Green Infrastructure Practices at the Ghirardi Family WaterSmart Park

Compiled by the

Texas Community Watershed Partners

A program of the Texas A&M AgriLife Extension Service

PREPARED IN COOPERATION WITH THE
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND
U.S. ENVIRONMENTAL PROTECTION AGENCY

Introduction

In suburban communities, much of the land is covered by impervious surfaces including buildings, pavement and compacted landscapes. All of these impact stormwater drainage systems and increase runoff volume and velocity from rain storms. This runoff often carries pollutants including: sediment; oil, grease and toxic chemicals from motor vehicles; pesticides and nutrients from lawns and gardens; viruses, bacteria and nutrients from pet waste and failing septic systems; heavy metals from roof shingles, motor vehicles and other sources. These pollutants, often referred to as nonpoint source pollution (NPS), can harm fish and wildlife, kill native vegetation, and make recreational areas unsafe and unpleasant.

In Texas, many of the creeks, bayous, rivers, lakes and streams are listed as impaired in the Texas Integrated Report of Surface Water Quality (303(d) List). The most common impairment is for fecal coliform bacteria with over 50% of the impaired waterbodies under this classification. Other common impairments include dissolved oxygen and total suspended solids. Many of the pollution sources that lead to these impairments are the same NPS issues listed above. These cannot be addressed through traditional permits and regulations like point source pollution. Many communities in the U.S. and throughout the world are using stormwater Best Management Practices (BMPs) to address NPS pollution.

This report reviews the BMPs installed at the Ghirardi Family WaterSmart Park (GFWP) in League City, TX as a very real solution for reducing NPS loading into local waterbodies. It also evaluates water and soil data from the park and compares percent reduction values to those found for a North Texas site with similarly designed BMPs and comparable soil types.

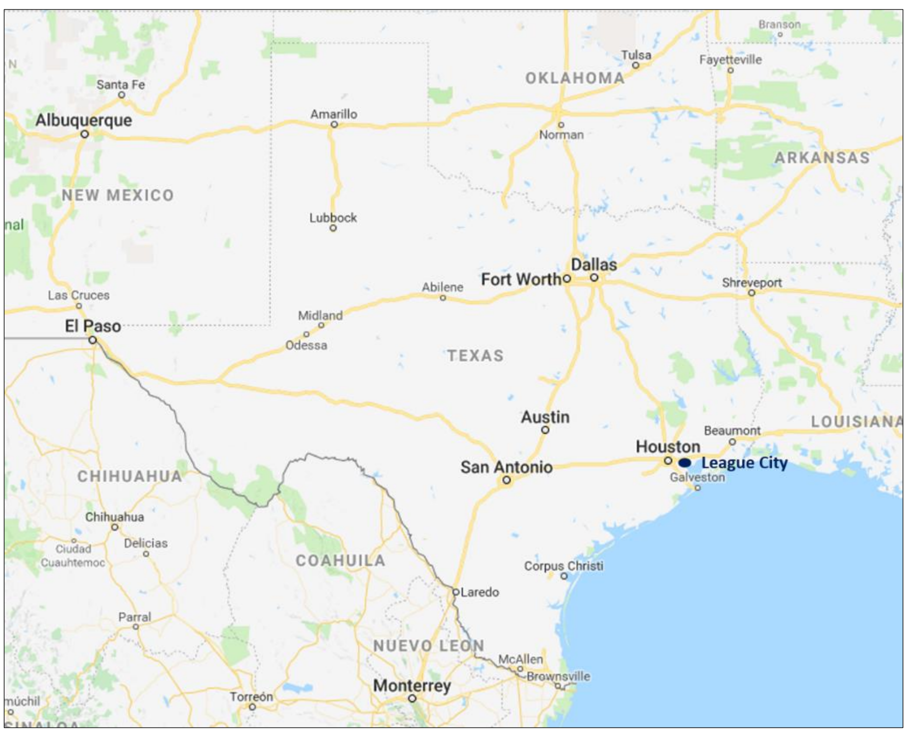

Figure 1. League City, TX is located on the Gulf Coast in Galveston County, on the banks of Clear Lake, a sub-bay of Galveston Bay.

The 3.75 acre Ghirardi Family WaterSmart Park is located on Louisiana Street in the Meadows Subdivision of League City (Figure 2). The Park was substantially completed and opened for public use in March of 2014. It contains amenities such as shaded walking trails, a playground, picnic area, and restroom facilities as well stormwater BMPs. It is first and foremost a public park and recreation area but it is so much more.

