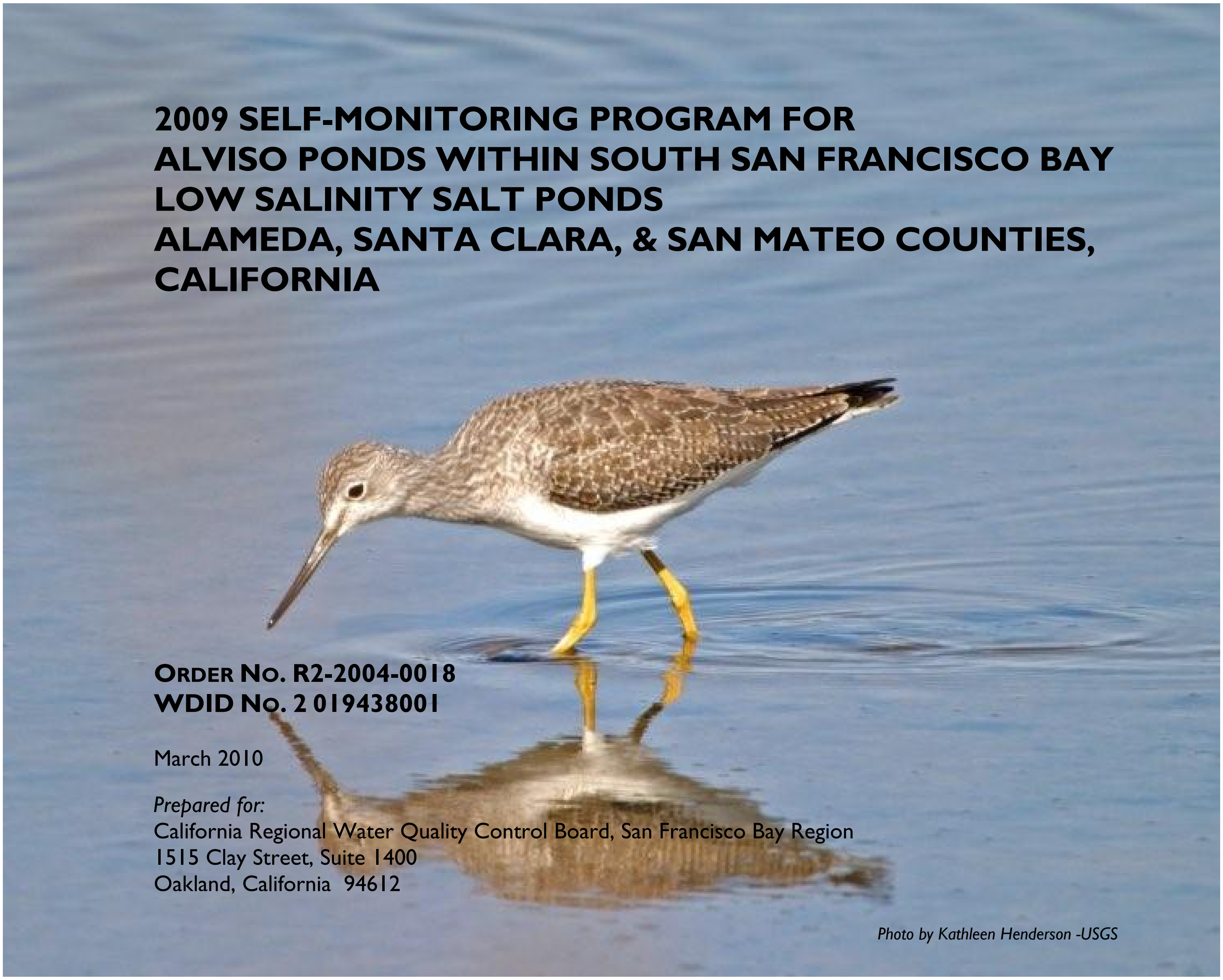

2009 SELF-MONITORING PROGRAM FOR ALVISO PONDS WITHIN SOUTH SAN FRANCISCO BAY LOW SALINITY SALT PONDS ALAMEDA, SANTA CLARA, & SAN MATEO COUNTIES, CALIFORNIA

ORDER NO. R2-2004-0018
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LIST OF ACRONYMS AND ABREVIATIONS

Acronym or Abbreviation	Full Phrase
Bay	South San Francisco Bay
CCM	Continuous Circulation Monitoring
CDFG	California Department of Fish and Game
DO	Dissolved Oxygen
FWS	United States Fish and Wildlife Service
GPS	Global Positioning System
IRP	Initial Release Period
mg/L	Milligrams per Liter
MLLW	Mean Lower Low Water
PAR	Photosynthetic Active Radiation
ppt	Parts per Thousand
Refuge	Don Edwards San Francisco Bay National Wildlife Refuge
RWQCB	California Regional Water Quality Control Board
USGS	United States Geological Survey

1. PROJECT OVERVIEW

SECTION 1
PROJECT OVERVIEW

This annual report summarizes the results of the 2009 water quality sampling conducted at the Alviso Ponds in Santa Clara County, California, which are part of the South San Francisco Bay (Bay) Low Salinity Salt Ponds. Operations occurred from June through October 2009. Sampling was performed on a continuous, weekly, monthly, or bi-monthly schedule as required by the California Regional Water Quality Control Board (RWQCB) Final Order (No. R2-2004-0018). Sampling was performed by the United States Geological Survey (USGS) on behalf of the United States Fish and Wildlife Service (FWS) in accordance with the waste discharge requirements.

The Final Order for the South San Francisco Bay Low Salinity Salt Ponds concerned 15,100 acres of ponds in Alameda, Santa Clara, and San Mateo Counties. The area encompasses the Alviso Pond Complex (Figure 1-1). This report covers the following pond systems within the complex: A3W, A7, A14, and A16. The systems are operated by the Don Edwards San Francisco Bay National Wildlife Refuge (Refuge) in Santa Clara County. The California Department of Fish and Game (CDFG) will submit a report for the Eden Landing (Baumberg) Ponds under a separate cover.

The ponds are generally being operated as flow-through systems with Bay or slough water entering an intake pond within each pond system at high tides through a tide gate, passing through one or more ponds, and exiting the particular system's discharge pond to either a tidal slough or the Bay at low tides. The ponds only discharge at low tides for about 6 or 8 hours per day. Two ponds in the A3W and A7 systems, Ponds A3N and A8, respectively, were operated as seasonal ponds during 2009 and were not connected to this flow-through system. Also, Ponds A12, A13, and A15, part of the A14 pond system, are designed as batch ponds. Discharge occurs from Pond A15 to Pond A16 when salinity reaches over 130 parts per thousand (ppt); it was not discharged on a batch basis in 2009.

The Final Order recognized two periods of discharges from the ponds. The first covered the Initial Release Period (IRP) when salinity levels would decrease from the initial levels in the ponds. The second period is the Continuous Circulation Monitoring (CCM) period after salinities went below the 44 ppt salinity discharge limit. Different monitoring plans were identified in the Final Order by RWQCB and revised in 2005 (March 25, 2005 letter) and 2008 (June letter) for each specific period and are reiterated below.

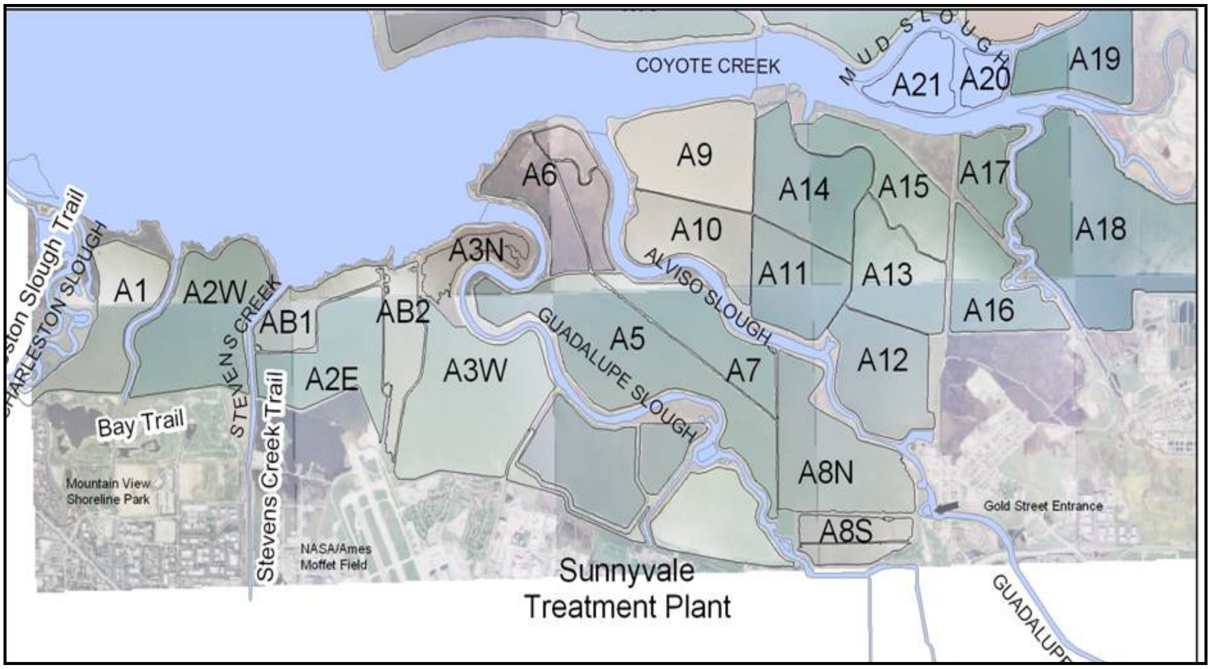

Figure 1-1: Alviso Pond Complex

1.1 RWQCB Initial Release Period Monitoring Plan

Receiving water samples from the slough and Bay were collected at discrete locations near the water surface and bottom from downstream and upstream of the discharge point. This occurred one week before initiating discharge, one day after the initial discharge, three days later, and then seven days later. Sampling continued on a weekly basis until the FWS was able to document that the discharge salinity levels were below 44 ppt. Once discharge began, discharge pond samples were collected prior to pond water mixing with receiving water using a continuous monitoring device. Dissolved oxygen (DO) levels in the pond water during discharge, calculated on a weekly basis, were required to remain above a 10th percentile of 3.3 milligrams per liter (mg/L). If the DO levels fell below this requirement, the FWS was required to accelerate receiving water monitoring in the slough and/or Bay to weekly, notify RWQCB staff, and implement best management practices to increase dissolved oxygen levels in discharged water, including within pond monitoring. For days it collects receiving water samples, the FWS also reported standard observations and documented what tidal phase samples were collected in. Additionally, the FWS made daily estimates of the quantity and time-period of discharge from the ponds and the strength of tides. All notes were recorded on standard monitoring sheets.

Samples for benthos were collected from discrete locations at the convenient stage of the tide at the following frequency: One week before initiating discharge; fourteen days after the initial discharge; 28 days following the second sampling; once in the late summer (August); and finally once in the late summer of the following year. Salinity samples were collected within ponds at least twice per month for at least the previous two months before discharges commenced. Dissolved oxygen samples were collected between 8:00 am and 10:00 am, with the times being recorded on the standard monitoring sheets.

1.2 RWQCB Continuous Circulation Period Monitoring Plan

In order to provide a better balance between within pond water quality and receiving water quality, the Final Order was revised in June 2008 to help better understand what modifications should be made to managed ponds to improve dissolved oxygen levels in the longer term.

Receiving water samples from the slough and Bay were collected at discrete locations near the water surface and bottom from downstream and upstream of the discharge point. Samples were collected on a monthly basis between July and October 2008 as close to low tide as practicable. For days it collects receiving water samples, the FWS also reported standard observations and documented what tidal phase samples were collected in. Additionally, the FWS made daily estimates of the quantity and time-period of discharge from the ponds and the strength of tides. All notes were recorded on standard monitoring sheets.

To provide an examination of both spatial and temporal variability of water quality parameters within ponds and across seasons from early summer through fall, each pond, (A3W, A14, and A16) were divided into four sampling areas (intake, discharge, borrow ditch, shallow) with a continuous monitor device in each location for a period of two weeks for three times during the season.

For each of the four sampling areas, a continuous monitoring device was installed for a period of two weeks and recorded: pH, temperature, dissolved oxygen, and salinity every 15 minutes. Also collected during each sampling period were dissolved oxygen transects, nutrients, chlorophyll a, water discharge flow, pore water profiles, and meteorological measurements.

From July 28 to October 10, 2009 a continuous monitoring device was installed at the discharge points for Ponds A3W and A7. Discharge pond samples were collected before pond water mixed with receiving water using a continuous monitoring device.

2. ANNUAL SUMMARY

SECTION 2
ANNUAL SUMMARY

This section summarizes the monitoring activities conducted by FWS during the 2009 calendar year at the Alviso Pond Complex to comply with the Final Order.

2.1 WATER QUALITY MONITORING METHODOLOGY

2.1.1 Continuous Pond Discharge Sampling

USGS installed continuous monitoring Datasondes (Hydrolab-Hach Company, Loveland, CO) in Alviso Ponds A3W, A14, A16, and A7. The meters were installed and began logging on 1 June 2009 through 31 October 2009. Datasondes were installed inside the ponds on the water control structures, where they could measure water quality at the outflow of the discharge into the adjacent slough or the Bay. They were secured within submerged perforated ABS tubes attached to water control structures to allow for free water circulation around the sensors. The devices were installed at a depth of at least 25 centimeters to ensure that all sensors were submerged, and these depths were monitored and adjusted to maintain constant submersion as the pond water level fluctuated.

Salinity, pH, temperature, and dissolved oxygen were collected at 15-minute intervals with a sensor and circulator warm-up period of two minutes. Data was downloaded weekly and Datasondes were serviced to check battery voltage and data consistency. A recently calibrated Hydrolab Minisonde (Hydrolab-Hach Company, Loveland, CO) was placed next to each Datasonde in a pond at the same depth, and readings of the two instruments were compared. Any problems detected with the Datasonde were corrected through calibration or replacement of parts or instruments. The sensors on the Datasonde were calibrated prior to deployment into salt ponds and were calibrated and cleaned on a biweekly schedule unless otherwise noted in service records. During the cleaning and calibration procedure, simultaneous readings were collected with a recently calibrated Hydrolab Minisonde to confirm data consistency throughout the procedure (initial, de-fouled, post-cleaned, and post-calibrated). The initial and de-fouled readings were also used to detect shifts in the data due to accumulation of biomaterials and sediment on the sensors.

In addition to the continuous monitoring Datasondes used at Alviso Ponds A3W, A14, A16, and A7 discharge locations, the USGS conducted intensive In-Pond Dissolved Oxygen Investigations in Alviso Ponds A3W, A16 and A14 from 1 June 2009 through 31 October 2009. During this time frame, additional Datasondes were placed within Ponds A14 and A3W and were left in these locations for the length of the study period, with the exception of cleaning and/or maintenance. In addition to continuous datasonde deployments, USGS also conducted dissolved oxygen transects in Ponds A3W and A14 during 11 weeks, and in Pond A16 during five weeks of the sample period.

From 1 June 2009 through 31 October 2009, the following sample types were collected:

- <u>Datasonde</u> – Three continuous sampling datasondes were installed in both Ponds A14 and A3W: one at the discharge location and two within the pond interior. For the interior locations, one datasonde was installed near the bottom of the water column, to record data from a deep location, and one datasonde was installed at the very top of the water column, to record data from a shallow location. In most cases these recorded salinity, pH, temperature, and DO at 15-minute intervals, with the exception of instrumentation failures. Additionally, one continuous sampling datasonde was installed at the discharge location in both Ponds A7 and A16.

- <u>DO transects</u> – To examine spatial variability across the ponds, we conducted DO transects approximately twice per month for Ponds A14 and A3W and once per month for Pond A16. One sampling event coincided with the lowest past DO readings during early morning (pre- or early dawn); while the second coincided with the highest past DO readings during mid to late afternoon. In all cases these transects were conducted on the same day and a minimum of 20 data points were collected from two perpendicular transects.

- <u>Nutrients</u> – To examine spatial variability across the ponds representative nutrient samples were collected from Ponds A3W, A14, and A16. From June through October three samples were collected once per month for each of these ponds. These samples were then analyzed for NO_3-N, NH_4-N, and total and soluble phosphorus.

- <u>Chlorophyll a</u> – To examine spatial variability across the ponds, a chlorophyll *a* sensor (Hach Hydrolab) was used to record values from each of these three ponds during dissolved oxygen transects. In conjunction with the chlorophyll *a* sensor, water samples were collected periodically to compare with sensor values. Chlorophyll investigations began in mid-August 2009 and ran through early November 2009. The number of samples collected varied between ponds and month. Samples were then filtered and analyzed for chlorophyll a and phaeopigments.

- <u>Meterological measurements</u> – A portable weather station was installed on Pond A7 as a location between the study ponds and was used to collect meteorological data. Wind speed and direction, air temperature, relative humidity, Photosynthetic Active Radiation (PAR), and solar radiation were collected at 15-minute intervals during each sample period.

2.1.2 Alviso Receiving Water (IRP/CCM):

Beginning 18 June 2009, samples were collected monthly from Pond A3W receiving water (Guadalupe Slough, 8 sites), Pond A7 receiving water (Alviso Slough, 7 sites), Pond A16 receiving water (Artesian Slough, 5-6 sites), and Pond A14 (Coyote Creek, 3 sites) through October 2009. Slough sampling sites were accessed via boat from the Bay and a GPS was used to navigate to sampling locations. When the boat was approximately 25 to 50 meters from the site, the engine would be cut or reduced to allow for drifting caused by current and wind to the site location. Every effort was made to ensure that the sample reading was collected from the center of the slough. A recently calibrated Hydrolab Minisonde was used to measure salinity, pH, temperature, and DO at each location. Samples were collected from the near-bottom of the water column in addition to the near-surface (25 centimeters) at each sampling location. Depth readings for sample locations were collected at the completion of each Minisonde measurement to account for drift during the reading equilibration period. The specific gravity of each site was additionally measured with a hydrometer (Ertco, West Paterson, New Jersey) scaled for the appropriate range. This sample was collected concurrently with the near-surface Minisonde measurement. The majority of the samples were collected on the rising or high tide in order to gain access to the sampling sites, which were not accessible at tides less than 3.0 feet mean lower low water (MLLW). Standard observations were collected at each site. These were:

A) observance of floating and suspended materials of waste origin;

B) description of water condition including discoloration and turbidity;

C) odor (presence or absence, characterization, source and wind direction);

D) evidence of beneficial use, presence of wildlife, fisherpeople and other recreational activities;

E) hydrographic conditions (time and height of tides, and depth of water column and sampling depths); and

F) weather conditions (air temp, wind direction and velocity, and precipitation).

Sections A, B, C, D and E were recorded at each sampling location. Section F was recorded at the beginning and ending of each slough, unless it had changed significantly.

2.1.3 Calibration and Maintenance:

All the instruments used for sampling as part of the South Bay Salt Pond Initial Stewardship Plan's Self-Monitoring Program were calibrated and maintained according to the USGS standard procedures. Datasondes were calibrated pre-deployment and maintained on a biweekly cleaning and calibration schedule unless they required additional maintenance. The problem of algae and other substances interfering with the moving parts such as on the self-cleaning brush and circulator was improved with the use of nylon stockings. This allowed for maximum water flow past the sensor but stopped algae from wrapping around and binding the moving parts. Copper mesh and wire was used to inhibit growth in ponds with high concentrations of barnacles and hard algae, which could interfere with sensor function. We performed a biweekly fouling check to detect shifts in data due to the accumulation of biomaterial and sediment on the sensors. A calibration and maintenance log was maintained for each pond.

2.2 CONTINUOUS CIRCULATION MONITORING

Pond systems A2W, A3W, and A7 have been opened to the Bay and slough since 2004 and were being monitored during their Continuous Circulation Phases. Pond Systems A14 and A16 were opened to the sloughs on March 31, 2005 and were also being monitored under Continuous Circulation. During the 2009 monitoring season, only Pond A3W and Pond A7 were monitored for discharge since these two ponds have typically shown low DO throughout the summer months. The results of the 2009 sampling events in the pond systems are documented below.

2.2.1 Pond A3W Discharge Samples

Data collected at the A3W discharge sonde in 2009 was compared to previous years (2005-2008). Daily averages for salinity, pH, and dissolved oxygen were most similar to data collected in 2007 and 2008 (Appendix A, Figures A-1, A-2, and A-3), and averages for temperature were similar across years (Appendix A, Figure A-4). Generally, salinity increased over the season across all years, and was highest in 2007-2009 compared with 2005-2006 (Appendix A, Figure A-1). This year's pH averages were higher than they were in 2008 but were similar to those found in 2005 and 2007 (Appendix A, Figure A-2). Temperatures recorded this year are consistent with data collected during all other years, which we highest during late June to early August (Appendix A, Figure A-4). This year, as well as all previous years, dissolved oxygen values have been highly variable within Pond A3W but generally decreased during the period of highest pond and ambient temperatures (Appendix A, Figures A-3 and A-5). Averages this year were most similar to values found in 2007 and 2008 where dissolved oxygen values were above 3.33 mg/L early in the season, fell below this threshold during the hotter, summer months, and rose above 3.33 mg/L late in the season. All weekly 10^{th} percentile values for pond A3W fell below 3.33 mg/L this year compared with previous years; similar patterns were observed in ponds A7, A14, and A16 (Appendix A, Figure A-5; Tables 2.2-1 through 2.2-4).

2.2.2 Pond A7 Discharge Samples

Data collected at the A7 discharge datasonde in 2009 was compared to previous years (2005-2008). Like Pond A3W, daily averages for salinity, pH, and dissolved oxygen on pond A7 were most similar to data collected in 2007 and 2008 (Appendix A, Figures A-6, A-7, and A-8), and averages for temperature were similar across years (Appendix A, Figure A-9). Salinity was higher this year than in 2005 and 2006 but similar to values seen in 2007 and 2008 (Appendix A, Figure A-6). In contrast with previous years, pH values in 2009 rose in June but fall below 8.5 by the sampling period (Appendix A, Figure A-7). Temperatures recorded this year are consistent with data collected during all other years, which we highest during late June to early August (Appendix A, Figure A-9). Dissolved oxygen values recorded this year remained below 3.33 mg/L longer than they had in previous years (Appendix A, Figure A-8; Table 2.2-2). Most weekly 10^{th} percentile values for pond A7 fell below 3.33 mg/L this year compared with previous years; similar patterns were observed in ponds A3W, A14, and A16 (Appendix A, Figure A-10; Tables 2.2-1 through 2.2-4).

Table 2.2-1: 10th Percentiles for Dissolved Oxygen during Dicharge in Pond A3W

Start Date	End Date	2009 data (mg/L)	2008 data (mg/L)	2007 data (mg/L)	2006 data (mg/L)	2005 data (mg/L)	2004 data (mg/L)
4/23	4/30	n/a	n/a	1.7	4.7	5.1	n/a
5/1	5/5	n/a	n/a	2.7	4.2	3.5	n/a
5/6	5/12	n/a	n/a	3.1	4.3	3.8	n/a
5/13	5/19	n/a	n/a	2.6	3.2	4.4	n/a
5/20	5/26	n/a	n/a	1.7	5.2	3.8	n/a
5/27	6/2	n/a	n/a	0.0	5.4	3.6	n/a
6/3	6/9	2.2	n/a	0.0	5.0	3.8	n/a
6/10	6/16	0.7	n/a	0.2	3.5	3.5	n/a
6/17	6/23	2.0	n/a	1.6	2.7	3.9	n/a
6/24	6/30	2.5	n/a	1.6	2.3	3.6	n/a
7/1	7/7	1.2	n/a	1.6	2.7	3.7	n/a
7/8	7/14	0.3	n/a	0.6	2.7	4.5	n/a
7/15	7/21	1.0	n/a	0.4	2.3	1.7	0.1
7/22	7/28	0.2	n/a	0.7	0.5	1.9	0.7
7/29	8/4	0.6	0.1	0.8	2.6	2.6	0.1
8/5	8/11	1.7	0.1	1.3	2.9	3.6	0.4
8/12	8/18	1.1	0.3	0.8	2.9	3.5	0.1
8/19	8/25	1.0	0.5	0.2	3.4	3.6	0.1
8/26	9/1	0.0	0.1	0.4	2.5	1.9	0.1
9/2	9/8	0.0	0.8	0.3	1.9	0.6	0.1
9/9	9/15	0.9	0.4	0.7	2.5	3.6	0.1
9/16	9/22	0.9	0.1	1.1	4.7	2.2	0.1
9/23	9/29	0.1	0.1	1.3	3.2	3.8	0.1
9/30	10/6	0.5	0.3	2.1	2.8	1.4	0.1
10/7	10/13	1.3	0.3	2.0	4.0	4.0	0.1
10/14	10/20	0.1	n/a	3.4	4.6	4.0	1.0
10/21	10/27	0.1	n/a	2.7	2.8	3.5	2.0
10/28	11/3	3.1	n/a	3.4	5.7	5.6	2.5
11/4	11/10	n/a	n/a	4.9	n/a	5.2	4.2
11/11	11/13	n/a	n/a	7.0	n/a	n/a	n/a

* Data is based on a 10th percentile with 3.33 mg/L being the trigger for reporting non-compliance

Table 2.2-2: 10th Percentiles for Dissolved Oxygen during Discharge in Pond A7

Start Date	End Date	2009 data (mg/L)	2008 data (mg/L)	2007 data (mg/L)	2006 data (mg/L)	2005 data (mg/L)	2004 data (mg/L)
4/24	4/30	n/a	n/a	n/a	5.9	3.2	n/a
5/1	5/6	n/a	n/a	n/a	4.8	1.3	n/a
5/7	5/12	n/a	n/a	3.5	5.5	2.2	n/a
5/13	5/19	n/a	n/a	4.8	4.9	1.9	n/a
5/20	5/26	n/a	n/a	3.9	5.3	2.5	n/a
5/27	6/2	n/a	n/a	3.6	5.9	2.7	n/a
6/3	6/9	5.4	n/a	4.0	2.7	3.5	n/a
6/10	6/16	4.4	n/a	3.6	3.4	3.1	n/a
6/17	6/23	3.1	n/a	4.0	3.5	4.0	n/a
6/24	6/30	1.9	n/a	3.9	4.0	2.8	n/a
7/1	7/7	0.8	n/a	3.6	5.4	3.8	n/a
7/8	7/14	3.3	n/a	3.2	4.5	4.7	n/a
7/15	7/21	4.0	n/a	3.8	4.4	4.7	n/a
7/22	7/28	2.8	n/a	3.5	3.9	4.7	0.7
7/29	8/4	1.5	0.1	3.6	5.3	4.7	0.2
8/5	8/11	1.8	1.0	4.7	6.0	4.7	2.5
8/12	8/18	0.4	0.0	4.6	5.9	4.6	2.7
8/19	8/25	0.3	0.3	2.8	5.8	5.1	2.7
8/26	9/1	0.9	0.0	1.5	4.1	4.1	1.5
9/2	9/8	1.2	0.0	0.1	3.5	2.8	0.6
9/9	9/15	0.9	n/a	0.1	4.1	3.2	0.5
9/16	9/22	0.8	1.1	2.2	4.4	2.1	1.2
9/23	9/29	0.9	1.0	0.3	2.9	1.2	0.4
9/30	10/6	1.4	0.1	0.6	2.4	1.4	2.3
10/7	10/13	1.1	1.9	0.2	3.5	2.8	3.3
10/14	10/20	1.5	n/a	1.5	4.0	2.7	3.0
10/21	10/27	5.0	n/a	3.3	4.1	2.4	2.2
10/28	11/3	1.8	n/a	1.3	5.7	4.5	0.9
11/4	11/10	n/a	n/a	3.4	n/a	4.2	2.5
11/11	11/17	n/a	n/a	5.8	n/a	n/a	3.8
11/18	11/19	n/a	n/a	5.0	n/a	n/a	4.5

Table 2.2-3: 10th Percentiles for Dissolved Oxygen during Discharge in Pond A16

Start Date	End Date	2009 data (mg/L)	2008 data (mg/L)	2007 data (mg/L)	2006 data (mg/L)	2005 data (mg/L)
4/23	4/30	n/a	n/a	n/a	3.70	6.57
5/1	5/5	n/a	n/a	8.16	5.07	6.03
5/6	5/12	n/a	n/a	7.67	6.97	5.30
5/13	5/19	n/a	n/a	6.73	2.87	5.70
5/20	5/26	n/a	n/a	4.83	2.94	6.60
5/27	6/2	n/a	n/a	3.92	4.34	3.50
6/3	6/9	4.98	n/a	6.38	4.19	3.50
6/10	6/16	4.06	n/a	7.12	3.72	3.84
6/17	6/23	2.95	4.13	6.43	1.48	3.91
6/24	6/30	1.15	5.7	7.53	2.01	2.70
7/1	7/7	2.91	n/a	6.94	1.54	3.30
7/8	7/14	2.34	n/a	5.77	5.82	2.30
7/15	7/21	2.77	n/a	5.12	3.00	3.15
7/22	7/28	2.61	n/a	4.93	4.57	2.70
7/29	8/4	1.72	n/a	3.67	6.18	2.82
8/5	8/11	2.57	n/a	3.42	6.58	0.63
8/12	8/18	0.27	n/a	2.28	1.06	5.92
8/19	8/25	0.12	0.1	2.17	2.61	2.50
8/26	9/1	0.12	0.3	1.25	4.25	2.60
9/2	9/8	0.13	n/a	0.28	5.17	3.30
9/9	9/15	0.13	n/a	2.82	2.04	4.40
9/16	9/22	0.12	n/a	2.04	4.16	4.23
9/23	9/29	0.06	n/a	4.53	4.41	3.60
9/30	10/6	0.12	n/a	3.78	4.20	4.01
10/7	10/13	0.67	n/a	3.83	7.61	4.65
10/14	10/20	0.15	n/a	2.84	5.46	4.80
10/21	10/27	0.16	5.8	0.10	2.77	3.80
10/28	11/3	n/a	4.3	0.90	4.00	4.90
11/4	11/10	n/a	n/a	0.90	n/a	3.50
11/11	11/13	n/a	n/a	n/a	n/a	n/a

* Data is based on a 10th percentile with 3.33 mg/L being the trigger for reporting non-compliance

Table 2.2-4: 10th Percentiles for Dissolved Oxygen during Discharge in Pond A14

Start Date	End Date	2009 data (mg/L)	2008 data (mg/L)	2007 data (mg/L)	2006 data (mg/L)	2005 data (mg/L)
3/24	3/26	n/a	n/a	n/a	n/a	5.40
3/27	4/2	n/a	n/a	n/a	n/a	4.90
4/3	4/9	n/a	n/a	n/a	n/a	5.44
4/10	4/16	n/a	n/a	n/a	n/a	5.50
4/17	4/23	n/a	n/a	n/a	n/a	4.64
4/24	4/30	n/a	n/a	2.79	1.05	n/a
5/1	5/5	n/a	n/a	3.28	0.05	2.35
5/6	5/12	n/a	n/a	5.31	0.01	0.08
5/13	5/19	n/a	n/a	6.30	0.01	0.10
5/20	5/26	n/a	n/a	4.80	0.37	0.00
5/27	6/2	n/a	n/a	4.65	0.19	0.00
6/3	6/9	1.90	n/a	5.19	0.16	3.20
6/10	6/16	1.93	n/a	4.71	0.19	0.50
6/17	6/23	2.39	n/a	4.10	0.34	1.18
6/24	6/30	1.88	n/a	4.43	0.26	0.72
7/1	7/7	1.25	n/a	4.39	1.84	0.76
7/8	7/14	2.10	0.61	3.61	0.89	2.45
7/15	7/21	0.27	1.21	3.54	1.03	1.20
7/22	7/28	0.49	n/a	3.67	1.56	1.67
7/29	8/4	1.53	n/a	4.83	1.87	1.08
8/5	8/11	1.47	n/a	4.73	0.12	1.34
8/12	8/18	0.41	n/a	4.32	0.15	2.37
8/19	8/25	0.04	n/a	3.51	0.11	2.07
8/26	9/1	0.34	n/a	2.04	0.10	0.35
9/2	9/8	0.20	n/a	1.44	n/a	0.59
9/9	9/15	0.40	0.50	2.58	1.31	0.44
9/16	9/22	0.19	0.40	2.83	0.21	0.70
9/23	9/29	0.09	n/a	2.62	0.03	0.10
9/30	10/6	0.23	n/a	3.83	0.04	1.28
10/7	10/13	1.55	n/a	4.57	0.09	0.61
10/14	10/20	1.08	n/a	4.20	1.73	0.61
10/21	10/27	1.94	n/a	4.41	0.64	0.08
10/28	11/3	3.40	n/a	5.31	1.01	1.31
11/4	11/10	n/a	n/a	n/a	n/a	2.93
11/11	11/17	n/a	2.48	n/a	n/a	1.46
11/18	11/24	n/a	n/a	n/a	n/a	0.25
11/25	11/30	n/a	n/a	n/a	n/a	3.16

* Data is based on a 10th percentile with 3.33 mg/L being the trigger for reporting non-compliance

2.3 RECEIVING WATER SAMPLING

2.3.1 Receiving Water Analyses

Receiving water data were collected for the Alviso Complex from June through October 2009 (Figure 2.3-1). Here we plot the receiving water samples collected and the pond discharge for water quality parameters of salinity, temperature, pH, and DO for each system in the Alviso Complex.

2.3.2 Pond A3W Receiving Water Samples

We compared data collected during receiving water sampling to average daily values for the same parameter collected at the A3W pond discharge location. Salinity was higher within the pond than in the Guadalupe Slough, with the exception of the month of October (Appendix A, Figure A-11). Vertical stratification was apparent in 2009, with salinity at bottom waters being 1to 11 ppt greater than surface waters. Generally pH values were higher at the pond discharge location compared with receiving waters by date (Appendix A, Figure A-12). Temperatures within Pond A3W were very similar to those within the slough; this was also the case for bottom and surface waters within Guadalupe Slough (Appendix A, Figure A-13). Very similar temperature values were recorded for each location but temperatures were generally higher at surface waters (Appendix A, Figure A-13). Dissolved oxygen was highly variable at the Pond A3W discharge but was always lower than DO values within the slough by date (Appendix A, Figure A-14).

2.3.3 Pond A7 Receiving Water Samples

We compared data collected during receiving water sampling to average daily values for the same parameter collected at the A7 pond discharge location. Salinity was higher within Pond A7 then within Alviso Slough (Appendix A, Figure A-15). There was also an obvious vertical stratification, where bottom waters always recorded higher salinity values that were 3 – 17 ppt higher than surface waters. Like salinity, pH values were higher at the discharge point than in receiving waters; vertical stratification can be seen in receiving waters where bottom waters were 0 to 0.13 units higher than surface waters (Appendix A, Figure A-16). Temperatures within Pond A7 were similar to those recorded in Alviso Slough. Temperatures at discharge waters were generally somewhere in between values recorded at bottom and surface waters, in which surface waters had slightly higher temperatures than bottom waters (Appendix A, Figure A-17). Surface waters typically had higher dissolved oxygen values than bottom or discharge waters (Appendix A, Figure A-18). The majority of daily means for discharge waters fell below 3.33 mg/L this year. Although low, dissolved oxygen values in 2009 have increased from 2008 where all discharge points fell below this threshold.

2.3.4 Pond A14 and A16 Receiving Water Samples

Dissolved oxygen and temperature values in A14 and A16 show vertical stratification, with higher values at surface waters (Tables 2.3-1 and 2.3-2). Salinity and pH values show the opposite trend and were generally higher at waters near the bottom of the slough.

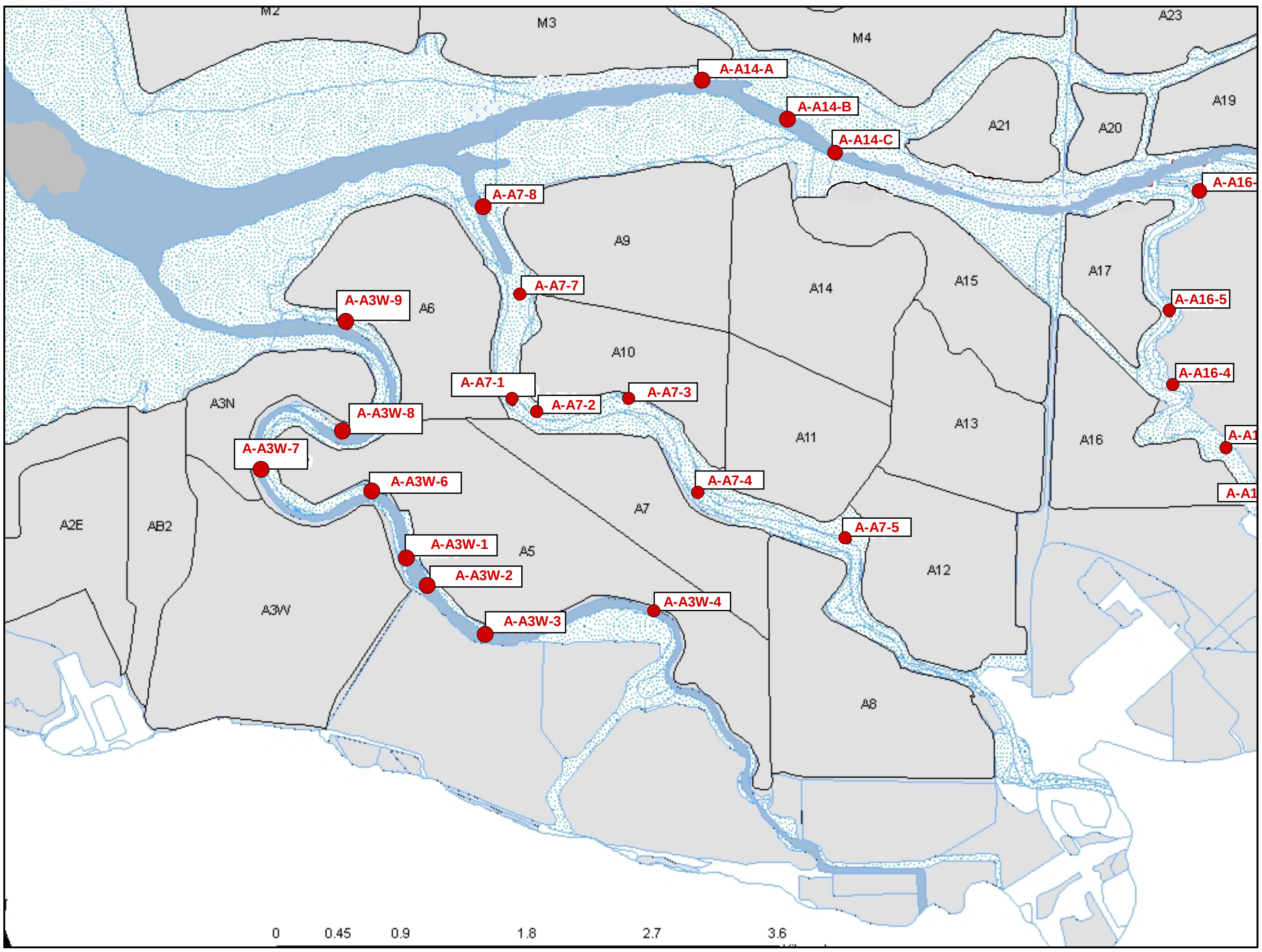

Figure 2.3-1: 2009 Receiving Water Sampling Locations

Table 2.3-1: Receiving water quality values (mean ± standard deviation) for ponds A3W and A7 by sampling date.

Pond	Date	Depth	Salinity (ppt)	Dissolved Oxygen (mg/L)	Temperature (°C)	pH (Units)
A3W	6/18/2009	Bottom	19.62 ± 3.5	4.42 ± 0.9	20.97 ± 0.3	7.96 ± 0.1
		Surface	18.64 ± 3.3	4.91 ± 0.6	21.84 ± 0.7	8.01 ± 0.2
	7/16/2009	Bottom	24.21 ± 1.4	3.34 ± 1.5	23.31 ± 0.4	7.77 ± 0.2
		Surface	22.71 ± 1.6	4.00 ± 1.0	23.12 ± 0.8	7.77 ± 0.1
	8/13/2009	Bottom	21.15 ± 3.0	2.99 ± 1.3	23.22 ± 0.3	8.03 ± 0.3
		Surface	19.34 ± 2.8	3.45 ± 0.9	23.28 ± 0.5	8.08 ± 0.2
	9/15/2009	Bottom	21.57 ± 4.6	3.15 ± 1.7	20.90 ± 0.1	7.77 ± 0.0
		Surface	20.73 ± 4.2	3.12 ± 1.7	21.02 ± 0.2	7.77 ± 0.1
	10/14/2009	Bottom	13.64 ± 8.0	5.35 ± 0.7	16.05 ± 0.0	5.85 ± 0.2
		Surface	7.07 ± 5.1	5.63 ± 0.1	16.55 ± 0.1	5.75 ± 0.3
A7	6/18/2009	Bottom	21.17 ± 2.8	3.64 ± 1.5	20.90 ± 0.2	8.06 ± 0.3
		Surface	15.78 ± 4.7	5.05 ± 0.9	22.81 ± 0.6	8.06 ± 0.2
	7/16/2009	Bottom	23.07 ± 1.5	2.88 ± 1.2	23.67 ± 0.3	7.79 ± 0.2
		Surface	15.06 ± 6.0	4.34 ± 0.4	23.74 ± 0.3	7.66 ± 0.1
	8/13/2009	Bottom	22.58 ± 1.6	2.30 ± 0.8	23.54 ± 0.2	7.83 ± 0.1
		Surface	12.79 ± 5.5	3.99 ± 0.2	23.70 ± 0.3	7.71 ± 0.0
	9/15/2009	Bottom	25.81 ± 4.4	3.96 ± 1.2	21.19 ± 0.1	7.77 ± 0.0
		Surface	22.89 ± 3.6	3.77 ± 1.0	22.40 ± 0.3	7.75 ± 0.0
	10/14/2009	Bottom	18.52 ± 8.7	5.62 ± 0.7	16.16 ± 0.3	6.88 ± 0.3
		Surface	1.67 ±1.6	6.03 ± 0.4	17.22 ± 0.1	7.13 ± 0.8

Table 2.3-2: Receiving water quality values (mean ± standard deviation) for Ponds A14 and A16 by sampling date.

Pond	Date	Depth	Salinity (ppt)	Dissolved Oxygen (mg/L)	Temperature (°C)	pH (Units)
A14	6/18/2009	Bottom	19.37 ± 3.0	3.96 ± 0.6	20.92 ± 0.9	7.86 ± 0.1
		Surface	16.33 ± 0.8	4.12 ± 0.1	22.23 ± 0.1	7.96 ± 0.0
	7/16/2009	Bottom	21.28 ± 2.2	3.49 ± 0.5	23.54 ± 0.3	7.63 ± 0.1
		Surface	16.03 ± 1.8	4.16 ± 0.1	24.84 ± 0.3	7.61 ± 0.0
	8/13/2009	Bottom	25.66 ± 1.0	3.71 ± 0.6	23.91 ± 0.7	7.92 ± 0.3
		Surface	14.53 ± 2.0	3.63 ± 0.2	25.53 ± 0.4	7.62 ± 0.0
	9/15/2009	Bottom	28.12 ± 2.8	4.55 ± 1.2	22.25 ± 1.5	7.91 ± 0.2
		Surface	27.14 ± 1.1	5.19 ± 0.1	22.79 ± 0.1	7.79 ± 0.0
	10/14/2009	Bottom	18.33 ± 6.1	5.81 ± 0.5	16.52 ± 0.4	7.62 ± 0.2
		Surface	14.77 ± 4.4	6.06 ± 0.4	17.23 ± 0.4	7.95 ± 0.4
A16	6/18/2009	Bottom	12.94 ± 1.8	5.35 ± 2.3	23.43 ± 1.0	8.54 ± 0.5
		Surface	3.21± 2.4	6.79 ± 1.2	25.41 ± 0.5	7.66 ± 0.1
	7/16/2009	Bottom	15.57 ± 2.4	3.04 ± 1.1	25.23 ± 0.2	8.21 ± 0.4
		Surface	3.32 ± 1.4	6.72 ± 1.0	26.69 ± 0.4	7.47 ± 0.2
	8/13/2009	Bottom	19.13 ± 2.1	2.69 ± 1.8	25.79 ± 0.7	8.31 ± 0.2
		Surface	4.40 ± 3.0	6.18 ± 1.7	27.27 ± 0.6	7.49 ± 0.2
	9/15/2009	Bottom	17.41 ± 2.8	2.48 ± 1.1	22.68 ± 0.8	7.92 ± 0.3
		Surface	6.96 ± 5.9	4.77 ± 1.9	25.24 ± 1.8	7.41 ± 0.1
	10/14/2009	Bottom	8.03 ± 4.9	4.60 ± 1.2	20.09 ± 2.0	6.27 ± 0.8
		Surface	2.79 ± 1.8	5.67 ± 1.2	21.54 ± 2.1	6.64 ± 1.0

3. POND A3W IN-POND SAMPLING

SECTION 3
POND A3W IN-POND SAMPLING

This section summarizes analyses of 2009 water quality data being conducted for Pond A3W to characterize spatial variability and patterns with respect to flow patterns and pond management. A brief description of our initial findings is presented below:

3.1 CONTINUOUS WATER QUALITY MONITORING

Datasondes were deployed at three locations within Pond A3W during the study period (Figure 3.1-1). We found that dissolved oxygen concentrations were highest in June and October, and lowest in August and September (Table 3.1-1). Conversely, salinity and temperatures were lowest in June and October and highest in August and September (Table 3.1-1). Generally, dissolved oxygen was lower in the deep compared with the shallow datasonde, indicating probable vertical stratification of dissolved oxygen concentrations within the water column of this pond.

We logged the highest mean dissolved oxygen value (9.35 mg/L) at the shallow datasonde location during the month of October (Table 3.1-1). October also had the highest average dissolved oxygen values, which may be due, in part, to lower temperatures during this month. These findings are similar to those from previous years (2005 through 2008) at the discharge location.

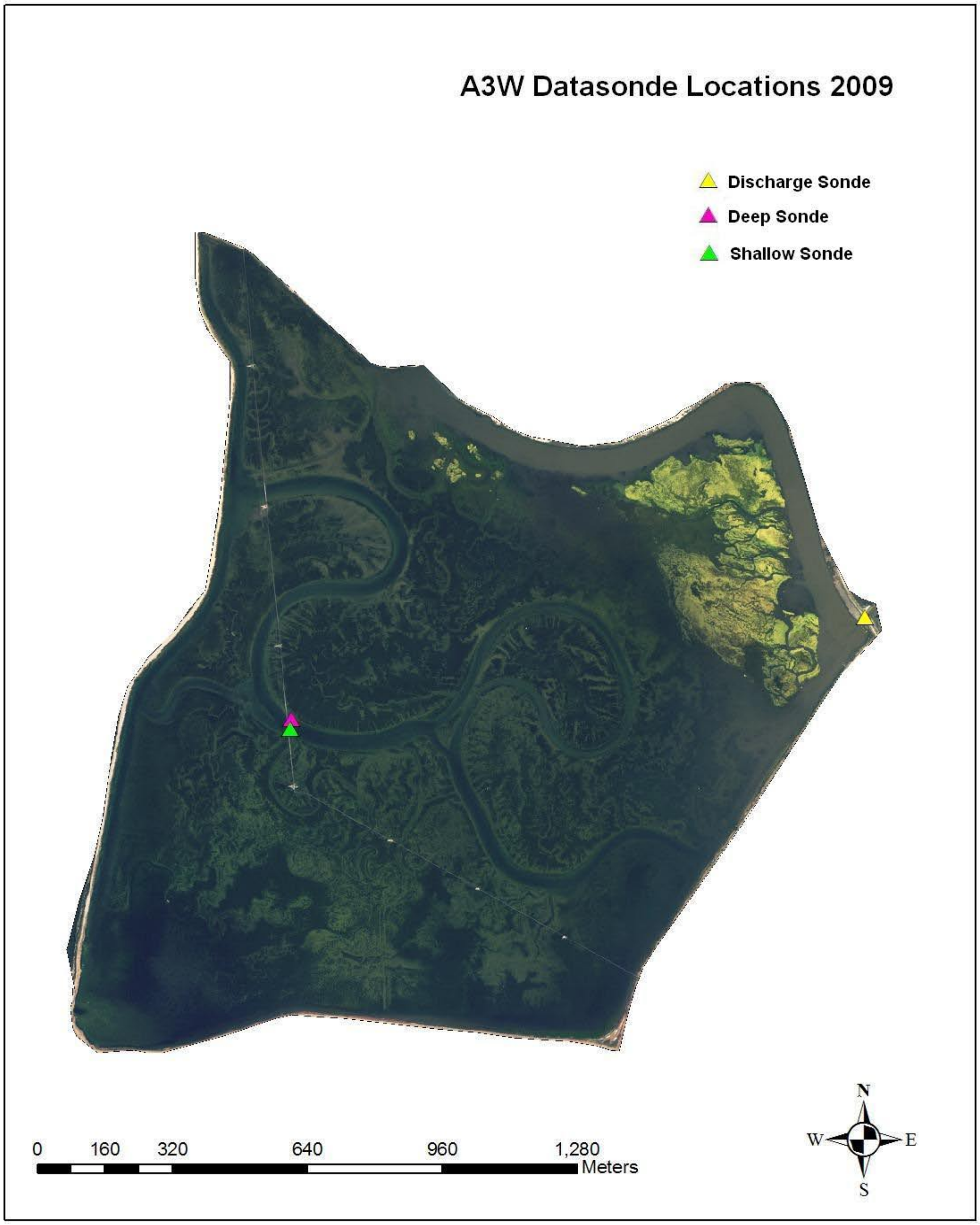

Figure 3.1-1: Datasonde Locations in Pond A3W

Table 3.1-1: Pond A3W summarized water quality values (mean ± standard deviation) by month

Pond	Month	Dissolved Oxygen (mg/L)	pH (Units)	Specific Conductivity (mS/cm)	Temperature (°C)	Salinity (ppt)
A3W	**June**					
	Overall	5.39 ± 2.36	8.60 ± 0.15	39.45 ± 3.96	21.74 ± 2.02	25.19 ± 2.79
	Discharge	4.70 ± 2.31	8.44 ± 0.15	34.60 ± 3.53	21.50 ± 1.91	21.76 ± 2.48
	Shallow	6.30 ± 2.18	8.69 ± 0.07	41.65 ± 1.22	21.92 ± 2.07	26.75 ± 0.85
	Deep	5.13 ± 2.30	8.64 ± 0.07	41.73 ± 1.03	21.79 ± 2.03	26.81 ± 0.74
	July					
	Overall	4.73 ± 2.92	8.60 ± 0.32	43.20 ± 4.24	22.93 ± 1.66	27.91 ± 3.05
	Discharge	2.25 ± 1.68	8.25 ± 0.17	37.75 ± 2.58	22.79 ± 1.64	23.97 ± 1.84
	Shallow	6.47 ± 2.39	8.97 ± 0.08	45.90 ± 1.03	23.29 ± 1.73	29.82 ± 0.75
	Deep	5.48 ± 2.69	8.75 ± 0.09	46.09 ± 1.07	22.88 ± 1.60	29.96 ± 0.78
	August					
	Overall	3.68 ± 3.50	8.83 ± 0.28	44.68 ± 4.14	22.77 ± 1.35	28.95 ± 3.01
	Discharge	2.55 ± 1.86	8.72 ± 0.24	39.43 ± 2.98	22.74 ± 1.53	25.17 ± 2.13
	Shallow	7.21 ± 2.70	9.10 ± 0.16	47.22 ± 0.74	23.14 ± 1.43	30.78 ± 0.78
	Deep	1.28 ± 2.57	8.69 ± 0.21	47.40 ± 0.76	22.43 ± 0.93	30.90 ± 0.83
	September					
	Overall	3.39 ± 3.80	8.50 ± 0.60	43.62 ± 4.70	22.12 ± 1.67	28.19 ± 3.41
	Discharge	1.73 ± 1.70	8.45 ± 0.21	37.91 ± 2.85	17.58 ± 1.72	24.09 ± 2.03
	Shallow	7.50 ± 3.07	9.00 ± 0.21	46.26 ± 1.20	22.48 ± 1.79	30.08 ± 1.04
	Deep	0.32 ± 1.04	7.94 ± 0.73	47.48 ± 0.95	21.58 ± 1.29	30.96 ± 0.95
	October					
	Overall	6.09 ± 4.13	8.49 ± 0.35	40.07 ± 5.04	17.46 ± 2.08	25.65 ± 3.55
	Discharge	4.09 ± 3.17	8.41 ± 0.20	35.92 ± 5.50	17.42 ± 1.98	22.72 ± 3.82
	Shallow	9.35 ± 3.50	8.42 ± 0.51	42.11 ± 3.18	17.61 ± 2.17	27.09 ± 2.29
	Deep	4.81 ± 3.53	8.65 ± 0.17	42.26 ± 3.03	17.34 ± 2.07	27.20 ± 2.18
	Overall					
	Discharge	3.08 ± 2.50	8.45 ± 0.25	37.14 ± 3.98	21.22 ± 2.75	23.56 ± 2.80
	Shallow	7.50 ±3.10	8.79 ± 0.42	44.47 ± 3.02	21.39 ± 2.91	28.79 ± 2.20
	Deep	3.46 ± 3.35	8.56 ± 0.42	44.75 ± 3.10	21.07 ± 2.68	28.99 ± 2.27

Dissolved Oxygen

Dissolved oxygen (DO) concentrations cycled with the tides and with the diurnal cycle throughout the study period from June 1 to October 31, 2009 (Figures 3.1-2 through 3.1-23). The recorded values differed at each of the three datasonde locations and were generally most variable at the discharge location. Overall, the discharge location had the lowest average DO values closely followed by the datasonde at the deep location. These low DO values were most frequently recorded early in the morning and during low tides. Extremely low DO concentrations (e.g. < 1.0 mg/L) were recorded from early August through late September at the deep datasonde location; the discharge datasonde also showed slightly lower levels during this period. Perhaps these low DO levels may be related to decreased photosynthetically active radiation (PAR) values during this period. However, the datasonde at the shallow location recorded fairly high values for DO during the month of September, and the cause of this variation remains unclear. We have no evidence from USGS calibration and maintenance records to indicate that the extremely low DO concentrations observed at the deep datasonde location during the late summer period were due to faulty equipment, and thus we believe that these low observed concentrations were pond-related.

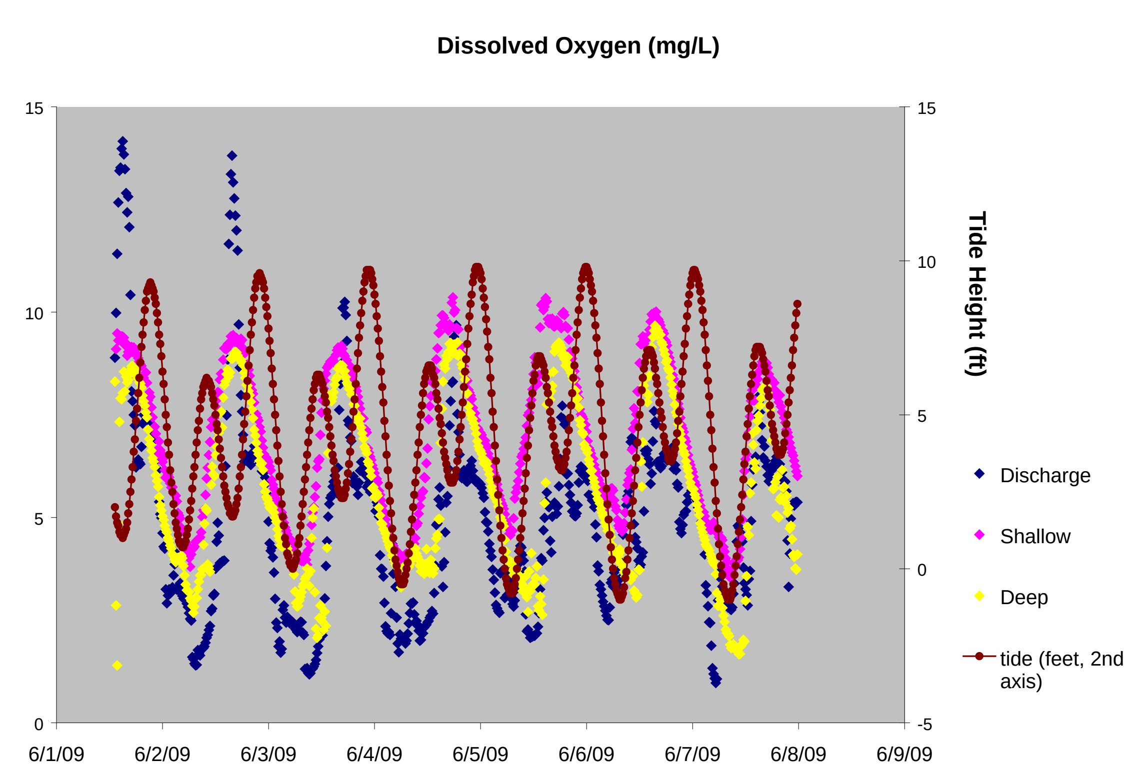

Figure 3.1-2: Pond A3W dissolved oxygen values at 3 pond locations during 1 June – 7 June

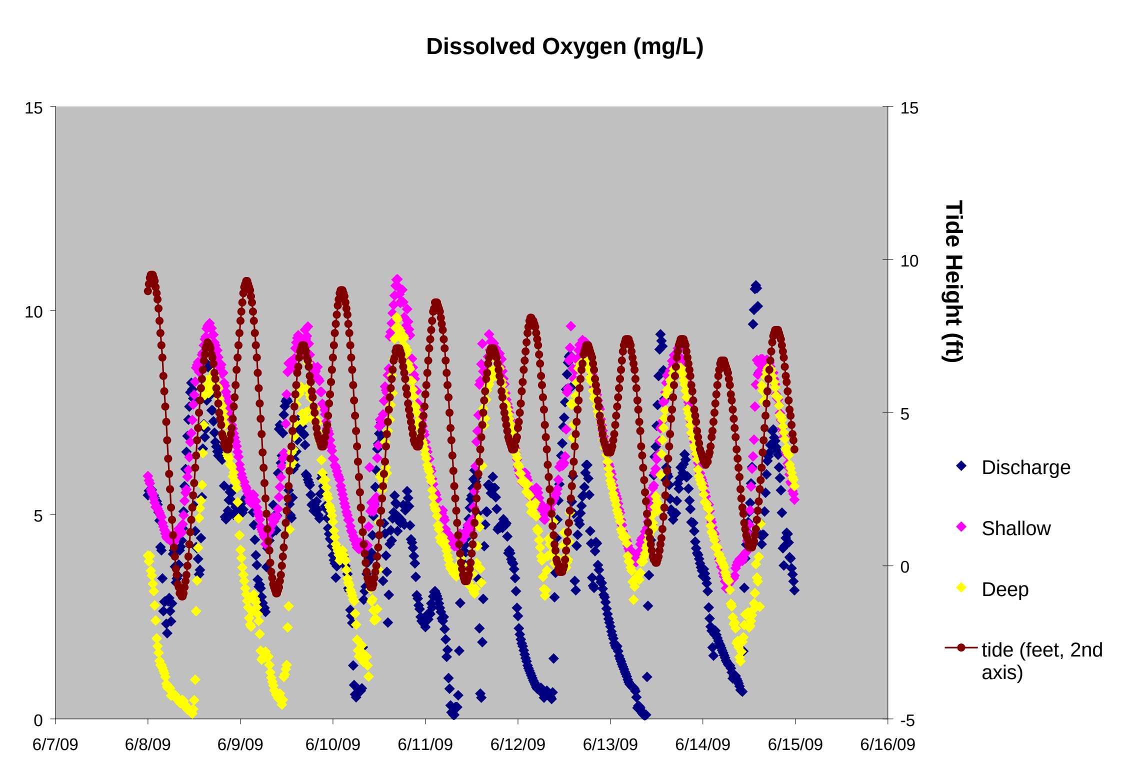

Figure 3.1-3: Pond A3W dissolved oxygen values at 3 pond locations during 8 June – 14 June

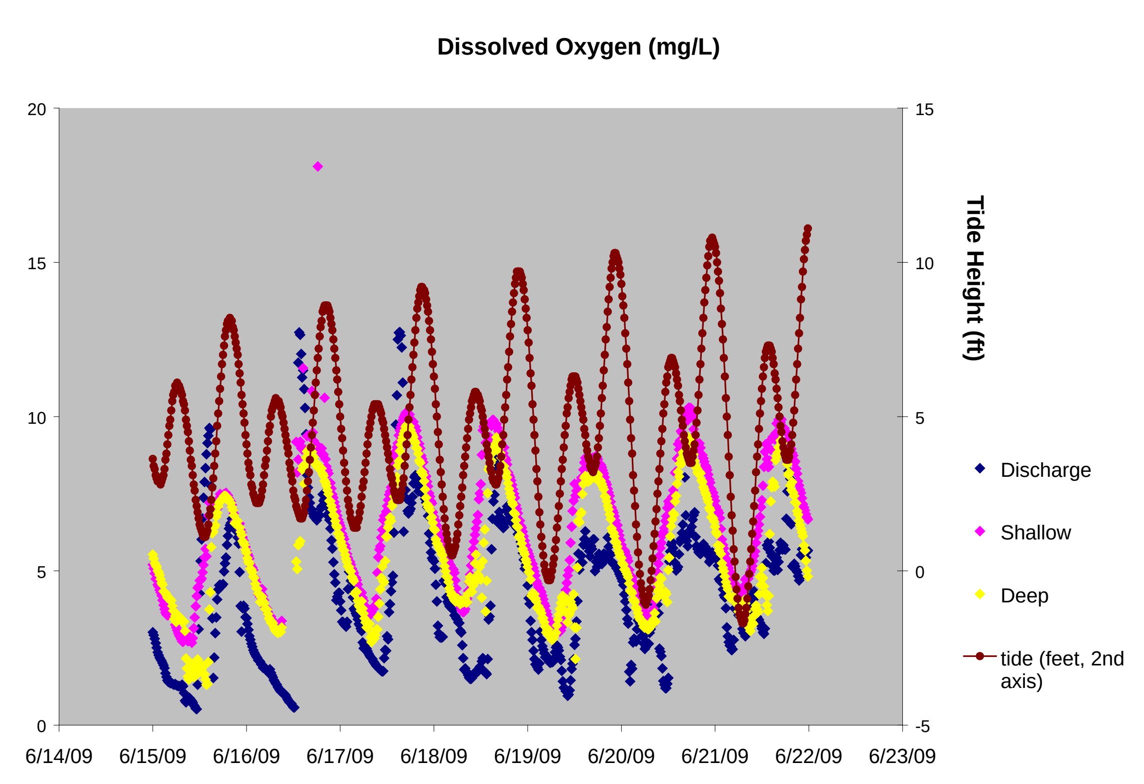

Figure 3.1-4: A3W dissolved oxygen values at 3 pond locations during 15 June – 21 June

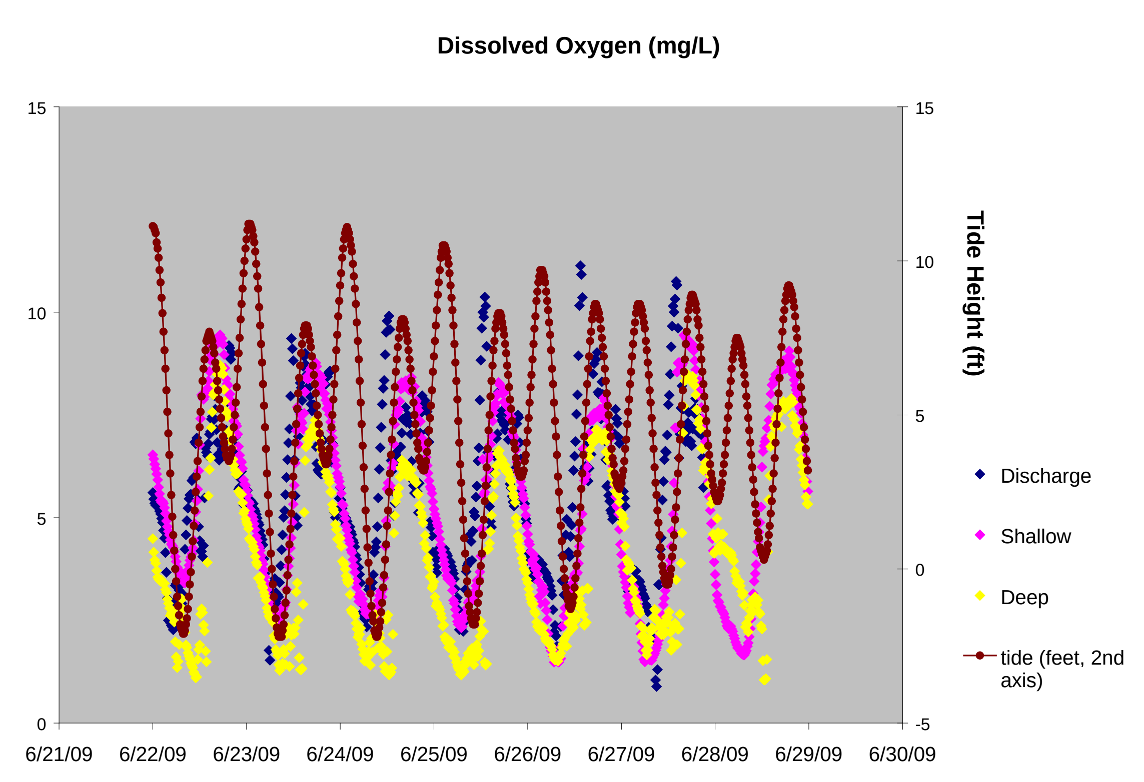

Figure 3.1-5: Pond A3W dissolved oxygen values at 3 pond locations during 22 June – 28 June

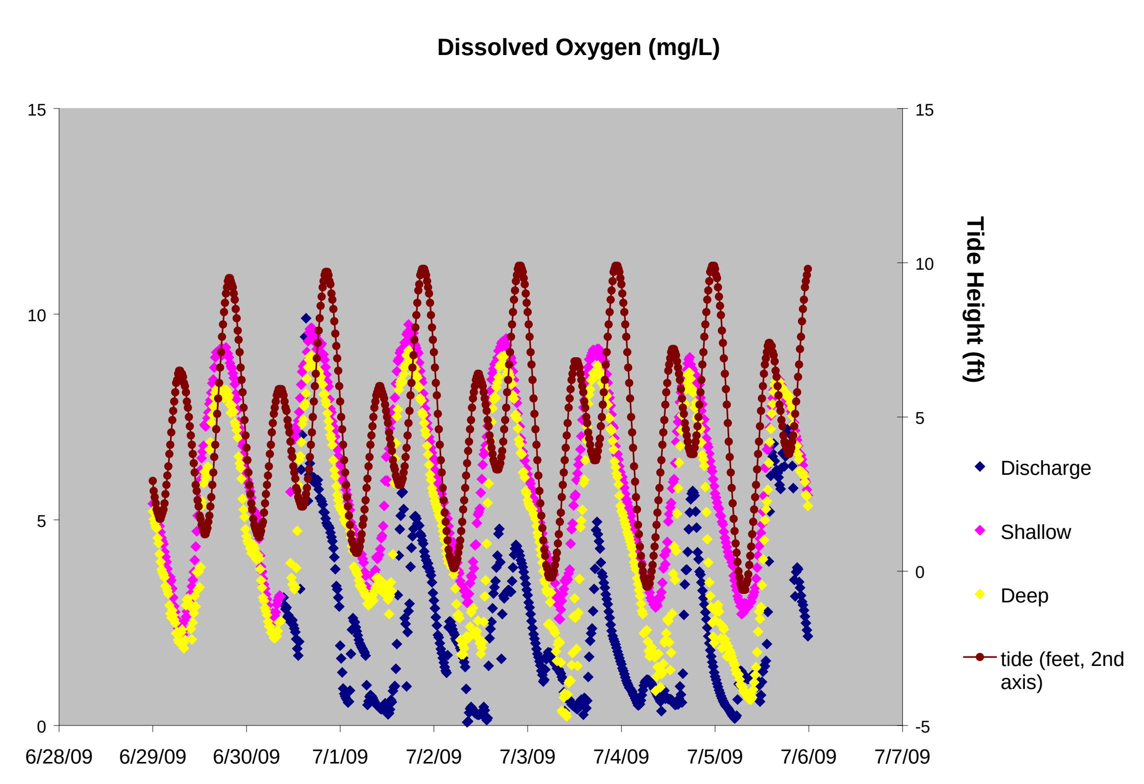

Figure 3.1-6: Pond A3W dissolved oxygen values at 3 pond locations during 29 June – 5 July

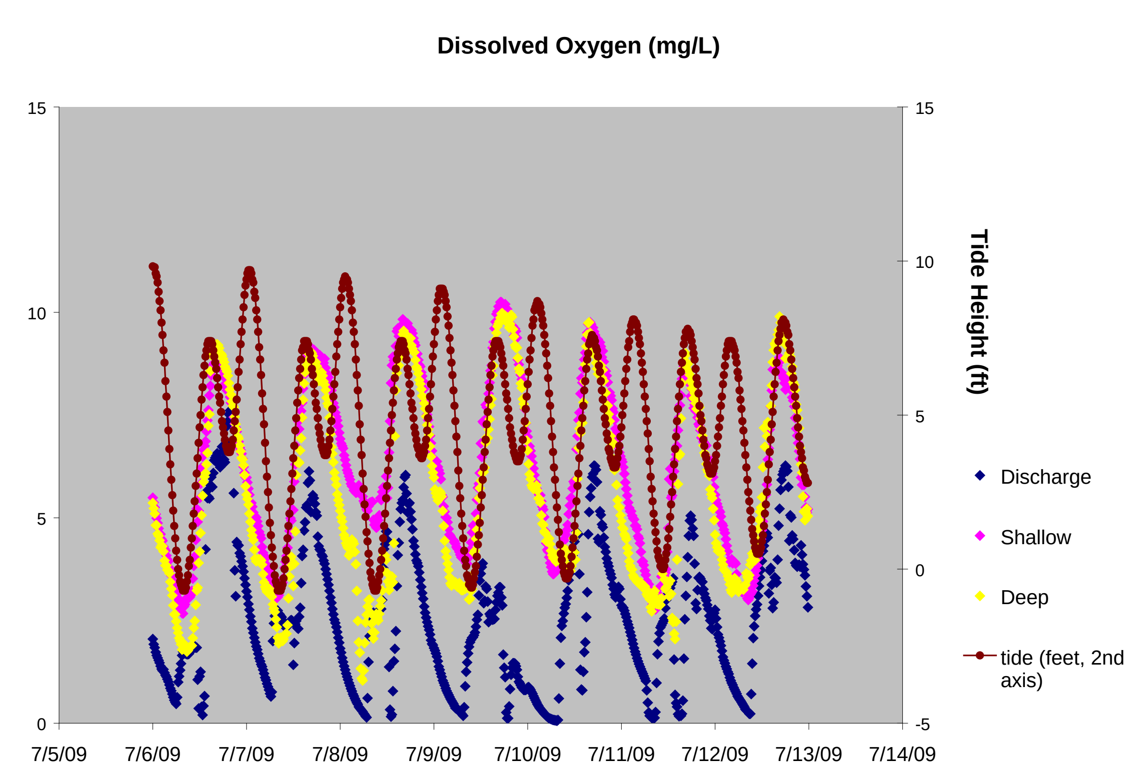

Figure 3.1-7: Pond A3W dissolved oxygen values at 3 pond locations during 6 July – 12 July

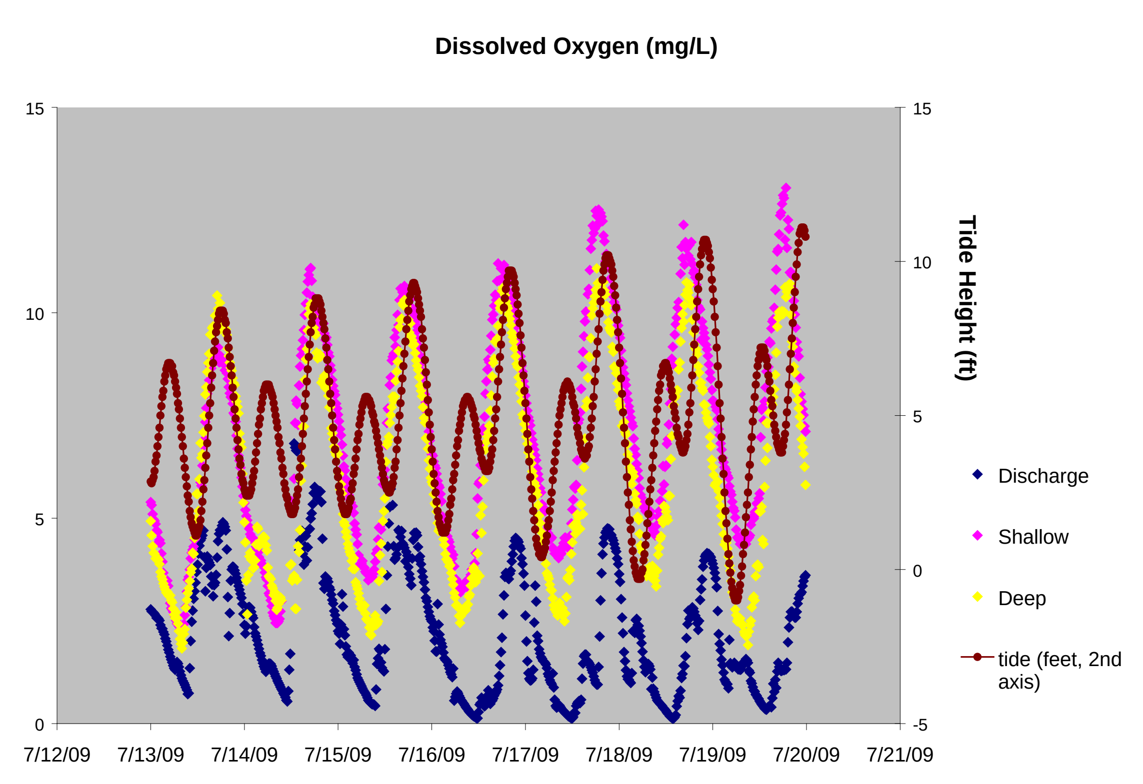

Figure 3.1-8: Pond A3W dissolved oxygen values at 3 pond locations during 13 July – 19 July

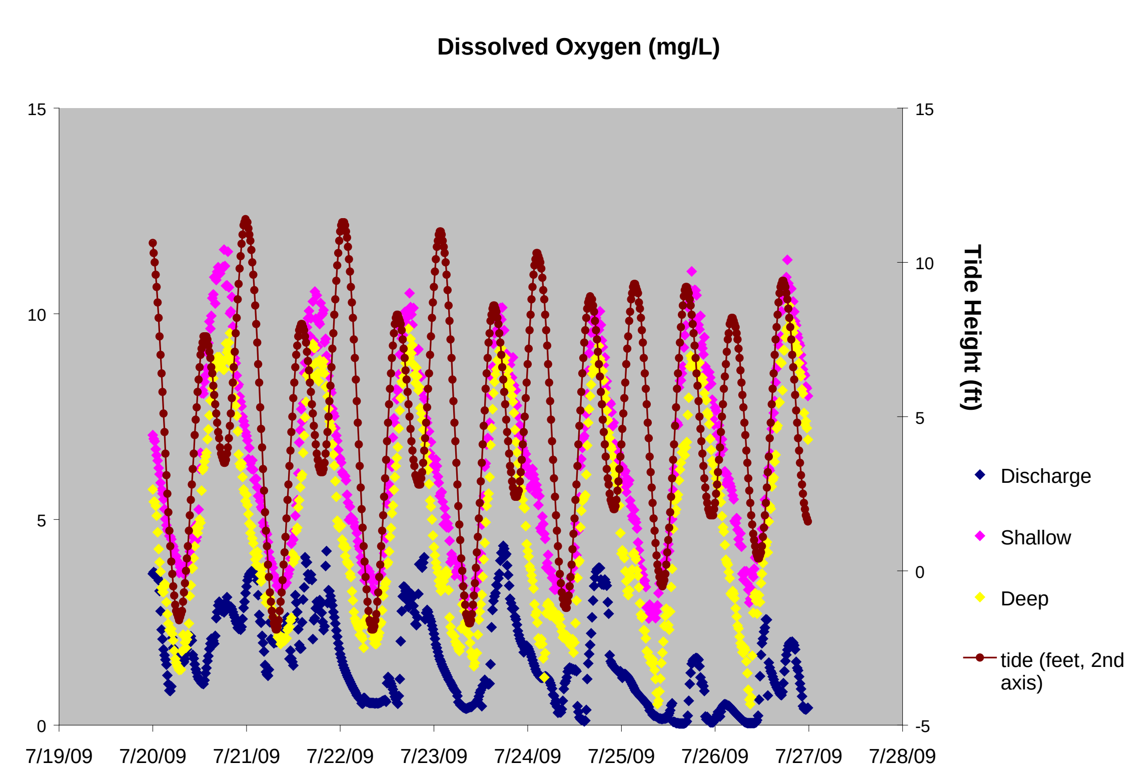

Figure 3.1-9: Pond A3W dissolved oxygen values at 3 pond locations during 20 July – 26 July

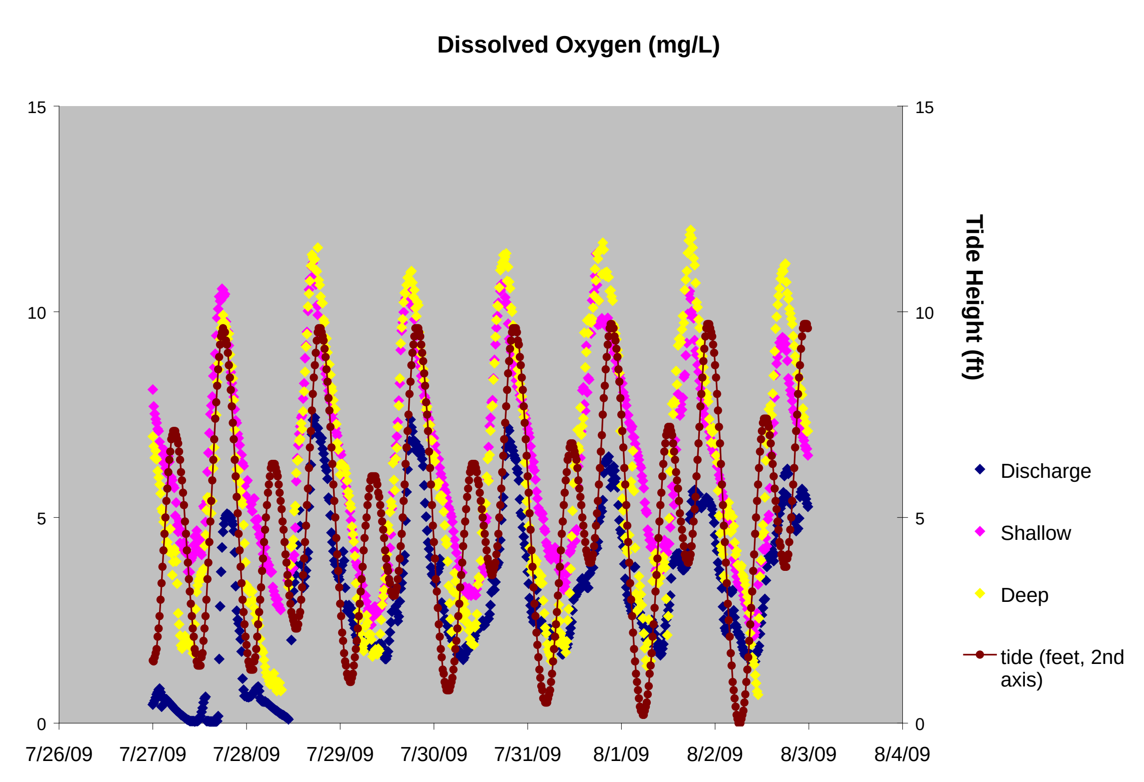

Figure 3.1-10: Pond A3W dissolved oxygen values at 3 pond locations during 27 July – 2 August

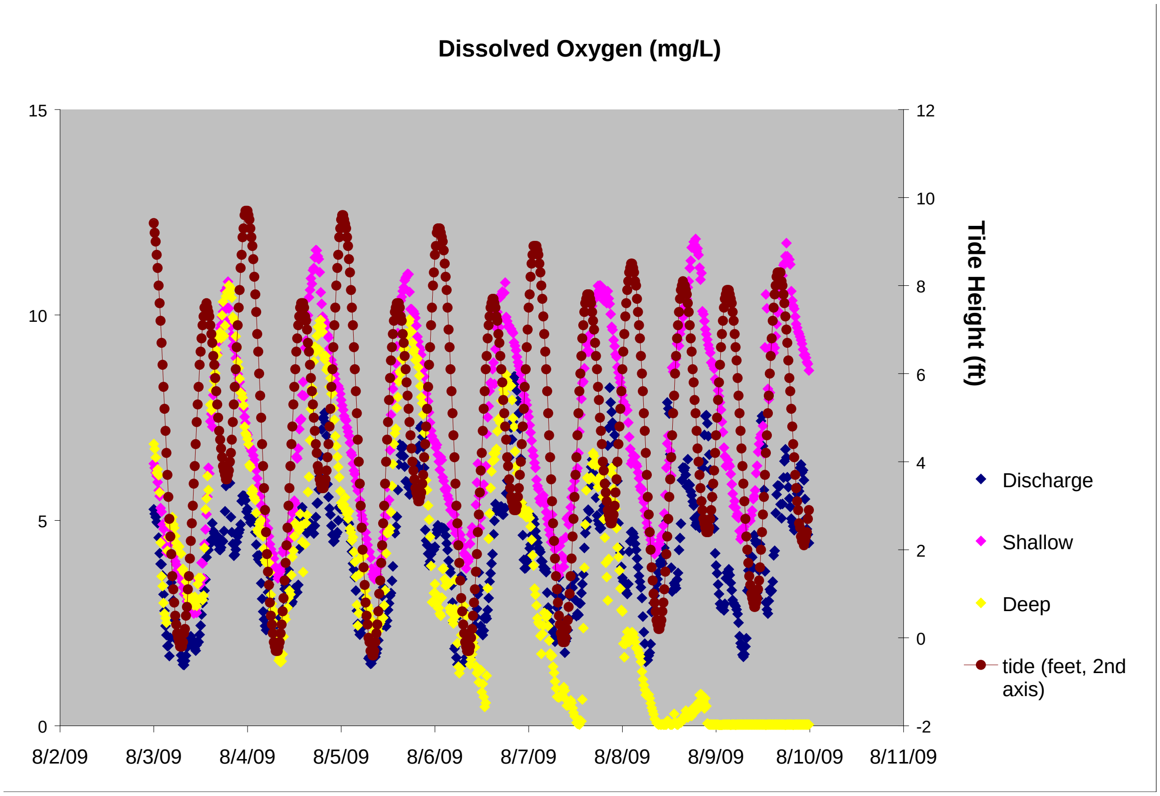

Figure 3.1-11: Pond A3W dissolved oxygen values at 3 pond locations during 3 August – 9 August

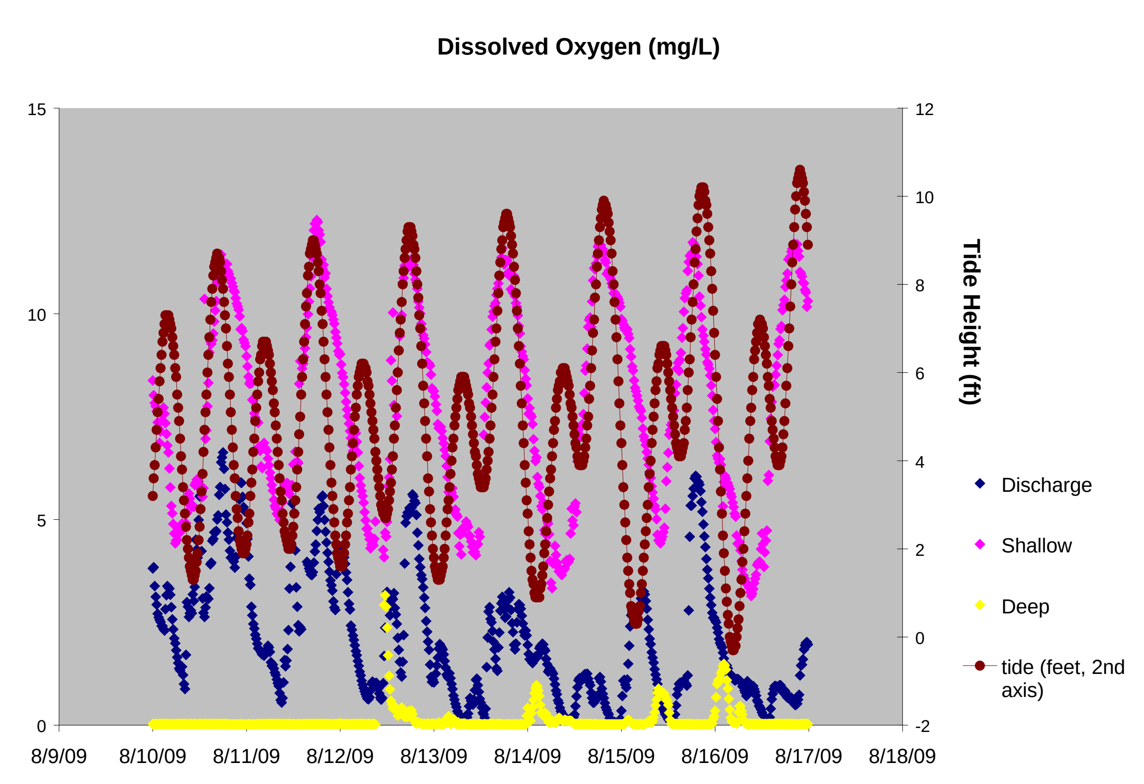

Figure 3.1-12: Pond A3W dissolved oxygen values at 3 pond locations during 10 August – 16 August

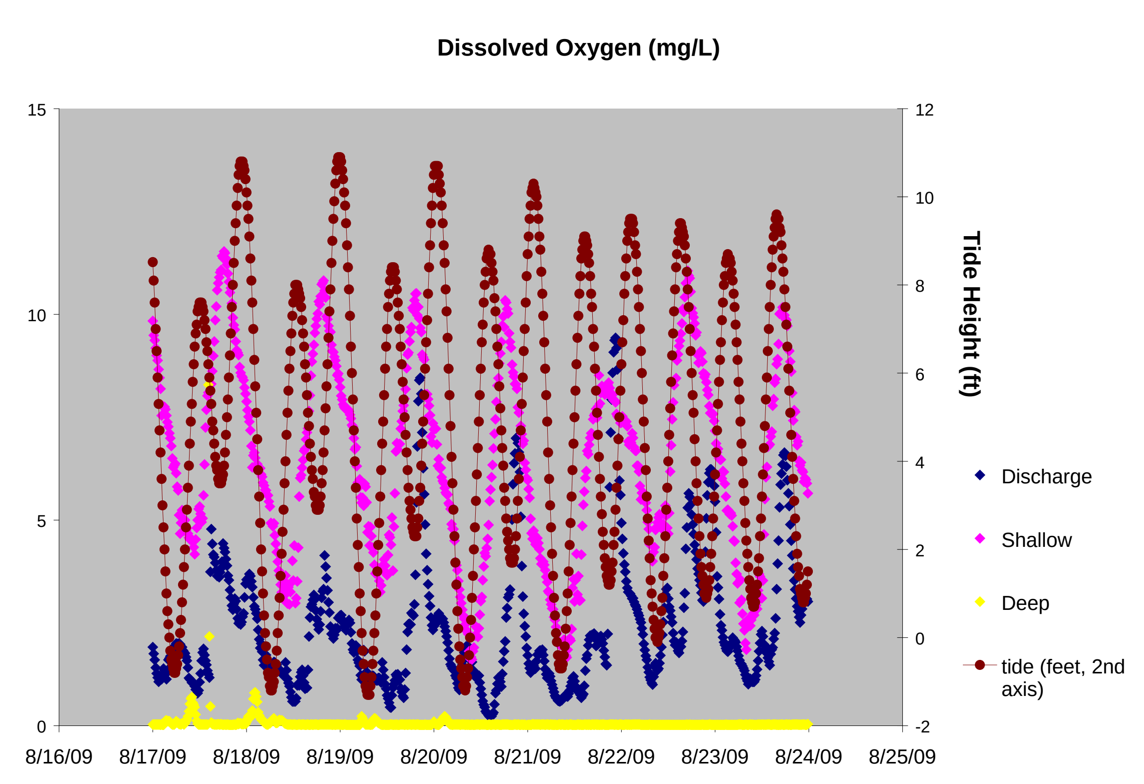

Figure 3.1-13: Pond A3W dissolved oxygen values at 3 pond locations during 17 August – 23 August

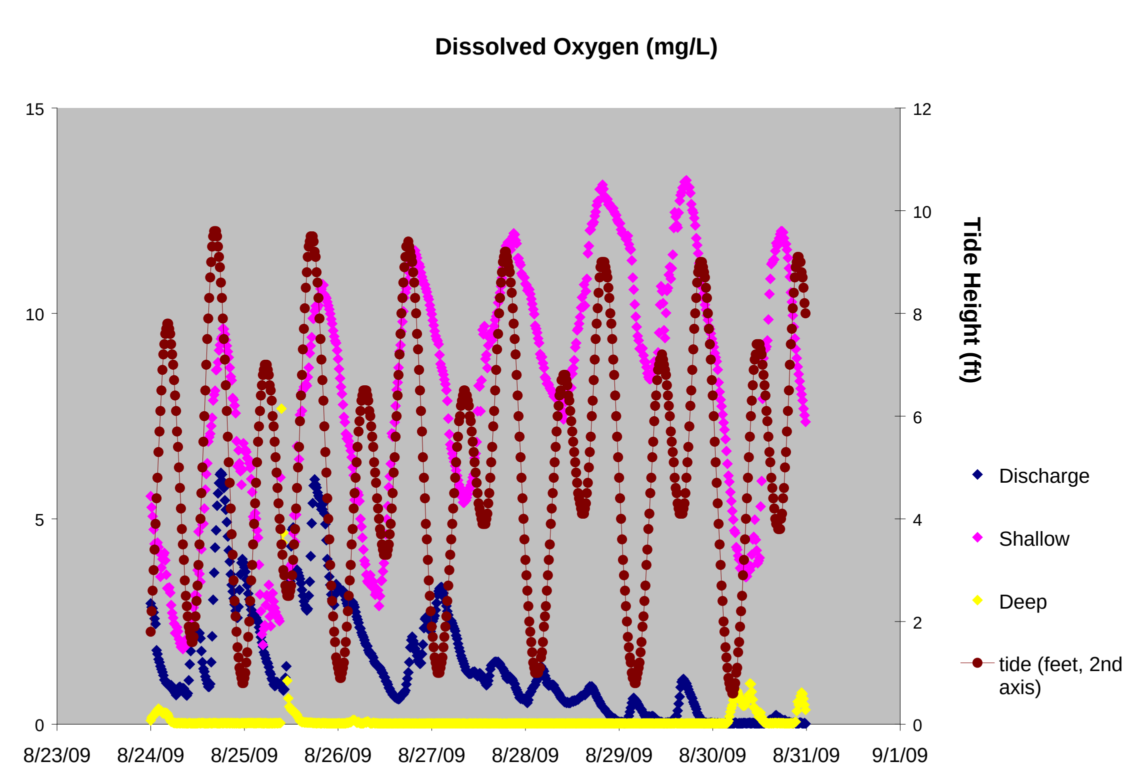

Figure 3.1-14: Pond A3W dissolved oxygen values at 3 pond locations during 24 August – 30 August

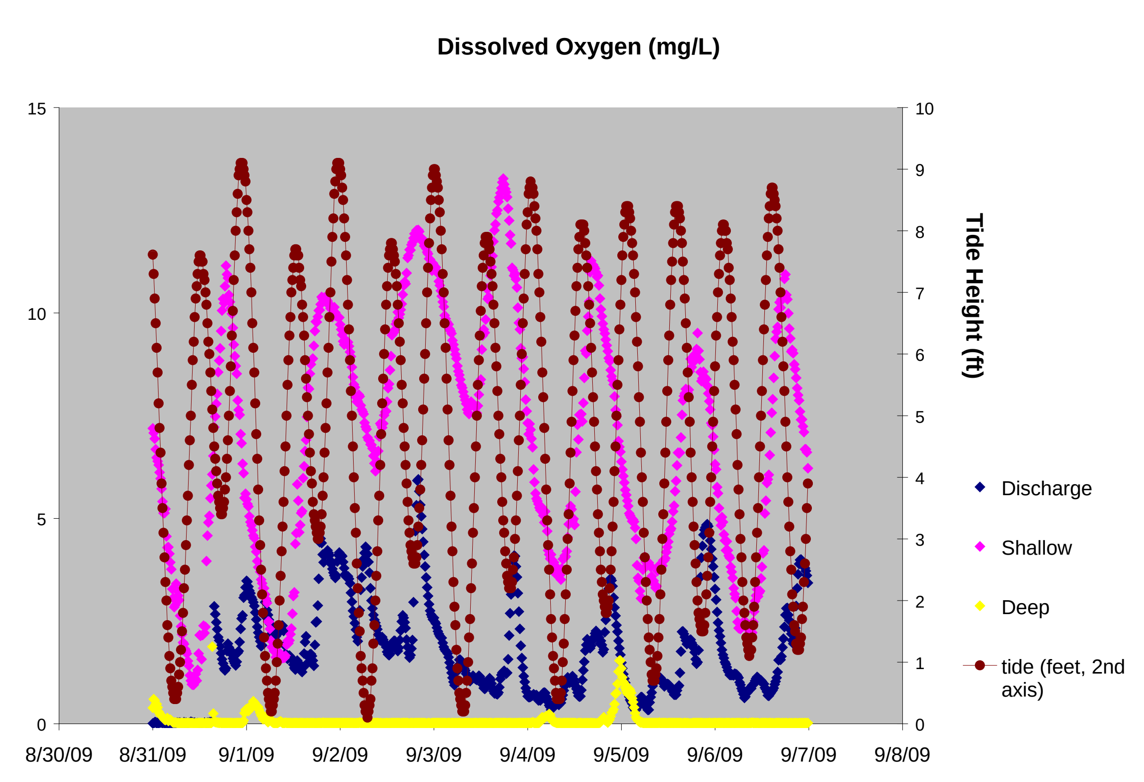

Figure 3.1-15: Pond A3W dissolved oxygen values at 3 pond locations during 31 August – 6 September

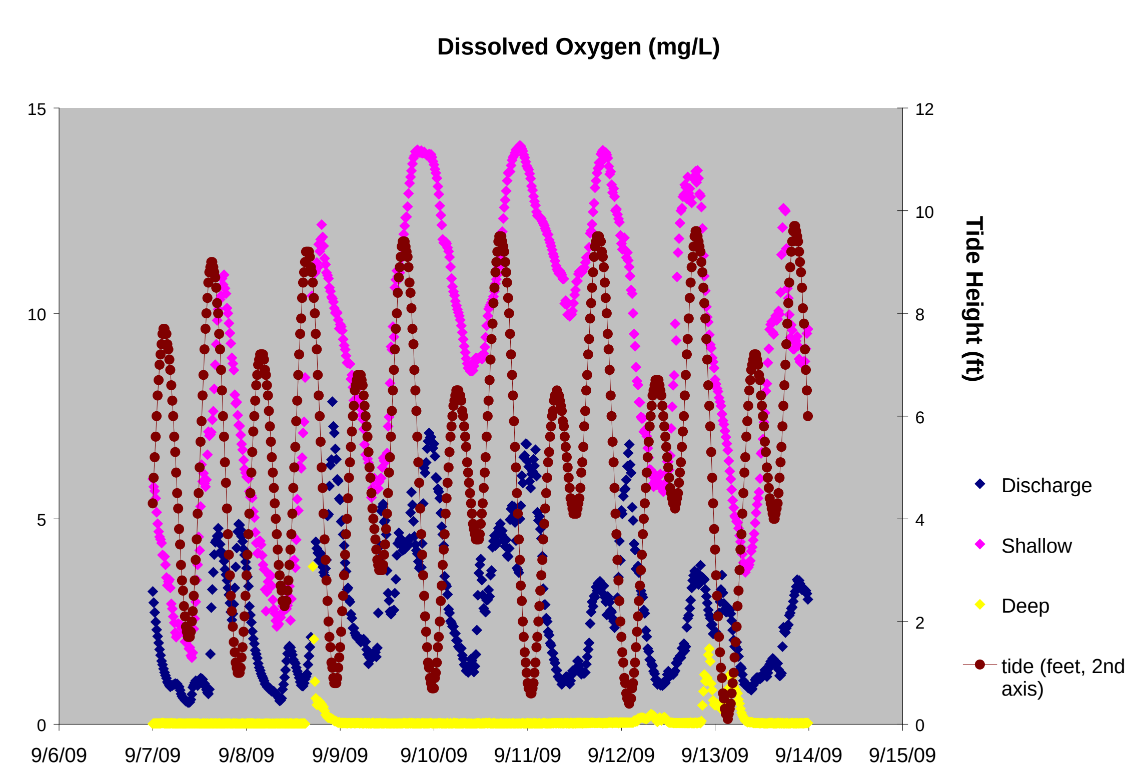

Figure 3.1-16: Pond A3W dissolved oxygen values at 3 pond locations during 7 September – 13 September

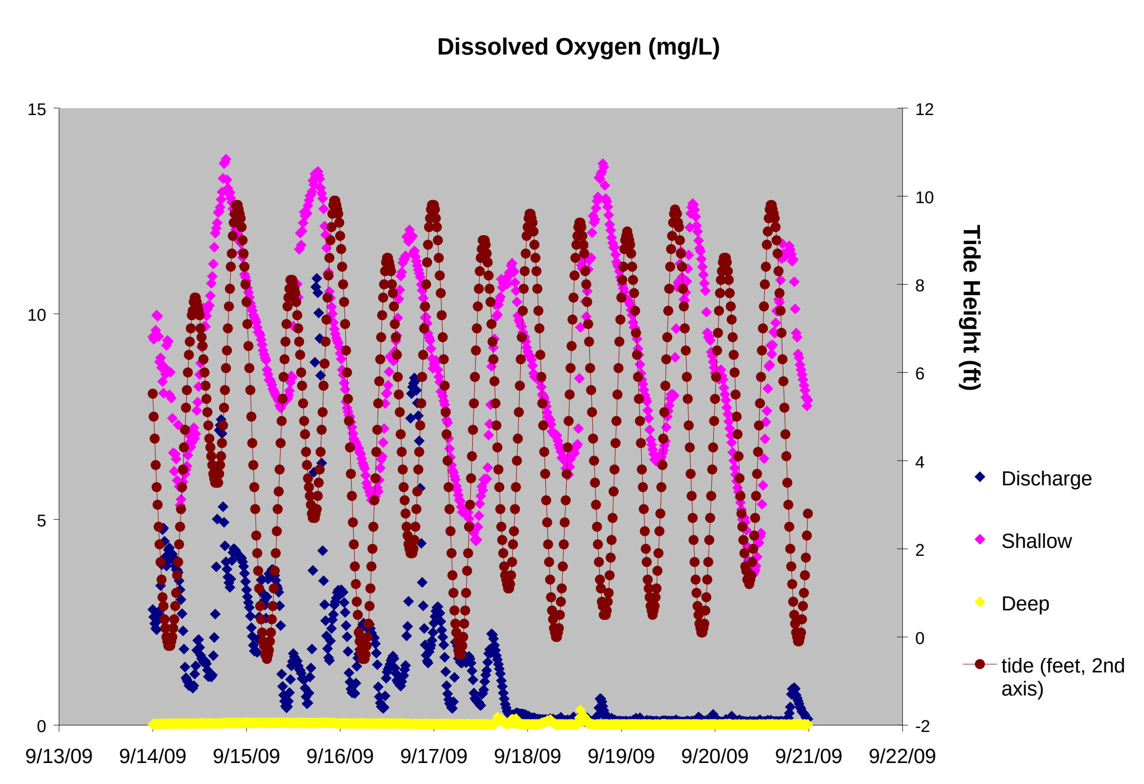

Figure 3.1-17: Pond A3W dissolved oxygen values at 3 pond locations during 14 September – 20 September

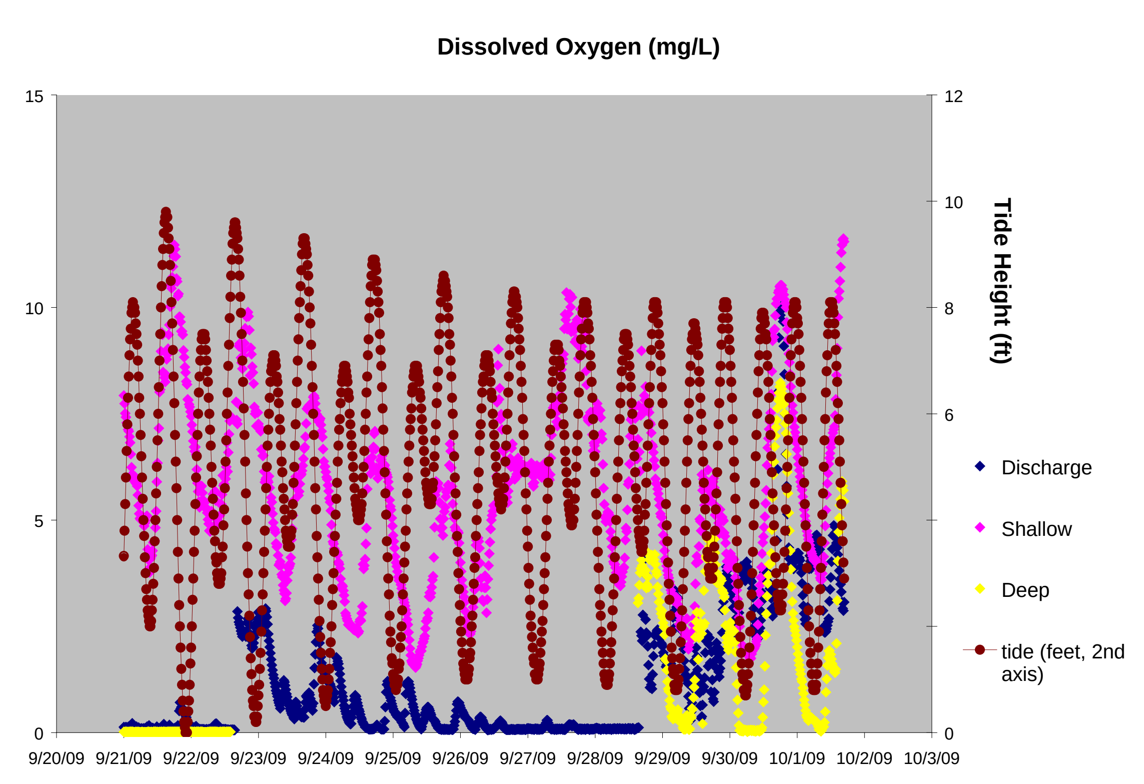

Figure 3.1-18: Pond A3W dissolved oxygen values at 3 pond locations during 21 September – 1 October

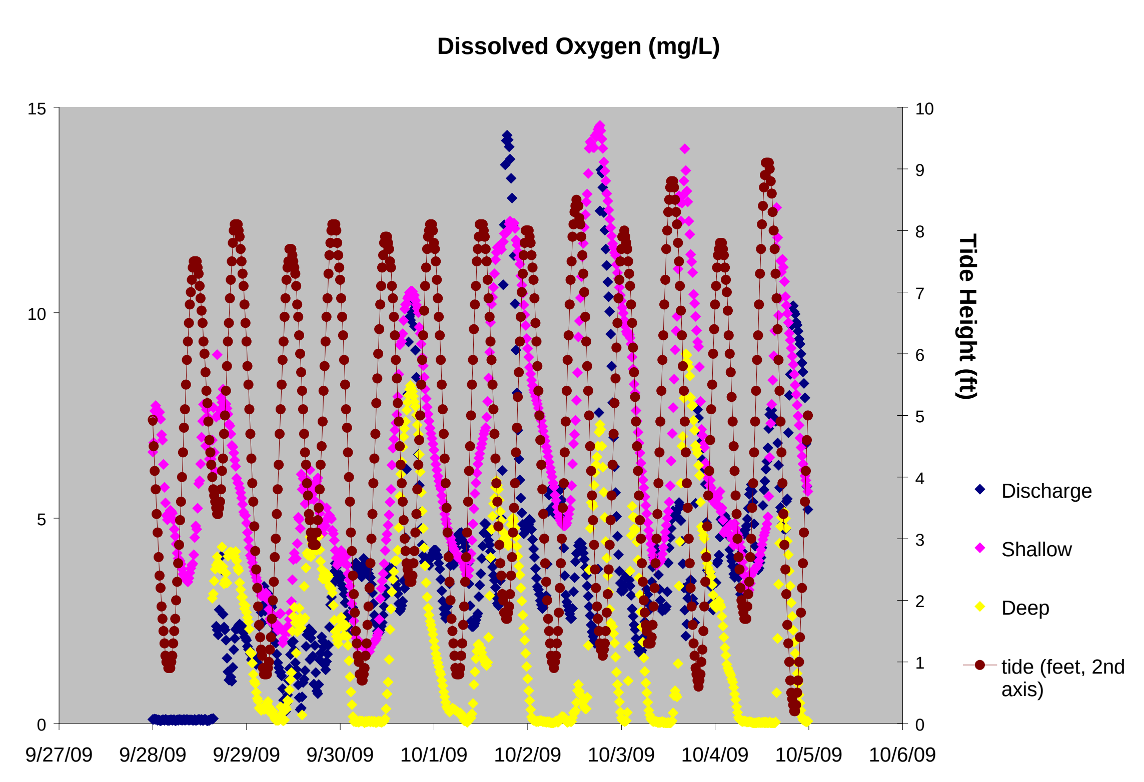

Figure 3.1-19: Pond A3W dissolved oxygen values at 3 pond locations during 28 September – 4 October

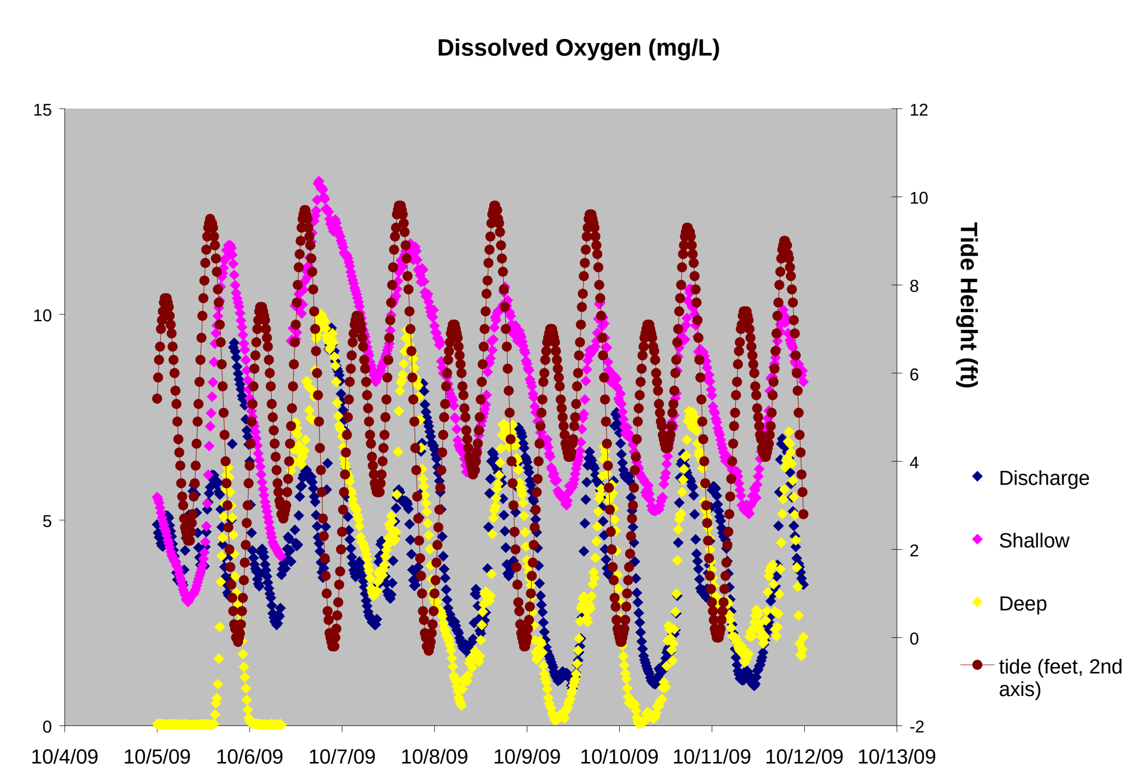

Figure 3.1-20: Pond A3W dissolved oxygen values at 3 pond locations during 5 October – 11 October

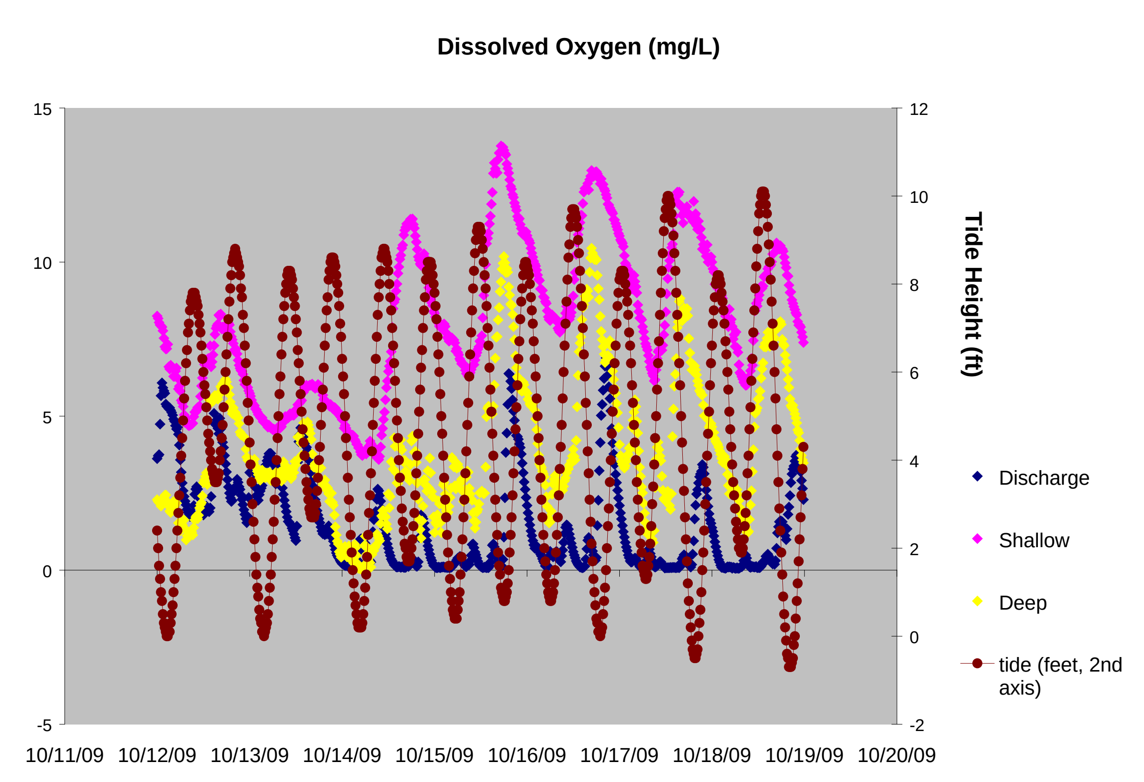

Figure 3.1-21: Pond A3W dissolved oxygen values at 3 pond locations during 12 October – 18 October

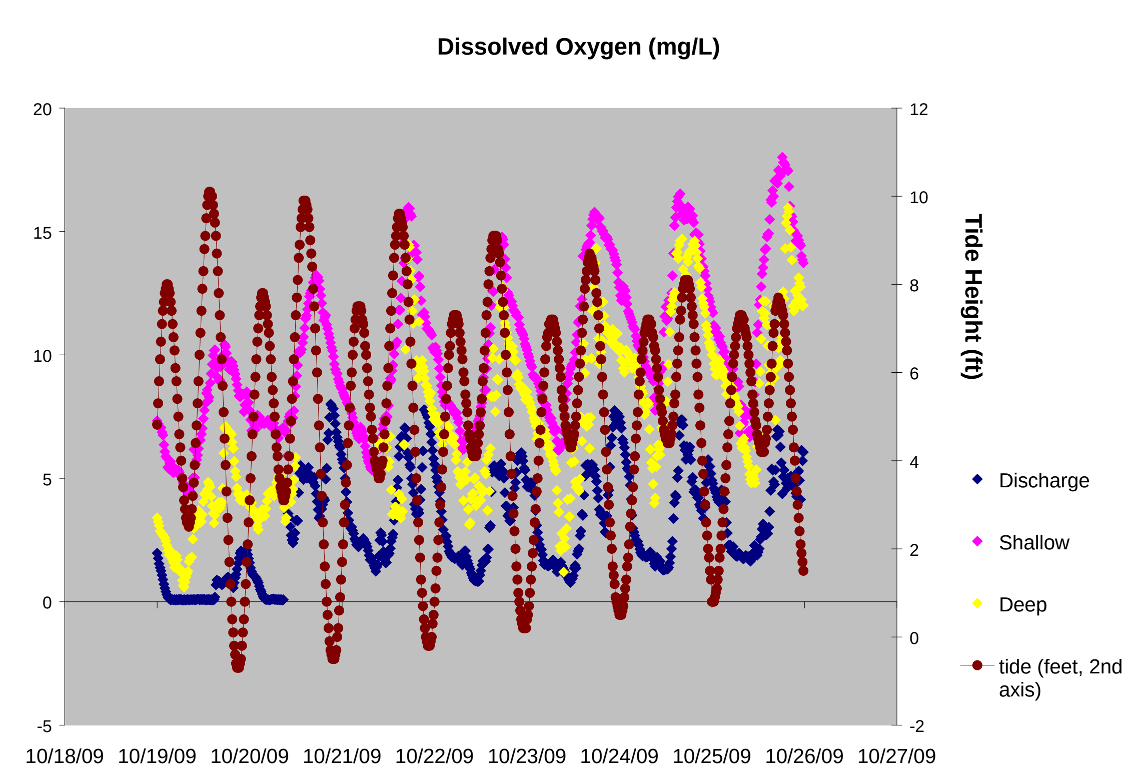

Figure 3.1-22: Pond A3W dissolved oxygen values at 3 pond locations during 19 October – 25 October

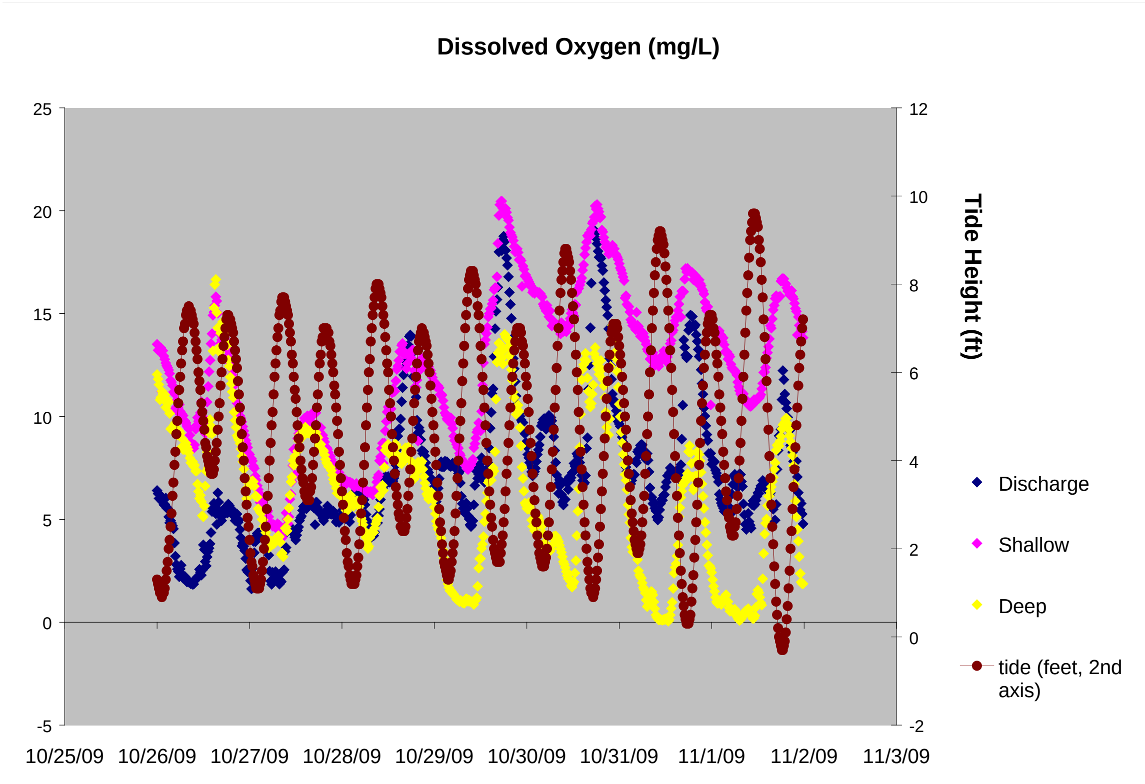

Figure 3.1-23: Pond A3W dissolved oxygen values at 3 pond locations during 26 October – 1 November

3.2 SALINITY

The discharge datasonde had overall lower salinity and greater variation in salinity over time than the two datasondes located in the interior of Pond A3W (Figures 3.2-1 through 3.2-22). Perhaps the greater variation in the discharge datasonde was due to greater tidal influence. Both the shallow and the deep datasondes recorded fairly stable salinity values throughout the study period. Salinity levels for all datasondes increased from June through August which may be partially explained by increased evaporation due to higher temperatures and solar radiation during these months. Similar patterns were observed in previous years (2005-2008).

