Bastrop Bayou Watershed Protection Plan

Prepared for the Bastrop Bayou Stakeholders Group by:

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The stakeholders wish to especially thank Commissioner Payne and Congressman Paul for their vision and support that have made this Watershed Protection Plan possible.

Statement of Purpose

The Bastrop Bayou Watershed Protection Plan (Plan) addresses bacteria water quality issues in a predominantly rural watershed that drains into Christmas Bay on the Texas Gulf Coast. While the Bayou and its tributaries are not currently on the State of Texas list of impaired water bodies (2008 303d list), projected future growth patterns and current water quality concerns have led area stakeholders to proactively address these issues. Some localized contamination issues, public health incidences, and projected impairments (draft 2010 303d list) have provided further impetus to act.

The ultimate goal of the Plan is to maintain and improve the water quality of the Bastrop Bayou Watershed (Watershed) through direct intervention by a coalition of local landowners, residents, governments, and local businesses. The measure of these efforts will be to keep bacteria levels under the threshold set by the State's recreational surface water quality standard, preventing the water bodies in the Watershed from appearing on the State of Texas' 303d list of impaired waterways. The Plan will guide the implementation of a suite of structural and behavioral management measures designed to identify, evaluate, prioritize and remediate or prevent the causes and sources of bacterial contamination in the Watershed.

The specific purposes of the Bastrop Bayou WPP are to promote stakeholder awareness of water quality issues in the Watershed, develop a comprehensive, stakeholder-led plan to address bacterial contamination from a variety of sources, guide the implementation of a cost-effective set of management measures to achieve the desired results, and obtain community commitment to ongoing management of their water resources. Towards this end, the WPP contains a design and implementation plan with structural and non-structural corrective measures to improve water quality, as well as a focus on integrated Community involvement. H-GAC, as guided by the Watershed stakeholders, has prepared this Plan in accordance with guidance for Watershed Protection Plans issued by the U.S. EPA.

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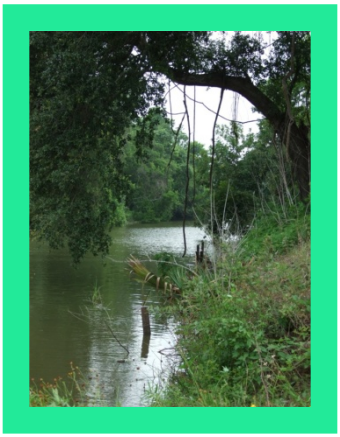

Located along the Texas Gulf Coast fifty miles south of Houston, Bastrop Bayou is a popular recreational destination for water skiers, boaters, anglers and birders in Brazoria County. Water from the Bastrop Bayou Watershed eventually makes its way to Christmas Bay, a pristine coastal estuary that is home to innumerable wildlife species and some of the last remaining sea grass beds along the upper Gulf Coast.

Much of the land in the Bastrop Bayou Watershed (the land area that drains to the Bayou and its tributaries) is currently used for agriculture (rice farming, cattle grazing and aquaculture), while its residents typically live in small cities and towns (Angleton, Danbury, Richwood, Demi-John, etc.), rural subdivisions, or homes along the Bayou.

Growing Concerns

Although much of the Watershed is currently rural, forecasted population growth for the region indicates that urban areas within and immediately adjacent to the Watershed will undergo substantial growth over the next twenty-five years. In addition to local growth, the Houston-Galveston Area Council (H-GAC) projects that the Houston metro area will add more that 3.5 million people by 2035. The number of households in Brazoria County alone will increase by 50 percent. These patterns of local and regional growth promise to exert increased pressure on natural resources, potentially endangering the Watershed unless measures are implemented in the mean time.

During the spring of 2004, residents in the Watershed began voicing concerns about existing and developing threats including land application of sludge, malfunctioning on-site sewage facilities (OSSFs, or septic systems), illegal dumping, and contamination from storm water discharges. The residents were specifically concerned with bacteria, turbidity, pesticide, and nutrient loading from these activities in Bastrop Bayou and Christmas Bay – and how these may adversely affect public health, natural resources and local economies. The importance of the WPP became especially apparent in early 2009 when the first indigenous case of cholera in the U.S. since 2004 was identified in the small Watershed community of Demi-John. Cholera is most often found in the developing world due to contact with untreated sewage. In this case,

contact with water contaminated by a large number of malfunctioning OSSFs was the cause of the infection, driving home the necessity for the WPP and efforts to restore and protect water quality in the Watershed.

Response

To address these complaints, and in an effort to quantify the water quality impacts within the Bastrop Bayou Watershed, the Galveston Bay Estuary Program (GBEP), H-GAC and the Texas Clean Rivers Program (CRP) conducted a Watershed Risk Assessment during the fall of 2004. As a result of the Risk Assessment, a **Watershed Protection Plan (WPP)** process began in the fall of 2006. WPPs are stakeholder-led efforts designed to identify, analyze, and attempt to remediate water quality issues in a watershed.

These voluntary plans are based on Nine Key Elements identified by the EPA in their guidance for developing WPPs. These elements guide community members through the process of assessing the condition of the Watershed, and then devising a plan and schedule for implementing solutions to water quality concerns. The purpose of the WPP is to serve as a comprehensive approach to water quality based on the "watershed approach" of focusing on the land uses of the area, and their impact on water bodies (a more detailed explanation of the Nine Key Elements is found in the following section).

The cumulative goal of these elements is to produce a comprehensive assessment of the Watershed, employ a practical site-specific approach to implementing best management practices (BMPs), encourage policy change at the local and county levels, offer sustainable funding options for watershed protection planning, and to increase the public awareness of environmental stewardship concerns. (Refer to Table 1 for further detail on these elements in the Bastrop Bayou WPP)

Potential Sources

Water quality monitoring undertaken as part of this WPP process indicated that Bastrop Bayou and its main tributaries did not yet contain elevated concentrations of bacteria that exceeded the State of Texas standards for contact recreation[1]. However, several potential sources of bacteria are present within the Watershed, including:

- Urban runoff
- Malfunctioning OSSFs
- Agricultural / ranching operations
- Wildlife
- Migratory bird flyways
- Pets

[1] The current list of impaired waterways maintained by the TCEQ indicates no segment in the Bastrop Bayou watershed is impaired for contact recreation. However, it is expected that one or more segments may be listed as impaired when the 2010 list is approved.

- Wastewater treatment operations

Modeling of source contributions indicated urban runoff, agricultural operations, and malfunctioning OSSFs were the primary sources of bacterial contamination, each representing a third of contributed bacteria in 2008, with malfunctioning OSSFs growing to represent 48% of the total loading by 2040, absent any additional controls or efforts. Contributions from cattle ranching (the predominant source of agricultural bacteria in the Watershed) are expected to diminish by 2040, due to increasing development pressure, but remain a significant portion of the overall loadings (16%).

Engaging Local Stakeholders

The development of the WPP resulted from the formation of an engaged local stakeholder group comprised of local homeowners, cattle ranchers, rice farmers, elected municipal officials, County Health District and Environmental Enforcement representatives and Watershed residents. The stakeholder group provided valuable input regarding local drainage features, potential sources of pollution, recreational uses, public access locations and effective approaches to educating local residents and Watershed visitors. H-GAC has worked closely with the stakeholder group to develop a WPP that identifies not only the current threats to the Bayou but a phased and feasible implementation strategy to current sources and help prevent or reduce contamination resulting from future growth.

Developing Solutions

After reviewing the preliminary modeling results, the stakeholders selected a suite of appropriate projects to mitigate these concerns. The projects are designed to meet contamination reduction targets that are based on projections of future growth, derived from current growth patterns. As these implementation costs for the initially selected measures exceeded the currently available funding, the stakeholders prioritized the most important projects to implement first. Cost and time necessary to complete the project were the primary concerns during project selection. Since urban runoff and future growth are the biggest threats to the Bayou, the stakeholders emphasized education and outreach-based implementation projects to avert or reduce contamination by targeting contributing behaviors. Relying solely on retroactive approaches like storm water detention and constructed wetlands would cure only the symptoms of urbanization. However, to address other sources, the stakeholders proposed a mix of educational and structural projects.

Voluntary solutions identified during this project include:

- Community waterway cleanup events
- Increased enforcement of applicable laws and standards (for OSSFs, illegal dumping, etc)
- Implementation of stream fencing, alternative watering sources for cattle and other agricultural BMPs
- Targeted education and outreach activities for Watershed residents, decision-makers, and visitors.

- Promoting and implementing constructed wetlands and stormwater detention basins
- Promoting and implementing green infrastructure through pilot/demonstration projects
- Implementing a Watershed signage project (watershed boundaries and illegal dumping)
- Facilitating acquisition of buffer areas, conservation easements, or other land conservation projects
- Promoting sanitary sewer systems in place of OSSFs, and/or addressing failing OSSFs through education or remediation, specifically in the Demi-John community.
- Improvement of municipal and Home Owner Association ordinances (for pet waste, OSSFs, green infrastructure, etc.)
- Implement pet waste management education and pet waste stations
- Ongoing water quality monitoring to evaluate water quality impacts

Implementation

In addition to devising this set of BMPs to address the water quality concerns of the Watershed, the stakeholders also constructed a plan and timeline for implementing the projects. The starting timeframe of the schedule for implementing these projects is based on obtaining approval of the WPP from the TCEQ and EPA. Once these approvals have been granted, the plan calls for a phased implementation of the projects over several years. The projects will be implemented by stakeholders and partners. The SAG intends to pursue additional grant funding to help facilitate or fund some projects. The general approach is designed to be collaborative. The schedule for these projects, as discussed in greater detail in the WPP, is expected to begin in 2011, with many educational and pilot projects kicking off concurrently. Ongoing and long-term projects, like development of large-scale stormwater detention capacity, will continue throughout the planning horizon. Most intermediate projects are expected to occur within the next 5 years, as funding is available.

Future Steps

From the inception of work in Bastrop Bayou in 2004 as a result of citizen concerns, through thirty-four public meetings, the stakeholders have worked hard to determine the sources and causes of pollution and select the projects to mitigate those concerns. The completion of this WPP allows the stakeholders to be very competitive in obtaining additional funds from private foundations and government agencies; funds that will be crucial in solving the water quality concerns in Bastrop Bayou. The stakeholders are currently discussing the best ways to carry out implementation projects outlined in the WPP. H-GAC will continue to provide data resources as well as technical assistance while the CRP will continue water quality monitoring of the Bayou. Additionally, the Plan allows a clear and decisive way to communicate with elected officials about the water quality priorities within the community. Perhaps the greatest accomplishment is the consensus that the stakeholders have reached in addressing the water quality concerns raised in 2004. The completion of the WPP is truly a beginning for the Bastrop Bayou Watershed, rather than an end in itself.

Nine Element Summary Matrix

The Bastrop Bayou Watershed Protection Plan incorporates the EPA's Nine Elements of a Watershed Protection Plan (Watershed-Based Plan). These elements help guide the process and ensure that the end product considers all the various aspects of a wide-scale watershed approach to addressing water quality concerns. The Nine Elements are:

1. Identify the sources and causes of pollution
2. Estimate the necessary load reductions
3. Describe Point Source and Nonpoint source management measures
4. Assess the technical and financial assistance needed
5. Design an informational/ educational component
6. Develop a schedule of implementation
7. Set interim measurable milestones for progress
8. Establish criteria to determine load reductions
9. Create a monitoring component

The aspects of this WPP that relate to each element are summarized and referenced in Table 1, which also serves as a roadmap to the WPP document and summary of the proposed solutions.

Table 1: Nine Element Summary Matrix

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 17-38)	**Estimated Potential Load Reduction** (Section 4, pp. 39-48)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 49-55)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 56-61)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 64-68)	**Schedule of Implementation for Each Measure** (Section 8, pp. 69-72)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 73-77)	**Indicators to Measure Progress** (Section 10, pp. 78, Section 9 pp. 73-77)	**Monitoring Component** (Section 11, pp. 79-84)	**Responsible Entity** (Sections 3,5, 6 and 8)
Urban Runoff	3% for this category in total.	Develop Small Scale Green Infrastructure (LID) pilot projects to include pervious pavement projects, green roof projects, and/or rain gardens at the Angleton Courthouse complex and elsewhere.	$575,000 for initial projects, additional projects as funding is available.	Education for municipal decision-makers, contractors and property managers on green infrastructure construction and maintenance, individual meetings	Begin pilot projects 2012, watershed-wide implementation begins 2013	Complete pilot projects, and evaluate watershed-wide deployment	Reduction in runoff-related bacteria, nutrients, and general pollutant loading concentrations watershed wide	Monitor BMP during pilot project; routine watershed monitoring for watershed-wide deployment	Cities and County
	3% for this category in total.	Develop Large Scale BMP's to include Stormwater Detention Ponds, new large Wetland Detention areas, and/or swales	7.7 million, as provided by partners.	Individual meetings for cities, contractors and property managers on large scale projects.	Begin pilot projects 2012, watershed-wide implementation begins 2013	Complete pilot projects, and evaluate watershed-wide deployment	Reduction in run off-related nutrient loading and flooding	Monitor BMP during pilot project; routine watershed monitoring for watershed-wide deployment	County, Cities, other drainage agencies.
	(Part of 2% of education)	Provide Watershed and illegal dumping signs (and illegal dumping hotline)for existing access points to Bastrop Bayou and its tributaries	$25,000	Signs and promotional materials	Beginning 2011	Signage designed, Signage installed, hotline set up.	Reduction in runoff-related bacteria concentrations watershed-side as well as reduction of litter and trash	Routine watershed monitoring	Cities, County

	3% for this category in total.	Land Acquisition assistance, for buffer strips and set asides	$10,000 for initial property, additional properties considered as funding available.	Promotional materials, individual meetings with partner agencies	Beginning 2011	Property identified, appraisal (etc.) needs defined, Appraisal (etc.) completed, property purchased.	Reduction in runoff-related bacteria concentrations watershed-side as well as reduction of litter and trash	Routine watershed monitoring	USFW

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OSSFs	4% (for this category in total)	Evaluation and Remediation of failing OSSFs	To be determined by results of Brazoria Health District, OSSF evaluations	Develop community training model, promotional materials, meeting with partner agencies	Evaluations ongoing (2010), remediation efforts starting 2011.	Number of failures located, number repaired.	Reduction in base flow-related bacteria concentrations	Routine Watershed monitoring	Brazoria County Health District, County, OSSF owners
	4% (for this category in total, 80-100% locally in Demi-John)	Support Demi-John sanitary sewer conversion	Staff time in supporting grant application, cost of conversion provided by partners.	Meeting with local and granting agencies, written support	2011-onward	Grant/funding approved, Construction initiated, construction completed, service begun.	Number of houses connected	With connection to WWTP there will be zero bacterial loading from the community	Brazoria County Fresh Water Supply district #2

	4% (for this category in total)	Develop model Home Owner Association by-laws for new communities. Request existing communities adopt HOA changes.	$5,000 for development and promotion, additional incentives provided by partners.	Onsite technical assistance provided to community. promotional materials and maintenance on OSSF Maintenance	Beginning 2011-2012 for development, implementation on-going	Bylaws/ ordinances developed, promoted.	Number of households with regular maintenance contracts for OSSFs	Routine Watershed monitoring	Individual Communities
	4% (for this category in total)	Evaluate/ Enhance OSSF Design Criteria	(provided by partners)	Meetings with partners (County and municipalities)	Beginning in 2011	Meetings with partner agencies held	Design Criteria evaluated	Routine Watershed monitoring	Brazoria County, Cities

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Cattle and Wildlife	7% (for this category in total)	Voluntary cattle management improvements including stream fencing and alternative water supplies. Provide incentives for the above-mentioned BMP's.	$40,000 for farmer incentives (shared with Additional Animal Waste BMP measures, additional incentives provided by participants and partner agencies)	Agrilife Extension seminars, TSSWCB seminars, Texas Stream Team, meeting with individual landowners	Begin 2011	Meetings with ranchers held, Plans for improvements made, Improvements made.	Number of landowners who adopt the management plans. The plans are legally enforceable by the TSSWCB	Routine monitoring	TSSWCB and Agrilife Extension

	7% (for this category in total) (Part of 2% for education)	Additional Animal Waste BMP's: Vegetated buffer strips to trap nutrient runoff, etc.	$40,000 for Farmer incentives (shared with Voluntary cattle programs), with additional incentives provided by partners	Promotional materials, Conduct workshops and technical assistance, On-site visits, in conjunction with partner agency efforts	To be developed, printed, and mailed in 2011, farmer incentives to begin in 2011	Meetings with landowners held, Plans for improvements made, Improvements implemented.	Reduction in base flow-related bacteria concentrations	Water Quality Monitoring – determine if there has been any reduction in fecal bacteria levels; on-site visits	TSSWCB Brazoria County Health District & Cities
	7% (for this category in total)	Feral Hog hunter training	$1000 for training class and event	Promotional materials, class(es)	Beginning in 2012	Development of curriculum	Training held	Routine Monitoring	Brazoria County, Cities

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
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Pet Waste	2% for this category in total	Pet Waste Disposal Stations in public areas (parks), with signage	$22,050 for stations, $10,000 for signage and promotional materials.	Promotional materials, school programs, signage, meetings with partners	2011 - 2013	Sites designated, Sites installed, signage installed and promoted.	Determine amount of pet waste occurring	Annual Monitoring of Parks and Pet Dispensers	City & County Parks Departments
	2% for this category in total	Improved HOA bylaws and model ordinances	$5,000 for printing of brochures	Promotional materials, meetings with partner agencies, school programs	Begin 2011 until 2012	Bylaws/ ordinances developed, promoted and presented,	Numbers of HOA who adopt the measures	Routine monitoring	Individual Communities
	2% for this category in total (part of 2% for education)	Increase awareness and enforcement of pet control ordinances	$5,000 for on-going public presentations, a brochure, and sign, additional funding provided by partners.	Public awareness and education by DBWP, Parks and Wildlife, Master Naturalist Program, and others.	Ongoing, starting in 2011	Enforcement levels evaluated, educational materials created and disseminated, public education conducted	Reduction in runoff-related bacteria concentrations Bayou-wide	Routine Watershed-wide monitoring	Cities and County

Notes on Table 1:

For the purposes of creating the Nine Element Summary Table, only those sources addressing the primary contaminant of concern (bacterial contamination) and those resulting in estimated load reductions are included.

Therefore, management measures related to trash (Illegal dumping/trash) are not included, nor are sources for which no specific measurable solutions are proposed (wildlife other than feral hogs, WWTPs, etc.) Additional measures not specific to a given source (enforcement capacity increases, abandoned boats, etc.) are not included here.

The education component measures (Project WET and WILD, etc.) discussed in Section 7 and are not referred to as separate measures in this table, but as the educational backing discussed in column e.

Additional detail reagrding all sources, educational components and management measures not specific to reducing bacteria, can be found in Sections 3, 4, 5, 6, 7, and 8.

1 Introduction

This Plan seeks to apply watershed management techniques to improve and sustain the water quality of Bastrop Bayou and its tributaries, and find practical and achievable solution for promoting land uses, technologies, practices, and behaviors in its Watershed that help achieve that goal. This section will provide background detail on the nature of the Plan and the principles in which it is based. More detailed information about the Watershed itself is found in Section 2.

1.1 Watersheds

A watershed is the area of land that sheds water to a given water body. When rain falls, a portion of it runs off the land to fill our creeks, streams, bayous, rivers and lakes. Where that water flows is based on the topography, or varying elevation, of the land around it. Therefore, the area that makes up a watershed is all the land whose precipitation flows into a common waterway, either directly or through small waterways that contribute to it (tributaries). “Watershed” is a general term that is applied to areas ranging from the large drainage basins of major rivers to the land that drains into small local creeks. In either case, the sum of the activities that take place on that land area has an impact on water quality. As water flows over the surface, it carries with it traces of everything that happens on the land, impacting the water quality in the receiving water bodies. The use of the land can also affect the volume and rate of the water entering the waterway. Because the land around the waterway can have a dramatic impact on water quality, what happens on that land plays an integral role in the health of the watershed.

Figure 1: Land Use in the Bastrop Bayou Watershed

1.2 Watershed Management

Watershed management is the name given to the application of efforts designed to improve and protect the health of waterways by addressing the causes and sources of pollution in the land that surrounds them. Because all of the land in a watershed can potentially impact a waterway, watershed management techniques approach water quality management from a regional, holistic perspective. There are two primary types of pollution in watershed: point source pollution and nonpoint source pollution.

> *Point source pollution* is any source of contamination that issues from a discrete, identifiable outfall or conveyance. Examples include discharge pipes from industries, outfalls from wastewater treatment facilities, or directly piped discharges of human sewage. Most of these sources are regulated by a variety of state and federal laws and programs, and most require a permit with a stringent set of requirements.
>
> *Nonpoint source pollution* is essentially all contamination that does not derive from a point source. In a watershed this term refers to contamination that is carried by rain as it flows across the surface, picking up the byproducts of the activities that occur on the land. Nonpoint source pollution does not come from a single, specific place or type of source, making it harder to identify, evaluate and regulate. Examples include animal waste from agricultural fields, malfunctioning OSSFs, and bacteria-contaminated runoff from urban areas.

Because point sources are often already under the jurisdiction of government programs and laws, addressing nonpoint source concerns is the primary purpose of watershed management approaches and this WPP. While there are a wide range of potential contaminants involved in watershed management, this WPP focuses on bacteria as the predominant contaminant of concern.

1.3 Watershed Protection Planning

While there are a variety of ways in which watershed management techniques may be employed in a watershed, Watershed Protection Plans offer a comprehensive solution based on local leadership, voluntary measures and effective monitoring and assessment of successes.

A *Watershed Protection Plan* (WPP) is a document based on the Nine Key Elements of watershed-based plans, as set forth by the United States Environmental Protection Agency (EPA). The document serves as a catalyst for engaging local stakeholders to identify water quality concerns, evaluate the potential causes and sources of pollution, estimate what needs to be done to address them, develop a suite of management measures to achieve their goals, and then implement and evaluate those measures. While similar watershed-based regulatory efforts (Total Maximum Daily Load

Implementation Plans, etc) often address single pollutants, a WPP attempts to balance all concerns within a watershed, with the goal of obtaining a locally-led and perpetuated stewardship for the water body it addresses.

To achieve this approach, a WPP must address both the physical aspects of contamination in a watershed (through structural projects like detention basins, agricultural BMPs, etc) and the patterns of behavior (through behavioral programs like education, promotion of change of activities/land uses, etc.) that can affect watershed health. Regardless of the specific solutions proposed under a WPP, a strong public education and outreach component is essential to engaging and involving the public, and is a key strength of the WPP approach.

1.4 Watershed Protection Planning for Bastrop Bayou

While there is growing concern over water quality in the Watershed, the level of contamination has not yet triggered a mandatory regulatory response (in the form of a TMDL study) to address water quality impairments. To prevent the Watershed from reaching the point at which that process is necessary, local stakeholders chose to use the WPP model to proactively address their water quality concerns in the Bayou. That decision lead to the formation of a Stakeholder Advisory Group (SAG) and the completion of this Bastrop Bayou WPP. Bacterial contamination was chosen as the focus of the WPP, given its potential to cause impairments in the water bodies within the Watershed.

1.5 The Bastrop Bayou Watershed Protection Plan

This document is the culmination of the efforts undertaken by the Watershed's stakeholders over a six year period. It is intended to serve as a road map to achieving their goals, and is laid out in accordance with the EPA's Nine Key Elements. The Watershed is characterized (Section 2), the causes and sources of its pollutants are identified (Section 3), and reductions in loadings to meet water quality goals are estimated (Section 4). A suite of management measures is developed to implement the reductions (Section 5) and the technical and financial resources necessary to implement these changes are quantified (Section 6). An outreach component (Section 7) is devised and an implementation schedule (Section 8) is delineated. Finally, milestones for measuring the progress of these efforts are determined (Section 9), criteria for measuring reductions on contamination loadings are established (Section 10), and the effectiveness of the prescribed approach is monitored (Section 11). In the end, the Plan offers some brief final words as we look toward the future and the next steps of this endeavor (Section 12).

2 The Bastrop Bayou Watershed

The Bastrop Bayou Watershed (Watershed) is located entirely within Brazoria County, Texas, in the Upper Gulf Coast Region. It is a popular recreational water body, and its Watershed is primarily rural and agricultural in character. The Watershed is composed of the land draining to Bastrop Bayou and its tributaries.

2.1 Major Population Centers

There are two large population centers in the Watershed, Angleton, the Brazoria County seat, and Lake Jackson. The Town of Angleton was founded in 1890 near the center of Brazoria County and hosts many events that draw people from the surrounding area to the Watershed, including Texas's largest county fair. Angleton is entirely located within the Bastrop Bayou Watershed.

Lake Jackson is located in the southwestern part of the Watershed. Named after an oxbow lake of the same name on the edge of town, the city was built in the early 1940s as a planned community in support of a Dow Chemical Company plant, and was incorporated March 14, 1944. Only the top section of Lake Jackson is contained within the Watershed. Lake Jackson remains a popular regional center for recreation, owing to its proximity to Freeport and the Gulf of Mexico, among other local destinations.

While both cities have been in existence for some time, they have seen continued outward expansion and infill in recent decades. It is expected that this trend, as indicated in regional growth forecasts, will continue. Both locations are popular jumping-off points for recreation in and around Bastrop Bayou.

2.2 Land use

Much of the area is rural. Ranching and rotation farming comprise the majority of the area by land use. The two major population centers, Angleton and Lake Jackson, comprise the majority of the urbanized development in the Watershed. An appreciable area of the southeast area of the Watershed is within the Brazoria National Wildlife Refuge, and therefore subject to US Fish and Wildlife Service regulation. Small pockets of development are found throughout the Watershed, with many small developments or rows of single houses located alongside Bastrop Bayou itself. Further detail and description of land use in the Watershed is provided in **Appendix A**. While this characterization describes the current conditions, forecasted regional growth predicts a decrease in agricultural and undeveloped areas, and an increase in suburban and urban development.

2.3 Demographic Data

According to the 2000 census there are approximately 18,000 residents in Angleton. The racial makeup of Angleton is 63.21% White, 23.19% Hispanic or Latino, 11.38% African American, 0.47% Native American, 1.12% Asian, 0.04% Pacific Islander, 9.63% from other races. There are approximately 28,000 residents in Lake Jackson. The racial makeup of Lake Jackson is 86.24% White, 3.88% African American, 0.39% Native American, 2.50% Asian, 0.02% Pacific Islander, and 5.19% from other races. The population in surrounding areas generally mirrors these constituencies.

2.4 Wildlife and Vegetation

The Watershed is home to many of the characteristic flora and fauna species of the Gulf Coast, including a large variety of shorebirds, wading birds and marsh-dwelling species. Additionally, the area is at the head of the Central Migratory Flyway through which pour innumerable migratory species several times a year, greatly increasing the volume of birds in the area. The area is primarily dominated by coastal vegetation, including sea grasses in bays and along lower reaches of waterways, and characteristic trees like southern live oak. The undeveloped habitat of much of the Watershed, especially in the estuarine environments of its coastal areas, is crucial in supporting large populations of indigenous and wintering waterfowl and other bird species. Invasive species, including feral hogs and some species of invasive plants, have become an issue for some areas of the Watershed, and are contributors to the bacteria issues.

2.5 Water Bodies

The main stem of Bastrop Bayou runs west to east and is tidally influenced. The tributaries (Flores, Austin and Brushy Bayous) are fresh water and run north to south. The water from the Bayou drains into Christmas Bay and associated coastal estuaries.

For an overview of the Watershed and its tributaries, please refer to Figure 2 and the maps in **Appendix A**.

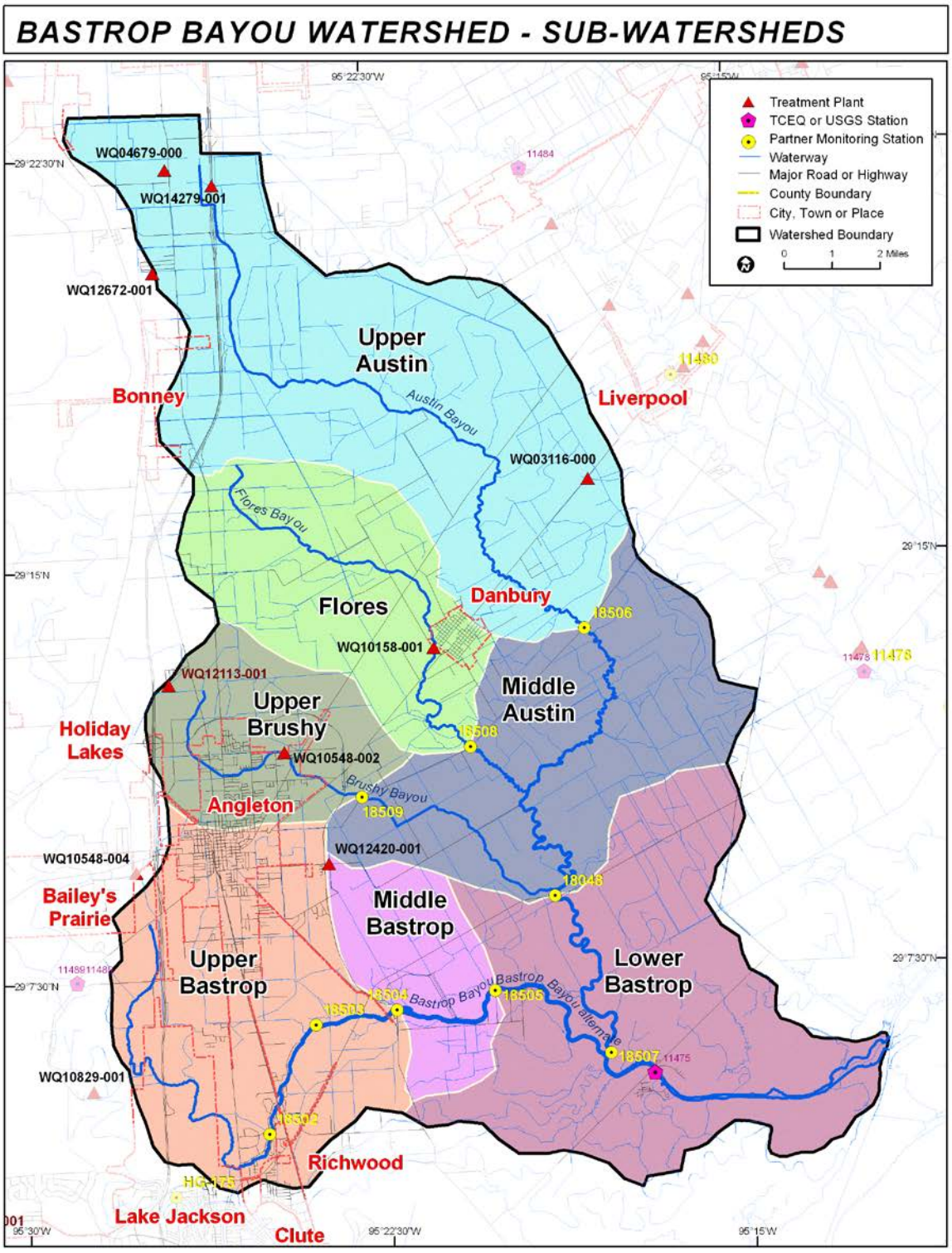

Figure 2: Bastrop Bayou, its Subwatersheds, and Monitoring Locations

3 Causes and Sources of Pollution Element A

Ambient water quality monitoring began for the Watershed in August 2004 under the Clean Rivers Program and continues to this day. The Risk Assessment (HGAC, 2005) used ambient water quality monitoring data and population forecasts to provide preliminary identification of the sources and causes of pollution. Stakeholders then gave input that was used to rank and prioritize these causes and sources.

3.1 Sources & Causes

Population growth will place increased pressure on the Bastrop Bayou Watershed, including urban growth within the cities of Angleton and Lake Jackson, residential growth in unincorporated areas (especially along the banks of Bastrop Bayou and its tributaries), and regional growth which increases the number of people using the Bayou for recreation. Current water quality data, the risk assessment report, population forecasts and field reconnaissance were used to assess the potential sources of contamination.

Sources for Bacteria, Nutrients and Other Pollutants
The focus of the WPP is on reducing bacteria from various sources to prevent bacterial impairments of water bodies in the Watershed. However, many pollutant sources contribute both E. coli and nutrients. In most cases, identification and management of bacteria sources will also reduce nutrient contributions, particularly when sources include human and animal waste. However, some land use and management practices, such as crop production and lawn/landscape fertilization, only affect nutrient loading and will need to be managed separately from control measures intended to reduce bacteria pollution. The primary categories of sources addressed under this WPP are WWTPs, OSSFs, agriculture (livestock/cattle), domestic animals, and urban runoff.

Figure 3: Cattle in Bastrop Bayou

Rank & Priority

The Watershed's stakeholder group identified and prioritized potential point and nonpoint sources of pollutants. As a result of public meetings, risk assessment report, a University of Houston – Clear Lake survey of the Watershed, and the monitoring data, the stakeholders have prioritized sources and ranked the BMP's in the following order. (This preliminary assessment was made prior to the subsequent modeling exercises.) BMPs mentioned in this section are discussed more fully in Section 5.

1. Agriculture and Wildlife – Cattle makes up a substantial portion of Agricultural sources in the Watershed. Based on the potential impact of this source, and the existence of feasible BMPs and programs available to deal with it, this was chosen as a priority source. While Wildlife was not chosen to be addressed through direct implementation actions, an educational component and potential partnership opportunities were suggested by the stakeholders. Suggested BMPs included:
    a. Implementing livestock management plans that prevent cattle from directly accessing Bastrop Bayou, its tributaries and associated canals.
    b. Water Quality Management Plans for agricultural producers through the Soil and Water Conservation District.
    c. Promoting these opportunities through public outreach and education.
    d. Promoting feral hog management and hunting.

2. OSSFs – The Watershed contains many aging OSSFs that can exhibit high failure rates, depending on their age. With many communities developed along the Bayous of the Watershed, failing OSSFs are a potentially large future source of contamination. While the individual nature of OSSFs might make addressing them daunting, they are an element over which there is existing regulatory control and existing remediation options. Potential means of addressing this

source include:

a. Developing and implementing a Watershed or County-wide program to prioritize the removal and replacement of malfunctioning OSSFs.
b. Enhancing Brazoria County's design criteria for OSSFs, including establishing guidelines for shared OSSFs within subdivisions and RV parks where soil conditions and lot size may preclude effective use of individual systems.
c. Promoting sanitary sewer in new or retrofitted development.
d. Providing education to local residents, including model HOA bylaws.

3. Illegal Dumping/Trash – Stakeholders felt that while litter was not necessarily a direct source of bacteria or nutrients, reducing it in the waterways would establish good stewardship principals and allow for increased community education. Suggested BMPs include:
    a. Developing volunteer-based community clean up events to reduce trash, litter along local waterways.
    b. Educating the public about the adverse impact of nonpoint source pollution.
    c. Providing signage, a hotline, and educational support to reduce illegal dumping.
    d. Identifying and removing existing dumping sites.

