# APPENDIX E

# EXPERT PANEL'S BMP PERFORMANCE ANALYSIS MEMORANDUM

# 2014/2015 RAINY SEASON

# Memorandum

Date: 27 August 2015

To: The Boeing Company (Boeing), Santa Susana Field Laboratory

From: Geosyntec Consultants and the Surface Water Expert Panel

Subject: BMP Performance Analysis, Santa Susana Field Laboratory
Geosyntec Project: SB0363V

The purpose of this memorandum is to evaluate the performance of treatment Best Management Practices (BMPs) in the Outfall 009 watershed of the Boeing Santa Susana Field Laboratory (Site). This is an update to a BMP performance analysis that is conducted annually, consistent with the 2010 Engineered Natural Treatment Systems (ENTS) and Expert Panel Work Plan for SSFL Outfalls 008 and 009 (Outfall 008/009 BMP Work Plan). This memorandum incorporates 2014/2015 rainy season data into a dataset that began in December 2009. The National Pollutant Discharge Elimination System (NPDES) constituents of concern (COCs) addressed in this analysis include total suspended solids (TSS), total lead, total copper, and dioxins (TCDD TEQ, DNQ excluded, BAFs included). 2014/2015 data were collected to assess effectiveness of culvert modification (CM) installations, the Lower l=Lot Biofilter, and the ELV stormwater treatment BMP. At the newly constructed B1436 detention bioswales, no influent samples were collected, and only one effluent sample was collected during the 2014/2015 rainy season[1]. Because a paired sample was not collected, performance of the detention bioswales is not evaluated in this memorandum. Figures 1-3 through 1-9 in the Annual Report show locations of all stormwater controls and monitoring sites.

The quantity of monitoring data collected during the 2014/2015 rainy season increased from the previous 2013/2014 rainy season, but data for the 2014/2015 season were still fairly sparse due to the low precipitation amount and fewer storm events compared to previous years. Long-term average annual rainfall at SSFL from 1960-2006 was 18.4 inches, compared to 11.22 inches in the 2014/2015 rainy season (beginning October 1, 2014). Nine rain events (where a "rain event" is defined as greater than 0.1 inches of rainfall in a 24-hour period and preceded by at least 72 hours of dry weather) occurred in the 2014/2015 period, with six of these storms producing observable flow at least one BMP monitoring site. This is compared with 13, 10, nine, and five events in prior rainy seasons 2010/2011, 2011/2012, 2012/2013, and 2013/2014, respectively. There was only one sample collected in the Outfall 008 watershed during the 2014/2015 rainy season. The sample was collected at Outfall 008 on 12/12/2014, and no exceedances were measured. As a result, BMP performance monitoring sites in the Outfall 008 watershed are not discussed in this memorandum.

[1] Construction was completed in December of 2014. For the events that occurred post-construction, influent samples were not collected due to flows not being observed at the time of collection. Only one effluent sample was collected due to challenges associated with the location and configuration of the effluent pipe.

Paired influent and effluent sampling data for each BMP for the same storm event were compared. Split samples were also collected and used for lab comparison purposes; however, only the primary samples were used in the analysis. For each of the six CM sites discussed here[2], the number of paired samples generally ranges from nine to 18 pairs for each COC for all years combined. Performance data for the Lower Lot Biofilter (construction of which was completed in 2013) were collected from three locations within the system (influent, effluent, and a mid-point sample) during five storm events in the 2014/2015 sampling year. As a result, there are seven sample pairs associated with this location to date, including one 2013/2014 biofilter effluent sample reflecting a blend of filtered underdrain flows and overflows that bypassed the filter media.

The ELV stormwater treatment BMP, implemented during the 2013/2014 rainy season, includes paired data taken during one event in the 2013/2014 season and two events in the 2014/2015 season. These data are shown in the line plots and statistical analyses in the following sections, though it should be noted that it is possible that the media bed for this system may still have been flushing fines during the first sampling event in 2013/2014 since this was the first rain event it experienced. During this event, the ELV stormwater treatment BMP was also heavily loaded by sediments eroded from the denuded ELV channel prior to implementation of recent erosion control improvements.

Only a single data pair was collected at an Interim Source Removal Action (ISRA) location during the 2014/2015 rainy season. This pair was collected at upgradient and downgradient locations for IEL-2 during one storm event. There was one data pair collected for IEL-2 during the 2011/2012 season, but at different influent and effluent locations. Therefore, only results from the most recent rainy season will be depicted.

With respect to sampling at the CM sites, influent grab samples are collected from flowing surface water upstream of the maximum extent of ponding at each CM as observed before that date.[3] All CMs include a media filter and a slipline HDPE lining through existing galvanized corrugated metal culvert pipes with the exception of B-1, which is a media bed with no slipline element. CM effluent grab samples are collected at the culvert outlets on the downstream side of the road, where the culvert pipes discharge to the Northern Drainage, with the exception of CM-9 and B-1, where effluent samples were collected from the underdrain outlets beginning in October 2011, rather than the culvert outlet. Flows from the culvert outlets may represent treated runoff (via sedimentation and media filtration) and partially treated runoff (flowing through or over the weir boards). At CM-3, the slipline HDPE pipes were inserted from both the influent and effluent sides and could not be sealed at the point where they meet, and subsurface flows through the road embankment are known to have entered the pipe during rain events from February 2010

[2] As described herein, CM-3 was excluded from this analysis due to post-storm dry weather flows observed at the outlet between February 2010 and March 2011 when no flows were observed entering the culvert, suggesting subsurface inflows were contributing to effluent samples, thus limiting the meaningfulness of an influent-effluent comparison.

[3] When the extent of ponding increased at the CM-1 and CM-3 culvert basins on December 22, 2010 during a heavy rainfall, the influent sample locations were moved upstream a sufficient distance to remain above the maximum ponded water footprint.

through March 2011[4] because water was observed discharging from the HDPE pipe outlet when no water was flowing into the inlet. Therefore, CM-3 performance as designed cannot be reliably assessed due to this bypassing of the media filter.

Monitoring sites at CM-1 (influent-east; see additional discussion in Section 1, below), CM-3, CM-8, and CM-11 receive runoff from drainage areas that do not include any known historic industrial activities, although the CM-3 drainage area does include a clean soil borrow area at the top of the watershed. Therefore, influent sample results at these four CM locations (not including CM-1 influent-west) are relatively good quality and considered reflective of "background" stormwater concentrations, making it difficult to achieve additional COC reduction through these CMs. These "background" CM locations were therefore statistically evaluated separately from the other CM locations. Sampling at these background CM locations was discontinued following the 2010/2011 rainy season.

During the 2014/2015 season, there were six monitored rain events[5], with eight new CM paired samples collected, five sample pairs for the Lower Lot Biofilter (influent and biofilter outlet), and two sample pairs for the ELV treatment BMP. As mentioned earlier, only one ISRA data pair was collected this season. The BMPs discussed in this memo and their respective drainage areas are shown in Table 1. While these areas are discussed specifically with respect to performance monitoring data, there are other areas of the SSFL site which are also addressed by BMPs, including CMs, asphalt removal, erosion control, and treatment control BMPs.

**Table 1. BMP Sites and Drainage Areas**

| BMP | Drainage Area (acres) | Approximate Impervious Cover (%) |
|---|---|---|
| CM-1 | 52.8 (pre-ELV improvements)<br>42.8 (post-ELV improvements) | 6.5<br>6.0 |
| CM-3 | 17.2 | 6.5 |
| CM-8 | 2.5 | 13.1 |
| CM-9 | 9.9 | 17.6 |
| CM-11 | 8.3 | 13.1 |
| B-1 Media Filter | 4.7 | 44 |
| ELV Treatment BMP | 6.2 (Helipad plug in place)<br>15.4 (Helipad plug removed) | 26<br>62 |
| Lower Lot Biofilter | 28.1[1] | 37.3 |

[1] A percentage of the 24-inch stormdrain drainage area is diverted to the Lower Lot Biofilter for treatment. As a result, the percent of runoff volume captured and treated from the smaller (approximately 4 acre) lower lot drainage area is greater than the percent captured and treated from the larger (approximately 24 acre) 24-inch stormdrain drainage area (approximately 57% of runoff from lower drainage area, or 41% capture of total runoff [upper and lower drainage areas combined] on average over the 2014/2015 rainy season after bioswale construction).

[4] Sampling at this site was discontinued after the 2010/2011 season, so no observations have been made since March 2011.

[5] Monitoring occurs when rain events result in observable flow.

# 1. PAIRED LINE PLOTS

The log-scale line plots presented in this section illustrate the changes in measured concentrations between influent and effluent sample pairs at each CM and biofilter monitoring site. Paired data were obtained from CM locations B-1, CM-1, CM-8, CM-9, and CM-11, the ELV treatment BMP, the lower parking lot biofilter, and the ISRA site IEL-2. Paired data are presented by COC in Figures 1 through 37. Pairs are color-coded based on the sampling year during which they were collected, and different symbology is used for different influent and effluent sample collection locations (symbology is defined in each graph). Additionally, non-detect results are displayed as the detection limit. The statistical analysis of the datasets is presented in Section 2 below.

In addition to evaluating BMP performance, the monitoring data have also been used in the site selection evaluations for consideration for enhancements to selected CMs for improved performance in areas where the effluent remains problematic. This was the case at CM-9 based on previous year results, and upgradient improvements were added in 2013. Other examples of improvements include asphalt removal and filter fabric installation. For these sites, separate graphs are shown for sample results that occurred before and after the improvements were made. At the B-1 site, media filter bleed-through was observed during initial sampling dates in the 2011/2012 sampling season. Results collected during this period were removed from the analysis.

Monitoring data were first collected at the new ELV treatment BMP during the 2013/2014 rainy season; since that was the first rain event that the system experienced, it is possible that the monitoring data reflect fines being flushed out of the system. In addition, during the February/March 2014 storm event, a plug in the storm drain under Helipad Road resulted in high flows from Helipad Road being routed to the ELV sump and treatment system. Additionally, inadequate erosion controls along the earthen ELV channel resulted in sediment filling the sump, and a power outage resulted in the sump pump turning off. The influent-effluent pollutant concentration reduction performance of the ELV stormwater treatment BMP is not expected to be affected by these conditions; however, the fraction of runoff volume captured from the ELV drainage area during each storm is expected to be reduced due to these factors. Although no overflow events as described previously were observed during the 2014/2015 rainy season, this plug was not removed for any storm events.

The B1436 detention bioswales were constructed in December of 2014, resulting in increased treatment capacity at the Lower Lot Biofilter. It is estimated that the average volume pumped to the biofilter has increased from approximately 52,000 gallons per inch of rainfall to approximately 82,000 gallons per inch of rainfall since the detention bioswales were constructed. Similarly, the estimated percent of total runoff volume (from both the 24-inch drain and the lower lot drainage areas) has increased from 22% to 44% on average since the detention bioswales were constructed.

Several CM locations (CM-1, CM-9, and the B-1 media filter) have multiple influent drainage areas:

- CM-1 receives runoff from an eastern tributary that is considered to reflect background concentrations as well as a western tributary comprising paved road and ELV hillside runoff (ELV hillside runoff is only reflected in samples collected prior to November 2013);
- CM-9 receives runoff from the Area I Landfill and former Building 1324 parking lot (demolished Summer/Fall 2011), as well as the paved road to the east; and

- B-1 receives runoff from the north, comprised of paved road runoff, and the south, comprised of the upper B-1 ISRA areas, the sedimentation basin, and paved road runoff.

The selection of the influent location used in the paired analysis was evaluated on a case by case basis, with similar sample dates taking precedence (between influent and effluent); in instances when two influent samples were available for the same effluent-sampling storm event, an impervious area-weighted average (used as an estimate of proportioned flowrate from each influent stream) was used to represent a single influent value. With regards to the CM line plots, the CM effect on influent concentrations above the Permit Limit is the most important since those below the Permit Limit are already of acceptable quality and are generally considered to be at levels unlikely to be further reduced using typical stormwater controls, especially considering the conditions that have been experienced to date in terms of precipitation and watershed erosion. As with most stormwater quality controls, the water quality improvements are largest when the influent concentrations are highest.

These charts are included for general visual assessment purposes only; the statistical tests that follow are used to make quantitative evaluations on BMP performance. It should be noted that these samples are all grab samples, and therefore highly variable in terms of water quality results, and may represent collection times that vary throughout the storm event hydrograph. Therefore, relatively large numbers of samples are needed to represent the varying conditions with reasonable statistical confidence and power.

Although not recorded for every event, based on field notes the following five effluent samples were collected during overflow/bypass conditions. These conditions are noted on the plots and indicate decreased performance. No other sampling dates were observed for overflow, so whether or not this occurred for other dates cannot be determined. In addition, observations of weir board overflows were collected starting in the 2011/2012 season. It is unknown which prior samples, if any, were collected during overflow. Sampling notes, which now more carefully track this information, have not noted any samples collected under overflow conditions since the 2011/2012 observations below.

CM-9, effluent underdrain samples:

- A1SW0009 on 10/5/2011 (max intensity = 0.18 in/hr; duration = 9 hours; total depth = 0.90 inches)
- A1SW0009 on 3/17/2012 (max intensity = 0.31 in/hr; duration = 29 hours; total depth = 1.51 inches)
- A1SW0009 on 3/25/2012 (max intensity = 0.51 in/hr; duration = 21 hours; total depth = 2.12 inches)

CM-1, effluent culvert outlet samples:

- A1SW0002 on 3/17/2012 (max intensity = 0.31 in/hr; duration = 29 hours; total depth = 1.51 inches)
- A1SW0002 on 3/25/2012 (max intensity = 0.51 in/hr; duration = 21 hours; total depth = 2.12 inches)

Table 2 summarizes rainfall events in which data were collected for the 2009-2015 seasons ('non sample collection events' represent precipitation events where samples were not collected). Not all BMPs had influent and effluent flows during each rain event.

**Table 2. Sample Collection Event Rainfall Data Summary (gray cells indicate dates that did not have data pairs sampled)**

| Date(s) | Average Intensity (in/hr) | Max Intensity (in/hr) | Event Total (in) | Event Duration (hrs) | Cumulative Rainfall for Sampled Events (in) |
|---|---|---|---|---|---|
| 10/13/2009 - 10/14/2009 | 0.05 | 0.24 | 2.48 | 35 | 2.48 |
| 12/7/2009 - 12/13/2009 | 0.02 | 0.25 | 3.43 | 57 | 5.91 |
| 1/17/2010 – 1/22/2010 | 0.05 | 0.52 | 6.88 | 123 | 12.79 |
| 2/5/2010 – 2/6/2010 | 0.04 | 0.20 | 1.84 | 43 | 14.63 |
| 2/9/2010 | 0.01 | 0.17 | 0.20 | 3 | 14.83 |
| 2/19/2010 | 0.01 | 0.05 | 0.14 | 8 | 14.97 |
| 2/24/2010 | 0.01 | 0.03 | 0.12 | 12 | 15.09 |
| 2/27/2010 | 0.06 | 0.34 | 1.52 | 17 | 16.61 |
| 3/6/2010 | 0.02 | 0.13 | 0.38 | 11 | 16.99 |
| 4/4/2010 - 4/5/2010 | 0.03 | 0.23 | 0.86 | 13 | 17.85 |
| 4/11/2010 - 4/12/2010 | 0.03 | 0.22 | 0.65 | 11 | 18.50 |
| *Non sample collection event total*[1] | | | *0.89* | | |
| **Total for 2009/2010 monitoring period** | | | **19.39** | | |
| | | | | | |
| 10/5/2010 - 10/6/2010 | 0.049 | 0.18 | 0.93 | 20 | 0.93 |
| 10/16/2010 - 10/25/2010 | 0.003 | 0.22 | 0.69 | 216 | 1.62 |
| 11/17/2010 - 11/21/2010 | 0.011 | 0.23 | 0.97 | 89 | 2.59 |
| 12/5/2010 | 0.018 | 0.09 | 0.41 | 10 | 3.0 |
| 12/17/2010 – 12/22/2010 | 0.054 | 0.37 | 7.22 | 131 | 10.22 |
| 12/25/2010 - 12/26/2010 | 0.030 | 0.22 | 0.57 | 9 | 10.79 |
| 12/29/2010 | 0.043 | 0.10 | 0.43 | 7 | 11.22 |
| 1/2/2011 - 1/3/2011 | 0.014 | 0.12 | 0.38 | 17 | 11.60 |
| 2/15/2011 – 2/20/2011 | 0.019 | 0.45 | 2.33 | 121 | 13.93 |
| 2/25/2011 - 2/26/2011 | 0.030 | 0.22 | 1.50 | 20 | 15.43 |
| 3/2/2011 - 3/3/2011 | 0.007 | 0.03 | 0.13 | 8 | 15.56 |
| 3/6/2011 - 3/7/2011 | 0.006 | 0.02 | 0.12 | 10 | 15.68 |
| 3/18/2011 - 3/27/2011 | 0.030 | -- | 6.00 | 197 | 21.68 |
| 5/15/2011 - 5/18/2011 | 0.009 | 0.08 | 0.67 | 76 | 22.35 |
| *Non sample collection event total*[1] | | | *1.04* | | |
| **Total for 2010/2011 monitoring period** | | | **23.39** | | |
| | | | | | |
| 10/5/2011 | 0.090 | 0.18 | 0.90 | 9 | 0.90 |
| 11/4/2011 - 11/6/2011 | 0.041 | 0.23 | 0.58 | 59 | 1.48 |
| 11/11/2011 - 11/12/2011 | 0.035 | 0.26 | 0.76 | 22 | 2.24 |
| 11/19/2011 - 11/21/2011 | 0.031 | 0.29 | 0.78 | 35 | 3.02 |
| 12/12/2011 - 12/17/2011 | 0.006 | 0.21 | 0.80 | 137 | 3.82 |
| 1/21/2012 – 1/23/2012 | 0.017 | 0.15 | 1.06 | 62 | 4.88 |
| 2/27/2012 | -- | -- | 0.00 | | |
| 3/16/2012 - 3/18/2012 | 0.052 | 0.31 | 1.51 | 29 | 6.39 |
| 3/25/2012 – 3/26/2012 | 0.079 | 0.51 | 2.12 | 21 | 8.51 |
| 4/10/2012 – 4/13/2012 | 0.034 | 0.36 | 2.37 | 64 | 10.88 |

| Date(s) | Average Intensity (in/hr) | Max Intensity (in/hr) | Event Total (in) | Event Duration (hrs) | Cumulative Rainfall for Sampled Events (in) |
|---|---|---|---|---|---|
| 4/23/2012 - 4/26/2012 | 0.003 | 0.09 | 0.26 | 80 | 11.14 |
| *Non sample collection event total*[1] | | | *0.19* | | |
| **Total for 2011/2012 monitoring period** | | | **11.33** | | |
| | | | | | |
| 11/14/2012 – 11/18/2012 | 0.010 | 0.36 | 0.99 | 99 | 0.99 |
| 11/28/2012 – 12/4/2012 | 0.011 | 0.12 | 1.49 | 139 | 2.48 |
| 12/12/2012 – 12/18/2012 | 0.005 | 0.07 | 0.68 | 129 | 3.16 |
| 12/22/2012 – 12/26/2012 | 0.013 | 0.18 | 1.13 | 87 | 4.29 |
| 1/23/2013 – 1/27/2013 | 0.020 | 0.18 | 1.78 | 89 | 6.07 |
| 2/8/2013 – 2/9/2013 | 0.008 | 0.07 | 0.12 | 15 | 6.19 |
| 2/19/2013 | 0.025 | 0.09 | 0.25 | 10 | 6.44 |
| 3/7/2013 – 3/8/2013 | 0.041 | 0.23 | 0.87 | 7 | 7.31 |
| 5/5/2013 - 5/6/2013 | 0.040 | 0.16 | 0.48 | 7 | 7.79 |
| *Non sample collection event total*[1] | | | *0.31* | | |
| **Total for 2012/2013 monitoring period** | | | **8.10** | | |
| | | | | | |
| 11/20/2013 – 11/21/2013 | 0.013 | 0.12 | 0.47 | 17 | 0.47 |
| 12/7/2013 | 0.070 | 0.09 | 0.28 | 4 | 0.75 |
| 2/6/2014 – 2/7/2014 | 0.015 | 0.15 | 0.28 | 16 | 1.03 |
| 2/26/2014 – 3/2/2014 | 0.052 | 0.47 | 4.62 | 89 | 5.65 |
| 4/1/2014[2] | | | 0.22 | | 5.87 |
| *Non sample collection event total*[1] | | | *0.20* | | |
| **Total for 2013/2014 monitoring period** | | | **6.07** | | |
| | | | | | |
| 10/31/2014 – 11/1/2014 | 0.045 | 0.33 | 0.36 | 8 | 0.36 |
| 11/30/2014 – 12/4/2014 | 0.033 | 0.40 | 3.20 | 97 | 3.56 |
| 12/11/2014 – 12/12/2014 | N/A[3] | N/A[3] | 2.62 | N/A[3] | 6.18 |
| 12/15/2014 – 12/17/2014 | 0.025 | 0.33 | 0.91 | 36 | 7.09 |
| 1/10/2015 – 1/11/2015 | 0.071 | 0.23 | 1.56 | 22 | 8.65 |
| 1/26/2015 – 1/27/2015 | 0.015 | 0.06 | 0.25 | 17 | 8.90 |
| 2/22/2015 – 2/23/2015 | 0.008 | 0.06 | 0.21 | 26 | 9.11 |
| 3/1/2015 – 3/3/2015 | 0.024 | 0.22 | 1.44 | 60 | 10.55 |
| 5/14/2015 – 5/15/2015 | 0.017 | 0.30 | 0.41 | 24 | 10.96 |
| *Non sample collection event total*[1] | | | *0.26* | | |
| **Total for 2014/2015 monitoring period** | | | **11.22** | | |

[1] Rainfall was measured, but not considered a rain event per the NPDES definition.

[2] Hourly rainfall data was only available through the first quarter of 2014 at the time of drafting of this memorandum. Intensity and duration values could therefore not be calculated for the 4/1/2014 event.

[3] Area I weather station malfunctioned during rain event, rainfall totals from Station 436 used but hourly rainfall not available.