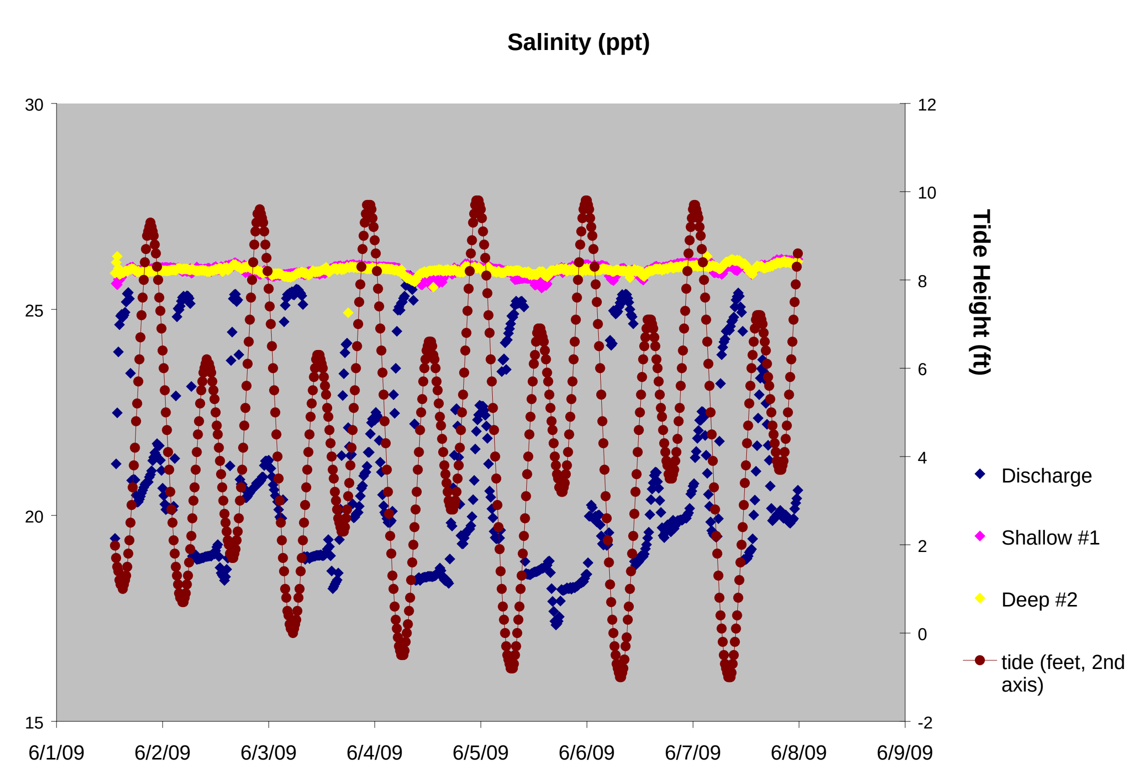

Figure 3.2-1: Pond A3W salinity values at 3 pond locations during 1 June – 7 June

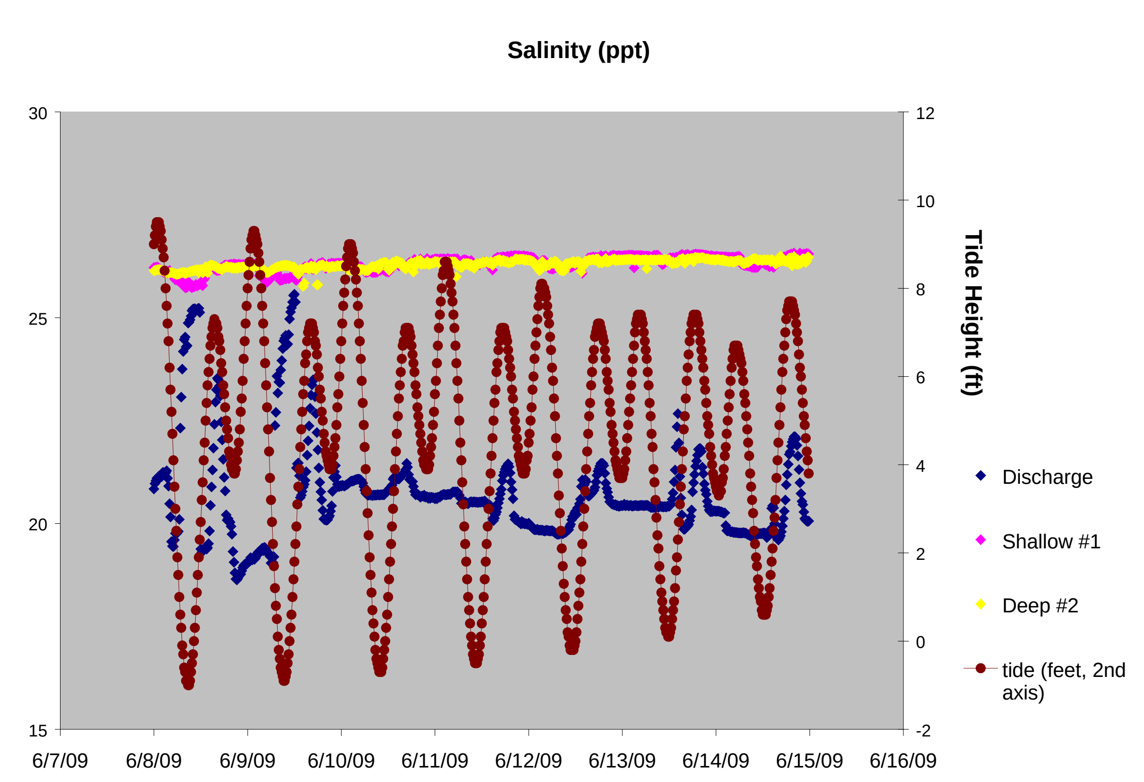

Figure 3.2-2: Pond A3W salinity values at 3 pond locations during 8 June – 14 June

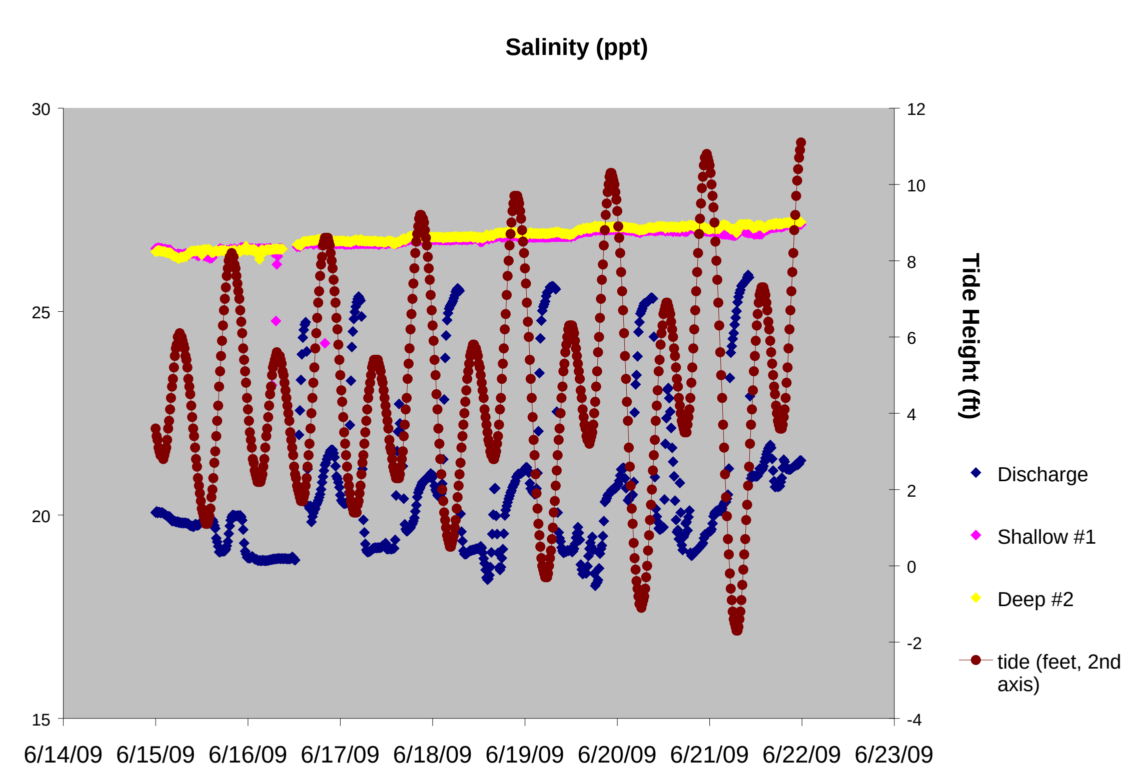

Figure 3.2-3: Pond A3W salinity values at 3 pond locations during 15 June – 21 June

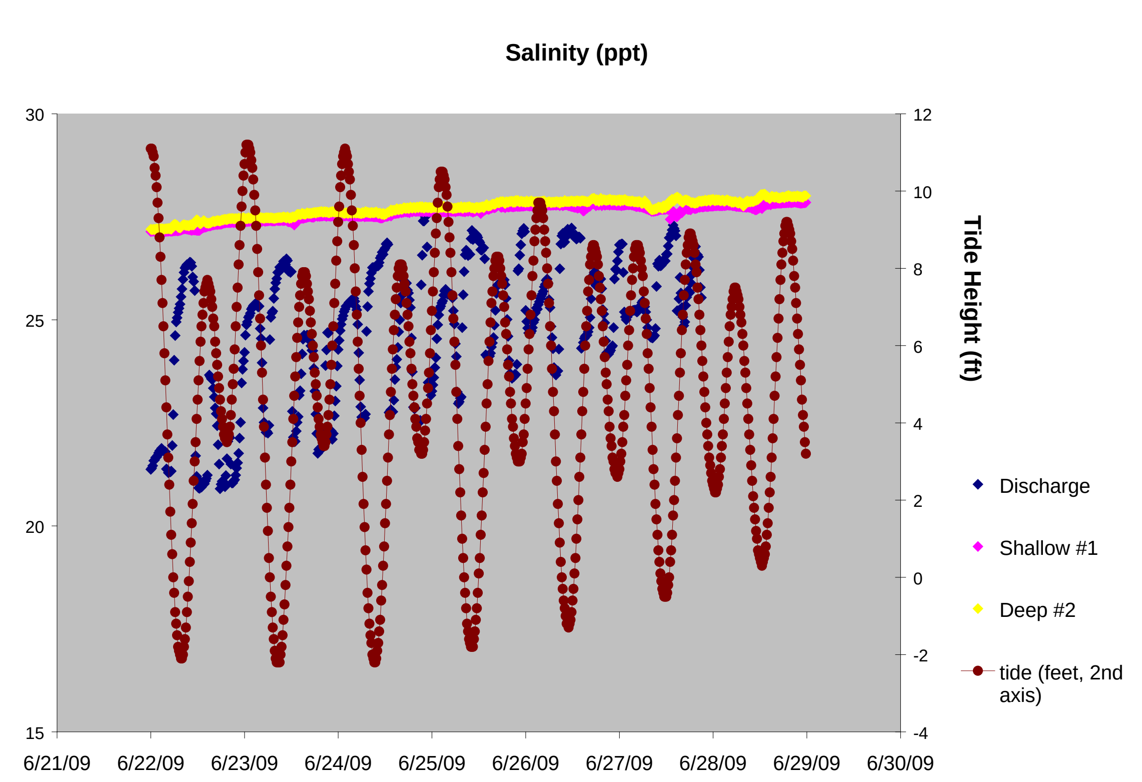

Figure 3.2-4: Pond A3W salinity values at 3 pond locations during 22 June – 28 June

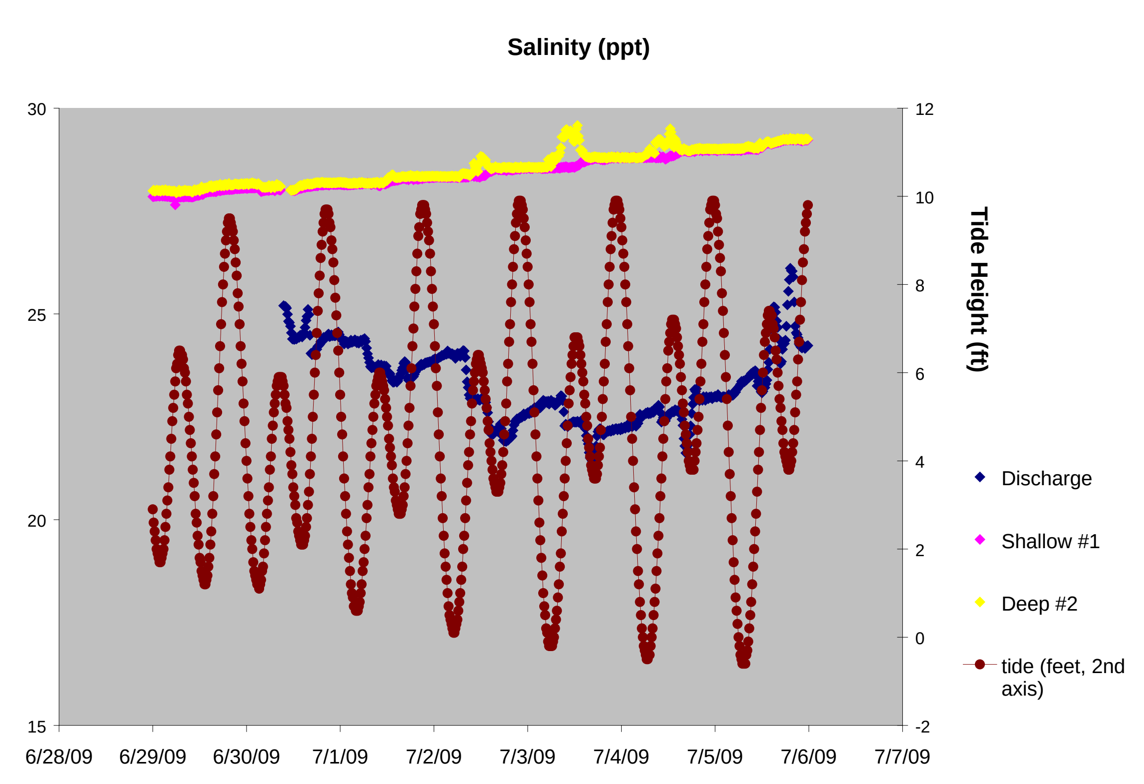

Figure 3.2-5: Pond A3W salinity values at 3 pond locations during 29 June – 5 July

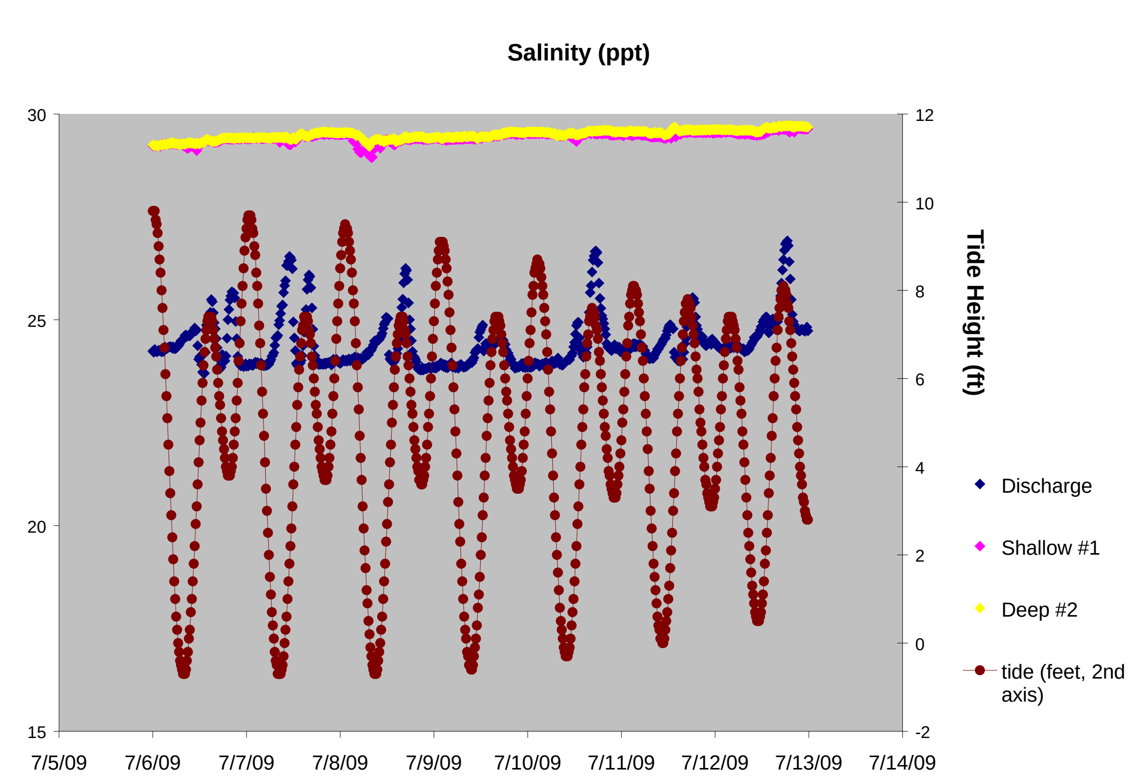

Figure 3.2-6: Pond A3W salinity values at 3 pond locations during 6 July – 12 July

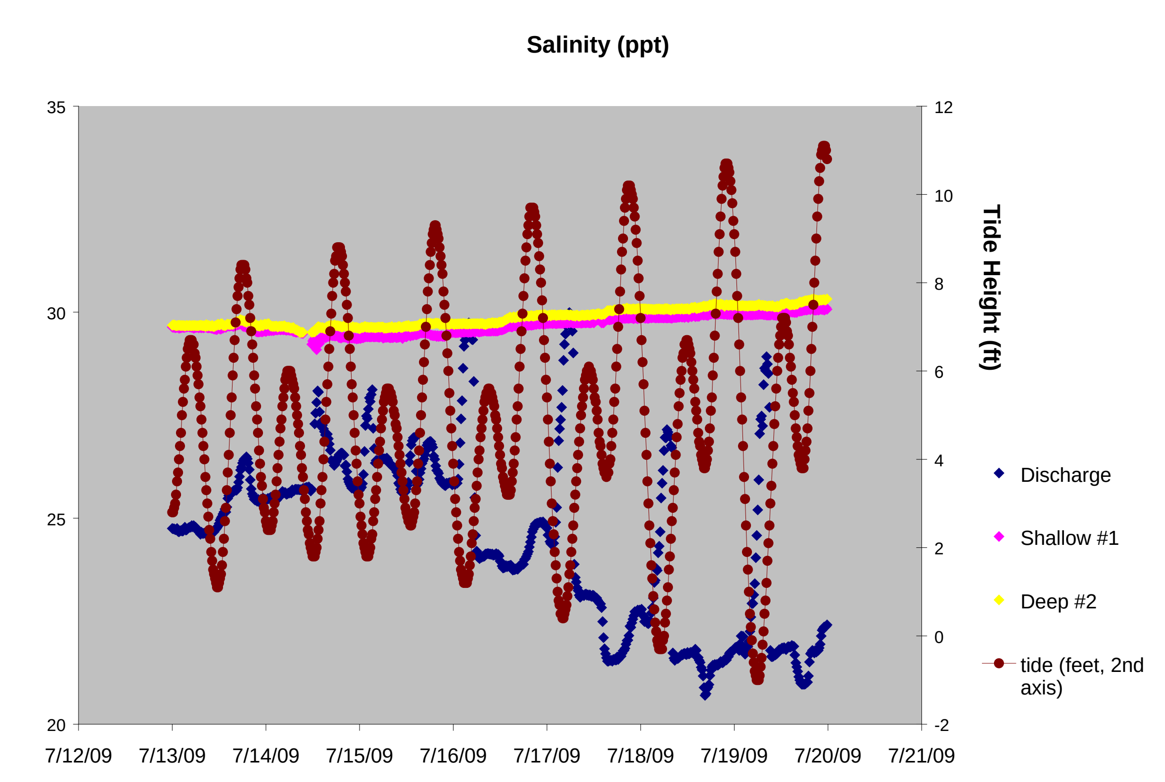

Figure 3.2-7: Pond A3W salinity values at 3 pond locations during 13 July – 19 July

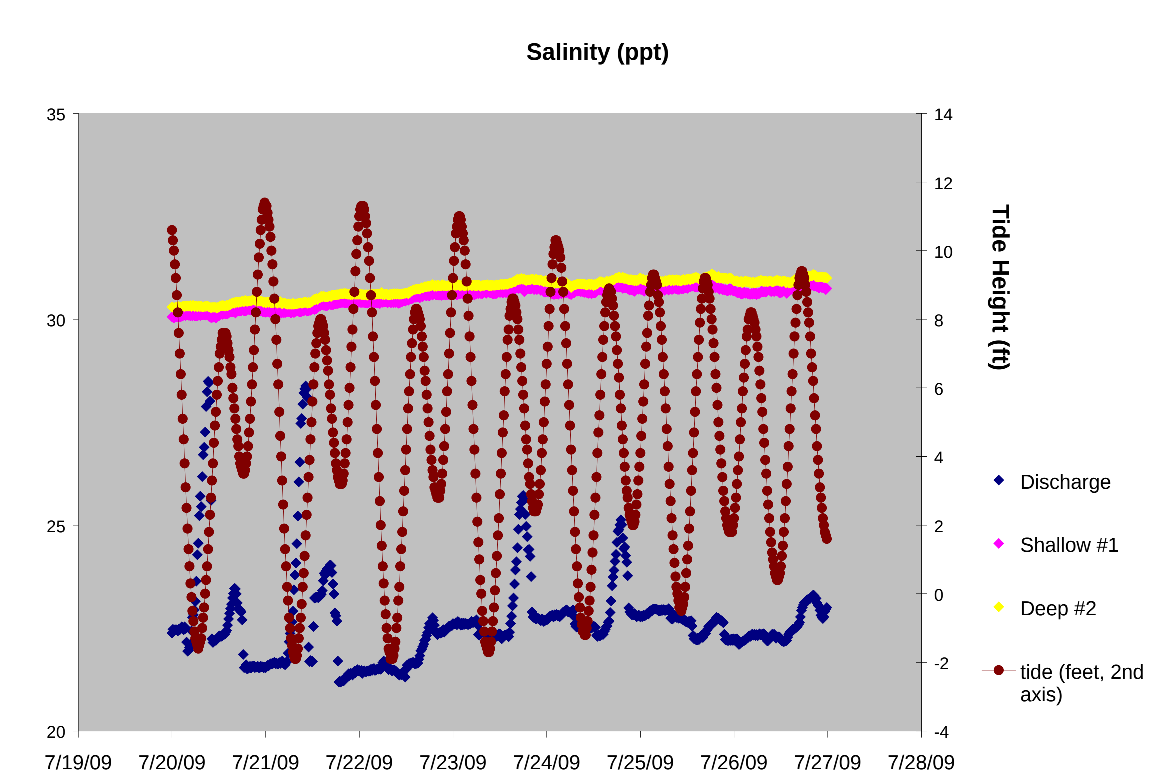

Figure 3.2-8: Pond A3W salinity values at 3 pond locations during 20 July – 26 July

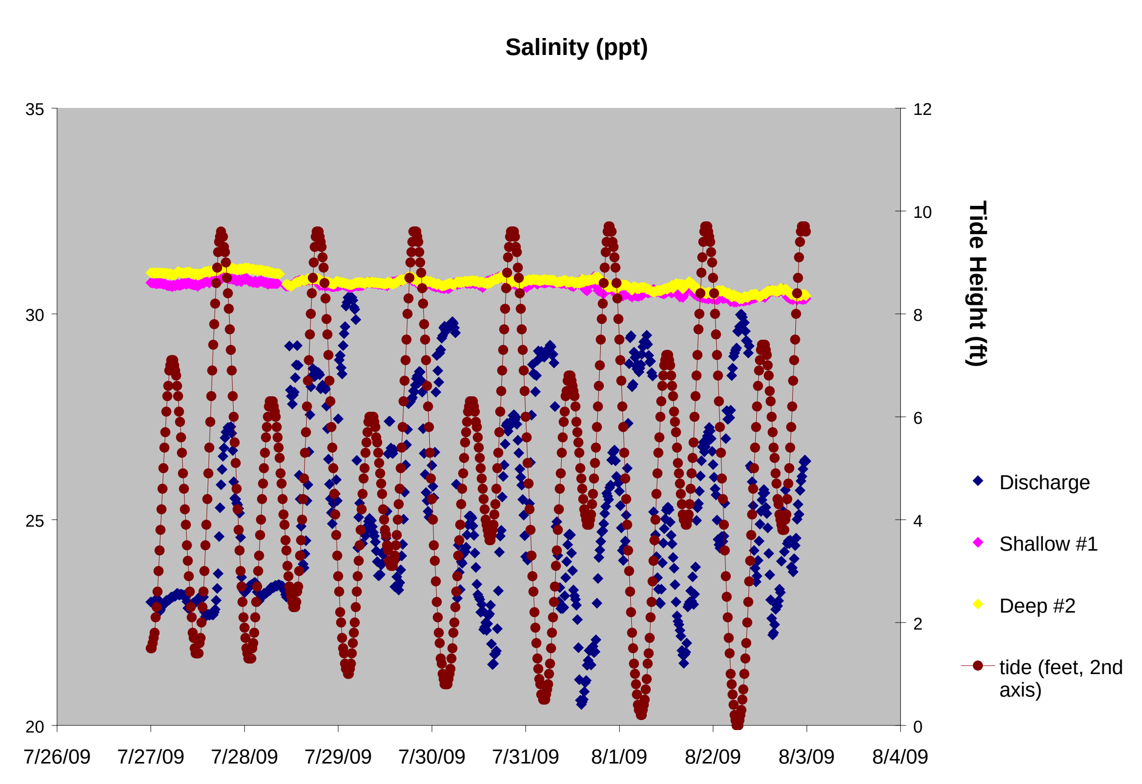

Figure 3.2-9: Pond A3W salinity values at 3 pond locations during 27 July – 2 August

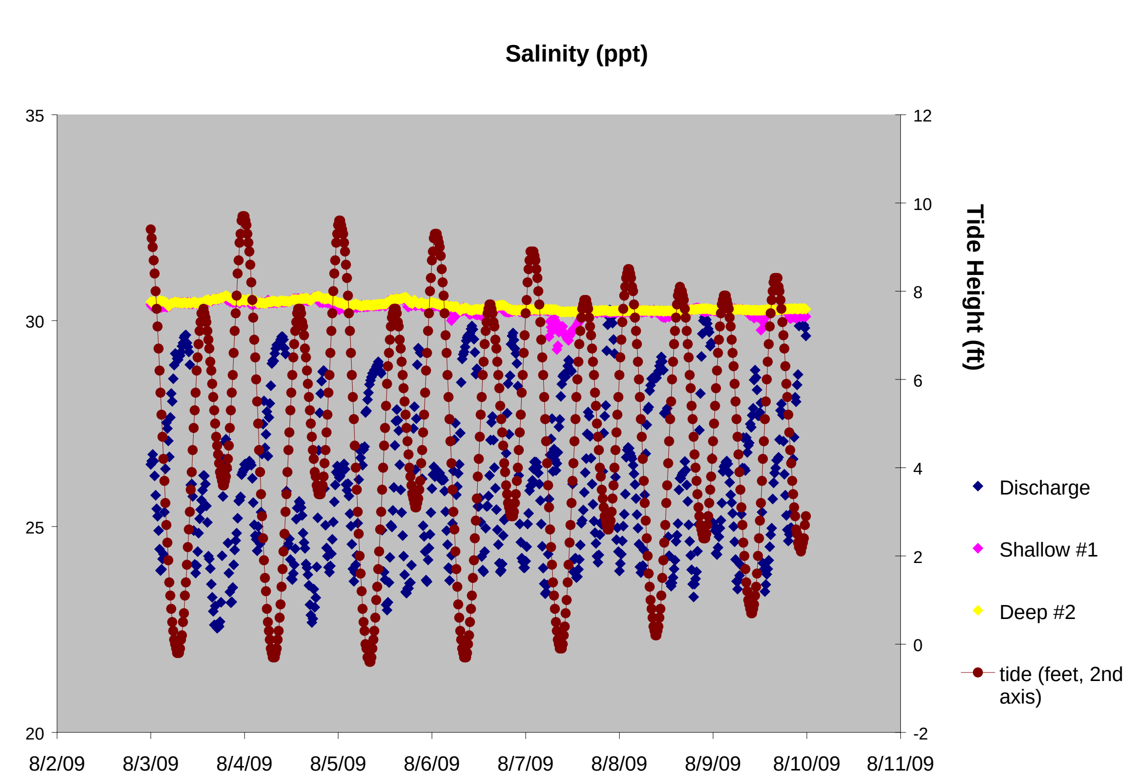

Figure 3.2-10: Pond A3W salinity values at 3 pond locations during 3 August – 9 August

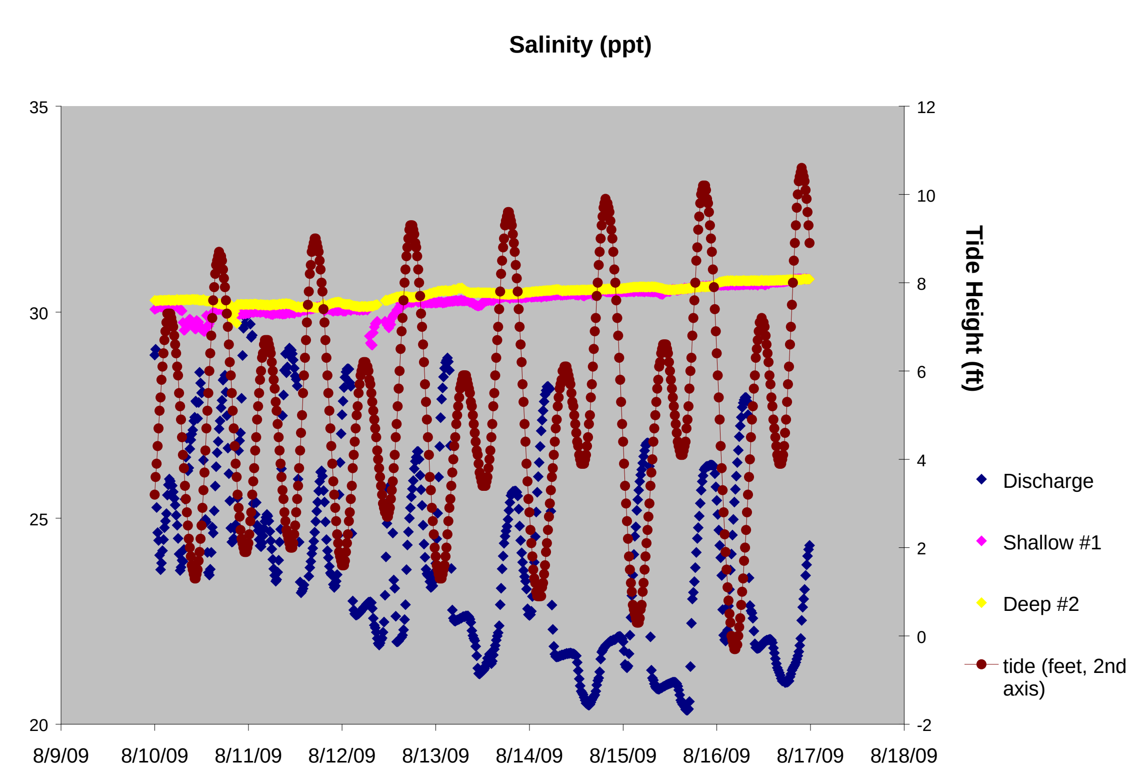

Figure 3.2-11: Pond A3W salinity values at 3 pond locations during 10 August – 16 August

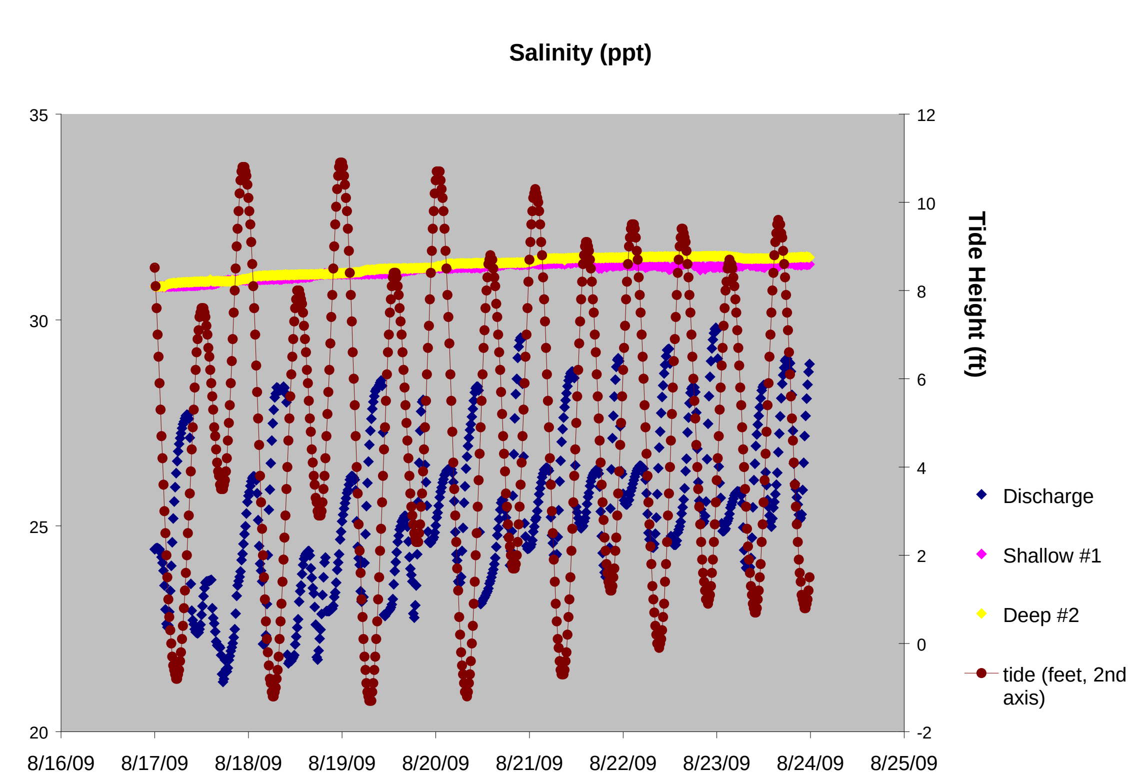

Figure 3.2-12: Pond A3W salinity values at 3 pond locations during 17 August – 23 August

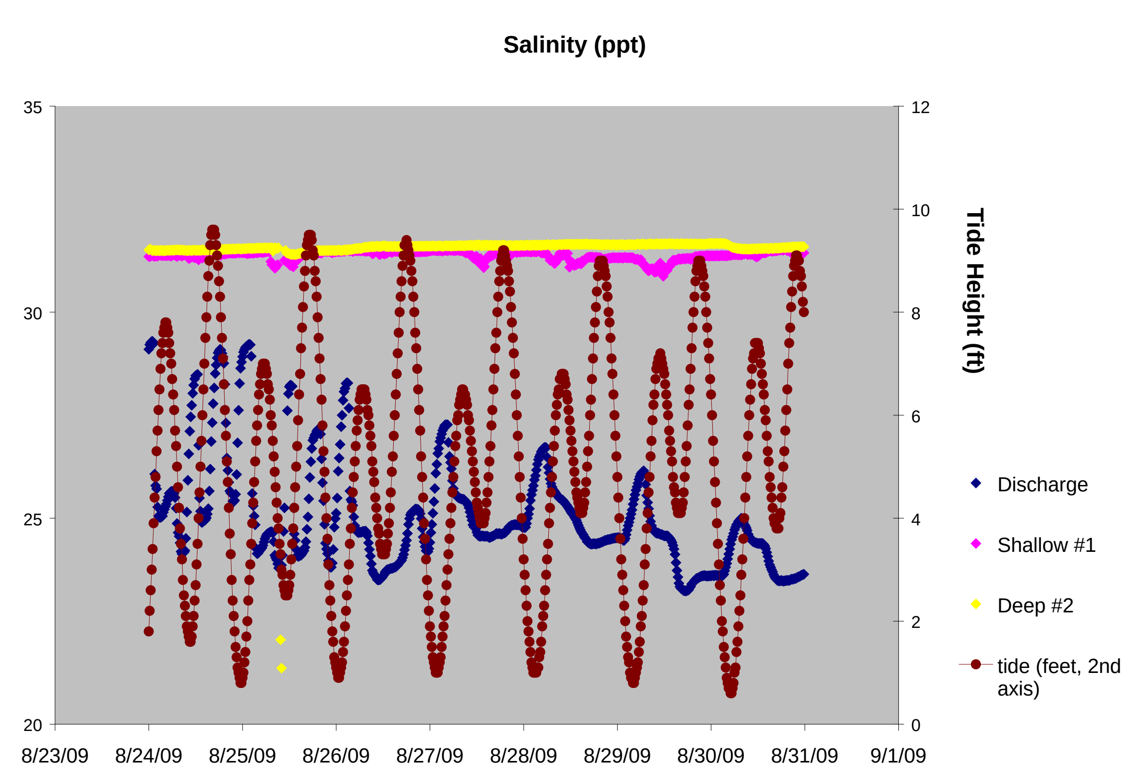

Figure 3.2-13: Pond A3W salinity values at 3 pond locations during 24 August – 30 August

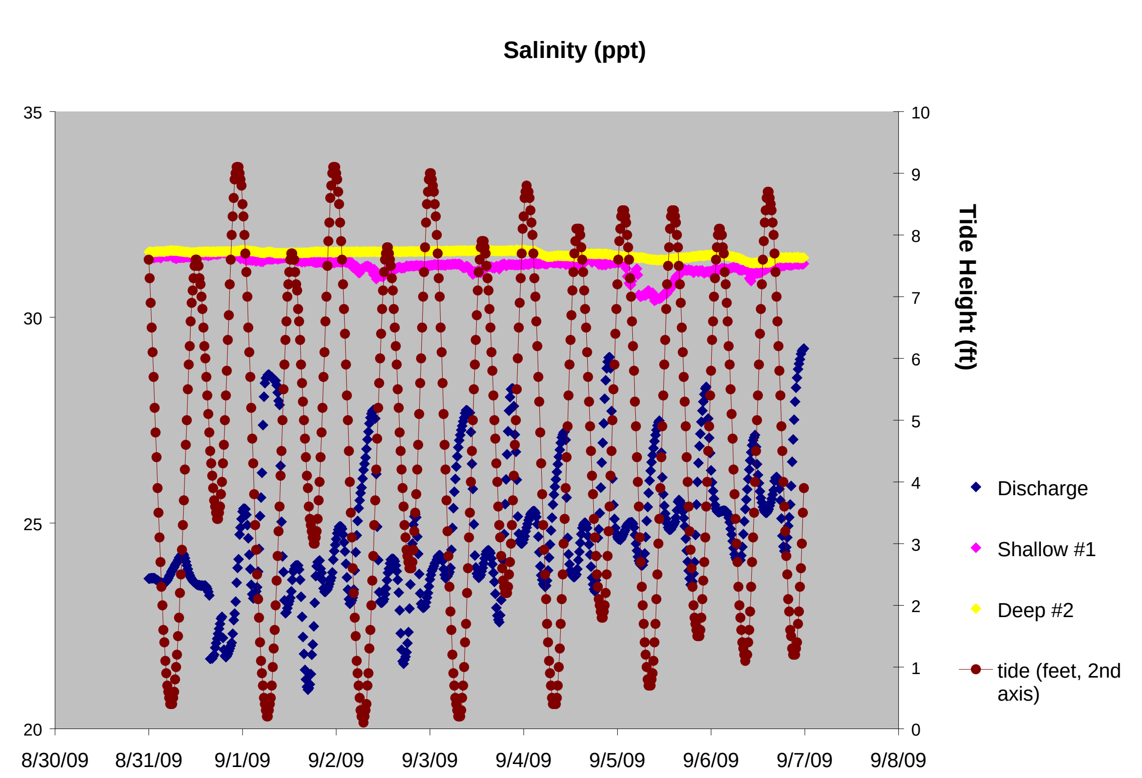

Figure 3.2-14: Pond A3W salinity values at 3 pond locations during 31 August – 6 September

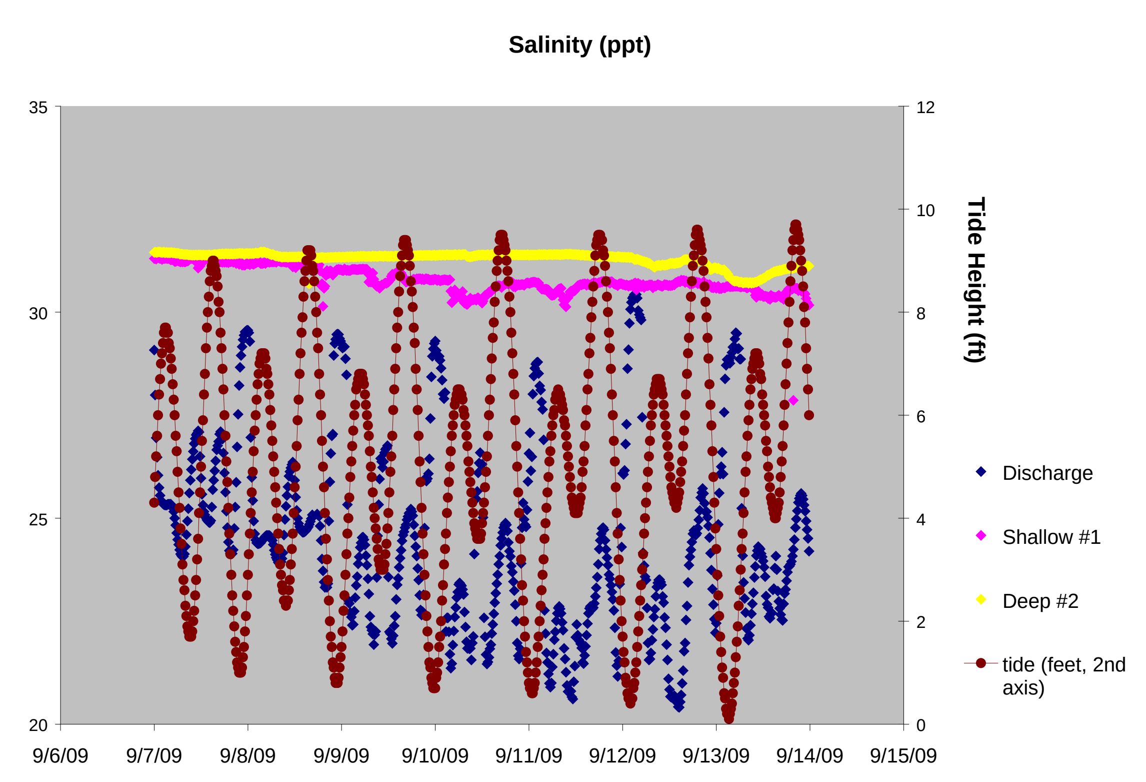

Figure 3.2-15: Pond A3W salinity values at 3 pond locations during 7 September – 13 September

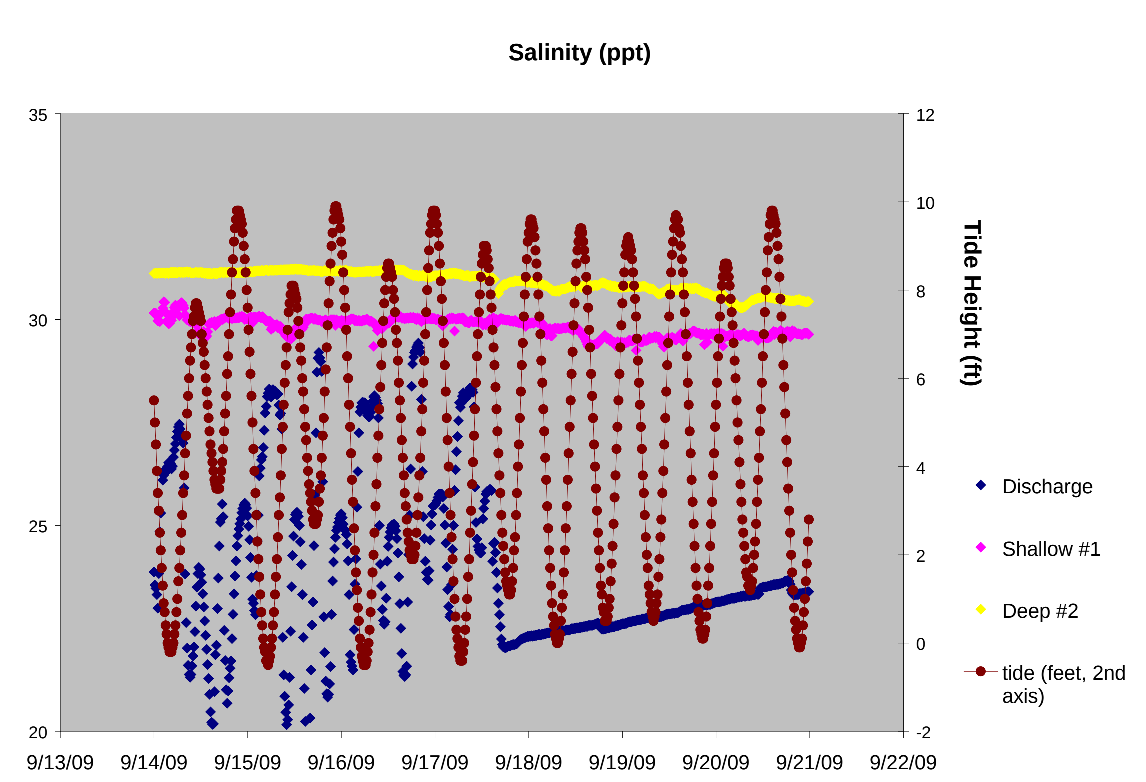

Figure 3.2-16: Pond A3W salinity values at 3 pond locations during 14 September – 20 September

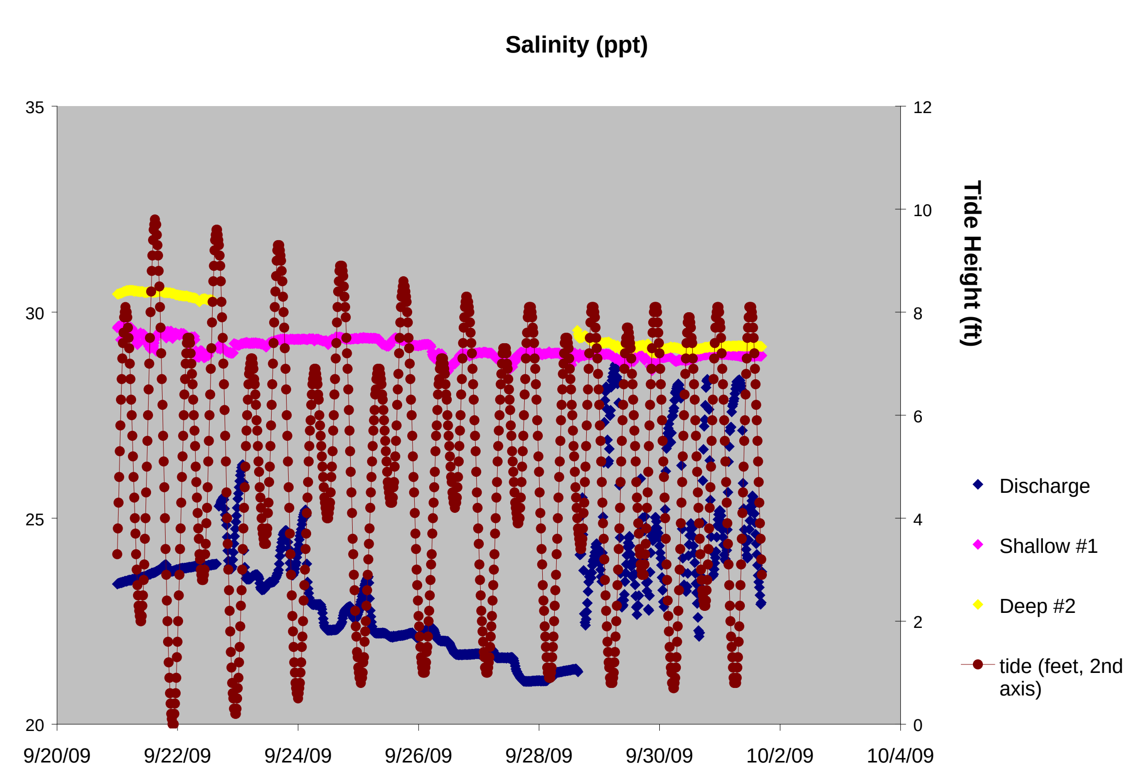

Figure 3.2-17: Pond A3W salinity values at 3 pond locations during 21 September – 1 October

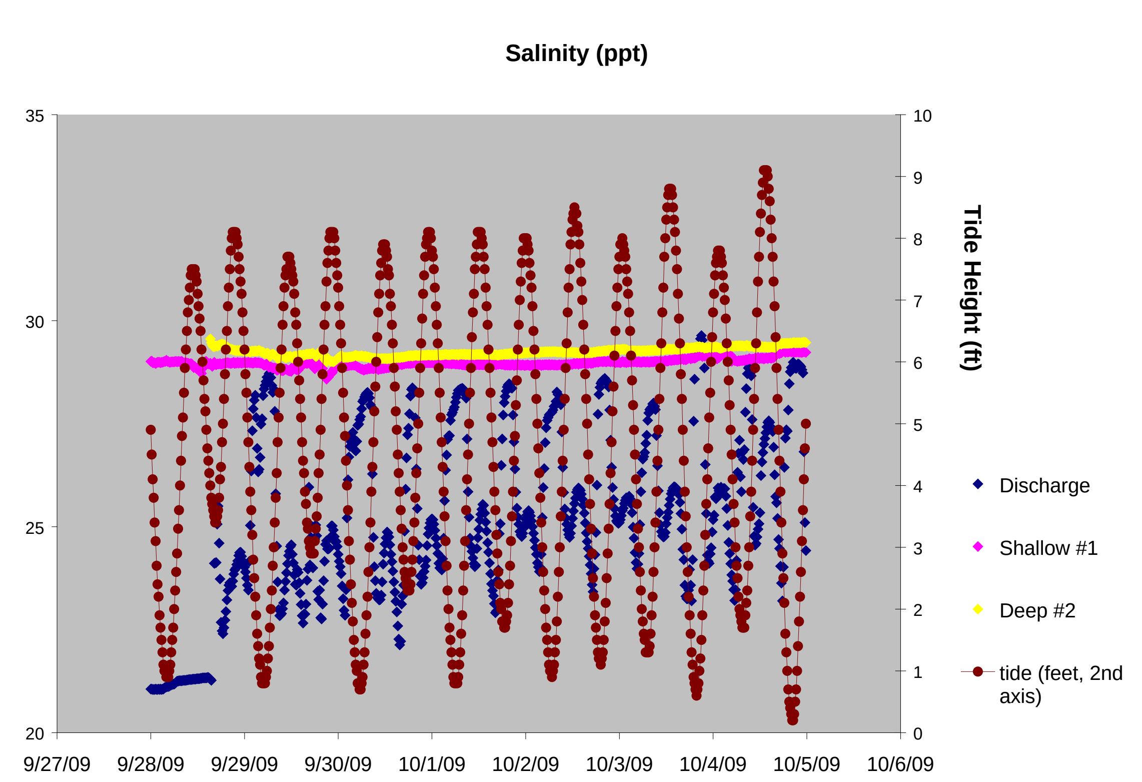

Figure 3.2-18: Pond A3W salinity values at 3 pond locations during 28 September – 4 October

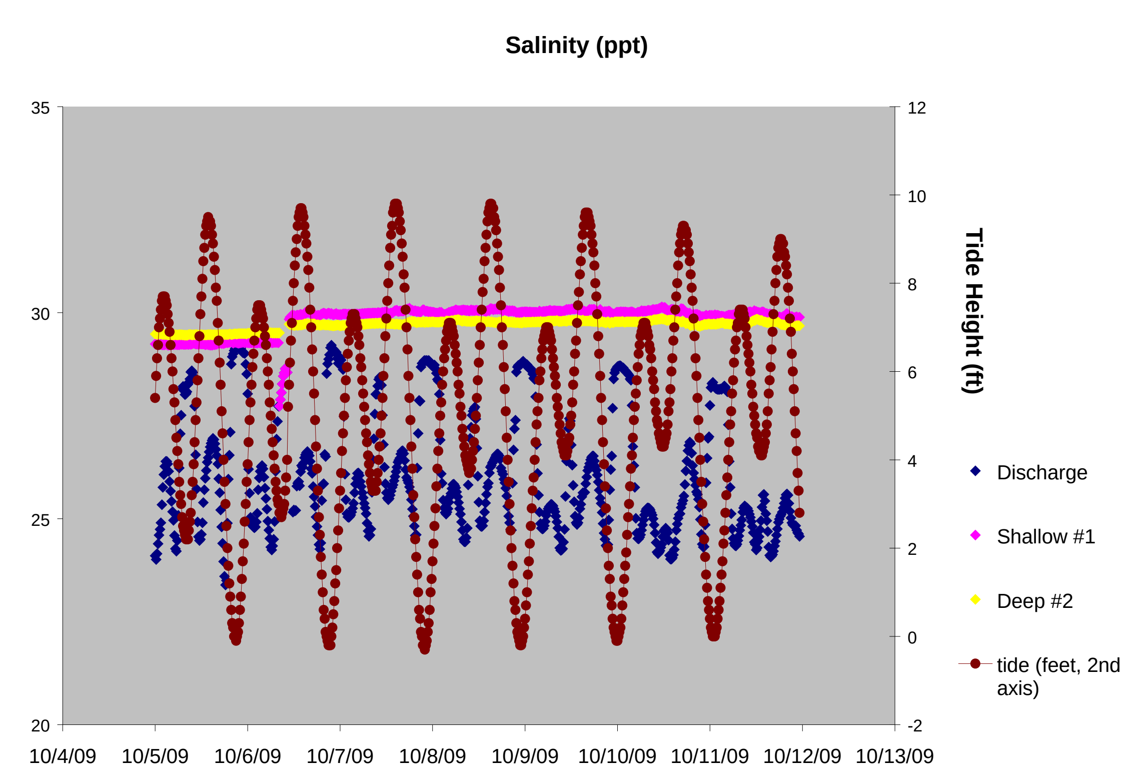

Figure 3.2-19: Pond A3W salinity values at 3 pond locations during 5 October – 11 October

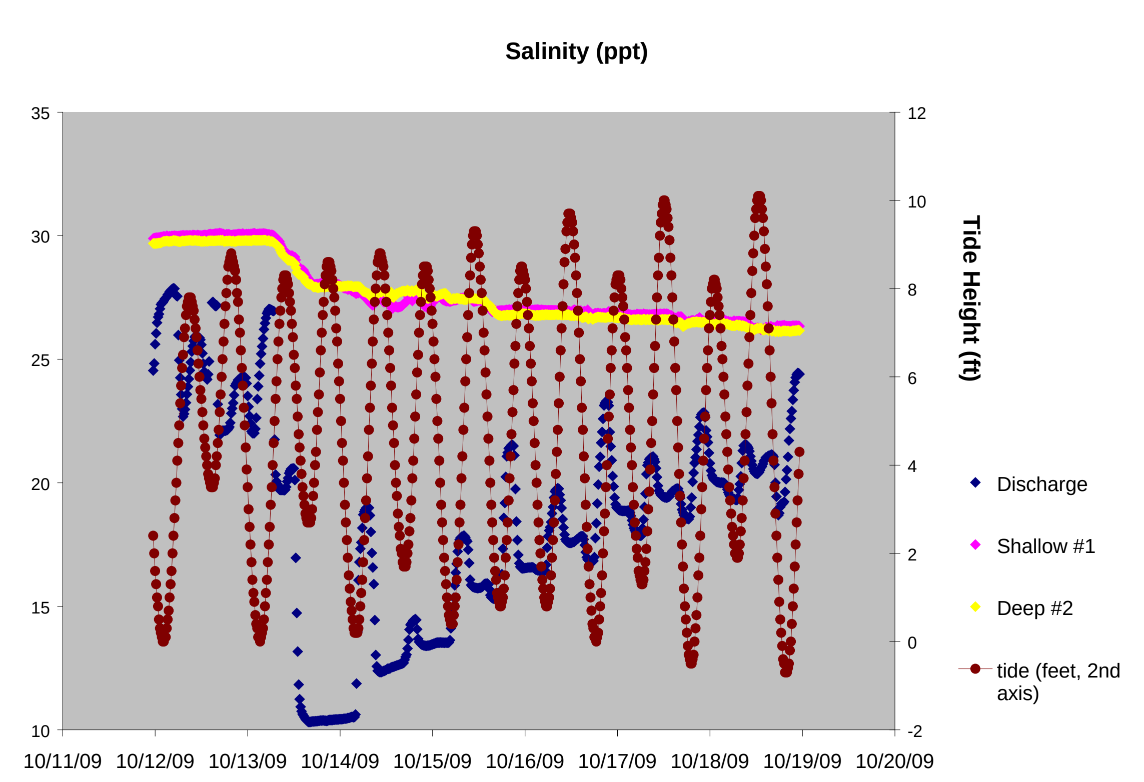

Figure 3.2-20: Pond A3W salinity values at 3 pond locations during 12 October – 18 October

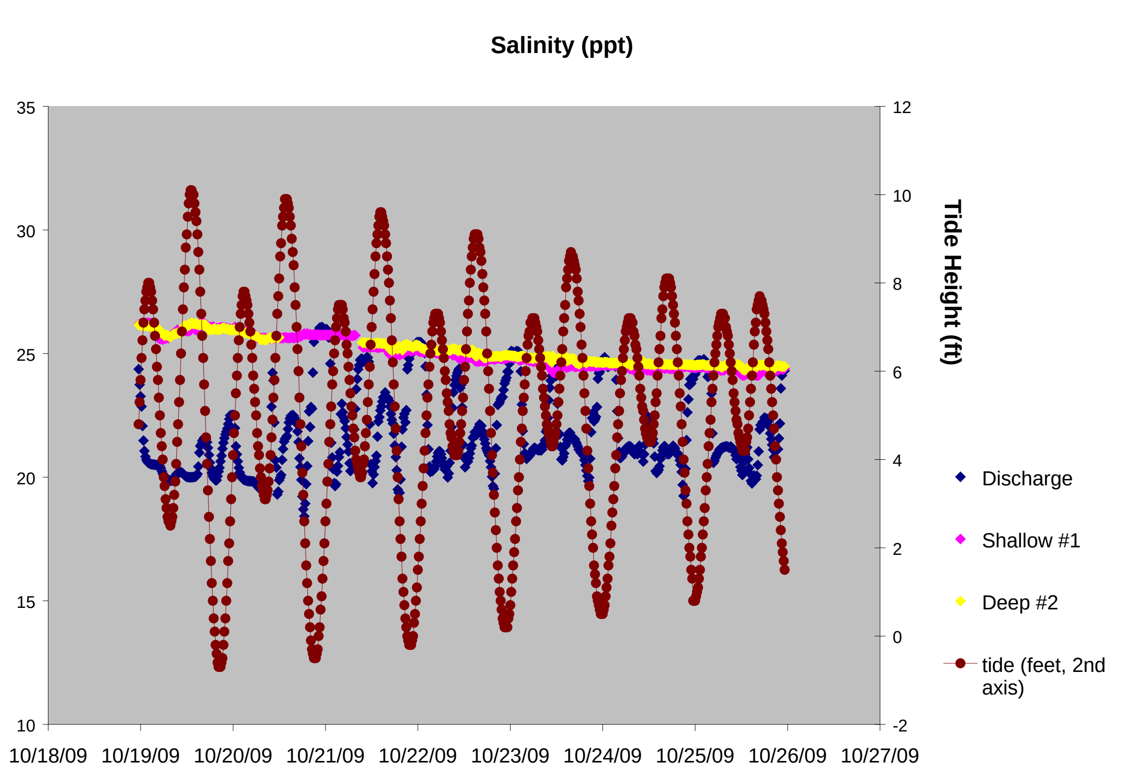

Figure 3.2-21: Pond A3W salinity values at 3 pond locations during 19 October – 25 October

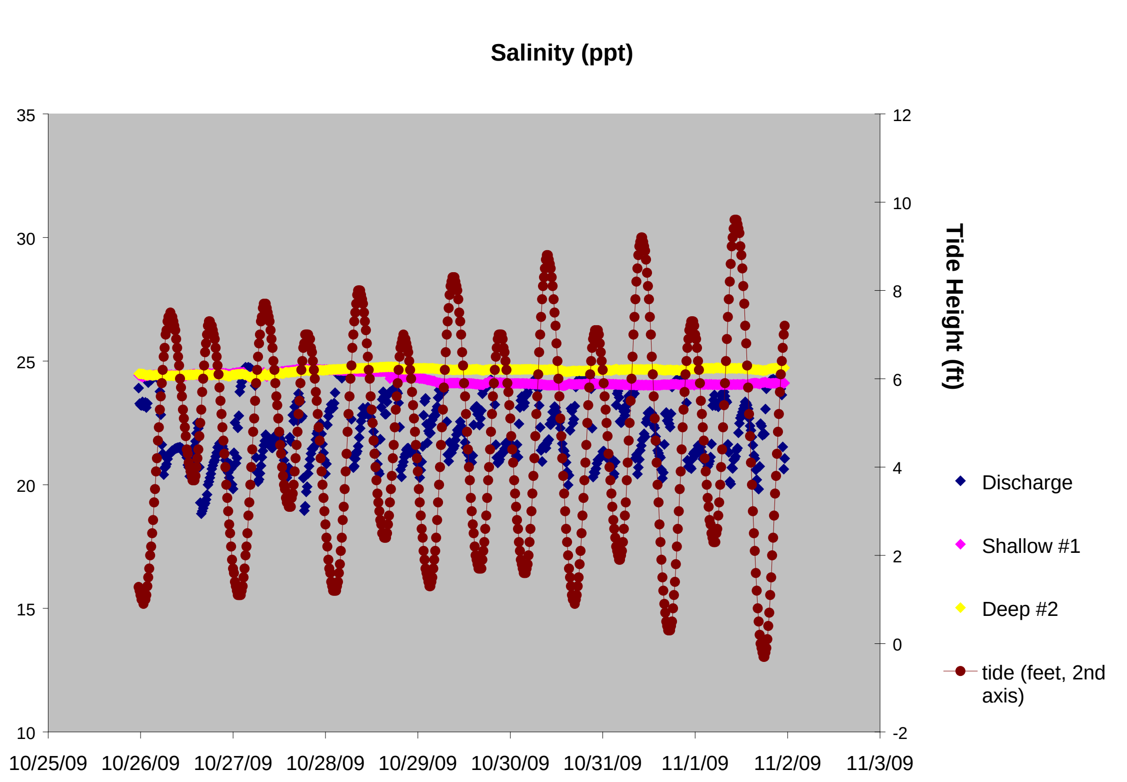

Figure 3.2-22: Pond A3W salinity values at 3 pond locations during 26 October – 1 November

3.3 pH

Recorded pH values within Pond A3W also seem to be influenced by a muted tidal cycles with greatest variation over time observed in the discharge datasonde (Figures 3.3-1 through 3.3-22). The pH varied by datasonde location, with lowest recorded pH values at the discharge location and highest pH values recorded at the shallow location. While the shallow and deep datasonde locations were relatively similar early in the season, pH at the shallow datasonde increased and pH at the deep datasonde decreased August and September (excluding the month of October when the deep datasonde logged the highest monthly pH average). Within Pond A3W, pH ranged from 6.83 to 9.52 with all datasondes recording pH values above 8.5. Values above 9.16 were recorded in the months of August and September 2009 only.

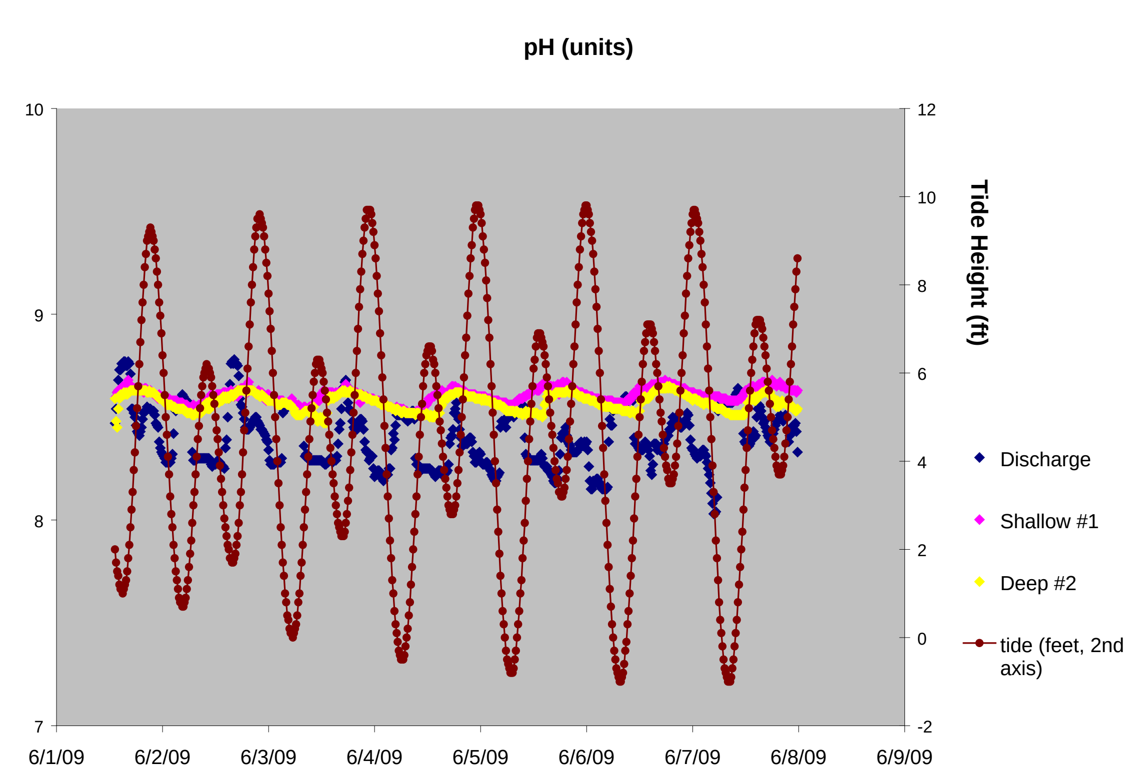

Figure 3.3-1: Pond A3W pH values at 3 pond locations during 1 June – 7 June

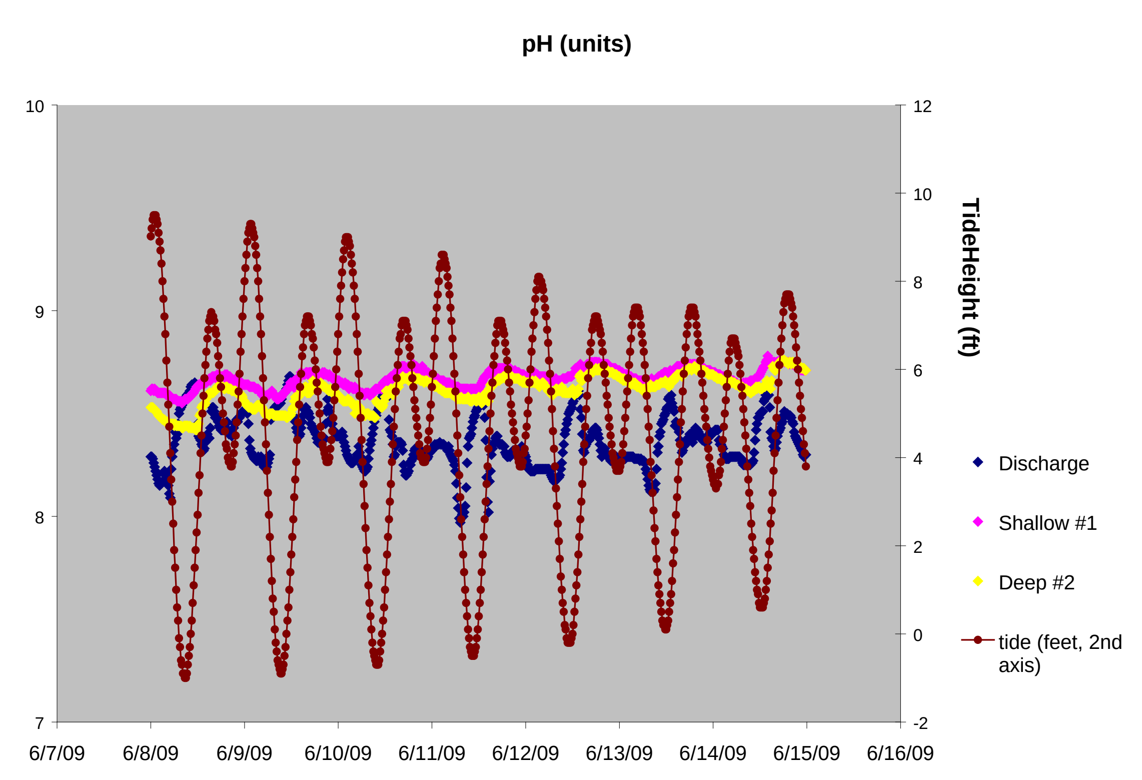

Figure 3.3-2: Pond A3W pH values at 3 pond locations during 8 June – 14 June

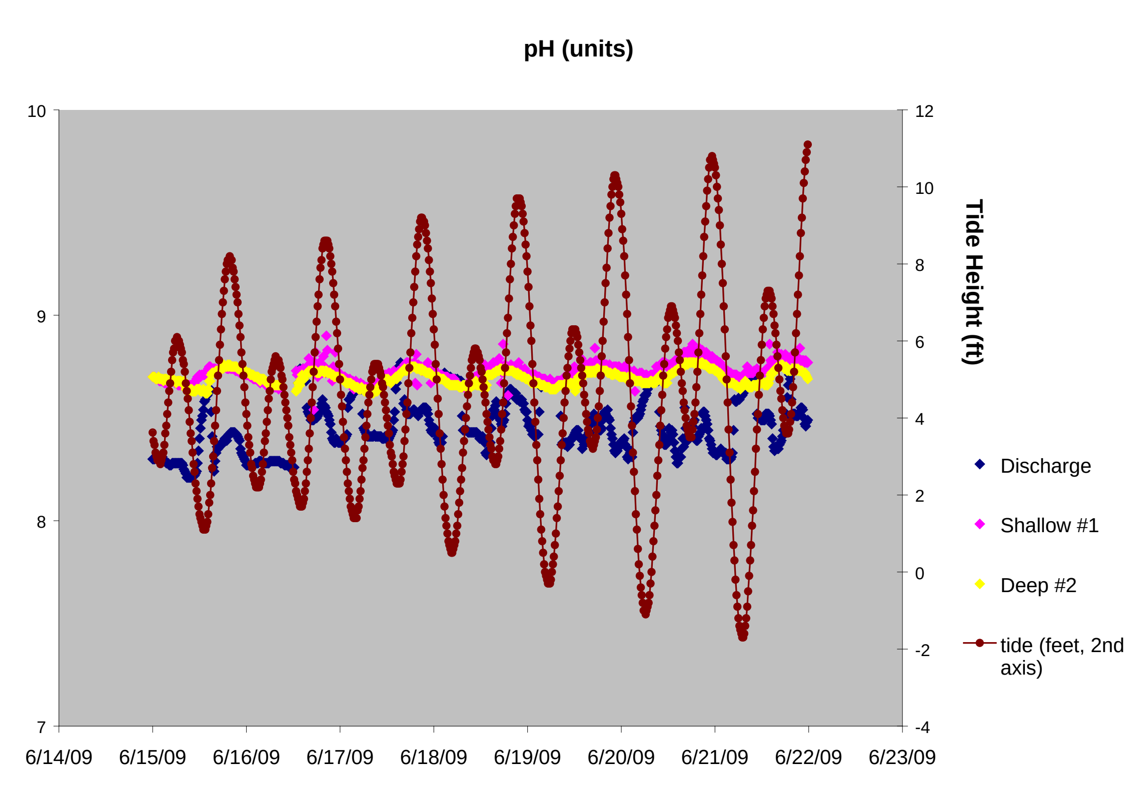

Figure 3.3-3: Pond A3W pH values at 3 pond locations during 15 June – 21 June

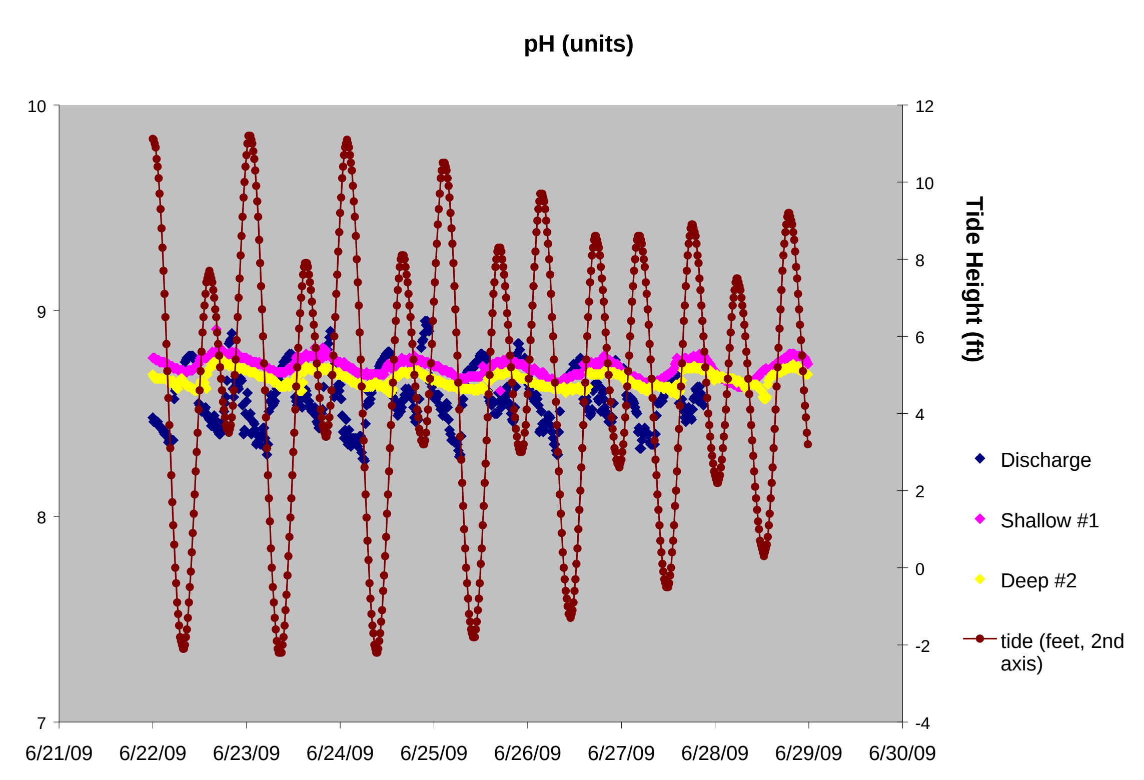

Figure 3.3-4: Pond A3W pH values at 3 pond locations during 22 June – 28 June

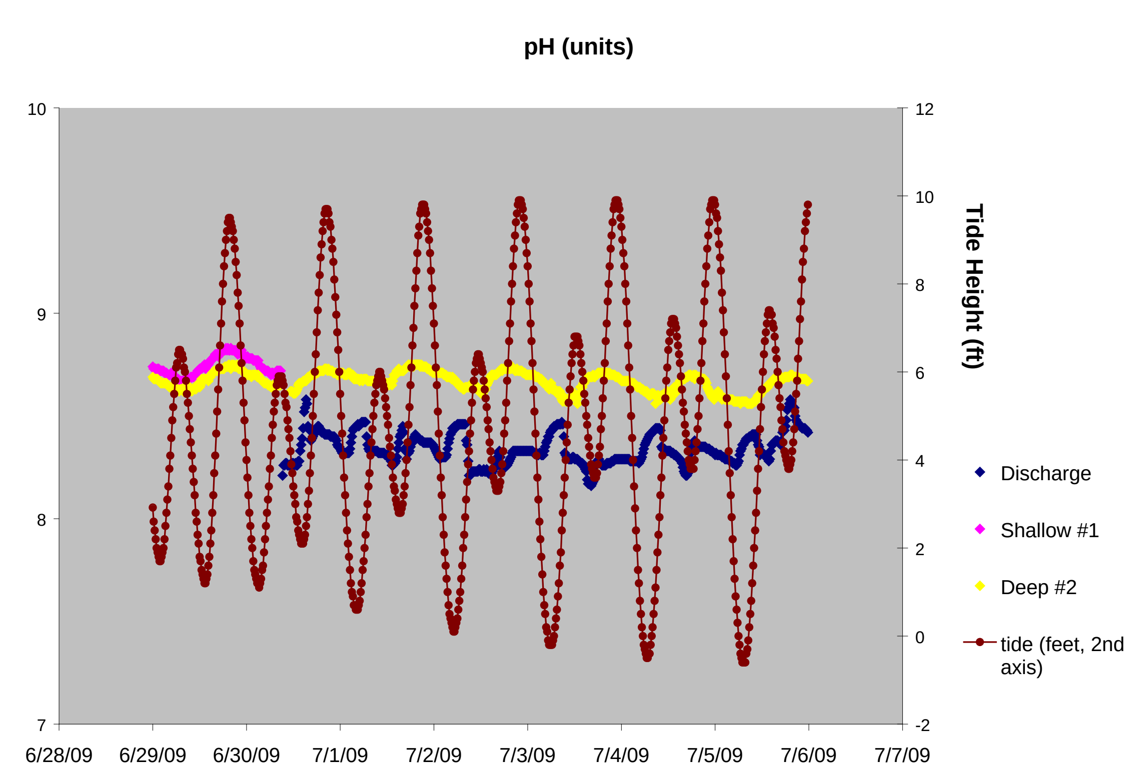

Figure 3.3-5: Pond A3W pH values at 3 pond locations during 29 June – 5 July

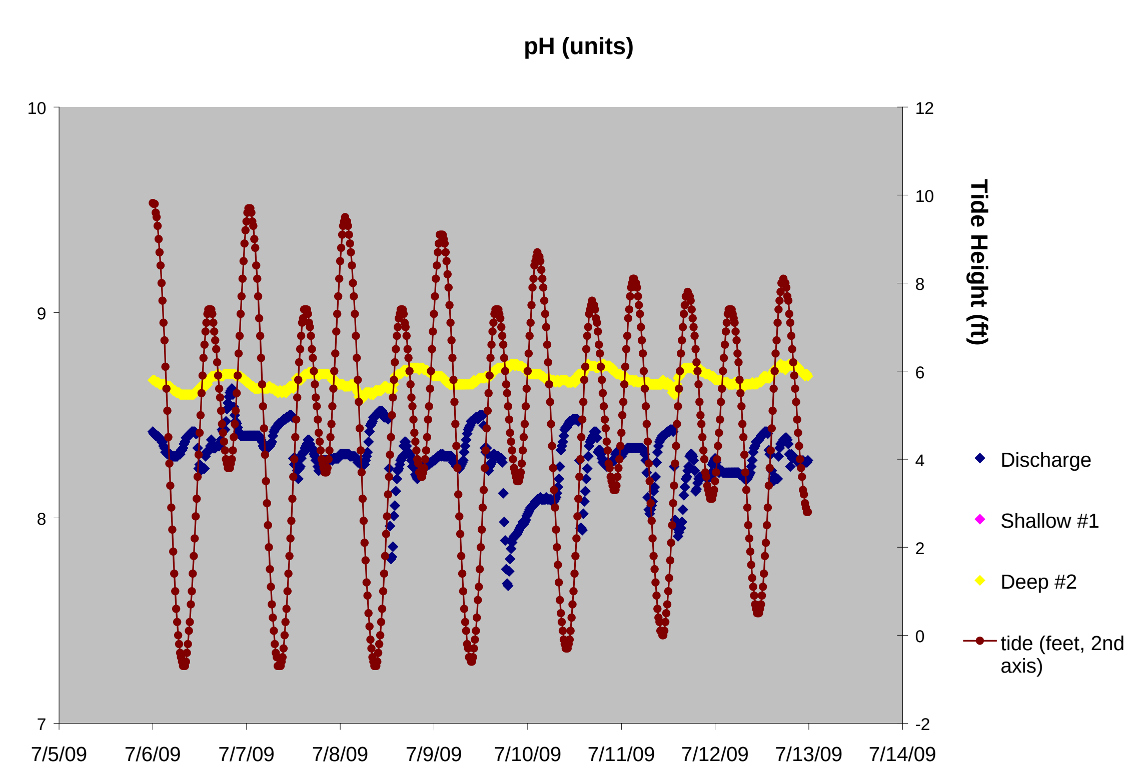

Figure 3.3-6: Pond A3W pH values at 3 pond locations during 6 July – 12 July

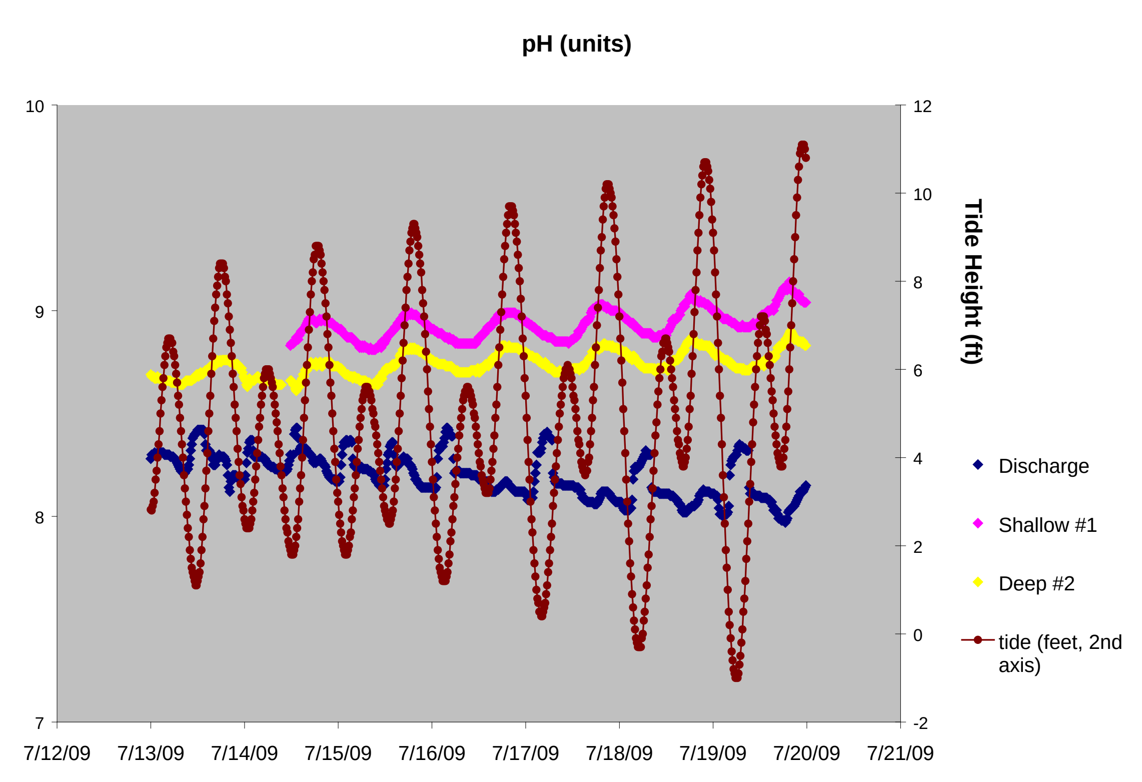

Figure 3.3-7: Pond A3W pH values at 3 pond locations during 13 July – 19 July

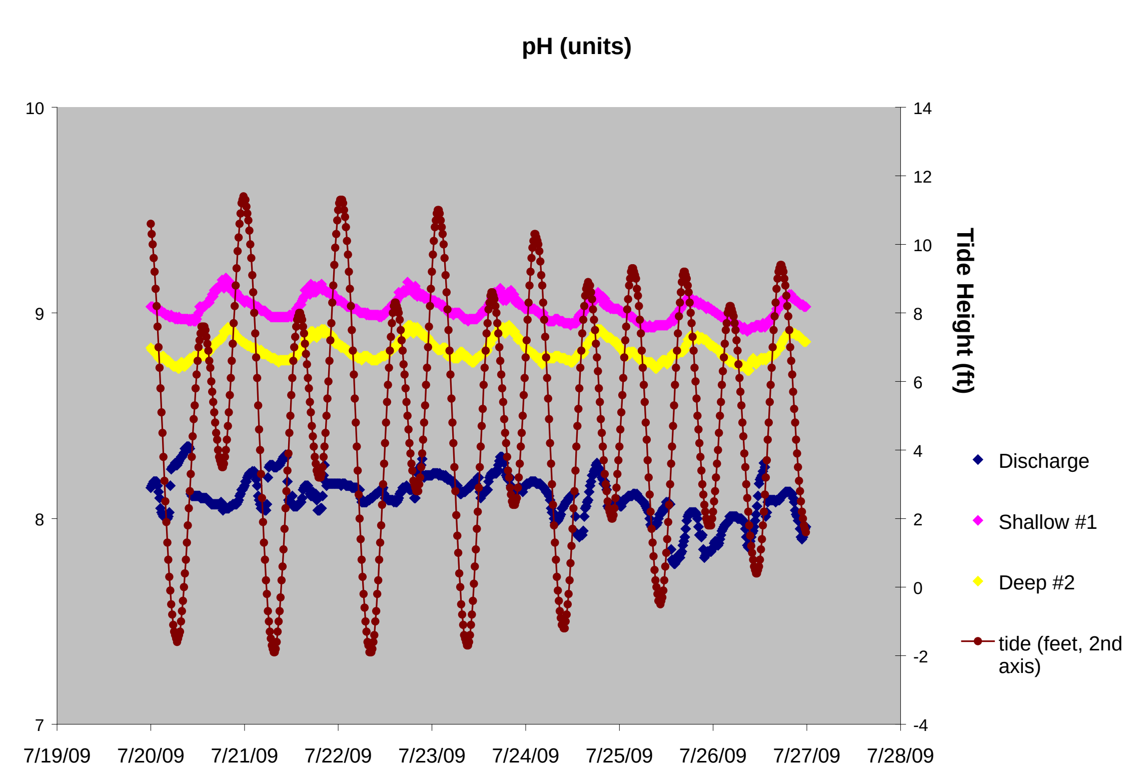

Figure 3.3-8: Pond A3W pH values at 3 pond locations during 20 July – 26 July

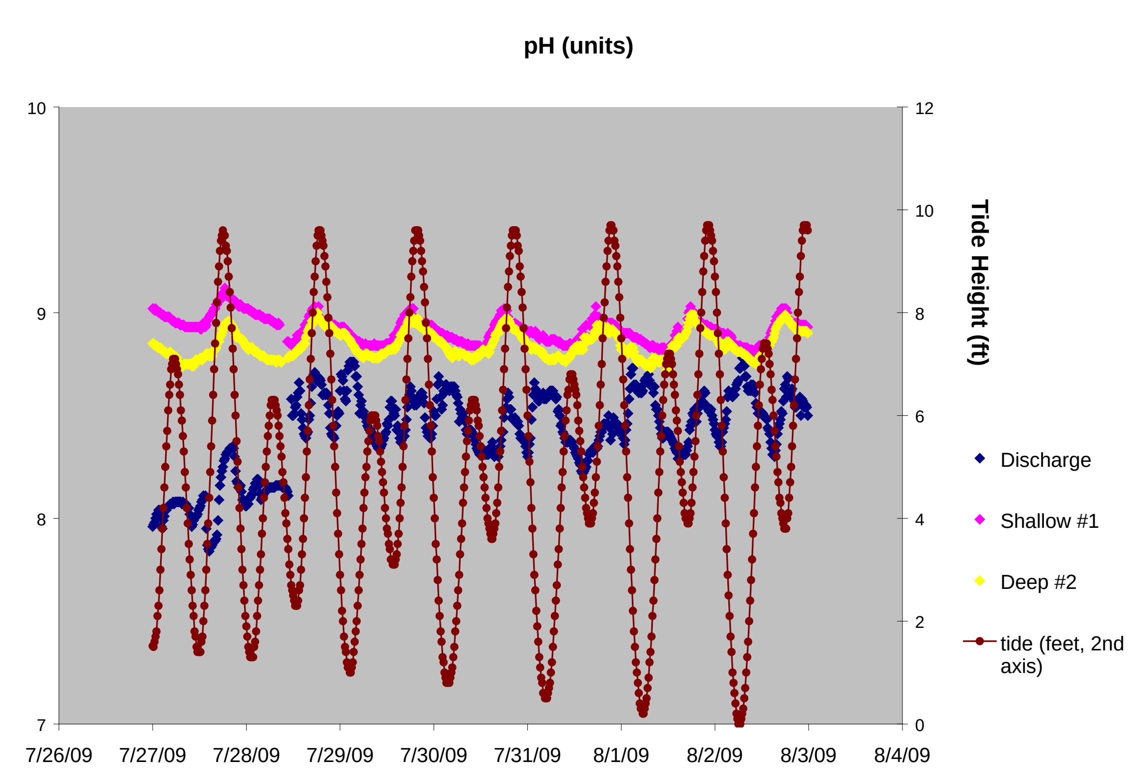

Figure 3.3-9: Pond A3W pH values at 3 pond locations during 27 July – 2 August

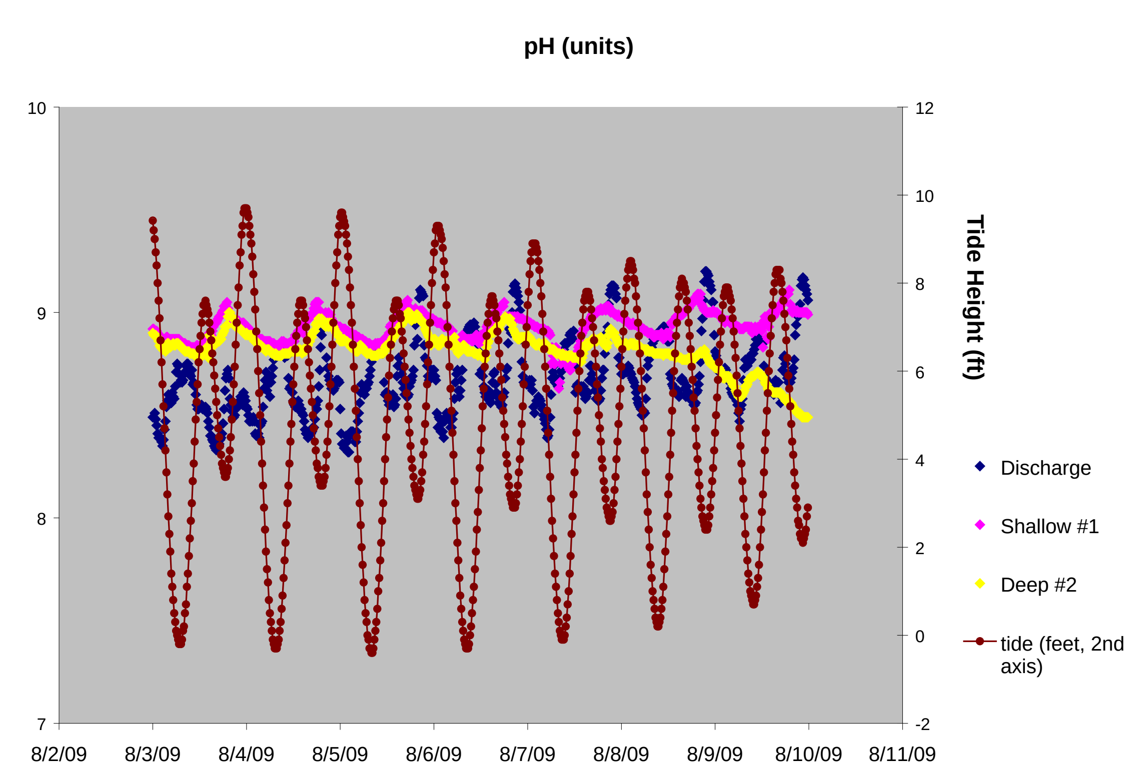

Figure 3.3-10: Pond A3W pH values at 3 pond locations during 3 August – 9 August

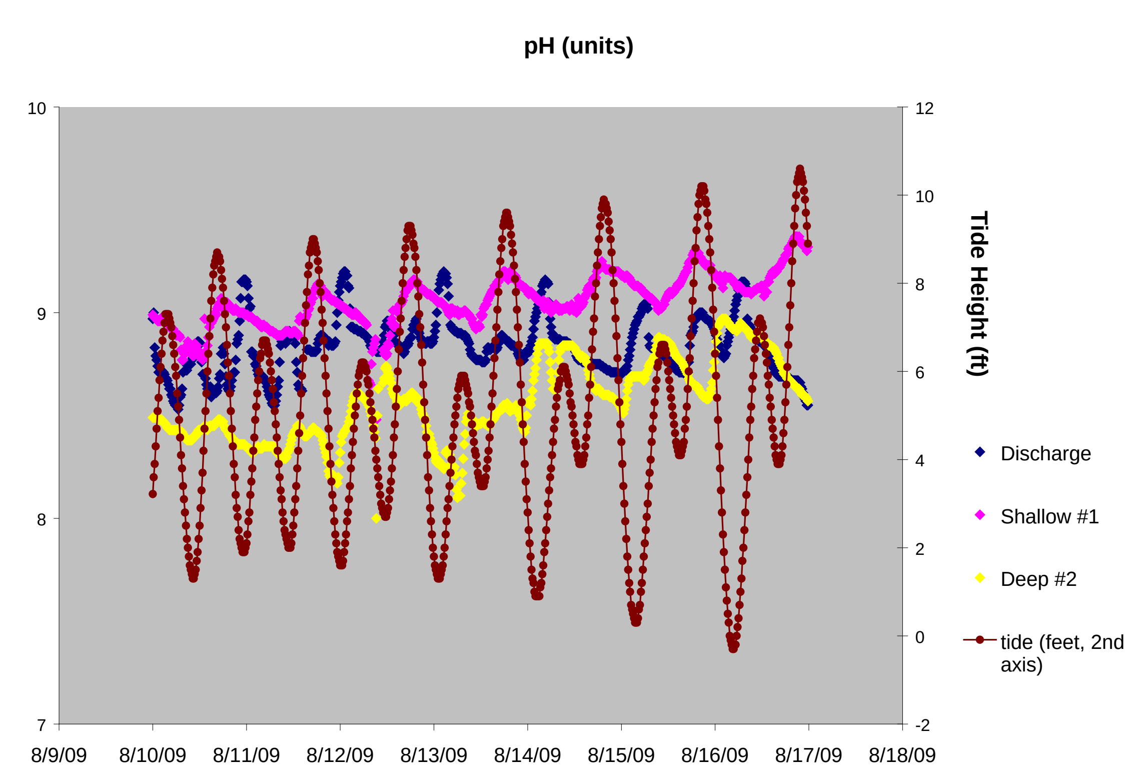

Figure 3.3-11: Pond A3W pH values at 3 pond locations during 10 August- 16 August

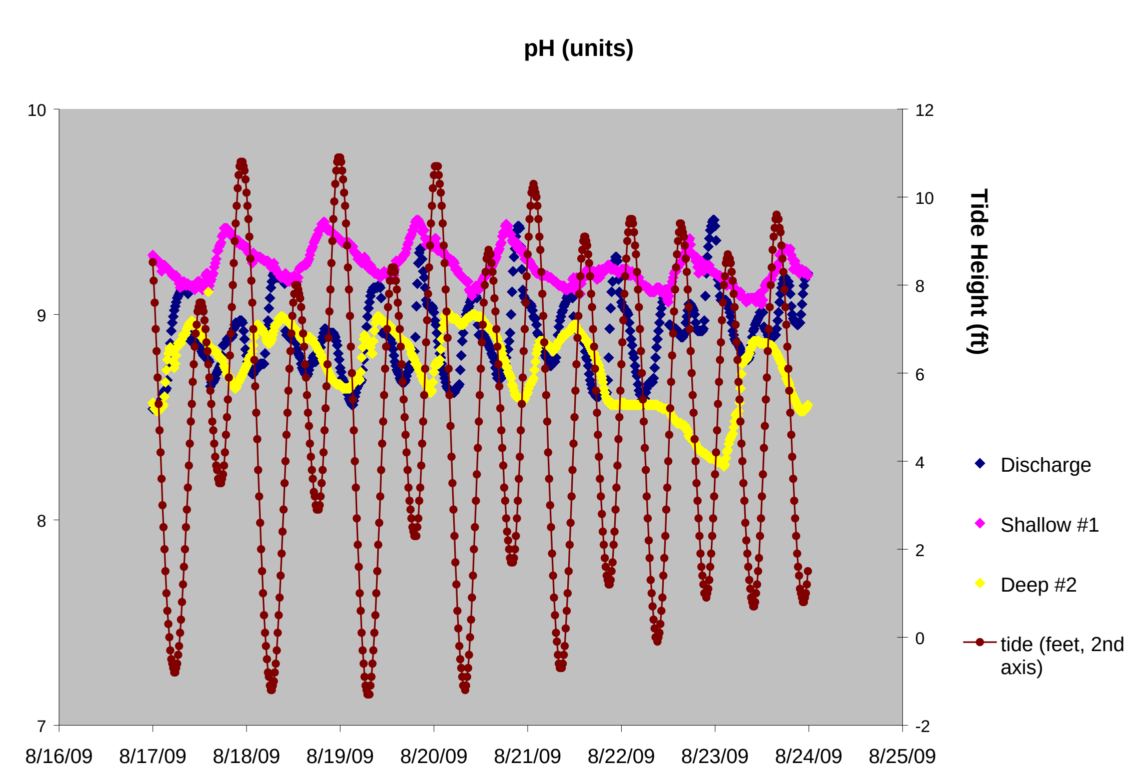

Figure 3.3-12: Pond A3W pH values at 3 pond locations during 17 August – 23 August

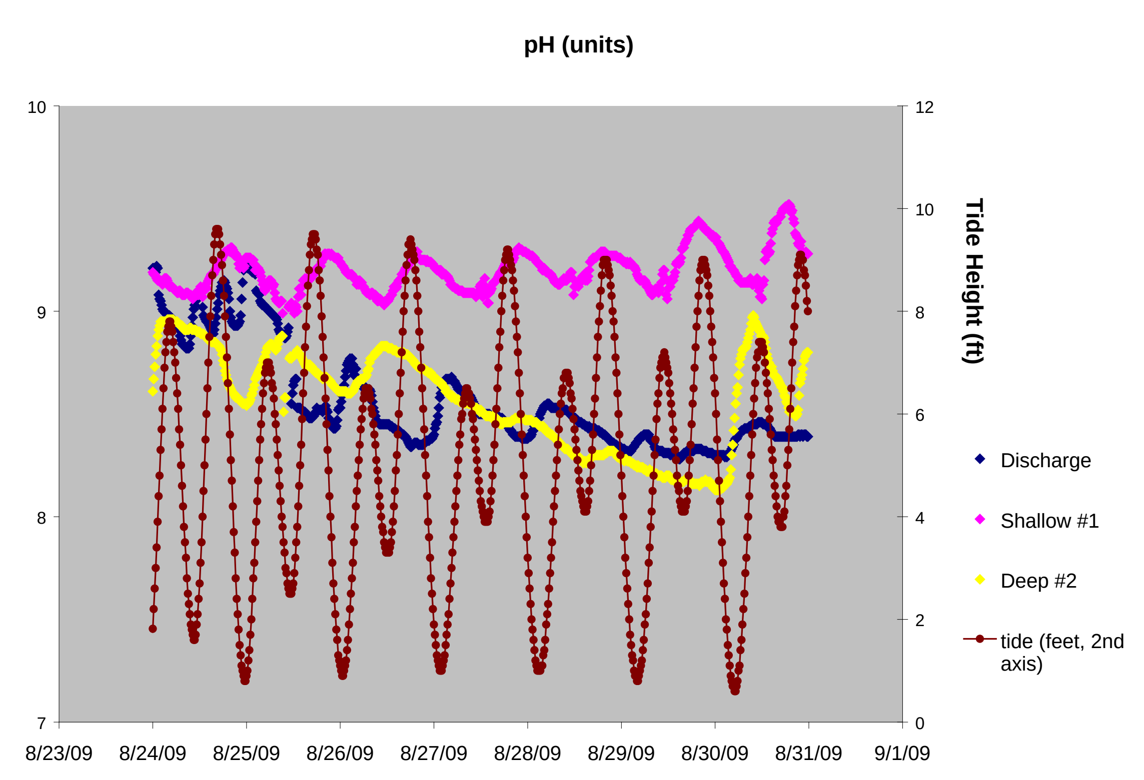

Figure 3.3-13: Pond A3W pH values at 3 pond locations during 24 August – 30 August

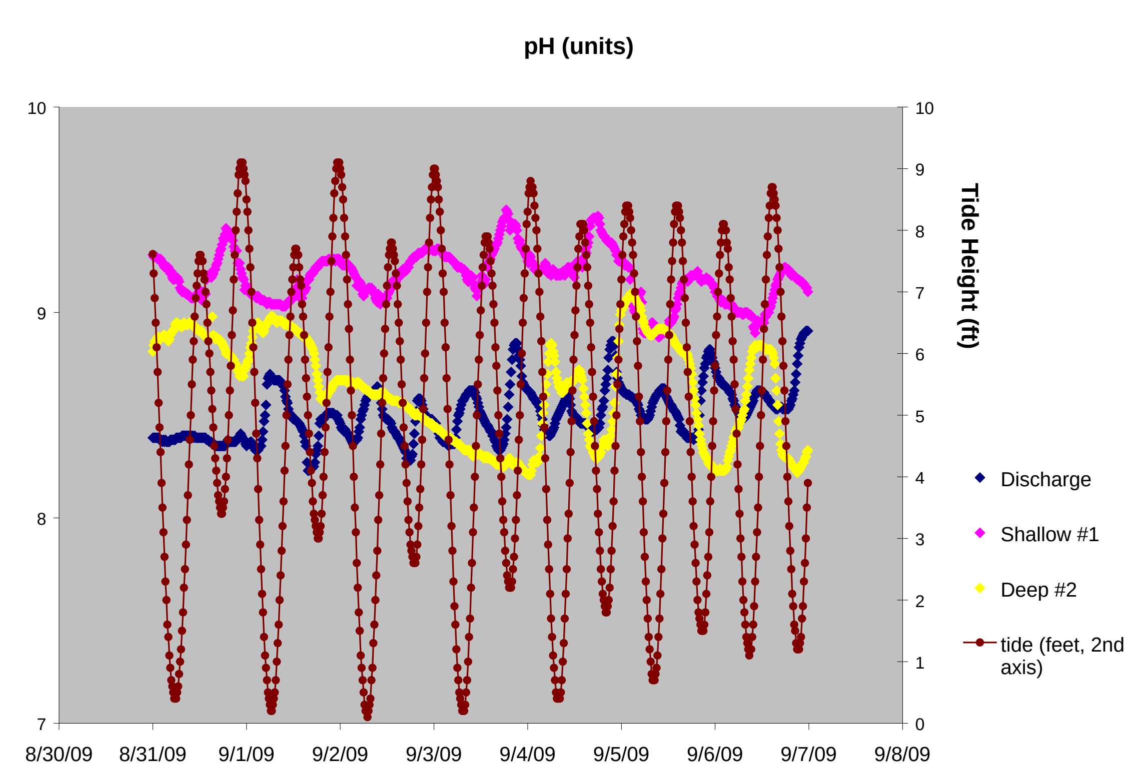

Figure 3.3-14: Pond A3W pH values at 3 pond locations during 31 August – 6 September

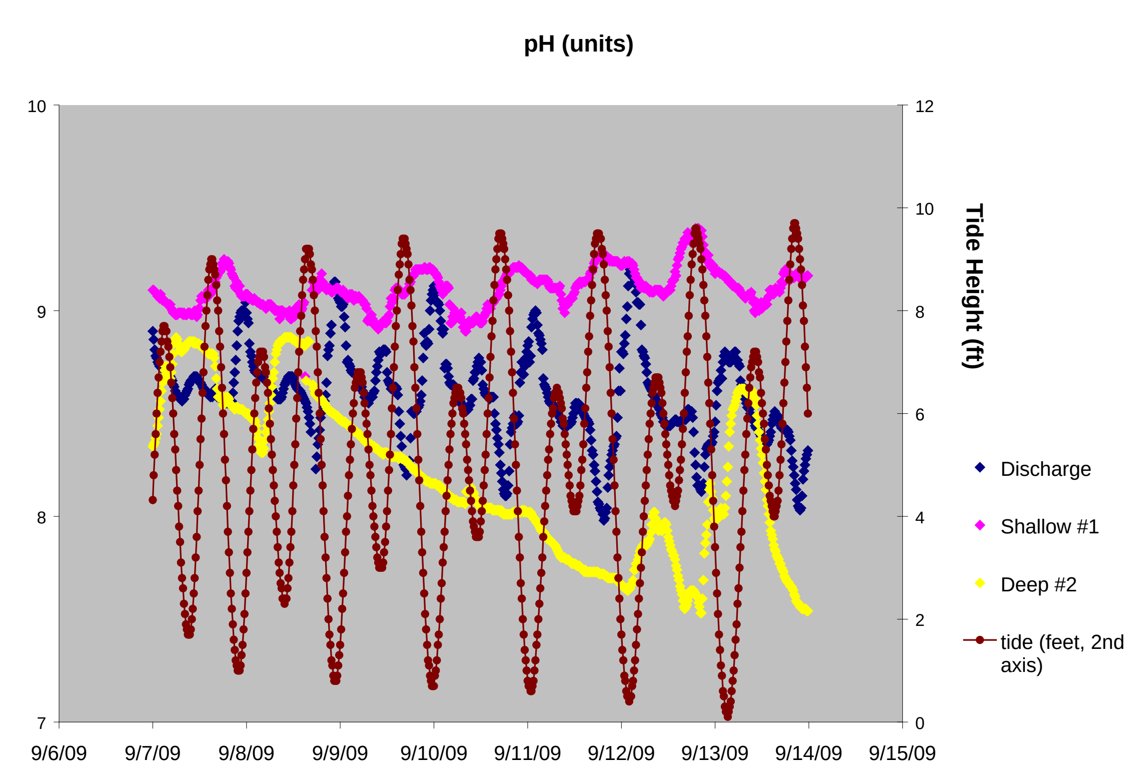

Figure 3.3-15: Pond A3W pH values at 3 pond locations during 7 September – 13 September