Figure 2. Ghirardi Family WaterSmart Park is located within a suburban neighborhood of League City, TX

The GFWP is a very public venue that showcases stormwater management techniques. The BMPs in the park serve both education and demonstration purposes. The park allows developers, city staff, community officials and residents to view functioning BMPs, learn how BMPs fit into the landscape, how BMPs can work together to form a treatment train, and how BMPs truly enhance the area while improving water quality. Five BMPs are showcased in this facility and were included in this study. They are:

- Rain gardens
- Bioswales
- Pervious pavers
- Rainwater harvesting
- Green roof

Each BMP was designed and engineered specifically for this space and represents best practices for the soil type and rain fall amounts typical of the Houston-Galveston region. This facility is also a living laboratory, where all of the BMPs can be studied throughout their lifecycle.

Best Management Practices

Five BMPs were selected for monitoring at the GFWP; however, limited data was collected for the rain garden and pervious pavers, so this white paper will focus primarily on three practices: bioswale, rainwater harvesting, and green roof.

All BMPs at the GFWP are sized to collect the 90th percentile storm which for this location is up to 0.29 inches of rainfall

BioSwale

The bioswale (Figure 3) is completely vegetated with Bermuda grass, and collects overland flow from within the park, only grassed areas contribute runoff, there are no impervious surfaces in this watershed.

Figure 3. Bioswale vegetated with turf grass. Sampling point for this BMP is the pipe pictured.

Green Roof & Rainwater Harvesting

The green roof and rainwater harvesting cistern are situated to collect runoff from the roof of the park pavilion (Figure 4). The pavilion has a split roof design so each practice has a discrete watershed contributing to the BMP. The green roof is a system of interlocking tray filled with engineered soil due to the pitch of the roof.

Figure 4. Pavilion at GFWP, the roof is split into two sections, allowing for both a green roof and rainwater harvesting practices on the same structure.

Sampling

Two rounds of data collection were completed for the park. The first in 2014 & 2015 funded by 582-11-13147 from the Texas Commission on Environmental Quality. The second in 2017 & 2018 funded by 582-16-60055 from the Galveston Bay Estuary Program. All sampling was completed under a Quality Assurance Project Plan (QAPP) as required by TCEQ.

Water quality

Wet weather sampling protocols were used for both projects. Inflow volumes were calculated using the curve number method, and outflow samples were collected to measure water quality parameters.

Outflow samples were collected and submitted to a NELAC accredited laboratory for processing for Nitrite + nitrate, total phosphorous, orthophosphate, total suspended solids (TSS), and E. coli. Field parameters collected were water temperature, dissolved oxygen, pH, and conductivity. These were measured using a hand-held YSI unit.

Soil

The GBEP funded project also added a soil sampling component. Soils are not routinely sampled as part of stormwater BMP monitoring. However, because several of the most commonly used BMPs encourage soil infiltration as a means of removing pollutants, preliminary soil data was collected for both the rain garden and bioswale at the GFWP, as well as three control sites. One sampling was conducted in April 2018; a soil particle size analysis was completed as well as arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, phosphorus, potassium, selenium, and zinc.

Results

Water quality

The data described here is from both projects, and therefore spans four years. The concentrations for outflow pollutant volumes for nitrogen, phosphorous, total suspended solids, and bacteria are shown in Figures 5, 6, 7 and 8.

Measured outflow for nitrogen is fairly similar for all sampling events across all three BMPs (Figure 5, Table 2). The exception being the green roof on two events (12.17.2017 and 3.29.2018), while these levels are higher than the other BMPs, they are not high enough to raise concerns.

