Monitoring water quality of urban stormwater runoff to receiving river systems in Dayton, Ohio: assessment of MS4 drainage areas

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Overview

The City of Dayton is responsible for effective management of urban portions of the Great Miami River, Mad River and Wolf Creek water quality through regular assessments of storm water outfalls to meet Ohio Environmental Protection Agency (OEPA) permit requirements for the National Pollutant Discharge Elimination System (NPDES). This includes the identification of water quality stressors, degradation, and improvements related to City of Dayton MS4 outfalls. The objective of this study conduct stormwater monitoring that will help the City meet NPDES permit EPA requirements. In particular, this project focused on measuring chemical features of the water system in relation to a series of outfall located in various locations throughout the City of Dayton. Sites were chosen in cooperation with members of the Division of Environmental Management with the goals to (a) meet the reporting needs of the city and (b) represent a range of conditions present in the city.

One further goal, or long-term focus, is to create the ability for the city to measure the efficacy of various Best Management Practices to influence water quality outcomes, as measured by effects on outfall water chemistry and biological parameters. For the first time, this year our scientific efforts were integrated with an outreach program associated with the University of Dayton River's Institute. See accompanying report on community outreach efforts to learn more about these activities.

Materials and Methods

Sampling design

All sampling efforts focused on determining contributions of selected water quality parameters from the outfalls (MS4s). We sampled in both wet and dry weather. A series of three MS4s were selected to sample. Wet-weather sampling was defined as rainfall > 0.1", and preceded by 3 d of dry weather. Each outfall was sampled within 2 h of first runoff. Sites were selected based on the presence of outfalls (MS4s) and all sampling sites were located river left (L). There were three sites on the Great Miami River (GML-27, GML-33, GML-76), two sites along the Mad River (MRL-01, MRL-02), and one on Stillwater River (SWR-08) (Table 1). All sites are located in Aggregate Ecoregion VI, and within the subecoregion 55 Eastern Corn Belt Plains (USEPA 2000).

Water sampling

At each location, sampling was established to characterize chemical conditions in each MS4 and determine if outfalls were contributing to degraded water quality. The results of our chemical sampling are presented henceforth. At each site, any water bottles, without preservative, were rinsed with site water three times prior to being filled. When practical, water samples were collected below the surface, and filled with little to no headspace. Nutrient samples (TKN, NO_3, and NH_3) were preserved with H_2SO_4 to a pH ~2, Orthophosphate samples were filtered through 0.45 µm in the lab within 1 hr of collection. *E. coli*, fecal coliforms, chlorine, and orthophosphate all had short hold times, and were transported to Pace Analytical (Englewood, Ohio) in a timely manner. All samples with short hold time were analyzed within the appropriate hold times, with the exception of chlorine and fecal coliforms. Chlorine has a 15 min hold time, and this parameter exceeded the hold time. A sample of water was brought back to the laboratory to measure Temperature, DO, specific conductivity, pH, and TDS for all sites. All samples were stored on ice in the field, and transported to the lab and any samples (TSS, hardness, and alkalinity) that were held at UD, and stored at 4°C until analysis. Pace Analytical provided all analytical methods and their original reports are attached below. Prior to samples being collected, clean glassware protocols were followed in the lab. All plastic bottles were washed with laboratory grade soap, acid washed (10% HCl), and rinsed 3x with deionized water (DI).

Results and Discussion

Nitrate-Nitrite (NO_3-NO_2)

All MS4 sites experienced measurable loadings of nitrates-nitrites (Figure 1). The outfall GMR 13 had the highest concentrations of NO_3-NO_2, both upstream and downstream were > 2.5 mg/L. The lowest concentrations were <0.5 mg/L. During the wet weather events in 2015 (Custer et al. 2015), NO_3 for GML-33 ranged from 0.3 – 1.0 mg/L and MRL-02 from 0.3 – 0.6 mg/L. We did not find evidence of variation upstream vs. downstream in this parameter (Figure 1).

Total Nitrogen

Total Nitrogen (TN) was below detectable limits (which show up as an absence of a bar in the figures) in 7 of the samples (Figure 2). The USEPA (2000) has proposed TN criteria for Ecoregion VI of 2.18 mg/L TN, and this represents the 25th percentile measured throughout the Eastern Corn Belt Plains. Urban runoff has been shown to contribute Nitrogen and other nutrients to the rivers and streams (Burton and Pitt 2002). As calculated, the TN concentrations at all of the outfalls sampled in this study were below the proposed USEPA concentration of 2.18 mg/L TN except for GMR 17 sample that was taken directly from in front of the outfall (indicated by ".O") where the level was > 3 (Figure 2). The outfalls are contributing TN to receiving waters; however, there would be a dilution effect outside of the mixing zone.

Biochemical Oxygen Demand (BOD)

Stormwater runoff in urban areas can have low dissolved oxygen concentrations (Burton and Pitt 2002). Dissolved oxygen concentrations are vital to the survival of aquatic biota, and numerical criteria has been established by the Ohio EPA (Rule 3745-1-07 of Ohio Administrative Code). The 5-day biochemical oxygen demand (BOD5) test determines how much oxygen is consumed by bacteria during the breakdown of organic matter in surface water (Delzer and McKenzie 2004). For many of the outfalls BOD was below detectable levels indicating good conditions for aquatic organisms (Figure 3). Dissolved oxygen concentrations in two of the samples (GMR 17D and GMR 17.O) were > 8.7 mg/L, and these concentrations exceed the criteria to support aquatic life (Rule 3745-1-07 of Ohio Administrative Code) (Figure 3). These results suggest there is a bacterial demand on oxygen at this outfall.

Total Phosphorus (TP) and Reactive Phosphorus (Orthophosphate)

Reactive orthophosphate concentrations were below detection limit for all six MS4 sites during the dry weather sampling on 1-Aug-2017; however, values were recorded in all of the wet weather outfalls except for GMR 17D. Total phosphorus (TP) concentrations were > 0.1 mg/L at GML-10 and GMR 13 for the dry weather sampling and for all of the outfalls except for GMR 17D for the wet weather sampling (Figure 4). These results suggest that these selected MS4 sites are contributing TP to receiving waters. A few states in the US have developed statewide nutrient criteria for TP in rivers and streams. The US EPA states that development of statewide nutrient criteria is progressing, and provides a website to track the progress of nutrient criteria development (https://www.epa.gov/nutrient-policy-data/state-progress-toward-developing-numeric-nutrient-water-quality-criteria). To our knowledge, Ohio has not yet developed river and stream nutrient criteria, and work is ongoing. For comparison purposes, Minnesota has established 0.05 – 0.1 mg/L for rivers, and Wisconsin has established 0.1 mg/L; however, other states on this list vary widely in their established nutrient criteria.

