Farm Pond Volunteer Water Quality Monitoring Program - Summary Report: 1998 to 2022

Rev_1-30-23

Introduction:

A volunteer water quality monitoring program has been characterizing the general state of Sherborn's premier 126-acre kettle pond since the program's inception in 1998, under the auspices of the Town's Farm Pond Advisory Committee (FPAC). Over the past three summer seasons (2020-2022) a noticeable and troubling deterioration of the general water quality (mainly water transparency) has been observed, as compared to the previous two decades of monitoring.

The following water quality parameters have been measured regularly at a mooring point located near the center (deep hole) of the lake: pH, Alkalinity, Secchi disk water transparency, Total Phosphorus, and complete water column temperature and dissolved oxygen depth profiles. Starting in summer of 2020, due to the appearance of the first potentially harmful cyanobacteria blooms ("HCB", also sometimes referred to as "HAB") at Farm Pond, additional work has been added by the FPAC volunteers for HCB identification and associated HCB trend analysis. Two HCB genera have been consistently identified within the lake in each of the past three seasons – *Microcystis* and *Dolichospermum.* A separate summary document on the HCB work and the 2020-2022 observations is available (see the accompanying "Farm Pond HCB 2020-22 Summary Report").

What follows here is a summary of the volunteer data collected for each of these lake parameters over the past 24 years. Please note that the volunteer program ranged in activity level every year, and thus the number of sampling events per season was not consistent, and indeed for a few years no volunteer work took place. The inception of this program received great early assistance and training at events and workshops held by the staff at the Massachusetts Water Watch Partnership (MassWWP), a program of the Water Resources Research Center at the University of Massachusetts – Amherst (https://www.umass.edu/mwwp/index.html). Since 1990, MassWWP has provided training and other technical assistance to citizen scientists who conduct water quality monitoring programs on the lakes, rivers, and estuaries of Massachusetts. In addition, the Sherborn program benefited from a state 319 grant in 1999 to FPAC for some key equipment (DO/T meter, depth sounder, GPS unit, and assorted supplies).

Besides the volunteer activities, a professional lakes consultant field study of Farm Pond was conducted in years 2013 and 2014, resulting in the publication of the 2015 Farm Pond Management Plan (FPMP), https://www.sherbornma.org/sites/g/files/vyhlif1201/f/uploads/development_plan.pdf . Please refer to the FPMP for additional water chemistry data, which includes copies of past lake surveys conducted at Farm Pond by various MA state agencies (MassDEP, MA DCR). FPAC is now engaging with a new lakes' consultant to further study Farm Pond for the upcoming 2023 and 2024 seasons, with the twin goals of completing an important state mandated MA Watershed Based Plan (WBP) along with making initial recommendations for the Town's options as to how to best control or mitigate the current deteriorating water quality (decreasing water clarity and HCB bloom formation) at this once very clear lake.

In addition to this water quality program, FPAC has conducted for several years an aquatic non-native invasives weed watcher volunteer program, with plant identification training sessions with MA DCR

personnel. Fortunately, except for some scattered purple loosestrife along the shoreline, no non-native invasive plants have been identified at Farm Pond.

Summary of Monitoring, 1998-2022:

Sampling Location

At the time the program first got started it was envisioned that monthly sampling events would occur at a mooring buoy anchored in the deepest area of Farm Pond, starting in the Spring after time of ice-out and continuing into the Fall before cold weather set in and made boating unsafe (teams of 2 volunteers in a rowboat, as motorized boats are not allowed on Farm Pond). Bathymetric maps available at the time showed a deep (about 52 feet, 16 meters) trench running in a line approximately northwest from the one island near the southern end of the lake towards the center of the lake. Sampling has continued in this general vicinity over the course of the program (at or about: 42 13 56 W, - 71 20 47 N), and GPS coordinates are recorded and confirmed at the time of each sampling event. The water depth at the mooring point is also checked at each event with a simple hand-held depth sounder, with 0.5-meter reportability (Speedtech SM-5 Depthmate portable sounder/depth meter).

Secchi Disk Water Transparency

The simple and low-cost Secchi disk tool has been used extensively by this program to follow the changes in clarity or water transparency of Farm Pond. The specific methodology followed by this program is per the MassWWP protocol (https://www.umass.edu/mwwp/protocols/lakes/secchi.html) and includes the use of a 4-inch diameter PVC "viewscope", to cut down on sun glare at the water's surface. At each sampling event two volunteers take turns independently conducting a SD measurement, followed by averaging the two values. Whenever the two measurements were found to differ by greater than 10%, the two volunteers repeated the process until the < 10% difference is achieved.

A complete list of all 137 Secchi disk (SD) measurements for Farm Pond is available (spreadsheet file, as is also the case for all the data tables and plots shown in this report). The SD data was further reduced to a listing of each of the year's minimum, maximum, and median SD values which are shown for the years 1998-20022 in Table 1 (page 6) and depicted as a plot in Figure 1 (page 7). As shown by Fig 1, at this time there is a clear trend of lower annual median transparency depths, with the last four seasons (2019-2022 YTD) medians all dropping below the 24-year average of the median SD value of 6.2 meters. Even more troubling has been the most recent set of 2022 seasons measurements, with some SD levels now dropping down to only 1.0 meter, see results copied here of all 2022 sampling events' SD values:

Date	SD, m	SD, ft
4/10/2022	6.6	21.7
5/1/2022	5.4	17.7
6/5/2022	5.8	19.0
7/9/2022	5.2	17.0
7/29/2022	4.3	14.1
8/18/2022	2.7	8.9
9/4/2022	1.5	4.9
9/16/2022	1.0	3.3

10/7/2022	1.0	3.3
10/22/2022	3.6	11.8
11/4/2022	3.6	11.8
11/29/2022	6.0	19.7

Four of the 2022 SD measurements (as shown in red, above, those ranging from 1.0 to 2.7 m) are the lowest SD depths we have ever recorded within the past 24 years at Farm Pond and were generally accompanied by a murky-green phytoplankton water column bloom noticeable from late July to early October across the entire lake.

pH and Alkalinity

Farm Pond surface water samples have been analyzed for pH and Alkalinity by the long-running UMASS-Amherst Water Resources Institute Acid Rain Monitoring (ARM) program (https://wrrc.umass.edu/research/acid-rain-monitoring-project). FPAC has been collaborating with this project since 2001, where FPAC volunteers collect samples and deliver them on the same day to a local lab designated by the ARM coordinator (with chain of custody documentation). In recent years labs at MIT and UMASS-Boston have been utilized. Interestingly, Farm Pond ARM sampling started in 1983, predating the start of the FPAC town committee. A complete list of pH and Alkalinity (as mg/L CaCO3, calcium carbonate) for the Farm Pond data is shown here in Table 2 and depicted as a plot in Figure 2.

Total Phosphorus, Nutrients

For many years Farm Pond surface water samples (0.5 meters, grab samples) have been taken for Total Phosphorus (TP) analysis, as we understand P to be the limiting nutrient for this lake's ecology (vs Nitrogen-related ions, as is the case for many marine waters, eg estuaries off Cape Cod). Most TP samples have been analyzed by the UMASS Amherst Water Resources Research Center, Environmental Analysis Lab (https://wrrc.umass.edu/eal) and shipped frozen/overnight along with completed chain of custody forms. A complete tabulation of surface water TP data for Farm Pond is shown here in Table 3 and depicted as a plot in Figure 3.

For many years surface TP sampling was mainly carried out around the recommended times of expected near-complete Spring and Fall "overturn" times at the lake, at which time a complete mixing of the water column top-to-bottom normally occurs (Farm Pond is known to be a classical "dimictic" lake, with periods of complete stratification twice a year – summer and winter, and complete mixing for the short times in the early Spring and late Fall). Due to the recent HCB blooms and new concerns over the potential for internal P loading within Farm Pond from bottom sediments P release (known phenomenon triggered by release of iron-bound phosphorus in the sediments as the dissolved oxygen levels drop to anoxic, < 2 ug/L, conditions), sampling frequency of TP at both the surface, and now also at various mid- and bottom-water depths has now been undertaken in late 2021 and through 2022. Depth sampling involves use of a Wisconsin depth sampler acquired by the Town in 2021.

A complicating factor for all the Total P determinations is the fact that Farm Pond surface concentrations of phosphorus have traditionally fallen just below or right around the method detection limit (MDL) for the lab Total P method. Farm Pond has traditionally been considered a low-nutrient lake or classifies as oligotrophic (Total P < 10 ug/L). This brings up two practical challenges: a) It is well-known that with any quantitative measurement the level of uncertainty (%RSD) increases as you approach the MDL. To help

address this, two Total P samples were always taken as field duplicates and the results averaged; and b) for several reasons in trace level environmental studies it has been recommended that for statistical treatment of data that one should not enter values of zero concentrations for values below the MDL, but rather use one simple approach widely adopted, which is to substitute an estimated value of ½ the MDL in these instances. That is how the Total P data here was treated, as shown in Table 3 and Figure 3. The UMASS WRRC EAL lab method detection limit, which on their lab reports is listed as a "Reporting Limit" has varied over the years from about 2 to 8 ug/L. with 8 ug/L being reported for the last several years.

Besides the surface Total P data, we are now starting to obtain measurements from water at multiple depths, where higher phosphorus levels may be expected due to contributions from "internal P loading" from the P released from the bottom sediments during times of strong stratification and low oxygen levels at the bottom depths. It was recommended we take three samples at each field event: 1) surface (epilimnion or top water layer) 0.5 m depth, mid-depth sample at about the thermocline (metalimnion layer), and bottom depth (about 1 meter above the bottom to avoid picking up sediments, hypolimnion layer).

