BACTERIA IMPLEMENTATION GROUP'S TOP FIVE MOST AND TOP FIVE LEAST IMPAIRED WATER BODIES

Final Report
May 31, 2017

Project funded through grants from the U.S Environmental Protection Agency through the Texas Commission on Environmental Quality's Galveston Bay Estuary Program.

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Prepared by the Houston-Galveston Area Council in cooperation with the Texas Commission on Environmental Quality's Galveston Bay Estuary Program and U.S. Environmental Protection Agency.

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List of Acronyms

BIG	Bacteria Implementation Group
CAR	Corrective Action Report
CFU	Colony-Forming Unit of Bacteria
COH	City of Houston
CRP	Clean Rivers Program
EPA	Environmental Protection Agency
GPS	Global Positioning System
GBEP	Galveston Bay Estuary Program
H-GAC	Houston-Galveston Area Council
IDDE	Illicit Discharge Detection and Elimination
I-Plan	Implementation Plan
LDC	Load Duration Curve
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
NELAP	National Environmental Laboratory Accreditation Program
OSSF	Onsite Sewage Facility
QAPP	Quality Assurance Project Plan
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
Top2/Least2	Top 2 Most Impaired/Top 2 Least Impaired Lists
Top5/Least5	Top 5 Most Impaired/Top 5 Least Impaired Lists
Top10/Least10	Top 10 Most Impaired/Top 10 Least Impaired Lists
USGS	United States Geological Survey
WPP	Watershed Protection Plan
WWTF	Wastewater Treatment Facility

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Executive Summary

In an area without mountains or other distinctive topography, the meandering bayous, streams, and gulf coast shoreline are what distinguish the Houston-Galveston region from other parts of the country. Clean water is essential to the region's ability to leverage this natural resource to promote an enhanced quality of life for its residents.

Currently, nearly half of the stream miles in the Houston-Galveston region have bacteria levels higher than the state standard for contact recreation. The Bacteria Implementation Group (BIG) was developed to address elevated levels of bacteria in 102 bacteria-impaired stream segments in the region. The BIG is responsible for development and approval of an Implementation Plan that helps reduce bacteria concentrations in the BIG project area and ultimately remove bacteria-impaired streams from the state's list of impaired water bodies.

The BIG I-Plan supports Illicit Discharge Detection and Elimination (IDDE) and other targeted bacteria monitoring projects as a valuable implementation tool that can help reduce bacteria levels. The BIG's Top Five Most and Top Five Least Impaired Water Bodies (Top 5/Least 5) project was developed to support IDDE by performing targeted bacteria monitoring investigations in the most and least bacteria-impaired water bodies in the BIG project area.

The Top 5/Least 5 project followed a structured, three-tiered approach. Project tasks were split into three phases with each phase building on the last. The project flow chart summarizes the primary components included in each phase of the project. Results and observations found during Phase I and II of the project are detailed in the Preliminary Action Report and the Bacteria Source Identification Report, respectively. A summary of bacteria results from each phase of sampling is shown in Table 1.

Table 1. Summary of bacteria data collected throughout the project. Concentrations greater than 126 MPN/100mL are in exceedance of state water quality standards for *E.coli.*

Most Bacteria-Impaired Streams				
Little White Oak Bayou (1013A_01)	**No. of Samples**	**Minimum**	**Maximum**	**Mean**
Phase I *E.coli* (cfu/100mL)	25	0	TNTC[1]	8,888[2]
Phase II Dry Weather *E.coli* (MPN/100mL)	8	161	7,700	1,317
Phase II Wet Weather *E.coli* (MPN/100mL)	8	11,200	24,200	22,575
Rummel Creek (1014N_01)	**No. of Samples**	**Minimum**	**Maximum**	**Mean**
Phase I *E.coli* (cfu/100mL)	13	100	2,275	552
Phase II Dry Weather *E.coli* (MPN/100mL)	4	175	1,860	834
Phase II Wet Weather *E.coli* (MPN/100mL)	5	8,660	24,200	17,792
Least Bacteria-Impaired Streams				
Canal C-147 (1007A_01)	**No. of Samples**	**Minimum**	**Maximum**	**Mean**
Phase I *E.coli* (cfu/100mL)	21	0	TNTC[1]	2,306[2]
Phase II Dry Weather *E.coli* (MPN/100mL)	4	5	605	167
Phase II Wet Weather *E.coli* (MPN/100mL)	7	63	24,200	9,860
Upper Panther Branch (1008B_02)	**No. of Samples**	**Minimum**	**Maximum**	**Mean**
Phase I *E.coli* (cfu/100mL)	15	20	3,420	496
Phase II Dry Weather *E.coli* (MPN/100mL)	4	52	185	111
Phase II Wet Weather *E.coli* (MPN/100mL)	4	5,790	9,800	7,533

[1]Samples with greater than 200 bacteria colonies formed per dish using the Phase I methodology were reported as Too Numerous To Count (TNTC).

[2]For Phase I mean calculations, samples reported as TNTC were given an estimated 20,000 cfu/100mL value because that is the upper limit of reliable bacteria concentrations measurable using Phase I methodology. Note that the reported mean concentrations are likely an underestimate due to this assumption.

Monitoring results were shared with local jurisdictions so that actions could be taken to address the issues. Overall, results indicate that the primary source of bacteria in the most impaired streams were related to point sources of pollution while the least impaired streams are impacted more so by nonpoint sources. Actions taken by local jurisdictions include follow up investigations to identify potential leaks and illicit discharges, infrastructure repairs, increased wastewater treatment facility sampling, and development of action plans and educational efforts for local residents.

Focusing efforts on the most and least bacteria-impaired waterways increases the likelihood of identifying significant sources of bacteria impacting the region while working toward removing impaired streams from the states list of impaired water bodies. Coordinating targeted bacteria monitoring and investigations with local jurisdictions also improves cost effectiveness for cities and counties managing municipal separate storm water system (MS4) permits by reducing duplication of effort, improving efficiency of corrective action implementation, and avoiding potential permit violations. The BIG's Top 5/Least 5 project can be used as a model for IDDE program implementation and efficient management of water resources in a rapidly growing metropolitan area.

Introduction

In an area without mountains or other distinctive topography, the 16,000 miles of meandering bayous, streams, and gulf coast shoreline are what distinguishes the Houston-Galveston region from other parts of the country. Clean water is essential to the region's ability to leverage this natural resource to promote an enhanced quality of life for its residents, provide healthy habitats for a diverse population of fish and wildlife, and set a precedent for efficient management of water resources in a rapidly growing metropolitan area.

With regional population growth of several million projected by the year 2040, there will be a greater strain on sustaining the quality and quantity of surface waters for future generations. Incoming residents will require water for everyday activities, increasing water supply needs and producing larger volumes of domestic wastewater. New residents will also utilize available recreational opportunities, increasing the need to ensure local waterways meet state water quality standards for contact recreation uses.

Currently, nearly half of the stream miles in the Houston-Galveston region have bacteria levels higher than the state standard for contact recreation (H-GAC 2016 Basin Summary Report). That equates to over 6,500 miles of bayous, streams, and gulf coast shoreline that pose a risk to human health during recreational activities. High bacterial concentrations may cause gastrointestinal illness or skin infections in swimmers or others who come into direct contact with polluted waters. Additionally, high bacterial concentrations may impact other water quality issues, like reducing dissolved oxygen levels, leading to potential fish kills that negatively impact ecotourism and commercial fishing in the region.

Several water quality and watershed management projects have been implemented over the years to address the ongoing bacteria problem in the region. These initiatives include development of Watershed Protection Plans (WPPs), Total Maximum Daily Loads (TMDLs), and Implementation Plans (I-Plans) to reduce bacteria levels through the implementation of best management practices (BMPs). One of the more robust efforts includes I-Plan development by the Bacteria Implementation Group (BIG), a partnership of government, business, and community leaders, that address elevated levels of bacteria in 102 bacteria-impaired stream segments in the Houston-Galveston Region. The BIG's Top Five Most and Top Five Least Impaired Water Bodies (Top 5/Least 5) project was developed to support the BIG's efforts in reducing bacteria concentrations in the most and least bacteria-impaired waterways in the BIG project area using a targeted monitoring approach.

The Houston-Galveston Area Council (H-GAC) is the Regional Council of Governments for the Gulf Coast State Planning Region and has been actively involved in regional water quality planning and public outreach activities since the 1970s. H-GAC is designated as the lead agency responsible for administration of the BIG's Top 5/Least 5 project. Funding was provided through grants from the U.S. Environmental Protection Agency (EPA) through the Texas Commission on Environmental Quality's (TCEQ) Galveston Bay Estuary Program (GBEP) and is intended to support the Non-point Source and Point Source action plans of The Galveston Bay Plan.

Project Significance and Background

The Texas Commission on Environmental Quality (TCEQ) continually assesses water quality conditions for stream segments in the State through established quarterly monitoring programs like the Texas Clean Rivers Program. The TCEQ uses data collected through this effort to develop state water quality standards and to maintain a list of stream segments that do not meet those standards. This list of impaired waterways is updated every two years and published in the Texas Integrated Report. Bacteria impairments continue to be the most pervasive water quality issue in the Houston-Galveston region.

The BIG was formed in 2008 to develop and approve an I-Plan that addresses elevated bacteria levels in 72 bacteria-impaired stream segments in the region. Since its inception, support for the BIG has continued to grow and now includes a project area covering a total of 102 bacteria-impaired stream segments (Figure 1). Success for the BIG will be achieved when waters assessed by the state in the BIG project area are no longer considered impaired for bacteria and contact recreation standards are met.

As part of this effort, the BIG developed a list of Top 10 Most Impaired and Top 10 Least Impaired streams to evaluate waterways with the highest bacteria concentrations above the state standard and waterways closest to meeting state water quality standards, respectively (Figures 2 and 3). Additionally, The BIG I-Plan supports Illicit Discharge Detection and Elimination (IDDE) and other targeted bacteria monitoring projects as a valuable implementation tool that can help reduce bacteria levels. The BIG's Top 5/Least 5 project was developed to support IDDE by performing targeted bacteria monitoring investigations in the most and least bacteria-impaired water bodies identified in the BIG project area.

Although the Clean Rivers Program provides data necessary to assess and monitor overall surface water quality conditions for stream segments throughout the state, it does not provide the information necessary to identify specific bacteria sources impacting those streams. Targeted bacteria monitoring and IDDE programs allow for expanded sampling of streams at outfall locations, tributaries, and surface waters in order to identify illicit discharges or other bacteria sources and work toward eliminating them.

Focusing investigative efforts on the most and least bacteria-impaired waterways in the project area increases the likelihood of identifying significant sources of bacteria and illicit discharges impacting the region. Additionally, coordinating targeted bacteria monitoring with MS4 permittees and local jurisdictions will improve the efficiency of implementing corrective actions in areas that need it most. The BIG's Top 5/Least 5 project can be used by MS4 permit holders as a model for IDDE program implementation that can help save costs while supporting effective management of water resources in rapidly growing metropolitan areas. This report outlines the methodology used during each phase of the project and can be a guide for those interested in implementing similar coordinated IDDE programs in their area.