4. Urban Runoff – While the majority of the watershed is rural in character, its urban areas contribute denser amounts of nonpoint source pollution related to greater impervious areas. Bacteria come from domestic pets and other human activities in urban areas, and are carried through stormwater runoff. With development slated to continue in these areas, the stakeholders designated them as an important source of bacteria. While often not direct sources of bacteria, the stakeholders felt that runoff from Construction sites, which is often heavy with sediment, trash and other constituents, represented a compounding factor for bacteria as well as being an issue in its own right for the waterways. They suggested that these sources be addressed by:
    a. Promoting the use of urban low impact development (LID)-type BMPs that reduce runoff in urban and residential areas. Examples include vegetated swales, filter strips, pervious surfaces, large-scale stormwater detention, and education for decision-makers and residents.
    b. Implementing green infrastructure/LID pilot projects.
    c. Promoting, through education, residential BMPs focused on reduced nutrients from yard care and reduced bacteria from domestic pets, including model HOA bylaws.
    d. Developing and implementing pet waste stations in public areas.
    e. Promoting the use of BMPs that reduce sediment, trash and debris loading during the construction of new residential and commercial development, including sediment barriers and other measures.

5. Land Acquisition – Just as impervious surfaces in urban areas serve to quickly transport contaminated stormwater into waterways, open, vegetated spaces help filter stormwater, slow water velocities, and reduce overall loadings, especially when they are located in riparian corridors. They also serve to foster the unique wildlife resources of the Watershed by providing valuable habitat. This is not a direct source of bacteria in and of itself, but preservation of open spaces and riparian buffers helps reduce bacteria inputs to streams through filtration. BMPS to address this source include:
    a. Acquisition of land to protect valuable habitat and water quality.
    b. Promotion of riparian buffers in new development.
    c. Support of conservation easements in the watershed.

6. Boater discharge – Bastrop Bayou is a popular recreational destination, and while contributions from boaters are not a large source of bacterial contamination, stakeholders felt it was important to encourage responsible handling of boater sewage, fish scraps and trash (though they did not advocate for further pursuit of this source in this WPP). Existing BMPs to address these issues include:
    a. Recognize the importance of responsible boating as promoted through the Texas Clean Boaters and Texas Clean Marinas programs (these are existing programs, rather than management measures to be undertaken as part of this Plan.)

Underlying all these efforts, while not part of the ranking prioritization itself, is a robust public education and outreach program, including items like printed materials, presentations, surveys and other events.

Subsequent to this ranking and prioritization exercise, the stakeholders discussed and formulated a data analysis approach to further quantify the extent of loadings from each source. Ambient water quality data from the Clean Rivers Program was used as the basis for the modeling conducted by the H-GAC and its subcontractors.

3.2 Modeling Approach

Modeling Overview

The progression of steps in the WPP process include quantification of sources, modeling of existing conditions, and the definition of reduction activities that will bring an impaired stream into compliance with state water quality standards (USEPA, 1999). If a stream segment does not support its designated use for a given contaminant it is listed as impaired on the Texas list of impaired waterways (referred to as the 303(d) list). In Texas sixty-one percent of the stream segments listed on the 303(d) list are impaired due to pathogens (TCEQ, 2005). E. coli is used as the indicator organism for pathogens from fecal contamination (USEPA, 1986). The Texas Commission on Environmental Quality (TCEQ) sets an E. coli limit of a geometric mean of 126 cfu/100

mL or a single grab sample of 394 cfu/100 mL (TCEQ, 2004). As bacteria is the focus of this WPP, the modeling efforts centered on this indicator.

For the regulatory Total Maximum Daily Load (TMDL) process addressing pathogen contamination, the EPA published recommendations to assess E. coli source contribution & identification, characterize the sources and estimate the E. coli load produced by each source (USEPA, 2001). The EPA document recommends identification of the location and densities of E. coli contributing source populations to characterize the loads in a watershed. The same process is used for the modeling in Bastrop Bayou.

The EPA recommends characterizing nonpoint sources by multiplying an individual species' excretion rate by corresponding species' population (USEPA, 2001). Then the estimates of nonpoint sources are combined with calculated point source contributions. Previous efforts have automated this non-spatial methodology using a spreadsheet program by dividing the watershed into smaller management units or subwatersheds (Zeckoski et al., 2005). Direct stream monitoring methods, such as ribotyping, use genetic testing to find the sources of the bacteria (Carson et al. 2001; Ahmed et al. 2005). Load duration curves identify the flow rates at which the water body's standards are most often exceeded, and therefore whether sources associated with low flow or with storm-driven flow are more critical. This method uses direct monitoring data of the stream flow and bacterial concentrations (Cleland, 2002; Bonta and Cleland, 2003).
Models are used as an alternative to intensive bacteria monitoring in order to save time, reduce cost, and provide forecasting of future conditions and the impacts of implementing solutions (Shirmohammadi et al., 2006). By understanding the influence of watershed characteristics to the contaminant load allocations, BMPs can be directed towards specific areas. The watershed can be spatially characterized and clustered into groups allowing for targeted efforts.

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) model (1987) was chosen for the purpose of initially estimating the extent and spatial distribution of bacteria sources. The objective was to use SELECT for the characterization of bacterial contamination in the Watershed. The second objective was to identify similar clusters of the subwatersheds with the most significant contribution to bacterial loads, and the bacterial sources most prevalent in the subwatersheds. Greater detail about the SELECT modeling approach and assumptions is found in **Appendix B**.

3.3 SELECT Modeling Results

The results of the SELECT model were computed in two ways. First the current loads were calculated. Secondly, the loadings for subsequent years were calculated. As the Watershed is currently not on the 303(d) list (as of the approved 2008 list) of impaired water bodies, a projection of when the Watershed would reach impaired status and be placed on the list is crucial. Although the population will change the type of housing was assumed to remain the same, single family homes. For growth of residential areas, an

assumption was made that new housing will be suburban single family homes on ¼ acre lots. Land use from pastures and farming was assumed to provide the land for growth. Secondly, the majority of homes (70%) would assumedly be on OSSFs and not WWTP's. The expansion of the existing WWTP's would cover an additional 30% of growth around the city of Angleton and north Lake Jackson. The data sets for forecasted growth were acquired from H-GAC's study of regional growth. The growth pattern of the county was used for the Watershed. For example the population growth for the county is expected to be 45% by 2035. The Watershed was also expected to have the same growth percentile even though the Watershed does not cover the entire county. Variables reflecting the percent land use are calculated using land use classification from the 2002 digital imagery. The results for each land use are averaged for each subwatershed for the purpose of SELECT modeling. The length of the stream is taken from the NHD dataset (USGS, 2002). The population of each for the individual subwatersheds is calculated based on SELECT results. The subwatersheds are based on contours and drainage canals utilized by local landowners (Figure 1).The SELECT model was run for each year beginning with 2010 until 2040 in five year increments. Each bacteria source is first distributed to the appropriate locations within the Watershed and then the load is calculated. The average daily potential load is calculated according to EPA guidance (USEPA, 2001). The population of sources is multiplied by a daily average fecal coliform excretion rate. The ratio of *E. coli* as a percent of total fecal coliform (FC), as represented by the geomean values in the most recent Texas Water Quality Standards, is used to generate the following load calculations,

3.3.1 Point Sources

Waste Water Treatment Plants

Waste Water Treatment Plants (WWTPs) are point sources permitted to discharge treated effluent into the Watershed. There are seven permitted WWTPs in the Watershed (see Figure 2), which release effluent into the streams. In many instances, an effluent standard or testing data for bacteria is not available, but a residual chlorine level is indicated. As an assumption, a value of half the contact recreation standard (63 mpn/100ml) was utilized. This value of 63 mpn/100ml isbased on decisions made by stakeholders in attempting to adequately represent the likely load of the systems. By plant design, chlorine or UV contact times should eliminate or reduce all appreciable levels of bacteria in effluent. However, many systems fail to meet this level. Without existing permit data or focused monitoring data or effluent, there was a need for an assumed concentration. Stakeholders were uncomfortable with assuming 0 mpn/100ml. Other projects (Bacteria Implementation Group for Houston area TMDLs) have utilized varying assumptions including the standard permit limit of 126 mpn/100ml. TCEQ has utilized half of the standard for some permit limits in impaired water bodies. Based on stakeholder preference, this half-standard value was used as a way of representing the average between effluent with no discharge, and effluent discharging at the concentration of the standard. . The load from each WWTP was calculated by multiplying the permitted concentration by the permitted effluent outflow. The results indicate potential values in cfu per 100 mL in millions (Figure 5). It should be noted that

the y-axis scale for this graph is dissimilar to that of other loadings graph figures on subsequent pages. WWTPs make up such a small assumed portion of the loading that their increase would appear as a straight line on the same scale as other graphs. Therefore a small scale was used to indicate the change. This discrepancy should be noted when comparing graphs from nonpoint source categories.

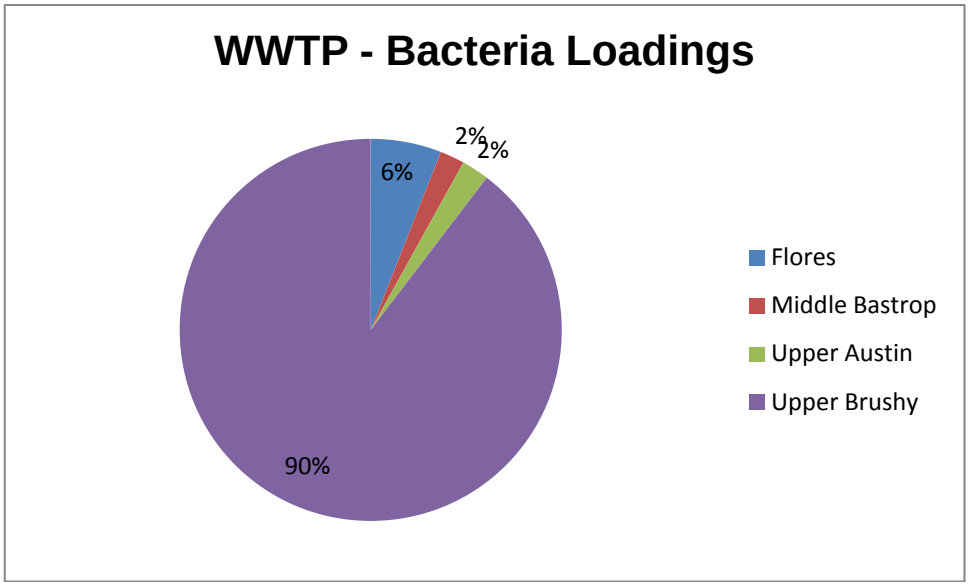

Figure 4: WWTP Bacterial Loading by Subwatershed (2008)

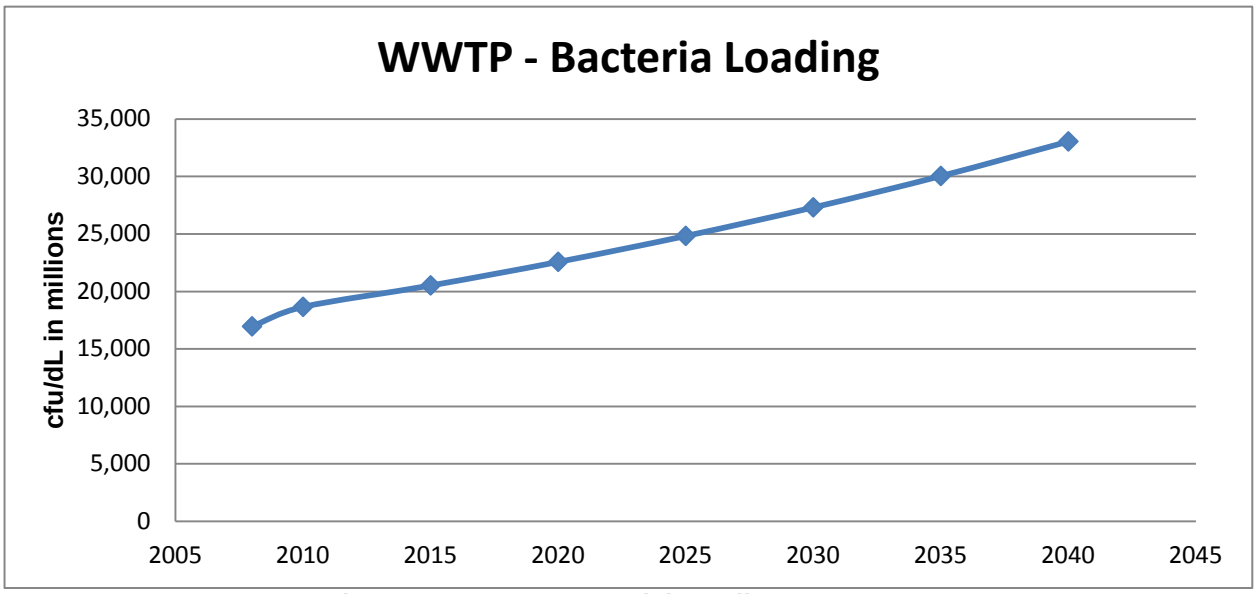

Figure 5: WWTP – Bacterial Loading, 2008-2040

3.3.2 Nonpoint Sources

Urban Runoff

Urban runoff includes bacteria that accumulate on surfaces from domestic animals and various human activities. A study was performed by the engineering firm PBS&J to measure the E. coli concentrations in runoff from different locations (PBS&J, 2000). Based on this data, PBS&J developed an empirical relationship to correlate the drainage area's percent impervious cover and the concentration of E. coli in the runoff. While this Austin-based study took place in slightly different conditions than those existing in the Watershed, it was the closest applicable source.

Using the empirical relationship reported by PBS&J, the E. coli concentration in the Watershed's runoff was then calculated from impervious cover percentages based on the exiting land use classifications for the urban areas. This concentration is transformed to a load by multiplying the concentration by a volume of runoff. The calculations from the original study include all urban sources. For the purpose of this exercise the loadings from dogs and wildlife may be over-calculated. The runoff from dogs has been calculated but closely tracks the urban run-off calculations. The loadings from urban runoff also likely overestimate the loadings from OSSFs The calculations for OSSFs exclude the urban component and only focus on OSSFs. For dogs, the calculations are based on population size and again may over-represent urban areas.

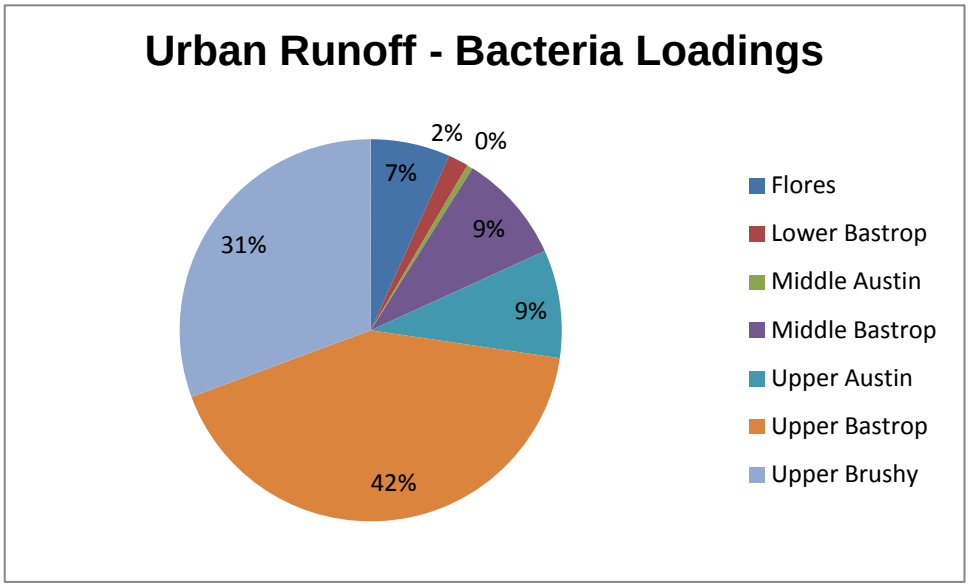

Figure 6: Urban Runoff – Bacterial Loading by Subwatershed (2008)

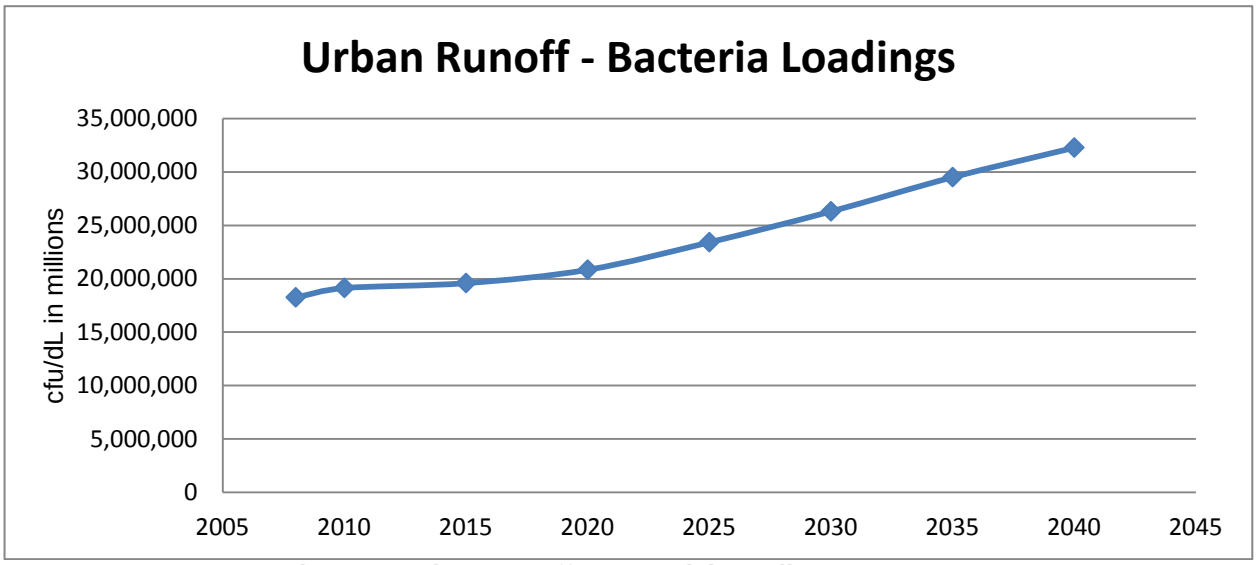

Figure 7: Urban Runoff – Bacterial Loading, 2008-2040

OSSFs

The predominant form of wastewater treatment for many areas of the Watershed is OSSFs, for both developments and single properties (see Figure 6). Malfunctioning OSSFs can contribute pathogens to a water body due to system failure and surface or subsurface malfunction (USEPA, 2001). According to stakeholder input, there are a number of older, malfunctioning systems within the Watershed. Based on a report for the Texas On-Site Waste Water Treatment Research Council, it is assumed that regulated OSSFs would have a failure rate of 12% and unregulated systems would have a 50% failure rate (Reed, Stowe & Yanke LLC, 2001). Based on Brazoria County Health Department assessment in one community, the failure rate is 79% for pre-1989 systems and 42% for post 1989 systems. As such, the values from Brazoria County were used instead of the published values. On-site wastewater treatment systems were regulated starting in 1989, while systems installed prior to 1989 remained unregulated (Lesikar, 2005).The number and location of households utilizing OSSFs was estimated by assuming those houses outside of a city limit or wastewater service area use an OSSF.. All census blocks that fall within the Watershed and are outside of a city limit were selected to calculate the number of households using OSSFs. Next, the number of malfunctioning systems was calculated. Tables with subdivision data containing the number of lots and the date the subdivision was built for Brazoria County. Based on each subdivision date, the number of malfunctioning systems in each subdivision was calculated. The appraisal data sets contained a number of errors. Primarily a default date was noted for many properties. This is likely the date that the records were entered in the computer system rather than the actual date of the property. In such case best professional judgment was used to estimate the date based on the 2000 census data. All households outside of a subdivision or city limits are assumed non-regulated and the number of malfunctioning systems calculated accordingly.

The number of systems in each subdivision was checked to ensure that they do not exceed the number of households reported in the census. If the number of households found from subdivision data exceeds the number of households reported by the census,

then the number of households reported by the census was assumed equal to the number of households in the subdivision.

Once the number of households are calculated (pre and post 1989) the number is multiplied by the failure rate. Based on Brazoria County's assessment on one community a failure rate of 79% pre 1989 and 42% post 1989 was utilized.

Next, the density of malfunctioning systems per raster cell was assessed. The area of each census block was found, and the density of malfunctioning systems per 900 m^2 calculated. The E. coli load was calculated based on an estimated 70 gal/person/day discharge and a 5 $\times 10^6$ cfu/100 mL concentration in this discharge (Brazoria County Health Department). The average number per household is the average number of people in each household as reported by the 2000 U.S. Census (USCB, 2000). The potential bacteria load was then aggregated for each subwatershed (Figure 7).

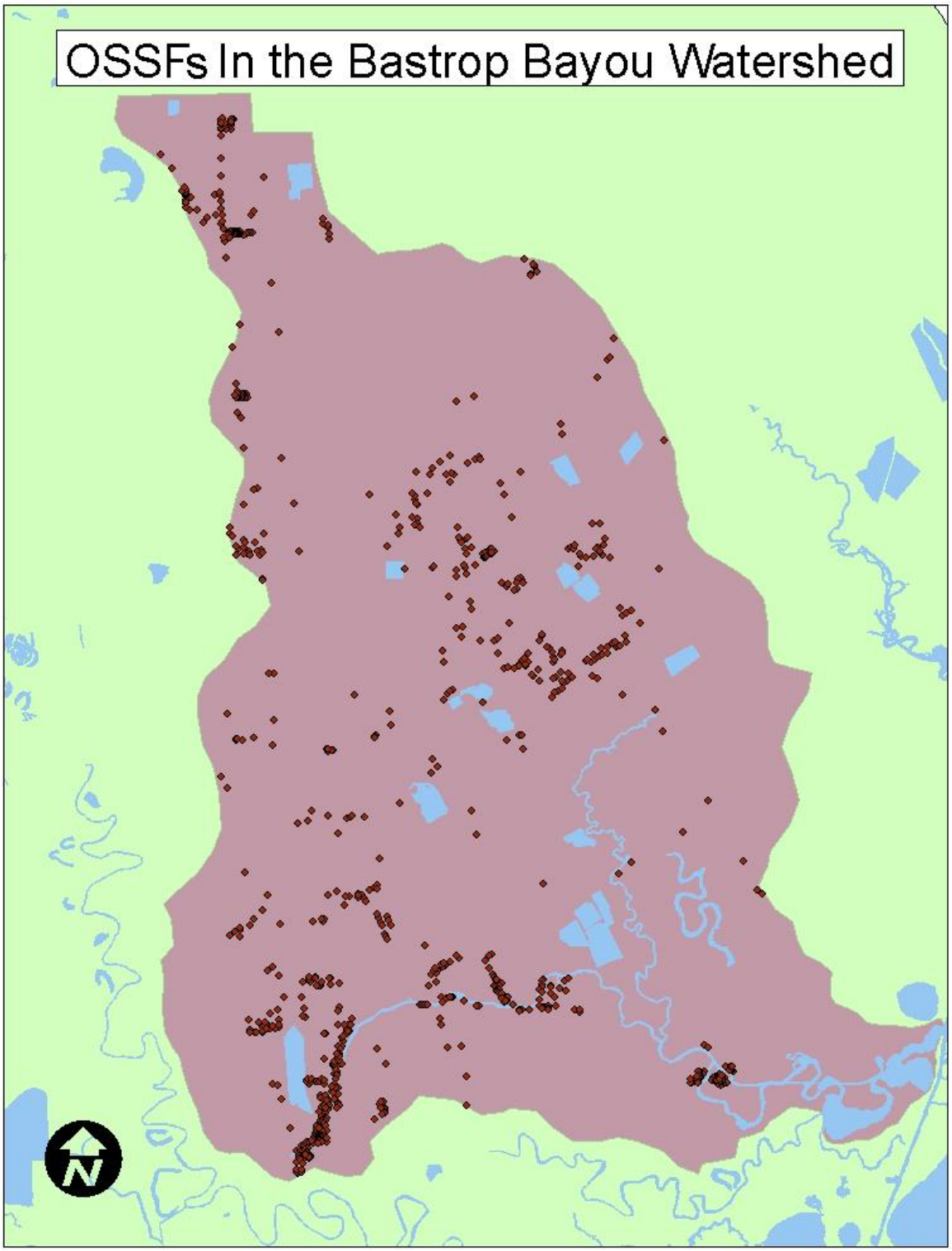

Figure 8: OSSFs in the Bastrop Bayou Watershed

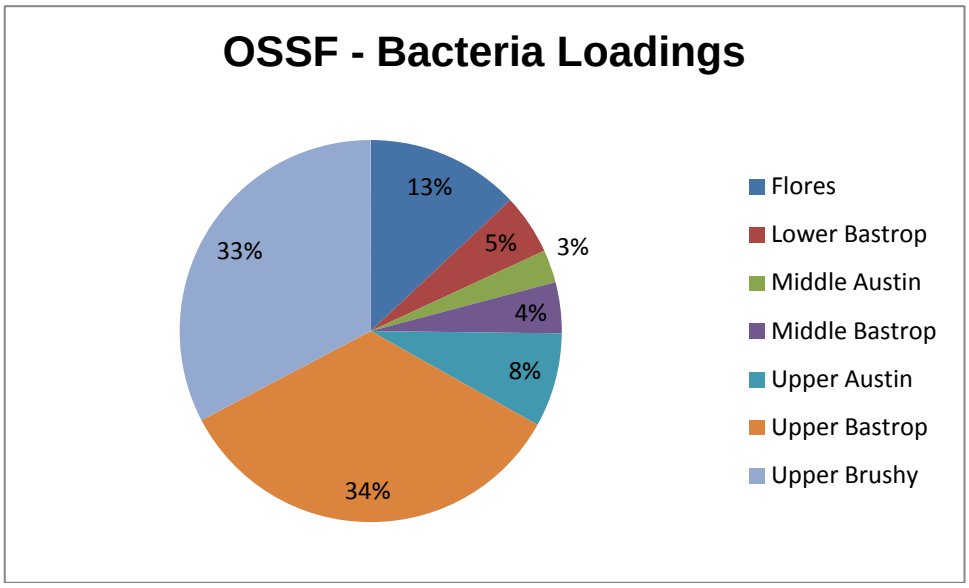

Figure 9: OSSFs – Bacterial Loading by Subwatershed (2008)

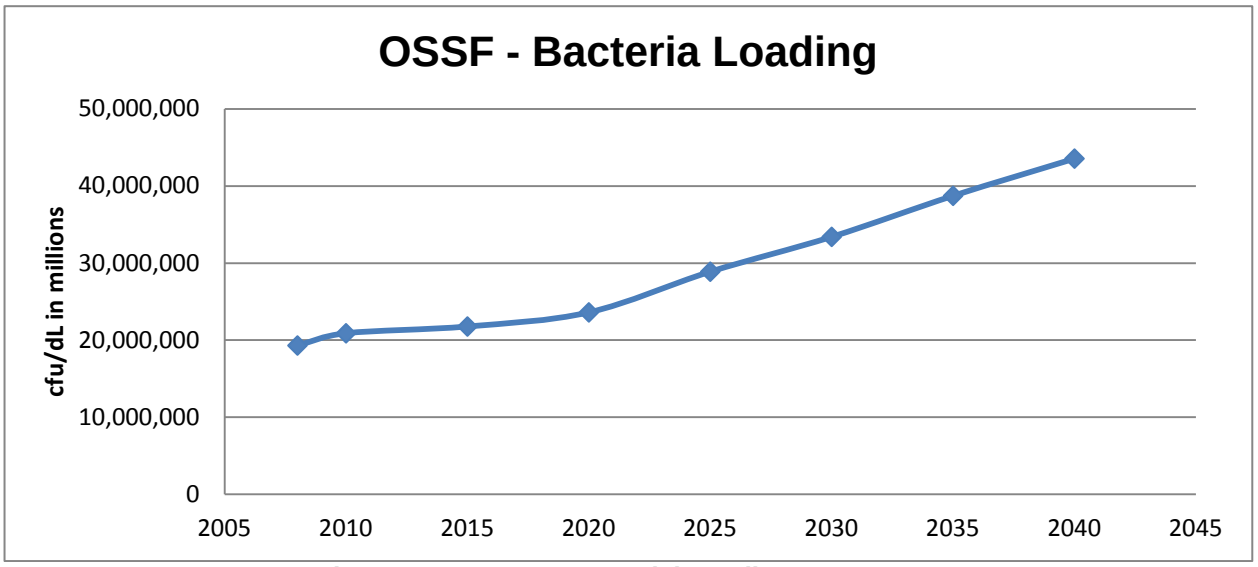

Figure 10: OSSFs – Bacterial Loading, 2008-2040

Dogs

Dog waste is a significant source of pathogen contamination of water resources (Geldreich, 1996). According to the American Veterinary Medical Association, Texans own 5.4 million dogs (AVMA, 2002, pp 1, 2, 13, 19). By dividing the number of households in Texas, the average number of dogs per household can be approximated (0.8 dogs per household). This average was multiplied by the number of households in each block to find an estimated number of dogs per census block. Using the area of each census block, a density of dogs per 900 m^2 was found. Then the census polygons were converted to a raster and the dog density is assigned to each 30m×30m cell. Published values report that dogs produce 5×10^9 fecal coliform organisms per day (USEPA, 2001). Again, the 50% rule of thumb is applied to find the E. coli load per day from each household. The potential E. coli load contribution from dogs was aggregated for each subwatershed. Dog concentration was expected to be closely correlated to urban populations. The results indicate that this was not the case. As the model is based on population density, the loading from dogs was overrepresented in urban areas and more accurate for rural areas. The PBS&J study likely accounts for the dogs and a separate inclusion double counts the results.

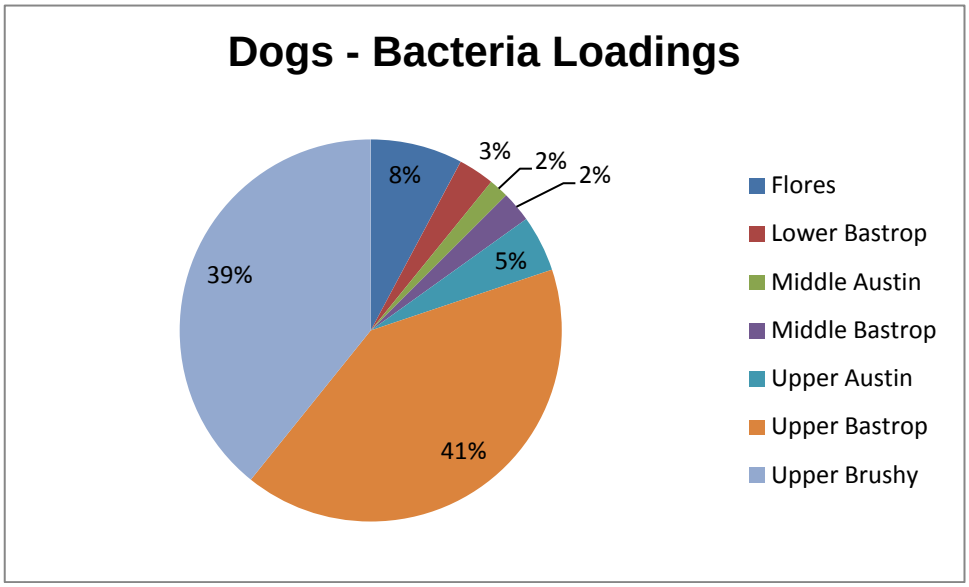

Figure 11: Dogs – Bacterial Loading by Subwatershed (2008)

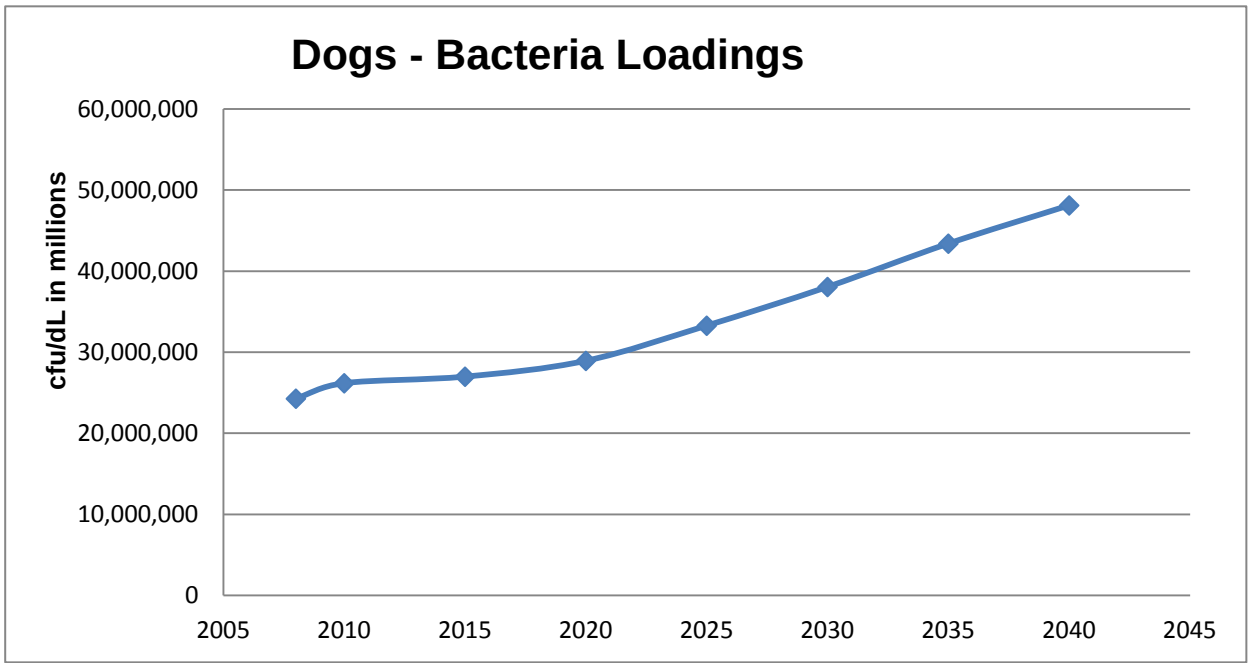

Figure 12: Dogs – Bacteria Loading, 2008-2040

Agriculture (Cattle)

Rural nonpoint sources include agricultural range animals and wildlife. Bacteria in animal manure either can be directly deposited into the stream or can be carried by runoff from the fields to the streams (Benham et al., 2006). Range animals such as cattle, sheep and goats are primarily kept in pasture and on rangeland. Horses are principally confined to pasture areas. Watershed areas that were classified as pasture and rangelands was selected from digitized land use data and the areas within the city limits eliminated. The animal populations were obtained from the United States Department of Agriculture (USDA) 2002 Agricultural Census and are aggregated per county (USDA-NASS, 2002). This data is assumed to be uniformly distributed across the range/pasture lands of Brazoria County. Based on this distribution, a density of animals per 900 m^2 is calculated. The appropriate lands in the Watershed are assigned these densities and multiplied by the fecal coliform excretion rate and then converted to E .coli potential (Figure 6). Bacteria loads are then aggregated to the subwatershed level. Upon stakeholder input, only the values for cattle were calculated, as cattle comprise over 90% of the total number of domesticated animals in the Watershed.

