
# Vertical Profiler Water Quality Monitoring in the Tred Avon River

January 30, 2015

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

## Executive Summary

During June-October 2014, the National Oceanic and Atmospheric Administration (NOAA) deployed a vertical profiler to monitor water quality conditions in the Tred Avon River, an important oyster restoration area in the Chesapeake Bay. The vertical profiler measured salinity, water temperature, pH, dissolved oxygen, chlorophyll, and turbidity at one meter intervals throughout the water column. Profiles were conducted once every hour.

During the 2014 monitoring period, the Maryland Department of Natural Resources (DNR) provided field support for the Tred Avon vertical profiler, monitored profiler operation, downloaded data files, and reviewed the data for quality assurance. Throughout the monitoring period, occasional equipment malfunction and operational difficulties resulted in some loss of data records. However, by closely monitoring profiler operation, examining in detail all data files and error logs, and communicating with the equipment manufacturer, DNR staff were able to properly identify and resolve following issues:

- **Software issues.** Software incompatibility prevented DNR staff from being able to communicate with the profiler during field visits. As a result, swapping the monitoring sonde during field maintenance procedures interrupted profiler operation. Also, a software bug in the profiler setup program limited data collection to 600 profile records and 100 hourly records. Older data records were lost when the profiler continued collecting data after the storage capacity was reached.

- **Equipment malfunction**. On several occasions, erroneous depth readings significantly underestimated the depth of the water column and triggered the profiler to stop conducting profiles. Another time, a likely hardware malfunction caused the profiler to collect multiple records in rapid succession at a single depth. Following each instance of equipment malfunction, the profiler had to be restarted remotely in order for data collection to continue.

- **Biofouling.** Extreme biofouling of the monitoring equipment occurred in the Tred Avon River. Biofouling contributed to a number of water quality data values being censored during the data QA process.

Vertical profiler data consisted of two types: the readings collected during profile sequences (profile data); and the readings collected when the monitoring sonde was parked in a fixed position awaiting the next profile sequence (hourly data). Salinity, pH, water temperature, chlorophyll, turbidity, and dissolved oxygen data from the vertical profiler show that water quality conditions in the Tred Avon River during 2014 were seasonally variable and generally suitable for oyster growth and survival.

# Vertical Profiler Water Quality Monitoring in the Tred Avon River

## Introduction

During June-October 2014, the National Oceanic and Atmospheric Administration (NOAA) deployed a vertical profiler to monitor water quality conditions in the Tred Avon River. The Tred Avon is a tributary of the Choptank River and part of the Choptank Complex that is targeted for oyster restoration activities. Water quality information from the profiler may be used to assess habitat suitability for oyster growth and survival.

In partnership with NOAA, the Maryland Department of Natural Resources (DNR) provided equipment maintenance and data management support for the Tred Avon vertical profiler. DNR currently operates a similar vertical profiler in nearby Harris Creek, and therefore has prior experience with the maintenance of this type of monitoring equipment.

The vertical profiler system deployed in the Tred Avon River consists of a water quality monitoring sonde (YSI Inc., Model 6600 V2) attached by a cable to a CR1000 datalogger (Campbell Scientific, Inc.). The CR1000 is mounted on a floating platform along with a winch mechanism that raises and lowers the sonde in the water column. The Tred Avon profiler is set up to conduct a profile every hour, with readings taken at 1 meter intervals throughout the entire water column. Profile sequences commence at the top of the hour and take approximately 5 to 8 minutes to complete.

The monitoring sonde measures the following water quality parameters: salinity, temperature, pH, dissolved oxygen, turbidity, and chlorophyll. Readings are stored in electronic files on the CR1000. In addition to water quality data, the vertical profiler can also store data files pertinent to instrument operation. Data are retrieved from the CR1000 either by connecting to the unit with a laptop computer, or by communicating remotely via telemetry connection.

## Field Support

After initial deployment by NOAA, DNR conducted regular field visits to the monitoring site to service the Tred Avon vertical profiler. Field visits were generally scheduled at two week intervals during the monitoring period. Routine maintenance tasks primarily included cleaning and recalibration of the monitoring sonde to ensure data integrity. During each field visit, a clean and freshly calibrated sonde was brought out to the site and swapped with the sonde that was already deployed at the profiler. The sonde that was removed was then returned to the DNR field office for cleaning and post-calibration. Post-calibration procedures are necessary to identify any drift in the measurements made by the sonde during deployment.

DNR staff visited the Tred Avon site a total of seven times during the 2014 monitoring season. Dates when field visits were conducted are listed in Table 1.

Table 1. Field visits to the Tred Avon vertical profiler by DNR personnel during the 2014 monitoring season.

| Date | Activity |
|---|---|
| June 30, 2014 | Swap sonde; troubleshoot (equipment not performing profiles) |
| July 28, 2014 | Swap sonde |
| August 11, 2014 | Swap sonde |
| August 26, 2014 | Swap sonde |
| September 9, 2014 | Swap sonde |
| September 30, 2014 | Swap sonde |
| October 16, 2014 | Swap sonde |

Profile data collection began on June 30, 2014. Although NOAA had deployed the instrument prior to that date, no profiles were being collected due to equipment malfunction. DNR and NOAA visited the site on June 30 and were able to initiate profiles by connecting to the CR1000 with a laptop computer and verifying that all system switches were properly set. The monitoring season concluded on November 3, 2014, when DNR (at NOAA's request) remotely triggered the profiler to stop performing profiles. NOAA retrieved the vertical profiling equipment from the Tred Avon River on November 5, 2014 and forwarded the sonde to the DNR field office for final post-calibration and cleaning.

## Data Management

### Data Acquisition

In addition to field support and equipment maintenance, DNR also assumed data management responsibilities for the Tred Avon vertical profiler. DNR's data quality assurance (QA) procedures for the Tred Avon vertical profiler were modeled after the data management activities for the Harris Creek profiler and the DNR Shallow Water Monitoring Program. Rather than have the data files collected by NOAA and then transferred to DNR for data QA, NOAA tasked DNR with acquiring the data directly from the profiler. Using the IP address of the profiler, DNR staff were able to connect to the profiler using the YSI Loggernet software. Using Loggernet for remote communication with the CR1000 allowed not only for data collection, but also for troubleshooting issues with profiler operation.

