Demonstration Pilot Project to Examine Whether Diffusers Will Improve the Ecological Condition of Dead-End Tidal Canals, Status Report, November 2014

Background

The Town of South Bethany (Figure 1) is a densely populated urban community initially developed in the 1950s. It consists of approximately 1,300 single family homes situated on 270 acres located in the southeastern part of Sussex County, Delaware, between the Atlantic Coast and the Little Assawoman Bay and the Assawoman Canal. South Bethany was developed before the 1990 stormwater management regulations and contains five (5) miles of dead-end canals. These canals are currently used mainly for boating and storm water management. In the past they were also used for swimming, fishing and crabbing. How-ever, due to increased pollution (excess nutrients, high Enterococcus levels and low dissolved oxygen) as a result of stormwater runoff these canals are rarely used for swimming, fishing and crabbing.

The canals perform the function of stormwater management ponds. Some have argued that since the canals are tidal that they in fact do not act as ponds. However this is not substantiated. The South Bethany Canals Flushing Study – Entrix 2005 – demonstrates that there is essentially no flushing in the ends of the canals (Figure 2, Residence Time in Canals). Residence Time is defined as the time it takes a concentration to reduce by 36.79%. The computer flushing model was run to simulate three months of tidal action. The areas in red did not reach the 36.79 % reduction in the three months. The areas in green reached the 36.79% reduction in one month. The areas in dark blue reached 36.79% reduction in about one day. The resulting finding is that the canals shown in red do indeed act as storm water management ponds since they have no significant exchange of water due to tidal action.

Based on the fact that the dead end canals act as stormwater management ponds, the Canal Water Quality Committee recommended to Town Council that diffusers, similar to aerators used in nearby stormwater management ponds, be placed in a test dead end canal as a means to increase circulation and dissolved oxygen in the test canal. Town Council supported the recommendation for a two year test program.

Figure 1. Town of South Bethany

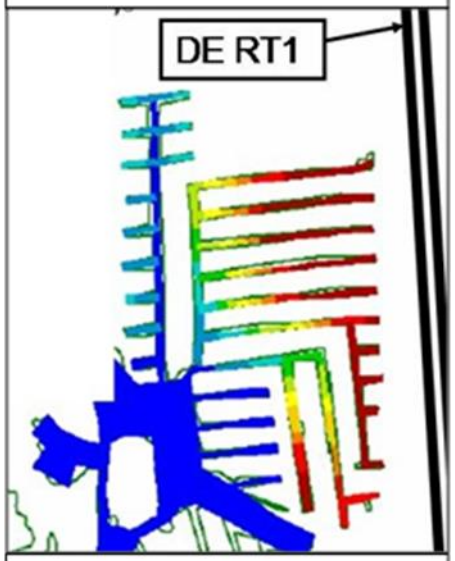


Figure 2. Residence Times in Canals

Description of the Diffuser Pilot Demonstration Project

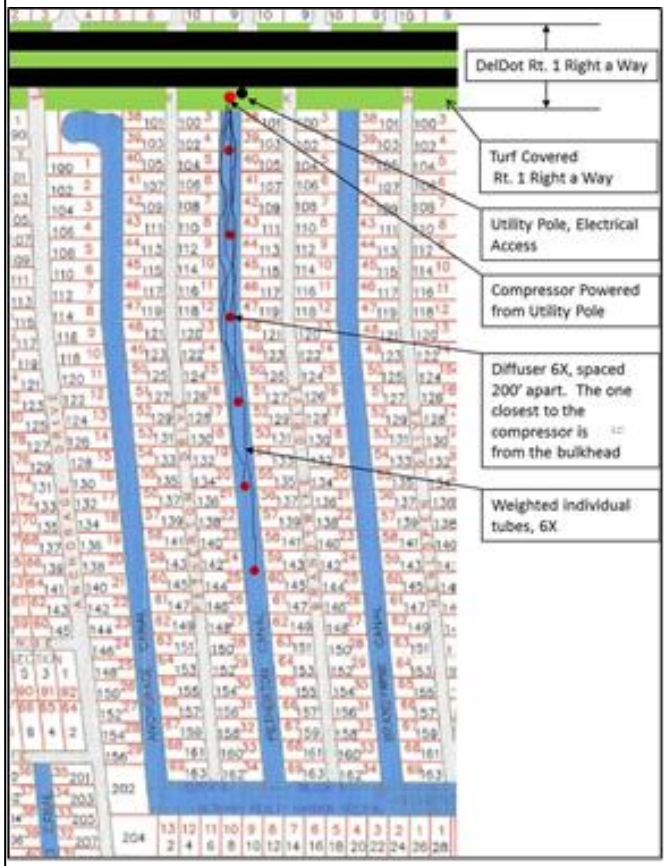
The primary objective of the two year pilot project is to determine if diffusers will provide a new method that works effectively in dead-end tidal canals, as they do in stagnant water management ponds, to increase dissolved oxygen and possibly reduce algae blooms. The secondary objective is to quantitatively measure the effectiveness of the improvement of the ecological conditions in support of a cost benefits analysis to justify installing diffusers into all impaired canals.

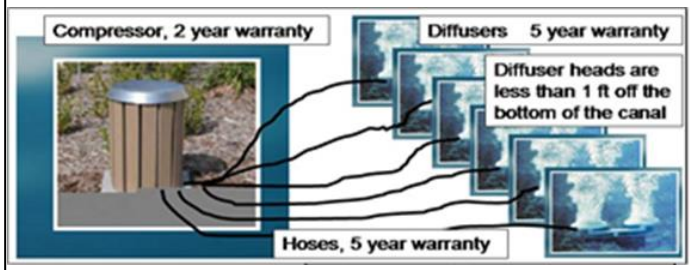
The Diffuser Demonstration is being conducted on three of the canals that have been determined to be among the most impaired from previous water quality monitoring programs. These are the Anchorage Canal, the Petherton Canal and the Brandywine Canal. The Petherton Canal is the test canal, the one with diffusers, and is located between the Anchorage and Brandywine Canals. The Brandywine Canal is the control canal. It was selected over the Anchorage Canal because it has the same drainage area (about 6 acres) as the Petherton Canal, while the Anchorage Canal has a drainage area of about 100 acres. The Anchorage Canal is a second reference canal since it is adjacent to the Brandywine Canal and it is the canal with the most historical data associated with it. Each canal has about two acres of surface area and each is about five feet deep. When the water is deep enough (12 to 15 feet) for a diffuser to operate at high efficiency, only one diffuser is needed per acre. When the depth is 4 to 11 feet the vendor suggests using 2 diffusers per acre. Since the canals have a very poor aspect ratio and they are very shallow, there are six (6) diffusers equally spaced along the most eastern 1,000 feet of the 1,600 foot Petherton Test Canal (about 4 diffuser per acre).

The diffuser system was professionally installed by Envirotech Environmental Consulting, Inc. (EECI) in the Petherton Canal on April 24, 2013. The system consists of the following components:

- **AquaAir 6 – 1 hp, 115/120V, Single Phase Compressor;**
- **Six (6) Single Membrane or Dual Diffusers, Stainless Steel Case,** Molded Base; and
- 3,900 feet of weighted tubing.

Each diffuser is independently supplied with compressed air though weighted tubes that lie along the bottom of the canal from one compressor that is located on shore at the east end of the canal.





Water Quality Monitoring Results

The diffusers have been running continuously since April 24, 2012 except for the month of July in 2014 when they were turned off to verify that the Petherton and Brandywine Canals behaved similarly, if diffusers were not present. The result of the July 2014 test did verify that the two canals behaved similarly, confirming the data from 2012 when there were no diffusers in either canal.

Water quality was monitored three different ways.

- Weekly water quality monitoring (Dissolved Oxygen (DO), salinity, temperature and secchi depth) was done from shore at the most eastern end of each of the three canals; Anchorage, Petherton and Brandywine. Since DO is lowest in the summer, the DO data for May, June, July, August and September for 2012, 2013 and 2014 is shown on slide 6 for comparison. Results show that DO appears to be increasing slowly over the last two years and that the canal with diffusers had consistently higher DO than the control canal since mid August 2014. Observations made on 8/12/14 show that there was potential for a fish kill in the Anchorage and Brandywine Canals while the diffusers in the Petherton Canal cause it to have significantly better water quality. See slides 6 to 9.
- Weekly water quality monitoring was conducted by boat. DO measurements were made at 15 locations along the 1,600 foot length of both the Petherton and Brandywine Canals at one foot deep and at three feet deep. Since the end of August the deep sensor has been located very close to the bottom instead of at 3 feet from the surface. The data from the boat trips are presented on slides 11 through 15. Moving the deep sensor closer to the bottom gives a better picture of the average DO. It shows that the canal with diffusers now has consistently higher average DO when compared to the control canal. This could be because of the lower sensor or because the diffusers are becoming more effective after 1.5 years.
- Continuous data was monitored at about 150 feet from the east end of the Anchorage, Petherton and Brandywine Canals. Slides 16 through 24 have the continuous DO data taken in 2012, 2013 and 2014. The data show that DO has been increasing slightly each year and that DO increases as you go from north to south.
- Monitoring from a kayak shows that The diffusers increase DO at water depth > 4 ft. resulting in a flat profile with depth close to the diffusers which is beneficial for the fish. See slides 26 to 28.

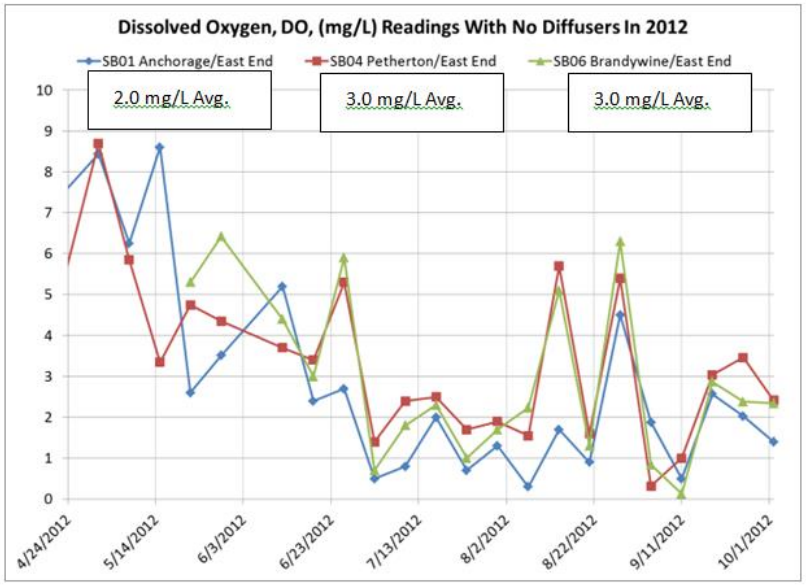
Since diffusers are used in some cases to eliminate muck, muck depth measurements were taken and are presented on slide 25.

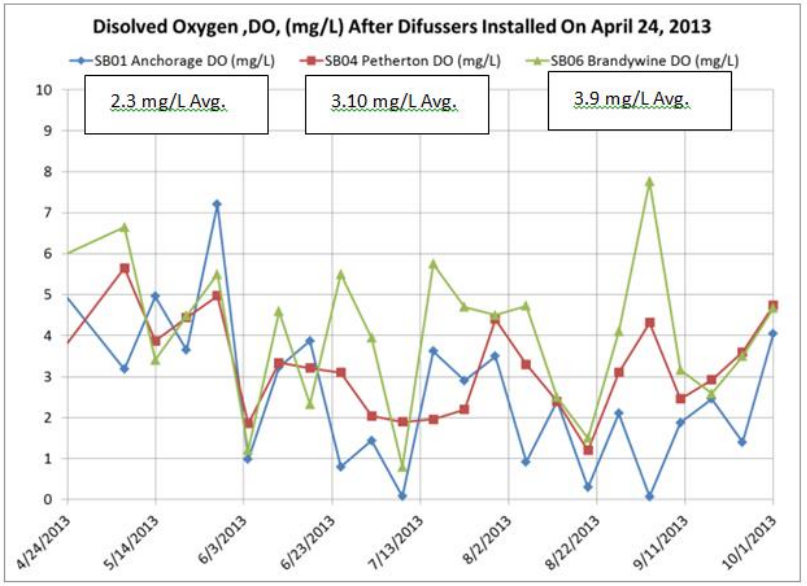
- It had been postulated in last years status report that DO was lower in the canal with diffusers, since diffusers could be used to reduce muck.
- Muck depth measurements are very difficult to make from a boat in the center of the canal.
- Three or four different muck measurement tools have been tried. Finally this summer we developed one that we like.
- The measurements have a lot of scatter.
- Even with the above caveats it appears that muck depth has been reduced slightly.
- We will continue to make muck depth measurements next year.

