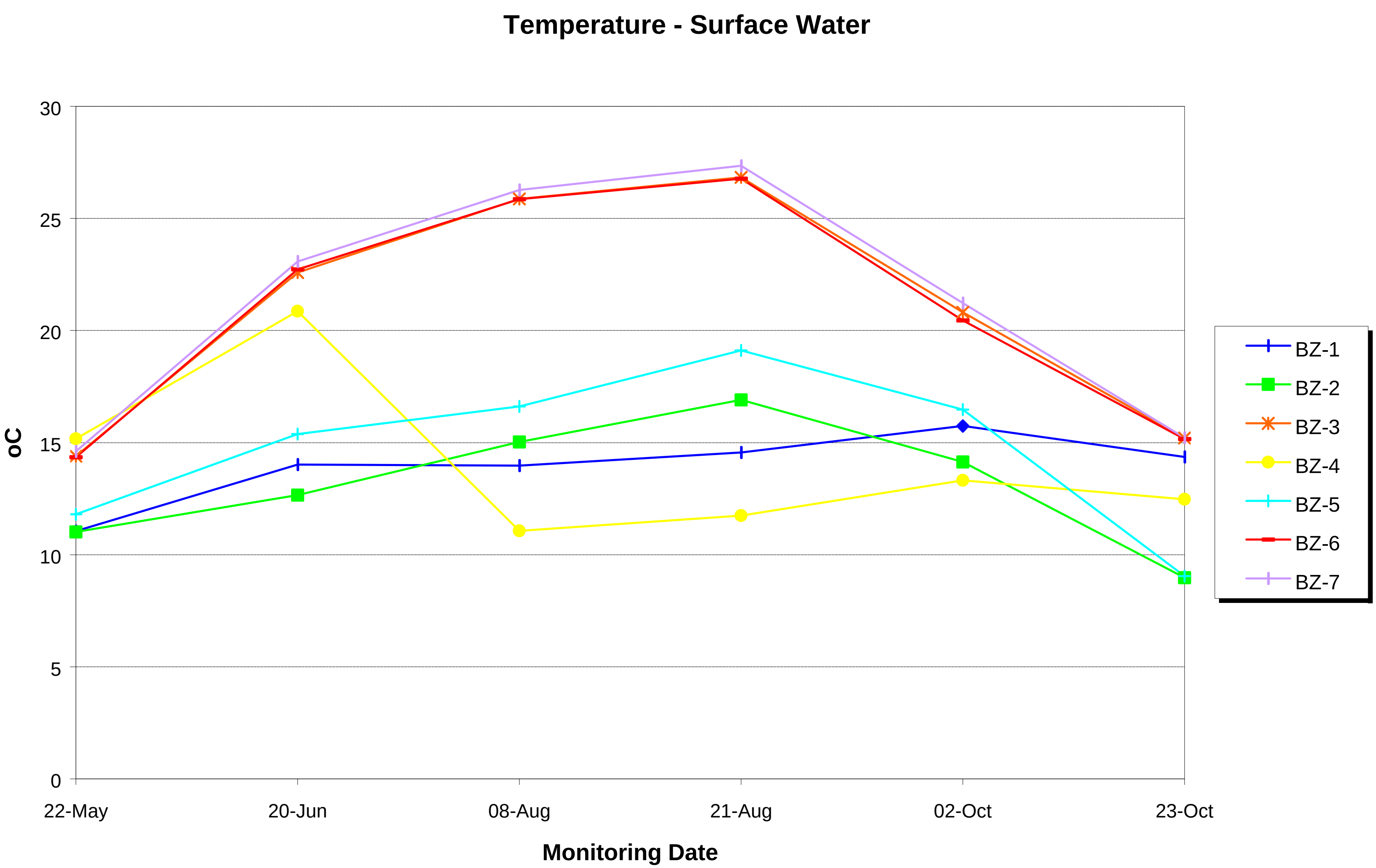

Figure 3-1. Surface water temperature (°C) measured at Beltzville Reservoir in 2002. See Appendix A for Summary of plotted values.

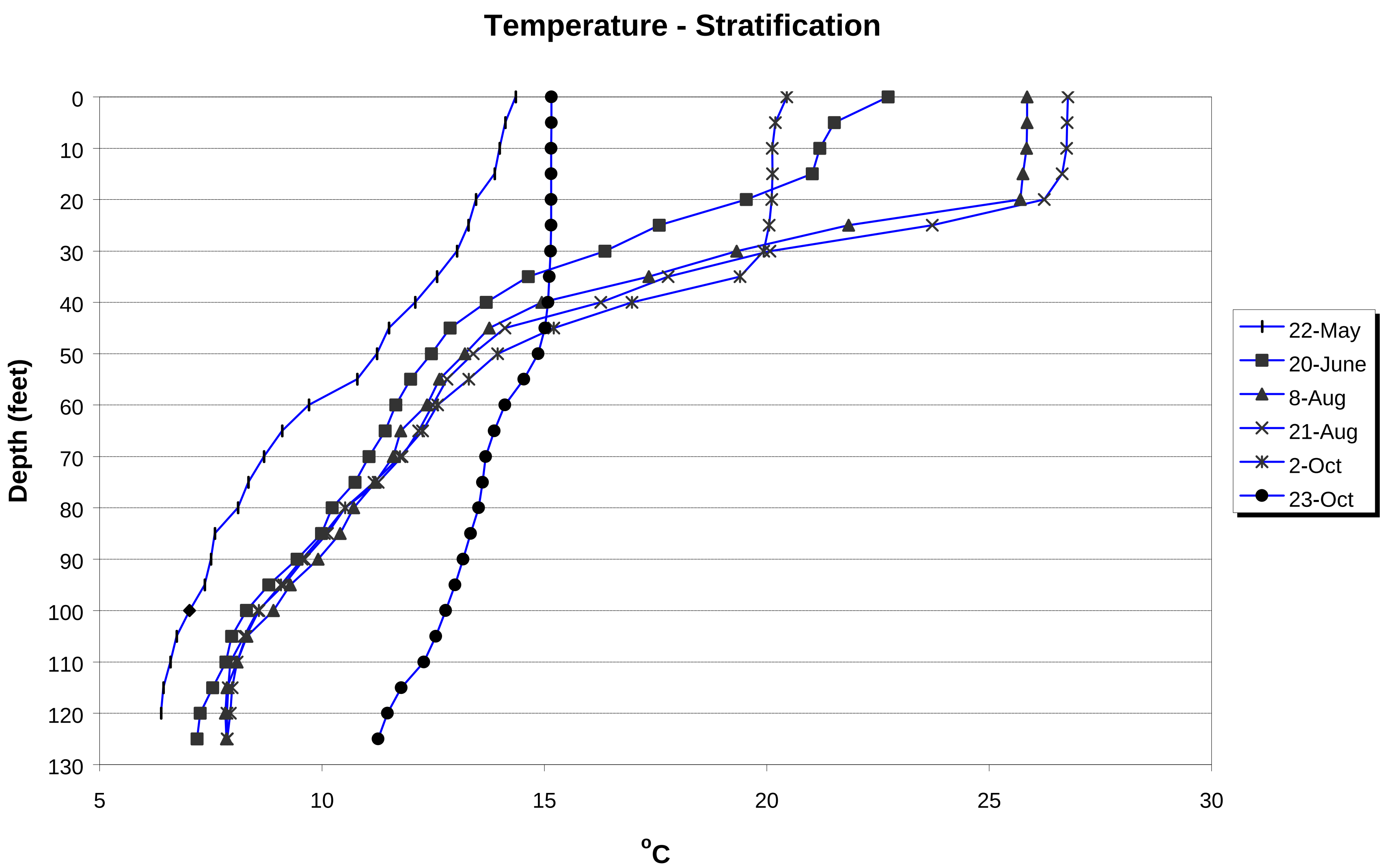

Figure 3-2. Temperature stratification at station BZ-6 of Beltzville Reservoir in 2002. See Appendix A for summary of plotted values.

3-3). Stations located in the reservoir-body (BZ-3, -6, and -7) averaged 8.9-mg/L throughout the monitoring period. Dissolved oxygen concentrations downstream of the reservoir (BZ-1) and at the upstream stations (BZ-2, -4, -5) were consistently higher and averaged 10.5-mg/L.

DO in the water column of Beltzville Reservoir was stratified from August through the first part of October (Fig. 3-4). From August through October, DO concentrations were severely depleted throughout most of the water column. In these months, DO was less than 5-mg/L from approximately 25-ft to the bottom, while concentrations nearer the surface were closer to 7.5-mg/L. Also during these months, DO exhibited a sinuous pattern with concentrations decreasing rapidly from the surface to approximately 35 feet, increasing to a depth of 50 feet, decreasing slightly to 70 feet, increasing to 80 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 were occasionally not in compliance with PADEP water quality standards during 2002. 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 from August through October. In addition, the concentrations of DO fell to 4.5-mg/L in the bottom 5 feet of the water column during June (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 2002, the deeper water column of Beltzville was affected by hypoxia (Fig. 3-5). Hypoxic water was encountered in August and October. Hypoxia occupied the lower 10-25 feet of the water column in August and occupied the lower three-quarters of the water column from around 35-ft to the bottom in October. 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-ft 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 (August and October) only as hypoxia was rarely observed in the spring (May and June). From the

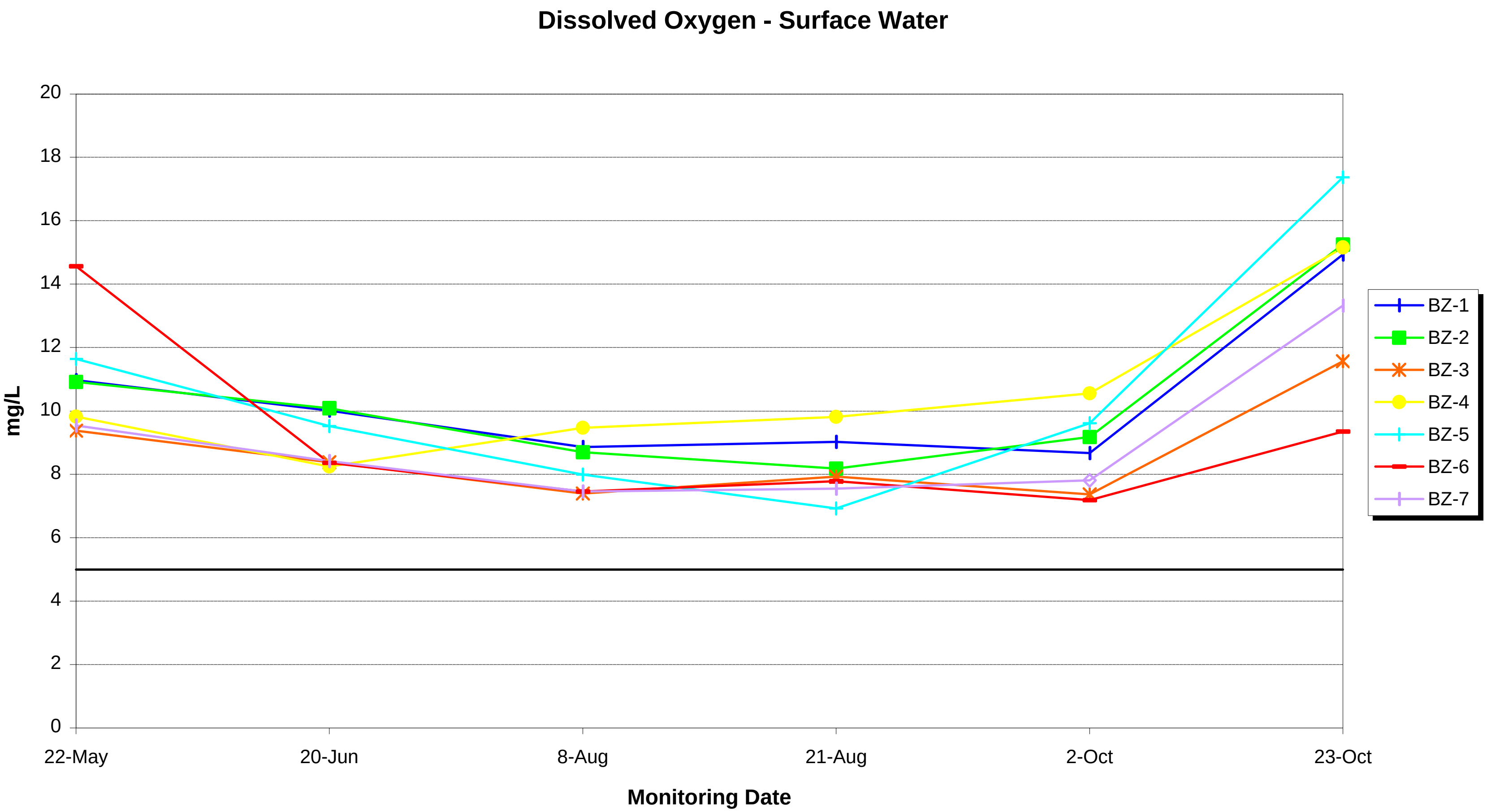

Figure 3-3. Dissolved oxygen concentrations measured in surface waters at Beltzville Reservoir in 2002. (The PADEP water quality standard for dissolved oxygen is a minimum concentration of 5 mg/L.) See Appendix A for summary of plotted values.

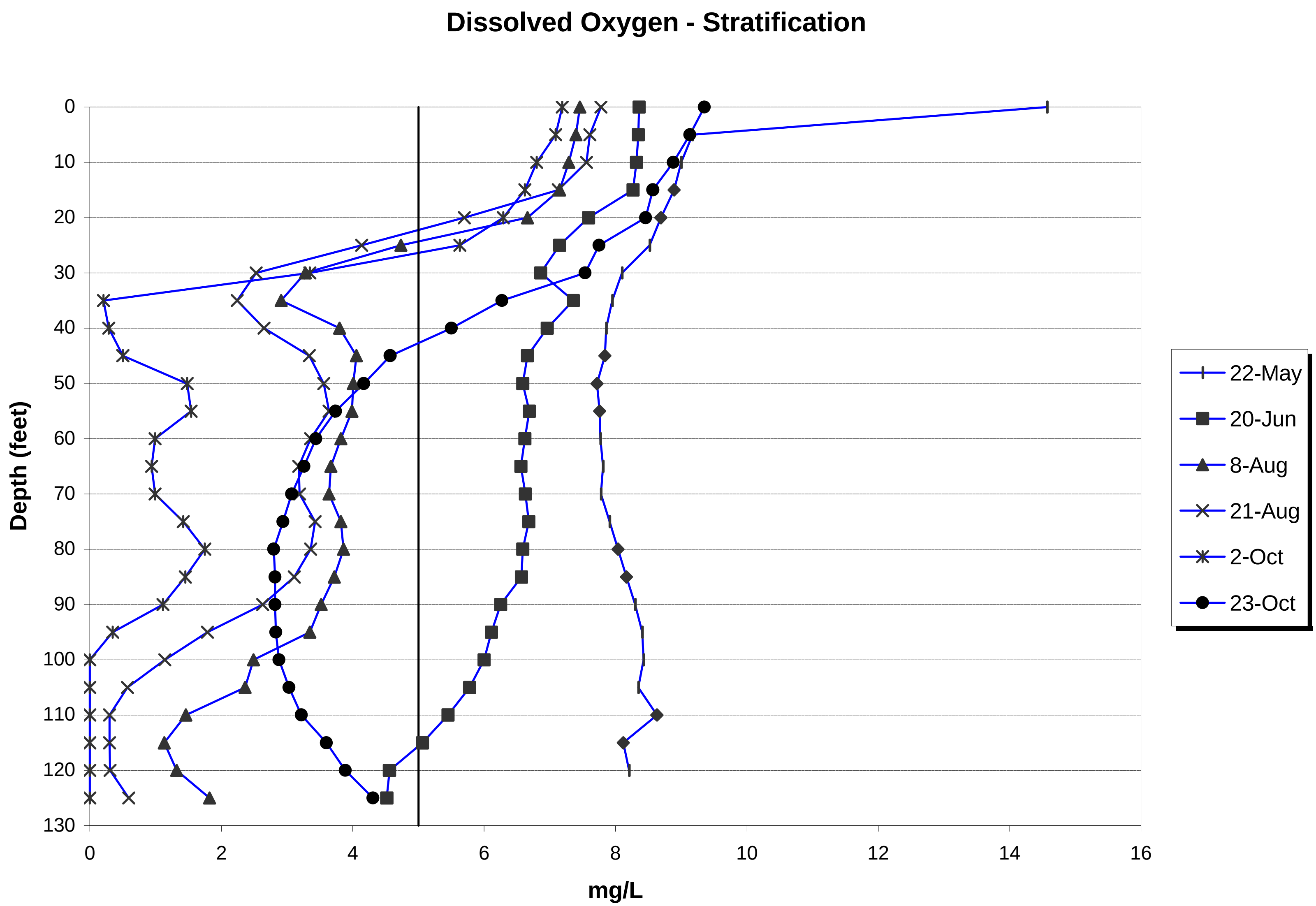

Figure 3-4. Dissolved oxygen stratification at station BZ-6 of Beltzville Reservoir in 2002. (The PADEP water quality standard for DO is a minimum concentration of 5 mg/L.) See Appendix A for summary of plotted values.

regression analysis, the level of hypoxia has not changed significantly ($P > 0.05$; $R^2 = 0.002$) 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 2002, the average depth at which hypoxia occurred was 85 feet.

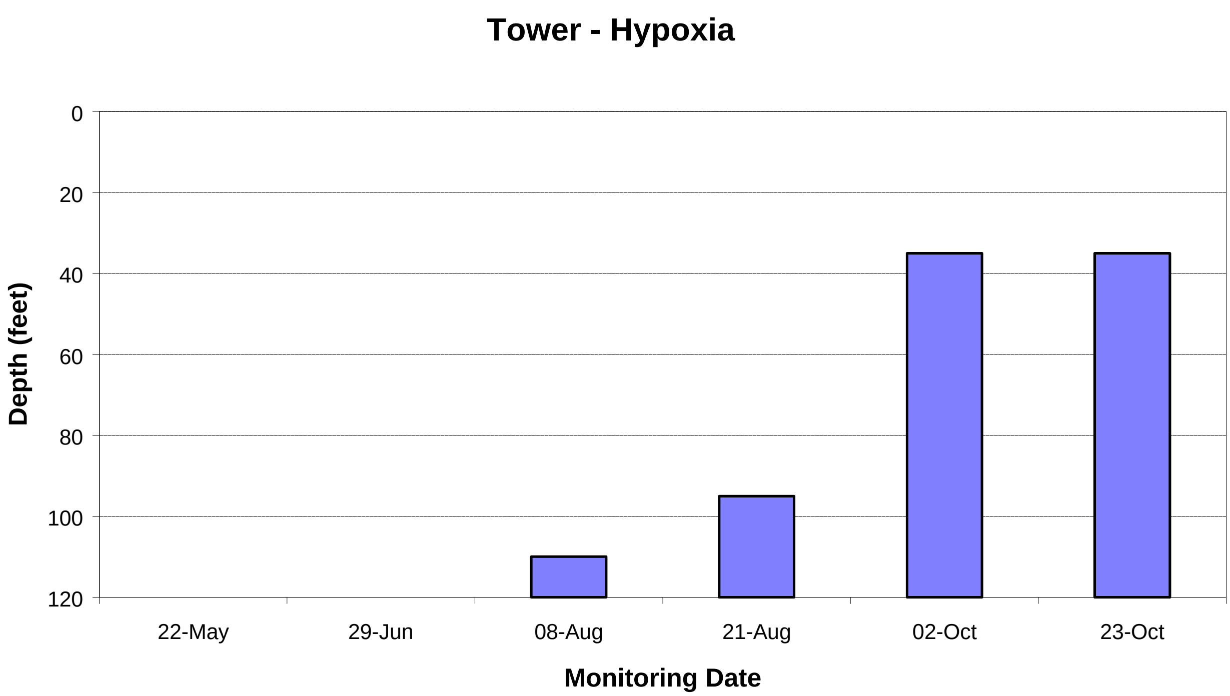

Figure 3-5. Spatial/temporal distribution of hypoxic reservoir water in Beltzville Reservoir measured at the "Tower" station in 2002. Histograms indicate dissolved oxygen concentrations in the water column below 2.0 mg/L.

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 October) 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 0.10 mg/L/year (Table 3-1).

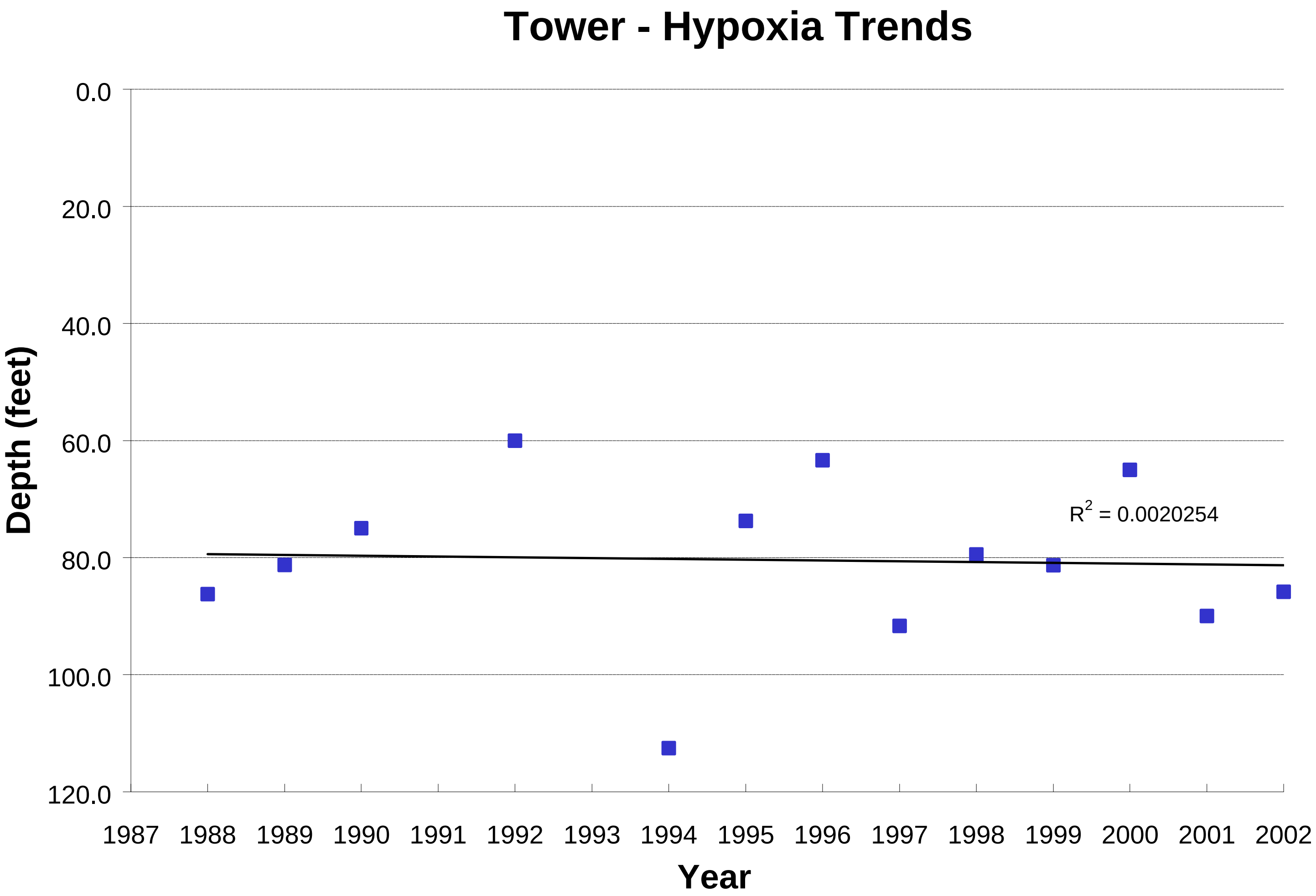

Figure 3-6. Trends in seasonal average hypoxia at the "Tower" station BZ-6. Measured as the depth at which hypoxia was observed in the water column.

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	24	NS	0.0178	NS	-0.0200
BZ-2	22	NS	0.0245	NS	0.0073
BZ-3	26	NS	-0.0206	<0.05	-0.0962
BZ-4	24	NS	0.0024	NS	0.0108
BZ-5	25/26	NS	0.0251	NS	-0.0019
BZ-6	7	NS	-0.1317	NS	0.3558
BZ-7	7	NS	-0.0779	NS	0.4267

3.1.3 pH

Measures of pH in surface water followed a similar pattern at Beltzville Reservoir during 2002 (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 6.8, with a maximum value of 7.96 at the surface of BZ-5 on October 2 and minimum values of 6.0 at station BZ-6 and 7 at the surface on October 23.

In 2002, pH in the water column of Beltzville Reservoir at station BZ-6 was fairly uniform (Fig. 3-8). In general, pH averaged 6.3 with a maximum value 7 at the surface on October 2 and a minimum value of 5.5 at 85 feet on October 23. On October 23, pH of the entire water column was lowest and ranged from 6.01 near the surface to 5.5 in the lower water column.

The pH measures in the lower water column of Beltzville Reservoir were not in compliance with PADEP water quality standards on October 23. The standard for pH is a range of acceptable measures between 6 and 9. On October 23, pH values at station BZ-6 were below the minimum value of the standard.

3.1.4 Conductivity

Conductivity measured in the surface waters of Beltzville Reservoir was generally consistent during 2002. 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 0.07-mS/cm throughout the monitoring period (Fig. 3-9).

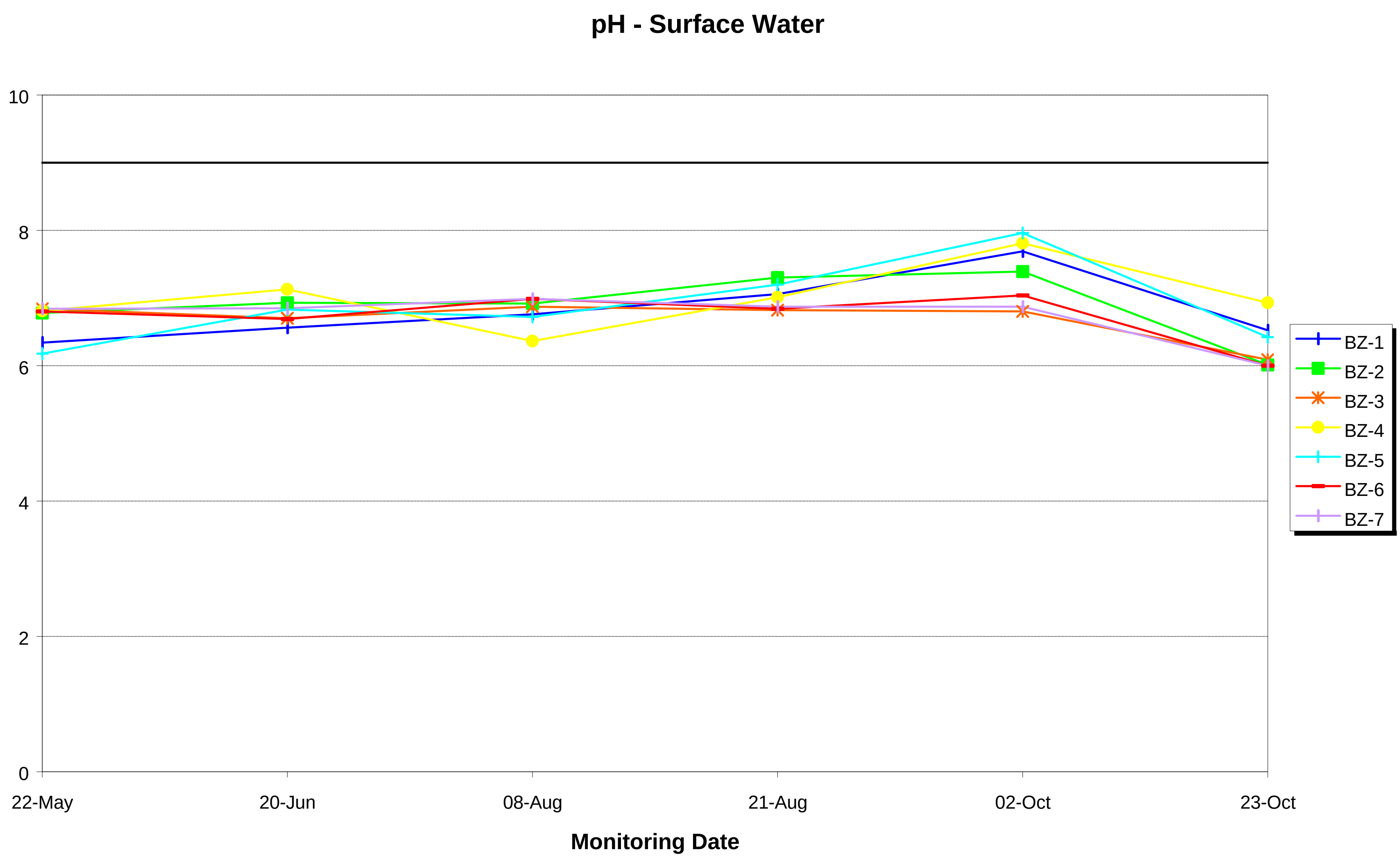

Figure 3-7. Surface water pH measured at Beltzville Reservoir in 2002. (The PADEP water quality standard for pH is from 6 to 9.) See Appendix A for summary of plotted values.

