3.0 RESULTS AND DISCUSSION

3.1 STRATIFICATION MONITORING

The following sections describe temporal and spatial patterns for the water quality parameters of temperature, dissolved oxygen (DO), percent saturation of DO, pH, and conductivity measured throughout the F.E. Walter Reservoir watershed during 2003. Additionally, patterns related to season and depths are described for station WA-2 located in the reservoir. Maximum depths for WA-2 vary between 45 to 95 feet due to several intense rain events. All of the data collected during the 2003 monitoring period are presented in Appendix Table A-1.

3.1.1 Temperature

Temperature of the surface waters of the F.E. Walter Reservoir watershed generally followed a similar pattern throughout the monitoring period. Average temperatures increased throughout the summer and peaked in July at approximately 22 °C, and decreased thereafter through September to 16 °C (Fig. 3-1). Temperatures in surface waters of the reservoir-body (station WA-2, -6, and -7) were generally warmer than in tributaries (stations WA-3, -4, and -5) and downstream of the dam (WA-1). Throughout the monitoring period the reservoir body averaged 3 °C higher.

The water column of F.E. Walter Reservoir was weakly stratified during 2003. Temperatures throughout the water column in all months were somewhat uniform, and the greatest difference between surface and bottom was about 5 °C in June (Fig. 3-2). In May, the temperature of the water column was lowest and averaged about 11 °C. In July, the temperature of the water column averaged 21 °C and peaked at 23.3 °C.

3.1.2 Dissolved Oxygen

Dissolved oxygen (DO) in the surface waters of F.E. Walter Reservoir followed a consistent pattern during 2003. Concentrations among all stations generally averaged 8.4 mg/L over the monitoring period and ranged from 6.5 to 10.6 mg/L (Fig. 3-3). DO concentrations decreased slightly through July and then rose through September. DO concentrations in surface waters of the reservoir-body (station WA-2, -6, and -7) were slightly lower than in tributaries (stations WA-3, -4, and -5) and downstream of the dam (WA-1). Throughout the monitoring period the reservoir body averaged 1 mg/L less.

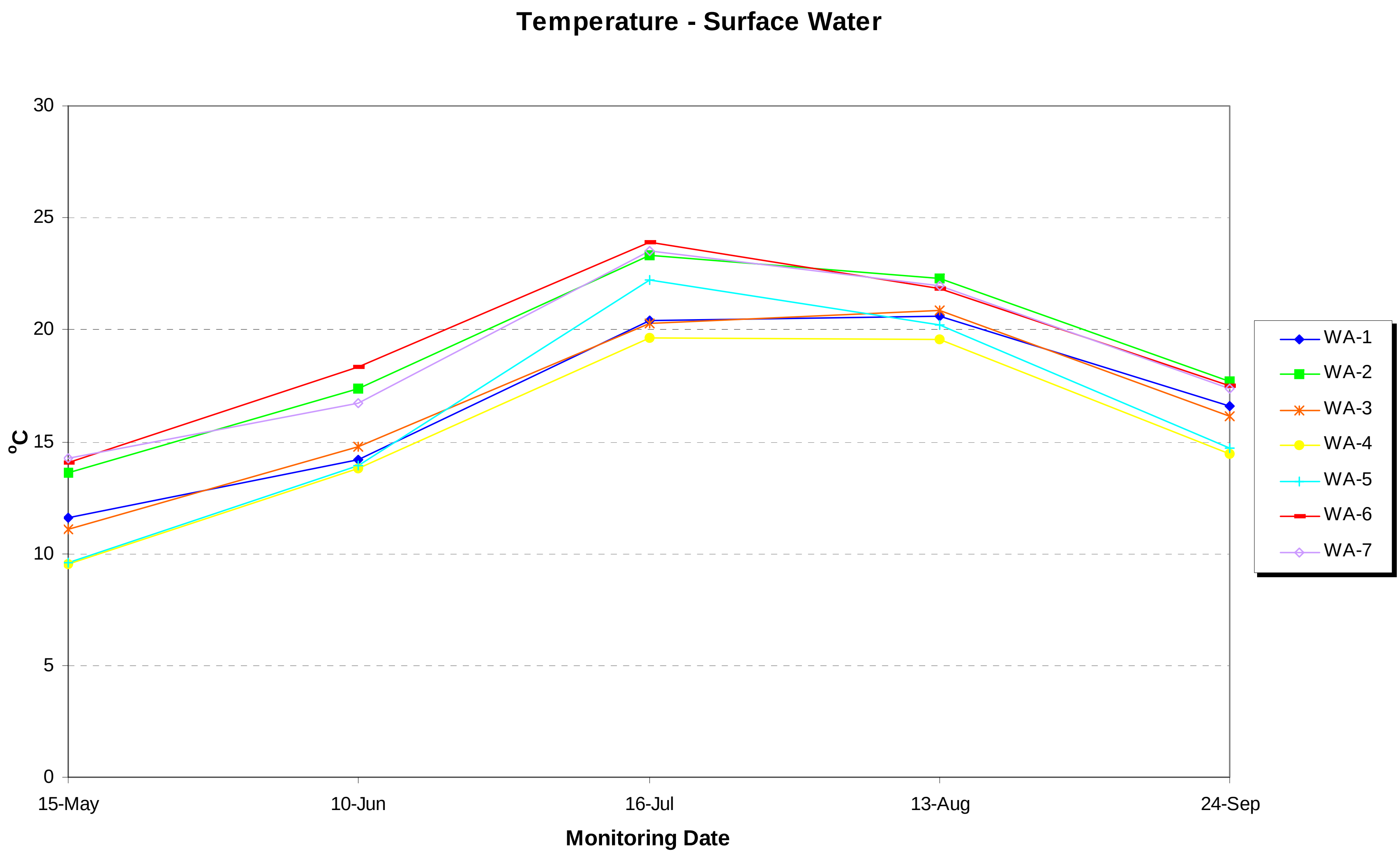

Figure 3-1. Temperature measured in surface waters of F.E. Walter Reservoir during 2003. See Appendix A for a summary of the plotted values.

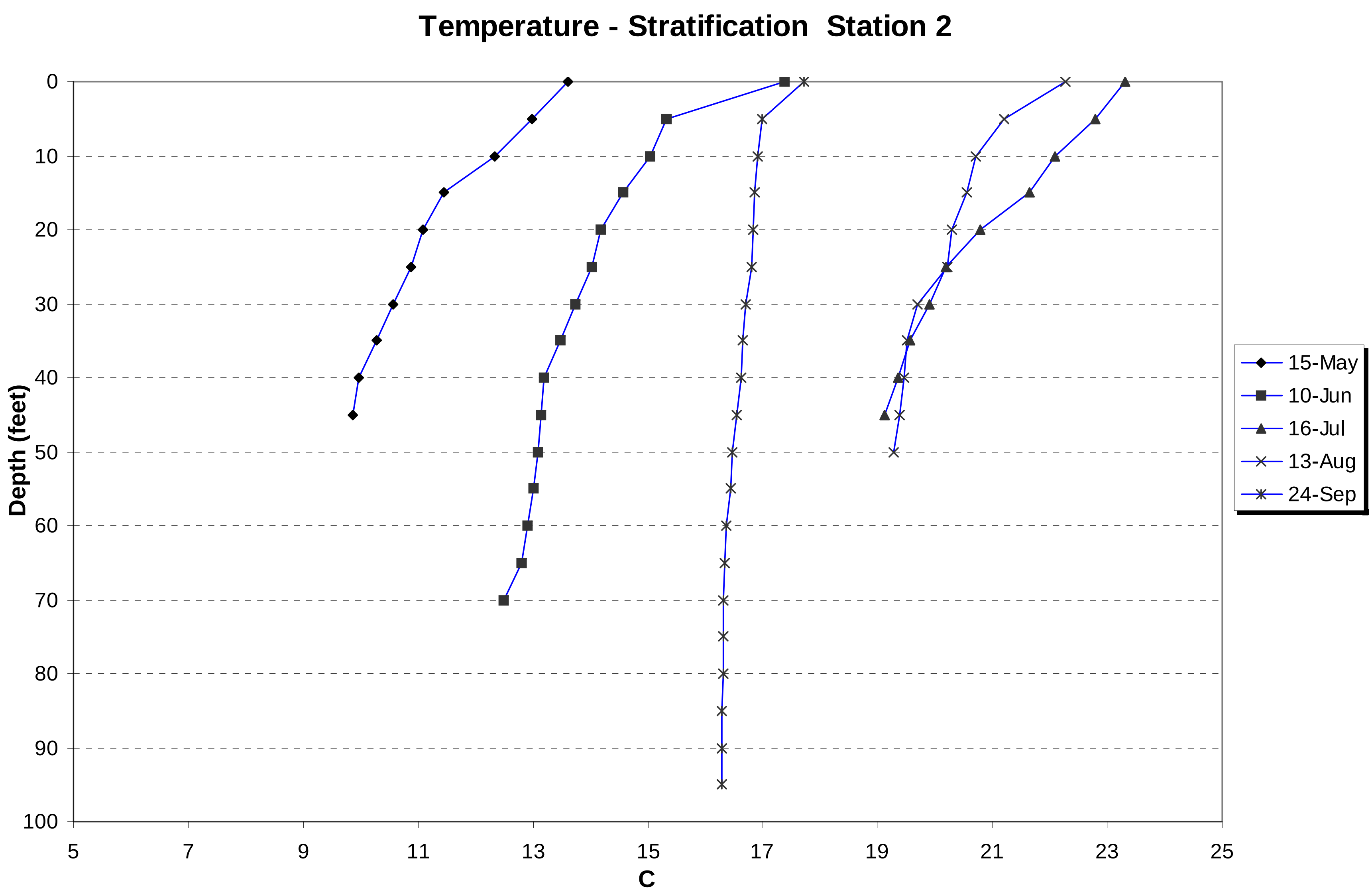

Figure 3-2. Stratification of temperature measured in the water column of F. E. Walter Reservoir at station WA-2 during 2003. See Appendix A for a summary of the plotted values.

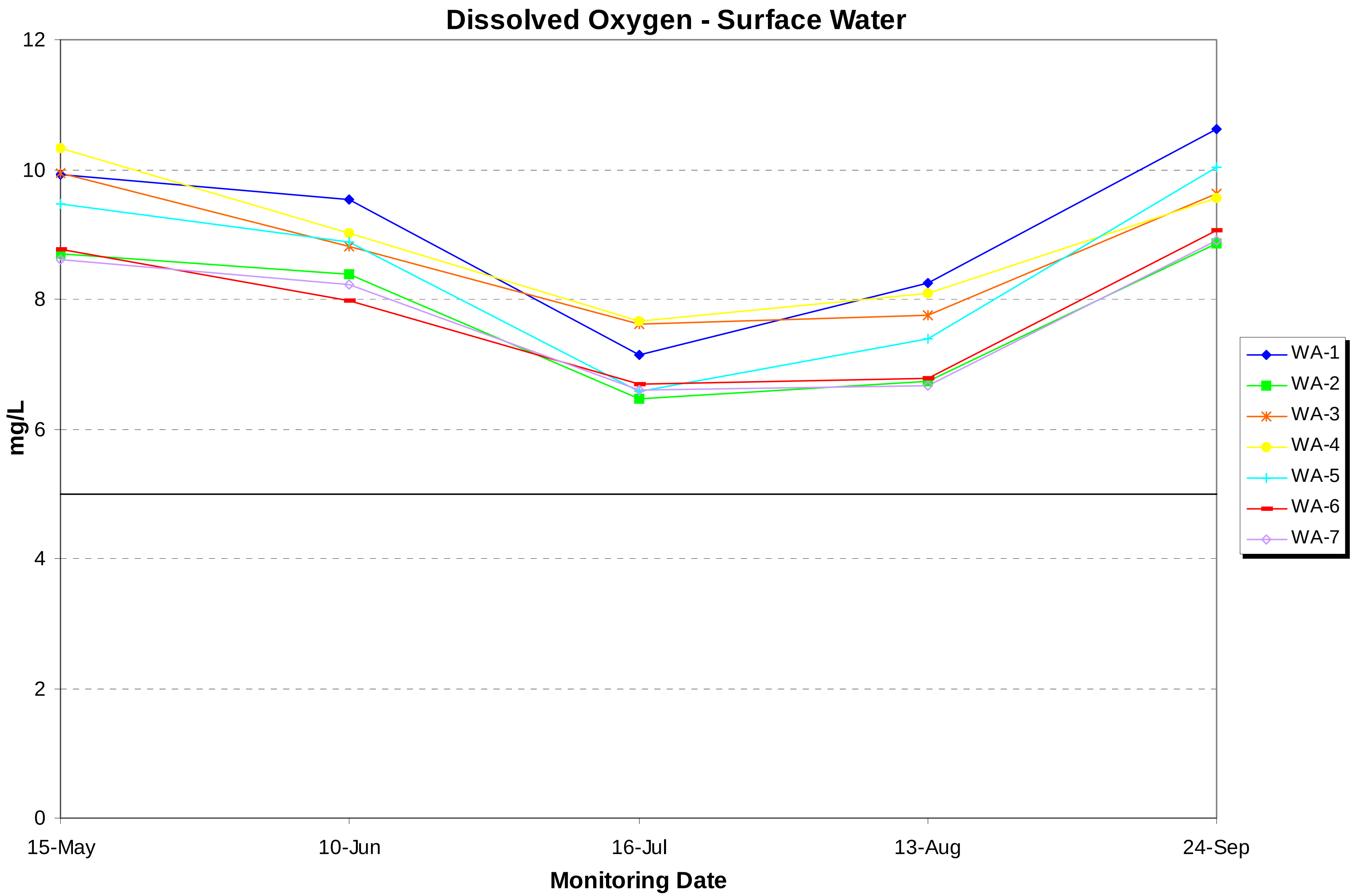

Figure 3-3. Dissolved oxygen measured in surface waters of F. E. Walter Reservoir during 2003. See Appendix A for a summary of the plotted values.

The water column of F.E. Walter Reservoir was weakly stratified with respect to DO during June (Fig. 3-4). During May, July, and September the water column was relatively uniform with concentrations remaining fairly stable throughout the water column. DO concentrations throughout the monitoring period averaged 8 mg/Lin.

The health of aquatic ecosystems can be impaired by low DO concentrations in the water column. Hypoxia, or conditions of DO concentrations less than 2 mg/L, is generally accepted as the threshold at which the most severe effects on biota occur. In 2003, the lower water column of F.E. Walter Reservoir was not affected by hypoxia (Fig. 3-4).

A seasonal trend analysis of DO was conducted for individual stations of F.E. Walter Reservoir, combining 2003 and historical data. The Mann-Kendall statistic was applied to station data collected over the past 25 years or more, separately for spring (April to June) and summer (July to October) seasons. Stations included in the analysis were representative of locations downstream (WA-1), main reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5). Significant decreasing trends were determined from the analysis for station WA-2 in the spring and WA-2 and WA-5 in the summer (Table 3-1).

Table 3-1. Seasonal trends of dissolved oxygen concentration at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic.

Station	# of Years Spring/Summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate (mg/L)
Surface Water					
WA-1	28	NS	0.0038	NS	-0.0350
WA-2	29	$P < 0.05$	-0.0472	$P < 0.05$	-0.0524
WA-3	28	NS	-0.0171	NS	-0.0286
WA-4	29	NS	-0.0237	NS	-0.0322
WA-5	25	NS	-0.0303	$P < 0.05$	-0.0834

3.1.3 pH

Measures of pH in surface waters of F.E. Walter Reservoir generally followed a similar pattern during 2003; however, slight differences were apparent between reservoir body, up and downstream waters (Figs. 3-5). Stations located in the reservoir body (WA-2, -6, and -7) averaged 6.3. Measures of pH downstream of the reservoir (WA-1) and the upstream stations (WA-3, -4, and –5) were slightly higher and averaged 6.5 (Fig. 3-5). The average pH at all stations in September was 5.8, this is likely due to the additional 25 feet of water pounded in the reservoir after Tropical Storm Isabel and subsequent flooding up and downstream.

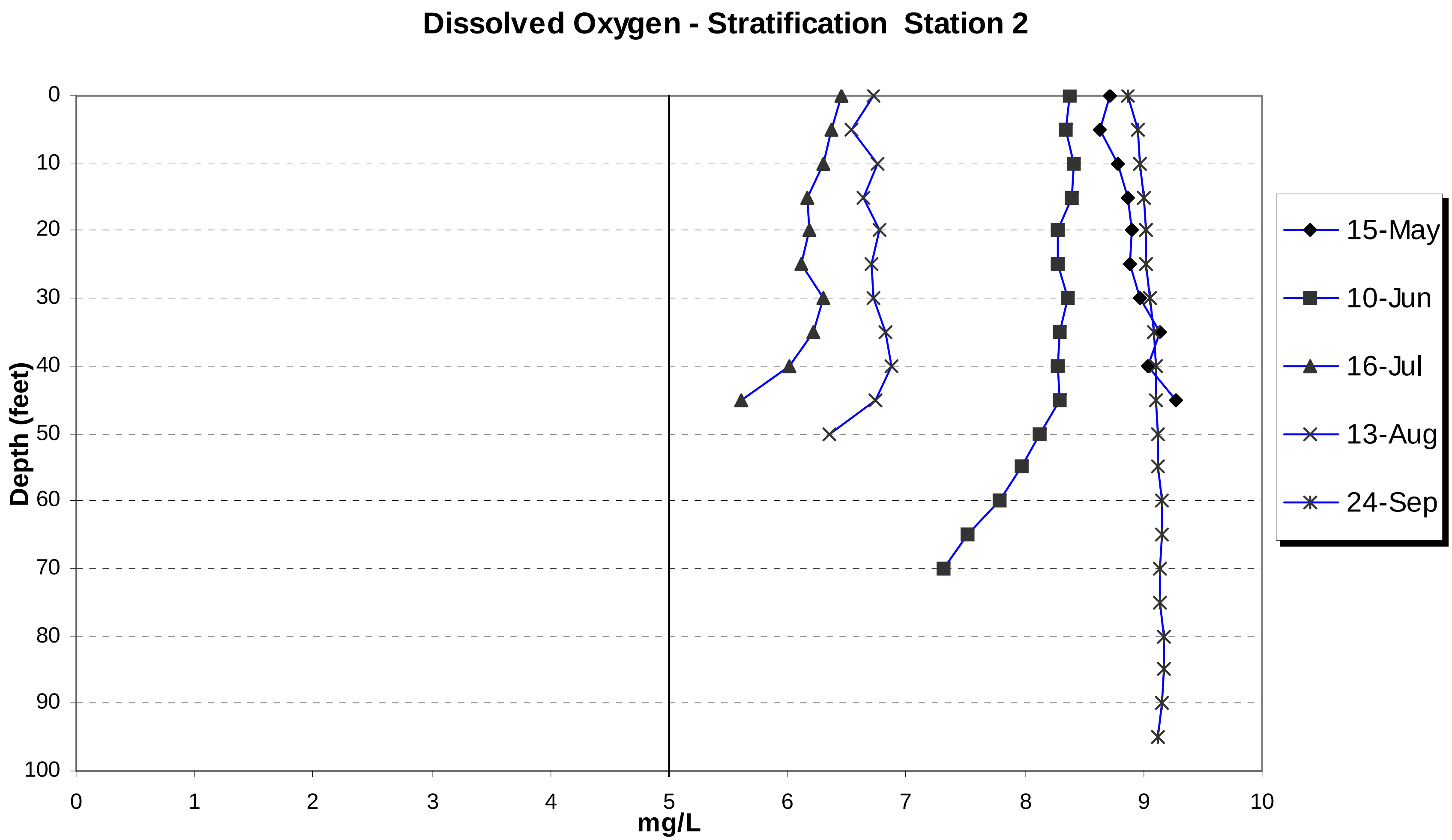

Figure 3-4. Dissolved oxygen measured in surface waters of F.E. Walter Reservoir at station WA-2 during 2003. The PADEP water quality standard for DO is a minimum concentration of 5 mg/L. See Appendix A for a summary of the plotted values.

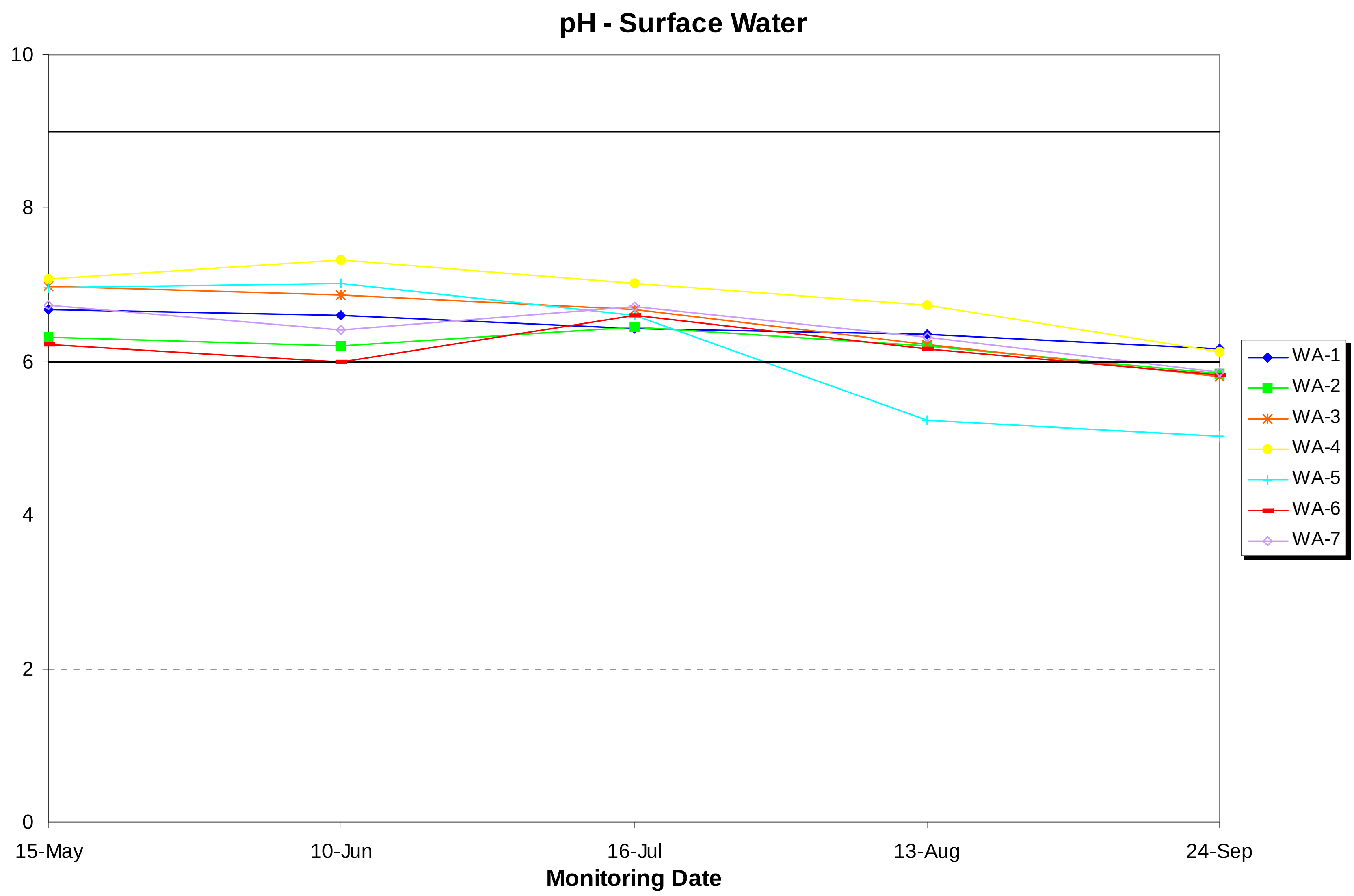

Figure 3-5. Measures of pH in surface waters of F.E. Walter Reservoir during 2003. The PADEP water quality standard for pH is an acceptable range from 6 to 9. See Appendix A for a summary of the plotted values.

The water column of F.E. Walter Reservoir was weakly stratified with respect to pH during 2003. On most monitoring dates, measures of pH were relatively uniform throughout the water column (Fig. 3-6). On 16 July, pH was highest and averaged about 6.3. During September, pH was lowest averaging 5.7 and ranged from 5.5 to 5.8.

During 2003, measures of pH in the water column of F.E. Walter Reservoir were not in compliance with PADEP water quality standards. The water quality standard for pH is a range of acceptable measures between 6 and 9. Station WA-6 was below standard in May and June. Stations WA-2, -5, and -6 were below the standard on 13 August. Additionally, stations WA-2, -3, -5, -6, and -7 were below the standard on 24 September (Appendix A).

3.1.4 Conductivity

For the most part, conductivity among the surface waters of F.E. Walter Reservoir followed a fairly consistent pattern during 2003. Conductivity at all stations averaged 0.064 mS/cm throughout the monitoring period and ranged from 0.039 to 0.103 mS/cm (Fig. 3-7). Conductivity was typically higher upstream of the reservoir at station WA-3 averaging 0.070 mS/cm.

Conductivity in the water column of F.E. Walter Reservoir was weakly stratified, if at all, during 2003. In most months, measures were generally uniform throughout, but followed a slight decreasing trend as the season progressed (Fig. 3-8). On 15 May, conductivity was highest at approximately 0.085 mS/cm. Thereafter, through 24 September, conductivity decreased on each monitoring date to an average of 0.044 mS/cm.

3.2 WATER COLUMN CHEMISTRY MONITORING

The following sections describe temporal, spatial, and depth related patterns for water quality measured in the water column of F.E. Walter Reservoir during 2003 (Table 3–2). Where appropriate, trends in surface water quality are discussed based on the regression and Mann-Kendall analysis of 2003 data and the F.E. Walter Reservoir water quality database.

