SOAH DOCKET NO. 582-22-0585
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APPLICATION BY CITY OF GRANBURY, FOR TPDES PERMIT NO. WQ0015821001	§ § § § §	BEFORE THE STATE OFFICE OF ADMINISTRATIVE HEARINGS

EXHIBIT GF-306

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 ROSS AVENUE, SUITE 1200
DALLAS, TX 75202-2733

APR 27 2011

Kelly Holligan, Director
Water Quality Planning Division (MC-206)
Texas Commission on Environmental Quality
P.O. Box 13087
Austin, TX 78711-3087

Dear Mr. Holligan:

Thank you for submitting the revisions to the Lake Granbury Watershed Protection Plan (WPP). We are pleased to inform you that we concur with your assessment that the WPP satisfies EPA's requirements outlined in the 2004 National Nonpoint Source (NPS) Program Guidelines (national guidelines). We congratulate the Texas Commission on Environmental Quality and the Brazos River Authority in developing and supporting the necessary partnerships to complete this plan and to begin efforts to protect water quality in Lake Granbury. We especially would like to congratulate Kerry Niemann of your staff, and Tiffany Morgan, of the Brazos River Authority, in their leadership and coordination in guiding this WPP to completion.

The WPP highlights a stakeholder process that engages numerous representatives and entities in the Lake Granbury watershed, including the city of Granbury. We are encouraged that stakeholders are considering several key options to address bacteria concerns in the coves, particularly those caused by malfunctioning and mismanaged septic systems. The potential to connect these communities surrounding the coves to wastewater treatment is encouraging to the long-term prospects of protecting water quality in Lake Granbury for generations to come.

It is crucial that the States and EPA work together to ensure that funds are targeted to maximize the likelihood of water quality improvements and restoration of nonpoint source impaired waterbodies. Elevated scrutiny of the NPS program and diminishing 319(h) resources increase accountability for both our agencies. As with other watershed-based plans, by accepting this plan as satisfying national guidelines, EPA is neither implying nor agreeing to commit future 319(h) funds for any or all portions of the plan. Any requests to implement portions of a watershed plan will be considered on a case-by-case basis, taking into account the merits of the proposal consistent with national guidelines, NPS priorities and funding availability.

We wish the Lake Granbury partnership success in implementing this plan, and we look forward to working with you to develop and implement watershed-based plans to restore water quality in other priority watersheds in the State. If you have any questions please contact me, or have your staff contact Brad Lamb at (214) 665-6683, or lamb.brad@epa.gov.

Sincerely,

Jane B. Watson, PhD.
Associate Director
Ecosystems Protection Branch

cc: Kerry Niemann, TCEQ
Monica Harris, TCEQ

Lake Granbury
Watershed Protection Plan

Prepared for:

U.S. Environmental Protection Agency
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July 7, 2010

Funding for the development of this Watershed Protection Plan was provided through a federal Clean Water Act §319(h) to the Brazos River Authority, administered by the Texas Commission on Environmental Quality from the U.S. Environmental Protection Agency.

TABLE OF CONTENTS

FIGURES

TABLES

Acronyms

ac-ft	Acre-feet
AMUD	Acton Municipal Utility District
AgriLife	Texas AgriLife Research and Extension
BRA	Brazos River Authority
BMP	Best Management Practices
Census	United States Census Bureau
CRP	Clean Rivers Program
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning System
HoodCAD	Hood County Appraisal District
HCHD	Hood County Health Department
IUP	Intended Use Plan
LGWPPSC	Lake Granbury Watershed Protection Plan Steering Committee
NLCD	National Land Cover Database
NPS	Nonpoint Source Pollution
NRCS	Natural Resource Conservation Service
OSSF	On-site Sewage Facility, septic tanks
State	State of Texas
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SSURGO	Soil Survey Geographic Database
STATGO	State Soil Geographic Database
TCEQ	Texas Commission on Environmental Quality
TPDES	Texas Pollutant Discharge Elimination System
TWDB	Texas Water Development Board
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WPP	Watershed Protection Plan
WWTP	Wastewater Treatment Plant
319	Section 319 of the Clean Water Act
305(b)	Texas Water Quality Report
303(d)	Texas Impaired Water Body List

0.0 EXECUTIVE SUMMARY

Lake Granbury is an impoundment of the Brazos River that lies fully within Hood County, Texas. The City of Granbury, the City of DeCordova Bend, and numerous residential developments surround this reservoir. Since the mid-1990s this reservoir has been identified by the stakeholders of Hood County as a priority water body for protection and restoration. The coves and canals of Lake Granbury exhibit elevated bacteria concentrations related to nonpoint source (NPS) water pollution from the surrounding watershed. These nonpoint bacteria sources can be controlled through an integrated program of education and voluntary compliance with best management practices (BMP). The effectiveness of implementing BMPs will be evaluated through water quality monitoring.

Periodic elevated concentrations of *E. coli* and fecal coliform bacteria have been found in the coves of Lake Granbury, causing a failure to meet the criteria for contact recreation use. A substantial portion of the developed area around Lake Granbury, which lies wholly within Hood County, consists of unincorporated subdivisions that do not have centralized sewage collection systems or treatment facilities. There are an estimated 9,000 on-site sewage facilities (OSSF) located around Lake Granbury with absorption fields installed on small lots in close proximity to the lake. Most of the inhabited areas around the lake exist on man-made coves. The coves are shallow, dead-end bodies of water with little mixing or interaction with the main body of the reservoir. New development in areas without collection and treatment systems relies on individual on-site sewage facilities and absorption fields.

In response to the concerns of stakeholders, the Brazos River Authority, in collaboration with the local stakeholders, embarked upon an effort to develop the Lake Granbury Watershed Protection Plan (WPP). This plan was developed as a "community-driven" plan that reflects the local stakeholders' concerns and water quality data. The overall objective of the Lake Granbury WPP is to improve and protect the chemical, physical and biological integrity of Lake Granbury and its designated uses. This plan identifies the shared vision of watershed residents, local governments, state agencies and elected officials. Stakeholder input has been used at all stages of the Lake Granbury WPP development to determine the source identification activities performed, develop specific water quality goals for Lake Granbury, and determine what solutions can most effectively be used to protect water quality for future generations. The WPP includes an inventory of the watershed, water quality assessment, subwatershed specific data, problem statements, goals, implementation strategies, monitoring and potential funding sources. The implementation plan sets goals and tasks for the reduction of pollutants that enter the lake.

Major findings and outcomes of this stakeholder-driven WPP development process are:

- While bacteria problems are not exhibited within the main body of the lake, elevated bacteria levels are exhibited in specific coves and canal water bodies attached to the lake
- Of numerous areas identified and 21 areas studied in detail by the stakeholders, 13 subdivision areas adjacent to the lake are targeted for specific future strategies to reduce bacteria loads
- Bacteria loading reductions within the isolated drainage areas of identified areas can significantly impact bacteria levels in identified areas; bacteria loading reductions in distant areas of the Lake Granbury watershed would not significantly impact bacteria levels within the identified areas

- Around the lake, four subdivision canal areas consistently exhibit undesirable bacteria conditions and improvement strategies are prioritized for these areas
- Bacteria source identification methods were relied-upon, including land use analysis, watershed modeling and lake water quality modeling
- A single source of bacteria is not evident for all areas of the lake; aging septic systems are a primary potential source in many areas while other areas are susceptible to a variety of sources including septic system, urban, wildlife and agricultural sources

Most Likely Bacteria Sources identified by watershed modeling of potential sources

Area	Most likely sources
Rolling Hills Shores	62% Septic, 38% Cattle, <1% Pets,<1%Deer
Arrowhead Shores	99% Septic, <1% Pets, <1% Deer
Oak Trail Shores	54% Septic, 46% Pets
Sky Harbor	82% Cattle, 13% Septic, 4% Pets, 2% Feral Hog
Nassau Bay II	98% Septic, 2% Pets
Waters Edge	Very low potential; Pets
Ports O' Call	>99% Septic, <1% Pets
Indian Harbor Cove	99% Septic, 1% Pets
Indian Harbor Canal	98% Septic, 2% Pets
Port Ridglea East	>99% Septic, <1% Pets
Blue Water Shores	Pets
Long Creek - Watershed	<98% Cattle, 2% Feral Hog, <1% Pets, <1% Deer
Long Creek - Cove	>99% Septic, <1% Pets
Walnut Creek	96% Cattle, 2% Feral Pets, <1% Pets, <1% Deer
McCarthy Branch	94% Cattle, 3.5% Pets, 2% Feral Hog, <1% Septic

- A bacteria (*E. coli*) goal for lake waters was identified by the stakeholder group: geometric mean less than or equal to 53 MPN/100mL

E.coli **Reductions Needed to Meet Stakeholder Goal**

Area	% *E. coli* Reduction
Port Ridglea East	27
Oak Trail Shores	24
Sky Harbor	16
Indian Harbor	24
Walnut Creek	57
Long Creek	66
Strouds Creek	49
Rucker Creek	47
Robinson Creek	30

- Implementation strategies have been identified to achieve goals:
  - A watershed coordinator should oversee implementation of this WPP; the coordinator should be capable of identifying funding sources, summarizing monitoring, coordinating with local entities and assembling the stakeholders, as necessary

- Regional collection and treatment of wastewater is preferred by stakeholders over onsite systems for areas surrounding Lake Granbury and within Hood County
- Area-targeted educational programs should be pursued, including:
    - Septic maintenance, pets, greywater
    - Agricultural and small acreage land owners
        - Record-keeping for routine and scheduled maintenance activities for septic permit holders should be enforced
        - Home Owners Association (HOA) rules should require approval of health department prior to HOA approval of lot modifications (e.g., a larger septic system should be installed during construction of a larger house or addition to existing structures)
        - While measures to improve circulation within coves and canals may reduce bacteria concentrations and be beneficial to related water quality conditions, available funding sources should first target reduction of bacteria sources

The Lake Granbury WPP was developed to identify the issues facing the watershed and offer solutions and direction to decision-makers and to the Lake Granbury community for the future. Using information and strategies outlined in this WPP, the local community can work toward protecting and improving water quality in Lake Granbury. While the goal of the grant is to bring all parts of Lake Granbury up to attainment of State bacteria water quality standards, local stakeholders have developed their own goals for Lake Granbury that are more protective than the State standards. This plan will be a "living document" that can be updated and/or amended to meet future needs of the watershed and incorporate new data that the stakeholders determine necessary.

1.0 INTRODUCTION

The Lake Granbury WPP aims to improve and protect water quality within Lake Granbury and restore areas of the lake impacted by nonpoint source bacterial pollution. The plan will include an assessment of the sources of bacteria pollution, an implementation strategy to reduce and/or eliminate NPS inputs into the lake and an education strategy for the community.

1.1 WATER QUALITY GOALS

The natural beauty and proximity to major population areas result in Lake Granbury serving as a major recreational resource in the region. Recognizing that some areas of the lake have historically exhibited consistently higher bacteria concentrations than other areas (Table 1), and recognizing that concentrations are typically below the state recreational standards of 126 MPN/100mL, the stakeholders decided to establish a new bacteria concentration goal for Lake Granbury. The expectation is that the goal is more protective than the state standards, thereby providing increased water quality protection and recreational safety. The state recreational standard is determined at an acceptable gastroenteritis rate of 8 illnesses per 1000 swimmers (EPA, 1986). The stakeholder goal of 53 MPN/100mL would reduce the acceptable gastroenteritis rate between 4 and 5 illnesses per 1000 swimmers. The goal is anticipated to be protective for current conditions and is also intended as a preventative measure to ensure exceptionally protective conditions into the future.

The long-term goal for bacteria levels in Lake Granbury, as determined by the stakeholders, is to maintain the geometric mean of *E. coli* concentrations in all parts of the lake, including man-made canals, at or below 53 MPN/100mL (Stakeholder Goal). This benchmark was set based on the 75th percentile of all *E. coli* data collected on compliant Lake Granbury coves from 2002 through 2007. The goal is anticipated to be sufficiently flexible that all areas of the lake can be expected to become compliant; concentrations lower than the goal are exhibited in cove/canals areas that do not have the same pollutant sources (Table 1).

1.2 PURPOSE OF THE WATERSHED PROTECTION PLAN

A Watershed Protection Plan (WPP) is a plan developed by local stakeholders to restore and/or protect water quality and designated uses of a waterbody through voluntary, non-regulatory water resource management and through local regulations and ordinances. Public participation is critical throughout plan development and implementation, as ultimate success of any WPP depends on stewardship of the land and water resources by local landowners, business and residents of the watershed. The Lake Granbury WPP defines a strategy and identifies opportunities for widespread participation of stakeholders across the watershed to work together and as individuals to implement voluntary practices and programs that restore and protect the quality of water in Lake Granbury.

The purpose of the Lake Granbury WPP is to reduce bacterial impairments in all parts of Lake Granbury that do not meet State water quality standards or the stakeholder goal. The main strategy to achieve the goal is by developing programs to aid in watershed clean-up to reduce bacteria loadings. The WPP has identified areas of Lake Granbury that are not currently meeting State standards and the Stakeholder Goal and will target these areas with local programs. The programs identified in the WPP will be administered on a local level by the Lake Granbury Watershed Protection Plan Stakeholders Committee (LGWPPSC) with continued citizen input and involvement facilitated by a Watershed Coordinator. The plan has goals and implementation strategies set up to bring all parts of Lake Granbury into compliance with State standards and the Stakeholder Goal.

The ultimate purpose of the WPP is to restore and maintain the environmental integrity of Lake Granbury. It is the Stakeholders Group's ambition to protect not only the water and land, but to provide protection for fish, wildlife and all living organisms in the Lake Granbury watershed.

Table 1. *E. coli* Bacteria concentration (MPN/100mL) by area, through May 2010

Area	E. coli Range (MPN/100mL)	Geometric Mean (MPN/100mL)	% Samples Above 53	% Samples Above 126	% Samples Above 394
Lake Granbury at Dam	1 - 326	2	2%	2%	0%
Lake Granbury at 51	1 - 2400	5	8%	7%	2%
Lake Granbury at Business 377	1 - 1400	6	7%	4%	1%
Port Ridglea East	1 - >2420	73	58%	31%	10%
Indian Harbor	1 - >2420	71	55%	29%	11%
Oak Trail Shores	1 - >2420	70	50%	34%	17%
Sky Harbor	1 - 24000	63	50%	29%	14%
Blue Water Shores	1 - >2420	37	36%	23%	9%
Rolling Hills Shores	1 - >2420	27	35%	24%	13%
Nassau Bay II	1 - 921	27	36%	16%	3%
Holiday Estates	1 - >2420	25	32%	17%	2%
Port Ridglea West	1 - 1120	26	28%	14%	5%
Lambert Branch	1 - 1600	22	29%	11%	4%
Mallard Pointe	1 - 410	9	16%	11%	2%
Waters Edge	1 - 1986	17	22%	10%	3%
Arrowhead Shores	1 - 1733	14	19%	8%	5%
Ports O' Call	1 - 170	9	10%	2%	0%
Canyon Creek Cove	1 - 2400	8	9%	5%	6%
Rough Creek Cove	1 - 249	8	9%	4%	0%
Long Creek	10 - 24000	156		43%	25%
Walnut Creek	7 - >2400	124		48%	20%
Strouds Creek	8 - >2400	105		34%	20%
Rucker Creek	5 - 6100	100		36%	23%
Robinson Creek	4 - >2400	76		30%	16%
Brazos River at Lake Country Acres	1 - 8665	28		25%	20%

1.3 ELEMENTS OF THE WATERSHED PROTECTION PLAN

The Lake Granbury WPP is produced under the auspices of the U. S. Environmental Protection Agency (EPA). To promote watershed based planning, the EPA has outlined nine elements necessary to successful establishment of a WPP and the Lake Granbury WPP addresses each of these elements. The following steps provide a template for creation, implementation and review of watershed protection efforts. While the composition and strategy of watershed plans vary, the basic elements of any plan should include:

1. Identification of Causes and Sources of Impairment
2. Expected Load Reductions from Management Measures
3. Proposed Management Measures
4. Technical and Financial Assistance Needs
5. Information, Education and Public Participation Component
6. Schedule for Implementing Management Measures
7. Interim Milestones for Progress in Implementation
8. Criteria for Determining Pollutant Load Reductions and Water Quality Improvement
9. Load Reduction and Water Quality Monitoring Component

1.4 UPDATES AND REVISIONS

The Lake Granbury WPP is a "living document," which can be updated and revised as new information emerges, implementation practices are put into place and as stakeholders reflect on accomplishments and forge ahead into the future. The water quality of Lake Granbury will improve with each individual's effort. This plan has been written to aid the development of water quality and community support. Short and long-term benefits will come from the implementation of the strategies laid out in this document.

1.5 SUMMARY OF EXISTING WATER QUALITY CONDITIONS

Since completion of the DeCordova Bend Dam in 1969 that resulted in the impoundment of Lake Granbury, numerous water quality parameters have been monitored for purposes of assessing water quality conditions within the lake. Conditions are assessed against protective criteria for designated uses that include public water supply, contact recreation and High aquatic life use. Lake Granbury is identified by TCEQ as water quality segment 1205. The lake is fully supporting of all uses currently assessed (TCEQ Draft 2010 Texas Integrated Report).

To assess current conditions and historical trends, a data evaluation report was developed as part of this WPP process (EC 2007). Elevated bacteria concentrations in the main body of the lake do not occur regularly nor are periods of high concentration persistent. Background levels of bacteria in the main body of Lake Granbury are less than 10 MPN per 100 mL (EC 2007). The main contributors of bacteria for the Lake Granbury Watershed (sub-watershed areas as analyzed in Figure 21) are livestock (primarily cattle), OSSFs (failing septic tanks), feral hogs, and pets (Table 2); however, low bacteria levels exhibited in monitoring data within the large, main body of the lake do not indicate significant watershed-wide bacteria problems.

Historically, local stakeholders expressed concerns about bacteria levels not within the main body of the lake but within canals. The BRA began a large-scale canals monitoring project in 2002 involving more than 50 sampling locations monitored monthly. The data developed through this effort are invaluable in identifying problem areas and problem conditions. Analysis indicates elevated levels of bacteria are found in many of the coves of Lake Granbury; levels are elevated compared to the bacteria in the lake and also elevated related to the state water quality standard of 126 MPN/100mL (Table 1). This WPP project was initiated to investigate and develop appropriate goals to address these conditions. Significant additional detail on location-specific bacteria assessment and on improvement strategies are provided in this WPP document. Generally, the main contributor of bacteria within cove areas can be attributed to malfunctioning OSSFs (Table 3); however, each localized cove drainage area exhibits unique characteristics where cattle and pets are also significant potential sources.

Table 2. Total Lake Granbury watershed daily potential bacteria loading by source

Source	Total Potential Load for Entire Watershed (trillions cfu/day)
Cattle	1,936
OSSF	41
Feral hogs	31
Pets	9
Deer	0.190
WWTP	0.026

Table 3. Relative potential bacteria load contributions within selected priority areas (% by source per area)

Subdivision	SepticLd	PetLd	CattleLd	DeerLd	FeralHogsLd
Sky Harbor	12.5%	3.9%	81.8%	-	1.8%
Rolling Hills Shores	61.8%	0.2%	37.9%	0.2%	-
Waters Edge	-	99.9%	-	-	-
Blue Water Shores	62.9%	37.1%	-	-	-
Port Ridglea East	99.8%	0.2%	-	-	-
Indian Harbor	99.7%	0.3%	-	-	-
Nassau Bay II	98.2%	1.8%	-	-	-
Oak Trail Shores	54.1%	45.9%	-	-	-

Results of the data evaluation also indicate that there is an increasing trend in nutrients in the main body of Lake Granbury (EC 2007). Decreasing trends in overall DO concentrations, daytime DO increases from photosynthesis, decreasing trends in secchi depth and increasing trends in chlorophyll-*a* concentrations were also observed in the initial data review (EC 2007). The evaluation included data through 2006 (EC 2007); to consider recent high and low flow periods, more recent data should be incorporated into the trend analysis. These trends are not addressed within this WPP process which focuses only on bacteria. However, it is hoped that addressing bacteria nonpoint sources will also result in reduction of nonpoint source nutrient loading to the lake.

1.6 PREVIOUS WATER QUALITY EFFORTS

In 1993, a cooperative study between the Texas Water Commission, the Brazos River Authority (BRA) and the Hood County Health Unit first identified an increase in fecal coliform levels in the lake. The *On-site Wastewater Treatment Units at Lake Granbury and the Possible Impact Upon the Water Quality of the Lake Study* identified the most notable area of concern to be in the coves.

In 1995, a study titled *Survey of Conditions and Impact of Septic Tank Pollution on the Water Quality in Lake Granbury* indicated that the soils in which septic tanks are installed around Lake Granbury are generally not well-suited for septic tanks and absorption fields. Another finding was that almost all on-site systems around the lake include absorption fields that do not provide a capacity that would comply with current State criteria.

The combination of previous studies indicate a concern for water quality from on-site sewage systems in addition to forecasts for Hood County population to increase from its current level of about 42,000 persons to more than 78,000 persons by the year 2030. With this information in mind, the development of a feasibility study to bring a regional sewage system to Hood County and eliminate the on-site sewage facilities was completed in 2000. The *Hood County Regional Sewerage System Feasibility Study* was a cooperative effort between the BRA and the Hood County Intergovernmental Coalition. The capital costs for this regional wastewater facility were estimated to be approximately $149.9 million with annual operation and maintenance costs estimated to be approximately $16.23 million.

In 2001, the 77th Texas Legislature formed the Lake Granbury Water Improvement District. The new district encompassed all of Hood County and was granted powers to collect, transport, process, dispose of and control all domestic, industrial and communal wastes. The formation of the district, which would have taxing authority, was subject to a confirmation election. The confirmation election was held in May 2002, but the district failed to be confirmed by the voters of Hood County. Post-election polling revealed that voters felt that the taxes to fund the district and regional wastewater system would be too high; the scope of the district was too large, it covered the entire county, not just the lakeside communities; and that there was not sufficient data documenting water quality concerns in the canals to justify the expenditure.

In response to stakeholder concerns, the BRA began a large-scale monitoring initiative in the canals of Lake Granbury to assess the water quality of the coves. Beginning in May 2002, the Authority began collecting water quality samples on a monthly basis at more than 50 cove locations. Some of the locations showed no elevated concentrations of *E. coli* and were later discontinued. Some locations were added after a year of monitoring as new information was acquired on possible source locations. The data generated from this effort indicate that many of the canals on Lake Granbury are impacted by elevated *E. coli* concentrations and declining water quality in Lake Granbury has begun to negatively affect the use of the lake. Lake Granbury is the lifeblood of Hood County, with the majority of the county's communities rely on the lake for drinking water, irrigation, industry and recreation. The economy in Hood County is closely tied to Lake Granbury, and the environmental condition of the lake is crucial to the county's residents.

Recognizing the high potential for development around the lake and resulting potential for impact on water quality, two independent studies were sponsored in 2007-2008 by BRA and the City of Granbury to identify appropriate development guidelines for residential canal subdivisions. At the time the BRA began comprehensive water quality monitoring of many of the canal systems in 2002, the BRA's Board of Directors (BOD) placed a moratorium on new canal construction to assess the impact of canals on water quality and the Authority's water resource. The City of Granbury expressed concern that placing a moratorium on canal development for the duration of the WPP would be detrimental to the economic development of the City and surrounding area. In March 2007, the BRA began a study to determine the feasibility of future canal systems on Lake Granbury and to develop engineering specification standards for future canal systems. The study commenced in April 2007 and concluded in July 2008 with the creation of minimum of canal development standards. A resolution to adopt the canal design standards was approved by the Board of Directors of the Brazos River Authority on July 28, 2008. Concurrently, a City of Granbury (City) study found conclusions similar to BRA's findings. The City amended their subdivision rules to regulate canal development that are in-line with the canal design standards approved by the BRA's BOD. Subsequently, the BOD lifted the moratorium on canal developments within the City's ETJ in January of 2009.

As a result of these studies and increased awareness and involvement in the WPP, Hood County enacted subdivision development ordinances that promote improved water quality in the lake. For development projects within 1 mile of the lake, the county now requires a minimum lot size of 3 acres if waste water treatment will be provided using on-site treatment facilities (septic systems). This county ordinance has led to annexation of some areas by the City of Granbury to allow for installation of waste water collection and treatment near the lake, which is consistent with one of the primary stakeholder goals.

2.0 LAKE GRANBURY WATERSHED OVERVIEW

Water quality conditions within Lake Granbury are influenced not only by river inflows but also by water draining into the lake from the surrounding watershed. Many watershed characteristics are important in determining the quantity and quality of water entering the lake, including climate, slope, vegetation and, particularly, soils composition. Wildlife and human activities become particularly important when they exceed the natural capacity of the watershed to assimilate changes.

This chapter presents both an overview of general watershed concepts and characteristics of the Lake Granbury watershed. Many of these watershed characteristics influence bacteria levels within the water body.

2.1 GENERAL WATERSHED CONCEPTS

2.1.1 Watershed Definition

A watershed is an area of land across, through or under which water flows on its way to a single common point in a stream, river, lake or ocean. Watersheds include not only waterbodies such as streams and lakes, but also the surrounding lands that contribute water to the system during and after precipitation as runoff. Water quality and quantity can have significant effects on the function and health of a watershed. Conversely, activities in the watershed can have dramatic impacts on water quality and quantity. Watersheds can be extremely large, covering many thousands of acres and are often divided into smaller "subwatersheds" and even smaller "microwatersheds" for the purpose of study and management.

2.1.2 Watersheds and Water Quality

To effectively address water issues, it is important to examine all natural processes and human activities occurring in a watershed that may affect water quality and quantity. Water from rainfall, snowmelt and irrigation that flows over agricultural, residential, industrial and undeveloped areas can carry pollutants into lakes, rivers, streams and oceans. Additionally, water from other sources containing pollutants may be released directly into a waterbody. To better enable identification and management, potential pollutants are classified based on their origin as to either point source or nonpoint source.

Point source pollution is pollution that is discharged from a defined location such as a pipe, ditch or channel. Point source pollution is typically deposited directly into a waterway and often contributes flow across all conditions, including both drought and flood. Point source pollution discharges must have a wastewater permit from the Texas Commission on Environmental Quality's (TCEQ) Texas Pollutant Discharge Elimination System (TPDES). These permits require specific pollutant limits for the effluent that aims to reduce the discharge's impact on the receiving waterbody.

Nonpoint source pollution refers to pollution that comes from a source that does not have a single point of origin. As the stormwater runoff from rain events moves over the land, it can pick up both natural and human-related pollutants, depositing them into waterbodies.

Ultimately, the types and amounts of pollutants entering a waterbody will determine the quality of water it contains and whether it is suitable for use for activities such as irrigation, fishing, swimming or drinking.

2.1.3 Watershed Approach to Improve Water Quality

This Lake Granbury Watershed Protection Plan was developed using a watershed-based approach. Because watersheds are determined by the topography of the landscape rather than political boundaries, watersheds often cross municipal, county and state boundaries. By using a watershed perspective, all potential sources of pollution entering a waterbody can be identified and evaluated.