Here below are the higher Total P concentrations (now frequently > 10 ug/L) that have been observed at the multi-depth samplings during the last two seasons:

Farm Pond Advisory Committee						
Volunteer Water Quality Monitoring Program						
Farm Pond Testing Data - Total Phosphorus (UMASS WRRC EAL)						
Total P, Depth Sampling						
Date	**Location Depth, m**	**Sample Depth. M**	**Results, ug/L (ppb):**			
			Sample	**Sample Dupl**	**Average**	**%RSD**
10/24/2021	16	0.5	10	4	7.0	-86
10/24/2021	16	15	159	164	161.5	3.1
4/10/2022	10.5	0.5	12.3	12.9	12.6	4.8
4/10/2022	10.5	10	11.2	16.7	14.0	39.4
7/9/2022	15.5	0.5	4	4	4.0	0.0
7/9/2022	15.5	13	15.6	16.6	16.1	6.2
8/18/2022	15.5	0.5	4	4	4.0	0.0
8/18/2022	15.5	7.5	9.9	12.1	11.0	20.0
8/18/2022	15.5	13.5	63.2	69.0	66.1	8.8
9/16/2022	15	0.5	21.3	20.7	21.0	-2.9
9/16/2022	15	7.5	24.6	24.6	24.6	0.0
9/16/2022	15	12.5	46.0	47.1	46.6	2.4
10/7/2022	15.5	0.5	16.5	16.0	16.3	-3.1
10/7/2022	15.5	10.5	19.5	18.3	18.9	-6.3

10/7/2022	15.5	14	75.2	70.5	72.9	-6.5
11/29/2022	15	0.5	14.1	11.9	13.0	-16.9
11/29/2022	15	7.5	14.6	15.7	15.2	7.3
11/29/2022	15	13	12.4	16.3	14.4	27.2
Note: Total P Vales of "4" were from BRL (Below Reporting Limit) results, 1/2 the BRL.						

These much higher concentrations of Total P at all depths, for example the 21 ug/L Total P at 0.5 m depth on September 16, could fuel cyanobacteria and/or green algae growth increases, as shown by the concurrent poor SD transparencies. In earlier years surface Total P values were typically < 10 ug/L.

Finally, there is also some limited depth Total P and nitrogen related nutrients data in the 2015 FPMP, and in the earlier state of MA studies contained therein.

Temperature and Dissolved Oxygen – Water Column Depth Measurements

With the use of a digital temperature and dissolved oxygen meter the measurements of these two important parameters have been taken from depths throughout the water column, top to bottom. DO/T depth profiles were initiated in the year 2000, using a YSI model 95 digital DO/T meter acquired through a state 319 grant to FPAC. This unit became problematic in 2003, at which time the Town purchased a YSI model 550A to replace it. In 2021 a YSI/Xylem model ODO/T meter was acquired by the town, a modern unit based on optical luminescence technology. In all years the DO/T probes were operated and calibrated per the manufacturer's directions. The earlier YSI models 95 and 550A were based on probe technology incorporating a semi-permeable membrane and an electrochemical cell, which required frequent membrane cap replacements and electrolyte additions. In the early program years, the DO/T data was recorded at 1.0 m depth intervals, measured from the water surface, but over the last two seasons a higher resolution 0.5 m depth sampling interval is being employed to better define the depths and total volumes of the three distinct layers present during periods of stratification.

For this summary report a series of temperature-depth and dissolved oxygen-depth plots are included for the last 7 seasons (2022, 2021, 2020, 2019, 2018, 2017, and 2016), and, 2 early program seasons (2001, 2001), all from the FPAC volunteer program. Also, some similar plots from the 2015 FPMP from 2014 sampling dates are included. Please see Figures 4 through 13.

Tables and Figures:

Table 1 – Secchi Disk Annual Minimum, Maximum, and Median values for Farm Pond, 1998 to 2022, in meters (1 meter = 3.28 feet).

Year	Min	Max	Median
1998	4.3	9.2	6.0
1999	4.8	8.0	6.6
2000	4.7	7.8	6.5
2001	5.0	7.3	5.3
2002	3.6	6.7	6.4
2003	5.5	8.2	6.2
2004	5.8	7.3	6.3
2005	6.8	9.0	7.0
2007	5.2	7.7	6.1
2008	5.2	8.2	7.3
2009	6.1	7.7	7.0
2013	5.2	7.4	7.1
2016	5.6	7.3	6.5
2017	5.7	6.7	6.2
2018	5.1	7.2	6.5
2019	3.8	8.0	5.1
2020	3.9	9.2	5.8
2021	5.1	6.8	5.8
2022	1.0	6.6	4.0
Ave/mean	4.9	7.7	6.2
Median	5.1	7.7	6.3
std dev ave	1.2	0.8	0.8

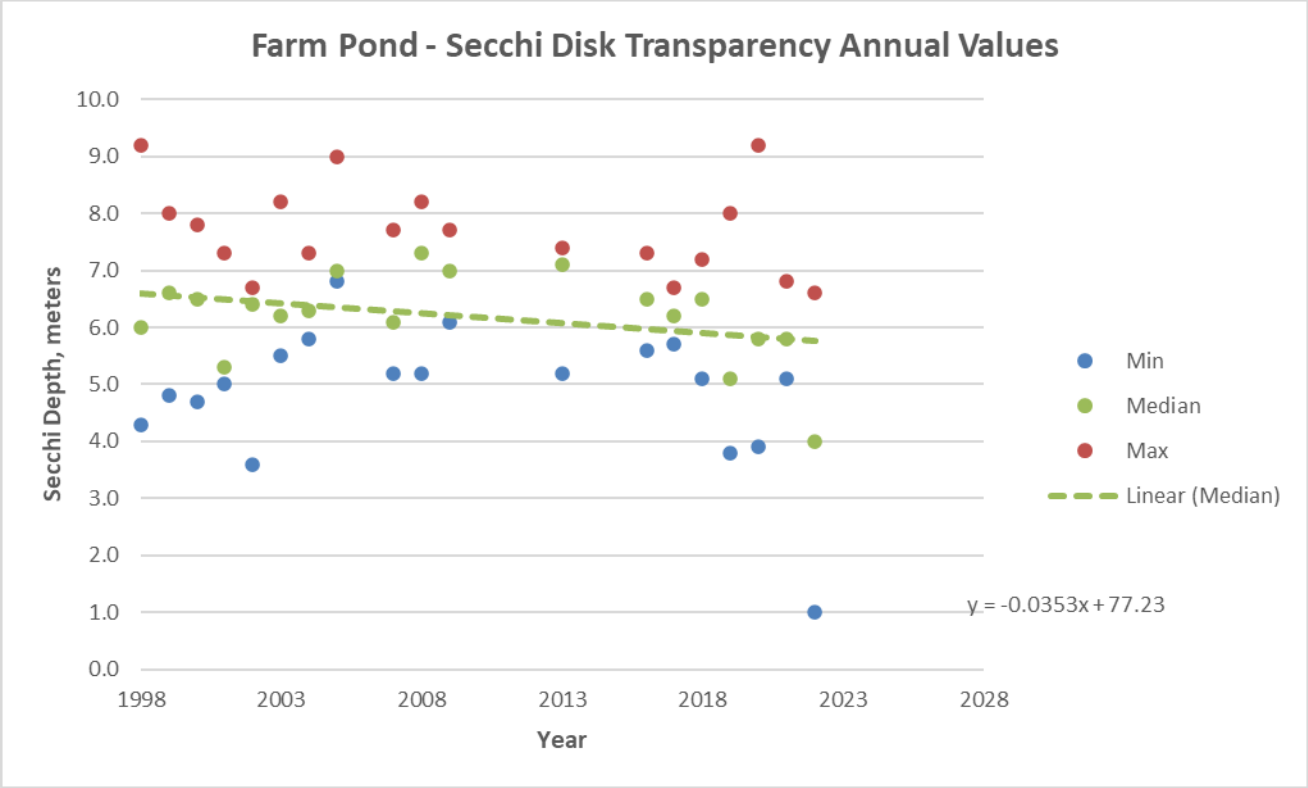


Figure 1. Secchi Disk Annual Minimum, Maximum, and Median values for Farm Pond, 1998 to 2022 (YTD).

Table 2. UMASS Acid Rain Monitoring (ARM) pH and Alkalinity – 1983 to 2022 (Alkalinity as mg/L CaCO3).

	UMASS Acid Rain Monitoring (ARM) Project - Farm Pond, Sherborn MA					
PALSITE	NAME	DATE	pH	ALK		
72039	Farm Pond	3/20/1983	6.35			
72039	Farm Pond	4/17/1983	5.9			
72039	Farm Pond	5/25/1983	7			
72039	Farm Pond	6/19/1983	6.2			
72039	Farm Pond	7/17/1983	6.1			
72039	Farm Pond	8/21/1983	6			
72039	Farm Pond	9/18/1983	6.6			
72039	Farm Pond	10/16/1983	6.6			
72039	Farm Pond	11/20/1983	6.7			
72039	Farm Pond	4/22/2001	6.3	1		
72039	Farm Pond	7/15/2001	6.33	1		
72039	Farm Pond	10/21/2001	6.13	1.2		
72039	Farm Pond	4/21/2002	6.34	1.1		
72039	Farm Pond	7/21/2002	6.19	2		
72039	Farm Pond	10/20/2002				
72039	Farm Pond	4/10/2011	3.05			
72039	Farm Pond	4/6/2014	6.43	2.25		
72039	Farm Pond	4/12/2015	6.3	3.5		
72039	Farm Pond	4/2/2017		2.6		
72039	Farm Pond	4/8/2018	6.62	5.4		
72039	Farm Pond	4/7/2019	6.63	3.2		
72039	Farm Pond	4/10/2022	6.8	3.5		
		Mean	6.23	2.43		
		SD of Mean	0.40	1.10		
		Median	6.34	2.13		
		N	20	11		
	Farm Pond	5/9/2014	8	2		
	Management	8/12/2014	8.7	2.8		
	Plan - 2015					

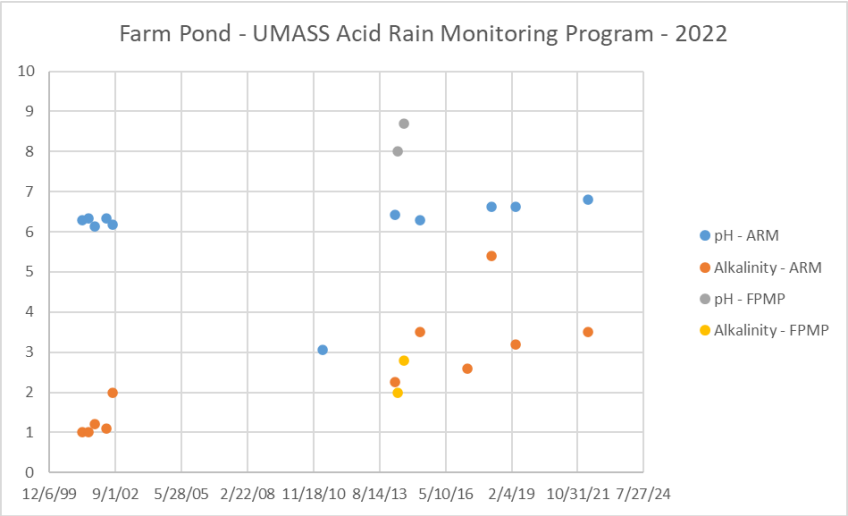


Figure 2. UMASS Acid Rain Monitoring (ARM) pH and Alkalinity – 1983 to 2022 (Alkalinity as mg/L CaCO3).