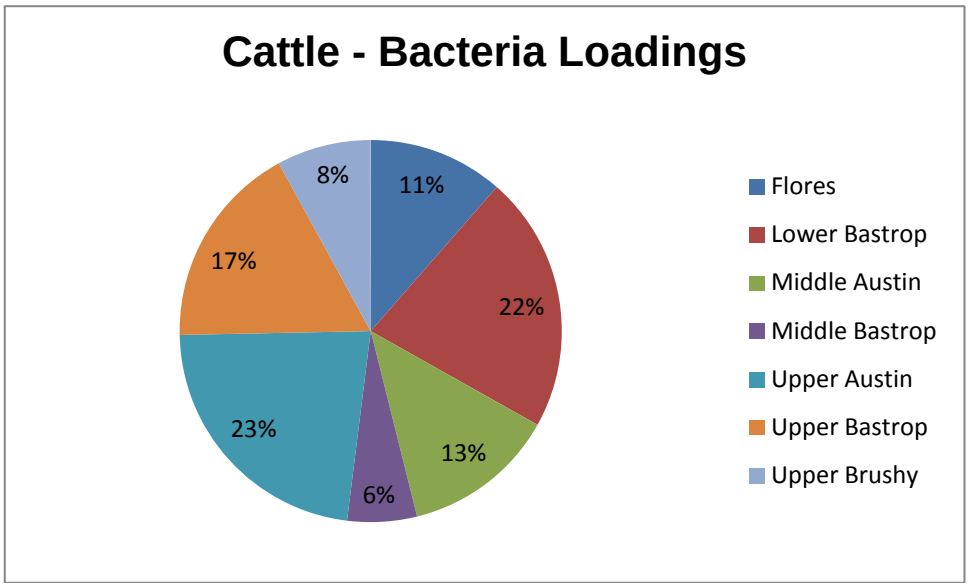

Figure 13: Cattle – Bacterial Loading by Subwatershed (2008)

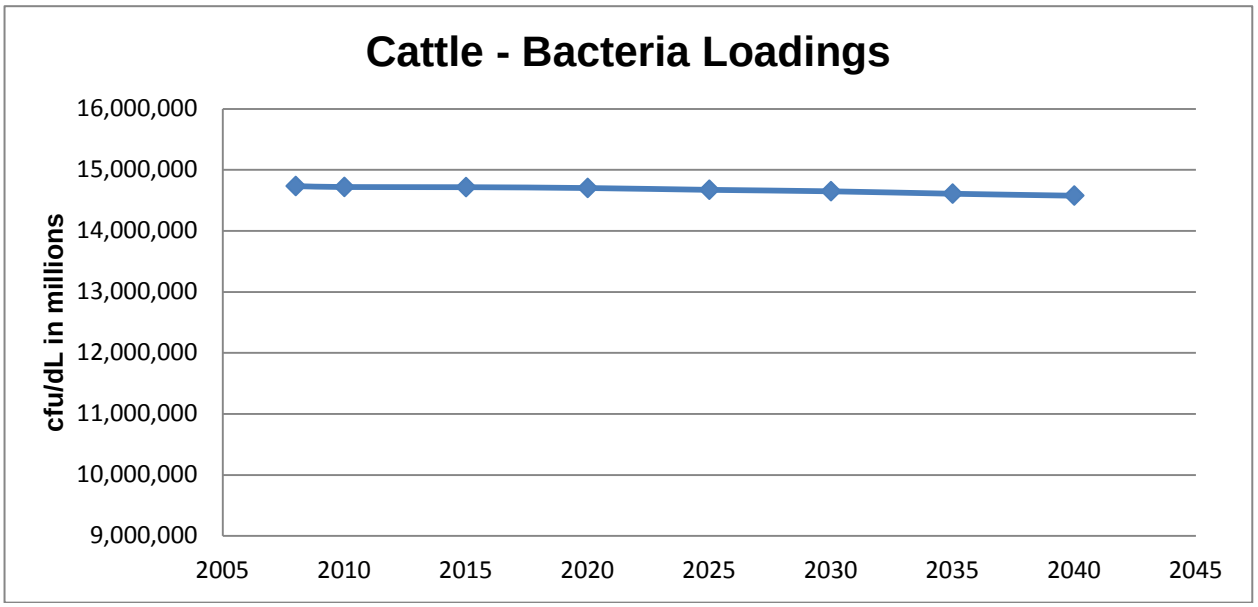

Figure 14: Cattle – Bacteria Loading, 2008-2040

Wildlife

Wildlife populations also contribute to bacterial contamination in the Watershed. Major wildlife contributors include deer and feral hogs. There are many other wildlife sources, such as birds, opossums, raccoons and coyotes. Migratory birds, specifically, can represent an appreciable seasonal contribution. However, there are not reliable methods to estimate these populations. Deer habitat includes scrubland and forest areas. Feral hogs primarily use riparian corridors in undeveloped or agricultural land uses.

To distribute the deer population within the Watershed, land use areas with a continuous area of greater than 20 acres are first selected. Texas Parks and Wildlife Department (TPWD) annual surveys report a density of deer per 1000 acres for resource management units (RMUs) (Lockwood, 2005). The total number of deer is calculated based on the area of Bastrop Bayou in each RMU. With the area of land use within each bayou's section of the appropriate RMU, a density of animals per 900 m^2 is calculated. The RMU vector data is converted to raster format using the same extent and cell size as the land use data, with the cells assigned the deer density per 900 m2. Then a fecal coliform excretion rate of 3.5 × 108 cfu/day-animal (Zeckoski et al., 2005) is multiplied by the deer per unit area in order to then find the E. coli load throughout the area. Then the potential bacteria load is aggregated to the subwatershed level.

Feral hog population densities and distribution data is scarce for the Watershed. Estimates of feral hog densities for the Rio Grande Plains and lower coastal prairie of Texas ranges from 3.2 to 6 hogs/km2 (Hellgren, 1997). Bastrop Bayou habitat is comparable to the landscape of the Rio Grande Plains and lower coastal prairies. A landscape wide density of five hogs/km^2 is applied to the entire Watershed to produce an estimate of the total number of hogs. These hogs are then assumed to be uniformly distributed to riparian corridors, or the undeveloped and undeveloped land within 100m of a stream. Feral hogs may utilize nearly all types of landscape, but prefer forested and shrub lands adjacent to river bottomlands. Based on the number of cells with appropriate habitat, the density of hogs per cell is determined and multiplied by the fecal coliform excretion standard. This is calculated with the assumption that 4.45 × 109 cfu/animal-day is the fecal coliform excretion rate multiplied by the 50% rule of thumb. Then the distributed bacteria load is aggregated to the subwatershed level (Figure 8). The results show hogs to be more prevalent than deer. The results are combined for both feral hogs and deer in the figures below. The decrease over time is related to increased development.

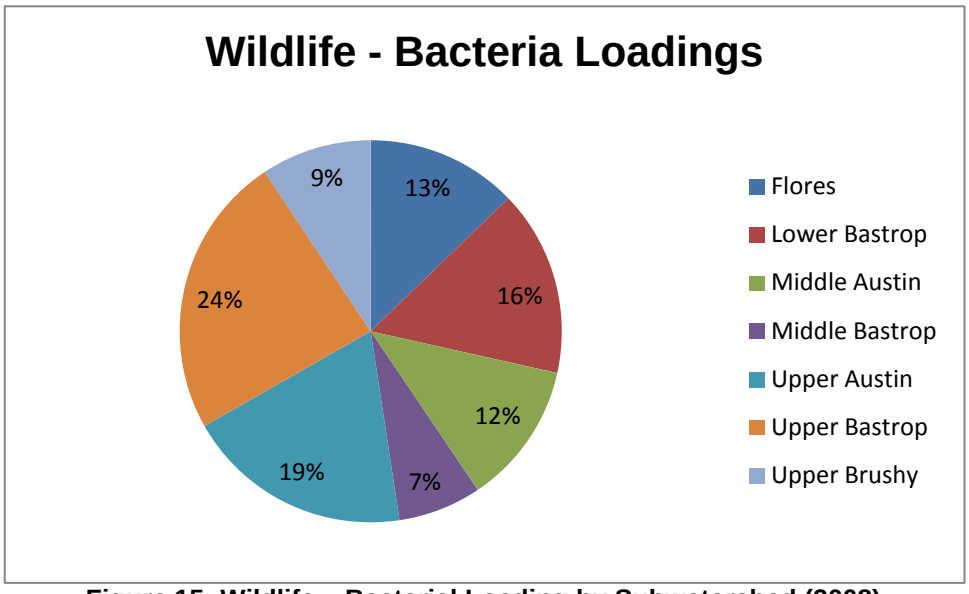

Figure 15: Wildlife – Bacterial Loading by Subwatershed (2008)

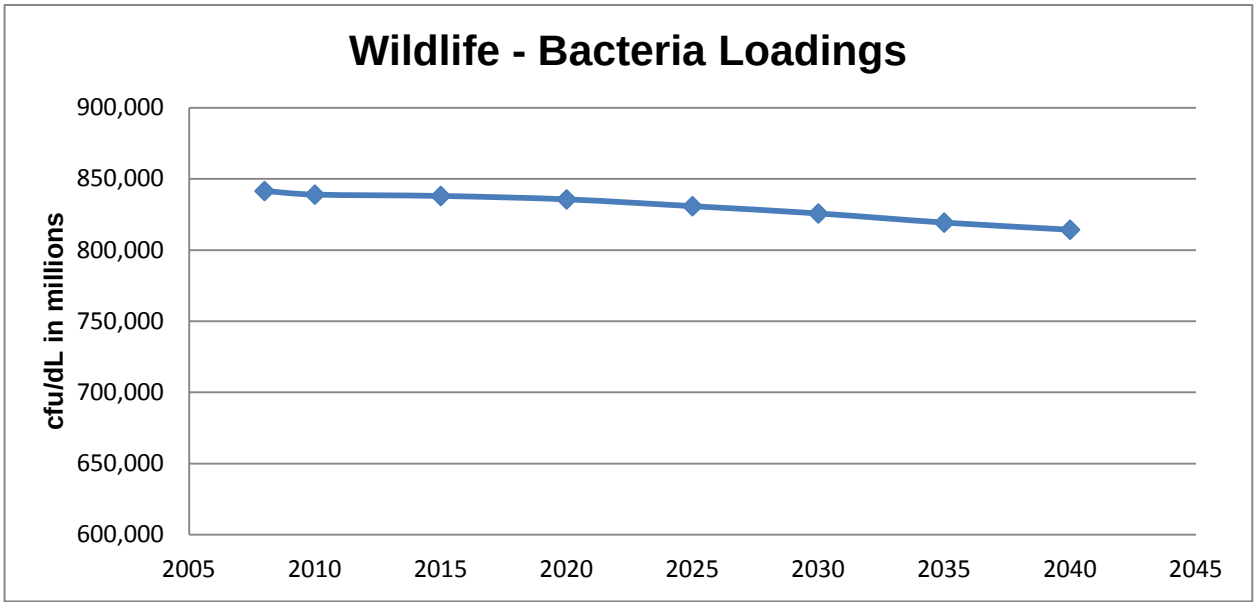

Figure 16: Wildlife – Bacteria Loading, 2008-2040

3.3.3 Totals

Combining the loadings from these separate sources created a total loading for the Watershed. As with the individual source categories, these loadings were projected out to 2040. The results of these projections are as follows:

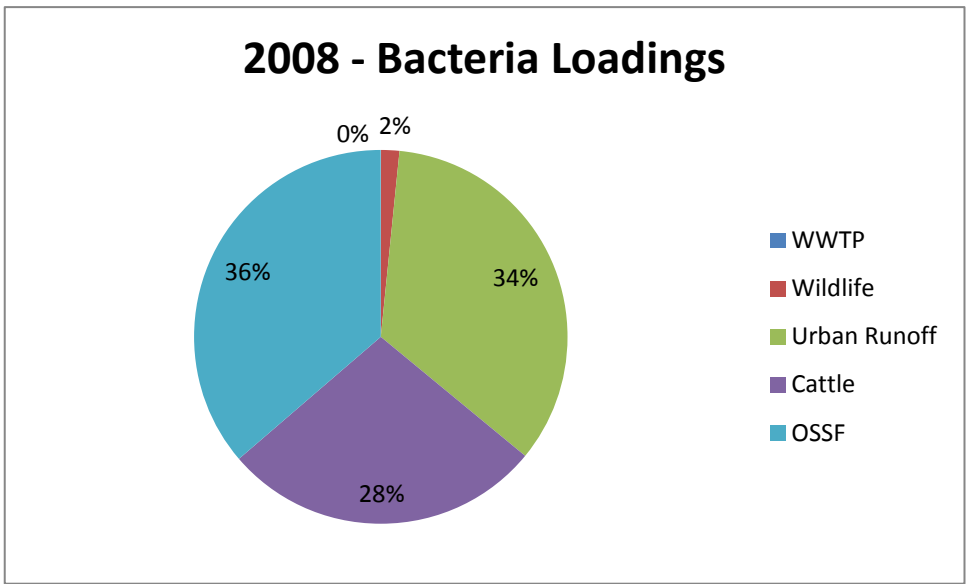

Figure 17: Total Bacteria Load by Source (2008)

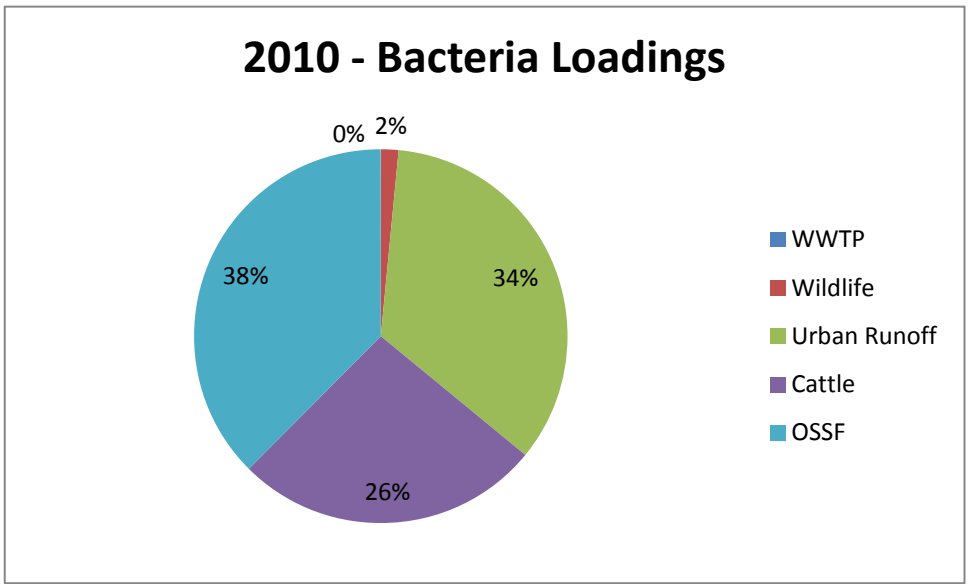

Figure 18: Total Bacteria Load by Source (2010)

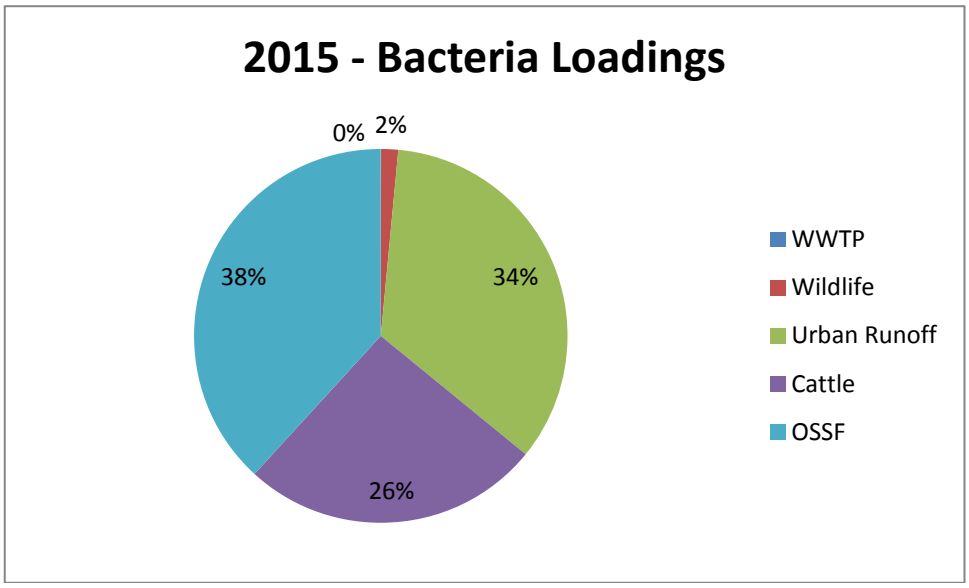

Figure 19: Total Bacteria Load by Source (2015)

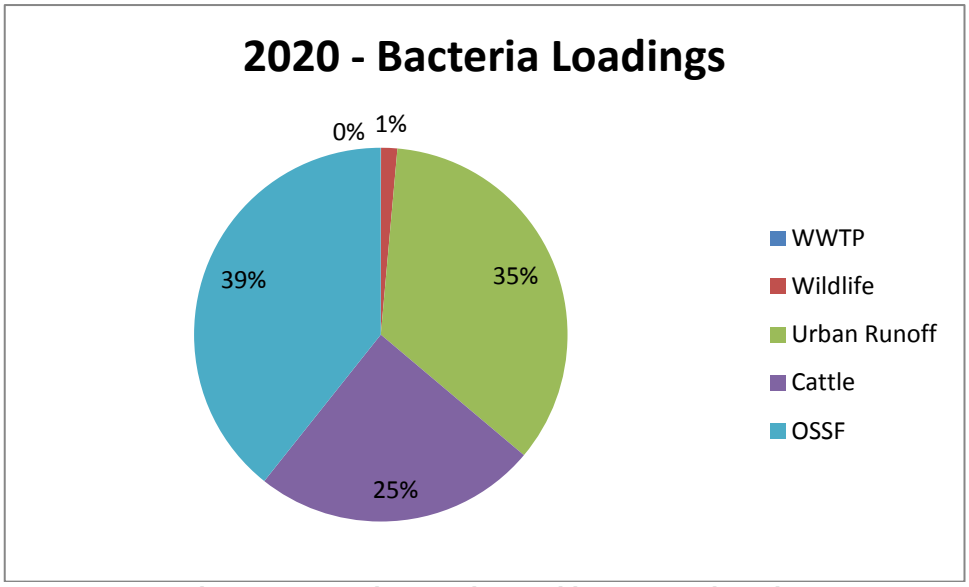

Figure 20: Total Bacteria Load by Source (2020)

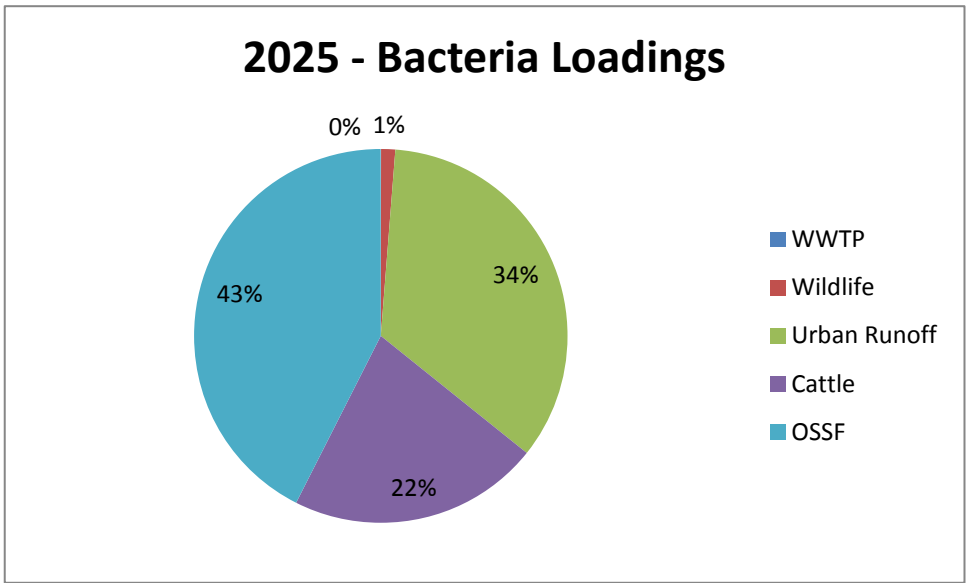

Figure 21: Total Bacteria Load by Source (2025)

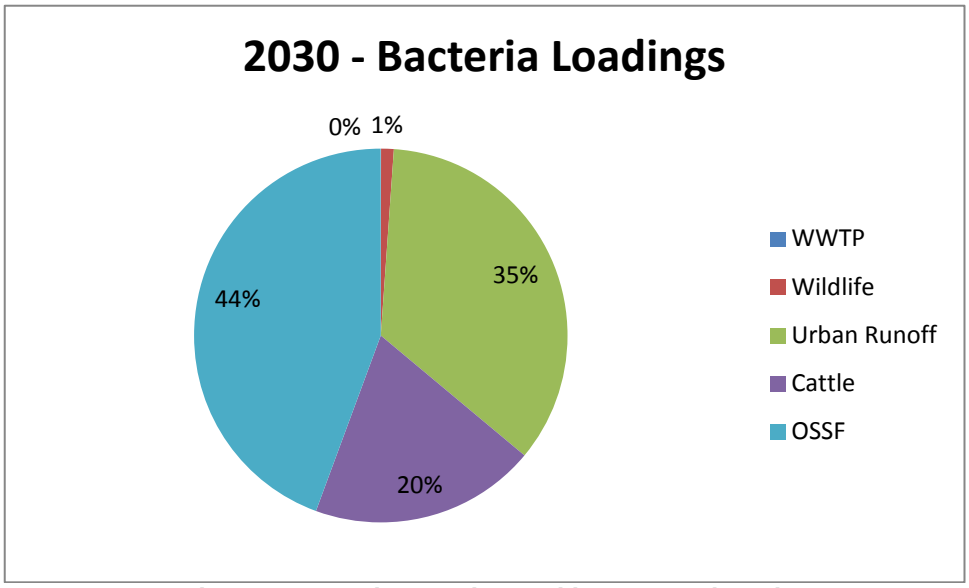

Figure 22: Total Bacteria Load by Source (2030)

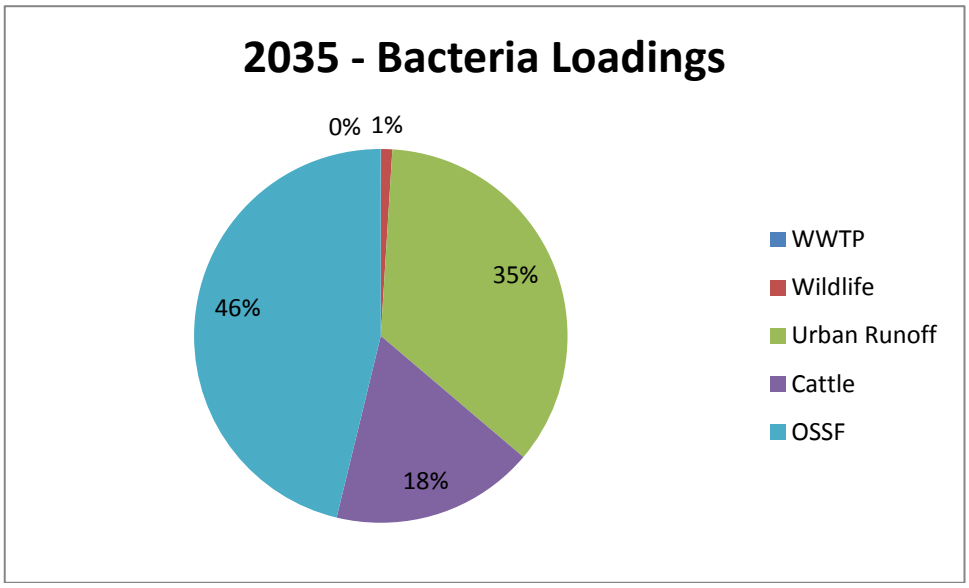

Figure 23: Total Bacteria Load by Source (2035)

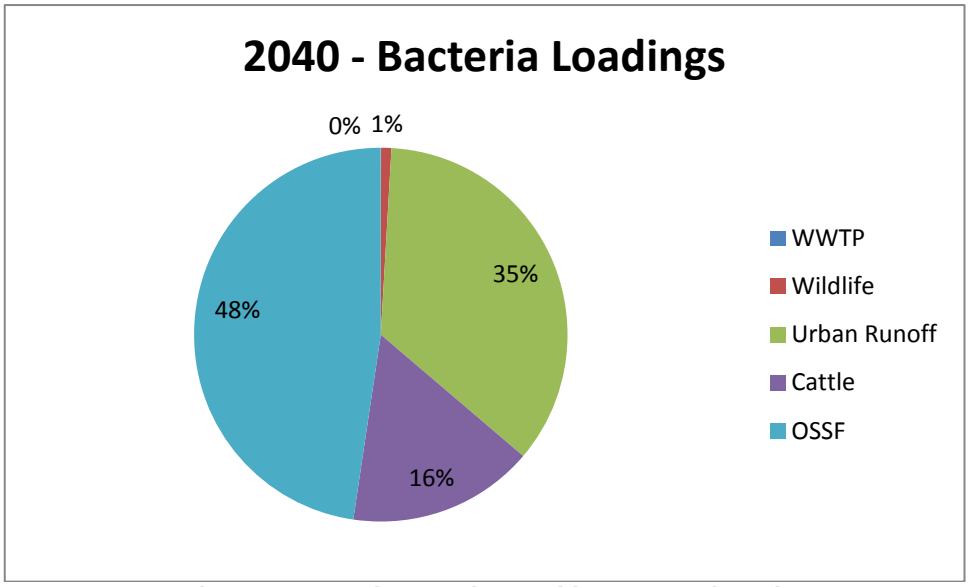

Figure 24: Total Bacteria Load by Source (2040)

Stakeholder Input on SELECT Modeling

In order to assist in reviewing the modeling approach and results, stakeholders received training from the Texas Watershed Steward program. Public meetings, web forums, and specialized training were used to disseminate the modeling results to the stakeholders. Texas Watershed Steward Course training was held on May 30, 2008 at

the Brazosport Community College. A section of the course specifically addresses water quality modeling. The SELECT model results were presented to the stakeholders after this class to maximize understanding of the results. The SELECT results were presented in December and January meetings with feedback requested at the meeting, by mail or email. The results and reference materials are also at the www.bastropbayou.org website. Additionally a forum section is available on the website to provide feedback and answer any questions that stakeholders may have. Originally, stakeholders reorganized into workgroups. However, after one meeting the stakeholders decided to utilize only one main group for future efforts. The ultimate goal of this project is to enable a 501(c)(3) organization to continue to improve water quality beyond August 2009. Although H-GAC and others can assist, the stakeholders must actively participate for the project to be effective.

Review of SELECT Modeling Applicability

When the results of SELECT are compared to the actual monitoring, SELECT overestimates the potential concentration at all sampling locations. This reinforces the known uncertainties of the models, including the exact distribution of the source populations. This overestimation is a result of incomplete knowledge of the transport processes. SELECT assumes that all bacteria will enter the stream. This does not account for settling, vegetative filtering, temperature or solar inactivation and other biological factors that will reduce the number of viable bacteria that will enter the stream. An assumption of 50% ("rule of thumb") is used when describing the transport process. In order to get a more accurate model of the E. coli contamination, SELECT should be coupled with a watershed model that models the transport of the E. coli. The model does not predict the E. coli survival or movement into the stream. In other words, the pathogen's environmental survival and replication is not modeled.

To further define the impacts of various factors in the water ways and model the influence of tidal action, additional modeling was completed utilizing the XPSWMM and EPD-RIV1 models. These models

Further information on the loading and land use modeling processes is contained in **Appendix A**, and further detail about the SELECT model can be found in **Appendix B**.

3.4 EPD-RIV1/Tidal Prism Modeling

As the Watershed is not currently on the 303(d) list, the Plan's goal is to maintain the current bacteria levels despite future changes in the Watershed. The general purpose of the modeling is to determine at what future point the standard for bacteria would be breached if no changes are implemented. This information will be key in determining how to prevent the Bayou and its tributaries from reaching that point. The SELECT modeling calculated the bacteria from the sources in five year increments until 2040, with 2025 defined as the boundary of the foreseeable future. While a hypothetical in-stream concentration could be calculated based on this loading per flow, this would not be representative of what occurs in the waterways, which are inherently dynamic

systems. The bacteria, once they have entered the waterway, are subject to a variety of processes, including die-off, regrowth, affects of UV radiation, and removal or redistribution based on tidal action. To properly understand the impact of the combination of these processes, more comprehensive modeling must be engaged to represent the physical and water quality processes acting on the target bacteria.

Towards this end, H-GAC sub-contracted the hydrodynamic modeling of both tidal and non-tidal sections of the bayou to consulting firm PBS&J. PBS&J set up a model of the Bastrop Bayou system using available bathymetric information. . The sub-contractor operated the model for a representative period and employed calibration and validation techniques to determine the rate at which tidal mixing removes materials from the bayou and the fate of bacteria in transport. Available CRP ambient water quality data from TCEQ's SWQM-IS was employed for calibration. For the non-tidal sections, PBS&J developed synthetic flow calculations from Chocolate Bayou's flow measurements. No USGS flow monitoring gauges are located in segment 1105, while a USGS flow measuring station is located in the adjacent Chocolate Bayou. Given the relatively close hydrologic character of both waterways, this was chosen as the option with the least inherent uncertainty. Estimations of current concentrations, projected future concentrations without BMPs, and projected future conditions with BMPs (a ~20% reduction in loading) were completed.

The end result of this modeling effort was to indicate that the projected BMPs and resulting source loading reductions (See Sections 4 and 5) would likely result in indicator bacteria concentrations below the water quality standard at the monitoring stations.

The methodology, details, and results of this modeling approach are found in the report in **Appendix C**.

4 Pollutant Loads and Required Reductions Element B

To reduce loadings of identified contaminants, the stakeholders will institute a variety of management measures throughout the Watershed. This section presents information on load reduction estimates for each category of management measures, which are explained in greater detail in Section 5.

The load reductions expressed in the following categories are given as percentages of the total loads estimated by the SELECT (see Section 3, and Appendices A, B, and C.)The sum of these estimated reductions were applied as an input to the EPD-RIV1 model's projected future conditions (with BMPs) as a reduction in loadings. The end result of the reductions on projected concentrations is reflected in the final concentrations generated by EPD-RIV1. However, the EPD-RIV1 model did not break out the reductions in concentration by BMP. Therefore, the following discussion of categorical reductions is based on loading reductions, prior to simulation of in-stream impacts. The total reduction estimates generated by the EPD-RIV1 (See Section 3 and **Appendix C** for more detail) effort are discussed in section 4.7.

The reductions estimated in 4.1-4.6 are drawn from a mix of literature values, assumptions made in similar watershed planning efforts, and calculated reductions specific to the character of this Watershed. The reductions are grouped by categories of related projects.

4.1 Education and Outreach Projects

Education and outreach is a major component of the strategies utilized in the plan to help reduce the bacteria load into Bastrop Bayou and its tributaries. These programs are some of the easiest and cheapest to implement, yet they can be some of the most effective. Not only does education and outreach produce a tangible reduction in nonpoint pollution to the water, but it also service as a public relations benefit for state and local governments and other entities.

An educational survey will be distributed to residents by the stakeholder group throughout the Watershed to solicit information and educate constituents. Pre- and post-survey information will be gathered by the school district's Project WET and WILD. Other general education and outreach efforts include the actual Watershed Protection Plan and Executive Summary. Upon completion and approval of this plan, the plan itself will serve as a tool for education and guidance to residents throughout the Watershed. Also, a website will be maintained to provide plans, updates, and other information. Press releases, newsletter articles, Texas Watersheds Stewards programs, and Dow's Living Laboratory will all provide general watershed and water quality stewardship information. Promotional materials and classroom activities used to advertise outreach programs will include homeowner information regarding proper OSSF maintenance, available livestock financial incentive programs, and low impact and large scale

development educational workshops. Additional education and outreach programs specific to other categories will also be described later in this section.

In many instances the value of outreach projects is defined as a range of effectiveness. A recent study evaluated numerous outreach techniques and the best method to compare the relative effectiveness (Abroms, et.al. 2008). Based on this study, an estimated 2% of the total load reduction from all sources necessary to meet the water quality standard can be reasonably achieved in the near term though outreach efforts in the Watershed. The 2% figure cited by Abroms & Maibach assumes that outreach activities are novel (i.e. not repetition of previously disseminated information, which might lead to diminishing returns, as the impact would not be cumulative). In this case, the 2% estimation was deemed appropriate for this Watershed because there have been few if any known similar watershed outreach efforts in the area. Because these activities are not redundant relative to previous outreach efforts, they can expect to achieve the full 2% reduction. Other successful Watershed Protection Plans have assumed similar reduction values. (e.g., Plum Creek, 2009)

The long term effects of outreach can be significant if the efforts are sustained and become pervasive. The selection of individual activities this Plan proposes to implement in order to achieve these reductions is outlined in section 7.

4.2 Animal Management

Agricultural range animals and wildlife are prominent nonpoint sources in rural areas. Bacteria in animal fecal matter can introduce bacterial contamination to waterways either through being directly deposited into the stream or by being carried by runoff from the fields to the streams. Because greater control can be exercised over domestic animals than wildlife, the range of BMPs suggested under this WPP focus on livestock rather than wild animals. However, as is detailed in Section 5, additional actions may be necessary to curtail the contributions of deer and feral hogs. Cattle comprise over 90% of the total number of domesticated animals in the Watershed. As such, they are the specific focus of conservation and load reduction efforts under this Plan. Implementation of the activities described below will result in a 25% decrease in the bacterial loading from this category, which translates to a 7% reduction in the total bacterial loading for the Watershed.

Based on the success of previous efforts (TSSWCB Water Management Plans, etc.) incentive-based, voluntary management can be achieved to prevent livestock waste from entering waterways, or greatly reduce its impact. BMPs employed toward these aims include fencing, providing alternative water sources and developing buffer areas to intercept or filter contaminated flow before it enters waterways.

For cattle, the expected load reduction from the implementation of these measures is based on an estimated 70% reduction in the loads that are deposited directly into the waterways for the parcels on which the BMP programs are implemented. This is

derived from a 2008 published study by Texas Agrilife (Wagner, et. al. 2008). Using radio-telemetry collars on cows, the study found that the time spent in or near a stream is reduced by 75% if alternative shade and fresh water are available. If implemented BMPs prevent cattle from wading in the stream, then loading from direct deposition is also reduced in the stream (TWRI, 2008). To account for variability in agricultural conditions and practices, a more conservative figure of 70% is utilized in this document. In the modeling for this category, the relocation of the fecal deposition from directly into the waterways is accounted for in the Select modeling.

As a default, SELECT overestimates the relationship between deposition and amount of bacteria in the actual stream by assuming that all bacteria in deposited fecal matter reaches the stream regardless of where it is deposited (Paul et. al, 2004). To relate this to actual conditions regarding transmittal of bacteria from land deposition, a 50% transmittal rate is used as rule of thumb default value, based on assumptions made in similar watershed studies, (Paul et. al, 2004). In other words, only 50% of the bacteria deposited on land are estimated to enter the stream. Therefore, in quantifying reductions, the following assumptions are made based on data from the aforementioned Texas Agrilife study: 1) Cattle spend approximately 45% of their time out of the water, and 55% in or adjacent to the water, 2) bacteria deposited on the land is reduced by 50% by the time it reaches the waterway, on average, 3) deposition that is reduced in the water, is added to land deposition, and 4) fecal deposition is at a constant rate.