Initial data records for the period June 30- July 7 were downloaded by NOAA and forwarded to DNR, after which DNR performed direct data downloads. Initially, DNR staff were unable to download data due to software incompatibility between Loggernet and the CR1000 data logger. After obtaining a more recent version of Loggernet, the first data download by DNR was performed on August 6, 2014. At that time, it was discovered that the profiler was not actively collecting profile records; the last record was on July 7, 2014. Examination of the vertical profiler event log file revealed that an erroneous depth reading had prompted the profiler to automatically switch into "standby" mode and stop performing profiles. DNR was able to restart the profiler through remote communication with the CR1000, however problems with profiler operation persisted throughout much of August. By monitoring profiler operation, routine

examination of data records, and communication with YSI personnel, a number of issues were identified (detailed below). Gaps in the data record are summarized in Table 2 and discussed in the paragraphs that follow.

Table 2. Time intervals missing profile data records during the 2014 monitoring season**.**

| Date of missing records | | Time interval | | | Possible cause |
|---|---|---|---|---|---|
| From | To | Days | Hours | Minutes | |
| 6/30/14 19:05 | 7/1/14 15:02 | 0 | 19 | 57 | Data storage limitation |
| 7/7/14 12:05 | 8/6/14 13:35 | 30 | 1 | 29 | Depth reading error; Software incompatibility |
| 8/11/14 17:06 | 8/13/14 17:38 | 2 | 0 | 32 | Sonde swap |
| 8/20/14 22:05 | 8/22/14 19:01 | 1 | 20 | 56 | Depth reading error |
| 8/26/14 13:07 | 8/26/14 18:01 | 0 | 4 | 54 | Sonde swap |
| 8/26/14 20:07 | 8/26/14 22:01 | 0 | 1 | 54 | Data storage limitation |
| 8/27/14 20:05 | 8/27/14 22:03 | 0 | 1 | 57 | Data storage limitation |
| 9/4/14 21:05 | 9/8/14 20:01 | 3 | 22 | 56 | Data storage limitation |
| 9/9/14 16:06 | 9/9/14 20:01 | 0 | 3 | 55 | Sonde swap |
| 9/10/14 12:07 | 9/11/14 23:07 | 1 | 10 | 60 | Data storage limitation |
| 9/30/14 14:07 | 10/1/14 13:01 | 0 | 22 | 54 | Sonde swap |
| 10/16/14 12:07 | 10/16/14 14:01 | 0 | 1 | 54 | Sonde swap |
| 11/2/14 11:02 | 11/3/14 17:01 | 1 | 5 | 58 | Electronic and/or software malfunction |

*1) Erroneous depth readings*

The Tred Avon vertical profiler uses a depth sounder to take a depth reading prior to the start of each profile sequence. This reading determines the maximum depth to which the sonde will be lowered during a profile sequence. The water depth at the monitoring site is approximately 5m and varies depending on tidal stage. If the initial depth reading was greater than 5m, then a profile would be conducted at one meter intervals to a final reading at 5m. If the water depth was less than 5m, the profile sequence concluded with a final reading at 4m depth.

Occasionally, the depth sounder recorded an erroneous initial depth of less than 1m. Since a profile sequence begins with a reading at 1 meter depth, internal checks by the system concluded that there was not enough water to even initiate a profile sequence. This triggered the profiler to automatically switch into "standby" mode and stop conducting profiles.

Examination of the event log files for the vertical profiler showed that this error occurred at least twice during the 2014 monitoring period. The error message "Start depth is greater than end depth" appeared in the Event Log file on July 7, 2014 and again on August 8, 2014. In both instances, DNR personnel were able to restart profiling sequences through remote communication with the CR1000.

*2) Limited data storage capacity*

DNR monitored profiler operation daily by logging in to the system daily and confirming that profiles were being conducted. In spite of error-free operation for a period of time, the data file had gaps of missing records. Through close examination of the data file and subsequent data downloads, DNR staff discovered that the data storage in the CR1000 was limited to just 600 profile records. Hourly readings recorded by the profiler and stored in a separate data file were limited to just 100 records. Once the maximum number of records was reached, the profiler would overwrite the oldest stored data with the newest data records thereby causing the observed data gaps.

Through communication with YSI technical support, it was determined that NOAA used an older version of the YSI setup program to initialize the CR1000 datalogger. This program contained a bug that limited the data file to just 600 stored profile records and 100 stored hourly records. YSI fixed the software bug by uploading an updated version of the setup program to the Tred Avon vertical profiler. The new version of the program was loaded to the CR1000 on Sept. 26, 2014. At that time, DNR also scheduled automatic data downloads to a DNR server daily at 12:00pm. The scheduled download file serves as a "back-up" to the manual data downloads and helps to minimize the risk of losing data records. YSI cautioned that any future changes to the profiler setup program should be made in such a way as to preserve the corrections made to expand data storage capacity.

*3) Field procedures*

In order to maintain data integrity, the monitoring sonde must be routinely serviced. Usually this is accomplished by swapping a sonde that is currently deployed in the field with a freshly cleaned and calibrated instrument. The old sonde is returned to the office for post-calibration procedures and cleaning. To perform this sonde swap in Harris Creek, DNR field staff typically connect to the profiler with a laptop computer, switch the vertical profiler to "standby" mode, swap sondes, and then restart the profiler. However, DNR field staff are currently unable to connect to the NOAA profiler on site. Because of this issue, swapping sondes in the field causes the NOAA profiler to automatically switch into standby mode and stop conducting profiles. The profiler must then be restarted through remote communication with the CR1000. Due to the lag time between swapping sondes in the field and restarting the profiler remotely from the office, some loss of data records occurred following field visits. Originally, this lag was on the order of a few days, but once the problem was discovered, the data gap was reduced to a few hours.

One notable observation from field visits and retrieval of the sondes is that biofouling of the equipment is a major issue at the Tred Avon site. Post calibration notes describing the condition of the sonde include remarks such as "heavy fouling" and "completely covered in hairy growth". Data QA revealed that the water quality parameters most influenced by the biofouling were salinity (the salinity sensor does not have a wiper to clear growth) and turbidity (growth was detected and translated into high turbidity readings). Fouling also may have contributed to the erroneous depth readings noted previously.

*4) Instrument malfunction*

Under normal operation, the Tred Avon vertical profiler was set to collect 4-5 readings each hour during a single profile sequence. Late in the monitoring season, an instrument malfunction occurred causing the vertical profiler to continuously collect a reading at the same depth every 9 seconds. The time stamp on the data records showed that during this time the profiler was not incrementing the internal time clock. YSI technical support was unable to determine the exact reason for this malfunction, but suggested that a hardware glitch with the CR1000 datalogger may have been to blame. The data records that were collected during this malfunction were not included in the final data set.

