# UPPER MISSISSIPPI RIVER RESTORATION
# FEASIBILITY REPORT
# WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

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# BEAVER ISLAND
# HABITAT REHABILITATION AND ENHANCEMENT PROJECT

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## POOL 14, UPPER MISSISSIPPI RIVER MILES 513.0-517.0
## CLINTON COUNTY, IOWA

## APPENDIX F

## WATER QUALITY

# UPPER MISSISSIPPI RIVER RESTORATION
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## APPENDIX F

## WATER QUALITY



**TABLES**



**FIGURES**[1]



[1] **All Figures - Pre-Project Dissolved Oxygen and pH Values Collected with a Continuous Monitor**

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## APPENDIX F

## WATER QUALITY

### I. PURPOSE

The purpose of this appendix is to evaluate the results from water quality monitoring performed by Corps personnel at two potential environmental enhancement sites located within the *Beaver Island Habitat Rehabilitation and Enhancement Project* (Project). Water quality monitoring was performed with the primary objective of defining pre-project baseline water quality conditions.

### II. INTRODUCTION

Baseline water quality monitoring was initiated at Beaver Island in order to determine pre-project conditions and assist with selecting and locating alternatives for habitat rehabilitation and enhancement. The Bellevue Long-Term Resource Monitoring (LTRM) station was contacted in an effort to determine if their office had any existing water quality information for the Project area. It was determined that main channel border sites upstream at river mile 520.6 near Clinton, Iowa, and downstream at river mile 511.4 near Camanche, Iowa, were monitored by Iowa Department of Natural Resources personnel. The U.S. Geological Survey (USGS) operates a water quality monitoring station within the main channel of the Mississippi River at Clinton, Iowa; however, the USGS was not aware of any significant water quality information available for areas within Beaver Island.

On December 16, 2008, Corps personnel initiated baseline water quality monitoring at Beaver Island at sites W-M513.4P and W-M513.5R (Plate 31, O-101) and continued through September 9, 2015, with eight samples collected during the summer months and three samples during the winter months each full year. Site W-M513.5R is located just below Lower Lake on an interior channel that traverses most of the length of the island, entering at Beaver Slough near the upper end of the island and exiting into the Mississippi River at the downstream end of the island. Site W-M513.4P is located in Blue Bell Lake, a backwater "finger" that branches from the interior channel near the lower part of the island. Aquatic vegetation has been observed in the area near site W-M513.4P, but was not observed near site W-M513.5R.

## III. METHODS

Monitoring was accomplished through a combination of collecting grab samples and deploying continuous monitors. In general, sampling date, time, water depth, Secchi disk depth, water velocity, wave height, air temperature, percent cloud cover, wind speed and direction, pH, water temperature, dissolved oxygen (DO), and specific conductance were recorded in the field. During the summer months a water sample was collected just below the surface at each sampling site. The sample was placed on ice and shipped to either Iowa State University, Ames, Iowa, or ARDL, Inc., Mt. Vernon, Illinois for total suspended solids and chlorophyll analyses. Water samples were collected year-round for turbidity and alkalinity analyses, which were performed in-house. Sample collection/preservation and field/laboratory analytical procedures were performed according to USEPA approved methods. In addition to the manually collected data, YSI and Hach multiparameter water quality monitoring instruments (sondes) were deployed on numerous occasions. Typically, the sondes were placed 1 to 2 feet from the bottom and were programmed to record DO, pH, temperature, depth, specific conductance and occasionally turbidity every 2 hours. Summer deployments typically lasted two weeks, while in the winter the sondes were deployed for approximately 6 weeks.

## IV. RESULTS AND DISCUSSION

**A. Site W-M513.4P.** The results from grab sample monitoring at site W-M513.4P are shown in Table F-1. This site, located in Blue Bell Lake, exhibited relatively low velocities with a median of 1.23 cm/sec. Winter velocities were generally lower (median of 0.41 cm/sec), while significantly higher velocities were observed during flood events (maximum of 32.21 cm/sec on July 2, 2013). Winter water temperatures were relatively warm, with a median of 1.9°C. The maximum water temperature, 30.0°C, was measured on July 17, 2012. DO concentrations ranged from 0.90 mg/L to 31.95 mg/L, with a median of 7.04 mg/L. Eleven DO concentrations were low (less than 5 mg/L), with nine occurring during the summer months and two during the winter. The majority of low DO concentrations occurred during the summer of 2010, when water levels and flow remained high for several weeks. During this high water period, algal numbers were depleted by the increased flow as indicated by the low chlorophyll a concentrations, and the associated reduction in photosynthesis resulted in low DO concentrations.

The two low winter DO concentrations, 3.05 mg/L on February 7, 2011 and 4.85 mg/L on February 19, 2014, occurred when there was significant snow and ice cover. Supersaturated DO concentrations (based on water temperature, pressure, and dissolved oxygen concentration) were occasionally measured during the winter and less often during the summer. Values of pH ranged from 6.83 to 9.50, with a median value of 7.97. The poorest recorded values of parameters indicative of water clarity (Secchi disk depth, turbidity and total suspended solids) occurred on June 2, 2009. Values were 18.8 cm, 57.1 NTU and 62.0 mg/L, respectively. An algal bloom contributed to these values, as chlorophyll a and b concentrations were at their maximum on this date.

A sonde was deployed at site W-M513.4P on nearly every sampling trip. It was common for DO concentrations to fall below 5 mg/L during the night and reach supersaturated levels during the day in the summer. Results from a typical summer deployment are shown in Figure F-1. During this deployment, DO concentrations fell below 5 mg/L during most nights but always recovered the following day. The diurnal DO concentration swing was typically 5-6 mg/L, but on August 16, 2013,

approached 10 mg/L. Extended periods of continuous low DO occurred during the summer months at site W-M513.4P from July 15 to 23, 2010, most of June 2011, July 12 to 28, 2011, July 30 to August 9, 2011, and most of June 2015. Water levels were higher than normal during all of these events. Figure F-2 shows the results from the July 15 to August 3, 2010 deployment. DO concentrations were close to zero early in the deployment, rose above 5 mg/L for a few days, then fell below 5 mg/L towards the end of the deployment. The very low concentrations at the beginning of this deployment were confirmed by a hand-held meter reading of 0.09 mg/L on July 15, 2010. The highest sustained summer DO concentrations occurred during the July 29, 2014 deployment (Figure F-3). DO concentrations were above saturation for much of this deployment, while the lowest value was 7.14 mg/L.

DO concentrations during winter deployments were generally related to snow cover. Snow depths in excess of 2 inches typically resulted in periods of low DO, while supersaturated DO concentrations were common when there was no snow cover. Six of the eleven winter deployments exhibited periods of at least one week where DO concentrations remained below 5 mg/L. The most extended period of low DO concentrations occurred during the December 17, 2013 deployment, from January 19 to February 19, 2014, as shown in Figure F-4. The snow depth at the beginning of this deployment was 2.5 inches and it increased to 4.5 inches by the end of the deployment. The winter of 2012-2013 exhibited the highest sustained DO concentrations. Supersaturated DO values were present for most of the period from December 19, 2012 to March 13, 2013 (Figure F-5), which spanned two deployments (December 19, 2012 to February 7, 2013 and February 7, 2013 to March 13, 2013). There was no snow cover recorded on the sampling days for these deployments.

**B. Site W-M513.5R.** The results from grab sample monitoring at site W-M513.5R are shown in Table F-2. This site is located just below Lower Lake on an interior channel that traverses most of the length of the island, entering at Beaver Slough near the upper end of the island and exiting into the Mississippi River at the downstream end of the island. This site exhibited more lotic tendencies than site W-M513.4P. Velocities were greater here, with a median of 5.31 versus 1.23 cm/sec (2.64 versus 0.41 cm/sec during the winter). Winter water temperatures were lower, with a median of 0.3 versus 1.9°C. Eleven DO concentrations were less than 5 mg/L and all occurred during the summer months. The majority of low DO concentrations occurred during the summer of 2010, when water levels remained high for most of June through August. The winter minimum DO concentration, 10.68 mg/L was significantly higher than the 3.05 mg/L winter minimum at site W-M513.4P. Supersaturated DO concentrations were occasionally measured during the winter and less often during the summer. Values of pH ranged from 6.95 to 9.02, with a median value of 7.80. Parameters indicative of water clarity (turbidity and total suspended solids), exhibited the following maximum values: 66.2 NTU and 66.0 mg/L, respectively. Secchi disk depth, another water clarity parameter, exhibited a maximum of 102.0 cm.

Sondes were deployed less frequently at site W-M513.5R due to their limited availability. Similar to site W-M513.4P, during the summer it was common for DO concentrations at site W-M513.5R to fall below 5 mg/L during the night and rise the following day. However, the diurnal DO concentration swings at site W-M513.5R were generally less pronounced than at W-M513.4P, as shown in Figure F-6 for the August 28 to September 11, 2012 deployments. The higher flow at site W-M513.5R likely limits algal blooms and associated larger diurnal swings in DO concentration. Extended periods of continuous low DO during the summer months were less common at site W-M513.5R, with the most severe occurring from July 3-12, 2012 (Figure F-7). This deployment was longer than normal due to

difficulty in locating the sonde during a high water period. The highest sustained summer DO concentrations likely occurred during the August 26, 2014 deployment (Figure F-8). DO concentrations were above saturation for much of this deployment, while the lowest value was 4.88 mg/L.