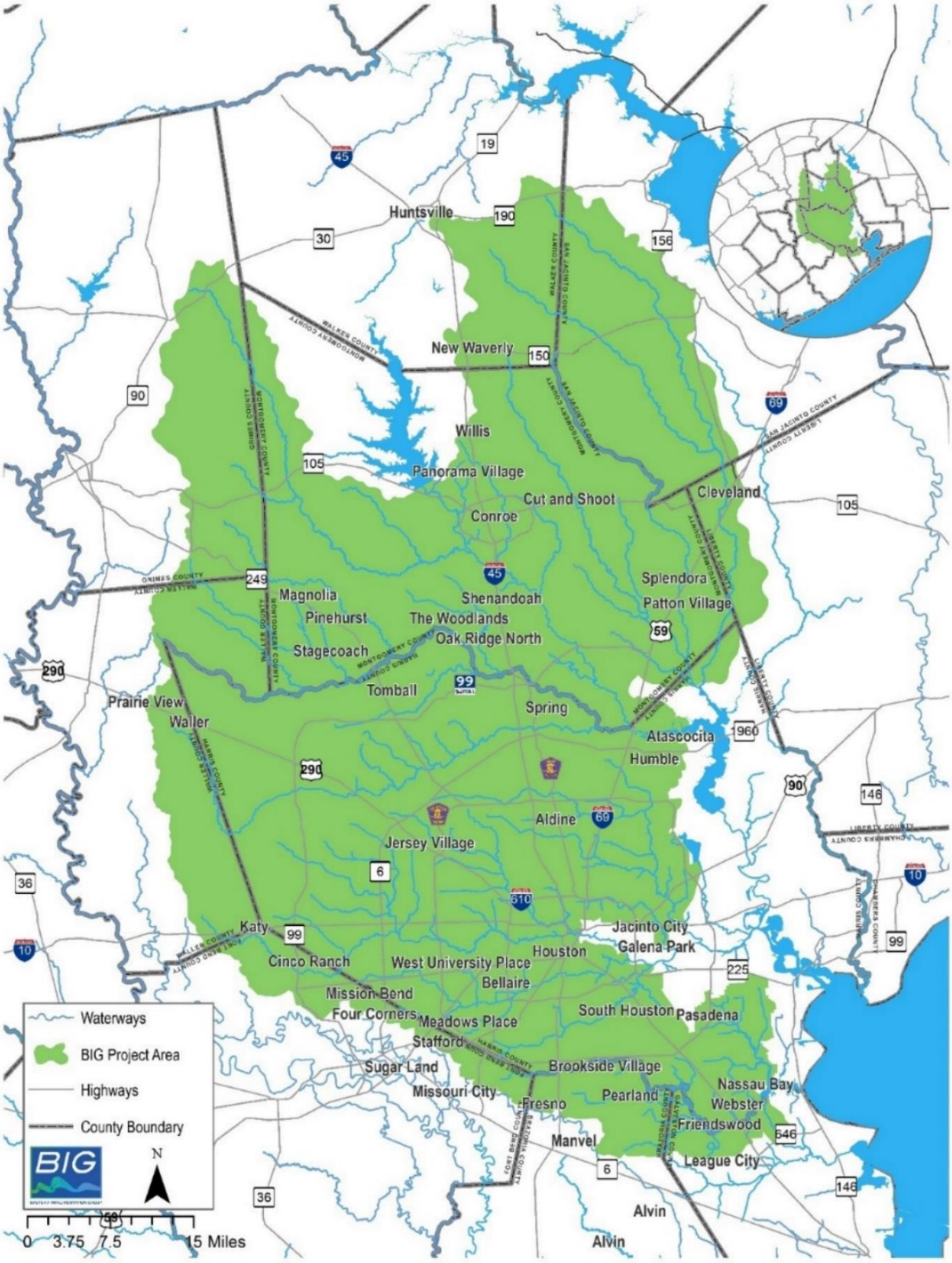

Figure 1. Map of BIG project area

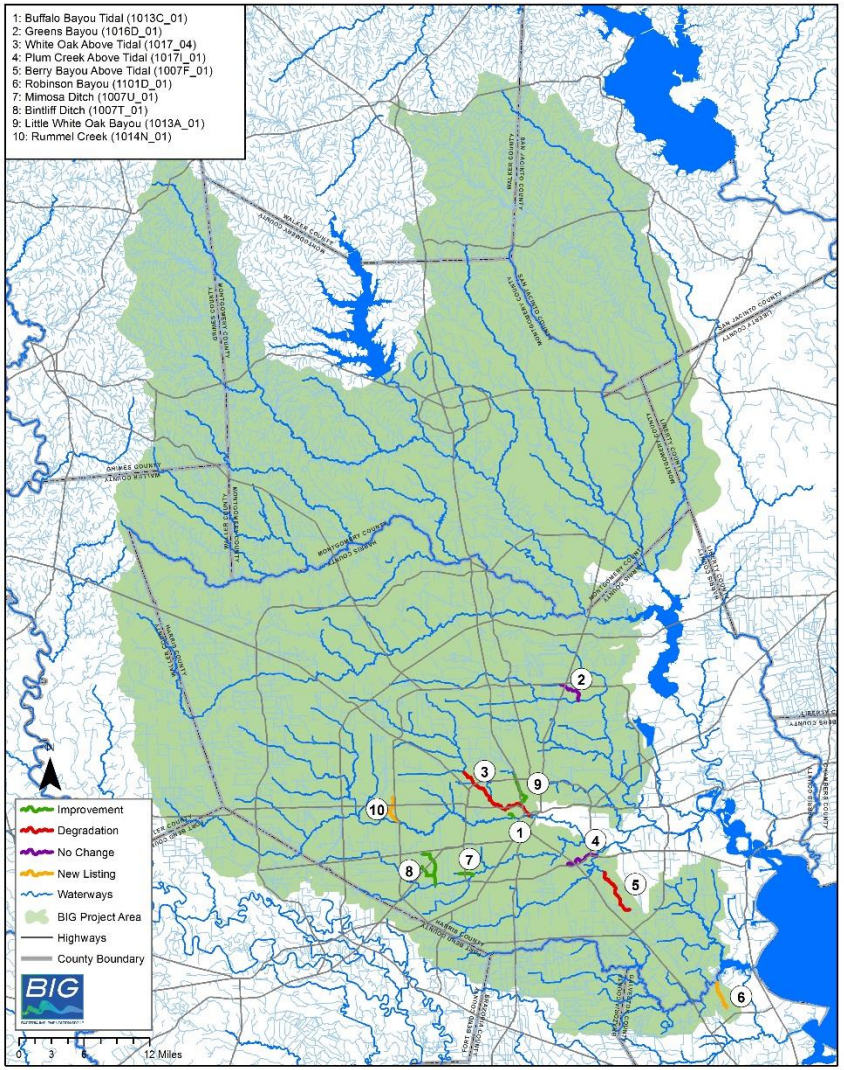

Figure 2. Top 10 Most Bacteria-Impaired streams from 2015

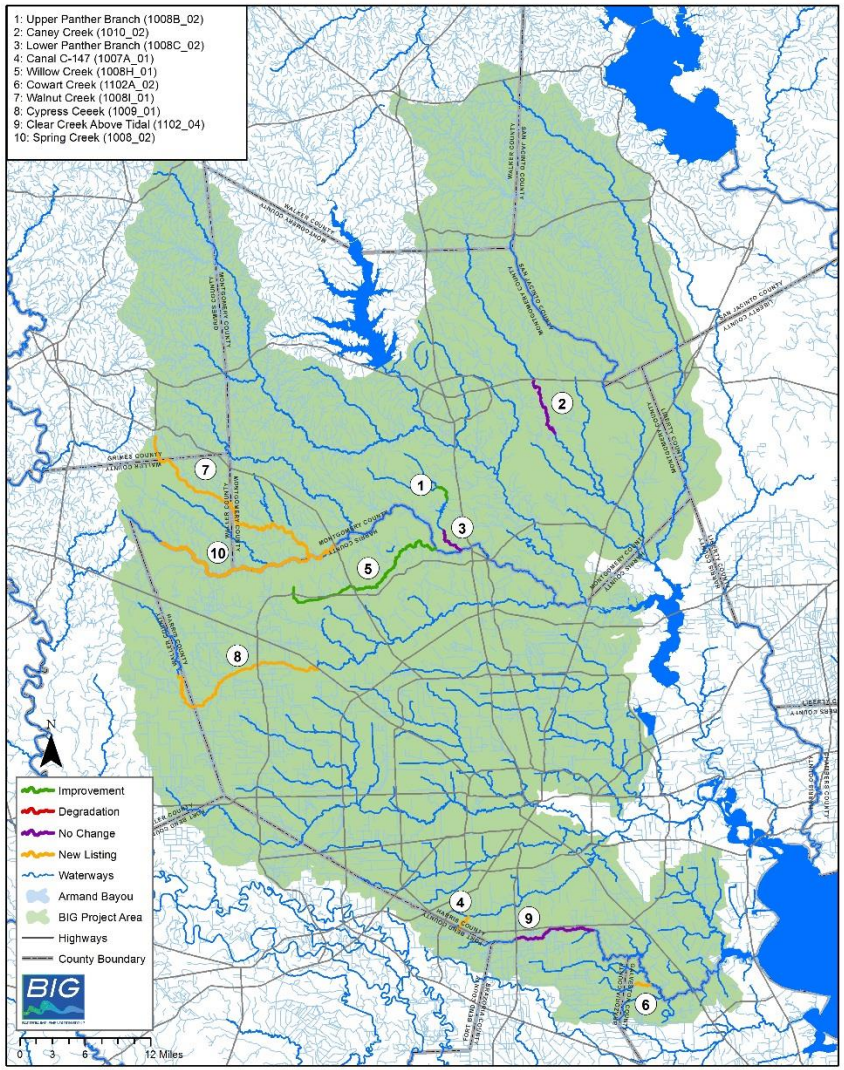

Figure 3. Top 10 Least Bacteria-Impaired streams from 2015

Methods

The Top 5/Least 5 project followed a structured, three-tiered approach. Project tasks were split into three phases with each phase building on the last. The acquisition, collection, and analysis of data followed standard approved methods outlined in the Quality Assurance Project Plan (QAPP) (Appendix A).

Phase I: Desk Review & Bacteria Screening

Phase I included initial desk review and analysis of existing data for the BIG's Top 10 Most and Top 10 Least Bacteria-Impaired (Top 10/Least 10) stream segments from 2015. Table 2 lists the data sources used and analyses performed during the desk review process.

Table 2. Phase I desk review analyses for BIG's Top 10/Least 10 streams segments from 2015.