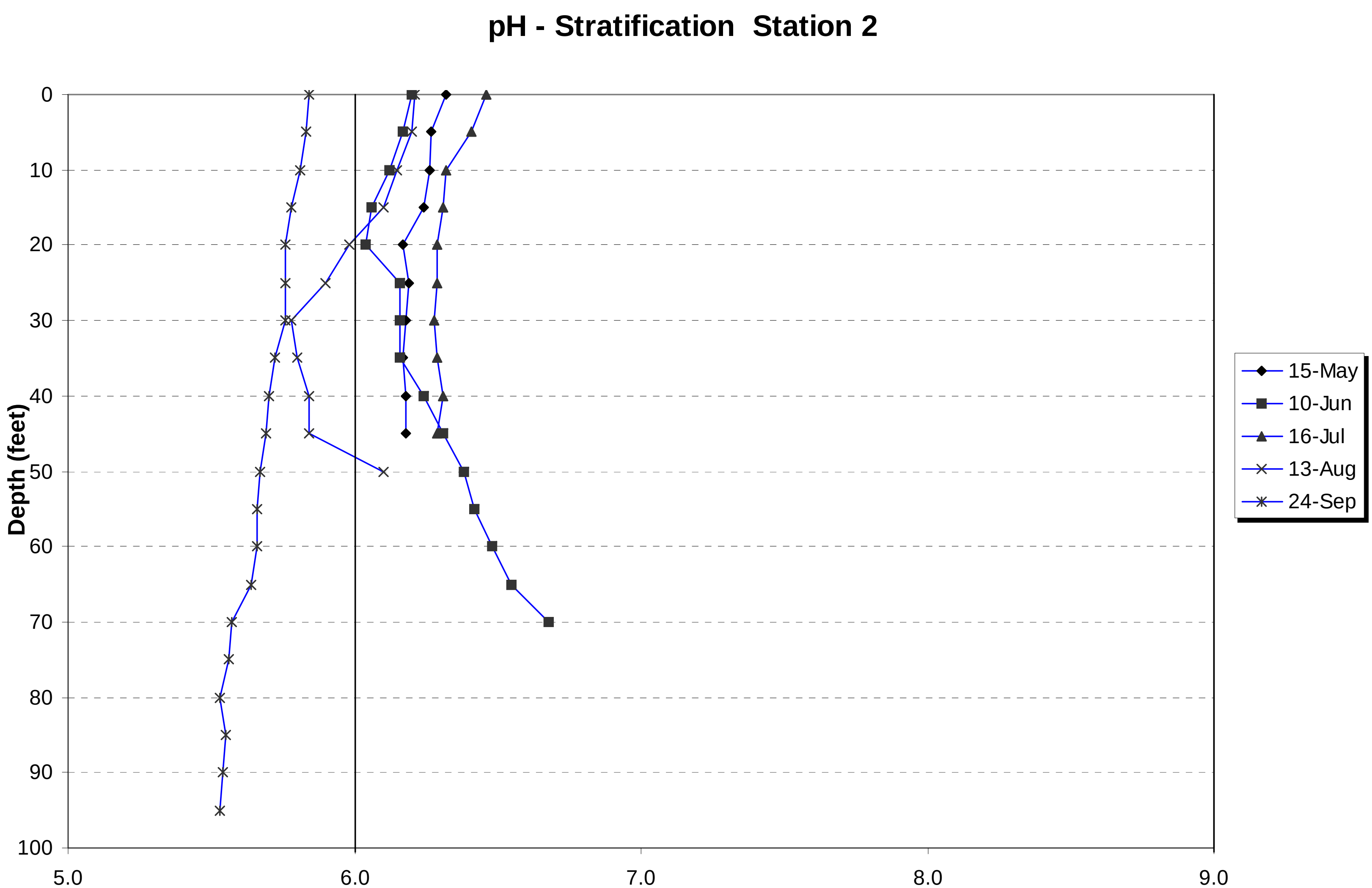

Figure 3-6. Stratification of pH measured in the water column of F.E. Walter Reservoir at station WA-2 during 2003. The PADEP water quality standard pH is an acceptable range from 6 to 9. See Appendix A for a summary of the plotted values.

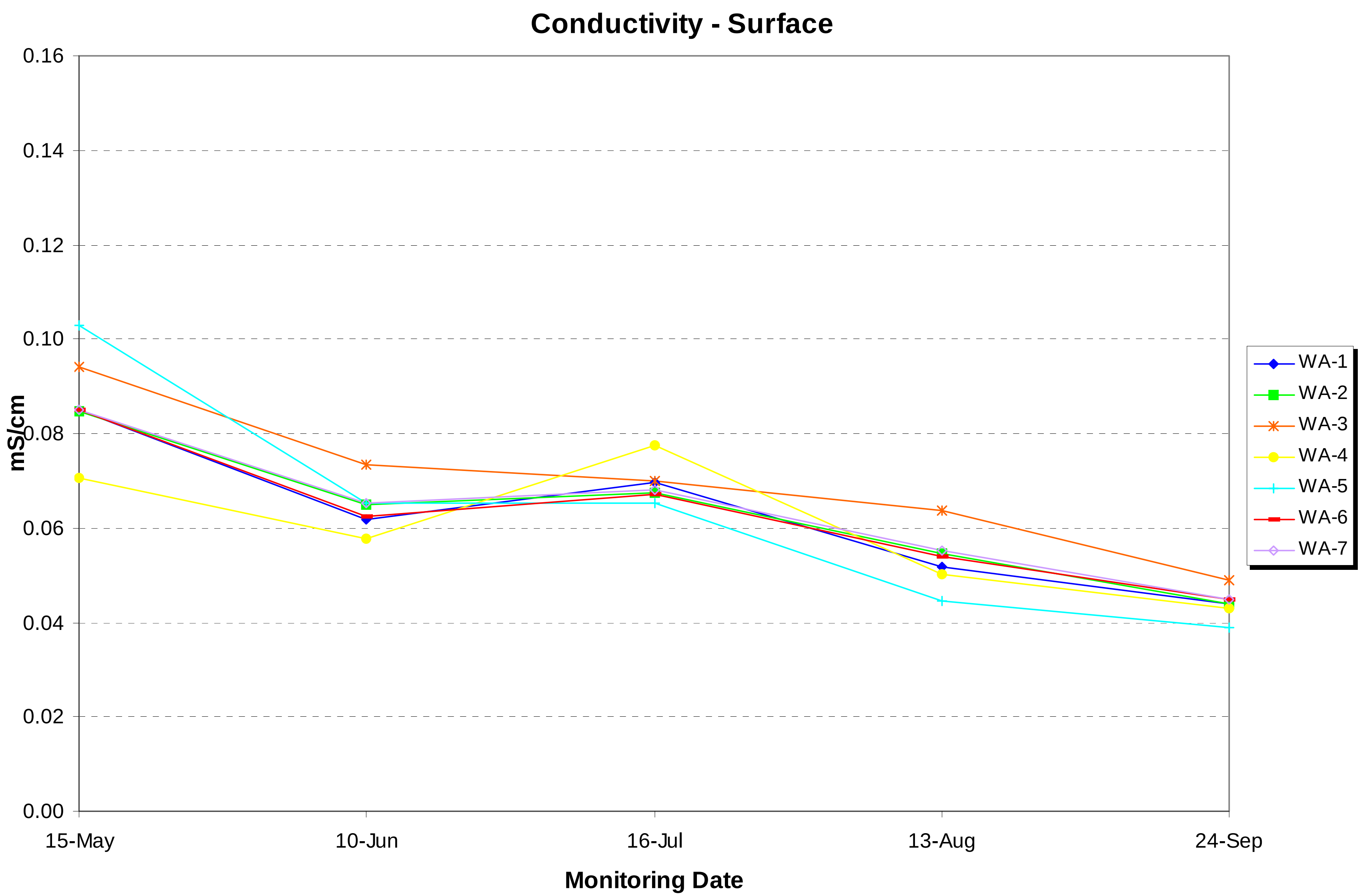

Figure 3-7. Conductivity measured in surface waters of F.E. Walter Reservoir during 2003. See Appendix A for a summary of the plotted values.

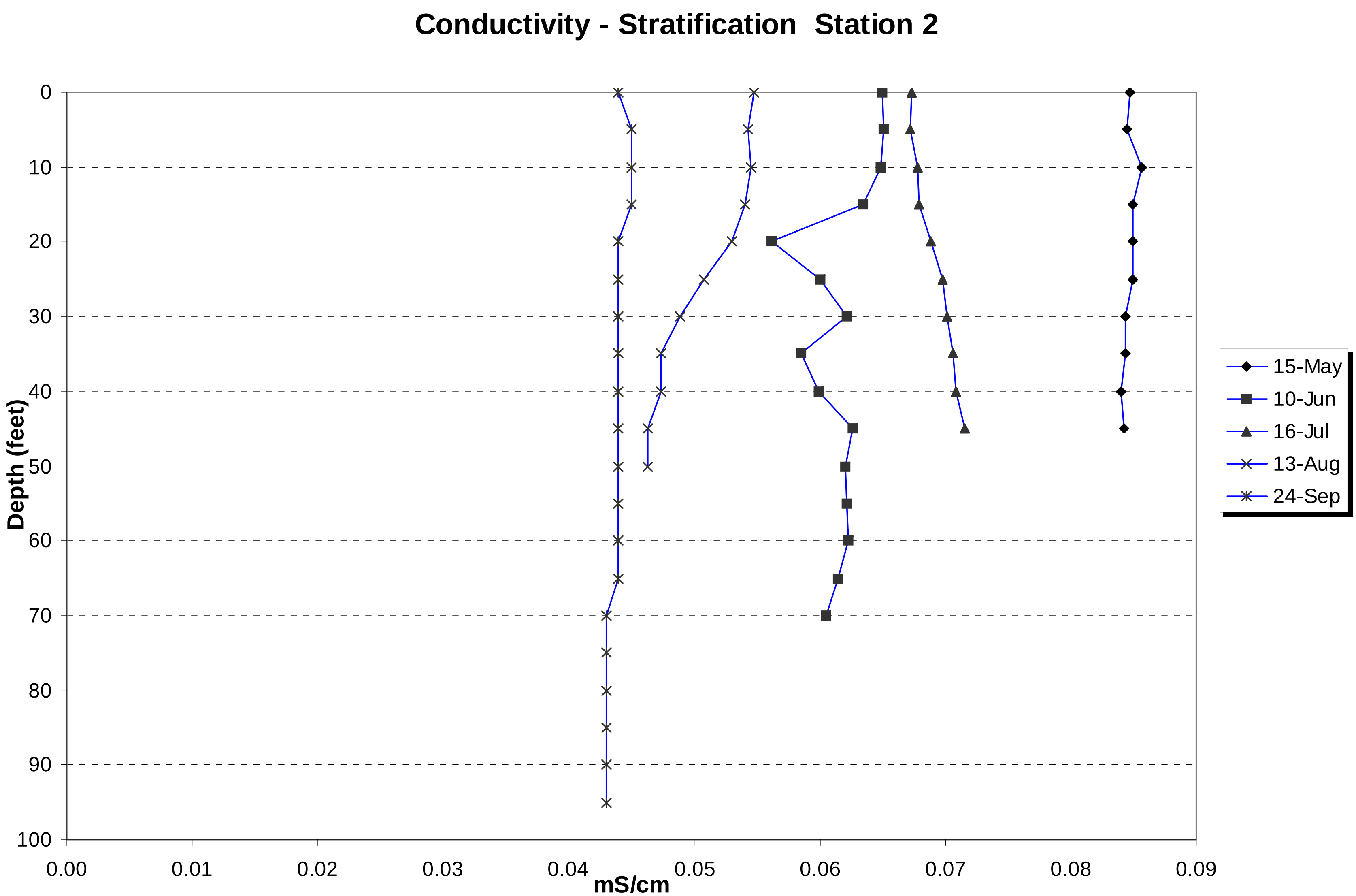

Figure 3-8. Stratification of conductivity measured in the water column of F. E. Walter Reservoir at station WA-2 during 2003. See Appendix A for a summary of the plotted values.

Table 3-2. Summary of surface, middle, and bottom water quality monitoring data for F.E. Walter Reservoir in 2003

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	DISS P	TOC	TIC	TC	CHLA
WA-1S	15-May	0.059	< 0.015	0.093	< 0.01	0.36	< 0.04	49	5.2	< 4.2	2.9	< 0.050	2.3	2.1	4.4	3.7
	10-Jun	0.038	< 0.015	0.074	< 0.01	0.93	< 0.04	39	< 3.0	< 4.2	2.0	< 0.050	5.8	1.6	7.5	6.3
	16-Jul	0.061	< 0.015	0.120	< 0.01	< 0.30	< 0.04	53	7.2	< 3.2	4.2	0.065	5	2.1	7.1	4.9
	13-Aug	0.076	< 0.015	< 0.040	< 0.01	0.49	< 0.04	51	3.6	< 3.9	2.2	0.074	9.8	2.1	12.0	8.5
	24-Sep	0.048	< 0.015	0.054	< 0.01	0.38	< 0.04	38	7.2	< 2.9	1.3	< 0.050	11.2	1.4	12.6	10.2
Mean		0.056	0.015	0.076	0.01	0.49	0.04	46	5.2	3.7	2.5	0.058	6.8	1.9	8.7	6.7
Maximum		0.076	0.015	0.120	0.01	0.93	0.04	53	7.2	4.2	4.2	0.074	11.2	2.1	12.6	10.2
Minimum		0.038	0.015	0.040	0.01	0.30	0.04	38	3.0	2.9	1.3	0.050	2.3	1.4	4.4	3.7
Std. Dev		0.014	0.000	0.032	0.00	0.25	0.00	7.1	2.0	0.6	1.1	0.011	3.6	0.3	3.5	2.6
No. of D		5	0	4	0	4	0	5	4	0	5	2	5	5	5	5
WA-2S	15-May	0.088	< 0.015	0.100	< 0.01	0.43	< 0.04	46.5	< 3.0	< 4.0	3.2	< 0.050	3.5	0.8	4.3	6.7
	10-Jun	< 0.030	< 0.015	0.082	< 0.01	0.35	< 0.04	39.5	< 3.0	< 4.6	2.3	< 0.050	6.6	1.5	8.1	4.4
	16-Jul	0.042	< 0.015	0.110	< 0.01	< 0.30	< 0.04	50	< 3.0	< 2.9	3.7	< 0.050	5.0	1.8	6.8	6.1
	13-Aug	0.046	< 0.015	< 0.040	< 0.01	0.52	< 0.04	38	3.2	< 3.9	2.7	0.073	10.4	2.6	13.0	9.6
	24-Sep	0.046	< 0.015	< 0.040	0.01	0.35	< 0.04	38	6.8	< 3.1	1.6	< 0.050	10.7	2.2	12.8	11.5
Mean		0.050	0.015	0.074	0.01	0.39	0.04	42	3.8	3.7	2.7	0.055	7.2	1.8	9.0	7.7
Maximum		0.088	0.015	0.110	0.01	0.52	0.04	50	6.8	4.6	3.7	0.073	10.7	2.6	13.0	11.5
Minimum		0.030	0.015	0.040	0.01	0.30	0.04	38	3.0	2.9	1.6	0.050	3.5	0.8	4.3	4.4
Std. Dev		0.022	0.000	0.033	0.00	0.09	0.00	5.5	1.7	0.7	0.81	0.010	3.2	0.7	3.8	2.9
No. of D		4	0	3	1	4	0	5	2	0	5	1	5	5	5	5
WA-2M	15-May	< 0.030	< 0.015	0.097	< 0.01	0.35	< 0.04	48.5	< 3.0	< 3.7	4.0	< 0.050	3.5	0.8	4.3	4.9
	10-Jun	< 0.030	< 0.015	0.081	< 0.01	0.40	< 0.04	33.5	< 3.0	< 4.4	1.7	< 0.050	5.5	1.3	6.8	6.2
	16-Jul	0.045	< 0.015	0.110	< 0.01	< 0.30	< 0.04	53.5	< 3.0	< 2.7	9.0	< 0.050	5.2	2.1	7.3	4.8
	13-Aug	0.074	< 0.015	< 0.040	< 0.01	0.43	< 0.04	43	4.0	< 3.3	1.2	0.068	8.6	1.8	10.4	7.5
	24-Sep	0.046	< 0.015	0.053	< 0.01	0.38	< 0.04	35	7.6	< 3.1	1.2	< 0.050	10.9	1.7	12.6	10.4
Mean		0.045	0.015	0.076	0.01	0.37	0.04	43	4.1	3.4	3.4	0.054	6.7	1.5	8.3	6.7
Maximum		0.074	0.015	0.110	0.01	0.43	0.04	54	7.6	4.4	9.0	0.068	10.9	2.1	12.6	10.4
Minimum		0.030	0.015	0.040	0.01	0.30	0.04	34	3.0	2.7	1.2	0.050	3.5	0.8	4.3	4.8
Std. Dev		0.018	0.000	0.029	0.00	0.05	0.00	8.6	2.0	0.65	3.3	0.008	3.0	0.5	3.2	2.3
No. of D		3	0	4	0	4	0	5	2	0	5	1	5	5	5	5
WA-2B	15-May	0.110	< 0.015	0.110	< 0.01	0.38	< 0.04	48	< 3.0	< 3.7	3.5	< 0.050	3.7	0.8	4.5	3.9
	10-Jun	< 0.030	< 0.015	0.082	< 0.01	0.41	< 0.04	34.5	10.4	< 4.0	1.7	< 0.050	4.9	1.0	5.9	8.0
	16-Jul	0.065	< 0.015	0.120	< 0.01	< 0.30	< 0.04	50.5	69.6	< 3.2	4.4	0.051	5.2	2.2	7.4	4.5
	13-Aug	0.056	< 0.015	0.041	< 0.01	0.49	< 0.04	31	8.4	< 5.5	0.85	0.067	7.7	1.3	9.0	6.0
	24-Sep	0.042	< 0.015	< 0.800	< 0.01	0.38	< 0.04	37	9.6	< 3.2	0.79	< 0.050	9.6	1.3	10.9	7.7
Mean		0.061	0.015	0.231	0.01	0.39	0.04	40	20.2	3.9	2.2	0.054	6.2	1.3	7.5	6.0
Maximum		0.110	0.015	0.800	0.01	0.49	0.04	51	69.6	5.5	4.4	0.067	9.6	2.2	10.9	8.0
Minimum		0.030	0.015	0.041	0.01	0.30	0.04	31	3.0	3.2	0.79	0.050	3.7	0.8	4.5	3.9
Std. Dev		0.031	0.000	0.320	0.00	0.07	0.00	8.6	27.8	0.9	1.6	0.008	2.4	0.5	2.5	1.8
No. of D		4	0	4	0	4	0	5	4	0	5	2	5	5	5	5
WA-3S	15-May	0.070	< 0.015	0.120	< 0.01	0.39	< 0.04	60	< 3.0	< 3.8	3.7	0.057	4.0	0.7	4.7	6.8
	10-Jun	< 0.030	< 0.015	0.074	0.021	0.40	< 0.04	48.5	4.0	< 4.2	3.2	< 0.050	8.2	2.4	10.6	8.6
	16-Jul	0.061	< 0.015	0.120	< 0.01	< 0.30	< 0.04	56	< 3.0	< 2.7	3.7	< 0.050	6.0	2.1	8.1	5.8
	13-Aug	0.054	< 0.015	0.130	< 0.01	0.56	< 0.04	61	< 3.0	< 5.8	3.8	0.074	13.1	3.8	16.9	11.1
	24-Sep	0.041	< 0.015	< 0.800	0.011	0.37	< 0.04	53	11.6	< 3.2	9.1	< 0.050	11.9	4.8	16.7	12.2
Mean		0.051	0.015	0.249	0.01	0.40	0.04	56	4.9	3.9	4.7	0.056	8.6	2.8	11.4	8.9
Maximum		0.070	0.015	0.800	0.02	0.56	0.04	61	11.6	5.8	9.1	0.074	13.1	4.8	16.9	12.2
Minimum		0.030	0.015	0.074	0.01	0.30	0.04	49	3.0	2.7	3.2	0.050	4.0	0.7	4.7	5.8
Std. Dev		0.016	0.000	0.309	0.00	0.10	0.00	5.1	3.8	1.2	2.5	0.010	3.8	1.6	5.4	2.7
No. of D		4	0	4	2	4	0	5	2	0	5	2	5	5	5	5
WA-4S	15-May	0.062	< 0.015	0.092	< 0.01	0.51	< 0.04	43	< 3.0	< 3.7	6.3	< 0.050	4.0	1.1	5.1	4.8
	10-Jun	< 0.030	< 0.015	0.050	< 0.01	0.38	< 0.04	33	3.6	< 4.2	3.2	< 0.050	5.3	1.5	6.9	16.7
	16-Jul	0.055	< 0.015	0.110	< 0.01	< 0.30	< 0.04	55	< 3.0	< 2.5	6.3	< 0.050	4.1	1.9	6.0	4.6
	13-Aug	0.042	< 0.015	0.043	< 0.01	0.59	< 0.04	41.5	10.4	< 5.6	3.7	0.088	8.9	2.5	11.4	8.8
	24-Sep	0.041	< 0.015	< 0.800	< 0.01	0.33	< 0.04	40	4.4	< 3.2	1.9	< 0.050	9.8	1.8	11.5	9.7
Mean		0.046	0.015	0.219	0.01	0.42	0.04	43	4.9	3.8	4.3	0.058	6.4	1.8	8.2	8.9
Maximum		0.062	0.015	0.800	0.01	0.59	0.04	55	10.4	5.6	6.3	0.088	9.8	2.5	11.5	16.7
Minimum		0.030	0.015	0.043	0.01	0.30	0.04	33	3.0	2.5	1.9	0.050	4.0	1.1	5.1	4.6
Std. Dev		0.013	0.000	0.326	0.00	0.12	0.00	8.0	3.1	1.2	2.0	0.017	2.7	0.5	3.1	4.9
No. of D		4	0	4	0	4	0	5	3.0	0	5	1	5	5	5	5

Table 3-2. (Continued)

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	DISS P	TOC	TIC	TC	CHLA
WA-5S	15-May	0.091	< 0.015	<0.040	< 0.01	0.40	< 0.04	47	3.2	< 3.1	0.68	0.058	3.7	< 0.6	3.9	2.9
	10-Jun	< 0.030	< 0.015	<0.040	0.024	<0.30	< 0.04	26.5	5.2	< 3.4	<0.41	0.070	4.4	1.1	5.5	3.4
	16-Jul	0.053	< 0.015	<0.040	< 0.01	<0.30	< 0.04	50	4.8	< 3.2	1.9	< 0.050	4.7	1.7	6.4	7.3
	13-Aug	0.040	< 0.015	<0.040	< 0.01	0.52	< 0.04	41	3.6	4.7	<0.41	0.069	8.6	1.9	10.5	6.4
	24-Sep	0.041	< 0.015	<0.800	0.012	<0.30	< 0.04	29.5	6.0	< 3.1	<0.41	< 0.050	8.0	0.91	8.9	7.6
Mean		0.051	0.015	0.192	0.01	0.36	0.04	39	4.6	3.5	0.76	0.059	5.9	1.2	7.0	5.5
Maximum		0.091	0.015	0.800	0.02	0.52	0.04	50	6.0	4.7	1.9	0.070	8.6	1.9	10.5	7.6
Minimum		0.030	0.015	0.040	0.01	0.30	0.04	27	3.2	3.1	0.41	0.050	3.7	0.6	3.9	2.9
Std. Dev		0.024	0.000	0.340	0.01	0.10	0.00	10.4	1.2	0.7	0.65	0.010	2.2	0.5	2.6	2.2
No. of D		4	0	0	2	2	0	5	5	1	2	3	5	4	5	5
WA-6S	15-May	0.093	< 0.015	0.110	< 0.01	0.39	< 0.04	49.5	< 3.0	< 3.5	3.2	0.084	3.5	0.7	4.2	6.5
	10-Jun	< 0.030	< 0.015	0.110	0.017	0.36	< 0.04	40	< 3.0	< 4.3	1.7	0.066	5.3	2.0	7.3	6.8
	16-Jul	0.050	< 0.015	0.094	0.018	<0.30	< 0.04	49	3.2	< 3.1	3.6	< 0.050	4.8	2.3	7.1	5.8
	13-Aug	0.038	< 0.015	0.070	< 0.01	0.56	< 0.04	49	< 3.0	4.1	2.4	0.074	10.3	2.5	12.8	8.9
	24-Sep	0.039	< 0.015	<0.800	< 0.01	0.39	< 0.04	34.5	7.6	< 3.4	1.5	< 0.050	11.1	1.6	12.7	11.9
Mean		0.050	0.015	0.237	0.01	0.40	0.04	44	4.0	3.7	2.5	0.065	7.0	1.8	8.8	8.0
Maximum		0.093	0.015	0.800	0.02	0.56	0.04	50	7.6	4.3	3.6	0.084	11.1	2.5	12.8	11.9
Minimum		0.030	0.015	0.070	0.01	0.30	0.04	35	3.0	3.1	1.5	0.050	3.5	0.7	4.2	5.8
Std. Dev		0.025	0.000	0.315	0.00	0.10	0.00	6.8	2.0	0.5	0.91	0.015	3.5	0.7	3.8	2.5
No. of D		4	0	4	2	4	0	5	2	1	5	3	5	5	5	5
WA-6M	15-May	0.078	< 0.015	0.094	< 0.01	0.37	< 0.04	51	6.0	< 3.5	3.2	0.084	3.4	0.7	4.1	5.6
	10-Jun	< 0.030	< 0.015	0.075	< 0.01	<0.30	< 0.04	36	3.6	< 3.9	0.65	0.069	3.9	1.1	5.0	3.6
	16-Jul	0.052	< 0.015	0.076	< 0.01	<0.30	< 0.04	50.5	3.6	< 3.0	4.1	< 0.050	5.0	2.2	7.2	4.7
	13-Aug	0.041	< 0.015	0.079	< 0.01	0.49	< 0.04	49.5	< 3.0	< 5.9	1.8	0.072	9.3	1.5	10.8	8.1
	24-Sep	0.067	< 0.015	<0.800	0.011	<0.30	< 0.04	33	9.2	< 3.7	1.3	< 0.050	10.6	1.7	12.2	9.1
Mean		0.054	0.015	0.225	0.01	0.35	0.04	44	5.1	4.0	2.2	0.065	6.4	1.4	7.9	6.2
Maximum		0.078	0.015	0.800	0.01	0.49	0.04	51	9.2	5.9	4.1	0.084	10.6	2.2	12.2	9.1
Minimum		0.030	0.015	0.075	0.01	0.30	0.04	33	3.0	3.0	0.65	0.050	3.4	0.7	4.1	3.6
Std. Dev		0.019	0.000	0.322	0.00	0.08	0.00	8.8	2.6	1.1	1.4	0.015	3.3	0.6	3.5	2.3
No. of D		4	0	4	1	2	0	5	4	0	5	3	5	5	5	5
WA-6B	15-May	0.100	< 0.015	0.058	< 0.01	0.33	< 0.04	43.5	4.0	< 3.1	1.3	0.098	3.0	< 0.60	3.3	4.7
	10-Jun	< 0.030	< 0.015	0.071	< 0.01	0.32	< 0.04	38.5	6.4	< 3.9	1.2	0.068	4.6	1.6	6.2	4.3
	16-Jul	0.057	< 0.015	0.087	< 0.01	<0.30	< 0.04	51	11.6	< 2.9	4.2	< 0.050	4.8	1.9	6.7	4.5
	13-Aug	0.038	< 0.015	0.080	< 0.01	1.10	0.25	44	200	4.1	1.5	0.120	8.8	1.7	10.6	7.0
	24-Sep	0.054	< 0.015	<0.800	< 0.01	<0.30	< 0.04	30	6.8	< 4.2	<0.41	< 0.050	8.3	0.75	9.1	6.7
Mean		0.056	0.015	0.219	0.01	0.47	0.08	41	45.8	3.6	1.7	0.077	5.9	1.3	7.2	5.4
Maximum		0.100	0.015	0.800	0.01	1.10	0.25	51	200	4.2	4.2	0.120	8.8	1.9	10.6	7.0
Minimum		0.030	0.015	0.058	0.01	0.30	0.04	30	4.0	2.9	0.41	0.050	3.0	0.6	3.3	4.3
Std. Dev		0.027	0.000	0.325	0.00	0.35	0.09	7.8	86.3	0.6	1.4	0.031	2.5	0.6	2.8	1.3
No. of D		4	0	4	0	3	1	5	5	1	4	3	5	4	5	5
WA-7S	15-May	0.080	< 0.015	0.059	< 0.01	0.36	< 0.04	52	< 3.0	< 3.3	3.3	0.076	3.7	0.6	4.3	5.9
	10-Jun	< 0.030	< 0.015	0.090	0.01	0.43	< 0.04	50.5	< 3.0	< 4.5	2.4	0.057	6.9	2.3	9.3	7.8
	16-Jul	0.050	< 0.015	0.082	0.011	<0.30	< 0.04	51	< 3.0	< 3.1	3.6	< 0.050	4.9	2.2	7.1	5.8
	13-Aug	0.035	< 0.015	0.077	< 0.01	0.54	< 0.04	56	< 3.0	< 5.9	2.7	0.070	10.5	2.3	12.8	10.0
	24-Sep	0.051	< 0.015	<0.800	0.01	< 0.3	< 0.04	36	6.0	< 4.5	1.7	< 0.050	10.6	1.4	12.1	11.4
Mean		0.049	0.015	0.222	0.01	0.39	0.04	49	3.6	4.3	2.7	0.061	7.3	1.8	9.1	8.2
Maximum		0.080	0.015	0.800	0.01	0.54	0.04	56	6.0	5.9	3.6	0.076	10.6	2.3	12.8	11.4
Minimum		0.030	0.015	0.059	0.01	0.30	0.04	36	3.0	3.1	1.7	0.050	3.7	0.6	4.3	5.8
Std. Dev		0.020	0.000	0.324	0.00	0.10	0.00	7.6	1.3	1.1	0.75	0.012	3.2	0.8	3.5	2.5
No. of D		4	0	4	3	3	0	5	1	0	5	3	5	5	5	5
WA-7M	15-May	0.1	< 0.015	0.063	< 0.01	0.31	< 0.04	49	< 3.0	< 3.1	3.6	0.150	3.7	0.9	4.6	5.2
	10-Jun	< 0.030	< 0.015	0.100	0.021	0.35	< 0.04	51.5	4.8	< 4.0	2.5	< 0.050	6.7	2.2	9.0	6.2
	16-Jul	0.049	< 0.015	0.080	< 0.01	<0.30	< 0.04	43.5	< 3.0	< 3.1	3.8	< 0.050	4.9	2.3	7.2	5.9
	13-Aug	0.036	< 0.015	0.079	< 0.01	0.56	< 0.04	46.5	< 3.0	< 5.9	2.9	0.070	10.5	2.5	13.0	9.4
	24-Sep	0.046	< 0.015	<0.800	< 0.01	0.34	< 0.04	35	6.8	< 4.2	1.3	< 0.050	12.1	1.6	13.7	10.4
Mean		0.052	0.015	0.224	0.01	0.37	0.04	45	4.1	4.1	2.8	0.074	7.6	1.9	9.5	7.4
Maximum		0.100	0.015	0.800	0.02	0.56	0.04	52	6.8	5.9	3.8	0.150	12.1	2.5	13.7	10.4
Minimum		0.030	0.015	0.063	0.01	0.30	0.04	35	3.0	3.1	1.3	0.050	3.7	0.9	4.6	5.2
Std. Dev		0.028	0.000	0.322	0.00	0.11	0.00	6.4	1.7	1.1	1.0	0.043	3.6	0.7	3.9	2.3
No. of D		4	0	4	1	4	0	5	2	0	5	2	5	5	5	5