Data Quality Assurance Procedures

Water quality data collected by the vertical profiler are of two types: profile readings and hourly readings. Profiles were conducted beginning at the top of each hour. During a profile sequence, the profiler took readings at one meter intervals as the sonde was lowered through the water column. A complete profile took less than 10 minutes to complete. Data collected during a profile sequence were stored as profile readings. After conducting a profile, the sonde returned to a depth of 1.0m and remained there until the next profile sequence. The profiler took an additional reading four minutes before the start of each hour as the sonde was resting in a parked position. Data collected while the sonde was parked were stored as hourly readings.

DNR staff analyzed the data using the same Excel macro used to QA similar data collected from the Harris Creek profiler. The macro was run to detect any extreme parameter values for closer examination. Post-calibration results, field notes, and plots of the data were reviewed to judge data validity. Data values determined to be of questionable quality were assigned an error code; no data were deleted. The file was saved as a "Q-file" which contains parameter values, error codes, and a comment field for additional remarks.

## Water Quality Monitoring Results

Profile Readings

As data files were downloaded from the profiler (and prior to data QA), the profile data were posted to the DNR "Eyes on the Bay" website (http://mddnr.chesapeakebay.net/eyesonthebay/noaaprofiler.cfm). Posted files included a data file for download and a graphic displaying the vertical profiler data results. The graphic was a contour plot that interpolated the data through the water column over time. An example of the data plot is shown in Figure 1. Plots were created for each week of data and archived on the web page.

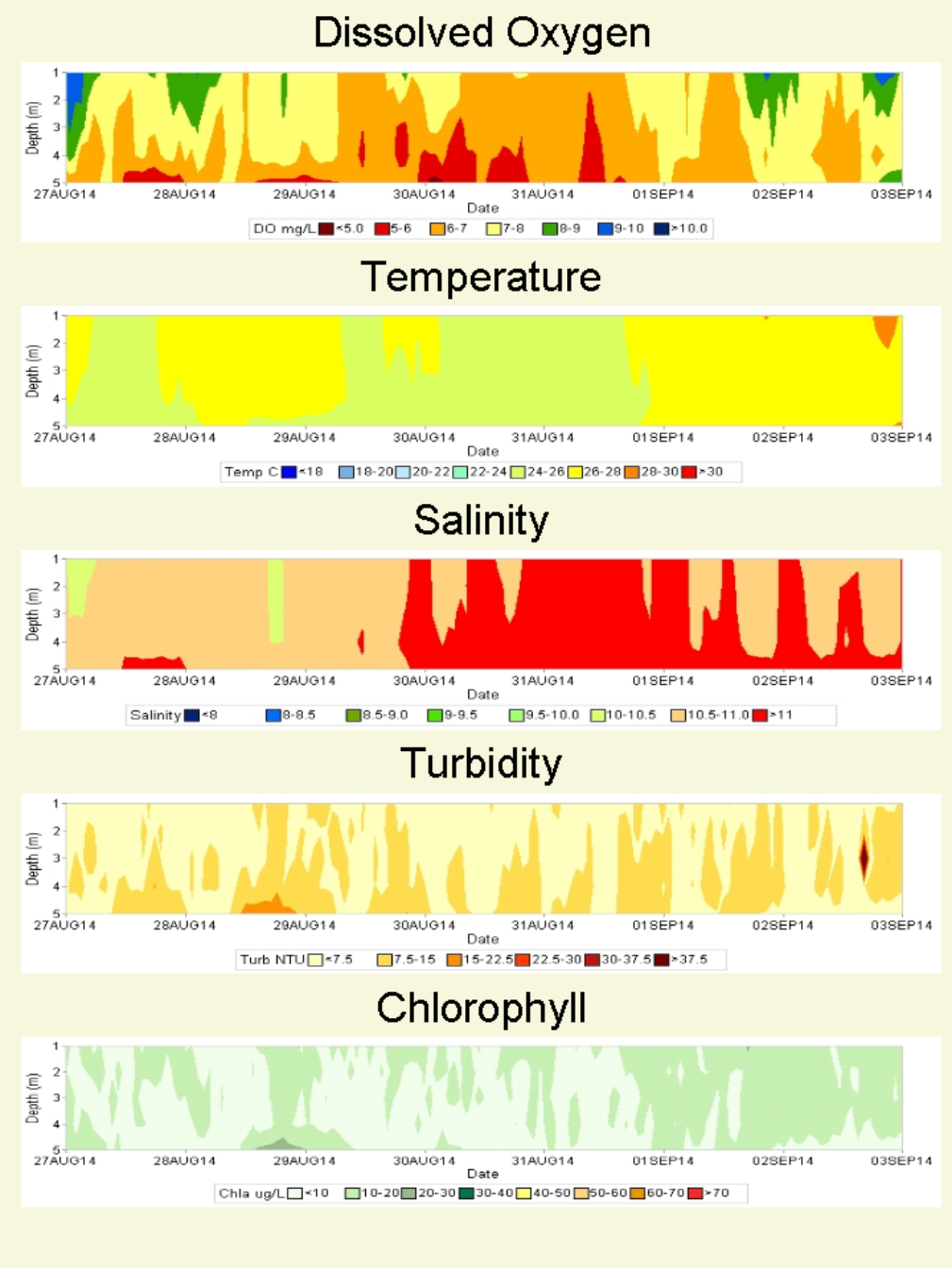


Figure 1. Tred Avon water quality data for the period August 27, 2014 to September 3, 2014.

One characteristic of the data that is evident in Figure 1 is the diel variation in dissolved oxygen. Oxygen levels peak during sunlight hours due to the active process of photosynthesis, and decrease during the nighttime hours due to respiration. This cycle is most evident near the surface of the water, where photosynthetic activity is more pronounced. Other data patterns are observed in the salinity and turbidity plots. The tidal cycle is illustrated in the salinity plots which show an intrusion of saline water during a flood stage and reduced salinities during an ebb

stage. Turbidity levels are most often observed at higher levels near the bottom of the water column.

Another data display is shown in Figure 2 through Figure 7. These plots show data values over time with the data at each depth represented by a different line. The data represented in Figures 2-6 have undergone QA procedures. Breaks in the line are due to gaps in the data record, either as a result of missing data collection or censoring the data through the QA process. Unlike the contour plots which show only one week of data, these plots show the entire data record from June through October. Thus, seasonal changes are evident. For example, obvious seasonal changes in temperature and salinity are apparent (Figures 2-3). Also, dissolved oxygen shows greater diel variability during the summer months (Figure 4). Although some of the lowest dissolved oxygen values were observed during the summer, only rarely did dissolved oxygen drop below 5 mg/l at the Tred Avon site.

