Chemical, Physical and Biological

Characterization of Devils Lake

1995 - 2003

Prepared by
James Meek
Environmental Scientist

North Dakota Department of Health
Division of Water Quality
1200 Missouri Ave.
Bismarck, N.D. 58506-5520
701.328.5210

February 2005

Acknowledgements

I would like to thank the many individuals and organizations who contributed to this report. Scott Elstad, formerly with the North Dakota Department of Health, Division of Water Quality was responsible for the Devils Lake sampling program prior 2003 and wrote the annual reports which are the foundation of the 2003 report. Mike Ell provided project guidance and oversight. Joe Gross performed database management and assistance. Numerous staff members and temporary employees with the North Dakota Department of Health, Division of Water Quality provided assistance with field sampling.

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1.0 Introduction

The Devils Lake Basin is comprised of 2.4 million acres in northeastern North Dakota (Figure 1). The watershed is located in the northern glaciated plains ecoregion and is an undulating mix of integrated and nonintegrated drainage patterns. Streams within the basin are primarily intermittent. The two primary drainages are Channel A and Big Coulee (Mauvais Coulee). Channel A drains the Dry Lake, Edmore, Starkweather and Sweetwater areas, while Big Coulee drains Lake Irving, Lake Alice, Chain of Lakes and Mauvais Coulee (Figure 2).

Devils Lake is a hypereutrophic saline lake comprising about 133,880 acres. It is located in southern Ramsey and northern Benson counties. The Devils Lake chain consists of several bays and East Devils Lake. Based on the dominant cations and anions in solution, water in Devils Lake is of the sodium-sulfate type.

Water levels for Devils Lake were first recorded in 1860. Since then there have been extreme fluctuations in the water level (Figure 3). Along with these water level changes have been corresponding changes in total dissolved solids (TDS) concentrations. These changes have affected the aquatic community structure. Fluctuating water levels are primarily related to the closed basin nature of the system. The absence of a surface outlet and the fact that annual evaporation frequently exceeds annual precipitation are important causes of the high TDS. Spring runoff, most of which enters the system through West Bay (naturally) and Six Mile Bay (Channel A), is the major source of water. According to the United States Geological Survey (USGS), about 80 percent of the water contributed to Devils Lake enters through these two sources (Greg Wiche pers. comm.). Groundwater also contributes to the hydrologic budget. As a result, Devils Lake is extremely vulnerable to widely fluctuating lake levels.

Nutrients and TDS are identified as the important variables affecting water quality in Devils Lake. High concentrations of nutrients in Devils Lake cause prolific algal blooms dominated by cyanophyta (blue-green algae). These algal blooms result in impaired water-based recreation. TDS affects fish reproduction, fish growth and algal blooms.

2.0 Methods

Currently, seven sites are sampled each year across the Devils Lake chain of lakes. The seven sites and their location are 380232 (West Bay); 384160 (SW West Bay); 380221 (Six Mile Bay); 380233 (Main Bay); 380234 (East Bay); 380235 (East Devils Lake); and 385029 (Pelican Lake) (Figure 2). Sampling was initiated at the Pelican Lake site in 1999 and the S.W. West Bay site in 1997 while the remaining sites were initiated in 1995. The sites are typically sampled four times annually, once in March (under ice cover), May, August, and October. At various times in the past, there were more sites sampled or more frequent sampling but this report will concentrate only on those sites currently in the Devils Lake sampling program.

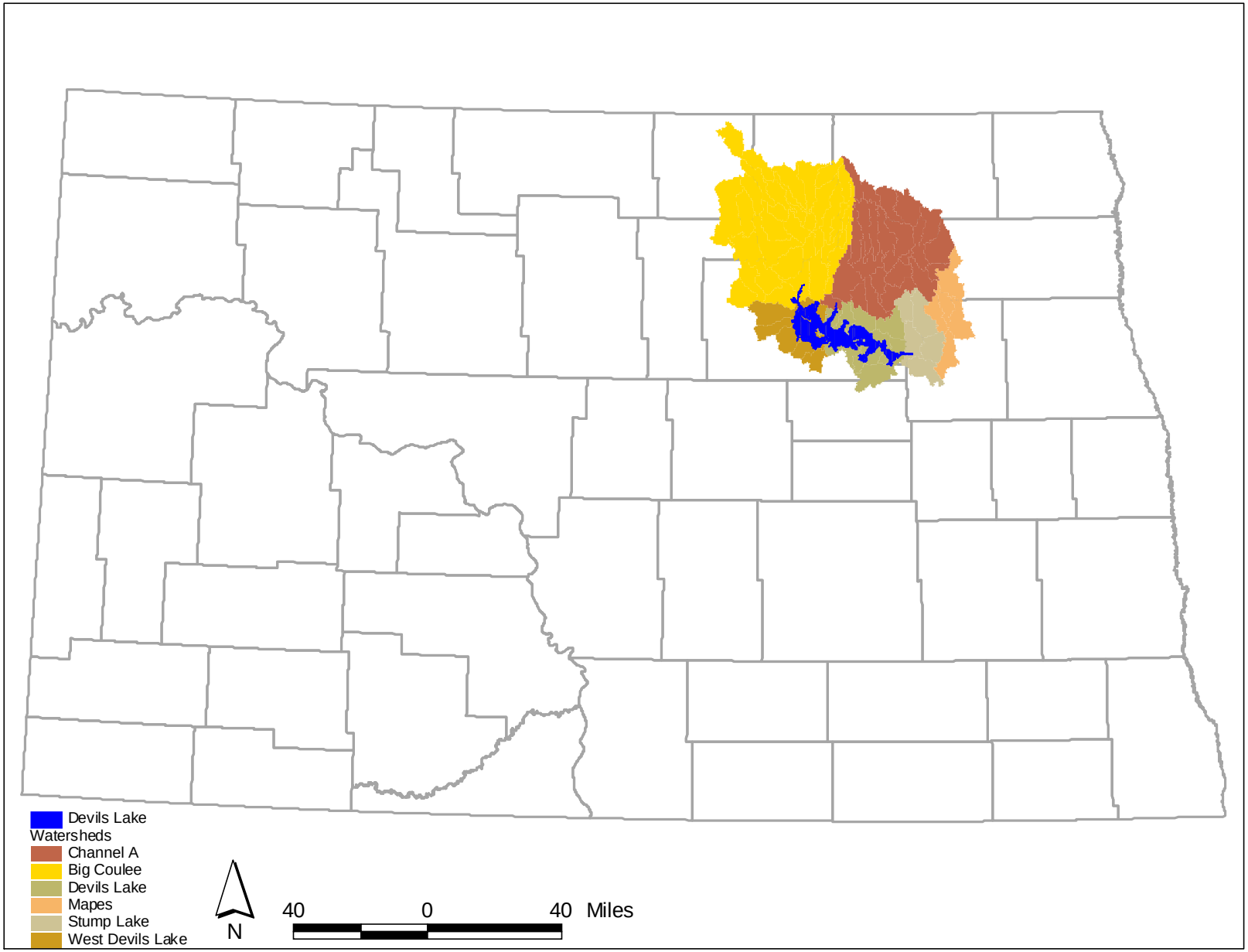


Figure1. Major Subwatersheds within the Devils Lake Basin.

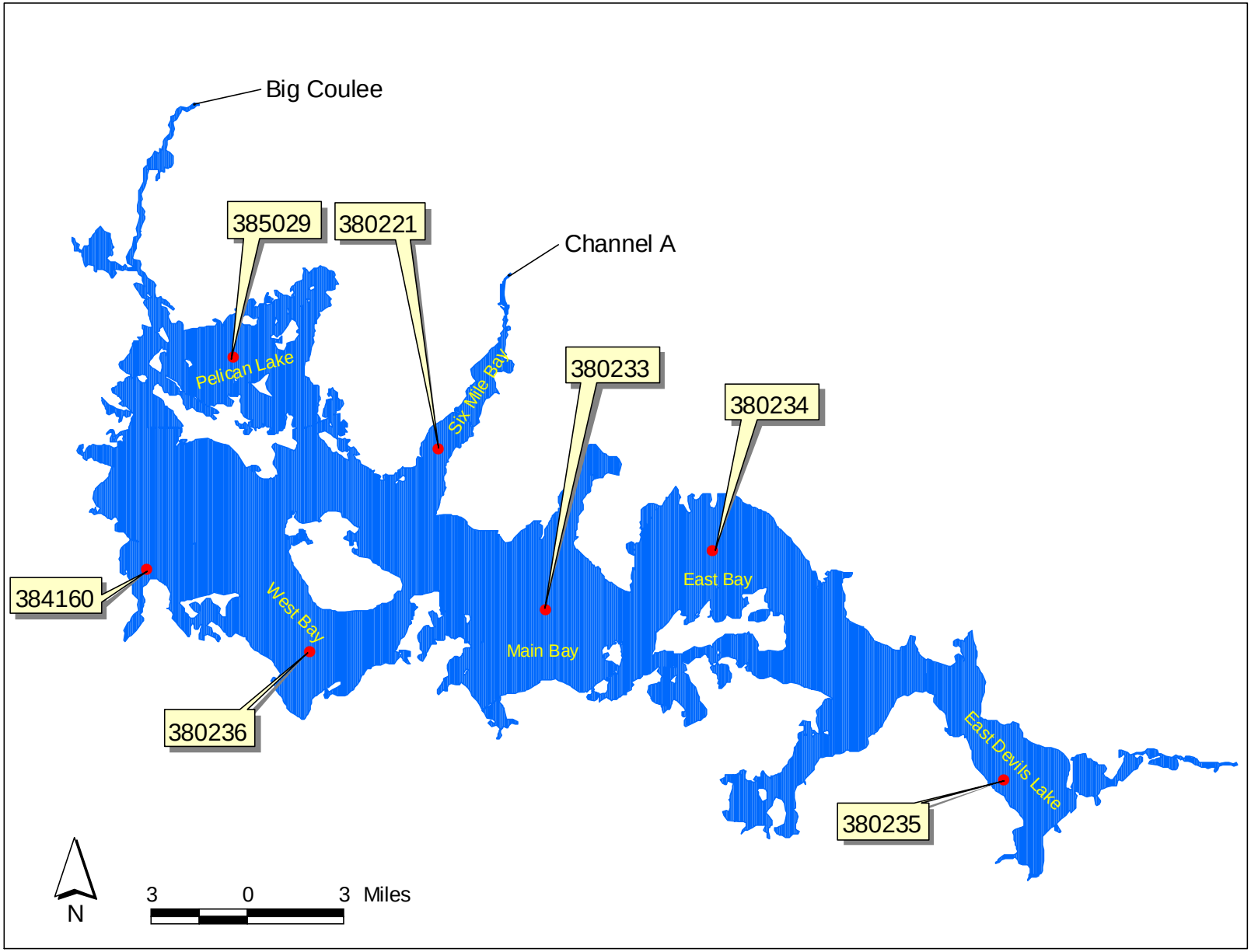


Figure 2. Locations of sample sites in Devils Lake.

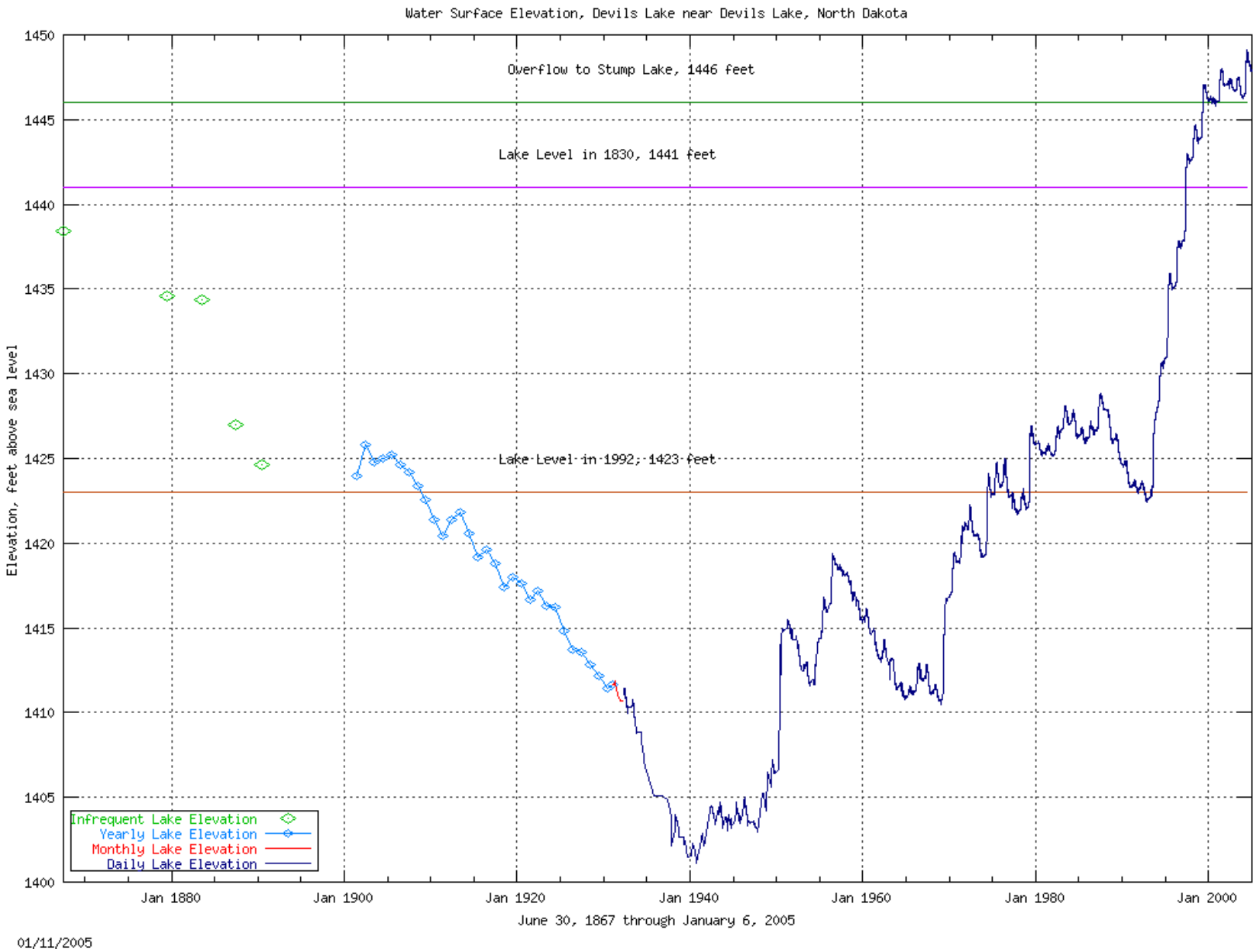


Figure 3. Average Daily Elevation of Devils Lake at United States Geological Survey (USGS) Station 05056500 near Devils Lake, ND.