Data Sources	Analyses Performed
TCEQ watershed areas	Review watershed size through map development
TCEQ stream segments	Review stream length through map development
Land use data	Review current land uses for each watershed assessed through map development
Wastewater outfall locations	Map location of wastewater outfalls for each watershed assessed
On-site sewage facility (OSSF) locations	Map location of OSSFs for each watershed assessed
Texas Clean Rivers Program water quality data	*E.coli* regression analysis for last 15 years of data; 7 year moving bacteria geometric mean plots; load duration curve analysis; days since last rain graphs
US Geological Survey flow gauge data	Load duration curve analysis
2014 Texas Integrated Report	Identify designated uses for each stream segment assessed; report current *E.coli* geometric mean value
Harris County Flood Warning System Website	Days since last rain graphs

A technical workgroup made up of representatives from local jurisdictions and water quality professionals provided feedback and guidance on which stream segments to investigate further based on the desk review analysis performed. Representatives from the following entities and jurisdictions participated in the workgroup:

- Bayou Preservation Association
- City of Houston Public Works and Engineering
- City of Houston Health Department
- Harris County Pollution Control Services Department
- Harris County Flood Control District
- Harris County Engineering Department
- City of Bellaire
- Galveston Bay Estuary Program
- Houston-Galveston Area Council
- Citizens Environmental Coalition
- San Jacinto River Authority

Multiple workgroup meetings were held to discuss the analyses performed and prioritize streams based on bacteria concentration, stream accessibility, designated uses, and level of interest expressed by the workgroup. Initial prioritization of the Top 10/Least 10 lists was discussed during a workgroup meeting in April 2016. The resulting Top 5/Least 5 prioritized stream segments were analyzed further and the watershed area was investigated through windshield surveys by H-GAC project staff. Windshield surveys included driving through watershed areas to observe and make note of potential bacteria sources located near the streams. The workgroup further prioritized the remaining stream segments down to a Top 2 Most Impaired and Top 2 Least Impaired (Top 2/Least 2) based on the additional analyses and information collected during the windshield surveys.

Table 3 lists the final Top 2/Least 2 streams that were selected for bacteria screening investigations. Bacteria screening involved intensive on-the-ground surveys where all outfalls were documented and water quality samples were collected from surface waters, tributaries, and discharging outfall locations. *E.coli* concentrations were measured using the Coliscan Easygel methodology outlined in the QAPP (Appendix A) to provide baseline data used to identify potential illicit discharges, hot spots, and areas of greatest concern for each of the streams investigated. Results and findings from the desk reviews, windshield surveys, and bacteria screening investigations are detailed in the Preliminary Action Report (Appendix B).

Table 3. Top 2 Most and Top 2 Least Impaired Water Bodies

Top 2 Most Impaired Water Bodies	Top 2 Least Impaired Water Bodies
Little White Oak Bayou (1013A_01)[1]	Upper Panther Branch (1008B_02)
Rummel Creek (1014N_01)	Canal C-147 (1007A_01)

[1]*Identification number included in parentheses represent TCEQ stream segment assessment unit.*

Phase II: Bacteria Source Identification

Bacteria screening results from Phase I were used as a precursor for the more targeted bacteria source identification surveys conducted for Phase II of the project. Phase II investigations focused on areas in the Top 2/Least 2 prioritized stream segments that had the highest bacteria screening concentrations and the greatest level of interest expressed by the technical workgroup and local jurisdictions. Sample collection during Phase II was intended to further refine source identification and aid in tracking sources of bacteria impairment to the greatest extent practicable. Bacteria source identification surveys included three main components:

1. Collection of wet weather and dry weather samples at each site.
2. Bacteria analysis at a National Environmental Laboratory Accreditation Program (NELAP) certified laboratory using more precise approved methods.
3. Collection of field water quality data including dissolved oxygen, temperature, specific conductance, pH, and other visual water quality parameters to supplement the bacteria data collected at each site.

Dry weather samples were collected following a minimum 72-hour antecedent dry period. Wet weather samples were collected during or immediately after a significant rain event (greater than 0.50 inches of rain)

following a minimum 72-hour antecedent dry period. The Harris County Flood Warning System website was used to determine if a monitoring event qualified as either wet or dry weather. Methods used and a detailed account of results and findings from the Phase II surveys are included in the Bacteria Source Identification Report (Appendix C).

Phase III: Report Findings & Agency Action

All Phase I and Phase II results and findings were reported to local jurisdictions and MS4 permittees to assist them in the identification and further investigation of illicit discharges and significant sources of bacteria impacting the Top 2/Least 2 stream segments. Significant findings detected during the Phase I and Phase II investigations were reported through direct contact or through Houston's 311 Help & Information application.

Additional contact with local jurisdictions involved meetings, emails, and conference calls to discuss findings, provide recommendations, and track any corrective actions implemented based on the results and findings from Phase I and II investigations. Communication with the following jurisdictions and entities were included in this phase of the project.

- The City of Houston Public Works and Engineering
- City of Houston Health Department
- Harris County Pollution Control
- San Jacinto River Authority
- The Woodlands Township
- Montgomery County

Outreach and Education

An important component of this project was the dissemination of information to local jurisdictions and other stakeholders interested in the results and findings acquired through this effort. Presenting methodology, results, and lessons learned to the appropriate audience can assist in future project development for entities interested in pursuing similar IDDE program and bacteria source identification projects while highlighting the benefits of coordinating a targeted monitoring approach. Table 4 lists meetings, workshops, and publications where the BIG's Top 5/Least 5 project were presented.

Table 4. Summary of project outreach and education efforts

Date	Event/Promotional Item	Topic
April 20, 2016	Top 5/Least 5 Technical Workgroup	Desktop Review 1 Results: Prioritizing Top 10/Least 10 to Top 5/Least 5
May 10, 2016	Clean Rivers Program Basin Steering Committee Meeting	Project Overview and Timeline
May 26, 2016	Top 5/Least 5 Technical Workgroup	Desktop Review 2 Results: Prioritizing Top 5/Least 5 to Top 2/Least 2

Date	Event/Promotional Item	Topic
August 3, 2016	Houston-Galveston Area Council Texas Stream Team Quarterly Newsletter	Project launch featured in newsletter
August 4, 2016	Natural Resources Advisory Committee	Phase I Results
September 13, 2016	Top 5/Least 5 Technical Workgroup	Phase I Results
October 25, 2016	Bacteria Implementation Group Meeting	Phase I Results
February 28, 2017	Clean Rivers Program Basin Steering Committee	Phase II Results
March 20, 2017	Bacteria Implementation Group Stormwater Workgroup	Phase II Results and Lessons Learned
May 3, 2017	Houston-Galveston Area Council Texas Stream Team Quarterly Newsletter	Project wrap up featured in newsletter
May 15, 2017	Houston-Galveston Area Council's 2017 Basin Highlights Report	Project summary featured in report
May 23, 2017	Bacteria Implementation Group Meeting	Project Wrap Up, Agency Actions, and Lessons Learned

Results and Observations

Phase I: Desk Review & Bacteria Screening

The following figures illustrate the prioritization of stream segments by the technical workgroup beginning with the BIG's Top 10 Most and Top 10 Least Impaired lists from 2015. A detailed account of the analysis and review of these streams is included in the Preliminary Action Report (Appendix B).

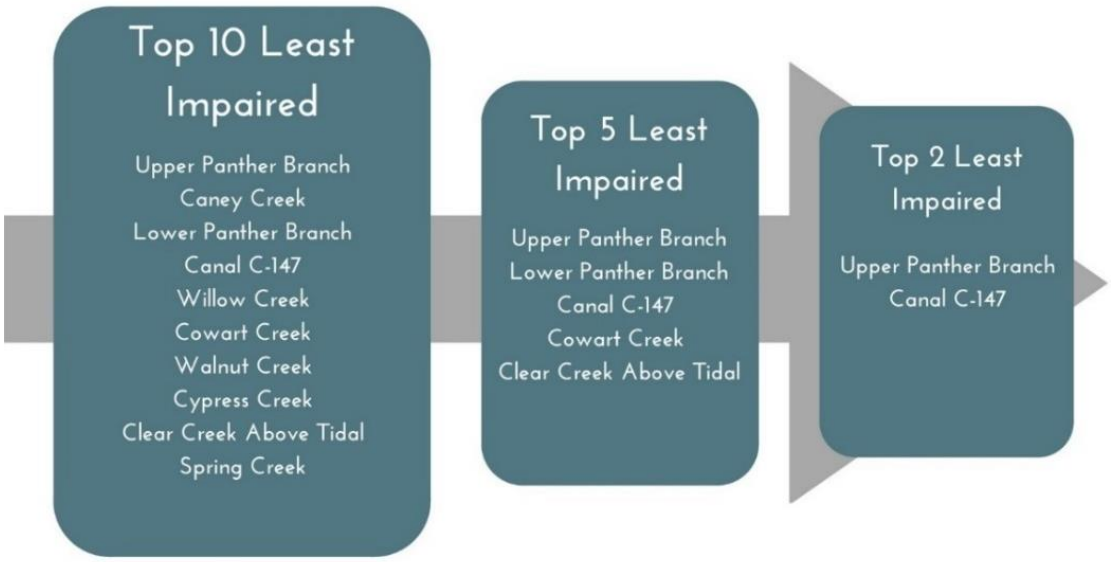

Figure 4. Prioritization of the least bacteria-impaired stream segments by the Technical Workgroup

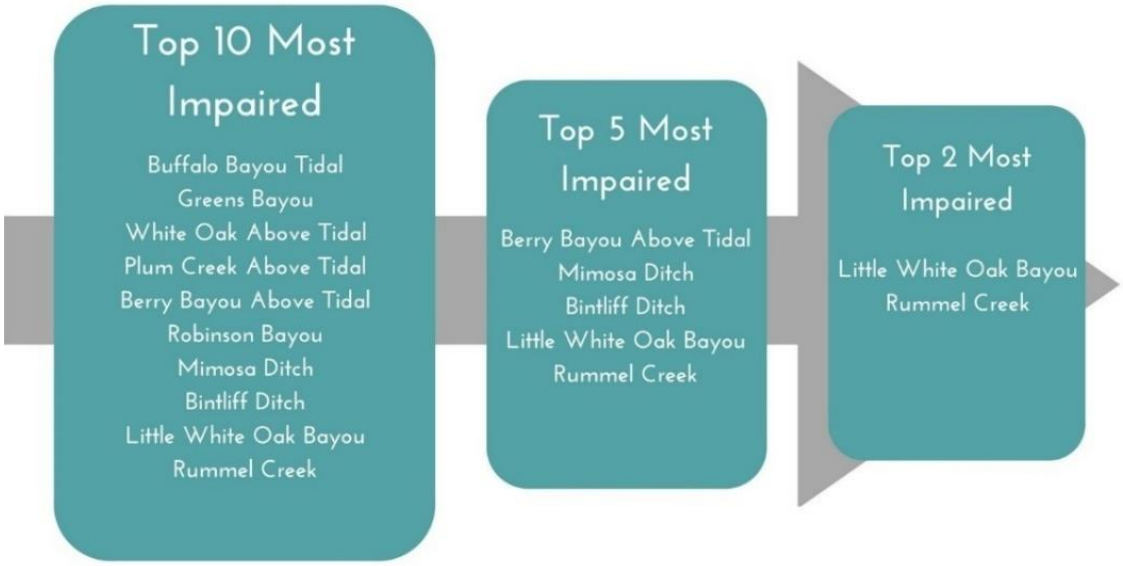

Figure 5. Prioritization of the most bacteria-impaired stream segments by the Technical Workgroup

The prioritized Top 2 Most Impaired and Top 2 Least Impaired stream segments were subject to intensive on the ground surveys where each water body was walked and all outfalls and tributaries were documented. Bacteria screening samples were collected from discharging outfalls, as well as from tributaries and surface waters. The following figures illustrate all Phase I sample locations for the four stream segments surveyed.