Unlike site W-M513.4P, which often exhibited extended periods when winter DO concentrations remained below 5 mg/L, low DO concentrations occurred only during one winter deployment at site W-M513.5R. As shown in Figure F-9, DO concentrations were below 5 mg/L from March 6 to 10, 2014. The snow depth at the beginning of this deployment was nine inches. DO concentrations during the winter of 2011-2012 were more typical of site W-M513.5R, with all values exceeding 5 mg/L and most supersaturated (Figure F-10) for a period covering two deployments (December 13, 2011 to January 12, 2012 and January 12, 2012 to March 8, 2012).

## V. CONCLUSIONS

Pre-project baseline water quality monitoring was performed at two Beaver Island sites (W-M513.4P and W-M513.5R) for the period December 16, 2008 to September 9, 2015. Monitoring was accomplished through the collection of discrete grab samples, as well as by utilizing continuous monitors. Site W-M513.4P exhibited more lentic water quality characteristics, while site W-M513.5R was more lotic. Water quality monitoring results indicated that low DO concentrations occurred more frequently during the summer than winter months at both sites, typically during high water events. While it was common for summer nighttime DO concentrations to fall below 5 mg/L at both sites, extended periods of low DO were more frequently observed at site W-M513.4P. It was rare for winter DO concentrations to fall below 5 mg/L at site W-M513.5R, while several extended low DO periods were observed at site W-M513.4P, especially during periods of heavy snow cover. Supersaturated DO concentrations, typically accompanied by high pH values, occurred at times during the summer and winter months at both sites. These conditions were likely indicative of intense algal photosynthesis. Both low DO and supersaturated conditions can be harmful to the fishery. The median winter water temperature was considerably warmer at site W-M513.4P relative to site W-M513.5R.

Dredging of channels in Beaver Island would allow for an increased volume of DO in these areas, thus affording fish a better chance for survival, particularly during periods of extended ice and snow cover. Dredging would also provide fish escape routes during the winter in areas that currently freeze to the bottom. During the summer months, dredged channels in lentic areas would stratify, providing cooler temperatures near the bottom for fish and other aquatic life, whereas during the colder months, these areas would provide warmer water preferred by overwintering fish. Implementation of the closure structure feature on the Upper Cut would reduce sediment input, but it would also reduce flow (and hence DO) to the interior portions of the island. Post-construction monitoring is needed to assure that DO concentrations in the dredged channels remain at sufficient levels.

**Table F-1:** Water Quality Monitoring Results from Samples Collected at Site W-M513.4P

| Date | Water Depth (m) | Velocity (cm/sec) | Water Temp (°C) | Dissolved Oxygen (mg/L) | pH (SU) | Secchi Disk Depth (cm) | Turbidity (NTU) | Total Suspended Solids (mg/L) | Chlorophyll a ($mg/m^3$) |
|---|---|---|---|---|---|---|---|---|---|
| 12/16/2008 | 0.660 | 0.42 | 2.5 | 20.47 | 8.50 | ** | 11.9 | - | - |
| 1/29/2009 | 0.790 | 0.47 | 1.1 | 7.19 | 7.50 | ** | 7.5 | - | - |
| 3/9/2009 | 1.860 | 1.86 | 3.2 | 15.66 | 8.00 | 25.0 | 44.0 | - | - |
| 6/2/2009 | 0.900 | 2.36 | 19.9 | 9.86 | 8.50 | 18.8 | 57.1 | 62.0 | 71.0 |
| 6/16/2009 | 0.918 | 1.59 | 22.6 | 9.08 | 8.30 | 25.2 | 37.0 | 44.0 | 45.0 |
| 6/30/2009 | 0.848 | 0.00 | 24.0 | 7.57 | 8.18 | 28.8 | 28.5 | 13.0 | 57.0 |
| 7/14/2009 | 0.662 | 2.84 | 24.9 | 7.64 | 8.41 | 20.4 | 40.9 | 50.0 | 39.0 |
| 7/28/2009 | 0.762 | 1.05 | 25.3 | 6.05 | 8.40 | 20.4 | 46.9 | 55.0 | 31.0 |
| 8/11/2009 | 0.964 | 0.64 | 25.4 | 8.12 | 8.40 | 39.8 | 24.2 | 27.0 | 31.0 |
| 8/25/2009 | 0.786 | 3.01 | 22.8 | 7.03 | 8.50 | 31.2 | 28.8 | 34.0 | 18.0 |
| 9/9/2009 | 0.548 | 1.20 | 22.4 | 5.80 | 7.80 | 45.0 | 14.8 | 21.0 | 15.0 |
| 12/21/2009 | 0.740 | 0.18 | 1.5 | 29.92 | 8.70 | ** | 3.8 | - | - |
| 2/4/2010 | 0.760 | 0.29 | 1.1 | 9.16 | 7.30 | ** | 7.7 | - | - |
| 3/10/2010 | 0.930 | 0.39 | 0.8 | 20.30 | 8.30 | ** | 1.9 | - | - |
| 6/8/2010 | 0.805 | 1.23 | 22.4 | 1.80 | 7.60 | 80.5 | 6.3 | 7.0 | 12.0 |
| 6/22/2010 | 1.765 | - | 24.7 | 7.04 | 7.70 | 176.5 | 3.1 | 3.0 | 2.0 |
| 7/7/2010 | 1.990 | - | 24.7 | 0.90 | 7.20 | 199.0 | 2.0 | 6.0 | 5.0 |
| 7/15/2010 | 1.785 | - | 26.4 | 2.76 | 7.40 | 178.5 | 2.0 | 1.0 | 2.0 |
| 8/3/2010 | 1.895 | - | 25.9 | 3.69 | 7.30 | 73.5 | 9.6 | 12.0 | 14.0 |
| 8/17/2010 | 1.680 | - | 25.7 | 5.37 | 7.60 | 48.0 | 21.0 | 25.0 | 23.0 |
| 8/31/2010 | 1.272 | - | 24.9 | 6.72 | 7.40 | 34.5 | 28.5 | 37.0 | 39.0 |
| 9/14/2010 | 1.060 | 3.14 | 21.4 | 7.90 | 8.00 | 26.0 | 26.9 | 31.0 | 42.0 |
| 12/15/2010 | 1.000 | 0.50 | 0.9 | 15.69 | 7.60 | ** | 9.0 | - | - |
| 2/7/2011 | 1.100 | 0.57 | 1.1 | 3.05 | 7.30 | ** | 9.1 | - | - |
| 3/7/2011 | 1.530 | 1.41 | 0.5 | 11.59 | 7.70 | ** | 5.1 | - | - |
| 6/1/2011 | 2.350 | 4.87 | 20.1 | 9.64 | 8.00 | 49.0 | 17.6 | 14.0 | 28.0 |
| 6/14/2011 | 2.200 | 3.81 | 20.7 | 4.83 | 7.40 | 50.0 | 7.9 | 17.0 | 12.0 |
| 6/28/2011 | 2.060 | 2.82 | 22.5 | 6.90 | 7.50 | 32.0 | 19.3 | 17.0 | 26.0 |
| 7/12/2011 | 1.960 | 1.78 | 27.4 | 5.82 | 7.60 | 51.4 | 10.8 | 10.0 | 25.0 |
| 7/26/2011 | 2.050 | 1.75 | 27.6 | 5.21 | 7.60 | 49.0 | 10.7 | 8.0 | 9.0 |
| 8/9/2011 | 1.860 | 2.64 | 25.9 | 4.30 | 7.40 | 31.0 | 28.5 | 28.0 | 12.0 |
| 8/23/2011 | 1.330 | - | 25.8 | 8.08 | 8.00 | 23.6 | 15.0 | 32.0 | 39.0 |
| 9/7/2011 | 0.960 | - | 19.4 | 6.95 | 8.00 | 28.5 | 13.8 | 28.0 | 36.0 |
| 12/13/2011 | 0.630 | - | 3.5 | 19.40 | 9.00 | ** | 5.9 | - | - |
| 1/25/2012 | 0.600 | 0.50 | 1.9 | 31.95 | 9.50 | ** | 4.0 | - | - |
| 3/8/2012 | 0.860 | - | 9.1 | 19.13 | 9.30 | 44.0 | 8.0 | - | - |
| 6/5/2012 | 1.690 | 0.51 | 21.5 | 11.31 | 8.50 | 45.0 | 7.9 | 16.8 | 48.2 |
| 6/19/2012 | 1.520 | - | 26.1 | 5.81 | 7.70 | 28.0 | 12.2 | 32.4 | 28.4 |
| 7/5/2012 | 2.000 | 3.51 | 29.6 | 7.16 | 7.7 | 68.0 | 3.4 | 7.2 | 12.9 |
| 7/17/2012 | 0.990 | - | 30.0 | 6.68 | 7.8 | 30.0 | 9.8 | 28.7 | 27.3 |
| 7/31/2012 | 0.750 | - | 28.4 | 6.42 | 8.1 | 30.0 | 10.4 | 31.0 | 26.9 |
| 8/14/2012 | 0.510 | - | 20.7 | 6.7 | 7.8 | 34.0 | 9.2 | 25.6 | 35.4 |