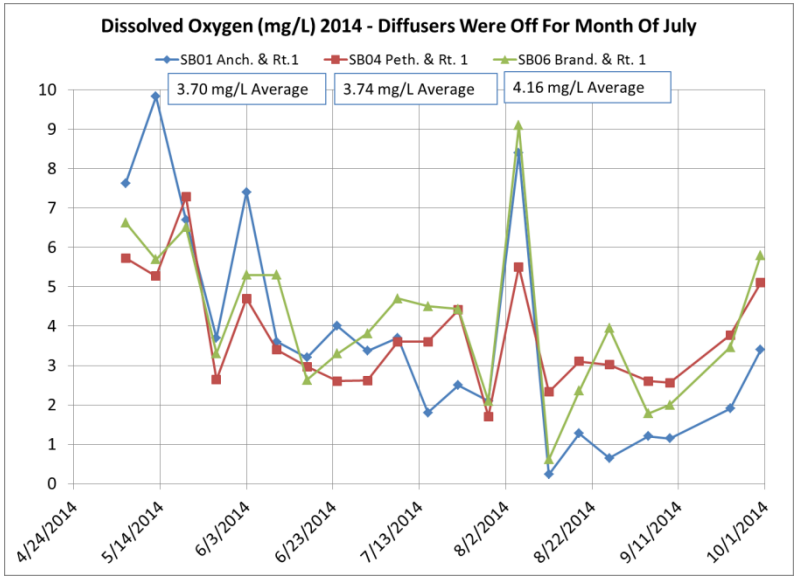
Conclusions and Recommendations After 18 Months

- The diffusers do not significantly increase the average dissolved oxygen (DO) in the Petherton Canal.
- The diffusers do significantly decrease stratification and the likelihood of a fish kill. However no fish kill has ever been reported in the Petherton Canal. To my knowledge the only fish kills that have occurred were in the Russell Canal.
- Since the diffusers have been installed there has been no significant algal bloom in any of the South Bethany Canals, so there is no data that can be used to determine if the diffusers would decrease algal blooms in the South Bethany Canals.
- I would recommend that we continue the diffuser project at least until there is a significant algal bloom so that the effect of the diffusers on algal blooms can be determined. The cost of doing this is about $150 per month for electricity.

DO Measurements From The Rt. 1 Bulkhead 2012,2013,2014







- Overall we may be doing something good! The average DO has increased in each of the three canals over the last two years.
- The 2012 data shows that the Petherton and Brandywine Canals behave similarly. Brandywine is a good control for the diffuser test.
- The diffusers cause the DO in the Petherton Canal to be more uniform, lower peaks and higher lows.
- When diffusers were turned off during July 2014, Petherton and Brandywine had identical readings on July 22 and 29.
- During 2013 and the beginning of 2014 Petherton had lower DO than Brandywine. Towards the end of 2014 Petherton had the higher DO.

Effect of Diffusers on DO at East Petherton Canal Bulkhead

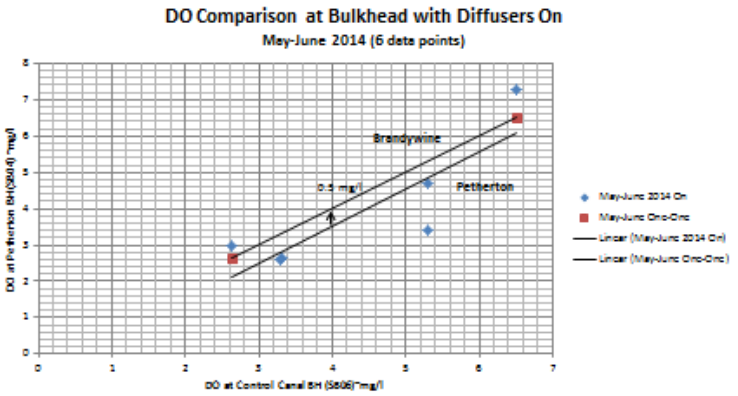
August 12, 2014

Dave Wilson

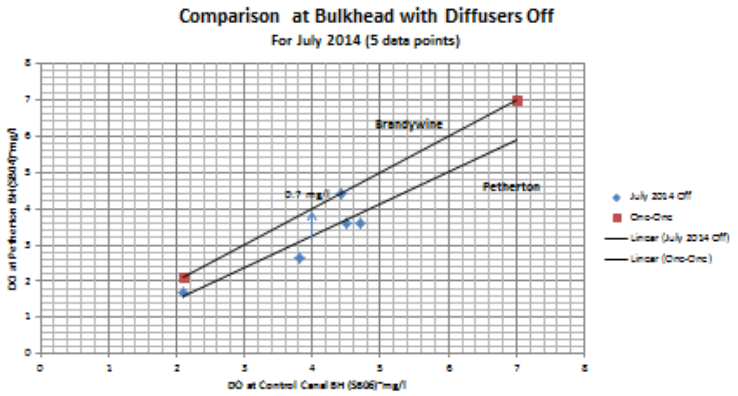
Results to Date for Diffuser Operation in Petherton Canal for Bulkhead Sites

- Diffusers installed at 6 locations along Petherton on April 26, 2013
- DO monitored at E end Bulkhead (SB04) and mid canal to west of diffusers (SB05)
- DO monitored at E end of Brandywine (SB06) canal adjacent to Petherton as a control
- Monitoring by boat also conducted in summers of 2013 and 2014
- Diffusers ran continuously to June 29, 2014
- Diffusers turned off for month of July 2014 to assess effectiveness
- 48 data points, 23 with diffusers off and 25 with diffusers on at bulkhead locations during summers of 2012, 2013, and 2014
- All data at approximately 1 ft depth

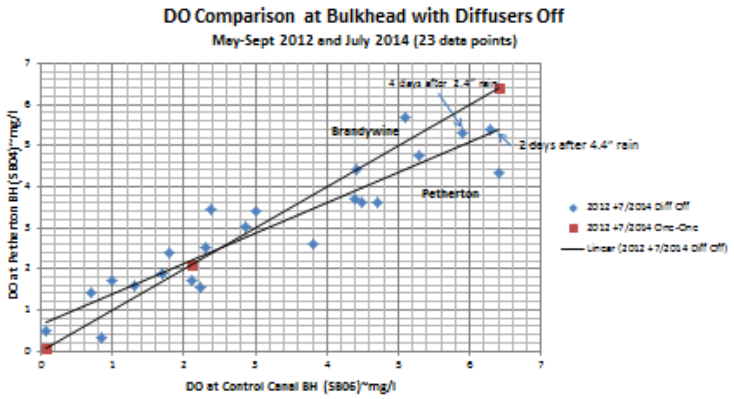
Petherton DO Lower than Control Canal in 6 Weeks Before Diffusers Turned Off



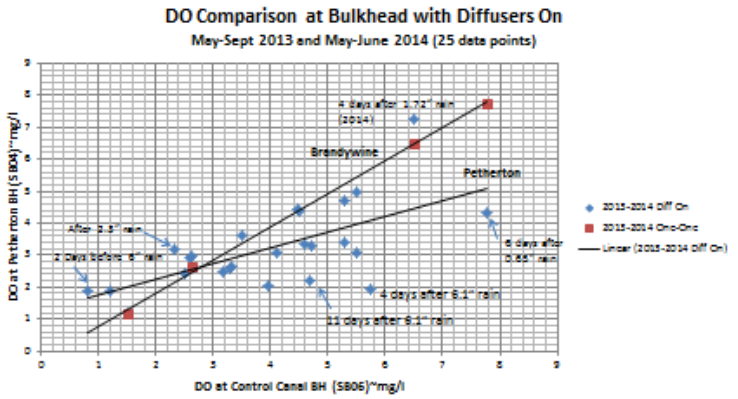
Loss in DO Increased Slightly When Diffusers Turned Off in July

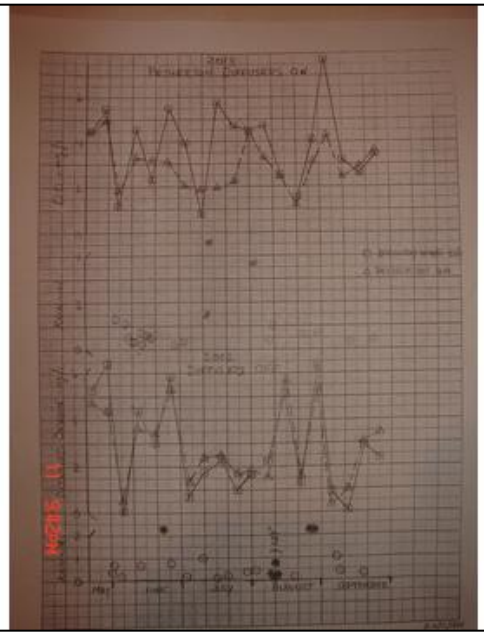


Multi Year Data Show Petherton Bulkhead DO Higher than Brandywine at Low DO levels with Diffusers Off

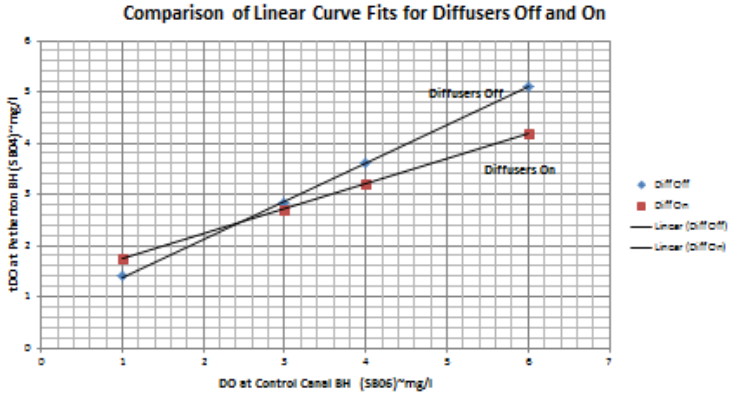


Rain Events in 2013 Increased Scatter with Diffusers On





Data To Date Show Diffusers Slightly Increase DO at Low Levels and Reduce DO at High Levels Bulkhead Locations



Comparative Observations at Bulkheads

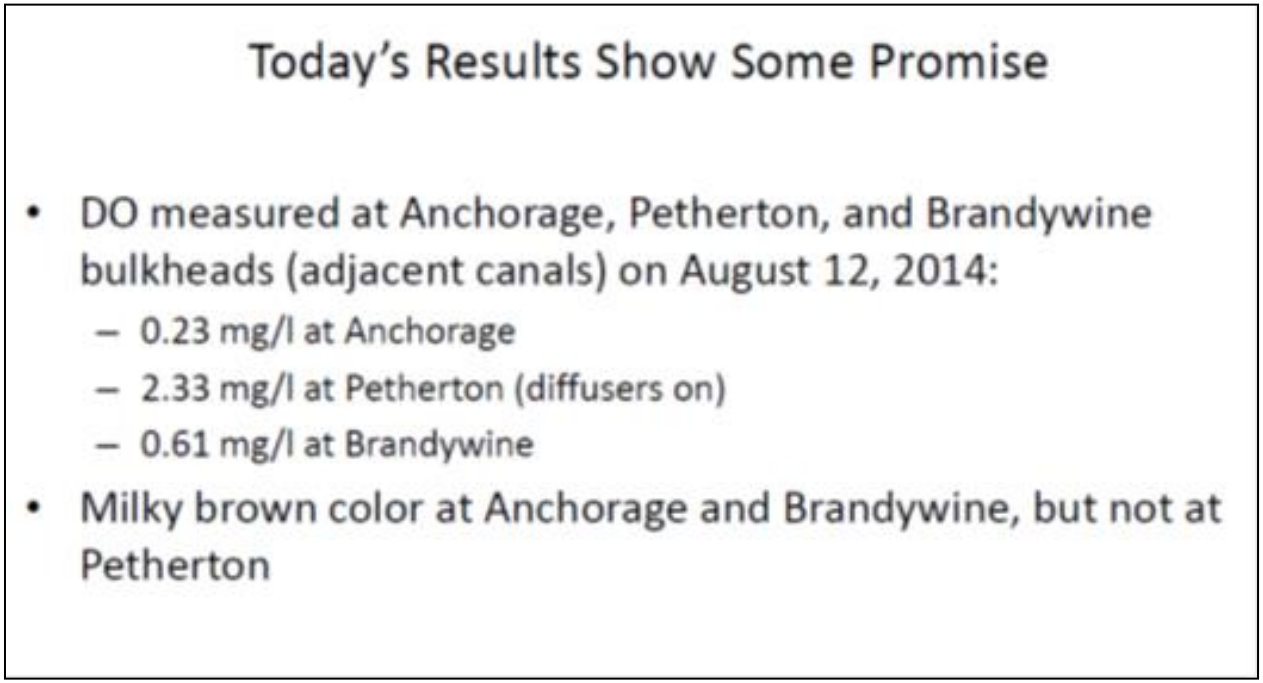
- Petherton has poor circulation based on
  - Amount of more debris accumulation at east bulkhead than Brandywine
  - Bacteria count substantially higher than Brandywine
  - Substantially higher Jellyfish count in region of bulkhead than Brandywine
- Consider moving first diffuser closer to bulkhead