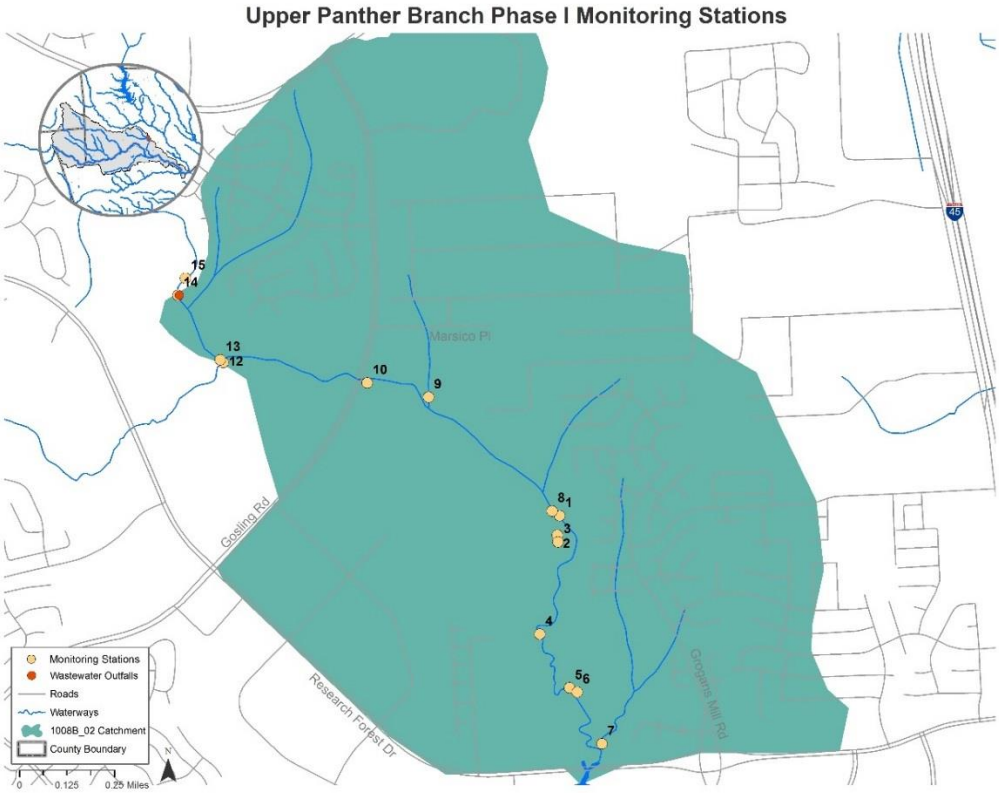

Figure 6. Phase I bacteria screening monitoring stations for Upper Panther Branch, Segment 1008B_02, from the Top 2 Least Impaired list.

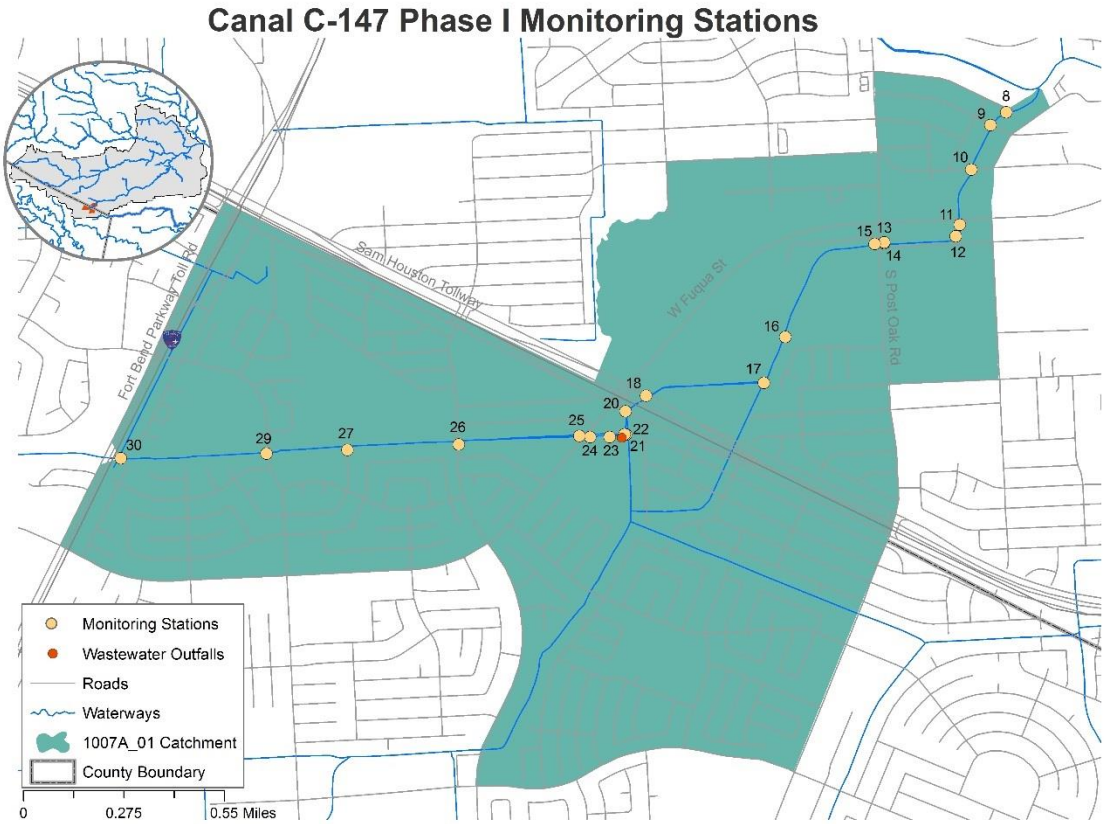

Figure 7. Phase I bacteria screening monitoring stations for Canal C-147, Segment 1007A_01, from the Top 2 Least Impaired list.

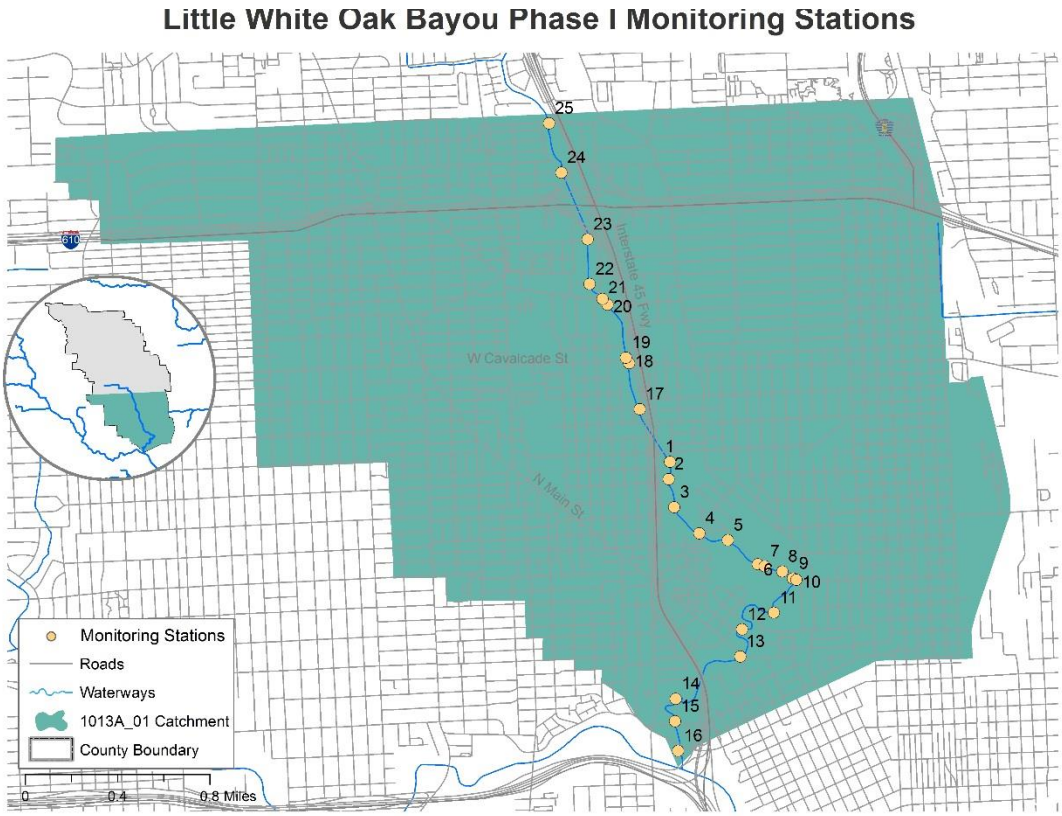

Figure 8. Phase I bacteria screening monitoring stations for Little White Oak Bayou, Segment 1013A_01, from the Top 2 Most Impaired list.

