COMPREHENSIVE
ENVIRONMENTAL
INCORPORATED

December 30, 2014

Mr. Chris Countie
Water Supply Manager
Pennichuck Water Works
200 Concord Street
Nashua, NH 03064

- Engineering
- Design
- Construction
- Inspection

Responsive service, cost-effective solutions, technical excellence

- Drainage & Flooding
- Energy & Sustainability
- Hazardous Waste
- Permitting & NEPA
- Stormwater & LID
- Transportation
- Water & Wastewater
- Watershed Restoration

RE: PENNICHUCK WATER WORKS
2007 – 2014 TRIBUTARY, GROUNDWATER AND IN-POND SAMPLING DATA

Dear Mr. Countie:

The purpose of this letter report is to present the results of the tributary sampling program performed May 2007 through December 2014. This report also presents the results of the groundwater piezometer sampling program performed July 2013 through December 2014, and briefly presents the results of the in-pond sampling program conducted by Pennichuck Water Works. Recommendations for changes to the monitoring program are also provided.

The program began in conjunction with the preparation of a Watershed Restoration Plan for the Pennichuck Brook Water Supply Watershed and included dry and wet weather sampling of nine tributaries and recording of continuous tributary flows through the use of data loggers. **Figure 1** shows the nine tributary sampling locations.

1.0 Background

Pennichuck Water Works, in coordination with the Nashua Regional Planning Commission (NRPC), has been collecting data from the watershed since 1991. Over this time, sampling locations and parameters varied until around 2005, at which time a sampling program using a specific set of water quality parameters was developed for nine tributary and five pond sampling locations within the watershed. This program was further refined in 2007 to include continuous flow monitoring and the collection of winter samples at tributary locations, beginning a more complete data set. Since then, water quality sampling and flow measurements at tributary locations have been ongoing, with modifications and adjustments made as needed.

In 2013, Pennichuck initiated a groundwater sampling program to evaluate phosphorus concentrations in the groundwater and how this compares with phosphorus concentrations used in the restoration plan model and those found in the tributaries. The model used a phosphorus groundwater concentration of 20 ppb as estimated from dry weather flow concentrations in the tributaries, which attributed about 20% of the watershed phosphorus load to groundwater inputs. The purpose of the groundwater evaluation is to allow for future adjustments of the watershed model and to determine whether additional recommendations to address this load are warranted.

This letter report focuses on the full data set collected from 2007 through 2014[1].

2.0 Monitoring Locations

Groundwater monitoring locations were selected to correspond with tributary sampling locations where possible (this was impractical in some cases due to property ownership). The nine groundwater and tributary sampling locations are shown on Figure 1 with descriptions provided in **Table 1**.

Table 1 – Groundwater and Tributary Sampling Locations

Groundwater Station ID	Tributary Station ID	Location / Description
01-BFB-MW	01-BFB-T	Boire Field Brook, Tinker Road, adjacent to tributary sampling location
09-PEN-MW	09-PEN-T	Holt Pond Dam, adjacent to tributary sampling location
09T-PEN-MW	09T-PEN-T	Route 101A Bridge, adjacent to tributary sampling location
09-XPB-MW[1] (01-CML)	09-XPB-T[1]	Unnamed Trib to Pennichuck Brook on 101A. (Craftsman Lane, Merrimack Valley Baptist Church, Merrimack)
01-WCH-MW	01-WCH-T	South Merrimack Road Bridge, adjacent to tributary sampling location
01-XWB-MW	01-XWB-T	Unnamed Trib to Witches Brook, adjacent to tributary sampling location
02-WCH-MW[1] (01-HAY)	02-WCH-T[1]	Ames Road Bridge on Route 122. (Hayden Road, Hollis, in PSNH electrical line easement)
12-PEN-MW	12-PEN-T	Nevins Road Bridge, adjacent to tributary sampling location
01-MUD-MW	01-MUD-T	Farley Road Bridge, adjacent to tributary sampling location

[1]Groundwater monitoring wells not installed adjacent to tributary sampling locations.

In addition, Pennichuck Water Works has been collecting in-pond data at five locations since 2007. In-pond stations and locations are shown on Figure 1 with descriptions provided in **Table 2**.

[1] No sampling was performed in 2009 due to ongoing discussions with the City of Nashua.

Table 2 – In-Pond Sampling Locations

Station	Description	Sample Locations
07F-PEN	Bowers Pond - 700' US of Bower	Surface and Bottom
08-PEN	Bowers Pond - Middle	Surface and Bottom
04-PEN	Harris Pond - 100' US of Harris	Surface and Bottom
06-PEN	Harris Pond - Middle	Surface and Bottom
07P-PEN	Bowers Pond - 1/4 mile DS of E	Surface Only

3.0 Data Collection

Monitoring activities presented in this report include those beginning in May of 2007 through December 2014 and excluding 2009 as previously described. During this time, Comprehensive Environmental Inc. (CEI) collected groundwater and tributary samples, while Pennichuck Water Works collected data from in-pond sampling locations.

Laboratory and Field Data
Tributary and groundwater samples were analyzed by assorted laboratories during the sampling program, most recently Granite State Analytical and Chemserve. Pennichuck Water Works also collected samples from in-pond locations for laboratory analysis of select parameters. The parameters analyzed for tributaries, groundwater and the ponds are summarized in **Table 3**.

Table 3 – Sampling Parameters

Field Analysis	Laboratory Analysis		
Tributaries and Groundwater	**Tributaries**	**Groundwater**	**Ponds**
• Conductivity • Dissolved Oxygen • pH • Temperature **Ponds** • Conductivity • Dissolved Oxygen • pH • Temperature • Turbidity	• Ammonia-N • Chloride • E. Coli • Fecal Coliform • Nitrate/Nitrite-N • TKN • Total Nitrogen • Total Phosphorus • TSS	• Ammonia-N • Chloride • Nitrate/nitrite-N • TKN • Total Nitrogen • Total Phosphorus	• Ammonia-N • Chloride • Chlorophyll • Color • E. Coli • Nitrate-N • Orthophosphate • TKN • Total Alkalinity • Total Coliform • Total Iron • Total Manganese • Total Phosphorus • TSS

TSS = Total Suspended Solids N = Nitrogen TKN = Total Kjehldahl Nitrogen

As recommended in the 2013 monitoring report, sodium sampling was eliminated from tributary and groundwater sampling to reduce costs and provide consistency with the in-pond sampling, which uses chloride analysis to represent salt concentrations.

Though all parameters are not discussed within this report, all data was tabulated and input into a water quality database, continuously updated since 2007.

In 2014, water samples were collected on the following dates:

- Tributaries and Groundwater – April 14th, May 8th, June 11th, July 14th, August 12th, September 18th, and November 5th. The sampling round scheduled for March was pushed to later in the year due to snow melt that could skew results.
- Ponds – June 18th, July 9th, July 23rd, August 7th, August 20th, September 10th, September 25th, & October 9th.

Staff Gauges, Data Loggers and Stage/Discharge Relationships
During previous monitoring efforts in 2005 and 2006, staff gauges were installed at the nine tributary locations and stage-discharge relationship equations were developed based on field measurements.

Electronic data loggers were installed at all tributary locations on May 21, 2007 to collect continuous, year-round stream elevations and to track long-term trends in flow. Data loggers collect and record stream elevations once per hour. The stage-discharge relationships are used to convert these elevations to an approximate flow for each tributary, which are used in flow-weighting sampling data. Several dataloggers did experience some damage or vandalism during portions of 2014 resulting in brief interruptions at stations 09T-PEN, 12-PEN, and 01-MUD, however, no major problems were encountered with data loggers in 2014.

4.0 Summary of Data Results

The sampling data results were analyzed for trends and correlations, as well as any unexpected data outliers. This section summarizes the overall results and trends of the multiple sampling programs, with more detailed discussion regarding specific parameters provided in Section 5.

Tributaries
Overall, the water quality in tributaries is similar to the last few years. Phosphorus concentrations continued to increase in tributaries compared with 2011-2012 levels, similar to what occurred in 2013.

Despite the recent increases in tributary phosphorus, the overall water quality trend for phosphorus since 2007 still shows an improvement. However, longer-term data is needed to draw any conclusions as to whether water quality is generally improving over time, as variability is expected to occur from year to year with changing weather conditions (e.g., temperature, rainfall volume, rainfall intensity, etc.).

In-Pond

In general, water quality in the ponds in 2014 was similar to previous years for most parameters. A decline in DO levels and phosphorus levels was generally noted. The decline in DO may be partially attributed to operational issues with the Harris Pond aerator and submerged boom in 2014, associated with the bridge rebuild on Manchester Street. Despite increasing phosphorus levels in the tributaries and the lower DO levels in the pond, which can promote the release of phosphorus from the pond sediments, phosphorus concentrations in the ponds were generally lower in 2014. The overall phosphorus trend since data collection in 2007 is still improving, however, variability in concentrations is expected from year to year and longer-term data is needed to draw any conclusions as to whether water quality is improving.

Groundwater

The 2014 groundwater and tributary phosphorus data correlates fairly well with highs and lows generally experienced in both the streams and groundwater at the same time in many cases. Elevated phosphorus concentrations were observed in groundwater, with site-wide averages ranging between 16.9 ug/L and 66.9 ug/L on a given date, and an overall average of 37.1 ug/L for all sampling rounds. Averages by location ranged from 23.8 ug/L to 56.8 ug/L. These averages exclude total phosphorus concentrations greater than 250 ug/L, which have been observed in 09T-PEN on a frequent basis and once in 09-XPB. The higher than typical concentrations in 09T-PEN are expected to be associated with fine silts in the well that pass through the filter. This well contains more silt than other locations and often results in clogging of the sampling equipment. The high concentrations in groundwater suggest groundwater is contributing a higher phosphorus load to the tributaries and ponds than predicted in the Watershed Restoration Plan model.

Chloride and conductivity levels in groundwater suggest that locations 01-BFB, 09-PEN, 09-XPB and 01-MUD are most influenced by road salting practices. With the exception of 01-MUD, higher chloride concentrations are also observed in the tributaries at these same locations.

5.0 Discussion of Sampling Parameters

Stream Flow

Stream flow is measured to assess trends including baseflow, to evaluate its influence on water quality parameters and to allow for conversion of pollutant concentrations to a mass loading.

Flow results measured at all tributary stations are roughly correlated to each other, as seen by similar rise and fall trends. Data available for the year is substantially complete with the exception of 12-PEN and 01-MUD during a 16 week period when dataloggers were vandalized. Additionally, a beaver dam or other obstruction during the fall at 12-PEN resulted in skewed staff gauge readings, making flows unreliable during this time. A brief data gap is present at station 09T-PEN when high spring flows inundated the datalogger. Data gaps are shown on the "Tributary Flow Data" figures for any missing or negative data, however, these data gap issues have been substantially reduced with the installation of new data loggers with larger or more efficient batteries.

Flow data for 09-XPB is only provided from September 2012 to the present. Previous data was deemed to be unreliable due to mechanical issues, and the datalogger has since been replaced. As recommended in the 2013 monitoring report, CEI re-measured flow velocities in the stream at 09-XPB during three separate events to better represent the range of water levels and flows in the stream under various conditions as previous data appeared unreliable outside of the known bounds of the stage-discharge curve. Even with these new measurements, the data appears to be unreliable due to the impacts the upstream culvert has on flow. Culvert crossings are typically good locations for measurements due to their accessibility and uniform dimensions for measuring flow, however, in this case it appears to restrict flow during high flow events and has relatively stagnant water during low flow events. Therefore, the stage-discharge relationship is somewhat unreliable during high and low flow events. A new location is recommended where the stream flows freely under various conditions (see recommendations Section 7).

Dissolved Oxygen

Dissolved oxygen (DO) is inversely proportional to temperature as it tends to fall during warmer months and recover during colder periods. Dissolved oxygen surface water quality standards specify a minimum concentration of 5.0 mg/L. Readings below 4.0 mg/L would be considered dangerous to aquatic organisms. DO in tributaries ranged between 1.66 mg/L and 12.44 mg/L. Similar, but slightly lower levels were observed in groundwater samples, however, a few groundwater samples exhibited higher DO than their tributary counterparts.

Samples from tributary stations 09T-PEN, 09-XPB, 01-WCH, 09-PEN and 01-MUD fell below standards multiple times in 2014, consistent with previous years. However, the spread between high and low DO concentrations was tighter in 2014 and overall the trendline between 2007 and 2014 continues to show an improvement. Tributary and groundwater DO trends are shown in **Figure 2**.

There was more variability in in-pond DO levels in 2014 than previous years. Several samples collected from near the pond surface fell below a DO of 4 mg/L in 2014, whereas in the past, these typically stayed above 4 mg/L, with only bottom samples falling below, which would be expected under stratified conditions. Overall, DO in the ponds was lower than past years with a high frequency of levels below 2 mg/L. This may be partially associated with the bridge rebuild on Manchester Street, which caused some operational issues with the Harris Pond aerator and submerged boom in 2014, which particularly influence 04-PEN DO levels. Low DO concentrations in the pond bottom can contribute to the release of phosphorus to the water column from bottom sediments when mixing occurs.

Total Suspended Solids (TSS)
TSS represents suspended material in the water. It can smother benthic macroinvertebrates as it settles to river bottoms, carry pollutants such as phosphorus, and contribute to declines in dissolved oxygen. TSS can also hide other pollutants, such as bacteria, complicating disinfection. High TSS levels may result from erosion of disturbed areas (e.g., construction sites) and of natural stream banks.

Dry weather TSS levels were low throughout the 2014 sampling period with small spikes noted in 12-PEN and 01-MUD in July 2014. These same locations show spikes in September 2013, and are generally below detection the remainder of the sampling periods. Historically, elevated levels of TSS have been associated with increased flows, which is to be expected as runoff washes sediments into the streams from surfaces and stream bank erosion. TSS does not have a numeric standard specified in the New Hampshire surface water quality standards. Very few states have a suspended solids criterion, and where they are in place, they range from 30 mg/L to 263 mg/L as a daily average/daily maximum depending on the type of water body (i.e., cold water vs. warm water).[2]

All tributary concentrations fell below 30 mg/L in 2014. All in-pond TSS concentrations also fell below 30 mg/L, with the exception of bottom sample 06-PEN, which had a high of 34 mg/L in October 2014. The overall average trend line for tributary TSS, considering all locations and excluding outliers >100 mg/L, is slightly increasing as shown on **Figure 3**. The same holds true for in-pond TSS concentrations. However, detection limits for in-pond samples were higher in 2014 than previous years, which can contribute to the increasing trendline.

Total Phosphorus
Phosphorus is a nutrient essential to plants and in excess amounts can cause algal blooms, particularly in fresh water systems. Algal blooms increase oxygen during the

---

[2] Developing Water Quality Criteria for Suspended and Bedded Sediments (SABS). Potential Approaches. A U.S. EPA Science Advisory Board Consultation. US EPA. Office of Water. Office of Science and Technology. August 2003.

day in turn decreasing oxygen at night. The resulting DO sag can impact fish habitat. Phosphorus can indicate the presence of sewage, animal waste, lawn fertilizer, erosion and may also come from natural wetlands.

Average phosphorus concentrations by location and by date are shown in **Table 4** and **Table 5**, respectively.

Table 4 – Comparison of Average Phosphorus Concentrations by Location (ug/L) – August 2013 – November 2014

Station ID	Groundwater	Tributaries
01-BFB	41.3	31.4
09-PEN	46.9	34.4
09T-PEN	30.3	30.8
09-XPB (01-CML)	56.8	32.9
01-WCH	30.7	32.2
09-XWB	31.1	29.6
02-WCH (01-HAY)	36.9	28.6
12-PEN	30.4	32.5
01-MUD	23.8	37.7

Note: Excludes outliers with concentrations greater than 250 ug/L.

Table 5 – Comparison of Average Phosphorus Concentrations by Date (ug/L)

Date	Groundwater[1]	Tributaries
8/16/2013	28.0	21.0
9/10/2013	29.3	28.8
10/28/2013	33.1	38.4
4/14/2014	31.3	36.4
5/8/2014	66.9	48.3
6/11/2014	45.6	29.8
7/14/2014	53.8	63.2
8/12/2014	16.9	24.0
9/18/2014	50.6	19.9
11/5/2014	15.1	12.4
Total Average	37.1	32.2

Notes:
[1]Excludes outliers with concentrations greater than 250 ug/L.
[2]Total phosphorus concentration at 09-XPB on 9/18/14 was 221 ug/L, which raises the average for this date. If 09-XPB data is excluded, the average is 26.3 ug/L.

Tributary phosphorus concentrations were similar to 2013, which are higher than the 2010 through 2012 period. On average, tributary stations 01-MUD, 09-PEN and 09-XPB showed the highest phosphorus concentrations in 2014 (refer to Table 4). This corresponds with high concentrations in groundwater locations 09-PEN-MW and 09-

XPB-MW, however groundwater phosphorus concentrations were lowest in 01-MUD. The highest phosphorus concentrations in both tributaries and groundwater occurred in May and July 2014 (tributary high of 63.2 ug/L and groundwater high of 66.9 ug/L) with the lowest concentrations in November 2014 (tributary low of 12.4 ug/L and groundwater low of 15.1 ug/L). Overall, average tributary phosphorus concentrations (average of all locations) compared well with average groundwater concentrations on most dates, with the exception of June 2014 and September 2014, where phosphorus concentrations in groundwater were significantly higher.

Groundwater samples are filtered using a 45-micron filter to remove sediment particles before analysis, thus, phosphorus concentrations represent dissolved phosphorus. Dissolved phosphorus concentrations in the filtered groundwater samples ranged from less than 10 ug/L to as high as 2,110 ug/L at 09T-PEN-MW, however, 09T-PEN-MW contains a lot of silt in the well, some of which makes it into the sample, despite double filtering. If we exclude 09T-PEN-MW data, the next highest phosphorus concentrations were observed at 09-XPB, with a high of 379 in ug/L in April 2014 and 221 ug/L in September 2014.

Excluding phosphorus concentrations that exceed 250 ug/L, the average phosphorus concentrations in groundwater ranged from 23.8 ug/L (01-MUD) to 56.8 ug/L (09T-XPB-MW) by location (refer to Table 4) with an overall average concentration of 37.1 ug/L over all sampling dates (refer to Table 5). All averages by location (Table 4) exceed the 20 ug/L assumed phosphorus groundwater concentration in the 2012 Restoration Plan model, suggesting that groundwater is contributing a higher phosphorus load to the tributaries and ponds than predicted in the Watershed Restoration Plan model.

While phosphorus concentrations have increased in tributaries since 2010, the overall phosphorus concentration trend excluding outliers >250 ug/L is still slightly improving since 2007 and the start of the watershed restoration program as shown on **Figure 4**. Since precipitation events and tributary flows can influence these concentrations, the data was flow weighted to determine the mass load of phosphorus during each sampling event. This represents the amount of the phosphorus in pounds in the stream on a given day (**Figure 5**). The data show increasing phosphorus load trends in four of the nine sampling locations, with decreasing or flat trend lines at the remaining locations. Locations 01-XWB and 09T-PEN show the greatest increase in phosphorus loads over the last two years.

In-pond phosphorus concentrations generally decreased since 2013, with an overall decreasing trend in phosphorus concentrations noted since 2007, despite generally lower DO levels in the pond, which can contribute to the release of phosphorus to the water column from bottom sediments. While the overall average water quality trend for all data is still improving (declining trend) as shown in **Figure 6**, there continues to be some variability from year to year and longer-term data is needed to determine whether there is an actual improvement.

While there is no numeric standard for phosphorus, for assessment purposes, as described in NHDES's Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology (CALM) used to assess the impairment status of waters, the thresholds for aquatic life are defined by trophic class as provided in Table 6. Concentrations below these values are assumed to support the aquatic life associated with the trophic status of the water body.

Table 6 – Aquatic Life Trophic Class

Trophic Status	**TP (ug/L)**
Oligotrophic	<8
Mesotrophic	≤12
Eutrophic	≤28

NHDES's Description of River Water Quality Parameters[3] indicates total phosphorus levels greater than 51 ug/L in streams is considered excessive and a potential nuisance concentration. For lakes and ponds, NHDES's VLAP Chemical Parameter Explanations[4] indicates that greater than 40 ug/L is considered excessive.
Ideally, only naturally occurring phosphorus should be present, typically from 14 ug/L to 17 ug/L under natural conditions. Several tributary and groundwater samples collected during 2014 exceed 50 ug/L, however, in-pond phosphorus concentrations were generally lower, with only a few samples exceeding 40 ug/L and an overall average phosphorus concentration of 17.8 ug/L in the surface waters of the ponds. The average in-pond concentration in 2014 was similar to the lower concentrations observed in 2011 and 2012. Refer to Table 7 and **Figure 7** for average in-pond phosphorus concentrations by year.

[3] http://des.nh.gov/organization/divisions/water/wmb/vrap/documents/wq-resultsinfo.pdf. Downloaded December 24, 2014.
[4] http://des.nh.gov/organization/divisions/water/wmb/vlap/documents/parameters.pdf. Downloaded December 24, 2014.

Table 7 – Average In-Pond Concentrations (ug/L)

Date	07F-PEN Bowers Pond (Lower)		08-PEN Bowers Pond (Upper)		04-PEN Harris Pond (Lower)		06-PEN Harris Pond (Upper)		07P-PEN Bowers Pond (Mid)	Average Bottom	Average Top	Average Top & Bottom
	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Top			
2007	20.0	16.0	22.0	17.5	19.5	19.5	32.5	18.5	54.0	23.5	25.1	24.4
2008	31.8	29.5	35.8	33.3	33.0	35.0	47.8	23.0	95.7	37.1	43.3	38.9
2009	26.0	24.0	34.0	24.0	50.0	58.0	26.0	24.0	0.0	34.0	26.0	33.3
2010	47.9	44.4	20.9	28.2	30.0	23.2	42.2	27.0	36.9	35.2	31.9	33.5
2011	32.0	15.0	22.3	15.7	16.3	15.8	25.2	15.8	17.7	24.0	16.0	19.5
2012	25.7	17.2	27.2	24.8	22.1	13.7	18.8	14.8	24.4	23.4	19.0	21.0
2013	49.1	33.2	38.8	45.8	32.6	34.6	65.6	39.5	46.0	46.5	39.8	42.8
2014	30.6	21.1	24.0	15.1	13.9	11.4	26.6	15.8	25.5	23.8	17.8	20.4

Escherichia Coliform Bacteria (*E.coli*)
E. coli represents bacteria associated with the fecal matter of warm-blooded animals. It is often used to determine whether water is safe for swimming and requires treatment for use as drinking water. It may indicate the presence of sewage or wildlife.

E.coli levels were generally higher in the tributaries compared to 2013, however, this varied by location and time of year. The overall trend of E.coli is slightly improving or straight at all stations with the exception of 01-BFB and 01-MUD, which showed a slight upward trend or increase in concentration. However, there was no pattern in the increase in concentration, with highest concentrations occurring on different dates for most locations.

In-pond E.coli levels were typically highest at surface locations, with all but two samples falling below 20 MPN/100 mL. The overall water quality trend continues to remain slightly improving since 2007, with typical variability from year to year.

Refer to **Figure 8** for data results between 2007 and 2014. E.coli data was not analyzed for groundwater samples.

E.coli should not exceed 153 cts/100 mL for any single sample, based on numeric standards for Class A waters. With the exception of seven out of 63 tributary samples, the remainder of samples (tributary and pond) met the numeric threshold for Class A waters.

Nitrogen

Nitrogen is also a nutrient essential for algae and other plant growth and excess amounts can lead to nuisance algae blooms, however, phosphorus is typically the limiting nutrient in fresh water systems.

Nitrates/Nitrites

Nitrates and nitrites are nitrogen-oxygen chemical units that combine with various organic and inorganic compounds. Nitrates are highly mobile and can leach into groundwater. Common sources of nitrate/nitrite include fertilizers and manure, animal feedlots, municipal wastewater and sludge, septic systems and nitrogen fixation from the atmosphere.

Total nitrate/nitrite-N tributary results were low in 2014, typically non-detect or below 1 mg/L. Nitrate/nitrite-N levels in groundwater varied considerably ranging from non-detect levels (>0.05 mg/L) to 3.6 mg/L at station 09-PEN-MW during November 2014. 09-PEN-MW also had some of the highest phosphorus concentrations. Only four stations had detectable levels of nitrate/nitrate in the groundwater in 2014, compared to seven stations in 2013. Refer to Attachment A for water quality graphs of nitrates/nitrites.

The EPA has established a Maximum Contaminant Level Goal (MCLG) for nitrates and nitrites in public drinking water systems of 10 mg/L and 1 mg/L, respectively.[5] Nitrites only exceeded 1 mg/L in groundwater at one location, 01-WCH in September 2014. The nitrate drinking water standard of 10 mg/L was not exceeded in 2014, however, low levels of nitrates were present at several locations. This combined with the phosphorus data suggest contributions from fertilizers, manure or wastewater.

Total Kjeldahl Nitrogen (TKN)

TKN represents organic nitrogen and ammonia nitrogen, which can indicate the presence of sewage, animal waste, fertilizer, erosion, or other types of pollution. TKN was detected at low concentrations at several tributary locations in 2014 compared to non-detect levels at all locations in 2013. It was also detected at three in-pond surface locations in 2014, compared to non-detect levels at all in-pond locations in 2013, but not unusual compared with historic data collected since 2007.

TKN in groundwater ranged from non-detect to 4.2 mg/L in April 2014 at 09T-PEN-MW. Most locations were non-detect throughout 2014, with the exception of 09T-PEN-MW and 09-PEN-MW. Refer to Attachment A for water quality graphs of TKN.

[5] NHDES Fact Sheet, Nitrate and Nitrite: Health Information Summary (ARD-EHP-16)

TKN does not have a numeric standard specified in the New Hampshire surface water quality standards. However, NHDES in conjunction with the Volunteer River Assessment Program (VRAP) has suggested that TKN concentrations <0.25 mg/L are ideal, and <0.40 mg/L are average.[6] Some of the filtered groundwater and non-filtered tributary samples were above 0.5 mg/L, along with three in-pond TKN concentrations; however, the majority of the samples collected are non-detect or below.

<u>Ammonia-Nitrogen</u>
As with TKN, ammonia is a nutrient that contributes to plant growth. Ammonia-nitrogen toxicity is dependent on pH levels. When the pH is below 8.75, $NH4^+$ dominates. Basic pH above 9.75 can cause NH3 to dominate, which is more toxic to aquatic species. Measurement of TKN and ammonia-nitrogen allows for estimation of organic nitrogen by subtracting the concentration of ammonia-nitrogen from TKN. Ammonia-nitrogen should be less than 0.64 mg/L as per New Hampshire water quality standards. All tributary and in-pond samples collected in 2014 were non-detect for ammonia-nitrogen.

pH
pH measures the acidity of water and can affect biological processes in water important to aquatic life. It can also affect the treatment process for drinking water.

pH appears relatively consistent in tributaries during the 2013 period, generally ranging between 6 and 8, further confirming that the extreme dips in pH identified at tributary locations in August of 2007 and October of 2008 are likely anomalies associated with equipment malfunctions. Groundwater pH is slightly lower, generally ranging between 5.5 and 7.5 as expected due to the generally acidic nature of soil in the area. pH levels in the ponds are generally between 6 and 7.5, similar to pH levels in tributaries. The dip in pH at 08-PEN TOP is anticipated to be associated with an equipment malfunction. The Class A NH Surface Water Quality Standard for pH is between 6.5 and 8.0 unless naturally occurring, and no groundwater standards are available. Refer to Attachment A for water quality graphs of pH.

Conductivity
Conductivity measures the total dissolved solids including free ion (charged particles) content in water and can indicate the presence of chlorides, and total dissolved solids including nitrates, sulfates, phosphates, and sodium, magnesium, calcium, iron, and aluminum ions. Possible sources include road salt, septic systems, wastewater treatment plants, urban/agricultural runoff or naturally occurring from surrounding geology. Polluted water usually has a higher conductivity than unpolluted water.

---

[6] NHDES Interpreting VRAP Water Quality Monitoring Parameters

Tributary conductivity levels were relatively consistent between sampling stations in 2014 with the highest concentrations in the spring (May), followed by summer (July and August), and decline in fall. This is consistent with historic concentrations with trends reflecting higher spring conductivity, likely associated with winter sanding/salting of roadways and spring snow melts. Location 01-BFB, located near the F.E. Everett Turnpike, continues to have the highest conductivity levels, likely associated with winter salting of the highway.

Conductivity in groundwater was also highest in the spring and summer with a notable decline in the fall. Conductivity in the ponds shows more variability in the rise and fall of concentrations, with the highest concentrations in the summer followed by a decline and then another rise into fall. Bottom samples generally have higher conductivity levels than near-surface samples.

New Hampshire water quality standards do not specify a numeric standard for conductivity, however, a waterbody with conductivity greater than 2,000 umhos/cm would be considered high in dissolved solids. All samples from 2014 are substantially less than 2,000 umhos/cm. Refer to Attachment A for water quality graphs of conductivity.

Sodium/Chloride

Sodium and chlorides represent salt content in the water, typically associated with salting of roadways. As recommended in the 2013 monitoring report, sodium sampling was eliminated from tributary and groundwater sampling to reduce costs and provide consistency with the in-pond sampling, which uses chloride analysis to represent salt concentrations.

Chloride levels were generally highest in August and September in the tributaries and in spring/early summer in in the groundwater. The highest tributary concentrations were at 01-BFB, 09-XPB and 09-PEN. The highest groundwater concentrations were at corresponding locations 01-BFB-MW, 09-XPB-MW and 09-PEN-MW. Higher concentrations were also observed at 01-MUD-MW, however, this does not correlate with the lower tributary concentrations at 01-MUD. Generally, the higher concentrations in both groundwater and tributary locations indicates the influence of roadway salting practices in these areas.

In-pond concentrations were more variable with swings in concentrations throughout the year, similar to those observed for conductivity.

In order to protect freshwater aquatic life, New Hampshire has adopted acute and chronic chloride water quality standards of 860 and 230 mg/L, respectively for surface waters. Consistent with past sampling results, chloride levels in the ponds fell below the water quality standards in all cases. Chloride levels in the tributaries fell below the water quality standards in all but three samples (two in 01-BFB at 259 and 246 mg/L and one in 09-XPB at 453 mg/L).

There are no standards for chloride in groundwater, however, typical background levels for pristine locations in New Hampshire are less than 30 mg/L.[7] Observed chloride levels in groundwater are above background concentrations at all locations, however, the surface water concentrations in the pond and tributaries generally remain below water quality standards. Refer to Attachment A for water quality graphs of chloride.

6.0 Conclusions

Overall water quality is consistent or improving since the start of the 2007 watershed restoration program as shown by the trendlines of key water quality parameters in Figures 2 through 8. Overall trends of total phosphorus, E.coli and DO since 2007 are still generally improving, despite some variability from year to year. Total suspended solids (TSS) concentrations show an increasing trend when outliers greater than 100 mg/L are excluded from the data set. If these outliers are included, a decreasing trend is observed with a lower frequency of extremely high concentrations in more recent years.

While overall improvements are noted since 2007, there still exists a substantial amount of variation between years, which can have greater influence over a shorter period of record. For example, an overall decline in total phosphorus was observed in 2011 and 2012 suggesting an overall improvement in water quality, however, 2013 and 2014 show higher concentrations, reflecting the variability from year to year. Considering this year to year variability, longer-term trends are needed to draw any conclusions as to whether the water quality is actually improving with time.

7.0 Recommended Changes to the Monitoring Program

Pennichuck has been collecting streamflow data since 2007. The data was originally collected to help calibrate the model used in the 2008 Watershed Restoration Plan and continues to be collected to provide overall trend data and information for future modeling efforts. Sampling in 2014 was largely successful on all fronts. Data loggers performed largely as expected, and dry weather sampling was performed as scheduled.

It is recommended that Pennichuck continue to download data from field data loggers approximately every six weeks. Additionally, it is recommended that the datalogger and staff gauge at station 09-XPB be relocated to a location not subject to standing water or flow constriction due to a nearby culvert. A recommended location is adjacent

[7] NHDES Fact Sheet, Sodium and Chloride in Drinking Water, 2010 (WD-DWGB-3-17)

to the groundwater monitoring well 01-CML off of Craftsman Lane, just upstream of the current location.

Dry weather tributary sampling should continue approximately as follows in Table 8:

Table 8 – Proposed Dry Weather Sampling Schedule

2014 Month			
March	April	May	July
August	September	November	

Future sampling programs should include analysis of the parameters included in Table 9, consistent with the 2014 sampling program.

Table 9 – Proposed Sampling Parameters

Field Analysis	**Laboratory Analysis**		
Tributaries and Groundwater	**Tributaries**	**Groundwater**	**Ponds**
• Conductivity • Dissolved Oxygen • pH • Temperature **Ponds** • Conductivity • Dissolved Oxygen • pH • Temperature • Turbidity	• Ammonia-N • Chloride • E. Coli • Fecal Coliform • Nitrate/Nitrite-N • TKN • Total Nitrogen • Total Phosphorus • TSS	• Ammonia-N • Chloride • Nitrate/nitrite-N • TKN • Total Nitrogen • Total Phosphorus	• Ammonia-N • Chloride • Chlorophyll • Color • E. Coli • Nitrate-N • Orthophosphate • TKN • Total Alkalinity • Total Coliform • Total Iron • Total Manganese • Total Phosphorus • TSS

TSS = Total Suspended Solids N = Nitrogen TKN = Total Kjehldahl Nitrogen

If you have any questions or require any additional information, please do not hesitate to contact me at (603) 424-8443.

Sincerely,

COMPREHENSIVE ENVIRONMENTAL INC.