Today's Results Show Some Promise

- DO measured at Anchorage, Petherton, and Brandywine bulkheads (adjacent canals) on August 12, 2014:
  - 0.23 mg/l at Anchorage
  - 2.33 mg/l at Petherton (diffusers on)
  - 0.61 mg/l at Brandywine
- Milky brown color at Anchorage and Brandywine, but not at Petherton

Conclusions from Bulkhead Data to Date

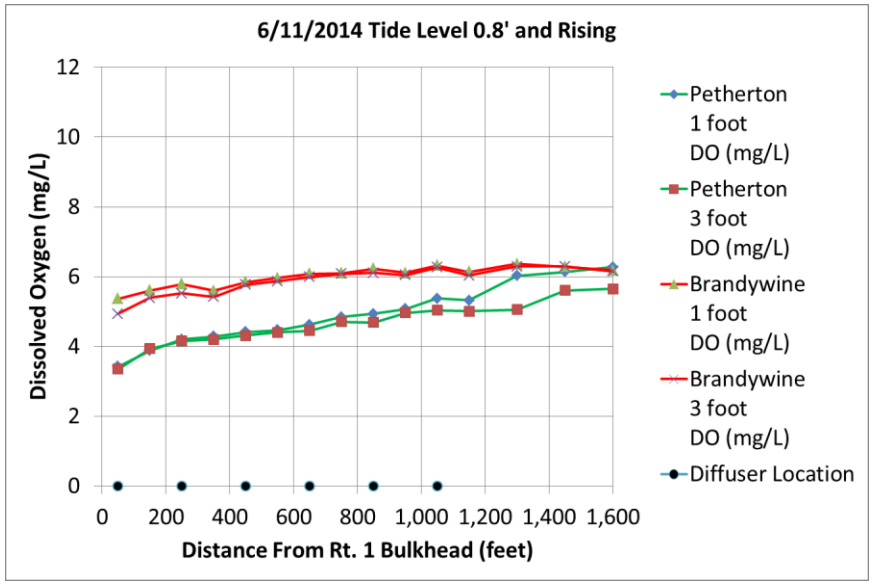
- Diffusers slightly increase DO at very low levels (<2.5 mg/l)
- Diffusers reduce DO at high levels (>4 mg/l)
- Rain events seem to negatively affect DO with diffusers on
- Need to look at continuous monitor 2013 data to track effect of rain events on Petherton DO (1.5" on July 11 and 4.6" on July 12 vs 1.72" on May 16 2014)
- Consider moving first diffuser closer to east bulkhead

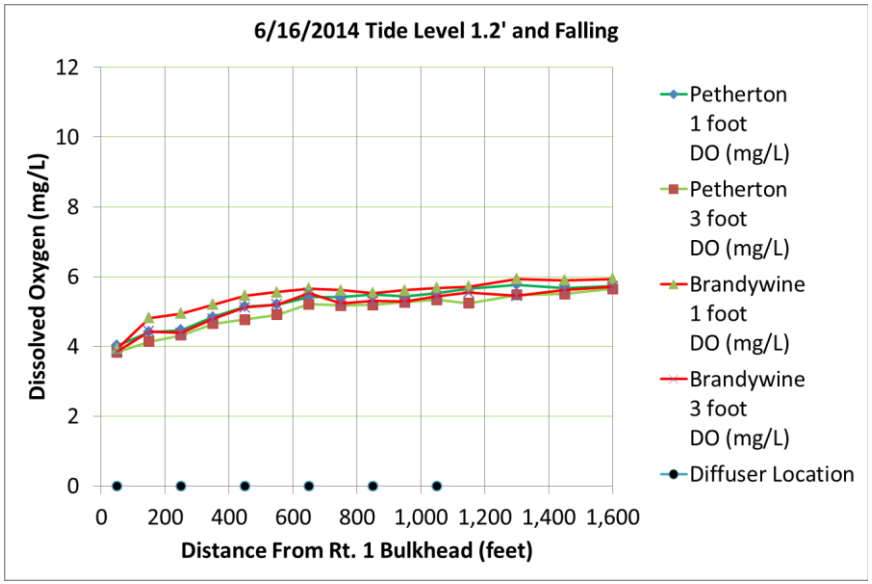


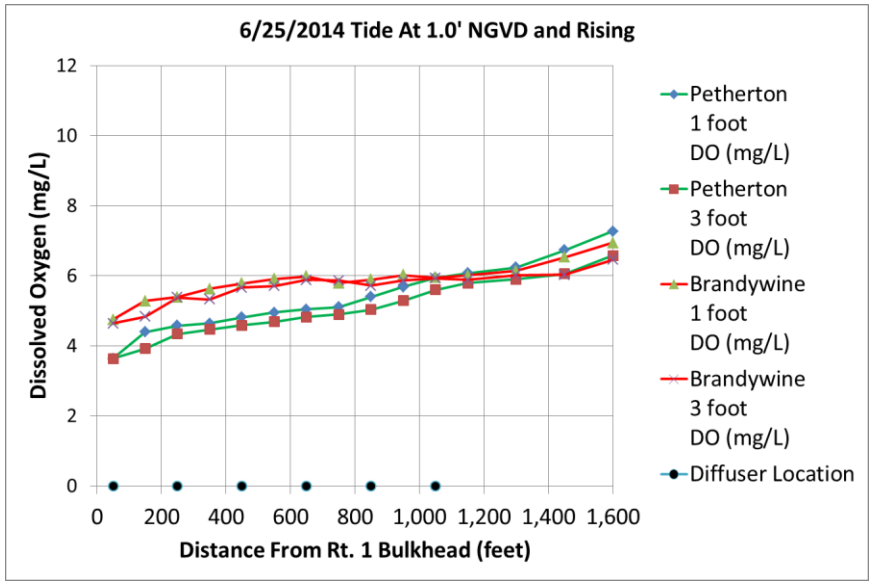
The slide above (From Dave Wilson's 8/12/14 Presentation) shows what the diffusers can really do. The description above, "milky brown color", relative to the Anchorage and Brandywine Canals, is what happened in the Russell Canal last year when we had a fish kill. DO went almost to zero. The Petherton Canal that was well stirred by diffusers had a DO of 2.33 mg/L and had no "milky brown color". The diffusers caused an environment in the Petherton Canal that would not cause a fill kill. Whereas the environment in the Anchorage and Brandywine Canals on 8/12/14 could have caused a fish kill.

The table below summarizes information from the next four slides. There are so many variables that it is difficult to determine a pattern. However it appears that the DO was consistently higher in the canal with diffusers at the end of the year.

Date	Tide Rising	Tide Falling	Stratification	Brandy DO > Peth DO	Peth DO > Brandy DO	DO Plots About the Same	Diffusers Off
6/11/2014	X		NO	2mg/L			
6/16/2014		X	NO			YES	
6/25/2014	X		NO	1mg/L			
7/2/2014		X	NO	1.5mg/L			YES
7/9/2014	X		NO			YES	YES
7/16/2014		X			1mg/L		YES
7/23/2014	X		NO			YES	YES
7/30/2014		X	NO			YES	YES
8/13/2014		X	NO	2mg/L			
8/20/2014	X		NO		1mg/L		
8/27/2014		X	NO		1mg/L		
9/3/2014		X			1mg/L		
9/10/2014		X			1mg/L		
10/15/2014		X			1mg/L		


6/11/2014 Tide Level 0.8' and Rising
Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Distance From Rt. 1 Bulkhead (feet)
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location


6/16/2014 Tide Level 1.2' and Falling
Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Distance From Rt. 1 Bulkhead (feet)
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location


6/25/2014 Tide At 1.0' NGVD and Rising
Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
0
200
400
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800
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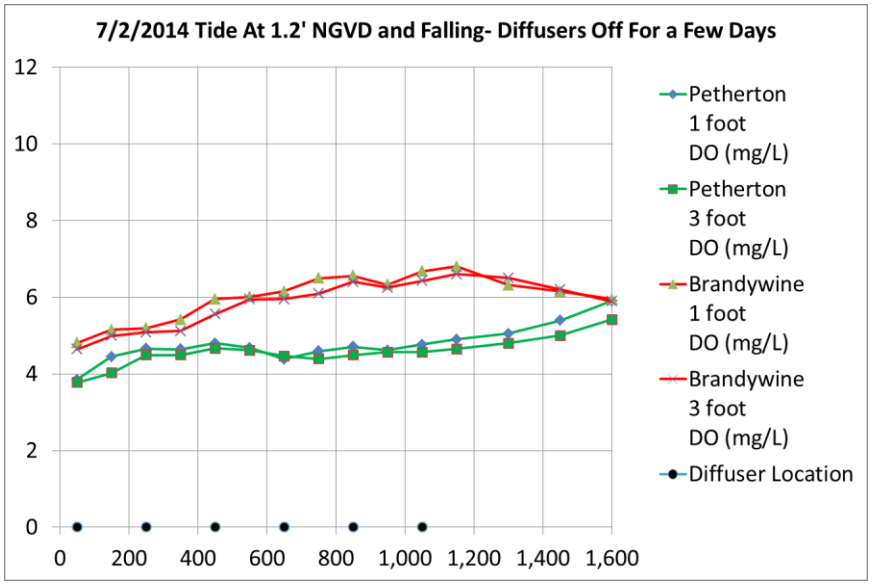
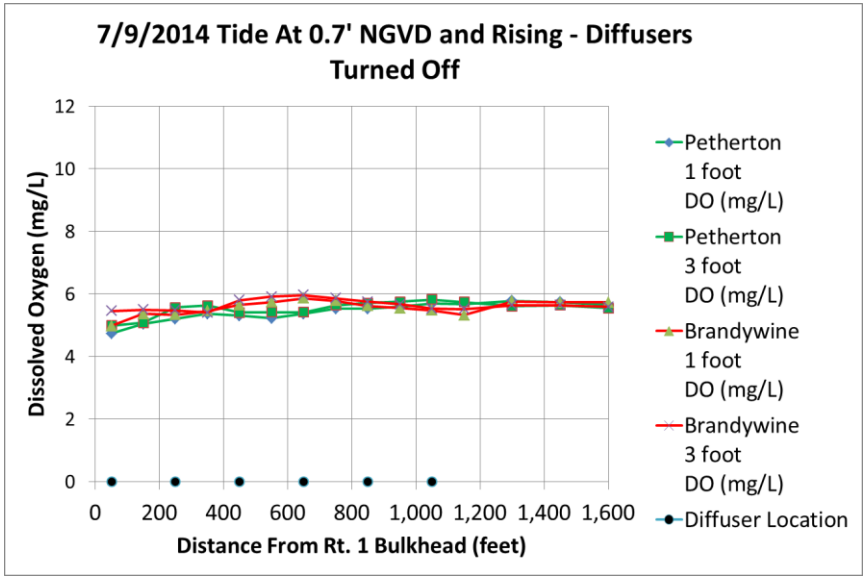
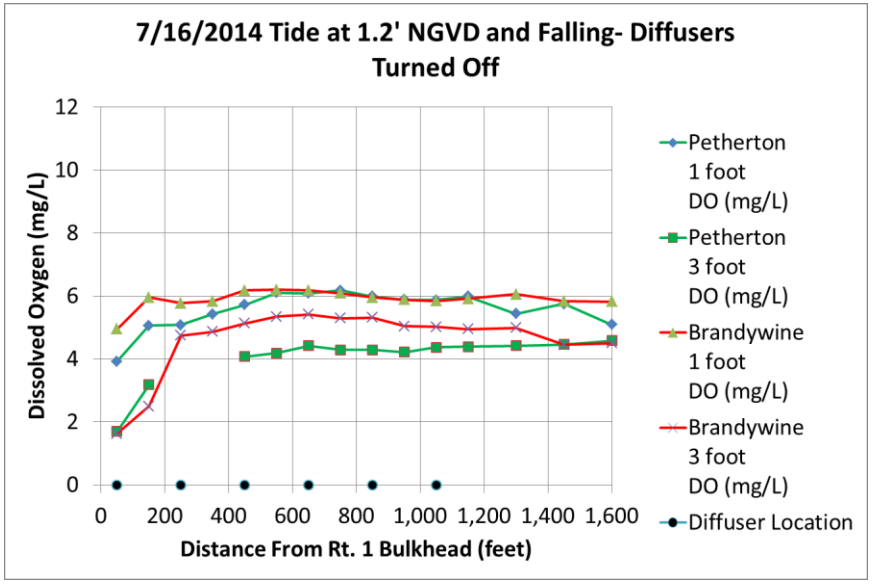
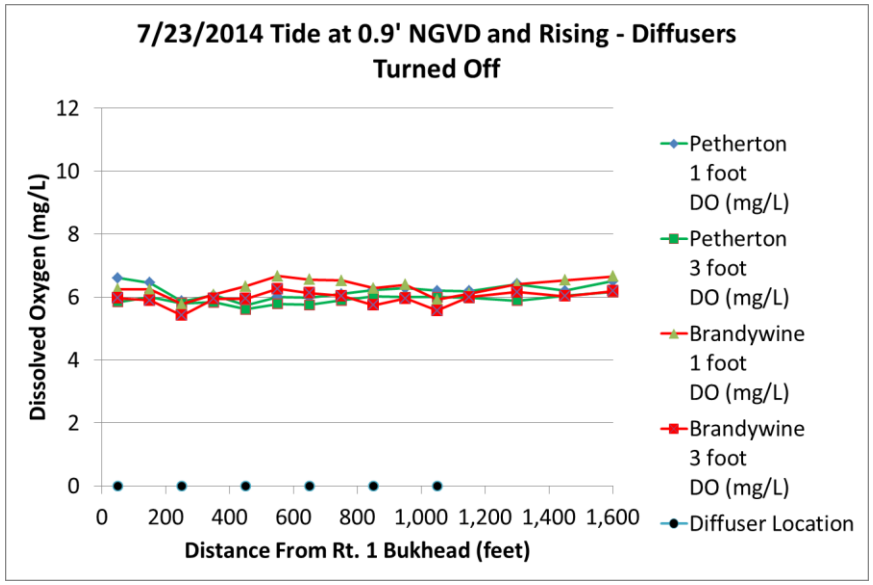
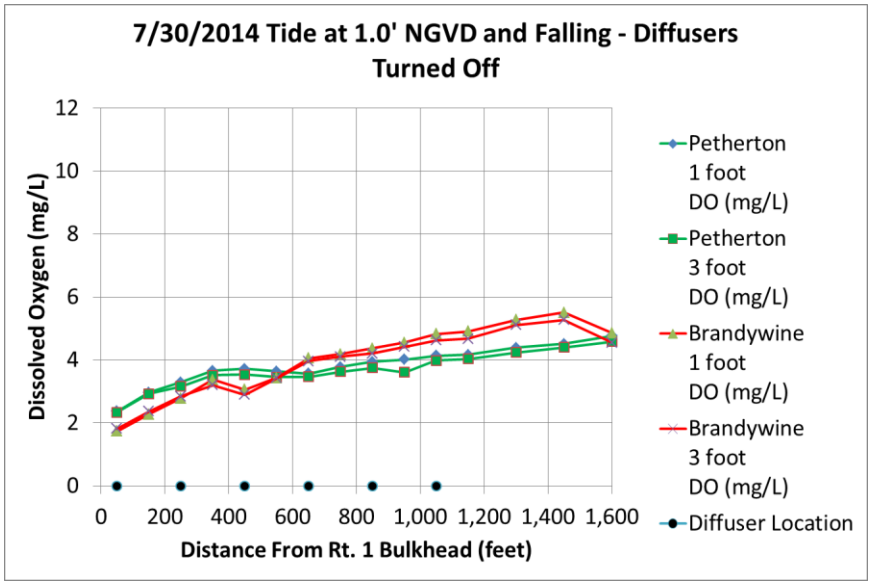
1,200
1,400
1,600
Distance From Rt. 1 Bulkhead (feet)
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