Water quality samples were collected, handled and tracked in accordance with standard procedures outlined in the North Dakota Department of Health, Division of Water Quality, Standard Operating Procedures for Field Samplers (NDSDHCL 1993). Quality assurance/quality control protocols are outlined in the Standard Operating Procedures for Field Samplers and in the Lake Water Quality Assessment (LWQA) Quality Assurance Project Plan (QAPP) (NDSDHCL 1991).

Physical, chemical and biological variables that are sampled at each site consist of the following: dissolved oxygen, pH, temperature and conductivity profiles; chlorophyll-*a*; phytoplankton; ammonia as N; total Kjeldahl nitrogen; nitrate-nitrate as N; total phosphate as P; dissolved phosphate as P; total dissolved solids; major cations/anions; and trace elements. Temperature, oxygen, pH and specific conductivity profiles were recorded at one-meter intervals. Chlorophyll-*a* and phytoplankton were collected as a composite sample of the top two meters of the water column. The remaining chemical variables were analyzed from two discrete samples collected at about one meter below the surface and one-half meter above the bottom. A mid-column sample also was collected at sites more than four meters deep. This sample was taken just below the thermocline, if present; otherwise it was taken at the center of the water column.

Analytical methods used for analysis of water quality samples are described in Section 9, 10 and 11 of the North Dakota Department of Health, Division of Chemistry Quality Assurance Manual, Volume 1. All methods used by the Division of Chemistry are approved Environmental Protection Agency (EPA) methods from 40 CFR 136 (NDSDHCL 1990). Quality control samples for the Division of Chemistry are described in the Division of Chemistry Quality Assurance Manual.

Field duplicate samples are checked to ensure sample integrity. Quality control charts are maintained by the Quality Assurance Representative (QAR) for all duplicate sample results collected. Quality control boundaries are established for all data collected by variable and are established based on the previous 100 duplicate sample results. Duplicate sample results, which exceed the mean percentage difference of the previous 100 results by more than one standard deviation, will be considered out-of-control margins. If field blank results exceed the quality control boundaries, corrective action is taken. Specific procedures for data review, validation and verification can be found in the North Dakota Department of Health, Division of Water Quality Standard Operating Procedures for Field Samplers (NDSDHCL 1993) and the LWQA QAPP (NDSDHCL 1991).

All field calibration procedures-including equipment calibration methods, equipment repair and calibration documentation-are described in the North Dakota Department of Health, Division of Water Quality Standard Operating Procedures for Field Samplers (NDSDHCL 1993). All results are available in the EPA's STORage and RETrieval database (STORET).

3.0 Results and Discussion

Considering the volume and relevancy of data collected in Devils Lake over the last nine years, this report will focus on surface (1 meter) concentrations and measurements of conductivity, chloride (CL^-), sulfate (SO_4^-), total dissolved solids (TDS), ammonia (NH_3), nitrate-nitrite (NO_3^--NO_2^{2-}), total nitrogen (TN), dissolved phosphorus (DP), total phosphorus (TP), and chlorophyll-a and secchi depth. This report will focus both on intra-year (within 2003, between seasons) and inter-year (between years, 1995-2003) spatial and temporal trends. The annual mean concentration was used for the inter-year value. The existence of a trend will be determined through visual investigation of the figures provided in this report. Further statistical testing, which is outside the scope of this report, would be needed to determine the statistical significance of these trends and to possibly detect trends not visible in the figures. In addition, the seasonal temperature and dissolved oxygen profiles for 2003 will be discussed in terms of thermal stratification and dissolved oxygen depletion.

Conductivity, Chloride, Sulfate and TDS

In 2003 and throughout the entire sampling period (1995-2003), there has been a consistent spatial trend in conductivity, chloride, sulfate, and TDS concentrations. These parameters are closely related and any one of them could be used to estimate the concentration of the others. In general, the concentrations of these four parameters increase as you move from west to east in Devils Lake. East Devils Lake has the highest concentrations by a considerable margin followed by East Bay. The concentrations in Main Bay, West Bay, SW West Bay, and Six Mile Bay are typically consistent with each other and Pelican Lake has the lowest concentrations (Figure 4a-d).

No intra-year temporal trends in conductivity, chloride, sulfate, or TDS concentrations were observed in 2003 (Figure 4a-d). However, there are some inter-year temporal trends in these four parameters. In East Bay and East Devils Lake, the annual mean concentrations of these four parameters have decreased considerably since 1995. The annual mean concentrations in Six Mile Bay and Main Bay have remained fairly consistent since 1995 while increasing slightly in Pelican Lake, SW West Bay, and West Bay (Figure 5a-d). There are conductivity values for Six Mile Bay, Main Bay, East Bay, East Devils Lake, and West Bay from 1990 and 1991 (Figure 5a). Considering the high conductivity and its relationship to chloride, sulfate, and TDS, it is reasonable to assume that all five bays also saw considerable decreases in concentrations from 1990 to 1995 (Figure 5a).

Nutrients, Chlorophyll-a and Secchi Depth

Both intra-year and inter-year spatial trends in nutrients and chlorophyll-a concentrations and Secchi depth are difficult to observe primarily because of the temporal variability inherent in those parameters. The exception involves East Devils Lake whose nitrate-nitrites, total nitrogen, and chlorophyll-a concentrations tended to be higher than the other sampling locations both

within 2003 (Figure 4f-g) and between 1995 and 2003 (Figure 5f-g).

In 2003, intra-year temporal trends are observable in ammonia, nitrate-nitrite, and chlorophyll-a concentrations and secchi depth. In 2003, the ammonia and nitrate-nitrite concentrations at the majority of the sampling locations decrease from the winter (February) to the spring (May) and then remain relatively constant in the summer (August) and fall (October) samples (Figure 4e-f). Chlorophyll-a concentrations increase and the secchi depth decreases at the majority of the sampling locations in the summer (Figure 4j-k). Inter-year temporal trends are observable in total nitrogen, total phosphorus, and dissolved phosphorus for some, but not all sites. The trends observable in the annual mean concentrations of total nitrogen are not consistent across all sampling locations. The total nitrogen concentrations in East Bay and Main Bay decrease considerably in 1998 and then remained relatively consistent through 2003. The total nitrogen concentrations in East Devils Lake trended just the opposite, increasing considerably in 1998 and remaining consistent through 2003 (Figure 5g). In contrast to total nitrogen, the trends observable in the annual mean total phosphorus and dissolved phosphorus concentration are consistent across the sampling locations. The total phosphorus and dissolved phosphorus concentrations appear to increase beginning in 1996, display a peak in concentration around 1998, 1999, or 2000, and then decrease over the next three to five years (Figure 5h-i).

Temperature and DO Profiles

In 2003, weak thermal stratifications sufficient enough to at least limit mixing were observed during the winter and fall visits at Six Mile Bay, Main Bay, West Bay, and Pelican Lake. Only Six Mile Bay in the fall, West Bay in the winter, and Pelican Lake in the fall and winter have a section in the temperature profile where the thermal gradient is greater than one degree Celsius per meter. Dissolved oxygen depletions commonly associated with thermal stratification were also observed during the winter and fall at the above mentioned locations (Figure 6a-g). The largest dissolved oxygen depletion occurred in West Bay during the winter reaching a low of 5.20 mg/L (Figure 6e). None of the sampling locations demonstrated any thermal stratification or dissolved oxygen depletion during the spring and summer visit (Figure 6a-g).

