Study on the Effectiveness of BMPs to Control Bacteria Loads

Contract No. 582-6-70860

Work Order No. 582-6-70860-05

Final Quarterly Report No. 1

Prepared by
University of Houston

Principal Investigator
Hanadi Rifai

Prepared for

Texas Commission on Environmental Quality
P.O. Box 13087, MC - 150
Austin, Texas 78711-3087

TCEQ Contact

Ronald Stein
TMDL Team
P.O. Box 13087, MC - 150
Austin, Texas 78711-3087
RStein@tceq.state.tx.us

March 2006

TABLE OF CONTENTS

TABLE OF CONTENTS ii

LIST OF TABLES iii

LIST OF FIGURES iv

CHAPTER 1 INTRODUCTION 1

1.1 SCOPE OF THE PROJECT 2

1.2 DESCRIPTION OF THE REPORT 3

CHAPTER 2 DATABASE DEVELOPMENT FOR HOUSTON AREA 5

CHAPTER 3 FUTURE WORK 12

APPENDIX A QAPP (Electronic) 16

LIST OF TABLES

Figure	Caption	Page
Table 1:	Existing/Permitted BMPs	7
Table 2:	Average Removal Efficiencies for Fecal Pathogen Indicators by BMP Type	11

LIST OF FIGURES

Figure **Page**

Figure 1: BMPs in the Houston Area.. 8

CHAPTER 1

INTRODUCTION

The Texas Commission on Environmental Quality (TCEQ) currently has Total Maximum Daily Load (TMDL) projects for Buffalo and White Oak Bayous, Clear Creek, and several other bodies of water in the Houston Metro Area. The TMDL for the Buffalo and White Oak Bayous has shown that storm water carries a high concentration of bacteria and that this may be a large source of bacteria for these water bodies. Studies performed in regions throughout the U.S. have shown that Best Management Practices (BMPs) can be used to reduce bacteria concentrations in storm water runoff. The data and results from this study may be used to help formulate the implementation plans of the TMDLs for Buffalo and White Oak Bayous, as well as, the other surface water bodies on the 303d list.

BMPs include both structural and non-structural practices designated for the management of stormwater runoff at its source. A wide range of practices from stenciling and street sweeping to wetland systems and wet ponds are included under this definition. Several BMPs, in particular, have demonstrated great potential to improve water quality. These include wet basins, dry basins, flood control/water quality basins, wetland systems, grass swales, and vegetative filter strips. Studies have shown that the mechanisms of bacterial removal in these are settling/sedimentation, temperature, sunlight, and filtration (Khatiwada and Polprasert 1999; Davies and Bavor 2000; Darakas 2001; Brookes et al., 2005; Characklis et al., 2005; Gannon et al., 2005).

There are several goals for this study. The first goal is to gather data that may be used in the implementation of the TMDL. An additional goal is to determine the ability of BMPs to reduce the bacteria loads from runoff in the Houston Metropolitan area.

1.1 SCOPE OF THE PROJECT

The scope of work to be performed in this project includes: (i) the identification of the BMPs available for sampling and determining the targets for sampling, (ii) the development of a strategy to sample storm water inflow and outflow, (iii) the preparation of an EPA approved Quality Assurance Project Plan (QAPP), and (iv) the analysis of data and determination of bacterial load reductions.

The six main tasks to be completed are:

1. Administer the project;
2. Participate in the stakeholder process:
3. Develop a database of the quantity and type of BMPs currently in use in the Houston-Harris County area;
4. Prepare a Work Plan/Sampling Plan;
5. Prepare a Quality Assurance Project Plan (QAPP); and
6. Gather the Data.

1.2 DESCRIPTION OF THE REPORT

This document constitutes the first quarterly report for Work Order No. 5 and summarizes the activities undertaken by the University of Houston from December 2005 through February 2006.

This report reflects the progress towards the following tasks delineated in the work plan:

Task 3 – Databases of the BMPs permitted by the City of Houston and Harris County have been obtained. The database is currently being reviewed and updated to reflect the requirements of this project.