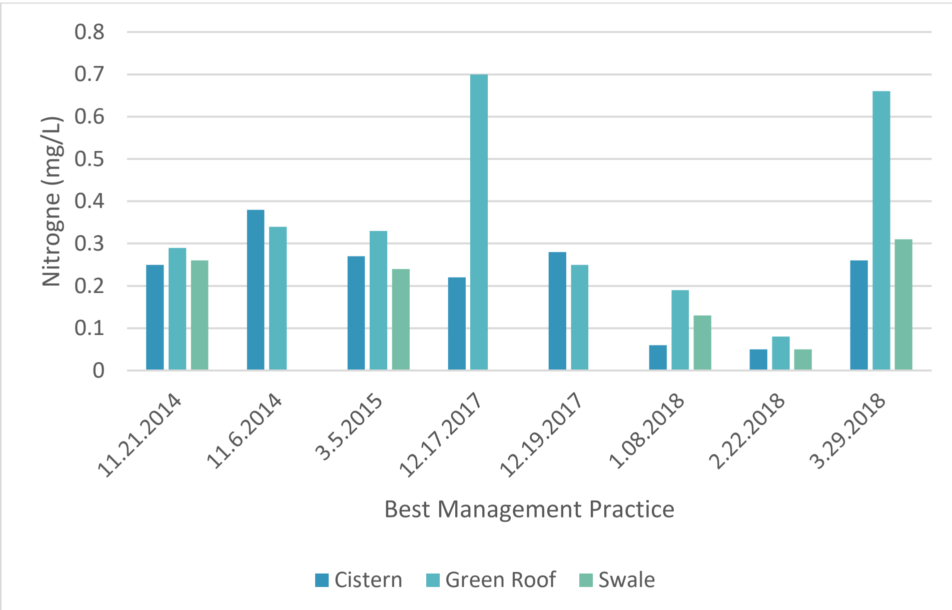

Figure 5. Measured outflow values for Nitrogen for all three BMPs

Measured outflow for phosphorous is fairly similar for all sampling events across all three BMPs (Figure 6, Table 3). Data for the 1.08.2018 sampling event for phosphorous is not included due to a sample preservation error. The final two sampling events (2.22.2018 and 3.29.2018) have higher measured phosphorous levels across all three BMPs than the other five events. Fertilization would be an obvious cause of the increased phosphorous levels, and could be the explanation for the bioswale, however neither the green roof nor the cistern watershed was fertilized, making this an unlikely explanation.

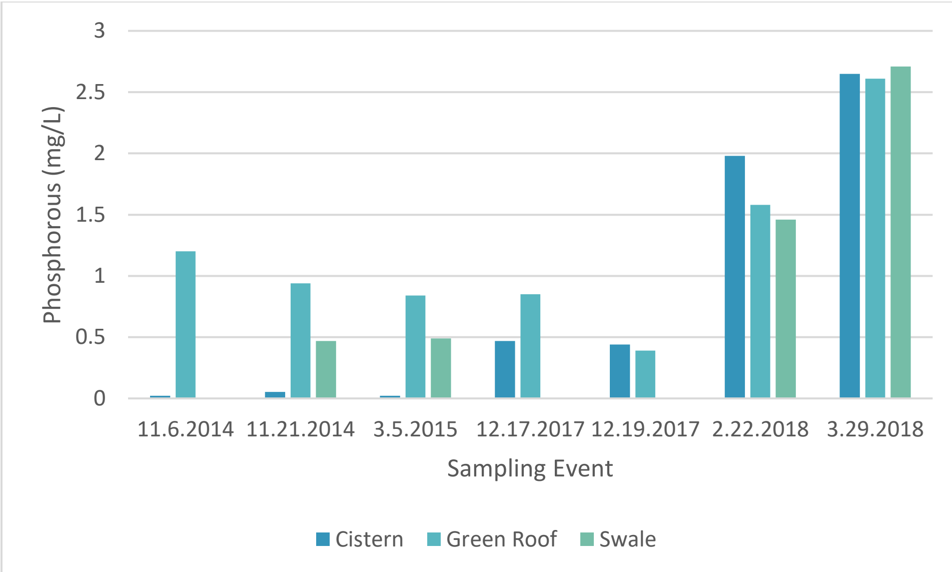

Figure 6. Measured phosphorus in outflow for all three BMPs

Overall, TSS values for all BMP outflows are relatively low. The highest values were for the bioswale in the spring/winter and spring of 2017 and 2018 (Figure 7, Table 4). There was a large amount of sediment build up at the mouth of swale that was washed back into the pipe during large rain events; this likely is the reason for high TSS values, not soil washing in from the BMP watershed. The sediment was due to the theft of rock used to stabilize the swale outflow pipe, when the rock was in place, the lower TSS values were observed. Since sampling has ended, the rock has been replaced.

