Bastrop Bayou
Watershed Protection Plan

Bastrop Bayou Watershed Protection Plan

Prepared for the stakeholders of the Bastrop Bayou Watershed by:

Houston-Galveston Area Council
3555 Timmons Lane, Suite 120
Houston, TX 77227

April 4, 2016

Funding for the Development of this Watershed Protection Plan was provided by the Environmental Protection Agency through federal Clean Water Act §319 (h) grants to the Houston-Galveston Area Council, administered by the Texas Commission on Environmental Quality and a grant from the Galveston Bay Estuary Program.

Acknowledgments

The Houston-Galveston Area Council (H-GAC) would like to thank the members of the Bastrop Bayou Stakeholder Advisory Group (SAG) and all the other stakeholders and community members who participated in the preparation of this WPP. Their dedication and hard work throughout the planning process are greatly appreciated.

Bastrop Bayou Stakeholders Advisory Group

Commissioner Donald "Dude" Payne – Brazoria County Commissioner
Mike Lange – United States Fish and Wildlife Service
Brian Koch – Texas State Soil and Water Conservation Board
Stephen Johnston – Galveston Bay Estuary Program
Don West – Brazoria County Fresh Water Supply District #2
Sharron Stewart – Galveston Bay Foundation
Jeff Mink – Brazoria County Sherriff's Office
Kyle Harris – Coastal Conservation Association
James Gore – United States Coast Guard
Corrie Bowen – County Extension Agent
Dianna Kile – Congressman Ron Paul's office
Melanie Oldham – Citizen
Kathy & Bill Mladenka - Citizens
Dixon Dryden – Citizen
Roy & Jan Edwards – Citizens
Karen Carrol – Brazoria County
Tom White - citizen
Scott Lewis – citizen

Special Thanks

This project could not have happened without the sustaining support of three programs of the Texas Commission on Environmental Quality: the Nonpoint Source Program (NPS), the Galveston Bay Estuary Program (GBEP), and the Texas Clean Rivers Program (CRP). The NPS Program administered the federal Clean Water Act Section 319(h) grant which provided primary funding for this effort. The expertise, monitoring partnerships and funding provided by GBEP and the CRP allowed H-GAC to quickly establish a monitoring network, rapidly gather data and spend time in the watershed earning the public's trust. Continuing the monitoring program beyond the life cycle of the WPP will play a critical role in cementing the partnerships needed to develop and implement the watershed protection strategy.

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 (WPP) addresses water quality issues in a predominantly rural watershed that drains into Christmas Bay on the Upper Texas Gulf Coast. The Bayou and a number of its tributaries are currently on the State of Texas' list of impaired water bodies[1] as a result of contamination by fecal bacteria. Projected future growth patterns and land use changes indicate that this contamination will worsen unless measures are taken to address its sources. This WPP represents a local effort to reduce contamination in Bastrop Bayou to serve public health, economy and environment of the local community.

The ultimate goal of the WPP 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 reduce and maintain bacteria levels under the threshold set by the State's contact recreation standard. Because the watershed will see increasing development in the coming decades, a long term planning horizon is used in conjunction with a phased implementation of solutions to address not only current causes and sources, but the growing impact of future development.

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 WPP to address bacterial contamination from a variety of sources
- Guide the implementation of a cost-effective set of best management practices (BMPs) to achieve the desired results
- Obtain community commitment to ongoing management of their water resources

The WPP will guide the implementation of a suite of structural and behavioral BMPs designed to identify, evaluate, prioritize and remediate, or prevent the causes and sources of bacterial contamination in the watershed. It contains an ongoing focus on robust local community involvement and decision-making.

This WPP was produced by H-GAC and stakeholders from the Bastrop Bayou Watershed in accordance with guidance for Watershed Protection Plans issued by the U.S. EPA.

[1] 2010 and Draft 2012 Texas Integrated Water Quality Report.

Table of Contents

Executive Summary

Located along the Texas Gulf Coast, fifty miles south of Houston in Brazoria County, Bastrop Bayou is a popular recreational destination for water skiers, boaters, anglers and birders. Water from the Bastrop Bayou Watershed (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 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.), as well as 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 to thirty 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 exacerbating water quality contamination in the watershed unless action is taken 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, including septic systems), illegal dumping, and contamination from stormwater 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.

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, also referred to as management measures), 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
Initial 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 at the start of the planning process. Routine monitoring since 2006 has shown a steady increase in indicator bacteria. Bastrop Bayou and a number of its tributaries have recently been added to the State of Texas' list of impaired waterways. The pollutant of primary concern to the Bastrop Bayou watershed is fecal matter, detected by the presence of indicator bacteria.

Several potential sources of bacteria are present within the watershed, including:

- Urban Runoff
- Malfunctioning OSSFs
- Agriculture/ranching operations
- Wildlife and Feral Hogs
- Pets
- Wastewater treatment operations

Modeling of source contributions indicated pet waste, livestock and malfunctioning OSSFs were the primary sources of bacterial contamination, each representing substantial portions of contributed bacteria load in current (2012) and future (2040) conditions, with malfunctioning OSSFs growing to over 60% of the total contribution to loading by 2040, absent any additional controls or efforts. Contributions from cattle ranching (the predominant source of agricultural bacteria in the watershed) and wildlife and feral hogs are expected to diminish by 2040, due to increasing development pressure, but remain significant sources.

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, 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 a phased and feasible implementation strategy to address 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. As these implementation costs for the initially selected measures exceeded the currently available funding, the stakeholders prioritized addressing the largest contributing sources first. Cost and time necessary to complete the project were the primary concerns during project selection. Since urban runoff and future growth are among 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 stormwater 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.

A selection of the voluntary solutions identified during this project includes:

- Community waterway cleanup events (including the annual Trash Bash event)
- Increased enforcement of applicable laws and standards (for OSSFs, illegal dumping, etc.)
- Implementation of stream fencing, alternative watering sources for cattle or other related 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/low impact development practices through pilot/demonstration projects
- Implementing a watershed signage project (watershed boundaries and illegal dumping)
- Facilitating acquisition or development of buffer areas, conservation easements, or other land conservation projects
- Remediating malfunctioning OSSFs, educating residents and businesses on proper OSSF maintenance, or promoting sanitary sewer systems in place of OSSFs, specifically in the Demi-John community.
- Improvement of municipal and Home Owner Association ordinances (for pet waste, OSSFs, green infrastructure, etc.)
- Implementation of pet waste management education and pet waste stations
- Removal of abandoned boats and other large debris in the waterways
- Ongoing water quality monitoring through the Clean Rivers Program and Texas Stream Team 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 WPP calls for a phased implementation of the projects over several years. Bastrop Bayou is a watershed in transition, so modeling and projections were completed for a 25-year planning horizon to account for current sources of contamination as well as those arising from increased growth in the coming decades. An initial 10-year period was chosen for the phased implementation of projects to reduce current levels of contamination. Additional implementation activities and management efforts will be needed throughout the 25-year period to address new and increased sources as they arise. Implementation 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 2012, 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. The implementation of the WPP will happen in conjunction with a variety of other local efforts, including the ongoing development and implementation of activities required under Phase II NPDES MS4 permits. While the activities of this WPP will be complementary to efforts required or undertaken as part of MS4 permits in the area, it is not intended to replace or substitute implementation activities for these permits.[2] All activities conducted as part of

[2] The timeframes of the Phase II TPDES MS4 permit implementation have a shorter planning horizon than the WPP. For example, the Brazoria County Stormwater Coalition's SWMP has a 5-year planning horizon. Due to this and the

this WPP are over and above those required under MS4 permits.[3] To the greatest extent practicable, the implementation and future update of this WPP will seek to coordinate with the other efforts to avoid redundancy and ensure complementary efforts.

Future Steps

From the inception of work in Bastrop Bayou in 2004 as a result of citizen concerns, through forty 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 coordinating on implementation projects outlined in the WPP, with several already having been put in place. H-GAC will continue to provide data resources as well as technical assistance while the CRP will continue water quality monitoring throughout the watershed. Additionally, the WPP 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. As part of an adaptive management process, the WPP will be reviewed on a regular basis and revised as the need arises. It is expected future revisions will be necessary prior to the later years of the planning period based on the pace and nature of growth that occurs. Future changes will be based on the same stakeholder-driven process involved in the initial development of this WPP.

lack of sufficient detail in the SWMPs and Annual Reports to project future bacteria loads or reductions, neither the projected future loads, nor the projected future reductions represented in this WPP include estimations of the potential future impact of the MS4 activities. Future updates of this WPP using an adaptive management process of review may revisit the potential impact of MS4 activities if supported by the data available at that time.

[3] The significant investment in large-scale stormwater detention improvements identified as BMPs under this WPP may be included in future revisions of the Stormwater Management Plans (SWMPs) of local MS4 permit holders. In that case, some portion of the activities and costs identified may be associated with the MS4 programs instead of this WPP. Regardless, this WPP does not call for Clean Water Act section 319 grant funds to be used for these specific activities.

Nine Element Summary Matrix

The Bastrop Bayou WPP is based on 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 BMPs
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. A definition of source and in-stream loads is provided on page 20 of this report, following **Table 1.**

Table 1 - Nine Element Summary Matrix

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 29-51)	**Estimated Source and In-stream Load Reduction Amounts (in 10^9 CFU/day.)** (Section 4, pp. 52-71)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 72-84)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 85-98)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 99-102)	**Schedule of Implementation for Each Measure** (Section 8, pp. 103-111)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 112-118)	**Indicators to Measure Progress** (Section 10, pp. 119-122)	**Monitoring Component** (Section 11, pp. 123-129)	**Responsible Entity** (Sections,5, 6 and 8)
Education and Outreach	The sum of the activities in this section is expected to reduce source loads by 290 (2%)	Project Promotion through a project website, executive summary, and press releases.	$30/year for domain registration, $3000 for development and dissemination of the executive summary, staff time to promote project.	This measure is an educational component.	The website is ongoing, the executive summary is scheduled for 2013, and press releases are ongoing.	Approval of WPP, creation of executive summary draft, and dissemination of summary in 2013.	Ambient water quality data; completion of milestones.	Ambient water quality monitoring.	H-GAC
		Educational materials for cattle management, OSSF maintenance, and pet waste disposal.	$3000/year to order and print materials, staff time to disseminate.	This measure is an educational component	Starting in 2013, and throughout the project.	Evaluation of cattle materials in 2013. Dissemination of materials 2013 onward.	Ambient water quality data; completion of milestones.	Ambient water quality monitoring.	H-GAC / entities with existing materials.
		Workshop and classroom activities including Texas Watershed Stewards, Project WET and WILD education, and OSSF workshops for residents.	$15,000/event for Texas Watershed Stewards, $5,750 first year for Project WET and WILD, $2,500 per event for OSSF workshops. Technical assistance required from AgriLife TWS and OSSF staff, and local ISDs.	This measure is an educational component	Texas Watershed Stewards – workshop in 2015. Project WET and WILD-to commence in 2015, throughout project. OSSF Workshops – first workshop in 2015; then every three years afterwards.	Texas Watershed Stewards: obtain agreement with AgriLife (2014); hold training (2015). Project Wet and Wild: Obtain permission from school (2014); Develop curriculum (2014); schedule instruction (2015). OSSF Workshop: Coordinate with AgriLife to hold workshop (2014); Hold workshops (2015, every three years after)	Ambient water quality data; events held.	Ambient water quality monitoring.	H-GAC, AgriLife.

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 29-51)	**Estimated Source and In-stream Load Reduction Amounts (in 10^9 CFU/day.)** (Section 4, pp. 52-71)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 72-84)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 85-98)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 99-102)	**Schedule of Implementation for Each Measure** (Section 8, pp. 103-111)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 112-118)	**Indicators to Measure Progress** (Section 10, pp. 119-122)	**Monitoring Component** (Section 11, pp. 123-129)	**Responsible Entity** (Sections,5, 6 and 8)
		Structural outreach activities including watershed signage, pet waste signage, Dow Woods educational trail signage, and outdoor message boards.	$2,700 for watershed signage and installation (completed), $100/sign for pet waste station signage, $20,000 for Dow Woods Unit educational signage (completed), $3,500 for outdoor message boards. Technical assistance required from Brazoria County and TxDOT (signage installation), local entities in maintaining pet waste signage and outdoor message boards, and USF&WS for maintaining and installing trail signage.	This measure is an educational component	Watershed signage was already installed in 2012. Pet Waste management signage will be installed in 2013/2014. Education Trail signage was installed in 2010-2012. Outdoor message boards were installed in 2012-2013.	Watershed Signage: completed. Pet Waste Signage: coordinate on design (2013); develop signs (2013); install stations (2013-2014). Educational Trail Signage: completed. Outdoor Message boards: coordinate on locations (completed); install (2012-2013); install materials on boards (2013)	Ambient water quality data; structural outreach measures installed.	Ambient water quality monitoring.	H-GAC, USF&WS, Brazoria County, TxDOT,
		Public participation opportunities through Texas Stream Team and watershed Trash Bash event.	$2,000/year in CRP staff time for Stream team coordination, $300/year for educational materials and outreach at Trash Bash.	This measure is an educational component	Texas Stream s ongoing throughout the project. Trash Bash is an annual event already in place; will continue annually.	Both events are ongoing and do not have specific interim milestones.	Ambient water quality data; number of volunteers who take part	Ambient water quality monitoring.	H-GAC, Clean Rivers Program, Trash Bash program, Texas Stream Team program

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 29-51)	**Estimated Source and In-stream Load Reduction Amounts (in 10^9 CFU/day.)** (Section 4, pp. 52-71)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 72-84)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 85-98)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 99-102)	**Schedule of Implementation for Each Measure** (Section 8, pp. 103-111)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 112-118)	**Indicators to Measure Progress** (Section 10, pp. 119-122)	**Monitoring Component** (Section 11, pp. 123-129)	**Responsible Entity** (Sections,5, 6 and 8)
Livestock	This category as a whole will generate: Source load reductions of 2,213 (16%) In-stream load reductions of 51 (15%) Source load reductions by subwatershed [load (% need to be reduced)]: **SW1**- 0 (0%) **SW2**- 535 (25.7%) **SW3**- 601 (25.3%) **SW4**- 133 (13.5%) **SW5**- 660 (17.4%) **SW6**- 264 (5.7%) **SW7**- 20 (2.8%)	TSSWCB WQMPs- Voluntary cattle and land management planning and BMPs. Provide incentives for landowners to implement BMPs from the Plans.	$10-$15,000 per Plan in development costs, through the TSSWCB. $40,000 for farmer incentives. Additional incentives provided by participants and partner agencies) Technical assistance from the TSSWCB and local S&WCDs required.	Agrilife Extension seminars, TSSWCB seminars, Texas Stream Team, meeting with individual landowners	Promotion of WQMPs will begin in 2014 (currently promoted by TSSWCB; ongoing), throughout the project.	Obtain permission from TSSWCB to promote (2013); promote program and recruit volunteers (2014-onward); TSSWCB develops and approves Plans (ongoing); Implement and maintain Plans (ongoing.)	Ambient water quality data; BMP effectiveness monitoring results; Number of acres covered by Plans.	Ambient water quality monitoring; Pre- and post-implementation BMP effectiveness monitoring	TSSWCB, H-GAC, local soil and water conservation districts, Agrilife, landowners.
		USDA NRCS Grant Programs – Cattle and Land Management BMPs (fencing, alternative water/shade, buffer strips, etc.)	Variable by project, property and NRCS grant program (EQIP, etc.) Technical assistance from the NRCS required.	Promotional materials, Conduct workshops and technical assistance, On-site visits, in conjunction with partner agency efforts	NRCS promotion of this program is ongoing; promotion under this project to begin in 2014; farmer incentives to begin in 2014; efforts throughout project.	Obtain NRCS permission to promote program (2013); promote and recruit volunteers (2014-onward); develop, approve grant projects (ongoing by NRCS); implement projects (ongoing).	Ambient water quality data; BMP effectiveness monitoring results; Number of acres covered by implemented projects.	Ambient water quality monitoring; Pre- and post-implementation BMP effectiveness monitoring	USDA NRCS, H-GAC, landowners.

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 29-51)	**Estimated Source and In-stream Load Reduction Amounts (in 10^9 CFU/day.)** (Section 4, pp. 52-71)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 72-84)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 85-98)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 99-102)	**Schedule of Implementation for Each Measure** (Section 8, pp. 103-111)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 112-118)	**Indicators to Measure Progress** (Section 10, pp. 119-122)	**Monitoring Component** (Section 11, pp. 123-129)	**Responsible Entity** (Sections,5, 6 and 8)
		Lone Star Healthy Streams program and materials – livestock module resources promoted to cattle ranchers.	Materials already exist, cost in staff time to promote and coordinate in the watershed. Technical assistance from TWRI/AgriLife/TAMU staff required.	This measure is an educational component; promotion will include disseminating and promoting resources to landowners.	LSHS staff already promote these resources. The project will begin to promote these projects in 2014.	Coordinate with LSHS staff on best way to promote; promote program (2013-onward)	Ambient water quality data; number of landowners reached.	Ambient water quality monitoring.	TAMU, H-GAC, TWRI, AgriLife
Wildlife and Feral Hogs	This category as a whole will generate: Source load reductions of 497 (16%) In-stream load reductions of 11 (16%) Source load reductions by subwatershed [load (% need to be reduced)]: **SW1**- 0 (0%) **SW2**- 116 (5.6%) **SW3**- 81 (3.4%) **SW4**- 16 (1.6%) **SW5**- 216	Feral hog workshops	$8000 per workshop. Technical assistance from AgriLife, TSSWCB, and Texas Wildlife Services required.	Promotional materials, class(es)	Beginning in 2013-2014, and continuing at a frequency of once every five years.	Coordinate with AgriLife (2013); hold workshop (2014 and every 5 years after)	Ambient water quality data; Number of attendees; Number of workshops held.	Ambient water quality monitoring.	AgriLife, Brazoria County, Cities, TSSWCB, H-GAC
		USF&WS Comprehensive Conservation Plan elements for feral hog management developed and implemented.	Plan under development by Brazoria National Wildlife Refuge. Technical assistance from USF&WS staff required in plan completion and implementation for feral hog elements. Implementation costs dependent on final recommendations.	Education for this component is conducted by USF&WS as part of their public outreach and public comment aspect of the Plan.	Plan is expected to be complete in 2013; implementation to begin thereafter, based on USF&WS prerogative.	Receive public comment (2012-2013); Approve Plan (2013); Implement Plan (2013-onward)	Ambient water quality data; number of feral hogs eradicated or managed by USFWS.	Ambient water quality monitoring.	USF&WS

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 29-51)	**Estimated Source and In-stream Load Reduction Amounts (in 10^9 CFU/day.)** (Section 4, pp. 52-71)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 72-84)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 85-98)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 99-102)	**Schedule of Implementation for Each Measure** (Section 8, pp. 103-111)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 112-118)	**Indicators to Measure Progress** (Section 10, pp. 119-122)	**Monitoring Component** (Section 11, pp. 123-129)	**Responsible Entity** (Sections,5, 6 and 8)
	(5.7%) **SW6**- 53 (1.2%) **SW7**- 14 (2.1%)	Lone Star Healthy Streams – Feral Hog management resources promoted to landowners	Staff time in promotion and coordination. Technical assistance from TWRI/AgriLife/TAMU staff required.	Staff promotion of this project, and dissemination of cattle management materials.	LSHS staff already promote these resources. The project will begin to promote these projects in 2014.	Coordinate with LSHS staff on best way to promote; promote program (2013-onward)	Ambient water quality data; Number of landowners reached.	Ambient water quality monitoring.	TAMU, H-GAC, TWRI, AgriLife
		Feral Hog hunting promotion event held in watershed.	$5,000 for event costs. Assistance from TSSWCB, AgriLife, TWRI, local hog hunting outfits, et al. required.	This element is an education/outreach component.	The event will be held in 2015.	Coordinate with stakeholders on timing and venue (2013); schedule event (2015).	Ambient water quality data; Number of attendees.	Ambient water quality monitoring.	TSSWCB, H-GAC, AgriLife, TWRI, local hog hunting interests.

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 29-51)	**Estimated Source and In-stream Load Reduction Amounts (in 10^9 CFU/day.)** (Section 4, pp. 52-71)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 72-84)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 85-98)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 99-102)	**Schedule of Implementation for Each Measure** (Section 8, pp. 103-111)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 112-118)	**Indicators to Measure Progress** (Section 10, pp. 119-122)	**Monitoring Component** (Section 11, pp. 123-129)	**Responsible Entity** (Sections,5, 6 and 8)
OSSF	This category as a whole will generate: Source load reductions of 7,330 (16%) In-stream load reductions of 176 (16%) Source load reductions by subwatershed [load (% need to be reduced)]: **SW1**- 0 (0%) **SW2**- 861 (41.4%) **SW3**- 1,062 (44.7%) **SW4**- 255 (25.8%) **SW5**- 2,011 (53.1%) **SW6**- 2,623 (56.8%) **SW7**- 518 (75.1%)	Remediation of failing OSSFs	Estimated costs of $2,000 (conversion to sanitary sewer), $5,000 (repair) or $10,000 (replacement) per system addressed. Incentive funding of up to $1,000 in design costs for residential projects for which funding and commitment is first secured. Technical assistance from Brazoria County and Brazoria County Freshwater Supply District #2 is required.	Promotional materials, meeting with partner agencies.	Remediation efforts ongoing by partner agencies; additional efforts under this project to begin starting in 2013-2014	Determine eligibility criteria (2013); locate grant funding (2013-onward); obtain local permission ((2014 onward); remediate systems ((2014-onward).	Ambient water quality data; Number of OSSFs remediated.	Ambient water quality monitoring; pre- and post-implementation BMP effectiveness monitoring.	Brazoria County Health District, Brazoria County, OSSF owners, H-GAC
		Support Demi-John sanitary sewer conversion; promote sanitary sewer where appropriate.	Staff time in supporting grant application, cost of conversion provided by partners.	Meeting with local and granting agencies, written support, and outreach support for Demi-John as requested.	2012-onward (projected project completion is in 2016 for Demi-John)	Promote Demi-John throughout installation; hold meetings periodically with partner agencies.	Ambient water quality data; Number of OSSFs converted.	Ambient water quality monitoring.	Brazoria County Fresh Water Supply District #2, Brazoria County, H-GAC

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 29-51)	**Estimated Source and In-stream Load Reduction Amounts (in 10^9 CFU/day.)** (Section 4, pp. 52-71)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 72-84)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 85-98)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 99-102)	**Schedule of Implementation for Each Measure** (Section 8, pp. 103-111)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 112-118)	**Indicators to Measure Progress** (Section 10, pp. 119-122)	**Monitoring Component** (Section 11, pp. 123-129)	**Responsible Entity** (Sections,5, 6 and 8)
		Evaluate/ Enhance OSSF Design Criteria	$30,000 to update design criteria and placement requirements for new systems. Technical assistance and coordination with Brazoria County and the Texas Environmental Health Association will be needed.	Meetings with partners (County and municipalities)	Beginning in 2014, expectation of completion by 2016.	Coordinate with Brazoria County on agreement to evaluate criteria (2014); evaluate criteria (2014); present to Commissioner's Court (2015); revise criteria (2015).	Ambient water quality data; milestones complete.	Ambient water quality monitoring.	Brazoria County, Cities, H-GAC
Urban Runoff	This category as a whole will generate: Source load reductions of 951 (17%) In-stream load reductions of 26 (17%) Source load reductions by subwatershed [load (% need to be reduced)]: **SW1**- 0 (0%)	Develop Small Scale Green Infrastructure (LID) pilot projects to include pervious pavement projects, green roof projects, and/or rain gardens.	$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 green roof pilot project development in 2014, with installation in 2015-2016. Begin green infrastructure pilot projects development in 2014, with installation of a primary project between 2015 and 2017. Additional project to be scheduled based on need and opportunity.	Green Roof Project: Obtain agreement with owner (2014); secure funding for project (2014); obtain permits for project (2014-2015); construct (2015-2016). Green Infrastructure projects: identify and get agreement on sites (2014); Design projects (2014); get permits (2014-2015); commence construction (2015-2016); Identify other projects as warranted by development.	Ambient water quality data; Number of acres of urban area affected by BMPs.	Ambient water quality monitoring.	H-GAC, Cities, Brazoria County

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 29-51)	**Estimated Source and In-stream Load Reduction Amounts (in 10^9 CFU/day.)** (Section 4, pp. 52-71)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 72-84)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 85-98)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 99-102)	**Schedule of Implementation for Each Measure** (Section 8, pp. 103-111)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 112-118)	**Indicators to Measure Progress** (Section 10, pp. 119-122)	**Monitoring Component** (Section 11, pp. 123-129)	**Responsible Entity** (Sections,5, 6 and 8)
	SW2- 104 (5.0%) **SW3**- 145 (6.1%) **SW4**- 163 (16.5%) **SW5**- 131 (3.5%) **SW6**- 386 (8.4%) **SW7**- 22 (3.2%)	Develop Large Scale BMP's to include Stormwater Detention Ponds, new large Wetland Detention areas, and/or vegetated swales for new and existing development.	7.7 million, as provided by partners, dependent on need driven by development. Technical expertise from Brazoria County, watershed municipalities, and Drainage Districts will be required in establishing need and siting.	Individual meetings for cities, contractors and property managers on large scale projects.	Stormwater detention projects – begin based on development, with discussions with partners starting in 2013. Stormwater filtration projects - begin pilot project location development in 2013, watershed-wide implementation begins 2015	Stormwater Detention: identify potential sites (2013-onward); obtain agreements, design projects; obtain permits; begin construction (as warranted by development). Stormwater Filtration: Identify sites (2013-onward); obtain agreements (2014-onward); design projects (2014-onward); obtain permits (2015 for initial project, and onward); construction (2015-2016), onward as warranted.	Ambient water quality data; Number of acres of drainage area affected by BMPs.	Ambient water quality monitoring.	Brazoria County, Cities, other drainage agencies.
Pet Waste	This category as a whole will generate: Source load reductions of 1,230 (17%) In-stream load reductions of 32 (17%) Source load reductions by	Development and promotion of model ordinances and HOA bylaws as a resource for watershed communities.	Staff time for developing and promoting model ordinances. Technical resources include legal assistance from municipal and HOA entities in developing individual ordinances.	Promotional materials, meetings with partner agencies/governm ents.	Develop model ordinances and bylaws in 2013; disseminate through the rest of the project.	Develop model bylaws/ ordinances: (2013-2014) l develop promotional campaign (2013-2014); promote to potential users (2014-onward).	Numbers of HOA/ municipalities who adopt the measures	Ambient water quality monitoring.	H-GAC, individual communities

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 29-51)	**Estimated Source and In-stream Load Reduction Amounts (in 10^9 CFU/day.)** (Section 4, pp. 52-71)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 72-84)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 85-98)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 99-102)	**Schedule of Implementation for Each Measure** (Section 8, pp. 103-111)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 112-118)	**Indicators to Measure Progress** (Section 10, pp. 119-122)	**Monitoring Component** (Section 11, pp. 123-129)	**Responsible Entity** (Sections,5, 6 and 8)
	subwatershed [load (% need to be reduced)]: **SW1**- 0(0%) **SW2**- 89 (4.3%) **SW3**- 189 (7.9%) **SW4**- 238 (24.1%) **SW5**- 207 (5.5%) **SW6**- 470 (10.2%) **SW7**- 37 (5.4%)	Installation of Pet Waste Disposal Stations in public areas, with signage	$5,000 for 5 stations in currently existing parks or other public areas. Technical assistance required from entity receiving station in installation and management.	Promotional materials, school programs, signage, meetings with partners	2013-2014; additional future installations based on need.	Identify potential sites (completed); obtain agreements (2013); coordinate with landowner on installation (2013-2014); install stations (2013-2014).	Ambient water quality data; Number of pet owners using stations.	Ambient water quality monitoring; local monitoring of dog waste bag use based on periodic cleanings.	H-GAC, Brazoria County, USF&WS, City of Angleton, Brazoria County Freshwater Supply District #2
		Installation of Dog Parks with signage and pet waste stations.	$20,000 per small parks. Technical assistance from municipal or County Parks staff required.	Promotional materials, school programs, signage, meetings with partners	Angleton Park installed in 2012. Additional parks to be evaluated on an ongoing basis starting in 2015.	Identify site (completed); secure funding (completed); install dog park in Angleton (completed); maintain dog park (2012-onward); identify future locations (2015-onward).	Ambient water quality data; Acres of dog park installed.	Ambient water quality monitoring; local monitoring of dog waste bag use based on periodic cleanings.	Brazoria County, other local governments as identified/
Illegal Dumping	This measure is anticipated to enable better management of other sources rather than directly impact a specific source. No specific	Trash Bash event held within watershed.	$5,000/year to maintain site. Technical assistance from local volunteer coordinator and H-GAC CRP in organizing and implementing event.	Trash Bash outreach is conducted through the event. Educational materials presented at the event.	Trash Bash is held annually as part of a regional event, and will continue to be held annually.	Ongoing event; no specific milestones.	Number of attendees; pounds of trash removed.	Not applicable.	H-GAC, CRP, Trash Bash program, local volunteers

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 29-51)	**Estimated Source and In-stream Load Reduction Amounts (in 10^9 CFU/day.)** (Section 4, pp. 52-71)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 72-84)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 85-98)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 99-102)	**Schedule of Implementation for Each Measure** (Section 8, pp. 103-111)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 112-118)	**Indicators to Measure Progress** (Section 10, pp. 119-122)	**Monitoring Component** (Section 11, pp. 123-129)	**Responsible Entity** (Sections,5, 6 and 8)
	deduction was modeled.	Implement illegal dumping hotline and signage.	$20,000/year for hotline costs, $2000 for creation and installation of related signage.	Signage and education through Brazoria County.	Development of the hotline and related materials y 2015; implementation ongoing thereafter.	Obtain agreement with County for hotline (2013); secure funding for hotline and related materials (2014); implement promotional campaign (2015); implement hotline (2015-onward)	Number of calls to hotline.	Ambient water quality monitoring.	Brazoria County
		Addressing dump sites	Technical assistance provided by Brazoria County in responding to and remediating dump sites.	Signage and education through Brazoria County.	This is an ongoing effort.	Obtain agreement with Brazoria County for cooperation; locate chronic dumping sites (2013-onward); clean dump sites (as needed).	Number of dump sites addressed; volume of dumped material addressed.	Ambient water quality monitoring.	Brazoria County
Land Acquisition	This measure is anticipated to enable better management of other sources rather than directly impact a specific source. No specific deduction was modeled.	Land Acquisition assistance.	$10,000 for initial property, additional properties considered as funding available.	Individual meetings with partner agencies, landowners.	Dow Woods property acquired in 2008. Evaluation of additional USF&WS or other partner acquisition opportunities in 2014.	Acquire Dow Woods property (complete); coordinate with partner agencies on additional sites (2013-onward); appraise property (2014); acquire properties (2015-onward).	Ambient water quality data; Acres of land acquired for conservation use.	Ambient water quality monitoring.	USFWS

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 29-51)	**Estimated Source and In-stream Load Reduction Amounts (in 10^9 CFU/day.)** (Section 4, pp. 52-71)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 72-84)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 85-98)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 99-102)	**Schedule of Implementation for Each Measure** (Section 8, pp. 103-111)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 112-118)	**Indicators to Measure Progress** (Section 10, pp. 119-122)	**Monitoring Component** (Section 11, pp. 123-129)	**Responsible Entity** (Sections,5, 6 and 8)
		Conservation easements	Estimated at $1,500/acre. Technical assistance required from the GLO Farm and Ranch Lands Conservation Program and/or other conservation easement development entities.	Outreach and education on this element is handled through GLO, with support from the stakeholders in promoting the program.	Four large tracts are currently in process by the GLO; Expected completion by 2014. Additional easements to be acquired based on opportunity throughout project.	Support GLO efforts (ongoing); work to identify other partners and opportunities (2014-onward)	Ambient water quality data; Acres of land acquired for conservation use.	Ambient water quality monitoring.	H-GAC, GLO, other partners as identified
		Promoting riparian buffers in new development	Staff time in promoting buffers. Technical assistance and coordination support necessary from watershed municipalities and Brazoria County.	Individual meetings with partner agencies and development interests.	Promotion to begin in 2013, and to last throughout the project.	Identify potential developments; hold meetings with partner agency / government; promote riparian buffers.	Ambient water quality data; Acres of buffer zone left undeveloped.	Ambient water quality monitoring.	H-GAC, Brazoria County
Abandoned Boats	This measure is anticipated to enable better management of other sources rather than directly impact a specific source. No specific deduction was modeled	Removal of abandoned and potentially leaking boats	$30,000/boat. Technical assistance required from the GLO in funding and managing boat removal process.	Individual meetings with partner agencies.	GLO removal of first boat completed in 2012. Additional boats to be identified in 2013. Removal efforts conducted as needed through 2018.	Identify abandoned boat (complete); secure funding to remove boat from GLO (complete); remove abandoned boat (completed); identify additional boats for removal (2013-onward).	Number of abandoned boats removed.	Not applicable.	GLO, Brazoria County, local jurisdictions

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
Causes and Sources of Impairment (Section 3, pp. 29-51)	**Estimated Source and In-stream Load Reduction Amounts (in 10^9 CFU/day.)** (Section 4, pp. 52-71)	**Management Measures and Targeted Critical Areas** (Section 5, pp. 72-84)	**Technical and Financial Assistance Needed for Each Measure** (Section 6, pp. 85-98)	**Education Component for Each Measure (and Other Education)** (Section 7, pp. 99-102)	**Schedule of Implementation for Each Measure** (Section 8, pp. 103-111)	**Interim Measurable Milestones for Each Measure** (Section 9, pp. 112-118)	**Indicators to Measure Progress** (Section 10, pp. 119-122)	**Monitoring Component** (Section 11, pp. 123-129)	**Responsible Entity** (Sections,5, 6 and 8)
Addition-al Enforcement Officers	This measure is anticipated to enable better management of other sources rather than directly impact a specific source. No specific deduction was modeled.	Increase awareness and enforcement related environmental issues.	$75,000 in personnel and training expenses per year. Technical assistance required from Brazoria County in managing internal Count staff logistics.	Public awareness and education by DBWP, Parks and Wildlife, Master Naturalist Program, and others.	Ongoing, starting in 2014	Obtain final commitment from County (2013); Train officers (2013-2014); deploy officers (2014-onward)	Ambient water quality data; Number of environmental incidents handled.	Ambient water quality monitoring.	Brazoria County

Notes on Table 1:

Contaminants loads are described as either source loads or in-stream loads.

> A **source load** is the total amount of pollutant entering a waterbody, measured in total units of the pollutant per period of time (e.g. CFU/day) attributed to a source. A potential source load is the total amount of pollutant estimated to be generated in a defined area, expressed in total potential pollutant units per period of time attributed to a source.
>
> An **in-stream load** is the estimation of the total pollutant load that is actually transmitted to a waterbody, expressed in pollutant units per period of time. Pollutant load within a waterbody is often expressed in terms of instream concentrations, measured by the units of pollutant per unit of volume (e.g. 126 CFU/100ML).

For the purposes of creating the Nine Element Summary Table, those measures addressing the primary contaminant of concern (bacteria) and those resulting in estimated load reductions are included. Additionally, some measures (abandoned boats, etc.) are included to indicate stakeholder priority and concerns beyond bacterial contamination. Additional detail regarding all sources, educational components and BMPs not specific to reducing bacteria, can be found in **Sections 3, 4, 5, 6, 7, and 8**.

Load reduction estimates are given by source, by subwatershed, based on estimated loadings in 2040. For example, livestock-oriented BMPs, as listed, will account for a 25.3 reduction in the projected load from livestock in subwatershed 3 in 2040. Greater detail on the estimation of load, load reduction targets, and BMP scaling to meet load reduction targets can be found in **Sections 3 and 4.** The BMPs were scaled to meet the necessary load reductions, which were generated in proportion to the contribution of sources within the watershed. It should be noted that while BMPs are scaled to address ultimate load reductions, the changing nature of the watershed will require ongoing adaptation of targets. Because SW1 is the furthermost downstream subwatershed, modeling indicated no reduction was required to meet the contact recreation standard. However, local areas in this subwatershed (Demi-John) have localized hot spots of bacteria. It is expected that BMPs will continue to be targeted at this subwatershed. Therefore the contribution to load reduction targets may be greater than the 0% represented 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. It is assumed that a comprehensive education campaign will result in a 2% reduction of total load (Abroms et al., 2008). Loads for subwatersheds were reduced by 2% prior to allocating reduction targets to contributing sources.

1 Introduction

This WPP seeks to apply watershed management techniques to improve and sustain the water quality of Bastrop Bayou and its tributaries, and find practical and achievable solutions 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 WPP and the principles on 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 drains 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 either directly into a common waterway, or through small contributing waterways (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 activities that take place on that land area have 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 - Example of Common Land Use Adjacent to the Bastrop Bayou

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 a watershed: point source pollution and nonpoint source pollution.

> *Point source pollution* is any source of contamination that comes from a discrete, identifiable outfall or conveyance. Examples include discharge pipes from industries, outfalls from wastewater treatment facilities (WWTFs), 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 on-site sewage facilities (OSSFs), and bacteria-contaminated runoff from urban areas.

Because point sources should already be under the jurisdiction of government regulation addressing nonpoint source concerns is the primary purpose of the watershed management approach behind this WPP. While there are a wide range of potential contaminants involved in watershed management, this WPP focuses on fecal indicator bacteria as the predominant contaminant of concern. It is expected that issues regarding low dissolved oxygen, nutrient contamination, and other concerns will also benefit from the same solutions attributed to addressing fecal bacteria. Additionally, stakeholder concerns about trash and illegal dumping are included in our discussion and selection of BMPs as part of the holistic WPP model.

1.3 Watershed Protection Planning

While there are a variety of ways in which watershed management techniques may be employed in a watershed, WPPs offer a comprehensive solution based on local leadership, sound science, voluntary measures and effectiveness monitoring and assessment.

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 BMPs to achieve their goals, and then implement and evaluate those measures. While similar watershed-based regulatory efforts (Total Maximum Daily Load [TMDL] studies and TMDL 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 education and outreach) 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

In addition to the growing concern over water quality in the watershed, the inability of a watershed to support the State of Texas' water quality standard for contact recreation (based on fecal bacteria concentrations) can trigger a mandatory regulatory response (TMDL) to address water quality impairments. After a Watershed Risk Assessment (Risk Assessment) study conducted by H-GAC and the Galveston Bay Estuary Program (GBEP) in late 2004 raised concerns about the future of the Bayou, local stakeholders chose to use the WPP model to proactively address their water quality concerns. 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 primary focus of the WPP, given its potential to cause impairments in the water bodies within the watershed. Subsequent to the initiation of this process, Bastrop Bayou and some of its tributaries have become impaired for indicator bacteria in excess of the contact recreation standard.

1.5 The Bastrop Bayou Watershed Protection Plan

This document is the culmination of the efforts undertaken by the watershed's stakeholders over a seven 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 BMPs 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 WPP offers some brief final words as we look toward the future and the next steps of this endeavor (**Section 12**).

1.6 Other Efforts

In addition to this WPP, much of the watershed area is part of the Brazoria County Storm Water Quality Coalition, a group engaged in stormwater planning under the requirements of the State of Texas TPDES Phase II MS4 General Permit No. TXR040000. Brazoria County, the primary urban centers of Angleton and Lake Jackson, several smaller urban areas and Drainage Districts are pursuing stormwater control measures as a joint program. It is expected that there will potentially be urban sources addressed by elements of this WPP and those of the Coalition. The implementation activities of the WPP are not intended to replace or substitute the MS4 activities, and MS4 activities are not part of the anticipated load reductions or recommended solutions referred to in this WPP. Cooperation, communication, and coordination will be crucial in sharing resources and reducing any potential redundancy between these two efforts. The potential impacts of the Coalition's efforts have not been modeled for the purpose of this WPP, but are expected to generate additional reduction of bacteria sources in urban areas. The WPP currently calls for significant investment in large-scale urban stormwater projects to provide detention and filtration. While the projects are not currently required activities of the Stormwater Management Plans (SWMPs) for local MS4s, they may be added in the future. It is not certain what portion of these activities and costs identified in this Plan will be associated with stormwater point sources or nonpoint sources. Regardless, this WPP does not identify Clean Water Act 319 grant funds for these large-scale practices.

In addition, the TCEQ provides technical and financial assistance to certain homeowners in the coastal zone of Texas for the maintenance and repair of OSSFs, through Texas AgriLife Research. Owners of systems located in areas less suitable for OSSFs may be eligible for financial assistance to have their systems inspected, pumped, repaired, or replaced.[4]

Figure 2 - Stakeholder Advisory Group Member Bill Mladenka with Watershed Signage

[4] Interested homeowners should contact Ryan Gerlich of Texas AgriLife Research at 979/458-4185.

2 The Bastrop Bayou Watershed

Bastrop Bayou 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, with a few small urban centers. The watershed is composed of the land draining to Bastrop Bayou and its tributaries (**Figure 3**).

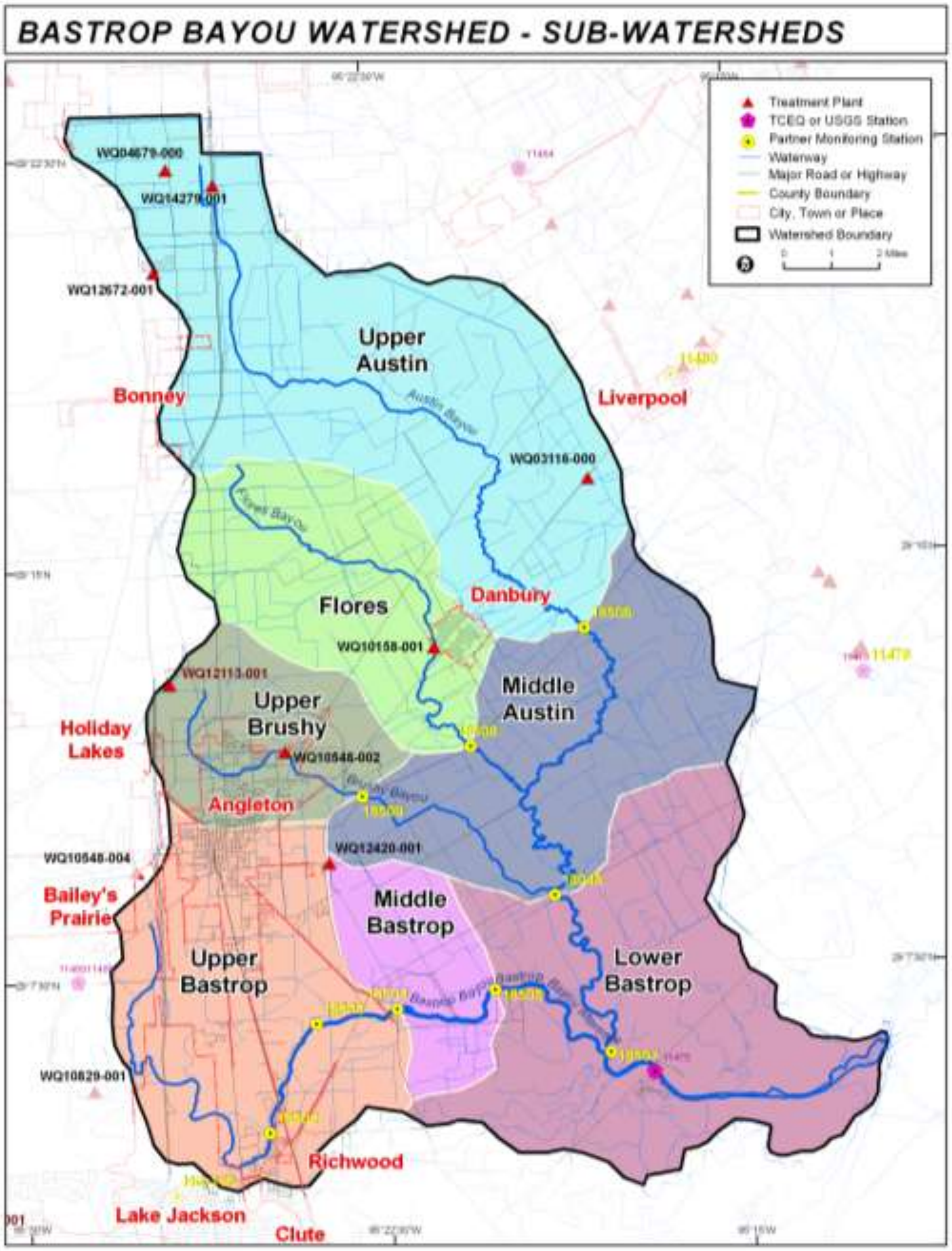


Figure 3 - Bastrop Bayou, its Subwatersheds, and Monitoring Locations

2.1 Major Population Centers

There are two urban population centers in the watershed; Angleton, the Brazoria County seat, and a portion of 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 watershed area is rural, with cattle ranching and rotation row crop farming comprising an appreciable portion of total land use. Angleton and Lake Jackson comprise the majority of the urbanized development in the watershed. A large portion 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 family 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 Change

Within the subwatershed, population is projected to grow from 10,543 households in 2011 to 18,730 households by 2040. Based on regional trends in growth[5], and Brazoria County's position on the edge of the region's urban core, it is likely that the majority of this growth will happen adjacent to existing urban areas and along primary transportation corridors. For example, according to the US Census Bureau data from

[5] Based on H-GAC's Regional Forecast data, the Houston Region is expected to grow by 3.5 to 4 million people by 2035, with much of the growth occurring in the ring of development at the edge of the urban core.

2011, there were 19,280 residents in Angleton, which represents an approximate 7% increase in population in the decade since the 2000 census.

2.4 Wildlife, Feral Hogs, 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 twice 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 non-domestic animals like feral hogs, have become an issue for some areas of the watershed, and can be appreciable contributors of bacteria.

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 freshwater and run in a generally southeasterly direction. The water from the Bayou drains into Bastrop Bay/Christmas Bay and associated coastal estuaries.

For an overview of the watershed and its tributaries, please refer to **Figure 3** and the maps in **Appendix A**.

2.6 Water Quality

Water quality in Bastrop Bayou and its tributaries has degraded over time. The primary constituent of concern is indicator bacteria levels in excess of the state water quality standard for contact recreation, as measured by *E. coli* in freshwater segments and Enterococcus in tidal segments. During the development of this WPP, the water quality data from Bastrop Bayou and its tributaries has shown increasing levels of indicator bacteria.

The Texas Integrated Report (previously the 305(b) report and 303(d) list assessments) describes the status of Texas' natural waters based on historical data. It identifies water bodies that are not meeting standards set for their use on the 303(d) list. The following is a summary of their findings for Bastrop Bayou and its tributaries in recent assessments.

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. However, three impairments were listed for two of its tributaries. Flores Bayou (1105A) and Brushy Bayou (1105E) have both been listed for bacteria impairments. Brushy Bayou has also been listed for depressed dissolved oxygen.

2012 Assessment
Previously, only tributaries have been impaired, but in the 2012 assessment, Bastrop Bayou Tidal (1105) itself was listed as impaired for elevated levels of bacteria.

2014 Assessment
Bastrop Bayou Tidal (1105) continued to be listed as impaired for bacteria, with concerns for dissolved oxygen. All of its tributaries were impaired for bacteria, except 1105D, which had a concern.

Now that Bastrop Bayou and its tributaries are listed as impaired for elevated levels of indicator bacteria, increased focus of BMP implementation will be placed on these segments. When the WPP was first started, there were no impairments listed on any of the water bodies in the watershed. The impairments show a degradation of water quality, which need to be addressed accordingly. Many impairments and concerns for were not present, and therefore were not discussed during the WPP development process. However, it is expected many of the proposed BMPs will have positive impact on these issues.

Table 2 - Water Quality Concerns and Impairments

TCEQ Integrated Report	Segment	Impairments			Concerns	
		Impairment Status	Impaired Parameter	Year First Listed for Impairment	Concern Level	Concern Parameter
2014	1105, Bastrop Bayou Tidal	5c	Bacteria	2012	CN	DO
	1105A, Flores Bayou	5c	Bacteria	2010		
	1105B, Austin Bayou Tidal	5c	Bacteria	2014	CS	DO
	1105C, Austin Bayou Above Tidal	5c	Bacteria	2014	CS	DO
	1105D, Unnamed Tributary to Bastrop Creek				CN CS	Bacteria DO
	1105E, Brushy Bayou	5c 5c	Bacteria DO	2010 2010	CS CS	Ammonia DO

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 is continuing. 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. After revised modeling in 2012, ranking of sources was reviewed and confirmed by the stakeholders.

3.1 Sources & Causes

By 2040[6], a number of factors will place increased pressure on the Bastrop Bayou Watershed, including urban growth in the cities of Angleton and Lake Jackson, residential growth in unincorporated areas (especially along the banks of Bastrop Bayou and its tributaries), regional growth which increases the number of people using the Bayou for recreation, increased pet waste from growing populations, greater chances of malfunction in aging OSSF infrastructure, and a growing presence of feral hog populations.[7] While agricultural sources are projected to decrease in the future, they will remain a prominent contributor of bacteria for much of the planning period. Current water quality data, stakeholder input, the Risk Assessment report, population forecasts and field reconnaissance were used to assess and characterize the potential sources of contamination.

Sources for Bacteria, Nutrients and Other Pollutants

The primary focus of this WPP is to reduce indicator bacteria concentrations in Bastrop Bayou and its impaired tributaries and prevent bacterial impairment in unimpaired water

[6] 2040 is the planning horizon for this project on which modeling efforts were based. While this planning horizon is further than some other watershed-based efforts, the stakeholders felt it was prudent to reflect the changing nature of the watershed in the coming decades. Located on the edge of the Houston metropolitan area, growth in Brazoria County is expected to increase appreciably in the coming decades, especially in the urban areas of the Bastrop Bayou watershed. While that growth is projected to be appreciable, it is not likely to be fully realized within a traditional WPP planning horizon. The impacts of development and growth are identified as causes and sources under this WPP and were of specific concern to the stakeholders. Therefore, the planning horizon and related modeling and projections were completed for a longer timeframe. While the initial focus of implementation activities is on the first 10 years and current causes and sources, the longer timeframe allows a more flexible approach to adapting to the expected new or exacerbated sources derived from increased development.

[7] Modeling for this project takes a conservative approach to estimating loads from feral hogs, because usable data on hog population growth and tendency to concentrate as a result to habitat loss was not available. Therefore, while it is generally believed that feral hog populations will likely increase, regardless of loss of habitat, the ultimate carrying capacity is not known. Future updates of the WPP will need to evaluate whether better data to quantify these factors exists at that time. For the purpose of this project, and the aims of the stakeholders, a conservative estimate is appropriate, as the BMPs to address feral hogs are scalable.