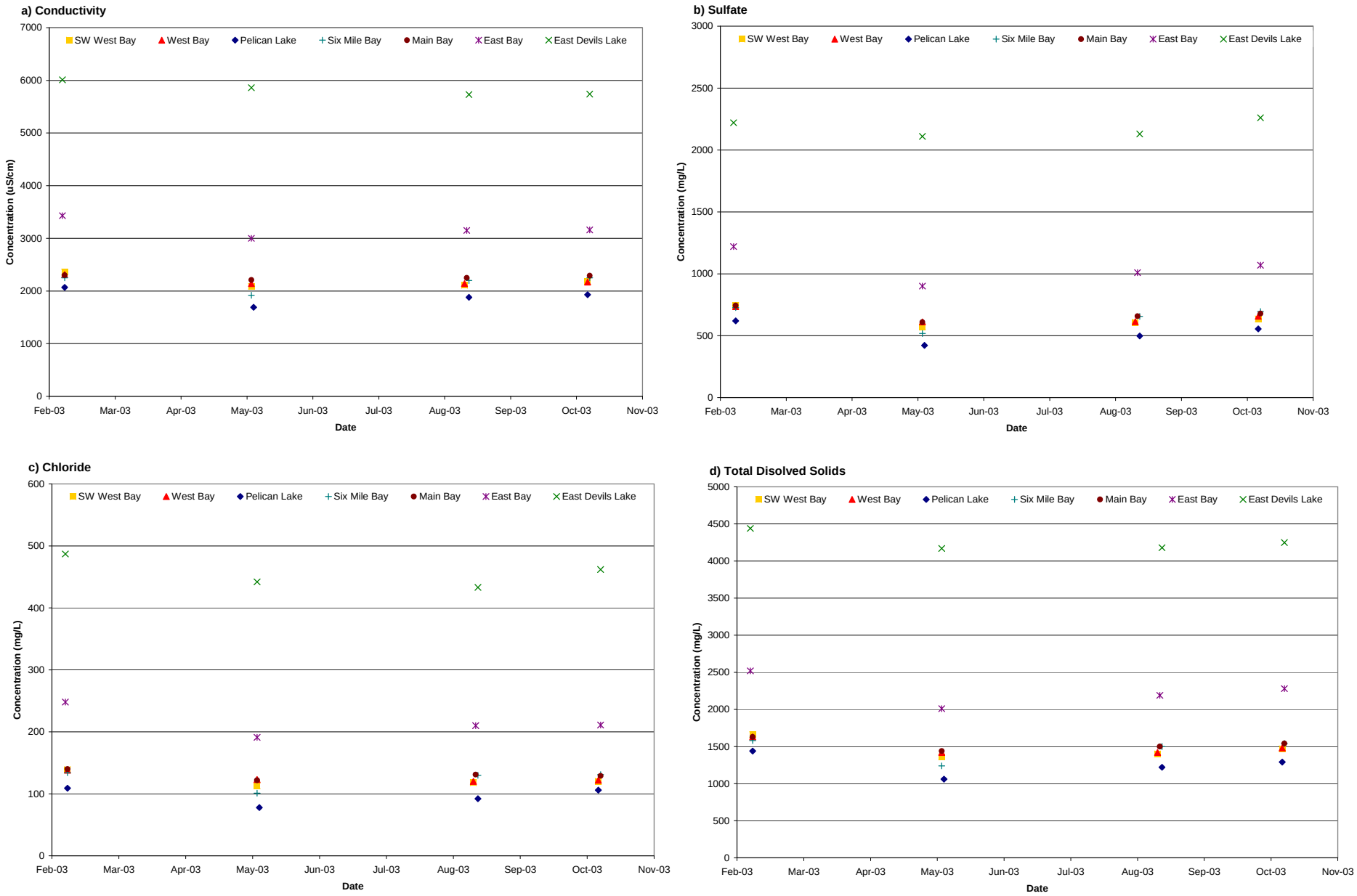
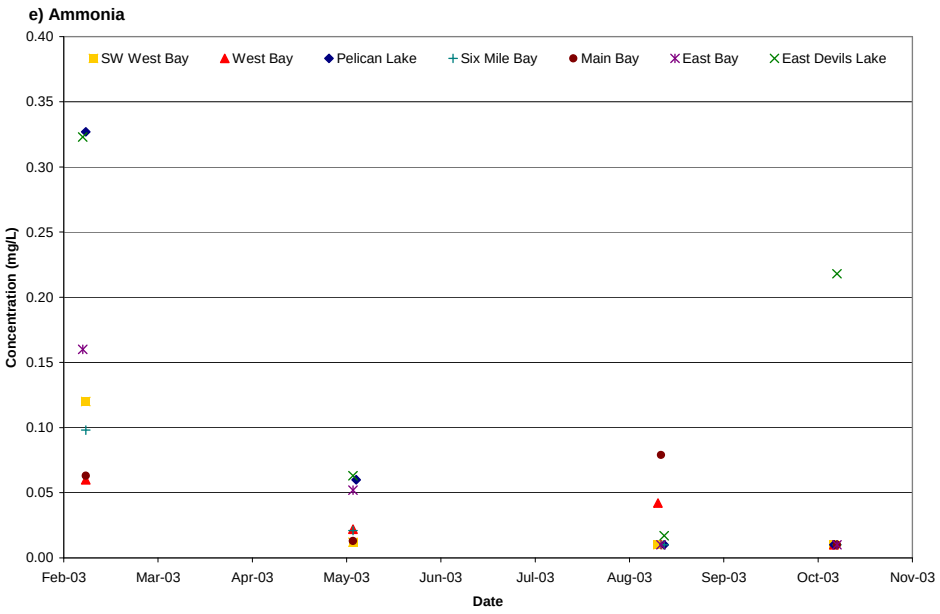
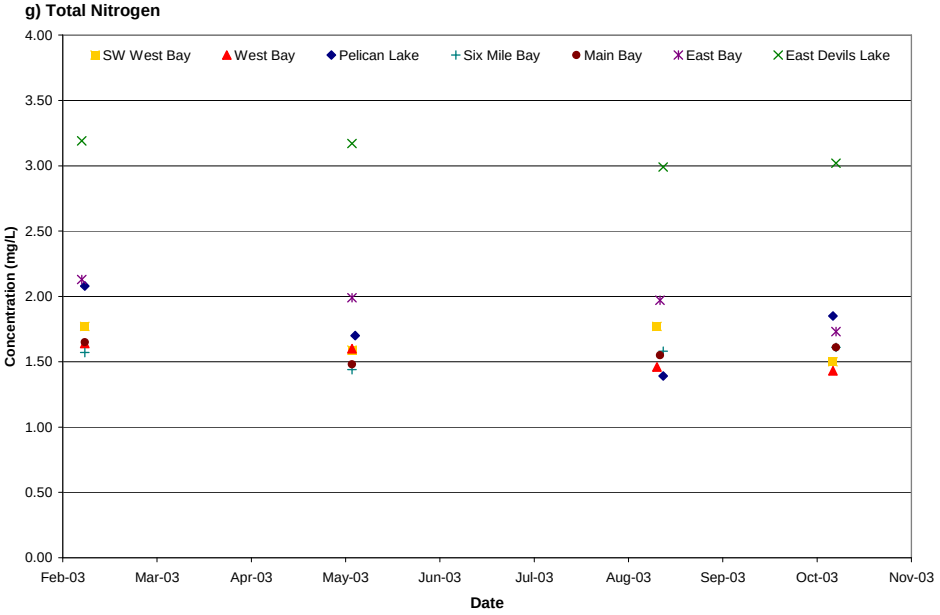
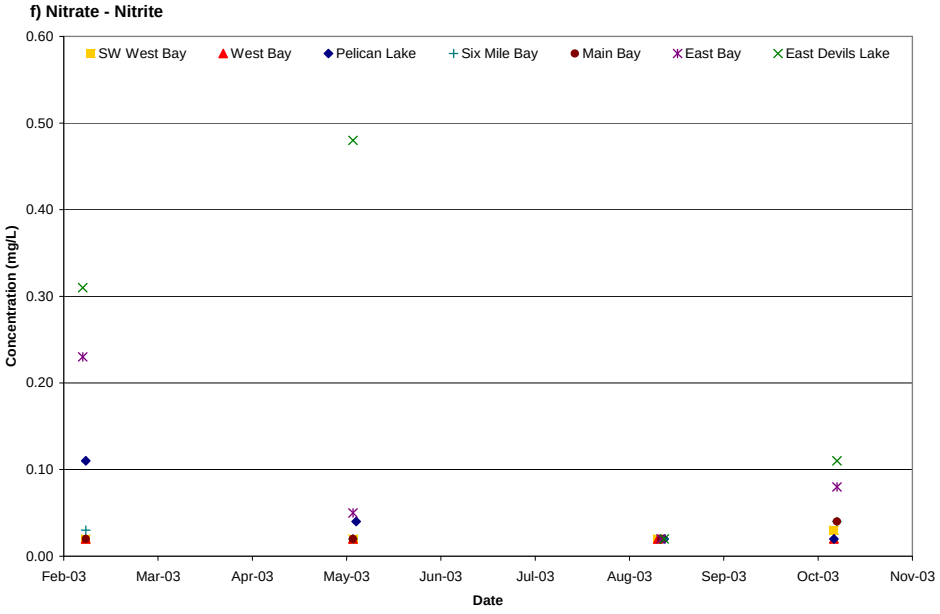
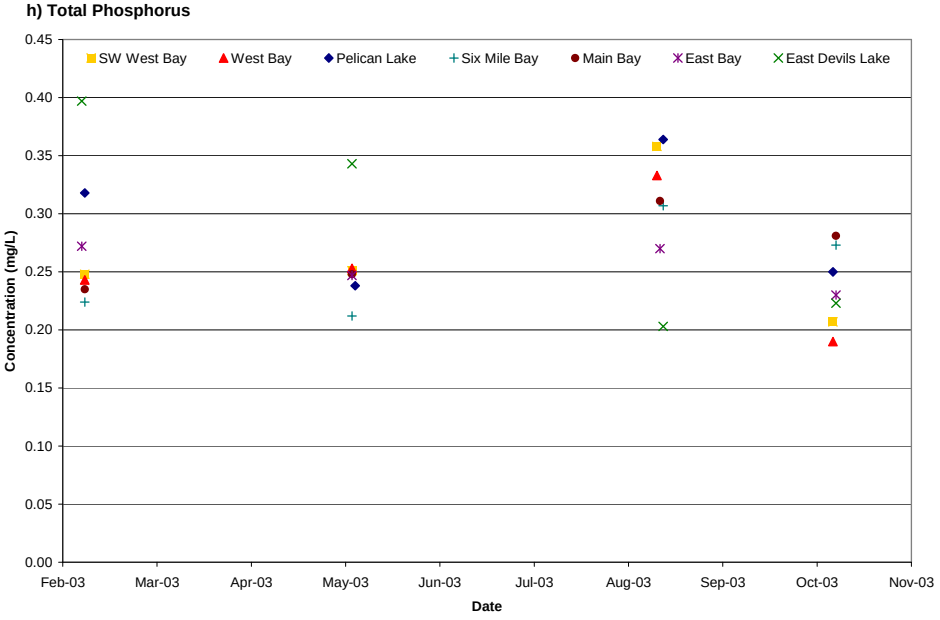


Figure 4. Surface concentrations (collected at 1 meter) of selected parameters and Secchi depth for each Devils Lake sampling site and event in 2003.









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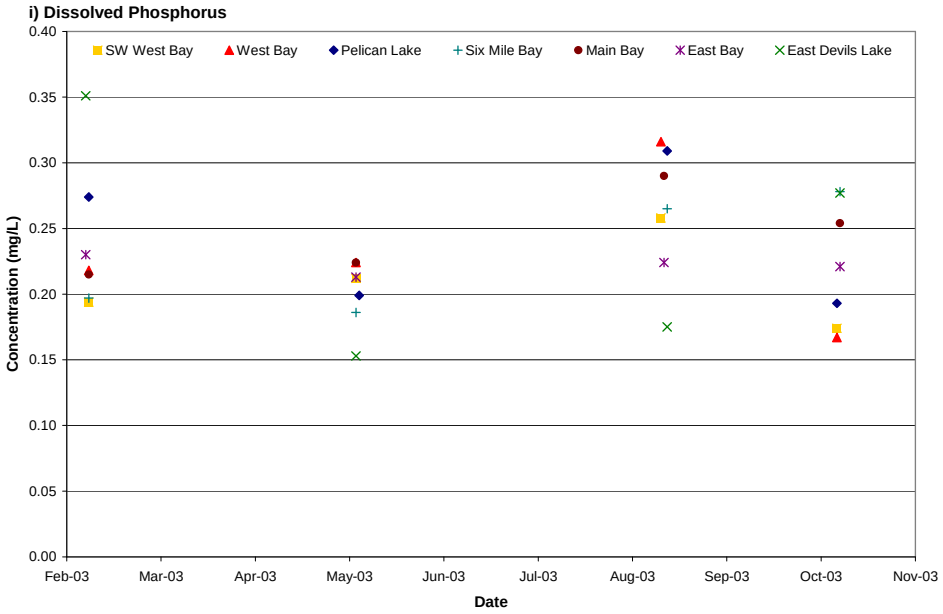