Table 3-2. (Continued)

STATION	DATE	NH3	NO2	NO3	PO4	TKN	TP	TDS	TSS	BOD5	ALK	DISS P	TOC	TIC	TC	CHLA
WA-7B	15-May	0.067	< 0.015	0.110	< 0.01	0.7	0.071	53	70.0	< 4.1	3.9	0.130	4.4	< 0.6	4.8	6.2
	10-Jun	< 0.030	< 0.015	0.110	< 0.01	0.37	< 0.04	45.5	8.4	< 4.2	2.8	0.055	6.6	2.6	9.2	6.5
	16-Jul	0.051	< 0.015	0.110	0.018	0.31	< 0.04	44	20.0	< 3.2	5.0	< 0.050	5.2	2.3	7.5	6.8
	13-Aug	0.036	< 0.015	0.075	0.023	0.79	0.065	47	60.4	< 6.0	2.9	0.094	10.9	2.1	13.0	9.3
	24-Sep	0.110	< 0.015	<0.800	< 0.01	0.46	< 0.04	37.5	5.6	< 4.3	1.3	< 0.050	12.1	1.8	13.9	11.6
Mean		0.059	0.015	0.241	0.01	0.53	0.05	45	32.9	4.4	3.2	0.076	7.8	1.9	9.7	8.1
Maximum		0.110	0.015	0.800	0.02	0.79	0.07	53	70.0	6.0	5.0	0.130	12.1	2.6	13.9	11.6
Minimum		0.030	0.015	0.075	0.01	0.31	0.04	38	5.6	3.2	1.3	0.050	4.4	0.6	4.8	6.2
Std. Dev		0.032	0.000	0.313	0.01	0.21	0.02	5.6	30.2	1.0	1.4	0.035	3.5	0.8	3.8	2.3
No. of D		4	0	4	2	5	2	5	5	0	5	3	5	4	5	5

3.2.1 Ammonia

Ammonia in the water column of F.E. Walter Reservoir was consistently low throughout the monitoring period (Fig. 3-9). Concentrations at most stations and depths averaged 0.05 mg/L. Measures of ammonia did not exceed 0.11 mg/L and ranged to less than the detection limit of 0.03-mg/L.

F.E. Walter Reservoir was in compliance with the PADEP water quality standard for ammonia during 2003. The water quality standard of ammonia is dependent on temperature and pH (Table 3-3). Throughout the monitoring period, all measures of ammonia were less than their respective criteria values.

Table 3-3. PADEP ammonia nitrogen criteria (Pennsylvania Code, Title 25 1984). Specific ammonia criteria dependent on temperature and pH.

PH	0 °C	5 °C	10 °C	15 °C	20 °C	25 °C	30 °C
6.50	25.5	25.5	25.5	17.4	12.0	8.4	5.9
6.75	23.6	23.6	23.6	16.0	11.1	7.7	5.5
7.00	20.6	20.6	20.6	14.0	9.7	6.8	4.8
7.25	16.7	16.7	16.7	11.4	7.8	5.5	3.9
7.50	12.4	12.4	12.4	8.5	5.9	4.1	2.9
7.75	8.5	8.5	8.5	5.8	4.0	2.8	2.0
8.00	5.5	5.5	5.5	5.8	4.0	2.8	2.0
8.25	3.4	3.4	3.4	2.3	1.6	1.2	0.9
8.50	2.0	2.0	2.0	1.4	1.0	0.7	0.6
8.75	1.2	1.2	1.2	0.9	0.6	0.5	0.4
9.00	0.8	0.8	0.8	0.5	0.4	0.3	0.3

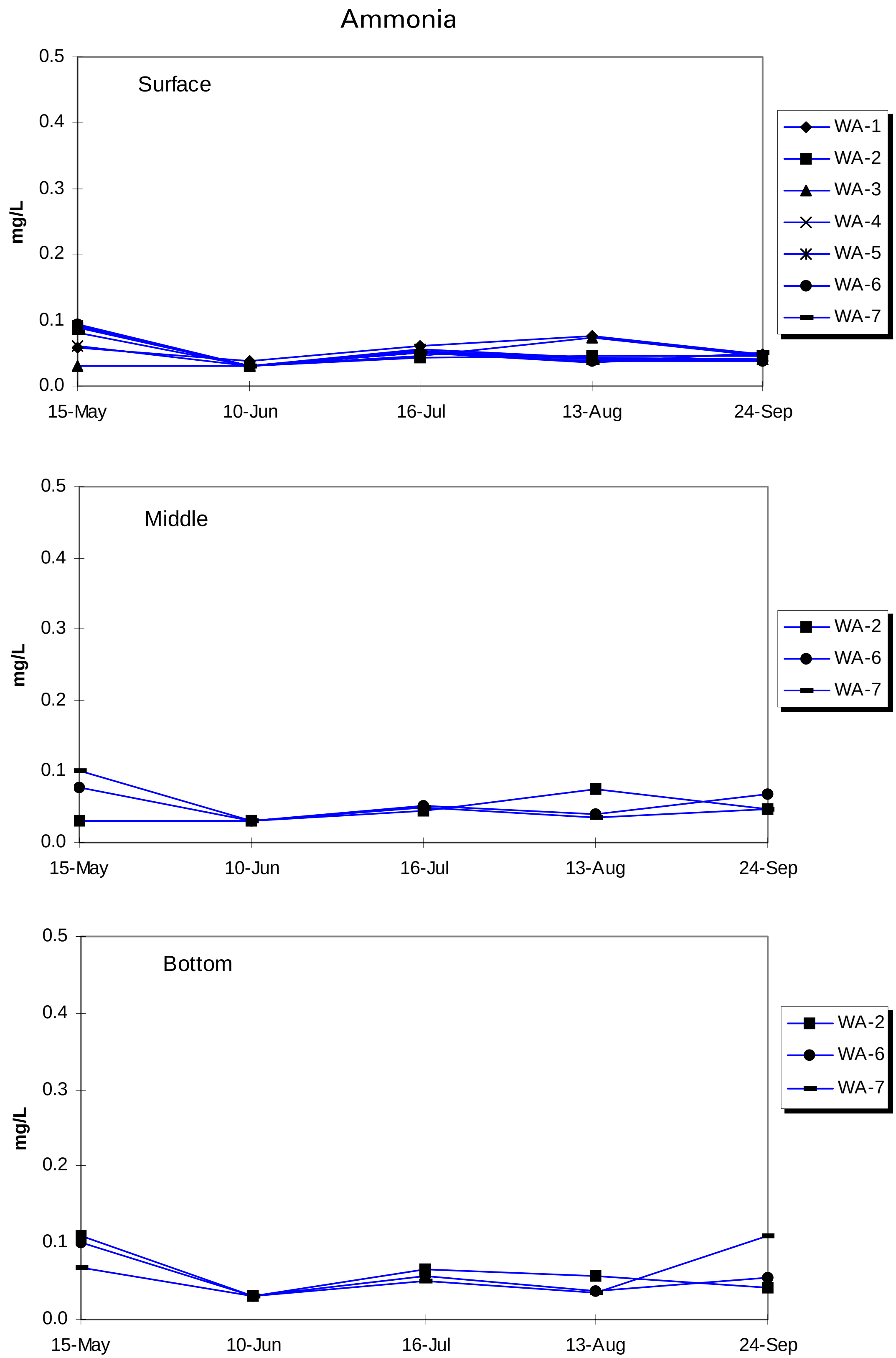

Figure 3-9. Ammonia measured in surface, middle, and bottom water of F. E. Walter Reservoir during 2003. The PADEP water quality standard for ammonia is dependent on temperature and pH.

A seasonal trend analysis of ammonia was conducted for individual stations of F.E. Walter Reservoir, combining 2003 and historical data. The Mann-Kendall statistic was applied to station data collected over the past 25 years or more, separately for spring (April to June) and summer (July to October) seasons. Stations included in the analysis represented locations downstream (WA-1), within the main reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5). Significant decreasing trends were determined from the analysis for stations WA-1, WA-2, WA-3, and WA-4 in the spring and WA-1, WA-2, and WA-4 in the summer (Table 3-4).

Ammonia concentrations appear to have decreased throughout the reservoir drainage area during both seasons. All but one of the stations, WA-5, had significant trends and reflected yearly decreases ranging from 0.0014 to 0.0053 mg/L (Table 3-4). In general, summer rates of decrease appeared to be slightly higher than for spring. The widespread trends appear to be driven by higher concentrations detected in the late 1970s; subsequently, most concentrations have been consistently lower at about 0.01 mg/L.

Table 3-4. Seasonal trends of ammonia concentration at individual stations of F.E. Walter 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					
WA-1	28	<0.05	-0.0017	<0.01	-0.0053
WA-2	29	<0.05	-0.0023	<0.01	-0.0025
WA-3	28	<0.05	-0.0018	NS	-0.0017
WA-4	29	<0.05	-0.0014	<0.01	-0.0017
WA-5	25	NS	-0.0009	NS	0.0000

3.2.2 Nitrite and Nitrate

Concentrations of nitrite in the water column of F.E. Walter Reservoir were consistently low during 2003. Concentrations of nitrite measured at all stations and all depths were less than method detection limits (0.01-mg/L) throughout the monitoring period (Fig. 3-10).

Nitrate was distributed uniformly in the water column of F.E. Walter Reservoir during 2003 (Fig. 3-11). At most stations and depths, concentrations ranged from less than the method detection limit (0.04 mg/L) to 0.13 mg/L. However, due to a laboratory error the detection limit for most stations in August was 0.8 mg/L causing an artificial

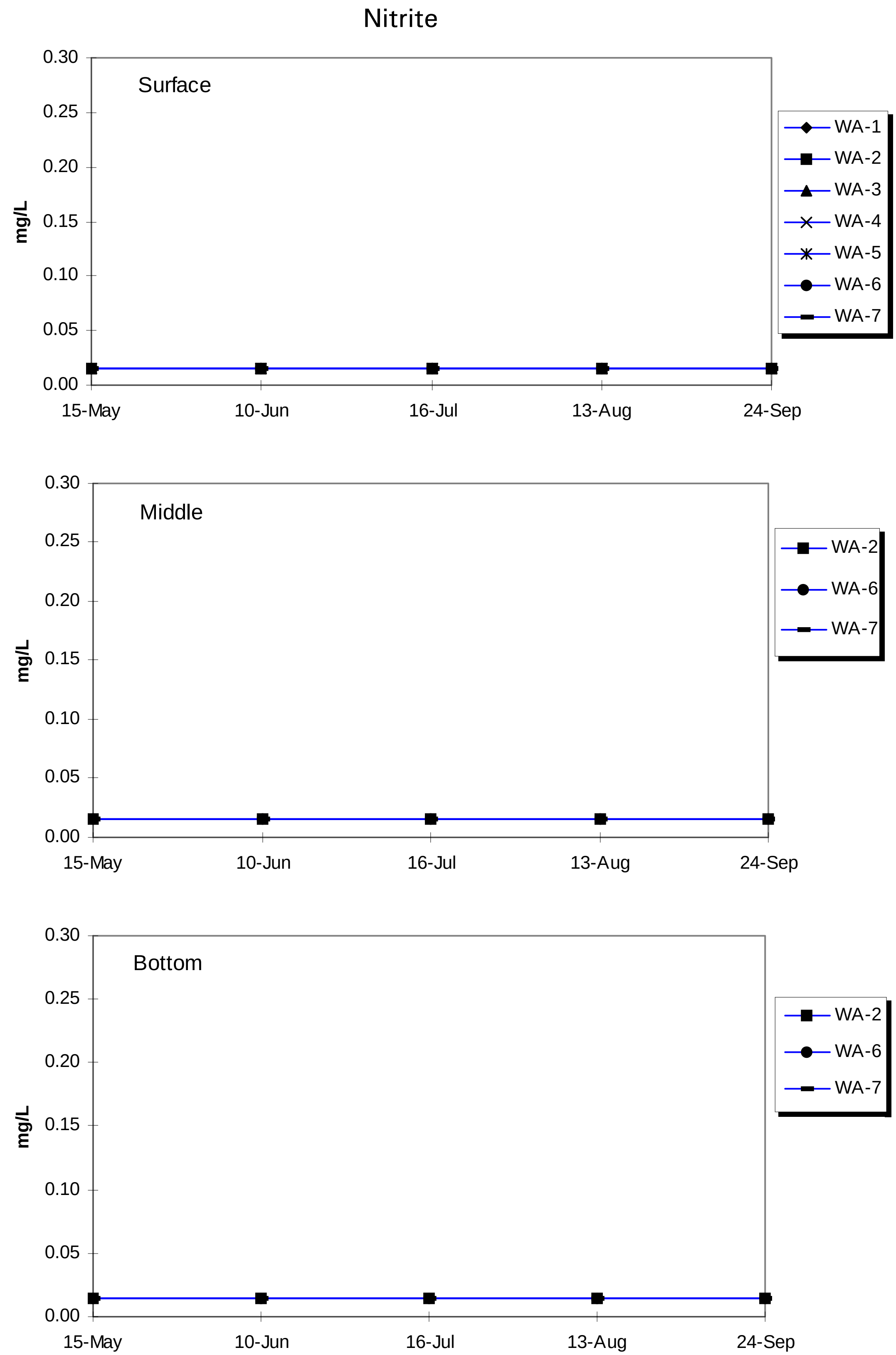

Figure 3-10. Nitrite measured in surface, middle, and bottom water of F. E. Walter Reservoir during 2003

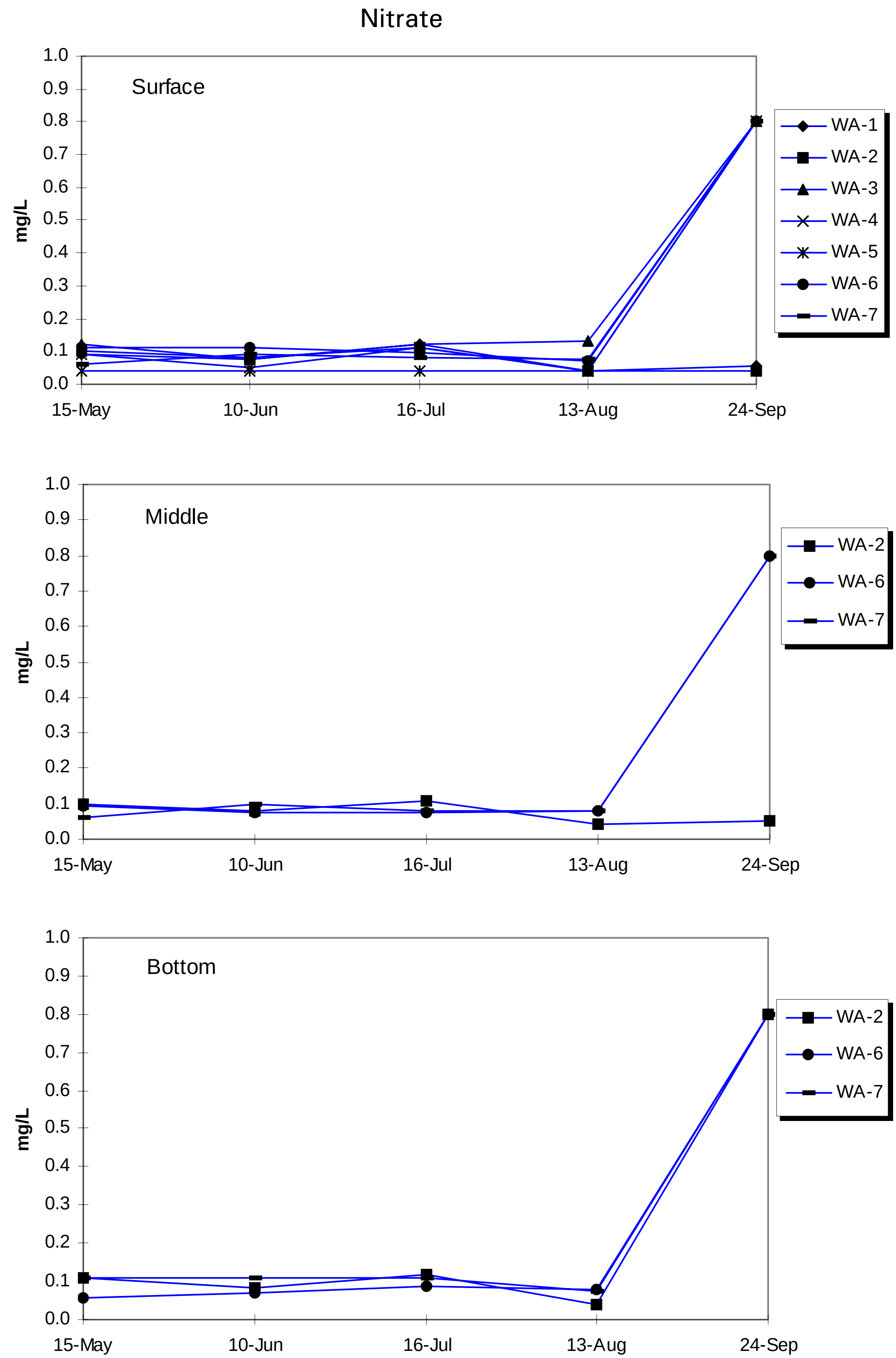

Figure 3-11. Nitrate measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003

spike at the end of the year. With the exception of elevated August samples, concentrations averaged 0.09 mg/L throughout the monitoring period.

In 2003, F.E. Walter Reservoir was in compliance with the PADEP water quality standard for nitrogen. The water quality standard for nitrogen is a summed concentration of nitrite and nitrate of less than 10-mg/L. Throughout the monitoring period, the summed concentrations for each station were less than 0.81-mg/L.

3.2.3 Total Inorganic Nitrogen

Concentrations of total inorganic nitrogen measured in 2003 and historical data collected from over the past 29 years were analyzed for seasonal trends (Figs. 3-12 and 3-13). The trend analysis was conducted for spring (April through June) and summer (July through September) periods, separately for stations representative of the reservoir and downstream. Concentrations of nitrogen have decreased in the reservoir and downstream during the summer (Fig. 3-13). Both regression lines were significant ($R2=0.21$ and 0.17, respectively; $P<0.05$), and corresponded to an average 10-year decrease of approximately 0.15-mg/L. The trend analyses conducted for reservoir and downstream stations in the spring season were not significant (Fig. 3-12).

A seasonal trend analysis of total nitrogen was conducted for individual stations of F.E. Walter Reservoir, combining 2003 and historical data. The Mann-Kendall statistic was applied to station data collected over the past 24 years or more, separately for spring (April to June) and summer (July to September) seasons (Table 3-5). Stations included in the analysis represented locations downstream (WA-1), within the main reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5). The only significant trend was at station WA-1 in the summer, with a decreasing rate of 0.0069 mg/L/year.

3.2.4 Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen (TKN) is a measure of organic nitrogen that includes ammonia. TKN in the water column of F.E. Walter Reservoir was generally low during 2003 (Fig. 3-14). Concentrations measured at most stations and depths averaged 0.41 mg/L throughout the monitoring period. The highest concentration was measured in August and ranged to 1.1 mg/L in the bottom water at station WA-6.