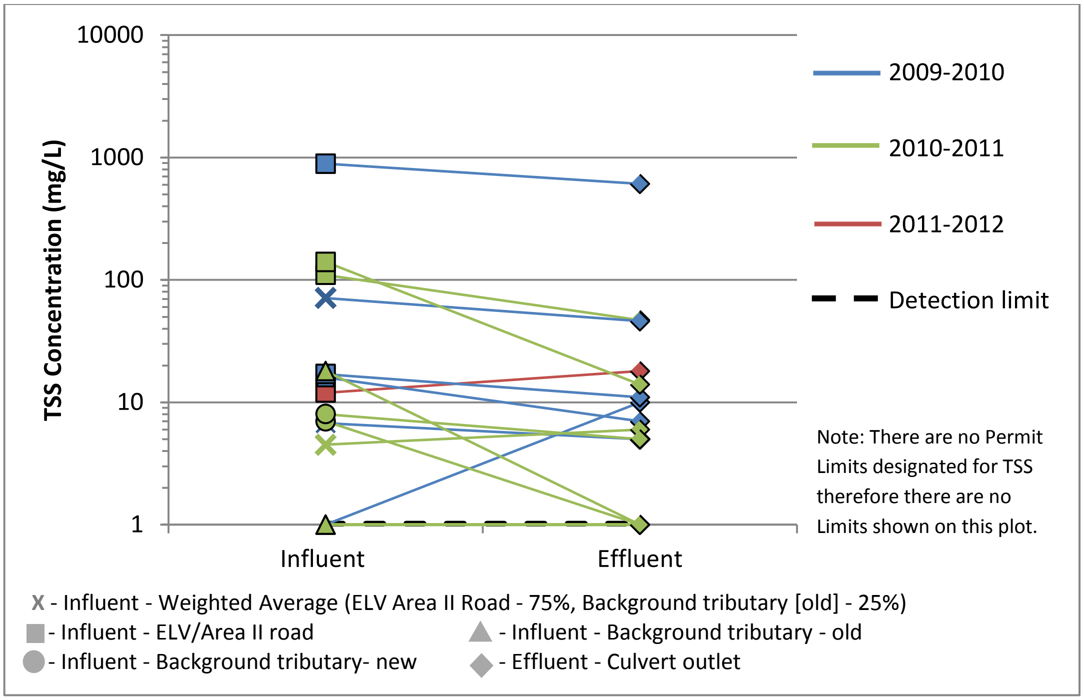


**Figure 1. TSS at CM-1, pre filter fabric installation**

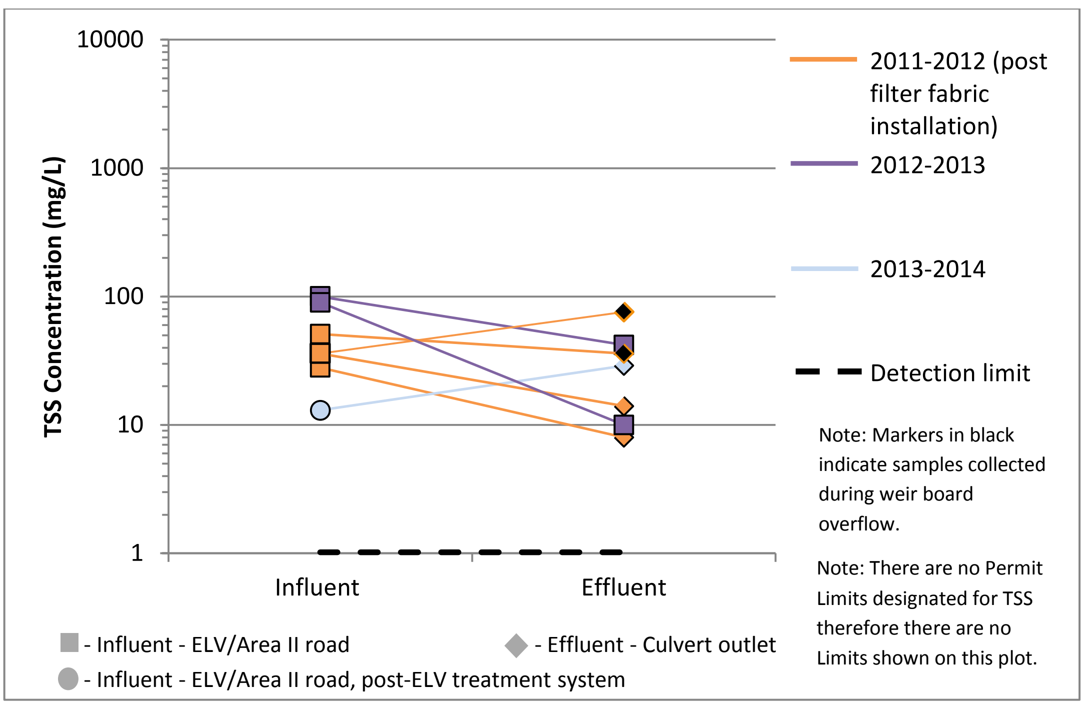


**Figure 2. TSS at CM-1, post filter fabric installation**

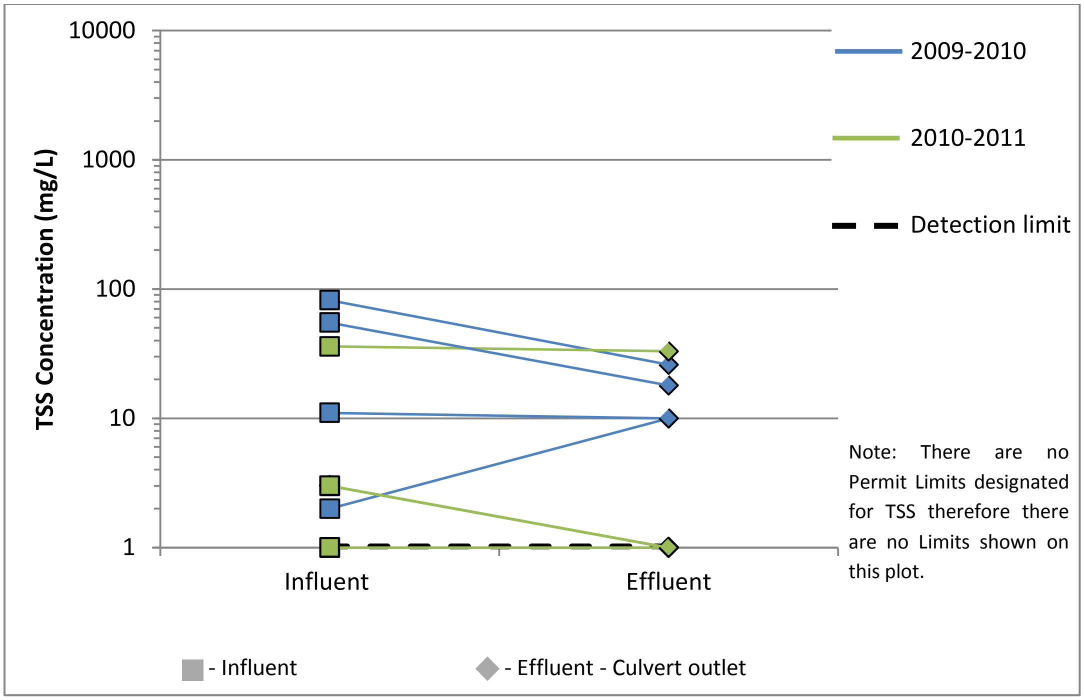


**Figure 3. TSS at CM-8**

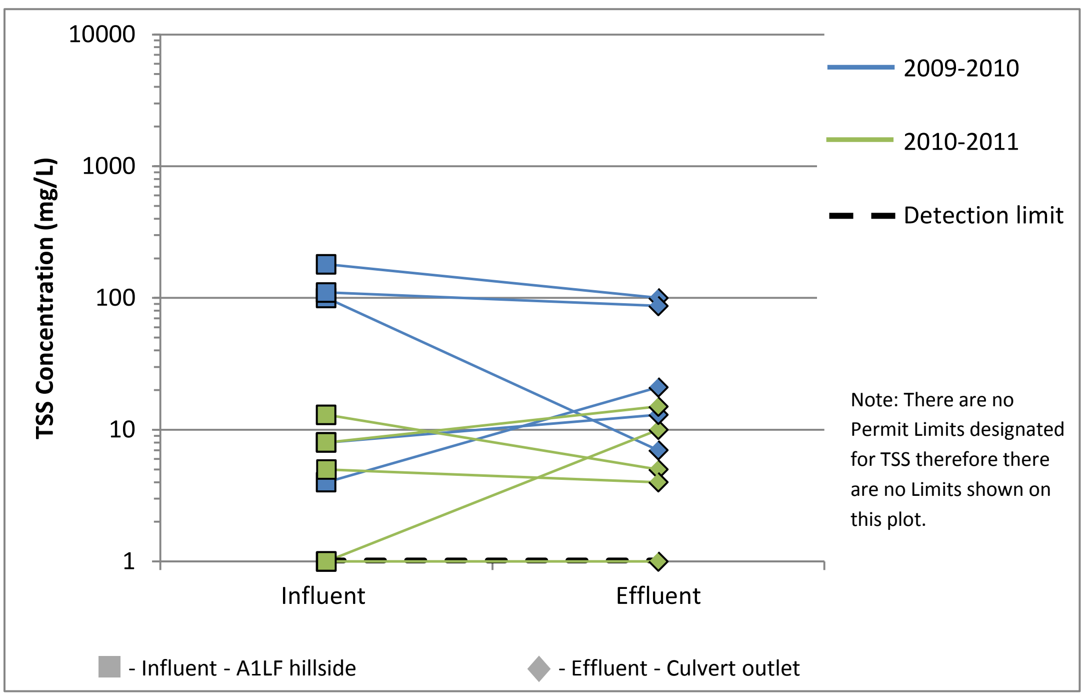


**Figure 4. TSS at CM-9, pre improvements**[6]

[6] CM-9 improvements include removal of A1LF asphalt and addition of CM weir board filter fabric.

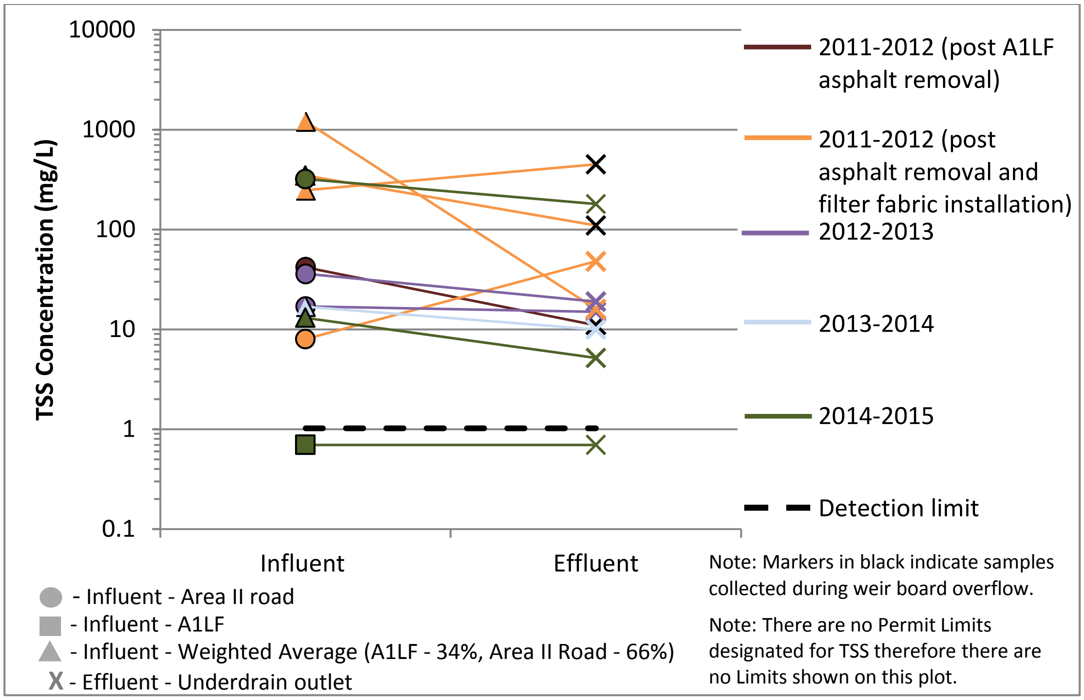


**Figure 5. TSS at CM-9, post improvements (removal of A1LF asphalt and addition of CM weir board filter fabric)**

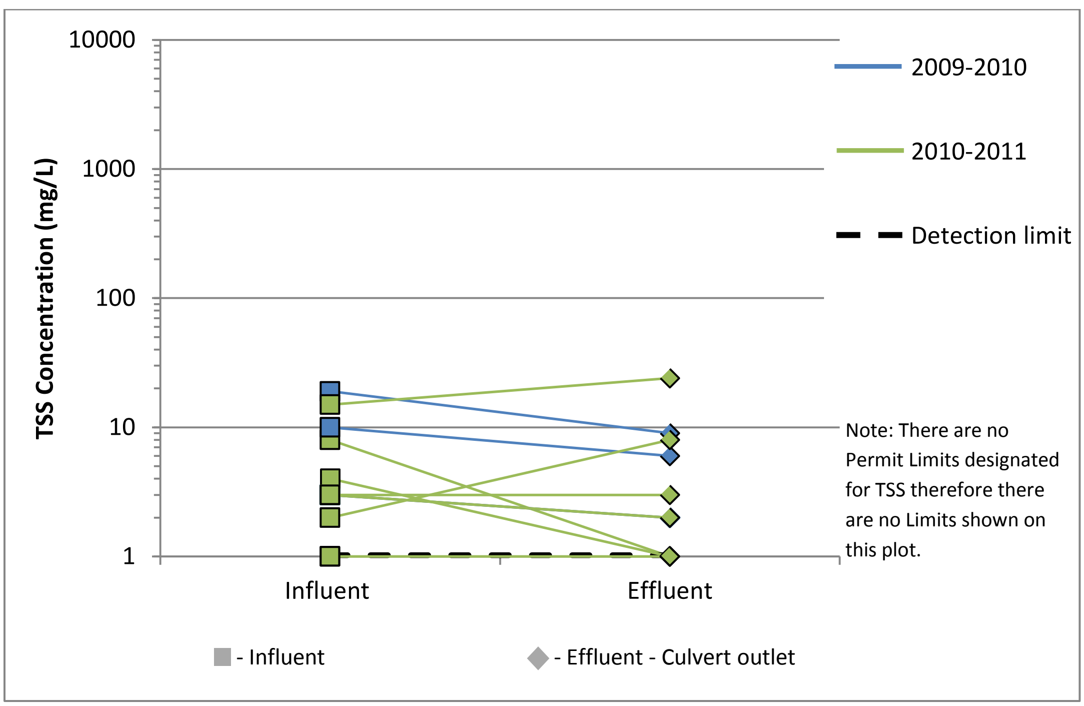


**Figure 6. TSS at CM-11**

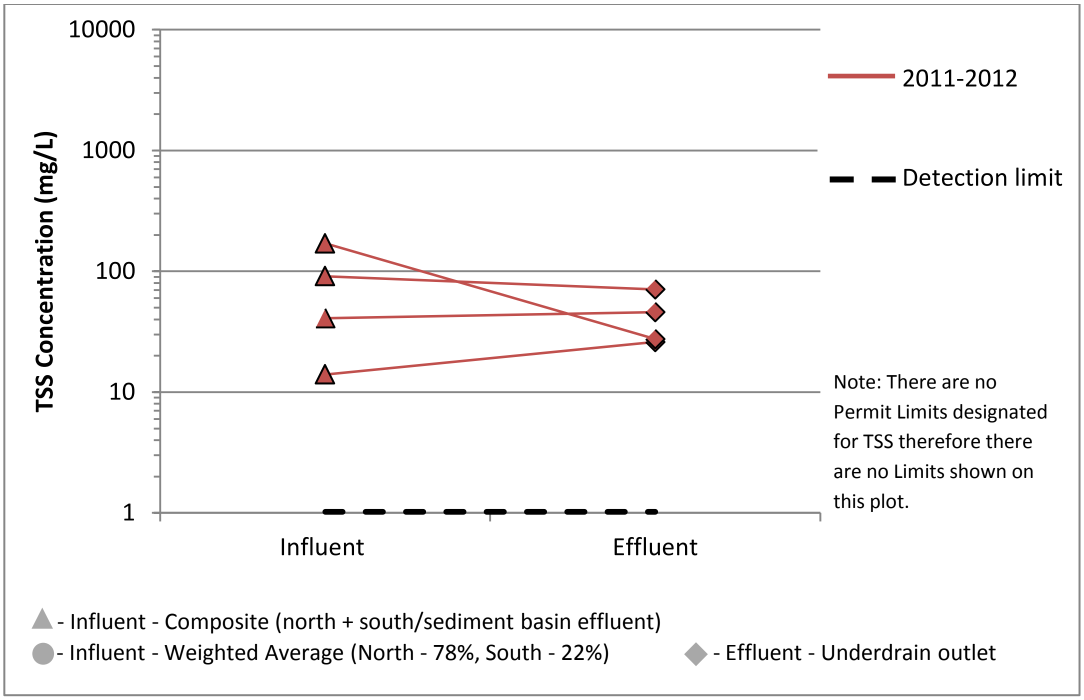


**Figure 7. TSS at B-1 Media Filter (CM), pre curb cuts**


**Figure 8. TSS at B-1 Media Filter (CM), post curb cuts**

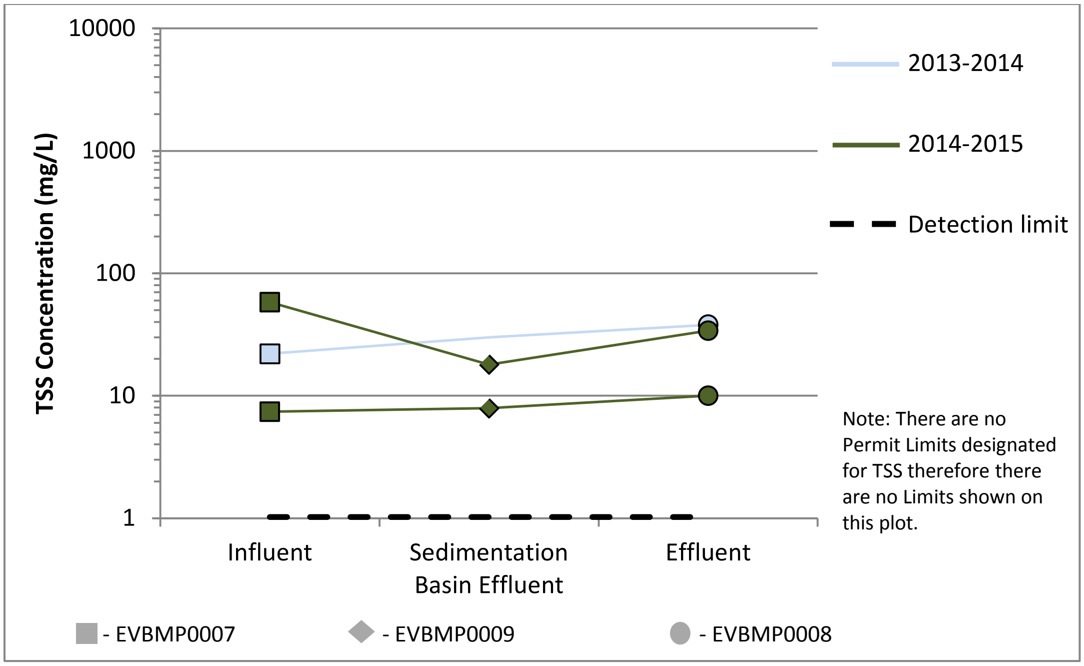


**Figure 9. TSS at ELV treatment BMP**

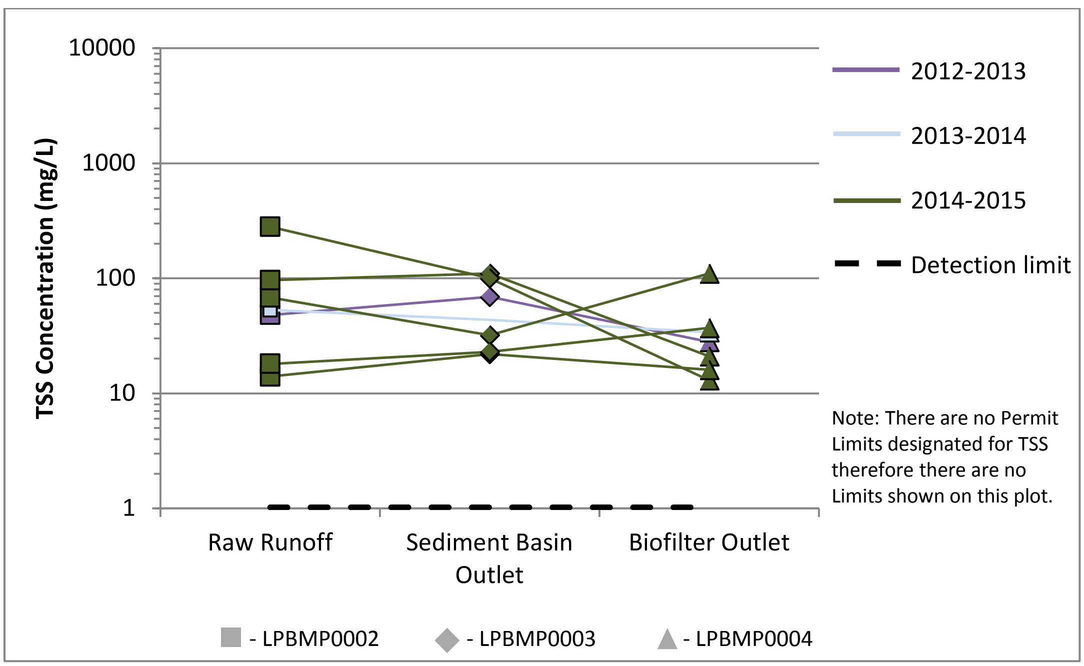


**Figure 10. TSS at Lower Lot Biofilter**[7]

[7] A sample was not taken at the biofilter inlet (post-sedimentation basin) during the 2013/2014 sampling year due to the sample location being submerged and inaccessible. The biofilter outlet sample from the 2013/2014 rainy season reflects a mix of filtered underdrain flow and unfiltered overflow.