Additionally, a watershed approach allows for all stakeholders in the watershed to be involved in the process. A watershed stakeholder is anyone who lives, works or engages in recreation in the watershed. They have a direct interest in the quality of the watershed and will be affected by planned efforts to address water quality issues. Municipalities, individuals, groups and organizations within a watershed can become involved as stakeholders in initiatives to protect and improve local water quality. Stakeholder involvement is critical for selecting, designing and implementing management measures to successfully improve water quality.

2.2 LAKE GRANBURY WATERSHED INVENTORY

The Lake Granbury watershed lies within the larger Brazos River Basin, which in total drains 44,000 square miles of Texas from the New Mexico Border near Lubbock across the State to its point of discharge into the Gulf of Mexico near Freeport. Areas contributing drainage to Lake Granbury include Possum Kingdom Lake's watershed of 14,030 square miles and a drainage area below Possum Kingdom Lake of 2,138 square miles. This area below Possum Kingdom Lake is Lake Granbury's watershed considered in this WPP project and includes all or portions of Erath, Hood, Palo Pinto and Parker counties. The total capacity of Lake Granbury is 136,823 ac-ft. For the purpose of this study and given the nature of the bacteria problem to be isolated in the immediate vicinity of the lake, stakeholders chose to evaluate a two-mile radius from the lake in great detail (Figure 1).

2.2.1 Water Resources

The watershed overlies the Trinity Aquifer which is a water-bearing geologic formation. The Trinity Aquifer is classified by the Texas Water Development Board (TWDB) as a major aquifer and furnishes small to moderate amounts of groundwater to entities in 17 counties. Hood County is in the recharge zone of the aquifer where development has resulted in significant declines in the water table.

Lake Granbury plays a major role in the watershed and supplies water for approximately 75,000 people in Hood and Johnson counties. Generally, its water quality is sufficient for agricultural uses, but elevated salinities caused by brine springs in the upper portion of the Brazos River basin require advanced treatment for municipal and most industrial uses.

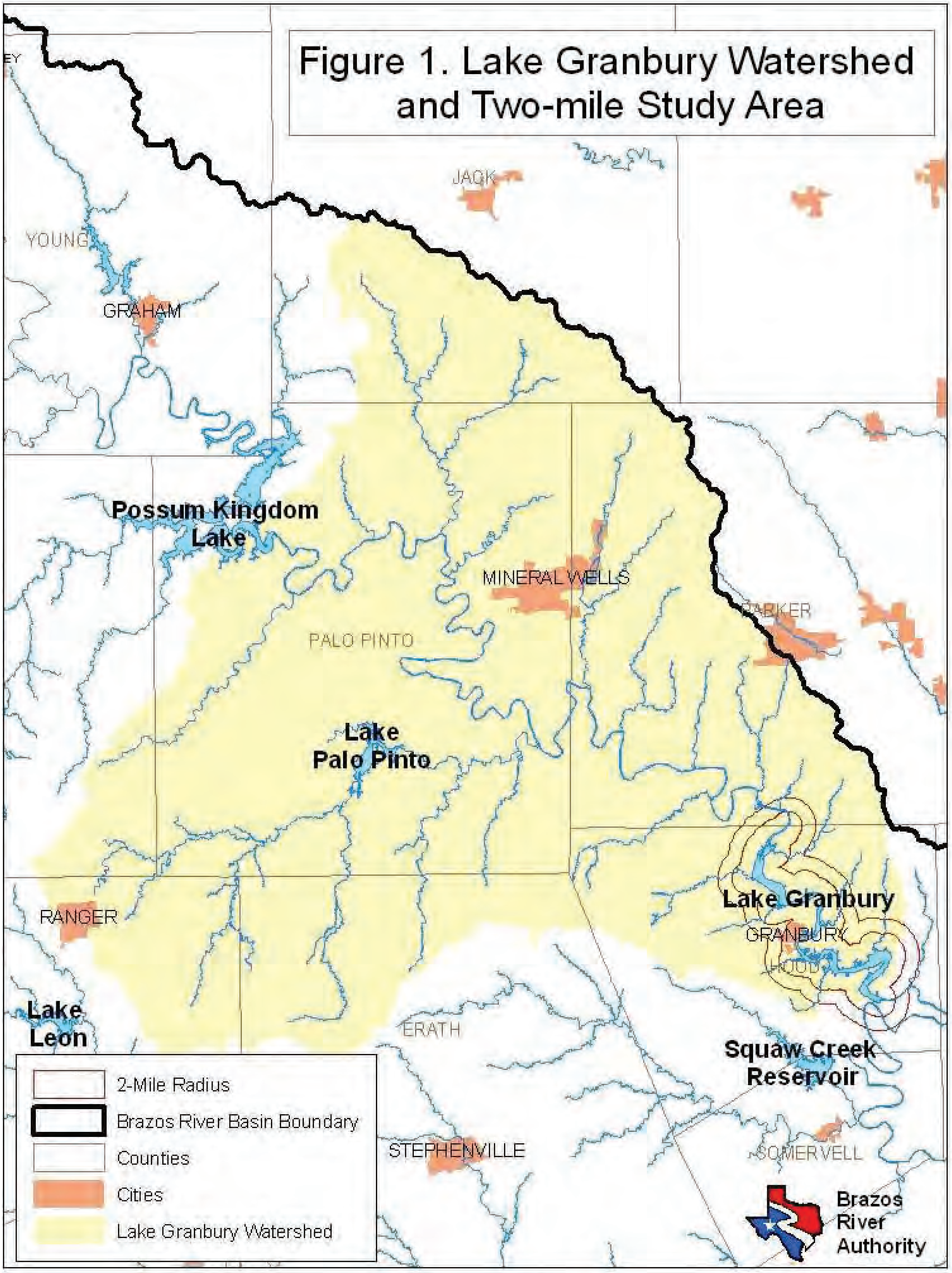


Figure 1. Lake Granbury watershed and 2-mile radius

2.2.2 Soils

Soils across the watershed are highly varied (Figure 2 and Figure 3) and tend to require significant planning or modification for the installation and proper function of traditional on-site sewage facilities (OSSFs, OWTFs or septic systems). Evaluation of soil characteristics assisted stakeholders in assessment of land use and potential bacteria sources (see subsequent chapters).

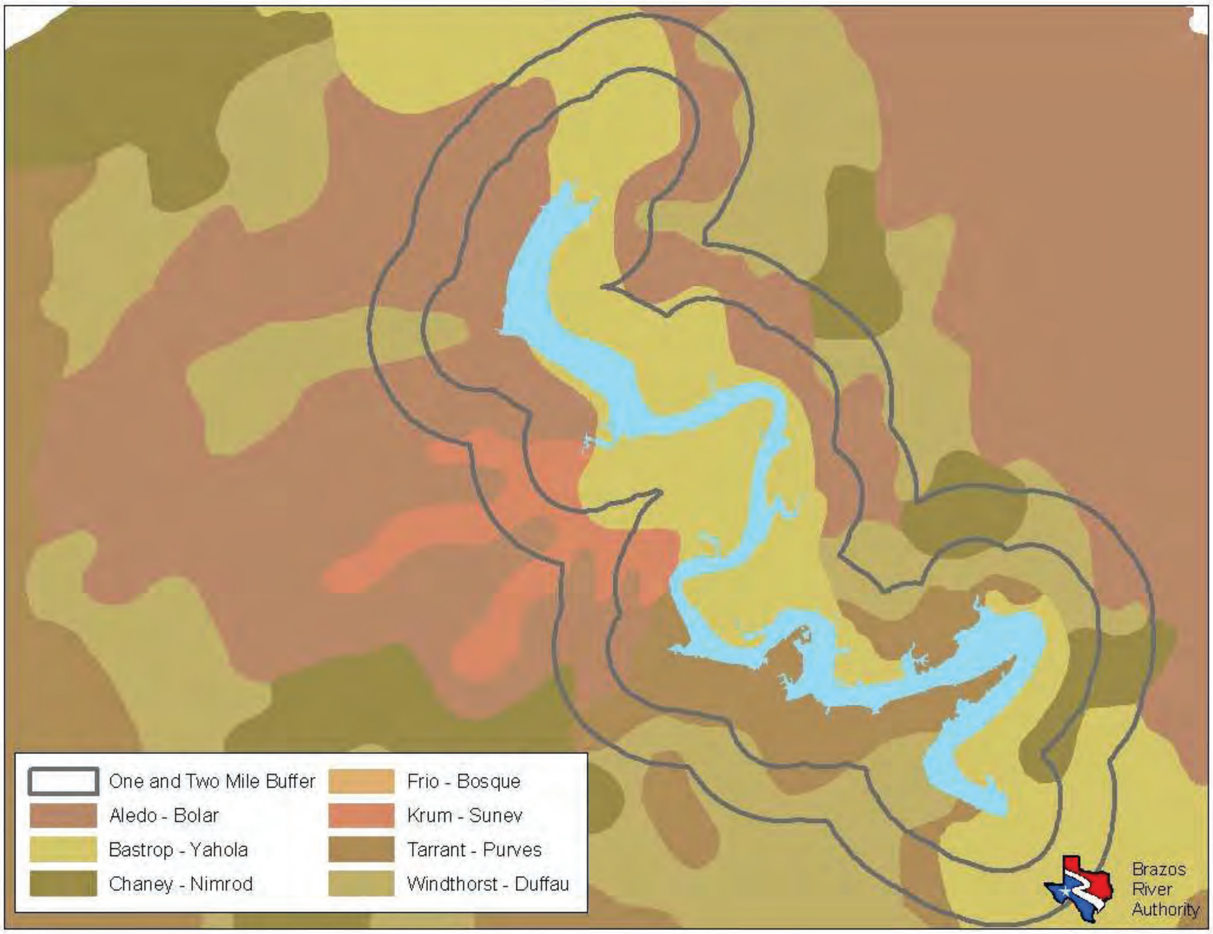


Figure 2. Major soil associations near Lake Granbury

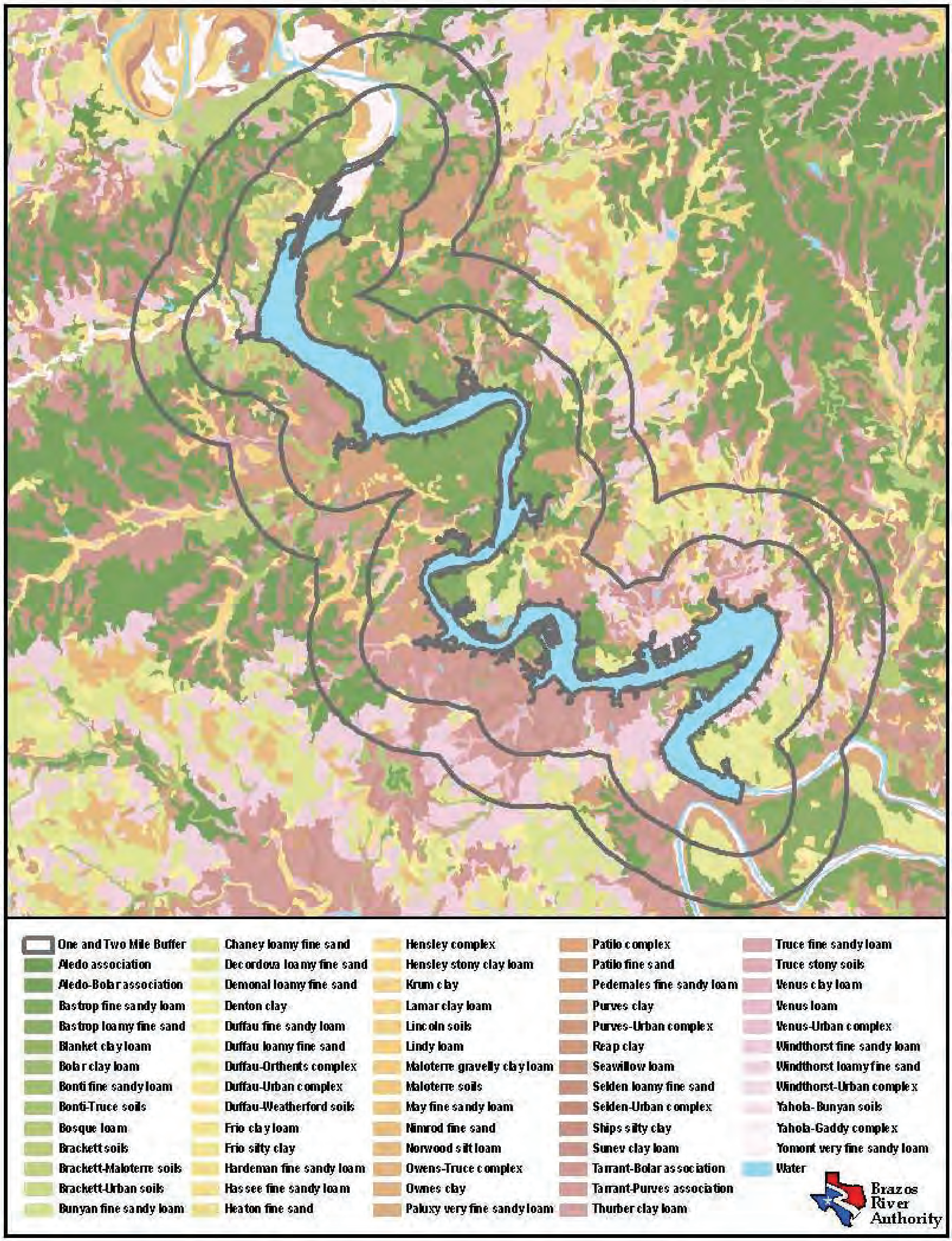


Figure 3. Hood and Parker County Individual Soil Types

2.2.3 Climate

The rainfall and temperature patterns in the watershed are typical and characteristic of the Cross Timbers ecoregion. These rainfall and temperature patterns have influence on bacteria levels in the watershed and receiving water bodies.

The amount of rainfall in the watershed varies considerably from year to year, but the average annual rainfall is approximately 34.7 inches (Table 4). In exceptionally wet years, much of the rain comes within short periods and causes excessive runoff; these events have high potential to cause overflows in sewage systems leading to migration of bacteria into water bodies. Additionally, runoff from these events flush accumulated organic material, including fecal matter, from terrestrial natural areas into water bodies. Sources of bacteria near a drainage pathway or a water body (for example feral hog rooting areas or lake-side developments with septic systems and pets) have greater potential to contribute bacteria to the water body compared to sources that are distant from drainage pathways.

Temperature changes are rapid, especially in winter and early spring when cold, dry polar air replaces warm, moist tropical air. Periods of cold weather are short and occur mostly in January; fair, mild weather is frequent. High daytime temperatures prevail for a long period in the summer when the maximum temperature reaches or exceeds 90°F daily. July is the hottest month with an average daily maximum temperature of 95°F. The high temperatures of summer are associated with fair skies, westerly winds and low humidity.

High ambient air temperatures with associated fair skies cause high water temperatures that are conducive to bacteria viability in the canals.

2.2.4 Ecology, Wildlife and Vegetation

The Lake Granbury watershed is located within the Osage Plains section of the Central Lowlands physiographic province. Topographic elevations range from about 600 to 1,600 feet above sea level for a total relief of 1,000 feet. In general, the land surface is gently rolling to semi-level. Prominent northeast sloping escarpments are formed by limestones and sandstones.

The ecology of the watershed reflects a history of negative disturbances including improper grazing procedures, soil erosion, lowered water tables in some areas, declining native grasslands and altered river ecosystems. The historic tall and mid-grass prairies have become a mesquite-short grass savanna.

Animals native to the area include white-tailed deer, beaver, bobcat, coyote, fox, skunk, raccoon, skunk, squirrel, turkey and a diverse array of small mammals and birds. In addition, feral hog populations in the area are believed to be significant and on the rise.

All rivers and streams in the Lake Granbury watershed are typical prairie stream ecosystems characterized by extreme fluctuations in water level. The native fish fauna are adapted to the variable flow regimes and extremes.

Lake Granbury supports fish species not typical of streams, including common carp, gizzard shad, warmouth, bluegill sunfish, longear sunfish, largemouth bass, white bass, spotted bass, striped bass, white crappie, flathead catfish and walleye.

The watershed, in addition to the remainder of the Cross Timbers, is important to migratory and winter waterfowl. During the migratory season, ducks and coots are distributed throughout the watershed wherever there are ponds or natural wetlands. Many species of migrating shorebirds, raptors, Neotropical songbirds and other birds stop over in the watershed to feed and rest.

At least 30 species of amphibians, reptiles and mammals are known to inhabit the watershed. Many of these species are aquatic or semi-aquatic. All toads require aquatic habitats to reproduce. A number of snakes known in the watershed are restricted to riparian habitats, including the copperhead, the western ribbon snake, the eastern coral snake and the Brazos water snake.

The golden-cheeked warbler is currently on the Federal list of endangered species and its known range includes the Lake Granbury watershed. The most significant threat to the existence of the warbler is the loss and fragmentation of habitat due to clearing of oak-juniper woodlands and brood parasitism by brown-headed cowbirds. The golden-cheeked warbler breeds exclusively in Texas, are present from early March to late August and winters from southern Mexico to Nicaragua.

The Brazos water snake is mostly aquatic, non-venomous and found only in north central Texas along the Brazos River system. Due to its limited range, it is considered to be a threatened species in the state of Texas. An adult snake can range from 16-32 inches in length. Its dorsal color ranges from brown to olive with two longitudinal rows of brown spots on each side of its body that creates the look of stripes, while the ventral surface is pink to orange with one row of dark spots on each side of the belly.

The original vegetation was tallgrass prairie in the upland areas and elm, pecan and hackberry in riparian areas, where deeper soils have developed in floodplain deposits or where the underlying clays have been exposed by limestone erosion. The invasive species Ashe juniper and, to a lesser extent, honey mesquite have increased since settlement. Cross Timbers grasses include big bluestem, yellow Indiangrass, little bluestem, hairy grama, Texas wintergrass, sideoats grama and Texas cupgrass. Present land uses include grazing on ridges with shallow soils and farming of corn, grain sorghum and wheat on the deeper soils on the flats.

Table 4. Monthly Temperature, Precipitation and Evaporation of the Lake Granbury Watershed

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature Data (1971-2000)													
Mean Minimum Temperature (°F)	29.0	33.9	41.3	49.6	59.5	67.4	71.3	70.1	62.8	51.4	40.4	31.7	50.7
Mean Maximum Temperature (°F)	54.2	59.5	67.8	75.8	82.7	90.1	95.2	95.2	88.0	78.1	65.6	56.9	75.8
Mean Temperature (°F)	41.6	46.7	54.6	62.7	71.1	78.8	83.3	82.7	75.4	64.8	53.0	44.3	63.3
Precipitation (1940 – 2000)													
Minimum Total Precipitation (inches)	0.01	0.11	0.38	0.29	1.19	0.11	0.00	0.00	0.26	0.04	0.24	0.03	19.40
Maximum Total Precipitation (inches)	5.05	7.93	6.89	11.72	9.85	10.73	5.97	7.30	7.27	9.79	8.35	9.78	52.20
Mean Total Precipitation (inches)	1.79	2.40	2.50	3.53	4.50	3.47	2.13	2.29	3.01	3.34	2.44	2.26	33.65
Evaporation (1954 – 2004)													
Minimum Total Evaporation (inches)	1.03	1.36	2.66	3.03	3.49	4.39	5.78	5.46	3.47	3.05	2.14	1.47	43.49
Maximum Total Evaporation (inches)	3.66	4.47	5.75	6.19	7.08	9.58	11.41	11.42	9.26	6.56	4.92	3.53	78.64
Mean Total Evaporation (inches)	2.06	2.46	4.04	4.84	5.05	6.84	8.38	7.84	5.96	4.73	3.14	2.29	57.63

Source: Temperature – National Climatic Data Center, Ashville, North Carolina; Precipitation and Evaporation – Texas Water Development Board, Austin, TX

2.3 HISTORY OF THE LAKE GRANBURY WATERSHED

Table 5. Population Trends for Hood County

1900	9,146
1910	10,008
1920	8,759
1930	6,779
1940	6,674
1950	5,287
1960	5,443
1970	6,368
1980	17,714
1990	28,981
2000	41,100
2010	54,900*
2014	64,200*
2030	100,000*
Sources: 1900 – 2000 (United States Bureau of the Census); *Projections from 2010 – 2030 (Hood County)	

Before settlers from the East ventured onto the prairie, the area was home to the Comanches, the Lipan Apaches and Kiowas. Settlers began to arrive in the area 10 or 15 years before the Civil War. The main concern facing these early settlers was the frequent raids by the Comanches.

In a move to spur settlement after the Mexican War for Independence, numerous colonies/municipalities were chartered in the 1820s and 1830s. The area now known as Hood County had been within the municipality of San Felipe de Austin as early as 1823 and the Municipality of Viesca in 1834. Hood County was formed in November 1866 by an act of the 11th Texas Legislature. Land donated to the newly formed county by two influential land owners and its vicinity to the Brazos River led to Granbury being named the county seat.

The last three decades of the 19th century saw a steady increase in the population. When the Fort Worth and Rio Grande Railway came through Granbury in 1887, residents were able to send their produce and livestock to market leading to a boom in agriculture in the county. By 1910, farming had reached a zenith in the area. The expansion of the rail lines fueled further settlement and led to construction of many buildings. Between 1910 and 1920, farming activities began to decline in the watershed and have continued to decline through the present. Cattle production in the watershed has been somewhat variable with many periods of high production followed by extreme declines in production.

In the late 1950s, discussions began regarding the construction of a dam in the area of DeCordova Bend of the Brazos River near Granbury. Negotiations regarding the dam and its configuration continued throughout most of the early 1960s with construction commencing in December 1966. The dam was completed by early 1969 and received the formal name of DeCordova Bend Dam and Lake Granbury. The reservoir filled by June 1970. The dam is a concrete and earthen structure 2,220 feet long and 82 feet high.

Economically, the effects of the development of Lake Granbury on the City of Granbury and Hood County have been astounding. The completion of the dam transformed Hood County into a popular recreation center, retirement community and tourist center virtually overnight. Between 1970 and 1980, Hood County ranked sixth among all United States counties in the category of highest growth rate.

Table 5 presents population data for Hood County from 1900 to 2000 and population projections from 2010 to 2030. The county has experienced steady growth from 1990 to 2000 increasing by 42 percent. A 100 percent growth is projected to occur from 2010 to 2030.

3.0 LAKE GRANBURY WATERSHED PROTECTION PLAN STEERING COMMITTEE (LGWPPSC) AND PROJECT TEAM

3.1 GOAL

The LGWPPSC is an organization of landowners, agricultural producers, city, county and municipal utility district officials, local business and industry representatives and concerned citizens working to improve the welfare of Lake Granbury. The goal of the LGWPPSC is to develop and implement a Watershed Protection Plan to improve and protect the water quality of Lake Granbury. The strategy presented in this report is a product of LGWPPSC members input and direction.

The LGWPPSC considered and incorporated the following into the development and implementation of the WPP:

- Impact on water quality;
- Economic feasibility, affordability, and growth;
- Unique environmental resources of the watershed; and
- Existing regional activities and cooperation.

3.2 PROJECT TEAM

The Lake Granbury WPP is a collaborative effort of many state and federal agencies and the LGWPPSC. Technical support and logistical leadership have each been provided by the Project Team. Funding for the project has been provided by the United States Environmental Protection Agency (USEPA), the Texas Commission on Environmental Quality (TCEQ) and the Brazos River Authority (BRA).

The Project Team consists of representatives from the Texas Commission on Environmental Quality, Brazos River Authority, Texas AgriLife Research, and Espey Consultants, Inc. The Project Team's role is to facilitate the LGWPPSC and help the LGWPPSC with technical and logistical knowledge and water quality expertise.

3.3 LGWPPSC

The LGWPPSC is the decision making body for the development of the WPP and is governed by the Lake Granbury Watershed Protection Plan Stakeholders Group Bylaws as adopted on March 24, 2006 and amended on February 13, 2007 (Appendix A). The LGWPPSC guides the Project Team by formulating recommendations for the drafting of the WPP and will guide the implementation of the WPP.

While formation of the LGWPPSC was facilitated by the Project Team, the LGWPPSC is an independent group of twenty-three watershed stakeholders with an interest in restoring and protecting the designated uses and overall health of Lake Granbury. The membership of the LGWPPSC reflects the diversity of interests within the Lake Granbury watershed. Categories of stakeholders sought for the group followed the guidance provided in the United State's Environmental Protection Agencies *Handbook for Developing Watershed Plans to Restore and Protect our Waters* and consist of representatives from:

- State and Federal Agencies,
- County government,
- Municipal government,,
- Local business and industry,
- Local landowners,
- Local soil and water conservation district,
- Citizen groups, and
- Local environmental and conservation groups.

Initially, the Project Team asked eighteen watershed stakeholders to volunteer their time and efforts to the LGWPPSC. These eighteen then chose to add five more positions to the group based on their local knowledge of concerned parties and then instituted a consensus-based system for limiting membership. Size of the LGWPPSC is limited in the Bylaws to a total of twenty-five. To effectively function as a decision-making body, the stakeholders elected to keep the group small to prevent the committee from becoming so large that it becomes impossible or impractical to function. The LGWPPSC will not elect a chair, but will remain a facilitated group. Facilitation of meetings will be conducted by TCEQ and/or BRA.

Stakeholder involvement is critical to the selection, design and implementation of management measures to successfully improve water quality. The members of the LGWPPSC offered the various perspectives of their constituents and created a plan that is not only feasible but palatable to those most impacted. LGWPPSC members are expected to participate fully in Committee deliberations and work constructively and collaboratively with each other to reach consensus. Committee members will be expected to assist with the following: identify desired water quality conditions and measurable goals; prioritization of programs and practices to achieve goals, help develop the WPP document; lead the effort to implement this plan at the local level; and communicate the plan and its implications to other affected parties in the watershed.

3.4 WORKGROUPS

As needed, members of the steering committee were asked to serve on selected work groups suited to their interests, experience and constituencies. Two work groups were formed by the steering committee during the development of the WPP, the Best Management Practice Selection Work Group and the Financial Work Group. The purpose of these groups is to focus on the establishment and funding of best management practices and affiliate programs designed to reduce bacteria loading into Lake Granbury. These teams advised the Project Team on the viability of proposed locations and strategies as well as review and provide input into the formulation of the WPP.

The LGWPPSC has expressed a desire to establish an Executive Committee to interact with the Watershed Coordinator frequently between meetings of the full committee. The Executive Committee will assist the Watershed Coordinator schedule meetings at appropriate times and will keep decision-makers apprised of relevant activities. The LGWPPSC has selected the following governmental entities and stakeholders to serve on the Executive Committee: Hood County, City of Granbury, Acton Municipal Utility District, the Granbury Chamber of Commerce and the Vice Chairman of the Brazos Valley Soil and Water Conservation District.