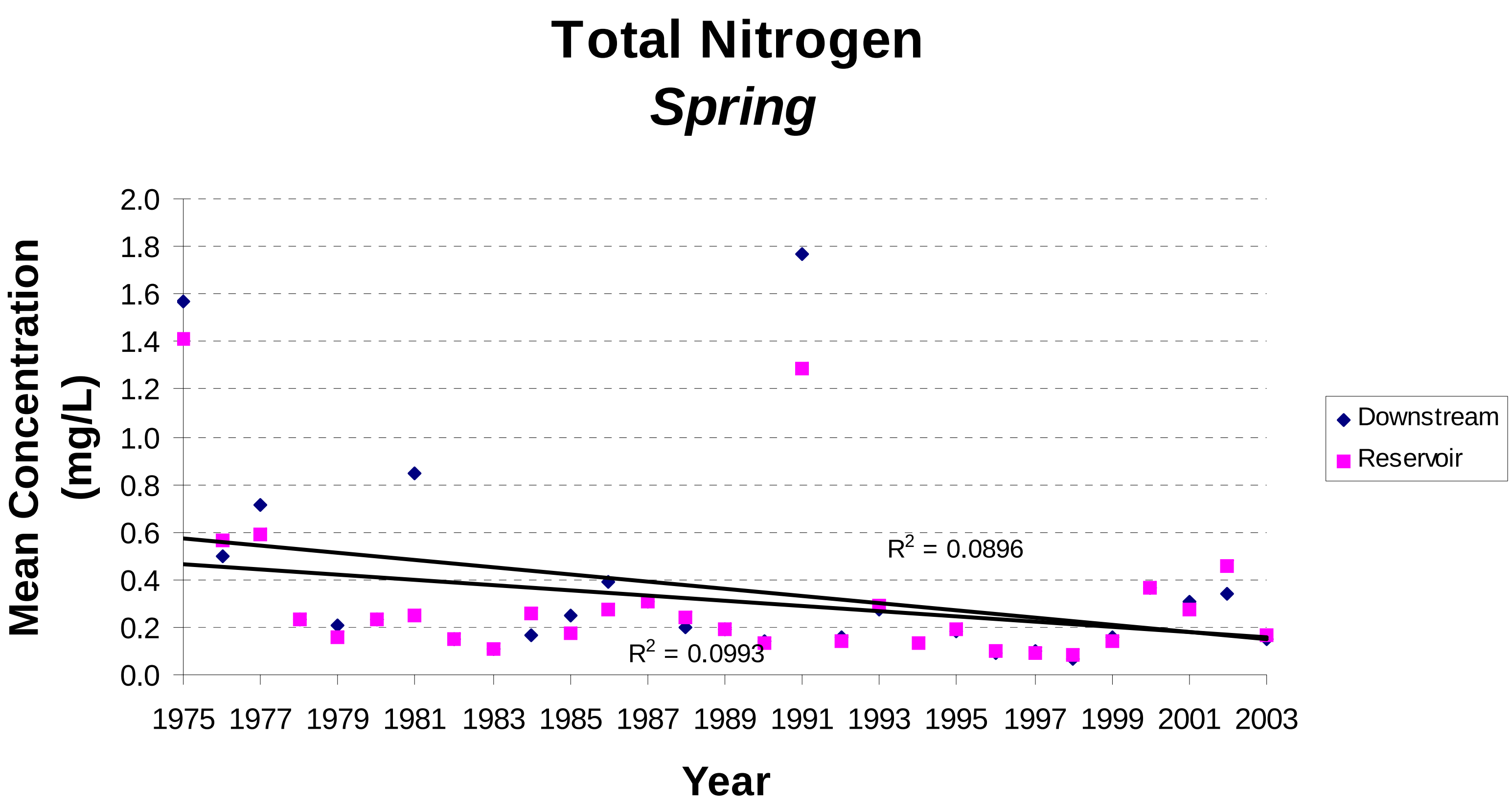

Figure 3-12. Seasonal trend analysis for total nitrogen (ammonia + nitrite + nitrate) measured during spring months (April, May, and June) at F. E. Walter Reservoir

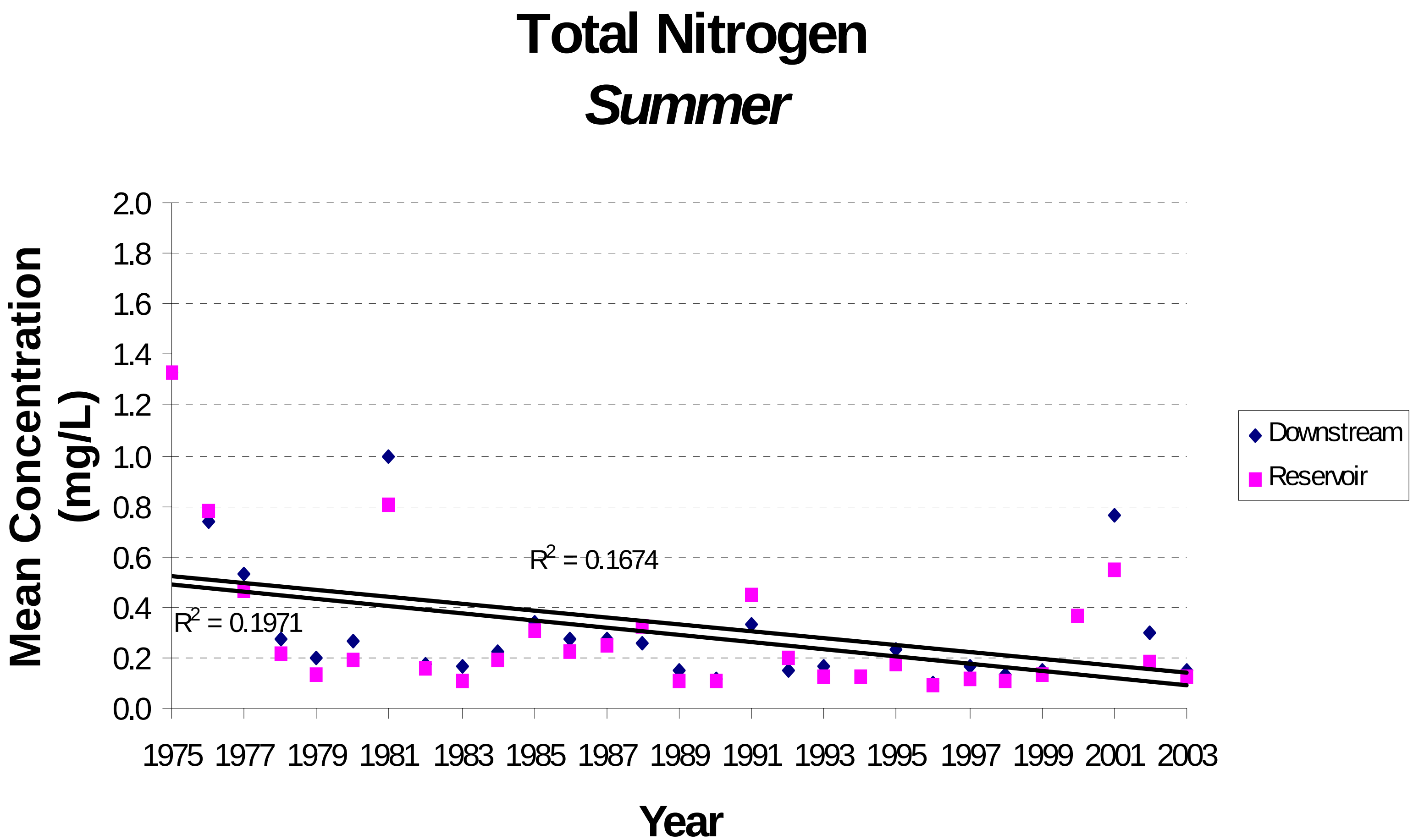

Figure 3-13. Seasonal trend analysis for total nitrogen (ammonia + nitrite + nitrate) measured during summer months (July, August, and September) at F.E. Walter Reservoir

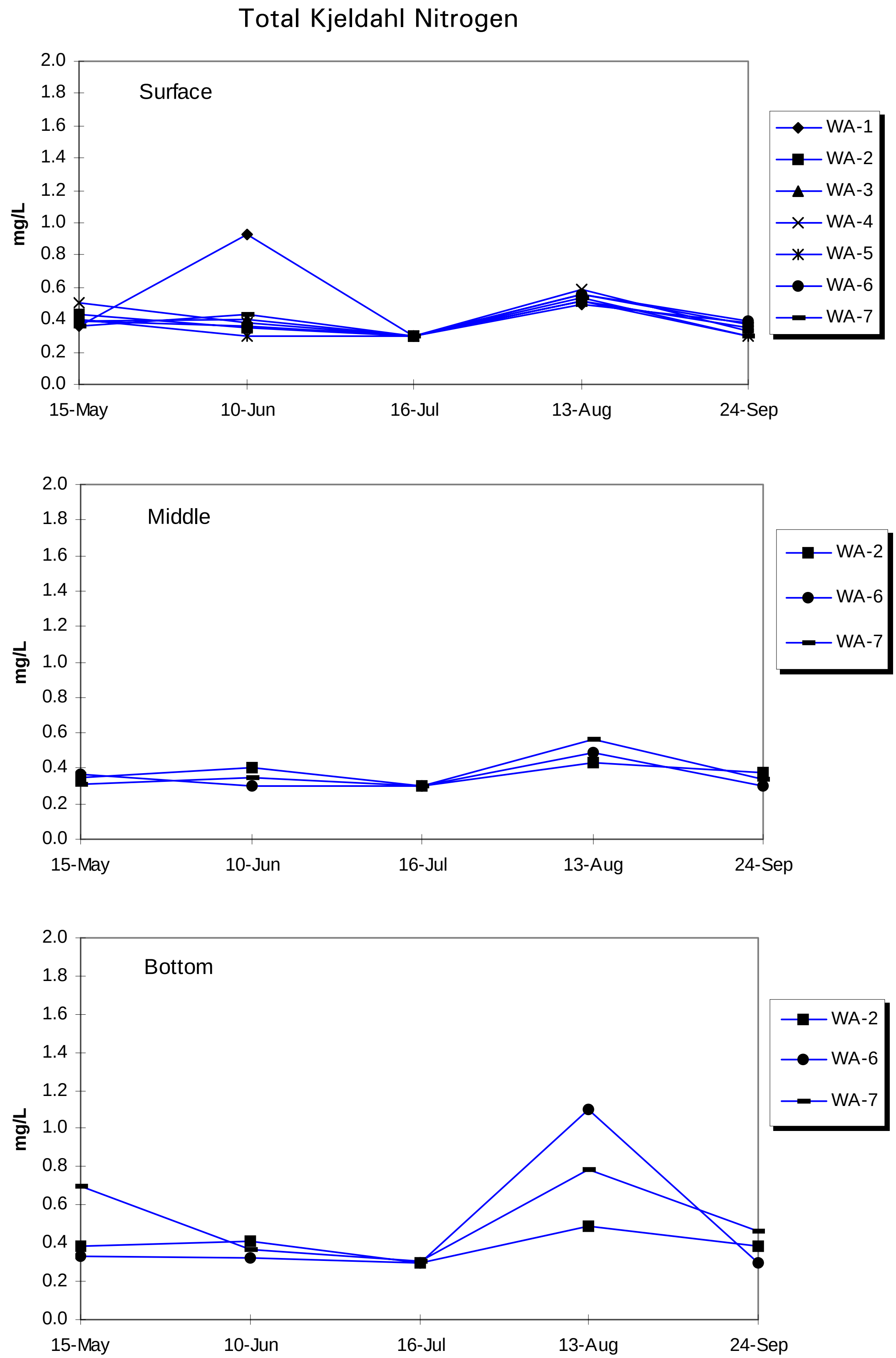

Figure 3-14. Total Kjeldahl nitrogen measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003

Table 3-5. Seasonal trends of total nitrogen concentration at individual stations of F.E. Walter 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					
WA-1	27/28	NS	-0.0069	<0.05	-0.0069
WA-2	28/29	NS	-0.0061	NS	-0.0046
WA-3	27/28	NS	-0.0042	NS	-0.0028
WA-4	28/29	NS	-0.0048	NS	-0.0045
WA-5	24/25	NS	-0.0027	NS	0.0003

3.2.5 Dissolved Phosphate

Dissolved phosphate in the water column of F.E. Walter Reservoir was consistently low during 2003. Concentrations measured at all stations and depths averaged 0.01 mg/L throughout the monitoring period (Fig. 3-15). The highest concentration of dissolved phosphate (0.024 mg/L) was measured in the surface waters upstream of the reservoir (WA-5) in June. In freshwater environments, dissolved phosphate is usually a limiting nutrient and is readily taken up by freshwater plants and algae.

3.2.6 Dissolved Phosphorus

Dissolved phosphorus in the water column of F.E. Walter Reservoir was consistently low during 2003 (Fig. 3-16) Concentrations of dissolved phosphate were generally at or below the detection limit of 0.05 mg/L and averaged 0.06 mg/L at most stations and depths. Two instances of high values were recorded, in May at WA-7 in the middle and bottom waters the concentrations were 0.15 and 0.13 mg/L.

3.2.7 Total Phosphorus

Concentrations of total phosphorus were fairly uniform throughout the reservoir (Fig. 3-17). EPA guidance for nutrient criteria in lakes and reservoirs suggests a maximum 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, 100% of the measures for total phosphorus with results greater than the detection limit from reservoir monitoring were greater than the EPA guideline with a high concentration of 0.25 mg/L at WA-6 at the bottom surface on 13 August. However, the 2003 detection limits for total phosphorus was 0.04-mg/L, which is greater than the guideline.

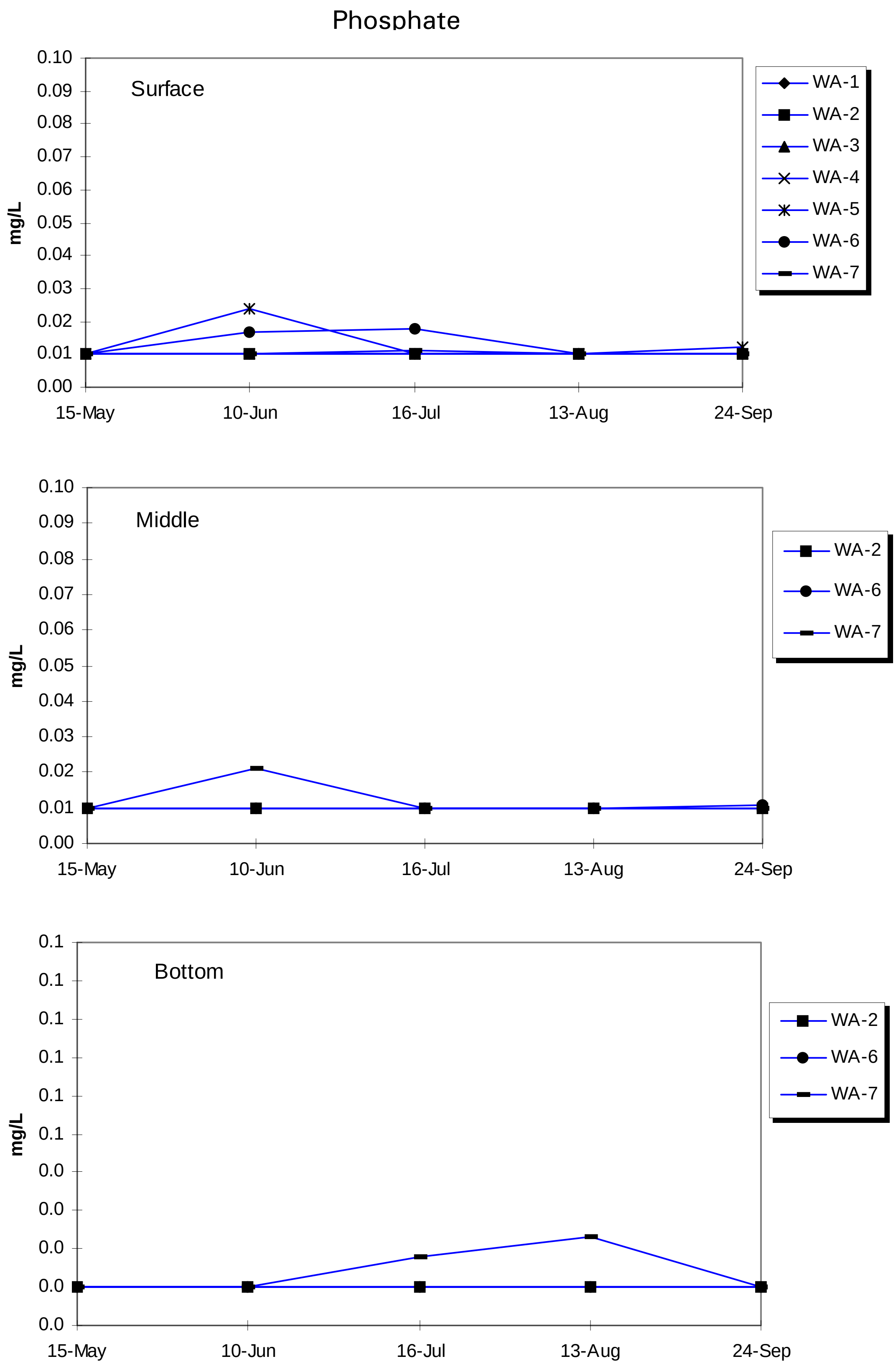

Figure 3-15. Total Phosphate measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003

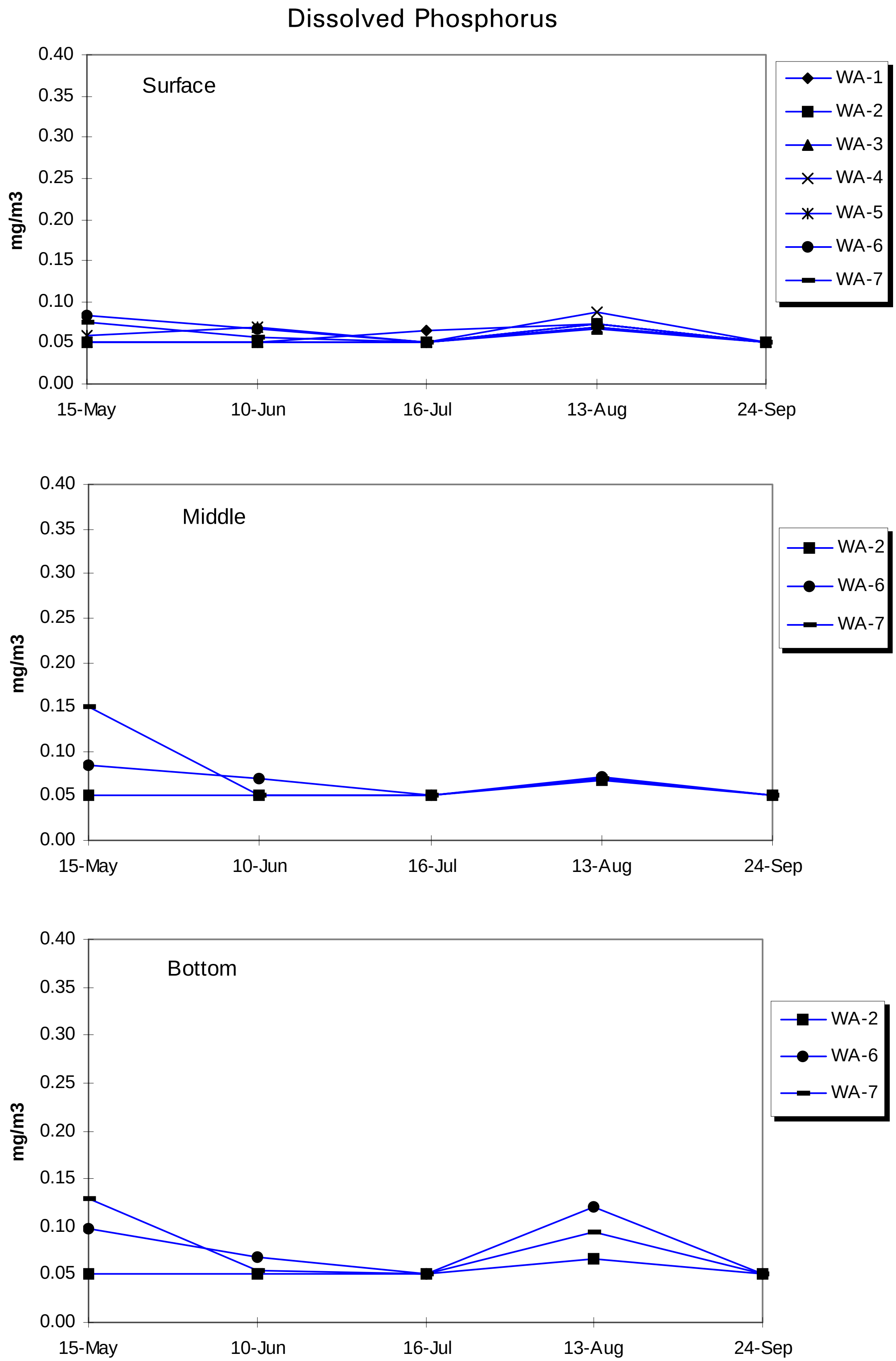

Figure 3-16. Total dissolved phosphorus measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003

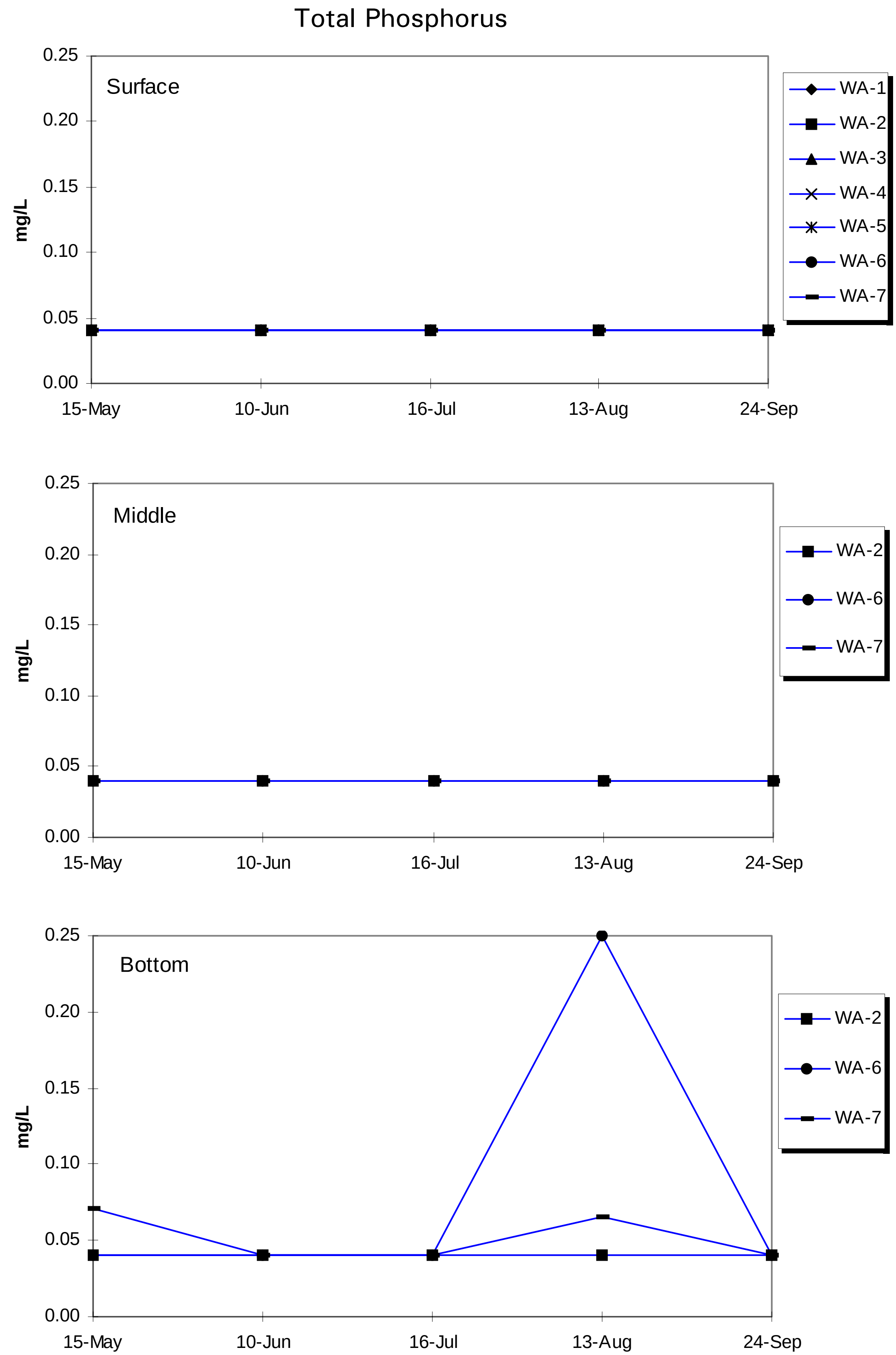

Figure 3-17. Total phosphorus measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003

A seasonal trend analysis of total phosphorus was also conducted for individual stations of F.E. Walter Reservoir, combining 2003 and historical data. The Mann-Kendall statistic was applied to station data collected over the past 23 years or more, separately for spring (April to June) and summer (July to October) seasons. Stations included in the analysis were representative of locations downstream (WA-1), within the main reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5). Based on this analysis, no significant trends were apparent for individual stations (Table 3-6).

Table 3-6. Seasonal trends of total phosphorus concentration at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic.

Station	# of Years	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate (mg/L)
Surface Water					
WA-1	23	NS	-0.0007	NS	0.0001
WA-2	24	NS	-0.0004	NS	-0.0003
WA-3	23	NS	-0.0003	NS	0.0001
WA-4	24	NS	-0.0002	NS	-0.0002
WA-5	24	NS	0.0001	NS	0.0002

Concentrations of total phosphorus measured in 2003 and historical data collected over the past 23 years were analyzed for seasonal trends using regression. The trend analysis was conducted for spring and summer periods, separately for stations representative of the reservoir and downstream. No trends were determined for either of the reservoir or downstream locations (Figs. 3-18 and 3-19). None of the regressions were significant ($P>0.05$).

3.2.8 Total Dissolved Solids

Total dissolved solids (TDS) in the water column of F.E. Walter Reservoir throughout, followed a similar pattern during 2003. Concentrations at all stations and depths averaged 52-mg/L over the monitoring period while ranging from 26.5 to 61 mg/L (Fig. 3-20). Concentrations at downstream station (WA-1) averaged slightly higher. The concentration at WA-1 averaged 48 mg/L.

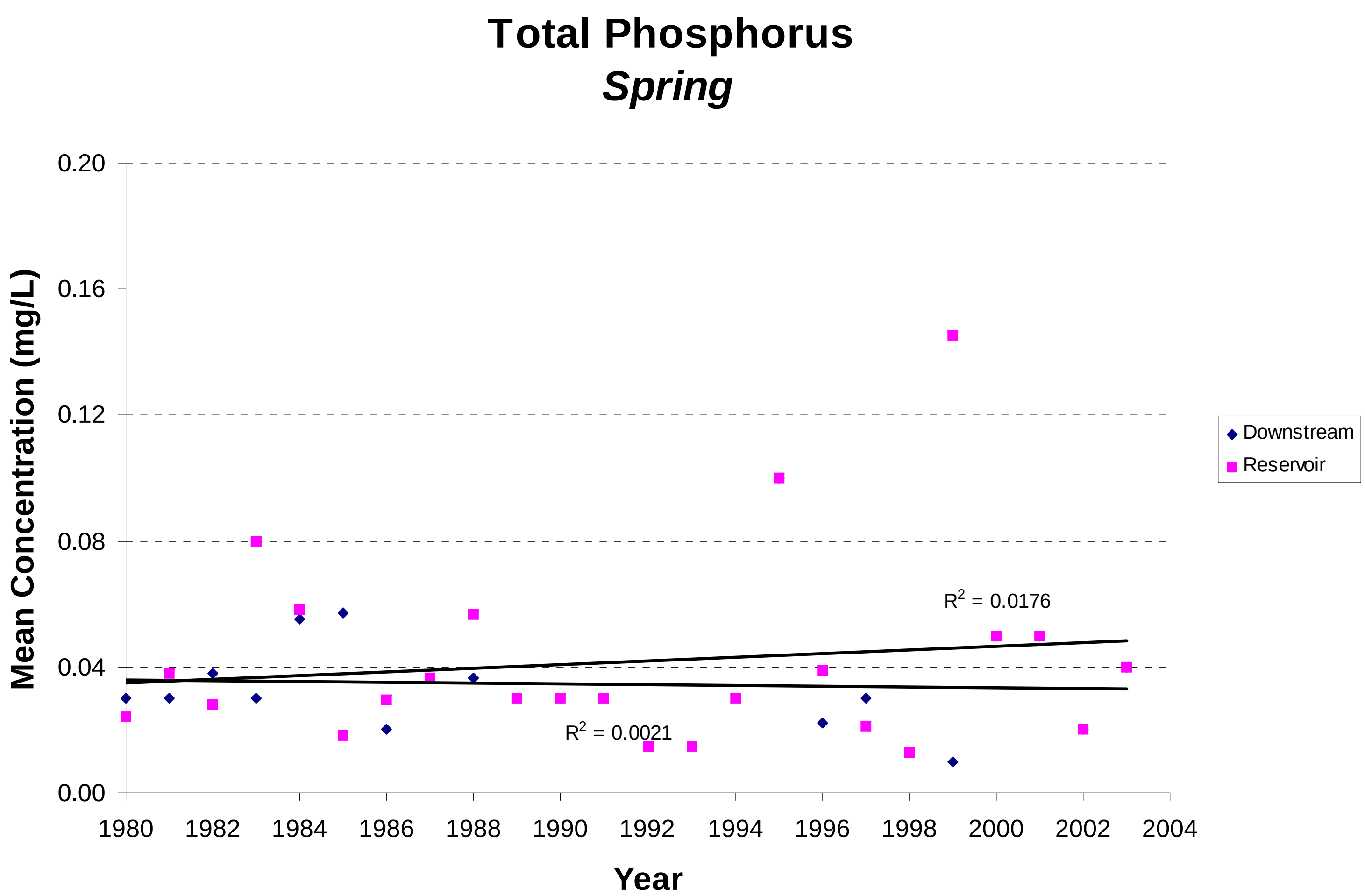

Figure 3-18. Seasonal trend analysis for total phosphorus measured during spring months (April, May, and June) at F.E. Walter Reservoir