Task 4 – The Work Plan was completed and submitted to the TCEQ. The sampling plan to collect water samples from inflow, outflow, and the stored water volumes at BMPs is under development. This plan will reflect the data that have been collected from previous studies performed on BMPs.

Task 5 – Development of the Quality Assurance Project Plan (QAPP) is underway and is included in Appendix A. The QAPP details the field collection methods, laboratory sample analysis, and quality control procedures that will be followed to ensure accurate data. All methods will follow the guidelines of the TCEQ and the EPA.

Task 6 – The process of data collection and analysis was initiated and will continue throughout the duration of the project. The data collected were entered into a database with available descriptions so that the processes and design parameters involved in bacteria removal can be understood.

Chapter 2 of this report presents a brief discussion of the storm water permitting program, different types of BMPs, and the potential for reduction of bacteria from stormwater runoff. Chapter 3 details some of the future work tasks to be performed for the next quarter of this study. Appendix A contains the first revision of the Quality Assurance Project Plan including the Sampling Plan.

CHAPTER 2

DATABASE DEVELOPMENT FOR HOUSTON AREA

The US Environmental Protection Agency (USEPA) determined that, in addition to flood control, BMPs are useful for providing water quality improvement of storm water runoff. BMPs include both structural and non-structural practices designed to manage the stormwater runoff at the source. By detaining water over a period of time over which settling and other process that encourage the death and removal of bacteria, the BMPs may be very useful for the reduction of bacteria loads from storm water in the Houston Metropolitan Area. For this region, the Joint Task Force on Stormwater (JTF) permits best management practices in accordance with the Municipal Storm Separate Sewer System (MS4) permit issued by the TCEQ.

Four agencies located in the Houston area formed the JTF to develop a plan for compliance with the requirements of the National Pollutant Discharge Elimination System (NPDES) aimed at reducing non-point source pollution. The four agencies that comprise the JTF are the City of Houston (COH), Harris County, the Harris County Flood Control District (HCFCD), and the Texas Department of Transportation (TxDOT). Together they obtained a Municipal Separate Storm Sewer System (MS4) permit under phase one of the NPDES program. Together with the TCEQ and, in accordance with the provisions of the NPDES program, the JTF permits BMPs based on the Municipal Storm Separate Sewer System (MS4) permit issued by the TCEQ.

Most of the BMPs installed in the Houston area are permitted by the JTF for commercial/residential developers and industrial facilities. The agencies in the JTF have implemented additional BMPs mostly for flood control purposes. These were specified in the Storm Water Pollution Prevention Plan that was included in the MS4 permit. The JTF releases a report on the progress of meeting the goals of the Storm Water Pollution Prevention Plan annually.

Table 1 contains a list of the numbers and types of BMPs that have been permitted in the Houston area by permitting agency. Harris County and the City of Houston have issued the majority of the permits for commercial, residential, and industrial uses. The locations of BMP with current permits in the Houston metro area are shown in Figure 1. Additional BMPs have been installed for the conveyance of stormwater as described in the MS4 permit. Dry ponds with detention basins are the most numerous of the BMPs permitted by Harris County. These operate through the retention of storm water runoff that is slowly discharged over a 48 hour period following the rainfall event. They function similar to wet basins (also known as wet ponds) which are far less numerous with 55 permitted by the JTF (45 in Harris County and only 9 in the City of Houston). The wet basins detain a permanent pool of water from each runoff event that is meant to be discharged only when replaced by runoff from the subsequent runoff event. Many other types of BMPs including combination basins (also known as dual use and flood control/water quality basins), street sweeping, vegetative filter strips, and grassy swales are currently used and may have an important effect on the bacterial concentrations of storm water runoff entering Texas surface water bodies in Houston. Although Oil/Grit/Trash Separators form