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 if excessive nutrients continue to be a persistent problem in the watershed, additional assessment of nutrient sources may need to be addressed by future revisions of this WPP. The primary categories of sources addressed under this WPP are WWTFs, OSSFs, agriculture (cattle, goats, sheep, and horses), dogs, wildlife and feral hogs, and urban runoff. More detail on the relative contributions from these sources can be found in **Section 3, Section 4, and Appendix A.**

Figure 4 - Cattle in Bastrop Bayou

Rank & Priority

The watershed's Stakeholder Advisory Group (SAG) identified and prioritized potential point and nonpoint sources of pollutants based on local knowledge of the watershed and information provided by H-GAC and partner agencies. As a result of public meetings, the Risk Assessment report, a University of Houston–Clear Lake survey of the watershed, and the monitoring data, the stakeholders have prioritized sources to address them in the following order.[8] Descriptions of priority BMPs designed to address these sources are found in **Section 5.**

1. **Agriculture, Wildlife, and Feral Hogs**[9] – Cattle makes up a substantial portion of the current agricultural sources of indicator bacteria in the watershed. Based on the potential impact of this source, and the existence of feasible BMPs and

[8] The preliminary assessment and prioritization was made prior to the subsequent modeling exercises. However, the prioritization of sources was also verified after the SELECT remodeling in summer 2012. A general emphasis on focusing on the greatest sources of ultimate contribution was verified with the stakeholders.

[9] During the original prioritization process, Agriculture and wildlife were considered as a single source category. In subsequent modeling and discussions, they have been treated as separate categories. In terms of BMP prioritization, the focus in this category was primarily on cattle contributions.

programs available to address it, agriculture was chosen as a priority source, and cattle were chosen as a primary focus within this source. While wildlife was not initially chosen to be addressed through direct structural implementation actions, an educational component and potential partnership opportunities were suggested by the stakeholders. Feral hogs (technically non-domestic animals rather than wildlife) were the primary concern.

2. **OSSFs** – The watershed contains many aging OSSFs that 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.

3. **Illegal Dumping/Trash**[10] – 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. Specific emphasis was put on illegal dumping, abandoned boats, and debris in waterways.

4. **Urban Runoff and Dogs**[11] – 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.

5. **Impervious Cover** – Impervious surfaces in urban areas serve to quickly transport contaminated stormwater into waterways. Impervious cover is not a direct source of bacteria in and of itself, but facilitates the more efficient transmission of bacteria to waterways. Conversely, preservation of open spaces and establishment of riparian buffers helps reduce bacteria inputs to streams through filtration. 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.

6. **Boater discharge** – Bastrop Bayou is a popular recreational destination, and

[10] While this source was ranked in this order, it is not considered directly in modeling or monitoring efforts regarding bacterial contamination, or in priority ranking of bacteria BMPs.

[11] As with Agriculture and Wildlife, Dogs were not initially broken out of this category until later in the WPP process. For the sake of later discussion of BMPs, the primary focus for this source category is dog waste, which was modeled separately from urban runoff.

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).

7. **Wastewater Treatment Plants** – Wastewater treatment plants were not considered an appreciable source of contamination. Later modeling results (SELECT) confirmed this to be the case.

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.

Throughout the process, as additional water quality modeling information was developed, H-GAC reviewed priorities with the stakeholders. The stakeholders have confirmed that these are their priorities. In additional, stakeholders have confirmed that the highest contributing sources should receive priority for implementation actions under this WPP. The top three priority sources of bacteria (agriculture, OSSFs, and dogs/urban runoff) conform to the highest contributions of bacteria as indicated in **Appendix A**.

The following discussion describes process by which sources were characterized, pollutant loads were established, and necessary load reductions were identified. A variety of modeling efforts helped guide stakeholder decisions by providing detailed information about existing and projected impacts of various sources in the watershed.

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). For the Bastrop Bayou watershed, both current impairments and the potential impairments related to future development were foci for modeling activities.

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) model was initially developed by the Spatial Sciences Laboratory and the Biological and Agricultural Engineering Department at Texas A&M University for the purpose of initially estimating the extent and spatial distribution of bacteria sources within a watershed. The objective was to use SELECT for the characterization of relative bacterial contamination in the watershed, and relative change of contribution over time. This information was used as an input in the subsequent EPDRiv1/XPSWMM[12] modeling effort, and as a guide for assigning load reductions. 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**.

Stakeholder Input on SELECT Modeling

In order to assist in reviewing the initial 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 initial SELECT model results were presented to the stakeholders after this class to maximize understanding of the results. The initial SELECT results were presented to the stakeholders for feedback. The results and reference materials are also at the www.bastropbayou.org website. SELECT was rerun in 2012 based on changing land use patterns and revised assumptions. The revised results were also brought to the Stakeholders during 2012 for review and feedback. As with previous modeling efforts, the revision to the SELECT load estimations was completed for current and future conditions on a long enough time scale to encapsulate anticipated growth in the watershed over the coming decades.

3.3 SELECT Modeling Results

An initial SELECT model was developed in 2008, and it was used in the preliminary development of this Plan. Over time, it was determined that new land use data and model assumptions warranted re-developing the SELECT model, and the model was re-run in 2012. All discussion of SELECT modeling for the remainder of this WPP will refer to the 2012 version unless otherwise stated.

The results of the SELECT model were used to find both the current potential bacteria loadings for the watershed as a whole and also for each of the seven subwatersheds. Additionally, each of the subwatersheds was also characterized by relative loading from each individual source category. Secondly, using forecasting data, loads were calculated for subsequent five year periods through 2040. While this timeframe is longer than typical WPP implementation periods, stakeholder preference was to evaluate a longer period of time based on current growth and development projections in the watershed. Without a longer time frame, the impact of future development may have been underestimated. In the previous SELECT modeling run of 2008, modeling was based on the seven large subwatershed areas. In the 2012 version the same

[12] The EPA-adopted Georgia Environmental Protection Division (EPD) version of the QUAL-CE-RIV1 model was used in conjunction with the XP Software version of the EPA's Stormwater Management Model (XPSWMM) to evaluate the fate and transport of bacteria loading when subjected to instream processes and transport on the Bayou and its tributaries.

subwatersheds were used, but bacterial loading was also calculated at a more "granular" level of spatial analysis – dividing the land use map into a grid of small areas based on individual units of the land use data – in order to show "hotspots" – areas of potentially high loading respective to either individual sources or cumulative impact of all sources. In this case, the granular detail was created by evaluating cumulative loading from each cell in the land use layer. At this level of detail, hotspots were visible and could be utilized in future implementation to better determine where higher, more specific, areas of bacteria loading are occurring with larger priority areas. These areas are the intended focus of implementation efforts. Maps showing the subwatershed and granular analyses are included in **Appendix A**. An example of the granular analysis is shown in **Figure 5**.

While the population of the watershed is projected to increase, single family homes were assumed to remain the predominant type of housing. The data sets for forecasted growth were acquired from H-GAC's regional forecasting data. The subwatersheds are based on contours and hydrologic barriers like drainage canals utilized by local landowners (as shown in **Figures 1 and 3**). Each bacteria source is first distributed to the appropriate locations (based on land use as defined in the SELECT methodology) within the watershed and then the load is calculated. Areas outside of a defined buffer around waterways contribute at 25% of their potential load to account for filtration and other reducing factors of sheet flow prior to entry in waterways. Areas inside the buffer contribute at 100%. The buffer methodology was developed with stakeholder input, and the results verified with them at public meetings. The buffer methodology derives from the SELECT model's equal treatment of sources, regardless of distance from the waterways. In real world conditions, the amount of bacteria transmitted to the waterway decreases as distance from the waterway increases, all other factors being equal. While the unbuffered approach accurately depicts the total potential load, it can misrepresent the relative impact of different source categories because it does not consider transmission potential. In the event that you have sources of equal contribution, in which source A is located primarily in the riparian corridor, and source B is located generally outside the riparian areas, SELECT will treat them as equivalent contamination risks. However, in actual conditions, source A is likely to have a greater actual contribution due to its proximity to the waterway. The buffered methodology attempts to provide a high-level conceptual view of transmission potential. It is not intended as a precise measurement of actual load. Its sole purpose is to provide perspective on the likely relative contribution of sources. In the example given, the buffered approach would weight Source A to a greater degree than Source B, showing that their relationship is likely not equal.

The results of the modeling efforts are discussed in the following subsections.

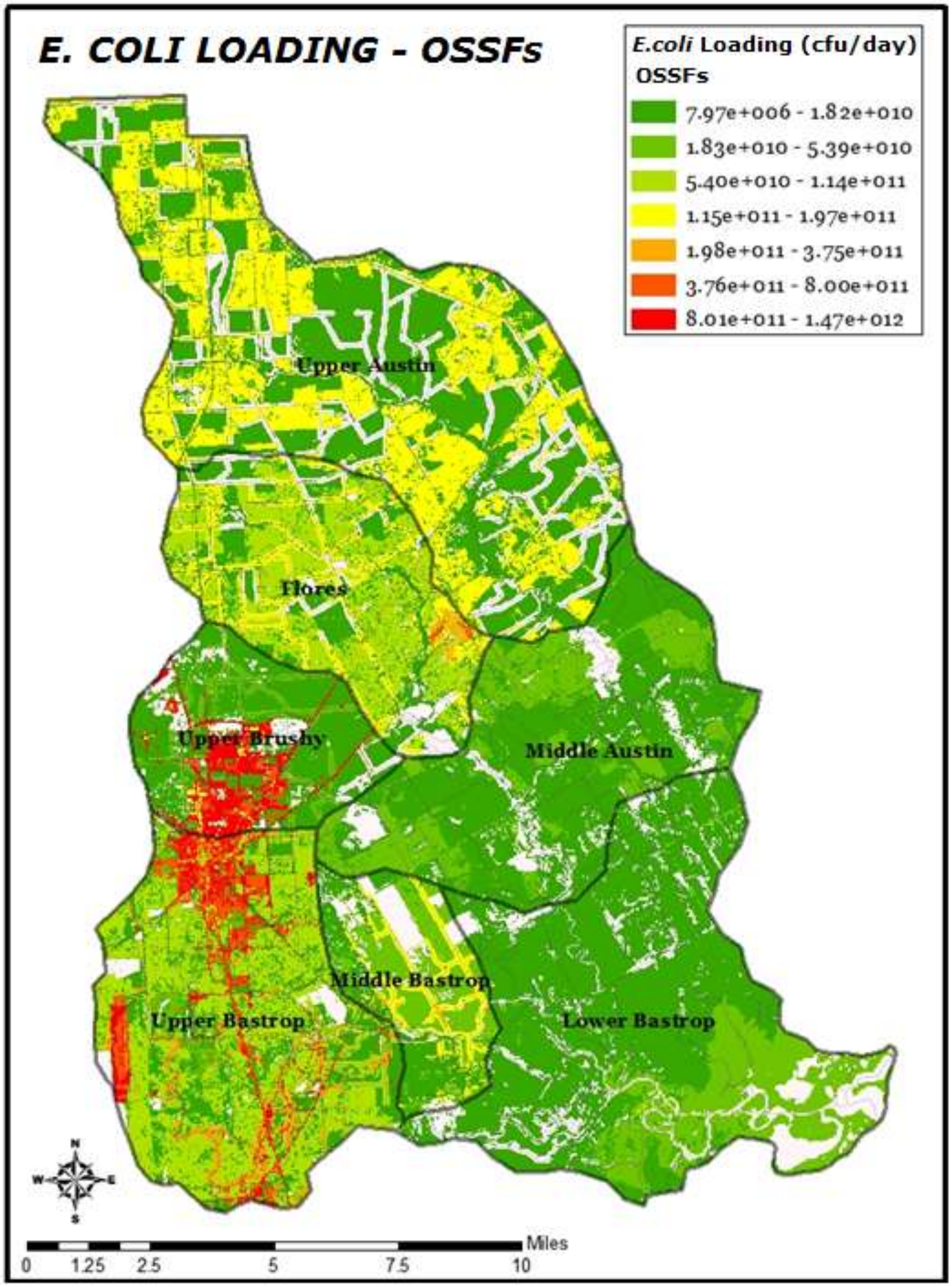


Figure 5 - Granular Level Analysis of E. coli Loading Rates from OSSFs

3.3.1 Wastewater Treatment Facilities

Wastewater Treatment Facilities (WWTFs) are point sources permitted to discharge treated effluent into the watershed. There are eight permitted WWTFs in the watershed (**Figure 3**), which release effluent into the streams. In many instances, an effluent standard or testing data for bacteria was not available until very recently as bacteria limits began to be added to permits, but a residual chlorine level is indicated. 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 CFU/100ml. Therefore, the contact recreation standard (126 CFU/100mL) was utilized for the concentration contributed by WWTFs. The load from each WWTF was calculated by multiplying the permitted concentration by the permitted effluent outflow. All loading results in this WPP indicate potential values in CFU per day. **Figure 6** shows the relative contribution of each subwatershed toward the total watershed load from urban runoff. **Figure 7** shows the forecasted urban runoff load from 2012 through 2040.

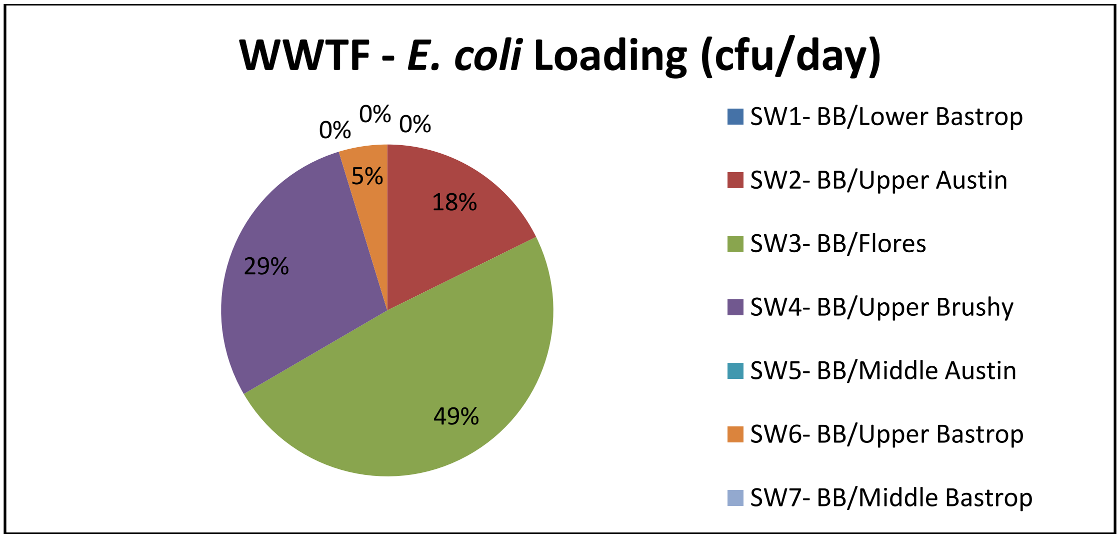


Figure 6 - WWTF E. coli Loading by Subwatershed (2012)

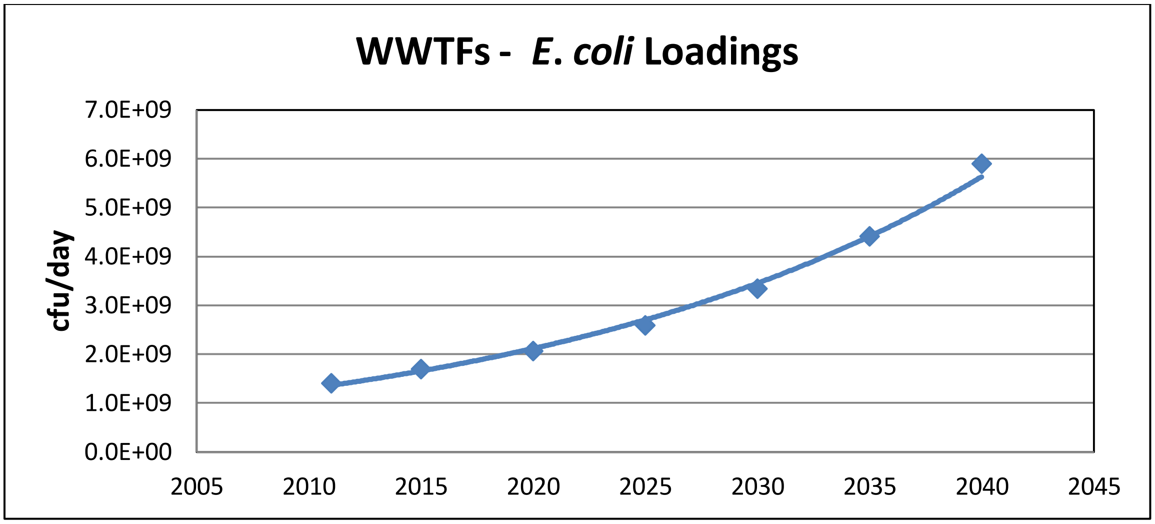


Figure 7 - WWTF –E. coli Source Loads, 2012-2040

3.3.2 Urban Runoff

Urban runoff includes bacteria that accumulate on impervious surfaces in developed areas within the watershed. While some bacteria included in urban runoff are contributed by pets and other sources calculated by SELECT, urban runoff generally accounts for ubiquitous bacteria sources that cannot otherwise be categorized in SELECT. For instance, leaking sanitary sewer pipes as well as sanitary sewer overflows (SSOs) can be a large source of bacteria to a water body. However, those bacteria are unable to be counted in another category, such as WWTFs. Further, the overlap between urban runoff and dogs was judged to be minor and to be offset by the fact that other pet and urban wildlife sources are not captured in the data for dogs (see Appendix B, pp. 189-190 for more discussion of this overlap.) As described in **Appendix B**, runoff contributions were developed from a study performed by the engineering firm PBS&J[13] to measure the *E. coli* concentrations in runoff from different locations (PBS&J, 2000). The volume of runoff was derived from a curve number developed using the average rainfall in the area. **Figure 8** shows the relative contribution of each subwatershed toward the total watershed load from urban runoff. **Figure 9** shows the forecasted urban runoff load from 2012 through 2040.

[13] PBS&J is now Atkins, and referred to as such in sections of the Plan for those activities happening subsequent to the switch.

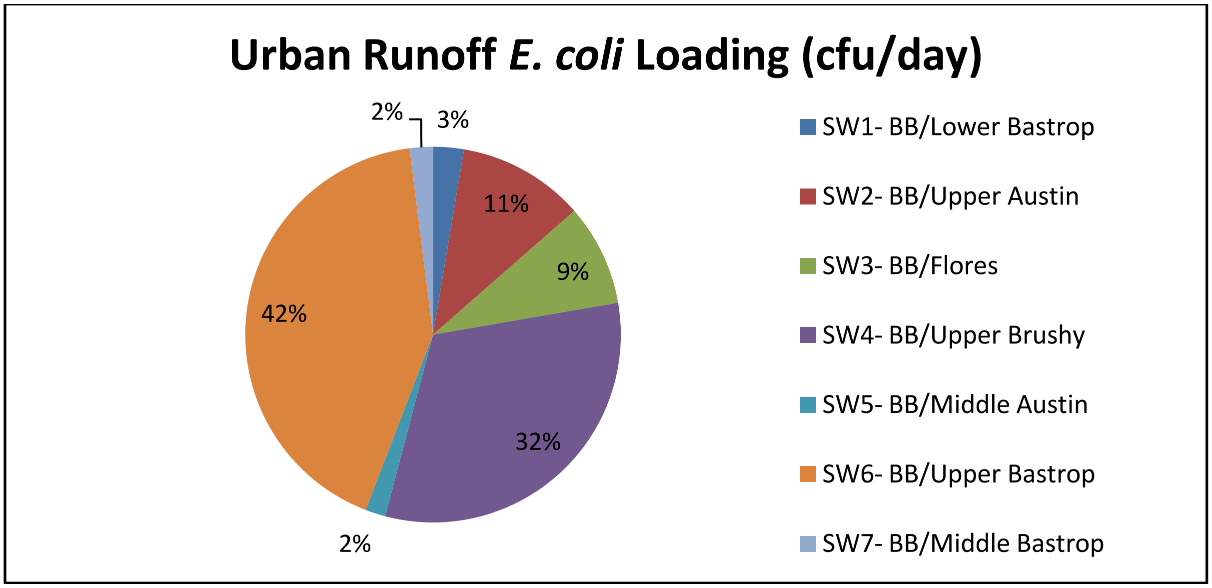


Figure 8 - Urban Runoff –E. coli Loading by Subwatershed (2012)

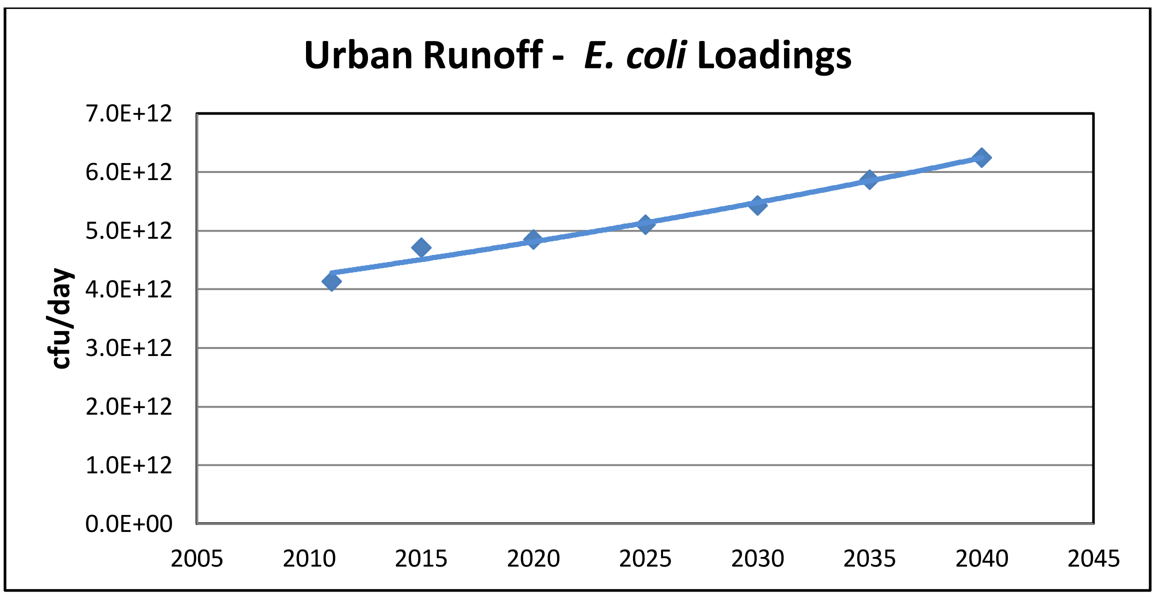


Figure 9 - Urban Runoff – E. coli Source Loads, 2012-2040

3.3.3 OSSFs

Because the Bastrop Bayou Watershed lies within a predominately rural area, OSSFs are a common wastewater treatment solution. 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.

The loading contributed by OSSFs were calculated based on whether they are permitted or unpermitted. Permitted OSSFs were located using a database maintained by H-GAC, which collects OSSF data from designated representatives throughout the region. In the case of Bastrop Bayou, Brazoria County is the designated representative. A 12% failure rate is assigned to permitted OSSFs installed subsequent to 1989 (Reed, et al., 2001). Unpermitted OSSFs were estimated by using GIS to find all of the households located outside of any wastewater service area boundary. Because the homes would not be served by a WWTF, they are assumed to have an OSSF. Because existing permit data incorporated into the H-GAC database is incomplete, it cannot be assumed that all unpermitted households (those not in the database) are unregulated (installed before 1989). Therefore, a ratio of 60% unregulated to 40% regulated is used, and a 50% failure rate[14] is assigned to the unregulated systems (Reed, et al., 2001). The extent of OSSF loading relies heavily on these assumptions, which were based on best available data, and vetted with the stakeholders. It is likely that OSSF results would be highly sensitive to changes in these assumptions. **Figure 10** shows the current known permitted systems in the watershed, located primarily on the outskirts of existing urban areas and transportation corridors. In some areas, large concentrations of OSSFs are known to be directly adjacent to waterways. **Figure 11** shows the relative contribution of each subwatershed toward the total watershed load from OSSFs. **Figure 12** shows the projected OSSF loads from 2012 through 2040.

[14] Some communities are known to have failure rates well in excess of these estimates. Brazoria County found that the Demi-John community in the southeastern end of the watershed was experiencing failure rates of 79% for pre-1989 systems and 42% for post-1989 systems. However, it is not expected that the circumstances of this partially island-based community are the norm for the rest of the watershed.

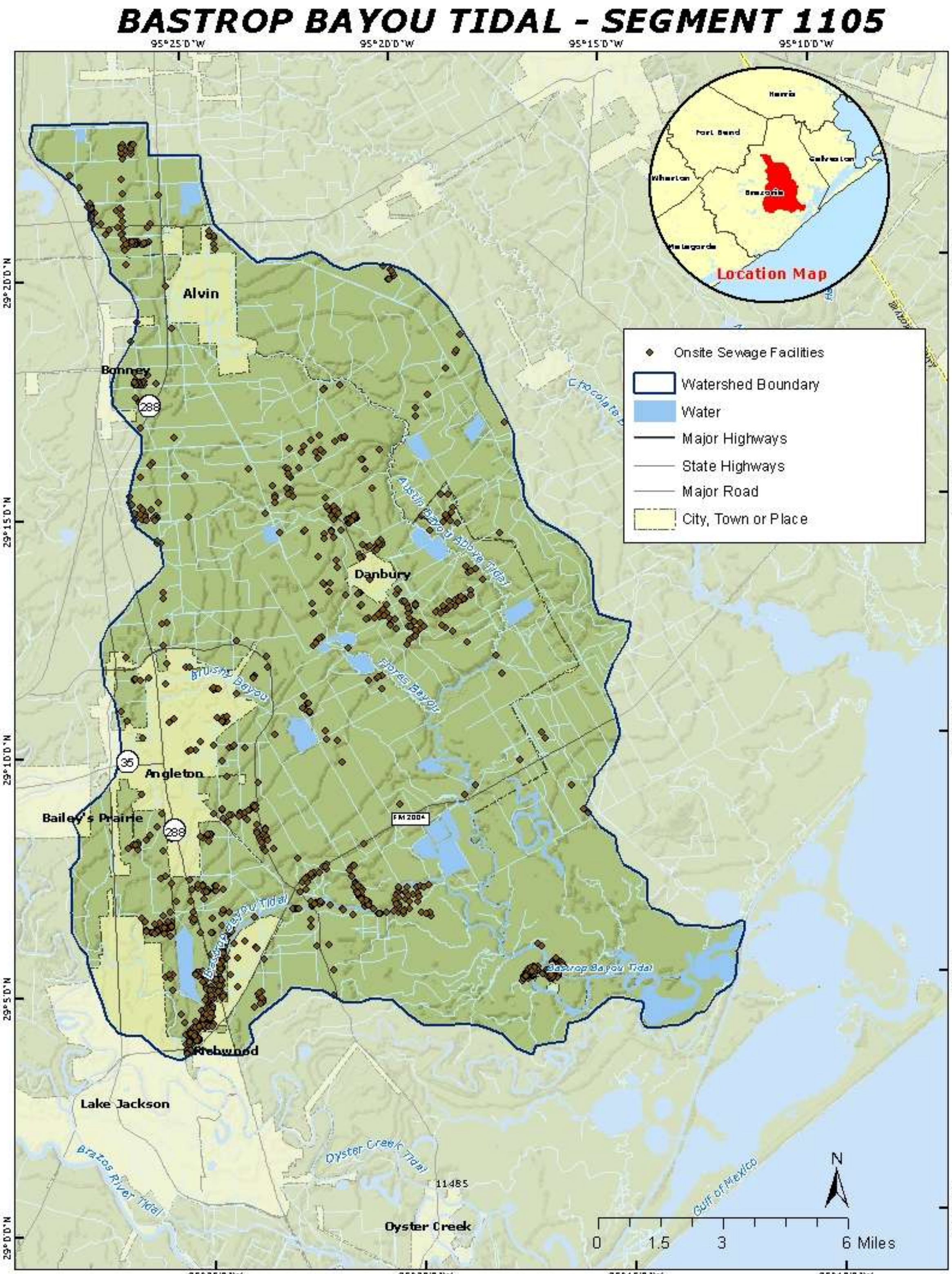


Figure 10 - OSSFs in the Bastrop Bayou Watershed

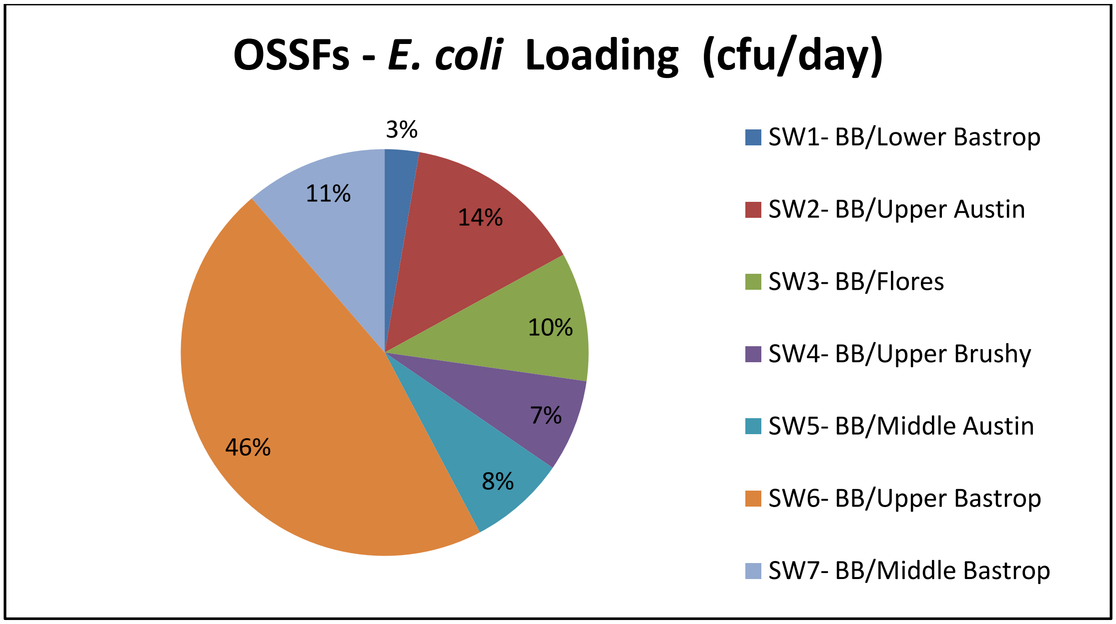


Figure 11 - OSSFs – E. coli Loading by Subwatershed (2012)

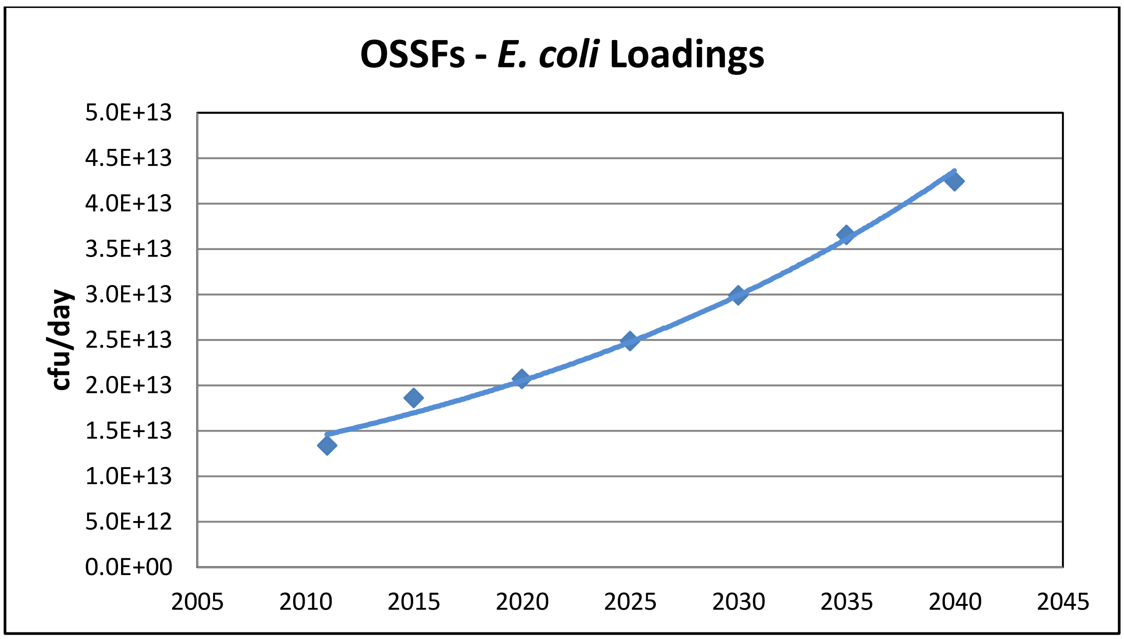


Figure 12 - OSSFs -- E. coli Source Loads, 2012-2040

3.3.4 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.). As development continues in this watershed, pets are expected to increase proportionately with new households. **Figure 13** shows the relative contribution of each subwatershed toward the total watershed load from dogs. **Figure 14** shows the forecasted load from dogs between 2012 through 2040.

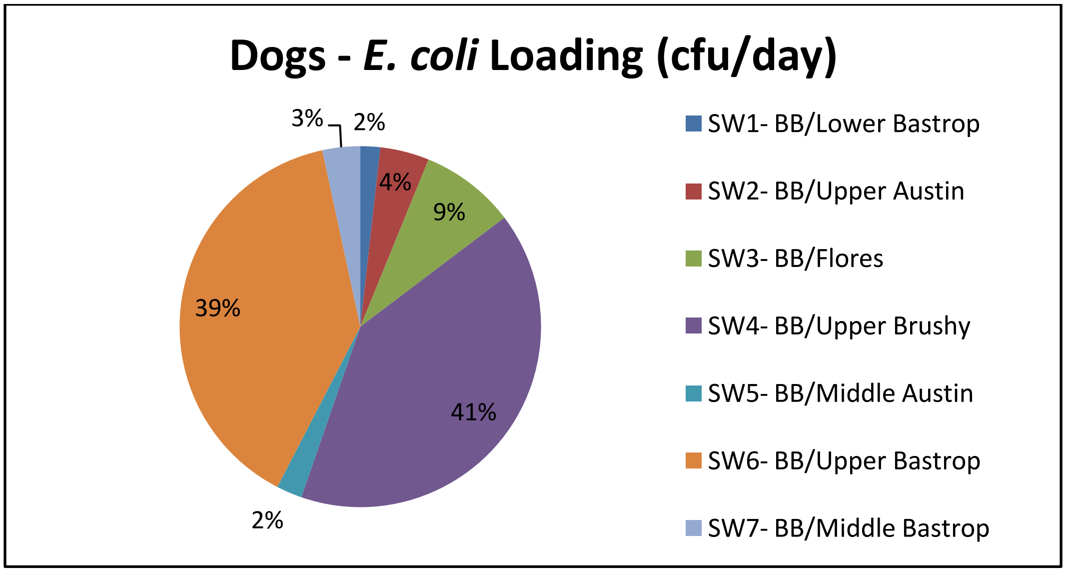


Figure 13 - Dogs – E. coli Loading by Subwatershed (2012)

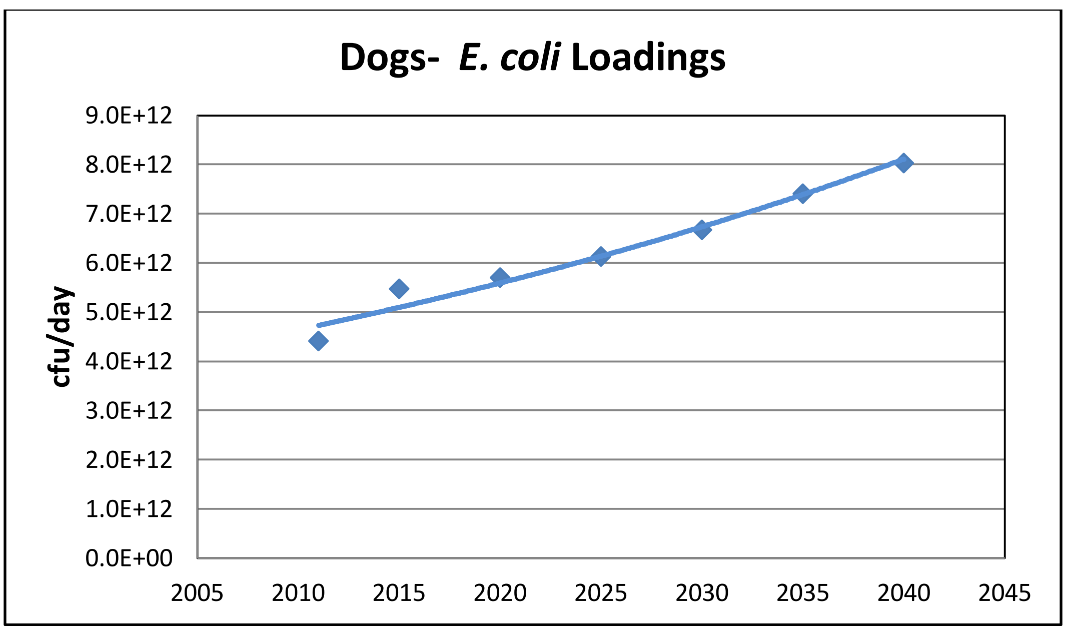


Figure 14 - Dogs –E. coli Source Loads, 2012-2040

3.3.5 Agriculture (Livestock)

In addressing agricultural sources, the primary contributions in the watershed are from livestock operations. Data was available for cattle, sheep, goats, and horses. 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). Livestock populations obtained from Agricultural Census data from the United States Department of Agriculture (USDA) were used to populate appropriate land uses (USDA, NASS, 2007). For the sake of the model, the animal populations represented by this data were assumed to be uniformly distributed within the appropriate land uses. Based on this distribution, a density of animals per acre is calculated. Using an excretion rate per animal, the total load from this source can be calculated. The stakeholders felt that cattle is the most prevalent livestock species providing a bacteria input in the watershed. Because cattle do provide over 90% of the total load from domesticated animals, the livestock BMPs focus on cattle.[15] **Figure 15** shows the relative contribution of each subwatershed toward the total watershed load from livestock. **Figure 16** shows the forecasted load from livestock between 2012 through 2040. **Appendix A** contains more information on the individual loading estimates for cattle, sheep and goats, and horses.

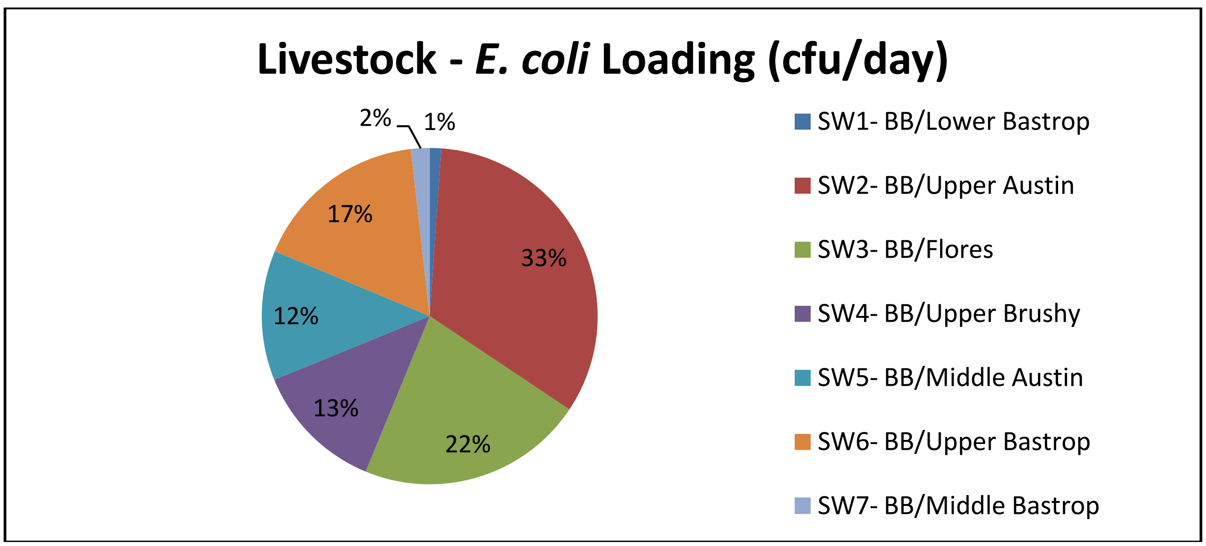


Figure 15 - Livestock –E. coli Loading by Subwatershed (2012)

[15] While BMPs focus specifically on cattle, the necessary load reductions attributed to this source category are inclusive of loadings from all livestock. BMPs for cattle will be implemented such that they meet necessary loads reductions for cattle and all other livestock.

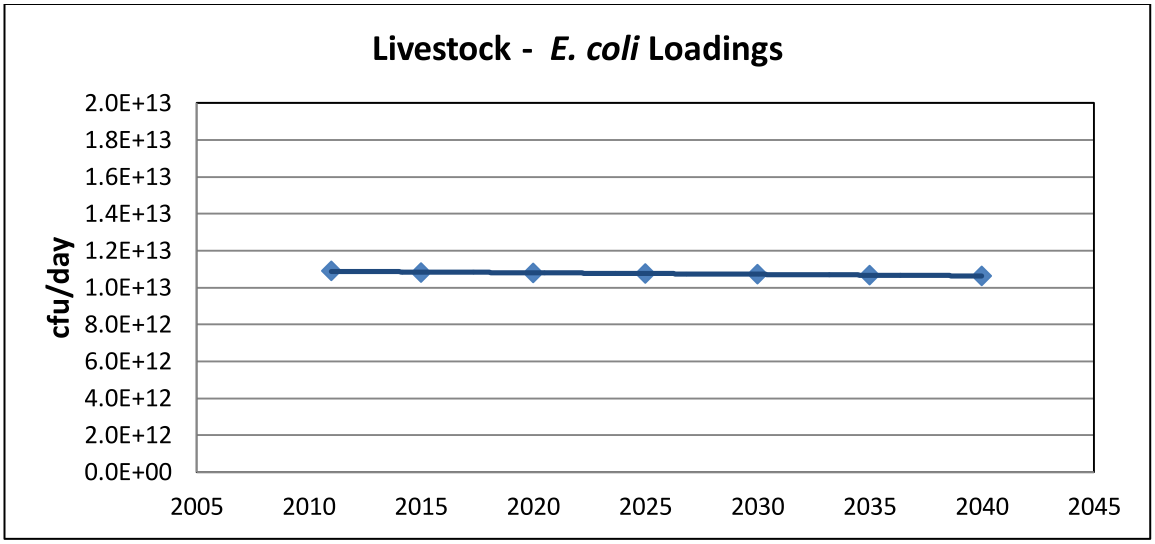


Figure 16 - Livestock – E. coli Source Loads, 2012-2040

3.3.6 Deer and Feral Hogs[16]

Wildlife and non-domestic invasive species populations also contribute to bacterial contamination in the watershed. Major contributors for this category include deer and feral hogs. There are many wildlife sources, including birds, opossums, raccoons, coyotes, deer, and non-domestic invasive species like feral hogs. Migratory birds, specifically, can represent an appreciable seasonal population. However, there are not reliable methods to estimate these populations, and the stakeholders did not choose to address this background level of bacteria contribution. Instead they chose to focus on delineating the impact of the primary contributors: deer and feral hogs.

Deer and feral hog population densities were applied to appropriate land uses to determine number and location of animals, and then excretion rates were used to determine loading.[17] The results for both feral hogs and deer are combined in the figures below.[18] **Figure 17** shows the relative deer and feral hog contribution of each

[16] In discussions of wildlife, feral hogs are a primary focus. In technical terms, feral hogs are not wildlife; they are non-domestic animals as they are not indigenous wildlife of the region, but invasives. For the sake of brevity, it can be assumed that the term wildlife in this document refers to “wildlife and non-domestic animals”, using the more general vernacular of “wildlife”. Because deer are the primary focus of the plan, subsequent references to loading simply specify “deer and feral hogs”.

[17] The SELECT model estimates feral hog loading based on availability of suitable habitat. Future projections indicate a decrease in habitat, leading to a modeled decrease in feral hog contribution. The stakeholders discussed whether this was accurate, based on an assumption that feral hogs will concentrate in remaining habitat. The SELECT model also assumes a static concentration of hogs in habitat, whereas stakeholders felt that concentrations may grow over time. However, reliable estimates of carrying capacity and population growth were not available at the time of this modeling effort. Therefore, it is possible that feral hogs are underestimated by this model, and their contribution may need to be reviewed in the future if more reliable data is available.

[18] As with livestock, the loadings and subsequent load reductions for wildlife are inclusive of deer and feral hogs even though BMPs only address feral hogs. Feral hog load reductions will be sufficient to cover both animals’ loading reduction targets.

subwatershed toward the total watershed load from deer and feral hogs. **Figure 18** shows the forecasted load from deer and feral hogs between 2012 through 2040.

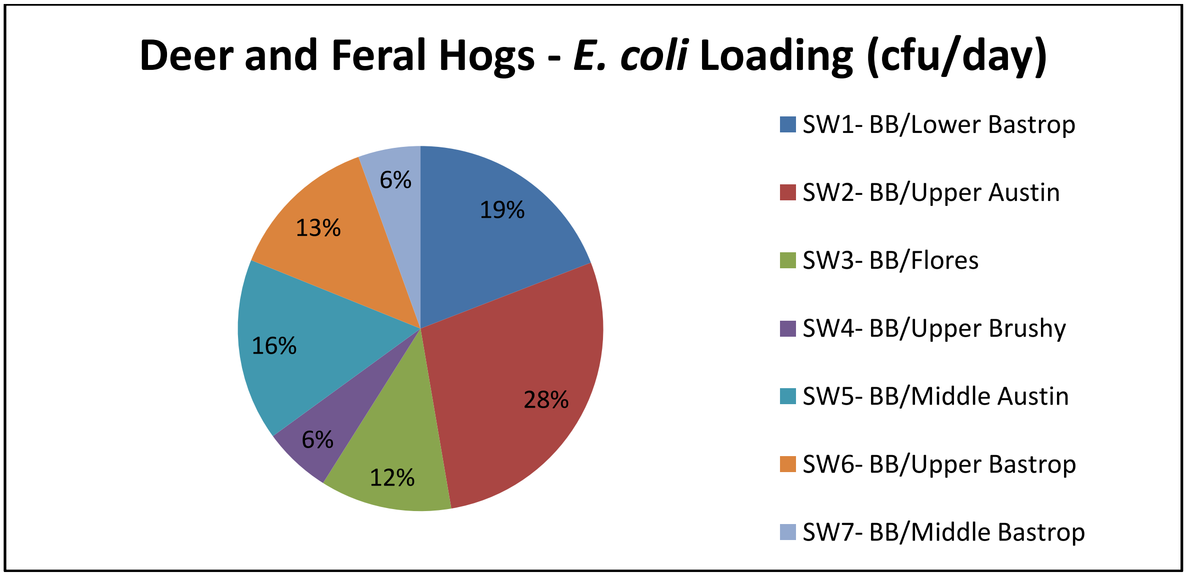


Figure 17 - Deer and Feral Hogs –E. coli Loading by Subwatershed (2012)

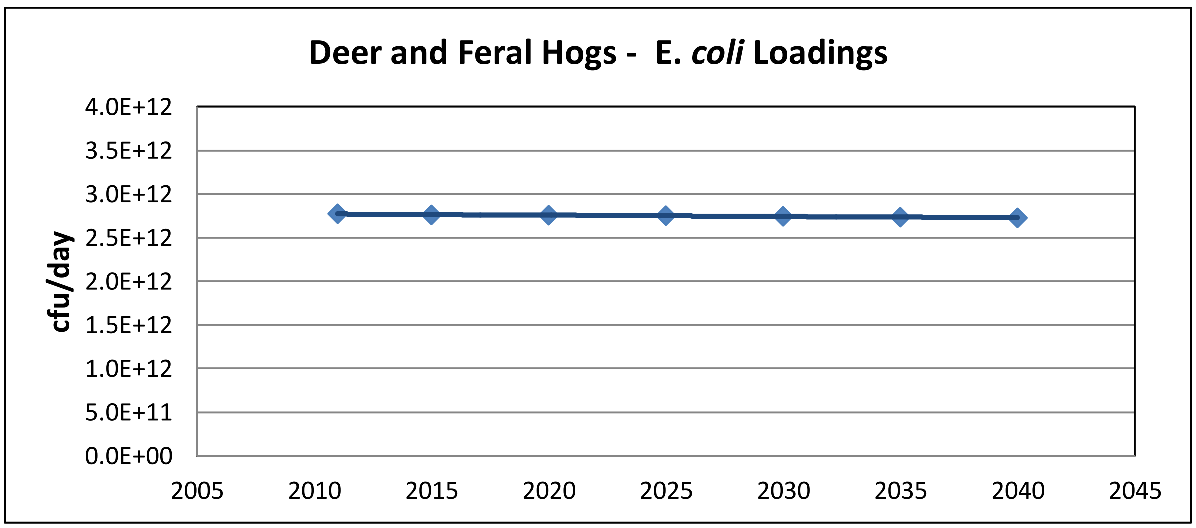


Figure 18 - Deer and Feral Hogs – E. coli Source Loads, 2012-2040

3.3.7 Totals

Combining the loadings from these separate sources created a total loading for the watershed (shown in terms of relative contribution by each subwatershed in **Figure 19**). The same process was completed for each subwatershed and each source. As with the individual source categories, these loadings were projected out to 2040, based on projected changes in land use and assuming no load reductions from new BMPs. The results of these "baseline" projections are shown in terms of total bacteria load generated from each source (**Table 3**), and percent contribution by source (**Table 4 and Figure 20**).