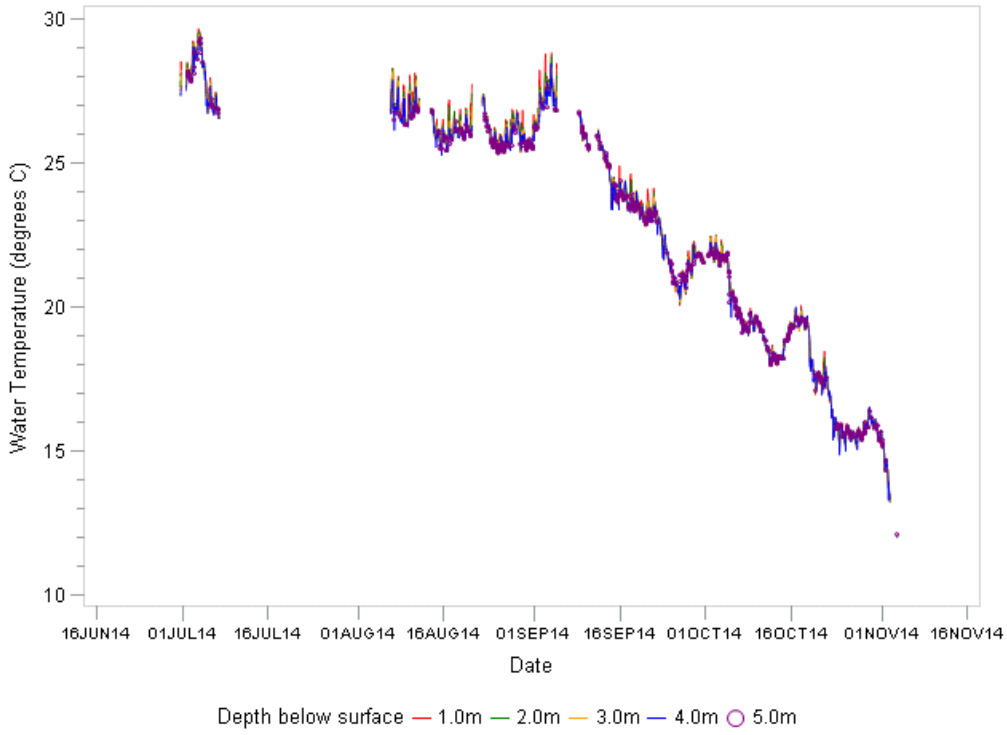


Figure 2. Water temperature in the Tred Avon River during 2014.

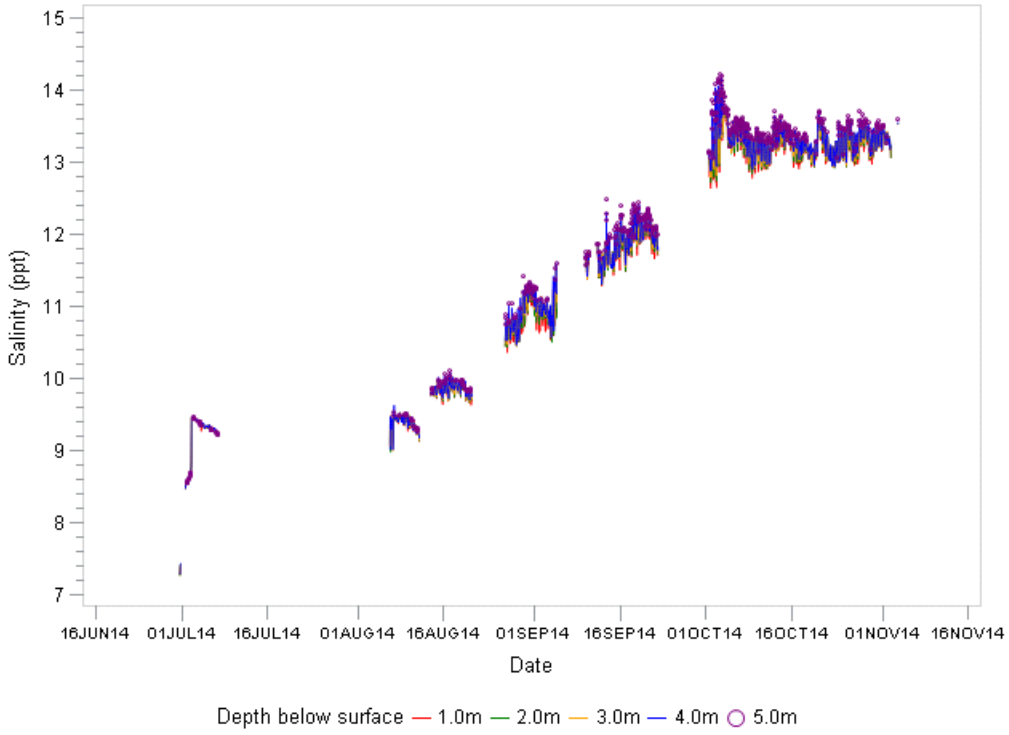


Figure 3. Salinity in the Tred Avon River during 2014.