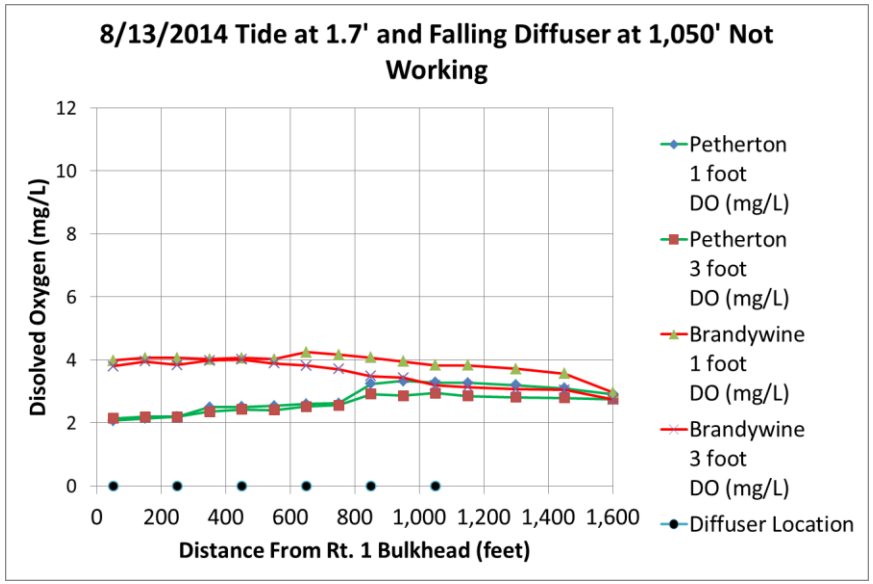

7/2/2014 Tide At 1.2' NGVD and Falling- Diffusers Off For a Few Days
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

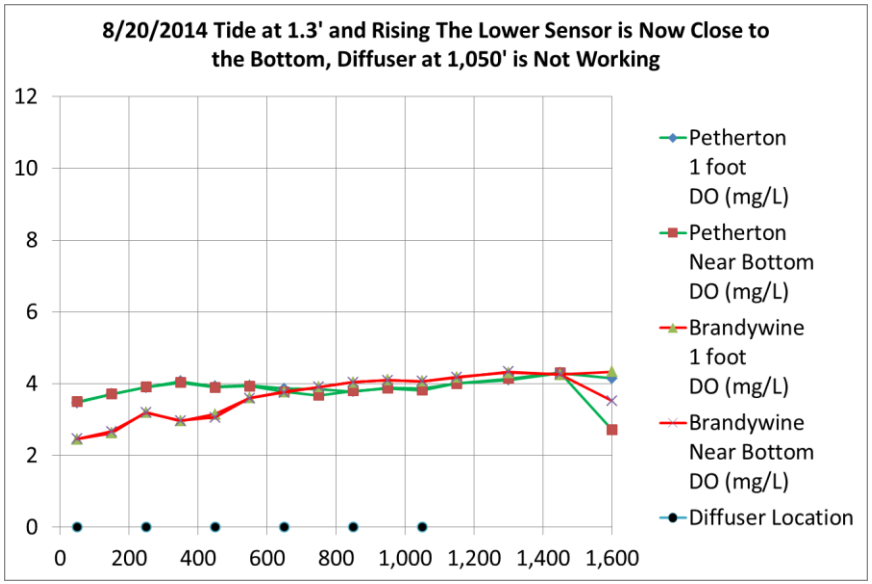

7/9/2014 Tide At 0.7' NGVD and Rising - Diffusers Turned Off
Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Distance From Rt. 1 Bulkhead (feet)
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

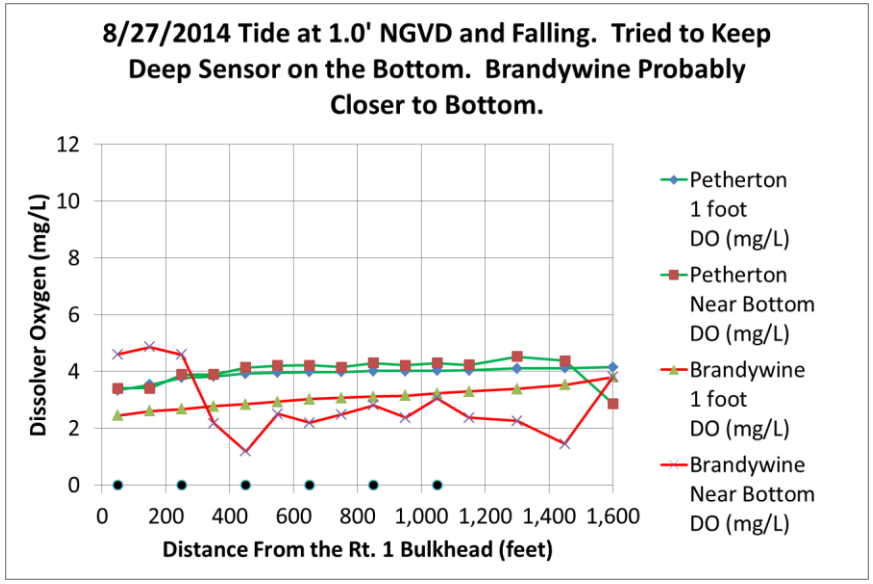

7/16/2014 Tide at 1.2' NGVD and Falling- Diffusers Turned Off
Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Distance From Rt. 1 Bulkhead (feet)
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

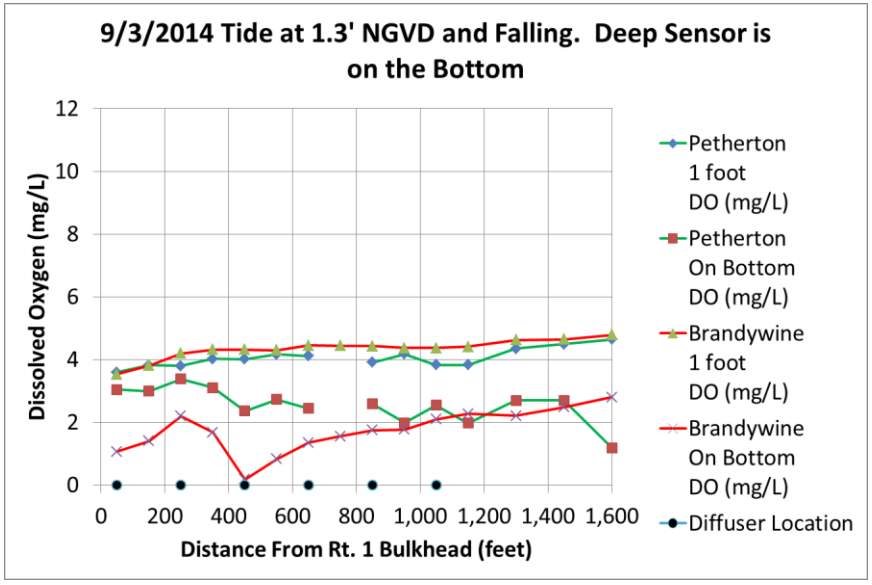

7/23/2014 Tide at 0.9' NGVD and Rising - Diffusers Turned Off
Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Distance From Rt. 1 Bukhead (feet)
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

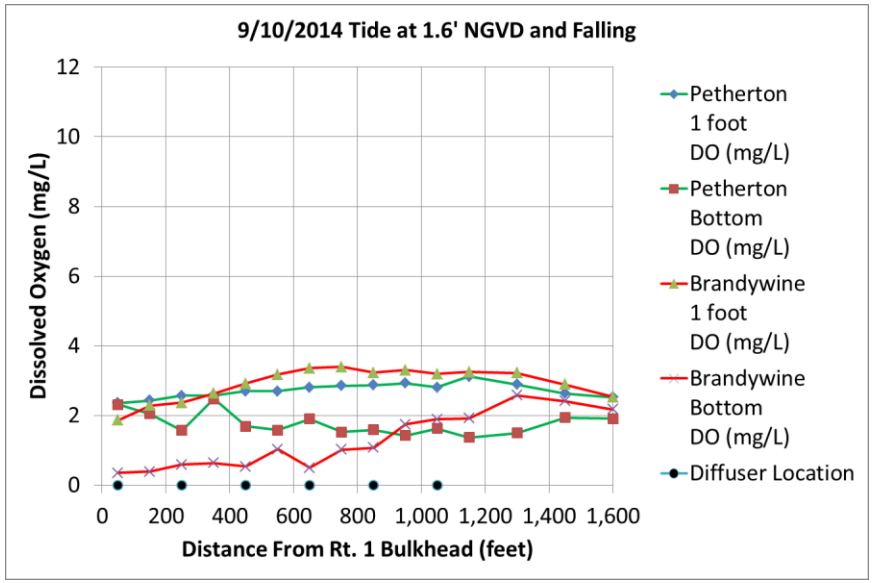

7/30/2014 Tide at 1.0' NGVD and Falling - Diffusers Turned Off
Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Distance From Rt. 1 Bulkhead (feet)
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