Escherichia coli and Fecal Coliforms

Escherichia coli and fecal coliforms are important parameters for protecting human health through criteria for human contact to water (USEPA 2012). *Escherichia coli* is the fecal indicator bacteria (FIB) for freshwater systems, and the preferred measure of bacterial contamination (USEPA 2012). The OEPA has recently revised the bacteria criteria to include *E. coli*, and have proposed to remove fecal coliform criteria (Rule 3745-1-07 of Ohio Administrative Code).

Fecal coliforms showed some growth in all samples collected except for GMR 17 in the outfall ("O) (Figure 5). GML-10 showed the highest bacterial colonies/100 mL with > 20000. *Escherichia coli* is the preferred FIB for bacteria contamination in freshwater systems. *Escherichia coli* colony growth was high in the wet weather samples of GML-10 and GML - 17 (Figure 6). *Escherichia coli* colony estimates were >2000 MPN/100 mL. Burton and Pitt (2001) state the fecal coliform levels can be very high during stormwater runoff events, and that fecal coliforms are not good predictors of pathogen levels. At all of the MS4 sites in the 2017 study, *E. coli* levels are likely contributing some increased pathogen levels to the respective receiving waters.

Specific Conductivity

The USEPA (2011) has recently established aquatic life benchmark criteria for specific conductivity. The USEPA (2011) defines specific conductivity as a measure of salinity, with several cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), and anions ($SO2^{4-}$, $CO3^{2-}$ Cl^{-}, and HCO^{-}) contributing to salinity in streams and rivers. Specific conductivity values were > 200 µS/cm for all but one of the samples (Figure 7). GMR-17 had the highest specific conductivity value of 893 µS/cm (Figure 7).

Total Ammonia (NH_3-N)

In this study, ammonia concentrations at all of the MS4s were below detection limit except for GMR-17 during the wet weather event. This contrasts the previous studies by Custer et al. (2015) and Benbow et al. (2012) where ammonia was being deposited. These data suggests that ammonia was low at most of the MS4s during the 2017 sampling.

Free cyanide

In the current 2017 study, all free cyanide concentrations at all of the MS4s were below detection limit.

Oil and Grease

In the current 2017 study, all oil and grease concentrations at all of the MS4s were below detection limit.

Chlorine

In the current 2017 study, all free chlorine concentrations at all of the MS4s were below detection limit. This data might have been affected by the hold time exceeded. This data has a short hold time (15 min), and for logistical purposes, the samples could not be transported and analyzed by Pace Analytical within this 15 min period.

Acknowledgements

We would like thank Taylor Buskey, Sean Mahoney, Meg Maloney, Joseph Murphy, Mitchell Kukla, Corey Kuminecz, and Dr. Albert Burky for all their help and support on this project. We also thank the staff at the City of Dayton - Division of Environmental Management and in the Department of Biology at the University of Dayton. Funding for this project was provided by the City of Dayton - Department of Water, Division of Environmental Management.

Main Figures

Figure 1. Nitrate-Nitrite at all outfall sampled, prior to the dash line was sampled on 1-Aug-17 during dry weather, after the dash line was sampled on 23-Oct-17 during wet weather.

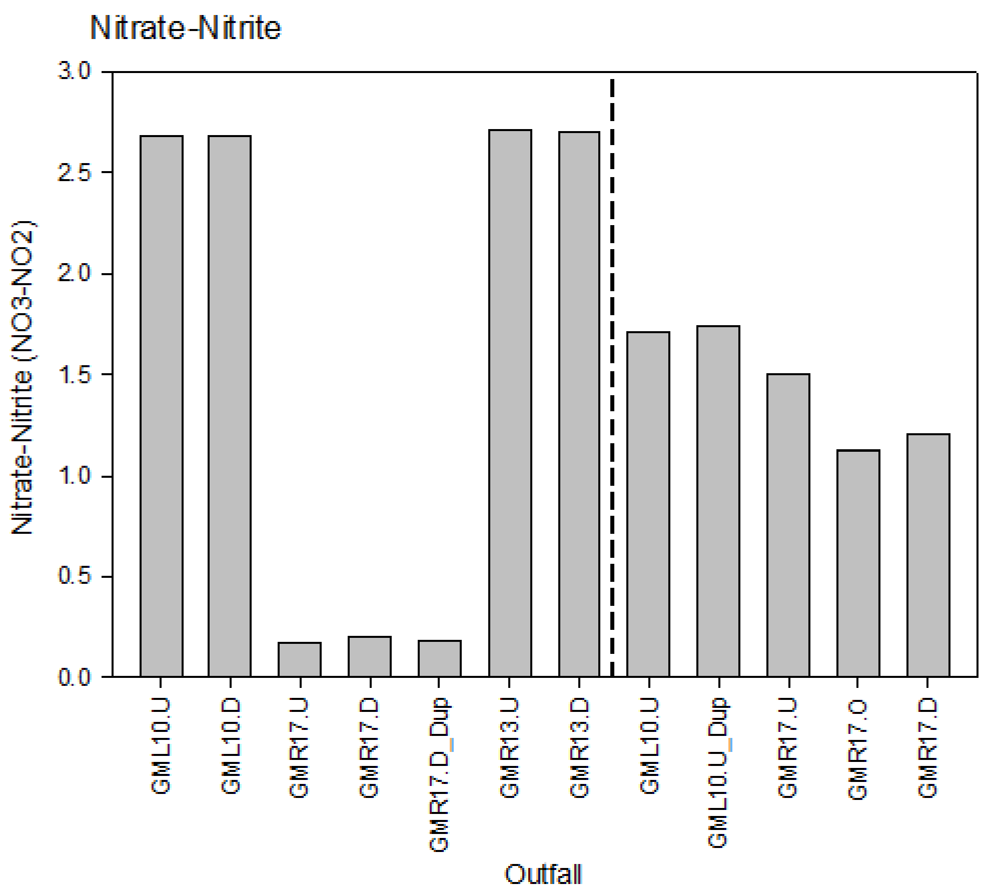


Figure 2. Total Nitrogen at all outfall sampled, prior to the dash line was sampled on 1-Aug-17 during dry weather, after the dash line was sampled on 23-Oct-17 during wet weather.