Table 3. Surface water Total Phosphorus Concentrations at Farm Pond (BRL = below reporting limit, Using 1/2 BRL's for non-detect values).

Farm Pond Advisory Committee				
Volunteer Water Quality Monitoring Program				
Farm Pond Testing Data - Total Phosphorus (UMASS WRRC EAL)				
Total P, Surface Sampling (0.5 meter)				
			Plotted	
Date	**Results, ug/L (ppb):**		**FPAC**	
	Sample	**Sample Dupl**	**Average**	**%RSD**
4/16/1999	6	10	8.0	93.8
10/22/1999	10	5	7.5	-66.7
4/14/2000	3	7	5.0	80.0
10/13/2000	5	5	5.0	0.0
4/22/2001	5	6	5.5	18.2
10/21/2001	8	9	8.5	11.8
4/19/2002	12	17	14.5	34.5
7/20/2002	8	9	8.5	11.8
8/25/2002	8	8	8.0	0.0
9/28/2002	10	11	10.5	9.5
10/27/2002	11	12	11.5	8.7
4/27/2003	14	11	12.5	-24.0
6/30/2003	8	9	8.5	11.8
9/21/2003	7	6	6.5	-15.4
10/10/2003	6	8	7.0	28.6
6/13/2004	9	10	9.5	10.5
7/11/2004	7	7	7.0	0.0
4/26/2005	7	6	6.5	-15.4
5/29/2005	4	4	4.0	0.0
4/19/2008	3.6	6.3	5.0	54.5
5/25/2008	5.6	9.4	7.5	50.7
10/16/2016	9	4	6.5	-76.9
4/23/2017	8	4	6.0	-66.7
10/22/2017	9	4	6.5	-76.9
5/11/2018	13	14	13.5	7.4
10/20/2018	4	4	4.0	0.0
11/4/2018	4	4	4.0	0.0
11/23/2019	4	4	4.0	0.0
7/27/2020	9.3	8.7	9.0	-6.7
11/22/2020	11.7	11.2	11.5	-4.4
4/10/2021	4	20	12.0	133.3

6/5/2021	21.7	15.2	18.5	-35.2
10/24/2021	10	4	7.0	-85.7
4/10/2022	12.3	12.9	12.6	4.8
7/9/2022	4	4	4.0	0.0
8/18/22	4	4	4.0	0.0
9/16/22	21.3	20.7	21.0	-2.9
10/7/22	16.5	16	16.3	-3.1
11/29/22	14.1	11.9	13.0	-16.9
		Ave Total P:	**8.7**	
		Std dev:	**4.2**	
		N:	**39**	

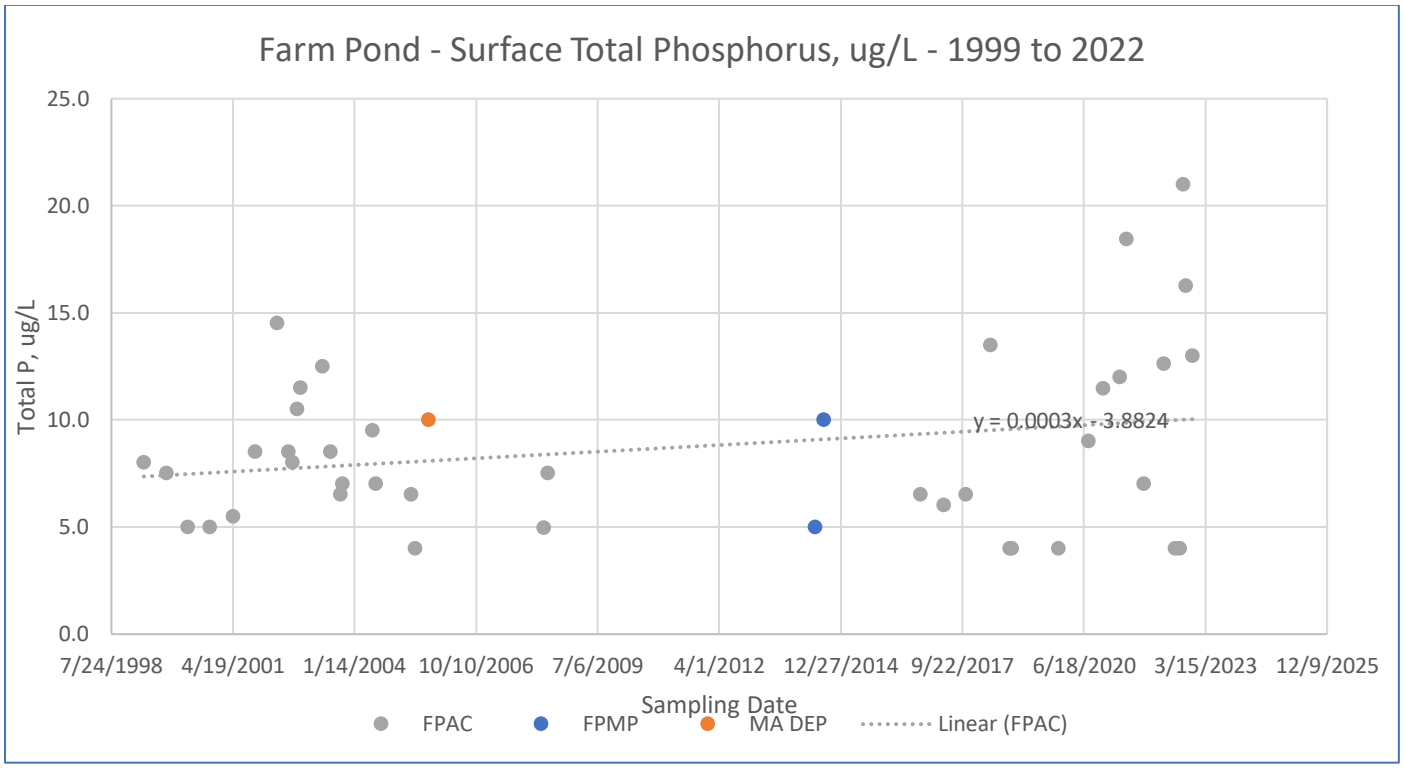
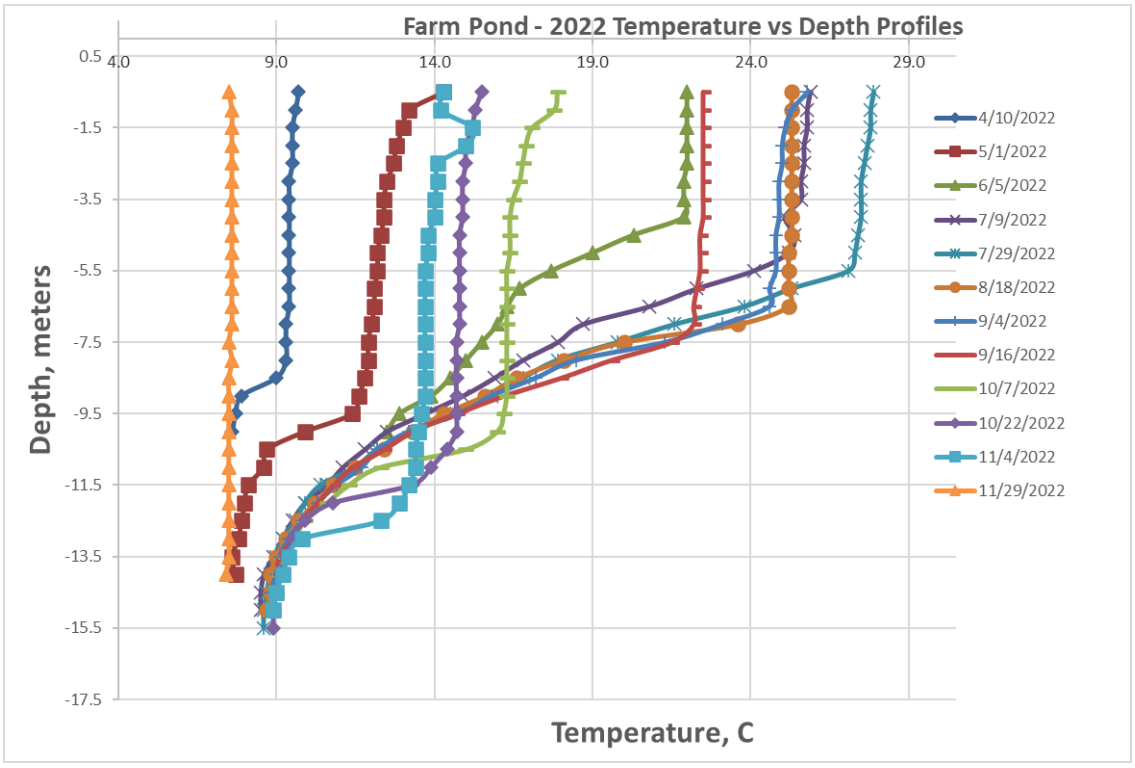


Figure 3. Surface water Total Phosphorus Concentrations at Farm Pond.

Figure 4 – 2022 Temperature – Depth and Dissolved Oxygen - Depth Plots. Note: Test mooring moved to deeper location after 6/5/22.