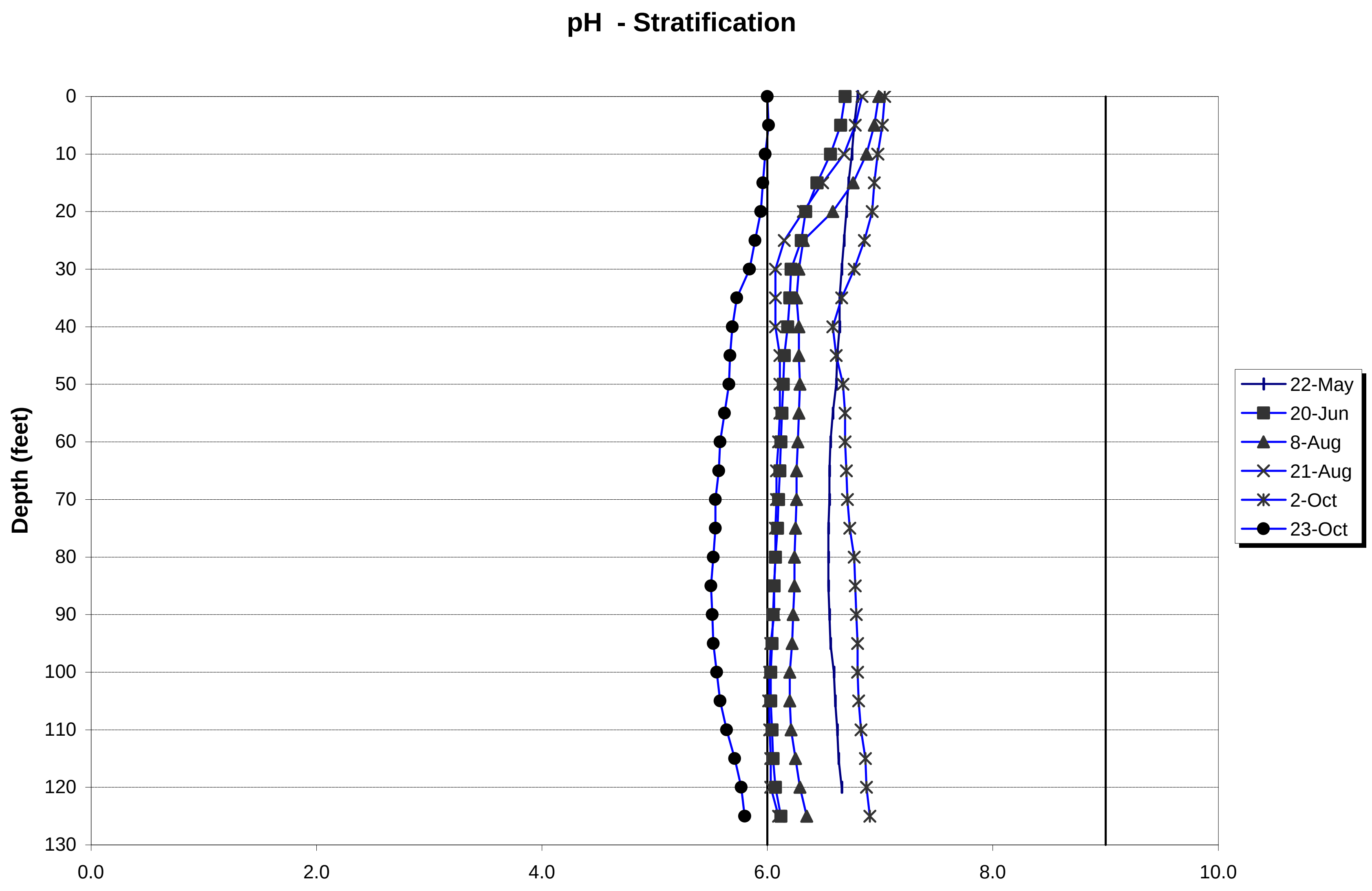

Figure 3-8. pH stratification at station BZ-6 of Beltzville Reservoir in 2002. (The PADEP water quality standard for pH is from 6 to 9.) See Appendix A for summary of plotted values.

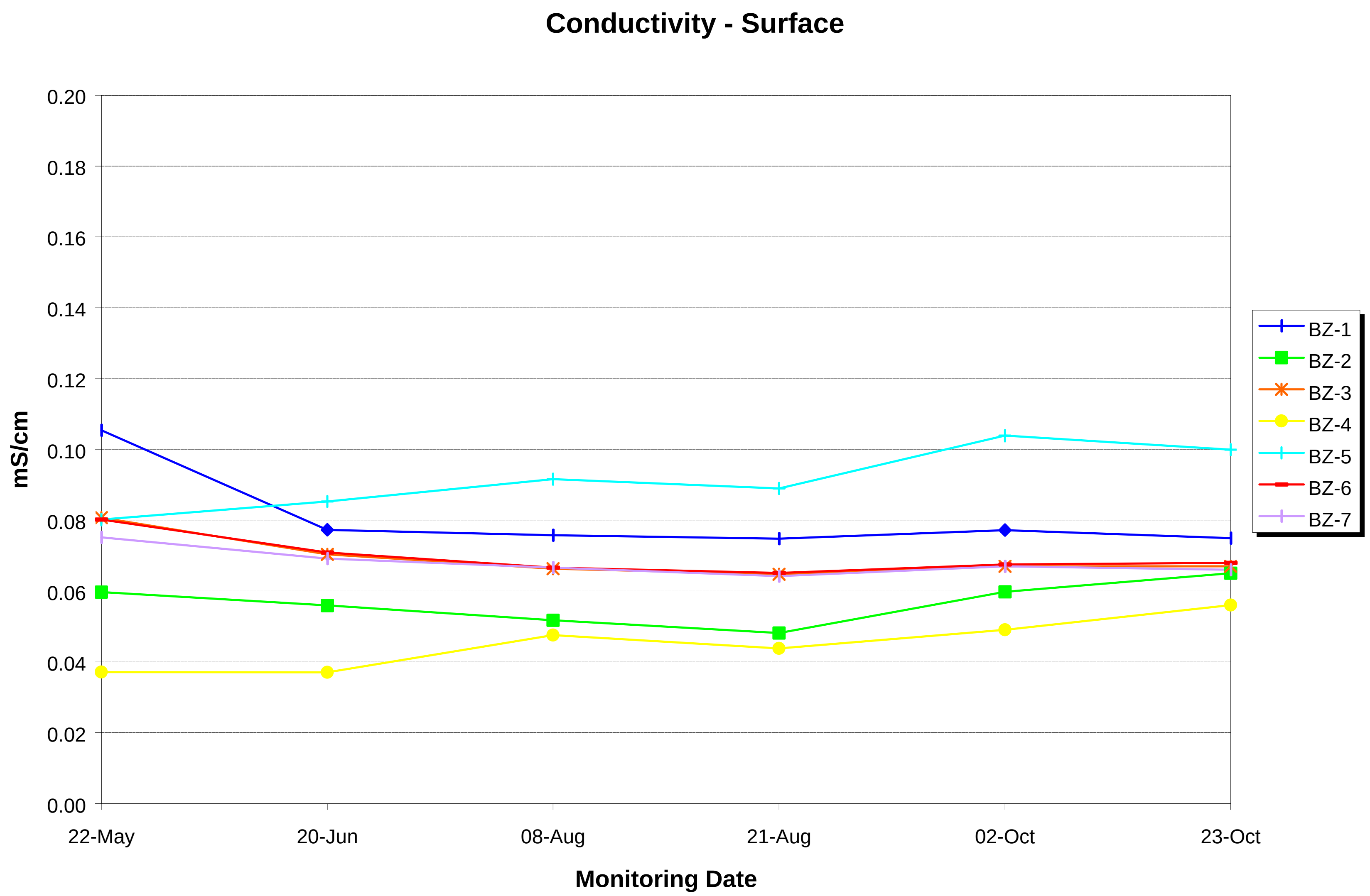

Figure 3-9. Surface water conductivity (mS/cm) measured at Beltzville Reservoir in 2002. See Appendix A for summary of plotted values.

Conductivity measured at Wild Creek (BZ-4) was consistently the lowest, averaging 0.045-mS/cm and ranging from 0.037-mS/cm in May and June to 0.56-mS/cm on October 23.

Conductivity throughout the water column of Beltzville Reservoir was also fairly consistent during 2002 (Fig. 3-10). Throughout the monitoring period measures averaged 0.076-mS/cm from surface to bottom. In May, measures were most consistent at about 0.082-mS/cm from surface to bottom. In the months of June, August and October 23, measures were lower at the surface than the bottom ranging from 0.065-mS/cm to 0.084-mS/cm. On October 2 conductivity increased from 0.067 at the surface to 0.107 at the bottom. The increasing conductivity in the lower water column during the monitoring period is an 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 2002 (Table 3-2). Where appropriate, long-term trends are discussed for surface water quality parameters incorporating 2002 data with the Beltzville Reservoir historical water quality database.

3.2.1 Ammonia

Ammonia concentrations were generally low in Beltzville Reservoir during 2002 (Fig. 3-11). Concentrations at most stations and depths were near or less than the method detection limit of 0.05 mg/L. The highest concentration of ammonia (0.24-mg/L) was measured in the surface water at station BZ-1 on the August 8 sampling event. Elevated ammonia in the lower water column of deep, stratified lakes and reservoirs usually results in those that are affected by eutrophication. However, high concentrations of ammonia were not observed on monitoring dates from June through 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 2002. 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 (7.96) and temperature (16.5 ^{o}C) was 0.09-mg/L.

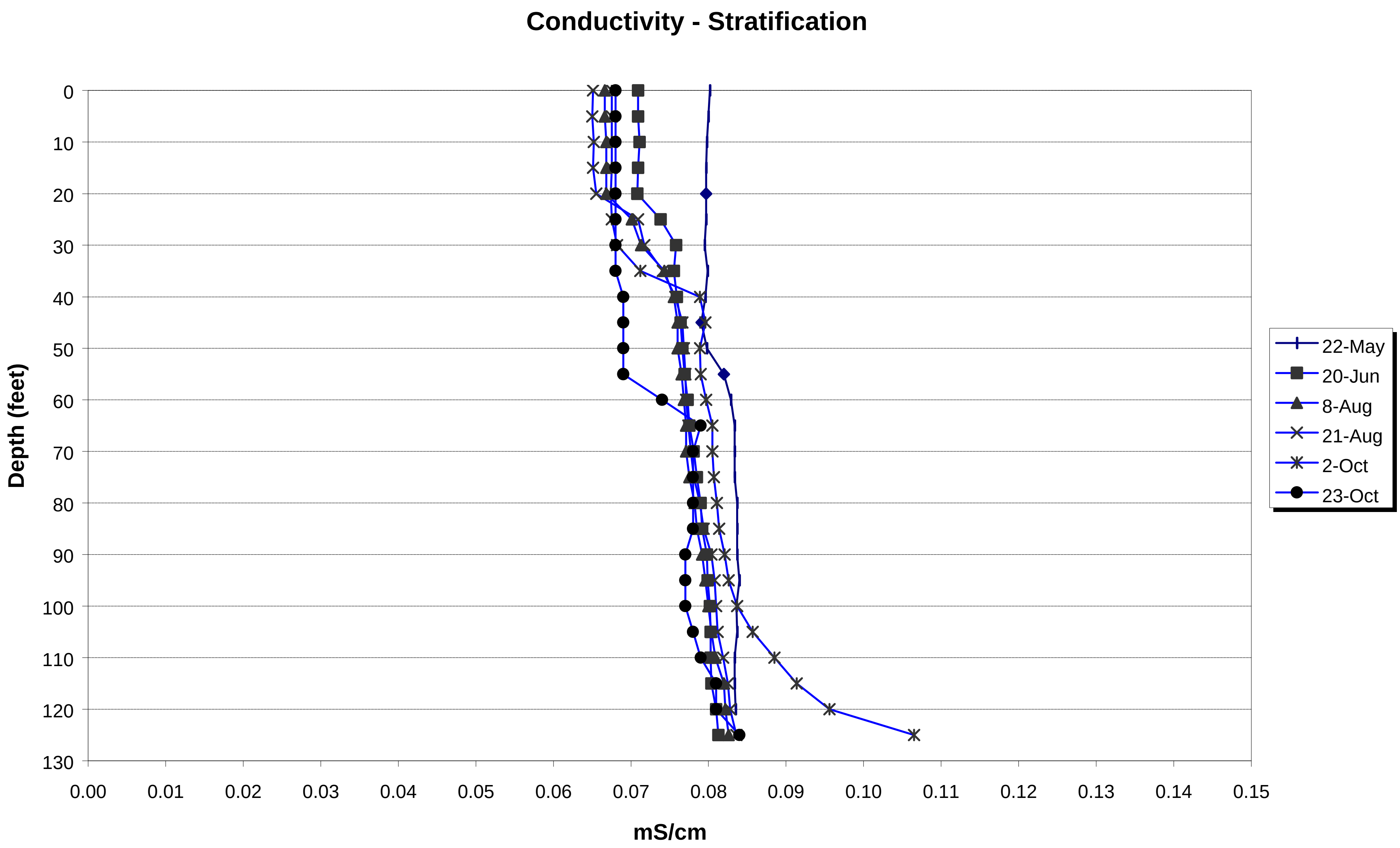

Figure 3-10. Conductivity stratification at station BZ-6 of Beltzville Reservoir in 2002. See Appendix A for summary of plotted values.

Table 3-2. Summary of surface, middle, and bottom water quality monitoring data for Beltzville Reservoir in 2002

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	DISS P	TOC	TIC	TC	CHLA
BZ-1S	22-May	0.10	< 0.010	0.80	0.07	0.30	0.02	84	2	< 2	9	0.02	< 1.0	1.0	2.0	1.9
	20-Jun	< 0.05	0.600	< 0.05	0.06	1.20	0.02	47	3	< 2	10	0.02	< 1.0	3.0	4.0	1.7
	08-Aug	0.24	< 0.010	0.25	0.03	1.00	0.01	55	1	< 2	12	0.01	1.0	2.0	3.0	1.4
	21-Aug	0.06	< 0.010	< 0.05	0.02	0.50	0.02	48	1	< 2	6	0.01	1.0	2.0	3.0	2.5
	02-Oct	0.12	< 0.010	0.50	< 0.01	0.40	0.01	34	11	< 2	6	< 0.01	2.0	2.0	4.0	5.2
	23-Oct	0.06	< 0.010	0.81	< 0.01	0.87	< 0.01	45	3	< 2	10	0.01	< 1.0	2.0	2.0	1.1
Mean		0.11	0.108	0.41	0.03	0.71	0.02	52	4	2	9	0.01	1.2	2.0	3.0	2.3
Maximum		0.24	0.600	0.81	0.07	1.20	0.02	84	11	2	12	0.02	2.0	3.0	4.0	5.2
Minimum		0.05	0.010	0.05	0.01	0.30	0.01	34	1	2	6	0.01	1.0	1.0	2.0	1.1
Std. Dev		0.07	0.241	0.35	0.03	0.36	0.01	17	4	0	2	0.01	0.4	0.6	0.9	1.5
No. of D		5	1	4	4	6	5	6	6	0	6	4	3	6	6	6
BZ-2S	22-May	< 0.05	< 0.010	0.60	0.08	< 0.05	0.03	78	11	2	4	0.02	3.0	< 1.0	3.0	1.7
	20-Jun	< 0.05	0.600	< 0.05	0.05	0.5	0.02	33	7	< 2	6	0.02	< 1.0	2.0	2.0	0.5
	08-Aug	0.18	< 0.010	0.06	0.04	0.3	0.01	43	4	< 2	10	0.01	< 1.0	2.0	2.0	1.0
	21-Aug	0.05	< 0.010	< 0.05	0.02	0.7	0.12	25	4	< 2	6	< 0.01	< 1.0	2.0	2.0	0.5
	02-Oct	0.11	< 0.010	0.34	0.01	0.4	0.01	31	8	< 2	6	< 0.01	2.0	1.0	3.0	1.9
	23-Oct	< 0.05	< 0.010	0.50	< 0.01	0.57	< 0.01	20	< 1	< 2	6	0.01	< 1.0	< 1.0	1.0	1.4
Mean		0.08	0.108	0.27	0.04	0.42	0.03	38	6	2	6	0.01	1.5	1.5	2.2	1.2
Maximum		0.18	0.600	0.60	0.08	0.70	0.12	78	11	2	10	0.02	3.0	2.0	3.0	1.9
Minimum		0.05	0.010	0.05	0.01	0.05	0.01	20	1	2	4	0.01	1.0	1.0	1.0	0.5
Std. Dev		0.05	0.241	0.25	0.03	0.23	0.04	21	4	0	2	0.01	0.8	0.5	0.8	0.6
No. of D		3	1	4	5	5	5	6	5	1	6	3	2	4	6	6
BZ-3S	22-May	< 0.05	< 0.010	0.80	0.07	< 0.05	0.03	62	6	2	12	0.02	< 1.0	3.0	3.0	5.9
	20-Jun	< 0.05	< 0.010	< 0.05	0.06	0.6	0.02	49	3	< 2	8	0.02	< 1.0	2.0	3.0	2.0
	08-Aug	0.09	< 0.010	0.13	0.02	0.3	0.01	50	2	< 2	6	< 0.01	< 1.0	2.0	3.0	3.9
	21-Aug	0.09	< 0.010	< 0.05	< 0.01	0.7	0.01	34	4	< 2	4	< 0.01	1.0	1.0	2.0	8.8
	02-Oct	0.10	< 0.010	0.36	< 0.01	0.5	0.01	30	8	< 2	6	< 0.01	3.0	< 1.0	4.0	4.2
	23-Oct	< 0.05	< 0.010	0.58	0.01	0.72	0.01	36	1	< 2	8	0.02	2.0	< 1.0	2.0	2.6
Mean		0.07	0.010	0.33	0.03	0.48	0.02	44	4	2	7	0.02	1.5	1.7	2.8	4.5
Maximum		0.10	0.010	0.80	0.07	0.72	0.03	62	8	2	12	0.02	3.0	3.0	4.0	8.8
Minimum		0.05	0.010	0.05	0.01	0.05	0.01	30	1	2	4	0.01	1.0	1.0	2.0	2.0
Std. Dev		0.02	0.000	0.31	0.03	0.26	0.01	12	3	0	3	0.01	0.8	0.8	0.8	2.5
No. of D		3	0	4	4	5	6	6	6	1	6	2	3	4	6	6
BZ-3M	22-May	< 0.05	< 0.010	0.80	0.09	< 0.05	0.03	54	< 1	< 2	8	0.03	< 1.0	1.0	2.0	1.8
	20-Jun	< 0.05	< 0.010	< 0.05	0.03	0.7	0.02	58	3	< 2	6	0.01	< 1.0	2.0	3.0	3.1
	08-Aug	0.08	< 0.010	0.29	0.02	0.2	0.01	57	1	< 2	10	0.01	1.0	2.0	4.0	0.8
	21-Aug	< 0.05	< 0.010	< 0.05	0.02	0.8	0.02	49	3	< 2	6	< 0.01	1.0	2.0	3.0	1.2
	02-Oct	0.11	< 0.010	0.38	0.01	0.5	0.01	35	8	< 2	6	< 0.01	3.0	< 1.0	3.0	5.7
	23-Oct	0.08	< 0.010	0.58	< 0.01	0.63	0.01	26	5	< 2	18	0.01	< 1.0	3.0	4.0	2.3
Mean		0.07	0.010	0.36	0.03	0.48	0.02	47	4	2	9	0.01	1.3	1.8	3.2	2.5
Maximum		0.11	0.010	0.80	0.09	0.80	0.03	58	8	2	18	0.03	3.0	3.0	4.0	5.7
Minimum		0.05	0.010	0.05	0.01	0.05	0.01	26	1	2	6	0.01	1.0	1.0	2.0	0.8
Std. Dev		0.02	0.000	0.30	0.03	0.30	0.01	13	3	0	5	0.01	0.8	0.8	0.8	1.8
No. of D		3	0	4	5	5	6	6	5	0	6	3	3	5	6	6
BZ-3B	22-May	0.10	< 0.010	0.80	0.09	0.07	0.01	64	3	< 2	10	0.03	< 1.0	2.0	3.0	1.4
	20-Jun	< 0.05	< 0.010	< 0.05	0.03	0.6	0.02	54	2	2	14	0.01	< 1.0	2.0	3.0	0.7
	08-Aug	0.10	< 0.010	0.28	0.04	0.3	0.01	60	1	< 2	10	0.01	1.0	3.0	4.0	0.6
	21-Aug	< 0.05	< 0.010	0.29	0.02	0.7	0.02	52	13	2	12	0.01	1.0	3.0	4.0	1.5
	02-Oct	0.10	< 0.010	0.73	0.01	0.3	0.02	36	5	< 2	6	< 0.01	2.0	3.0	5.0	4.0
	23-Oct	< 0.05	< 0.010	0.56	< 0.01	0.41	< 0.01	35	6	< 2	6	0.01	3.0	< 1.0	2.0	4.7
Mean		0.08	0.010	0.45	0.03	0.40	0.02	50	5	2	10	0.01	1.5	2.3	3.5	2.1
Maximum		0.10	0.010	0.80	0.09	0.70	0.02	64	13	2	14	0.03	3.0	3.0	5.0	4.7
Minimum		0.05	0.010	0.05	0.01	0.07	0.01	35	1	2	6	0.01	1.0	1.0	2.0	0.6
Std. Dev		0.03	0.000	0.29	0.03	0.23	0.01	12	4	0	3	0.01	0.8	0.8	1.0	1.8
No. of D		3	0	5	5	6	5	6	6	2	6	4	4	5	6	6

Table 3-2. (Continued)

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	DISS P	TOC	TIC	TC	CHLA
BZ-4S	22-May	< 0.05	< 0.010	0.50	0.09	< 0.05	0.02	38	2	< 2	5	0.03	1.0	< 1.0	2.0	3.3
	20-Jun	< 0.05	< 0.010	< 0.05	0.05	0.9	0.02	29	3	< 2	4	0.02	< 1.0	1.0	2.0	0.9
	08-Aug	0.07	< 0.010	0.28	0.03	0.3	0.01	42	5	< 2	10	0.01	< 1.0	3.0	4.0	0.5
	21-Aug	< 0.05	< 0.010	0.08	< 0.01	0.5	0.02	23	1	< 2	6	< 0.01	1.0	< 1.0	2.0	2.0
	02-Oct	0.10	< 0.010	0.34	< 0.01	0.4	0.02	32	1	< 2	6	< 0.01	2.0	2.0	4.0	2.2
	23-Oct	< 0.05	< 0.010	0.72	< 0.01	0.38	< 0.01	22	< 1	< 2	8	0.01	< 1.0	2.0	2.0	1.8
Mean		0.06	0.010	0.33	0.03	0.42	0.02	31	2	2	7	0.02	1.2	1.7	2.7	1.8
Maximum		0.10	0.010	0.72	0.09	0.90	0.02	42	5	2	10	0.03	2.0	3.0	4.0	3.3
Minimum		0.05	0.010	0.05	0.01	0.05	0.01	22	1	2	4	0.01	1.0	1.0	2.0	0.5
Std. Dev		0.02	0.000	0.25	0.03	0.28	0.01	8	2	0	2	0.01	0.4	0.8	1.0	1.0
No. of D		2	0	5	3	5	5	6	5	0	6	3	3	4	6	6
BZ-5S	22-May	< 0.05	< 0.010	1.10	0.09	< 0.05	0.03	66	1	< 2	12	0.03	1.0	1.0	2.0	1.8
	20-Jun	< 0.05	0.600	1.00	0.06	0.4	0.02	79	7	2	12	0.02	< 1.0	2.0	2.0	1.0
	08-Aug	0.10	< 0.010	0.37	0.12	0.2	0.04	54	5	2	16	0.04	1.0	2.0	4.0	1.3
	21-Aug	< 0.05	< 0.010	0.81	0.06	0.6	0.09	57	7	2	14	0.02	1.0	2.0	4.0	3.0
	02-Oct	0.09	< 0.010	1.14	0.05	0.5	0.05	71	5	< 2	12	0.02	3.0	2.0	4.0	7.0
	23-Oct	< 0.05	< 0.010	1.84	0.02	0.35	0.02	63	6	< 2	10	0.05	< 1.0	2.0	3.0	1.4
Mean		0.07	0.108	1.04	0.07	0.35	0.04	65	5	2	13	0.03	1.3	1.8	3.2	2.6
Maximum		0.10	0.600	1.84	0.12	0.60	0.09	79	7	2	16	0.05	3.0	2.0	4.0	7.0
Minimum		0.05	0.010	0.37	0.02	0.05	0.02	54	1	2	10	0.02	1.0	1.0	2.0	1.0
Std. Dev		0.02	0.241	0.48	0.03	0.20	0.03	9	2	0	2	0.01	0.8	0.4	1.0	2.3
No. of D		2	1	6	6	5	6	6	6	3	6	5	4	6	6	6
BZ-6S	22-May	0.10	< 0.010	0.80	0.07	0.05	0.03	44	3	< 2	10	0.02	2.0	2.0	4.0	4.1
	20-Jun	< 0.05	< 0.010	< 0.05	0.06	0.5	0.02	38	2	2	8	0.02	< 1.0	1.0	2.0	2.7
	08-Aug	0.07	< 0.010	0.13	0.04	0.7	0.2	37	1	< 2	6	0.01	1.0	2.0	3.0	3.9
	21-Aug	< 0.05	< 0.010	0.20	0.01	0.6	0.03	25	3	< 2	4	< 0.01	1.0	< 1.0	2.0	5.0
	02-Oct	0.09	< 0.010	0.36	< 0.01	0.4	0.01	29	1	< 2	6	< 0.01	3.0	1.0	4.0	18.5
	23-Oct	< 0.05	< 0.010	0.57	< 0.01	0.41	< 0.01	38	< 1	< 2	8	0.01	< 1.0	2.0	3.0	1.8
Mean		0.07	0.010	0.35	0.03	0.44	0.05	35	2	2	7	0.01	1.5	1.5	3.0	6.0
Maximum		0.10	0.010	0.80	0.07	0.70	0.20	44	3	2	10	0.02	3.0	2.0	4.0	18.5
Minimum		0.05	0.010	0.05	0.01	0.05	0.01	25	1	2	4	0.01	1.0	1.0	2.0	1.8
Std. Dev		0.02	0.000	0.29	0.03	0.22	0.07	7	1	0	2	0.01	0.8	0.5	0.9	6.2
No. of D		3	0	5	4	6	5	6	5	1	6	3	4	5	6	6
BZ-6M	22-May	< 0.05	< 0.010	0.80	0.08	0.16	0.03	36	1	< 2	10	0.02	< 1.0	1.0	2.0	1.7
	20-Jun	< 0.05	< 0.010	< 0.05	0.05	0.8	0.02	41	3	2	6	0.02	< 1.0	2.0	2.0	1.4
	08-Aug	0.10	< 0.010	0.23	0.02	0.3	0.01	49	< 1	< 2	10	0.01	1.0	2.0	3.0	2.9
	21-Aug	< 0.05	< 0.010	< 0.05	0.02	0.7	0.03	45	3	< 2	8	0.01	< 1.0	2.0	2.0	2.2
	02-Oct	0.11	< 0.010	0.29	0.01	0.3	0.02	66	3	< 2	12	< 0.01	2.0	3.0	5.0	3.3
	23-Oct	< 0.05	< 0.010	0.90	< 0.01	0.44	< 0.01	46	< 1	< 2	12	< 0.01	3.0	1.0	4.0	1.8
Mean		0.07	0.010	0.39	0.03	0.45	0.02	47	2	2	10	0.01	1.5	1.8	3.0	2.2
Maximum		0.11	0.010	0.90	0.08	0.80	0.03	66	3	2	12	0.02	3.0	3.0	5.0	3.3
Minimum		0.05	0.010	0.05	0.01	0.16	0.01	36	1	2	6	0.01	1.0	1.0	2.0	1.4
Std. Dev		0.03	0.000	0.37	0.03	0.25	0.01	10	1	0	2	0.01	0.8	0.8	1.3	0.7
No. of D		2	0	4	5	6	5	6	4	1	6	3	3	6	6	6
BZ-6B	22-May	0.10	< 0.010	0.80	0.09	0.49	0.03	< 10	3	5	10	0.03	< 1.0	1.0	2.0	1.7
	20-Jun	< 0.05	0.600	< 0.05	0.05	0.6	0.02	51	3	2	6	0.02	< 1.0	1.0	2.0	5.4
	08-Aug	0.07	< 0.010	0.20	0.05	0.1	0.01	65	2	2	12	0.01	1.0	2.0	3.0	0.8
	21-Aug	0.05	< 0.010	0.51	0.01	0.4	0.04	41	8	< 2	8	< 0.01	< 1.0	3.0	4.0	0.8
	02-Oct	0.09	< 0.010	0.58	0.01	0.3	0.01	35	6	< 2	8	< 0.01	2.0	3.0	5.0	9.8
	23-Oct	< 0.05	< 0.010	0.76	< 0.01	0.49	0.01	55	< 1	< 2	10	0.01	< 1.0	3.0	3.0	1.6
Mean		0.07	0.108	0.48	0.04	0.40	0.02	43	4	3	9	0.02	1.2	2.2	3.2	3.4
Maximum		0.10	0.600	0.80	0.09	0.60	0.04	65	8	5	12	0.03	2.0	3.0	5.0	9.8
Minimum		0.05	0.010	0.05	0.01	0.10	0.01	10	1	2	6	0.01	1.0	1.0	2.0	0.8
Std. Dev		0.02	0.241	0.30	0.03	0.18	0.01	19	3	1	2	0.01	0.4	1.0	1.2	3.6
No. of D		4	1	5	5	6	6	5	5	3	6	3	2	6	6	6

