Executive Summary

Bacteria are the most common water quality impairment in the Houston-Galveston region, with 51% of the segments being impaired for the contact recreation use. When a waterway is designated as impaired, a Total Maximum Daily Load (TMDL) must be developed for each of the segments. A TMDL "is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards" (United States Environmental Protection Agency). Once a TMDL is completed, an Implementation Plan (I-Plan) must be developed. An I-Plan recommends best management practices designed to reduce the pollutant of concern and restore the waterway to its designated use.

The segments included in this I-Plan were first listed on the state of Texas' 303(d) list in 1996, 1998, 2002, and 2006 as impaired due to high levels of bacteria. In accordance with requirements of Section 303(d) of the federal Clean Water Act, the Texas Commission on Environmental Quality (TCEQ) adopted or will adopt TDMLs for all of the affected segments. The ultimate goal in this I-Plan is the reduction of bacteria concentrations in the 72 bacteria impaired segments included in this plan that do not meet water quality standards for contact recreation. This document applies to the segments that have been impaired for bacteria, as listed in 303(d) lists. It also applies to adjacent and nearby segments and their encompassing watersheds, as indicated in Figure 1. BIG project area. Additionally any segments in the BIG project area that become impaired for bacteria while implementation under this plan is still occurring will be considered covered by this plan.

The TDMLs and their status are outlined in Table 1. Briefly, 18 TMDLs for bacteria in Buffalo and Whiteoak Bayous and their tributaries were adopted by TCEQ on April 8, 2009. Nine TMDLs for bacteria in Clear Creek and its tributaries were adopted September 10, 2008. Eight TMDLs in the Greens Bayou Watershed were adopted on June 2, 2010. TMDLs for the remaining Houston Metro and Lake Houston TMDL projects have not been adopted as of August 12, 2010.

Table 1. TMDL adoption and approval dates

TMDL	Segments in the TMDL	TCEQ adoption date	USEPA approval date
Eighteen Total Maximum Daily Loads for Bacteria in Buffalo and Whiteoak Bayous and Tributaries	1013, 1013A, 1013C, 1014, 1014A, 1014B, 1014E, 1014H, 1014K, 1014L, 1014M, 1014N, 1014O, 1017, 1017A, 1017B, 1017D, and 1017E	April 8, 2009	June 11, 2009
Nine Total Maximum Daily Loads for Bacteria in Clear Creek and Tributaries	1101, 1101B, 1101D, 1102, 1102A, 1102B, 1102C, 1102D, and 1102E	September 10, 2008	March 6, 2009
Eight Total Maximum Daily Loads for Indicator Bacteria in Greens Bayou Above Tidal and	1016, 1016A, 1016B, 1016C, and 1016D	June 2, 2010	Not yet approved

Tributaries			
Five Total Maximum Daily Loads for Indicator Bacteria in Brays Bayou and Tributaries	1007B, 1007C, 1007E, and 1007L	Not yet adopted	Not yet approved
Four Total Maximum Daily Loads for Indicator Bacteria in Sims Bayou and Tributaries	1007D and 1007N	Not yet adopted	Not yet approved
Four Total Maximum Daily Loads for Indicator Bacteria in Halls Bayou and Tributaries	1006D, 1006I, and 1006J	Not yet adopted	Not yet approved
Thirteen Total Maximum Daily Loads for Indicator Bacteria in the Eastern Houston Bayous and Tributaries	1006F, 1006H, 1007F, 1007G, 1007H, 1007I, 1007K, 1007M, 1007O, and 1007R	Not yet adopted	Not yet approved
Seventeen Total Maximum Daily Loads for Indicator Bacteria in Lake Houston and Tributaries	1004E, 1008, 1008H, 1009, 1009C, 1009D, 1009E, 1010, and 1011	Not yet adopted	Not yet approved

Items described in this I-Plan:

- the steps the TCEQ and its stakeholders will take to achieve the pollutant reductions identified in the TMDL reports,
- the schedule for implementation activities,
- a description of the legal authority under which the participating agencies may require implementation of the implementation activities,
- the tracking and monitoring plan to determine the effectiveness of the implementation activities
- the measureable outcomes for assessing progress, and
- communication strategies that will be used.

Based on the TMDLs, the following reductions are needed to meet respective criteria defined in the state water quality standards:

- 25 to 91 percent reductions in bacterial loading for Clear Creek TMDLs,
- 59 to 99 percent reduction in bacterial loading for Buffalo and Whiteoak Bayous' TMDLs,
- 46 to 99 percent reductions in bacterial loading for Houston Metropolitan TMDLs, and
- 41 to 87 percent reductions in bacterial loading for Lake Houston TMDLs.