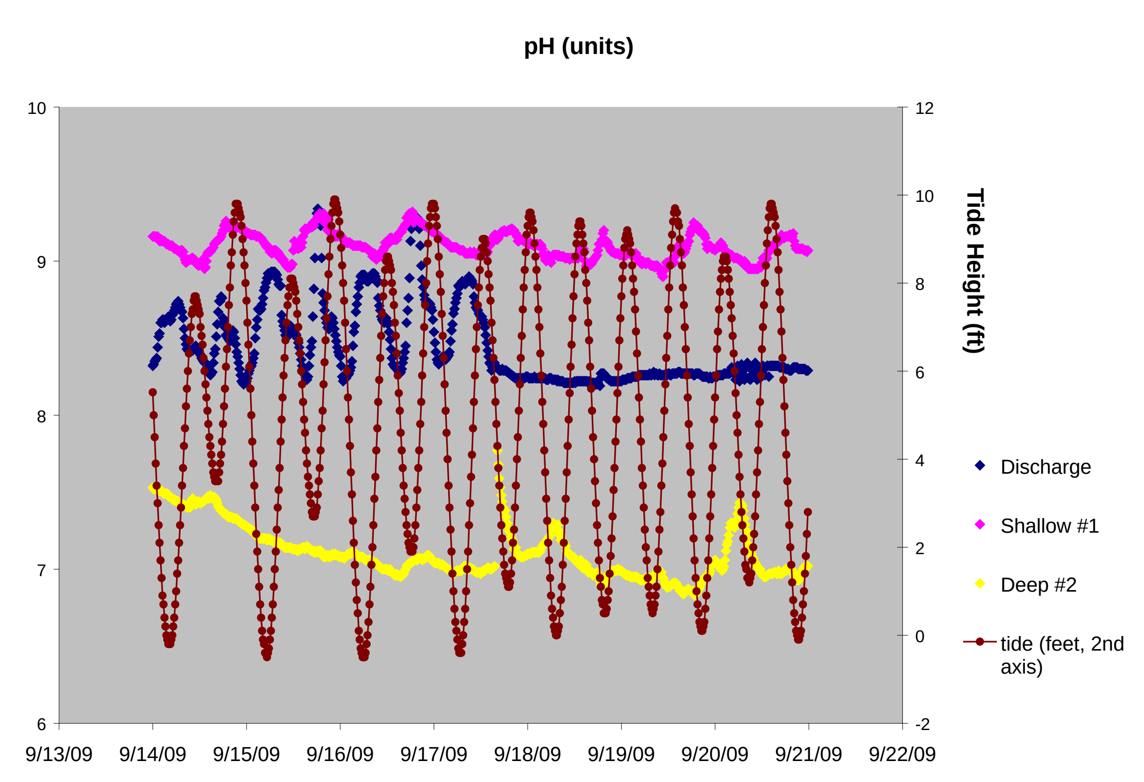

Figure 3.3-16: Pond A3W pH values at 3 pond locations during 14 September – 20 September

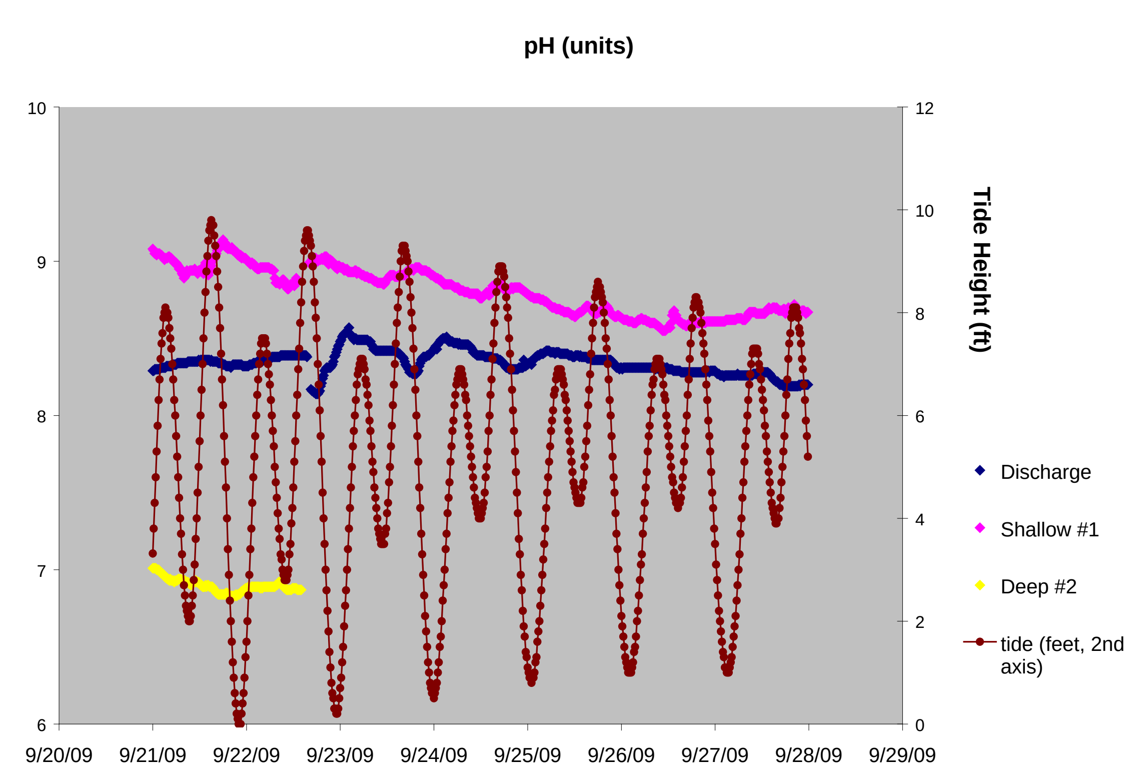

Figure 3.3-17: Pond A3W pH values at 3 pond locations during 21 September – 27 September

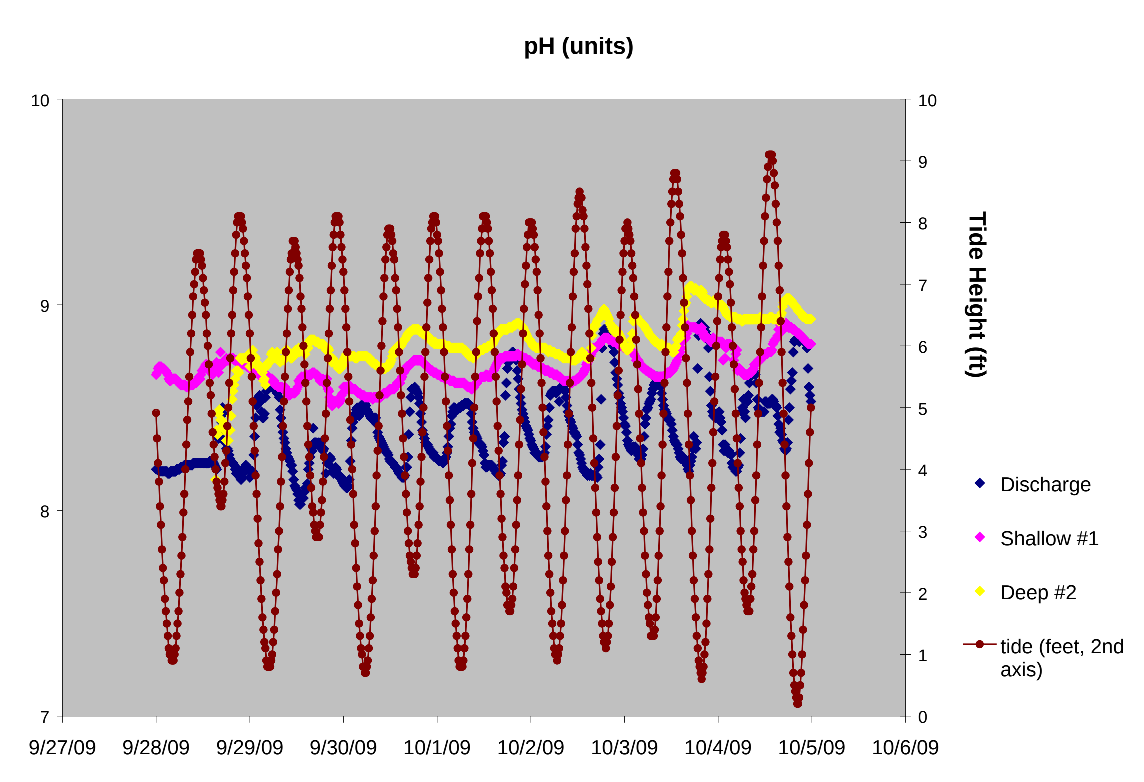

Figure 3.3-18: Pond A3W pH values at 3 pond locations during 28 September – 4 October

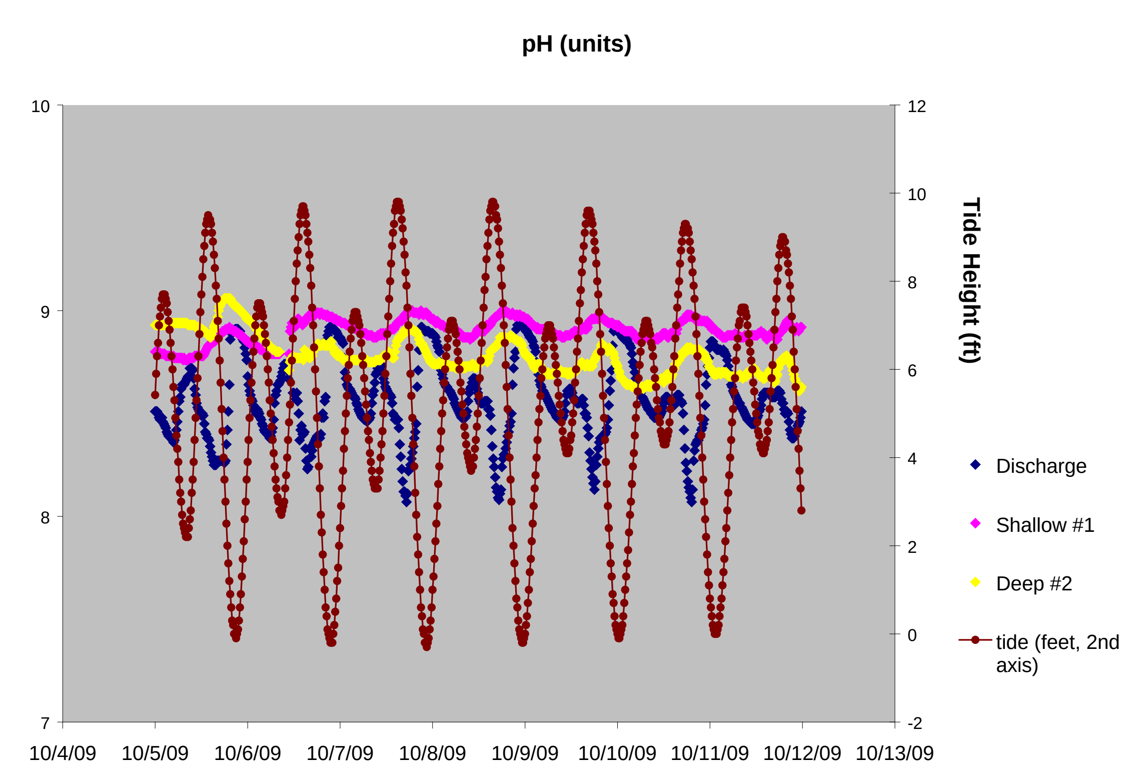

Figure 3.3-19: Pond A3W pH values at 3 pond locations during 5 October – 11 October

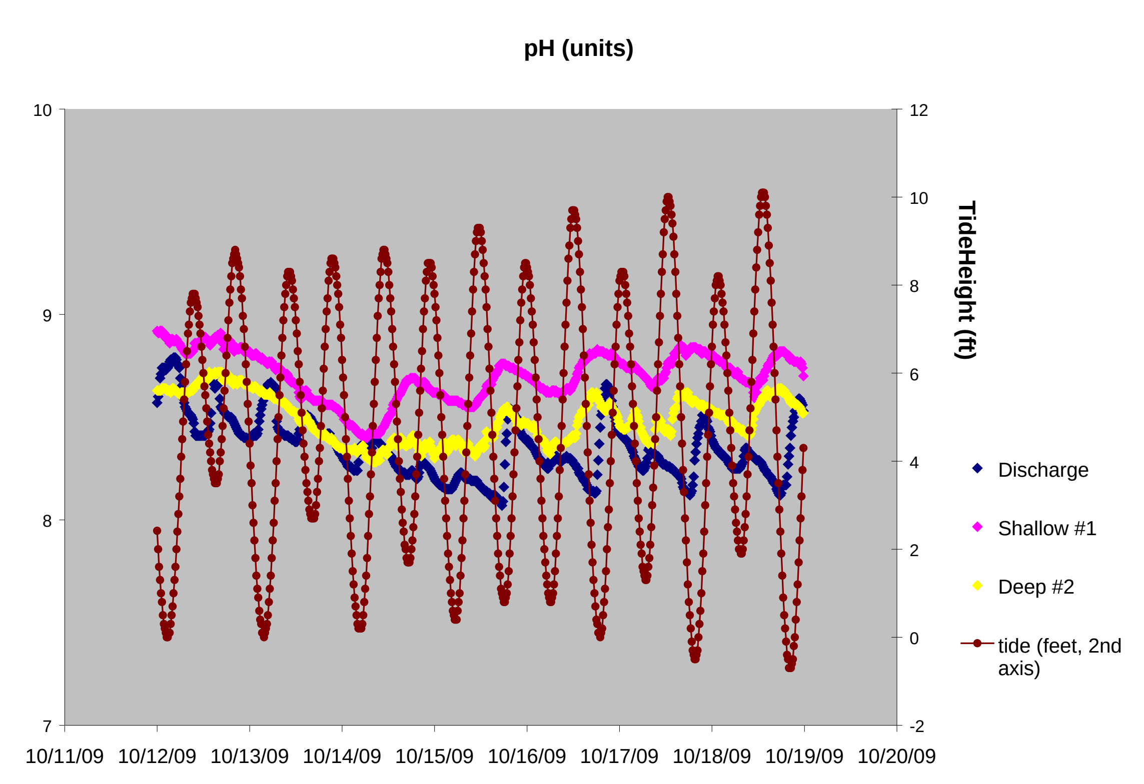

Figure 3.3-20: Pond A3W pH values at 3 pond locations during 12 October – 18 October

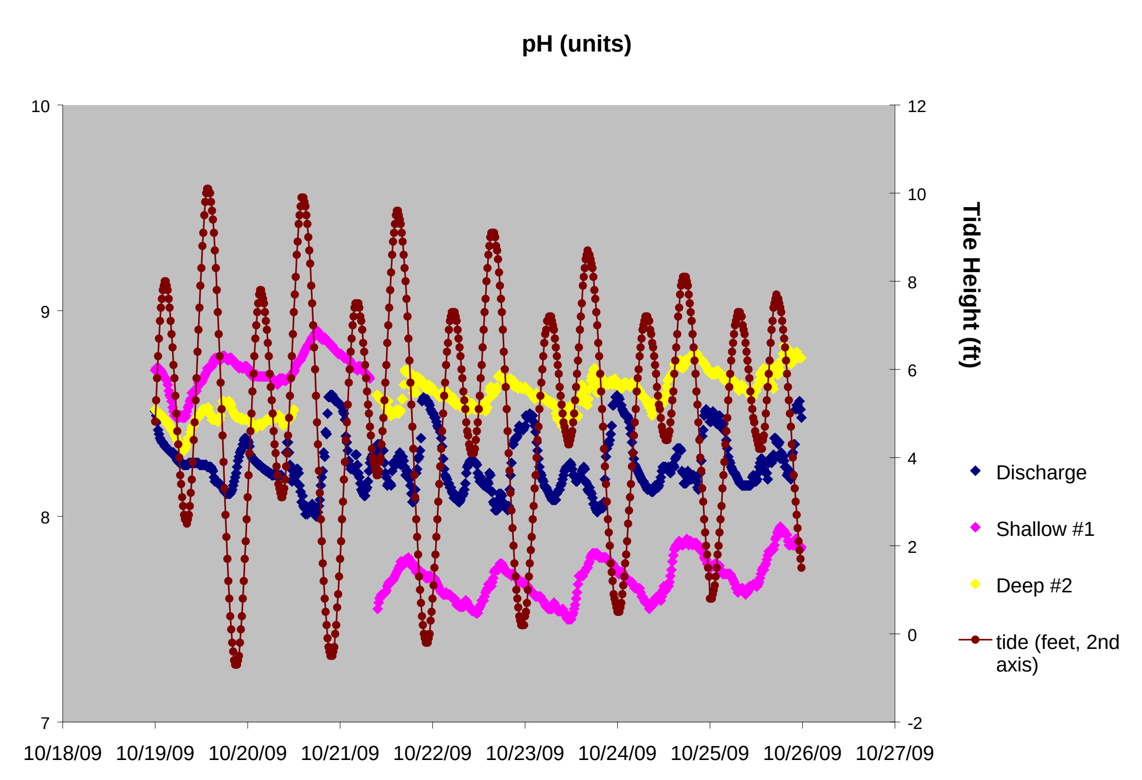

Figure 3.3-21: Pond A3W pH values at 3 pond locations during 19 October – 25 October

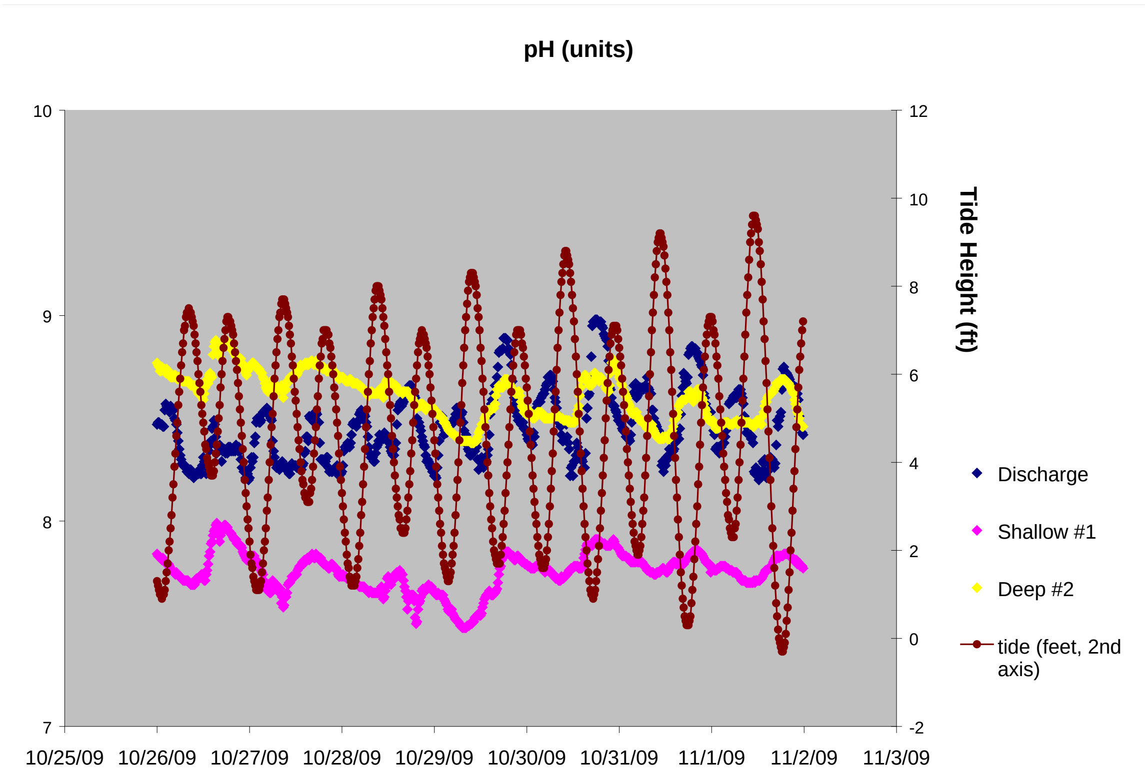

Figure 3.3-22: Pond A3W pH values at 3 pond locations during 26 October – 1 November

3.4 TEMPERATURE

Water temperature within Pond A3W showed a strong cyclic pattern, likely due to both the tidal and diurnal cycles (Figures 3.4-1 through 3.4-22). From June through July 2009, these tidal influences were fairly consistent between datasonde locations with daily minima and maxima being slightly more pronounced at the discharge location. From August to the beginning of September temperatures recorded by the deep datasonde become more stable compared with those at the discharge and shallow locations. Large shifts in temperatures across days likely mimic air temperatures.

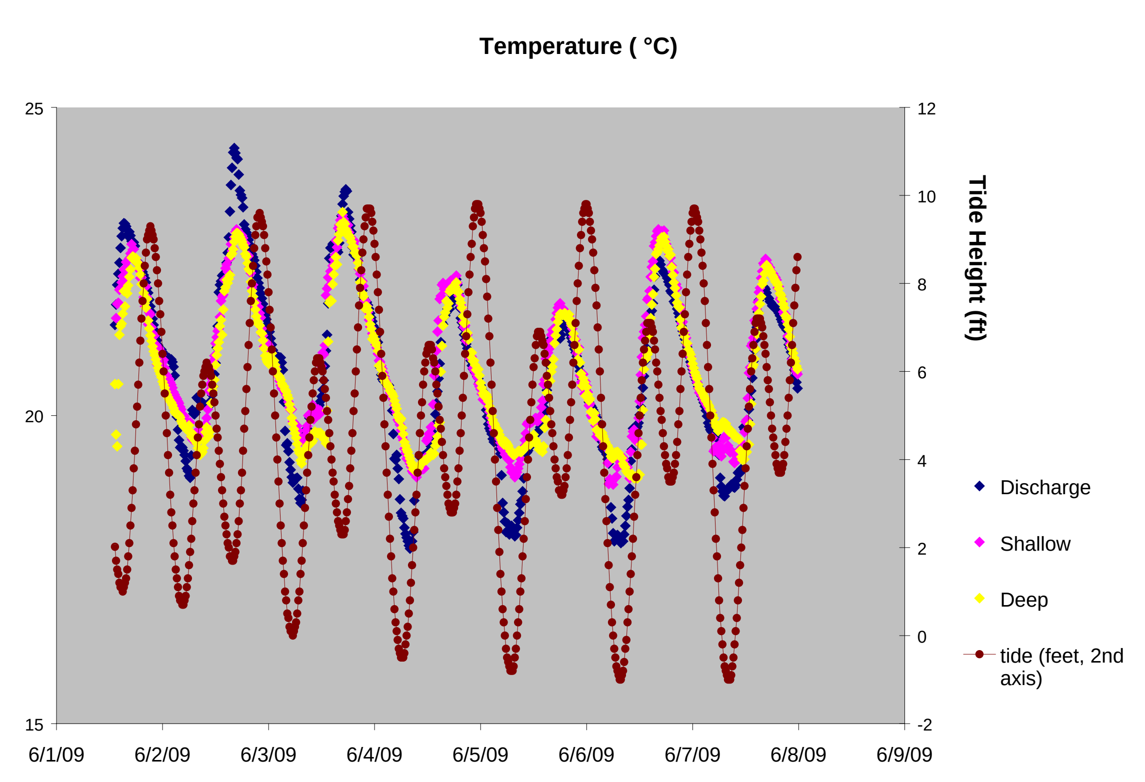

Figure 3.4-1: Pond A3W temperature values at 3 pond locations during 1 June – 7 June

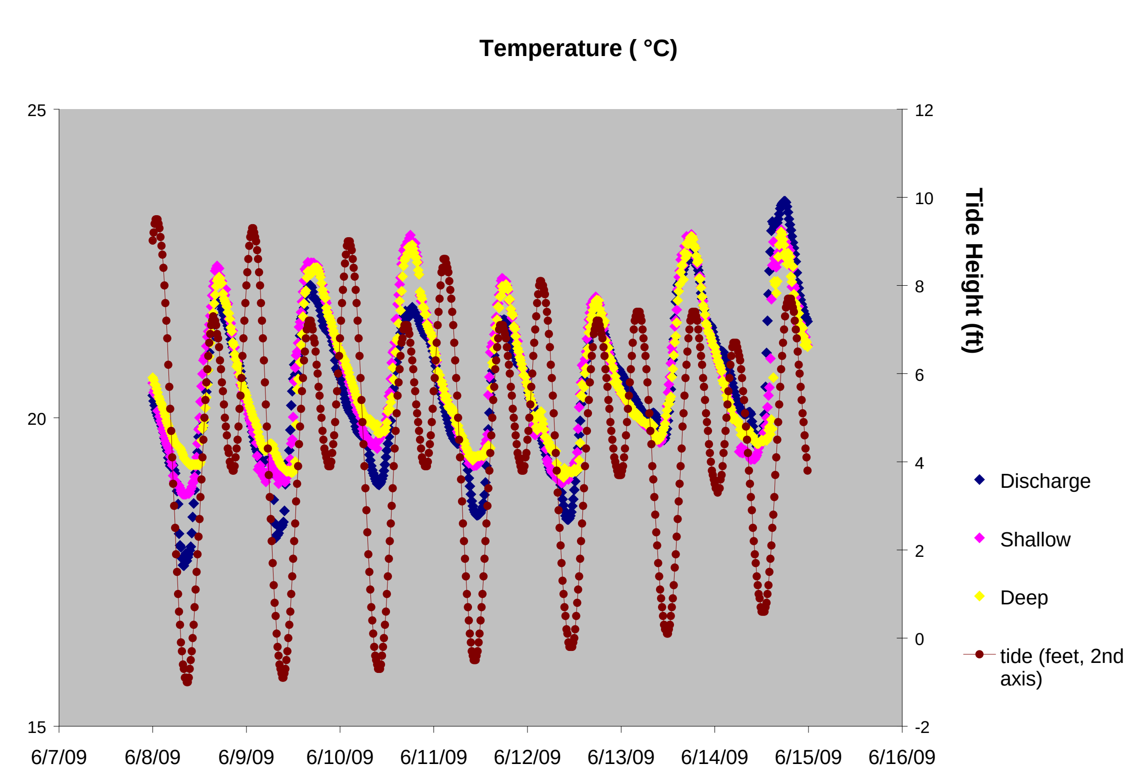

Figure 3.4-2: Pond A3W temperature values at 3 pond locations during 8 June – 14 June

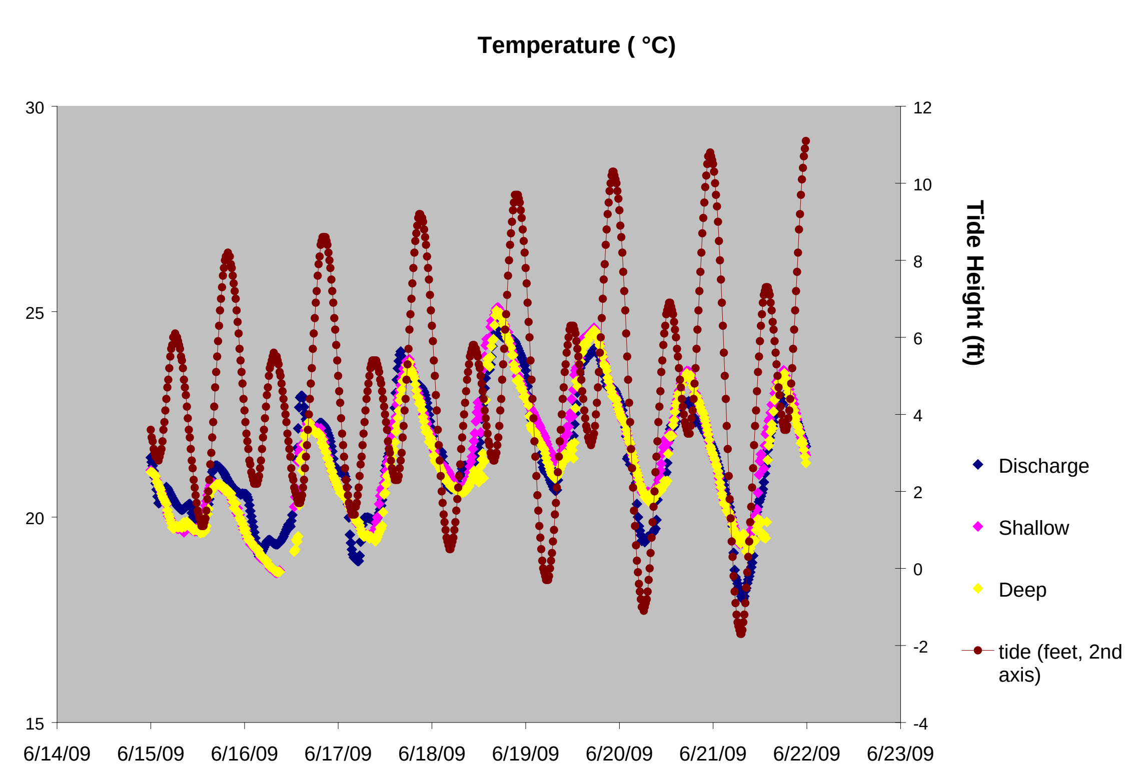

Figure 3.4-3: Pond A3W temperature values at 3 pond locations during 15 June – 21 June

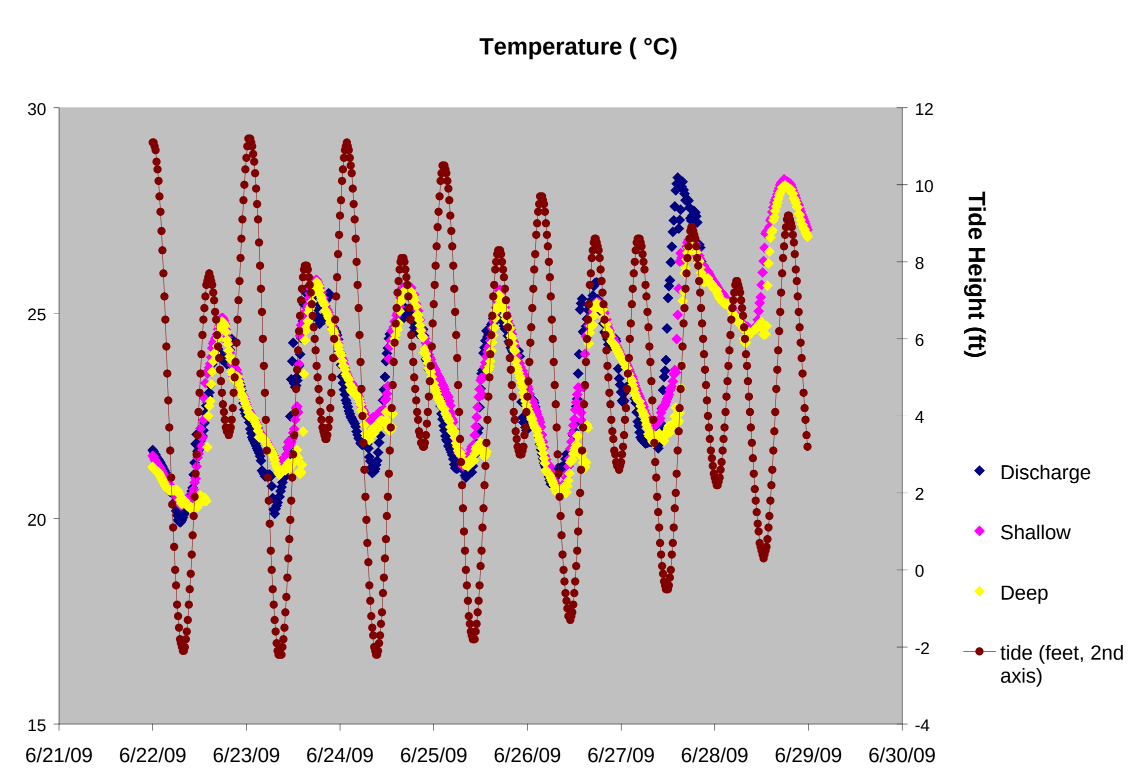

Figure 3.4-4: Pond A3W temperature values at 3 pond locations during 22 June – 28 June

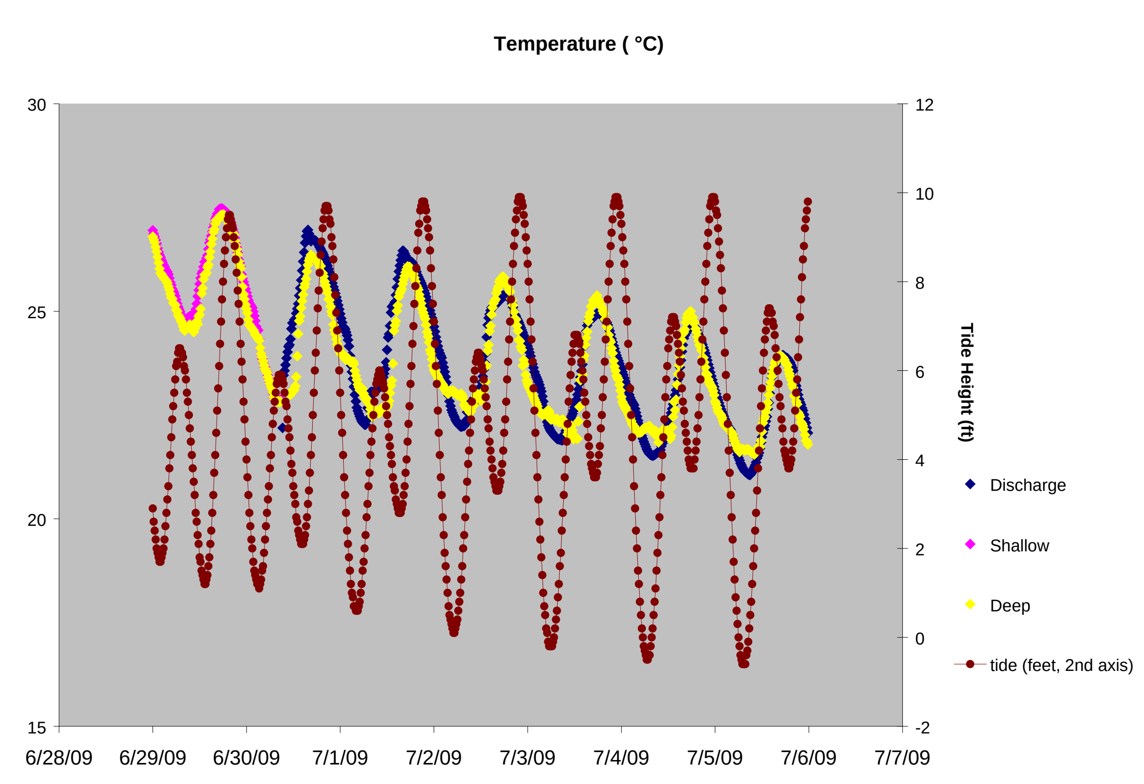

Figure 3.4-5: Pond A3W temperature values at 3 pond locations during 29 June – 5 July

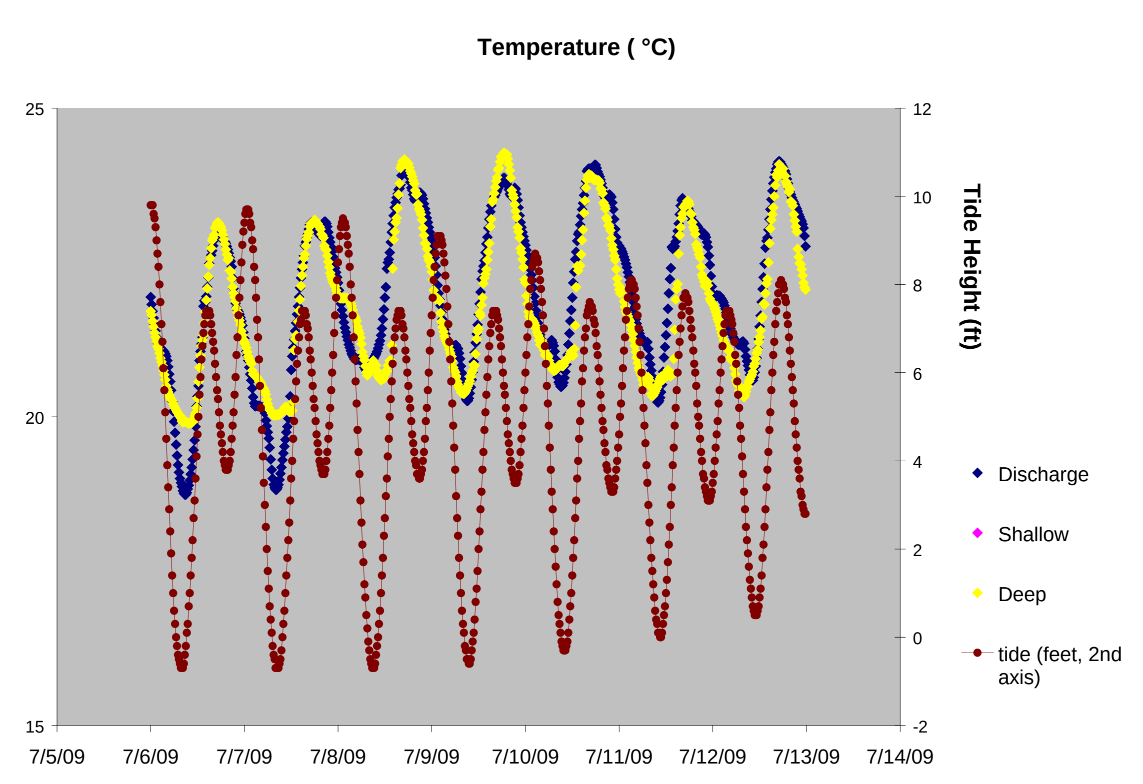

Figure 3.4-6: Pond A3W temperature values at 3 pond locations during 6 July – 12 July

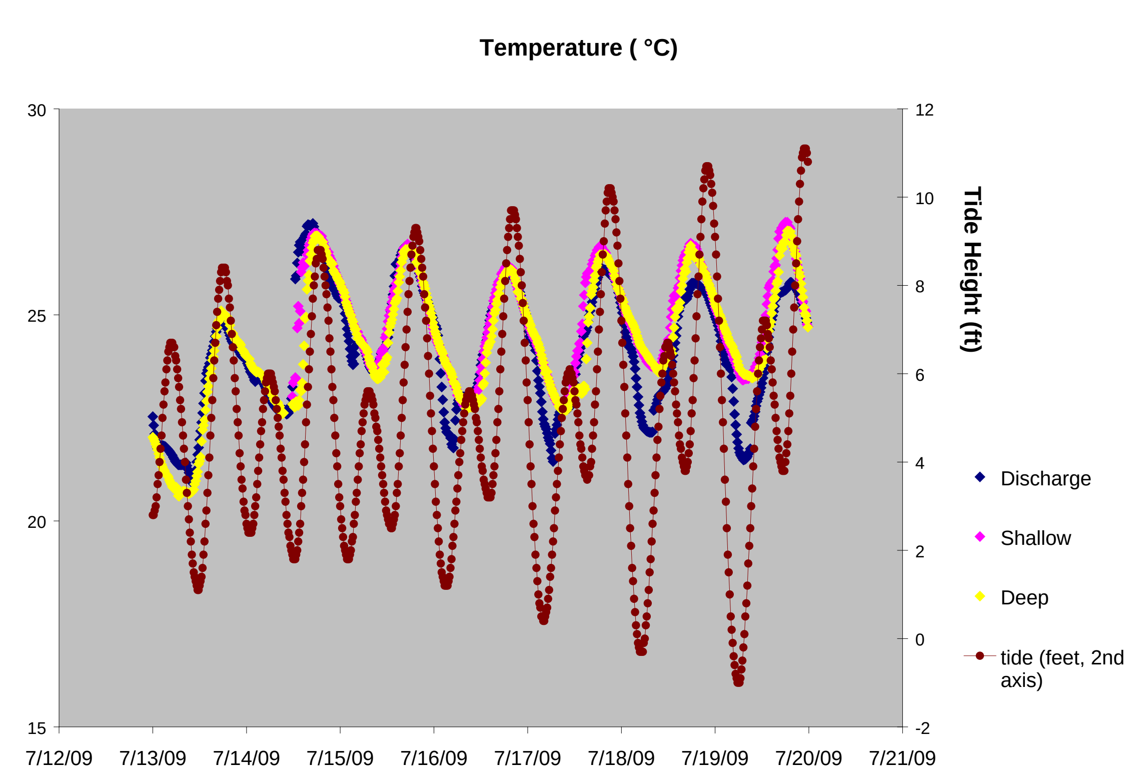

Figure 3.4-7: Pond A3W temperature values at 3 pond locations during 13 July – 19 July

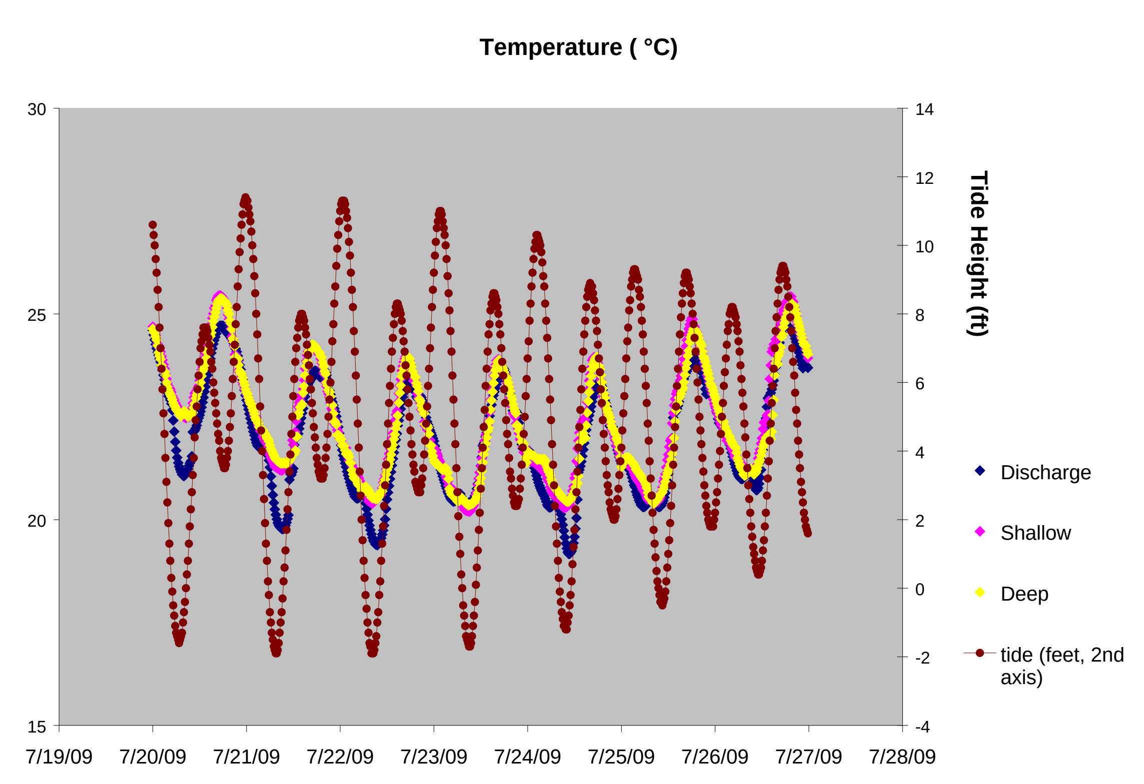

Figure 3.4-8: Pond A3W temperature values at 3 pond locations during 20 July – 26 July

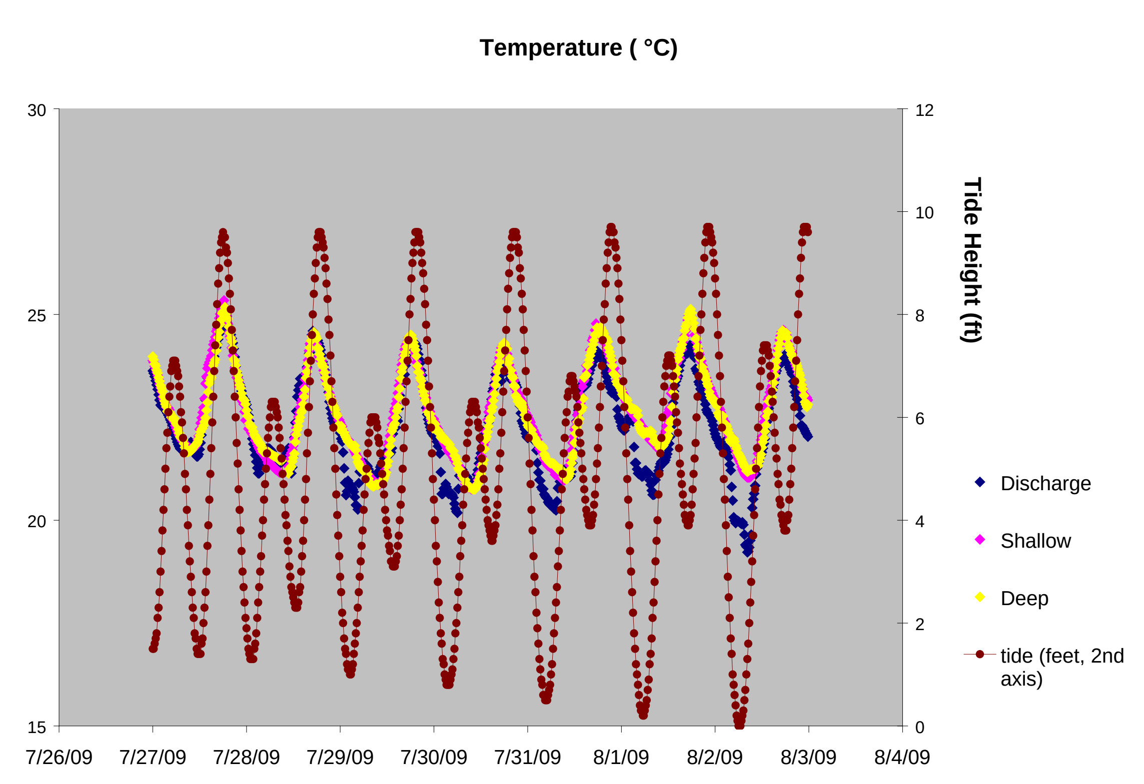

Figure 3.4-9: Pond A3W temperature values at 3 pond locations during 27 July – 2 August

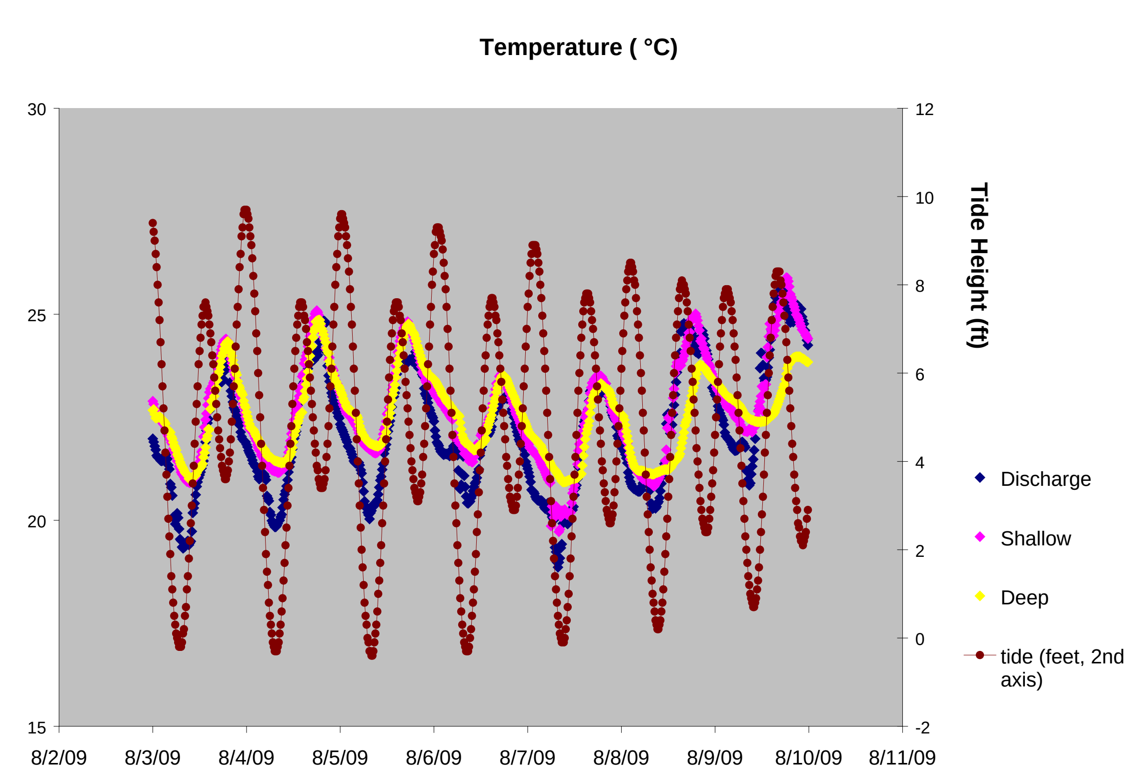

Figure 3.4-10: Pond A3W temperature values at 3 pond locations during 3 August – 9 August

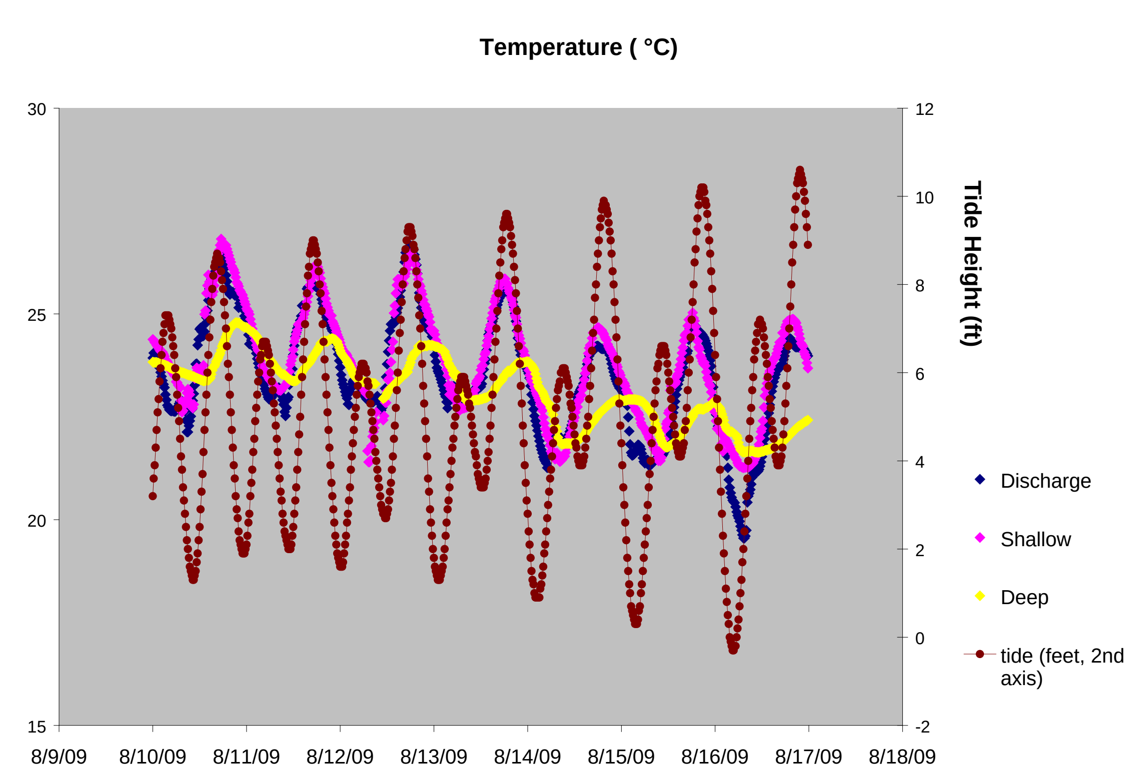

Figure 3.4-11: Pond A3W temperature values at 3 pond locations during 10 August – 16 August

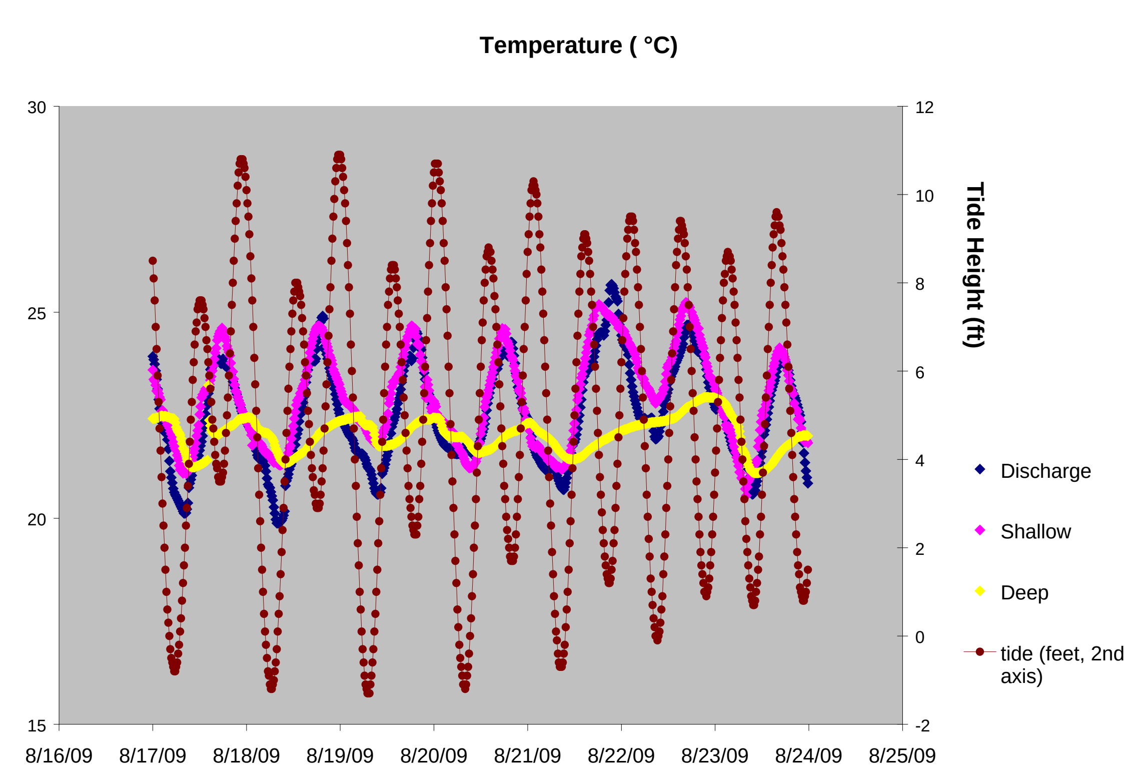

Figure 3.4-12: Pond A3W temperature values at 3 pond locations during 17 August – 23 August

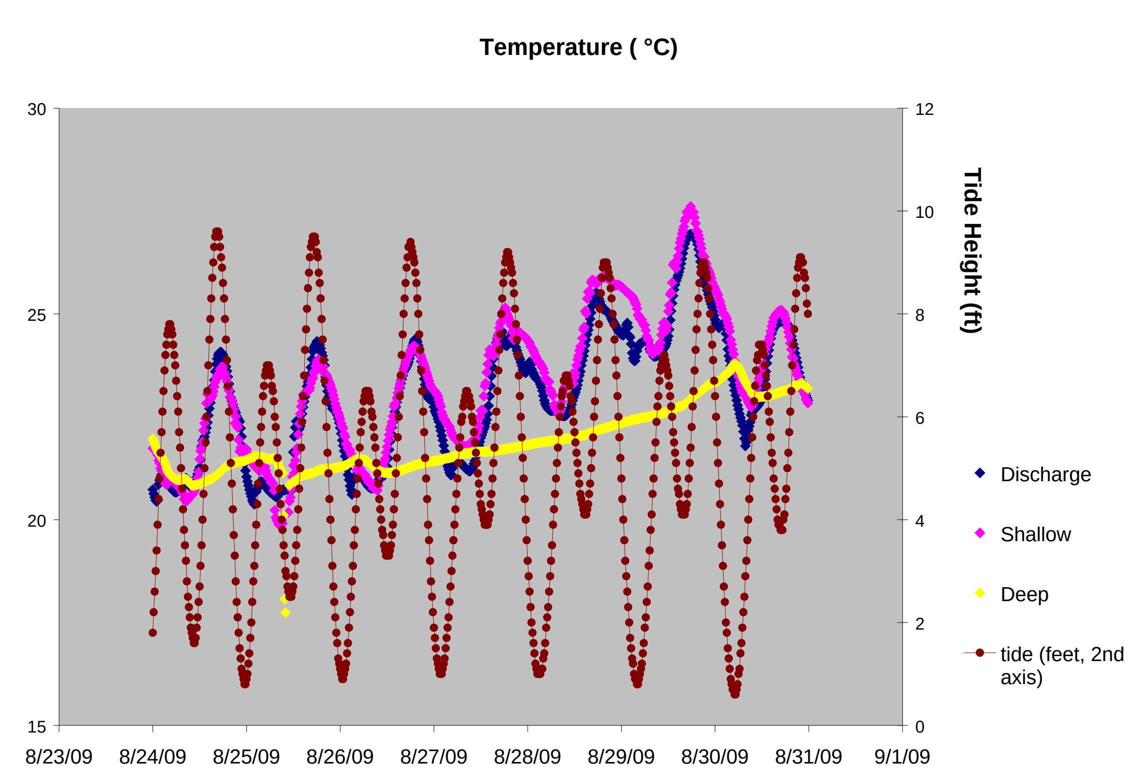

Figure 3.4-13: Pond A3W temperature values at 3 pond locations during 24 August – 30 August

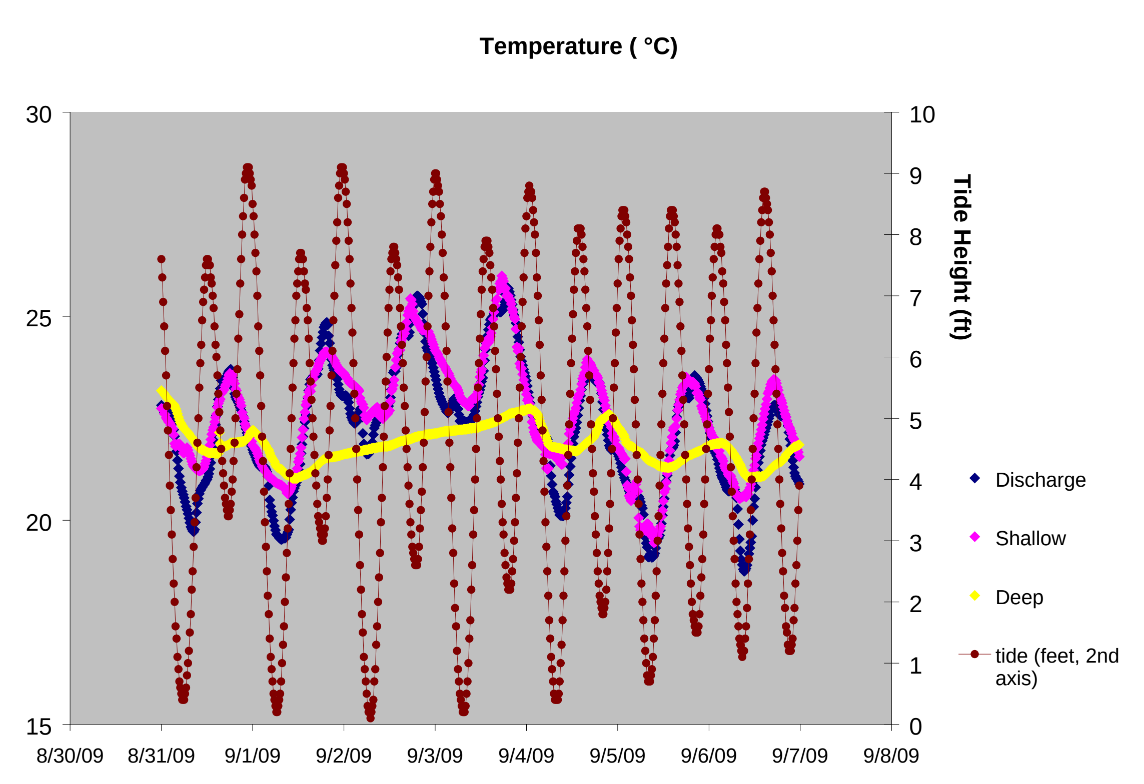

Figure 3.4-14: Pond A3W temperature values at 3 pond locations during 31 August – 6 September

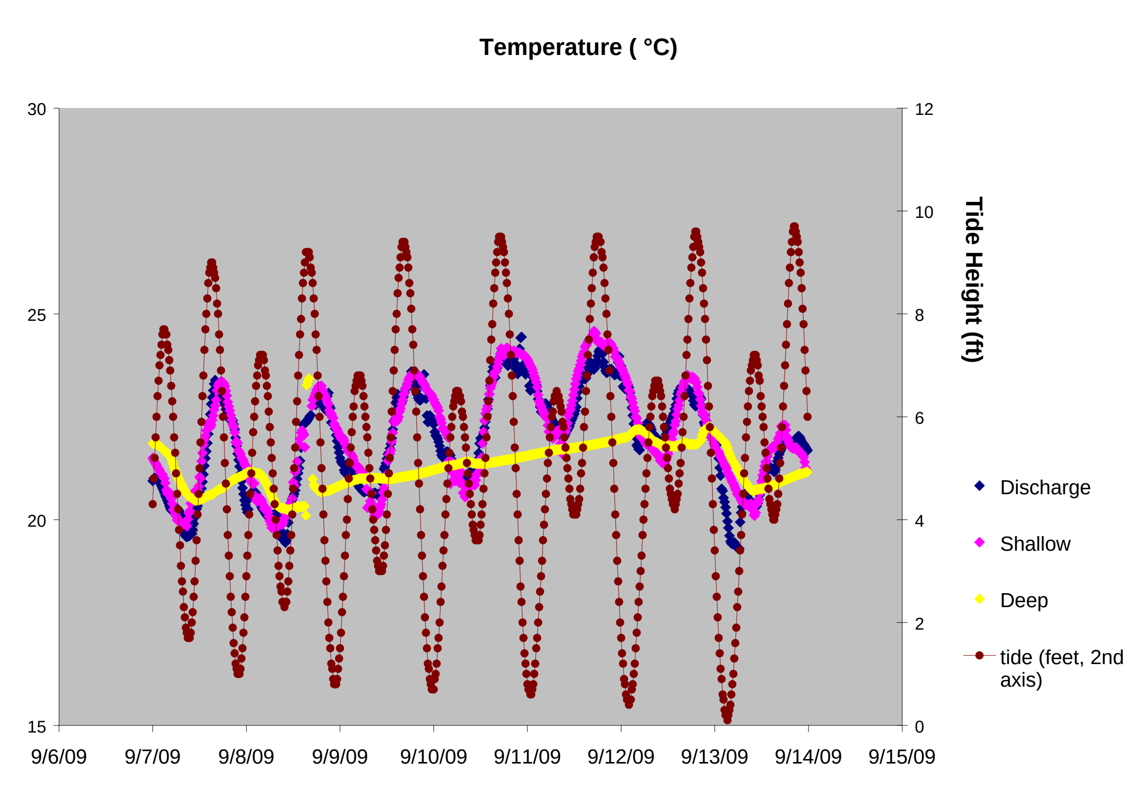

Figure 3.4-15: Pond A3W temperature values at 3 pond locations during 7 September – 13 September

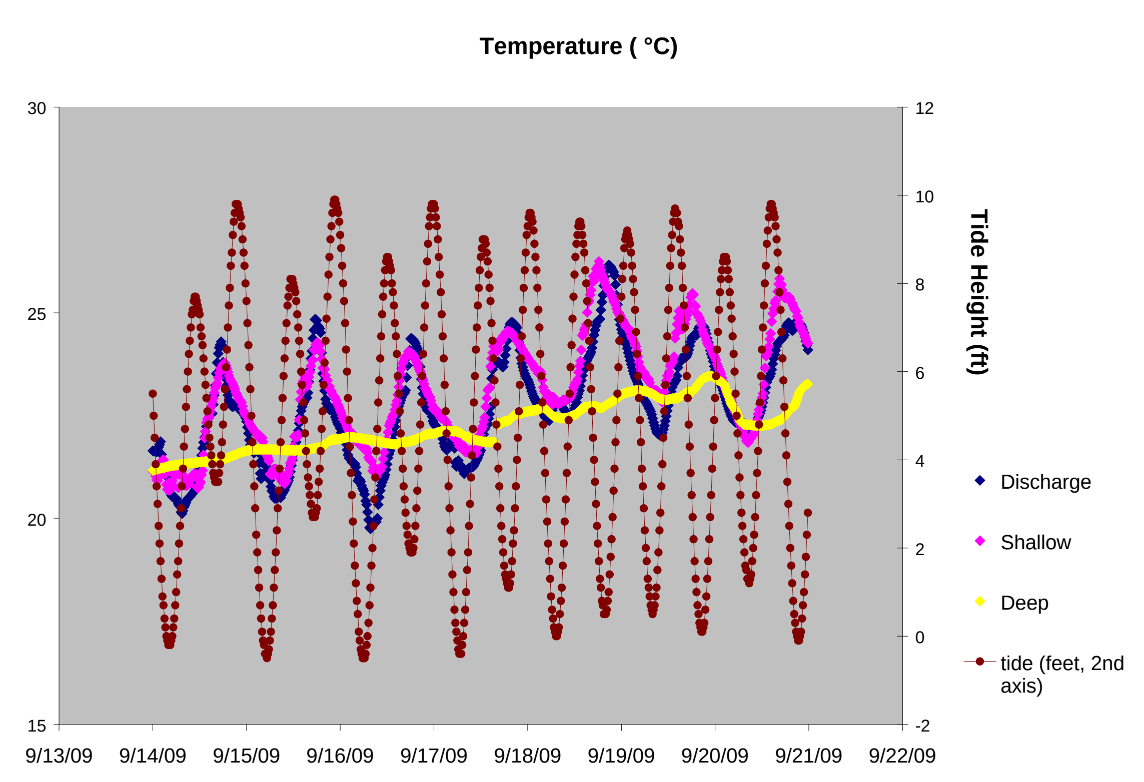

Figure 3.4-16: Pond A3W temperature values at 3 pond locations during 14 September – 20 September

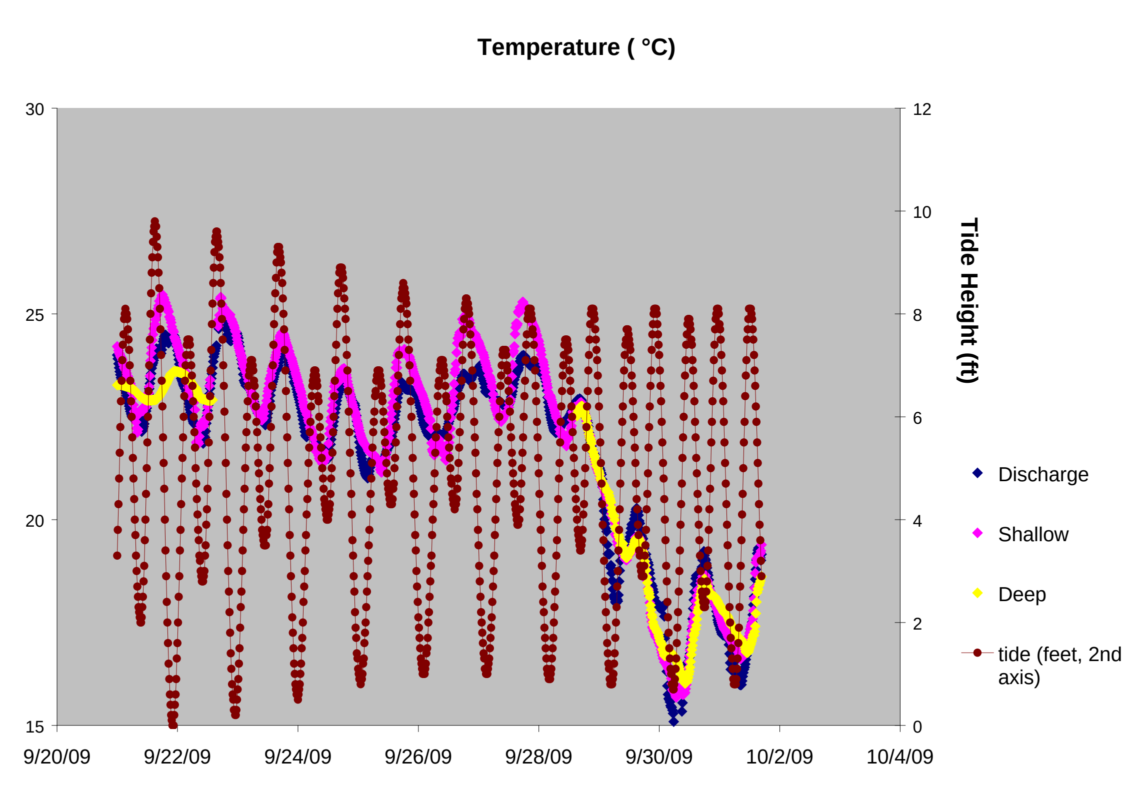

Figure 3.4-17: Pond A3W temperature values at 3 pond locations during 21 September – 1 October

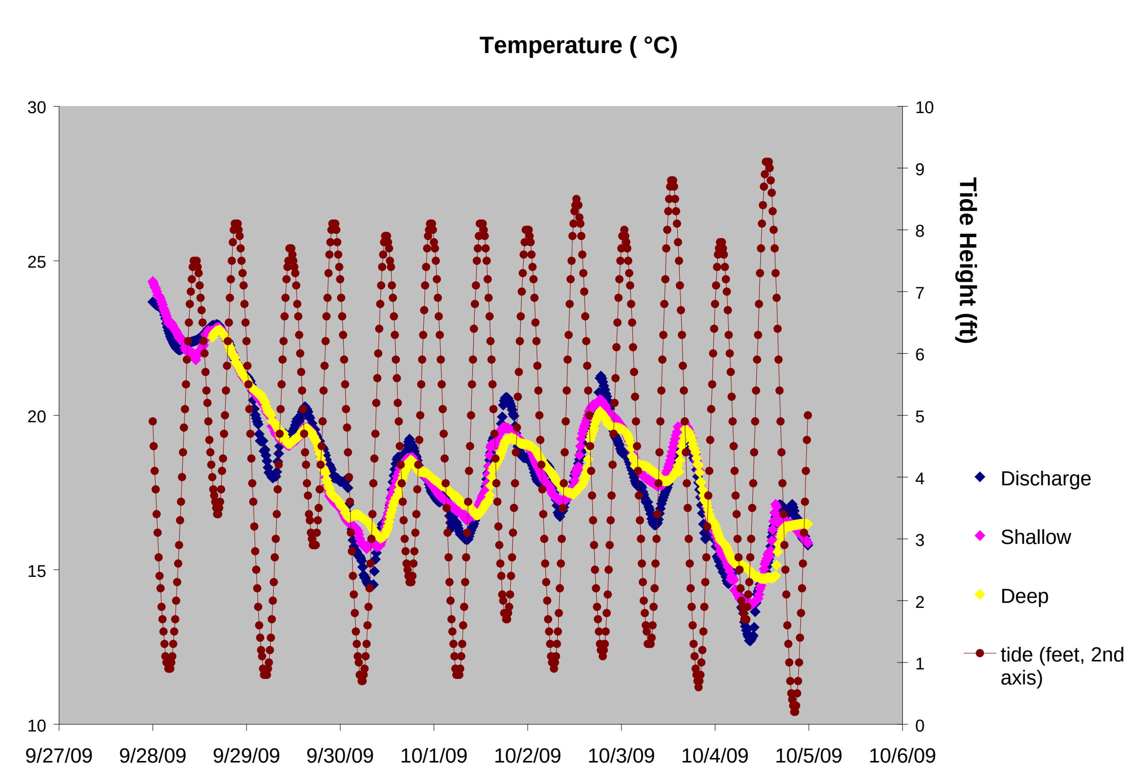

Figure 3.4-18: Pond A3W temperature values at 3 pond locations during 28 September – 4 October

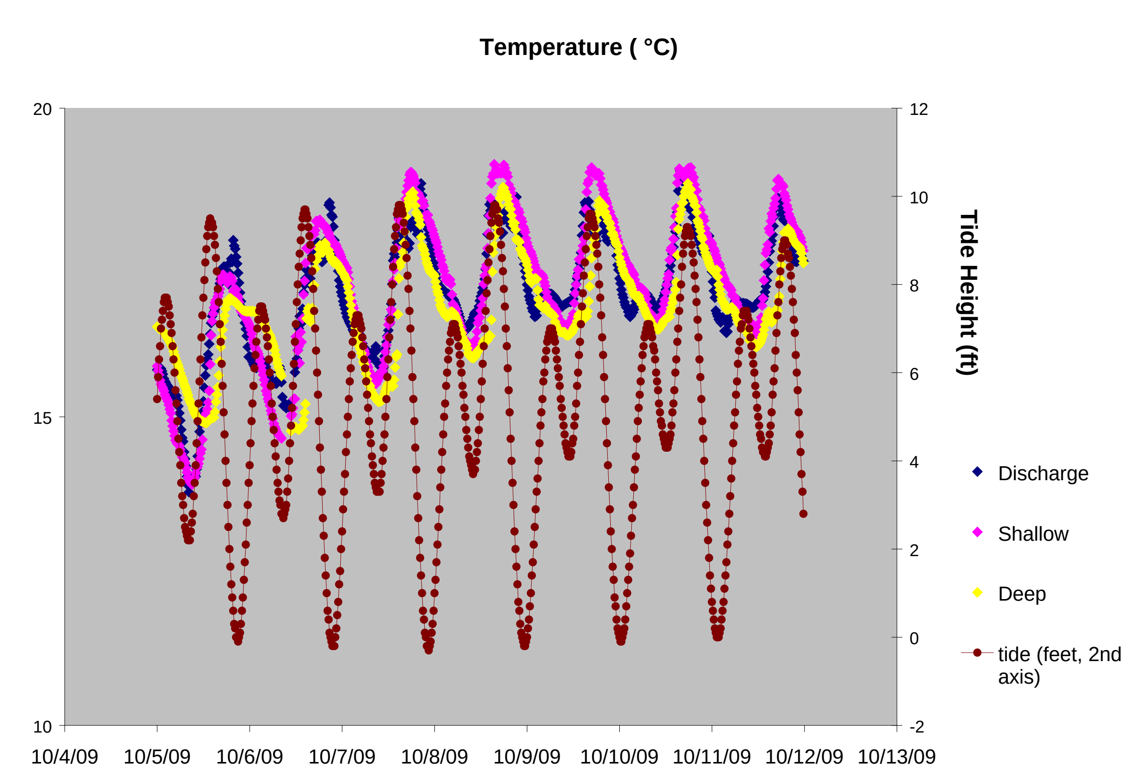

Figure 3.4-19: Pond A3W temperature values at 3 pond locations during 5 October – 11 October

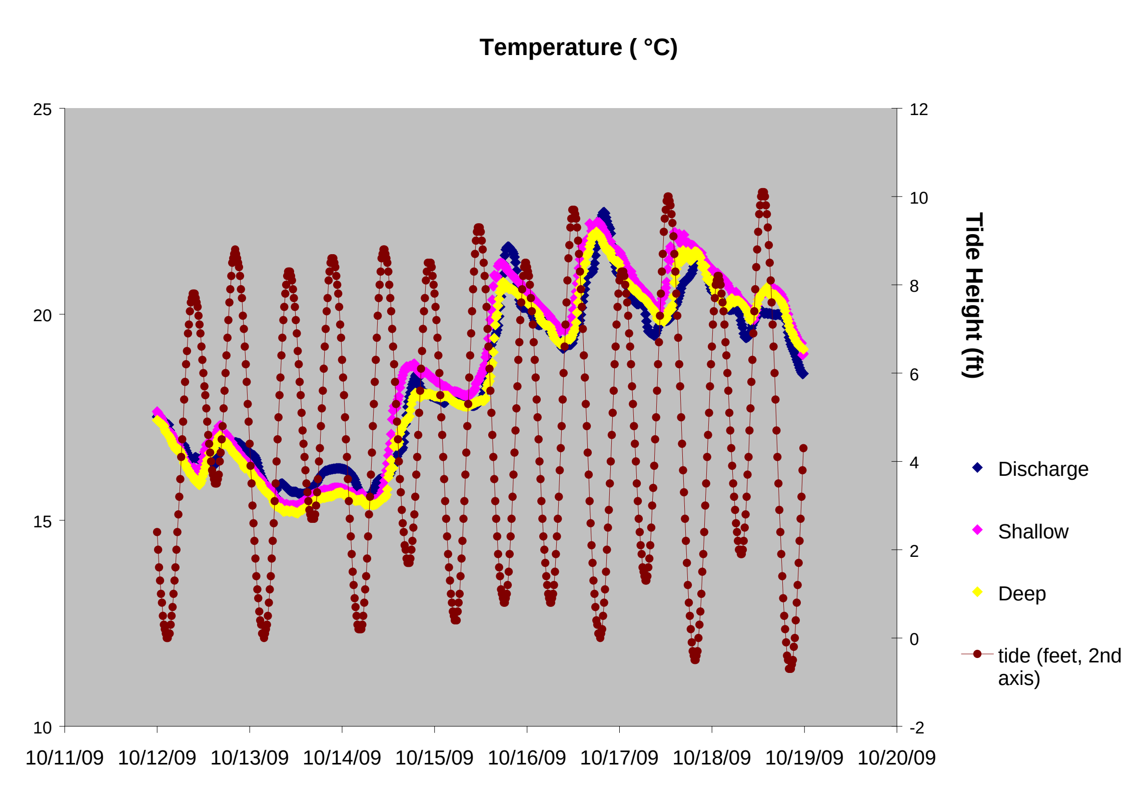

Figure 3.4-20: Pond A3W temperature values at 3 pond locations during 12 October – 18 October

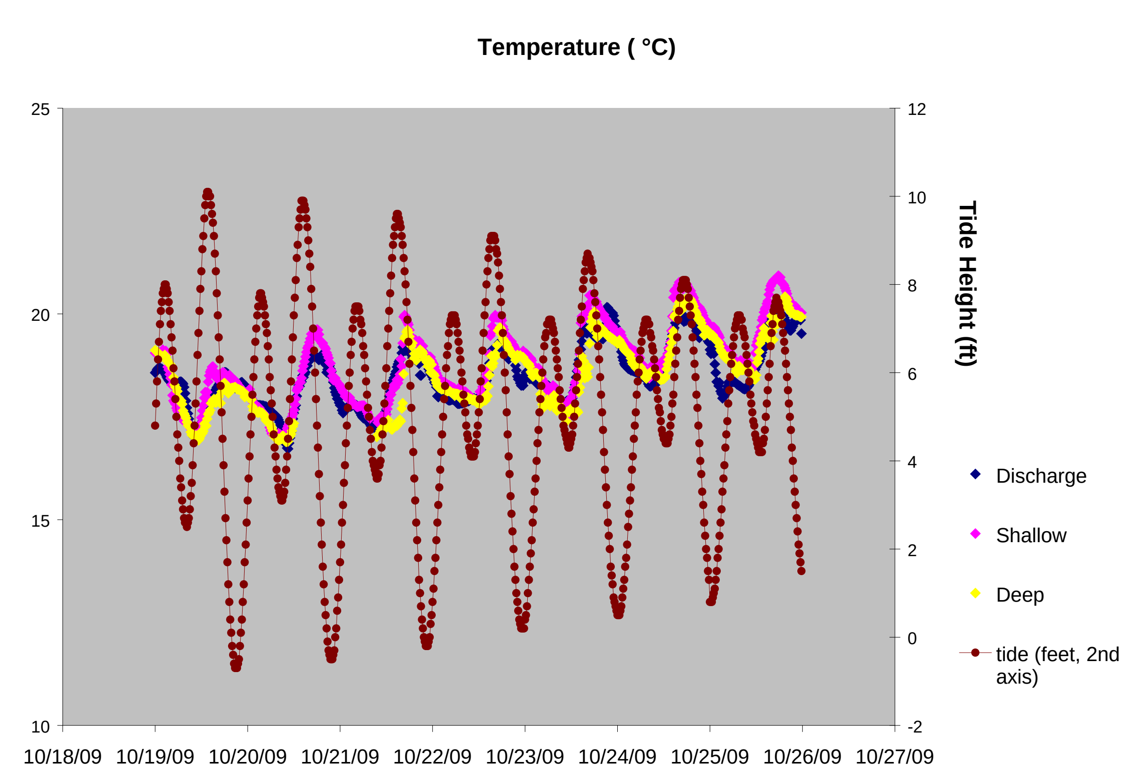

Figure 3.4-21: Pond A3W temperature values at 3 pond locations during 19 October – 25 October

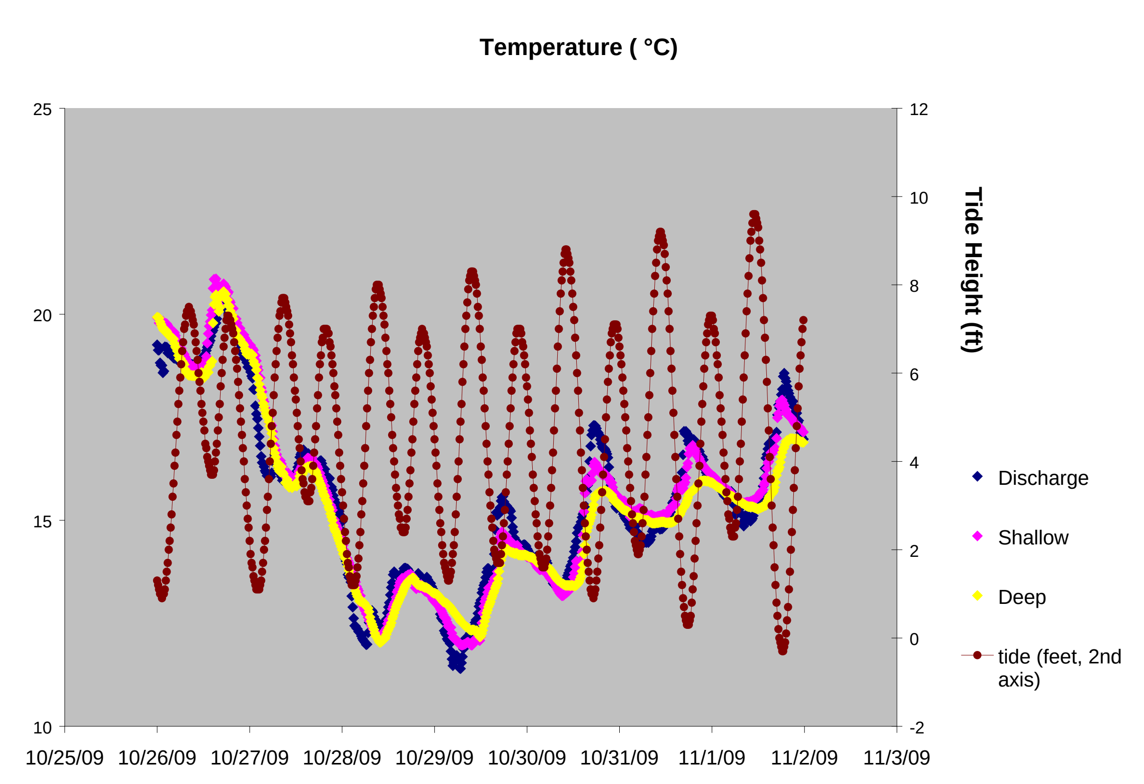

Figure 3.4-22: Pond A3W temperature values at 3 pond locations during 26 October – 1 November

3.5 DISSOLVED OXYGEN TRANSECTS

Generally, morning transects recorded lower DO values than afternoon transects (Figures 3.5-1 through 3.5-22). Morning transects run in late August and late September recorded DO values mostly at or below 3.33 mg/L. In contrast, morning transects run in early September and early October recorded DO values mostly above 3.33 mg/L. Afternoon transects recorded much higher DO values and rarely recorded values at or below 3.33 mg/L. Generally there was a great deal of spatial variability in DO across transects over all dates sampled.

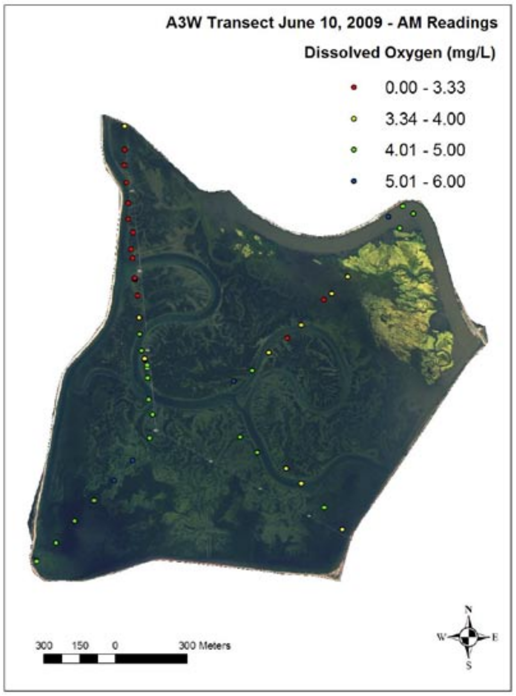

Figure 3.5-1: Dissolved oxygen transect in Pond A3W, AM 10 June 2009

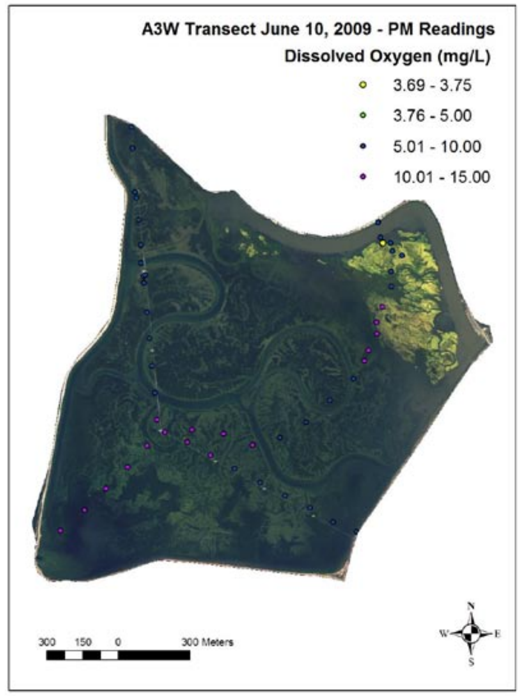

Figure 3.5-2: Dissolved oxygen transect in Pond A3W, PM 10 June 2009.

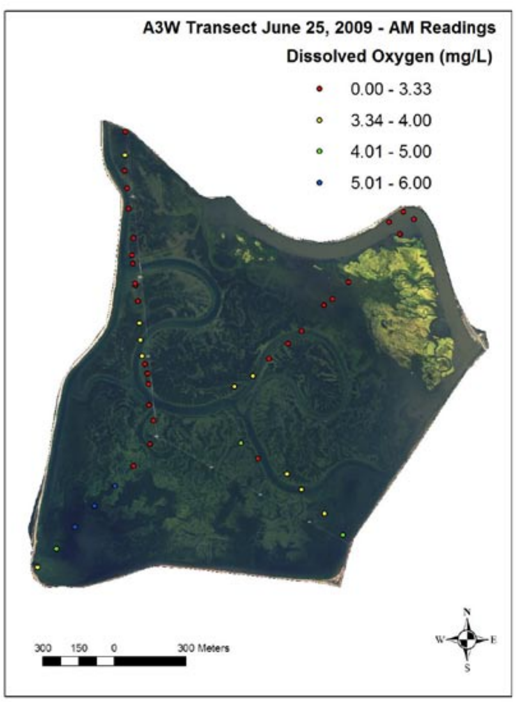

Figure 3.5-3: Dissolved oxygen transect in Pond A3W, AM 25 June 2009.

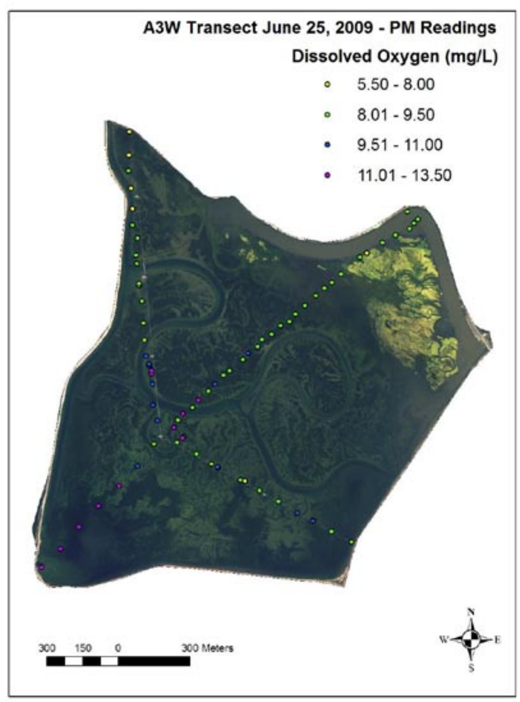

Figure 3.5-4: Dissolved oxygen transect in Pond A3W, PM 25 June 2009.

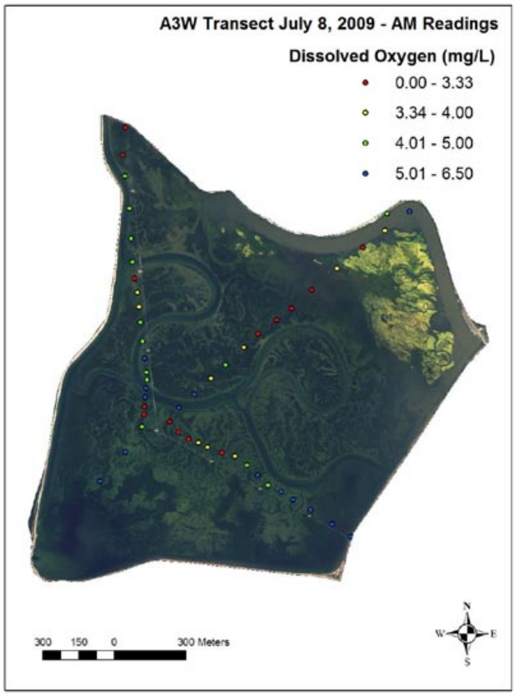

Figure 3.5-5: Dissolved oxygen transect in Pond A3W, AM 8 July 2009.

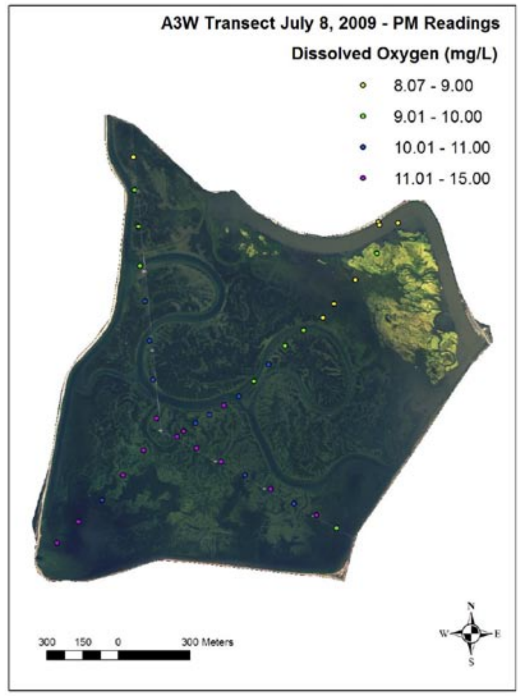

Figure 3.5-6: Dissolved oxygen transect in Pond A3W, PM 8 July 2009.

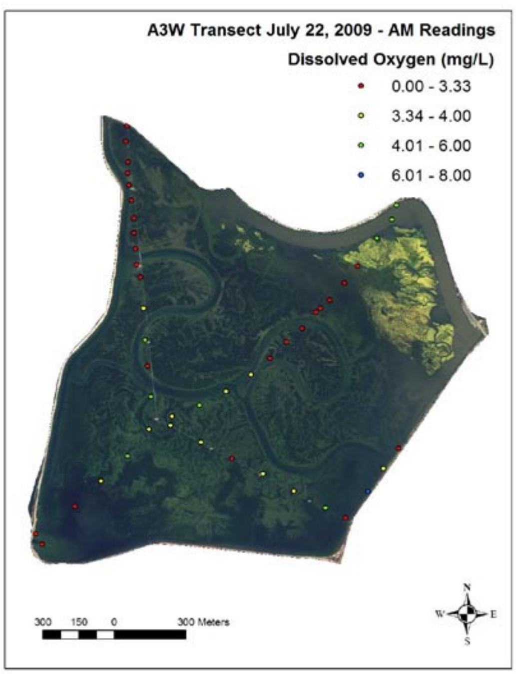

Figure 3.5-7: Dissolved oxygen transect in Pond A3W, AM 22 July 2009.

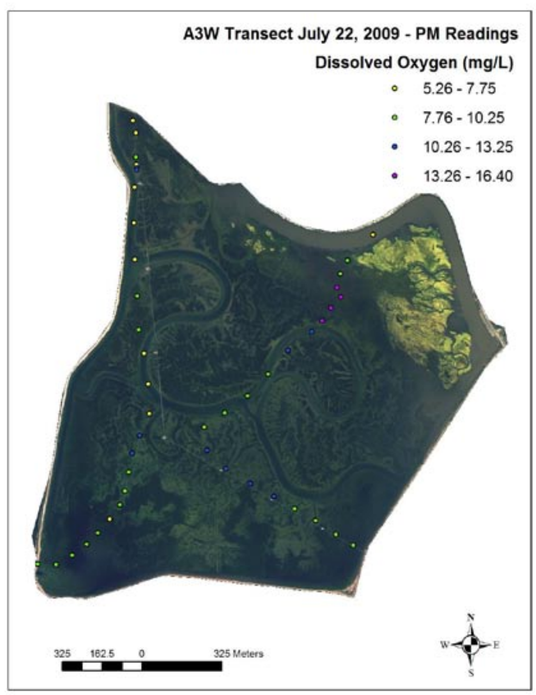

Figure 3.5-8: Dissolved oxygen transect in Pond A3W, PM 22 July 2009.

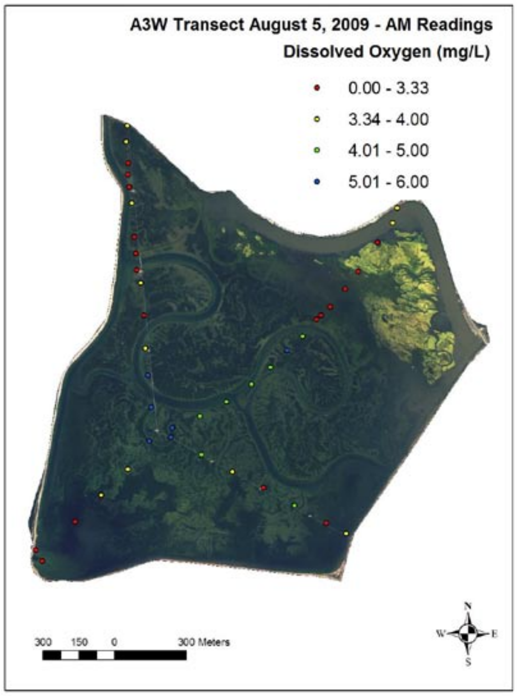

Figure 3.5-9: Dissolved oxygen transect in Pond A3W, AM 5 August 2009.

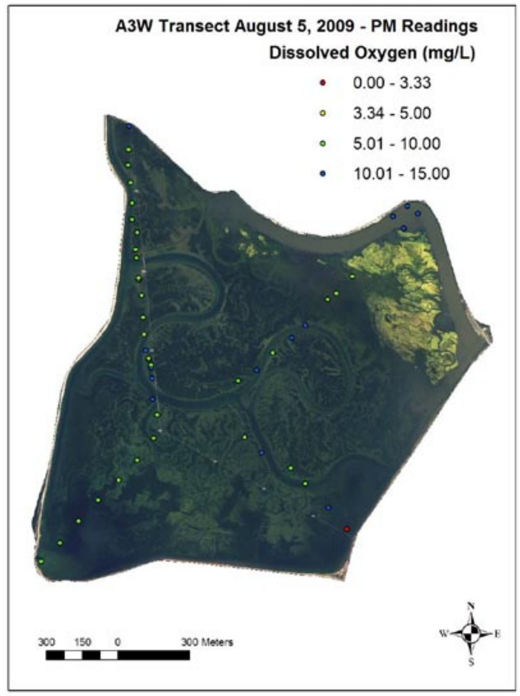

Figure 3.5-10: Dissolved oxygen transect in Pond A3W, PM 5August 2009.

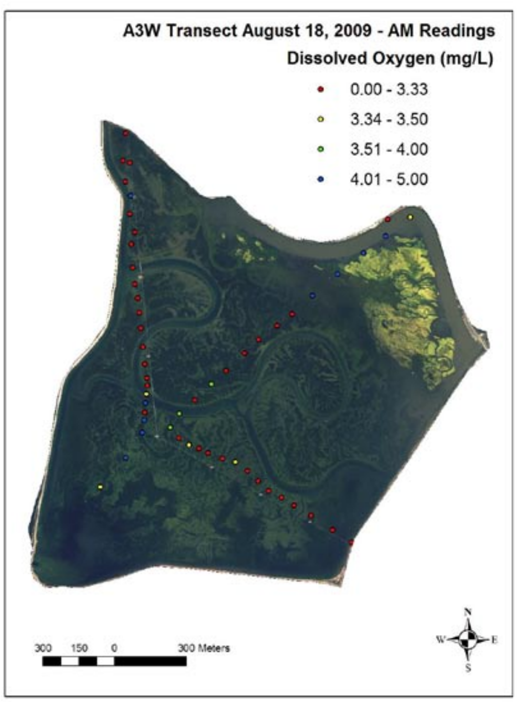

Figure 3.5-11: Dissolved oxygen transect in Pond A3W, AM 18 August 2009.

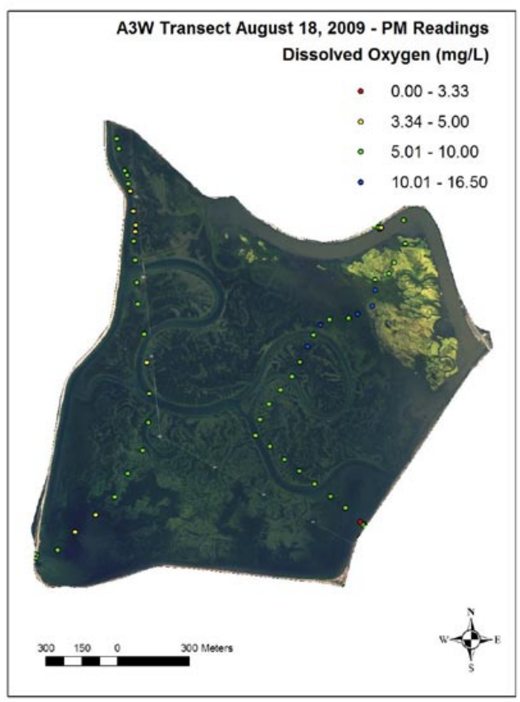

Figure 3.5-12: Dissolved oxygen transect in Pond A3W, PM 18 August 2009.

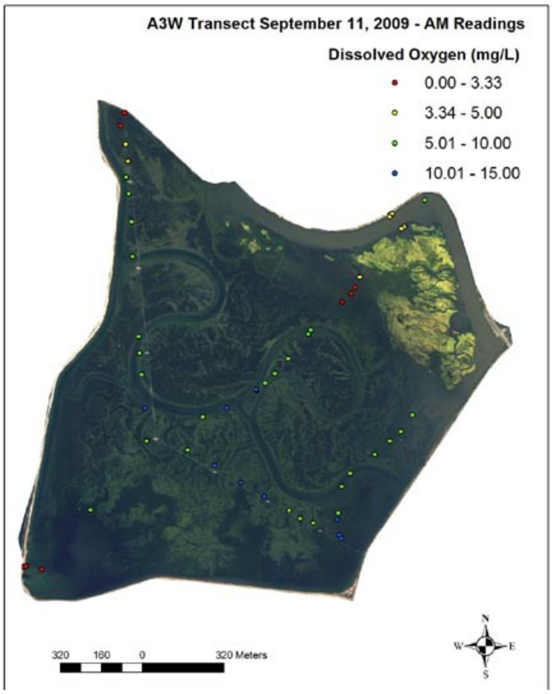

Figure 3.5-13: Dissolved oxygen transect in Pond A3W, AM 11 September 2009.

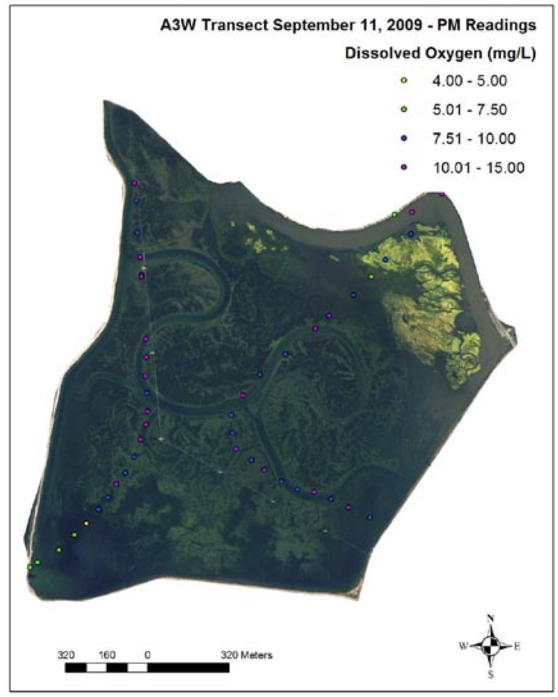

Figure 3.5-14: Dissolved oxygen transect in Pond A3W, PM 11 September 2009.

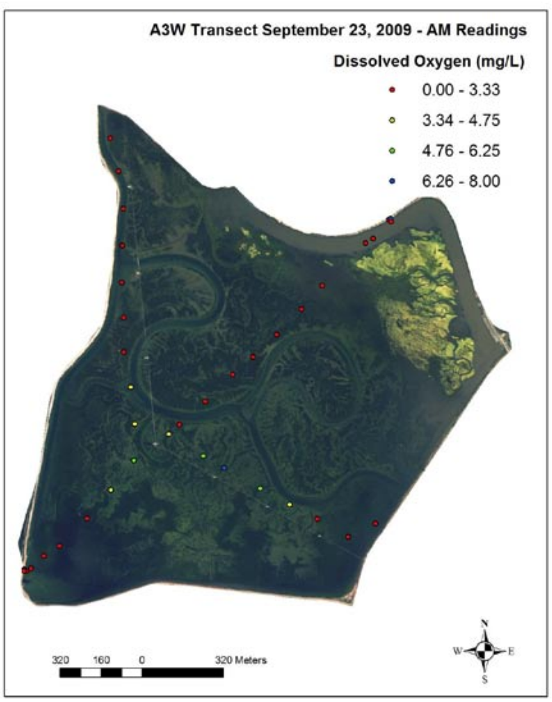

Figure 3.5-15: Dissolved oxygen transect in Pond A3W, AM 23 September 2009.

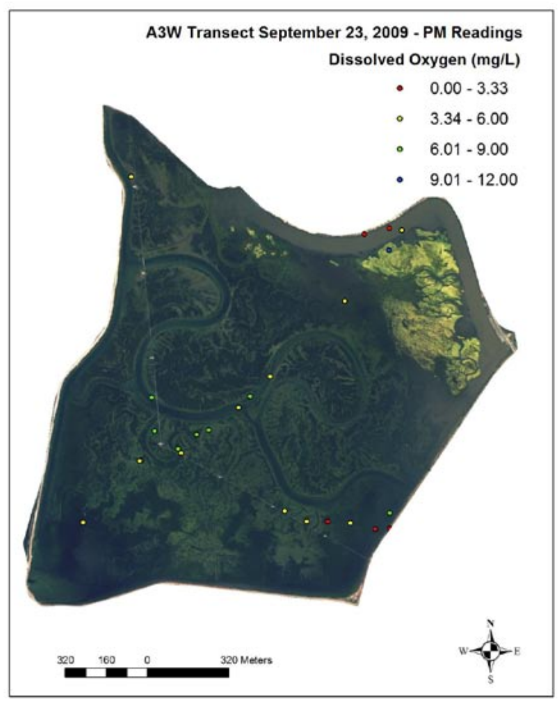

Figure 3.5-16: Dissolved oxygen transect in Pond A3W, PM 23 September 2009.

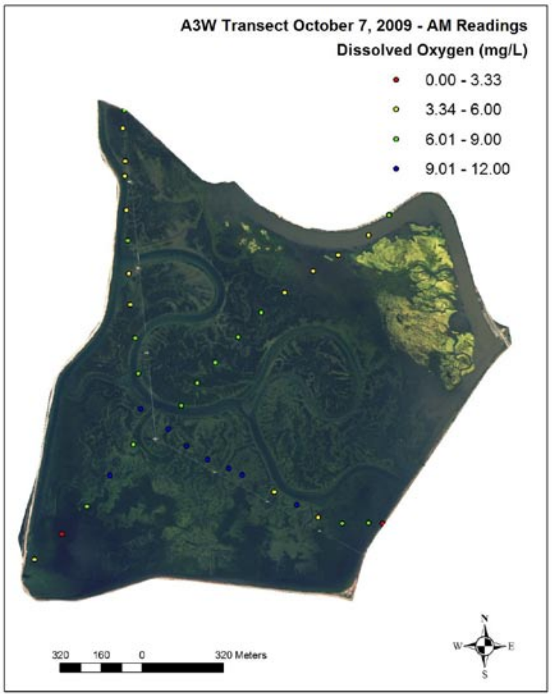

Figure 3.5-17: Dissolved oxygen transect in Pond A3W, AM 7 October 2009.

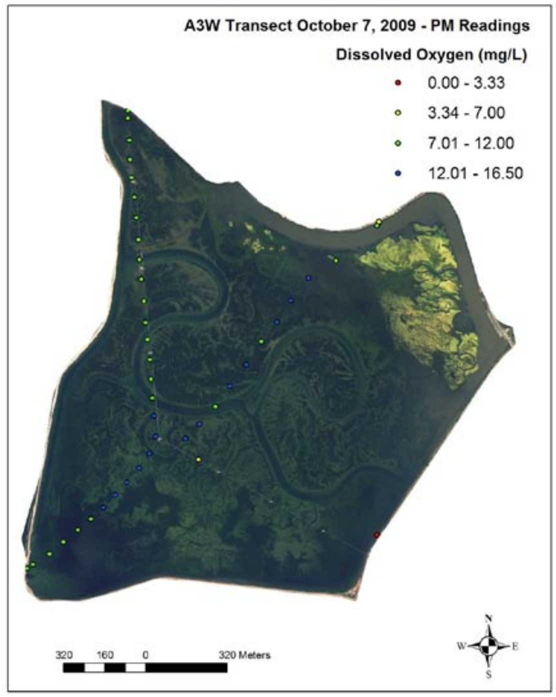

Figure 3.5-18: Dissolved oxygen transect in Pond A3W, PM 7 October 2009.

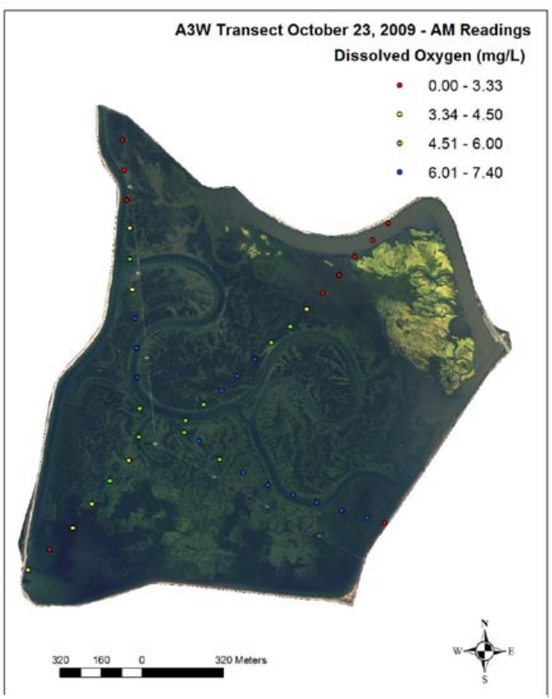

Figure 3.5-19: Dissolved oxygen transect in Pond A3W, AM 23 October 2009.

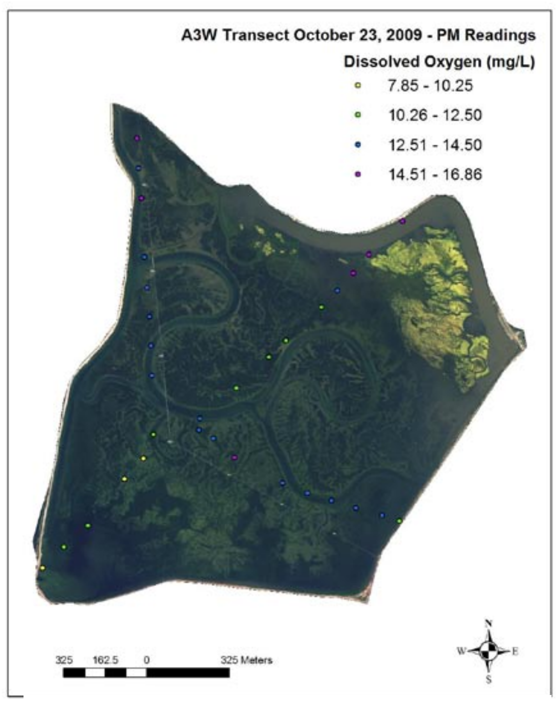

Figure 3.5-20: Dissolved oxygen transect in Pond A3W, PM 23 October 2009.

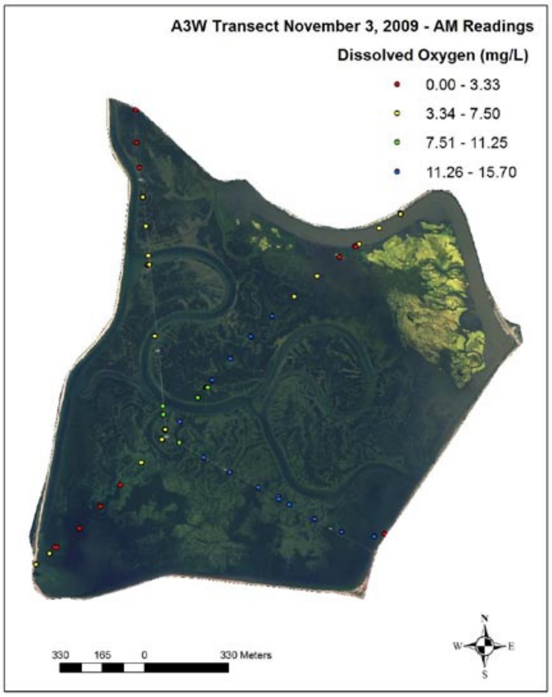

Figure 3.5-21: Dissolved oxygen transect in Pond A3W, AM 3 November 2009.