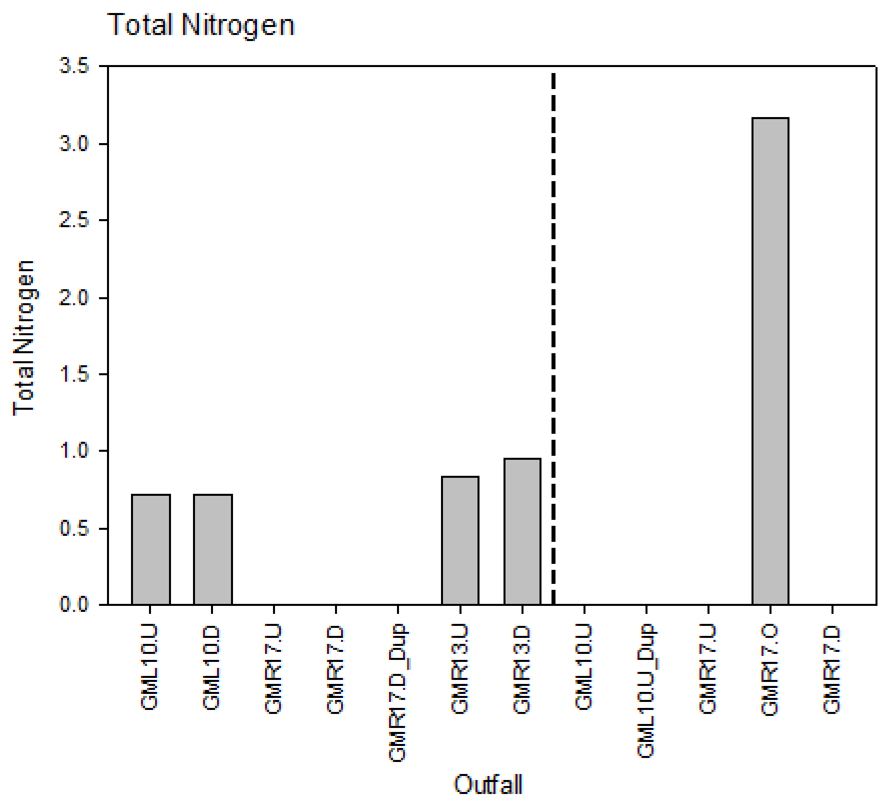


Figure 3. Biological oxygen demand at all outfall sampled, prior to the dash line was sampled on 1-Aug-17 during dry weather, after the dash line was sampled on 23-Oct-17 during wet weather.

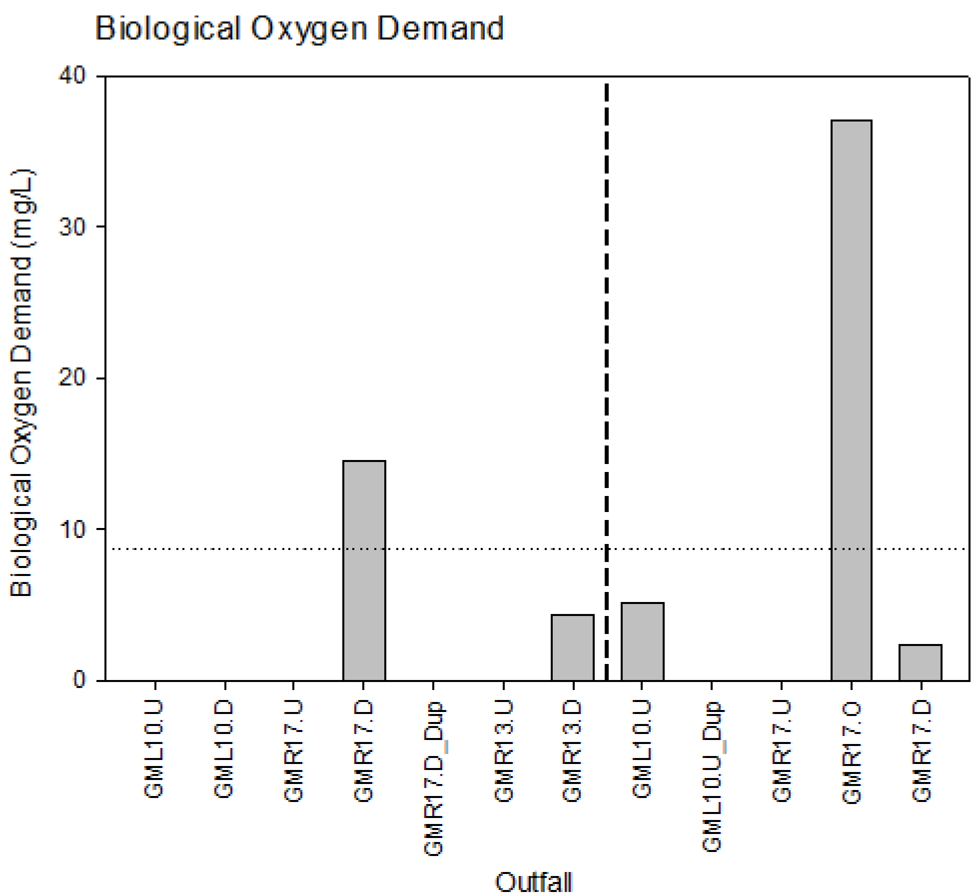


Figure 4. Phosphorus at all outfall sampled, prior to the dash line was sampled on 1-Aug-17 during dry weather, after the dash line was sampled on 23-Oct-17 during wet weather.