During development of the TMDLs, the TCEQ identified possible point and nonpoint sources of bacteria and quantified the appropriate reductions necessary to comply with established water

quality standards. Field assessments identified possible sources of bacteria, which include wastewater treatment facilities (WWTFs), sanitary sewer systems, on-site sewage facilities, storm water runoff, illicit discharges, agriculture, livestock, wildlife, pets, sediment re-suspension, and bacterial regrowth.

Implementation activities that will be used to reduce bacteria levels are organized in this document by category. The primary focus of the implementation activities in each section can be found in Table 2.

Table 2. Summary of recommended implementation activities

I-Plan Section	Activity Category	Focus of Implementation Activities
Implementation Strategy 1.0	Wastewater Treatment Facilities	Increase monitoring requirements, impose stricter bacteria limits than those designated by the state, require updates to facilities not able to comply with limits, and increase enforcement.
Implementation Strategy 2.0	Sanitary Sewer Systems	Require all systems to develop and implement a utility asset management program and to protect against power outages at lift stations.
Implementation Strategy 3.0	On-site Sewage Facilities	Address failing systems and inadequate maintenance.
Implementation Strategy 4.0	Storm Water and Land Development	Expand storm water quality programs, develop a recognition program, and petition TCEQ to facilitate reimbursement of bacteria reduction measures.
Implementation Strategy 5.0	Construction	Improve compliance and enforcement of existing storm water quality permits.
Implementation Strategy 6.0	Illicit Discharges and Dumping	Increase efforts to address direct and dry-weather discharges, and better control waste hauler activities.
Implementation Strategy 7.0	Agriculture and Animal	Expand existing cost-share programs and the management of feral hog populations.
Implementation Strategy 8.0	Residential	Expand public education efforts.
Implementation Strategy 9.0	Monitoring and Plan Revision	Maintain databases of ambient and non-ambient water quality monitoring data and implementation activities, review I-Plan progress, and update I-Plan.
Implementation Strategy 10.0	Research	Examine effectiveness of storm water activities, bacteria persistence and regrowth, and appropriate indicators for use in water quality monitoring.

Many of the strategies in this I-Plan are new to this region, and limited data is available on their effectiveness and cost-effectiveness in our region. Stakeholders developed the implementation strategies, based on their best professional judgments, through a series of workgroup meetings

for each source of bacteria. Accordingly, an iterative management approach is recommended, so that data from early implementation efforts can be used to refine strategies throughout the life of the I-Plan. The Houston Galveston Area Council (H-GAC) staff will track the implementation of activities and monitor water quality results to assess effectiveness of the various efforts. Additional information regarding the I-Plan implementation monitoring strategy can be found in Implementation Strategy 9.0, which includes a recommendation for the creation and maintenance of a regional implementation activity database.

Recommendations in this Plan are presented in sections describing the various sources of bacterial pollution identified through stakeholder and TMDL processes. These include a description of activities, identification of the parties responsible for implementing the activities, a schedule for implementation, the goals associated with the activities, and a process for tracking, evaluating, and reporting progress. A process of implementation, monitoring, analyses, adaptation, and review is also outlined to so the I-Plan is regularly updated. In this way, the I-Plan provides a pragmatic and scientifically based approach to meet water quality goals within a reasonable timeframe.

Introduction

Throughout Texas, waterbodies are impaired for a variety of pollutants such as bacteria, dissolved oxygen, and temperature. In Texas most waterbodies are required to meet the bacteria standard for contact recreation use, either *E. coli* or *Enterococcus* depending on waterway characteristics. In the Houston-Galveston region, bacteria is the most common pollutant of concern. The 72 bacteria impaired segments covered by the plan outlined in this document represent 65% of assessed streams. It is this high level of bacteria impairment which is the focus of this document.

When a waterway is designated as impaired, a Total Maximum Daily Load (TMDL) must be developed for each of the segments. A TMDL "is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards" (United States Environmental Protection Agency). Once a TMDL is completed, an Implementation Plan (I-Plan) must be developed. An I-Plan recommends implementation activities designed to reduce the pollutant of concern and restore the waterway to its designated use. This I-Plan describes activities to reduce bacteria levels in many of the impaired waterways and adjacent areas in the Houston-Galveston region.