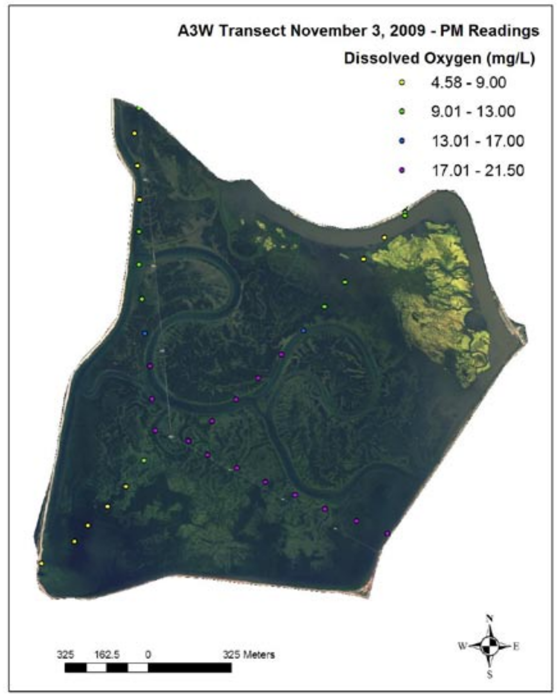

Figure 3.5-22: Dissolved oxygen transect in Pond A3W, PM 3 November 2009.

3.6 NUTRIENTS AND CHLOROPHYLL

Nutrient measurements were highly variable within pond A3W (Table 3.6-1). Further analysis is needed to assess spatial and temporal patterns in conjunction with water quality and meteorological data. Measurements for chlorophyll within Pond A3W were also highly variable, with substantial spatial variation in chlorophyll across transects over all sampling dates (Figures 3.6-1 through 3.6-5).

Table 3.6-1: Pond A3W summarized nutrient data by sampling period

Sampling Date	Sample Location	Nitrate + Nitrite (NO_3 +NO2) µM	Ammonium (NH4) µM	DIN (dissolved inorganic nitrogen) µM	Phosphate (PO4) µM	Silicate µM
6/24/2009	A	25.44	0.83	26.27	22.39	61.95
6/24/2009	B	0.00	2.54	2.54	22.02	13.66
6/24/2009	C	0.00	1.13	1.13	22.08	18.92
7/15/2009	A	17.31	8.12	25.43	25.64	70.8
7/15/2009	B	0.00	1.82	1.82	18.65	6.18
7/15/2009	C	0.00	0.59	0.59	21.36	24.1
7/22/2009	A	31.47	7.96	39.43	26.57	42.59
7/22/2009	B	0.00	1.38	1.38	20.62	57.62
7/22/2009	C	0.00	1.38	1.38	24.42	38.49
9/23/2009	A	0.00	1.35	1.35	19.12	67.74
9/23/2009	B	89.00	24.11	113.11	35.21	118.41
9/23/2009	C	0.00	206.69	206.69	47.00	222.49
10/23/2009	A	0.00	1.58	1.58	18.44	5.81
10/23/2009	B	25.69	2.05	27.74	19.02	88.97
10/23/2009	C	29.50	1.54	31.04	23.81	29.9

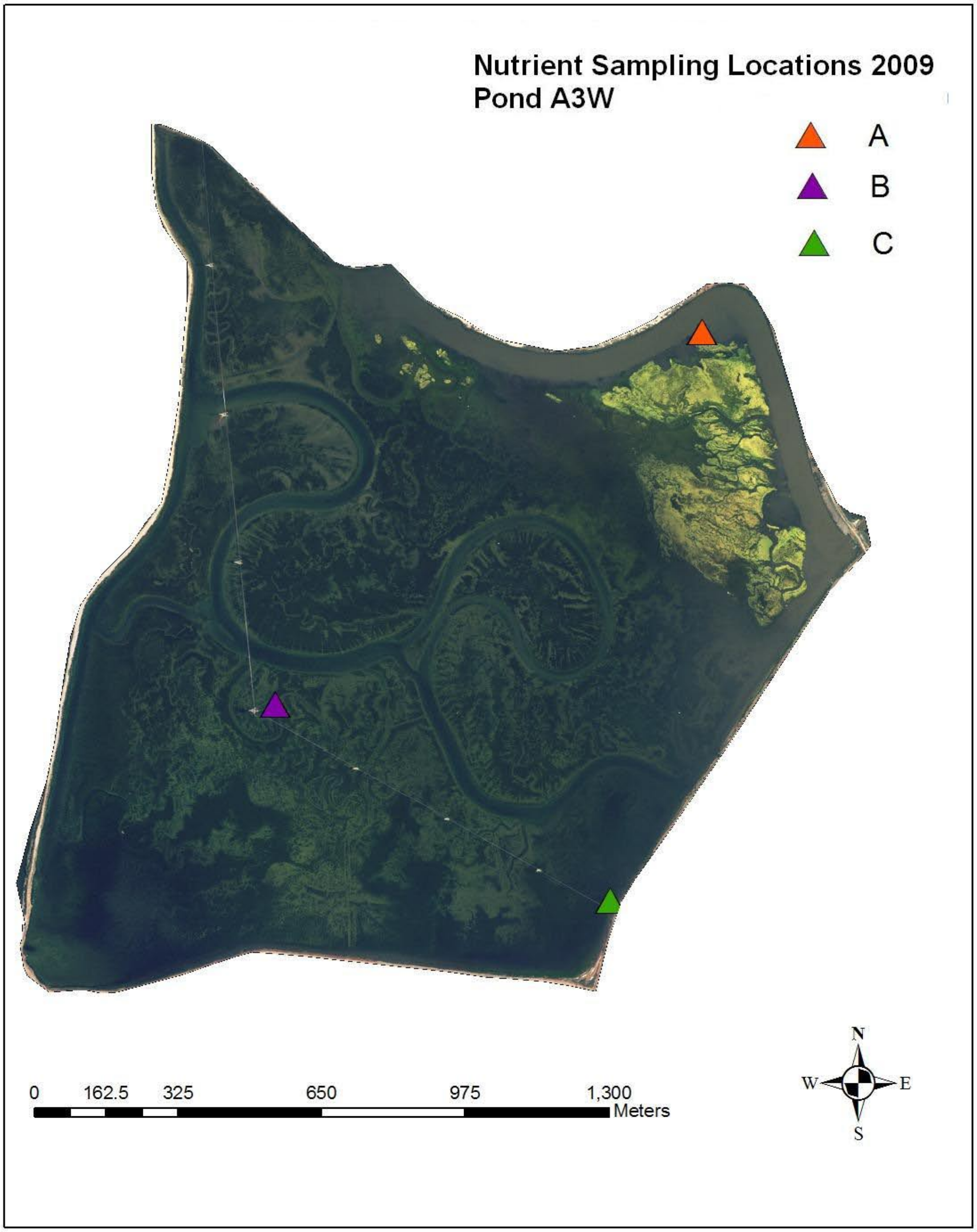

Figure 3.6-1: Nutrient sampling locations for Pond A3W, 2009.

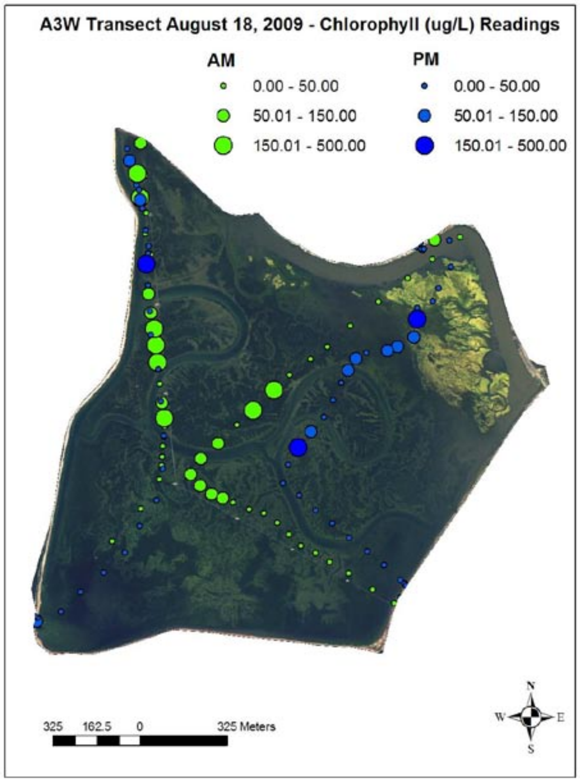

Figure 3.6-2: Chlorophyll transect in
Pond A3W, 18 August 2009.

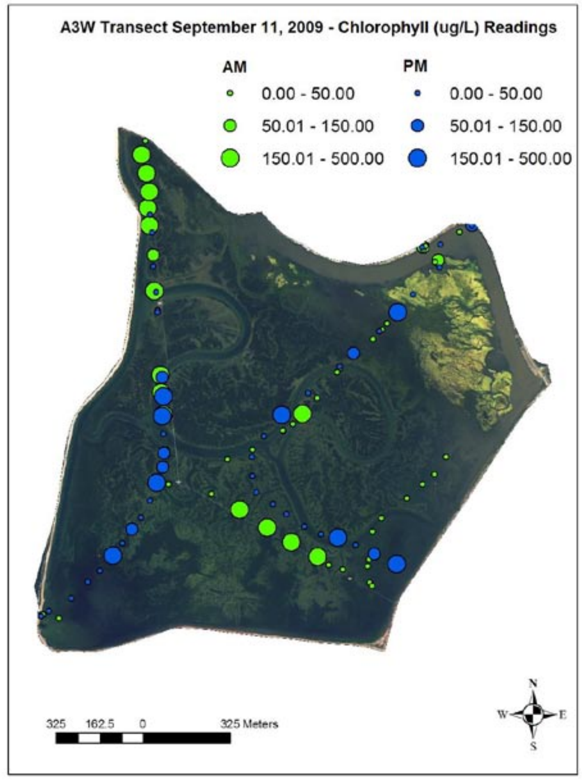

Figure 3.6-3: Chlorophyll transect in
Pond A3W, 18 August 2009.

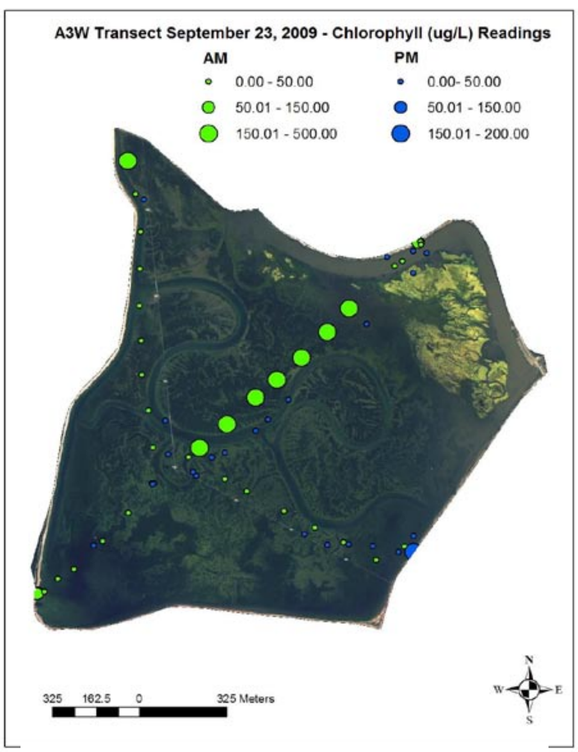

Figure 3.6-4: Chlorophyll transect in
Pond A3W, 23 September 2009.

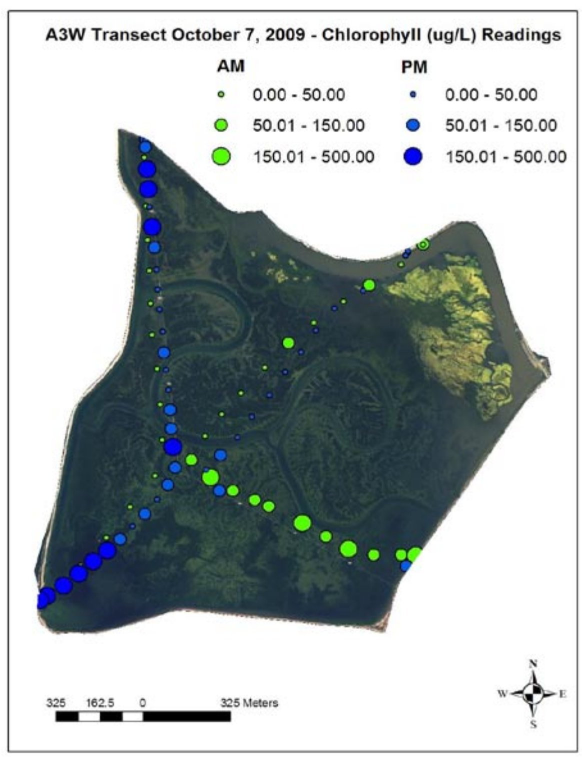

Figure 3.6-5: Chlorophyll transect in
Pond A3W, 7 October 2009.

3.7 METEOROLOGICAL MEASUREMENTS

Meteorological data were relatively consistent during the study period (Table 3.7-1). Wind was primarily from the south and averages ranged from 5 to 7 miles per hour (mph). Gusts ranged from 0 to 45 mph where gust averages ranged from 8.30 to 11.00 mph. Relative humidity remained fairly consistent throughout the study period. Rainfall was scarce throughout the study period; however, October did experience a very small amount of precipitation. Monthly mean temperatures were also pretty consistent and ranged from 16.00 degrees Celsius to 19.50 degrees Celsius. Photosynthetically active radiation and solar radiation were variable during the study period, but varied largely due to diurnal cycles.

Table 3.7-1: Summarized weather values (mean ± standard deviation) for all ponds by month

Month	Temperature (°C)	Relative Humidity (%)	Rainfall (cm)	Primary Wind Direction	Wind Speed (mph)	PAR Light (uM/m^2s)	Solar Radiation (wat/m2)
June	17.93 ± 1.0	71.81 ± 12.65	0.00 ± 0.0	South	7.04 ± 5.64	1083.21 ± 750.1 Max: 2748	448.51 ± 330.6 Max: 1208
July	17.99 ± 1.0	77.56 ± 14.00	0.00 ± 0.0	South - Southwest	6.55 ± 5.50	1140.64 ± 815.4 Max: 2454	475.10 ± 342.5 Max: 1054
August	19.20 ± 1.1	74.35 ± 16.42	0.00 ± 0.0	South	5.94 ± 5.51	1084.71 ± 719.5 Max: 2124	460.00 ± 323.1 Max: 917
September	19.45 ± 1.0	73.14 ± 16.43	0.00 ± 0.0	South - Southeast	5.03 ± 5.21	976.52 ± 626.6 Max: 2079	414.60 ± 275.7 Max: 911
October	16.00 ± 0.9	73.30 ± 18.90	0.00 ± 0.0	South	5.95 ± 6.04	760.90 ± 519.4 Max: 1834	324.60 ± 232.9 Max: 762

4. Pond A14 In-Pond Sampling

SECTION 4
POND A14 IN-POND SAMPLING

This section summarizes analyses of 2009 water quality data being conducted for Pond A14 to characterize spatial variability and patterns with respect to flow patterns and pond management. A brief description of our initial findings is presented below:

4.1 CONTINUOUS WATER QUALITY MONITORING

Datasondes were deployed at 3 locations within Pond A14 during the study period: one at the discharge location and two datasondes at the intake including one deep and one shallow (Figure 4.1-1). Average DO concentration was highest and salinity and temperature were lowest during June and October (Table 4.1-1). In contrast, average DO was lower during July through September, with average concentrations less that 3.3 mg/L for at least one datasonde. The datasonde at the shallow location generally had higher average DO concentration compared with the shallow and discharge datasonde locations across months. At 3.01 mg/L, September averaged the lowest monthly DO values and was the only month in which the overall average across datasondes within the pond fell below 3.33 mg/L (Table 4).

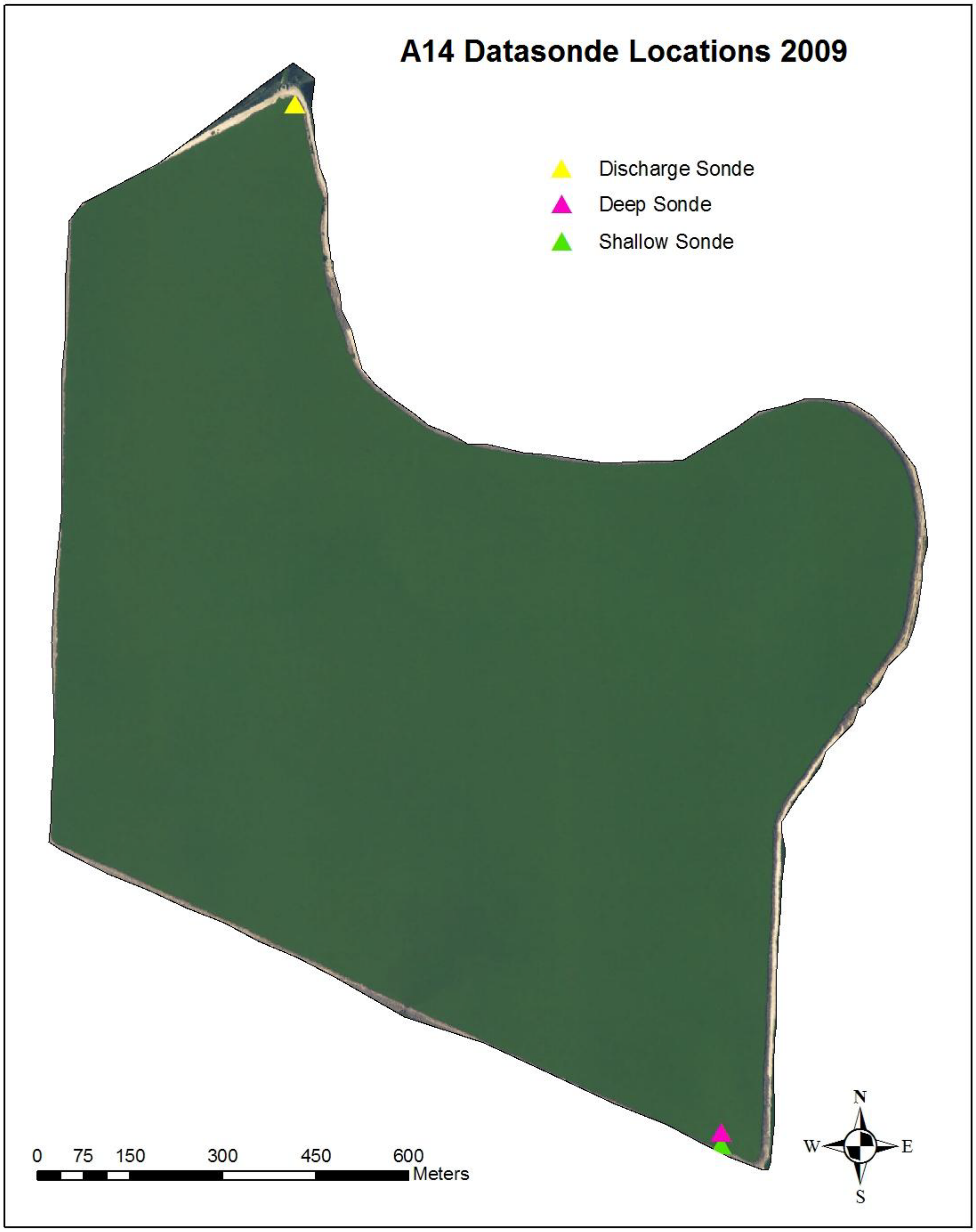

Figure 4.1-1: 2009 Datasonde locations in Pond A14

Table 4.1-1: Pond A14 summarized water quality values (mean ± standard deviation) by month.

Pond	Month	Dissolved Oxygen (mg/L)	pH (Units)	Specific Conductivity (mS/cm)	Temperature (°C)	Salinity (ppt)
A14	**June**					
	Overall	5.05 ± 2.02	8.26 ± 0.18	44.65 ± 2.20	22.00 ± 2.21	28.92 ± 1.56
	Discharge	4.19 ± 1.89	8.42 ± 0.10	45.42 ± 1.65	21.77 ± 2.11	29.47 ± 1.17
	Shallow	5.61 ± 1.78	8.09 ± 1.55	44.44 ± 1.55	22.08 ± 2.21	28.76 ± 1.12
	Deep	5.38 ± 2.09	8.27 ± 0.09	44.08 ± 2.89	22.15 ± 2.28	28.51 ± 2.04
	July					
	Overall	3.36 ± 2.45	8.06 ± 0.56	48.84 ± 1.30	23.34 ± 1.60	31.97 ± 0.95
	Discharge	3.95 ± 2.27	8.31 ± 0.07	49.79 ± 1.05	23.07 ± 1.62	32.66 ± 0.77
	Shallow	4.23 ± 2.00	8.26 ± 0.07	47.39 ± 0.68	23.71 ± 1.60	30.91 ± 0.50
	Deep	2.22 ± 2.45	7.68 ± 0.77	48.79 ± 0.91	23.39 ± 1.52	31.94 ± 0.67
	August					
	Overall	3.87 ± 3.04	8.18 ± 0.16	50.42 ± 1.42	23.37 ± 1.46	33.11 ± 1.27
	Discharge	3.03 ± 2.09	8.29 ± 0.09	51.68 ± 0.91	22.99 ± 1.35	34.06 ± 0.67
	Shallow	6.13 ± 3.26	8.06 ± 0.15	49.39 ± 1.13	23.49 ± 1.44	32.35 ± 1.22
	Deep	2.29 ± 2.12	8.18 ± 0.16	50.09 ± 1.10	23.64 ± 1.50	32.86 ± 1.18
	September					
	Overall	3.01 ± 2.36	8.09 ± 0.26	50.98 ± 1.19	22.60 ± 1.51	33.54 ± 0.88
	Discharge	3.13 ± 2.28	8.25 ± 0.06	52.02 ± 0.59	22.35 ± 1.53	34.31 ± 0.44
	Shallow	4.58 ± 1.48	8.10 ± 0.10	49.63 ± 0.65	22.77 ± 1.60	32.55 ± 0.48
	Deep	0.66 ± 1.35	7.92 ± 0.37	51.30 ± 0.69	22.69 ± 1.35	33.78 ± 0.51
	October					
	Overall	5.00 ± 2.82	7.38 ± 1.45	48.00 ± 2.62	17.45 ± 1.84	31.36 ± 1.91
	Discharge	4.27 ± 1.83	8.16 ± 0.15	48.93 ± 2.13	16.96 ± 1.94	32.04 ± 1.56
	Shallow	6.75 ± 2.64	8.15 ± 0.10	45.93 ± 2.50	17.67 ± 1.95	29.85 ± 1.82
	Deep	0.52 ± 1.83	5.29 ± 1.30	49.09 ± 1.81	17.93 ± 1.35	32.15 ±1.34
	Deep Backup	4.42 ± 0.81	8.25 ± 0.06	50.29 ± 0.61	16.43 ± 0.53	33.04 ± 0.45
	Overall					
	Discharge	3.70 ± 2.16	8.29 ± 0.13	49.61 ± 2.74	21.52 ± 2.81	32.54 ± 2.00
	Shallow	5.48 ± 2.47	8.12 ± 0.14	47.42 ± 2.54	21.98 ± 2.77	30.93 ± 1.89
	Deep	2.70 ±2.71	7.63 ± 1.16	48.66 ± 3.03	22.27 ± 2.47	31.84 ± 2.23

*Note: Throughout October, the deep datasonde experienced problems and values should be used cautiously.

Dissolved Oxygen

Dissolved oxygen concentration had a strong cyclical pattern in all datasondes, likely following both diurnal and tidal cycles (Figures 4.1-2 through 4.1-23). The cyclic pattern was more pronounced at the discharge datasonde which also recorded generally lower DO concentrations through June. The deep datasonde recorded very low DO concentrations during July and from September through the end of the sampling period. Based on service records, we believe that these low DO concentrations were pond related except during 7 July to 12 July and 21 September to 20 October, during which we believe we had problems with the equipment. Equipment failure during the latter period was further confirmed with deployment of a backup datasonde on 12 October.

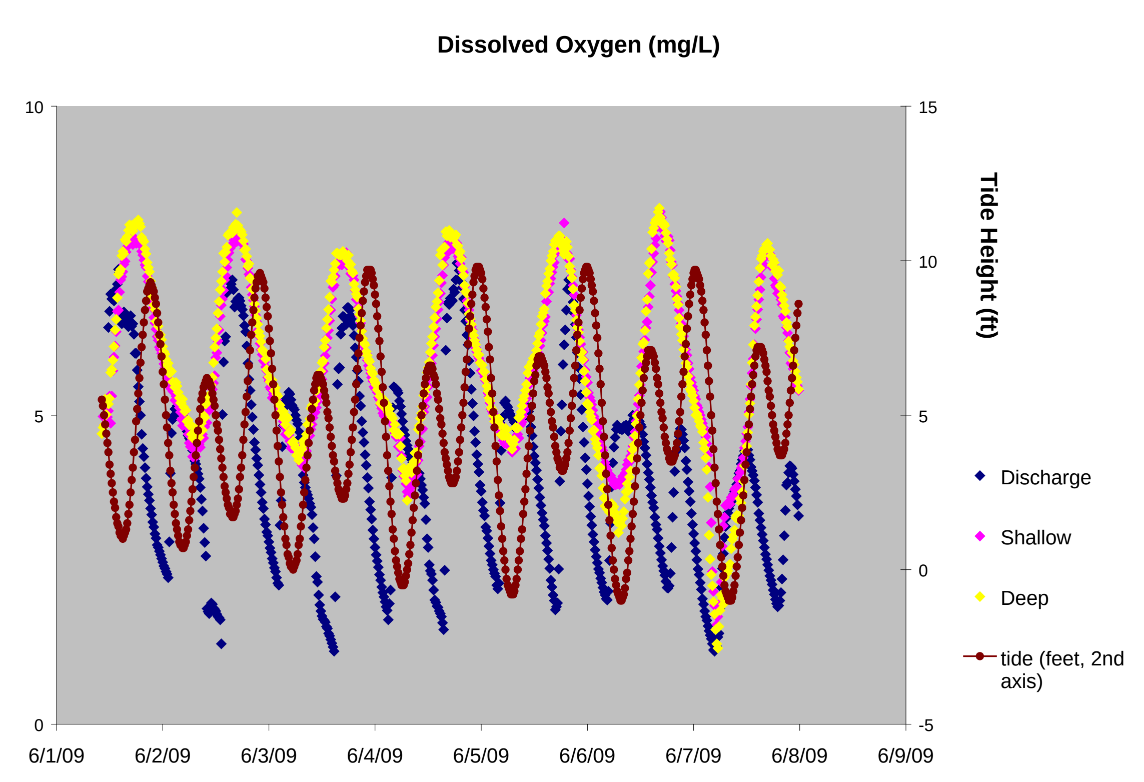

Figure 4.1-2: Pond A14 dissolved oxygen values at 3 pond locations during 1 June – 7 June

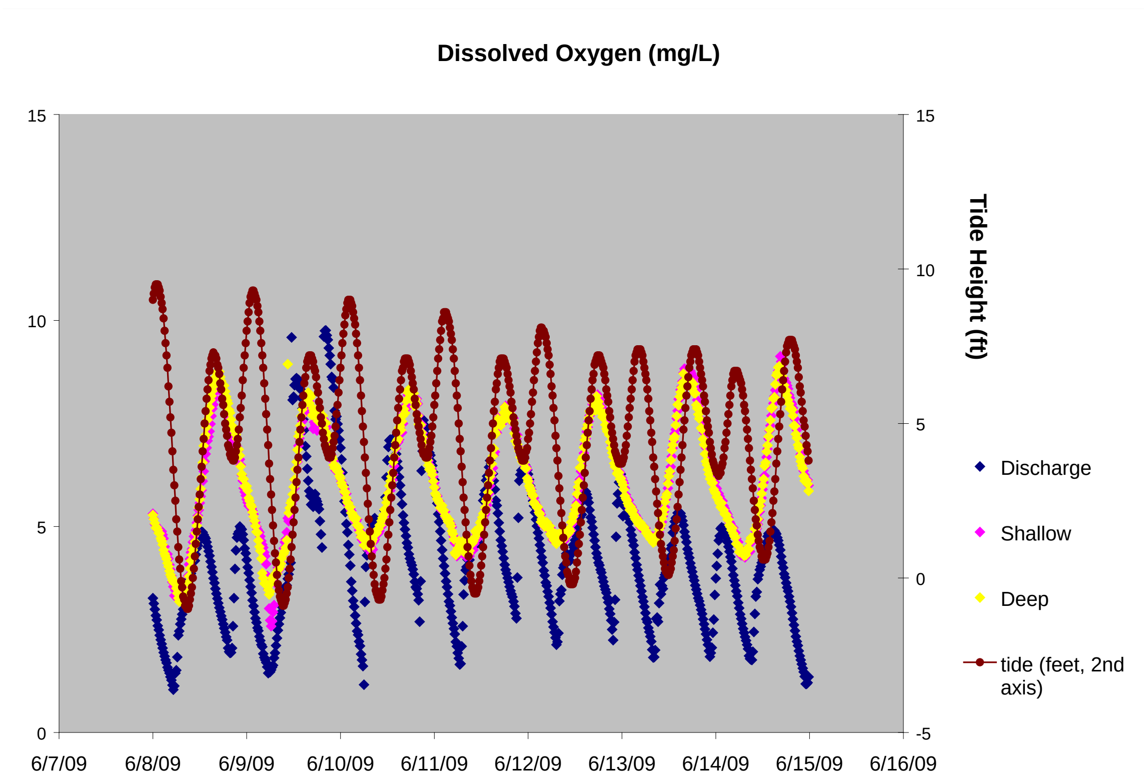

Figure 4.1-3: Pond A14 dissolved oxygen values at 3 pond locations during 8 June – 14 June

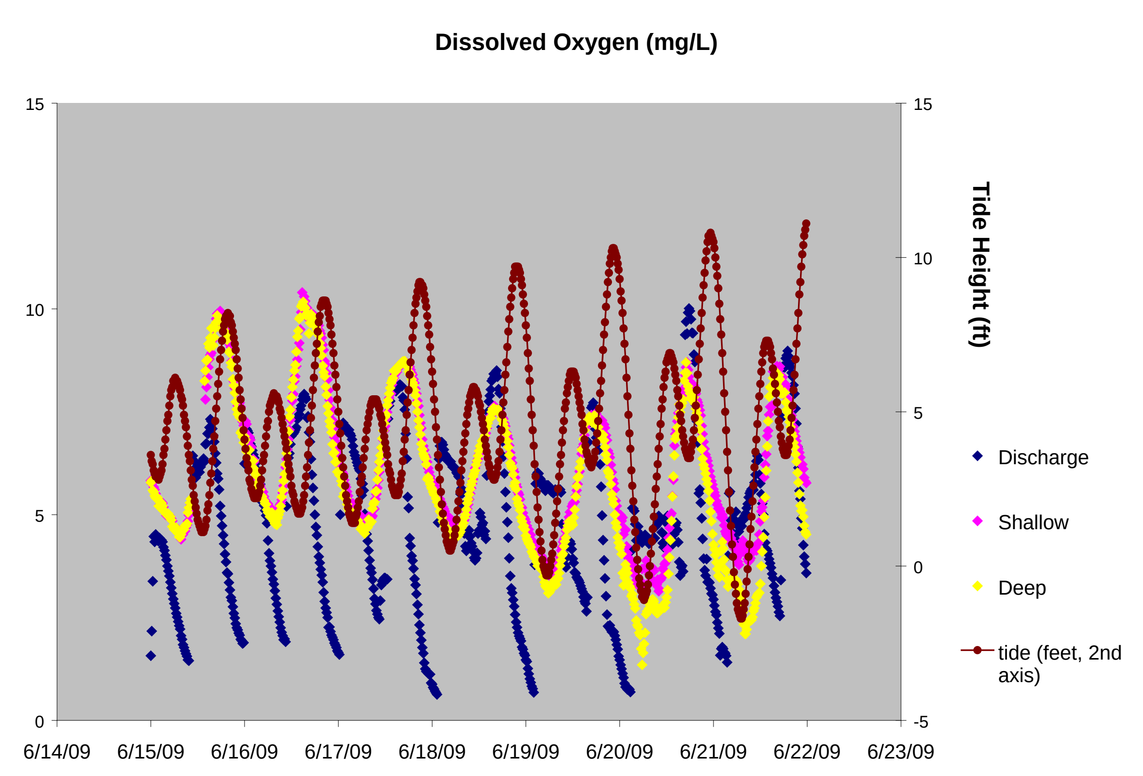

Figure 4.1-4: Pond A14 dissolved oxygen values at 3 pond locations during 15 June – 21 June

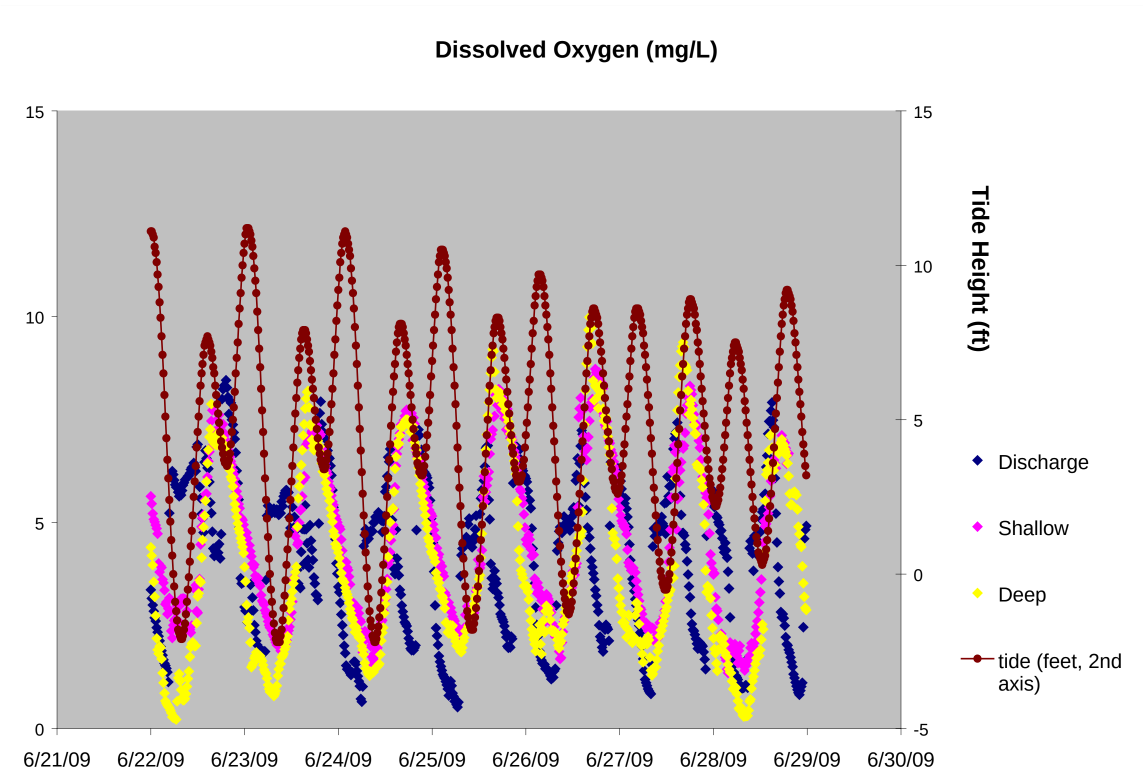

Figure 4.1-5: Pond A14 dissolved oxygen values at 3 pond locations during 22 June – 28 June

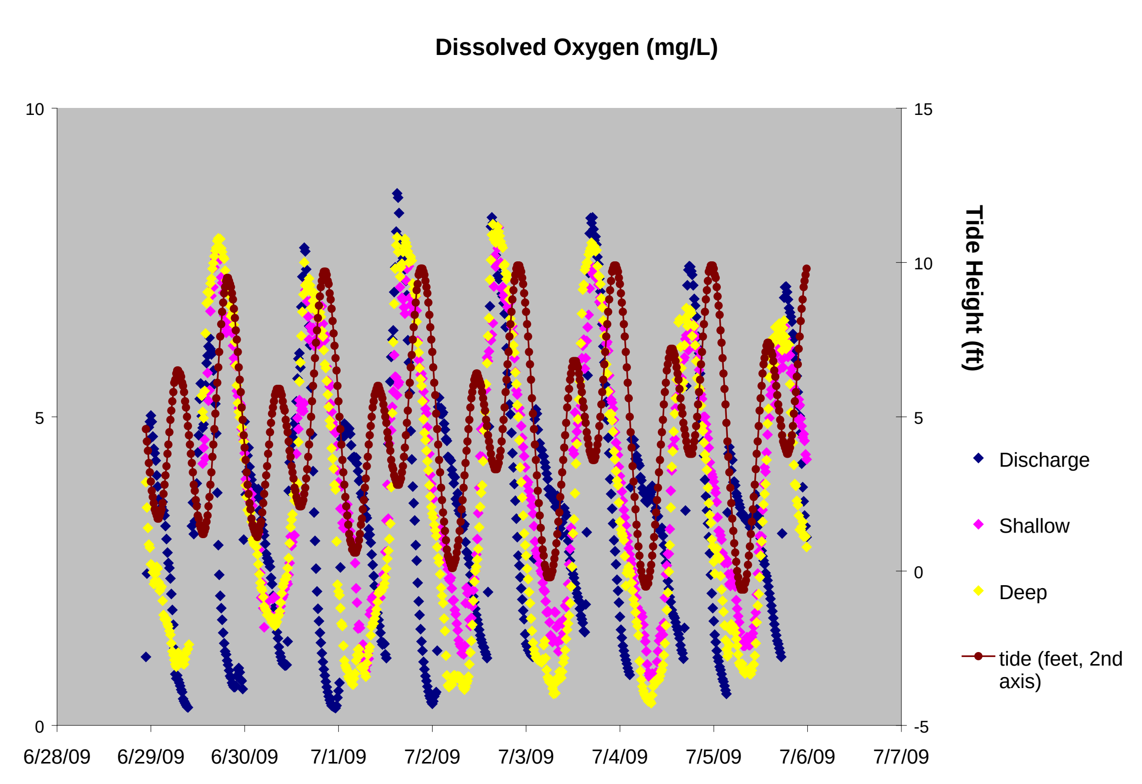

Figure 4.1-6: Pond A14 dissolved oxygen values at 3 pond locations during 29 June – 5 July 2009

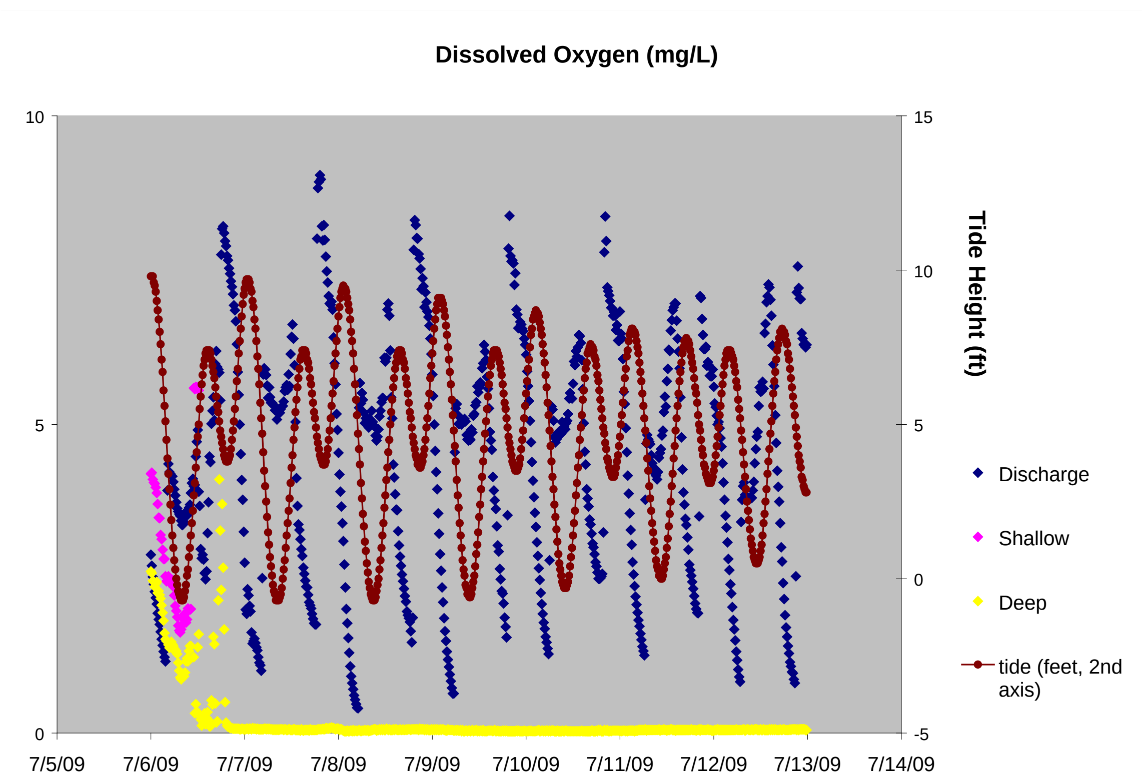

Figure 4.1-7: Pond A14 dissolved oxygen values at 3 pond locations during 6 July – 12 July 2009

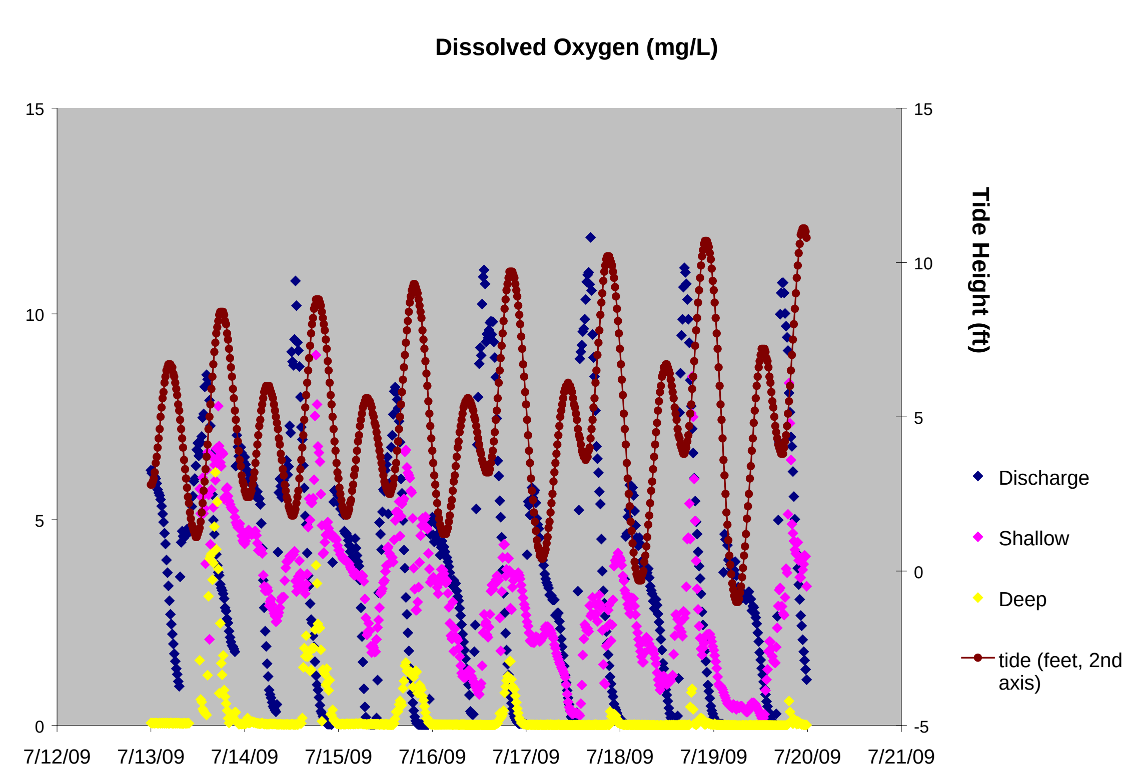

Figure 4.1-8: Pond A14 dissolved oxygen values at 3 pond locations during 13 July – 19 July

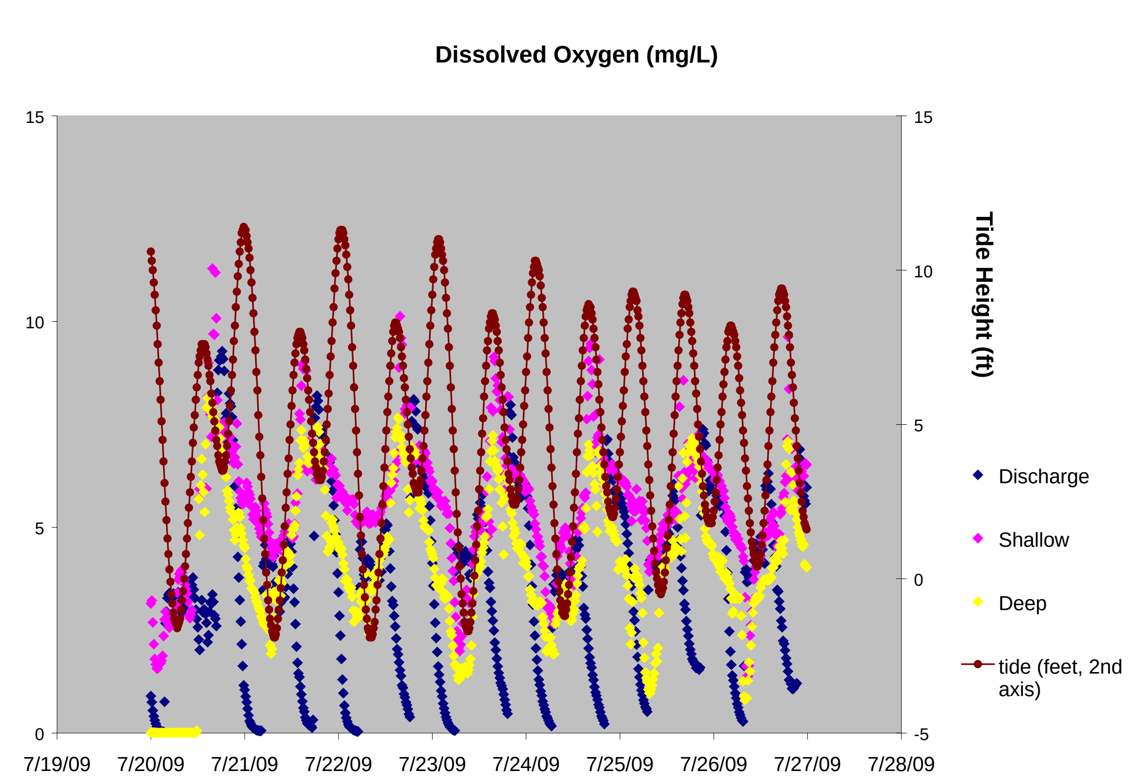

Figure 4.1-9: Pond A14 dissolved oxygen values at 3 pond locations during 20 July – 26 July

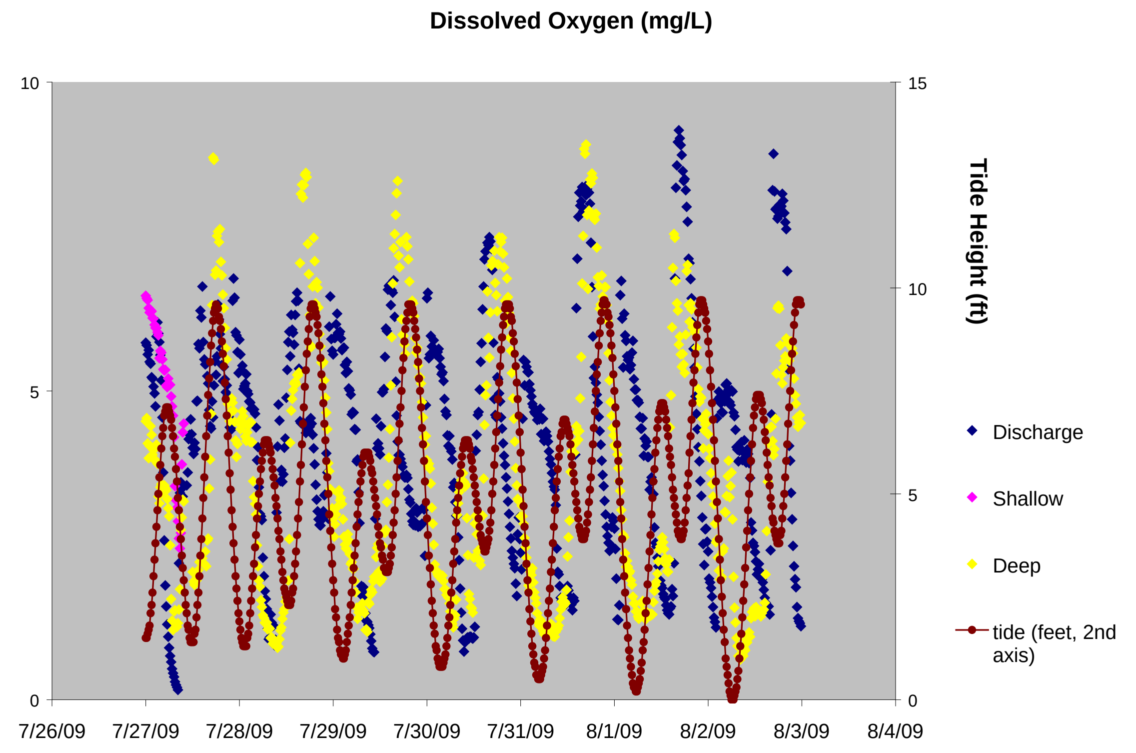

Figure 4.1-10: Pond A14 dissolved oxygen values at 3 pond locations during 27 July – 2 August

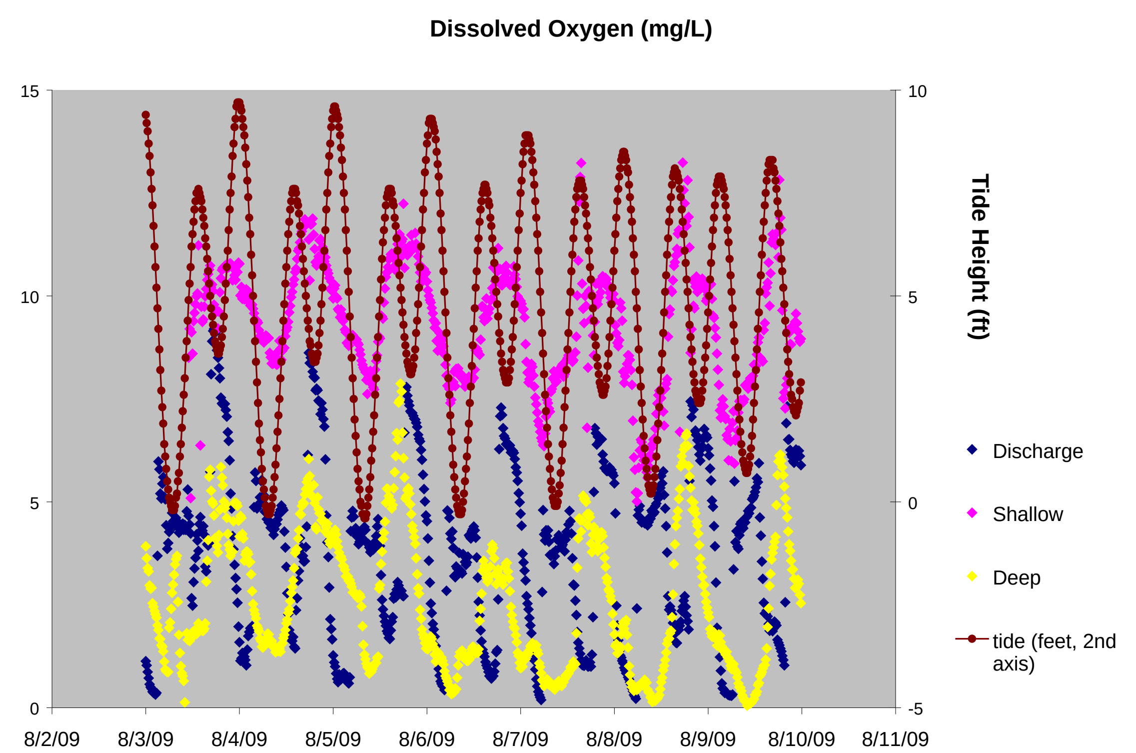

Figure 4.1-11: Pond A14 dissolved oxygen values at 3 pond locations during 3 August – 9 August

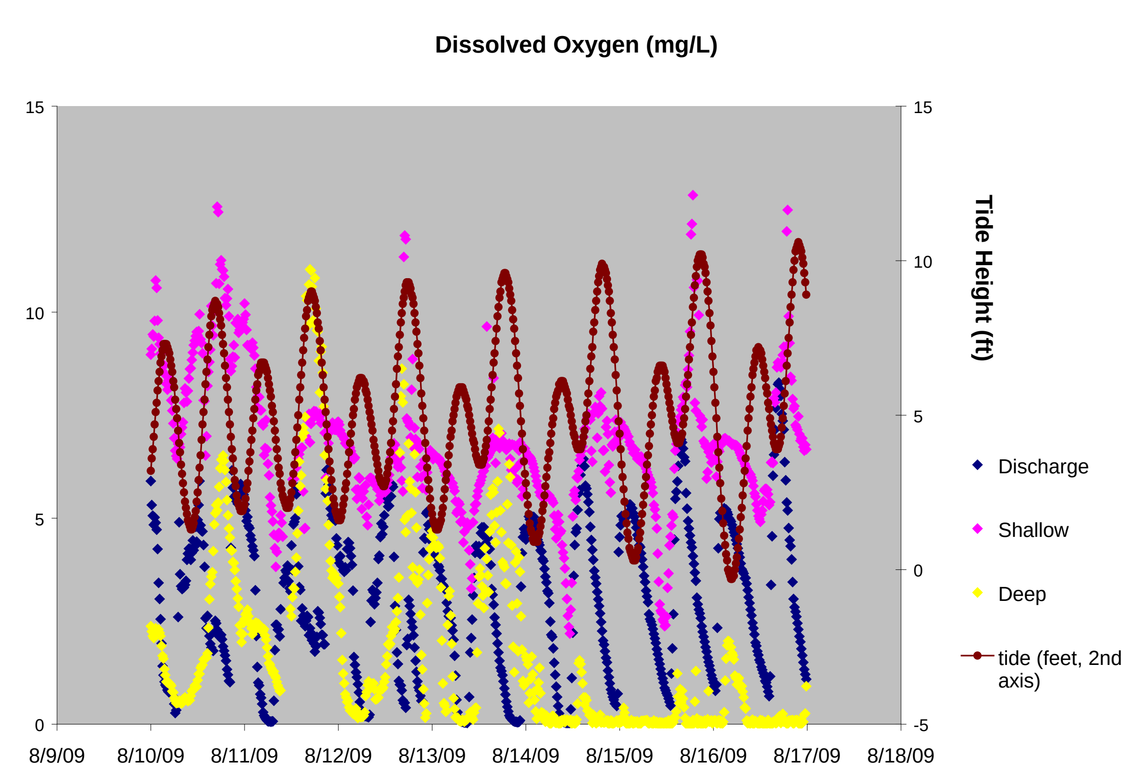

Figure 4.1-12: Pond A14 dissolved oxygen values at 3 pond locations during 10 August – 16 August

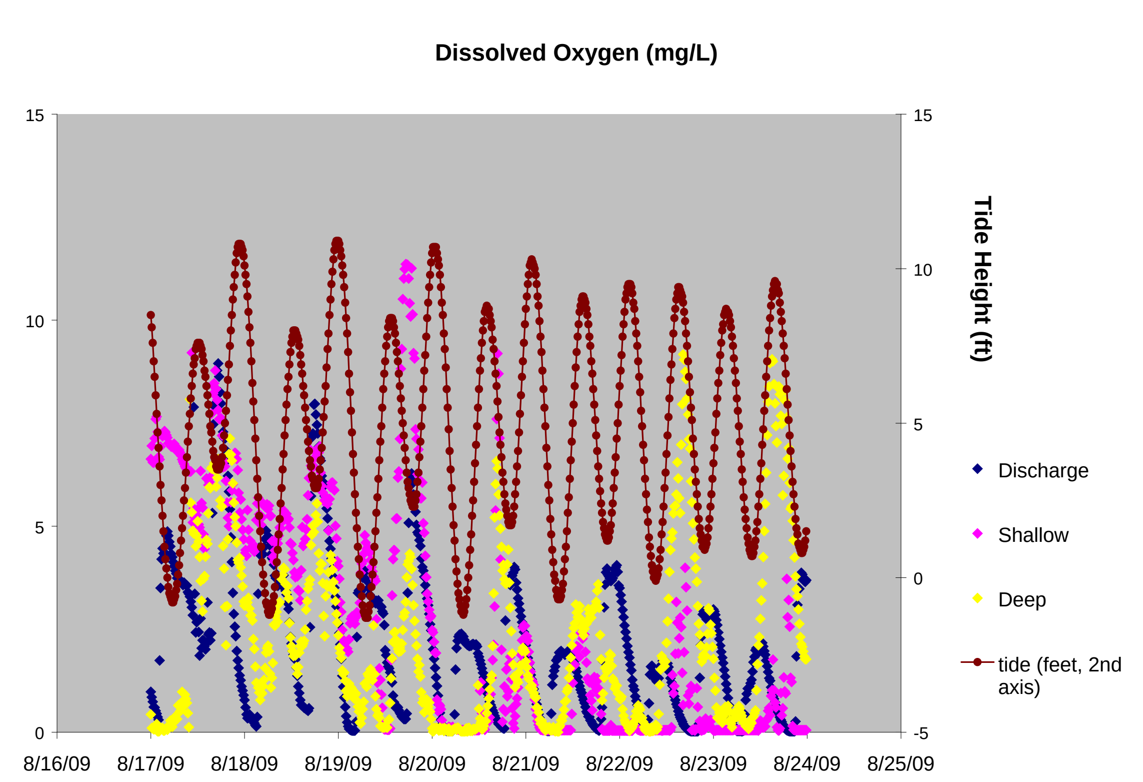

Figure 4.1-13: Pond A14 dissolved oxygen values at 3 pond locations during 17 August – 23 August

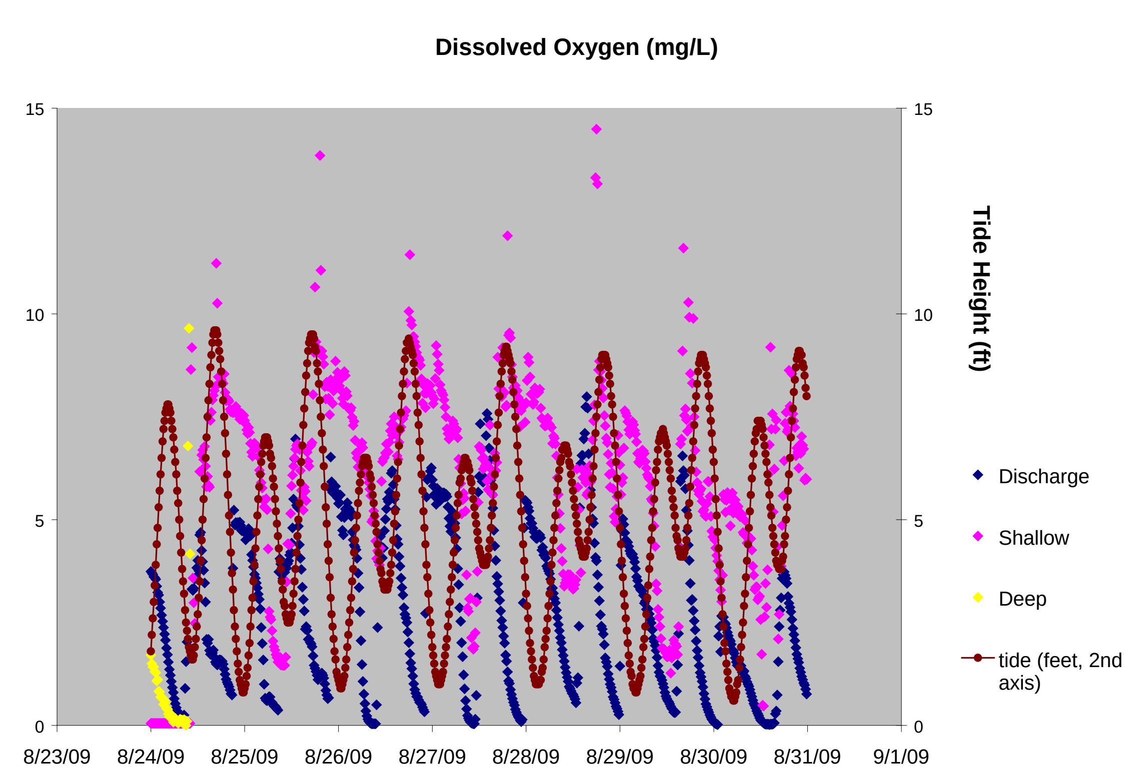

Figure 4.1-14: Pond A14 dissolved oxygen values at 3 pond locations during 24 August – 30 August

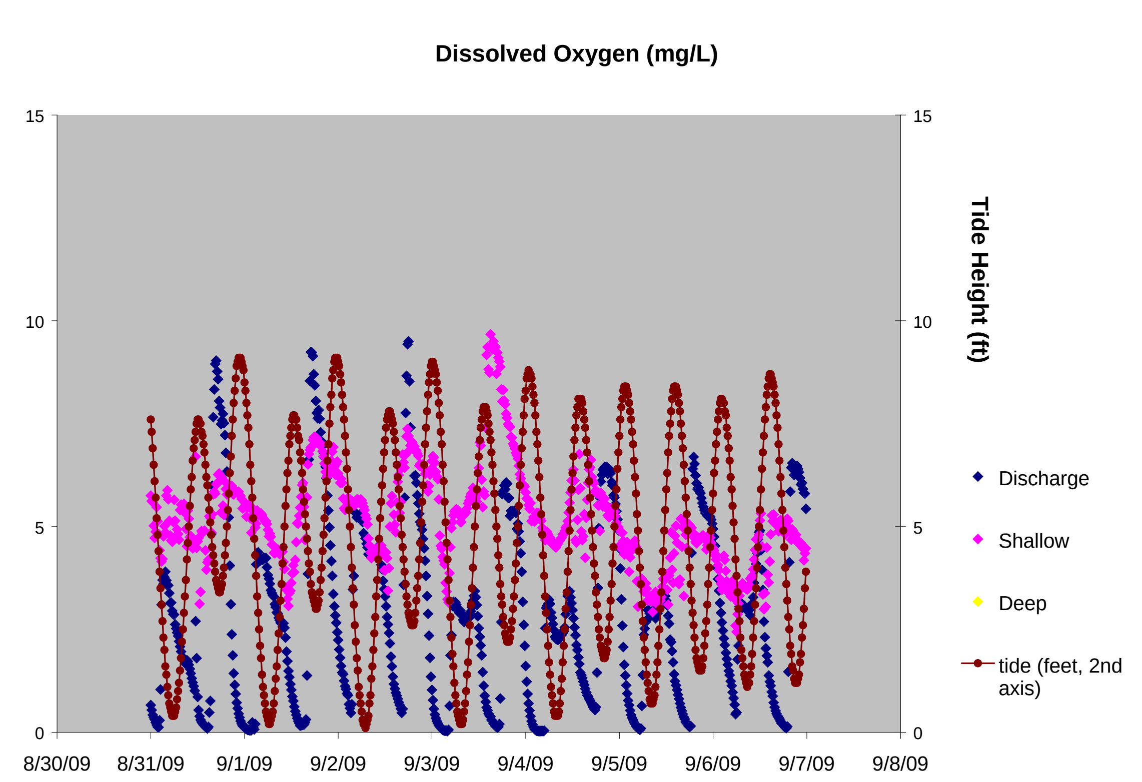

Figure 4.1-15: Pond A14 dissolved oxygen values at 3 pond locations during 31 August – 6 September

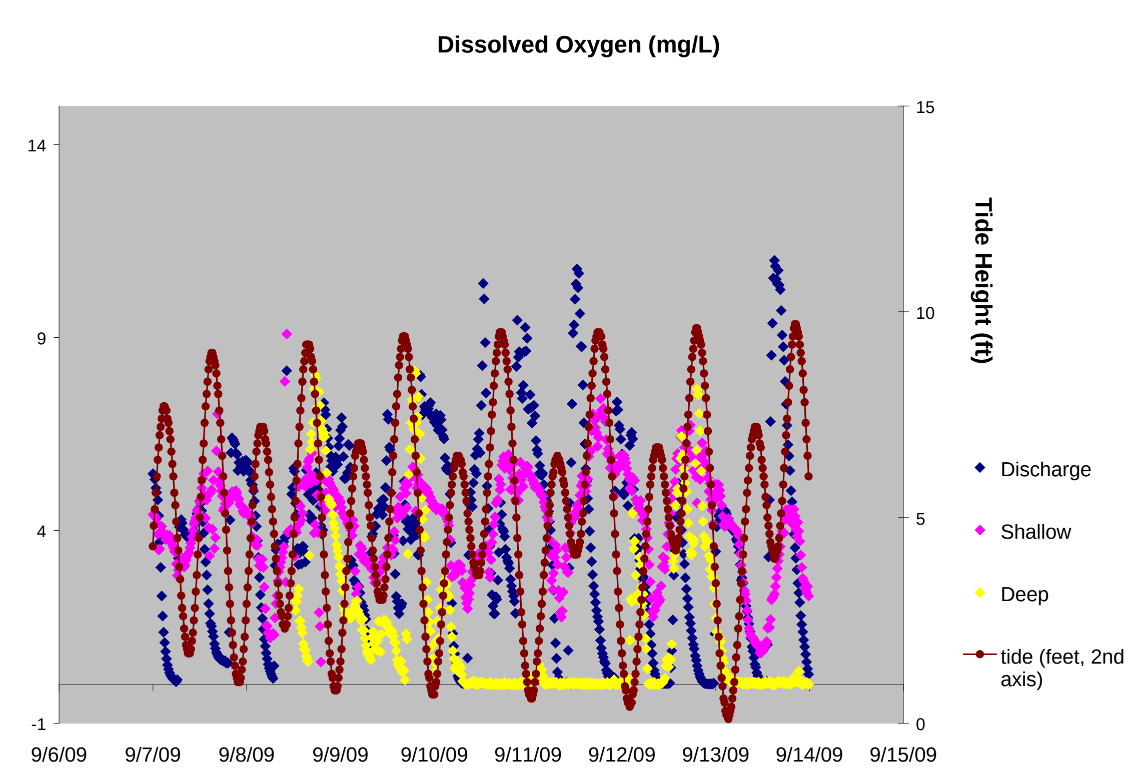

Figure 4.1-16: Pond A14 dissolved oxygen values at 3 pond locations during 7 September – 13 September

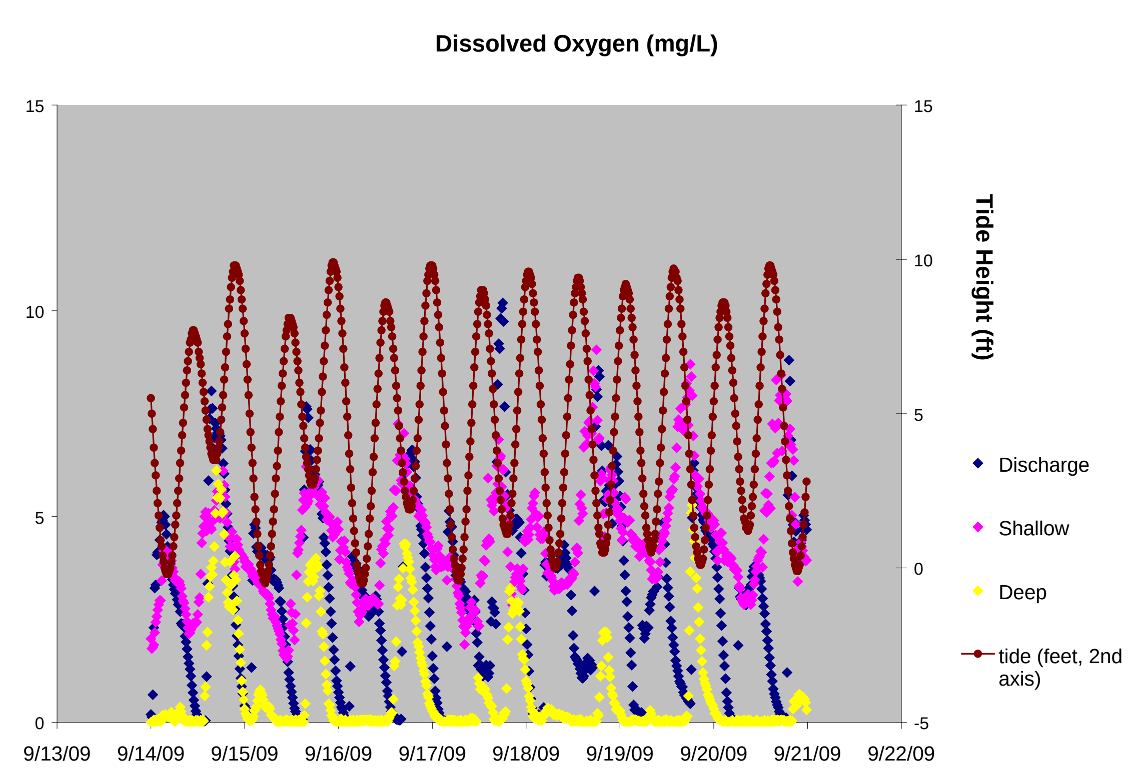

Figure 4.1-17: Pond A14 dissolved oxygen values at 3 pond locations during 14 September – 20 September

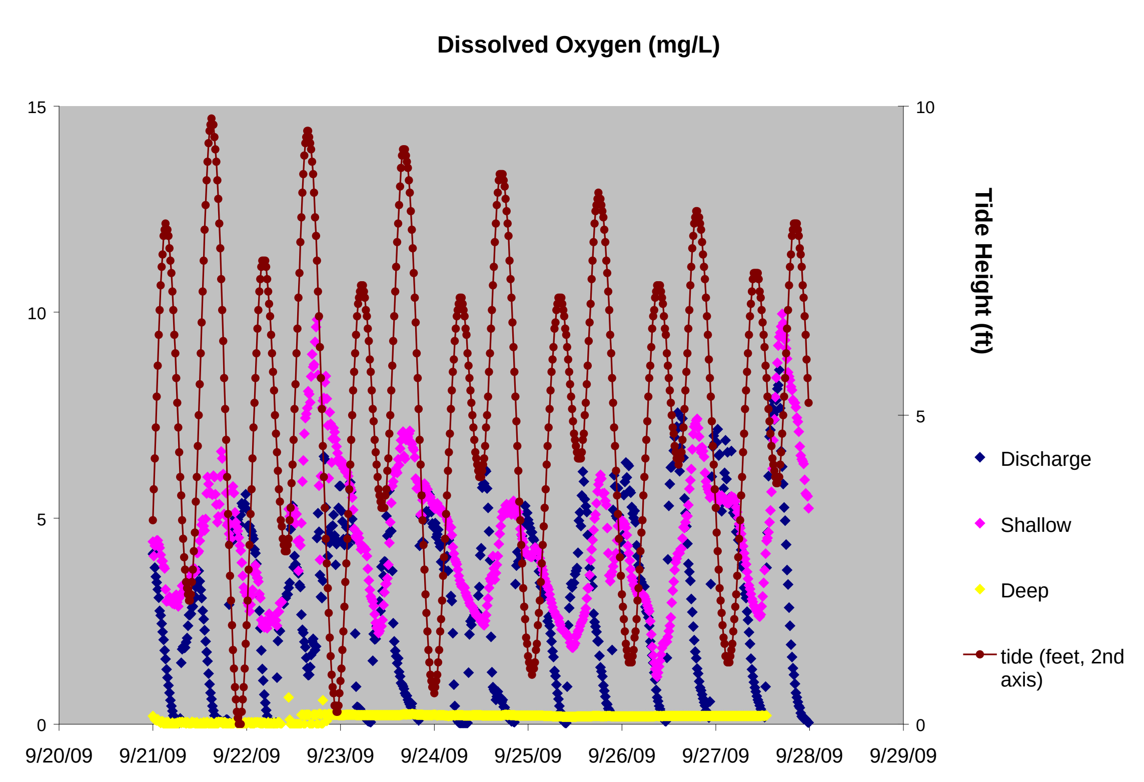

Figure 4.1-18: Pond A14 dissolved oxygen values at 3 pond locations during 21 September – 27 September

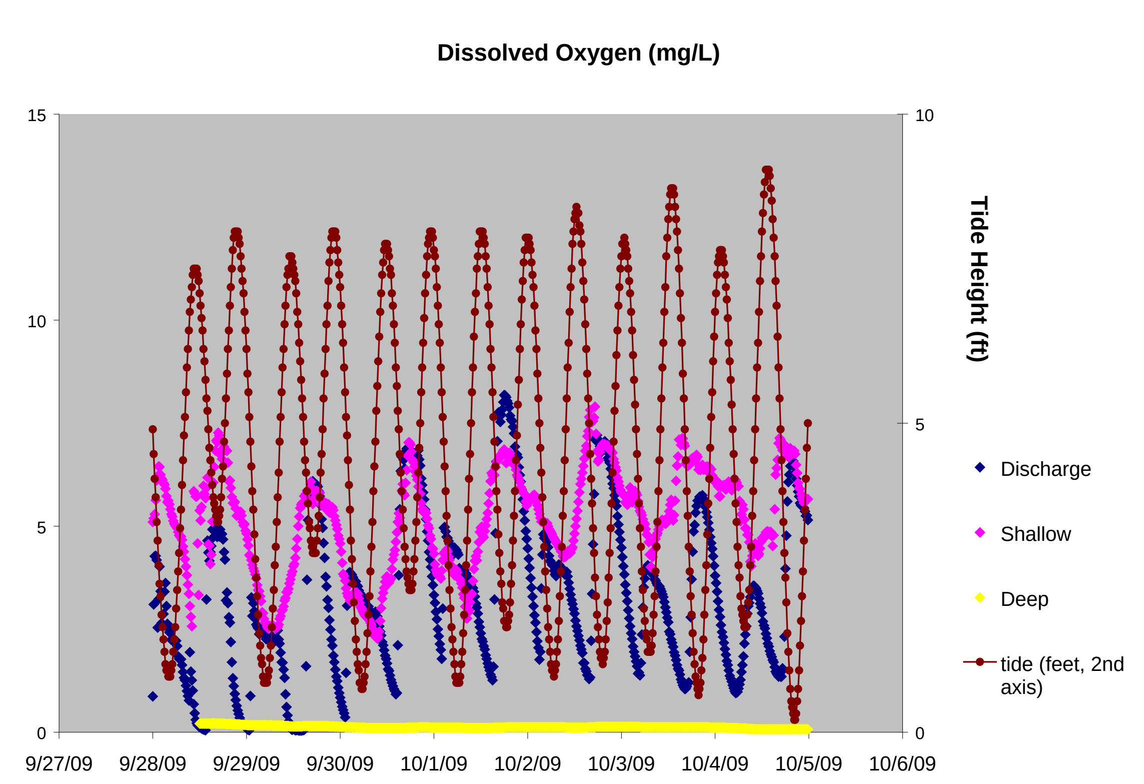

Figure 4.1-19: Pond A14 dissolved oxygen values at 3 pond locations during 28 September – 4 October

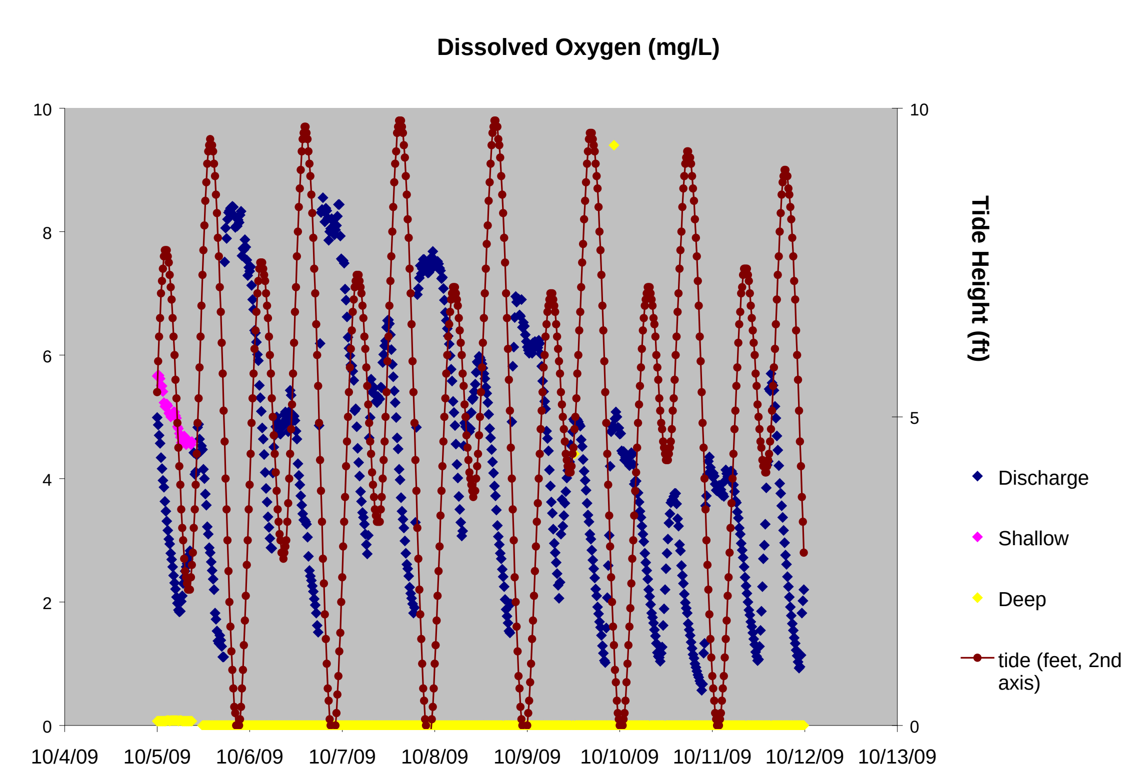

Figure 4.1-20: Pond A14 dissolved oxygen values at 3 pond locations during 5 October – 11 October

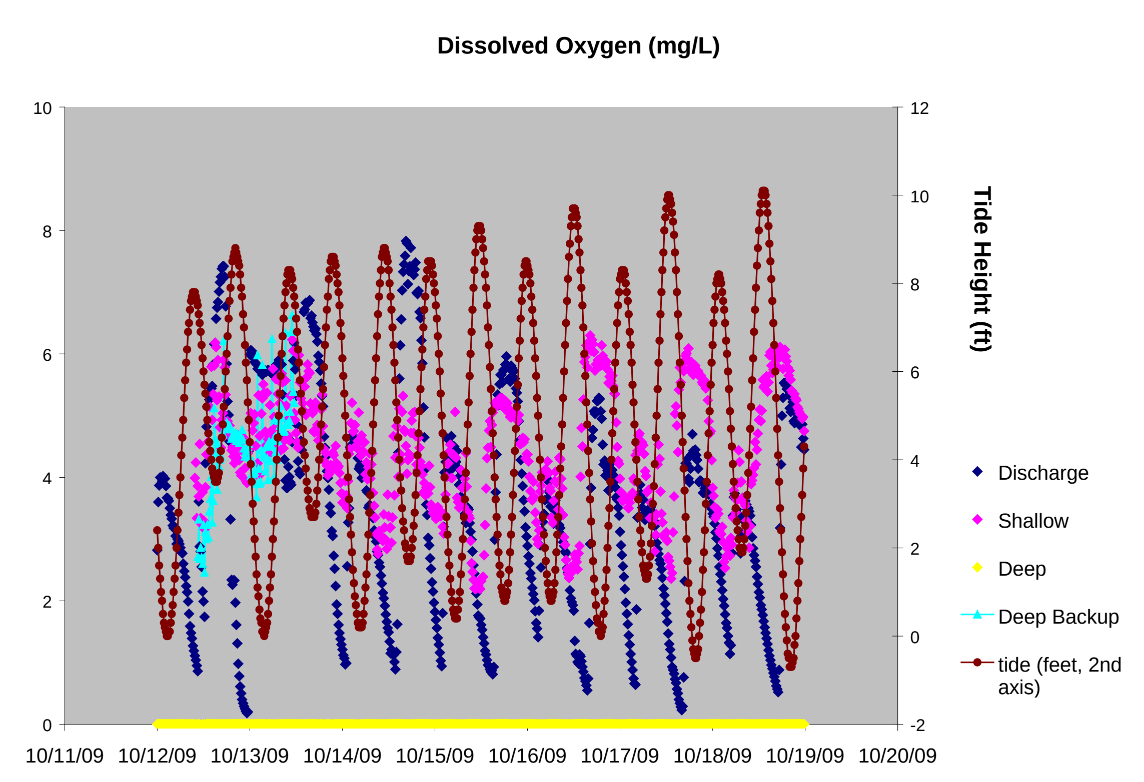

Figure 4.1-21: Pond A14 dissolved oxygen values at 3 pond locations during 12 October – 18 October

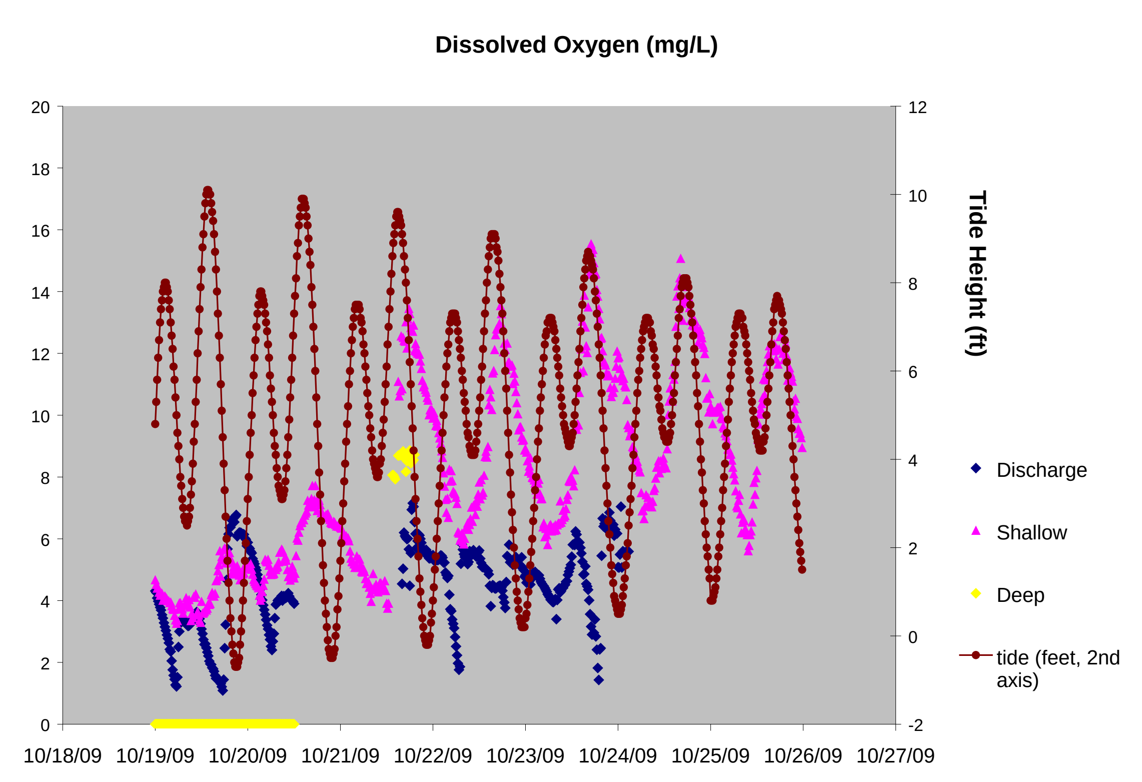

Figure 4.1-22: Pond A14 dissolved oxygen values at 3 pond locations during 19 October – 25 October

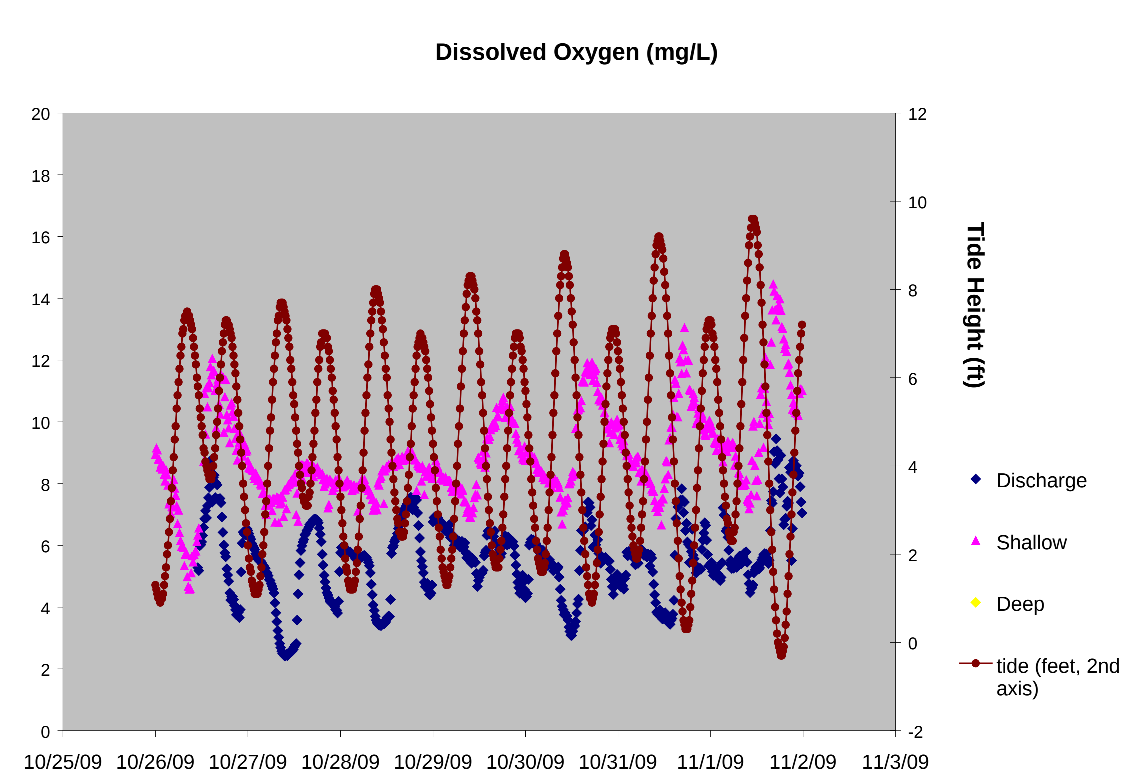

Figure 4.1-23: Pond A14 dissolved oxygen values at 3 pond locations during 26 October – 1 November

4.2 SALINITY

Salinity within Pond A14 increased but remained fairly stable until 19 June, 2009 after which salinity becomes more cyclic; it is unclear whether a specific management activity may have increased tidal cycling during the latter period (Figures 4.2-1 through 4.2-22). The magnitude of the maxima and minima varied by datasonde but was generally less intense at the discharge datasonde where cyclical changes occurred more frequently but were less extreme towards the latter part of the season. Discharge waters, in general, had higher salinity values than the other locations. Salinity was generally lowest at the shallow location with the exception of June when the deep datasonde had the lowest monthly average.

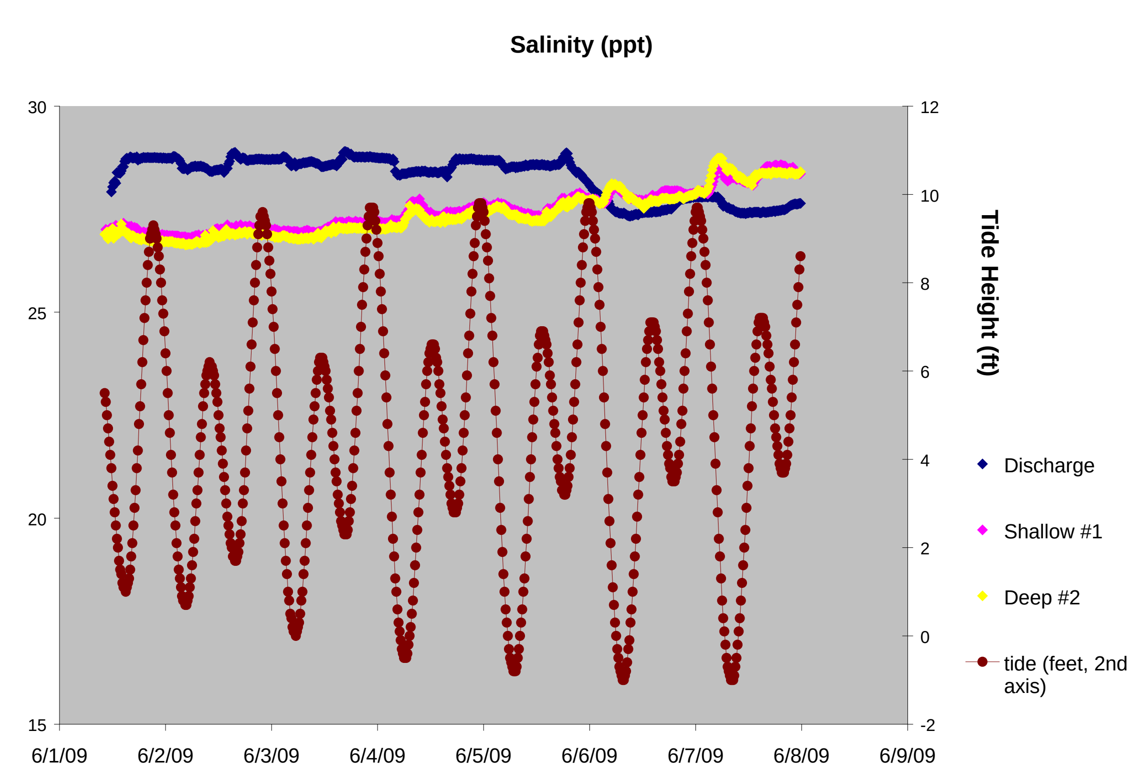

Figure 4.2-1: Pond A14 salinity values at 3 pond locations during 1 June – 7 June

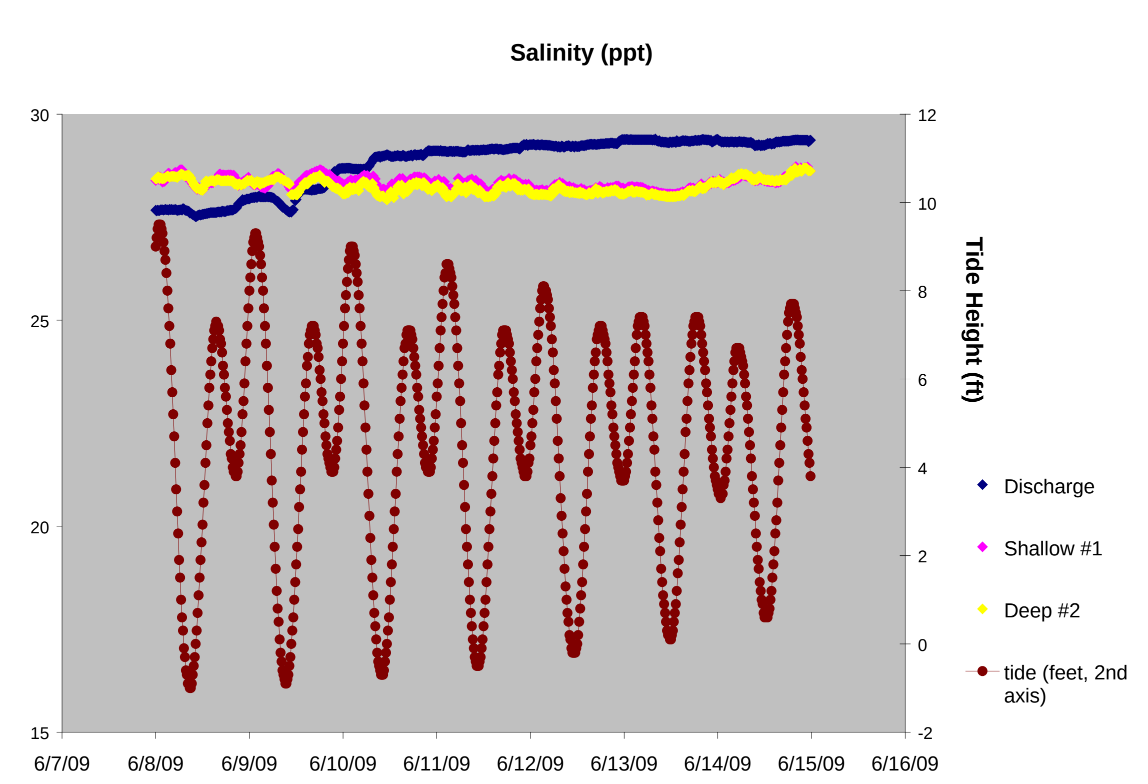

Figure 4.2-2: Pond A14 salinity values at 3 pond locations during 8 June – 14 June

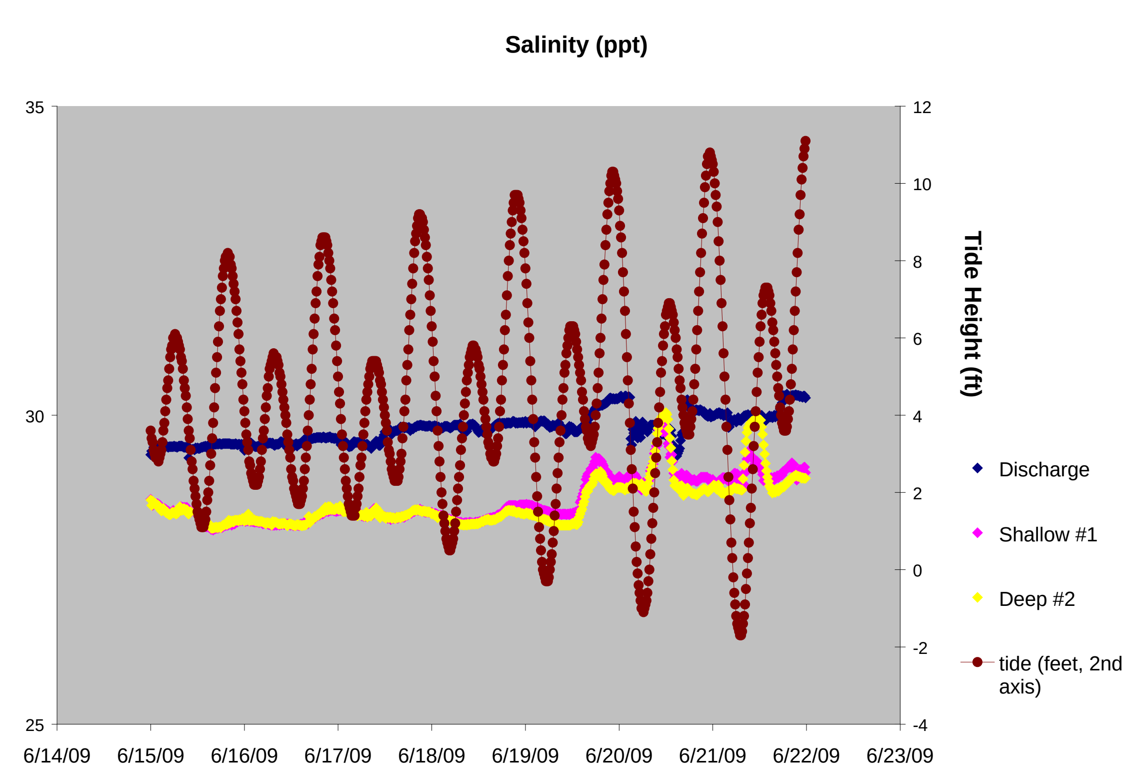

Figure 4.2-3: Pond A14 salinity values at 3 pond locations during 15 June – 21 June

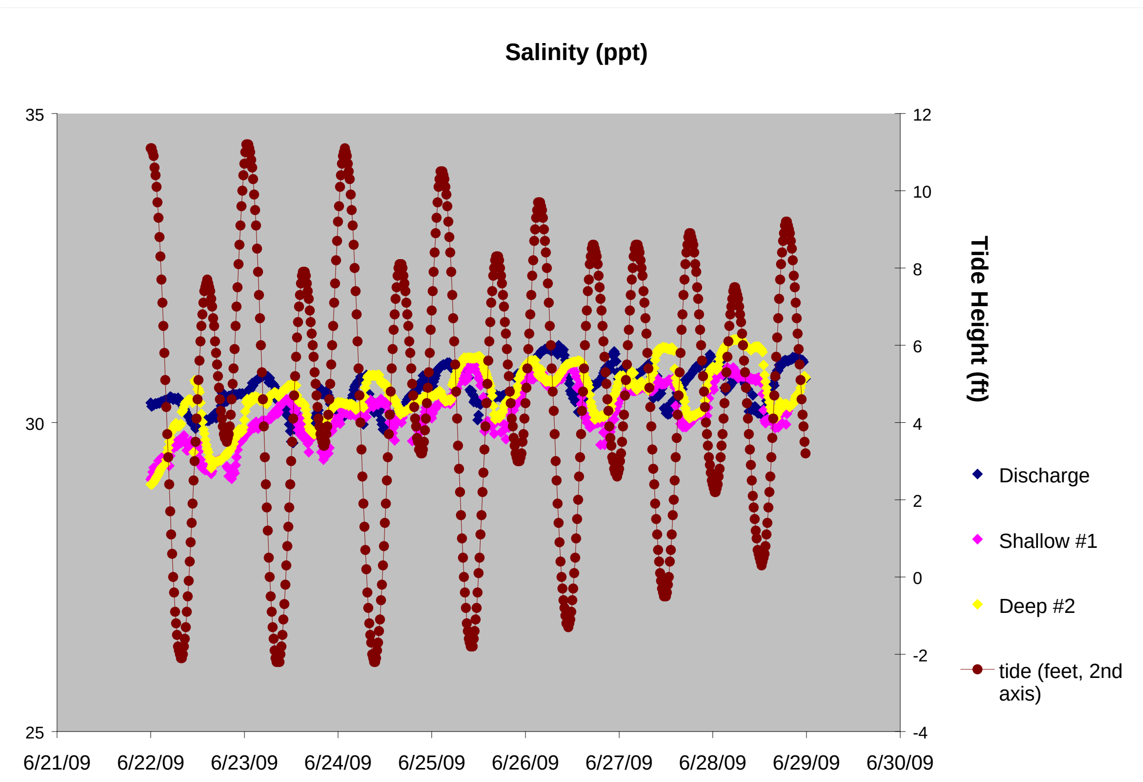

Figure 4.2-4: Pond A14 salinity values at 3 pond locations during 22 June – 28 June

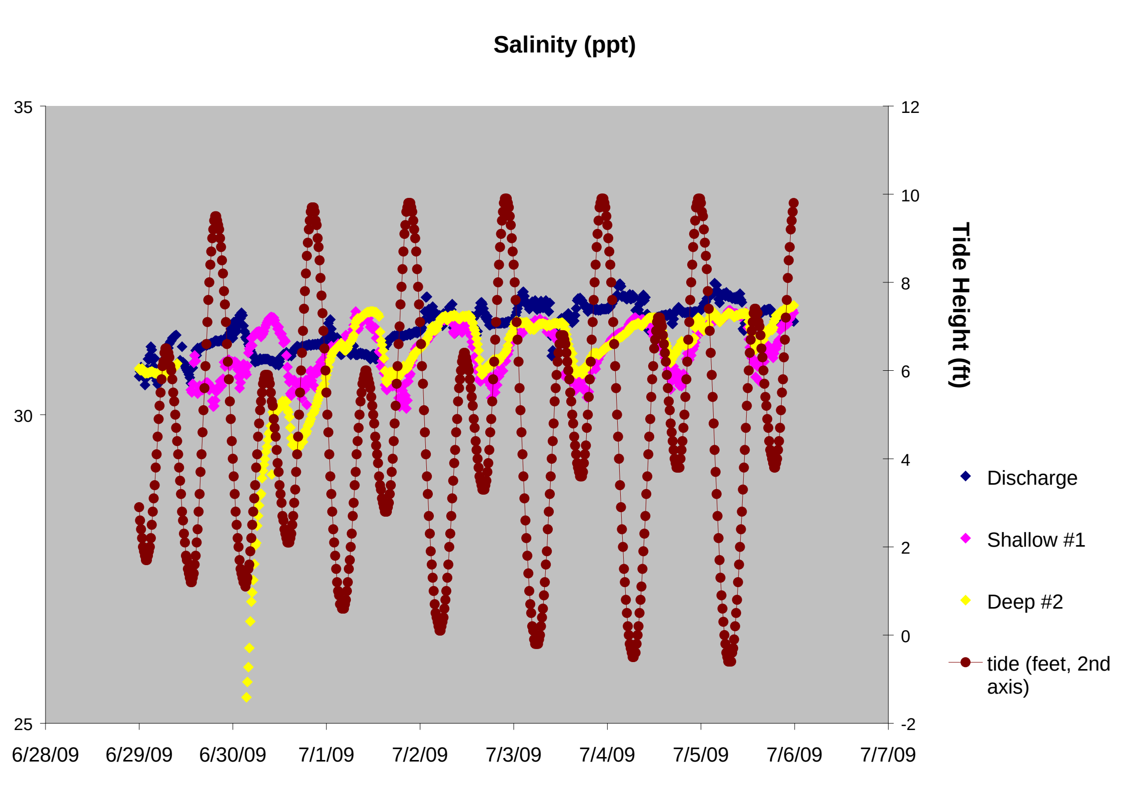

Figure 4.2-5: Pond A14 salinity values at 3 pond locations during 29 June – 5 July

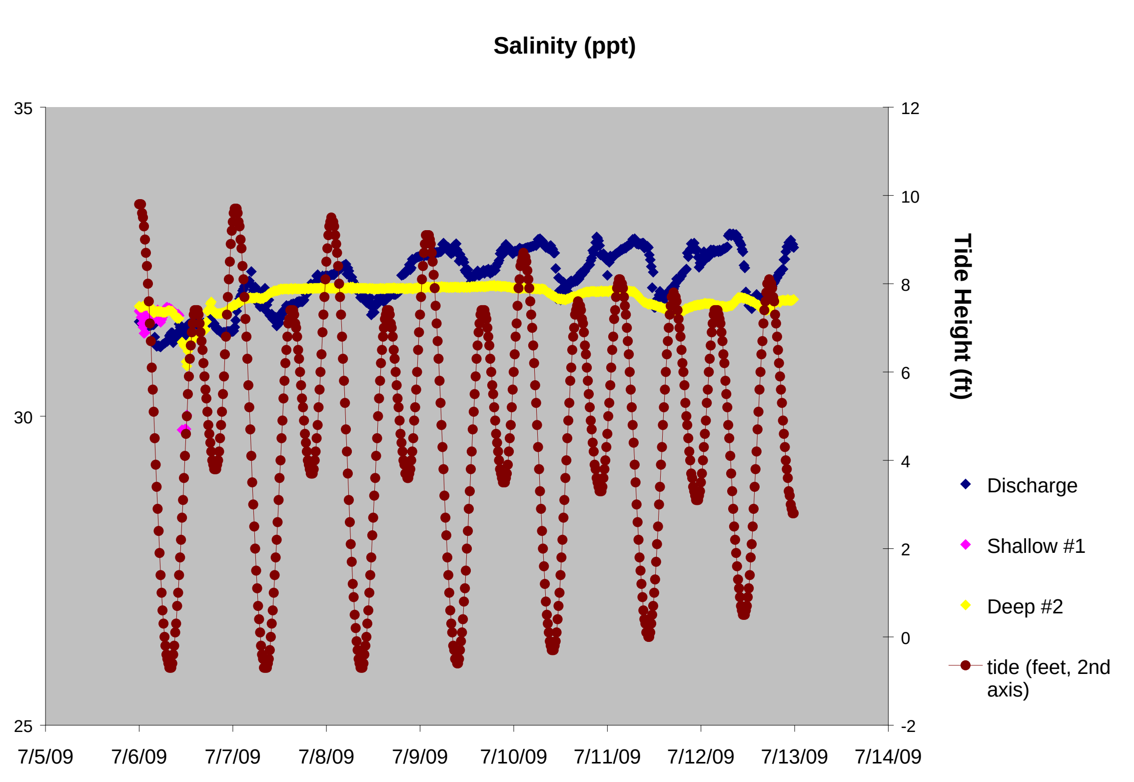

Figure 4.2-6: Pond A14 salinity values at 3 pond locations during 6 July – 12 July

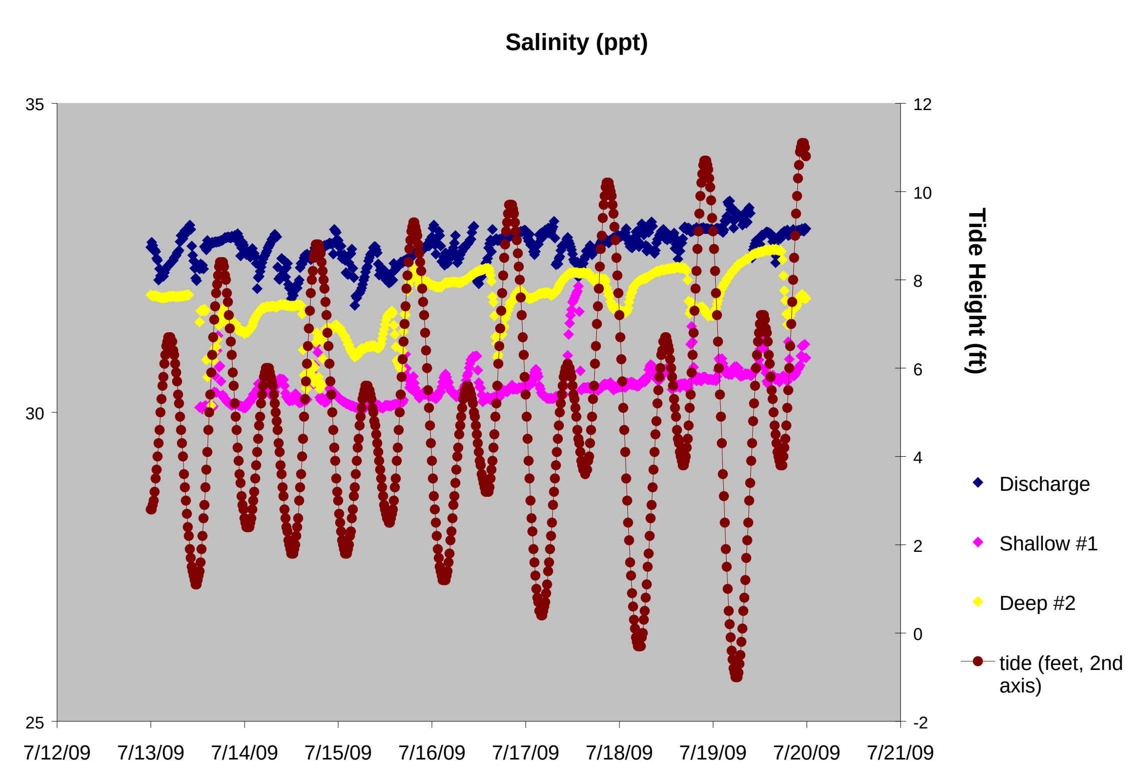

Figure 4.2-7: Pond A14 salinity values at 3 pond locations during 13 July – 19 July

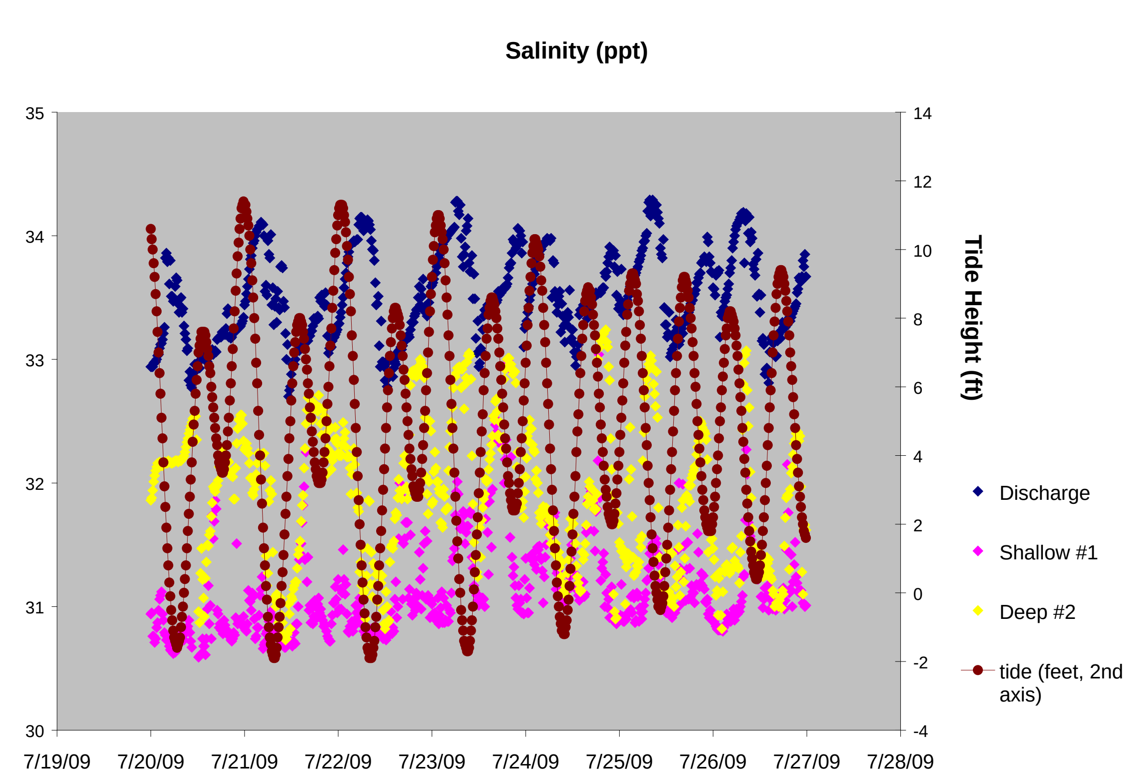

Figure 4.2-8: Pond A14 salinity values at 3 pond locations during 20 July – 26 July

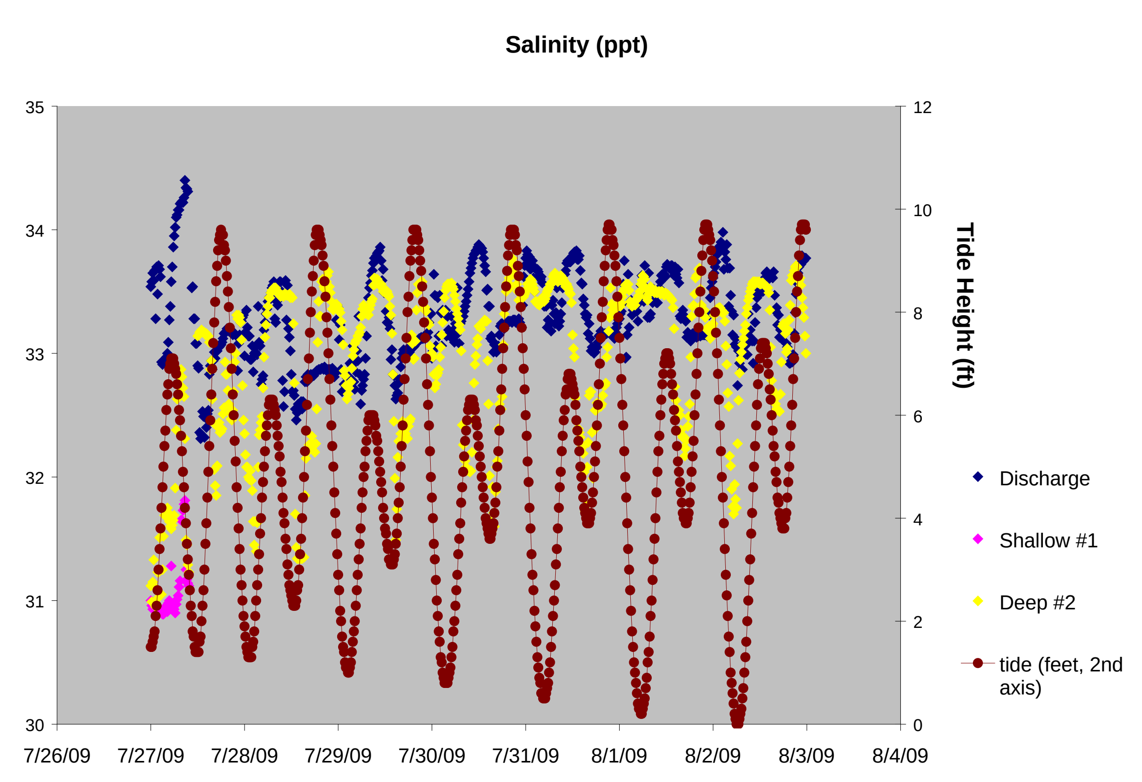

Figure 4.2-9: Pond A14 salinity values at 3 pond locations during 27 July – 2 August

Figure 4.2-10: Pond A14 salinity values at 3 pond locations during 3 August – 9 August

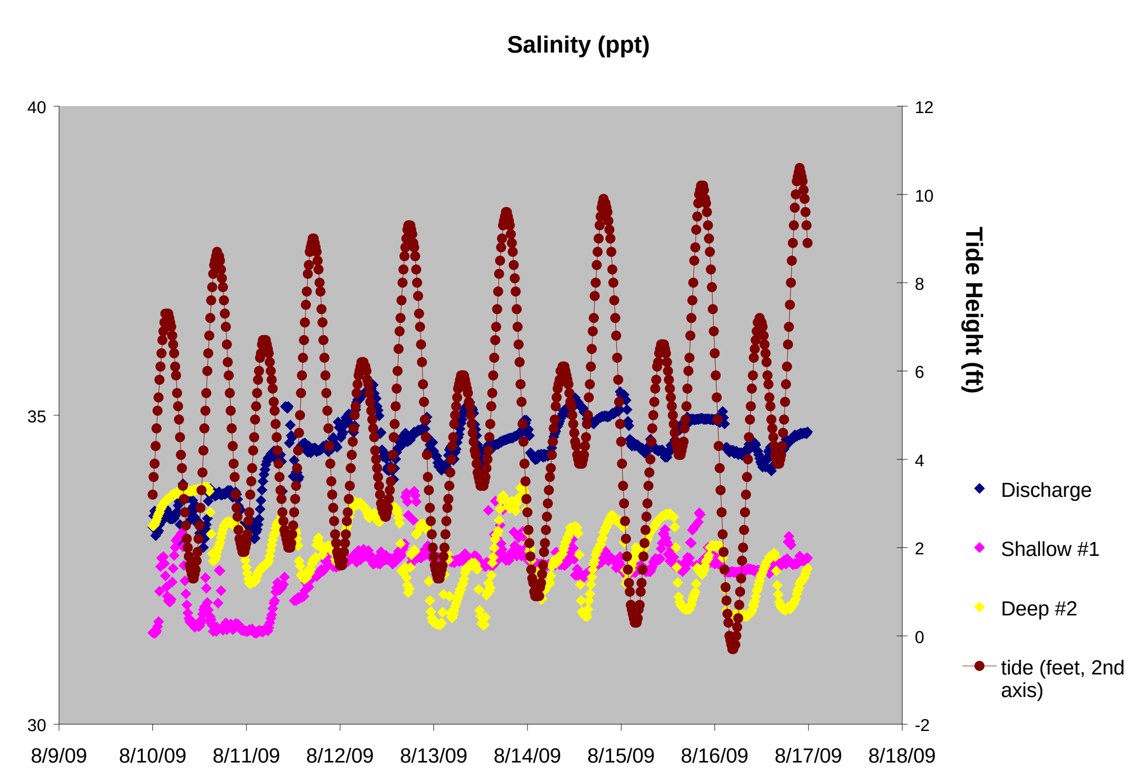

Figure 4.2-11: Pond A14 salinity values at 3 pond locations during 10 August – 16 August

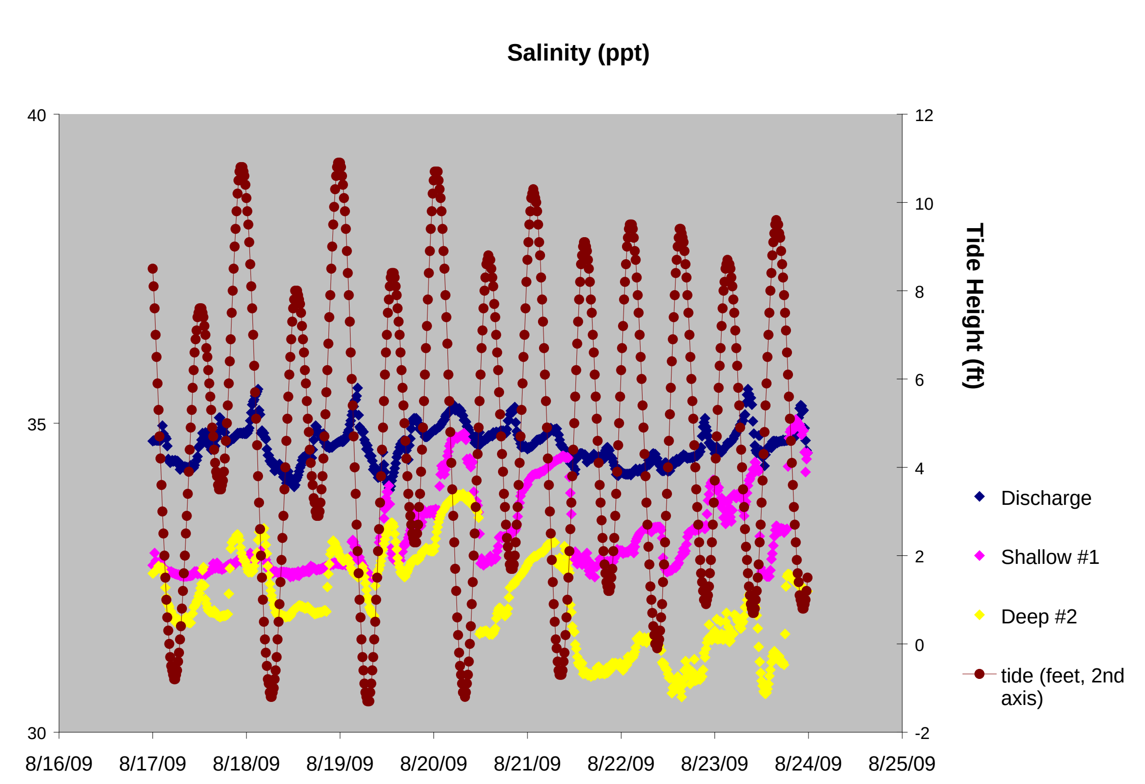

Figure 4.2-12: Pond A14 salinity values at 3 pond locations during 17 August- 23 August

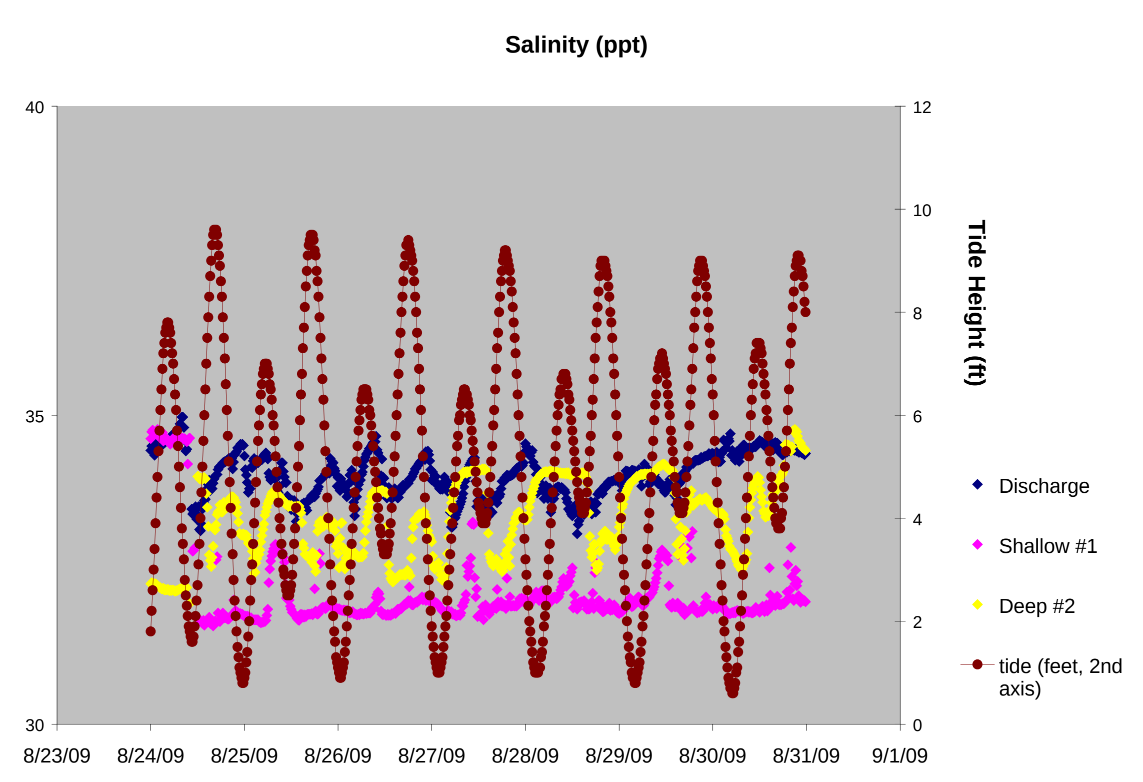

Figure 4.2-13: Pond A14 salinity values at 3 pond locations during 24 August – 30 August.