Rebecca Balke

Rebecca Balke, P.E.
Project Manager

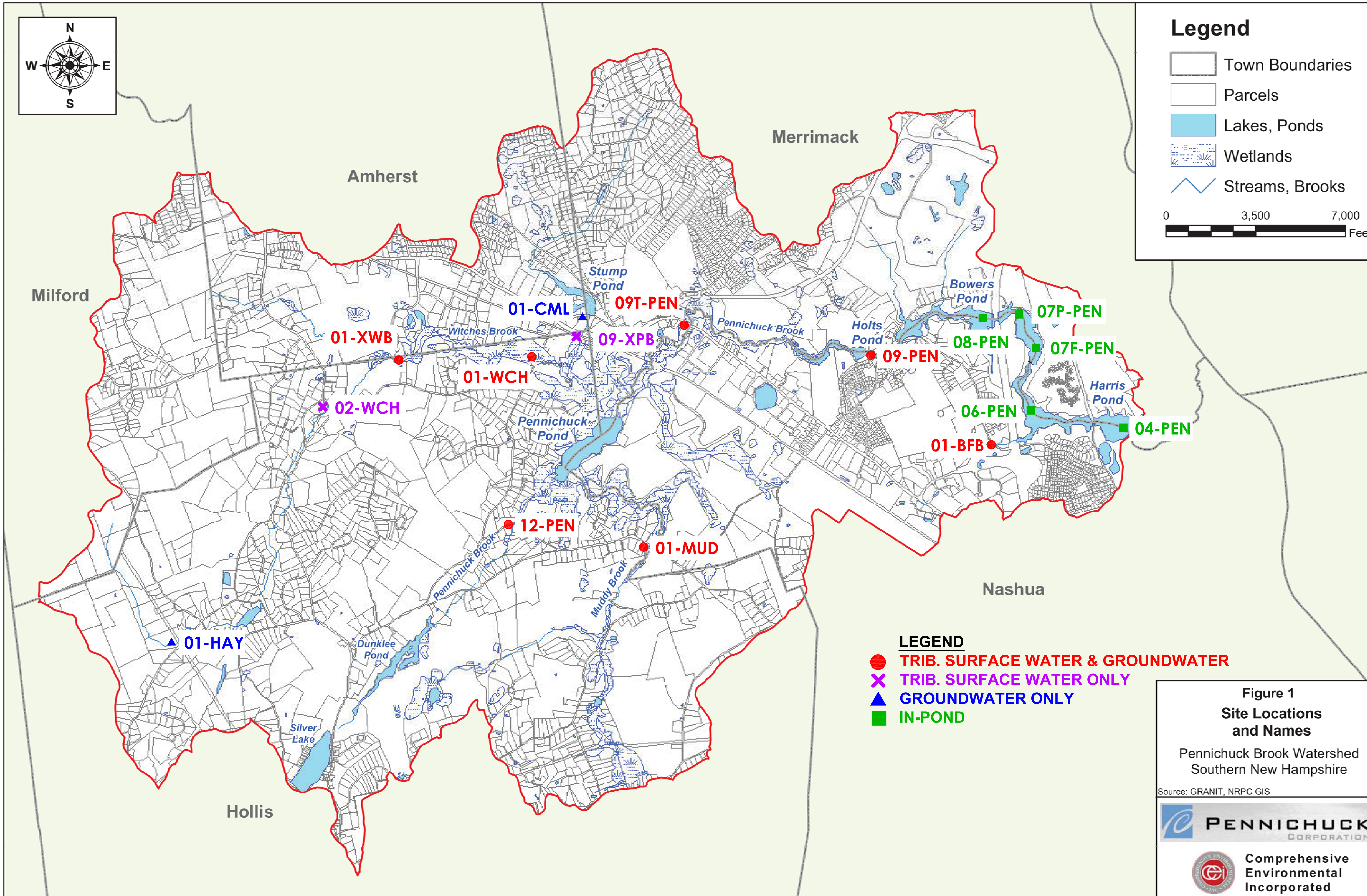
cc: Donald Ware, P.E., Chief Operating Officer, Pennichuck Corporation
Eileen Pannetier, President, CEI
Richard Cote, Principal, Manager of Engineering, CEI
Nick Cristofori, Project Engineer, CEI

Figures:

- Figure 1: Site Locations and Names
- Figure 2: Dissolved Oxygen Trends in Tributaries, 2007-2014
  Dissolved Oxygen in Groundwater, 2012-2014
- Figure 3: TSS Trends in Tributaries, 2007-2014
- Figure 4: Phosphorus Trends in Tributaries, 2007-2014
  Phosphorus in Groundwater, 2012-2014
- Figure 5: Phosphorus Load Trends in Tributaries, 2007-2014
- Figure 6: Phosphorus Trends for In-Pond Locations, 2007-2014
- Figure 7: Average Phosphorus Concentrations and Trends for In-Pond Locations, 2007-2014, Surface Locations and Bottom Locations
- Figure 8: E.coli Trends in Tributaries, 2007-2014
  E.coli Trends in Ponds, 2007-2014

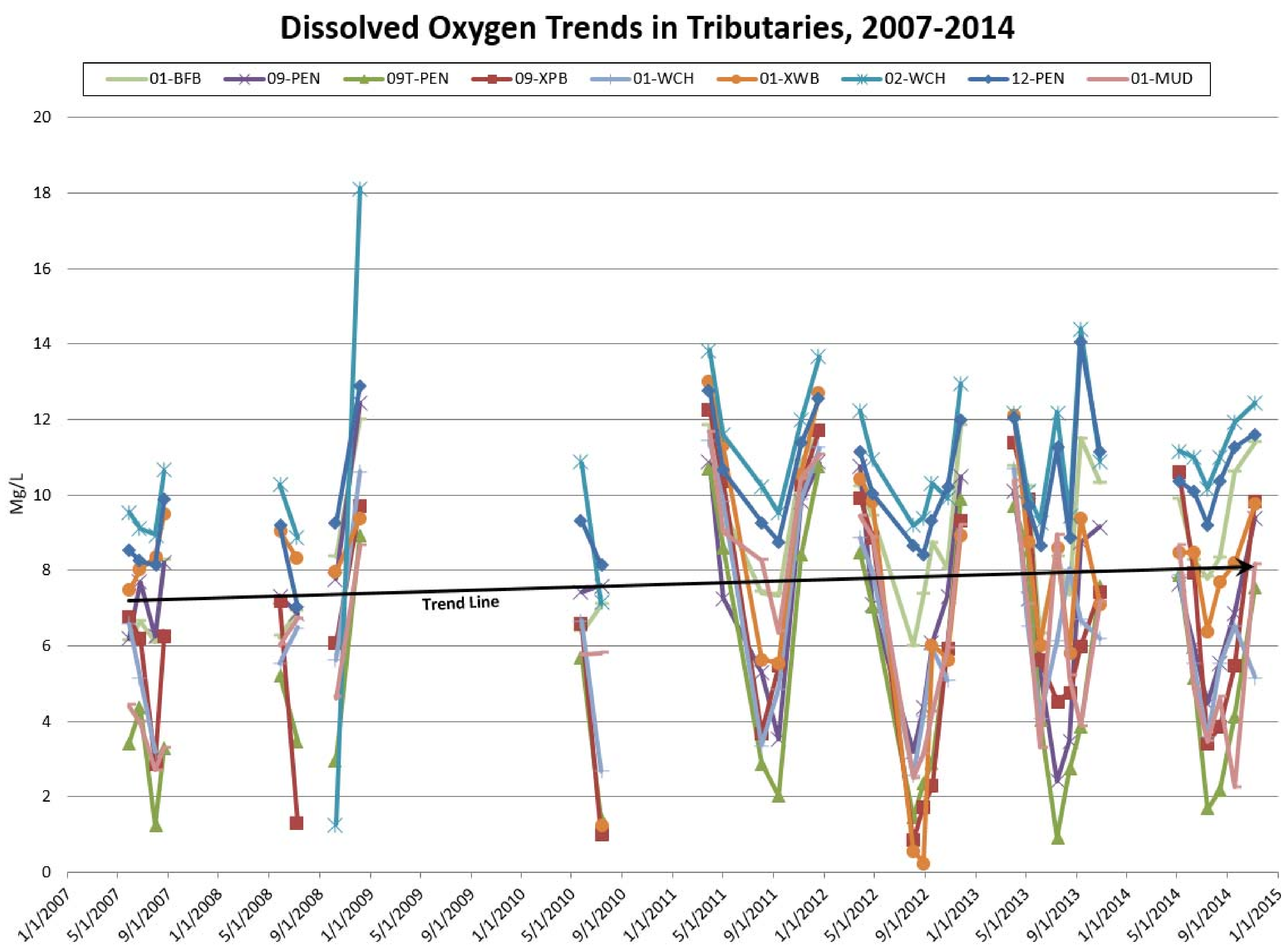
Attachment A – Supporting Graphs

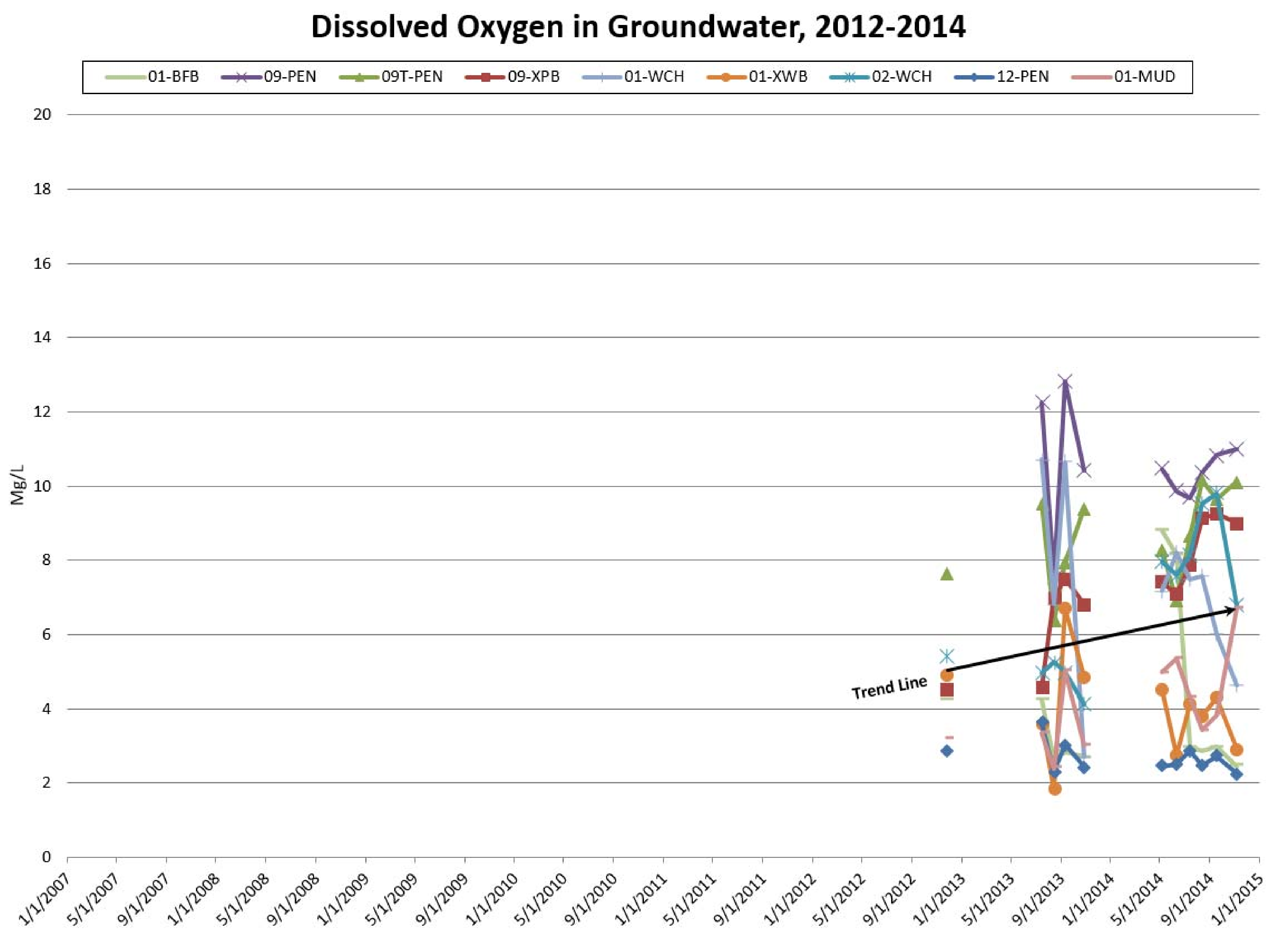
- Tributary Flow Data Graphs
- 2007-2014 Tributary Trendline Graphs
- 2007-2014 Groundwater Trendline Graphs
- 2007-2014 In-Pond Trendline Graphs



N
W
E
S
Legend
Town Boundaries
Parcels
Lakes, Ponds
Wetlands
Streams, Brooks
0
3,500
7,000
Feet
Merrimack
Amherst
Milford
Nashua
Hollis
Stump Pond
Bowers Pond
Holts Pond
Harris Pond
Pennichuck Pond
Dunklee Pond
Silver Lake
Witches Brook
Pennichuck Brook
Muddy Brook
01-CML
09T-PEN
01-XWB
09-XPB
01-WCH
02-WCH
09-PEN
08-PEN
07P-PEN
07F-PEN
06-PEN
04-PEN
01-BFB
12-PEN
01-MUD
01-HAY
LEGEND
TRIB. SURFACE WATER & GROUNDWATER
TRIB. SURFACE WATER ONLY
GROUNDWATER ONLY
IN-POND
Figure 1
Site Locations and Names
Pennichuck Brook Watershed
Southern New Hampshire
Source: GRANIT, NRPC GIS
PENNICHUCK CORPORATION
Comprehensive Environmental Incorporated

Figure 2: Dissolved Oxygen





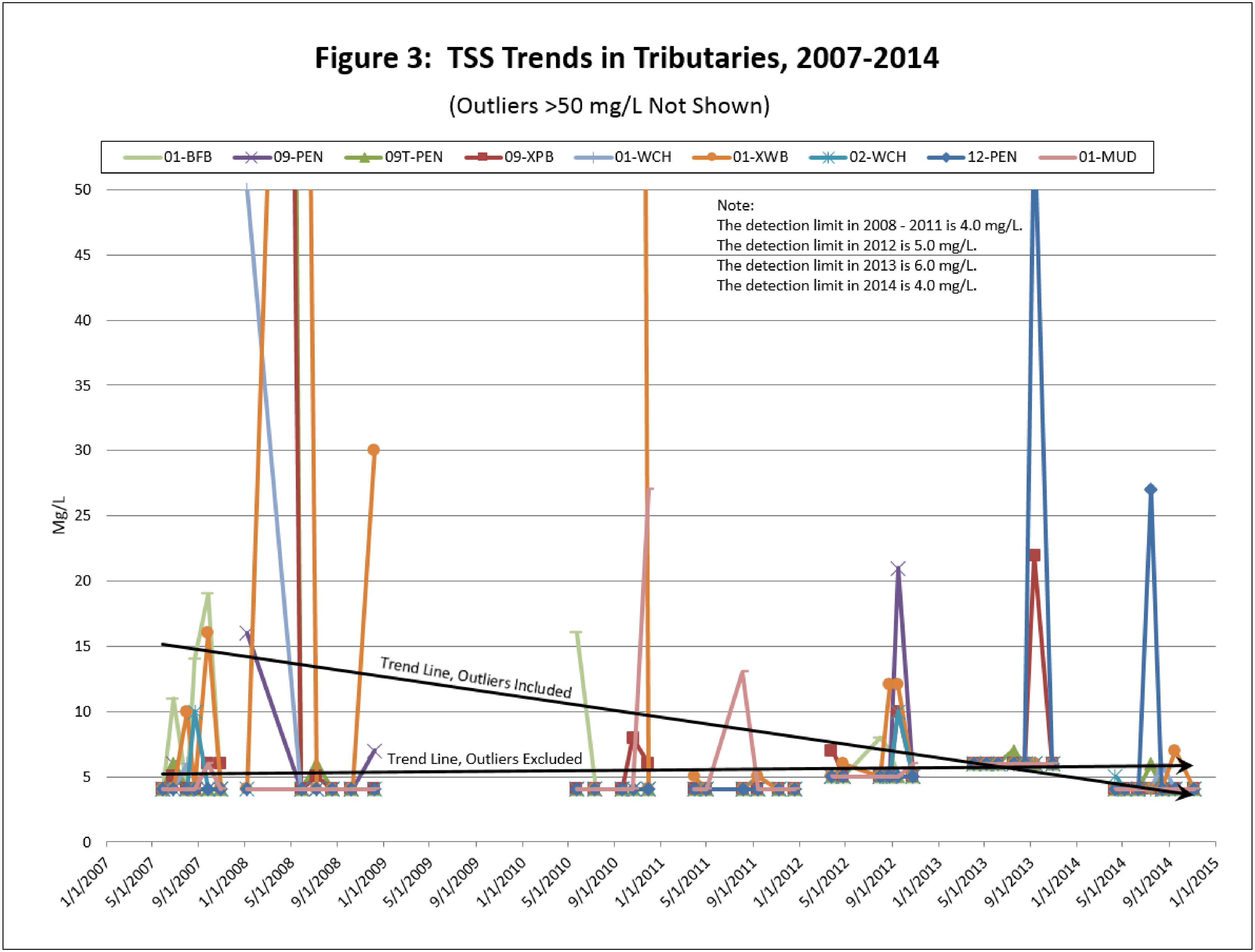
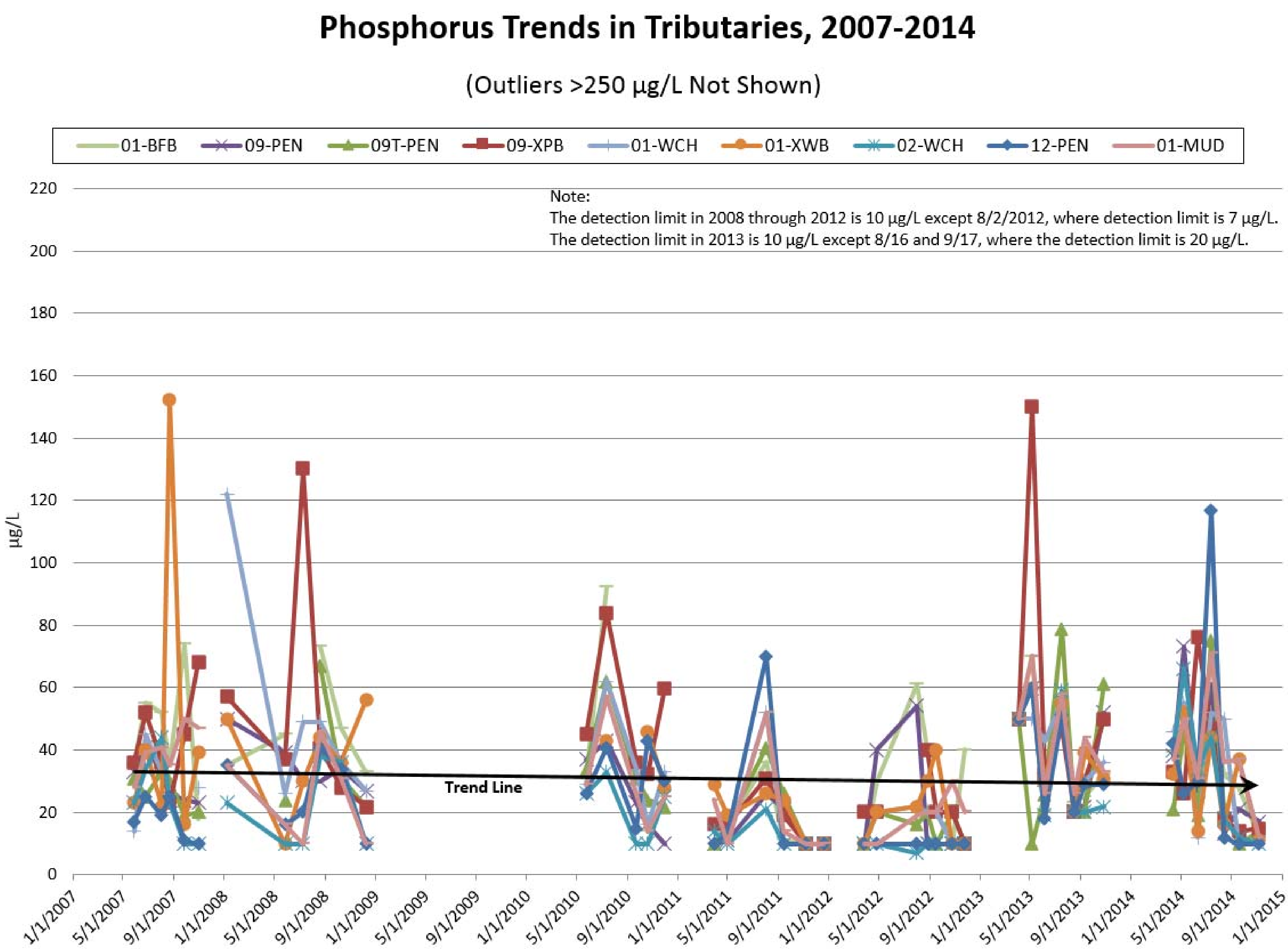


Figure 3: TSS Trends in Tributaries, 2007-2014
(Outliers >50 mg/L Not Shown)
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Note:
The detection limit in 2008 - 2011 is 4.0 mg/L.
The detection limit in 2012 is 5.0 mg/L.
The detection limit in 2013 is 6.0 mg/L.
The detection limit in 2014 is 4.0 mg/L.
Trend Line, Outliers Included
Trend Line, Outliers Excluded
Mg/L
50
45
40
35
30
25
20
15
10
5
0
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015

Figure 4: Total Phosphorus



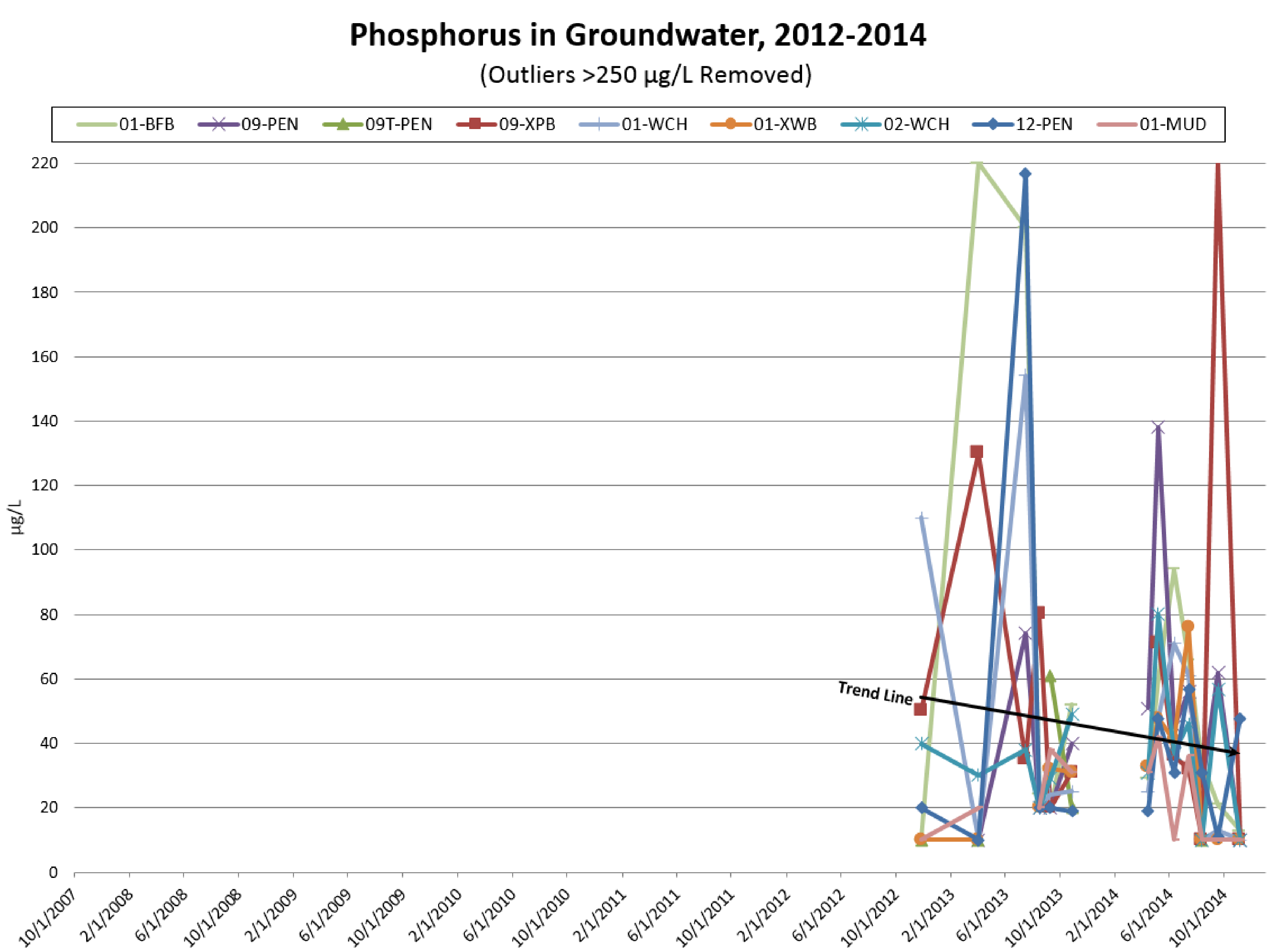


Figure 5: Phosphorus Load Trends in Tributaries, 2007-2014

(Outliers >250 µg/L Removed)

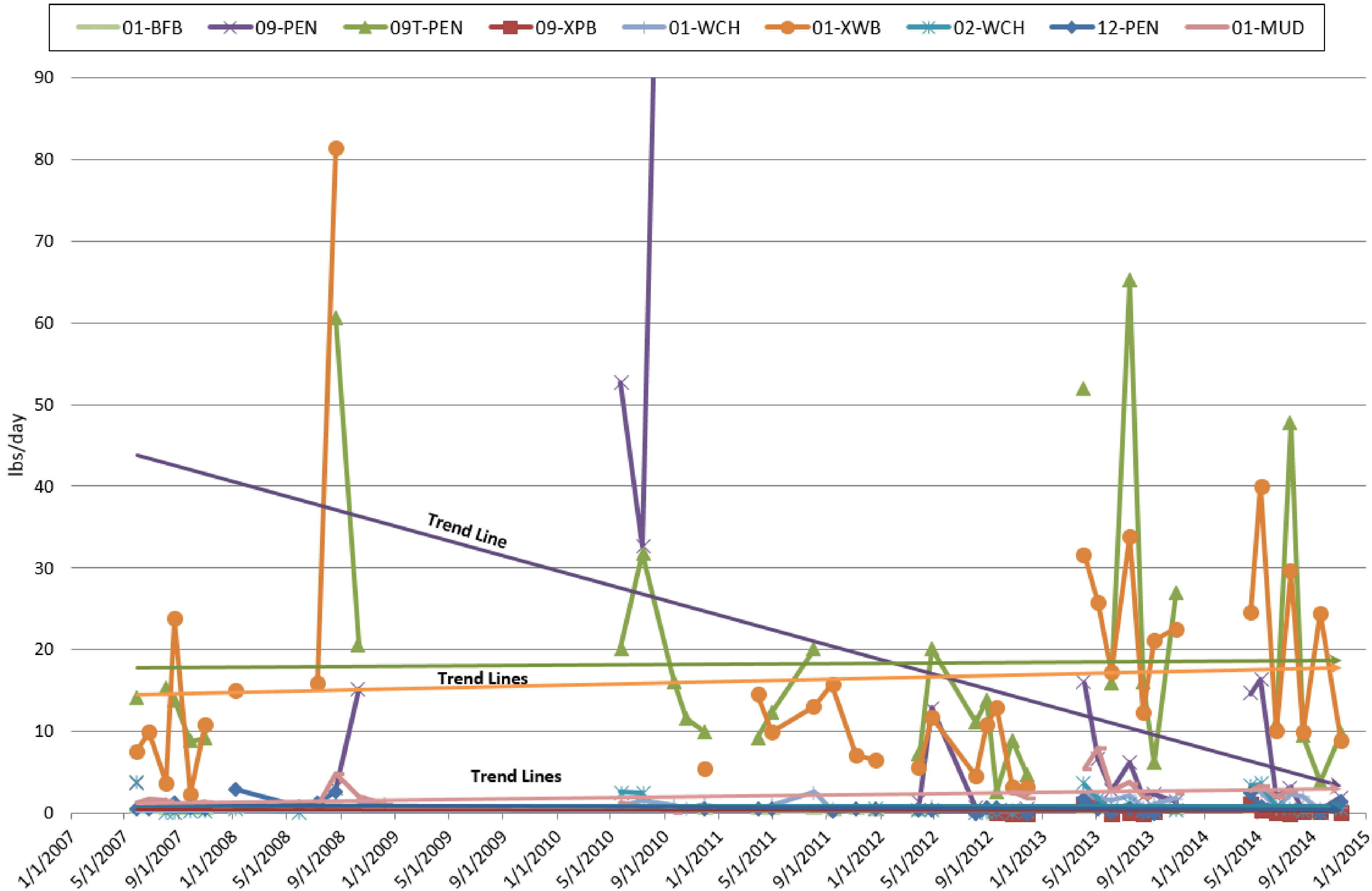


Figure 6: Phosphorus Trends for In-Pond Locations 2007-2014

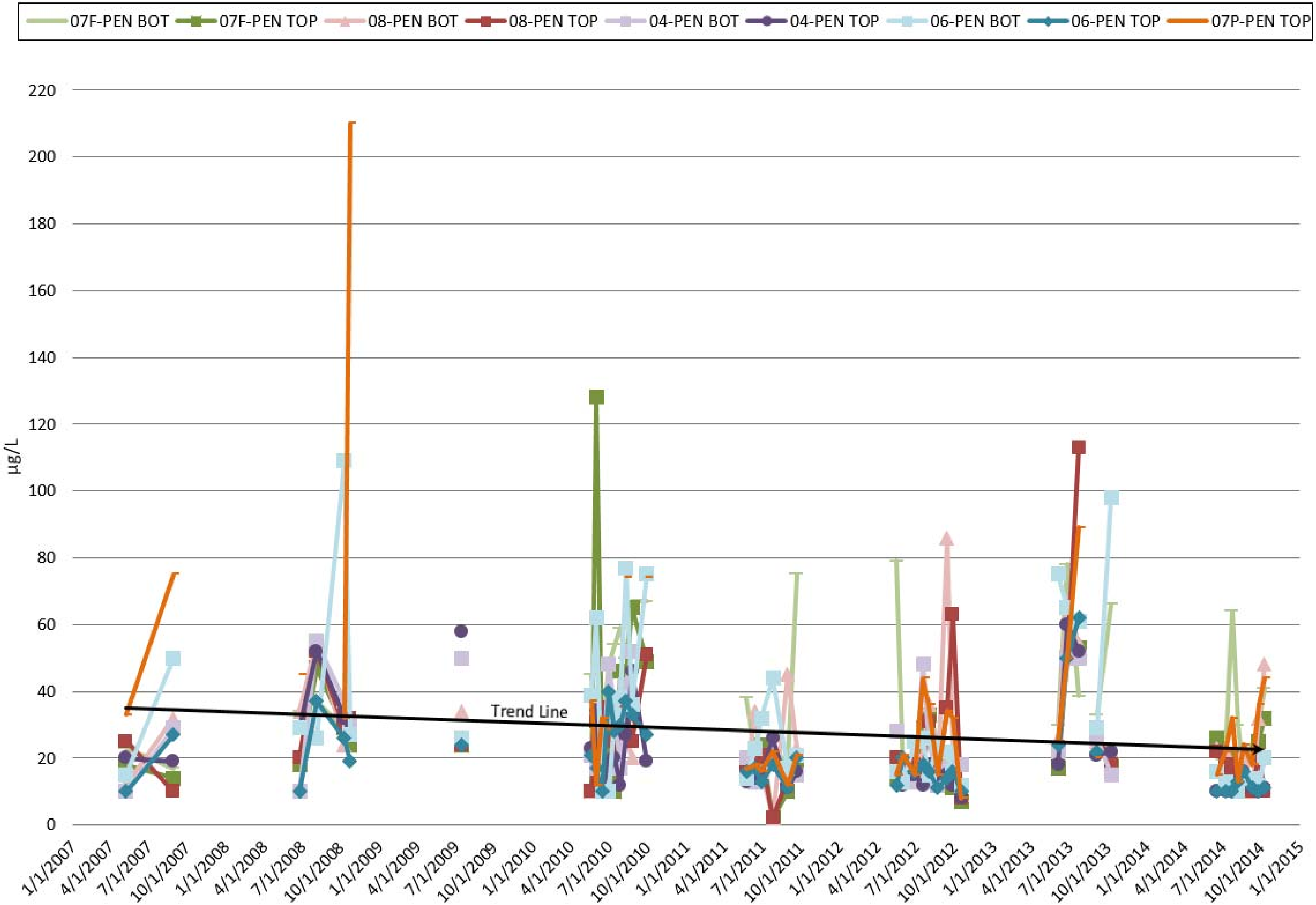
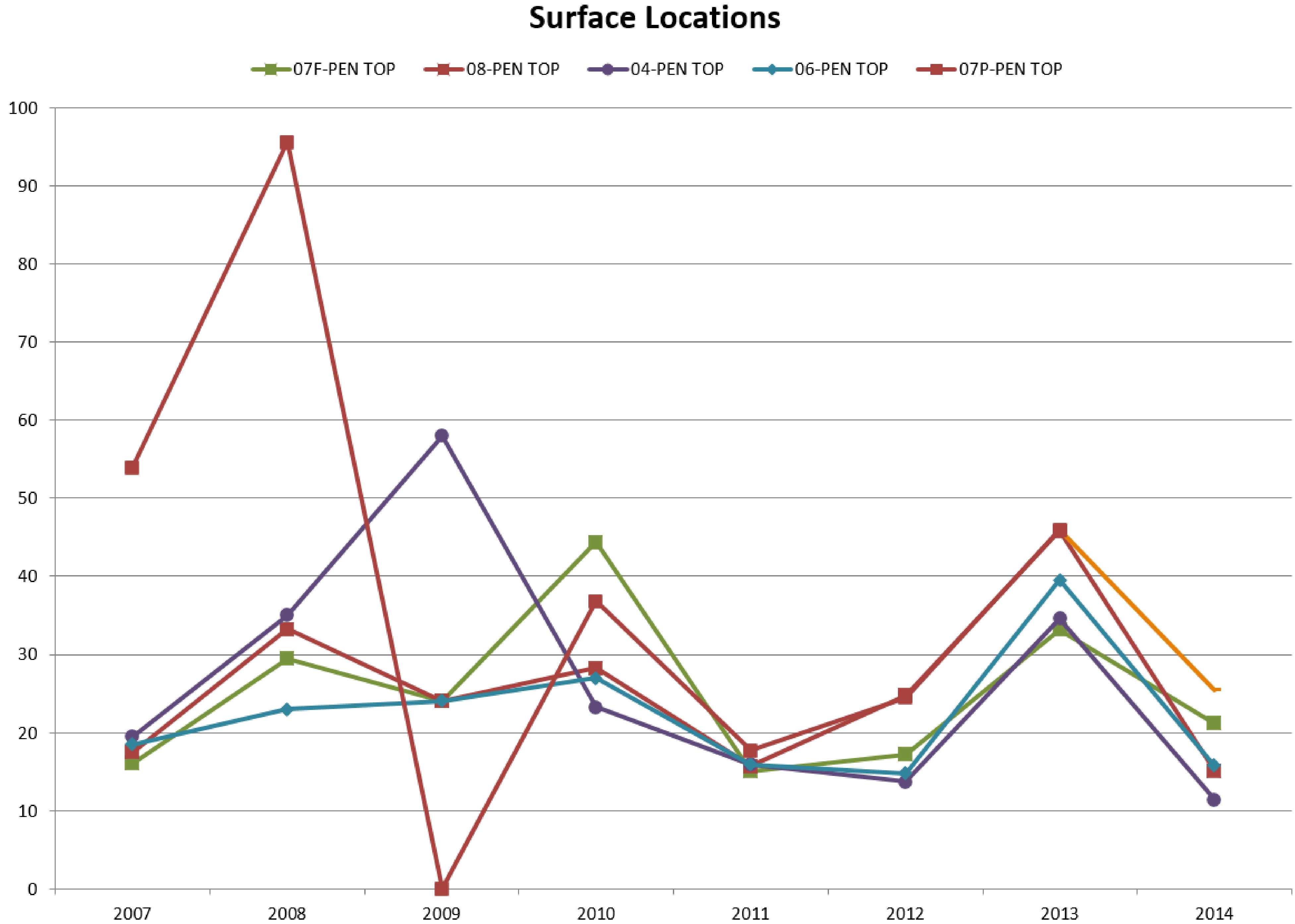