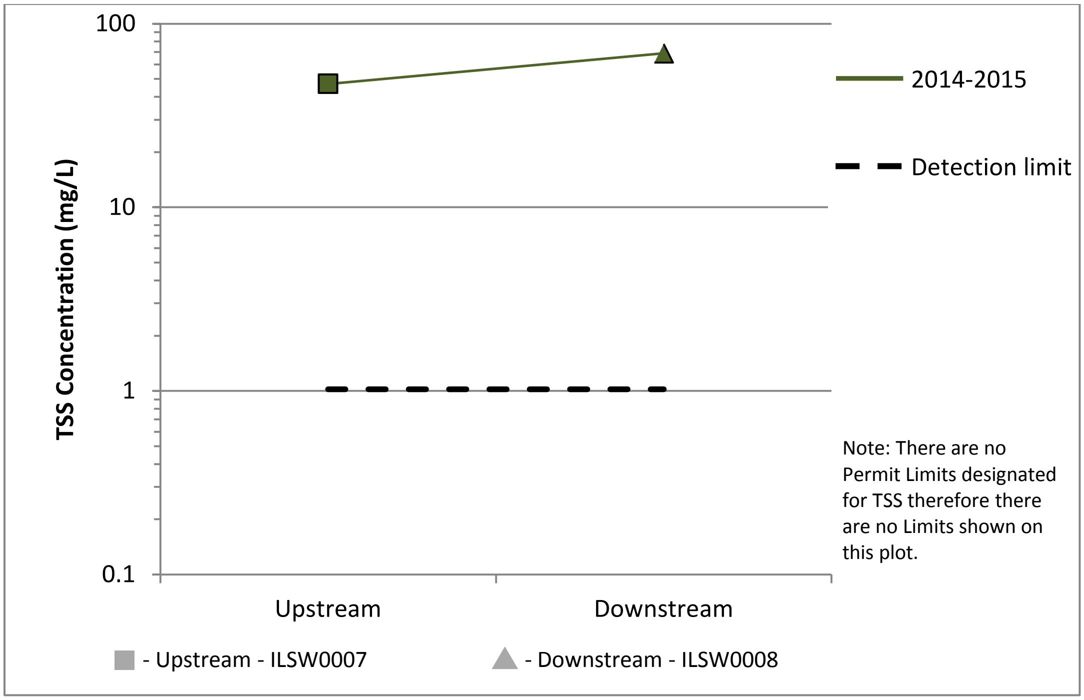


**Figure 11. TSS at IEL-2**

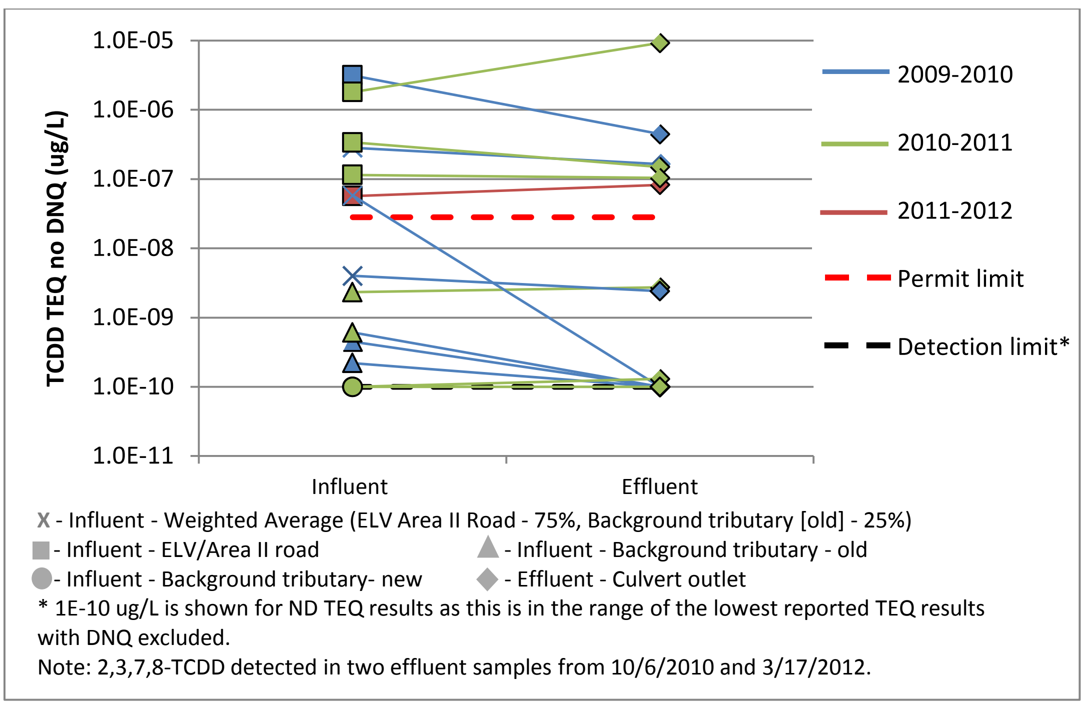


**Figure 12. Dioxins at CM-1, pre filter fabric installation**

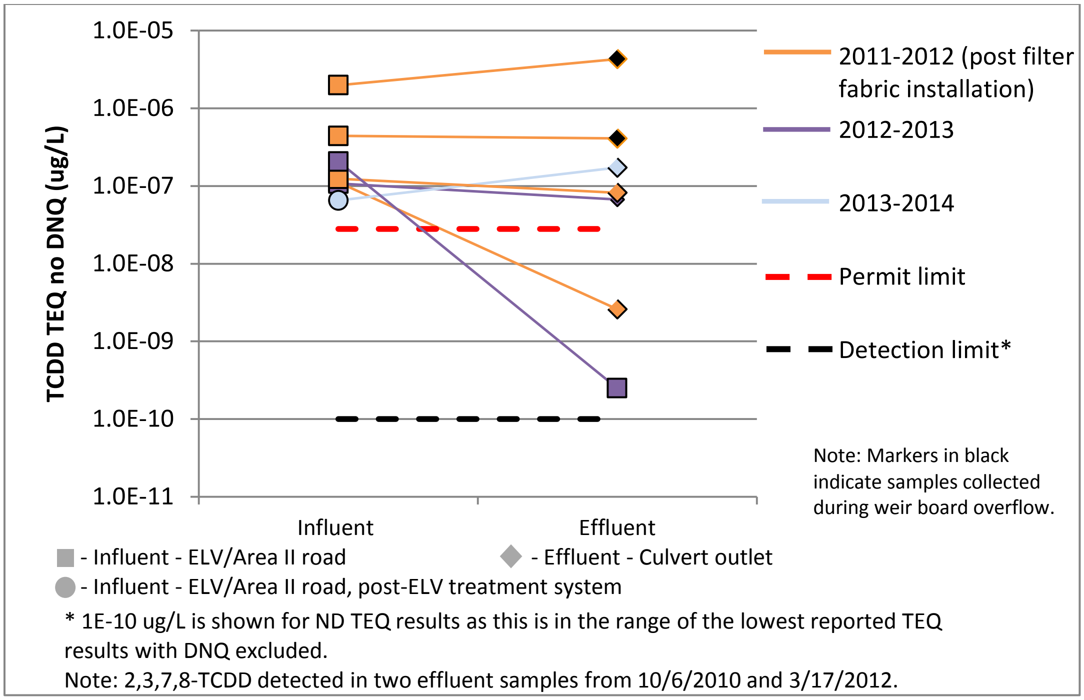


**Figure 13. Dioxins at CM-1, post filter fabric installation**

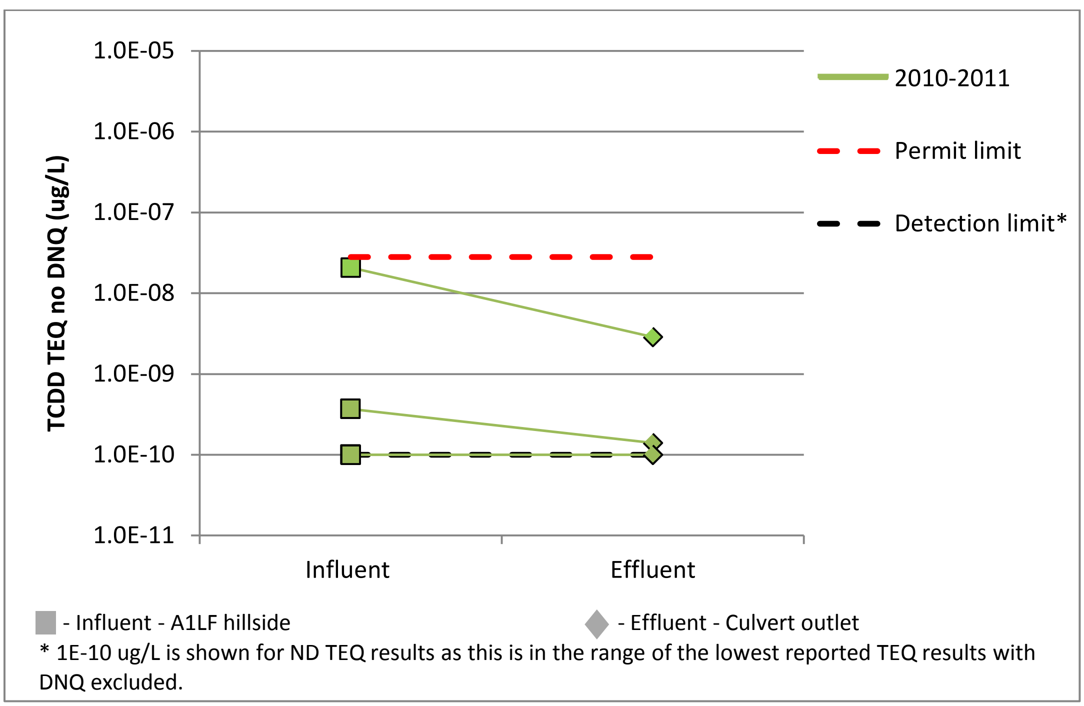


**Figure 14. Dioxins at CM-9, pre improvements**

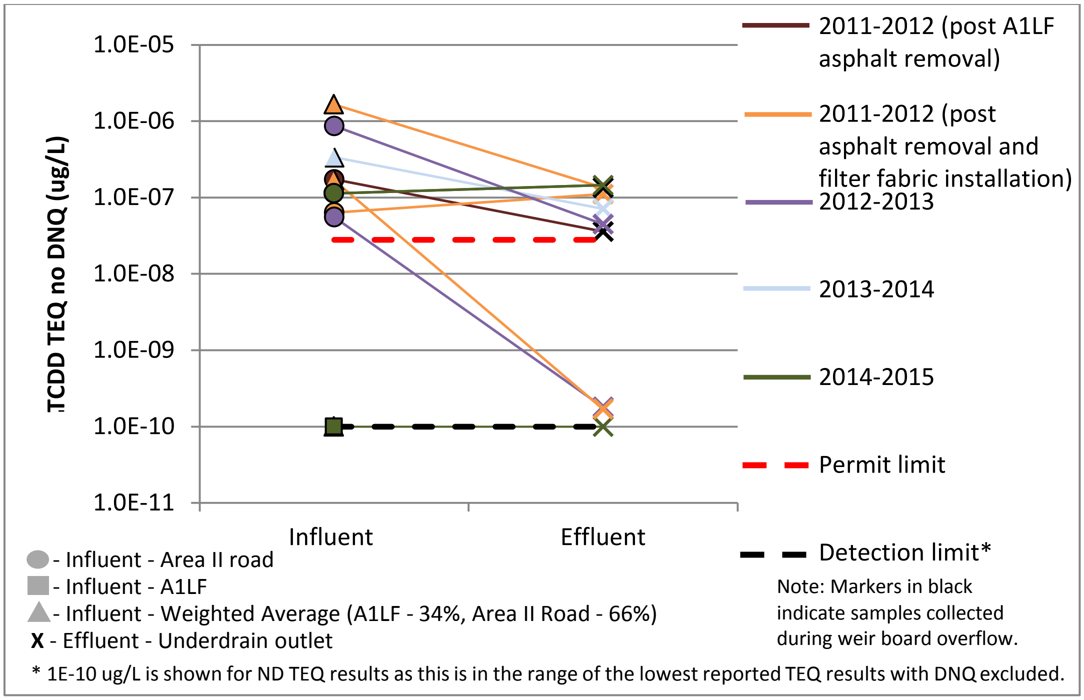


**Figure 15. Dioxins at CM-9, post improvements (removal of A1LF asphalt and addition of CM weir board filter fabric)**

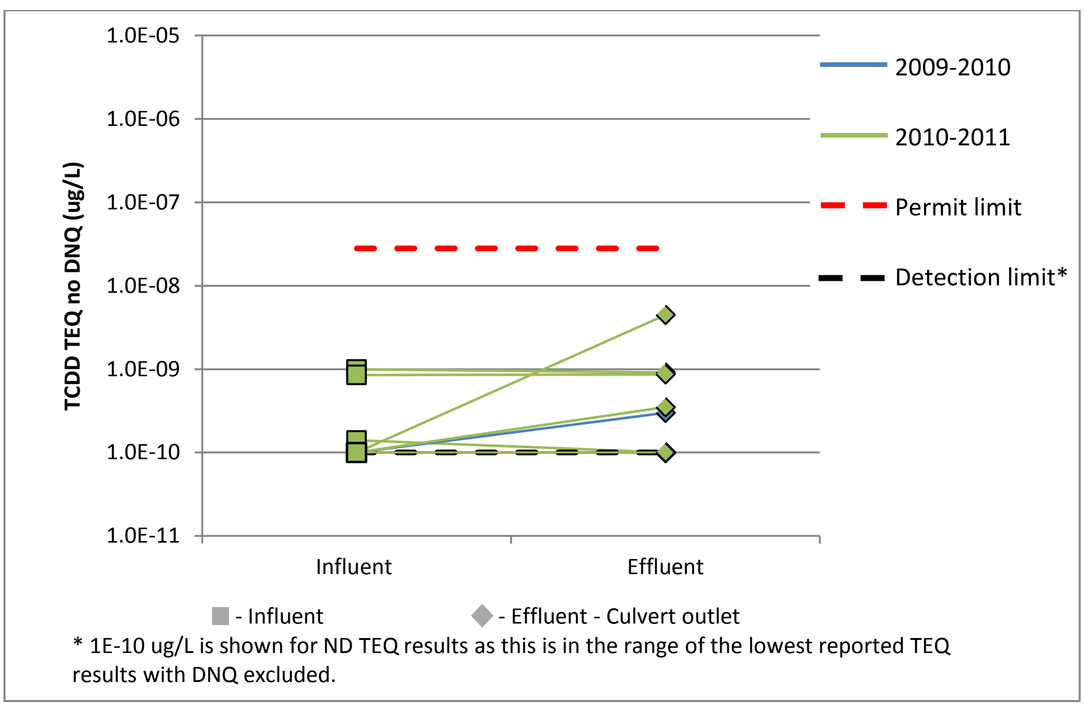


**Figure 16. Dioxins at CM-11**

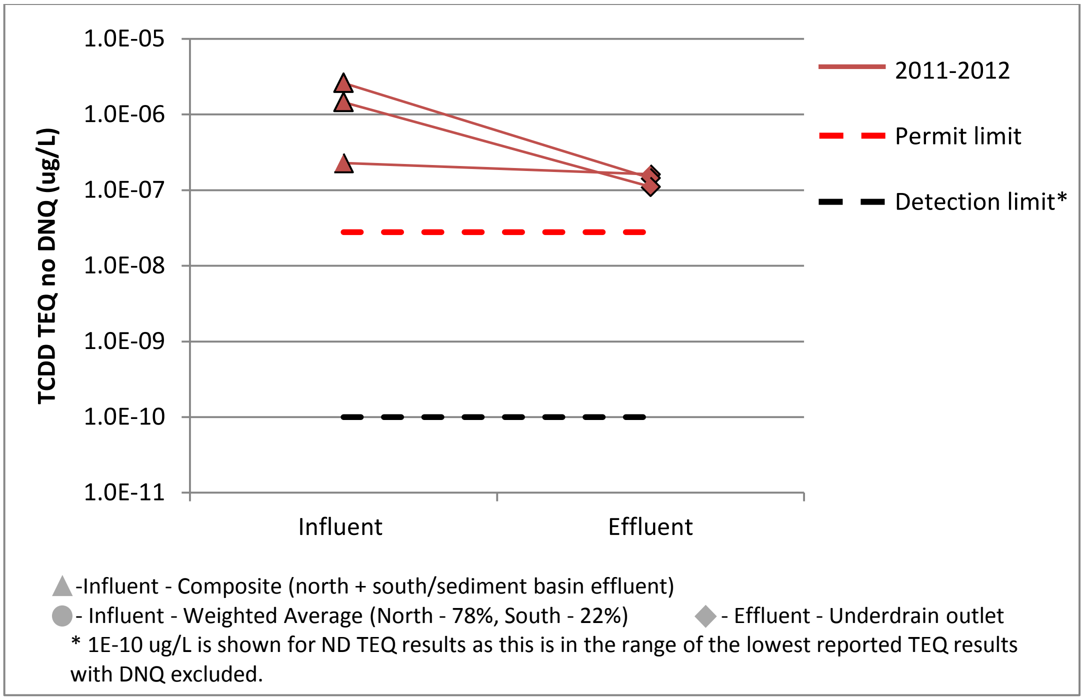


**Figure 17. Dioxins at B-1 Media Filter (CM), pre curb cuts**

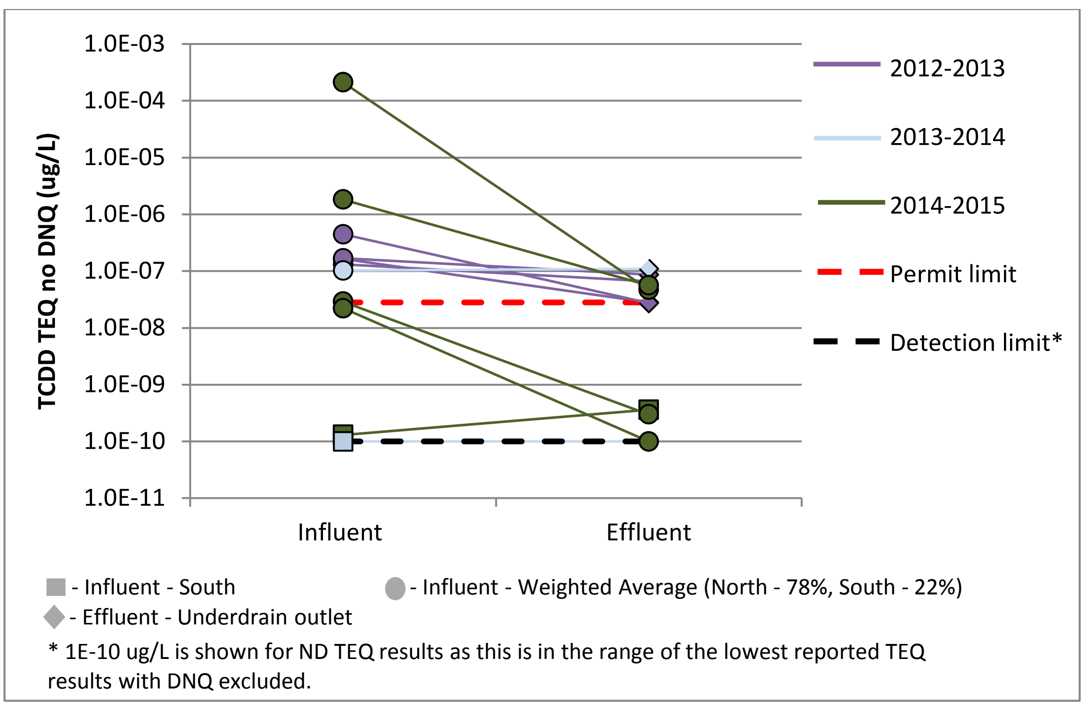


**Figure 18. Dioxins at B-1 Media Filter (CM), post curb cuts**

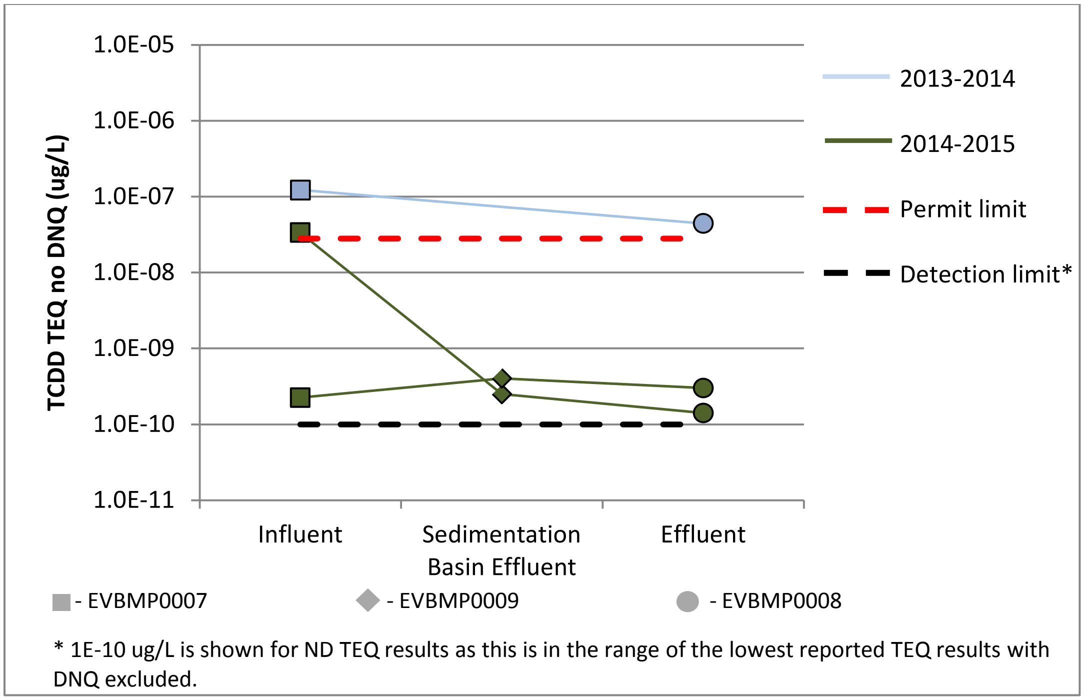


**Figure 19. Dioxins at ELV treatment BMP**

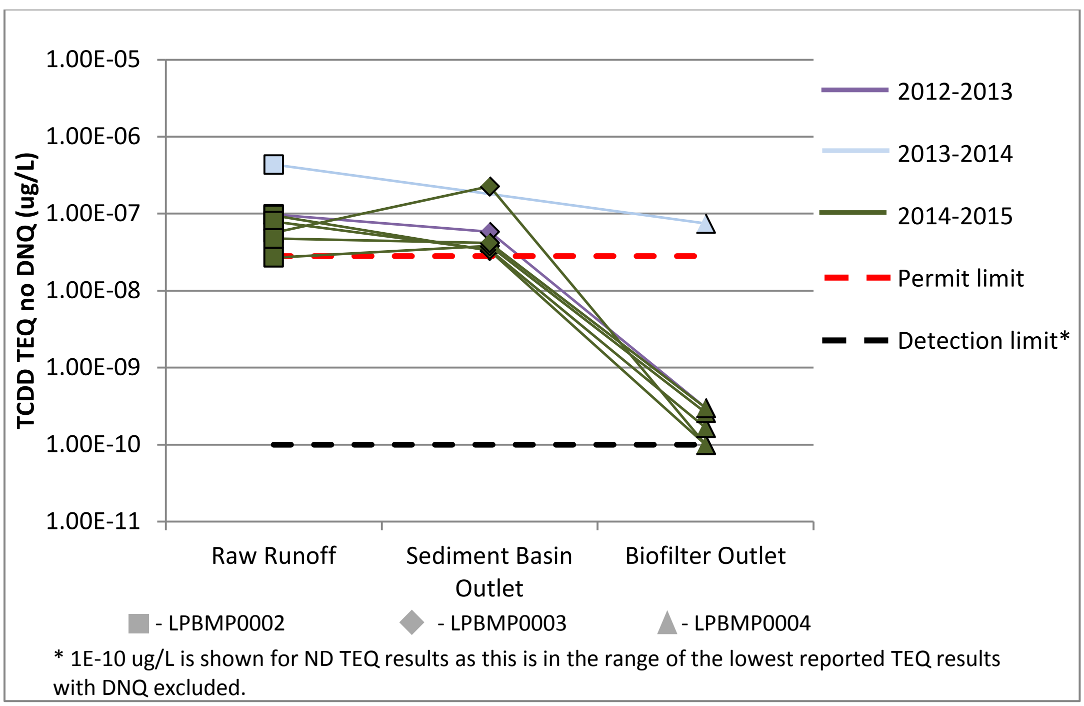


**Figure 20. Dioxins at Lower Lot Biofilter[7]**

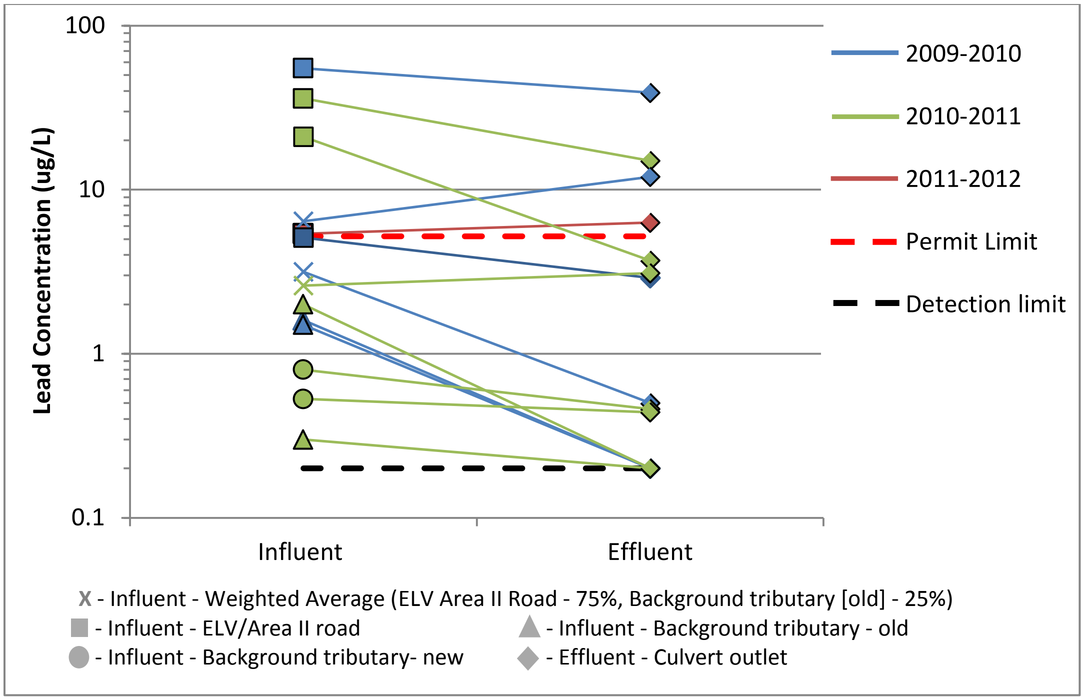


**Figure 21. Lead at CM-1, pre filter fabric installation**

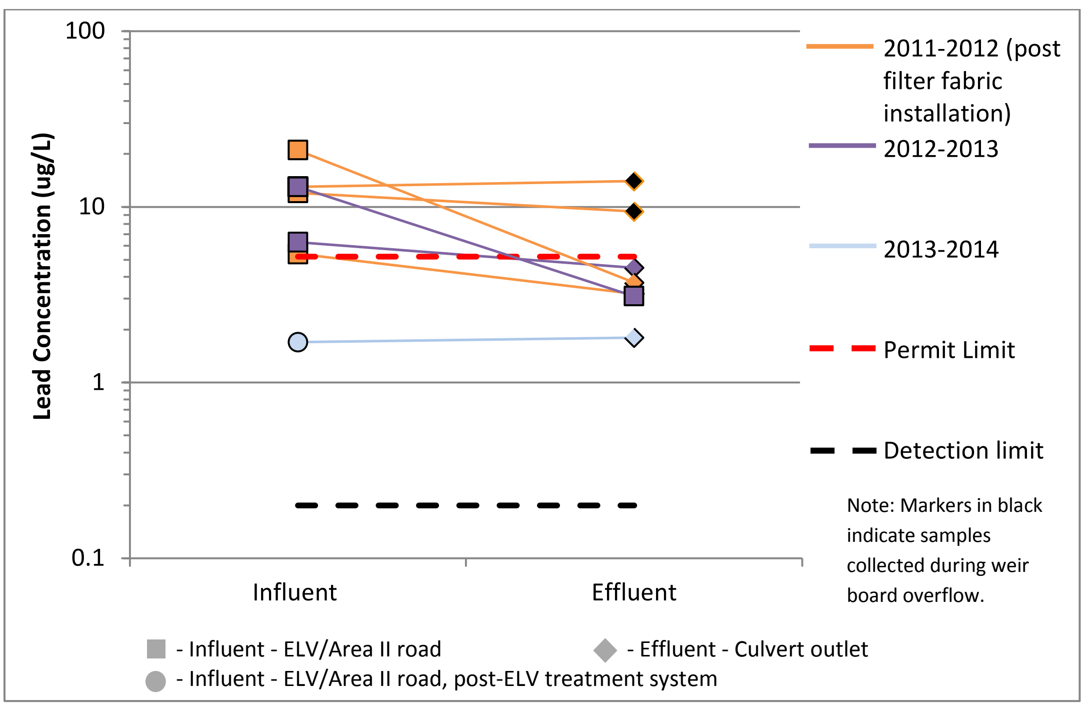


**Figure 22. Lead at CM-1, post filter fabric installation**

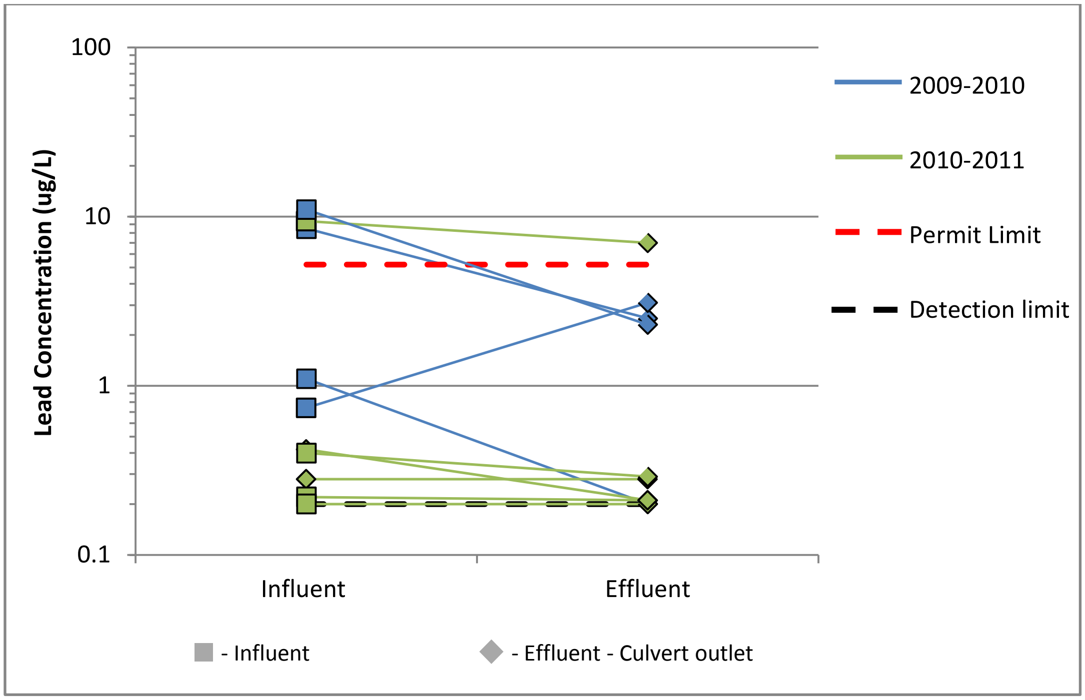


**Figure 23. Lead at CM-8**

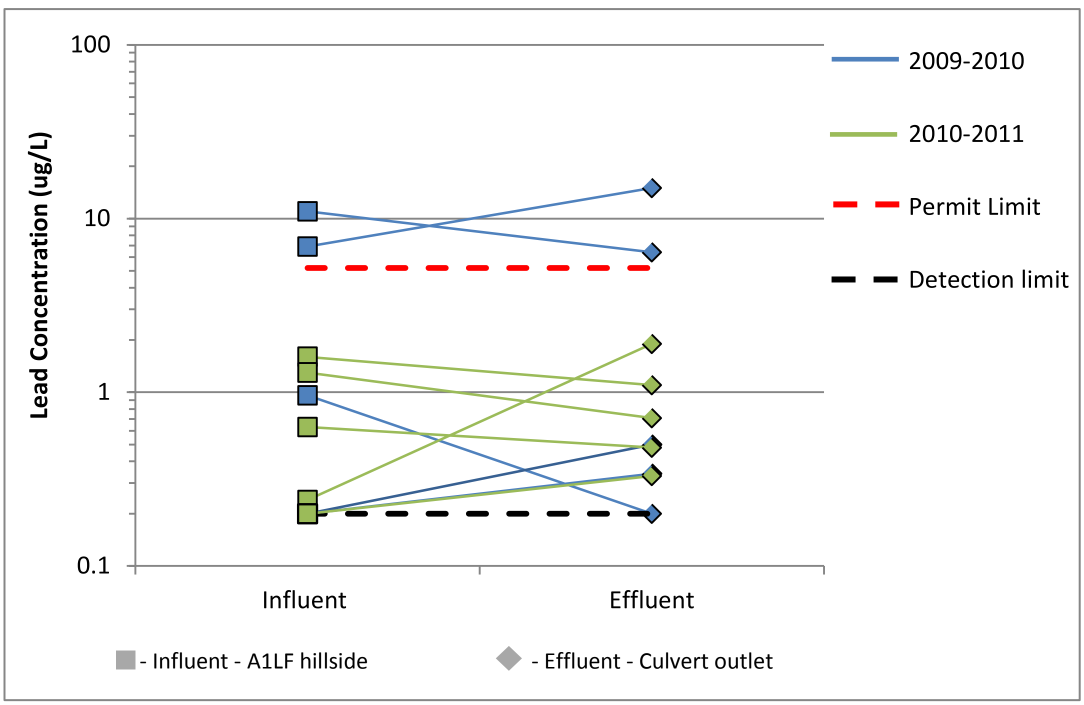


**Figure 24. Lead at CM-9, pre improvements**

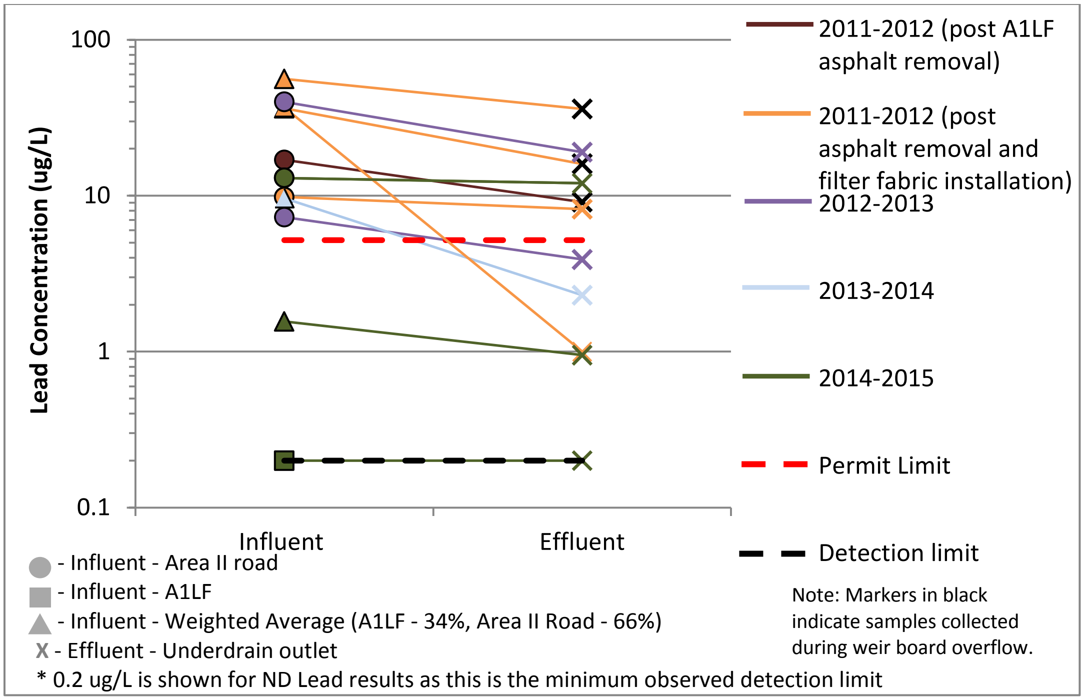


**Figure 25. Lead at CM-9, post improvements (removal of A1LF asphalt and addition of CM weir board filter fabric)**

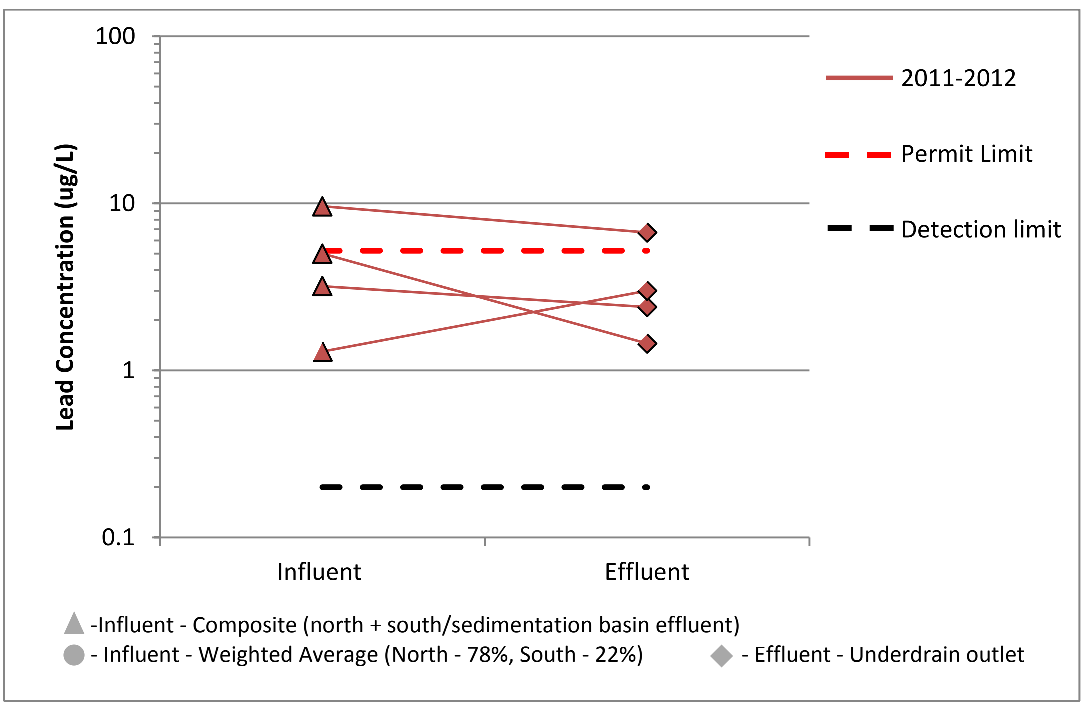


**Figure 26. Lead at B-1 Media Filter (CM), pre curb cuts**

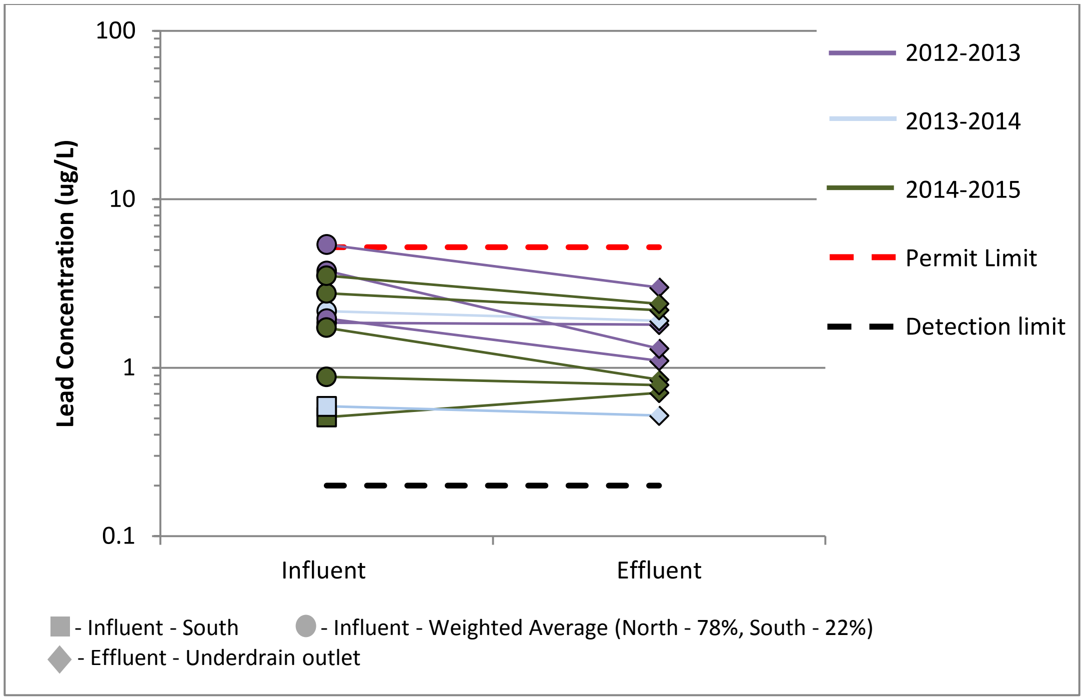


**Figure 27. Lead at B-1 Media Filter (CM), post curb cuts**

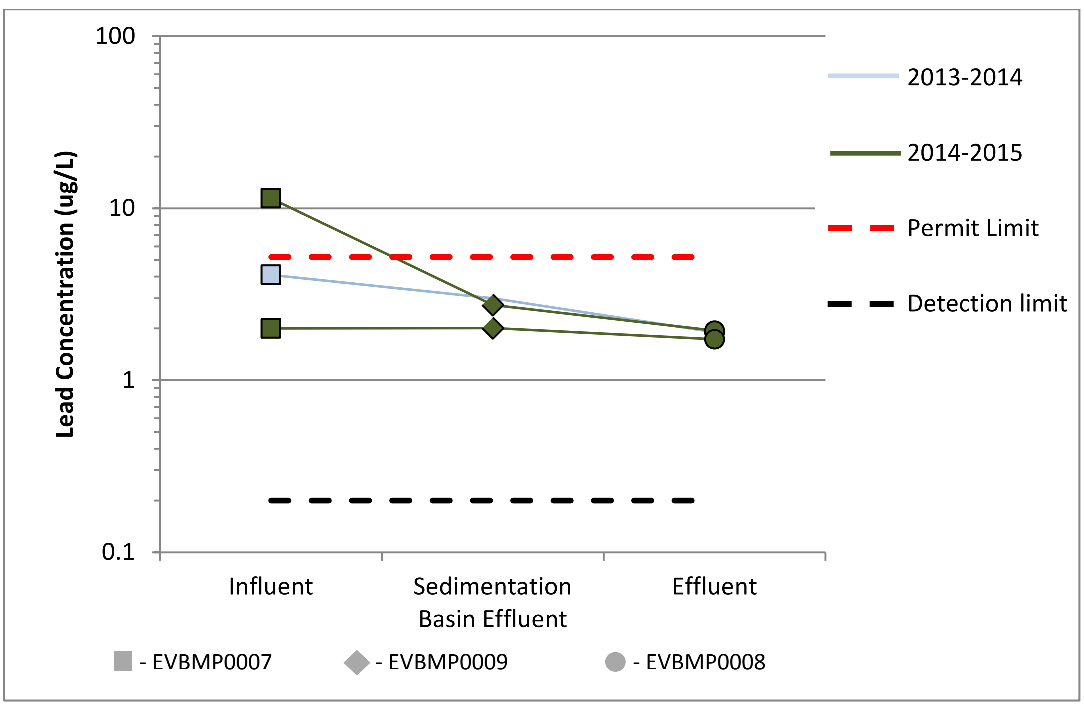


**Figure 28. Lead at ELV treatment BMP**

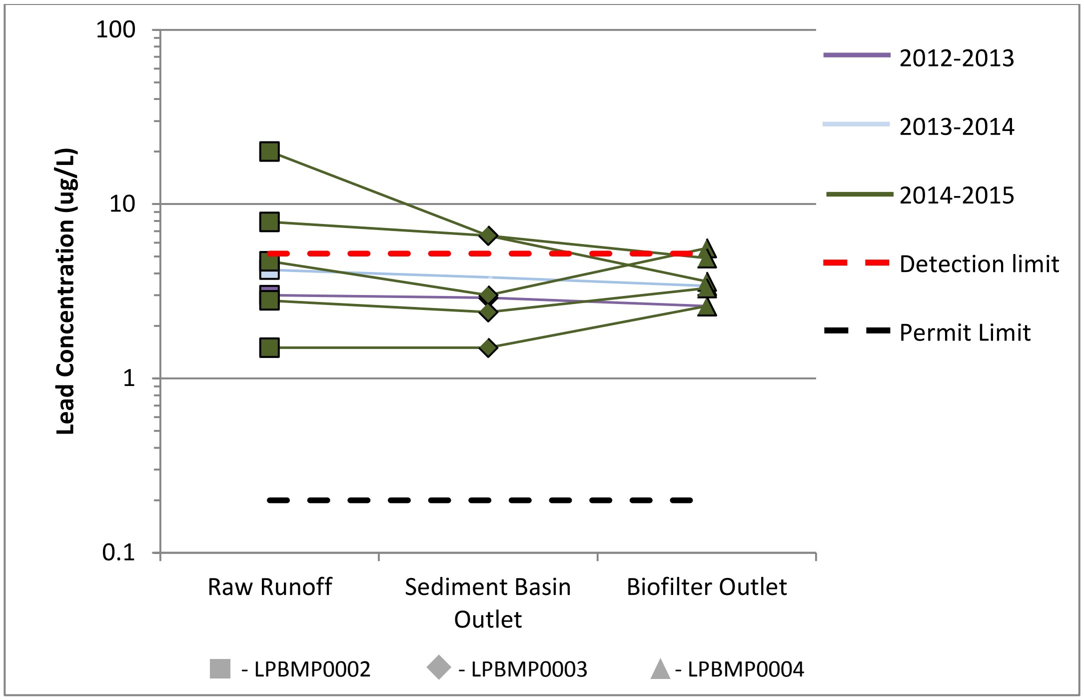


**Figure 29. Lead at Lower Lot Biofilter[7]**

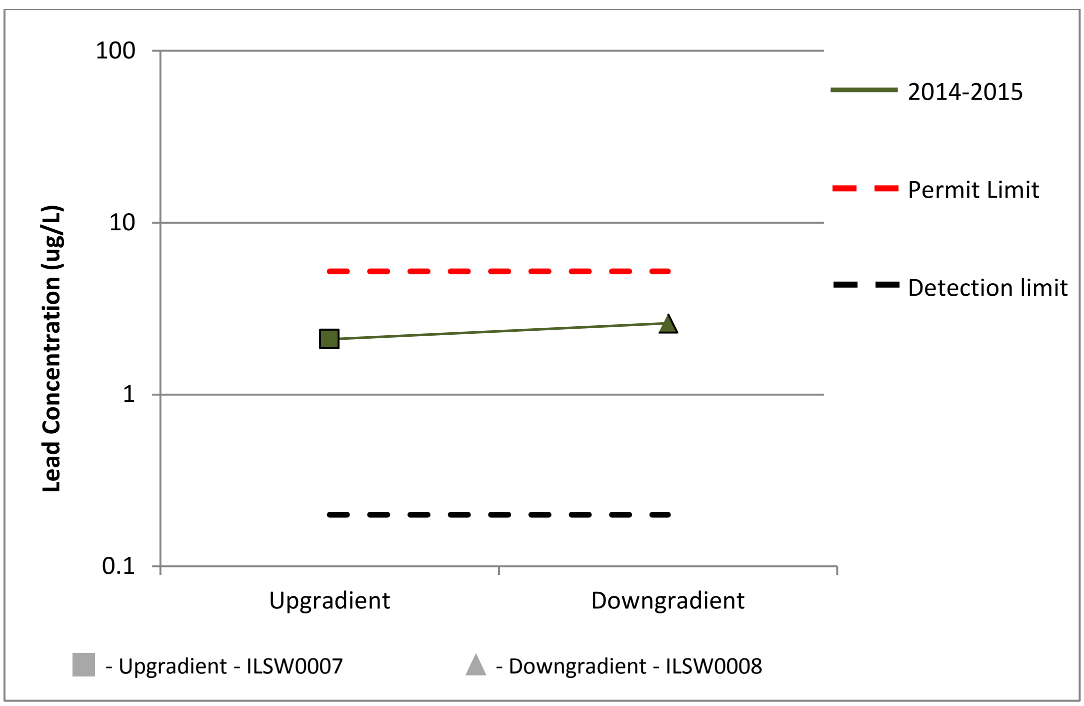


**Figure 30. Lead at IEL-2**

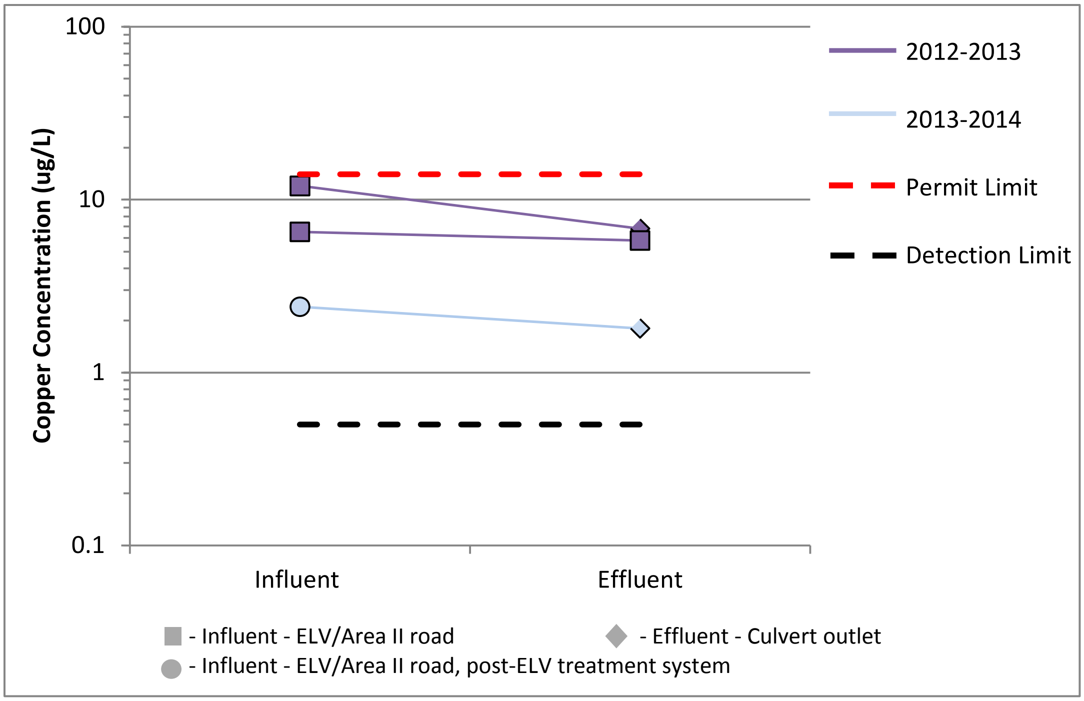


**Figure 31. Copper at CM-1, post filter fabric installation**

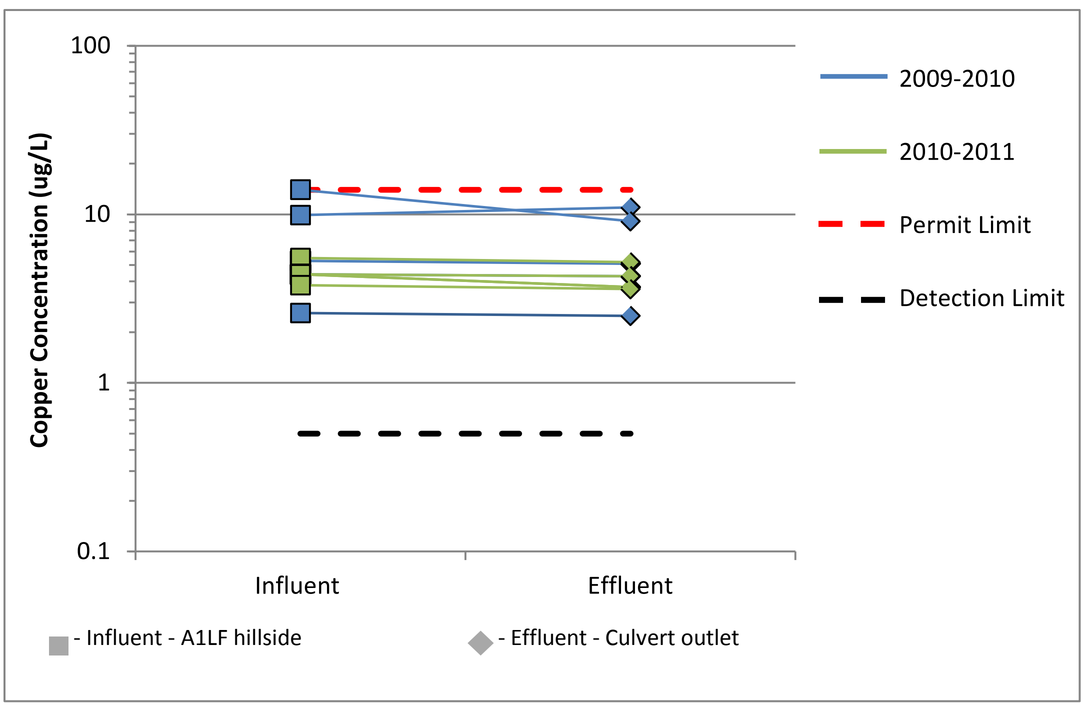


**Figure 32. Copper at CM-9, pre improvements**

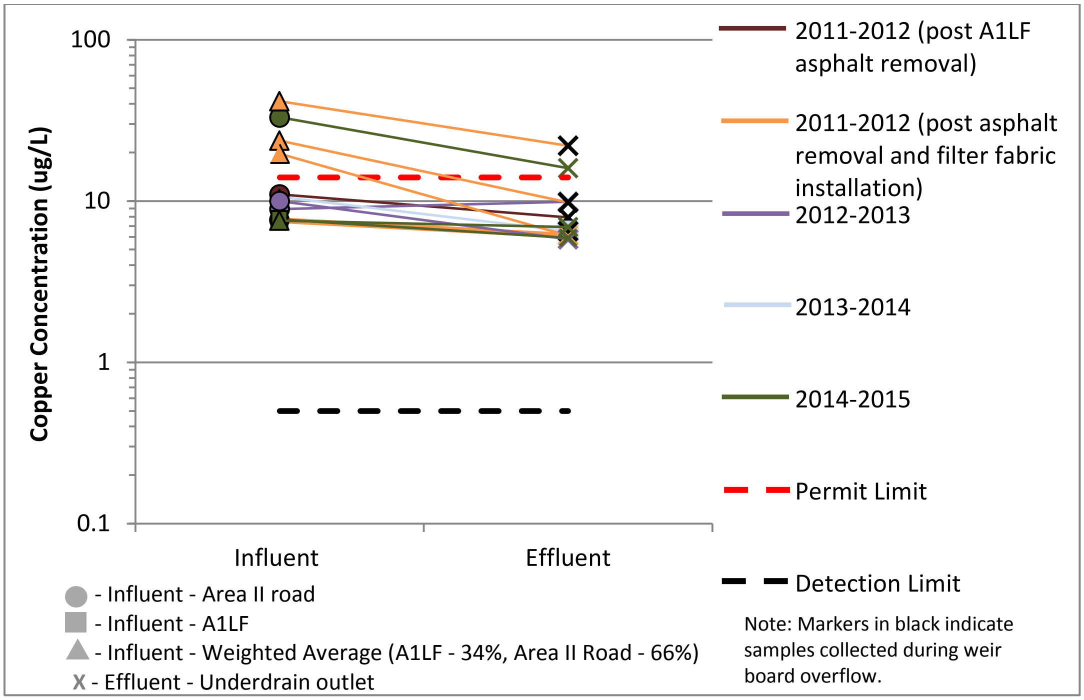


**Figure 33. Copper at CM-9, post improvements (removal of A1LF asphalt and addition of CM weir board filter fabric)**

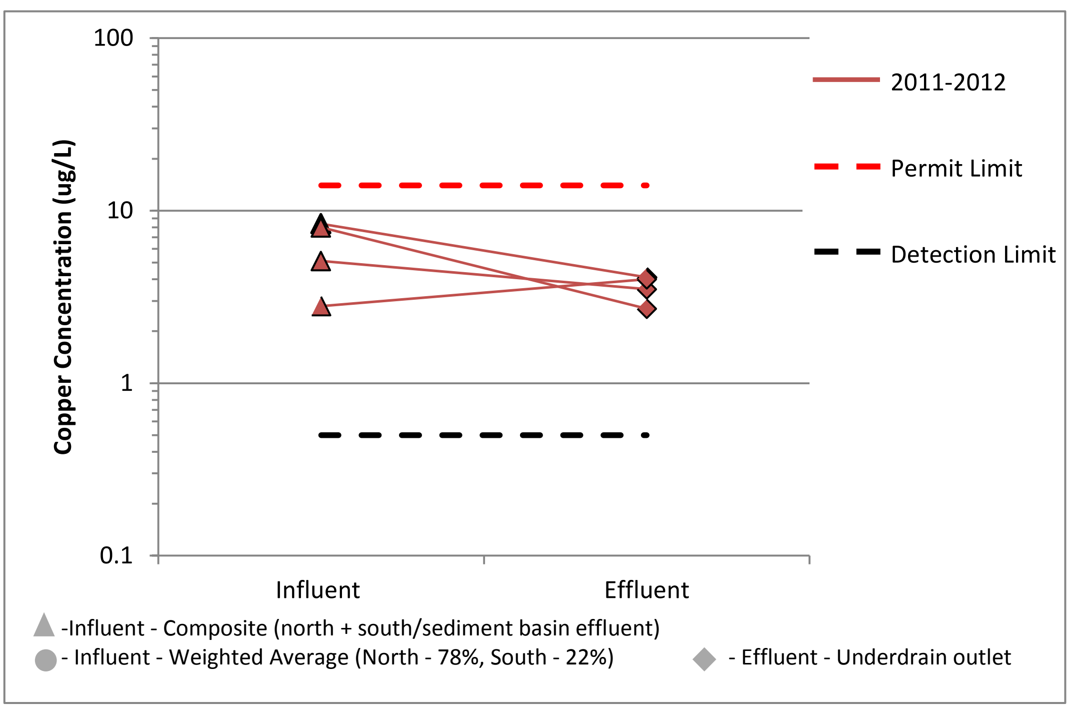


**Figure 34. Copper at B-1 Media Filter (CM), pre curb cuts**

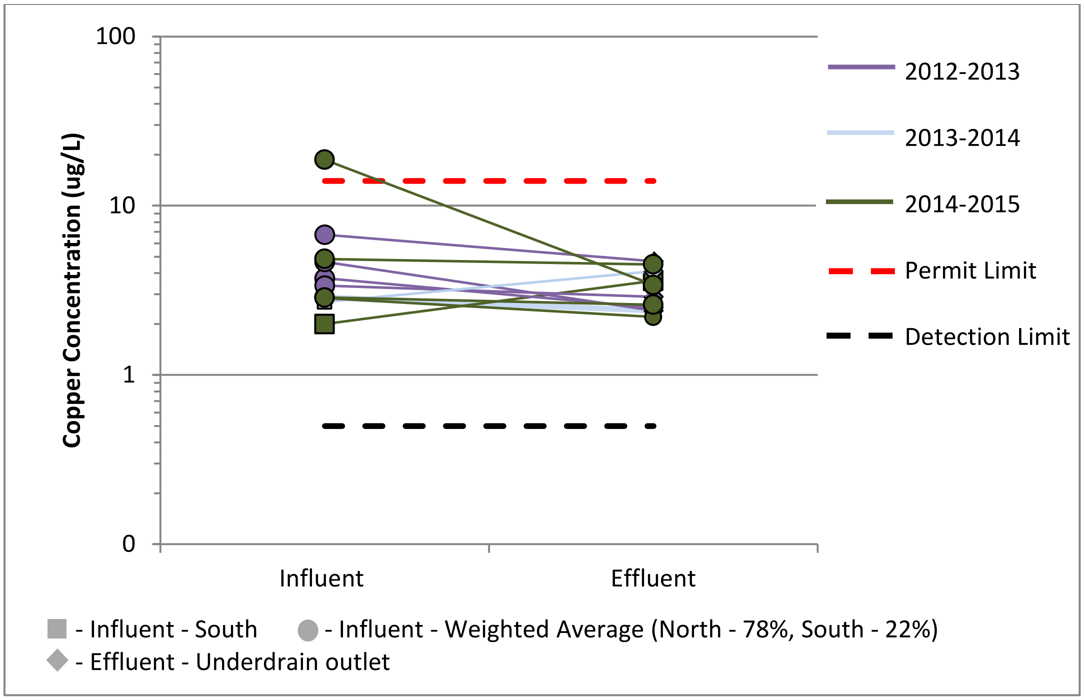


**Figure 35. Copper at B-1 Media Filter (CM), post curb cuts**

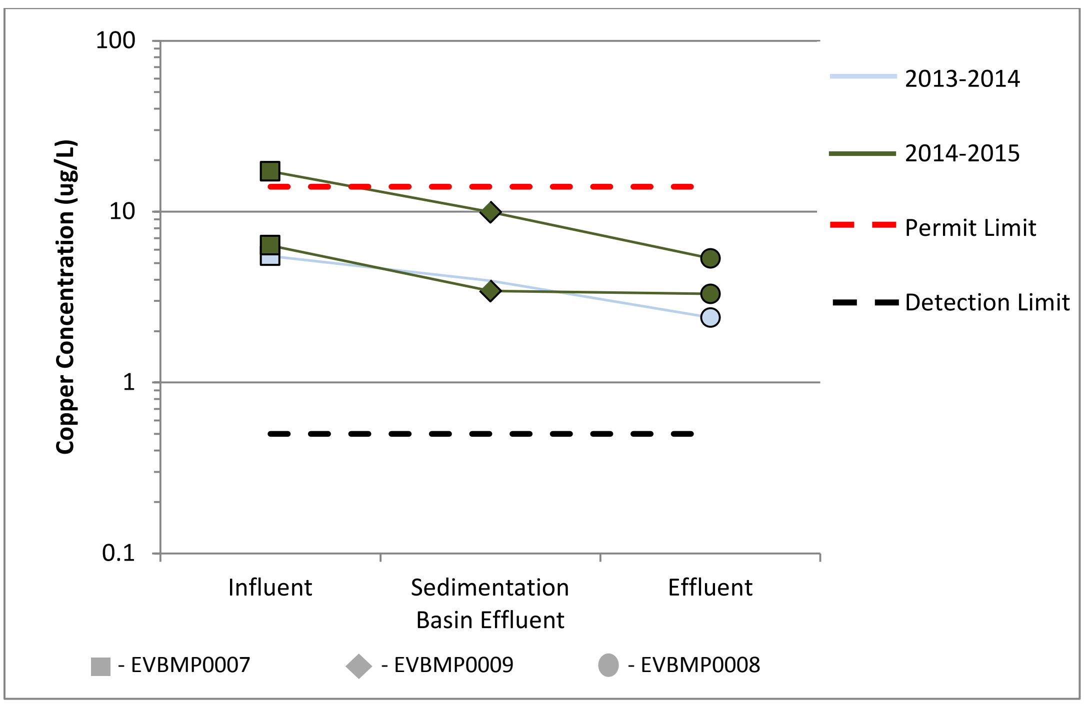


**Figure 36. Copper at ELV Treatment BMP**

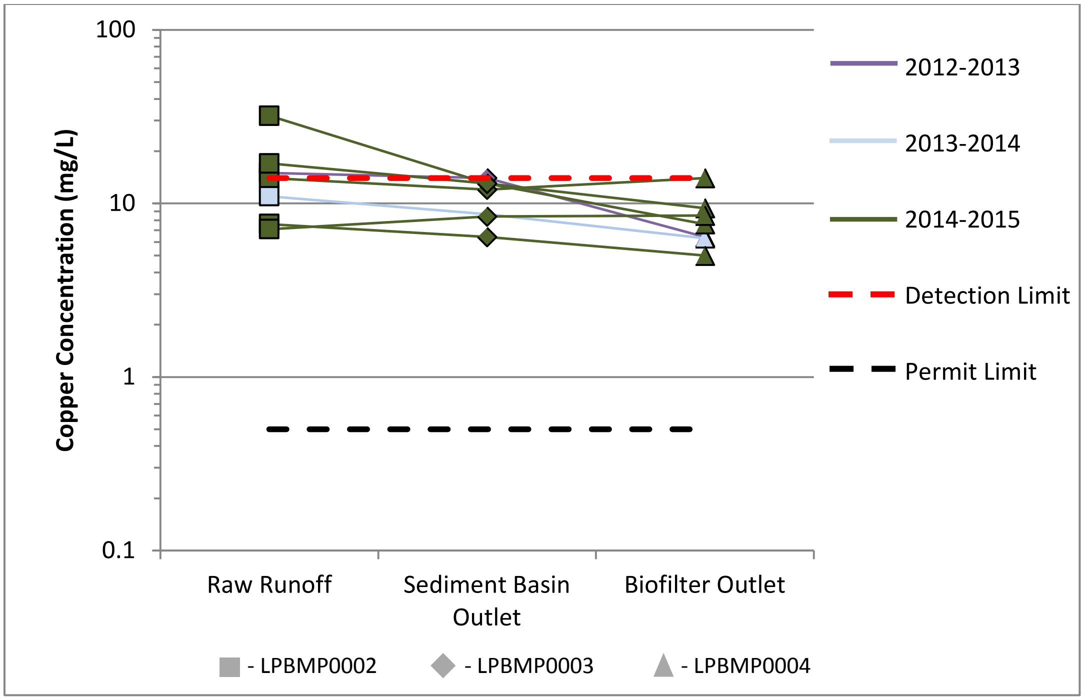


**Figure 37. Copper at Lower Lot Biofilter**[7]

## 2. STATISTICAL ANALYSIS

Statistical summaries of the Site cumulative paired data over the 2009-2015 sampling period using the non-parametric 1-tailed sign test are shown for the paired datasets in Tables 3 through 12. This test is used to evaluate statistical differences between paired data points, or in this case, between influent and effluent stormwater samples. For this analysis, data pairs that were taken during observed bypass/overflow events were removed (specific locations, events, and rainfall characteristics were listed previously in Section 1).

### *Culvert Modification Areas*

At the six monitored CMs (B-1, CM-1, CM-3, CM-8, CM-9, and CM-11), the total number of combined influent and effluent data pairs ranged from 36 (for copper) to 73 (for TSS).

Table 3 and Table 4 summarize the paired data statistics for these locations. CM-8, CM-11, and select CM-1 paired statistics are presented separately since the influent flows to these sites come largely from unimpaired/background sites, and therefore significant reduction of the COC concentrations (which are already generally very low) in those flows by CMs is unlikely. No data were collected from these background sites in the 2014/2015 sampling season. Data from the CM-3 background site were excluded since post-storm dry weather flows were observed at the outlet between February 2010 and March 2011 when no flows were observed entering the culvert, suggesting subsurface inflows were contributing to effluent samples. Therefore, this CM cannot be reliably assessed based on the effluent sample results. At the B-1 site, media filter bleed-through was observed during initial sampling dates in the 2011/2012 sampling season. Since this was a malfunction that was subsequently corrected, results from these sample dates were removed from the analysis. As noted in the paired plots, the CM-1 effluent sample collected on 2/28/2014 represented a blend of underdrain flow and seepage through the upstream weir boards.

In the non-background CM sites, for TSS, 29 out of 46 (63%) of influent concentrations were greater than their paired effluent concentrations, with an average decrease of 57%. For lead, 34 out of 46 (74%) influent concentrations were greater than their paired effluent concentrations, with an average decrease of 45%. For copper, 31 out of 36 (86%) influent concentrations were greater than effluent concentrations with an average decrease of 32%. For dioxins, 27 out of 39 (69%) influent concentrations were greater than effluent concentrations with an average decrease of 95%; however, it should be noted that this removal average is heavily influenced by one data pair taken during the 2010/2011 season prior to the upgrade at CM-1, and another data pair at B-1 media filter in the 2014/2015 rainy season with a very high influent concentration. If these pairs are removed from the analysis, the average removal is 82% for dioxins. These results show that the comparison of influent concentrations are significantly greater than the effluent concentrations for copper, dioxins, TSS, and lead ($p < 0.05$).

Statistically significant decreases from influent to effluent were seen in TSS and lead in background sites (42% and 54%, respectively), as shown in Table 4[8], though again it should be noted that no data were collected from these sites in the most recent sampling year. There was a statistically insignificant increase

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[8] Copper data were not collected for background sites.

from influent to effluent for dioxins for the background sites; however, as noted earlier, the influent concentrations at these sites are very low (none of the dioxins samples at these sites, either influent or effluent, were above Permit Limits), so further reductions would be difficult to achieve.

**Table 3. CM-1 ("background" samples excluded), CM-9, and B-1 Non-Background Statistical Analysis**

| | TSS (mg/L) | Dioxins (µg/L) | Copper (µg/L) | Lead (µg/L) |
|---|---|---|---|---|
| Total pairs of observations[1] | 46 | 39 | 36 | 46 |
| Number of influent samples having larger concentrations than effluent samples | 29 | 27 | 31 | 34 |
| Number of effluent samples having larger concentrations than influent samples | 15 | 7 | 5 | 11 |
| p by paired nonparametric 1-tailed sign test[2] | 0.024 | 0.0004 | 0.000006 | 0.0004 |
| Average (and COV) influent concentrations | 88.52 (2.47) | 5.82E-06 (5.82) | 7.34 (0.83) | 7.99 (1.49) |
| Average (and COV) effluent concentrations | 37.73 (2.44) | 3.01E-07 (4.89) | 4.99 (0.57) | 4.42 (1.54) |
