Interim Report on the Retrofit of an Existing Flood Control Facility to Improve Pollutant Removal in an Urban Watershed

Amy Gilpin[2], MS and Michael Barrett[1], Ph.D., P.E., M.ASCE and

[1]Center for Research in Water Resources, 10100 Burnet Rd., Bldg. 119, Austin, TX 78758
PH (512) 471-0935, FAX (512) 471-0072, email: mbarrett@mail.utexas.edu
[2]Department of Civil, Architectural, and Environmental Engineering, The University of Texas at Austin, 301 E. Dean Keeton St., C1786, Austin, TX 78712, email: acgilpin@utexas.edu

ABSTRACT

Levels of bacteria in excess of acceptable standards for contact recreational designated use have been documented in Gilleland Creek, located in northeast Travis County, Texas. Stormwater monitoring showed increased bacteria levels after rainfall runoff events in Gilleland Creek, and analysis indicates the bacteria is of a nonpoint source origin. The objective of this research was to modify a flood control basin in an urban area in the upper part of the Gilleland Creek watershed to determine whether it is possible to substantially increase bacteria removal by retaining stormwater in the basin for 24 hours after a storm event. Bacteria reduction was predicted as a result of sedimentation and exposure to sunlight. The outlet of one basin was retrofitted with an automated gate valve to control outflow and acted as the test basin; a nearby basin was unmodified and acted as the control basin. Stormwater monitoring at the inlet and outlet to both basins over the course of 10 storm events showed an increase in bacteria die-off in the modified basin, as well as additional removal of suspended solids and nitrate/nitrite. Sampling results from a May 2013 storm event show 88% removal of *E. coli*, 94% removal of nitrate/nitrite, and 98% removal of total suspended solids in the test basin versus 39% removal of *E. coli*, no removal of nitrate/nitrite, and 71% removal of total suspended solids in the control basin. Based on this work, the modification of flood control basins in other parts of Texas and the rest of the US may offer a cost effective template to address bacteria and other impairments in other urban watersheds.

INTRODUCTION

Large parts of urban areas were developed prior to the adoption of the Clean Water Act as it applies to nonpoint source pollution. Consequently, many receiving waters in urban areas have been declared impaired and placed on states' 303(d) lists. Stormwater discharges from urban land uses frequently have bacteria concentrations that far exceed contact recreation standards. Levels of bacteria in excess of acceptable standards for contact recreational designated use have been documented for Gilleland Creek in northeast Travis County resulting in its inclusion in Texas Commission on Environmental Quality's (TCEQ) 2004 Federal Clean Water Act 303(d) List. In June 2005, Lower Colorado River Authority (LCRA) prepared a study titled, "Assessment of Water Quality Impairment of Gilleland Creek" for the TCEQ to determine the source of bacterial contamination in Gilleland Creek and to perform additional monitoring. This

report reviewed historic water quality data and reaffirmed the 303(d) listing of Gilleland Creek for high bacteria. LCRA stream monitoring also showed increased bacteria levels after rainfall runoff events in Gilleland Creek.

The slopes of load duration curves representing *E. coli* conditions in dry and wet weather were compared to determine whether bacteria concentrations varied in response to runoff events. If the source of bacteria was point source, different slopes for the dry and wet weather events would be expected as a result of dilution. At all but one site, the slopes of wet and dry weather data were not significantly different, indicating that the bacteria loading to Gilleland Creek is of a nonpoint source origin. Probable nonpoint sources of pollution in the Gilleland Creek watershed include malfunctioning septic tanks, storm sewers, agriculture practices, pet and wildlife waste, and other natural sources. Much of the upper section of the Gilleland Creek watershed where bacteria standards have been routinely exceeded consist of urban areas, similar to those monitored in this study. Consequently, bacteria reduction in stormwater runoff from the test watershed may substantially improve the quality of stormwater runoff discharged to Gilleland Creek.

There are no facilities in the Gilleland Creek watershed built specifically to address water quality concerns, but flood control basins are widespread. Retrofitting the drainage system to incorporate standalone water quality facilities is prohibitively expensive due to the lack of available space in the built environment and hydraulic constraints associated with the existing system. The objective of the study was to determine the degree that modified flood control facilities would reduce the input of bacteria and other pollutants discharged from urban areas.