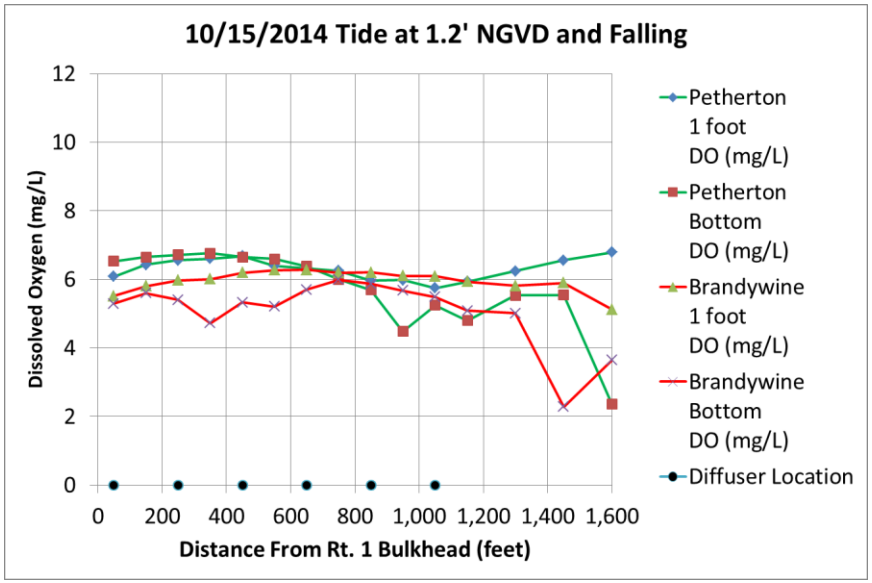

8/13/2014 Tide at 1.7' and Falling Diffuser at 1,050' Not Working
Disolved Oxygen (mg/L)
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Distance From Rt. 1 Bulkhead (feet)
Petherton 1 foot DO (mg/L)
Petherton 3 foot DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine 3 foot DO (mg/L)
Diffuser Location

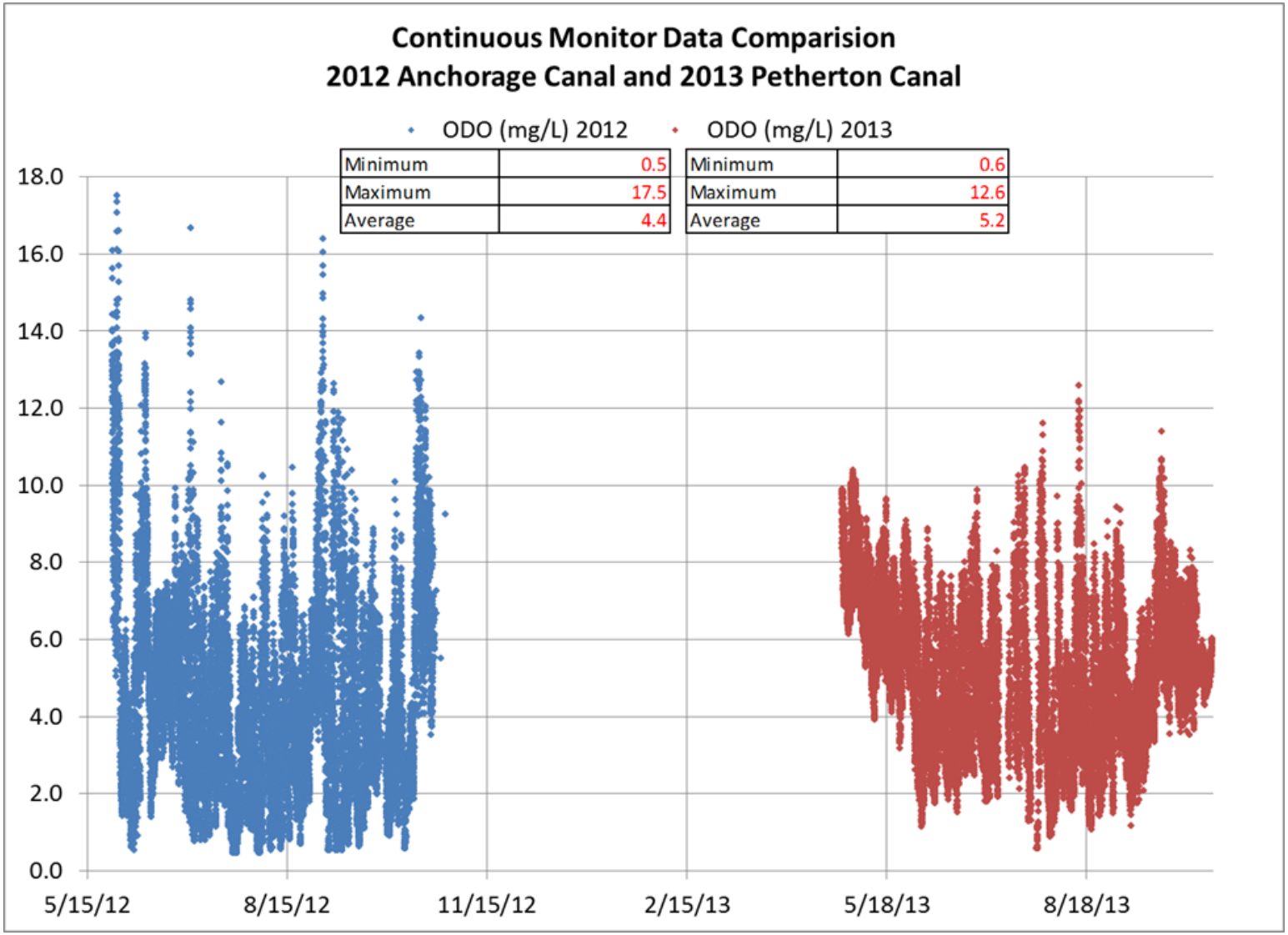

8/20/2014 Tide at 1.3' and Rising The Lower Sensor is Now Close to the Bottom, Diffuser at 1,050' is Not Working
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Petherton 1 foot DO (mg/L)
Petherton Near Bottom DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine Near Bottom DO (mg/L)
Diffuser Location


8/27/2014 Tide at 1.0' NGVD and Falling. Tried to Keep Deep Sensor on the Bottom. Brandywine Probably Closer to Bottom.
Dissolver Oxygen (mg/L)
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Distance From the Rt. 1 Bulkhead (feet)
Petherton 1 foot DO (mg/L)
Petherton Near Bottom DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine Near Bottom DO (mg/L)

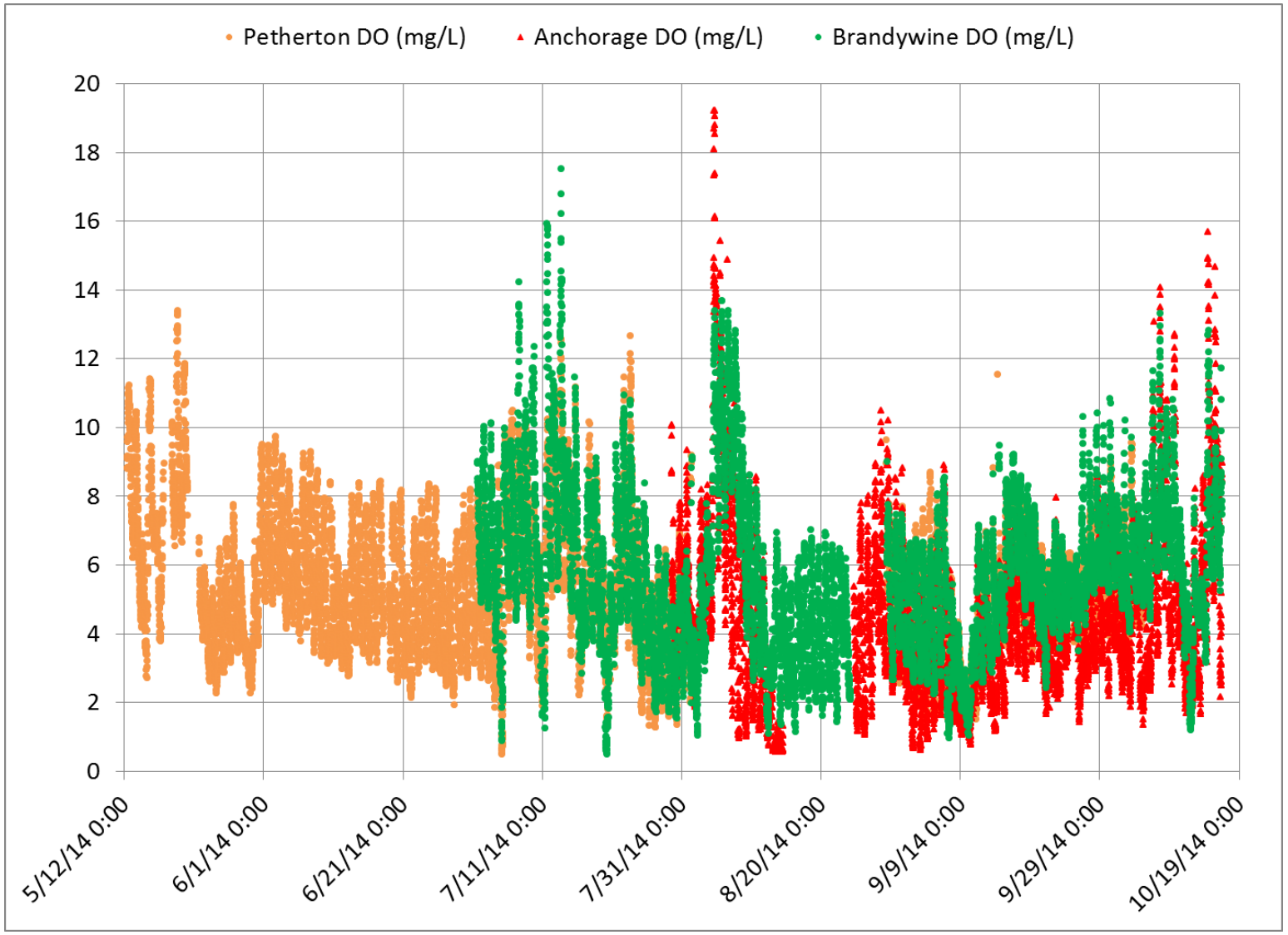

9/3/2014 Tide at 1.3' NGVD and Falling. Deep Sensor is on the Bottom
Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Distance From Rt. 1 Bulkhead (feet)
Petherton 1 foot DO (mg/L)
Petherton On Bottom DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine On Bottom DO (mg/L)
Diffuser Location


9/10/2014 Tide at 1.6' NGVD and Falling
Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Distance From Rt. 1 Bulkhead (feet)
Petherton 1 foot DO (mg/L)
Petherton Bottom DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine Bottom DO (mg/L)
Diffuser Location