3.5 PARTICIPATION BY THE GENERAL PUBLIC

The LGWPPSC provides the method for public participation in the planning process and will be instrumental in obtaining local support to move into the implementation phase of the project. While the LGWPPSC was the formal decision making body for the development of the WPP, it was recognized that other watershed stakeholders could also provide valuable input. To that end all LGWPPSC meetings were open to the public. The LGWPPSC benefitted from having several active watershed residents that also participated in the process even if they were not a formal member of the LGWPPSC.

3.6 LGWPPSC RESOLUTIONS

The stakeholder group participated heavily in decision-making, and provided valuable local insight in both interpretation of findings and identification of appropriate issues and strategies this WPP should address. As part of that process, several key decisions were made leading to development of this WPP. Many decisions were made by resolutions voted on by a quorum of the stakeholders. Each of the resolutions is listed in Table 6 below.

Table 6. LGWPPSC Resolutions

Resolution Subject	"BE IT RESOLVED by the Lake Granbury Watershed Protection Plan Stakeholders Group that...	Adopted/Not Adopted Date	Votes "For"	Votes "Against"
Governing Bylaws	...the group adopts the Lake Granbury Watershed protection Plan Stakeholder Group Bylaws as the guiding document for the stakeholder process."	March 24, 2006	15	0
Proposed New Members - Agriculture	...Local Livestock Producer, Joe Langdon be added as a representative for the Agricultural Group Category."	March 24, 2006	15	0
Proposed New Members - Business/Industry	...Dick Cary be added as a representative for the Business/Industry Group Category to represent the Oil and Gas Industry."	March 24, 2006	15	0
Proposed New Members - General Public	...two additional positions be added as representatives for the General Public Group Category. BE IT FURTHER RESOLVED that these positions will be selected by closed ballot"	March 24, 2006	15	0
Proposed New Members - Affected Area	...one additional position be added as a representative for the Affected Area Group Category	March 24, 2006	3	12
Proposed New Members - Business/Industry	...Ronnie Mowrey be added as a representative for the Business/Industry Group Category to represent the Septic Tank Industry."	March 24, 2006	15	0
Water Quality Monitoring Plan	...the water quality monitoring plan as presented and discussed on May 10, 2006 and represented on the "Lake Granbury Water Quality Monitoring	May 10, 2006	19	0

Resolution Subject	**"BE IT RESOLVED by the Lake Granbury Watershed Protection Plan Stakeholders Group that...**	**Adopted/Not Adopted Date**	**Votes "For"**	**Votes "Against"**
	Sites" Map be implemented by the Brazos River Authority on September 1, 2006."			
Proposed New Members - Remaining Position	...the unfilled position remain open."	May 10, 2006	19	0
Bacterial Source Tracking and Representative to State BST Task Force	...the Bacterial Source Tracking Scope of Work as presented and discussed on February 13, 2007 be implemented by the Brazos River Authority upon contract execution between the Brazos River Authority and El Paso Agricultural Research and Extension Center and Texas Commission on Environmental Quality approval of the Quality Assurance Project Plan. BE IT FURTHER RESOLVED Watershed Coordinator will serve as Stakeholders Group Representative to the State led Task Force on using Modeling and Bacterial Source Tracking for TMDLs."	September 28, 2006	22	0
Stakeholder Attendance Issue	...the Sierra Club be removed as the representative for the Environmental and Conservation Group Category. BE IT FURTHER RESOLVED that the Hood County Chapter of the Brazos River Conservation Coalition be added as the representative for the Environmental and Conservation Group Category.""	February 13, 2007	18	0
Bylaw Amendment	...the amendment Article IV of the Lake Granbury Watershed Protection Plan Stakeholders Group Bylaws as presented and discussed on September 28, 2006 be adopted."	February 13, 2007	18	0
Bacterial Source Tracking	...the Bacterial Source Tracking Scope of Work as presented and discussed on February 13, 2007 be implemented by the Brazos River Authority upon contract execution between the Brazos River Authority and El Paso Agricultural Research and Extension Center and Texas Commission on Environmental Quality approval of the Quality Assurance Project Plan."	February 13, 2007	19	0
Land Use Analysis	...the land use analysis as presented on discussed on May 10, 2006, September 28, 2006 and February	February 13, 2007	20	0

Resolution Subject	"BE IT RESOLVED by the Lake Granbury Watershed Protection Plan Stakeholders Group that...	Adopted/Not Adopted Date	Votes "For"	Votes "Against"
	13, 2007 are acceptable to the Stakeholders Group and no additional analyses will be performed until 2007 NCTCOG aerial photography is available."			
Water Fowl Survey	...the Water Fowl Survey as presented and discussed on February 13, 2007 be implemented by the Brazos River Authority in February 2007."	February 13, 2007	20	0
Stakeholder Goals	...the preliminary goals as discussed on May 22, 2007 and represented on slide number 8 are approved as written."	May 22, 2007	16	0
Modeling Approach	...the modeling approach as presented and discussed on May 22, 2007 is acceptable to the Stakeholders Group."	May 22, 2007	17	0
Water Quality Modeling - Literature Value to be Used for Urban Runoff	...the literature value to be used for Urban Runoff in the Lake Granbury WPP Water Quality Model be 16,048 MPN/100 mL based on a mean of City of Austin, Corpus Christi and Galveston Bay urban runoff data."	February 20, 2008	19	0
Water Quality Modeling - Literature Value to be Used for Raw Sewage	...the literature value to be used for Raw Sewage in the Lake Granbury WPP Water Quality Model be 550,000 MPN/100mL based on Raw Sewage from Georgia (Kuntz, 2003)."	February 20, 2008	19	0
Water Quality Modeling - Literature Value to be Used for Wastewater Generation from a Single Residence	...the literature value to be used for wastewater generation from a single residence in the Lake Granbury WPP Water Quality Model be 200 gallons/day based on TCEQ recommended values."	February 20, 2008	19	0
Water Quality Modeling - Fecal Coliform to *E. coli* Ratio	...the ratio to be used to relate fecal coliform to *E. coli* in the Lake Granbury WPP Water Quality Model be 1:0.7 based on BRA Generated Data from Lake Granbury."	February 20, 2008	19	0
Water Quality Modeling - Literature Value to be Used for Bacteria Decay Rates	...the literature value to be used for bacteria decay rates in the Lake Granbury WPP Water Quality Model be 0.2/day based on 2001 EPA study."	February 20, 2008	19	0
Water Quality Modeling - Random Sampling of Wastewater Treatment	...the random sampling performed on wastewater treatment facilities is acceptable to the Stakeholders Group and no additional monitoring will be performed."	February 20, 2008	16	0

Resolution Subject	**"BE IT RESOLVED by the Lake Granbury Watershed Protection Plan Stakeholders Group that...**	**Adopted/Not Adopted Date**	**Votes "For"**	**Votes "Against"**
Facilities				
Stakeholder Membership Issues - Economic Development Corporation	...the Granbury/Hood County Economic Development Corporation be removed as a representative for the Business/Industry Group category."	August 7, 2008	21	0
Land Use Study - Final	...the land use analysis as presented and discussed on August 7, 2008 are acceptable to the Stakeholder's Group. BE IT FURTHER RESOLVED that no additional land use analyses will be performed , and BE IT FURTHER RESOLVED that the draft Source Identification Chapter will be revised to reflect changes in land use from 2003 values to 2007 values."	August 7, 2008	21	0
Source Prioritization	...the area source priorities selected and discussed on January 22, 2009 be used for BMP investigation and analysis."	January 22, 2009	20	0
Source Prioritization	...the average age per on-site sewage facility (OSSF) used for developing Life Cycle Costs be 20 years."	August 18, 2009	17	0
Number of Lots	...the number of lots per subdivision used for developing the Annual Cost Index be calculated at: ____ lots for Oak Trail Shores, 629 lots for Sky Harbor, 236 lots for Indian Harbor, and ____ lots for Arrowhead Shores."	September 3, 2009	17	0
Matrix Ranking or Sorting	...the method for evaluating management measures be sorting measures by order of importance of selection criteria, with the order of sorting being bacteria, cost index then time to implement."	September 3, 2009	16	0
Eliminated Management Measures	...Bacteria Management Measures the group no longer want to pursue as options for inclusion in the Lake Granbury Watershed Protection Plan are, by area: Rolling Hills Shores - Septic system replacement along the cove; Oak trail Shores - Cove dynamics-fill, Cove dynamics-partial fill; Nassau Bay II - Local centralized wastewater treatment (independent), Local centralized wastewater treatment (aggregate); Port Ridglea East - Local centralized wastewater treatment (independent), Local centralized wastewater treatment	September 3, 2009	16	0

Resolution Subject	**"BE IT RESOLVED by the Lake Granbury Watershed Protection Plan Stakeholders Group that...**	**Adopted/Not Adopted Date**	**Votes "For"**	**Votes "Against"**
	(aggregate); Indian Harbor - Local centralized wastewater treatment (independent)."			
Stakeholder Goals	...the water quality goal for *E. coli* concentrations in the canals of Lake Granbury be to reduce and/or maintain *E. coli* geometric mean concentrations in the canals at or below 53 MPN/mL. BE IT FURTHER RESOLVED that the goal of reducing and/or maintaining bacteria percent exceedence of 394 MPN/mL in the canals below 5% be eliminated from the goals of the Lake Granbury WPP."	November 17, 2009	14	0
Final Draft WPP	…the Final Draft of the Lake Granbury Watershed Protection Plan as presented and discussed on July 7, 2010 is acceptable to the Stakeholders Group, BE IT FURTHER RESOLVED that Final Report, in long format, will be submitted to the Texas Commission on Environmental Quality and United States Environmental Protection Agency by July 31, 2010.	July 7, 2010	17	1

4.0 BACTERIA SOURCE IDENTIFICATION

4.1 LINKING WATERSHED TO WATER QUALITY

Since watersheds can encompass a large land mass, the activities of humans such as agriculture, industry and property development have an effect on the amount of pollutants and sediments that are delivered into waterbodies. Natural processes also play a role in impacting water quality through evaporation, precipitation, infiltration and the decomposition of organic matter. While knowledge of the function and potential of these processes is helpful to accessing current conditions, the purpose of watershed planning is to identify and mitigate the sources of pollutants produced by human activities. By evaluating the impact of pollutants on these natural processes, watershed planners can simulate the potential impact of bacteria within the watershed. Because a watershed represents a basin that drains into a common water body, investigation of climate, land use, human activity, and soil types of the entire watershed area factor in to the equation of water quality.

Watersheds are determined by the landscape and not political boundaries, watersheds often cross municipal and county boundaries. By using a watershed perspective, all potential sources of pollutants entering a waterway can be identified and evaluated and stakeholders in the watershed can be involved in the process.

4.2 AMBIENT WATER QUALITY MONITORING

The Texas Commission on Environmental Quality (TCEQ) evaluates the condition of the state's water bodies on a periodic basis under the Clean Water Act (CWA) Section 305(b). The results are contained within the Texas Water Quality Inventory and 303(d) List and are comprised of a complete listing of all water quality concerns in the state. The Texas Water Quality Inventory, 305(b) report, provides an overview of surface water quality throughout the state, including issues relating to public health, fitness for use by aquatic species and other wildlife, and specific pollutants and their possible sources. Waterbodies that do not meet established water quality standards are placed on the 303(d) List and are referred to as "impaired."

These water quality impairments are identified by comparing concentrations in the water to numerical criteria that represent the state's water quality standards or screening levels to determine if the waterbody supports its designated uses, such as suitability for aquatic life, for contact recreation, or for public water supply. This process determines if fish and aquatic insects have adequate oxygen, if people swimming in the water are exposed to pathogens that may cause illness and if the water is fit to be used as a source for public drinking water.

Water quality standards numerical criteria are used by TCEQ as the maximum or minimum instream concentrations that may result from permitted discharges and/or nonpoint sources and still meet designated uses. To resolve the issues of regional and geological diversity of the state, standards are developed for classified segments. Classified segments are defined segments of waterways that are unique from other segments. Lake Granbury is Segment 1205, while the Brazos River above Lake Granbury (below Possum Kingdom Lake) is Segment 1206. Appropriate water uses such as contact recreation, public water supply, and aquatic life are then applied to the segments. Specific water quality criteria have been developed for water temperature, dissolved oxygen, pH, bacteria, chloride, sulfate and total dissolved solids for classified segments. Many streams that are not classified segments, such as Robinson Creek, Rucker Creek, Walnut Creek, etc., are assessed throughout the state and are considered unclassified segments. These unclassified segments do not have specific water quality standards developed for them. For assessment purposes, unclassified streams are assessed using the numeric criteria developed for the classified segment into which the stream flows.

In response to local concerns, the BRA began a large-scale monitoring initiative in the canals of Lake Granbury to assess the water quality of the coves. Beginning in May 2002, the Authority began collecting water quality samples on a monthly basis at more than 50 cove locations. Some of the locations showed no elevated concentrations of *E. coli* and were later discontinued. Some locations were added after a year of monitoring as new information was acquired on possible source locations. The data generated from this effort indicates that many of the canals on Lake Granbury are impacted by *E. coli* issues and indicates a concern for public health and contact recreation. The data also indicates that the water quality in the coves is more influenced by the surrounding land use rather than the main body of the lake.

The BRA's Lake Granbury canal monitoring program was the basis for the Ambient Water Quality Monitoring Plan adopted by the LGWPPSC. The LGWPPSC elected to add most of the BRA's canal monitoring locations for the Ambient Water Quality Monitoring Plan plus requested additional canal sites in the areas of Port Ridglea West, Mallard Point, Lambert Branch, Indian Harbor, Canyon Creek and Rough Creek (Figure 4). Additionally, the LGWPPSC requested monitoring on the major tributaries to Lake Granbury including: the Brazos River above Lake Granbury, Robinson Creek, Strouds Creek, Long Creek, Rucker Creek and Walnut Creek.

The sample collection and analysis under the Ambient Water Quality Monitoring Plan was implemented by the BRA's Field Operations Crew and Environmental Services Laboratory on September 1, 2006. A total of 47 sites are sampled monthly for water temperature, dissolved oxygen, pH, conductivity, salinity, chloride, sulfate, nitrate-nitrogen, orthophosphate phosphorus and *E. coli*.

Ambient water quality monitoring data in the canals reveals that the canal areas exhibit little or no circulation and mix slowly with the main body of the reservoir. This data collection effort has identified bacteria impairments in many of these canals and concerns for dissolved oxygen and elevated nutrient levels in a few of the canals. This seems to be a result of the stagnant conditions in the canals and lack of mixing with the main body of the lake. These concerns are not observed in the main body of Lake Granbury.

E. coli data from the ambient water quality monitoring program has been evaluated for compliance with both the State Water Quality Standard of 126 MPN/100mL and against the LGWPPSC's Goal of 53 MPN/100ml (Figure 5).

While all of the canal sites are in compliance with the State Water Quality Standard at this time, several are not in compliance with the LGWPPSC's Goal. Canals in Oak Trail Shores, Sky Harbor, Port Ridglea East, Indian Harbor and Blue Water Shores consistently fail to meet the goal standard determined by the LGWPPSC.

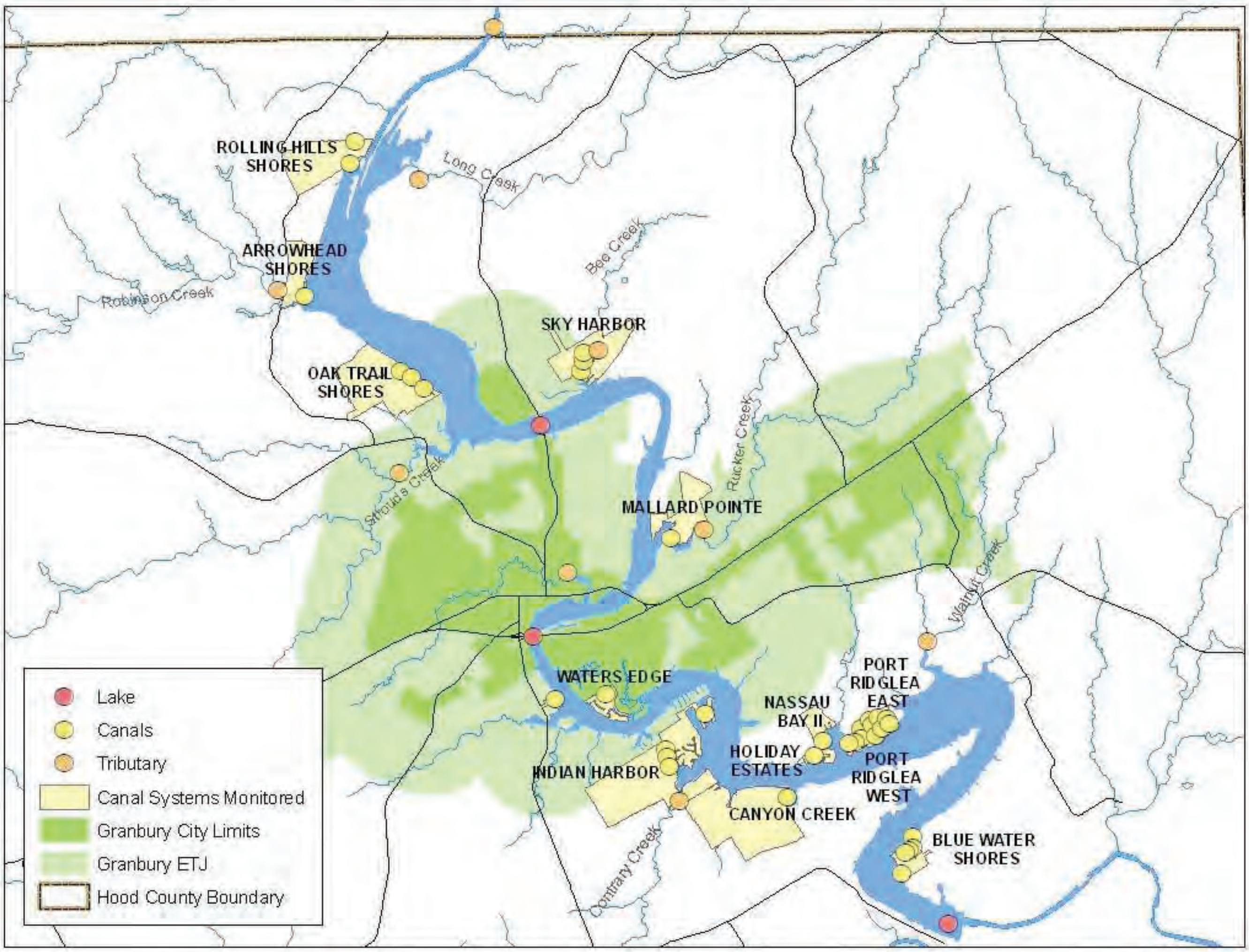


Figure 4. Ambient Water Quality Monitoring Plan Monitoring Sites and Canal Systems Assessed

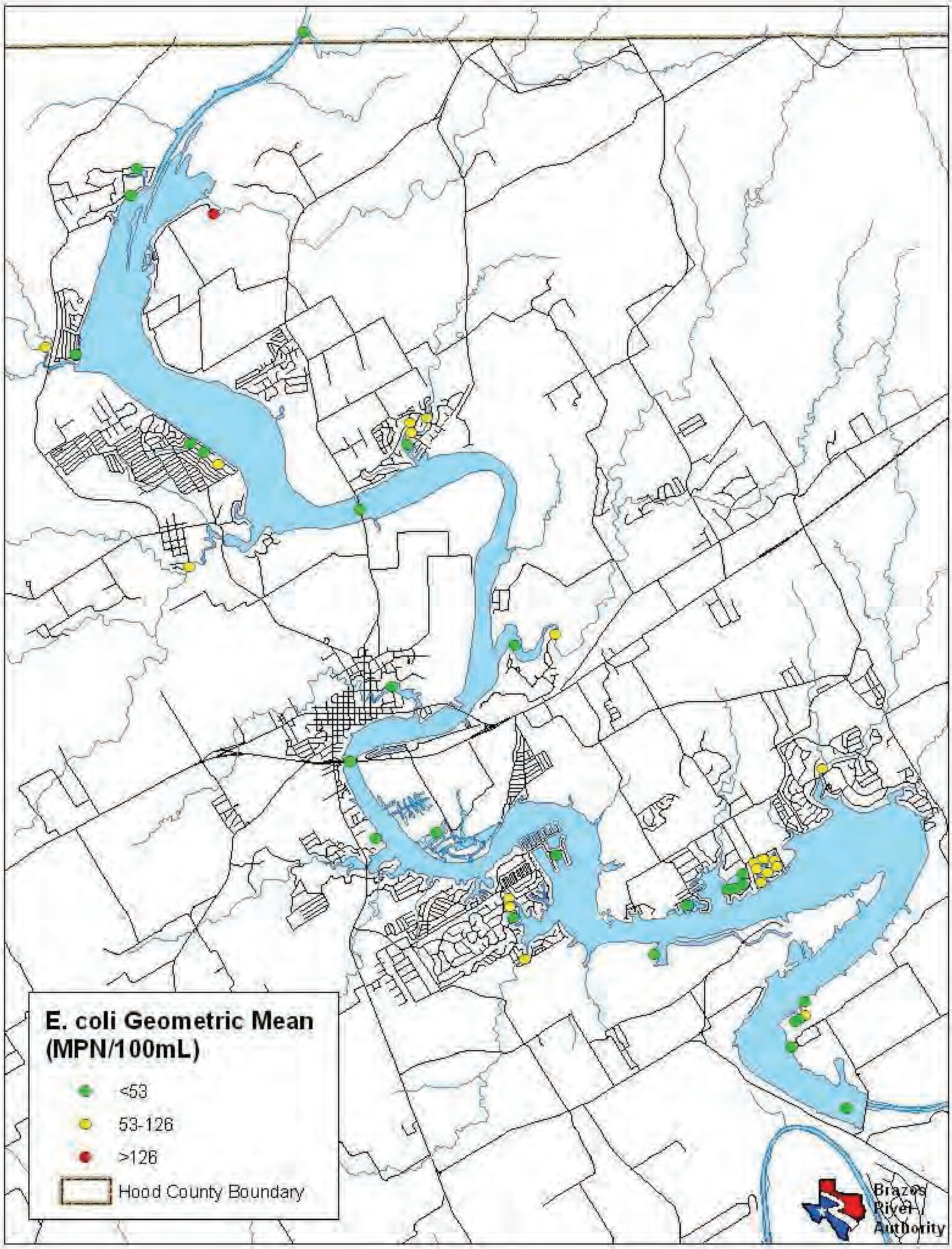


Figure 5. Lake Granbury *E. coli* Assessment Results through September 2009

4.3 LAND USE ASSESSMENT

Several items were evaluated for the land use analysis. A two-mile radius around Lake Granbury that includes portions of both Hood and Parker counties was selected by the Stakeholders for land use analysis (Figure 6). Basic land use analysis was conducted using one-foot aerial photography provided by the North Texas Council of Governments. The aerial photographs utilized for land use analysis were produced in 2007. When land use could not definitively be determined using aerial photography those parcels of land were identified by ground-truthing conducted by both Brazos River Authority Staff and the Stakeholder Group representative from the Granbury Association of Realtors. This land use assessment was also used as basis for additional, supplemental land use evaluation conducted as part of the SELECT watershed modeling bacteria source evaluation (see Section 4.7).

Land use using the aerial photographs was evaluated using the following categories:

- Multi-Family Residential;
- Single-Family Residential;
- Commercial/Services;
- Industrial;
- Utilities/Transportation;
- Recreational;
- Cropland and Pasture;
- Orchards;
- Other Agricultural;
- Rangeland; and
- Quarries and Gravel Pits.

Residential land uses range from Multi-Family Residential, which are represented by high-density, multiple-unit structures of urban cores, such as apartment buildings and condominiums. Single-Family Residential are represented by low-density housing, with no more than one residential structure per lot; however, in some developments lot sizes of single-family residences are small leading to a higher density of homes than would traditionally be observed in this category. Areas of sparse residential land use, such as farmsteads, were included in categories to which they are related.

Commercial/Services areas are those used predominantly for the sale of products and services. Components of the Commercial/Services category are urban central business districts, shopping centers, commercial strip developments, and resorts. The main buildings, secondary structures and areas supporting the basic use included office buildings, warehouses, driveways, sheds, parking lots, landscaped areas and waste disposal areas. Commercial/Services areas may include some noncommercial uses too small to be separated out such as churches and schools.

Industrial areas include a wide array of land uses from light manufacturing to heavy manufacturing plants to junkyards and salvage facilities. Identification of light industries, those focused on design, assembly, finishing, processing and packaging of products, were often determined based on the type of building, parking and shipping arrangements.

The land uses included in the Utilities/Transportation category include major highways and railways. The highways include rights-of-way, areas used for interchanges and service and terminal facilities. Rail facilities include stations, parking lots, roundhouses, repair and switching yards and related areas, as well as overland track and spur connections of sufficient width for delineation.

Airport facilities including the runways, intervening land, terminals, service buildings, navigation aids, fuel storage, parking lots and a limited buffer zone are also included in the Utilities/Transportation category. Communications and utilities areas such as those involved in processing, treatment and transportation of water, gas, oil and electricity and areas used for airwave communications are also included in this category.

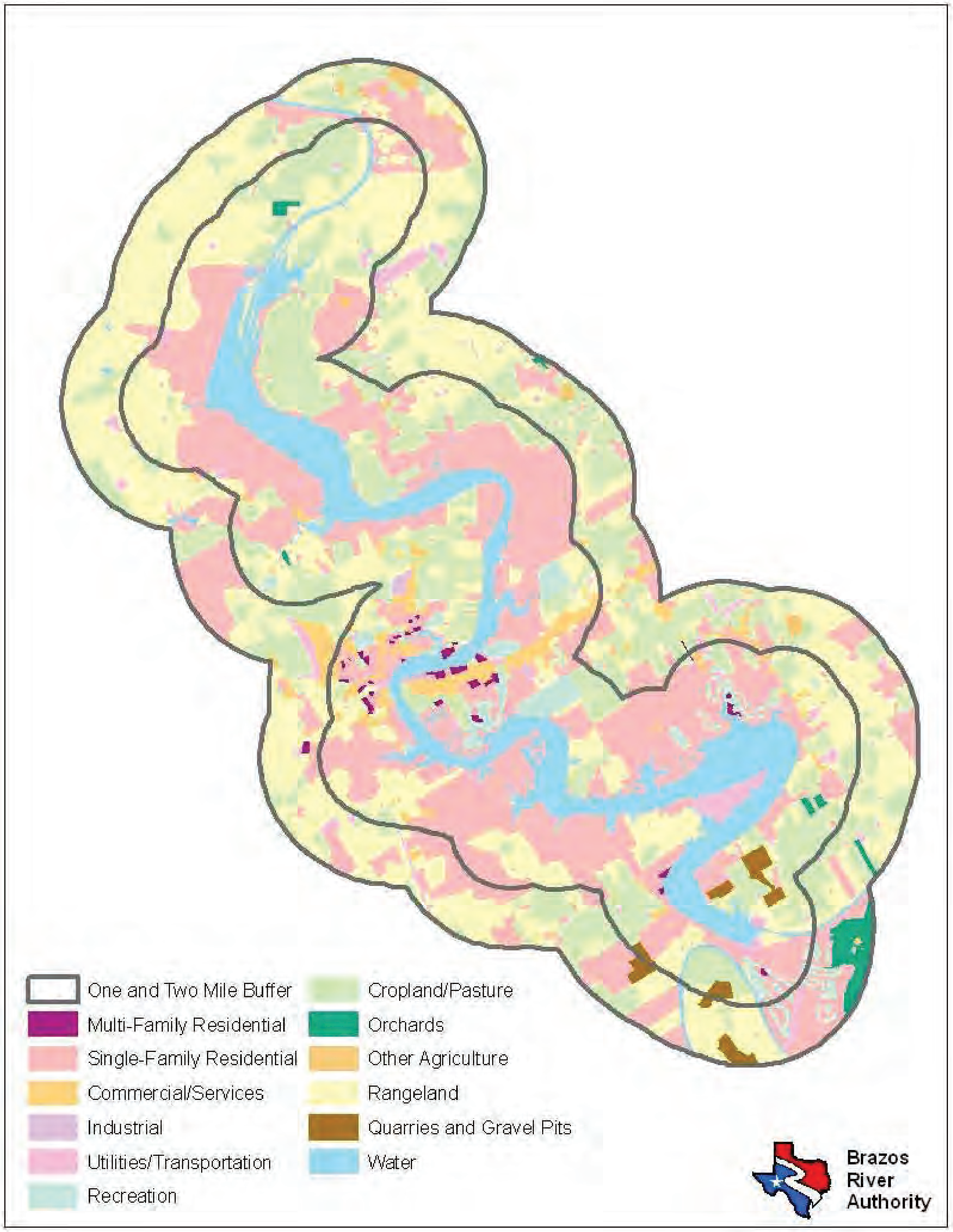


Figure 6. Land Use Within Two Miles of Lake Granbury 2007

The Recreational category typically consists of uses such as golf courses, driving ranges, zoos, urban parks, cemeteries and undeveloped land within an urban setting.