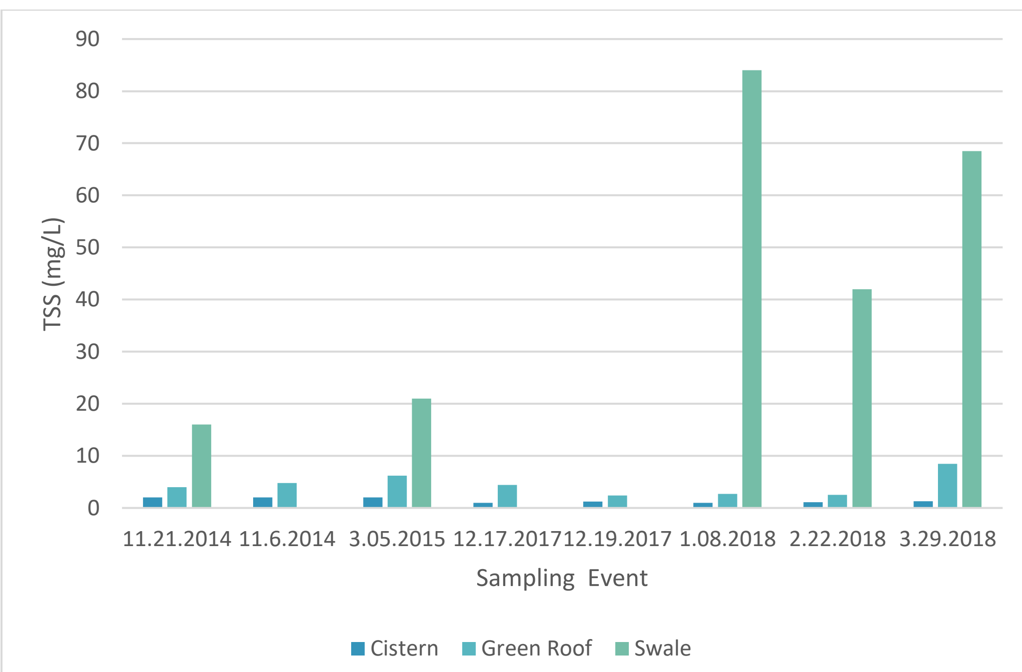

Figure 7. Measured Total Suspended Solids in outflows for all three BMPs

E. coli values are fairly similar across sampling dates, except for the bioswale (Figure 8, Table 5). During the winter/spring of 2018 high outflow values were observed for three sampling events. A large number of local residents walk their dogs in the park. While there is a pet waste station in the park, it is not near the watershed for the swale, a grassy area where pets can run and play. On more than one occasion dog waste was seen in the area near the sampling location for the bioswale which was likely the cause of high bacteria counts. No stormwater from outside of the park drains into the GFWP or the swale, therefore typical sub-urban sources of bacteria such as leaking sewer pipes are unlikely the cause of the elevated E. coli values.