Problem Definition

Impairments for the contact recreation use of the 72 segments have been identified in the 1996, 1998, 2002, and 2006 *Texas Water Quality Inventory and 303(d) Lists* (See Table 3). Projects were initiated to identify possible point and nonpoint sources of bacteria, and to quantify appropriate reductions necessary to comply with established water quality standards.

Table 3. Segments categorized by year of first listing for bacteria impairment

Year placed on the *Texas Water Quality Inventory and 303(d) List*	**Segment ID**
1996	1004, 1008, 1009, 1013, 1014, 1016, 1017, 1101, 1102,
1998	1113A
2002	1006D, 1006F, 1006H, 1006I, 1006J, 1007B, 1007C, 1007D, 1007E, 1007F, 1007G, 1007H, 1007I, 1007K, 1007L, 1007M, 1007N, 1007O, 1007R, 1013A, 1013C, 1014H, 1014K, 1014M, 1014N, 1014O, 1016A, 1016B, 1016C, 1016D, 1017A, 1017B, 1017D, 1017E, 1101B, 1102A, 1102B,
2006	1002, 1003, 1004D, 1004E, 1005, 1006, 1007, 1007A, 1008B, 1008H, 1009C, 1009D, 1009E, 1010, 1011, 1014A, 1014B, 1014E, 1014L, 1101D, 1102C, 1102D, 1102E, 1113, 1113B,

The BIG project area is depicted in Figure 1. On the map, the portions of waterways considered to be impaired, as indicated on the 303(d) list, are shown in red. Almost all of the waterways shown in Figure 1 have been designated as appropriate for primary contact recreation. Primary contact recreation can be defined as recreational activities, such as swimming, waterskiing, or

wading by children, that present a high probability of ingesting water. Criteria have been developed that reflect the risk associated with participating in primary contact recreation in water with various levels of indicator bacteria.

The numeric criteria defined in the standards for support of the primary contact recreation use are as follows:

- *E. coli*
  - The geometric mean of *E. coli* in freshwater should not exceed 126 *E. coli* per 100 milliliters (126 org per 100mL).
  - Single samples of *E. coli* in freshwater should not exceed 399 org per 100mL more than 25 percent of the time.[1]
- *Enterroccocus*
  - The geometric mean of enterococci in saltwater should not exceed 35 enterococci per 100 milliliters.
  - Single sample of enterococci in saltwater should not exceed 104 enterococci per 100 milliliters.

While these numbers represent the standards for primary contact recreation adopted by TCEQ on June 30, 2010, other standards may have been in place prior to that date that led to a stream being identified as impaired for bacteria.

This document applies to the segments that have been impaired for bacteria, as listed in 303(d) lists. It also applies to adjacent and nearby segments and their encompassing watersheds, as indicated in Figure 1. BIG project area.