The several components of the Cropland and Pasture category include harvested cropland, cultivated summer fallow and idle cropland, land on which crop failure occurs, cropland used only for pasture in rotation with crops and pasture on land more or less permanently used for that purpose. From imagery alone, it generally is not possible to make a distinction between cropland and pasture; therefore, these uses were grouped into a single category for analysis purposes.

The Orchards category includes orchards, groves and vineyards that produce the various fruit and nut crops. Also, tree nurseries, which provide seedlings for plantation forestry, are included here.

The Other Agricultural category for the two-mile radius around Lake Granbury primarily includes holding areas for livestock such as corrals and breeding and training facilities on horse farms.

The Rangeland category was applied where the natural vegetation is predominantly grasses, grasslike plants, forbs or shrubs and where natural herbivory is an important influence. For this study, rangeland was not further subdivided into herbaceous range, shrub and brush rangeland and mixed rangeland.

Quarry and Gravel Pits were applied to extractive mining activities where vegetative cover and overburden are removed to expose such deposits as sand, gravel, limestone and sandstone. Current mining activity is not always distinguishable. Inactive, unreclaimed and active strip mines, quarries, borrow pits and gravel pits are included in this category.

The land use within a two-mile radius of Lake Granbury is almost equally divided between rangeland, crop and pasture land and single-family residences (Figure 7). Within a one-mile radius of Lake Granbury the dominant land use changes to single-family residences (Figure 8).

An analysis of the suitability of soils for use for septic absorption fields in the two-mile radius around Lake Granbury was also undertaken. The data for this analysis were provided by the United States Department of Agriculture's Natural Resource Conservation Service (USDA-NRC) Soil Survey Geographic Database (SSURGO). The SSURGO database ranks soil suitability by three categories:

1. Slight – soils are generally favorable for use for septic absorption fields;
2. Moderate – soil properties are unfavorable for use for septic absorption fields but limitations can be overcome by special planning and design; and
3. Severe – soil properties are so unfavorable for use for septic absorption fields and difficult to overcome that major soil reclamation, special designs, and intensive maintenance are required.

69 percent of the soils within in a two-mile radius of Lake Granbury are rated severe, 13 percent are rated moderate and 18 percent are rated slight (Figure 9).

Microwatershed determinations, made using United States Geological Survey (USGS) digital elevation models and hypsography data, revealed that while there are a few cove areas with natural drainages where water quality may be impacted by watershed activities, most of the canal areas have small, isolated microwatersheds and are primarily impacted by activities in the immediate proximity to the cove. Land use analyses results for each individual microwatersheds surrounding the lake are included in Appendix B. Only a small group of microwatersheds were evaluated in this WPP focusing the modeling efforts on the areas of greatest concern/priority based on water quality monitoring data. The stakeholders felt the focus areas were good representative cases for the remainder of the lake.

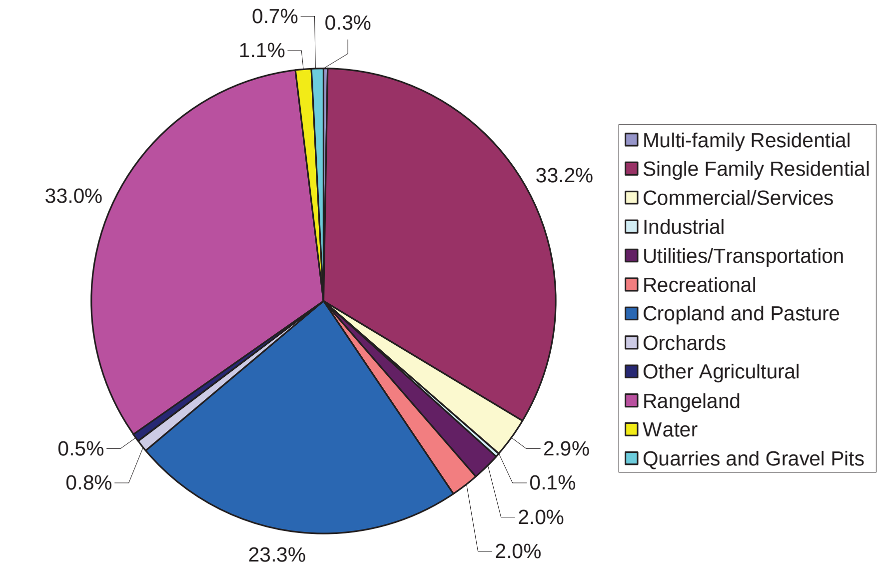


Figure 7. Land Use Between One and Two Mile Radius of Lake Granbury

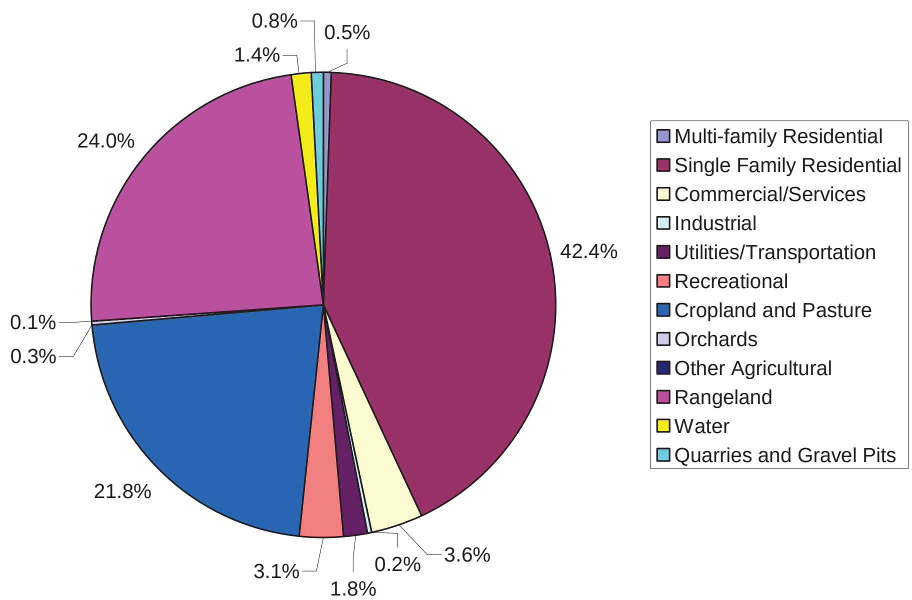


Figure 8. Land Use Between One Mile Radius and Lake Granbury

Subdivision development data and sewage disposal methodologies were determined using several sources including map data from the Hood County Appraisal District (HoodCAD), plating data filed at the Hood County courthouse, a survey of local utilities, input from the Hood County Health District (HCHD) and input from the Granbury Association of Realtors Stakeholder Group representative.

Age of development for subdivisions was also analyzed and it was determined that 74 percent of the subdivisions within two miles of Lake Granbury were developed prior to 1989 (Figure 10) when the Texas Legislature enacted the State's On-site Sewage Disposal System Rules (Texas Health & Safety Code §§ 366.001-.0923). Before the adoption of Texas Health & Safety Code §§ 366.001-.0923, there were no significant regulations regarding system configuration and siting; septic system owners merely had to register their system. Further analysis also determined that 86 percent of the subdivisions within a two-mile radius of Lake Granbury rely on septic systems for waste disposal (Figure 11).

Animal populations were examined, at the county level, using data provided by the Lake Granbury Chamber of Commerce, the American Veterinary Medical Association and the USDA's Agricultural Census. Humans account for 51 percent of the total mammal/avian population in Hood County (Table 7). Cattle are the second most dominant group with 32 percent of the total mammal/avian population. The USDA's Agricultural Census data indicate that after a peak in 1997, the total livestock population in Hood County is declining (Figure 12).

Table 7. Hood County Population Counts

Category	Population	Percent of Total Population
Humans	47,627	51%
Dogs	3,489	4%
Cats	3,491	4%
Cattle	30,059	32%
Horses	1,889	2%
Swine	123	<1%
Goats	4,000	4%
Sheep/Lambs	606	<1%
Chickens	1,386	1%
Domestic Ducks/Geese	119	<1%
Domestic Turkeys	138	<1%
Emus	28	<1%

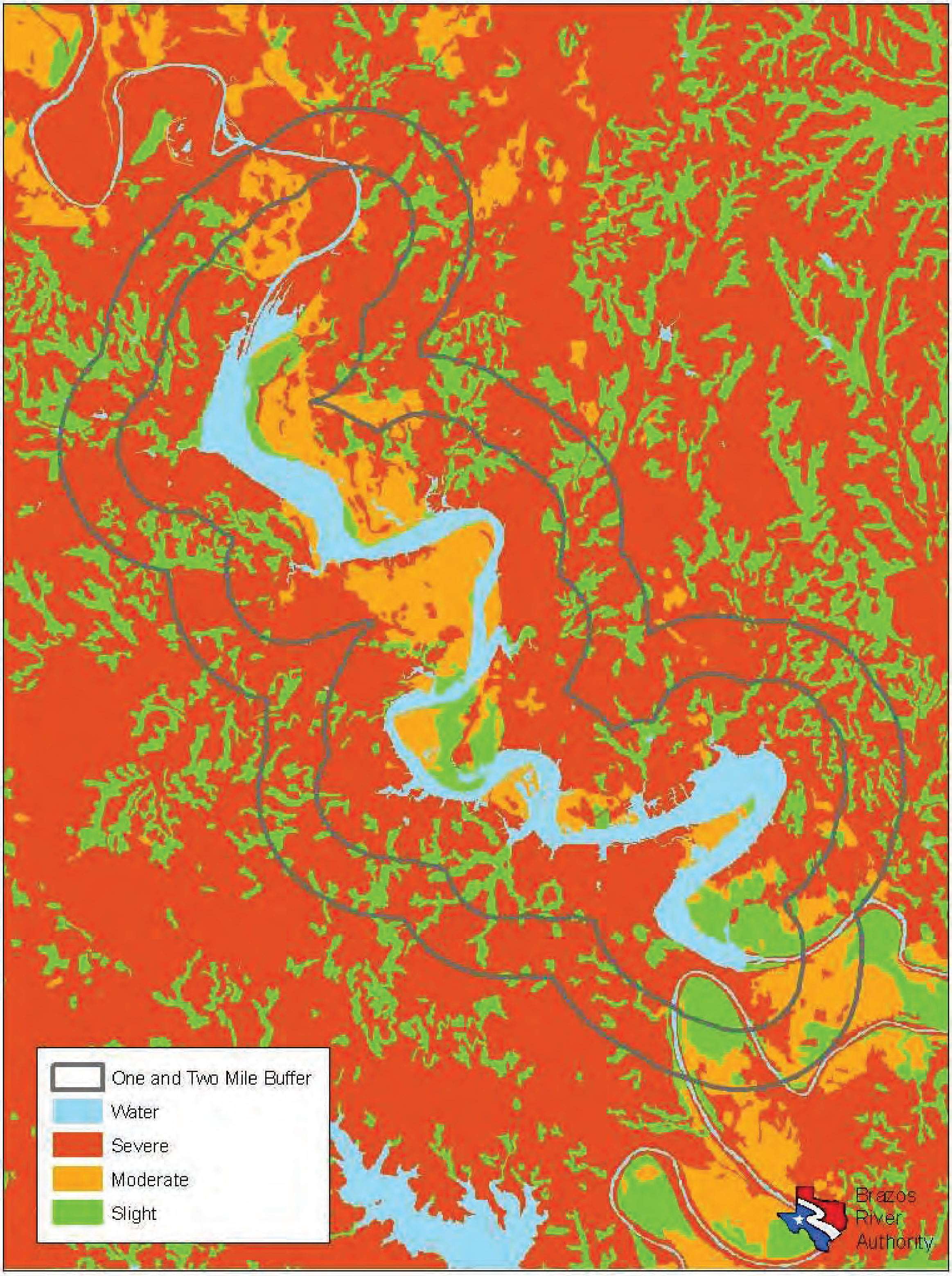


Figure 9. SSURGO Soil Suitability Rating for Septic Absorption Fields.

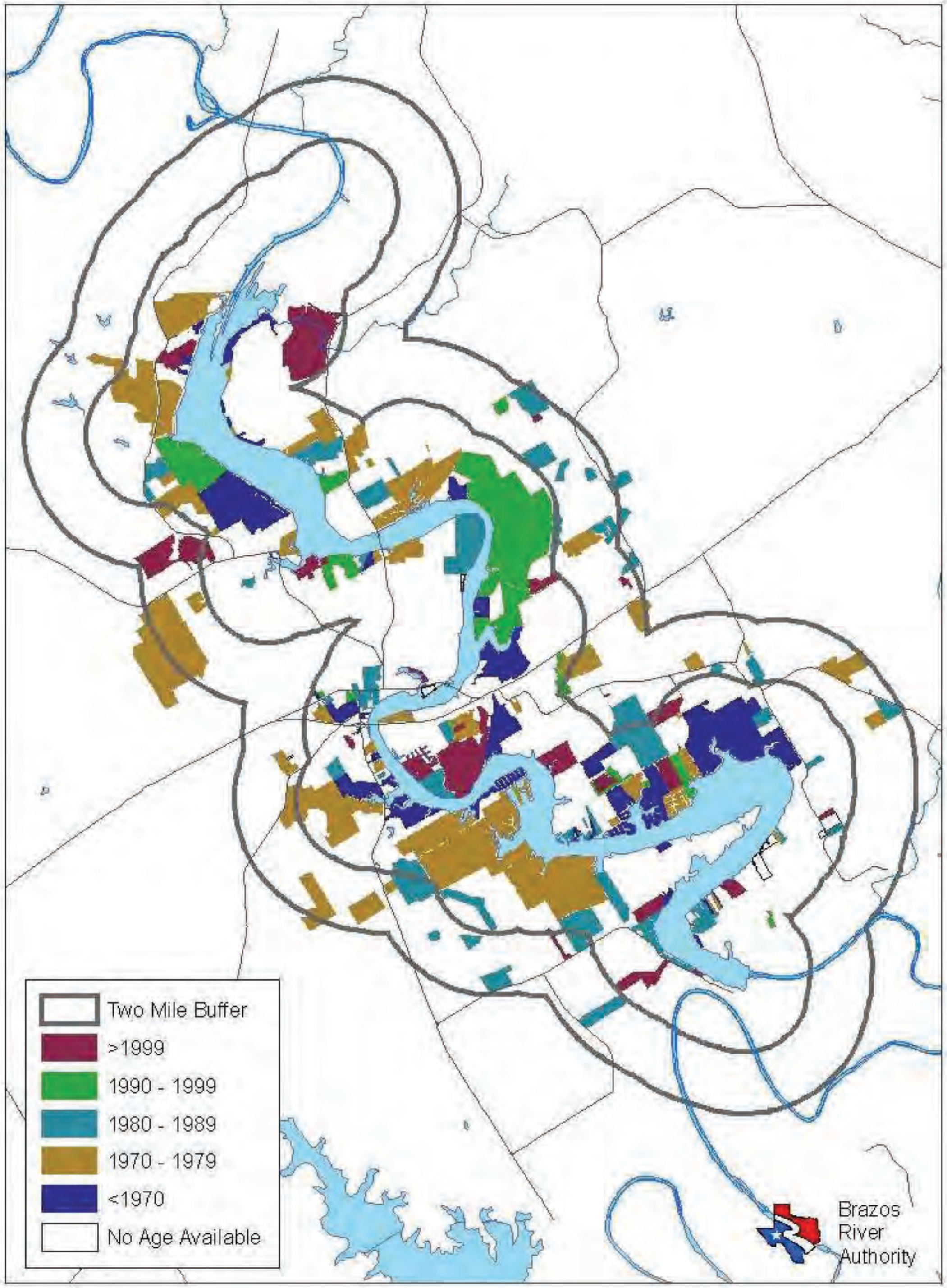


Figure 10. Age of Subdivisions within Two Miles of Lake Granbury.

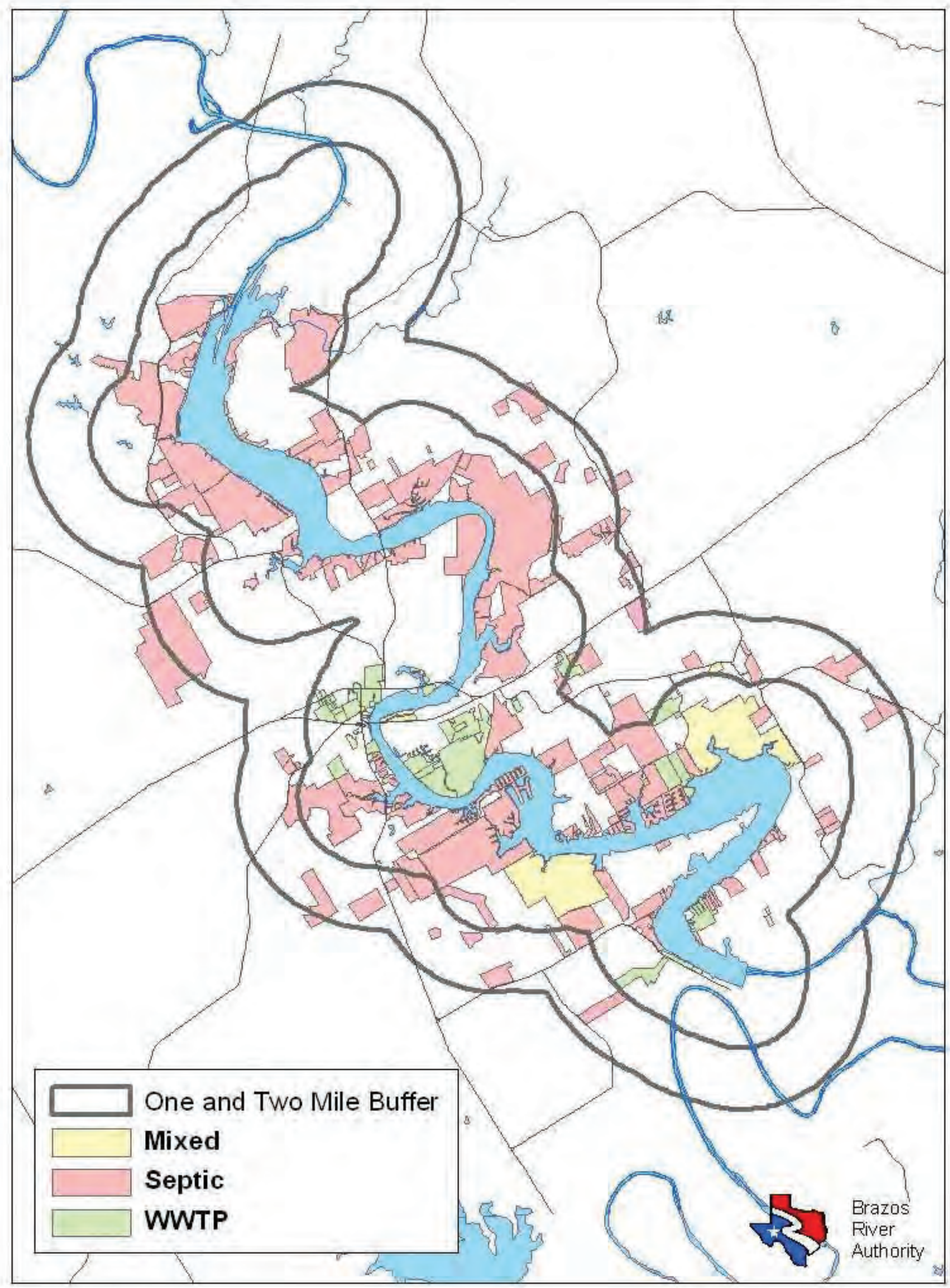


Figure 11. Sewage Disposal Methods within Two Miles of Lake Granbury.

Figure 12. Total Head of Livestock in Hood County (NASS)

4.3.1 Land use assessment summary

Land use analysis seems to indicate that a chief source of bacterial contamination may be from human and pet sources. Thirty-three percent of the land use within two miles of Lake Granbury is single-family residential homes with most of those homes disposing of wastes via septic systems. Within one mile of the lake, land use by single-family residential properties increases to 42 percent. With nearly three-quarters of the residential properties developed prior to the development of the current stringent OSSF regulations and most of those early systems not meeting current standards, it seems to indicate that human sources may be impacting canals, especially in areas with little to no influence from the surrounding watershed. Additionally, the livestock population in Hood County is stabilizing, while the human population and urban/suburban land use are on the rise. With a rise in human population comes an increase in the pet population. Improper pet waste management may also be impacting the canals.

All areas demonstrating water quality concerns are dominated by single-family residential land use, OSSF for waste management and soils that are not desirable for OSSF applications without significant manipulation. This further supports the implication that sources found on residential properties may be significantly impacting the canals of concern.

While the land use analysis points toward human and pet sources; additional source identification activities have been undertaken to confirm these findings. Both water quality modeling and bacterial source tracking results, along with these land use results, were evaluated to make the final source determination. Supplemental watershed and land use characterization is presented in subsequent sections relating to watershed modeling source identification.

4.4 PRELIMINARY ASSESSMENT OF FECAL POLLUTION SOURCES IMPACTING LAKE GRANBURY AS DETERMINED BY BACTERIAL SOURCE TRACKING

On March 26, 2006, a presentation by the Texas Farm Bureau staff regarding the use of bacterial source tracking (BST) technology in Lake Waco and Lake Belton, Texas was presented to the Stakeholders. Following the presentation, Stakeholders expressed interest in the developing technology and requested that a BST assessment be developed for Lake Granbury. The Authority worked with Dr. George DiGiovanni of Texas AgriLife Research at El Paso, who performed the work on Lake Waco and Lake Belton, to develop a draft 10-site sampling approach. The stakeholders selected the 10 sites and indicated that 5 of these sites were preferred. This 10-site sampling approach was presented to the stakeholders on February 13, 2007. Stakeholders approved the plan and directed the Authority to pursue a contract with Texas AgriLife Research. Unfortunately, due to budget constraints, all 10 sites were not financially feasible and the BST study was finalized using the stakeholders 5 most preferred sites.

The five sites on Lake Granbury selected for bacterial source tracking (BST) included Lake Granbury at Highway 377 (11861); Sky Harbor (18015); Waters Edge (18018); Indian Harbor (20215); and Port Ridglea East (18038). BST involved monthly targeted grab sampling from the sampling sites for a period of six months. BRA collected 100 ml water grab samples from the selected sites for both *E. coli* detection using USEPA Method 1603 with modified mTEC medium (USEPA 2005) and *Bacteroidales* analysis. Method 1603 modified mTEC plates with *E. coli* colonies were sent to AgriLife Research for isolation and analysis of *E. coli*. Water samples for *Bacteroidales* analysis were filtered, placed in lysis buffer and frozen, then sent on dry ice to AgriLife Research for analysis.

Additionally, fifty-nine known source samples from wildlife, domestic septage/sewage, pets, and livestock from the Lake Granbury area were collected and shipped to AgriLife Research. These samples were used to evaluate the distribution of *Bacteroidales* host-specific markers in the Lake Granbury watershed. In addition, *E. coli* isolated from the samples were included in the *E. coli* identification library.

Assessment and identification of fecal pollution sources using *E. coli* utilized the BST library developed by the El Paso AgriLife Research Environmental Microbiology Laboratory (Texas *E. coli* source library) which contains over 2,000 *E. coli* isolates from over 1,500 different domestic sewage and animal fecal samples. The library contains diverse *E. coli* isolates which were selected after screening over 4,500 isolates by genetic fingerprinting to exclude identical isolates from the same sample and include isolates with unique genetic fingerprints. In addition, the library-independent *Bacteroidales* PCR method was used to assess fecal pollution sources.

The BST methods used included DNA fingerprinting of *E. coli* bacteria isolated from water samples using ERIC-PCR and RiboPrinting, and the PCR detection of *Bacteroidales* fecal bacteria present in water samples.

4.4.1 ERIC-PCR and RiboPrinting of *E. coli*

In the BST project for Lake Waco and Belton Lake, *E. coli* isolates were analyzed using four BST techniques: RiboPrinting (RP), ERIC-PCR, pulsed field gel electrophoresis (PFGE) and Kirby-Bauer antibiotic resistance analysis (KB-ARA) (Casarez, Pillai et al. 2007). BST analyses were performed using the individual techniques, as well as composite data sets. The four-method composite library generated the most desirable BST results in regards to accuracy and ability to identify water isolates. However, as few as two methods in combination were found to be useful based on congruence measurements, library internal accuracy (i.e. rates of correct classification, RCCs), and comparison of water isolate identifications. In particular, the combinations of ERIC-PCR and RiboPrinting (ERIC-RP), or ERIC-PCR and Kirby-Bauer antibiotic resistance analysis (ERIC-ARA) appeared promising. These two-method composite data sets were found to have 90.7% and 87.2% congruence, respectively, to the four-method composite data set. More importantly, based on the identification of water isolates, they identified the same leading sources of fecal pollution as the four-method composite library. The combination of ERIC-PCR and ERIC-RP was recommended by Dr. DiGiovanni and selected by the stakeholders for analysis of water samples for this study.