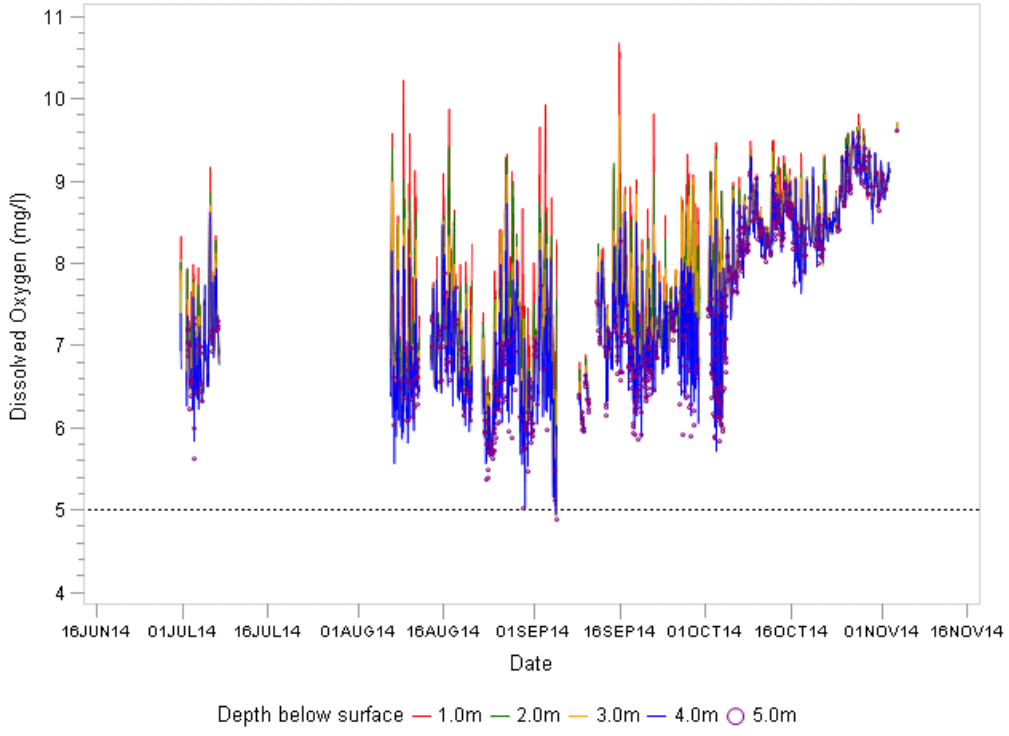


Figure 4. Dissolved oxygen in the Tred Avon River during 2014.

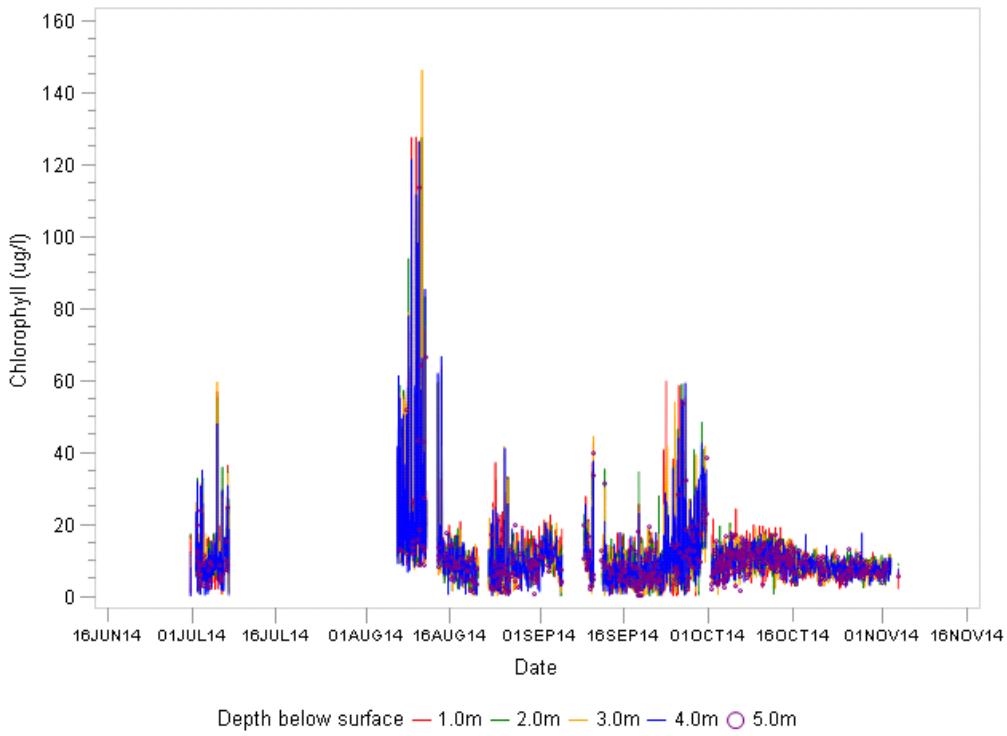


Figure 5. Chlorophyll in the Tred Avon River during 2014.

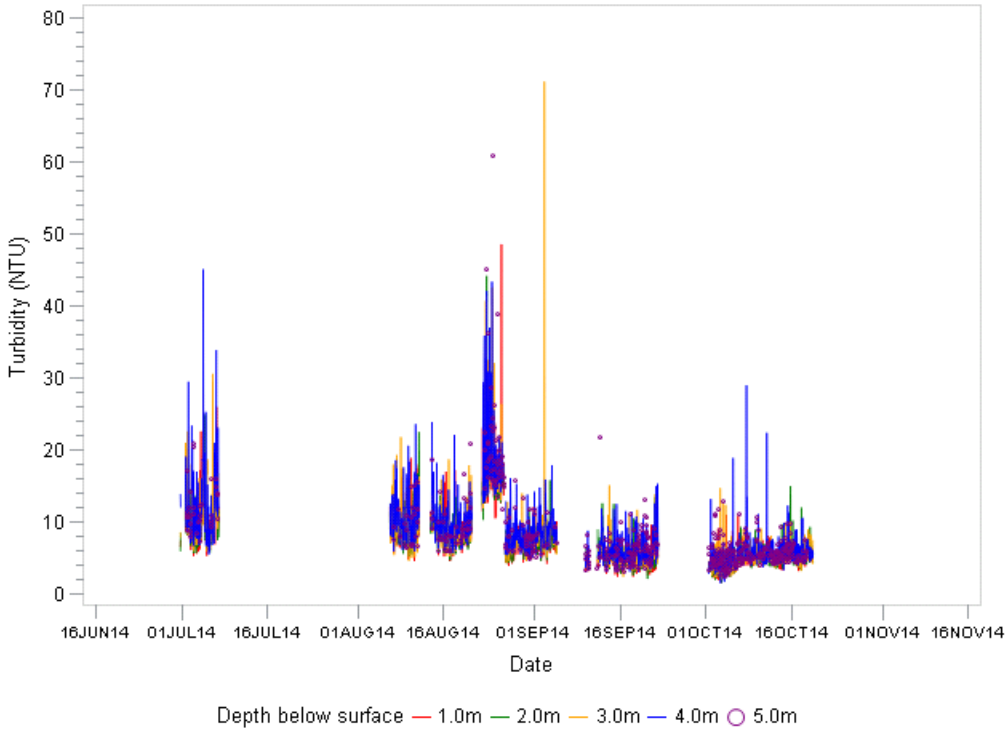


Figure 6. Turbidity in the Tred Avon River during 2014.