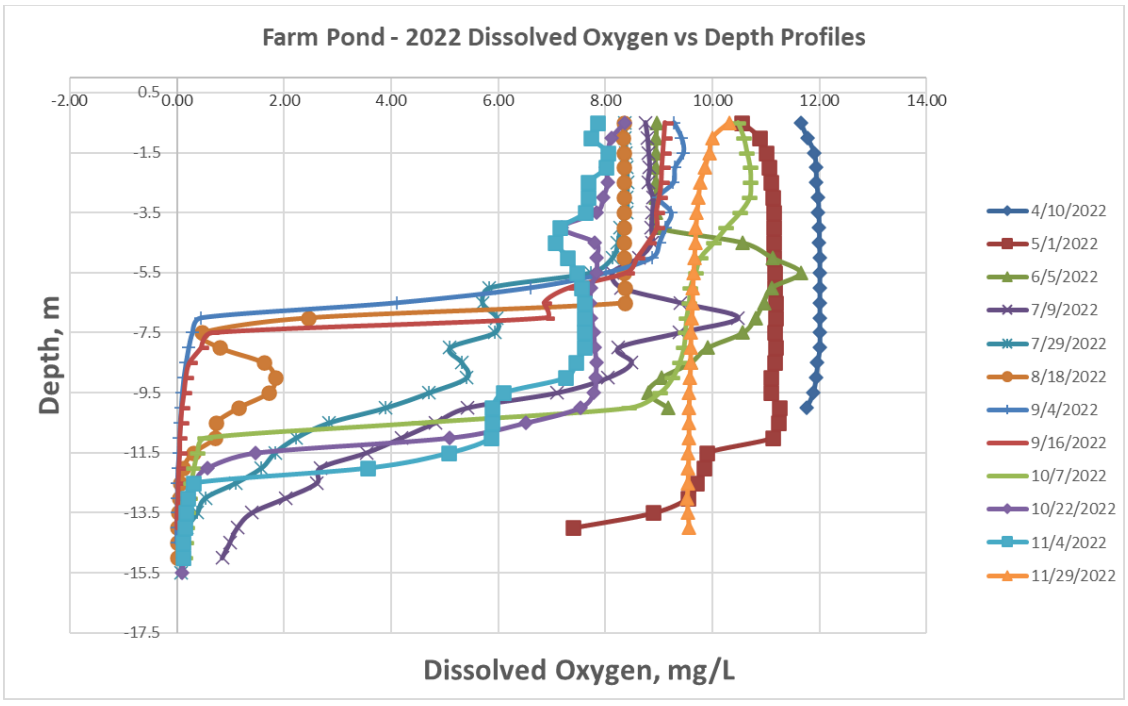
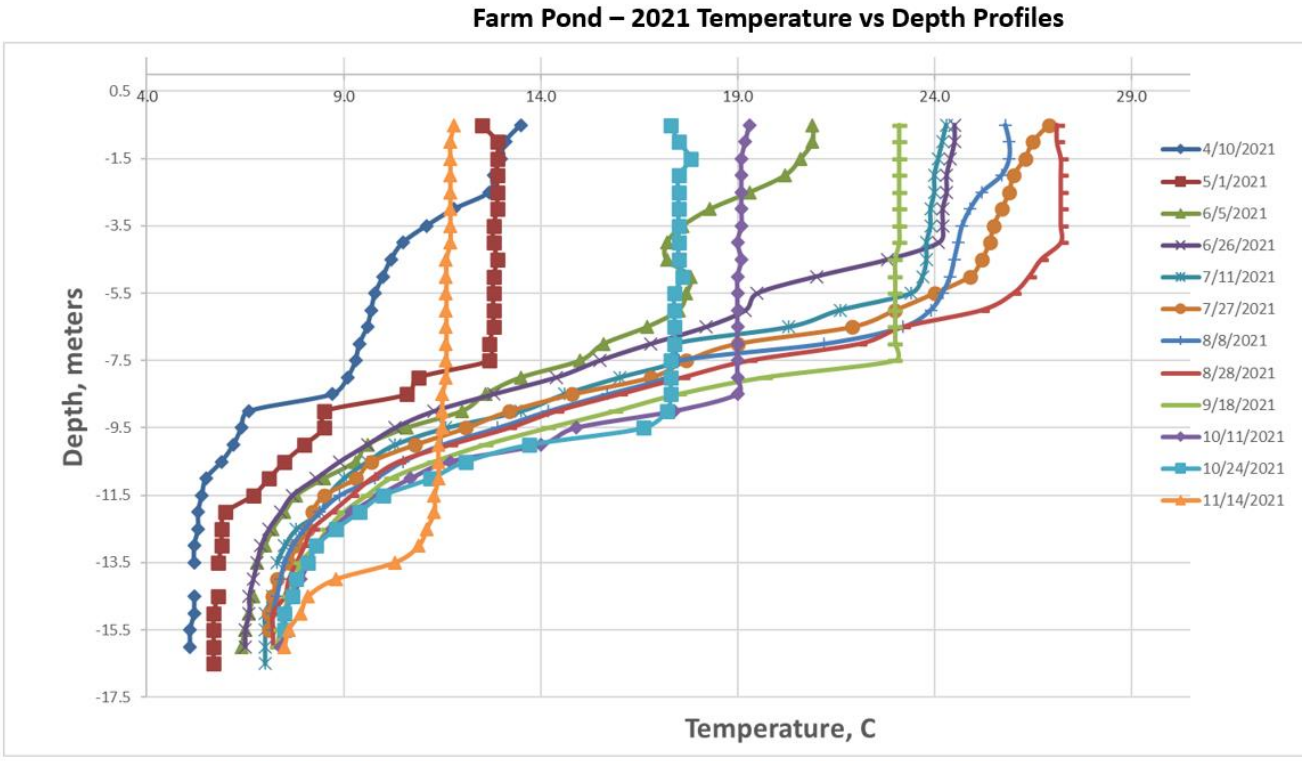
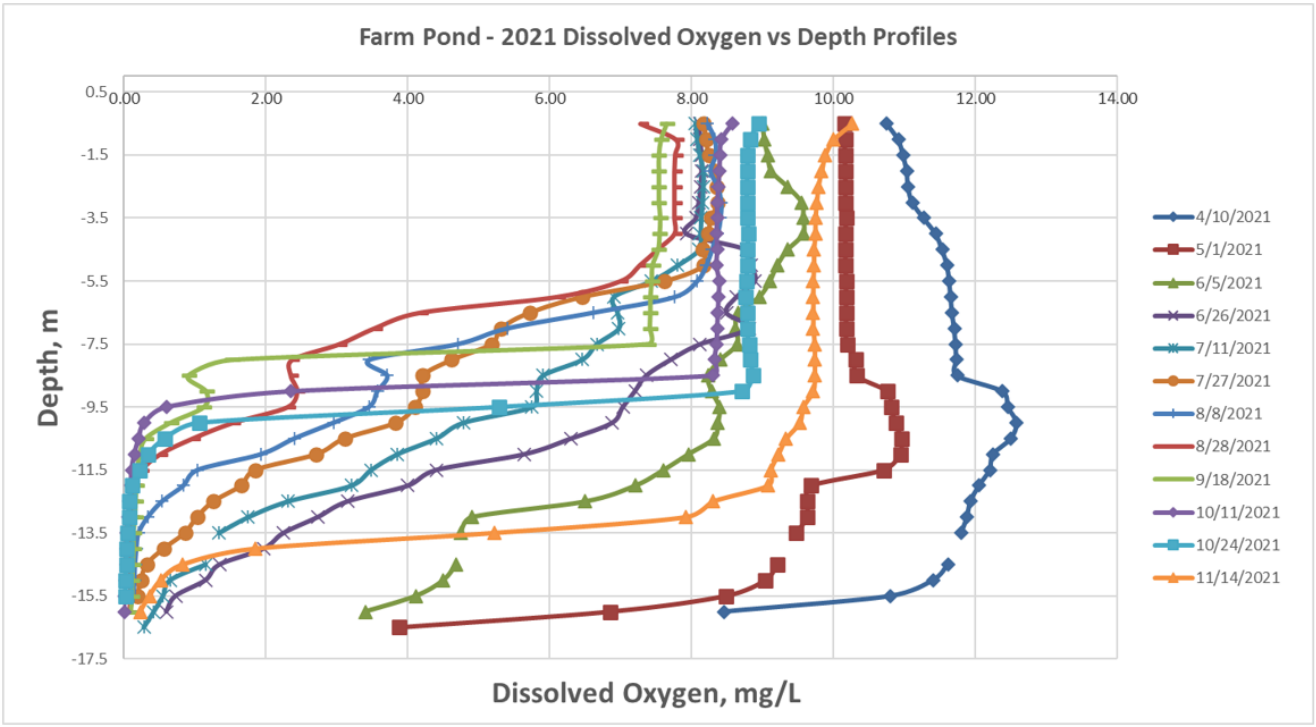


Figure 5 – 2021 Temperature – Depth and Dissolved Oxygen - Depth Plots.

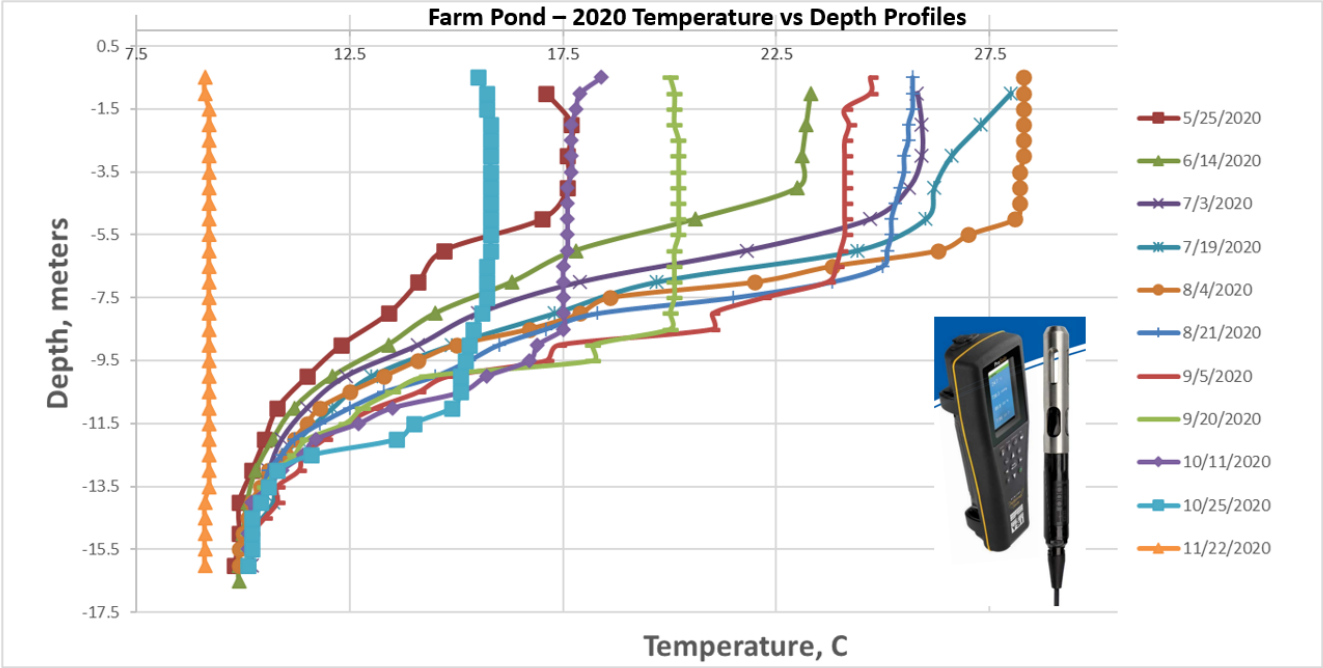


Note: 0.5 m data collection intervals (YSI ProDigital meter, sensor replaced 10-9-21).