E. coli isolates from water samples and source samples were DNA fingerprinted using a repetitive sequence polymerase chain reaction (rep-PCR) method known as enterobacterial repetitive intergenic consensus sequence PCR (ERIC-PCR) (Versalovic, Schneider et al. 1994). For source samples, ERIC-PCR was used to identify unique *E. coli* isolates from each sample to maximize the diversity of isolates added to the local library and eliminate further analysis of identical isolates (clones). At least one *E. coli* isolate from each fecal, wastewater, etc. sample will be included in the local library, even if it is identical to a previously isolated *E. coli*.

Following ERIC-PCR analysis, *E. coli* water isolates and selected source isolates were RiboPrinted using the automated DuPont Qualicon RiboPrinter and the restriction enzyme Hind III (“RiboPrinting”). All bacterial isolate sample processing is automated using standardized reagents and a robotic workstation, providing a high level of reproducibility.

Analysis of composite ERIC-RP DNA fingerprints was performed using Applied Maths BioNumerics software. Genetic fingerprints of *E. coli* from ambient water samples were compared to fingerprints of known source *E. coli* isolates in the Texas library and the likely host of origin (e.g. cattle, wildlife, human) identified. To identify the potential sources of the unknown water isolates, their ERIC-RP composite patterns were compared to the library using a best match approach and an 80% similarity cutoff. If a water isolate was not at least 80% similar to a library isolate, it was considered unidentified. Although fingerprint profiles are considered a match to a single entry, identification is to the host source class, and not to the individual animal represented by the best match. Host sources were divided into five groups, 1) domestic sewage (human); 2) pet; 3) livestock (including cattle and other non-avian livestock); 4) avian (includes wild and domestic) and; 5) wildlife (non-avian, and including deer and feral hog).

4.4.2 *Bacteroidales* PCR and quantitative PCR (qPCR)

Library-independent source tracking methods have been developed as alternatives to the library-dependent methods, and may prove to be a more rapid and cost-effective approach for assessment of fecal pollution in source water. The *Bacteroidales* PCR method is a culture-independent molecular method which targets genetic markers of *Bacteroides* and *Prevotella* spp. fecal bacteria that are specific to humans, ruminants (including cattle and deer) and pigs (including feral hogs) (Bernhard and Field 2000; Dick, Bernhard et al. 2005). There is also a general *Bacteroidales* marker (GenBac) that can be used as a general indicator of fecal pollution. The method has high specificity and moderate sensitivity (Field, Chern et al. 2003). For this method, 100 ml water grab samples were concentrated by filtration, DNA extracted from the concentrate and purified, and aliquots of the purified DNA analyzed by PCR. Results are expressed as either the qualitative presence/absence of the host-specific genetic markers, or semi-quantitative marker abundance as determined by quantitative PCR.

In theory, the GenBac marker detects the majority of the *Bacteroidales* in the samples, including those detected with the host-specific markers. GenBac standard curves were developed using 10^0, 10^{-1}, 10^{-2}, and 10^{-3} dilutions of each water sample DNA (36 standard curves). Since the actual copy number of GenBac target sequences in each sample was unknown, arbitrary values of 10,000; 1,000; 100 and 10 were assigned to the dilutions, respectively. All GenBac standard curves had R^2 values of $\geq$0.9. The Hog, Human and Ruminant host-specific markers were quantified using the GenBac standard curve for each water sample. This attempted to make the marker quantitation data for different water samples comparable by accounting for sample-to-sample variation in *Bacteroidales* DNA concentration and any effects of PCR inhibitors on quantitation. This approach makes it possible to compare the relative abundance of each marker between stations or at the same station over time. However, it is not appropriate to compare the abundance of one marker to another (e.g. Hog vs. Human), since that would require DNA extraction controls and marker-specific quantitation standards which were not employed in the current study.

4.4.3 Bacteria Source Tracking Results

4.4.3.1 Texas *E. coli* identification library, including Lake Granbury source isolates (local library)

A total of 80 *E. coli* isolates obtained from 59 different fecal specimens collected in the Lake Granbury area (i.e. local library) were included in the Combined Texas Restricted Cross-Validated library. The Restricted Cross-Validated library was derived from the larger Combined Texas Library (almost 2,000 isolates from over 1,500 fecal samples), and consists of 150 *E. coli* isolates selected specifically for their geographic stability (presence in more than one Texas watershed) and host specificity. Description of the identification library used for this study and evaluation of its identification accuracy is included in (Table 8). Rates of correct classification (RCC; identification accuracy) ranged from 67% to 92% for a five-way split of pollution sources, and were much higher than random based on library composition.

Table 8. *E. coli* identification library composition and source identification rates of correct classification (RCC)

Source Class	Lake Granbury Local Library		Combined Texas Restricted Cross Validated Library and Lake Granbury Local Library			
	# fecal samples	# isolates	# fecal samples	# isolates	% Random RCC	% RCC
Sewage/Septage	17	21	96	101	44	**92**
Pets	2	3	7	8	4	**67**
Livestock (includes cattle + other non-avian)	5 (1+4)	6 (1+5)	37 (24+13)	39 (25+14)	17	**81**
Avian (includes wild and domestic)	6	11	27	32	14	**70**
Wildlife (non-avian)	29	39	40	50	22	**79**
Total	59	80	207	230	100	

Although this identification library is composed of *E. coli* isolatates derived from a large number of fecal samples and isolates from other studies, it does only have a small number of isolates from the Lake Granbury area. In particular, there are only a small number of isolates from Lake Granbury pet and domestic sewage/septage sources, and this could affect accurate identification of those sources of fecal pollution.

4.4.3.2 Identification of *E. coli* isolates from water at each sampling site

Approximately 50 *E. coli* isolates from each of the five sampling sites were analyzed by ERIC-RP composite DNA fingerprinting. Identification of these isolates by site is described in Figure 13 through Figure 17 below. In contrast to previous studies able to identify almost 70% of water isolates using the restricted library, only 57% of the Lake Granbury water isolates were identifiable. Identification of additional Lake Granbury water isolates would only be possible through expansion of the library with additional *E. coli* from Granbury fecal sources.

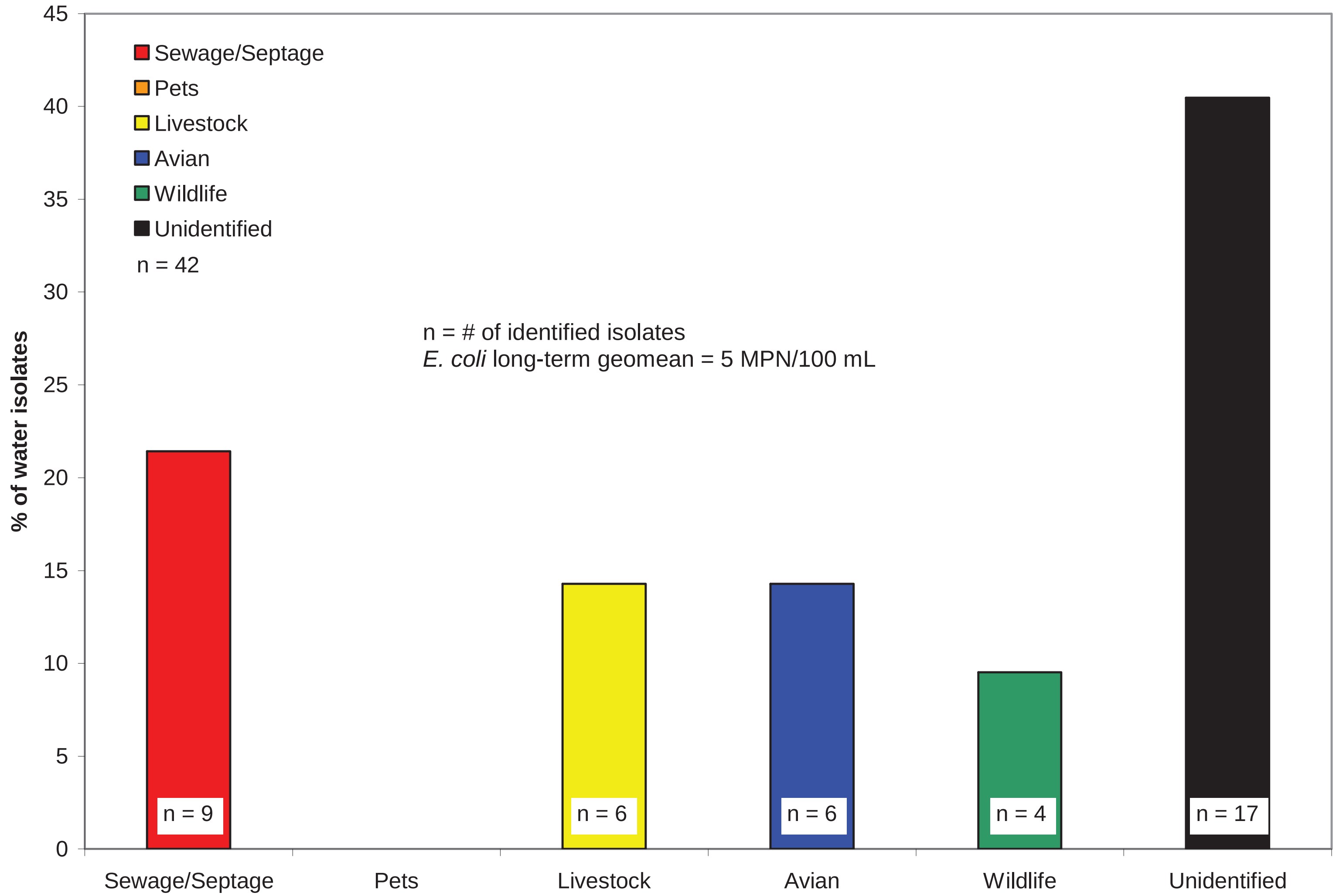


Figure 13. *E. coli* source identification for the Lake Granbury at Highway 377 (11861) site. The *E. coli* long-term geometric mean at this site is low (5 MPN/100 ml).

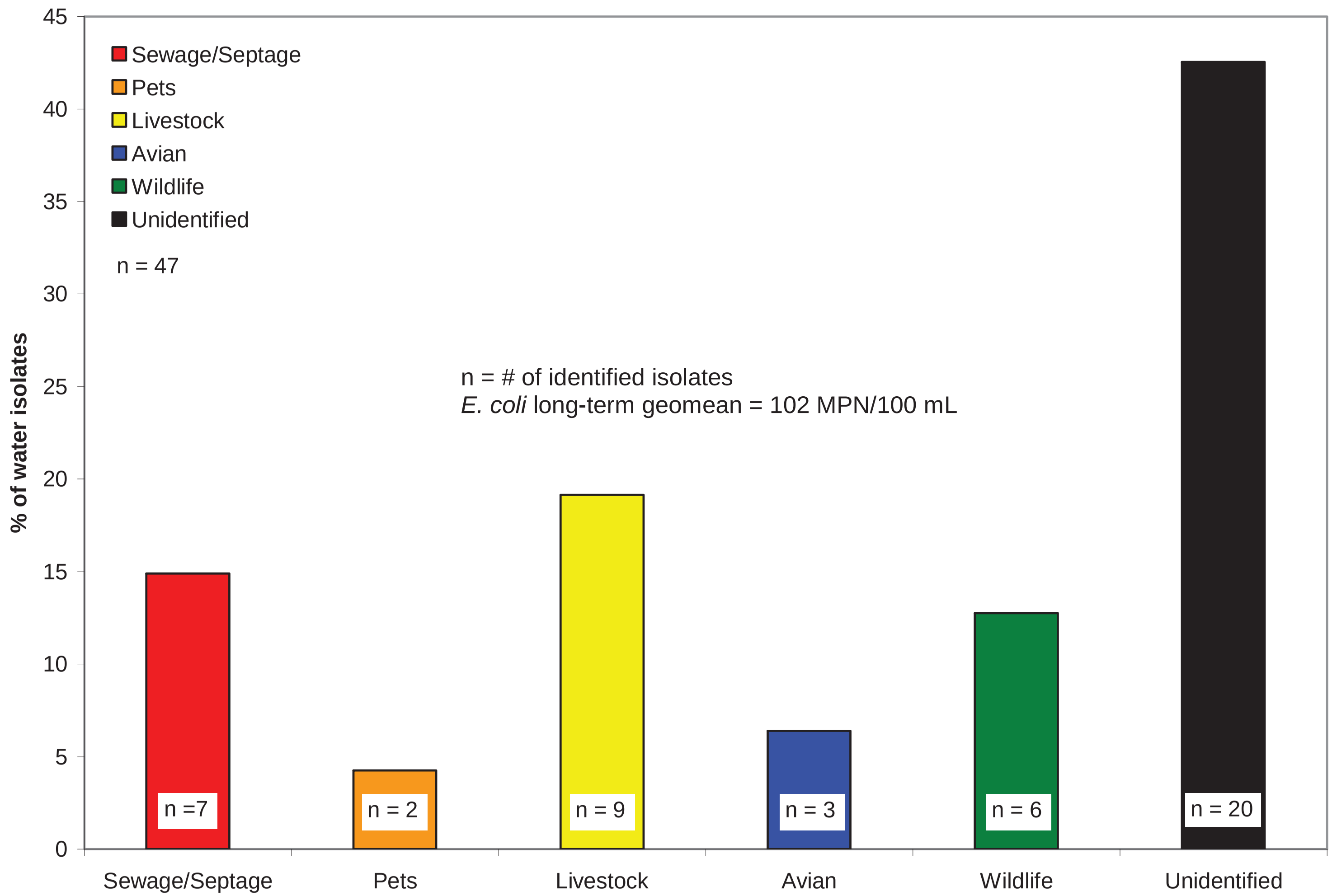


Figure 14. *E. coli* source identification for the Sky Harbor (18015) site. The *E. coli* long-term geometric mean at this site is moderately high (102 MPN/100 ml).

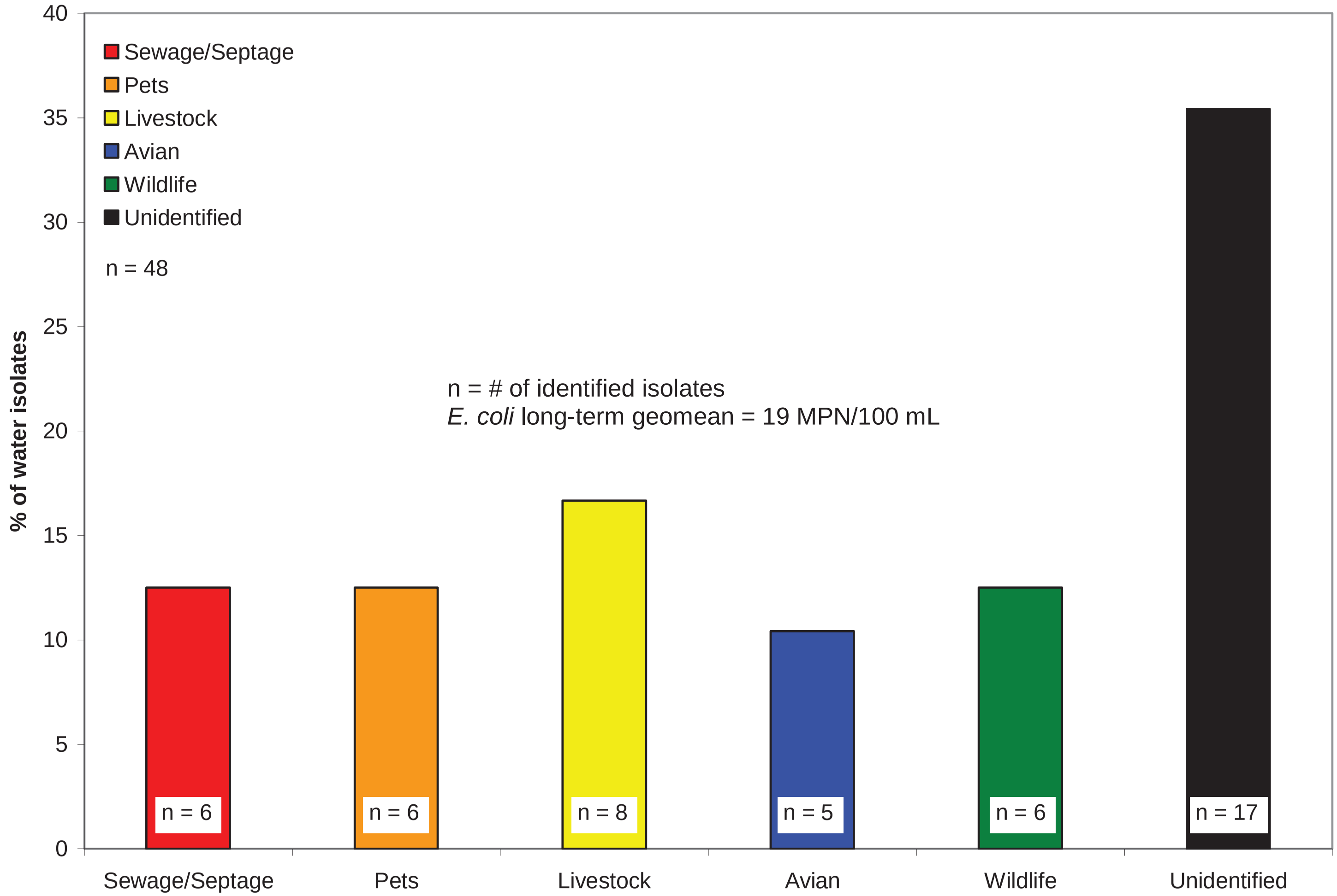


Figure 15. *E. coli* source identification for the Waters Edge (18018) site. The *E. coli* long-term geometric mean at this site is low (19 MPN/100 ml).

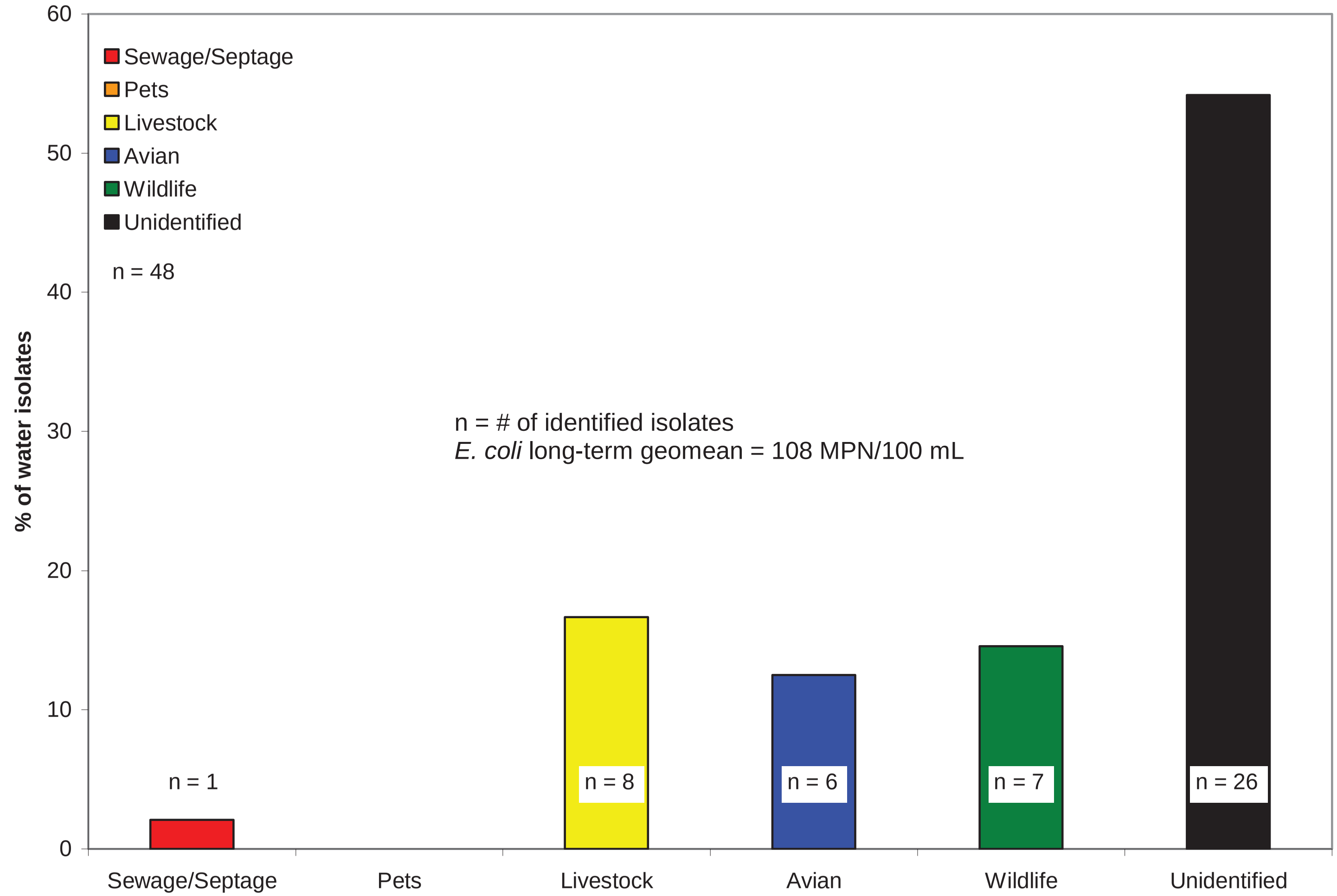


Figure 16. *E. coli* source identification for the Indian Harbor (20215) site. The *E. coli* long-term geometric mean at this site is moderately high (108 MPN/100 ml).

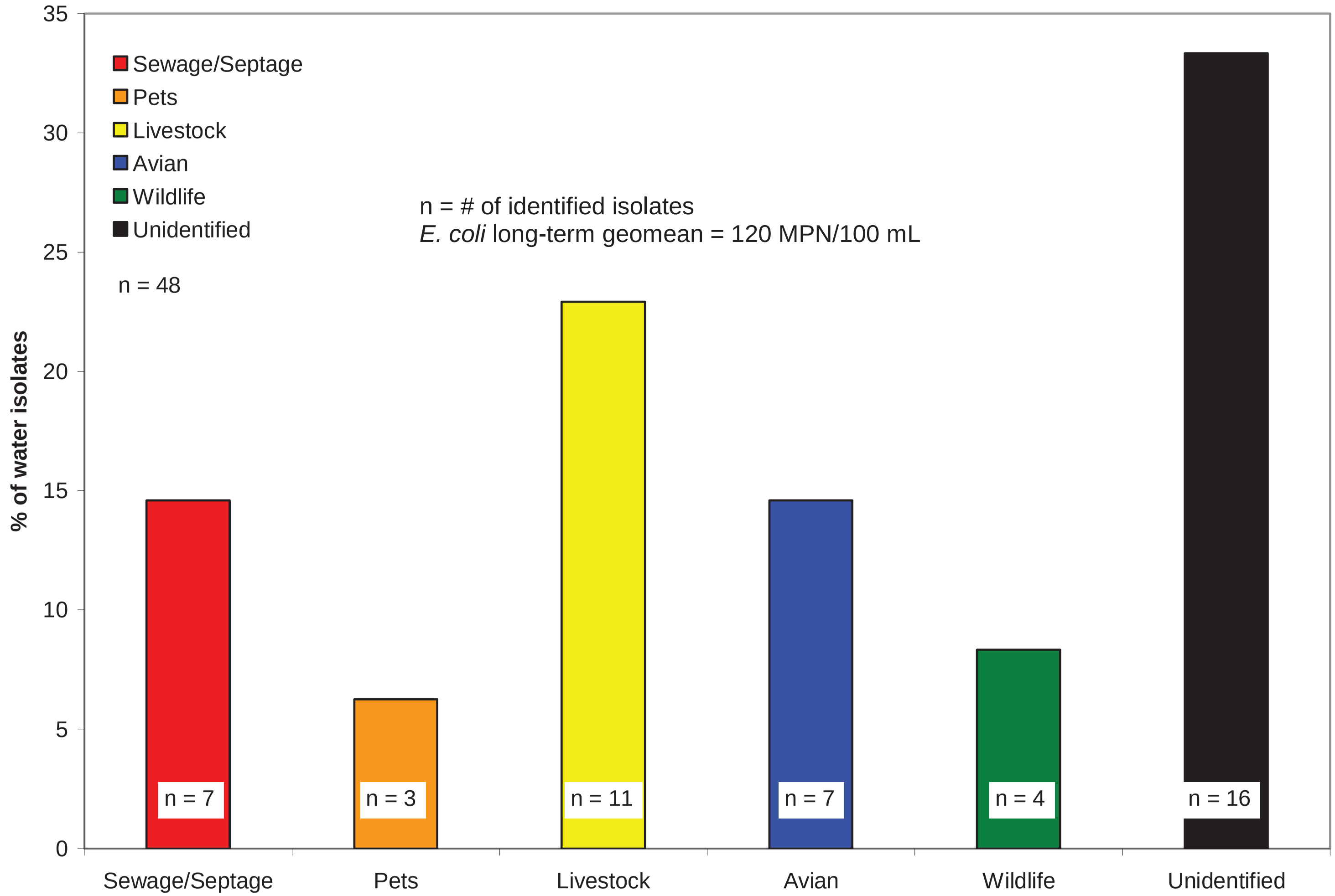


Figure 17. *E. coli* source identification for the Port Ridglea East (18038) site. The *E. coli* long-term geometric mean at this site is high (120 MPN/100 ml).

4.4.3.3 *Bacteroidales* marker distribution in Lake Granbury known source fecal samples

A total of 94 known source fecal samples from the Lake Granbury area were analyzed for the presence of *Bacteroidales* PCR host markers (Table 9). This allowed us to determine the local distribution of the markers in both target and non-target human and animal host groups.

Table 9. Bacteroidales marker occurrence for Lake Granbury known fecal samples

		Marker occurrence			
Host class	**# Samples**	**GenBac**	**Hog**	**Human**	**Ruminant**
Lamb	1	1/1	0/1	0/1	1/1
Llama	3	3/3	0/3	0/3	3/3
Goat	2	2/2	0/2	0/2	2/2
Deer	2	2/2	0/2	1/2	2/2
Cow	4	4/4	0/4	0/4	4/4
Compost	5	0/5	0/5	0/5	0/5
Horse (includes mini-horse)	4	4/4	0/4	0/4	0/4
Domestic Pig	6	6/6	6/6	0/6	5/6
Feral Hog	7	7/7	7/7	0/7	6/7
Septic	6	6/6	0/6	3/6	0/6
Domestic Sewage	10	10/10	8/10	10/10	0/10
Pets (Dogs and Cats)	10	9/10	0/10	0/10	0/10
Rabbit (includes jack rabbit)	7	7/7	0/7	5/7	0/7
Coyote	8	5/8	0/8	3/8	0/8
Raccoon	11	5/11	0/11	1/11	0/11
Armadillo	1	0/1	0/1	0/1	0/1
Possum	1	1/1	0/1	0/1	0/1
Ducks (includes domestic duck)	3	2/3	0/3	0/3	0/3
Domestic Goose	1	1/1	0/1	0/1	0/1
Chicken	1	0/1	0/1	0/1	0/1
Buzzard	1	0/1	0/1	0/1	0/1

In most cases, the occurrence of the *Bacteroidales* host source markers were as anticipated. The exceptions were for the Ruminant and Human markers. Other research teams have recently reported that the Ruminant marker may be detected in other non-ruminant animal populations. In particular, the Ruminant marker is often present in feces from domestic pigs and feral hogs. Therefore, water samples positive for the Ruminant marker may indicate fecal pollution not only by ruminant animal sources, but also feral hogs. The Hog marker appears quite specific, with the exception that domestic wastewater samples often give a weak signal. However, the Human marker signal from wastewater samples is much more intense, and therefore sites impacted by domestic sewage (and not hogs) would be positive for the Human marker, but not likely provide a false-positive for the Hog marker. The Human marker may also occasionally be detected in the feces from some animal groups, such as coyotes and raccoons. Of the tested fecal samples from Lake Granbury, 3 of 8 coyote and 1 of 11 raccoon samples tested positive for the Human marker. We also had 5 of 7 rabbit samples test positive for the Human marker, but 4 of these were pet rabbits in close contact with humans.