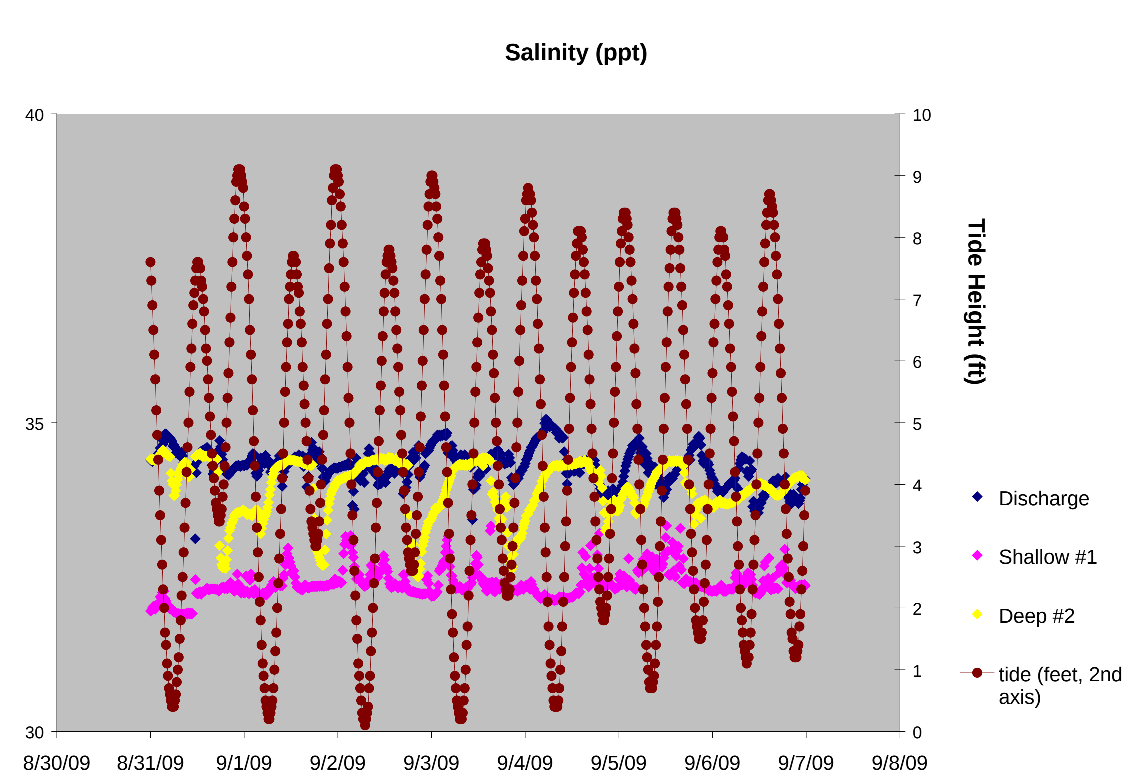

Figure 4.2-14: Pond A14 salinity values at 3 pond locations during 31 August – 6 September

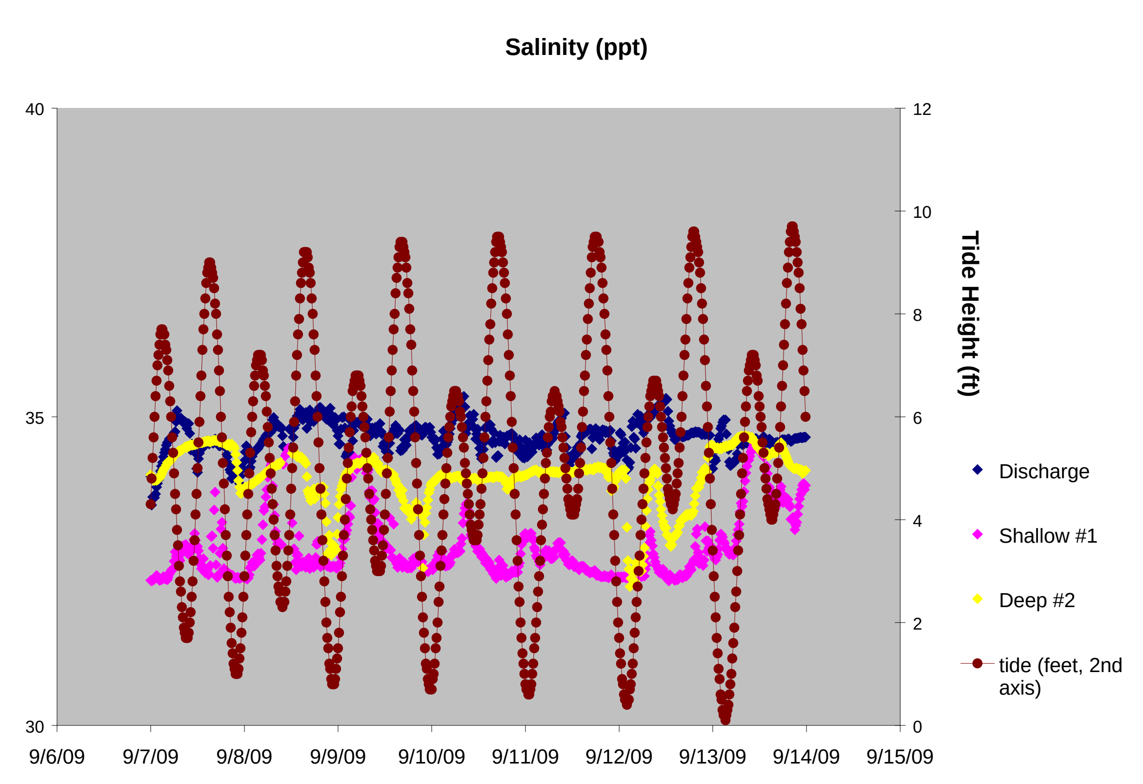

Figure 4.2-15: Pond A14 salinity values at 3 pond locations during 7 September – 13 September

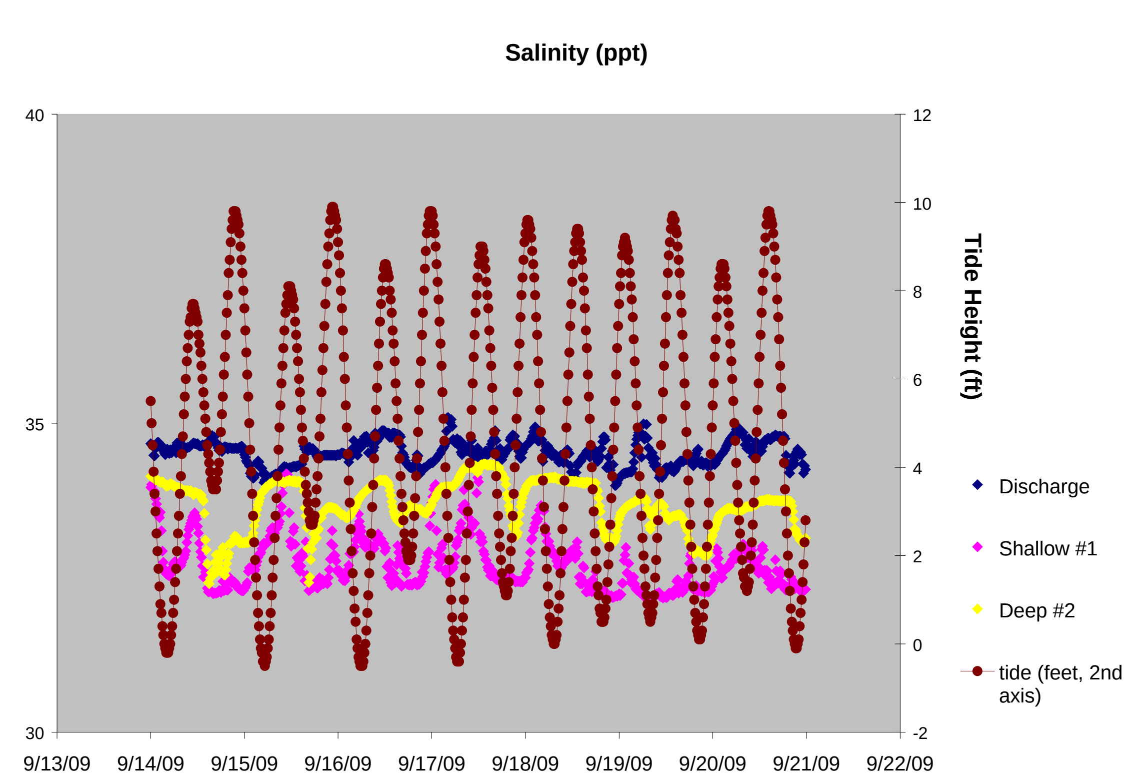

Figure 4.2-16: Pond A14 salinity values at 3 pond locations during 14 September – 20 September

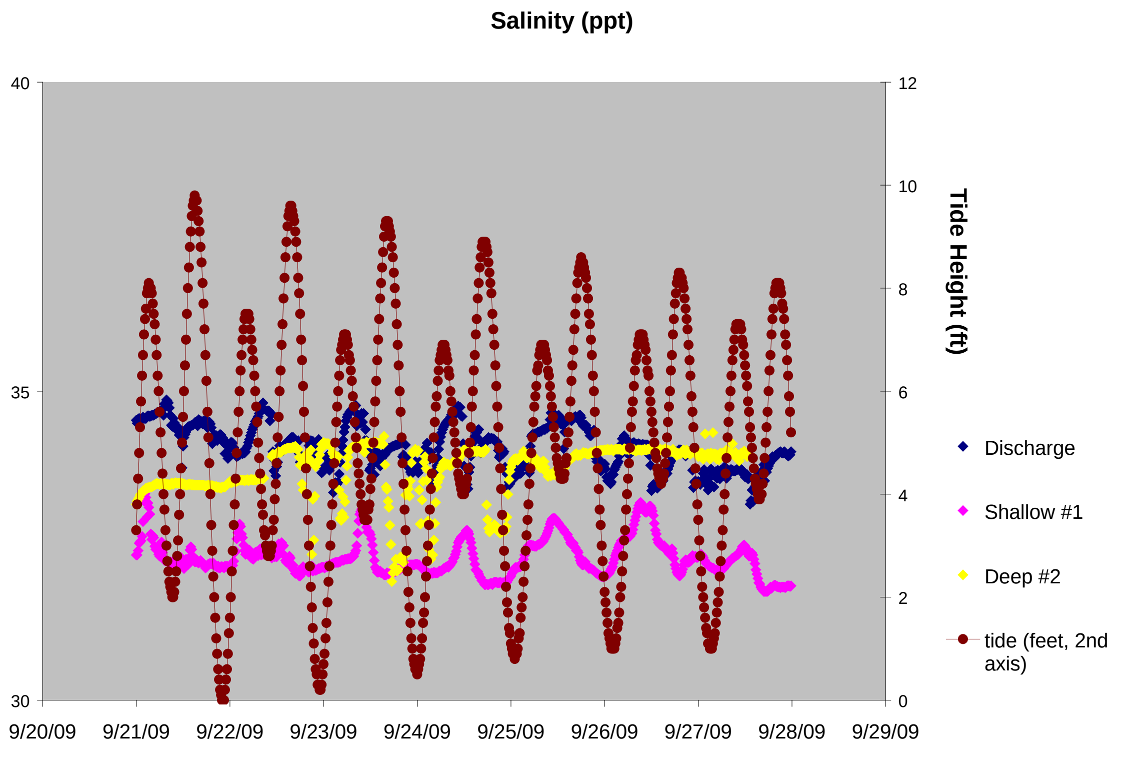

Figure 4.2-17: Pond A14 salinity values at 3 pond locations during 21 September – 27 September

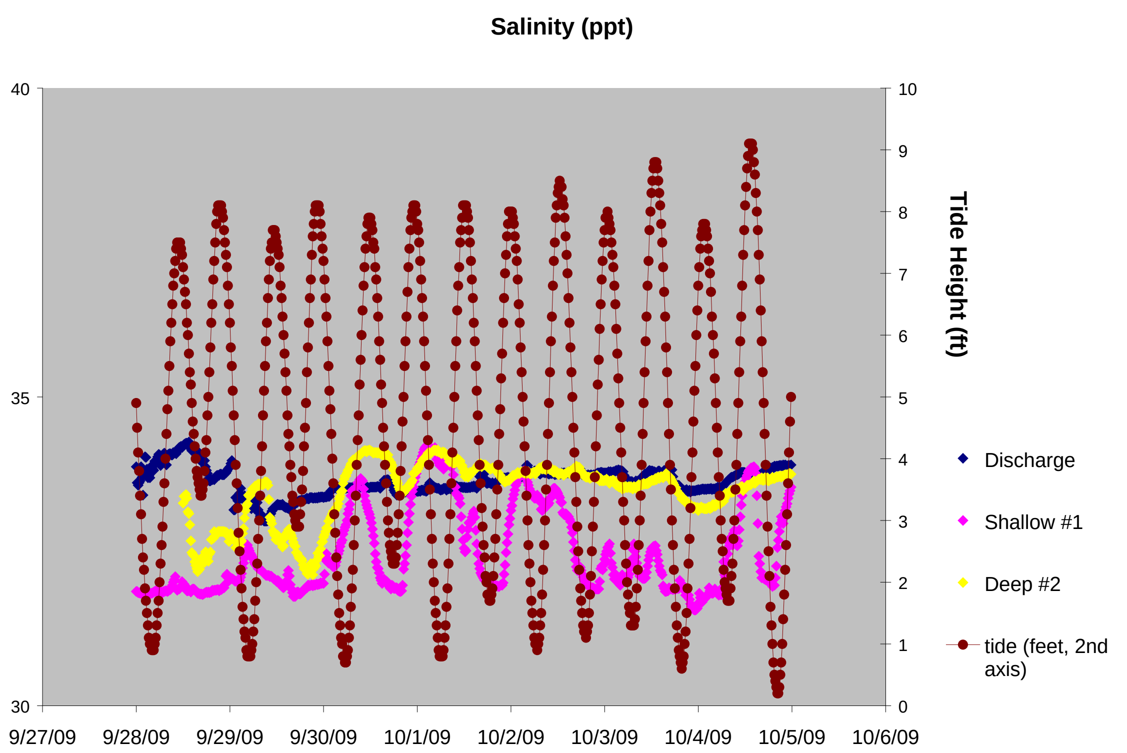

Figure 4.2-18. Pond A14 salinity values at 3 pond locations during 28 September – 4 October.

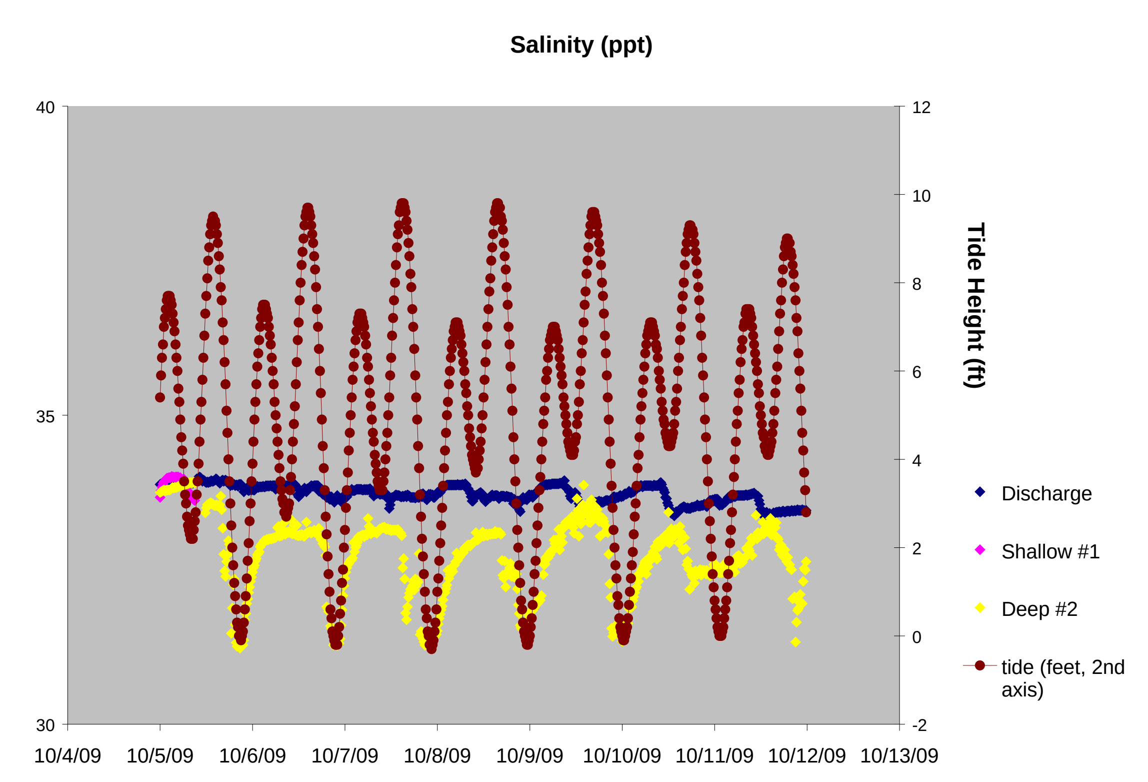

Figure 4.2-19: Pond A14 salinity values at 3 pond locations during 5 October – 11 October

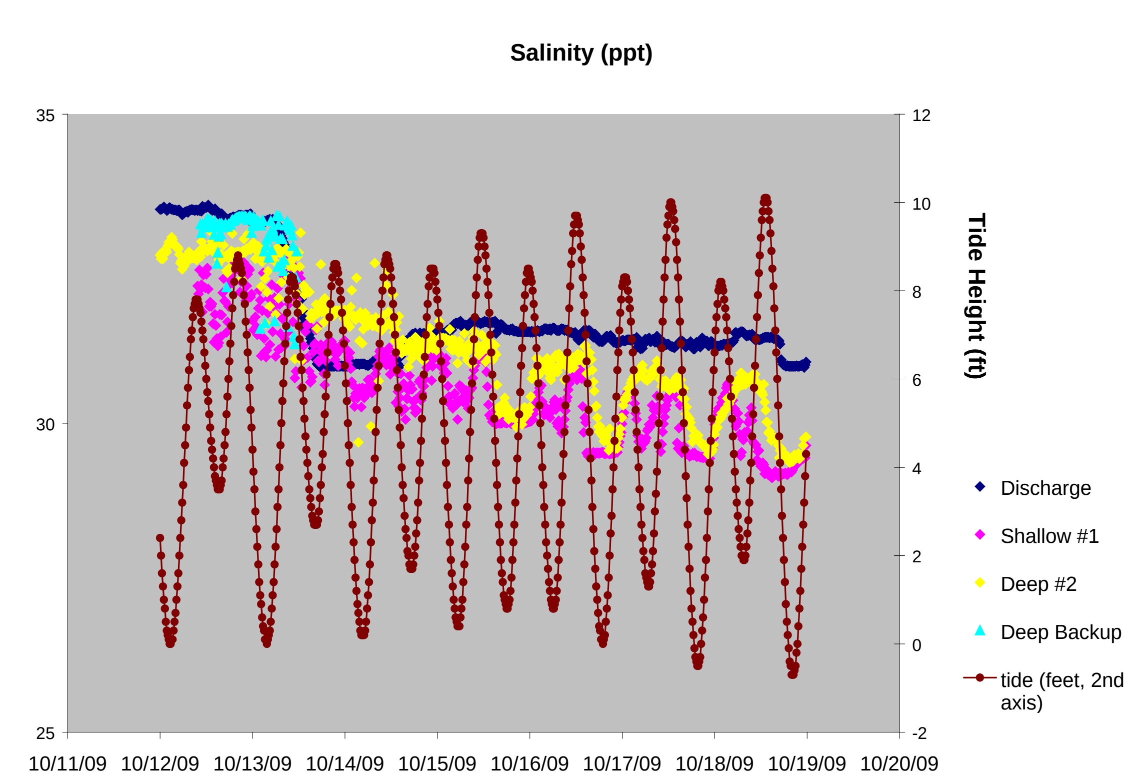

Figure 4.2-20: Pond A14 salinity values at 3 pond locations during 12 October – 18 October

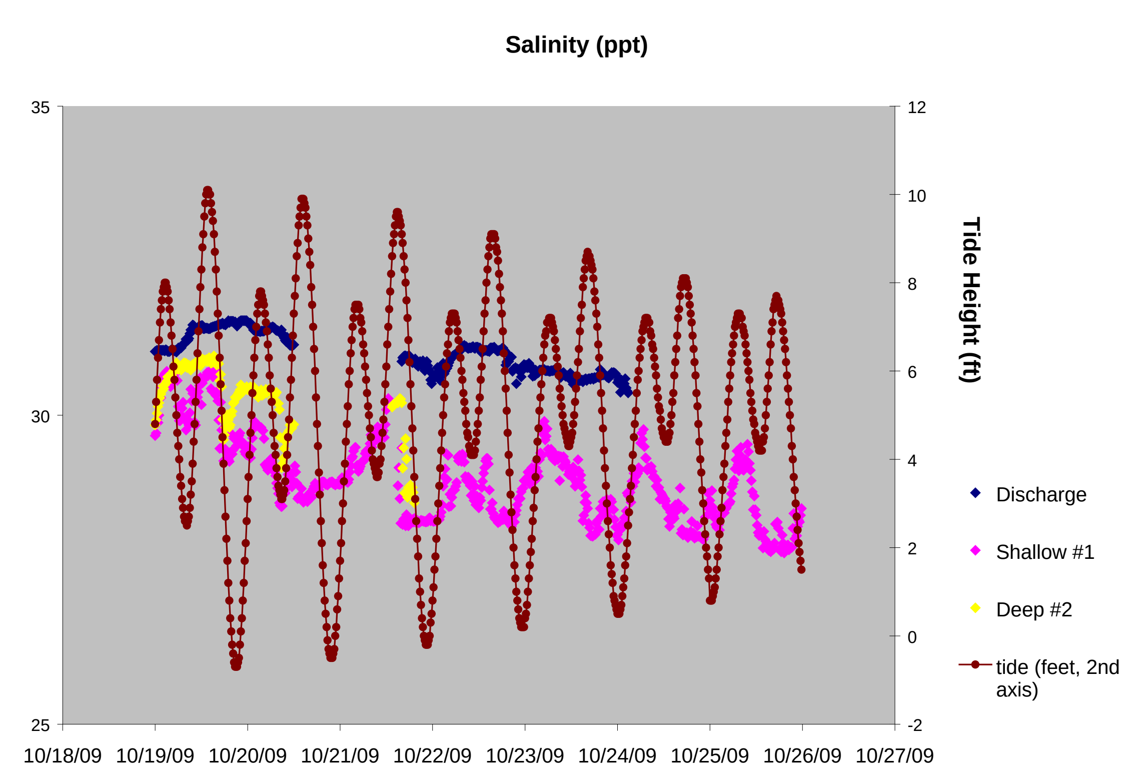

Figure 4.2-21. Pond A14 salinity values at 3 pond locations during 19 October – 25 October

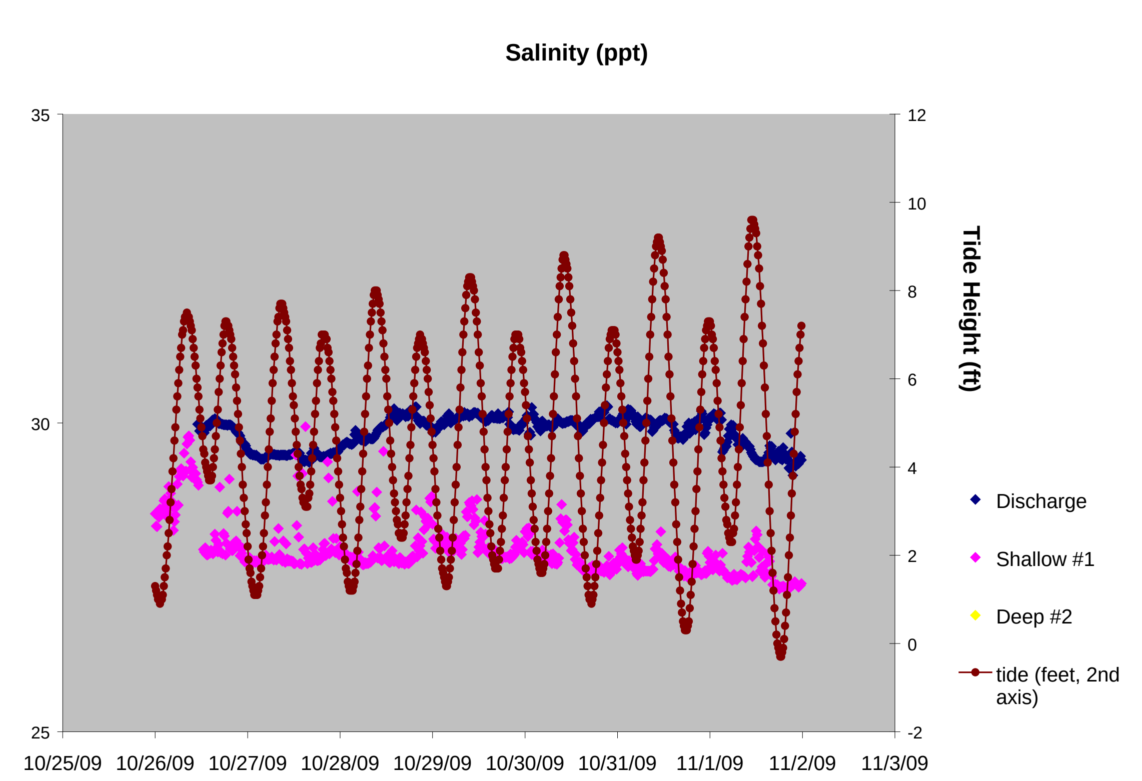

Figure 4.2-22: Pond A14 salinity values at 3 pond locations during 26 October – 1 November

4.3 PH

In Pond A14, pH ranged from 7.3 to 8.6 (Figures 4.3-1 through 4.3-22), except at the deep datasonde during the latter part of the sampling period. pH was cyclical throughout the study period, perhaps due to tidal influence, but pH values became more consistent after early October. Like salinity within Pond A14, the magnitude of pH minima and maxima at the discharge location was less intense than at the other two locations. We found that the highest values in pH were generally logged at discharge waters and lowest values were recorded at the intake pond locations. However, based on equipment records, we believe that the low pH values for the deep location from 5 October through the end of the sampling period was due to equipment failure.

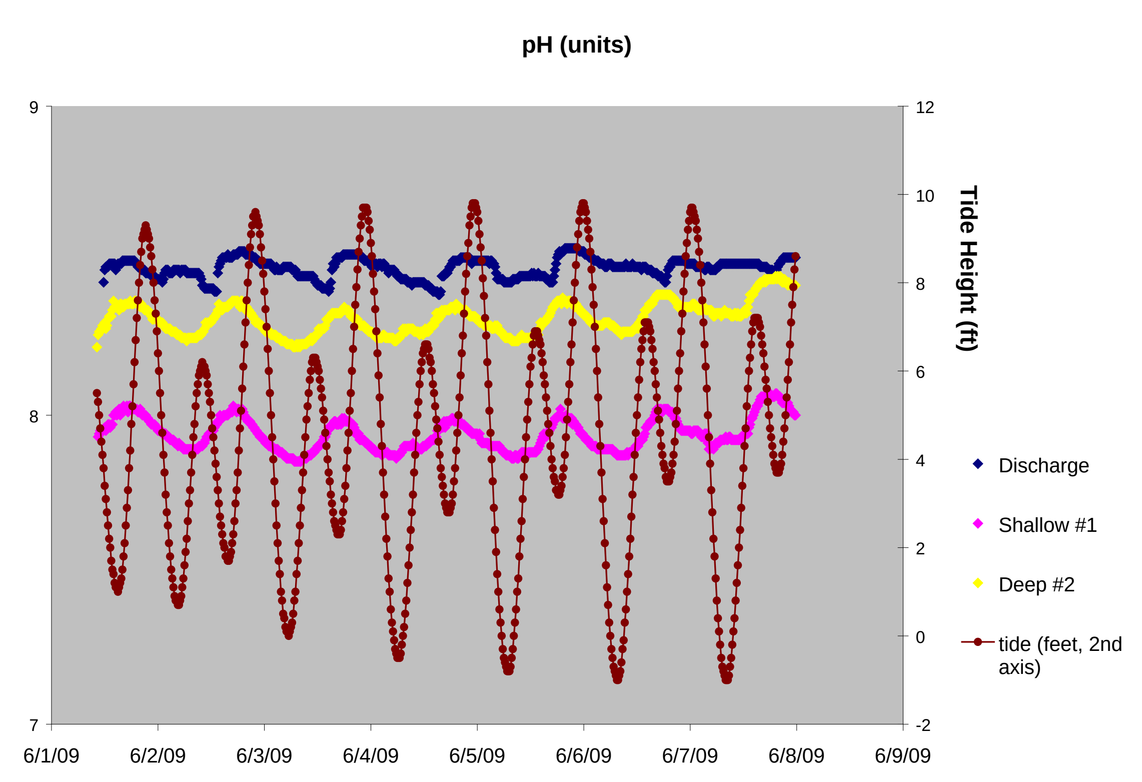

Figure 4.3-1: Pond A14 pH values at 3 pond locations during 1 June – 7 June

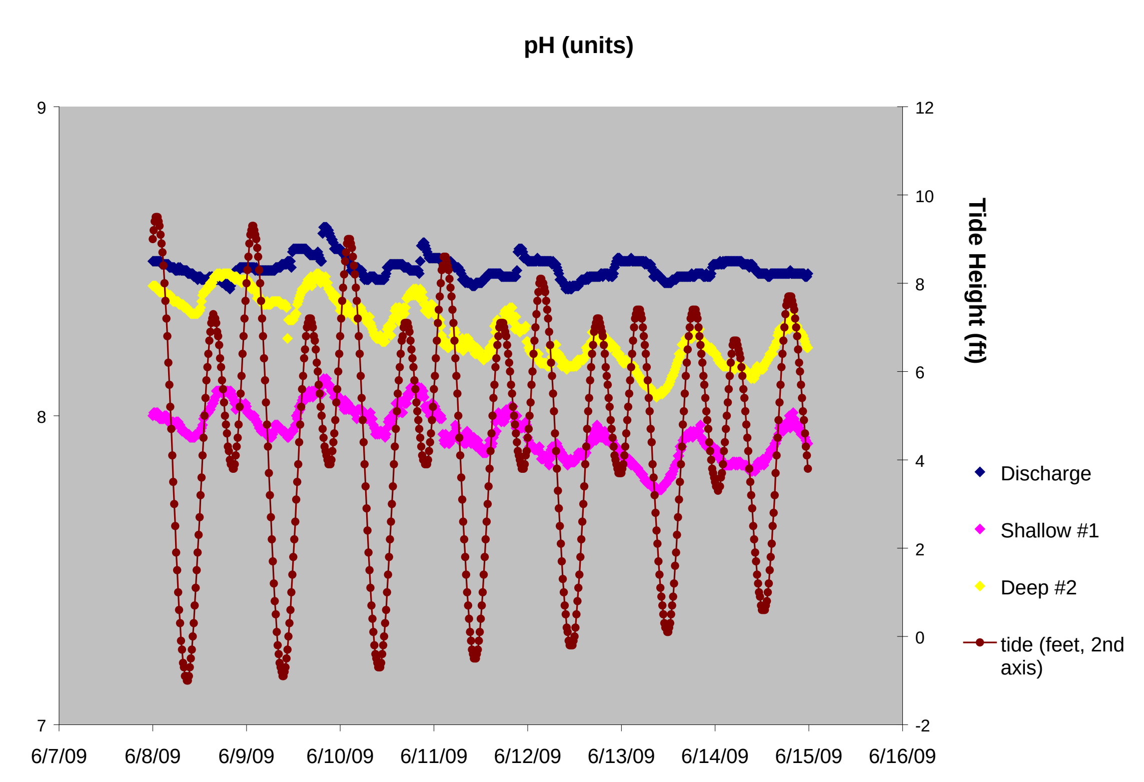

Figure 4.3-2: Pond A14 pH values at 3 pond locations during 8 June – 14 June 2009.

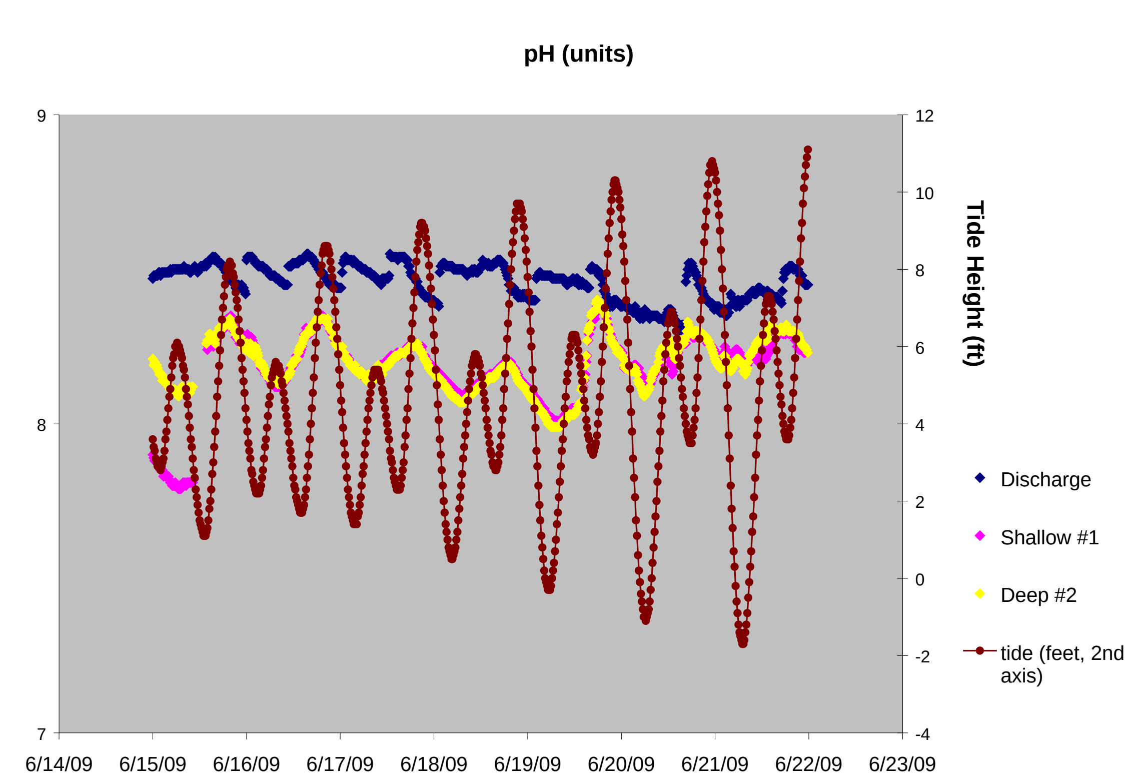

Figure 4.3-3: Pond A14 pH values at 3 pond locations during 15 June – 21 June

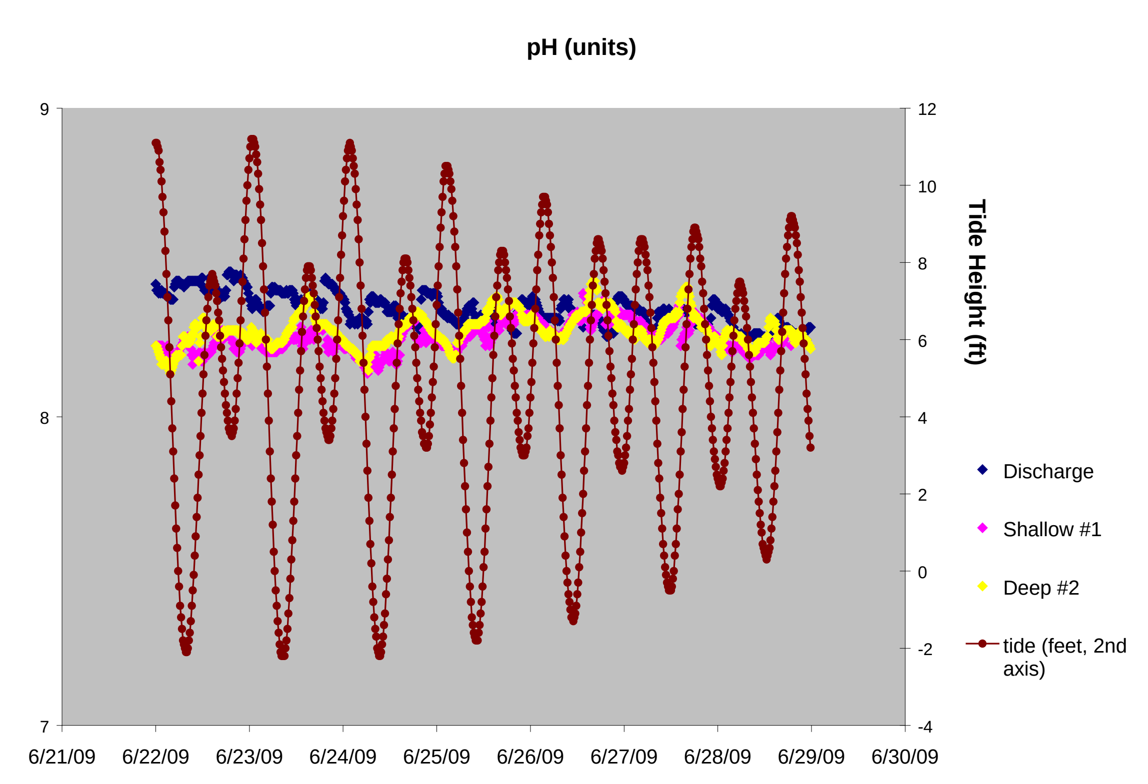

Figure 4.3-4: Pond A14 pH values at 3 pond locations during 22 June – 28 June

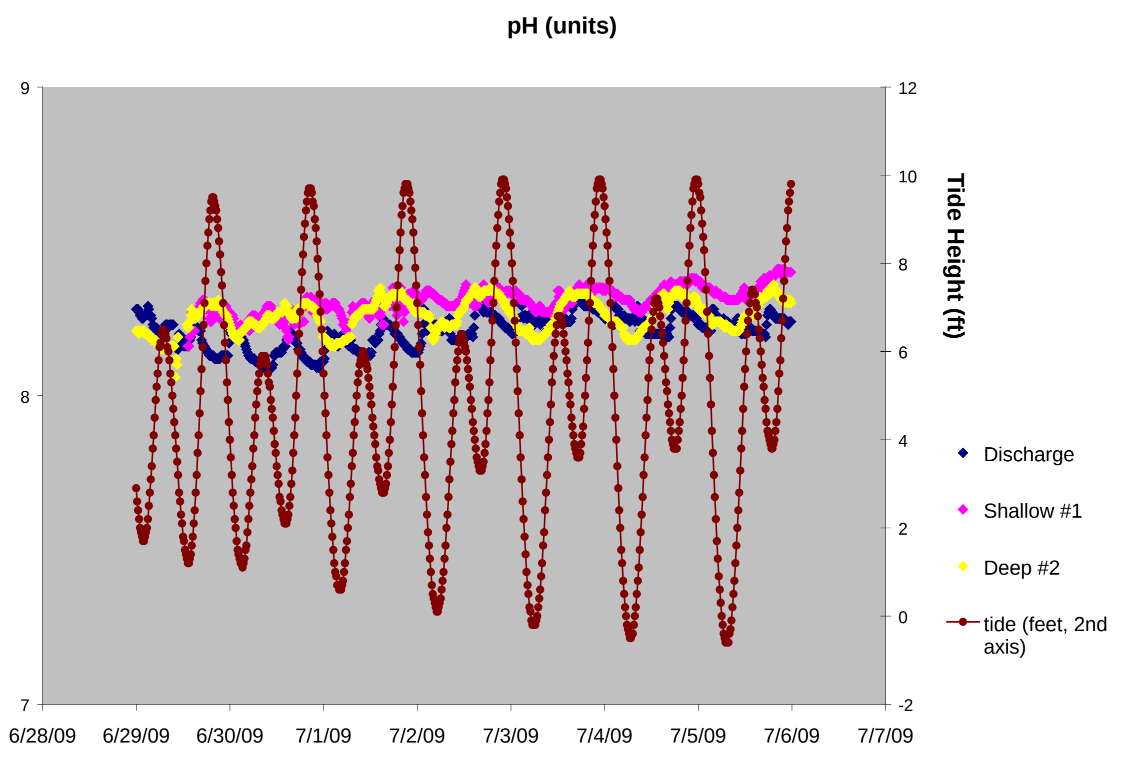

Figure 4.3-5: Pond A14 pH values at 3 pond locations during 29 June – 5 July

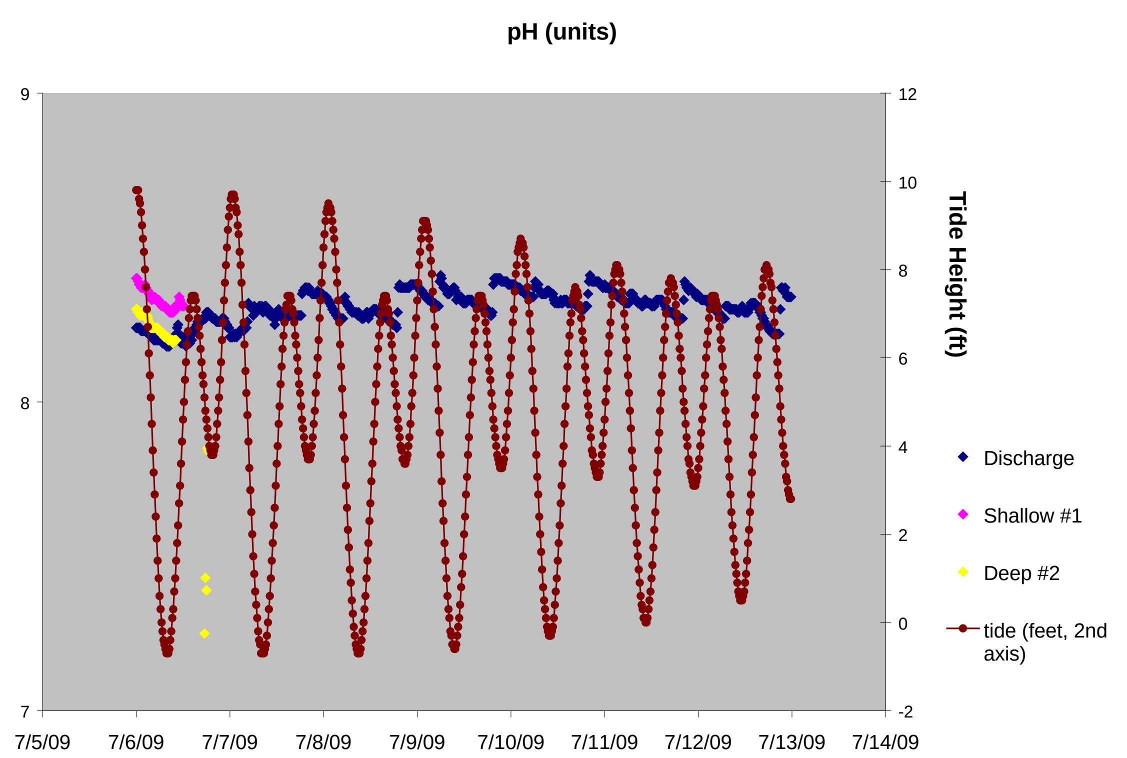

Figure 4.3-6: Pond A14 pH values at 3 pond locations during 6 July – 12 July

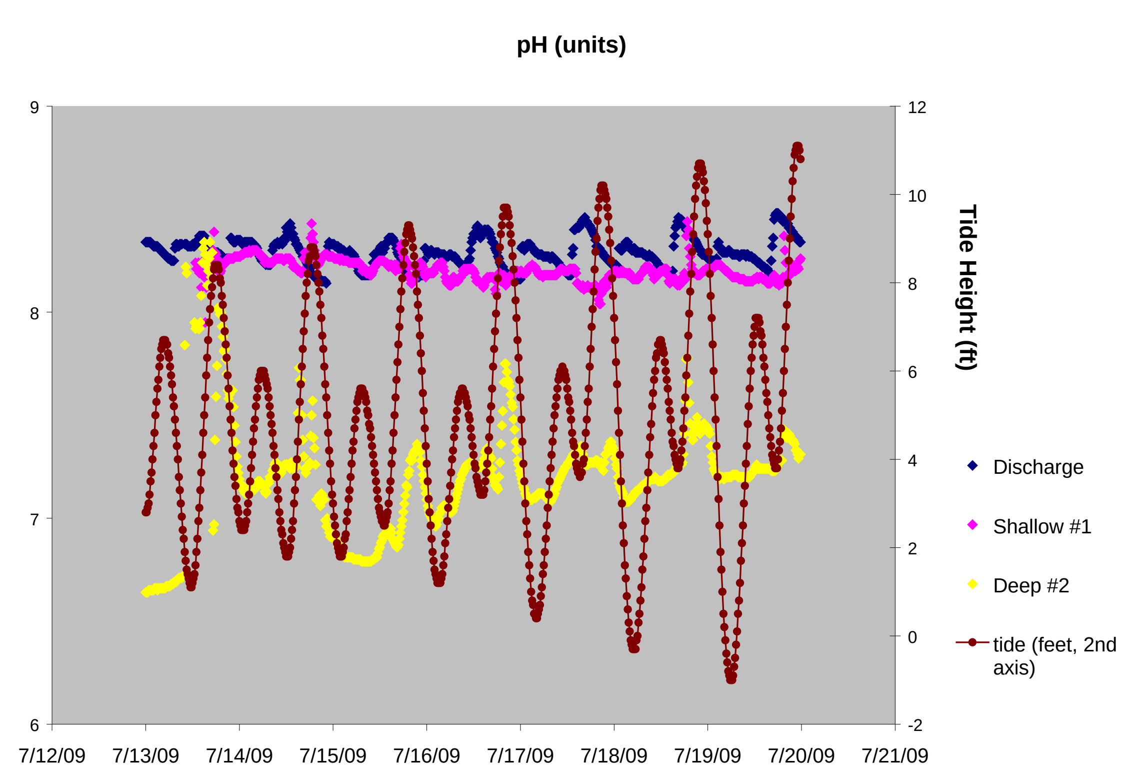

Figure 4.3-7: Pond A14 pH values at 3 pond locations during 13 July – 19 July

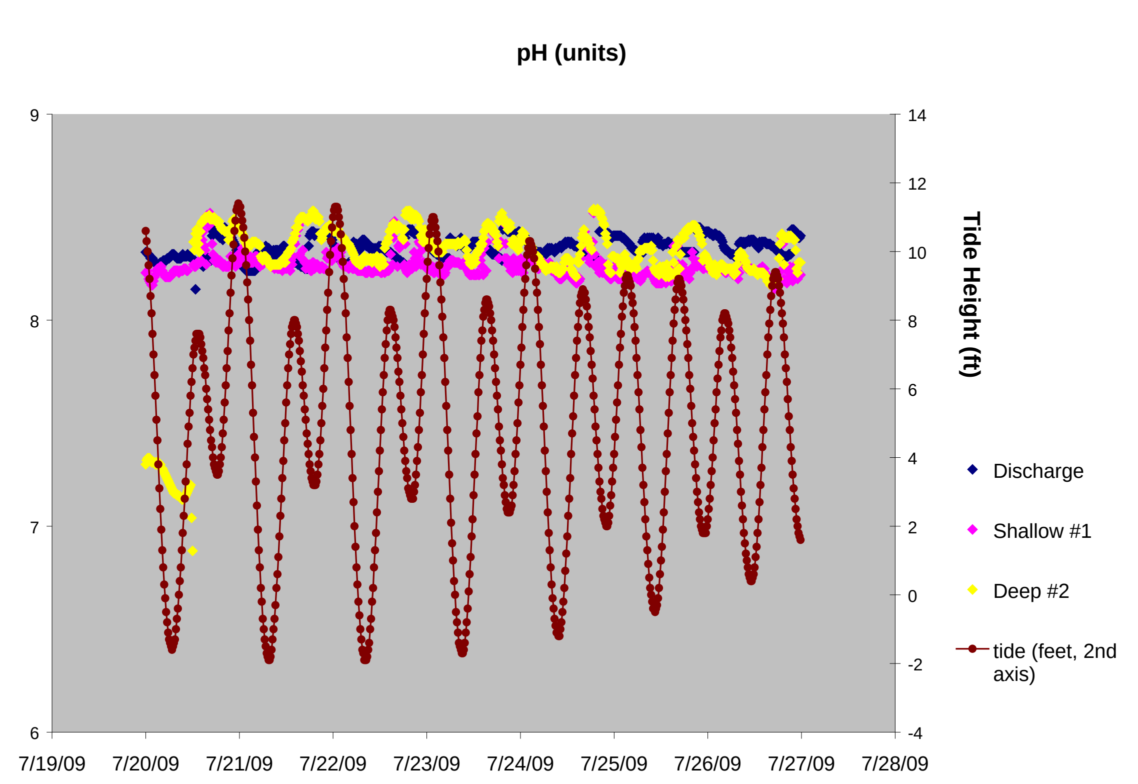

Figure 4.3-8: Pond A14 pH values at 3 pond locations during 20 July – 26 July

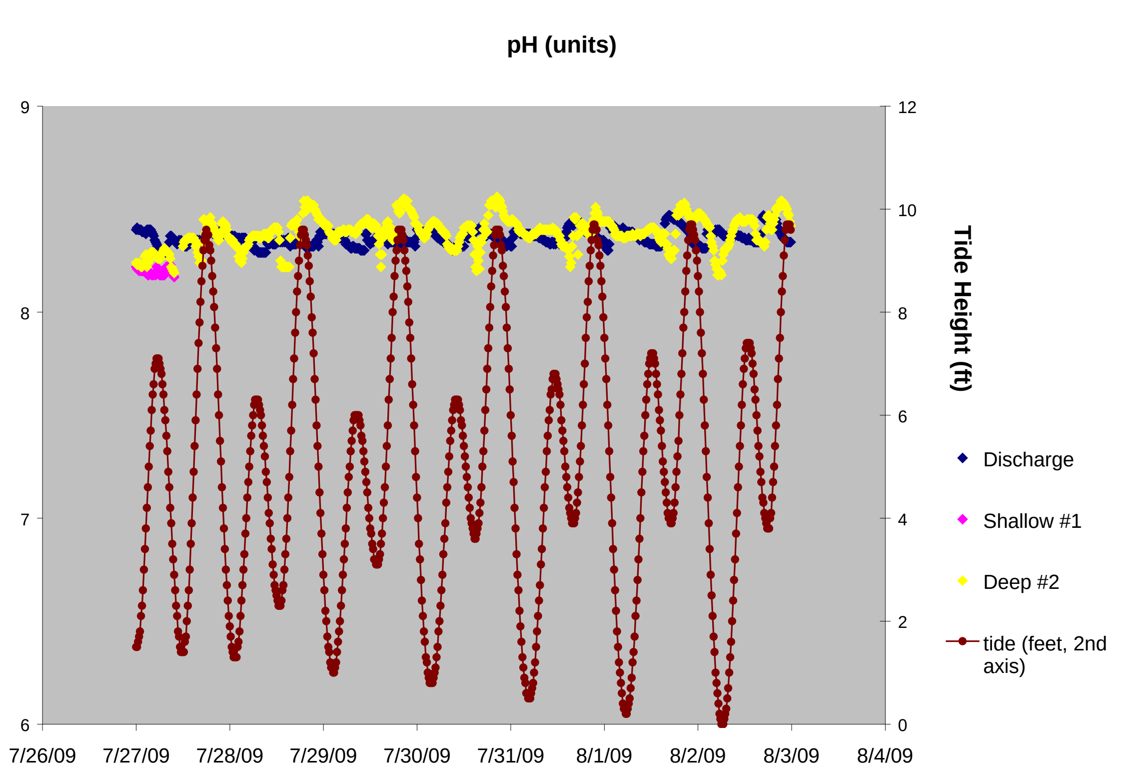

Figure 4.3-9: Pond A14 pH values at 3 pond locations during 27 July – 2 August

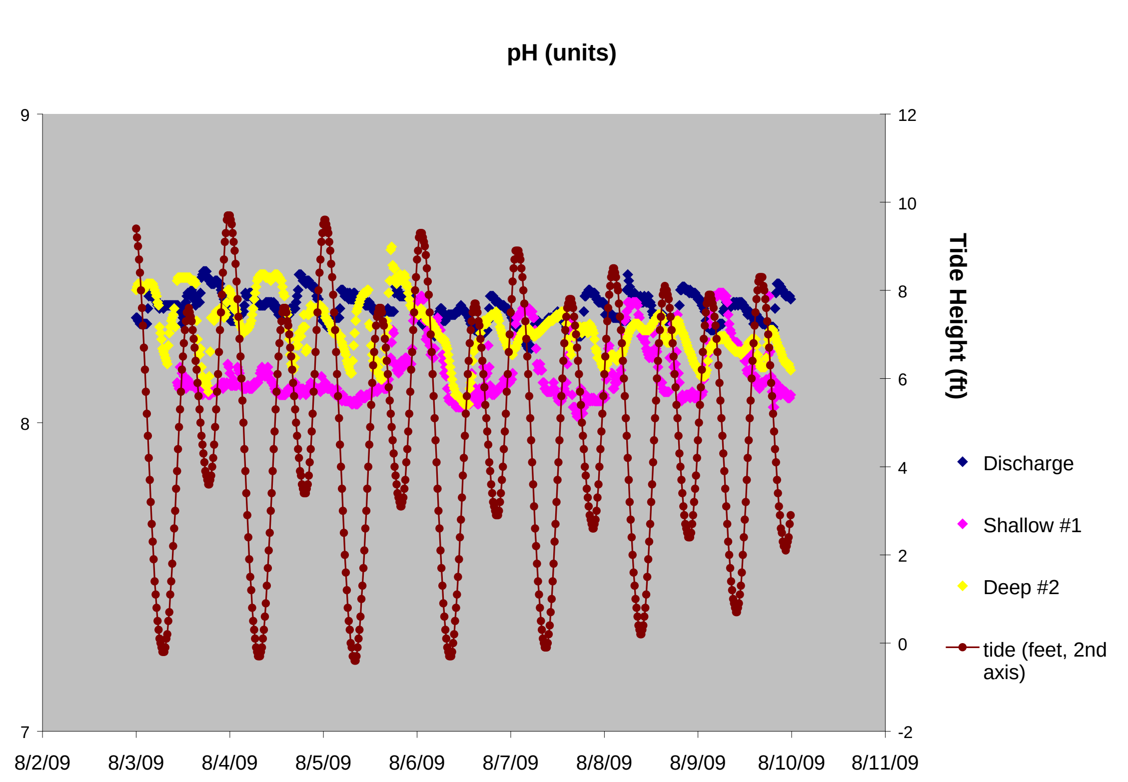

Figure 4.3-10: Pond A14 pH values at 3 pond locations during 3 August – 9 August

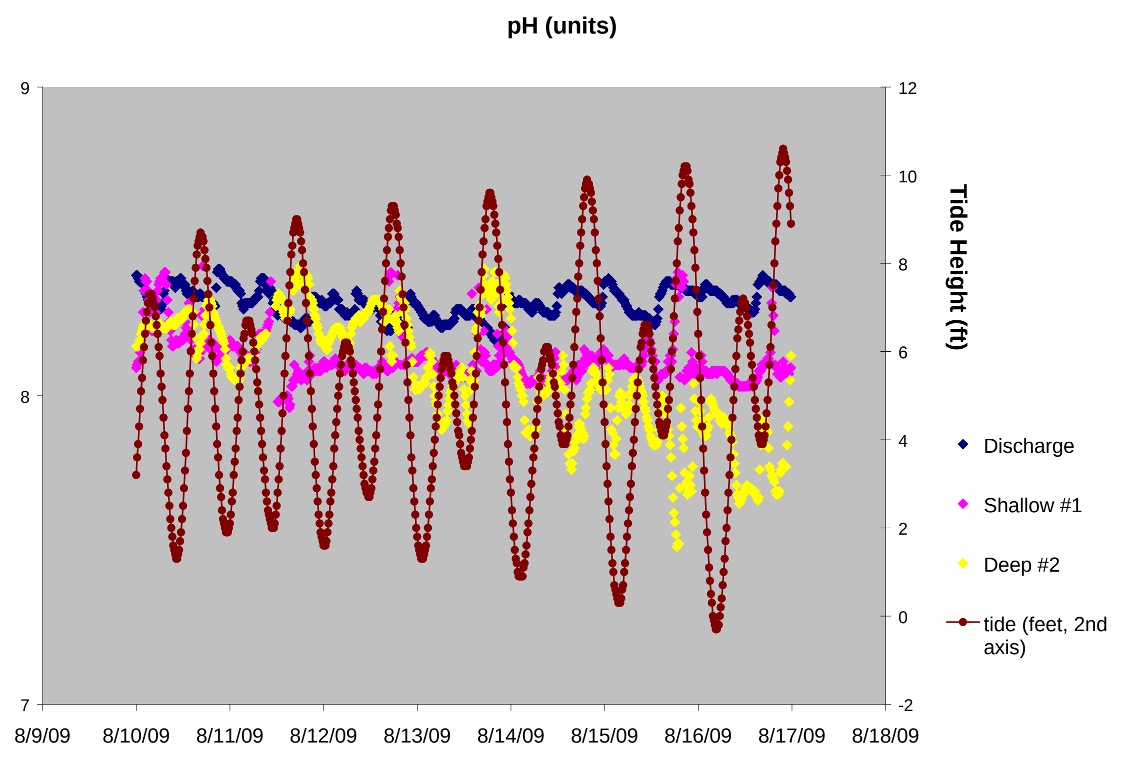

Figure 4.3-11: Pond A14 pH values at 3 pond locations during 10 August – 16 August

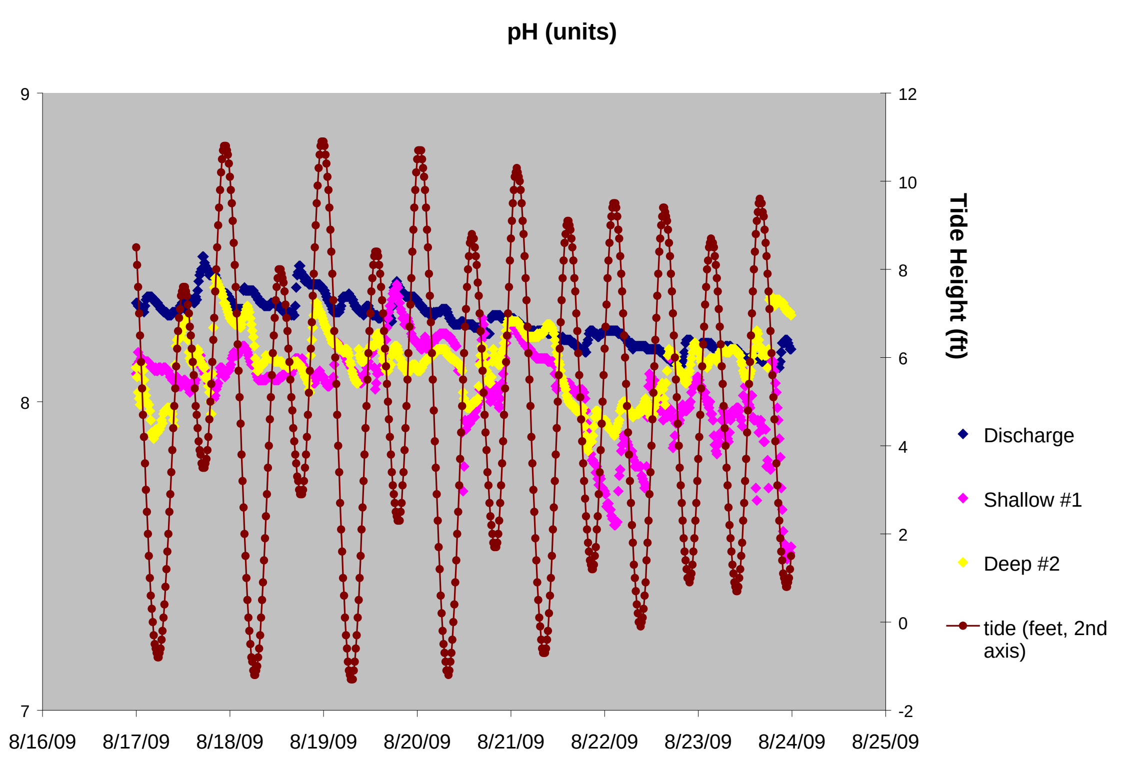

Figure 4.3-12: Pond A14 pH values at 3 pond locations during 17 August – 23 August

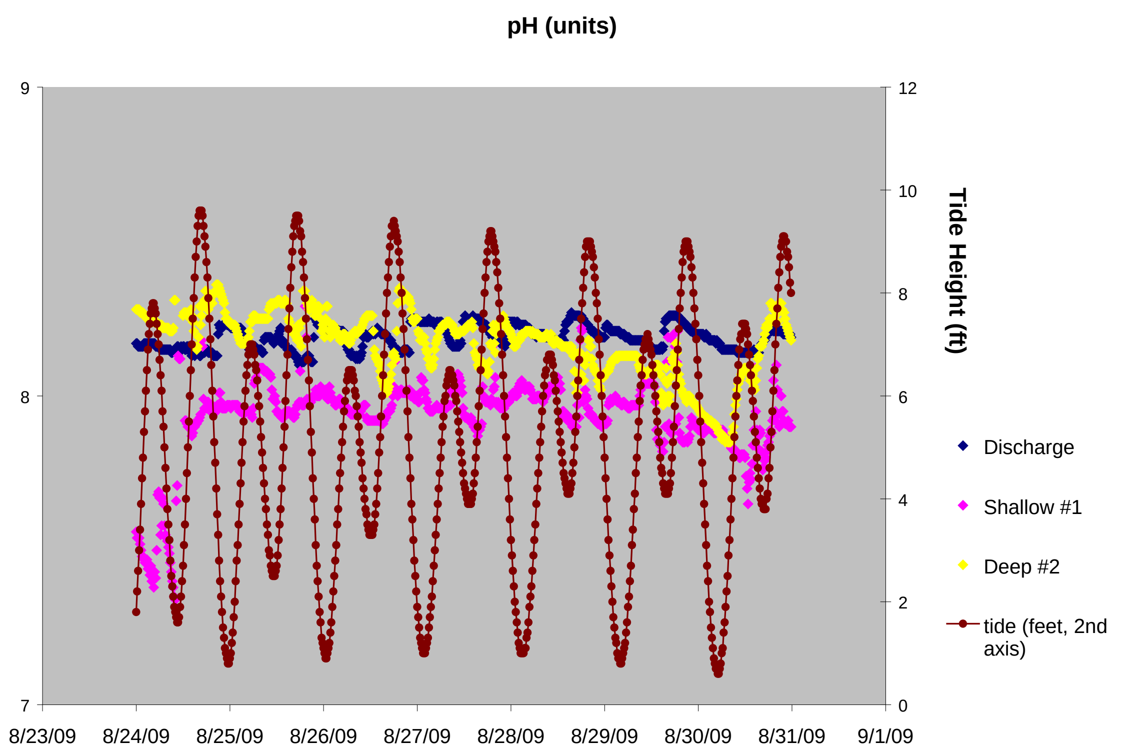

Figure 4.3-13: Pond A14 pH values at 3 pond locations during 24 August – 30 August

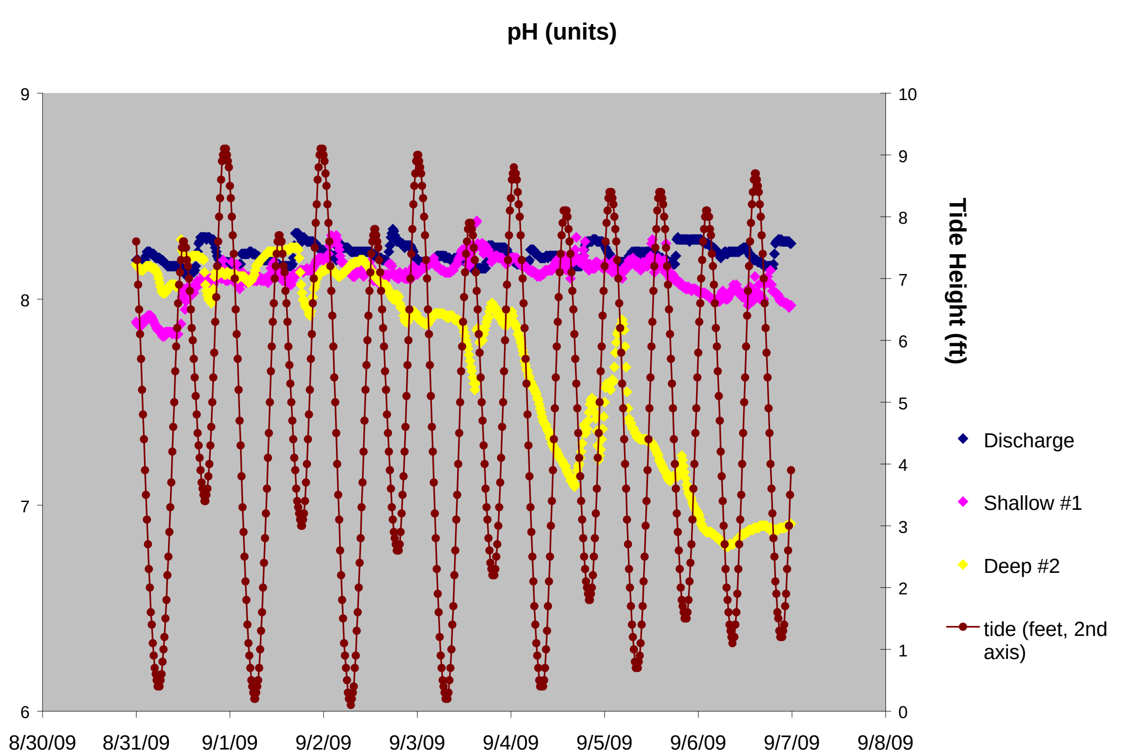

Figure 4.3-14: Pond A14 pH values at 3 pond locations during 31 August – 6 September

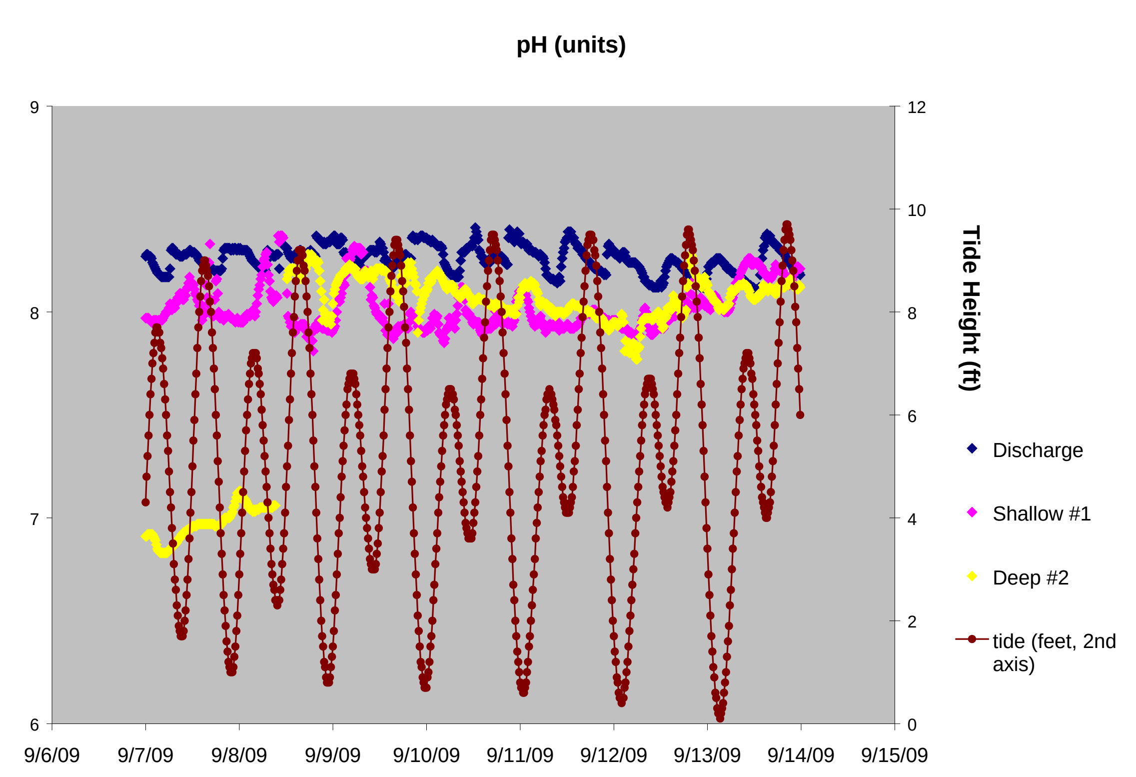

Figure 4.3-15: Pond A14 pH values at 3 pond locations during 7 September – 13 September

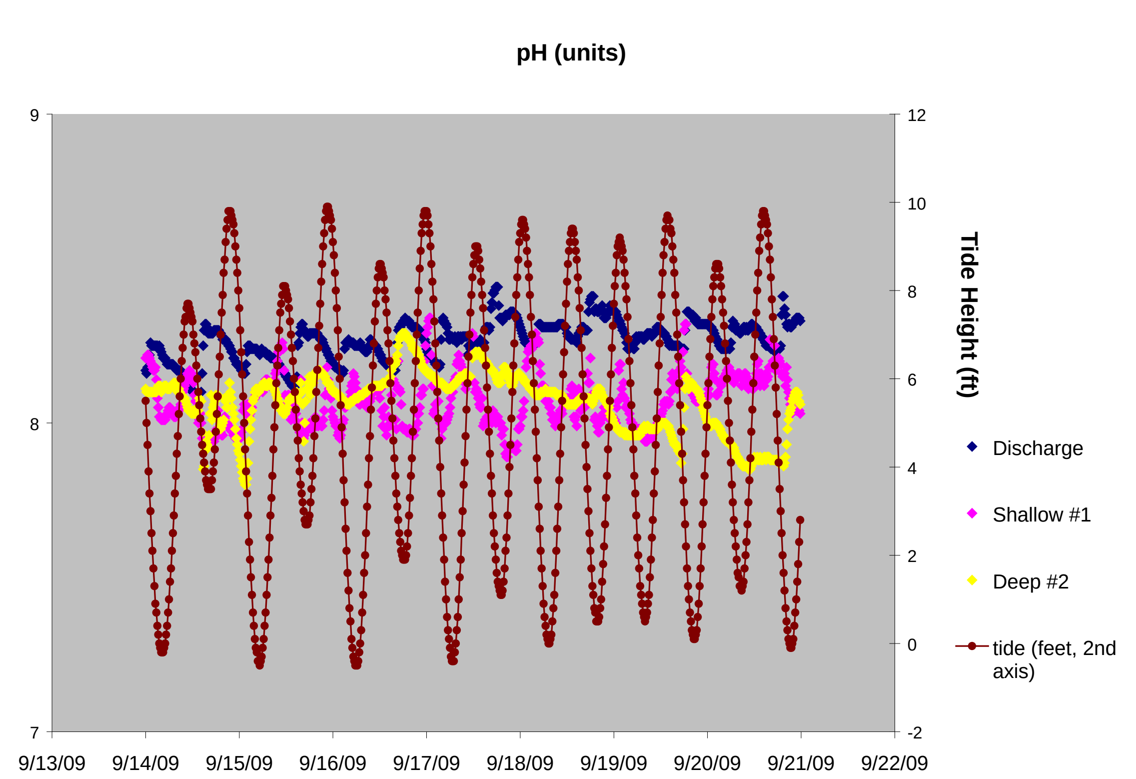

Figure 4.3-16: Pond A14 pH values at 3 pond locations during 14 September – 20 September

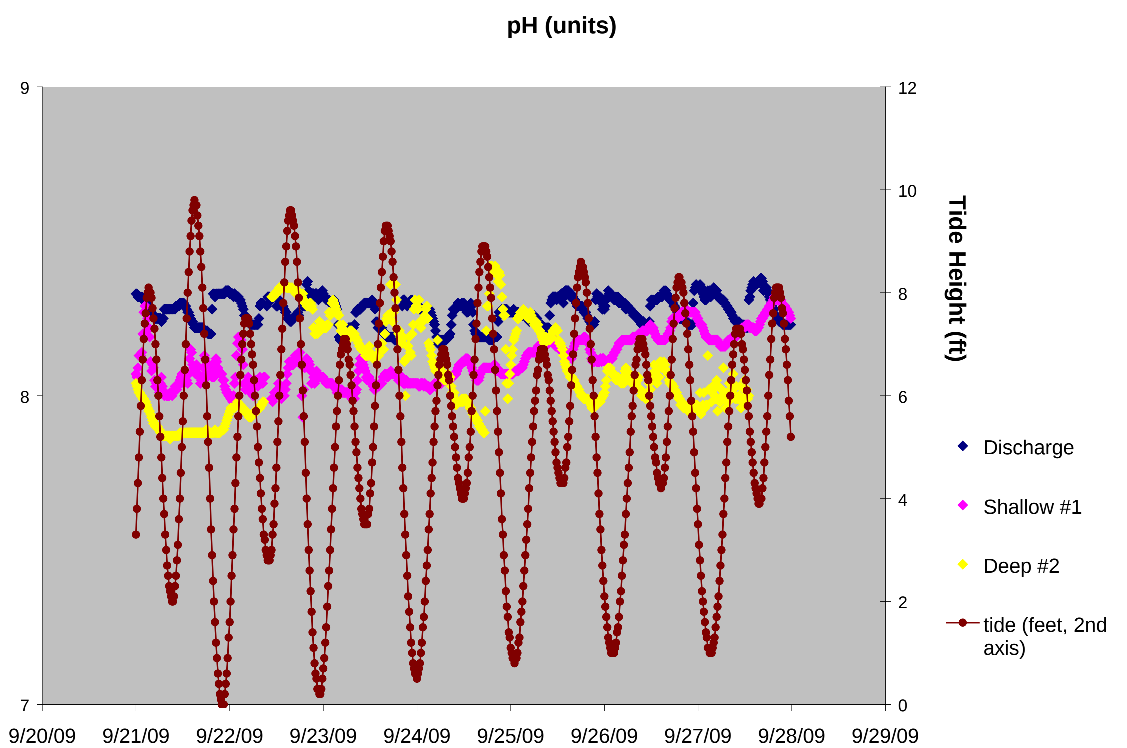

Figure 4.3-17: Pond A14 pH values at 3 pond locations during 21 September – 27 September

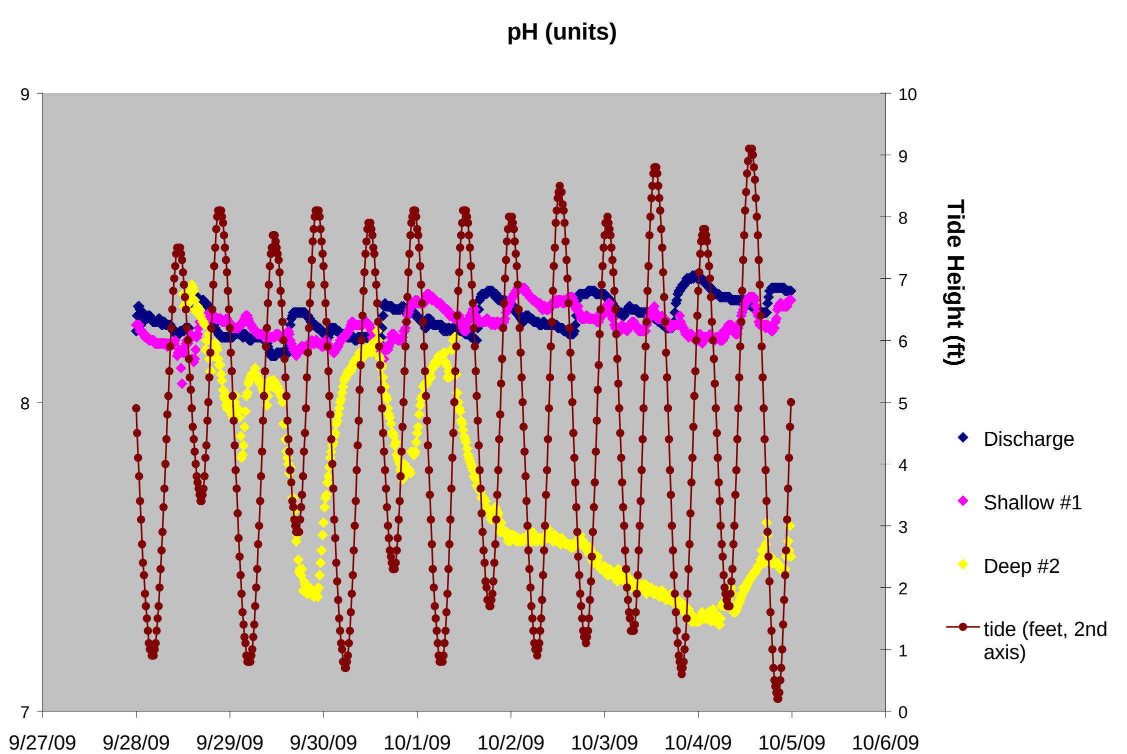

Figure 4.3-18: Pond A14 pH values at 3 pond locations during 28 September – 4 October

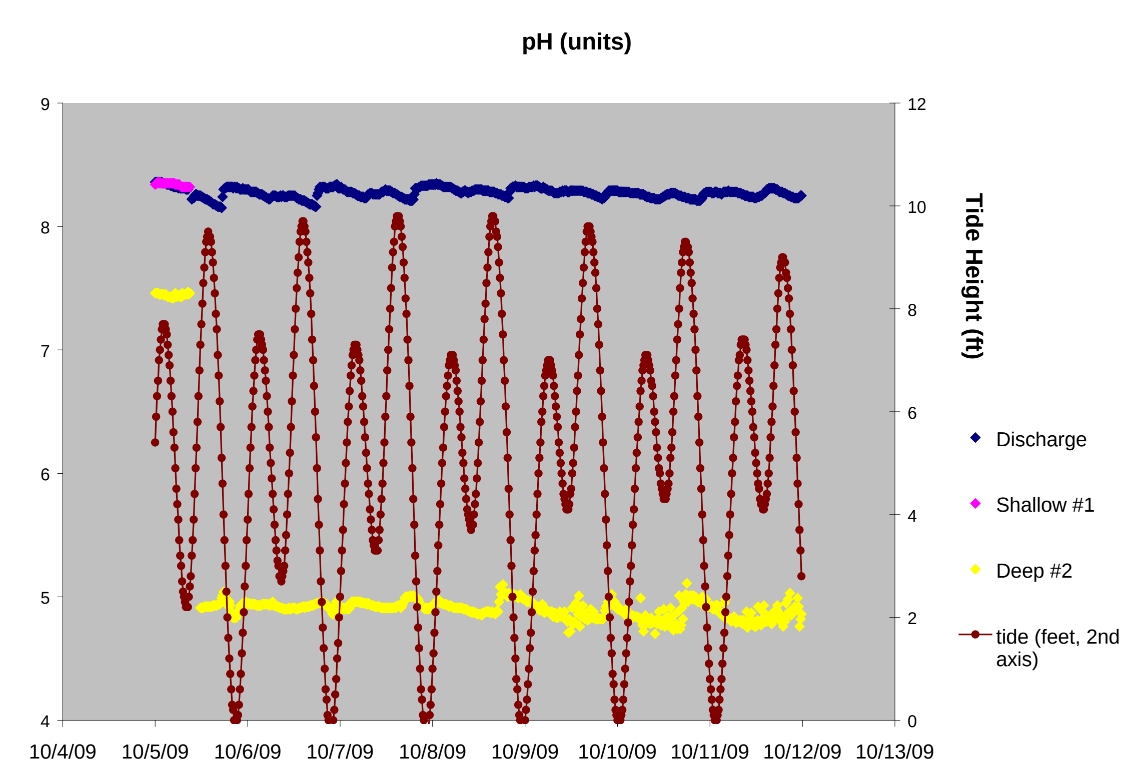

Figure 4.3-19: Pond A14 pH values at 3 pond locations during 5 October – 11 October

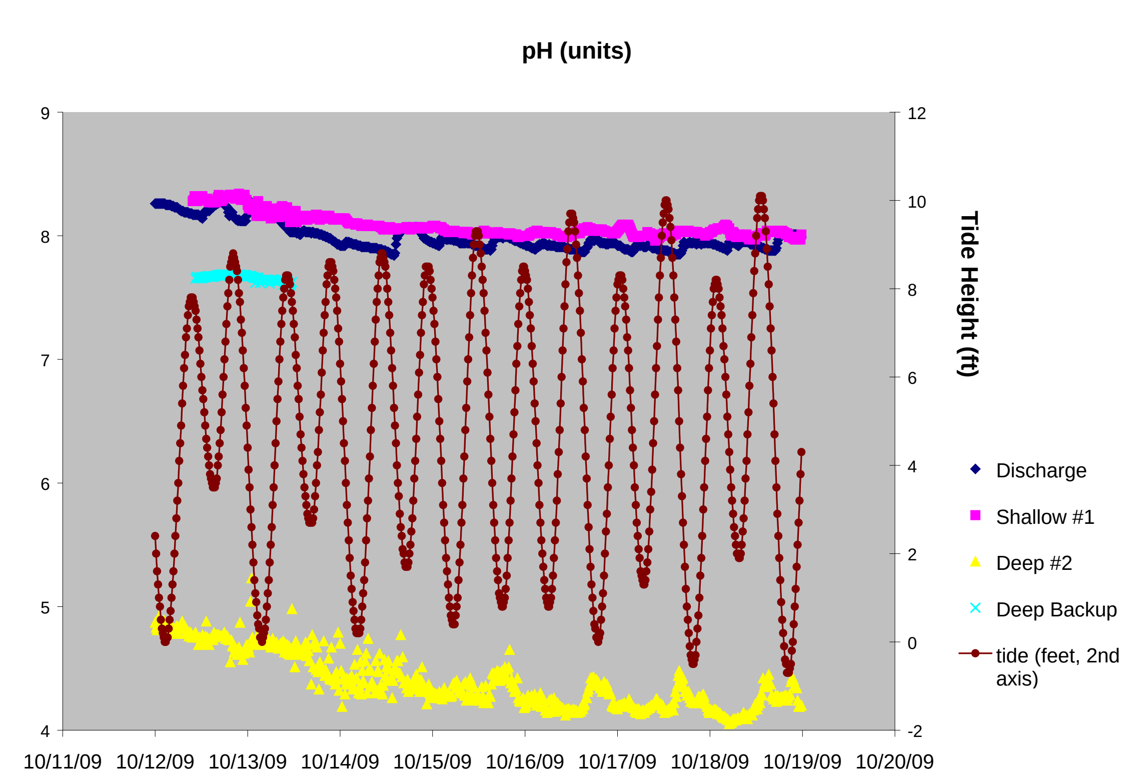

Figure 4.3-20: Pond A14 pH values at 3 pond locations during 12 October – 18 October

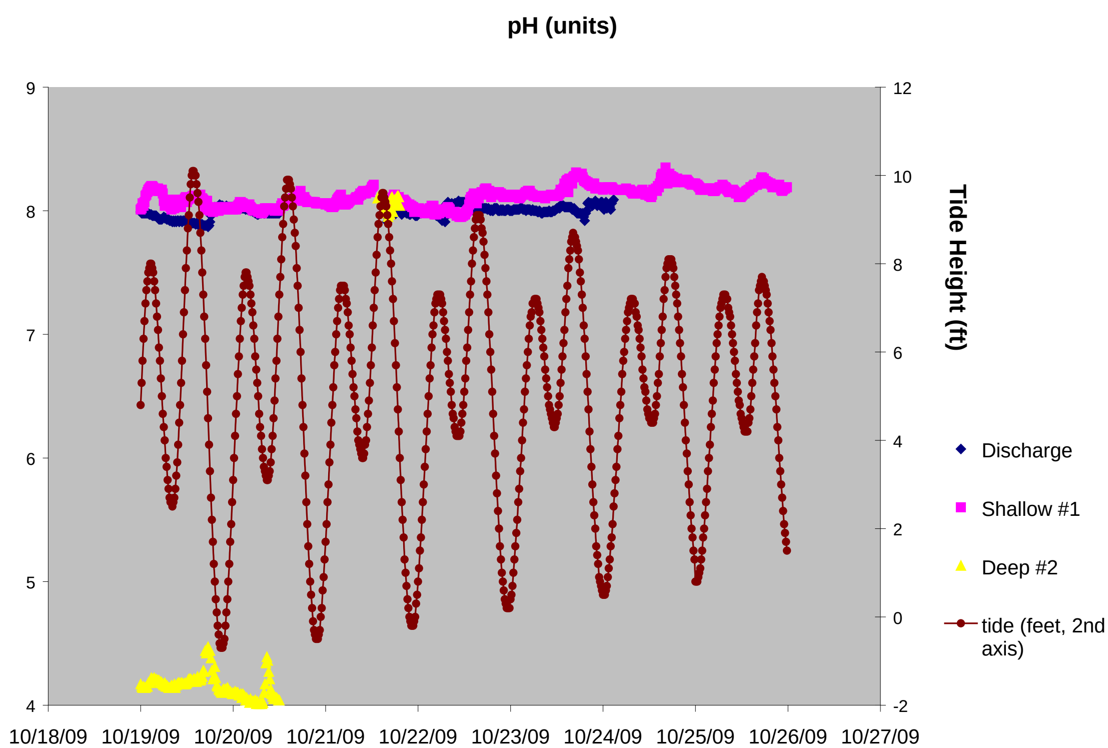

Figure 4.3-21: Pond A14 pH values at 3 pond locations during 19 October – 25 October

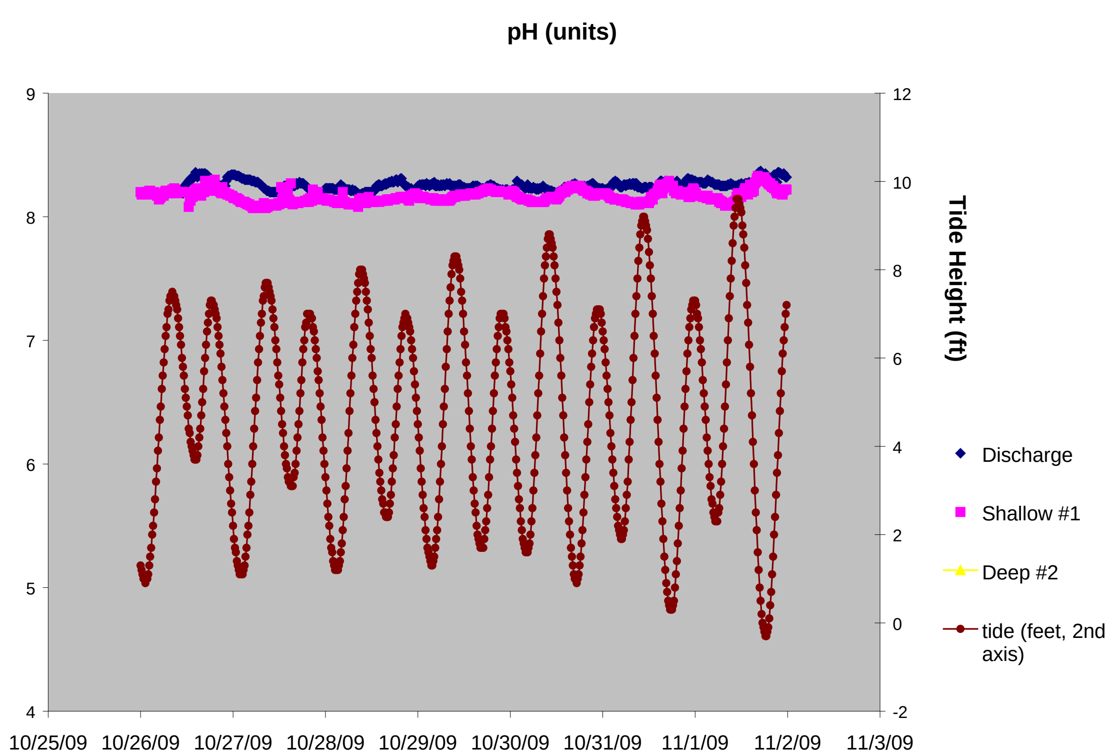

Figure 4.3-22: Pond A14 pH values at 3 pond locations during 26 October – 1 November

4.4 TEMPERATURE

Tidal influence on temperature values within Pond A14 was seen throughout the study but was most obvious early in the season (Figures 4.4-1 through 4.4-22). Temperature fluctuations become less intense during September and October, in which, solar radiation values and average monthly temperatures fell. Large patterns of temperature variation across days were likely related with changes in ambient temperature.