In a study conducted by the University of Texas for the Texas Department of Transportation (TxDOT), a sedimentation basin in northwest Austin was retrofit with an automated outlet (Middleton and Barrett, 2008). The study documented a 91% reduction in Total Suspended Solids (TSS) and a 52% reduction in total phosphorus. Bacteria reduction was not measured; however, there are a variety of reasons to expect a substantial improvement. First, bacteria are typically attached to solids, so removal of solids (particularly the smaller fraction) will reduce bacteria concentrations. In addition, there was a substantial amount of research in the 1950's on die-off of bacteria in wastewater ponds. Much of this reduction is associated with exposure to the Ultraviolet (UV) radiation in sunlight, which will also be an effective mechanism in the retrofit flood control basins (Morowitz, 1950).

Reduction in bacteria concentrations are expected as a result of sedimentation and exposure to sunlight. Experiments conducted in the graduate program at the University of Texas using water and sediment collected from Gilleland Creek, indicates that a substantial amount of bacteria is associated with sediment (Sejkora, 2010). The geometric mean initial concentration of *E. coli* of samples that contained streambed sediments in addition to the stream water was three times greater than that in the plain stream water. Additionally, the maximum initial concentration of *E. coli* in the samples with sediment was almost five times greater than the maximum concentration observed in the samples containing just stream water. These results indicate that the resuspension of sediment can cause inland streams to exceed surface water quality standards. Consequently, we expect that improved sedimentation in the flood control facilities will result in a substantial reduction in bacteria concentrations.

MATERIALS AND METHODS

Site Characteristics

The study includes the monitoring of two flood control basins in the Gilleland Creek watershed, Pon Court basin and Copperhead Drive basin. The relative proximity of Pon Court basin and Copperhead Drive basin can be seen in Figure 1 below. These two basins were selected for a number of reasons. The basins are relatively close in proximity and serve different portions of the same residential development. As a result, the drainage area and land use is virtually the same for both sites. In addition, the spillways for both facilities drain directly to Gilleland Creek.

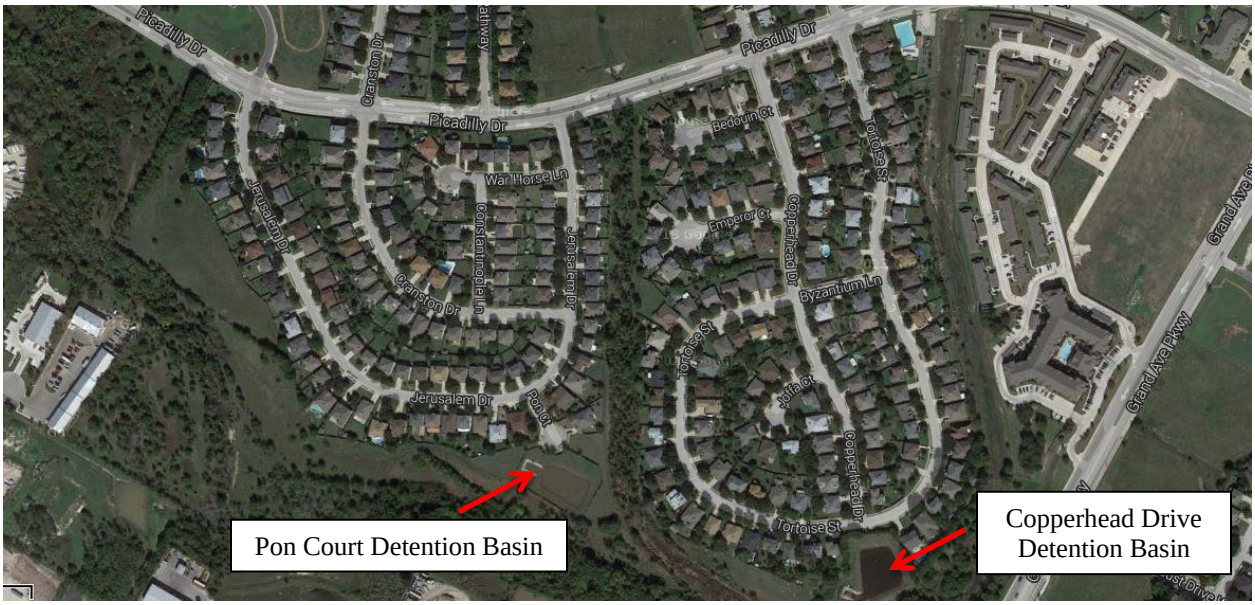

Figure 1. Location of Pon Court and Copperhead Drive detention basins in Pflugerville, TX.