| Average percent change (- sign indicating higher effluent results) | 57% | 95% | 32% | 45% |

[1] Some pairs consisted of influent concentrations that were equal to effluent concentration; this explains why rows 2 and 3 do not necessarily sum to the total pairs of observations.

[2] One-tail sign test used to evaluate data. Results where influent and effluent concentrations were equal were not used in sign test. P values of ≤ 0.05 are considered statistically significant.

[3] Average change in dioxins is heavily influenced by one pair at CM-1 that was taken during the 2010/2011 season (prior to improvements at that CM) and one pair at the B-1 media filter from the 2014/2015 season that had a very high influent concentration. Exclusion of this pair results in an average change of 82% (p = 0.0003). Without this sample, the average influent and effluent concentrations are 3.63E-07 and 6.60E-08 respectively, and the influent and effluent COVs are 2.0 and 1.3 respectively.

**Table 4. CM-1[1], CM-8 and CM-11 Background Statistical Analysis[2]**

| | TSS (mg/L) | Dioxins (µg/L) | Copper (µg/L) | Lead (µg/L) |
|---|---|---|---|---|
| Total pairs of observations[3] | 27 | 17 | No data pairs available for copper at background sites | 16 |
| Number of influent samples having larger concentrations than effluent samples | 17 | 5 | | 13 |
| Number of effluent samples having larger concentrations than influent samples | 4 | 6 | | 1 |
| p by paired nonparametric 1-tailed sign test[4] | 0.004 | 0.500 | | 0.001 |
| Average (and COV) influent concentrations | 11.74 (1.58) | 3.88E-10 (1.49) | | 2.44 (1.49) |
| Average (and COV) effluent concentrations | 6.85 (1.27) | 6.34E-10 (1.88) | | 1.12 (1.64) |
| Average percent change (- sign indicating higher effluent results) | 42% | -64% | | 54% |

[1] Only CM-1 samples that were taken from east/background tributary influent sites are included in this analysis
[2] As noted earlier in this memorandum, the CM-3 performance cannot be reliably assessed based on the effluent sample results. For this reason, the CM-3 paired data were excluded from the statistical analysis presented in this table.
[3] Some pairs consisted of influent concentrations that were equal to effluent concentrations; this explains why rows 2 and 3 do not necessarily sum to the total pairs of observations.
[4] One-tail sign test used to evaluate data. Results where influent and effluent concentrations were equal were not used in sign test.

### *Lower Lot Biofilter Treatment Train*

Construction of the Lower Lot Biofilter, located in the Outfall 009 watershed, was completed in 2013. To date, samples were taken at this location during seven rain events that occurred after the construction was completed, with samples collected at three locations within the biofilter treatment train (influent, post-sedimentation basin, and post-biofilter) for one rain event during the first year, two locations (influent and post-biofilter) for a single rain event in the 2013/2014 sampling year, and three locations within the treatment train (influent, post-sedimentation basin, and post-biofilter) for five rain events during the most recent sampling year. The post-biofilter samples collected in early 2014 represents a blend of filtered underdrain water and overflow. A sample was not taken at the biofilter inlet (post-sedimentation basin) during the 2013/2014 sampling year due to the sample location being submerged and inaccessible. During one event in the 2014/2015 season, unusually turbid water was observed in the biofilter; this may have been due to sediment-laden run-on from the Building 1436 detention bioswale construction area (Figure 38).

**Figure 38: A photo of the biofilter taken on 12/2/2014**

Table 5, Table 6, and Table 7 summarize the paired sampling data for the biofilter. The pairs in Table 5 (runoff to sedimentation basin outlet) and Table 6 (sedimentation basin to biofilter outlet) were collected during the 2012/2013 and 2014/2015 rainy seasons. The pairs in Table 7 (runoff to biofilter outlet) include one pair from each of the 2012/2013 and 2013/2014 rainy seasons and five pairs from the 2014/2015 season. For TSS, concentrations were found to increase between the influent runoff and the sedimentation basin outlet locations during the 2012/2013 sample event (at that time, the sedimentation basin was eroding, which increased TSS levels at the outlet structure). However, TSS decreased from the sedimentation basin outlet to the biofilter outlet during the 2012/2013 sample event, resulting in a net reduction across the system, and decreased from the influent runoff to the biofilter outlet during the 2013/2014 sample event. Results from the most recent rainy season showed that two sample pairs increased in TSS from runoff to the sedimentation basin outlet and then decreased from the basin outlet to the biofilter outlet, although one pair resulted in a net reduction across the system while the other resulted in a net increase. One pair showed a decrease in TSS concentration at both steps in the system (overall net reduction), and another pair exhibited an increase in each step (overall net increase). The final sample pair from 2014/2015 showed a decrease in TSS from runoff to the sedimentation basin and an increase from the sedimentation basin outlet to the biofilter outlet, resulting in a net increase across the system. Overall, four out of seven (57%) TSS influent concentrations were greater than their paired effluent concentrations, and the average reduction of TSS across the system for all seven storm events sampled to date is approximately 55%. For copper, five out of seven (71%) of influent concentrations were greater than their paired effluent concentrations. Four out of seven (57%) influent concentrations for lead samples were greater than paired effluent concentrations, and seven out of seven (100%) paired samples for dioxins had greater influent concentrations than their paired effluent concentrations. Copper, lead, and dioxins had net reductions across the system of 45%, 41%, and 91%, respectively. It should be noted that sample concentrations of lead were below Permit Limits with the exception of two influent (runoff), two sedimentation basin outlet, and one effluent (biofilter outlet) samples. All sample results that were above Permit Limits for lead occurred in the current monitoring year. Influent (runoff) for copper exceeded Permit Limits for two samples to date, but effluent (biofilter outlet) concentrations reduced to below Permit Limits. Influent (runoff) for dioxins exceeded the Permit Limits for all but one event, and exceeded at the effluent for only one event.

**Table 5. Lower Lot Biofilter Performance Data – Influent Runoff to Sedimentation Basin Outlet**

| | TSS (mg/L) | Dioxin (µg/L) | Copper (µg/L) | Lead (µg/L) |
|---|---|---|---|---|
| Total pairs of observations | 6 | 6 | 6 | 6 |
| Number of influent samples having larger concentrations than effluent samples | 2 | 4 | 5 | 5 |
| Number of effluent samples having larger concentrations than influent samples | 4 | 2 | 1 | 0 |
| p by paired nonparametric sign test | 0.344 | 0.344 | 0.11 | 0.0313 |
| Average (and COV) influent concentrations | 123 (0.87) | 6.71E-08 (0.42) | 16 (0.59) | 6.7 (1.04) |
| Average (and COV) effluent concentrations | 778 (0.45) | 7.20E-08 (1.06) | 11 (0.27) | 3.8 (0.58) |