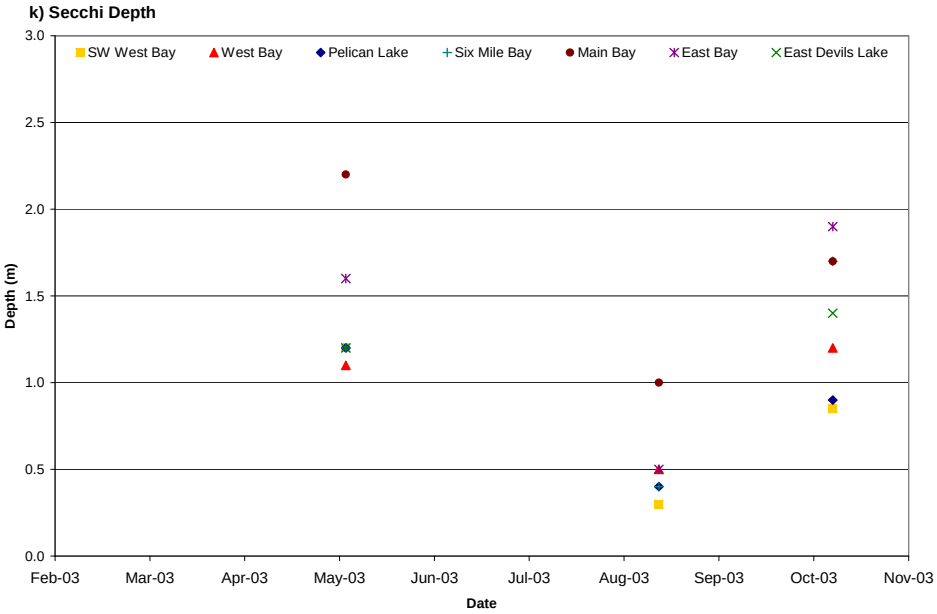

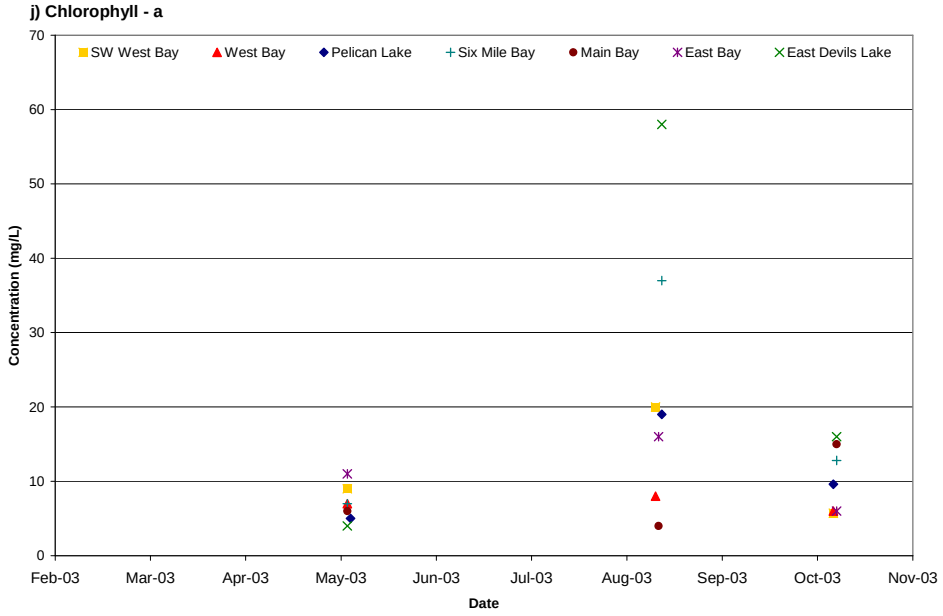

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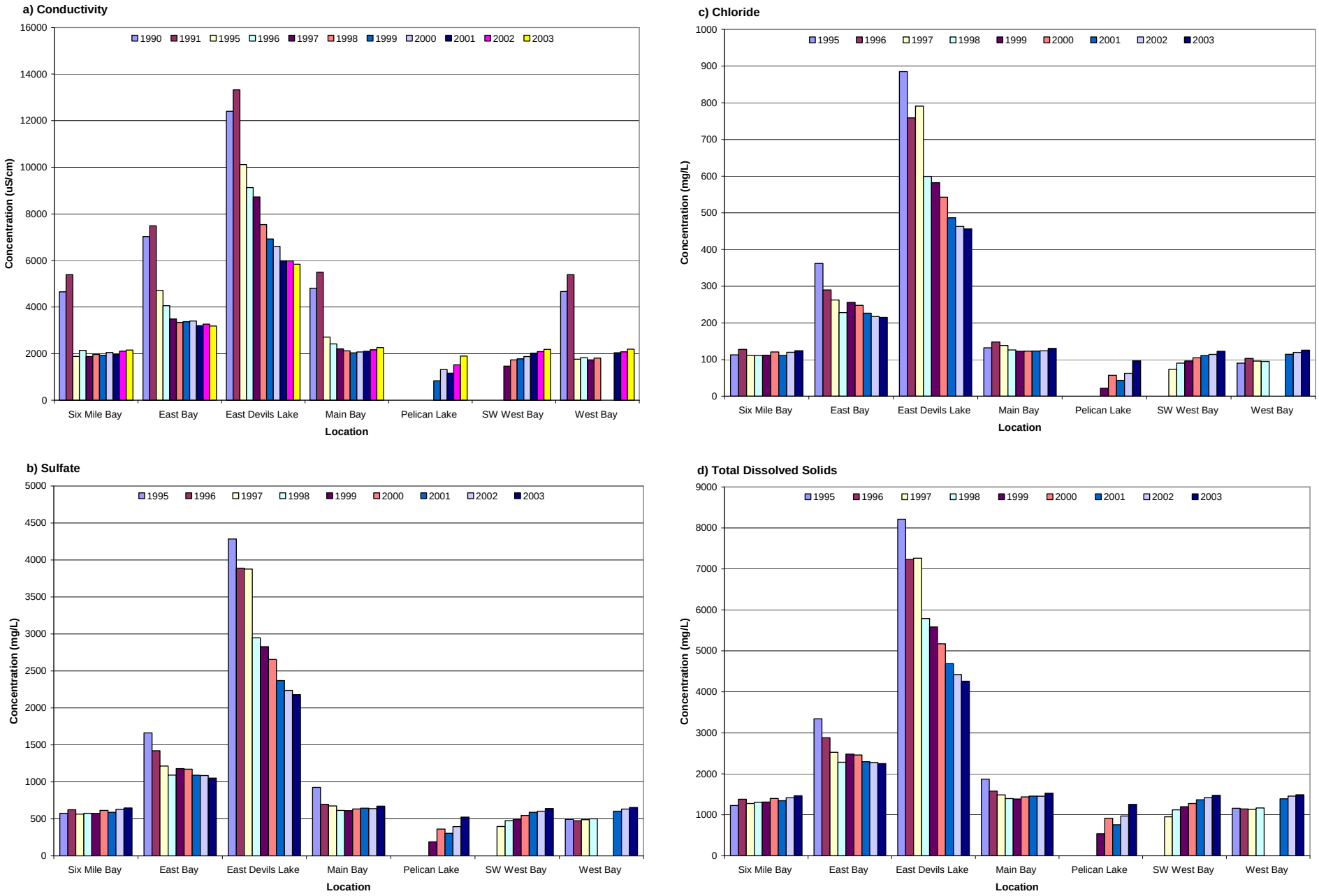
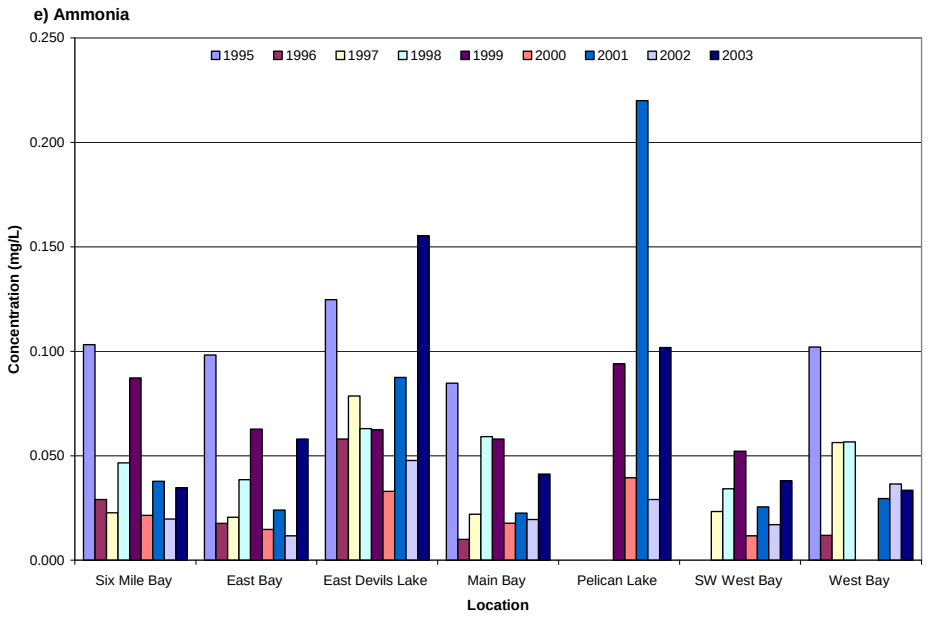
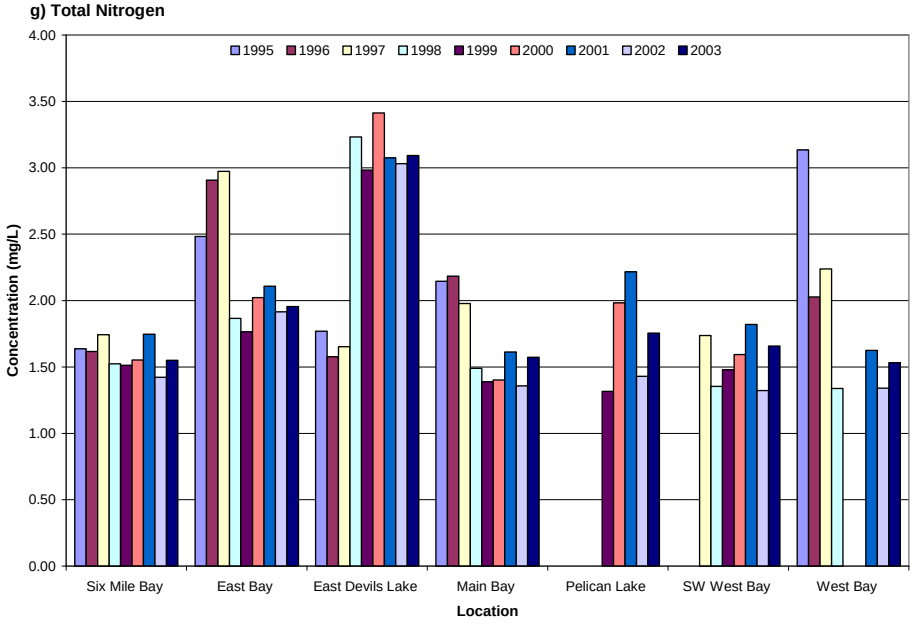
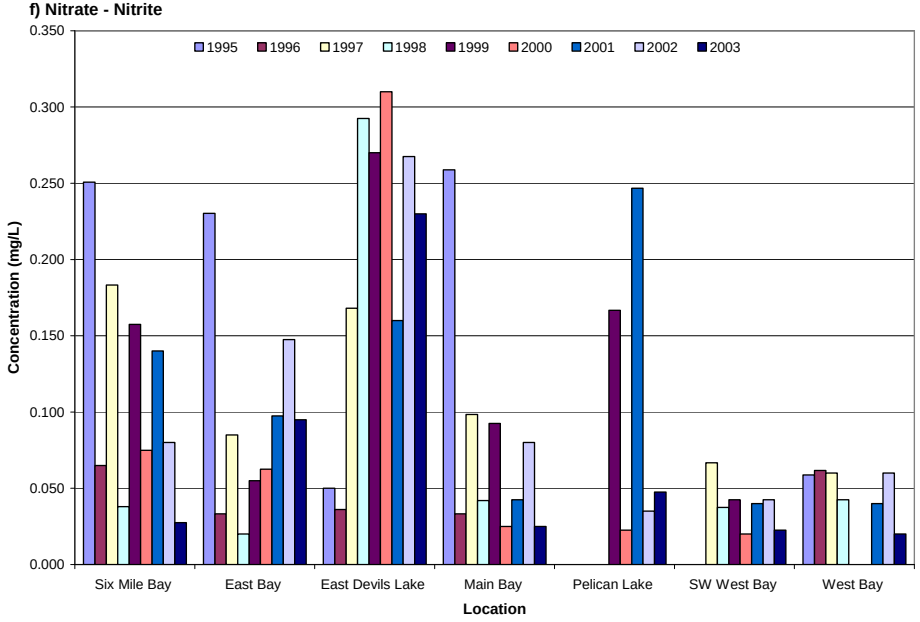
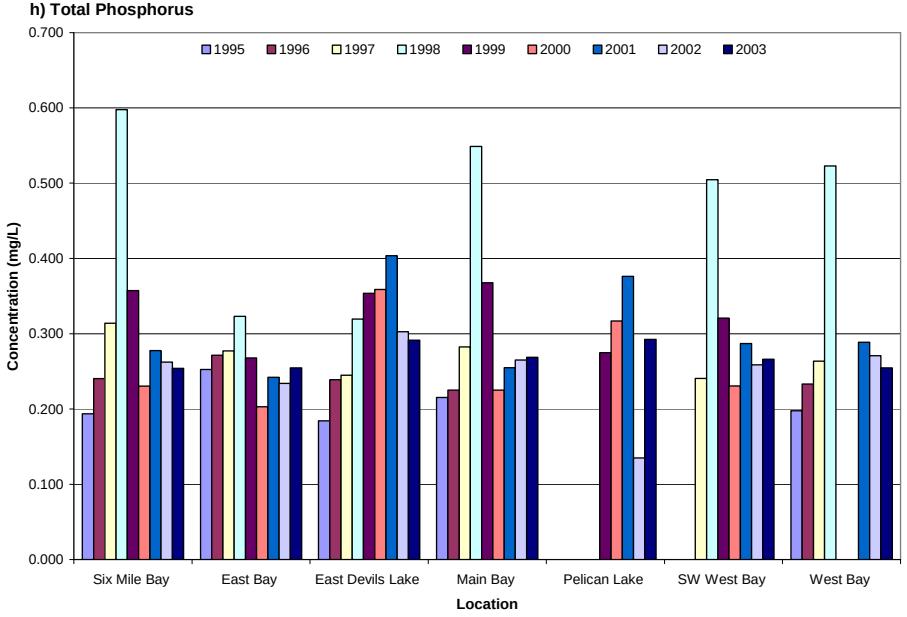


Figure 5. Annual mean concentration at current Devils Lake sampling sites of selected parameters for the period of 1995 – 2003.









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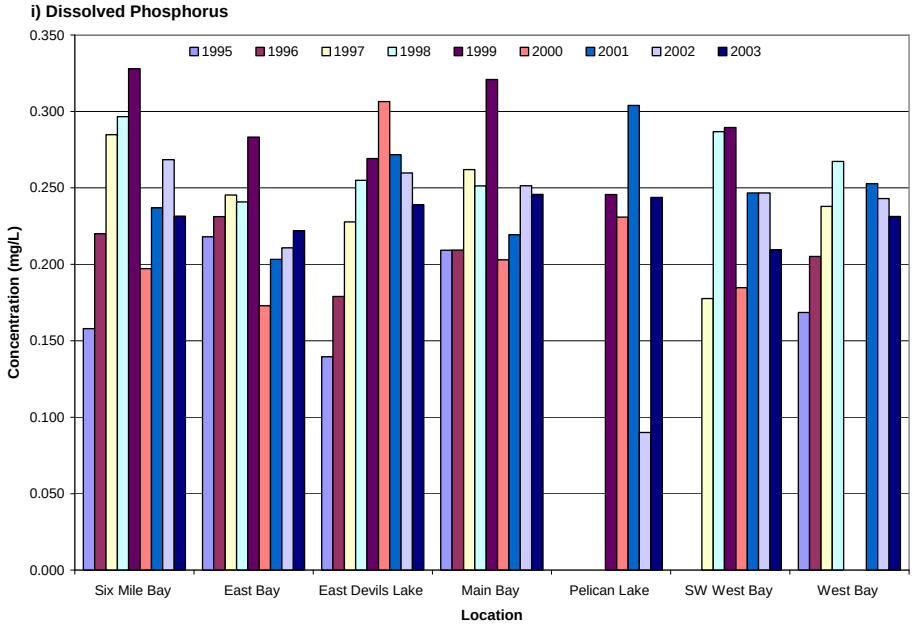