One of the basins, Pon Court, acted as the test site and its outlet pipe was retrofitted with an automated valve, which allowed all of the runoff from the contributing watershed to remain in the basin for any desired length of time. The valve could be remotely opened after a period of time (24 hours for the purpose of this study), allowing the runoff to discharge to Gilleland Creek. The second basin, Copperhead Drive, acted as the control site and its outlet was not modified. In general, only storms exceeding 0.25 inches of precipitation provide sufficient sample for analysis.

Equipment and Programming

Field construction of the outlet control structure at Pon Court basin consisted of first excavating to a depth of twelve inches in front of the existing concrete pad at the outlet and pouring a new concrete slab. The new slab was underlain with wire mesh for reinforcement and keyed into the existing concrete slab with concrete anchors. The structure housing the actuated gate valve was mounted onto the new concrete pad with L-brackets and concrete anchors. The

control structure that was installed is commonly used in agricultural applications and more detailed information can be obtained from http://www.agridrain.com/watercontrolproductsinline.asp. A PVC union was installed to connect the actuated outlet structure to the outlet pipe.

An ultrasonic level sensor was mounted externally near the top of the structure to record water level readings in the basin. The ultrasonic level sensor was replaced with a submersible pressure transducer in August 2013 in order to achieve steadier and more reliable level readings. A battery enclosure was mounted onto the structure, as was a main enclosure housing the electronic components of the setup. A solar panel was mounted near the top of the structure, oriented and angled to capture maximum sunlight and positioned to shade the battery and main enclosures. Electrical cable was run between the solar panel, battery enclosure, main enclosure, water level sensor, and valve actuator. A grounding rod, grounding cables, and corresponding connections to equipment were installed. The existing riser pipe on the basin outlet was capped with PVC, and the holes on the riser pipe were plugged with heavy duty water proof electrical tape. Figure 2 below shows the field installation of the retrofitted basin.

Figure 2. Valve outlet structure installed at Pon Court basin.

Once construction and installation of the valve structure was completed, the monitoring and control interface was brought online, which allowed remote viewing of water level and rain gauge data and also allowed remote operation of the gate valve. OptiTRC, developed by Geosyntec Consultants, acts as the control interface for the structure. Figure 3 below shows a screenshot of the web-based OptiRTC interface for monitoring and operating the control structure.

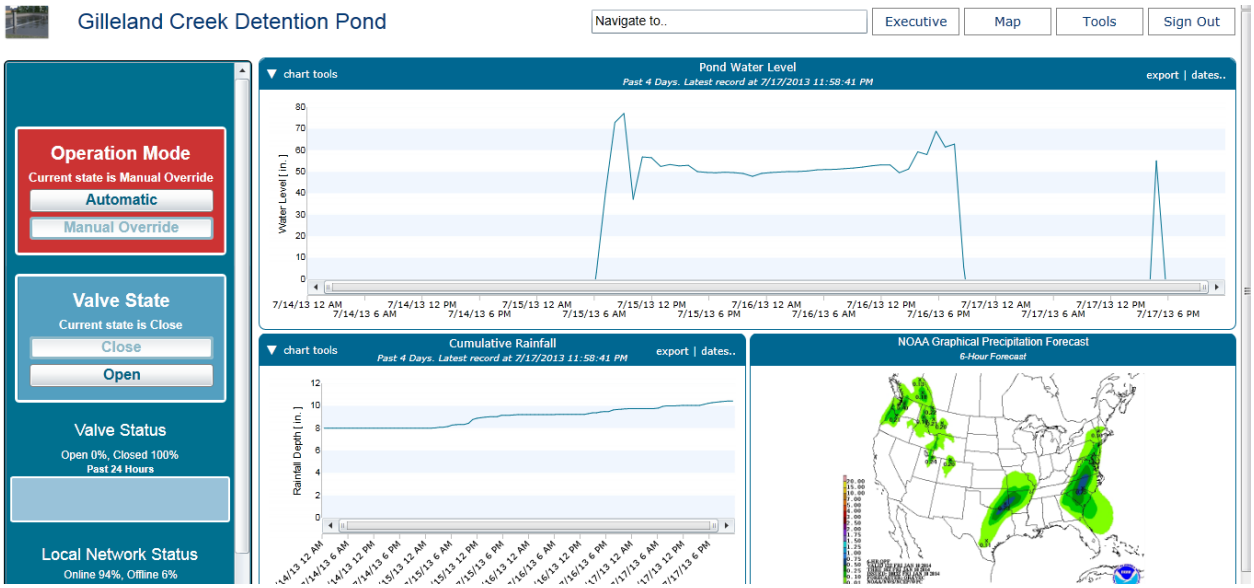

Figure 3. Screenshot of the OptiRTC system for controlling the gate valve structure from July 2013 storm event.