Table 3-2. (Continued)

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	DISS P	TOC	TIC	TC	CHLA
BZ-7S	22-May	< 0.05	< 0.010	0.60	0.08	0.41	0.03	32	3	< 2	9	0.03	1.0	1.0	3.0	5.0
	20-Jun	< 0.05	0.700	< 0.05	0.05	0.6	0.02	47	3	2	8	0.02	1.0	1.0	2.0	2.5
	08-Aug	0.05	< 0.010	0.12	0.03	0.1	0.01	41	< 1	< 2	6	0.01	2.0	< 1.0	3.0	4.2
	21-Aug	< 0.05	< 0.010	0.26	0.01	0.5	0.04	31	3	< 2	6	< 0.01	1.0	< 1.0	2.0	3.3
	02-Oct	0.09	< 0.010	0.38	0.01	0.4	0.02	25	6	< 2	4	< 0.01	3.0	< 1.0	4.0	3.0
	23-Oct	< 0.05	< 0.010	0.40	< 0.01	0.43	0.03	57	1	< 2	6	0.01	< 1.0	1.0	2.0	2.3
Mean		0.06	0.125	0.30	0.03	0.41	0.03	39	3	2	7	0.02	1.5	1.0	2.7	3.4
Maximum		0.09	0.700	0.60	0.08	0.60	0.04	57	6	2	9	0.03	3.0	1.0	4.0	5.0
Minimum		0.05	0.010	0.05	0.01	0.10	0.01	25	1	2	4	0.01	1.0	1.0	2.0	2.3
Std. Dev		0.02	0.282	0.20	0.03	0.17	0.01	12	2	0	2	0.01	0.8	0.0	0.8	1.0
No. of D		2	1	5	5	6	6	6	5	1	6	3	5	3	6	6
BZ-7M	22-May	< 0.05	< 0.010	0.70	0.08	0.15	0.03	32	4	2	10	0.02	1.0	1.0	2.0	3.3
	20-Jun	< 0.05	0.600	< 0.05	0.05	0.5	0.03	41	3	2	8	0.02	< 1.0	1.0	2.0	4.8
	08-Aug	0.09	< 0.010	0.26	0.05	0.2	0.02	50	2	< 2	10	0.02	1.0	2.0	3.0	1.8
	21-Aug	0.09	< 0.010	< 0.05	0.01	0.8	0.05	35	29	2	8	< 0.01	1.0	< 1.0	2.0	1.8
	02-Oct	0.08	< 0.010	0.38	0.03	0.4	0.03	26	3	< 2	6	0.01	3.0	< 1.0	4.0	3.8
	23-Oct	< 0.05	< 0.010	0.68	< 0.01	0.35	0.01	46	1	< 2	6	0.01	< 1.0	< 1.0	2.0	1.8
Mean		0.07	0.108	0.35	0.04	0.40	0.03	38	7	2	8	0.02	1.3	1.2	2.5	2.9
Maximum		0.09	0.600	0.70	0.08	0.80	0.05	50	29	2	10	0.02	3.0	2.0	4.0	4.8
Minimum		0.05	0.010	0.05	0.01	0.15	0.01	26	1	2	6	0.01	1.0	1.0	2.0	1.8
Std. Dev		0.02	0.241	0.29	0.03	0.23	0.01	9	11	0	2	0.01	0.8	0.4	0.8	1.3
No. of D		3	1	4	5	6	6	6	6	3	6	4	4	3	6	6
BZ-7B	22-May	< 0.05	< 0.010	0.90	0.06	0.71	0.03	46	5	< 2	9	0.02	1.0	1.0	2.0	2.8
	20-Jun	< 0.05	< 0.010	< 0.05	0.06	0.5	0.03	53	4	2	12	0.02	1.0	2.0	3.0	1.2
	08-Aug	0.07	< 0.010	0.21	0.08	0.2	0.03	68	3	< 2	14	0.03	1.0	2.0	4.0	0.8
	21-Aug	0.07	< 0.010	0.40	0.01	0.9	0.07	65	6	2	12	< 0.01	< 1.0	3.0	4.0	1.5
	02-Oct	0.10	< 0.010	0.29	0.03	0.5	0.02	29	7	< 2	14	0.01	3.0	1.0	4.0	4.0
	23-Oct	< 0.05	< 0.010	0.83	0.02	0.36	0.02	47	< 1	< 2	6	0.05	< 1.0	1.0	2.0	3.7
Mean		0.07	0.010	0.45	0.04	0.53	0.03	51	4	2	11	0.02	1.3	1.7	3.2	2.3
Maximum		0.10	0.010	0.90	0.08	0.90	0.07	68	7	2	14	0.05	3.0	3.0	4.0	4.0
Minimum		0.05	0.010	0.05	0.01	0.20	0.02	29	1	2	6	0.01	1.0	1.0	2.0	0.8
Std. Dev		0.02	0.000	0.34	0.03	0.25	0.02	14	2	0	3	0.02	0.8	0.8	1.0	1.4
No. of D		3	0	5	6	6	6	6	5	2	6	4	4	6	6	6

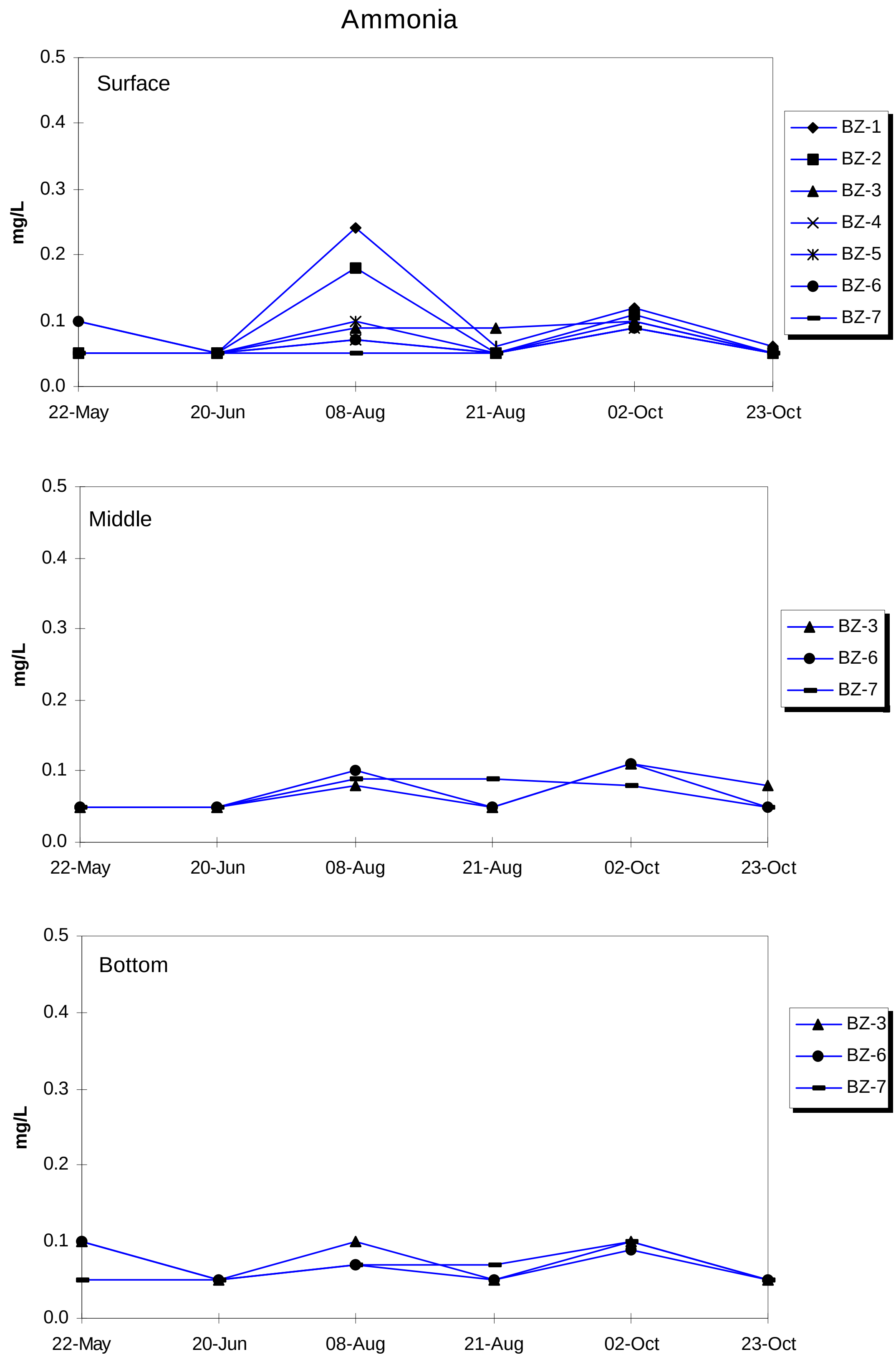

Figure 3-11. Ammonia measured in surface, middle, and bottom waters of Beltzville Reservoir in 2002

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, 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 0.003 mg/L/year. Station BZ-5 also had significant decreasing spring season rate 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	25/24	NS	-0.0012	< 0.05	-0.0030
BZ-2	23	NS	-0.0008	NS	-0.0011
BZ-3	27/26	NS	-0.0006	< 0.05	-0.0020
BZ-4	26/25	NS	-0.0009	< 0.01	-0.0017
BZ-5	26	< 0.01	-0.0013	< 0.01	-0.0024
BZ-6	7	NS	0.0113	NS	0.0083
BZ-7	7	NS	0.0040	NS	0.0080

3.2.2 Nitrite and Nitrate

Nitrite concentrations in the water column of Beltzville Reservoir were low during 2002 (Fig. 3-12). Concentrations measured at 92% of all stations and depths were less than the method detection limit of 0.1-mg/L throughout the monitoring period. Concentrations at stations BZ-1, 2, 5, 6, and 7 were slightly elevated during June. Concentrations of nitrite at stations at the surface and middle sampling points at BZ-7 were 0.7 and 0.6-mg/L respectively. Surface concentrations of nitrite at BZ-1, 2, 5, and as well as the bottom sample at BZ-6 were all 0.6-mg/L.

Nitrate was distributed uniformly in the water column of Beltzville Reservoir during 2002 (Fig. 3-13). At most stations and depths, concentrations ranged from less than the method detection limit (0.05-mg/L) to 0.9-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 0.42-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 0.4 to 1.8-mg/L. Nitrate measured downstream of the reservoir (BZ-1) was consistent over the monitoring period at about 0.41-mg/L.

Beltzville Reservoir was in compliance with the PADEP water quality standard for nitrite and nitrate during 2002. 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 1.85-mg/L on October 23 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).

Seasonal trends (spring and summer) for total nitrogen in surface water were also determined for individual stations using the non-parametric Mann-Kendall statistic (Table 3-5). 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 27-year time series, total nitrogen concentrations generally averaged 0.82-mg/L; however, in 2002, concentrations were slightly lower at about 0.66-mg/L. The yearly decrease rates averaged about 0.01 mg/L per year.

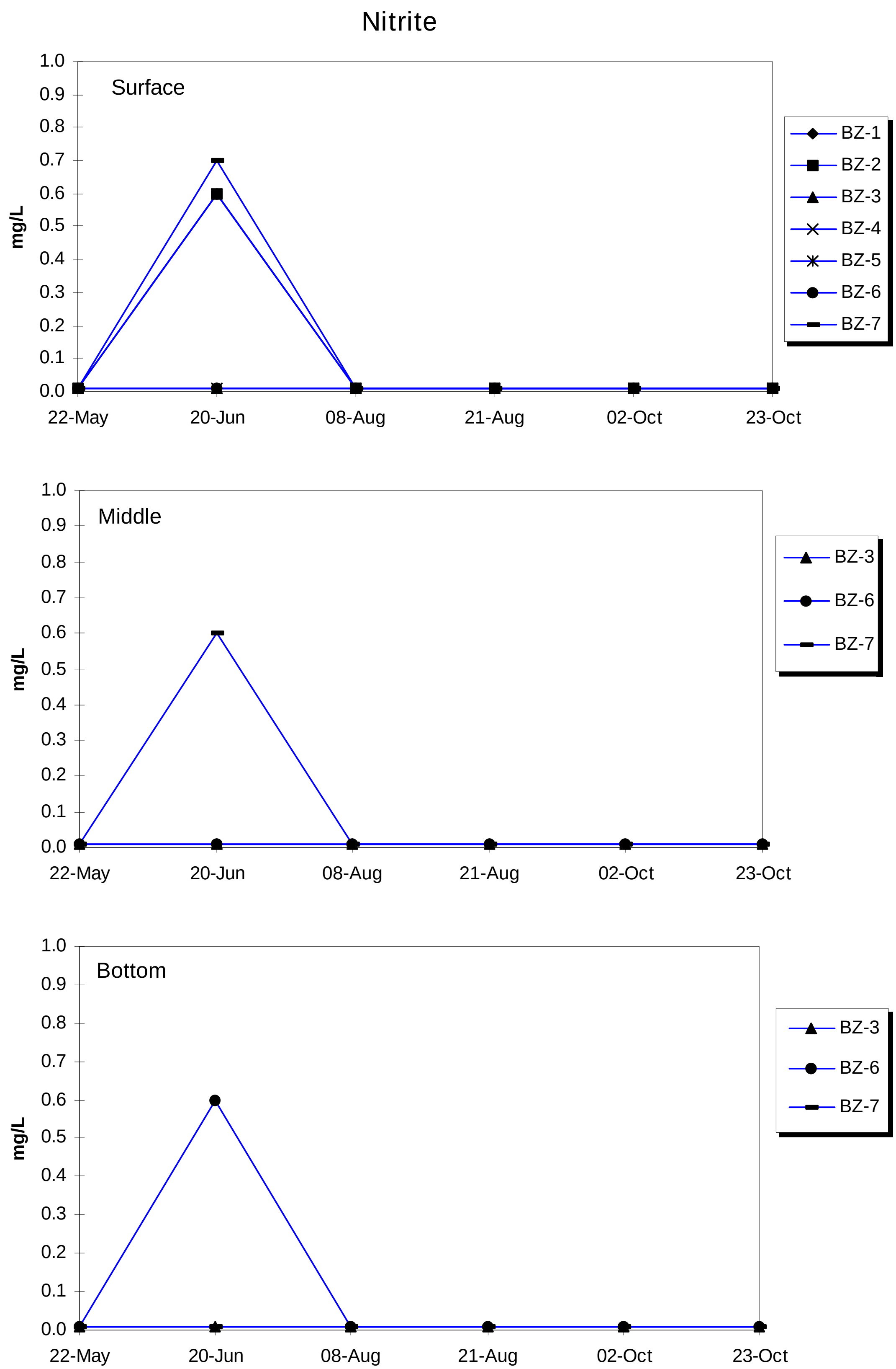

Figure 3-12. Nitrite measured in surface, middle, and bottom waters of Beltzville Reservoir in 2002

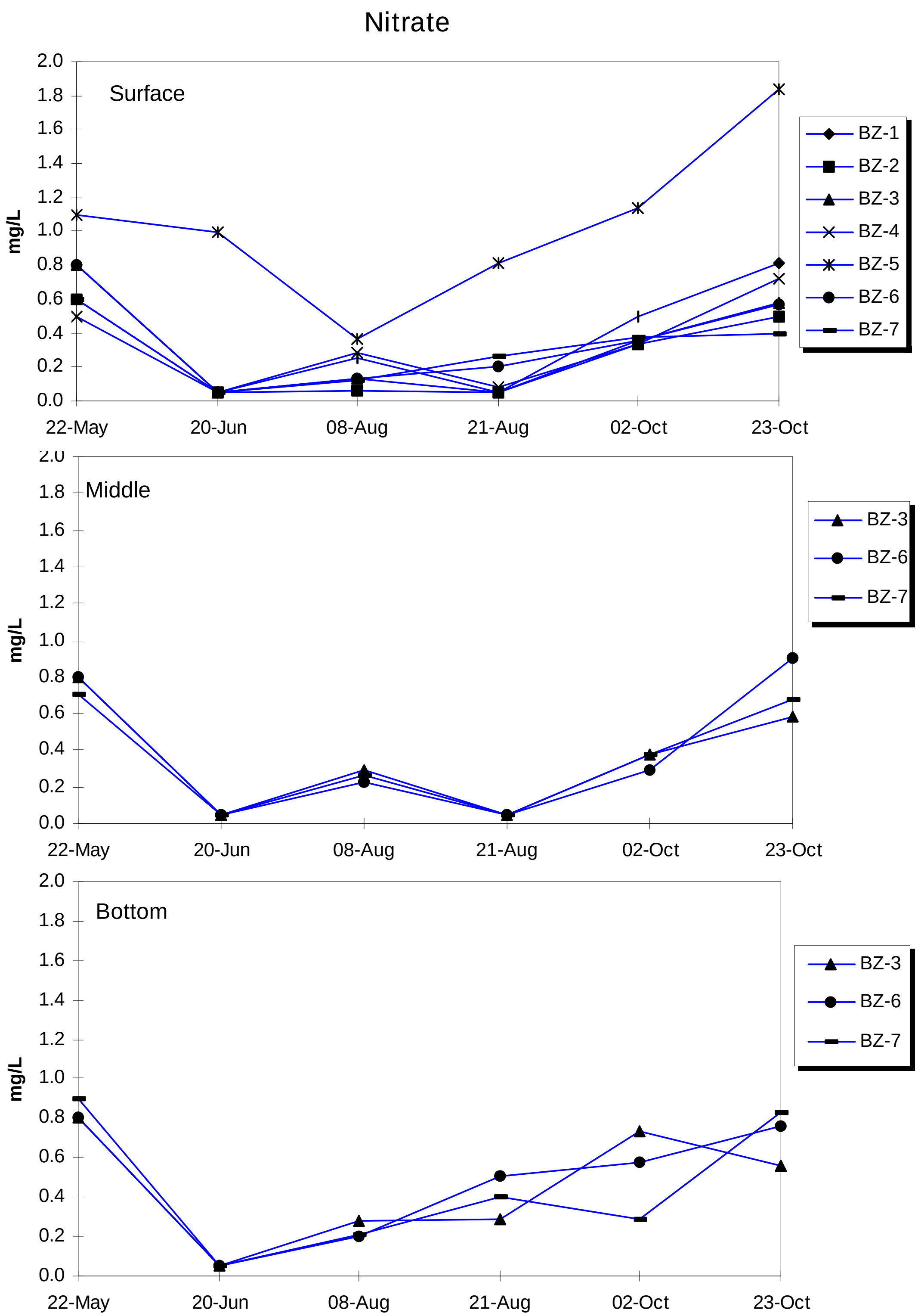

Figure 3-13. Nitrate measured in surface, middle, and bottom waters of Beltzville Reservoir in 2002

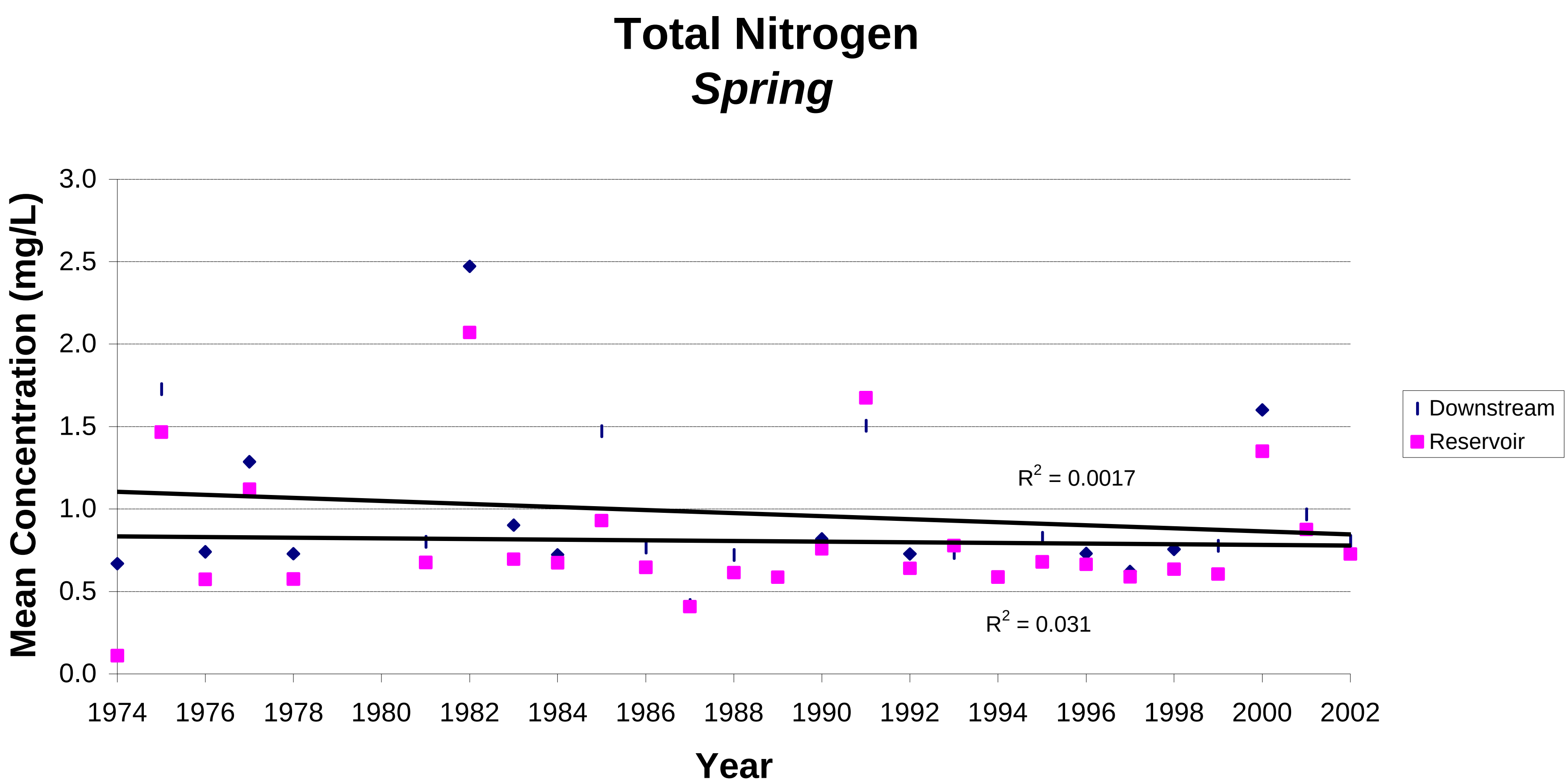

Figure 3-14. Seasonal trends of total nitrogen (ammonia + nitrite + nitrate) in the spring at Beltzville Reservoir.

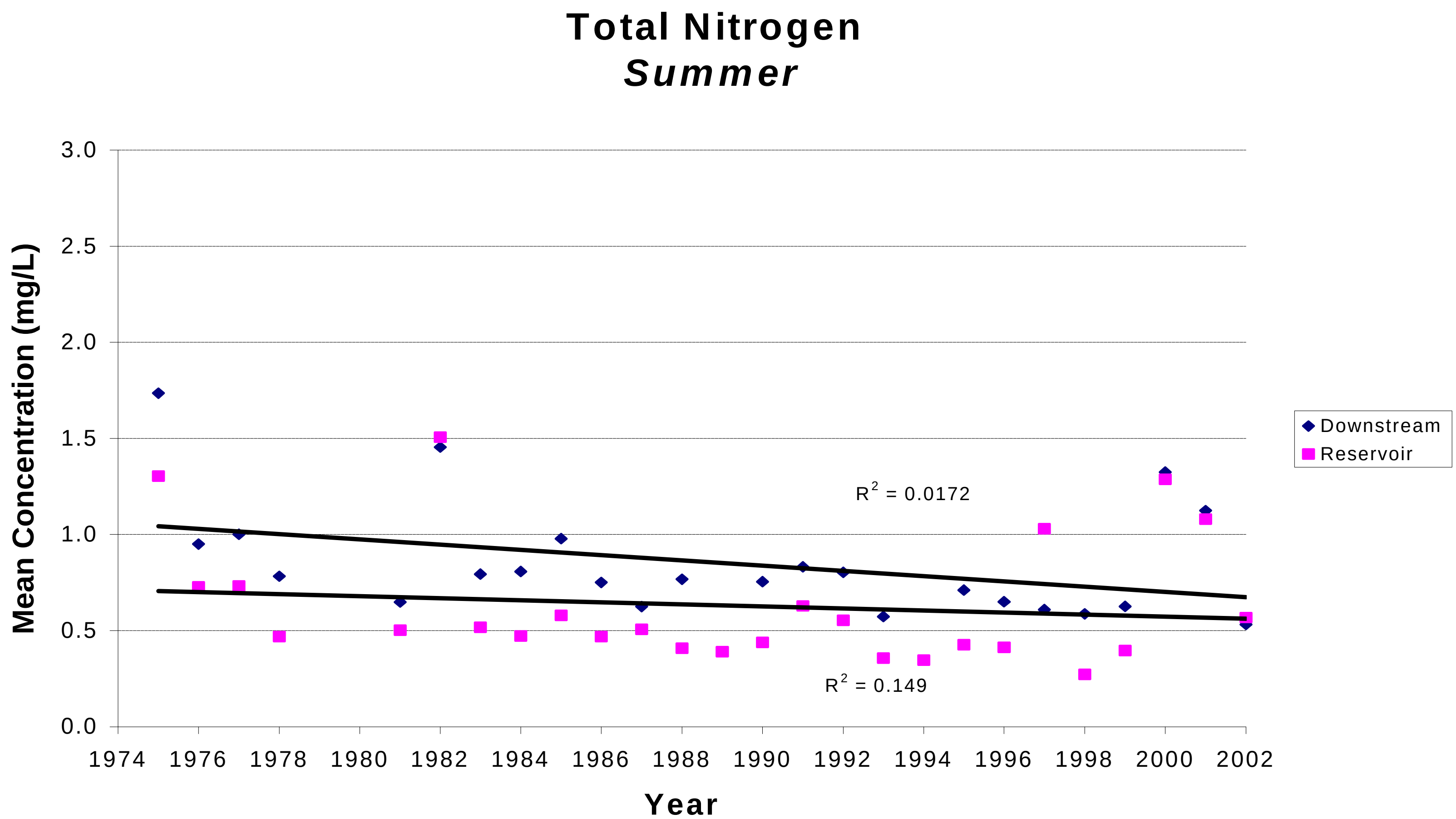

Figure 3-15. Seasonal trends of total nitrogen (ammonia + nitrite + nitrate) in the summer at Beltzville Reservoir.

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 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	25/24	NS	-0.0025	< 0.01	-0.0136
BZ-2	23	NS	-0.0033	NS	0.0006
BZ-3	27/26	NS	-0.0027	< 0.01	-0.0088
BZ-4	26/25	NS	-0.0029	< 0.05	-0.0112
BZ-5	26	NS	-0.0042	NS	0.0013
BZ-6	7	NS	-0.0292	NS	-0.0041
BZ-7	7	NS	-0.0062	NS	-0.0017

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 2002 (Fig. 3-16). Throughout the monitoring period, concentrations measured at all depths ranged less than 1.2-mg/L. Average concentrations measured at upstream stations BM-2, -4, and –5 were 0.42, 0.42, and 0.35-mg/L, respectively. Concentrations within the reservoir body at stations BZ-3, -6, and -7 and below the reservoir at station BZ-1 were also low. Concentrations at these stations measured 0.49, 0.44, 0.41, and 0.7-mg/L, respectively.

3.2.5 Dissolved Phosphate

Dissolved phosphate was not a significant nutrient parameter at Beltzville Reservoir in 2002 (Fig. 3-17). Concentrations of dissolved phosphate were generally low, averaging 0.037-mg/L at all stations and depths. Concentrations throughout the monitoring period at upstream station (BZ-5) were consistently higher averaging 0.067-mg/L. In freshwater environments, dissolved phosphate is usually a limiting nutrient and is readily taken up by freshwater plants and algae.