**Table F-1 (cont.):** Water Quality Monitoring Results from Samples Collected at Site W-M513.4P

| Date | Water Depth (m) | Velocity (cm/sec) | Water Temp (°C) | Dissolved Oxygen (mg/L) | pH (SU) | Secchi Disk Depth (cm) | Turbidity (NTU) | Total Suspended Solids (mg/L) | Chlorophyll a ($mg/m^3$) |
|---|---|---|---|---|---|---|---|---|---|
| 8/28/2012 | 0.580 | 0.82 | 24.9 | 5.05 | 8 | 41.0 | 10.7 | 25.7 | 4.6 |
| 9/11/2012 | 0.550 | 0.45 | 20.0 | 6.07 | 8.3 | 23.0 | 13.0 | 45.5 | 5.2 |
| 12/19/2012 | 0.600 | - | 3.0 | 11.74 | 8.29 | 62.0 | 6.4 | - | - |
| 2/7/2013 | 0.600 | 0.10 | 2.2 | 20.42 | 9.03 | ** | 2.4 | - | - |
| 3/13/2013 | 1.960 | 0.17 | 0.1 | 12.98 | 6.83 | ** | 39.6 | - | - |
| 6/4/2013 | 3.250 | 25.84 | 19.2 | 6.79 | 7.42 | 32.0 | 11.2 | 23.1 | 1.3 |
| 6/18/2013 | 2.500 | 6.75 | 23.1 | 5.18 | 7.67 | 35.0 | 10.7 | 22.1 | <1.0 |
| 7/2/2013 | 3.380 | 32.21 | 23.1 | 5.93 | 7.68 | 25.0 | 13.4 | 34.7 | <1.0 |
| 7/16/2013 | 2.200 | 2.46 | 27.3 | 6.99 | 7.31 | 52.0 | 6.5 | 12.6 | 3.4 |
| 7/30/2013 | 0.810 | 0.85 | 22.5 | 14.73 | 8.64 | 35.0 | 17.6 | 38.8 | 19.6 |
| 8/13/2013 | 0.710 | 2.21 | 22.8 | 7.48 | 8.74 | 36.0 | 12.7 | 29.6 | 7.3 |
| 8/27/2013 | 0.620 | 1.92 | 27.2 | 3.73 | 8.18 | 37.0 | 13.6 | 36.1 | 5.2 |
| 9/10/2013 | 0.600 | 0.99 | 26.4 | 4.71 | 8.38 | 26.2 | 18.8 | 43.5 | 4.7 |
| 12/17/2013 | 0.640 | 0.25 | 3.2 | 10.32 | 7.88 | ** | 5.6 | - | - |
| 2/19/2014 | 0.610 | 0.28 | 3.3 | 4.85 | 7.50 | ** | 6.8 | - | - |
| 3/14/2014 | 0.950 | 0.75 | 0.7 | 12.95 | 7.66 | ** | 4.2 | - | - |
| 6/3/2014 | 2.670 | 9.84 | 23.2 | 5.45 | 7.37 | 41.0 | 21.3 | 23.2 | 1.2 |
| 6/18/2014 | 2.590 | 7.40 | 24.0 | 5.97 | 7.68 | 63.0 | 14.3 | 15.0 | <1.0 |
| 7/1/2014 | 3.685 | 29.40 | 24.3 | 6.05 | 7.69 | 30.0 | 46.7 | 52.0 | <1.0 |
| 7/15/2014 | 3.000 | 13.06 | 22.9 | 6.89 | 7.96 | 56.0 | 20.4 | 23.4 | <1.0 |
| 7/29/2014 | 1.240 | 0.53 | 22.7 | 8.77 | 7.87 | 43.0 | 15.3 | 16.8 | 7.6 |
| 8/12/2014 | 0.800 | 2.34 | 23.6 | 6.90 | 8.20 | 41.0 | 20.9 | 19.5 | 4.8 |
| 8/26/2014 | 1.030 | 2.97 | 27.1 | 8.70 | 8.20 | 48.0 | 13.2 | 14.3 | 4.8 |
| 9/9/2014 | 1.340 | 1.71 | 24.0 | 9.68 | 8.56 | 46.0 | 12.9 | 12.3 | 3.7 |
| 12/19/2014 | 0.830 | 0.89 | 3.9 | 16.23 | 8.56 | - | 13.2 | - | - |
| 2/3/2015 | 0.740 | 0.31 | 3.1 | 15.91 | 7.97 | - | 5.0 | - | - |
| 3/10/2015 | 0.680 | 0.37 | 1.8 | 20.22 | 7.74 | - | 7.6 | - | - |
| 6/2/2015 | 1.745 | 0.69 | 19.7 | 8.41 | 8.08 | 55.0 | 12.9 | 12.7 | 2.7 |
| 6/16/2015 | 2.395 | - | 23.2 | 4.83 | 7.60 | 53.0 | 14.3 | 12.0 | 2.5 |
| 6/30/2015 | 1.520 | - | 23.3 | 7.51 | 7.70 | 52.0 | 12.2 | 12.2 | 6.7 |
| 7/14/2015 | 1.180 | - | 26.3 | 9.30 | 8.12 | 55.0 | 13.7 | 14.8 | 8.0 |
| 7/28/2015 | 0.990 | - | 27.2 | 6.27 | 8.06 | 47.0 | 25.2 | 26.8 | 12.3 |
| 8/11/2015 | 0.945 | - | 24.6 | 8.43 | 8.56 | 39.5 | 9.6 | 28.4 | 7.2 |
| 8/25/2015 | 0.880 | - | 20.7 | 6.95 | 8.29 | 42.0 | 22.0 | 28.8 | 4.3 |
| 9/9/2015 | 0.860 | - | 24.6 | 5.04 | 8.18 | 32.0 | 20.8 | 20.4 | 4.4 |
| **MIN.** | **0.510** | **0.00** | **0.1** | **0.90** | **6.83** | **18.8** | **1.9** | **1.0** | **1.2** |
| **MAX.** | **3.685** | **32.21** | **30.0** | **31.95** | **9.50** | **199.0** | **57.1** | **62.0** | **71.0** |
| **AVG.** | **1.325** | **3.47** | **18.1** | **9.14** | **-** | **47.7** | **15.4** | **24.4** | **18.3** |
| **MEDIAN** | **0.990** | **1.23** | **22.8** | **7.04** | **7.97** | **41.0** | **12.7** | **23.3** | **12.0** |