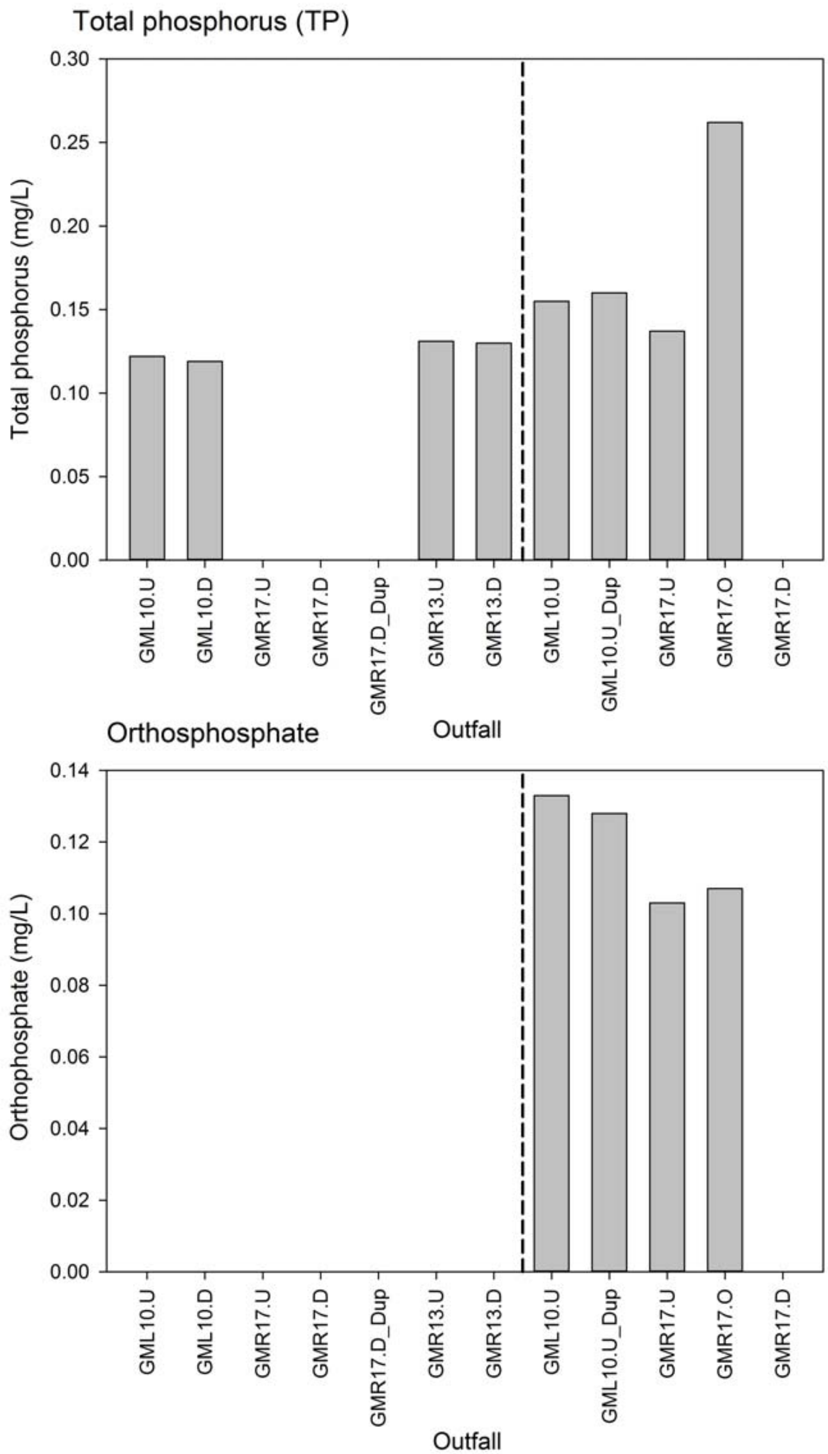


Figure 5. Fecal coliform at all outfall sampled, prior to the dash line was sampled on 1-Aug-17 during dry weather, after the dash line was sampled on 23-Oct-17 during wet weather.

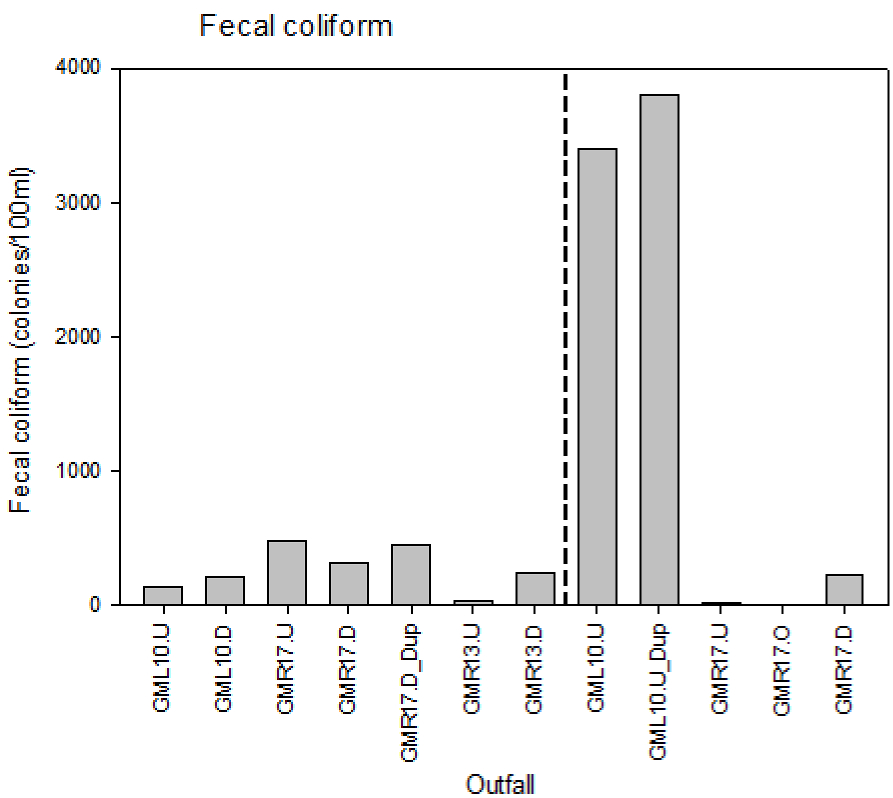


Figure 6. Fecal coliform at all outfall sampled, prior to the dash line was sampled on 1-Aug-17 during dry weather, after the dash line was sampled on 23-Oct-17 during wet weather.