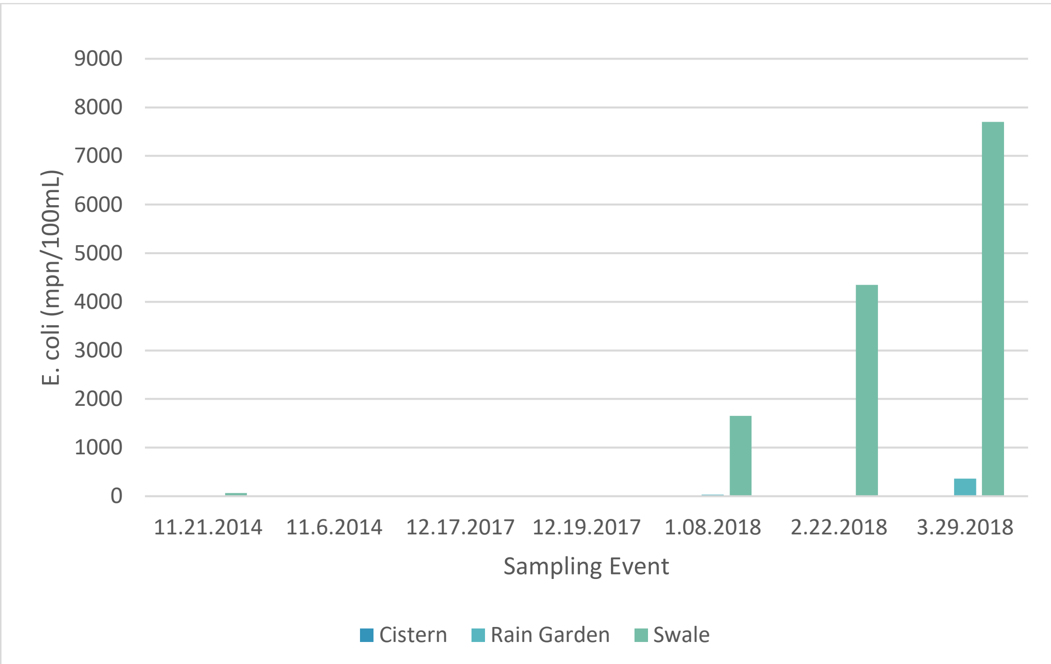

Figure 8. Measured bacteria in outflows for all three BMPs

Percent Reductions

Table 1 shows the percent reduction for the pollutants in each BMP for both the GFWP and the Dallas AgriLife Extension Center. There are no overall similarities or discernable patterns between the two sites. Overall, at GFWP nitrogen was removed from BMPs. Phosphorus had a negative percent reduction, meaning P values were larger in outflow data than those calculated for inflow. TSS was removed by all three BMPs, and E. coli values were less in measured outflow than in calculated inflows (Inflows were calculated using the Simple Method[1] and locally derived even mean concentrations[2], this method may have overestimated the inflow values, therefore showing higher than expected percent reductions). In Dallas, all BMPs showed positive percent removals except for the green roof for nitrogen. However, the percent increase was still smaller than the percent increase at the GFWP by an order of magnitude.

[1] Schueler, T. (1987) Controlling urban runoff: a practical manual for planning and designing urban BMPs. Metropolitan Washington Council of Governments. Washington, DC.
[2] Newell, C.J., Rifai, H.S., and Bedient, P.B. (1992) Characterization of Non-Point Sources and Loadings to Galveston Bay, GBNEP-15. Prepared for the Galveston Bay National Estuary Program, Houston, TX.

Table 1. Percent Reductions for Nitrogen, Phosphorous, Total Suspended Solids, and E. coli for both the Ghirardi Family WaterSmart Park and the Dallas AgriLife Reserach Center

	Percent Reduction GFWP				Percent Reduction Dallas Center[3]			
	Nitrogen	**Phosphorous**	**Total Suspended Solids**	**E. coli**	**Nitrogen**	**Phosphorous**	**Total Suspended Solids**	**E. coli**
Bioswale	93	-1200*	17	99.9	NS	NS	NS	NS
Green Roof	81	-800*	93	99.9	-11*	49	75	89
Rainwater Harvesting	20	-1100*	68	99.9	50	79	52	NS

*A negative value for percent reduction, indicates that the measured level in the outflow was greater than the calculated expected value for inflow

NS- Not sampled

Soil

Particle-size Distribution

The soil textures of each sample are plotted on Figure 9. The soil texture triangle in Figure 9 is based on the United States Department of Agriculture (USDA) particle size criteria, whereas as the data is reported with the United States Geological Survey (USGS) criteria. The USDA classifies clay as anything finer than two micrometers, whereas the USGS boundary is at four micrometers. The plotted points therefore may be clayier than the actual values. Nonetheless, the plot does show relationships between the samples very well.

The Control Site (CS) points were tightly clustered right in the middle of the silty clay loam texture. Both the Rain Garden (RG) and Bioswale (BS) points had a much greater spread across the texture diagram. The CS points were from undisturbed areas and appear to be reflective of the native soils. The RG samples, on the other hand, were taken from areas where additional soil materials were added, particularly compost and mulch. The RG samples did cluster somewhat tightly in the clay loam texture area. The RG samples in fact had about the same percentage of clay as the CS sites, but about 20% more sand and 20% less silt. The landscapers may well have added significant sand to the RG sites.

[3] Jaber, F. 2015. Dallas Urban Center Stormwater BMPS Final Report. https://www.tceq.texas.gov/assets/public/waterquality/nps/projects/40155_FinalReport.pdf

The most variable samples were those taken from the bioswale. The bioswale is a much longer depressional feature than the rain garden, and thus we might expect more soil variation along the bioswale.

All of the samples clustered fairly tightly in the silty clay, silty clay loam, and clay loam texture fields. This pattern is consistent with a silty clay loam initial soil across the park, modified by landscaping construction.