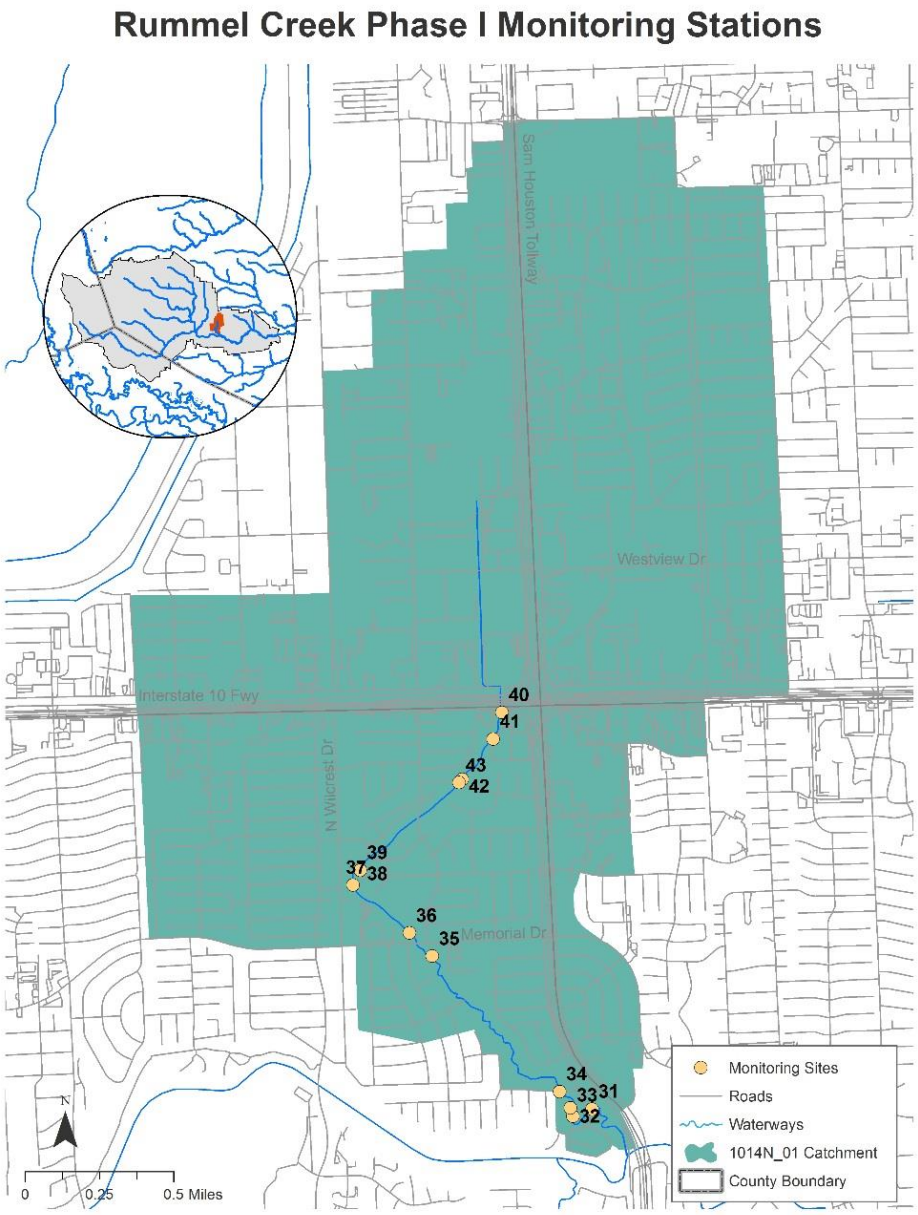

Figure 9. Phase I bacteria screening monitoring stations for Rummel Creek, Segment 1014N_01, from the Top 2 Most Impaired list.

Table 5 includes the *E.coli* concentrations measured using the Coliscan Easygel method for each sample collected during Phase I. Samples with greater than 200 colonies per dish were reported as Too Numerous To Count (TNTC). All samples with *E.coli* concentrations greater than 126 MPN/100mL are in exceedance of state water quality standards for bacteria. According to the bacteria screening results, the majority of samples collected during this phase were significantly greater than the standard with Little White Oak Bayou representing the stream segment with the most significant bacteria problem. Refer to the Preliminary Action Report (Appendix B) for additional results and findings from the Phase I bacteria screening surveys.

Table 5. Phase I bacteria screening results.

Upper Panther Branch																								
Station No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15									
***E.coli* (cfu/100mL)**	170	310	3420	140	100	580	60	50	1040	390	230	270	400	20	260									
Canal C-147																								
Station No.	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	25	26	27	29	30			
***E.coli* (cfu/100mL)**	800	230	290	200	180	TNTC	1770	190	510	TNTC	40	320	190	230	50	10	530	0	2130	230	520			
Little White Oak Bayou																								
Station No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
***E.coli* (cfu/100mL)**	575	700	450	250	1025	150	0	0	TNTC	TNTC	0	TNTC	TNTC	TNTC	TNTC	TNTC	10900	13300	7300	1350	6650	9450	4300	5800	TNTC
Rummel Creek																								
Station No.	31	32	33	34	35	36	37	38	39	40	41	42	43											
***E.coli* (cfu/100mL)**	125	225	775	252	425	2275	100	400	700	925	350	125	225											

Phase II: Bacteria Source Identification

Results and findings from the bacteria screening process were used as a precursor to Phase II assessments where only the stations with the highest bacteria screening concentrations from Phase I were subject to follow up bacteria source identification surveys. Additional information about the Phase II station selection process can be found in the Bacteria Source Identification Report (Appendix C). The following figures illustrate the monitoring stations sampled during the Phase II investigations. Sample numbers from Phase I were re-used for Phase II assessments to ensure facilitated tracking of sample locations.

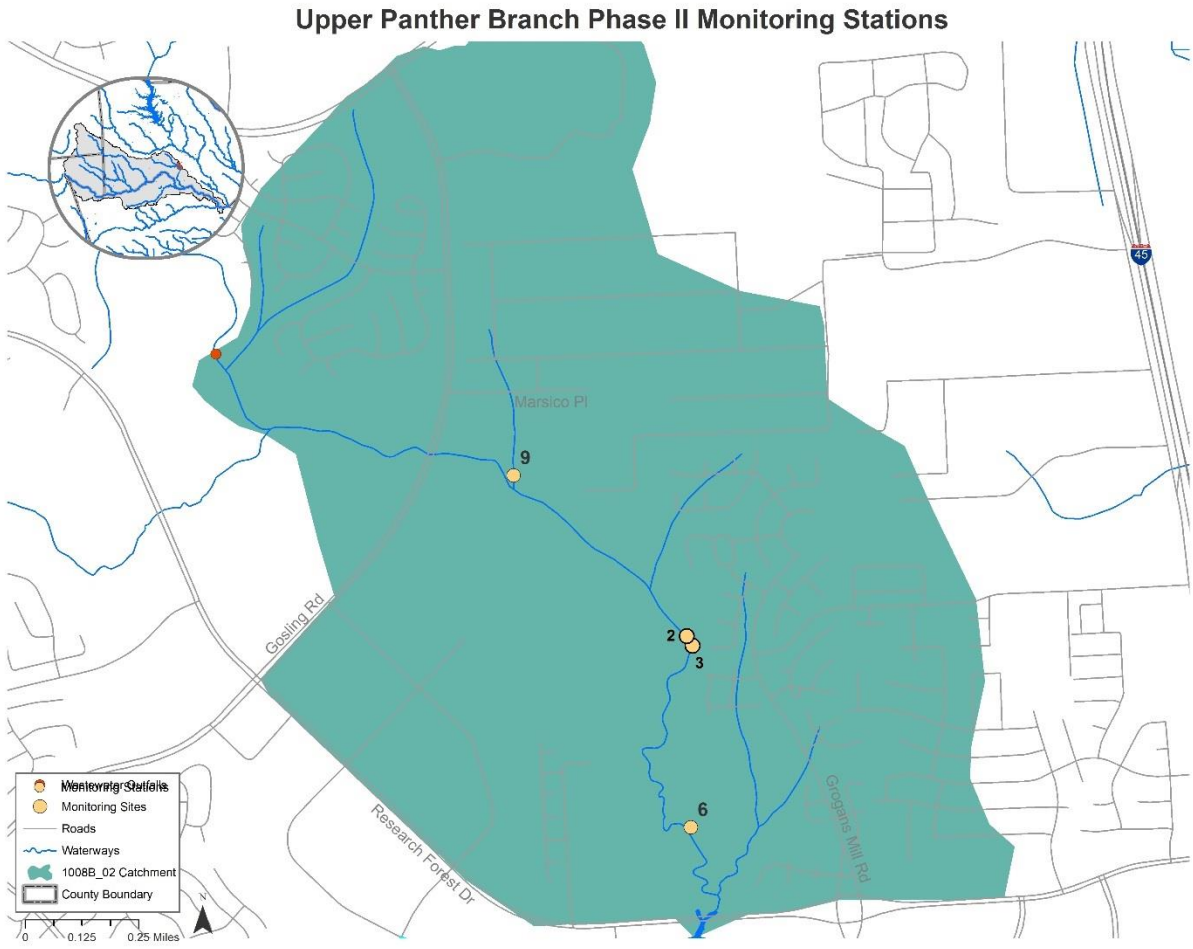

Figure 10. Phase II bacteria source identification monitoring stations for Upper Panther Branch, Segment 1008B_02, from the Top 2 Least Impaired list.

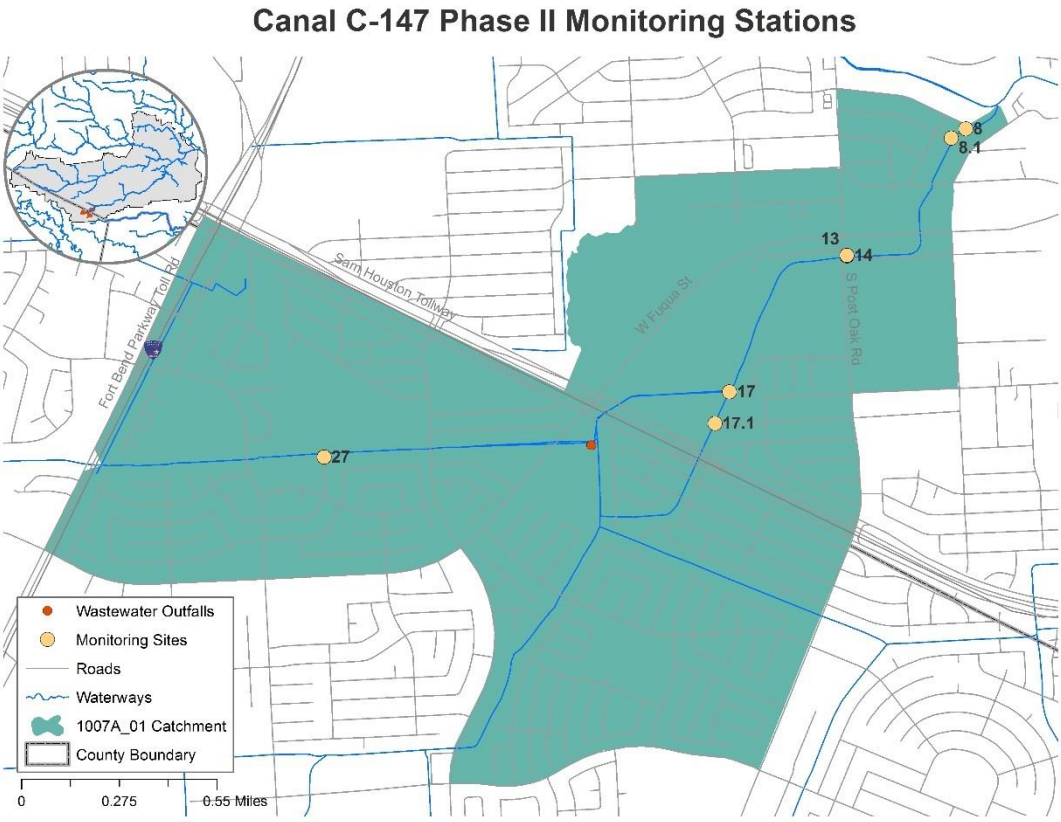

Figure 11. Phase II bacteria source identification monitoring stations for Canal C-147, Segment 1007A_01, from the Top 2 Least Impaired list.