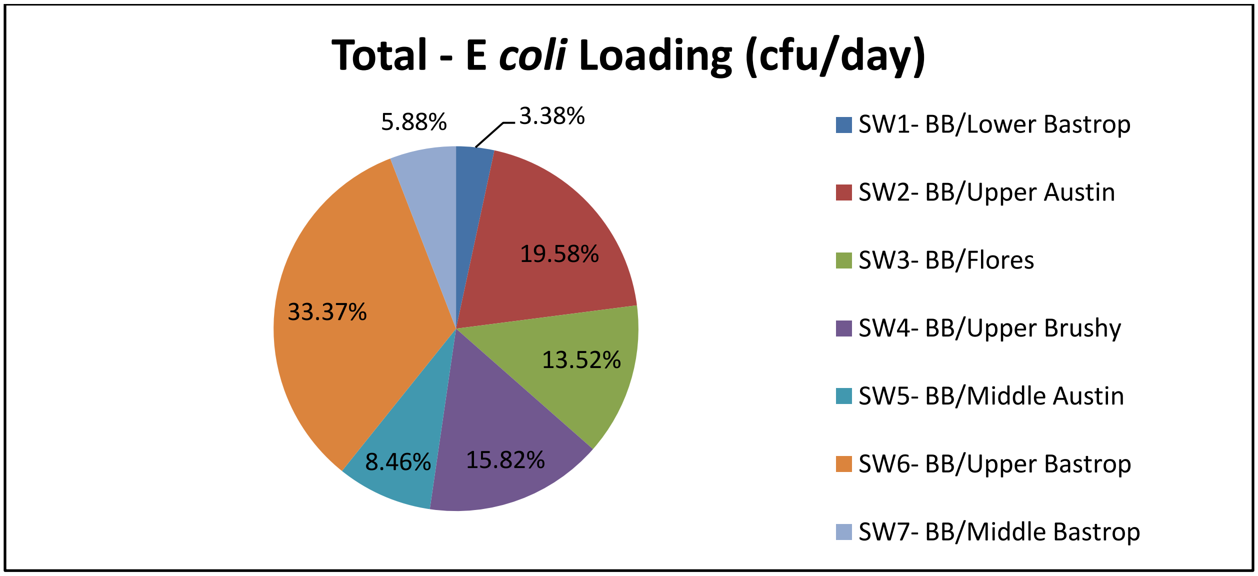


Figure 19 - Total Bacteria Load by Subwatershed (2012)

Table 3 - Total Watershed E. coli Source Loads by Source Type (2012-2040)

ALL CATEGORIES-Loading (in 10^9 CFU-day)							
SOURCES	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
OSSFs	13,300	18,600	20,700	24,800	29,900	36,500	42,400
WWTFs	1.40	1.69	2.06	2.59	3.34	4.41	5.90
Urban Runoff	4,130	4,710	4,850	5,100	5,430	5,870	6,240
Dogs	4,410	5,470	5,700	6,130	6,670	7,400	8,030
Livestock	10,900	10,800	10,800	10,800	10,700	10,700	10,600
Deer and Feral Hogs	2,770	2,760	2,760	2,750	2,750	2,740	2,730
TOTAL	35,600	42,300	44,800	49,600	55,400	63,200	70,000

Table 4 - Total Watershed E. coli Source Load Percent Contribution by Source Type (2012-2040)

ALL CATEGORIES-Percent							
SOURCES	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
OSSFs	37.51	43.87	46.16	50.08	53.87	57.77	60.55
WWTFs	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Urban Runoff	11.62	11.12	10.83	10.29	9.79	9.28	8.91
Dogs	12.40	12.92	12.73	12.36	12.03	11.71	11.46
Livestock	30.67	25.55	24.12	21.72	19.36	16.90	15.18
Deer and Feral Hogs	7.80	6.52	6.16	5.55	4.95	4.33	3.89
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00

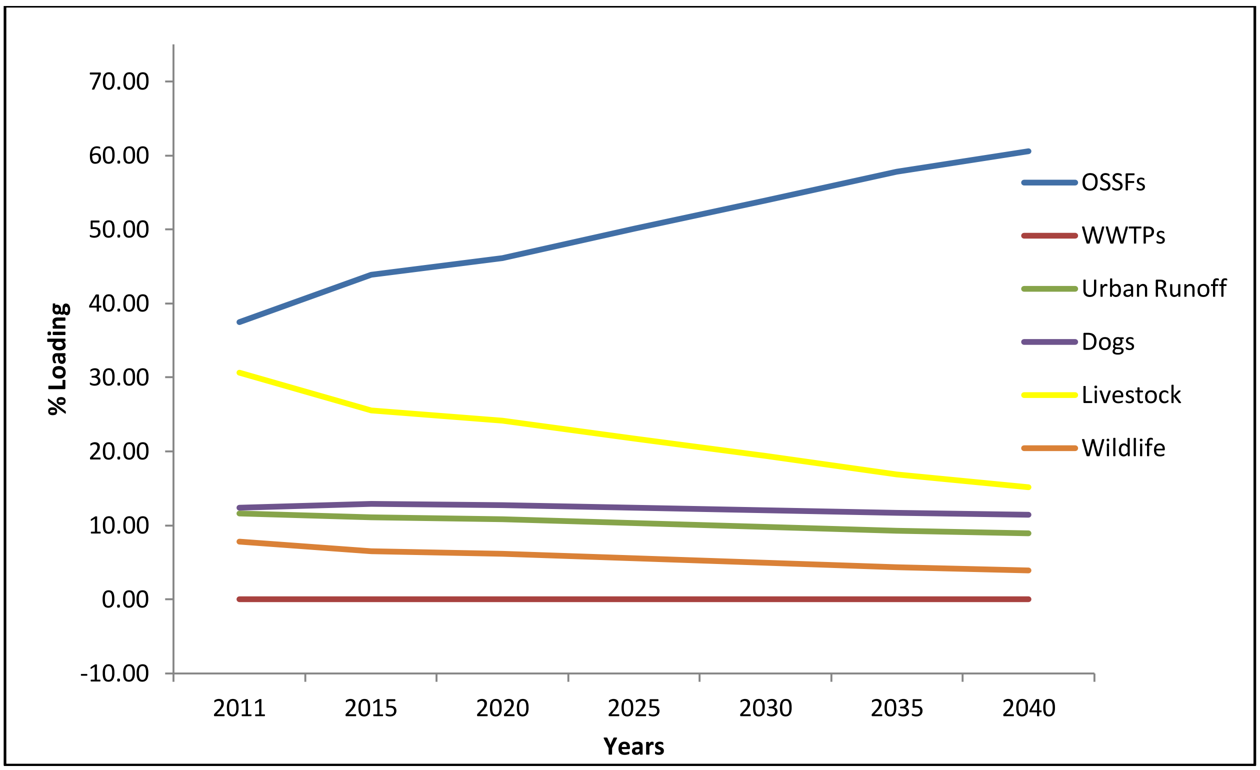


Figure 20 - Change in E. coli Source Contributions (2012-2040)

Review of SELECT Modeling Applicability
When the results of SELECT are compared to 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. In other words, the pathogen's environmental survival and replication is not modeled, only the potential contribution of various sources, arrayed spatially. In order to get a more accurate model of the *E. coli* contamination, SELECT was coupled with a watershed model that models the transport of the *E. coli* and the impacts of in-stream processes.

Further information on the loading and land use modeling outcomes is contained in **Appendix A**, and further detail about the SELECT model assumptions and methodology can be found in **Appendix B**. To further define the impacts of various factors in the waterways and model the influence of tidal action, additional modeling was completed utilizing the XPSWMM and EPDRiv1 models.

3.4 EPDRiv1[19] Modeling

At the start of the WPP development process, no segment of Bastrop Bayou was impaired for bacteria. The WPP's original goal was to maintain the current bacteria levels despite future changes in the watershed. However, in the intervening time frame, three segments became listed for elevated levels of bacteria. The goal of the WPP and the modeling efforts, therefore, are to determine what load reductions are necessary to reduce the bacteria concentrations so that the impaired segments may be delisted and that all segments could maintain concentrations below the standard.

The SELECT modeling calculated the bacteria load from identified sources in five year increments through 2040. 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. Once bacteria have entered the waterway they are subject to a variety of processes including die-off, regrowth, effects 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 was necessary to represent the physical and water quality processes acting on the target bacteria.

The EPDRiv1 model[20] was set up a model of the Bastrop Bayou system using available bathymetric information and calibrated it to existing ambient monitoring data from H-

[19] The EPDRiv1 model was developed by the Georgia Environmental Protection Division (EPD) as a version of the CE-QUAL-RIV1 model, and is available from the EPA at http://www.epa.gov/athens/wwqtsc/html/epd-riv1.html.

GAC's Clean Rivers Program sampling. The model was operated for a representative period to determine the fate of bacteria in transport and the impact of tidal processes. For the non-tidal sections, synthetic flow calculations were developed 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 proximity and similarity of hydrologic character to Bastrop Bayou, Chocolate Bayou was chosen as the option with the least inherent uncertainty. Based on the revised SELECT model effort in 2012, the EPDRiv1 model was re-run to incorporate the revised projections. Estimations of current concentrations and projected future concentrations were completed using relative change between current and future loadings in SELECT as a scaling factor. After the expected bacteria concentrations were generated for future conditions, additional model runs were made to determine the reductions necessary to lower the bacteria concentration levels to the contact recreation standard. This step was taken to ensure that load reductions and BMP scaling would be sufficient to meet the standard at all of the stations (end of each subwatershed). The initial model output indicated geomeans below the standard prior to implementation of BMPs. To better approximate the impact of NPS in storm events, flow-weighted geomeans were used as a basis for estimating needed reductions in 2040.[21] While the time frame evaluated is longer than other similar implementation efforts, and extends

[20] During the initial round of EPDRiv1 modeling, this firm was named PBS&J. Prior to the second round, the firm's name was changed to Atkins.

[21] The conventional geometric mean was calculated by averaging the hourly values of EC levels obtained from the EPDRiv-1 model. The flow-weighted geometric mean was estimated by summing the product of the bacteria concentrations and flows, and dividing the sum by sum of flows so that the high flow periods receive a greater weight and vise versa with low flows. This way, the effect of flow variation on the EC loading can be addressed. The choice to use the flow-weighted approach was based on several factors. The use of Load Duration Curves under TMDL processes has used a similar approach. The geomean target is set for a limited portion of the load duration curve, reflecting specific aspects of the flow regimes. In many cases this is the higher flow ranges, so that the criteria for WQ standards will be met during higher flow conditions as well as lower flow conditions. This approach mirrors the conservative approach discussed with the stakeholders and use of flow-weighted geomeans in this project. If LDCs had been the primary modeling tool for Bastrop Bayou, a similar approach would undoubtedly been used to conform to TCEQ TMDL modeling practices. Secondly, throughout the development of the WPP, and specifically in descriptions of the original and revised EPDRIV-1 modeling runs, the use of flow-weighted geomeans as part of a conservative approach was discussed with the stakeholders. This adherence to a conservative approach has been highlighted in response to concerns over rapid development in the watershed, and is consistent with the rest of the WPP. Third, one of the confounding factors in developing this WPP was the uncertain linearity of growth in the watershed, and the high projected growth rate. Instead of a direct linear growth progression, it is likely that the watershed will see punctuated equilibrium, with spurts of growth. Additionally, the watershed is on the growth boundary of the greater Houston area, in which rapid development is taking place. Previous "current" projections and even current monitoring data may be a questionable basis for future projections without weighting to attempt to account for this transitional state. Fourth, review of current monitoring data as collected and evaluated by the Clean Rivers Program and reflected in the current and draft Integrated Reports, the watershed is moving more rapidly toward greater impairment than the un-weighted geomeans suggest. While this is not necessarily a justification for the original decision, it does indicate that the conservative approach which led to it seems to be justified so far. Periodic review of data will need to be completed to ensure this remains the case, but the existing impairments indicate water quality is tracking more closely to the weighted version (which shows impairment) than the un-weighted (which generally does not indicate concentrations in excess of the WQS). Lastly, the approach mirrored the best professional judgment of the modelers, and their long experience with modeling Texas coastal systems.

beyond the initial 10 year implementation focus of the project, stakeholders placed importance on understanding the full impact of growth in the watershed. As much of the growth driven by the expanding Houston area and petrochemical industry may not be realized until after the initial 10-year period, the longer modeling time frame provides a basis for activities or long term focus that may not be reflected in interim conditions.

A summary of the EPDRiv1 estimated future concentrations and future flow-weighted concentrations are shown in **Table 5.** A summary of the required instream load reductions is shown in **Table 6.**

Table 5 - EPDRiv1 Estimated E. coli Concentrations by Subwatershed (2040)

SUBWATERSHED	SW1-BB/Lower Bastrop	SW2-BB/Upper Austin	SW3-BB/Flores	SW4-BB/Upper Brushy	SW5-BB/Middle Austin	SW6-BB/Upper Bastrop	SW7-BB/Middle Bastrop
Existing Conditions							
EC Geometric Mean Conc (#/dL)	22	52	40	99	28	59	48
EC Flow-Weighted Geo Mean Conc (#/dL)	193	435	564	646	360	209	210
Future Conditions							
EC Geometric Mean Conc (#/dL)	31	89	68	123	81	81	87
EC Flow-Weighted Geo Mean Conc (#/dL)	384	683	909	911	733	374	450

Table 6 - EPDRiv1 Estimated E. coli Source Load Reductions by Subwatershed (2040)

SUBWATERSHED	SW1-BB/Lower Bastrop	SW2-BB/Upper Austin	SW3-BB/Flores	SW4-BB/Upper Brushy	SW5-BB/Middle Austin	SW6-BB/Upper Bastrop	SW7-BB/Middle Bastrop
Load Reduction							
EC NPS Loads (#/day X 10^9)	55.3	2,080	2,380	985	3,790	4,620	690
EC WWTP Loads (#/day X 10^9)	0	2.23	1.92	1.50	0	0.237	0
Total EC Loads (#/day X 10^9)	55.3	2,080	2,380	986	3,790	4,620	690
EC Geometric Mean Conc (#/dL)	16	32	22	33	20	50	45
ECFlow-Weighted Geo Mean Conc (#/dL)	64	126	126	125	121	124	123
EC Load Reductions (#/day X 10^9)	-	**-1,740**	**-2,120**	**-821**	**-3,290**	**-3,870**	**-624**
EC Load Reductions (%)	-	**-83.7%**	**-89.2%**	**-83.2%**	**-86.9%**	**-83.9%**	**-90.5%**

The methodology, details, and results of this modeling approach are found in the report in **Appendix C**. Load reduction targets derived from this modeling effort are discussed in **Section 4**, and the management measures used to meet load reduction targets are discussed in **Section 5**.

4 Pollutant Loads and Required Reductions Element B

Based on pollutant load and fate and transport estimates developed in **Section 3,** this section will discuss the generation of load reduction estimates for each subwatershed, the allocation of those load reductions to the pollutant sources within the subwatersheds, and the scale of implementation activities necessary to achieve the reductions. To reduce loadings of identified contaminants, the stakeholders will implement a variety of BMPs throughout the watershed. The BMPs are explained in greater detail in **Section 5.** Greater detail on generation of load reduction targets and implementation scaling can be found in **Appendices C and D**. In general, the load reductions in this watershed are likely to be a moving target. Changing agricultural landscapes and waves of development are already in process. Reductions are discussed in terms of current and ultimate demand, with the ultimate demand based on 2040 estimates, which are related to many other regional data projection horizons. However, it is likely that the reduction of bacteria during that time period will not be a linear progression, as causes and sources will not remain static. Addressing nonpoint sources in the Bastrop Bayou Watershed is likely to be a challenge for the foreseeable future, as development and other factors cause an increase in sources concurrent with implementation. The efforts of this WPP are not only to address current loads, but to attempt to slow the rate of increase of future loads.

Generating Loads

As discussed in **Section 3**, the SELECT model calculated load inputs to the system based on estimated bacteria contribution from different sources and land cover data for the watershed in both present day and in five-year increments through 2040. One of the primary uses of this data was to indicate the relative change of loading contribution over time. These relative loading factors were used as an input to the EPDRiv1 model, which produced in-stream concentrations at the end of each subwatershed based on flow-weighted geomeans. The subwatershed designations and common names are: SW1 – Lower Bastrop Bayou; SW2 – Upper Austin Bayou; SW3 – Flores Bayou; SW4 – Upper Brushy Bayou; SW5 – Middle Austin Bayou; SW6 – Upper Bastrop Bayou; and SW7 – Middle Bastrop Bayou.

Deriving Load Reductions

Additional runs of the EPDRiv1 model calculated the amount of load reduction, per subwatershed, that was required to meet the contact recreation standard in the year 2040. Flow weighted geomeans were used as the basis of determining the reduction targets for each subwatershed.

Future conditions were used for the reduction criteria so that the WPP can be implemented over time in order to reach the contact recreation standard. **Table 6** in the preceding section shows the necessary load reduction targets for each subwatershed. The approach of this WPP was to develop individual load reductions on the subwatershed level, to mirror the outcomes of the modeling results and allow for flexibility in addressing the sources of greatest prominence in that subwatershed. The EPDRiv1 model calculated loadings and required reductions at the subwatershed level from the upstream portions of the watershed to the bottom, so the model assumed that the reduction measures in the upstream portions affected the contribution to downstream portions.[22]

Allocating Load Reduction to Sources within Subwatersheds

Because not all subwatersheds have the same relative contributions from the identified sources, it was decided to treat each subwatershed individually when determining scaling of BMP implementation. To allocate the overall load reduction for the subwatershed to each source within the subwatershed, the relative contribution of that source was used. The load reductions were allocated proportionate to the contribution of each source, such that a source contributing 50% of the load to a subwatershed would be responsible for meeting 50% of the load reduction target. This methodology is based on the same consensus reached by the stakeholders regarding priority of sources, and priority of BMPs.

Scaling BMP Implementation to Meet Load Reduction Targets

In determining potential impact of implementation activities, spatial distribution of sources derived from SELECT was an important consideration. As discussed previously, SELECT created a buffer around the water bodies inside of which bacteria transmission rates to water were 100%, and outside of which they were reduced to 25%. In general, BMPs will be focused on areas within the buffer as much as possible because they have the greatest potential impact on the reduction of bacteria in the water. Therefore, in deriving load reduction estimates, it was assumed that BMPs were applied first to sources within the buffer.[23]

Subsections 4.1 through 4.6 describe the load reduction targets for each source, the mix of strategies that will be applied to those sources, and the expected scale of the implementation needed to meet the targets. The reductions generated by BMPs are

[22] EPDRiv1 calculated loadings and required reductions at the subwatershed level from the uppermost part of the watershed to the bottom, so the model assumed that the cumulative reduction measures in the upstream portions affected the downstream portions. Therefore, if reductions are fully achieved in the six subwatersheds above the Lower Bastrop subwatershed, the model does not require any reduction measures to take place in Lower Bastrop. It calculates that the Lower Bastrop subwatershed will be below the contract recreation standard by 2040 without intervention. In reality, Lower Bastrop will likely have enough localized bacteria loading concerns to require further BMPs to ensure that the bacteria standard will be met. Even though the model outputs and charts in this section do not require a load reduction, this WPP assumes that Lower Bastrop will receive BMPs to reduce bacteria loading in that subwatershed as deemed appropriate by water quality monitoring and stakeholder input. The allocations presented here are targets, and actual implementation may vary from these targets as feasibility dictates, while still meeting the same load reductions for the watershed as a whole. This decision was made based on localized issues and sources identified and prioritized in this subwatershed, including malfunctioning septic systems in Demi-John that can have local impacts even if they do not cause the whole subwatershed to break the standard.

[23] E.g., in remediating OSSFs, priority will be given to systems inside the buffer, all other factors being equal. Therefore in determining the number of systems needing to be remediated to meet the load reduction, it was assumed that the pool of buffer area systems was addressed first (at 100% per unit reduction) and then if additional reduction remained, non-buffer systems were used to meet the need (at 25% per unit reduction).

drawn from a mix of literature values, assumptions made in similar watershed planning efforts, SELECT model assumptions about spatial distribution[24], and calculated reductions specific to the character of this watershed. The end result of this process was a determination of how many representative BMP units[25] needed to be addressed by BMPs specific to that source. This estimation represents the scale at which those BMPs would need to be implemented. **This WPP calls for phased implementation of BMPs at the scale necessary to meet the reduction necessary by 2040**. However, reductions in bacteria are unlikely to proceed in a linear fashion during that extended time period due to anticipated waves of growth and countercurrents of agricultural land use change. Therefore, while the scaling focuses on the long term maintenance of the watershed, the implementation activities will initially focus on the first 10-year period.

Each subsection contains two tables; a description of the load reduction targets per subwatershed, and the number of BMP units needed to generate the reductions using the prescribed BMPs. Additionally, a summary figure of load reductions is included. Detail about the derivation of assumptions and load reduction estimates is explained in greater detail in **Appendix D.** The proposed BMPs related to the reductions are discussed in general terms; greater detail is available in **Section 5.**

4.1 Education and Outreach Projects

Education and outreach is a major component of the strategies utilized in this WPP to help reduce the bacteria load into Bastrop Bayou and its tributaries. Well-designed education and outreach efforts produce a cumulative 2% reduction in nonpoint source pollution contamination (Abroms et al. 2008), while also serving as a way for a wide array of stakeholder groups to participate in the WPP. The long term effects of outreach can be significant if the efforts are sustained and become pervasive.

In general, the approach in Bastrop Bayou will be a comprehensive program of public appearances, educational seminars and programs, outreach venues like the project website, surveys, and classroom oriented materials.

Because education and outreach will encompass all sources, and because it cannot be spatially located, its impact is achieved by reducing total needed reduction from the subwatershed by 2% prior to allocating load reduction targets to the source categories.

The full scope of educational BMPs is described in **Sections 5 and 7**.

[24] As discussed further in Appendix D, the load reduction potential of managing the waste from a cow, for example, is dependent on whether that cow is inside or outside the buffer area.

[25] BMP units are the measurable points of scalable implementation. In terms of livestock source, the BMP may be cattle fencing, and the BMP units may be the number of cows excluded, the numbers of acres served by the BMP, etc. Total load reduction needed is divided by load per unit to produce number of units needed (i.e., scale of implementation). Units are representative of the assumptions discussed in Appendix D (e.g., BMP scaling for cattle refers to a representative cow. Depending on the spatial distribution of the actual cattle being addressed, more cattle may need to be addressed.)

4.2 Livestock Management

Agricultural range animals 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. While horses, sheep and goats are present, cattle comprise the vast majority 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 WPP. Reductions from cattle BMPs will be used to meet the combined livestock load reduction targets.

Based on the success of previous efforts (USDA NRCS EQIP financial incentive projects, TSSWCB Water Management Plans, etc.) incentive-based, voluntary management can be achieved to prevent livestock waste from entering waterways, or greatly reduce its impact. Examples of BMPs employed toward these aims include prescribed grazing, stream fencing, providing alternative water and shade sources and developing buffer areas to intercept or filter contaminated flow before it enters waterways. In the process of determining BMP implementation, the WPP focuses on prioritizing parcels that are adjacent to the streams.

For the basis of determining implementation scaling for cattle, an individual representative animal is used as the BMP unit. For greater detail on the BMP scaling methodology for cattle, refer to Appendix D. The load reduction targets for each subwatershed are contained in **Table 7**. The scale of the implementation of livestock BMPs is reflected in the number of cattle to be managed[26], as described in **Table 8.**

[26] As indicated in Appendix D, the number of cattle to be managed is based on a representative animal and assumes a 100% reduction of load. Because BMPs vary in both average and site-specific removal rates, the number of actual cattle to be addressed may increase if less than 100% load reduction is achieved per animal.

Table 7 - Required E. coli Source Load Reduction for Cattle per Subwatershed[27] in 2040

		SW1- BB/ Lower Bastrop	SW2- BB/ Upper Austin	SW3- BB/Flores	SW4- BB/Upper Brushy
Total # of Cattle	Buffer	39	1379	889	484
	Out-Buffer	118	3085	2066	1207
Value need to be reduced (in 10^9 CFU/day)		0	535	601	133
% need to be reduced		0	25.7	25.3	13.5

		SW5- BB/Middle Austin	SW6- BB/Upper Bastrop	SW7- BB/Middle Bastrop
Total # of Cattle	Buffer	522	589	62
	Out-Buffer	1127	1798	200
Value need to be reduced (in 10^9 CFU/day)		660	264	19.7
% need to be reduced		17.4	5.7	2.8

Table 8 - Number of Cattle to be Addressed by BMPs per Subwatershed in 2040

Subwatershed		# Cattle to address	Total cattle[28]
SW2	Buffer	567	1379
	Out-Buffer		
SW3	Buffer	636	889
	Out-Buffer		
SW4	Buffer	140	484
	Out-Buffer		
SW5	Buffer	698	522
	Out-Buffer	988	1127
SW6	Buffer	280	589
	Out-Buffer		
SW7	Buffer	21	62
	Out-Buffer		

[27] This section is addressing the total livestock contribution to the bacteria load. BMPs are being only applied to cattle, so cattle reduction will achieve the required load reduction from all livestock types.
[28] This column indicates the total number of cattle expected to be present in the watershed in 2040.

4.3 Feral Hog Management

Deer and feral hogs are the two primary bacteria contributors in the watershed for this category. The stakeholders chose to address the total loading reduction target inclusive of both of these sources by solely addressing feral hogs.

The feral hog (Sus scrofa) is an invasive, non-domestic animal species that is prevalent throughout the watershed. The hogs spend a large amount of time in and around the waterways, and contribute an appreciable amount of bacteria directly into the water. Stakeholders claim that feral hogs even live outside of the watershed and travel into the watershed at night.[29] Not only are the hogs contributors of bacteria, but they also cause large amounts of damage to agricultural crops and landscaping in suburban areas. The stakeholder group will encourage hog hunting and removal through events, educational seminars, and support of partner efforts.

For the basis of determining implementation scaling for deer and feral hogs, an individual representative feral hog is used as the BMP unit. The load reduction targets for each subwatershed are contained in **Table 9**. The scale of the implementation of feral hog BMPs is reflected in the number of feral hogs to be managed, as described in **Table 10.**

Table 9 - Required E. coli Source Load Reduction for Feral Hogs in 2040, per Subwatershed

		SW1- BB/ Lower Bastrop	SW2- BB/ Upper Austin	SW3- BB/ Flores	SW4- BB/ Upper Brushy
Total # of Feral Hogs in 2040	Buffer	146	226	94	45
	Out-Buffer	360	486	194	107
Value need to be reduced (in 10^9 CFU/day)		0	116	81.2	16.0
% need to be reduced		0	5.6	3.4	1.6

		SW5- BB/Middle Austin	SW6- BB/Upper Bastrop	SW7- BB/Middle Bastrop
Total # of Feral Hogs in 2040	Buffer	137	91	43
	Out-Buffer	247	265	98
Value need to be reduced (in 10^9 CFU/day)		216	53.5	14.5
% need to be reduced		5.7	1.2	2.1

[29] This migration between watersheds was not able to be modeled under this effort. The primary example of this potential transfer is hogs living on various parts of the Brazoria National Wildlife Refuge. Anecdotal accounts indicate these hogs may shelter in Refuge locations during the day, and move outwards at night.

Table 10 - Number of Feral Hogs to be Removed by BMPs in 2040, per Subwatershed

Subwatershed		# Hogs to be Removed	Total Hogs[30]
SW2	Buffer	52	226
	Out-Buffer		
SW3	Buffer	36	94
	Out-Buffer		
SW4	Buffer	7	45
	Out-Buffer		
SW5	Buffer	97	137
	Out-Buffer		
SW6	Buffer	24	91
	Out-Buffer		
SW7	Buffer	7	43
	Out-Buffer		

4.4 Wastewater Treatment Plants

No bacteria effluent testing was required under any of the plant permit requirements during the production of this WPP. New state regulations will require bacteria testing such that, as the WWTFs renew their five-year permits, bacteria testing requirements will become mandatory, based on an expected 126 CFU/100 mL effluent limit. Absent that information when initial modeling was conducted, the load from each WWTF under these load reduction estimates was calculated by multiplying the permitted concentration by the permitted effluent outflow. The contact recreation standard (126 mpn/100 mL) was used as the assumption for the bacterial concentration in effluent from each plant.

Overall, permitted WWTF discharges account for 0.01% or less of the watershed's future bacterial loading. It is expected that the introduction of the bacteria testing requirements will result in a reduction in bacteria for any plants discharging greater than the standard. To reflect the potentially growing amount of treatment provided by WWTFs in subsequent years, the reductions expected from increased monitoring, and potential education and outreach efforts targeted at plant operations, it was assumed that there would not be an increase in percent load contributed by WWTFs. Given the uncertainty with these estimates, and the very small portion of total loading they represent, these reductions were not graphed or reflected in any required, or expected, load reduction. A review of WWTF effluent data should be required as plant permits are amended to ensure that actual discharges are at or below the standard.

[30] This column indicates the total number of feral hogs expected to be present in the watershed in 2040 absent any control efforts.

4.5 OSSFs

OSSFs can contribute pathogens to a water body due to system failure and surface or subsurface malfunction. As described in **Section 3**, it is estimated that 50% of systems installed before 1989 are failing, and it is assumed that a majority of the homes within the watershed were built prior to that date. Because of this, OSSFs are a major contributor to bacteria loading within the watershed, especially in areas outside the urban centers.

Modeling results show that OSSFs contribute more than a quarter of the total load in all but one of the subwatersheds, and they even contribute the majority of the total load in Upper and Middle Bastrop subwatersheds. BMPs for OSSFs include remediating malfunctioning systems, enhancing design, promoting maintenance education among owners, and promoting sanitary sewer as an alternative to OSSFs where appropriate.

In order to meet the required bacteria reduction target, the SELECT model assumes that the total load from OSSFs addressed by management measures is removed from the system. Any number of OSSF BMPs can be combined in order to meet the reduction level. Similar to the other categories, the SELECT model targeted homes within the buffer as the first OSSFs to manage because the contributed bacteria are more likely to be transmitted into the water. In subwatersheds that did not have enough homes within the buffer to meet the required reduction, OSSFs outside the buffer were targeted.

For the basis of determining implementation scaling for OSSFs, an individual representative OSSF is used as the BMP unit. The load reduction targets for each subwatershed are contained in **Table 11**. The scale of the implementation of OSSF BMPs is reflected in the number of OSSFs to be managed through remediation or removal, as described in **Table 12.**

Table 11 - Required E. coli Source Load Reduction for OSSFs in 2040, per Subwatershed

Total OSSFs in 2040		SW1- BB/ Lower Bastrop	SW2- BB/ Upper Austin	SW3- BB/ Flores	SW4- BB/ Upper Brushy
Unregulated	Buffer	77	143	110	49
	Out-Buffer	240	369	264	123
Regulated	Buffer	15	214	166	74
	Out-Buffer	55	554	396	184
Value need to be reduced (in 10^9 CFU/day)		0	861	1,062	255
% need to be reduced		0	41.4	44.7	25.8

Total OSSFs in 2040		SW5- BB/ Middle Austin	SW6- BB/ Upper Bastrop	SW7- BB/ Middle Bastrop
Unregulated	Buffer	110	369	121
	Out-Buffer	241	1014	137
Regulated	Buffer	165	553	181
	Out-Buffer	361	1522	26
Value need to be reduced (in 10^9 CFU/day)		2,010	2,623	518
% need to be reduced		53.1	56.8	75.1

Table 12 - Number of Malfunctioning OSSFs to be Remediated by BMPs in 2040, per Subwatershed

SW2		OSSFs to be removed[31]	Total OSSFs[32]
Unregulated	Buffer	46	143
	Out-Buffer		
Regulated	Buffer		
	Out-Buffer		
SW3			
Unregulated	Buffer	57	110
	Out-Buffer		
Regulated	Buffer		
	Out-Buffer		
SW4			
Unregulated	Buffer	14	49
	Out-Buffer		
Regulated	Buffer		
	Out-Buffer		
SW5			
Unregulated	Buffer	108	110
	Out-Buffer		
Regulated	Buffer		
	Out-Buffer		
SW6			
Unregulated	Buffer	141	369
	Out-Buffer		
Regulated	Buffer		
	Out-Buffer		
SW7			
Unregulated	Buffer	28	121
	Out-Buffer		
Regulated	Buffer		
	Out-Buffer		

[31] "Removed" here indicates a reduction in bacteria loading equivalent to one malfunctioning OSSF (see Appendix D for discussion of BMP scaling methodology). OSSFs may be removed, replaced, or repaired, or operations & maintenance practices may be improved. BMPs may reduce an OSSF's load partially or completely.

[32] This column indicates the total number of OSSFs expected to be malfunctioning in the watershed in 2040.

4.6 Urban Runoff

Stormwater runoff from urban areas contains bacteria from various sources that accumulates on land surfaces as well as overflows and leaks from sanitary sewer collection systems. During a rain event the bacteria are washed into Bastrop Bayou and its tributaries. Runoff is a prevalent source of pollutants for the watershed, and increased population density and urbanization will only magnify this impact. The WPP intends to achieve load reductions through implementation of low impact development (LID) practices and incorporation of water quality concerns into large scale development projects. A representative 50% reduction based on bacteria removal rates for buffer strips was used as an average impact of a range of BMP practices (Boyer, 2008).

The BMPs used to address urban runoff include a mix of smaller scale LID practices (buffer strips, rain gardens, etc.) and larger scale development practices (wet-bottom detention, constructed wetlands, water quality features in flood management projects, etc.) to reduce and filter storm flow. Not included in these estimations are some ongoing stakeholder efforts like management of WWTF collection system leaks and overflows.

The SELECT model calculated the load reduction from urban runoff BMPs by calculating a weighted average for developed areas inside and outside the buffer area for each subwatershed. The weighted average accounts for the fact that stormwater enters the water body through direct discharges and also through sheet flow over buffer areas. The 50% reduction provided by LID projects is applied to the loading in order to calculate a number of acres that must be addressed by BMPs in order to reach the required reduction.

For the basis of determining implementation scaling for urban runoff, a representative acre of urban area is used as the BMP unit. The load reduction targets for each subwatershed are contained in **Table 13**. The scale of the implementation of urban runoff BMPs is reflected in the number of acres of urban area to be addressed through BMPs, as described in **Table 14.**[33]

[33] The extent of impact of other efforts, including the advent of Phase II MS4 permits in the area, was not able to be modeled during the development of this WPP due to unmatched implementation timelines and lack of detail in SWMPs and Annual Report. The SWMP(s) developed concerning urban areas of the watershed did not have enough specific information regarding implementation activities impacting bacteria to include these activities as part of the WPP. It is unknown the extent or scale of activities that may occur, especially in thefuture beyond the current five year time frame, so this WPP has taken a conservative approach in not counting reductions from these efforts. While it is expected that some ancillary benefit may be derived from MS4 permit activities, they are not part of the WPP, and no element of the WPP will be used as a substitute or replacement for required activities under an MS4 permit.

Table 13 - Required E. coli Source Load Reductions in 2040 for Urban Runoff per Subwatershed

	SW1- BB/Lower Bastrop	SW2- BB/Upper Austin	SW3- BB/Flores	SW4- BB/Upper Brushy
Total acres of urban area	408	855	884	2500
Value need to be reduced from Urban runoff (in 10^9 CFU/day)	0	104	145	163
% need to be reduced	0	5.0	6.1	16.5
	SW5- BB/Middle Austin	**SW6- BB/Upper Bastrop**	**SW7- BB/Middle Bastrop**	
Total acres of urban area	286	4227	248	
Value need to be reduced from Urban runoff (in 10^9 CFU/day)	131	386	22.1	
% need to be reduced	3.5	8.4	3.2	

Table 14 - Acres of Urban Area to be Addressed by BMPs in 2040, per Subwatershed

Subwatershed	Weighted ave. loading (in 10^9 CFU/day/acre)	Urban acres to be addressed	Total urban acres[34]
SW2	0.817	127	855
SW3	0.643	225	884
SW4	0.650	250	2500
SW5	0.942	139	286
SW6	0.603	640	4227
SW7	0.922	24	248

[34] This column represents the total acreage forecast to be urban area in 2040, per each subwatershed.

4.7 Dog Waste Management

Pets can be a considerable source of bacteria in urban, suburban, and rural areas. Based on stakeholder input, dogs are the primary ambient source of pet waste in the watershed. The focus of reductions for this WPP is on removing dog waste from the environment, where its bacteria may enter waterways.

This WPP will address bacteria contributions from dogs by addressing dog owners' behaviors and providing measures to reduce the volume of pet waste entering the water bodies. BMPs include installing pet waste stations, providing educational materials, adding or strengthening provisions in HOA requirements, addition or strengthening of pet waste ordinances, and enhanced enforcement by watershed partners. Heightened community awareness and local ordinance enforcement can complement LID practices and other related urban measures. Some implementation of these goals has already gone into to place. The City of Angleton opened the watershed's first dog park in 2012, which includes educational materials and requires visitors to pick up after their pets using the park's pet waste stations.

SELECT was used to calculate a weighted average of the loading from dogs in each subwatershed. H-GAC's forecasting data includes the number of homes in the watershed in 2040. SELECT incorporates a loading per home (assuming 0.8 dogs per home) inside and outside the buffer. Because the forecasting data assumes a uniform distribution of homes throughout the land cover classes, the weighted average was used to calculate one value of loading throughout each subwatershed. Using the required reduction value provided by the EPDRiv1 model, SELECT was able to calculate the number of dogs whose waste needed to be managed in order to achieve required reduction attributed to pet waste for each subwatershed.

For the basis of determining implementation scaling for urban runoff, a representative individual dog is used as the BMP unit. The load reduction targets for each subwatershed are contained in **Table 15**. The scale of the implementation of dog waste BMPs is reflected in the number of dogs whose waste is to be addressed through BMPs, as described in **Table 16.**

Table 15 - Required E. coli Source Load Reductions for Dogs in 2040, per Subwatershed

	SW1- BB/Lower Bastrop	SW2- BB/Upper Austin	SW3- BB/Flores	SW4- BB/Upper Brushy
Total # of Dogs	735	1047	1319	4690
Value need to be reduced from Dogs (in 10^9 CFU/day)	0	88.9	189	238
% need to be reduced	0	4.3	7.9	24.1
	SW5- BB/Middle Austin	**SW6- BB/Upper Bastrop**	**SW7- BB/Middle Bastrop**	
Total # of Dogs	701	5976	516	
Value need to be reduced from Dogs (in 10^9 CFU/day)	207	470	37.5	
% need to be reduced	5.5	10.2	5.4	

Table 16 - Number of Dogs to be Addressed by BMPs in 2040, per Subwatershed

Subwatershed	Dogs to address[35]	Total dogs[36]
SW2	166	1047
SW3	352	1319
SW4	444	4690
SW5	386	701
SW6	878	5976
SW7	70	516

[35] This column represents the number of representative dogs to be addressed, based on 100% removal of the waste load of the representative dog from the system. Additional information on scaling for this category is contained in Appendix D.

[36] This column represents the total projected population of dogs in 2040, per subwatershed.

4.8 Totals Reduction Estimates

Total loading reduction targets for the watershed in general were produced as a cumulative total of the load reduction targets for each subwatershed.

By implementing the BMPs identified by the stakeholders at a scale sufficient to meet these reduction targets, the contact recreation standard can be met and maintained for all subwatersheds. **Table 17** shows the total load reduction targets for the watershed by source. **Table 18** shows the percent reduction by source, indicating that the estimated 2040 bacteria loading in each subwatershed would have to be reduced between 80-90%. **Table 19** and **Figure 21** shows the cumulative source load reduction targets over time. **Table 20** shows the relationship between source loads, in-stream loads, load reductions, and bacteria sources by subwatershed. It will require an ongoing commitment project partners to apply BMPs to the required number of animals, OSSFs, and acreage to achieve the required bacteria concentration.

In addition to bacteria, it is expected that many of the BMPs designed to retard bacteria inputs would also serve to reduce nutrient loads. Nutrients were not specifically modeled, and therefore no reduction estimates were produced.

Table 17 - Required Source Load Reductions for each E. coli Source in 2040, per Subwatershed

Load Reduction (in 10^9 CFU/day)	SW1- BB/ Lower Bastrop	SW2- BB/ Upper Austin	SW3- BB/ Flores	SW4- BB/ Upper Brushy
OSSF	0	-861	-1,062	-255
WWTP	0	-0.333	-0.491	-0.150
Urban Runoff	0	-104	-145	-163
Dogs Excretion	0	-88.9	-189	-238
Livestock	0	-535	-601	-133
Feral Hogs	0	-116	-81.2	-16.0
Total	0	**-1,710**	**-2,080**	**-804**

Load Reduction (in 10^9 CFU/day)	SW5- BB/ Middle Austin	SW6- BB/ Upper Bastrop	SW7- BB/ Middle Bastrop
OSSF	-2,011	-2,623	-518
WWTP	0	-0.0359	0
Urban Runoff	-131	-386	-22.1
Dogs Excretion	-207	-470	-37.5
Livestock	-660	-264	-19.7
Feral Hogs	-216	-53.5	-14.5
Total	**-3,220**	**-3,800**	**-612**

Table 18 - Percent Required Source Load Reduction for each E. coli Source in 2040, per Subwatershed[37]

Load Reduction By Percentage	SW1- BB/Lower Bastrop	SW2- BB/Upper Austin	SW3- BB/Flores	SW4- BB/Upper Brushy
OSSF	0	-41.41	-44.69	-25.82
WWTP	0	-0.02	-0.02	-0.02
Urban Runoff	0	-5.00	-6.09	-16.52
Dogs Excretion	0	-4.27	-7.94	-24.12
Livestock	0	-25.74	-25.26	-13.45
Feral Hogs	0	-5.56	-3.42	-1.63
Total	**0**	**-82.00**	**-87.43**	**-81.55**

Load Reduction By Percentage	SW5- BB/Middle Austin	SW6- BB/Upper Bastrop	SW7- BB/Middle Bastrop
OSSF	-53.10	-56.76	-75.07
WWTP	0.00	0.00	0.00
Urban Runoff	-3.46	-8.36	-3.21
Dogs Excretion	-5.46	-10.18	-5.43
Livestock	-17.43	-5.72	-2.85
Feral Hogs	-5.70	-1.16	-2.10
Total	-85.16	-82.17	-88.66

[37] All numbers in this column represent percent of total subwatershed load.

Table 19 - Source Load Reduction Targets[38] by Source based on Cumulative Effect of BMPs (in 10^9 CFU/day)

	2015	2020	2025	2030	2035	2040[39]
Daily Source Load, Baseline	7,499	8,908	10,316	11,724	13,132	14,541
Livestock load reduction	0	443	885	1,328	1,770	2,213
OSSF load reduction	0	1,466	2,932	4,398	5,864	7,330
Feral hog load reduction	0	99	199	298	397	497
WWTP load reduction	0	0	0	0	0	0
Urban Runoff load reduction	0	190	380	571	761	951
Dogs load reduction	0	246	492	738	984	1,230
Daily Load (from Source): After All BMPs	7,499	6,464	5,428	4,392	3,356	2,320
Meet Standards[40]	2,320	2,320	2,320	2,320	2,320	2,320
In-stream Loads[41]	7,514	6,456	5,397	4,339	3,280	2,222

[38] Targets for intermediate years add 20% for each increment starting with 2020 - 20%, 2025 - 40%, 2030 - 60%, 2035 - 80%, 2040 - 100%. All target percentages except 2040 are based on a linear progression which may not match actual implementation or load growth.
[39] 2040 loads were based on the scaled EPDRiv1 source loads for 2040.
[40] This row represents the estimated total load contributions in 2040, minus the total load reductions required; it is the same amount of load after all the BMPs in 2040.
[41] The total instream load is derived from the EPDRIV1 calculations (shown by subwatersheds in Table 5) for current conditions (without BMPs) and future conditions (that met the water quality standard.) The intermediate year projections are based on a linear progression of load reduction reflecting that noted in footnote 38.

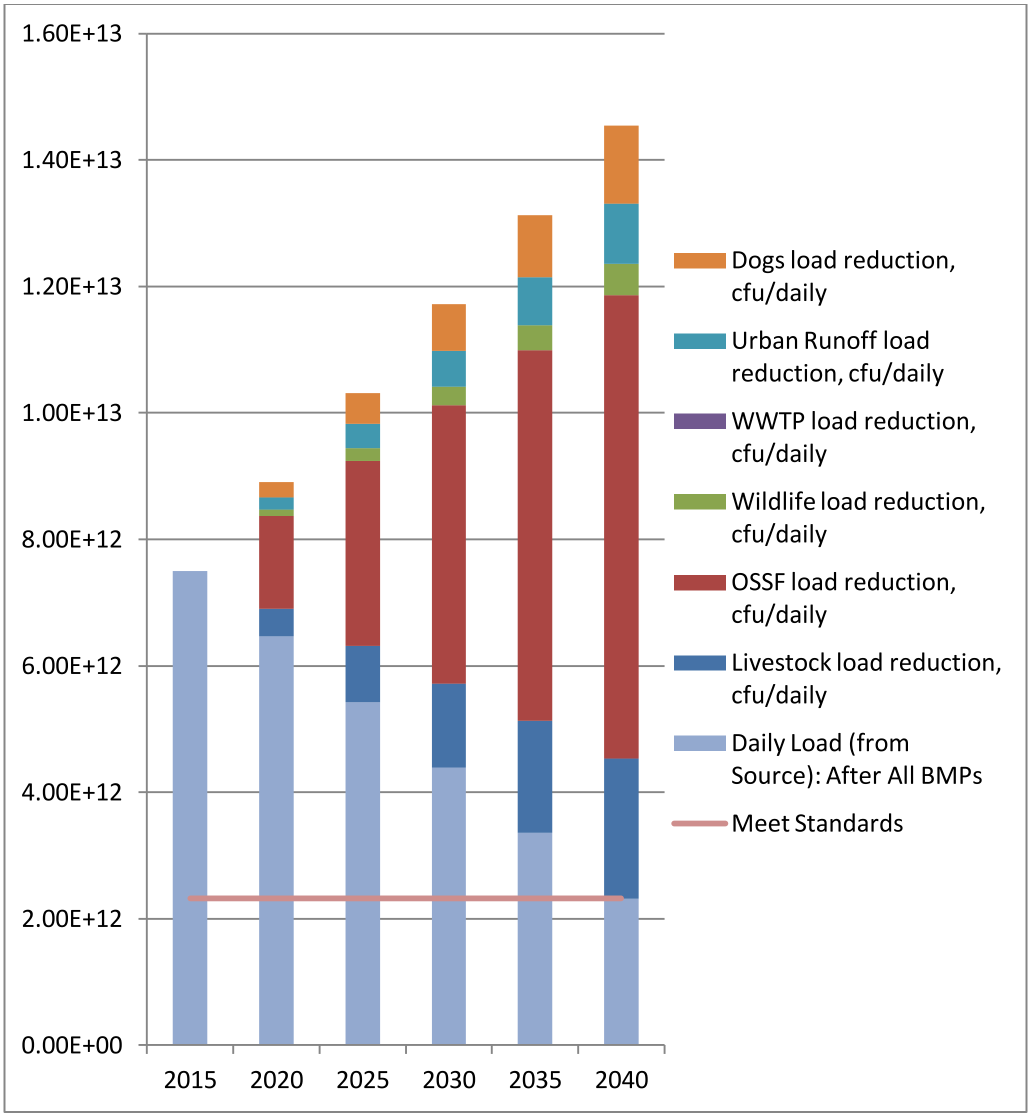


Figure 21- Daily Source Load Reduction Targets by Bacteria Source

Table 20- Source Loads and Load Reductions by Source and Subwatershed, 2040 (in 10^9 CFU/day)

Loads and Reductions, in 10^9 CFU/day	SW1	SW2	SW3	SW4	SW5	SW6	SW7	Total
Livestock - total source load	NA	653	685	161	768	320	20	2,607
Livestock - total instream load	NA	107	74	27	101	52	2	362
Livestock - Instream reduction	NA	17	8	4	13	8	0	51
Livestock - Source Load reduction amt	NA	535	601	133	660	264	20	**2,213**
Livestock Source Load (to Meet Standard)	NA	117	84	29	108	56	1	395
Feral Hogs - total load (from source)	NA	141	93	20	254	65	16	589
Feral Hogs - total load: Instream	NA	23	10	3	33	11	2	82
Feral Hogs - Instream reduction amt	NA	4	1	1	4	2	0	11
Feral Hogs - Source Load reduction amt	NA	116	81	16	216	53	14	**497**
Feral Hogs Source Load (to Meet Standard)	NA	25	12	4	38	12	2	92
OSSF - total load (from source)	NA	1050	1,215	312	2,361	3,192	584	8,715
OSSF - total load: Instream	NA	171	131	52	309	515	56	1,236
OSSF - Instream reduction amt	NA	27	14	9	40	82	5	176
OSSF - Source Load reduction amt	NA	861	1,062	255	2,011	2,623	518	**7,330**
OSSF Source Load (to Meet Standard)	NA	189	153	58	350	569	66	1,385

Loads and Reductions, in 10^9 CFU/day	SW1	SW2	SW3	SW4	SW5	SW6	SW7	Total
Urban runoff - total load (from source)	NA	127	166	200	154	470	25	1,141
Urban runoff - total load: Instream	NA	21	18	34	20	76	2	171
Urban runoff - Instream reduction amt.	NA	3	2	6	3	12	0	26
Urban runoff - Source Load reduction amt	NA	104	145	163	131	386	22	**951**
Urban Runoff Source Load (to Meet Standard)	NA	23	21	37	23	84	3	190
Pet waste - total load (from source)	NA	108	216	292	243	572	42	1,474
Pet waste - total: Instream	NA	18	23	49	32	92	4	218
Pet waste - Instream reduction amt.	NA	3	2	8	4	15	0	32
Pet waste - Source Load reduction amt	NA	89	189	238	207	470	37	**1,230**
Pet Waste Source Load (to Meet Standard)	NA	20	27	54	36	102	5	243
WWTF total Load[42] (from source)	NA	0.3	0.5	0.2	0	0	0	1
TOTAL BASELINE LOAD- ALL SOURCES								14,532
TOTAL BASELINE LOAD REDUCTION - ALL SOURCES								12,221
TOTAL LOAD REDUCTION %								**84%**
TOTAL LOAD REMAINING AFTER BMP IMPLEMENTATION								2,311

[42] No load reduction is attributed to WWTFs.

5 Management Measures Element C

Achieving the load reduction targets described in **Sections 3 and 4** requires the targeted implementation of a suite of management measures.[43] This section describes the development, prioritization, and intended application methods of these stakeholder-selected measures for reducing bacteria concentrations. The ultimate aim of this WPP is to implement a proportional mix of these BMPs on a scale and timeline sufficient to reduce bacteria concentrations in all subwatersheds to at or below the contact recreation standard. As conditions change in the watershed, meeting the recreation standard is likely to be a moving target. While the implementation period for this WPP includes an extended planning horizon, the initial focus of implementation will be on priority areas in the first ten year period. Schedules, milestones, and monitoring efforts are all designed to support this implementation approach.

Development and Prioritization

To address the bacteria sources and other stakeholder concerns in the Bastrop Bayou watershed, the stakeholders identified and prioritized potential BMPs. 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 the course of several public meetings during the development of this WPP, which allowed for ample discussion of each idea. To select and prioritize the potential BMPs, the stakeholders selected three ideas/projects each. The numbers of votes for each project were tallied and results presented to the stakeholders for confirmation. The stakeholders approved the projects and a ranking was developed for implementation. 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. Subsequent to revised modeling efforts in 2012, the stakeholders confirmed their BMP priorities, with emphasis on addressing priority sources using the intended application methods. In general the targeting of BMPs, all other factors being equal, will attempt to address "hot spots" of loading as detailed in the granular level analysis of total loading and by source.[44] While the BMPs are designed to focus on changing conditions in the watershed over an extended timeframe, specific focus is given to the first ten-year period. Per the adaptive management process spelled out in this WPP, the approach and mix of BMPs will be revised as necessary by changing conditions, efficacy of solutions, and feasibility throughout the time frame.