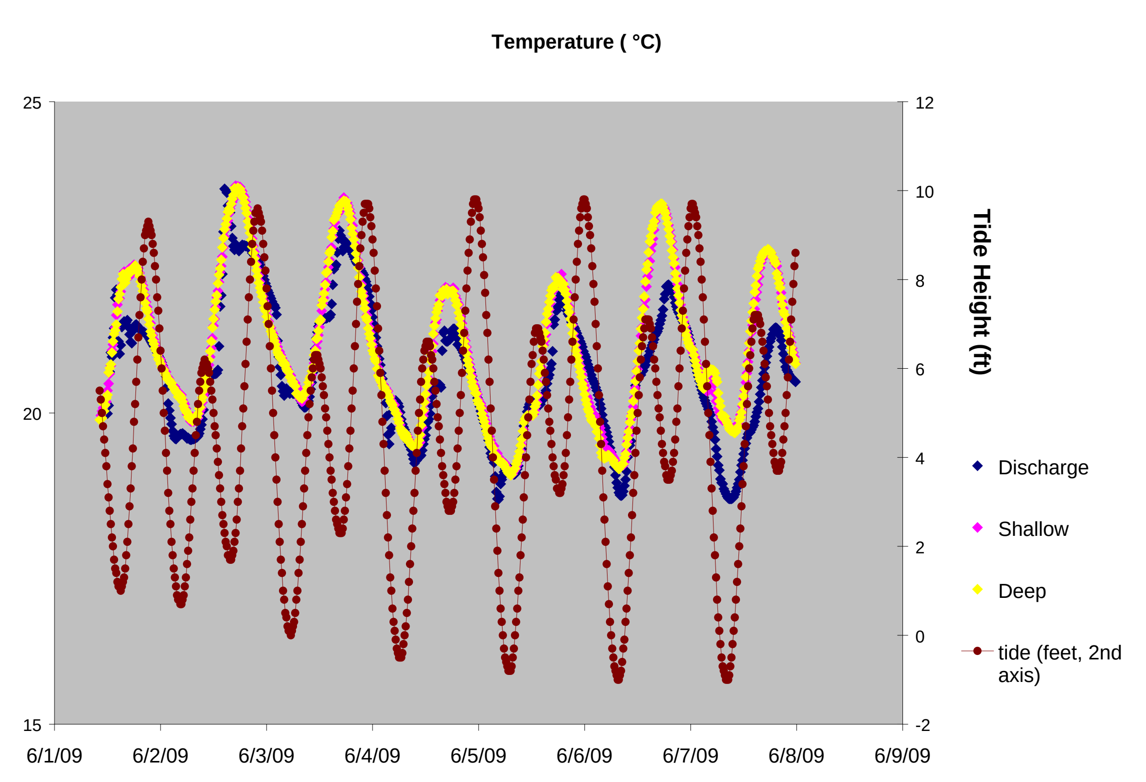

Figure 4.4-1: Pond A14 temperature values at 3 pond locations during 1 June – 7 June

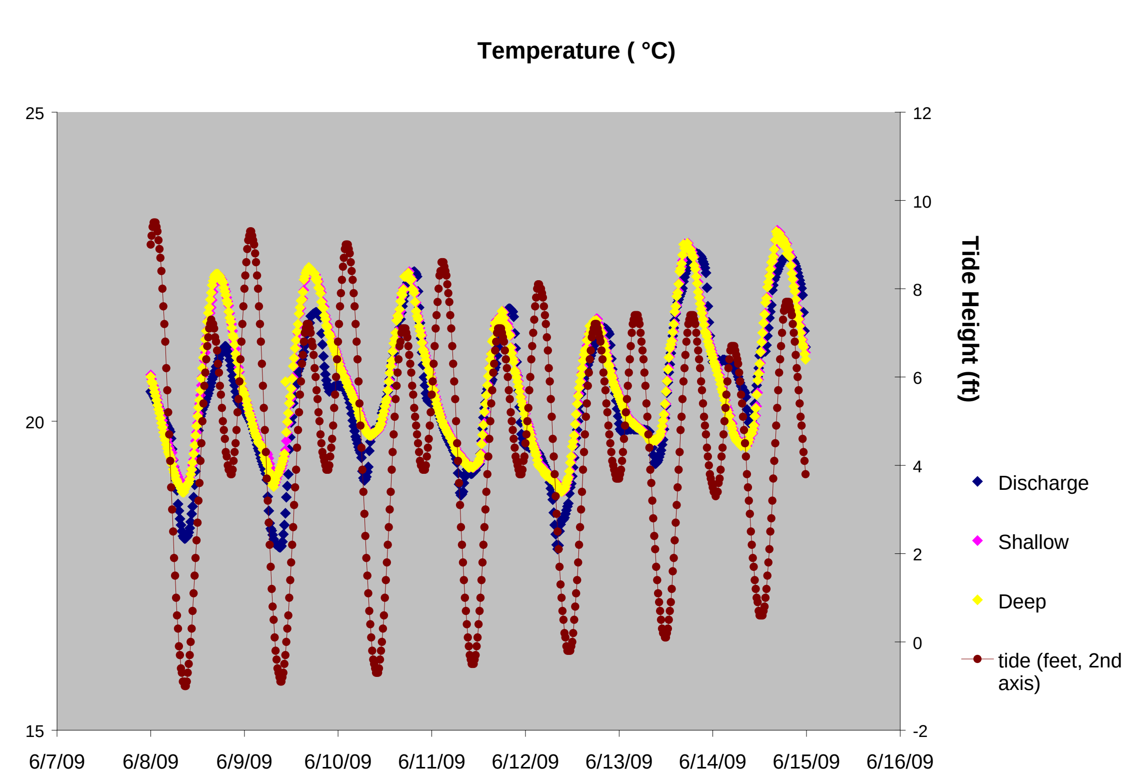

Figure 4.4-2: Pond A14 temperature values at 3 pond locations during 8 June – 14 June

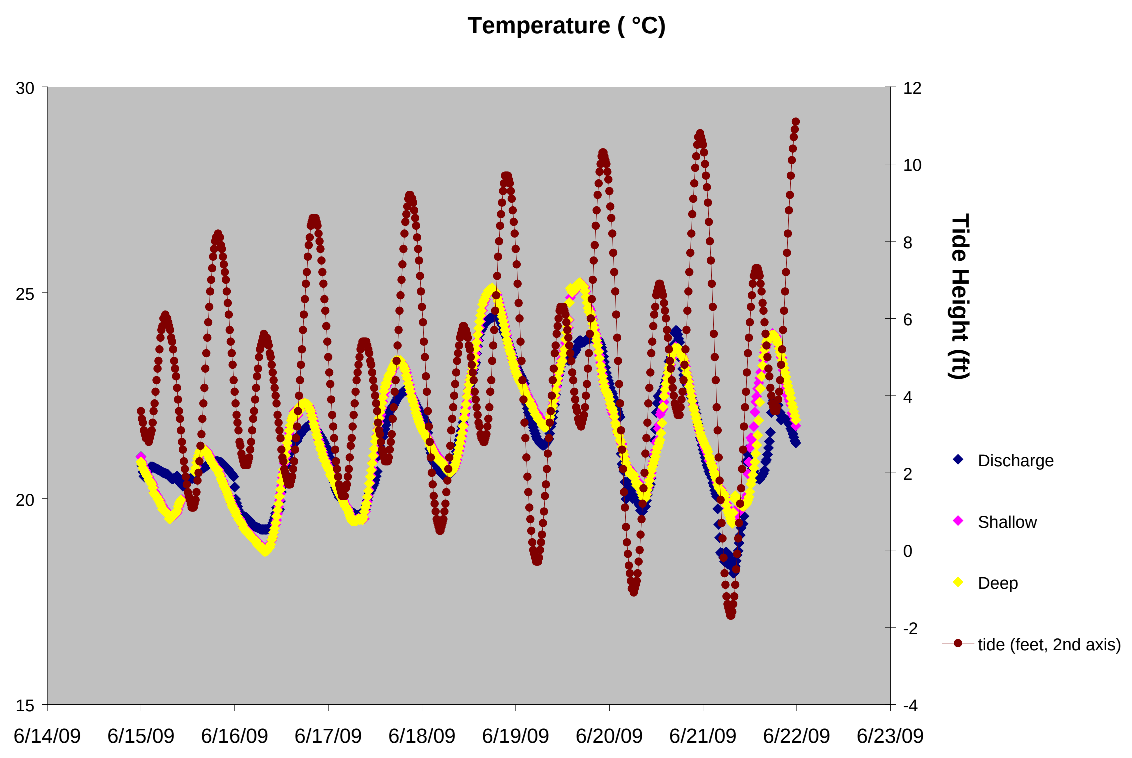

Figure 4.4-3: Pond A14 temperature values at 3 pond locations during 15 June – 21 June

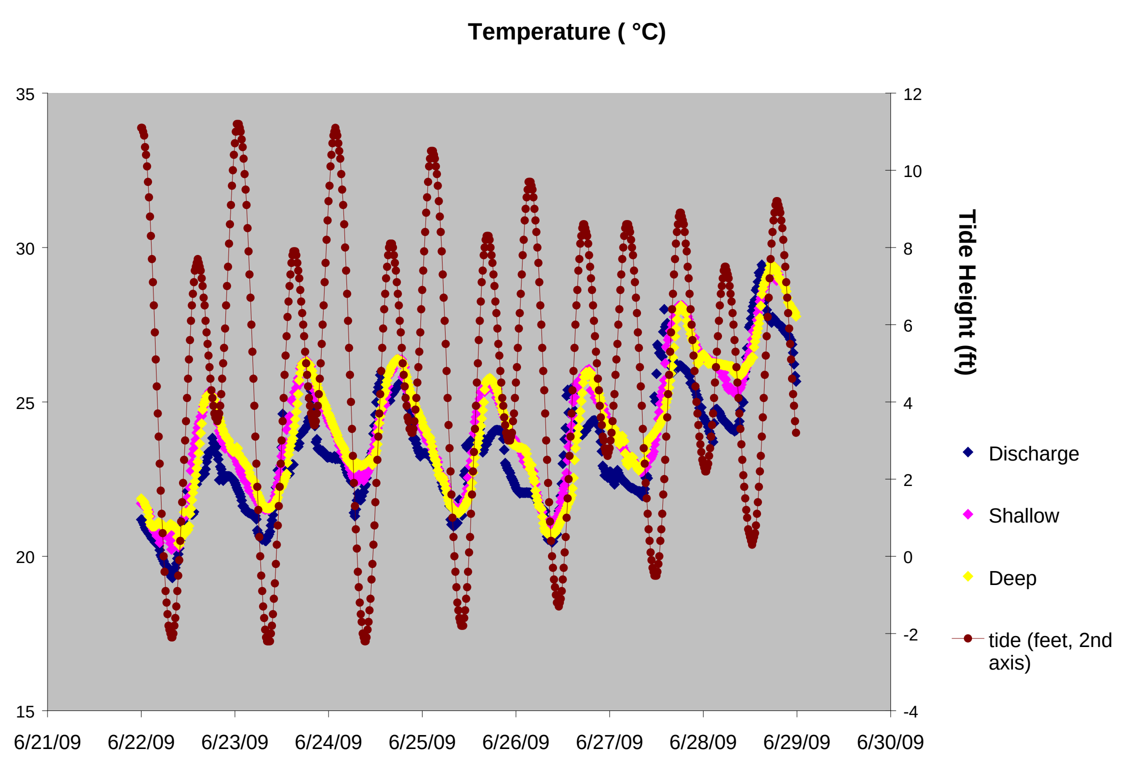

Figure 4.4-4: Pond A14 temperature values at 3 pond locations during 22 June – 28 June

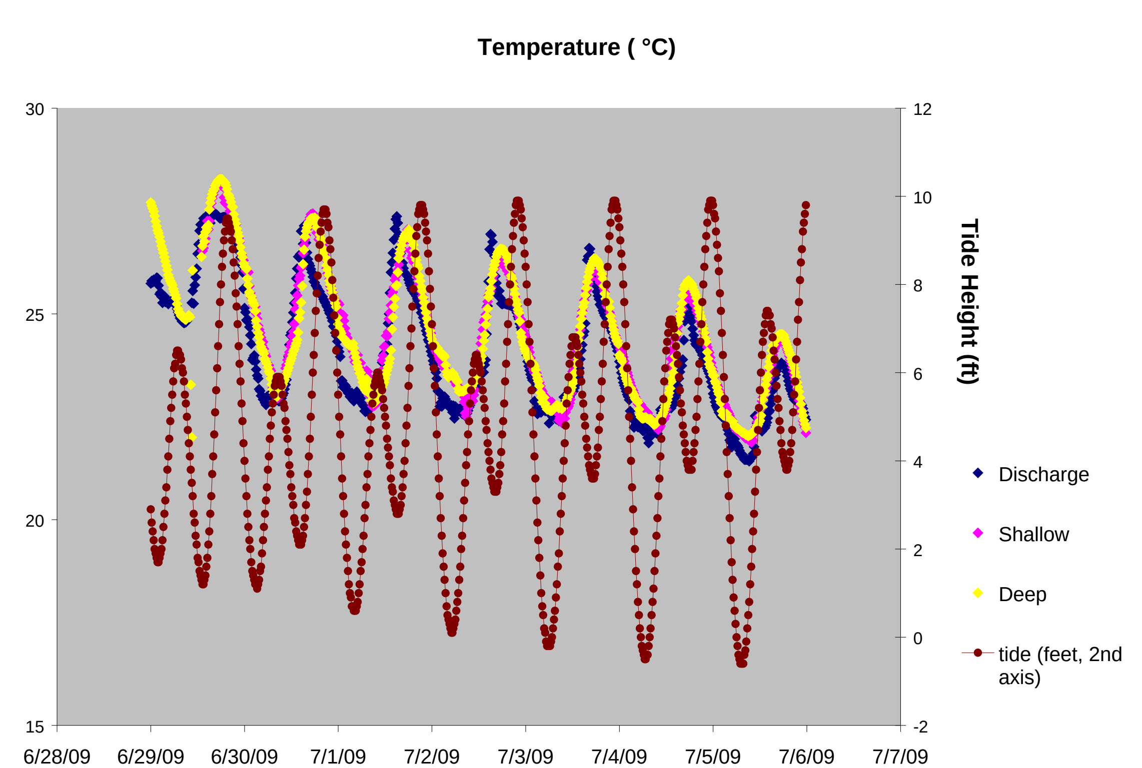

Figure 4.4-5: Pond A14 temperature values at 3 pond locations during 29 June – 5 July

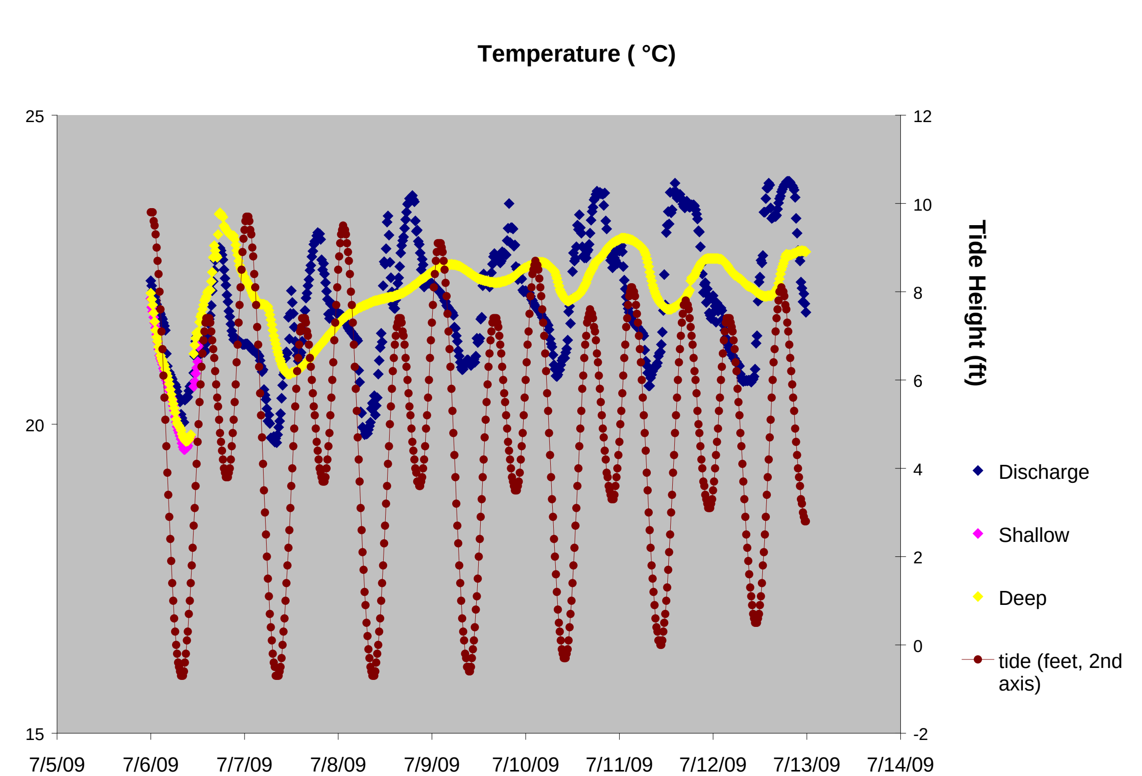

Figure 4.4-6: Pond A14 temperature values at 3 pond locations during 6 July – 12 July

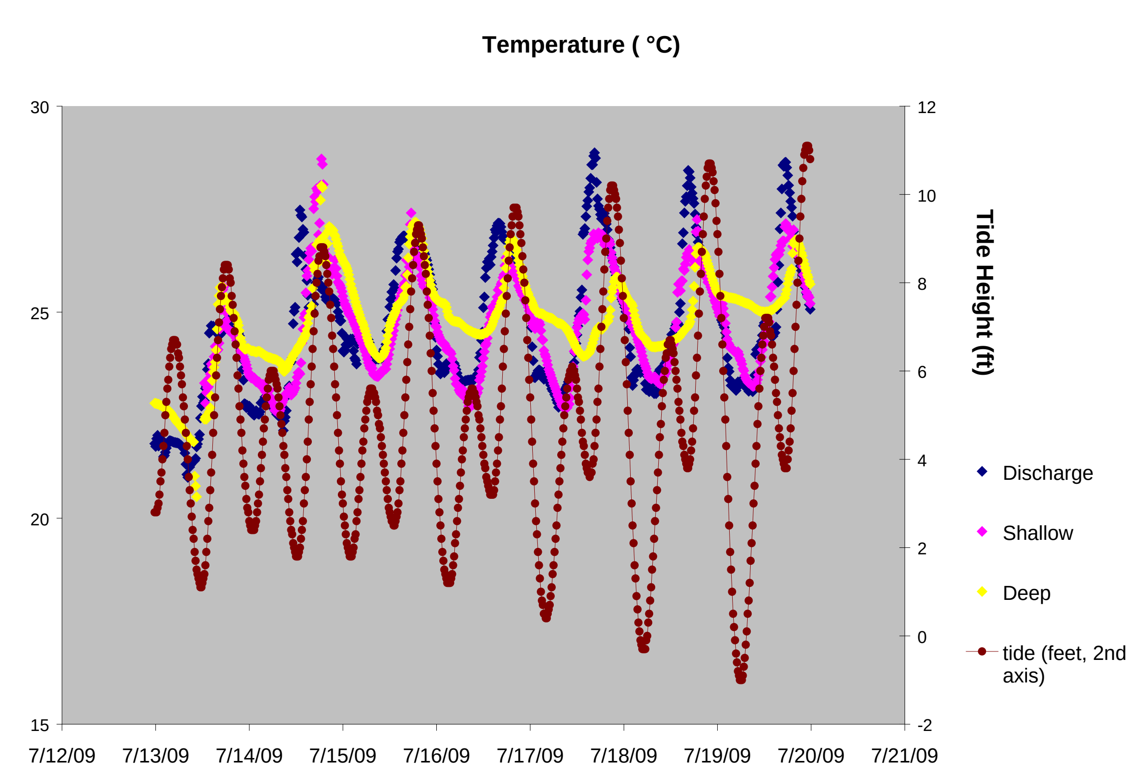

Figure 4.4-7: Pond A14 temperature values at 3 pond locations during 13 July – 19 July

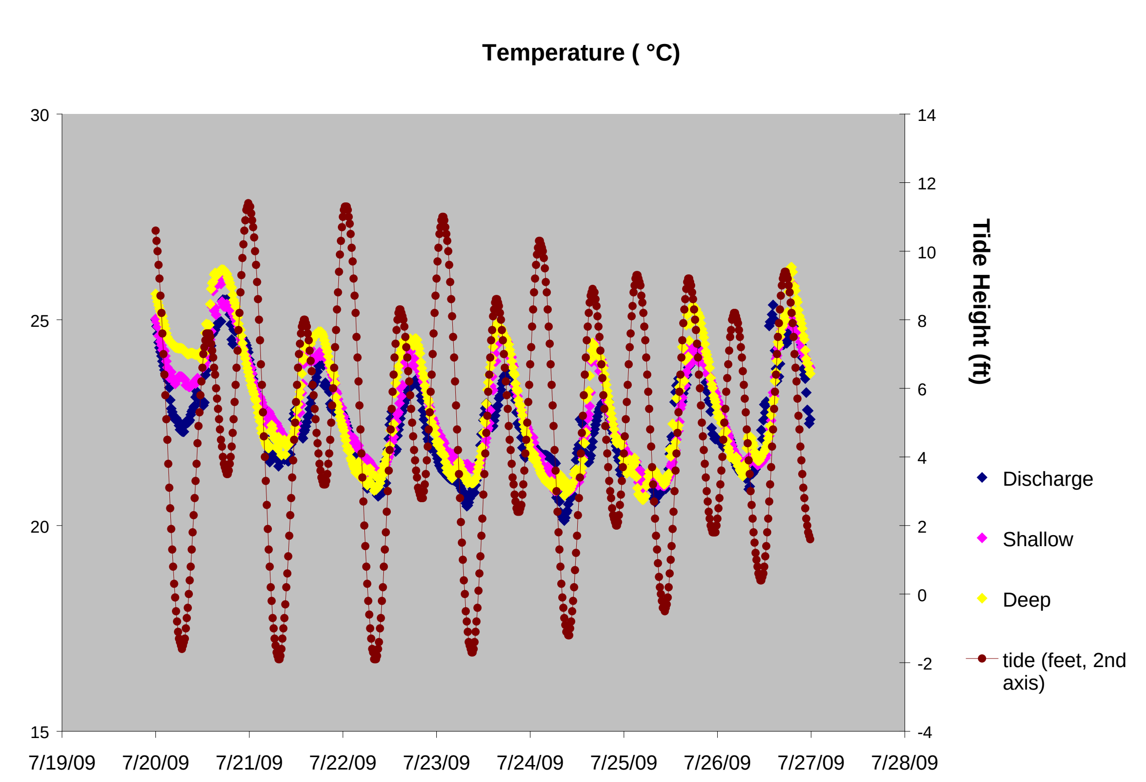

Figure 4.4-8: Pond A14 temperature values at 3 pond locations during 20 July – 26 July

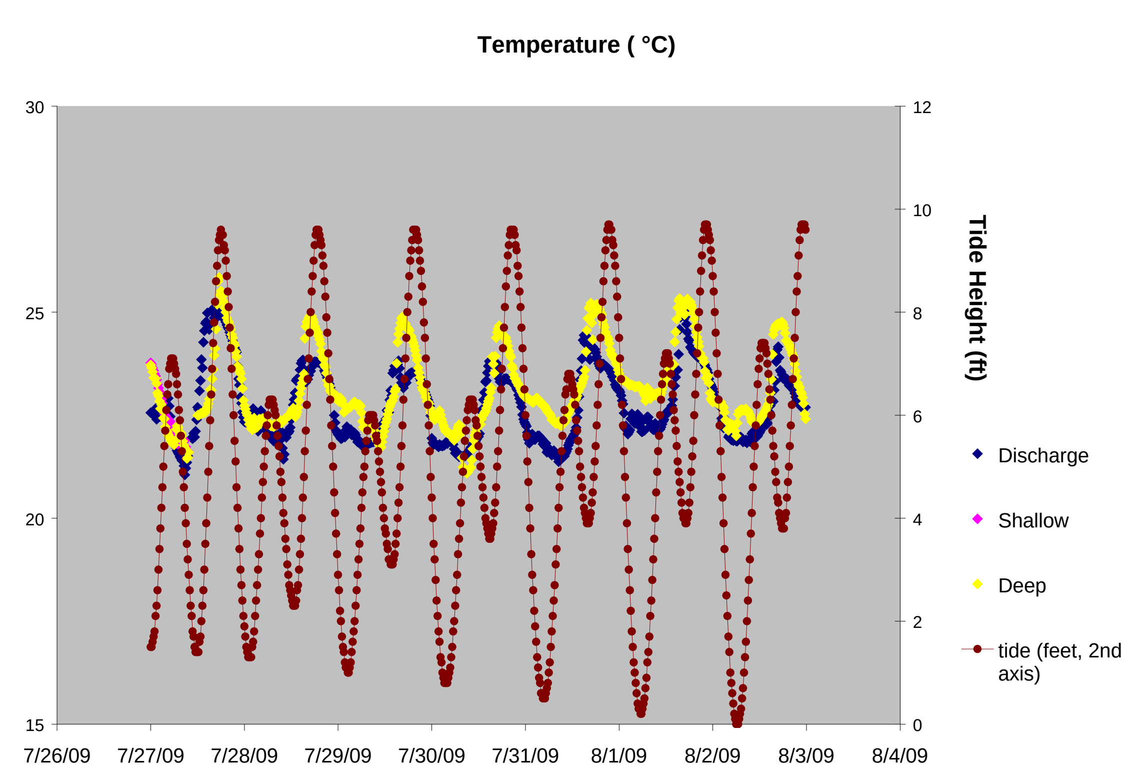

Figure 4.4-9: Pond A14 temperature values at 3 pond locations during 27 July – 2 August

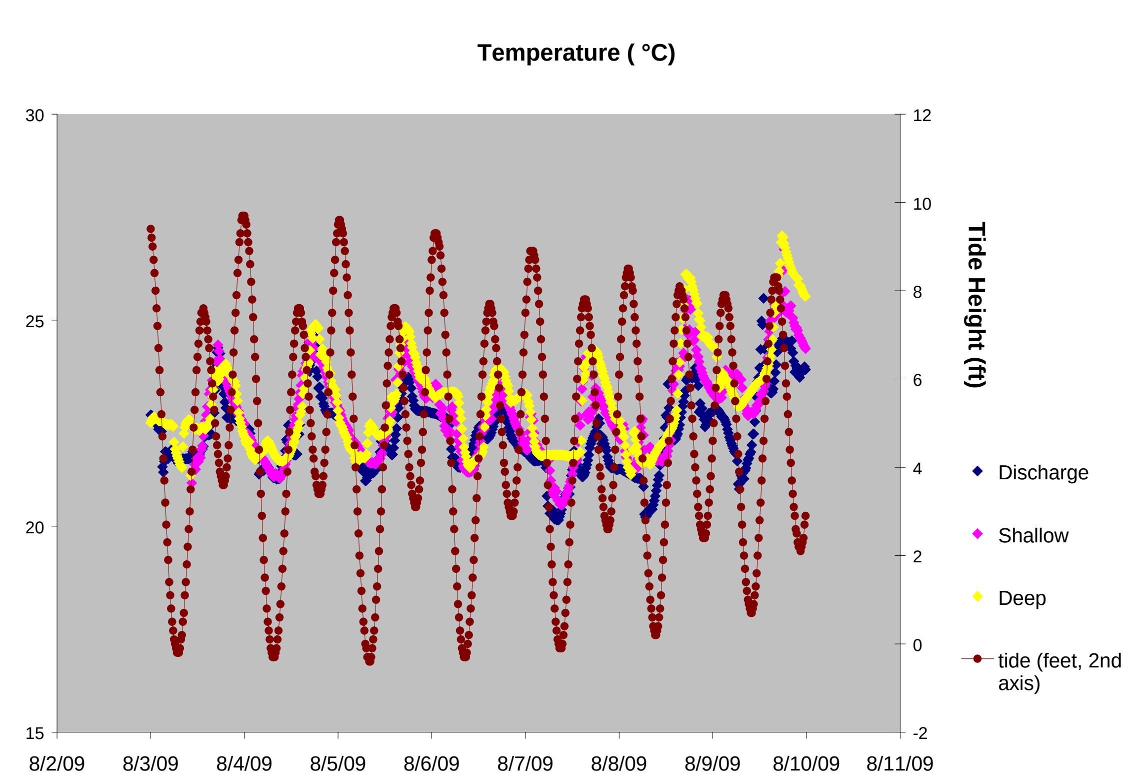

Figure 4.4-10: Pond A14 temperature values at 3 pond locations during 3 August – 9 August

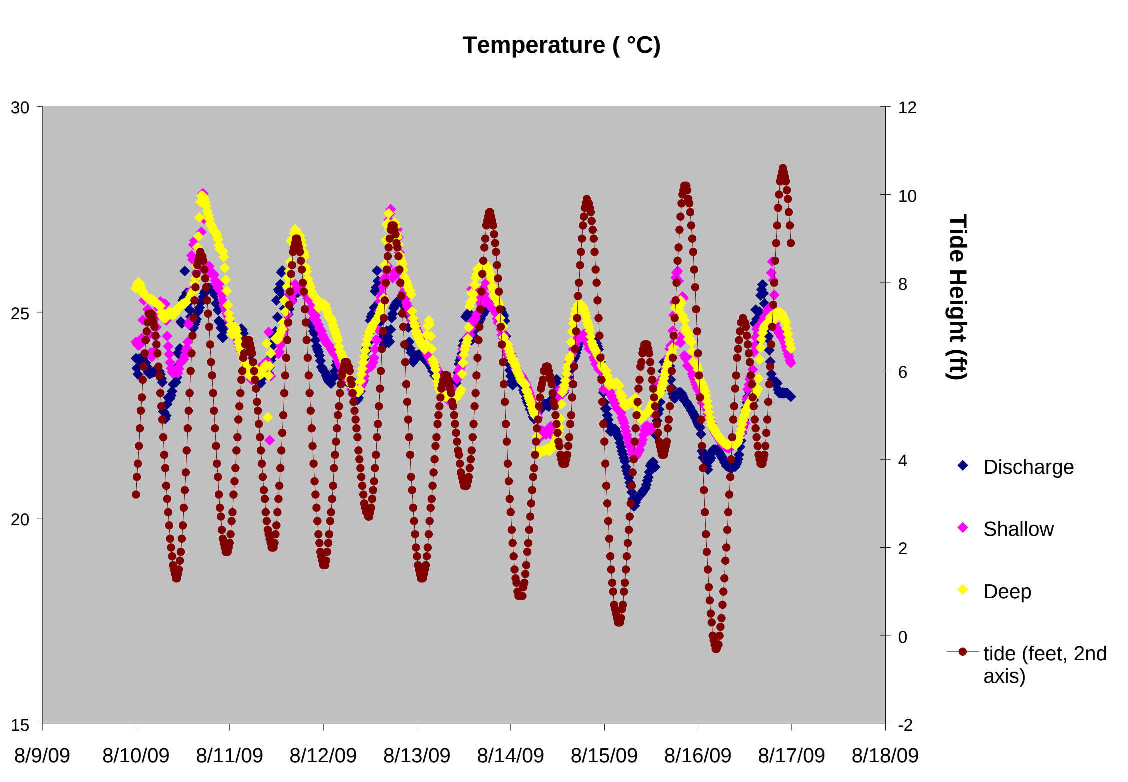

Figure 4.4-11: Pond A14 temperature values at 3 pond locations during 10 August – 16 August

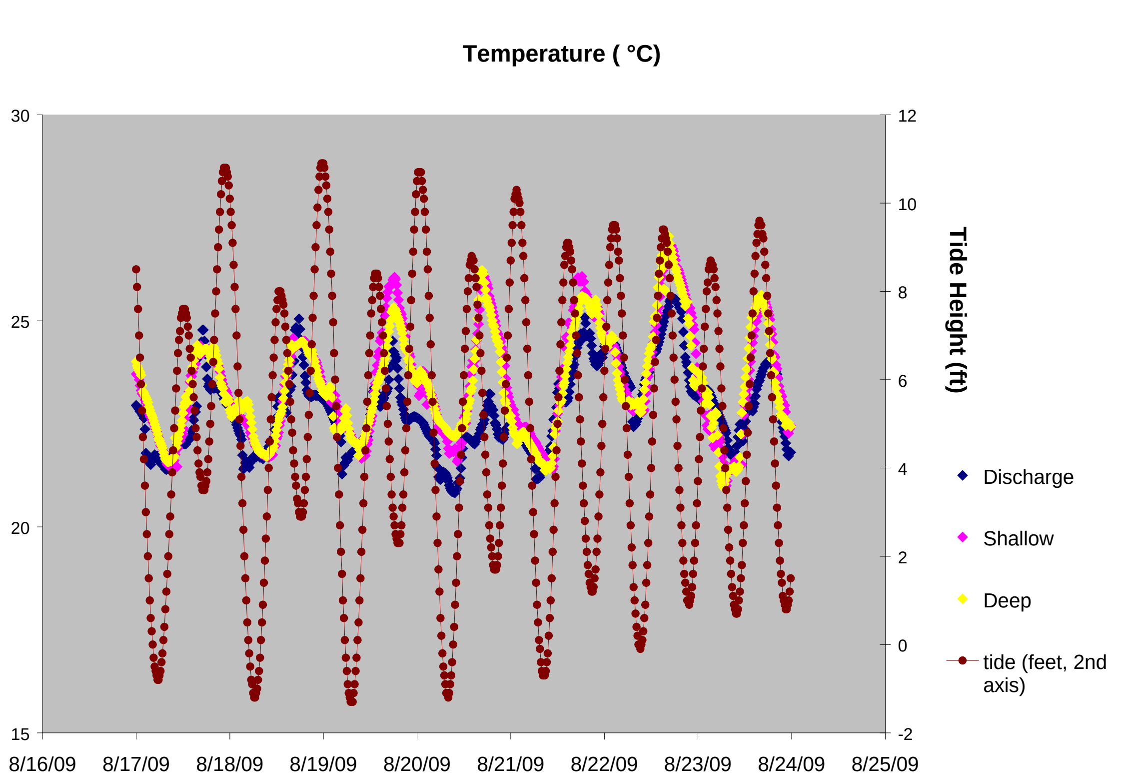

Figure 4.4-12: Pond A14 temperature values at 3 pond locations during 17 August – 23 August

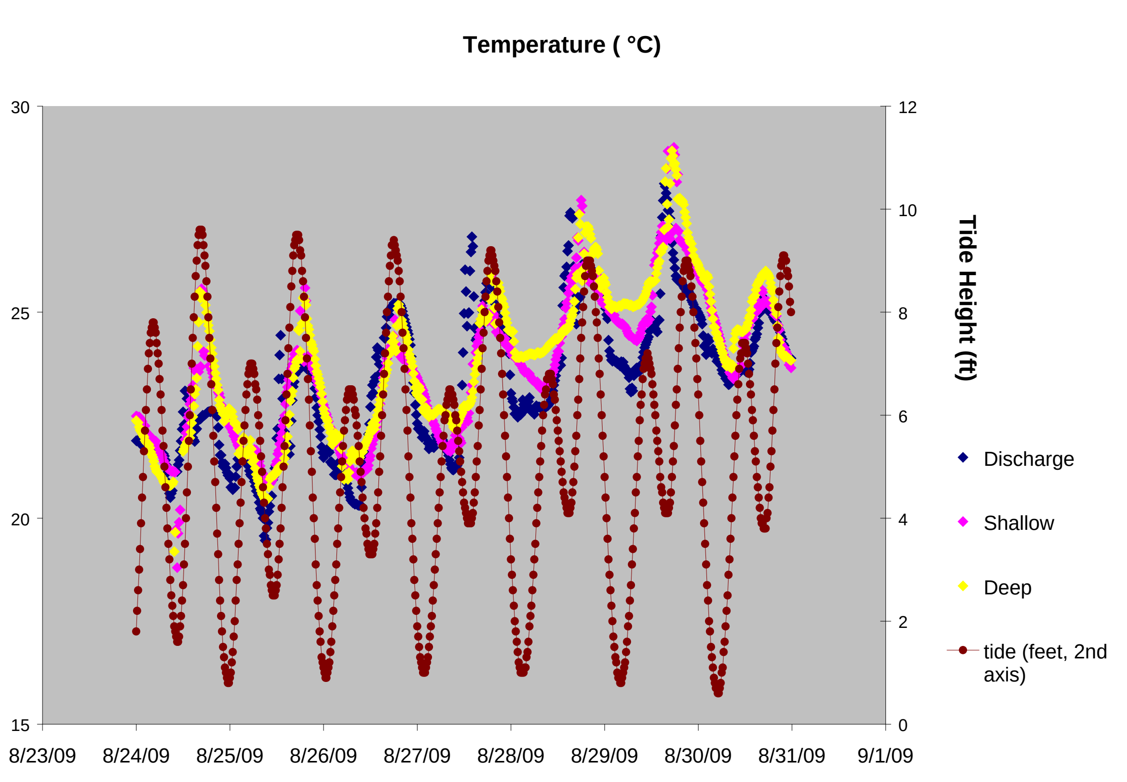

Figure 4.4-13: Pond A14 temperature values at 3 pond locations during 24 August – 30 August

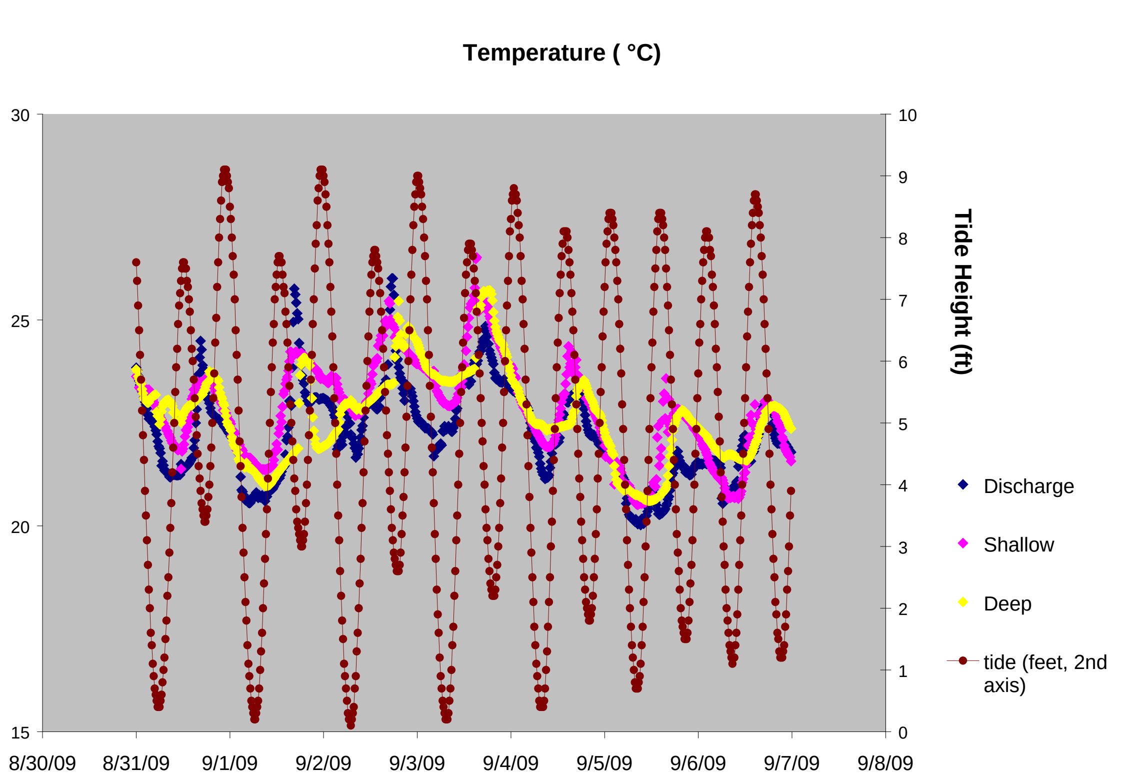

Figure 4.4-14: Pond A14 temperature values at 3 pond locations during 31 August – 6 September

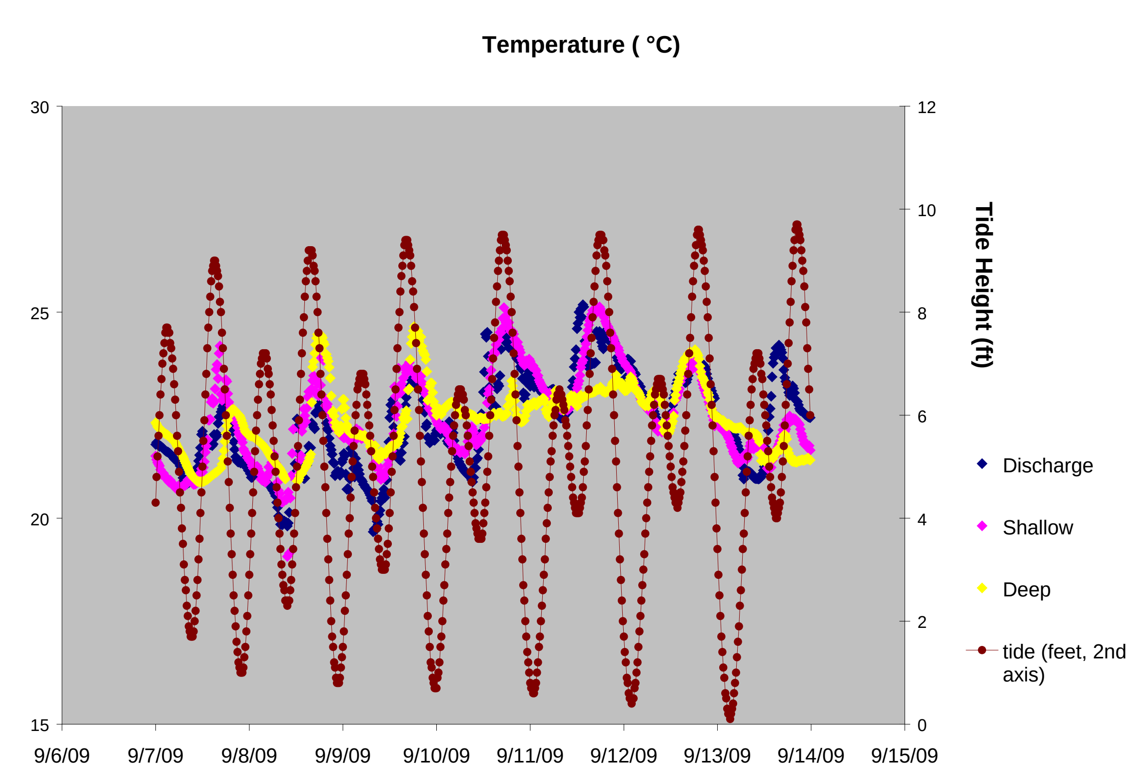

Figure 4.4-15: Pond A14 temperature values at 3 pond locations during 7 September – 13 September

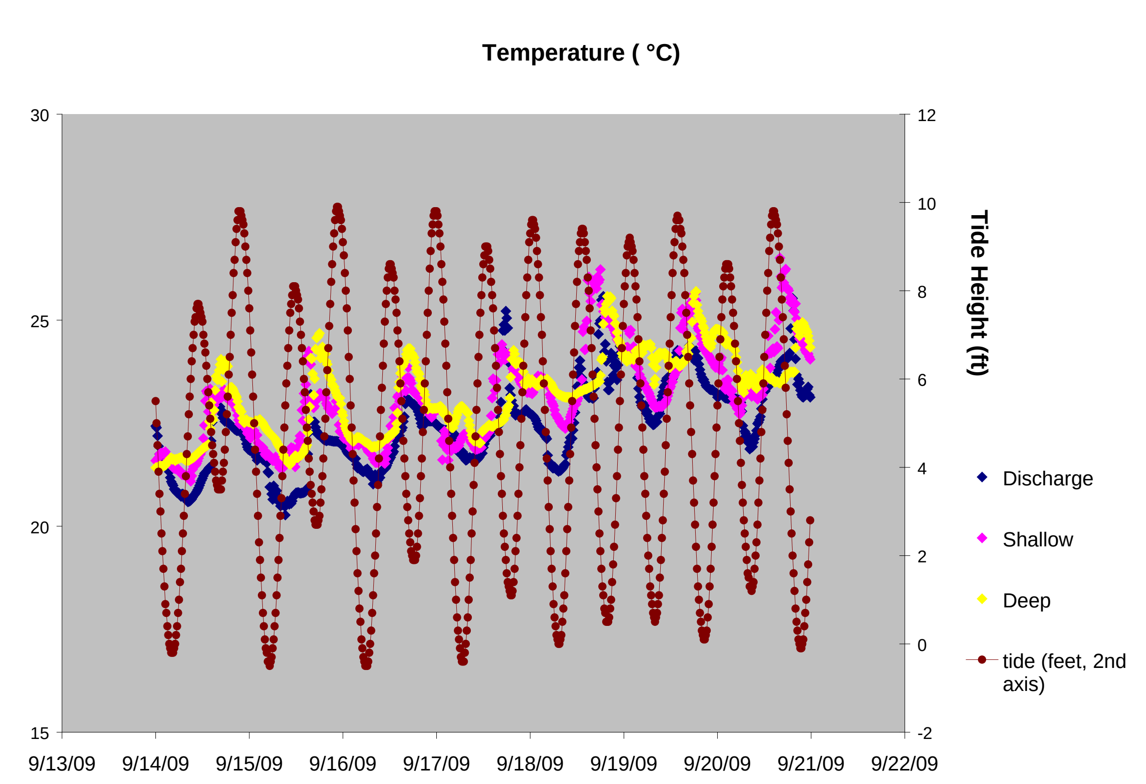

Figure 4.4-16: Pond A14 temperature values at 3 pond locations during 14 September – 20 September

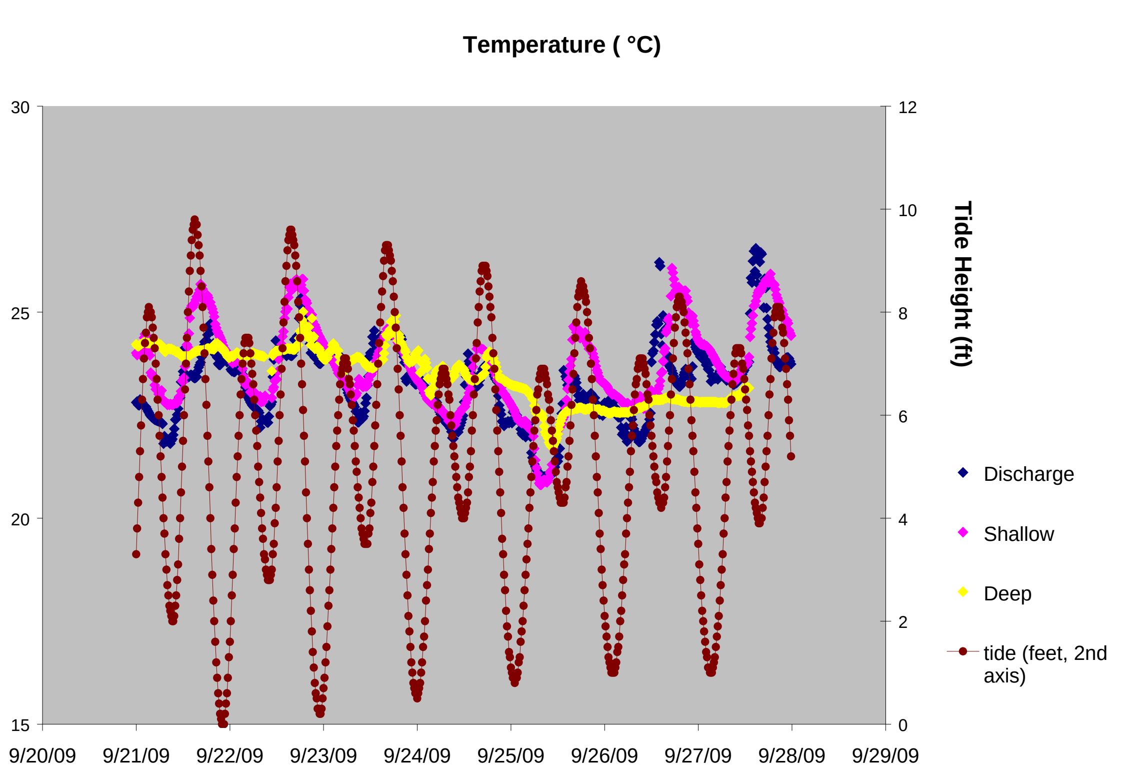

Figure 4.4-17: Pond A14 temperature values at 3 pond locations during 21 September – 27 September

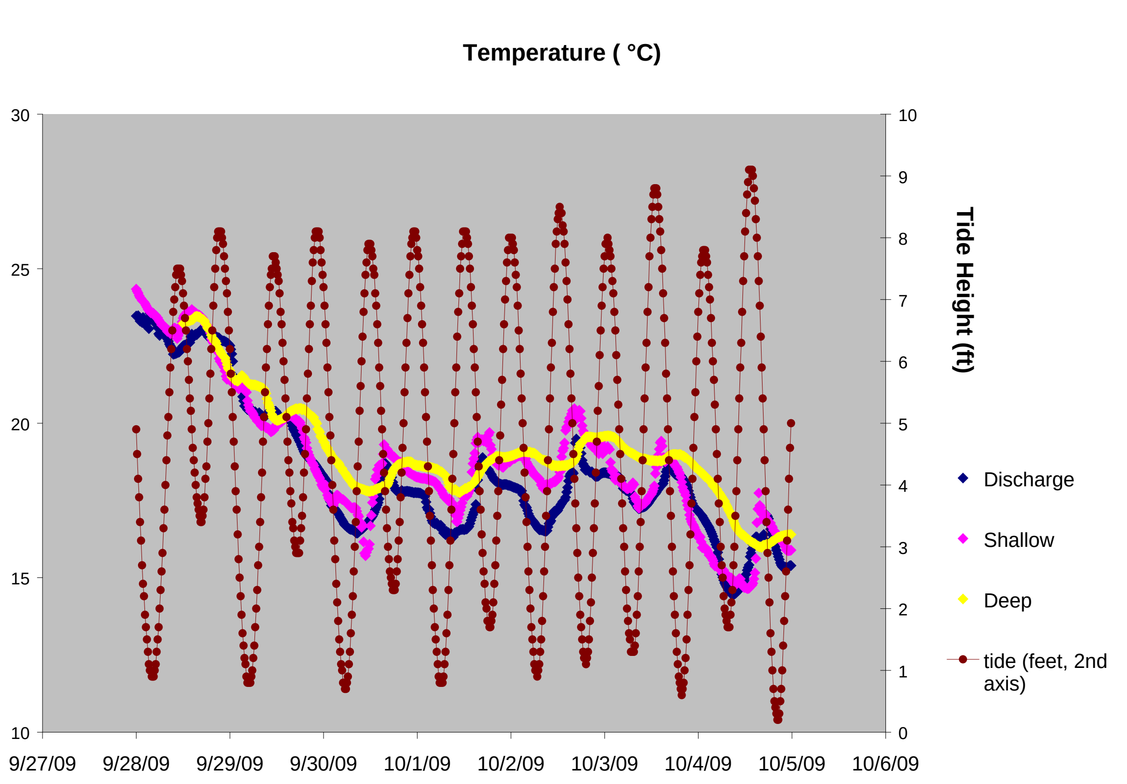

Figure 4.4-18: Pond A14 temperature values at 3 pond locations during 28 September – 4 October

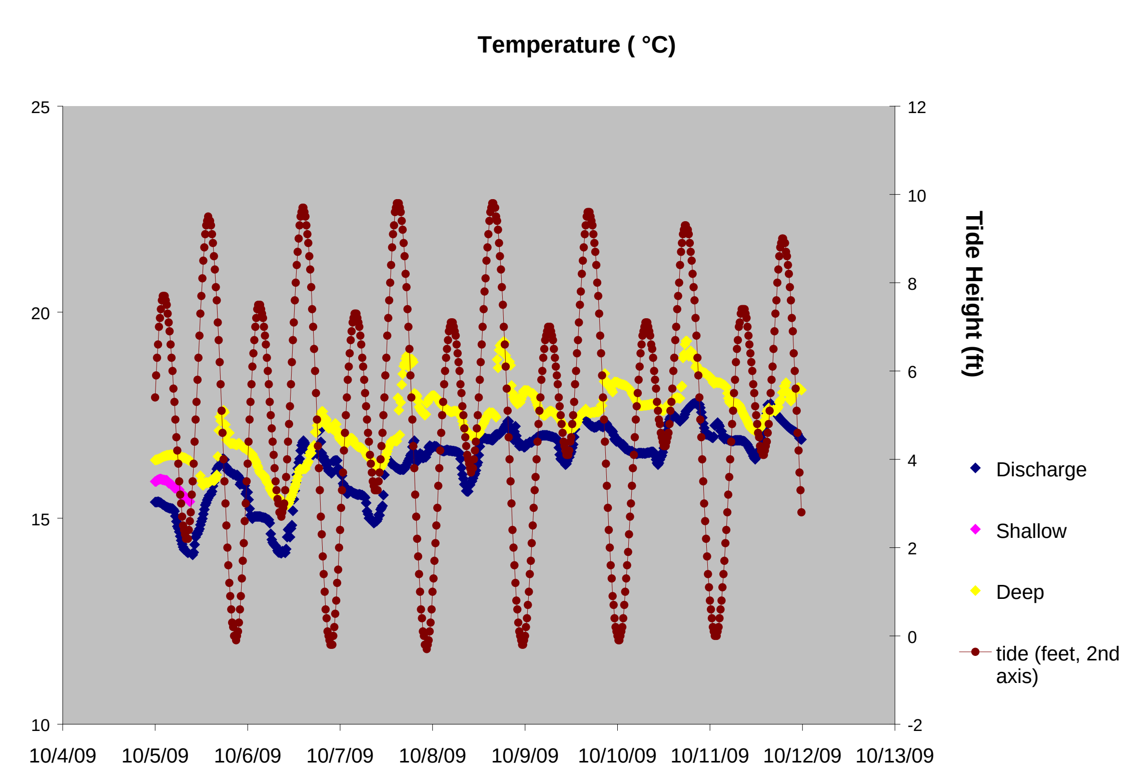

Figure 4.4-19: Pond A14 temperature values at 3 pond locations during 5 October – 11 October

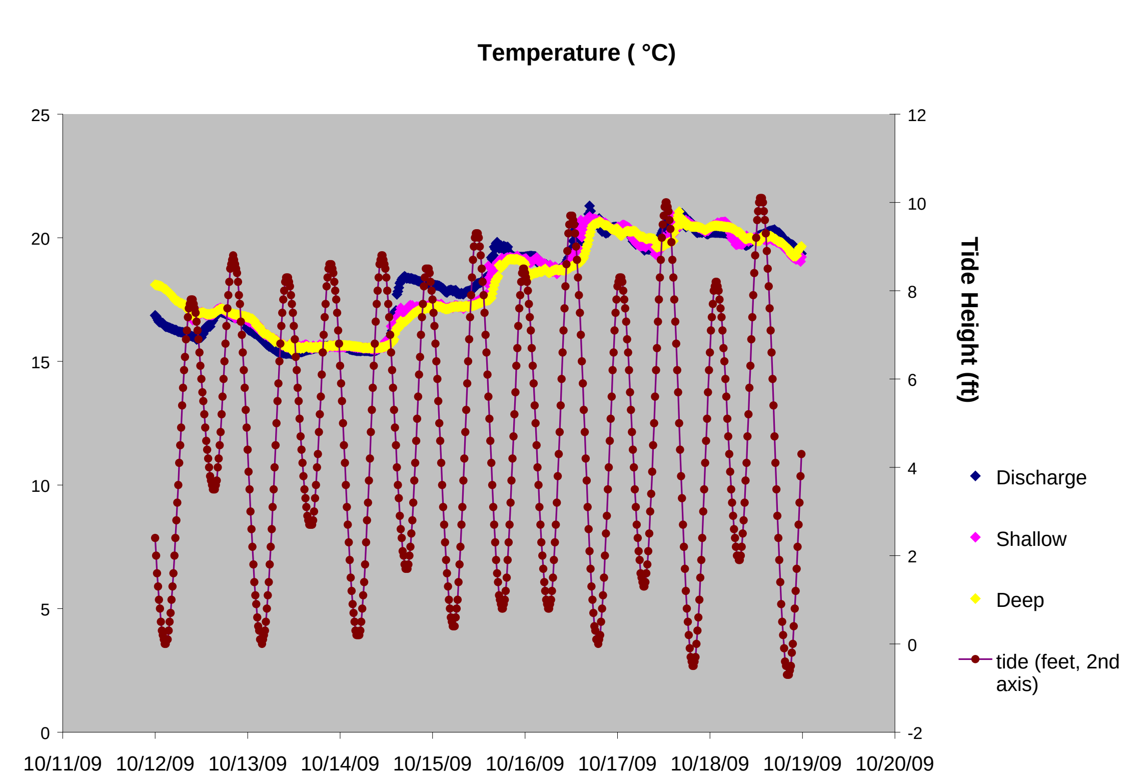

Figure 4.4-20: Pond A14 temperature values at 3 pond locations during 12 October – 18 October

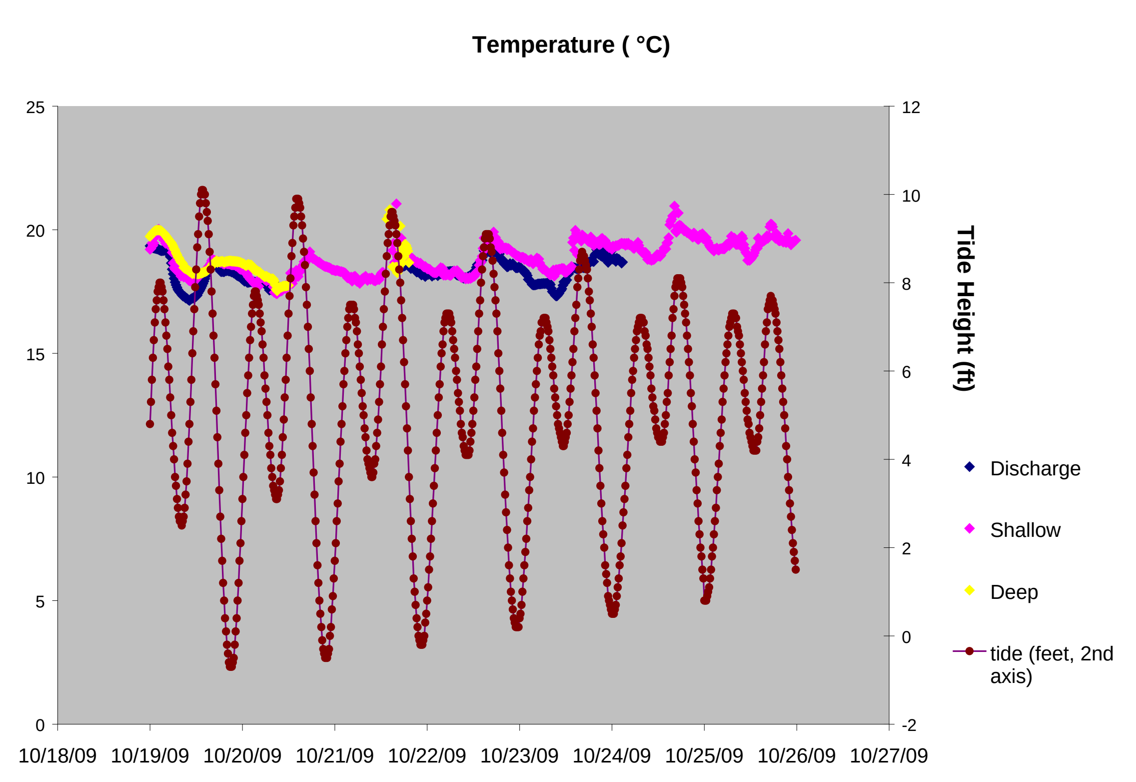

Figure 4.4-21: Pond A14 temperature values at 3 pond locations during 19 October – 25 October

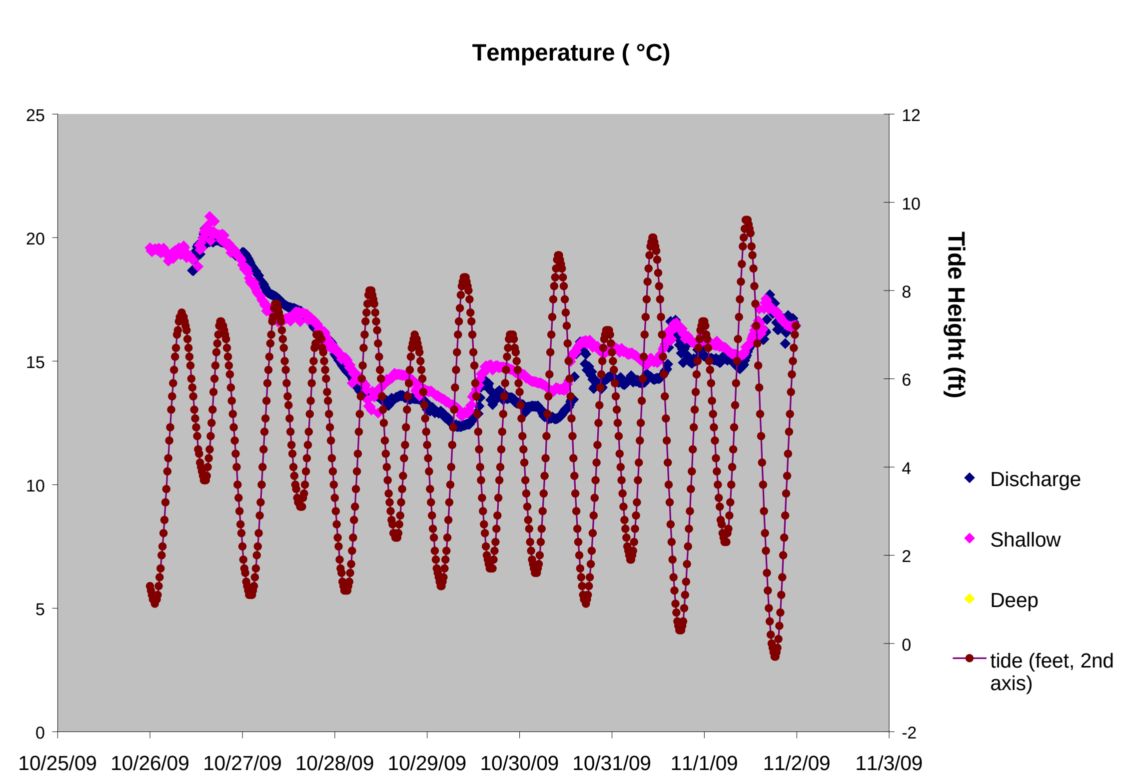

Figure 4.4-22: Pond A14 temperature values at 3 pond locations during 26 October – 1 November

4.5 DISSOLVED OXYGEN TRANSECTS

While in 2008 transects were contained within barrow ditches, this year dissolved oxygen transects were conducted to determine spatial and temporal variability across ponds (Figures 4.5-1 through 4.5-22). Generally, morning transects had lower dissolved oxygen values than the same transects run during afternoon hours. Until the month of October, most morning transects were primarily composed of points with dissolved oxygen levels at or below 3.33 mg/L. In contrast, morning transects run during October and early November had very few or no points where dissolved oxygen values were at or below 3.33 mg/L. Throughout the study, afternoon transects had few to no dissolved oxygen values at or below 3.33 mg/L.

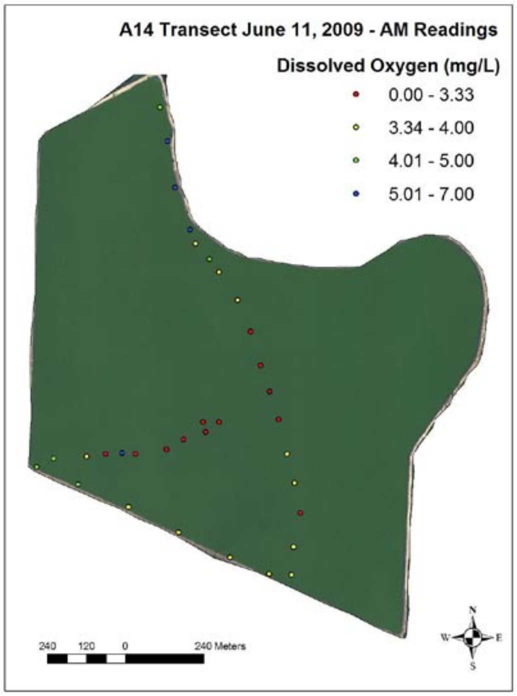

Figure 4.5-1: Dissolved oxygen transect in Pond A14, AM 11 June 2009.

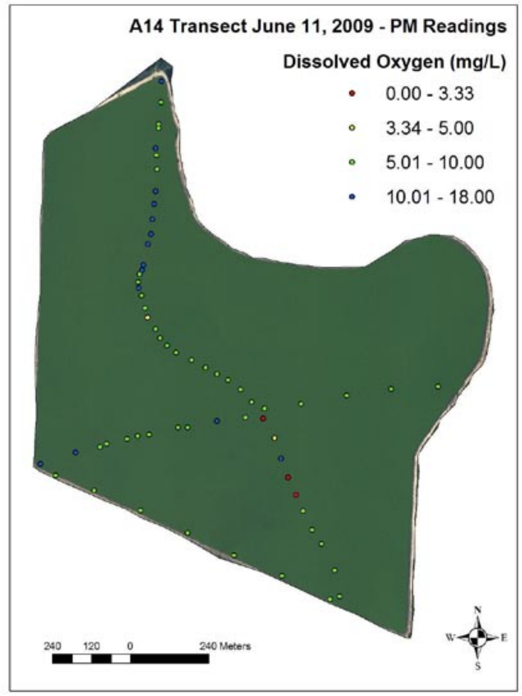

Figure 4.5-2: Dissolved oxygen transect in Pond A14, PM 11 June 2009.

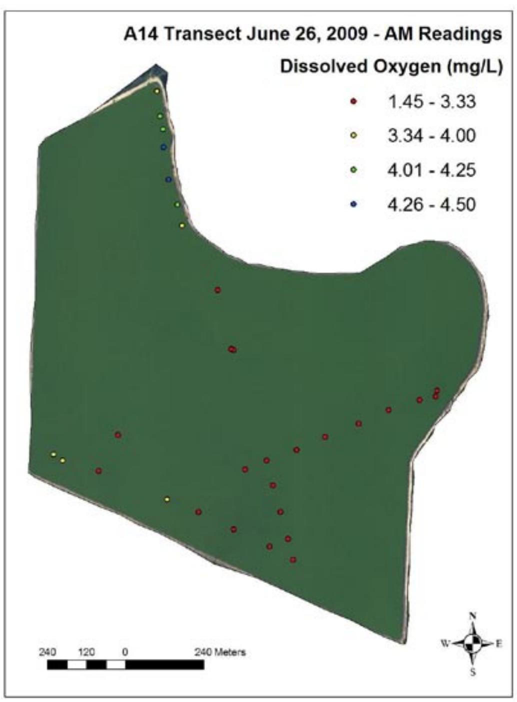

Figure 4.5-3: Dissolved oxygen transect in Pond A14, AM 26 June 2009.

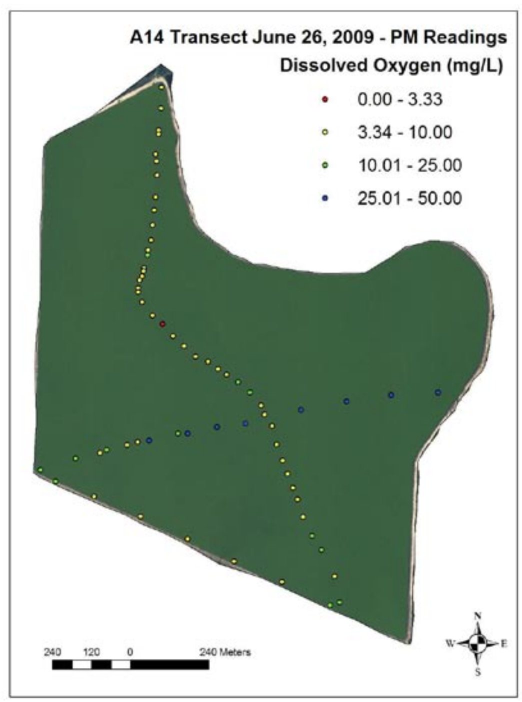

Figure 4.5-4: Dissolved oxygen transect in Pond A14, PM 26 June 2009.

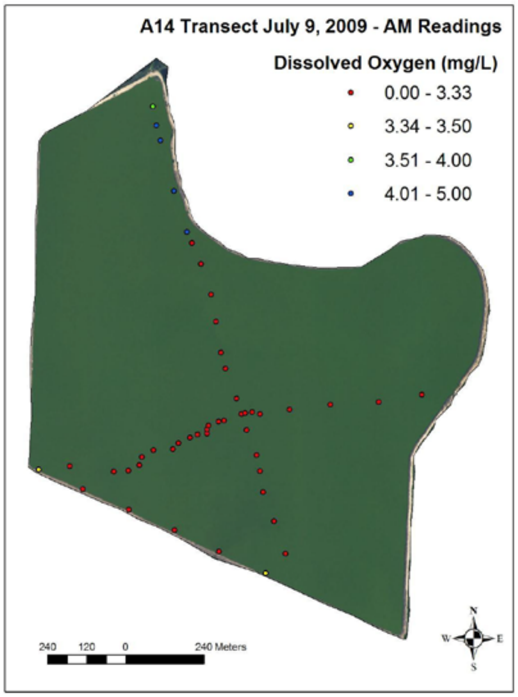

Figure 4.5-5: Dissolved oxygen transect in Pond A14, AM 9 July 2009.

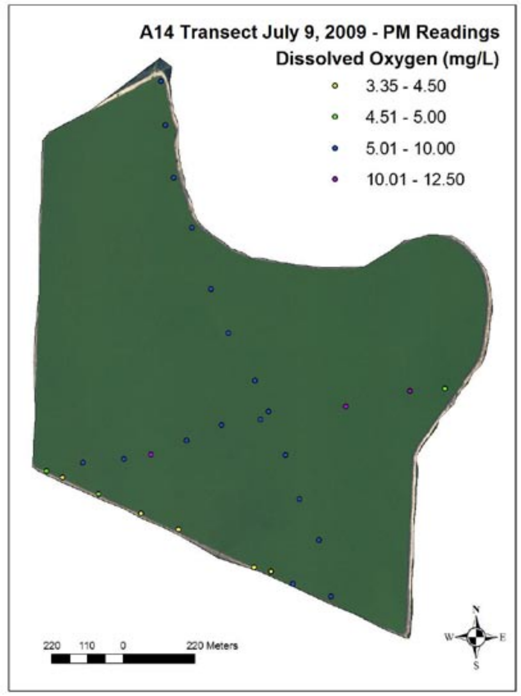

Figure 4.5-6: Dissolved oxygen transect in Pond A14, PM 9 July 2009.

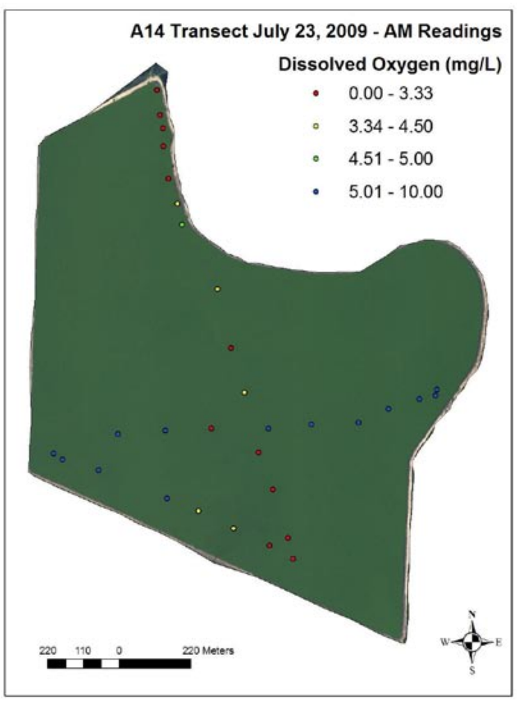

Figure 4.5-7: Dissolved oxygen transect in Pond A14, AM 23 July 2009.

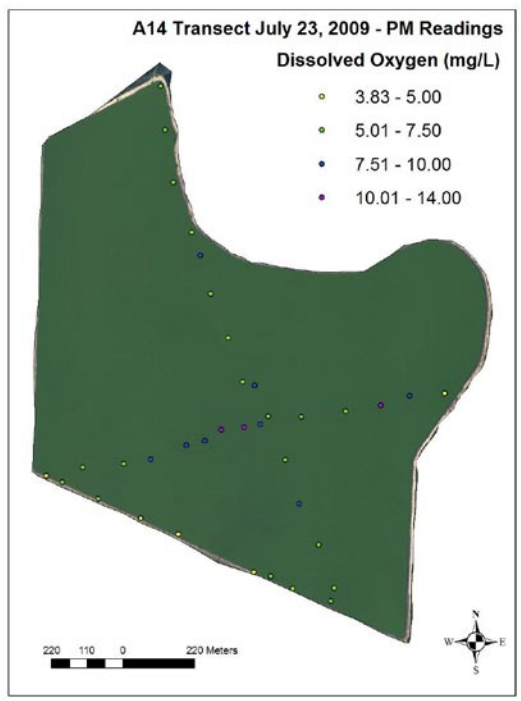

Figure 4.5-8: Dissolved oxygen transect in Pond A14, PM 23 July 2009.

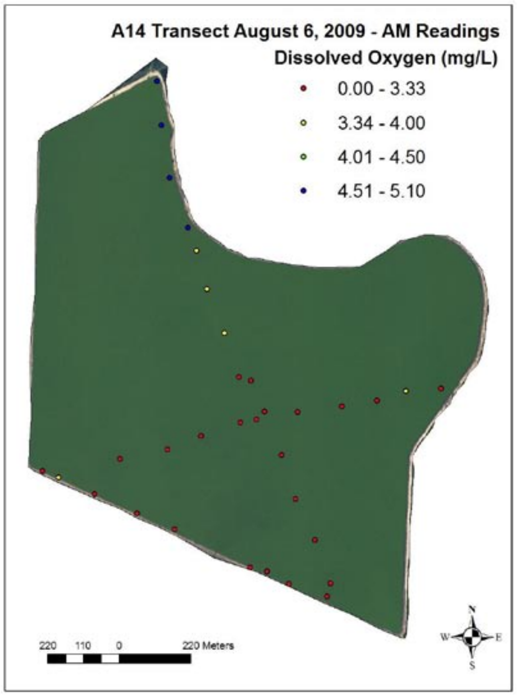

Figure 4.5-9: Dissolved oxygen transect in Pond A14, AM 6 August 2009.

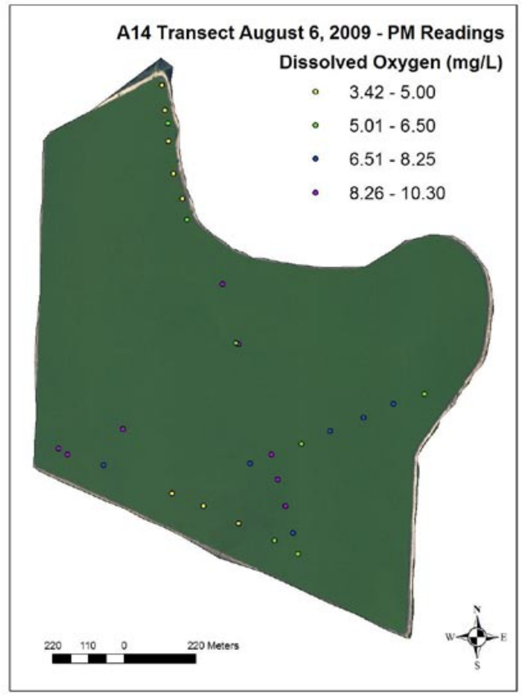

Figure 4.5-10: Dissolved oxygen transect in Pond A14, PM 6 August 2009.

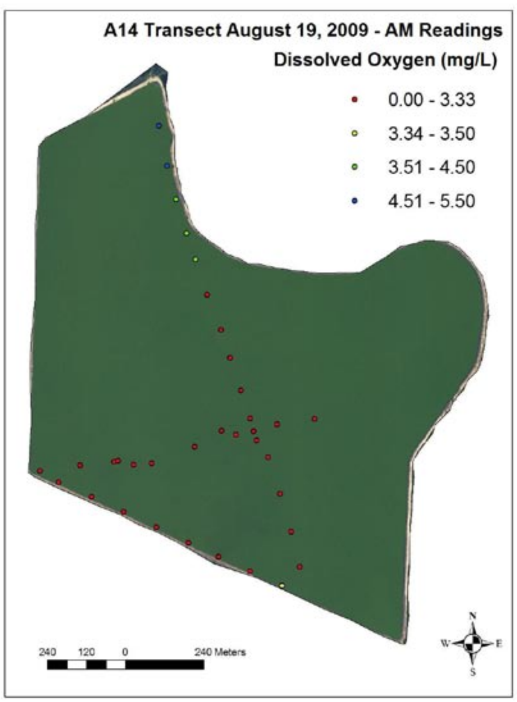

Figure 4.5-11: Dissolved oxygen transect in Pond A14, AM 19 August 2009.

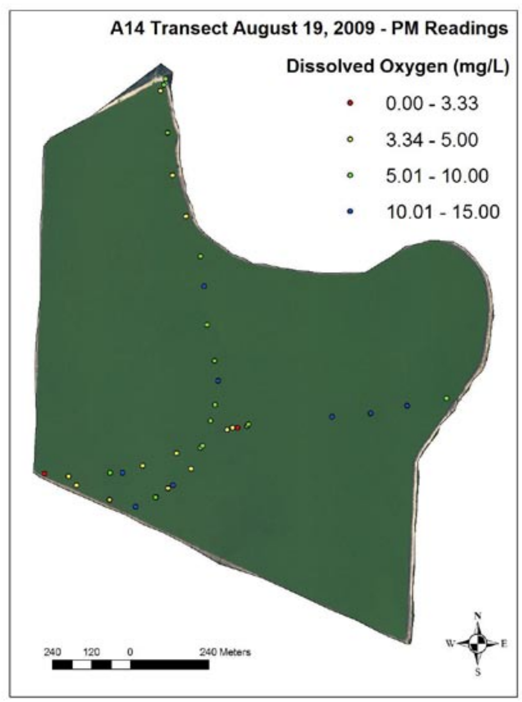

Figure 4.5-12: Dissolved oxygen transect in Pond A14, PM 19 August 2009.

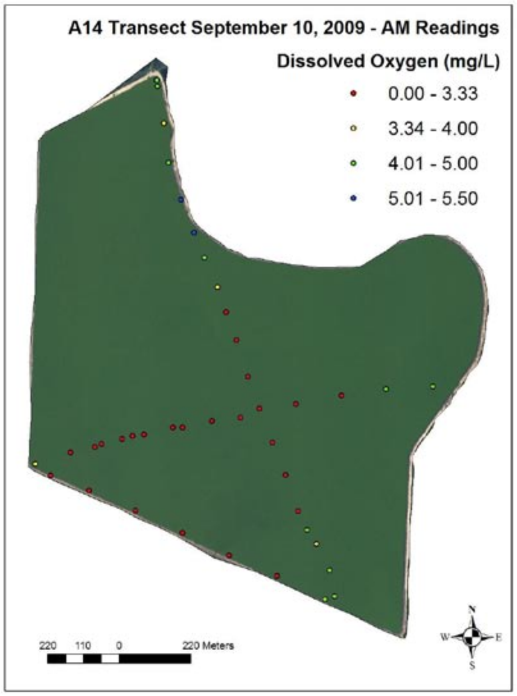

Figure 4.5-13: Dissolved oxygen transect in Pond A14, AM 10 September 2009.

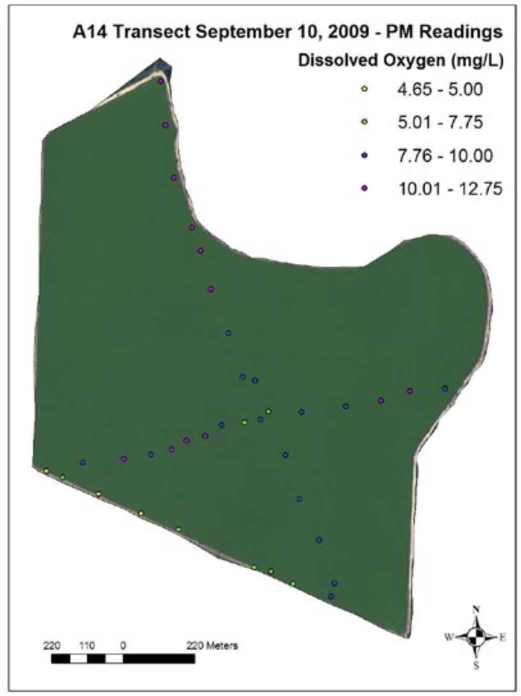

Figure 4.5-14: Dissolved oxygen transect in Pond A14, PM 10 September 2009.

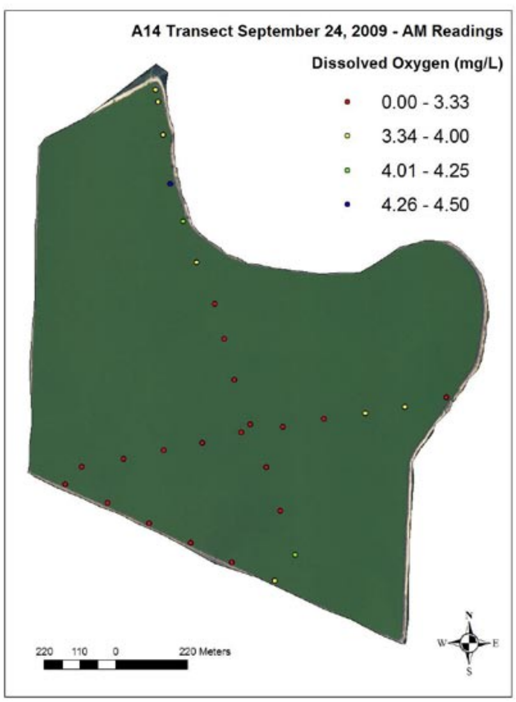

Figure 4.5-15: Dissolved oxygen transect in Pond A14, AM 24 September 2009.

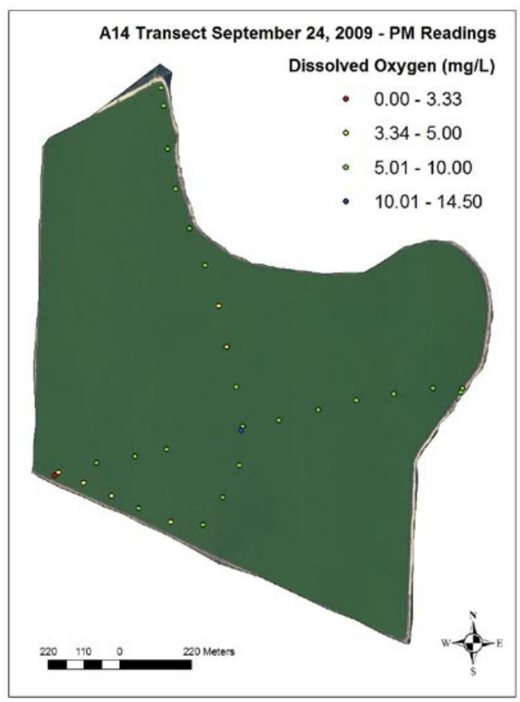

Figure 4.5-16: Dissolved oxygen transect in Pond A14, PM 24 September 2009.

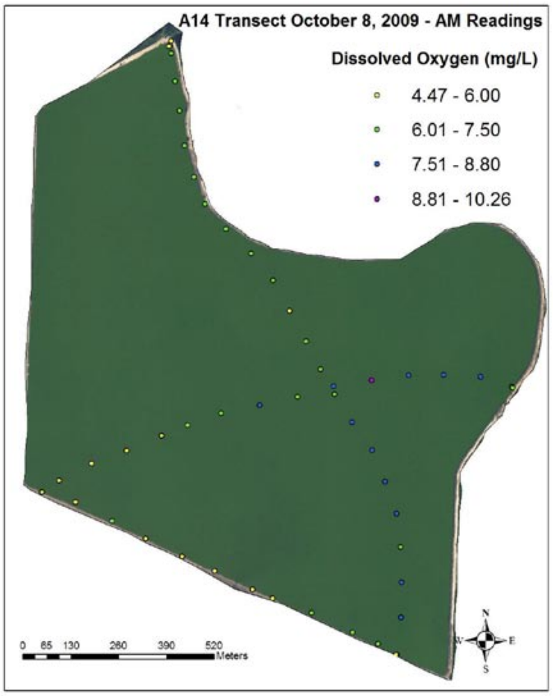

Figure 4.5-17: Dissolved oxygen transect in Pond A14, AM 8 October 2009.

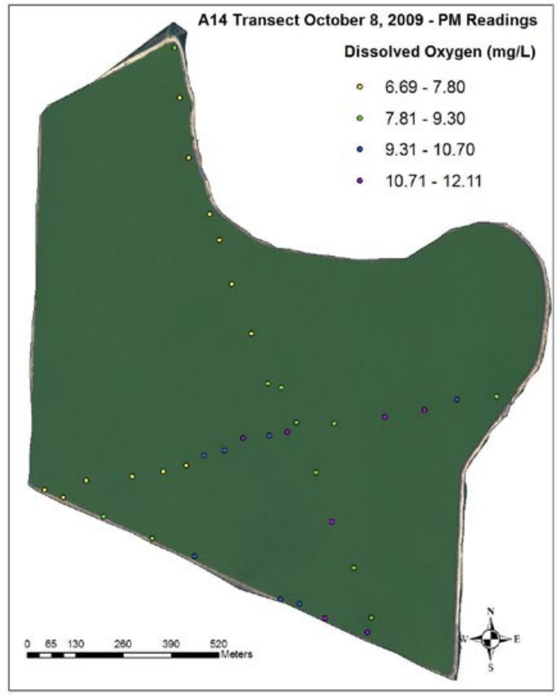

Figure 4.5-18: Dissolved oxygen transect in Pond A14, PM 8 October 2009.

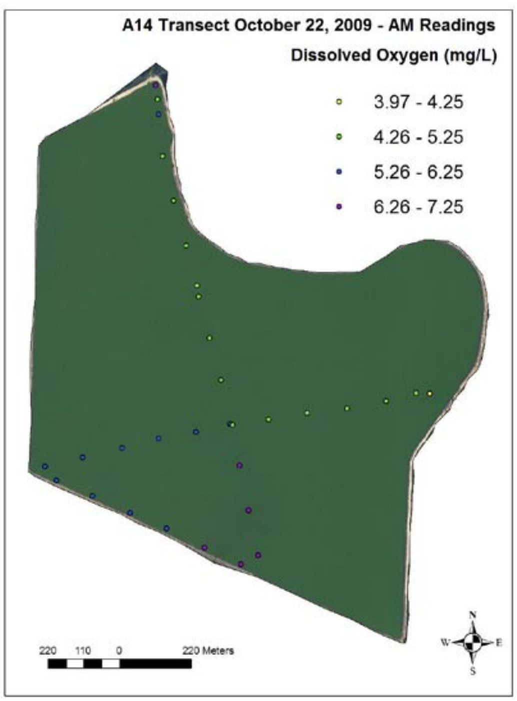

Figure 4.5-19: Dissolved oxygen transect in Pond A14, AM 22 October 2009.

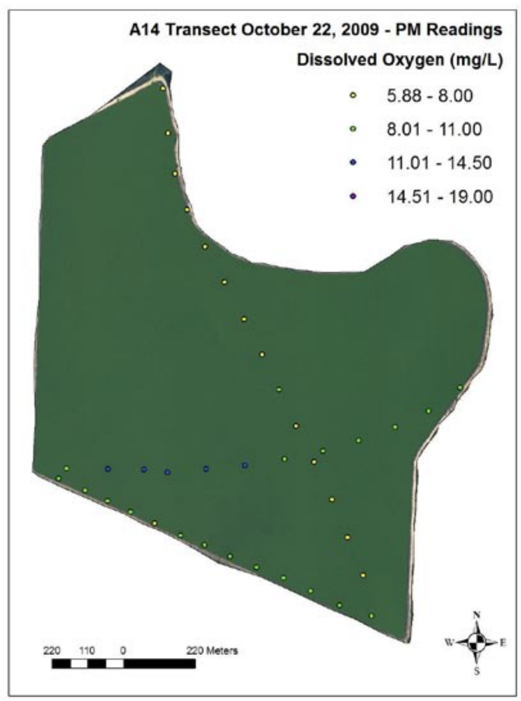

Figure 4.5-20: Dissolved oxygen transect in Pond A14, PM 22 October 2009.

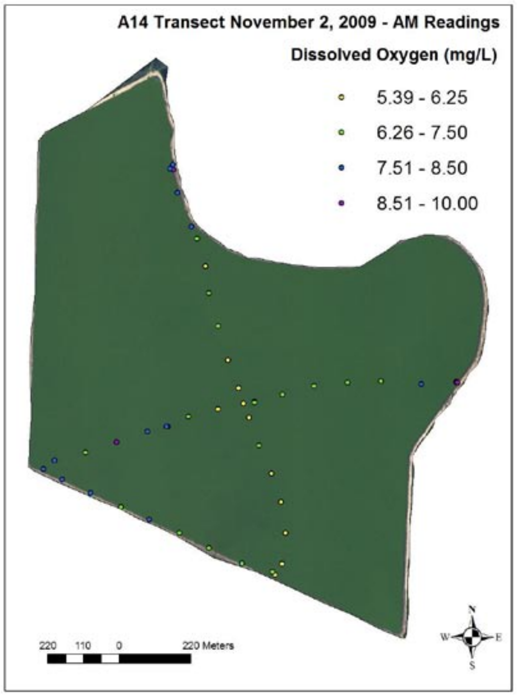

Figure 4.5-21: Dissolved oxygen transect in Pond A14, AM 2 November 2009.

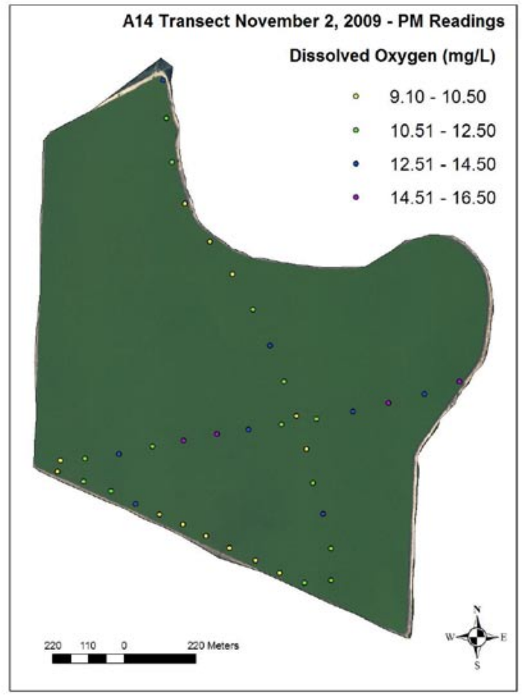

Figure 4.5-22: Dissolved oxygen transect in Pond A14, PM 2 November 2009.

4.6 NUTRIENTS AND CHLOROPHYLL

Nutrient measurements were highly variable within pond A14 (Table 4.6-1). Further analysis is needed to analyze the spatial and temporal patterns in conjunction with water quality and meteorological data. Measurements for chlorophyll within Pond A3W were also highly variable, with substantial spatial variation in chlorophyll across transects over all sampling dates (Figures 4.6-1 through 4.6-5).

Table 4.6-1: Pond A14 summarized nutrient data by sampling period

Pond	Sampling Date	Sample Location	Nitrate + Nitrite (NO_3 +NO2) µM	Ammonium (NH4) µM	DIN (dissolved inorganic nitrogen) µM	Phosphate (PO4) µM	Silicate µM
A14	6/25/2009	A	0.00	1.04	1.04	17.22	48.24
	6/25/2009	B	0.00	1.83	1.83	15.62	30.89
	6/25/2009	C	0.00	2.47	2.47	12.68	36.18
	7/19/2009	A	0.00	2.10	2.10	20.69	51.16
	7/19/2009	B	0.00	2.68	2.68	23.15	44.45
	7/19/2009	C	0.00	4.62	4.62	22.04	65.45
	7/23/2009	A	0.00	0.69	0.69	17.52	38.1
	7/23/2009	B	0.00	0.91	0.91	19.11	42.59
	7/23/2009	C	0.00	4.26	4.26	17.91	36.06
	9/24/2009	A	0.00	2.38	2.38	22.61	109.96
	9/24/2009	B	0.00	1.23	1.23	23.22	109.64
	9/24/2009	C	9.74	17.95	27.69	21.01	190.53
	10/22/2009	A	5.19	20.97	26.16	16.54	59.2
	10/22/2009	B	10.18	20.01	30.19	16.29	68.18
	10/22/2009	C	12.82	0.32	13.14	15.69	61.34

Figure 4.6-1: Nutrient sampling locations for Pond A14, 2009.

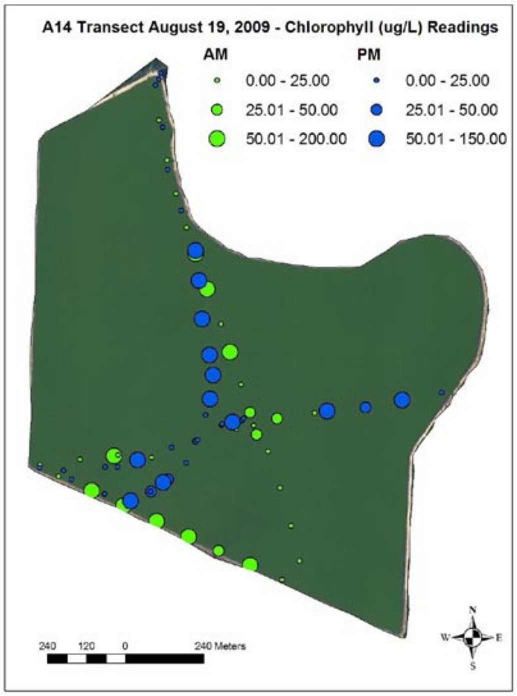

Figure 4.6-2: AM and PM chlorophyll levels in Pond A14 on 19 August 2009.

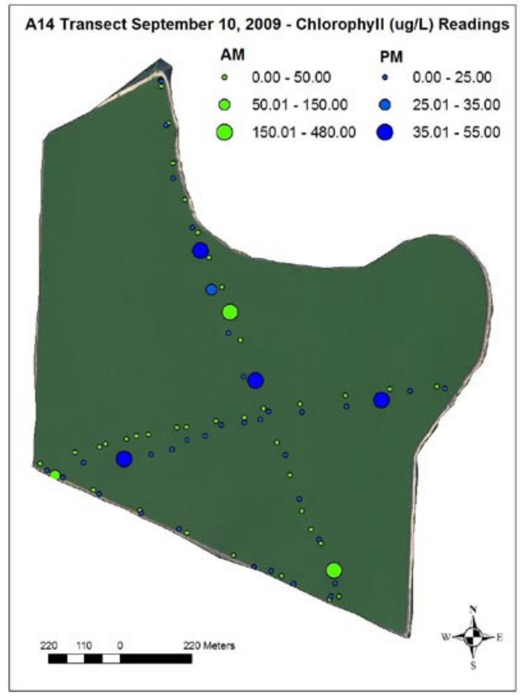

Figure 4.6-3: AM and PM chlorophyll levels in Pond A14 on 10 September 2009.

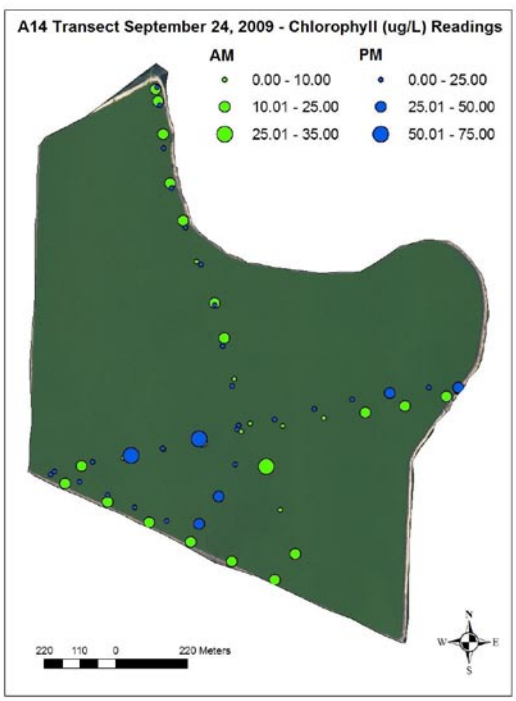

Figure 4.6-4: AM and PM chlorophyll levels in Pond A14 on 24 September 2009.

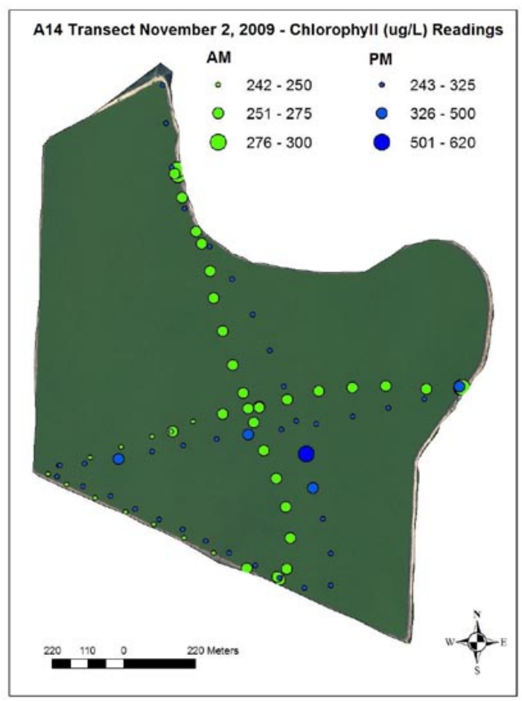

Figure 4.6-5: AM and PM chlorophyll levels in Pond A14 on 2 November 2009.

4.7 METEOROLOGICAL MEASUREMENTS

Meteorological data were relatively consistent during the study period (Table 4.7-1). Wind was primarily from the south and averages ranged from 5 to 7 mph. Gusts ranged from 0 to 45 mph where gust averages ranged from 8.30 to 11.00 mph. Relative humidity remained fairly consistent throughout the study period. Rainfall was scarce throughout the study period; however, October did experience a very small amount of precipitation. Monthly mean temperatures were also pretty consistent and ranged from 16.00 degrees Celsius to 19.50 degrees Celsius. Photosynthetically active radiation (PAR) and solar radiation were variable during the study period, but varied largely due to diurnal cycles.

Table 4.7-1: Summarized weather values (mean ± standard deviation) for all ponds by month

Month	Temperature (°C)	Relative Humidity (%)	Rainfall (cm)	Primary Wind Direction	Wind Speed (mph)	PAR Light (uM/m^2s)	Solar Radiation (wat/m2)
June	17.93 ± 1.0	71.81 ± 12.65	0.00 ± 0.0	South	7.04 ± 5.64	1083.21 ± 750.1 Max: 2748	448.51 ± 330.6 Max: 1208
July	17.99 ± 1.0	77.56 ± 14.00	0.00 ± 0.0	South - Southwest	6.55 ± 5.50	1140.64 ± 815.4 Max: 2454	475.10 ± 342.5 Max: 1054
August	19.20 ± 1.1	74.35 ± 16.42	0.00 ± 0.0	South	5.94 ± 5.51	1084.71 ± 719.5 Max: 2124	460.00 ± 323.1 Max: 917
September	19.45 ± 1.0	73.14 ± 16.43	0.00 ± 0.0	South - Southeast	5.03 ± 5.21	976.52 ± 626.6 Max: 2079	414.60 ± 275.7 Max: 911
October	16.00 ± 0.9	73.30 ± 18.90	0.00 ± 0.0	South	5.95 ± 6.04	760.90 ± 519.4 Max: 1834	324.60 ± 232.9 Max: 762

5. POND A16 IN-POND SAMPLING

SECTION 5
POND A16 IN-POND SAMPLING

This section summarizes analyses of 2009 water quality data being conducted for Pond A16 to characterize spatial variability and patterns with respect to flow patterns and pond management. A brief description of our initial findings is presented below:

5.1 CONTINUOUS WATER QUALITY MONITORING

One datasonde was deployed at the discharge location of Pond A16 during the study period of 1 June 2009 through 31 October 2009 (Figure 5.1-1). Aside from cleaning and servicing the datasonde, it was continuously deployed in pond A16 throughout the study period. Based on monthly averages, the most significant change was highlighted when comparing water quality parameters for August and September (Table 5.1-1). DO and pH decreased steadily during this period while salinity and temperature increased.

Dissolved oxygen

Dissolved oxygen concentrations cycled throughout the study period in pond A16, likely related with the time of day, temperature, salinity, and tide height (Figures 5.1-2 through 5.1-22). Overall, dissolved oxygen was generally lowest during morning hours and during high tides. Dissolved oxygen levels were at their highest during June and October, which coincided with lowest monthly temperatures. When temperatures rose during the months of August and September, dissolved oxygen levels inversely fell.

Figure 5.1-1: 2009 Datasonde locations in Pond A16

Table 5.1-1: Pond A16 summarized water quality values (mean ± standard deviation) by month for 2009.

Pond	Month	Dissolved Oxygen (mg/L)	pH (Units)	Specific Conductivity (mS/cm)	Temperature (°C)	Salinity (ppt)
A16	June	6.44 ± 2.85	8.88 ± 0.23	31.66 ± 2.95	23.13 ± 2.15	19.71 ± 2.02
	July	5.87 ± 3.43	8.87 ± 0.11	38.22 ± 0.98	24.46 ± 1.49	24.30 ± 0.70
	August	3.90 ± 3.08	8.89 ± 0.18	41.72 ± 0.90	24.49 ± 1.47	26.80 ± 0.65
	September	3.04 ± 3.41	8.59 ± 0.14	42.30 ± 0.55	24.05 ± 1.48	27.22 ± 0.40
	October	6.99 ± 6.37	9.07 ± 0.33	39.46 ± 1.88	18.72 ± 1.60	25.18 ± 1.34

5.2 SALINITY

Salinity within pond A16 was relatively stable during the study period but varied by time of year (Figures 5.1-2 through 5.1-22). The lowest recorded salinity value was 11.69 ppt on 13 June 2009, and the highest recorded value was 28.20 ppt on 30 August 2009. Salinity values increased then decreased over the study period, likely related with changes in evaporation due to solar radiation that varies with the season.

5.3 PH

Pond A16 pH ranged from 8.15 to 9.65 (Figures 5.1-2 through 5.1-22). Values greater than 9.4 were recorded only during the month of October and values below 8.38 were recorded only in September. pH values werwe fairly stable throughout the study with no significant changes recorded. Overall, average pH for Pond A16 during the study period was 8.84.

5.4 TEMPERATURE

Temperature change in Pond A16 was very cyclic and seemed to vary with diurnal and tidal cycles (Figures 5.1-2 through 5.1-22). Temperatures ranged from 15.6ºC to 29.44ºC. Values above 27.7ºC were only recorded in June, July, and August and values below 19.7ºC were only recorded in October.