3.2.6 Total Dissolved Phosporus

Total dissolved phosphorus in the water column of Beltzville Reservoir was consistently low during 2002. Concentrations measured at all stations and depths averaged 0.015-mg/L throughout the monitoring period (Fig. 3-18). The highest concentrations of total dissolved phosphorus (0.05-mg/L) were measured upstream of the reservoir at BZ-5 and in the bottom water of reservoir station BZ-7 on October 23.

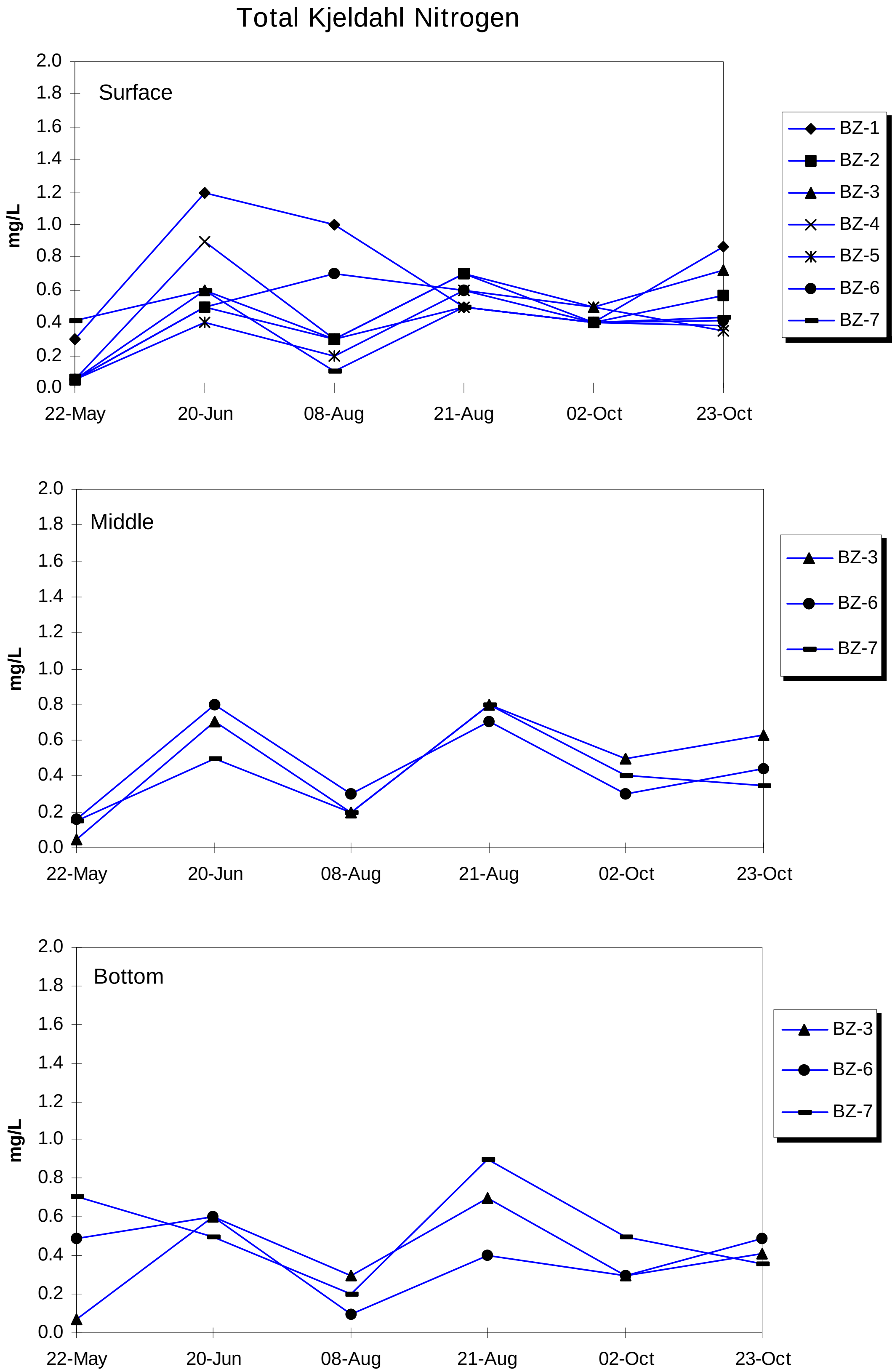

Figure 3-16. Total Kjeldahl nitrogen measured in surface, middle, and bottom waters of Beltzville Reservoir in 2002.

Phosphate

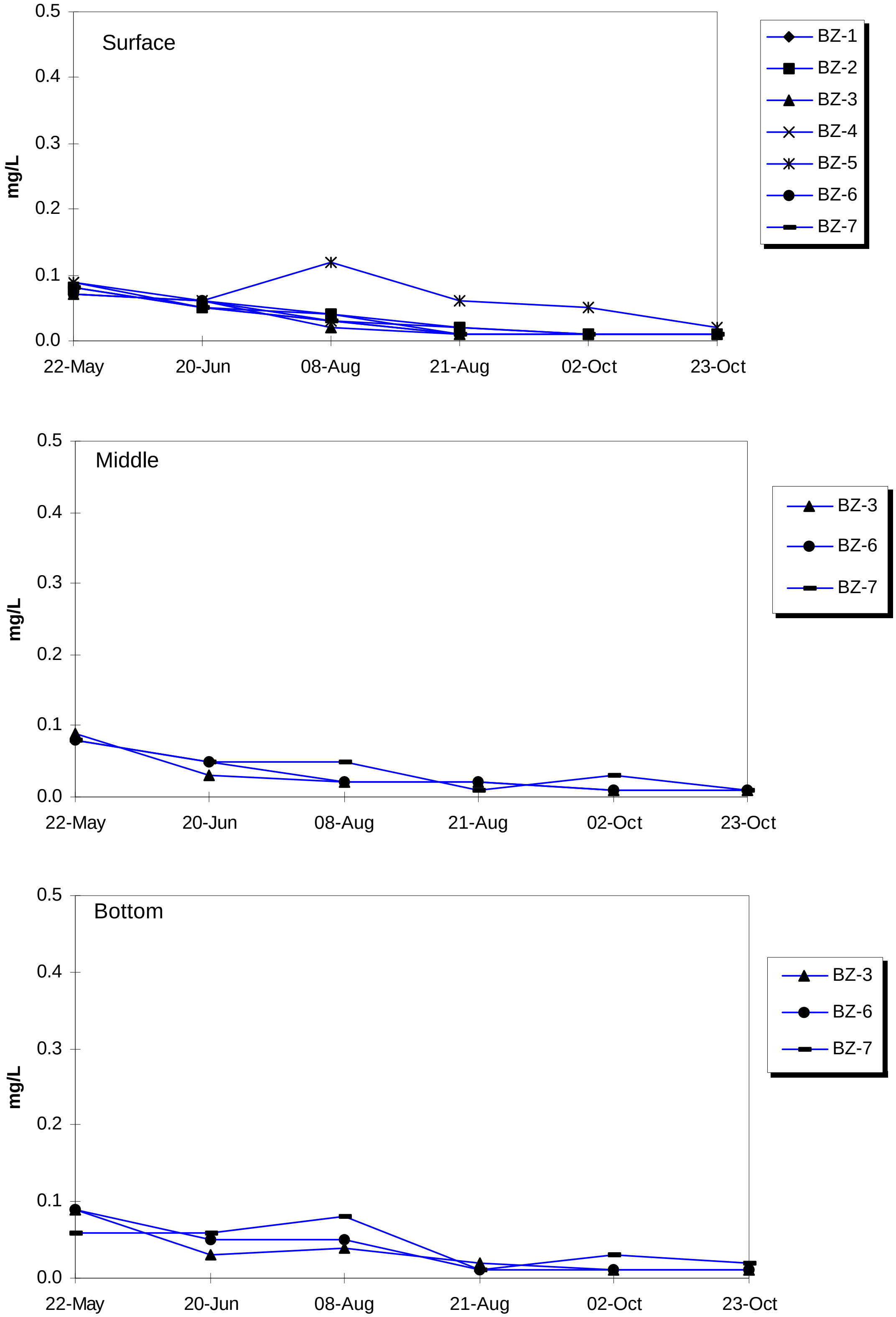

Figure 3-17. Dissolved phosphate measured in surface, middle, and bottom waters of Beltzville Reservoir in 2002

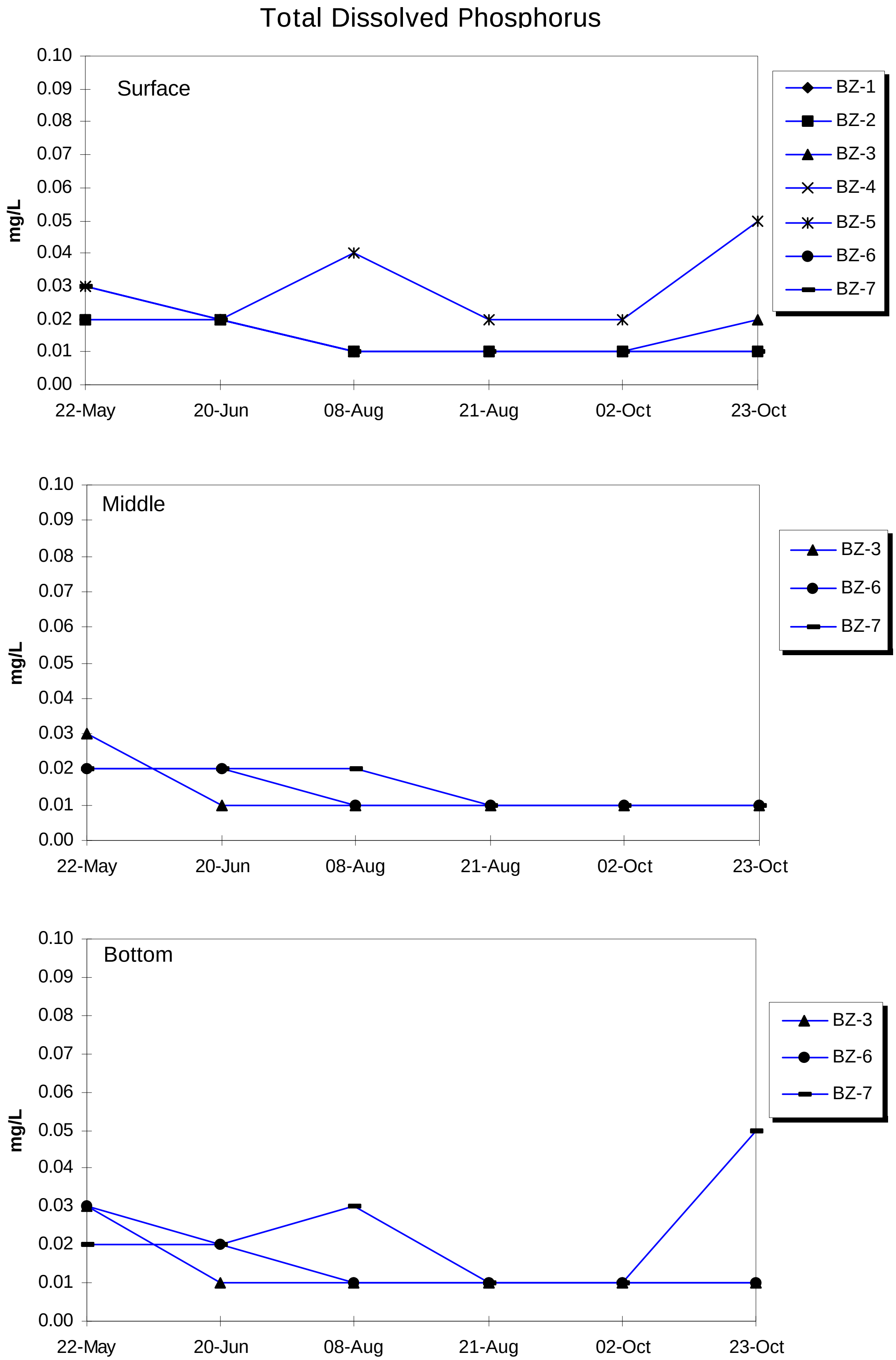

Figure 3-18. Dissolved phosphorus measured in surface, middle, and bottom waters of Beltzville Reservoir in 2002

3.2.7 Total Phosphorus

Total phosphorus in the water column of Beltzville Reservoir was frequently measured at high concentrations during 2002 (Fig. 3-19). 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, 65% of the measures for total phosphorus with results greater than or equal to the detection limit from reservoir monitoring were greater than the EPA guideline. The remaining 27 results were less than a detection limit of 0.01-mg/L, which is equal to the guideline.

Concentrations of total phosphorus were fairly uniform throughout the reservoir and generally less than 0.12-mg/L (Fig. 3-19). The average total phosphorus level throughout the reservoir was 0.025 mg/L; however, a high concentration of 0.20-mg/L resulted at BZ-6 at the surface on August 8.

Total phosphorus concentrations measured during 2002 and historical data from the past 21 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. 3-20 and 3-21). 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 22 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 0.0034-mg/L/year.

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	0.0001
BZ-2	21	NS	0.0001	NS	-0.0002
BZ-3	22/21	NS	0.0	NS	-0.0003
BZ-4	21/20	NS	0.0002	<0.05	-0.0034
BZ-5	21	NS	-0.0001	NS	0.0003
BZ-6	6	NS	0.0037	NS	0.0108
BZ-7	6	NS	0.0035	NS	0.0031

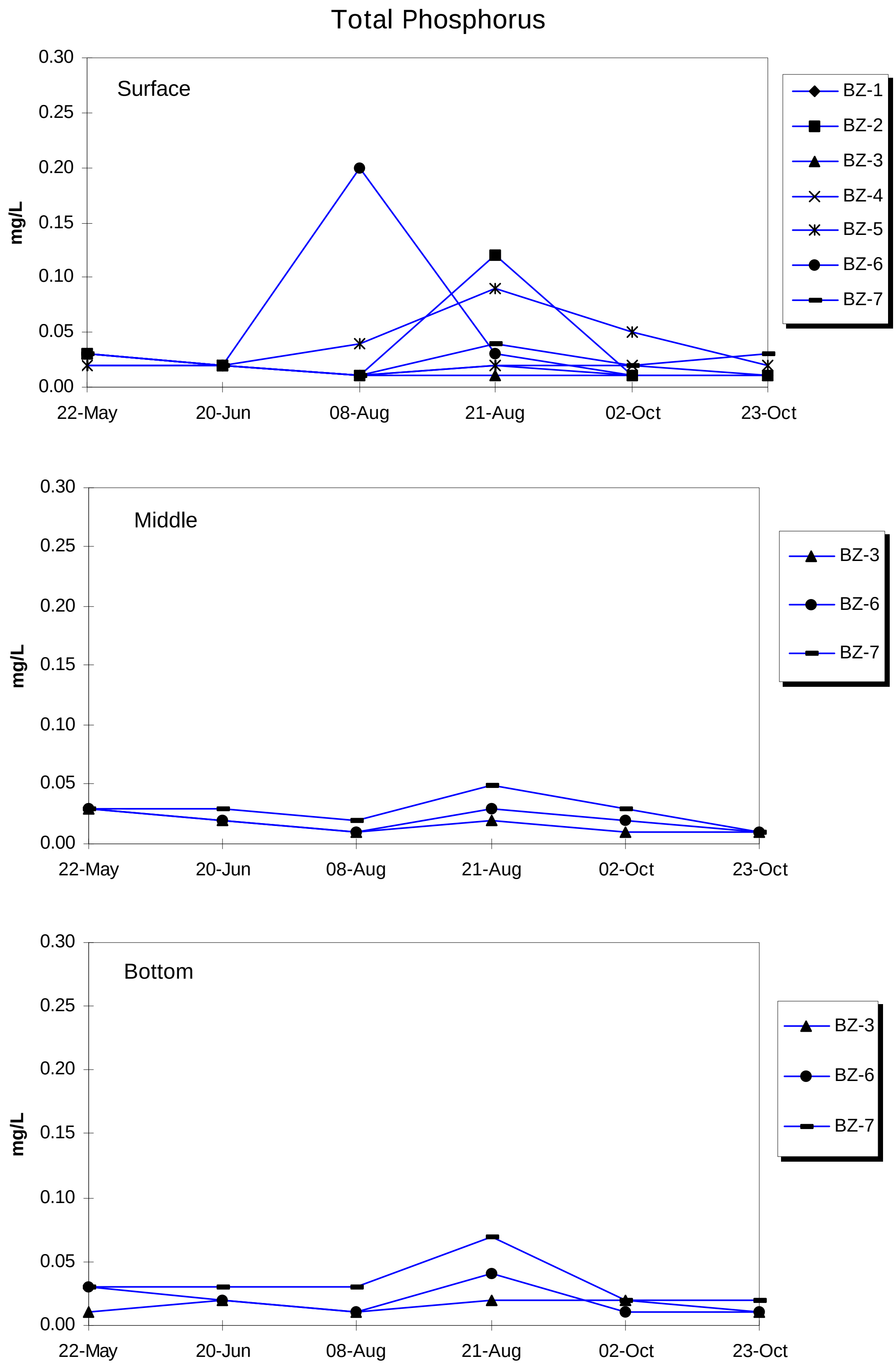

Figure 3-19. Total phosphorus measured in surface, middle, and bottom waters of Beltzville Reservoir in 2002

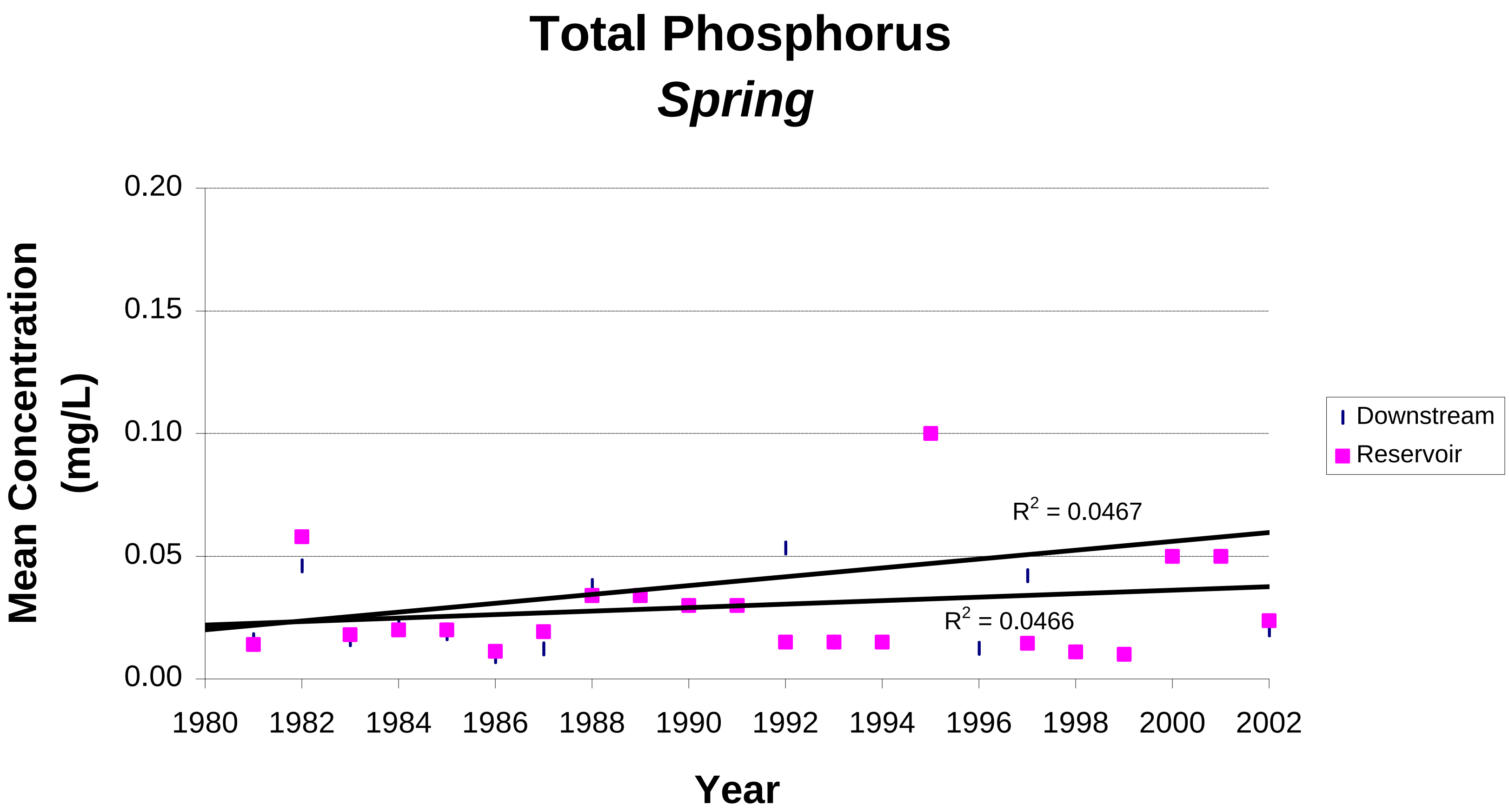

Figure 3-20. Seasonal trends of total phosphorus in spring at Beltzville Reservoir.

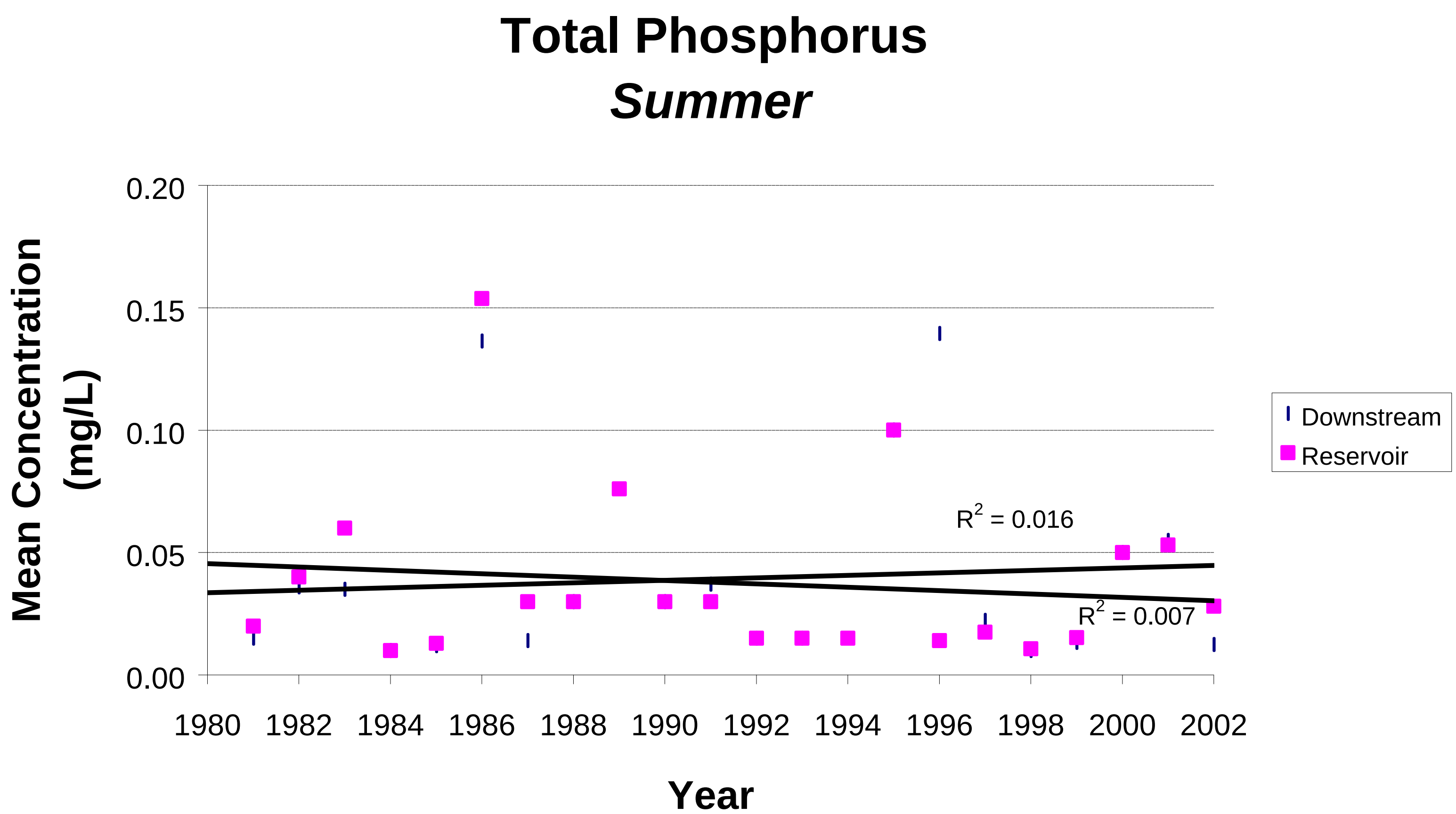

Figure 3-21. Seasonal trends of total phosphorus in summer at Beltzville Reservoir.

3.2.8 Total Dissolved Solids

Concentrations of total dissolved solids (TDS) in the water column of Beltzville Reservoir were variable during 2002 (Fig. 3-22). 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 84-mg/L. Overall, measures of TDS at all stations and depths averaged 45-mg/L.

TDS concentrations measured at Beltzville Reservoir in 2002 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. 3-22).

Total dissolved solids concentrations have exhibited no discernible pattern over the past 27 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. 3-23 and 3-24). Average TDS concentrations calculated this year were similar to levels observed in previous 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 three decades (Table 3-7). Significant decreasing trends were observed for Pine Creek and Wild Creek tributaries (stations BZ-2 and BZ–4) in the summer. The estimated rates of decrease among trends were similar at about 0.86-mg/L/year.

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	24	NS	0.1456	NS	-0.4129
BZ-2	23	NS	-0.3889	< 0.05	-0.9077
BZ-3	26	NS	-0.4889	< 0.05	-0.6190
BZ-4	25	NS	-0.2988	< 0.05	-0.8978
BZ-5	26	NS	0.3143	NS	-0.3133
BZ-6	7	NS	8.8333	NS	4.0000
BZ-7	7	NS	1.7500	NS	-2.3333

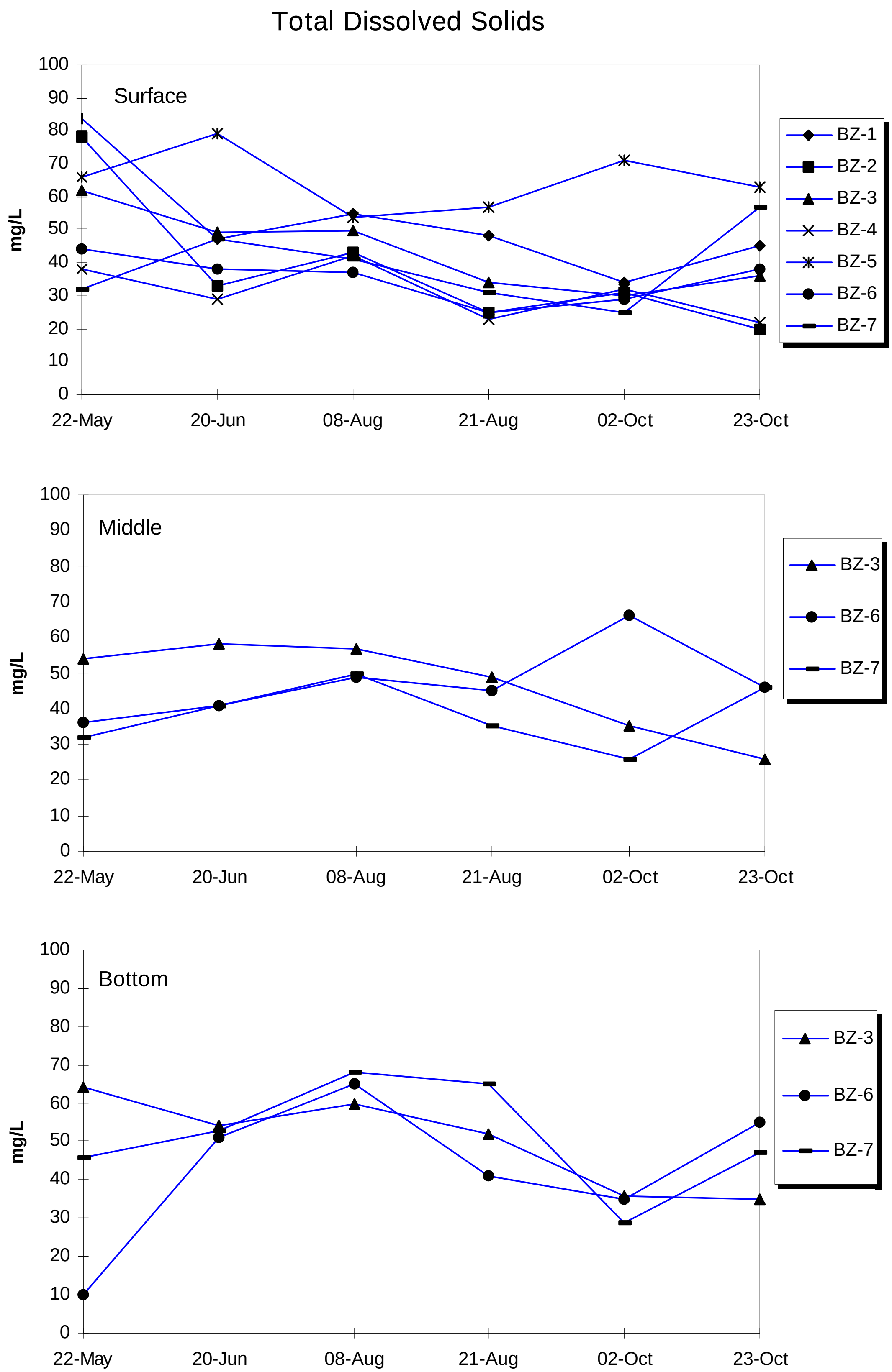

Figure 3-22. Total dissolved solids in surface, middle, and bottom waters of Beltzville Reservoir in 2002. (The PADEP water quality standard for TDS is a maximum concentration of 500 mg/l.)