**Table F-2:** Water Quality Monitoring Results from Samples Collected at Site W-M513.5R

| Date | Water Depth (m) | Velocity (cm/sec) | Water Temp (°C) | Dissolved Oxygen (mg/L) | pH (SU) | Secchi Disk Depth (cm) | Turbidity (NTU) | Total Suspended Solids (mg/L) | Chlorophyll a ($mg/m^3$) |
|---|---|---|---|---|---|---|---|---|---|
| 12/16/2008 | 1.060 | - | 0.6 | 19.70 | 8.20 | ** | 4.7 | - | - |
| 1/29/2009 | 1.170 | 2.64 | 0.1 | 15.91 | 7.70 | ** | 4.0 | - | - |
| 3/9/2009 | 2.290 | - | 2.6 | 15.42 | 8.00 | 24.0 | 51.2 | - | - |
| 6/2/2009 | 0.478 | 8.48 | 19.10 | 5.88 | 7.60 | 21.2 | 66.2 | 66.0 | 11.0 |
| 6/16/2009 | 1.240 | 7.32 | 21.8 | 5.19 | 7.60 | 20.4 | 60.3 | 58.0 | 6.0 |
| 6/30/2009 | 1.128 | 2.33 | 24.0 | 6.38 | 7.84 | 17.8 | 65.5 | 64.0 | 11.0 |
| 7/14/2009 | 1.120 | 2.34 | 25.3 | 10.15 | 8.46 | 23.4 | 42.0 | 36.0 | 24.0 |
| 7/28/2009 | 1.198 | 3.06 | 25.0 | 7.94 | 8.30 | 25.0 | 40.3 | 52.0 | 13.0 |
| 8/11/2009 | 1.382 | 4.30 | 25.1 | 6.45 | 8.10 | 50.8 | 12.8 | 15.0 | 19.0 |
| 8/25/2009 | 1.124 | 2.49 | 22.8 | 9.43 | 8.50 | 36.6 | 23.0 | 28.0 | 35.0 |
| 9/9/2009 | 1.020 | 3.66 | 22.8 | 6.14 | 7.90 | 102.0 | 6.4 | 9.0 | 7.0 |
| 12/21/2009 | 1.100 | 2.39 | 0.3 | 17.08 | 8.20 | ** | 6.0 | - | - |
| 2/4/2010 | 1.080 | 1.10 | 0.0 | 13.06 | 7.60 | ** | 5.6 | - | - |
| 3/10/2010 | 1.265 | 5.31 | 0.1 | 13.47 | 7.80 | ** | 7.9 | - | - |
| 6/8/2010 | 1.115 | 3.91 | 22.9 | 3.33 | 7.50 | 29.5 | 53.6 | 56.0 | 4.0 |
| 6/22/2010 | 2.065 | - | 24.1 | 4.38 | 7.60 | 38.5 | 28.0 | 35.0 | 2.0 |
| 7/7/2010 | 2.355 | - | 25.2 | 4.33 | 7.60 | 58.0 | 15.5 | 20.0 | 2.0 |
| 7/15/2010 | 2.145 | - | 26.8 | 4.48 | 7.60 | 63.0 | 10.0 | 13.0 | 3.0 |
| 8/3/2010 | 2.405 | - | 25.9 | 4.05 | 7.40 | 69.5 | 11.9 | 15.0 | 8.0 |
| 8/17/2010 | 2.100 | - | 25.3 | 5.23 | 7.70 | 41.0 | 25.1 | 31.0 | 13.0 |
| 8/31/2010 | 1.720 | - | 24.4 | 5.58 | 7.40 | 34.5 | 28.5 | 35.0 | 15.0 |
| 9/14/2010 | 1.570 | 11.32 | 19.7 | 6.90 | 7.90 | 23.4 | 34.3 | 39.0 | 15.0 |
| 12/15/2010 | 1.520 | 5.78 | 0.2 | 14.16 | 7.70 | ** | 7.1 | - | - |
| 2/7/2011 | 1.420 | - | 0.3 | 10.68 | 7.80 | ** | 8.5 | - | - |
| 3/7/2011 | 2.020 | 16.77 | 0.2 | 13.21 | 7.80 | 68.0 | - | - | - |
| 6/1/2011 | 2.710 | 27.38 | 19.5 | 9.83 | 8.20 | 47.0 | 19.6 | 24.0 | 35.0 |
| 6/14/2011 | 2.560 | 28.58 | 20.3 | 5.73 | 7.50 | 20.3 | 21.5 | 41.0 | 15.0 |
| 6/28/2011 | 2.240 | 26.31 | 21.9 | 6.97 | 7.70 | 23.0 | 36.9 | 42.0 | 20.0 |
| 7/12/2011 | 2.260 | 26.59 | 27.3 | 4.74 | 7.60 | 26.4 | 31.5 | 44.0 | 11.0 |
| 7/26/2011 | 2.330 | 28.55 | 27.8 | 4.74 | 7.60 | 30.0 | 26.2 | 35.0 | 5.0 |
| 8/9/2011 | 2.270 | 24.34 | 26.1 | 5.33 | 7.60 | 25.0 | 38.6 | 47.0 | 5.0 |
| 8/23/2011 | 1.670 | 1.89 | 26.2 | 6.88 | 8.00 | 15.0 | 34.5 | 61.0 | 15.0 |
| 9/7/2011 | 1.370 | 1.29 | 19.5 | 6.19 | 8.00 | 25.0 | 23.4 | 45.0 | 10.0 |
| 12/13/2011 | 0.850 | 2.04 | 2.6 | 16.40 | 8.60 | ** | 6.2 | - | - |
| 1/25/2012 | 0.900 | 1.29 | -0.1 | 15.9 | 8.40 | ** | 6.2 | - | - |
| 3/8/2012 | 1.270 | 7.60 | 7.4 | 18.09 | 9.00 | 52.0 | 6.8 | - | - |
| 6/5/2012 | 2.060 | 17.79 | 21.4 | 7.08 | 7.90 | 33.0 | 10.5 | 29.2 | 15.1 |
| 6/19/2012 | 1.970 | 17.97 | 25.3 | 6.04 | 7.70 | 30.0 | 11.8 | 29.0 | 12.0 |
| 7/5/2012 | 2.380 | 25.00 | 29.2 | 5.87 | 7.60 | 42.0 | 7.2 | 20.8 | 11.5 |
| 7/17/2012 | 1.350 | - | 29.1 | 6.19 | 8.00 | 42.0 | 6.4 | 18.5 | 18.5 |
| 7/31/2012 | 1.130 | 5.81 | 29.0 | 7.27 | 8.20 | 37.0 | 8.8 | 25.6 | <1.0 |
| 8/14/2012 | 1.030 | 1.68 | 21.4 | 5.89 | 7.80 | 39.0 | 7.7 | 18.0 | 18.0 |

**Table F-2 (cont.):** Water Quality Monitoring Results from Samples Collected at Site W-M513.5R

| Date | Water Depth (m) | Velocity (cm/sec) | Water Temp (°C) | Dissolved Oxygen (mg/L) | pH (SU) | Secchi Disk Depth (cm) | Turbidity (NTU) | Total Suspended Solids (mg/L) | Chlorophyll a ($mg/m^3$) |
|---|---|---|---|---|---|---|---|---|---|
| 8/28/2012 | 1.150 | 2.06 | 25.7 | 3.05 | 7.70 | 58.0 | 6.9 | 12.2 | 1.6 |
| 9/11/2012 | 0.550 | 0.45 | 20.0 | 6.07 | 8.30 | 23.0 | 13.0 | 45.5 | 5.2 |
| 12/19/2012 | 1.120 | - | 3.0 | 11.43 | 8.16 | 58.0 | 8.0 | - | - |
| 2/7/2013 | 1.017 | 0.48 | 0.3 | 19.43 | 8.69 | ** | 4.2 | - | - |
| 3/13/2013 | 2.350 | 4.82 | -0.1 | 12.40 | 6.95 | ** | 55.2 | - | - |
| 6/4/2013 | 3.740 | 51.75 | 19.3 | 6.28 | 7.60 | 30.0 | 12.3 | 23.2 | 1.3 |
| 6/18/2013 | 2.910 | 25.92 | 23.1 | 5.57 | 7.71 | 24.0 | 13.8 | 39.5 | 1.3 |
| 7/2/2013 | 3.930 | 53.01 | 23.1 | 5.80 | 7.71 | 28.0 | 14.6 | 32.3 | <1.0 |
| 7/16/2013 | 2.670 | 26.04 | 27.2 | 6.21 | 7.16 | 32.0 | 8.7 | 22.0 | 2.0 |
| 7/30/2013 | 1.210 | 7.10 | 22.6 | 8.15 | 8.22 | 33.0 | 11.7 | 42.5 | 2.8 |
| 8/13/2013 | 1.220 | 1.34 | 23.5 | 10.11 | 9.02 | 26.0 | 18.6 | 30.8 | 11.7 |
| 8/27/2013 | 1.050 | 0.26 | 27.7 | 4.72 | 8.40 | 38.0 | 11.4 | 26.2 | 4.4 |
| 9/10/2013 | 1.040 | 1.15 | 1.0 | 3.62 | 8.15 | 27.4 | 13.4 | 23.0 | 3.4 |
| 12/17/2013 | 1.030 | 1.21 | 0.3 | 13.73 | 7.37 | ** | 4.8 | - | - |
| 2/19/2014 | 0.900 | 0.53 | 0.2 | 10.82 | 7.50 | ** | 5.6 | - | - |
| 3/14/2014 | 1.250 | 4.56 | 0.5 | 10.81 | 7.46 | ** | 15.9 | - | - |
| 6/3/2014 | 2.800 | 24.30 | 23.4 | 6.57 | 7.59 | 31.0 | 38.0 | 51.2 | 1.9 |
| 6/18/2014 | 2.960 | 24.98 | 23.5 | 6.49 | 7.73 | 41.0 | 28.8 | 45.4 | <1.0 |
| 7/1/2014 | - | 70.36 | 24.3 | 6.03 | 7.77 | 31.5 | 31.1 | 37.7 | <1.0 |
| 7/15/2014 | 3.530 | 47.11 | 22.9 | 6.76 | 7.97 | 54.0 | 22.3 | 28.8 | <1.0 |
| 7/29/2014 | 1.650 | 13.51 | 22.3 | 7.60 | 8.16 | 58.5 | 13.4 | 19.4 | 2.8 |
| 8/12/2014 | 1.200 | 2.52 | 23.5 | 7.30 | 8.33 | 55.0 | 16.1 | 21.5 | 2.1 |
| 8/26/2014 | 1.410 | 6.89 | 25.9 | 5.02 | 8.12 | 58.0 | 13.7 | 15.2 | 1.3 |
| 9/9/2014 | 1.710 | 14.44 | 24.4 | 8.71 | 8.47 | 31.0 | 18.7 | 16.7 | 2.9 |
| 12/19/2014 | 1.350 | 4.60 | 0.2 | 16.41 | 8.39 | - | 5.3 | - | - |
| 2/3/2015 | 1.270 | 2.93 | 0.1 | 13.28 | 7.62 | - | 3.8 | - | - |
| 3/10/2015 | 1.000 | 0.23 | 0.8 | 16.91 | 7.63 | - | 4.5 | - | - |
| 6/2/2015 | 2.250 | 16.89 | 19.9 | 5.91 | 7.68 | 36.0 | 25.4 | 35.5 | <1.0 |
| 6/16/2015 | 2.560 | - | 22.7 | 4.98 | 7.64 | 35.0 | 32.5 | 23.7 | <1.0 |
| 6/30/2015 | 1.600 | - | 23.6 | 5.54 | 7.75 | 36.0 | 30.8 | 35.7 | <1.0 |
| 7/14/2015 | 1.490 | - | 25.6 | 6.44 | 8.06 | 65.5 | 6.3 | 9.2 | <1.0 |
| 7/28/2015 | 1.590 | - | 26.2 | 5.45 | 7.89 | 55.0 | 17.9 | 10.6 | <1.0 |
| 8/11/2015 | 1.430 | - | 25.1 | 8.02 | 8.48 | 63.5 | 8.4 | 10.8 | 3.8 |
| 8/25/2015 | 1.480 | - | 21.3 | 7.61 | 8.32 | 33.0 | 19.6 | 22.4 | 1.6 |
| 9/9/2015 | 1.430 | - | 24.4 | 5.02 | 8.08 | 45.0 | 14.3 | 15.0 | 1.8 |
| **MIN.** | **0.478** | **0.23** | **-0.1** | **3.05** | **6.95** | **15.0** | **3.8** | **9.0** | **1.3** |
| **MAX.** | **3.930** | **70.36** | **29.2** | **19.70** | **9.02** | **102.0** | **66.2** | **66.0** | **35.0** |
| **AVG.** | **1.675** | **12.49** | **17.4** | **8.52** | **-** | **39.0** | **19.6** | **31.2** | **9.4** |
| **MEDIAN** | **1.425** | **5.31** | **22.8** | **6.57** | **7.80** | **34.8** | **13.8** | **29.1** | **6.5** |