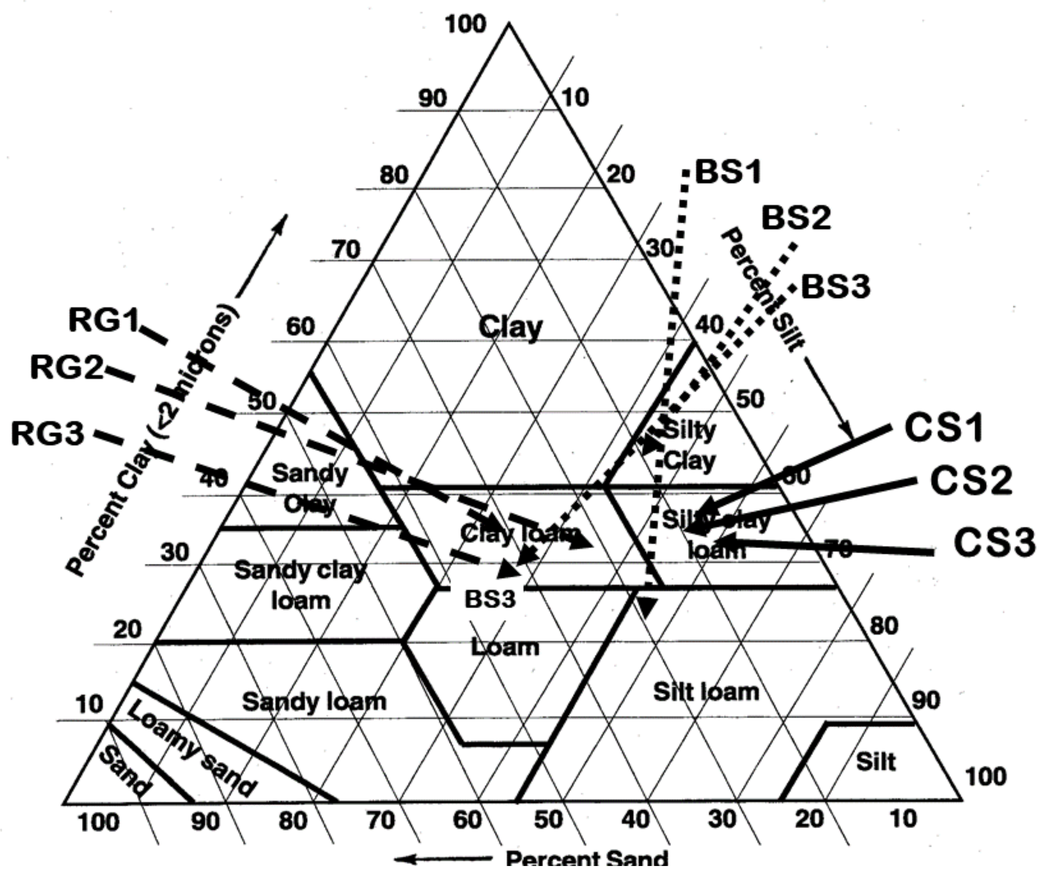

Figure 9. Soil textures of each sampling site plotted on the USDA texture triangle. CS=control sites; RG=rain garden; BS=bioswale.

Heavy Metals

A standard profile of heavy metals was run on all sites. Heavy metal concentrations varied widely across the entire site, but all of the values are within the range of values for "normal" soils as reported in the literature.[4]

---

[4] Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States. U.S. Geological Survey Professional Paper 1270. 1984. Shacklette, H.T. and J.G. Boerngen. USGS, Alexandria, VA

The values for the control sites had approximately the same spread for each element as was found in the bioswale and the rain garden. No patterns were observed for any of the other analytes.

Conclusions

Overall, there is additional data needed to fully understand the functionality of the BMPs at the GFWP. Data from the two studies included in this paper show a general trend for pollutant removal for grassed bioswales, green roofs, and rainwater harvesting practices, with the exception of phosphorous. Results do indicate that the BMP designs used are functional for the soil type and climate in League City, TX.

Water quality

No unusual results were seen in this study. The percent increase for phosphorous increases instead of reductions could be an artifact of the estimated inflow values instead of using measured inflow. Calculated values could underestimate the actual amounts seen at the GFWP. Or, there could be high phosphorous levels that cannot be adequately addressed by these BMPs. A mesocosm experiment could be designed to better understand inflow values. These results could be used to reevaluate the GFWP data to better understand the actual percent removals for pollutants.