Figure 7: Average Phosphorus Concentrations and Trends for In-Pond Locations, 2007-2014



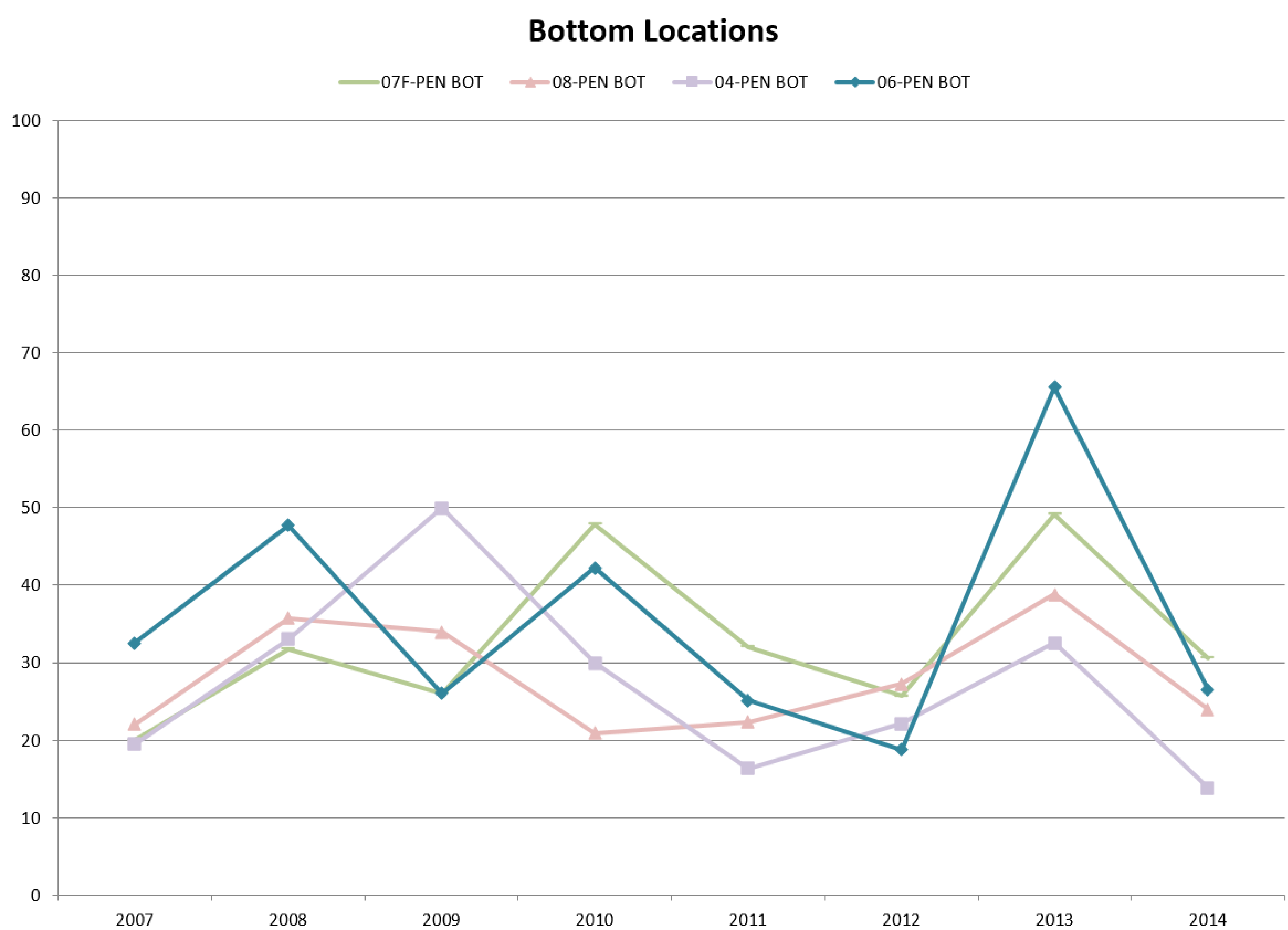
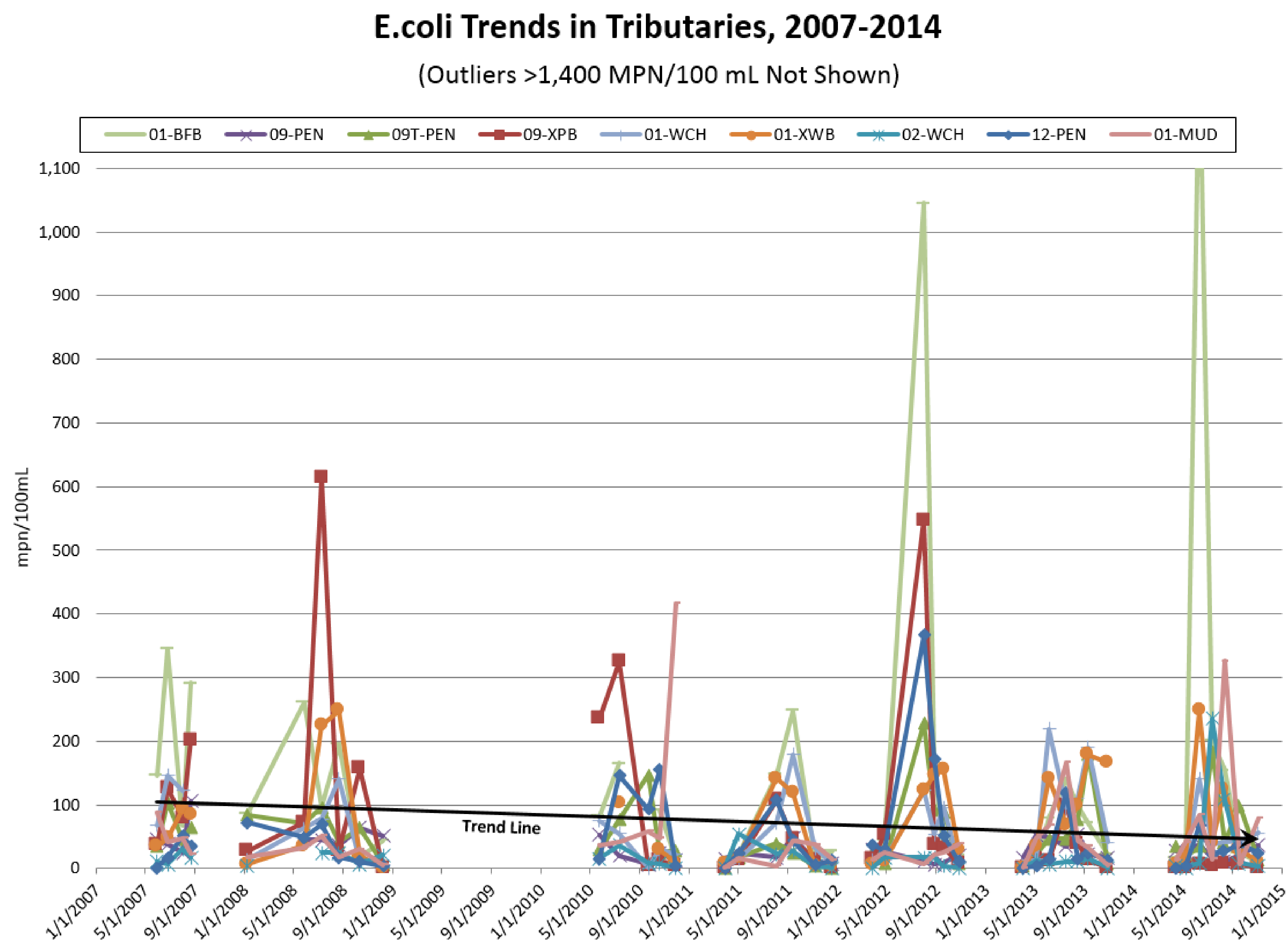
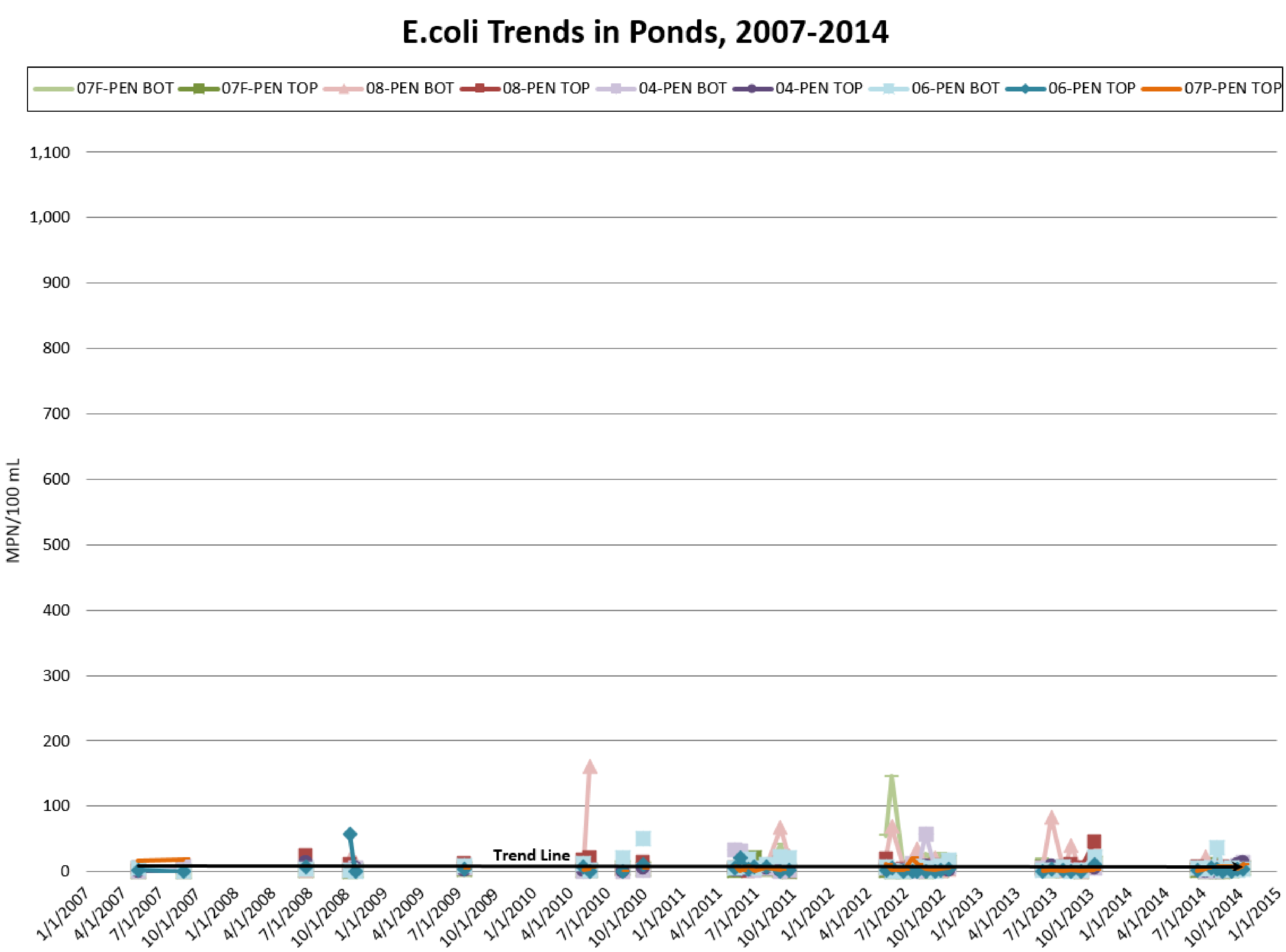


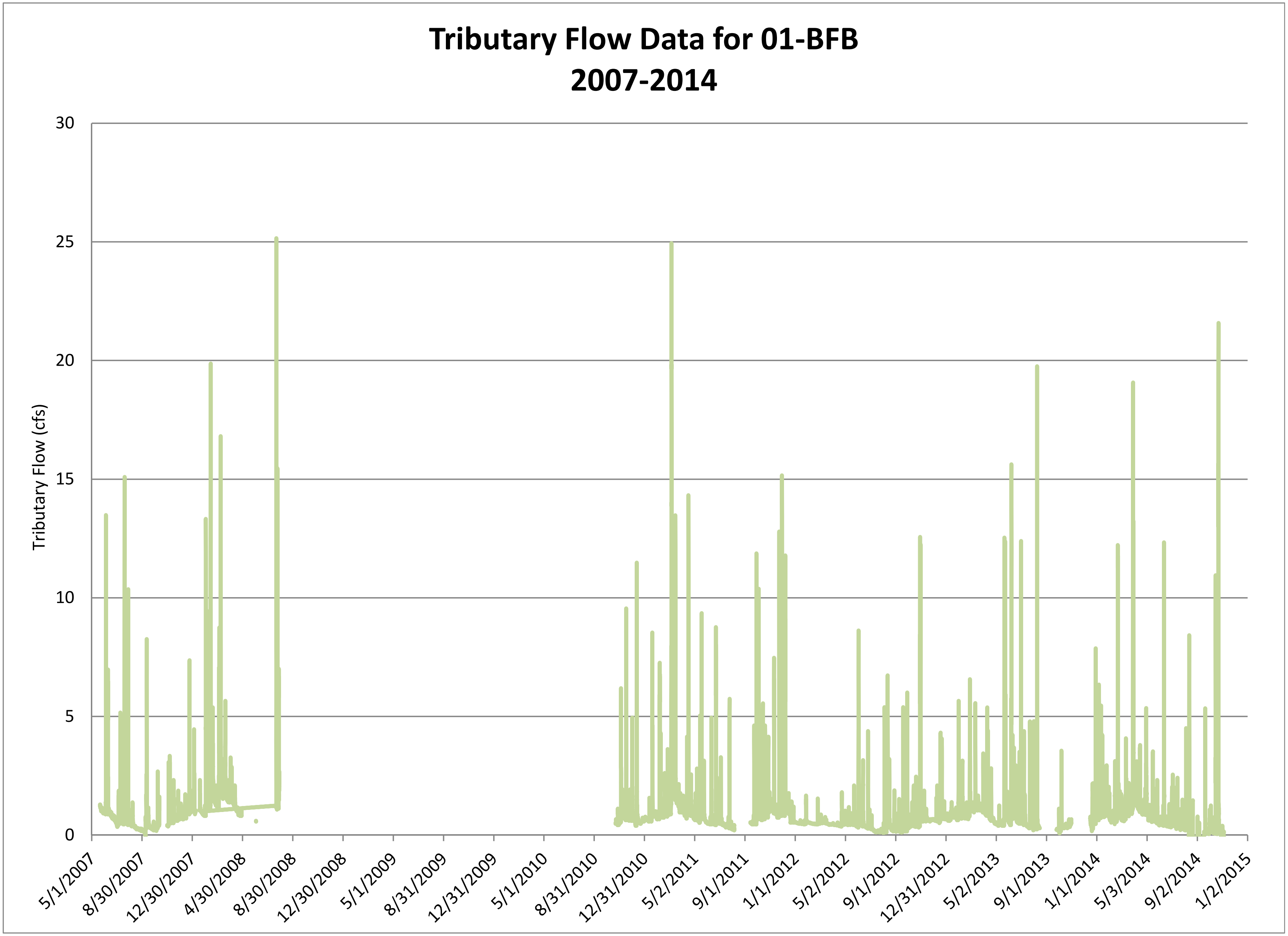
Figure 8: E.coli

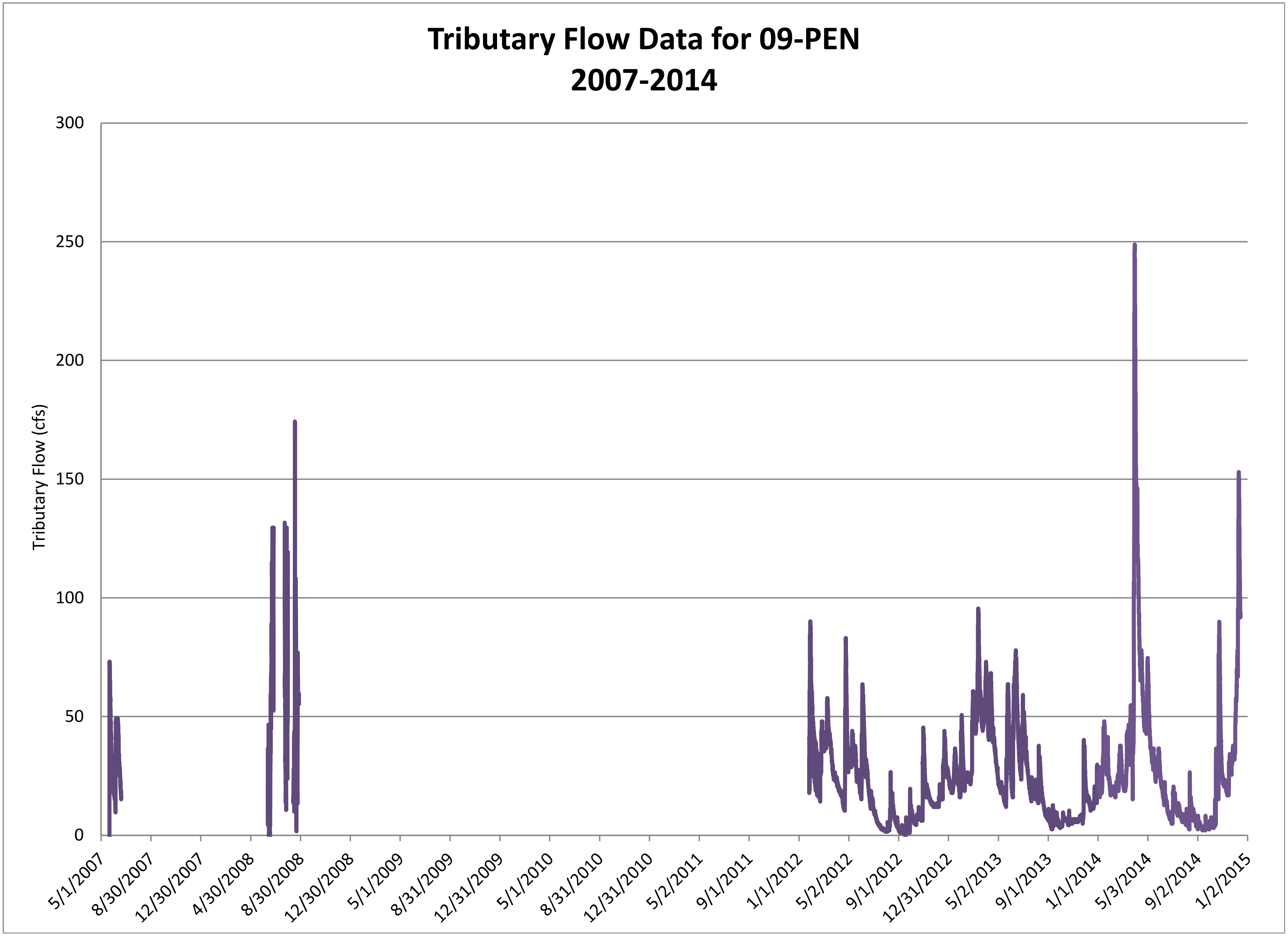




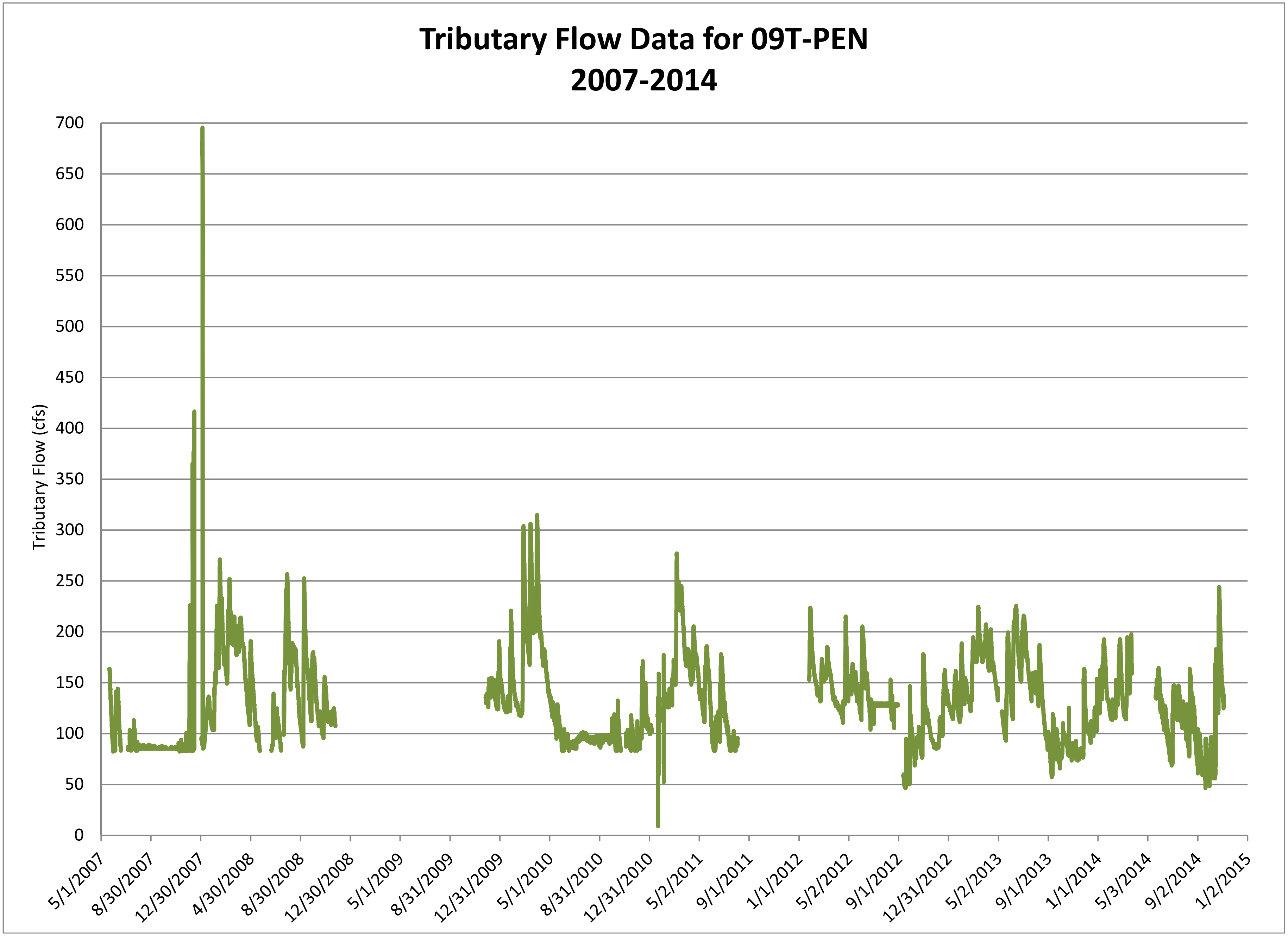
Attachment A – Supporting Graphs

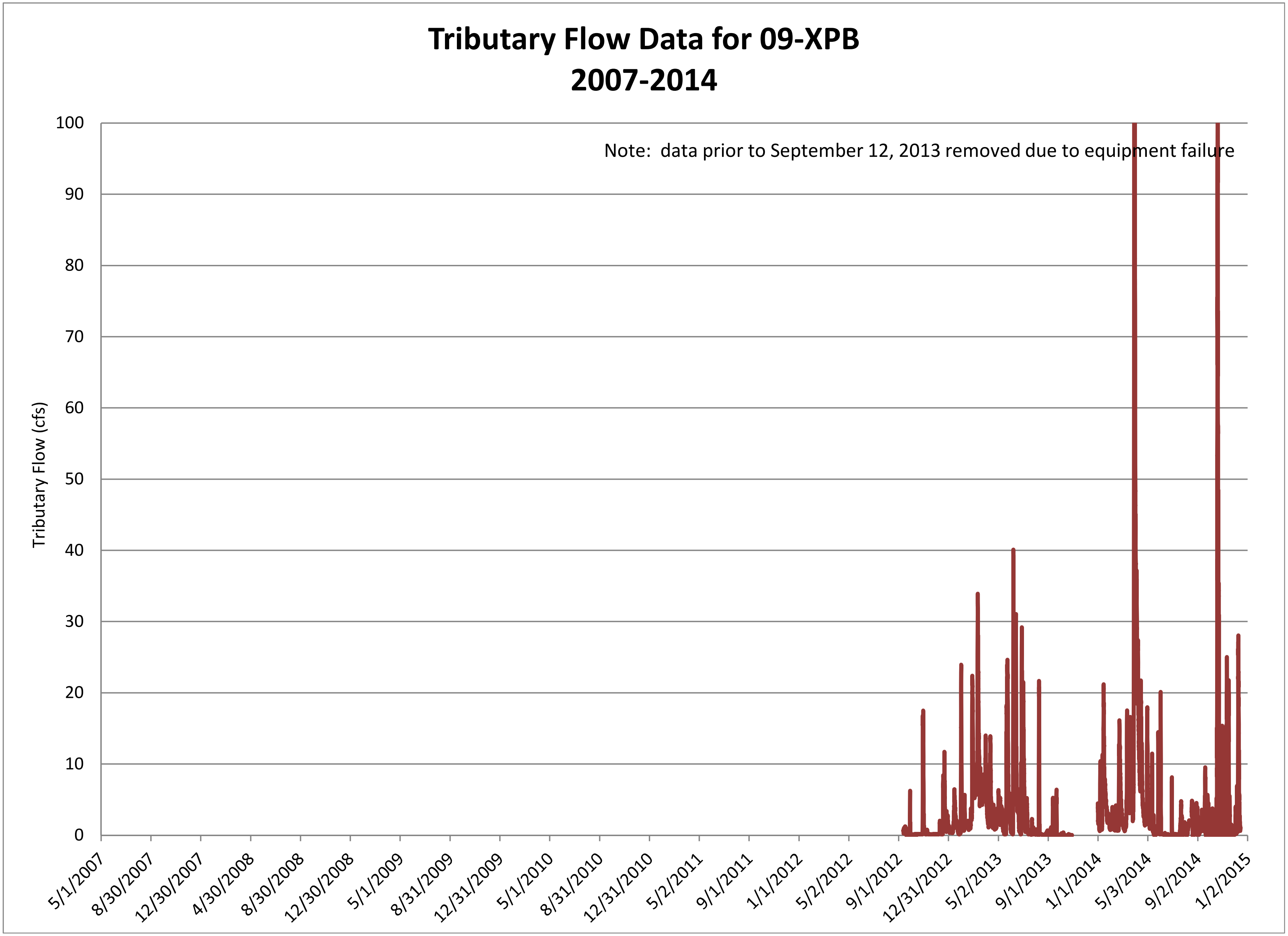
Tributary Flow Data Graphs


Tributary Flow Data for 01-BFB
2007-2014
Tributary Flow (cfs)
30
25
20
15
10
5
0
5/1/2007
8/30/2007
12/30/2007
4/30/2008
8/30/2008
12/30/2008
5/1/2009
8/31/2009
12/31/2009
5/1/2010
8/31/2010
12/31/2010
5/2/2011
9/1/2011
1/1/2012
5/2/2012
9/1/2012
12/31/2012
5/2/2013
9/1/2013
1/1/2014
5/3/2014
9/2/2014
1/2/2015

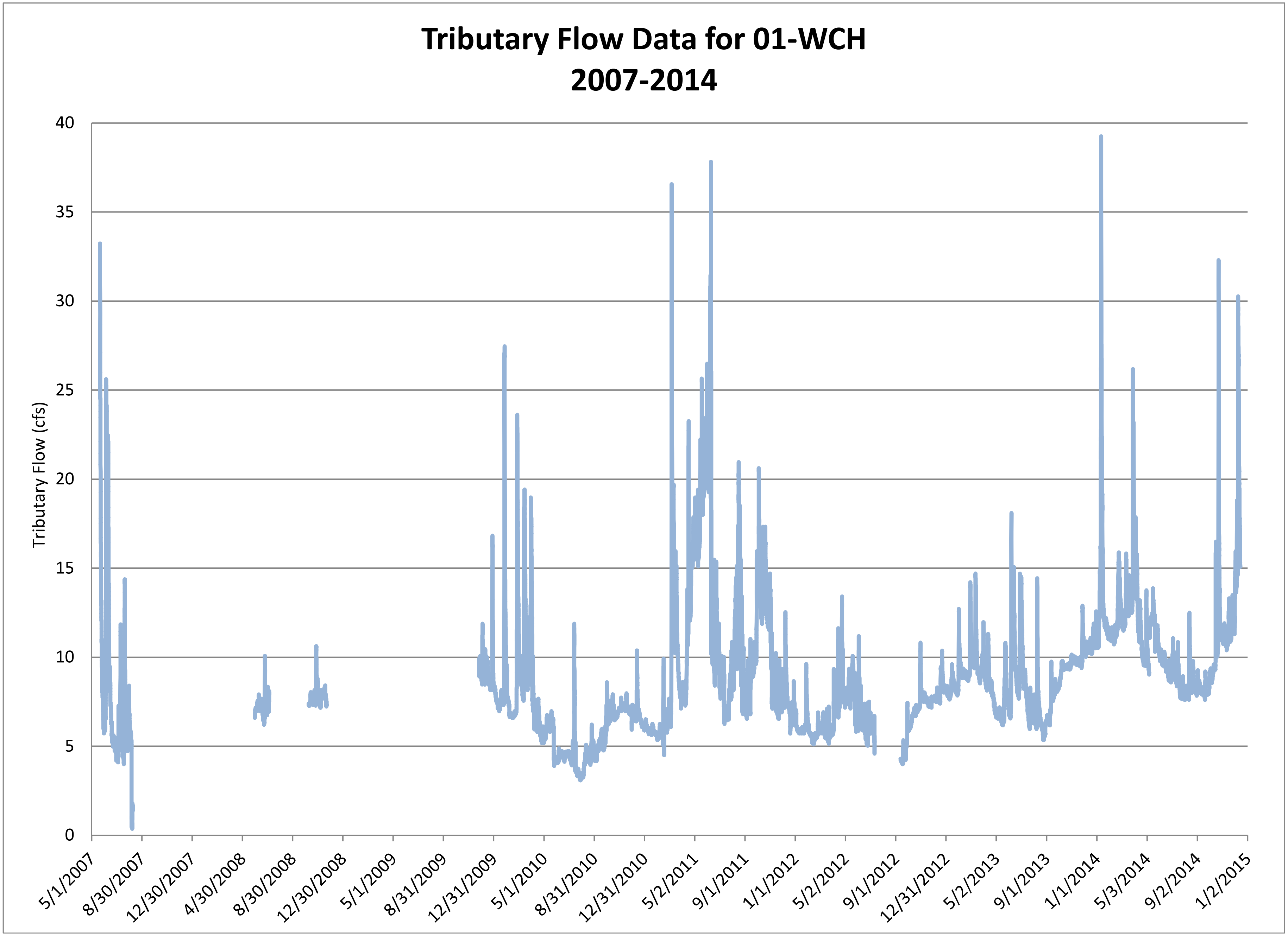


Tributary Flow Data for 09-PEN
2007-2014
Tributary Flow (cfs)
0
50
100
150
200
250
300
5/1/2007
8/30/2007
12/30/2007
4/30/2008
8/30/2008
12/30/2008
5/1/2009
8/31/2009
12/31/2009
5/1/2010
8/31/2010
12/31/2010
5/2/2011
9/1/2011
1/1/2012
5/2/2012
9/1/2012
12/31/2012
5/2/2013
9/1/2013
1/1/2014
5/3/2014
9/2/2014
1/2/2015