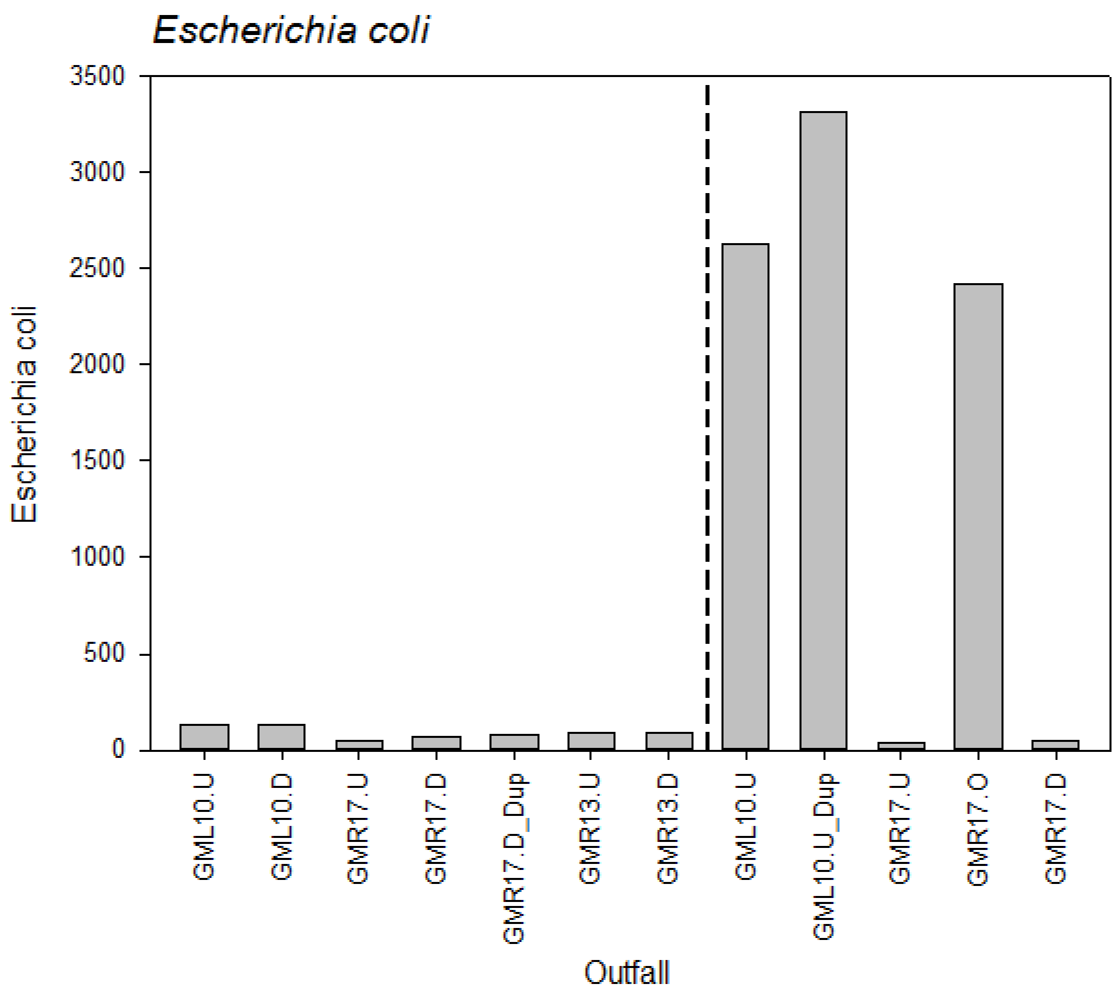


Figure 7. Conductivity at all outfall sampled, prior to the dash line was sampled on 1-Aug-17 during dry weather, after the dash line was sampled on 23-Oct-17 during wet weather.