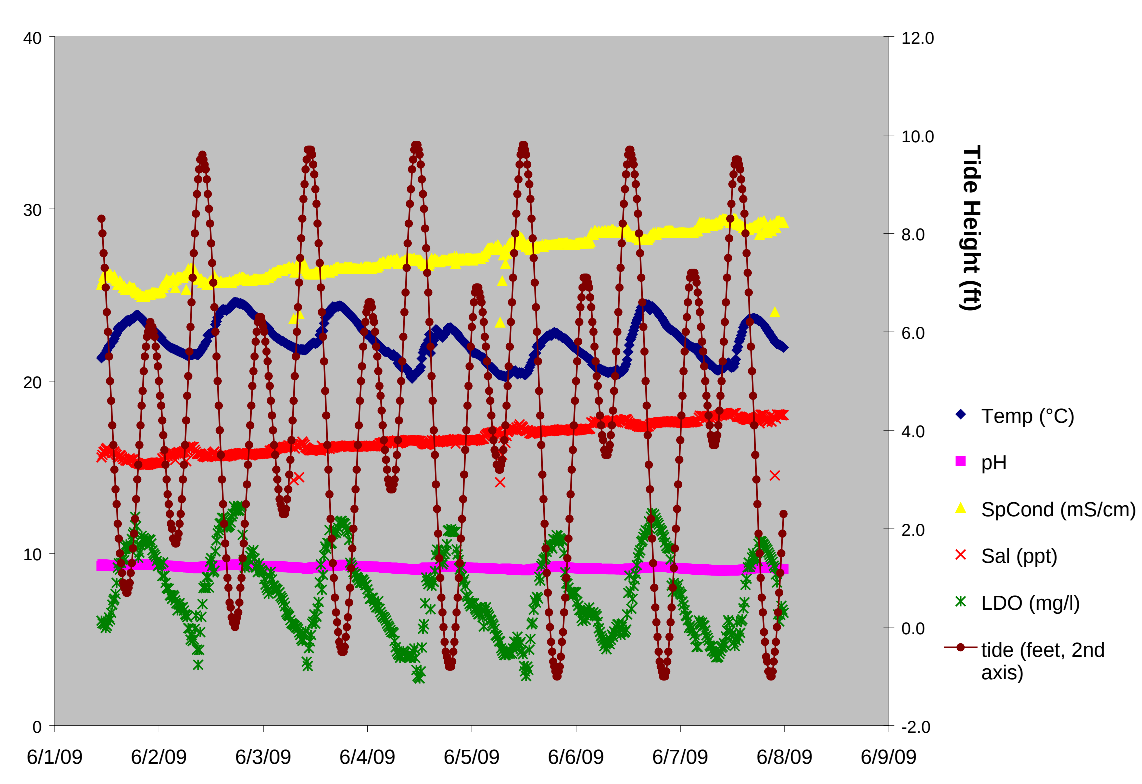

Figure 5.1-2: Pond A16 water quality values during 1 June – 7 June

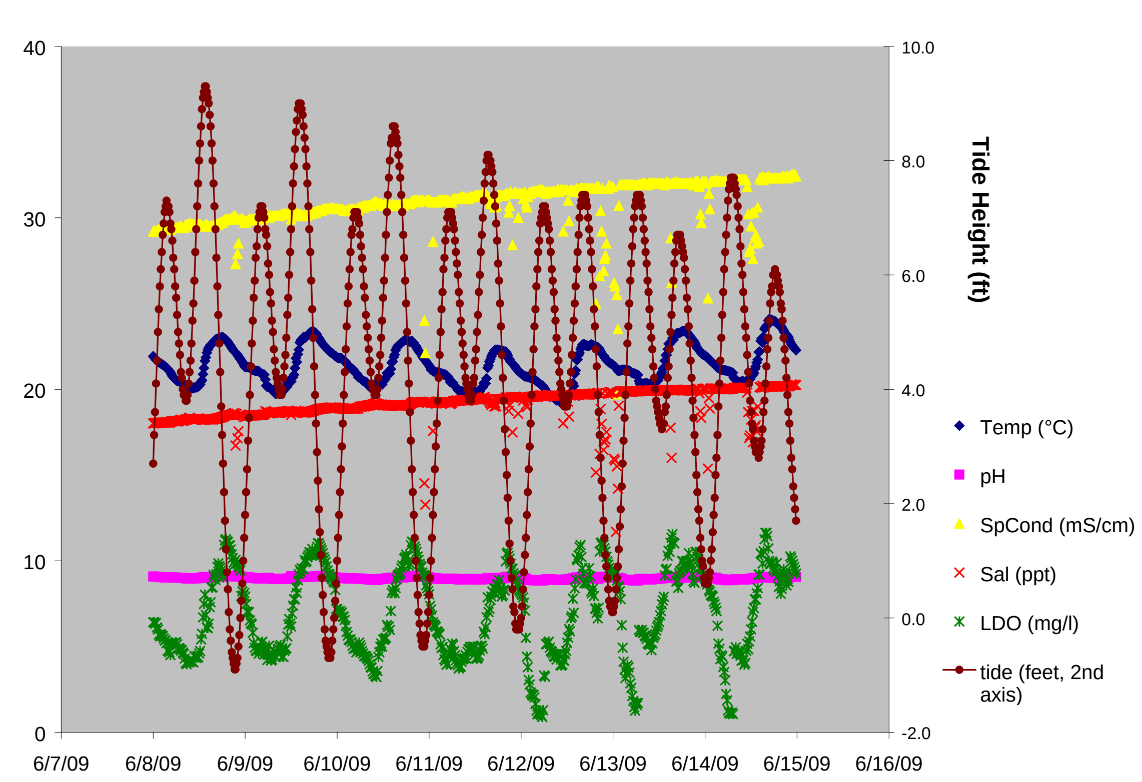

Figure 5.1-3: Pond A16 water quality values during 8 June – 14 June

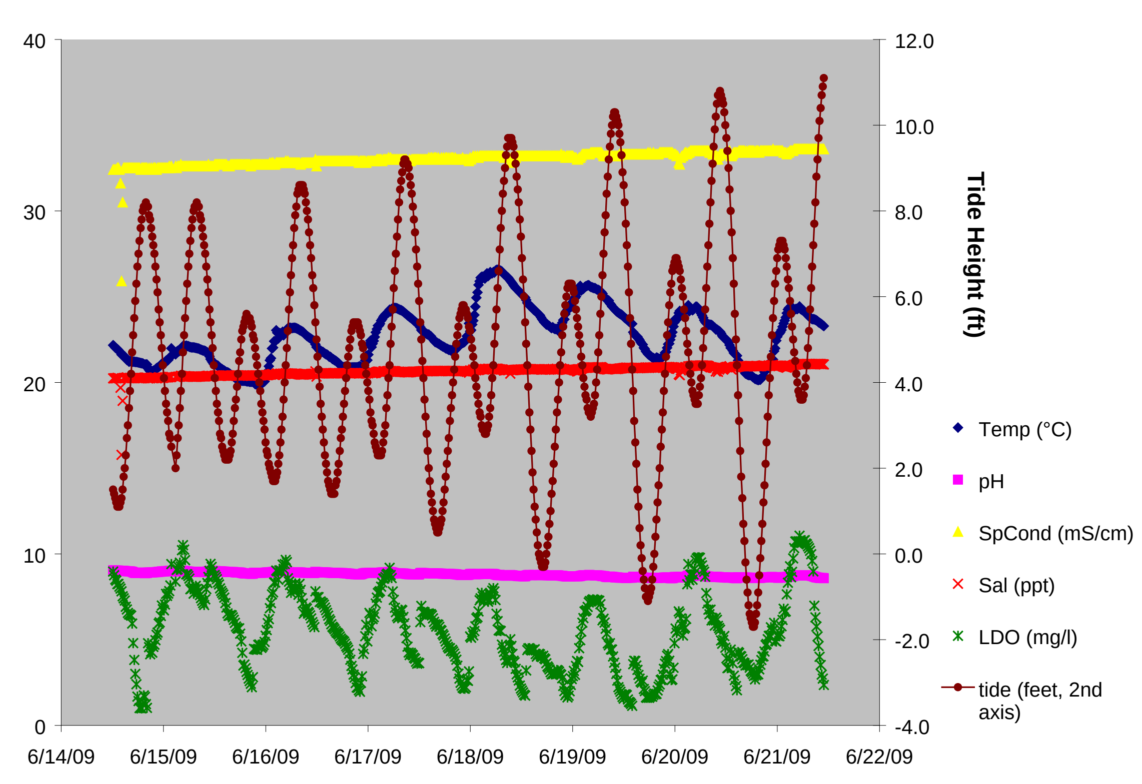

Figure 5.1-4: Pond A16 water quality values during 15 June – 21 June

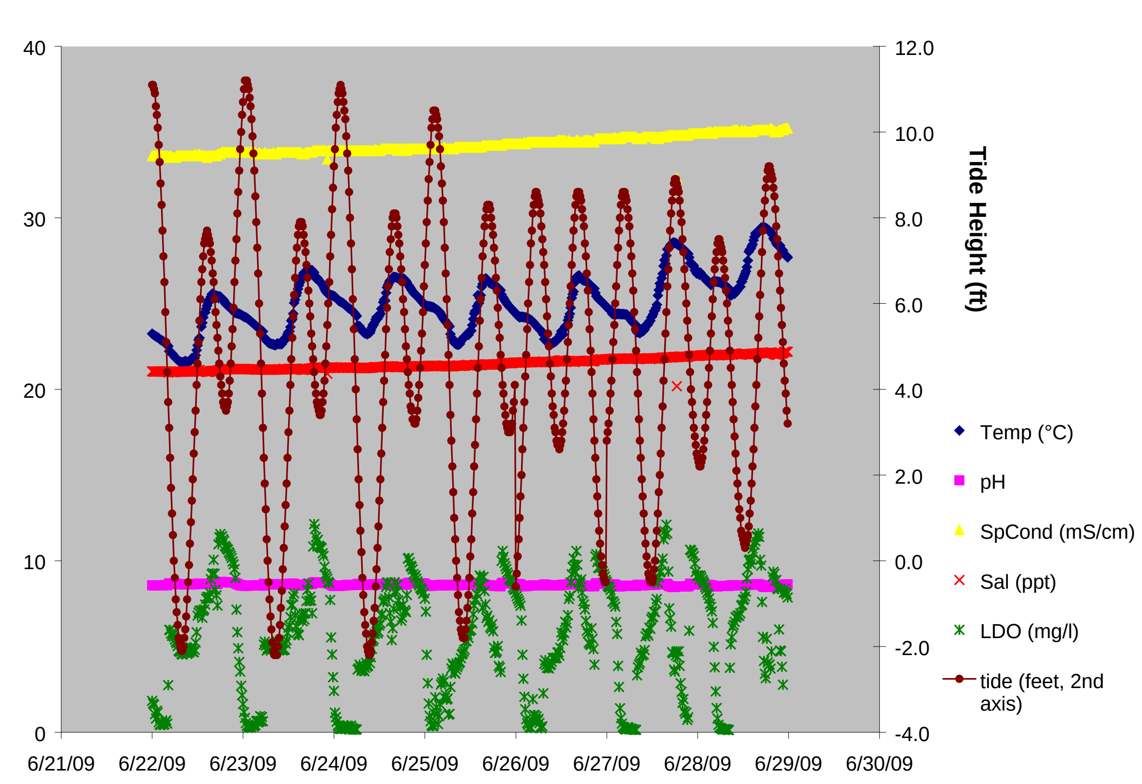

Figure 5.1-5: Pond A16 water quality values during 22 June – 28 June

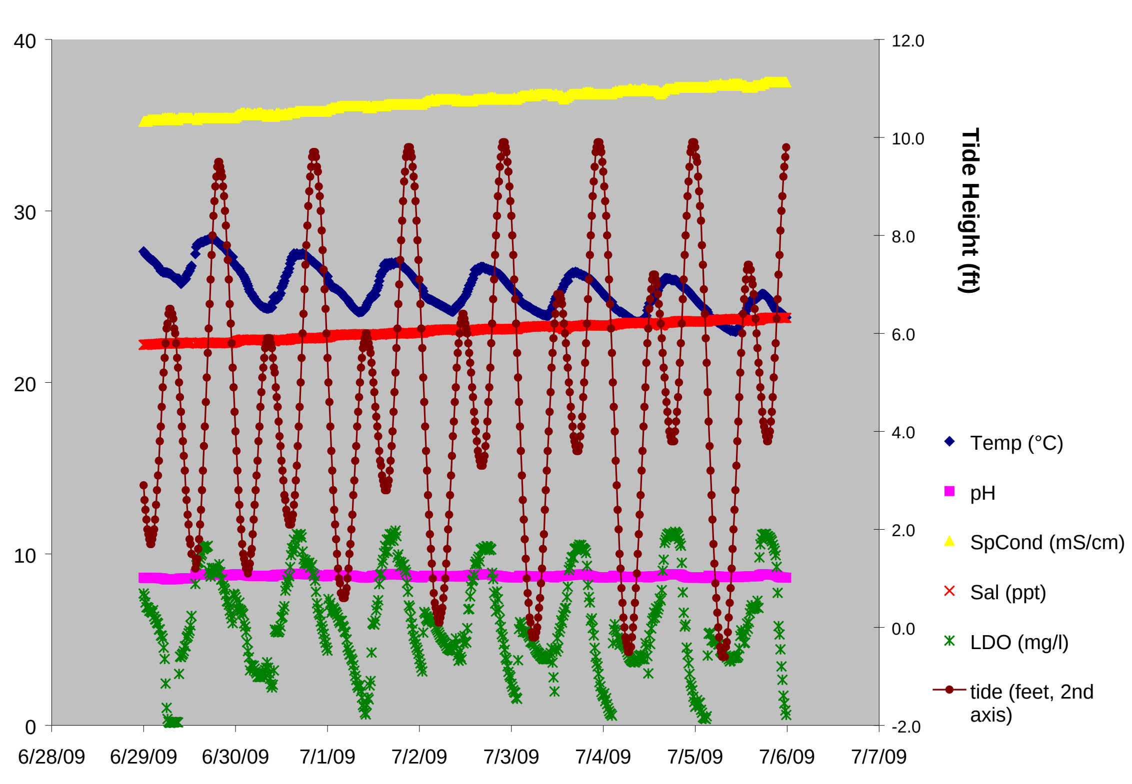

Figure 5.1-6: Pond A16 water quality values during 29 June – 5 July

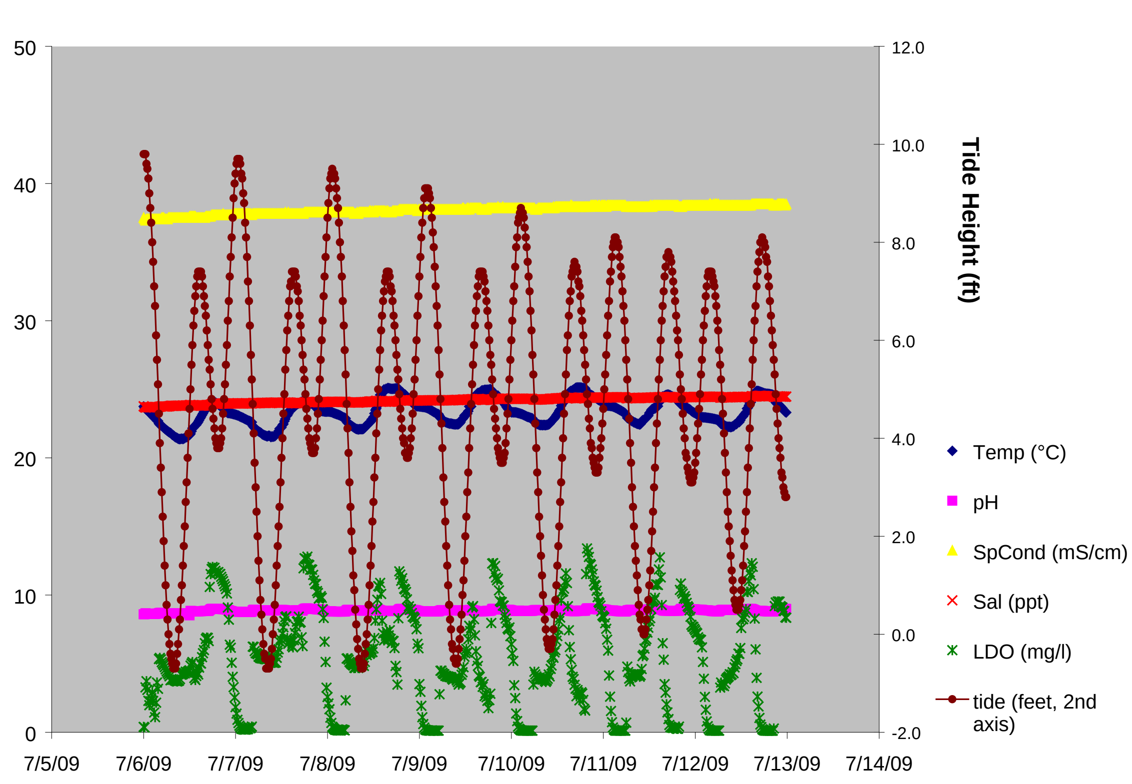

Figure 5.1-7: Pond A16 water quality values during 6 July – 12 July

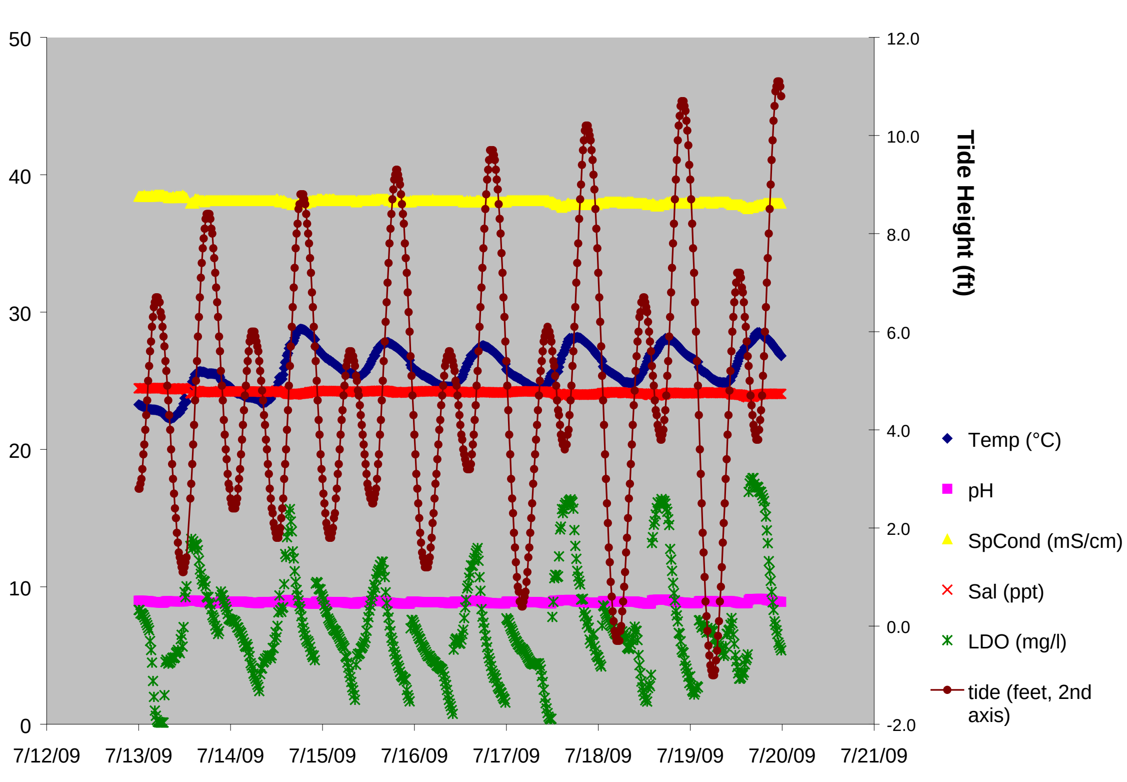

Figure 5.1-8: Pond A16 water quality values during 13 July – 19 July

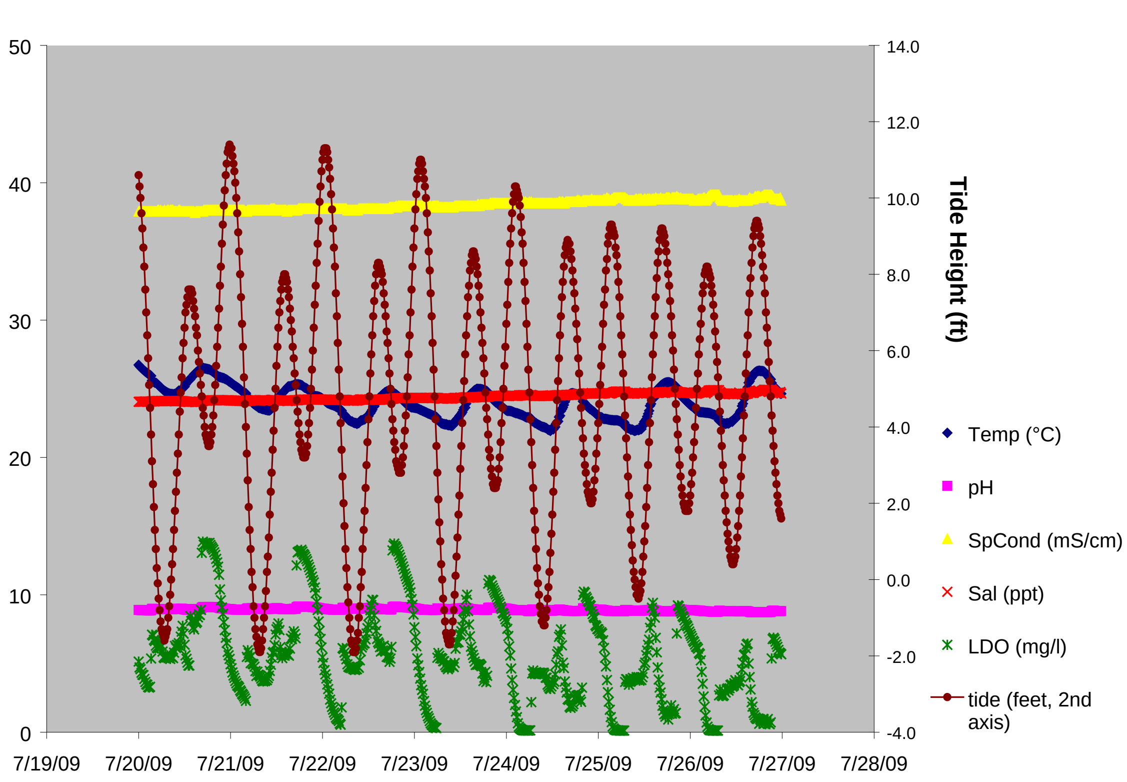

Figure 5.1-9: Pond A16 water quality values during 20 July – 26 July

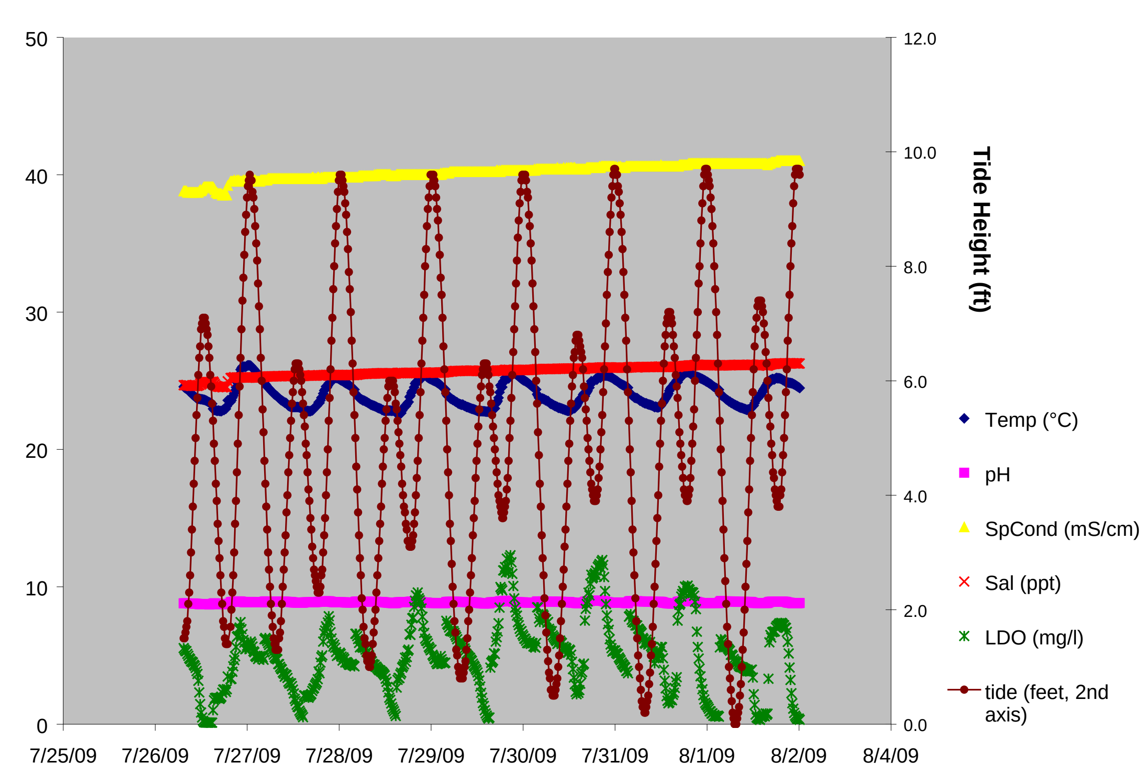

Figure 5.1-10: Pond A16 water quality values during 27 July – 2 August

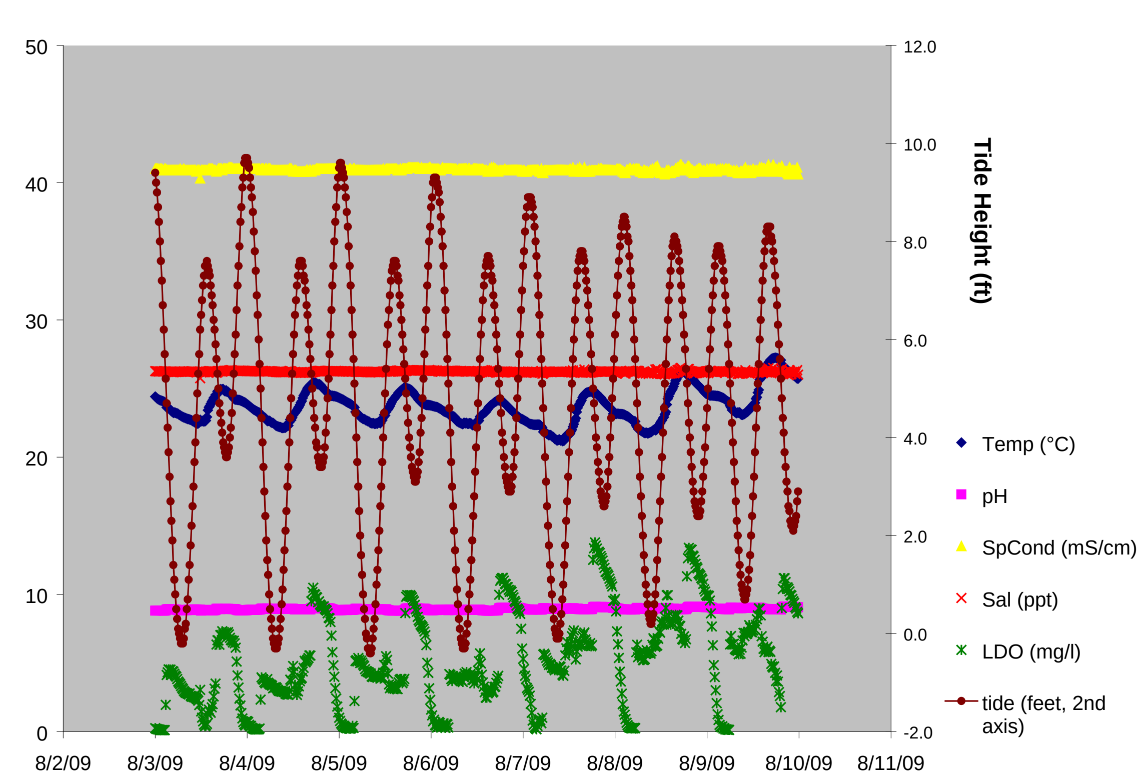

Figure 5.1-11: Pond A16 water quality values during 3 August – 9 August

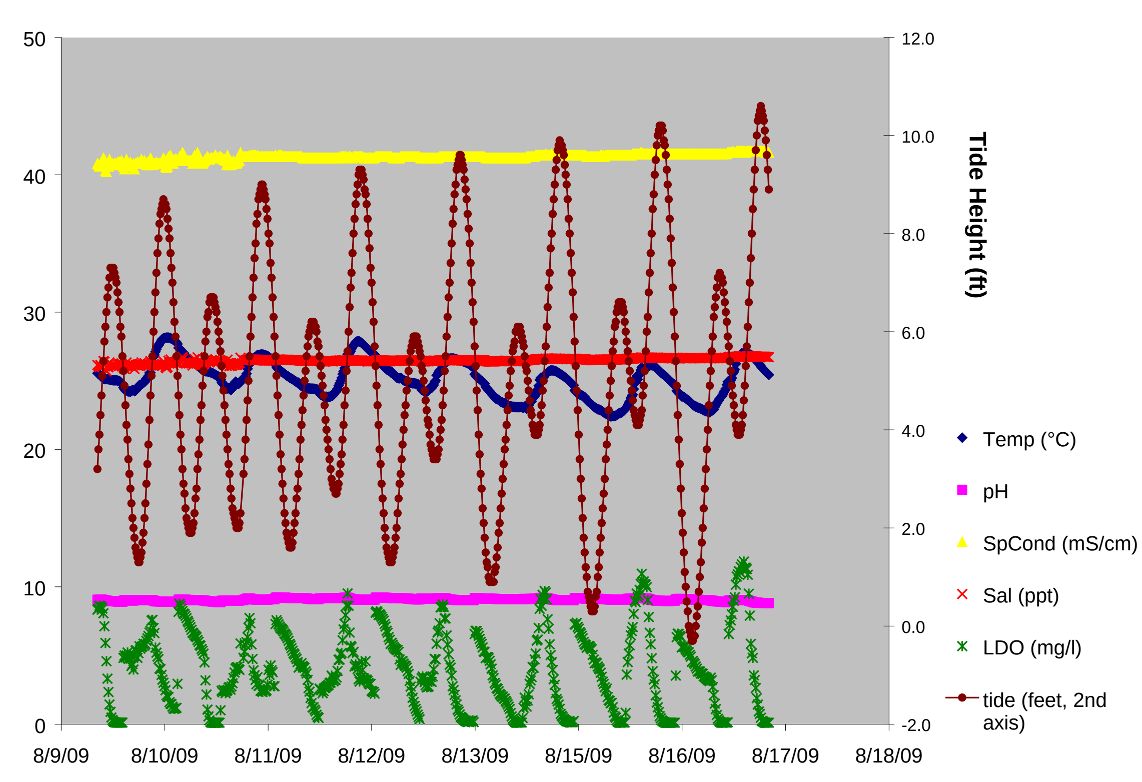

Figure 5.1-12: Pond A16 water quality values during 10 August – 16 August

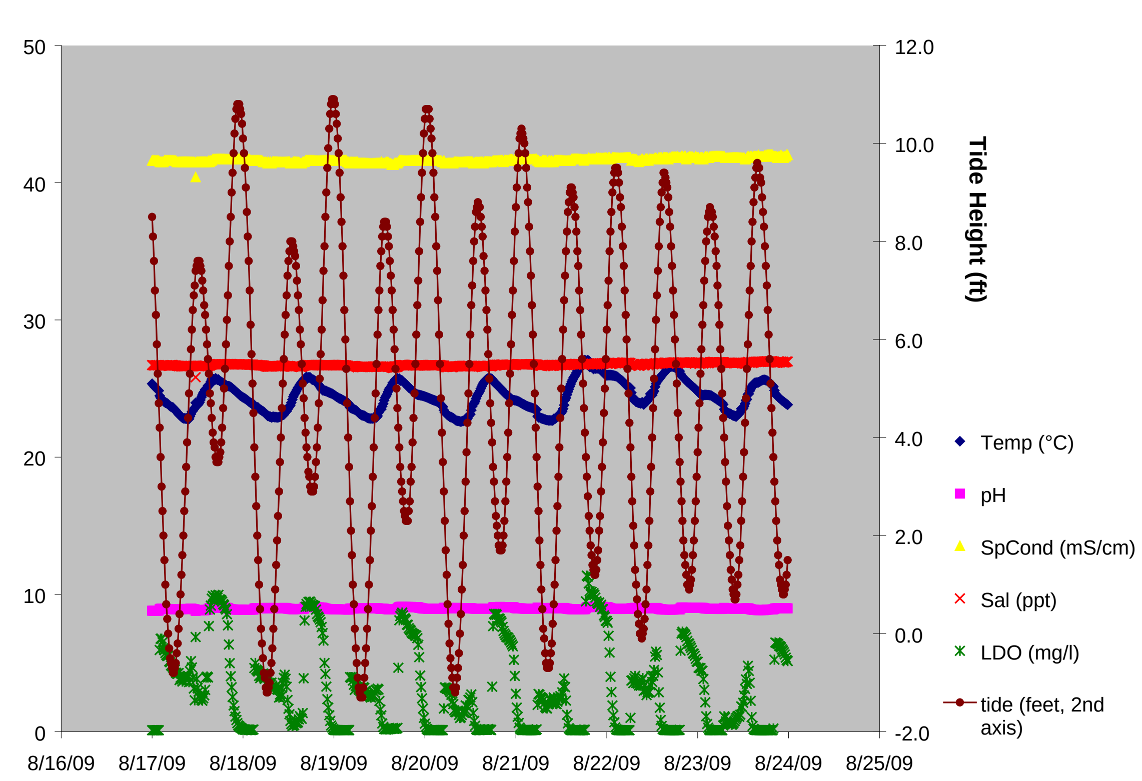

Figure 5.1-13: Pond A16 water quality values during 17 August – 23 August

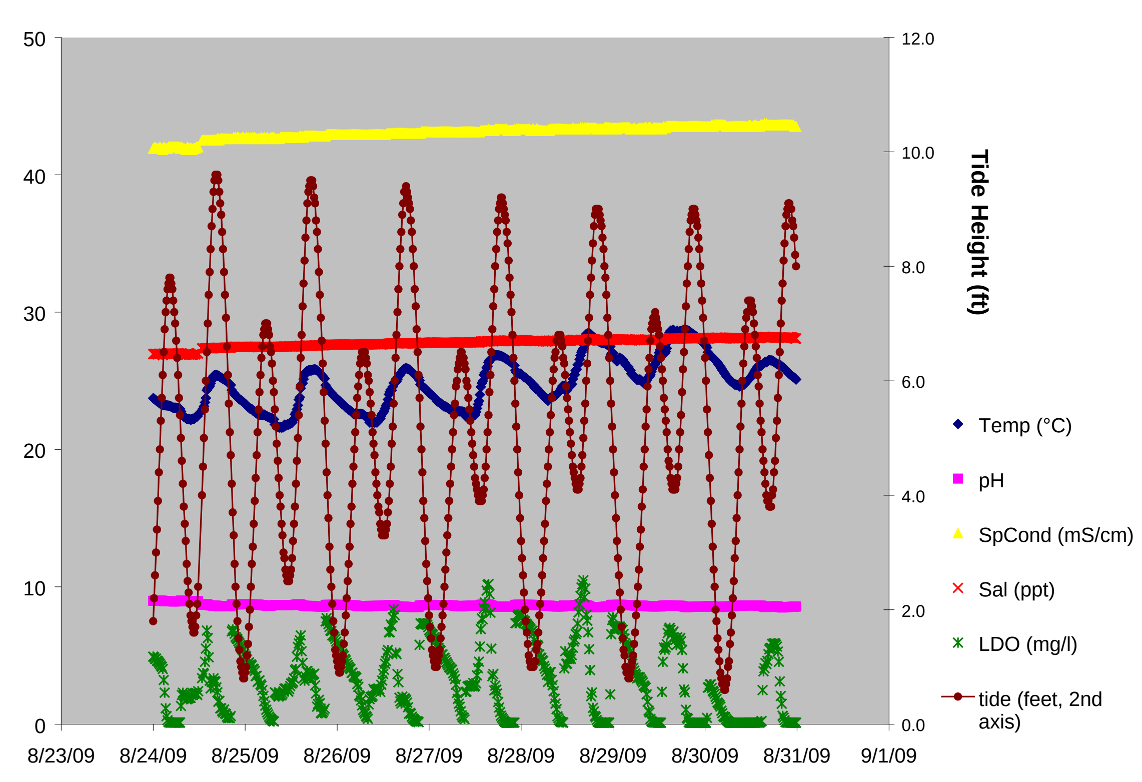

Figure 5.1-14: Pond A16 water quality values during 24 August – 30 August

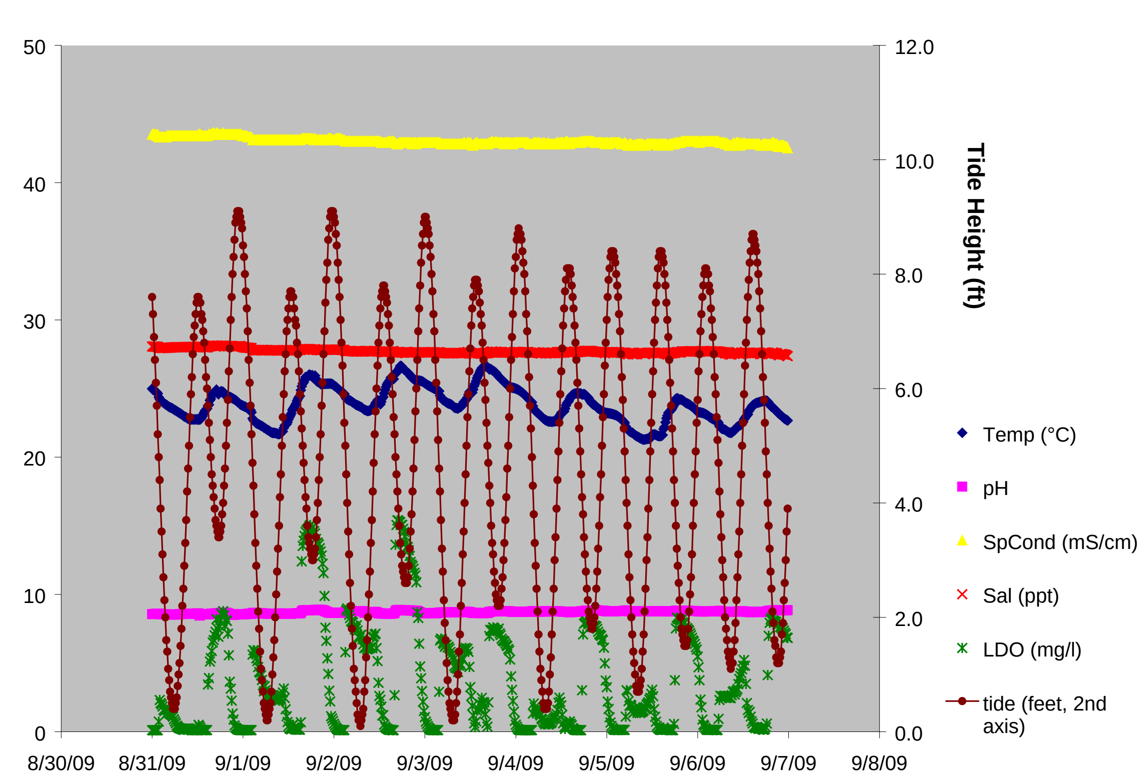

Figure 5.1-15: Pond A16 water quality values during 31 September – 6 September

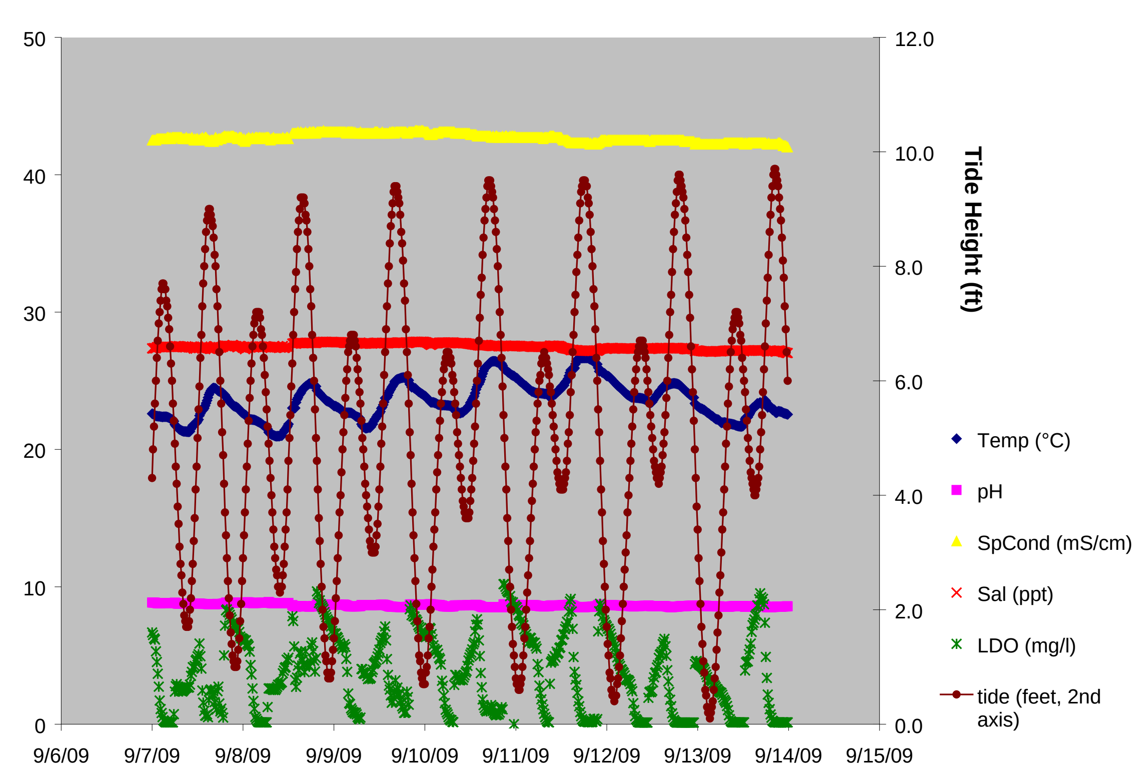

Figure 5.1-16: Pond A16 water quality values during 7 September – 13 September

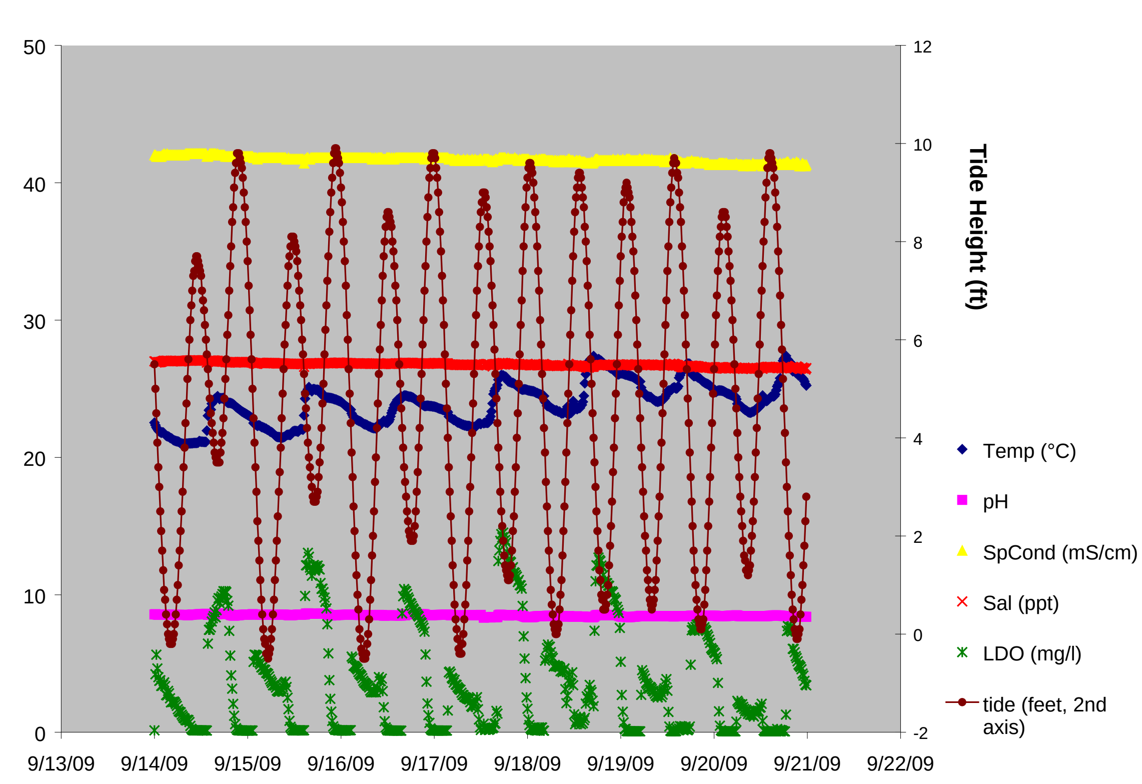

Figure 5.1-17: Pond A16 water quality values during 14 September – 20 September

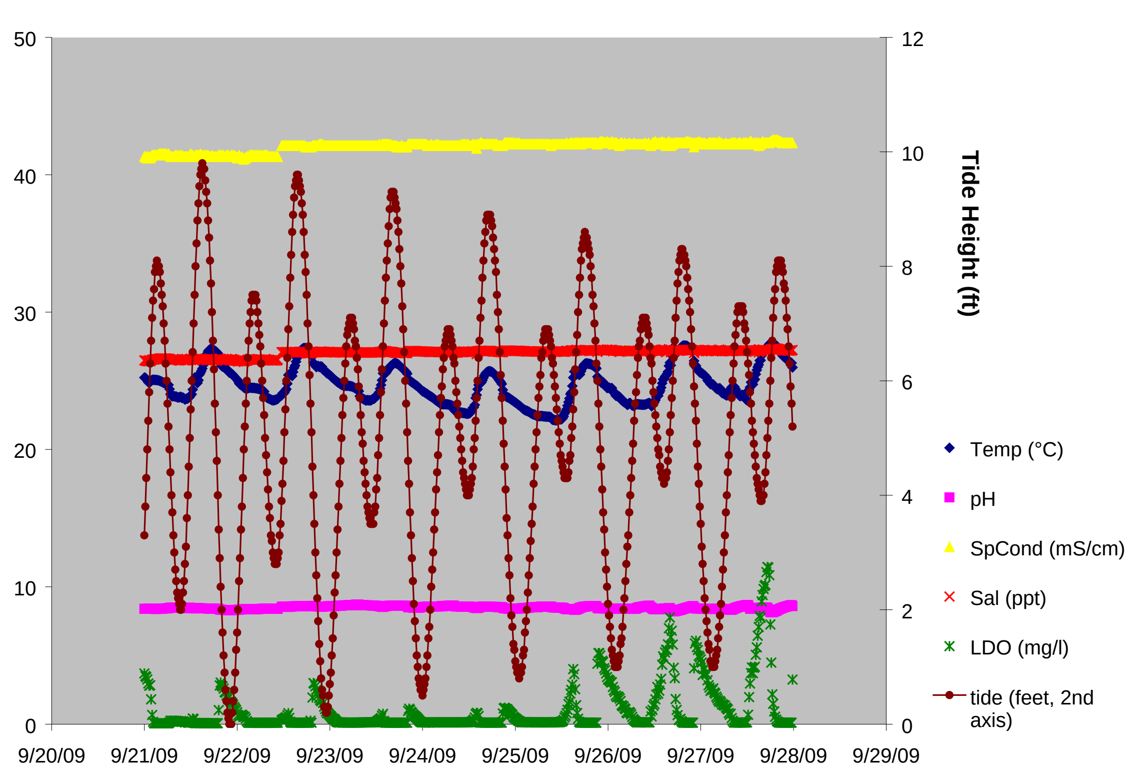

Figure 5.1-18: Pond A16 water quality values during 21 September – 27 September

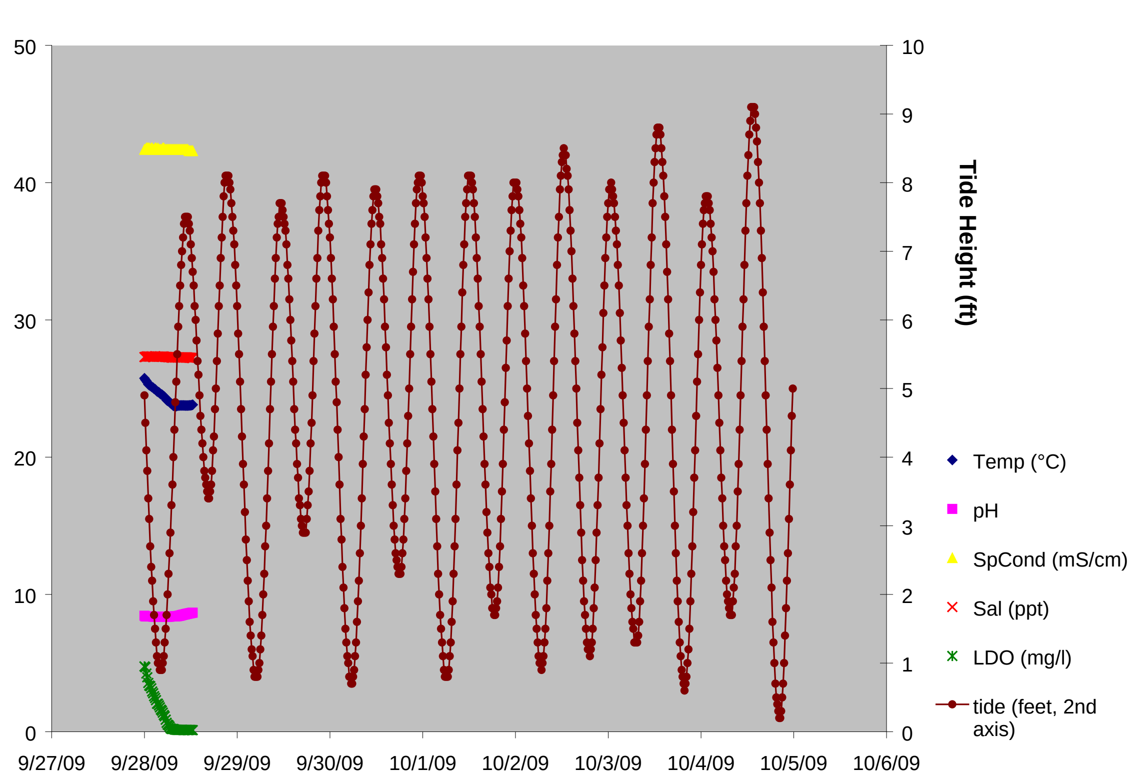

Figure 5.1-19: Pond A16 water quality values during 28 September – 4 October

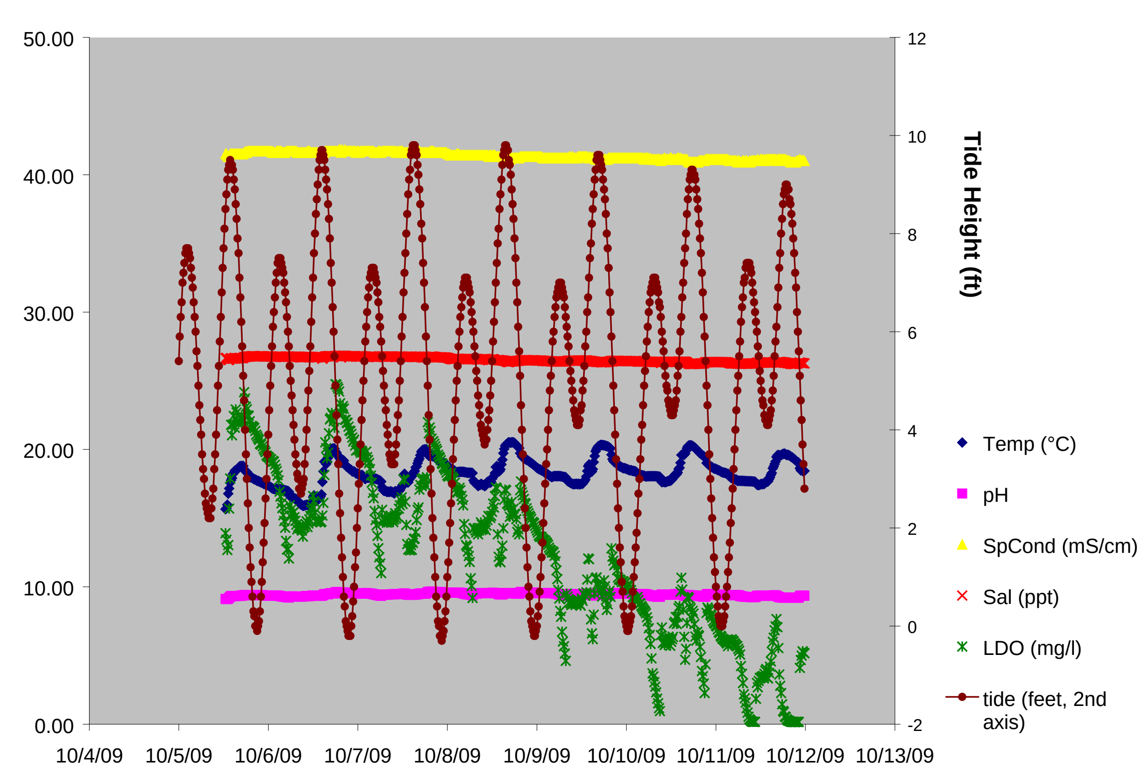

Figure 5.1-20: Pond A16 water quality values during 5 October – 11 October

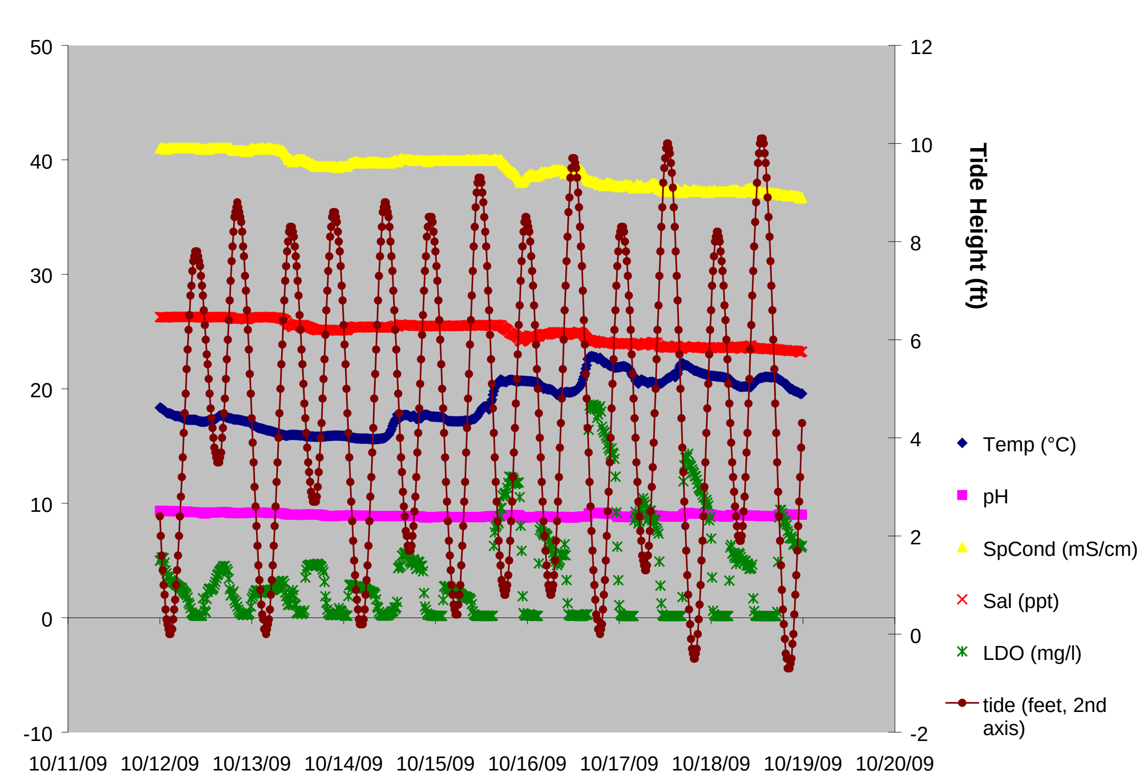

Figure 5.1-21: Pond A16 water quality values during 12 October – 18 October

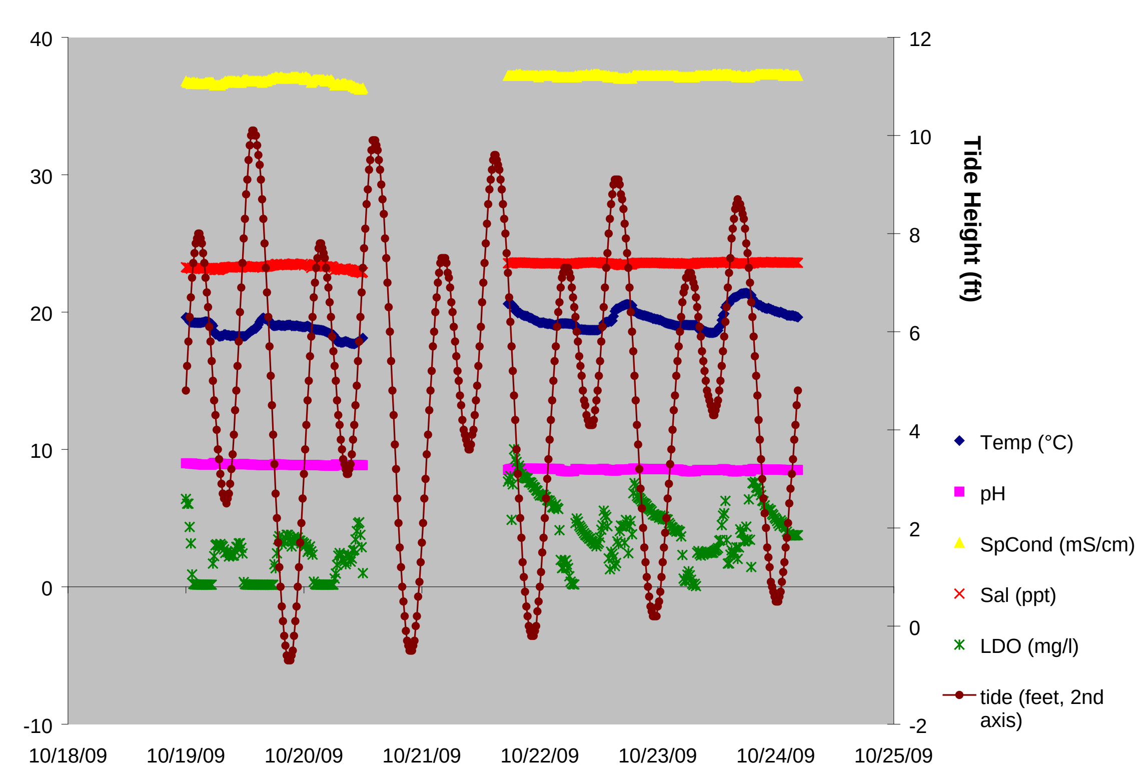

Figure 5.1-22: Pond A16 water quality values during 19 October – 24 October

5.5 Dissolved Oxygen Transects

While in 2008 transects were contained within barrow ditches, this year dissolved oxygen transects were conducted to determine spatial and temporal variability across ponds (Figures 5.5-1 through 5.5-10). Generally, morning transects recorded lower DO values than afternoon transects and had more points with values below 3.33 mg/L. September and August morning transects were both mostly comprised of points with DO values below 3.33 mg/L. In contrast, afternoon transects recorded higher DO values with no points at or below 3.33 mg/L. August afternoon transect recorded the greatest amount of higher DO values with the majority of points being above 11.01 mg/L.

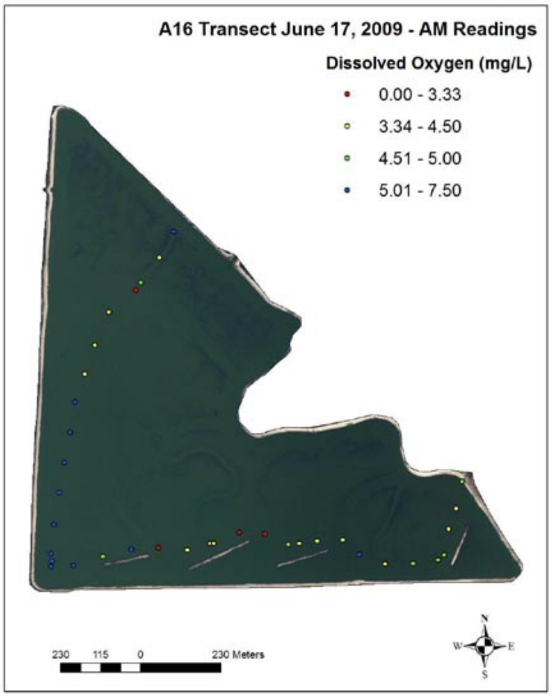

Figure 5.5-1: Dissolved oxygen transect in Pond A16, AM 17 June 2009.

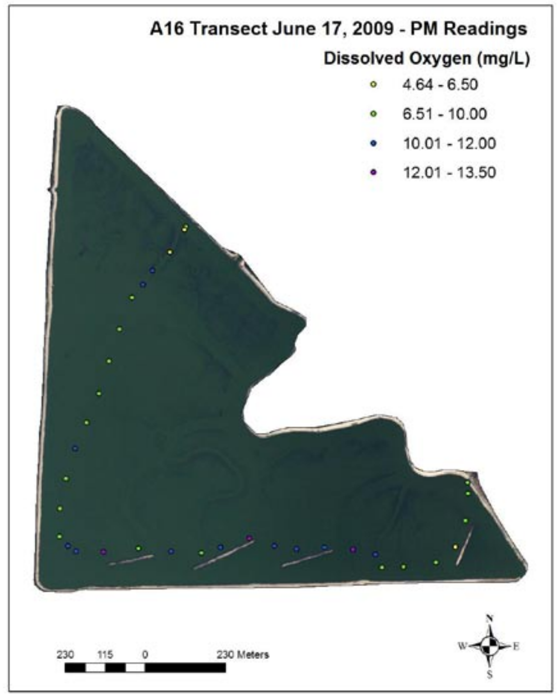

Figure 5.5-2: Dissolved oxygen transect in Pond A16, PM 17 June 2009.

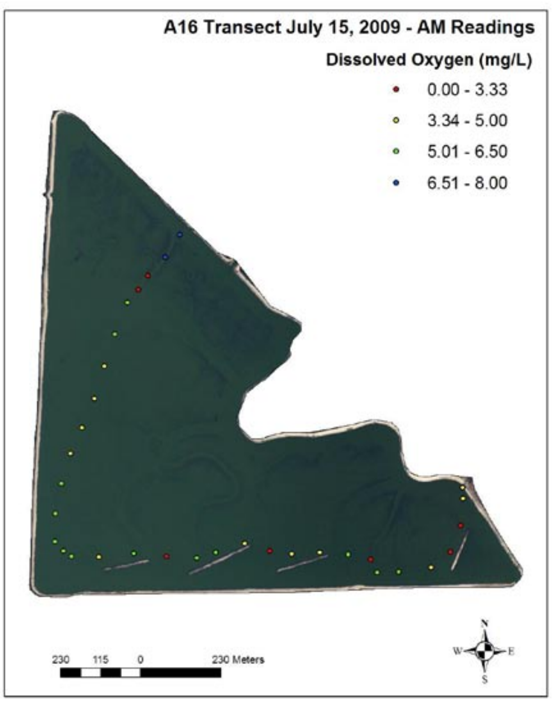

Figure 5.5-3: Dissolved oxygen values in Pond A16, AM 15 July 2009.

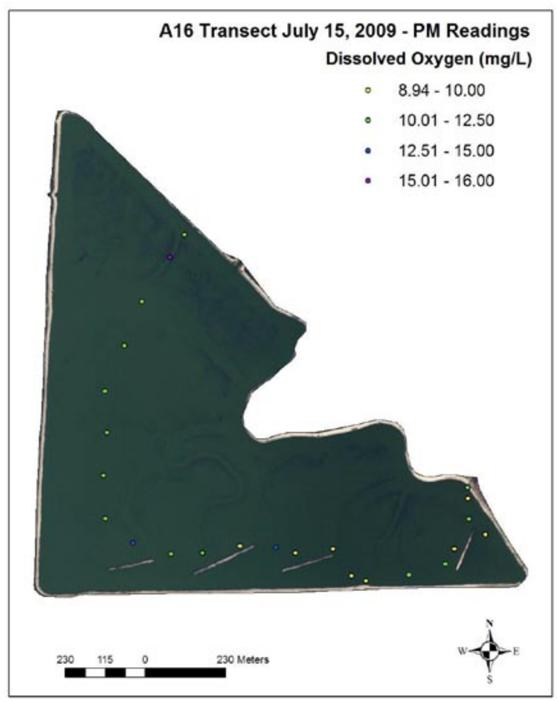

Figure 5.5-4: Dissolved oxygen values in Pond A16, PM 15 July 2009.

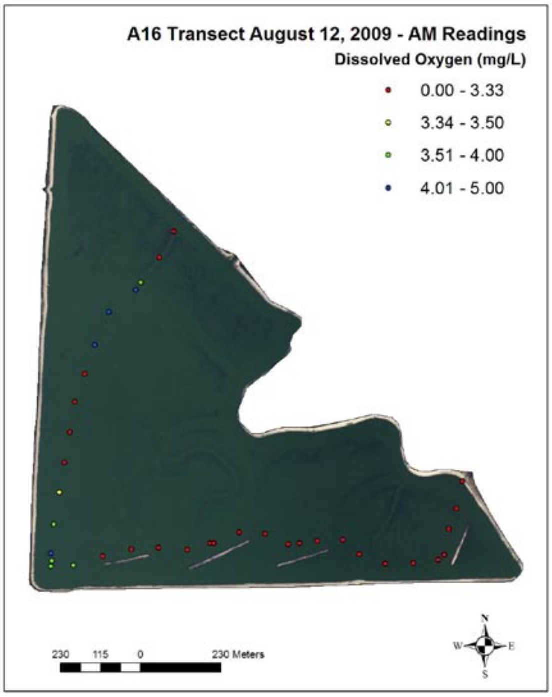

Figure 5.5-5: Dissolved oxygen transect in Pond A16, AM 12 August 2009.

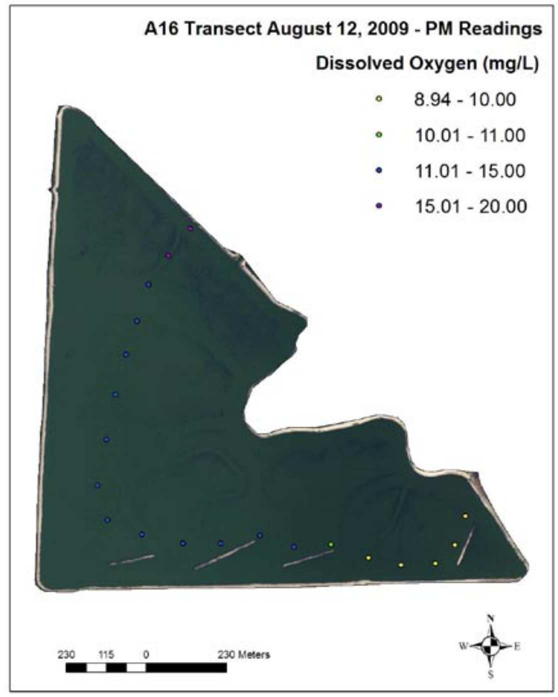

Figure 5.5-6: Dissolved oxygen transect in Pond A16, PM 12 August 2009.

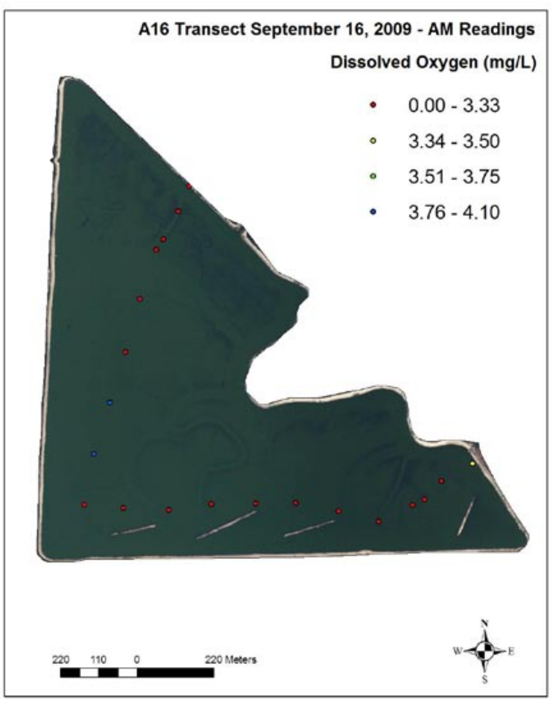

Figure 5.5-7: Dissolved oxygen transect in Pond A16, AM 16 September 2009.

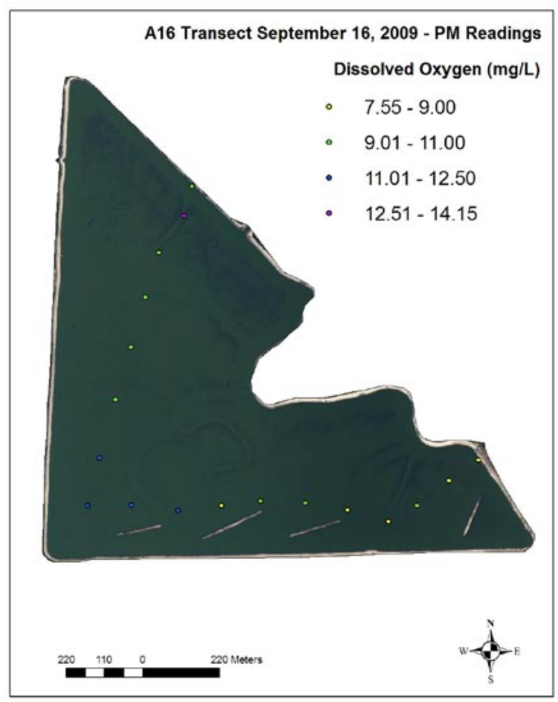

Figure 5.5-8: Dissolved oxygen transect in Pond A16, PM 16 September 2009.

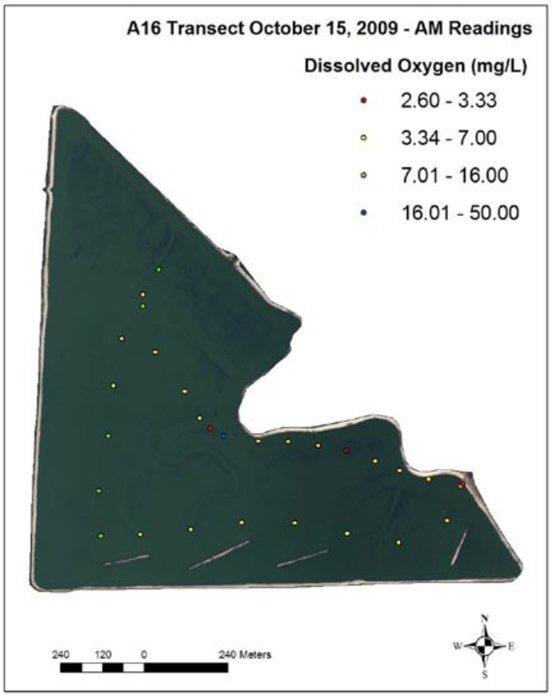

Figure 5.5-9: Dissolved oxygen transect in Pond A16, AM 15 October 2009.

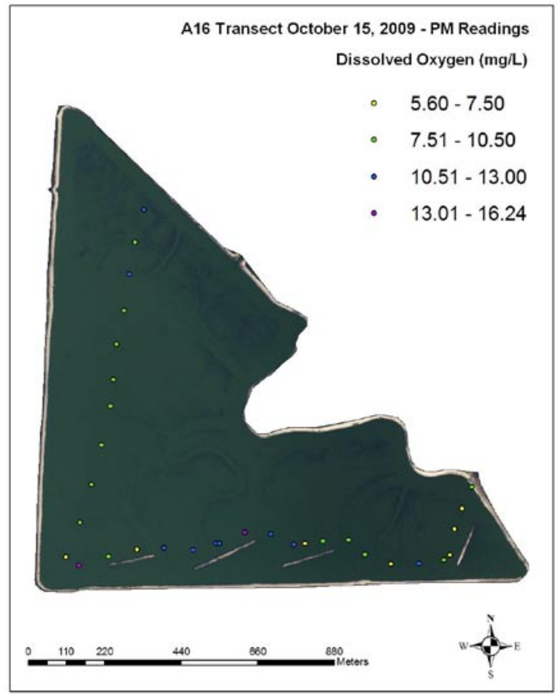

Figure 5.5-10: Dissolved oxygen transect in Pond A16, PM 15 October 2009.

5.6 NUTRIENTS AND CHLOROPHYLL

Nutrient measurements were highly variable within pond A14 (Table 5.6-1). Further analysis is needed to analyze the spatial and temporal patterns in conjunction with water quality and meteorological data. Measurements for chlorophyll within Pond A3W were also highly variable, with substantial spatial variation in chlorophyll across transects over all sampling dates (Figures 5.6-1 through 5.6-3).

Table 5.6-1: Pond A16 summarized nutrient values (mean ± standard deviation) by sampling period.

Pond	Sampling Date	Sample Location	Nitrate + Nitrite (NO_3 +NO2) µM	Ammonium (NH4) µM	DIN (dissolved inorganic nitrogen) µM	Phosphate (PO4) µM	Silicate µM
A16	6/17/2009	A	22.52	1.89	24.41	15.81	21.6
	6/17/2009	B	0.00	0.92	0.92	13.47	9.08
	6/17/2009	C	95.37	1.89	97.26	11.36	53.83
	7/15/2009	A	0.00	1.45	1.45	16.06	75.97
	7/15/2009	B	0.00	2.68	2.68	13.56	42.81
	7/15/2009	C	31.01	0.87	31.88	12.58	45.39
	8/12/2009	A	0.00	0.99	0.99	9.18	36.77
	8/12/2009	B	0.00	1.33	1.33	8.33	48.9
	8/12/2009	C	0.00	1.15	1.15	8.82	77.65
	9/16/2009	A	0.00	1.73	1.73	12.70	94.43
	9/16/2009	B	0.00	0.74	0.74	12.95	112.76
	9/16/2009	C	0.00	1.29	1.29	9.91	101.22
	10/15/2009	A	23.25	6.43	29.68	10.97	84.96
	10/15/2009	B	5.99	11.31	17.3	13.74	72.4
	10/15/2009	C	1.70	22.02	23.72	15.29	69.92

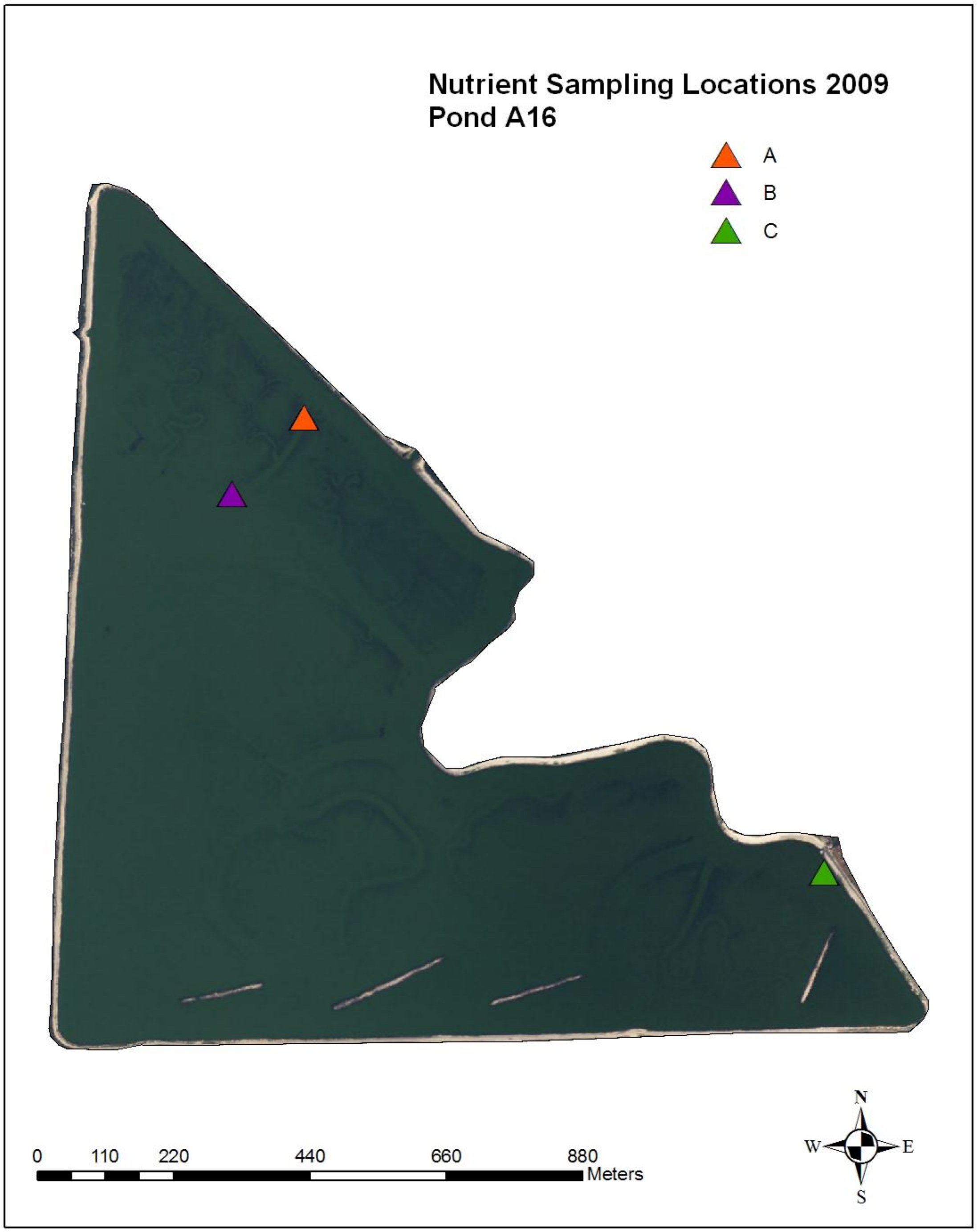

Figure 5.6-1: Nutrient sampling locations for Pond 16, 2009.

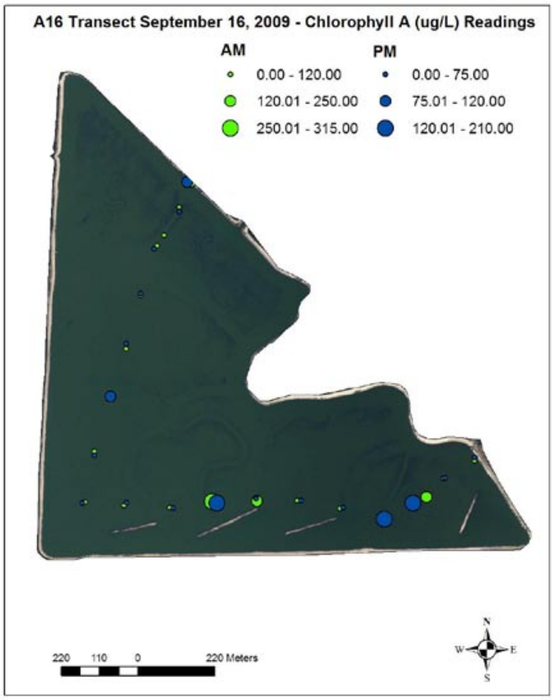

Figure 5.6-2: AM and PM Chlorophyll levels in Pond A16 on 16 September 2009.

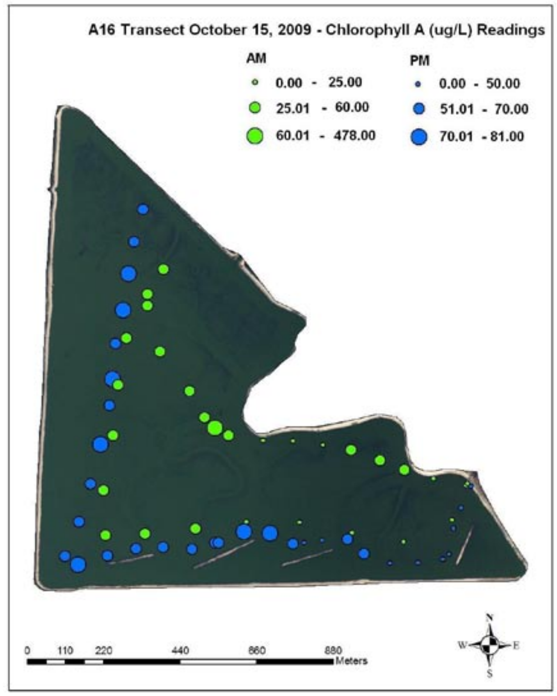

Figure 5.6-3: AM and PM Chlorophyll levels in Pond A16 on 15 October 2009.

5.7 METEOROLOGICAL MEASUREMENTS

Meteorological data were relatively consistent during the study period (Table 5.7-1). Wind was primarily from the south and averages ranged from 5 to 7 mph. Gusts ranged from 0 to 45 mph where gust averages ranged from 8.30 to 11.00 mph. Relative humidity remained consistent throughout the study period. Rainfall was scarce throughout the study period; however, October did experience a very small amount of precipitation. Monthly mean temperatures were also consistent and ranged from 16.00degrees Celsius to 19.50degrees Celsius. Photosynthetically active radiation (PAR) and solar radiation were variable during the study period, but varied largely due to diurnal cycles.

Table 5.7-1: Summarized weather values (mean ± standard deviation) for all ponds by month

Month	Temperature (°C)	Relative Humidity (%)	Rainfall (cm)	Primary Wind Direction	Wind Speed (mph)	PAR Light (uM/m^2s)	Solar Radiation (wat/m2)
June	17.93 ± 1.0	71.81 ± 12.65	0.00 ± 0.0	South	7.04 ± 5.64	1083.21 ± 750.1 Max: 2748	448.51 ± 330.6 Max: 1208
July	17.99 ± 1.0	77.56 ± 14.00	0.00 ± 0.0	South - Southwest	6.55 ± 5.50	1140.64 ± 815.4 Max: 2454	475.10 ± 342.5 Max: 1054
August	19.20 ± 1.1	74.35 ± 16.42	0.00 ± 0.0	South	5.94 ± 5.51	1084.71 ± 719.5 Max: 2124	460.00 ± 323.1 Max: 917
September	19.45 ± 1.0	73.14 ± 16.43	0.00 ± 0.0	South - Southeast	5.03 ± 5.21	976.52 ± 626.6 Max: 2079	414.60 ± 275.7 Max: 911
October	16.00 ± 0.9	73.30 ± 18.90	0.00 ± 0.0	South	5.95 ± 6.04	760.90 ± 519.4 Max: 1834	324.60 ± 232.9 Max: 762

6. Pond A7 In-Pond Sampling

SECTION 6
POND A7 IN-POND SAMPLING

This section summarizes analyses of 2009 water quality data being conducted for Pond A7 to characterize spatial variability and patterns with respect to flow patterns and pond management. A brief description of our initial findings is presented below:

6.1 CONTINUOUS WATER QUALITY MONITORING

A single datasonde was continuously deployed at the discharge location of Pond A7 from 1 June 2009 to 31 October 2009. Monthly averages show similarities in water quality parameters between June and October (Table 6.1-1). These two months show highest DO concentrations but lowest salinity and temperature values compared with July, August and September. In contrast, pH remained fairly consistent throughout the study period.

Table 6.1-1: Pond A7 summarized water quality values (mean ± standard deviation) by month.

Pond	Month	Dissolved Oxygen (mg/L)	pH (Units)	Specific Conductivity (mS/cm)	Temperature (°C)	Salinity (ppt)
A7	June	4.00 ± 2.32	8.62 ± 0.16	40.09 ± 1.22	21.56 ± 1.90	25.63 ± 0.87
	July	3.18 ± 1.58	8.38 ± 0.06	44.01 ± 1.11	21.84 ± 0.99	28.45 ± 0.80
	August	2.32 ± 1.58	8.28 ± 0.07	46.5 ± 0.81	22.38 ± 1.16	30.27 ± 0.59
	September	2.90 ± 1.80	8.23 ± 0.06	47.46 ± 1.27	21.82 ± 1.58	30.96 ± 0.93
	October	4.49 ± 2.03	8.08 ± 0.17	42.21 ± 3.82	16.87 ± 2.04	27.17 ± 2.74
	Overall	3.39 ± 2.04	8.30 ± 0.21	44.12 ± 3.40	20.75 ± 2.66	28.59 ± 2.45

Dissolved oxygen

Dissolved oxygen levels cycled throughout the study period, and seemed to be influenced primarily by the tidal and diurnal cycles (Figures 6.1-1 through 6.1-22). Dissolved oxygen rates were highest in June and October, perhaps due to lower ambient temperatures. July, August, and September had decreased dissolved oxygen levels, with monthly averages all below 3.33 mg/L.

6.2 SALINITY

Tide cycles did not seem to have much impact on salinity within Pond A7 with the exception of the last half of October (Figures 6.1-1 through 6.1-22). During this time frame, salinity values within Pond A7 fluctuated due to a crack in the intake structure, this then allowed water from Alviso Slough to enter the pond. Salinity within Pond A7 increased from June to September and fell in October. Salinity was highest in Pond A7 during August and September when temperatures were also high.

6.3 PH

Throughout the study period, pH within Pond A7 remained relatively stable and did not seem to be impacted by tidal influence (Figures 6.1-1 through 6.1-22). Data from 2008 also shows little variation in pH values. Monthly pH averages declined from 8.62 in June to 8.08 in October. pH ranged from 7.5 to 8.9 with an average monthly value above 8.5 being recorded only in June. In contrast, pH values above 8.5 were recorded in July, August, and September during 2008.

6.4 TEMPERATURE

Unlike pH values, temperature data for Pond A7 did appear to oscillate according to tide and diurnal cycles (Figures 6.1-1 through 6.1-22). This tidal influence on temperature can also be seen in data collected in 2005-2008. Temperature in Pond A7 increased from June to August and began to decline in September and October.

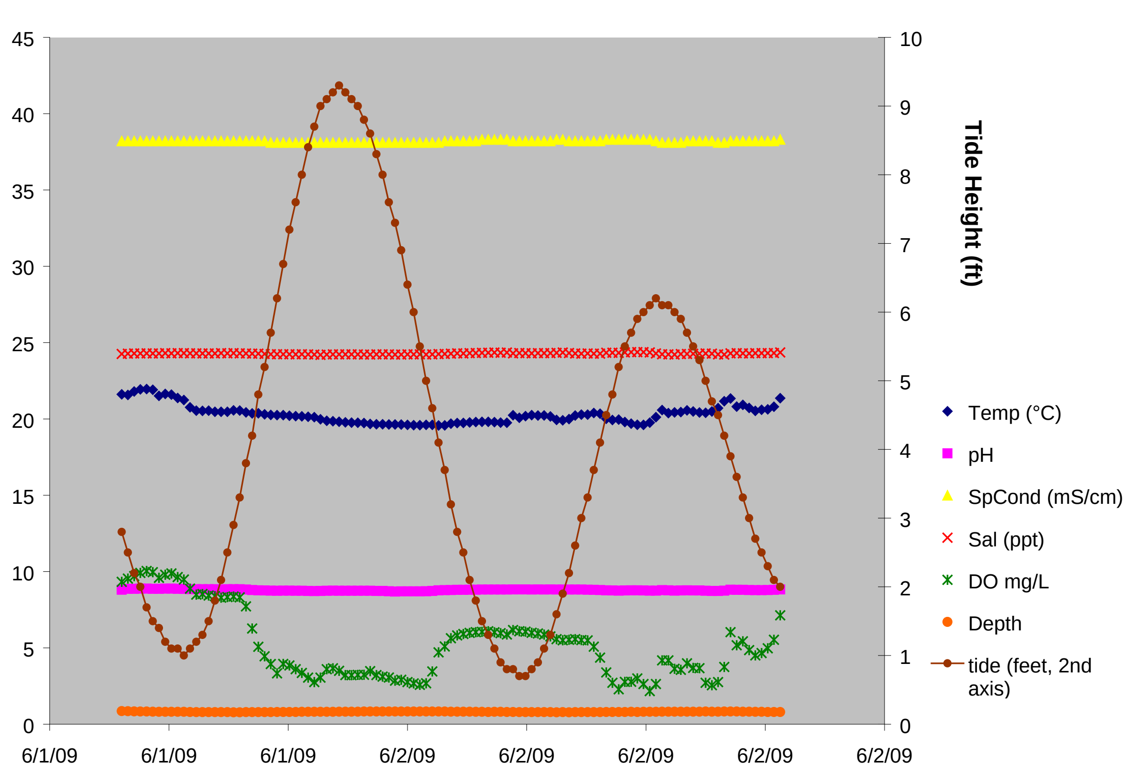

Figure 6.1-1: Pond A7 water quality values during 1 June – 2

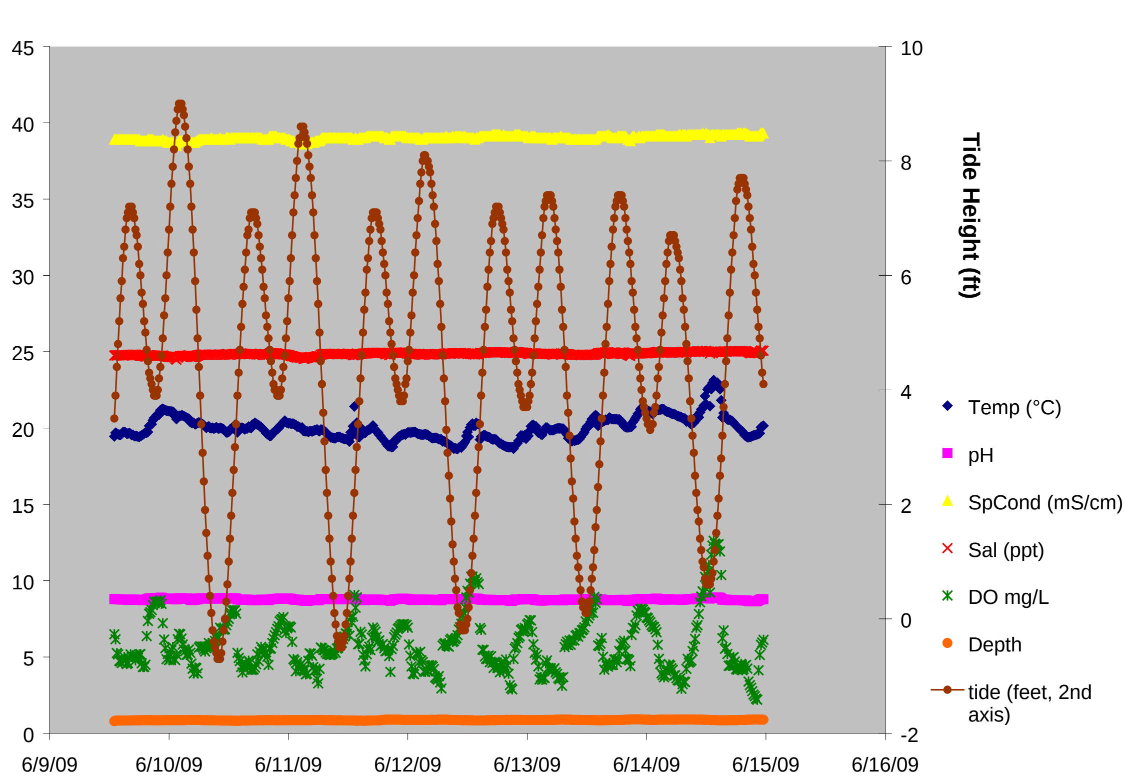

Figure 6.1-2: Pond A7 water quality values during 10 June – 14 June

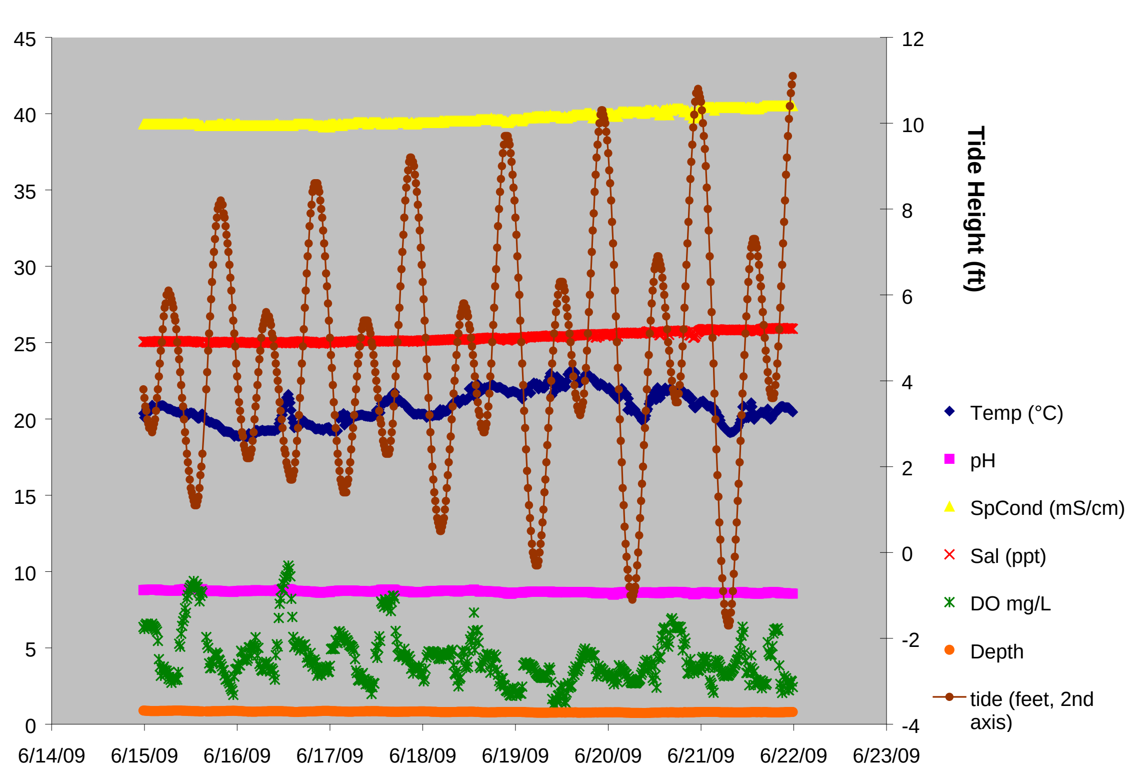

Figure 6.1-3: Pond A7 water quality values during 15 June – 21 June

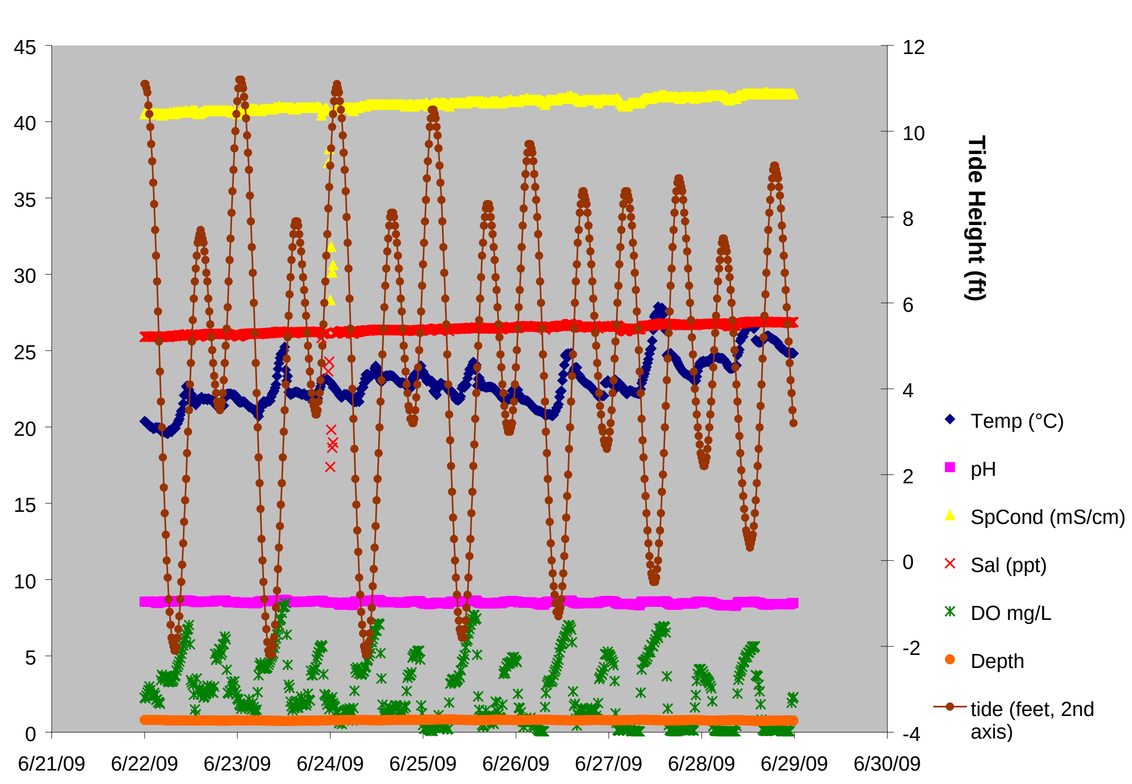

Figure 6.1-4: Pond A7 water quality values during 22 June – 28 June

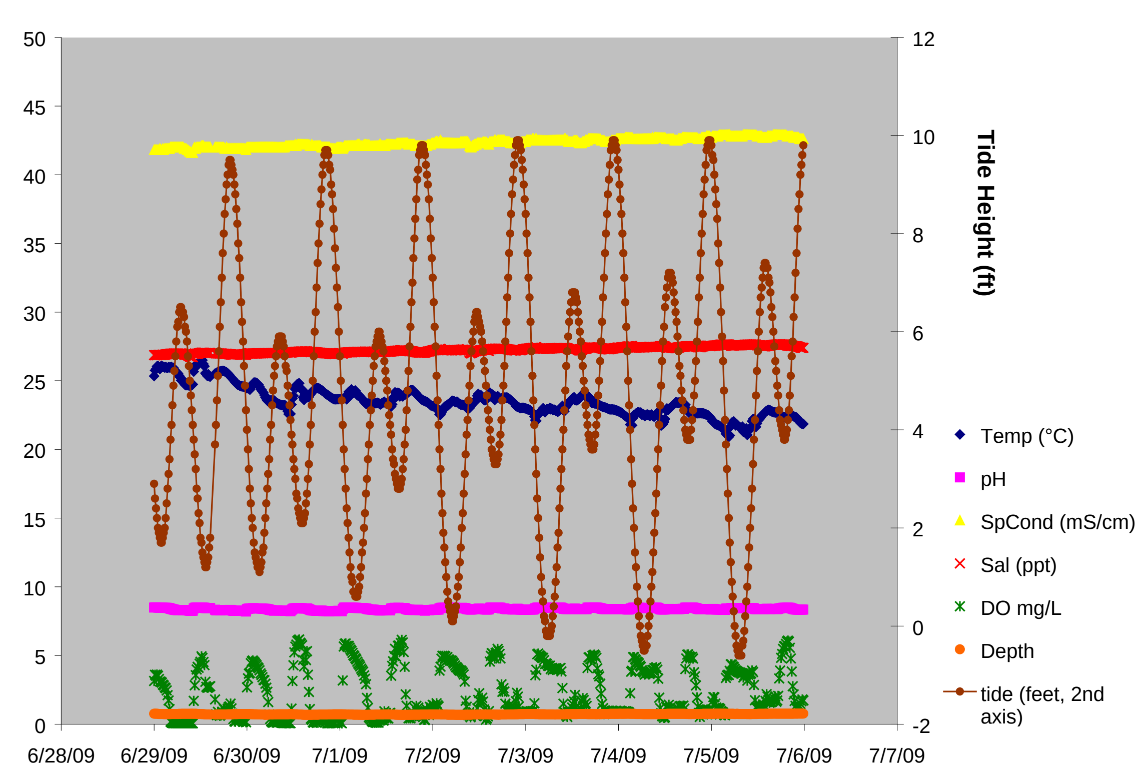

Figure 6.1-5: Pond A7 water quality values during 29 June – 5 July

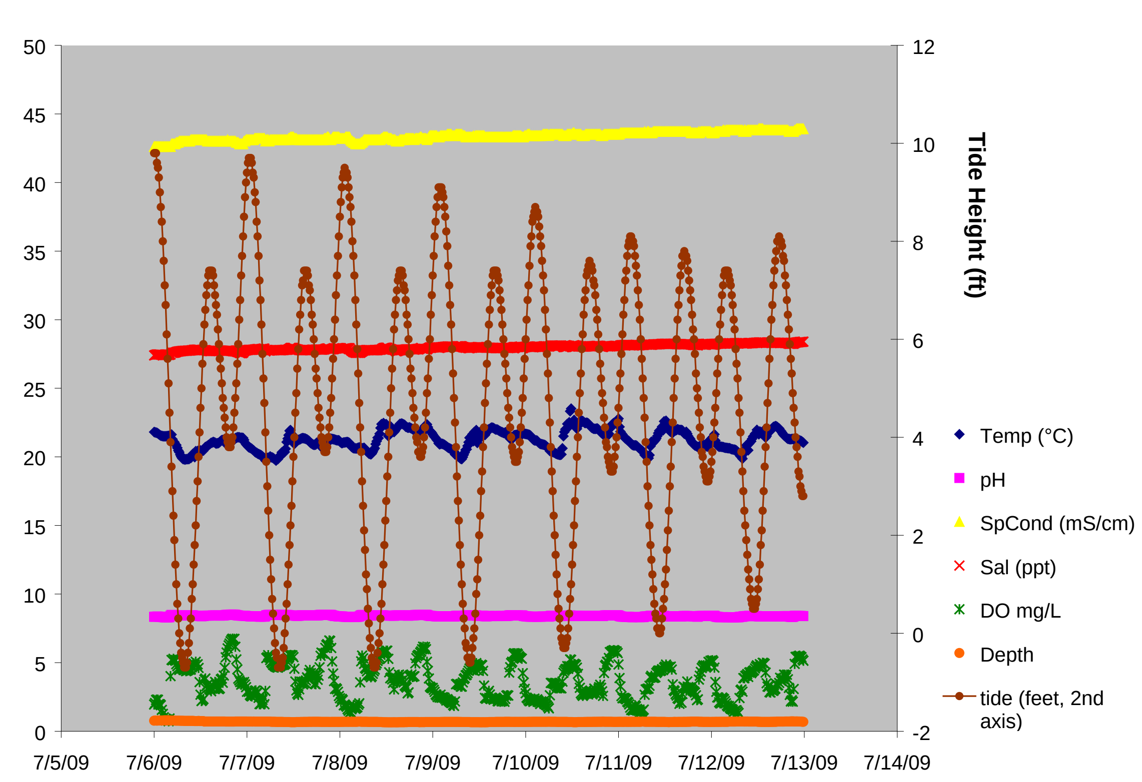

Figure 6.1-6: Pond A7 water quality water during 6 July – 12 July

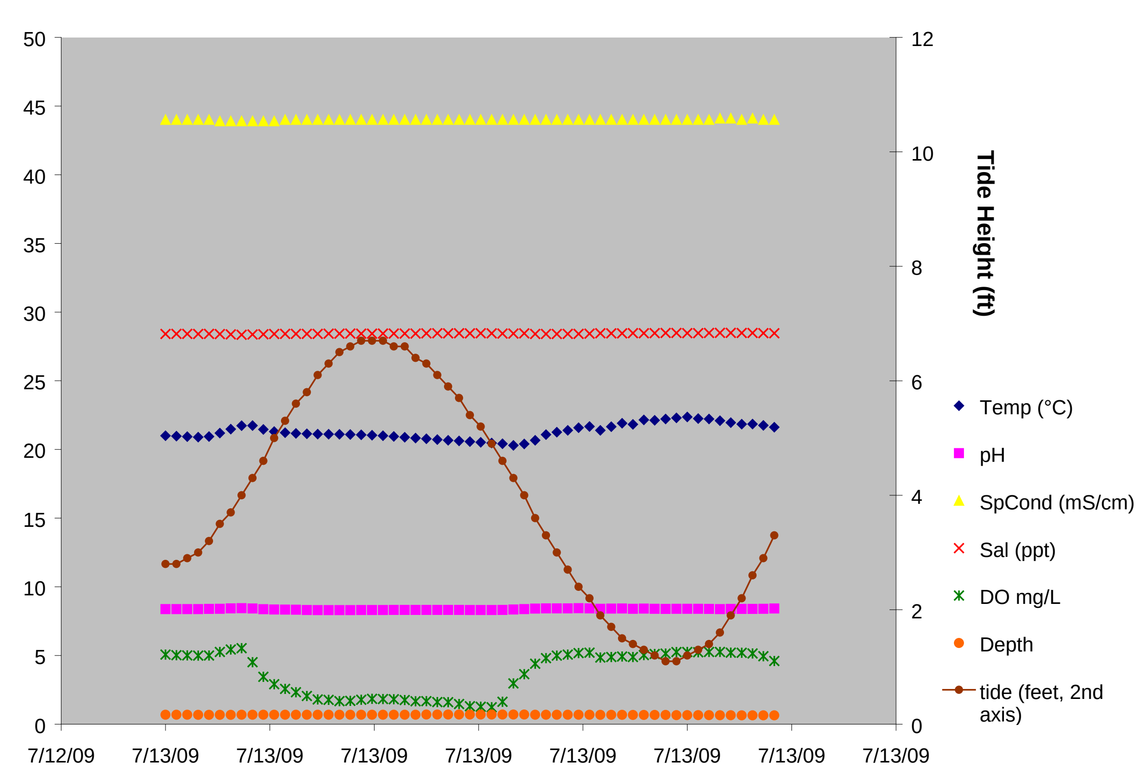

Figure 6.1-7: Pond A7 water quality values during 13 July

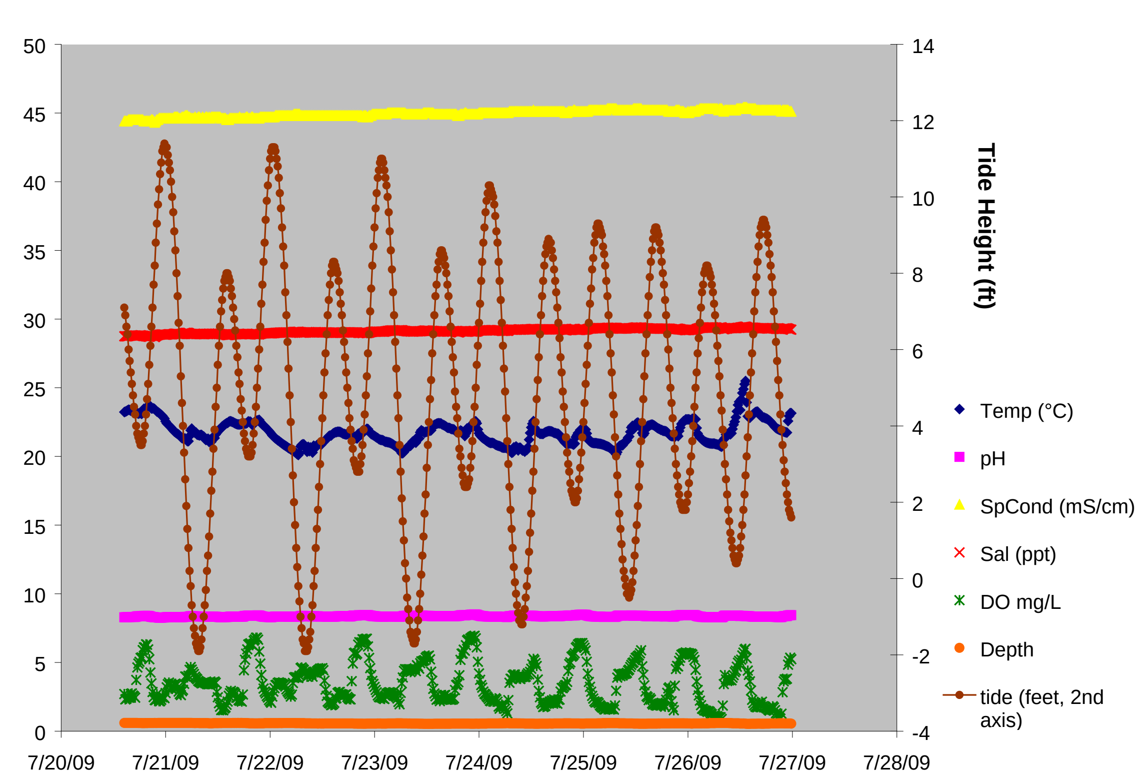

Figure 6.1-8: Pond A7 water quality values during 21 July – 26 July

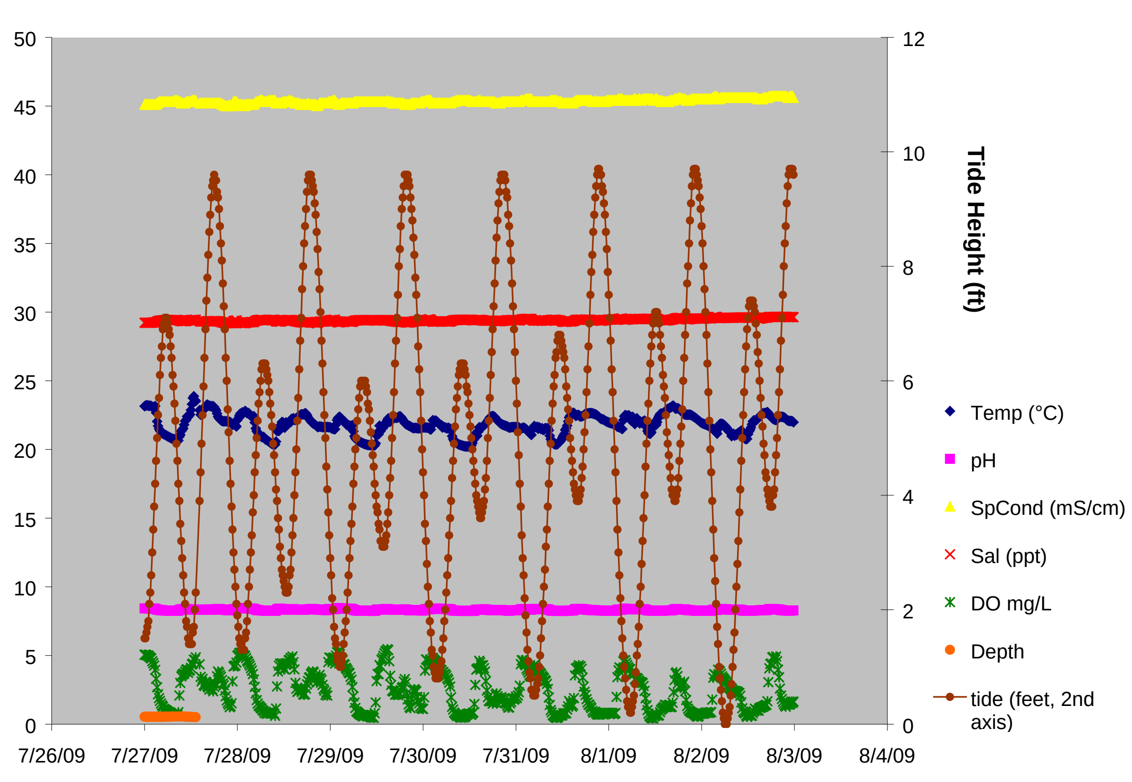

Figure 6.1-9: Pond A7 water quality values during 27 July – 2 August

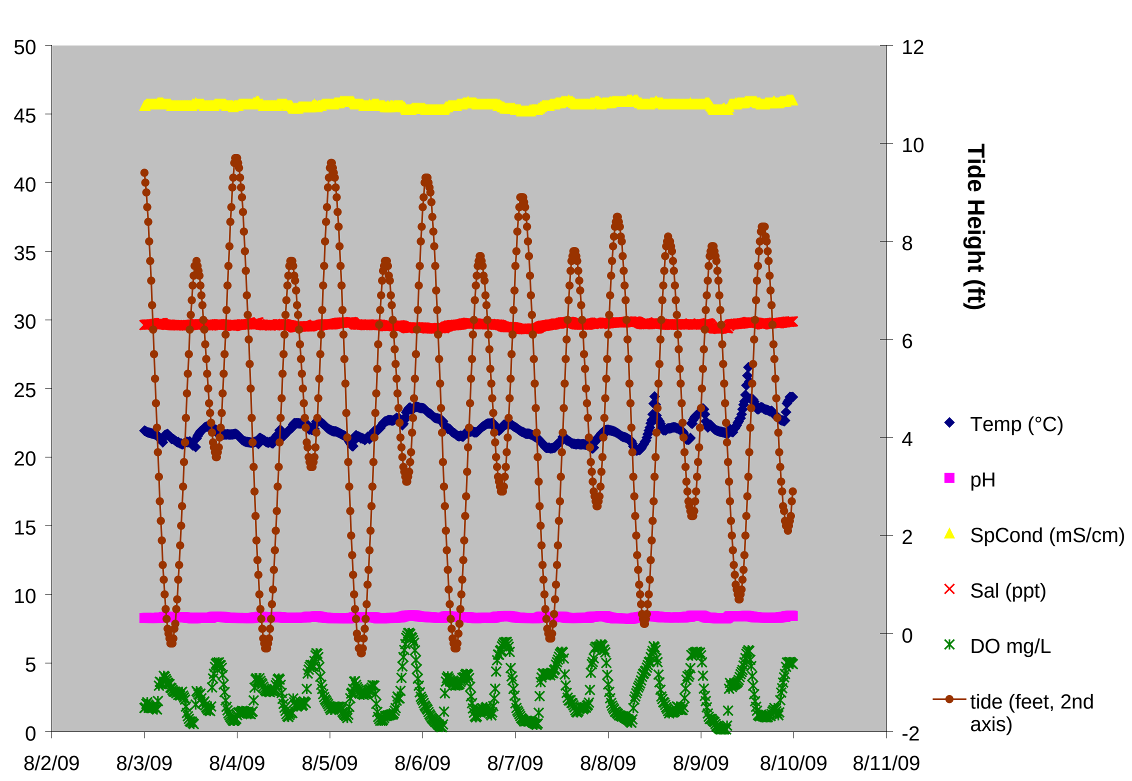

Figure 6.1-10: Pond A7 water quality values during 3 August – 9 August

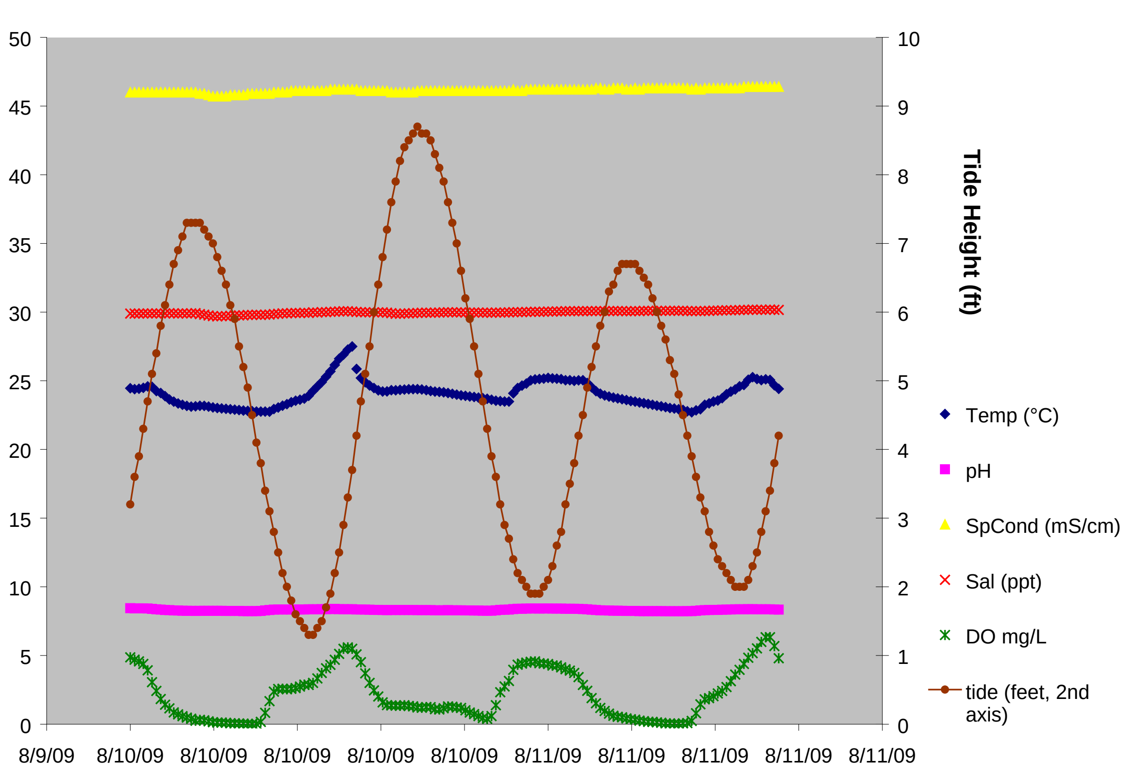

Figure 6.1-11: Pond A7 water quality values during 10 August – 11 August

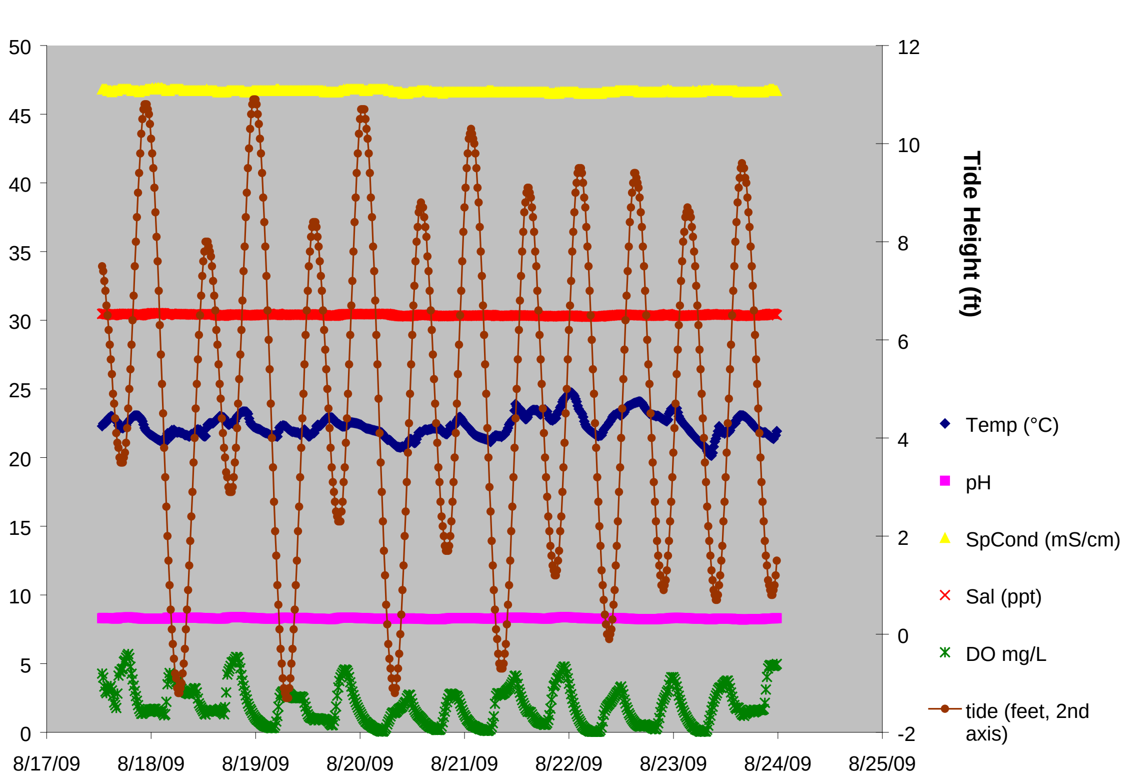

Figure 6.1-12: Pond A7 water quality values during 17 August – 23 August

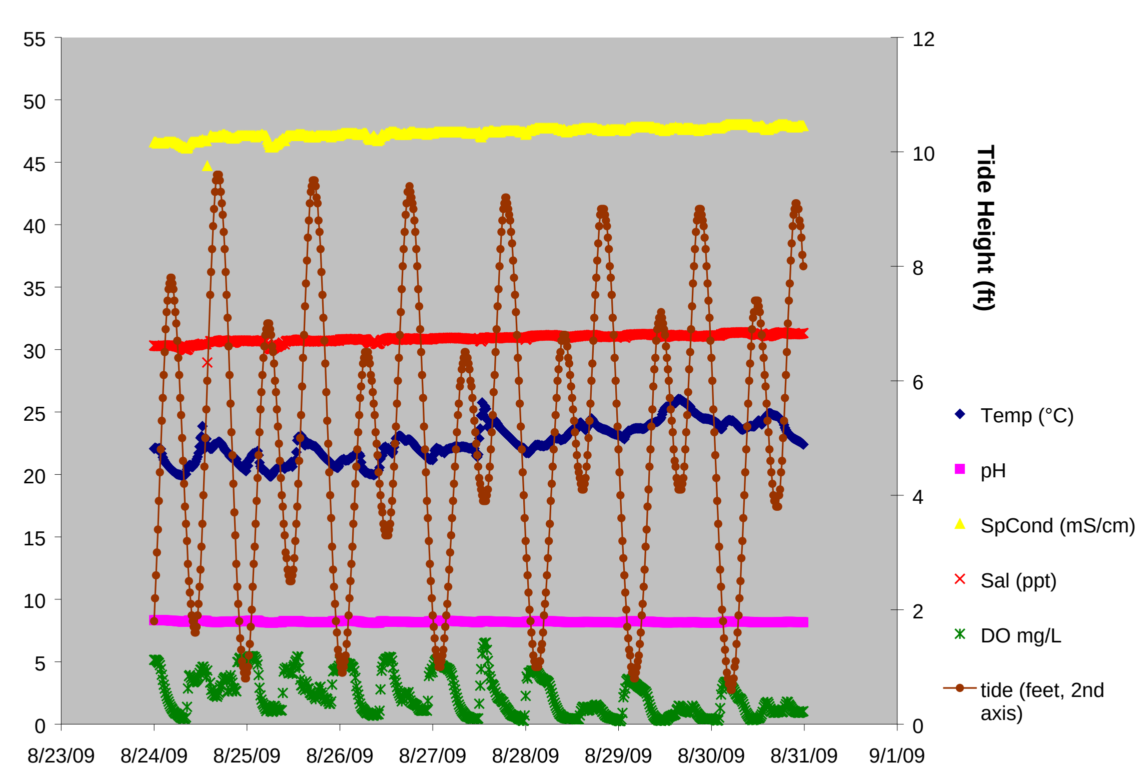

Figure 6.1-13: Pond A7 water quality values during 24 August – 30 August

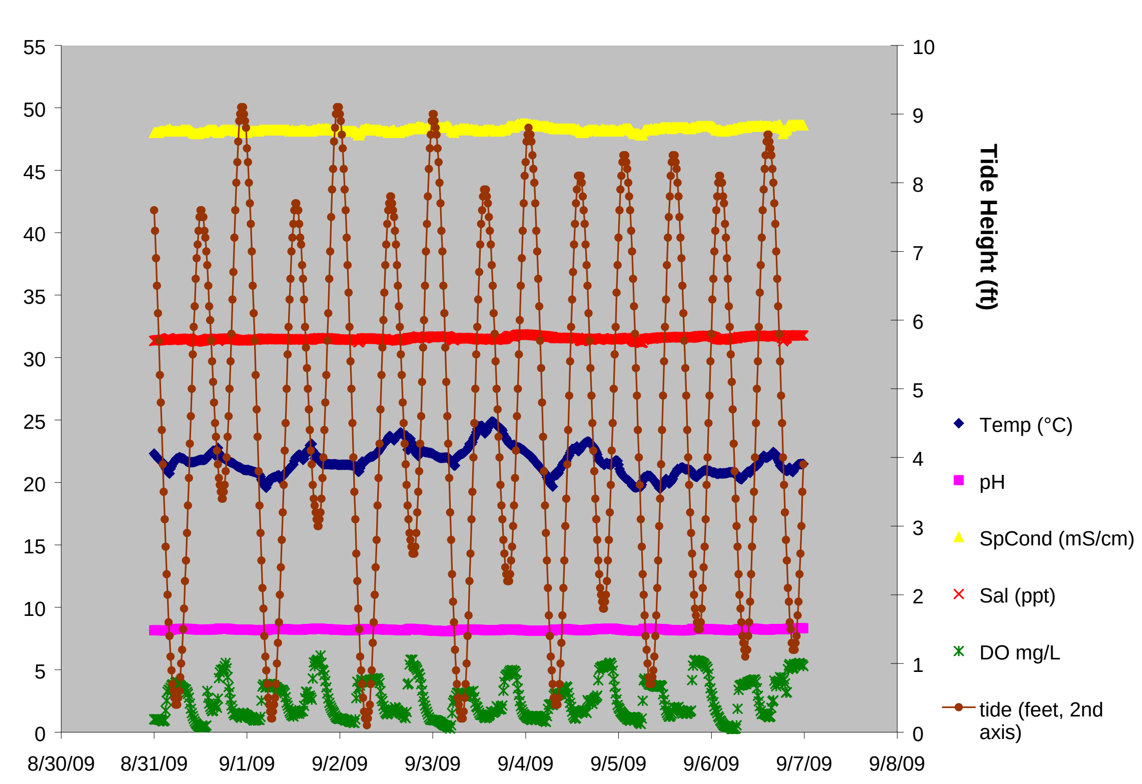

Figure 6.1-14: Pond A7 water quality values during 31 August – 6 September

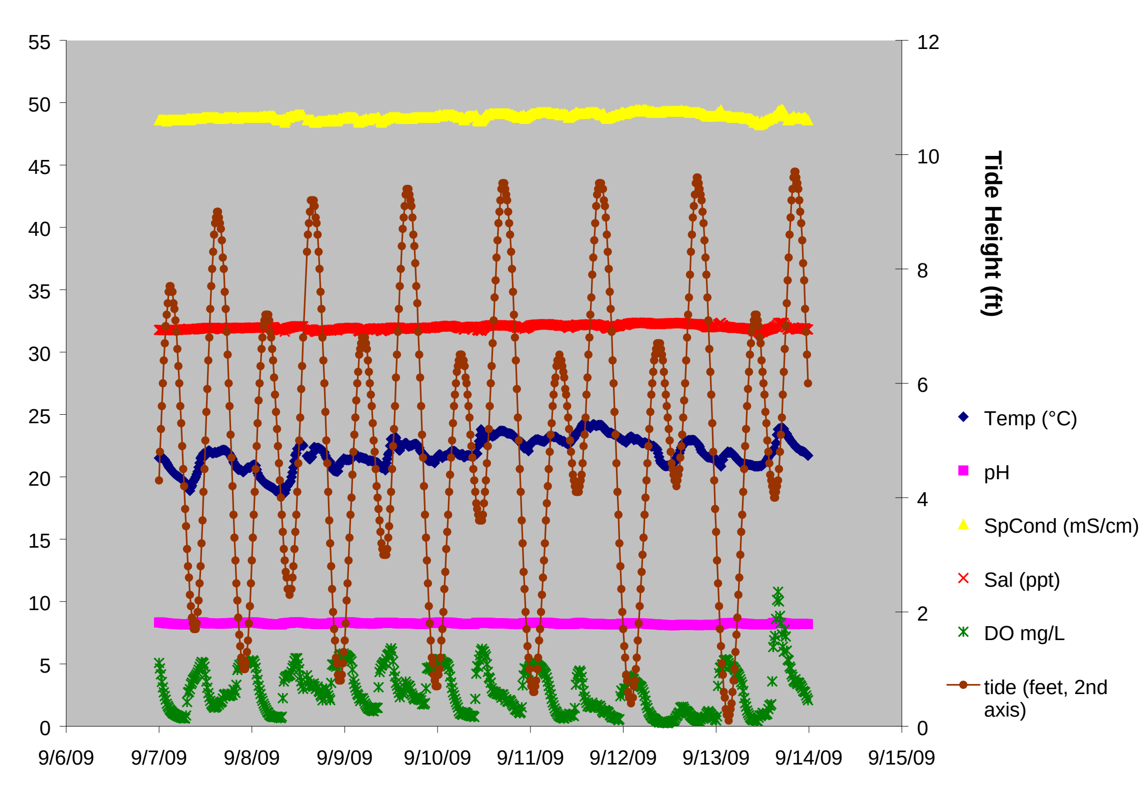

Figure 6.1-15: Pond A7 water quality values during 7 September – 13 September

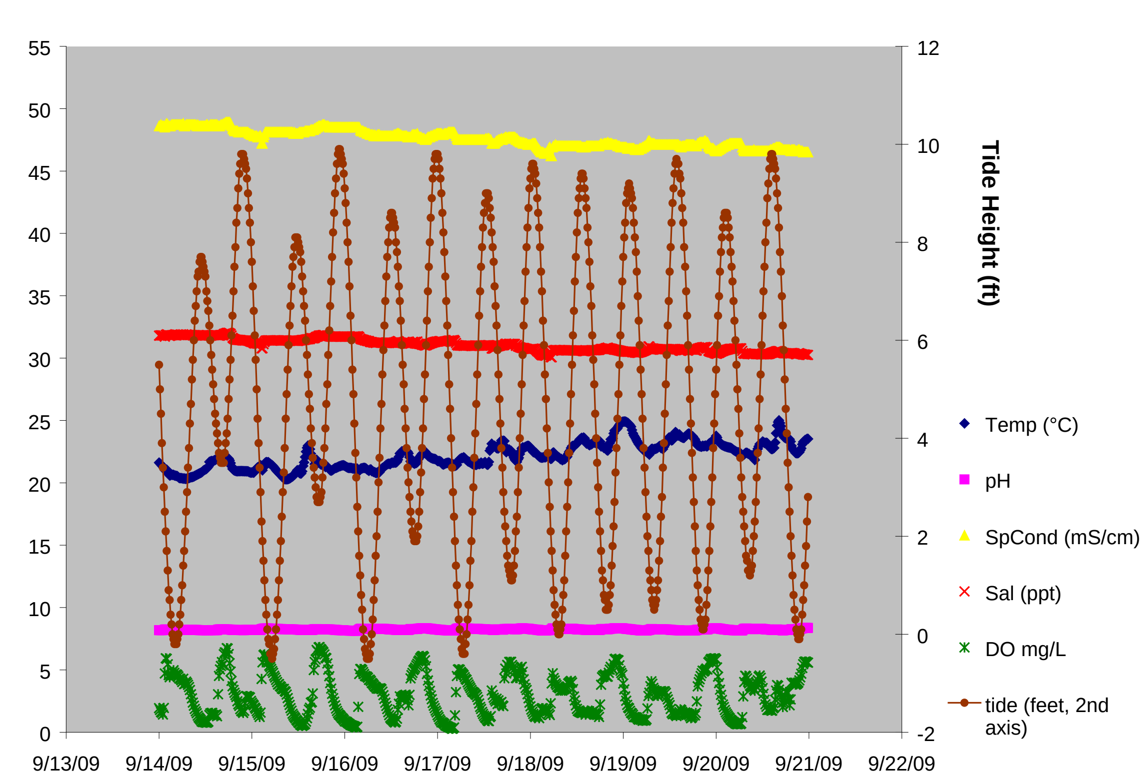

Figure 6.1-16: Pond A7 water quality values during 14 September – 20 September

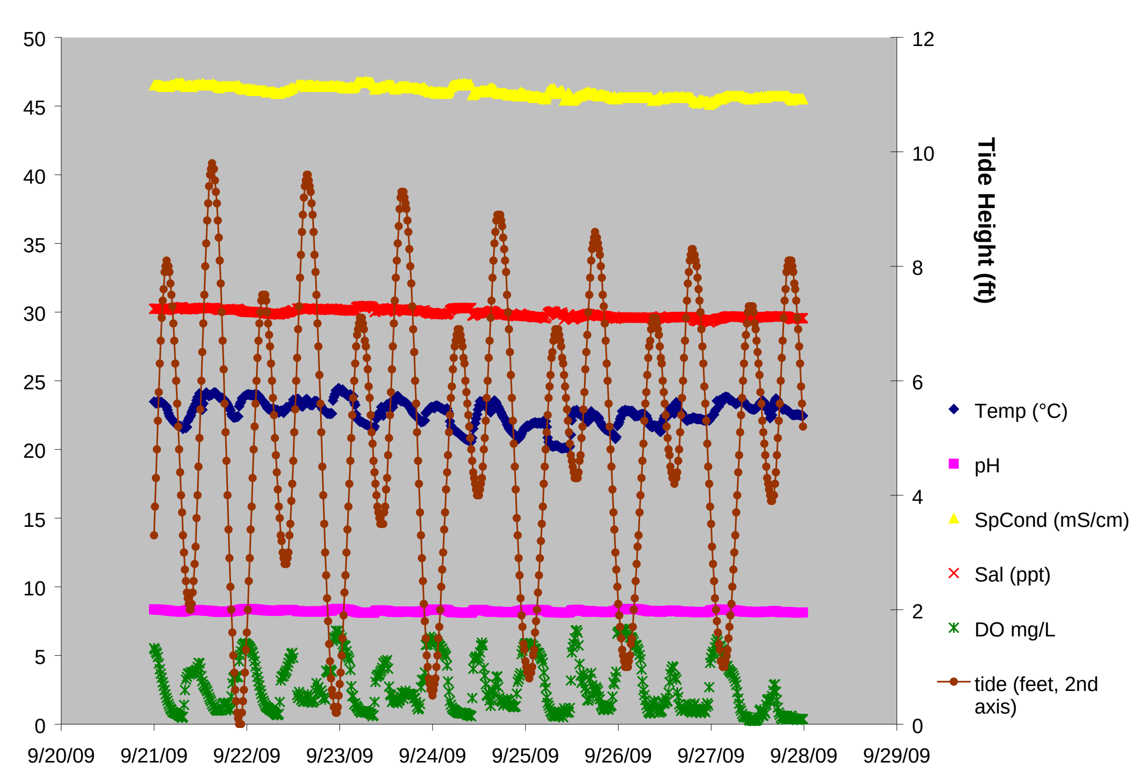

Figure 6.1-17: Pond A7 water quality values during 21 September – 27 September

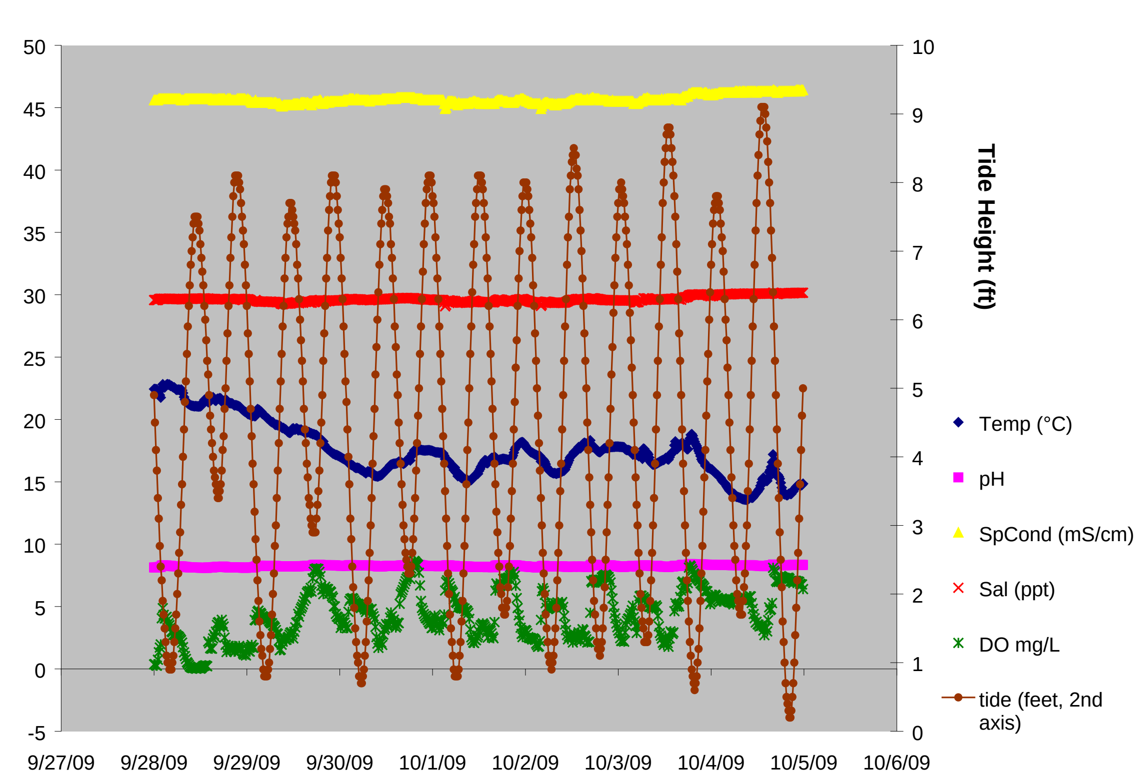

Figure 6.1-18: Pond A7 water quality values during 28 September – 4 September

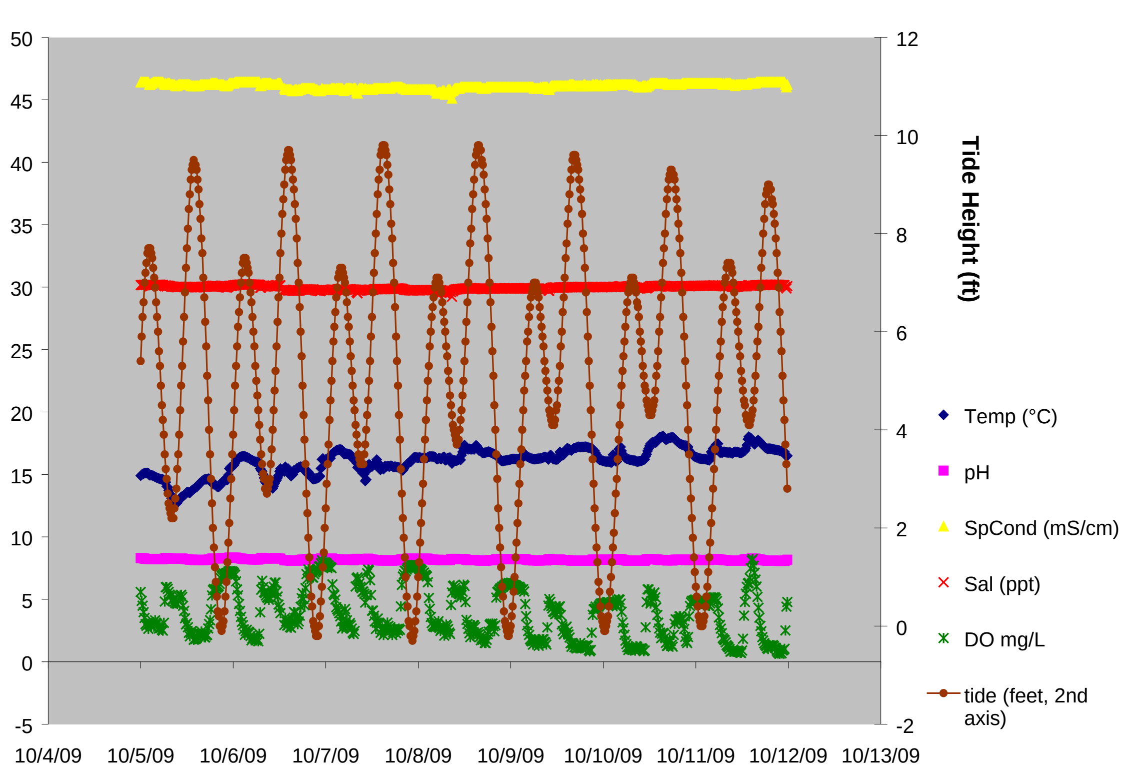

Figure 6.1-19: Pond A7 water quality values during 5 October – 11 October

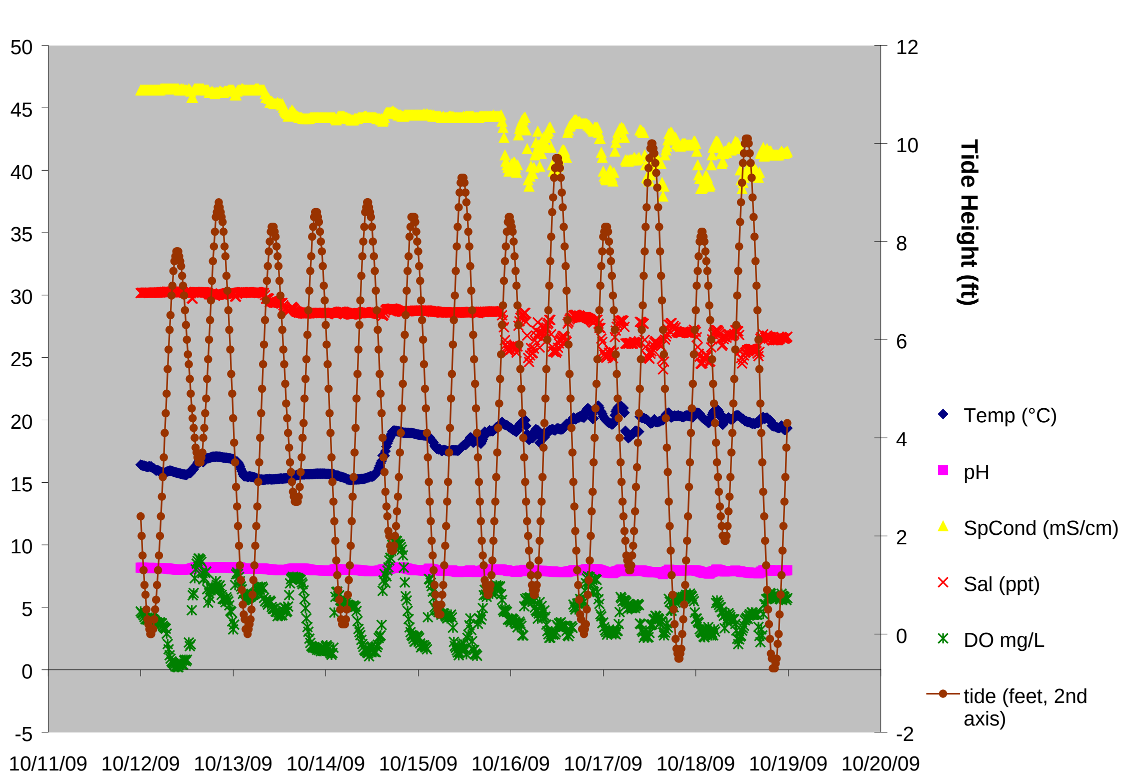

Figure 6.1-20: Pond A7 water quality values during 12 October – 18 October

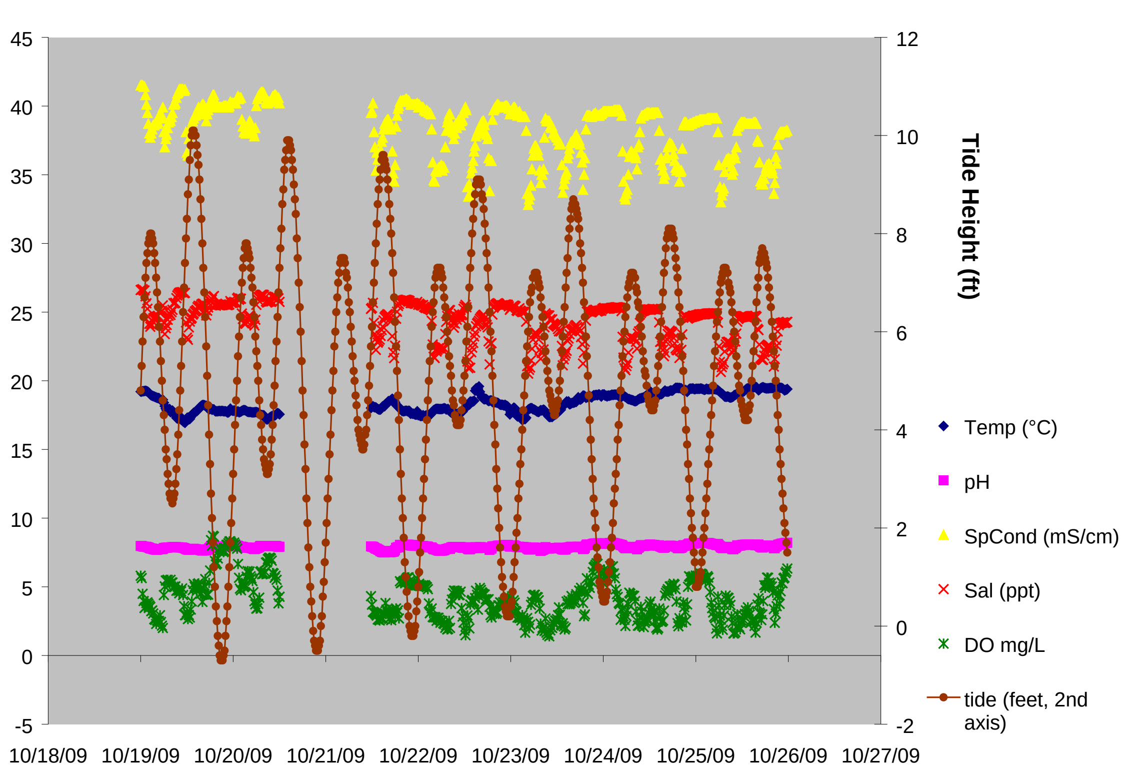

Figure 6.1-21: Pond A7 water quality values during 19 October – 25 October

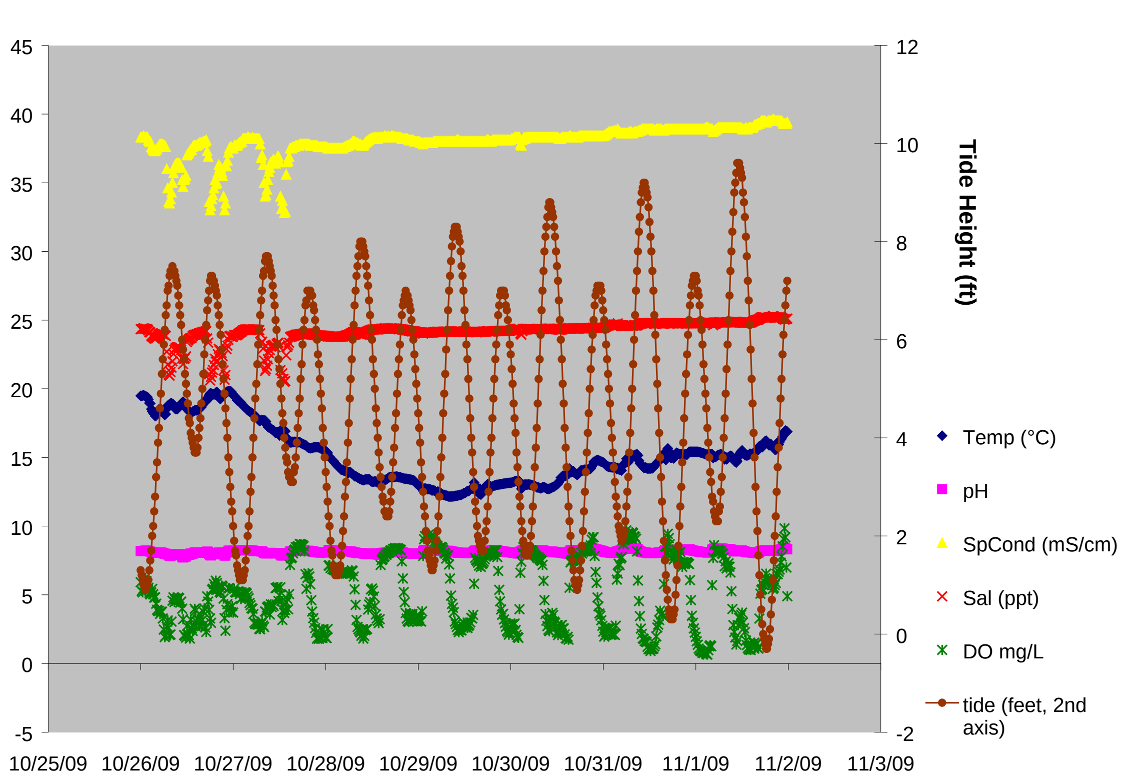

Figure 6.1-22: Pond A7 water quality values during 26 October – 1 November

6.5 METEOROLOGICAL MEASUREMENTS

Meteorological data were relatively consistent during the study period (Table 6.5-1). Wind was primarily from the south and averages ranged from 5 to 7 mph. Gusts ranged from 0 to 45 mph where gust averages ranged from 8.30 to 11.00 mph. Relative humidity remained fairly consistent throughout the study period. Rainfall was scarce throughout the study period; however, October did experience a very small amount of precipitation. Monthly mean temperatures were also pretty consistent and ranged from 16.00 degrees Celsius to 19.50 degrees Celsius. Photosynthetically active radiation (PAR) and solar radiation were variable during the study period, but varied largely due to diurnal cycles.