Using these assumptions, a reduction of 70% of the fecal matter deposited in the water is equivalent to a 25% reduction in overall bacterial loading to the stream from cattle. As loading from this category accounts for 28% of the total Watershed loading (Figure A30), this categorical reduction will account for a 7% reduction of total loading. Note that this reduction does not take into account potential beneficial impacts for multiple barriers to fecal contamination to streams which might include combinations of fencing and filter strips, etc., to address land and water deposition rather than just single BMPs. This approach was chosen to maintain a conservative estimate and to reflect the variability of applicability of any one BMP to all potential sites. Some sites may not be suitable for multiple BMPs, and therefore, a single representative BMP was chosen. Additionally, these reductions specifically speak to reductions in originating loads, rather than end concentrations, as represented by the EPD-RIV1 modeling.

While the WPP includes potential BMPs aimed at wildlife bacteria reduction (regarding feral hogs), it is unlikely that the Hog population in the area will be significantly reduced in the near future. Therefore, no reductions are assumed from these BMPs. However, there is value in the proposed projects (educational elements, hog hunting events, etc) stemming from a long-term shift in behavior. Addressing wildlife in an appreciable way in the short term would likely involve greater resources than are available, and the benefit per cost is likely to be less than other approaches.

In the process of determining potential sites for BMP implementation, the Plan focuses on identifying parcels that are adjacent to the streams in the Watershed and have cattle ranching operations. Of these identified parcels, twenty landowners have expressed

interest in implementing TSSWCB Management Plans on their property in the short term. Based on these twenty parcels, there are currently 2,804 acres under Management Plans. Given the ongoing success of the TSSWCB's Water Management Plan model, it is expected that subsequent plans will be completed for additional landowners and additional parcels. Based on the current participation trends, that expected growth in participation is expected to result in a total of 3,779 acres being covered under a water management plan by 2040. This process will be supported under this Plan through existing communication networks and partners. It is assumed that the percentage of land allocated to ranching operations will decrease based on increased pressure from urbanization. Reductions seen in the future incorporate both the impact of improved management of existing ranching operations and the impacts of reduction of land availability for ranching operations. .

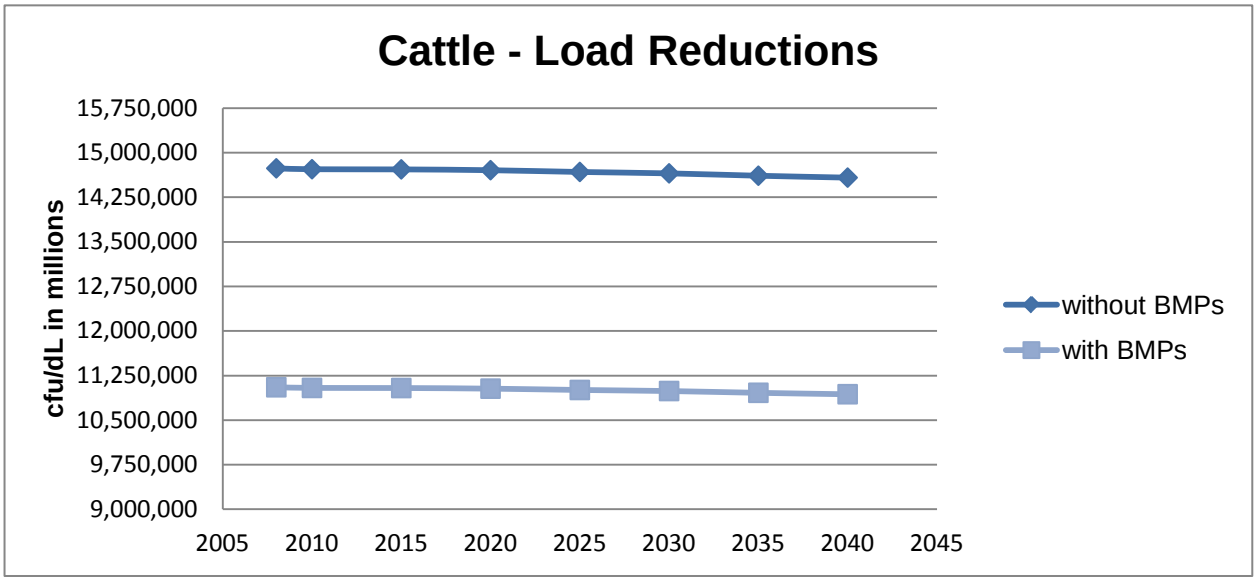

Figure 25: Expected Loads and Load Reductions – Cattle

4.3 Wastewater Treatment Plants

No bacteria effluent testing was required under any of the plant permit requirements during the production of this Plan. New state regulations will require bacteria testing such that, as the WWTPs renew their five-year permits, bacteria testing requirements will become mandatory, based on an expected 126 cfu/100 mL effluent limit. . Absent that information in the short term, the load from each WWTP under these load reduction estimates was calculated by multiplying the permitted concentration by the permitted effluent outflow. A value of half the contact recreation standard (63 mpn/100 mL) is assumed to be the loading from the plant. This assumption, used in the absence of historical effluent testing data for bacteria, is based on similar assumptions in local TMDL studies, and was developed as a result of best professional judgment of the stakeholder group.

If enhanced maintenance measures are adopted by the WWTPs then a reduction of 15% of the loading from this category can be expected over time. The enhanced maintenance measures are being developed for the Houston-Galveston area by the local TMDL projects' Bacteria Implementation Group, and include many of the maintenance and operational practices recommended under the EPA's CMOM program template (EPA, 2005). Overall, point sources account for 1% or less of the Watershed's current bacterial loading. It is expected that the introduction of the bacteria testing requirements will result in a inherent reduction in bacteria. To reflect the potentially growing amount of treatment provided by WWTPs in subsequent years, the reductions expected from increased monitoring, and potential education and outreach efforts targeted at plant operations, a reduction of total loading of 1% was assumed for the purpose of subsequent modeling. Given the uncertainty with these estimates, and the very small portion of total loading they represent, these reductions were not graphed.

4.4 OSSFs

OSSFs can contribute pathogens to a water body due to system failure and surface or subsurface malfunction. Based on Brazoria County Health Department assessment of the Demi-John community in the Watershed, which had experienced high levels of OSSF failure, the failure rate is 79% for pre-1989 systems and 42% for post-1989 systems. Malfunctioning or inadequate systems can contribute a significant amount of pathogens to the waterways. Their impact on the Watershed is significant enough that Brazoria County is currently suing the Demi-John community over OSSF issues. Overall, the Community contributes 1.2% of the bacteria loading of the Watershed. Between remediation of Demi-John and general enforcement and education activities (Assumed 2-3% reduction overall) a 4% overall reduction (8% reduction in the loading for the category, equivalent to 4% total reduction in 2040) was used for this category. Some factors (change from OSSFs to sanitary sewer systems, choice of treatment in new development, etc) are not able to be modeled, so some degree of uncertainty is reflected in the 4% estimate. However, this is a conservative estimate to balance that uncertainty.

Among the communities in the Watershed, Demi-John has the highest known OSSF failure rate, and therefore is the short-term focus of attention for mitigation efforts. There are a total of 319 homes in Demi John. If the malfunctioning septic systems in Demi-John are repaired, a 58% overall short–term load reduction is a reasonable expectation. This figure is based on repairing the 79% of OSSFs that are currently malfunctioning, without replacing the 21% that are not. However, while 21% of OSSFs are currently sound, it is expected that they will begin to malfunction in the future. It is currently expected that a WWTP option will be completed rather than remediation of OSSFs.

The number of homes in the whole of the Watershed was determined based on the service area boundaries from the WWTPs. Census data was then used to determine the total number of homes in the Watershed to derive the number of homes estimated

to be on OSSFs. There are 12,135 of homes using OSSFs in the Watershed. Of these 6,893 are expected to require repair. This estimate is based on a comparison of the average ages of the OSSFs by the percent that fall within each failure rate. An average percentage was derived from this comparison, and used to generate the expected average failure rate of 57%.

Over time, assuming current trends stay constant, 9,383 homes will have malfunctioning systems and the overall loads associated with malfunctioning OSSFs will increase from 36% to 48%. A reduction of 57% for the Watershed as a whole will be necessary. Home-owner education is expected to result in 2% repairs resulting in 186 OSSFs. Due to better siting criteria and increased enforcement, new OSSFs will have a lower failure rate than currently observed, though this number will be offset by growth in the area. Additional reductions will come from increased enforcement activities. Brazoria County has indicated its willingness to pursue legal remedies with Demi-John in order to force the repair of malfunctioning OSSFs. As such, any residents in the Watershed who are financially able to repair their systems will likely do so, to avoid the greater costs of non-compliance. The estimated number of residents with malfunctioning OSSFs will be 4,854 due to the increased enforcement and Education & Outreach efforts.

H-GAC, in coordination with County officials, will work to obtain grants or other funding sources for residents who are financially unable to make repairs to malfunctioning OSSFs. According to OSSF installers, the average estimated cost to repair a malfunctioning OSSF in Brazoria County is $2,500.

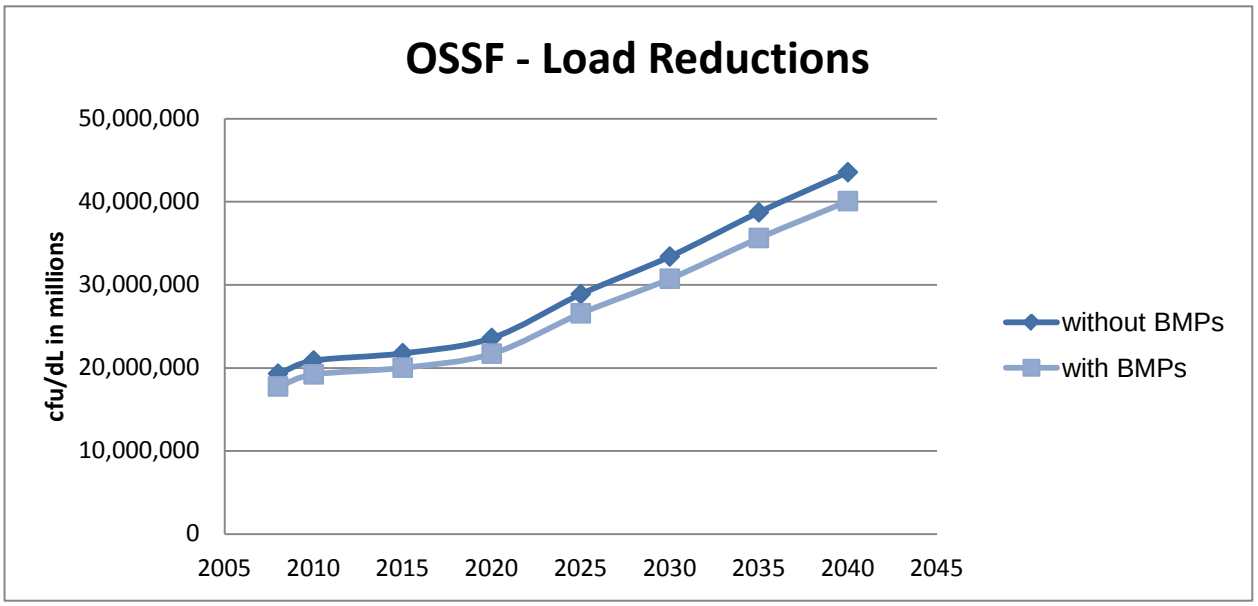

Figure 26: Expected Loads and Load Reductions – OSSFs

4.5 Urban Runoff

Storm water runoff from urban areas contains bacteria from various sources that accumulates on land surfaces. During a rain event the bacteria are washed into Bastrop Bayou and its tributaries. Runoff is by the far the most prevalent source of pollutants for the Watershed, and increased population density and urbanization will only magnify this impact. The Plan intends to achieve load reductions through promotion of low impact development (LID) practices and incorporation of water quality concerns into large scale development projects. The implementation of LID practices and large scale development projects is estimated to produce an 8% reduction in the bacterial loading from this category, which represents a 3% reduction of the total loading for the Watershed.

Low Impact Development - Urban Runoff

Development of small-scale BMP's includes pervious pavement projects, promoting rain water to soak into the ground instead of flow into the waterways; green roof projects, designed to collect rain water for plant use; and rain gardens, developed to collect rain water for plant use and to serve as detention for flowing storm water runoff. These practices are often most appropriate in suburban settings where there is sufficient space to implement them. Vegetated swales, for example, are not always appropriate in dense urban areas. However, there are a range of practices available for all levels of development. A green roof, for example, could find application in almost any setting.

WaterSmart demonstration gardens or similar green infrastructure pilot projects can be installed at city halls, county parks and other public areas. These gardens not only offer a destination for residents, they also exhibit proper landscaping, plant selection and gardening techniques to best manage storm water runoff.

On a given property, a 20% reduction of bacterial loading from runoff can be expected based on similar Low Intensity Development practices as found by the HUD 2003 study titled "The Practice of Low Impact Development." (HUD, 2003) The bacterial reduction was interpolated from reduction in all of the pollutant sources listed. Specifically, Total Suspended Solids were reduced by at least 20-80% using various LID practices. As such, bacteria can be expected to be reduced by at least 20% from those properties which implement these measures (Figure 12). Currently there is one planned LID project area in the Watershed, and estimates from stakeholder input and professional judgment are that up to a fifth of the urban acreage (including new development) could utilize similar practices. To quantify urban acreage, low and high intensity developed land were totaled, resulting in 4,637 urban acres. Thus, a 20% reduction for 20% of the urban acreage, or approximately 927 acres, is equivalent to a 4% reduction for the loading from urban runoff in general. This in turn is equivalent to a 1.5% reduction to the total bacterial loading (urban runoff accounts for 34% and 35% of total loading in 2008 and 2040, respectively.)

Large-Scale Development Practices - Urban Runoff

Cities within the Watershed address flooding in a variety of ways, including implementing and enforcing stormwater management ordinances which regulate development characteristics, participating in federal, state and regional programs

designed to reduce flooding impacts, and creating plans to address multi-partner and collaborative opportunities with other local jurisdictions, regional government(s), educational institutions, non-profits and special purpose districts.

The Federal Emergency Management Agency (FEMA) plays a major role in setting national policy to reduce and abate natural and man-made disasters and provides funding for projects. In the context of flood abatement, FEMA ensures that local cities implement appropriate regulations/processes through the Community Rating System. The Community Rating System is a point based system that allows a reduction in Flood Insurance premiums for all policyholders of the community if the community adopts and successfully implements certain regulatory standards and adopts processes intended to publicize related information. FEMA provides funding for disaster relief and mitigation, which is distributed through the Texas Division of Emergency Management in accordance with State mitigation priorities.

Entities working in the Watershed can utilize several strategies for reducing the risk of flooding from these waterways and promote the protection of water quality. These solutions include: storm water detention ponds, a permanent pool of water designed to collect and naturally filter storm water; new wetland detention areas, larger, more complex detention areas with wetlands, marshes and vegetation; and vegetated swales, shallow channels with dense vegetation.

Based on the 2003 HUD study at least a 20-80% reduction in contamination can be expected following implementation of these activities. For the purpose of load reductions a conservative 20% reduction is utilized for the load reduction calculations (Figure 12). Based on stakeholder input, known efforts in the Watershed, and best professional judgment, it is assumed that another fifth of the urban acreage could be served by large scale development practices that incorporate bacteria reduction as a goal. Therefore, a 20% reduction from 20% of the acreage (927 acres) is equivalent to a 4% reduction for the total urban runoff loading. This, in turn, is equivalent to a 1.5% reduction to the total bacterial loading (urban runoff accounts for 34% and 35% of total loading in 2008 and 2040, respectively.)

This Plan assumes that the LID practices and large scale bacteria reduction projects are not serving the same acreage. In the case that they are, it is not expected that the load reductions would be a cumulative 8%, as the LID practices would reduce the bacterial content of inflow to detention basins serving the same area, etc. However, given the balancing impact of the conservative nature of the reduction estimates, they are treated as cumulative reductions serving separate areas, and thus a total load reduction of 8% of urban runoff contribution, or 3% of total watershed loading.

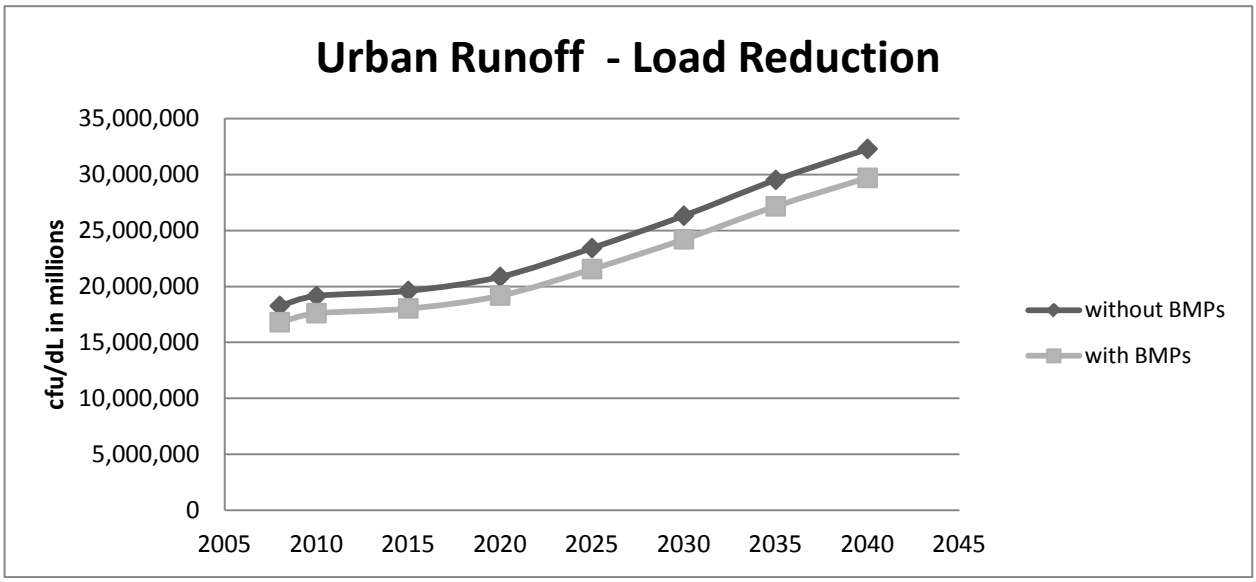

Figure 27: Expected Loads and Load Reductions – Urban Runoff

For future consideration, density of development may be a desirable goal to pursue. Promoting density in urban growth may be the best option to conserving natural areas and reducing polluted runoff. On a watershed scale, higher density can result in much less polluted runoff, because much less land is occupied.

For example, at typical suburban densities of 3,000 people per square mile, 100,000 people occupy at least 30 square miles of land. At 15,000 people per square mile (the approximate density of the French Quarter in New Orleans), only about 7 square miles of land are used, a savings of 23 square miles of natural area. Communities developed under New Urban or Smart Growth principles can easily achieve densities of 15,000 to 30,000 people per square mile. It is unlikely that all new growth in the Bastrop Bayou Watershed will occur at that density. A very minimal increase in density, to 6,000 people/square miles, easily achieved just by narrowing lot sizes and street widths and encouraging a few more town home developments, would result in an open space savings of 200 acres. A geographic advantage for the Watershed is the fact that aerial photos from Angleton show a grid pattern conducive to mixed-use development that may encourage walking and promote density.

4.6 Pet Waste Management

The calculation of bacterial loading from pets can be problematic. The density of pets is directly linked to population and urbanization. In urban areas, pet waste is double counted, both in the runoff and as a separate category. Therefore, a portion of the bacterial runoff from urban areas is generated through pet waste, and is addressed by the practices outlined in section 4.5 above. Lowering urban-runoff will also reduce the impact from pet wastes which comprise a part of the urban runoff. However,

heightened community awareness and local ordinance enforcement can complement LID practices, etc., and will help decrease the amount of pet waste allowed to enter waterways. We will support this through dissemination of printed materials and through reference at community meetings and other outreach efforts. Through educational efforts, HOAs can be encouraged by stakeholders, residents, and local businesses to include pet waste reduction provisions in new and existing by-laws. As no structural provisions are required for this specific measure, retroactive by-laws could easily be adopted. “Pooper scooper” laws have not been effective as a sole approach in many communities in the United States, but enhanced enforcement by local governments is the primary recommendation under this WPP, and represents a more direct and comprehensive approach. The effectiveness of these combined outreach efforts are likely to 2% in reducing load reductions in the watershed. (Abroms, et al., 2003) The Plan also calls for addition of pet waste stations and related materials. Given that no reliable reduction estimates are available for the impact of these elements, they are being considered part of the combined 2% outreach efforts reduction estimate.

Table 2: Summary of Expected Load Reductions

Source	Reduction expected (as % of total loading by 2040)	Reduction In million cfu/year	Source of estimate
~~Education and Outreach~~	~~2%~~		~~Literature values~~
Livestock	7%		lit values and existing/proposed acreage under BMP
Wastewater Treatment Plants	1%		lit values regarding CMOM/other improvements
OSSFs	4%		lit values, proposed projects
Urban Runoff	3%		lit values, proposed projects
Pets	2%		lit values (for education efforts and HOA efforts)
Total	**19% reduction of total load**		

4.7 Totals Reduction Estimates

The total reductions of potential loadings represented by the estimates in section 4.1-4.6 (See Table 2) were applied under the EPD-RIV1 modeling effort. Given that some categories included potential ranges of reductions, a general reduction of 19% of source loadings was applied under EPD-RIV1. Because EPD-RIV1 uses different categories and sources of input, the 19% was broken and applied to the inputs most related to the original sources (see **Appendix C** for more detail).

When the impacts of the 19% total reduction in sources were modeled against future conditions, it resulted in reductions in overall concentrations at the monitoring stations.

The end result indicates that, with the suite of BMPs recommended under the WPP, the bacteria concentrations for the waterways would likely remain below the water quality standard. While nutrients are not specifically modeled, and therefore no reduction estimates were produced, it is expected that many of the BMPs designed to retard bacteria inputs would also serve to reduce nutrient loads (buffer areas, education, addressing OSSFs, etc)

5 Management Measures Element C

To address the concerns in Bastrop Bayou Watershed, the stakeholders identified and prioritized potential management measures. Ideas for projects were solicited from stakeholders and local decision makers, and taken from existing watershed protection efforts. The ideas were presented to the stakeholders over three monthly meetings which allowed for ample discussion of each idea. Finally the stakeholders selected three ideas/projects each. The numbers of votes for each project were tallied and results presented to the stakeholders. The stakeholders approved the projects and a ranking was developed for implementation. The same priorities were used for the projects presented here. The stakeholders felt that education and outreach were the most important activity. This was a universal across all of the stakeholders. Enforcement and addressing issues through the HOA's were felt to be the least effective. Some detail regarding these management measures is contained in Section 3. The following is a discussion of the suite of management measures selected for implementation, in ranked order.

5.1 Education & Outreach

Outreach and educational efforts are a core part of the WPP model. The following management measures, grouped into categories, are recommended for the education and outreach component of the Plan's prescribed solutions. They are part of the efforts described in Sections 5.2-6.0, and should be not be considered in terms of rank. These are specific items, which will be supported through presence at local events and other general outreach as deemed appropriate.

1. **Informational/Promotional Materials-** The materials will be disseminated to the public to cover a variety of issues. Because many of the materials have already been developed, these promotional items are free of charge, even in large quantities, from EPA, TCEQ and other local groups. These materials may also be used in conjunction with enforcement activities. It is expected that these informational materials will be a mix of general and locally-specific components.
    a. **Cattle management materials** will be used to promote existing state financial incentive programs to ranchers.
    b. **OSSF maintenance materials** will be aimed towards homeowners and community groups in order to disseminate materials providing proper OSSF maintenance techniques.
    c. **Urban runoff project signage** will be displayed at various locations where low impact and large scale development projects have been installed. These will serve as a demonstrative classroom experience to describe the methods that stormwater BMPs use to improve surface water quality.

2. **Public Relations-** Public relations materials will include a website for the watershed which will provide updates of upcoming events and current information that is valuable to residents of the watershed. Press releases and newsletter articles will be written and published on a regular basis also to update residents of pertinent information regarding Bastrop Bayou and its tributaries.
3. **Model Homeowner Association (HOA) bylaws-** HOA bylaws hold the potential for enhancing enforcement of septic system regulations and promoting pet waste management in new communities. By using HOA's, the community can distribute informational materials and even enforce regulations on septic systems and pet wastes. H-GAC will provide a set of model guidelines to assist local HOAs with pursuing such changes. The model ordinances will be made available to all HOAs, but it is intended only as an educational tool for the HOA. No community will be required to enact any ordinances based on this recommendation.
4. **Watershed Signage-** Signage regarding watershed boundaries and illegal dumping will be erected and an illegal dumping hotline number will be posted at popular fishing locations. The county would construct the signs and provide the hotline to report illegal dumping. The signs would act as an educational and enforcement tool.
5. **Workshop and Classroom Activities-** Many organizations offer workshops to provide a hands-on experience. The activities can be varied depending on the educator and the audience.
    a. **Project WET and WILD** would be taught in the classroom as an adjunct to the Science curriculum. Both WET and WILD are certified by the Texas Education Agency for use in classrooms. The Brazosport ISD would also use Texas Stream Team kits in the classroom as an adjunct to the regular laboratory work. This is intended for grades 6 and onwards.
    b. **Educational kits** will be demonstrated at the public events, including the Trash Bash event. The Enviroscape kits are a popular hands-on-activity at fairs and provide a fun way to learn about watersheds.
    c. **An educational trail** would be used by the local community and feature educational signs and offer a place for ecological tours within the Watershed. DOW Chemical is working with the US Fish and Wildlife Service on dedicating land within the Watershed as part of the National Wildlife Refuge system (DOW Woods).
    d. **Texas Watershed Stewards** is a one day classroom program facilitated by Texas AgriLife Extension. The program is a free event which invites local residents to learn general watershed stewardship and information specific to the watershed in which they reside. Teachers and professionals can also receive continuing education credits for attending.
6. **Educational Survey-** An education survey will be used to assess knowledge among the local residents, and serve as an informative tool.

7. **Public Participation Opportunities-** For those seeking a greater level of involvement, volunteer opportunities are available. Such opportunities also have the ability to provide immediate, direct, and quantifiable impact upon the environment.
    a. The first **Trash Bash** event was held on March 28, 2009, and was featured in the Texas Salt Water Fishing magazine and the Facts newspaper, with nearly 150 volunteers. Trash Bash returned again in 2010, and will continue to be supported on an annual basis. This is the only community cleanup event in the area.
    b. **Texas Stream Team** training events. There are currently eight volunteer monitors in the Watershed, with the goal to increase training events and participation. To support the volunteers, monitoring kits, training and replacement chemicals would be provided.

5.2 Cattle and Wildlife Management

8. **Cattle Programs-** As the primary domesticated animal in the Watershed, Cattle are the focus of livestock management efforts. Incentive-based, voluntary management can prevent livestock waste from entering waterways by fencing them out, and providing alternative water and shade. Upon approval of the WPP, the TSSWCB has agreed to match $5,000 in cash to landowners/lease holders who voluntarily agree to limit runoff from their property. Individual Water Quality Management Plans are reviewed and approved by TSSWCB and are a legal contract. There are 15-25 parcels of property with direct access to the Bayou that may be prime candidates for participation. Additionally, implementation of the WPP will include facilitation and promotion of water quality management plans and similar measures through the TSSWCB and other agricultural agencies. Specific targets are reducing cattle presence in waterways through fencing, and alternative water and shade sources. To support these efforts, an educational component (see 5.1) will help spread the word to landowners.
9. **Feral Hogs-** While no direct action will be taken by the stakeholder group regarding feral hog populations, they will work with partners in the watershed to promote hunter education classes focused on feral hog management and a feral hog hunting promotional event.

5.3 Wastewater Treatment Plants

WWTPs are the most easily identifiable potential point sources of bacteria in the Watershed. Recent state requirements for new permits to include bacterial monitoring of effluent will help provide a better picture of bacterial loading by WWTPs, and also help to catch any noncompliant facilities. There are no management measures suggested for sanitary sewer other than to promote it as a treatment option over OSSFs (see 5.4) and to utilize future bacterial sampling data in Plan review and update processes.

5.4 OSSFs

Based on Brazoria County Health Department assessments, the failure rate is 79% for pre-1989 OSSFs and 42% for post 1989 systems. To address this source, the following management measures were selected. Due to the huge potential costs involved with remediating infrastructure, the extent of some elements of these BMPs will be subject to available funding and partner participation.

10. **Remediate Malfunctioning OSSFs-** For areas where a WWTP is not feasible, the project proposes to promote and potentially fund aspects of assistance programs for low income homeowners to replace malfunctioning systems as funding allows. The homeowner would normally agree to maintain the system as a condition of the assistance. This is likely a long-term element, and relies heavily on partner participation and funding. The extent of the scope will be determined by investigation of existing OSSFs
11. **Enhancing OSSF Design Criteria-** Stakeholders recommended working with Brazoria County to enhance their OSSF design criteria for OSSFs to ensure better siting and OSSF types appropriate to local soil conditions, potentially including shared systems for RV parks and other cluster developments.
12. **Promoting Sanitary Sewer Service-** Sanitary sewer system will be promoted as alternatives to new OSSFs or remediation of old systems in communities through education and coordination with interested parties at the County level. The community of Demi-John is trying to replace malfunctioning septic systems with a WWTP. The WPP group, through the H-GAC has already lent support to grant applications to meet this goal. This is a priority element of this management measure.

5.5 Illegal Dumping/Trash

The stakeholders felt strongly that reducing illegal dumping was an important aspect of promoting pride and awareness of their local waterways and of addressing secondary factors related to contamination. Illegal dumping and trash in the waterways was identified as an ongoing issue in the Watershed. The following management measures were selected to address these issues.

13. **Trash Reduction Events-** The Plan will support and encourage participation in Watershed-wide trash reduction events focused on removing accumulated trash from water bodies and their immediate surroundings. The annual Trash Bash event was selected as a priority aspect of this goal.
14. **Addressing Illegal Dumping-** Stakeholders recommended erecting signage and implementing an illegal dumping hotline through the County to provide education and aid enforcement aimed at curbing illegal dumping.
15. **Addressing Dump Sites-** The Plan calls for supporting the County and other partners in locating existing dump sites and removing dumped materials.

5.6 Urban Runoff

While the majority of the watershed is rural in character, its urban areas can be an appreciable source of runoff contamination. The management measures to address this issue focused on both smaller scale green infrastructure pilot projects, and promoting large scale runoff remediation projects. Construction site runoff was also targeted under these considerations.

Low Impact Development - Urban Runoff

Development of small-scale green infrastructure BMPs includes a variety of pilot projects used to demonstrate and evaluate green infrastructure principles, including:

16. **Angleton Courthouse Annex Project-** A green infrastructure project will be implemented for Angleton's courthouse annex or other suitable public location;
17. **Green Roof Pilot Project-** A green roof pilot project designed to collect rain water for plant use will be implemented with a project partner (site to be determined); and
18. **Green Infrastructure Pilot Projects-** This management measure involves installation of pilot rain gardens or other green infrastructure pilot projects, developed to collect rain water for plant use and/or to serve as a barrier to flowing storm water runoff. These gardens and other projects would not only offer a destination for residents, they also exhibit proper landscaping, plant selection, and gardening techniques to best manage storm water runoff. The selection of the projects will depend on sites and partner preference.

Large-Scale Development Practices - Urban Runoff

Being so close to the coast, flooding is a major concern for the residents in the Watershed. Municipalities have passed and enforce development practices, and collaborate with other local, regional and federal jurisdictions. Promoting storm water detention ponds, constructed wetlands, and similar large scale projects serve both the flood control function and water quality improvement function. Wet-bottom detention ponds have been shown to offer the greatest reduction in bacteria, as compared to similar large scale mitigation efforts. Regional entities like the Harris County Flood Control District have started to implement similar projects, incorporating flood control, water quality, habitat, and recreational aims into detention basins (such as the Project Brays sites along Brays Bayou in Houston). The projects recommended under this Plan are:

19. **Storm Water Detention-** This measure involves supporting, and potentially partially funding where feasible and appropriate, the promotion, development and implementation of large scale storm water detention facilities. Priorities under this management measure are large-scale wet-bottom detention basins and/or constructed wetlands.
20. **Storm Water Filtration -** This measure involves supporting, and potentially partially funding where feasible and appropriate, the promotion, development and implementation of stormwater filtration projects, including vegetative swales, constructed wetlands, and other related elements.

Construction Site Runoff

The stakeholders felt that construction site runoff was an appreciable issue in terms of sediment loading, trash accumulation, and other contaminants. This aspect of urban runoff was targeted for general promotion of partner efforts, including County and municipal efforts to enforce existing stormwater regulations (Phase I/II TPDES requirements, County and municipal codes and ordinances, etc) and general promotion of BMPs to reduce contamination from construction sites, including sediment barriers and similar measures. No specific measures outside of aspects of the overall educational and outreach campaigns were identified for this Plan.

HOA Regulation Enforcement

The mention of model HOA regulations and materials in the Education and Outreach section above refers to H-GAC's development of example information and guidelines for the HOAs. This section refers to the actual enforcement of septic system or pet waste regulations by the HOAs themselves. By regulating more strict management of OSSFs or pet waste cleanup ordinances, the HOAs can pursue a more active method for reducing the bacterial load. In order to avoid double counting of HOA regulations, all load reduction will be applied to the development of regulation materials in the Education and Outreach section.

5.7 Pet Waste Management

These management measures, initially ranked by the stakeholders as part of the urban runoff source, are described separately here to distinguish them from larger-scale BMPs addressed in section 5.6. Pet waste is often an appreciable component of bacteria loading from urban runoff. The Plan recommends that pet waste be addressed through the following management measures, in conjunction with a robust educational component:

21. **Model Ordinances -** Development and support for model bylaws for HOAs, "pooper-scooper"-type ordinances for municipalities, and related requirements for other organizations, Cities, and HOAs will be encouraged to include pet waste reduction provisions in new and existing by-laws and/or ordinances. As no structural provisions are required for this measure, retroactive by-laws could easily be adopted. Residents will be encouraged to manage their pet wastes via education and outreach efforts.
22. **Pet Waste Stations** – this structural element would involve supporting the siting, design, and implementation of one or more pet waste stations in urban or suburban areas in the watershed. The pet waste stations would include a disposal container and pet waste disposal materials (often plastic gloves or bags). The final design and size of the facility will be based on partner preference/existing design codes or other regulation. Local municipalities will be encouraged to install additional pet waste stations in higher use public areas. Specific focus will be given to public parks and events. Signage will be erected with the stations.
23. **Pet Waste Outreach** – A public education and outreach program will be designed for residents and local decision-makers to encourage proper pet

waste disposal. Existing programmatic elements from successful national campaigns will be utilized for this purpose.

5.8 Land Acquisition

Buffers of open land, especially in riparian buffer areas, can aid in reducing contamination from bacteria-laden stormwater. Large tracts of land in the county were last sold prior to the economic crisis. If a large landowner were to sell the property, they would experience a loss, whereas if they donate the property then they can use the property valuations from 2007, which are significantly higher. This creates a unique opportunity to acquire property given the currently economic situation. Congress already allocates monies to US F&W's purchases of land, but not the appraisal of property. The project would only appraise properties while the US F&W would actually purchase the property. Tracts of land adjacent to the bayous or in undeveloped areas can serve as buffers to contaminated runoff. Additionally, through an educational component and existing programs, local landowners and businesses will be encouraged to consider conservation easements in the watershed, especially along riparian buffer zones. Management measures for this category include:

24. **Land Acquisition** – Funding from the project, depending on availability, will help support the acquisition of land for conservation purposes, for costs other than the purchase of the land itself (appraisal, etc). The primary intended partner for this measure is the US F&WS, but other interested organizations may be considered as is feasible.
25. **Conservation Easements –** Where feasible, the stakeholders and local partners will seek to coordinate or facilitate conservation easement education and support conservation easements in the watershed.
26. **New Development Riparian Buffers –** The stakeholders will work with local governing bodies and developers to promote the inclusion of riparian buffers in new development.