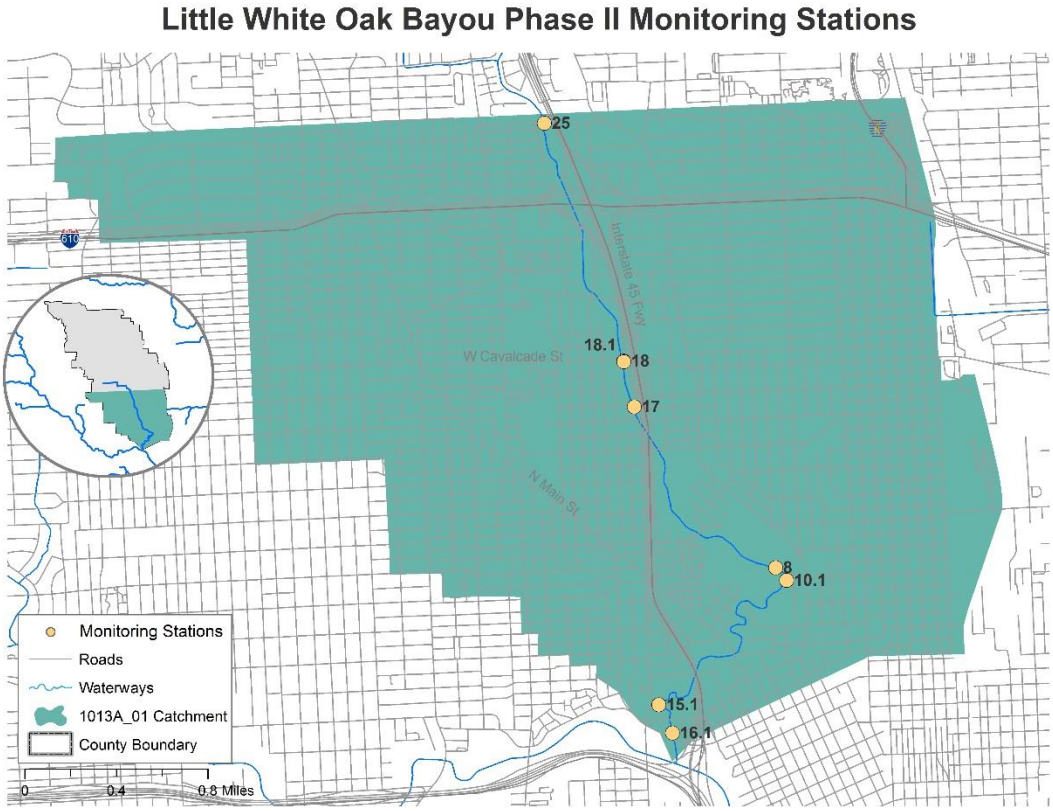

Figure 12. Phase II bacteria source identification for Little White Oak Bayou, Segment 1013A_01, from the Top 2 Most Impaired list.

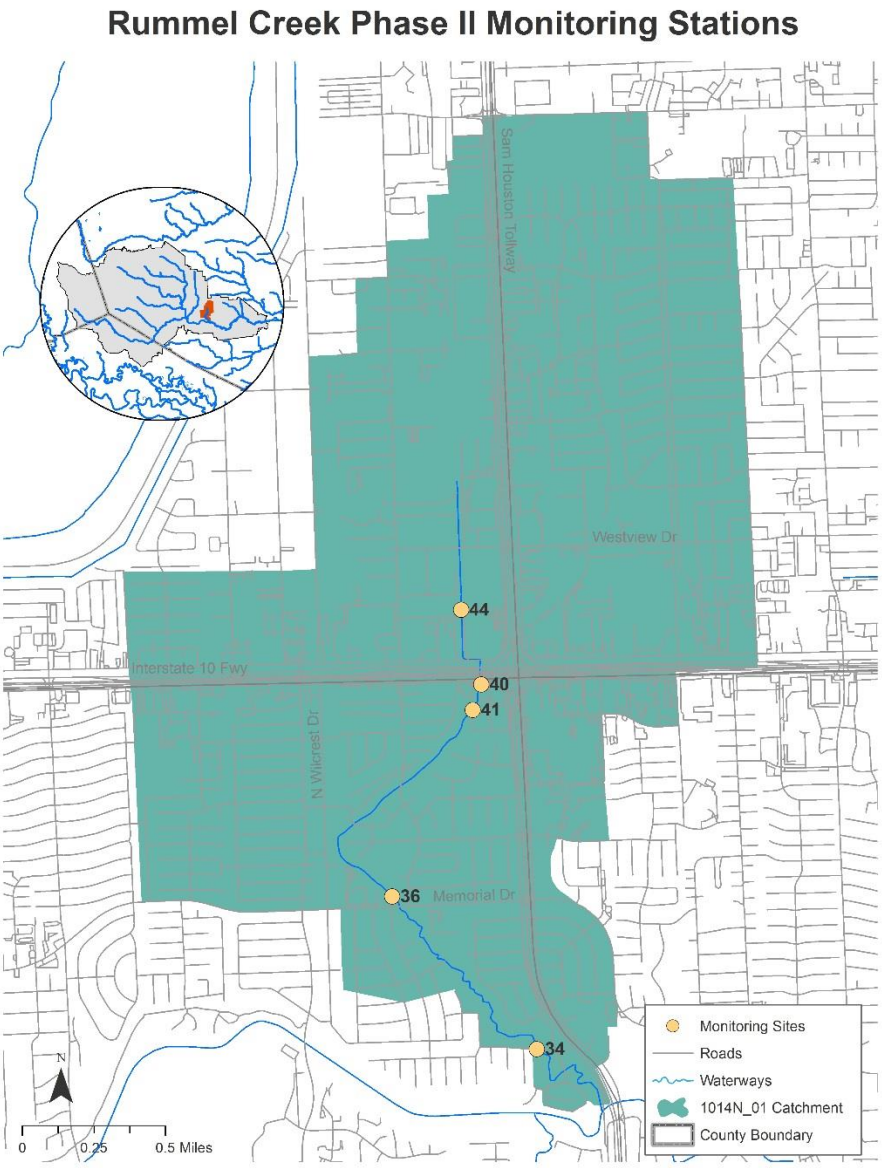

Figure 13. Phase II bacteria source identification monitoring stations for Rummel Creek, Segment 1014N_01, from the Top 2 Most Impaired list.

A NELAP certified laboratory was used for the *E.coli* analysis to provide more accurate and precise bacteria concentration data for the Phase II investigations. Figures 14-17 summarize the water quality data collected during Phase II dry and wet weather surveys.

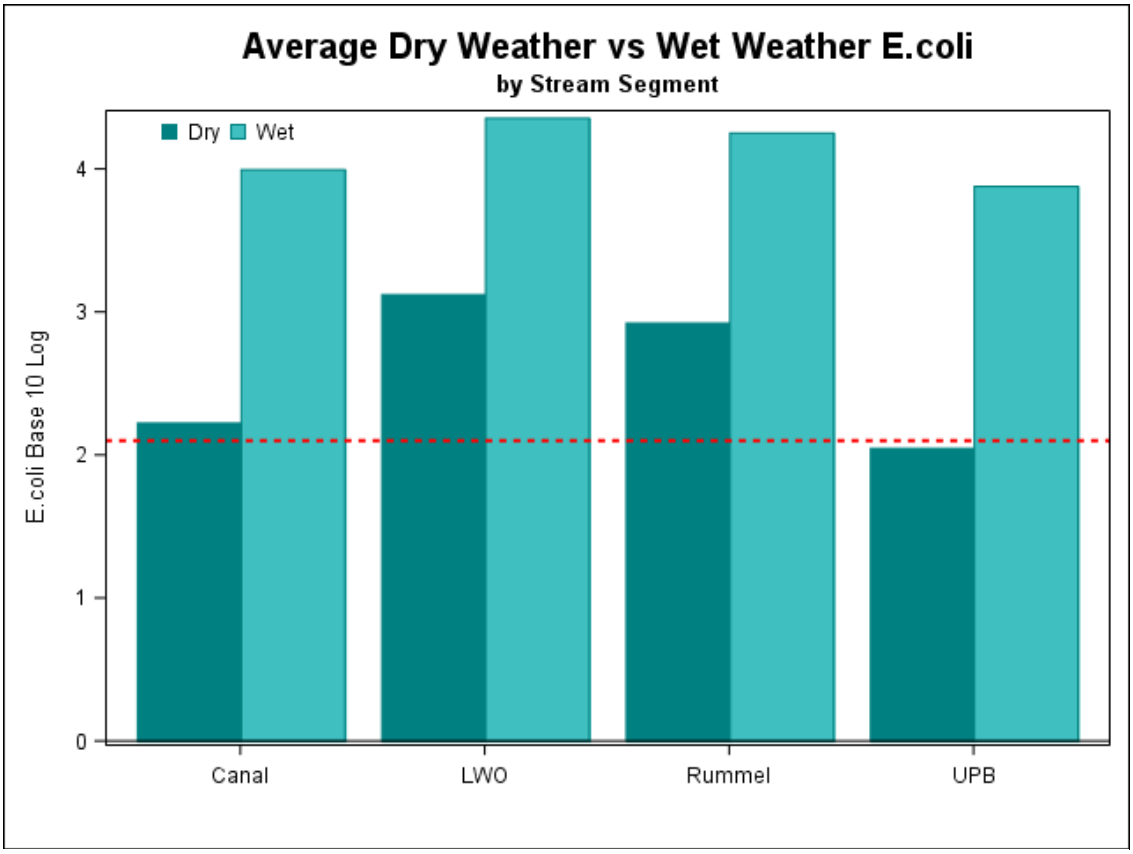

Figure 14. Average *E.coli* concentrations by stream segment for wet and dry weather surveys. Red dotted line represents the 126 MPN/100mL standard.