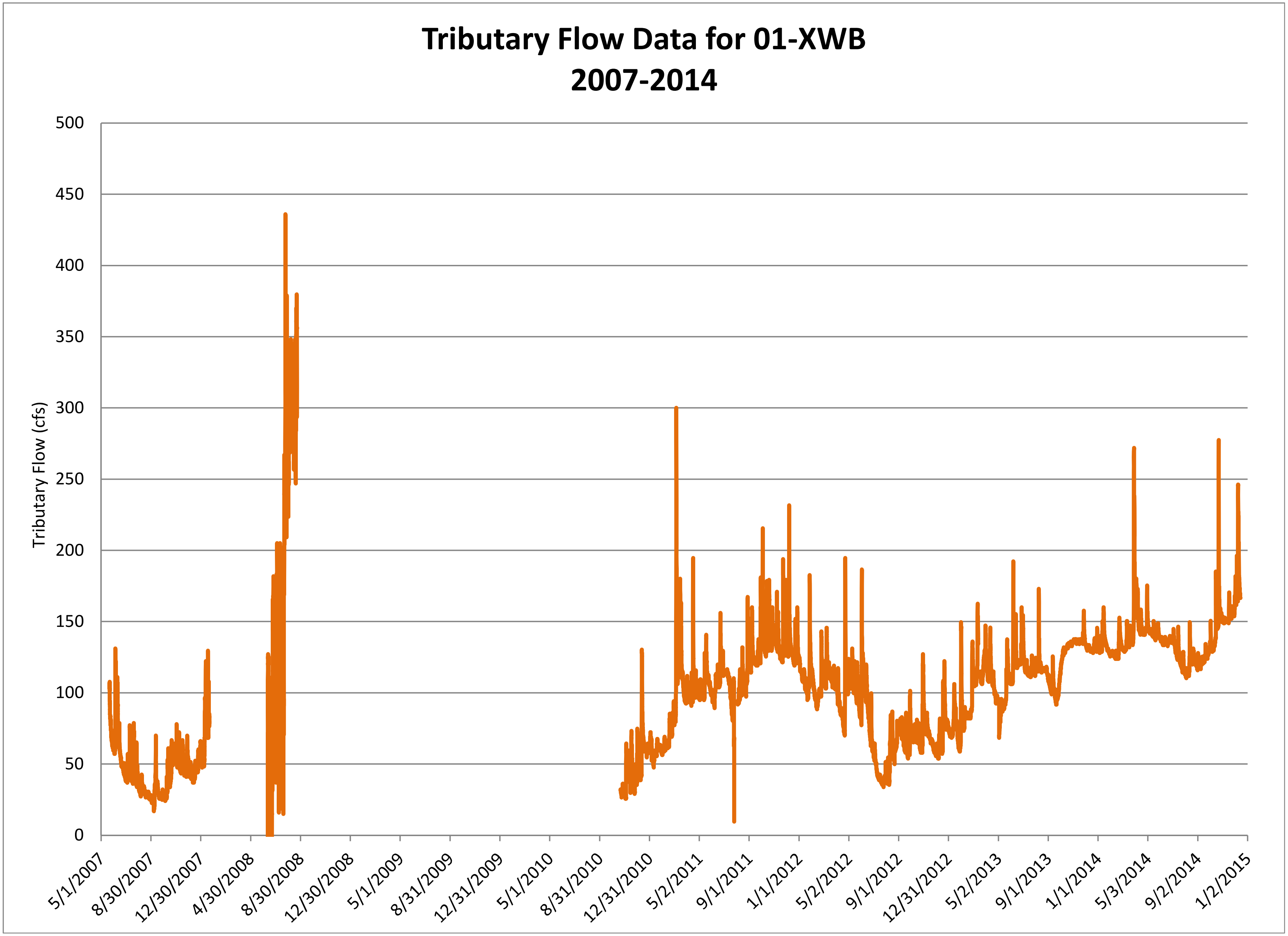

Tributary Flow Data for 09T-PEN
2007-2014
Tributary Flow (cfs)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
5/1/2007
8/30/2007
12/30/2007
4/30/2008
8/30/2008
12/30/2008
5/1/2009
8/31/2009
12/31/2009
5/1/2010
8/31/2010
12/31/2010
5/2/2011
9/1/2011
1/1/2012
5/2/2012
9/1/2012
12/31/2012
5/2/2013
9/1/2013
1/1/2014
5/3/2014
9/2/2014
1/2/2015



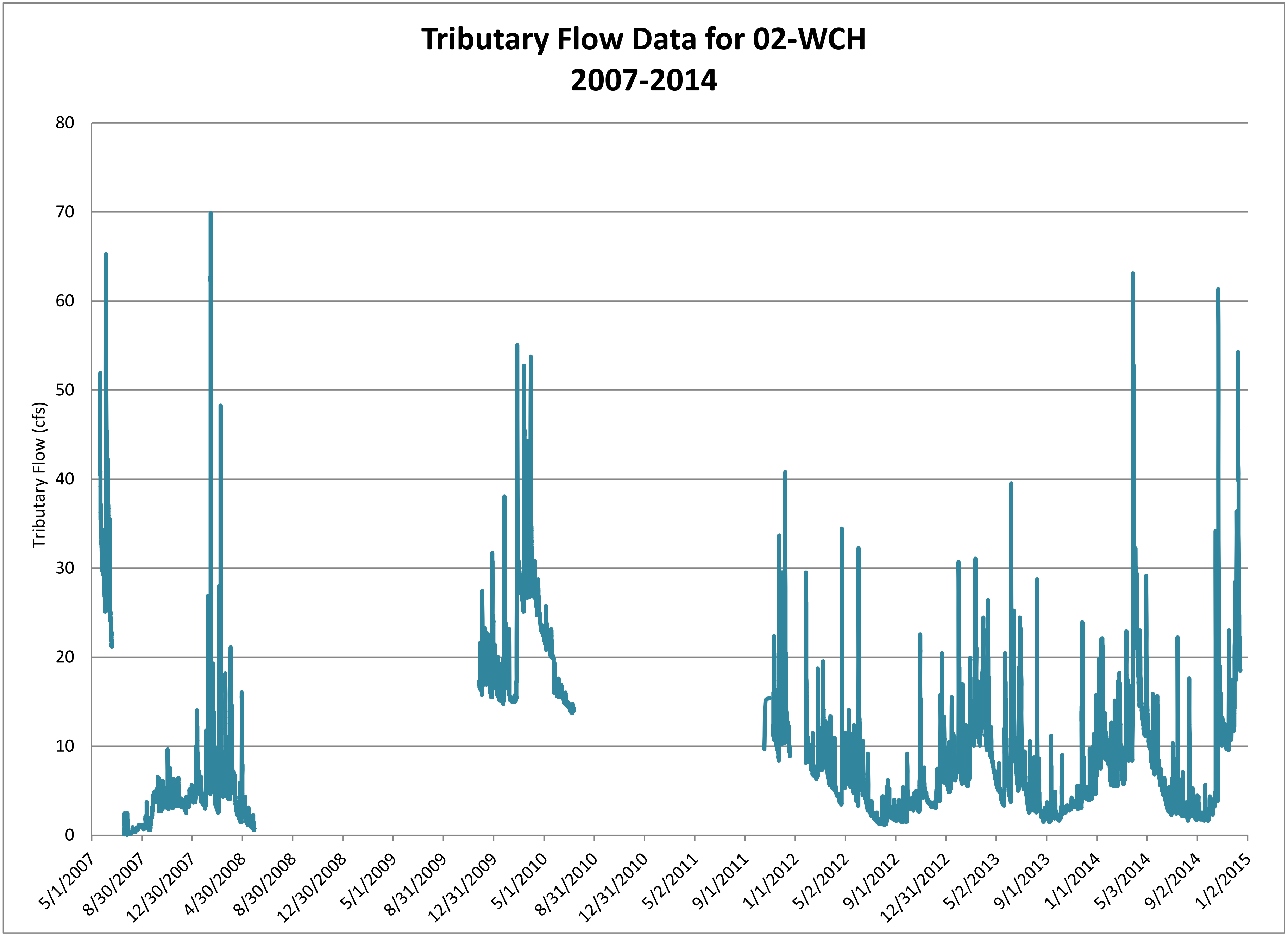
Tributary Flow Data for 09-XPB
2007-2014
Note: data prior to September 12, 2013 removed due to equipment failure
Tributary Flow (cfs)
100
90
80
70
60
50
40
30
20
10
0
5/1/2007
8/30/2007
12/30/2007
4/30/2008
8/30/2008
12/30/2008
5/1/2009
8/31/2009
12/31/2009
5/1/2010
8/31/2010
12/31/2010
5/2/2011
9/1/2011
1/1/2012
5/2/2012
9/1/2012
12/31/2012
5/2/2013
9/1/2013
1/1/2014
5/3/2014
9/2/2014
1/2/2015

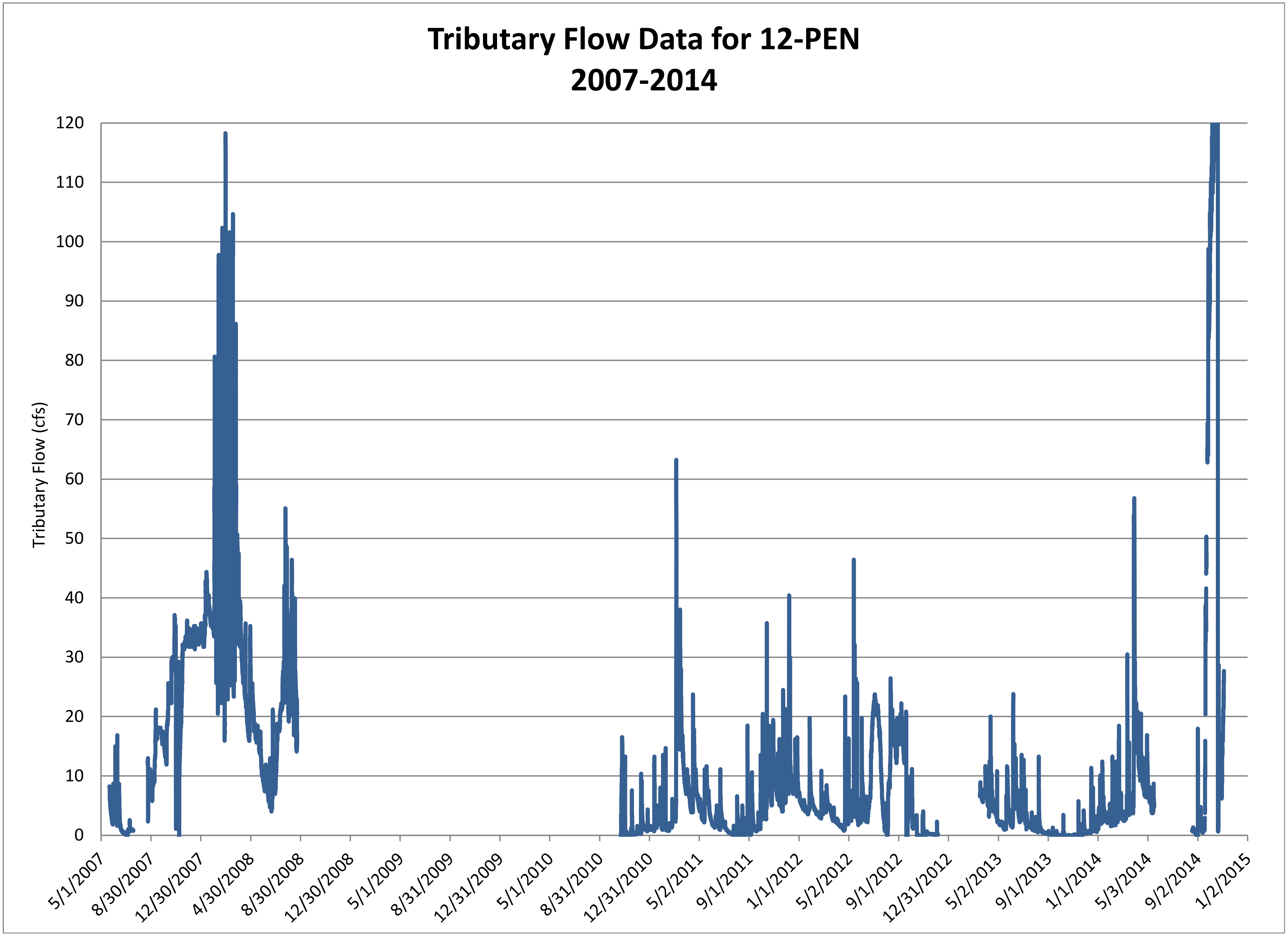


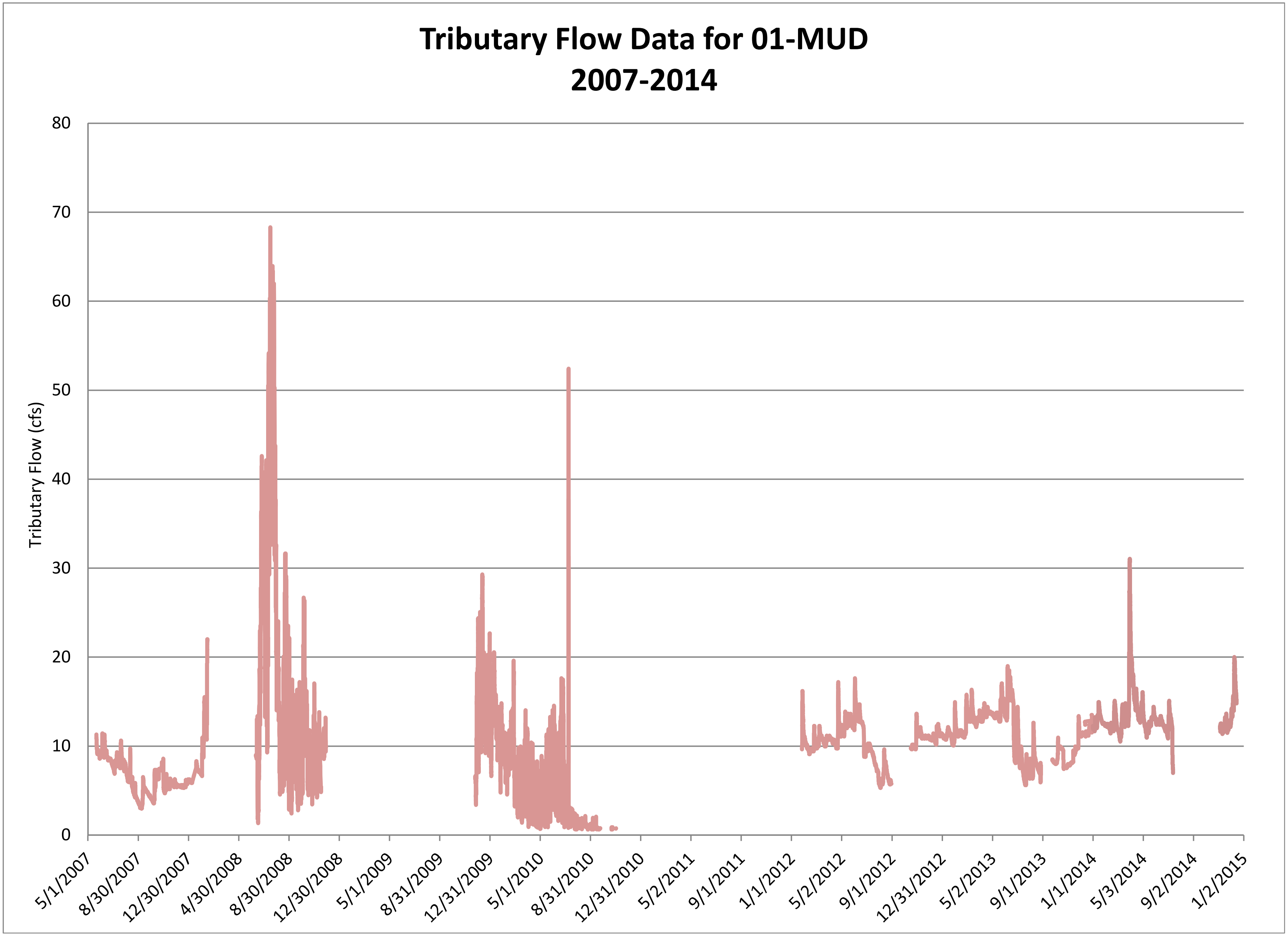
Tributary Flow Data for 01-WCH
2007-2014
Tributary Flow (cfs)
0
5
10
15
20
25
30
35
40
5/1/2007
8/30/2007
12/30/2007
4/30/2008
8/30/2008
12/30/2008
5/1/2009
8/31/2009
12/31/2009
5/1/2010
8/31/2010
12/31/2010
5/2/2011
9/1/2011
1/1/2012
5/2/2012
9/1/2012
12/31/2012
5/2/2013
9/1/2013
1/1/2014
5/3/2014
9/2/2014
1/2/2015



Tributary Flow Data for 01-XWB
2007-2014
Tributary Flow (cfs)
500
450
400
350
300
250
200
150
100
50
0
5/1/2007
8/30/2007
12/30/2007
4/30/2008
8/30/2008
12/30/2008
5/1/2009
8/31/2009
12/31/2009
5/1/2010
8/31/2010
12/31/2010
5/2/2011
9/1/2011
1/1/2012
5/2/2012
9/1/2012
12/31/2012
5/2/2013
9/1/2013
1/1/2014
5/3/2014
9/2/2014
1/2/2015

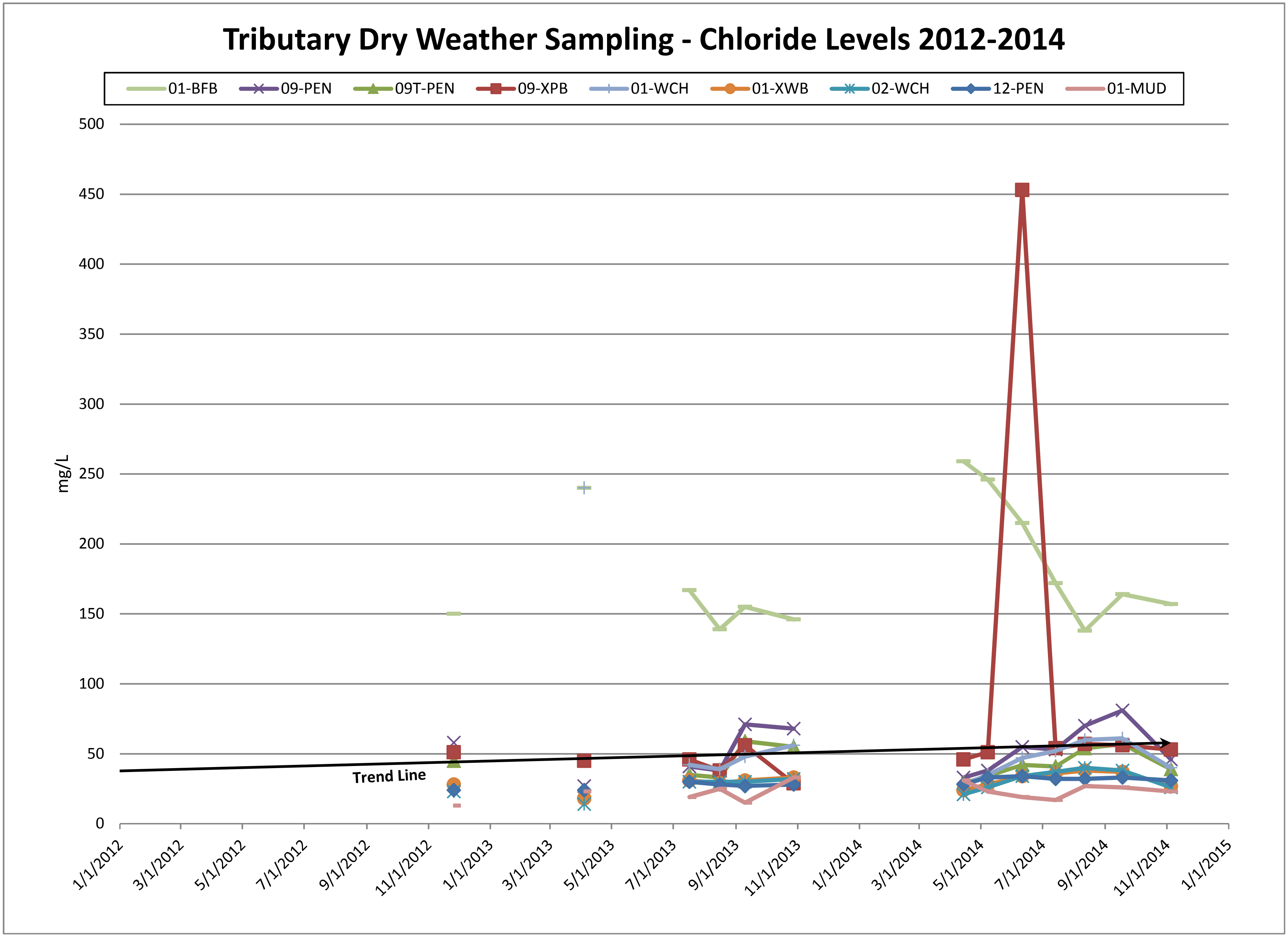

Tributary Flow Data for 02-WCH
2007-2014
Tributary Flow (cfs)
80
70
60
50
40
30
20
10
0
5/1/2007
8/30/2007
12/30/2007
4/30/2008
8/30/2008
12/30/2008
5/1/2009
8/31/2009
12/31/2009
5/1/2010
8/31/2010
12/31/2010
5/2/2011
9/1/2011
1/1/2012
5/2/2012
9/1/2012
12/31/2012
5/2/2013
9/1/2013
1/1/2014
5/3/2014
9/2/2014
1/2/2015


Tributary Flow Data for 12-PEN
2007-2014
Tributary Flow (cfs)
120
110
100
90
80
70
60
50
40
30
20
10
0
5/1/2007
8/30/2007
12/30/2007
4/30/2008
8/30/2008
12/30/2008
5/1/2009
8/31/2009
12/31/2009
5/1/2010
8/31/2010
12/31/2010
5/2/2011
9/1/2011
1/1/2012
5/2/2012
9/1/2012
12/31/2012
5/2/2013
9/1/2013
1/1/2014
5/3/2014
9/2/2014
1/2/2015

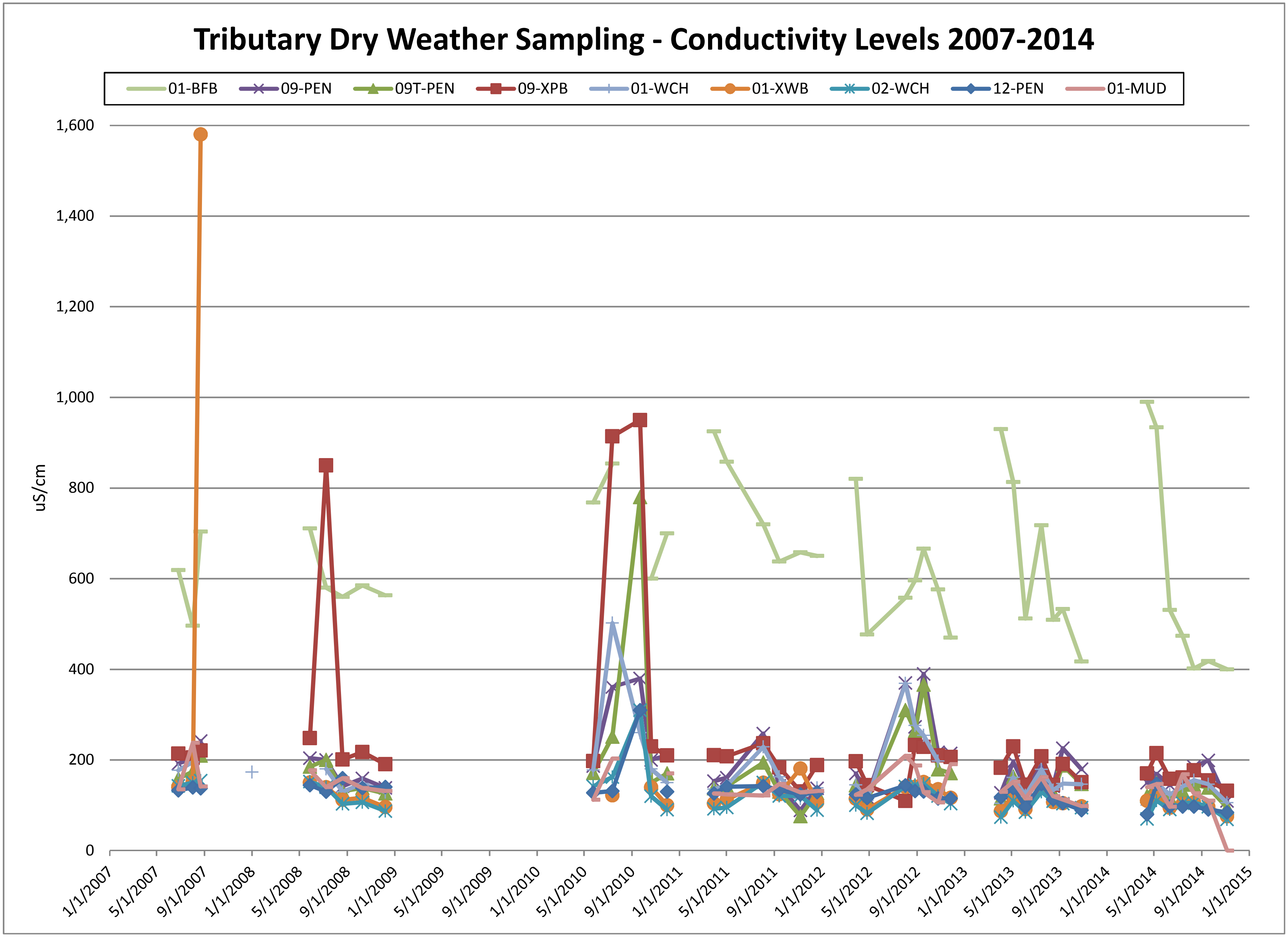


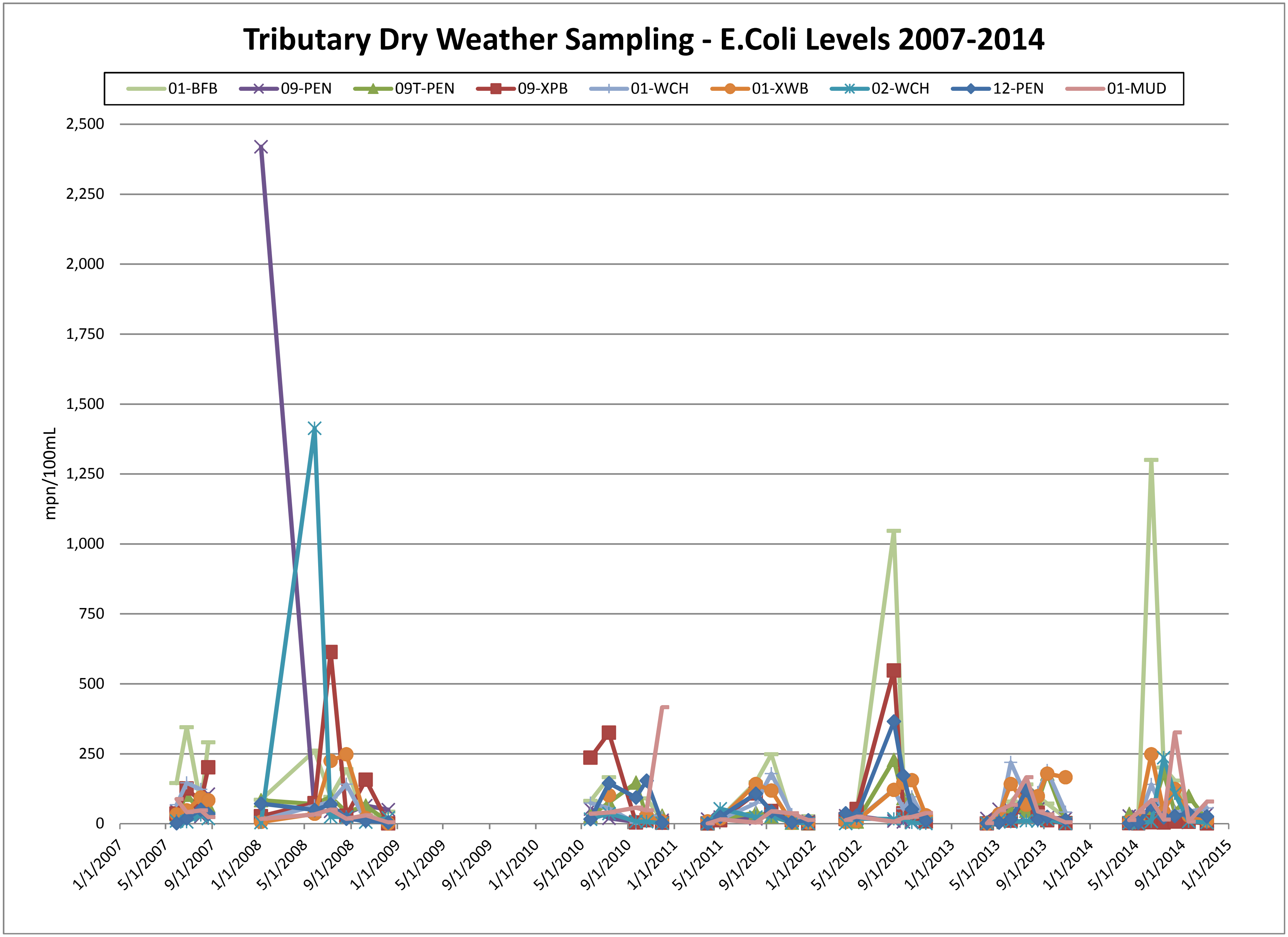
Tributary Flow Data for 01-MUD
2007-2014
Tributary Flow (cfs)
0
10
20
30
40
50
60
70
80
5/1/2007
8/30/2007
12/30/2007
4/30/2008
8/30/2008
12/30/2008
5/1/2009
8/31/2009
12/31/2009
5/1/2010
8/31/2010
12/31/2010
5/2/2011
9/1/2011
1/1/2012
5/2/2012
9/1/2012
12/31/2012
5/2/2013
9/1/2013
1/1/2014
5/3/2014
9/2/2014
1/2/2015

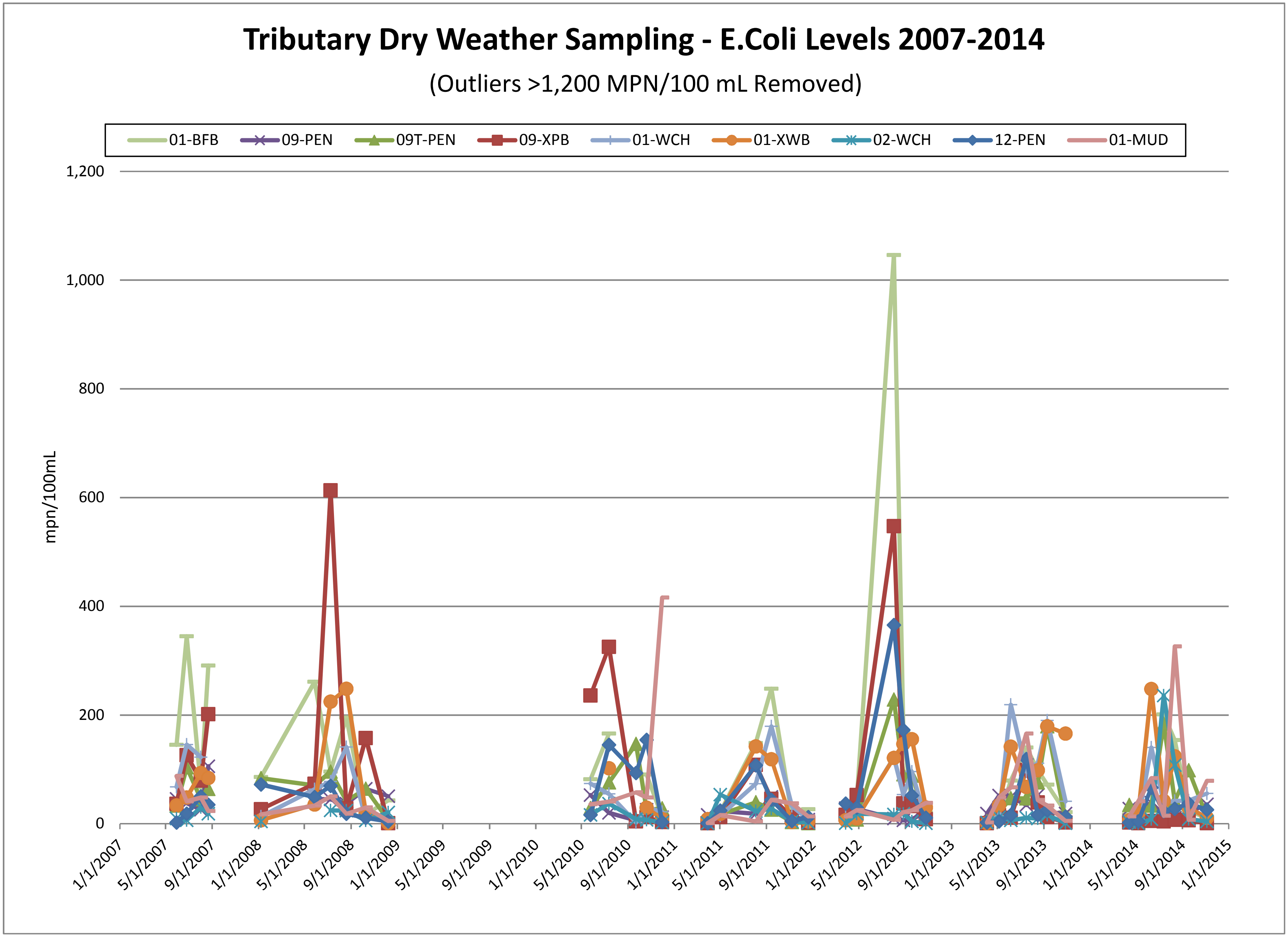
2007-2014 Tributary Graphs



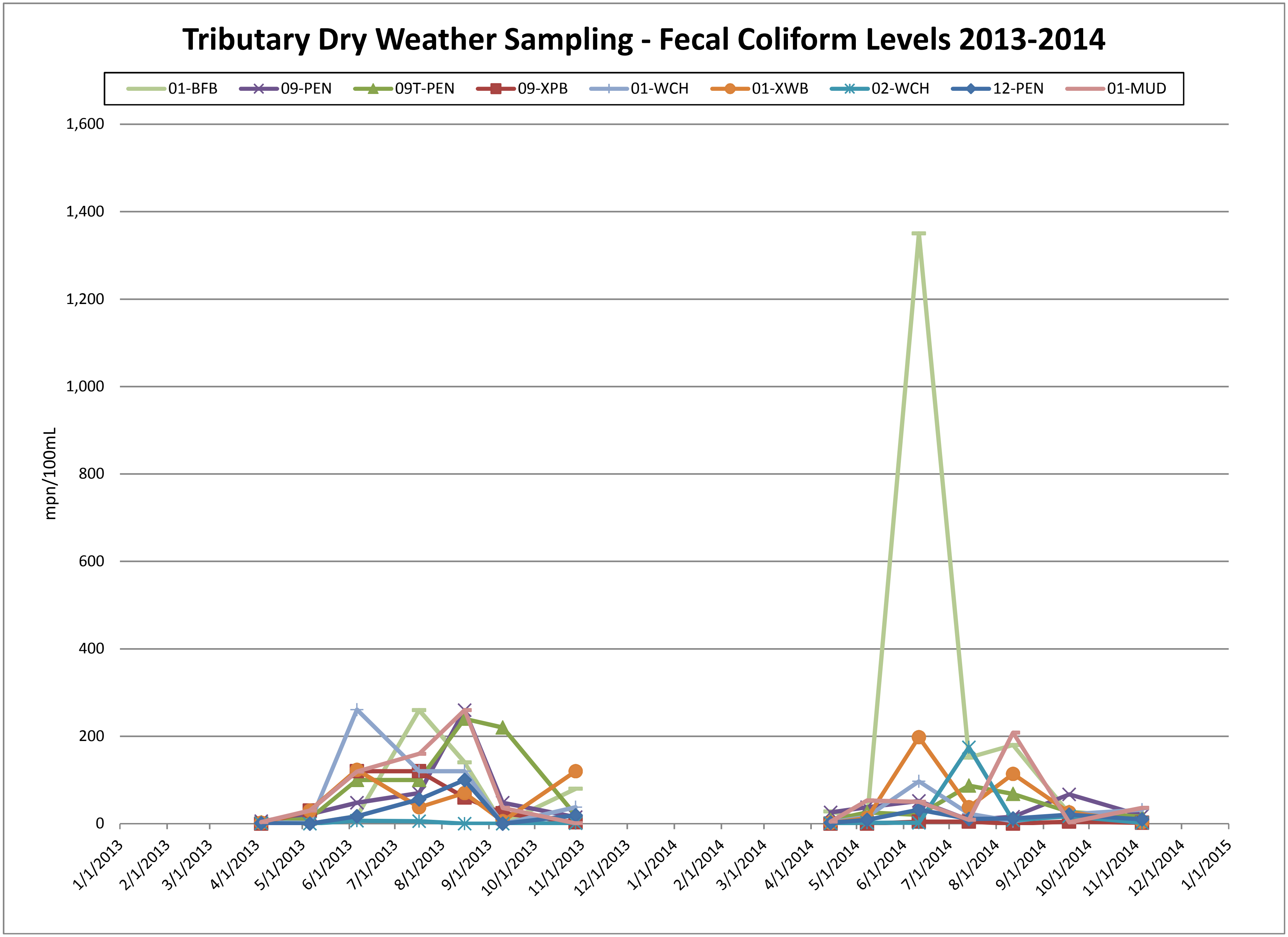
Tributary Dry Weather Sampling - Chloride Levels 2012-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
mg/L
500
450
400
350
300
250
200
150
100
50
0
Trend Line
1/1/2012
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
1/1/2013
3/1/2013
5/1/2013
7/1/2013
9/1/2013
11/1/2013
1/1/2014
3/1/2014
5/1/2014
7/1/2014
9/1/2014
11/1/2014
1/1/2015