5.9 Abandoned Boats

An abandoned shrimp boat was discovered in the Bayou during March, 2009. The boat was abandoned following Hurricane Ike with engine markings removed.

27. The Plan recommends supporting the removal of the boat from the Bayou and disposing of the oils and other hazardous materials safely.

5.10 Enforcement

There is currently limited environmental enforcement capacity for Brazoria County. The stakeholders recommended that the County enhance its enforcement capacity by the following measures:

28. Additional Officers – The Stakeholders recommended that the County agree to staff two additional environmental enforcement officers. Due to economic conditions, the may not be able to directly hire officers at this time, but may consider loaning two sheriff deputies to the environmental enforcement division. The new officers would report to and be supervised by the Environmental Enforcement Division. Timing and duration of personnel support will be based on economic and logistic resources available.

6 Technical and Financial Resources Element D

Identifying technical and financial needs and then matching them to available funding and capacities is a critical first step in mobilizing the resources needed to implement the solutions identified under this Plan. The estimation of costs and timing is dependent on available funding and subject to potential change dependant on economic conditions and outlook.

The needs, costs and matched resources for each category of management measures are detailed in the following subsections. Costs that are not specific to this Plan (i.e. services routinely provided by a given governmental entity) are not included. Additionally, while a matching value is applied to volunteer efforts, efforts undertaken by volunteers are represented as $0 for the sake of accounting for actual costs (rather than in-kind value). The costs below reflect costs to potentially be funded by this WPP project rather than by external sponsors, matching funds, or partners. A full summary is provided as Table 4.

6.1 Education and Outreach

1. Informational Materials.
    a. Model Homeowner Association (HOA) by-laws
        i. Distribute materials - $10,000 for printing and mail outs of previously developed brochures from the County.
        b. General public outreach materials, including an educational survey - $5,000, with emphasis put on utilizing previously-developed
        i. Enforce regulations on septic systems and pet wastes - $0, volunteer enforcement.
2. Workshop and Classroom Activities
    a. Project WET and WILD - $24,000
        i. Cost of classroom materials – $22,900
        ii. Cost of substitute teachers are the ten regular teachers get trained - $1,100
        iii. Expendable worksheets, diagrams for the exercises in the workbooks for ten classrooms (per annum) – $4,500
        iv. Curriculum design and teaching guides - $0, normal service provided by the School district
        v. Teaching of watershed concepts - $0, normal service provided by Teachers and the School District
    b. Texas Stream Team kits – $12,750
        i. Cost of ten kits - $4,000
        ii. Training by a qualified instructor for all three phases, for ten volunteers - $8,750

iii. Replacement of chemicals (per annum) for ten kits - $750
iv. Staff support for ten volunteers, QAPP, QA/QC, Data Review, data submission etc. (per annum) - $9,500
v. Monthly testing and reporting of data - $0 provided by volunteers

c. Enviroscape kits - $2,400
   i. Two kits - $2,400
   ii. Replacement of parts and minor maintenance - $250
   iii. Space for storage of kits while not in use - $0, no cost service provided by County
d. An educational trail - $20,000
   i. Develop educational signage - $0, existing templates or provided by non-profit organizations
   ii. Printing of Signage - $20,000
   iii. Materials and installation of signage - $0, provided by DOW Chemical
   iv. Trail construction on which the signage will be placed - $0, provided by DOW Chemical
   v. Maintenance of signage (per annum) - $0 provide by non-profit organization

3. Participation Opportunities
   a. Trash Bash – $5000 per site with matching dollars from the Texas Conservation Fund (TCF).
      i. Cost for two sites - $10,000
      ii. Trash collection - $0 provided by volunteers
      iii. Food for the event - $0 provided by TCF
      iv. Even organization - $0 provided by TCF
      v. Door prizes - $0 provided by TCF
      vi. Disposal of Wastes - $0 provided by corporate sponsors
      vii. White goods, Hazardous Waste removals - $0 provided by corporate sponsors
      viii. Expendable Materials - $0 provided by TCF
   b. Texas Stream Team
      i. Please see above

6.2 Cattle and Wildlife Management

1. Cattle Projects: - $40,000
   a. Cost for eight land owners - $40,000 (with an additional $40,000 provided by TSSWCB as matching funds)
   b. Consultation for appropriate BMP - $0 provided by the County Extension agent and USDA office staff
   c. Plan development - $0 provided by the local USDA office
   d. Legal and Deed preparation - $0 provided by the TSSWCB
   e. Project materials - $0 provided by land owner, TSSWCB or included in the original contribution
   f. Project construction - $0 provided by the land owner

2. Feral Hog Projects
    a. Hunter Training - $500, provided by partner agencies.
    b. Feral Hog event - $500, additional funding provided by partner agencies.

6.3 Wastewater Treatment Plants

There are no identified expenditures on behalf of this project or future projects under this category. However there are efforts underway by watershed partners that are identified as priorities in the Plan, including the transition of the Demi-John community to sanitary sewer. The dollar figures given are not 319h expenditures.

a. Land Acquisition: $50,000 (if necessary) provided by Demi-John or granting agency.
b. Design of Plant: $75,000, provided by Demi-John or granting agency
c. Pipes and connection to the plant from each household: $0 with $3.3 million – provided by the Texas Water Development Board or other granting agency.
d. Cost of the plant: $0 with $2.5 million – provided by the Texas Water Development Board or other granting agency
e. Grant writer part time (If necessary): (valued at $75,000, but no funds currently projected in this Plan. Demi-John has already submitted a grant application for the projected sanitary option. If additional grant opportunities arise, this item may be amended into future budgets).
f. Operators, maintenance and materials for plant operations for twenty years - $0 provided by residents as Taxes

6.4 OSSFs

1. Low income assistance programs – total costs dependant on available funding and need in the future. No funding is currently projected for this task, and the extent of future repairs will be dependent on further evaluation of watershed OSSFs.
    a. Cost of system repair or replacement - $2,500 / $6,500 per system.
    b. Maintenance cost per annum - $0 provided by home owners
    c. Develop program guidance and enforcement - $0 provided by County Health Department
    d. Inspection fees - $0 provided by County Health Dept.
    e. Legal and Deed restriction as needed - $0 provided by County
    f. Promoting OSSF assistance programs

6.5 Illegal Dumping/Trash

1. Signage and an illegal dumping hotline number - $23,000
    a. Cost for five signs non Texas Dept. of Transportation Standards - $500

b. Labor and materials to install the signage – $4500
c. Hotline, per year costs - $20,000
d. Dispatch of enforcement officers - $0 provided by County
e. Clean-up of materials as discovered - $0 provided by County
f. White goods or hazardous material fees - $0 provided by County

6.6 Urban Runoff - Low Impact Development

Construction costs are highly variable for large projects. These are the typical unit costs for major projects for Brazoria County. County engineers utilize specialized software to calculate the costs of complex projects. Costs inputs used in the software for conventional projects are listed below (Table 3).

Table 3: Major Projects Cost Figures

Improvement	Cost
Roads, Grading	$29.00 per linear foot
Roads, Paving (26-foot width)	$87.50 per linear foot
Roads, Curb and Gutter	$19.00 per linear foot
Total Cost of Road	$121.00 per linear foot
Sidewalks	$15.00 per linear foot
Storm Sewer (24 inches)	$23.50 per linear foot
Driveway Aprons	$650 per apron
Parking Spaces	$1,100 per parking space ($2.75 per square foot)
Clearing (wooded property)	$1,500 per acre
Sediment Control	$800 per acre
Storm water Management	$5,000 to $60,000 per impervious acre
Water/Sewer	$6,000 per lot (variable)
Well/Septic	$6,500 per lot (variable)

Working with County Officials, and the HUD 2003 report the benefits and drawbacks are summarized below (Table 4). Although grants are available for construction, County officials are most concerned with the maintenance of roads and other projects. Although pervious concrete is great for the water quality, it has very high maintenance costs. The pores trap dirt particles and water droplets. During rain events, a thin layer of slippery mud develops as a result. Gravel roads are low cost, not maintenance intensive and offer very high water quality benefits. However, residents do not like gravel roads because they offer a bumpy car ride.

Table 4: Material Benefits Comparison

Material	Initial Cost	Maintenance Cost	Water Quality Benefits
Asphalt/Concrete	Medium	Low	Low
Pervious Concrete	High	High	High
Porous Asphalt	High	High	High
Turf Block	Medium	High	High
Brick	High	Medium	Medium
Natural Stone	High	Medium	Medium
Concrete Unit Paver	Medium	Medium	Medium
Gravel	Low	Medium	High
Wood Mulch	Low	Medium	High
Cobbles	Low	Medium	Medium

6.7 Urban Runoff - Large-Scale Development Practices

Large scale projects are even more dependent on maintenace costs. The following list details the approximate cost for such projects based on the values derived from the Texas' Department of Transportation software package. The output with guidance from the County officials is listed below. These sums are not provided under funding for this or subsequent projects, but are from various partners or other funding sources.

1. Landscape gardens at a Park within the Watershed - $75,000, Community Develeopment Block Grants (CDBG)
2. For the Courthouse Annex, pervious pavement, a green roof projects, and a rain garden - $500,000 – provided by CDBG
3. Stormwater Detention Ponds - $3,234,840 – provided by Flood Control district, CDBG
4. Wetland Detention areas, and swales $4,467,160 - provided by Flood Control district, CDBG

6.8 Pet Waste Management

1. Homeowner Association (HOA)
    a. Distribute materials - $10,000 for printing and mail outs of preexisting brochures from the County.
    b. Enforce neighborhood pet waste code - $0, volunteer enforcement.
2. City Parks (three)
    a. Signage for parks - $2,250

b. Cost of stations at each park - $2,400
c. Materials and labor for installation - $0 provided by Parks Dept.
d. Expendable supplies (gloves, bags etc.) (per annum) - $2,700
e. Disposal of wastes - $0 provided by City

6.9 Land Acquisition

For the sake of this Plan, the cost per property is assumed as the initial funded cost during implementation. As additional funding is available, more properties may be considered.

1. Appraisal of Property - $10,000 per property, provided by project or granting agency.
2. Property acquisition - $0, staff resources provided by USFWS
3. Property Donation - $0 provided by the land owner

6.10 Abandoned Boats

1. Boat removal - $25,000
2. Disposal of removed materials - $0 provided by the County
3. Disposal of hazardous materials or sludge - $0 provided by the County

6.11 Enforcement

1. Environmental Unit
    a. Permanent loan of two officers - $0, (valued at $75,000 in personnel and training costs), provided by the County

6.12 Monitoring

Cost for all three categories of BMP monitoring is lumped together because monitoring events will be conducted during the same trip. Cost includes staff time, mileage, and lab costs.

1. Ambient monitoring - $0, funding provided as match by Clean Rivers Program
2. BMP pre- and post-implementation monitoring - $3,900

N.b. The dollar figures listed throughout this section are assumed to come from the 319(h) or other Federal, State or private grants where not attributed to other sources. Since most public and private grants require a matching component, the matching sources are also listed. The assumption is that a grant would provide 60% of funds with the remainder as match.

Table 5: Technical and Financial Resources Summary

Category	Cost
Education and Outreach	**84,150**
Informational Materials	**15,000**
Public Outreach materials	*5,000*
Model HOA Bylaws	*10,000*
Workshop and Classroom Activities	**59,150**
Project WET and WILD	*24,000*
Texas Stream Team Sponsorship	*12,750*
Enviroscape Kits	*2,400*
Educational Trail	*20,000*
Participation Opportunities	**10,000**
Trash Bash	10,000
Texas Stream Team	n.a.
Cattle and Wildlife Management	**41,000**
Cattle Projects	40,000
Feral Hog projects	1,000
OSSFs	(Variable)
OSSF Low Income Assistance Program	(variable)
Illegal Dumping/Trash	25,000
Dumping and Watershed Signage	5,000
Hotline Costs (per year)	20,000
Urban Runoff*	**0**
Demonstration Rain Gardens	75,000
Green Infrastructure Projects at the Courthouse Annex	500,000
Stormwater Detention Ponds	3,234,840
Wetland Detention Areas	4,467,160
Pet Waste Management	**32,050**
Educational Materials	10,000
Pet Waste Stations with Signage	22,050
Land Acquisition	**10,000**
Property Appraisal or other Services	10,000
Abandoned Boats	**25,000**
Removal of Beached Shrimp Boat	25,000
Enforcement	**0***
Loan of Additional Enforcement Officers	75,000*
Monitoring	**3,900**
Ambient Monitoring	0
BMP monitoring	3,900

*** Costs are shown to indicate scope of partner contributions. However there are no projected costs to be funded under grant projects associated with this Plan.**

Summary

The extent to which these costs could be funded by future state and federal funding related to this WPP will be dependent on available funding and ability of local entities to contribute. Therefore the apportionment of costs will be equally reliant on project opportunities as they arise, and the ability of partners to contribute specific to the project and timing. The above lists represent a total of all identified projects recommended under this WPP. The implementation of these projects will be largely dependent on funding availability and economic conditions. Furthermore, projects will be prioritized based on the established priority ranking of the categories (further information on implementation is provided in Section 8.

7 Education and Outreach Element E

Education and outreach activities are a vital aspect of a WPP, and complement structurally oriented BMPs by addressing human behaviors. While structural management measures remediate the impacts of a contamination-causing activity, behavioral measures address the root causes. In this way, the two types of solutions are complimentary. This plan includes a variety of different types of education and outreach opportunities which are intended to impact all sources of bacteria loading into Bastrop Bayou and its tributaries. In order to quantify the load reductions contributed by each component, all the different types of outreach and education were grouped together to compose one category of load reduction. The outreach and education efforts detailed in this Plan are categorized as Promotional materials, Workshop or Classroom Activities, and Public Participation activities.

7.1 Promotional Materials

These materials are publications that have been printed or are online and are often readily available. They also include videos that can be borrowed or otherwise obtained for viewing. These are valuable to supplement presentations and to hand out at fairs and other outreach events with mass attendance. The material is standardized, and therefore the message is presented equally to all audiences. Printed materials help reinforce a message that may be lost, as they can be read and re-read at leisure. Because they have already been produced, these promotional items can usually be obtained free of charge, even in large quantities. Homeowner Associations (HOA) and other projects can use these promotional materials to distribute their message to residents of the Watershed. The Plan will utilize the following promotional materials:

1. **Watershed Protection Campaign Brochure and Executive Summary**
   A watershed protection brochure titled “Bastrop Bayou Watershed” was updated to educate individuals about the impacts of individual activities on water quality and how to reduce those impacts. An update of the brochure is planned when the current printing runs out. A glossy “executive summary” publication was produces as a companion to the WPP. It provides a general summary of the WPP in an easily accessible format.

2. **Website**
   The Bastrop Bayou website www.bastropbayou.org is maintained by H-GAC. Information on the Watershed, press releases, upcoming meeting announcements and information presented at previous meetings can be currently found on the site. An online discussion forum, links to project partners, access to the Watershed Protection Plan, water quality data and an event calendar have been added. An additional domain name www.bastropbayou.net has been purchased and seamlessly links to the web page as well.

3. **Press Releases**
   H-GAC creates and submits news releases to numerous media outlets, including 5 local newspapers and approximately 50 additional local and regional newspapers, magazines, radio programs and TV stations in the Watershed. Additional public information articles were developed and will be submitted to key outlets to announce completion of the WPP and to encourage stakeholder involvement in the implementation process, as funding allows.

4. **Newsletter Articles**
   Watershed updates will be written for the "Coordinated Watershed Protection in Southeast and South Central Texas" newsletter, which is prepared and disseminated by the TSSWCB. The newsletter is distributed monthly/bimonthly by mail and email and is available on the TSSWCB, Texas Watershed Steward websites. These updates provide information to a broader regional audience about activities, approaches and progress in the Watershed and serve as an important component of partnerships with similar groups in the state. During subsequent phases of the Plan implementation, other opportunities to disseminate professional information about the WPP will be utilized, including professional organizations, conferences, and other community organization outreach efforts.

5. **Signage** will also be used to distribute information. If a hotline number is attached then the sign becomes an enforcement tool as well. **Road signs** would be developed and delivered to the county transportation department. They will be posted along major roads notifying travelers that they are entering the Watershed or when they are crossing a significant tributary. By adding a hotline number they can serve an enforcement component as well.

6. **Cattle Management**
   In order to reach ranchers who may be interested in the financial incentives projects, existing promotional materials from the TSSWCB and USDA will be used. It is expected local representatives from those groups will also pursue interested property owners through their existing programs.

7. **OSSFs**
   In order to reach homeowners, the local HOAs or similar community groups will be used. Existing literature from the Health Department and other watershed protection efforts will be used as an education aid to home owners.

8. **Pet Waste Management**

HOAs and signage at parks will be used to inform the community about pet waste management. The easy gloves and bags and a disposal site will serve to enhance compliance with ordinances.

7.2 Workshop and Classroom Activities

Outreach efforts can also be categorized as Workshop and Classroom activities. Many organizations offer workshops to provide a hands-on experience. These range from creating a wildlife-friendly habitat on school grounds, to wading knee-deep into the Bayou to collect and examine "bugs" (macroinvertebrates), to locally-based ecology courses through organizations like the Master Naturalists. In some cases, the participants enroll and attend at a specific organization's facility or educators go to schools and teach students in their classrooms as part of their school curriculum. In addition, the activities can be varied depending on the educator and the audience, for a more individualized lesson. **This Plan will utilize:**

1. **Texas Watershed Stewards**
   Texas Watershed Stewards is a science-based watershed education program designed to help citizens identify and take action to address local water quality impairments. One training event was held on May, 2008 for the Watershed, and additional training events will be held as warranted and feasible.

2. **Project WET and WILD**
   These projects are developed as an adjunct to the science curriculum through a grant from the National Science Foundation. The purpose of the Project WET program is to teach children in junior and senior high schools about watersheds. Project WILD is the same type of program for elementary students. Both are certified by the Texas Education Agency.

3. **Texas Stream Team (TST)**
   TST volunteers help provide valuable information about local water conditions by conducting routine water quality monitoring. The kits used by TST can also be used by junior and senior high school students. Students can learn about science by using a hands on approach, and a class can adopt a stream to monitor with their teacher.

4. **Enviroscape kits**
   These are simple models to demonstrate the concept of a watershed. The participant sprays colored water onto the plastic model and watches the water move into the stream. They will be utilized by various partners at public events.

5. **Educational Trail**
   Educational trails offer tactile way to understand ecology. Signs inform visitors about ecological concepts. The entire trail can be a "classroom" with

well designed interpretative signage. The Brazoria National Wildlife Refuge, and the proposed DOW Woods location, maintained by the US F&WS, utilize such trails to help promote conservation education.This site will serve as an outdoor classroom, or “living laboratory” for watershed education.

6. **Low Impact and Large Scale Development Projects**
   These projects can serve as a demonstrative classroom experience, by describing methods for improving water quality through the use of interpretative signage.

7.3 Public Participation Opportunities

The third way in which outreach efforts can be categorized is as public participation opportunities. For those seeking a greater level of involvement, numerous opportunities for direct public participation exist. Storm drain marking, regular water quality monitoring, local recycling programs, clean-up days, and other activities are organized by municipalities and other organizations in the area. Such opportunities also have the ability to provide immediate, direct, and quantifiable impact upon the environment. The implementation of this Plan will provide the following public participation opportunities:

1. **Texas Stream Team (formerly Texas Watch)**
   TST is a network of volunteers and supportive partners who are trained to collect quality-assured water quality information. H-GAC supports the TST efforts in the area and actively recruits volunteers. Participants in TST are certified at various levels depending on their monitoring activities. Participants must complete a monitoring plan before training begins to specify their environmental goals and concerns. Volunteers complete three phases of training using a test kit that measures physical and chemical parameters in water, and are asked to make a two-year commitment to monitoring their site(s)at the same time of day each month. Phase I Training is a hands-on in a classroom setting and was held in February, 2009. Phase II Training provides the volunteers the opportunity to conduct the monitoring procedures in the field was also conducted in February, 2009. Phase III Training is conducted as a one-on-one session with a Trainer and each volunteer at his or her monitoring site. Eight volunteers are scheduled to undergo this training, and more volunteers will be sought in the future. Program monies, as available, will be spent on the lab kits as well training events for the TST Program.

2. **Illegal Dumping/Litter Campaign (Trash Bash)**
   Community cleanup events sponsored by H-GAC were conducted to remove smaller debris from Watershed bayous and capitalize on public involvement to improve awareness of the overall project. Local volunteers collect the

litter/trash, and corporate volunteers transport the waste to landfills or recycling centers. Educational materials were distributed at the event and provided to cities and counties for other community-sponsored events in the Watershed. The event was held in March 2009 and several articles were published in Salt Water Fishing Magazine and Brazosport Facts. This is a yearly event and will be ongoing at two sites in the Watershed.

The sum of these efforts will be a Watershed-wide outreach campaign aimed at a diverse range of stakeholders. The goal of this campaign is to reduce contamination by altering the behaviors that create it to the greatest practicable extent. To the greatest degree possible, stakeholders will seek to coordinate with existing programs and events, take advantage of existing contact lists and outreach materials, and structure their education campaign in such a way that it fits the financial resources available.

8 Implementation Schedule Element F

Once the stakeholders selected a comprehensive set of management measures, the next step in addressing contamination concerns in the Watershed was to devise a schedule for implementation. The goal of the schedule is to maximize reductions by using an ongoing, phased mix of projects targeting both structural and behavioral causes of bacterial contamination.

Based on funding availability, stakeholder approval, and community participation, implementation scheduling is not estimated with exact dates. Instead, the schedule reflects an anticipated start time frame, assuming funding is available and needed approvals are obtained. The actual start date may vary as a result of feasibility, or the dictates of adaptive management. Many start dates reflect ongoing or initiated projects by partners that are not dependant on future 319 grant funding, and therefore may start before the final approval of this Plan.

Some projects, especially education and outreach, will begin immediately and can continue for long periods of time. Construction project projects have more definite start and end times. More detailed project descriptions can be found in previous sections. All of the implementation projects are depicted in the timeline shown in Table 6 at the end of this section. Additional elements or details may be discussed in Sections 3, 5 and 7 for each category, respectively.

8.1 Education & Outreach

1. Informational Materials. Because they have already been produced, these promotional items are free of charge, and readily available
    a. Model Homeowner Association (HOA) by-laws developed and presented at HOA meetings (2011-2012)
    b. Signage and an illegal dumping hotline number printed and installed throughout watershed(2011 and 2012)
2. Workshop and Classroom Activities. Many organizations offer workshops to provide a hands-on experience
    a. Project WET and WILD as an adjunct to the science curriculum developed and provided to teachers/schools and/or presented to students(duration of the Plan)
    b. Texas Stream Team kits provided to students in the classroom as an adjunct to the regular laboratory work (duration of the Plan)
    c. The Enviroscape kits provided to students and local residents to create a fun way to learn about watersheds. (2011)
    d. An educational trail with educational signage, interpretative materials as well as brochures and publications developed and installed/displayed (2011-2012)
3. Public Participation Opportunities. For those seeking a greater level of involvement, volunteer opportunities are available

a. Annual Trash Bash publicized annually to promote active participation by residents to clean up Bastrop Bayou and/or its tributaries (duration of the Plan)
b. Texas Stream Team volunteer monitoring promoted and supported to facilitate water quality monitoring and awareness by the public (duration of the Plan)

8.2 Cattle and Wildlife Management

There are 15-25 parcels of cattle ranching property with direct access to the Bayou that may participate. Stakeholders will work within the timeframes and resources of existing programs from the TSSWCB and others. (2011-duration of the Plan)

The feral hog hunter training and promotion events will be held in conjunction with partner schedules, and as of yet are not scheduled. Cattle BMPs are the primary focus of this management measure category, therefore the feral hog items will be opportunistic as time and funding makes feasible. (2011-duration of the Plan)

8.3 Wastewater Treatment Plants

The community of Demi-John is planning to replace malfunctioning septic systems with a WWTP. The stakeholders are currently supporting grant application(s) by the Brazoria County Freshwater Supply District No. 2 to address this project.
(2010-duration of the plan, with potential use of grant writer and Plant design scheduled for 2011)

8.4 OSSFs

For areas where a WWTP is not feasible, the project proposes to assist low income homeowners to replace malfunctioning systems. The homeowner would agree to maintain the system as a condition of the assistance. (2011 through the duration of the Plan, with enforcement ongoing and remediation by partner agencies as needed.)

8.5 Pet Waste Management

HOA's can be encouraged to include pet waste reduction provisions in their by-laws. Additionally, HOAs, municipalities and other entities will be encouraged to implement pet waste stations and signage in parks and public areas. (2011-duration of the plan for promotional materials, with signage and stations at the park beginning in 2011)

8.6 Land Acquisition

Appraisal support would help for property acquisition that serves the goals of the WPP. (The appraisal phase would begin in 2011, focusing on short term acquisitions, although the process may last through 2013)

8.7 Abandoned Boats

The project would remove the boat from the Bayou and dispose of the oils and other hazardous materials safely (Boat removal to begin in 2011.)

8.8 Enforcement

The new officers will report to and be supervised by the Environmental Enforcement Division, to enhance environmental investigations in the County (permanent loan of two officers starting in 2011).

8.9 Urban Runoff

Low Impact Development - Urban Runoff
A pervious pavement project for Angleton's courthouse annex, with a green roof rain gardens developed and installed. (Landscape projects at a park in 2012-2013, projects at the Courthouse Annex in 2013-2014.)

Large-Scale Development Practices - Urban Runoff
Stormwater Detention Ponds, wetland detention areas and swales developed and installed. (Stormwater detention ponds in 2013-2015, with wetlands and swale development in 2012-2014.)

Table 6: Implementation Schedule Summary

10 Year Implementation Schedule	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Education and Outreach												
Informational/Promotional materials												
Public relations materials		x	x	x	x	x	x	x	x	x	x	x
Model HOA by-laws			x	x								
Signage and illegal dumping hotline			x	x								
Workshop and Classroom activities		x	x	x	x	x	x	x	x	x	x	x
Enviroscape kits			x									
Educational trail			x	x								
Trash Bash	x	x	x	x	x	x	x	x	x	x	x	x
Texas Stream Team	x	x	x	x	x	x	x	x	x	x	x	x
Texas Watershed Stewards	x											
Cattle and Wildlife Management												
Cattle Projects			x	x	x	x	x	x	x	x	x	x
Feral Hogs		x	x	x	x	x	x	x	x	x	x	x
Wastewater Treatment Plants												
Land acquisition			x	x	x	x	x	x	x	x	x	x
Design of plant			x									
OSSFs												
System enforcement and repair		x	x	x	x	x	x	x	x	x	x	x
Illegal Dumping / Trash												
Address illegal dumpsites			x	x	x	x	x	x	x	x	x	x
Low Impact Development												
Demonstration Green Infrastructure				x	x							
Courthouse Annex projects (pervious pavement, green roof, rain garden)					x	x						
Large-Scale Development Projects												
Stormwater Detention Ponds					x	x	x					
Wetland Detention areas/swales				x	x	x						
Construction Site Runoff												
No specific measures	n/a											
Pet Waste Management												
Print and distribute materials			x	x	x	x	x	x	x	x	x	x
Signage for parks			x									
Pet Waste Stations			x									
Land Acquisition												
Appraisal of Property			x	x	x							
Abandoned Boats												
Boat Removal			x									
Enforcement												
Loan of Two officers to enforcement			x	x								

9 Interim Milestones Element G

The ultimate goal of implementing the management measures is improvement of water quality and protection from future deterioration in the Bastrop Bayou Watershed. In order to ensure that goal is being served by the selected measures this Plan prescribes, results must be measured at pre-determined intervals. Throughout the implementation process, varying obtainable milestones will trigger periodic measurement of success. The following interim milestones, grouped by category of management measures, will indicate the advancement and success of this Plan. Each numbered subcategory represents a class of milestones, and each Roman numeral under the class represents a discrete milestone.

9.1 Education & Outreach

Informational Materials

1. Model Homeowner Association (HOA) by-laws
   i. Develop model by-laws (2011)[2]
   ii. Develop promotion, education and campaign materials for residents (2011)
   iii. Obtain funding to reimburse Texas fees for alteration of by-laws (2012)
   iv. Obtain approval from the HOA board (2012)
   v. Hold election to approve changes (2012)

2. Signage and an illegal dumping hotline number
   i. Determine location of signage (2012)
   ii. Determine if a particular sign would need to comply with DOT requirements (2012)
   iii. Design signage (2012)
   iv. Develop procedures with enforcement division for follow up of complaints (2012)
   v. Develop narrative for hotline operators (2012)
   vi. Print signage (2012)
   vii. Obtain hotline number and sign contract for answering service (2012)
   viii. Develop procedures for disposal of illegally dumped materials (2012)
   ix. Install signage (2012)

Workshop and Classroom Activities

3. Project WET and WILD
   i. Obtain permission from the Teachers (2010)
   ii. Obtain permission from the curriculum coordinator (2010)
   iii. Obtain permission from the principal (2010)
   iv. Obtain permission from the School Board (2010)

[2] Dates in parenthesis indicate expected year the milestone will be completed.

v. Obtain materials from the project WET and WILD foundations (2011)
vi. Develop a curriculum (2011)
vii. Schedule instruction for Teachers (2012 – throughout project)
viii. Hire substitute for classrooms while the Teachers are being trained (2012 – throughout project)

4. Texas Stream Team kits
   i. Obtain permission from the Teachers (2009)
   ii. Obtain permission from the curriculum coordinator (2009)
   iii. Obtain permission from the principal (2009)
   iv. Obtain permission from the School Board (2009)
   v. Obtain and distribute kits (2010 – throughout project)

5. Enviroscape kits
   i. Obtain permission from Commissioners court for use and display (2011)
   ii. Develop instructional narrative (2011)
   iii. Obtain kits (2011)

6. Educational trail
   i. Obtain permission from USFW (2011)
   ii. Develop and design educational signage (2011)
   iii. Printing of Signage (2012)
   iv. Install signage (2012)

Participation Opportunities

7. Trash Bash
   i. Select site coordinator (2009)
   ii. Select site (2009)
   iii. Assemble a team of volunteers (2009 – throughout project)
   iv. Obtain permission from TCF/Trash Bash Board (2009)
   v. Obtain permission from local Commissioners court (2009)
   vi. Develop outreach campaign for the event (2009)
8. Texas Stream Team
   i. Obtain kits (2009)
   ii. Recruit volunteers (2009 – throughout project)
   iii. Determine sites for monitoring (2009)
   iv. Schedule all three phases of training (2009 – throughout project)
   v. Certify volunteers (2009 – throughout project)

9.2 Cattle and Wildlife Management

9. Cattle Projects
   i. Obtain permission from TSSWCB and USDA offices (2011)
   ii. Recruit volunteers (2011 – throughout project)
   iii. Determine sites (2011 – throughout project)

iv. Develop conservation plan (2011)
v. Adopt conservation plan (2011)
vi. Prepare legal and deed documents (2012 – throughout project)
vii. Construct BMPs (2012 – throughout project)

10. Feral Hogs
    i. Obtain agreement from Texas AgriLife (2011)
    ii. Schedule site locations (2011)
    iii. Hold training events (2011)

9.3 Wastewater Treatment Plants

11. Demi-John
    i. Develop plant designs (2011)
    ii. Obtain federal, and state approval of the plans (2011)
    iii. Install connections to the plant (2012)
    iv. Construct plant (2012)

9.4 OSSFs

12. Promote low income assistance
    i. Determine eligibility criteria (2011)
    ii. Obtain local permission (2011)
    iii. Obtain agreements with homeowners for maintenance of the systems (2011)
    iv. Obtain local and state permits for the systems (2012)
    v. Select contactors and install or repair systems (2012 – throughout project)

9.5 Illegal Dumping

13. Address illegal dump sites
    i. Obtain agreement from Brazoria County (2011)
    ii. Locate chronic dumping sites (2012)
    iii. Routinely, or as needed, clean dump sites (2012)

9.6 Urban Runoff

Low Impact Development

13. Landscape gardens at a Park within the Watershed
    i. Obtain agreement with land owners (2012)
    ii. Design project (2012)
    iii. Obtain federal state and local permits for the project (2012)
    iv. Commence construction (2013)
14. For the Courthouse Annex, pervious pavement, a green roof projects, and a rain garden

i. Obtain agreement with land owners (2013)
ii. Design project (2013)
iii. Obtain federal, state and local permits for the project (2013)
iv. Begin construction (2014)

Large-Scale Development Practices - Urban Runoff

15. Stormwater Detention Ponds
    i. Obtain agreement with land owners (2013-2014)
    ii. Design project (2013-2014)
    iii. Obtain federal, state and local permits for the project (2013-2014)
    iv. Begin construction (2014-2015)
16. Wetland Detention areas, and swales
    i. Obtain agreement with land owners (2012-2013)
    ii. Design project (2012-2013)
    iii. Obtain federal, state and local permits for the project (2012-2013)
    iv. Begin construction (2013-2014)

9.7 Pet Waste Management

17. Homeowner Association (HOA)
    i. Develop model by-laws (2011)
    ii. Develop promotion, education and campaign materials for residents (2011 – throughout project)
    iii. Obtain funding to reimburse Texas fees for alteration of by-laws (2011 – throughout project)
    iv. Obtain approval from the HOA board (2011 – throughout project)
    v. Hold election to approve changes (2011 – throughout project)
18. City Parks or other Public Areas (three)
    i. Obtain permission from local governments (2011)
    ii. Finalize disposal options for the wastes (2011)
    iii. Design signage (2011)
    iv. Obtain materials (2011)
    v. Install signage and stations (2011)

9.8 Land Acquisition

19. Recruit land owners (2011-2013)
20. Appraise Property (2011-2013)
21. Property Acquired by Partners (2011-2013)

9.9 Abandoned Boats

22. Obtain permission from the Coast Guard (2011)
23. Determine disposal options (2011)
24. Select Contractor (2011)
25. Removal of Boat and Materials (2011)

9.10 Enforcement

26. Environmental Unit Expansion
    i. Obtain agreement with Sheriff's department, and County Judge (2011)
    ii. Officers trained

These milestones represent graduated measures of implementation, and are designed to aid in the adaptive management process inherent in the WPP model. By determining the individual progress of a given management measure, as well as the sum progress of the Plan's implementation, changes can be made as necessary to better meet the stated goals.

10 Load Reduction Criteria Element H

Bastrop Bayou is not yet listed on the state's 303(d) list of impaired waterways. Therefore, the goal of the project is to keep the Bayou and its tributaries from being placed on the list.

Because the water bodies of the Bayou are not yet listed as impaired, the primary focus of measuring success for this WPP, in terms of reduction criteria, will be continuing to meet the water quality standard. The growth and development in the watershed will be counteracted by the BMPs recommended, as feasible, such that the ideal situation would be a steady state concentration or improvement. Therefore, the primary criteria for this WPP is anti-degradation based, rather than meeting reductions to the standard. The criteria at any point during this WPPs implementation will remain the contact recreation standard. If the standard changes, the adaptive management process will necessitate updating the Plan accordingly.