Table 1 - Existing/Permitted BMPs

AGENCY	BEST MANAGEMENT PRACTICES (BMPs)	TYPE	COUNT
Harris County	Dry Basin	Permit	286
	Wet Basin	Permit	45
	Flood Control/Water Quality Basin	Permit	19
	Wetland	Permit	1
	Grass Swale	Permit	12
	Vegetative Filter Strips	Permit	5
	Other	Permit	186
City of Houston	Dry Basin	Permit	166
	Wet Basin	Permit	9
	Flood Control/Water Quality Basin	Permit	1
	Grass Swale	Permit	5
	Vegetative Filter Strips	Permit	2
	Other	Permit	47
	Road sweeping & minimization plans for street maintenance yards	SWMP	75% of yards
	Prevent Illicit discharges and Improper disposal	SWMP	N/A
	Industrial and high risk runoff	SWMP	N/A
	Wet screaning of area served by the MS4	SWMP	50% of total area
	Manhole cleaning, storm sewer cleaning/flushing, repairs and investigations	SWMP	N/A
Harris County Flood Control District (HCFCD)	Wet basins	SWP3	N/A
	Detention basins	SWP3	N/A
	Vegetation/Stabilization of Drainageways	SWMP	>50 miles of drainageways
	Wet Pond Extended Retrofit Sampling	SWMP	If deemed necessary
	Inlet Basket to Surge Basin	SWMP	1
	Maintenance of detention basins and drainage channels	SWMP	N/A
	Monitoring of BMPs for Water Quality	SWMP	N/A
	Trash Skimmer (Boat)	SWMP	1
	Netting overlay (at White Oak Bayou Basin Outfall)	SWMP	1
	Natural trash trap	SWMP	1
	Planted Gabion Wall	SWMP	1
Texas Department of Transportation (TxDOT)	Detention ponds	SWMP	N/A
	Pump stations	SWMP	N/A
	Grassy swales	SWMP	N/A
	Vegetative filter strips	SWMP	N/A
	Public Education Programs (Don't Mess W/ Texas, Adopt-A-Highway, etc.)	SWMP	N/A
Joint Task Force	Public Education Program	SWMP	N/A

Notes:
Permit - BMPs permitted through the JTF for stormwater quality
HCFCD - Harris County Flood Control District
SWMP - Storm Water Management Program from the NPDES Permit
SWP3 - Storm Water Pollution Prevention Plan