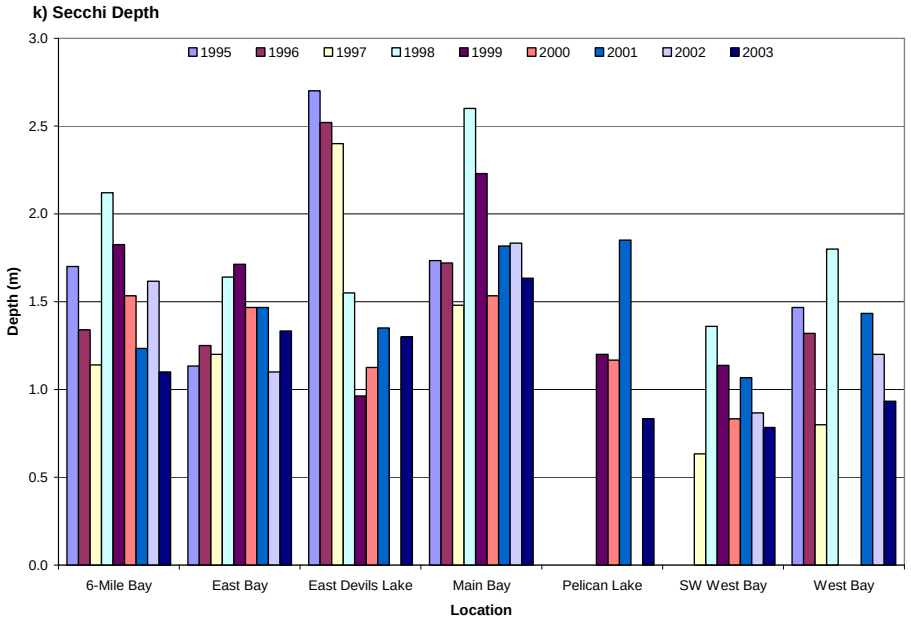

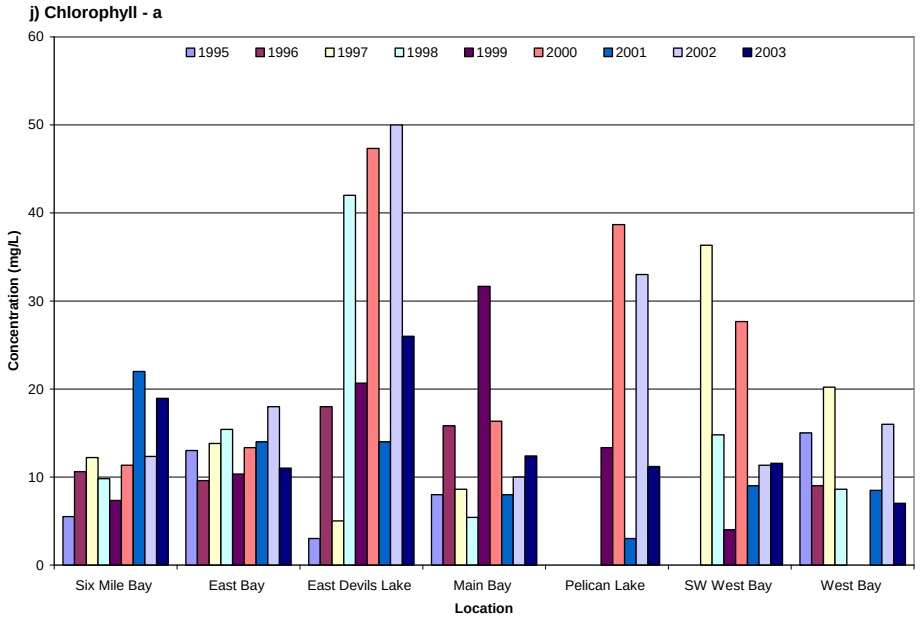

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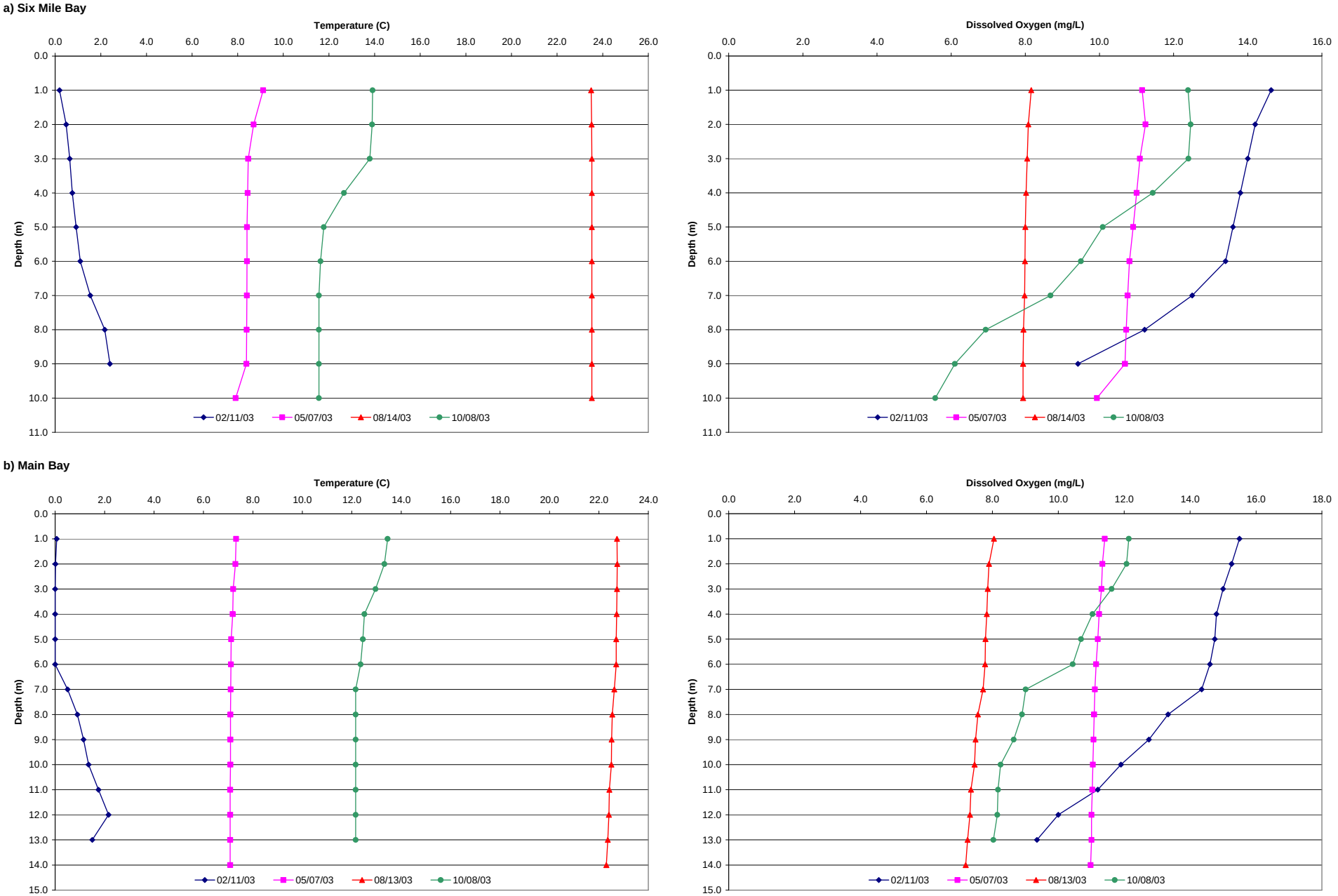
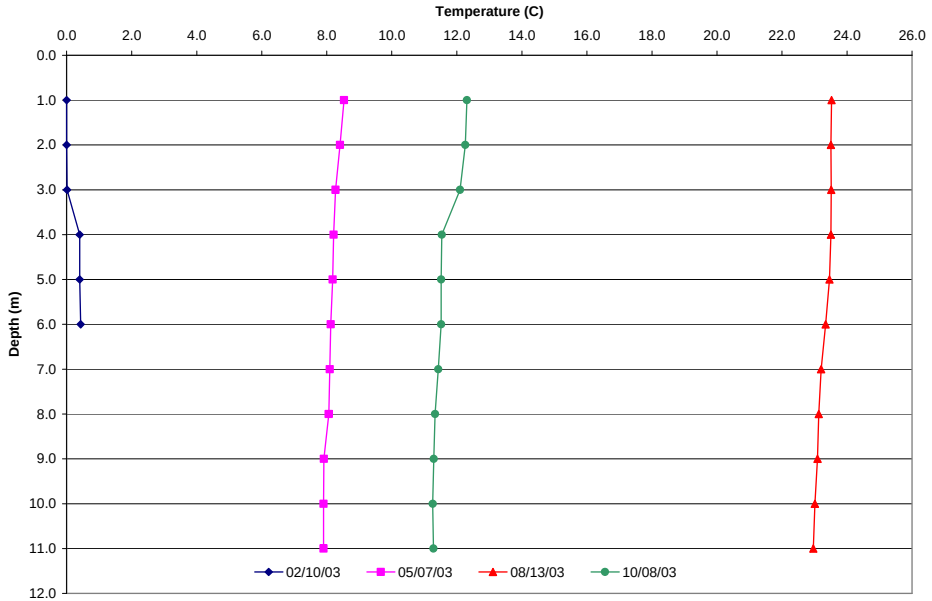
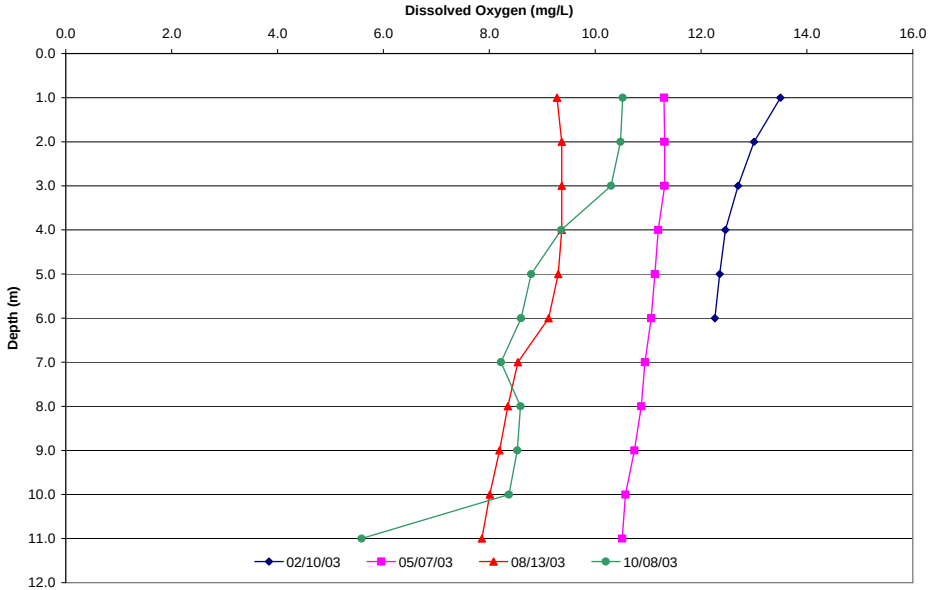


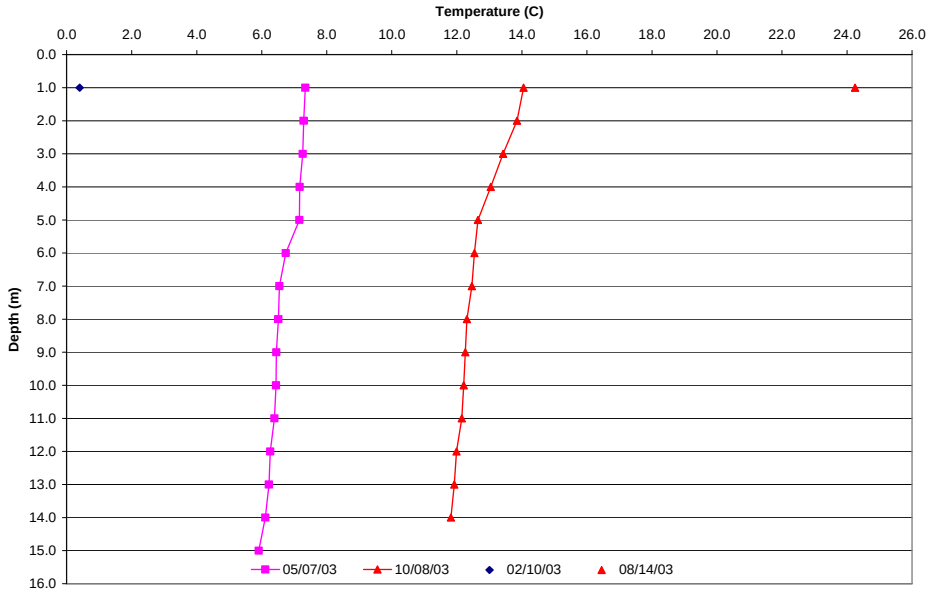
Figure 6. Temperature and dissolved oxygen profiles for each Devils Lake sampling site and event in 2003.