The following are the BMPs selected by the stakeholders, grouped by the source category they address.

[43] Throughout the WPP, the terms "BMP" and "management measure" are interchangeable.
[44] As represented by Figure 5 and Appendix A Figures 14,16,19,21,24,27,30,33,36,39, and 42.

Management Measures/BMPs

5.1 Education & Outreach

Outreach and educational efforts are a core part of the WPP model. The outreach and education measures identified for this WPP are described in **Section 7**.

5.2 Livestock Management

1. **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 providing alternative water and shade. This WPP will support the efforts of the TSSWCB, USDA NRCS and other organizations through promotion of their programs and incentivizing landowner participation as appropriate. Programs identified by stakeholders for inclusion in this WPP are:
    a. **WQMPs –** The TSSWCB, in conjunction with local Soil and Water Conservation Districts, work with individual land owners to create and implement WQMPs. Animal wastes can be a component of these plans. During the initial development of this WPP stakeholders identified 15-25 parcels of property with direct access to the Bayou that may be prime candidates for participation. Implementation of the WPP will include facilitation and promotion of water quality management plans and similar measures through the TSSWCB and other agricultural agencies. To support these efforts, an educational component (see 5.1) will help spread the word to landowners. The stakeholders suggested that matching funds of up to $5,000 each for 8 landowners should be provided through this project could incentivize landowners to implement cattle-oriented BMPs.
    b. **USDA NRCS Projects –** The USDA, through its Conservation Plans, EQIP funding, and similar programs, offers financial incentives to land owners who manage their land for conservation purposes. Promotion of these programs in this watershed will focus on projects to reduce cattle presence in and near water bodies and add filtration capacity to riparian corridors. Specific targets are reducing bacteria transmission to water bodies through filter strips and contour plowing, and reducing cattle presence in waterways through alternative water and shade sources and cross fencing for pasture management.
    c. **Lone Star Healthy Streams Programs –** Lone Star Healthy Streams[45] is an educational program put on by the Texas Water Resources Institute (TWRI) whose goal is the protect Texas waterways from bacterial contamination from agricultural sources including cattle and horses. The program publishes resource manuals to rural

[45] More information can be found online at http://lshs.tamu.edu/

landowners, which provide excellent information about applicable BMPs, implementation costs, and available funding opportunities. Stakeholders will work with TWRI to utilize this program's resources for the landowners in the watershed.

5.3 Deer and Feral Hog Management

2. **Feral Hogs-** The stakeholders will work with partners in the watershed to promote hunter and landowner education events focused on feral hog management. Partners will pursue removal of hogs as appropriate. Specific measures include:
    a. **Feral Hog Workshops -** Texas A&M AgriLife Extension (AgriLife) is currently developing a state-wide feral hog management education program. When that program is finalized, the stakeholder group will work with AgriLife to provide that program in the watershed. TSSWCB has received funding to offer feral hog workshops in priority watershed areas such as Bastrop Bayou. The purpose of these workshops is to provide landowners with tools and knowledge to address feral hogs on their properties.
    b. **USF&WS Conservation Plan -** USFWS is developing its Comprehensive Conservation Plan (CCP) and an environmental assessment (EA) for managing the Texas Mid-Coast National Wildlife Refuge Complex, which includes the Brazoria National Wildlife Refuge, for the next 15 years. The plan calls for the management of invasive species by hunting and trapping in order to control feral hogs. The stakeholder group will support and promote this program as needed.
    c. **Lone Star Healthy Streams Programs –** Lone Star Healthy Streams[46] is an educational program put on by the Texas Water Resources Institute (**TWRI**) whose goal is the protect Texas waterways from bacterial contamination from agricultural sources including feral hogs. The program publishes resource manuals to rural landowners, which provide excellent information about applicable BMPs, implementation costs, and available funding opportunities. Stakeholders will work with TWRI to utilize this program's resources for the landowners in the watershed.

5.4 Wastewater Treatment Plants

WWTF 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 WWTFs, and also help to catch any noncompliant facilities. There are no BMPs suggested for sanitary sewer

[46] More information can be found online at http://lshs.tamu.edu/

other than to generally promote it as a treatment option over OSSFs (see 5.5) and to utilize future bacterial sampling data in WPP review and update processes as part of monitoring and adaptive management.

5.5 OSSFs

To address malfunctioning OSSFs in the watershed, the following BMPs 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.

3. **Remediate Malfunctioning OSSFs-** The stakeholders will seek funding from sources including Coastal Impact Assistance Program (CIAP) funds, Clean Water Act 319(h) nonpoint source grants, the existing TCEQ program of technical and financial assistance to certain homeowners in the coastal zone to remediate failing OSSFs, and Supplemental Environmental Projects (SEP) funds to remediate or incentivize remediation of OSSFs. The community of Demi-John is an identified priority for this activity. It is expected that, outside of the efforts and funding sources identified by this WPP, some OSSFs will be addressed by residents alone, or through enforcement actions of Brazoria County. Incentive funds from grant sources may be used to fund design work for residents if funding for repair or replacement has been secured. Project staff will provide support for Demi-John conversion through outreach, grant proposal development, or other tasks not directly related to sanitary infrastructure design and construction.
4. **Enhance OSSF Design Criteria-** Stakeholders recommended working with Brazoria County to enhance their OSSF design criteria for OSSFs to ensure better siting and selection of OSSF types appropriate to local soil conditions, potentially including shared systems for RV parks and other cluster developments.
5. **Promote 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. Brazoria County and the community of Demi-John are actively replacing malfunctioning septic systems with a sanitary sewer collection system. Sanitary sewer systems may not be appropriate for all locations.

5.6 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/debris in the waterways were identified as ongoing issues in the watershed. The following BMPs were selected to address these issues.

6. **Trash Reduction Events-** The WPP 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.
7. **Addressing Illegal Dumping-** Stakeholders recommended erecting signage and implementing an illegal dumping hotline throughout the County to provide education and aid enforcement aimed at curbing illegal dumping.
8. **Addressing Dump Sites-** The WPP calls for supporting the County and other partners in locating existing dump sites and removing dumped materials.

Figure 22- Trash Bash Volunteers on Bastrop Bayou

5.7 Urban Runoff

While the majority of the watershed is rural in character, its urban areas can be an appreciable source of runoff contamination. The BMPs 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. The majority of the area within the watershed is party to the Brazoria County Stormwater Quality Coalition as a result of TPDES Phase II permit requirements. Stakeholders are actively involved in addressing sources of bacteria and other contaminants as part of the permit requirements. To the greatest extent possible, without funding Phase II requirements with 319 (h) grant funds, WPP stakeholders will coordinate efforts with the Coalition. However, for the sake of this WPP, the unknown impact of the Phase II permit activities is not counted toward reductions, and required elements in the SWMP did not have enough detail to include as recommended activities for future conditions. No element of this WPP is intended as a substitute for required efforts under the Phase II permit. It is expected that the Coalition's efforts will drive a greater reduction in urban bacteria sources than is projected here, but sufficient information to model those impacts was not available during the development of this Plan.[47] Therefore, the elements identified under this WPP may not need to be implemented in the scale identified in Section 4.

Low Impact Development

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

9. **Green Roof Pilot Project-** A green roof pilot project designed to collect rain water for irrigation use will be implemented with a project partner. The Angleton courthouse annex was identified as a potential site.
10. **Small-scale Green Infrastructure Pilot Projects-** This BMP involves installation of pilot rain gardens, small vegetated swales, small infiltration planters or other related green infrastructure (also referred to as Low Impact Development, or LID) pilot projects, developed to collect rain water for plant use and/or to serve as a barrier to flowing stormwater 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 stormwater runoff. The selection of the projects will depend on sites and partner preference. Angleton's courthouse annex was identified as a site for a variety of green infrastructure elements (pervious pavement/rain garden. Stakeholders recommended utilizing a local park for a rain garden. Other suitable public locations will be considered by the stakeholders as development warrants, opportunities exist, and funding allows.

Large-Scale Development Practices

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 stormwater 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

[47] There was insufficient information about the scale and potential impact of activities listed under the SWMPs of the watershed's permittees to develop reduction estimates attributable to these efforts. Additionally, the 5 year planning horizon for the SWMPs does not provide enough information or long enough timeframe to match the "future" projections used by this WPP.

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 WPP[48] are:

11. **Stormwater Detention-** This measure involves supporting, and potentially partially funding where feasible and appropriate, the promotion, development and implementation of large scale stormwater detention facilities with water quality enhancing features such as wetland plantings or wet bottom detention areas. Priorities under this BMP are large-scale wet-bottom detention basins and/or constructed wetlands.
12. **Stormwater 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, biofiltration basins, sand filters, and other related elements.

5.8 Pet Waste Management

These BMPs, 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 subsection 5.6. Pet waste is often an appreciable component of bacteria loading from urban runoff. The WPP recommends that pet waste be addressed through the following BMPs, in conjunction with a robust educational component:

13. **Model Ordinances and Bylaws -** 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.
14. **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. Currently identified sites include two public parks in

[48] The activities described represent a significant investment in large-scale stormwater infrastructure to provide filtration and detention. While these large-scale activities are not currently required by the SWMPs of local MS4 permit holders, they may be added in the future. Future updates of the WPP will seek to remove any redundancy between this WPP and MS4 SWMPs. Regardless, this WPP does not anticipate the use of Clean Water Act section 319 grant funds for these activities.

Angleton, the Dow Woods Unit trailhead, and two sites in the Demi-John Community.

15. **Dog Parks** – In conjunction with pet waste stations, the development of dog park areas helps sequester dogs and waste in an area with proper disposal that is routinely cleaned by operating staff. During the development of this WPP the first dog park in the watershed was implemented in the City of Angleton.

Figure 23 - Pet Waste Education at the Angleton Dog Park

5.9 Land Acquisition

Although much of Brazoria County is rural, urban and suburban growth is projected to increase in the coming years. As land is sold and subdivided, rangeland, pasture, and cropland is fragmented and developed into land cover types that increase impervious cover, and may reduce bacteria filtration efficiency. Habitat is lost and water quality is likely to diminish. Tracts of undeveloped land, especially in riparian buffer areas, can aid in reducing contamination from bacteria-laden stormwater. Federal and state funds are available as an incentive for landowners to conserve undeveloped or agricultural land. USFWS, the Texas General Land Office (GLO), and other agencies have programs that use public money to purchase conservation easements on the privately owned land. The landowners retain ownership of the land, but agree to maintain it in its undeveloped state. Even if the land is sold in the future, the new owner is bound by the easement and is prohibited from developing the land. 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. BMPs for this category include:

16. **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.[49]
17. **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. Stakeholders will coordinate with existing statewide programs to the greatest degree practicable. Existing examples of easement programs in the watershed include the Texas General Land Office's (GLO) Texas Farm and Ranch Lands Conservation Program.[50]

---

[49] Subsequent to the stakeholders prioritizing this BMP, but prior to the submission of this WPP, USF&WS worked with DOW to acquire the tract of land that now serves as the DOW Woods unit of the San Bernard National Wildlife Refuge.

[50] The GLO's program currently has four conservation easement projects in the watershed that, when complete, will cover over 2400 acres of farm and ranch land. Several tracts of land in the watershed have been converted to conservation easements through the GLO's Texas Farm and Ranch Lands Conservation Program (TFRLCP) in the past few years. The GLO program was created to facilitate the acquisition of development rights on agricultural land. Funding is secured through a variety of state, federal, and private sources. Their projects include:

- Savannah Oaks Farm and Ranch[50] is a 700 acre tract of managed wetlands and wildlife-friendly farmland in the Middle Austin subwatershed. Savannah Oaks Farm and Ranch, Galveston Bay Estuary Program (GBEP), and the TFRLCP contributed funding to allow Ducks Unlimited to manage the conservation easement.

18. **New Development Riparian Buffers –** The stakeholders will work with local governing bodies and developers to promote the inclusion of riparian buffers in new development. Promotion will be conducted through individual meetings and promotional materials.

Figure 24 - Savannah Oaks GLO Project Property

5.10 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. During the development of this WPP, watershed stakeholders worked with the GLO to remove the boat. Removal was completed in 2012. Stakeholders would like to see this partnership continue with additional abandoned boats.

- Lone Pines Farm[50] completed its conservation project through the TFRLCP in 2012. The easement is managed by the Galveston Bay Foundation. The farm is approximately 1,100 acres of rice farms, cattle pasture, and wildlife habitat located near Danbury, Texas, in the Middle Austin subwatershed.
- Bulanek Farm[50] consists of two tracts of land that have been converted into conservation easements through the TFRLCP. Together the tracts are composed of more than 660 acres of rice, grain, and soybean farms, along with cattle grazing and wildlife habitat. The easement is managed by the Texas Agricultural Land Trust, and is also located in the Middle Austin subwatershed near Savannah Oaks.

19. **Removal of Abandoned Boats –** This WPP recommends supporting the removal of abandoned boats from the Bayou and disposing of the oils and other hazardous materials safely.

5.11 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:

20. **Additional Officers –** The Stakeholders recommended that the County agree to staff two additional environmental enforcement officers. Due to economic conditions, they 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.

Guidelines for Application of BMPs

The BMPs selected by the stakeholders represent the range of options to meet the reduction targets for each subwatershed. The application of the BMPs will adhere to the following guidelines.

1) **Stakeholder Priority –** As stated previously, the stakeholders went through a series of prioritization efforts for both sources and BMPs. To the greatest extent practicable in meeting reduction targets, stakeholder prioritization will be used in allocating resources.
2) **Subwatershed Need –** The needs of each subwatershed, based on current and projected loading and load reduction targets will guide selection and application of BMPs. For those subwatersheds with high livestock loading, livestock BMPs will be more appropriate.
3) **Phased Approach –** The WPP has a planning horizon and load reduction targets based on the year 2040. As indicated in the load estimations, some sources will likely increase in the latter part of the planning period (urban runoff, OSSFs) while some may decrease (livestock, feral hogs). Stakeholders will implement BMPs to address current sources, with an understanding that the focus of implementation will shift with land use change over the coming decades. The focus of the implementation schedule is the first 10 year period. However, expected growth is likely to occur well past that initial timeframe. Toward that end, the mix of BMPs considers current, short term conditions as well as ultimate planning horizon conditions. The phased approach will focus on the first ten years, but will be scaled as necessary to meet eventual load reduction needs.
4) **Coordinated Approach –** As with the development of the WPP, implementation will focus on coordinated efforts between stakeholders. Careful coordination will be especially important to ensure that WPP and MS4 permit activities are complementary rather than overlapping.
5) **Buffer Areas and Hot Spots –** Bacteria deposited in or near the waterways have the greatest potential to make it into the water. In modeling assumptions, only 25% of the deposition of bacteria outside of buffer areas is assumed to make it to the waterways. Implementation resources spent on BMPs in buffer

areas, with all other factors being equal, will likely have more efficient results than the same BMP in non-buffer areas. For example, remediating an OSSF adjacent to a water body will have a greater impact than an OSSF outside of the riparian area. Additionally, the 2012 revisions to the SELECT model were conducted to evaluate areas within the subwatershed sections that had higher potential to contribute to bacteria loading. These “hot spots” will be a focus in the same manner as the buffer areas.[51]

6) **Existing Programs –** To the greatest extent possible, stakeholders will coordinate efforts through existing programs (WQMPs, USDA NRCS, GLO Farm and Ranch Lands Conservation Program, etc.) to limit redundancy and benefit from established efforts.
7) **Adaptive Management –** A fundamental aspect of the WPP model is the continual review and assessment of how effective efforts are in meeting established water quality goals. Based on targeted monitoring, ambient monitoring data from the H-GAC CRP, and other measures of progress, the implementation approach described in this WPP will be adjusted as needed to meet its stated goals. It is expected that the reduction requirements will be a moving target in this dynamic watershed, and that the reductions may not follow a linear path between current conditions and the ultimate planning horizon.

[51] As represented by Figure 5 and Appendix A Figures 14,16,19,21,24,27,30,33,36,39, and 42.

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 implementing the solutions identified under this WPP. The estimation of costs and timing is dependent on available funding and subject to potential change dependent on economic conditions and outlook.

The needs, costs and matched resources for each category of BMPs are detailed in the following subsections. Costs that are not specific to the impact of this WPP (i.e. ongoing services routinely provided by a given governmental entity such as OSSF enforcement activities by Brazoria County or the implementation of required elements of Phase II stormwater permits[52]) are not included unless they are utilized directly as part of implementation (e.g. routine municipal sampling costs providing data for project monitoring components). 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). References to staff time refer to H-GAC or a successor agency in the role of WPP facilitator. All known or estimated costs are provided, regardless of funding source. For each individual BMP or WPP element, the anticipated funding source is listed in parentheses after the description.[53] **Table 24** represents the expected cost and level of effort for the initial 10 year implementation focus period. Additional information regarding costs for each activity is included in this section, Section 7, and Section 11. Additional information regarding schedule of implementation is provided in Section 8.

6.1 Education and Outreach

Project Promotion

1. Website - $30 a year to retain the domain name, and staff time to update content. (*319h grant)*
2. WPP Executive Summary - $3,000 for printing and mailing costs and staff time to develop the document. *(H-GAC, 319h grant)*

[52] It is expected that an appreciable investment in staff time and capital costs may result from the implementation of Phase II MS4 permits in the watershed. Insufficient information is available regarding the potential future costs or specific capital activities to be addressed under the SWMP of the Brazoria Stormwater Coalition. Because these activities are not elements recommended by this WPP, are not eligible for 319 funding, and are not intended to be funded under other resources of this WPP, their costs are not reflected here. Similarly, the WPP does not count on the reductions from these MS4 activities. The relationship between the programs is wholly complementary.

[53] The anticipated funding source is based on current funding opportunities or identified sources. However, this WPP assumes that funding availability will fluctuate over time. The approach to funding elements will be inherently opportunistic, making use of funds when they become available. Therefore, the anticipated funding source may differ for some elements from the actual funding source utilized in the future. Unless otherwise stated it is assumed that coordination of these activities will involve staff time among involved parties, including 319h grant funding and H-GAC matching funds for H-GAC staff time.

3. Press Releases – Staff time to develop and submit notices *(H-GAC, 319h grant)*

Educational Materials

1. Cattle Management - $1,000/year to order or print materials *(H-GAC, 319h grant, AgriLife and TSSWCB for existing materials)*
2. OSSF Maintenance - $1,000/year to order or print materials *(H-GAC, 319h grant*)
3. Pet Waste Disposal - $1,000/year to order or print materials. *(H-GAC, 319h grant)*

Workshop and Classroom Activities

1. Texas Watershed Stewards - $15,000 per event[54], (*cost is incurred by TSSWCB through its contract with AgriLife).*
2. Project WET and Project WILD - $5,750 (*first year, Project WET/WILD funding, local ISD funding, 319h grant)*
   a. Cost of classroom materials – $4,600
   b. Cost of substitute teachers as the two regular teachers get trained - $250/year
   c. Expendable worksheets, diagrams for the exercises in the workbooks for two classrooms (per annum) – $900
   d. Teaching of watershed concepts - $0, normal service provided by Teachers and the School District
3. OSSF Workshop - $2,500 per event. *(H-GAC, 319h grant*

Structural Outreach

1. Watershed Signage - $2,700 in sign costs and installation labor provided by Brazoria County and TxDOT, using 30 existing watershed signs. (These costs have already been incurred.) *(Clean Rivers Program, Brazoria County, TxDOT)*
2. Pet Waste Signage - $100, estimated costs for signage and signage installation in conjunction with a pet waste station. *(H-GAC, 319h grant*
3. Dow Woods Unit Educational signage - $20,000 (these costs have already been incurred) *(USF&WS)*
4. Outdoor Message Boards - $3,500 ($700 per unit, inclusive of unit cost and installation.) Five boards are currently installed in the watershed. *(H-GAC, 319h grant, Brazoria County)*

Public Participation Opportunities

1. Texas Stream Team - $2,000/year in CRP staff time to train and coordinate volunteers. (*(H-GAC, Clean Rivers Program)*
2. Trash Bash - $300/year to provide education and outreach activities at the Trash Bash sites (see 6.6). *(Costs incurred by the H-GAC CRP as part of*

[54] Based on an estimation of per-event TSSWCB contract costs located here: http://www.tsswcb.texas.gov/files/docs/nps-319/projects/11-05-WP-TWS-11-01-11.pdf.

Trash Bash coordination through either CRP funds or separate 319(h) grant funding.)

6.2 Livestock Management

Cattle Programs

1. WQMPs – $10,000-$15,000 per Plan Stakeholders recommending incentivizing eight landowners by providing up to $5000 in matching funds from this project, each for a total of $40,000. Staff time required to coordinate and promote the program in the watershed. Landowner cost participation required. (*Costs incurred by the TSSWCB. Costs to implement practices by landowners vary depending on BMPs selected.)*
2. USDA NRCS Grant Programs – EQIP or equivalent funding varies greatly by availability and specific project. Landowner cost participation required. Staff time required to coordinate and promote the program in the watershed. *(319h/H-GAC for staff time; USDA NRCS and landowners for EQIP)*
3. Lone Star Healthy Streams – No cost for access to manuals and materials; staff time required to coordinate and promote in the watershed. *(H-GAC, 319h)*

6.3 Deer and Feral Hog Management

Feral Hogs

1. Feral Hog Workshop – $8,000 per workshop, funding provided through Texas AgriLife Extension Service, TSSWCB, and Texas Wildlife Services. Staff time required to coordinate and promote for the watershed. (*AgriLife, TSSWCB, Texas Wildlife Services; H-GAC, 319h for staff time)*
2. USF&WS Conservation Plan – Costs incurred as part of normal operations of Brazoria National Wildlife Refuge.[55]
3. Lone Star Healthy Streams – No cost for access to manuals and materials; staff time required to coordinate and promote in the watershed. *(H-GAC. 319h)*
4. Watershed Feral Hog Hunting Promotional Event - $5,000 for a small feral hog hunting promotional event. . *(Brazoria County)*

[55] The current ongoing implementation of the Refuge's Conservation Plan is considered routine, and not part of the economic burden of this project. Any costs specific to feral hog management activities conducted in coordination with this WPP will be identified in future WPP revisions when the USF&WS has identified them.

6.4 Wastewater Treatment Facilities

Plant Operations

1. ***E. coli* Testing** – $25/sample, with the total cost based on the sampling frequency of plants involved. Costs are paid for by WWTFs as part of testing for bacteria under revised permit limits. *(local WWTFs)*

6.5 OSSFs

1. **Remediate Malfunctioning OSSFs** – Average cost of $5,000 for repair of malfunctioning system; average cost of $10,000 for replacement; average cost of $2,000/house to connect to sanitary sewer. Funding is expected to be provided by SEP funds, resident contribution, CIAP funds, and incentive funding for design through 319(h) implementation grant funds. Maintenance costs provided by resident. Op to $1,000 in grant funds per OSSF may be provided for design work to incentivize residential remediation projects for which funding and commitment has already been secured. Staff time required to support Demi-John sanitary conversion with outreach, grant proposal development, etc. (*mix of SEP funds, resident contribution, H-GAC, 319h, CIAP, CDBG depending on location and availability)*
2. **Enhance OSSF Design Criteria** – $30,000 to update design criteria and placement requirements for new systems to ensure adequate space and soil types. (*Brazoria County, CIAP)*
3. **Promote Sanitary Sewer** – Staff time required for promotion; cost of sanitary sewer system varies by size. *(H-GAC, 319h for staff time; sewer improvements/installation based on specific locality, but may include local funding, Brazoria County, CIAP, CDBG, TWDB State Revolving Fund)*

6.6 Illegal Dumping/Trash

1. **Trash Bash Event** – $5000/year to maintain the Trash Bash sites (see 6.1). *(H-GAC, 319h)*
2. **Addressing Illegal Dumping** – $25,000 for signage and an illegal dumping hotline(*Brazoria County)*
    - Cost for five signs non TxDOT - $500
    - Labor and materials to install the signage – $1500
    - Hotline, per year costs - $20,000
3. **Addressing Dump Sites** – Variable, dependent on size and nature of site. Brazoria County is the designated jurisdictional party for such work. *(Brazoria County)*
    - Dispatch of enforcement officers – variable, provided by County

- Clean-up of materials as discovered – variable, provided by County
- White goods or hazardous material fees – variable, provided by County

6.7 Urban Runoff

Cost estimates for urban runoff-oriented projects can range widely depending on the scale and type of project involved. **Table 21** shows representative scalable costs for typical LID projects.[56]

Table 21 - Representative Scalable Cost Figures

LID Project Type	Scalable Cost
Rain Garden	$10-$12/square foot
Green Roof	$5-$50/square foot
Stormwater Wetlands (small)	$39,000 - $82,000/acre
Vegetated Swale	$10/linear foot
Wet Bottom Detention	$4/square foot
Stormwater Infiltration Planters	$8/square foot

During the development of the WPP, stakeholders worked with County engineers and officials to develop potential project costs and identified the Angleton courthouse annex, as a potential site for LID demonstration projects. Costs were developed for representative projects, based on 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 in **Table 22**.

[56] These costs reference installation costs unless otherwise noted. Maintenance costs are variable based on the scale of the BMP implemented. Costs are based on Low Impact Best Management Practice (BMP) Information sheets developed in 2008 by the Charles River Watershed Authority, as referenced here: http://www.crwa.org/projects/peabody_green.html.

Table 22 - 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
Stormwater 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 of different materials were summarized in **Table 23**.

Table 23 - 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

Although grants are available for construction, County officials are most concerned with the life cycle maintenance costs and logistics of projects. For example, while pervious concrete can have a positive impact on 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. Therefore the stakeholders considered it as best suited for small scale parking lot or similar surface development.

The following list details the approximate cost for such projects based on the values derived from the County engineers' software package. The output with guidance from the County officials was used to generate the cost estimates.

Low Impact Development

1. **Green Roof Pilot Project** – Installation of a green roof at a site to be determined. Costs will be dependent on size and character of selected site. (*Brazoria County, City of Angleton, CDBG)*
2. **Small Scale Green Infrastructure Pilot Projects** –$500,000, as part of an Angleton courthouse annex project with pervious pavement and a rain garden. Another identified project was the development of a rain garden for a local park, estimated at $75,000.Additional projects will be variable based on costs and types represented in Table 20. *(Brazoria County, CDBG, City of Angleton, 319h)*

Large-scale Development Practices

1. **Stormwater Detention Basins** – $3,234,840, for detention basins to be funded as part of County drainage projects, or private development projects, or through CDBG or other appropriate grant funding. (Brazoria County or private development, CDBG, CIAP)
2. **Stormwater Infiltration** – $4,467,160, for constructed wetland detention areas and swales, to be funded as part of County drainage projects, or private development projects, or through CDBG or other appropriate grant funding. (Brazoria County or private development, CDBG, CIAP)

6.8 Pet Waste Management

1. **Development of Model Ordinances** – Staff time for development of ordinances. (*H-GAC, 319h)*
2. **Pet Waste Stations** – $1,000 per unit, inclusive of installation, unit, and signage. Five sites are currently identified for the watershed. *(H-GAC, 319h, local funds)*
3. **Dog Parks** – $20,000 per small dog park, inclusive of signage, park structures, and related materials. Based on a City of Angleton park established in the watershed during the development of this WPP. *(CDBG, local municipal or private developer funds)*

6.9 Land Acquisition

1. **Land Acquisition** – $10,000 per acquisition, for appraisal and related costs. Cost of acquisition varies by location and size. Stakeholders have worked with landowners to donate tracts of land in the watershed, including the Dow Woods Unit, now part of the San Bernard National Wildlife Refuge. *(private donations, USF&WS)*
2. **Conservation Easements** – $1500/acre, based on recent costs for large conservation easements developed under the GLO's Farm and Ranch Lands Conservation Program. Funding to be provided under existing conservation easement programs. (*GLO, private landowners)*
3. **New Development Riparian Buffers** – Variable, based on size and location. Leaving buffers in areas adjacent to waterways may have little cost if no improvement is completed, i.e., if undeveloped swaths are left wild along the waterway. Staff time will be involved in promoting riparian buffers to new development as opportunities arise. (*H-GAC, 319h – staff time; private developers, landowners, Brazoria County-land value and maintenance)*

6.10 Abandoned Boats

1. **Removal of Abandoned Boats** – $30,000/boat based on recent GLO costs[57] for removing a large shrimp boat from the watershed. Disposal of removed materials and any hazardous substances is variable based on the boat involved. *(GLO, Brazoria County)*

6.11 Enforcement

1. **Additional Officers** – $75,000 in personnel and training costs/year based on Brazoria County estimates. *(Brazoria County, through transfer of existing employees.)*

6.12 Monitoring

1. **Ambient Monitoring** – $2,800/quarter, based on CRP sampling costs for existing sites in the watershed. *(Clean Rivers Program)*
2. **BMP Effectiveness Monitoring[58]** – $10,000 for staff time, sampling costs, and travel based on similar projects. *(H-GAC, 319h)*

---

[57] The GLO was able to remove a 50-60' steel hulled boat, which is estimated to have been in the water for approximately 25 years. The cost for this project was approximately $24,500.

[58] Description of BMP effectiveness monitoring is found in **Section 11**.

Funding Sources

The dollar figures listed throughout this section are attributed to known sources of funding from Federal, State or private grants and local funding from municipalities, Brazoria County, and other stakeholder entities in the watershed. Currently anticipated sources include:

- Clean Water Act Section 319(h) funds
- Clean Water Act Section 106 funds
- Clean Water Act Section 604(b) funds
- CIAP
- Clean Rivers Program
- US Fish and Wildlife Service
- SEP funds through existing SEPs or under H-GAC's OSSF SEP.
- CDBG
- USDA NRCS (EQIP, etc.)
- Private landowners

Additionally, as noted, funding from stakeholders through existing projects and for select new projects is expected to come from Brazoria County, TSSWCB, AgriLife, H-GAC CRP, Brazoria County Freshwater Supply District 2 (Demi-John, et al.), private residents, the City of Angleton, the City of Lake Jackson and other entities involved specific to each project. Since most public and private grants require a matching component, the matching sources are also listed. Additional state resources through the RESTORE Act may be available in the coming decade.[59]

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 and guidelines for implementation in **Section 5**. Costs are represented in present dollars. Future costs will vary based on change in prices, due to a phased implementation of BMPs (See **Section 8** for more detail). Growth is predicted to continue in the watershed over several decades, making implementation a potentially moving target. Regular assessment of water quality as part of the monitoring component of this WPP, coupled with the

[59] As of the time of the development of this WPP, the potential for future RESTORE Act funding has not been quantified at the state level, and mechanisms for project prioritization and selection have not been identified. If this funding source becomes viable in the future, WPP revisions will indicate its potential application to this project.

scalable BMP implementation approach, may mean that costs may differ from current projections.[60]

Resource Summary – Initial Implementation

While some costs are variable based on the scaled BMP approach, **Table 24** provides a summary of the expected costs and responsible parties for the various management activities and outreach efforts. The intent of this table is to provide a visual link between the resource needs, responsibilities, and time frames in the initial 10 year period of implementation. Additional detail about scheduling, outreach activities, and monitoring are included in Sections 7-11. This table should not be taken to imply all funding for all measures is currently committed. In many cases additional funding may need to be acquired.

Table 24 - Initial Implementation Summary

Management Measure	Responsible Party	Cost per Unit/ Year	Number Implemented per Year Yr. 1 to 3	Yr. 4 to 6	Yr. 7 to 10	Total Cost
Education and Outreach						
Project Promotion						
Website, Press Releases	H-GAC	$500	ongoing	ongoing	ongoing	$5,000
Executive Summary	H-GAC	$3,000	1			$3,000
Educational Materials						
Cattle Management	H-GAC, TSSWCB, TWRI, AgriLife, USDA NRCS/ existing materials	$1,000	1 printing	1 printing	1 printing	$3,000
OSSF Maintenance	H-GAC/Existing materials	$1,000	1 printing	1 printing	1 printing	$3,000
Pet Waste Disposal	H-GAC/Existing materials	$1,000	1 printing	1 printing	1 printing	$3,000
Workshops						

[60] If the complementary impacts of other efforts, such as the Brazoria County Stormwater Coalition, result in lower bacteria loading levels than current project projections, project costs may decrease. BMP implementation is scaled to reduction requirements, and designed to be flexible to change as the loading levels change. If the SWMPs implementation appreciably changes loading levels for urban sources, the WPP may scale down urban BMP implementation in future revisions to avoid redundancy. In that eventuality, costs will scale down respectively. With limited information on projected costs or impacts of the Coalition's SWMP, its potential impacts are not able to be evaluated during the development of this WPP. Therefore the WPP takes a conservative position of not counting on any future cost reduction due to the SWMP implementation.

Management Measure	Responsible Party	Cost per Unit/ Year	Number Implemented per Year Yr. 1 to 3	Yr. 4 to 6	Yr. 7 to 10	Total Cost
Texas Watershed Stewards	AgriLife	$15,000	1			$15,000
Project WET/WILD	Project WET/WILD	$5,750	1			$5,750
OSSF Workshop	H-GAC	$2,500	1	1	1	$7,500
Structural Outreach						
Watershed Signs	CRP, Brazoria County, TxDOT	$2,700	1 deployment			$2,700
Pet Waste Signage	H-GAC	$100/sign	5			$500
Educational Trail Signage	USF&WS	$20,000	1 deployment			$20,000
Outdoor Message Boards	H-GAC, Brazoria County	$700	5			$3,500
Public Participation Opportunities						
Texas Stream Team	CRP, H-GAC	$2,000	Annual	Annual	Annual	$20,000
Trash Bash Event	*(Refer to Illegal Dumping/Trash Section)*					
Livestock Management						
Cattle Programs						
WQMPs	TSSWCB, landowners	$10,000-15,000	(variable based on size of individual properties)	(variable based on size of individual properties)	(variable based on size of individual properties)	(variable based on size of individual properties)
USDA NRCS Projects	USDA NRCS, landowners	(variable)	(variable based on size of individual properties)	(variable based on size of individual properties)	(variable based on size of individual properties)	(variable based on size of individual properties)
Lone Star Healthy Streams Programs	TSSWCB, H-GAC	$300	1	1	1	$600
Deer and Feral Hog Management						
Feral Hogs						
Feral Hog Workshops	AgriLife	$8,000	1		1	$16,000
USF&WS Conservation Plan	USF&WS	NA	1			NA
Lone Star Healthy Streams Programs	TSSWCB, H-GAC	$300	1	1	1	$600

Management Measure	Responsible Party	Cost per Unit/ Year	Number Implemented per Year Yr. 1 to 3	Yr. 4 to 6	Yr. 7 to 10	Total Cost
Feral Hog Hunting Event	AgriLife, Brazoria County	$5,000	1			$5,000
OSSFs						
Remediate Malfunctioning OSSFs	H-GAC	Average of $5,000; $1,000-$10,000 range	70	20	20	$550,000
Enhance OSSF Design Criteria	Brazoria County	$30,000		1		$30,000
Promote Sanitary Sewer Service	H-GAC, Brazoria County	NA	ongoing	ongoing	ongoing	NA
Illegal Dumping/Trash						
Trash Reduction Event (Trash Bash)	H-GAC/CRP, local volunteers	$5,000	3	3	4	$45,000
Addressing Illegal Dumping	Brazoria County	$25,000	Initial deployment	ongoing	ongoing	$185,000
Addressing Dump Sites	Brazoria County	(variable)	(variable)	(variable)	(variable)	(variable based on sites identified)
Urban Runoff						
Low Impact Development						
Green Roof Pilot Project	Brazoria County, City of Angleton	(variable)		1		(variable based on site)
Small-scale Green Infrastructure Pilot Projects	Brazoria County, City of Angleton	$575,000		Project initiation		$575,000
Large Scale Development Practices						

Management Measure	Responsible Party	Cost per Unit/ Year	Number Implemented per Year Yr. 1 to 3	Yr. 4 to 6	Yr. 7 to 10	Total Cost
Stormwater Detention	Brazoria County	$323,484 (estimated annual portion of total cost)	variable based on need	variable based on need	variable based on need	Estimated $3,234,840 , variable based on need; driven by development
Stormwater Filtration	Brazoria County/Private Development	$446,7,16 (estimated annual portion of total cost)	variable based on need	variable based on need	variable based on need	Estimated $4,467,160 , variable based on need; driven by development
Pet Waste Management						
Model Ordinances and Bylaws	H-GAC	NA	ongoing	ongoing	ongoing	negligible cost in staff time; existing resources
Pet Waste Stations	H-GAC	$1,000	5			$5,000
Dog Parks	City of Angleton	$20,000	1			$20,000
Land Acquisition						
Land Acquisition	USF&WS	$10,000		1		$10,000
Conservation Easements	GLO, Private Landowners	$1500/acre	variable based on partner funding	variable based on partner funding	variable based on partner funding	variable based on partner funding
New Development Riparian Buffers	H-GAC, Brazoria County, Private developers	(variable based on participation, buffer value/size)	(variable based on participation, buffer value/size)	(variable based on participation, buffer value/size)	(variable based on participation, buffer value/size)	(variable based on participation, buffer value/size)

Management Measure	Responsible Party	Cost per Unit/ Year	Number Implemented per Year Yr. 1 to 3	Yr. 4 to 6	Yr. 7 to 10	Total Cost
Abandoned Boats						
Removal of Abandoned Boats	GLO, Brazoria County	$30,000/boat	1	1		$60,000
Enforcement						
Additional Officers	Brazoria County	$75,000	3	3	4	$750,000
Monitoring						
Ambient Monitoring	CRP	$11,200	quarterly	quarterly	quarterly	$112,000
BMP Effectiveness Monitoring	H-GAC	$10,000	Pre-implementation deployment		interim/post-implementation deployment	$20,000

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 BMPs remediate the impacts of a contamination-causing activity, behavioral measures address the root causes. In this way, the two types of solutions are complementary. This WPP 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.[61] The outreach and education efforts detailed in this WPP are categorized as project promotion, educational materials, workshop or classroom activities, structural outreach, or public participation activities. The cumulative impact of these activities is expected to be a 2% reduction in total bacteria loading (Abroms et al., 2008).

7.1 Project Promotion

The aim of these efforts is to educate stakeholders about the goals of the WPP, promote implementation efforts, and raise general awareness of project activities.

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.

Bastrop Bayou WPP Executive Summary
A short executive summary of the WPP and its goals will be prepared by H-GAC for dissemination to local stakeholders.

Press Releases
H-GAC creates and submits news releases to numerous media outlets, including local and regional newspapers, newsletters, magazines, radio programs and TV stations in the watershed. Additional public information articles will be submitted to key outlets as project events warrant.

[61] Some specific outreach efforts dealing with specific source contributions, such as feral hog workshops or development of model pet waste ordinances, are not included in this section. Please refer to **Section 5** for more detail on these activities.

7.2 Educational Materials

These elements of the education and outreach program are topic-specific printed or digital materials targeted at specific populations (pet owners, OSSF owners, etc.). Whenever practicable, existing materials will be utilized to save resources on development. These are valuable to supplement presentations and to hand out at fairs and other outreach events with mass attendance. Printed materials help reinforce a message that may be lost, as they can be read and re-read at leisure. Because many of these materials have already been produced, they can usually at low cost in large quantities. Community organizations, local governments, and other stakeholder groups can use assist in disseminating these materials.

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

OSSF Maintenance
Existing bilingual OSSF maintenance literature from H-GAC and resources from local governments and other stakeholders will be disseminated to targeted populations based on local need. These materials will also be used in conjunction with residential OSSF workshops.

Pet Waste Disposal – Existing printed materials and other outreach elements from successful pet waste reduction campaigns will be used. An example of potential materials can be found at the EPA's NPS Outreach Toolbox[62] or through local sources like H-GAC's pet waste website.[63] Materials will be selected based on the community targeted for outreach.

7.3 Workshop and Classroom Activities

Workshop or classroom activities cover an array existing and proposed participatory learning experiences. Many local and regional organizations offer workshops addressing a variety of the sources of bacteria in the watershed.

Texas Watershed Stewards

[62] http://cfpub.epa.gov/npstbx/index.html
[63] http://www.h-gac.com/community/publicawareness/pet-waste/default.aspx

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.

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.

OSSF Workshop

Residential maintenance of OSSFs varies in effectiveness based on the owner's level of knowledge of their system. AgriLife has developed a workshop presentation for residential OSSF owners that has been utilized in other watershed efforts. H-GAC and other local partners have also developed similar materials. A periodic series of workshops would be held for residents in the watershed to help promote responsible maintenance of OSSFs and prevent malfunctions or failures.

7.4 Structural Outreach

Structural outreach activities involve education and outreach conducted through installation of permanent or semi-permanent structures. Elements of this structural outreach have already begun during the development of this WPP.

Watershed Signage was identified by the stakeholders as a priority for outreach and branding for the watershed. During the development of this WPP, H-GAC worked with Brazoria County and TxDOT to install 30 signs at strategic road and marina locations throughout the watershed.

Pet Waste Management

Signage alerting dog owners to rules and information regarding disposing of wastes will be used in conjunction with pet waste stations and dog parks.

Educational Trail Signage

Educational trails offer tactile way to understand ecology. Signs inform visitors about ecological concepts. The Brazoria National Wildlife Refuge, and the San Bernard Wildlife Refuge Dow Woods Unit location, maintained by the USF&WS, utilizes such trails to help promote conservation education.

Outdoor Message Boards

Educational message boards were identified by the stakeholders as a potential way to have a semi-permanent passive education opportunity. During the development of the WPP, H-GAC worked with Brazoria County, USF&WS, the community of Demi-John, and the City of Angleton to install a series of educational message boards at public parks and other high traffic areas. The message boards are enclosed and half of their space is devoted to watershed education materials, while half is available for the maintaining entity to display other information (park regulations, etc.).

7.5 Public Participation Opportunities

Direct public participation has proven to be an effective way to engage stakeholders. 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 stakeholders identified

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 classrooms. Students can learn about science by using a hands-on approach, and a class can adopt a stream to monitor with their teacher. While the efforts of this volunteer group are based on water quality sampling, engaging stakeholders through this effort is considered an outreach measure. The TST program is augmented by holding trainings in the watershed. One training was held in the watershed during the development of this WPP.

Trash Bash
The Rivers, Lakes, Bays ‘N Bayous Trash Bash event is an annual effort to reduce illegal dumping and refuse built up in local waterways. One permanent site and one satellite site are located in the southern reach of the watershed, in which more than 18 miles of shoreline have been cleaned by hundreds of local volunteers on a yearly basis since 2009. This event can capitalize on public involvement to improve awareness of the WPP and its goals.

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 BMPs, 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. Many start dates reflect ongoing or initiated projects by partners that are not dependent on future 319 grant funding, and therefore have started or may start before the final approval of this WPP.

Some projects, especially education and outreach, are already ongoing and will continue throughout the implementation period. Construction 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 timelines shown in **Table 25** at the end of this section. A ten-year period was selected as being representative of the foreseeable future, although implementation is scheduled to continue through 2040. Due to the changing nature of the watershed, stakeholders felt that a longer than usual timeframe for implementation was necessary, but that focus should be on the first 10-year period. Expected waves of growth and industrial development are expected outside of a 10-15 year implementation timeframe. Reassessment of conditions under the adaptive management process will allow for flexibility in implementation past that time frame (or internal to it). Reductions are likely to be a nonlinear, moving target rather than s steady linear progression from current to ultimate conditions.[64] Additional elements or details may be discussed in **Sections 3, 5, 6 and 7** for each category, respectively.

8.1 Education & Outreach

Project Promotion

1. **Website** – The website already exists, and will be updated periodically throughout implementation.
2. **Bastrop Bayou WPP Executive Summary** – The Executive Summary will be produced pending the approval of the WPP, expected in 2016.

[64] Because a scalable approach to BMP implementation was selected for this WPP (see sections 10.2 and Appendix D) the number of implemented units of some BMPs is variable based on the scale of each individual unit. For example, the implementation of WQMPs is scaled by total acreage to be impacted. A single WQMP covering 10,000 acres may be the equivalent of multiple WQMPS covering smaller acreages.

3. **Press Releases** – Press releases will be sent periodically throughout implementation.

Educational Materials

1. **Cattle Management Materials** – Materials exist for all identified programs, and are promoted through the respective agencies. Dissemination to continue as needed throughout implementation.
2. **OSSF Maintenance Materials** – Materials exist for all identified programs. Dissemination to begin in 2013, and continue as needed throughout implementation.
3. **Pet Waste Disposal** – Materials exist for all identified programs. Dissemination to begin in 2013, and continue as needed throughout implementation.

Workshop and Classroom Activities

1. **Texas Watershed Stewards** – Original workshop held in 2009. Additional workshop to be developed for 2016.
2. **Project WET and WILD** – Development of opportunities with schools to commence in 2017, and continue through the duration of implementation.
3. **OSSF Workshops** – First workshop to be held in 2014, second in 2016, and scheduled for every three years.

Structural Outreach

1. **Watershed Signage** – 30 watershed signs were installed on state and county roads at the boundary of the watershed and at select locations within it in 2012.
2. **Pet Waste Management Signage** – Pet waste station signage will begin to be implemented with five pet waste stations in 2013/2014[65].
3. **Educational Trail Signage** – Signage was installed at the Dow Woods Unit during the development of this WPP (2010-2012). Additional signage may be installed as needed.
4. **Outdoor Message Boards** – Four message boards were installed in 2012. Additional message boards will be installed as opportunities arise. Materials will be updated as needed.

Public Participation Opportunities

1. **Texas Stream Team** – Texas Stream Team coordination and training is already active in the Watershed, and expected to continue through the duration of the project.
2. **Trash Bash Event** – The Trash Bash event will be held yearly throughout the duration of the project.

[65] This implementation activity has already been achieved prior to the approval of this WPP.

8.2 Livestock Management

Cattle Programs

1. **WQMPs** – Potential WQMP locations will be developed in coordination with TSSWCB staff, and WQMPS will be promoted to landowners through the duration of the project.
2. **USDA NRCS Grant Projects** – H-GAC staff began to promote the USDA NRCS programs in 2014. Potential project locations will be identified in coordination with NRCS staff, starting in 2014 and continuing through the duration of the project.
3. **Lone Star Healthy Streams** – H-GAC staff began assist in promoting the LSHS resources in 2014, and continue to do so throughout the duration of the project.

8.3 Deer and Feral Hog Management

Feral Hog Management

1. **Feral Hog Workshops** – Texas A&M Agrilife and TSSWCB have allocated grant funding starting in 2013 to hold feral hog workshops throughout the state. Bastrop Bayou Watershed was identified as a priority watershed for this grant. A workshop for an area including the watershed was held in 2013.The stakeholder group will work with AgriLife to schedule one or more workshops in 2016, and every 5 years during the course of the project.
2. **USF&WS Conservation Plan** – The Conservation Plan is currently being implemented, and will continue throughout the project.
3. **Lone Star Healthy Streams** – H-GAC staff and partners began to promote the USDA NRCS programs in 2014, and continue to do so throughout the duration of the project.
4. **Feral Hog Hunting Event** – Stakeholders will work to plan a feral hog hunting event in 2017/2018. Stakeholders will coordinate with existing feral hog hunting guides and services, as well as existing feral hog eradication programs.

8.4 WWTFs

1. **Bacteria Monitoring in WWTF Effluent** – WWTFs in the watershed received bacteria limits in their permits during the 5 year permit renewal cycle concurrent with WPP development and approval. Monitoring evaluated under this project will be collected from 2014 onward.

8.5 OSSFs

1. **Remediate Malfunctioning OSSFs** – H-GAC and partner agencies began to seek funding for OSSF remediation in 2014 from SEP and other sources and remediate malfunctioning systems as funds allow. These efforts will continue through the duration of the project. The Demi-John sanitary sewer conversion and Brazoria County efforts to remediate OSSFs in the Demi-John area began in 2012 with expected completion in 2016.
2. **Enhance OSSF Design Criteria** – H-GAC will work with Brazoria County starting in 2017 to evaluate OSSF design and siting criteria.
3. **Promote Sanitary Sewer Service** – The stakeholders will work with existing and new communities to promote sanitary sewer service throughout the duration of the project, starting in 2014.

8.6 Illegal Dumping/Trash Reduction

1. **Trash Reduction Events** – The Trash Bash event will continue to be held annually at one primary and one satellite location in the watershed.
2. **Addressing Illegal Dumping** – The hotline and related materials will be developed by 2017, and continued throughout the duration of the project as use dictates.
3. **Addressing Dump Sites** – The County addresses dump sites as they are reported and will continue to do so throughout the duration of the project.

8.7 Urban Runoff[66]

Low Impact Development

1. **Green Roof Pilot Project** – Sites for a green roof project, including the previously identified Angleton courthouse annex, will be evaluated in 2017. Projects will be planned for initiation starting in 2018-2019.
2. **Green Infrastructure Pilot Projects** – Sites for LID pilot projects, including the previously identified Angleton courthouse annex, will be evaluated in 2017. Projects will be planned for initiation starting in 2018-2020.

Large-scale Development Practices

1. **Stormwater Detention** – New detention projects will be dependent on new development and drainage/flood control needs. Evaluation of potential sites will be ongoing through the County.

[66] The schedule and timing of these activities reflects items above and beyond any requirements of an MS4 permit. Timing of implementation activities under Phase II permits is not reflected in this WPP, and was not known during the development of this WPP.

2. **Stormwater Filtration** –Opportunities for wetland areas and swales will be evaluated starting in 2017. Development and installation of an initial project is scheduled for 2018-2020.

8.8 Pet Waste Management

1. **Model Ordinances/Bylaws** – Model ordinances and bylaws will be developed in 2015, and disseminated throughout the rest of the project.
2. **Pet Waste Stations** – At least five pet waste stations will be installed in 2014. Additional pet waste stations may be installed based on need.
3. **Dog Parks** – One dog park was installed in the watershed in 2012 by the City of Angleton. Stakeholders will look for additional opportunities to install dog parks as growth continues throughout the duration of the project. Specific opportunities will be evaluated in 2017.

8.9 Land Acquisition

1. **Land Acquisition** – The USF&WS worked with the Dow Chemical Company to acquire the DOW woods unit in 2008, and installed signage and trail amenities through its public opening in 2011. Starting in 2014, stakeholders will support future acquisitions by providing appraisal funding, as appropriate, to the USF&WS and other public entities for conservation acquisitions throughout the duration of the project.
2. **Conservation Easements** – The GLO's Farm and Ranch Lands Conservation Program is actively completing four large scale conservation easement projects in the watershed. The Savannah Oaks project has already been completed. Stakeholder will promote the pursuit of additional conservation easements by the GLO and other partner agencies throughout the duration of the project.
3. **New Development Riparian Buffers** – Stakeholders will promote riparian buffers (through filter strips, undeveloped swaths, etc.) starting in 2014 and lasting throughout the project. Development is expected to continue in the watershed throughout the implementation period.