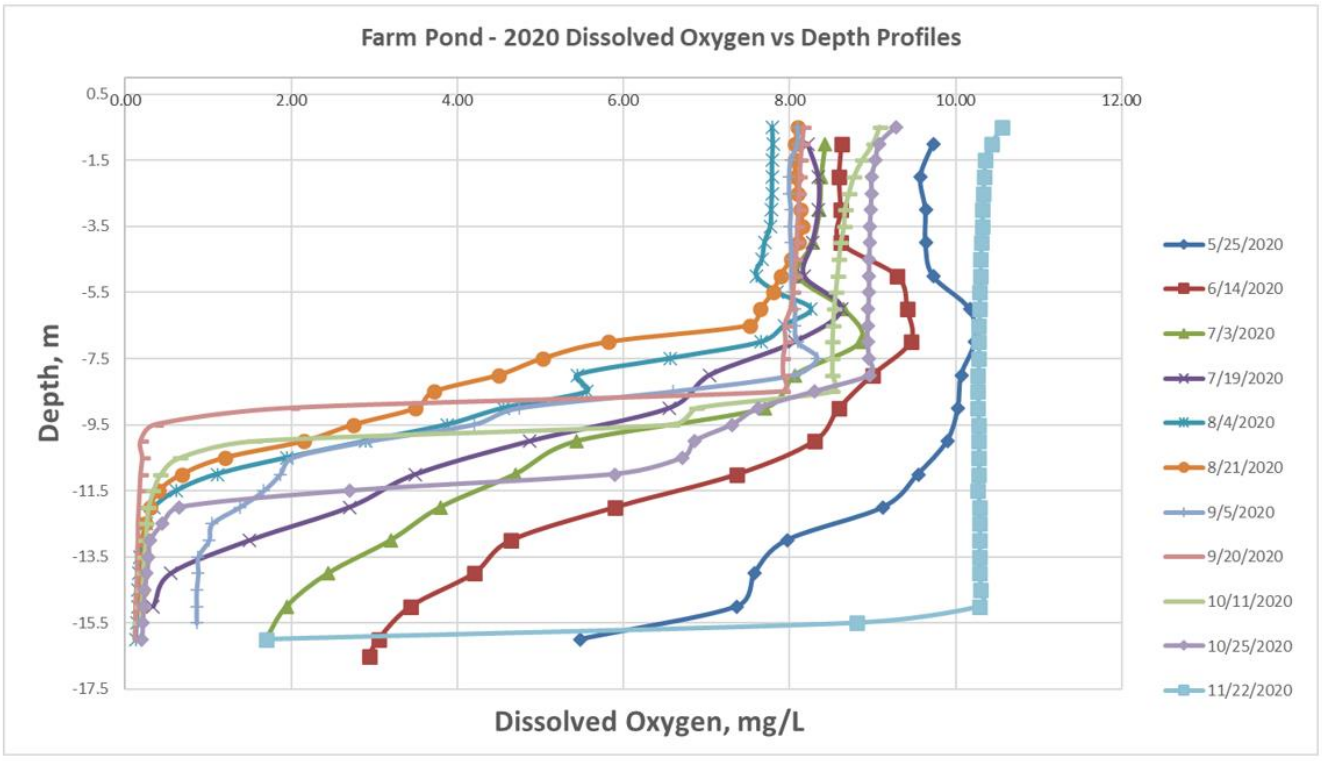


Note: 0.5 m data collection intervals (YSI ProDigital meter, sensor replaced 10-9-21).

Figure 6 – 2020 Temperature – Depth and Dissolved Oxygen - Depth Plots.

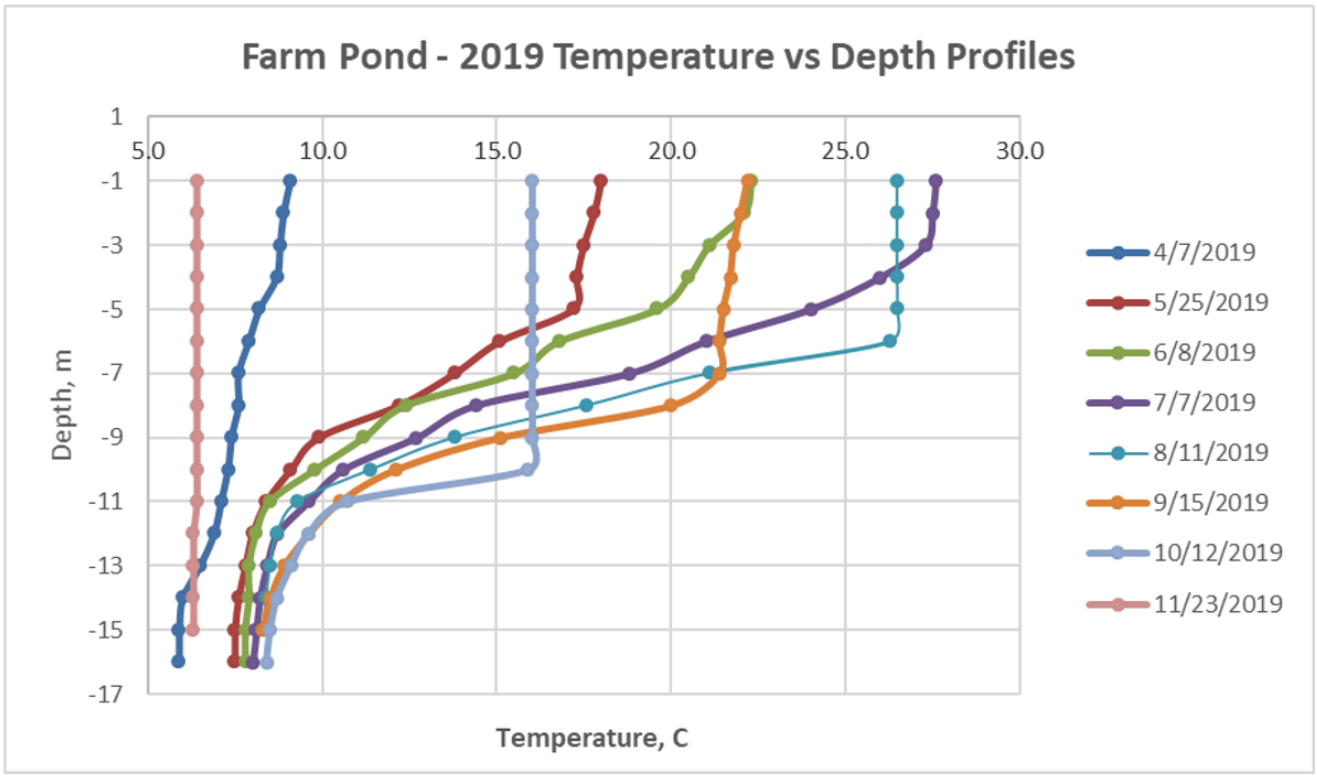


Note: New ProSolo Optical DO/T probe for 2020 season. Starting on 8/4/20 changed to 0.5 m data collection intervals from original 1.0 m intervals.



Note: Starting on 8/4/20 changed to 0.5 m data collection intervals from original 1.0 m intervals.

Figure 7 – 2019 Temperature – Depth and Dissolved Oxygen - Depth Plots.