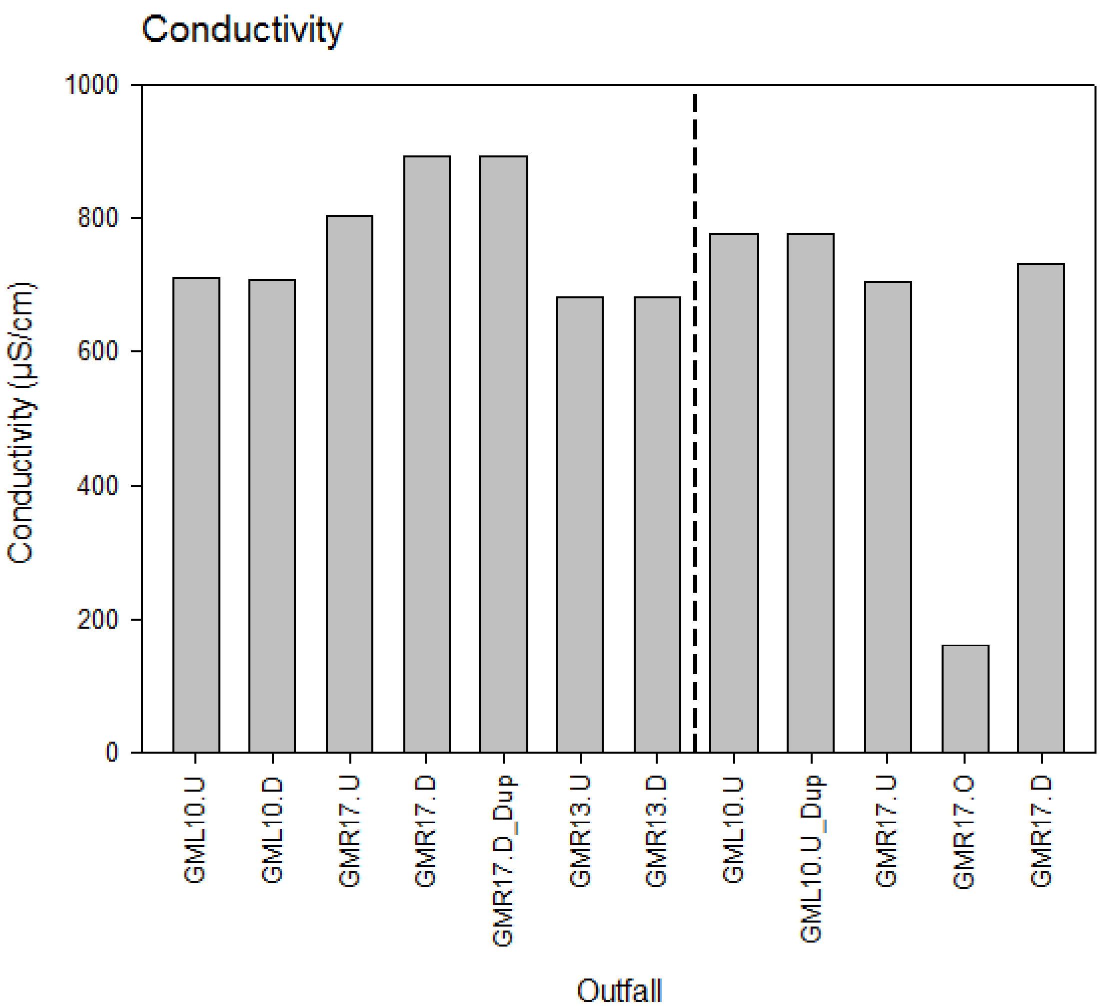
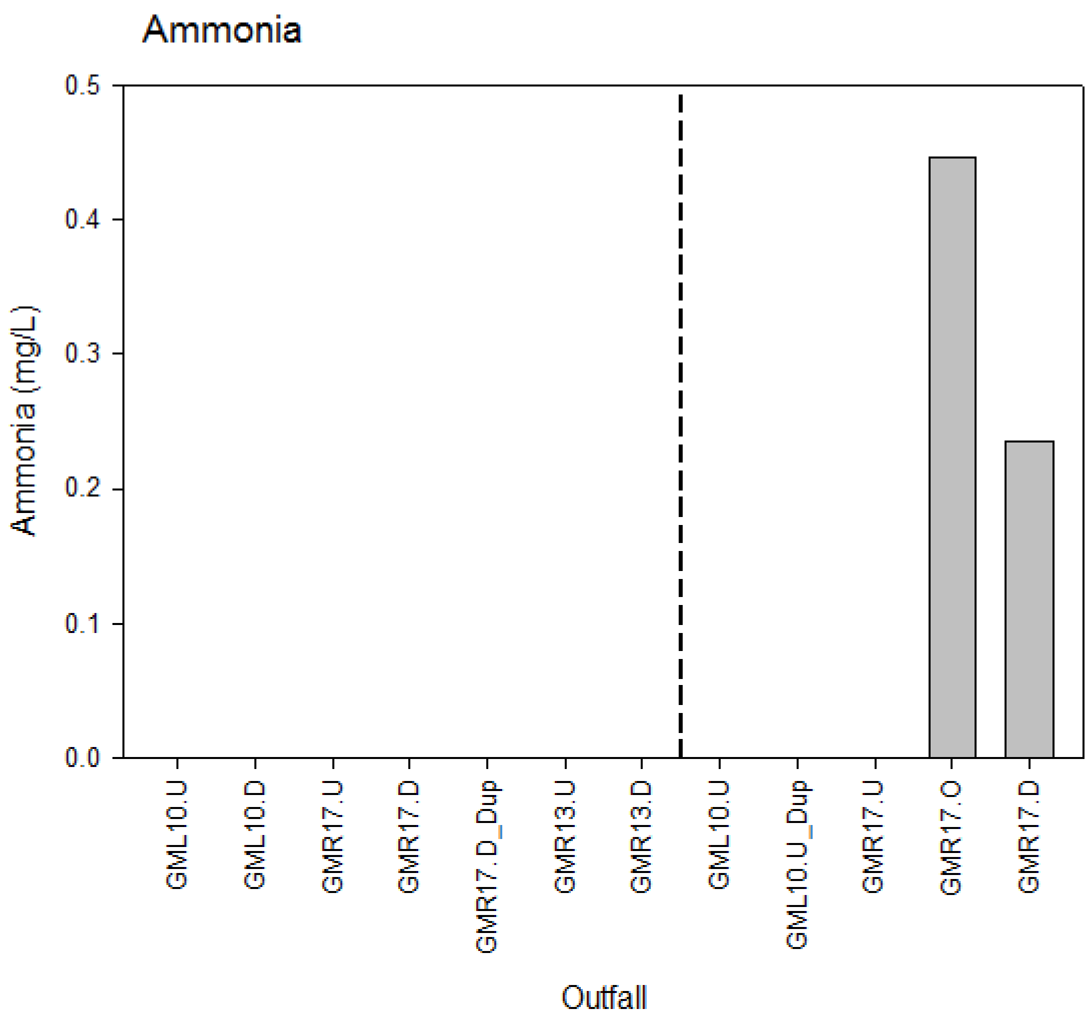


Figure 8. Water temperature at all outfall sampled, prior to the dash line was sampled on 1-Aug-17 during dry weather, after the dash line was sampled on 23-Oct-17 during wet weather.



Supplementary Figures

Figure s1. Water temperature at all outfall sampled, prior to the dash line was sampled on 1-Aug-17 during dry weather, after the dash line was sampled on 23-Oct-17 during wet weather.