Project Area Description

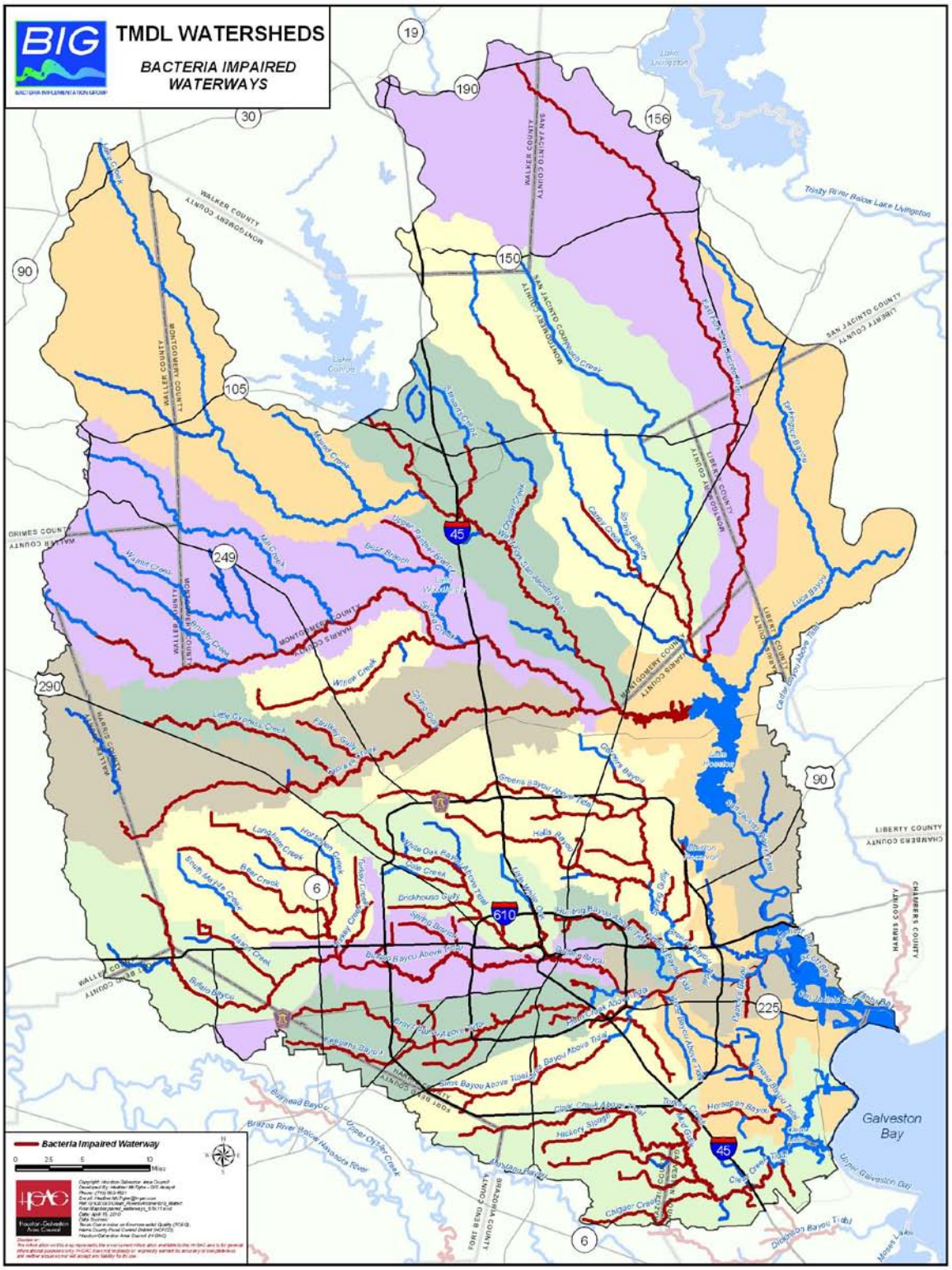
The Texas Commission on Environmental Quality (TCEQ) developed Total Maximum Daily Loads (TDMLs) for most of the segments mentioned above. The TMDL is a technical analysis that:

- determines the amount of a particular pollutant that a water body can receive and still meet applicable water quality standards and
- estimates how much the pollutant load must be reduced to comply with water quality standards.

TCEQ grouped several impaired segments together based on geography to create TMDL projects. TMDL projects allow for evaluation and analysis of related waterbodies to be considered together, both by scientists and by stakeholders. Stakeholders indicated that they would like to develop an I-Plan that was common to all four TMDL project areas. Stakeholders also decided to expand the BIG project area beyond the scope of the four project areas. Many of these other watersheds are either connected to the impaired waterways, share political jurisdictions with impaired watersheds, or are thought to have high levels of bacteria not identified because of lack of sampling results.

[1] http://www.tceq.state.tx.us/assets/public/legal/rules/rule_lib/adoptions/RG-194.pdf p 24

Figure 1. BIG project area



BIG Project Area

The BIG project area is roughly 3,799 square miles and has a population of about 4.7 million people (H-GAC 2010 projection). The area encompasses almost all of the City of Houston and part or all of another 78 cities and 11 counties. It stretches from Galveston Bay and the Clear Creek watershed in the south to the City of Huntsville in the north and to the cities of Waller and Katy in the west. Appendix A contains tables listing all of the monitored stream segments in the BIG area, along with information about whether the waterway is impaired or tidally influenced.

The following are the TMDL projects encompassed by the BIG project area and addressed by this document.

Clear Creek TMDL Project Area

The nine impaired segments of Clear Creek, consisting of two main segments and seven tributaries, are located southeast of and in the city of Houston, Texas. The Clear Creek watershed encompasses approximately 180 square miles of land with approximately 40 percent within Brazoria County, 35 percent within Harris County, 20 percent within Galveston County, and 5 percent within Fort Bend County. The eastern and central portions of the watershed are primarily urban and residential, with some commercial and industrial uses. The western and southern parts of the watershed include rural and agricultural land uses, which continue to transition over time from cultivated and woody land to developed land.