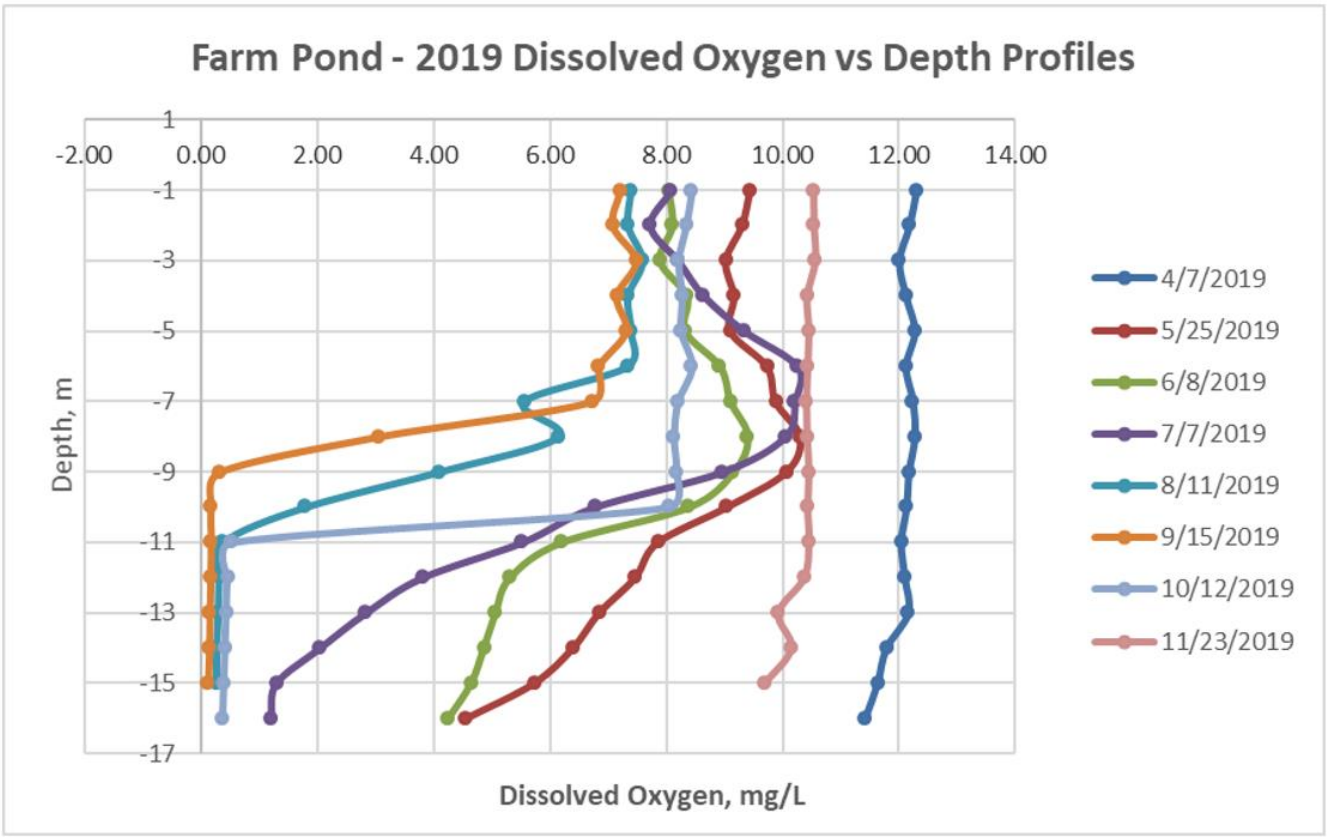
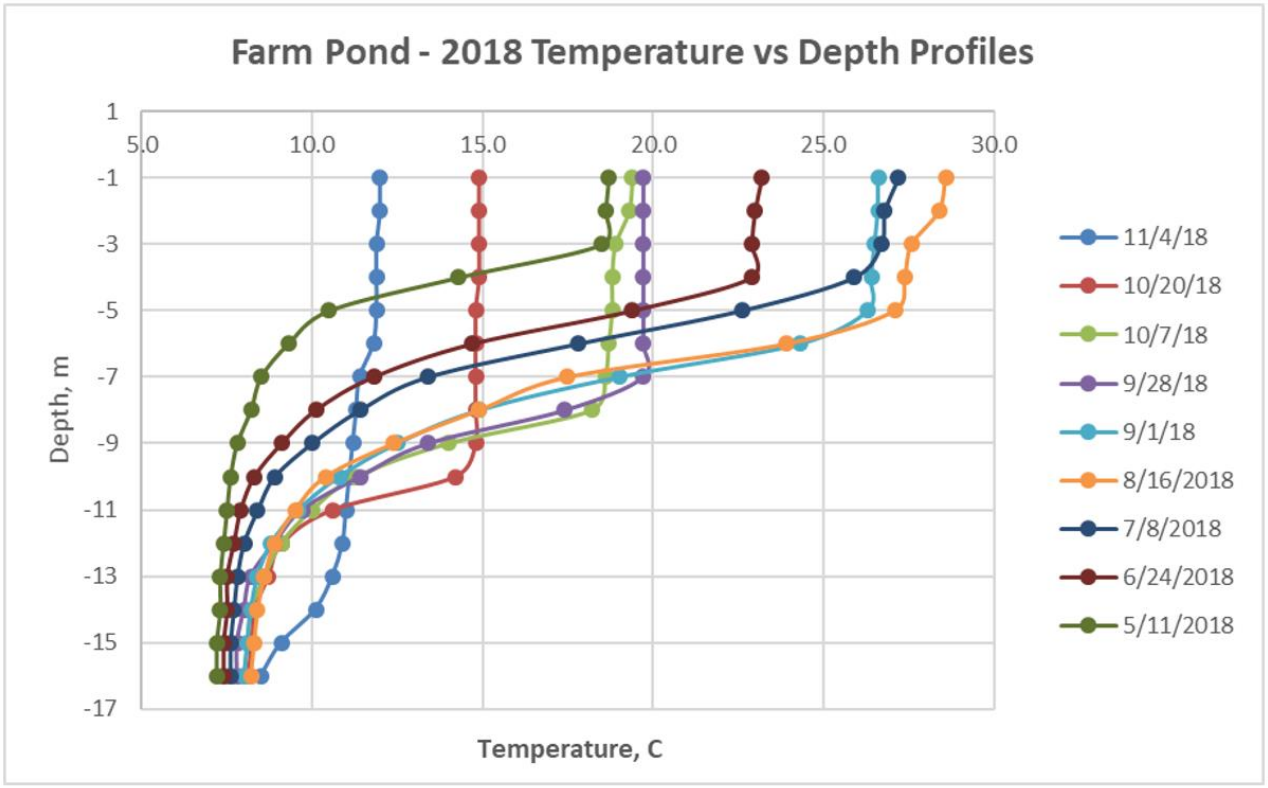


Figure 8 – 2018 Temperature – Depth and Dissolved Oxygen Depth - Plots.



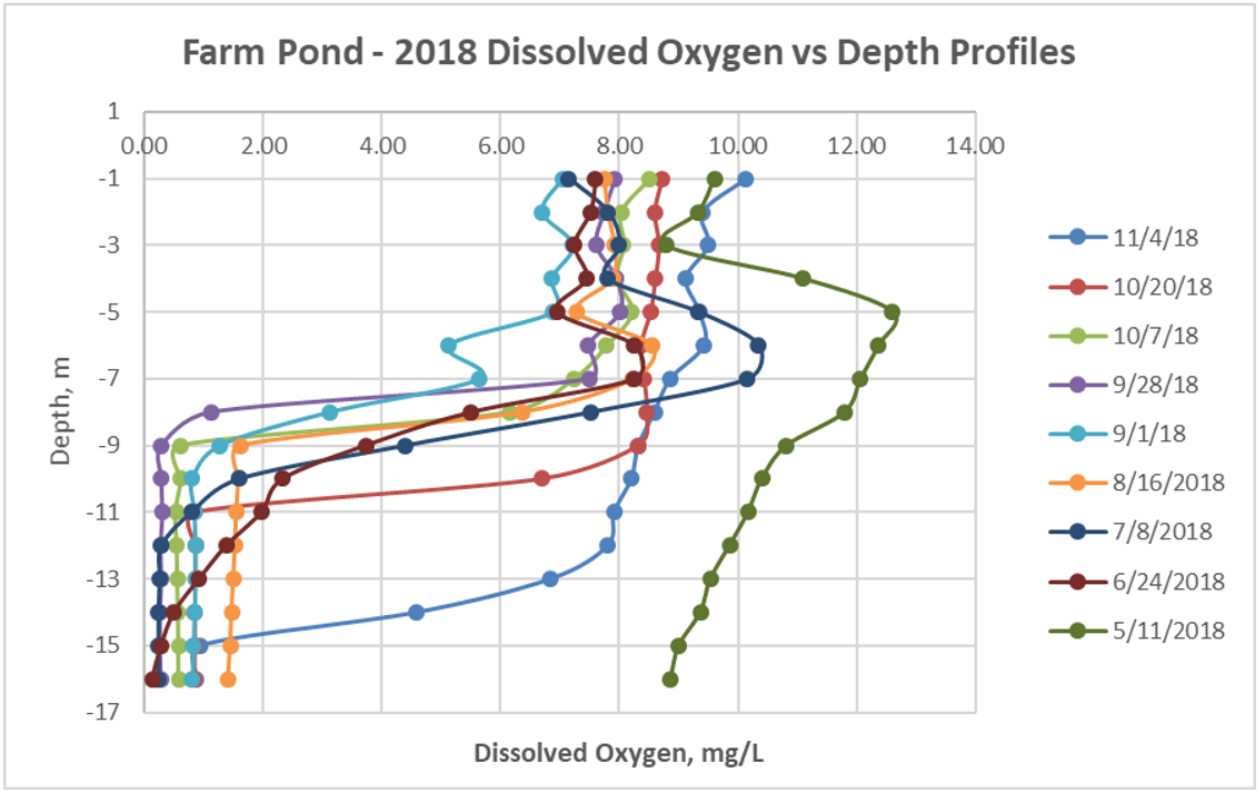
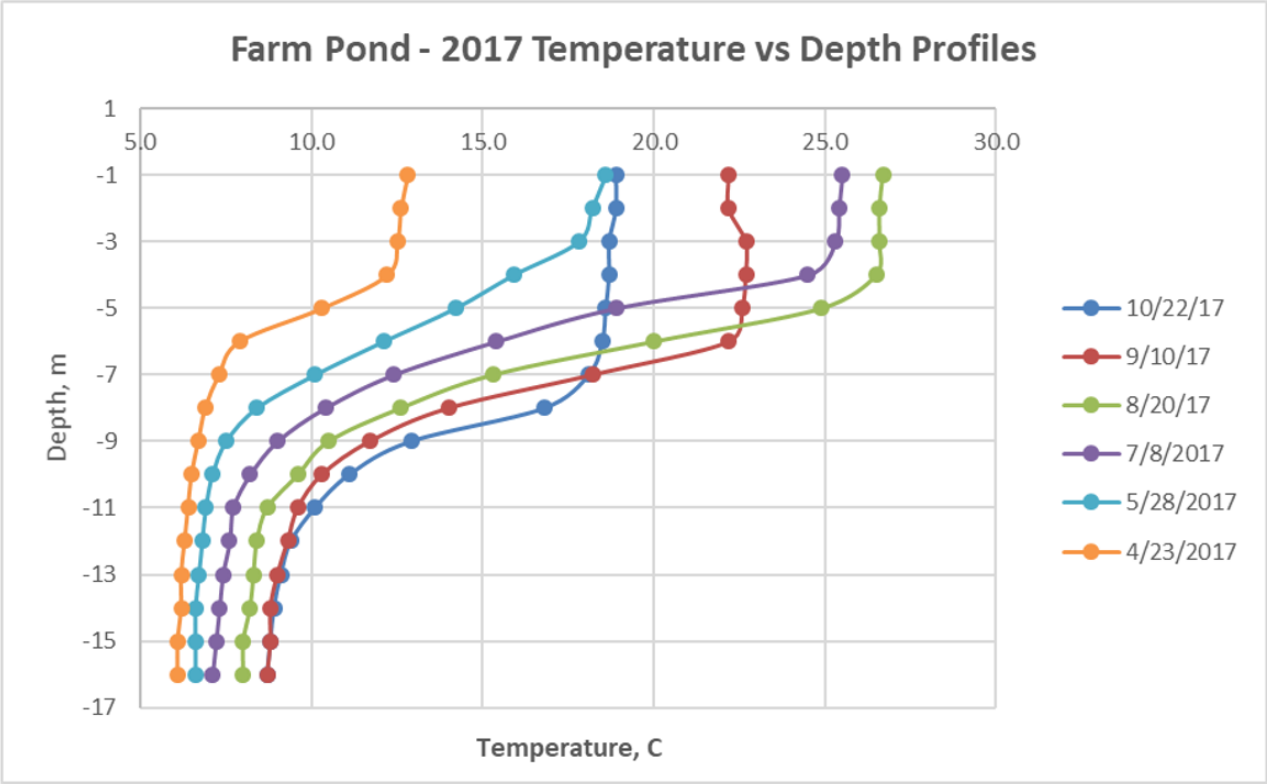


Figure 9 – 2017 Temperature – Depth and Dissolved Oxygen - Depth Plots.