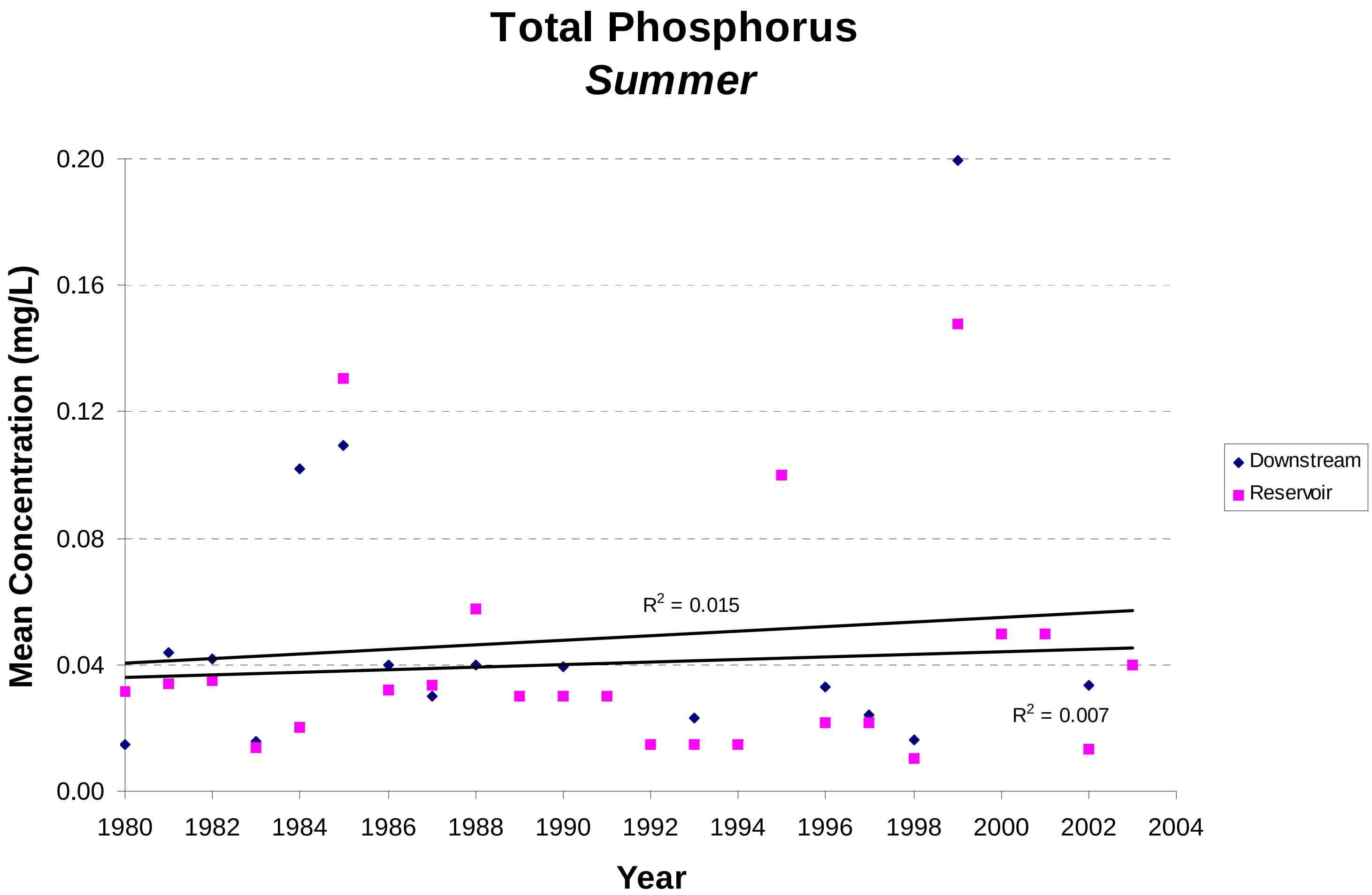

Figure 3-19. Seasonal trend analysis for total phosphorus measured during summer months (July, August, and October) at F.E. Walter Reservoir

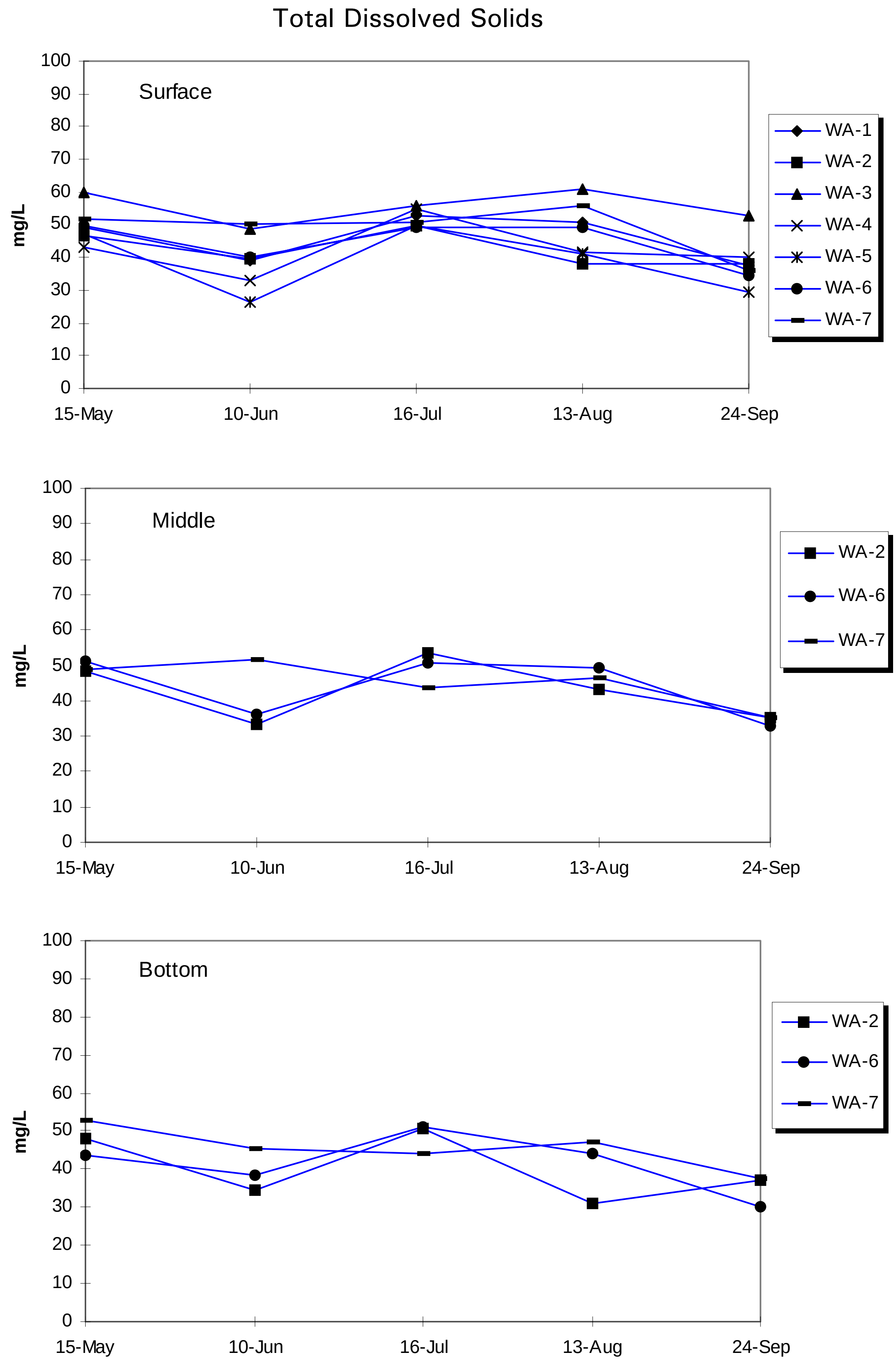

Figure 3-20. Total dissolved solids measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003. The PADEP water quality standard for TDS is a maximum concentration of 500 mg/L

F.E. Walter Reservoir was in compliance with the PADEP water quality standard for total dissolved solids during 2003. The water quality standard is a maximum concentration of 500-mg/L. Throughout the monitoring period, concentrations measured at all stations were always at least nine times less than the standard.

Concentrations of total dissolved solids measured in 2003 and historical data collected over the past 26 years were analyzed for seasonal trends. The trend analysis was conducted for spring and summer periods, separately for stations representative of the reservoir and downstream. TDS concentrations at F.E. Walter Reservoir have not changed consistently over the time series (Fig. 3-21 and 3-22). No significant trends were identified by the regression analyses ($P>0.05$) for either season at reservoir and downstream stations.

A seasonal trend analysis of TDS was also conducted for individual stations of F.E. Walter Reservoir combining 2003 and historical data. The Mann-Kendall statistic was applied to station data collected over the past 24 years or more, separately for spring (April to June) and summer (July to October) seasons. Stations included in the analysis represented: downstream (WA-1), main reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5). Based on this analysis, no significant trends were apparent for individual stations (Table 3-7).

Table 3-7. Seasonal trends of total dissolved solids concentration at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic.

Station	# of Years Spring/Summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate (mg/L)
Surface Water					
WA-1	28	NS	-0.2012	NS	-0.1831
WA-2	29	NS	-0.1582	NS	-0.2402
WA-3	28	NS	0.5492	NS	0.0609
WA-4	29	NS	0.2188	NS	0.2472
WA-5	25	NS	-0.3307	NS	0.6667

3.2.9 Total Suspended Solids

Total suspended solids (TSS) in the water column of F.E. Walter Reservoir were consistently low in 2003. For the most part, concentrations measured throughout the reservoir ranged less than 75 mg/L (Fig. 3-23). Overall concentrations at stations and all depths averaged 11 mg/L and ranged from less than the detection limit of 3 to an isolated 200 mg/L (Fig. 3-23). An isolated high level of suspended solids was detected in the

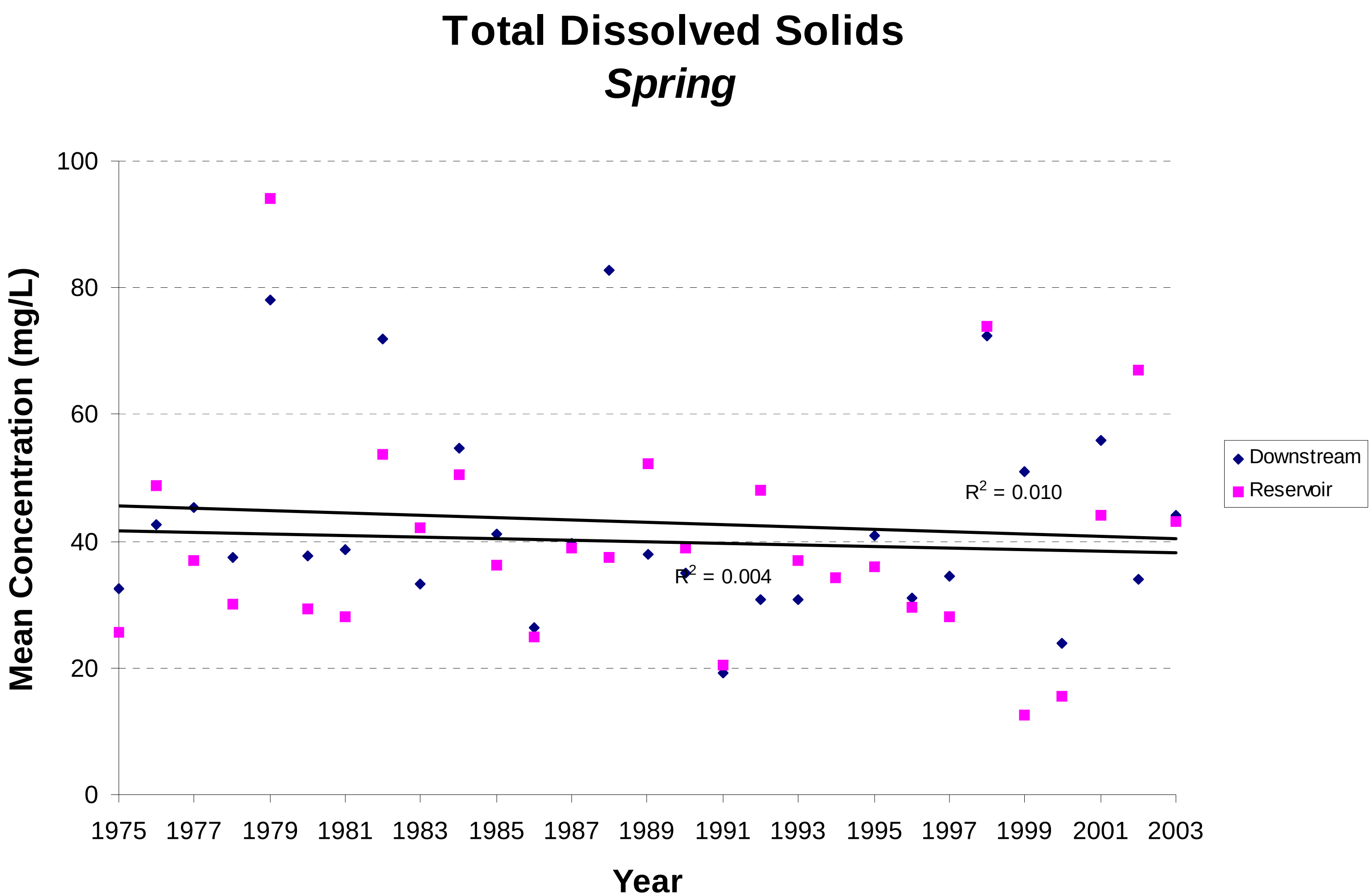

Figure 3-21. Seasonal trend analysis for total dissolved solids measured during spring months (April, May, and June) at F.E. Walter Reservoir

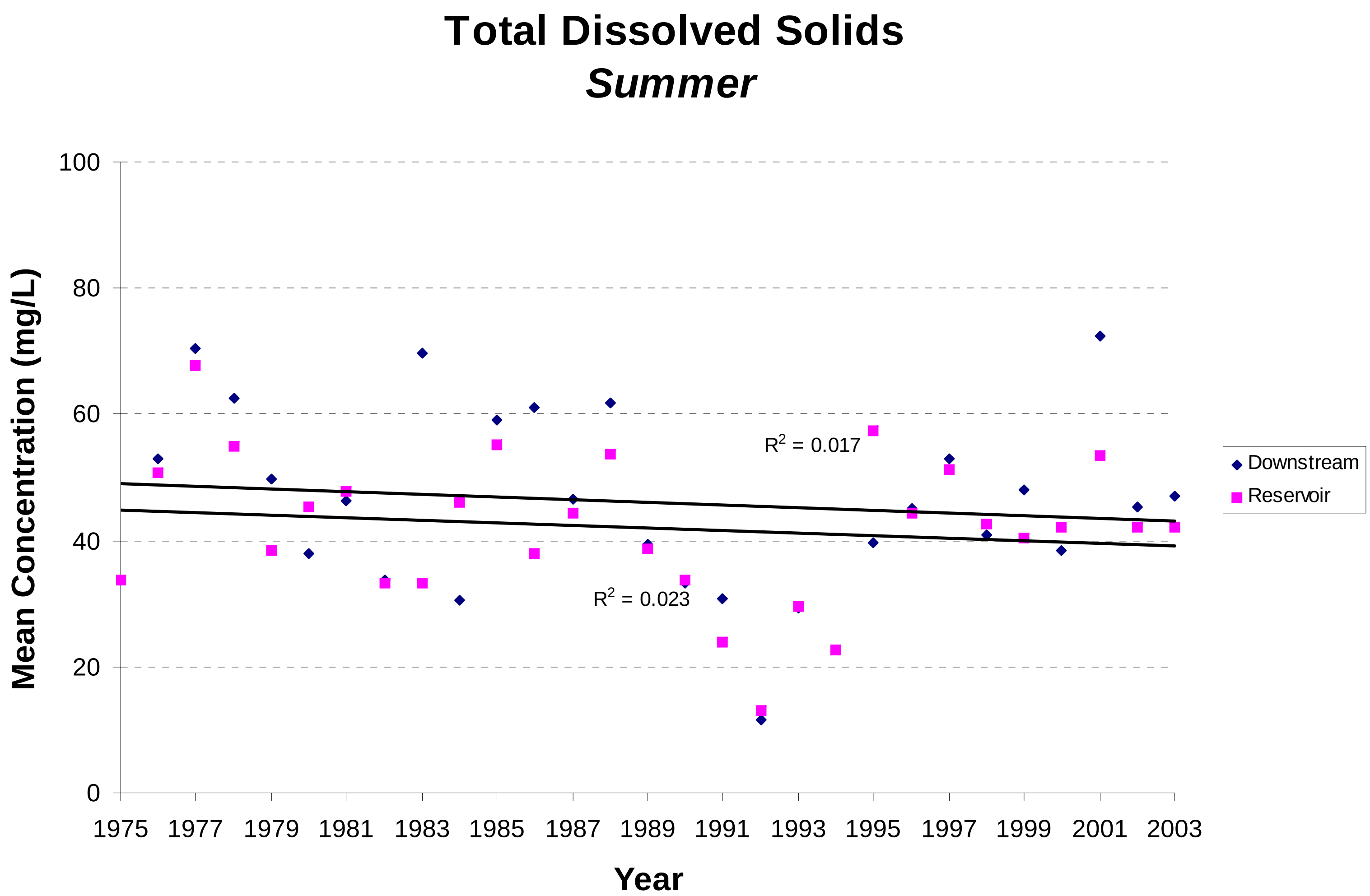

Figure 3-22. Seasonal trend analysis for total dissolved solids measured during summer months (July, August, and October 3) at F.E. Walter Reservoir

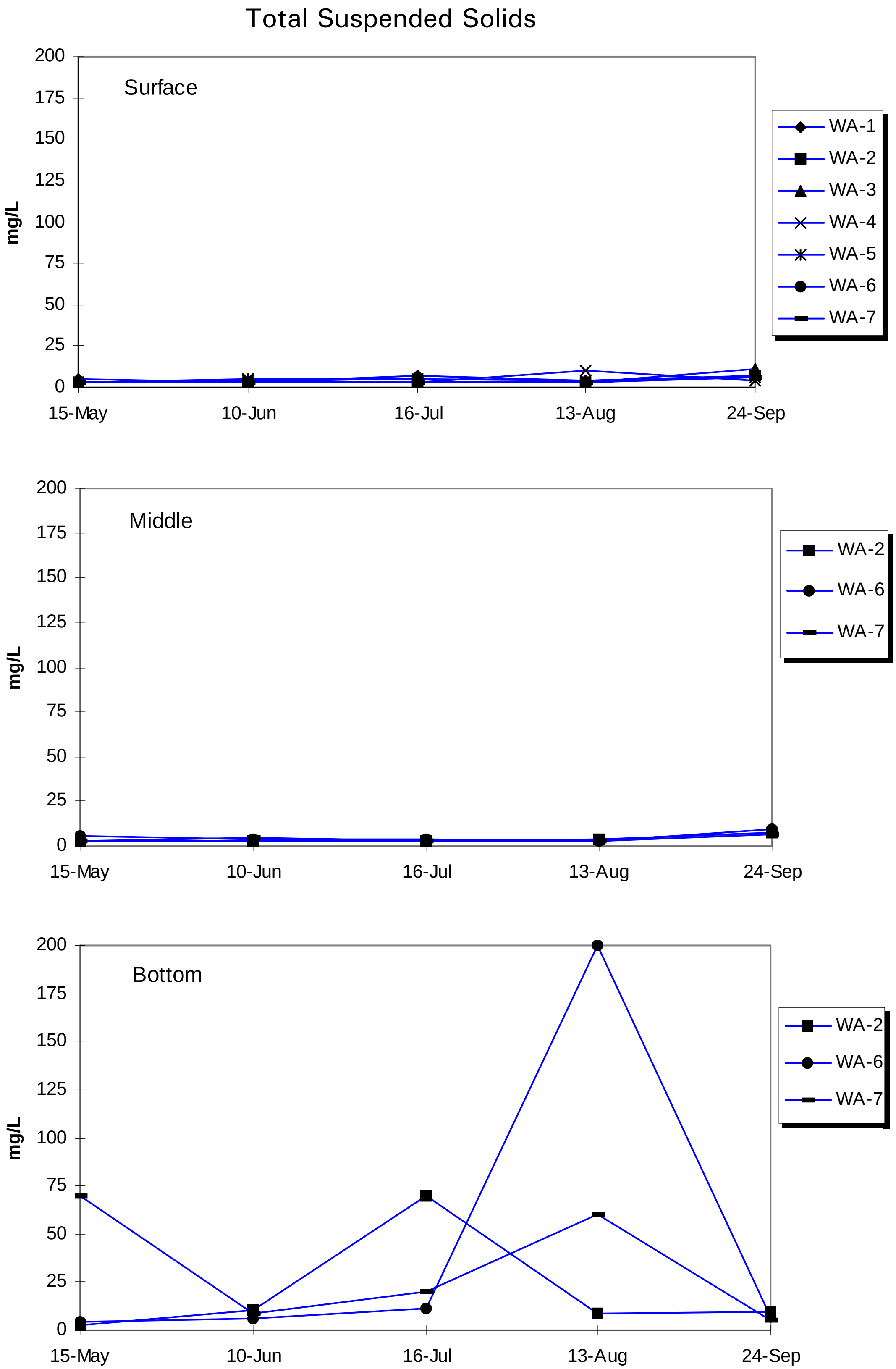

Figure 3-23. Total suspended solids measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003

bottom water of station WA-6 during August. This is likely due to contamination of sediment in the sampling apparatus.

3.2.10 Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) in the water column of F.E. Walter Reservoir was consistently low during 2003. With several exceptions, concentrations measured at all stations and depths were less than or equal to the method detection limit (0.08 mg/L) throughout the monitoring period (Fig. 3-24). Concentrations of BOD in the surface waters at stations WA-5 and -6 during August as well as the bottom waters of WA-6 in August were 4.7, 4.1, and 4.1 mg/L respectively.

Concentrations of BOD measured in 2003 and historical data collected from over the past 23 years were analyzed for seasonal trends. The trend analysis was conducted for spring and summer periods, separately, for stations representative of the reservoir and downstream. No seasonal trends were determined for either of the reservoir and downstream locations (Fig. 3-25 and 3-26). None of the regressions were significant ($P>0.05$). The analyses; however, has probably been confounded by low concentrations measured in recent years. Since 1995, the seasonal averages at both locations have been near or less than the method detection limits which ranged from 0.8 to 4-mg/L.

A seasonal trend analysis of BOD was also conducted for individual stations of F.E. Walter Reservoir combining 2003 and historical data. The Mann-Kendall statistic was applied to station data collected over the past 23 years or more, separately, for spring (April to June) and summer (July to September) seasons. Stations included in the analysis were representative of locations downstream (WA-1), within the reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5). Based on this analysis, no significant trends were identified for individual stations (Table 3-8).

Table 3-8. Seasonal trends of BOD concentration at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic.

Station	# of Years Spring/Summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate (mg/L)
Surface Water					
WA-1	23	NS	-0.0000	NS	0.0000
WA-2	24	NS	-0.0265	NS	-0.0099
WA-3	23	NS	-0.0000	NS	0.0000
WA-4	24	NS	-0.0010	NS	0.0000
WA-5	24	NS	0.0000	NS	0.0000

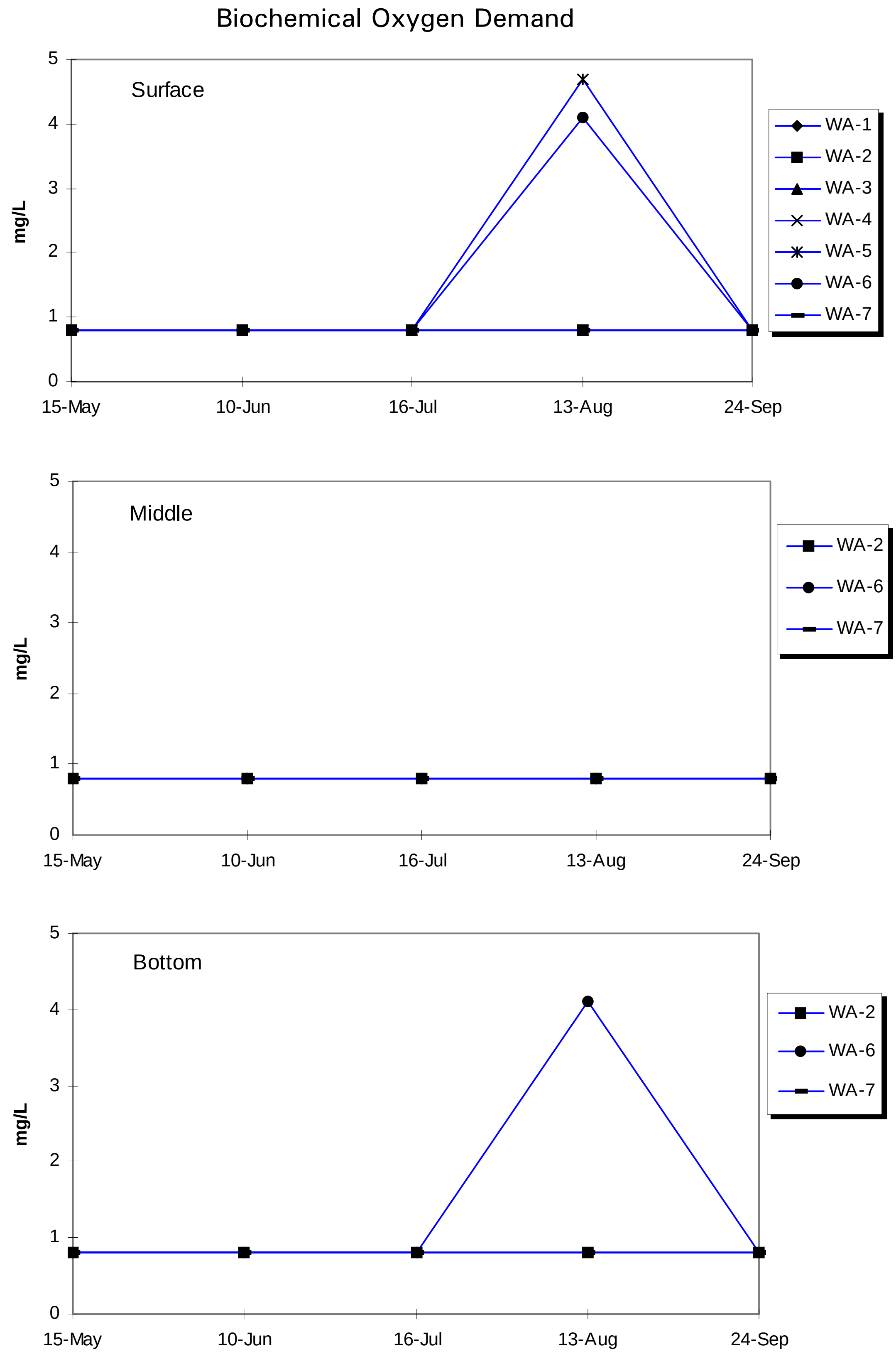

Figure 3-24. Biochemical oxygen demand (5-day) measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003