8.10 Abandoned Boats

1. **Abandoned Boat Removal** – The GLO completed removal of the first identified abandoned boat in 2012. Additional boats will be identified starting in 2013, with removal efforts expected to be conducted as needed through 2018.

8.11 Enforcement

1. **Additional Officers** – The new officers will report to and be supervised by the Environmental Division, to enhance environmental investigations in the county starting in 2018.

Table 25 - Implementation Schedule Summary[67,68]

10 Year Implementation Schedule	*Previous*	*2013*	*2014*	*2015*	2016	2017	2018	2019	2020	2021	2022	2023
Education and Outreach												
Project Promotion												
Website	x	x	x	x	x	x	x	x	x	x	x	x
Bastrop Bayou WPP Executive Summary					x							
Press Releases	x	x	x	x	x	x	x	x	x	x	x	x
Educational Materials												
Cattle Management Materials	x	x	x	x	x	x	x	x	x	x	x	x
OSSF Maintenance Materials	x	x	x	x	x	x	x	x	x	x	x	x
Pet Waste Disposal			x	x	x	x	x	x	x	x	x	x
Workshop and Classroom activities												
Texas Watershed Stewards	x				x							
Project WET and WILD						x	x	x	x	x	x	x
OSSF Workshop			x		x					x		
Structural Outreach												
Watershed Signage	x											
Pet Waste Management Signage		x	x									
Educational Trail Signage	x											
Outdoor Message Boards	x	x	x	x	x	x	x	x	x	x	x	x
Public Participation Opportunities												
Texas Stream Team	x	x	x	x	x	x	x	x	x	x	x	x
Trash Bash Event	x	x	x	x	x	x	x	x	x	x	x	x

[67] The "Previous" column refers to activities that were completed during the development of the WPP, or were ongoing for that period. The WPP was initially developed prior to 2013. Dates reflect intended start dates based on the original development, unless they have been delayed pending WPP approval.

[68] It is expected that activities noted as being ongoing through 2023 will continue through at least 2030. The ten year time period was selected as being the period in time necessary to conduct initial implementation efforts, establish ongoing programs, and evaluate impacts. The WPP and its implementation activities are designed to be an ongoing process, and therefore it is not expected efforts will terminate in 2023. Projected development and change in watershed land use will likely be an important factor after this initial time frame. Projection beyond that period will need revised growth and development data, assessment of impacts within that period, etc. as implementation progresses.

10 Year Implementation Schedule	Previous	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Livestock Management												
Cattle Projects												
WQMPs			x	x	x	x	x	x	x	x	x	x
USDA NRCS Grant Projects			x	x	x	x	x	x	x	x	x	x
Lone Star Healthy Streams			x	x	x	x	x	x	x	x	x	x
Deer and Feral Hog Management												
Feral Hog Management												
Feral Hog Workshops		x			x					x		
USF&WS Conservation Plan		x										
Lone Star Healthy Streams		x	x	x	x	x	x	x	x	x	x	x
Feral Hog Hunting Event							x					
Wastewater Treatment Plants												
Bacteria Monitoring of WWTF Effluent		x	x	x	x	x	x	x	x	x	x	x
OSSFs												
Remediate Malfunctioning OSSFs			x	x	x	x	x	x	x	x	x	x
Enhance OSSF Design Criteria						x	x					
Promote Sanitary Sewer Service		x	x	x	x	x	x	x	x	x	x	x
Illegal Dumping/Trash Reduction												
Trash Reduction Event (Trash Bash)	x	x	x	x	x	x	x	x	x	x	x	x
Address Illegal Dumping						x	x	x	x	x	x	x
Address Dump Sites	x	x	x	x	x	x	x	x	x	x	x	x
Urban Runoff												
Low Impact Development												
Green Roof Pilot Project						x	x	x	x	x		
Green Infrastructure Pilot Projects						x	x	x	x	x		
Large-Scale Development Projects												
Stormwater Detention		x	x	x	x	x	x	x	x	x	x	x
Stormwater Filtration		x	x	x	x	x	x	x	x	x	x	x

10 Year Implementation Schedule	Previous	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Pet Waste Management												
Model Ordinances/Bylaws			x	x	x	x	x	x	x	x	x	x
Pet Waste Stations	x		x									
Dog Parks	x					x						
Land Acquisition												
Land Acquisition	x						x	x	x	x	x	x
Conservation Easements	x	x	x	x	x	x	x	x	x	x	x	x
New Development Riparian Buffers			x	x	x	x	x	x	x	x	x	x
Abandoned Boats												
Abandoned Boat Removal	x	x	x	x	x	x	x	x	x	x	x	X
Enforcement												
Additional Officers						x	x	x	x	x	x	x

9 Interim Milestones Element G

The ultimate goal of implementing the BMPs 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 WPP 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 BMPs, will indicate the advancement and success of this WPP.[69] As part of the adaptive management process of WPP review and update, a framework for review of progress, and the milestones by which is it measured, is included as part of Section 10.

9.1 Education & Outreach

Project Promotion

1. **Website** – The project website is an ongoing effort and does not have specific milestones**.**
2. **Bastrop Bayou WPP Executive Summary**
    - Approval of the Bastrop Bayou WPP (expected 2016)
    - Creation of a draft Executive Summary for TCEQ review (2016)
    - Dissemination of approved Executive Summary to stakeholders (2016)
3. **Press Releases** – Press releases are an ongoing efforts and do not have specific milestones.

Educational Materials

1. **Cattle Management Materials**
    - Evaluation of existing materials (2013)
    - Dissemination of materials (2013 onward)
2. **OSSF Maintenance Materials**
    - Evaluation of existing materials (2013)
    - Dissemination of materials (2013 onward)
3. **Pet Waste Disposal**
    - Evaluation of existing materials (2013)
    - Dissemination of materials (2013 onward)

[69] As indicated previously, the focus of implementation for this WPP is on the first 10 years, although the restoration time frame is longer due to the intermediate impacts of development. Timing and milestones of implementation activities past the ten year mark will be scaled to meet the changing nature of the watershed at that point. In general, unless otherwise noted, the activities are anticipated to be ongoing or to continue at the frequency established in the first 10 years.

Workshop and Classroom Activities

1. **Texas Watershed Stewards**
   - Hold initial training event (completed during development of WPP)
   - Obtain agreement from AgriLife to hold another training (2016)
   - Hold second event (2017)
2. **Project WET and WILD**
   - Obtain permission from the Teachers (2017)
   - Obtain permission from the curriculum coordinator (2017)
   - Obtain permission from the principal and School Board (2017)
   - Obtain materials from the project WET and WILD foundations (2017)
   - Develop a curriculum (2017)
   - Schedule instruction for Teachers (2017 – throughout project)
   - Hire substitute for classrooms while the Teachers are being trained (2017 – throughout project)
3. **OSSF Workshop**
   - Coordinate with AgriLife on holding a residential OSSF workshop (2014)
   - Hold initial workshop (2014)
   - Hold additional workshops (2016, 2021, 2024, and onward)

Structural Outreach

1. **Watershed Signage**
   - Coordinate with stakeholders to identify potential sign locations (completed 2012)
   - Coordinate with Brazoria County and TxDOT on installations (completed 2012)
   - Install 30 signs throughout watershed (completed 2012)
2. **Pet Waste Management Signage**
   - Coordinate with pet waste station recipients on acceptable signage design (2013)
   - Develop signs with consultant (2013-2014)
   - Install signage with Pet waste stations (2014)
3. **Education Trail Signage**
   - Develop and design educational signage (completed by USF&WS, 2008-2011)
   - Printing of Signage (completed by USF&WS, 2008-2011)
   - Install signage (completed by USF&WS, 2008-2011)
4. **Outdoor Message Boards**
   - Coordinate with stakeholders on potential locations (completed, 2012)
   - Order and receive boards (completed, 2012)
   - Coordinate with County and USF&WS on installation (2012 -2013)
   - Install boards (2012-2013)
   - Install materials on boards (2012-2013)

Public Participation Opportunities

1. **Texas Stream Team** – Texas Stream Team volunteer coordination and training is an ongoing activity and does not have specific milestones.
2. **Trash Bash Event** – Education at the Trash Bash event is an ongoing activity and does not have specific milestones.

9.2 Livestock Management

Cattle Programs

1. **WQMPs**
    - Obtain permission from TSSWCB to promote program (2013)
    - Promote program and assist TSSWCB in recruiting volunteers (2014 – throughout project)
    - Develop and approve plans (ongoing, as conducted by TSSWCB/local Soil and Water Conservation Districts)
    - Implement WQMP BMPs/recommendations (ongoing, as conducted by landowners)
2. **USDA NRCS Grant Projects**
    - Obtain permission from USDA NRCS to promote program (2013)
    - Promote program and assist USDA NRCS in recruiting volunteers (2014 – throughout project)
    - Develop and approve financial incentive projects (ongoing, as conducted USDA NRCS)
    - Implement projects/BMPs (ongoing, as conducted by USDA NRCS and landowners)
3. **Lone Star Healthy Streams**
    - Coordinate with LSHS program staff to determine best cattle-based materials for the watershed
    - Promote program/materials (2013 – throughout project)

9.3 Deer and Feral Hog Management

Feral Hog Management

1. **Feral Hog Workshops**
    - Coordinate with AgriLife on holding a feral hog workshop (2013)
    - Hold initial workshop (2014)
    - Hold additional workshops (2016, 2021, and onward)
2. **USF&WS Conservation Plan**
    - Provide public comment to USF&WS in favor of feral hog management (2012-2013)
    - Conservation Plan is approved by USF&WS (2013)
    - Conservation Plan is implemented by USF&WS (2013 onwards)
3. **Lone Star Healthy Streams**

- Coordinate with LSHS program staff to determine best feral hog-based materials for the watershed
- Promote program/materials (2013 – throughout project)

4. **Feral Hog Hunting Event**
    - Coordinate with local stakeholders and feral hog hunting interests in determining timing and character of event (2017)
    - Schedule event and venue (2018)

9.4 WWTFs

1. **Bacteria Monitoring in WWTF Effluent**
    - WWTFs receive permit standards for bacteria (2013-2015)
    - WWTFs begin to sample for bacteria (2013 onward)
    - Review sampling data (2016, and every two years thereafter)

9.5 OSSFs

1. **Remediate Malfunctioning OSSFs**
    - Determine eligibility criteria (2013)
    - Locate grant funding through SEP/CIAP/etc. (2013 onward)
    - Obtain local permission (2013 onward)
    - Identify homeowners for remediating systems (2016 onward)
    - Remediate systems (2016 onward)
2. **Enhance OSSF Design Criteria**
    - Coordinate with Brazoria County on agreement to evaluate criteria (2017)
    - Evaluate criteria (2017)
    - Present recommendations to County Commissioners Court (2018)
    - Revise criteria as necessary (2018)
3. **Promote Sanitary Sewer Service** – This effort is ongoing throughout the project and does not have specific milestones associated with it.

9.6 Illegal Dumping/Trash Reduction

1. **Trash Reduction Events (Trash Bash)** – Trash Bash is an ongoing event and doesn't have specific milestones.
2. **Addressing Illegal Dumping**
    - Obtain agreement from Brazoria County on maintenance of a hotline (2017)
    - Secure funding for hotline and related materials (2017)
    - Develop promotion campaign for hotline (2017)
    - Implement promotional campaign (2018)

- Implement hotline (2018 onward)

3. **Addressing Dump Sites**
    - Obtain agreement from Brazoria County (TBD, if needed)
    - Locate chronic dumping sites (2013 – throughout project)
    - Routinely, or as needed, clean dump sites (2014 – throughout project)

9.7 Urban Runoff

Low Impact Development

1. **Green Roof Pilot Project**
    - Obtain agreement with the owner (2017)
    - Secure funding for project (2017)
    - Design project (2018-2019)
    - Obtain federal state and local permits for the project (2019-2020)
    - Commence construction (2020-2021)
2. **Install green infrastructure projects at the Angleton courthouse complex and at a Park within the Watershed**
    - Obtain agreement with land owners (2017)
    - Design project (2018)
    - Obtain federal state and local permits for the project (2018-2019)
    - Commence construction (2019-2020)
3. **Other Green Infrastructure Pilot Projects**
    - Identify sites (2017)
    - Obtain agreements with land owners (2018)
    - Design projects (2018-2019)
    - Obtain federal state and local permits for the project (2019-2020)
    - Commence construction (2020-2021)

Large-scale Development Practices

3. **Stormwater Detention**
    - Identify potential sites (2013 onwards as warranted by development or drainage needs)
    - Obtain agreement with land owners (as warranted)
    - Design projects (as warranted)
    - Obtain federal, state and local permits for the project (as warranted)
    - Begin construction (as warranted)
4. **Stormwater Filtration**
    - Identify potential sites (2013 for intital project site, onwards as warranted by development or drainage needs)
    - Obtain agreement with land owners (2014 for initial project, as warranted)
    - Design projects (2014 for initial project, onward as warranted)

- Obtain federal, state and local permits for the project (2015 for intial project, onward as warranted)
- Begin construction (2015-2016, onward as warranted)

9.8 Pet Waste Management

1. **Model Ordinances/Bylaws**
    - Develop model by-laws (2013-2014)
    - Develop promotion, education and campaign materials for residents (2013-onward)
    - Promote model materials to local governments (ordinances) and HOAs (bylaws) for their use (2015 onward)
    - Entities enact or revise pet waste requirements using model materials (as warranted)
2. **Pet Waste Stations**
    - Identify potential sites for initial five stations (completed in 2012)
    - Obtain agreement from landowners to install stations (completed 2013)
    - Order stations based on landowner approval (completed 2013)
    - Coordinate with landowner on installation of stations (completed 2013-2014)
    - Install stations with signage (completed 2014)
3. **Dog Parks**
    - Identify dog park site (completed by City of Angleton, 2011-2012)
    - Secure funding for dog park (completed by City of Angleton, 2011-2012)
    - Install dog park, pet waste station and signage (completed by City of Angleton, 2012)
    - Maintain dog park (2012 onward)
    - Identify potential future dog park locations (2017)
    - Work with landowners to install future parks (ongoing as warranted)

9.9 Land Acquisition

1. **Land Acquisition**
    - Acquire tract of property from Dow Chemical Company (completed by USF&WS in 2008)
    - Coordinate with USF&WS and other agency partners on identifying additional land acquisition opportunities (2017 onward)
    - Appraise Property (2018 onward)
    - Property Acquired by Partners (2019 onward)
2. **Conservation Easements**

- Support GLO efforts to create conservation easements through the Farm and Ranch Lands Conservation Program. (2013 through end of project).
- Work with other partner agencies to promote additional conservation easement acquisition. (2014 onwards)

3. **New Development Riparian Buffers –** This effort is ongoing throughout the project and does not have defined milestones.

9.10 Abandoned Boats

1. **Abandoned Boat Removal**
    - Identify abandoned boat (completed during the development of this WPP)
    - Secure funding to remove abandoned boat (completed during the development of this WPP by the GLO)
    - Remove abandoned boat (completed in 2012 by the GLO)
    - Identify additional abandoned boats with stakeholder input (2013 onward)

9.11 Enforcement

1. **Additional Officers**
    - Obtain final commitment from Brazoria County (2017)
    - Train officers (2017-2018)
    - Officers available for enforcement (2018 onwards)

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 BMP, as well as the sum progress of the WPP's implementation, changes can be made as necessary to better meet the stated goals. The progress toward goals will be evaluated in an annual review of advancement toward milestones, and through water quality monitoring. In addition to these milestones, addressing a cumulative number of representative BMP units (see Section 10) equivalent to source load reduction targets will be considered general milestones throughout the project. The projected course of reduction is represented in Figure 21.

10 Indicators to Measure Progress Element H

When the WPP was first being developed, neither Bastrop Bayou nor any of its tributaries had any water quality impairments Prior to the release of the draft 2012 Integrated Report's list of impaired water bodies, Bastrop Bayou had not been impaired for elevated bacteria levels. In the 2010 list, Flores and Brushy Bayous were listed as impaired for bacteria. The goal of the WPP at that time was to prevent the bacteria levels from reaching that standard. Now that the three of the segments are above the standard, the goal of this WPP must be stated differently. While the overall outcome should continue to be to lower the bacteria levels, the WPP must now focus on delisting these segments while also maintaining water quality in the unimpaired segments of the watershed. Indicators to measure progress toward these goals are based on primary criteria and secondary indicators. Tracking of milestones and indicators will be conducted by the entity facilitating the implementation at the time progress is accomplished. Tracking will involve analysis of water quality (Section 10.1), accounting of secondary indicators (Section 10.2), and comparison against interim milestones (Section 9).

10.1 Primary Criteria

The primary criteria of measuring success for this WPP will be:

- **Maintaining indicator bacteria concentrations below the contact recreation standard for unimpaired segments; and**

- **Improving water quality impaired segments such that the contact recreation standard can be met and maintained.**

Water quality monitoring data will be key to assessing the progress toward maintaining the contact recreation standard. 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 WPP and the overall quality of Bastrop Bayou and its tributaries. Ambient monitoring through the H-GAC CRP will establish general conditions in the watershed. BMPs will be monitored in specific locations throughout the watershed 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 choose different BMPs, increase the stringency of the BMPs, increase the scale of their implementation, or shorten the timeframe for their implementation.
If the standard changes, the adaptive management process will necessitate updating the WPP accordingly.

10.2 Secondary Indicators

In **Sections 3 and 4**, land use change, load estimation and load reduction targets based on comprehensive watershed modeling efforts are discussed. Due to the specific conditions of the watershed, load reduction targets are based on flow-weighted geomeans rather than non-weighted geomeans. This was deliberately chosen based on the difference between observable ambient conditions and potential NPS loading in storm events. Load reductions were allocated on a subwatershed basis in proportion to the contribution of sources in future conditions (2040 load reduction estimations). The current sources of bacteria, as well as those arising from growth and development in the watershed will be addressed by the recommended BMPs in **Section 5**. As a general evaluative indicator, it is expected that 40% of the scaled BMP implementation will be completed within the first 10 years of the implementation period. This implementation goal represents an approximation of the proportion of the initial ten-year implementation period to the overall implementation period.

To determine the scale of BMP implementation needed, representative BMP units were established (**Appendix D**). For example, pet waste BMPs are scaled based on a representative dog. The dog is assumed to excrete a certain amount, some portion of which is assumed to enter the waterway. The load from this representative dog is divided into the total required load reduction for pet waste from that subwatershed to produce the number of dogs to be managed.

The secondary indicators of progress, therefore, include the number of representative BMP units that are addressed by BMPs. This will include:

- number of cattle (livestock)
- acres or urban area (urban runoff)
- number of dogs (pet waste)
- number of feral hogs
- number of OSSFs

The secondary indicators also include quantifying the number of activities conducted for those BMPs which do not directly address a primary source, but instead affect sources indirectly. These indicators include:

- education/outreach activities conducted
- acres of land acquired or placed under conservation easement
- abandoned boats removed
- trash reduction activities conducted (also, pounds of trash removed)
- enforcement actions taken
- volunteers who take part in activities.

Secondary indicators will be tracked and reported based on the framework of the facilitating entity for implementation. For the foreseeable future, H-GAC is facilitating the stakeholders' efforts in implementing the WPP, including managing grant funded projects. Tracking and reporting is intended to be contained within the required progress reports of these grant projects, tracked by the units or measures specified for each indicator. If roles change in the future, responsibility for tracking and reporting of these indicators will be re-evaluated.

10.3 Adaptive Management Framework

Continual review of intended actions, milestones, and progress indicators is an integral part of this WPP. The ultimate measures of progress for these efforts will be the impact on water quality as shown through decreases in concentrations of indicator bacteria. However, because positive and negative changes in bacteria concentrations may result from factors outside the influence of this WPP (pace of development, economic conditions impact on funding availability, etc) a framework for assessing the success of the WPP is necessary.

Stakeholders will meet at least annually to assess the progress of the WPP, and a formal review will happen at least every five years. They will use a combination of three assessments as the criteria to determine if changes are necessary.

- Water Quality (Primary Criteria) – Stakeholders will review the assessment of Bastrop Bayou and its associated stream segments found in the then-current TCEQ Integrated Report. As appropriate or available, they will use additional water quality data analysis from the Clean Rivers Program as contained in the most current Basin Summary or Basin Highlights Report for the Houston-Galveston Region. The evaluation will focus on whether any change in impairment status has been achieved, or whether a trend in geomeans in the individual segments is apparent.
    - Outcome – In conjunction with the other two assessments, stakeholders will interpret a negative change in water quality as a need for review and change the WPP.

- Review of Timeline, Milestones and Secondary Indicators – Stakeholders will review the overall progress of the WPP in meeting the anticipated timeline, based on expected milestones and secondary indicators. This evaluation will be reviewed for each category of BMPs.
    - Outcome – In conjunction with the other two assessments, stakeholders will interpret delays or lower-than expected numbers for the secondary indicators as a need to review and change the WPP

- Consideration of External Factors – Stakeholders will evaluate, as appropriate, available data concerning growth trends in the area (H-GAC regional population projections, etc.), the then-current ability of the stakeholders to meet committed activities (based on economic conditions), aggravating factors such as expansion of feral hog populations or hydrologic changes in the watershed, ,

- Outcome – In conjunction with the other two assessments, stakeholders will interpret negative change (increase in projected growth, decrease in available or committed funding, and increase in aggravating factors like growing feral hog populations) as a need to review and change the WPP.

Stakeholders will make changes to the WPP based on the adaptive management criteria in the following circumstances:

- If the outcome of the assessments indicates that additional action is needed, stakeholders will meet to discuss potential options, including increasing the scale of implementation activities, or changing old activities out for new solutions, as appropriate to current economic conditions and local decision-making. A WPP amendment will be initiated to account for these modifications.
- If the outcome indicates a positive change, and that no additional action is needed, stakeholders will review the scheduled implementation activities to identify any activities that may be scaled down or delayed. A WPP amendment may be initiated to account for these modifications.
- If no specific trend or need is noted, but individual activities are identified as either more or less successful than anticipated, the stakeholders may elect to change the scale of implementation of individual activities, or replace them. A WPP Amendment may be initiated if these changes are substantial to the balance of activities in the WPP.

11 Effectiveness Monitoring Element I

Due to the dynamic nature of watersheds, some uncertainty is to be expected when a WPP is developed and implemented. As the recommended BMPs of the WPP 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. 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 CRP 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 3**.

The ambient monitoring is conducted under an approved TCEQ QAPP, and the resultant data is submitted to SWQMIS to be used for assessing the water bodies as part of the Integrated Report process. In addition to CRP ambient water quality data, Texas Stream Team volunteers will collect data and observations at sites throughout the watershed. The ambient and volunteer observational data will provide the background to assess the effectiveness of the WPP efforts.

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.

The overall goal of the ambient monitoring is to track the general impact of WPP efforts. However, some factors affecting water quality are beyond the scope of this WPP, including the impact of rapid development of the area, and regional issues such as expanding feral hog populations and changing precipitation patterns. Because ambient results are impacted by all these factors, and not solely by the WPP efforts, the use of ambient data will not portray a precise picture of interim success for the WPP efforts. Interim successes will be measured in part by assumed impacts based on the BMP scaling assumptions, in part by any observable impact on ambient quality in general for the sum of efforts, but also by specific effectiveness monitoring for BMP classes. The interim focus of adaptive management is on the efficiency of the mix of BMPs. Therefore interim successes will be dependent on evaluating and addressing the impact of those BMP classes.

11.1 Ambient Monitoring

Sample Design Rationale

The sample design is utilized to characterize water quality conditions in support of the 305(b)/303(d) Integrated Report 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 stormwater 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, sampling station 18508 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 collecting agency and analytical laboratory can change according when the work is put out for bid by H-GAC. The QAPP must be approved by TCEQ for anyone to conduct the sampling and analysis.

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.

11.2 BMP Effectiveness Monitoring

BMP effectiveness monitoring for this WPP is designed to acquire comparable data representative of bacterial loading during storm events from each type of BMP implemented. Effectiveness monitoring will be conducted under this WPP on three representative BMP installation sites.[70]

The BMPs being implemented under this WPP include categories of BMPs that:

- Have direct spatial connections (livestock management, OSSF management) and can be effectively monitored on a local scale;

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

- Affect more diffuse sources or whose effects are not easily monitored by effectiveness sampling (urban runoff management, education and outreach, dog waste management, deer and feral hog management);
- Are not expected to directly address indicator bacteria levels (illegal dumping, abandoned boats); or that
- Are focused on preventing future sources contamination that does not yet exist and cannot yet be monitored (land management).

Those BMPs that have directly spatial connections allow for meaningful BMP effectiveness sampling in a variety of means. pre- and post-implementation sampling of a specific point, upstream and downstream sampling of a site, sampling of two similar sites with differing BMPs, and combinations thereof.

The effectiveness of the latter three categories will be measured through secondary indicators identified in **Section 10** and as part of general improvements shown in ambient water quality monitoring data.

Upon completion and adoption of this WPP, three planned spatially discrete BMP sites will be monitored as a representative evaluation of whether 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.

11.2.1 OSSF Conversion to Sanitary Sewer – BMP 1

Demi John is pursuing the installation of a sanitary collection system in lieu of individual septic systems. The community is located in a tidal portion of Bastrop Bayou adjacent to a monitoring station, and has an OSSF failure rate as high as 79%. Station 11475 has been monitored by the TCEQ's region office since the early 1980's, and that existing location will be used for the effectiveness monitoring.

Monitoring: Pre-implementation monitoring will include three monitoring events from the most recent historical data[71] prior to implementation. Post-implementation monitoring will also include three monitoring events at the same location. Post-implementation will occur after the sanitary sewer 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.[72]

[71] Demi-John is likely to have installed their system prior to WPP approval and grant funding for additional sampling is secured.
[72] All BMP monitoring will be conducted under a TCEQ/EPA approved QAPP dictating sampling methodology.

11.2.2 Livestock Management Improvement – BMP 2

This monitoring effort will evaluate the impact of cattle-oriented livestock management BMP. Sites will be identified prior to BMP installation, based on coordination with TSSWCB, AgriLife, USDA NRCS, and other agencies involved in developing, funding or promoting agricultural BMP programs, as identified in **Section 5**.

Monitoring: Pre-implementation monitoring will include three wet weather monitoring events at a representative location upstream and downstream of discharge or access from the parcel containing the cattle management BMP. Samples will be collected before the BMP is implemented, 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.

11.2.3 Land Management Improvement – BMP 3

This monitoring effort will evaluate the impact of land management BMP other than the BMP (or collection of BMPs) monitored under the BMP 2 effectiveness sampling. Sites will be identified prior to BMP installation, based on coordination with TSSWCB, AgriLife, USDA NRCS, and other agencies involved in developing, funding or promoting agricultural BMP programs, as identified in **Section 5**.

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 BMP is implemented, 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.

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 will be incorporated as a fourth effectiveness monitoring effort. In the future, if the bacteria load trend continues to increase, it may be determined that more BMP monitoring should occur. As project funding allows, increased monitoring efforts would provide more data to be able to better evaluate the effectiveness of specific BMP types and locations.

11.3 Evaluating BMP Effectiveness

As BMP's are implemented, the monitored sites will be surveyed and background conditions recorded. 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 WPP execution is successful and determine the need for new action or refocusing of existing programs.

If water quality does not meet targets at current monitoring stations (**Figure 3**), activities will be adjusted based on direction from the Stakeholder Group. Measures of success (as referenced in **Section 10**) will be based on both interim water quality conditions and assumption of complete implementation of the WPP and pollutant load reduction by the end of the planning period as outlined in **Sections 3 and 8**. While some of the less complex BMPs 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 not accounted for by land use changes will be tied to the implementation of BMPs 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.

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. It arose from stakeholder concerns about the impacts of growth on water quality as the Houston region continues its robust expansion. At the time, the Bayou and its tributaries were not yet designated as impaired waterways. However, in the last several years, water quality has degraded to the point that there are now three segments in the watershed listed as impaired for elevated bacteria levels. Growth projections and land cover changes are projected to exacerbate this issue, even beyond a short term implementation time frame. While a number of issues can arise from changes in the way we use land in the Bastrop Bayou Watershed, the stakeholders prioritized bacteria as the contaminant of greatest concern. It is expected that other water quality issues evident in the watershed (low dissolved oxygen, high levels of nutrients, sedimentation, etc.) will benefit from the mix of solutions chosen by the stakeholders. Additionally, the stakeholders felt that refuse, illegal dumping, and other debris in the waterway was an important issue to address with this WPP.

While developing this WPP, watershed modeling was used to determine the bacteria contributors in the watershed and their impact on in-stream water quality. To incorporate stakeholder concerns about future growth in this developing watershed, conditions were modeled through an ultimate planning horizon of 2040. The largest current and future sources of impairment are malfunctioning OSSFs, pet waste, and livestock. These sources are among many, however. While these sources have been prioritized by the stakeholders, the implementation of this WPP will seek to address all sources as funding, stakeholder participation, and opportunity allow.

The strategies in this WPP were developed by the watershed’s stakeholders to address these sources of bacteria as part of a coordinated effort. Utilizing the comprehensive mix of voluntary structural and behavioral elements outlined within, the Plan lays out a road map to achieving its stated goals. Funding for implementation of the WPP will rely on a mix of grant funds and local contribution of time and resources. The organizations and interests represented by the diverse stakeholder group will be key partners in these efforts, some of which have already begun during the development of the WPP. The activities, resources, and impact of the activities defined in this WPP are complementary to other ongoing efforts in the watershed, such as the Phase II permit activities of the Brazoria County Stormwater Coalition. The Demi-John community is already moving forward with in transitioning from its failing OSSFs to a new sanitary sewer system;

Brazoria County has worked with H-GAC to install watershed signage and educational kiosks throughout the community; the GLO has created a series of open space conservation easements through its Texas Farm and Ranch Lands Conservation Program; TSSWCB has identified Bastrop Bayou watershed as a priority location for feral hog workshops; and the City of Angleton has installed a dog park with required pet waste disposal. These are just a few examples o the commitment from local partners to the success of this WPP, and example of the integration of its aims with those of other community priorities. As implementation moves forward, the ongoing focus will be on achieving the greatest possible reduction at the most practicable cost. Priority for implementation is given to those projects that address sources prioritized by the stakeholders, in areas with the greatest risk of transmitting bacteria to water bodies.

An ongoing monitoring program 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 BMPs 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 was removed from the Bayou due to coordinated stakeholder action.

Tying it all together is a core focus on education and outreach to the residents of the watershed. Road signs and educational kiosks have already been placed to promote increased awareness and ownership of the community's resource, and additional elements will follow in the coming years.

The stated goal of the Plan is to reduce the concentration of indicator bacteria in Bastrop Bayou and its tributaries below the contact recreation standard, 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 WPP.

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 commitments of its stakeholders that drive the efforts in this WPP.

References

Abroms & Maibach, The effectiveness of mass communication to change public behavior. Annual Review of Public Health. 01/02/2008; 29:219-34.

Agrilife Extension. 2012. Coping with Feral Hogs. Texas A & M University. Available at: http://feralhogs.tamu.edu/. Accessed December, 14th 2012.

Ahmed W., R. Neller, and M. Katouli. 2005. Host species-specific metabolic fingerprint database for Entercocci and *Escheria coli* and its application to identify sources of fecal contamination in surface waters. *Applied and Environmental Microbiology* 71(8): 4461-4468.

AVMA. 2002. *US Pet Ownership and Demographics Source Book*. Schaumburg, IL., Center for Information Management, American Veterinary Association.

Benham, et al. 2006. Modeling bacteria fate and transport in watershed to support TMDLs. Trans. ASABE. 49 (4): 987 – 1002.

Bonta, J., and B. Cleland. 2003. Incorporating natural variability, uncertainty, and risk into water quality evaluations using duration curves. *Journal of American Water Resources Association* 39(6): 1481-1496.

Borel, K. E., Karthikeyan, R., Smith, P. K., Srinivasan, R. 2012. Predicting E. coli concentrations in surface waters using GIS. Journal of Natural and Environmental Science. 3 (1): 19-33.

Boyer, Allison. Reducing Bacteria with Best Management Practices. Delaware Department of Natural Resources and Environmental Control. Available at: http://www.wr.udel.edu/ChristinaTribTeam/Fact%20Sheets/ReducingBacteria_wBMPs.pdf

Carson, C., B. Shear, M. Ellersieck, and A. Asfaw. 2001. Identification of fecal *Escheria coli* from humans and animals by ribotyping. *Applied and Environmental Microbiology* 67(4): 1503-1507.

Charles River Water Authority. 2008. Low Impact Best Management Practice (BMP) Information Sheet. Weston, MA: Charles River Watershed Authority. Available at http://www.crwa.org/projects/peabody_green.html. Accessed December, 2012.

Cleland, B. 2002. TMDL development from the “Bottom Up” – Part II: Using duration curves to connect the pieces. In *National TMDL Science and Policy 2002 – WEF Specialty Conference*. 7-14. Washington, D.C.: America’s Clean Water Foundation.

Doyle, M. and M. Erikson. 2006. Closing the door on the Fecal Coliform assay. *Microbe* 1(4): 162-163.

Hellgren, E. 1997. Biology of feral hogs (*Sus scrofa*) in Texas. In Feral Swine Symposium. College Station, TX: Texas Cooperative Extension Service. Jackson, D. 1993. Stopping rules in principal component analysis: A comparison of heuristical and statistical approaches. *Ecology* 74(8): 2204-2214.

HGAC report, 2005. Bastrop Bayou Watershed Risk Assessment and Protection Strategy prepared for the Galveston Bay Estuary Program, May 2006.

Lesikar, B. 2005. *OWTS 101 : Basics of Onsite Wastewater Treatment Systems*. Chapter 1 Introduction to onsite wastewater treatment systems. 4. College Station, TX.: Texas Cooperative Co-operative Extension. Lockwood. 2005.

NCDC. 2007. Historic Climate Records. Lake Jackson, TX.: National Water Service Forecast Office. Available at: http://www.srh.noaa.gov/ewx/html/cli/monthdaily.htm. Accessed May 9, 2008.

NCDC. 2012. Historic Climate Records. Angleton, TX. Available at: http://gis.ncdc.noaa.gov/map/cdo/?thm=themeAnnual. Accessed: July 30, 2012.

Paul, S., R. Srinivasan, J. Sanabria, P. Haan, S. Muktar, and K. Neimann. 2006. Groupwise modeling study of bacterially impaired watersheds in Texas : Clustering analysis. *Journal of the American Water Resource Association* August: 1017-1031.

PBS&J. 2000. Final Report Predicting Effects of Urban Development on Water Quality in the Cities of New Braunfels, San Marcos, Seguin and Victoria. Chapter 2. 16. Austin, TX.: Guadalupe-Blanco River Authority and Texas Natural Resource Conservation Commission.

Petersen, T., H. Rifai, M. Suarex, and R. Stein. 2005. Bacterial loads from point and nonpoint sources in an urban watershed. *Journal of Environmental Engineering* 131(10): 1414-1425.

Peterson, Jennifer L., Redmon, Larry A., and McFarland, Mark L. Reducing Bacteria with Best Management Practices for Livestock. Texas A&M AgriLife Extension. Available at: http://forages.tamu.edu/pubs.html

Plum Creek Watershed Protection Plan, 2009, Texas A&M Agrilife Extention, Available at: http://pcwp.tamu.edu/WPP.aspx

The Practice of Low Impact Development. July, 2003. U.S. Department of Housing and Urban Development Office of Policy Development and Research Washington, D.C.

Reed, Stowe, & Yanke LLC. 2001. Study to Determine the Magnitude of, and Reasons for Chronically Malfunctioning On-Site Sewage Facility Systems in Texas, pp vi and x.. Austin, TX: Texas On-Site Wastewater Treatment Research Council.

Riebschleager, Kendra Jean (2008). Development and application of the spatially explicit load enrichment calculation tool (select) to determine potential E. coli loads in watersheds. Master's thesis, Texas A&M University. Available electronically from http : / /hdl .handle .net /1969 .1 /ETD -TAMU -2881.

SAS User's Guide: Statistics. Ver. 8. Cary, NC.: SAS Institute, Inc.

Schueler, T. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices. MWCOG. Washington, D.C.

Schueler. 1999. Microbes in urban watershed. *Watershed Protection Techniques* 3(1): 551-600.

Shirmohammadi, A., I. Chaubey, R. Marmel, D, Bosch, R, Munoz-Carpena, C. Dharmasri, A. Sexton, M. Arabi, M. Wolfe, J. Frankenberger, C. Graff, and T. Sohrabi. 2006. Uncertainty in TMDL models. *Transactions of ASABE* 49(4): 1033-1049.

TCEQ. 2005. Overview of surface water quality in Texas : 2004 Water quality inventory and 303(d) List. Austin, TX.: TCEQ. Available at http://www.tceq.state.tx.us/assets/public/compliance/monops/water/04twqi/04_overview.pdf. Accessed May 2, 2008.

TCEQ, 2010. Final Surface Water Quality Standards, Chapter 307 Rule Amendment. Austin, TX: TCEQ. Available at http://www.tceq.texas.gov/assets/public/waterquality/standards/TSWQS2010/TSWQS2010_rule.pdf

TCEQ, 2012. 2012 Guidance for Assessing and Reporting Surface Water Quality in Texas. Austin, TX: TCEQ.

Teague, A., Karthikeyan, R., Babbar-Sebens, M., Srinivasan, R., Persyn, R. A. 2009. Spatially Explicit Load Enrichment Calculation Tool (SELECT) to identify potential E. coli sources in watersheds. Transactions of the ASABE. 52 (4): 1109 – 1120.

The Practice of Low Impact Development. July, 2003. U.S. Department of Housing and Urban Development Office of Policy Development and Research Washington, D.C.

US Census Bureau. Available at: http://www.census.gov/geo/www/tiger/index.html. Accessed on December, 14, 2006.

USDA-NASS. 2002. 2002 Census of agriculture-county data. pp 560-634, 716-718, 719-729, 730-732, 733-734.Washington, D.C.: USDA National Agricultural Statistics Survey.

USDA-NASS. 2007. 2007 Census of agriculture-county data. Available at: http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Texas/. Accessed on July 30, 2012.

USEPA. 1986. Ambient water quality criteria for bacteria. EPA440/5-84-002. pp. 15-16.Washington, D.C.:

USEPA Office of Water Regulations and Standards. USEPA. 1991. Guidance for water quality-based decisions: The TMDL process. EPA440/4-91-001. pp 3-1–3-17. Washington, D.C.:

USEPA Office of Water USEPA. 1996. TMDL development cost estimated : Case studies of 14 TMDLs. EPA841-R/96/001. pp. I-6–I-17. Washington, D.C.: USEPA Office of Water.

UEPA. 1999. Draft guidance for water quality based decisions: The TMDL process. 2nd ed. EPA841-D-99-001. pp. 3-1-3-18. Washington, D.C.: USEPA Office of Water.

USEPA. 2001. Protocol for developing pathogen TMDLs: source assessment. 1st ed. EPA841-R-00-002. pp 5-1 to 5-18. Washington, D.C.:USEPA Office of Water.

USGS. 2002. National Hydrography Dataset. USGS, Reston, VA. Available at http://nhd.usgs.gov/index.html. Accessed on May 4, 2006.

Wagner, K., L. Redmon, T. Gentry, D. Harmel, A. Jones, Environmental Management of Grazing Lands, Texas Water Resources Institute Technical Report TR-334, October 2008.

Weiskel, P., B. Howes, and G. Heufelder. 1996. Coliform contamination and transport pathways. *Environmental Science and Technology* 30(6): 1872-1881.

White-tailed deer population trends. Federal Aid in Fish and Wildlife Restoration. Project. W-127-R-14. Texas Parks and Wildlife Department. Austin TX.

Appendices

Appendix A: Land Cover Characterization and Load Estimation

Load Estimation and Modeling to Evaluate Water Quality Impairments

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 of the Integrated Report). Contamination from fecal bacteria is one of the most significant impairments for Texas waterways (TCEQ, 2005). *E. coli* and Enterococcus are used as the indicator organisms for pathogens from fecal contamination (USEPA, 1986) in fresh and saline environments, respectively. The Texas Commission on Environmental Quality (TCEQ) sets an *E. coli* limit of a geometric mean of 126 CFU[73]/100 mL (TCEQ, 2012). The Enterococcus limit is set at a geomean of 35 CFU/100ml. As bacteria is the focus of this WPP, the modeling efforts centered on these indicators.

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.

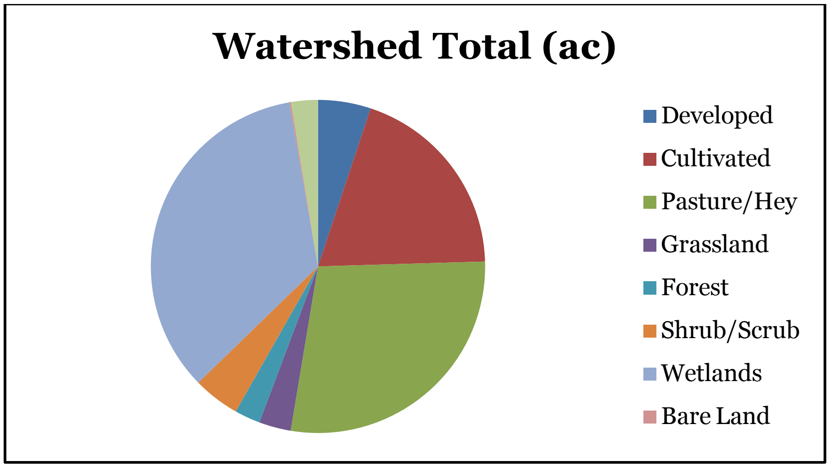
The EPA recommends characterizing nonpoint sources by multiplying an individual species' excretion rate by corresponding species' population (USEPA, 2001). Then the estimates of nonpoint sources are combined with calculated point source contributions. Previous efforts have automated this non-spatial 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 figures and tables in this appendix represent the characterization of land cover and load potential estimation derived from the SELECT model, as described in **Section 3**.

[73] For the purpose of this discussion, CFU and MPN are used interchangeably, although the Plan recognizes that these two methods are different and have differing levels of precision.

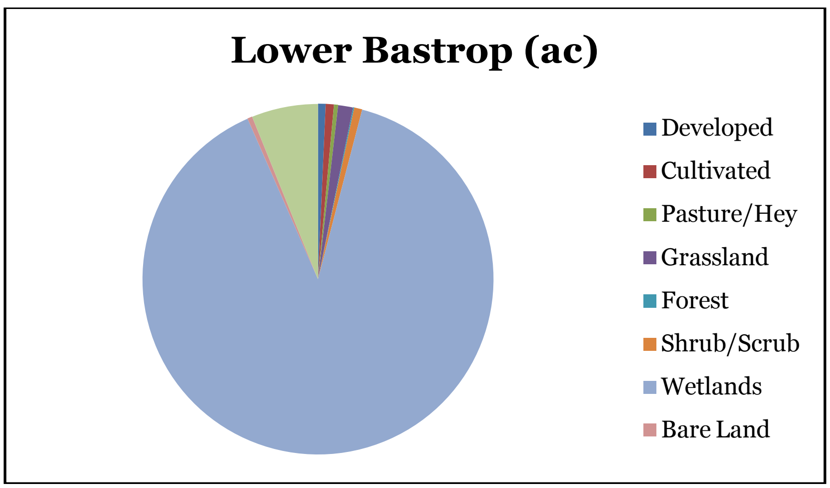
Land Use/Land Cover

These figures and tables represent the breakdown of land use/land cover for the watershed and each of its component subwatersheds.



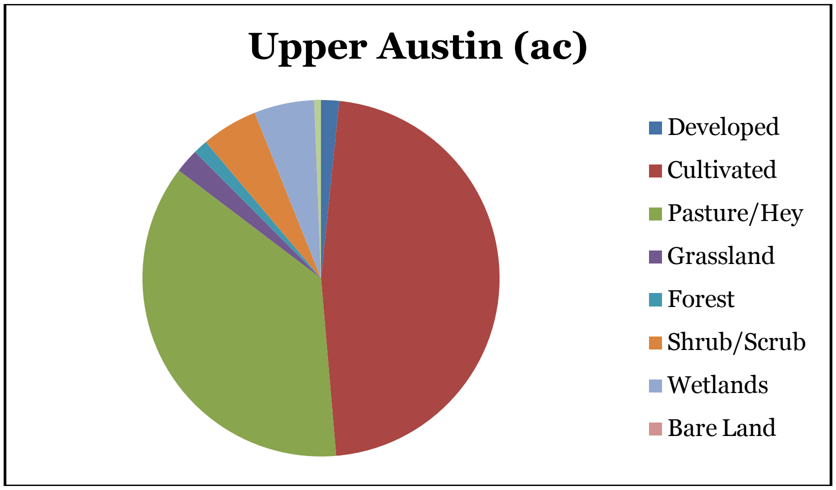
LC types	Watershed Total (ac)
Developed	7116.21
Cultivated	27026.13
Pasture/Hey	39087.71
Grassland	4304.64
Forest	3462.20
Shrub/Scrub	6295.35
Wetlands	48050.20
Bare Land	219.55
Water	3604.63

Figure A1: Land Use/Land Cover – Watershed Total



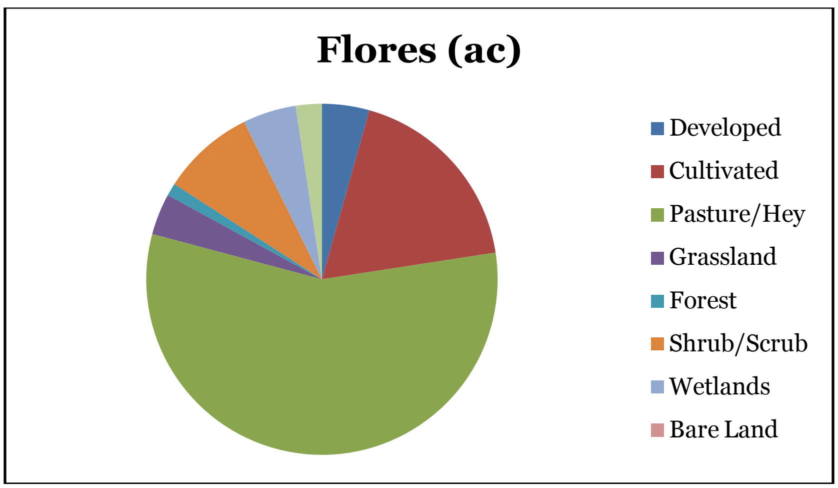
LC types	Lower Bastrop (ac)
Developed	193.00
Cultivated	208.19
Pasture/Hey	105.80
Grassland	377.60
Forest	29.32
Shrub/Scrub	204.21
Wetlands	24615.68
Bare Land	124.41
Water	1689.04

Figure A2: Land Use/Land Cover – Lower Bastrop



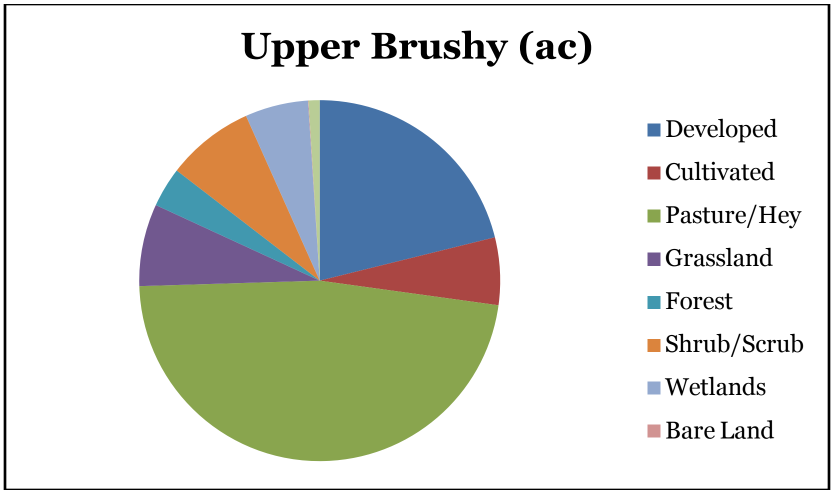
LC types	Upper Austin (ac)
Developed	595.48
Cultivated	17058.16
Pasture/Hey	13310.57
Grassland	798.10
Forest	473.93
Shrub/Scrub	1850.89
Wetlands	1980.94
Bare Land	6.23
Water	217.18

Figure A3: Land Use/Land Cover – Upper Austin



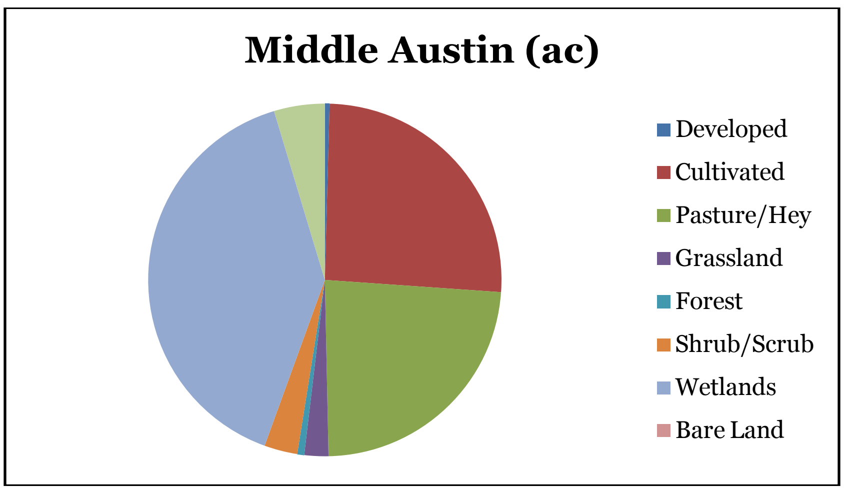
LC types	Flores (ac)
Developed	677.78
Cultivated	2827.85
Pasture/Hey	8787.11
Grassland	590.36
Forest	180.20
Shrub/Scrub	1331.97
Wetlands	761.04
Bare Land	2.67
Water	371.74

Figure A4: Land Use/Land Cover – Flores



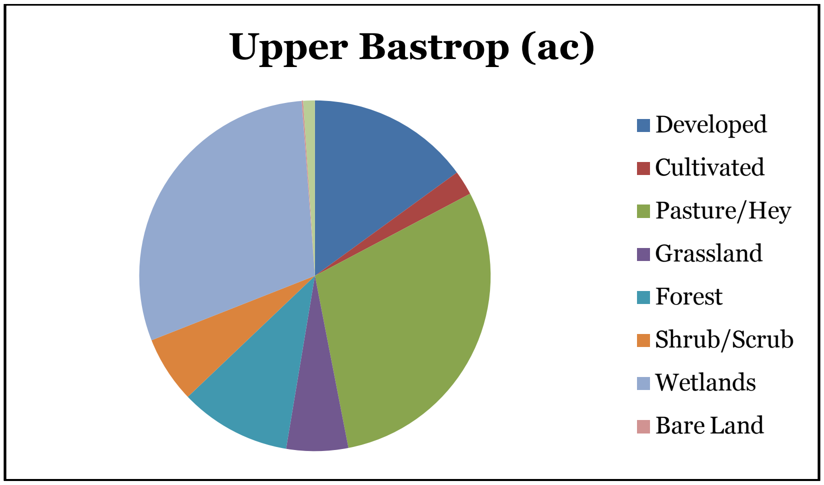
LC types	Upper Brushy (ac)
Developed	2133.29
Cultivated	609.72
Pasture/Hey	4777.09
Grassland	743.22
Forest	360.42
Shrub/Scrub	793.11
Wetlands	570.82
Bare Land	4.89
Water	99.92

Figure A5: Land Use/Land Cover – Watershed Total



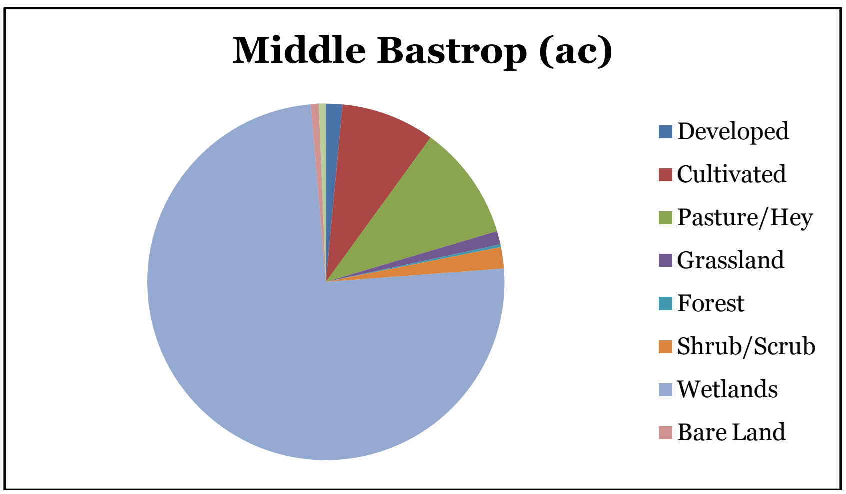
LC types	Middle Austin (ac)
Developed	87.99
Cultivated	5199.93
Pasture/Hey	4773.49
Grassland	446.03
Forest	129.06
Shrub/Scrub	616.28
Wetlands	8061.53
Bare Land	1.11
Water	942.24

Figure A6: Land Use/Land Cover – Middle Austin



LC types	Upper Bastrop (ac)
Developed	3319.45
Cultivated	501.80
Pasture/Hey	6572.77
Grassland	1260.07
Forest	2271.87
Shrub/Scrub	1357.52
Wetlands	6593.67
Bare Land	28.46
Water	237.90

Figure A7: Land Use/Land Cover – Upper Bastrop



LC types	Middle Bastrop (ac)
Developed	109.22
Cultivated	620.47
Pasture/Hey	760.88
Grassland	89.27
Forest	17.41
Shrub/Scrub	141.37
Wetlands	5466.53
Bare Land	51.78
Water	46.62

Figure A8: Land Use/Land Cover – Middle Bastrop

Load Estimation by Source

The following figures and tables represent the load estimates developed by the SELECT model for each primary source, using the buffered methodology. Each set of data indicates the relative contribution of source-specific load from each subwatershed, the change in total source-specific load between 2012 and 2040, and the total loads by subwatershed between 2012 and 2040. The map figures are a spatial depiction of load using a granular level analysis. Please note that the livestock loading figures are inclusive of the loads from cattle, horses, and sheep and goats combined. Additionally, the deer and feral hog loading figures are inclusive of the loads from feral hogs and deer. The separate load estimations for the component sources are also included for reference.