Water quality monitoring equipment was installed at the inlet and outlet to both the retrofitted site and the control site to evaluate the bacteria concentrations entering and exiting the flood control basins. One area velocity meter and one sampler were installed at the inlet to both the Pon Court test basin and the Copperhead Drive control basin. At the Copperhead Drive basin, the area velocity meter probe was installed in one of two 48" inlet pipes, while the sampler inlet was installed on the concrete pad slightly downstream from where the flowpaths from both inlet pipes merge together. One bubble flow meter and one sampler were installed at the outlet of both basins. Equipment was placed in tamper resistant field boxes for security. The power for each set of monitoring equipment was drawn from a deep cycle marine battery which maintained charge via a connection to a solar panel mounted on top of each field box.

Rating curves for the control basin and test basin were developed and used to program the flow meters. A composite sampling regime, consisting of a mixture of a number of individual sample aliquots was used at Pon Court inlet, and Copperhead Drive inlet and outlet. The aliquots were collected at specific intervals of flow during the storm events and combined to form a single sample for laboratory analysis. The samplers were programmed to take equal volume aliquots (300mL). Sample pacing was determined after observing the runoff volume for the first few rain events prior to beginning the monitoring period. At least 8 aliquots must have been collected to ensure representativeness of the sample, so the sample pacing was set as the volume of runoff from a 0.25 inch storm divided by 8. Sample collection ended at either the end of runoff or when 28 individual aliquots had been collected.

The runoff coefficient was determined by dividing the measured runoff volume, obtained from flow meters installed at the sites, by the rainfall depth, measured at a rainfall gauge at the site.

Stormwater Monitoring

With the installation of all field equipment complete, the period of stormwater monitoring began in March 2013. The first several rain events that the basins received were used to determine the hydraulic and drainage characteristics of the detention basins. These rain events

were also used as a means to identify any equipment failures and as a trial run for sample collection. Beginning in May 2013, two paired samples were collected during storm events for the two facilities. Table 1 below summarizes the sample collection dates and locations as well as corresponding rainfall depths.

Following an early morning storm event on May 15, 2013, samples were collected from Pon Court inlet, Copperhead Drive inlet, and Copperhead Drive outlet and submitted to the LCRA laboratory. After a 24 hour holding window, both grab and automated samples were collected from Pon Court outlet and submitted to the LCRA laboratory. This storm and round of sampling qualified as the first of ten monitoring events. As part of an effort to modify the QAPP to allow grab sampling from the Pon Court outlet, one grab sample and one automated sample were collected from Pon Court outlet on May 13, 2013 and submitted to the LCRA laboratory. This comparison sampling followed a storm event that occurred on May 10, 2013, which was a Friday, ruling out the occurrence of a complete round of sampling.

One sample was collected from Pon Court inlet, and two samples were collected from both Copperhead Drive inlet and Copperhead Drive outlet from a storm event on July 15, 2013. These five samples were submitted to the LCRA laboratory. After a 24 hour holding window, one automated sample was collected from Pon Court outlet on July 16, 2013 and submitted to the LCRA laboratory. This storm and round of sampling qualified as the second of ten monitoring events.

Finally, one sample was collected from Pon Court inlet from a storm event on October 16, 2013 and submitted to the LCRA laboratory the same day. After a 24 hour holding window, a grab sample was collected from Pon Court outlet on October 17, 2013 and submitted to the LCRA laboratory the same day. Copperhead Drive basin was not sampled during this storm event because the basin was backed up with standing water from a previous storm event.

Table 1. Summary of sample collection dates and locations for storm events.