Tributary Dry Weather Sampling - Conductivity Levels 2007-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
uS/cm
1,600
1,400
1,200
1,000
800
600
400
200
0
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015

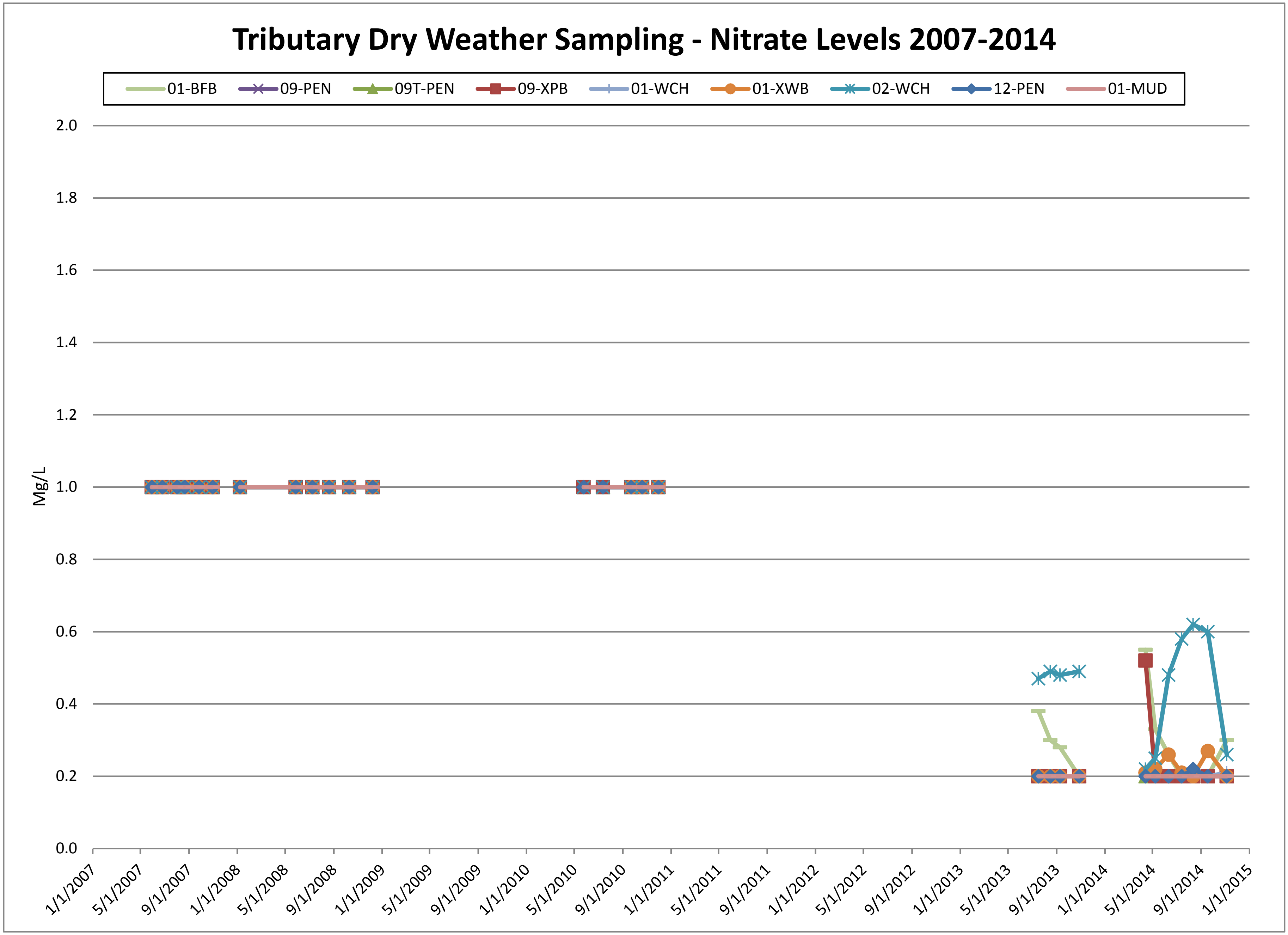

Tributary Dry Weather Sampling - E.Coli Levels 2007-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
mpn/100mL
2,500
2,250
2,000
1,750
1,500
1,250
1,000
750
500
250
0
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015

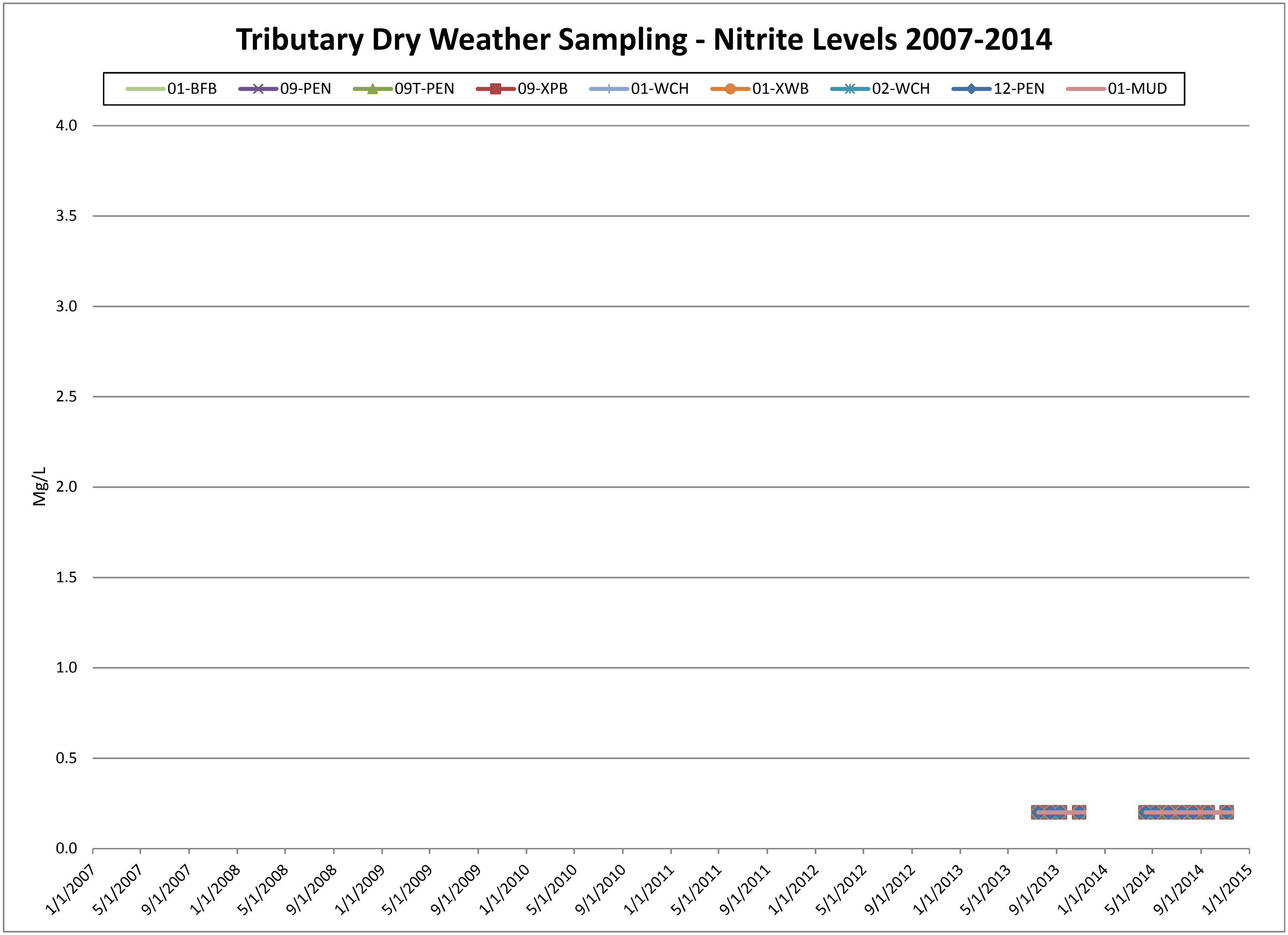


Tributary Dry Weather Sampling - E.Coli Levels 2007-2014
(Outliers >1,200 MPN/100 mL Removed)
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
mpn/100mL
1,200
1,000
800
600
400
200
0
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015



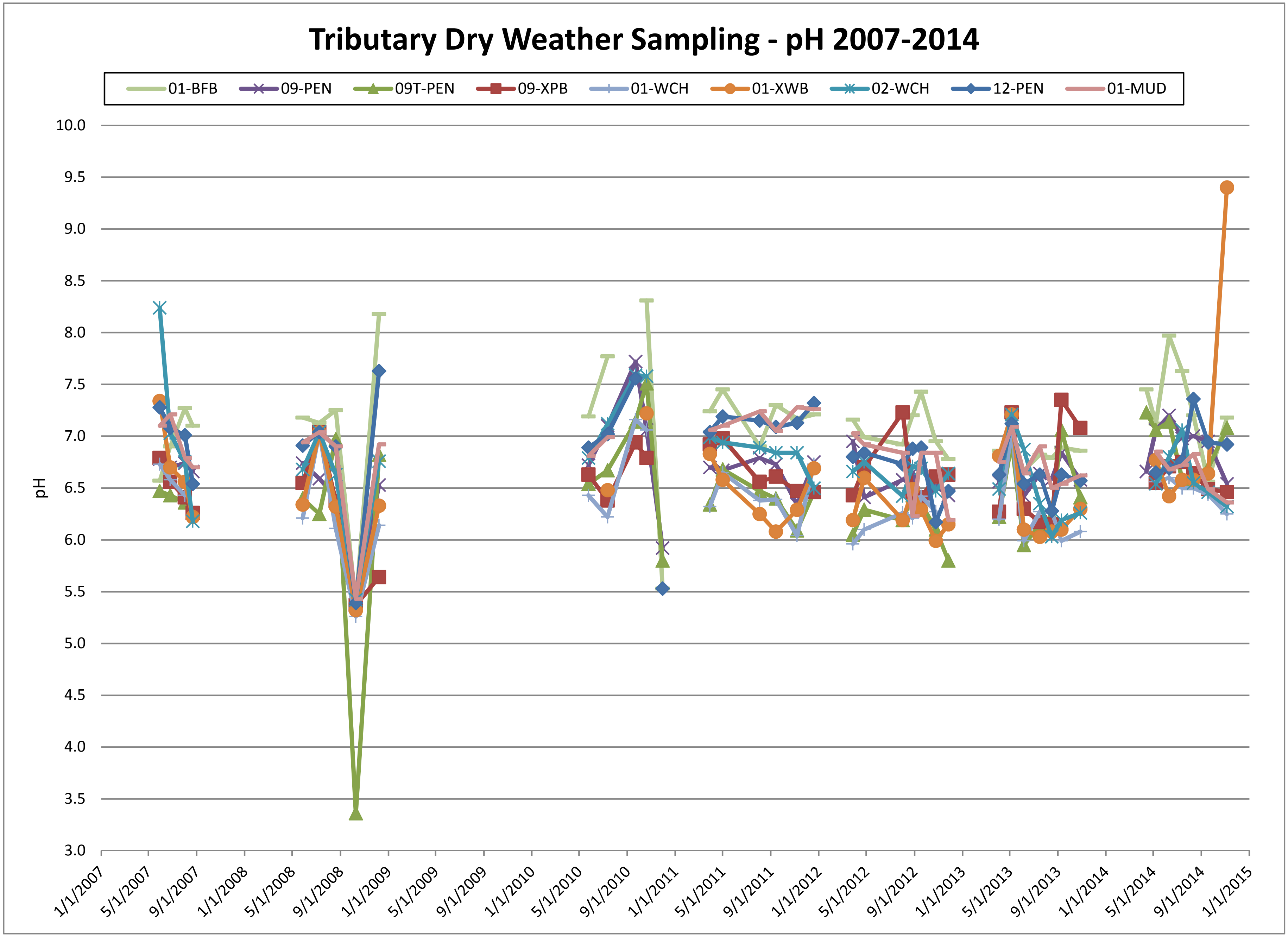
Tributary Dry Weather Sampling - Fecal Coliform Levels 2013-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
mpn/100mL
1,600
1,400
1,200
1,000
800
600
400
200
0
1/1/2013
2/1/2013
3/1/2013
4/1/2013
5/1/2013
6/1/2013
7/1/2013
8/1/2013
9/1/2013
10/1/2013
11/1/2013
12/1/2013
1/1/2014
2/1/2014
3/1/2014
4/1/2014
5/1/2014
6/1/2014
7/1/2014
8/1/2014
9/1/2014
10/1/2014
11/1/2014
12/1/2014
1/1/2015

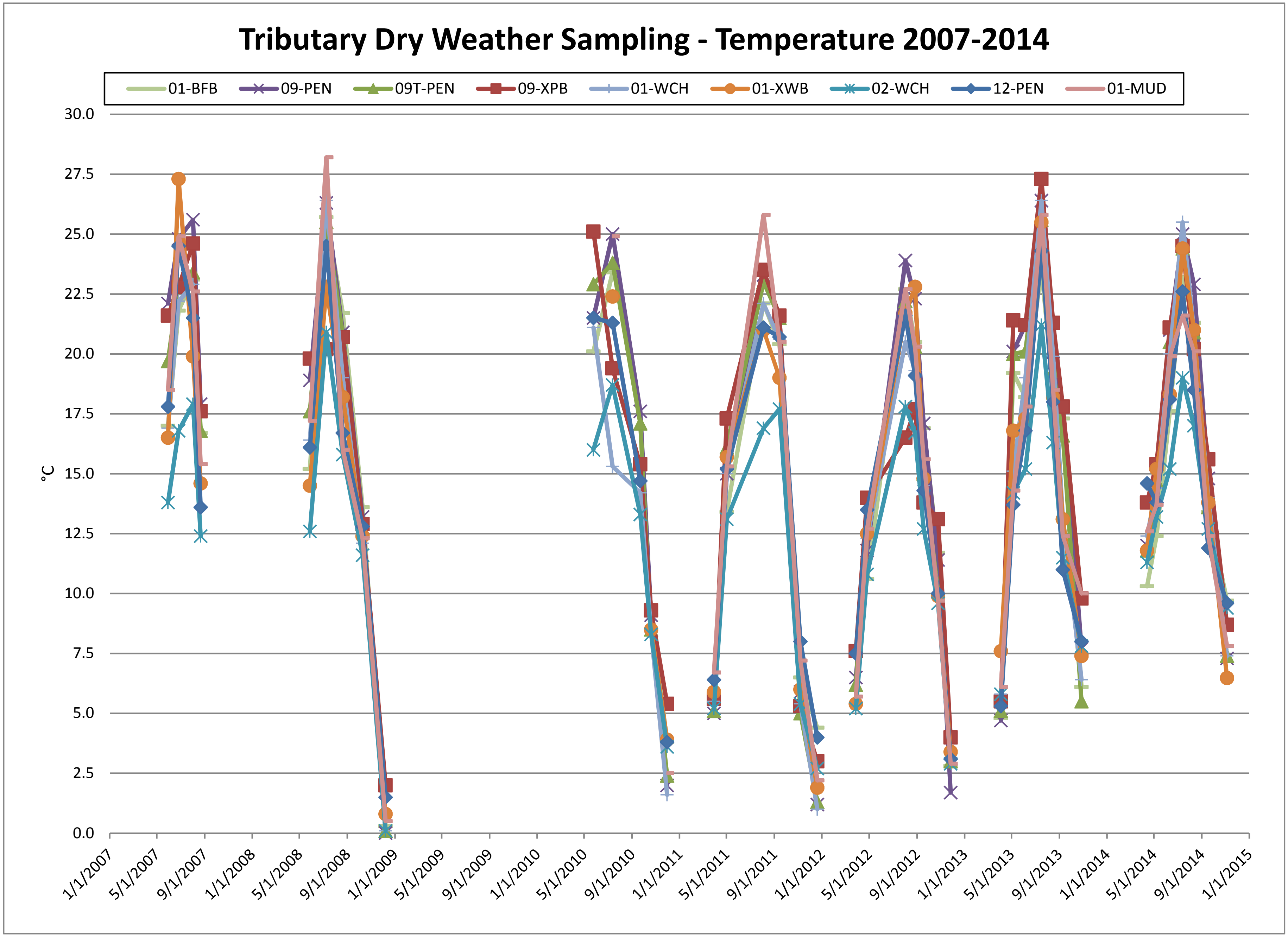

Tributary Dry Weather Sampling - Nitrate Levels 2007-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Mg/L
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015

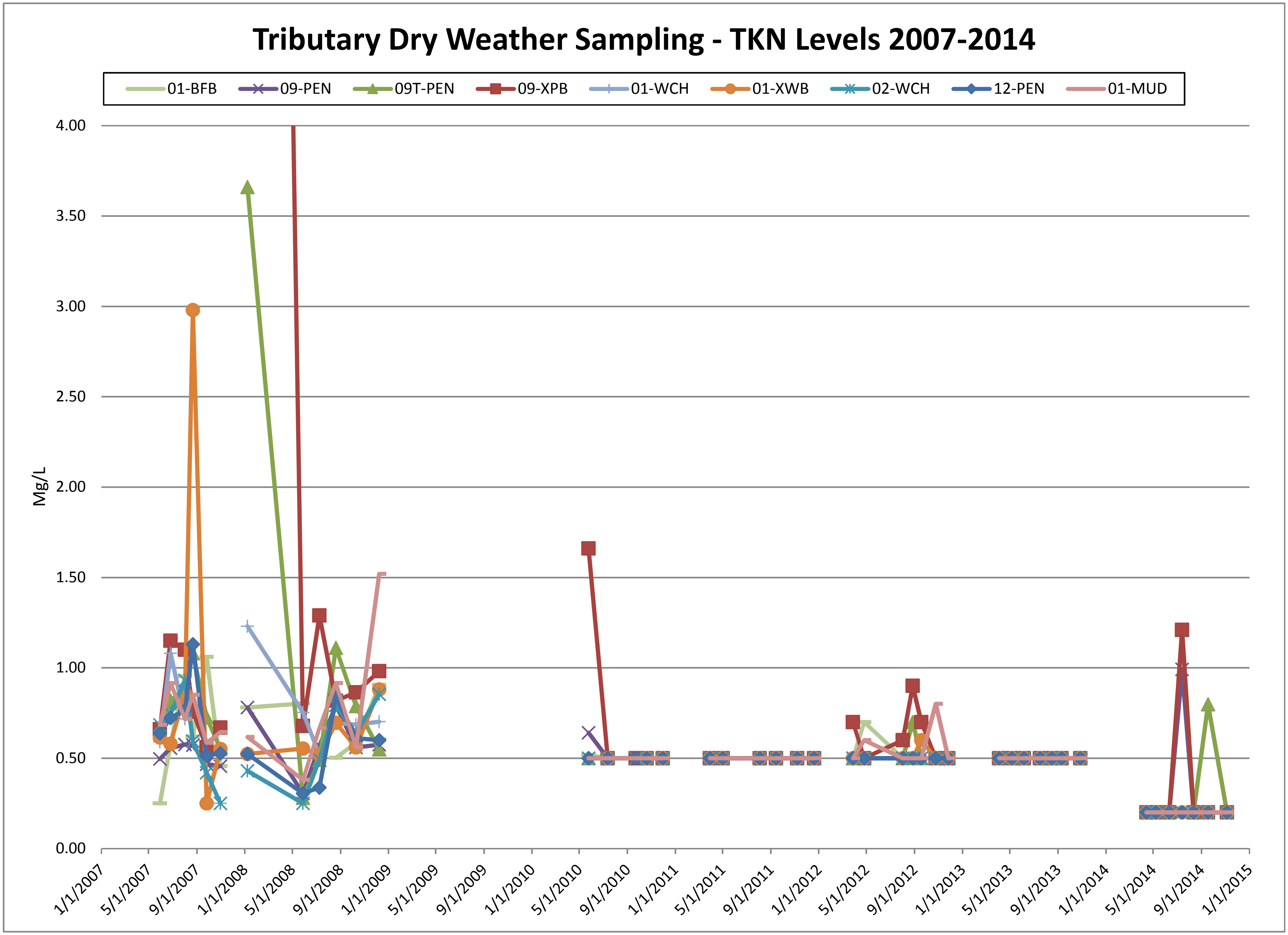


Tributary Dry Weather Sampling - Nitrite Levels 2007-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Mg/L
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015

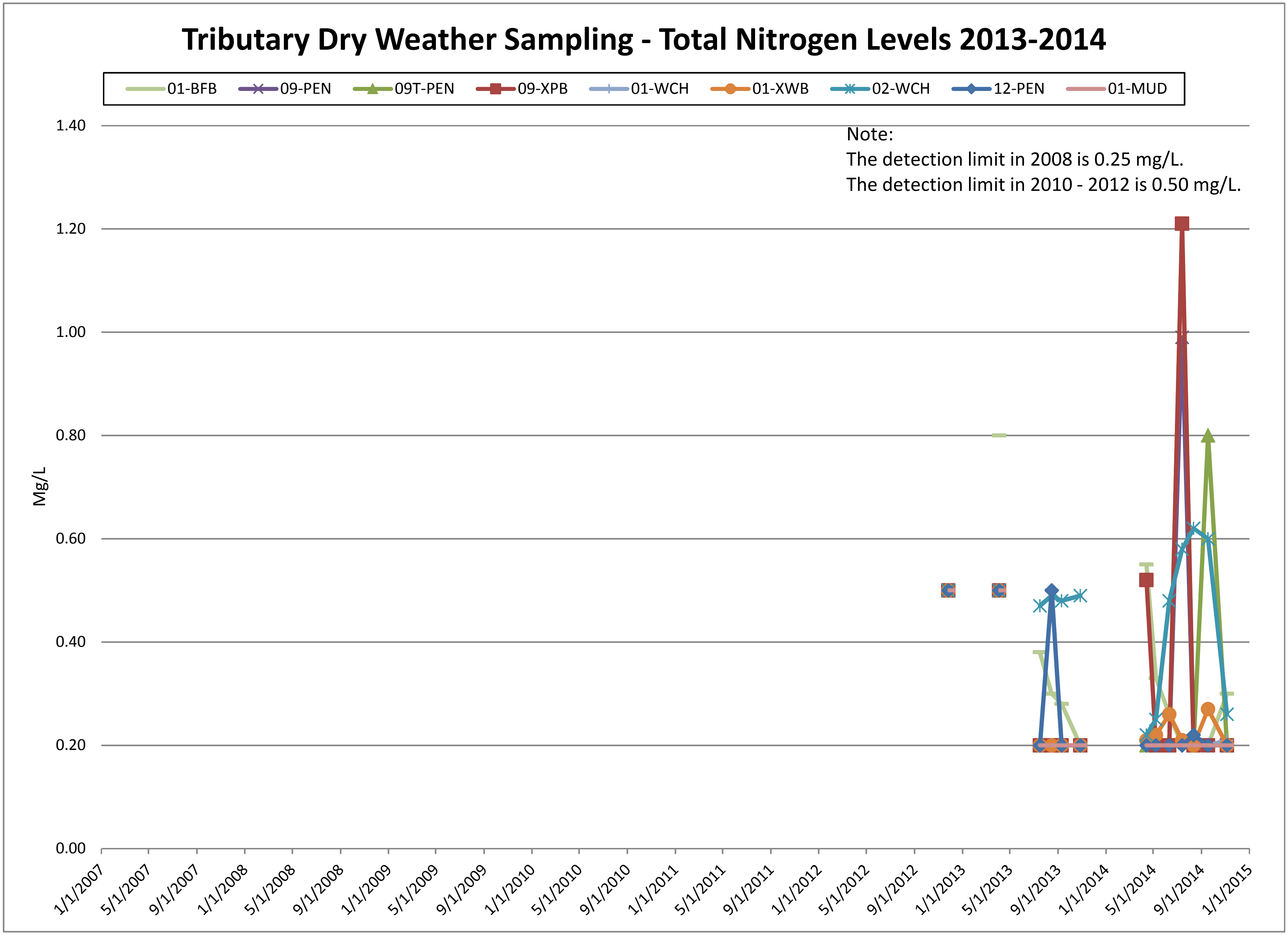
Tributary Dry Weather Sampling - pH 2007-2014



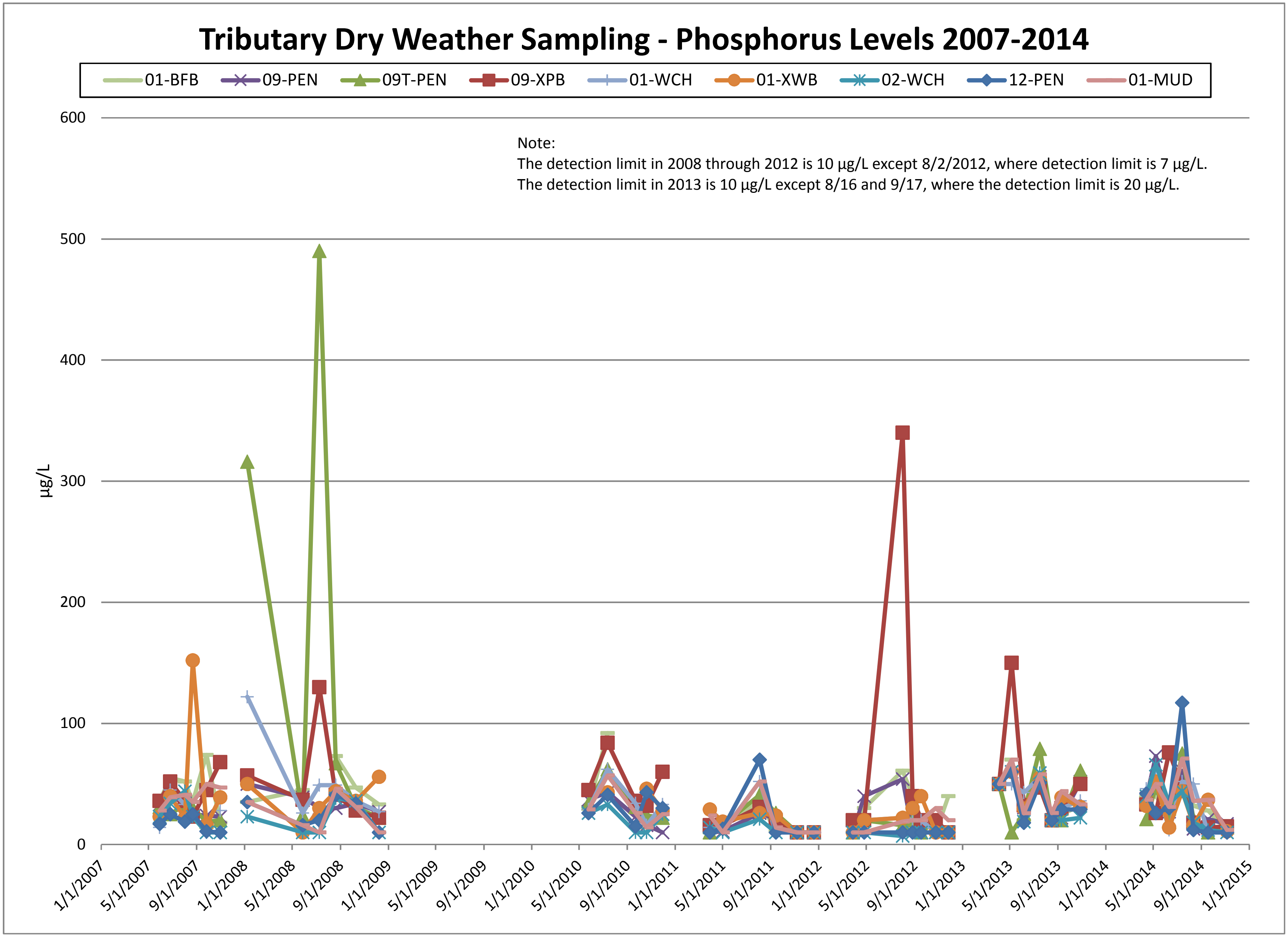

Tributary Dry Weather Sampling - Temperature 2007-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
°C
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015

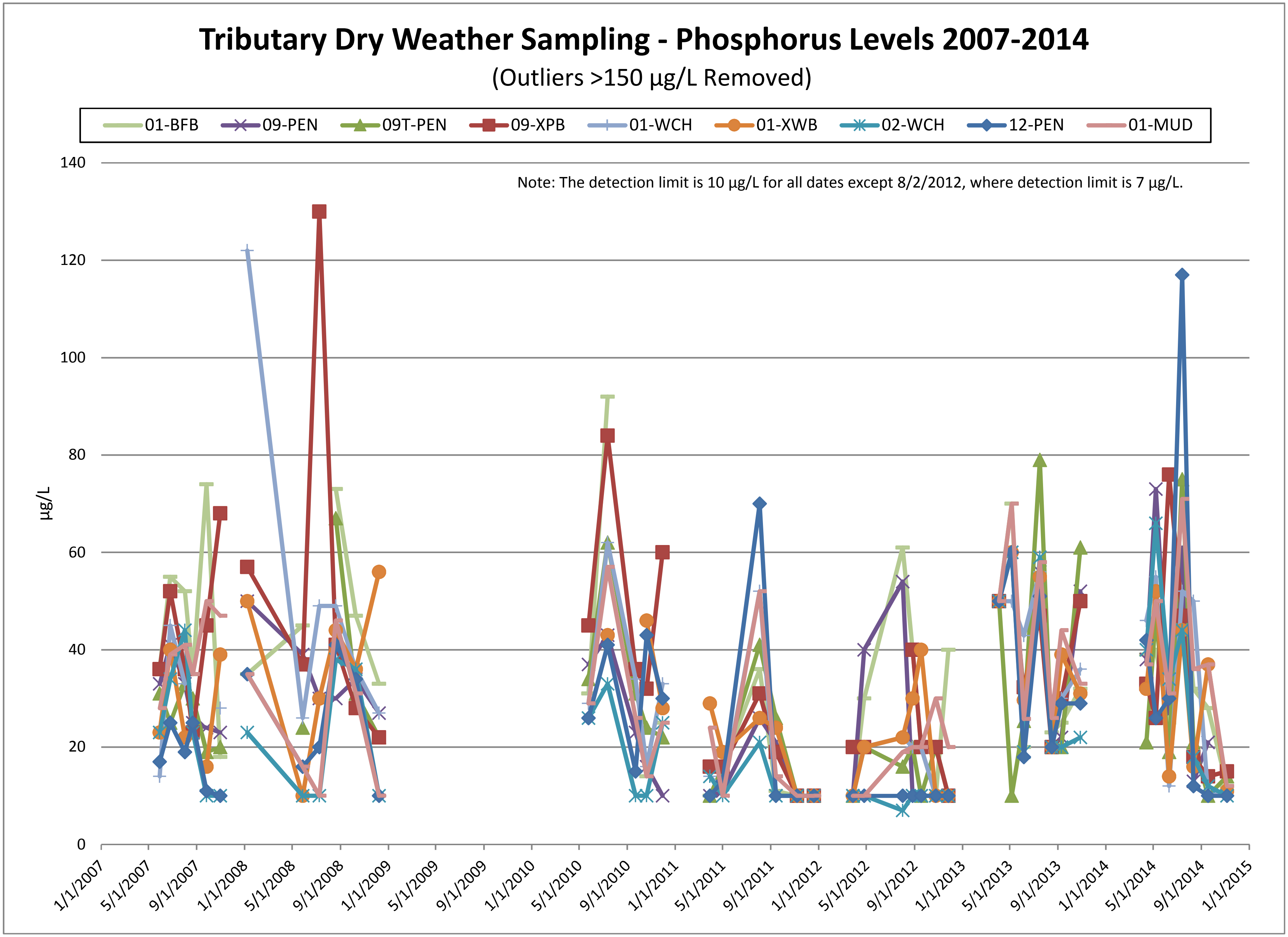


Tributary Dry Weather Sampling - TKN Levels 2007-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Mg/L
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015