4.4.3.4 Detection of *Bacteroidales* host markers in water samples from each sampling site

A total of 36 grab water samples were collected for *Bacteroidales* PCR analysis. Six sets of samples were collected from each sampling site, and duplicate samples were collected from the Sky Harbor (18015) site. *Bacteroidales* results are presented in two different formats, either percentage of positive samples (Table 10), or relative abundance of markers (Figure 18 through Figure 20). It is important to note that while specific marker abundance can be compared between sites, it is not appropriate to compare the abundance of one marker to another (e.g. Hog vs. Human), since that would require DNA extraction controls and marker-specific quantitation standards which were not employed in the current study.

Table 10. Bacteroidales marker occurrence for Lake Granbury known fecal samples, by site

Site	Name	# samples	% GenBac	% Hog	% Human	% Ruminant*
11861	Main Lake	6	100	33	50	83
18015	Sky Harbor	6	100	67	50	50
18015	Sky Harbor Field Duplicate	6	100	83	67	50
18018	Waters Edge	6	100	50	33	50
20215	Indian Harbor	6	100	50	50	100
18038	Port Ridglea E.	6	100	67	0	100

*Ruminant marker may detect cattle, deer, goats, sheep, llamas and other non-ruminant feral hogs

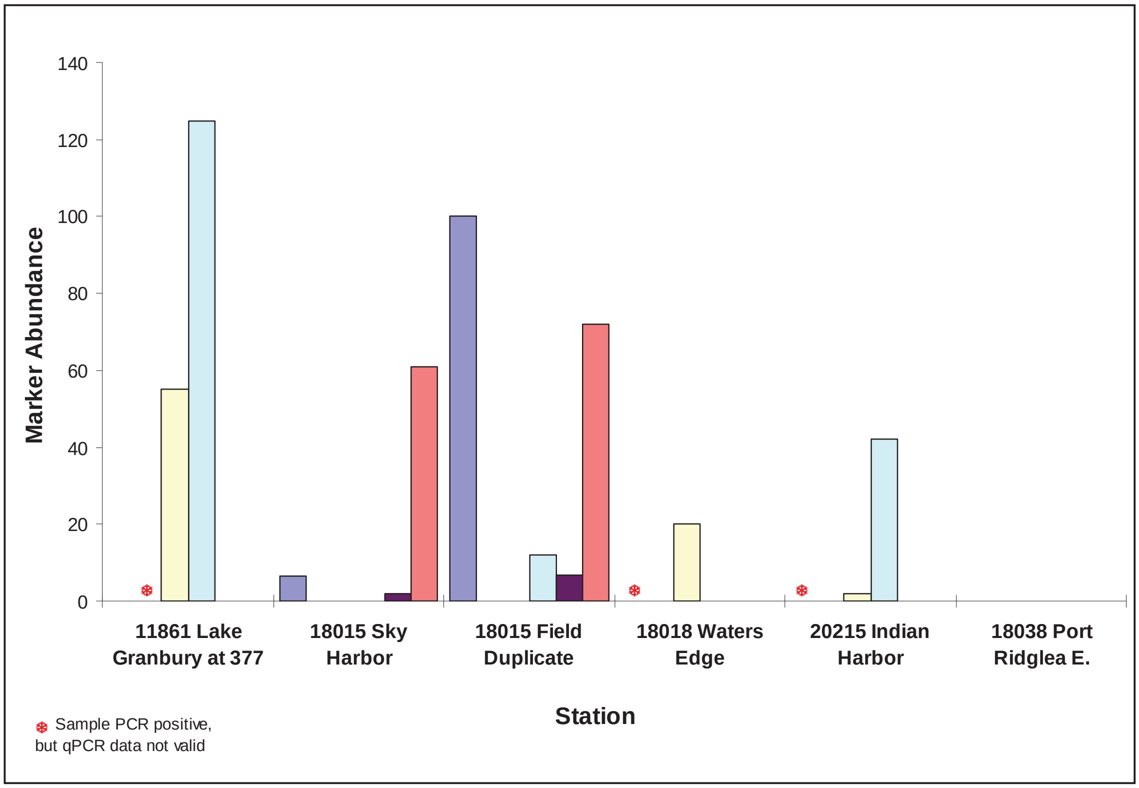


Figure 18. Bacteroidales Human marker abundance by site for the six sets of samples.

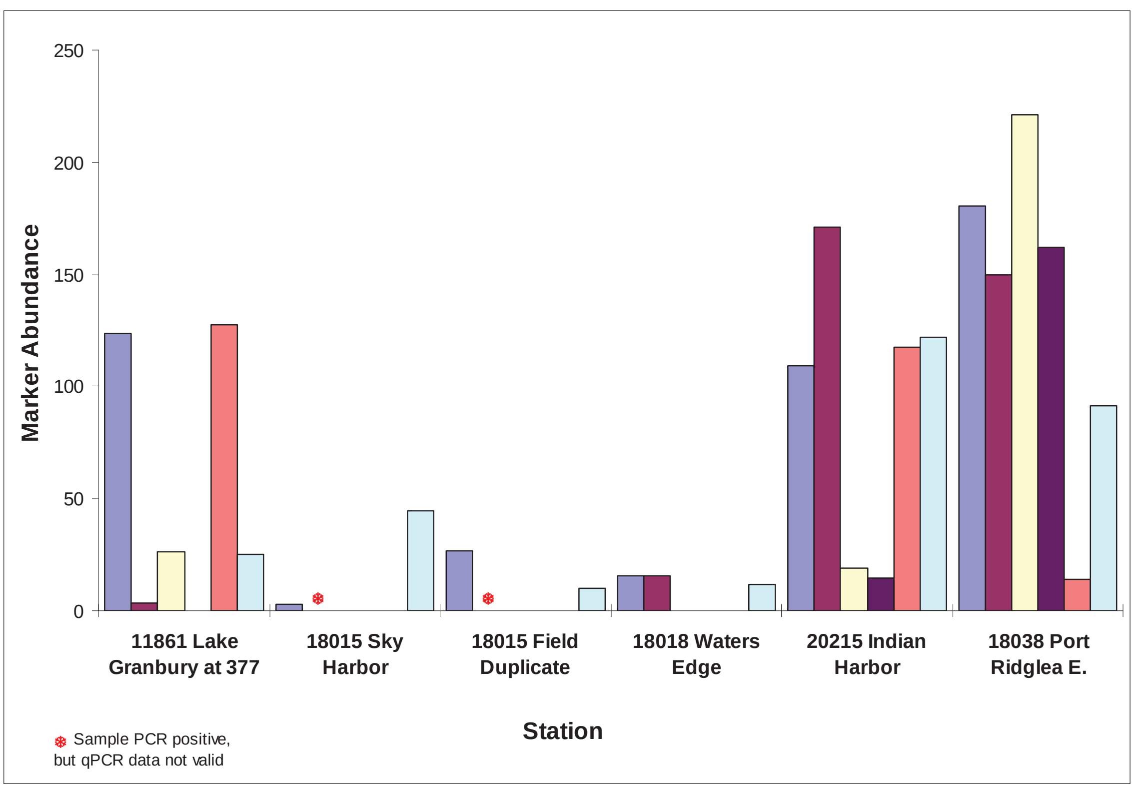


Figure 19. Bacteroidales Ruminant marker abundance by site for the six sets of samples.

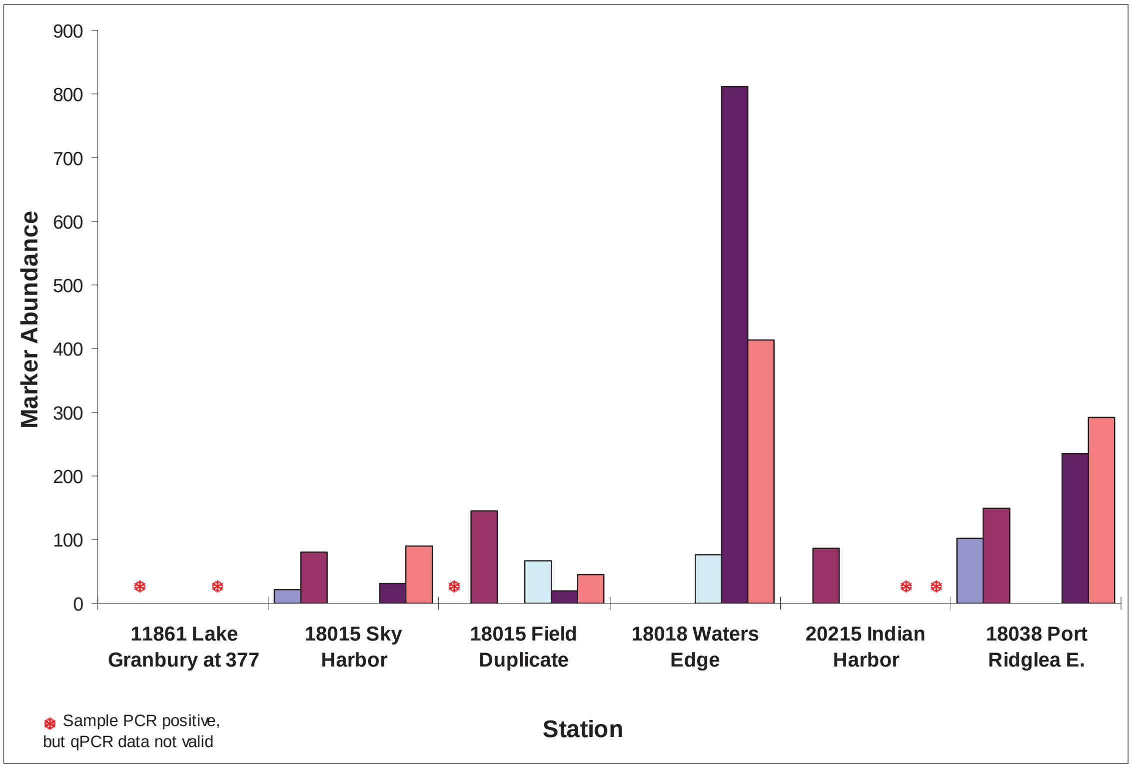


Figure 20. Bacteroidales Hog marker abundance by site for the six sets of samples.

4.4.3.5 *Bacteroidales* results for additional Waters Edge and Port Ridglea East water samples

E. coli and *Bacteroidales* BST results suggested that the sites were impacted primarily by animal-derived (wildlife) fecal pollution. These findings were surprising, particularly for the Port Ridglea East site that was assumed to be highly impacted by human fecal pollution from leaking septic systems. Unexpectedly, Waters Edge also had two samples with high Hog marker occurrence.

As a follow-up, more intensive sampling was performed at the Port Ridglea East and Waters Edge sites in December, 2008. Two sets of samples were collected approximately two weeks apart from five locations within Waters Edge and ten locations within Port Ridglea East for *Bacteroidales* analysis (Table 11). Additional fecal samples were also collected in an attempt to identify possible animal populations (other than deer and feral hogs), which may have contributed to the unanticipated Ruminant and Hog marker results at those sites. One possible source discussed at the December, 2008 stakeholder meeting was compost used for lawn fertilizer, as this may represent a possible source of Ruminant and Hog marker. *Bacteroidales* PCR results for fecal samples and compost samples are presented in Table 9.

Table 11. Bacteroidales marker and *E. coli* occurrence for additional Waters Edge and Port Ridglea East water samples*

Location	Site #	# Samples	GenBac	Hog	Human	Ruminant	*E. coli* (MPN/100 mL) on 12-08-08	*E. coli* (MPN/100 mL) on 12-12-08
Waters Edge	18017	2	+/+	-/-	-/-	-/+	17	27
Waters Edge	18018	2	+/+	-/-	+/-	+/+	24	16
Waters Edge	18019	2	+/+	-/-	+/-	-/-	7	14
Waters Edge	18020	2	+/+	-/-	-/-	-/+	8	2
Port Ridglea East	18031	2	+/+	-/-	-/-	+/-	550	120
Port Ridglea East	18032	2	+/+	-/-	-/-	+/+	410	96
Port Ridglea East	18033	2	+/+	-/-	-/-	+/-	61	93
Port Ridglea East	18034	2	+/+	+/-	-/-	+/+	330	78
Port Ridglea East	18035	2	+/+	+/+	-/-	+/+	2400	1300
Port Ridglea East	18036	2	+/+	+/+	-/-	+/-	370	77
Port Ridglea East	18037	2	+/+	-/-	-/-	+/+	310	86
Port Ridglea East	18038	2	+/+	-/-	-/-	+/+	86	45
Port Ridglea East	18039	2	+/+	-/-	-/-	+/+	150	73
Port Ridglea East	18040	2	+/+	-/-	-/-	+/+	24	62
Port Ridglea East	18040 FD**	2	+/+	-/-	-/-	-/+	30	62

* Samples collected on 12-08-08 and 12-12-08
** FD, Field Duplicate

Compost samples tested negative for all *Bacteroidales* markers, so this does not appear to be a potential source, and no other wildlife sources of the Ruminant marker were identified. Follow-up Waters Edge samples tested negative for the Hog marker. Therefore, the fecal pollution source responsible for the previous Hog marker occurrence remains unidentified, and the low levels of fecal pollution observed at Waters Edge appear to be due to various nonpoint sources. In contrast, water samples from Port Ridglea East again revealed the presence of animal fecal pollution and the absence of human source pollution, despite some of the samples having very high *E. coli* levels. It should also be noted that the water samples were collected under base flow water conditions (no rainfall events for several weeks prior to sampling), so runoff was not a factor. Sample collectors noted numerous ducks in the Port Ridglea East coves during collection of the follow-up samples. In addition, Port Ridglea East water samples were also tested for two additional markers of human fecal pollution using PCR: *Methanobrevibacter smithii* and human polyomavirus. Only the Port Ridglea East 18040 and 18040FD (field duplicate) samples from the second set of follow-up samples tested positive for the human polyomavirus.

4.4.4 BST Source Identification Summary

Large disparities existed between the BST results and the results of Land Use Analysis, Watershed Modeling and local stakeholder knowledge of the watershed. These disparities caused uncertainty among all stakeholders related to the accuracy and usefulness of BST in its current form as a tool to identify sources. The Lake Granbury Watershed Protection Plan Steering Committee (LGWPPSC) indicated that they feel, after reviewing the BST results, that BST technology is not currently developed well enough for them to base management decisions using this data. The LGWPPSC chose not to rely heavily on the BST results. When directing the project team to pursue management measures for specific sources, the LGWPPSC made their decisions for these areas based on local watershed knowledge, Land Use Analysis, Watershed Modeling and Water Quality Modeling.

4.5 MODELING ASSESSMENT OF FECAL POLLUTION SOURCES IMPACTING LAKE GRANBURY

Land Use Analysis and Watershed Modeling of the Lake Granbury watershed reveal a shift toward increased urbanization and the resulting issues. This region was farmed and ranched extensively during the early part of the 20th Century. After completion of Lake Granbury in 1969 and as agricultural usage in the watershed gradually transitioned through the 1970s and 1980s to the modern urban environment, new water quality issues in Lake Granbury began to arise. While the old concerns for agricultural impact still exist (e.g. increased erosion, sedimentation, animal waste) in the watershed, those potential sources are more removed from the vicinity of Lake Granbury than they were several decades ago. Stormwater runoff from residential properties, greater totals of impervious cover, reduced vegetation buffers between developed property and the lake, increased effluent from wastewater treatment plants, and an increased concentration of aging septic systems are all products of the rapidly increasing development of the Lake Granbury watershed and are the greatest threat to the long-term health of the lake.

Watershed and lake water quality modeling tools to consider these factors were developed as part of this WPP project. The SELECT watershed modeling approach (Teague 2007; Teague 2009; Riebschleager 2008) was used to evaluate how potential sources of bacteria differed for sub-watershed areas surrounding the lake, considering differences in land use patterns. Lake modeling tools were also developed to evaluate how bacteria concentration in lake and cove waters responds to differences in inflow, precipitation and cove geometry. The modeling parameters, approaches and tools for both watershed and lake environments were developed by the Espey Consultants, Inc., (EC) project team in collaboration with project team expert advisors Dr. Srinivasan and Dr. Karthikeyan (both of Texas A&M University with expertise in watersheds and bacteria modeling) and Dr. Ward and Dr. Armstrong (both of University of Texas with expertise in water body water quality modeling). The modeling approaches were also vetted through TCEQ staff modeling professionals assembled by the TCEQ management team. Additional discussion and advisement on modeling purposes, inputs and outputs was provided by the stakeholders to the project team.

Watershed modeling focused on the sources and magnitude of fecal bacteria on the ground surface that could potentially be transported during rainfall runoff events to nearby waterbodies and ultimately Lake Granbury. To characterize the production and distribution of waste and associated pathogens, the SELECT approach was utilized for the Lake Granbury watershed. This approach addresses the major sources of fecal bacteria production (and associated pathogens), as estimated through land use analysis, literature review, and experimental data. Wildlife such as migratory birds and rodents are a "background" source of bacteria that are often present but not easily quantified and thus are not included in the model. Additionally, a characteristic animal such as beef cattle can be used for load estimation but could be serve as a surrogate for analysis of other similar species of livestock. Similarly, dogs are used as a surrogate for domestic pets. Stakeholder input is important in identifying sources of bacteria in site-specific areas.

The lake/cove water quality modeling of the canals along Lake Granbury ("lake/cove models") focused on scenario analyses to evaluate the type of loading occurring by comparison with actual observation data. This evaluation depends upon theoretical rather than actual loads from either direct (point) or diffuse (nonpoint) sources and thus does not identify animal specific sources or magnitudes. This approach does however characterize the movement of pollutants through the specific canal waterbodies based on site specific properties such as dispersion coefficients and channel geometries.

Together with the land use analysis, the watershed models and lake/cove models were used as part of a multi-pronged approach to identify most likely sources of bacteria for each area. Since the watershed and cove models consider different inputs and characteristics, a direct comparison or a direct linkage between the two models is not possible. However, the suite of models developed throughout the WPP area enabled evaluation of a range of potential sources and mechanisms affecting bacteria levels in the lake (Table 12).

Table 12. Sources evaluated by lake/cove and watershed modeling approaches

Sources evaluated	
Lake/Cove Model	**Watershed Model**
Point sources	
1. Direct discharge into canals by malfunctioning OWTF (human) a) continuous discharge b) intermittent discharge* 2. Main-lake as a bacteria source to canals*	4. WWTP (human)
Distributed non-point sources within the watershed	
3. Non-species-specific watershed non-point source (urban runoff related to rainfall events)	5. OWTF (human) 6. Dog 7. Cattle 8. Deer 9. Feral Hogs

*in selected subdivisions

4.6 DATA TO SUPPORT MODELING EFFORTS

Playing an active role in this WPP process, the stakeholder group provided input on use of parameters important to the development of watershed and lake models to ensure they are representative of watershed areas affecting water quality of Lake Granbury. Assumptions and decision points used in the watershed and lake models were presented, and the stakeholders found that some of these literature values exhibited large variation. For example, dispersion coefficients have been recorded from 0.02 to 44 m^2/s (Peeters et al. 1996, Goodwin 1991, and Thomann and Mueller 1987) and raw sewage fecal coliform bacteria were reported in the range of 50,000 to 10,000,000 MPN/100mL (USEPA 2001). Based upon the wide range of literature values and the sensitivity of results to these values, the stakeholders identified parameters for which they felt site-specific data was necessary. For other less sensitive parameters, the stakeholder group chose values derived from literature or existing data (Table 13).

Table 13. Model parameter resolutions based on literature values or existing data

Ratio of *E. coli* to Fecal Coliform	0.7:1
Non-point source (NPS) concentration in urban runoff	Fecal coliform count 16,048 MPN/100mL
Residential wastewater generation	200 gpd/house
Bacteria decay rate at 15ºC	0.2/day
Temperature correction, $K = K1 * \Theta^{(T - T1)}$ Median summer temperature 28ºC Θ = 1.07 (Thomann and Mueller 1987)	
Bacteria decay rate @ 28ºC	0.5/day

Three specific field evaluations were conducted to develop model parameter values (Table 14). These included (1) cove circulation studies to calculate dispersion coefficients (2) a bacteria concentration study for two waste water treatment plants (WWTPs) to calculate a representative raw sewage bacteria concentration and (3) a septic system leakage study to test the hypothesis that leaky septic systems contribute directly to the high bacteria concentrations in canals. The sampling protocol for these studies is described in the Lake Granbury Watershed Septic Tracer, Circulation Study, and Additional Water Quality Sampling, Quality Assurance Project Plan (BRA 2007).

Table 14. Model parameter resolutions based on field data

Raw sewage *E. coli* count	6.68 million MPN/100mL
Site-specific dispersion values	0.02 to 0.18 m/s^2

4.6.1 Cove circulation studies - Dispersion Coefficients

Espey Consultants, Inc. (EC) performed a circulation study February 18th through 22nd, 2008. The purpose of the circulation study is to develop field data from which to calculate dispersion coefficients in specific coves/canal areas. The circulation study was performed by releasing predetermined volumes of 20% solution of Rhodamine WT (RWT 20%) dye in several canal systems within Lake Granbury (details provided in Appendix C). The specific cove systems characterized by this field test were Oak Trail Shores, Sky Harbor, Port Ridglea East, Waters Edge, Indian Harbor, and Ports O' Call subdivisions. Each canal system was revisited multiple times to measure the concentration of the dye.

Circulation patterns, and therefore circulation studies, are sensitive to wind, flow and lake recreation in the study area. Inflows to and outflows from the lake were relatively low and decreasing during the period of the study (60 to 120 cfs). A temporary wind station was set up to collect wind data on-site during the study. Boat traffic inside the canals can potentially impact circulation dye studies, but boat traffic was negligible during the study period.. Disruption due to survey boat velocity was minimized by traveling at low velocity.

Several approaches can be used to estimate the dispersion parameter using conservative (non-reactive) dye as the tracer substance (Thomann and Mueller 1987, USGS 2002, Ward 1985). Ward (1985) performed a dye study for Texas bays, and methods used for that study were adopted to calculate the dispersion coefficients for Lake Granbury (Table 15). Dispersion parameters for unvisited canals were estimated according to similarity to canals where field studies were conducted.

Table 15. Calculated Dispersion coefficients

Subdivision	Dispersion Coefficients (m2/s)
Indian Harbor	0.02
Oak Trail Shores	0.1
Port Ridglea East	0.125
Ports O' Call	0.09
Sky Harbor	0.18
Waters Edge	0.08

Dispersion coefficients for the Lake Granbury coves are comparably lower than most literature values, which is reasonable considering the more constrained condition in the canal systems. Wind speed between field tested and NCDC data for the Granbury area were compared (Appendix C). The wind speed is much lower over the cove/canal waterbodies compared with NCDC wind speed recorded at unobstructed stations 30 feet above ground.

4.6.2 Raw Sewage Bacteria Concentration Sampling

An important parameter for modeling direct discharge into the lake is the raw sewage bacteria concentration. Literature values of fecal coliform concentrations vary by location. Two wastewater treatment plants (WWTPs) in the Lake Granbury area that provide service to residential communities were sampled by Authority staff between March 5th and April 30th, 2008, for bacteria concentrations in raw sewage influent. The first WWTP discharges near the DeCordova Bend subdivision and the other near the Blue Water Shores subdivision. Over the nine week period, the WWTPs were visited every Wednesday for sampling. From each visit, at each plant, 20 bacteria analyses were carried out for both total coliform concentration and *E. coli* concentration.

The bacteria concentrations were determined by incubating the water sample for 24 hours and then counting the number of bacterial colonies that grew during that time. The unit for reporting fecal bacteria is "colony-producing units" (CPU) per 100 milliliters of water (CPU/100 mL). CPUs/100 mL is used interchangeably with "most probable number" (MPN) per 100 mL (MPN/100 mL).

A portion of the *E. coli* sampling data for DeCordova Bend plant are shown in Table 16 as an example.

Table 16. Raw Sewage E. Bacteria Concentration (100,000 MPN/100mL) for the DeCordova Bend WWTP

E Coli (MPN*100,000)	5-Mar-08	12-Mar-08	19-Mar-08	26-Mar-08	2-Apr-08	9-Apr-08	16-Apr-08	23-Apr-08	30-Apr-08
DCB #1	86	10.8	26.5	96.0	34.5	81.6	39.7	88.2	51.2
DCB #2	58.3	10.9	19.9	<1	38.8	81.3	35.9	44.1	44.1
DCB #3	75.4	3	27.2	98.8	46.2	58.3	35.9	63.8	69.7
DCB #4	81.6	8.4	23.1	88.2	34.5	81.6	49.6	95.9	54.8
DCB #5	62.7	8.6	23.1	84.2	49.5	79.8	50.4	56.5	49.6
DCB #6	71.7	4.1	25.3	67.0	59.4	73.3	116.9	68.3	49.5
DCB #7	65.7	14.4	33.1	90.8	50.4	81.6	35.9	73.3	65.7
DCB #8	39.3	3.1	18.5	66.3	36.9	77.1	31.3	104.6	59.1
DCB #9	51.2	9.7	17.1	88.4	39.3	55.6	113.7	52.9	79.4
DCB #10	52.1	8.5	23.3	78.9	27.5	129.6	72.7	70.0	62.7

Arithmetic mean (average) of 360 samples (20 analyses, 9 visits, two plants) was calculated as 6,688,176 MPN/100mL. This value was adopted for model use for the Lake Granbury area *E. coli* concentration in raw sewage.

4.6.3 Septic Tracer Dye Study

The septic tracer study was performed on April 7 through 11, 2008, by injecting predetermined volumes of a 20% solution of Rhodamine WT (RWT 20%) dye into residential septic systems (generally via kitchen sink or bathtub drain) and then running water to flush the dye through the system. The entire process for one residence took approximately 30 minutes. Once the injection was complete, the drain field (yard) and the adjacent cove was monitored for the next few days, once in the morning and again in the evening, to determine the amount of time necessary for the colored dye to show up in the water around the cove. The intention of this test was to characterize normal or abnormal water movement from septic systems into the nearby canals. The details of the data collection methods and results are located in Appendix C.

In all of the subdivisions visited, study participants were concerned about water quality in the lake, citing a range of reasons such as property values, aesthetics, swimming and fishing. As a statistical summary, 16% of participants did not know when their septic system was last serviced; 30% knew their systems had not been serviced within the last 5 years; and 11% had new systems less than 5 years old at the time of the survey.