| Average percent change (- sign indicating higher effluent results) | 37% | -7.3% | 28% | 42% |

**Table 6. Lower Lot Biofilter Performance Data – Sedimentation Basin Outlet to Biofilter Outlet**

| | TSS (mg/L) | Dioxin (µg/L) | Copper (µg/L) | Lead (µg/L) |
|---|---|---|---|---|
| Total pairs of observations | 7 | 7 | 7 | 7 |
| Number of influent samples having larger concentrations than effluent samples | 5 | 7 | 5 | 4 |
| Number of effluent samples having larger concentrations than influent samples | 2 | 0 | 2 | 3 |
| p by paired nonparametric sign test | 0.227 | 0.0078 | 0.23 | 0.500 |
| Average (and COV) influent concentrations | 110 (0.71) | 6.17E-08 (1.21) | 11 (0.25) | 4.5 (0.6) |
| Average (and COV) effluent concentrations | 41 (0.95) | 1.89E-10 (0.5) | 8.1 (0.37) | 4.0 (0.31) |
| Average percent change (- sign indicating higher effluent results) | 62% | 99.7% | 28% | 12% |

**Table 7. Lower Lot Biofilter Performance Data – Influent Runoff to Biofilter Outlet**

| | TSS (mg/L) | Dioxin (µg/L) | Copper (µg/L) | Lead (µg/L) |
|---|---|---|---|---|
| Total pairs of observations | 7 | 7 | 7 | 7 |
| Number of influent samples having larger concentrations than effluent samples | 4 | 7 | 5 | 4 |
| Number of effluent samples having larger concentrations than influent samples | 3 | 0 | 1 | 3 |
| p by paired nonparametric sign test | 0.50 | 0.0078 | 0.11 | 0.50 |
| Average (and COV) influent concentrations | 82 (1.11) | 1.20E-07 (1.18) | 145 (0.57) | 6.3 (1.01) |
| Average (and COV) effluent concentrations | 37 (0.9) | 1.08E-08 (2.6) | 8.2 (0.36) | 3.7 (0.31) |
| Average percent change (- sign indicating higher effluent results) | 55% | 91% | 45% | 41% |

### *ELV Treatment BMP*

The ELV treatment BMP was installed in November 2013. To date, samples have been collected at this location only during the February/March 2014 storm event and two events in the 2014/15 rainy season. Extenuating circumstances relevant to this site during the February/March 2014 storm event included high flows from Helipad Road to the ELV treatment system (resulting in excess inflows to the sump), inadequate erosion controls along the earthen ELV channel (resulting in excess sediment in the sump [approximately one foot in sump and less than an inch in the sedimentation tanks]), and a power outage (resulting in the sump pump turning off). The February/March 2014 ELV stormwater treatment BMP effluent data are still considered representative for the analysis herein, although it is recognized that because this monitoring event was the first at the ELV, media bed loss may have been occurring.

Samples were collected at three locations within the ELV treatment train (influent, sedimentation tank outlet, and media tank effluent) during the most recent rainy season, and samples were only collected at two locations (influent and effluent) during the 2013/2014 season. Table 8, Table 9, and Table 10 summarize the paired data for this location. Because there were only two paired samples for the influent to sedimentation tank outlet and sedimentation tank outlet to effluent locations, statistical analyses were not performed in Table 8 and Table 9. Three sample pairs were collected for the influent to effluent locations, so a statistical analysis was performed in Table 10. For copper and lead, three out of three (100%) of influent concentrations were greater than their paired effluent concentrations. Two out of three (67%) of influent concentrations for dioxins samples were greater than their paired effluent concentrations. For the one event where dioxins concentrations increased from influent to effluent, there was an increase from influent to the mid-point and a reduction from the mid-point location to effluent. TSS showed a net decrease from influent to effluent concentrations for one of the three (33%) sampled events. For one of the two cases where a net increase in TSS occurred, during the 2013/2014 rainy season, the ELV stormwater treatment BMP was heavily loaded by sediments eroded from the denuded ELV channel prior to implementation of recent erosion control improvements. The other case showing a net increase in TSS across the system (in the 2014/2015 rainy season) had an increase in concentration from the influent to mid-point and a reduction from the mid-point to effluent. Copper, lead, dioxins, and TSS had net reductions across the system of 62%, 68%, 71%, and 6%, respectively.

**Table 8. ELV Stormwater Treatment BMP Performance Data – Influent to Sedimentation Tank Effluent**

| | TSS (mg/L) | Dioxin (µg/L) | Copper (µg/L) | Lead (µg/L) |
|---|---|---|---|---|
| Total pairs of observations | 2 | 2 | 2 | 2 |
| Number of influent samples having larger concentrations than effluent samples | 1 | 1 | 2 | 1 |
| Number of effluent samples having larger concentrations than influent samples | 1 | 1 | 0 | 1 |
| p by paired nonparametric sign test[1] | N/A | N/A | N/A | N/A |
| Average influent concentrations | 33 | 1.69E-08 | 12 | 6.7 |
| Average effluent concentrations | 13 | 3.28E-10 | 6.7 | 2.4 |
| Average percent change (- sign indicating higher effluent results) | 60% | 98% | 43% | 65% |

[1] A statistical analysis (p-value) was not performed because there were only two paired samples (COV also not calculated for average influent and effluent concentrations)

**Table 9. ELV Stormwater Treatment BMP Performance Data – Sedimentation Tank Effluent to Media Tank Effluent**

| | TSS (mg/L) | Dioxin (µg/L) | Copper (µg/L) | Lead (µg/L) |
|---|---|---|---|---|
| Total pairs of observations | 2 | 2 | 2 | 2 |
| Number of influent samples having larger concentrations than effluent samples | 0 | 2 | 2 | 2 |
| Number of effluent samples having larger concentrations than influent samples | 2 | 0 | 0 | 0 |
| p by paired nonparametric sign test[1] | N/A | N/A | N/A | N/A |
| Average influent concentrations | 13 | 3.28E-10 | 6.7 | 2.4 |
| Average effluent concentrations | 22 | 2.22E-10 | 4.3 | 1.8 |
| Average percent change (- sign indicating higher effluent results) | -70% | 32% | 36% | 23% |

[1] A statistical analysis (p-value) was not performed because there were only two paired samples (COV also not calculated for average influent and effluent concentrations)

**Table 10. ELV Treatment System Performance Data – Influent to Media Tank Effluent**

| | TSS (mg/L) | Dioxin (µg/L) | Copper (µg/L) | Lead (µg/L) |
|---|---|---|---|---|
| Total pairs of observations | 3 | 3 | 3 | 3 |
| Number of influent samples having larger concentrations than effluent samples | 1 | 2 | 3 | 3 |
| Number of effluent samples having larger concentrations than influent samples | 2 | 1 | 0 | 0 |
| p by paired nonparametric sign test | 0.500 | 0.500 | 0.13 | 0.1250 |
| Average (and COV) influent concentrations | 29<br>(0.89) | 5.19E-08<br>(1.2) | 9.7<br>(0.67) | 5.8<br>(0.85) |
| Average (and COV) effluent concentrations | 27<br>(0.55) | 1.49E-08<br>(1.7) | 3.7<br>(0.41) | 1.9<br>(0.06) |
| Average percent change (- sign indicating higher effluent results) | 6% | 71% | 62% | 68% |

### *ISRA Locations*

Only one paired sample was collected at an ISRA location (IEL-2) during the 2014/2015 rainy season, and sample results only represent lead and TSS concentrations during this event. The last ISRA data pair prior to this was from the 2011/2012 rainy season. Therefore, the analysis of ISRA locations does not strongly reflect recent monitoring data.