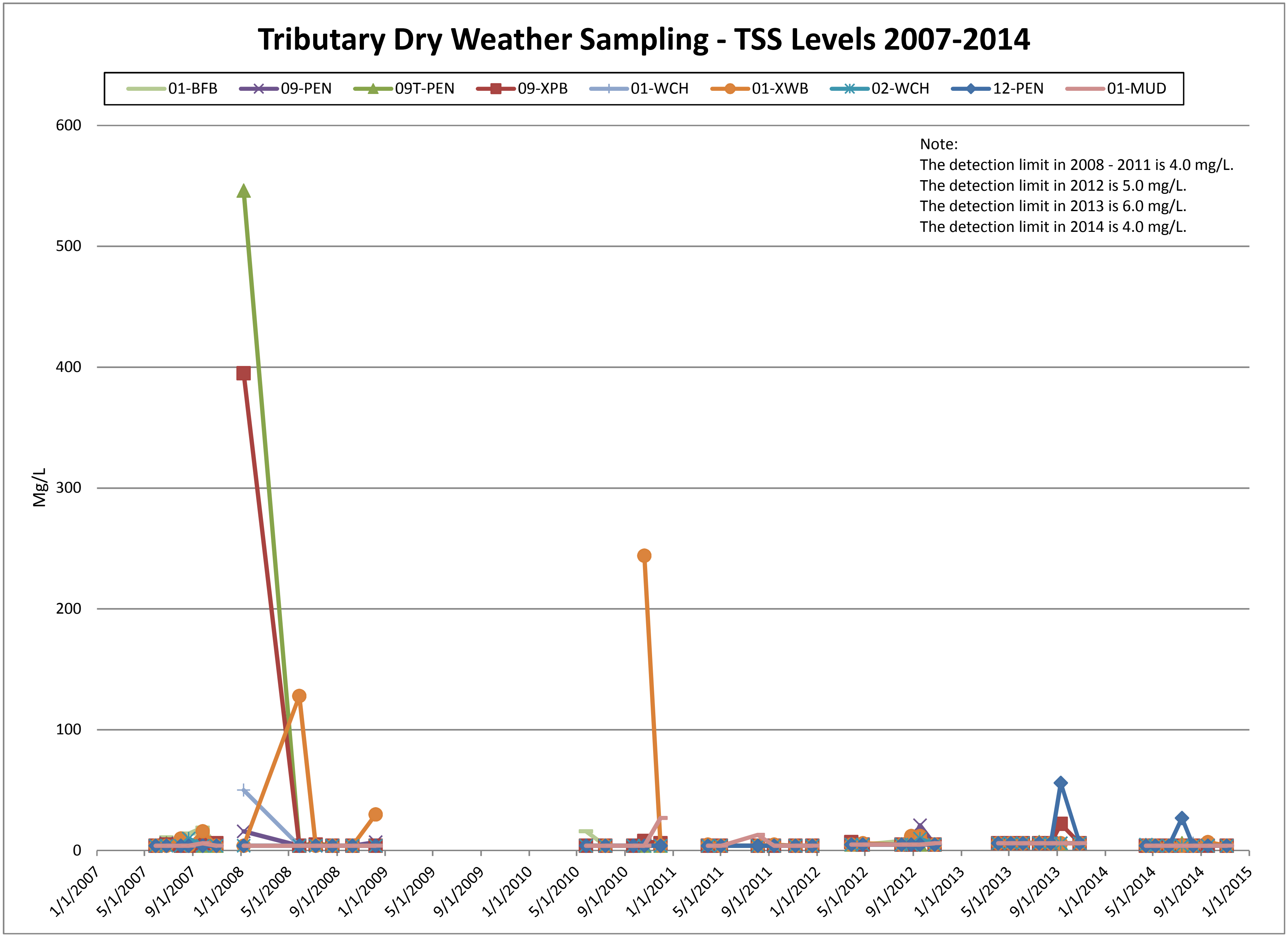


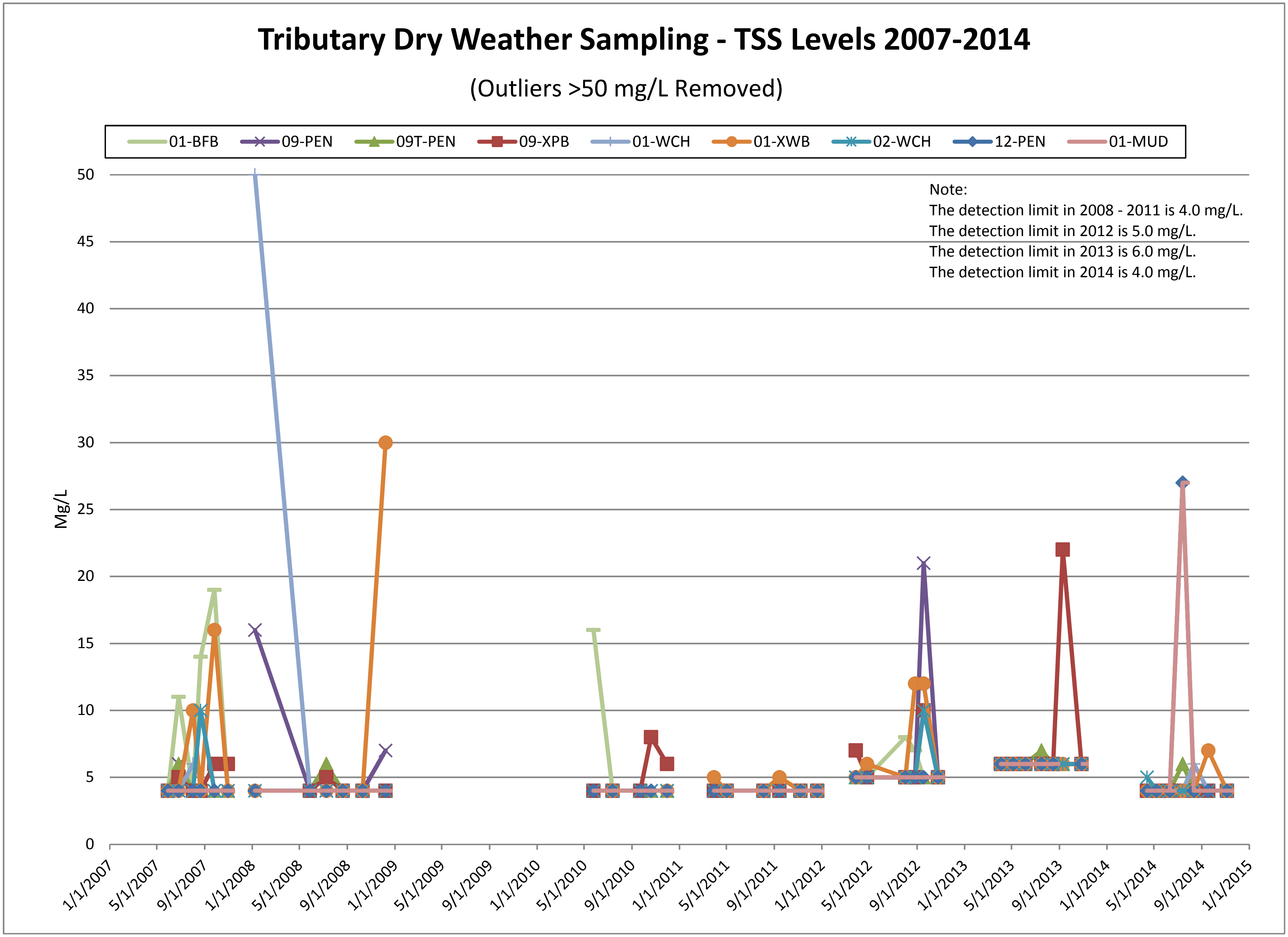
Tributary Dry Weather Sampling - Total Nitrogen Levels 2013-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Note:
The detection limit in 2008 is 0.25 mg/L.
The detection limit in 2010 - 2012 is 0.50 mg/L.
Mg/L
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015


Tributary Dry Weather Sampling - Phosphorus Levels 2007-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Note:
The detection limit in 2008 through 2012 is 10 µg/L except 8/2/2012, where detection limit is 7 µg/L.
The detection limit in 2013 is 10 µg/L except 8/16 and 9/17, where the detection limit is 20 µg/L.
µg/L
0
100
200
300
400
500
600
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015

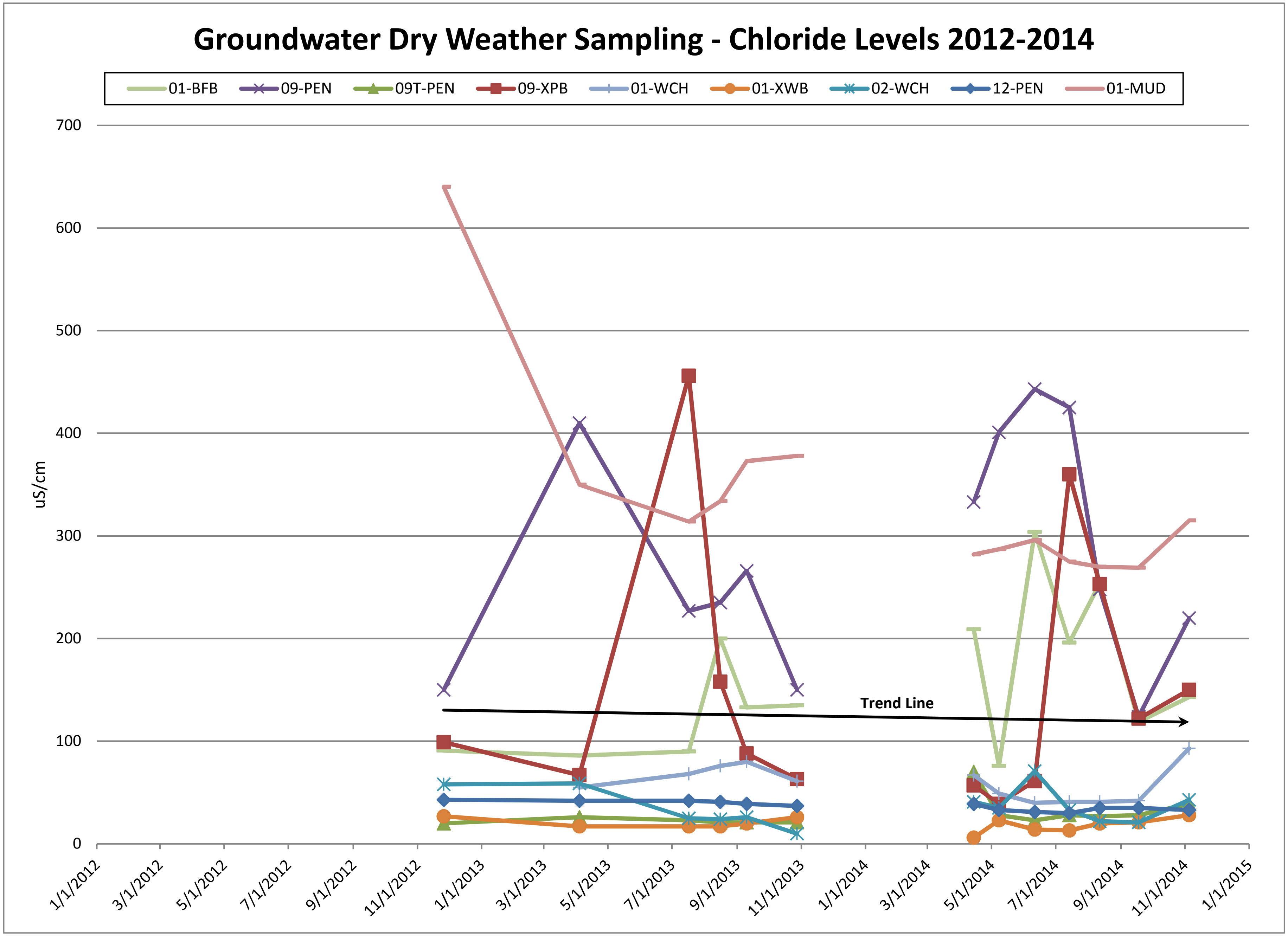


Tributary Dry Weather Sampling - Phosphorus Levels 2007-2014
(Outliers >150 µg/L Removed)
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Note: The detection limit is 10 µg/L for all dates except 8/2/2012, where detection limit is 7 µg/L.
µg/L
0
20
40
60
80
100
120
140
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015

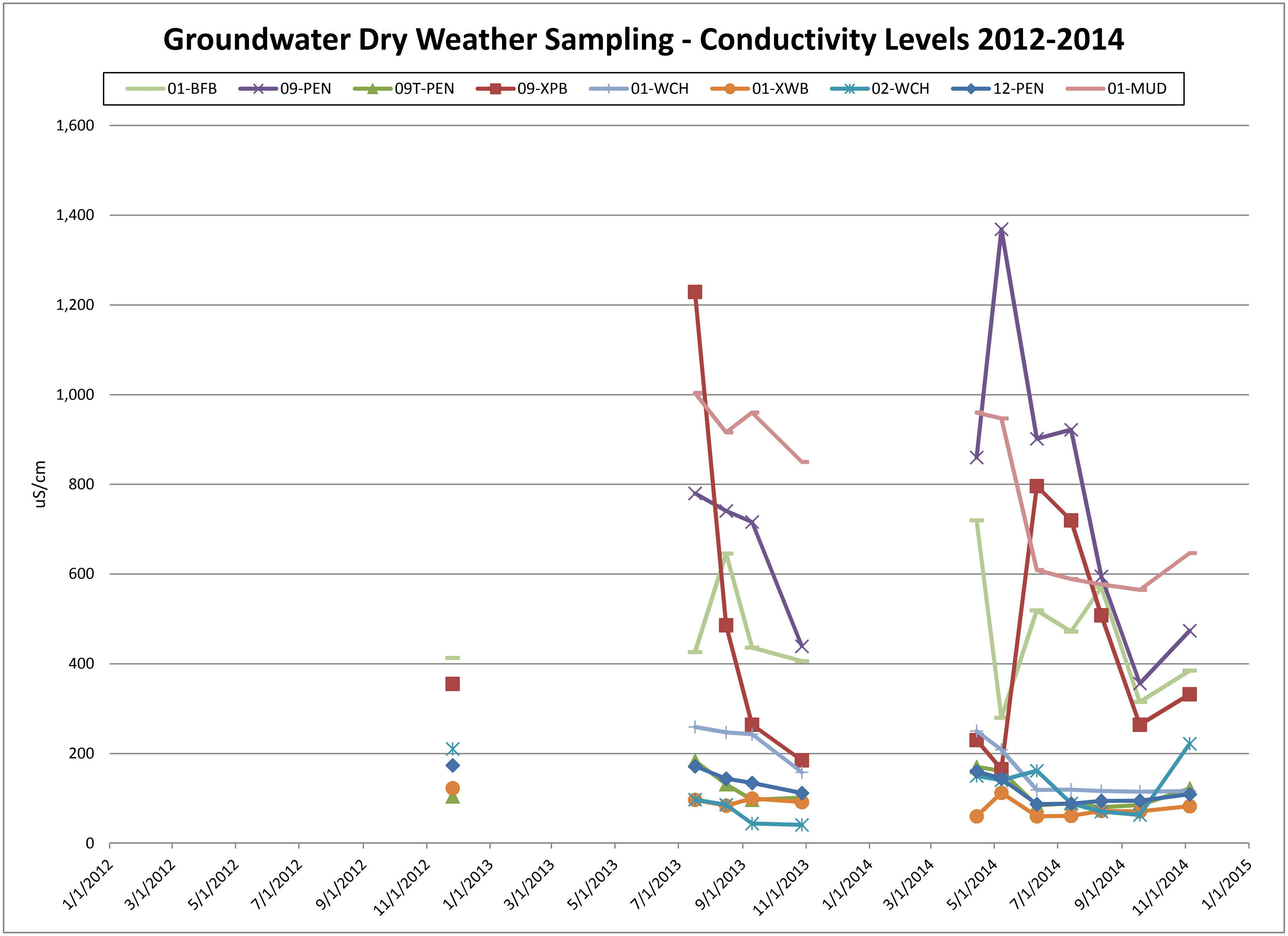

Tributary Dry Weather Sampling - TSS Levels 2007-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Note:
The detection limit in 2008 - 2011 is 4.0 mg/L.
The detection limit in 2012 is 5.0 mg/L.
The detection limit in 2013 is 6.0 mg/L.
The detection limit in 2014 is 4.0 mg/L.
Mg/L
600
500
400
300
200
100
0
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015


Tributary Dry Weather Sampling - TSS Levels 2007-2014
(Outliers >50 mg/L Removed)
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Note:
The detection limit in 2008 - 2011 is 4.0 mg/L.
The detection limit in 2012 is 5.0 mg/L.
The detection limit in 2013 is 6.0 mg/L.
The detection limit in 2014 is 4.0 mg/L.
Mg/L
0
5
10
15
20
25
30
35
40
45
50
1/1/2007
5/1/2007
9/1/2007
1/1/2008
5/1/2008
9/1/2008
1/1/2009
5/1/2009
9/1/2009
1/1/2010
5/1/2010
9/1/2010
1/1/2011
5/1/2011
9/1/2011
1/1/2012
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
5/1/2014
9/1/2014
1/1/2015

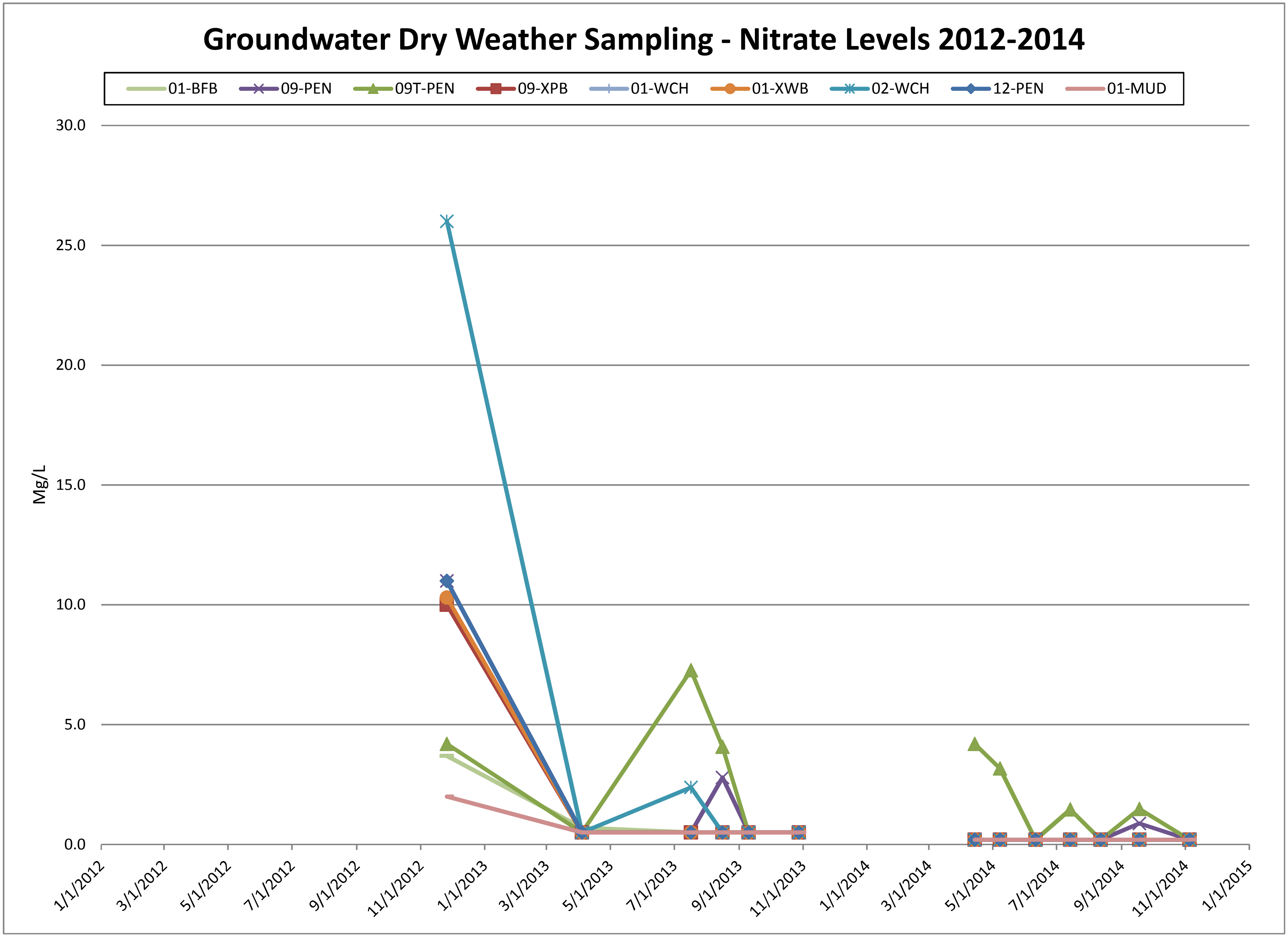
2007-2014 Groundwater Graphs



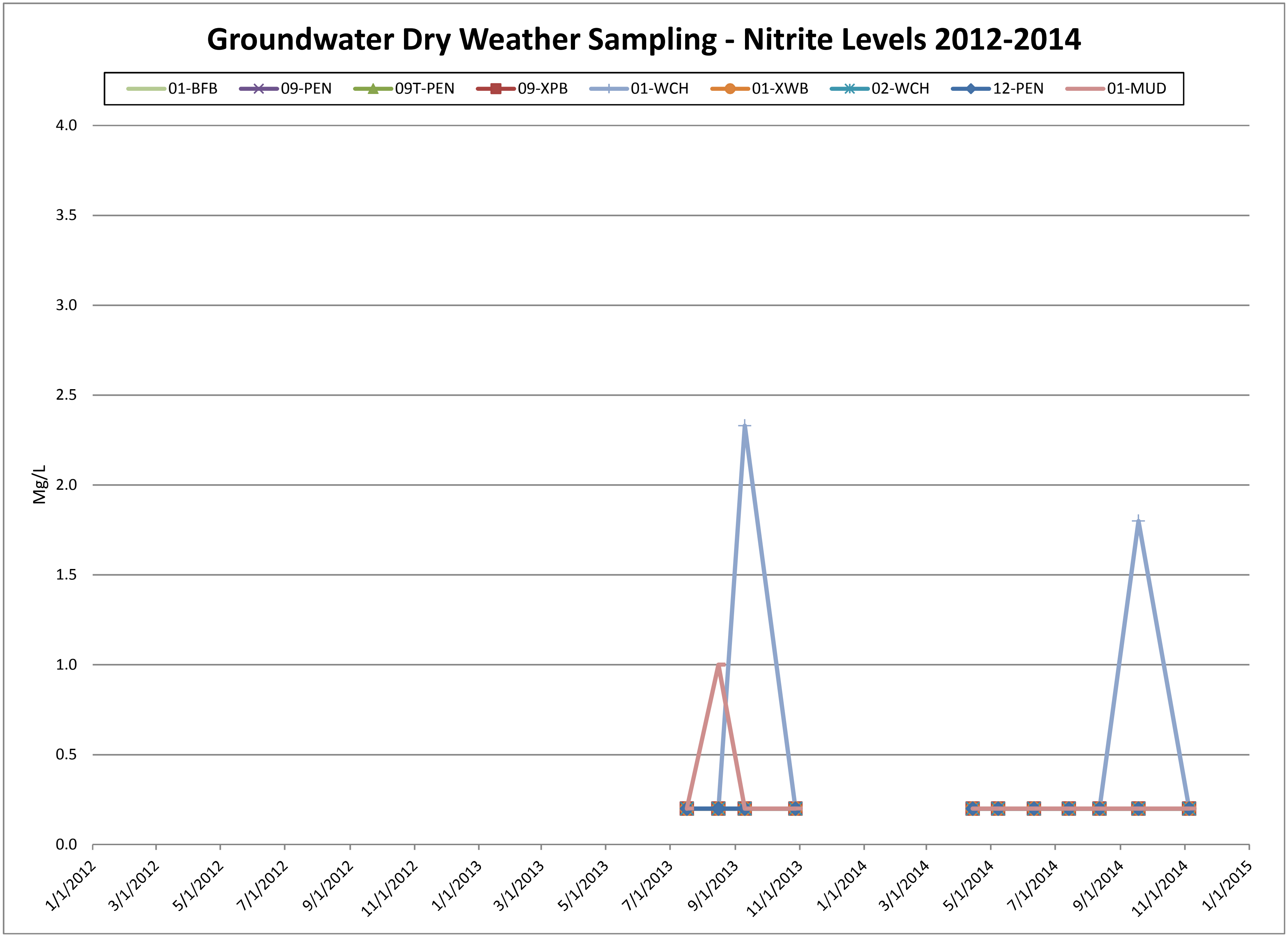
Groundwater Dry Weather Sampling - Chloride Levels 2012-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
uS/cm
700
600
500
400
300
200
100
0
Trend Line
1/1/2012
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
1/1/2013
3/1/2013
5/1/2013
7/1/2013
9/1/2013
11/1/2013
1/1/2014
3/1/2014
5/1/2014
7/1/2014
9/1/2014
11/1/2014
1/1/2015

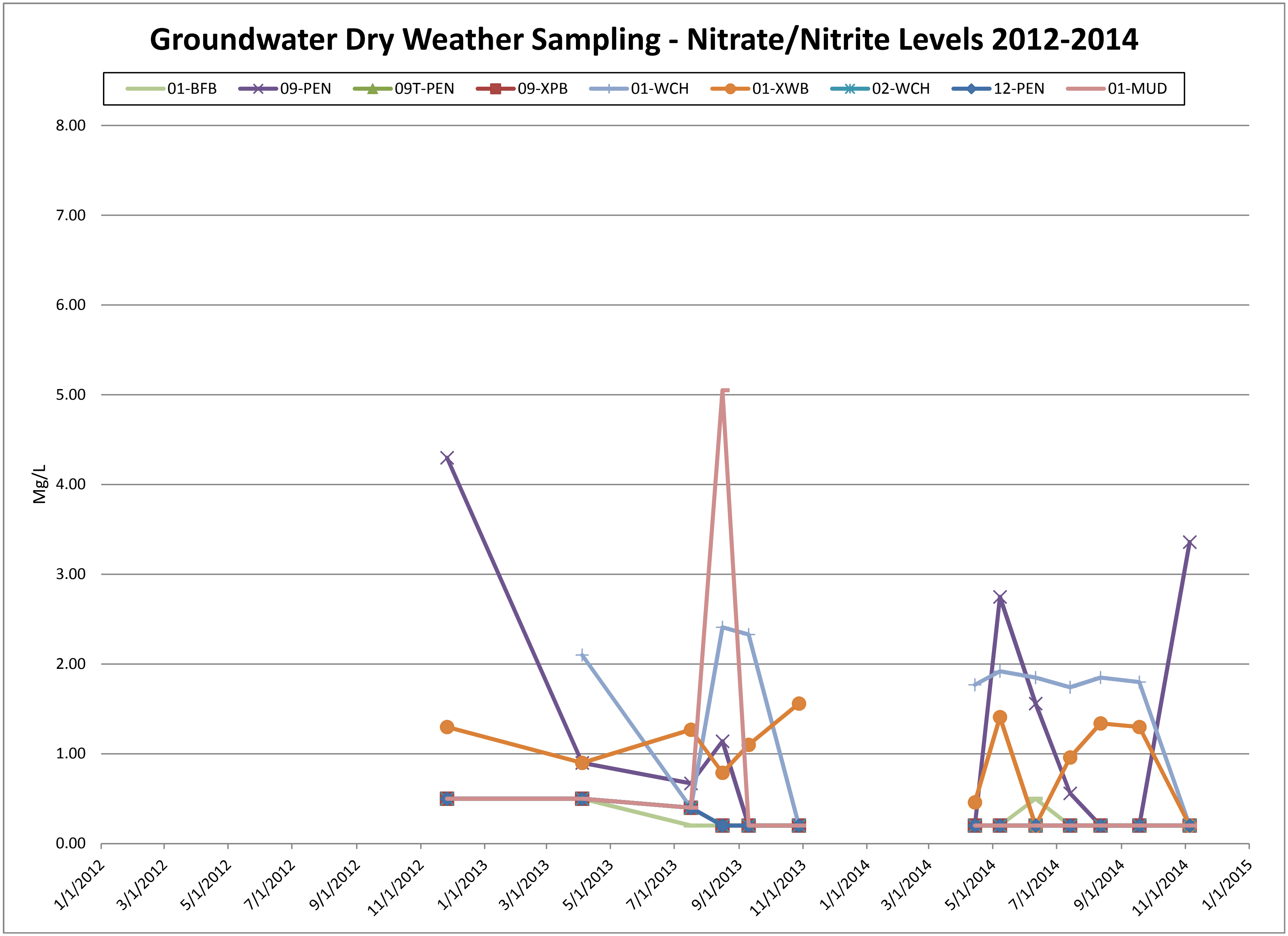


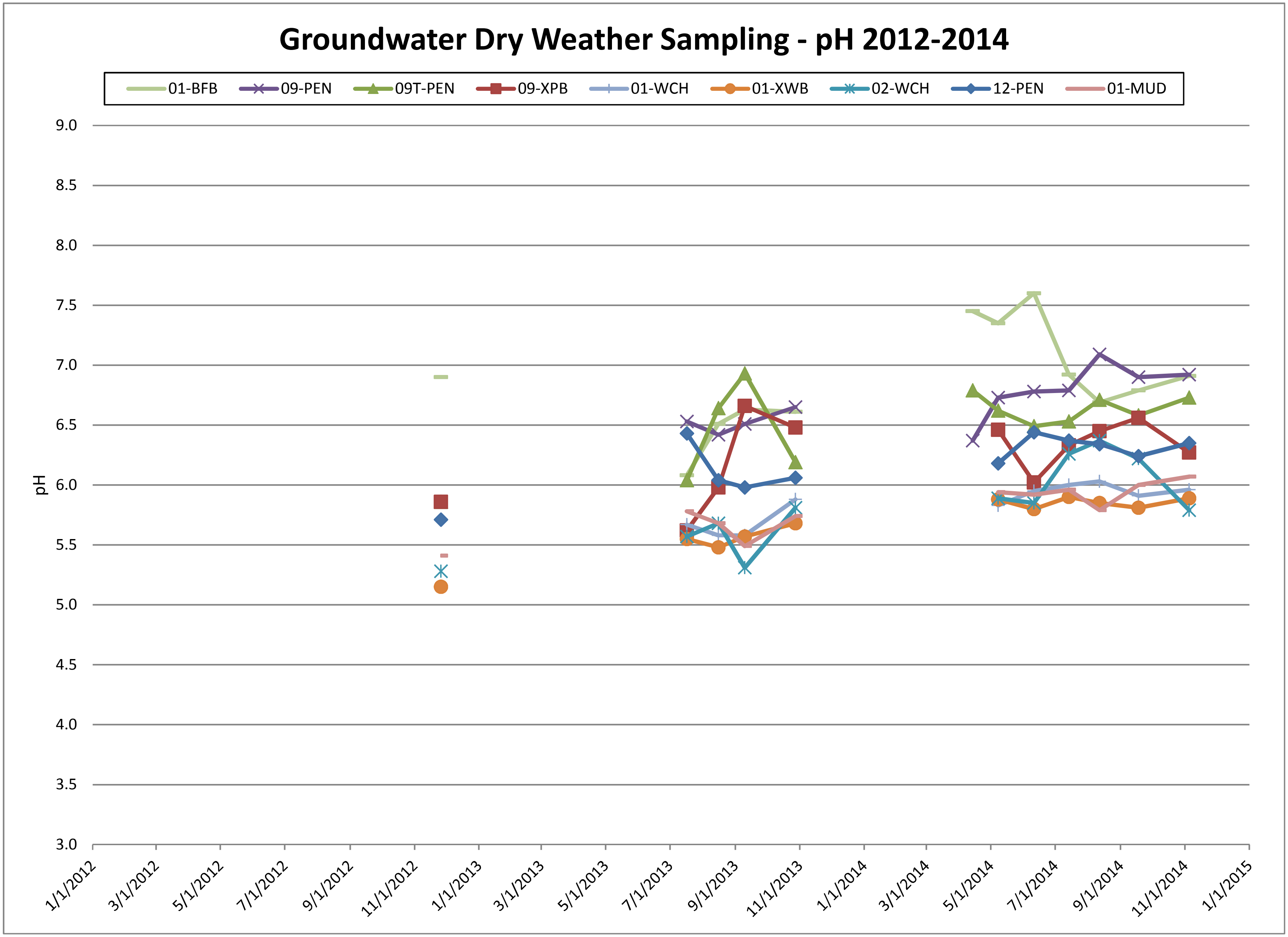
Groundwater Dry Weather Sampling - Conductivity Levels 2012-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
uS/cm
1,600
1,400
1,200
1,000
800
600
400
200
0
1/1/2012
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
1/1/2013
3/1/2013
5/1/2013
7/1/2013
9/1/2013
11/1/2013
1/1/2014
3/1/2014
5/1/2014
7/1/2014
9/1/2014
11/1/2014
1/1/2015