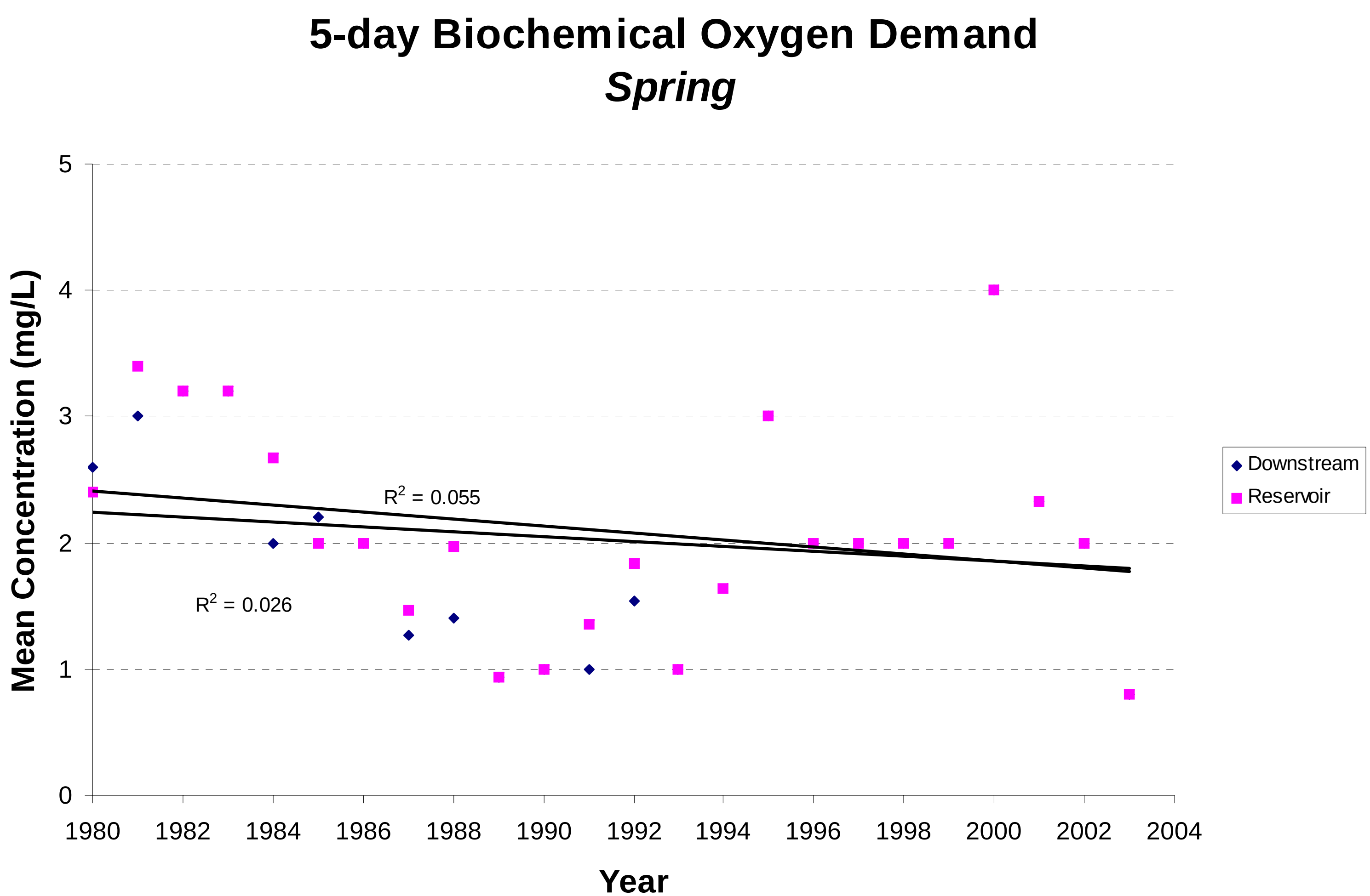

Figure 3-25. Seasonal trend analysis for biochemical oxygen demand (5-day) measured during spring months (April, May, and June) at F.E. Walter Reservoir .

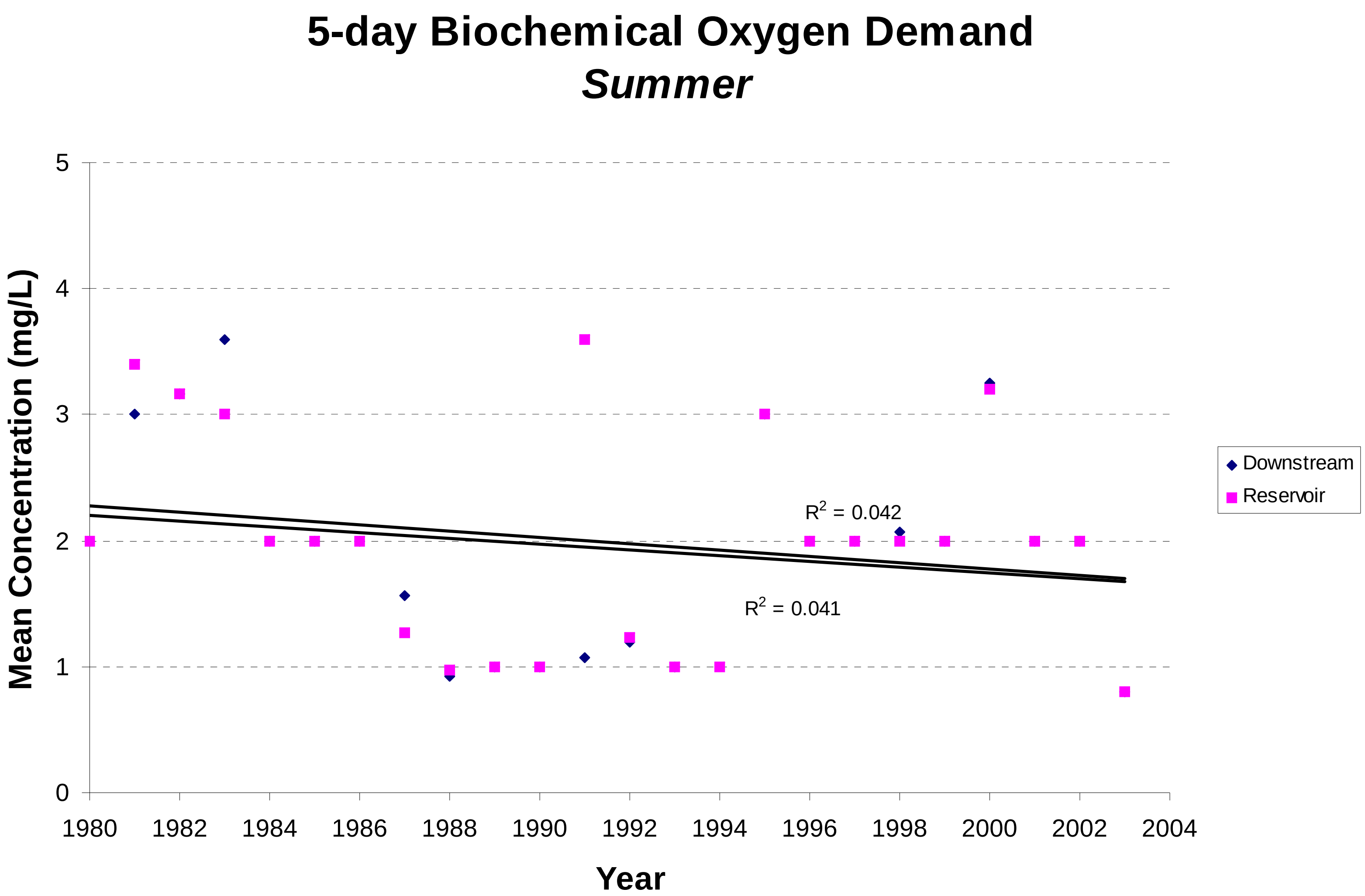

Figure 3-26. Seasonal trend analysis for biochemical oxygen demand (5-day) measured during summer months (July, August, and October 3) at F.E. Walter Reservoir

3.2.11 Alkalinity

Alkalinity in the waters of F.E. Walter Reservoir was very low during 2003. Concentrations measured at all stations and depths averaged 4.4-mg/L and ranged less than 12-mg/L throughout the monitoring period (Fig. 3-27). Alkalinity is a measure of the acid-neutralizing capacity of water. The PADEP standard 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 F.E. Walter Reservoir probably results from the regional geology, which is primarily sandstone and shale (Van Diver 1990).

3.2.12 Total Inorganic and Organic Carbon

Total inorganic carbon (TIC) and total organic carbon (TOC) in the water column of F.E. Walter Reservoir were present in low concentrations during 2003 (Fig. 3-28 and Fig. 3-29). Concentrations of TIC at all stations and depths ranged from 4.8 mg/L to less than the method detection limit of 0.6 mg/L and averaged 1.7 mg/L. Additionally, concentrations of TOC at all stations and depths ranged from 13.1 mg/L to 2.3 mg/L and averaged 6.9 mg/L.

Total carbon is the sum of TIC and TOC. Total carbon in the water column of Walter Reservoir at all stations and depths averaged 8.64 mg/L and ranged from 3.3 to 16.9 mg/L (Fig. 3-30).

3.2.13 Chlorophyll *a*

For the most part, chlorophyll *a* was low in the water column of F.E. Walter Reservoir during 2003 (Fig. 3-31). Concentrations at all stations and depths averaged 2.9 mg/m^3 and ranged up to 16.7 mg/m^3 throughout the monitoring period.

3.3 TROPHIC STATE DETERMINATION

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

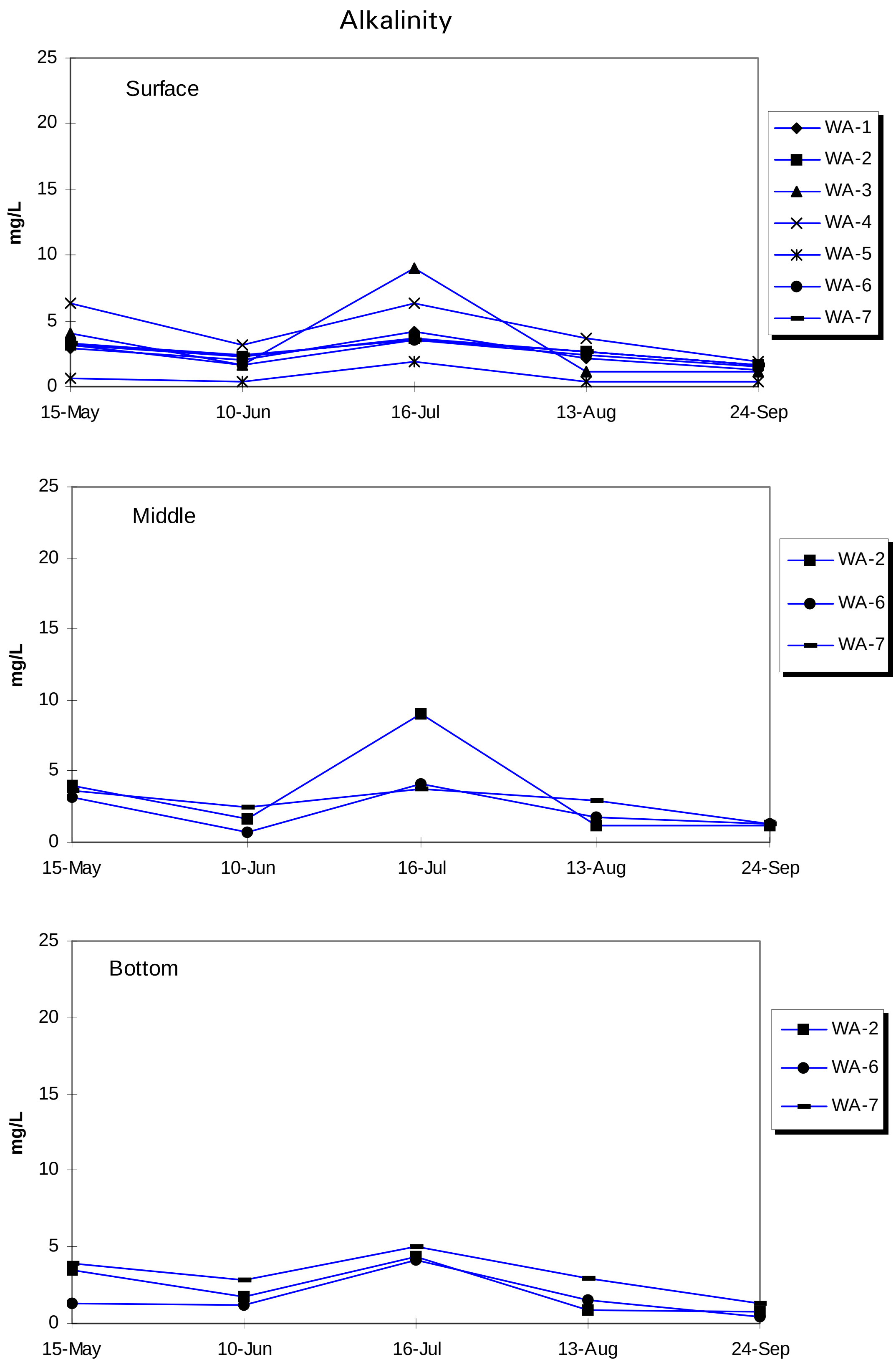

Figure 3-27. Alkalinity measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003. The PADEP water quality standard for alkalinity is a minimum concentration of 20 mg/L.

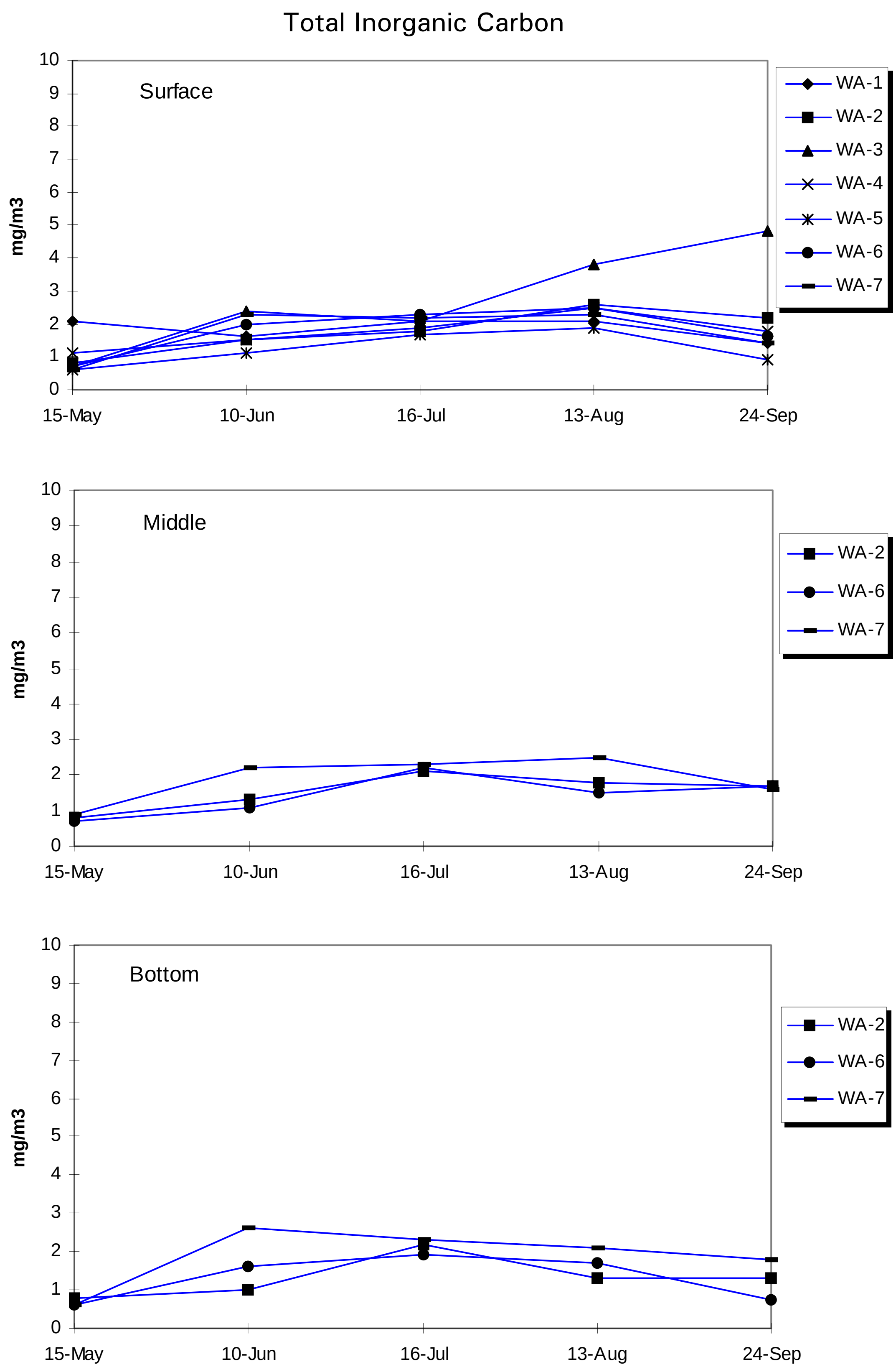

Figure 3-28. Total inorganic carbon measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003.

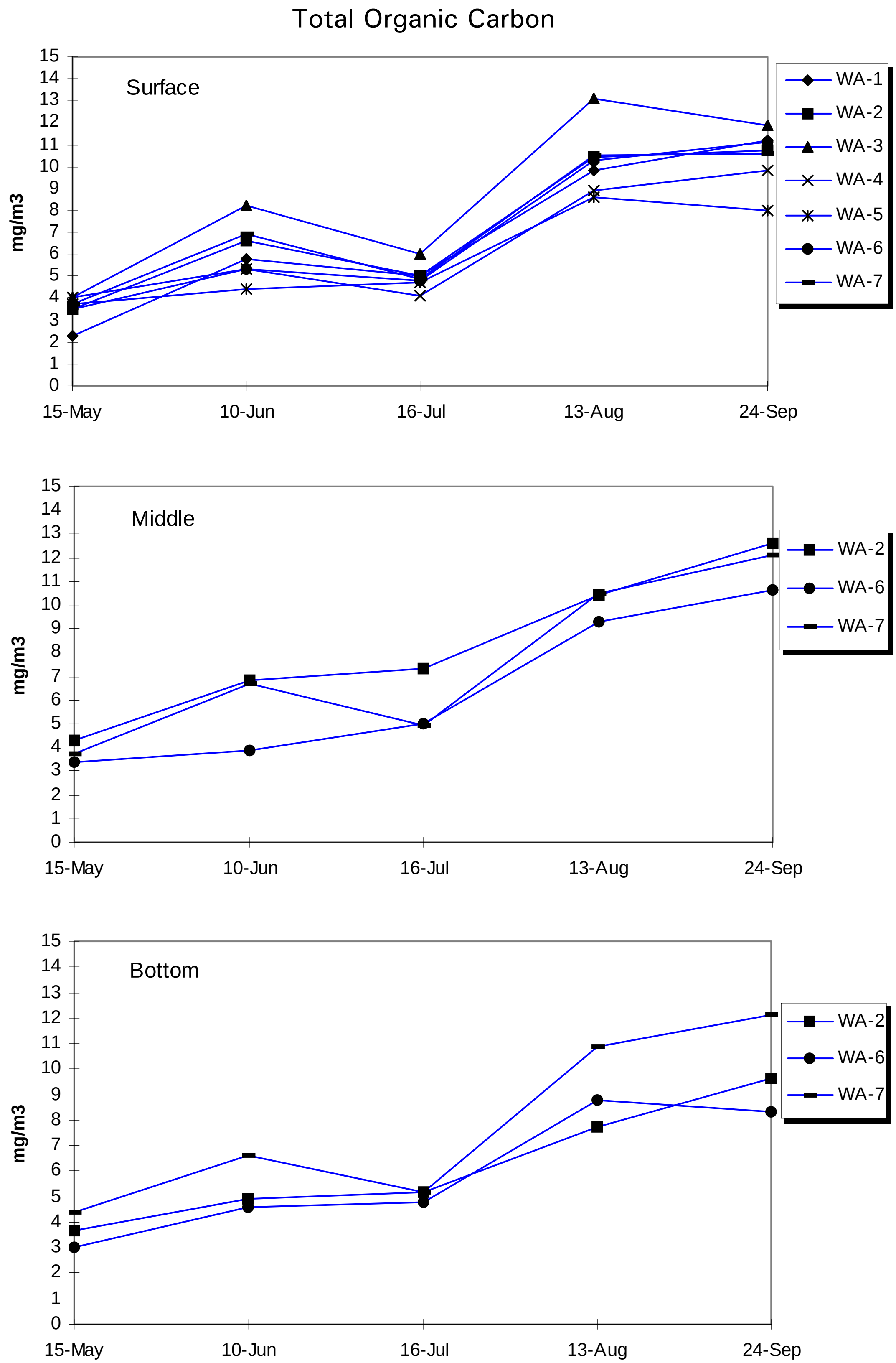

Figure 3-29. Total organic carbon measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003

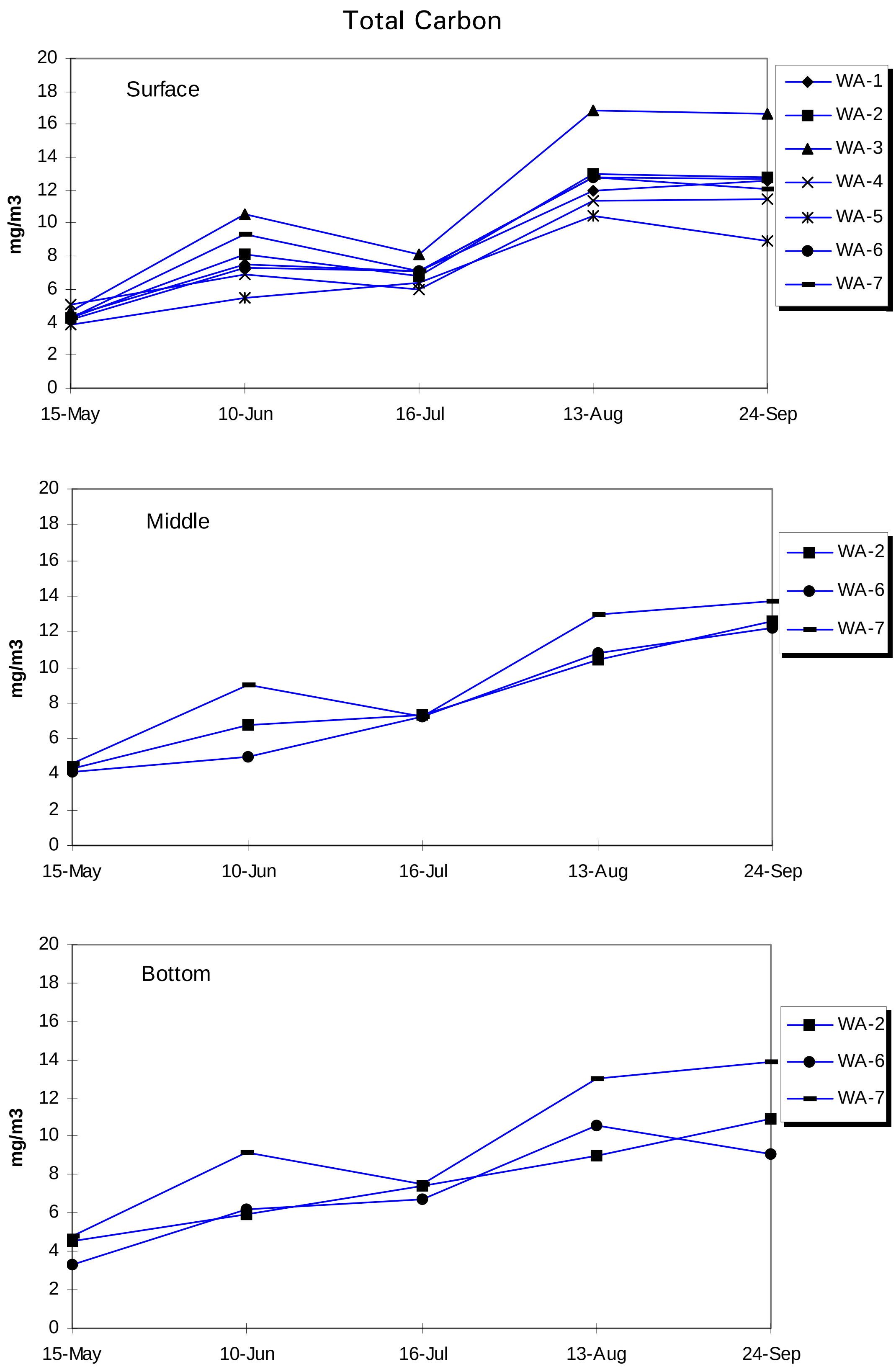

Figure 3-30. Total carbon measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003

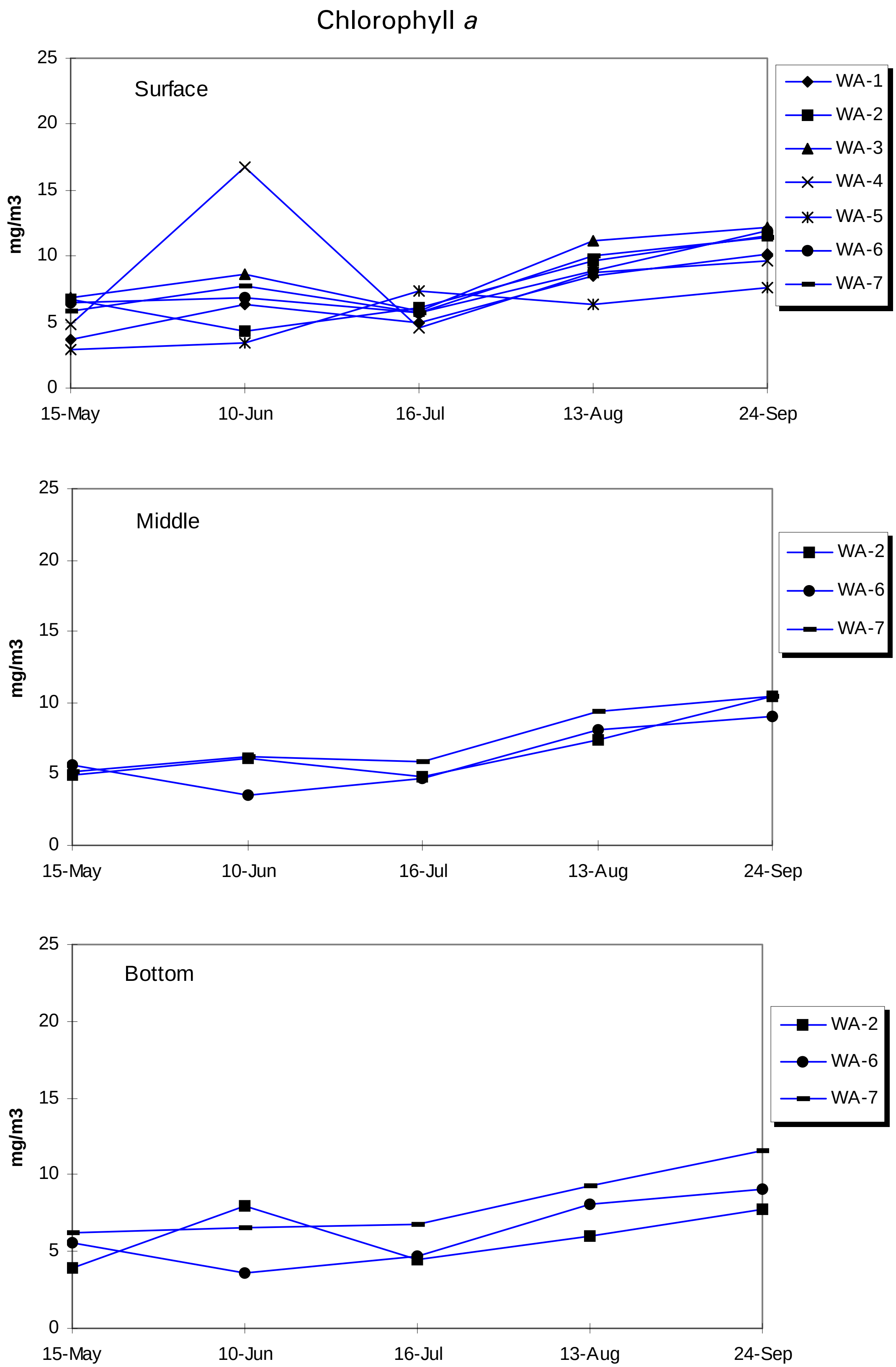

Figure 3-31. Chlorophyll *a* measured in surface, middle, and bottom water of F.E. Walter Reservoir during 2003

TSIs for total phosphorus are not accurately represented for measures of classification for F.E. Walter Reservoir because the lab was unable to meet a minimum detection limit required to do this analysis.