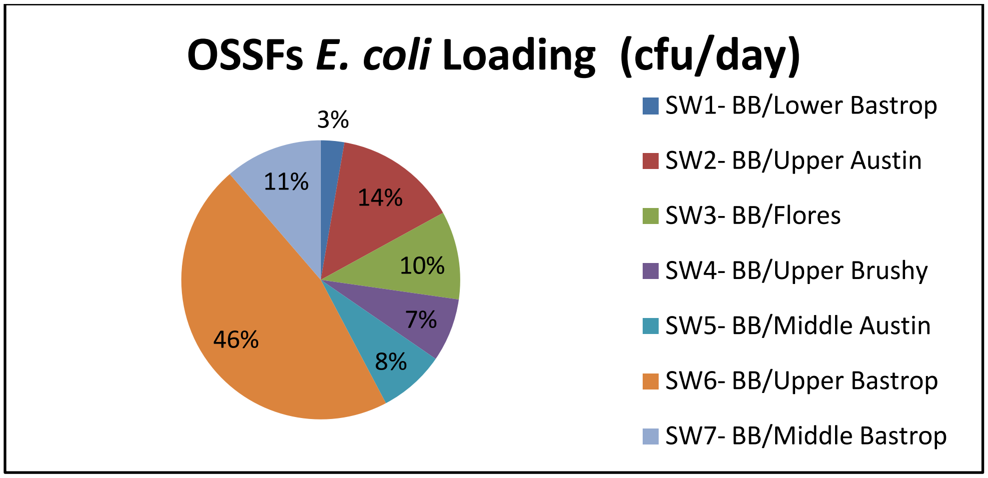


Figure A9: Relative Contribution to E. coli Loading - OSSFs

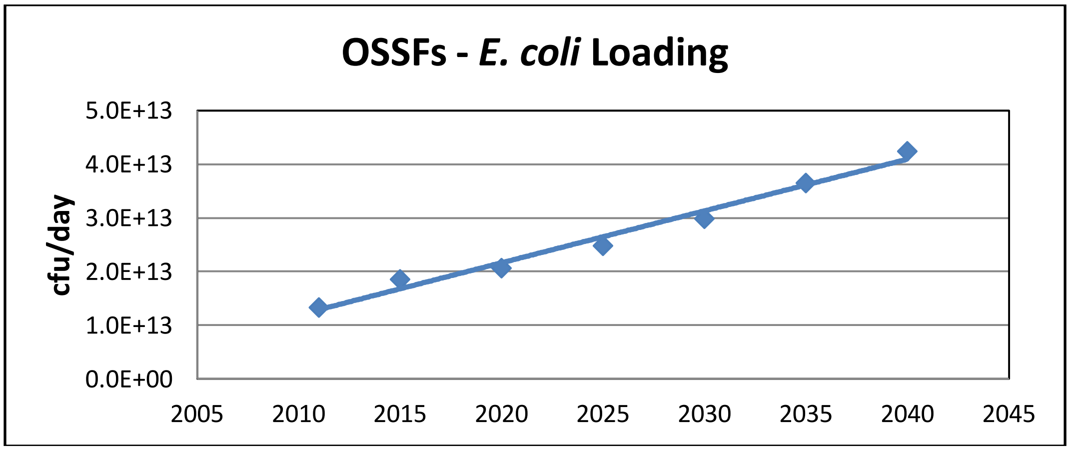


Figure A10: E. coli Source Loading (2012-2040) - OSSFs

Table A1: E. coli Source Loads by Subwatershed - OSSFs

OSSFs *E. coli* Loading (in 10^9 CFU/day)							
SUBWATERSHED	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	363	639	818	1,340	1,910	2,580	3,120
SW2- BB/Upper Austin	1,910	2,620	2,940	3,460	4,110	5,100	5,780
SW3- BB/Flores	1,360	1,640	1,860	2,190	2,970	3,620	4,170
SW4- BB/Upper Brushy	978	1,480	1,670	1,880	2,170	2,400	2,540
SW5- BB/Middle Austin	1,020	1,250	1,400	1,930	2,960	3,480	4,130
SW6- BB/Upper Bastrop	6,190	8,810	9,480	10,800	11,800	14,500	17,300
SW7- BB/Middle Bastrop	1,510	2,120	2,500	3,190	3,970	4,810	5,350
TOTAL	**13,300**	**18,600**	**20,700**	**24,800**	**29,900**	**36,500**	**42,400**
Contribution to the total	37.51%	43.87%	46.16%	50.08%	53.87%	57.77%	60.55%

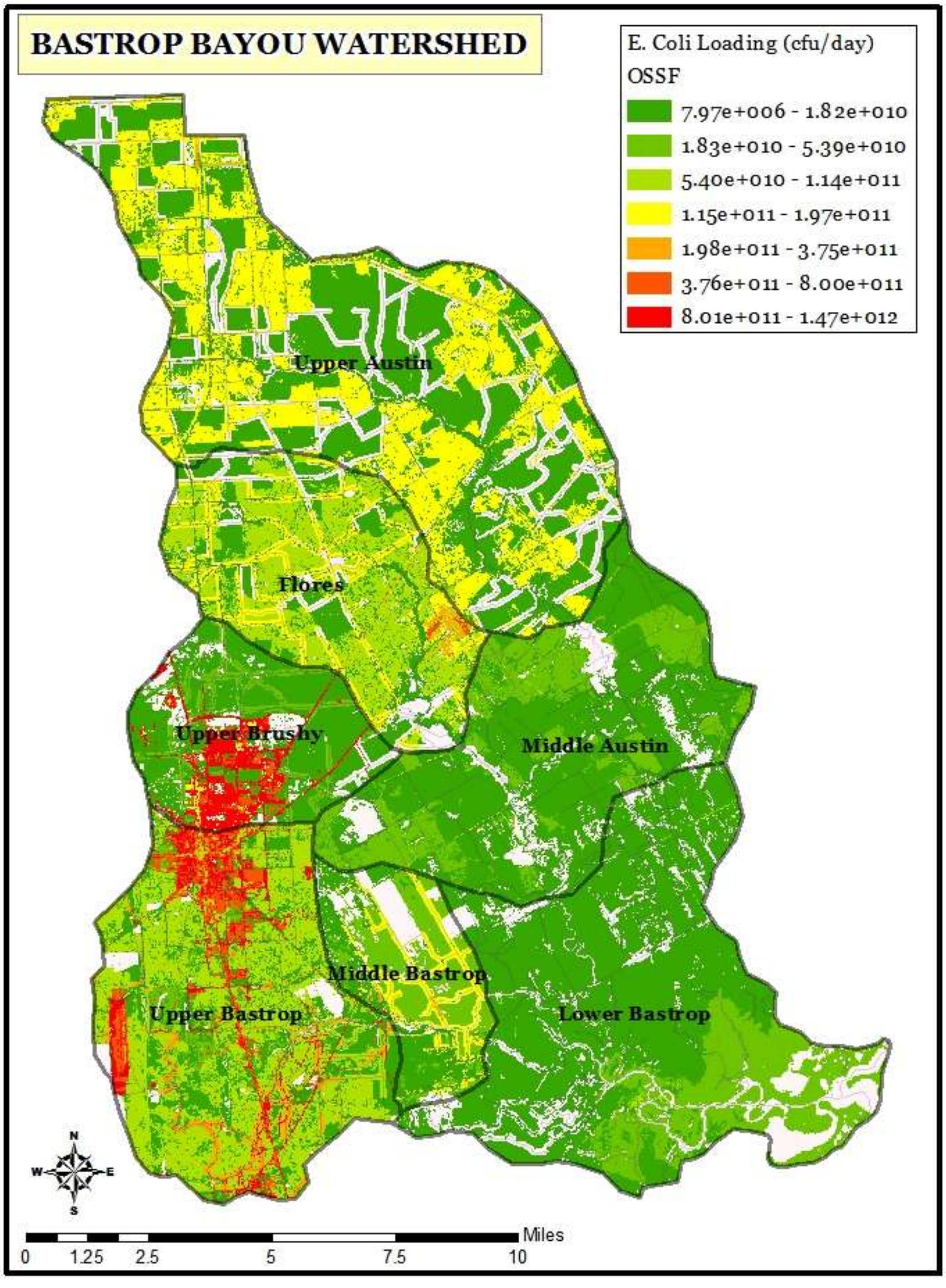


Figure A11: Granular Spatial Loading Characterization - OSSFs

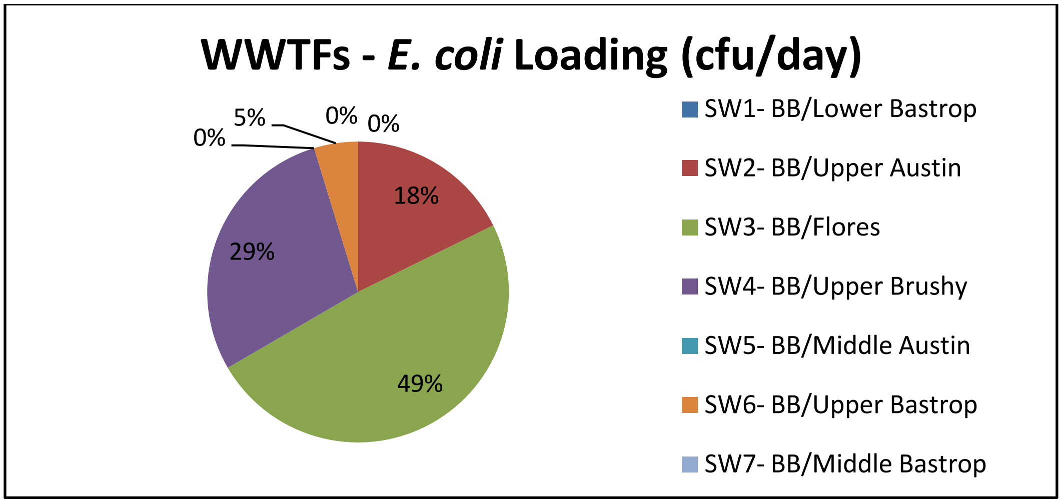


Figure A12: Relative Contribution to E. coli Loading - WWTFs

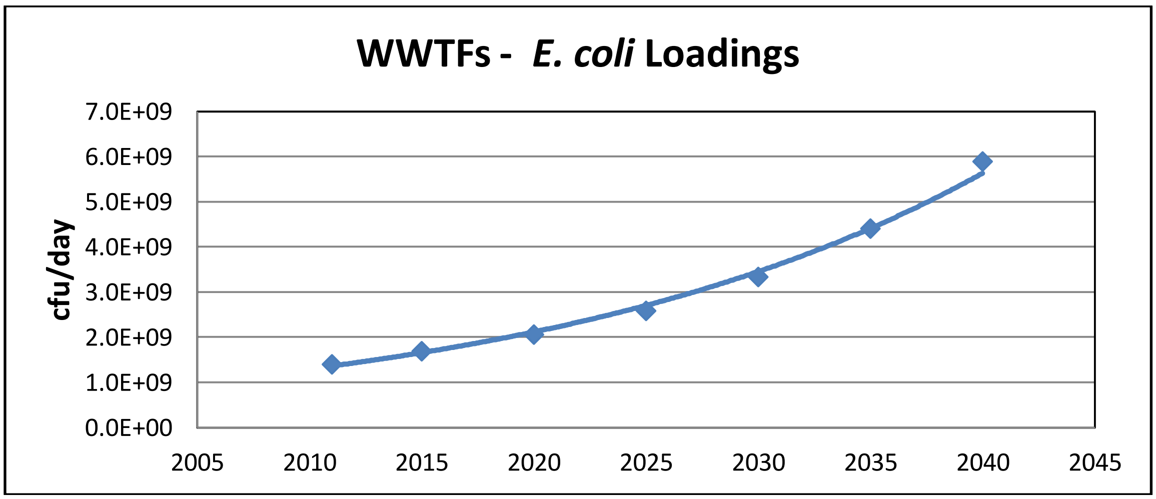


Figure A13: Source Loading (2012-2040) - WWTFs

Table A2: E. coli Source Loads by Subwatershed - WWTFs

WWTF *E. coli* Loading (in 10^9 CFU/day)							
SUBWATERSHED	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	0	0	0	0	0	0	0
SW2- BB/Upper Austin	0.249	0.348	0.486	0.708	1.04	1.52	2.23
SW3- BB/Flores	0.687	0.780	0.887	1.03	1.25	1.55	1.92
SW4- BB/Upper Brushy	0.403	0.489	0.599	0.738	0.917	1.17	1.50
SW5- BB/Middle Austin	0	0	0	0	0	0	0
SW6- BB/Upper Bastrop	0.0663	0.0772	0.0909	0.110	0.136	0.177	0.237
SW7- BB/Middle Bastrop	0	0	0	0	0	0	0
TOTAL	**1.40**	**1.69**	**2.06**	**2.59**	**3.34**	**4.41**	**5.90**
Contribution to the total	0.00%	0.00%	0.00%	0.01%	0.01%	0.01%	0.01%

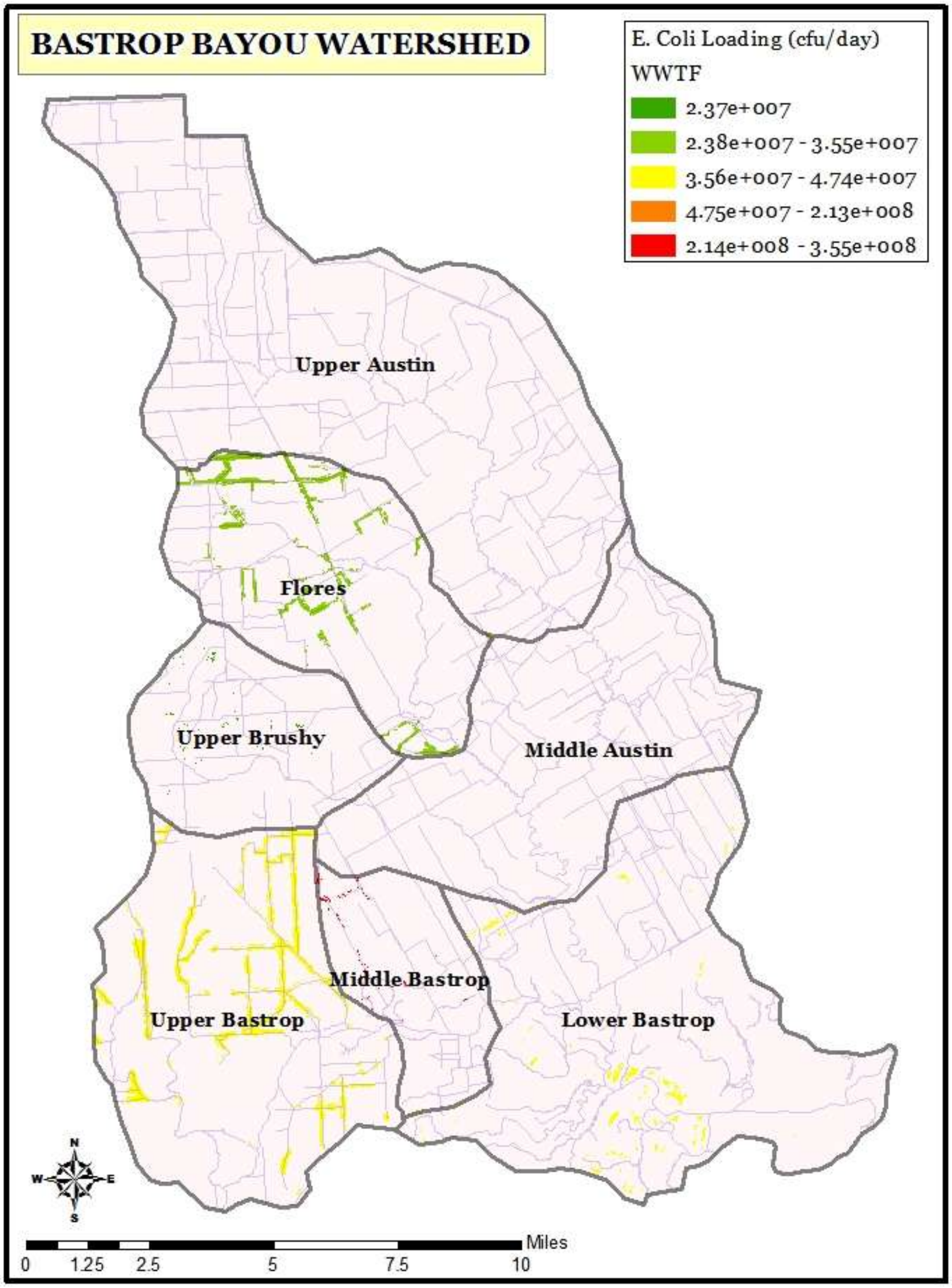


Figure A14: Granular Spatial Loading Characterization - WWTFs

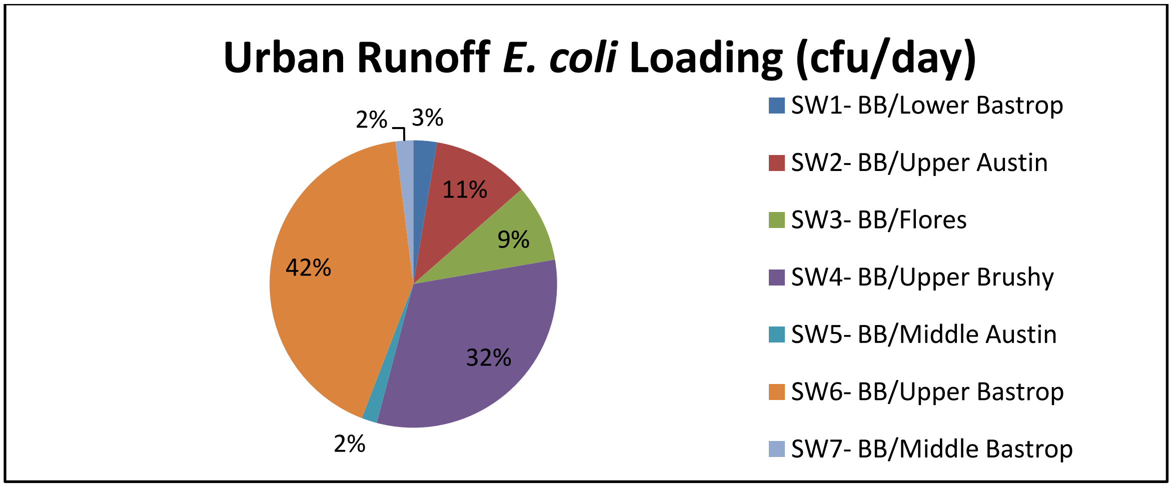


Figure 37: Relative Contribution to E. coli Loading – Urban Runoff

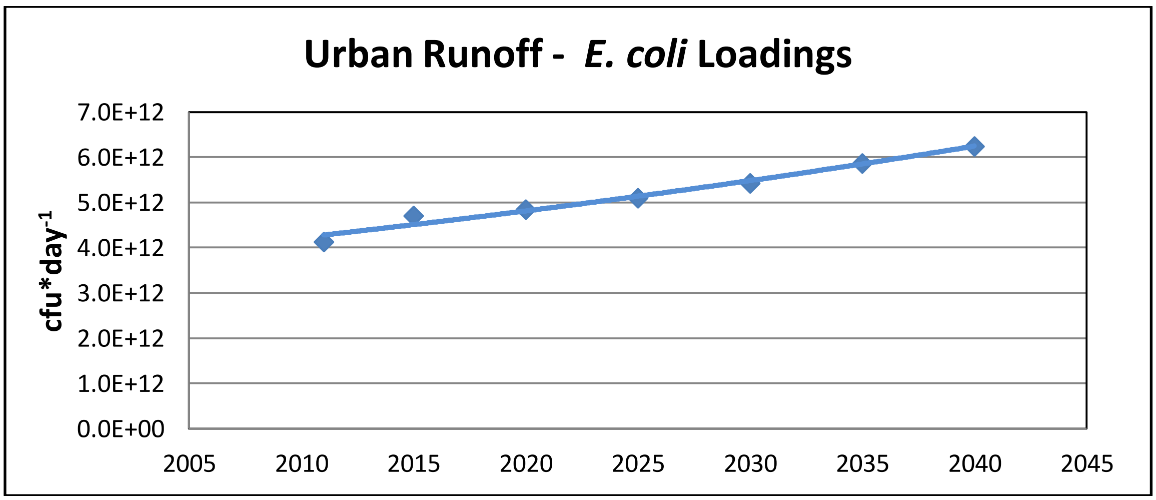


Figure A15: Source Loading (2012-2040) – Urban Runoff

Table A3: E. coli Source Loads by Subwatershed – Urban Runoff

Urban Runoff *E. coli* Loading (in 10^9 CFU/day)							
SUBWATERSHED	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	109	131	145	179	222	266	304
SW2- BB/Upper Austin	451	497	517	548	589	653	698
SW3- BB/Flores	361	388	403	425	483	529	568
SW4- BB/Upper Brushy	1,310	1,510	1,530	1,540	1,560	1,600	1,630
SW5- BB/Middle Austin	71.8	86.9	96.3	129	194	227	269
SW6- BB/Upper Bastrop	1,740	1,980	2,030	2,130	2,200	2,380	2,550
SW7- BB/Middle Bastrop	82.5	113	129	152	179	211	229
TOTAL	**4,130**	**4,710**	**4,850**	**5,100**	**5,430**	**5,870**	**6,240**
Contribution to the total	11.62%	11.12%	10.83%	10.29%	9.79%	9.28%	8.91%

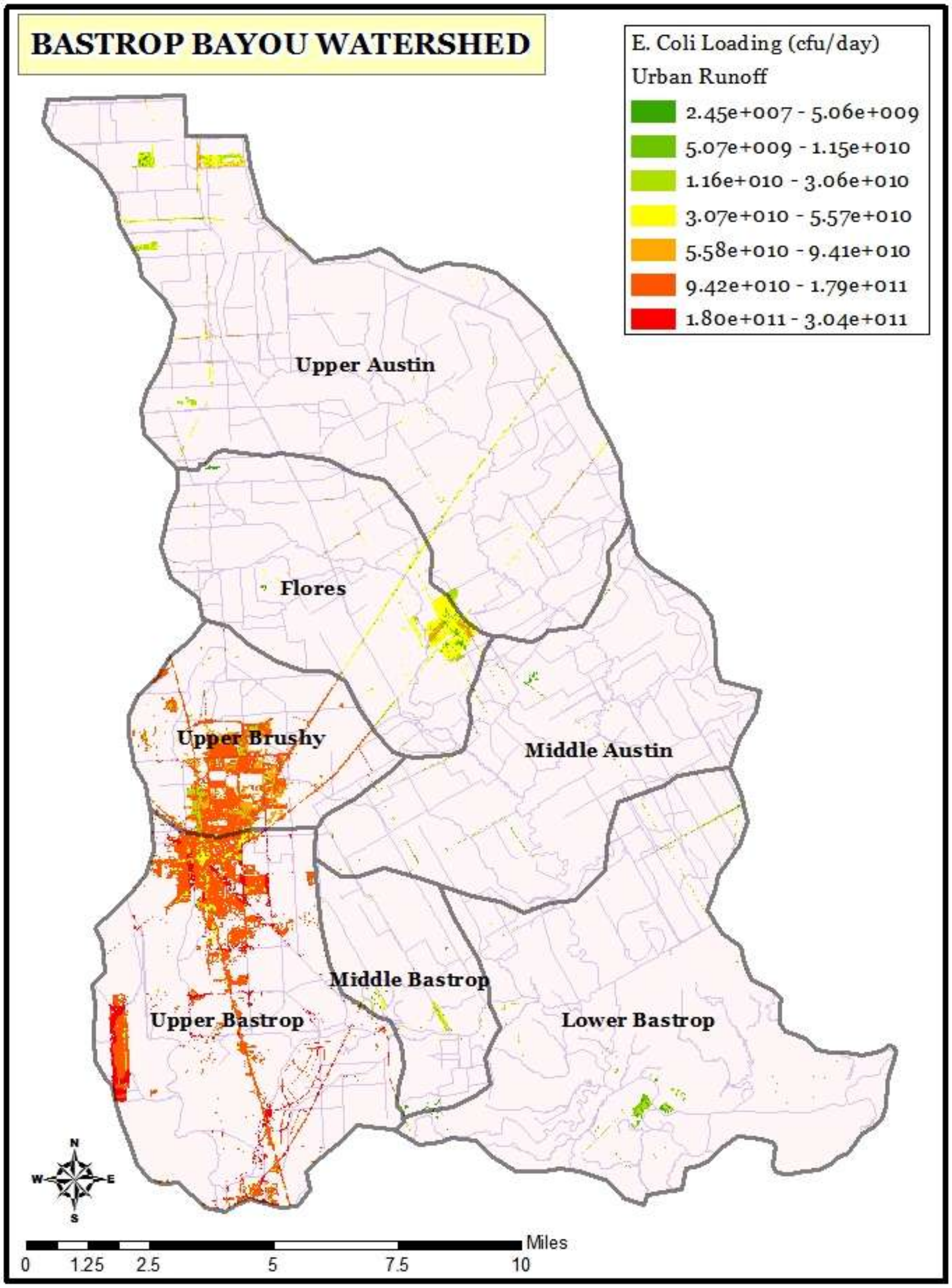


Figure A16: Granular Spatial Loading Characterization - Urban Runoff

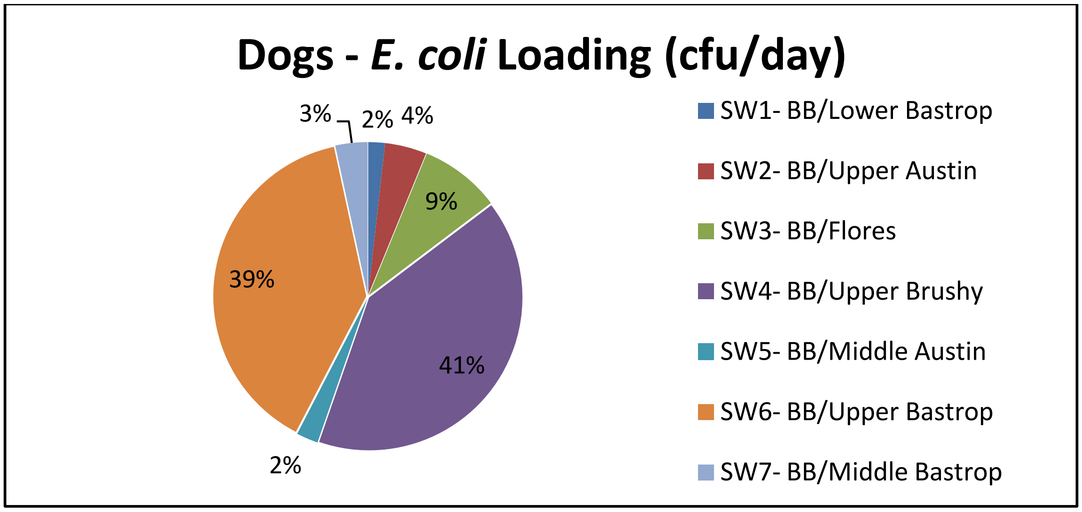


Figure A17: Relative Contribution to E. coli Loading - Dogs

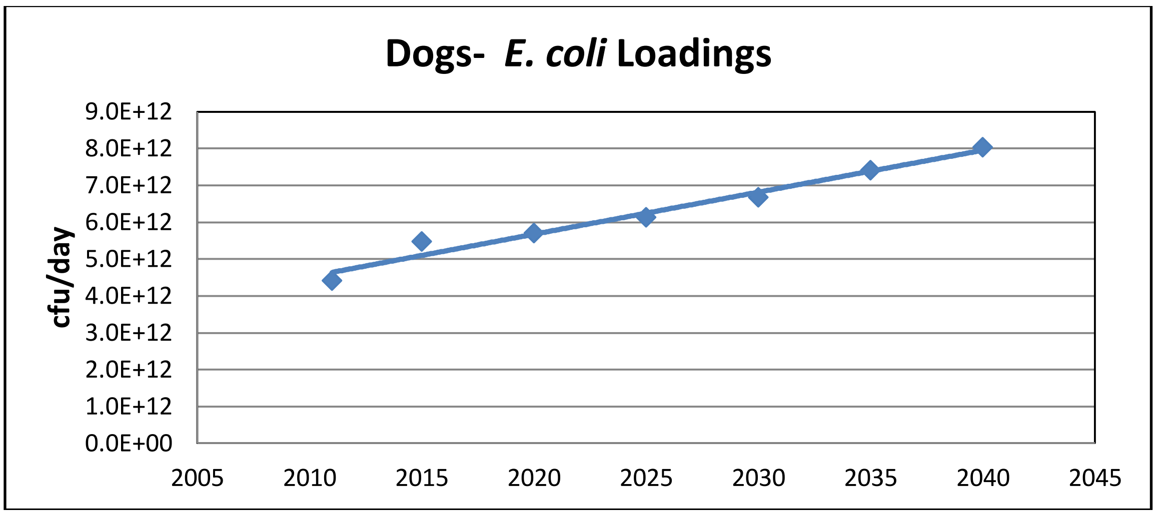


Figure A18: Source Loading (2012-2040) – Dogs

Table A4: E. coli Source Loads by Subwatershed - Dogs

Dogs E. *coli* Loading (in 10^9 CFU/day)							
SUBWATERSHED	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	78.0	117	139	194	264	335	397
SW2- BB/Upper Austin	194	269	302	353	420	524	597
SW3- BB/Flores	376	438	463	503	599	676	741
SW4- BB/Upper Brushy	1,790	2,160	2,190	2,220	2,260	2,330	2,370
SW5- BB/Middle Austin	102	126	142	196	303	356	425
SW6- BB/Upper Bastrop	1,720	2,160	2,240	2,400	2,520	2,820	3,110
SW7- BB/Middle Bastrop	150	199	225	263	306	358	387
TOTAL	**4,410**	**5,470**	**5,700**	**6,130**	**6,670**	**7,400**	**8,030**
Contribution to the total	12.40%	12.92%	12.73%	12.36%	12.03%	11.71%	11.46%

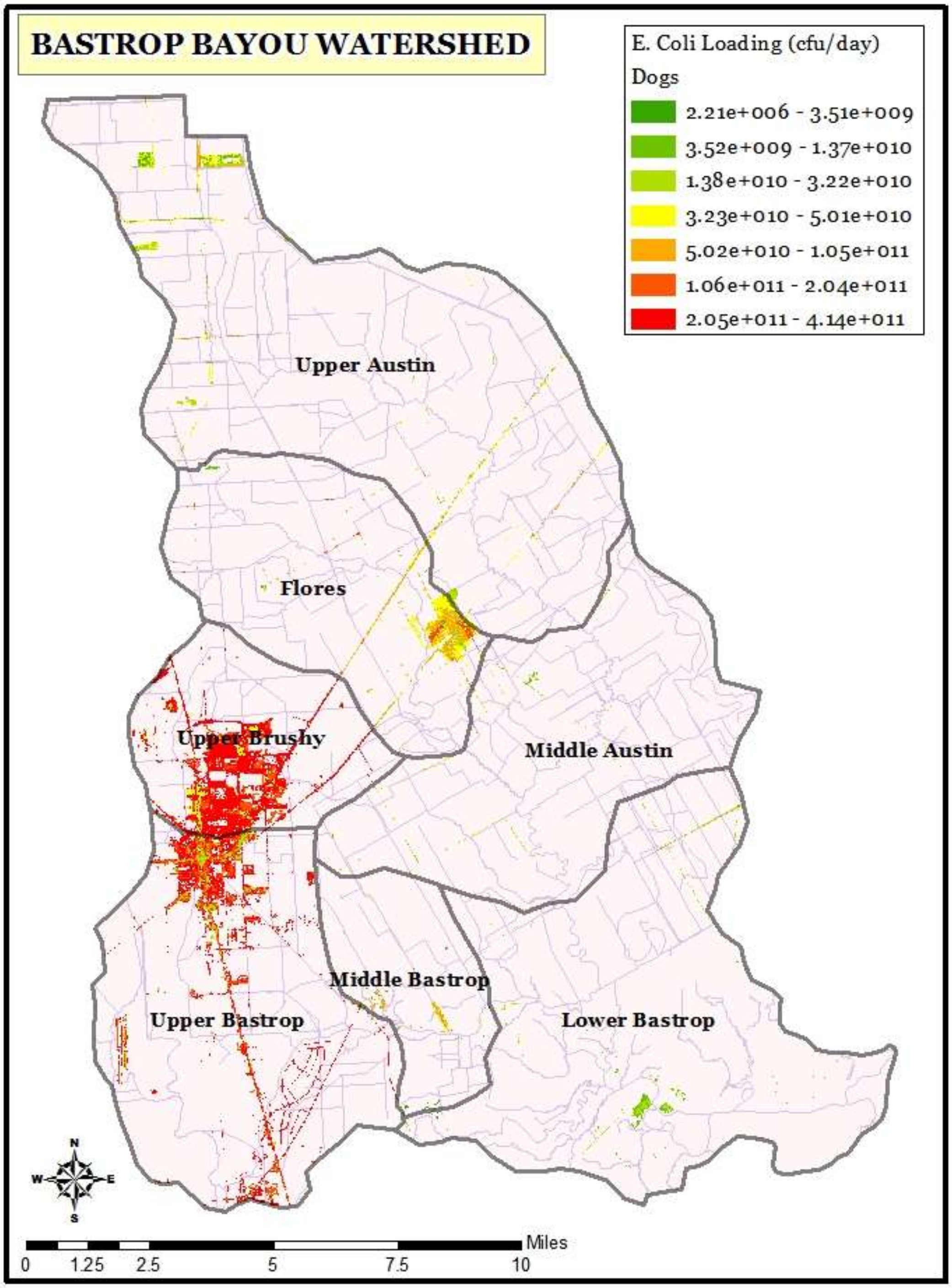


Figure A19: Granular Spatial Loading Characterization - Dogs

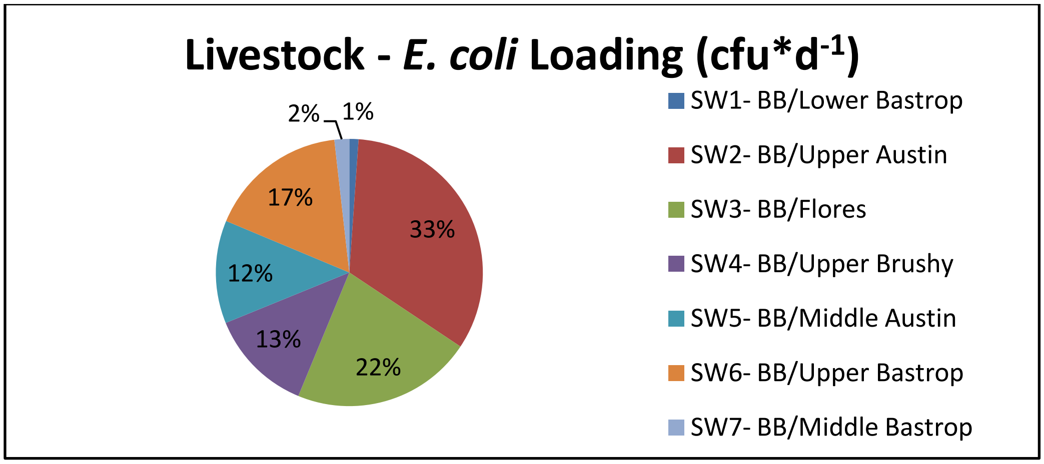


Figure 43: Relative Contribution to E. coli Loading - Livestock

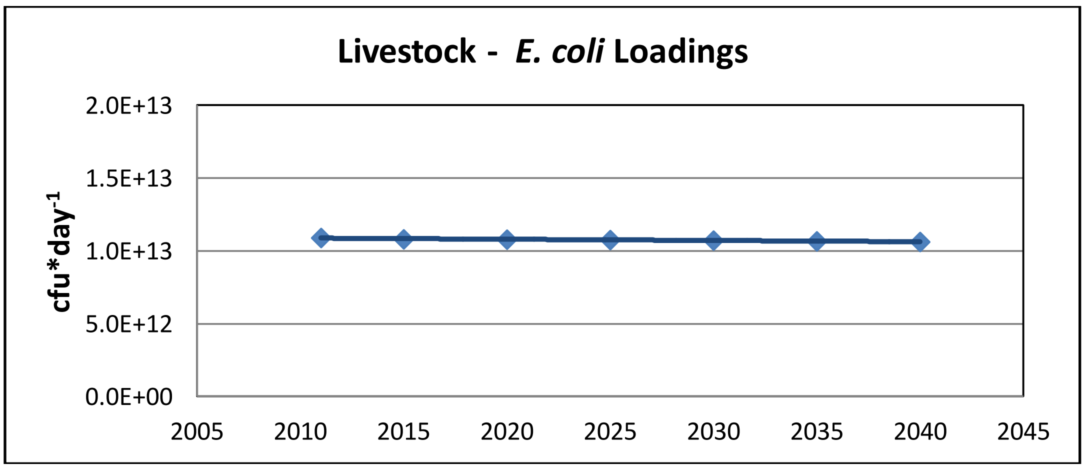


Figure A20: Source Loading (2012-2040) - Livestock

Table A5: E. coli Source Loads by Subwatershed - Livestock

Livestock *E. coli* Loading (in 10^9 CFU/day)							
SUBWATERSHED	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	120	119	119	118	117	115	114
SW2- BB/Upper Austin	3,630	3,620	3,620	3,610	3,610	3,600	3,590
SW3- BB/Flores	2,380	2,380	2,380	2,370	2,360	2,360	2,350
SW4- BB/Upper Brushy	1,370	1,330	1,330	1,330	1,320	1,320	1,310
SW5- BB/Middle Austin	1,360	1,360	1,360	1,360	1,350	1,350	1,340
SW6- BB/Upper Bastrop	1,840	1,810	1,800	1,790	1,780	1,760	1,730
SW7- BB/Middle Bastrop	195	194	193	191	190	187	187
TOTAL	**10,900**	**10,800**	**10,800**	**10,800**	**10,700**	**10,700**	**10,600**
Contribution to the total	30.67%	25.55%	24.12%	21.72%	19.36%	16.90%	15.18%

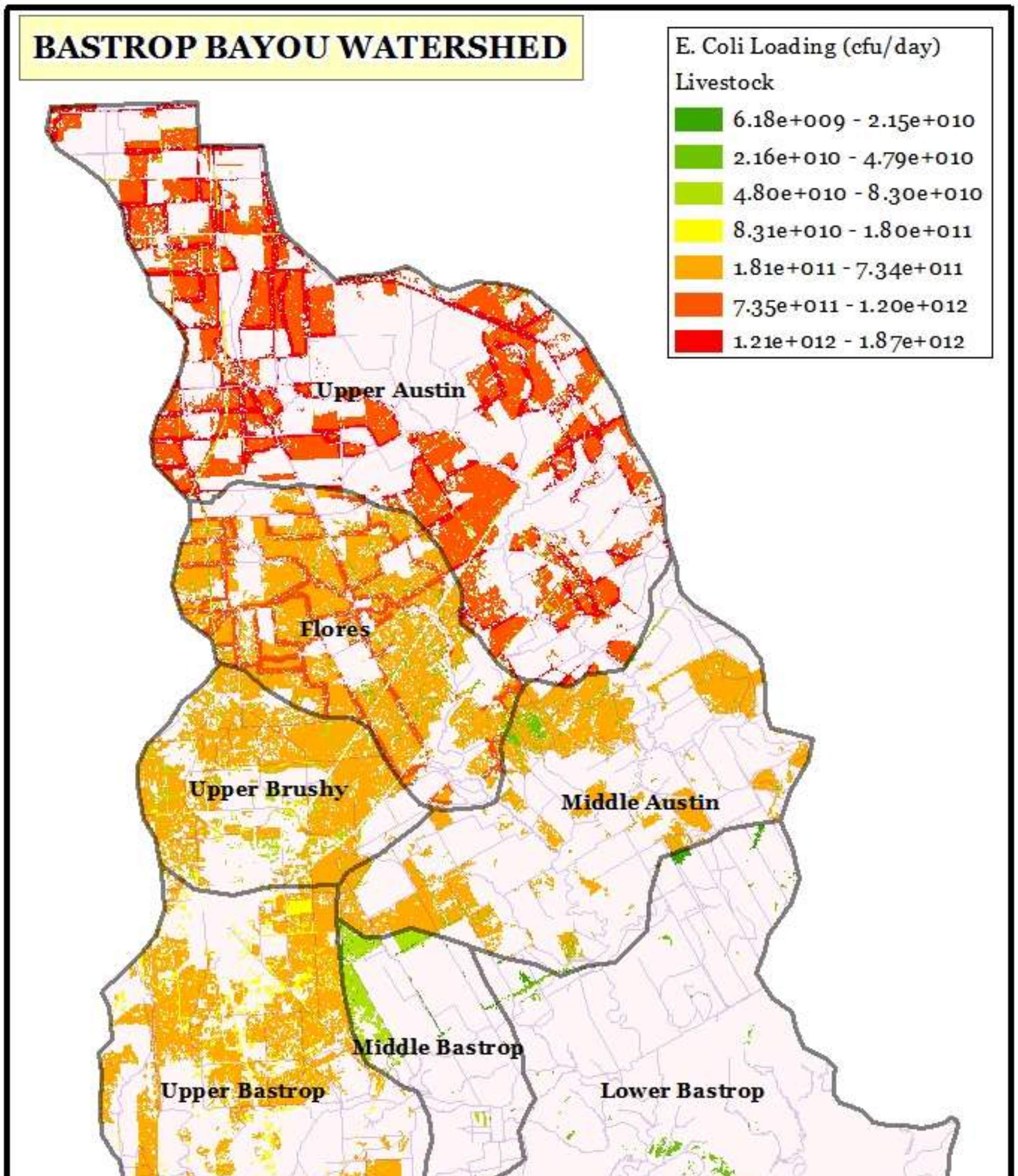


Figure A21: Granular Spatial Loading Characterization - Livestock

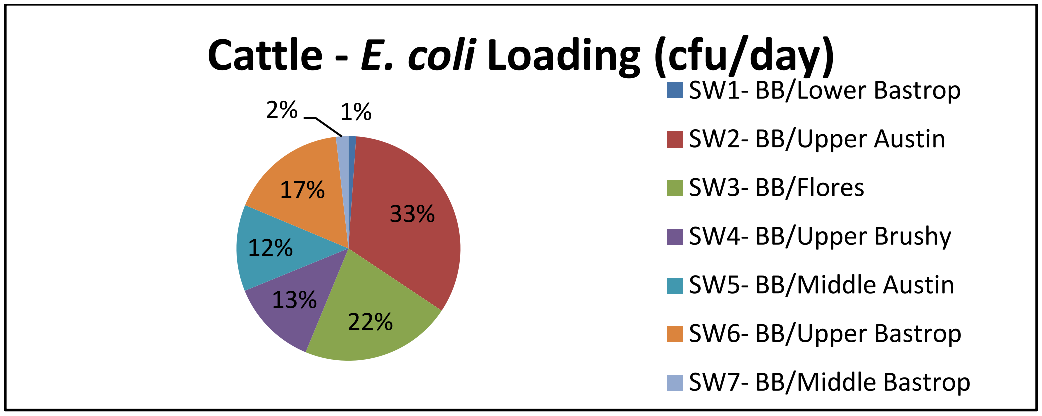


Figure A22: Relative Contribution to E. coli Loading - Cattle

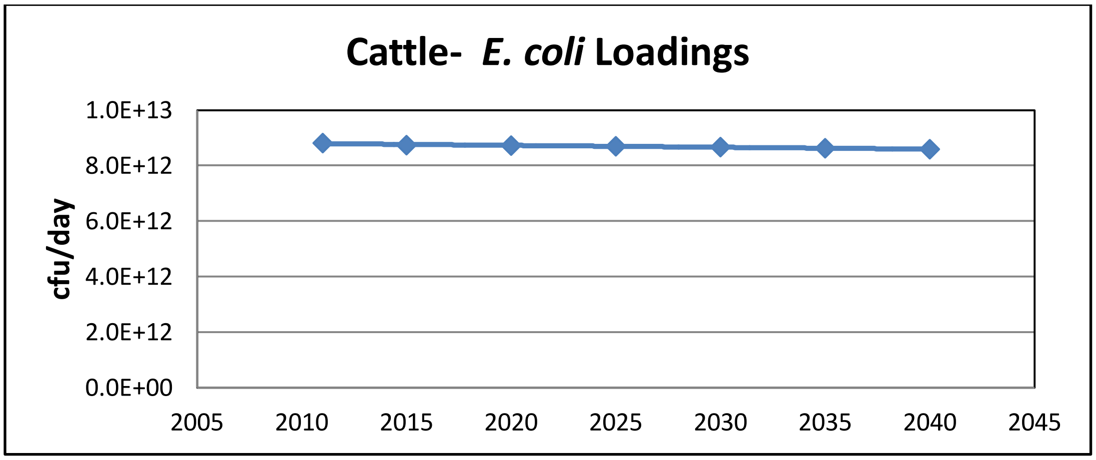


Figure A23: Source Loading (2012-2040) - Cattle

Table A6: E. coli Source Loads by Subwatershed - Cattle

Cattle *E. coli* Loading (in 10^9 CFU/day)							
SUBWATERSHED	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	97.3	96.2	95.9	95.0	94.1	93.0	91.9
SW2- BB/Upper Austin	2,930	2,930	2,920	2,920	2,910	2,910	2,900
SW3- BB/Flores	1,930	1,920	1,920	1,920	1,910	1,900	1,900
SW4- BB/Upper Brushy	1,110	1,080	1,070	1,070	1,070	1,060	1,060
SW5- BB/Middle Austin	1,100	1,100	1,100	1,100	1,090	1,090	1,090
SW6- BB/Upper Bastrop	1,490	1,460	1,450	1,440	1,440	1,420	1,400
SW7- BB/Middle Bastrop	158	157	156	155	153	151	151
TOTAL	8,810	8,740	8,720	8,700	8,670	8,630	8,590
Contribution to the total	24.78%	20.64%	19.48%	17.54%	15.64%	13.65%	12.26%