Buffalo and Whiteoak Bayous TMDL Project Area

The eighteen impaired segments of Buffalo and Whiteoak Bayous, consisting of three main segments and fifteen tributaries, are located within and to the west of the city of Houston, Texas. The Buffalo and Whiteoak Bayous' watersheds encompass approximately 492 square miles of land in Harris County, Fort Bend County, and Waller County, with the majority being within Harris County. Buffalo Bayou flows from the outlying, less-developed portions of Waller, Harris, and Fort Bend counties, joining Whiteoak Bayou Above Tidal in the highly urbanized central part of the Houston business district. An important, unique feature of the Buffalo Bayou watershed is that two flood control reservoirs are located in the upstream end of Buffalo Bayou Above Tidal. The U. S. Army Corps of Engineers operates the reservoirs to minimize flooding downstream on Buffalo Bayou.

Houston Metropolitan TMDL Project Area

The twenty-four impaired segments of Houston Metropolitan watersheds are located primarily within Harris County, Texas, with only a small portion of Brays and Sims Bayous' watersheds reaching into Fort Bend County. The watersheds encompass approximately 416 square miles of land. The Houston Metropolitan watersheds are highly developed with a mix of residential, commercial, and industrial uses, although some undeveloped areas still exist.

Lake Houston TMDL Project Area

The fourteen impaired segments of the Lake Houston watershed are located within the San Jacinto River Basin in East Texas. The Lake Houston watershed encompasses approximately 2,362 square miles of land, primarily in Harris and Montgomery Counties, but also with portions

in Grimes, Liberty, San Jacinto, Walker, and Waller Counties. The southern portion of the watershed includes portions of the City of Houston and its northern suburbs. The Woodlands and the City of Conroe are the largest communities located entirely within the watershed. The northern portions of the watershed are relatively rural and include portions of the Sam Houston National Forest.

Potential Sources of Bacteria

Pollutants may come from several sources, both point and nonpoint. Possible sources of bacteria in the impaired segments, in no particular order, include:

- non-compliant wastewater treatment facility (WWTF) discharges;
- industrial and construction site discharges;
- municipal separate storm sewer systems;
- unpermitted storm sewer systems;
- sanitary sewer overflows;
- leaking wastewater infrastructure;
- dry weather discharges/illicit discharges into and from storm sewers;
- sediment re-suspension;
- bacteria regrowth;
- failing on-site sewage facilities (septic systems);
- agricultural activities and domesticated animals;
- wildlife; and
- pets.

Methods for Estimating Bacteria Loads

In the development of the Houston-Galveston area bacteria TMDLs, various methods were used to analyze indicator bacteria loads, in-stream water quality, and load reductions. Relating bacteria loading to in-stream bacteria levels is difficult because of the dynamics of bacteria populations. Bacteria populations can be affected by factors such as sunlight, water temperature, nutrients, sediment, etc.

The specific models for each project area were chosen based on available information about how various models work and characteristics of the waterbodies. For the Clear Creek TMDL, load duration curve (LDC) analyses were used for the seven freshwater segments and a tidal prism method was used for the two tidal segments. Three methods of analysis were used to analyze bacteria loads for the Buffalo and Whiteoak Bayous' TMDLs: LDC analyses, a mass balance analysis using Bacteria Load Estimator Spreadsheet Tool (BLEST), and a Hydrologic Simulation Program Fortran (HSPF) analysis for simulation of watershed hydrology and water quality. LDC analyses were used for all Houston Metropolitan and Lake Houston waterways.

In LDCs, a line displays the maximum allowable load over the complete range of flow conditions based on the calculation of flow multiplied by the criterion. Using LDCs, a TMDL can be expressed as a continuous function of flow, equal to the line, or as a discrete value derived from a specific flow condition. LDCs do not simulate the fate of contaminants; rather, they

calculate allowable loading for a given flow and they show the distribution of bacteria exceedences during different flow levels.

A time-varying tidal prism modeling approach with a moderate level of spatial resolution allows for the calculation of bacteria loadings in tidal waterways. The tidal prism is the volume of water between low and high tide levels or between the high tide elevation and the bottom of the tidal waterway. The model incorporates the three mechanisms through which bacteria loadings enter the impaired systems, runoff, direct point source discharges, and tidally influenced loadings.

BLEST is designed to calculate or estimate the indicator bacteria loads and load reductions for each segment needed to attain the water quality standard for the segment. It estimates load reductions for a fixed time interval and a given segment and does not incorporate the temporal variations associated with pathogen loads. However, it does allow an evaluation of loads by subwatershed.

The HSPF model is a continuous simulation model for watershed hydrology and water quality. The model can account for both point source and nonpoint source loadings in the watershed. HSPF includes simulation of the receiving stream that receives mass loadings from the watershed.