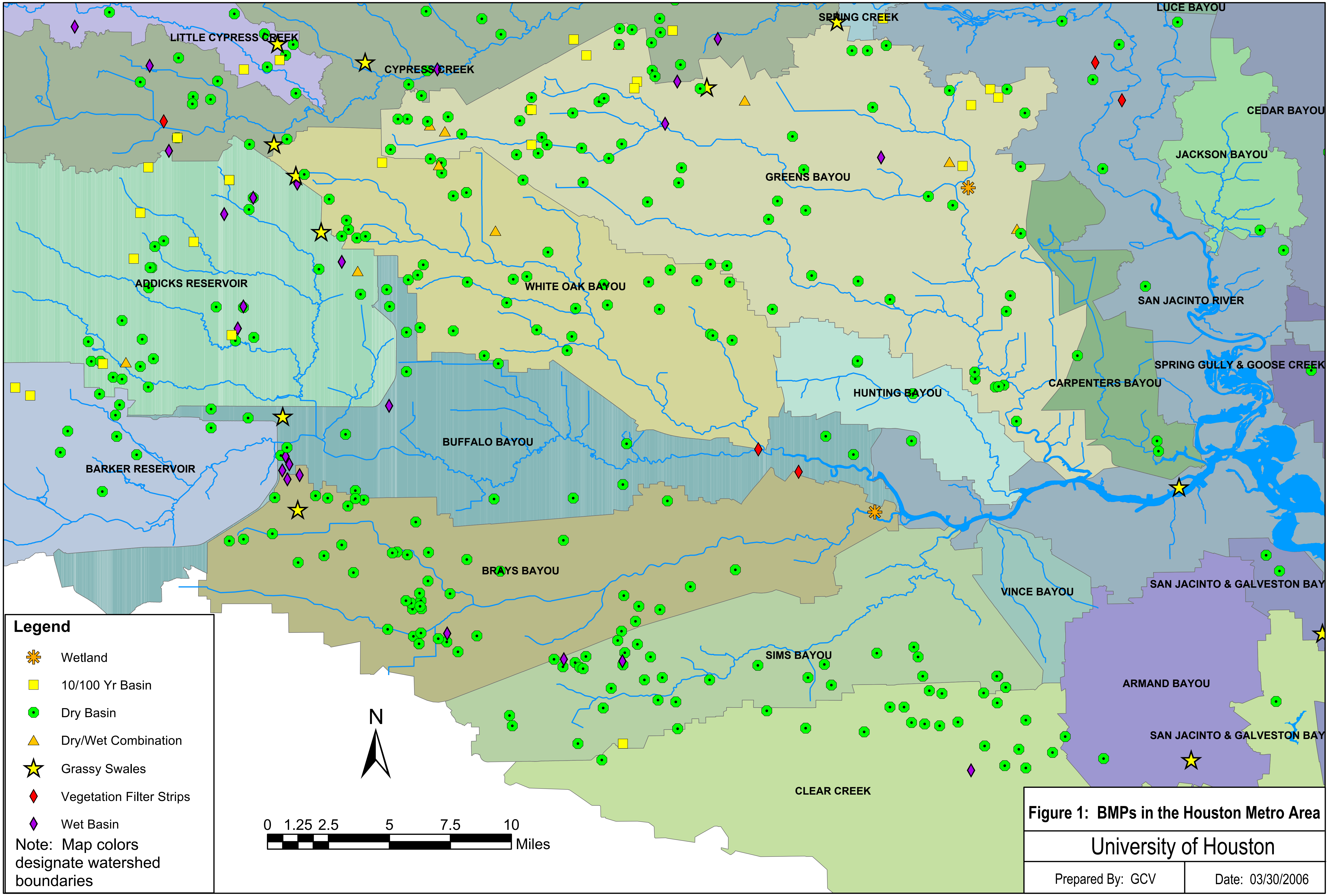

Figure 1: BMPs in the Houston Metro Area

University of Houston

Prepared By: GCV | Date: 03/30/2006

the second most numerous type of BMPs in use, these are believed to have a less pronounced effect on the loads (JTF 2001a). Thus, these have not been chosen for sampling in this project.

The COH, HCFCD, and Harris County prepared the "Storm Water Quality Management Guidance Manual" and the "Minimum Design Criteria for Implementation of Certain Best Management Practices for Storm Water Runoff Treatment Options" for the Houston area. These manuals discuss the types of best management practices approved for use in the Houston region. They contain important information about the design requirements of wet ponds and other BMPs. The manuals also provide important maintenance information, formulas that can be used to design features of the BMPs, and examples of effective BMP designs (JTF 2001a; JTF 2001b).

As discussed previously, studies on the water quality efficiencies of BMPs have predominantly focused on several types: Dry Basins, Wet Basins, Flood Control/Water Quality Basins, Wetlands, Vegetative Filter Strips, and Grassy Swales. To determine those with the greatest potential for reduction of the bacteria concentrations in runoff, a database of studies that have tested efficiencies is currently being developed. Table 2 presents a summary of the results from those studies. The table shows the percent removals for all the different indicators that were tested for each type of BMP and the average percent removal for these. The table also shows the number of BMPs that were tested for each sample type, the minimum number of samples that were collected, and the overall average of the percent removals for each type of BMP (listed as sample type "All").

The highest percent removals of fecal pathogen indicators are observed with the retention of water using a dry basin. It is noted, however, that as of February 2006, data from only one study performed on a dry basin were available. The dry basin tested achieved a reduction of 90% of the bacteria from the inflow. Wetland systems achieved the second highest percent removal of bacteria with 88.3%. Wet basins achieved a 47% removal based on 11 sites. Vegetative filter strips had almost 32% removal. The only grassy swale study found at this time showed a large percent increase of bacteria from the inlet to the outlet of the swale. The concentrations increased by 338% for fecal coliform.

Table 2, as of February, has results from 82 different combinations of wetland systems and indicator types tested. Wetlands were the most studied BMP by far. Studies on wet basins were the second most common.