**FIGURE F-1. PRE-PROJECT DISSOLVED OXYGEN AND pH VALUES COLLECTED WITH A CONTINUOUS MONITOR AT SITE W-M513.4P FROM 8/13/13-8/27/13**

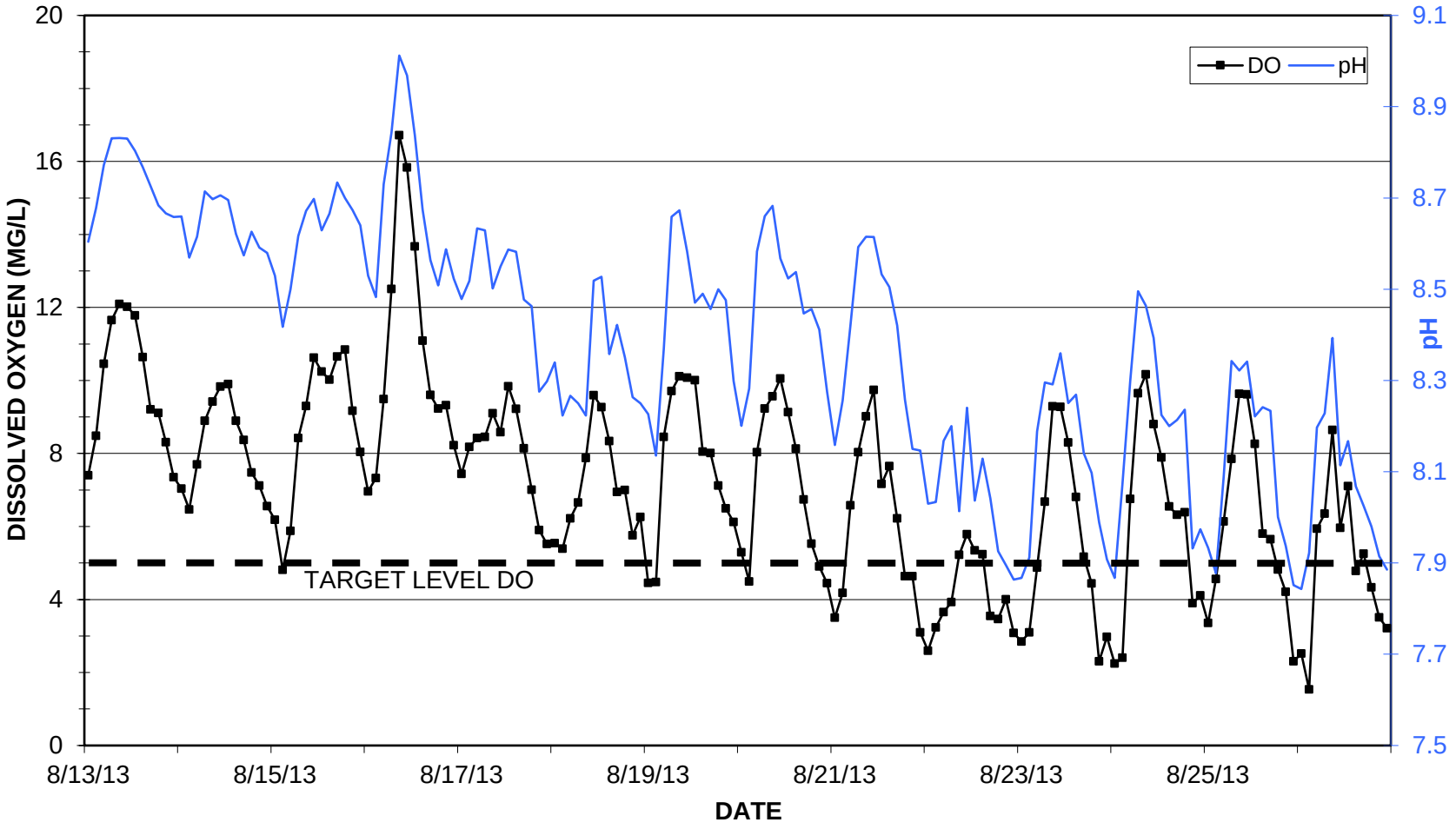

**FIGURE F-2. PRE-PROJECT DISSOLVED OXYGEN AND pH VALUES COLLECTED WITH A CONTINUOUS MONITOR AT SITE W-M513.4P FROM 7/15/10-8/3/10**

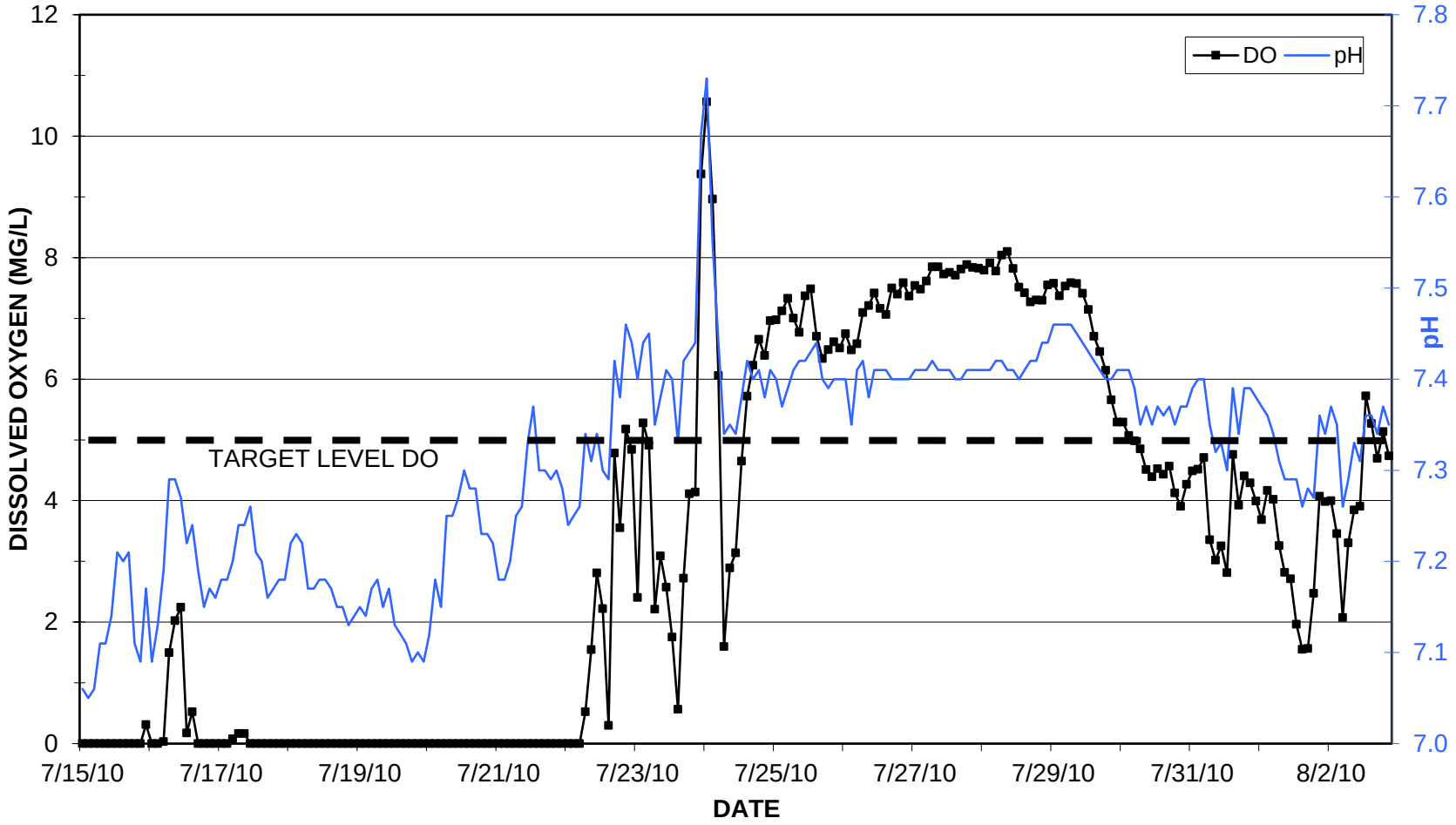

**FIGURE F-3. PRE-PROJECT DISSOLVED OXYGEN AND pH VALUES COLLECTED WITH A CONTINUOUS MONITOR AT SITE W-M513.4P FROM 7/29/14-8/12/14**