Sample Collection Date	Rainfall Depth (inches)	Location
5/13/2013	1.28	Pon Court outlet (grab)
		Pon Court outlet (automated sampler)
5/15/2013	0.13	Pon Court inlet
		Copperhead Drive inlet
		Copperhead Drive outlet
5/16/2013	0.13	Pon Court outlet
7/15/2013	0.55	Pon Court inlet
		Copperhead Drive inlet
		Copperhead Drive outlet
7/16/2013	0.55	Pon Court outlet
10/16/2013	0.62	Pon Court inlet
10/17/2013	0.62	Pon Court outlet

RESULTS AND DISCUSSION

Data collected during the stormwater monitoring was analyzed to determine whether the retrofitted facility reduced the concentrations of indicator bacteria in stormwater discharges. In

addition, the discharge data was analyzed to determine whether the bacteria concentrations were less than the contact recreation threshold.

Analytical results and load reduction calculations from the May storm event can be found below in Table 2 and Table 3. Bacteria concentrations decreased by one order of magnitude (1940 to 222 MPN/100ml) between the inlet and the outlet in the Pon Court test basin during the May storm event, and bacteria concentrations at the outlet fell below the contact recreation threshold (399 MPN /100ml). In contrast, bacteria concentrations were of the same order of magnitude at the inlet and outlet to the Copperhead Drive control basin, and both concentrations exceeded the contact recreation threshold.

Table 2. *E. coli* concentrations for Pon Court detention basin from May 15, 2013 storm event.

	E. coli (MPN)
Pon Inlet	1940
Pon Outlet Grab	187
Percent Removal	90.4%
Pon Outlet Composite	222
Percent Removal	88.6%

Table 3. *E. coli* concentrations from Copperhead Drive detention basin from May 15, 2013 storm event.

	E. coli (MPN)
Copperhead Inlet	6020
Copperhead Outlet	3640
Percent Removal	39.5%

Analytical results and load reduction calculations from the July storm event can be found below in Table 4 and Table 5. Although bacteria concentrations decreased by one order of magnitude (3410 to 768 MPN/100ml) between the inlet and the outlet in the Pon Court test basin during the July storm event, bacteria concentrations at the outlet still exceeded the contact recreation threshold (399 MPN /100ml). Bacteria concentrations at Copperhead Drive control basin increased from the inlet to the outlet and exceeded recreational contact values, though concentrations were of the same order of magnitude.

Table 4. *E. coli* concentrations at Pon Court detention basin from July 15, 2013 storm event.

	E. coli (MPN)
Pon Inlet	3410
Pon Outlet	768
Percent Removal	77.5%

Table 5. *E. coli* concentrations from Copperhead Drive detention basin from July 15, 2013 storm event.

	E. coli (MPN)
Copperhead Inlet A	4350
Copperhead Outlet A	8860
Percent Removal	-103.7%
Copperhead Inlet B	10800
Copperhead Outlet B	11000
Percent Removal	-1.9%

One of the concerns about the quality of Gilleland Creek is that an effluent dominated stream with high levels of nutrients could result in eutrophication. Consequently, this study also analyzed for a more complete suite of nutrient forms including dissolved phosphorus, TKN, and nitrate+nitrite to determine the effect of basin retrofit on these additional constituents.

Analytical results and load reduction calculations from the May storm event can be found below in Table 6 and Table 7. Nitrate+nitrite and total suspended solids concentrations both showed greater than a 90% removal in the Pon Court test basin. Dissolved phosphorus showed no removal, while TKN and total phosphorus both showed moderate removal between Pon Court inlet and outlet. In contrast, TKN, nitrate+nitrite, total phosphorus, and dissolved phosphorus concentrations all increased between the inlet and outlet of Copperhead Drive control basin. However, total suspended solids did show a 71% removal at Copperhead Drive basin.

Table 6. Analytical results for Pon Court detention basin from May 15, 2013 storm event.

	TKN (mg/L)	Nitrate/Nitrite as N (mg/L)	Total P (mg/L)	Dissolved P (mg/L)	TSS (mg/L)
Pon Inlet	2.06	0.596	0.295	0.107	174
Pon Outlet Grab	0.935	0.0467	0.179	0.129	4.84
Percent Removal	54.6%	92.2%	39.3%	-	97.2%
Pon Outlet Composite	0.9	0.0343	0.182	0.121	3.49
Percent Removal	56.3%	94.2%	38.3%	-	98.0%

Table 7. Analytical results from Copperhead Drive detention basin from May 15, 2013 storm event.