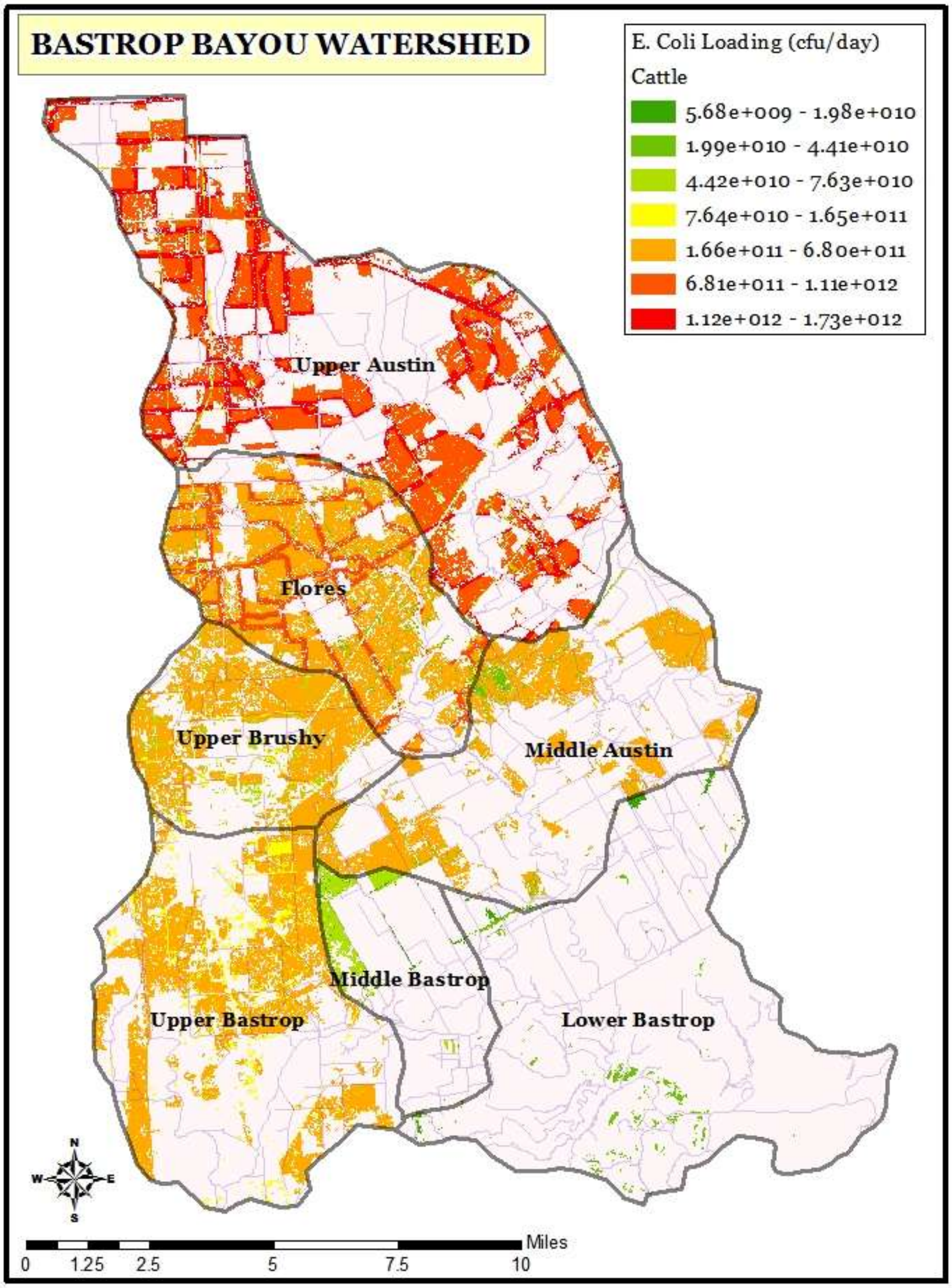


Figure A24: Granular Spatial Loading Characterization - Cattle

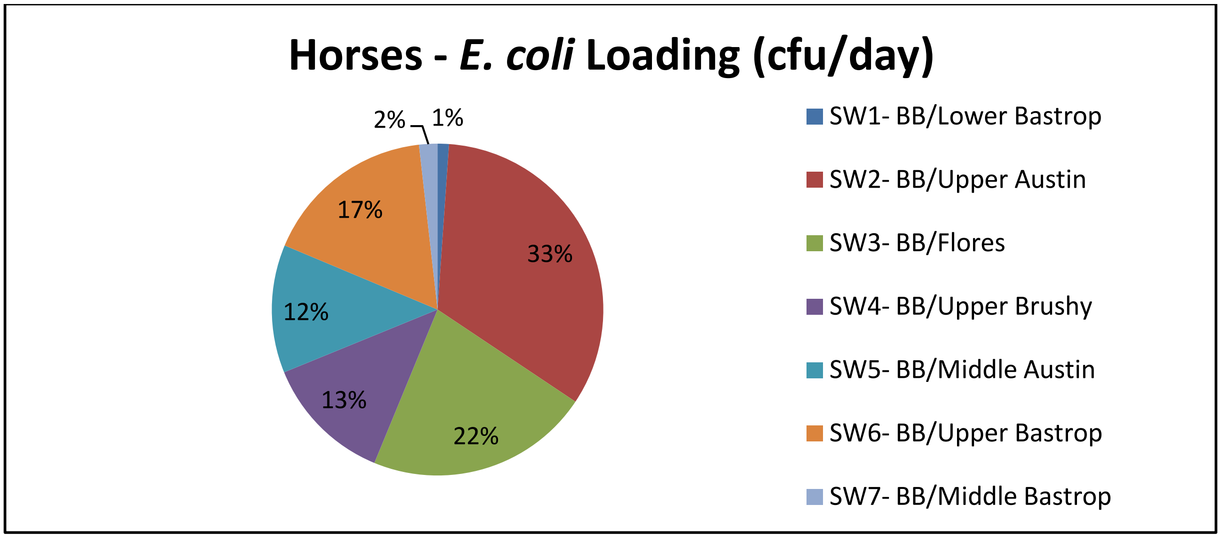


Figure A25: Relative Contribution to E. coli Loading - Horses

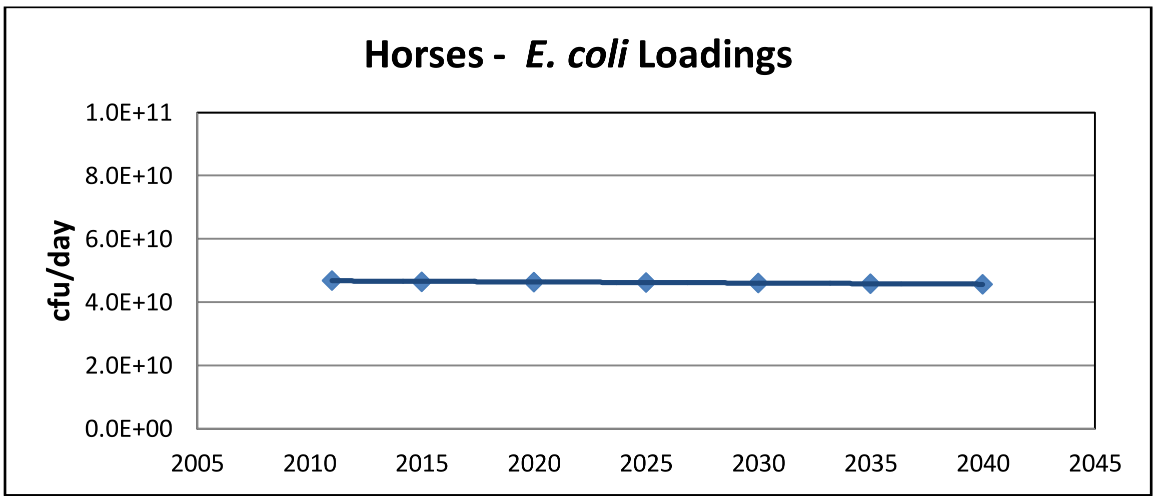


Figure A26: Source Loading (2012-2040) - Horses

Table A7: E. coli Source Loads by Subwatershed - Horses

Horses *E. coli* Loading (in 10^9 CFU/day)							
SUBWATERSHED	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	0.517	0.511	0.510	0.505	0.500	0.494	0.488
SW2- BB/Upper Austin	15.6	15.5	15.5	15.5	15.5	15.5	15.4
SW3- BB/Flores	10.2	10.2	10.2	10.2	10.1	10.1	10.1
SW4- BB/Upper Brushy	5.90	5.73	5.71	5.70	5.68	5.65	5.63
SW5- BB/Middle Austin	5.85	5.84	5.83	5.82	5.80	5.78	5.77
SW6- BB/Upper Bastrop	7.91	7.75	7.72	7.67	7.63	7.53	7.45
SW7- BB/Middle Bastrop	0.839	0.834	0.830	0.821	0.814	0.805	0.801
TOTAL	**46.8**	**46.4**	**46.3**	**46.2**	**46.1**	**45.8**	**45.6**
Contribution to the total	0.13%	0.11%	0.10%	0.09%	0.08%	0.07%	0.07%

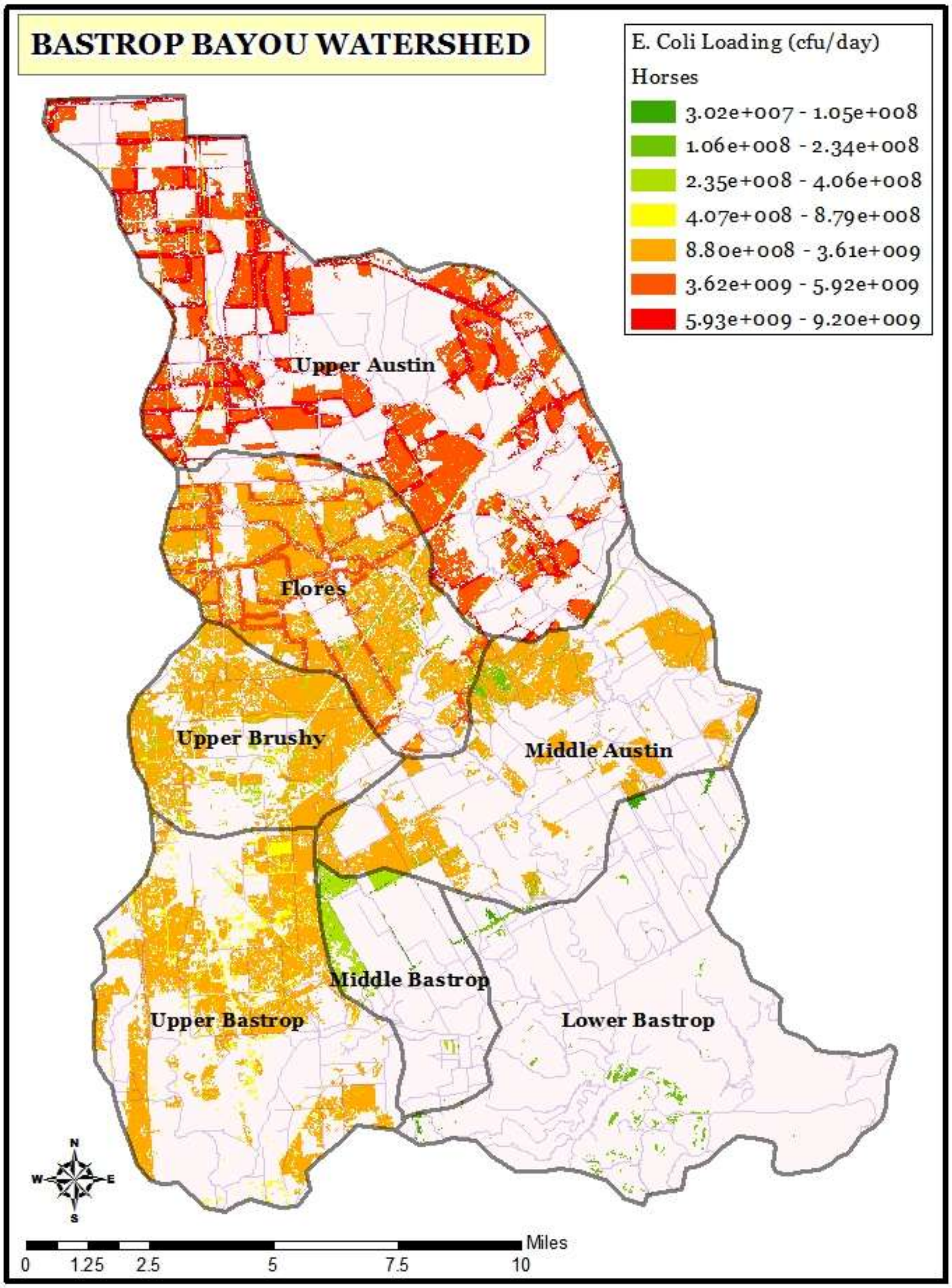


Figure A27: Granular Spatial Loading Characterization - Horses

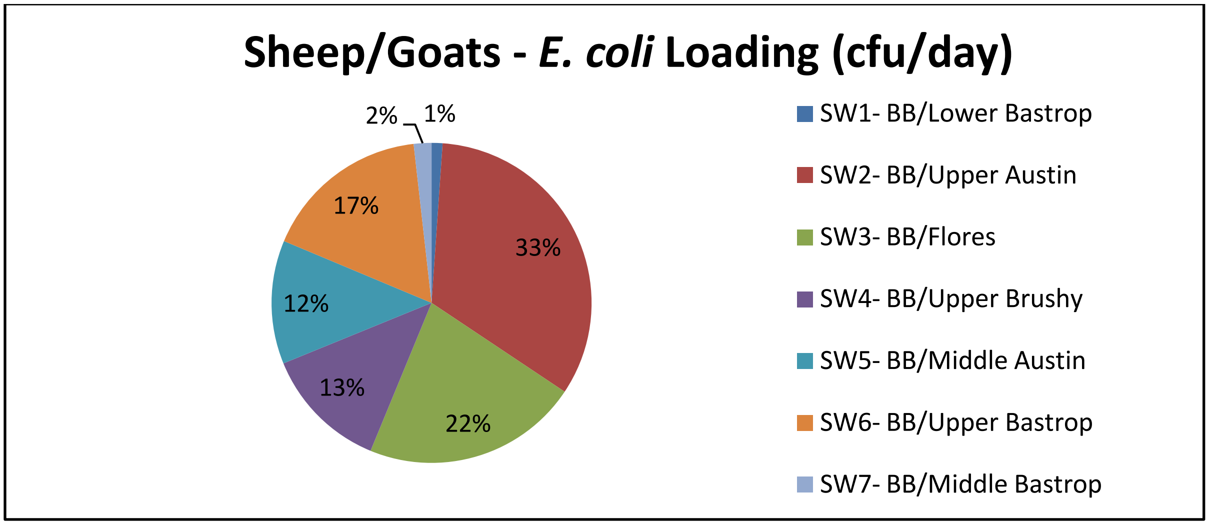


Figure A28: Relative Contribution to E. coli Loading – Sheep and Goats

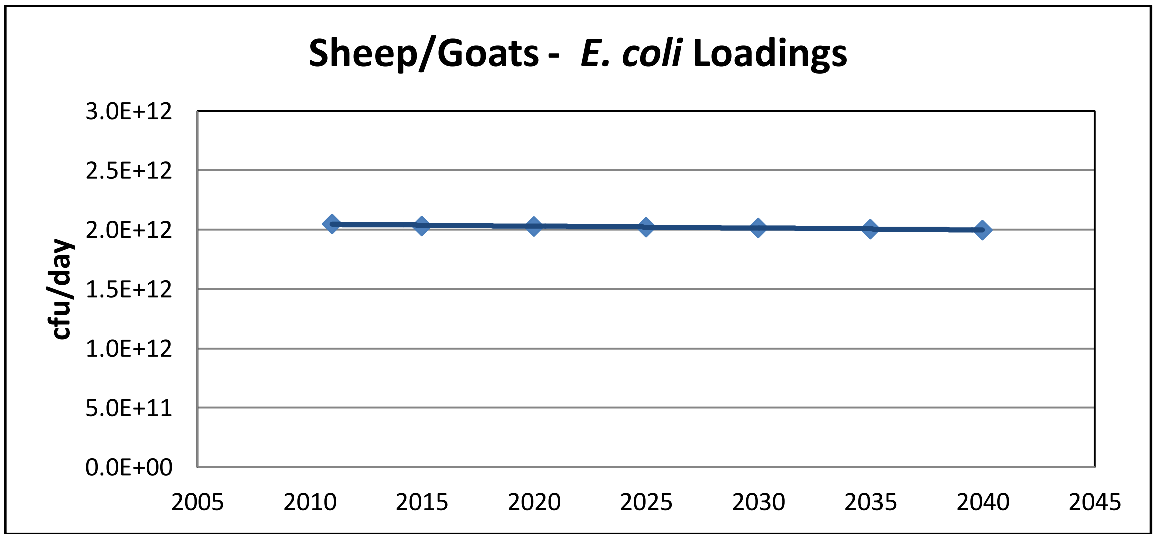


Figure A29: Source Loading (2012-2040) – Sheep and Goats

Table A8: E. coli Source Loads by Subwatershed – Sheep and Goats

Sheep/Goats *E. coli* Loading (in 10^9 CFU/day)							
SUBWATERSHED	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	22.6	22.4	22.3	22.1	21.9	21.6	21.4
SW2- BB/Upper Austin	682	680	680	679	678	676	675
SW3- BB/Flores	448	447	447	446	444	443	441
SW4- BB/Upper Brushy	258	251	250	249	249	247	247
SW5- BB/Middle Austin	256	256	255	255	254	253	252
SW6- BB/Upper Bastrop	346	339	338	336	334	330	326
SW7- BB/Middle Bastrop	36.7	36.5	36.3	35.9	35.6	35.2	35.1
TOTAL	**2,050**	**2,030**	**2,030**	**2,020**	**2,020**	**2,010**	**2,000**
Contribution to the total	5.76%	4.80%	4.53%	4.08%	3.64%	3.17%	2.85%

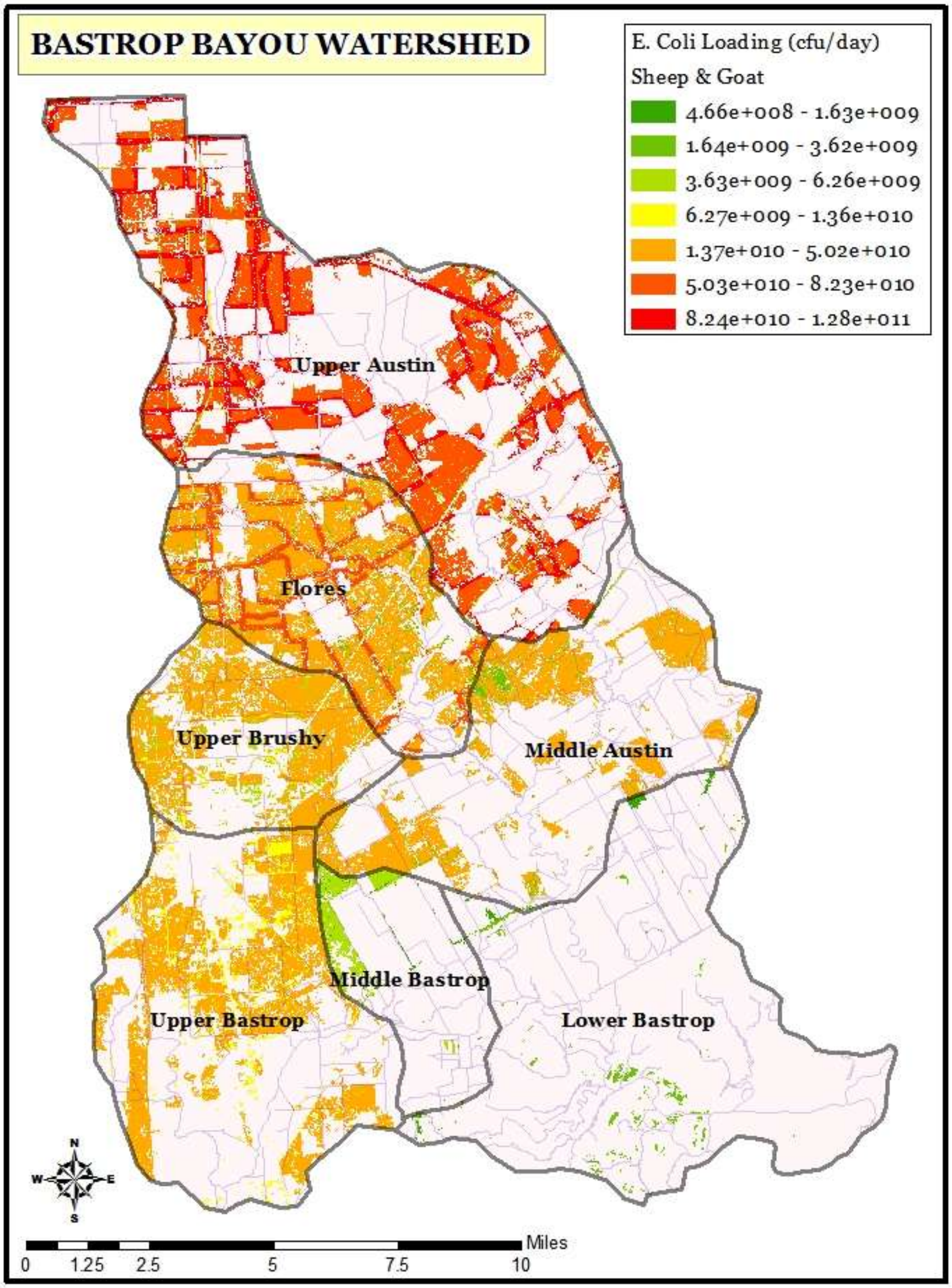


Figure A30: Granular Spatial Loading Characterization – Sheep and Goats

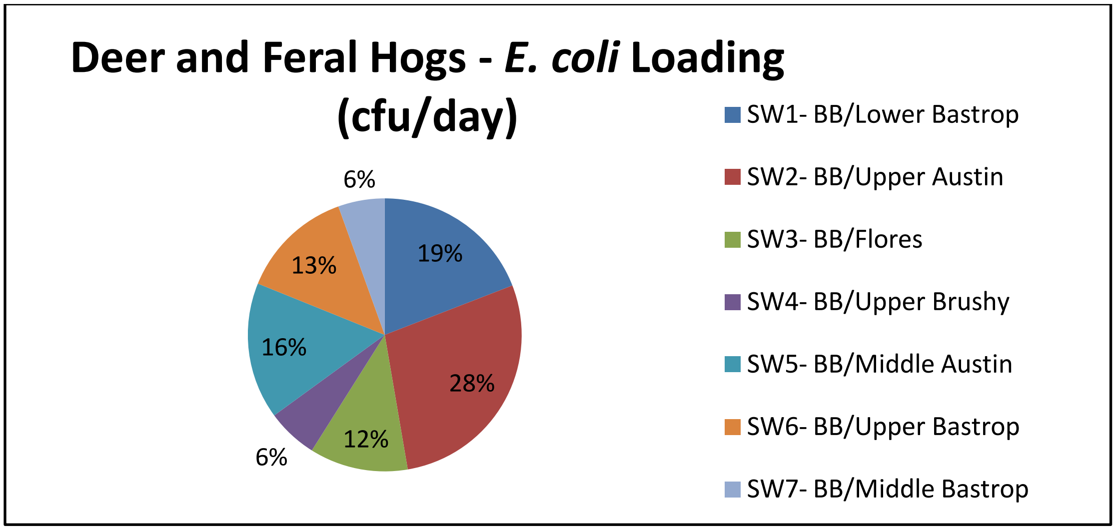


Figure A31: Relative Contribution to E. coli Loading – Deer and Feral Hogs

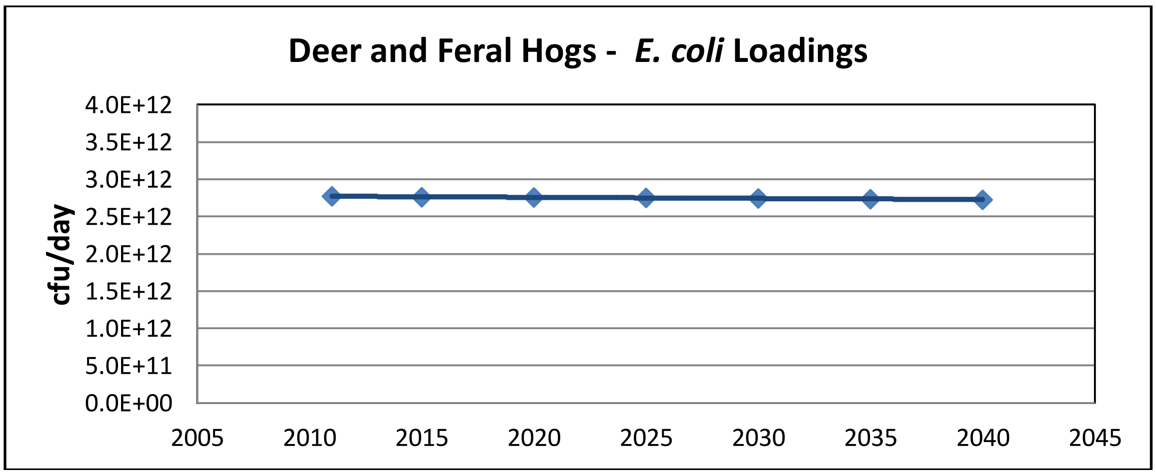


Figure A32: Source Loading (2012-2040) – Deer and Feral Hogs

Table A9: E. coli Source Loads by Subwatershed – Deer and Feral Hogs

Deer and Feral Hogs *E. coli* Loading (in 10^9)							
SUBWATERSHED	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	530	530	530	529	528	527	526
SW2- BB/Upper Austin	782	781	780	780	779	777	776
SW3- BB/Flores	323	323	322	322	320	319	319
SW4- BB/Upper Brushy	167	163	162	162	161	161	160
SW5- BB/Middle Austin	448	447	447	446	445	444	443
SW6- BB/Upper Bastrop	371	366	364	362	361	357	353
SW7- BB/Middle Bastrop	153	152	152	151	151	150	150
TOTAL	2,770	2,760	2,760	2,750	2,750	2,740	2,730
Contribution to the total	7.80%	6.52%	6.16%	5.55%	4.95%	4.33%	3.89%

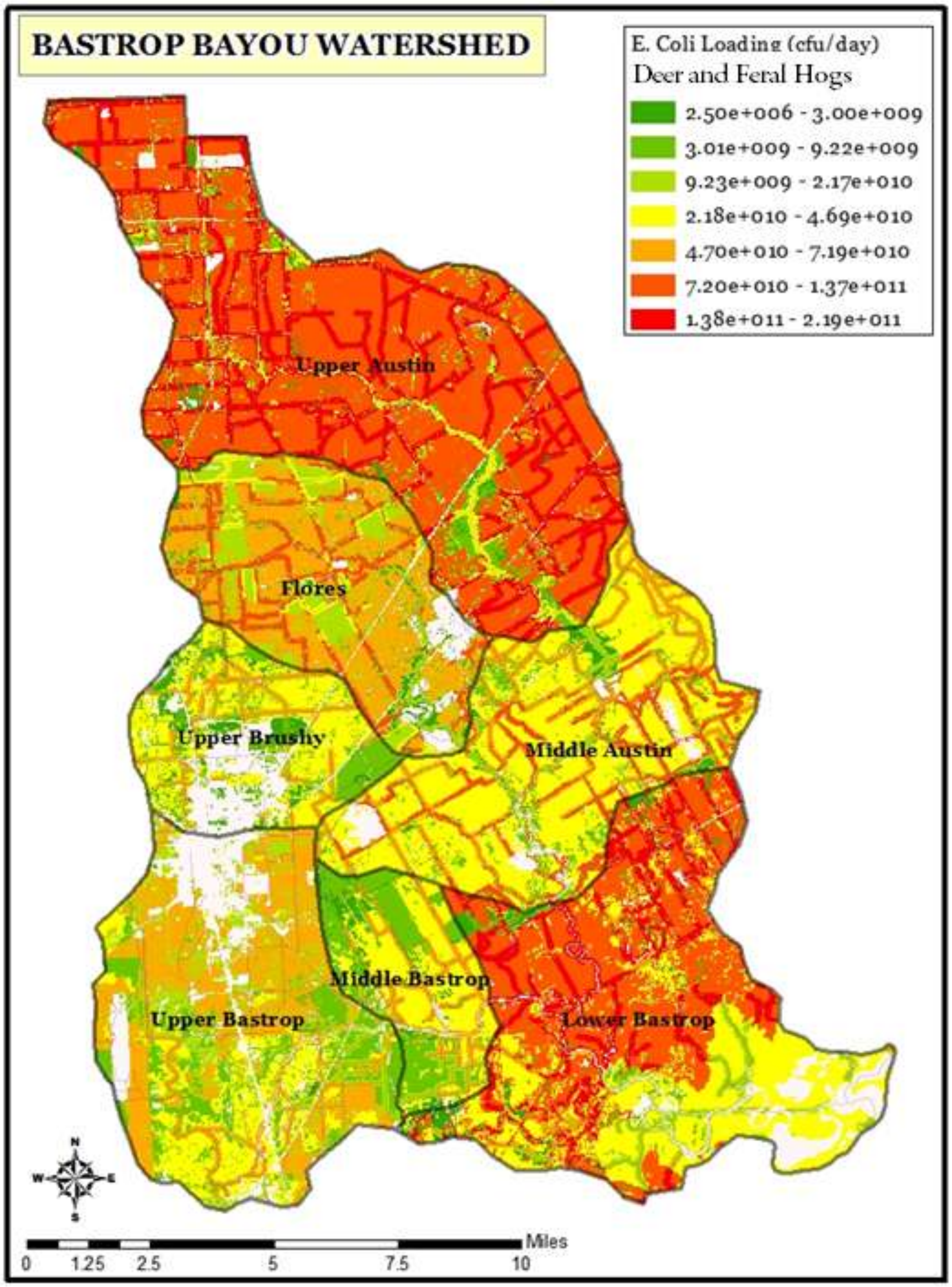


Figure A33: Granular Spatial Loading Characterization - Deer and Feral Hogs

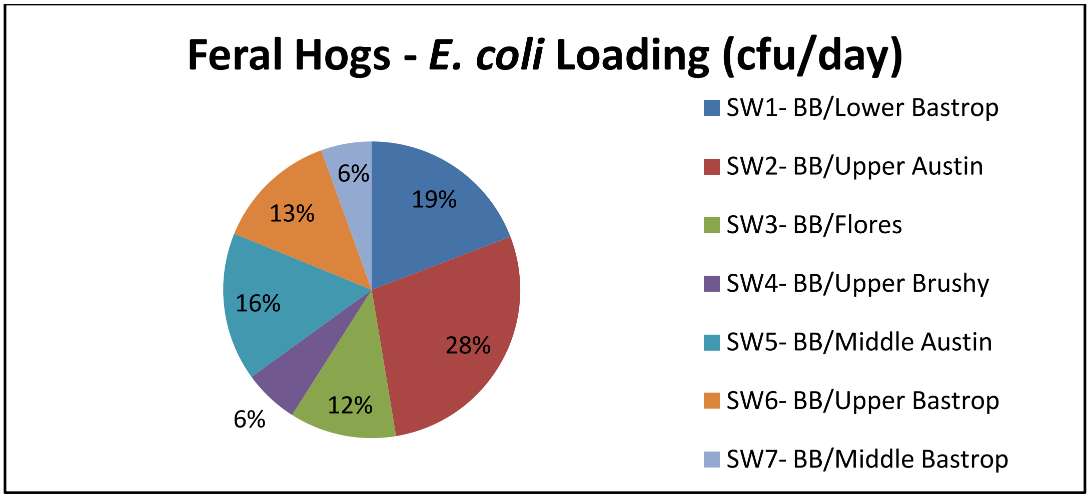


Figure A34: Relative Contribution to E. coli Loading – Feral Hogs

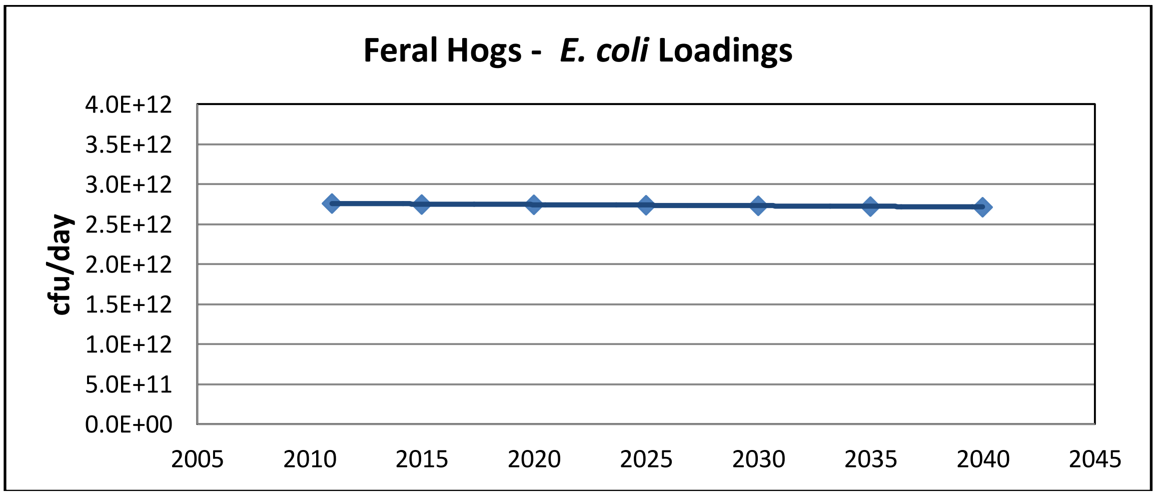


Figure A35: Change in Loading (2012-2040) – Feral Hogs

Table A10: E. coli Source Loads by Subwatershed – Feral Hogs

Feral Hogs *E. coli* Loading (in 10^9 CFU/day)							
SUBWATERSHED	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	530	529	529	528	527	526	526
SW2- BB/Upper Austin	779	778	778	777	776	775	774
SW3- BB/Flores	321	321	320	320	319	318	317
SW4- BB/Upper Brushy	165	161	161	160	160	159	159
SW5- BB/Middle Austin	447	446	446	445	444	443	442
SW6- BB/Upper Bastrop	367	362	361	359	357	353	350
SW7- BB/Middle Bastrop	153	152	152	151	151	150	149
TOTAL	**2,760**	**2,750**	**2,750**	**2,740**	**2,730**	**2,720**	**2,720**
Contribution to the total	7.77%	6.50%	6.14%	5.53%	4.93%	4.31%	3.88%

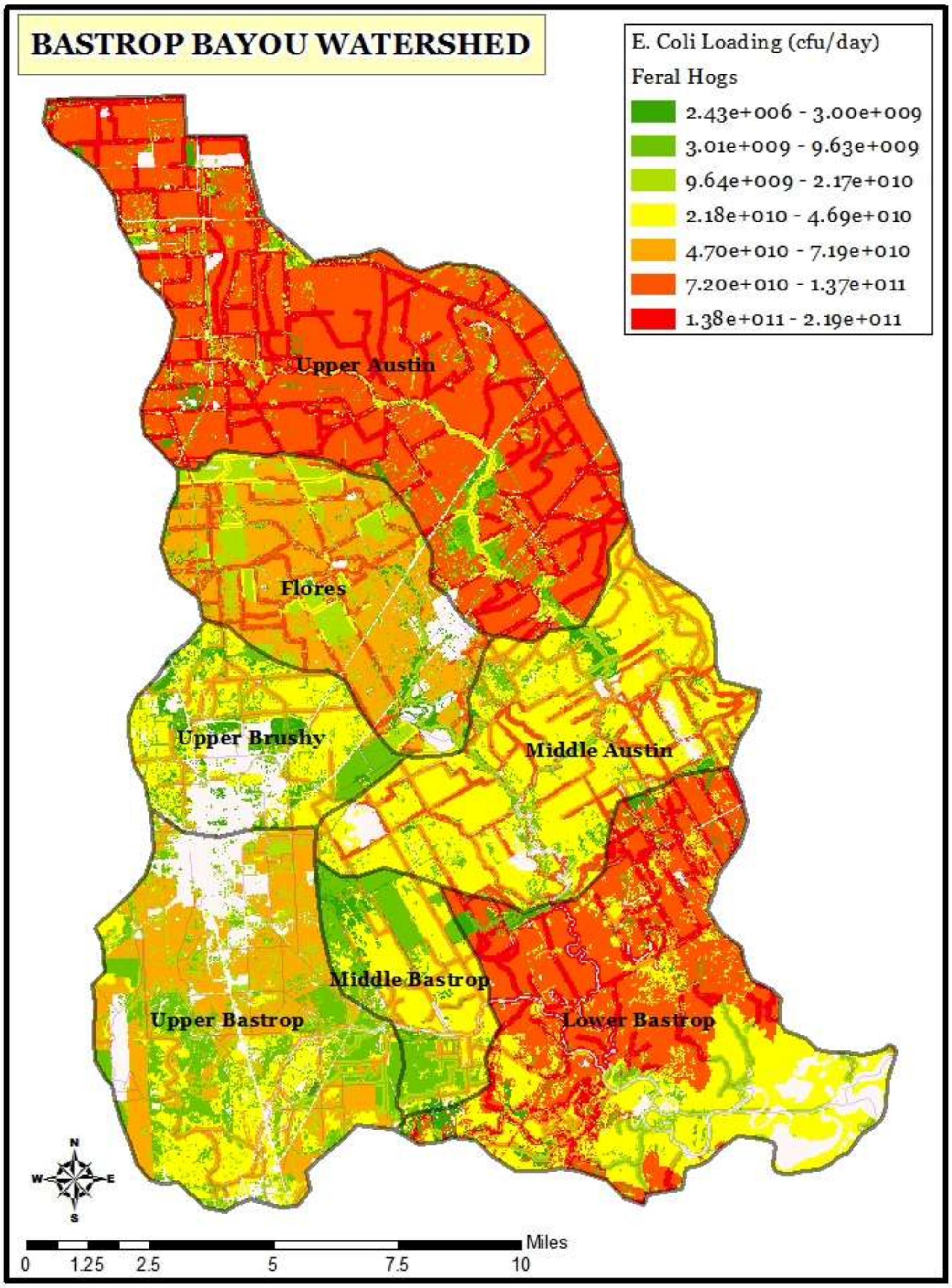


Figure A36: Granular Spatial Loading Characterization – Feral Hogs

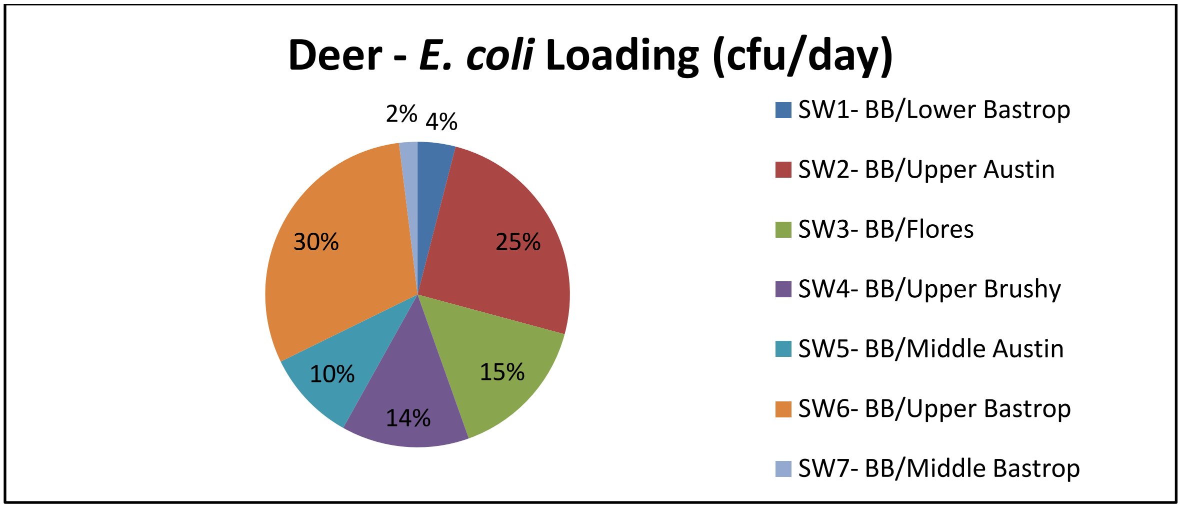


Figure A37: Relative Contribution to E. coli Loading - Deer

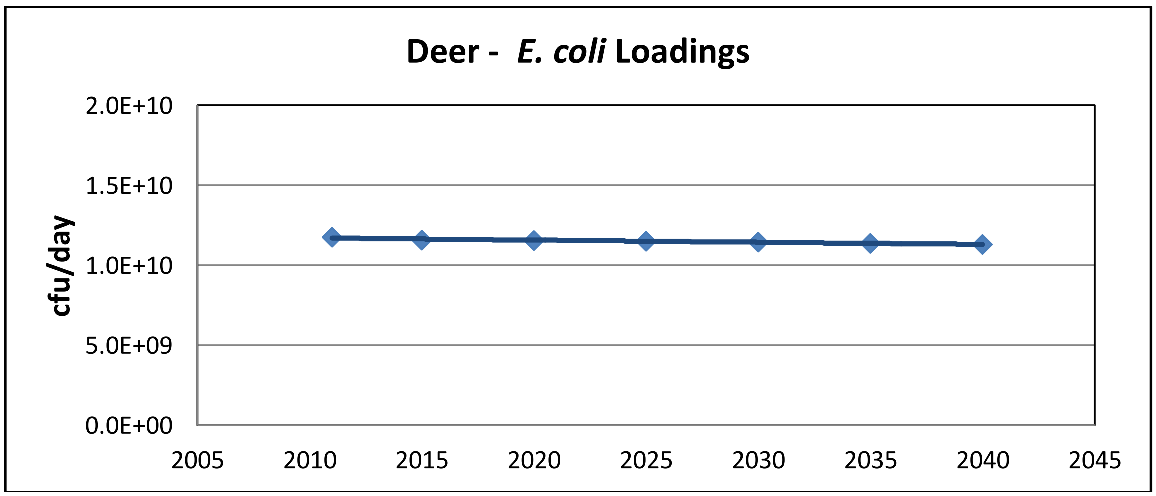


Figure A38: Change in Source Loads (2012-2040) - Deer

Table A11: E. coli Source Loads by Subwatershed - Deer

Deer *E. coli* Loading (in 10^9 CFU/day)							
SUBWATERSHED	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	0.473	0.468	0.467	0.464	0.460	0.455	0.451
SW2- BB/Upper Austin	2.96	2.96	2.95	2.95	2.95	2.94	2.93
SW3- BB/Flores	1.81	1.80	1.80	1.80	1.79	1.78	1.78
SW4- BB/Upper Brushy	1.60	1.52	1.51	1.51	1.50	1.49	1.48
SW5- BB/Middle Austin	1.14	1.13	1.13	1.13	1.12	1.12	1.12
SW6- BB/Upper Bastrop	3.57	3.49	3.48	3.45	3.43	3.38	3.34
SW7- BB/Middle Bastrop	0.229	0.226	0.224	0.221	0.218	0.214	0.212
TOTAL	**11.8**	**11.6**	**11.6**	**11.5**	**11.5**	**11.4**	**11.3**
Contribution to the total	0.03%	0.03%	0.03%	0.02%	0.02%	0.02%	0.02%

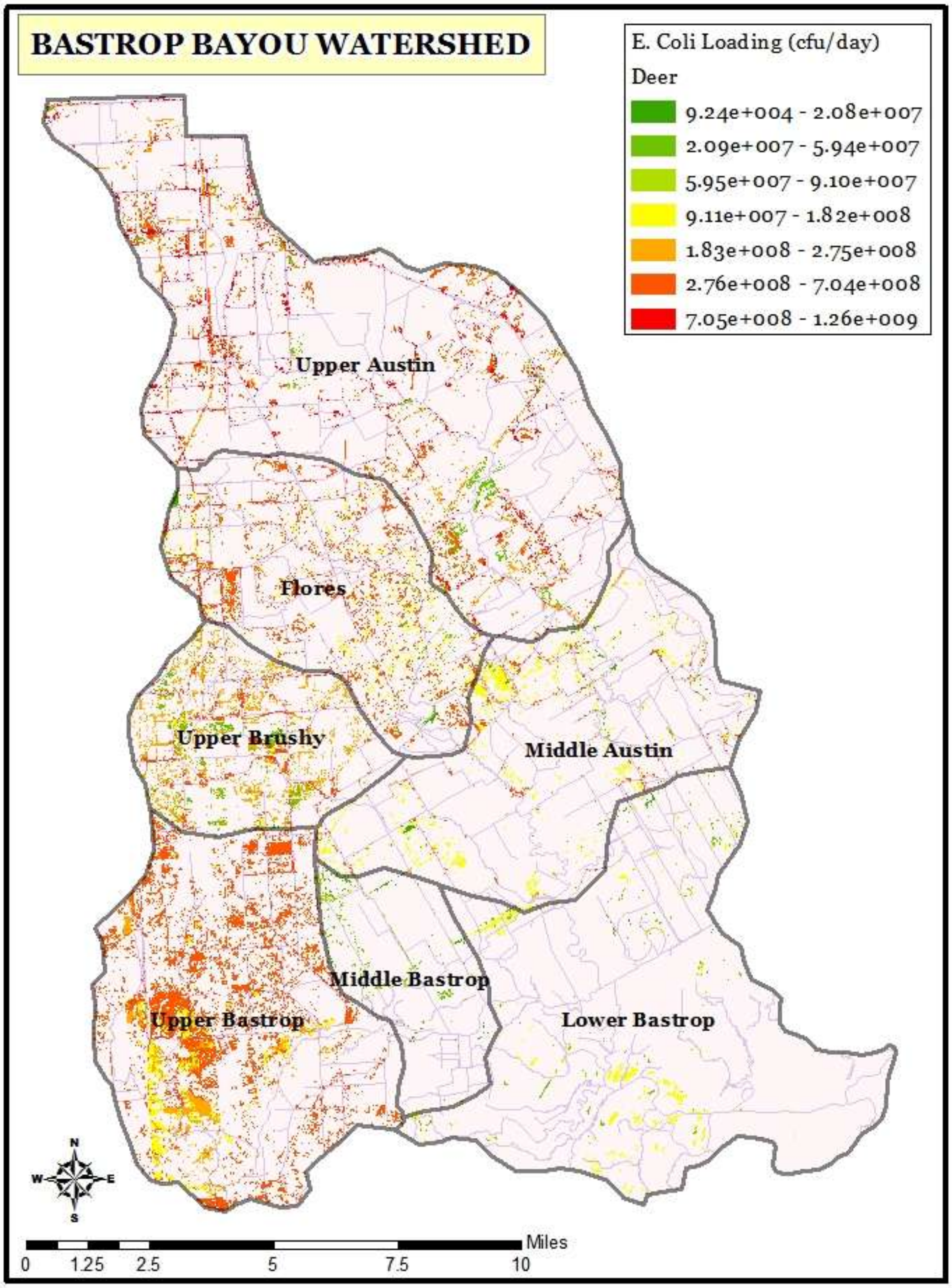


Figure A39: Granular Spatial Loading Characterization - Deer

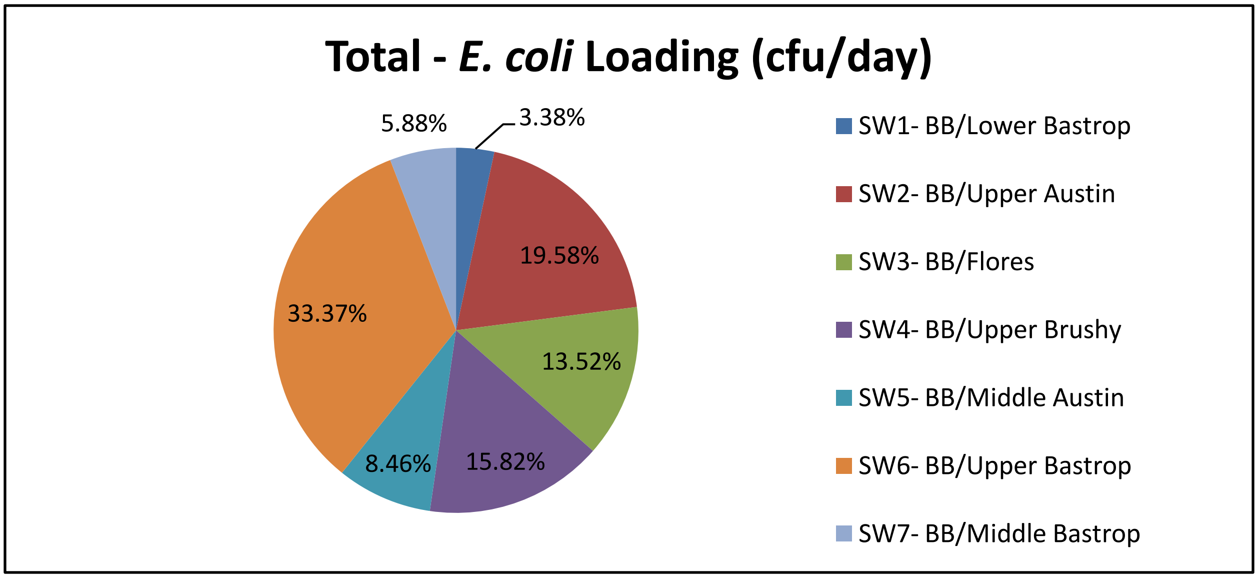


Figure A40: Relative Contribution to E. coli Loading - Total

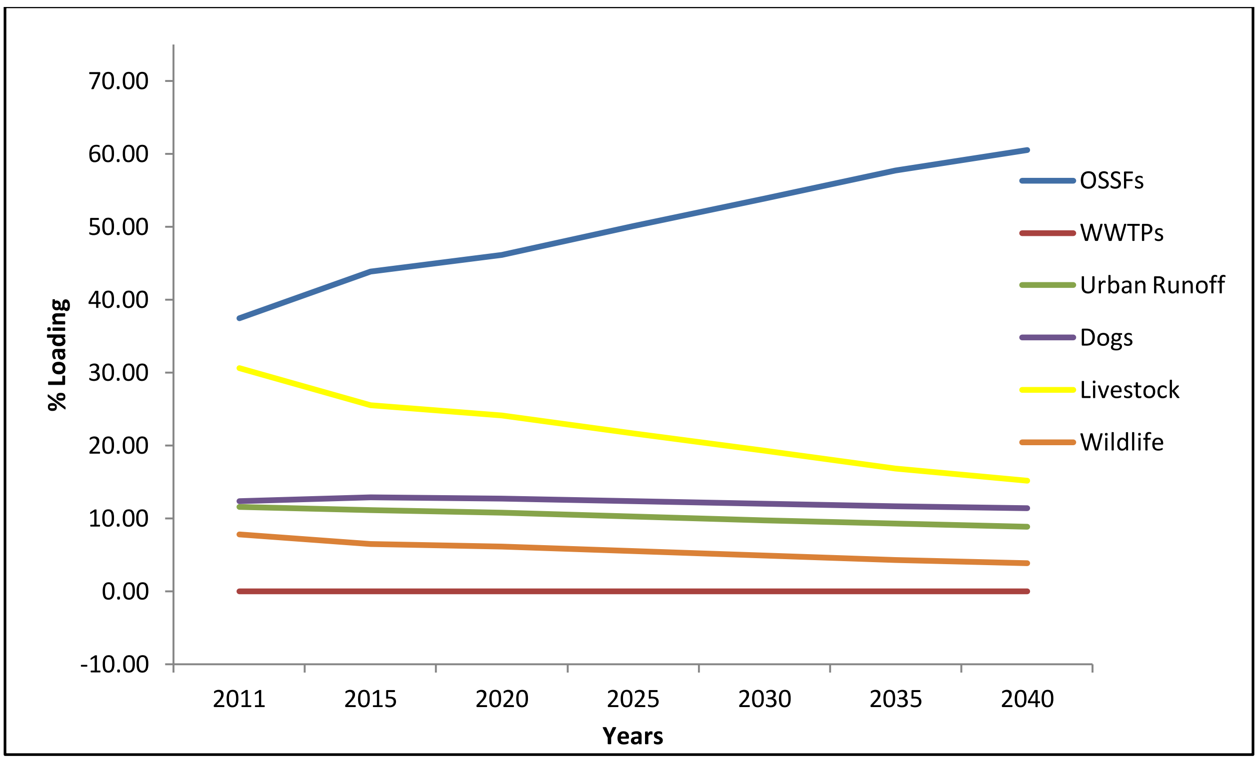


Figure A41: Change in Relative Loading Contribution by Source (2012-2040)