Additionally, the WPP, and any applicable impact on load reduction criteria, should be revised when the change analysis from the land/use land cover study are completed in late 2011. The original study was completed in 2002, while a new study was completed in 2009. At the time of the modeling the new land use study was not available, though it has subsequently become available. Of specific importance are the changes that have occurred over the last 6 years in the Bayou. As implementation begins, the SELECT modeling may require an update to reflect the changes in land use.

However, given current assumptions, the existing contact recreation standard of 126 MPN/100ml geomean will continue to be used as a load "reduction" criteria for the progress of the WPP. H-GAC and the Clean Rivers Program will conduct a comprehensive data analysis of the Bayou in 2011 for the basin summary report. The Bayou will also be reviewed of any changes in the Basin Highlights Report on an annual basis. If the trend lines continue on the present trajectory in the 2011 report then this WPP should be revised to update proposed strategies and projects to reduce the bacteria load into the Bayou.

In the following section, the plan for ambient and specific BMP monitoring is outlined. Data from those monitoring activities will be the key component in determining the efficacy of the plan and the overall quality of Bastrop Bayou and its tributaries. As stated, the goal of the plan is to prevent *E. coli* levels from breaching the contact recreation standard throughout all of the waterbodies. If data reveals that bacteria levels continue to increase despite implemented activities from this plan, additional strategies will need to be put in place. BMPs will be monitored in specific locations throughout the watershed. Because monitoring will be done on such a small scale, it will be easy to determine if water quality is improving or degrading at the exact location of the BMP. If

bacteria levels are unaffected by the BMPs, it will be likely be necessary to increase the stringency of the BMPs or increase them in number.

11 Effectiveness Monitoring Element I

Due to the dynamic nature of watersheds and the countless variables they entail, some uncertainty is to be expected when a WPP is developed and implemented. As the recommended restoration measures of the Plan are put into action, it will be necessary to track the water quality response over time and make any needed adjustments to the implementation strategy. Currently H-GAC has established a network of nine monitoring stations within the Bastrop Bayou Watershed. The monitoring stations are intended to establish baseline ambient water quality conditions, and are a part of the Clean Rivers Program regional monitoring network. H-GAC selected the station locations based on geographic distribution, availability of safe and continued access, and land use patterns. Five stations are located along the main stem of Bastrop Bayou and four along the major tributaries (Flores, Austin and Brushy bayous). Additionally there is a historical TCEQ monitoring station located at the bottom reach of the Bayou near Demi-John. In all there are ten monitoring stations in the Watershed. Sampling locations are summarized below and displayed previously on Figure 2.

The monitoring plan in Section 11 outlines the monitoring to be done to establish the effectiveness of the BMPs. The ambient monitoring is conducted under an approved TCEQ QAPP, and the resultant data is used in the assessment. The ambient monitoring will continue beyond the current project allowing for continued assessment. Brazoria County has also expressed interest in expanding the sites. The Watershed is now home to eight Texas Stream Team volunteers who collect data under an approved TCEQ QAPP. The ambient and volunteer data will provide the background to assess the effectiveness of the WPP to keep the Bayou from the 303(d) list.

Transitions in the Watershed

The Watershed is in transition from a rural to suburban/urban watershed. As newer land use data is acquired, the sites will be reexamined for relevancy annually through the Coordinated Monitoring Program. Of particular interest will be the new development, which is taking place near the Highway 288 corridor. The corridor is in the Watershed but not adjacent to the waterways. Many other housing and retail developments are expected, but have not yet begun construction. Several developers have purchased land in the Watershed, but have not begun to build on the sites. Given the current economic slowdown, predicting construction starts is not possible. Census bureau forecasts can be valuable estimates, and the land cover data can provide concrete changes that have already occurred. Both will be used in the analysis, with emphasis on current conditions.

11.1 Monitoring Design

Sample Design Rationale

The sample design is utilized to characterize water quality conditions in support of the 305(b) and 303(d) assessments and to identify significant long-term water quality trends. H-GAC coordinates closely with the TCEQ and other participants to ensure a comprehensive water monitoring strategy for the Clean Rivers Program within the Watershed. No data was collected using experimental procedures or for research purposes for which no standardized methodology exists.

CRP ambient monitoring, along with future BMP monitoring efforts, will allow for H-GAC or a successor agency to evaluate the changes in the water quality of Bastrop Bayou and its tributaries. Because ambient monitoring in the Watershed currently takes place as part of H-GAC's CRP program, there is already an ongoing program to analyze data and trends throughout the watershed. H-GAC will provide data from both the ambient water quality monitoring and future BMP monitoring programs to the TCEQ SWQMIS database at least quarterly. Data will be transferred using the TCEQ file structure, and H-GAC will provide a data summary. BMP monitoring sites will also receive TCEQ station numbers, so Station Location Requests will be submitted to TCEQ.

Site Selection Criteria

The site monitoring began in 2004 and data from USGS sediment sampling and historical sites was utilized. Much of the historical data was collected in the late 1970's and mid 1980's thus was of limited use. Methodology used has significantly changed in the past twenty years. This data collection effort involves monitoring routine water quality, using procedures that are consistent with the TCEQ SWQM program, for the purpose of data entry into the statewide database maintained by the TCEQ. All monitoring activities have been developed in coordination with the CRP Steering Committee and with the TCEQ. Sites monitored in the development of this WPP are described below. Sites for future monitoring activities (BMP effectiveness monitoring, etc.) will be selected based on the data objectives of those sampling efforts.

Site Description

Bastrop Bayou – Upper Reach

Two sampling stations are located along upper Bastrop Bayou, 18502 and 18503. Station 18502 is the upper most station in the monitoring network and located just north of the City of Lake Jackson. Water samples represent water quality within the headwaters of Bastrop Bayou and storm water runoff from wooded areas along the upper portion of the riparian corridor. Station 18503 is the second downstream location in the network and is located in a relatively undeveloped area of the Watershed.

Bastrop Bayou – Middle Reach

Two sampling stations (18504 and 18505) are located along the middle reach of Bastrop Bayou. Station 18504 is located near the onset of clustered residential development and canal subdivisions along the main stem of the Bayou. This location also marks a change in shoreline habitat from wooded riparian zones to coastal prairies, and agricultural uses (i.e., cattle grazing). Station 18505 is located in the middle reach of Bastrop Bayou, downstream of "dead end canal" subdivisions and at the inlet of a

major man-made drainage feature (Ditch D). This location is heavily influenced by residential development and cattle grazing. It also is the first station that is directly influenced by drainage from the Central portion of the Watershed. Water from Ditch "D" is directly derived from the headwaters of Brushy Bayou and fields located between station 18509 and 18505.

Bastrop Bayou – Lower Reach
Station 18507 is located along the lower reach of Bastrop Bayou. The station is the most downstream location in the ambient monitoring network and located at the confluence of Bastrop Bayou and Austin Bayou. The location captures water draining from over 90% of the Watershed and is located in a portion of the Watershed that is heavily influenced by coastal wetlands. It is located approximately 1.5 miles upstream from the Isle of Demi John and the village of Mims.

Tributary – Brushy Bayou
18509 is located at the crossing of Brushy Bayou and FM 523, less than one mile east of the City of Angleton. The station includes water from the western portion of the Watershed and is located immediately adjacent to a large reservoir. This location is heavily influenced by agricultural use - especially cattle grazing. It is also the location closest to the city of Angleton.

Tributary – Flores Bayou
Located at the crossing of Flores Bayou and FM 523, approximately two miles south of the Town of Danbury, this sampling station includes water from the central portion of the Watershed and is located immediately downstream from a series of reservoirs. Land cover in the area is dominated by coastal prairie and agricultural fields. Flores Bayou extends into the northern third of the Watershed.

Tributary – Austin Bayou
18506 is located at the crossing of Austin Bayou and FM 523, approximately two miles east of the Town of Danbury. The location includes water from the upper, undeveloped reaches of the Watershed. While the immediate riparian buffer near the station is wooded, nearby land cover is primarily open prairie and agricultural fields. 18048 is located just downstream of the confluence of Austin Bayou and Brushy Bayou, this sampling station includes water from the three major tributaries draining the northern and central sections of the Watershed. The station appears to be tidally influenced, occasionally mixing with the brackish water of Bastrop Bayou.

Sampling Frequency and Parameters
The Environmental Institute of Houston (EIH) collects samples on a quarterly basis in accordance with the sampling procedures contained in CRP's QAPP. Monitoring parameters include 12 laboratory parameters and 16 field observations. Laboratory parameters include, ammonia-nitrogen, chloride, bacteria (*Enterococcus,* based on water type), nitrate + nitrite-nitrogen, ortho-phosphate-phosphorus, sulfate, total dissolved solids, total organic carbon, total phosphorus, total suspended solids and volatile suspended solids. Field observations and measurements include, conductivity,

days since last significant rainfall, dissolved oxygen, flow, pH, present weather, salinity, sampling depth, Secchi depth, temperature, total water depth, turbidity, water color, water odor, water surface, and wind intensity.

EIH conducts all field observations and measurements. Eastex Environmental Laboratories, Inc. is a NELAC accredited laboratory and performs the laboratory analyses. Specific field techniques, laboratory methods, and other specifications are included in the TCEQ approved CRP-QAPP. The colleting agency and analytical laboratory can change according when the work is sent for bidding by H-GAC. The QAPP must be approved by TCEQ for anyone to conduct the sampling and analysis.

2008 Assessment
For the 2008 Assessment Bastrop Bayou was not on the 303(d) List of Impaired Waters. Specifically there is adequate data to analyze support of contact recreation with enterococcus, and the indication is currently "Fully Supporting." There is limited data for the assessment of aquatic life use with 24H dissolved oxygen, but the indication is currently "No Concern." There is adequate data for the assessment of aquatic life use with grab dissolved oxygen, and the indication is currently "Fully Supporting" and "No Concern" for the DO grab minimum and the DO grab screening level respectively.

2010 Assessment

The assessment for Bastrop Bayou did not change in 2010. There are still no impairments listed for Bastrop Bayou itself. In 2010, however, three impairments were listed for two of its tributaries. Flores Bayou and Brushy Bayou have both been listed for bacteria impairments. Brushy Bayou has also been listed for depressed dissolved oxygen.

Now that two tributaries to Bastrop Bayou have been listed with impairments, increased focus of BMP implementation should be placed on these segments. When the plan was first started, there were no impairments listed on any of the waterbodies in the Watershed. The impairments show a degradation of water quality, which need to be addressed accordingly.

11.2 Monitoring Implementation

BMP & Targeted Water Quality Monitoring
BMP effectiveness monitoring with this project is designed to acquire comparable data representative of bacterial loading during storm events from each type of BMP implemented. There will be three types of BMPs implemented and, weather permitting, there will be three monitoring events conducted at each type.

The behavior modification from the BMPs is broad and can only be reflected in the ambient monitoring. The best management projects being implemented can be classified into five broad categories: Public education, increased enforcement, OSSF

repairs, wastewater infrastructure, and land management. Three types of BMPs will be monitored during the course of this project[3].

Upon completion and adoption of this WPP, the conceptual plan is that a set of BMPs will be monitored to help determine whether the steps taken in this plan will promote watershed stewardship and improve water quality enough to eventually remove the recently listed segments from the TCEQ's 303d list of impaired waterbodies. While not all BMPs recommended in the plan will be monitored, a small sample can provide a glimpse at whether any of the strategies can be effective at reducing bacteria levels and improving the overall quality of the water in Bastrop Bayou and its tributaries. This monitoring effort will include pre- and post-implementation stages to compare effectiveness on a local basis.

BMP #1: OSSF Conversion to WWTP: A group of homes will be removed from its connections to OSSFs and will be replaced with a newly constructed WWTP..

- Demi John is pursuing the installation of a WWTP in lieu of individual septic systems. The community is located in a tidal portion of Bastrop Bayou adjacent to a monitoring station. Station 11475 has been monitored by the TCEQ's region office since the early 1980's. If the community is able to finance the WWTP, then the existing locations will be used for the effectiveness monitoring.

-Monitoring: Pre-implementation monitoring will include three monitoring events at a representative location in a canal in the Demi John community before the WWTP is brought online. Post-implementation monitoring will also include three monitoring events at the same location. Post-implementation will occur after the WWTP is in operation and has begun to provide service to a majority of the homes in the Demi John community. Sampling events during both pre- and post-implementation phases will not be biased for wet or dry weather events; however, because the sampling location will be tidally influenced, sampling events should be scheduled to take place at a consistent tidal level based on the location of the sample site[4].

BMP #2: Land Management Improvement (option #1): A rancher will provide an alternate water source and shade for his livestock but will not prevent their access to the waterway with fencing.

-Monitoring: Pre-implementation monitoring will include three wet weather monitoring events at a representative location upstream and downstream of the area of bayou that livestock have been utilizing. Samples will be collected before the alternate water source and shade is provided, and will be taken according to CRP sampling guidelines. Post-implementation monitoring will also include three wet weather monitoring events at the same location. Post-implementation

[3] The costs of the BMP monitoring programs are referenced in Section 6.

[4] All BMP monitoring will be done according to CRP sampling guidelines and will be done under a TCEQ/EPA approved QAPP.

monitoring will take place at least one month and at least one rainfall event after the BMP has been implemented.

BMP #3: Land Management Improvement (option #2): An alternate water source is provided and fencing is installed to prevent livestock access to the waterway.

-Monitoring: Pre-implementation monitoring will include three wet weather monitoring events at a representative location upstream and downstream of the area of bayou that livestock have been utilizing. Samples will be collected before the fence is constructed, and will be taken according to CRP sampling guidelines. Post-implementation monitoring will also include three wet weather monitoring events at the same location. Post-implementation monitoring will take place at least one month and at least one rainfall event after the BMP has been implemented.

There will be at least one and up to three example BMPs sampled for each type of BMP implemented. This short-term intensive monitoring effort will refine the focus of management efforts as well as track the performance of ongoing implementation activities during the study. If the project budget allows, urban storm flow monitoring and wastewater effluent sampling will be incorporated.

Evaluating BMP Effectiveness

As BMP's are implemented, the sites will be surveyed and background conditions recorded. All monitoring conducted currently on Bastrop Bayou and its tributaries are done so as part of CRP's approved monitoring QAPP. Any future monitoring that will not be part of the CRP monitoring program, including BMP monitoring, will need its own TCEQ and EPA approved QAPP. Before and after BMP implementation, the site will be sampled to gauge the effectiveness of the BMP. Wet weather sampling along upstream and downstream sections of the BMPs will offer an accurate assessment of the effectiveness of the implemented BMPs. The ambient monitoring will continue in addition to the targeted monitoring and adjustments will be made accordingly. As efforts continue, the incorporation of new data will improve understanding of the Watershed and drive a more efficient implementation process. Adaptive management allows initial results to guide restoration strategies as stakeholders learn through experience. By tracking stream trends, stakeholders will evaluate whether plan execution is successful and determine the need for new action or refocusing of existing programs.

This adaptive approach relies on constant input of watershed information. If water quality does not meet targets at current monitoring stations (Figure 1), activities will be adjusted based on direction from the Stakeholder Group. Pollutant concentrations targets (as referenced in Section 10) will be based on an assumption of complete implementation of the Watershed Protection Plan and assume full accomplishment of

pollutant load reductions by the end of the planning period as outlined in Table 6. While some of the less complex management measures recommended will be relatively simple to implement early in the process, implementation of other measures will require more time, energy, and funding. For this reason, reductions in pollutant loads and associated concentrations initially may be gradual. However, it can be assumed that reductions in the loading of bacteria and nutrients will be tied to the implementation of management measures throughout the Watershed. Thus, these projected pollutant targets will serve as benchmarks of progress, indicating the need to adjust or maintain planned activities. While water quality conditions likely will change and may not precisely follow the projections indicated here, these estimates serve as a tool to facilitate stakeholder evaluation and decision-making based on adaptive management.

Stream Biological Assessment

In addition to water quality analyses, biological and habitat assessments were completed in the Watershed in 2005. The bayous provide recreational activities to the residents and fishing appears to the most popular activity cited during personal discussions. The survey of the fish and macroinvertebrate communities in the stream as well as the plant communities and physical characteristics of the environment adjacent to the stream serve as indicators of positive or negative response to changes in stream conditions. The survey determined no water quality trends results in measurable changes in the biological communities in the Watershed. The evaluation was conducted by EIH and USGS in 2005.

12 Conclusion

The Bastrop Bayou WPP is a collaborative effort between a diverse set of stakeholders to address and alleviate water quality concerns on Bastrop Bayou. While the Bayou and its tributaries are not currently designated as being impaired, they are unlikely to remain off the 303d list in the near future without direct intervention. Future growth projections and current levels of bacteria and other contaminants promise that, left unaddressed, the issues of today will become the increasing contamination of tomorrow.

While developing this plan, the SELECT model was created to determine the bacteria contributors in the watershed. The largest current, and future, sources of impairment are septic systems, urban runoff, and livestock. The Plan seeks to bring the Watershed's stakeholders together in a coordinated effort to address these concerns that they share for their water bodies. While structural projects will help hold the line against current sources of contamination, the long term success of these efforts will be dependent on

changes in behavior and growth patterns. Prevention of contamination will be key to guaranteeing the future of the Bayou. It is always better to prevent a problem then remediate it.

Utilizing this comprehensive mix of structural and behavioral elements, the plan lays out a road map to achieving its stated goals. Stakeholders will be called upon to volunteer time and resources to implement some key features of the plan. One community is already moving forward with a plan to revitalize its aging wastewater infrastructure. Other landowners will be asked to voluntarily implement agricultural management practices that should greatly improve the water quality throughout the bayous. The plan calls for a monitoring program that will allow stakeholders to make a definitive evaluation of the change in water quality as the plan is implemented. With an eye toward cost-effectiveness and measurable/achievable results, the efficiency of the prescribed management measures will be reviewed at regular intervals and at key milestones. Additionally, stakeholder concerns that may not have a direct impact on bacteria levels but influence the Bayou will be addressed as appropriate. For example, a shrimp boat that has been submerged for more than 25 years will soon be removed from the bayou due to stakeholder actions.

Tying it all together is a core focus on education and outreach to the residents of the Watershed. Road signs will promote increased awareness and ownership of the community's resource. The stated goal of the plan is to keep the bacteria level of Bastrop Bayou and its tributaries below the contact recreation standard for *E. coli*, and the strategies identified here will provide the means to do so. However, the ultimate goal will be to engender conservatorship for water quality among the residents of Bastrop Bayou watershed, toward the end of establishing a perpetual community group to carry on the aims of the Plan.

You never see the same waterway twice. Perpetually flowing, the only constants the water can have is the land over which it flows and the attitudes of the people who reside within its borders. In the Bastrop Bayou Watershed, that land is in flux as it transitions from agricultural to urban and suburban development. In this changing atmosphere, it must be the attitude of its people that remains steadfast. We do not know what either the water or the years will carry with them as both flow past us. Therefore it must be our commitment to be constant in our vigilance for the effect our activities have on the land, the water, and ultimately, ourselves.

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Appendices

Appendix A:

Load and Land Use Characterization

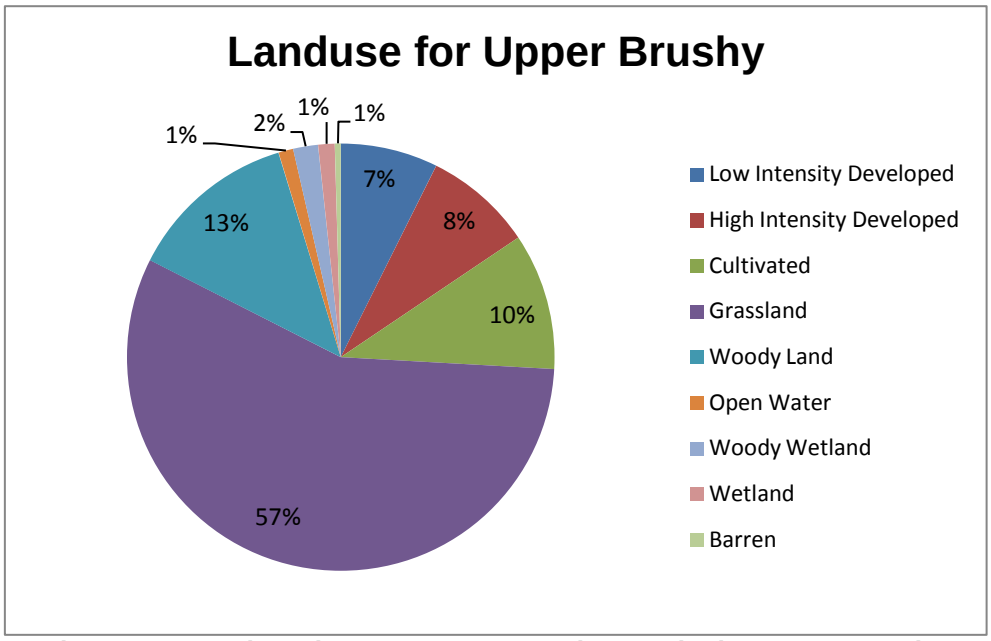

Figure A 1: Land use in Bastrop Bayou Subwatersheds – Upper Brushy

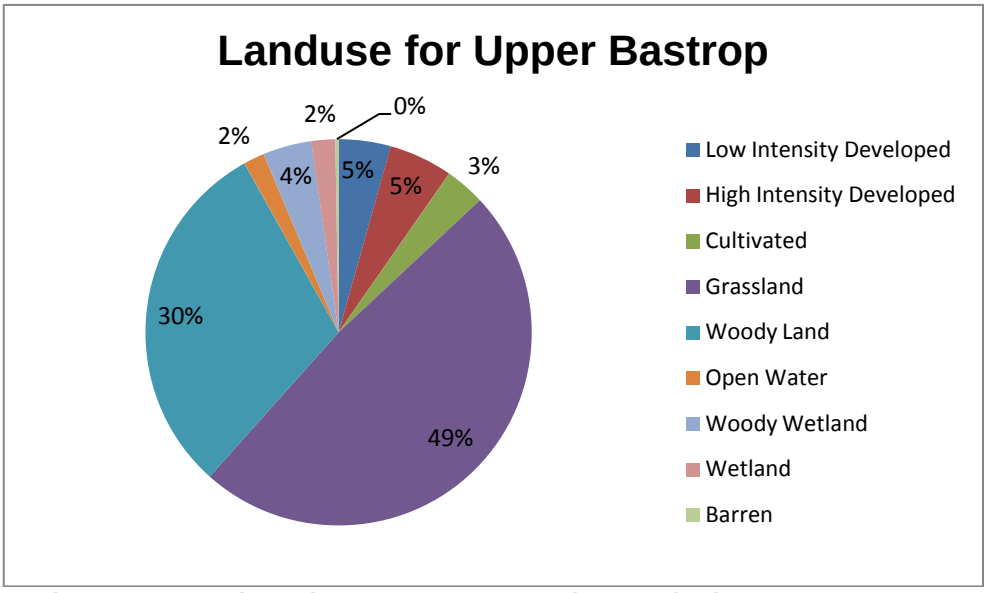

Figure A 2: Land Use in Bastrop Bayou Subwatersheds – Upper Bastrop

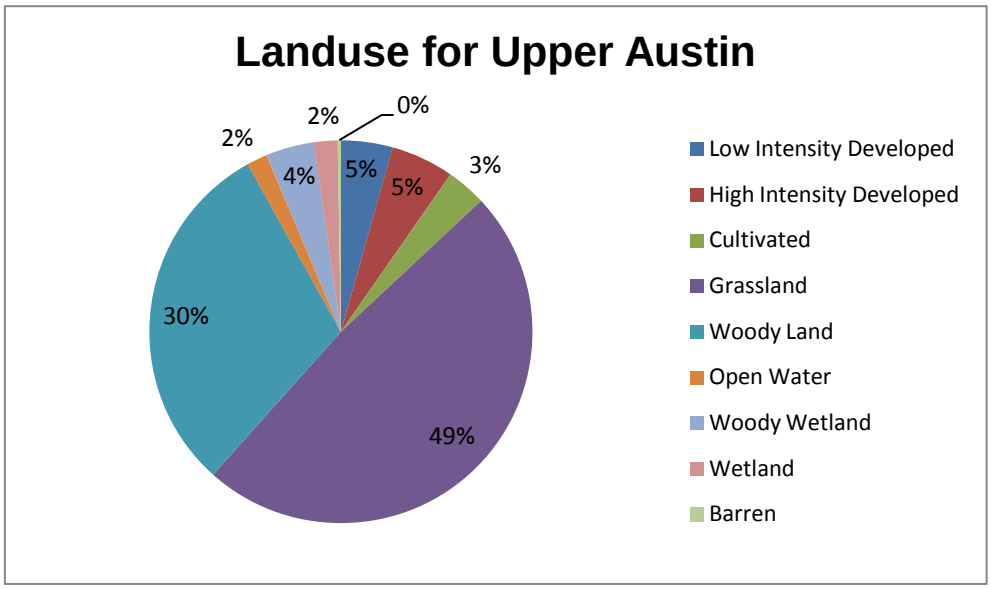

Figure A 3: Land use in Bastrop Bayou Subwatersheds – Upper Austin

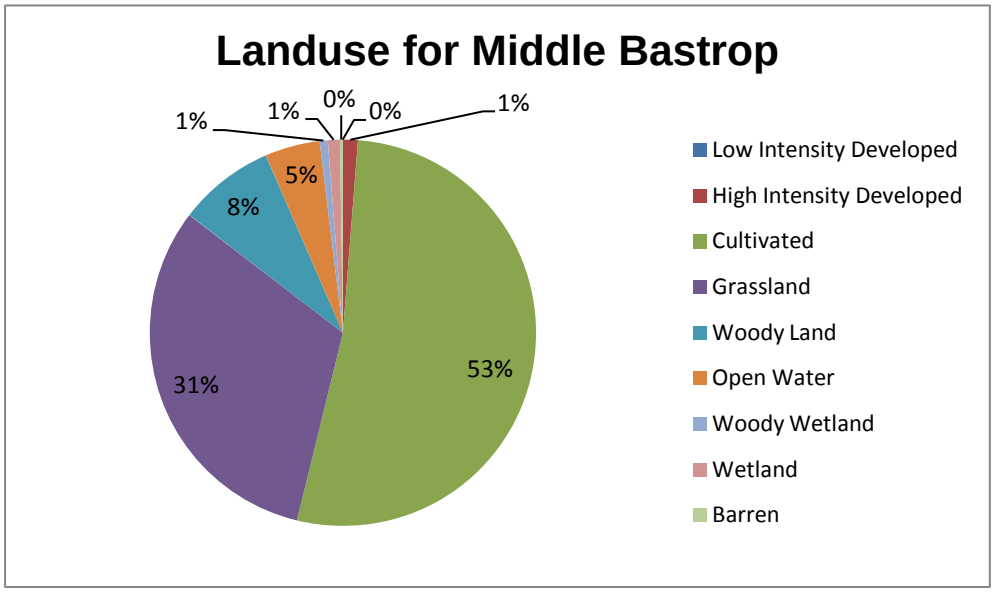

Figure A 4: Land Use in Bastrop Bayou Subwatersheds – Middle Bastrop

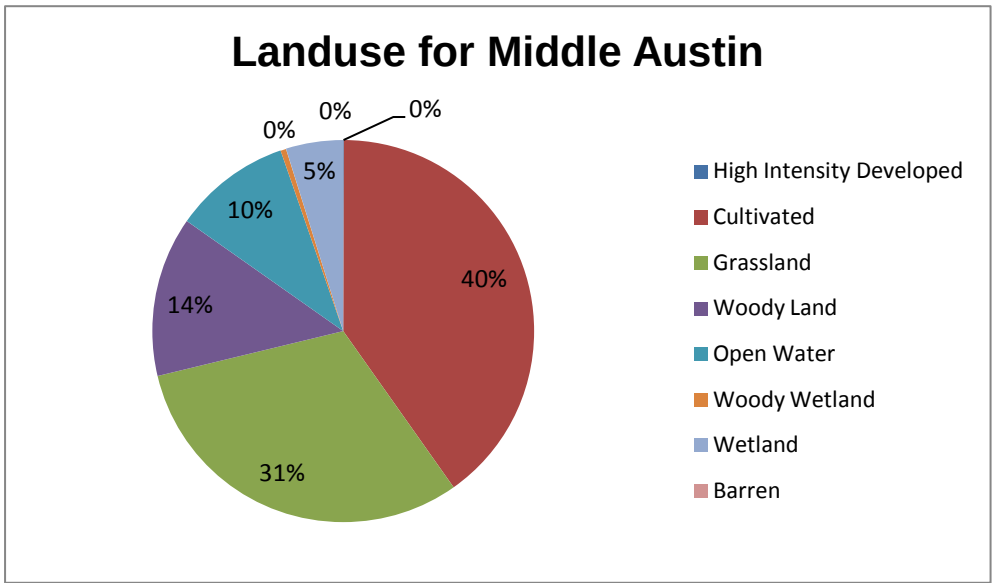

Figure A 5: Land Use in Bastrop Bayou Subwatersheds – Middle Austin

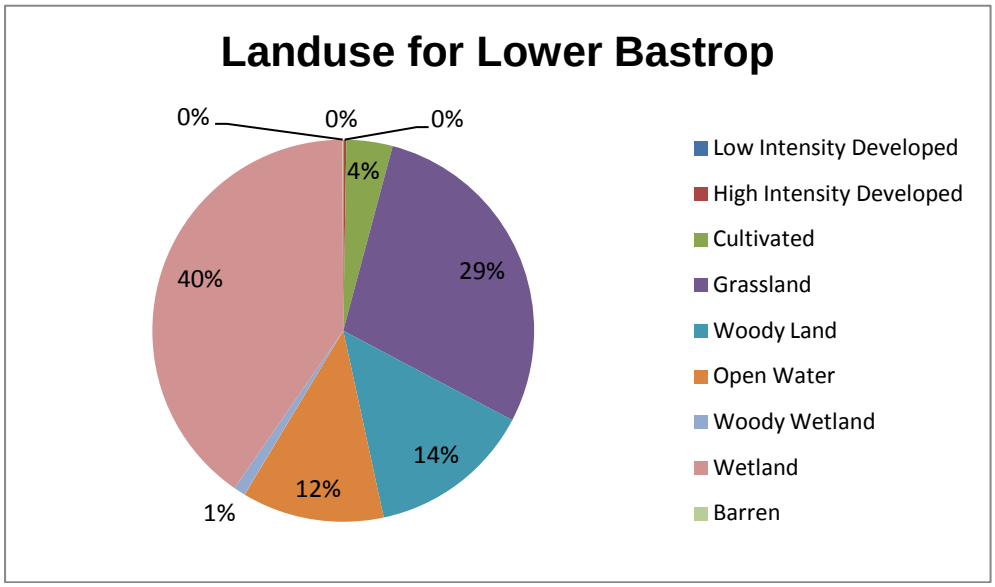

Figure A 6: Land Use in Bastrop Bayou Subwatersheds – Lower Bastrop

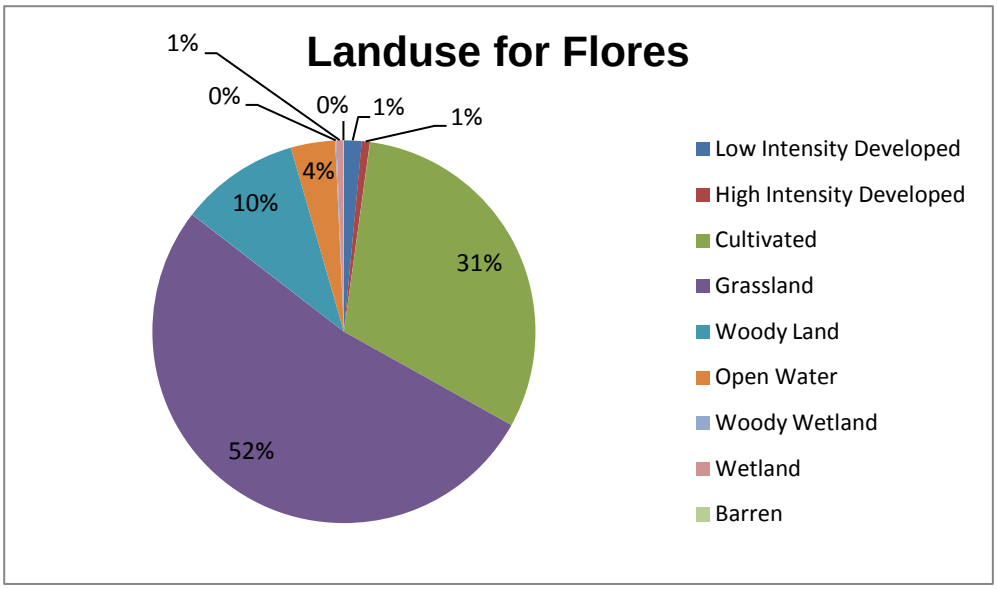

Figure A 7: Land Use in Bastrop Bayou Subwatersheds - Flores

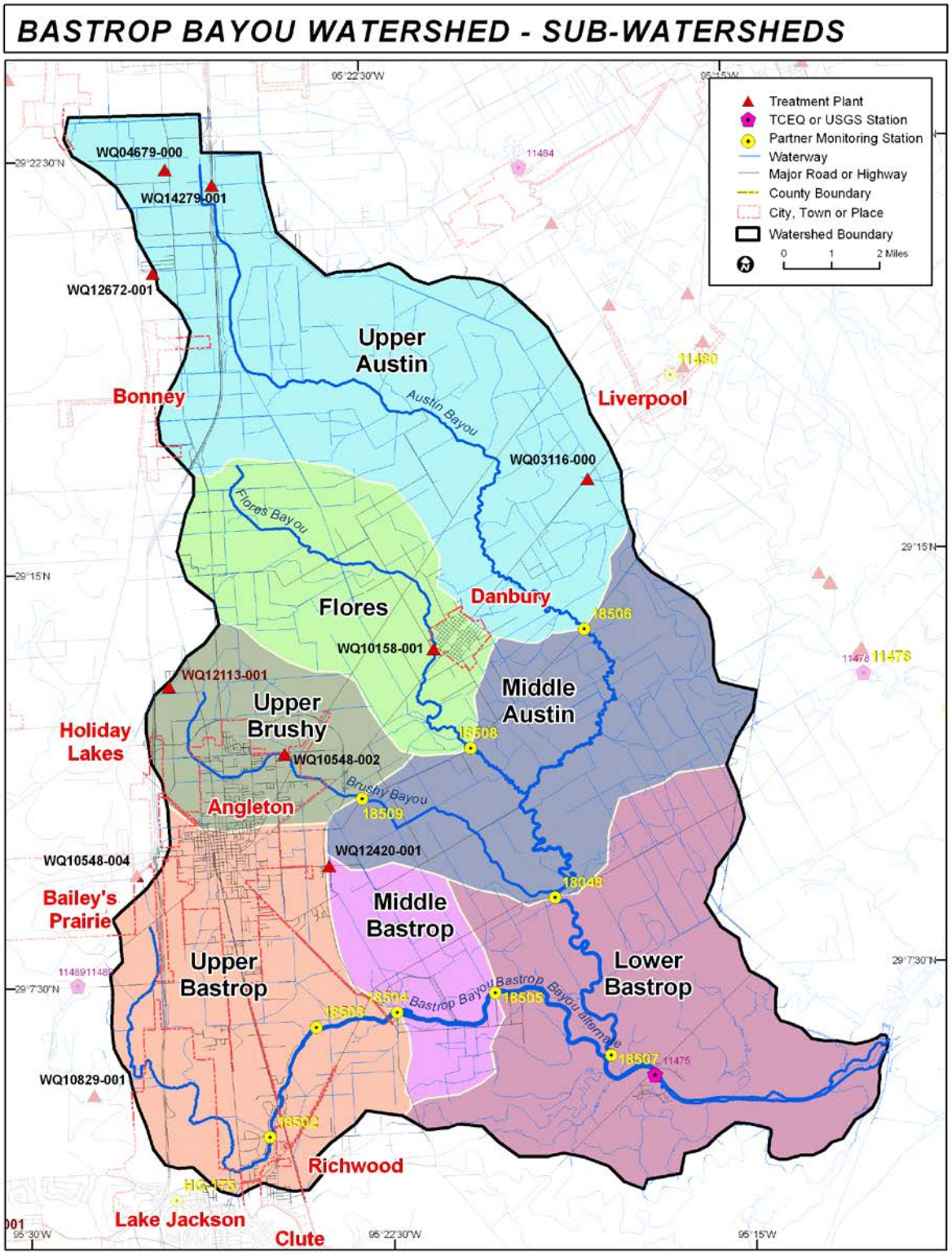

Figure A 8: Watershed, Subwatersheds, and Monitoring Locations

Table A 1: Bastrop Bayou Land Use

Bastrop Bayou Land Use				
	LANDUSE	WATERSHED	ACRES	PERCENT
1	Low Intensity Developed	Upper Brushy	743	7.4%
2	High Intensity Developed	Upper Brushy	827	8.2%
3	Cultivated	Upper Brushy	1,042	10.3%
4	Grassland	Upper Brushy	5,713	56.6%
5	Woody Land	Upper Brushy	1,293	12.8%
6	Open Water	Upper Brushy	113	1.1%
7	Woody Wetland	Upper Brushy	191	1.9%
8	Wetland	Upper Brushy	126	1.3%
9	Barren	Upper Brushy	45	0.4%
	TOTAL			100.0%
1	Low Intensity Developed	Upper Bastrop	966	4.4%
2	High Intensity Developed	Upper Bastrop	1,180	5.3%
3	Cultivated	Upper Bastrop	741	3.3%
4	Grassland	Upper Bastrop	10,755	48.6%
5	Woody Land	Upper Bastrop	6,710	30.3%
6	Open Water	Upper Bastrop	387	1.7%
7	Woody Wetland	Upper Bastrop	902	4.1%
8	Wetland	Upper Bastrop	441	2.0%
9	Barren	Upper Bastrop	61	0.3%
	TOTAL			100.0%
1	Low Intensity Developed	Upper Austin	2	0.0%
2	High Intensity Developed	Upper Austin	448	1.2%
3	Cultivated	Upper Austin	19,088	52.6%
4	Grassland	Upper Austin	11,456	31.6%
5	Woody Land	Upper Austin	2,925	8.1%
6	Open Water	Upper Austin	1,672	4.6%
7	Woody Wetland	Upper Austin	245	0.7%
8	Wetland	Upper Austin	368	1.0%
9	Barren	Upper Austin	88	0.2%
	TOTAL			100.0%
1	Low Intensity Developed	Middle Bastrop	10	0.1%
2	High Intensity Developed	Middle Bastrop	37	0.5%
3	Cultivated	Middle Bastrop	1,363	18.7%
4	Grassland	Middle Bastrop	3,227	44.2%
5	Woody Land	Middle Bastrop	2,101	28.8%
6	Open Water	Middle Bastrop	196	2.7%
7	Woody Wetland	Middle Bastrop	13	0.2%