The 2016 International Stormwater BMP Database Summary Statistics Report[5] compiles results from a number of studies in the database. This report shows an overall increase in phosphorus levels for grassed bioswales, this is in line with the results of this study at the GFWP. The Summary Report also found an increase in nitrogen values for grassed bioswales, a result contrary to that at the GFWP. There was not a sufficient number of studies for green roofs for inclusion in the Summary Report.

The 2017 and 2018 sampling events were after Hurricane Harvey ravaged the Texas Gulf Coast and dropped record setting rainfalls in League City, which submerged large portions of the community, including the GFWP. Increased levels of TSS for the swale could be related to this flooding, as a large amount of sediment was moved and re-deposited by flood waters. After Harvey, the area went several months without rainfall, therefore, transported sediments could be a source of measured TSS during the sampling period.

Soil

No unusual results were found during the soil analysis. However, this study has provided baseline data for the infiltration BMPs at the GFWP. It is recommended that soil sampling be repeated in several years time to see if any noticeable changes have occurred, especially for the rain garden. This rain garden collects run off from the park driveway and overflow parking area. It is a site where heavy metals would likely wash into the system and build up in the soil layer slowly over time. Normal values were observed during this sampling, but that could change with time.

Recommendations

[5] WERF, 2016. Final Report International Stormwater BMP Database 2016 Summary Report. http://www.bmpdatabase.org/Docs/03-SW-1COh%20BMP%20Database%202016%20Summary%20Stats.pdf

At the request of League City staff, the GFWP water quality sampling protocol was developed such that ISCO samplers were not kept on site. Because the BMPs are so prominent at the GFWP, Parks Department staff were concerned that sampling equipment kept on site would detract from the facility. Therefore, ISCO samplers were kept offsite, transported to the park and set up prior to each sampled storm event, then removed after each rainfall. Thelmar weirs in hard to reach pipes and some other pieces of sampling equipment were maintained on site. The ISCO samplers selected for this project are labeled by the manufacturer as “portable”, but AgriLife staff feel that transporting the samplers, disconnecting and reconnecting hoses, batteries, etc. led to some of the sampling issues. If the samplers had been maintained on-site, charged with solar panels, and connections contained continuously, we anticipate that less sampler errors would have occurred. We recommend using this approach on future projects.

Appendix A – Data Tables

Table 2. Measured outflow values for Nitrogen (mg/L) for all three BMPs by sampling date

	Cistern	Green Roof	Bioswale
11/06/2014	0.38	0.34	NS
11/21/2014	0.25	0.29	0.26
03/05/2015	0.27	0.33	0.24
12/17/2017	0.22	0.7	NS
12/19/2017	0.28	0.25	NS
01/08/2018	0.06	0.19	0.13
02/22/2018	0.05	0.08	0.05
03/29/2018	0.26	0.66	0.31

NS- No sample

Table 3. Measured outflow values for Phosphorous (mg/L) for all three BMPs by sampling date

	Cistern	Green Roof	Bioswale
11/06/2014	0.021	1.2	NS
11/21/2014	0.053	0.94	0.47
03/05/2015	0.021	0.84	0.49
12/17/2017	0.47	0.85	NS
12/19/2017	0.44	0.39	NS
02/22/2018	1.98	1.58	1.46
03/29/2018	2.65	2.61	2.71

NS- No sample

Table 4. Measured outflow values for total suspended solids (mg/L) for all three BMPs by sampling date

	Cistern	Green Roof	Bioswale
11/06/2014	2	4.8	NS
11/21/2014	2	4	16
03/05/2015	2	6.2	21
12/17/2017	1	4.4	NS
12/19/2017	1.2	2.4	NS
01/08/2018	1	2.7	84
02/22/2018	1.1	2.5	42
03/29/2018	1.3	8.5	68.5

NS- No sample

Table 5. Measured outflow values for E. coli (mpn/110mL) for all three BMPs by sampling date

	Cistern	Green Roof	Bioswale
11/06/2014	1	6	NS
11/21/2014	0	3	66
03/05/2015	2	2	NS
12/17/2017	10	10	NS
12/19/2017	10	31	NS
01/08/2018	10	10	4350
02/22/2018	10	364	7700
03/29/2018	0	3	66

NS- No sample