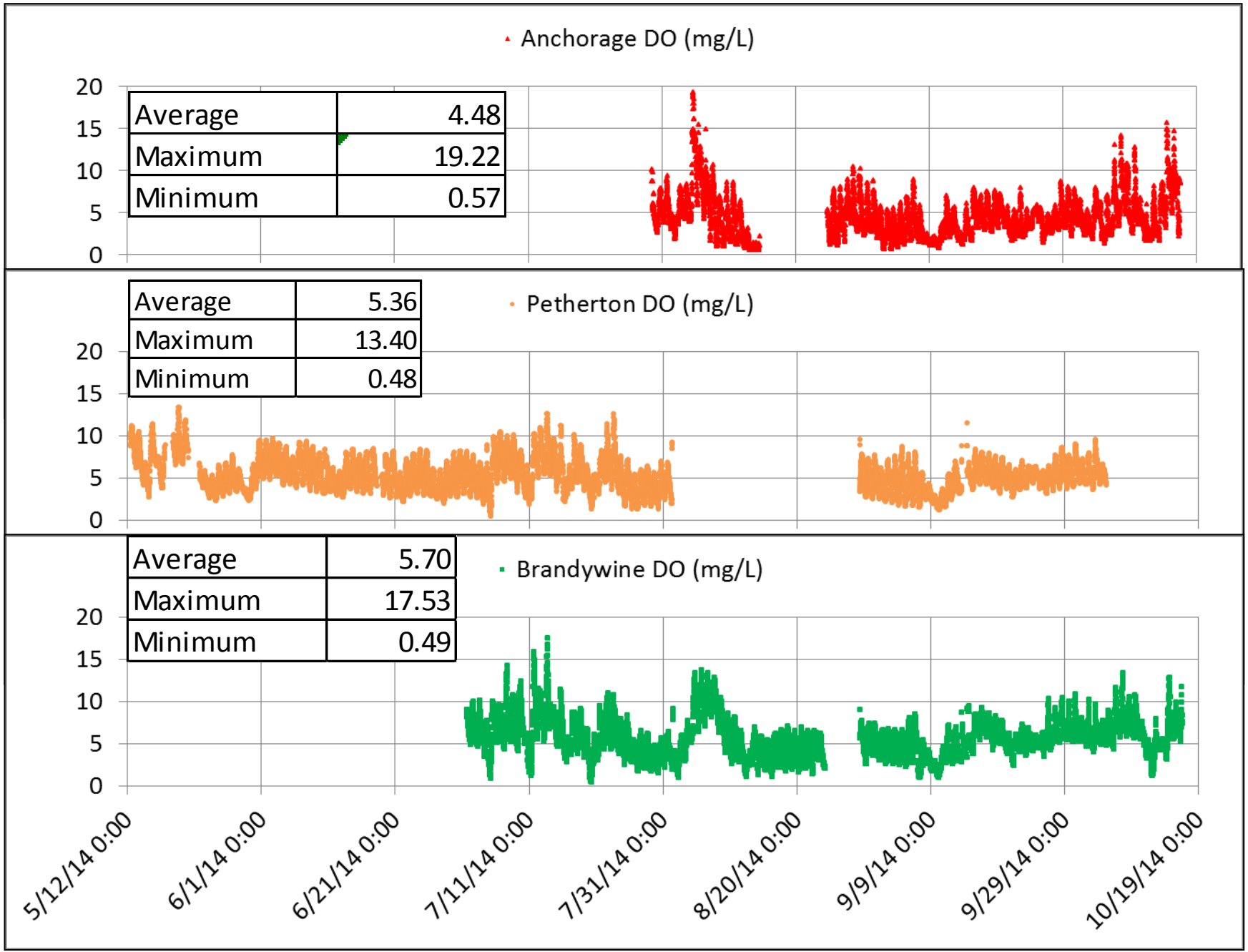

10/15/2014 Tide at 1.2' NGVD and Falling
Dissolved Oxygen (mg/L)
0
2
4
6
8
10
12
0
200
400
600
800
1,000
1,200
1,400
1,600
Distance From Rt. 1 Bulkhead (feet)
Petherton 1 foot DO (mg/L)
Petherton Bottom DO (mg/L)
Brandywine 1 foot DO (mg/L)
Brandywine Bottom DO (mg/L)
Diffuser Location


Continuous Monitor Data Comparision
2012 Anchorage Canal and 2013 Petherton Canal
ODO (mg/L) 2012
ODO (mg/L) 2013
Minimum 0.5
Maximum 17.5
Average 4.4
Minimum 0.6
Maximum 12.6
Average 5.2
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
5/15/12
8/15/12
11/15/12
2/15/13
5/18/13
8/18/13

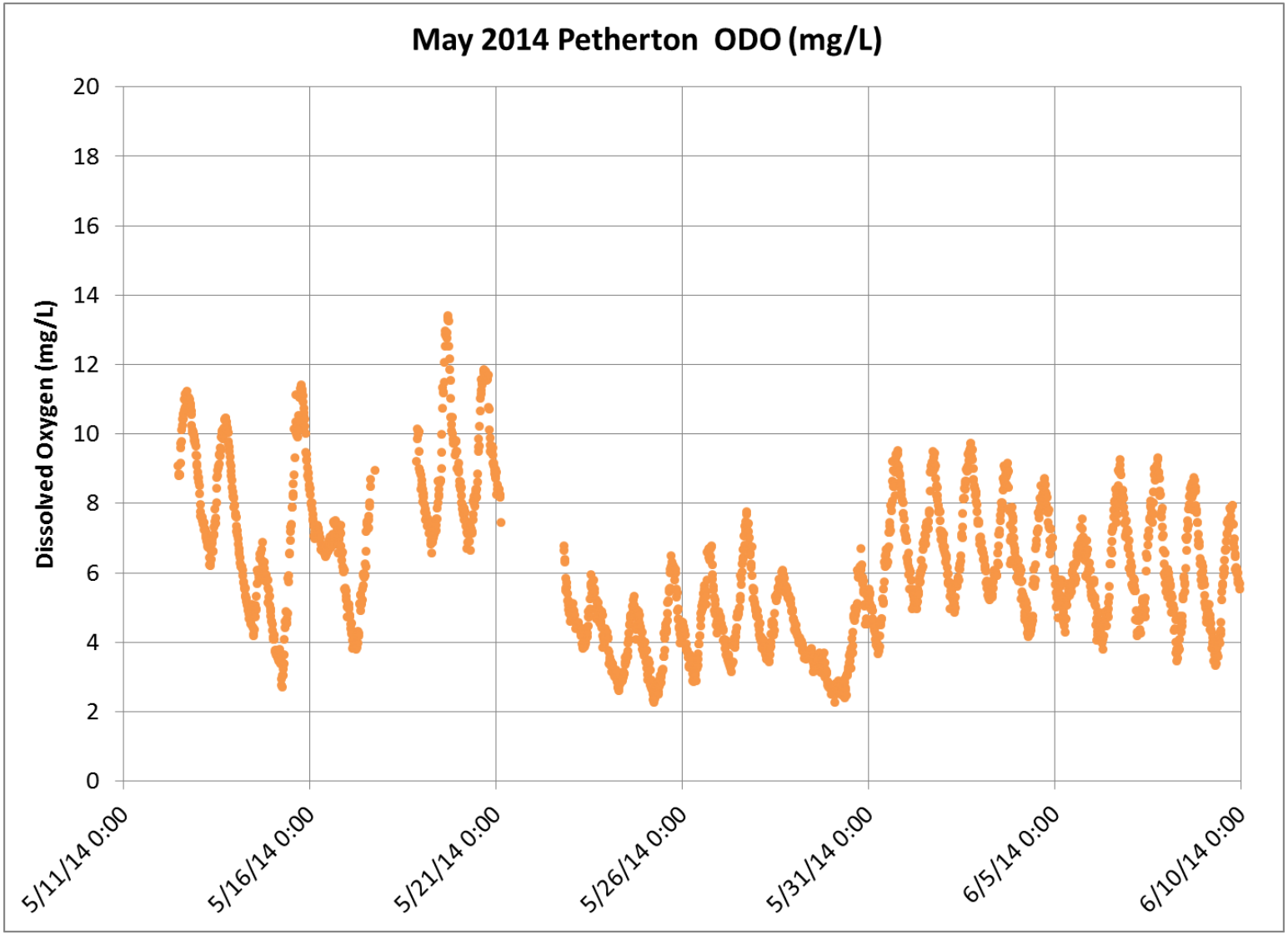
All Continuous Data That Was Recorded In 2014



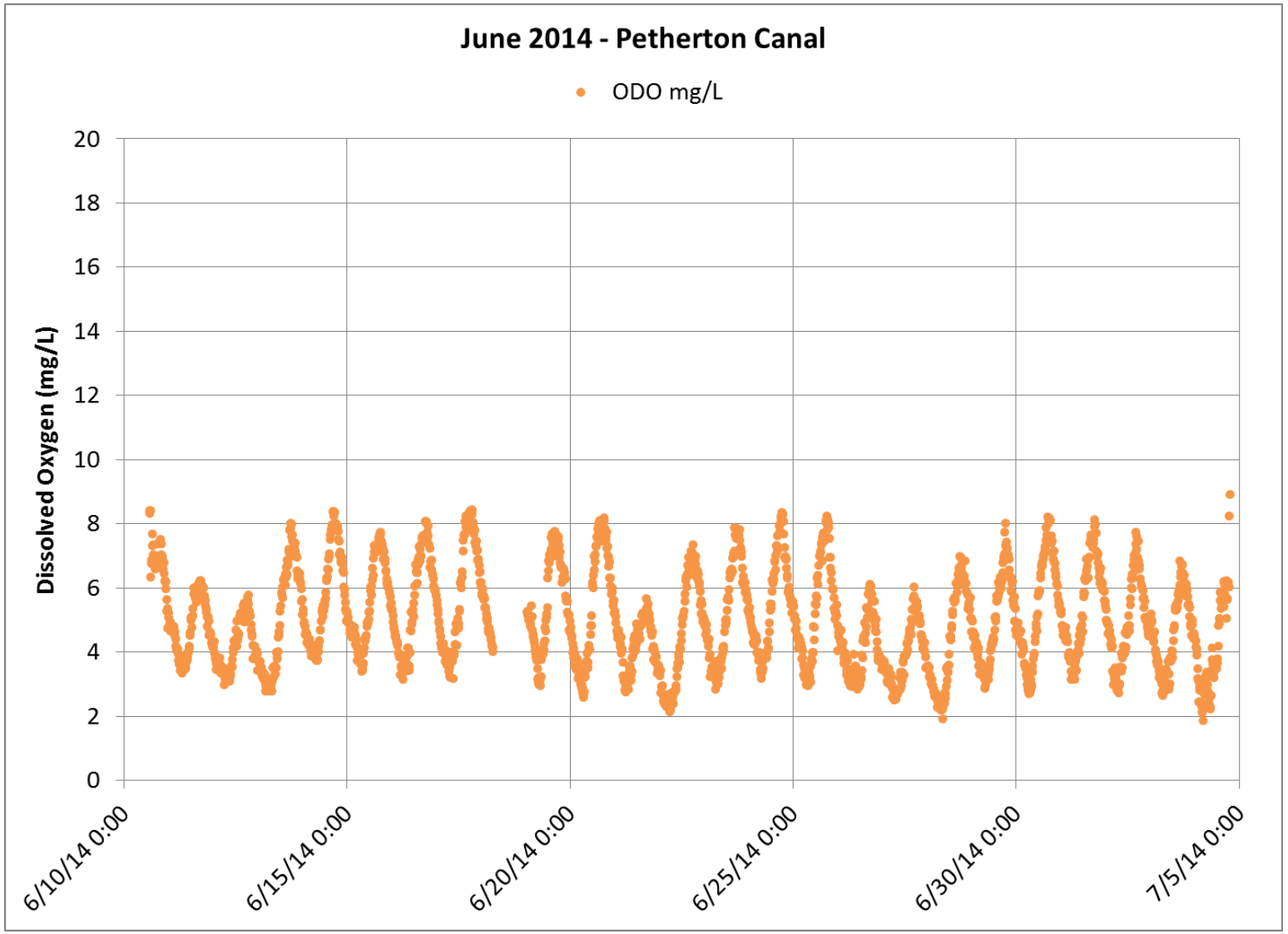
All Continuous Data Plotted Separately by Canal Location.