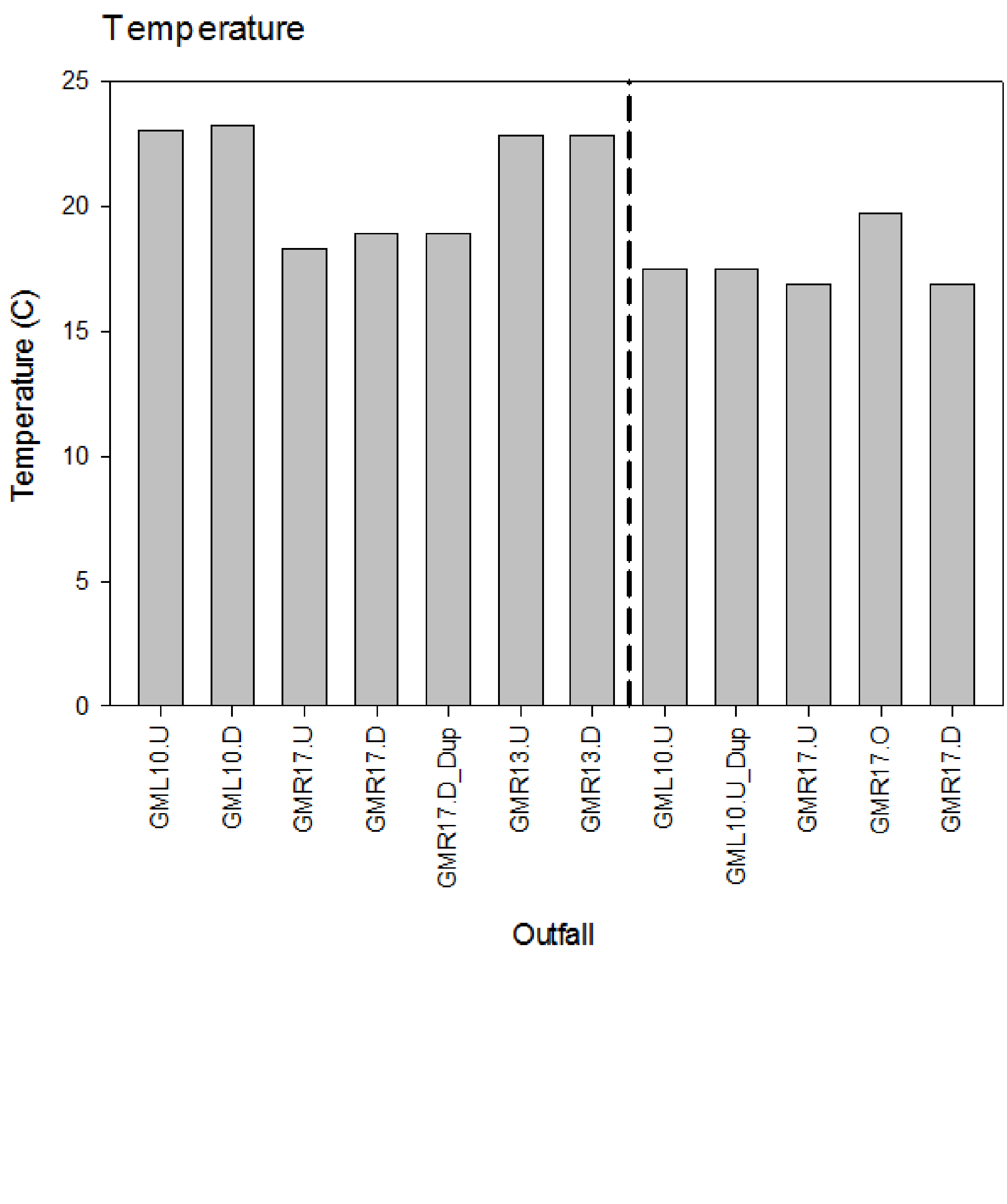


Figure s2. Dissolved Oxygen at all outfall sampled, prior to the dash line was sampled on 1-Aug-17 during dry weather, after the dash line was sampled on 23-Oct-17 during wet weather.

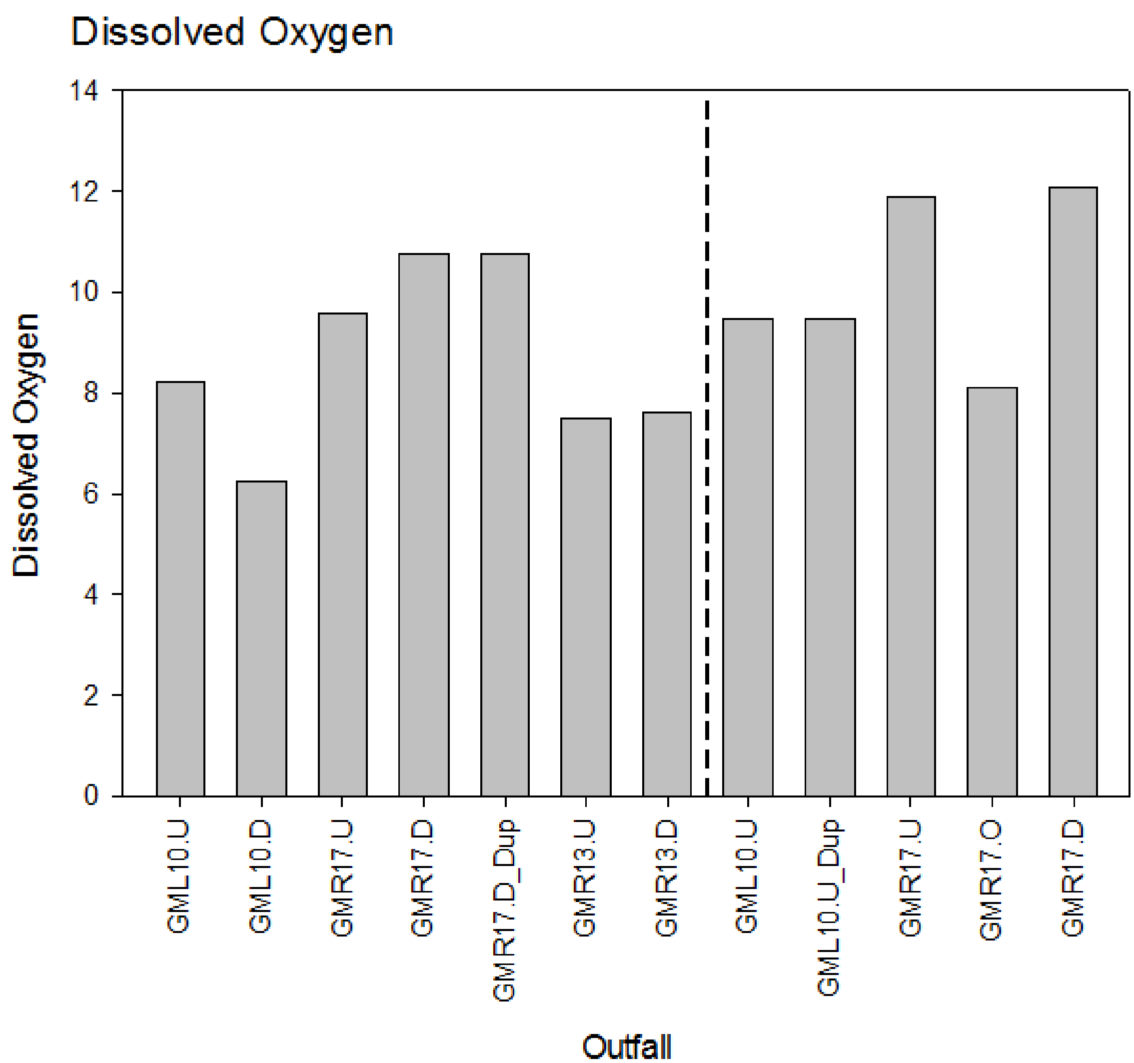


Figure s3. Total Dissolved Solids at all outfall sampled, prior to the dash line was sampled on 1-Aug-17 during dry weather, after the dash line was sampled on 23-Oct-17 during wet weather.