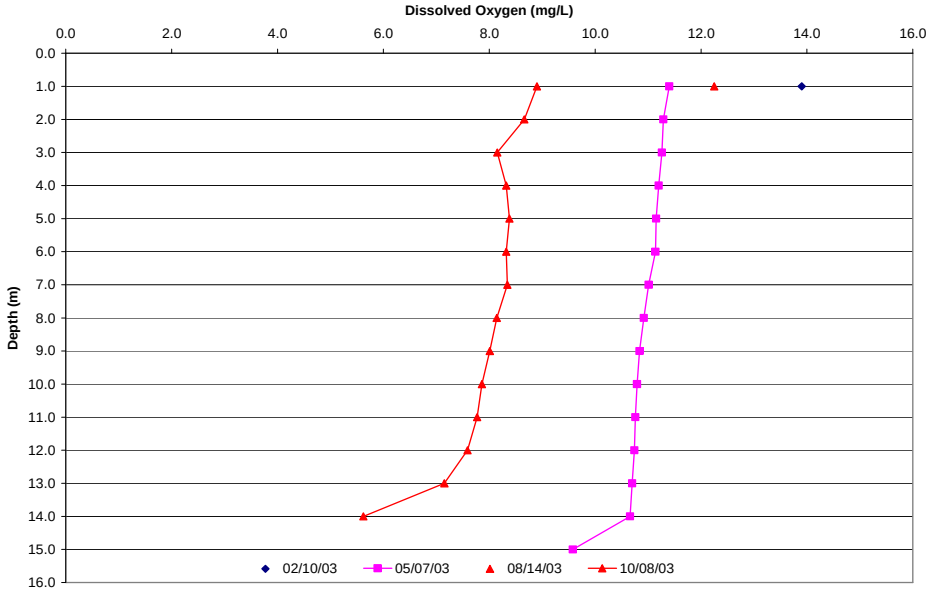
c) East Bay





d) East Devils Lake





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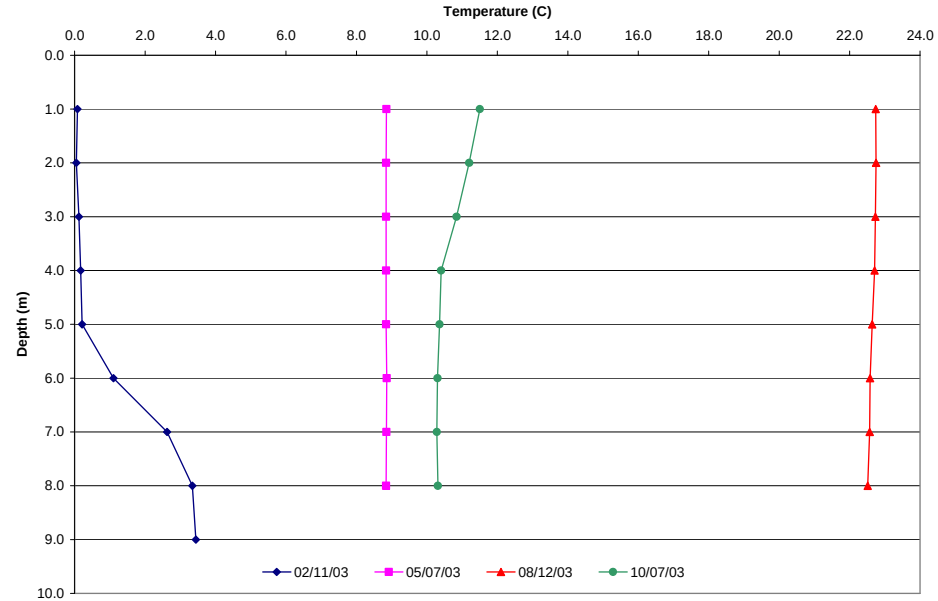
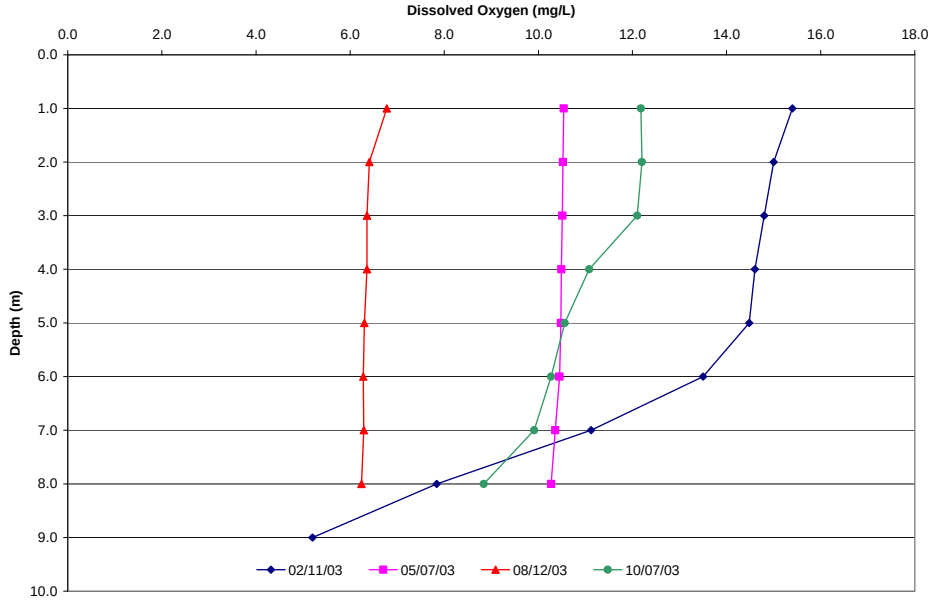
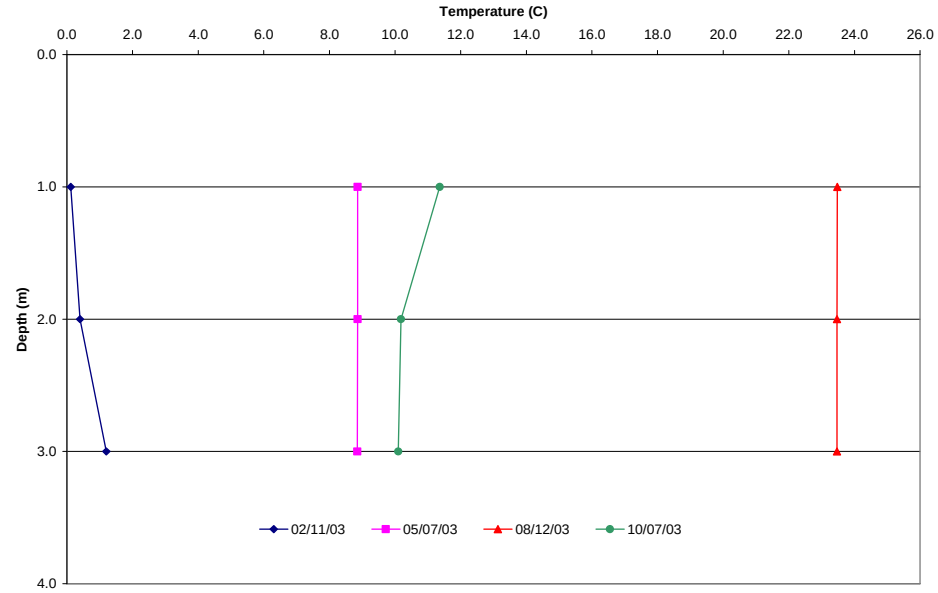
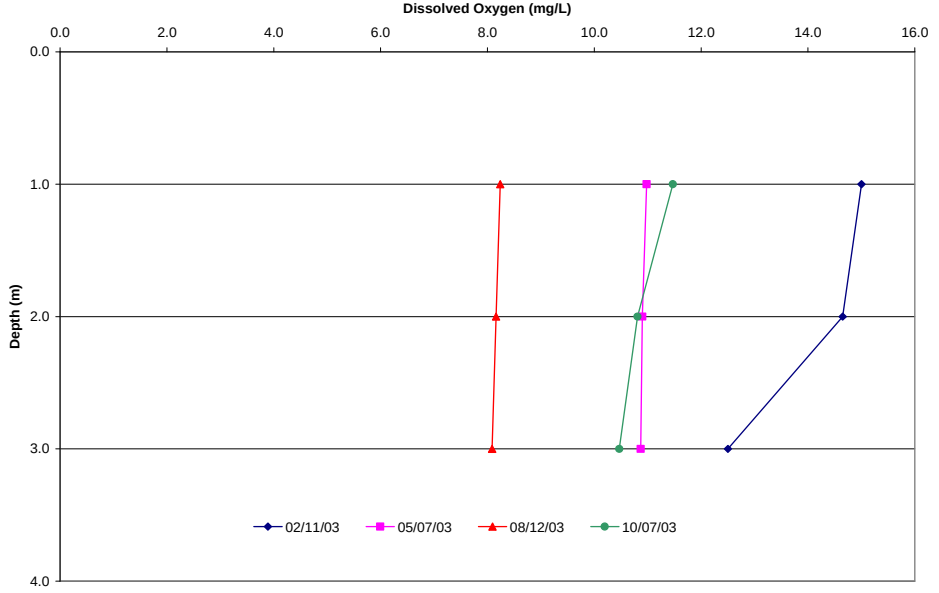
e) West Bay





f) SW West Bay





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g) Pelican Lake

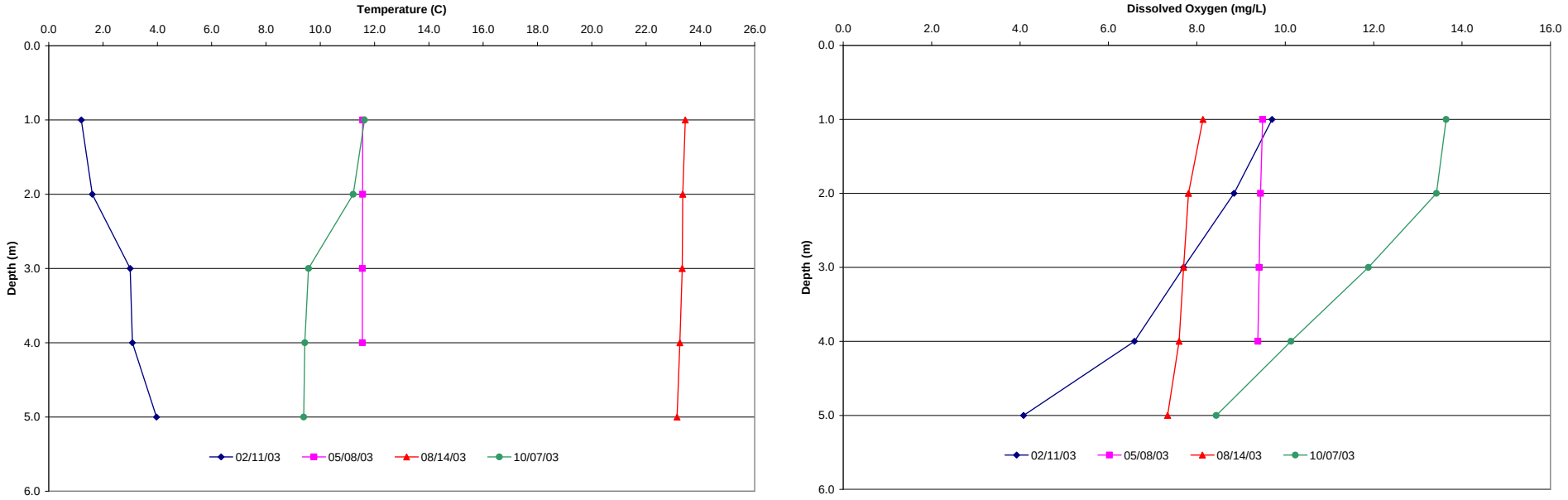

Figure 6. Continued

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Appendix A
Water Quality Results for Devils Lake 1995-2003

Devils Lake Report

Analyte	Collection Date	Detect Limit	Depth	380221	380233	380234	380235	380236	384160	385029
Ammonia (N)										
	3/15/1995		0.5	0.258	0.214	0.18	0.39	0.281		
	5/15/1995		1	0.055	0.056	0.023	0.035	0.107		
	7/25/1995	0.010	1	0.09	0.059		0.033	*ND		
	7/27/1995		1			0.18				
	10/3/1995	0.010	1	*ND	*ND	*ND	0.041	*ND		
	3/25/1996	0.010	1	*ND	*ND	*ND		*ND		
	5/20/1996	0.010	1	*ND	*ND	0.016	0.012	0.021		
	6/4/1996		1	0.085	0.038	0.101	0.062	0.136		
	6/4/1996		0	0.085	0.038	0.101	0.062	0.136		
	6/17/1996	0.010	1		*ND					
	7/1/1996	0.010	1	*ND	*ND	0.03	0.055	*ND		
	8/5/1996	0.010	1	*ND	*ND	*ND	*ND	*ND		
	9/3/1996	0.010	1	0.078	*ND	0.03	0.062	*ND		
	9/30/1996	0.010	1	0.056	*ND	*ND	0.151	*ND		
	3/4/1997		1	0.01	0.051	0.037	0.243	0.121		
	5/14/1997	0.010	1	0.061	0.029	*ND	0.042	*ND		
	7/8/1997	0.010	1	*ND	*ND	*ND		0.177		
	7/16/1997	0.010	1				*ND			
	8/4/1997	0.010	1	*ND	*ND	*ND	*ND	*ND	*ND	
	9/2/1997	0.010	1	0.035	0.022	0.029	0.088	*ND	0.05	
	10/6/1997	0.010	1	*ND	*ND	0.027		*ND	*ND	
	5/19/1998		1	0.047	0.156	0.099	0.058	0.167	0.098	
	7/6/1998	0.010	1	*ND	*ND	*ND	*ND	*ND	*ND	
	8/3/1998	0.010	1	0.085	0.033	0.064	*ND	0.047	0.021	
	9/8/1998	0.010	1	*ND	0.022	*ND		0.021	*ND	
	10/19/1998	0.010	1	0.081	0.075	*ND		0.038	0.032	
	10/21/1998		1				0.174			
	2/23/1999		1	0.154	0.104	0.057	0.162	0.095	0.056	
	5/25/1999		1	0.175	0.108	0.174	0.068		0.133	0.262
	8/2/1999	0.010	1	*ND	*ND	*ND	*ND		*ND	*ND
	10/11/1999	0.010	1	*ND	*ND	*ND	*ND		*ND	*ND
	2/14/2000		1	0.045	0.041	0.029	0.102		0.017	0.021
	5/2/2000	0.010	1	*ND	*ND	*ND	*ND		*ND	0.117
	8/1/2000	0.010	1	0.021	*ND	*ND	*ND		*ND	*ND
	10/9/2000	0.010	1	*ND	*ND	*ND	*ND	*ND	*ND	*ND
	3/19/2001		1	0.046	0.03	0.019	0.042	0.046	0.035	0.421
	5/14/2001	0.010	1	*ND	*ND	*ND	*ND	*ND	*ND	0.197