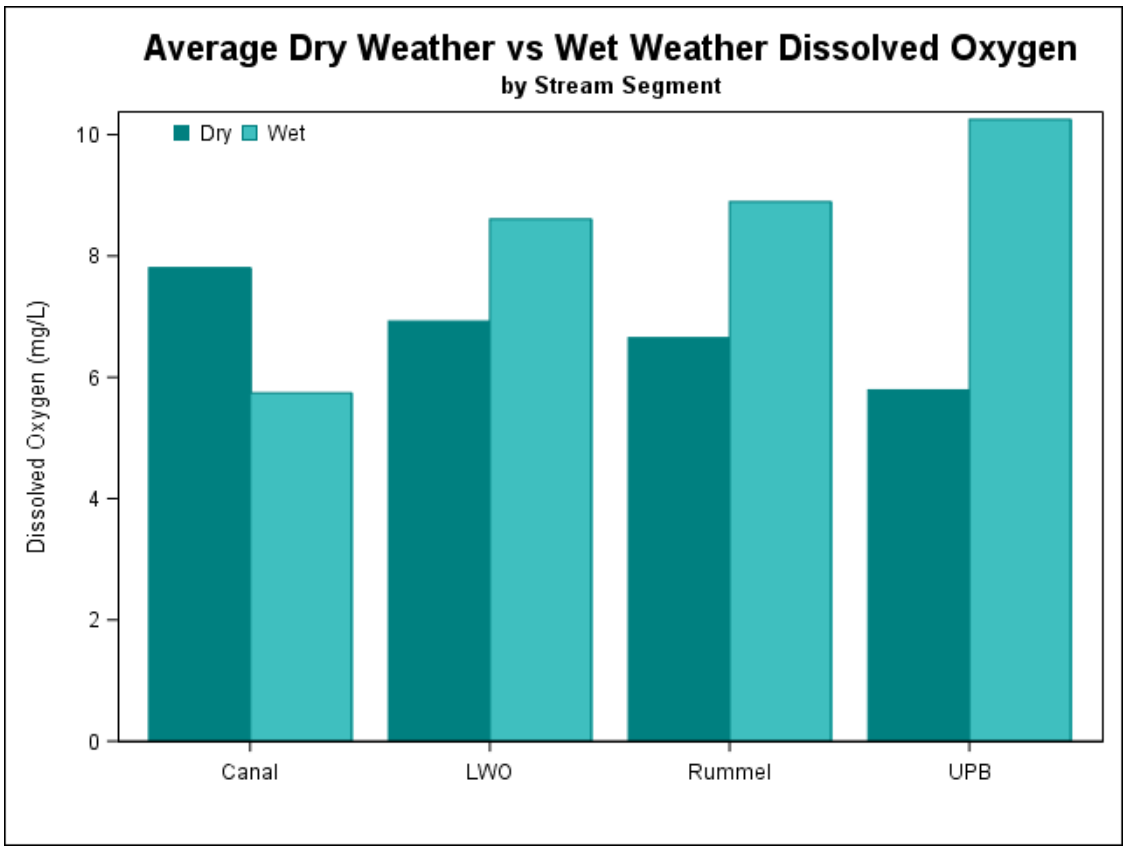

Figure 15. Average dissolved oxygen levels by stream segment for wet and dry weather surveys.

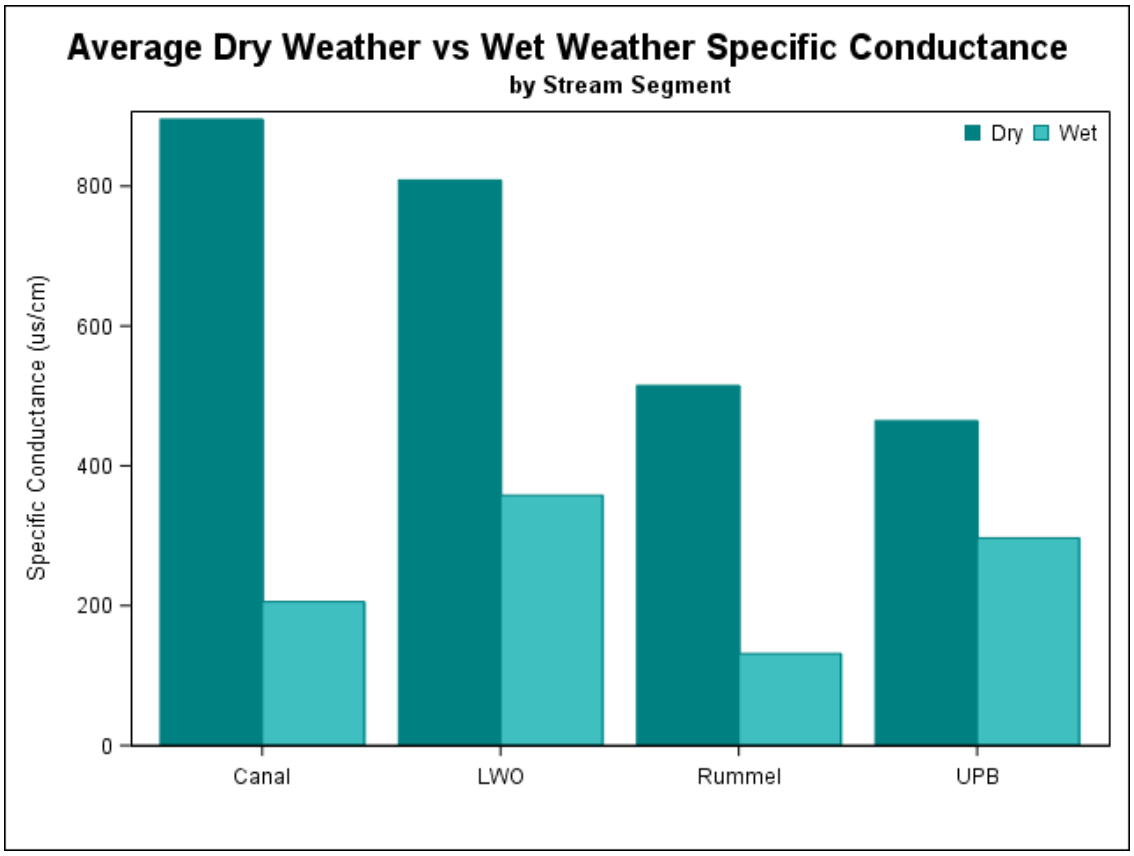

Figure 16. Average specific conductance by stream segment for wet and dry weather surveys.

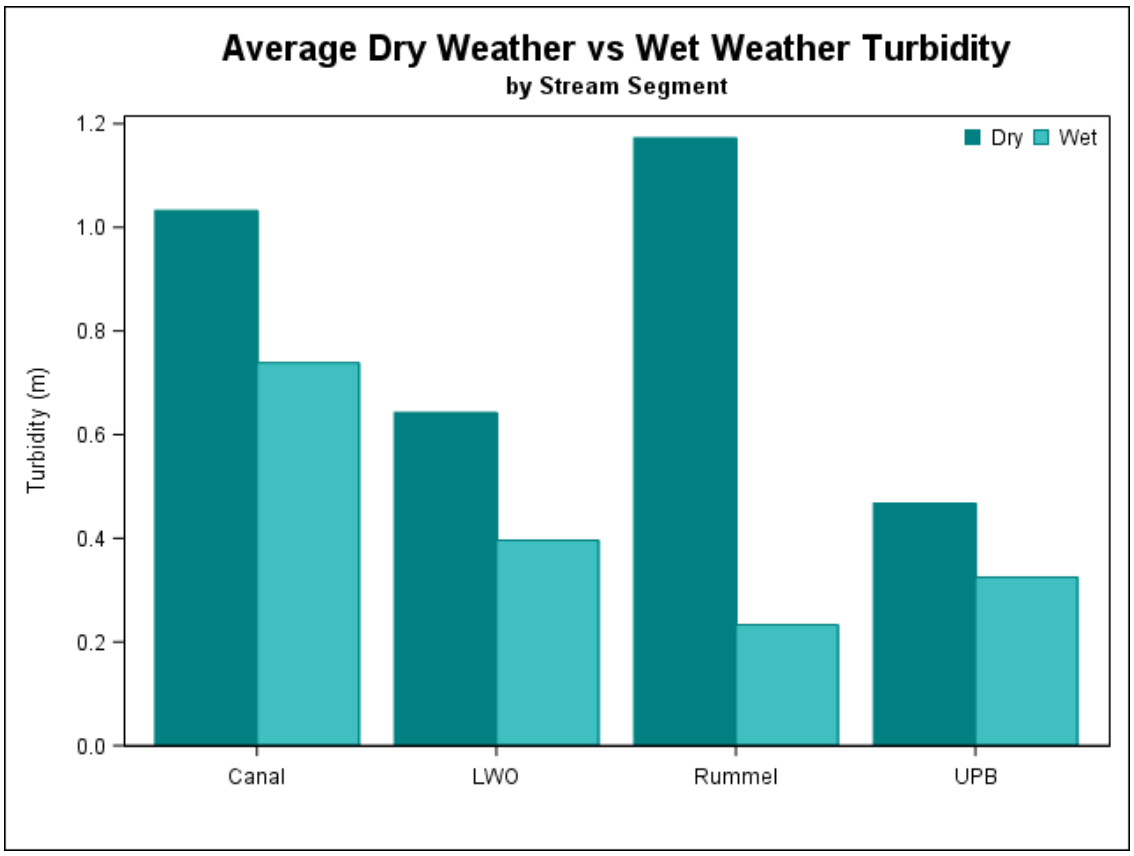

Figure 17. Average turbidity levels by stream segment for wet and dry weather surveys.

Overall, Phase II bacteria levels for the Top 2 Least Impaired segments, Upper Panther Branch and Canal C-147, were typically in compliance during dry weather conditions but were significantly greater during wet weather conditions. Phase II results for the Top 2 Most Impaired segments, Little White Oak Bayou and Rummel Creek, yielded the highest bacteria concentrations during both wet and dry weather conditions. Additionally, specific conductance was consistently higher during dry weather conditions compared to wet weather even though water clarity (turbidity level) was lower during wet weather events. This is likely because wastewater discharges and high evaporation rates during dry weather conditions increase the level of dissolved constituents in water resulting in higher conductivity and water clarity. After a significant rain event, the level of dissolved constituents decreases while suspended solids from sediment runoff increases, resulting in lower conductivity and water clarity.

Refer to the Bacteria Source Identification Report (Appendix C) for additional Phase II water quality data, detailed station descriptions for each stream segment, and recommendations to local jurisdictions for further investigation.

Phase III: Report Findings & Agency Action

Table 6 lists significant findings, responses, and actions taken by local jurisdictions to address bacteria sources and other issues or concerns. Communication with local jurisdictions has been ongoing and follow up investigations and corrective action implementation is expected to continue after completion of this project. H-GAC will not correct the issues, but will continue to work with local jurisdictions to reduce or eliminate pollutions sources found through this effort.

Table 6. Significant findings reported to local jurisdictions and actions taken.