Table A12: Change in Total E. coli Source Loading Contribution by Source (2012-2040)

ALL CATEGORIES-Loading (in 10^9 CFU/day)							
Sources	2011	2015	2020	2025	2030	2035	2040
OSSFs	13,300	18,600	20,700	24,800	29,900	36,500	42,400
WWTPs	1.40	1.69	2.06	2.59	3.34	4.41	5.90
Urban Runoff	4,130	4,710	4,850	5,100	5,430	5,870	6,240
Dogs	4,410	5,470	5,700	6,130	6,670	7,400	8,030
Livestock	10,900	10,800	10,800	10,800	10,700	10,700	10,600
Deer and Feral Hogs	2,770	2,760	2,760	2,750	2,750	2,740	2,730
TOTAL	35,600	42,300	44,800	49,600	55,400	63,200	70,000

Table A13: Change in Relative E. coli Source Loading Contribution by Source (2012-2040)

All Categories-Percent							
Sources	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
OSSFs	37.51	43.87	46.16	50.08	53.87	57.77	60.55
WWTPs	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Urban Runoff	11.62	11.12	10.83	10.29	9.79	9.28	8.91
Dogs	12.40	12.92	12.73	12.36	12.03	11.71	11.46
Livestock	30.67	25.55	24.12	21.72	19.36	16.90	15.18
Deer and Feral Hogs	7.80	6.52	6.16	5.55	4.95	4.33	3.89
TOTAL	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table A14 - Current Potential Load by Source and Subwatershed (in percent of total subwatershed load)

Subwatershed	Sw1- Bb/ Lower Bastrop	Sw2- Bb/ Upper Austin	Sw3- Bb/ Flores	Sw4- Bb/ Upper Brushy	Sw5- Bb/ Middle Austin	Sw6- Bb/ Upper Bastrop	Sw7- Bb/ Middle Bastrop
OSSF	30.22%	27.40%	28.37%	17.39%	34.07%	52.18%	72.22%
WWTP	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%
Urban Runoff	9.09%	6.47%	7.50%	23.37%	2.39%	14.68%	3.95%
Dogs Excretion	6.49%	2.79%	7.82%	31.83%	3.38%	14.49%	7.16%
Cattle Excretion	8.10%	42.09%	40.05%	19.74%	36.58%	12.55%	7.56%
Deer Excretion	0.04%	0.04%	0.04%	0.03%	0.04%	0.03%	0.01%
Feral Hogs Excretion	44.13%	11.19%	6.68%	2.94%	14.85%	3.10%	7.31%
Horses Excretion	0.04%	0.22%	0.21%	0.10%	0.19%	0.07%	0.04%
Sheep Goat excretion	1.88%	9.79%	9.32%	4.59%	8.51%	2.92%	1.76%

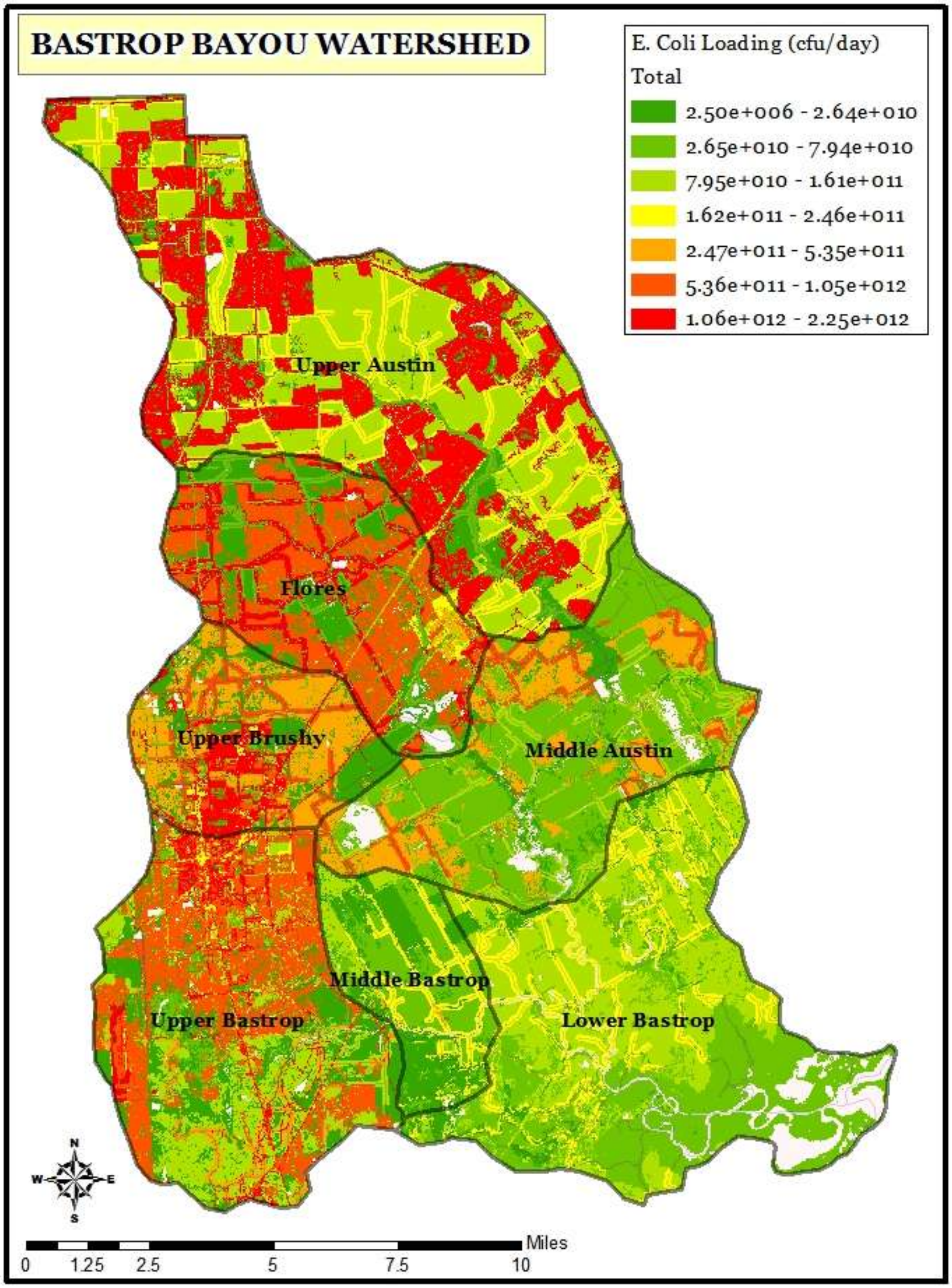


Figure A42: Granular Spatial Loading Characterization - Total

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 (Plum Creek Watershed Protection Plan, 2009). 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, deer and feral hogs, human households, pets and OSSFs, as well as the location of permitted wastewater treatment facilities (WWTFs), a pollutant load can be estimated for each potential source.

The model is developed in ArcGIS 10 and Microsoft Excel environments 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 to the corresponding land cover types, 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 spatial land cover units in each subwatershed 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 10 with the Spatial Analyst extension available from ESRI. This spatially explicit method divided the watershed into 7 subwatersheds and 22 land cover classes within each subwatershed. For each of the land cover types within the subwatersheds the *E. coli* loads were estimated from the sources that are potentially present at each location. Custom land cover classification available at the H-GAC for the year 2011 was used as the spatial unit for all the calculations. Seven subwatershed GIS dataset was obtained from the previous run of SELECT and it was originally delineated by based on TCEQ recommendations. 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 (cattle, sheep, goat and horses), wildlife (deer and feral hogs) and OSSF failure (Teague, 2009; Borel, 2012; USEPA, 2003). Detailed methodologies for the loading estimations from each source are described later in this section.

Loading estimates from the SELECT model were reviewed by the stakeholders and matched with local knowledge about the watershed. Using estimated distributions of livestock, deer and feral hogs, human households, pets, and OSSFs, as well as the location of permitted wastewater treatment facilities (WWTFs), 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. Based on the data availability, stakeholder comments, TCEQ's recommendations, and previous studies the most suitable assumptions were made and loading estimations were performed solely based on them. Apart from below mentioned assumptions, some assumptions are discussed in each source type descriptions.

1. Buffer strips – considering bacteria decaying conditions, it was assumed that the sources within 100m range from the streams has a 100% contribution and outside of 100m range assumed contributes only 20% of their total loadings
2. Animal density – based on the best available data on animal counts and their spatial distribution it was assumed that the total livestock counts (cattle, sheep and goat, and horses) for the entire county are equally distributed within their designated habitats.
3. OSSF loading – apart from H-GAC database for permitted septic systems, it was assumed that each household that are outside the Services Area Boundary has a septic system and considered that 60% of them are permitted and 40% are unpermitted. All the permitted OSSFs were assumed to have a 12% failure rate and unpermitted systems assumed to have a 50% failure rate.
4. WWTFs – due to lack of availability of flow records from waste water treatment plants, it was assumed that 60% of the permitted flow is discharged from those which have 0 recorded flows.

5. Feral Hogs – there are no recorded statistics for certain wildlife and animals such as feral hogs. Therefore, based on the population dynamics of feral hogs published by the Institute of Renewable Natural Resources at Texas A&M University, the feral hog densities were decided. It was considered that all the land cover classes other than develop and open water are habitats for feral hogs. The density was assumed; 3 hogs/Km^2 in Bare lands and 5 hogs/Km^2 for all the other habitats.
6. Dogs – According to the American Veterinary Medical Association Statistics (AMVA, 2002), 0.8 dogs per household was assumed.
7. Tidal segments - 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.
8. 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 EPDRiv1. A second model may be necessary if the quantified results do not match the targeted monitoring data from implementation activities. Due to compatibility, EPDRiv1 can be run as an adjunct to SELECT.

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 B1: Data Source Inventory

NameD	Source	Date	Description
ABI Businesses	(Census Data)	2000	GIS- Business in Brazoria County, includes some housing data
Land Cover	**NOAA**	**2011**	**GIS - Complete data set**
Land use	(H-GAC)	2011	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
Service Area Boundary	**H-GAC**	**2011**	**GIS Shapefiles complete set for 2000**
Livestock data	**USDA Animal**	**2007**	**Tabular data**
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.	**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

NameD	Source	Date	Description
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**
WWTF Outfalls	**H-GAC**	**2007**	**GIS Shapefiles - complete set, some areas not covered**
Parcel Data	BCAD	2003	incomplete data set
Soil	**NRCS**	**-2000**	**GIS Shapefiles - date uncertain**
Septic Systems	H-GAC	2012	GIS Shapefile
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**	**2010**	**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

Detail Methodology:

Land Cover data preparation:

The 2011 30m resolution land cover dataset was obtained from NOAA Coastal Change Analysis Program (C-CAP) Regional Land Cover Database. This dataset was originally available in raster format and it was converted to vector format at the H-GAC for easy use with other GIS datasets. Twenty two land cover classes were identified in the dataset and four different develop categories were identified based on the percentage on imperviousness. The land cover dataset was overlaid and clipped with subwatersheds and parcel shapefiles. The stream network of Bastrop Bayou watershed was overlaid on top of this and 100m buffer zone was created around the streams. Identity analysis was performed with above mentioned layers and final GIS shapefile was created with attributes having land cover within 100m buffer and outside of buffer for each subwatershed. All the SELECT analysis was based on this “granular” level land cover dataset which also included the household information.

Point Sources:

WWTFs loading estimation:
Waste water treatment plants (WWTFs) are the only point sources identified in the Bastrop Bayou watershed, which discharge treated effluents from develop areas of the watershed. There are eight facilities located in the watershed; two of them do not release effluents into the streams. H-GAC maintained a GIS/MS Access based database which includes the location information, permitted flow and average self reported flow of each facility in the watershed. Each WWTF was permitted to release effluents at the standard water quality concentration of 126 CFU/ dL. According to the equation 1 the load from each WWTF was calculated by multiplying the average self reported effluent outflow by permitted concentration (126 CFU/dL) and units were appropriately converted (Teague, 2009). In estimating the average self reported flow for the facilities that do not have recorded flow, 60% of the permitted flow was accounted.

$$WWTP = Self\ Reported\ Flow\ (MGD) * \left(\frac{126\ cfu}{100\ mL}\right) * \frac{10^6\ gal}{MGD} * \frac{3758.2\ mL}{gal}$$

Equation 1 (EPA, 2001; Teague, 2009; Riebschleager, 2008)

Table B2: E. coli Loading Estimation from WWTFs by Subwatershed

Subwatershed	#	Permitted Flow (MGD)	Average Self Reported Flow (MGD)	WWTF FC Loading (cfu/d)	WWTF *E.coli* Loading (cfu/d)
Lower Bastrop	0	0	0	0.00E+00	0.00E+00
Upper Austin	3	0.435	0.105	4.97E+08	2.49E+08
BB/Flores	1	0.504	0.29	1.37E+09	6.87E+08
Upper Brushy	2	0	0.17	8.05E+08	4.03E+08
Middle Austin	0	0	0	0.00E+00	0.00E+00
Upper Bastrop	2	0.048	0.028	1.33E+08	6.63E+07
Middle Bastrop	0	0	0	0.00E+00	0.00E+00
TOTAL	**8**	**0.987**	**0.593**	2.81E+09	1.40E+09

Forecasting the loading from WWTF was estimated based on the household projections using H-GAC's socioeconomic forecasting tools. Since the WWTFs collect sewage only from the households that within the service area boundary, the households those that are located within the boundary was considered. The tools estimated the potential number of households for next thirty years in five year interval. The changing rate of households in each subwatershed was multiplied by the current loading values from total WWTFs in the subwatershed. **Table B3** presents the number of existing and forecasted households that are located inside the service area boundary and **Table B4** presents the estimated current and future total loadings from each subwatershed.

Table B3: Number of Existing and Forecasted Households within Service Area Boundaries

	Total # of HH within SAB						
Subwatershed	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	107	123	124	124	124	125	125
SW2- BB/Upper Austin	19	27	27	28	28	28	28
SW3- BB/Flores	573	651	651	667	693	709	714
SW4- BB/Upper Brushy	4,222	5,130	5,173	5,203	5,244	5,366	5,432
SW5- BB/Middle Austin	0	0	0	0	0	0	0
SW6- BB/Upper Bastrop	2,999	3,491	3,532	3,628	3716	3,897	4,013
SW7- BB/Middle Bastrop	0	0	0	0	0	0	0

Table B4: E.coli Loading Estimates from WWTFs for Current and Future Conditions (in 10^9 CFU/day)

Subwatershed	**2011**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	0	0	0	0	0	0	0
SW2- BB/Upper Austin	0.249	0.348	0.486	0.708	1.04	1.52	2.23
SW3- BB/Flores	0.687	0.780	0.887	1.03	1.25	1.55	1.92
SW4- BB/Upper Brushy	0.403	0.489	0.599	0.738	0.917	1.17	1.50
SW5- BB/Middle Austin	0	0	0	0	0	0	0
SW6- BB/Upper Bastrop	0.0663	0.0772	0.0909	0.110	0.136	0.177	0.237
SW7- BB/Middle Bastrop	0	0	0	0	0	0	0
Total	**1.40**	**1.69**	**2.06**	**2.59**	**3.34**	**4.41**	**5.90**

Non-point sources:

OSSFs loading estimation:
Loading contributions from OSSFs were calculated in two ways; permitted and unpermitted. The permitted OSSF database is maintained by H-GAC based on the regular information obtained from the data obtained from designated representatives throughout the region. Point GIS shapefile was overlaid with the stream buffer and identified the locations falling within the buffer and outside the buffer. The permitted OSSF database contain the installation year. The systems installed before 1989 considered as unregulated and everything after considered as regulated (Lesikar, 2005; Teague, 2009). For those which have no installation year, 60% of them were considered as regulated and 40% as unregulated. However, this OSSF dataset is not complete and it has not covered every household in the region. Therefore, it is safe to assume that all the households that are located outside the service area boundary (SAB) have an individual septic system. Based on this assumption, the numbers of households that are within and outside the 100m buffer zone were estimated for each subwatershed and the number of permitted OSSFs was subtracted from them in estimating the households that have no permitted septic system and no services from WWTFs. As the unpermitted OSSFs do not have an installation day, it was assumed 60% of them as regulated and the rest 40% as unregulated. Bacteria loading is occur when a septic system fails. To estimate number of fail systems, it was considered that 12% of failure rate in regulated systems and 50% failure rate in unregulated systems (Teague, 2009; Reed, Stowe and Yanke LLC, 2001). This criteria was applied to both the permitted systems and unpermitted systems.

The total potential E. coli loading was then determined by multiplying the number of failed septic systems by average number of people per household (2.8), the effluent concentration of E. coli ($5*10^6$ CFU/dL), the discharge rate (70 gal/person-day ($2.65*10^6$ ml) and contribution factors for 100m buffer zones (Teague, 2009). This resulted in potential daily E. coli load for corresponding land cover types which was then aggregated to the subwatershed level to yield the potential E. coli load in CFU/day on a subwatershed basis. The calculations were performed according to the equation 1 and units were appropriately converted. Sample loading estimation for a subwatershed (Upper Austin) is presented in **Table B5**.

$$EC = \#\, of\, failing\, systems * average\, \#\, of\, person\, per\, HH * \frac{5*10^5\, cfu}{100\, mL} * \frac{2.65*10^6\,\mathrm{mL}}{\mathrm{person/day}}$$

Equation 02 (Teague, 2009; Riebschleager, 2008)

Table B5: E. coli Loading Estimation from OSSFs in Upper Austin Subwatershed

SW2-BB/Upper Austin		Permitted OSSFs	Unpermitted OSSFs	%failure	E. coli load/ Person	Discharge rate	Average # people/ HH	% Contrib. to Streams	E. coli Load
				(%)	(CFU/ml)	(ml/person/day)			(in 10^9 CFU/ day)
Unregulated	Inside Buffer	1	44	0.5	5.00E+03	2.65E+06	2.8	1	826
	Outside Buffer	4	120	0.5	5.00E+03	2.65E+06	2.8	0.25	577
Regulated	Inside Buffer	53	14	0.12	5.00E+03	2.65E+06	2.8	1	297
	Outside Buffer	129	58	0.12	5.00E+03	2.65E+06	2.8	0.25	208
TOTAL OSSFs		187	235						1,910

Next, future loadings were forecasted using H-GAC's socioeconomic forecasting tools in five year interval up to 2040. Changing rate of total number of households outside the WWTF service area for each subwatershed was projected and it was multiplied by the existing amounts of total permitted and unpermitted systems**. Table B6** presents the total number of households outside the SAB and **Table B7** presenting the forecasted loading in subwatershed basis.

Table B6: Forecasted Number of Households outside the Service Area Boundary by Subwatershed

Subwatershed		# Of HH outside the SAB						
		2011	2015	2020	2025	2030	2035	2040
SW1- BB/Lower Bastrop	Within Buffer	11.5	29.1	43.2	72.5	117.5	155.7	191.8
	Out Buffer	80.5	132.9	164.5	268.6	366.4	498.1	601.1
SW2- BB/Upper Austin	Within Buffer	111.3	154.2	174.9	204.4	244.4	311.0	357.2
	Out Buffer	311.0	425.1	476.0	560.7	665.4	817.9	923.1
SW3- BB/Flores	Within Buffer	78.2	90.6	107.1	129.5	187.1	233.6	275.8
	Out Buffer	227.9	278.5	311.0	362.9	480.2	577.7	659.4
SW4- BB/Upper Brushy	Within Buffer	74.0	89.6	93.0	99.1	108.8	116.4	123.0
	Out Buffer	91.6	161.9	189.2	219.2	258.0	289.2	307.4
SW5- BB/Middle Austin	Within Buffer	62.9	79.8	89.5	124.2	193.6	228.6	274.2
	Out Buffer	154.8	186.0	208.5	285.9	435.8	511.3	602.3
SW6- BB/Upper Bastrop	Within Buffer	406.0	536.1	568.6	633.1	678.9	792.5	921.5
	Out Buffer	830.6	1223.0	1323.8	1529.6	1671.3	2109.2	2535.9
SW7- BB/Middle Bastrop	Within Buffer	138.8	180.6	199.6	222.5	248.7	284.5	301.7
	Out Buffer	43.0	75.3	101.3	162.3	229.7	294.5	343.0
TOTAL	Within Buffer	882.7	1160.0	1275.9	1485.2	1779.1	2122.4	2445.2
	Out Buffer	1739.5	2482.6	2774.3	3389.1	4106.9	5097.8	5972.0
	Total	2622.2	3642.6	4050.2	4874.4	5885.9	7220.2	8417.2

Table B7: Estimated E. coli Loading From Each Subwatershed for Existing and Future Conditions

Subwatershed	*E. Coli* Loading (in 10^9 CFU/day)						
	2011	2015	2020	2025	2030	2035	2040
SW1- BB/Lower Bastrop	363	639	818	1,340	1,910	2,580	3,120
SW2- BB/Upper Austin	1,910	2,620	2,940	3,460	4,110	5,100	5,780
SW3- BB/Flores	1,360	1,640	1,860	2,190	2,970	3,620	4,170
SW4- BB/Upper Brushy	978	1,480	1,670	1,880	2,170	2,400	2,540
SW5- BB/Middle Austin	1,020	1,250	1,400	1,930	2,960	3,480	4,130
SW6- BB/Upper Bastrop	6,190	8,810	9,480	10,800	11,800	14,500	17,300
SW7- BB/Middle Bastrop	1,510	2,120	2,500	3,190	3,970	4,810	5,350
TOTAL	13,300	18,600	20,700	24,800	29,900	36,500	42,400

Loadings from Livestock:

Waste generated from range animals can be directly deposited into water streams or carried by runoff from their habitats to the streams (Teague, 2009; Benham et al., 2006). Animal manure contains considerable amount of *E. coli* that contribute to the bacterial levels in streams. Range animals such as cattle, Sheep, Goat, and Horses were considered as the major contributors of bacteria in this watershed.

The animal populations were extracted from the USDA-NASS, 2007 statistics for Brazoria County. Deciding the habitat land cover types for each animal was challenging. They were decided based on the comments from stakeholders and previous studies in nearby watersheds (San Bernard River WPP; Teague, 2009). Next, it was assumed that the total number of each animal type was equally distributed within the designated land cover type. Based on this approach, the animal density for the entire county for cattle, sheep and goat, and horses were determined per acre basis. **Table B8** provides the total count of each livestock, assigned land cover types and density of each animal type.

Table B8: Livestock Counts and Land Cover Allocation by Animal Type

Brazoria County	# of Animals	Density (per acre)	Habitats
Cattle	78560	0.353	Grassland, and 90% of Pasture/Hey
Horses	5367	0.024	Grassland, and 90% of Pasture/Hey
Sheep & Goat	5481	0.025	Grassland, and 90% of Pasture/Hey

Loading estimation was conducted from each sources for granular level (land cover basis for each subwatershed) using the land cover dataset overlaid with 100m buffer around the streams in GIS. The loading estimation protocol was developed originally by EPA and later applied in several other watershed analyses such as San Bernard River WPP, Plum creek watershed (Teague, 2009). According to the equations used in these assessments, presented in below **(Table B9),** the final loadings were estimated. Area acreages of habitats within 100m buffer and outside the buffer were multiplied by the each animal density and the loading rate of CFU/day/animal. The contribution factors of 100% and 25% were applied to the calculated loadings that are within buffer and outside the buffer consequently. For all these estimations, a 50% conversion factor was applied to convert fecal coliform to E. coli (Teague, 2009; Riebschleager, 2008). Estimated numbers of cattle and loadings are presented in **Table B10** which followed the same method for the other animal types.

Table B9: Equations Used in Estimating E. coli Loadings from Livestock

Source	Calculation equation
Cattle	$EC = \#\ of\ Cattle * 2.7 *\ 10^9\ cfu\ day^{-1}\ head^{-1}$
Horses	$EC = \#\ of\ Horses * 2.1 *\ 10^8\ cfu\ day^{-1}\ head^{-1}$
Sheep and Goat	$EC = \#\ of\ Sheep\ \&\ Goat * 9.0 *\ 10^9\ cfu\ day^{-1}\ head^{-1}$

Table B10: Estimated Total Numbers and E. coli Loading from Livestock Sources

		Lower Bastrop	Middle Bastrop	Upper Bastrop	Middle Austin	Upper Austin	Upper Brushy	Flores
# of Cattle	Within Buffer	40.43	64.87	626.40	528.80	1392.07	503.67	902.95
	Outside Buffer	126.42	208.28	1905.86	1144.71	3117.17	1275.87	2096.27
Fecal Coliform Loading (in 10^9 CFU/day)	Within Buffer	109	175	1,690	1,430	3,760	1,360	2,440
	Outside Buffer	341	562	5,150	3,090	8,420	3,440	5,660
E. Coli Loading (in 10^9 CFU/day)	Within Buffer	54.6	87.6	846	714	1,880	680	1,220
	Outside Buffer	42.7	70.3	643	386	1,050	431	707
Total		97.3	158	1,490	1,100	2,930	1,110	1,930

Loadings from Deer and Feral Hogs:

Deer and feral hog sources can include many types of wild animals and birds. In this area, the known wildlife includes 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. Deer loading estimation was followed the similar methodology as for livestock loading. Deer data was obtained from the information from Oak Prairie wildlife district, Texas Parks and Wildlife. The total number of deer for the entire county was divided by the determined habitats in estimating the density per acre. According to stakeholders' comments and biology grasslands, shrubs/scrubs, and all the forest categories (Deciduous, Evergreen, and Mixed) can be considered as the habitats for deer. Then, using the 2011 land cover GIS dataset with 100m stream buffer, numbers of deer were estimated for each subwatershed within and outside the buffer by multiplying the deer density with the habitat acreage. According to the EPA recommended protocol, below equation was employed to estimate the loading from deer. Again, buffer contribution factors of 100% within 100m buffer and 25% outside the buffer and 50% conversion rule of thumb were applied. Estimated numbers of deer and loadings are presented in **Table B11**.

$$EC = \#\ of\ Deer * 1.75 * \ 10^8\ cfu\ day^{-1}\ head^{-1}$$

Deer loading equation (Teague, 2009; Riebschleager, 2008)

Table B11: Deer Count and Estimated E. coli Loadings

		Lower Bastrop	Middle Bastrop	Upper Bastrop	Middle Austin	Upper Austin	Upper Brushy	Flores
# of Deer	Within Buffer	3.2	1.8	22.4	9.5	24.7	11.9	13.8
	Outside Buffer	8.7	2.9	73.3	13.8	36.4	25.2	27.4
Fecal Coliform Loading (in 10^9 CFU/day)	Within Buffer	0.562	0.327	393	167	434	209	242
	Outside Buffer	153	0.523	12.8	242	637	442	479
E. Coli Loading (in 10^9 CFU/day)	Within Buffer	0.281	0.164	196	0.833	217	104	121
	Outside Buffer	0.192	0.0654	1.6	0.302	0.797	0.552	0.599
Total (in 10^9 CFU/day)		0.473	0.229	3.57	1.14	2.96	1.6	1.81

Feral hog population densities and distribution data were scarce for Bastrop bayou watershed. Based on Institute of Renewable Natural Resources at Texas A&M University studies, estimates of feral hogs densities for the region range from 3 hogs/Km^2 to 5 hogs/Km^2. Feral hogs utilize nearly all types of landscape, but in these estimates we assumed that no feral hogs were found in developed land cover types and open water. In their habitats, the densities were assumed to be 3 hogs/Km^2 in bare land and 5 hogs/Km^2 in all the other habitats. The total number of hogs was estimated by assuming these densities were uniformly distributed within the relevant land cover types. Then, the below equation was employed in estimating the loading from hogs which are within and outside the buffer area. Both the contribution and conversion factors were applied to estimate final E. coli loadings (**Table B12**).

$EC = \# \; of \; Hogs * 4.45 * \; 10^9 \; cfu \; day^{-1} \; head^{-1}$

Feral hogs loading equation (Teague, 2009)

Table B12: Feral Hog Estimation and E. coli Loading Calculation

		Lower Bastrop	Middle Bastrop	Upper Bastrop	Middle Austin	Upper Austin	Upper Brushy	Flores
Total # of Feral Hogs		121.0	64.6	356.8	256.0	714.1	156.1	289.2
Fecal Coliform Loading (in 10^9 CFU/day)	Within Buffer	170	80.0	396	395	1,000	200	419
	Outside Buffer	368	208	1,190	744	2,170	495	868
E. Coli Loading (in 10^9 CFU/day)	Within Buffer	85.2	40.0	198	198	502	100	209
	Outside Buffer	46.0	25.9	14.9	93.0	272	61.8	109
Total (in 10^9 CFU/day)		131	65.9	347	291	774	162	318

Loadings from Urban Runoff:

In the calculation of bacteria loads generated from urban runoff, two main aspects need to be considered: runoff volume generated during rainfall events and bacteria concentrations from urban sources. Estimation of runoff volumes from urban sources was performed using Curve Number (CN) method. In the 2011 NOAA land cover classification, all the areas that have impervious surfaces are categorized in four develop classes (High intensity, medium intensity, low intensity, and open space developed). Therefore, in this estimation the average daily runoff generated only from the four develop categories were considered. The overlaid GIS shapefile which include the land cover, subwatershed, and soil information was used. C&E department at the H-GAC possesses a GIS/SAS based tool to calculate the weighted runoff curve number, based on hydrologic soil groups for each land cover types. Using this tool, the weighted average curve number was generated for the develop land cover categories within each subwatershed separately (**Table B13**).

Table B13: Calculated Weighted CN Values for Subwatershed 1 – Lower Bastrop

2011 LC Category/Class		Weighted CN Value
High Intensity Developed	Within Buffer	95
	Out Buffer	95
Medium Intensity Developed	Within Buffer	93
	Out Buffer	93
Low Intensity Developed	Within Buffer	92
	Out Buffer	92
Developed Open Space	Within Buffer	80
	Out Buffer	80

In estimating the runoff using CN method, it requires average daily precipitation. 20 year precipitation records ware obtained from NOAA, National Climate Data Center for the station Angleton, TX. Since, Angleton was the only station which has reliable data available for 20 year time period, it was selected and assumed that the all the area throughout the watershed was received the same amount of rainfall in recorded rain events. The NCDC data (NCDC, 2007) includes the total annual rainfall for each year and the number of rainy days within that particular year. The average daily precipitation was estimated averaging the total annual rainfall by the number of days rained. The calculated daily average was 0.878 in. Then the estimated CN values and daily rainfall was applied to the universal CN equations (equation 1, 2, and 3), and the average daily runoff from the develop land cover areas that are within and outside of 100m buffer was calculated for each subwatershed.

$$S = \frac{1000}{CN} - 10 \quad \Rightarrow \quad Ia = 0.2S \quad \Rightarrow \quad Q = \frac{(P - Ia)}{(P - Ia) + S}^{2}$$

CN equation 1, 2 and 3

Where;
CN = weighted curve number
S = Potential maximum retention after runoff begins (in)
Ia = Initial abstraction (in)
P = Average daily Rainfall (in)
Q = runoff volume (in)

Table B14: Estimated Runoff for Lower Bastrop Watershed

2011 LC Category/Class		CN Value	max. retention (S)	Initial Abstraction (Ia)	Daily Precip (in)	Av. Daily Runoff (in)
High Intensity Developed	Within Buffer	95	0.53	0.11	0.88	0.46
	Out Buffer	95	0.53	0.11	0.88	0.46
Medium Intensity Developed	Within Buffer	93	0.75	0.15	0.88	0.36
	Out Buffer	93	0.75	0.15	0.88	0.36
Low Intensity Developed	Within Buffer	92	0.87	0.17	0.88	0.31
	Out Buffer	92	0.87	0.17	0.88	0.31
Developed Open Space	Within Buffer	80	2.51	0.50	0.88	0.05
	Out Buffer	80	2.51	0.50	0.88	0.05

Estimation of bacteria concentrations from urban runoff was followed mainly based on the empirical study conducted by PBS&J (2000) in Austin Texas. In this study, an empirical relationship between *E. coli* concentrations and percentage of imperviousness was developed (**Figure B1**). The percent of imperviousness associate to each land cover was extracted mainly from USEPA land cover classification criteria and other studies (**Table B15**). The impervious percentages were compared with the EMC chart and the corresponding loading of Fecal coliform was estimated for each land cover type that are located within and outside of the 100m buffer. Because this study includes all bacteria sources potentially present in urban stormwater events, including dogs and OSSFs (if present), there is the potential for some double-counting of contributions from these sources in urban areas. However, OSSFs are primarily located outside of the primary urban areas in this watershed and are not expected to represent an appreciable issue in this case. Dogs are located in urban areas. However, because the study does not differentiate the proportional amount of bacteria loading from dogs (as opposed to all other sources, including cats and urban wildlife, etc.) and because it only considers loading from storm events in the urban areas, dogs were modeled separately to ensure their full contribution was included. The majority of the watershed is not within urban areas, and therefore urban runoff is not the only vehicle by which dog wastes reach the waterway. This modeling effort errs on the side of caution by modeling dogs separately.

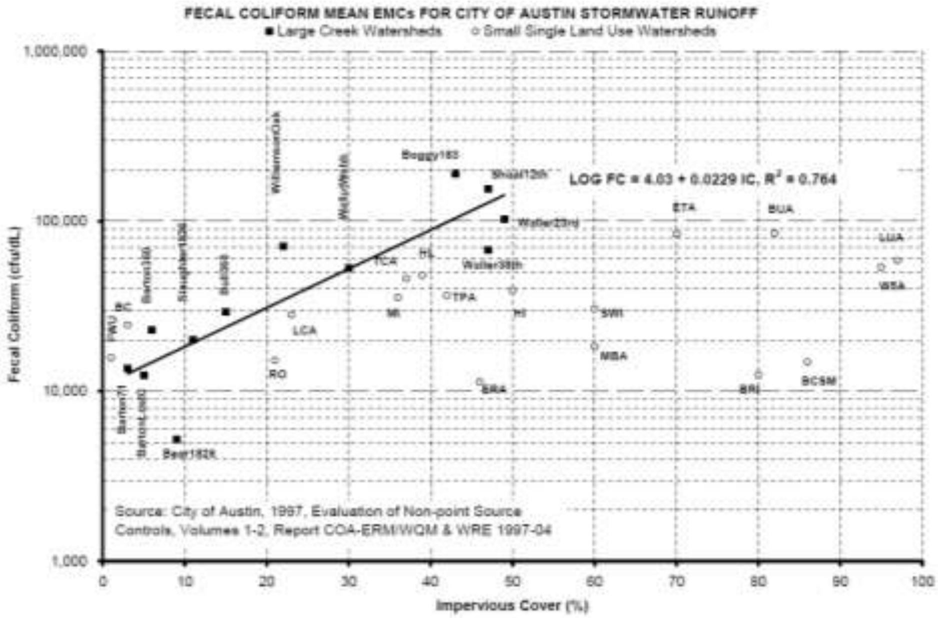


Figure B1: Bacteria Loading Estimation from OSSFs in Upper Austin Subwatershed

Table B15: Bacteria Loading Estimation from OSSFs in Upper Austin Subwatershed

LAND COVER	% of Imperviousness	SOURCE
High Intensity Developed	85	USEPA/TSARP
Medium Intensity Developed	75	USEPA/Exum
Low Intensity Developed	50	USEPA/Exum
Bare or Transitional	17	USEPA/Exum
Cultivated Crops	8	USEPA/Exum
Open Water	0	USEPA/Exum
Hay Pasture	5	USEPA/Exum
Deciduous Forest	2	USEPA/Exum
Herbaceous Wetland	1	USEPA/Exum
Grassland	9	USEPA/Exum
Herbaceous	9	USEPA/Exum
Shrub Scrub	9	USEPA/Exum
Open Space Developed	15	USEPA/Exum
Evergreen Forest	4	USEPA/Exum
Woody Land	5	USEPA/Exum
Mixed Forest	5	USEPA/Exum
Woody Wetlands	5	USEPA/Exum
% Impervious		
Curve Number		

Sources:

Exum, 2005 - Estimating and Projecting Impervious cover in the Southeastern United States
TSARP: Tropical Storm Alison Recovery Project
USEPA: US Environmental Protection Agency, Land cover classification

The final estimation of loading was followed the simple methodology, which the Event Mean Concentration (EMC) of bacteria from each land cover type multiplied by the average daily runoff volumes (New Hampshire Storm Water manual, 2008). As it was in the other loading sources, 50% rule of thumb was applied and considered that 100% contribution from buffer areas and 25% from outside the buffer areas. For the forecasting, the land cover forecast tools from H-GAC generated the projected amounts of develop land cover classes. Assuming all the other variables stay unchanged except land cover, the future loadings were estimated for next 30 years in 5 year interval (**Table B16**).

Table B16: Current and Future Estimates of E. coli Source Loading From Each Subwatershed (CFU/day)

Subwatershed	*E. coli* Loading (in 10^9 CFU/day)						
	2011	2015	2020	2025	2030	2035	2040
SW1- BB/Lower Bastrop	1,200	1,500	1,800	2,400	3,000	3,800	4,500
SW2- BB/Upper Austin	7,000	7,800	8,200	8,800	9,500	11,000	11,000
SW3- BB/Flores	4,800	5,200	5,400	5,800	6,700	7,500	8,100
SW4- BB/Upper Brushy	5,600	6,700	6,900	7,100	7,500	7,800	8,000
SW5- BB/Middle Austin	3,000	3,300	3,400	4,100	5,300	5,900	6,600
SW6- BB/Upper Bastrop	12,000	15,000	16,000	18,000	19,000	22,000	25,000
SW7- BB/Middle Bastrop	2,100	2,800	3,200	4,000	4,800	5,700	6,300
TOTAL	36,000	42,000	45,000	50,000	55,000	63,000	70,000

Loadings from Pets:

Dogs were the only pets considered to contribute to pet waste loading within the watershed. American Veterinary Medical Association published that Texans own 5.4 million dogs (AVMA, 2002; Teague, 2009). By dividing this number by the number of households in Texas, the average number of dogs per household was found to be 0.8. Using the overlaid GIS shapefile which includes the number of households and land cover information, the total number of dogs was estimated by multiplying number of households by 0.8. This outcome included the number of dogs per each subwatershed that are within and outside the 100m buffer area. USEPA protocol reports that dogs produce $5*10^9$ fecal coliform organisms per day (USEPA, 2001). Again, the 50% rule of thumb was applied to find the *E. coli* load per day from each household and the 100% and 25% contribution factors were applied. The *E. coli* load was calculated according to the equation given below. Potential *E. coli* load contribution from dogs was aggregated for each subwatershed (**Table B17**).

$$EC = \# \, of \, HH * 0.8 \frac{dogs}{HH} * 5 * 10^9 \, cfu \, day^{-1} \, head^{-1}$$

Dogs loading equation (Teague, 2009; Riebschleager, 2008)

Table B17: Estimated Number of Dogs and Loading for Each Subwatershed

Subwatershed		# of HH	# of Dogs	E. Coli Loading (in 10^9 CFU/day)
Lower Bastrop (1)	Within Buffer	37	30.0	37.5
	Out Buffer	162	129.6	40.5
Upper Austin (2)	Within Buffer	112	89.4	112
	Out Buffer	330	264.0	825
Flores (3)	Within Buffer	208	166.5	208
	Out Buffer	671	536.8	168
Upper Brushy (4)	Within Buffer	925	739.6	925
	Out Buffer	3463	2770.4	866
Middle Austin (5)	Within Buffer	63	50.3	62.9
	Out Buffer	155	123.8	38.7
Upper Bastrop (6)	Within Buffer	881	704.6	88.1
	Out Buffer	3355	2683.9	83.9
Middle Bastrop (7)	Within Buffer	139	111.0	139
	Out Buffer	43	34.4	10.8

The projected total number of households estimated by the socioeconomic forecasting models at H-GAC was used in estimating the future potential loadings from dogs. The current rate of loading was multiplied by the household increasing rate and added to the existing loading amounts. **Table B18** presents the forecasted loadings from dogs for each subwatershed. As noted previously, this approach errs on the side of caution by including urban areas. Dog waste is also presumed to be a portion of the urban runoff loadings, but as they are based on EMCs instead of separated source volumes, they cannot easily be broken out. In additional, household ownership does not account for feral populations in urban areas, and the urban runoff loading only includes stormwater conditions. Therefore the stakeholders took a conservative approach toward dog source loading, acknowledging there is potential overlap, but not wanting to discount the large number of urban dogs.

Table B18: Estimated Projected E. coli Loading from Dogs for Each Subwatershed

SUBWATERSHED	*E. coli* Loading (CFU/day)						
	2011	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
SW1- BB/Lower Bastrop	78.0	117	139	194	264	335	397
SW2- BB/Upper Austin	194	269	302	353	420	524	597
SW3- BB/Flores	376	438	463	503	599	676	741
SW4- BB/Upper Brushy	1,790	2,160	2,190	2,220	2,260	2,330	2,370
SW5- BB/Middle Austin	102	126	142	196	303	356	425
SW6- BB/Upper Bastrop	1,720	2,160	2,240	2,400	2,520	2,820	3,110
SW7- BB/Middle Bastrop	150	199	225	263	306	358	387
TOTAL	**4,410**	**5,470**	**5,700**	**6,130**	**6,670**	**7,400**	**8,030**

Appendix C: EPDRiv1 Modeling Detail

(Please refer to report on attached media)

Appendix D: BMP Scaling Methodology

BMP Scaling Methodology

To meet bacteria load reduction targets generated by the EPDRiv1 model (**Section 3 and 4)**, this WPP proposes the implementation of a comprehensive selection of BMPs (**Section 5**). BMPs must be implemented on a scale significant enough to generate the required load reductions. The scale of BMP implementation was generated using the following methodology.

Generating Load Reduction Targets by Subwatershed

The EPDRiv1 model generated load reduction targets on a subwatershed basis, in which reductions were based on modeling the decrease in load necessary to meet the contact recreation standard. The basis for meeting the standard was based on a flow-weighted geomean generated for the terminal end of the subwatershed. Each subwatershed was responsible for generating load reductions to meet its own excessive contributions.

Allocating Load Reduction by Source within Subwatershed

Within each subwatershed, the total reduction amount was allocated among the bacteria sources. The allocation was made based on the relative contribution of the sources. For example, if 40% of the 2040 load came from OSSFs, then 40% of the load reduction was to be generated by OSSFs. Or, in other words, each source would need to reduce a proportionate share of its load to meet the reduction target for the subwatershed as a whole.

Developing Representative BMP Units

BMPs developed by the stakeholders were categorized by the source they addressed. To determine the scale of BMP implementation, H-GAC developed scaling factors based on representative BMP unit for each source category. The BMP units were derived from literature values and spatial considerations, and are designed to be representative per unit reduction values related to their respective sources. In essence, the BMP Unit is a single unit of known source reduction value. The scale of BMP implementation is tied to how many BMP units need to be addressed to generate the reduction value.

Table D1: BMP Units

Bacteria Source	BMP Unit
Livestock	Cow/Bull
OSSFs	OSSF
Pet Waste	Dog
Urban Runoff	Acre addressed by BMP
Deer and Feral Hogs	Feral Hog

Excretion or load generation rates were available for all of these units, making then helpful measures of BMP scale.

Spatial Considerations

Because the SELECT loading results were based in part on spatial proximity to water bodies, the spatial distribution of sources had to be considered in developing the load assigned to each representative load for each BMP unit. It was assumed that 100% of the bacteria contributed by a cow in the SELECT buffer area would make it to the waterway, while only 25% of the bacteria from a cow outside the buffer would be transmitted. Therefore, to generate BMP scaling numbers, both loading scenarios would need to be taken into account.

Reduction Values

In additional to spatial considerations, the reduction potential of BMPs addressing the respective sources was considered. Removing a malfunctioning OSSF would result in a 100% reduction in the load from the OSSF. Applying a filter strip as a LID BMP to address urban runoff, however, would only be expected to have a 50% reduction based on literature values regarding the efficiency of that BMP. These reduction values were determined for each category of BMPs and applied as detailed in the following.

BMP Unit Load Estimations

The following assumptions were made to develop load reduction values from BMP units using SELECT.

Deer and Feral Hogs

The representative unit for deer and feral hogs is the feral hog. To identify the BMP scaling for addressing feral hogs, the following steps were used.

1. Because BMPs focus on promoting feral hog removal, it is assumed that the BMP reduction value is 100%.
2. In terms of spatial considerations, feral hogs are assumed to be distributed equally in their habitat.
3. The area acreage of buffer and non-buffer habitat land cover was generated in GIS.
4. The total number of hogs for each subwatershed was generated in SELECT based on the total habitat acreage multiplied by the population density assumed in the SELECT model (hogs/acre X acres = total number of hogs).
5. The numbers of buffer hogs and of non-buffer hogs were determined based on the land cover acreage of habitats within and outside of the buffer.
6. It was assumed that hogs in buffer areas would be the priority for BMP application, and therefore buffer hogs would be the representative unit.
7. The excretion rate per day for a buffer hog was divided into the total load reduction for Deer and feral hogs to produce the number of hogs needing to be addressed by BMPs.

8. The projected number of hogs to be addressed was checked against the available hogs in the buffer area in 2040 to ensure we were not assuming BMPs would address a greater number of hogs than the buffer areas held.[74]

Livestock

1. Because BMPs focus on reducing cattle load rather than removing the cows, BMP reduction values were based on literature values regarding efficiency of related BMPs. BMPs addressing buffer areas were assigned a 70% reduction rate based on literature values, while BMPs addressing non-buffer areas were assigned a 50% reduction rate based on literature values. Therefore BMPs addressing buffer cows had a 70% reduction of the 100% of their load that made it to the water, while BMPs addressing non-buffer cows had a 50% reduction in the 25% of their load that made it to the water.
2. In terms of spatial considerations, cattle are assumed to be distributed equally in their habitat land uses.
3. The total number of cattle for each subwatershed was generated in SELECT based on agricultural census data divided by available habitat acreage.
4. The area acreage of buffer and non-buffer habitat land cover was generated in GIS.
5. The numbers of buffer cattle and of non-buffer cattle were determined based on the land coverage acreage of habitats within and outside of the buffer.
6. It was assumed that keeping cattle waste out of buffer areas would be the priority for BMP application, and therefore buffer cattle would be the representative unit.
7. The excretion rate per day for a buffer cow was divided into the total load reduction for Livestock to produce the number of cattle needing to be addressed by BMPs.
8. The projected number of cattle to be addressed was checked against the available cattle in the buffer area in 2040 to ensure we were not assuming BMPs would address a greater number of cattle than the buffer areas held.

OSSFs

1. Because BMPs focus on removing or remediating OSSFs, it was assumed that the BMP reduction value was 100%.
2. OSSF locations are either known as permitted systems with spatial coordinates, or based on forecasted household growth.
3. The number of buffer OSSFs and non-buffer OSSFs were generated in SELECT. These OSSFs were assumed to be distributed equally.
4. Failure rates from literature values were applied to each OSSF to generate the loadings from malfunctioning OSSFs.
5. The loading value of a malfunctioning OSSF from the SELECT assumptions was divided into the load reduction target for OSSFs for each subwatershed to produce the number of buffer OSSFs that needed to be addressed.

[74] If there were not enough hogs projected to be in the buffer in 2040, a number of hogs from the non-buffer area would be addressed. In this case, the 25% reduction of load from non-buffer areas would mean that four non-buffer hogs would need to be addressed in the place of each unavailable buffer hog.

6. The projected number of buffer OSSFs for 2040 was checked against the number to be reduced to ensure we were not assuming BMPs would address a greater number of OSSFs that were available.

Urban Runoff

1. Because BMPs focus on reducing loads, a variety of standard LID BMPs were reviewed to determine a representative reduction rate. The average of reduction rates in a study (Boyer, DNREC) was approximately 50% (range of 43% to 57%), which was also the approximate reduction value of filter/buffer strips, a popular BMP. It was assumed that 50% was representative of likely urban runoff BMP removal efficiencies.
2. To project the extent of the urban area in and out of the buffer zone, forecasting projections of household growth were used.
3. Bacteria loadings were estimated from buffer and non-buffer urban surfaces for each subwatershed based on empirical studies conducted by PBS&J (PBS&J, 2000).
4. Because flow from urban areas can enter into waterways from drainage systems and also from sheet flow, it cannot be assumed that the buffer area applies to a representative unit or that a BMP in or outside of the buffer area would only impact that area. Therefore, a weighted average was developed based on the total load per acre proportionally from the ratio of buffer areas to non-buffer areas.
5. The weighted average load was applied to the representative BMP unit: an acre addressed by BMP(s).
6. The weighted average load per acre was divided into the total load reduction target for Urban Runoff to produce the number of acres needing to be addressed by BMPs.
7. The total available acreage in 2040 was compared to the number of acres needing to be addressed to ensure that enough acreage was available.

Dogs

1. Because BMPs focused on removing dog waste from the system (pet waste stations, etc), a 100% BMP reduction rate was used.
2. The number of dogs was generated in SELECT based on assumed dogs per household in 2040.
3. The number of future (2040) buffer dogs and non-buffer dogs was generated, by multiplying the forecasted number of households that are inside and outside of the buffer with assumed dogs per household.
4. Because dog waste BMPs are not spatially discrete (i.e. pet waste stations may remove waste that comes from buffer or non-buffer dogs, regardless of the location of the station) a weighted average load for dogs was produced. The weighted average was derived from the forecasted ratio of buffer and non-buffer dogs developed in #3 as applied to an excretion rate.

5. The weighted average load was divided into the load reduction needed from dogs to find the number of dogs whose waste needed to be addressed by BMPs.

BMP Scaling

The results of the BMP scaling exercise are represented in the tables in **Section 4.**