TSIs calculated for measures of secchi disk depth classified F.E. Walter Reservoir as mesoeutrophic with values ranging from 50 to 54. The end of the summer (September), the TSI value increased to 63, which classifies the reservoir as eutrophic (Fig. 3-32).

TSIs calculated for measures of chlorophyll *a* classified F.E. Walter Reservoir as mesotrophic throughout most of the summer with TSI values ranging from 46 and 49 (Fig. 3-32). TSIs calculated for measures of chlorophyll *a* increased in June and September, with TSI values of 54 and 53.

Carlson (1977) warned against averaging TSI values estimated for different parameters, and instead suggested giving priority to chlorophyll *a* during the summer and to phosphorus in the spring, fall, and winter. With this in mind, and the general agreement in pattern between TSI values for secchi disk depth and chlorophyll *a*, it is our estimation that the reservoir was mesotrophic/mesoeutrophic during 2003.

The EPA (1983) also provides criteria for classifying the trophic conditions of lakes of the North Temperate Zone based on concentrations of total phosphorus, chlorophyll *a*, and secchi disk depth (Table 3-9). Concentrations of total phosphorus were not calculated for the EPA trophic classifications for the same reason the TSI's were not calculated. Concentrations of chlorophyll *a* were mesotrophic for most of the summer except June, which would be classified as eutrophic. Secchi disk depth classified the lake as eutrophic throughout the monitoring period. Taking into account the general agreement between the EPA classifications with that of the TSIs, the trophic condition of F.E. Walter Reservoir was mesotrophic/eutrophic.

Table 3-9. EPA trophic classification criteria and average monthly measures for F.E. Walter Reservoir in 2003

Water Quality Variable	Oligo-trophic	Meso-trophic	Eutrophic	15 May	10 June	16 July	13 August	24 September
Total phos. (μg/l)	<10	10-20	>20	40	40	40	40	40
Chlorophyll (mg/m^3)	<4	4-10	>10	6.3	10.4	4.6	5.6	10.0
Secchi depth (m)	>4	2-4	<2	2.0	1.5	1.9	1.6	0.79

NM = not measured

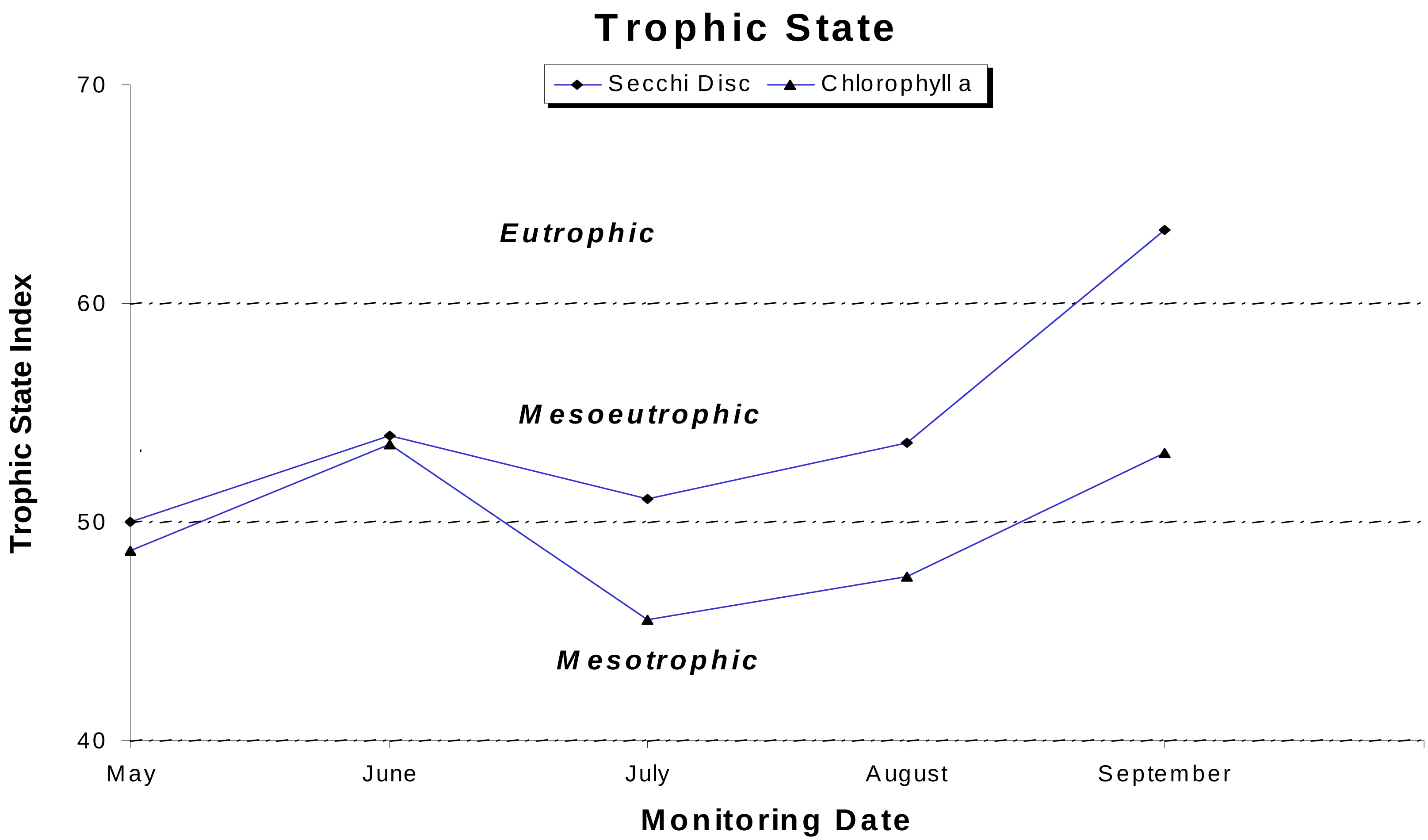

Figure 3-32. Trophic state indices calculated from secchi disk depth and concentrations of chlorophyll *a* measured in surface water of F.E. Walter Reservoir during 2003 reservoir bacteria monitoring

Two forms of coliform bacteria contamination were monitored at F.E. Walter Reservoir during 2003 including total and fecal coliform (Table 3-10). 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.

Total coliform contamination was high at F.E. Walter Reservoir during 2003. Total coliform measures ranged from 260 to 17,000-clns/100-ml and averaged 3,693-clns/100-ml (Table 3-10; Fig. 3-33). The highest count (17,000-clns/100-ml) was at station WA-6 during 24 September sampling event. All of the stations had high coliform counts during the 13 August and 24 September sampling event. At station WA-4 and WA-5, total coliform counts were always above 1,000-clns/100-ml.

Fecal coliform contamination at F.E. Walter Reservoir during 2003 ranged from less than the detection limit of 2 to 2,000-clns/100-ml throughout the monitoring period and averaged 182-clns/100-ml (Table 3-10; Fig. 3-34). Fecal coliform levels were observed in September to be high at every station, averaging 451-clns/100/ml.

Coliform bacteria contamination was for the most part low at F.E. Walter Reservoir with respect to PADEP water quality standards throughout the monitoring period. The water quality standard for bacteria contamination is a geometric mean among fecal coliform samples less than 200 colonies/100-ml (Table 3-11; Fig. 3-35). The geometric means were less than the PADEP standard for May through August. In August the geometric mean began to increase and by September the geometric was two times greater than the PADEP water quality standards (200 colonies/100-ml).

Flow data from USGS gauging stations within the F. E. Walter Reservoir watershed (Stoddartsville and Blakeslee) were analyzed to qualitatively correlate precipitation events with coliform bacteria data (Fig 2-2 through 2-6). Precipitation appears to have contributed to elevated coliform levels in the reservoir during the August and September sampling events. A week before 13 August, a storm event with 3 inches of precipitation resulted in high coliform levels. The day before 24 September, a storm event with 2 inches of precipitation resulted in the highest values of total coliform recorded for the monitoring period.

Fecal coliform counts for 2003 and historical data from the past 21 years or more were analyzed for seasonal trends. The trend analysis was conducted for spring and summer seasons separately for stations representative of the reservoir and downstream (Figs. 3-36 and 3-37). From the analysis, fecal coliform contamination appears to have increased downstream of the reservoir during the summer season. The increasing trend was significant ($R^2=0.33$; $P<0.007$), and appeared to be driven by higher average counts (about 200 colonies/100-ml) from 1996 to present (Fig. 3-37). Significant trends were not determined for the reservoir in either season, or downstream of the reservoir for the spring.

Table 3-10. Bacteria counts (colonies/100 ml) at F.E. Walter Reservoir during 2003.

STATION	DATE	Total Coliform (TC)	Fecal Coliform (FC)
WA-1S	15-May	870	10
	10-Jun	2000	33
	16-Jul	990	14
	13-Aug	5800	2000
	24-Sep	4100	560
WA-2S	15-May	650	6
	10-Jun	2400	16
	16-Jul	260	8
	13-Aug	5800	10
	24-Sep	4900	620
WA-3S	15-May	870	<2
	10-Jun	2000	13
	16-Jul	1700	31
	13-Aug	2600	40
	24-Sep	9800	330
WA-4S	15-May	1100	10
	10-Jun	>2400	62
	16-Jul	1400	21
	13-Aug	6900	240
	24-Sep	4600	250
WA-5S	15-May	1300	4
	10-Jun	>2400	6
	16-Jul	2500	29
	13-Aug	6900	250
	24-Sep	9200	300
WA-6S	15-May	550	20
	10-Jun	580	6
	16-Jul	310	2
	13-Aug	7700	240
	24-Sep	17000	600
WA-7S	15-May	390	2
	10-Jun	>2400	15
	16-Jul	300	2
	13-Aug	4600	125
	24-Sep	12000	500

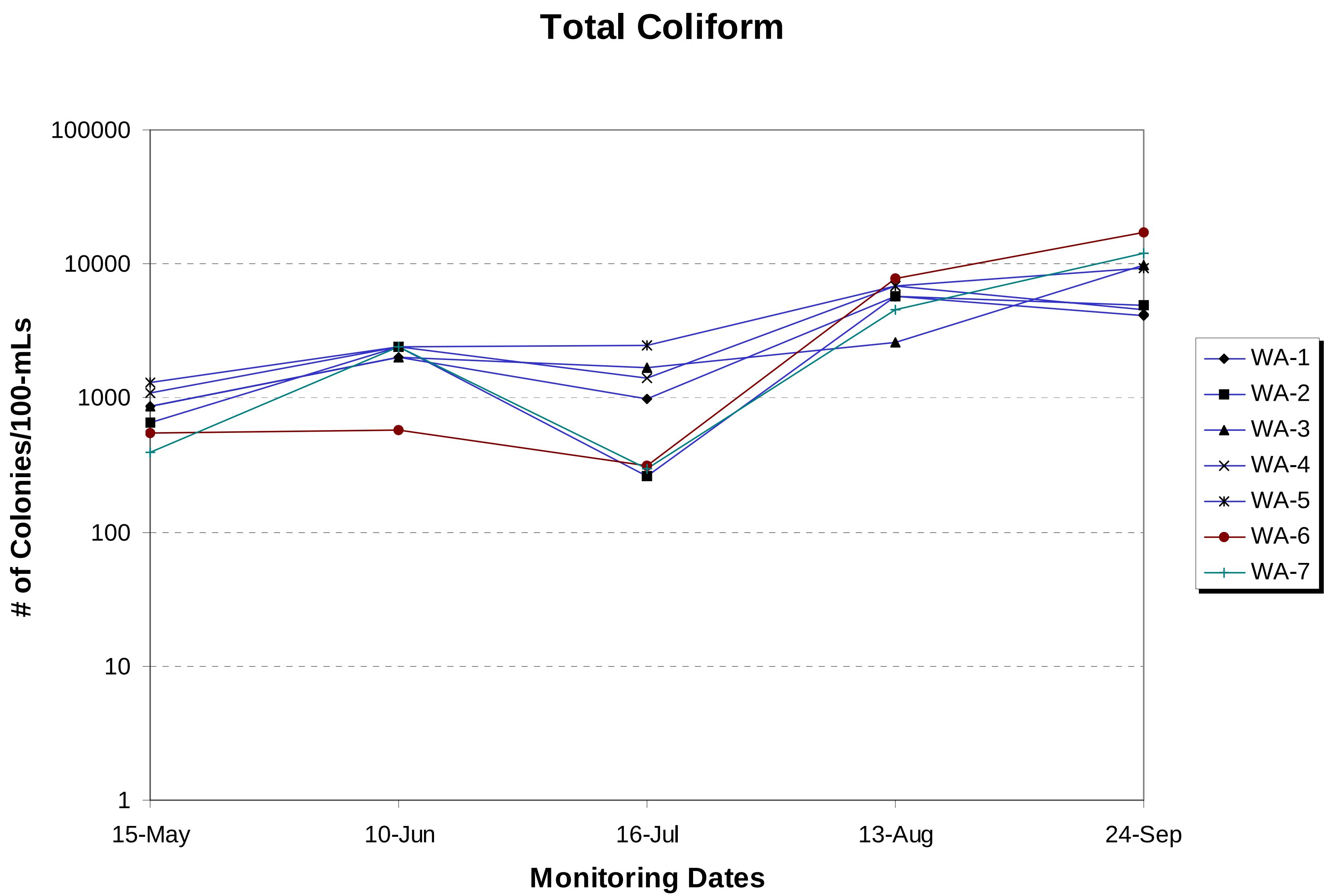

Figure 3-33. Counts of total coliform bacteria in surface waters of F.E. Walter Reservoir during 2003

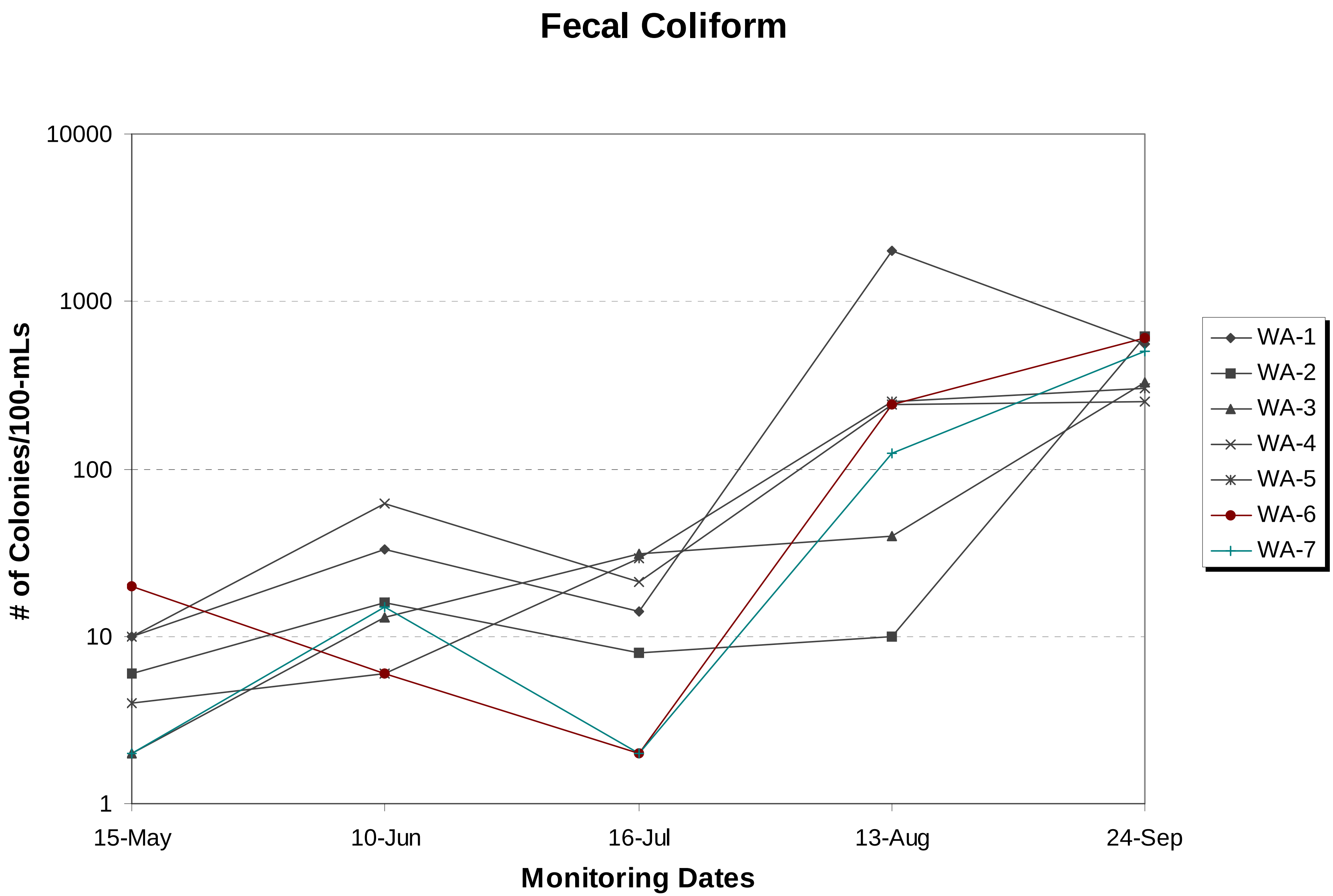

Figure 3-34. Counts of fecal coliform bacteria in surface waters of F.E. Walter Reservoir during 2003

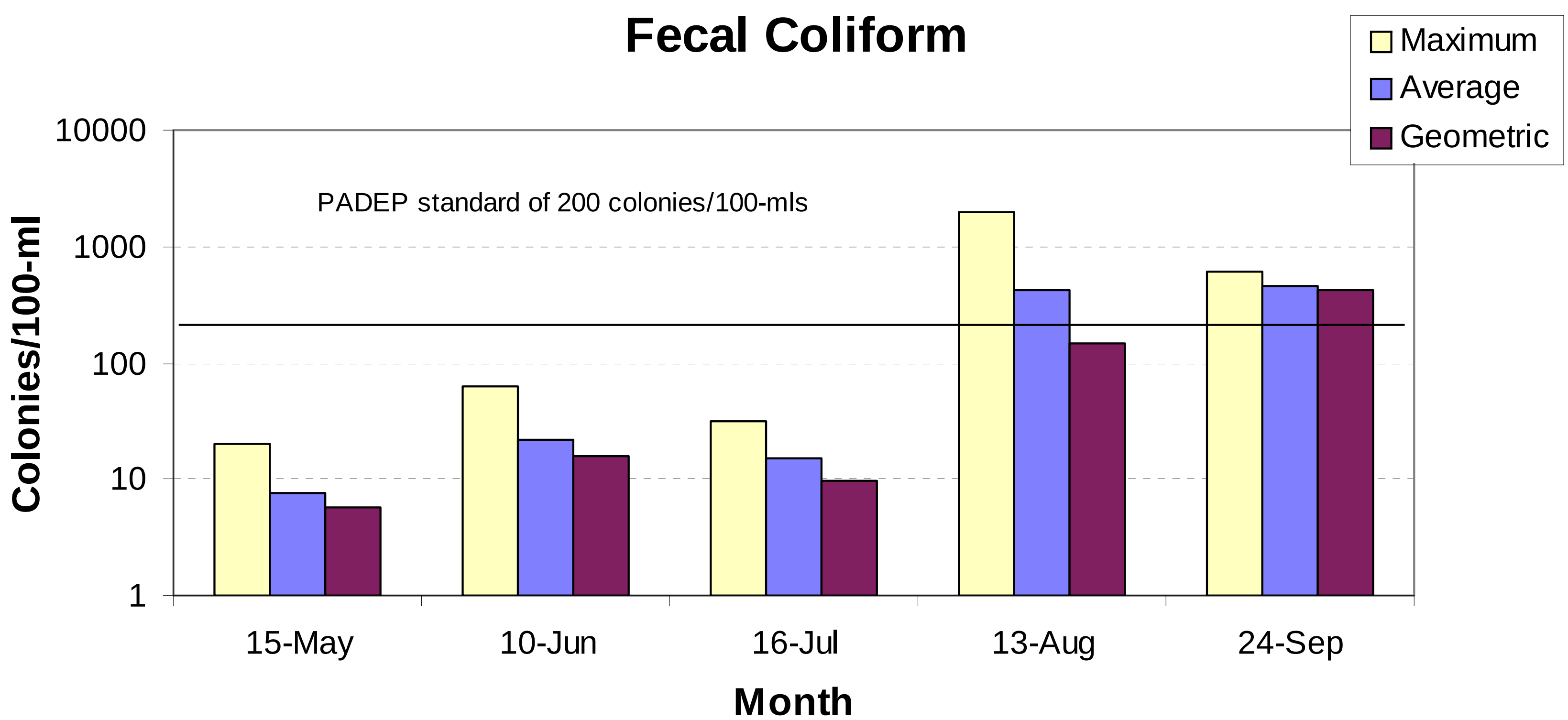

Figure 3-35. Maximum average, and geometric mean of fecal coliform counts (colonies/100-ml) for all stations monitored at F.E. Walter Reservoir in 2003

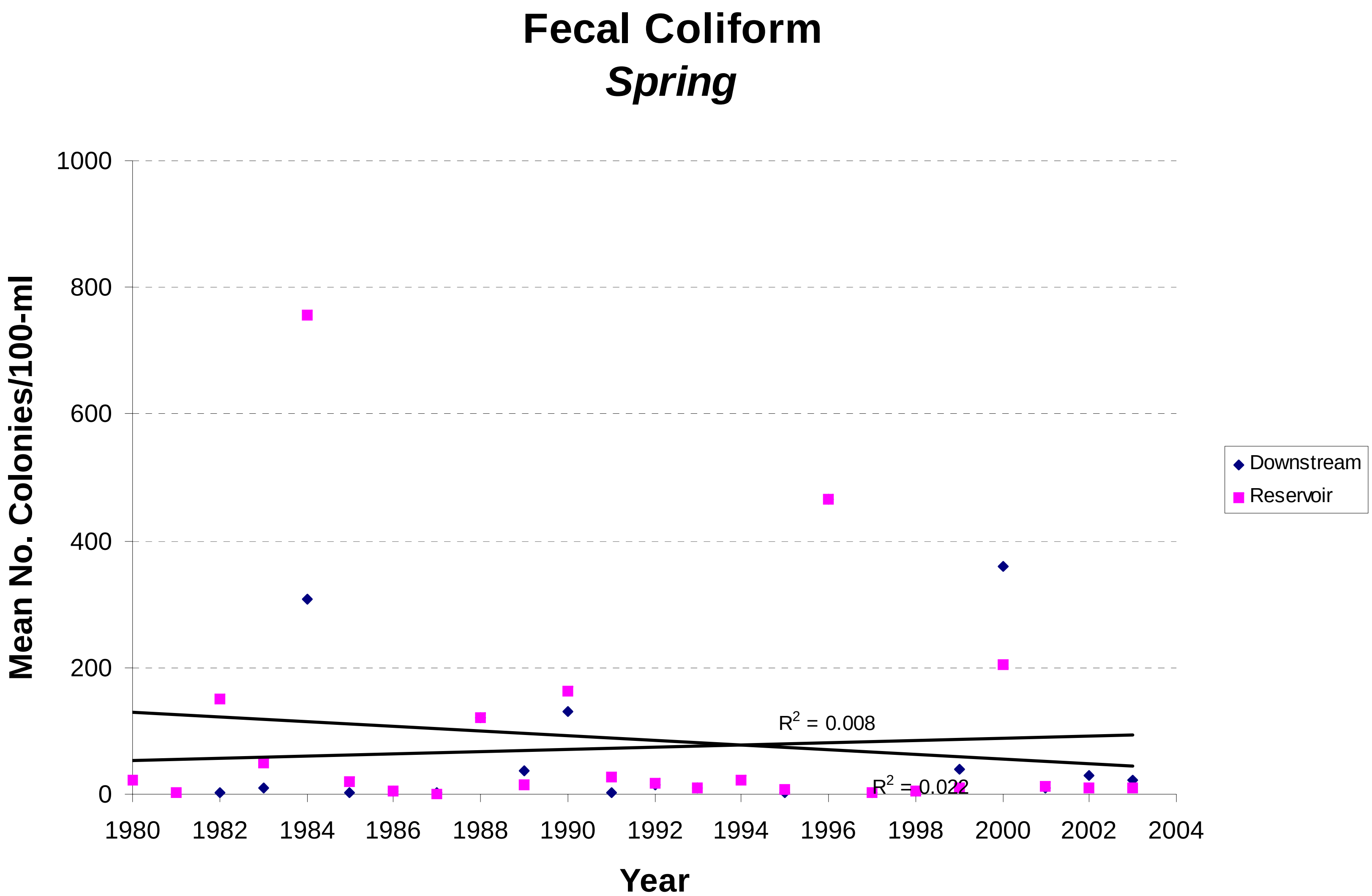

Figure 3-36. Seasonal trend analysis for counts of fecal coliform bacteria during spring months (Apirl, May, and June) at F.E. Walter Reservoir