In 44 systems tested in this septic study, leakage was found in two systems, one in Oak Trail Shores and one in Port Ridglea East. In both cases, pooling on the ground surface were observed following laundry loads, which indicated that there was minor leaking of the septic system. Before the tests, both systems were thought by participants to be properly functioning as they had performed maintenance or repairs within the last two years. This indicated that septic systems exhibited imperfect functions sooner than residents expected; regular inspection and maintenance could alert owners of necessary repairs.

Water quality monitoring was conducted as a component of this study in the subdivisions visited. *E. coli* concentrations tested on April 10, 2008, are listed in Table 17 for each subdivision. Despite on-ground pooling at two locations, and subsequent precipitation events during the study, no dye was observed entering the canals. This indicates that the systems tested were not significant contributing sources to bacteria levels at the time of the study.

Table 17. *E. coli* concentration monitored on 04/10/2008

Subdivision	E. Coli Conc. (MPN/100mL)
Oak Trail Shores	>2000
Rolling Hills Shores	>1635
Port Ridglea	PRE 416/ PRW 297
Sky Harbor	>1875

4.6.4 Adopted Modeling Resolutions

Considering sensitivity of selected model inputs, stakeholders adopted resolutions related to specific model inputs.

1. The site-specific conversion of 1 FC:0.7 *E. coli* was adopted in this study. The current pathogen indicator for fecal contamination is reported in *E. coli* concentration (MPN/100mL). In the past, fecal coliform was the indicator bacteria used for monitoring bacteria; therefore, more data is available and more research has been performed for the fecal coliform indicator making available model inputs from literature based on fecal coliform concentrations. To make fecal coliform literature relevant to this study, a conversion factor between fecal coliform and *E. coli* concentrations is needed to compare modeling results and monitoring data. As a local reference the Brazos River Authority (BRA) reported a ratio of 1:0.6 to 1:0.7 (fecal: *E. coli*) for monitoring data at Lake Granbury between 2002 and 2004. The ratio 1:0.7 was adopted for this study.

2. *E. coli* concentration in runoff used in lake modeling is calculated as 11,234 MPN/100 mL. In the City of Austin Environmental Criteria Manual (2007), fecal coliform concentration in a multi-family residence area is 8,400 colonies/100 mL; CRWR (1996) quoted fecal coliform concentration for residential areas as 20,000 colonies/100 mL; and CCBNEP (1996) reported fecal coliform as 19,743 colonies/100 mL for high density residential areas. The average fecal coliform concentration from the above references, 16,048 colonies/100 mL, was adopted as the FC concentration for the Lake Granbury area. Using Bacteria FC:EC conversion factor of 1:0.7, *E. coli* concentration in runoff used in lake modeling is calculated as 11,234 MPN/100 mL.

3. Site-specific dispersion values range between 0.02 and 0.18 m^2/s for the coves modeled in this WPP effort. As described previously, field circulation studies were conducted in February 2008 to calculate site-specific dispersion coefficients.

4. The value of 6,688,176 MPN/100mL was adopted as the Lake Granbury area *E. coli* concentration in raw sewage. An important parameter for modeling direct discharge into the lake is the raw sewage bacteria concentration. The broad range of literature values indicates the bacteria concentrations found in raw sewage may be dependent upon location. To establish a site specific reference for the Lake Granbury area, bacteria sampling were conducted from March 5 through April 30, 2008, at two WWTPs in the Lake Granbury area: DeCordova Bend and Blue Water Shores. The arithmetic mean (average) of 360 *E. coli* samples (20 analyses, 9 visits, two plants) was calculated as 6,688,176 MPN/100mL.

4.7 WATERSHED MODEL SOURCE IDENTIFICATION

4.7.1 Watershed Delineation

The Lake Granbury Watershed was delineated into subwatersheds (Figure 21) using ArcSWAT (SWAT, 2005). EC created a custom landuse classification by modifying the BRA 2007 landuse shapefile (Figure 22**Error! Reference source not found.**), for use in the watershed model using the most recent aerial photography, and merging with the National Land Cover Database (NLCD) 2001 (Figure 23).

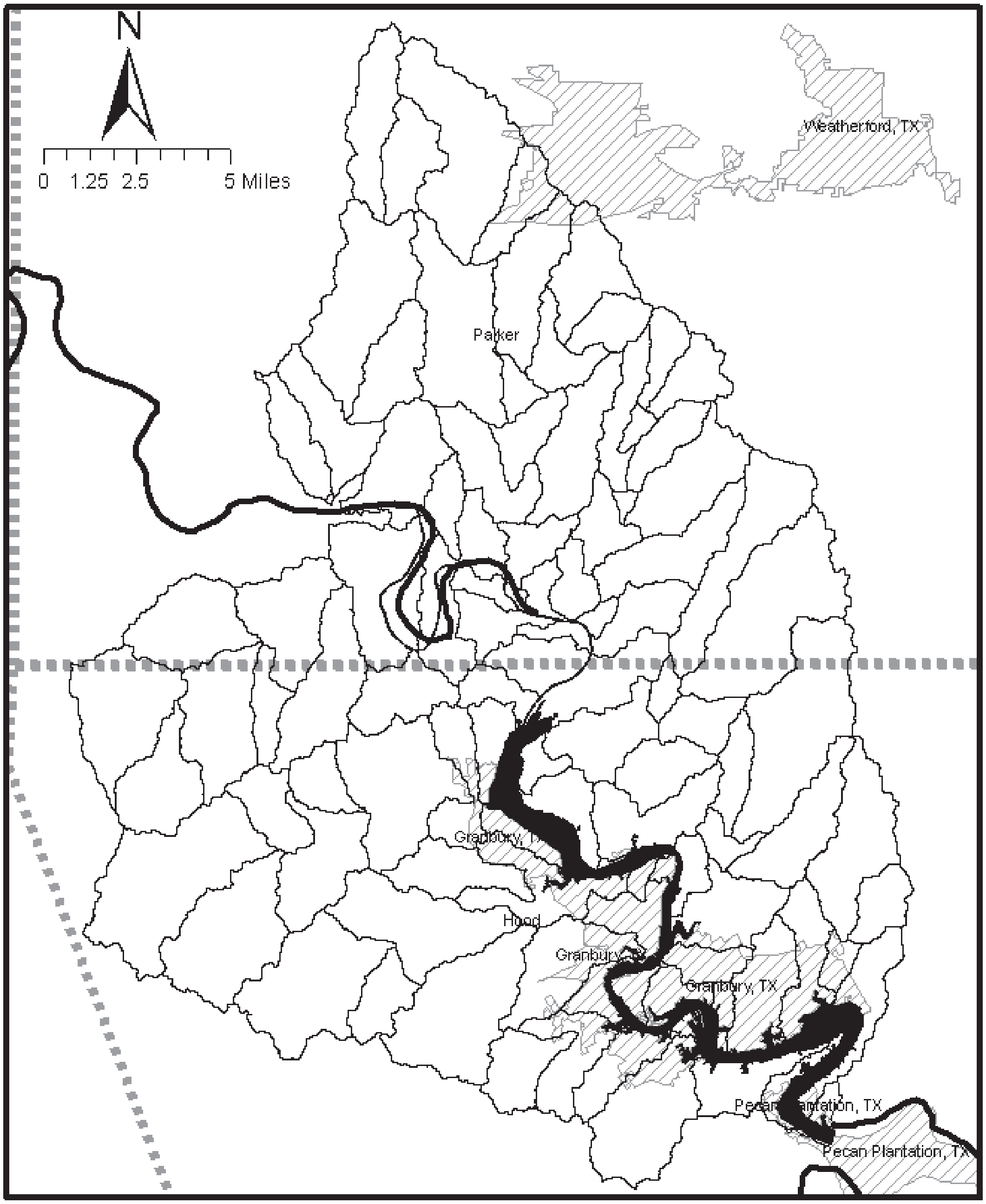


Figure 21. Location of Lake Granbury with Subwatersheds Delineated using SWAT.

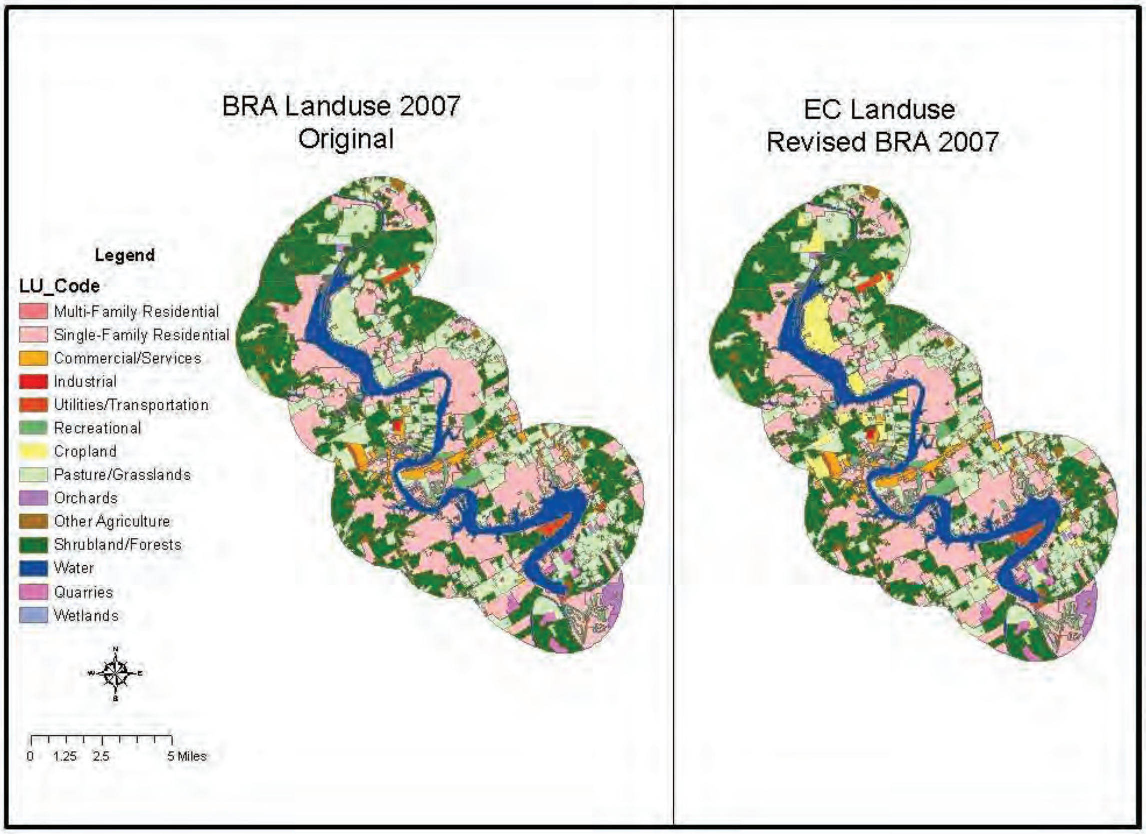


Figure 22. BRA 2007 Landuse and EC Revisions to the BRA 2007 Landuse Classification File.

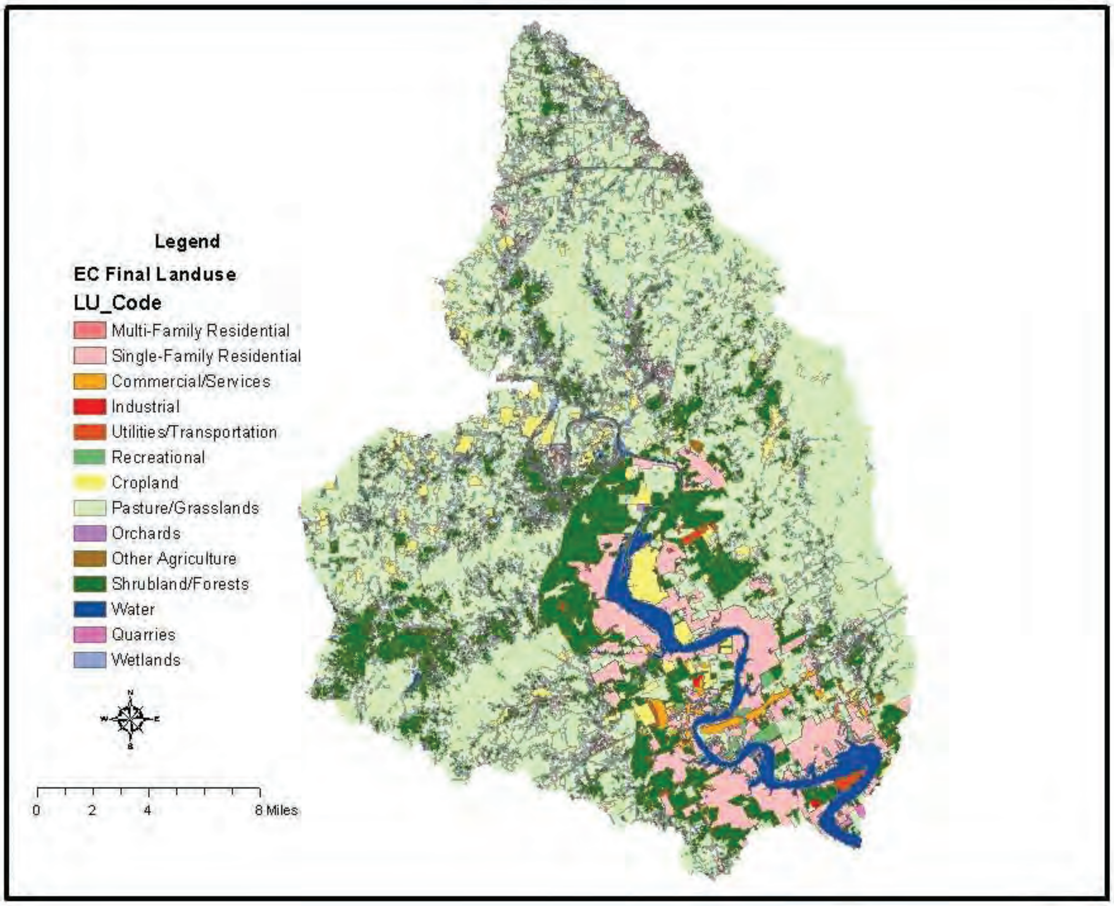


Figure 23. Landuse Classification of Lake Granbury Watershed (EC/BRA 2007 merged with NLCD 2001).

Modeling of large subwatersheds provided information on potential bacteria loads across the entire area of coverage (Appendix D). Since distant watersheds may have limited effects on Lake Granbury waters, microwatersheds pertinent to priority subdivisions were delineated for investigation (Figure 24) based upon site visits and topographic maps to determine drainage patterns. Identification of priority subdivisions were based on analysis of available monitoring data where bacteria levels were found to be elevated; these areas included Rolling Hills Shores, Oak Trail Shores, Indian Harbor, Sky Harbor, Port Ridglea East and Blue Water Shores. While data does not indicate current high bacteria levels, additional areas Arrowhead Shores, Ports O' Call and Nassau Bay are identified in historical reports as having potential bacteria concerns; microwatersheds for these subdivisions were also evaluated. The land use analysis for all microwatersheds surrounding Lake Granbury can be found in Appendix B.

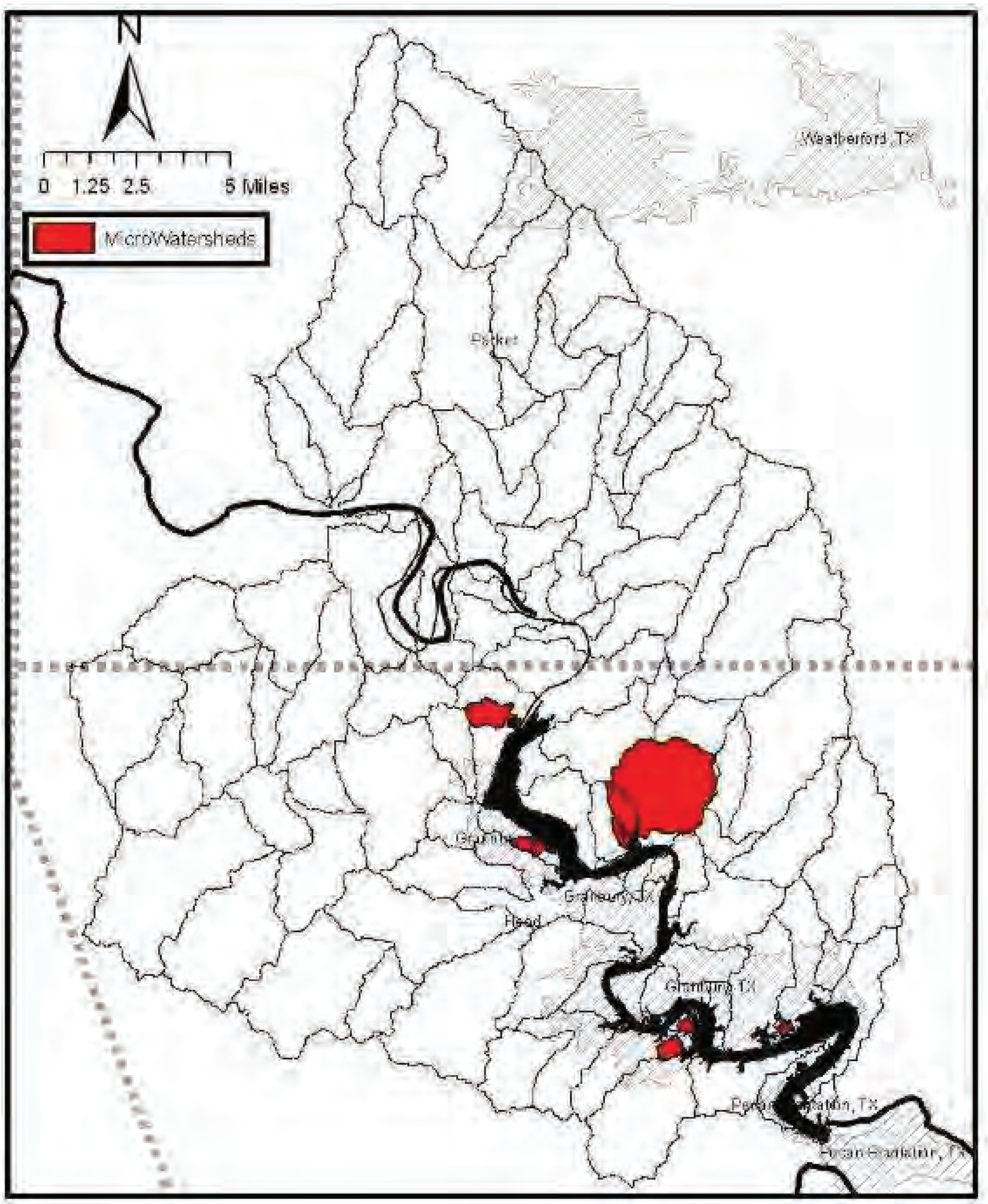


Figure 24. Location of Microwatersheds in the Greater Lake Granbury Watershed

4.7.2 Methodology

Application of SELECT helped stakeholders identify the areas potentially contributing to pathogen contamination of waterbodies without using complex hydrologic models. An additional pollutant connectivity factor (PCF) component was developed (Riebschleager 2008) based on three indicative factors for contamination: a) potential pollutant loading, b) runoff potential, and c) travel distance to streams and other waterbodies.

The SELECT approach for characterizing the *E. coli* sources is similar to the methodology developed by Teague (2007) for the Plum Creek Watershed Protection Plan, with the exception of on-site wastewater treatment systems (referred to here as OWTS, sometimes referred to as on-site sewage facilities). The approach outlined here for SELECT represents on that is expanded, revised, and automated for extending its application to diverse watersheds (Riebschleager 2008).

To characterize the production and distribution of waste and associated pathogens, sources contributing to contamination were determined by using agricultural census information provided by National Agriculture Statistics Service (NASS); talking to the local extension agents and wildlife experts; obtaining permitted Waste-Water Treatment Plants (WWTP) discharges from the EPA Envirofacts Data Warehouse; and researching previous pathogen TMDLs and WPPs. Land use is the factor that has the greatest effect on potential *E. coli* loading because the type of land use / land cover dictates whether the area is suitable for pollutant contribution. For example, it can be assumed that cattle will be confined to pasture and grazing lands and will not be found in cultivated cropland or residential neighborhoods. The fecal production rates for the various sources can be calculated using the EPA Protocol for Developing Pathogen TMDLs (USEPA, 2001) which includes a summary of source-specific pathogen and fecal indicator concentrations.

In SELECT the potential loading on a daily time scale is calculated by estimating the source populations, distributing the sources uniformly across suitable habitats, applying daily fecal production rates, and then aggregating to the level of interest for analysis. In the case of Lake Granbury, potential loading was determined for both the larger subwatersheds (Figure 21) and the micro-watersheds (Figure 24) associated with the subdivisions of interest.

SELECT simulated potential *E. coli* load resulting from cattle, deer, feral hogs, pets (dogs), malfunctioning OWTS, and Waste-Water Treatment Plants. The default fecal production rate values used for this project where chosen as the highest from the range of values provided in the EPA Protocol for Developing Pathogen TMDLs (USEPA 2001) for all *E. coli* sources identified in the Lake Granbury Watershed (Table 18). Default values for *E. coli* concentrations were used for all sources except malfunctioning OWTS; the stakeholder resolutions on raw sewage effluent were used for this source.

Details related to SELECT model assumptions are located in Appendix D.

Table 18. Calculation of *E. coli* Loads from Source Populations

Source	Calculation
Cattle	$E.coli = \# Cattle * 10 * 10^{10} cfu/day * 0.7$
Deer	$E.coli = \# Deer * 3.5 * 10^{8} cfu/day * 0.7$
Feral Hogs	$E.coli = \# Feralhogs * 1.1 * 10^{10} cfu/day * 0.7$
Dogs	$E.coli = \# Households * \frac{0.8 dogs}{Household} * 5 * 10^{9} cfu/day * 0.7$

Malfunctioning OWTS	$E.coli = \#OWTSs * MalfunctionRate * \frac{9.554x10^6 cfu}{100mL} * \frac{200 gal}{household / day} * \frac{3785.4mL}{gal} * 0.7 * 0.133$
WWTP	$E.coli = PermittedMGD * \frac{126cfu}{100mL} * \frac{10^6 gal}{MGD} * \frac{3785.4mL}{gal}$

4.7.3 Pollutant Connectivity Factor

The pollutant connectivity factor (PCF) was developed to weigh the influence of the driving forces of contamination with the total pollution present. The PCF indicates areas within the watershed vulnerable to contributing bacteria to waterbodies. This component of the model utilizes the curve number, which directly relates to runoff potential, and the distance to streams, which directly relates to fate and transport. The total pollutant connectivity factor was calculated using a weighted combination of the normalized potential loading, curve number grid, and the inverse of the normalized flow length to streams (Figure 25). This allowed stakeholders to identify areas of greatest concern for water quality impairment. The flow length is derived from a digital elevation model (DEM) using ArcHydro Tools within ArcGIS. The curve number grid is created from intersecting the SSURGO soils hydrologic soil grouping (HSG) and the NRCS 2001 land use classification and then using a NRCS Curve Number Lookup Table. The resulting PCF is a ranking of potential contribution from subwatershed without considering any detailed fate and transport processes in the watershed. The following is the weighted overlay expression for determining the pollutant connectivity factor (PCF):

$$PCF = W_P \times P_I + W_R \times R_I + W_D \times 1 / D_I$$

Equation 1

Where,
PCF = Pollutant Connectivity Factor
W_P = weighting factor for the pollutant indicator, P_I
P_I = pollutant indicator, normalized pollutant load on scale from 0 to 100
W_R = weighting factor for the runoff indicator, R_I
R_I = runoff indicator, curve number
W_D = weighting factor for the distance indicator, D_I, and
D_I = distance indicator, normalized flow length on scale from 0 to 100

Appropriate weighting should be based on best knowledge available or expert opinion. Alternatively, sensitivity of weighting factors can be determined by running multiple trials of the pollutant connectivity factor across a range of weighting schemes (Table 19). If a particular subwatershed consistently is determined to be a 'hot spot' for contributing to contamination, then it is likely this subwatershed is of great concern and should be more readily addressed. On the other hand if a particular watershed is consistently rated low, then this watershed should not be of concern when determining management practices. The ‘hot spot’ evaluation approach was used for the Lake Granbury watershed.

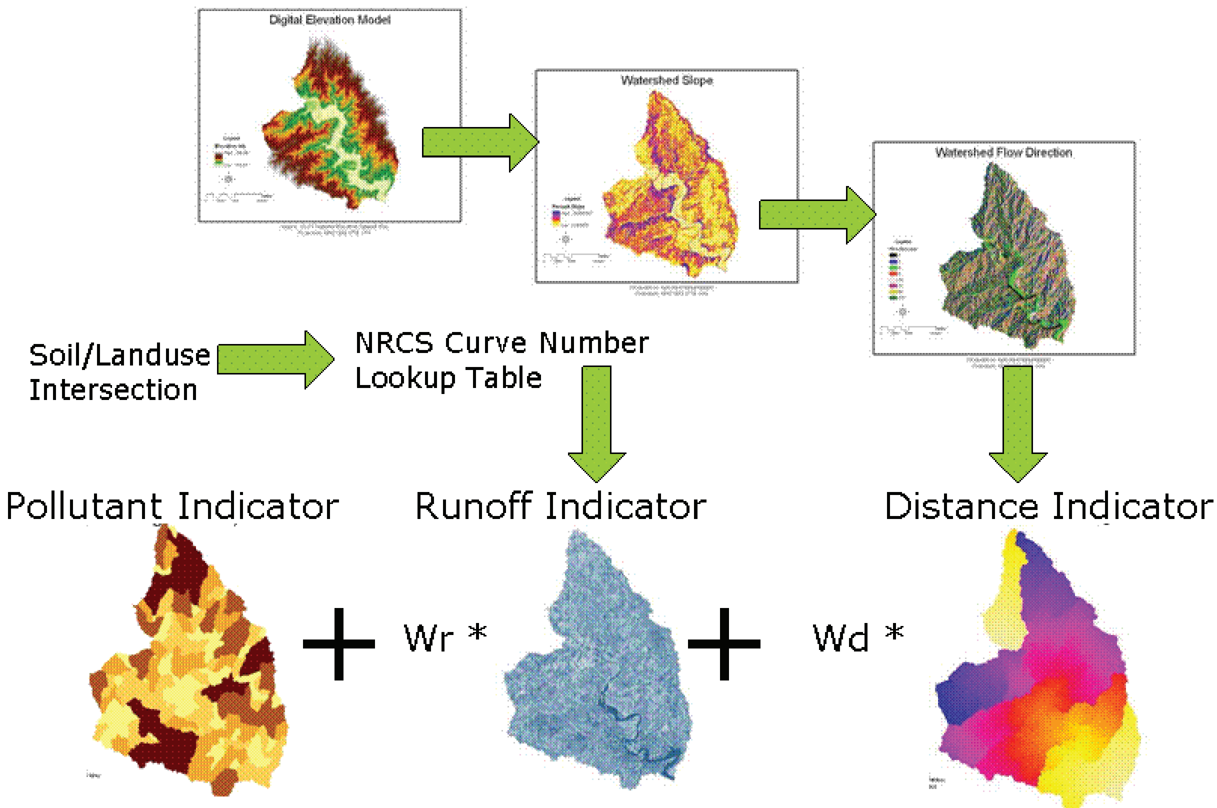


Figure 25. Spatial and Hydrologic Processes to Determine the Pollutant Connectivity Factor (PCF).