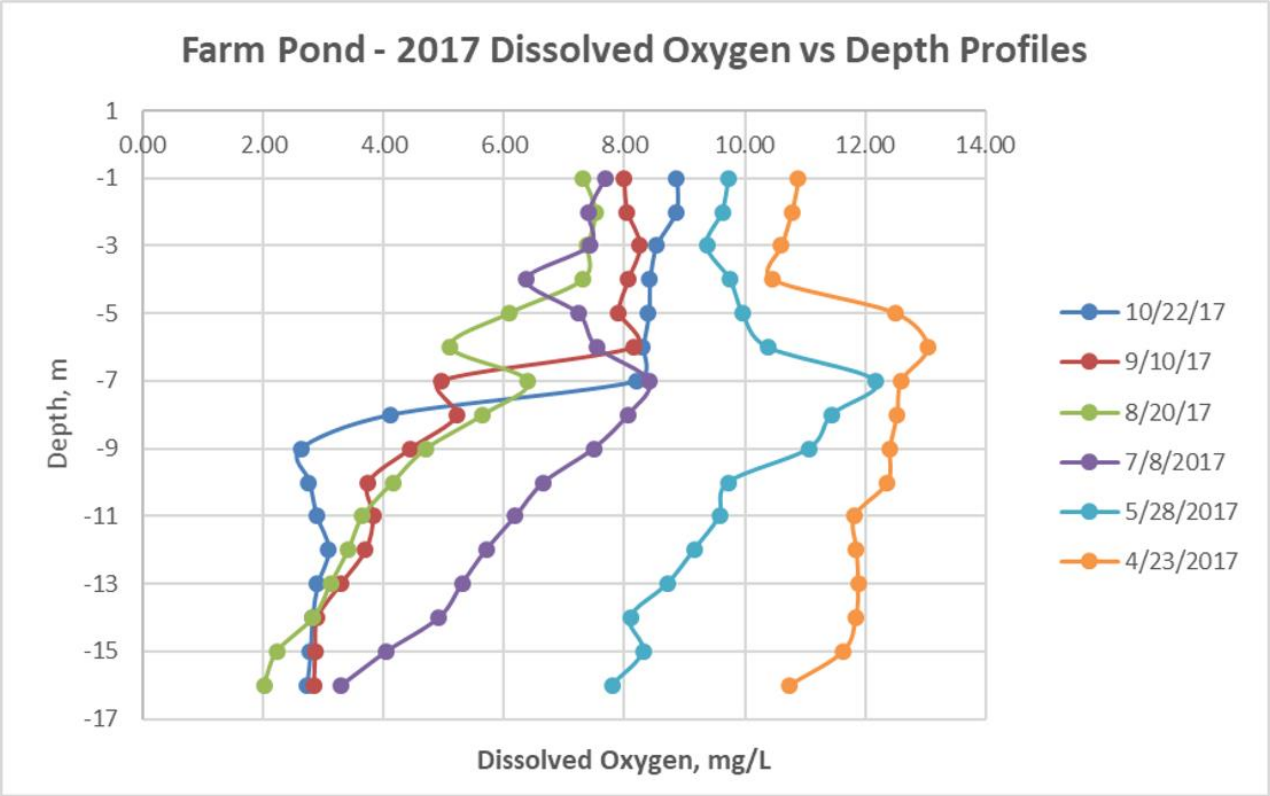
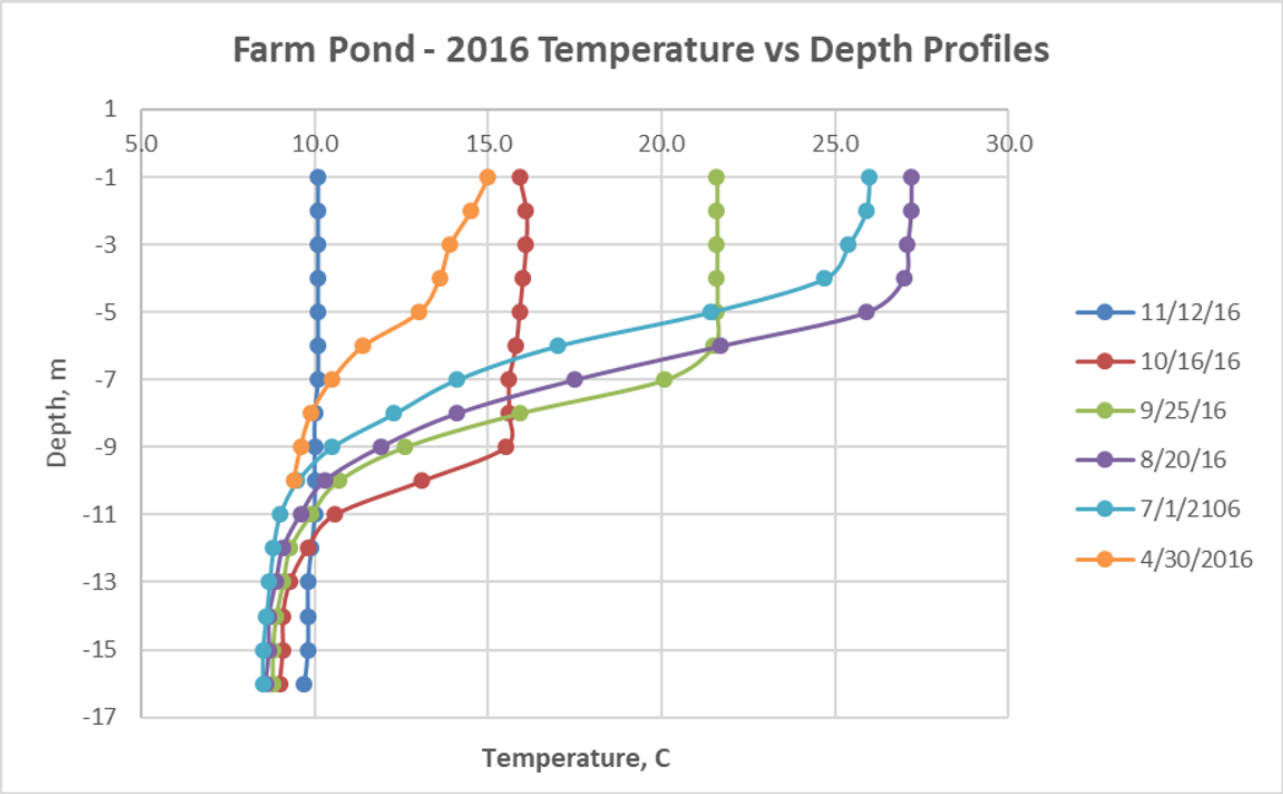


Figure 10 – 2016 Temperature – Depth and Dissolved Oxygen - Depth Plots.



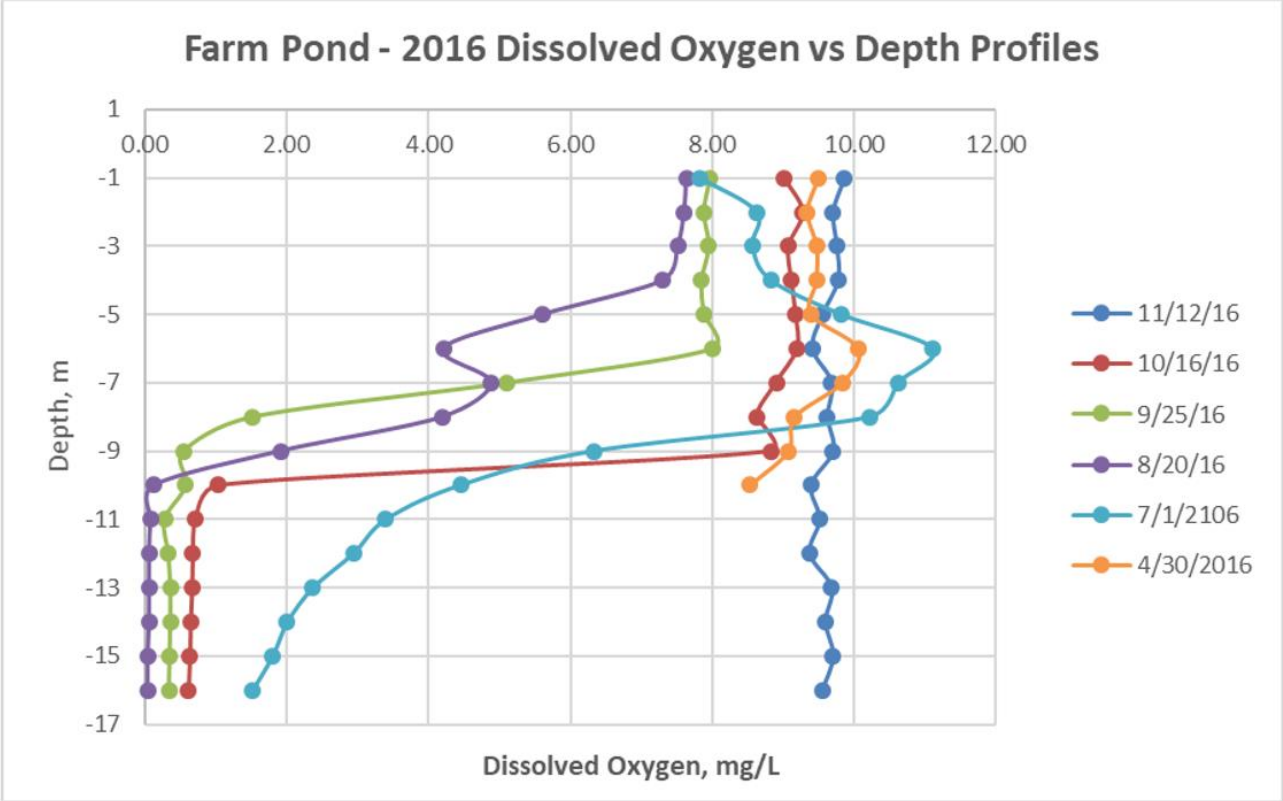
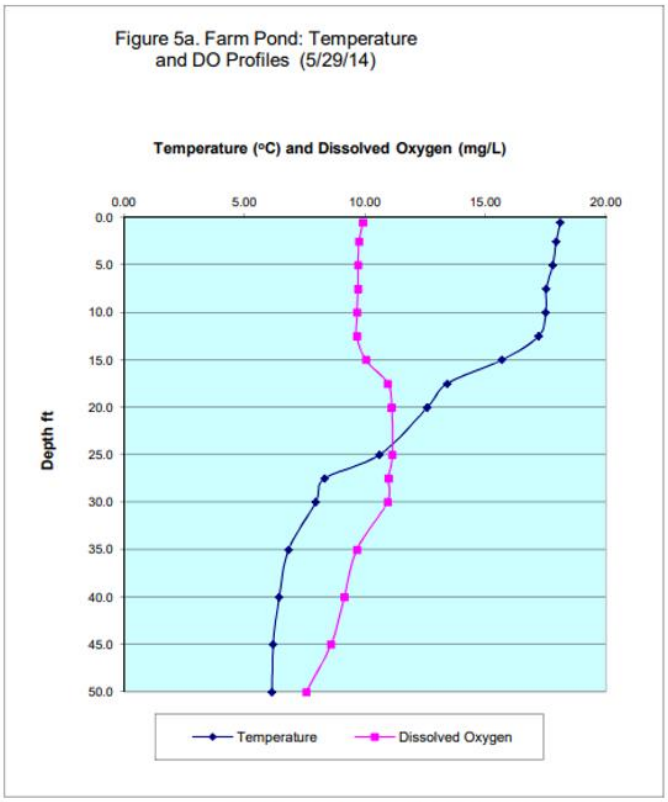