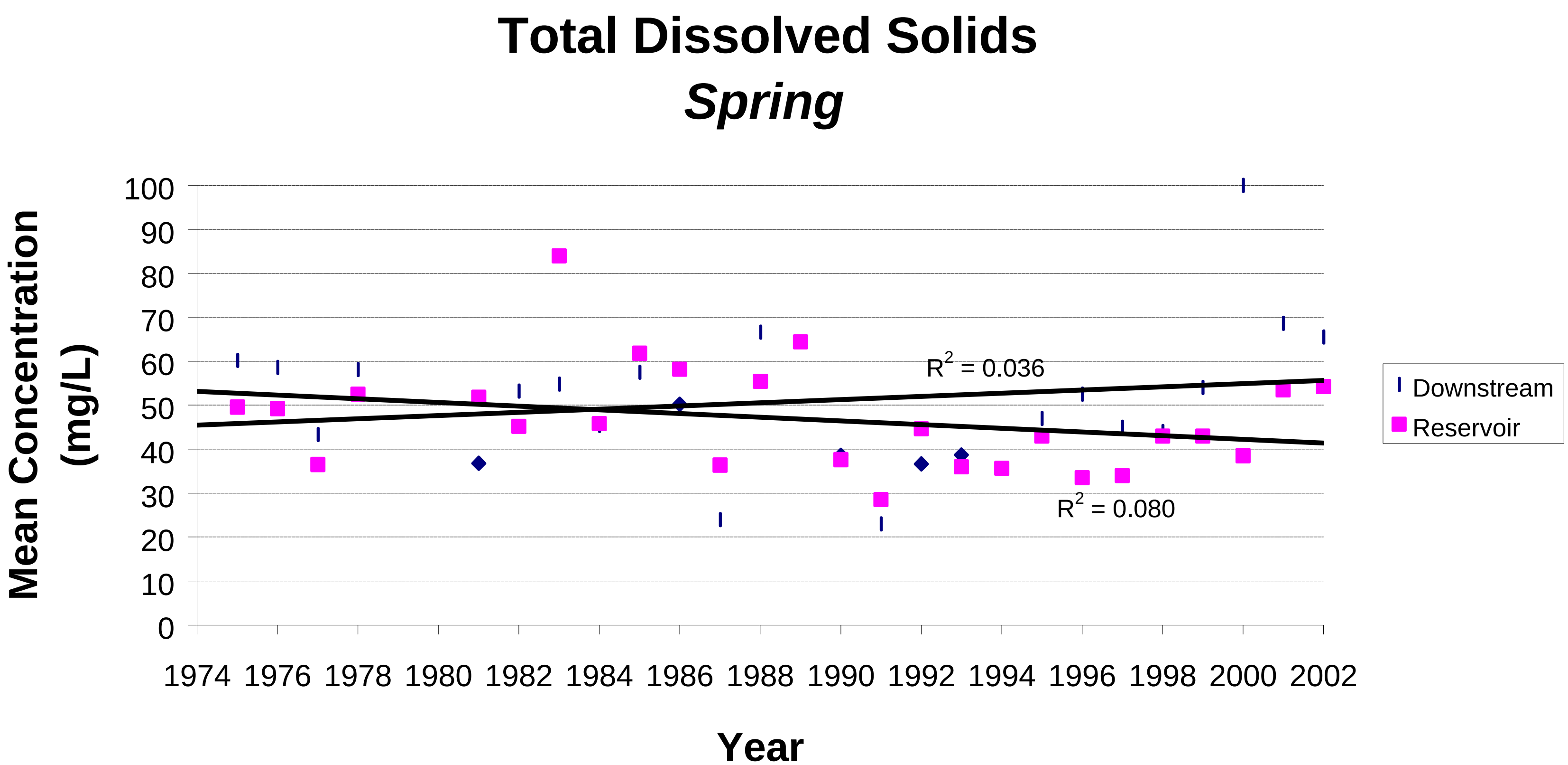

Figure 3-23. Seasonal trends of total dissolved solids in spring at Beltzville Reservoir.

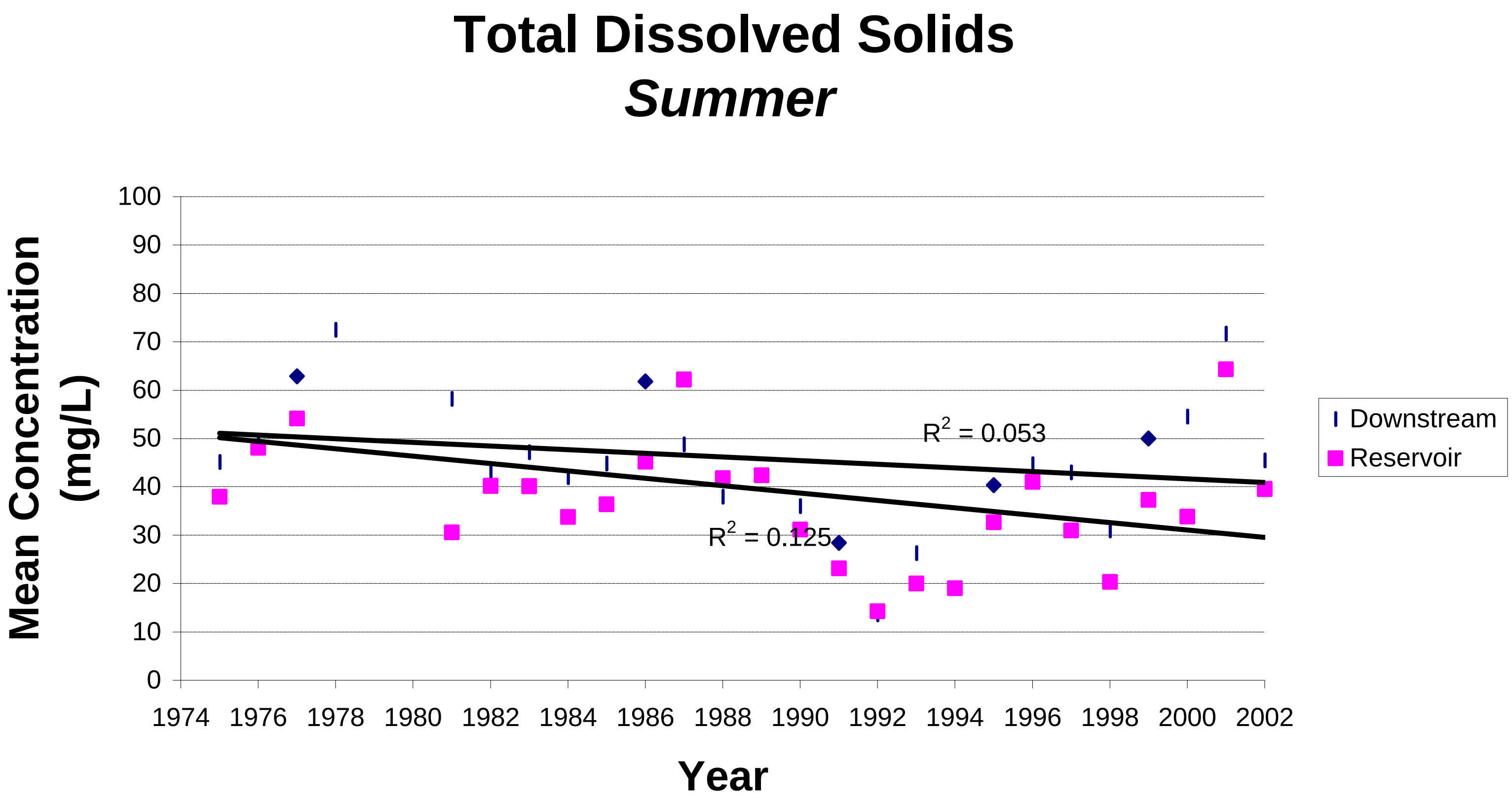

Figure 3-24. Seasonal trends of total dissolved solids in summer at Beltzville Reservoir.

3.2.9 Total Suspended Solids

Total suspended solids (TSS) concentrations in the water column of Beltzville Reservoir were low during 2002 (Fig. 3-25). All concentrations measured at all stations and depths ranged less than 29 mg/L. Concentrations of TSS averaged 3.92-mg/L and ranged from 29-mg/L in the middle water column sampling point of BZ-7 on August 21 to less than the detection limit of 1-mg/L.

3.2.10 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 consistently low in 2002 (Fig. 3-26). Throughout the monitoring period, concentrations of BOD measured at most stations and most depths were less than the method detection limit (2-mg/L). The only exception was in the bottom water of BZ-6 on 22 May. BOD on 22 May in the bottom water was 5-mg/L.

Based on trend analyses using 2002 and historical data, BOD does not appear to have changed significantly in the reservoir or downstream (Figs. 3-27 and 3-28). 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 0.0285-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	20	NS	-0.0035	NS	-0.0285
BZ-2	22	NS	0	NS	-0.0000
BZ-3	22	NS	-0.0125	NS	-0.0089
BZ-4	21	NS	0	NS	0.0000
BZ-5	22	NS	0	NS	-0.0370
BZ-6	7	NS	0.1000	NS	0.0000
BZ-7	7	NS	0	NS	0.0000

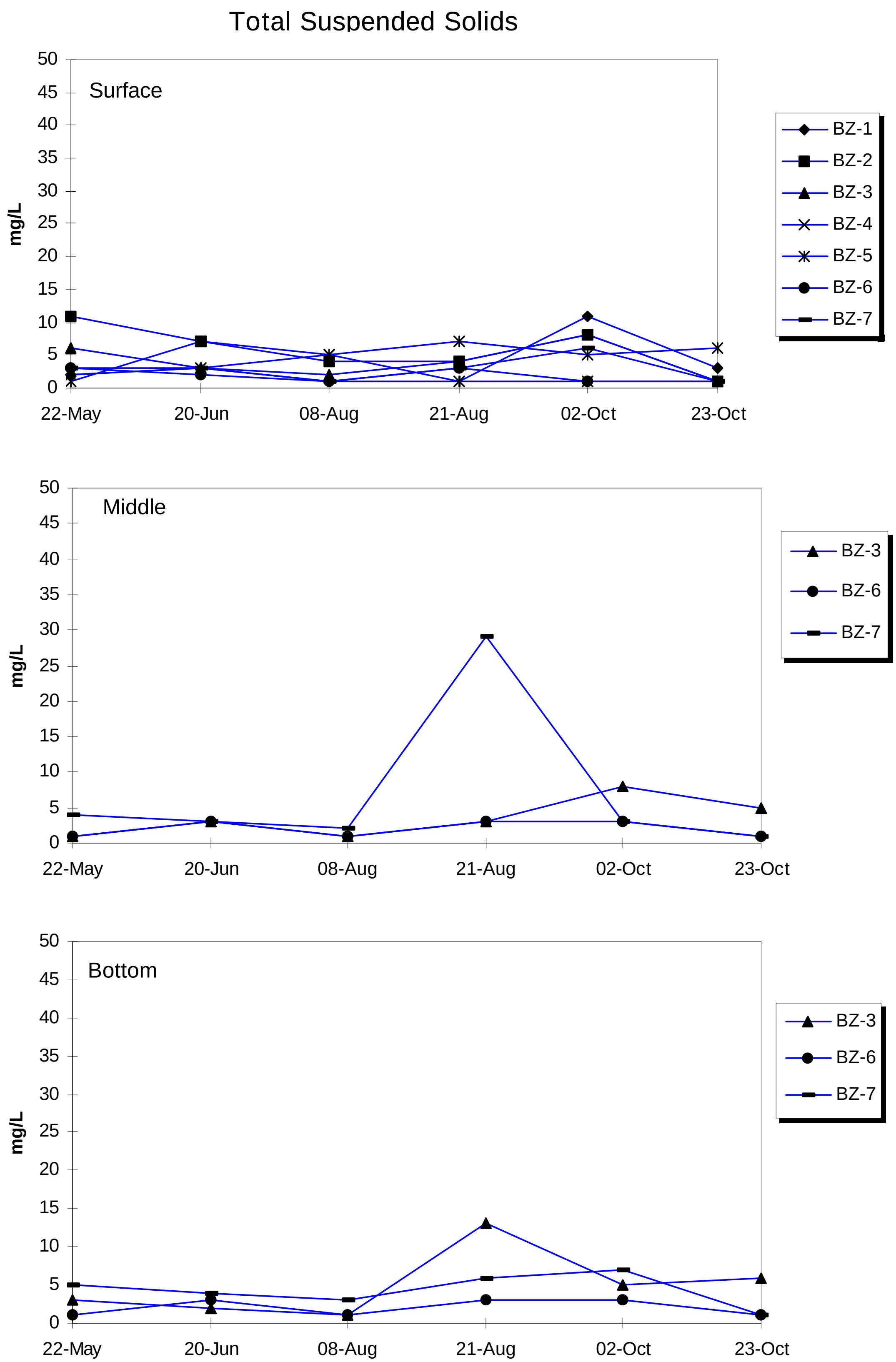

Figure 3-25. Total suspended solids in surface, middle, and bottom waters of Beltzville Reservoir in 2002.

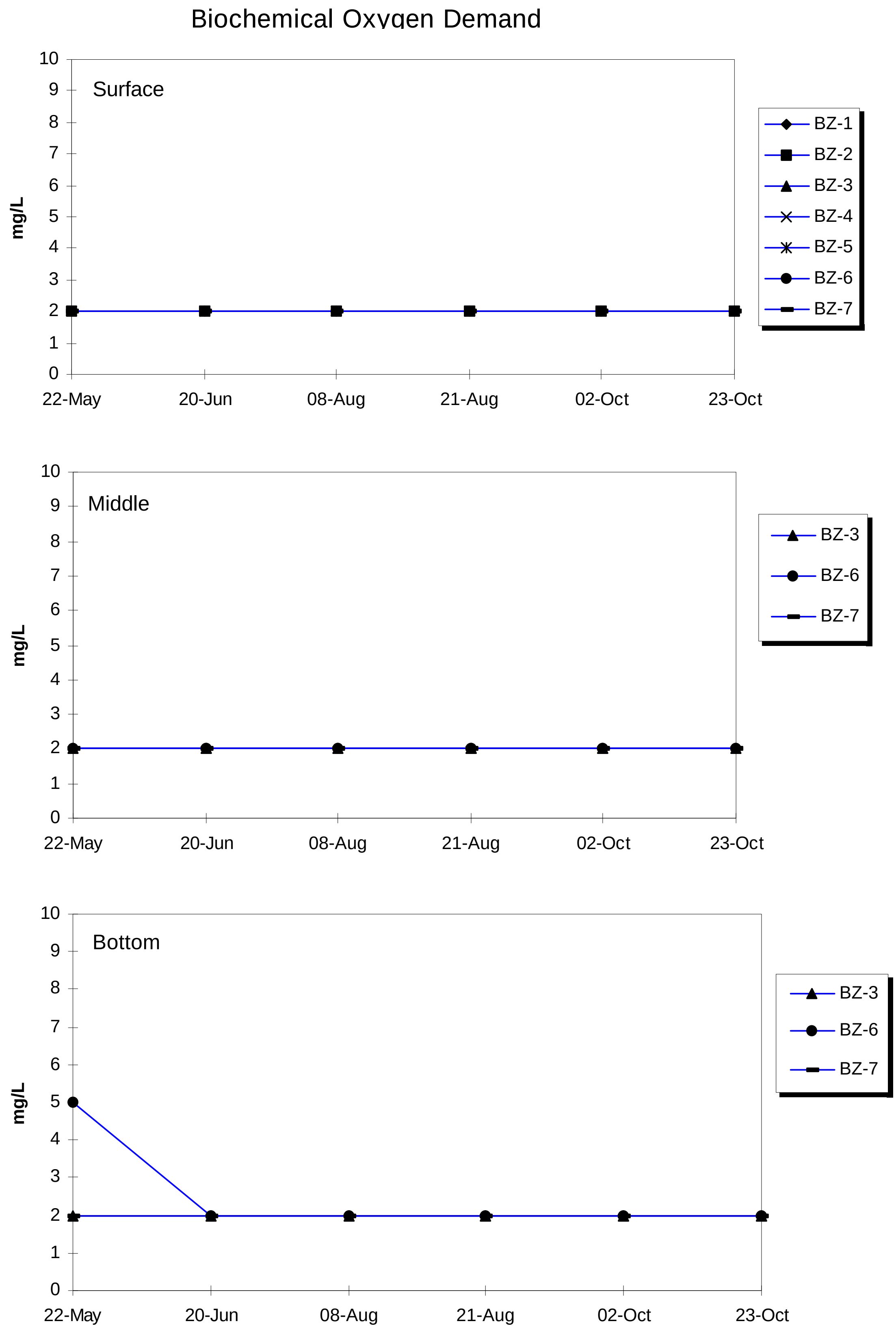

Figure 3-26. Biochemical oxygen demand in surface, middle, and bottom waters of Beltzville Reservoir in 2002.

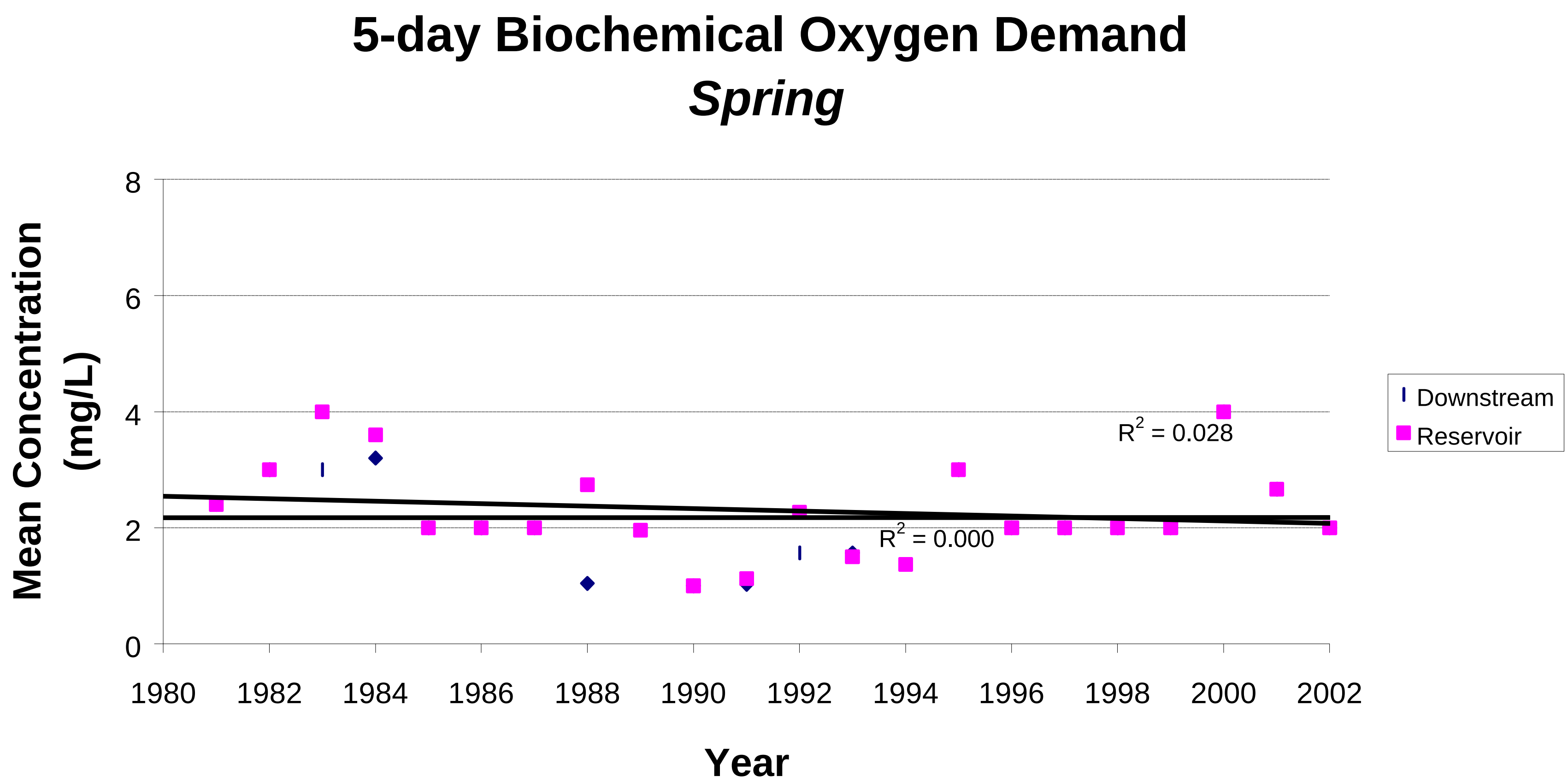

Figure 3-27. Seasonal trends of five-day biochemical oxygen demand in spring at Beltzville Reservoir.

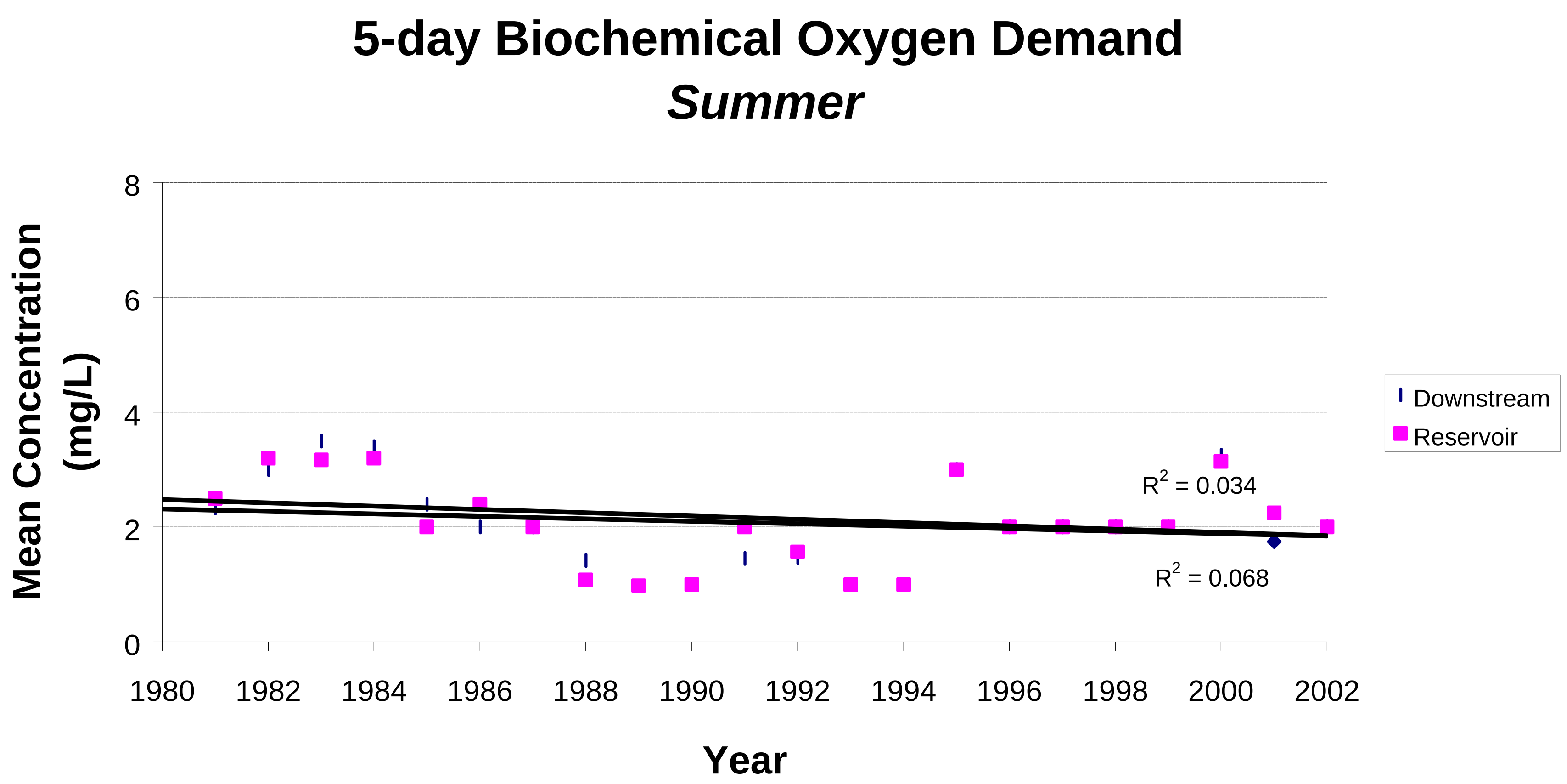

Figure 3-28. Seasonal trends of five-day biochemical oxygen demand in summer at Beltzville Reservoir.

3.2.11 Alkalinity

Alkalinity is a measure of the acid-neutralizing capacity of water. Alkalinity in the water column of Beltzville Reservoir was relatively low during 2002 (Fig. 3-29). Throughout the monitoring period, concentrations measured at all stations and depths ranged between 4 and 18-mg/L and averaged 8.6-mg/L.

Concentrations of alkalinity measured at Beltzville Reservoir were in compliance with PADEP water quality standards during 2002. 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).

3.2.12 Total Organic and Inorganic Carbon

Total inorganic carbon (TIC) and total organic carbon (TOC) in the water column of Beltzville Reservoir were present in low concentrations during 2002 (Fig. 3-30 and Fig. 3-31). Concentrations of TIC at all stations and depths ranged from 3-mg/L to less than the method detection limit of 1-mg/L and averaged 1.71-mg/L. Additionally, concentrations of TOC at all stations and depths ranged from 3-mg/L to less than the method detection limit of 1-mg/L and averaged 1.37-mg/L. Total carbon is the sum of TIC and TOC. Total carbon in the water column of Beltzville Reservoir at all stations and depths averaged 2.92-mg/L and ranged from 1-mg/L to 5-mg/L (Fig. 3-32).

3.2.13 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 2002 (Fig. 3-33). Concentrations measured at all stations and depths ranged between 0.05 and 18.5-mg/m^3. Concentrations were highly variable throughout the reservoir and its tributaries and averaged 2.9- mg/m^3.

3.2.14 BTEX

Concentrations of benzene, toluene, ethylbenzene, o-xylene and m,p-xylenes (BTEX) in surface waters of Beltzville Reservoir were consistently low during 2002 (Table 3-9). All of the parameter concentrations were less than method detection limits of 1.0 µg/L.