Table 2: Average Removal Efficiencies for Fecal Pathogen Indicators by BMP Type

BMP Tested	Sample Type	Percent Removal[1]	No of BMPs Tested	Total Samples Collected	Reference
Dry Basin	fecal coliform	90	1	N/A	BMP Database Project [3]
Dry Basin	All[2]	90	1	N/A	N/A
Grassy Swale	fecal coliform	-338	1	5	Dayton Ave Project [4]
Grassy Swale	All[2]	-338	1	5	N/A
Vegetative Filter Strips	*E. coli*	13	6	N/A	Goel, et al.
Vegetative Filter Strips	fecal coliform	54	6	N/A	Goel, et al.
Vegetative Filter Strips	total coliform	28	6	N/A	Goel, et al.
Vegetative Filter Strips	All[2]	32	18	N/A	N/A
Wet Basin	coliphage	40	1	15	Gerba et al.
Wet Basin	*Cryptosporidium*	89	1	15	Gerba et al.
Wet Basin	Enterococci	23	1	20	Davies et al.
Wet Basin	fecal coliform	47	4	102	Gerba et al., Mallin
Wet Basin	*Giardia* cysts	98	1	15	Gerba et al.
Wet Basin	heterotrophic bacteria	22	1	20	Davies et al.
Wet Basin	thermotolerant coliform	-3	1	20	Davies et al.
Wet Basin	total coliform	62	1	15	Gerba et al.
Wet Basin	All[2]	47	11	222	N/A
Wetland	*Clostridium*	97	2	N/A	Stenstrom and Carlander
Wetland	coliphage	86	8	85	de J. Quinonez-Diaz et al., Gerba et al., Karpiscak et al., Stenstrom and Carlander
Wetland	*Cryptosporidium*	90	6	76	de J. Quinonez-Diaz et al., Karpiscak et al.
Wetland	*Cryptosporidium* oocysts	64	2	30	Gerba et al.
Wetland	*E. coli*	99	3	N/A	Stenstrom and Carlander
Wetland	enteric virus	97	5	70	de J. Quinonez-Diaz et al., Karpiscak et al.
Wetland	Enterococci	85	1	20	Davies et al.
Wetland	fecal coliform	93	23	352	de J. Quinonez-Diaz et al., Gerba et al., Khatiwada et al., Neralla et al.
Wetland	fecal enterococci	100	2	N/A	Stenstrom and Carlander
Wetland	*Giardia*	93	6	76	de J. Quinonez-Diaz et al.
Wetland	*Giardia* cysts	81	2	30	Gerba et al.
Wetland	heterotrophic bacteria	87	1	20	Davies et al.
Wetland	sulfite reducing anaerobic sporeformers	83	1	N/A	Stenstrom and Carlander
Wetland	thermotolerant coliform	79	1	20	Davies et al.
Wetland	total coliform	91	19	202	de J. Quinonez-Diaz et al., Gerba et al., Neralla et al.,Stenstrom and Carlander
Wetland	All[2]	88	82	981	N/A

Notes:

N/A - values are not available for this parameter

Data for Flood Control/Water Quality Basins from previous studies was not found

Negative values reflect increase in concentration between influent and effluent

Studies used for analyses are listed in Appendix I

[1] Percent removal was calculated as the average of the percent removals measured at each BMP tested

[2] Percent removal for "All" was calculated as the average for all indicators tested

[3] Data obtained from the International Stormwater Best Management Practices (BMP) Database at http://www.bmpdatabase.org/

[4] From study conducted by the Mississippi Department of Marine Resources -

http://www.dmr.ms.us/CoastalEcology/Storm/APPENDIX-C/Dayton%20Biofilter%20Grass%20Swale.pdf#search='dayton%20biofilter'

CHAPTER 3

FUTURE WORK

During the subsequent quarter (March 1, 2006 through May 31, 2006), the project team will focus on the following tasks:

- Completion and submittal of the Final Sampling Plan and QAPP to the TCEQ;
- Completion of site location and reconnaissance;
- Preparation for field sampling activities and analysis for the selected locations;
- Continue building and refining the databases for BMPs in the Houston metro area and for bacteria removal efficiencies.