8	Wetland	Middle Bastrop	348	4.8%
9	Barren	Middle Bastrop	8	0.1%
	TOTAL			100.0%
2	High Intensity Developed	Middle Austin	15	0.1%
3	Cultivated	Middle Austin	8,132	40.1%
4	Grassland	Middle Austin	6,280	31.0%
5	Woody Land	Middle Austin	2,744	13.5%
6	Open Water	Middle Austin	2,010	9.9%
7	Woody Wetland	Middle Austin	95	0.5%
8	Wetland	Middle Austin	978	4.8%
9	Barren	Middle Austin	4	0.0%
	TOTAL			100.0%
1	Low Intensity Developed	Lower Bastrop	3	0.0%
2	High Intensity Developed	Lower Bastrop	69	0.2%
3	Cultivated	Lower Bastrop	1,076	3.9%
4	Grassland	Lower Bastrop	7,870	28.6%
5	Woody Land	Lower Bastrop	3,819	13.9%
6	Open Water	Lower Bastrop	3,315	12.0%
7	Woody Wetland	Lower Bastrop	270	1.0%
8	Wetland	Lower Bastrop	11,108	40.3%
9	Barren	Lower Bastrop	17	0.1%
	TOTAL			100.0%
1	Low Intensity Developed	Flores	231	1.5%
2	High Intensity Developed	Flores	106	0.7%
3	Cultivated	Flores	4,804	30.9%
4	Grassland	Flores	8,133	52.4%
5	Woody Land	Flores	1,562	10.1%
6	Open Water	Flores	583	3.8%
7	Woody Wetland	Flores	15	0.1%
8	Wetland	Flores	88	0.6%
9	Barren	Flores	9	0.1%
	TOTAL			100.0%