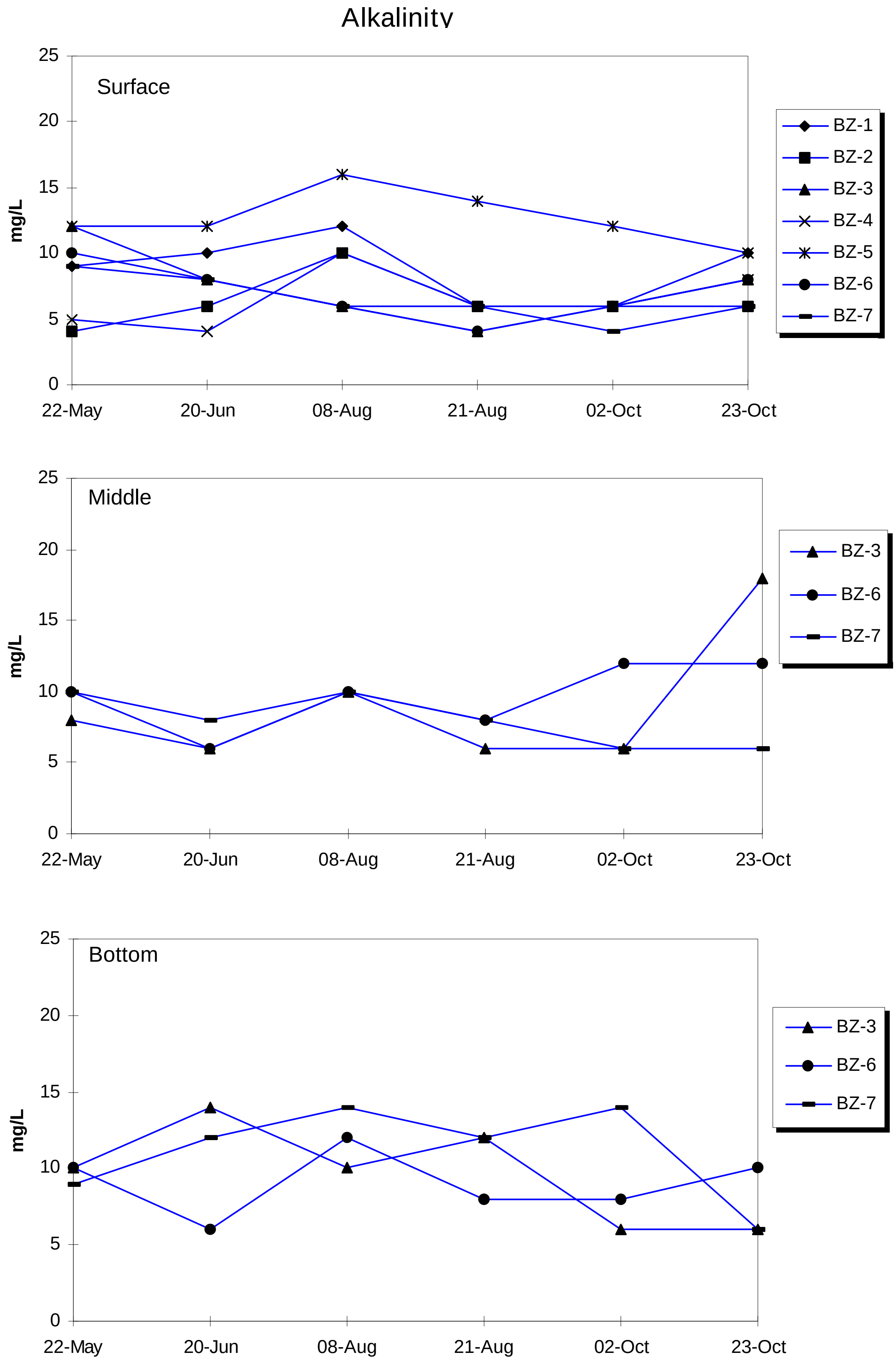

Figure 3-29. Alkalinity in surface, middle, and bottom waters of Beltzville Reservoir in 2002. (The PADEP water quality standard for alkalinity is a minimum concentration of 20 mg/L, except where natural conditions are less.)

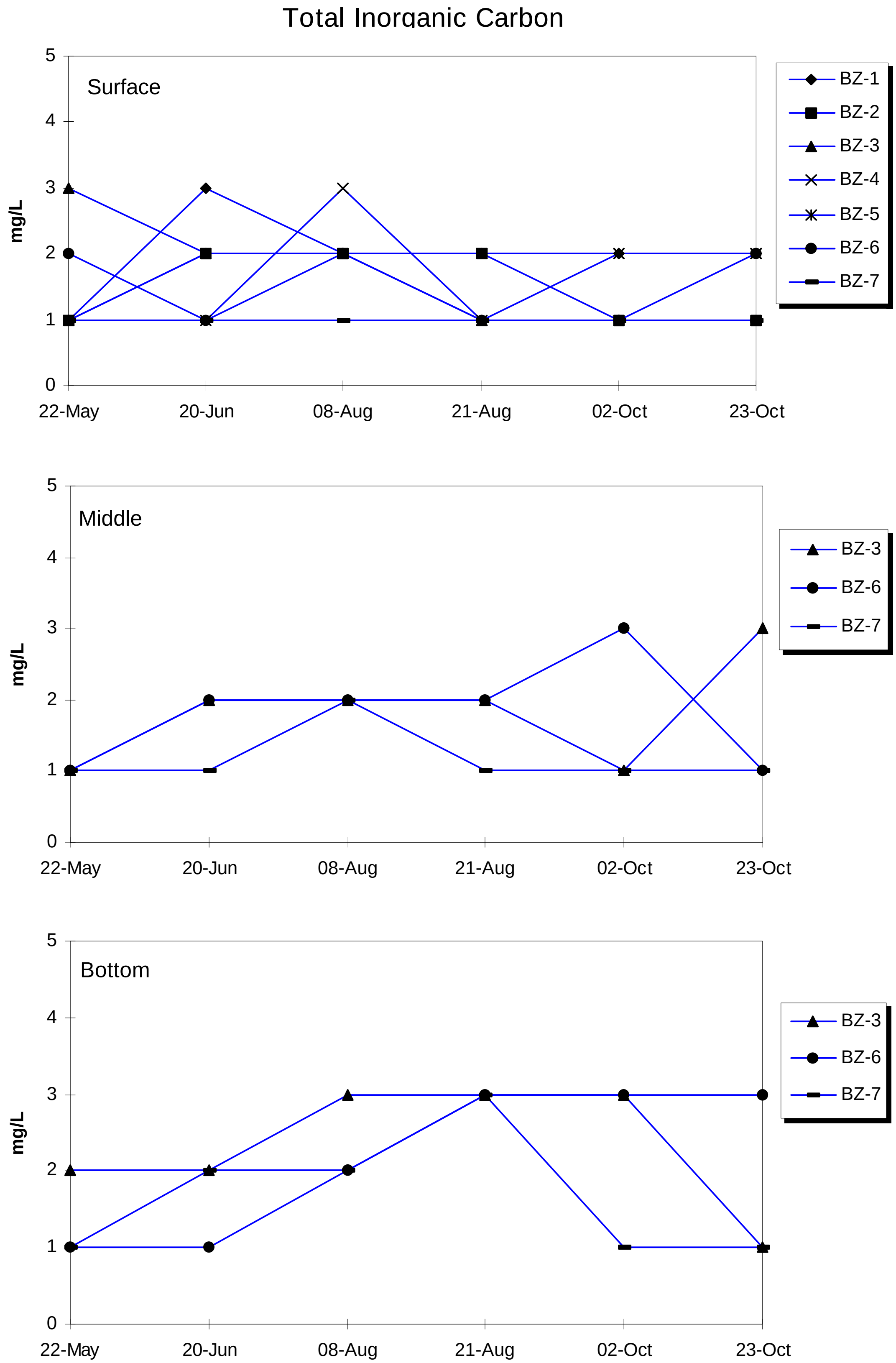

Figure 3-30. Total inorganic carbon in surface, middle, and bottom waters of Beltzville Reservoir in 2002

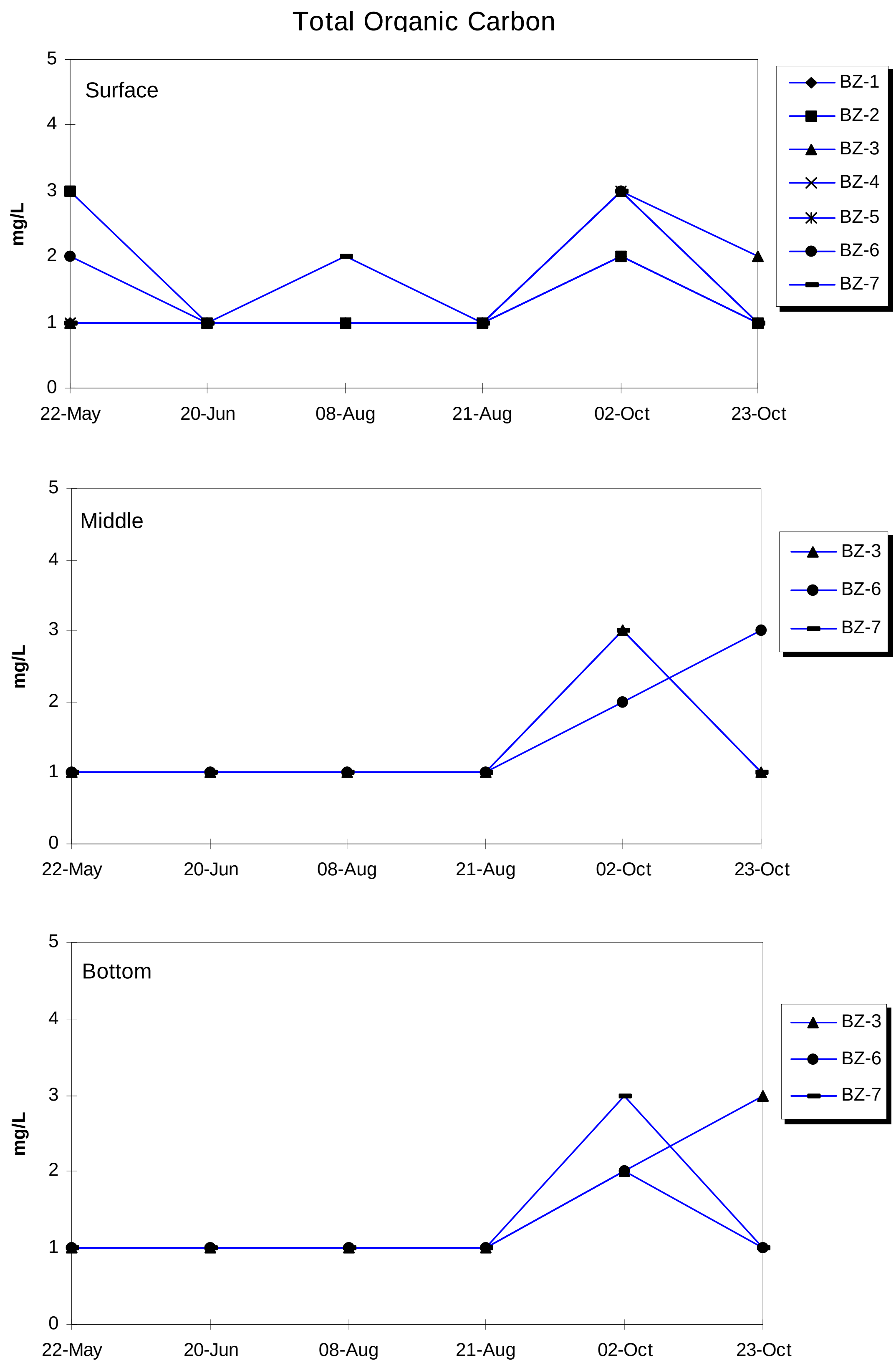

Figure 3-31. Total organic carbon in surface, middle, and bottom waters of Beltzville Reservoir in 2002

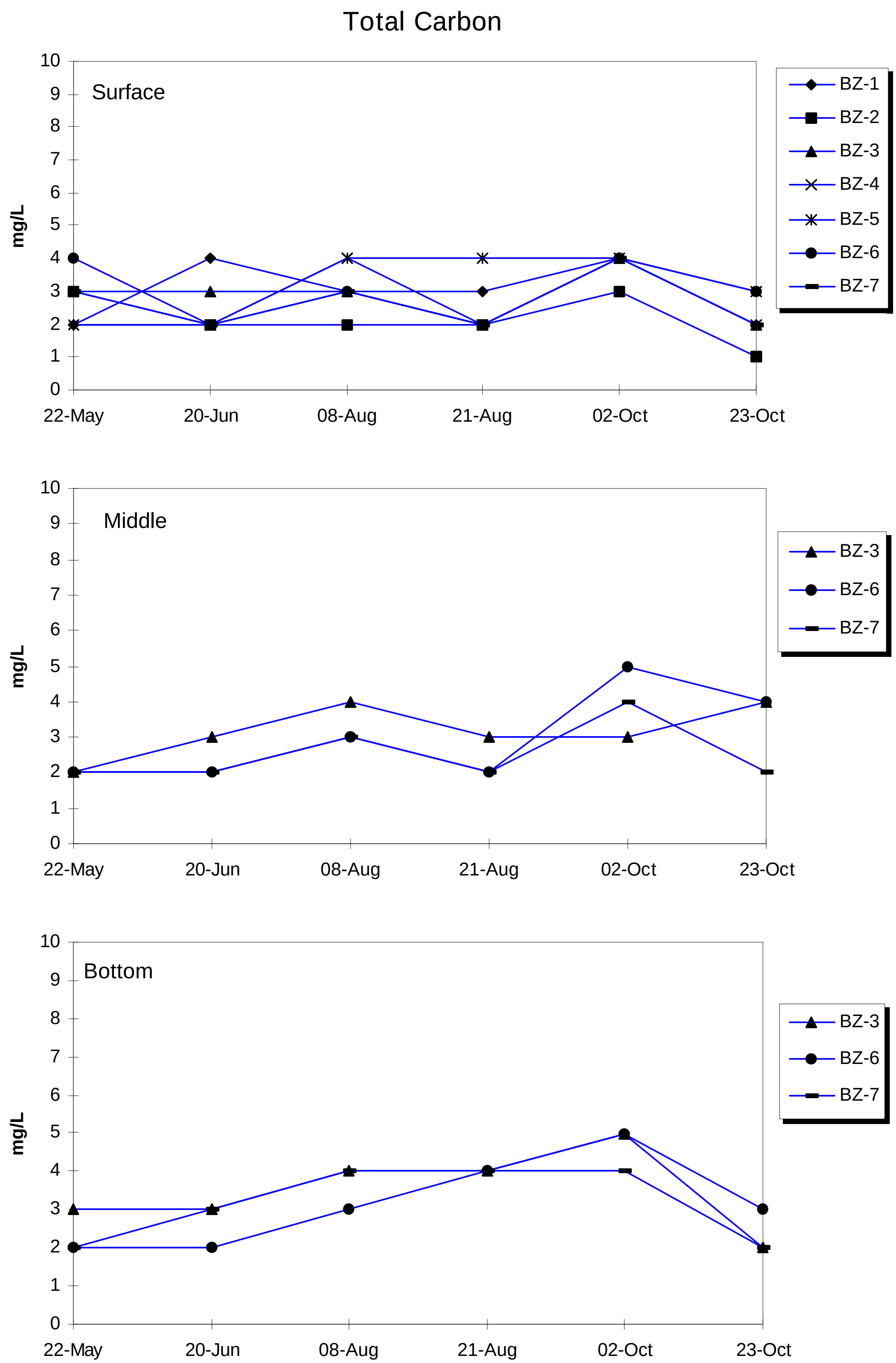

Figure 3-32. Total carbon in surface, middle, and bottom waters of Beltzville Reservoir in 2002

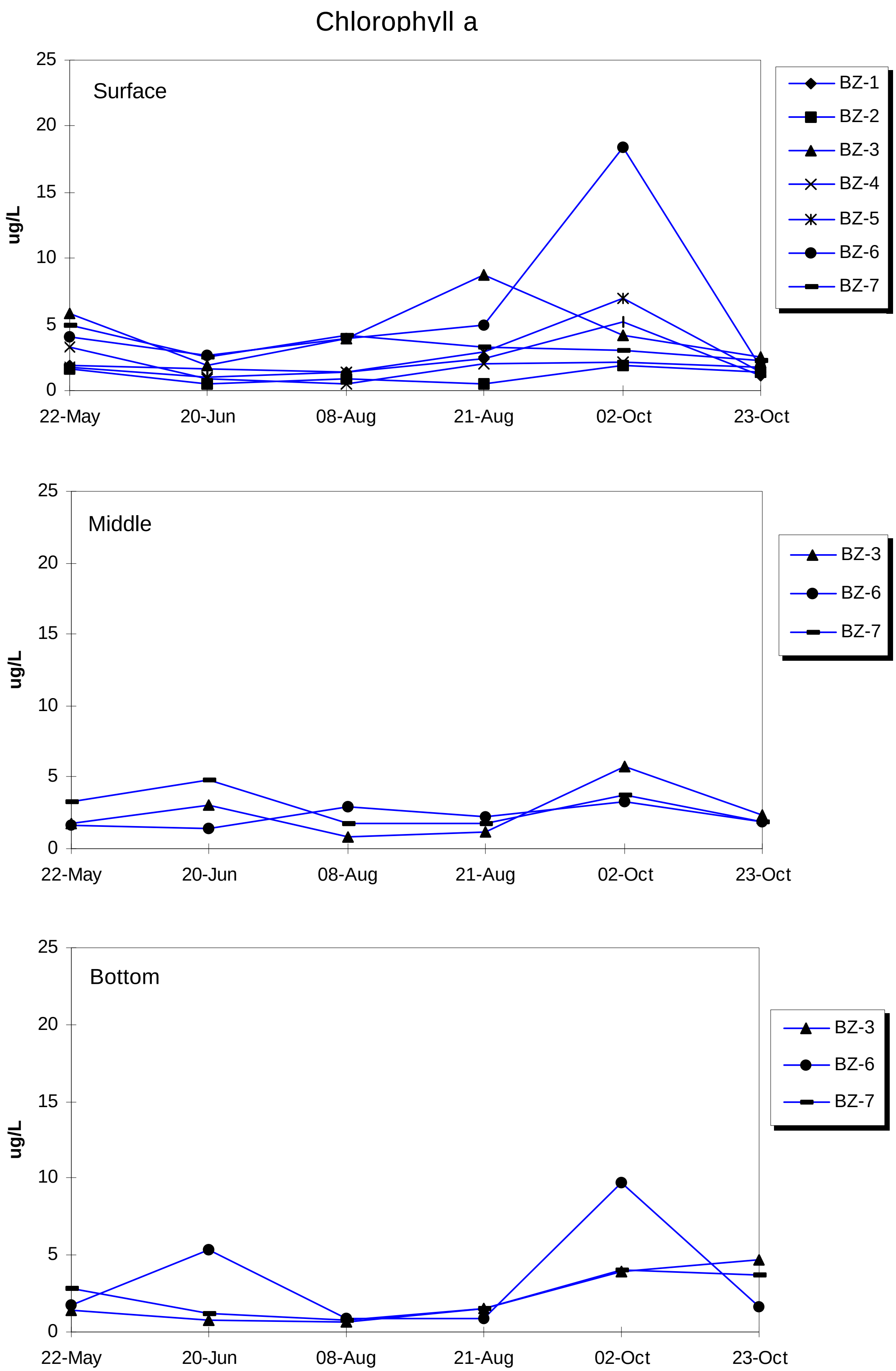

Figure 3-33. Total Chlorophyll *a* in surface, middle, and bottom waters of Beltzville Reservoir in 2002.

Table 3-9. Concentrations of BTEX parameters (mg/l) measured in surface water at Beltzville Reservoir during 2002

Ethylbenzene	Date	Benzene	Ethylbenzene	Toluene	Xylene
BZ-3	22 May	< 0.001	< 0.001	< 0.001	< 0.001
	20 June	< 0.001	< 0.001	< 0.001	< 0.001
	8 August	< 0.001	< 0.001	< 0.001	< 0.001
	21 August	< 0.001	< 0.001	< 0.001	< 0.001
	2 October	< 0.001	< 0.001	< 0.001	< 0.001
BZ-6	22 May	< 0.001	< 0.001	< 0.001	< 0.001
	20 June	< 0.001	< 0.001	< 0.001	< 0.001
	8 August	< 0.001	< 0.001	< 0.001	< 0.001
	21 August	< 0.001	< 0.001	< 0.001	< 0.001
	2 October	< 0.001	< 0.001	< 0.001	< 0.001
BZ-7	22 May	< 0.001	< 0.001	< 0.001	< 0.001
	20 June	< 0.001	< 0.001	< 0.001	< 0.001
	8 August	< 0.001	< 0.001	< 0.001	< 0.001
	21 August	< 0.001	< 0.001	< 0.001	< 0.001
	2 October	< 0.001	< 0.001	< 0.001	< 0.001

Beltzville Reservoir was in compliance with PADEP water quality standard for BTEX parameters during 2002. 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).

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: oligotrophic (TSI < 40), 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 mesotrophic during 2002 (Fig. 3-34). The TSI values ranged from 39 to 42.

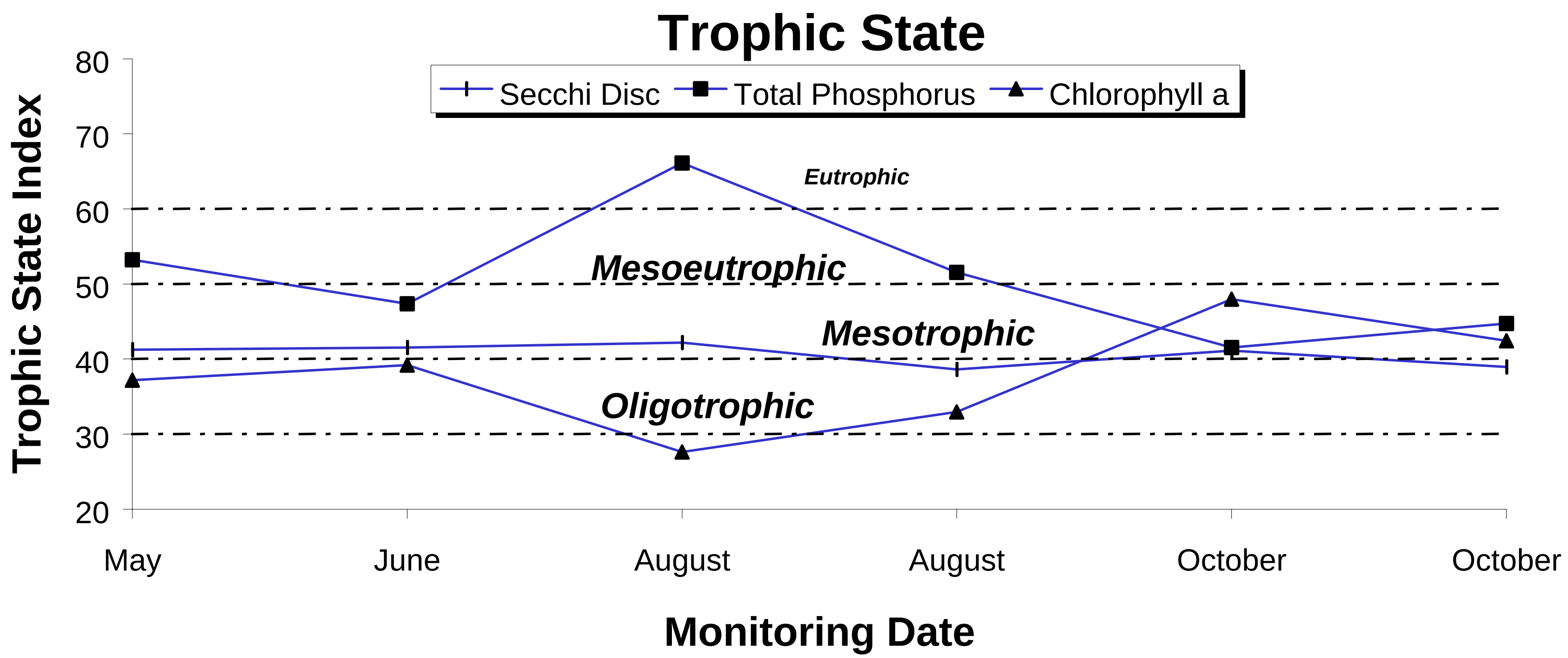

Figure 3-34. Trophic state indices calculated from secchi disk depth and concentrations of total phosphorus and chlorophyll *a* at Beltzville Reservoir in 2002

TSIs calculated for measures of total phosphorus classified Beltzville Reservoir as mesoeutrophic in the beginning of the summer with TSI value of 53 (Fig. 3-34). In June the TSI value decreased 47 classifying the lake as mesotrophic. The first sampling in August classified Beltzville as eutrophic with a TSI value of 66. Later that month the TSI value decreased to 52 classifying it as mesoeutrophic. In October, TSI values are 42 and 45 classifying the lake as mesotrophic. Average TSI value of 51 classifies Beltzville Reservoir as mesoeutrophic during 2002.

TSIs calculated for measures of chlorophyll *a* classified Beltzville Reservoir as oligotrophic for the summer of 2002 (Fig. 3-34). The values ranged from 28 to 39. In October, the TSI values were 43 and 48, which classifies the lake as mesotrophic.

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 oligotrophic during 2002.

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). Concentrations of total phosphorus ranged from eutrophic (May to August) to mesotrophic (October). Concentrations of chlorophyll *a* ranged from oligotrophic (May to August) to mesotrophic (October). Secchi disk depth ranged mesotrophic (May through 8 August and 2 October) and was oligotrophic (21 August and 23 October). 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 2002

Water Quality Variable	Oligo-trophic	Meso-trophic	Eutrophic	May	Jun	8 Aug	21 Aug	2 Oct	23 Oct
Total phos. (µg/l)	< 10	10-20	> 20	30	20	73	27	13	17
Chlorophyll (mg/m^3)	< 4	4-10	> 10	2.0	2.4	0.7	1.3	5.9	3.4
Secchi depth (m)	> 4	2-4	< 2	3.7	3.6	3.4	4.4	3.7	4.3

3.4 RESERVOIR BACTERIA MONITORING

Three forms of coliform bacteria contamination were monitored at Beltzville Reservoir during 2002 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 2002 monitoring period (Fig. 3-35). No station appeared to have consistently higher counts over the monitoring period. However, all stations during the 2 October sampling event had higher total coliform counts that ranged from 110 to 760-clns/100ml. The highest counts of 760-clns/100-ml were found at station BZ-5, on 2 October.

Fecal coliform counts were generally lower than the counts for total coliform (Fig. 3-36). On 8 August monitoring, BZ-5 had the highest count of 400-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 two stations BZ-2 and BZ-5 (Table 3-11 and Fig. 3-37). On 21 August station BZ-5 had the highest count of 410-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 the detection limit.

With respect to PADEP water quality standards, coliform bacteria contamination was low at Beltzville Reservoir during 2002 (Table 3-12; Fig. 3-38). 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. Fecal streptococcus was high at two stations BZ-2 and BZ-5 during the two August sampling events. This may

Table 3-11. Bacteria counts (colonies/100ml) at Beltzville Reservoir during 2002.