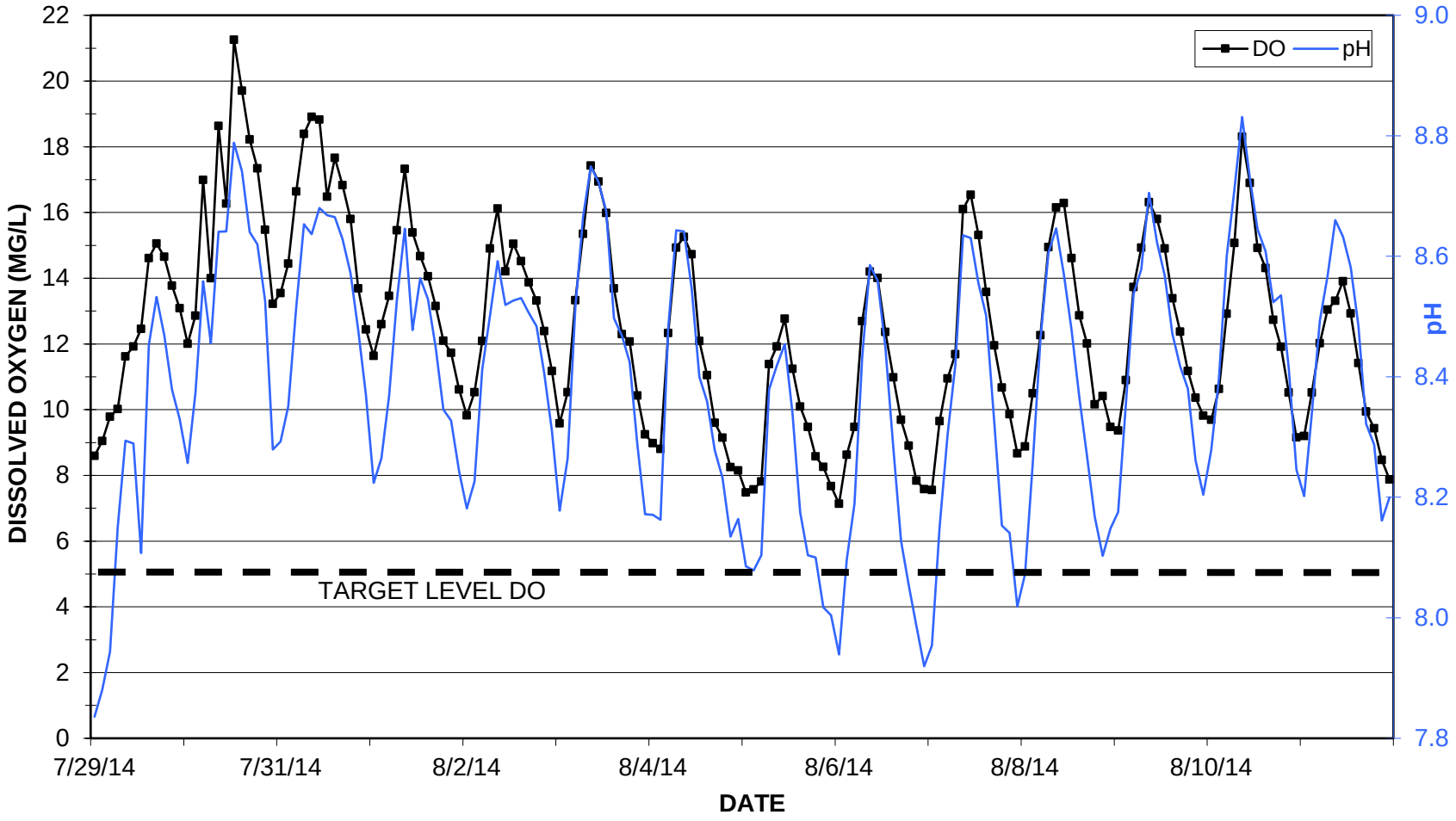

**FIGURE F-4. PRE-PROJECT DISSOLVED OXYGEN AND pH VALUES COLLECTED WITH A CONTINUOUS MONITOR AT SITE W-M513.4P FROM 12/17/13-2/19/14**

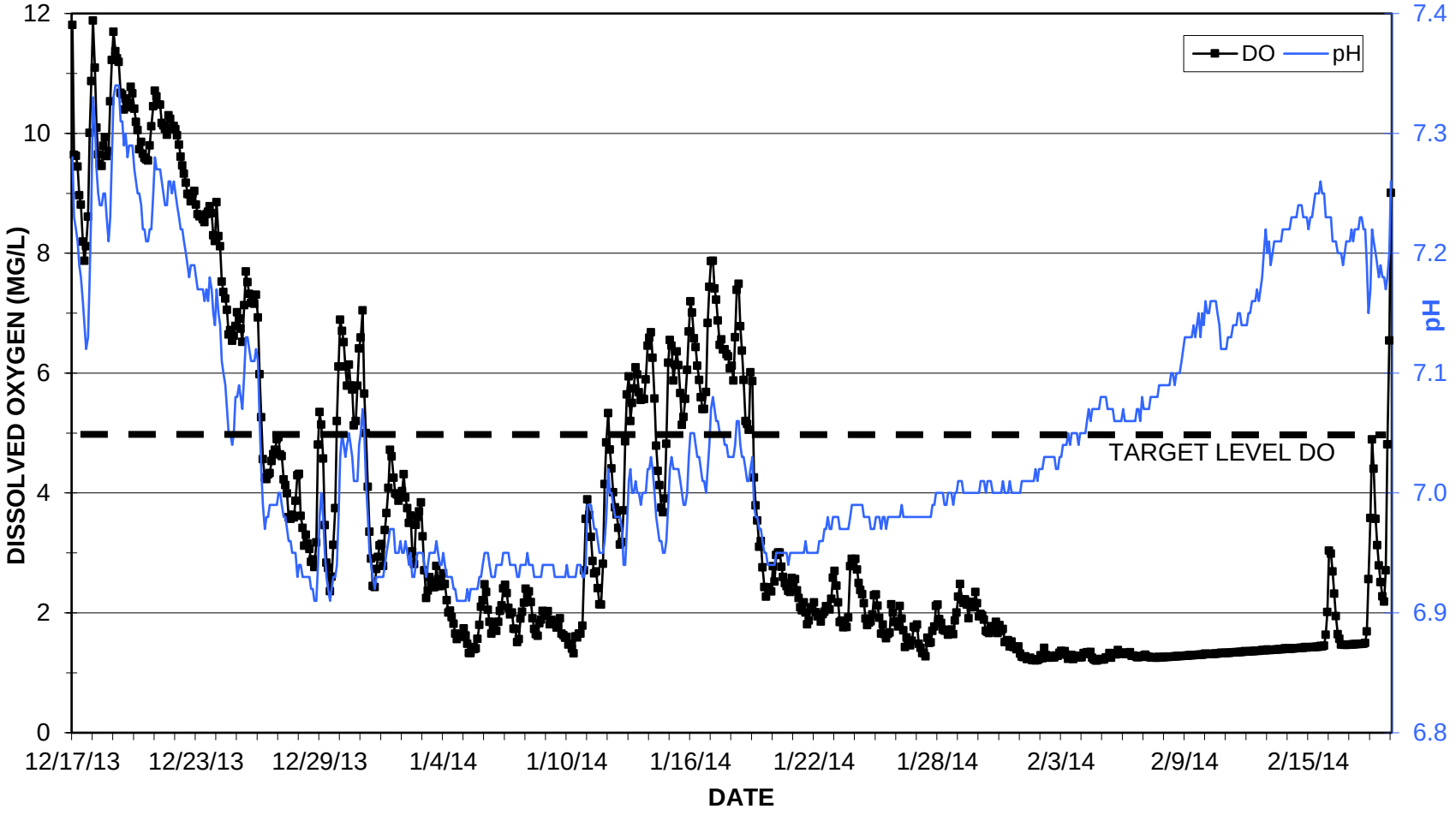

**FIGURE F-5. PRE-PROJECT DISSOLVED OXYGEN AND pH VALUES COLLECTED WITH A CONTINUOUS MONITOR AT SITE W-M513.4P FROM 12/19/12-3/13/13**