Stream	Finding	Response	Action
Little White Oak Bayou (1013A_01)	City of Houston (COH) informed H-GAC of a faulty sewer system junction box located at Wrightwood Street that is a potential bacteria source to Little White Oak Bayou.	H-GAC staff met with COH Engineer at Wrightwood St bridge and observed what looked to be a faulty junction box adjacent to the Bayou. Toilet paper and strong sewage odor was evidence of recent overflow events. H-GAC field staff also submitted a 311 service request about this finding on 10/26/2016. Report: https://seeclickfix.com/issues/3024826	Communication with COH engineers and investigators about junction box repairs is ongoing. Some repairs have been made, including raising the box approximately 5 feet higher to reduce chances of overflows during flood events. Additional repairs are underway and investigative staff will continue to monitor the area once work has been completed.
Little White Oak Bayou (1013A_01)	Sample collected from station 8 during Phase I resulted in a 0 cfu/100mL bacteria concentration. This was suspect considering all bacteria concentrations measured around that storm drain location were significantly higher.	City of Houston was notified of the results through the Preliminary Action Report.	COH Storm Water Quality Enforcement investigated this site further through dye testing and visual inspection. A water leak was detected originating east of the storm drain but has not been linked to a specific source. No corrective actions have been implemented at this location.

Stream	Finding	Response	Action
Little White Oak Bayou (1013A_01)	An oily sheen and strong hydrocarbon/diesel odor was observed at Little White Oak Bayou at the Stokes St bridge during the dry weather Phase II investigation.	H-GAC field staff submitted a 311 service request about this finding on 10/17/2016. Report: http://seeclickfix.com/issues/3004815	COH closed the report and referred the problem to Harris County for further investigation. H-GAC has not received additional information about the status of this investigation.
Little White Oak Bayou (1013A_01)	The storm drain located at Hayes Road (station 10) was identified as one of the most significant bacteria contributors to Little White Oak during both Phase I and Phase II investigations.	City of Houston was notified of the results through the Preliminary Action Report and Source Identification Report.	COH Storm Water Quality Enforcement investigated this site further and detected copper leachate in addition to high bacteria concentrations. It was speculated the source is from old pipelines. No corrective actions have been implemented at this location.
Little White Oak Bayou (1013A_01)	A faulty manhole with evidence of recent overflows was detected during Phase I and Phase II investigations near station 17.	City of Houston was notified about the issue through the Preliminary Action Report, Source Identification Report, and at meetings with City of Houston investigative staff.	COH Storm Water Quality Enforcement investigators identified the manhole as an active line and reported the hole to the wastewater department for repairs.
Rummel Creek (1014N_01)	Results from the station 36 outfall near Rummel Creek Elementary showed consistently high bacteria concentrations during all site visits and was flagged as one of the more significant sources of bacteria to Rummel Creek.	City of Houston was notified about the issue through the Preliminary Action Report, Source Identification Report, and through communications at meetings with investigative staff.	COH Pollution Control conducted follow-up *E.coli* testing at this outfall and found bacteria levels are still significantly greater than the standard. COH Pollution Control and Public Works and Engineering working together to collect samples from surrounding manholes and perform leak testing to identify bacteria source. Investigation will continue through the summer.
Little White Oak Bayou (1013A_01), Canal C-147 (1007A_01), and Rummel Creek (1014N_01)	Three of the four stream segments investigated for this project were in Harris County.	Harris County Pollution Control was notified of the results through the Preliminary Action Report, Source Identification Report, and other outreach efforts.	Harris County Pollution Control Services has proposed increased sampling at three wastewater treatment facilities located upstream of Little White Oak Bayou and Rummel Creek. Sampling will be increased from annually to quarterly at The Park on White Oak and Duree Manor for Little White Oak Bayou, and at City of Houston-West District for Rummel Creek. Additionally, Pollution Control personnel speculate that bridge dwelling bat colonies over the stream segments may also be a potential bacteria contributor.

Stream	Finding	Response	Action
Canal C-147 (1007A_01)	High bacteria concentrations were detected at station 8 during the Phase I investigations.	City of Houston was notified through the Preliminary Action Report and at workgroup meetings.	COH Pollution Control investigated this outfall location and detected a potable water leak. The leak was fixed and all samples collected during Phase II were in compliance with state water quality standards for bacteria.
Canal C-147 (1007A_01)	Large storm drain on right side of Canal C-147 at Post Oak Blvd flagged as potential contributor of bacteria into the Canal based on Phase I and Phase II bacteria results.	City of Houston was notified about the issue through the Preliminary Action Report, Source Identification Report, and through communications at meetings with investigative staff.	COH Pollution Control suspects a potable water leak within first 150 feet of water line running parallel to stormwater line leading to outfall. Problem referred to Public Works and Engineering Department for repair. Bacteria source suspected to be from natural sources (ex. birds, nonpoint sources)
Canal C-147 (1007A_01)	During the Phase II investigation of Canal C-147 on 10/19/2016, a significant amount of trash, tires, and furniture were observed at the downstream end of the watershed in the neighborhoods adjacent to the waterway.	H-GAC field staff submitted a 311 service request about this finding on 10/19/2016. Report: http://seeclickfix.com/issues/3010911	COH closed the report on 11/10/2016 stating that the issue has been resolved.
Upper Panther Branch (1008B_02)	High chlorine concentrations were observed during Phase I and Phase II dry weather investigations at Upper Panther Branch.	H-GAC PM contacted staff at the San Jacinto River Authority (SJRA) Lake Conroe Division to inform them of this finding.	SJRA staff informed H-GAC that it is unlikely the high chlorine levels are coming from the WWTF because UV is the primary means of tertiary treatment. It was speculated that the chlorine source may be related to the use of bleach to clean equipment at the WWTF. Improper maintenance of residential pools may also be a source of chlorine into the stream. Additional investigation and resident education is recommended to address this issue.
Upper Panther Branch (1008B_02)	Upper Panther Branch was investigated and bacteria sources and chlorine detection was reported in both project reports.	The Woodlands Township was notified of the results through the Preliminary Action Report and Source Identification Report.	The Water Conservation Program at the Woodlands Township is interested in initiating an action plan to inform and educate residents about current water quality problems in their area. Education plan should promote proper pet waste disposal and swimming pool maintenance practices that limit negative impacts to nearby waterway.

Discussion

The BIG's Top Five Most and Top Five Least Impaired Water Bodies project provided a structured approach to addressing the region's bacteria impairment problem one stream at a time. With 102 bacteria-impaired stream segments in the BIG project area, focusing efforts on the Top 10 Most and Top 10 Least Impaired streams was an effective way to initiate investigations in areas that would make the greatest impact.

Investigating the most impaired stream segments can aid in identifying and eliminating some of the most significant bacteria sources and help reduce overall bacteria levels in the BIG project area. Targeting the least impaired streams can help local jurisdictions implement corrective actions that will help bring those streams into compliance with state water quality standards for bacteria. Additionally, having a third-party organization such as H-GAC perform the initial on-the-ground investigations allows local jurisdictions to spend more time and resources correcting problems rather than finding them. Coordinating targeted bacteria monitoring and investigations with local jurisdictions also improves cost effectiveness for cities and counties managing MS4 permits by reducing duplication of effort, improving efficiency of corrective action implementation, and avoiding potential permit violations.

The development of a Technical Workgroup comprised of key members from local jurisdictions being involved in project development early on also contributed to the success of the project. Workgroup meetings during Phase I of the project helped raise interest and develop working relationships with investigative and enforcement staff that would be involved in follow up investigations. However, due to reporting delays related to wet weather water quality monitoring during Phase II, reduced communication with the workgroup resulted in a lower interest level as the project approached completion. Future recommendations regarding the Technical Workgroup would be to set up most meetings after Phase I and II investigations have been completed to review results and develop an action plan rather than conducting all workgroup meetings during the desk review process in Phase I.

Overall, project results indicate that the most significant sources of bacteria impacting the Top 2 Most Impaired segments are dry weather discharges (illicit discharges, leaking or faulty collection systems and pipelines, etc.), whereas bacteria sources impacting the Top 2 Least Impaired segments are likely related to nonpoint sources of pollution. However, illicit discharges and leaking or faulty collection systems and pipelines were observed in all stream segments surveyed except Upper Panther Branch. The most significant concern found at Upper Panther Branch was the detection of elevated chlorine levels throughout the entire segment during all dry weather sampling events. Sanitary sewer overflows following significant rain events were also a major source of bacteria identified through this effort. Little White Oak Bayou is especially susceptible to bacteria contributions through sanitary sewer overflows due to aging wastewater collection systems and rapid growth in the area. Further investigation into the source of chlorine in Upper Panther Branch and actions to help reduce frequency of sanitary sewer overflows in Little White Oak Bayou are recommended.

Summary

Currently, nearly half of the stream miles in the Houston-Galveston region have bacteria levels higher than the state standard for contact recreation. I-Plan development and approval by the BIG addresses this issue in 102 bacteria-impaired stream segments in the region. The BIG'sTop 5/Least 5 project was developed to support the BIG's efforts in reducing bacteria concentrations in the most and least bacteria-impaired waterways in the BIG project area.

The Top 5/Least 5 project was split into three phases with each phase building on the last. Phase I included initial analysis and review of the BIG's Top 10 Most and Top 10 Least bacteria-impaired lists from the 2015 BIG annual report. A Technical Workgroup made up of water quality professionals and representatives from local jurisdictions provided input and asissted in prioritizing the Top 10 and Least 10 lists to a Top 2 and Least 2 list that was subject to further investigation. H-GAC staff was responsible for conducting intensive bacteria screening investigations on the Top 2 and Least 2 prioritized stream segments to provide baseline data and identify potential illicit discharges, hot spots, and areas of greatest concern for each of the streams investigated.

Phase II investigations focused on areas in the Top 2 and Least 2 prioritized stream segments that had the highest Phase I bacteria screening concentrations and the greatest level of interest expressed by the technical workgroup and local jurisdictions. Sample collection during Phase II was intended to further refine source identification and aid in tracking sources of bacteria impairment to the greatest extent practicable. Results and observations found during Phase I and II of the project are detailed in the Preliminary Action Report (Appendix B) and the Source Identification Report (Appendix C), respectively.

Overall, results indicate the most significant sources of bacteria impacting the Top 2 Most Impaired segments, Little White Oak Bayou and Rummel Creek, include dry weather discharges and sanitary sewer overflows whereas bacteria sources impacting the Top 2 Least Impaired segments, Canal C-147 and Upper Panther Branch, are likely related to nonpoint sources of pollution.

Phase III of the project included reporting investigative results to local jurisdictions and providing recommendations for further action. Actions taken by local jurisdictions include follow up investigations to identify potential leaks and illicit discharges, infrastructure repairs, increased wastewater treatment facility sampling, and development of action plans and education campaigns for local residents.

Focusing efforts on the most and least bacteria-impaired waterways increases the likelihood of identifying significant sources of bacteria and guiding local jurisdictions in implementing corrective actions in areas that need it most. This targeted approach helps reduce duplication of effort and provides a more efficient means of correcting pollution sources while assisting the BIG achieve its long-term goal of removing bacteria-impaired streams from the State's list of impaired water bodies. This report provides a detailed outline of project methods that can be used as a guide in implementing similar coordinated IDDE programs geared toward improving bacteria conditions in area waterways.

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