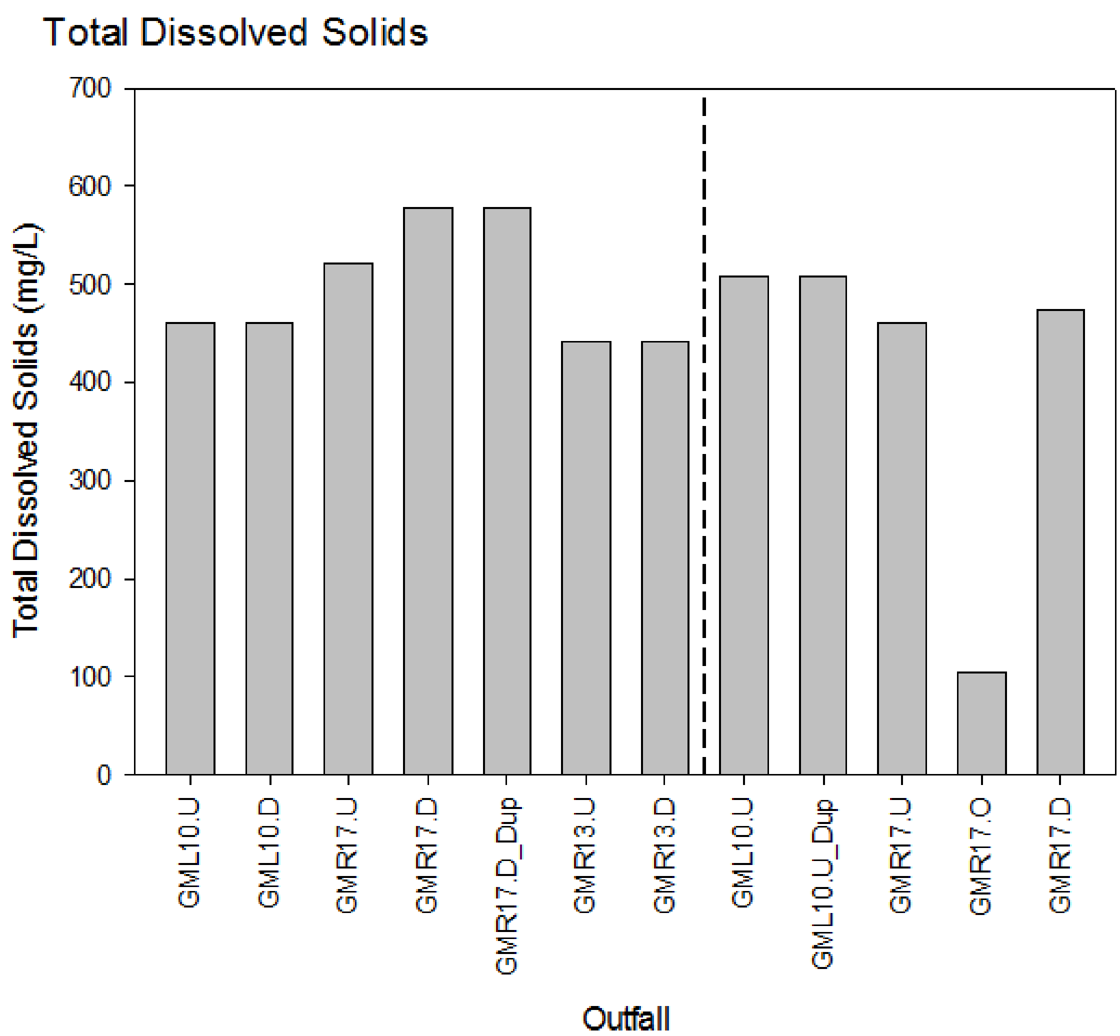
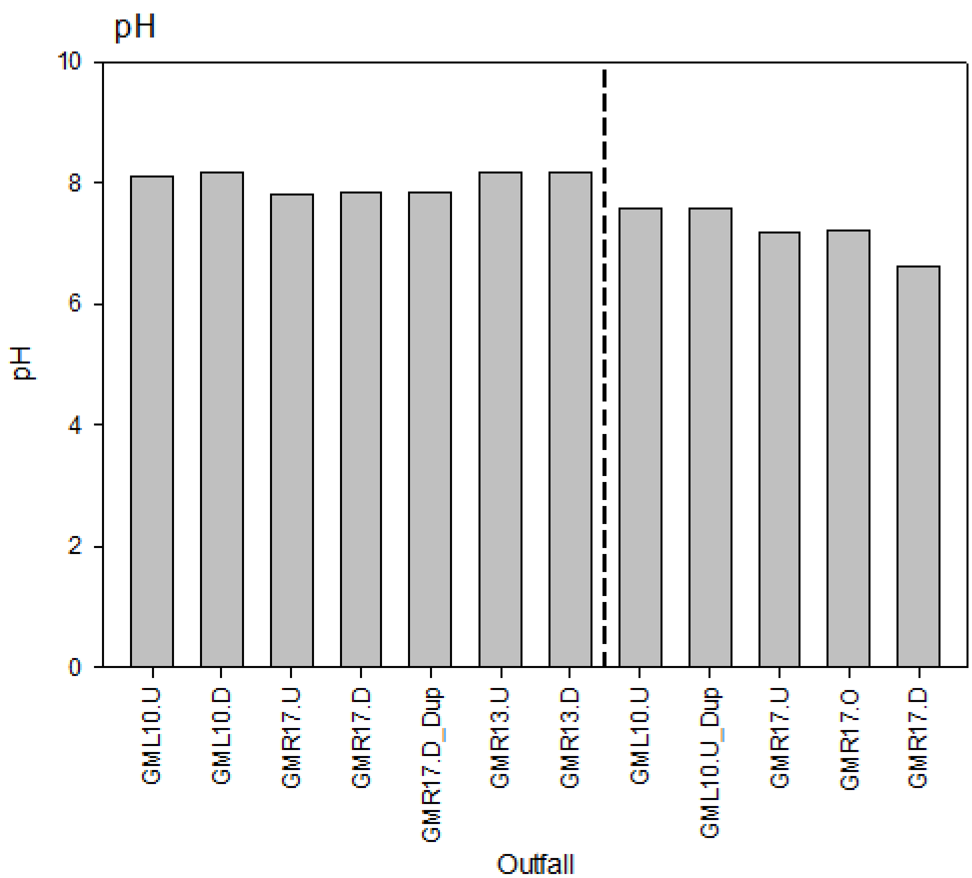


Figure s4. Total Dissolved Solids at all outfall sampled, prior to the dash line was sampled on 1-Aug-17 during dry weather, after the dash line was sampled on 23-Oct-17 during wet weather.



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