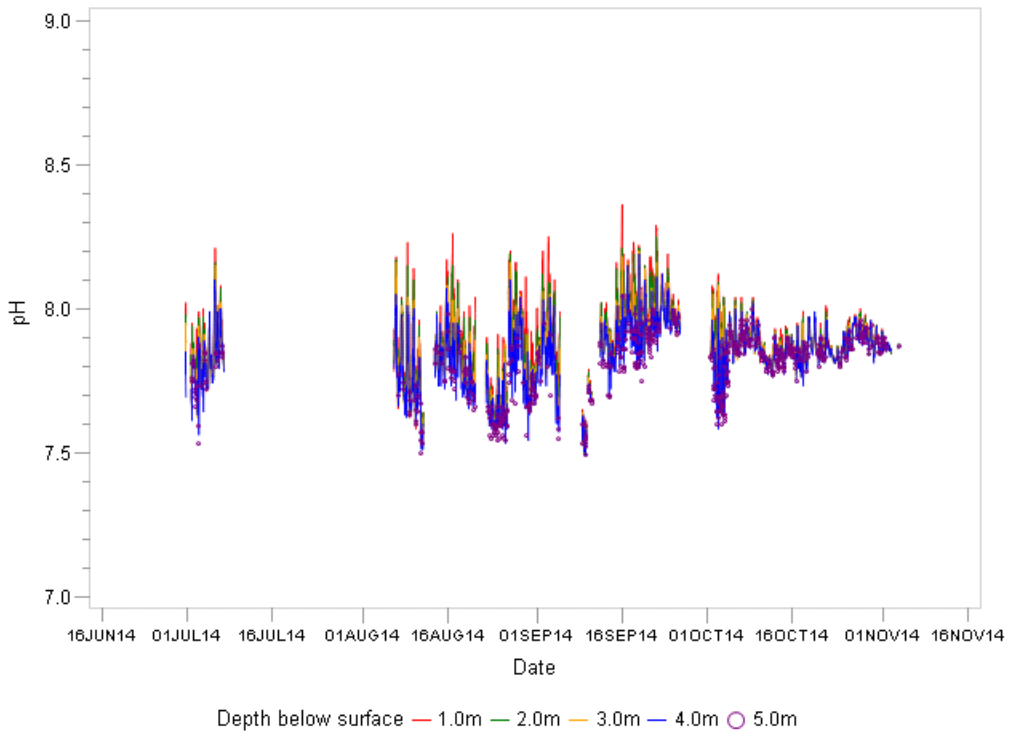


Figure 7. pH in the Tred Avon River during 2014.

Hourly Readings

The results of the hourly readings are presented in Figures 8-13. These readings were collected once per hour as the sonde was in a parked position, generally at a depth of 1m. When errors caused the vertical profiler to switch to "standby" mode and stop performing profiles, the instrument usually continued to collect hourly readings. Thus, the data record for the hourly readings is slightly more complete than the record for profile readings. As can be seen in the plots, the hourly readings in the Tred Avon River occasionally were measured at depths other than 1m, most notably at 4m. This occurred if the profiler switched to "standby" mode during a step in the profile sequence and before the full profile was completed. In such an instance, the sonde did not receive a signal to return and park at 1m depth, but instead remained at the depth where the error (and the last profile reading) occurred. As a result, the hourly readings were recorded at that same depth until the instrument was restarted and normal operation resumed.

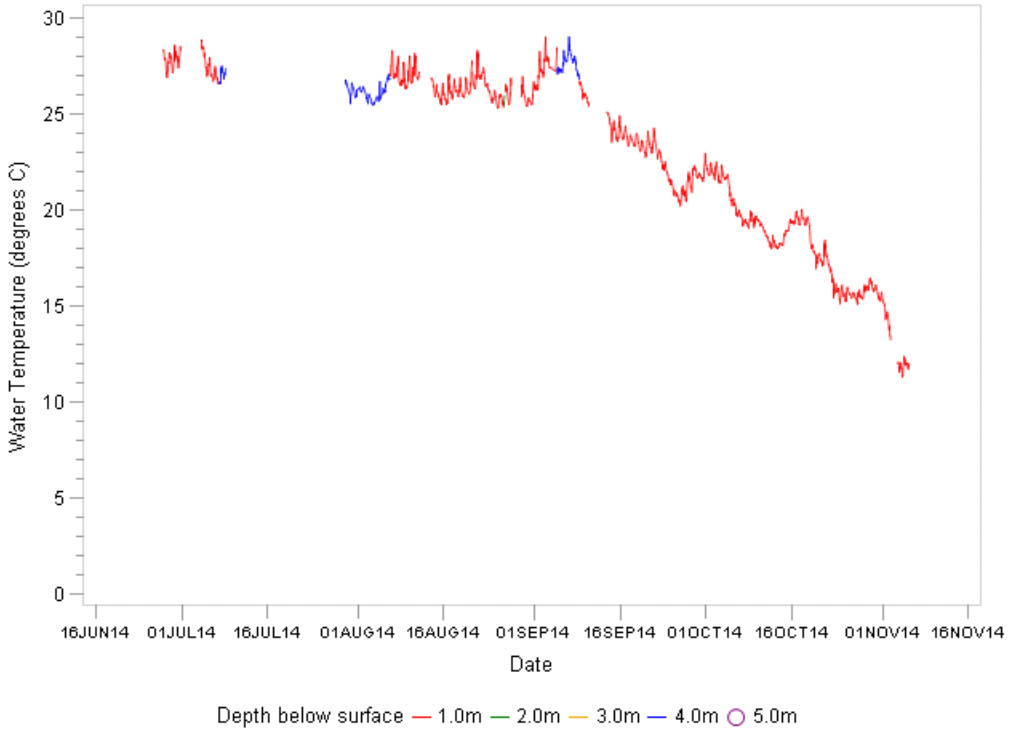


Figure 8. Hourly readings for water temperature in the Tred Avon River during 2014.