	TKN (mg/L)	Nitrate/Nitrite as N (mg/L)	Total P (mg/L)	Dissolved P (mg/L)	TSS (mg/L)
Copperhead Inlet	1.89	0.839	0.211	0.116	71.8
Copperhead Outlet	2.41	1.33	0.291	0.197	20.8
Percent Removal	-27.5%	-58.5%	-37.9%	-69.8%	71.0%

Analytical results and load reduction calculations from the July storm event are provided in Table 8 and Table 9. The total suspended solids concentration showed the greatest load reduction between the inlet and outlet of Pon Court test basin, while TKN and nitrate+nitrite showed moderate load reduction. Similar to the May storm event, TKN, nitrate+nitrite, total

phosphorus, and dissolved phosphorus concentrations all increased between the inlet and outlet of Copperhead Drive control basin in the first sample collected. However, total suspended solids again showed significant removal at the Copperhead Drive basin.

Table 8. Analytical results from Pon Court detention basin from July 15, 2013 storm event.

	TKN (mg/L)	Nitrate/Nitrite as N (mg/L)	Total P (mg/L)	Dissolved P (mg/L)	TSS (mg/L)
Pon Inlet	0.453	0.248	0.0888	0.0585	28.6
Pon Outlet	0.353	0.146	0.0993	0.0766	3.46
Percent Removal	22.1%	41.1%	-11.8%	-30.9%	87.9%

Table 9. Analytical results from Copperhead Drive detention basin from July 15, 2013 storm event.

	TKN (mg/L)	Nitrate/Nitrite as N (mg/L)	Total P (mg/L)	Dissolved P (mg/L)	TSS (mg/L)
Copperhead Inlet A	1.30	0.946	0.209	0.0814	95.5
Copperhead Outlet A	1.54	1.56	0.249	0.178	12.7
Percent Removal	-18.5%	-64.9%	-19.1%	-118.7%	86.7%
Copperhead Inlet B	1.93	0.302	0.311	0.0571	312
Copperhead Outlet B	0.378	0.304	0.0966	0.0637	25.4
Percent Removal	80.4%	-0.7%	68.9%	-11.6%	91.9%

CONCLUSION

The sample design rationale for this study was based on the intent to determine improved removal of phosphorus, nitrogen, sediment, and *E. coli* in the modified flood detention basin as compared to a similar, unmodified facility. Stormwater monitoring demonstrated *E. coli* concentration reductions between 70% and 90% between the inlet and outlet of Pon Court test basin after stormwater was held in the basin for a period of 24 hours. The Copperhead Drive control basin did not provide *E. coli* concentration reductions of this magnitude. Success in the removal of TKN, nitrate+nitrite, total phosphorus, dissolved phosphorus, and total suspended solids as a result of the installation of the modified outlet structure at Pon Court basin varied. In general, total suspended solids showed the greatest reduction from inlet to outlet in both the Pon Court and Copperhead Drive basins.

Many urban areas in the United States have stormwater systems that are similar to the Pon Court and Copperhead Drive detention basins in the Gilleland Creek watershed. In addressing the negative effects of stormwater runoff on local watersheds, retrofitting drainage systems to incorporate standalone water quality facilities is often prohibitively expensive for municipalities. However, in many other parts of Texas and the rest of the United States, where flood control basins are prevalent, modifying these flood control facilities with a simple gate valve structure as installed in this study presents an opportunity to reduce the input of bacteria and other pollutants that are discharged to the local receiving water. The modification of flood control basins in this manner offers a cost effective way for municipalities to address TMDLs in relation to bacteria and other impairments in urban areas.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Geosyntec Consultants for design and installation of the control structure, the City of Pflugerville for ongoing maintenance of the detention basins during the stormwater monitoring period, and the City of Austin for financing laboratory analytical costs. Brandon Klenzendorf of Geosyntec Consultants deserves particular acknowledgment for his troubleshooting and problem solving efforts related to the control structure. The preparation of this report was financed through grants from the U.S. Environmental Protection Agency through the Texas Commission on Environmental Quality.

REFERENCES

Middleton, John, and Barrett, Michael, 2008, Water quality performance of a batch type stormwater detention basin, Water Environment Research, Vol. 80, No. 2, pp. 172-178.

Morowitz, H.J., 1950, Absorption effects in volume irradiation of micro organisms, Science, Vol. 111, No. 2879, pp. 229-230.

Sejkora, P., 2010, Evaluation of Fecal Indicator Bacteria Loadings from a Wildlife Point Source and Sediment Resuspension in Inland Streams, Thesis, Department of Civil, Architectural, and Environmental Engineering, University of Texas at Austin.