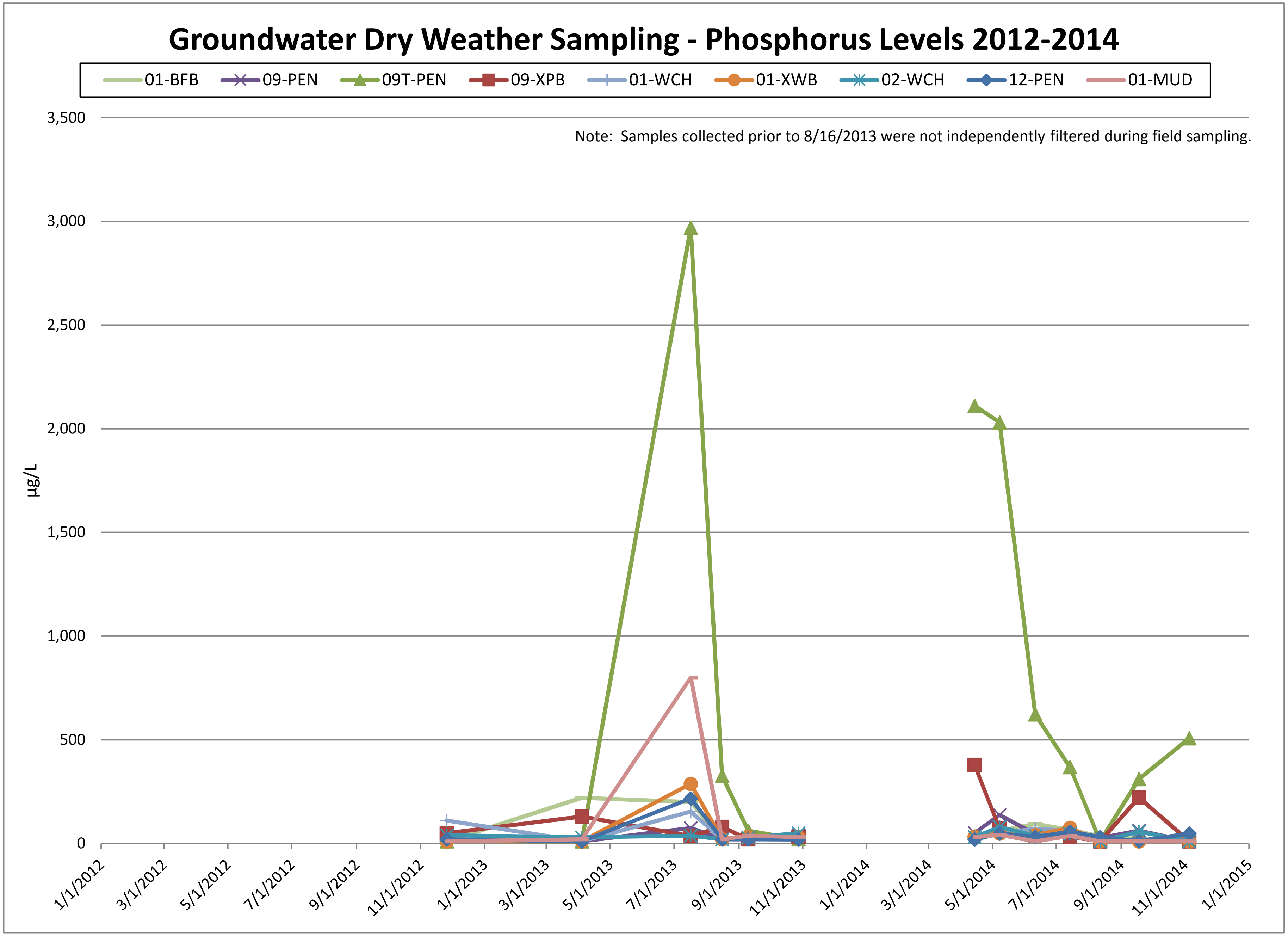


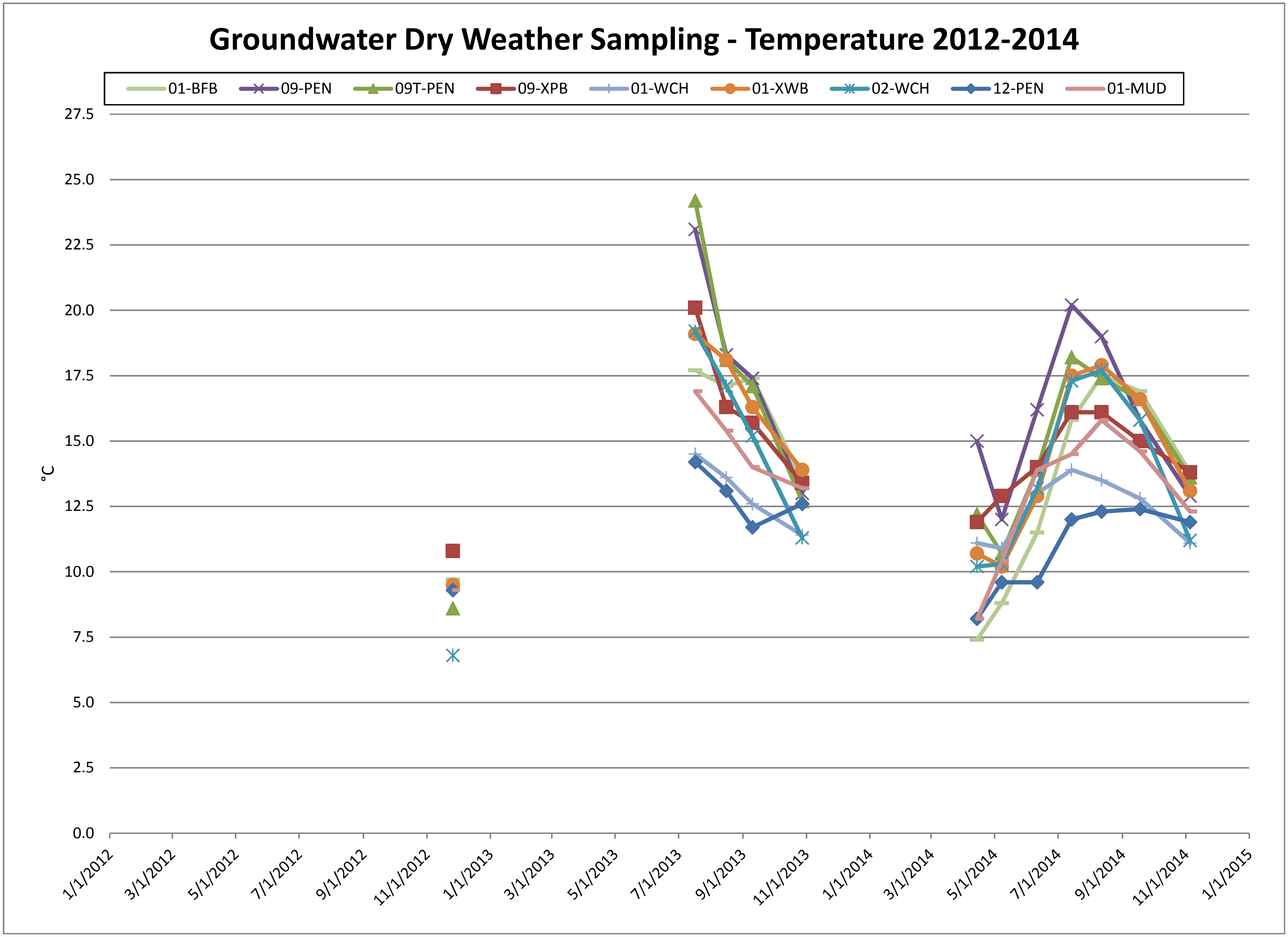
Groundwater Dry Weather Sampling - Nitrate Levels 2012-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Mg/L
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1/1/2012
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
1/1/2013
3/1/2013
5/1/2013
7/1/2013
9/1/2013
11/1/2013
1/1/2014
3/1/2014
5/1/2014
7/1/2014
9/1/2014
11/1/2014
1/1/2015


Groundwater Dry Weather Sampling - Nitrite Levels 2012-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Mg/L
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1/1/2012
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
1/1/2013
3/1/2013
5/1/2013
7/1/2013
9/1/2013
11/1/2013
1/1/2014
3/1/2014
5/1/2014
7/1/2014
9/1/2014
11/1/2014
1/1/2015

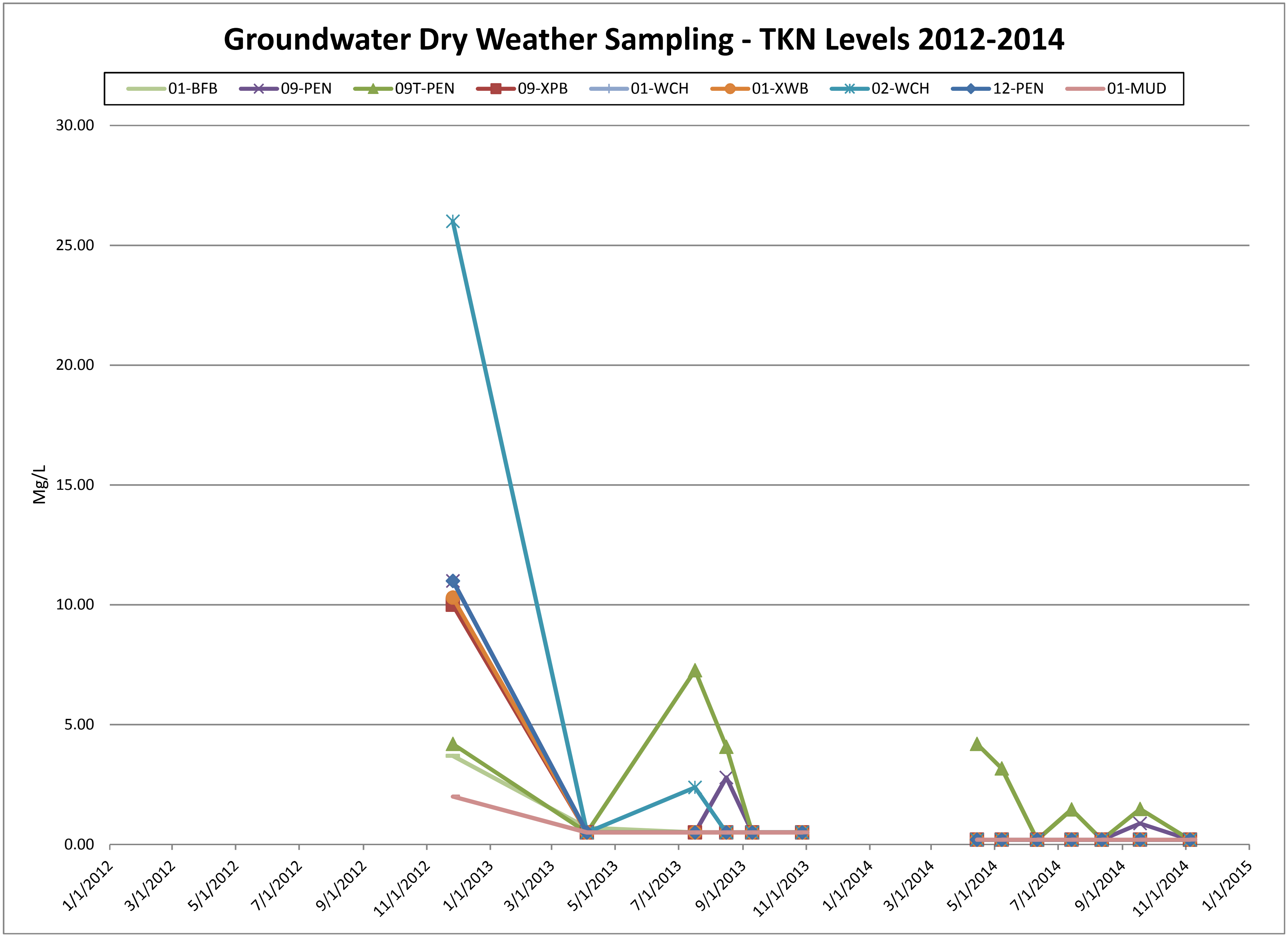

Groundwater Dry Weather Sampling - Nitrate/Nitrite Levels 2012-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Mg/L
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1/1/2012
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
1/1/2013
3/1/2013
5/1/2013
7/1/2013
9/1/2013
11/1/2013
1/1/2014
3/1/2014
5/1/2014
7/1/2014
9/1/2014
11/1/2014
1/1/2015


Groundwater Dry Weather Sampling - pH 2012-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
1/1/2012
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
1/1/2013
3/1/2013
5/1/2013
7/1/2013
9/1/2013
11/1/2013
1/1/2014
3/1/2014
5/1/2014
7/1/2014
9/1/2014
11/1/2014
1/1/2015

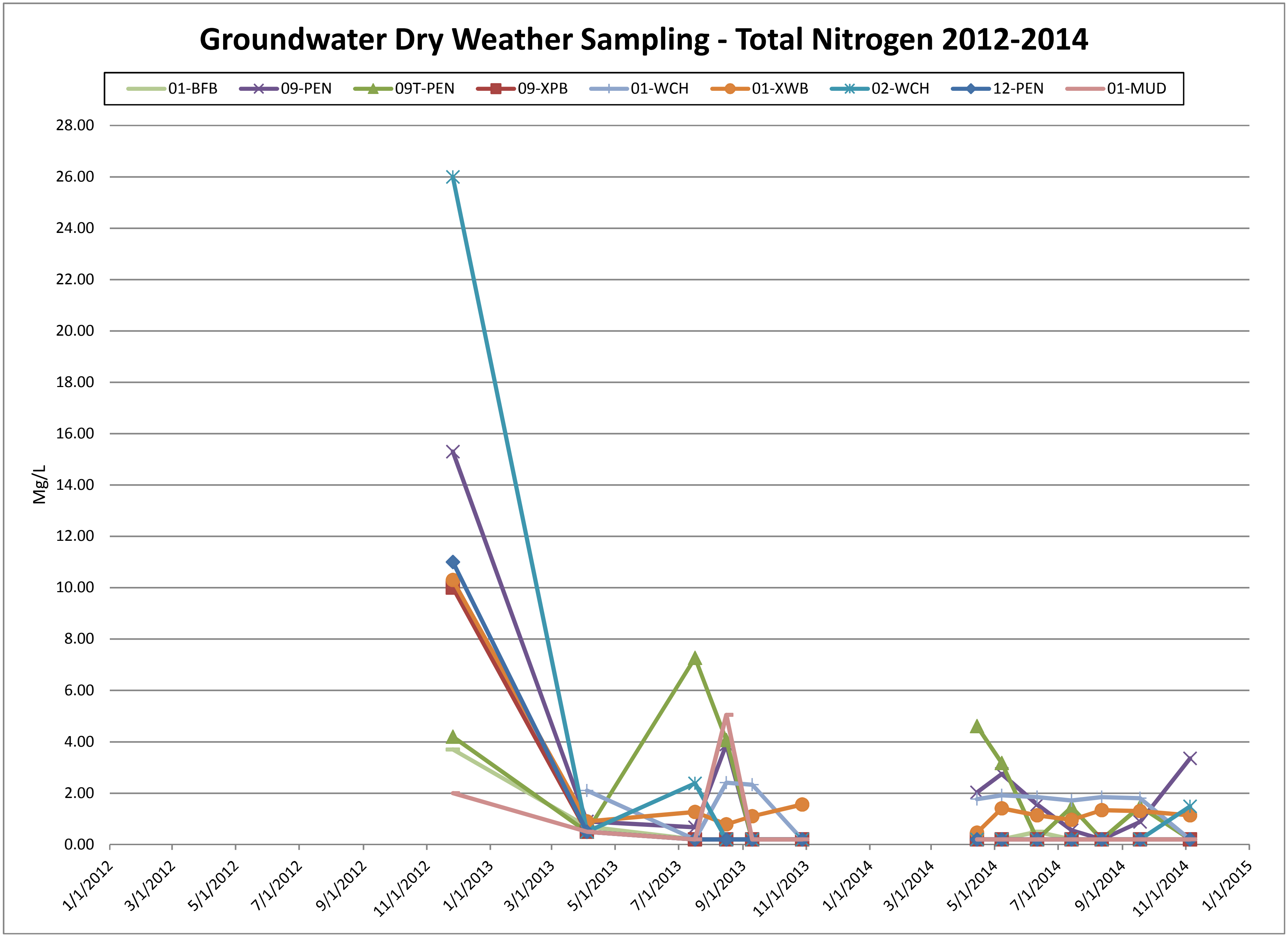

Groundwater Dry Weather Sampling - Phosphorus Levels 2012-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Note: Samples collected prior to 8/16/2013 were not independently filtered during field sampling.
µg/L
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1/1/2012
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
1/1/2013
3/1/2013
5/1/2013
7/1/2013
9/1/2013
11/1/2013
1/1/2014
3/1/2014
5/1/2014
7/1/2014
9/1/2014
11/1/2014
1/1/2015



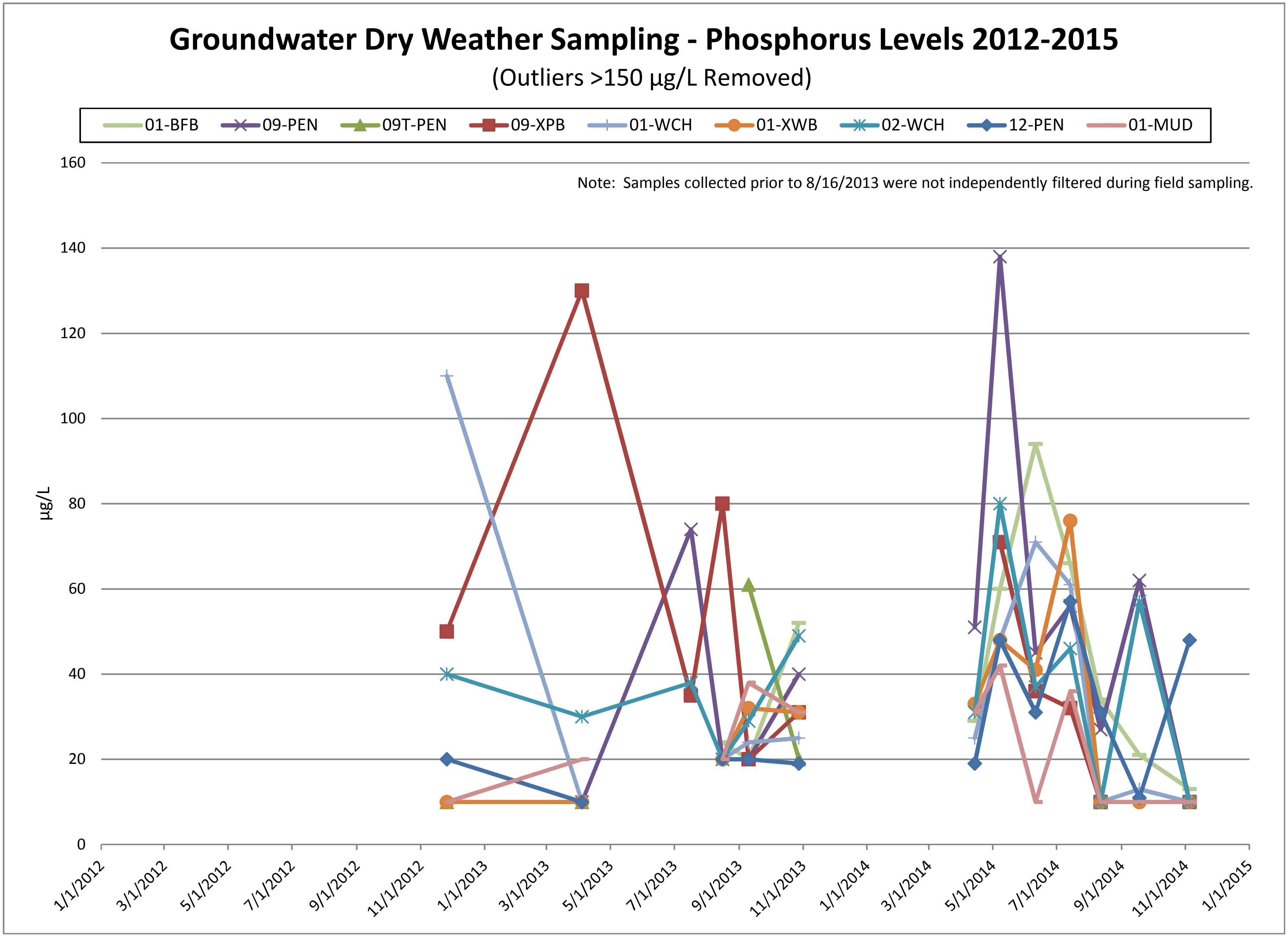
Groundwater Dry Weather Sampling - Temperature 2012-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
°C
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
1/1/2012
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
1/1/2013
3/1/2013
5/1/2013
7/1/2013
9/1/2013
11/1/2013
1/1/2014
3/1/2014
5/1/2014
7/1/2014
9/1/2014
11/1/2014
1/1/2015



Groundwater Dry Weather Sampling - TKN Levels 2012-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Mg/L
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1/1/2012
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
1/1/2013
3/1/2013
5/1/2013
7/1/2013
9/1/2013
11/1/2013
1/1/2014
3/1/2014
5/1/2014
7/1/2014
9/1/2014
11/1/2014
1/1/2015

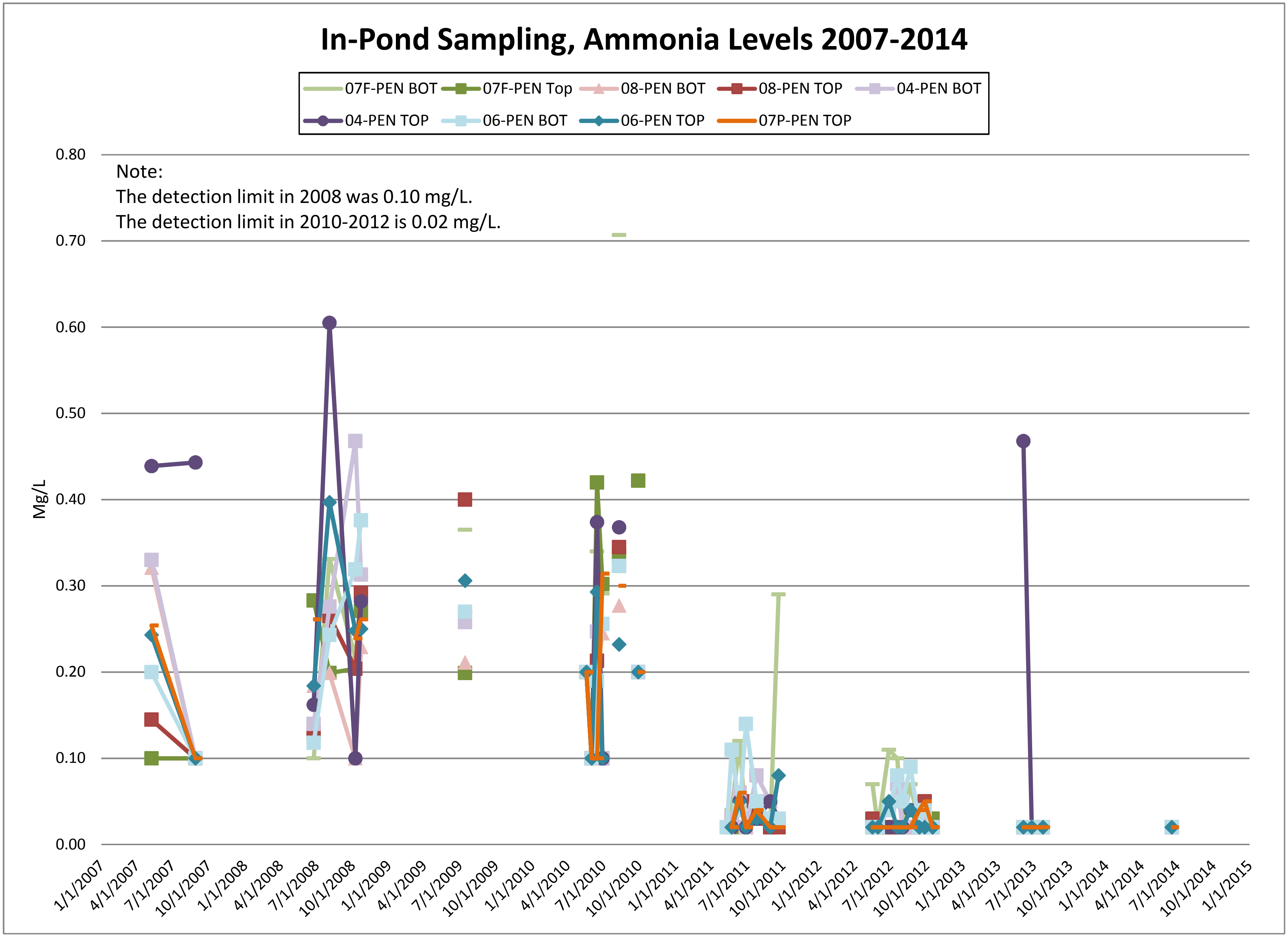


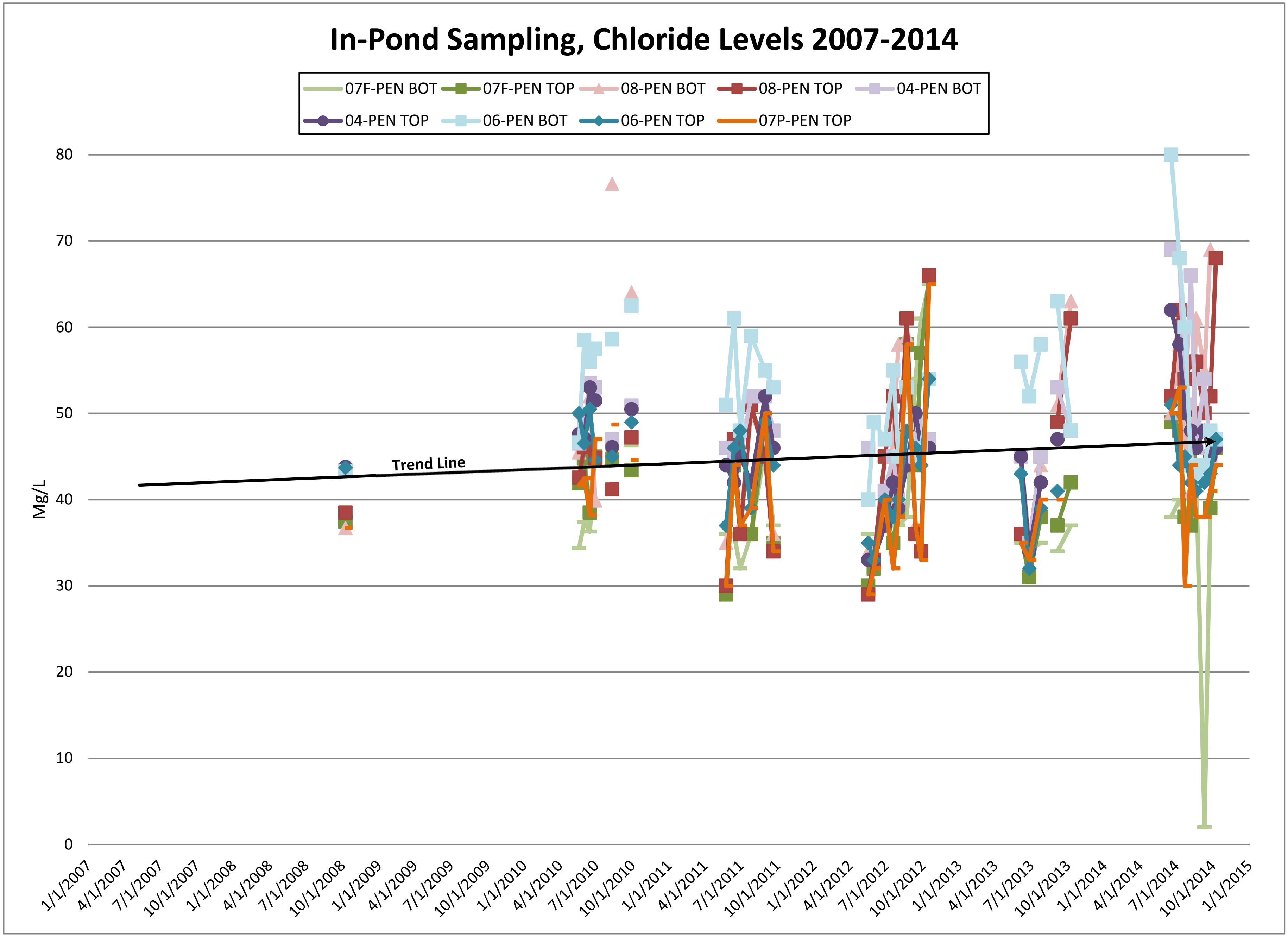
Groundwater Dry Weather Sampling - Total Nitrogen 2012-2014
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Mg/L
28.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1/1/2012
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
1/1/2013
3/1/2013
5/1/2013
7/1/2013
9/1/2013
11/1/2013
1/1/2014
3/1/2014
5/1/2014
7/1/2014
9/1/2014
11/1/2014
1/1/2015



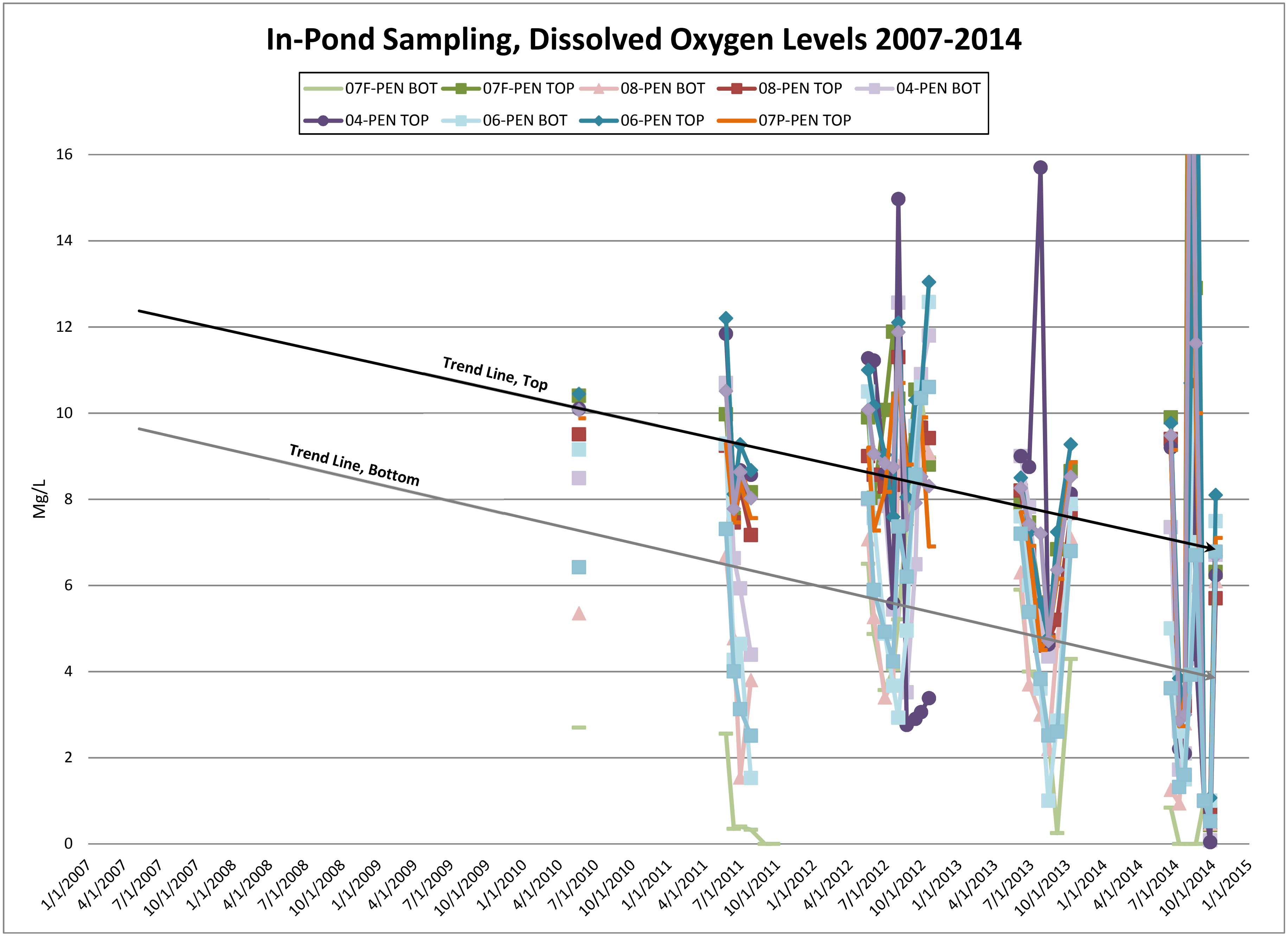
Groundwater Dry Weather Sampling - Phosphorus Levels 2012-2015
(Outliers >150 µg/L Removed)
01-BFB
09-PEN
09T-PEN
09-XPB
01-WCH
01-XWB
02-WCH
12-PEN
01-MUD
Note: Samples collected prior to 8/16/2013 were not independently filtered during field sampling.
µg/L
0
20
40
60
80
100
120
140
160
1/1/2012
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
1/1/2013
3/1/2013
5/1/2013
7/1/2013
9/1/2013
11/1/2013
1/1/2014
3/1/2014
5/1/2014
7/1/2014
9/1/2014
11/1/2014
1/1/2015