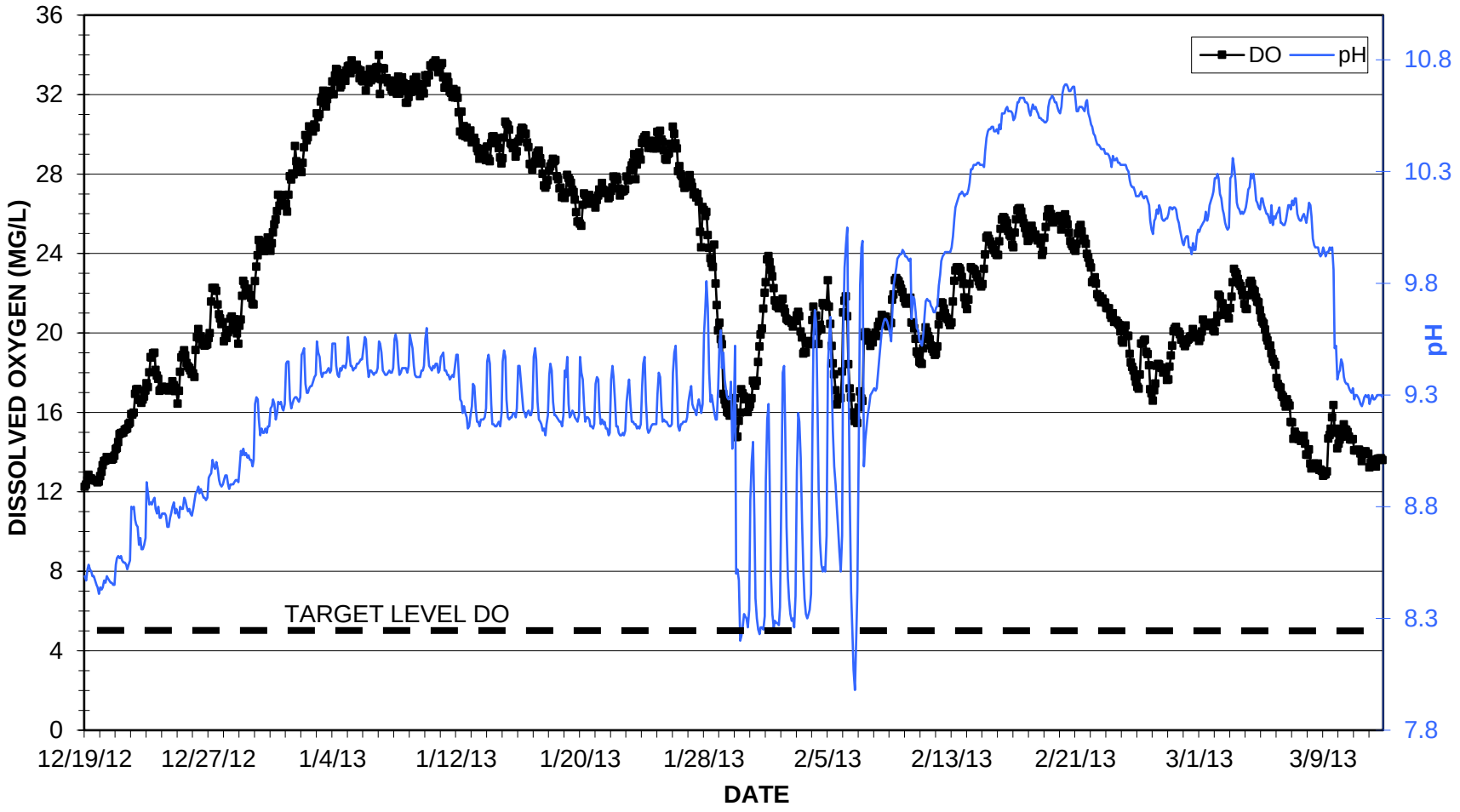

**FIGURE F-6. PRE-PROJECT DISSOLVED OXYGEN CONCENTRATIONS COLLECTED WITH A CONTINUOUS MONITOR AT SITES W-M513.4P AND W-M513.5R FROM 8/28/12-9/11/12**

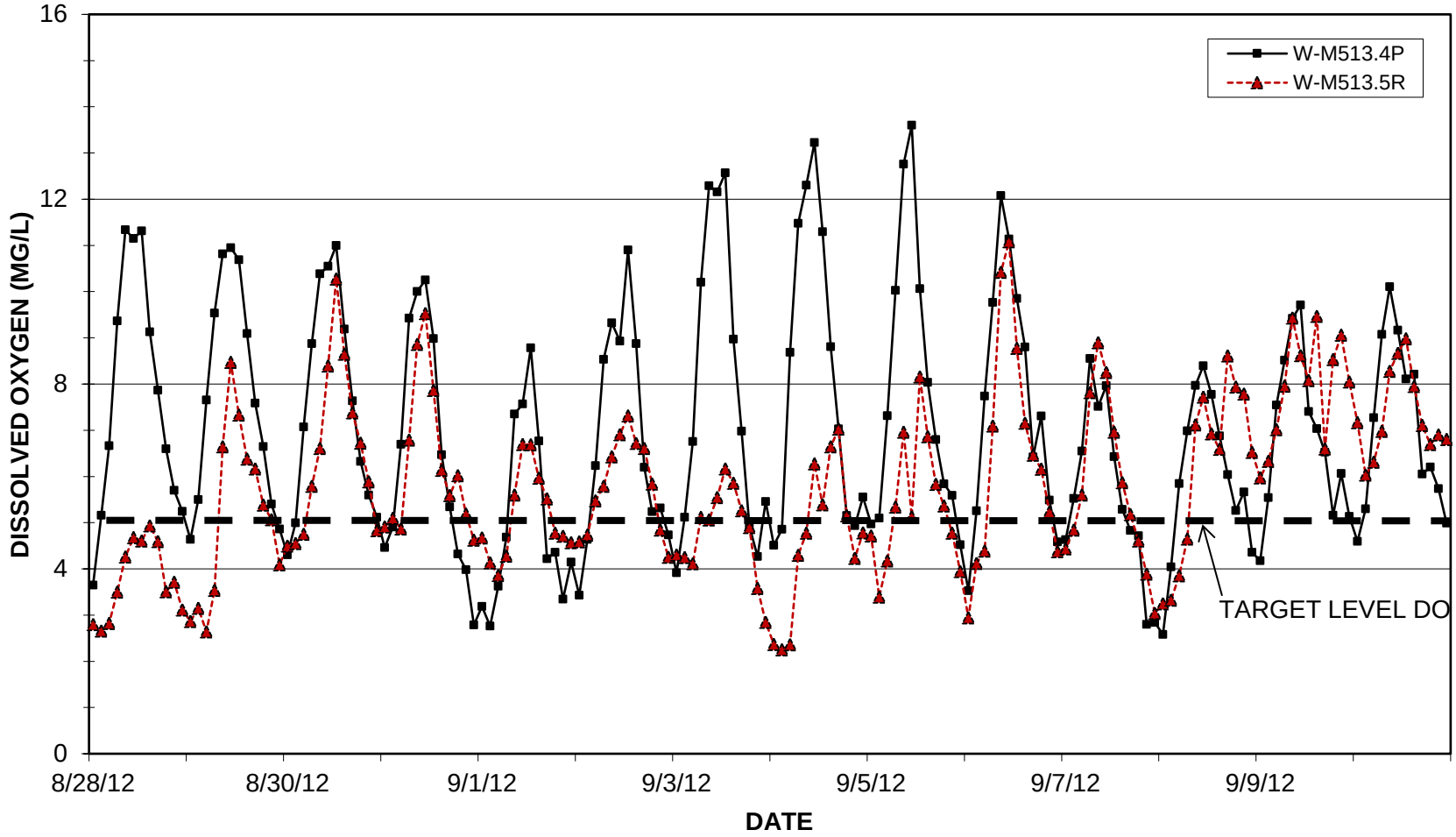

**FIGURE F-7. PRE-PROJECT DISSOLVED OXYGEN AND pH VALUES COLLECTED WITH A CONTINUOUS MONITOR AT SITE W-M513.5R FROM 6/5/12-7/17/12**

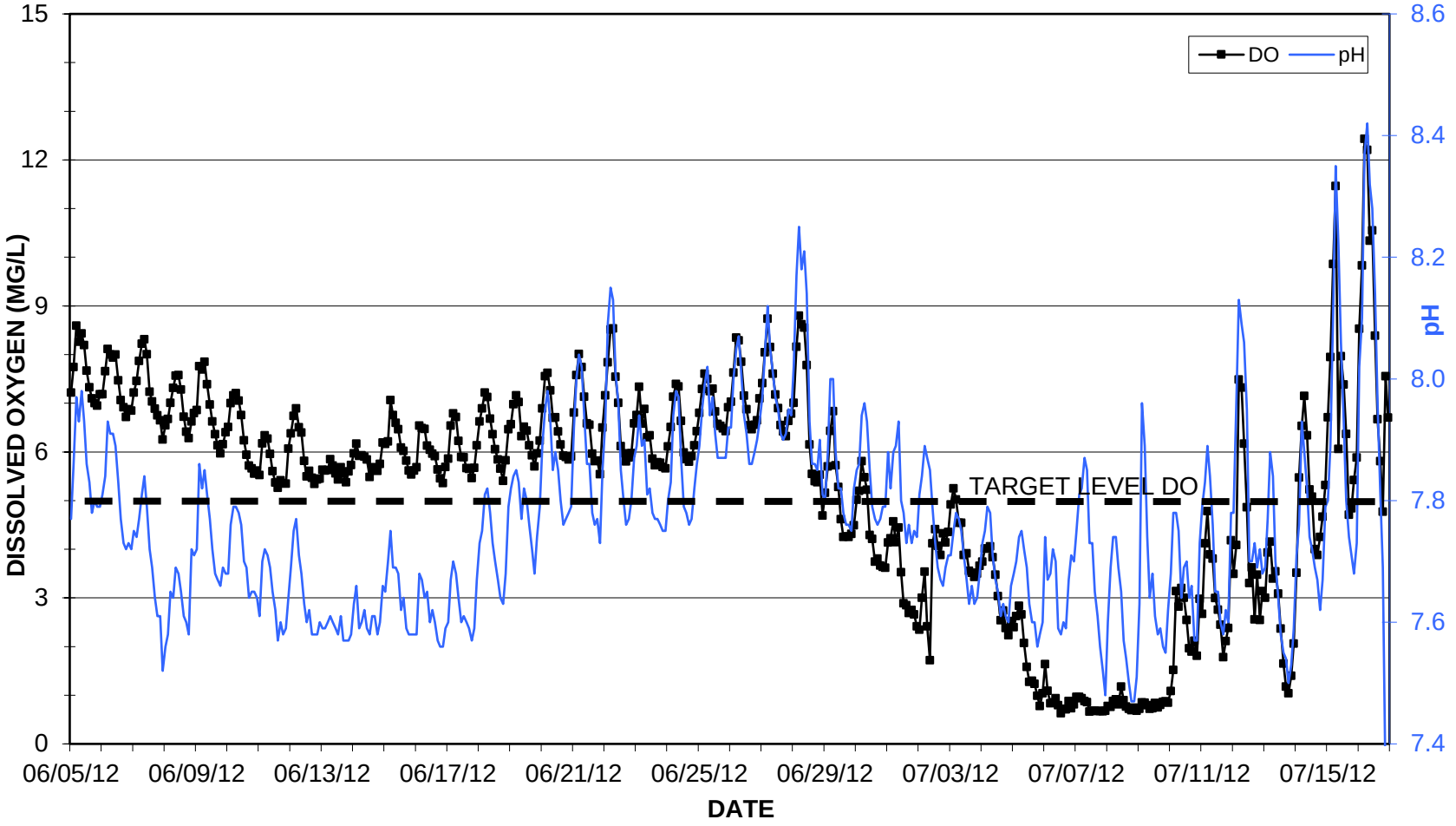

**FIGURE F-8. PRE-PROJECT DISSOLVED OXYGEN CONCENTRATIONS COLLECTED WITH A CONTINUOUS MONITOR AT SITE W-M513.5R FROM 8/26/14-9/9/14**