Three out of six (50%) of influent concentrations for dioxins were greater than their paired effluent concentrations, with an average net reduction of 89% (Table 11). TSS, copper, and lead all had net increases from influent to effluent locations, with average percent increases of 109%, 45%, and 61%, respectively. For TSS, three out of ten (30%) of influent concentrations were greater than their paired effluent concentrations. Two out of five (40%) of influent concentrations for copper samples were greater than their paired effluent concentrations, and two out of seven (29%) of paired samples had higher influent concentrations than effluent for lead.

**Table 11. ISRA Location Performance Data**

| | TSS (mg/L) | Dioxin (µg/L) | Copper (µg/L) | Lead (µg/L) |
|---|---|---|---|---|
| Total pairs of observations[1] | 10 | 6 | 5 | 7 |
| Number of upgradient samples having larger concentrations than downgradient samples | 3 | 3 | 2 | 2 |
| Number of downgradient samples having larger concentrations than upgradient samples | 7 | 2 | 3 | 5 |
| p by paired nonparametric sign test | 0.17 | 0.50 | 0.50 | 0.23 |
| Average (and COV) upgradient concentrations | 72.52<br>(1.09) | 4.65E-07<br>(2.38) | 6.29<br>(0.42) | 3.68<br>(1.02) |
| Average (and COV) downgradient concentrations | 151.70<br>(1.08) | 5.23E-08<br>(1.57) | 9.12<br>(0.5) | 5.92<br>(1.03) |
| Average percent change (- sign indicating higher downgradient results) | -109% | 89% | -45% | -61% |

[1]Some pairs consisted of influent concentrations that were equal to effluent concentration; this explains why rows 2 and 3 do not necessarily sum to the total pairs of observations.

## 3. INFLUENT v. EFFLUENT CORRELATION CHARTS

Figures 39 through 50 compare influent to effluent concentrations for the paired data presented above for CM sites (B-1, CM-9, and CM-1 non-background sites; CM-1, CM-3, CM-8, and CM-11 background sites are excluded), Lower Lot Biofilter, and the ELV stormwater treatment BMP. A least-squares regression was used to fit a line to log-transformed data (log(y) = mlog(x) + b). The slope of the lines, m, is shown in the lower right corner of the graph. In addition to the slope, the p-value is also shown to indicate the significance of the value of the reported slope. In other words, if the p-value is less than 0.05, the significance of the non-zero value of the slope, m, can be said to be 95%. A 1:1 line was also added to each plot. **Data above the 1:1 line indicate an effluent increase in concentrations, while data below the 1:1 line indicate an effluent decrease in concentrations (or positive BMP performance in the case of the CMs). Additionally, the location where the 1:1 line intersects the best-fit line represents the irreducible concentration for each constituent (e.g. ~ 10 mg/L for TSS at CM sites).** Pairs where one or both results were not detected were included on these graphs with different symbols.