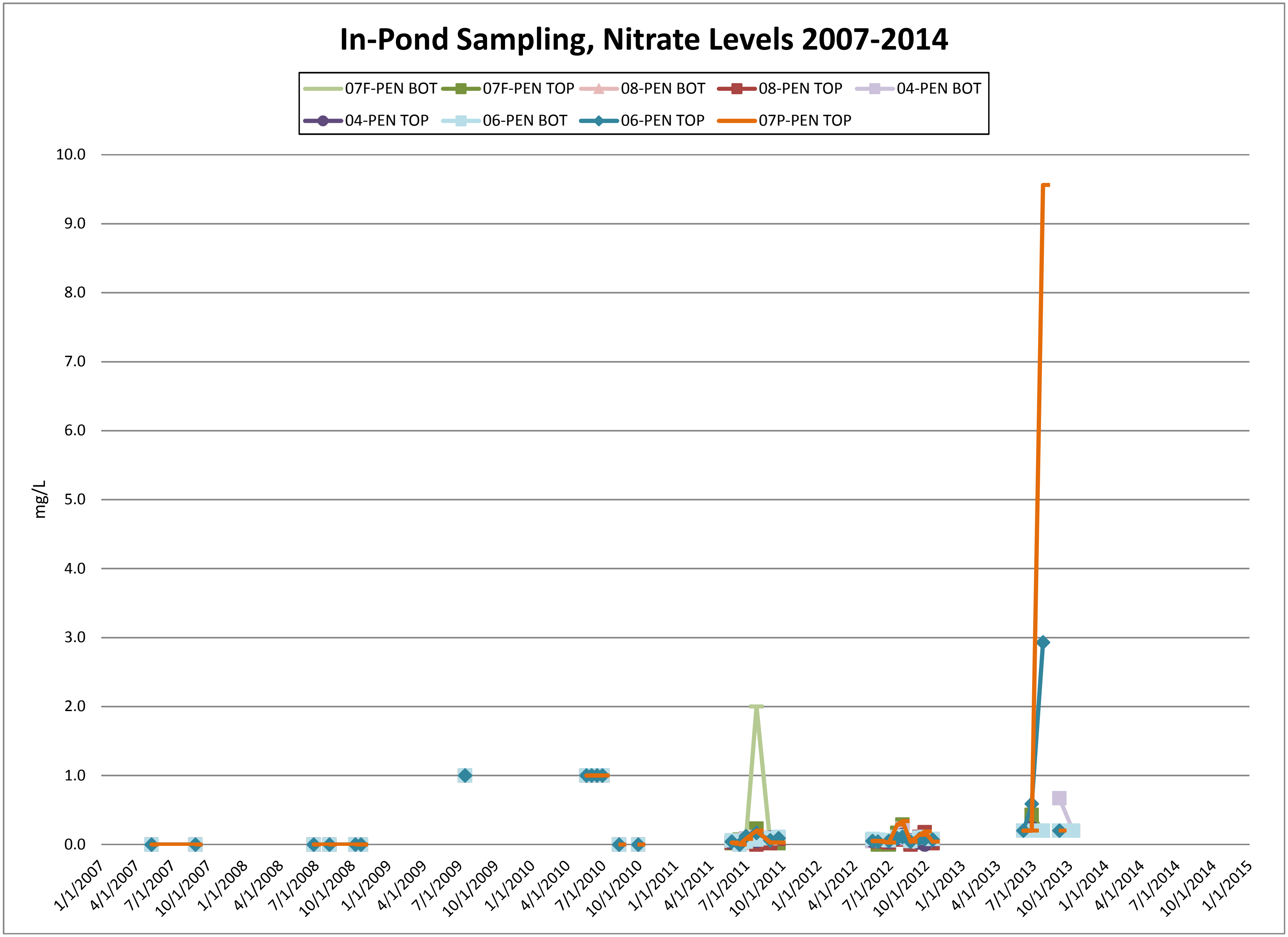
2007-2014 In-Pond Graphs


In-Pond Sampling, Ammonia Levels 2007-2014
07F-PEN BOT
07F-PEN Top
08-PEN BOT
08-PEN TOP
04-PEN BOT
04-PEN TOP
06-PEN BOT
06-PEN TOP
07P-PEN TOP
Note:
The detection limit in 2008 was 0.10 mg/L.
The detection limit in 2010-2012 is 0.02 mg/L.
Mg/L
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
1/1/2015

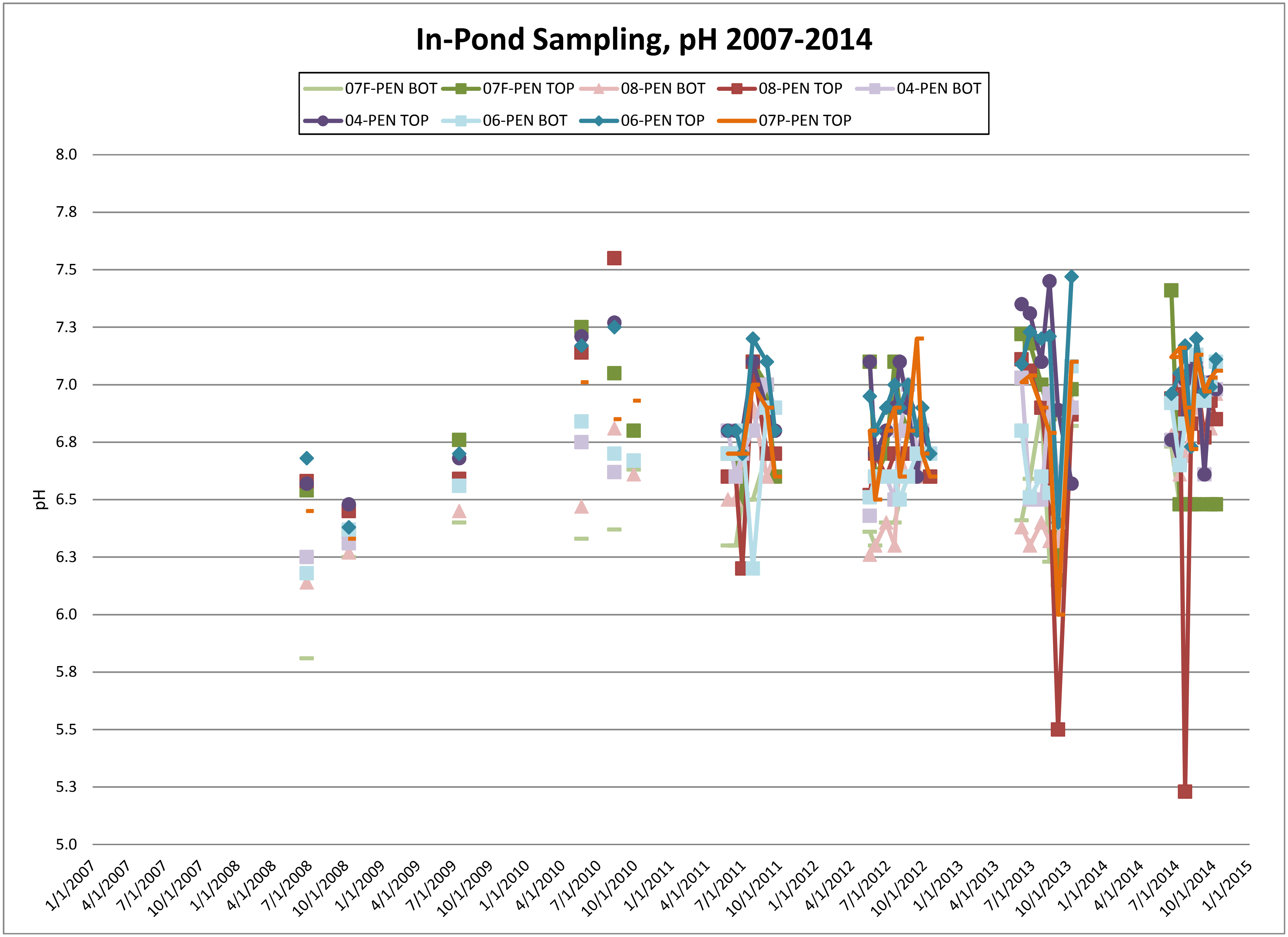


In-Pond Sampling, Chloride Levels 2007-2014
07F-PEN BOT
07F-PEN TOP
08-PEN BOT
08-PEN TOP
04-PEN BOT
04-PEN TOP
06-PEN BOT
06-PEN TOP
07P-PEN TOP
Trend Line
Mg/L
80
70
60
50
40
30
20
10
0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
1/1/2015

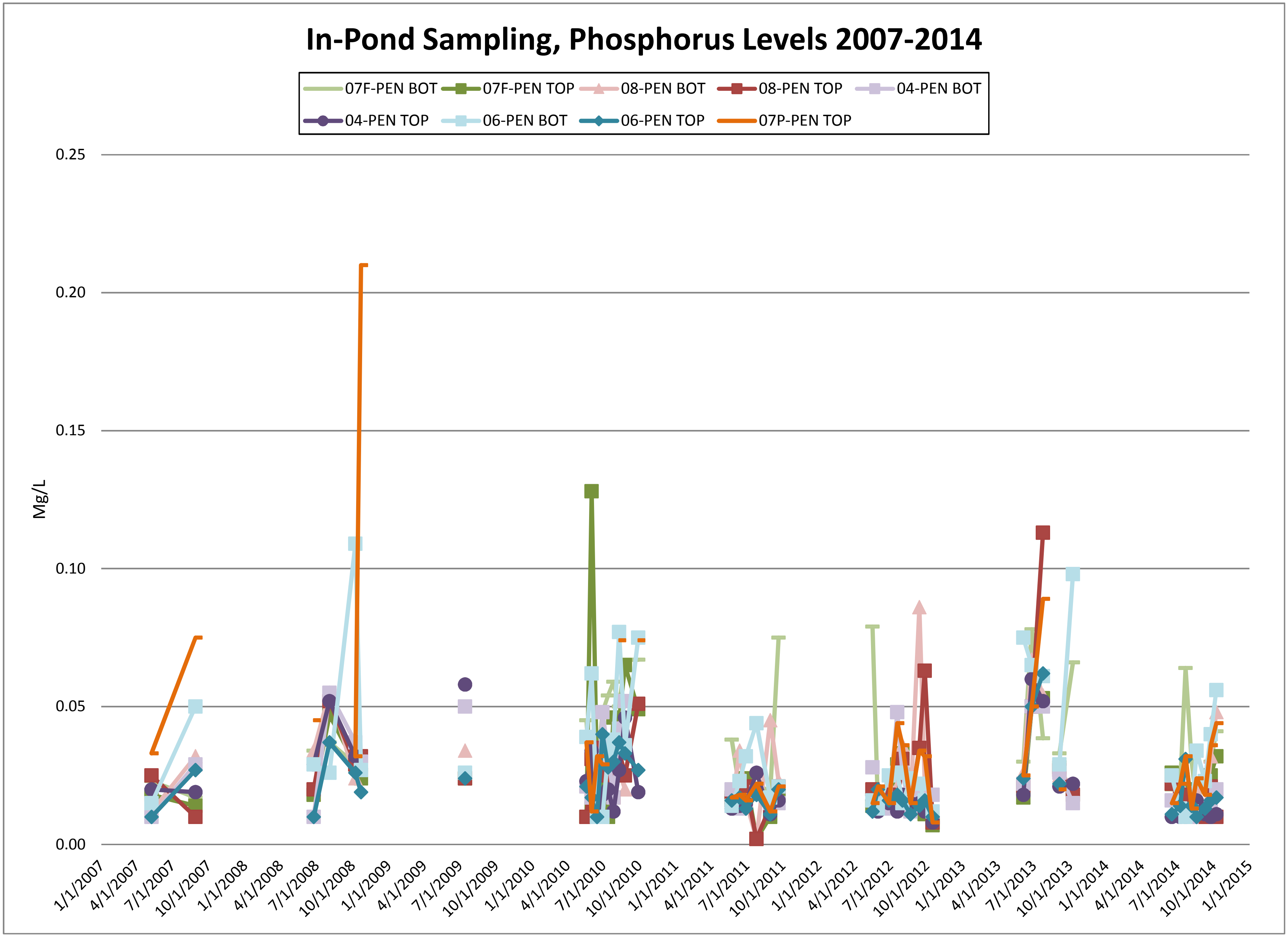

In-Pond Sampling, Dissolved Oxygen Levels 2007-2014
07F-PEN BOT
07F-PEN TOP
08-PEN BOT
08-PEN TOP
04-PEN BOT
04-PEN TOP
06-PEN BOT
06-PEN TOP
07P-PEN TOP
Mg/L
16
14
12
10
8
6
4
2
0
Trend Line, Top
Trend Line, Bottom
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
1/1/2015



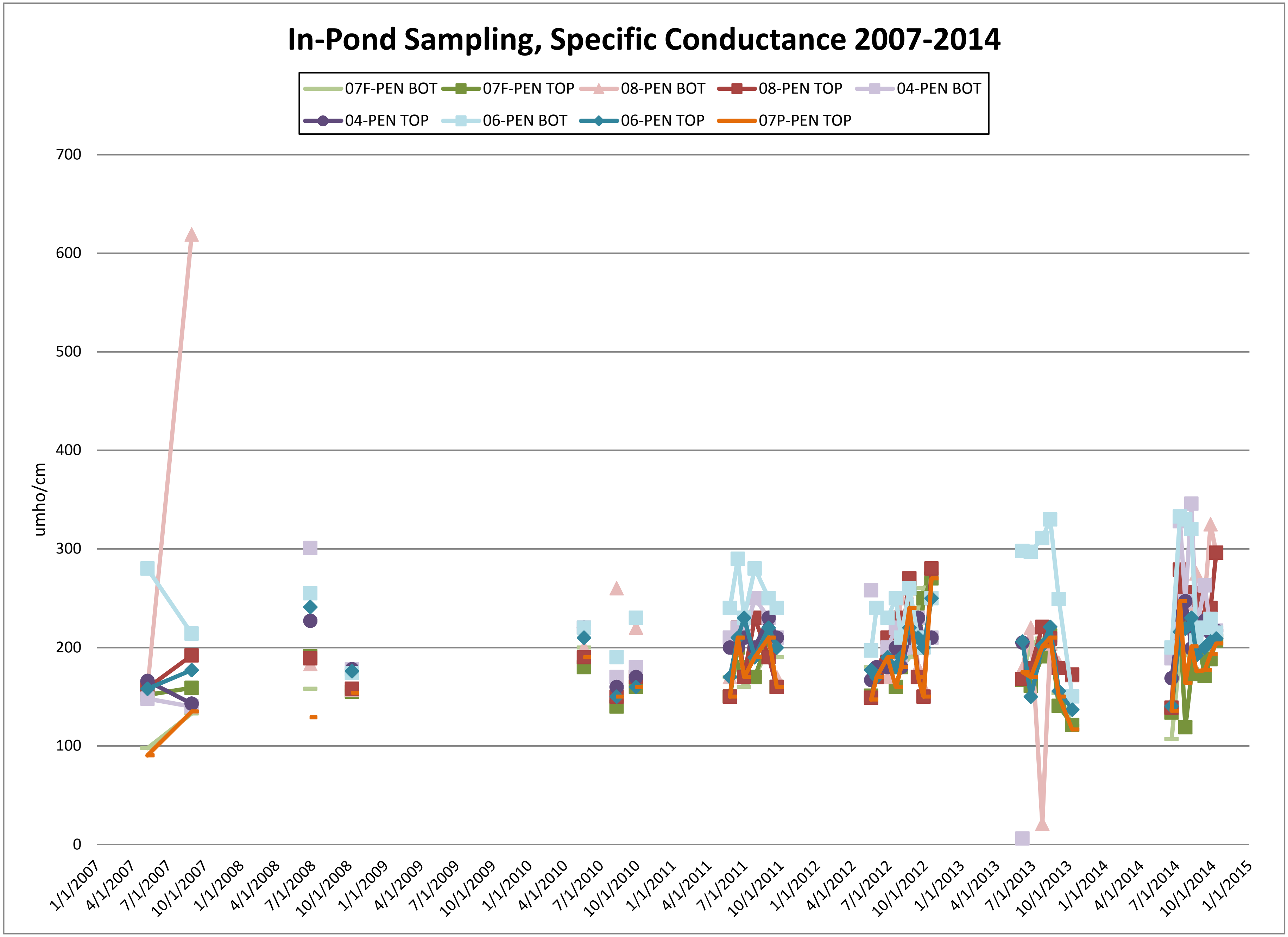
In-Pond Sampling, Nitrate Levels 2007-2014
07F-PEN BOT
07F-PEN TOP
08-PEN BOT
08-PEN TOP
04-PEN BOT
04-PEN TOP
06-PEN BOT
06-PEN TOP
07P-PEN TOP
mg/L
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
1/1/2015



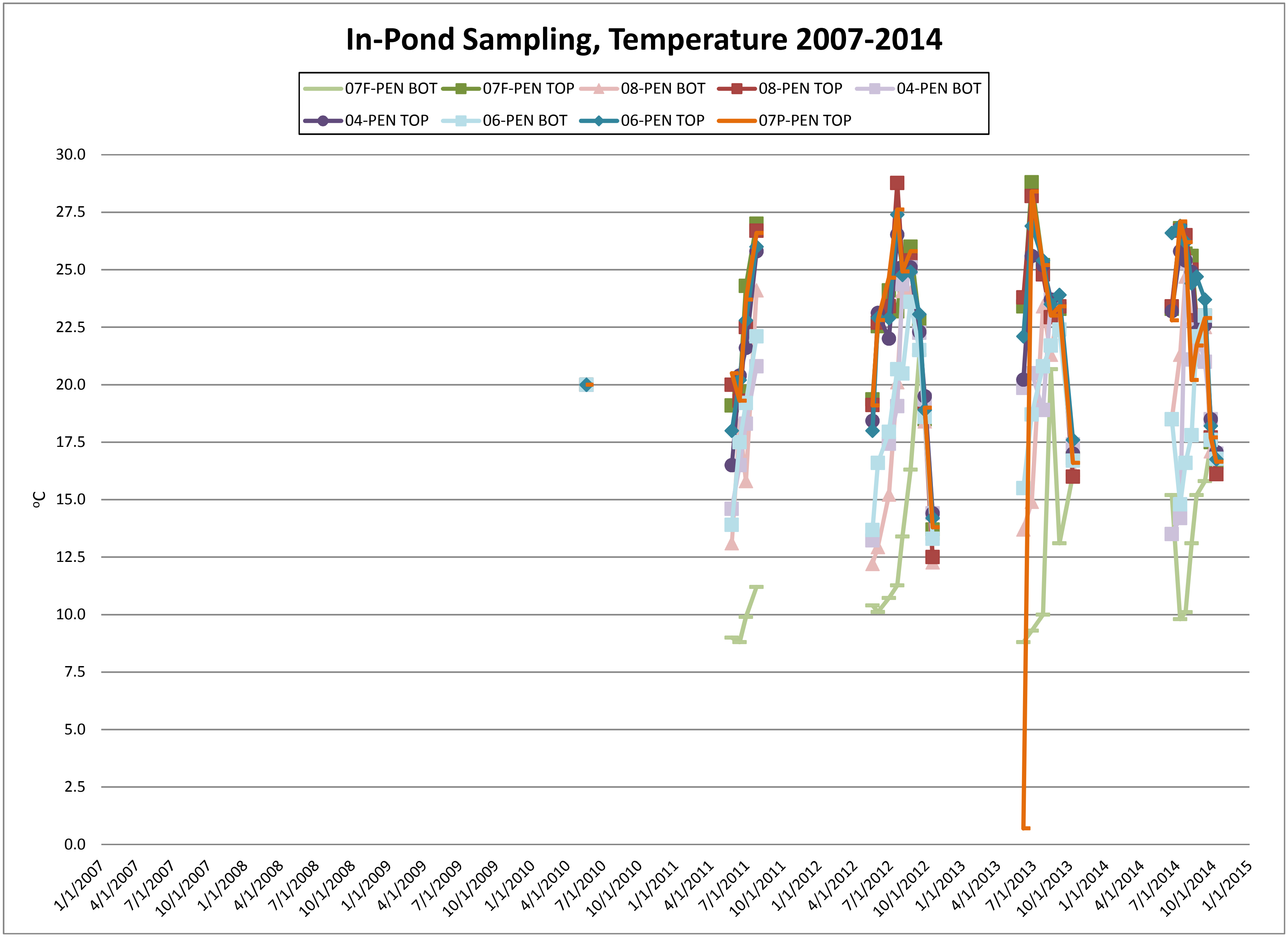
In-Pond Sampling, pH 2007-2014
07F-PEN BOT
07F-PEN TOP
08-PEN BOT
08-PEN TOP
04-PEN BOT
04-PEN TOP
06-PEN BOT
06-PEN TOP
07P-PEN TOP
pH
8.0
7.8
7.5
7.3
7.0
6.8
6.5
6.3
6.0
5.8
5.5
5.3
5.0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
1/1/2015



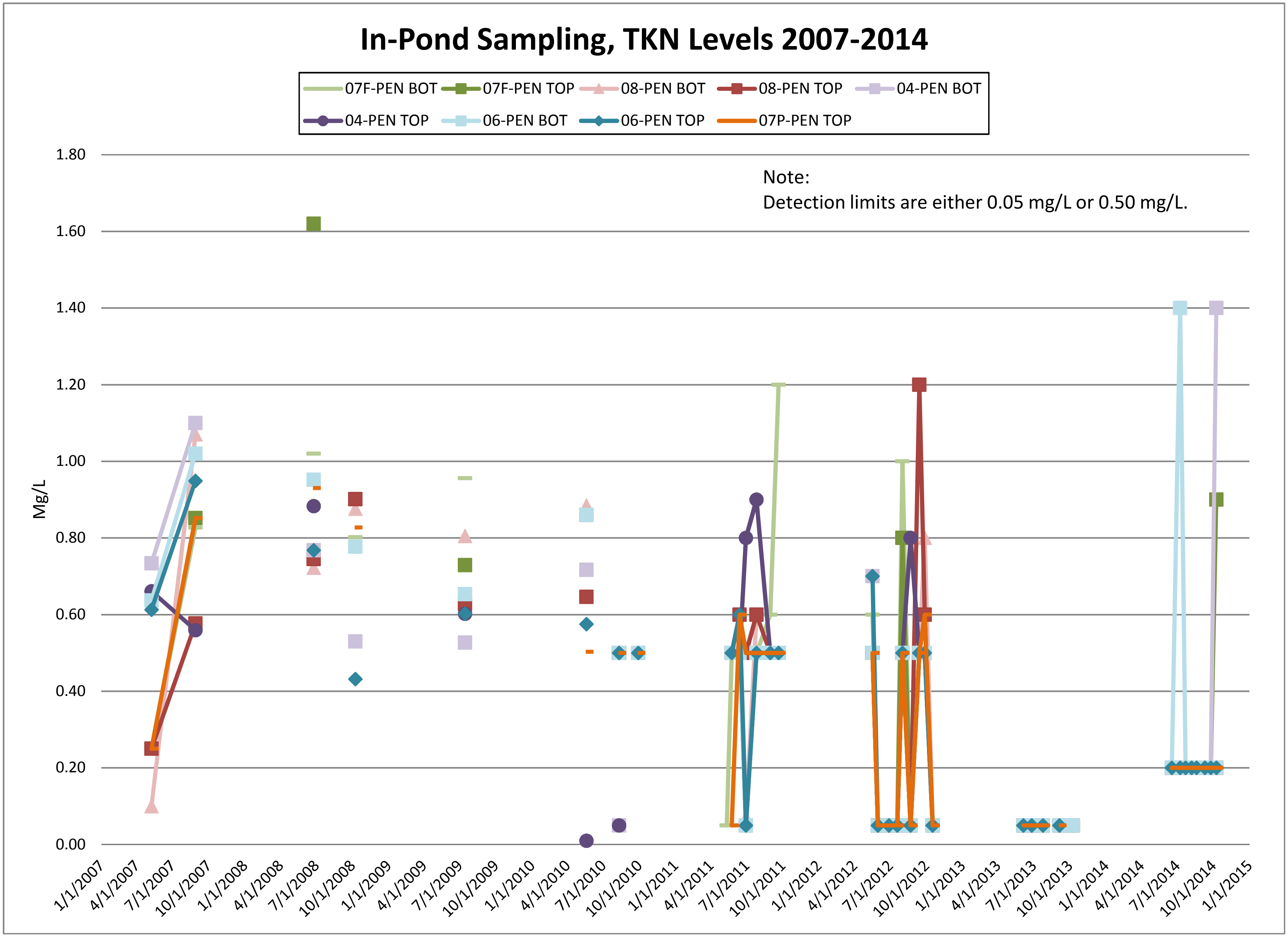
In-Pond Sampling, Phosphorus Levels 2007-2014
07F-PEN BOT
07F-PEN TOP
08-PEN BOT
08-PEN TOP
04-PEN BOT
04-PEN TOP
06-PEN BOT
06-PEN TOP
07P-PEN TOP
Mg/L
0.25
0.20
0.15
0.10
0.05
0.00
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
1/1/2015



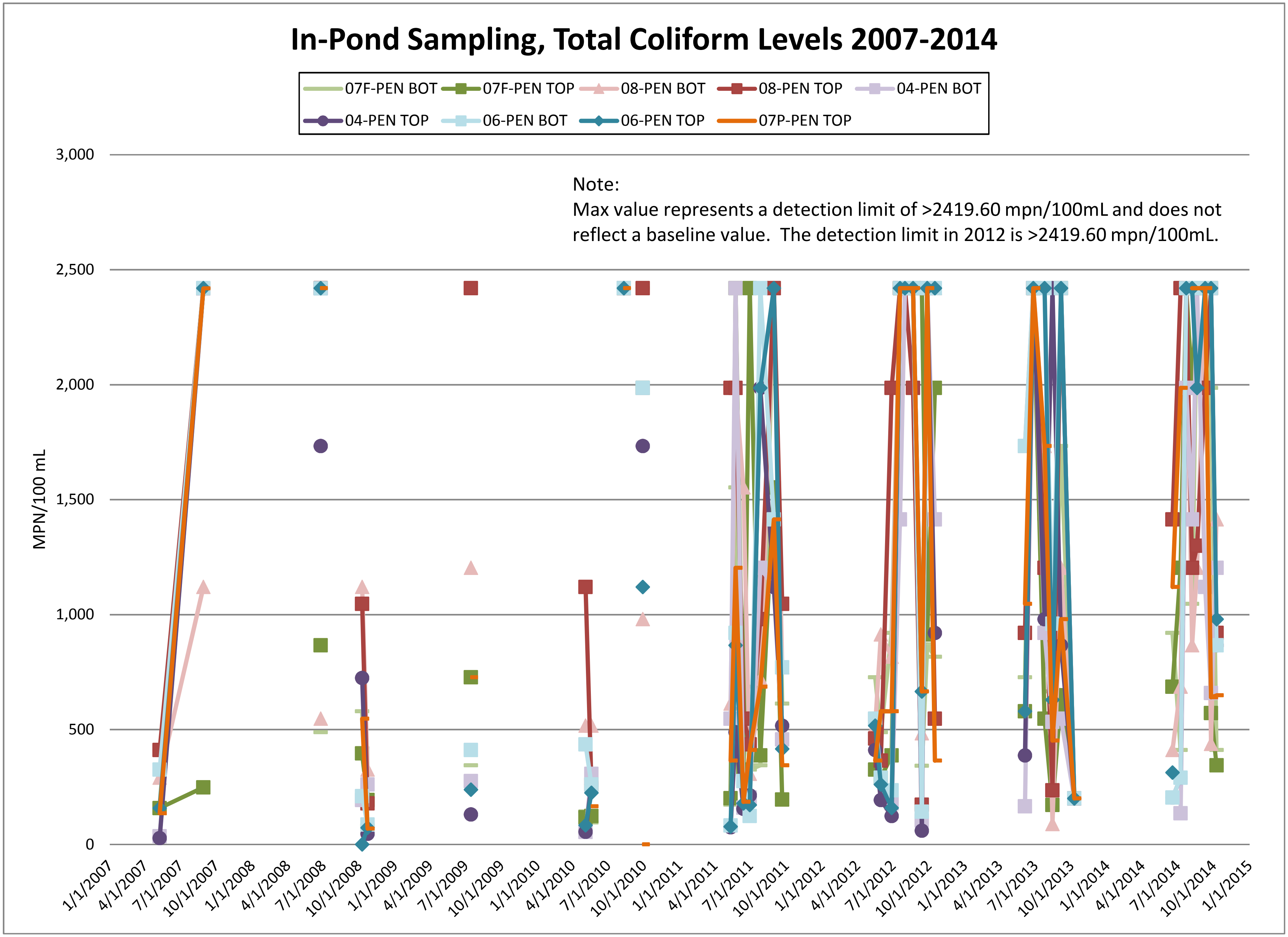
In-Pond Sampling, Specific Conductance 2007-2014
07F-PEN BOT
07F-PEN TOP
08-PEN BOT
08-PEN TOP
04-PEN BOT
04-PEN TOP
06-PEN BOT
06-PEN TOP
07P-PEN TOP
umho/cm
0
100
200
300
400
500
600
700
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
1/1/2015

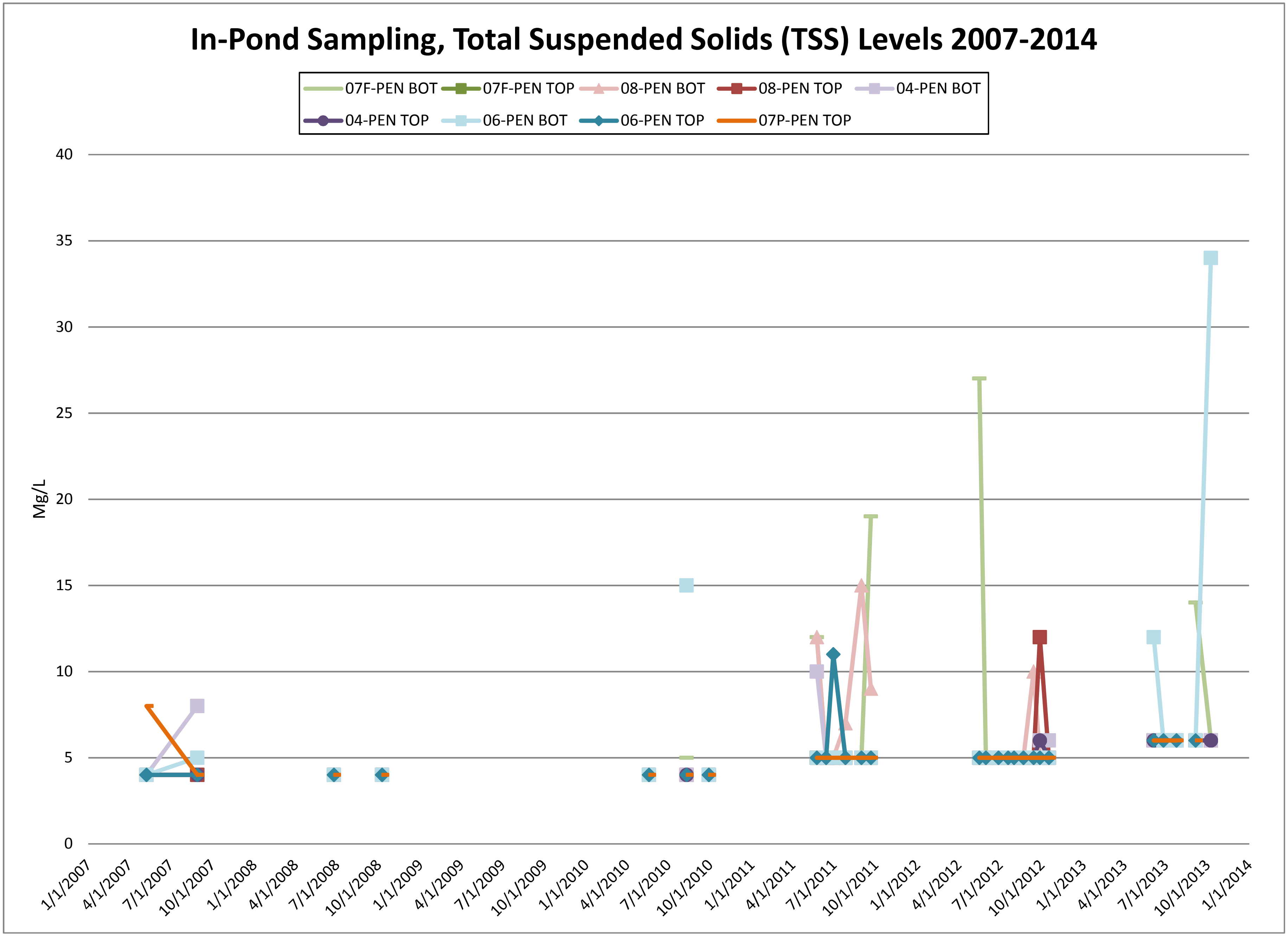


In-Pond Sampling, Temperature 2007-2014
07F-PEN BOT
07F-PEN TOP
08-PEN BOT
08-PEN TOP
04-PEN BOT
04-PEN TOP
06-PEN BOT
06-PEN TOP
07P-PEN TOP
°C
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
1/1/2015



In-Pond Sampling, TKN Levels 2007-2014
07F-PEN BOT
07F-PEN TOP
08-PEN BOT
08-PEN TOP
04-PEN BOT
04-PEN TOP
06-PEN BOT
06-PEN TOP
07P-PEN TOP
Note:
Detection limits are either 0.05 mg/L or 0.50 mg/L.
Mg/L
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
1/1/2015


In-Pond Sampling, Total Coliform Levels 2007-2014
07F-PEN BOT
07F-PEN TOP
08-PEN BOT
08-PEN TOP
04-PEN BOT
04-PEN TOP
06-PEN BOT
06-PEN TOP
07P-PEN TOP
Note:
Max value represents a detection limit of >2419.60 mpn/100mL and does not reflect a baseline value. The detection limit in 2012 is >2419.60 mpn/100mL.
MPN/100 mL
3,000
2,500
2,000
1,500
1,000
500
0
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014
4/1/2014
7/1/2014
10/1/2014
1/1/2015


In-Pond Sampling, Total Suspended Solids (TSS) Levels 2007-2014
07F-PEN BOT
07F-PEN TOP
08-PEN BOT
08-PEN TOP
04-PEN BOT
04-PEN TOP
06-PEN BOT
06-PEN TOP
07P-PEN TOP
Mg/L
0
5
10
15
20
25
30
35
40
1/1/2007
4/1/2007
7/1/2007
10/1/2007
1/1/2008
4/1/2008
7/1/2008
10/1/2008
1/1/2009
4/1/2009
7/1/2009
10/1/2009
1/1/2010
4/1/2010
7/1/2010
10/1/2010
1/1/2011
4/1/2011
7/1/2011
10/1/2011
1/1/2012
4/1/2012
7/1/2012
10/1/2012
1/1/2013
4/1/2013
7/1/2013
10/1/2013
1/1/2014