STATION	DATE	Total Coliform (TC)	Fecal Strep (FS)	Fecal Coliform (FC)	FC/FS
BZ-1S	05/22/2002	40	< 10	10	NC
	06/20/2002	20	10	20	0.50
	08/08/2002	100	< 10	30	NC
	08/21/2002	120	20	80	0.25
	10/02/2002	540	< 10	< 10	NC
	10/23/2002	180	< 10	40	NC
BZ-2S	05/22/2002	200	< 10	70	NC
	06/20/2002	20	90	20	4.50
	08/08/2002	80	230	40	5.75
	08/21/2002	110	80	70	1.14
	10/02/2002	520	< 10	< 10	NC
	10/23/2002	170	< 10	20	NC
BZ-3S	05/22/2002	10	< 10	< 10	NC
	06/20/2002	< 10	< 10	< 10	NC
	08/08/2002	< 10	< 10	< 10	NC
	08/21/2002	20	< 10	10	NC
	10/02/2002	260	< 10	< 10	NC
	10/23/2002	80	< 10	20	NC
BZ-4S	05/22/2002	30	< 10	10	NC
	06/20/2002	< 10	< 10	< 10	NC
	08/08/2002	60	60	60	1.00
	08/21/2002	160	80	40	2.00
	10/02/2002	280	20	20	1.00
	10/23/2002	340	10	10	1.00
BZ-5S	05/22/2002	90	< 10	80	NC
	06/20/2002	190	60	190	0.32
	08/08/2002	400	180	400	0.45
	08/21/2002	30	410	< 10	NC
	10/02/2002	760	50	100	0.50
	10/23/2002	470	40	220	0.18
BZ-6S	05/22/2002	10	< 10	< 10	NC
	06/20/2002	< 10	< 10	< 10	NC
	08/08/2002	10	< 10	< 10	NC
	08/21/2002	< 10	< 10	< 10	NC
	10/02/2002	160	< 10	< 10	NC
	10/23/2002	50	< 10	< 10	NC
BZ-7S	05/22/2002	10	< 10	< 10	NC
	06/20/2002	< 10	< 10	< 10	NC
	08/08/2002	20	< 10	< 10	NC
	08/21/2002	< 10	< 10	< 10	NC
	10/02/2002	110	< 10	10	NC
	10/23/2002	10	< 10	< 10	NC

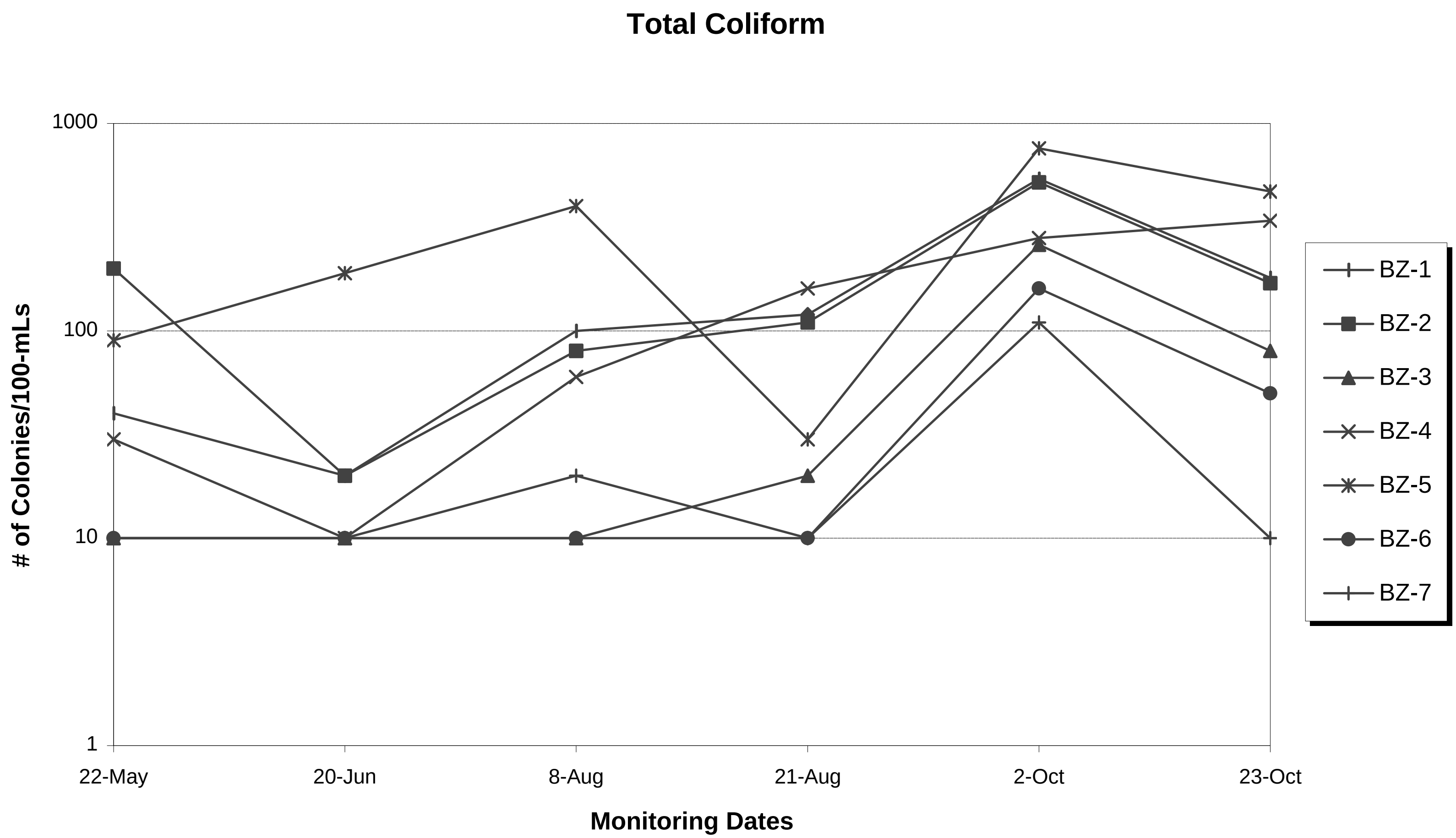

Figure 3-35. Total coliform counts in surface waters of Beltzville Reservoir in 2002

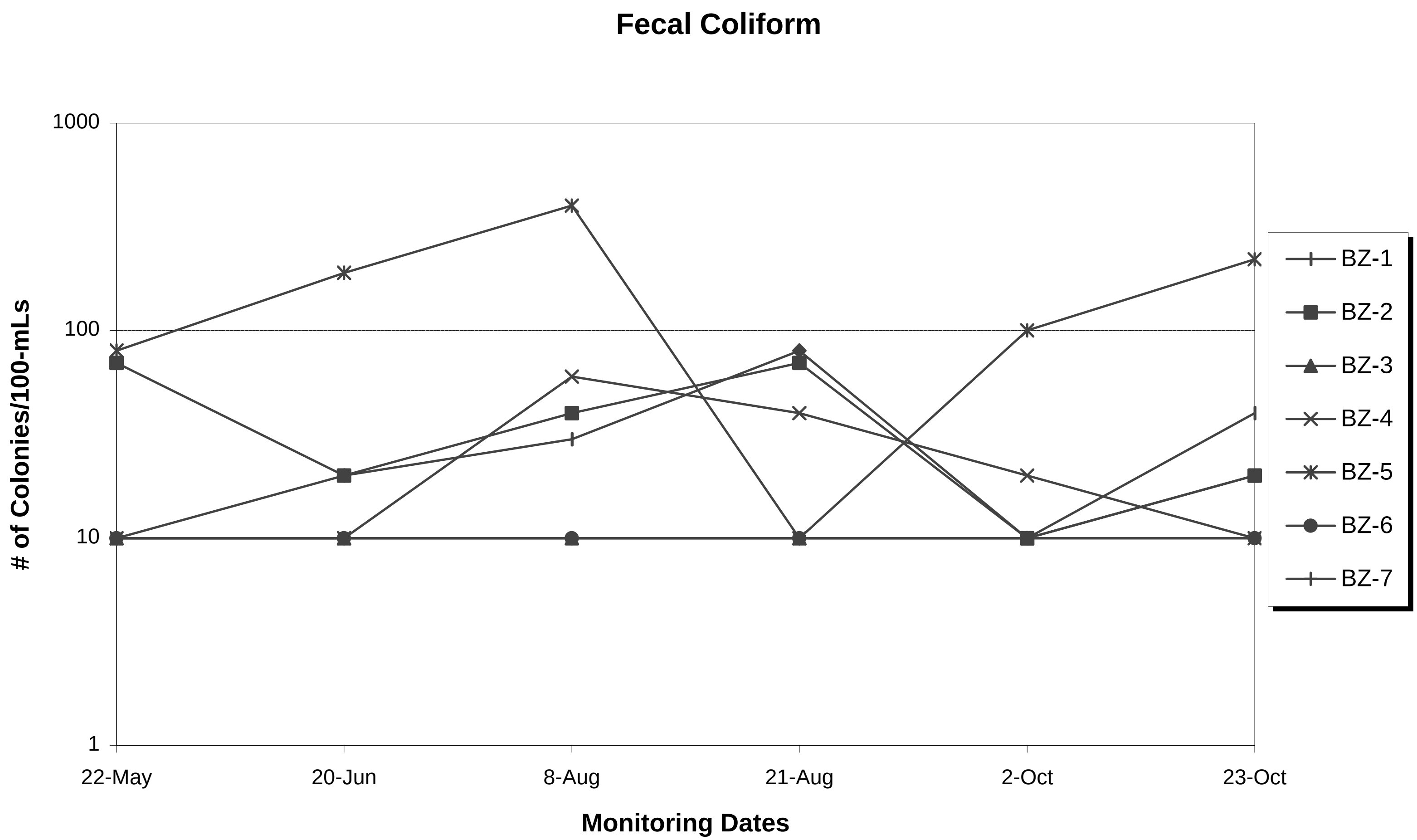

Figure 3-36. Fecal coliform counts in surface waters of Beltzville Reservoir in 2002. (PADEP water quality standard for fecal coliform is less than 200 colonies/100 mls.)

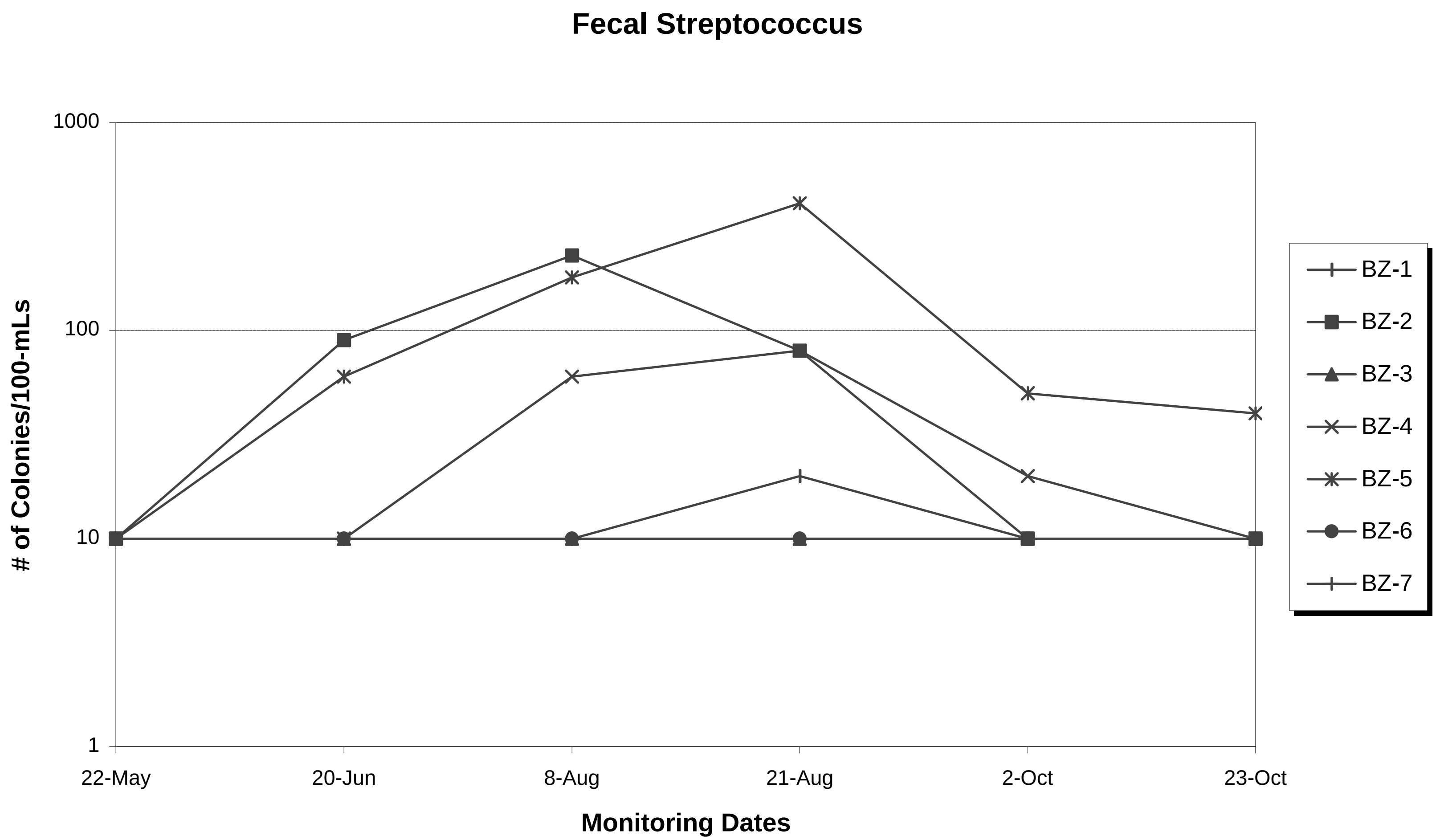

Figure 3-37. Fecal streptococcus counts in surface waters of Beltzville Reservoir in 2002

have been caused by the lack of rain in 2002. During August there was an average rainfall of only 0.13 inches.

Table 3-12. Summary statistics of fecal coliform counts (colonies/100-ml) among all stations of Beltzville Reservoir during 2002. (PADEP water quality standard for fecal coliforms is a geometric mean not greater than 200 colonies/ 100-ml).

	Geometric Mean	Arithmetic Mean	Maximum Count
05/22/2002	10.0	10.0	10.0
06/20/2002	17.7	26.3	90.0
08/08/2002	30.6	65.0	230.0
08/21/2002	34.0	78.8	410.0
10/02/2002	13.9	16.3	50.0
10/23/2002	12.2	13.8	40.0

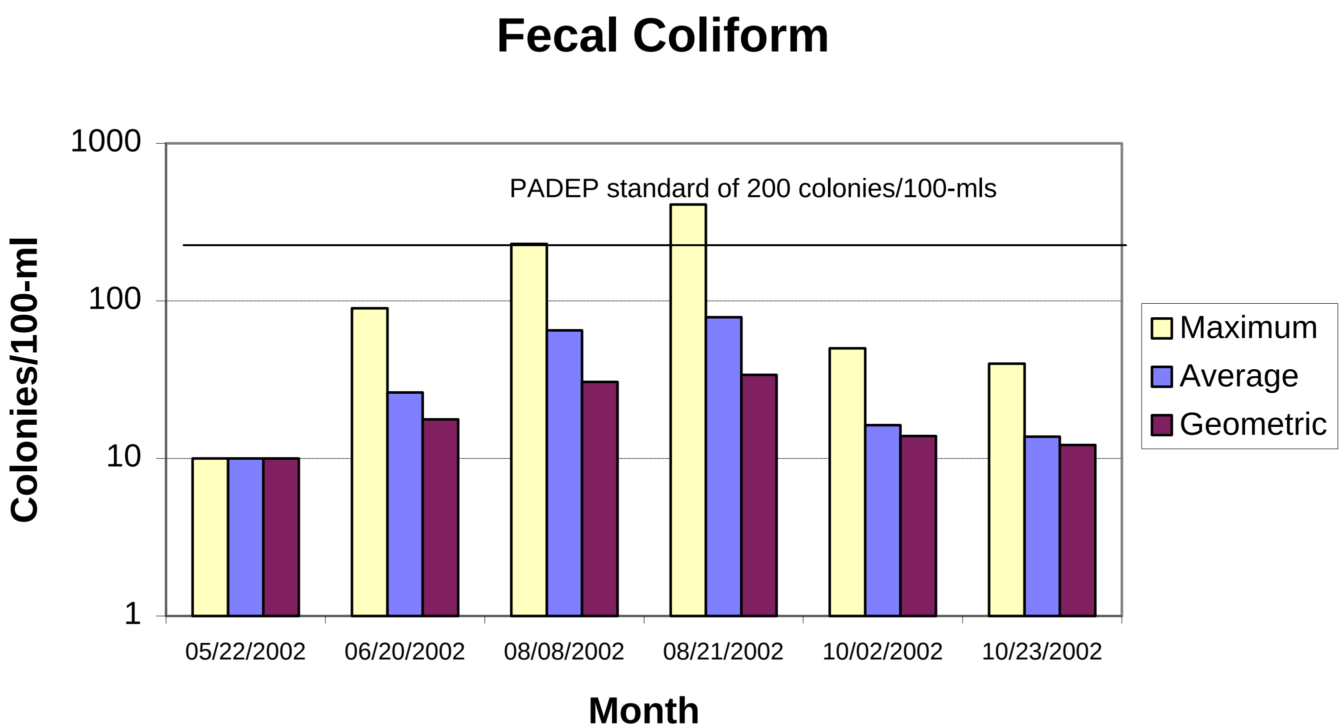

Figure 3-38. Maximum, average, and geometric mean of fecal coliform counts (colonies/100-ml) for all stations monitored at Beltzville Reservoir in 2002

An analysis for trends was conducted on fecal coliform data collected during 2002 and historical data collected over the past 22 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. 3-39 and 3-40). However, the plotted averages for both reservoir and downstream sites over the past 22-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 fecal coliforms (Table 3-13). For total coliforms there were two trends that were determined to be significant; station BZ-3 and BZ-4 in the spring (Table 3-13). The rates of decrease estimated for the trends are 2.794 and 7.167 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	18	NS	0.206	NS	1.3750
BZ-2	22	NS	0.950	NS	2.2857
BZ-3	22	NS	-0.100	NS	-0.9271
BZ-4	22	NS	-0.467	NS	0.4881
BZ-5	22	NS	5.708	NS	5.6000
BZ-6	7	NS	2.000	NS	0.3333
BZ-7	7	NS	-0.500	NS	-78.7500

Table 3-14. Seasonal trends of total 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	18/17	NS	0	NS	9.2262
BZ-2	22	NS	-4.647	NS	5.0000
BZ-3	22/21	< 0.05	-2.794	NS	-1.1406
BZ-4	22/21	< 0.05	-7.167	NS	-6.3095
BZ-5	22	NS	-23.219	NS	0.0000
BZ-6	7	NS	0.667	NS	3.6667
BZ-7	7	NS	-2	NS	-45.0000

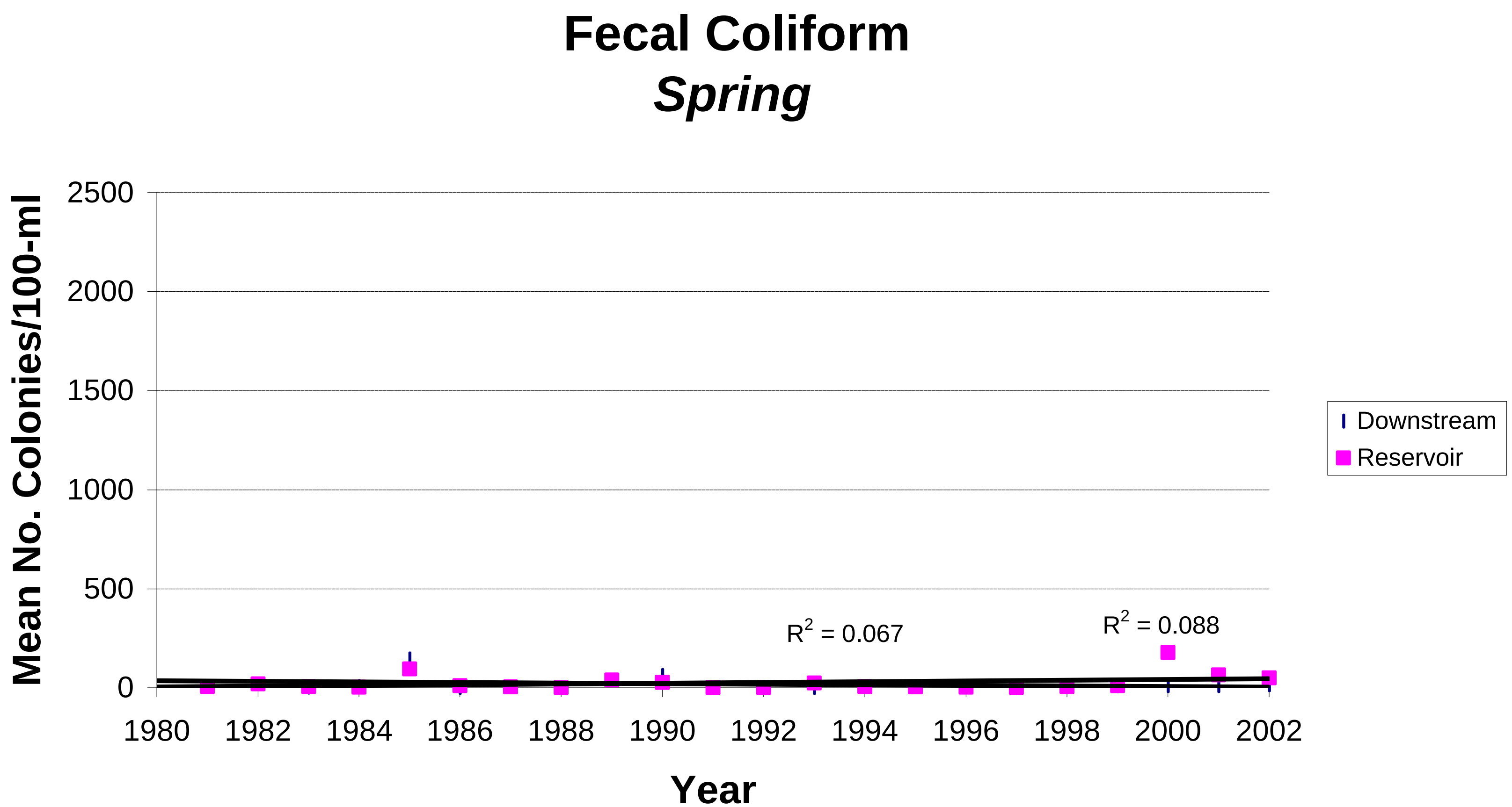

Figure 3-39. Seasonal trends of fecal coliform in spring at Beltzville Reservoir

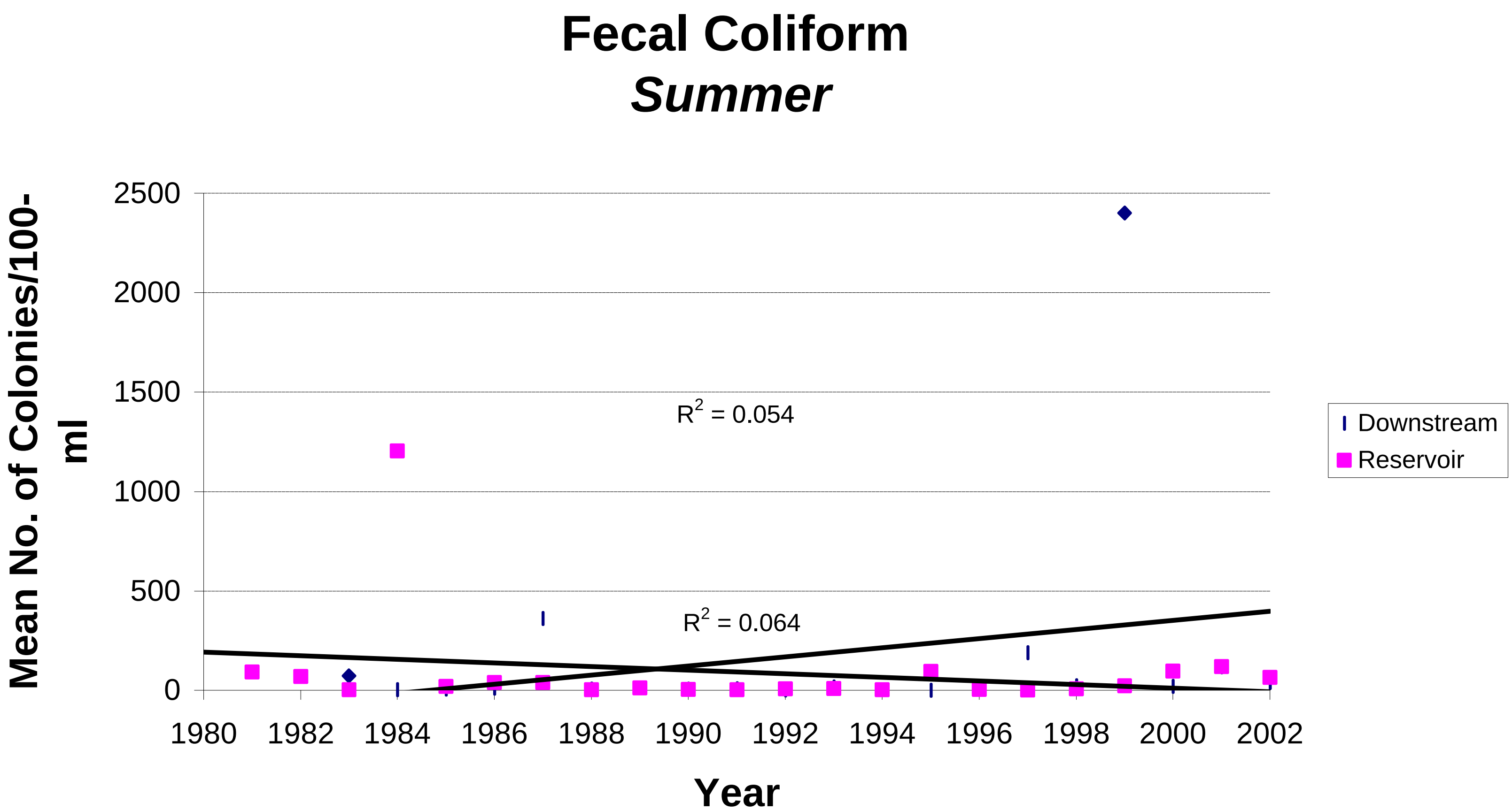

Figure 3-40. Seasonal trends of fecal coliform in summer at Beltzville Reservoir

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 13 were calculated. Of these, ratios ranged from 0.18 to 5.75, and only 5 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 1 – PCB's, pesticides, and volatile organic compounds. 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 two criteria.

Of the 93 priority pollutant contaminants analyzed in Beltzville Reservoir sediments, none were detected and all parameters were measured at levels below sediment screening levels (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 for inorganic nitrogen (nitrate and nitrite) and coliform bacteria contaminants during 2002. 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 is 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 with the exception of iron and manganese (Table 3-16). Iron and manganese are primary drinking water contaminants. In August, these contaminants exceeded their level in both the initial and secondary sample. Iron has a regulatory level of 0.3 mg/L and the initial sample was 0.45 mg/L and the secondary sample was 0.442 mg/L. Manganese has regulatory level of 0.05 mg/L and the initial sample was 0.052 mg/L and the secondary sample was 0.051 mg/L. 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 3-15. PCB's, pesticides, and volatile organic compounds (Group 1) concentrations measured in sediments of Beltzville Reservoir in 2002.

	Residential Direct Contact Soil Cleanup Criteria	Non-Residential Direct Contact Soil Cleanup Criteria	Units	Method Detection Limit	BZ-6
Percent Solids			ppb	0.1	27
PCBs - Method 8082					
Aroclor-1016			ppb	100	ND
Aroclor-1221			ppb	100	ND
Aroclor-1232			ppb	100	ND
Aroclor-1242			ppb	100	ND
Aroclor-1248			ppb	100	ND
Aroclor-1254			ppb	100	ND
Aroclor-1260			ppb	100	ND
Pesticides - Method 8081A					
4,4'-DDD	3000	12000	ppb	5	ND
4,4'-DDE	2000	9000	ppb	5	ND
4,4'-DDT	2000	9000	ppb	5	ND
alpha-BHC			ppb	5	ND
a-Chlordane			ppb	5	ND
Aldrin	40	170	ppb	5	ND
beta-BHC			ppb	5	ND
Chlordane, technical			ppb	25	ND
delta-BHC			ppb	5	ND
Dieldrin	42	180	ppb	5	ND
Endosulfan I	340000	6200000	ppb	5	ND
Endosulfan II	340000	6200000	ppb	5	ND
Endrin	17000	310000	ppb	5	ND
Endrin aldehyde			ppb	5	ND
Endrin ketone			ppb	5	ND
Endosulfan Sulfate			ppb	5	ND
gamma-BHC (Lindane)	520	2200	ppb	5	ND
g-Chlordane			ppb	5	ND
Heptachlor	150	650	ppb	5	ND
Heptachlor epoxide			ppb	5	ND
Methoxychlor	280000	5200000	ppb	25	ND
Toxaphene	100	200	ppb	25	ND
Volatile Organic Compounds - Method 8260B					
1,1,1,2-Tetrachloroethane	170000	310000	ppb	1	ND
1,1,1-Trichloroethane	210000	1000000	ppb	1	ND
1,1,2,2-Tetrachloroethane	34000	70000	ppb	1	ND
1,1,2-Trichloroethane	22000	420000	ppb	1	ND
1,1-Dichloroethane	570000	1000000	ppb	1	ND

Table 3-15. (Continued).