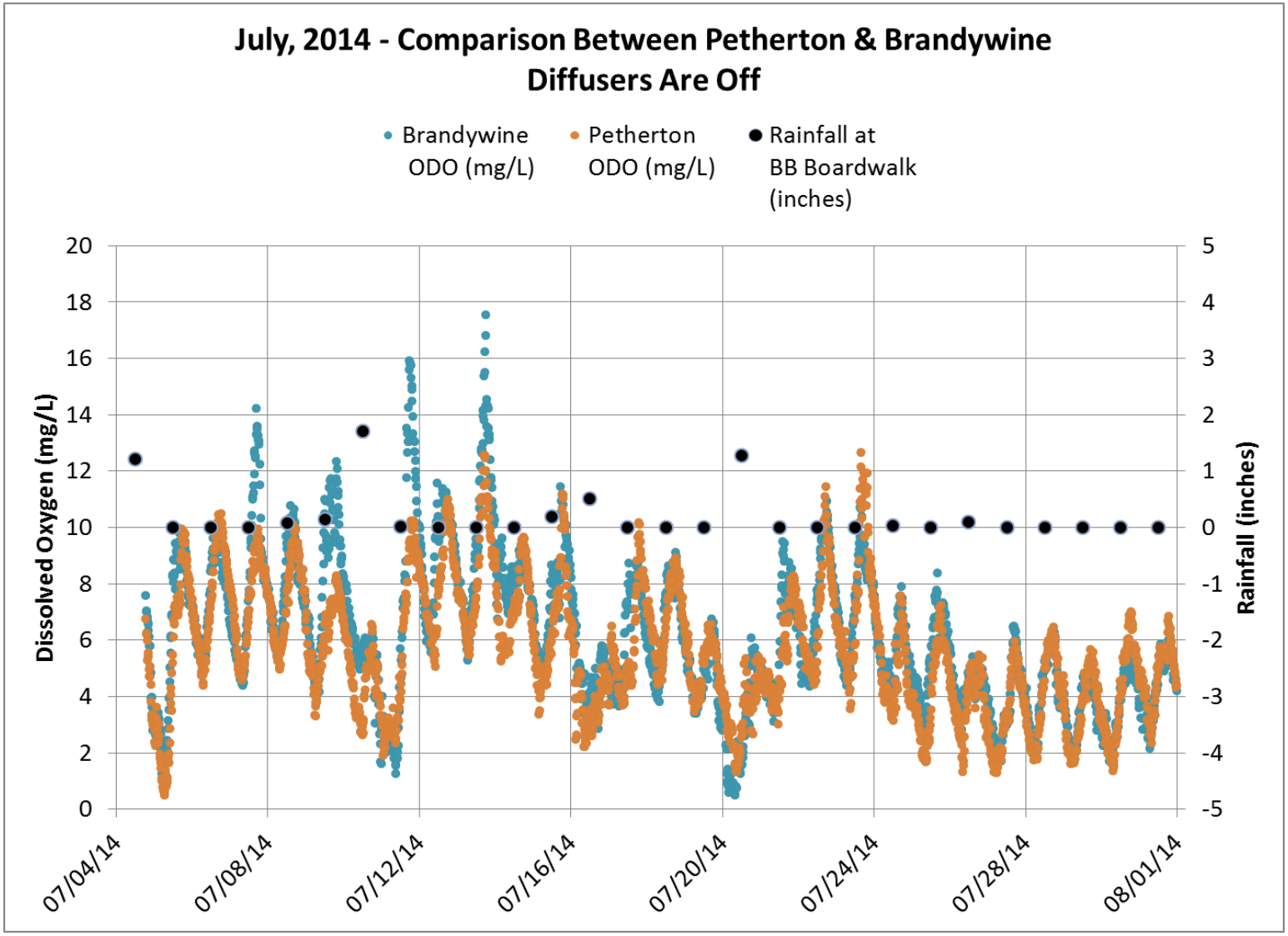
Only one of the three continuous monitors was operated in May, so no comparison is available.

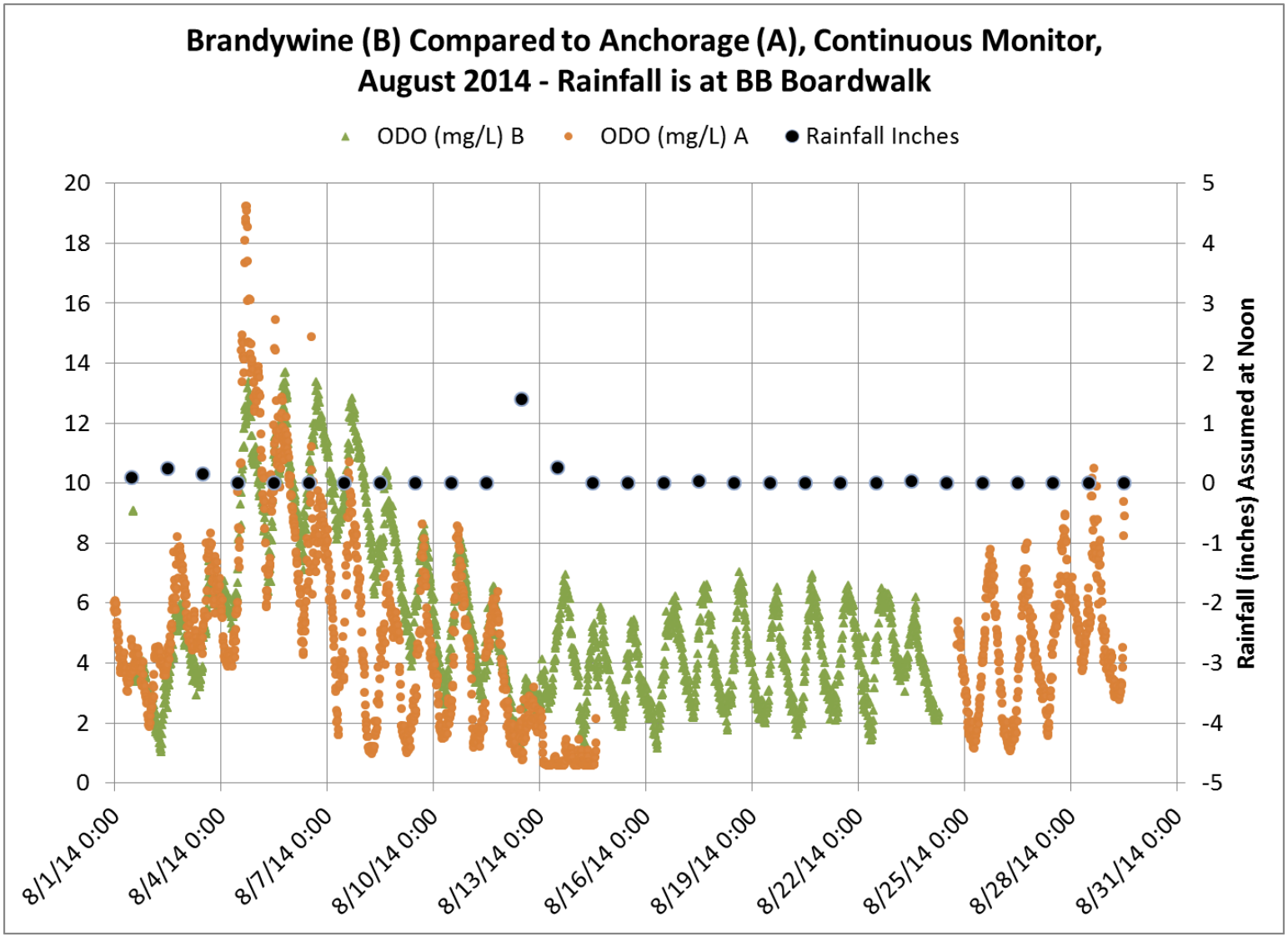


Only one of the three continuous monitors was operated in June, so no comparison is available.

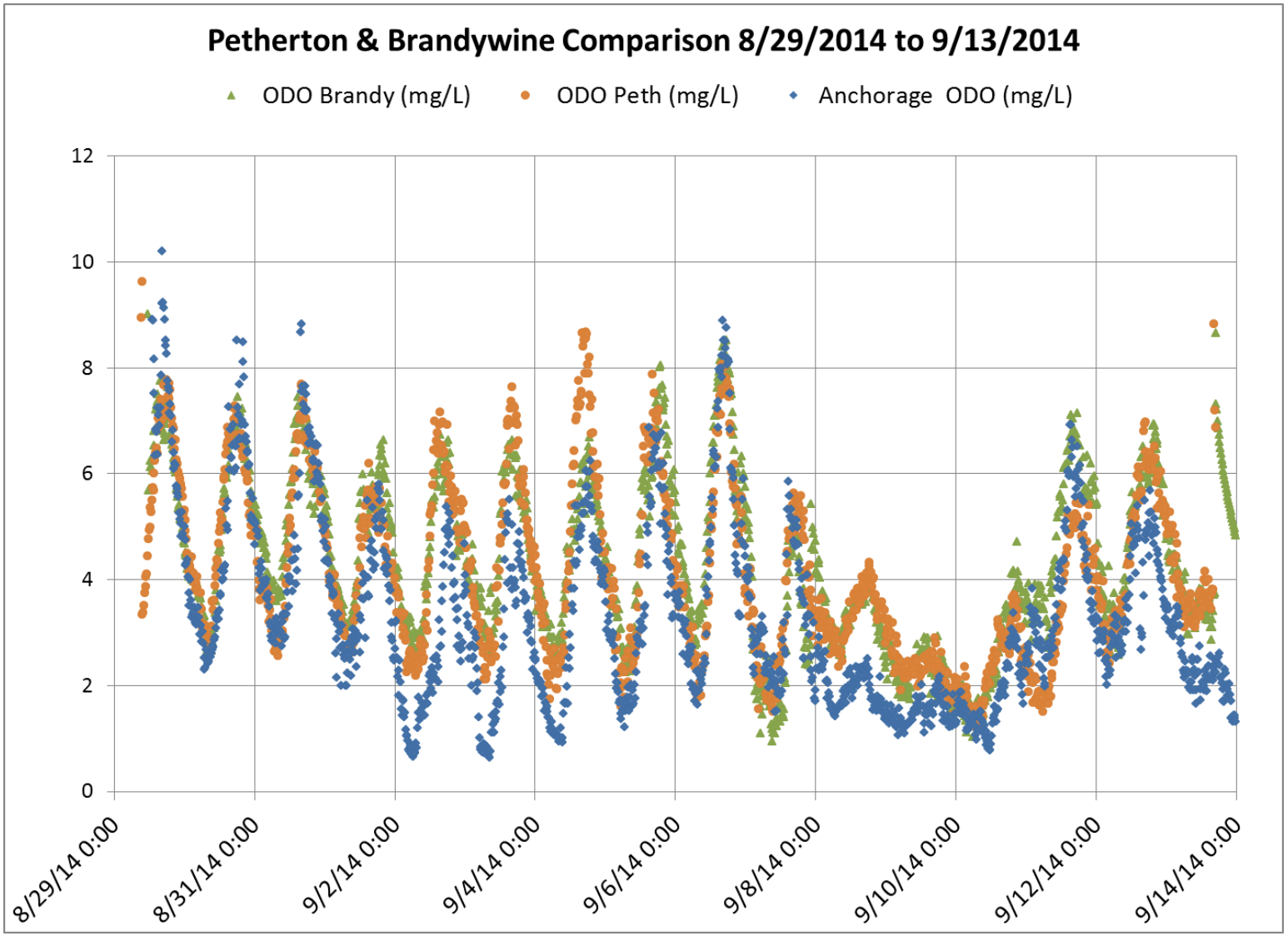


The diffusers were turned off for the month of July. In the beginning of July Brandywine had some higher peak DO values. Later in the month the DO values were very similar for Petherton and Brandywine Canals. Conclusion from the continuous data is that the two canals behave similarly when the diffusers are off. It also appears that rainfall could have caused a reduction in DO. Although during other times there is data that show this is not always true.