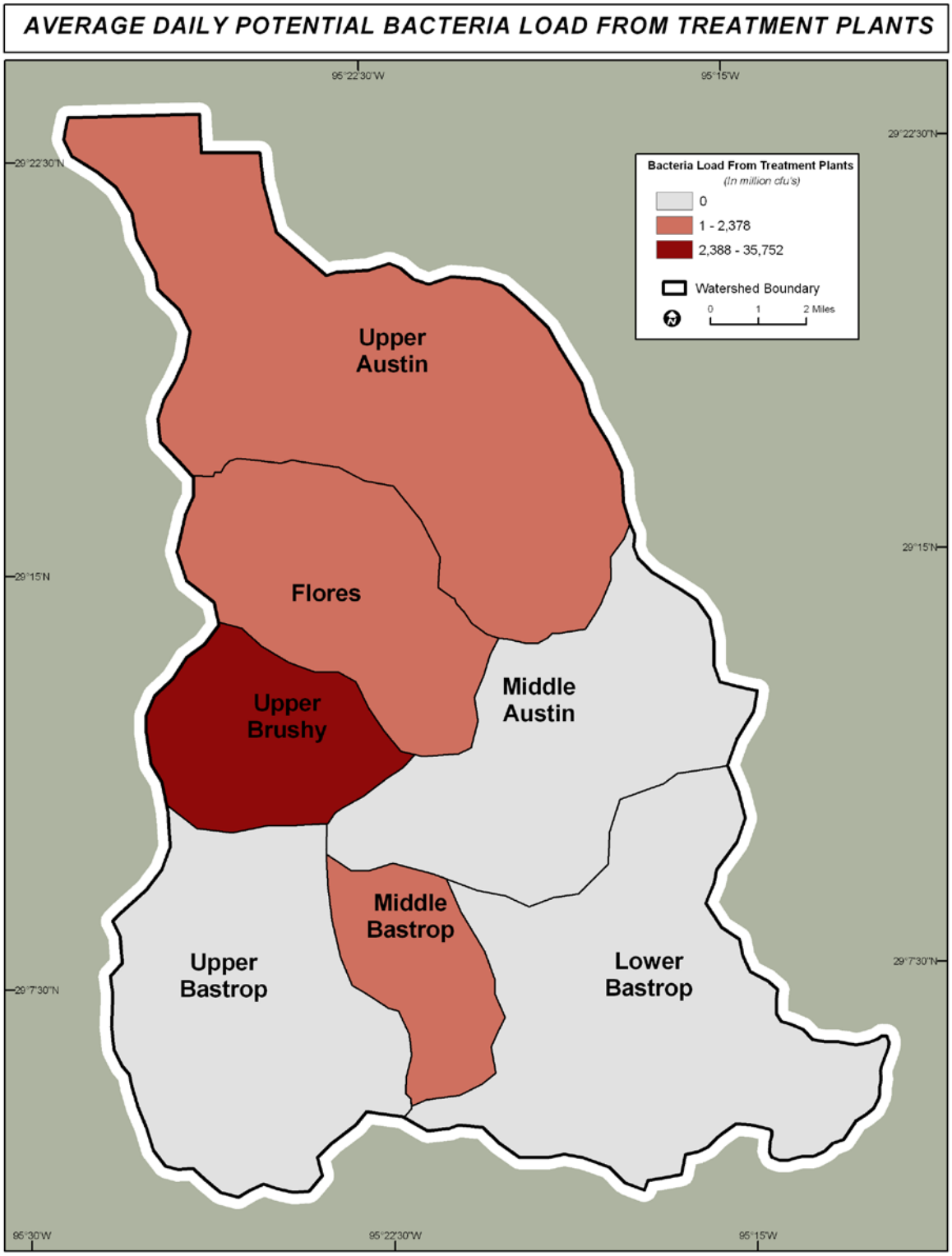

Figure A 9: Average Daily Potential Bacteria Load from WWTPs

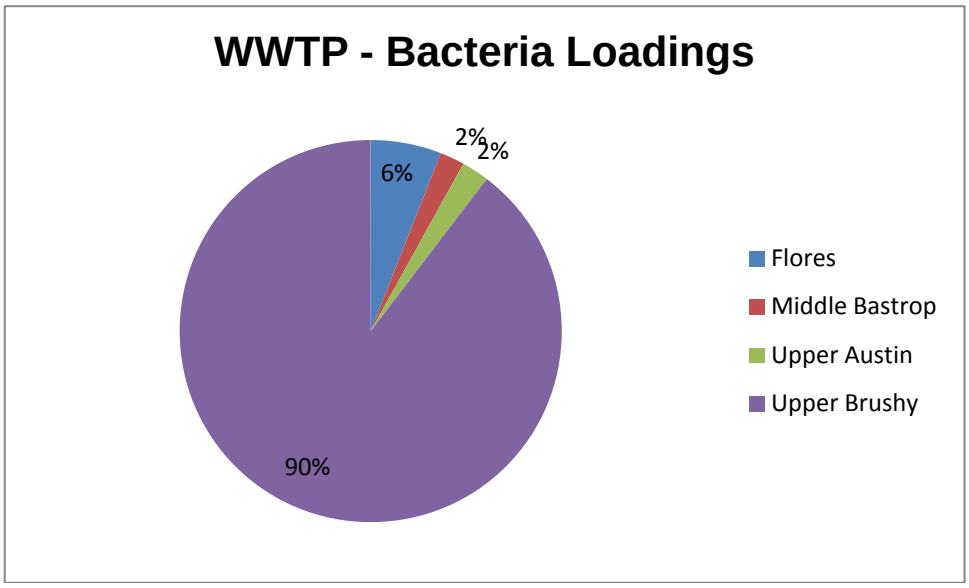

Figure A 10: WWTP Bacteria Loading by Subwatershed

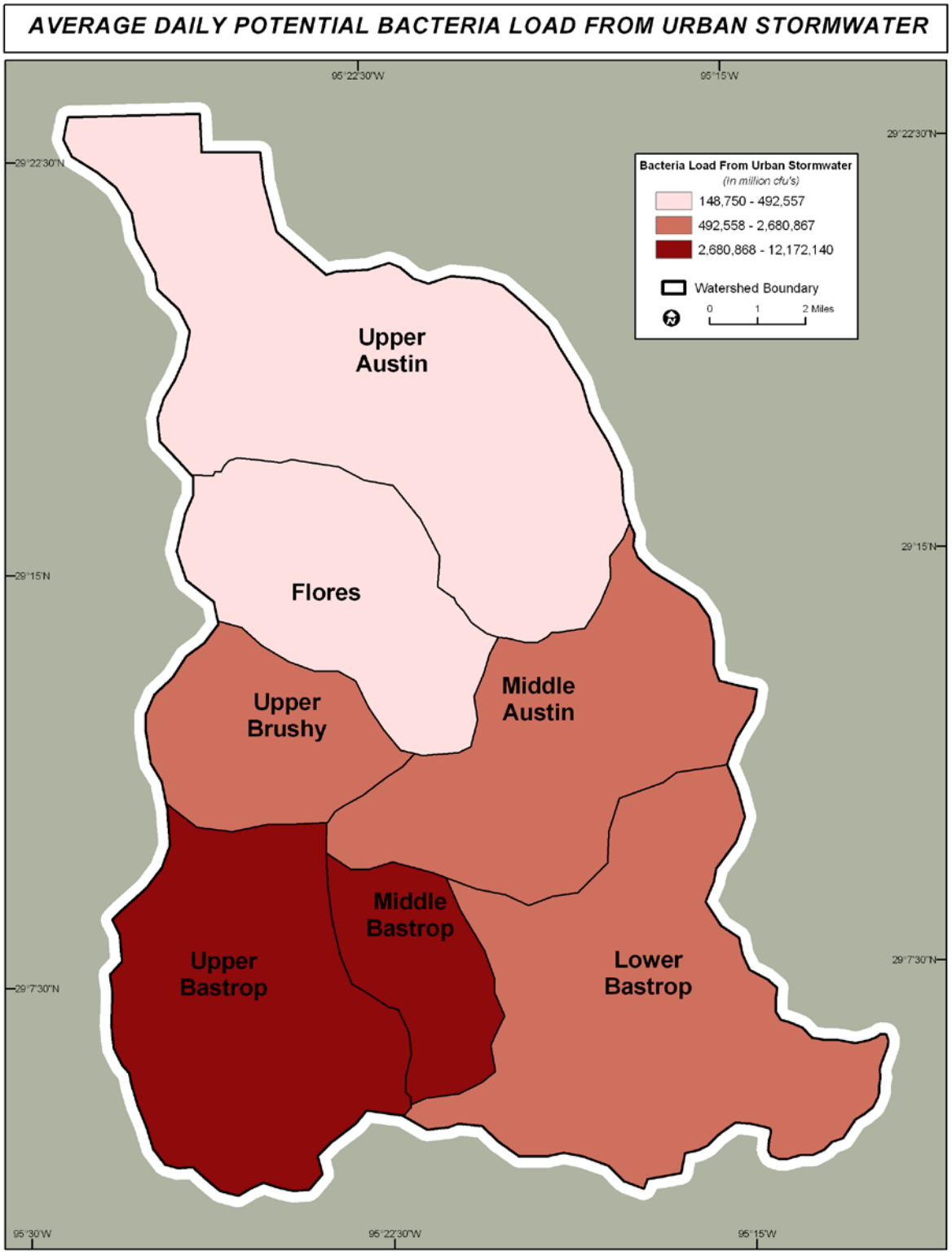

Figure A 11: Average Daily Potential Bacteria Load from Urban Stormwater

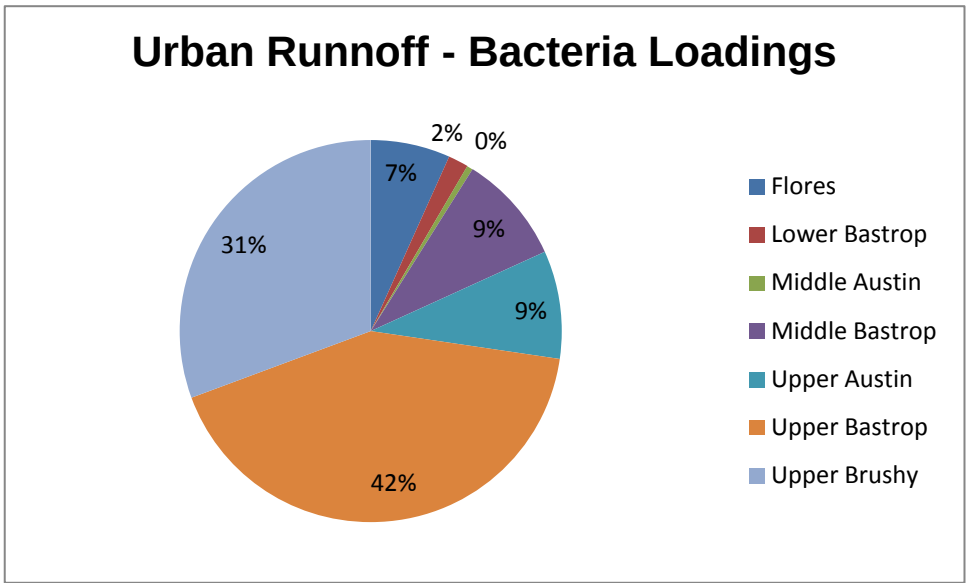

Figure A 12: Urban Runoff Bacteria Loading by Subwatershed

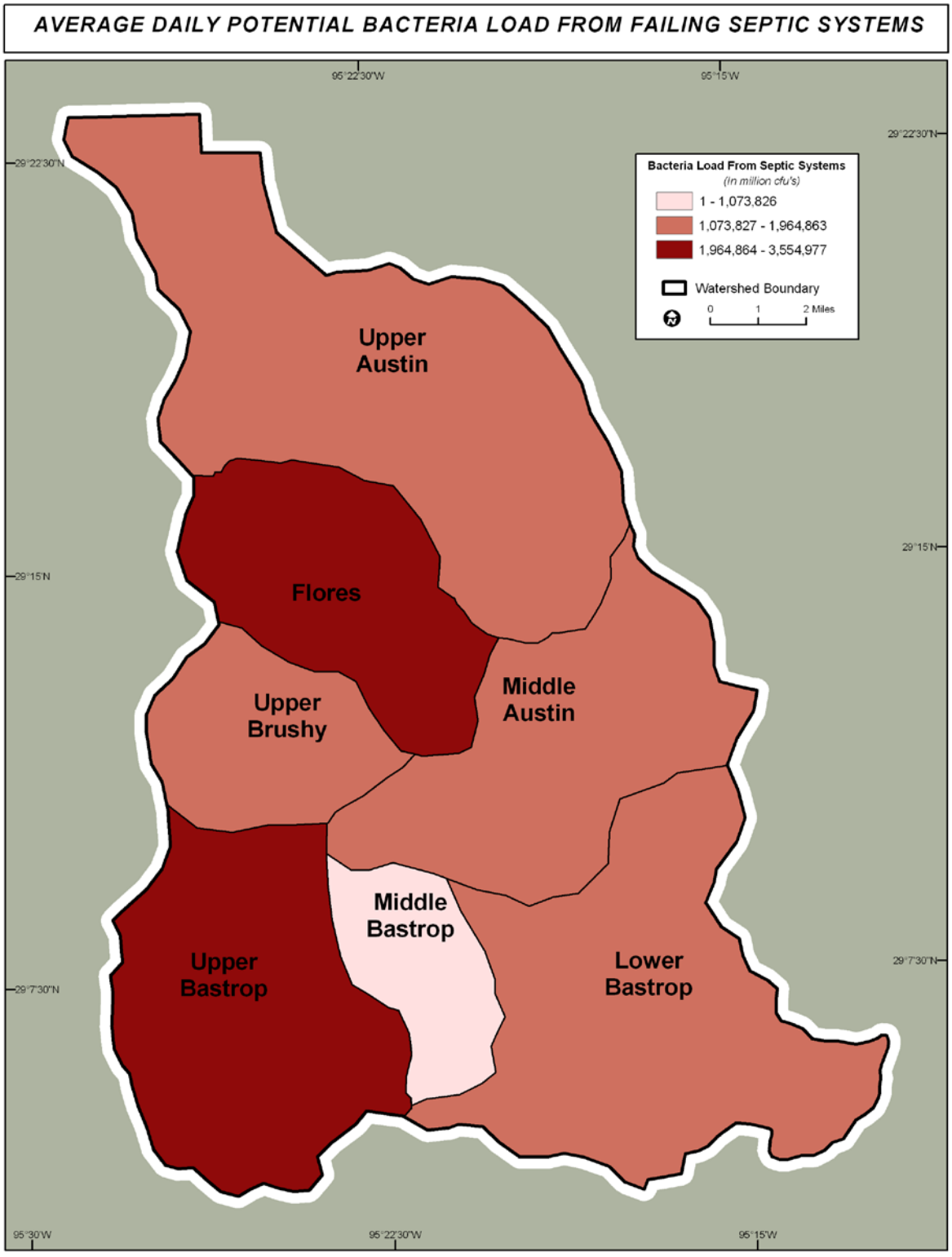

Figure A 13: Average Daily Potential Bacteria Load from OSSFs

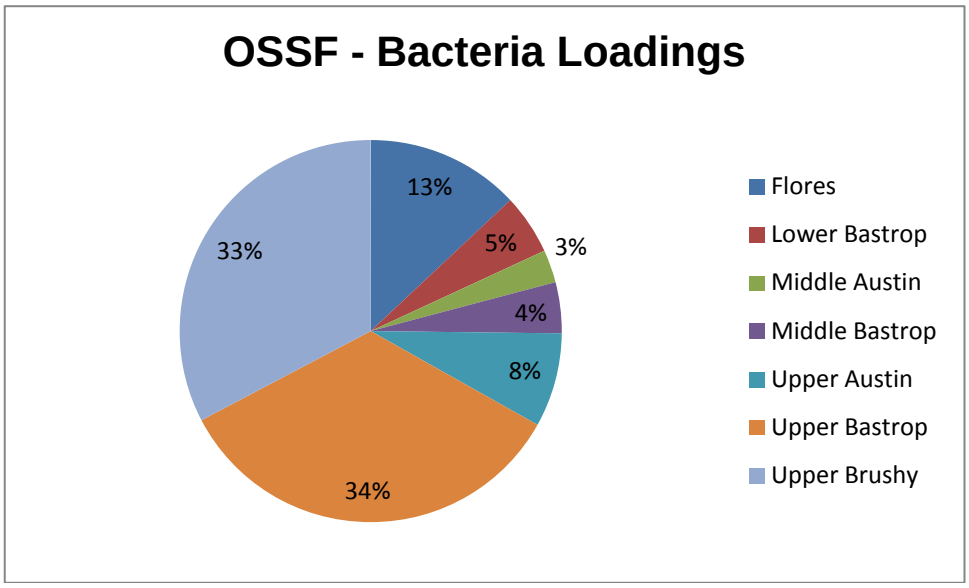

Figure A 14: OSSF Bacteria Loading by Subwatershed

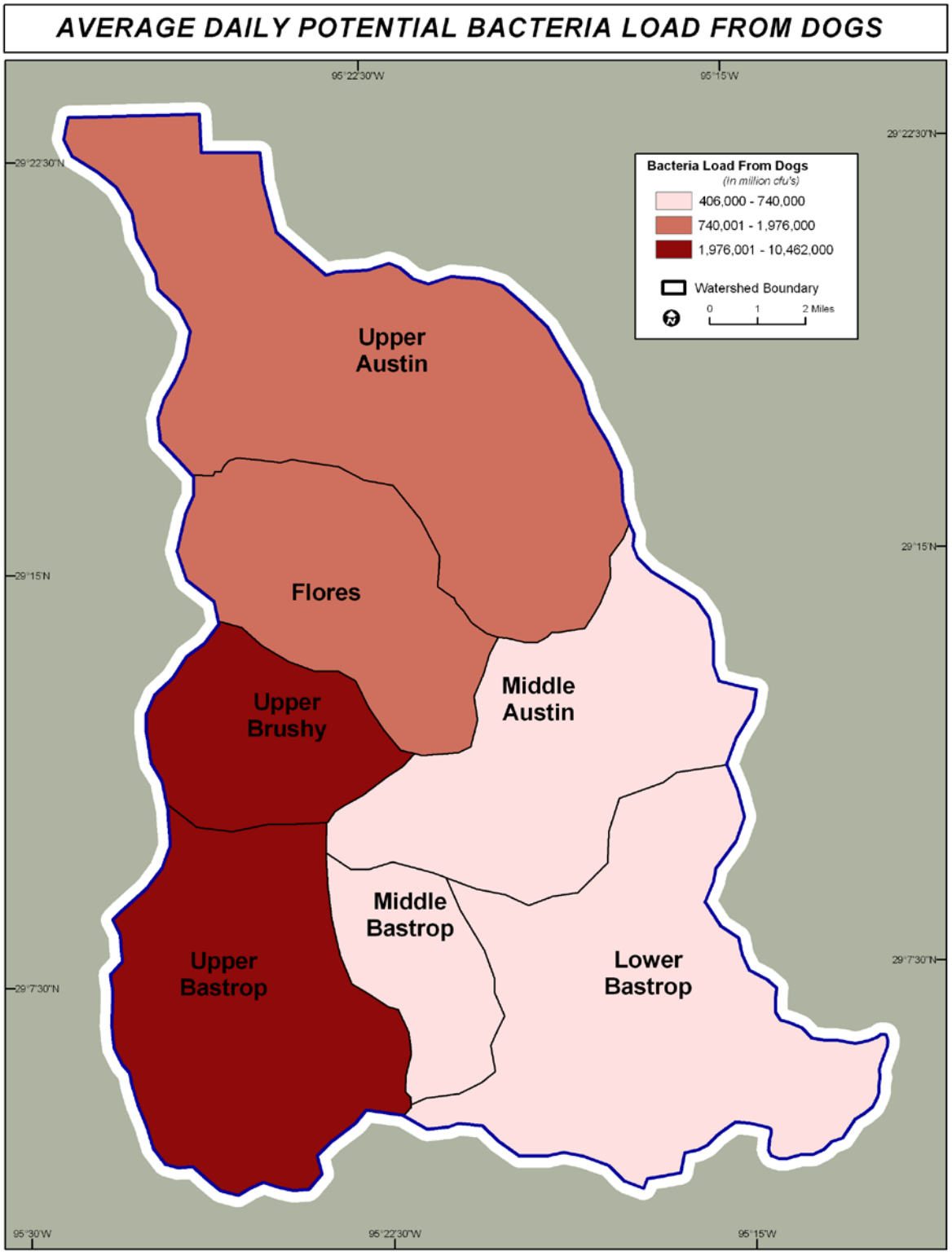

Figure A 15: Average Daily Potential Bacteria Load from Dogs

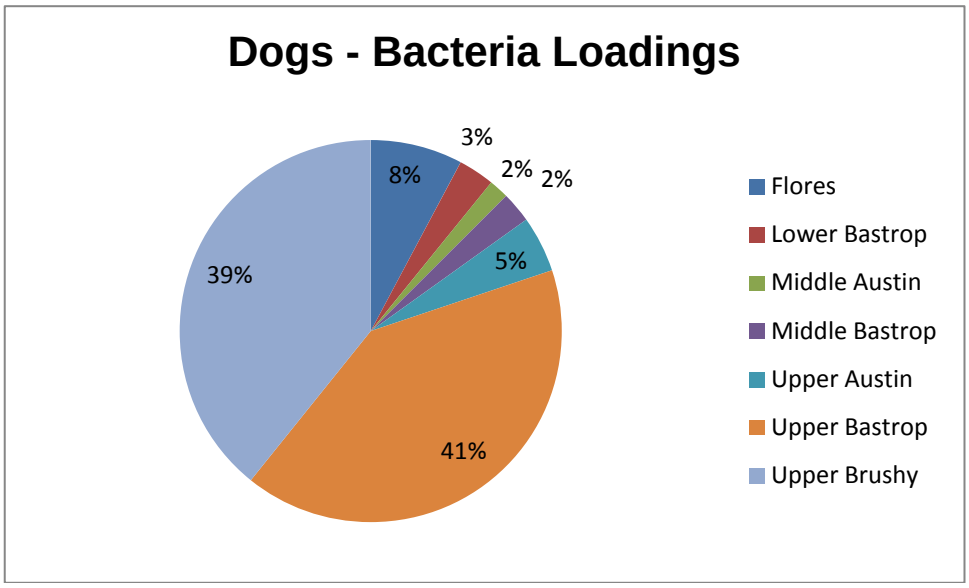

Figure A 16: Dogs – Bacteria Loading by Subwatershed

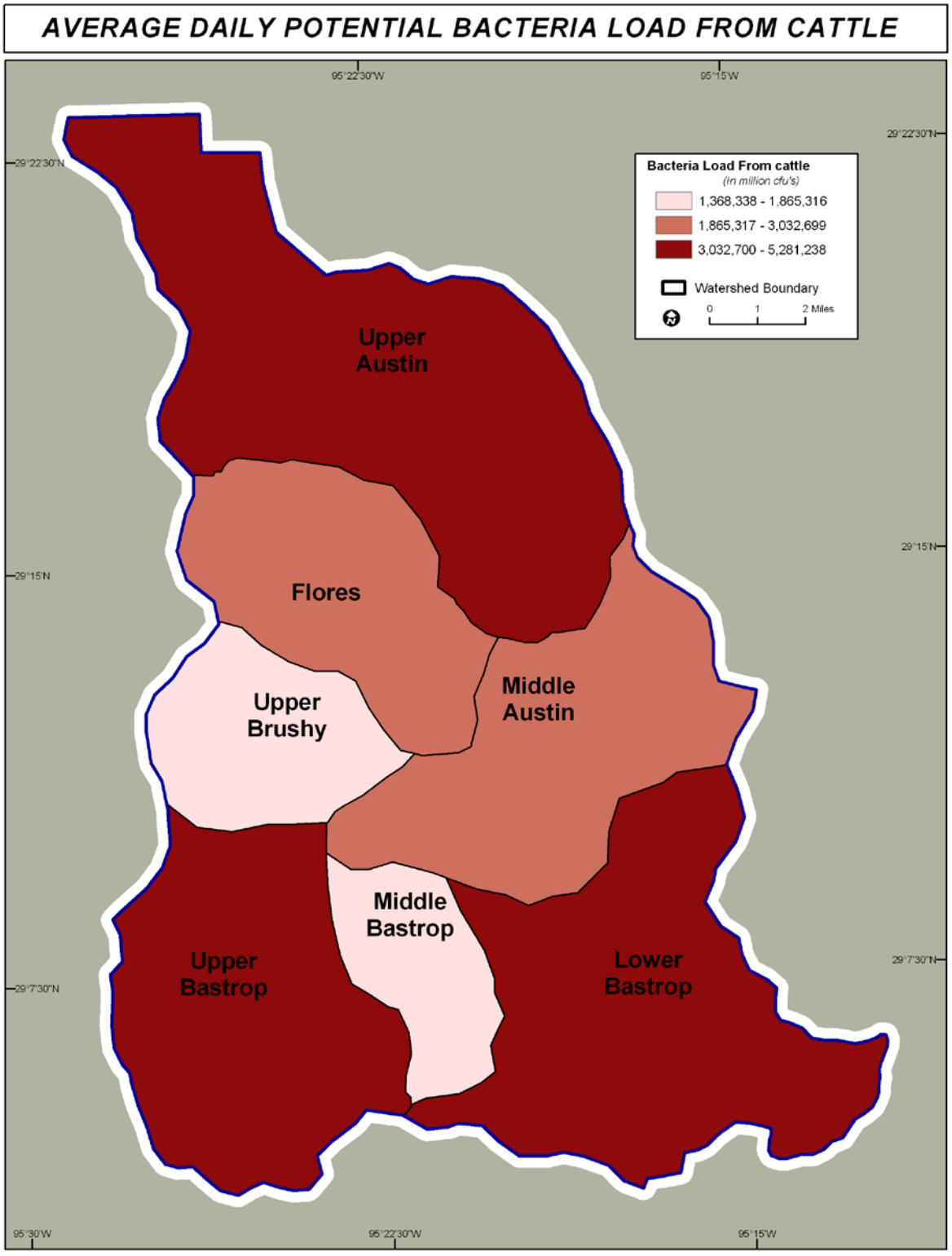

Figure A 17: Average Daily Potential Bacteria Load from Cattle

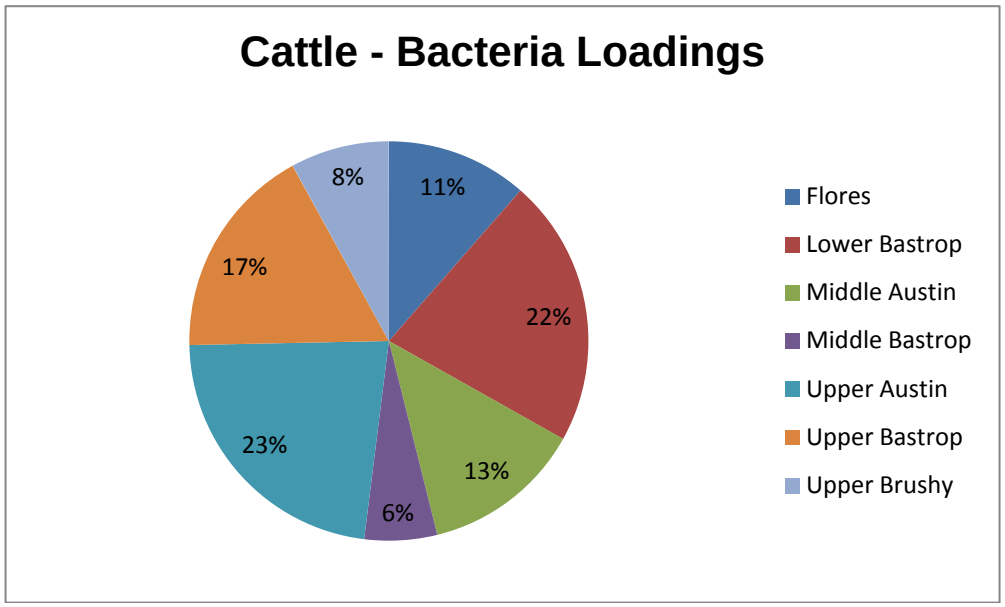

Figure A 18: Cattle – Bacteria Loading by Subwatershed

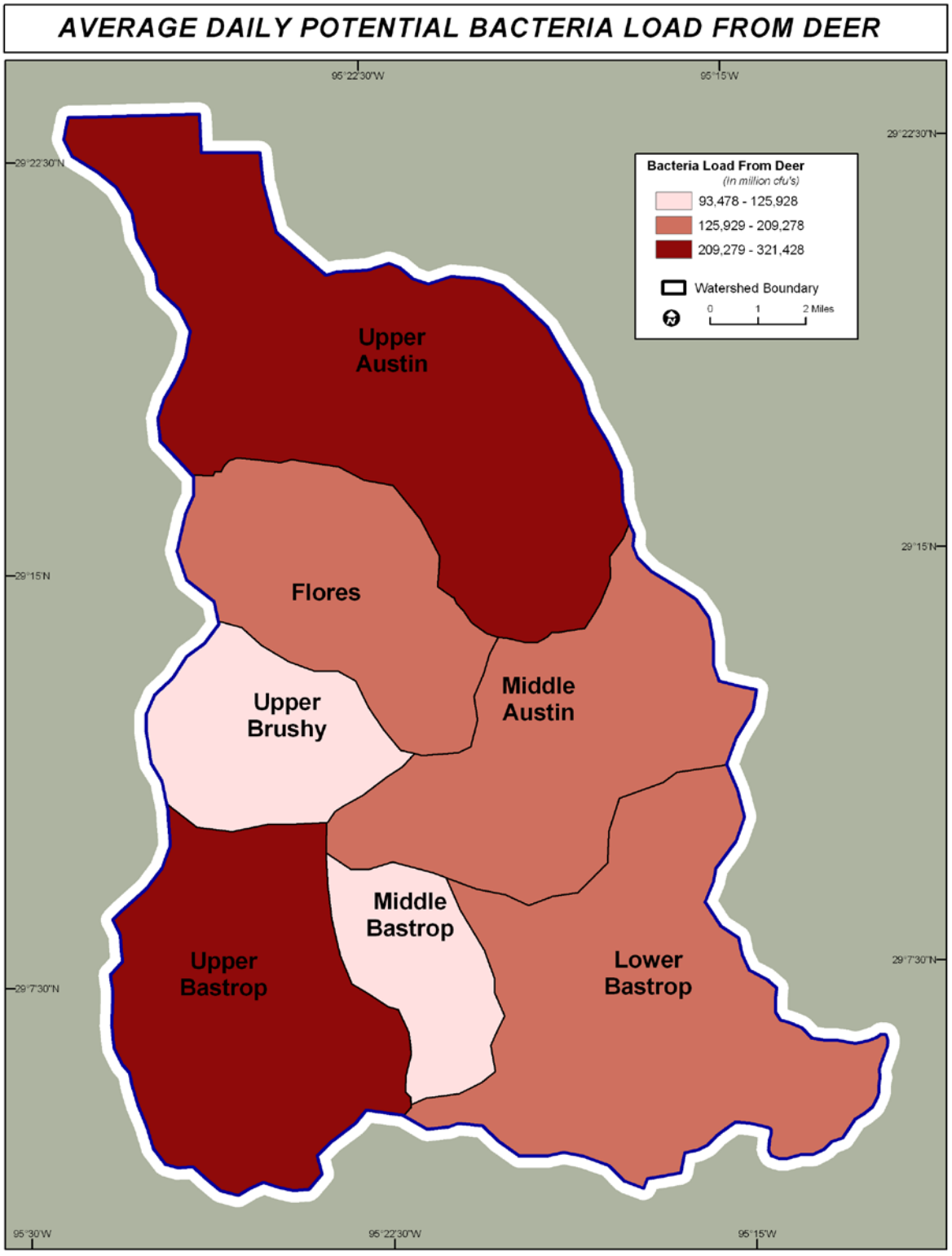

Figure A 19: Average Daily Potential Bacteria Load from Deer

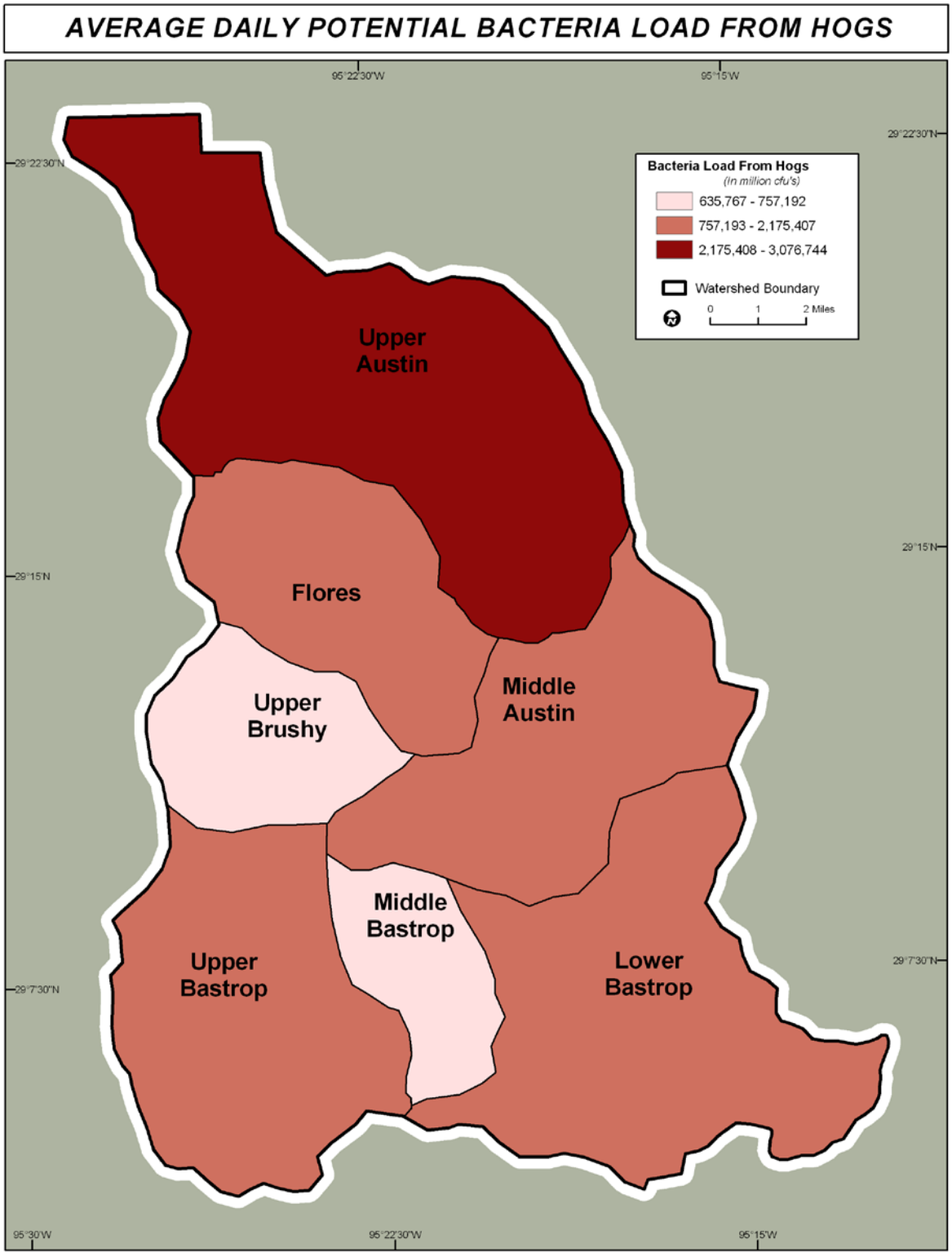

Figure A 20: Average Daily Potential Bacteria Load from Hogs

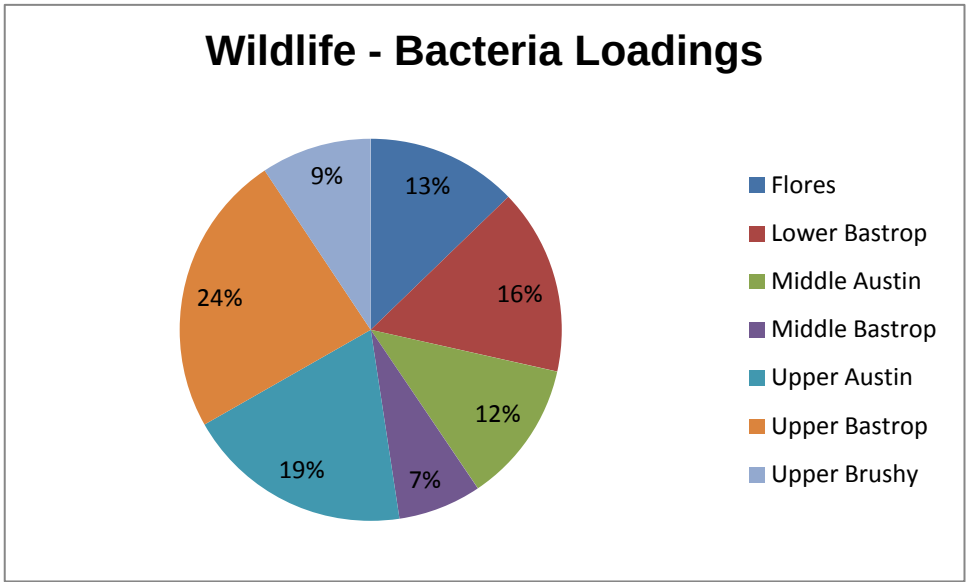

Figure A 21: Wildlife – Bacteria Loading by Subwatershed

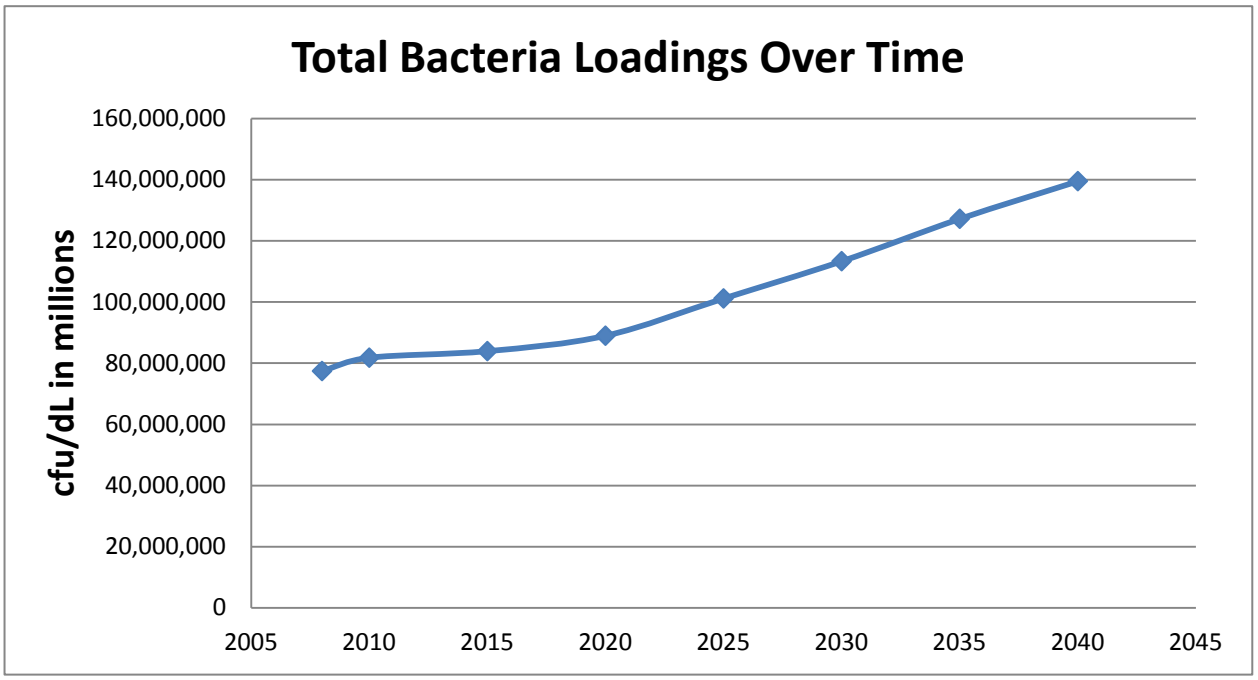

Figure A 22: Total Bacteria Loading, 2008-2040

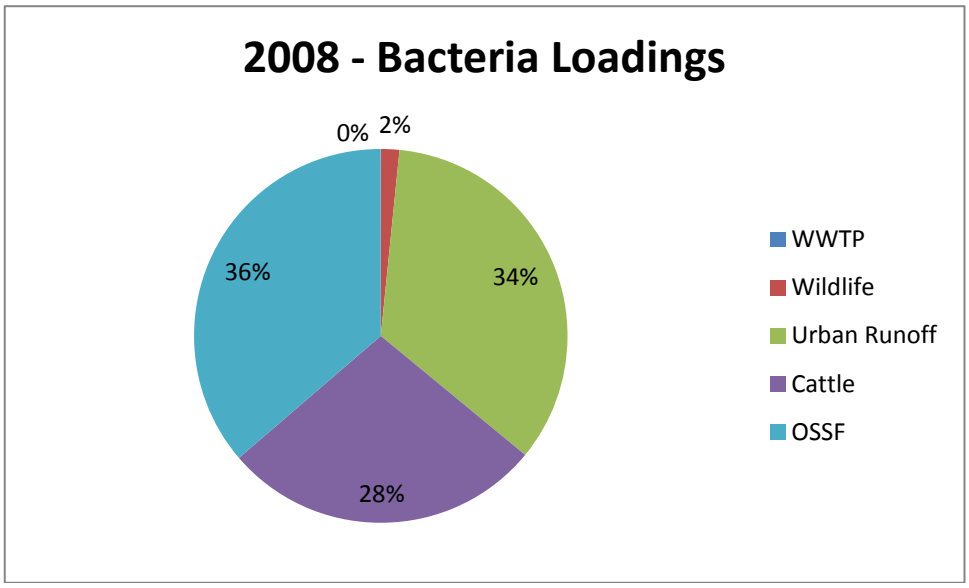

Figure A 23: Total Bacteria Loading by Source (2008)

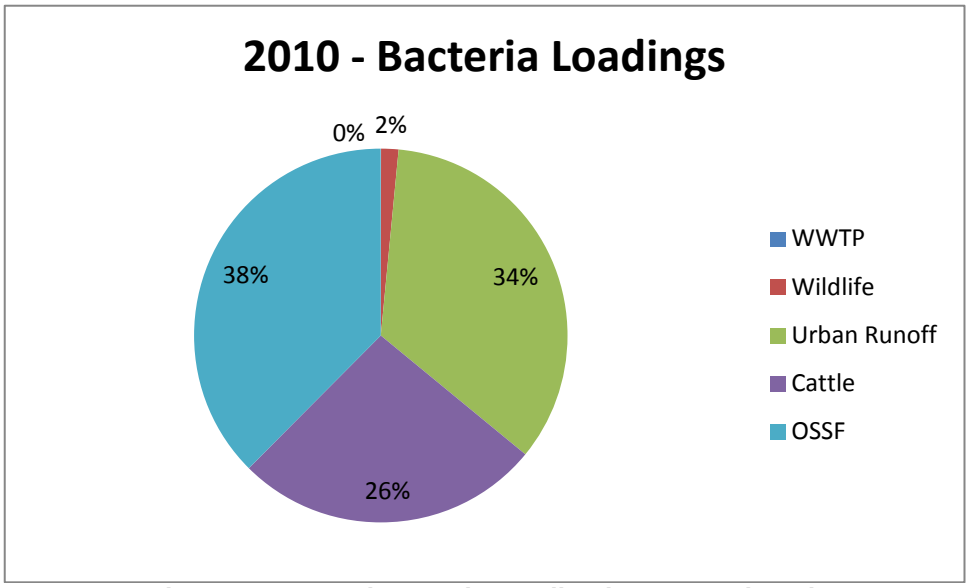

Figure A 24: Total Bacteria Loading by Source (2010)

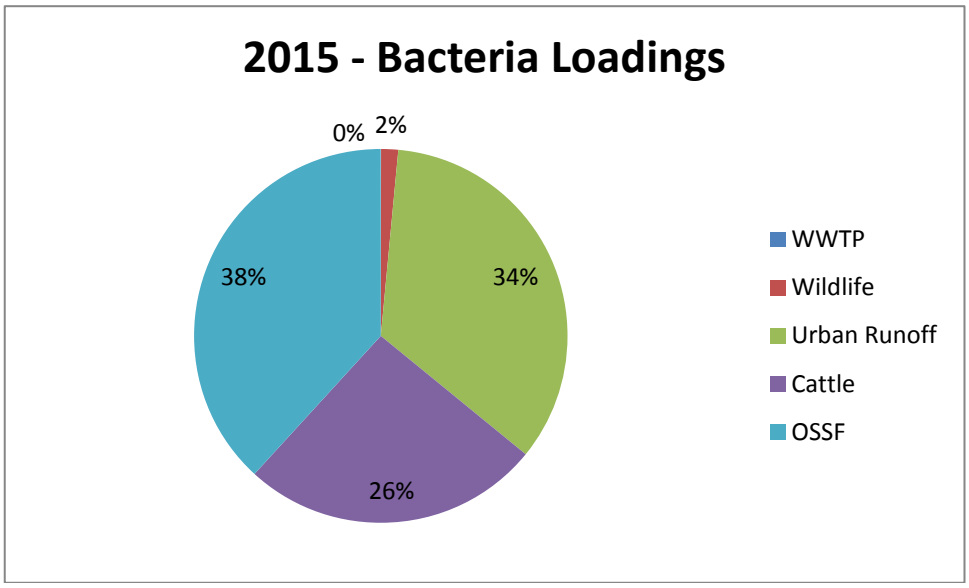

Figure A 25: Total Bacteria Loading by Source (2015)

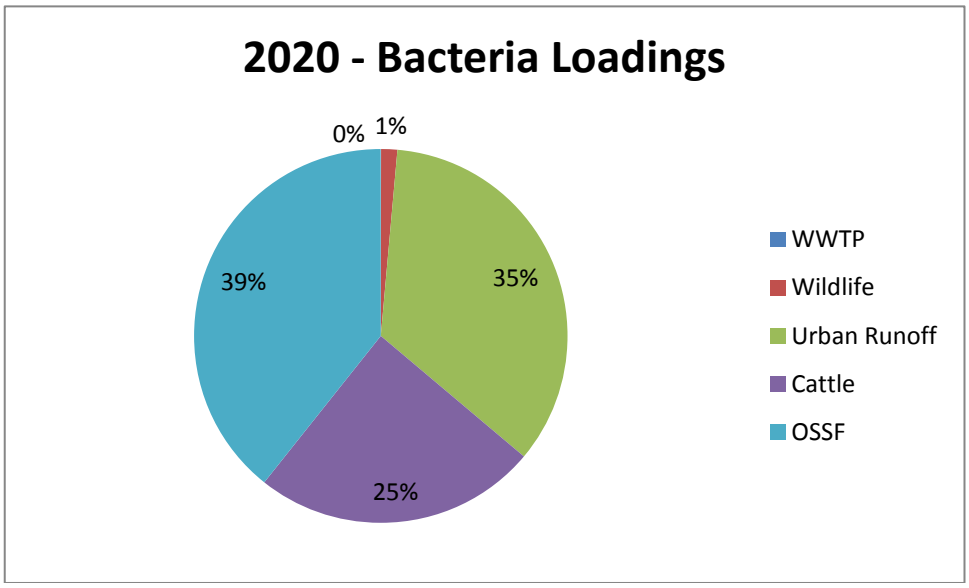

Figure A 26: Total Bacteria Loading by Source (2020)

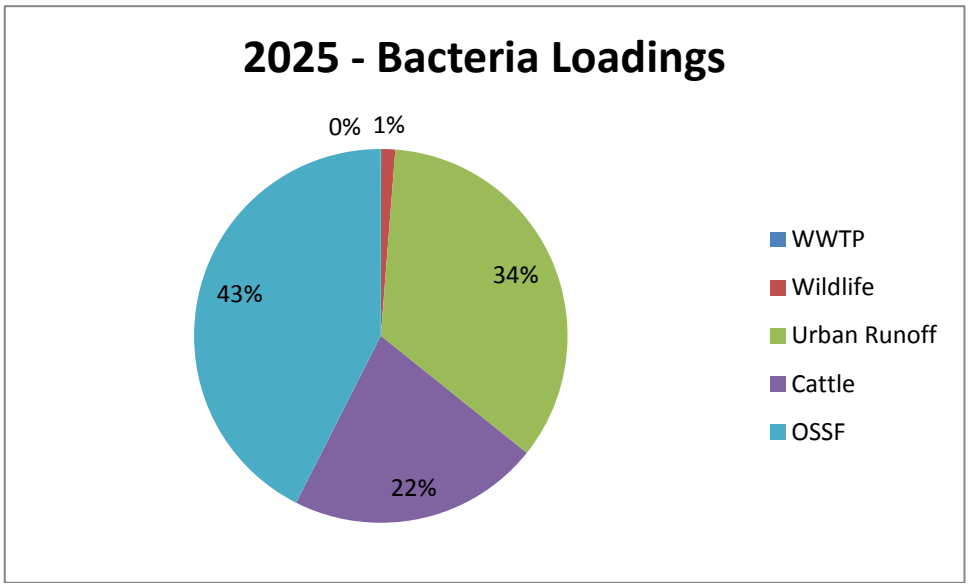

Figure A 27: Total Bacteria Loading by Source (2025)

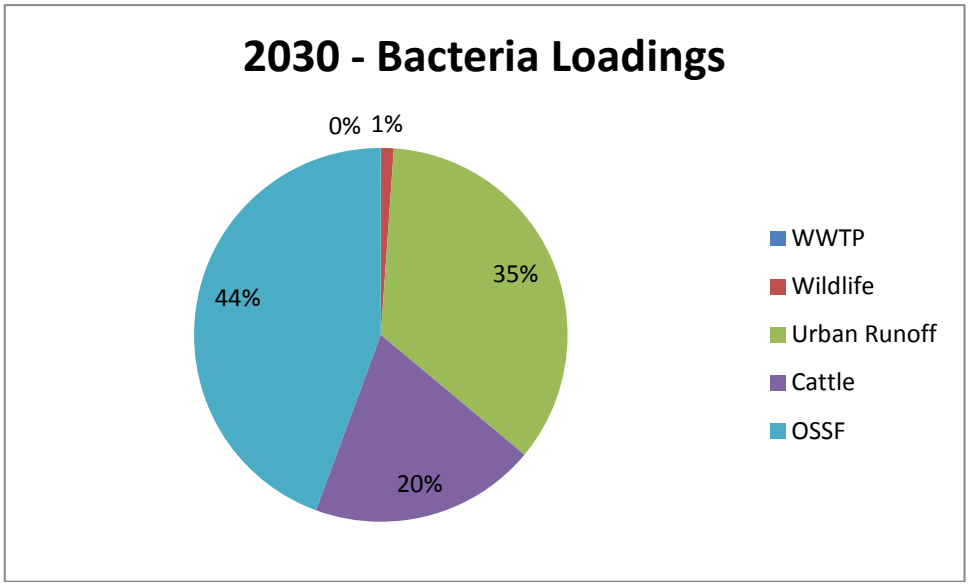

Figure A 28: Total Bacteria Loading by Source (2030)

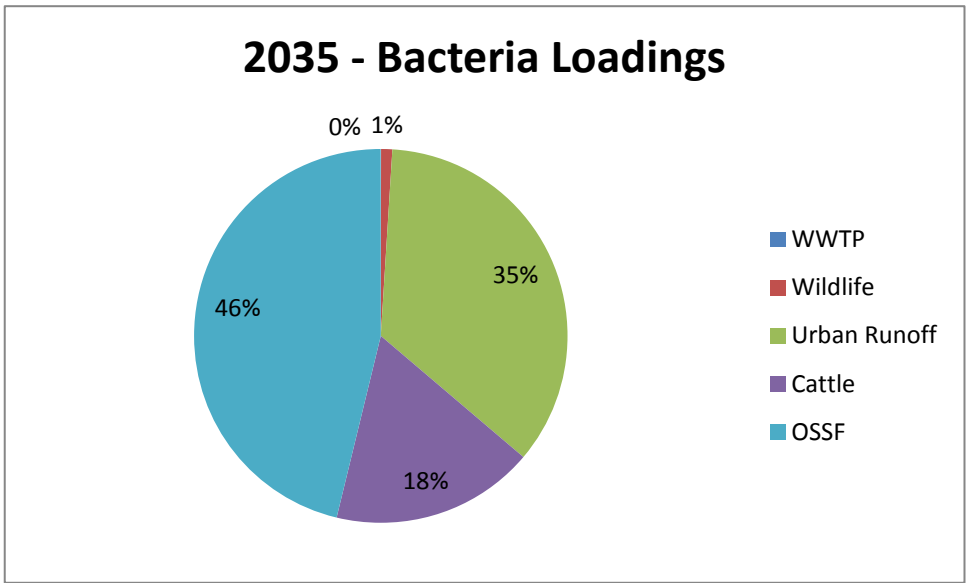

Figure A 29: Total Bacteria Loading by Source (2035)

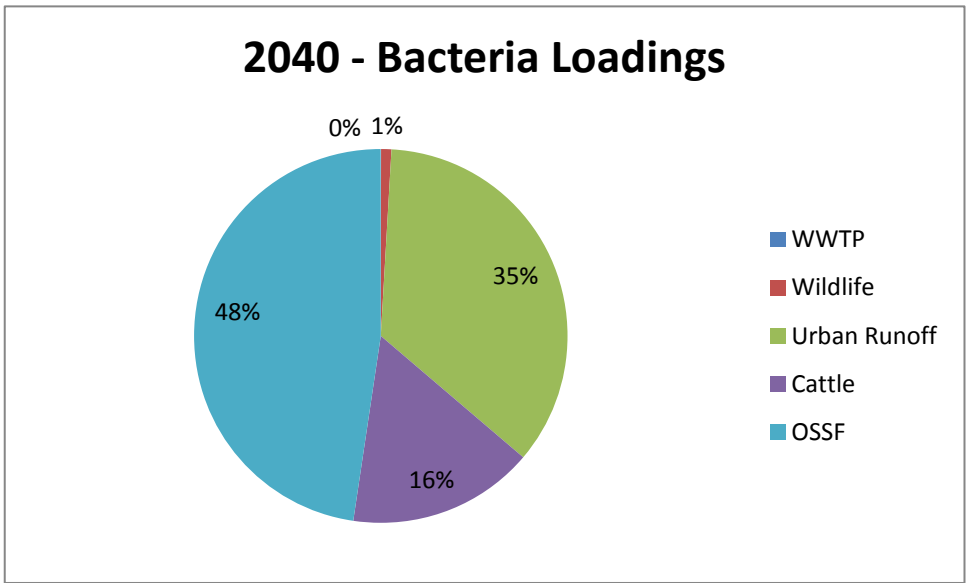

Figure A 30: Total Bacteria Loading by Source (2040)

Appendix B:

SELECT Modeling Detail

SELECT (Spatially Explicit Load Enrichment Calculation Tool)

The Spatially Explicit Load Enrichment Calculation Tool is an analytical approach for developing an inventory of potential bacterial sources, particularly nonpoint source contributors, and distributing their potential bacterial loads based on land use and geographical location. The model was originally developed for rural areas that are experiencing rapid growth and change. The model is ideal for Bastrop Bayou watershed as the area is experiencing rapid development and is predominantly rural at this point. As precedent, the model has performed quite well in the Plum Creek Watershed. Land use classification data and other data are used as inputs in a Geographical Information Systems (GIS) software format. Pollutant sources are then identified and targeted where they are most likely to have significant effects on water quality, rather than looking at contributions on a whole-watershed basis. In other words, using estimated distributions of livestock, wildlife, human households, pets and OSSFs, as well as the location of permitted wastewater treatment facilities (WWTPs), a pollutant load can be estimated for each potential source.

The model is developed in ArcGIS 9.X environment and is used to determine loadings of bacteria from point and nonpoint sources within a watershed. H-GAC added GIS files such as land use, watershed delineation, soils, subdivisions, and census blocks into the ArcGIS map application. The source load concentrations and defecation rates (for cattle, dogs, etc.) are preset based on published literature reviewed by HGAC. The model calculates the loadings from each source, aggregates the sum to geometric probability means, and creates a map of the loadings. This provides a visual representation of the contributing sources in a watershed. The approach evaluates each pollutant source and identifies which subwatersheds have the greatest potential to contribute to bacteria loads based on both the average bacteria production rate and the concentration of a source within a subwatershed. This evaluates the potential for pollution from the possible sources and subwatersheds, resulting in a relative approximation for each area. Sources with high potential were then evaluated to determine if the necessary controls are already in place or if action should be taken to reduce pollutant contributions. Specifically, land cover data, ambient monitoring, demographics, agricultural operations, permitted discharges and other GIS variables identified in the data inventory was used as input for the SELECT software. The model is based on ArcGIS architecture and is most sensitive to bacteria levels. Bacterial contamination is the main concern for the watershed and this model was developed specifically to model bacteria levels. After the pollutant loadings are quantified by model, the results were reviewed by the stakeholders and matched with local knowledge about the watershed.

SELECT Methodology

The SELECT methodology was developed using ArcGIS 9.0 with the Spatial Analyst extension available from ESRI. This spatially explicit method divided the watershed into a raster grid of 30 m × 30 m cells. For each of the cell locations within the watershed the E. coli loads are estimated from the sources that are potentially present at each location. Custom land use classification was conducted by H-GAC in 2002 using satellite imagery and National Agricultural Imagery (NAIP) aerial photographs. Although

a 2008 imagery was available, they were not completed at the time when SELECT model was run. The data from the 2008 imagery will be available in early 2009 and the change analysis between 2002 and 2008 would be available in early 2010.

The SELECT method identifies point and nonpoint sources throughout urban and rural areas. The identified point sources are active wastewater treatment plants. Nonpoint sources from urban areas include urban runoff, OSSF failure and dogs. Nonpoint sources from rural areas include runoff from livestock, dogs (Schueler 1999), wildlife (Weiskel et al., 1996) and OSSF failure (Reed, Stowe & Yanke LLC, 2001). Wildlife sources can include many types of wild animals and birds. In this area, the known wildlife includes feral hogs, whitetail deer, raccoons, rodents, opossums and migratory birds. Feral hogs and deer are the only wildlife sources to be included within SELECT because they are the only populations of concern with available data. Livestock productions within the area are primarily cattle, horses, sheep and goats.

The SELECT Model was initially used to calculate loadings from urban runoff in the Bastrop Bayou Watershed. Loadings were calculated from point and nonpoint sources. Pollutant concentrations were obtained from Newell, et al. (1992). Given that total annual loading of nitrogen was calculated to be more than twice that of phosphorus (the primary nutrients of concern), we used the Total Nitrogen values to represent nutrients.

Loading estimates from the SELECT model were reviewed by the stakeholders and matched with local knowledge about the Watershed. Using estimated distributions of livestock, wildlife, human households, pets, and OSSFs, as well as the location of permitted wastewater treatment facilities (WWTPs), a pollutant load was estimated for each potential source. Stream segments in subwatersheds were designated by land cover type. For example, urban areas received a different runoff curve number than an agricultural area with row crops or grazing land. This approach allowed the subsequent designation of customized BMPs based on specific land use and land cover types. The precise data sources used to feed the model are described later in this section.

Assumptions in the Model

There are several assumptions and use criteria related to mathematical models. First, nonpoint sources are the most significant source of pollutants in the Watershed. Second, parts of the Watershed are tidally influenced. (Bastrop Bayou contains both freshwater and tidally influenced streams.) The freshwater areas use E. coli as an indicator while Enterococcus is used for the tidally influenced coastal areas. WASP is the best model that incorporates coastal and freshwater elements. SELECT also accommodates both types of streams. Published literature indicates a conversion factor between Fecal Coliform and E. coli. No definitive study was found to link Enterococcus results with E. coli results at the suggestion of TCEQ, the ratio of the geomean values of the contact recreation standards for the two bacteria types were used as the conversion factor. Third, the results from the model should be compatible and the data should easily feed other models. SELECT output can be utilized as a feed for the WASP and other models. A second model may be necessary if the quantified results do not match the targeted monitoring data from implementation activities. Due to compatibility,

WASP can be run as an adjunct to SELECT. Fourth, agricultural/ranching practices are prevalent throughout the Watershed. Based on Stakeholder feedback, only cattle loadings are presented. Although calculations for other domesticated animals were performed, the stakeholders felt that the central issue to be cattle. For cattle, several assumptions were made. First cattle will occupy 25% of their time in marshy areas with the remainder in pastures. Second, due to crop rotation, some areas with are pasture now will be converted to row crops and vice versa. Fifth, the model should allow customizable BMP's. Subwatershed evaluation is more valuable than overall Watershed loading analysis. By using subwatersheds and land cover information SELECT customizes BMP's for each subwatershed rather than gross measures. Sixth, OSSFs are a significant source of pollutants for the Watershed. No model currently available is particularly adept at estimating loads from OSSFs. SELECT is designed to incorporate OSSF information, but is far from perfect. The high number of OSSFs in a watershed will increase the inaccuracy of any model. Based on Brazoria County data for one community on the waterway, a malfunction/failure rate of 79% was utilized for systems older than 1989 and a rate of 47% for homes that were built after 1989. Finally, nonpoint sources are inherently difficult to model and raise the inaccuracy of the final estimate. The targeted monitoring data will used to gauge, supplement and verify SELECT model results.

Specific assumptions are noted in the results section.

Accuracy of the Model

No model is completely accurate. As the numbers of nonpoint sources increase the uncertainty of a model also increases. Individuals who live or work in the Watershed are an excellent resource to gauge the accuracy of the model.

Data inventory resources

All datasets to feed the model are listed below including, CRP ambient water quality data, demographic information, number of agricultural operations, permitted discharges and updated land cover information. Examples of demographic information include number of households, average number of people per household, building types, estimated acreage, etc. Examples of information from the permitted discharges database include the number of outfalls, location of outfalls, permit number, permitted flow, parameters monitored, renewal date, etc. Four criteria were used in evaluating the data inventory: model requirements, source, date and completeness. The sets listed below met all of these criteria and were evaluated as inputs for the SELECT model. All of the data sets listed were acquired for the project and only those highlighted in bold were actually used in the modeling. In some cases redundant information was available from two sources. In this case only the latest or most complete data sets were used. In the analysis, the Bayou was assumed to support high aquatic life.

Table B 1: Data Inventory Resources

Name	Source	Date	Description
ABI Businesses	(Census Data)	(2000)	GIS- Business in Brazoria County, includes some housing data
Land Cover	**H-GAC**	**2002**	**GIS - Complete data set**
Land use	(H-GAC)	(2000)	GIS - Source unknown appears to be from 2000
Hydrography	NHD	(2000)	GIS - newer sets available below
Hydrography	Census Bureau	1990	GIS - Older data set
Hydrography	Census Bureau	2000	GIS Shapefiles
Hydrography	(H-GAC)	(2000)	GIS - Source unknown appears to be from 2000
Watershed	**(TCEQ)**	**2003**	**GIS - from TCEQ**
Coastal Preserve	**GLO\USGS**	**(2000)**	**GIS Shapefiles**
County Line	Census Bureau	1990	Forecast - Older census data
County	**TXDOT**	**(2000)**	**GIS Shapefiles**
DEM	(H-GAC)	(2000)	GIS Shapefiles
Urban Centers	**Census Bureau**	**2000**	**GIS Shapefiles complete set for 2000**
Roads	**TXDOT**	**(2000)**	**GIS Shapefiles**
Roads	**H-GAC-Starmap**	**2007**	**GIS Shapefiles - complete and most accurate**
Roads	Census Bureau	1990	GIS Shapefiles
Roads	Census Bureau	2000	GIS Shapefiles
Main Roads	TNRIS	(2000)	GIS Shapefiles
Continuous Monitoring System (incl. ambient)	H-GAC	2006	GIS Shapefiles - complete
Continuous Monitoring System (incl. ambient)	**H-GAC**	**2007**	**GIS Shapefiles - complete and most accurate**
Continuous Monitoring System (incl. ambient) (historic)	H-GAC (TCEQ)	(2000)	GIS Shapefiles - complete

Aerial Imagery	H-GAC	2006	GIS Shapefiles - complete and most accurate
Aerial Imagery	H-GAC	2004	GIS Shapefiles - complete
Aerial Imagery	NAIP	2005	GIS Shapefiles - complete, high quality
DOQQs	H-GAC	1990	Unknown date most likely 1990
Wastewater SA	**H-GAC**	**2007**	**GIS Shapefiles - complete**
WWTP Outfalls	**TCEQ**	**2007**	**GIS Shapefiles - complete set, some areas not covered**
Parcel Data	BCAD	2003	incomplete data set
Soil	**NRCS**	**(2000)**	**GIS Shapefiles - date uncertain**
Potential Septic System	H-GAC	2005	incomplete data set, not comprehensive for several zip codes
Lidar Elevation	**FEMA**	**2006**	**Most recent**
Contours	(USGS)	(2000)	GIS - Shapefiles
Congressional Dist	Census Bureau	2004	GIS - Shapefiles, errors in elected officials but not precincts, can combine with contact database for accurate precinct reps
Flood Zones	FEMA	(2000)	GIS - Older data set, date unknown
Population	**Census Bureau**	**2006**	**Tabular**
Housing Units	**Appraisal District**	**2006**	**Tabular - from model**
Inventory of Buildings	Appraisal District	2006	Tabular incl. housing
Property Valuations	Appraisal District	2006	Tabular - protests not included

Appendix C:

EPD-RIV1 Modeling Detail

Appendix D:

Water Quality Data Tables