Table 6.5-1: Summarized weather values (mean ± standard deviation) for all ponds by month

Month	Temperature (°C)	Relative Humidity (%)	Rainfall (cm)	Primary Wind Direction	Wind Speed (mph)	PAR Light (uM/m^2s)	Solar Radiation (wat/m2)
June	17.93 ± 1.0	71.81 ± 12.65	0.00 ± 0.0	South	7.04 ± 5.64	1083.21 ± 750.1 Max: 2748	448.51 ± 330.6 Max: 1208
July	17.99 ± 1.0	77.56 ± 14.00	0.00 ± 0.0	South - Southwest	6.55 ± 5.50	1140.64 ± 815.4 Max: 2454	475.10 ± 342.5 Max: 1054
August	19.20 ± 1.1	74.35 ± 16.42	0.00 ± 0.0	South	5.94 ± 5.51	1084.71 ± 719.5 Max: 2124	460.00 ± 323.1 Max: 917
September	19.45 ± 1.0	73.14 ± 16.43	0.00 ± 0.0	South - Southeast	5.03 ± 5.21	976.52 ± 626.6 Max: 2079	414.60 ± 275.7 Max: 911
October	16.00 ± 0.9	73.30 ± 18.90	0.00 ± 0.0	South	5.95 ± 6.04	760.90 ± 519.4 Max: 1834	324.60 ± 232.9 Max: 762

7. Future Actions

SECTION 7
FUTURE ACTIONS

On February 2, 2010, the Refuge and USGS met with representatives from the RWQCB, California Coastal Conservancy, California Department of Fish and Game as part of the South Bay Salt Pond Technical Advisory Committee. This meeting included a water quality breakout session where the group addressed key questions including:

1. How should water quality data be collected and analyzed in the future (2010 and beyond)?
2. How should the lack of funding and resources (staff) for data analysis be addressed?
3. How can we reconcile the differences between monitoring to meet the Final Order requirements and answering science question?
4. What are the Data gaps (benthic flora and fauna, water column zooplankton and planktivorous fish, ecological value of managed ponds)?
5. What Management triggers are appropriate (should we increase or decrease in residence time)?
6. How much are uplands causing low DO in sloughs?

In addition, the group recommended that applied or directed studies should look at or involve determining 1) if pond water is affecting DO; 2) the oxygen balance (sources/sinks); 3) the primary production and effect on birds; 4) what management actions can change that balance; 5) hydraulic experiments (e.g., making flow unidirectional) to answer questions; and 6) whether we should focus monitoring and studies down to one or two ponds instead of spreading efforts/resources across three ponds. Other recommendations included:

1. To continue with Kuwabara proposal and define paramenters of other focused studies
2. Incorporate some of USGS' (Tara Schraga) data

3. Hire someone to interpret/analyze existing data from the past 2 years

4. Don't reconsider the DO objective since it's not practical (it's an extensive basin planning process, not a permitting process) and it's not the issue (we should focus rather on determining causal issues and effects of pond management)

The Refuge and USGS will continue to coordinate with the RWQCB to identify studies that will move science in direction of better understanding the ecological implications of water quality issues in managed ponds. It is anticipated that a follow-up meeting between the Refuge, USGS, and the RWQCB will occur this spring to make the best determination for the monitoring approach for 2010.

APPENDIX A
ADDITIONAL FIGURES

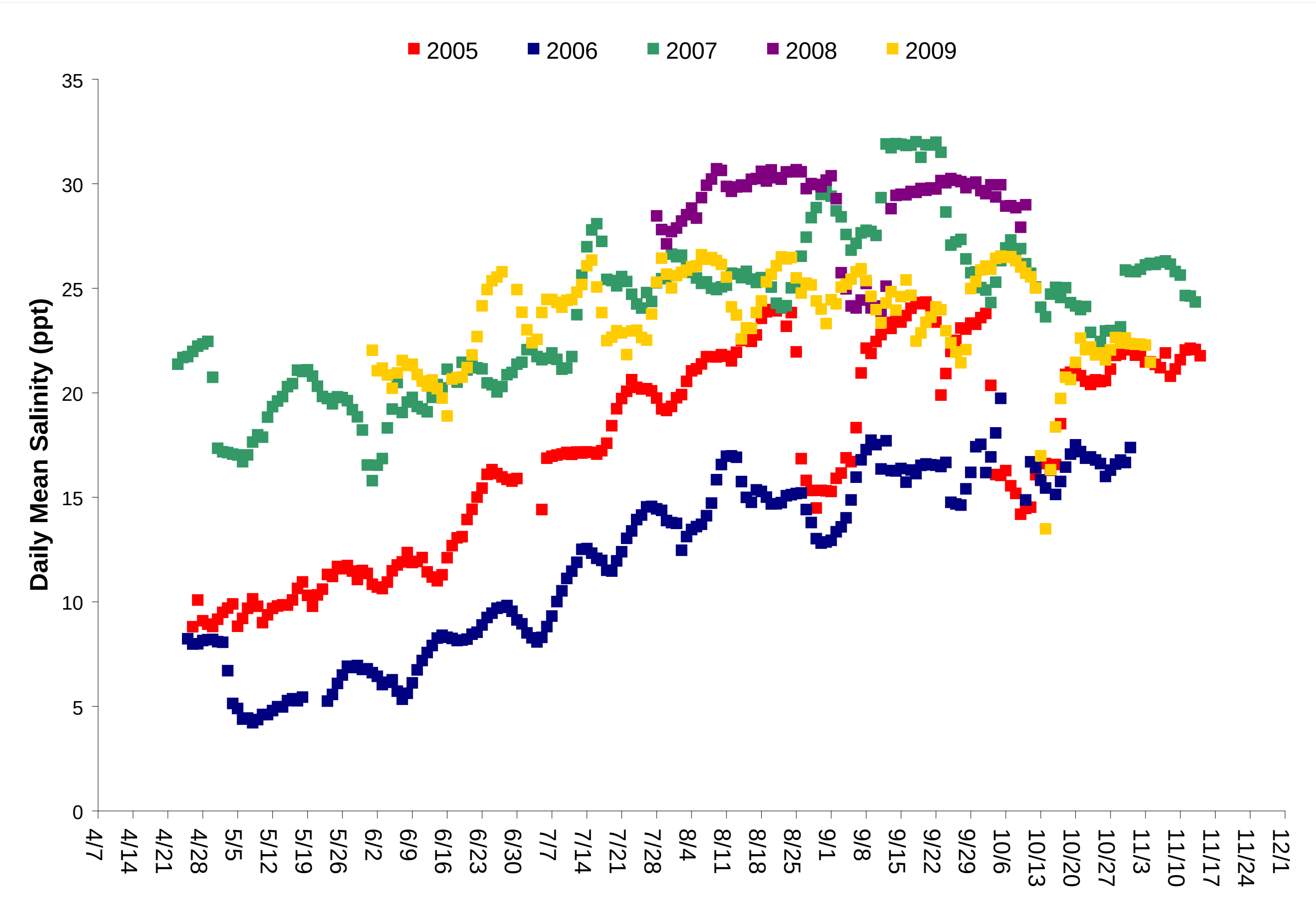

Figure A-1: Salinity of Pond A3W from 2005 – 2009

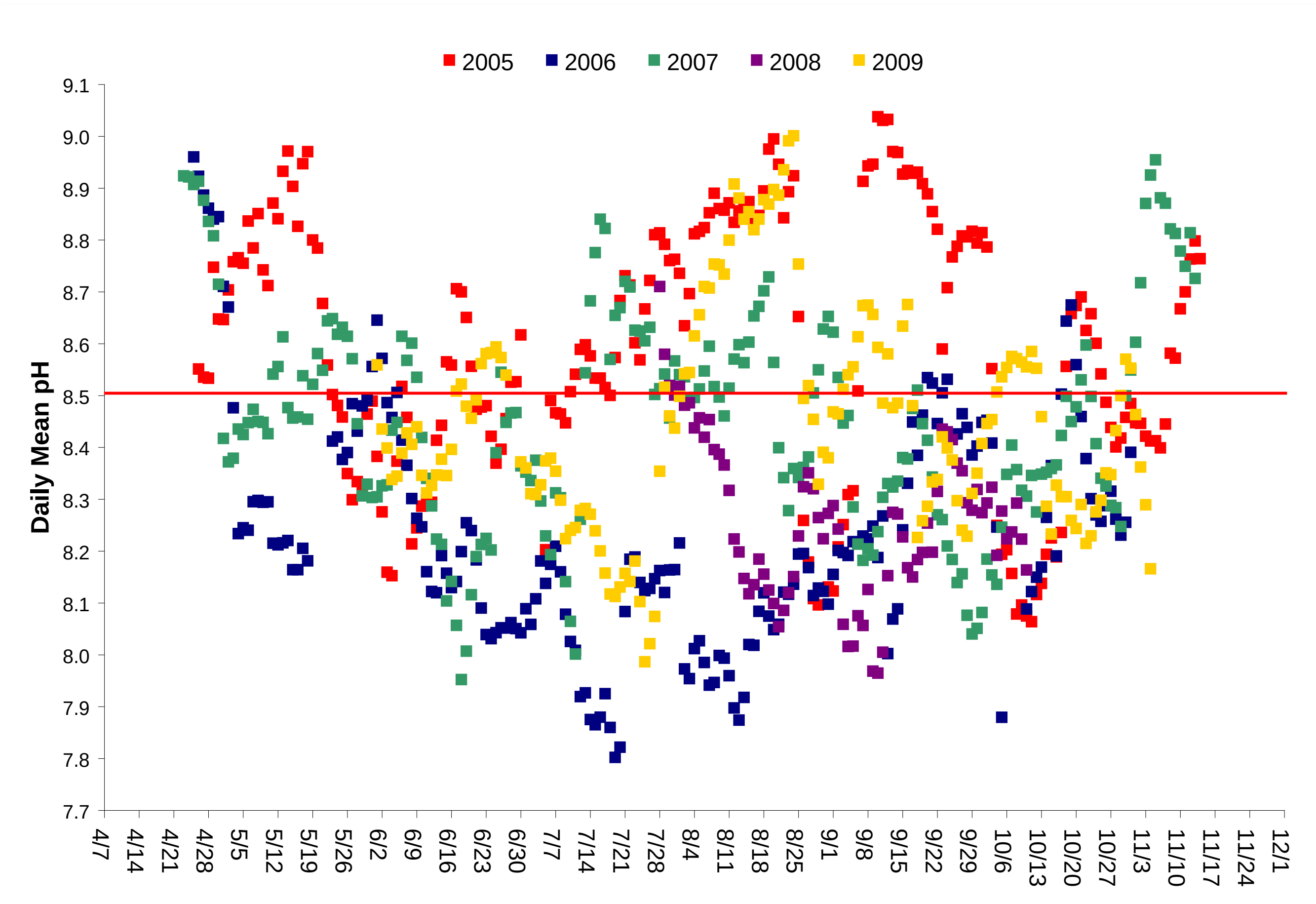

Figure A-2: pH of Pond A3W from 2005 – 2009

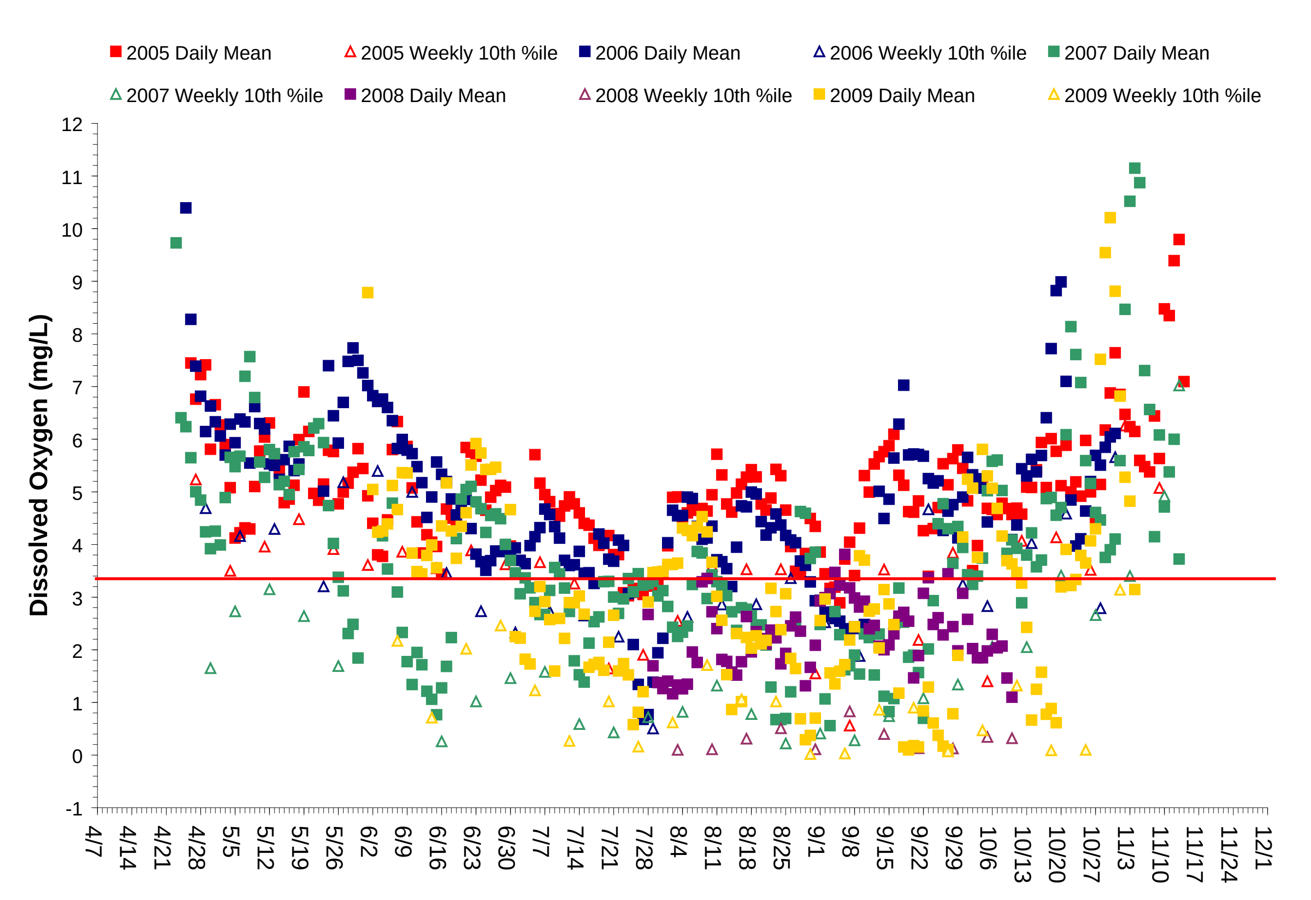

Figure A-3: Dissolved oxygen in Pond A3W from 2005 - 2009

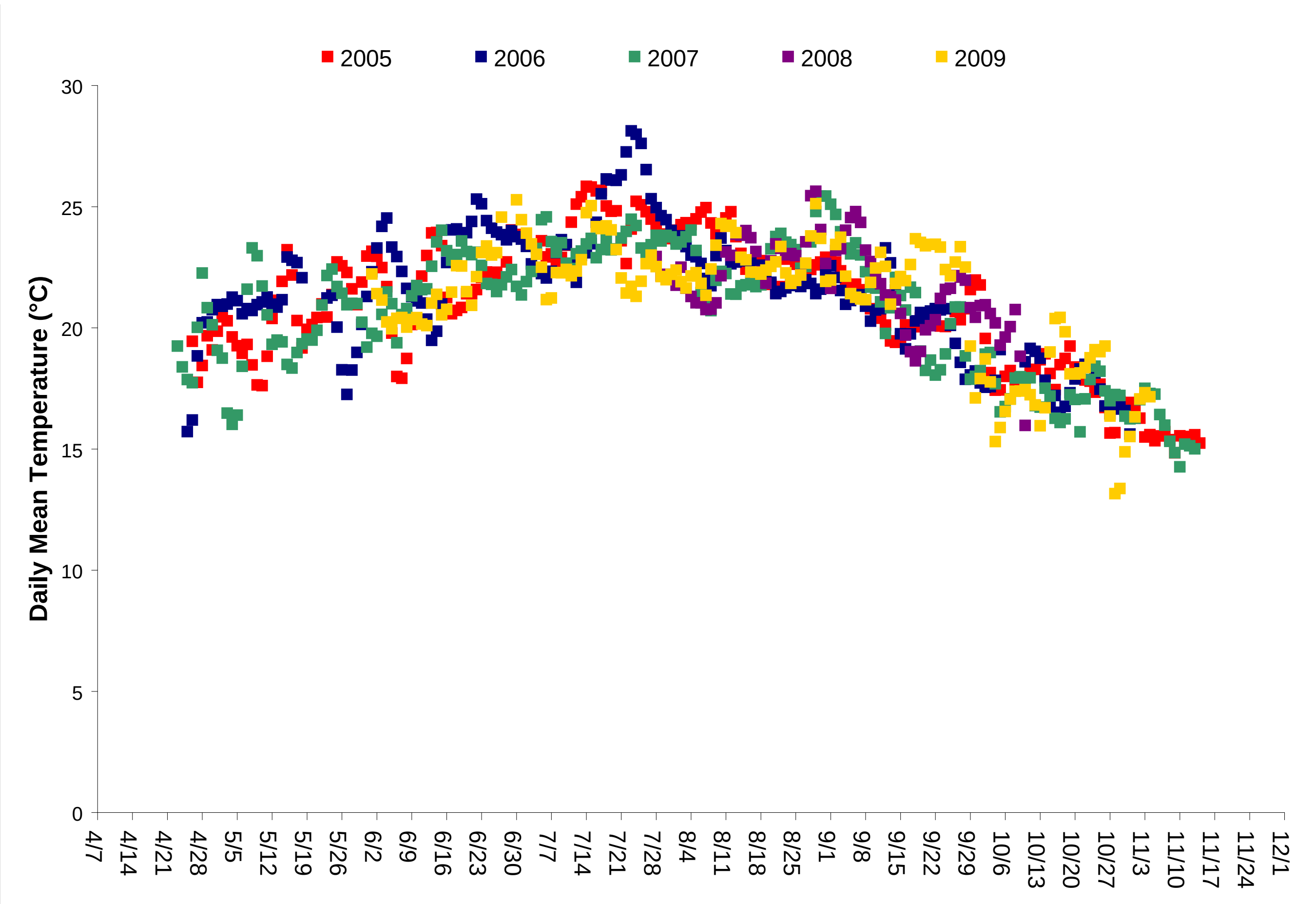

Figure A-4: Temperature of Pond A3W from 2005 – 2009

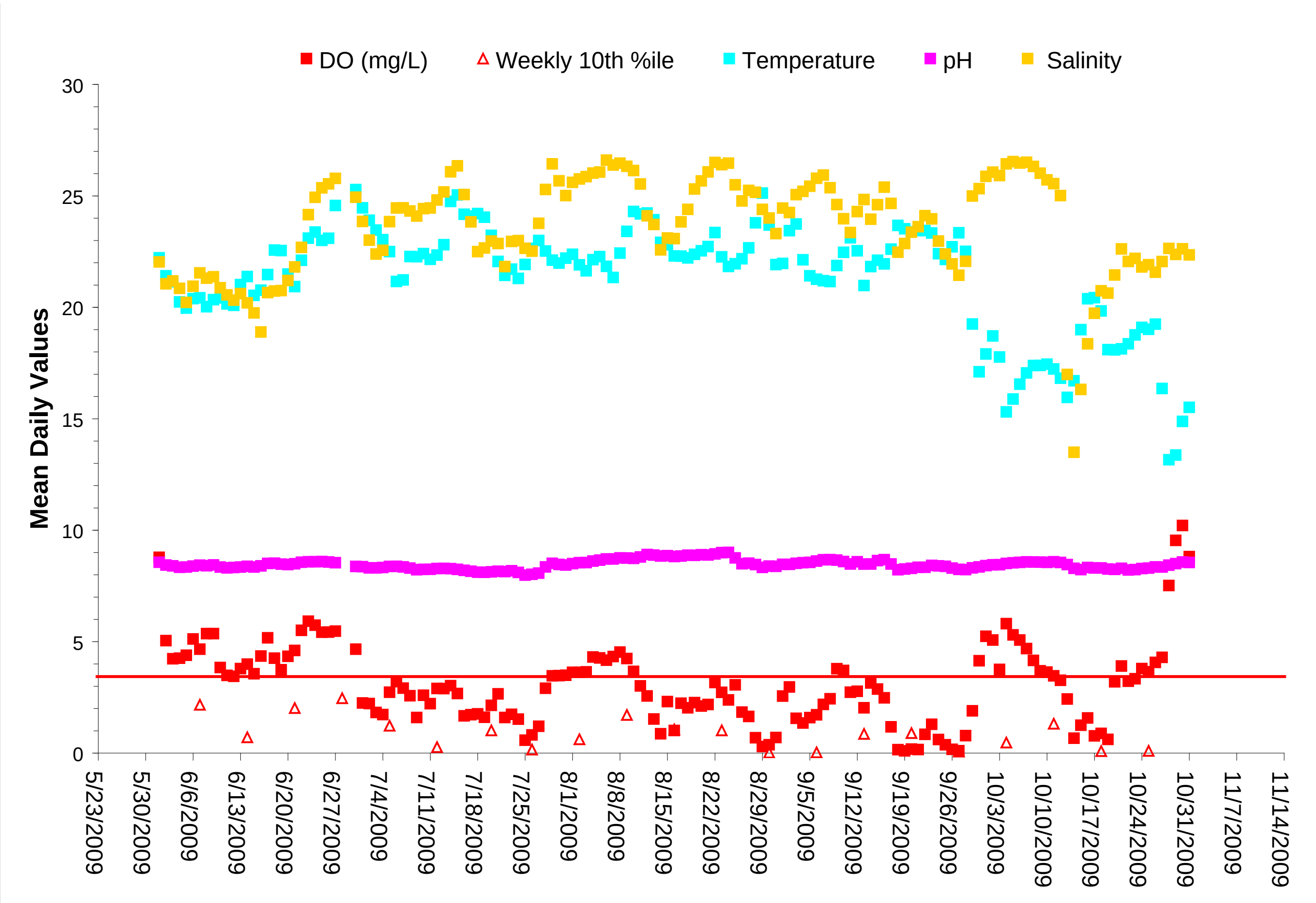

Figure A-5: Mean Values of Pond A3W for All Water Quality Parameters

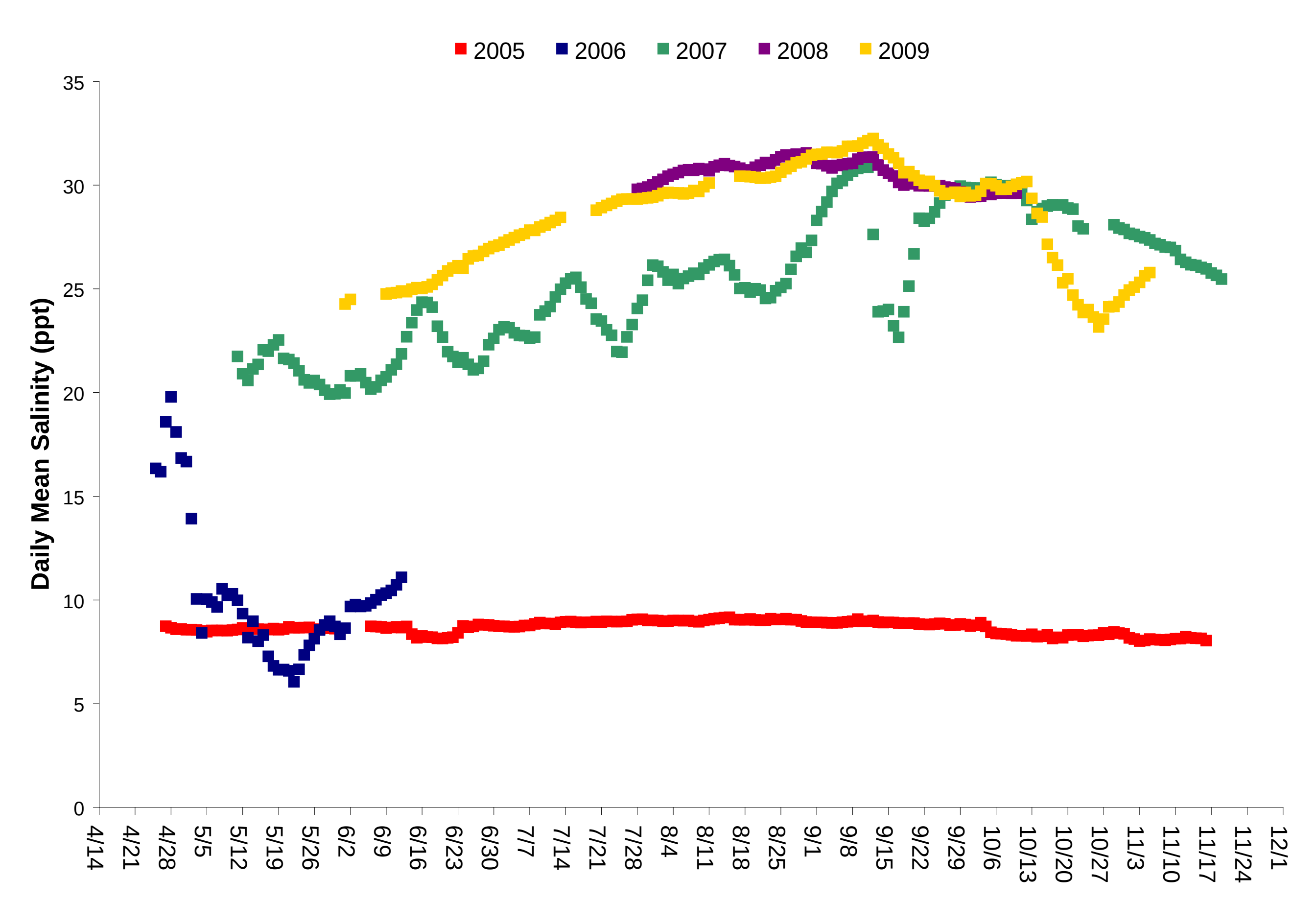

Figure A-6: Salinity of Pond A7 from 2005 - 2009

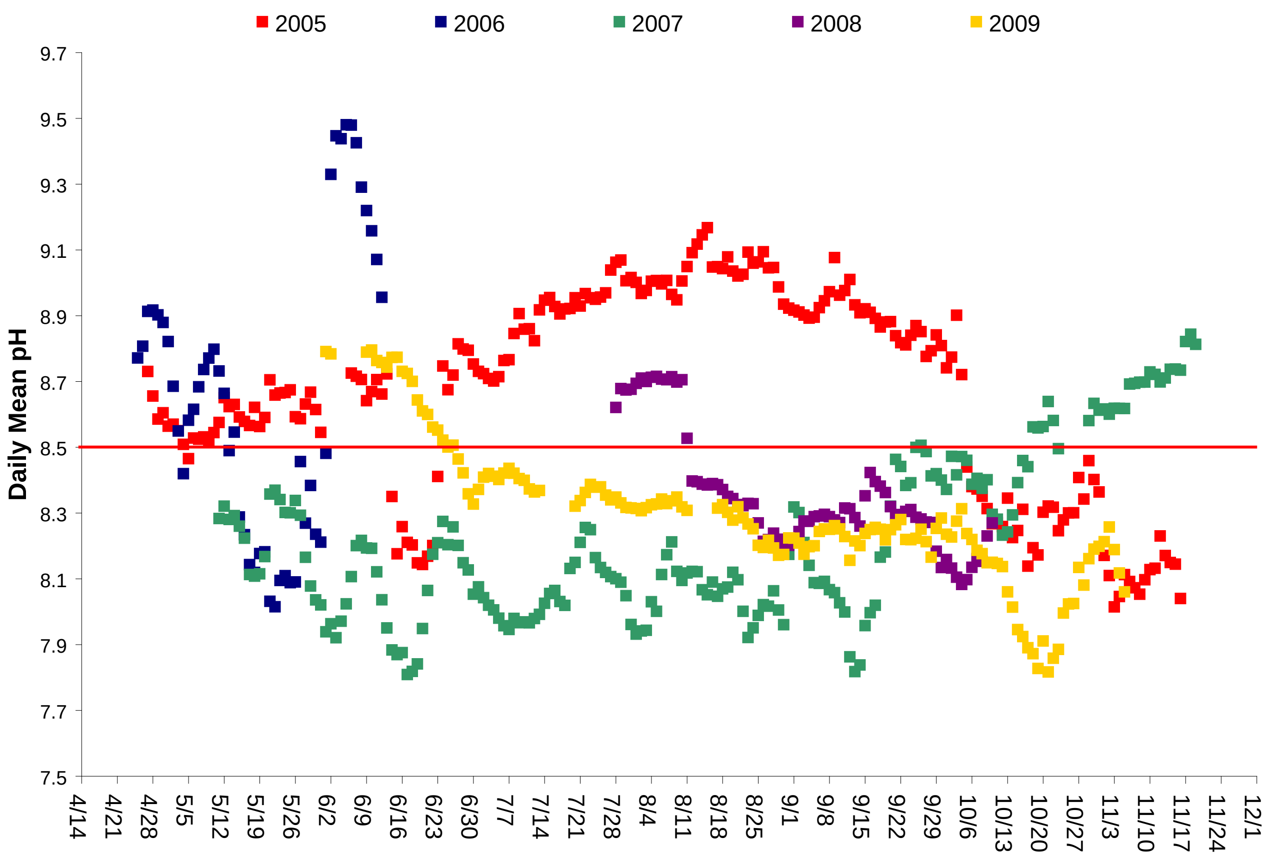

Figure A-7: pH of Pond A7 from 2005 - 2009

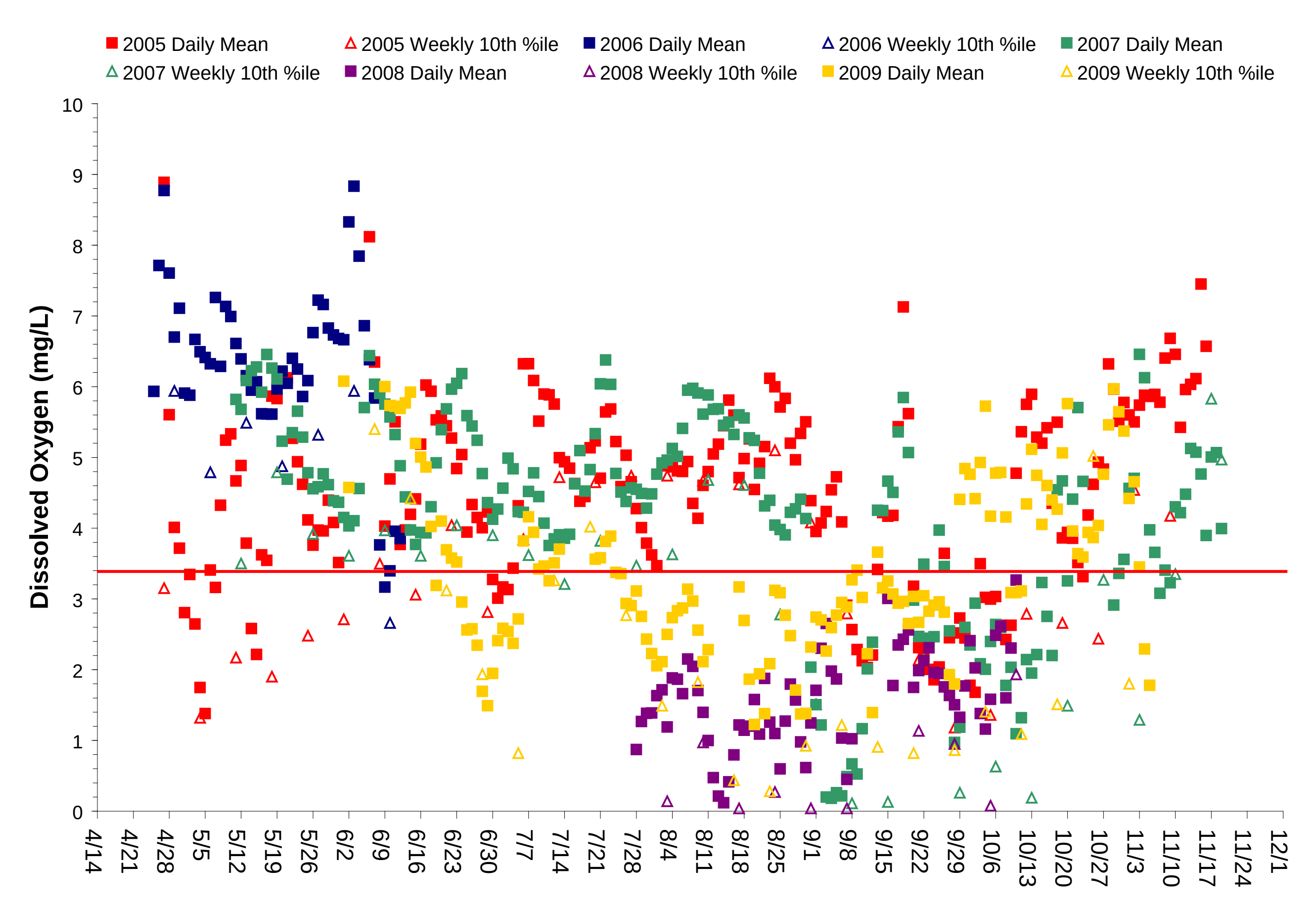

Figure A-8: Dissolved oxygen of Pond A7 from 2005 - 2009

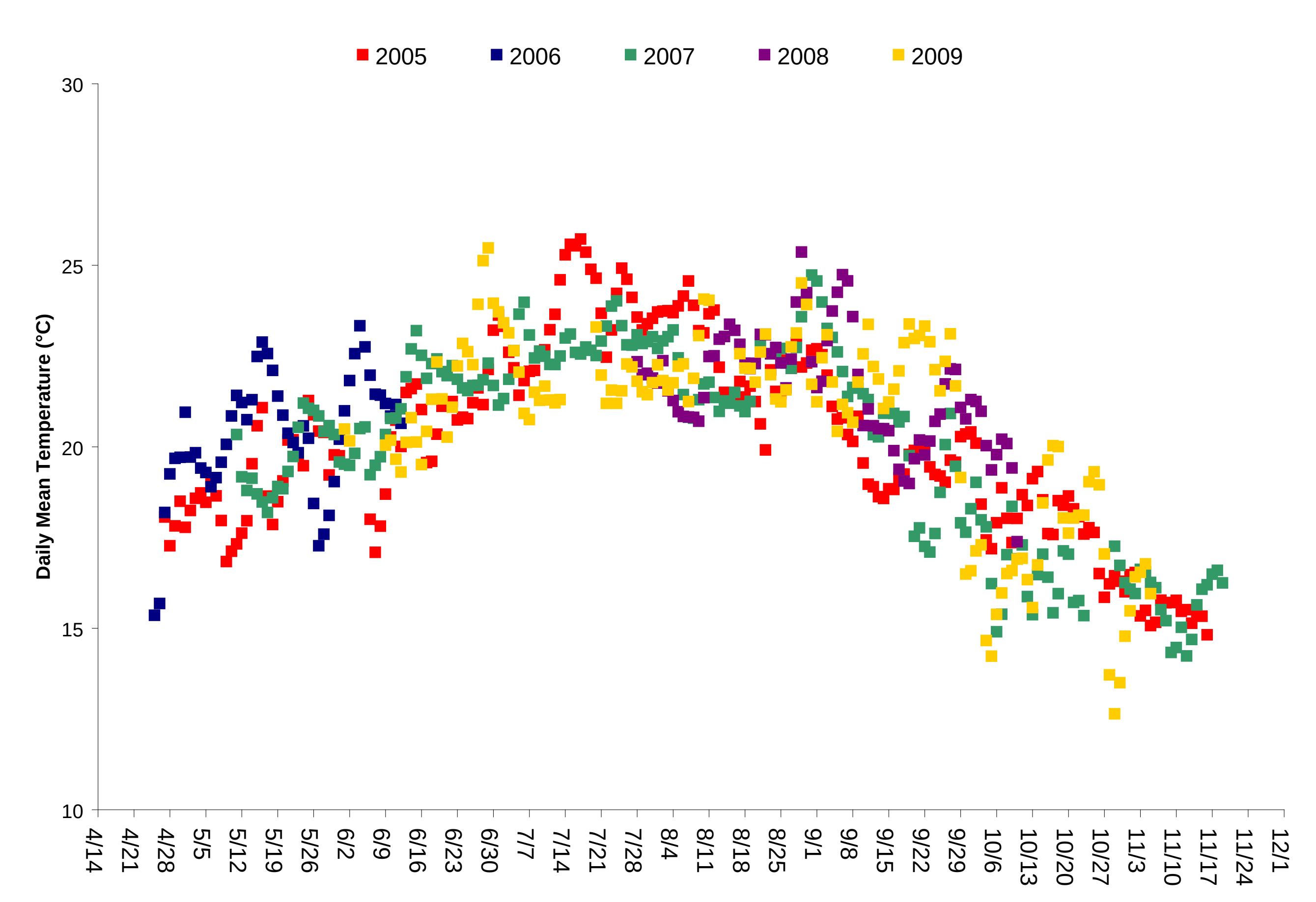

Figure A-9: Temperature of Pond A7 from 2005 - 2009

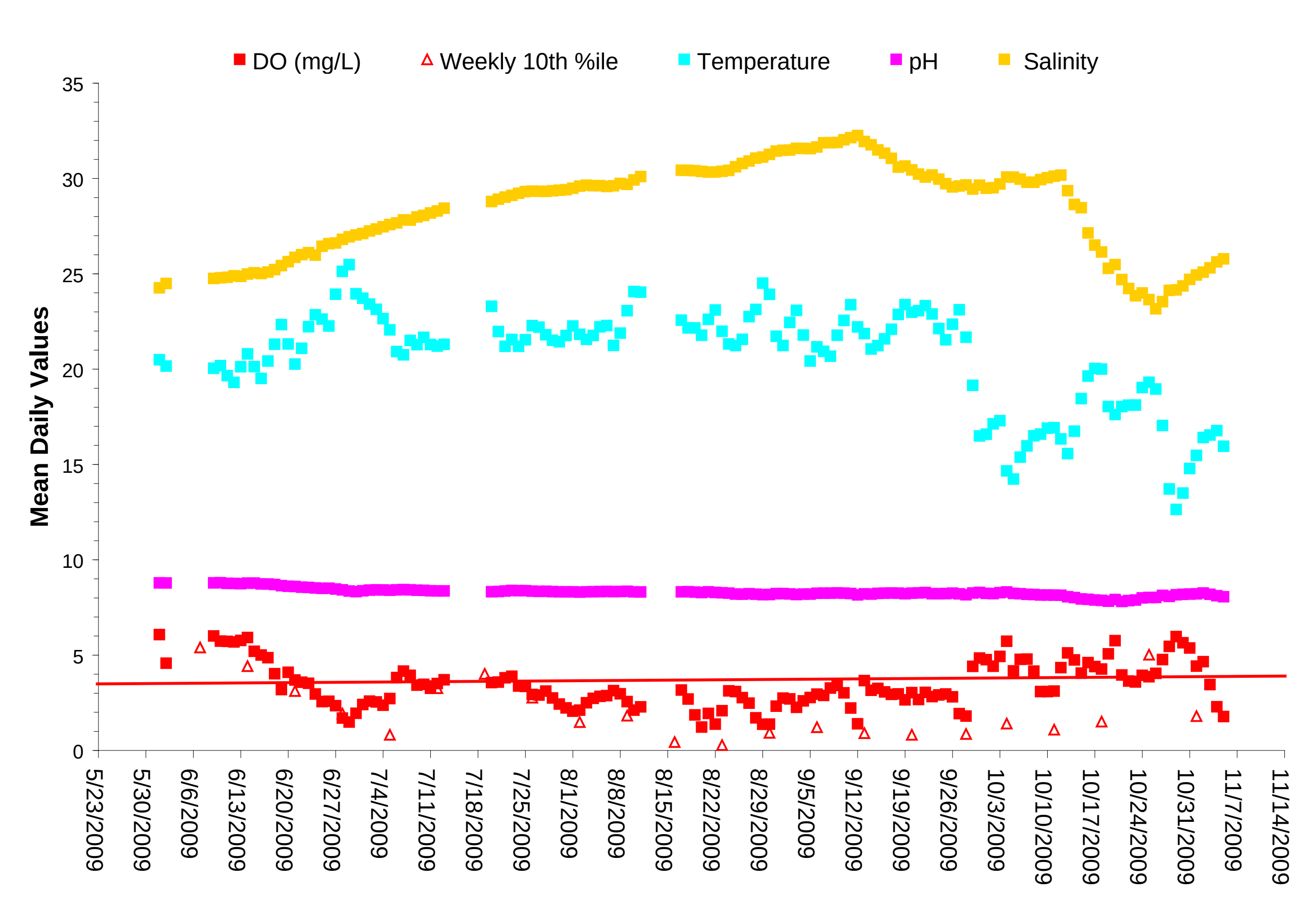

Figure A-10: Mean values of Pond A7 for All Water Quality Parameters

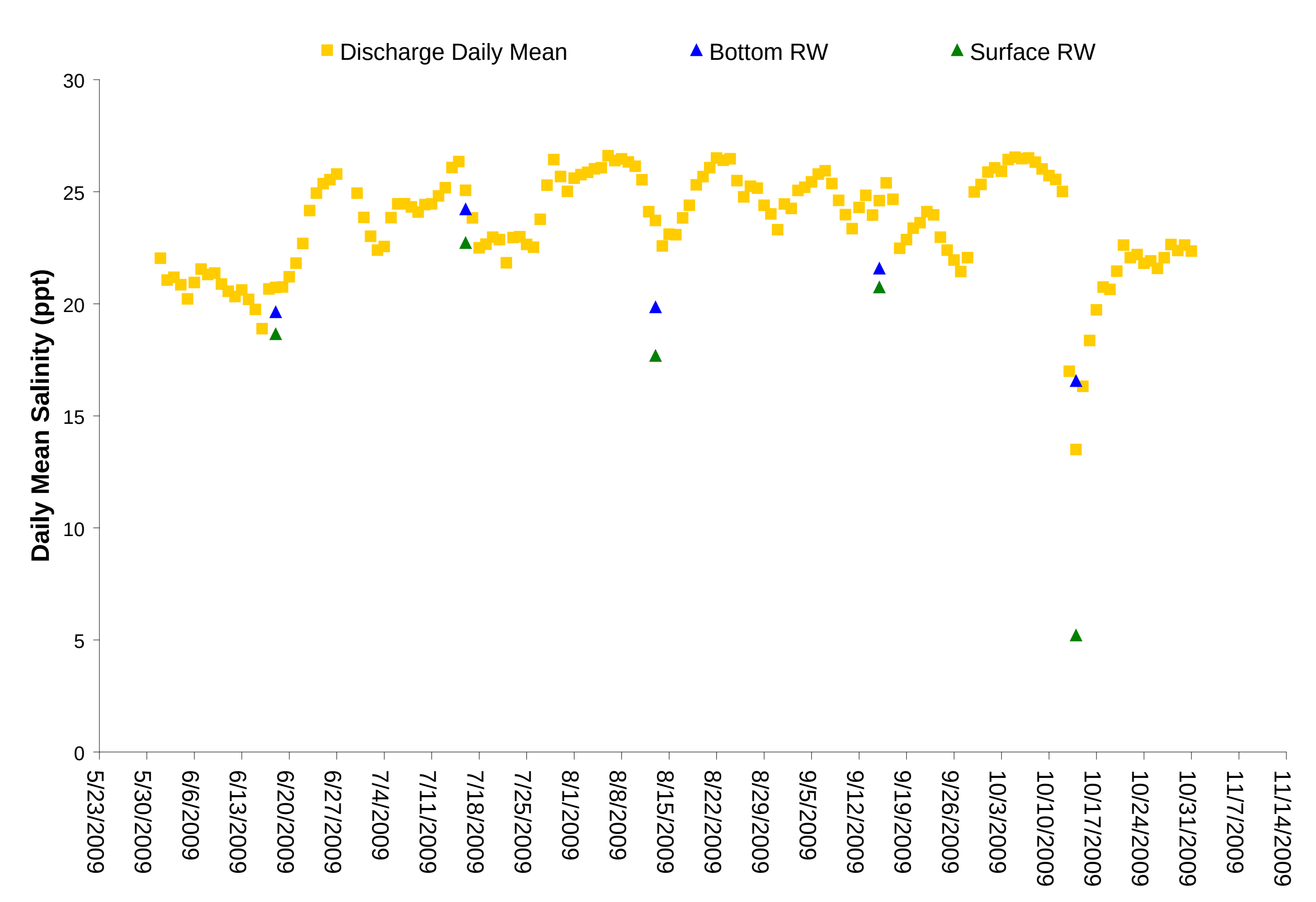

Figure A-11: Salinity of Pond A3W vs. Guadalupe Slough

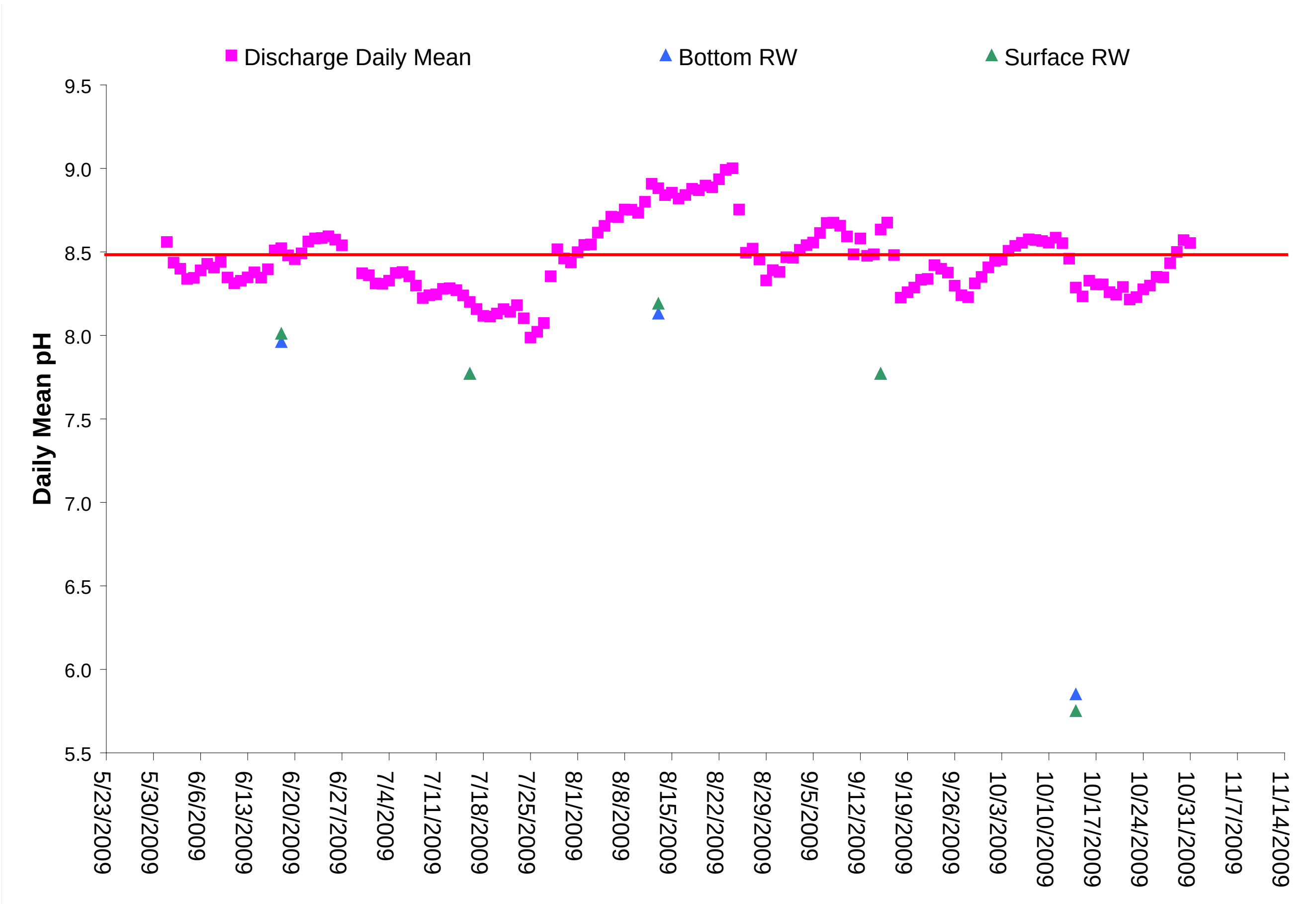

Figure A-12: pH of Pond A3W vs. Guadalupe Slough

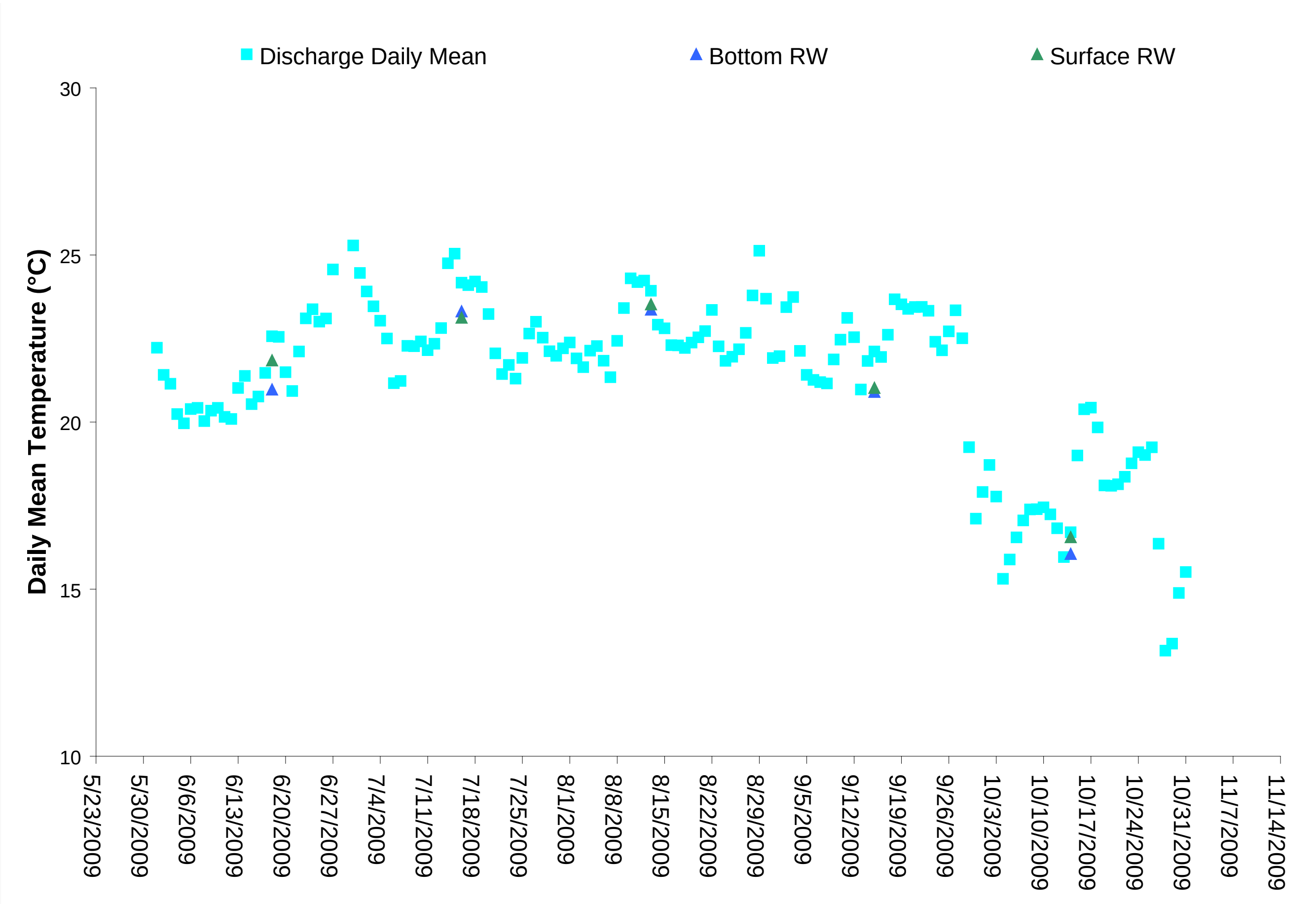

Figure A-13: Temperature of Pond A3W vs. Guadalupe Slough

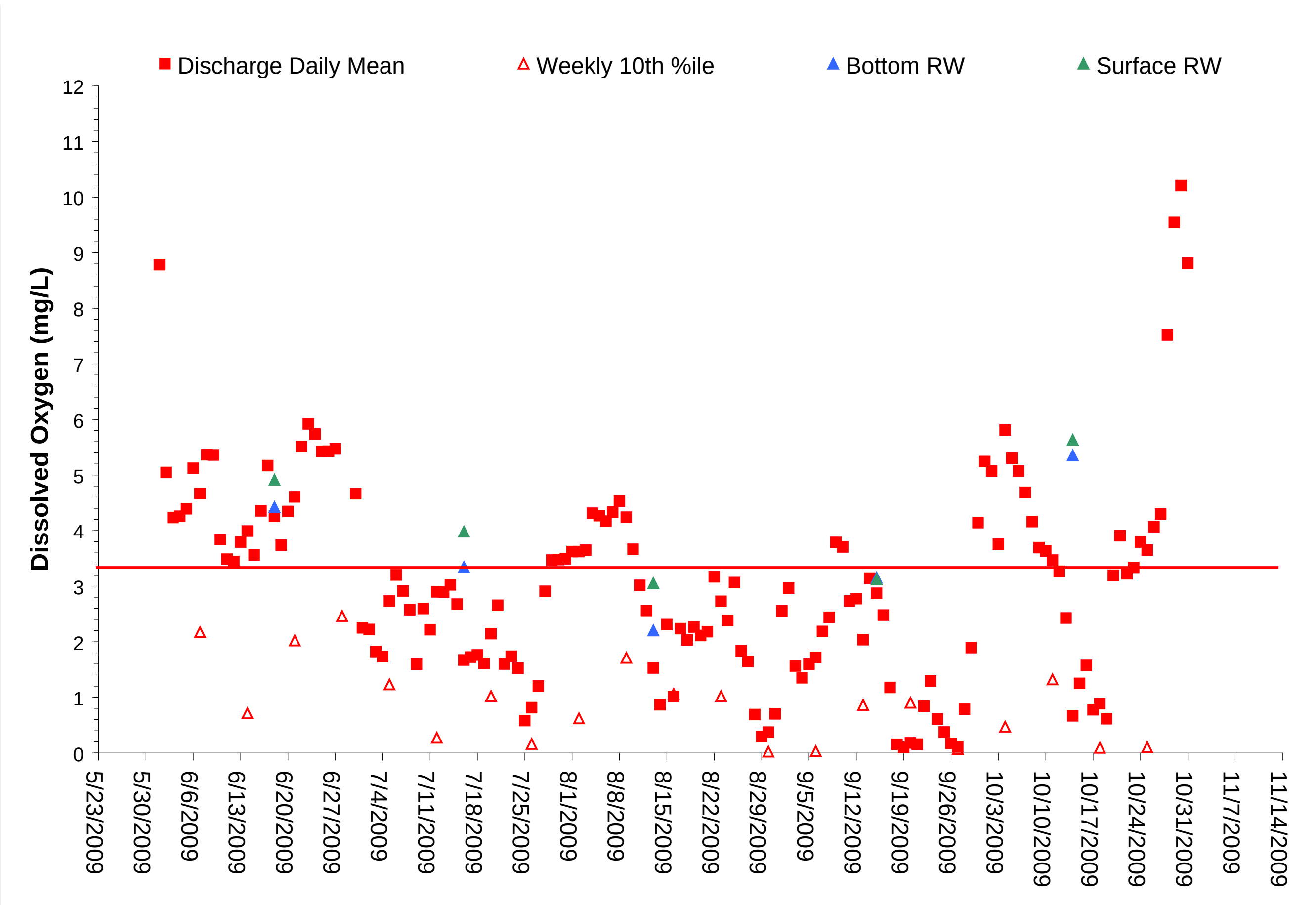

Figure A-14: Dissolved oxygen of Pond A3W vs. Guadalupe Slough

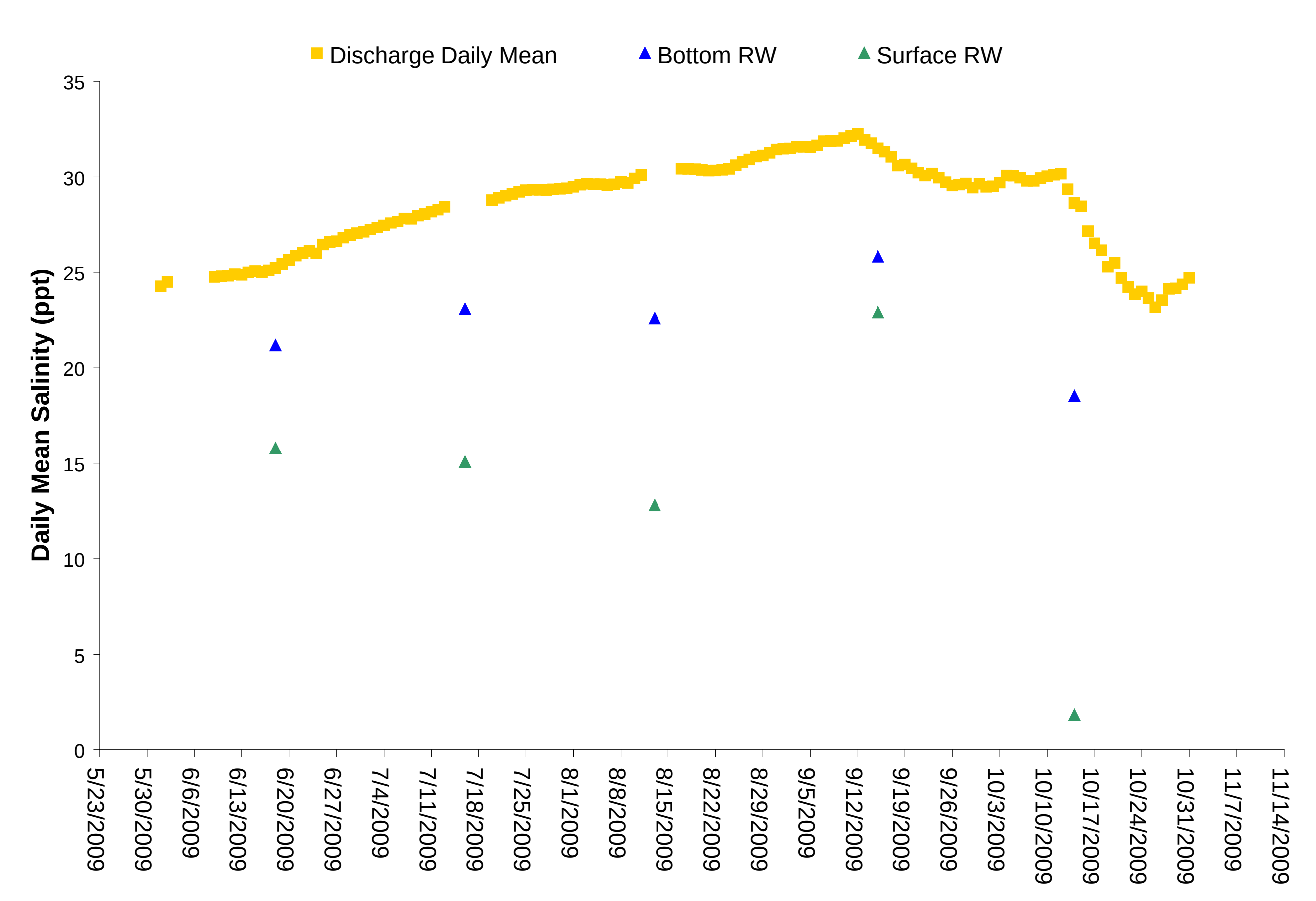

Figure A-15: Salinity of Pond A7 vs. Alviso Slough

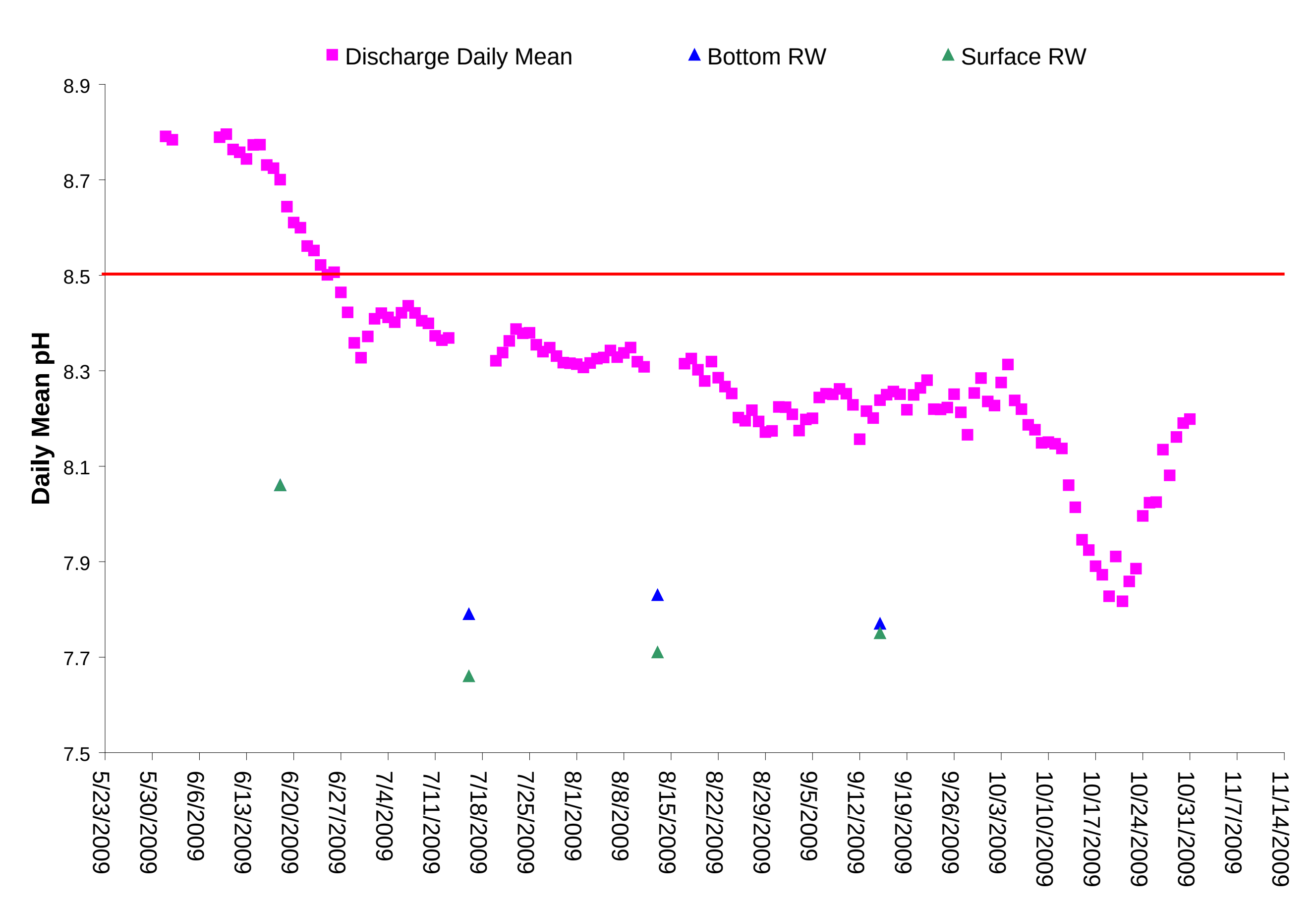

Figure A-16: pH of Pond A7 vs. Alviso Slough

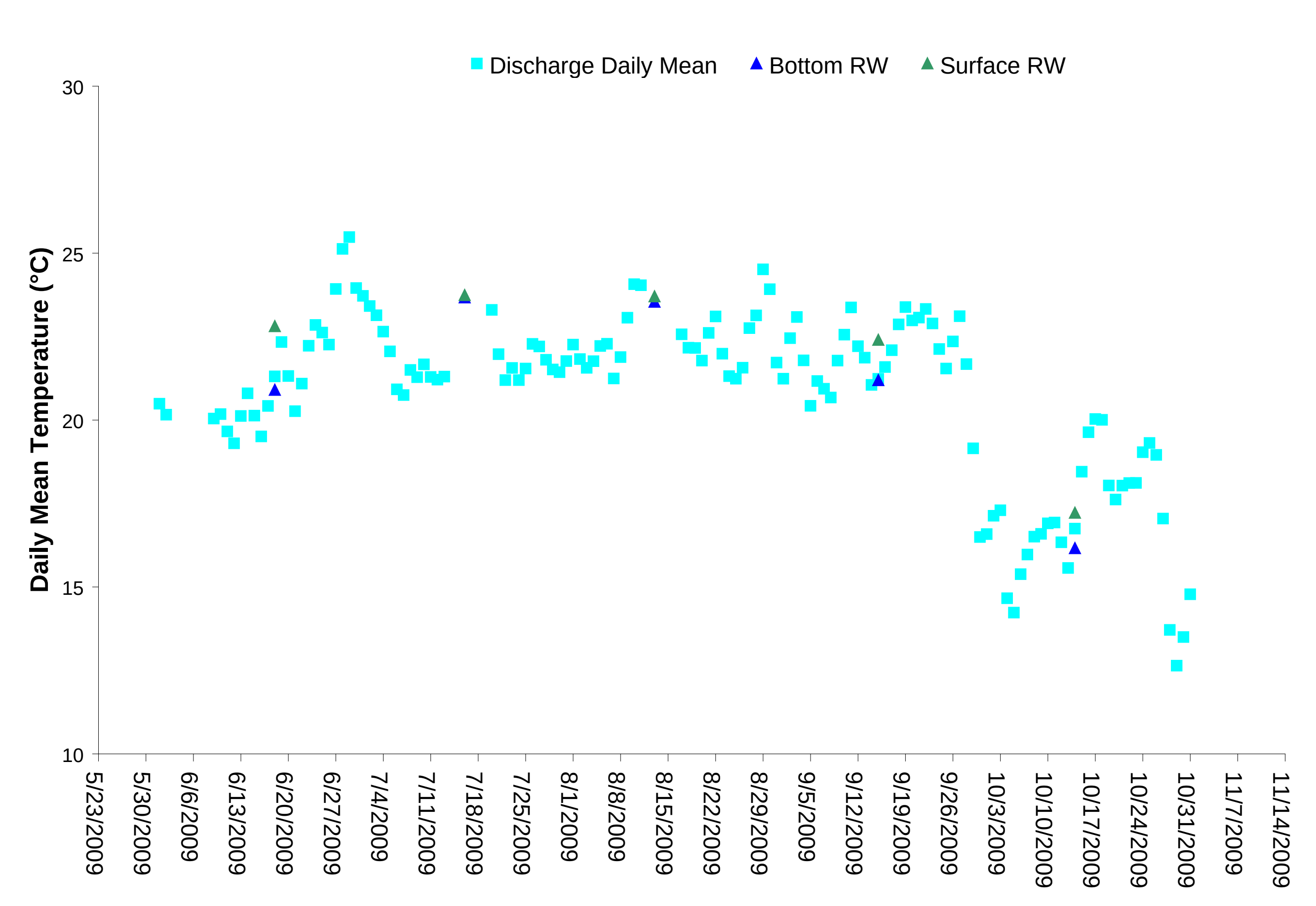

Figure A-17: Temperature values of Pond A7 vs. Alviso Slough

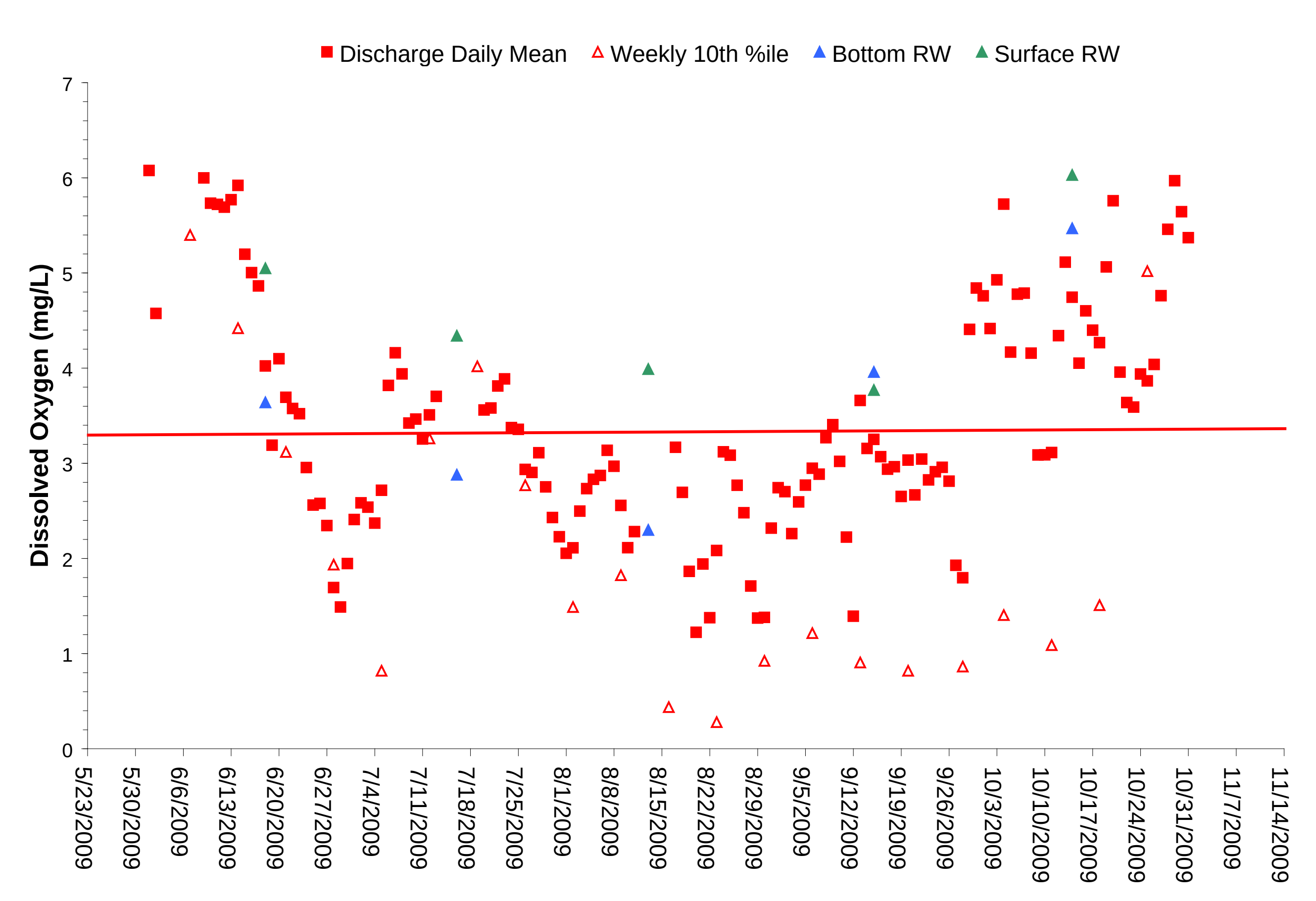

Figure A-18: Dissolved oxygen of Pond A7 vs. Alviso Slough

APPENDIX B
DISSOLVED OXYGEN SOURCES AND SINKS FOR ALVISO PONDS A3W, A14, AND A16

Dissolved oxygen sources and sinks for Alviso ponds A3W, A14 and A16

Greg Shellenbarger, including data and analysis from Nicole Athearn, Kathleen Henderson, Brent Topping, and James Kuwabara.

Background

During the summer of 2008, a directed study on oxygen dynamics was conducted by the USGS in Alviso ponds A3W, A14, and A16. Each pond was instrumented for three rotating periods of two weeks using water quality sondes that measured temperature, salinity, and dissolved oxygen concentrations at a 15-minute interval. In addition, pond inflow and out-flow rates were periodically measured, and benthic oxygen flux profilers were deployed in each pond for one 24-hour period. The details of the sampling can be found in Mruz *et al.* (2009) and Topping *et al.* (2009). Presented here are initial results from a preliminary analysis to quantify the strength of different pond sources and sinks of dissolved oxygen.

Methods for quantifying dissolved oxygen sources and sinks

Numerous methods exist for computing dissolved oxygen (DO) budgets in the environment. We have selected to use a technique detailed in Thebault *et al.* (2008), which was successfully applied to Alviso pond A18 in a 2006 study. This technique utilizes the time-series of measured dissolved oxygen concentrations, along with a variety of measured physical parameters, to compute net ecosystem metabolism as the difference between the calculated photosynthetic and respiration rates in the pond. The general equation for the change in dissolved oxygen in the system through time is:

$$dC/dt = P-R+D,$$

where dC/dt is the change in dissolved oxygen concentration in the pond per unit of time, P is the photosynthetic rate, R is the respiratory rate, and D is the diffusion rate of oxygen moving into and out of the water from the atmosphere. This equation can be rewritten as:

$$P-R=dC/dt-D$$

The terms dC/dt and D can be computed from measured parameters (water and air temperatures, salinity, wind speed, atmospheric pressure, average pond depth, and dissolved oxygen concentration). This result can be used to calculate P-R (the difference between the photosynthetic and respiratory rates). During the night, when there is no solar radiation, P=0, so R=-dC/dt+D. Using the averaged hourly R values calculated during the night (and assuming that R is constant throughout a 24-hour period), P can be computed as P=dC/dt-D+R.

The equations required for the solution to the above equation are detailed at the end of this report. This form of the dissolved oxygen equation ignores advective fluxes of dissolved oxygen from water moving into and out of the pond (i.e., inflow and discharge). We feel that initially this is a valid assumption, because the volume of the pond is large relative to the volume of inflow and discharge. Therefore, dissolved oxygen that enters or leaves the pond as a result of flow will contribute minimally to the overall sources and sinks of oxygen. This assumption will be evaluated if better water budgets can be developed for each pond.

The values for pond temperature, salinity, and dissolved oxygen concentrations that were used for the computations were an average of up to six sondes deployed in a variety of locations (intake, discharge, two shallow, and two deep locations) throughout a pond during a specific study period. Wind velocity, air temperature, and solar irradiance values were measured with a weather station deployed adjacent to the Alviso ponds by USGS-BRD. Atmospheric pressure values were obtained from a NOAA weather station located in the Port of Redwood City via the NOAA National Data Buoy Center website (station RTYC1, http://www.ndbc.noaa.gov/).

Results

The results for the computed respiratory (R) and photosynthetic (P) rates presented herein are preliminary. The high values of R and P in these ponds, relative to those reported by Thebault *et al.* (2008) for pond A18, and the negative values for photosynthetic rates (as seen in the first study period for pond A3W, Table 2) are unexpected, and further analysis must be performed to ensure that the presented rates are accurate.

Estimates of the daily rates of P and R for pond A3W are presented in Figure 1. The sampling period in July/August exhibits much lower rates than the September/October period. This is unexpected because the first period is warmer and has higher solar radiation (data not shown). One possible explanation results from the fact that this method relies on rates of change of DO concentrations in the pond. Pond A3W has lower and less variable DO concentrations in July/August (2.9 +/- 1.1 mg/L, average +/- standard deviation, range: 0.82-5.85 mg/L) than in September/October (3.8 +/- 2.6 mg/L, range: 0.12-9.23 mg/L). The DO concentrations during the earlier period appear to be so low that large rates of change in DO concentration cannot happen, unlike during the second period of study. Low DO concentrations during the first period may be limiting respiration (and perhaps limiting photosynthesis by affecting the 'health' of primary producers), or this method of analysis may not be suitable for quantifying R and P rates at low DO concentrations. In addition, the unexpected negative values for the daily photosynthetic rate during the first study period suggest a problem with the method or that the assumption of a constant respiration rate throughout the day may not be valid for this period. The rates during the second period better reflect a balance of P and R rates. However, these rates are the highest reported in this study and appear to be roughly a factor of 10 higher than those reported for pond A18 (Thebault *et al.* (2008)). We have not determined if this is related to differences in management of the two ponds.

The P and R rates calculated for ponds A14 (Figure 2) and A16 (Figure 3) are closer to expectations, with higher rates during the warmer, sunnier, first sampling period for each pond (Table 2). The first sampling period for A14 shows higher rates than the first sampling period in A16, while the reverse is true for the second sampling period. Because the sampling in each pond was not simultaneous, it is difficult to understand this reversal of pattern. However, it is likely that this results from the particulars of the biological populations in each pond (*e.g.*, short-lived phytoplankton blooms that differentially occur in each pond could dramatically affect the P and R rates).
A preliminary comparison of the oxygen consumption calculated from the Biochemical Oxygen Demand (BOD) and benthic diffusive oxygen flux (or Sediment Oxygen Demand, SOD) sampling is presented in Table 1. The BOD and SOD samples were collected from the same area during the same time period and should be relatively intercomparable (at least for the values reported in kg/day). Overall, the water column oxygen demand (BOD) appears to be the strongest oxygen sink in all three ponds. Both the BOD and SOD results show the same pattern *i.e.*, A3W > A16 >> A14 in terms of oxygen consumption. Pond A14 exhibits very low BOD and SOD overall. Ponds A3W and A16 are more similar to each other than to pond A14. This is particularly obvious when calculating the ratio of BOD to SOD: A3W=1.9, A16=3.5, and A14=20. However, these results suggest that SOD may be an important oxygen sink in pond A3W, where SOD oxygen consumption is about half of the BOD oxygen consumption, but it does not appear to be a very strong oxygen sink in A16 or A14.

At this stage of our analysis we do not feel comfortable comparing the oxygen consumption terms presented in Tables 1 and 2. The Thebault *et al.* (2008) method produces very different results from the BOD and SOD analyses. BOD and SOD are two components, although not the only components, of R (but the expectation for these ponds is that SOD and BOD would be the major components of R). The different methods simply may not produce comparable results, because the tests have different sensitivities and use different assumptions. However, Thebault *et al.* (2008) describes a method to calculate the relative contribution of heterotrophic (*e.g.*, bacteria, zooplankton, fish) versus autotrophic (phytoplankton) respiration to the respiration term. It appears we have sufficient data to perform this calculation. This could prove insightful to understanding what organisms are controlling the respiration in the ponds and may allow a comparison to the BOD or SOD results.

Work on the water budgets for A3W and A14 is continuing, but accurate results have been hampered by insufficient temporal and spatial resolution of pond water surface elevations. We will not be able to compute a water budget for pond A16 because of the highly variable and unpredictable flow through the channel connecting the pond to A17. Where possible, we will estimate inflow and outflow rates, along with measured oxygen concentrations, to determine if inflow and outflow are important sources or sinks of oxygen relative to our calculated P and R values. In addition, using methods described in Thebault *et al.* (2008), we plan to estimate autotrophic versus heterotrophic respiration in the ponds. This could allow a more detailed understanding of the oxygen sinks in the ponds.

Recommendations for 2010

The 2008 study was productive in that we learned ponds that have had dissolved oxygen issues in the past are not the same in terms of some of the dissolved oxygen sinks (*e.g.,* BOD and SOD). However, improvements to our study could lead to a better understanding of dissolved oxygen behavior in the ponds, and the implications for the ability of management actions to control dissolved oxygen concentrations. The following are recommendations for an improved study conducted in 2010:

- Focus the study on one pond during the entire season. This allows us to concentrate our efforts and continuously monitor a pond during the entire summer, since conditions are constantly changing. The downside is not learning as much about other ponds (*e.g.*, we know that A3W and A14 have very different SODs and BODs, but we do not know why). However, concentrating limited resources in one pond will help to understand what is driving changes in the ponds throughout the season. We suggest focusing on pond A3W, since, with the highest BOD and SOD, it is most likely to have issues with low dissolved oxygen concentrations. The culvert flow structures (versus open-channels or weirs) tend to be easier to measure and predict for the purpose of a water budget. In addition, construction is planned in A16 within the next two years, and a recent breach in the levee between A11 and A14 will make the water budget for A14 difficult.
- Collect higher frequency water surface elevation data. Even though the water surface elevations appear reasonably constant on a weekly scale, small changes in elevation or higher frequency fluctuations can impact the water budget. Installing a water-quality sonde with a depth sensor at a know elevation would be useful (ideally referenced to NAVD88).
- Obtaining an accurate elevation, instead of height above the levee, for the anemometer on the weather station would allow an accurate determination of the height of the anemometer above the water surface (inaccuracies in this value do not have a large effect on the calculations, but if we can do better, we should).
- Collect more flow measurements for developing accurate rating curves for the flow structures, particularly when there are changes in control gate settings. Collect additional chlorophyll samples, particularly if it is important to quantify autotrophic versus heterotrophic respiration. Collect additional and more spatially varied BOD and SOD samples. These additional samples will naturally result from concentrating efforts on one pond instead of three.
- Collect samples (BOD, SOD, chlorophyll, nutrients) in an algal mat to understand better how these areas of the pond maybe impacting the dissolved oxygen concentrations throughout the pond.
- Conducting 'light' and 'dark' bottle studies would give us independent estimates of primary productivity that could be compared to the primary productivity estimates calculated from the Thebault *et al.* (2008) method. The light and dark bottle method may be more sensitive to capturing net primary productivity during periods of low DO concentrations in the pond.
- Ensure better coordination with management control of the pond. Changes to the control structures should be kept to a minimum and coordinated with the sampling efforts. It is possible that, if properly controlled, the study could capture the effects of changing management actions.

Literature Cited

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Thebault, J., T.S. Schraga, J.E. Cloern, and E.G. Dunlavey. 2008. Primary production and carrying capacity of former salt ponds after reconnection to San Francisco Bay. Wetlands, 28: 841-851.

Topping, B.R., J.S. Kuwabara, N.D. Athearn, J.Y. Takekawa, F. Parchaso, K.D. Henderson, and Sara Piotter. 2009. Benthic oxygen demand in three former salt ponds adjacent to south San Francisco Bay, California. US Geological Survey, Open-File Report 2009-1180, 21 p.

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Table 1. Comparison of the dissolved oxygen demand by the water column (BOD) and sediments (SOD) in concentration and load of oxygen per day. Negative values are sinks that remove dissoved oxygen from the pond system.

+BOD values are averages of 18 samples collected during the benthic oxygen profiler deployments. Data were provided by USGS-BRD (Kathleen Henderson).

*SOD values are benthic diffusive oxygen fluxes. Values reported here are an average of the two fluxes reported by Topping *et al.* (2009). Please note that the Topping report miscalculated SOD values in units of kg/day. This table reflects the corrected values.

Pond	Collection Date	BOD+ g/L/day	SOD* $g/m^2/day$	BOD+ kg/day	SOD* kg/day
A3W	30 Sept.	-0.0025	-0.50	-2,160	-1,120
A14	11 Sept.	-0.0005	-0.02	-442	-22.5
A16	27 Aug.	-0.0015	-0.42	-1,470	-416

Table 2. Comparison of the averaged daily dissolved oxygen production (P, photosynthesis) or demand (R, respiration) for each deployment period. Negative values are sinks that remove dissoved oxygen from the pond system. The P and R values are daily averages for the entire pond. R is composed of BOD and SOD, plus other sources of respiration.

Pond	Study Period	P (g/L/day)	R (g/L/day)	P (kg/day)	R (kg/day)
A3W	28 Jul. - 7 Aug.	-0.009	-0.093	-8,100	-80,159
A14	9-Sept. - 18 Sept.	0.257	-0.253	227,000	-224,000
A16	19 Aug. - 28 Aug.	0.151	-0.156	149,000	-154,000
A3W	29 Sept. - 9 Oct.	0.327	-0.326	282,000	-282,000
A14	11 Nov. - 20 Nov.	0.130	-0.141	115,000	-125,000
A16	21 Oct. - 30 Oct.	0.142	-0.154	140,000	-151,000

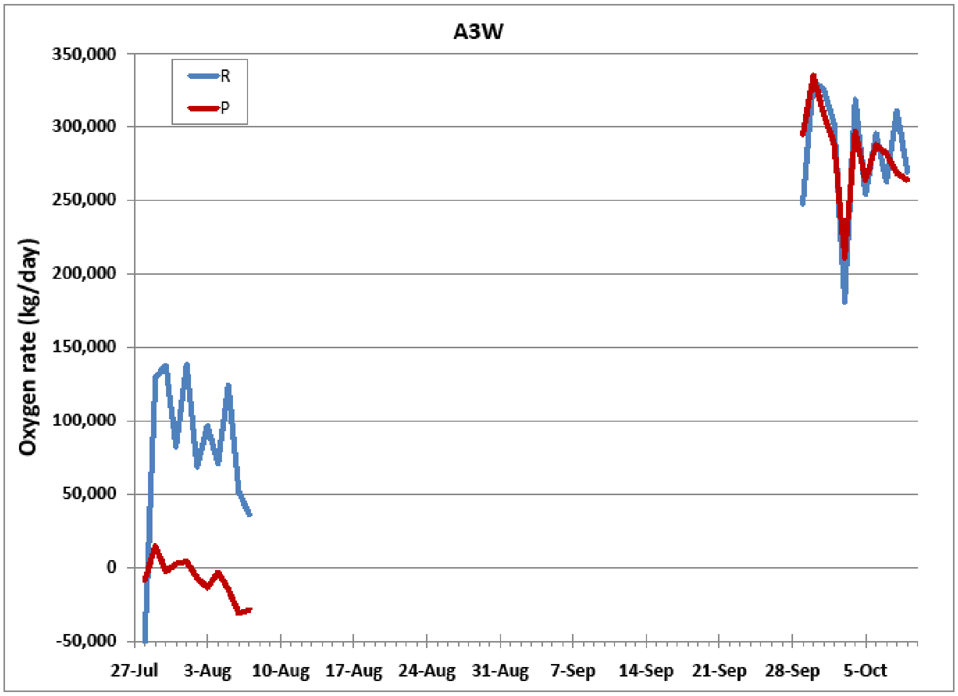

Figure 1. Comparison of the computed daily oxygen production/consumption rates of photosynthesis (P) and respiration (R) for pond A3W during both study periods. Respiration rates are presented as positive values to allow for easy visual comparison.

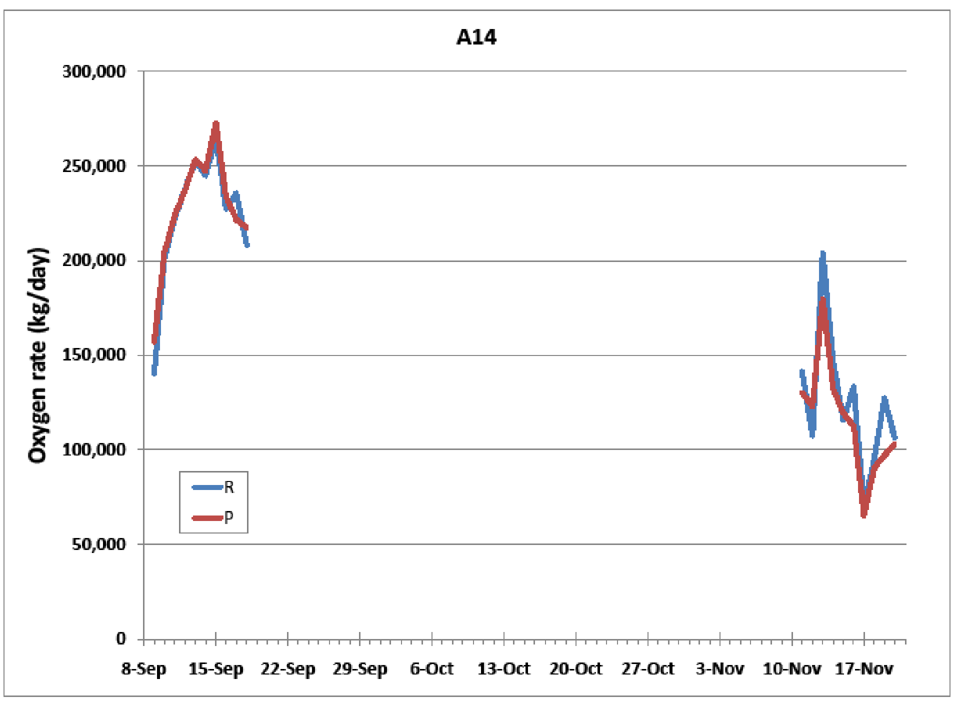

Figure 2. Comparison of the computed daily oxygen production/consumption rates of photosynthesis (P) and respiration (R) for pond A14 during both study periods. Respiration rates are presented as positive values to allow for easy visual comparison.

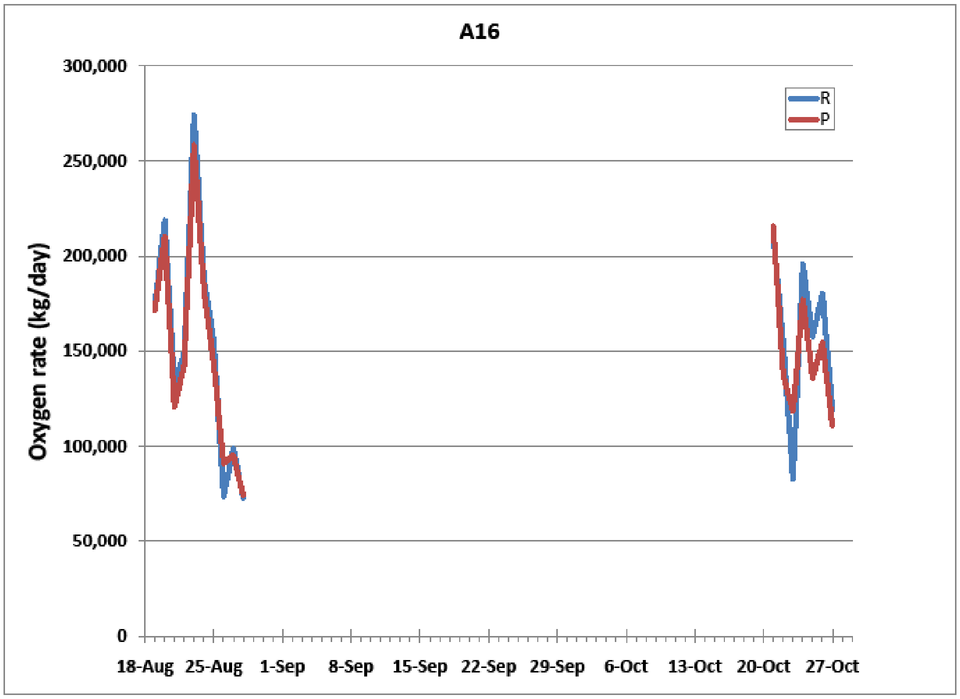

Figure 3. Comparison of the computed daily oxygen production/consumption rates of photosynthesis (P) and respiration (R) for pond A16 during both study periods. Respiration rates are presented as positive values to allow for easy visual comparison.

Equations and data sources for DO budgets using Thebault *et al.* (2008) techniques

Rate of dissolved oxygen concentration change: (Thebault *et al.* (2008), Eqn. 1)
$dC/dt=P-R+D$
or when rewritten:
$P-R=dC/dt-D$,
where dC/dt is the rate of change of dissolved oxygen in the pond (measured), D is the rate of diffusion across the water surface (computed using the below equations), and P and R are the photosynthetic and respiratory rates in the water column, respectively (computed).

Rate of oxygen uptake of pond by diffusion: (Thebault *et al.* (2008), Eqn. 2)
$D=k_a(C_s-C)$
where C is the oxygen concentration in the pond (measured), C_s is saturation oxygen concentration in water for given conditions (computed, see below), and k_a is the volumetric reaeration coefficient (computed, see below)

Dissolved oxygen saturation concentration: (Thebault *et al.* (2008), Eqn. 3)
$\ln C_s=-135.29996+1.572288*10^{5}*T^{-1}-6.637149*10^{7}*T^{-2}+1.243678*10^{10}*T^{-3}-8.621061*10^{11}*T^{-4}-(0.020573-12.142*T^{-1}+2363.1*T^{-2})*S$
where T is the water temperature (measured) and S the salinity (measured)

This term needs to be in the correct units and can be converted using Thebault *et al.* (2008), Eqn. 4
C_s (mg O_2/L) = C_s (□ mol O_2/kg) *$□_w$*31.9988*10-6
where $□_w$ is the density of water (computed, see below)

Volumetric reaeration coefficient: (Thebault *et al.* (2008), Eqn. A11)
$k_a = (1/24)*(K_L/H)$
where K_L the oxygen mass transfer coefficient (computed, see below), and H is the average water depth (estimated from staff gauge readings and pond stage:area:volume relationships)

Oxygen mass transfer coefficient: (Thebault *et al.* (2008), Eqn. A10)
$K_L=0.24*170.6*(D_w/□_w)^{0.5}*(□_a/□_w)^{0.5}*U_{10}^{1.81}$
where D_w is the diffusivity of oxygen in water (computed, see below), $□_w$ is the kinematic viscosity of water (computed, see below), $□_a$ and $□_w$ are the density of air and water respectively (computed, see below), and U_{10} is the wind speed at 10 meters above the surface (computed, see below)

Wind speed at 10 m: (Thebault *et al.* (2008), Eqn. A8)
$U_{10}=U_z*(\ln(10/z_0)/\ln(z/z_0))$
where z is the height of the anemometer (measured), z_0 the length scale for surface roughness (estimated at 10^{-5} for smooth water), and U_z is the wind velocity (measured).

Density of seawater: (code from Phil Morgan, CSIRO, 1992 using the UNESCO 1983 Equation of State polynomial for seawater at atmospheric pressure)
The standard polynomial is too complex to reproduce here. It is computed based on the water temperature and salinity (measured).

Density of air: (Thebault *et al.* (2008), Eqn. A6)

$\square_a=(P_{atm}-P_v)/(R_dT_{air})+(P_v/(R_vT_{air}))$
where P_{atm} is the air pressure (measured) P_v is the saturation vapor pressure of water (computed, see below) R_d is the gas constant for dry air (287.05 J/kgK), R_v is the gas constant for water vapor (461.495 J/kgK), T_{air} is the air temperature (measured).

Kinematic viscosity: (Thebault *et al.* (2008), Eqn. A2)
$\square_w=\square_w/\square\square_w$
where $\square_w$ is the dynamic viscosity of water (computed, see below), $\square_w$ the water density (computed, see above).

Dynamic viscosity of water: (Thebault *et al.* (2008), Eqn. A3)
$\square_w=\square_{pw}*(1+(5.185*10^{-5}*T+1.0675*10^{-4})*(\square_w*S/1806.55)^{0.5}+(3.3*10^{-5}*T+2.591*10^{-3})*(\square_w*S/1806.55))$
where T is the water temperature (measured), S is the salinity (measured), $\square_w$ is the water density (computed, see above), and is the dynamic viscosity of pure water (computed, see below)

Dynamic viscosity of pure water: (Thebault *et al.* (2008), Eqn. A4)
$\square_{pw}=1.002*10^{-3}*10\text{^}(1.1709*(20-T)-1.827*10^{-3}*(T-20)^2)/(T+89.93))$
where T is the water temperature (measured), and S is the salinity (measured)

Diffusivity of O_2 in water: (developed from data in Table 6.2 from Denny (1993), which is reprinted from Armstrong (1980))
Use $D_w=5.59\text{x}10^{-11}*T+9.86\text{x}10^{-10}$
where T is water temperature (measured).

Saturation water vapor pressure: (Flatau *et al.*, (1992))
$P_v= a_1+a_2*T+a_3*T^2+a_4*T^3+a_5*T^4+a_6*T^5+a_7*T^6$
where T is water temperature (measured) and a_{1-7} are constants (see reference Table 3 for constants)