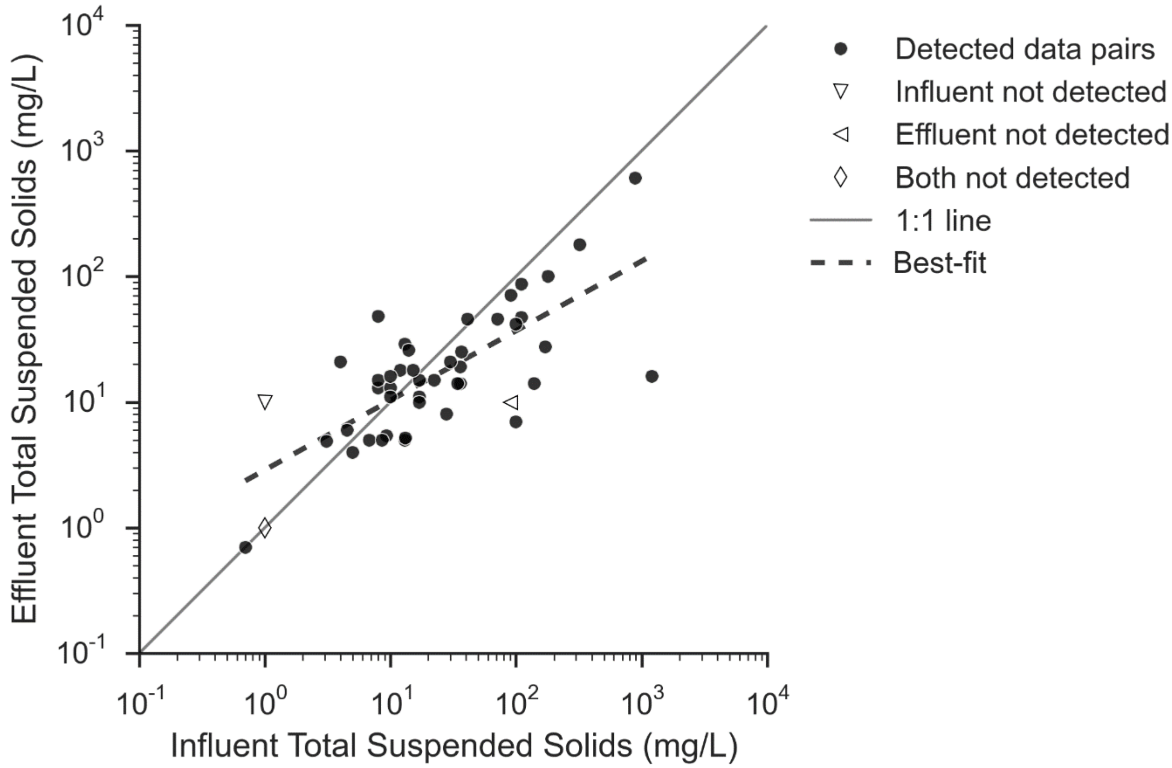


**Figure 39. Paired TSS Concentrations at CM Sites**

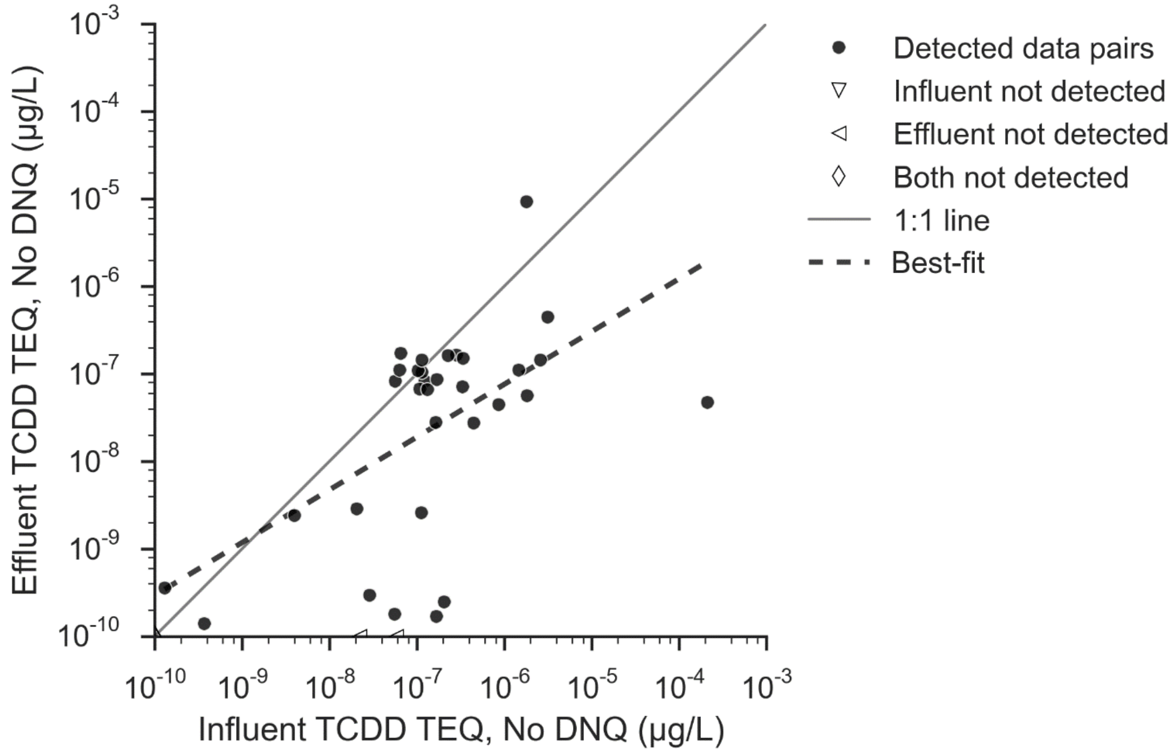


**Figure 40. Paired Dioxins Concentrations at CM Sites**

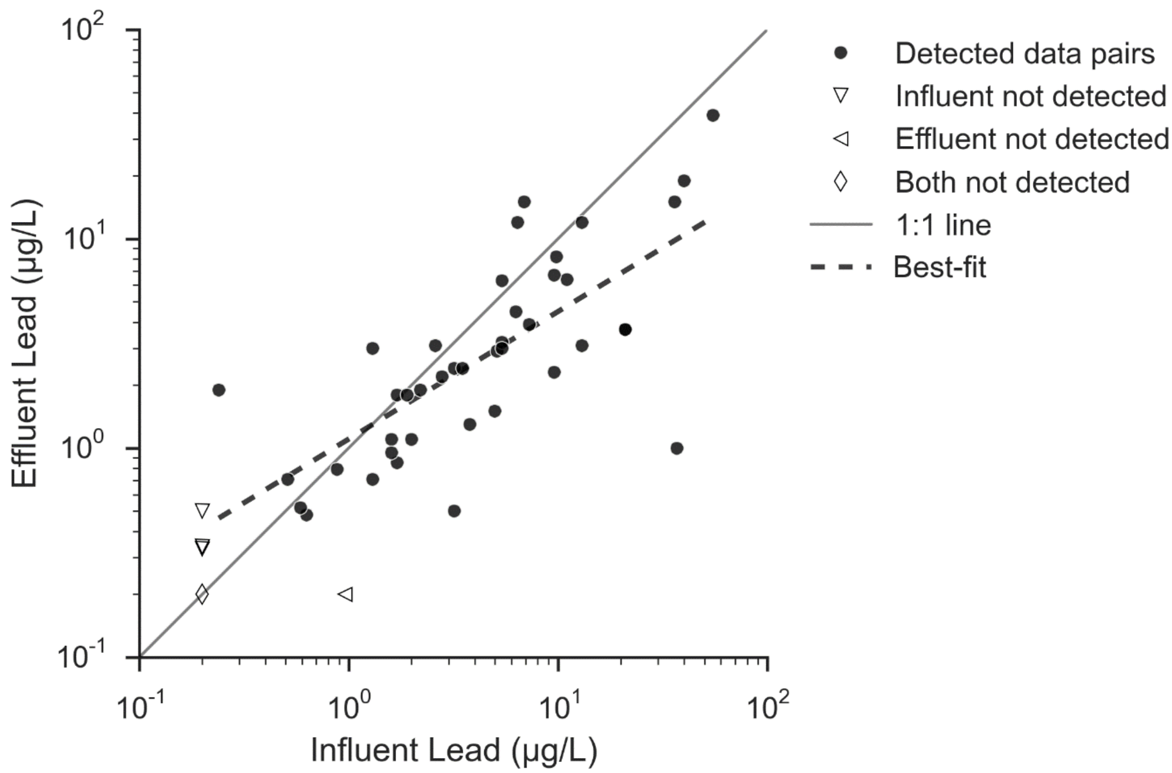


**Figure 41. Paired Lead Concentrations at CM Sites**

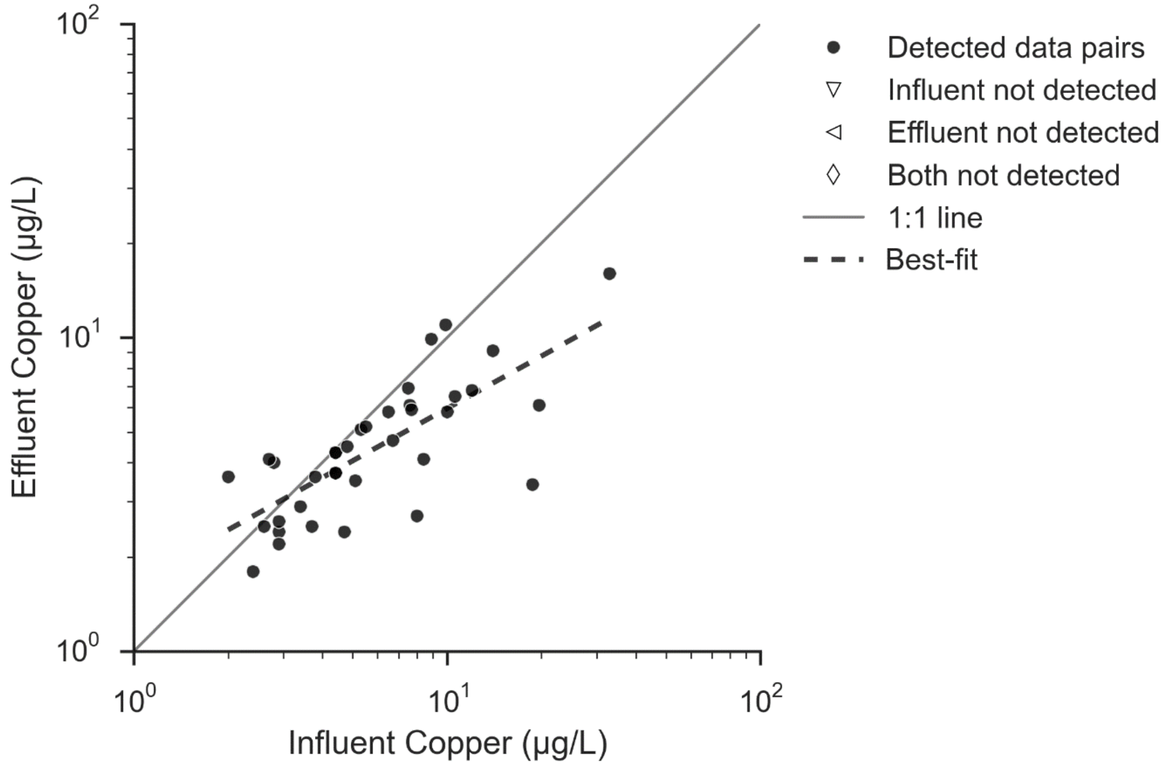


**Figure 42. Paired Copper Concentrations at CM Sites**

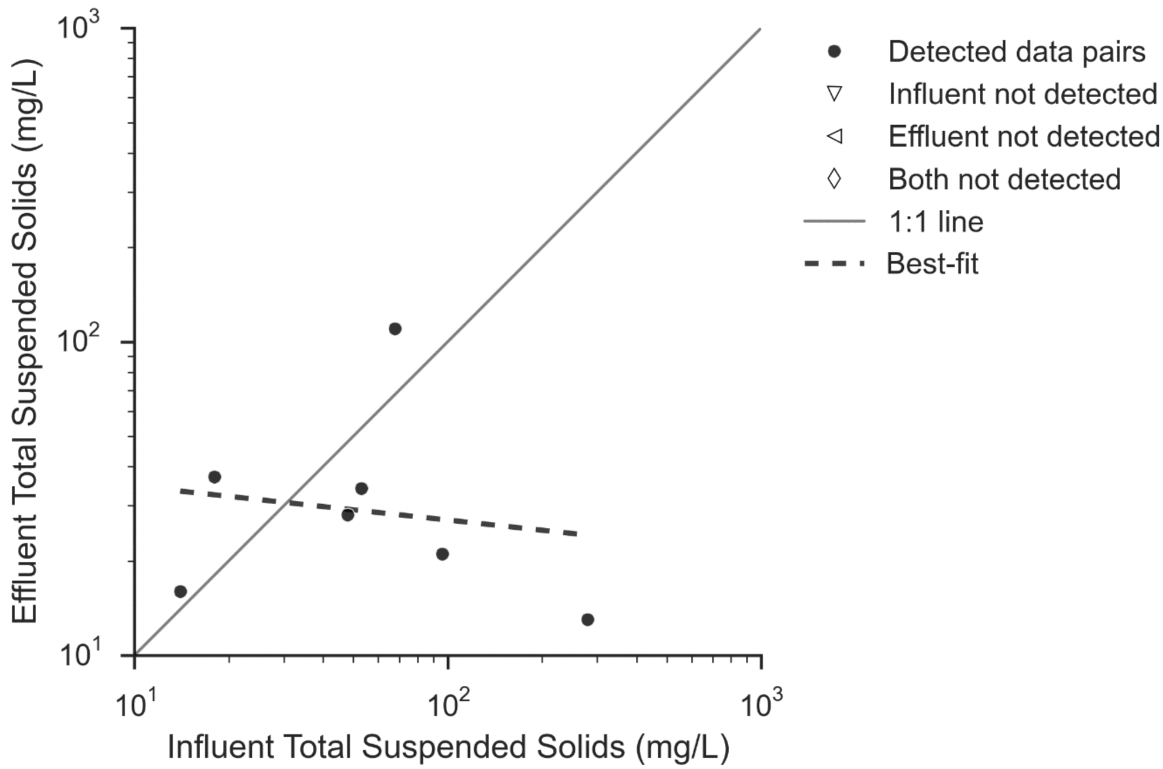


**Figure 43. Paired TSS Concentrations at Lower Lot Biofilter**

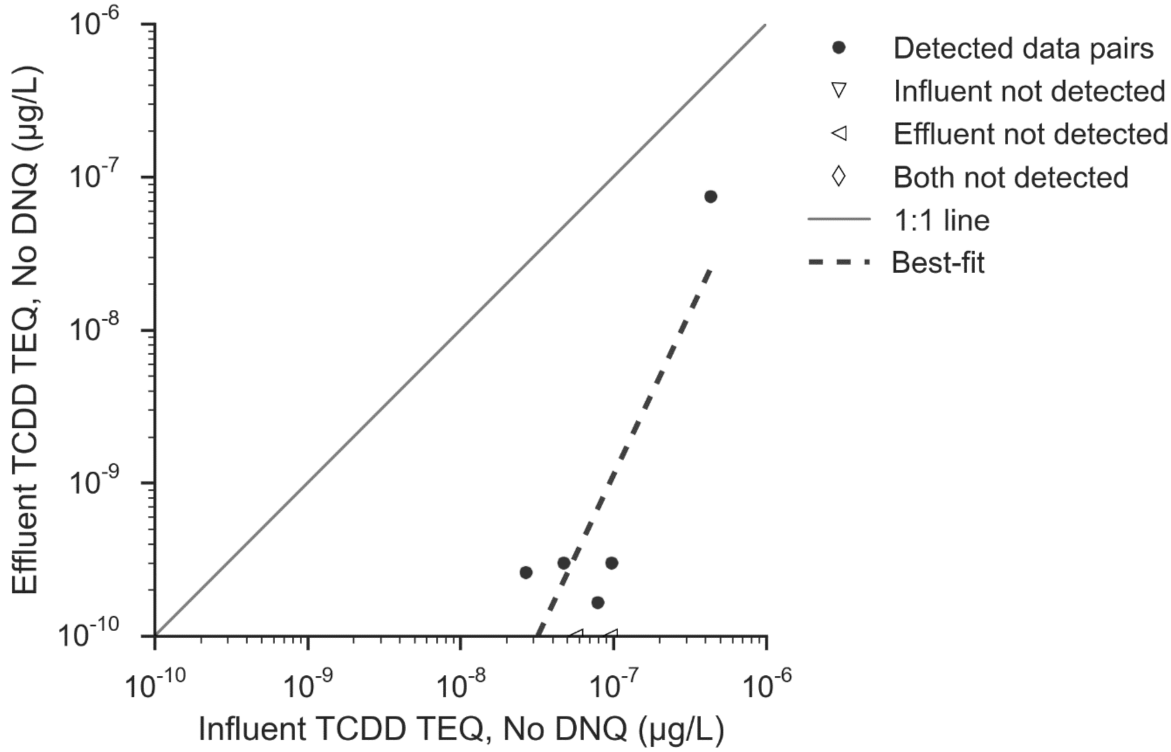


**Figure 44. Paired Dioxins Concentrations at Lower Lot Biofilter**

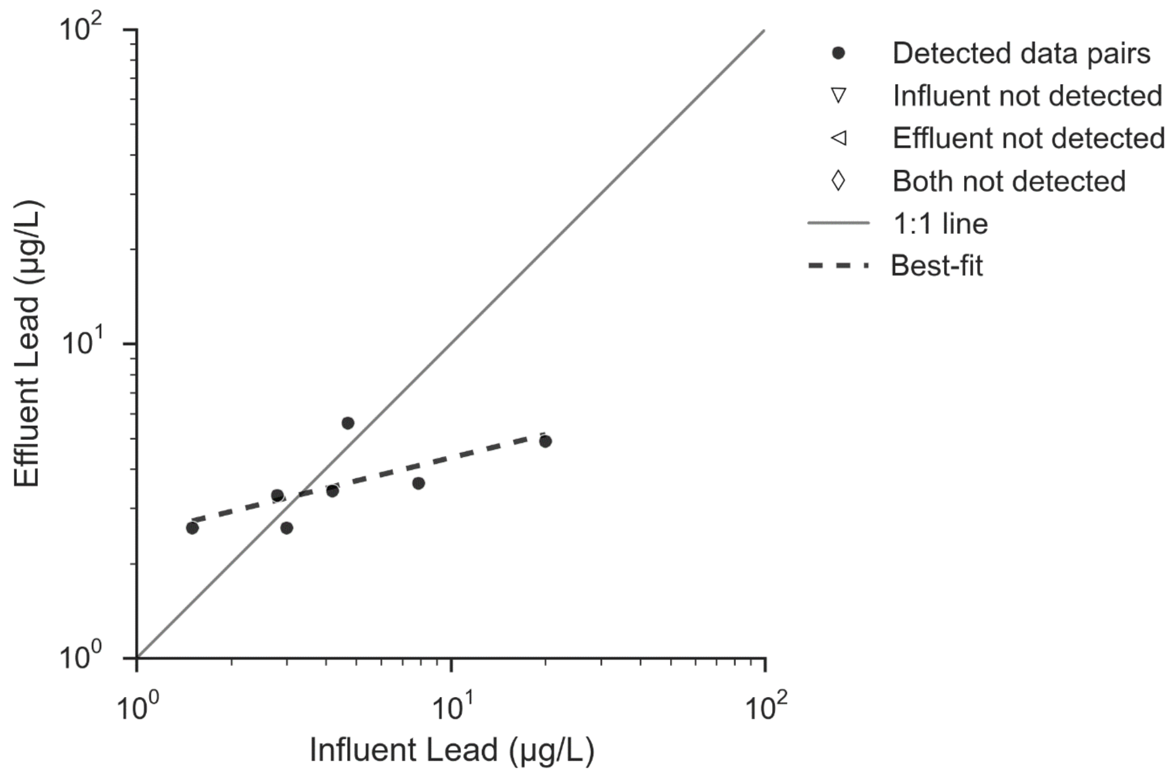


**Figure 45. Paired Lead Concentrations at Lower Lot Biofilter**

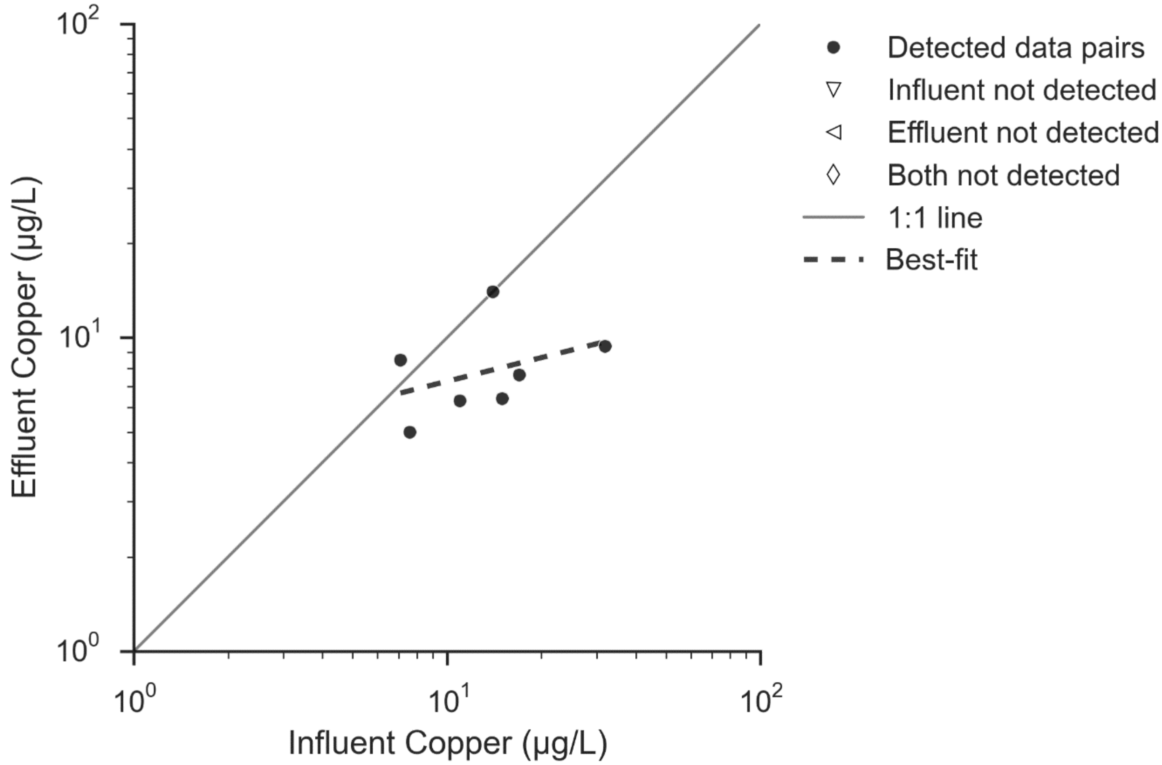


**Figure 46. Paired Copper Concentrations at Lower Lot Biofilter**

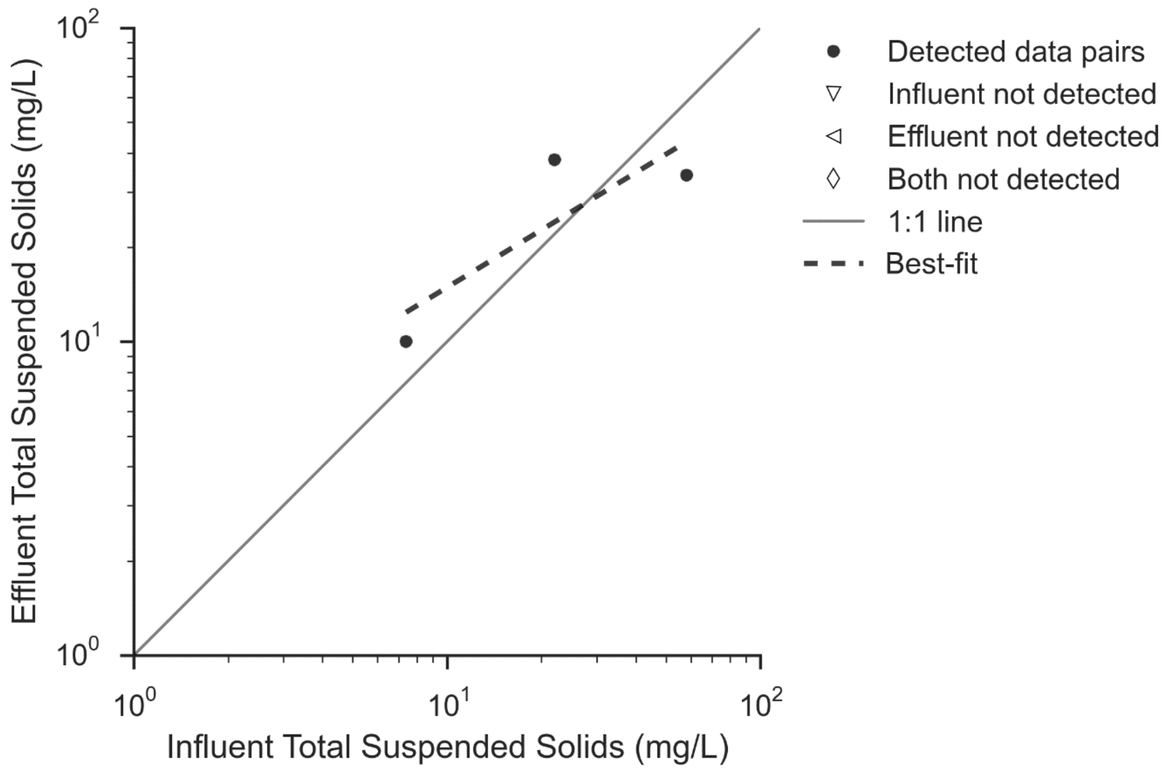


**Figure 47. Paired TSS Concentrations at ELV Stormwater Treatment BMP**

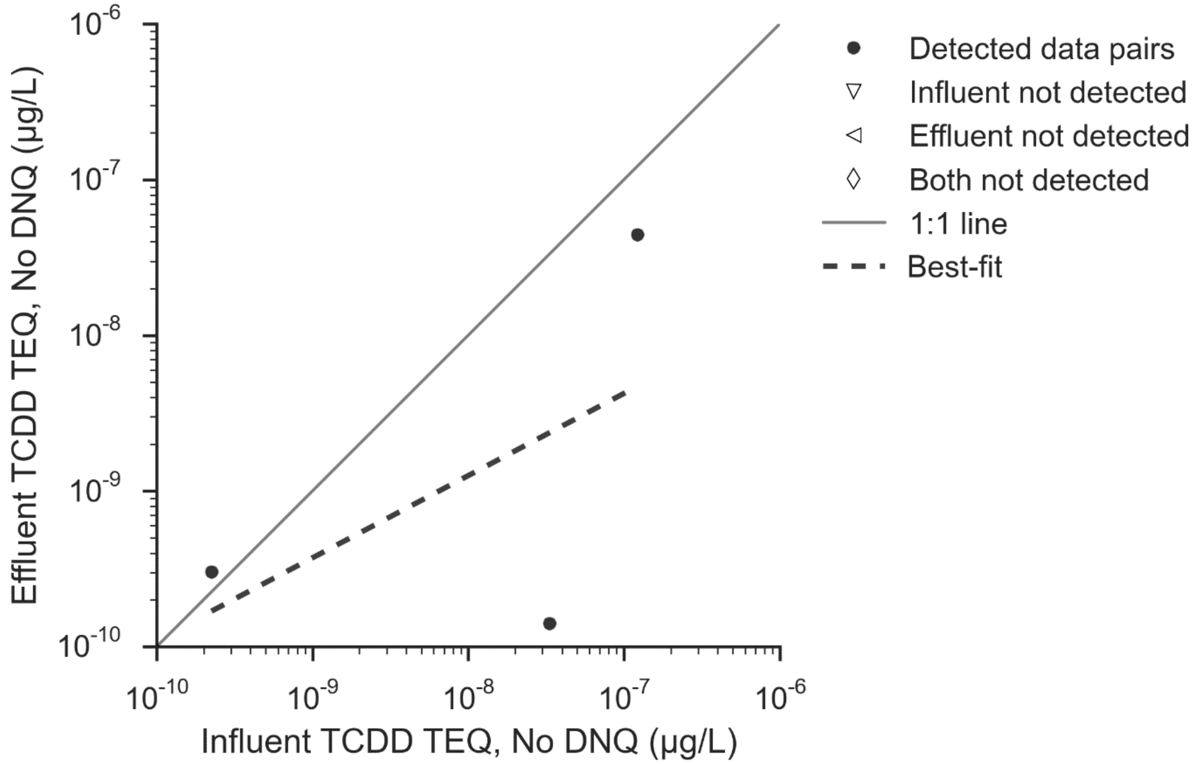


**Figure 48. Paired Dioxins Concentrations at ELV Stormwater Treatment BMP**

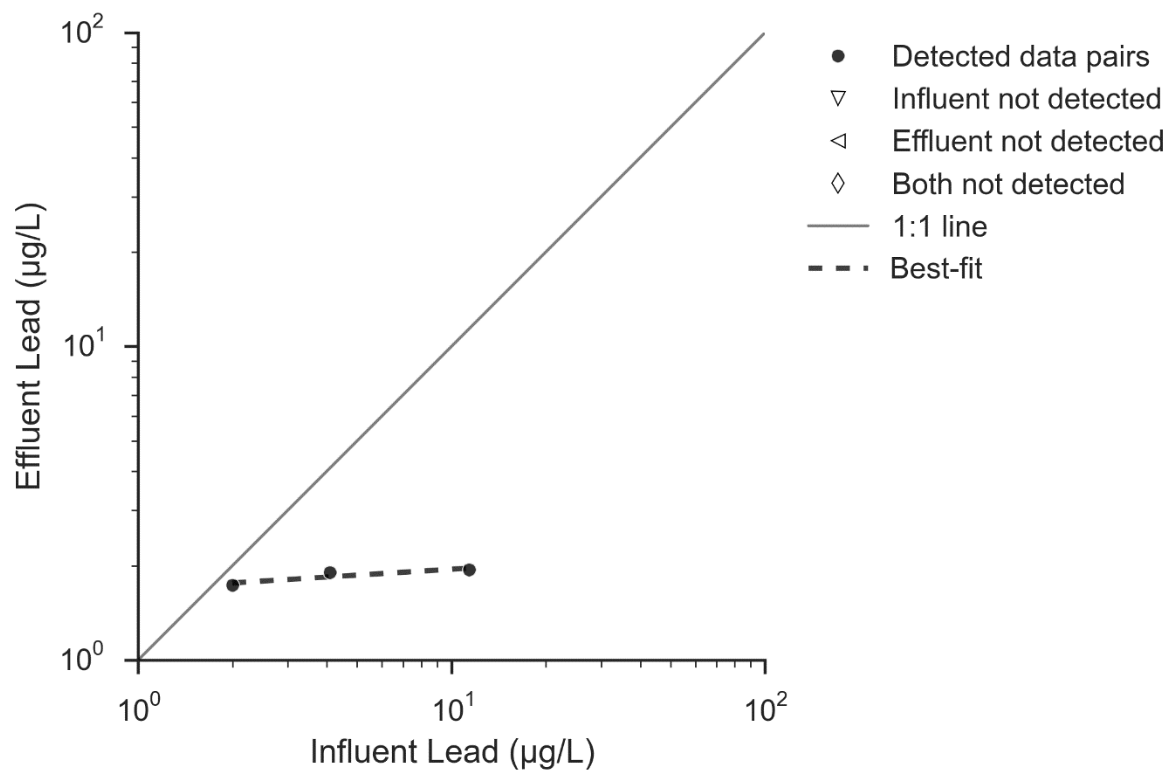


**Figure 49. Paired Lead Concentrations at ELV Stormwater Treatment BMP**

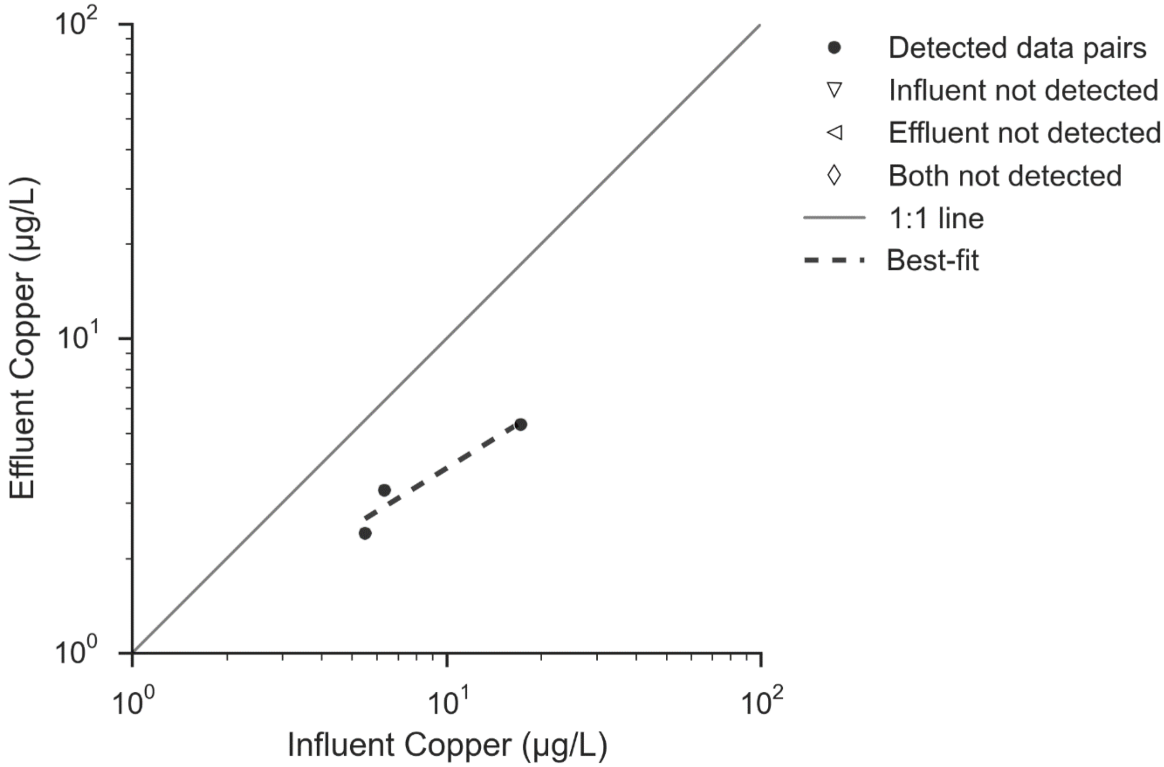


**Figure 50. Paired Copper Concentrations at ELV Stormwater Treatment BMP**

## 4. PROBABILITY PLOTS

Probability plots for CM sites (B-1, CM-9, and CM-1 non-background sites), excluding CM-1 background areas, CM-3, CM-8, and CM-11 (due to the substantial flows that they receive from unimpaired/background areas), are shown in Figures 51 through 54. Probability plots for the Lower Lot Biofilter are shown in Figures 55 through 58, and plots for the ELV stormwater treatment BMP are displayed in Figures 59 through 62. These probability plots are prepared by ranking the available data and calculating their probability of occurrence. These probability values (shown on the vertical axis) are plotted against their concurrent concentrations. While determining the plotting positions, non-detect (ND) data were sorted independently and assigned to the lowest positions, effectively truncating the probability plots at the fraction of non-detected samples. Therefore, only detected results positions are plotted, which leads to the correct probability of occurrence for the observed data, while values less than the detection limit show their unknown specific occurrences. The figures also contain some basic statistics describing the data shown on the graphs. For each influent and effluent dataset, the number of ND results is compared to the total number of results in the dataset and the coefficient of determination ($R^2$), and the significance values resulting from an Anderson-Darling test for normal and lognormal distributions are shown. The coefficient of determination describes how well the (logarithmic) best-fit line fits the data. The Anderson-Darling results represent the confidence level with which one can say how consistent the data are with the examined distributions. For instance, in the case of influent lead at CM locations, one can be 99% confident that the data are consistent with a lognormal probability distribution, but less than 85% (i.e. not confident) that they are consistent with a normal distribution.

Where influent data (blue diamonds) consistently fall to the right of the effluent points (green squares), consistent water quality improvement is occurring at these areas. The horizontal distance between the datasets (noting it is a log scale) also indicates the magnitude of the concentration change at these BMP types.

The relative difference in the amount of scatter observed in these plots indicates that BMP effectiveness may vary depending on the location and constituent. These plots indicate the influent concentrations above which the CMs are most effective (low concentrations are expected to represent concentrations unlikely to be significantly reduced by the BMP).