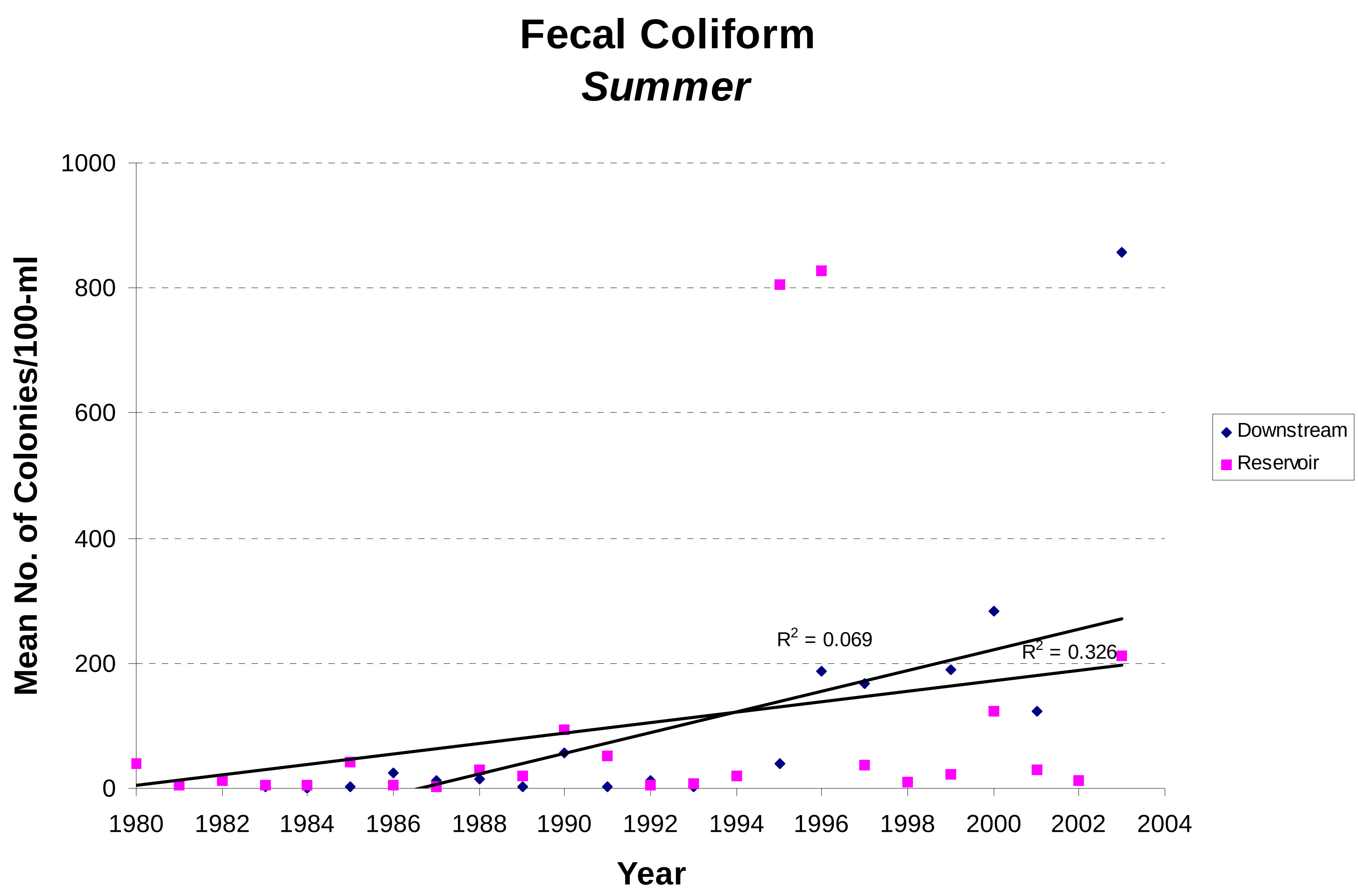

Figure 3-37. Seasonal trend analysis for counts of fecal coliform bacteria during summer months (July, August, and October 3) at F.E. Walter Reservoir

Table 3-11. Summary statistics of fecal coliform counts (colonies/100-ml) among all stations of F.E. Walter Reservoir during 2003. (PADEP water quality standard for fecal coliforms is a geometric mean not greater than 200 colonies/100-ml.)			
Date	**Geometric Mean**	**Arithmetic mean**	**Maximum Count**
15-May	5.7	7.7	20.0
10-Jun	15.6	21.6	62.0
16-Jul	9.8	15.3	31.0
13-Aug	146.4	415.0	2000.0
24-Sep	426.8	451.4	620.0

Seasonal trend analyses of total and fecal coliform bacteria were conducted for individual stations of F.E. Walter Reservoir, combining 2003 and historical data (Tables 3-12 and 3-13). The Mann-Kendall statistic was applied to station data collected over the past 21 years or more, separately for spring (April to June) and summer (July to October) seasons. Stations included in the analysis were representative of downstream (WA-1), within the main reservoir (WA-2), and upstream sources on Tobyhanna Creek (WA-3), Lehigh River (WA-4), and Bear Creek (WA-5). For fecal coliform, all of the stations except WA-2 were significant during the summer. The increasing values ranged from 2.31 to 4.41 mg/L/year. There were no significant trends for total coliform this year.

Table 3-12. Seasonal trends of fecal coliforms/100-ml at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic. Shaded values are significant at P=0.05.

Station	**# of Years Spring/Summer**	**Spring**		**Summer**	
		P Level	**Rate (mg/L)**	**P Level**	**Rate**
Surface Water					
WA-1	21	NS	0.4247	< 0.01	2.3125
WA-2	24	NS	-0.7947	NS	0.8240
WA-3	24	NS	0.2417	< 0.05	4.4078
WA-4	23	NS	2.2222	< 0.01	3.8750
WA-5	23	NS	-0.1250	< 0.05	4.0917

Table 3-13. Seasonal trends of total coliforms/100-ml at individual stations of F.E. Walter Reservoir calculated with the Mann-Kendall Statistic.

Station	# of Years Spring/Summer	Spring		Summer	
		P Level	Rate (mg/L)	P Level	Rate
Surface Water					
WA-1	21	NS	-12.7708	NS	5.1997
WA-2	24	NS	-8.0750	NS	0.2520
WA-3	24/23	NS	-5.8125	NS	15.3125
WA-4	23	NS	10.7368	NS	12.1667
WA-5	23	NS	-1.5909	NS	17.1500

3.4 SEDIMENT PRIORITY POLLUTANT MONITORING

Sediment samples were collected at stations WA-2 and analyzed for priority pollutant contaminants, Group 2 – metals and acid/base neutral extractables. Resulting concentrations were compared to New Jersey Soil Cleanup Criteria (NJDEP 1999). The NJDEP criteria are human health based with categories addressing residential and non-residential settings, and impacts to groundwater. For our comparison, we reported the most conservative of the three criteria.

A total of 13 metals were analyzed in F.E. Walter Reservoir sediments (Table 3-14). Three metals were measured at concentrations that exceeded USACE screening levels: beryllium, chromium, and thallium. Beryllium (2.50 mg/kg) and thallium (6.87 mg/kg) exceeded both the New Jersey residential and non-residential screening level of 2 mg/kg. Chromium had a concentration of 22.9 mg/kg, respectively, exceeded the non-residential screening level of 20 mg/kg. To be conservative total chromium concentrations were compared to the lower chromium VI soil cleanup criteria (if there were any chromium VI present in the sediments, it would be a smaller percentage of the total chromium).

A total of 57 acid/base neutral extractables were analyzed in F.E. Walter Reservoir sediments (Table 3-14). None of the compounds detected in the sediment samples for station WA-2, exceeded the screening criteria.

3.5 TEMPERATURE PROBE MONITORING

Daily mean temperatures calculated from the data recorded by the TidbiT^{tm} probes deployed at five Lehigh River monitoring stations were examined and compared to PADEP water use criteria for temperature. Stations WA1 (just below the F. E. Walter dam outfall), LH3 (Tannery Bridge), and LH10 (Lehighton) were plotted together along with the season specific temperature criteria for High Quality Cold Water Fisheries (HQ-CWF; Fig. 3-38).

Table 3-14. Metal and acid/base neutral extractables (Group 2) concentrations measured in sediments of F.E. Walter Reservoir in 2003.				
METALS	**Station**	**WA-2**	**New Jersey Residential SCC**	**New Jersey Non-Residential SCC**
	Core Section	**16-Jul**		
Antimony	mg/kg	< 3.07	14	340
Arsenic	mg/kg	8.91	20	20
Beryllium	mg/kg	2.50	2	2
Cadmium	mg/kg	4.11	39	100
Chromium	mg/kg	22.9	240 [b] 270 [c]	6100 [b] 20 [c]
Copper	mg/kg	32.0	600	600
Lead	mg/kg	74.2	400	600
Mercury	mg/kg	0.209	14	270
Nickel	mg/kg	35.6	250	2,400
Selenium	mg/kg	< 2.18	63	3,100
Silver	mg/kg	< 0.697	110	4,100
Thallium	mg/kg	6.87	2	2
Zinc	mg/kg	496	1,500	1,500
ACID/BASE NEUTRAL EXTRACTABLES				
1,2,4-Trichlorobenzene	ug/kg	< 160	68,000	1,200,000
1,2-Dichlorobenzene	ug/kg	< 160	5,100,000	10,000,000
1,2-Diphenylhydrazine		< 160		
1,3-Dichlorobenzene	ug/kg	< 160	5,100,000	10,000,000
1,4-Dichlorobenzene	ug/kg	< 160	570,000	10,000,000
2,4,6-Trichlorophenol	ug/kg	< 160	62,000	270,000
2,4-Dichlorophenol	ug/kg	< 160	170,000	3,100,000
2,4-Dimethylphenol	ug/kg	< 160	1,100,000	10,000,000
2,4-Dinitrophenol	ug/kg	< 3,100	110,000	2,100,000
2,4-Dinitrotoluene	ug/kg	< 310	1,000	4,000
2,6-Dinitrotoluene	ug/kg	< 160		
2-Chloronaphthalene	ug/kg	< 160		
2-Chlorophenol	ug/kg	< 160	280,000	5,200,000
2-Nitrophenol	ug/kg	< 160		
3,3'-Dichlorobenzidine	ug/kg	< 310	2,000	6,000
4,6-Dinitro-2-methylphenol	ug/kg	< 780		
4-Bromophenyl-phenylether	ug/kg	< 160		
4-Chloro-3-methylphenol	ug/kg	< 310	10,000,000	10,000,000
4-Chlorophenyl-phenylether	ug/kg	< 160		
4-Nitrophenol	ug/kg	< 780		
Acenaphthene	ug/kg	< 160	3,400,000	10,000,000
Acenaphthylene	ug/kg	< 160		

Table 3-14. (Continued)

ACID/BASE NEUTRAL EXTRACTABLES (Continued)	Station Core Section	WA-2 16-Jul	New Jersey Residential SCC	New Jersey Non-Residential SCC
Anthracene	ug/kg	< 160	10,000,000	10,000,000
Benzidine		< 3,100		
Benzo(a)anthracene	ug/kg	< 160	900	4,000
Benzo(a)pyrene	ug/kg	< 160	660	660
Benzo(b)fluoranthene	ug/kg	< 160	900	4,000
Benzo(g,h,i)perylene	ug/kg	< 160		
Benzo(k)fluoranthene	ug/kg	< 160	900	4,000
bis(2-Chloroethoxy)methane	ug/kg	< 160		
bis(2-Chloroethyl)ether	ug/kg	< 160	660	3,000
bis(2-Chloroisopropyl)ether		< 160		
bis(2-Ethylhexyl)phthalate	ug/kg	1,100	49,000	210,000
Butylbenzylphthalate	ug/kg	< 310	1,100,000	10,000,000
Chrysene	ug/kg	< 160	9,000	40,000
Dibenz(a,h)anthracene	ug/kg	< 160	660	660
Diethylphthalate	ug/kg	< 310	10,000,000	10,000,000
Dimethylphthalate	ug/kg	< 310	10,000,000	10,000,000
Di-n-butylphthalate	ug/kg	< 310	5,700,000	10,000,000
Di-n-octylphthalate	ug/kg	< 310	1,100,000	10,000,000
Fluoranthene	ug/kg	180	2,300,000	10,000,000
Fluorene	ug/kg	< 160	2,300,000	10,000,000
Hexachlorobenzene	ug/kg	< 160	660	2,000
Hexachlorobutadiene	ug/kg	< 310	1,000	21,000
Hexachlorocyclopentadiene	ug/kg	< 780	400,000	7,300,000
Hexachloroethane	ug/kg	< 160	6,000	100,000
Indeno(1,2,3-cd)pyrene	ug/kg	< 160	900	4,000
Isophorone	ug/kg	< 160	1,100,000	1,000,000
Naphthalene	ug/kg	< 160	230,000	4,200,000
Nitrobenzene	ug/kg	< 160	28,000	520,000
N-Nitrosodimethylamine		< 310		
N-Nitroso-di-n-propylamine	ug/kg	< 160	660	660
N-Nitrosodiphenylamine	ug/kg	< 160	140,000	600,000
Pentachlorophenol	ug/kg	< 780	6,000	24,000
Phenanthrene	ug/kg	< 160		
Phenol	ug/kg	< 160	10,000,000	10,000,000
Pyrene	ug/kg	170	1,700,000	10,000,000

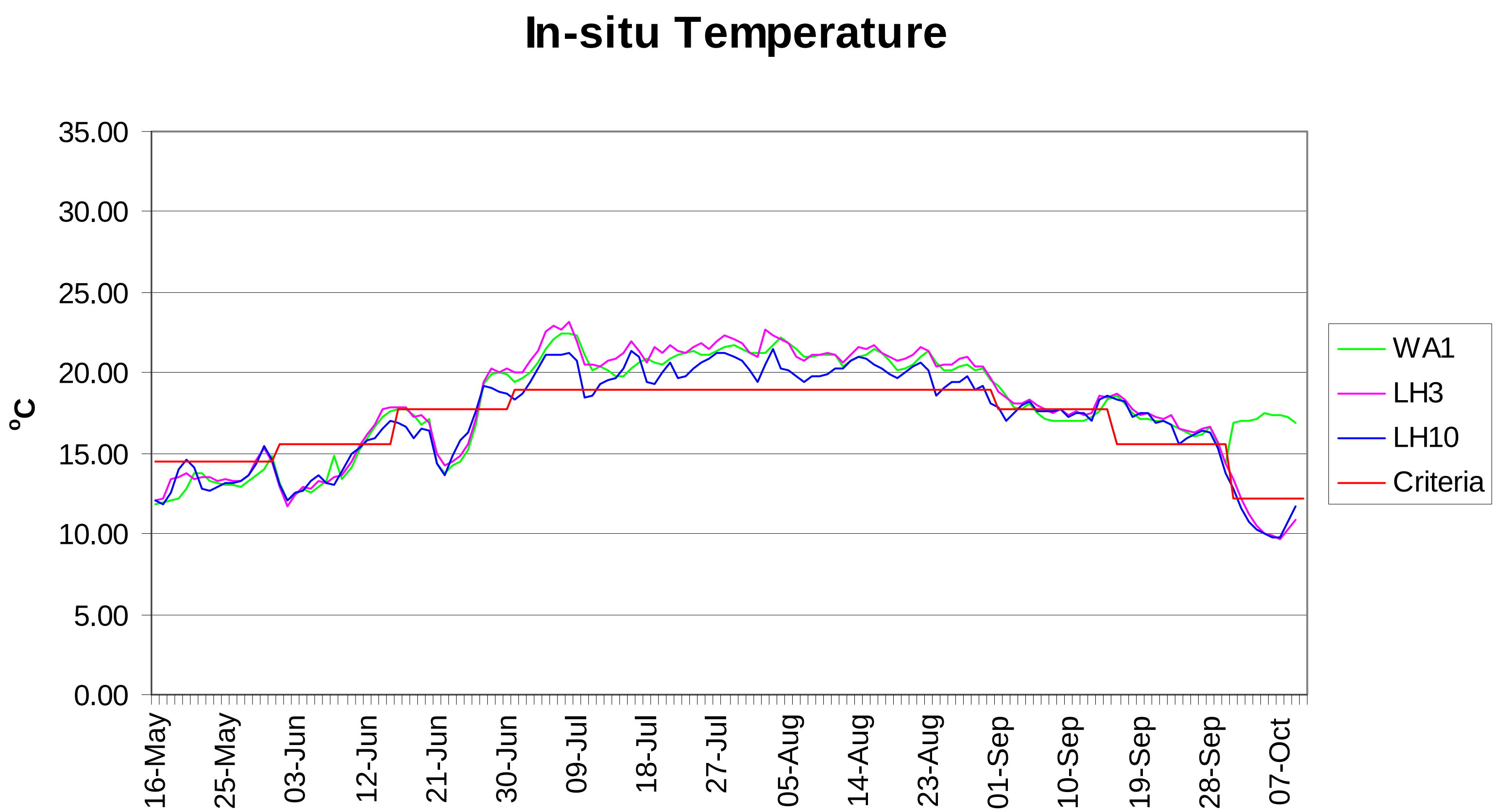

Figure 3-38. In-situ temperature measured in surface waters of Lehigh River during 2003.

Stations LH15 (Walnutport Gauge) and LH17 (Northampton) are classified a Trout Stocking Fishery (TSF) and observed water temperatures relative to seasonal specific temperature criteria are presented in Figure 3-39. This analysis indicated that stations WA1, LH3, and LH10 were not in compliance with temperature requirements for a high quality cold-water fishery for most of monitoring period (Fig. 3-38).

The sampling stations at LH15 and downstream at LH17 were categorized as a TSF by the PADEP. Figure 3-39 compares the season water temperature requirements to those observed from the in-situ temperature monitors. These data show that, with one exception on 17 July at LH17, these stations met the PADEP requirements.

3.6 DRINKING WATER

Drinking water from the utility sink located in the maintenance building of F. E. Walter 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 2003. 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

F. E. Walter Reservoir drinking water was in compliance with PADEP water quality standards for all the primary and secondary contaminants with the exception of manganese and pH (Table 3-15). Manganese is a primary drinking water contaminant with a regulatory level of 0.05 mg/L. On 10 June, manganese had a concentration 0.051 mg/L. PH is a secondary drinking water contaminant with a regulatory level of 6.5-8.5. On 10 June, pH had a concentration 5.3 for the initial sample and 5.34 for the secondary sample.

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.

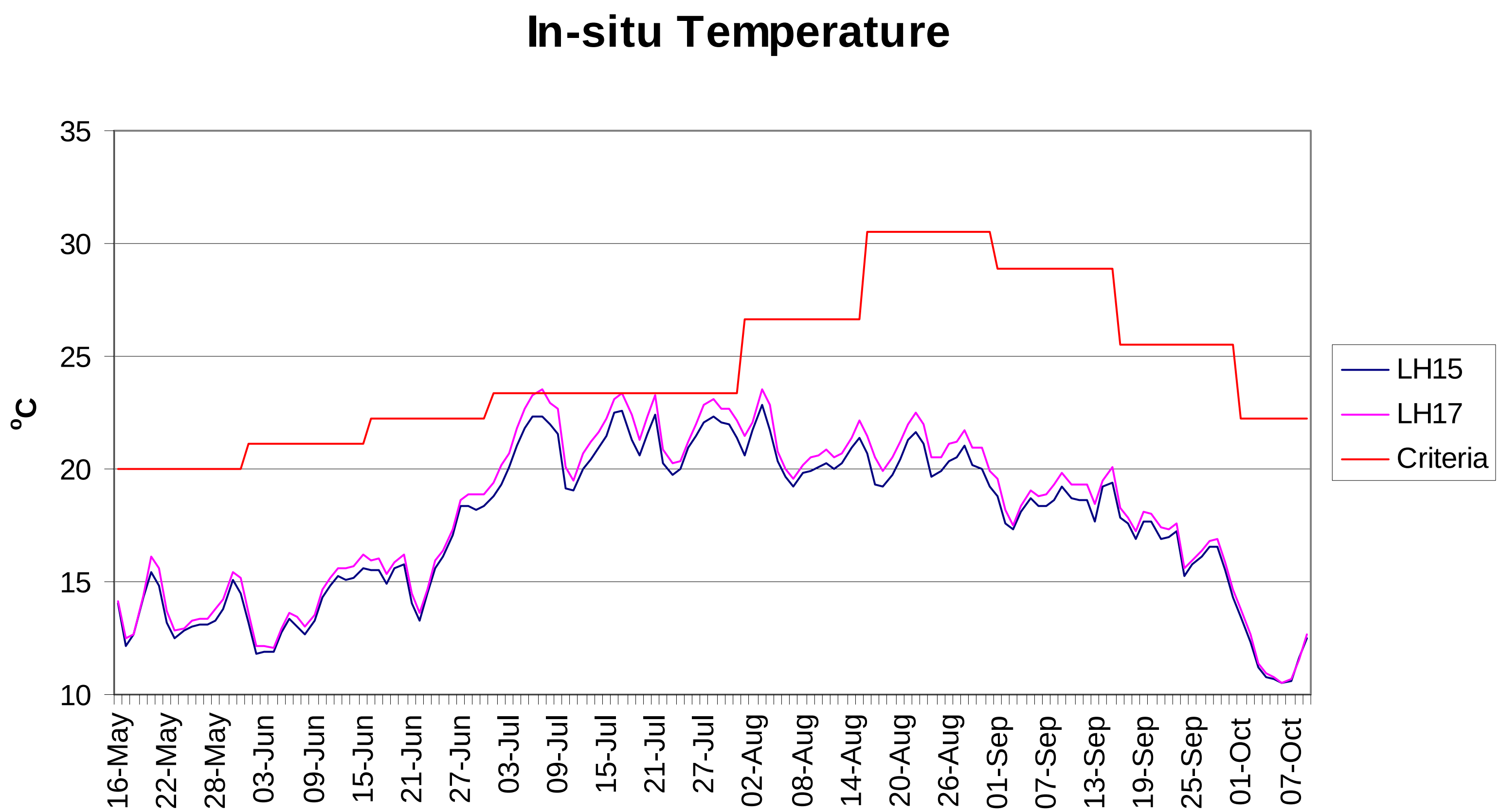

Figure 3-39. In-situ temperature measured in surface waters of Lehigh River during 2003.

Table 3-15. Concentrations of primary and secondary contaminants in drinking water at F.E. Walter Reservoir in 2003. 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 10 June	PADEP Regulatory Level	Detection Limits	EPA Method
Aluminum	0.06	0.2	0.02	200.8
Antimony	ND	0.006	0.003	200.8
Arsenic	ND	0.05	0.005	200.8
Barium	ND	2.0	0.4	200.8
Cadmium	ND	0.005	0.001	200.8
Chromium	ND	0.1	0.02	200.8
Copper	0.338	1.3	0.001	200.8
Iron	0.03	0.3	0.02	200.7
Lead	0.004	0.015	0.001	200.8
Magnesium	0.6	NL	0.5	SM3111B
Manganese	0.051	0.05	0.005	200.8
Mercury	ND	0.002	0.0004	245.1
Nickel	ND	0.1	0.005	200.8
Selenium	ND	0.05	0.01	200.8
Silver	ND	0.1	0.005	200.8
Sodium	ND	NL	0.5	SM3111B
Thallium	ND	0.002	0.001	200.8
Zinc	0.018	5.0	0.005	200.8
Chloride	1	250	1	300
Cyanide, free	ND	0.2	0.04	335.4
Fluoride	ND	2.0	0.5	SM4500-F-C/300.0
Foaming Agents	0.036	0.5	0.025	SM5540C
PH	5.3/5.34	6.5-8.5	1	SM4500H-B
Sulfate	4	250.0	1	300
Total Dissolved Solids	11	500.0	1	SM2540C

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

3.6.2 Inorganic Nitrogen and Coliform Bacteria

F. E. Walter Reservoir drinking water was in compliance with PADEP criteria for inorganic nitrogen contaminants, nitrate and nitrite, and coliform bacteria contaminants (Table 3-16). There were no coliform contaminants present throughout the sampling period. All of the tests for nitrite and nitrate were not detected. Following laboratory testing, drinking water monitoring results were recorded on Safe Drinking Water Act (SDWA-S and SDWA-4) forms and submitted to the appropriate state environmental agencies.

3.6.3 Historical Drinking Water Quality

Drinking water quality has been monitored at F. E. Walter Reservoir over the past 23 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, 4 had incidences of noncompliance with drinking water standards from 1983 to present (Table 3-17). Cadmium and pH were most often not in compliance with PADEP criteria; manganese and pH were the two parameters slightly out of compliance once again during the 2003 monitoring.

Table 3-16. Concentrations of nitrate and nitrite, and results of coliform bacteria monitoring of drinking water sampled from the woman's restroom located in the office at F.E. Walter Reservoir during 2003.

Parameter	**Sampling Dates**		**PADEP Regulatory Level**	**Detection Limits**	**Method**
	10 June	**24 September**			
Nitrate as N (mg/L)	ND	ND	10.0	1	300.0
Nitrite as N (mg/L)	ND	ND	1.0	0.1	300.0
Fecal Coliform (CFU)	Absence	Absence	Presence	1	SM 9222D
Total Coliform (CFU)	Absence	Absence	Presence	1	SM 9223B

CFU – colony forming units
ND – Not Detected
N/A- Not Available

Table 3-17. Drinking water parameters exceeding PADEP criteria at F.E. Walter Reservoir from 1983 to 2003			
Parameter	**Monitoring Date**	**Result**	**Criteria**
CADMIUM (MG/L)	15 June 1987	0.006	0.005
	26 July 1988	0.008	0.005
	4 April 1991	0.007	0.005
	27 July 1994	0.040	0.005
COPPER (MG/L)	10 June 1998	2.83	1.3
	20 June 2000	2.03	1.3
CORROSIVITY	10 June 1998	-1.80	NON-NEGATIVE
	22 June 1999	NEG	NON-NEGATIVE
	20 June 2000	-5.3	NON-NEGATIVE
PH	10 June 1998	5.9	6.5-8.5
	22 June 1999	5.6	6.5-8.5
	20 June 2000	5.5	6.5-8.5
	14 June 2001	5.4	6.5-8.5
	19 June 2002	4.76 / 4.62	6.5-8.5
	10 June 2003	5.3/5.34	6.5-8.5
MANGANESE	14 June 2001	0.053	0.05
	19 June 2002	0.057 / 0.061	0.05
	10 June 2003	0.051	0.05