Analyte	Collection Date	Detect Limit	Depth	380221	380233	380234	380235	380236	384160	385029
	8/6/2001		1	0.059	0.039	0.037	0.11	0.052	0.044	0.042
	10/10/2001	0.010	1	0.036	0.011	0.03	0.188	*ND	0.013	0.028
	2/11/2002	0.010	1	*ND	*ND	*ND	0.119	*ND	*ND	0.075
	5/13/2002		1	0.046	0.027	0.017	0.051	0.116	0.038	0.021
	8/13/2002	0.010	1	0.013	0.031	*ND	0.011	*ND	*ND	*ND
	10/7/2002	0.010	1	*ND	*ND	*ND	*ND	*ND	*ND	*ND
Chloride										
	3/15/1995		0.5	62	20.4	330	975	101		
	5/15/1995		1	104	182	379	858	91.5		
	7/25/1995		1	135	165	377	867	76.1		
	10/3/1995		1	151	161	362	840	93.1		
	3/25/1996		1	164	177	207		127		
	5/20/1996		1	110	155	292	741	108		
	6/4/1996		1	95.8	158	302	738	99		
	6/4/1996		0	95.8	158	302	738	99		
	7/1/1996		1	97.2	141	321	788	94.8		
	8/5/1996		1	126	123	301	701	96.9		
	9/3/1996		1	137	148	330	816	95.8		
	9/30/1996		1	133	144	289	749	94.9		
	3/4/1997		1	146	150	251	860	131		
	5/14/1997		1	64.6	151	292	903	97.8		
	7/8/1997		1	112	127	248		79.6		
	7/16/1997		1				742			
	8/4/1997		1	111	129	278	721	85.3	71.6	
	9/2/1997		1	116	137	252	728	92.2	67.9	
	10/6/1997		1	118	136	254		88	82	
	5/19/1998		1	102	137	207	659	89.5	79.3	
	7/6/1998		1	105	122	210	565	89.7	84.4	
	8/3/1998		1	115	119	232	568	98.9	93.4	
	9/8/1998		1	111	125	238		97	99.3	
	10/19/1998		1	120	128	254	606	98.5	95.6	
	2/23/1999		1	130	140	277	631	123	118	
	5/25/1999		1	93.3	121	249	573		85.9	18.6
	8/2/1999		1	108	110	247	555		85.5	25.8
	10/11/1999		1	116	119	252	570		94.7	20.9
	2/14/2000		1	121	125	267	566		107	29.2
	5/2/2000		1	115	118	243	545		97.9	55.8
	8/1/2000		1	122	124	238	539		107	69.7
	10/9/2000		1	125	124	243	520	108	108	73.3
	3/19/2001		1	128	124	199	436	120	121	33.2
	5/14/2001		1	83	126	250	487	115	108	38

Analyte	Collection Date	Detect Limit	Depth	380221	380233	380234	380235	380236	384160	385029
	8/6/2001		1	113	117	221	497	109	103	59.1
	10/10/2001		1	121	126	236	526	114	112	59.8
	2/11/2002		1	126	127	226	513	126	124	62.5
	5/13/2002		1	112	107	212	401	110	93.3	63.1
	8/13/2002		1	116	125	219	480	117	115	83
	10/7/2002		1	126	136	212	457	126	125	41.7
Chlorophyll A										
	7/25/1995	3.000	0	8	13		*ND	21		
	7/27/1995		0			23				
	10/3/1995	3.000	0	*ND	*ND	*ND	*ND	9		
	5/20/1996	3.000	0	16	5	7	15	*ND		
	6/4/1996	3.000	1	*ND	*ND	*ND	*ND	*ND		
	6/4/1996	3.000	0	*ND	*ND	*ND	*ND	*ND		
	7/1/1996	3.000	0	6	52	*ND	*ND	14		
	8/5/1996		0	9	12	22	25	11		
	9/3/1996		0	19	16	11	11	6		
	9/30/1996	3.000	0	*ND	*ND			11		
	10/2/1996		0			5	36			
	5/14/1997	3.000	0	23	14	10	*ND	19		
	7/8/1997	3.000	0	*ND	*ND	36		6		
	7/16/1997		0				4			
	8/4/1997	3.000	0	11	7	6	*ND	42	42	
	9/2/1997		0	15	9	12	10	19	25	
	10/6/1997		0	9	10	5		15	42	
	5/19/1998	3.000	0	6	*ND	*ND	5	*ND	*ND	
	7/6/1998	3.000	0	18	*ND	11	*ND	7	11	
	8/3/1998		0	9	12	16	140	18	21	
	9/8/1998	3.000	0	13	5			*ND		
	9/10/1998		0			18			19	
	10/19/1998	3.000	0	*ND	4	29	20	12	20	
	5/25/1999	3.000	0	*ND	*ND	*ND	*ND		*ND	*ND
	8/2/1999	3.000	0	*ND	16	5	*ND		*ND	9
	10/11/1999	6.000	0	16	76	23	56		*ND	28
	5/2/2000	3.000	0	8	11	9	24		9	*ND
	8/1/2000		0	16	14	12	77		57	78
	10/9/2000		0	10	24	19	41	11	17	35
	5/14/2001	6.000	0	30	14			*ND	*ND	
	5/15/2001	3.000	0			9	20			*ND
	10/10/2001		0	14	7	19	8	11	12	
	5/13/2002	3.000	0	*ND	*ND	8	9	*ND	6	22
	8/13/2002		0	23	15	36	108	27	16	35

Analyte	Collection Date	Detect Limit	Depth	380221	380233	380234	380235	380236	384160	385029
	10/7/2002		0	11	9	10	33	18	12	42
Conductivity										
	3/15/1995		0.5	1040	3060	4480	11000	2100		
	5/15/1995		1	1800	2830	4780	9900	1700		
	7/25/1995		1	2270	2410	4790	9650	1500		
	10/3/1995		1	2410	2560	4820	9920	1760		
	3/25/1996		1	2660	2730	3140		2100		
	5/20/1996		1	1870	2450	4180	8980	1870		
	6/4/1996		0	1740	2440	4270	9170	1800		
	6/4/1996		1	1740	2440	4270	9170	1800		
	7/1/1996		1	1830	2330	4300	9270	1760		
	8/5/1996		1	2060	2280	4130	8950	1720		
	9/3/1996		1	2180	2310	4280	9070	1730		
	9/30/1996		1	2250	2400	4320	9370	1800		
	3/4/1997		1	2490	2540	3670	9820	2360		
	5/14/1997		1	1250	2320	3860	8920	1710		
	7/8/1997		1	1900	2090	3410		1530		
	7/16/1997		1				8380			
	8/4/1997		1	1840	2050	3350	8210	1540	1360	
	9/2/1997		1	1820	2080	3290	8310	1600	1440	
	10/6/1997		1	1950	2160	3330		1650	1580	
	5/19/1998		1	1890	2130	3150	8020	1740	1620	
	7/6/1998		1	1940	2130	3280	7530	1780	1700	
	8/3/1998		1	1990	2120	3400	7390	1810	1750	
	9/8/1998		1	1960	2100	3390		1860	1790	
	10/19/1998		1	2060	2130	3480	7230	1850	1800	
	2/23/1999		1	2190	2240	3720	7510	2120	2120	
	5/25/1999		1	1670	2000	3100	6750		1600	702
	8/2/1999		1	1900	1920	3310	6720		1640	864
	10/11/1999		1	1930	1970	3350	6710		1730	932
	2/14/2000		1	2080	2110	3580	6810		1940	1310
	5/2/2000		1	2000	2030	3380	6530		1780	1300
	8/1/2000		1	2000	2020	3290	6480		1810	1420
	10/9/2000		1	2120	2130	3360	6610	1930	1960	1250
	3/19/2001		1	2290	2260	3150	5950	2250	2310	1120
	5/14/2001		1	1540	2020	3240	5860	1980	1890	1070
	8/6/2001		1	1960	2010	3170	6000	1930	1880	1290
	10/10/2001		1	2050	2110	3240	6150	2000	1990	1330
	2/11/2002		1	2210	2200	3450	6380	2190	2240	1610
	5/13/2002		1	2080	2130	3200	5890	2000	1960	1520
	8/13/2002		1	2040	2170	3250	5970	2080	2070	1700

Analyte	Collection Date	Detect Limit	Depth	380221	380233	380234	380235	380236	384160	385029
	10/7/2002		1	2080	2160	3160	5700	2050	2060	1250
Dissolved Phosphorus as P										
	3/15/1995		0.5				0.176	0.277		
	7/25/1995		1	0.253	0.222	0.254	0.13	0.188		
	10/3/1995		1	0.197	0.202	0.267	0.179	0.139		
	3/25/1996		1	0.201	0.148	0.173		0.253		
	5/20/1996		1	0.131	0.166	0.193	0.115	0.139		
	6/4/1996		0	0.183	0.188	0.241	0.167	0.222		
	6/4/1996		1	0.183	0.188	0.241	0.167	0.222		
	6/17/1996		1		0.183					
	7/1/1996		1	0.244	0.193	0.261	0.187	0.206		
	8/5/1996		1	0.24	0.25	0.295	0.179	0.271		
	9/3/1996		1	0.228	0.241	0.233	0.2	0.238		
	9/30/1996		1	0.276	0.258	0.232	0.214	0.124		
	3/4/1997		1	0.282	0.243	0.291	0.261	0.143		
	5/14/1997		1	0.294	0.304	0.216	0.312	0.249		
	7/8/1997		1	0.299	0.242	0.261		0.223		
	7/16/1997		1				0.185			
	8/4/1997		1	0.256	0.229	0.234	0.157	0.295	0.173	
	9/2/1997		1	0.318	0.306	0.254	0.224	0.3	0.238	
	10/6/1997		1	0.26	0.248	0.216		0.218	0.122	
	5/19/1998		1	0.22	0.23	0.223	0.256	0.218	0.206	
	7/6/1998		1	0.194	0.193	0.179	0.272	0.186	0.205	
	8/3/1998		1	0.341	0.276	0.3	0.22	0.352	0.322	
	9/8/1998		1	0.29	0.296	0.29		0.352	0.318	
	10/19/1998		1	0.438	0.262	0.212	0.272	0.229	0.383	
	2/23/1999		1	0.469	0.486	0.413	0.294	0.431	0.404	
	5/25/1999		1	0.265	0.296	0.244	0.317		0.317	0.25
	8/2/1999		1	0.315	0.258	0.3	0.242		0.276	0.334
	10/11/1999		1	0.263	0.244	0.176	0.224		0.161	0.153
	2/14/2000		1	0.156	0.177	0.157	0.338		0.148	0.106
	5/2/2000		1	0.173	0.181	0.16	0.3		0.173	0.205
	8/1/2000		1	0.206	0.249	0.193	0.268		0.221	0.38
	10/9/2000		1	0.254	0.205	0.182	0.32	0.208	0.197	0.233
	3/19/2001		1	0.179	0.155	0.197	0.325	0.181	0.199	0.315
	5/14/2001		1	0.207	0.162	0.165	0.203	0.208	0.194	0.26
	8/6/2001		1	0.27	0.262	0.223	0.231	0.32	0.296	0.337
	10/10/2001		1	0.292	0.299	0.228	0.328	0.302	0.298	0.058
	2/11/2002		1	0.206	0.237	0.172	0.26	0.21	0.211	0.008
	5/13/2002		1	0.331	0.237	0.194	0.279	0.241	0.227	0.056
	8/13/2002		1	0.298	0.287	0.244	0.257	0.286	0.268	0.256