TMDL Equation

The standard TMDL equation is "TMDL = WLA + LA + MOS" where TMDL is Total Maximum Daily Load, WLA is Waste Load Allocation, LA is Load Allocation, and MOS is Margin of Safety, a factor to account for uncertainty and future growth. The equation is used to allocate loads amongst different sources of a pollutant.

Wasteload allocations (WLA) were determined for point sources in each TMDL. These point sources include effluent discharges from permitted wastewater treatment facilities, permitted storm water runoff, and other point sources. Load allocations (LA) for nonpoint sources generally include background loads, upstream loads, storm water runoff not subject to permit, on-site sewage facility loads, and other direct nonpoint sources such as direct animal deposition and leaking wastewater infrastructure. Allocated loads for all TMDLs covered by this document can be found in Appendix ##.

Implementation Plan Overview

In order to keep Texas' commitment to restore and maintain water quality in impaired rivers, lakes, bayous, and bays, the TCEQ recognizes that it must establish implementation plans for each TMDL. This Implementation Plan (I-Plan) is designed to guide activities that will reduce bacteria in the 65 segments as defined in the adopted TMDLs in addition to seven other segments in the BIG project area impaired for bacteria. The ultimate goal of the I-Plan is to restore the contact recreation use, where appropriate, by reducing concentrations of bacteria, specifically *E. coli* and *Enterococcus*, to levels that meet the criteria established in the water quality standards for contact recreation, 126 *E. coli*/100mL and 35 enterococci/100mL respectively.

This I-Plan is a flexible tool that governmental and nongovernmental organizations involved in implementation will use to guide their program management. The participating organizations may accomplish the activities described in this I-Plan through appropriate voluntary or

regulatory measures. Progress will be evaluated on a regular basis with updates/changes being made to the plan as appropriate.

This I-Plan contains the following components:

1) a description of implementation activities and management measures that will be implemented to achieve the water quality targets;
2) a schedule for implementing activities;
3) a description of the legal authority under which the participating agencies may require implementation of the implementation activities;
4) a follow-up tracking and monitoring plan to determine the effectiveness of the implementation activities and management measures undertaken;
5) identification of measureable outcomes and other considerations the TCEQ will use to determine whether the I-Plan has been properly executed and water quality standards are being achieved, or whether the plan needs to be modified; and
6) identification of communication strategies the TCEQ will use to disseminate information to stakeholders and other interested parties.

This I-Plan includes all of the nine key elements (Tables **) for watershed-based plans as prescribed in the *FY 2004 Guidelines for the Award of Section 319 Nonpoint Source Grants to States and Territories* (USEPA, 2004). Consequently, projects developed to implement nonpoint source elements of this Plan that meet the conditions of the USEPA's Section 319(h) incremental grant program are eligible to receive this funding. I-Plans differ from Watershed Protection Plans (WPPs) in two key ways. First, I-Plans typically address only one pollutant in a waterbody or waterbodies while WPPs address all sources and causes of watershed impairments and threats. Second, I-Plans are usually regulatory and state driven while WPPs are usually voluntary and locally driven.

Primary bacteria sources of concern include wastewater treatment facilities, sanitary sewer systems, on-site sewage facilities, and stormwater, however, loadings from the various sources cannot be quantified at this time. Top implementation activities for these sources include more stringent bacteria monitoring requirements and bacteria limits for wastewater treatment facilities, requirements for all sanitary sewer systems to develop and implement an operations and maintenance program, the creation of a geographic inventory of on-site sewage facilities, and the geographic expansion of storm water quality programs.

The following is a list of the sections in this document:

Implementation Strategy 1.0 Wastewater Treatment Facilities

Implementation Strategy 2.0 Sanitary Sewer Systems

Implementation Strategy 3.0 Onsite Sewage Facilities (including septic systems)

Implementation Strategy 4.0 Stormwater and Land Development

Implementation Strategy 5.0 Construction

Implementation Strategy 6.0 Illicit Discharges and Dumping

Implementation Strategy 7.0 Agriculture and Animals

Implementation Strategy 8.0 Residential

Implementation Strategy 9.0 Monitoring and Plan Revision

Implementation Strategy 10.0 Research

The H-GAC Community and Environmental Planning Department prepared this I-Plan in collaboration with the Bacteria Implementation Group (BIG), a stakeholder group appointed by the H-GAC Board charged with the plan's development.

The commission approved this I-Plan on [date].