Figure 11 – 2014 Temperature – Depth and Dissolved Oxygen Depth Plots (from 2015 FPMP).



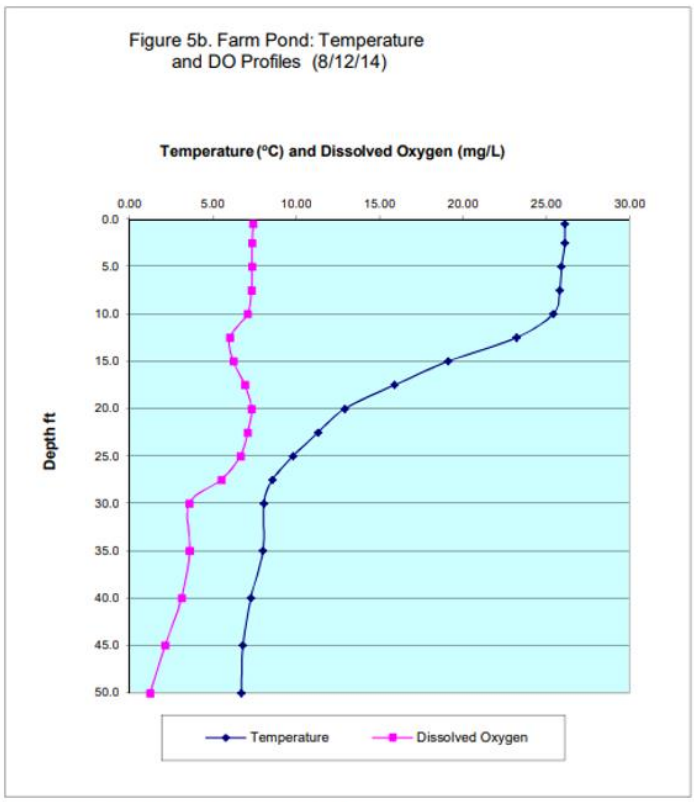
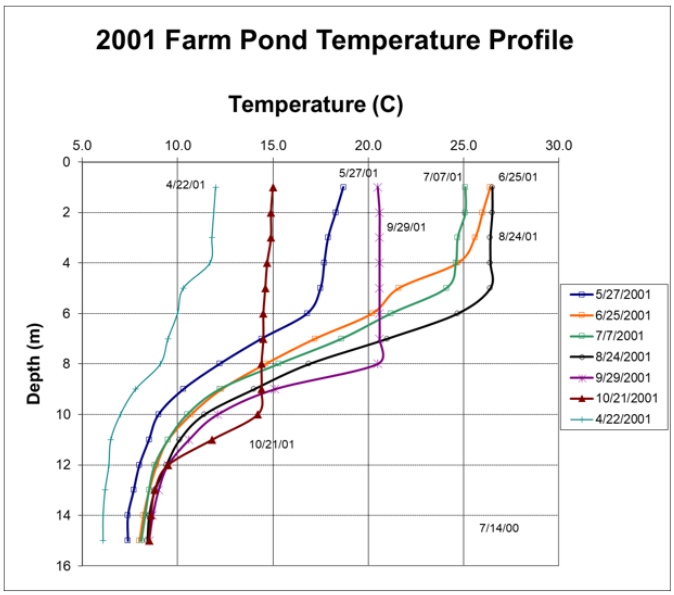


Figure 5. Farm Pond Temperature and DO Depth Profiles: Summer 2014.

Figure 12 – 2000 Temperature – Depth and Dissolved Oxygen - Depth Plots.



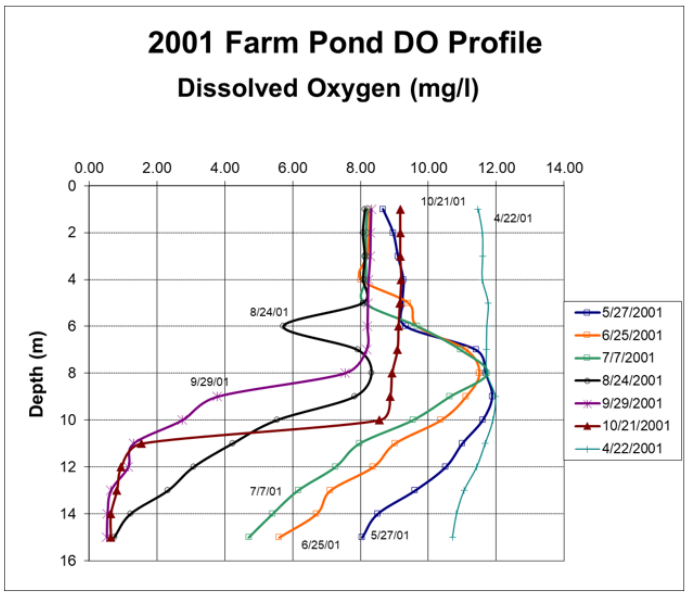
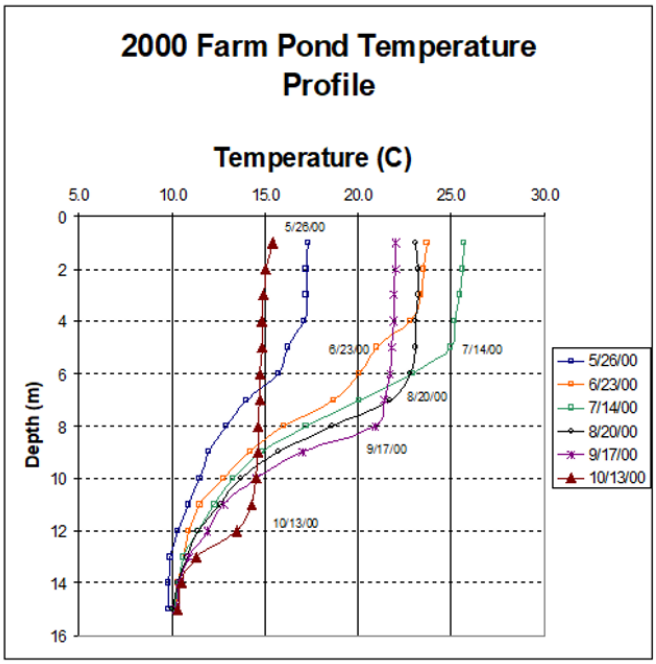


Figure 13 – 2000 Temperature – Depth and Dissolved Oxygen - Depth Plots.


2000 Farm Pond Temperature Profile
Temperature (C)
5.0
10.0
15.0
20.0
25.0
30.0
Depth (m)
0
2
4
6
8
10
12
14
16
5/26/00
6/23/00
7/14/00
8/20/00
9/17/00
10/13/00
5/26/00
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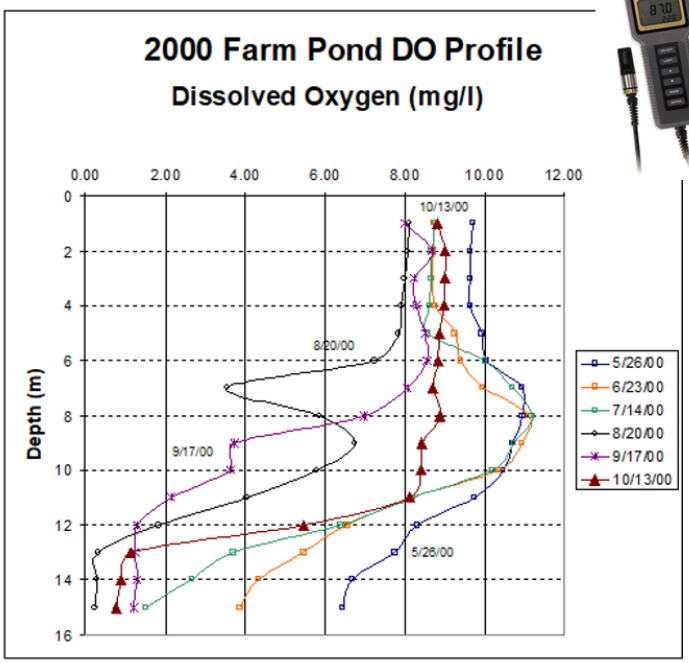
7/14/00
8/20/00
9/17/00
10/13/00


2000 Farm Pond DO Profile
Dissolved Oxygen (mg/l)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Depth (m)
0
2
4
6
8
10
12
14
16
10/13/00
8/20/00
9/17/00
5/26/00
5/26/00
6/23/00
7/14/00
8/20/00
9/17/00
10/13/00