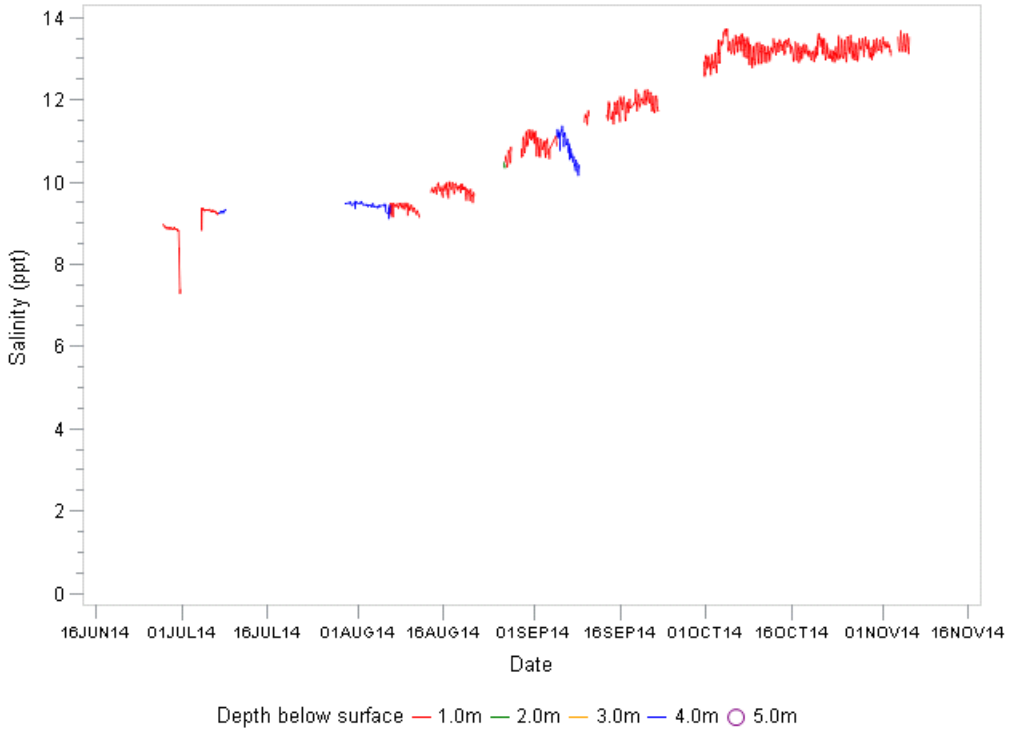


Figure 9. Hourly readings for salinity in the Tred Avon River during 2014.

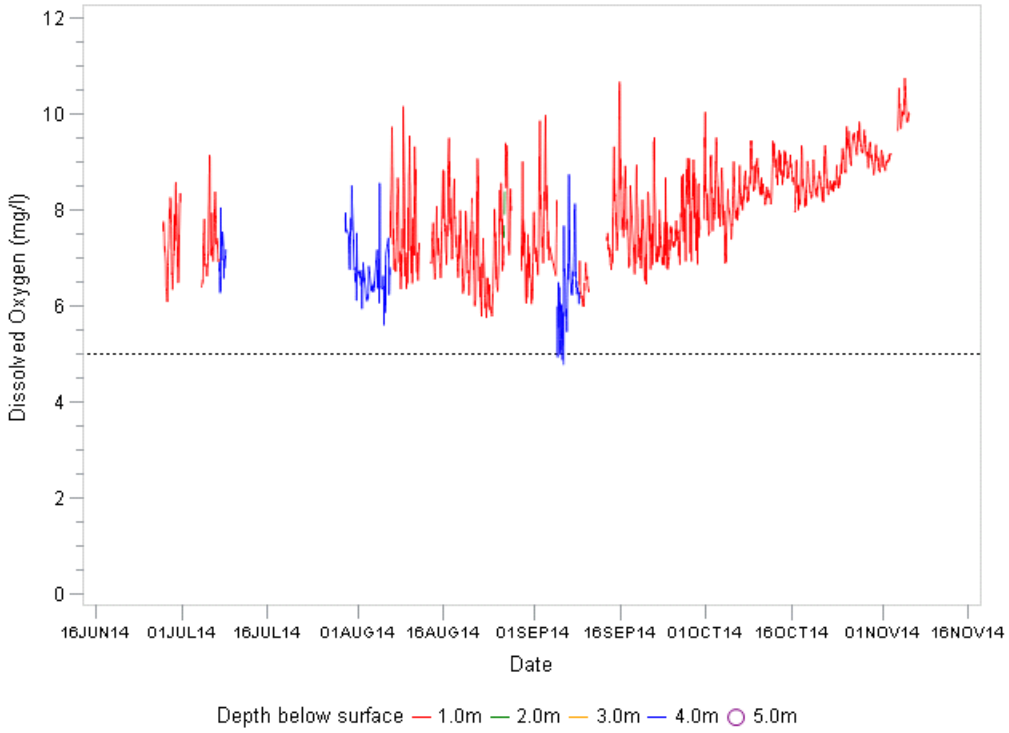


Figure 10. Hourly readings for dissolved oxygen in the Tred Avon River during 2014.

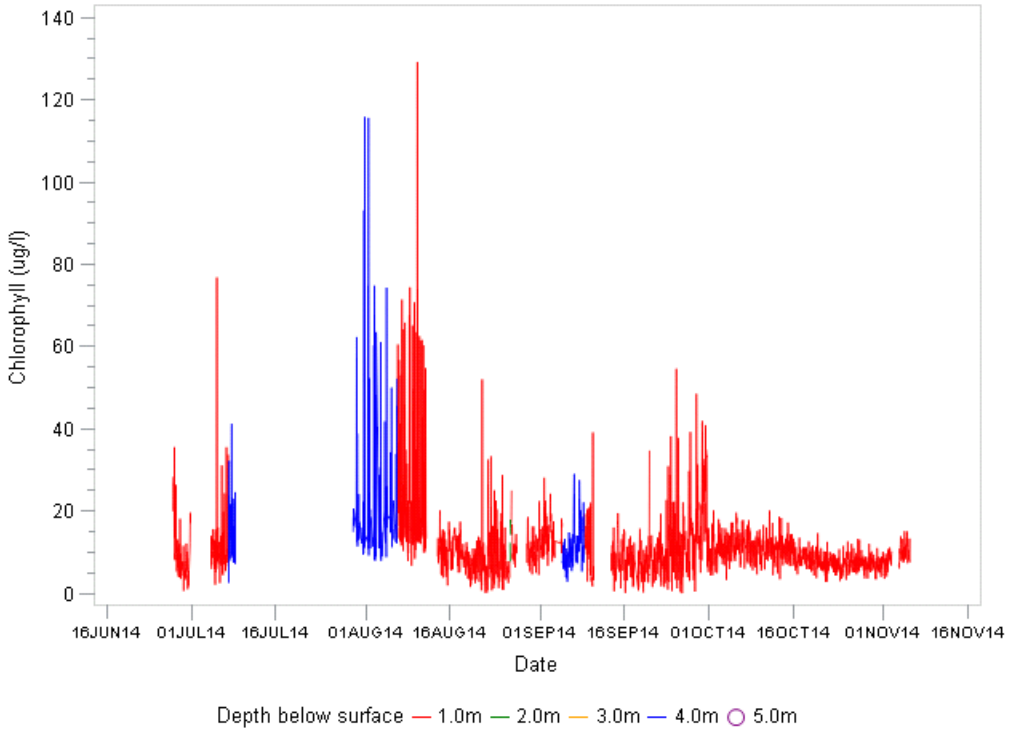


Figure 11. Hourly readings for chlorophyll in the Tred Avon River during 2014.