	Residential Direct Contact Soil Cleanup Criteria	Non-Residential Direct Contact Soil Cleanup Criteria	Units	Method Detection Limit	BZ-6
1,1-Dichloroethene	8000	150000	ppb	1	ND
1,1-Dichloropropene			ppb	1	ND
1,2,3-Trichlorobenzene			ppb	1	ND
1,2,3-Trichloropropane			ppb	1	ND
1,2,4-Trichlorobenzene	68000	1200000	ppb	1	ND
1,2,4-Trimethylbenzene			ppb	1	ND
1,2-Dibromo-3-chloropropane			ppb	1	ND
1,2-Dichloroethane	6000	24000	ppb	1	ND
1,2-Dichlorobenzene	5100000	10000000	ppb	1	ND
1,2-Dichloropropane	10000	43000	ppb	1	ND
1,2-Dibromoethane			ppb	1	ND
1,3,5-Trimethylbenzene			ppb	1	ND
1,3-Dichlorobenzene	5100000	10000000	ppb	1	ND
1,3-Dichloropropane			ppb	1	ND
1,4-Dichlorobenzene	570000	10000000	ppb	1	ND
2,2-Dichloropropane			ppb	1	ND
2-Chlorotoluene			ppb	1	ND
2-Hexanone			ppb	10	ND
4-Chlorotoluene			ppb	1	ND
Acetone	1000000	1000000	ppb	10	ND
Benzene	3000	13000	ppb	1	ND
Bromochloromethane			ppb	1	ND
Bromodichloromethane	11000	46000	ppb	1	ND
Bromobenzene			ppb	1	ND
Bromoform	86000	370000	ppb	1	ND
Bromomethane	79000	1000000	ppb	1	ND
c-1,2-Dichloroethene	79000	1000000	ppb	1	ND
c-1,3-Dichloropropene	4000	5000	ppb	1	ND
Carbon Tetrachloride	2000	4000	ppb	1	ND
Chlorobenzene	37000	680000	ppb	1	ND
Chloroethane			ppb	1	ND
Chloroform	19000	28000	ppb	1	ND
Chloromethane	520000	1000000	ppb	1	ND
Methylene Chloride (DCM)	49000	210000	ppb	1	ND
Dibromochloromethane	110000	1000000	ppb	1	ND
Dibromomethane			ppb	1	ND
Dichlorofluoromethane			ppb	1	ND
Ethylbenzene	1000000	1000000	ppb	1	ND
Hexachloro1,3-butadiene	1000	21000	ppb	1	ND
Isopropylbenzene (cumene)			ppb	1	ND
m,p-Xylene			ppb	1	ND
2-Butanone(MEK)	1000000	1000000	ppb	10	ND

Table 3-15. (Continued).					
	Residential Direct Contact Soil Cleanup Criteria	**Non-Residential Direct Contact Soil Cleanup Criteria**	**Units**	**Method Detection Limit**	**BZ-6**
4-Methyl-2-pentanone (MIBK)	1000000	1000000	ppb	10	ND
Methyl-tert-butylether (MTBE)			ppb	1	ND
n-ButylBenzene			ppb	1	ND
n-Propylbenzene			ppb	1	ND
Naphthalene	230000	4200000	ppb	1	ND
o-Xylene			ppb	1	ND
p-Isopropyltoluene			ppb	1	ND
Tetrachloroethene	4000	6000	ppb	1	ND
sec-Butylbenzene			ppb	1	ND
Styrene	23000	97000	ppb	1	ND
trans-1,2-dichloroethene	1000000	1000000	ppb	1	ND
t-1,3-Dichloropropene	4000	5000	ppb	1	ND
t-Butylalcohol			ppb	10	ND
Trichloroethene	23000	54000	ppb	1	ND
Toluene	1000000	1000000	ppb	1	ND
Trichlorofluoromethane			ppb	1	ND
Vinyl chloride	2000	7000	ppb	1	ND

Table 3-16. Concentrations of primary and secondary contaminants in drinking water at Beltzville Reservoir in 2002. 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		PADEP Regulatory Level	Detection Limits	EPA Method
	13 March	21 August			
Aluminum	ND	ND	0.2	0.025	200.7
Antimony	ND	ND	0.006	0.024	200.7
Arsenic	ND	ND	0.05	0.018	200.7
Barium	0.003	ND	2.0	0.005	200.7
Cadmium	0.002	0.001	0.005	0.001	200.7
Chromium	ND	ND	0.1	0.006	200.7
Copper	0.215	0.052	1.3	0.002	200.7
Iron	0.371	0.45/0.442	0.3	0.005	200.7
Lead	ND	ND	0.015	0.01	200.7
Magnesium	1.88	2.481	NL	0.02	200.7
Manganese	0.033	0.052/0.051	0.05	0.002	200.7
Mercury	0.0008	ND	0.002	0.0002	245.1
Nickel	0.003	0.001	0.1	0.003	200.7
Selenium	ND	ND	0.05	0.02	200.7
Silver	ND	ND	0.1	0.003	200.7
Sodium	2.16	3.822	NL	0.02	200.7
Thallium	ND	ND	0.002	0.063	200.7
Zinc	2.135	1.165	5.0	0.003	200.7
Chloride	2.4	3.1	250	0.5	300
Cyanide, free	ND	ND	0.2	0.009	SM 4500CN-I
Fluoride	ND	ND	2.0	0.1	300
Foaming Agents	ND	ND	0.5	0.01	SM 5540C
PH	6.8	6.91	6.5-8.5	+/-0.01	150.1
Sulfate	1.2	15	250.0	5	300
Total Dissolved Solids	104	70	500.0	10	160.1

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

3.6.2 Inorganic Nitrogen and Coliform bacteria

Beltzville Reservoir drinking water was in compliance with PADEP criteria for inorganic nitrogen contaminants, nitrate and nitrite, and coliform bacteria contaminants (Table 3-17). During the October sampling event Nitrate was detected with a concentration of 0.08 mg/L, which does not exceed the PADEP regulatory level. All of the tests for *E. co*li and total coliform resulted in the absence coliform contaminants. 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.

3.8.3 Historical Drinking Water Quality

Drinking water quality has been monitored at Beltzville Reservoir over the past 21 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). Iron, manganese and corrosivity were most often not in compliance with PADEP criteria; iron and manganese were the parameters slightly out of compliance during the 2002 monitoring.

Table 3-17. Concentrations of nitrate and nitrite, and results of coliform bacteria monitoring of drinking water sampled from the women's restroom located in the office at Beltzville Reservoir during 2002

Parameter	**Sampling Dates**				**PADEP Regulatory Level**	**Detection Limits**	**Method**
	13 March	**20 June**	**21 August**	**23 October**			
Nitrate as N (mg/L)	ND	ND	ND	0.08	10.0	0.5	300
Nitrite as N (mg/L)	ND	ND	ND	ND	1.0	0.5	300
E. coli (CFU)	Absence	Absence	Absence	Absence	Presence	10	SM 9223
Total Coliform (CFU)	Absence	Absence	Absence	Absence	Presence	10	SM 9223

CFU – colony forming units
ND – Not Detected

Table 3-18. Drinking water parameters exceeding PADEP criteria at Beltzville Reservoir from 1986 to 2002

Parameter	Monitoring Date	Result	Criteria
Iron (mg/L)	20 June 2000	0.993	0.30
	16 June 1987	0.60	0.30
	16 June 1988	1.48	0.30
	21 August 2002	0.45	0.442
Manganese (mg/L)	18 June 1997	0.075	0.05
	13 June 1996	0.080	0.05
	20 June 1995	0.087	0.05
	21 August 2002	0.052	0.051
Lead (mg/L)	20 June 1995	0.016	0.015
Corrosivity	20 June 2000	-3.1	Non-negative
	19 August 1999	NEG	Non-negative
	24 June 1999	NEG	Non-negative
	10 June 1998	-1.38	Non-negative
	21 August 1997	-1.26	Non-negative
	18 June 1997	-1.82	Non-negative
	22 August 1996	-1.27	Non-negative
	13 June 1996	-1.30	Non-negative

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 2002 monitoring program of Beltzville Reservoir comprised four major elements:

- water quality of physical/chemical parameters at fixed stations from May through October;
- monthly water quality monitoring of nutrient parameter concentrations and bacteria contamination from May to October;
- sediment priority pollutant monitoring for PCB's, pesticides, and volatile organic compounds at a fixed station in the deepest part of the reservoir;
- drinking water monitoring of the women's restroom sink located in the USACE Dam office; and
- Meteorological monitoring of air temperature, relative humidity, solar radiation, wind speed and direction every ½hour at the Beltzville Reservoir discharge tower.

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 August and October. Measures of pH throughout the water column of the reservoir met the conditions of the water quality standard except BZ-6 on October 23. On October 23 the entire water column at BZ-6 was below the PADEP criteria of 6. Beltzville Reservoir contained acceptable levels of nutrients during 2002. Ammonia, nitrate + nitrite, TDS, and alkalinity were in compliance with state water quality standards throughout the reservoir watershed. Measures for total phosphorus with results greater than the detection limit exceed the EPA guideline in 65% of the samples. Organic contamination in the reservoir was low during 2002. Concentrations of toluene, o-xylene and m,p-xylenes were not measured above detection limits throughout the monitoring period.

The trophic status of Beltzville Reservoir was defined, with, Carlson's trophic state indices and EPA criteria. Carlson's trophic state indices indicated the reservoir to be in oligotrophic condition during 2002. EPA criteria indicated the reservoir to be in oligotrophic/mesotrophic condition during 2002.

Beltzville Reservoir was in compliance with the PADEP water quality standard for bacteria contamination during 2002. 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 2002. Concentrations of PCB's, pesticides, and volatile 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 27 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 during the summer. Total nitrogen was decreasing at stations BZ-1, -3 and -4 in the summer. Total phosphorus was decreasing only at station BZ-4 in summer. TDS was decreasing at stations BZ-2 and BZ-4 in the summer. BOD was decreasing in the summer at station BZ-1, downstream of the reservoir. Total coliform was decreasing at stations BZ-3 and BZ-4 in the summer.

4.4 DRINKING WATER MONITORING

Drinking water from the women's restroom sink located in the USACE office building of Beltzville Reservoir was in compliance with PADEP water quality standards for all the primary and secondary contaminants with the exception of iron and manganese. Iron and manganese are primary drinking water contaminants. In August, these contaminants exceeded their level in both the initial and secondary sample. Iron has a regulatory level of 0.3 mg/L and the initial sample was 0.45 mg/L and the secondary sample was 0.442 mg/L. Manganese has regulatory level of 0.05 mg/L and the initial sample was 0.052 mg/L and the secondary sample was 0.051 mg/L.

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: Adjust nutrient concentration to account for yearly differences in flow.

The trends presented in this report have not taken into account the effects of flow volume on parameter concentrations. Further analyses using concentrations weighted for stream flow (from USGS gauging stations) would provide a better estimate of trends within the system. These data could be used to calculate total nutrient loadings (kg/day) and could form the basis for creating a nutrient budget for the system. The observed trends should be correlated to management practices in the watershed (e.g., sewage treatment plant construction or upgrades, changes in agricultural activities) to help explain water quality improvements or degradations observed during the monitoring period.

Recommendation 3: 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

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APPENDIX A

STRATIFICATION MONITORING

Table A-1. Summary of stratification monitoring at Beltzville Reservoir in 2002							
Station	**Date**	**Depth (F)**	**Temp ©**	**pH**	**DO (mg/L)**	**DO (%)**	**Cond (ms/cm)**
BZ1	22-May	0	11.05	6.34	10.97	99.7	0.1054
	20-Jun	0	14.03	6.56	10.01	97.2	0.0773
	08-Aug	0	13.98	6.76	8.86	85.9	0.0758
	21-Aug	0	14.57	7.06	9.02	88.7	0.0748
	02-Oct	0	15.74	7.69	8.67	87.4	0.0772
BZ2	22-May	0	11.02	6.78	10.91	99	0.0597
	20-Jun	0	12.66	6.93	10.09	95.1	0.0559
	08-Aug	0	15.04	6.92	8.7	86.4	0.0518
	21-Aug	0	16.9	7.3	8.18	84.5	0.0482
	02-Oct	0	14.14	7.39	9.18	89.4	0.0598
BZ3	22-May	108	6.92	6.6	7.91	65	0.0866
		105	6.94	6.57	8.7	71.6	0.0857
		100	7.01	6.56	7.9	65.1	0.0854
		95	7.3	6.55	7.93	65.8	0.0851
		90	7.64	6.55	8.05	67.4	0.085
		85	7.81	6.55	8.11	68.2	0.0847
		80	7.96	6.54	8.1	68.4	0.0845
		75	8.28	6.54	7.95	67.6	0.0841
		70	8.85	6.55	7.93	68.4	0.0841
		65	9.11	6.55	7.89	68.5	0.0841
		60	9.76	6.56	7.84	69.1	0.0835
		55	10.65	6.58	7.86	70.7	0.0826
		50	11.26	6.58	7.8	71.2	0.0819
		45	11.65	6.59	7.68	70.7	0.0816
		40	12.03	6.6	7.69	71.4	0.0817
		35	12.35	6.63	8.03	75.1	0.0795
		30	13.3	6.65	8.41	80.4	0.08
		25	13.47	6.69	8.87	85	0.0802
		20	13.78	6.72	8.95	86.5	0.0803
		15	13.93	6.75	9.06	87.7	0.0803
		10	13.97	6.79	9.2	89.2	0.0805
		5	14.16	6.82	9.13	88.9	0.0806
		0	14.4	6.84	9.38	91.8	0.0807
	20-Jun	100	8.73	6.42	5.69	48.9	0.0803
		95	9.02	6.34	5.71	49.4	0.08
		90	9.39	6.3	5.87	51.3	0.0796
		85	9.81	6.27	6.14	54.2	0.0794
		80	10.43	6.25	6.34	56.7	0.0786
		75	10.76	6.24	6.39	57.7	0.0783
		70	11.05	6.23	6.45	58.6	0.0779
		65	11.4	6.22	6.49	59.4	0.0776
		60	11.67	6.22	6.47	59.6	0.0774
		55	12.13	6.21	6.46	60.1	0.077
		50	12.42	6.21	6.39	59.9	0.0767
		45	13.16	6.22	6.47	61.6	0.0761

Table A-1. (Continued)							
Station	**Date**	**Depth (F)**	**Temp ©**	**pH**	**DO (mg/L)**	**DO (%)**	**Cond (ms/cm)**
BZ3 (Con't)	20 Jun (Con't)	40	14.15	6.24	6.89	67.1	0.0759
		35	15.17	6.24	6.76	67.3	0.0772
		30	16.34	6.27	6.86	70	0.0743
		25	17.27	6.3	7.03	73.1	0.0742
		20	19.83	6.37	7.7	84.4	0.0704
		15	20.71	6.49	8.47	94.5	0.0711
		10	21.14	6.61	8.42	94.8	0.0703
		5	21.6	6.67	8.38	95.1	0.0709
		0	22.59	6.7	8.38	97	0.0704
	08-Aug	105	8.62	6.35	1.96	16.8	0.0816
		100	8.71	6.31	1.71	14.7	0.0815
		95	8.95	6.26	1.74	15.1	0.0808
		90	9.48	6.23	1.86	16.3	0.08
		85	10.06	6.23	2.16	19.2	0.079
		80	10.63	6.24	2.52	22.6	0.0784
		75	11.2	6.23	2.71	24.7	0.0778
		70	11.63	6.24	2.99	27.5	0.0775
		65	11.98	6.24	3.02	28.1	0.0773
		60	12.36	6.22	2.61	24.4	0.0777
		55	12.69	6.21	2.34	22	0.0776
		50	13.44	6.24	2.76	26.4	0.0772
		45	14.02	6.25	3.16	30.7	0.0767
		40	15.18	6.24	2.93	29.2	0.0762
		35	16.99	6.22	2.8	28.9	0.0757
		30	19.22	6.25	2.68	29	0.0731
		25	21	6.33	4.58	51.4	0.0721
		20	25.59	6.48	5.74	70.3	0.0664
		15	25.77	6.58	6.65	81.6	0.0663
		10	25.84	6.72	7.09	87.1	0.0663
		5	25.87	6.81	7.3	89.8	0.0663
		0	25.87	6.87	7.4	91	0.0663
	21-Aug	105	8.72	6.16	1.21	10.4	0.0836
		100	8.87	6.14	1.01	8.7	0.0833
		95	9.07	6.12	0.92	7.9	0.0829
		90	9.89	6.12	1.23	10.8	0.081
		85	10.17	6.12	1.64	14.6	0.0802
		80	10.89	6.11	2.03	18.4	0.0792
		75	11.09	6.1	2.08	18.9	0.0792
		70	11.63	6.1	2.08	19.2	0.0788
		65	12.1	6.09	2.16	20.1	0.0784
		60	12.39	6.09	2.15	20.1	0.0781
		55	12.88	6.08	1.7	16.1	0.0784
		50	13.41	6.09	2.17	20.8	0.0783
		45	14.12	6.1	2.19	21.3	0.0778
		40	15.78	6.08	2.23	22.5	0.0775

Table A-1. (Continued)							
Station	**Date**	**Depth (F)**	**Temp ©**	**pH**	**DO (mg/L)**	**DO (%)**	**Cond (ms/cm)**
BZ3 (Con't)	21 Aug (Con't)	35	17.64	6.08	1.93	20.3	0.0755
		30	20.14	6.09	2.24	24.7	0.0734
		25	22.89	6.14	3.43	39.9	0.0721
		20	26.22	6.33	6	74.2	0.0655
		15	26.7	6.47	7.13	89.1	0.0646
		10	26.78	6.6	7.53	94.1	0.0645
		5	26.81	6.71	7.72	96.5	0.0645
		0	26.83	6.82	7.92	99.1	0.0647
	02-Oct	95	9.4	6.38	0	0	0.0879
		90	9.65	6.35	0	0	0.0867
		85	10.07	6.34	0.03	0.3	0.0841
		80	10.68	6.34	0.12	1.1	0.0824
		75	11.2	6.32	0	0	0.0834
		70	11.84	6.32	0	0	0.082
		65	12.35	6.32	0	0	0.0819
		60	12.69	6.3	0	0	0.0827
		55	13.1	6.31	0.12	1.2	0.0817
		50	13.89	6.31	0.75	7.3	0.079
		45	15.34	6.3	0.78	7.8	0.0794
		40	17.27	6.32	0.09	0.9	0.0811
		35	19.32	6.42	2.72	29.5	0.0731
		30	19.95	6.53	4.49	49.3	0.0679
		25	20.09	6.61	6.02	66.3	0.0676
		20	20.16	6.64	6.35	70.1	0.0675
		15	20.25	6.74	6.87	75.9	0.0673
		10	20.36	6.77	7.18	79.5	0.0672
		5	20.52	6.79	7.41	82.3	0.0671
		0	20.82	6.8	7.37	82.4	0.067
BZ4	22-May	0	15.18	6.81	9.82	97.7	0.0371
	20-Jun	0	20.86	7.13	8.24	92.1	0.037
	08-Aug	0	11.06	6.36	9.47	86	0.0476
	21-Aug	0	11.75	7.01	9.81	90.5	0.0438
	02-Oct	0	13.32	7.81	10.55	100.9	0.0491
BZ5	22-May	0	11.8	6.18	11.64	107.6	0.0802
	20-Jun	0	15.39	6.83	9.52	95.2	0.0853
	08-Aug	0	16.61	6.72	7.99	82	0.0916
	21-Aug	0	19.11	7.2	6.92	74.8	0.089
	02-Oct	0	16.47	7.96	9.61	98.4	0.1039

Table A-1. (Continued)							
Station	**Date**	**Depth (F)**	**Temp ©**	**pH**	**DO (mg/L)**	**DO (%)**	**Cond (ms/cm)**
BZ6	22-May	120	6.38	6.66	8.21	66.6	0.0835
		115	6.43	6.63	8.12	65.9	0.0834
		110	6.59	6.62	8.63	70.4	0.0834
		105	6.73	6.6	8.35	68.4	0.0837
		100	7.02	6.59	8.43	69.5	0.0836
		95	7.36	6.56	8.41	70	0.084
		90	7.5	6.55	8.3	69.3	0.0837
		85	7.59	6.54	8.17	68.3	0.0837
		80	8.11	6.54	8.04	68.1	0.0837
		75	8.34	6.54	7.91	67.4	0.0834
		70	8.69	6.55	7.78	66.8	0.0834
		65	9.1	6.55	7.81	67.7	0.0834
		60	9.7	6.56	7.77	68.4	0.0829
		55	10.79	6.58	7.76	70	0.082
		50	11.23	6.61	7.72	70.4	0.0798
		45	11.5	6.62	7.84	72	0.0791
		40	12.09	6.64	7.86	73.1	0.0796
		35	12.58	6.64	7.95	74.8	0.0799
		30	13.03	6.66	8.1	77	0.0795
		25	13.29	6.68	8.52	81.4	0.0797
		20	13.46	6.7	8.69	83.3	0.0797
		15	13.88	6.72	8.89	86.1	0.0797
		10	13.99	6.75	9	87.3	0.0798
		5	14.12	6.77	9.17	89.2	0.08
		0	14.35	6.8	14.57	142.5	0.0802
	20-Jun	125	7.19	6.12	4.52	37.4	0.0813
		120	7.26	6.07	4.56	37.8	0.081
		115	7.54	6.05	5.06	42.3	0.0804
		110	7.84	6.04	5.45	45.9	0.0803
		105	7.97	6.03	5.78	48.8	0.0803
		100	8.3	6.03	6	51.1	0.0802
		95	8.8	6.04	6.11	52.6	0.0799
		90	9.44	6.05	6.25	54.7	0.0798
		85	9.99	6.06	6.57	58.3	0.0792
		80	10.23	6.07	6.59	58.7	0.079
		75	10.74	6.09	6.68	60.2	0.0785
		70	11.06	6.1	6.63	60.2	0.0781
		65	11.42	6.11	6.56	60.1	0.0775
		60	11.66	6.12	6.62	61	0.0773
		55	11.99	6.13	6.69	62	0.0769
		50	12.46	6.14	6.59	61.8	0.0766
		45	12.88	6.15	6.66	63	0.0764
		40	13.69	6.18	6.96	67.1	0.0759
		35	14.64	6.2	7.36	72.5	0.0755
		30	16.36	6.21	6.86	70.1	0.0758

Table A-1. (Continued)

Station	Date	Depth (F)	Temp ©	pH	DO (mg/L)	DO (%)	Cond (ms/cm)
BZ6 (Con't)	20 Jun (Con't)	25	17.58	6.3	7.15	74.9	0.0738
		20	19.54	6.34	7.59	82.8	0.0708
		15	21.02	6.44	8.27	92.8	0.0709
		10	21.19	6.56	8.32	93.7	0.0711
		5	21.52	6.65	8.35	94.7	0.0709
		0	22.73	6.69	8.36	97	0.0709
	08-Aug	125	7.85	6.35	1.82	15.3	0.0826
		120	7.83	6.29	1.32	11.1	0.0822
		115	7.86	6.25	1.13	9.5	0.082
		110	8.09	6.21	1.46	12.4	0.0809
		105	8.31	6.2	2.36	20.1	0.0804
		100	8.91	6.2	2.49	21.5	0.08
		95	9.29	6.22	3.35	29.2	0.0796
		90	9.91	6.23	3.52	31.2	0.0792
		85	10.41	6.24	3.72	33.2	0.0785
		80	10.71	6.24	3.86	34.8	0.0782
		75	11.2	6.25	3.82	34.8	0.0775
		70	11.6	6.26	3.64	33.5	0.0771
		65	11.77	6.26	3.67	33.9	0.0771
		60	12.36	6.27	3.82	35.8	0.0768
		55	12.64	6.28	3.99	37.6	0.0765
		50	13.21	6.29	4.01	38.2	0.076
		45	13.76	6.28	4.06	39.2	0.076
		40	14.94	6.28	3.8	37.6	0.0755
		35	17.35	6.26	2.91	30.3	0.0743
		30	19.32	6.28	3.28	35.6	0.0713
		25	21.84	6.32	4.73	53.9	0.0701
		20	25.7	6.58	6.66	81.6	0.0668
		15	25.76	6.76	7.15	87.7	0.0668
		10	25.84	6.88	7.29	89.6	0.0668
		5	25.85	6.95	7.4	91	0.0666
		0	25.85	6.99	7.46	91.7	0.0666
	21-Aug	125	7.87	6.1	0.59	4.9	0.0836
		120	7.86	6.03	0.31	2.7	0.0828
		115	7.89	6.03	0.3	2.5	0.0825
		110	7.94	6.02	0.3	2.5	0.0819
		105	8.25	6.01	0.57	4.9	0.0812
		100	8.56	6.02	1.14	9.7	0.081
		95	9.14	6.03	1.79	15.5	0.0808
		90	9.6	6.06	2.63	23.1	0.0804
		85	10.12	6.06	3.11	27.6	0.0794
		80	10.52	6.07	3.36	30.2	0.0789
		75	11.26	6.07	3.43	31.3	0.0781
		70	11.8	6.08	3.19	29.5	0.0777
		65	12.17	6.08	3.18	29.6	0.0774

Table A-1. (Continued)							
Station	Date	Depth (F)	Temp ©	pH	DO (mg/L)	DO (%)	Cond (ms/cm)
BZ6 (Con't)	21 Aug (Con't)	60	12.49	6.1	3.36	31.5	0.0771
		55	12.81	6.11	3.64	34.4	0.077
		50	13.4	6.11	3.56	34.1	0.0768
		45	14.11	6.11	3.34	32.5	0.0766
		40	16.27	6.07	2.65	27	0.0757
		35	17.78	6.07	2.24	23.5	0.0741
		30	20.07	6.07	2.53	27.9	0.0717
		25	23.72	6.15	4.14	49	0.0709
		20	26.24	6.32	5.7	70.5	0.0655
		15	26.64	6.49	7.13	89	0.0651
		10	26.74	6.68	7.56	94.5	0.0652
		5	26.75	6.78	7.61	95.1	0.065
		0	26.77	6.84	7.78	97.3	0.0651
	02-Oct	125	7.87	6.91	0	0	0.1065
		120	7.94	6.88	0	0	0.0956
		115	7.98	6.87	0	0	0.0914
		110	8.09	6.83	0	0	0.0885
		105	8.29	6.81	0	0	0.0857
		100	8.58	6.8	0	0	0.0837
		95	9.08	6.8	0.35	3.1	0.0826
		90	9.55	6.79	1.11	9.7	0.0821
		85	10.05	6.78	1.45	12.8	0.0814
		80	10.52	6.77	1.75	15.7	0.0811
		75	11.17	6.73	1.42	12.9	0.0807
		70	11.75	6.71	0.99	9.1	0.0805
		65	12.26	6.7	0.94	8.7	0.0805
		60	12.6	6.69	0.99	9.3	0.0797
		55	13.3	6.69	1.54	14.7	0.079
		50	13.95	6.67	1.48	14.3	0.0789
		45	15.21	6.61	0.5	5	0.0796
		40	16.97	6.58	0.29	3	0.0789
		35	19.4	6.66	0.21	2.3	0.0712
		30	19.93	6.77	3.35	36.8	0.0682
		25	20.05	6.86	5.63	62	0.0675
		20	20.11	6.93	6.29	69.3	0.0674
		15	20.13	6.95	6.62	73	0.0675
		10	20.12	6.98	6.8	75	0.0675
		5	20.19	7.02	7.09	78.3	0.0675
		0	20.45	7.04	7.19	79.8	0.0675

Table A-1. (Continued)							
Station	Date	Depth (F)	Temp ©	pH	DO (mg/L)	DO (%)	Cond (ms/cm)
BZ7	22-May	52	11.33	6.58	9.97	91.1	0.1018
		50	11.34	6.59	9.74	89.1	0.1002
		45	11.52	6.6	9.64	88.5	0.0989
		40	11.44	6.61	9.64	88.3	0.0985
		35	11.79	6.63	9.55	88.2	0.0961
		30	12.4	6.66	9.49	88.9	0.0926
		25	13.26	6.69	9.33	89.1	0.0874
		20	13.86	6.72	9.16	88.6	0.0855
		15	13.94	6.74	9.26	89.8	0.0858
		10	14.44	6.8	9.31	91.2	0.0771
		5	14.56	6.83	9.23	90.6	0.0753
		0	14.61	6.84	9.54	93.8	0.0752
	20-Jun	50	12.36	6.74	5.33	49.9	0.0797
		45	12.91	6.62	5.31	50.3	0.0792
		40	13.58	6.57	5.48	52.7	0.08
		35	15.18	6.53	6.27	62.5	0.0823
		30	16.66	6.54	7.8	80.1	0.0838
		25	17.78	6.59	8.35	87.8	0.0821
		20	19.1	6.66	8.06	87.1	0.0757
		15	20.01	6.72	7.88	86.8	0.0641
		10	20.9	6.74	7.89	88.3	0.0643
		5	21.8	6.8	8.37	95.3	0.0692
		0	23.08	6.85	8.41	98.3	0.0692
	08-Aug	50	13.24	6.37	1.07	10.3	0.0814
		45	13.83	6.31	0.5	4.8	0.0812
		40	15.37	6.27	0.48	4.8	0.0807
		35	17.23	6.25	0.93	9.7	0.0792
		30	19.71	6.26	1.62	17.7	0.0786
		25	22.44	6.56	5.29	61	0.0825
		20	24.06	6.52	4.64	55.2	0.078
		15	26.11	6.83	7.13	88.1	0.0665
		10	26.15	6.89	7.21	89.1	0.0663
		5	26.27	6.96	7.2	89.2	0.0666
		0	26.27	6.99	7.46	92.4	0.0666

Table A-1. (Continued)							
Station	Date	Depth (F)	Temp ©	pH	DO (mg/L)	DO (%)	Cond (ms/cm)
BZ7 (Con't)	21-Aug	52	13.13	6.5	0.2	1.9	0.0842
		50	13.39	6.47	0.09	0.9	0.0846
		45	13.88	6.43	0	0	0.0841
		40	15.63	6.4	0	0	0.0831
		35	18.11	6.36	0.06	0.6	0.0809
		30	21.43	6.37	0.79	9	0.0789
		25	23.57	6.41	3.02	35.6	0.0799
		20	24.7	6.45	3.82	45.9	0.0742
		15	25.87	6.6	6.46	79.4	0.0687
		10	27.26	6.74	7.18	90.5	0.0641
		5	27.34	6.82	7.38	93.2	0.0642
		0	27.34	6.87	7.55	95.4	0.0642
	02-Oct	50	13.83	6.53	1.35	13	0.0982
		45	15.15	6.51	0.77	7.7	0.0871
		40	18.03	6.63	3.43	36.2	0.0871
		35	18.99	6.73	6.61	71.2	0.0806
		30	20.16	6.79	6.93	76.5	0.069
		25	20.29	6.79	7.08	78.3	0.0686
		20	20.71	6.81	7.26	81	0.0673
		15	20.75	6.84	7.57	84.6	0.0672
		10	20.79	6.85	7.63	85.2	0.0673
		5	21.06	6.87	7.76	87.1	0.0671
		0	21.23	6.87	7.81	88	0.067

APPENDIX B

WATER COLUMN CHEMISTRY MONITORING LABORATORY ANALYSIS CERTIFICATES

APPENDIX C

SEDIMENT PRIORITY POLLUTANT
LABORATORY ANALYSIS CERTIFICATES

APPENDIX D

DRINKING WATER MONITORING
LABORATORY ANALYSIS CERTIFICATES

APPENDIX E

METEOROLOGICAL DATA
(See CD for file)

APPENDIX F

SCOPE OF WORK