Analyte	Collection Date	Detect Limit	Depth	380221	380233	380234	380235	380236	384160	385029
	10/7/2002		1	0.239	0.245	0.233	0.243	0.235	0.281	0.04
Dissolved Solids(C)-Total										
	3/15/1995		0.5	638	1890	3090	9000	1400		
	5/15/1995		1	1070	1840	3270	7570	1000		
	7/25/1995		1	1440	1880	3410	8120	960		
	10/3/1995		1	1760	1870	3600	8160	1280		
	3/25/1996		1	1890	1790	2260		1350		
	5/20/1996		1	1090	1500	2750	7650	1110		
	6/4/1996		0	1110	1640	3040	7750	1140		
	6/4/1996		1	1110	1640	3040	7750	1140		
	7/1/1996		1	1150	1530	3060	7520	1110		
	8/5/1996		1	1290	1450	2910	7300	1110		
	9/3/1996		1	1470	1720	3450	7030	1080		
	9/30/1996		1	1380	1490	2850	6660	1090		
	3/4/1997		1	1790	1550	2610	8200	1450		
	5/14/1997		1	812	1660	2910	7860	1160		
	7/8/1997		1	1250	1370	2430		981		
	7/16/1997		1				6740			
	8/4/1997		1	1300	1490	2570	6860	1090	944	
	9/2/1997		1	1200	1400	2280	6640	1020	902	
	10/6/1997		1	1300	1440	2350		1080	1010	
	5/19/1998		1	1230	1360	2140	6310	1100	1050	
	7/6/1998		1	1260	1390	2170	5620	1130	1090	
	8/3/1998		1	1290	1340	2240	5500	1150	1110	
	9/8/1998		1	1310	1440	2380		1250	1160	
	10/19/1998		1	1430	1460	2480	5730	1210	1190	
	2/23/1999		1	1480	1490	2750	6080	1490	1450	
	5/25/1999		1	1130	1390	2340	5430		1090	447
	8/2/1999		1	1290	1300	2380	5380		1110	564
	10/11/1999		1	1340	1360	2460	5450		1140	596
	2/14/2000		1	1440	1470	2590	5410		1330	865
	5/2/2000		1	1360	1420	2450	5180		1230	851
	8/1/2000		1	1400	1420	2380	5110		1250	936
	10/9/2000		1	1400	1440	2420	4990	1310	1300	1020
	3/19/2001		1	1540	1500	2180	4540	1470	1510	721
	5/14/2001		1	1050	1440	2350	4590	1380	1310	699
	8/6/2001		1	1360	1410	2240	4700	1340	1290	854
	10/10/2001		1	1430	1480	2420	4930	1370	1350	877
	2/11/2002		1	1540	1520	2400	4800	1530	1540	1030
	5/13/2002		1	1380	1320	2210	4050	1340	1230	945
	8/13/2002		1	1360	1490	2280	4550	1460	1460	1090

Analyte	Collection Date	Detect Limit	Depth	380221	380233	380234	380235	380236	384160	385029
	10/7/2002		1	1370	1490	2220	4290	1500	1450	822
Nitrate + Nitrite (N)										
	3/25/1996		1	0.11	0.04	0.07		0.27		
	5/20/1996	0.020	1	*ND	*ND	*ND	*ND	*ND		
	6/4/1996	0.020	0	*ND	*ND	0.02	0.03	0.05		
	6/4/1996	0.020	1	*ND	*ND	0.02	0.03	0.05		
	6/17/1996	0.020	1		*ND					
	7/1/1996	0.020	1	0.03	*ND	0.03	0.06	0.02		
	8/5/1996	0.020	1	*ND	*ND	*ND	*ND	*ND		
	9/3/1996	0.020	1	*ND	*ND	*ND	*ND	*ND		
	9/30/1996	0.020	1	0.19	0.08			*ND		
	10/2/1996		1			0.04	0.06			
	3/4/1997		1	0.5	0.24	0.33	0.26	0.09		
	5/14/1997	0.020	1	0.29	0.11	*ND	0.51	*ND		
	7/8/1997		1	0.06	0.04	0.02		0.05		
	7/16/1997	0.020	1				*ND			
	8/4/1997	0.020	1	*ND	*ND	*ND	*ND	*ND	*ND	
	9/2/1997		1	0.04	0.03	0.02	0.03	0.05	0.07	
	10/6/1997		1	0.19	0.15	0.1		0.13	0.11	
	5/19/1998		1	0.1	0.08		0.57			
	7/6/1998	0.020	1	*ND	*ND	*ND	0.37	0.04	0.08	
	8/3/1998	0.020	1	0.03	*ND	*ND	*ND	0.03	*ND	
	9/8/1998	0.020	1	*ND	*ND	*ND		0.04	0.03	
	10/19/1998	0.020	1	*ND	0.07	0.02		0.06	0.02	
	10/21/1998		1				0.21			
	2/23/1999	0.020	1	0.3	0.2	0.13	0.46	0.05	*ND	
	5/25/1999		1	0.22	0.13	0.05	0.48		0.11	0.22
	8/2/1999	0.020	1	*ND	*ND	*ND	*ND		*ND	*ND
	10/11/1999	0.020	1	0.09	*ND	*ND	0.12		*ND	0.26
	2/14/2000	0.020	1	0.06	*ND	0.02	0.48		*ND	*ND
	5/2/2000	0.020	1	*ND	*ND	*ND	0.48		*ND	0.03
	8/1/2000	0.020	1	0.02	*ND	*ND	*ND		*ND	*ND
	10/9/2000		1	0.2	0.04	0.19	0.26	0.09	0.02	0.02
	3/19/2001		1	0.11	0.05	0.27	0.51	0.07	0.09	0.66
	5/14/2001	0.020	1	0.36	*ND	*ND	0.02	0.04	*ND	0.06
	8/6/2001	0.020	1	*ND	*ND	*ND	0.03	*ND	*ND	0.02
	10/10/2001		1	0.07	0.08	0.08	0.08	0.03	0.03	0.09
	2/11/2002		1	0.22	0.19	0.32	0.46	0.14	0.06	0.04
	5/13/2002	0.020	1	0.06	0.07	0.09	0.48	0.06	*ND	0.02
	8/13/2002	0.020	1	0.02	0.04	0.03	0.03	*ND	0.02	0.06
	10/7/2002		1	0.02	0.02	0.15	0.1	0.02	0.07	0.02

Analyte	Collection Date	Detect Limit	Depth	380221	380233	380234	380235	380236	384160	385029
Nitrogen (Total)										
	5/19/1998		1	1.83	1.95		4			
	7/6/1998		1	1.5	1.1	1.61	2.83	1.11	1.32	
	8/3/1998		1	1.42	1.33	1.8	3.12	1.59	1.55	
	9/8/1998		1	1.35	1.54	2.25		1.44	1.4	
	10/19/1998		1	1.52	1.53	1.8	2.98	1.21	1.14	
	2/23/1999		1	1.81	1.59	2.1	3.62	1.43	1.51	
	5/25/1999		1	1.67	1.6	1.94	3.14		2.02	1.5
	8/2/1999		1	1.34	1.18	1.49	2.3		1.26	1.05
	10/11/1999		1	1.23	1.18	1.53	2.87		1.12	1.4
	2/14/2000		1	1.49	1.37	1.98	3.31		1.46	2.3
	5/2/2000		1	1.4	1.3	1.93	3.3		1.41	1.64
	8/1/2000		1	1.71	1.52	2.01	3.02		1.98	2.35
	10/9/2000		1	1.61	1.42	2.17	4.02	1.58	1.52	1.64
	3/19/2001		1	1.66	1.51	2.12	3.34	1.69	2.01	2.54
	5/14/2001		1	1.7	1.45	1.95	2.46	1.47	1.51	1.56
	8/6/2001		1	2.09	1.97	2.48	3.74	1.8	2.17	2.55
	10/10/2001		1	1.54	1.52	1.88	2.76	1.54	1.59	1.53
	2/11/2002		1	1.83	1.46	2.38	4.45	1.47	1.49	1.93
	5/13/2002		1	1.38	1.37	1.8	2.84	1.53	1.53	1.48
	8/13/2002		1	1.09	1.35	1.61	2.42	1.09	1.02	1.23
	10/7/2002		1	1.39	1.25	1.87	2.42	1.27	1.25	1.08
Phosphorus (Total) (P)										
	3/15/1995		0.5	0.136	0.225	0.253	0.2	0.306		
	5/15/1995		1	0.125	0.178	0.191	0.176	0.101		
	7/25/1995		1	0.298	0.232	0.269	0.148	0.215		
	10/3/1995		1	0.216	0.226	0.297	0.213	0.169		
	3/25/1996		1	0.19	0.151	0.172		0.269		
	5/20/1996		1	0.174	0.195	0.243	0.181	0.176		
	6/4/1996		0	0.198	0.194	0.262	0.168	0.215		
	6/4/1996		1	0.198	0.194	0.262	0.168	0.215		
	6/17/1996		1		0.169					
	7/1/1996		1	0.27	0.217	0.298	0.216	0.239		
	8/5/1996		1	0.266	0.257	0.286	0.214	0.27		
	9/3/1996		1	0.247	0.262	0.34	0.232	0.281		
	9/30/1996		1	0.296	0.268	0.29	0.351	0.164		
	3/4/1997		1	0.303	0.244	0.32	0.276	0.158		
	5/14/1997		1	0.286	0.281	0.257	0.284	0.228		
	7/8/1997		1	0.315	0.303	0.309		0.253		
	7/16/1997		1				0.223			
	8/4/1997		1	0.315	0.223	0.219	0.186	0.381	0.269	

Analyte	Collection Date	Detect Limit	Depth	380221	380233	380234	380235	380236	384160	385029
	9/2/1997		1	0.354	0.332	0.277	0.255	0.314	0.262	
	10/6/1997		1	0.31	0.312	0.281		0.248	0.191	
	5/19/1998		1	0.926	0.948		0.266			
	7/6/1998		1	0.417	0.359	0.276	0.361	0.449	0.404	
	8/3/1998		1	0.824	0.717	0.265	0.326	0.77	0.851	
	9/8/1998		1	0.412	0.352	0.459		0.482	0.485	
	10/19/1998		1	0.409	0.368	0.292	0.325	0.39	0.278	
	2/23/1999		1	0.398	0.488	0.318	0.336	0.316	0.298	
	5/25/1999		1	0.442	0.475	0.278	0.537		0.492	0.261
	8/2/1999		1	0.355	0.296	0.289	0.283		0.315	0.374
	10/11/1999		1	0.234	0.212	0.186	0.259		0.178	0.189
	2/14/2000		1	0.186	0.182	0.151	0.34		0.162	0.195
	5/2/2000		1	0.219	0.2	0.209	0.42		0.221	0.242
	8/1/2000		1	0.239	0.277	0.226	0.31		0.298	0.54
	10/9/2000		1	0.278	0.241	0.226	0.365	0.255	0.242	0.29
	3/19/2001		1	0.214	0.176	0.22	0.344	0.205	0.236	0.397
	5/14/2001		1	0.261	0.21	0.233	0.231	0.253	0.238	0.282
	8/6/2001		1	0.318	0.323	0.267	0.705	0.36	0.346	0.45
	10/10/2001		1	0.318	0.311	0.248	0.335	0.336	0.328	0.07
	2/11/2002		1	0.248	0.236	0.2	0.304	0.236	0.231	0.024
	5/13/2002		1	0.247	0.245	0.234	0.324	0.276	0.261	0.114
	8/13/2002		1	0.3	0.309	0.254	0.298	0.307	0.273	0.308
	10/7/2002		1	0.254	0.27	0.248	0.284	0.264	0.27	0.094
Sulfate as (SO4)										
	3/15/1995		0.5	288	1020	1590	4850	554		
	5/15/1995		1	461	870	1580	3770	397		
	7/25/1995		1	697	930	1780	4280	423		
	10/3/1995		1	859	882	1700	4230	600		
	3/25/1996		1	950	757	1140		562		
	5/20/1996		1	458	643	1300	4120	465		
	6/4/1996		0	469	708	1510	4420	484		
	6/4/1996		1	469	708	1510	4420	484		
	7/1/1996		1	525	725	1570	4120	474		
	8/5/1996		1	547	648	1440	3970	452		
	9/3/1996		1	692	773	1710	3760	448		
	9/30/1996		1	565	643	1370	3480	443		
	3/4/1997		1	777	686	1170	4460	626		
	5/14/1997		1	348	780	1500	4200	504		
	7/8/1997		1	569	642	1180		427		
	7/16/1997		1				3640			
	8/4/1997		1	574	662	1200	3580	467	386	

Analyte	Collection Date	Detect Limit	Depth	380221	380233	380234	380235	380236	384160	385029
	9/2/1997		1	540	632	1110	3510	440	382	
	10/6/1997		1	581	655	1130		468	424	
	5/19/1998		1	546	596	999	3270	477	440	
	7/6/1998		1	545	599	993	2790	470	447	
	8/3/1998		1	585	597	1090	2780	511	486	
	9/8/1998		1	583	632	1150		524	495	
	10/19/1998		1	622	652	1230	2950	529	516	
	2/23/1999		1	663	674	1310	3080	622	595	
	5/25/1999		1	490	607	1120	2760		449	155
	8/2/1999		1	553	562	1110	2690		452	195
	10/11/1999		1	589	605	1180	2780		485	219
	2/14/2000		1	622	636	1220	2710		560	321
	5/2/2000		1	614	644	1200	2740		539	338
	8/1/2000		1	611	629	1140	2640		540	385
	10/9/2000		1	617	627	1130	2530	561	554	404
	3/19/2001		1	662	635	971	2210	627	632	283
	5/14/2001		1	463	663	1150	2400	610	577	282
	8/6/2001		1	600	627	1090	2390	582	554	350
	10/10/2001		1	628	655	1150	2480	599	591	354
	2/11/2002		1	671	683	1120	2480	687	682	415
	5/13/2002		1	582	552	1040	1920	579	492	357
	8/13/2002		1	635	663	1120	2330	634	632	473
	10/7/2002		1	622	660	1060	2220	632	611	336