REFERENCES

ASCE (2002). National Stormwater Best Management Practices (BMP) Database, http://www.bmpdatabase.org/. American Society of Civil Engineers.

Brookes, J. D., Matthew R. Hipsey, Michael D. Burch, Rudi H. Regel, Leon G. Linden, Christobel M. Ferguson, and Jason P. Antenucci (2005). "Relative Value of Surrogate Indicators for Detecting Pathogens in Lakes and Reservoirs." Environmental Science & Technology **39**(22): 8614-8621.

Characklis, G. W., Mackenzie J. Dilts, Otto D. Simmons III, Christina A. Likirdopulos, Leigh-Anne H. Krometis, Mark D. Sobsey (2005). "Microbial Partitioning to settleable Particles in Stormwater." Water Research **39**: 1773-1782.

Darakas, E. (2001). "E. Coli Kinetics - Effect of Temperature on the Maintenance and Respectively the Decay Phase." Environmental Monitoring and Assessment **78**: 101-110.

Davies, C. M., H.J. Bavor (2000). "The Fate of Stormwater-Associated Bacteria in Constructed Wetland and Water Pollution Control Pond Systems." Journal of Applied Microbiology **89**(2): 349.

De J. Quinonez-Diaz, M., Martin M. Karpiscak, Eric D. Ellman, Charles P. Gerba (2001). "Removal of Pathogenic and Indicator Microorganisms by a Constructed Wetland Receiving Untreated Domestic Wastewater." Journal of Environmental Science and Health **A36**(7): 1311-1320.

Gannon, V. P. J., G.D. Duke, J.E. Thomas, J. VanLeeuwen, J. Byrne, D. Johnson, S.W. Kienzle, J. Little, T. Graham, B. Selinger (2005). "Use of In-stream Reservoirs to Reduce Bacterial Contamination of Rural Watersheds." Science of the Total Environment **348**: 19-31.

Gerba, C. P., J. A. Thurston, J. A. Falabi, P. M. Watt, and M. M. Karpiscak (1999). "Optimization of Artificial Wetland Design for Removal of Indicator Microorganisms and Pathogenic Protozoa." Water Science and Technology **40**(4-5): 363-368.

Goel, P. K., R. P. Rudra, B. Gharabaghi, S. Das, N. Gupta (2004). Pollutants Removal by Vegetative Filter Strips Planted with Different Grasses. 2004 ASAE/CSAE Annual International Meeting. Ottawa, Ontario, Canada.

JTF (2001a). Minimum Design Criteria for Implementation of Certain Best Management Practices for Storm Water Runoff. J. T. F. S. W. Quality.

JTF (2001b). Storm Water Quality Management Guidance Manual. S. W. M. J. T. Force**:** 204.

Karpiscak, M. M., C. P. Gerba, P. M. Watt, K. E. Foster, and J. A. Falabi (1996). "Multi-Species Plant Systems for Wastewater Quality Improvements and Habitat Enhancement." Water Science and Technology **33**(10-11): 231-236.

Khatiwada, N. R., C. Polprasert (1999). "Kinetics of Fecal Coliform Removal in Constructed Wetlands." Water Science and Technology **40**(3): 109-116.

Mallin, M. A., S. H. Ensign, T. L. Wheeler, D. B. Mayes (2002). "Surface Water Quality: Pollutant Removal Efficacy of Three Wet Detention Ponds." Journal of Environmental Quality **31**: 654-660.

Neralla, S., R. W. Weaver, B. J. Lesikar, and R. A. Persyn (2000). "Improvement of domestic wastewater quality by subsurface flow constructed wetlands." Bioresource Technology **75**(2000): 19-25.

Stenstrom, T. A., and A. Carlander (2001). "Occurence and Die-off of Indicator Organisms in the Sediment in Two Constructed Wetlands." Water Science and Technology **44**(11-12): 223-230.

APPENDIX A

QUALITY ASSURANCE PROJECT PLAN

(Electronic)