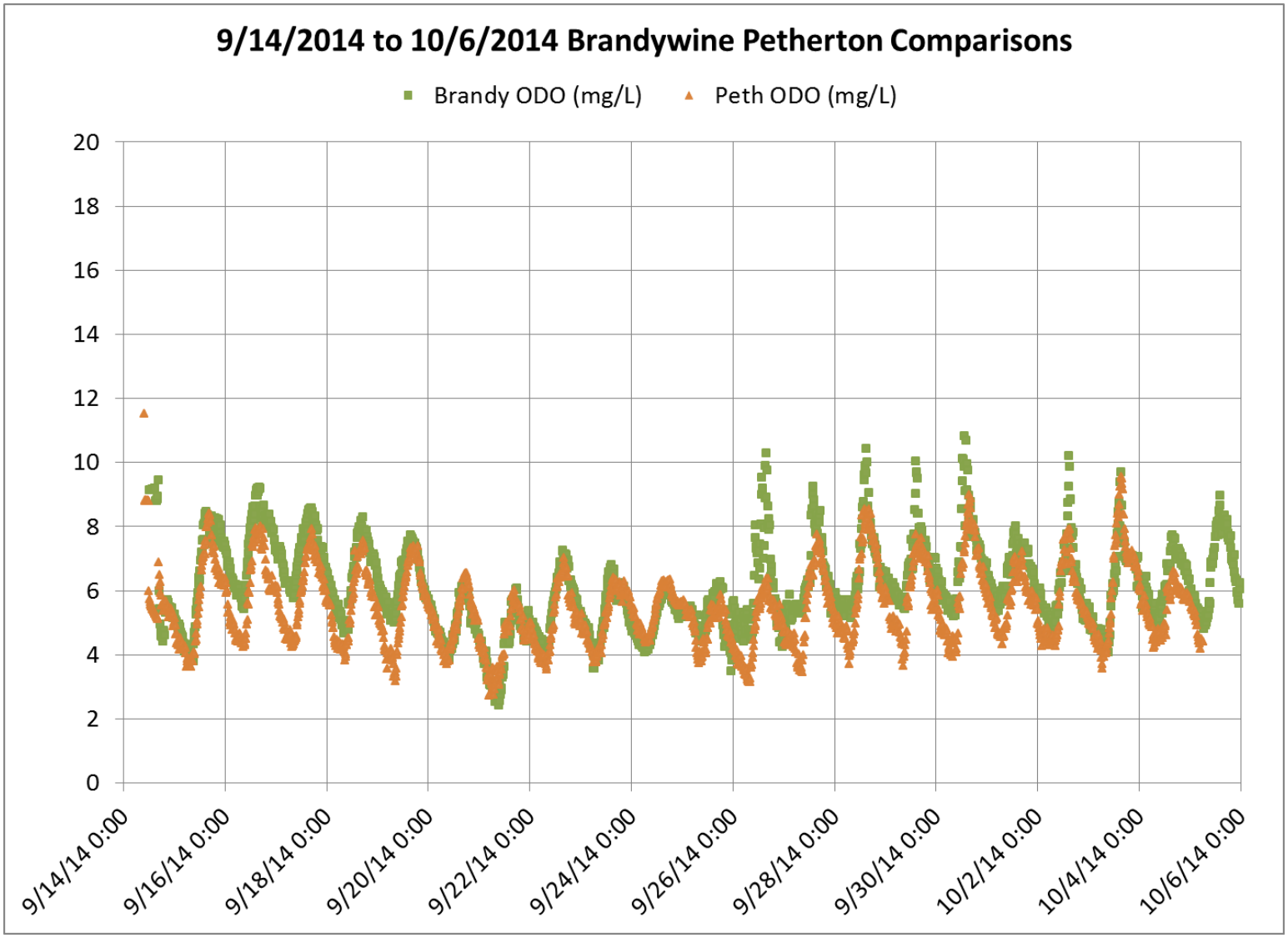



Brandywine (B) Compared to Anchorage (A), Continuous Monitor, August 2014 - Rainfall is at BB Boardwalk
ODO (mg/L) B
ODO (mg/L) A
Rainfall Inches
20
18
16
14
12
10
8
6
4
2
0
5
4
3
2
1
0
-1
-2
-3
-4
-5
Rainfall (inches) Assumed at Noon
8/1/14 0:00
8/4/14 0:00
8/7/14 0:00
8/10/14 0:00
8/13/14 0:00
8/16/14 0:00
8/19/14 0:00
8/22/14 0:00
8/25/14 0:00
8/28/14 0:00
8/31/14 0:00

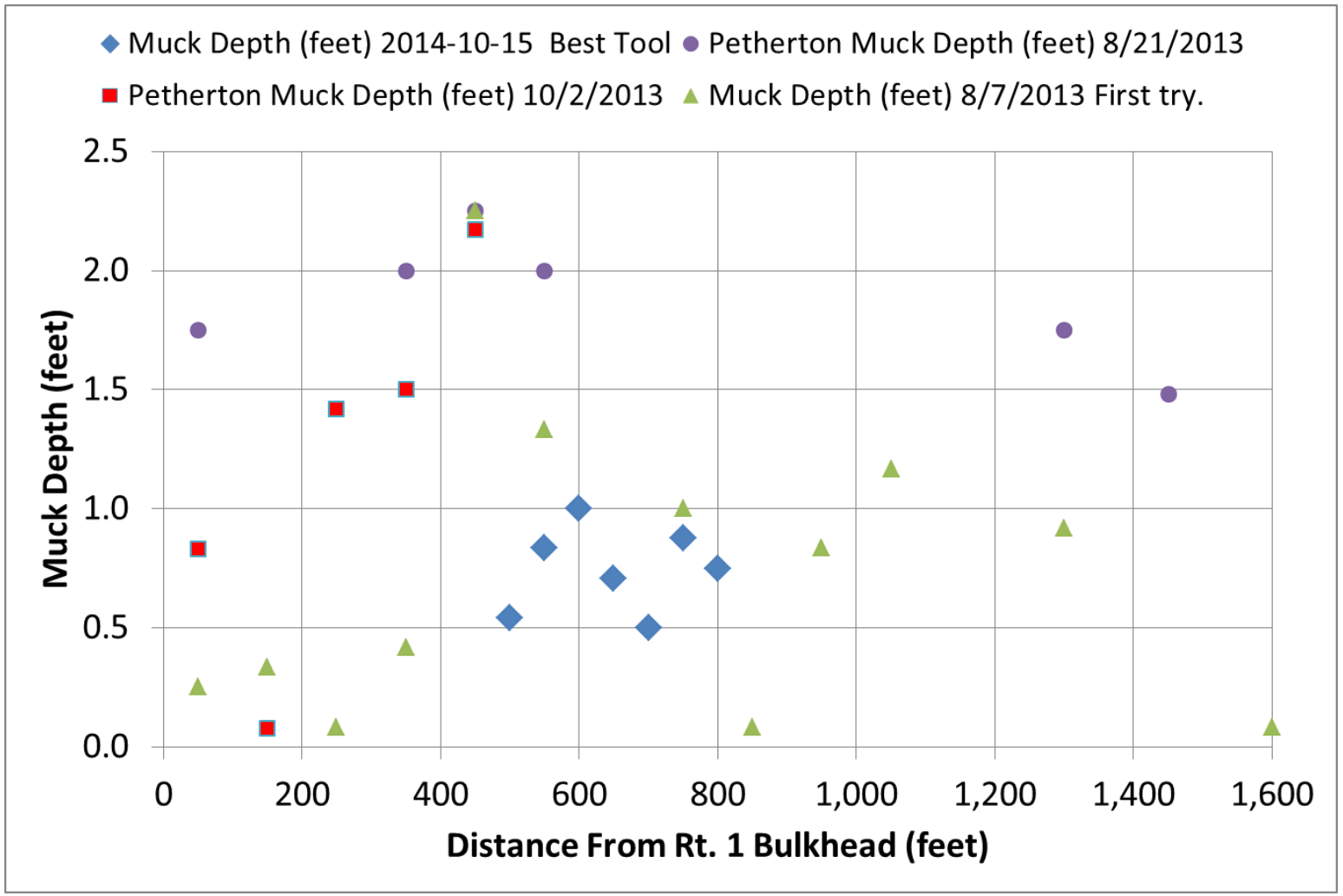
The Anchorage Canal Typically has lower DO than the other two canals.



Brandywine Canal usually has slightly higher DO than the Petherton Canal.



Muck Depth Measurements



Effect of Diffusers on Dissolved Oxygen Profile with Water Depth

November 11, 2014

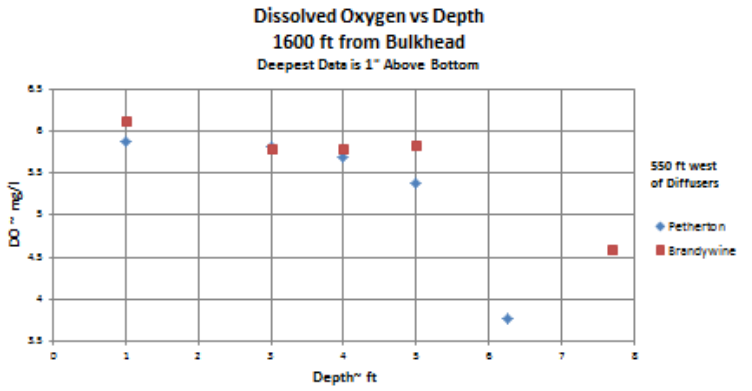
DO Measured in Brandywine and Petherton Canals by Kayak

- 5 different depths at 5 locations along each canal on September 18, 2014
- Deepest measurement 1 inch above bottom
- Six diffusers operational in Petherton Canal
- Calm with bright sun and ebb tide with water level dropping from 1.7 to 1.53ft NGVD during measurements

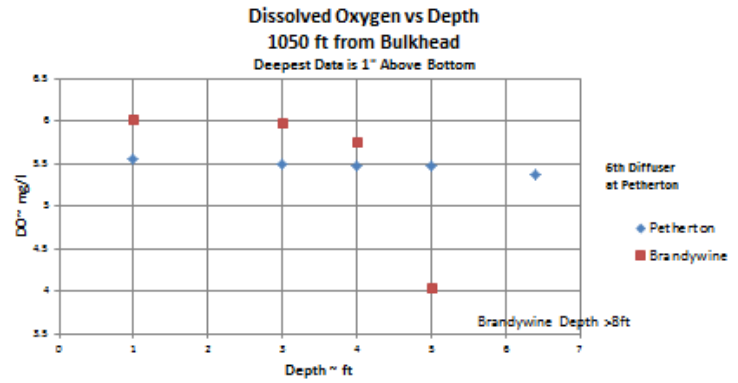
DO Measured in Brandywine and Petherton Canals by Kayak

- 5 different depths at 5 locations along each canal on September 18, 2014
- Deepest measurement 1 inch above bottom
- Six diffusers operational in Petherton Canal
- Calm with bright sun and ebb tide with water level dropping from 1.7 to 1.53ft NGVD during measurements

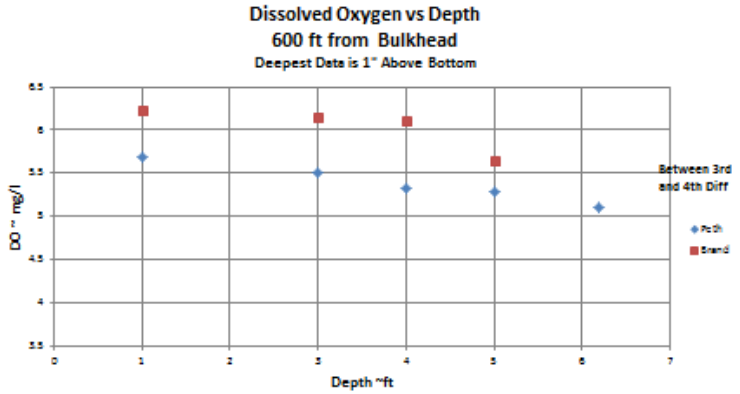
DO Depth Profile Away from Diffusers



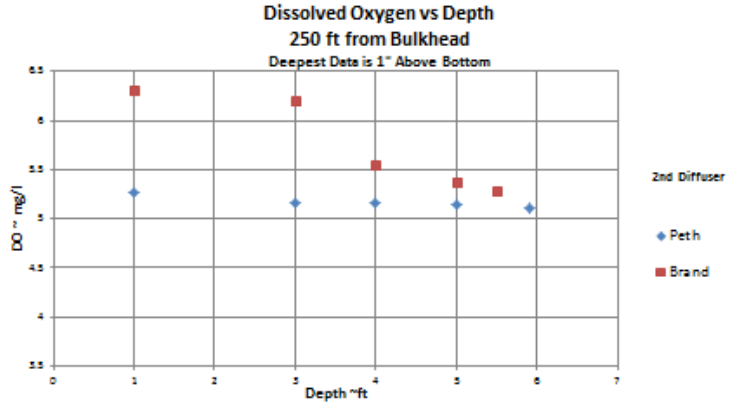
DO Depth Profile at Sixth Diffuser



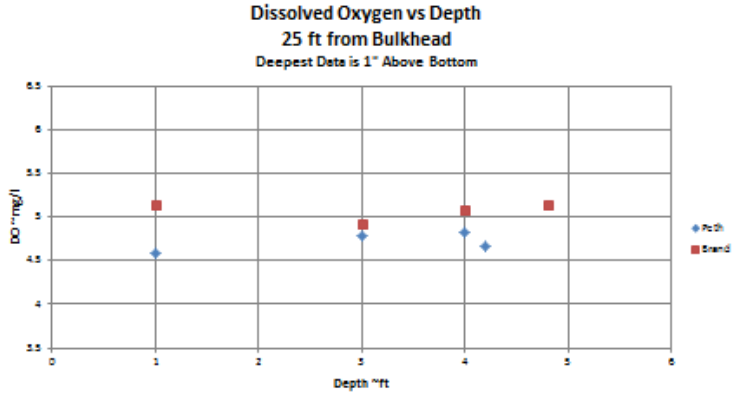
DO Depth Profile Between 3rd and 4th Diffusers



DO Depth Profile at 2nd Diffuser



DO Depth Profile 25 ft from Bulkhead



Simple Average DO for all 5 depth Readings Show Diffusers Do Not Increase DO Above Control Canal