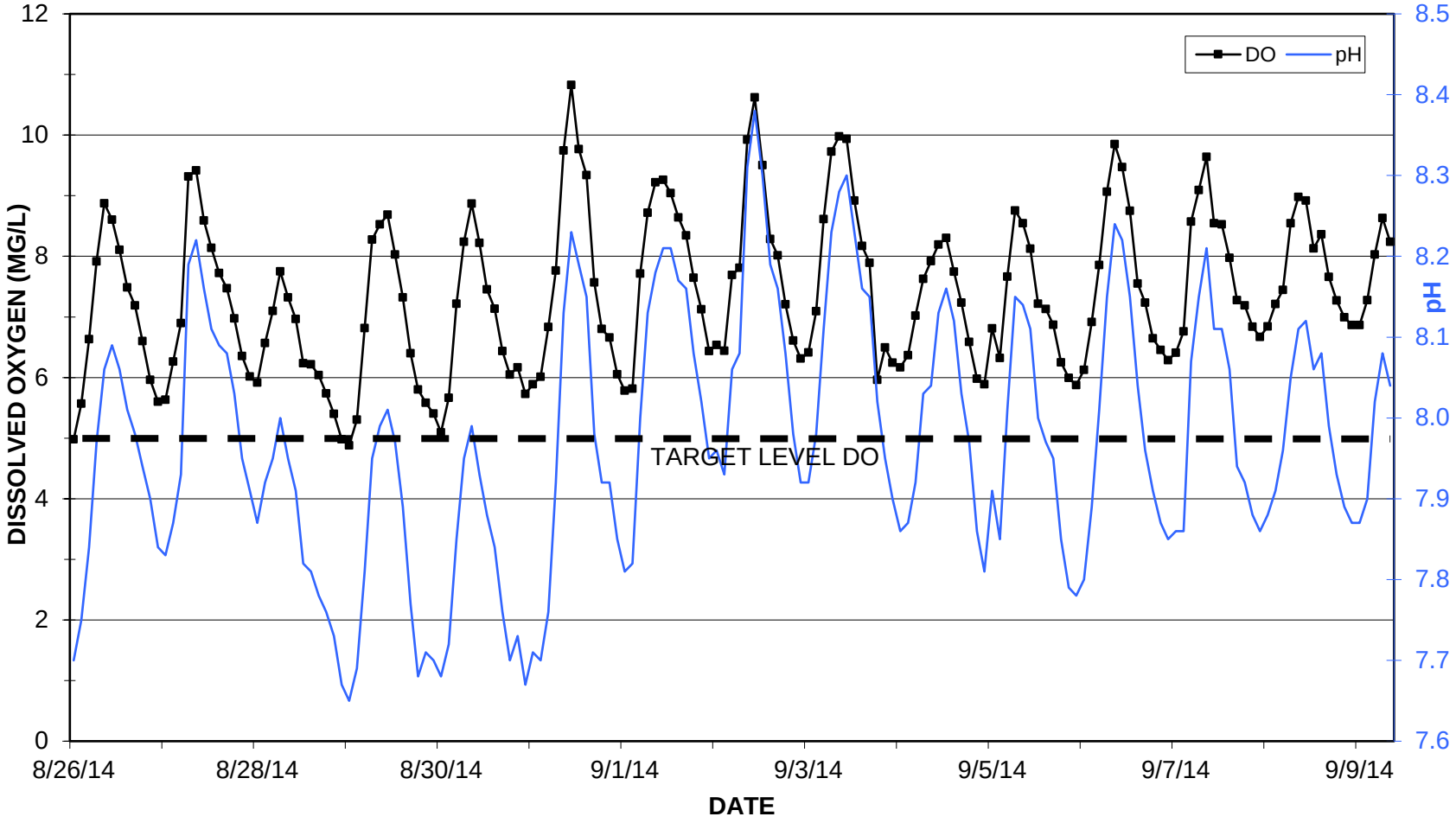

**FIGURE F-9. PRE-PROJECT DISSOLVED OXYGEN AND pH VALUES COLLECTED WITH A CONTINUOUS MONITOR AT SITE W-M513.5R FROM 2/19/14-3/14/14**

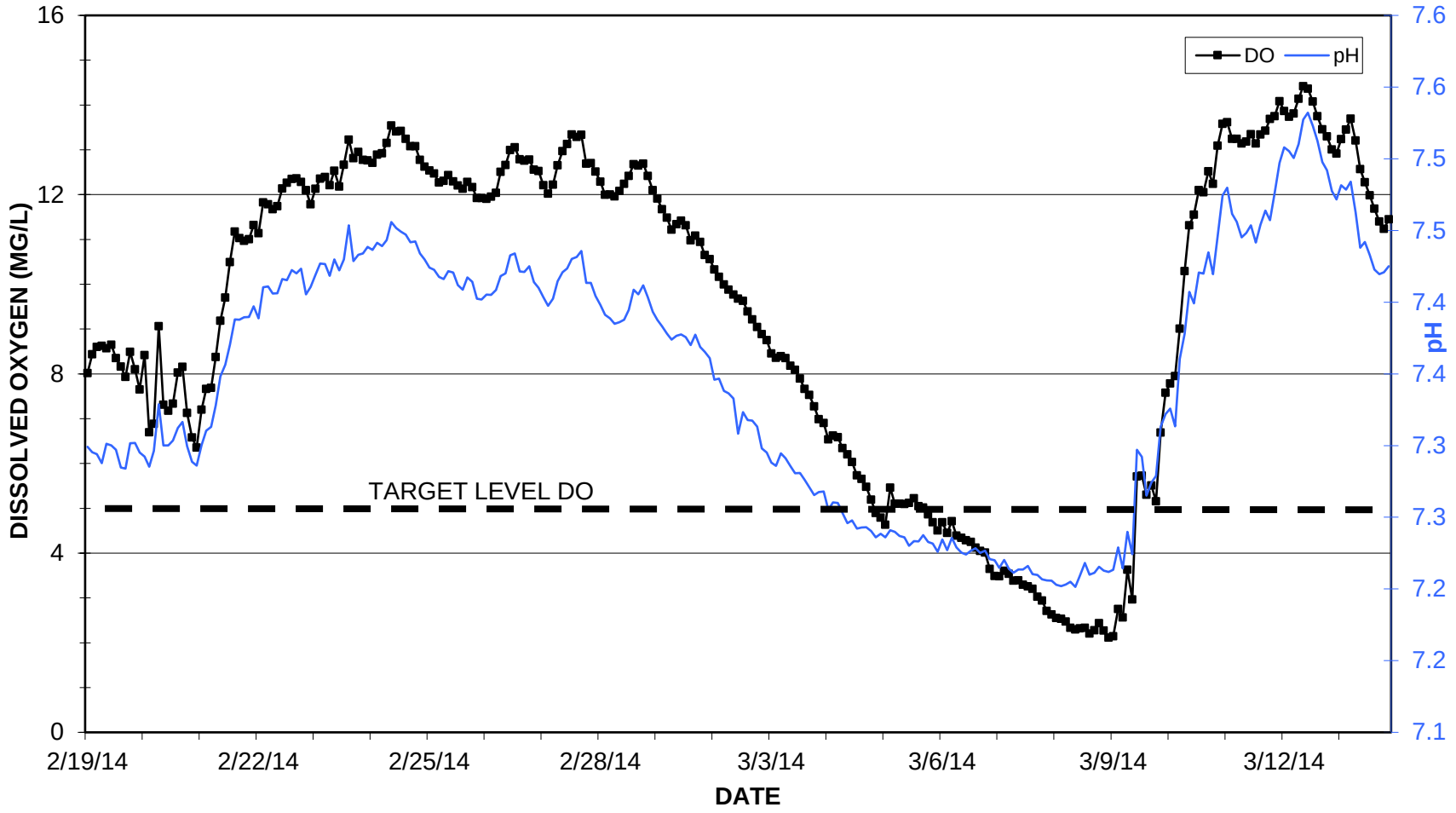

**FIGURE F-10. PRE-PROJECT DISSOLVED OXYGEN AND pH VALUES COLLECTED WITH A CONTINUOUS MONITOR AT SITE W-M513.5R FROM 12/13/11-3/8/12**