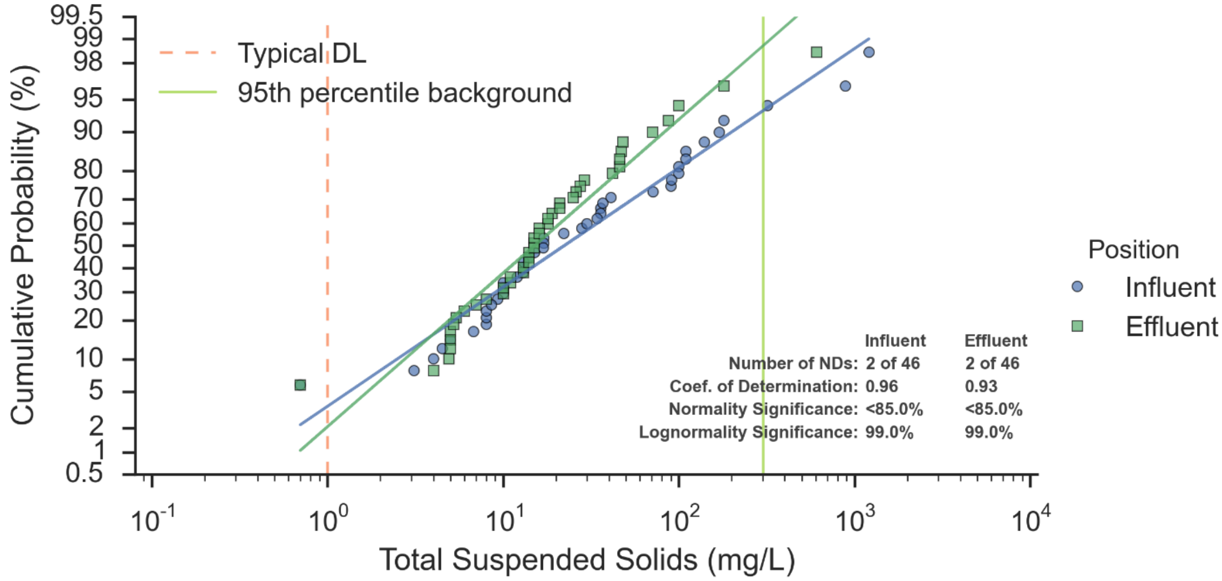


**Figure 51. Probability Plot of TSS at CM Locations**

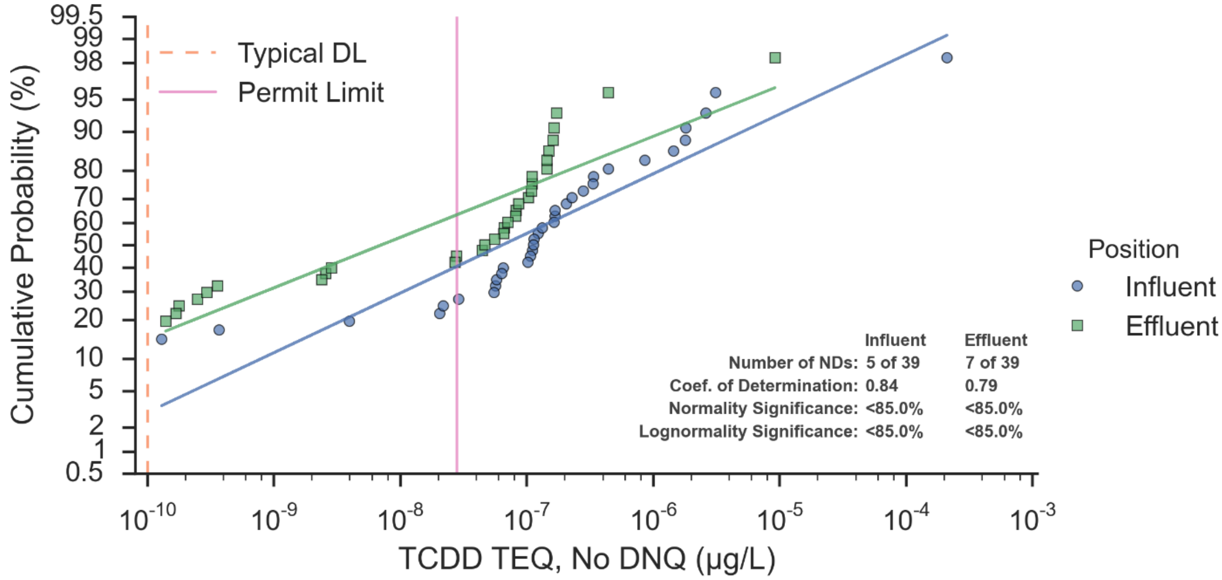


**Figure 52. Probability Plot of Dioxins at CM Locations**

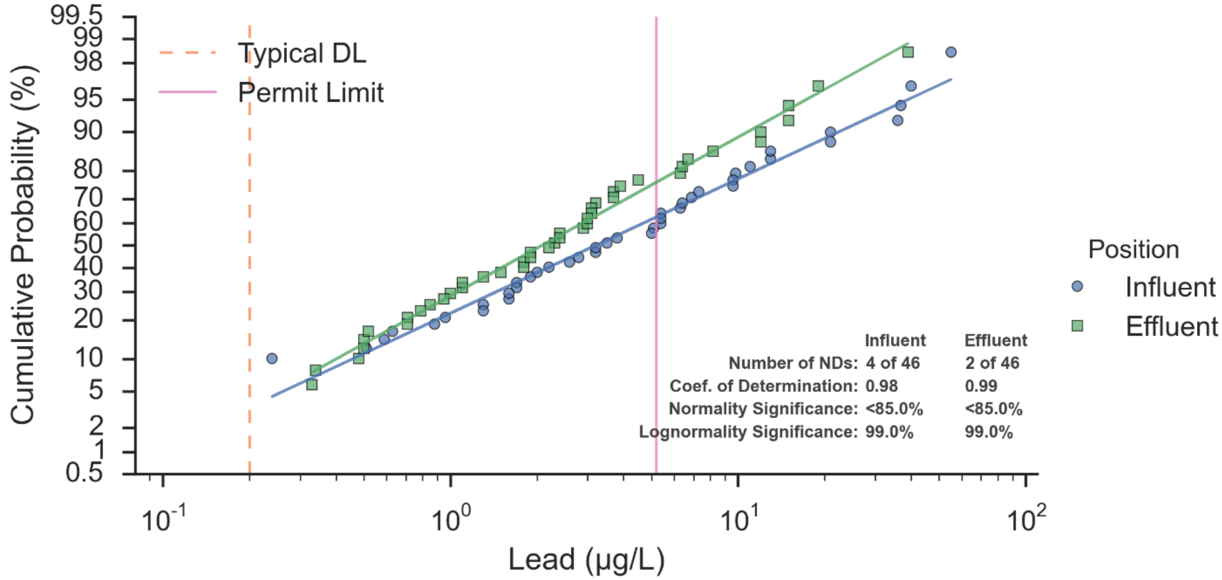


**Figure 53. Probability Plot of Lead at CM Locations**

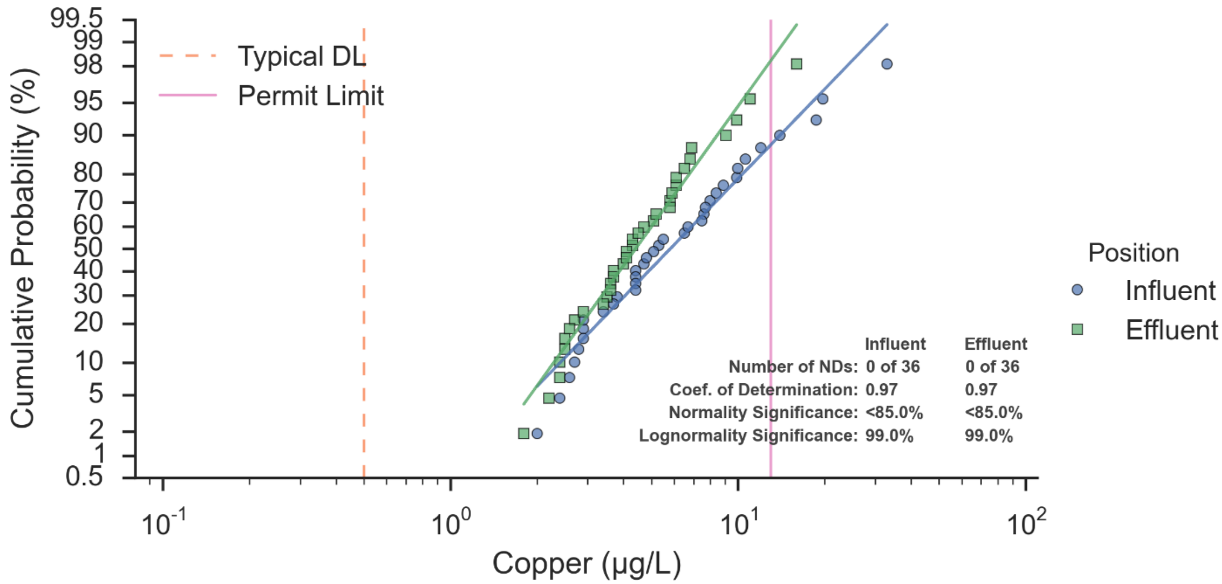


**Figure 54. Probability Plot of Copper at CM Locations**

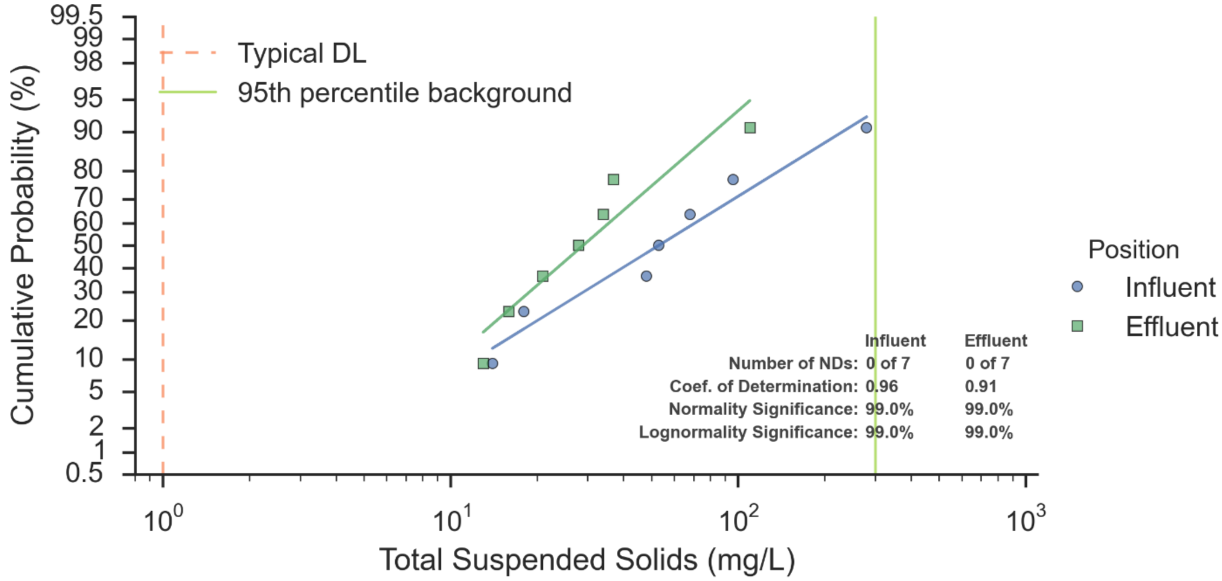


**Figure 55. Probability Plot of TSS at Lower Lot Biofilter**

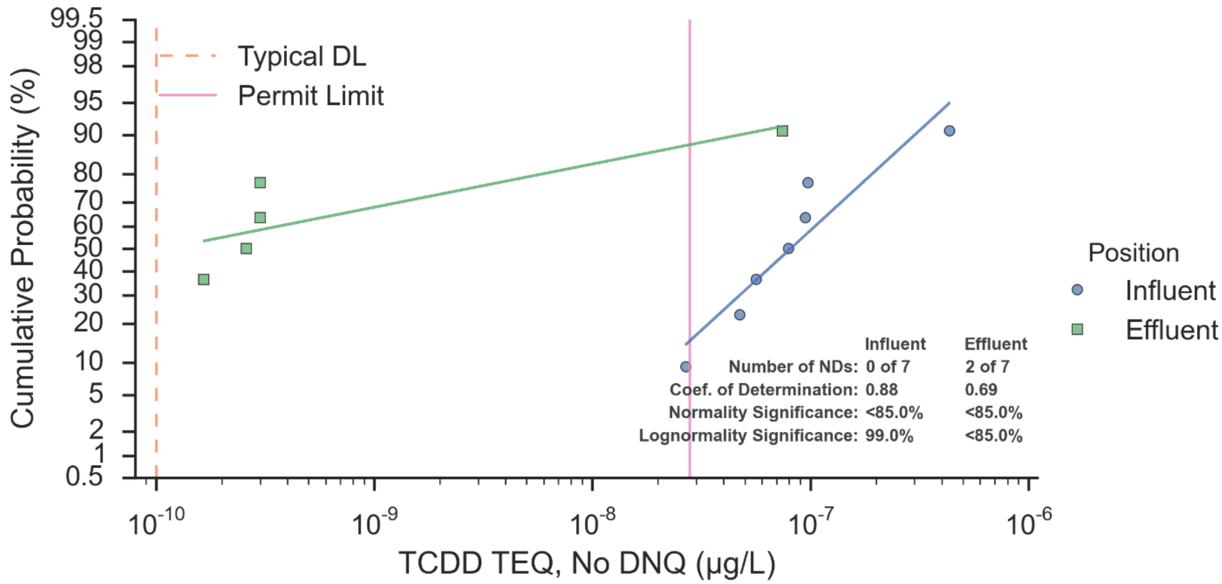


**Figure 56. Probability Plot of Dioxins at Lower Lot Biofilter**

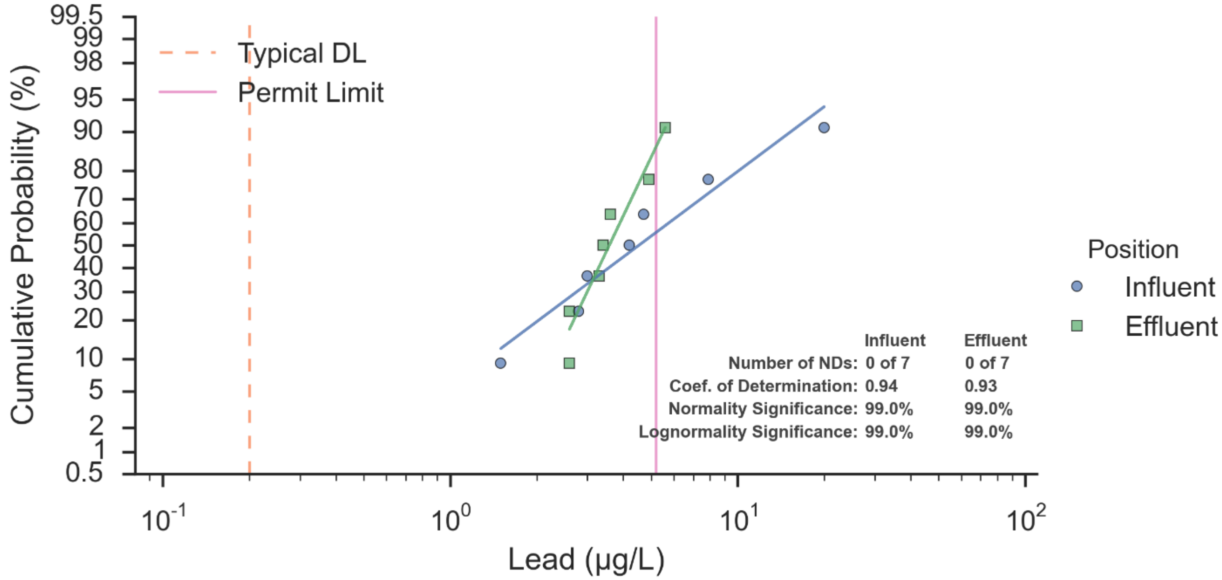


**Figure 57. Probability Plot of Lead at Lower Lot Biofilter**

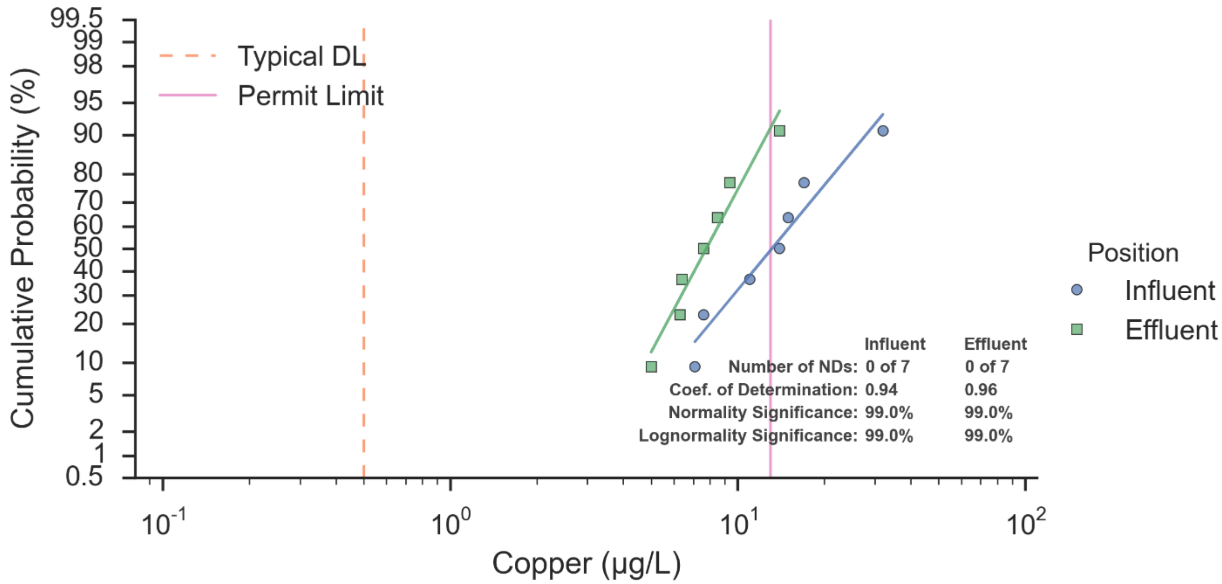


**Figure 58. Probability Plot of Copper at Lower Lot Biofilter**

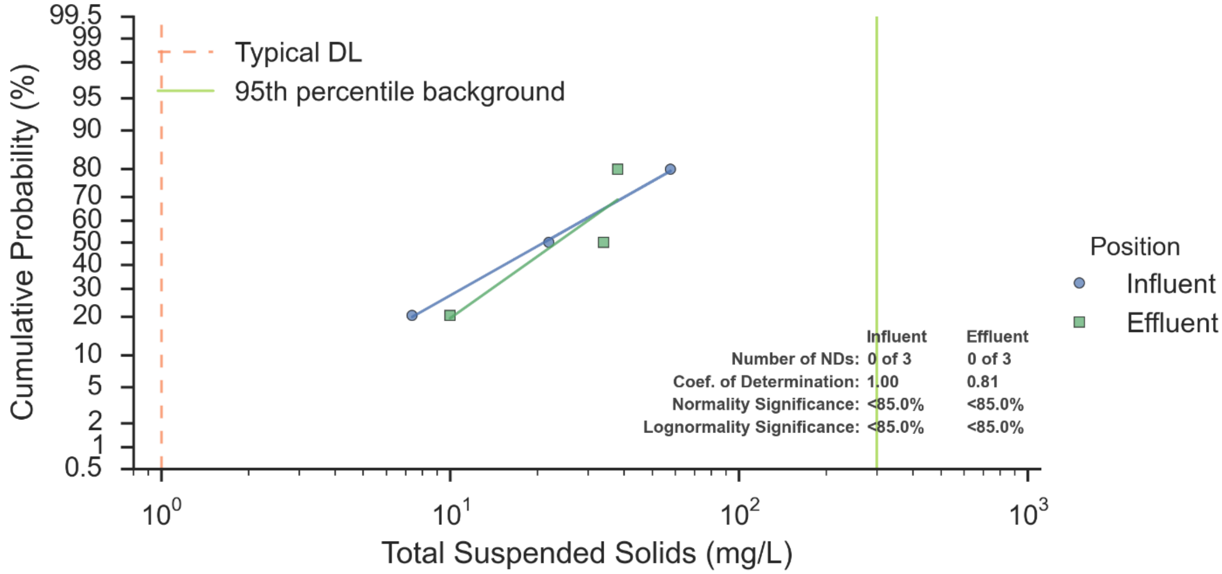


**Figure 59. Probability Plot of TSS at ELV Stormwater Treatment BMP**

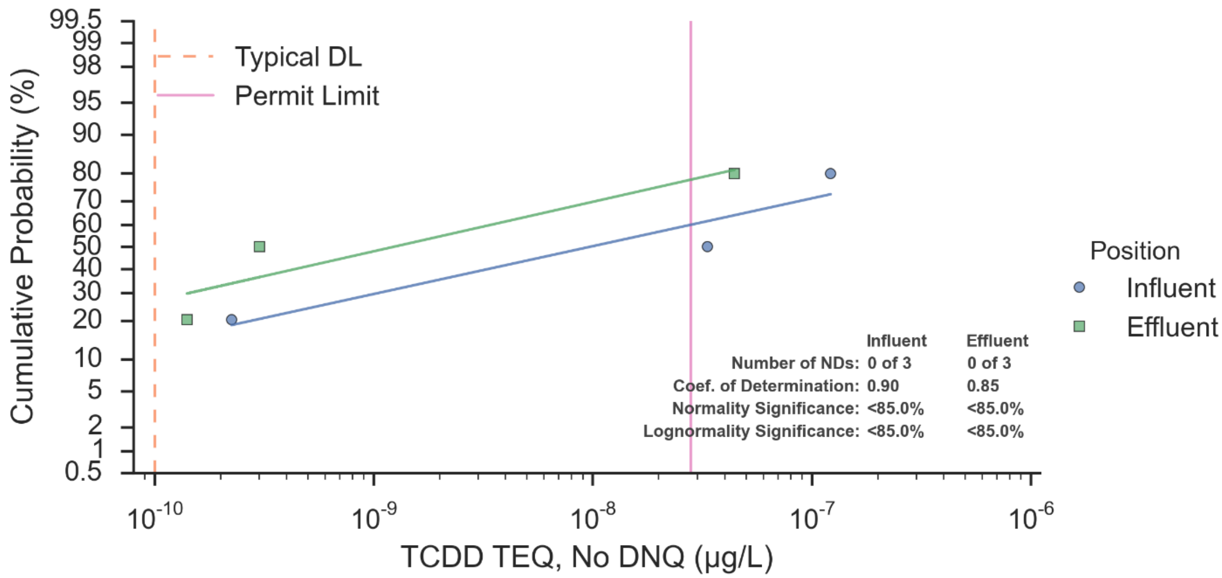


**Figure 60. Probability Plot of Dioxins at ELV Stormwater Treatment BMP**

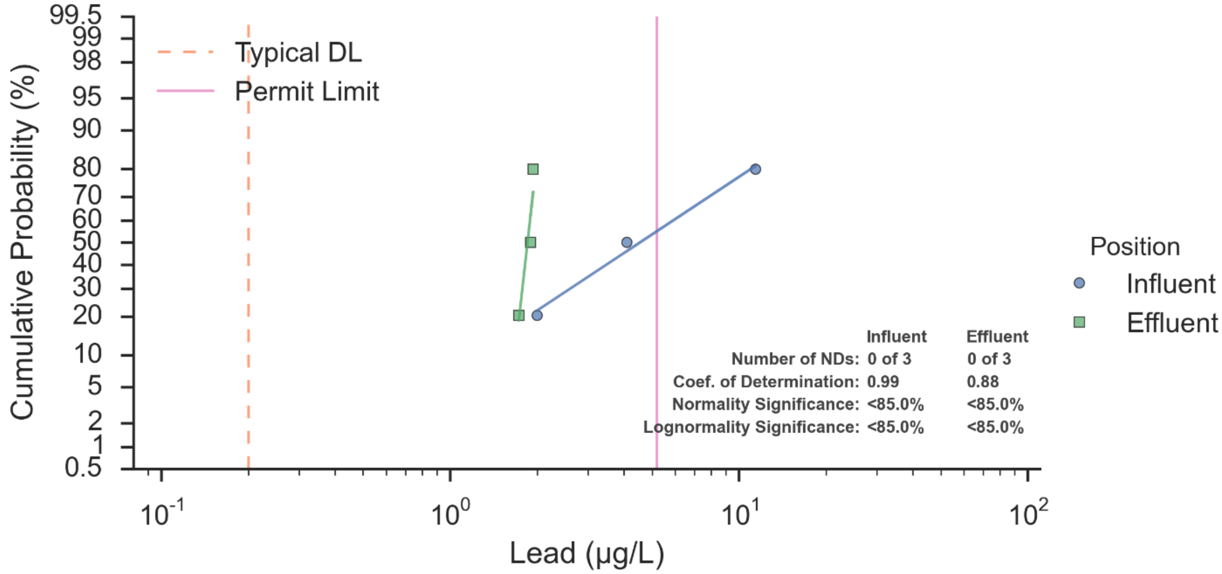


**Figure 61. Probability Plot of Lead at ELV Stormwater Treatment BMP**

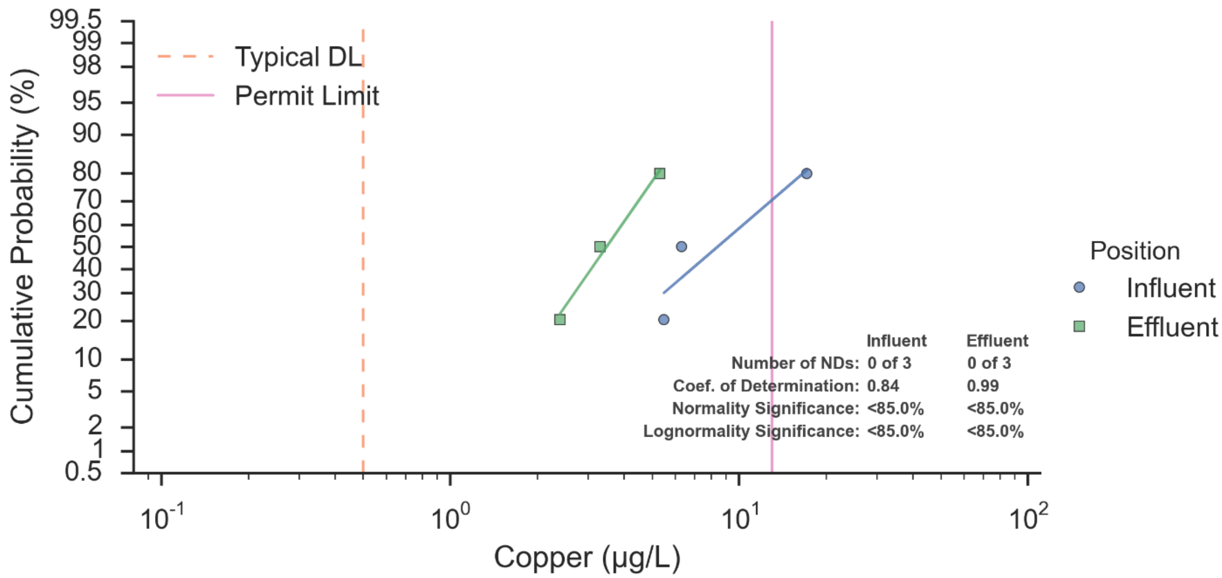


**Figure 62. Probability Plot of Copper at ELV Stormwater Treatment BMP**

The number of results greater than the Permit Limits for each of the influent and effluent samples at B-1, CM-9, and CM-1 are summarized in Table 12. This comparison for Lower Lot Biofilter and the ELV stormwater treatment BMP is shown in Table 13 and Table 14, respectively. For CM sites analyzed, influent concentrations were more often higher than the Outfall 009 Permit Limits as compared to effluent concentrations for copper (three influent samples exceeded and one effluent sample exceeded), lead (19 influent vs. 10 effluent), and dioxins (30 influent vs. 21 effluent). Looking at the maximum and average ratios of concentration to Permit Limit, a higher ratio is calculated for lead influent than lead effluent, suggesting lead reduction through the CMs. Higher ratios for copper influent (2.4 maximum and 1.7 average) compared to copper effluent (1.1 maximum and average) suggest that copper reduction through the CMs is also achieved. This pattern is also true for dioxins in that the influent ratios (7,566 maximum and 271 average) are greater than the effluent ratios (330 max and 20 average). This result is skewed by one effluent result of $9.3x10^{-6}$ ug/L and one exceptionally high influent result of $2.12x10^{-4}$ ug/L. If those results are removed, then the maximum influent ratio drops to 113 and the average becomes 19, while the maximum effluent ratio decreases to 16 and the average drops to 4.3. These results reflect the same general trend of effluent ratios lower than the influent ratios, suggesting that in general dioxins are also reduced in the CMs. These results enhance the weight of evidence, especially when not enough samples are available for statistical tests.

The number of results exceeding the Permit Limits for the influent and effluent samples at the Lower Lot Biofilter are summarized in Table 13. Influent concentrations were more often higher than the Outfall 009 Permit Limits as compared to effluent concentrations for copper (only three influent samples exceeded), lead (two influent vs. one effluent), and dioxins (six influent vs. one effluent). Observation of the maximum and average ratios of concentration to Permit Limit show that a higher ratio is calculated for influent than effluent samples for copper, lead, and dioxins, suggesting reduction in all three pollutants through the Lower Lot Biofilter.

Similar trends are observed for the ELV stormwater treatment BMP, as shown in Table 14. There were a greater number of influent sample concentrations exceeding the Outfall 009 Permit Limits compared to effluent concentrations for copper, lead, and dioxins. Only one influent sample exceeded Permit Limits for copper and lead, while there were two exceedances over limits of influent samples and only one exceedance of effluent samples for dioxins. As observed with the CM sites and Lower Lot Biofilter, higher maximum and average ratios of concentration to Permit Limits were calculated for influent samples compared to effluent samples. This trend suggests reduction in copper, lead, and dioxins through the ELV stormwater treatment BMP.

**Table 12. Influent and Effluent Summary as compared to the Outfall 009 Permit Limits (B-1, CM-9, and CM-1 Non-Background Sites), 2009-2015**

| Parameter | Number Samples Greater than Permit Limits | | Maximum Exceedance Ratio (Result : Permit Limit) | | Average Exceedance Ratio (Result : Permit Limit) | |
|---|---|---|---|---|---|---|
| | Influent | Effluent | Influent | Effluent | Influent | Effluent |
| Copper | 3 | 1 | 2.4 | 1.1 | 1.7 | 1.1 |
| Lead | 19 | 10 | 11 | 7.5 | 3.2 | 2.7 |
| TCDD TEQ no DNQ | 30 | 21 | 7,566 | 330 | 271 | 20 |

**Table 13. Influent and Effluent Summary as compared to the Outfall 009 Permit Limits (Lower Lot Biofilter), 2012-2015**

| Parameter | Number Samples Greater than Permit Limits | | Maximum Exceedance Ratio (Result : Permit Limit) | | Average Exceedance Ratio (Result : Permit Limit) | |
|---|---|---|---|---|---|---|
| | Influent | Effluent | Influent | Effluent | Influent | Effluent |
| Copper | 3 | 0 | 2.3 | 0 | 1.5 | N/A |
| Lead | 2 | 1 | 3.8 | 1.1 | 2.7 | 1.1 |
| TCDD TEQ no DNQ | 6 | 1 | 16 | 2.7 | 4.8 | 2.7 |

**Table 14. Influent and Effluent Summary as compared to the Outfall 009 Permit Limits (ELV Stormwater Treatment BMP), 2013-2015**

| Parameter | Number Samples Greater than Permit Limits | | Maximum Exceedance Ratio (Result : Permit Limit) | | Average Exceedance Ratio (Result : Permit Limit) | |
|---|---|---|---|---|---|---|
| | Influent | Effluent | Influent | Effluent | Influent | Effluent |
| Copper | 1 | 0 | 1.2 | 0 | 1.2 | N/A |
| Lead | 1 | 0 | 2.2 | 0 | 2.2 | N/A |
| TCDD TEQ no DNQ | 2 | 1 | 4.4 | 1.6 | 2.8 | 1.6 |

## 5. DISCUSSION AND OBSERVATIONS

The following general observations were made based on an evaluation of the aforementioned data summary charts and tables.

1. The CMs were originally installed as provisional (pending further evaluation) stormwater controls that could be installed in areas where existing culverts carried the stormwater below the roads. As a result, they handle the wide range of flows during a typical rain year and experience relatively short treatment residence times and the weirs overflow during average to large size storms. However, the performance monitoring results indicate that statistically significant pollutant concentration reductions are occurring at the non-background CMs as a result of their sedimentation and media treatment unit processes. Average pollutant reductions in the non-background CMs (i.e., CM-1, CM-9, and B-1) ranged from 32-95%[9].

2. Cumulative performance monitoring data (as summarized by the statistical analysis tables, correlation charts, and probability plots) indicate that CM, Lower Lot Biofilter, and ELV stormwater treatment BMP effluent concentrations were lower than corresponding influent samples for all COCs evaluated, with statistically significant pollutant removal observed for most COCs for all treatment system types, with the exception of dioxins at the CM background locations (i.e., CM-8 and CM-11, where influent concentrations were likely at levels low enough that they were unlikely to be significantly reduced by the specific BMPs installed).

3. Collectively, the treatment controls are expected to be supporting water quality improvement and NPDES compliance at Outfall 009, where lead and dioxin compliance challenges persist. The only COC-BMP combination to have an average effluent concentration above its Permit Limit was dioxins for the non-background CMs (i.e., 54% of the 39 total paired effluent samples), in contrast to 77% of the 39 total paired influent samples. For lead at the non-background CMs, 41% of the 46 total paired influent samples were above the Permit Limit, and 22% of the 46 total paired effluent samples were above the Permit Limit. Average paired influent concentrations to these treatment controls were 2.3 and 12.5[10] times higher than average Outfall 009 concentrations for lead and dioxins, respectively, during this same time period, suggesting that the treatment control drainage areas are pollutant generating source areas that, without treatment, would have worsened water quality at the downstream NPDES compliance location. This is further supported by the BMP Ranking Analysis (Appendix F to the 2014/2015 Annual Report), which ranks Outfalls 008 and 009 lower based on their multi-pollutant score (a score intended to indicate "quality" of runoff sampled; a lower rank indicates better runoff quality), than many of the potential source areas (Outfalls 008 and 009 were ranked 68 and 69, respectively, out of a maximum score of 75.5).

[9] As described in observation #2, the high value of 95% (for dioxins) was heavily influenced by two data pairs. If these pairs are removed, the range will instead be 32-82%.
[10] This ratio excludes two influent results also excluded from prior analyses due to anomalies: 1) A2SW0001 on 10/6/2010 (1.81E-6 ug/L), and 2) B1BMP0004 on 12/2/2014 (4.00E-4 ug/L).

4. Data collected to date at the Lower Lot Biofilter showed net TSS, dioxins, copper, and lead reductions of 55%, 91%, 45%, and 41%, respectively, for the seven monitoring events available since completion of the biofilter; these reductions likely underestimate the actual reduction through the biofilter since the 2013/14 effluent sample was taken during overflow, so it reflects a blend of treated and untreated flows. Data collected during the most recent rainy season at the biofilter showed net TSS, dioxins, copper, and lead reductions of 59%, 100%, 43%, and 46%, respectively, exhibiting apparent net reductions that are slightly higher (with the exception of copper) as compared to previous monitoring seasons This improvement is likely attributable to the recently constructed B1436 detention bioswales, which as of December 2014, slow and treat a portion of the drainage area which would have previously flowed to the Lower Lot Biofilter. It is estimated that the average volume pumped to the biofilter has increased from 52,000 gallons per inch of rainfall to 82,000 gallons per inch of rainfall since the detention bioswales were constructed. Similarly, the estimated percent of total runoff volume (from both the 24-inch drain and the lower lot drainage areas) has increased from 22% to 44% on average since the detention bioswales were constructed.

5. Limited runoff occurred at Outfall 008 during the 2014/15 monitoring period, as only one sample was collected at Outfall 008 during the December 11-12, 2014 rain event (total rainfall = 2.62 inches; average intensity unavailable due to weather station malfunction). No exceedances in the Permit Limits during this event were measured, suggesting positive performance of the new erosion and sediment controls that were installed in 2012 in the Outfall 008 watershed. It should be noted that approximately 1.4% of the rainfall resulted in runoff at Outfall 008 during this event, indicating that this watershed is either highly infiltrative, highly depressed, or both.

# 6. RECOMMENDATIONS

1. Based on evaluation of CM performance, the Panel recommends there be continued inspection and maintenance including the following:

    - Inspection after large storms and at the start of the rainy season, removal of accumulated sediment and debris in ponded footprints above the weir boards (particularly when accumulation depth exceeds 10% of weir board height);

    - Inspection of underdrain flows during storms to ensure water is still flowing effectively through media beds;

    - Replacement of filter fabric when they are damaged or non-functioning;

    - Collection of field notes during sampling to note whether weir board overflow is occurring, etc.

    Furthermore, the Panel will continue to provide specific improvement recommendations for CM areas during current and future monitoring periods, if warranted and likely to be effective.

2. If media clogging or media failure is a concern during field inspections and during sample collection, video inspections would be useful in order to inspect underdrains for signs of clogging, material movement into the pipe, or a cracked pipe. The Panel recommends doing video inspections while the system is dry, and then again after water is introduced upstream of the weir boards in a controlled manner, such as from a water truck. In the "water" inspection, it would be helpful to determine the drainage rate of the ponded water (check to see if ponded more than a day after the rain ended).

3. The Panel recommends continued monitoring at all non-background BMP performance monitoring sites (CM-1, CM-9, ELV stormwater treatment BMP, the Lower Lot Biofilter, the newly constructed B1436 detention bioswales, and B-1) in order to confirm continued stormwater quality improvement as upstream controls are added and re-vegetation continues.