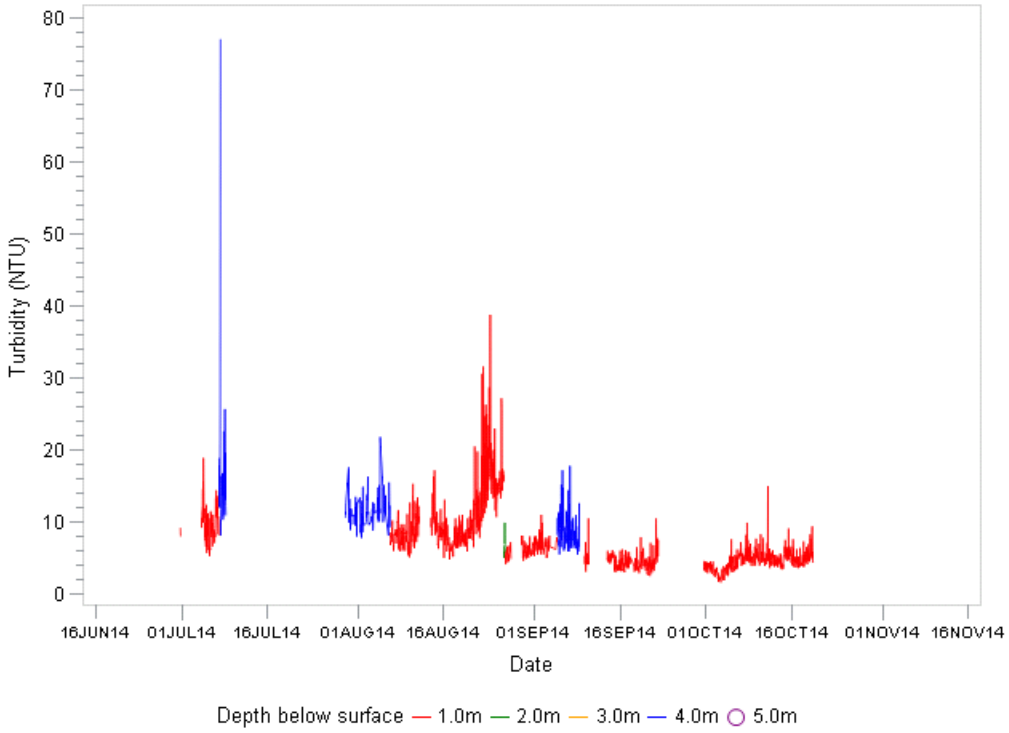


Figure 12. Hourly readings for turbidity in the Tred Avon River during 2014.

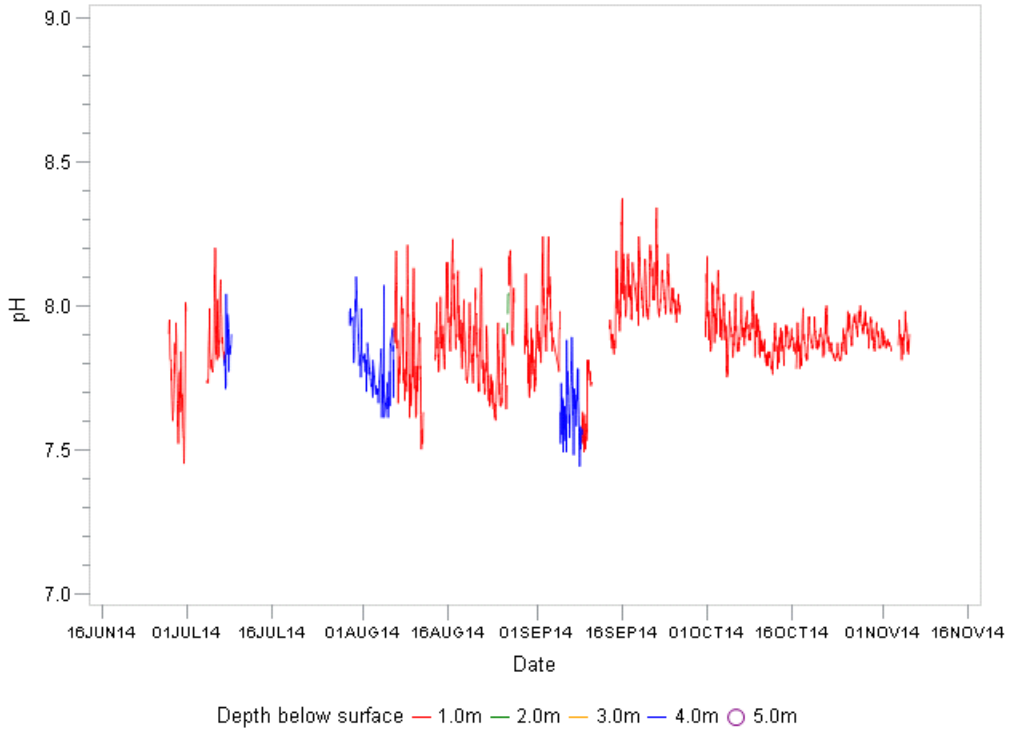


Figure 13. Hourly readings for pH in the Tred Avon River during 2014.

**Recommendations**

If water quality monitoring is to continue next year with the deployment of a vertical profiler in the Tred Avon River, the following recommendations should be considered:

1) Upon initial setup, verify that data storage on the CR1000 exceeds 600 records of profiler data and 100 records of hourly data.
2) Verify that all computer software programs (particularly Loggernet) are compatible so that field personnel and office staff can monitor and communicate with the CR1000.
3) Instrument operation should be monitored closely, especially during the early weeks of deployment, to ensure that the equipment is functioning properly.
4) To reduce incidences of lost data records, scheduled data downloads should continue. Scheduled downloads should include data files for profile records and hourly records, as well as the Event Log file to aid with troubleshooting errors.
5) Biofouling may need to be addressed, either with more frequent visits to the site or with the use of additional anti-fouling techniques.