Table 19. Weighting Scheme for Sensitivity Analyses of Pollutant, Runoff, and Distance Indicators for determining the Pollutant Connectivity Factor (PCF).

Trial Number	W_p	W_r	W_d
1	5	3	2
2	5	2	3
3	4	4	2
4	4	3	3
5	4	2	4
6	3	5	2
7	3	4	3
8	3	3	4
9	3	2	5
10	2	5	3
11	2	4	4
12	2	3	5
13	3.33	3.33	3.33

4.7.4 Results

The potential loading component of SELECT can help identify source contributions spatially distributed across the watershed. However, this is only a daily snapshot of the amount of *E. coli* potentially present in the watershed (Figure 26 and Figure 28). The Pollutant Connectivity Factor (PCF) applied weighting to important fate and transport factors such as runoff capabilities and travel distance to provide helpful information to determine whether *E. coli* from various sources potentially contaminate the waterbodies. For the Lake Granbury Watershed, PCF analyses was based on applying multiple weighting schemes (Table 19) and then ranking the subwatersheds (Figure 27 and Figure 29) for potential water quality problems due to bacteria. The resultant ranked PCF maps for each source can be found in Appendix D.

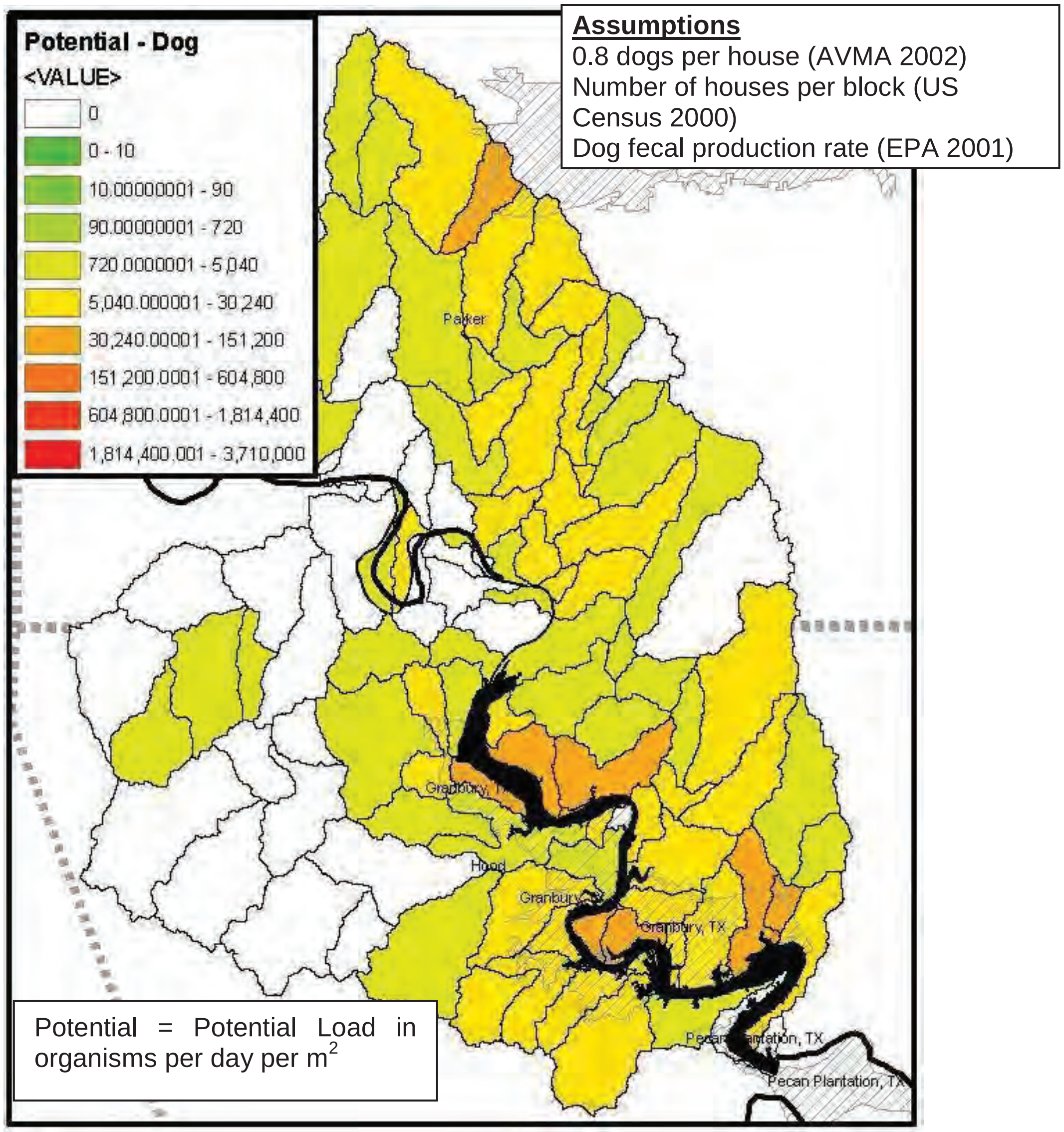


Figure 26. Area Weighted Potential *E. coli* Loading from Dogs

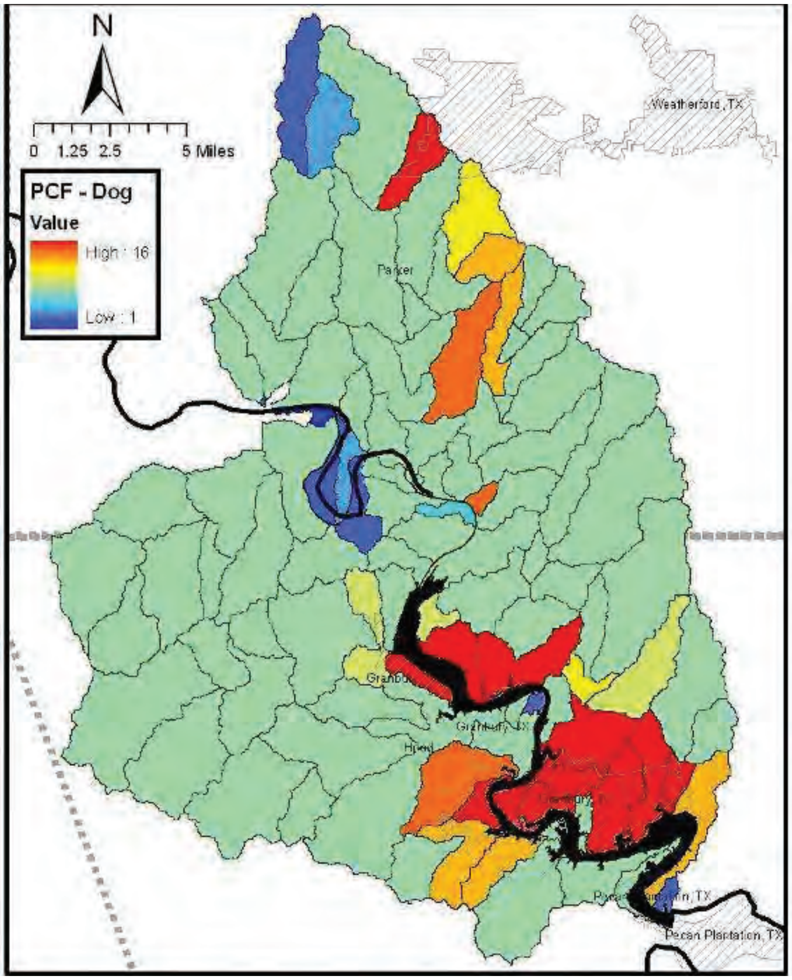


Figure 27. Ranked PCF using Area Weighted Potential *E. coli* Loadings from Dogs

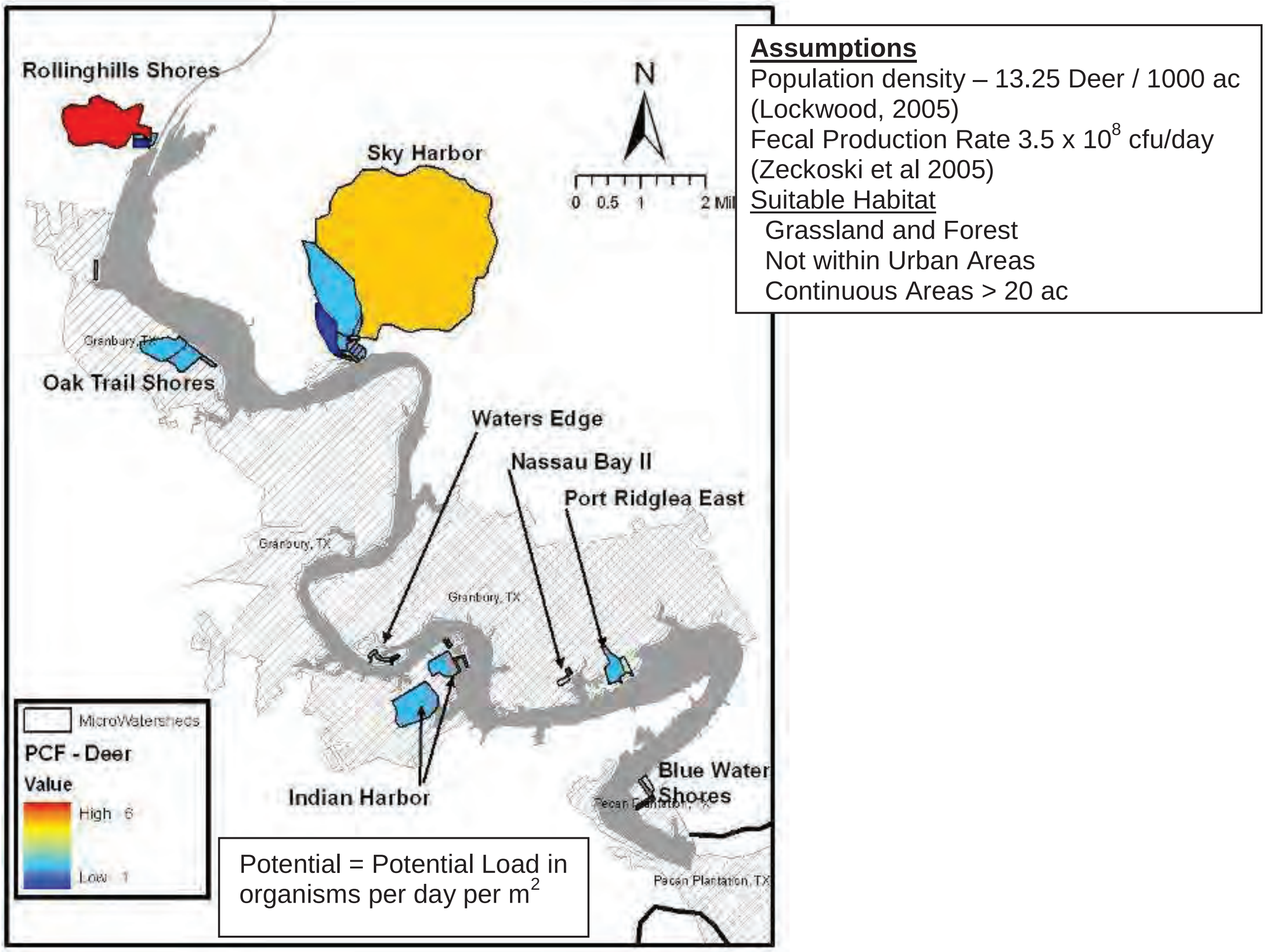


Figure 28. Microwatershed Area Weighted Potential *E. coli* Loading from Deer

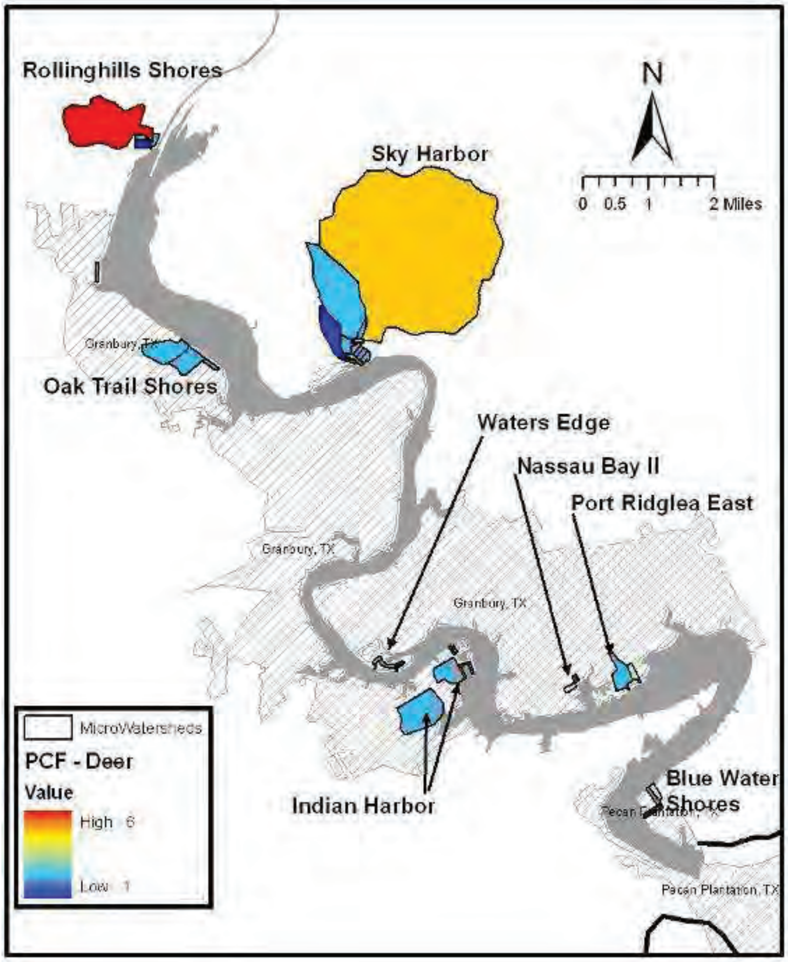


Figure 29. Microwatershed Ranked PCF using Area Weighted Potential *E. coli* Loading from Deer

Seven wastewater treatment plant facilities operate within the watershed (Figure 30). These facilities contribute large amounts of treated effluents if unintentional release of improperly treated wastewater was to occur.

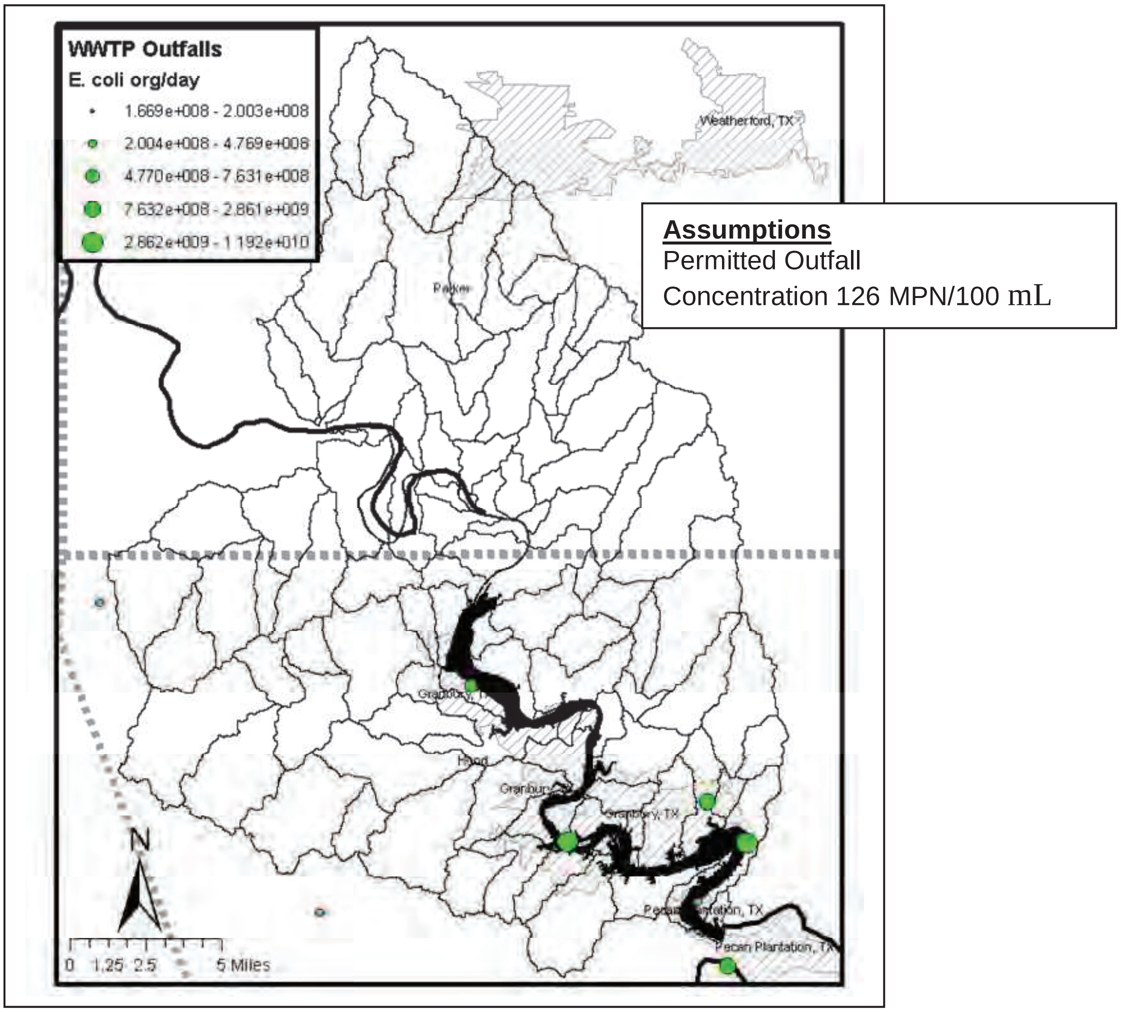


Figure 30. Potential *E. coli* Loading from Wastewater Treatment Plants.

4.8 LAKE/COVE WATER QUALITY MODEL SOURCE IDENTIFICATION

4.8.1 Methodology

Given the shallow depths (generally less than 6' deep) in each of the residential cove/canal systems, vertical stratification is not considered a driving issue for consideration of bacteria in this project. Thus a segmented well-mixed mass balance spreadsheet model is used for modeling of each canal system. The lake/cove model considers longitudinal gradients of concentration from the lake boundary to the dead-end reaches of a canal system, and considers time-varying inflow conditions. Several assumptions for the mass balance model are listed as follows:

- The simple segmented mass balance model applies to the canals or coves; i.e., canal waters are well-mixed and homogeneous within a given segment.
- Boundary conditions, i.e., exchanges between the canal and the lake main body, can be suitably applied to each canal's simple segmented mass balance model.
- Wave-induced circulation patterns in the canals are insignificant and resultant mixing could be modeled indirectly with diffusion (particle motion or turbulent mixing) and/or dispersion (variation in velocity) coefficients.

Assume segment 1 is in connection with segment 2. The mass balance equation for segment 1 is expressed as (Thomann and Mueller 1987):

$$V_1 \frac{ds_1}{dt} = W_e + Q_r s_r - Q_{12} s_1 + E'_{12}(s_2 - s_1) - V_1 K_1 s_1$$ Equation 2

Where:

V_1 – Volume for segment 1
s_1 – Concentration of segment 1
t – Time
W_e – Mass input rate
Q_r – Runoff inflow
s_r – Runoff concentration
Q_{12} – Flow between segment 1 and 2
s_2 – Concentration of segment 2
K_1 – Decay rate for segment 1
$E_{12'}$ - Bulk exchange coefficient; $E'_{12} = \frac{E_{12} A_{12}}{\Delta x_{12}}$

The following is a list of the required input data for each canal model:

Inflow timeseries (from local watershed runoff or stream flow)
Depth
Volume
Segmentation
Exchange between segments and boundary

Cross sectional area and distance between segments
Dispersion coefficient
Bacteria concentration/loading
Bacteria decay rates

The mass balance model is generally completed using a spreadsheet approach. Mass balance models were developed for 10 representative subdivisions as shown highlighted on the subdivision map for Lake Granbury area in Figure 31. The chosen canals include:

Rolling Hills Shores
Arrowhead Shores
Oak Trail Shores
Ports O' Call
Indian Harbor
Nassau Bay
Sky Harbor
Port Ridglea East
Blue Water Shores
Waters Edge

These subdivisions were chosen for modeling by Stakeholders because they exhibit a range of conditions (length, width, orientation, and depth) that allow inferences to be made on other canal systems with similar configurations. Moreover, based on analysis of available monitoring data, bacteria levels in the canals of these subdivisions were found to be currently or historically high, with the exception of Waters Edge, and therefore have most potential for improvement. Waters Edge subdivision was chosen for modeling as a control, to show applicability of the model framework at low bacterial concentrations.

Model segmentation was assigned according to flow directions and canal geometry. Take Oak Trail Shores as an example, the canal system is divided into five segments as shown in Figure 32. Mass balance using Equation 1 is calculated for each segment in the spreadsheet model. The flow directions are: 1→2, 2→5, 3→4, 4→5, 5→lake. Approximate dimensions and volumes of each segment are tabulated in Table 20 for Oak Trail Shores.

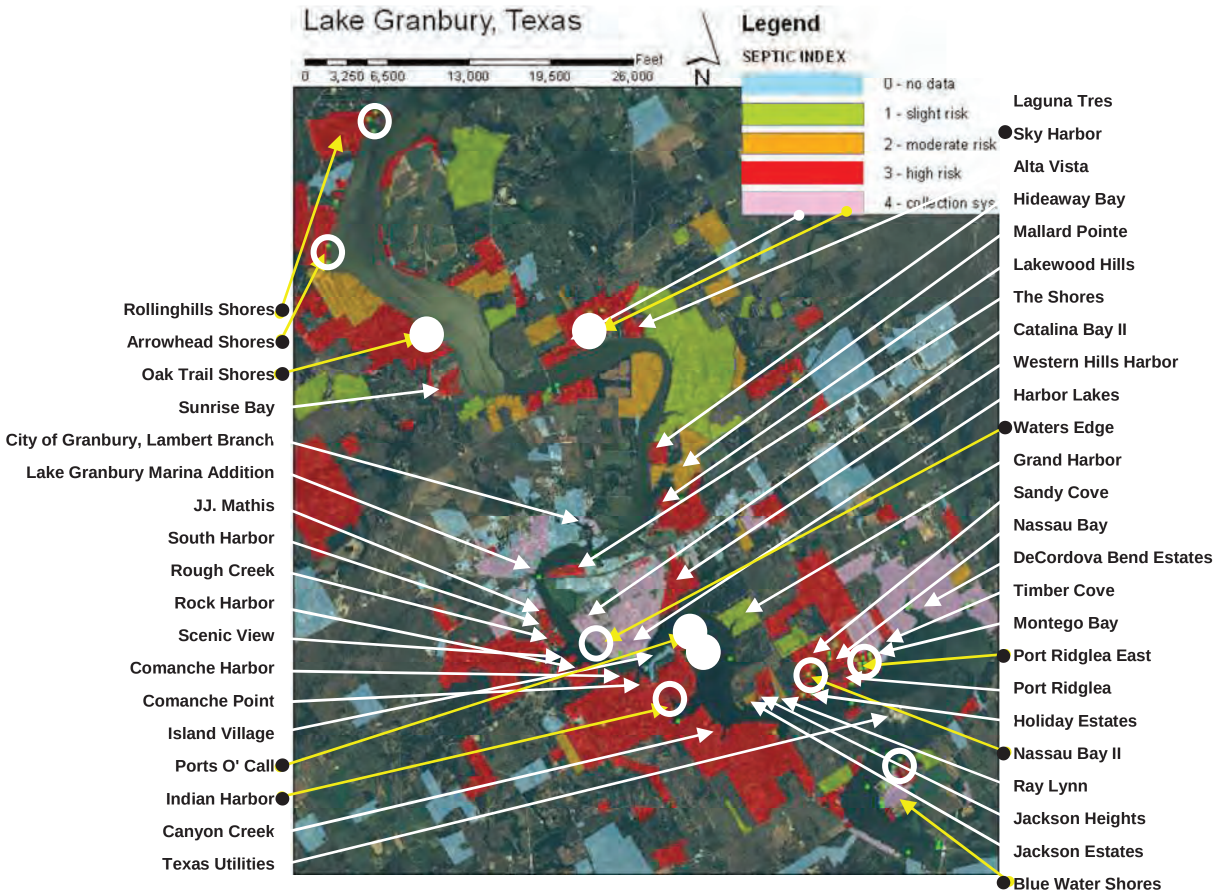


Figure 31.Aerial photo and subdivision map with septic index

Figure 32. Segmentation of Oak Trail Shores for Canal Modeling

Table 20. Dimensions and Volumes for each segment in Oak Trail Shores

Segment	1	2	3	4	5
Length (m)	169.3	161.6	173.7	183.7	107.3
Width (m)	8.9	9.5	9.8	9.8	9.2
Depth (ft)	3.4	3.4	3.7	3.7	4.5
Depth (m)	1.04	1.04	1.13	1.13	1.37
Volume (m^3)	1561	1591	1920	2030	1354
Volume (L)	1561496	1590958	1919741	2030261	1353989

Similar segmentation and modeling processes were conducted for the other nine subdivisions. The segmentation illustration for each subdivision can be found in Appendix E.

4.8.2 Lake/Cove Model Scenarios

The mass balance model for each subdivision is executed for four bacteria loading situations: continuous septic point source, intermittent septic point source, lake source and local watershed non-point source. The initial condition for all scenarios is for the initial waterbody bacteria concentration to be zero.

4.8.2.1 Direct Discharge (Septic Point Source) Scenario

Two generalized modeling scenarios have been developed to evaluate septic systems as a point source of bacteria pollution to lake and cove water bodies.

The first scenario is continuous direct discharge from a point source, without rainfall events. If one residence discharges into the canal continuously, total daily point load of 5.06×10^{12} MPN is applied to the corresponding segment and is distributed evenly in time across each time increment (typically 6 minutes). In the water quality model, once this continuous point load is added, bacteria concentration for every segment would reach a steady state value in a short period of time. To continue using Oak Trail Shores as an example, with 1 residence discharging continuously to segment 1, the steady state concentration in segment 1 after 10-15 days is predicted at about 482,700 MPN/100mL (Figure 33).

However in most cases, a complete malfunction, reflecting 100% of daily discharge contributed to the canal, does not occur. Rather, partial malfunction of the septic system is more common, e.g., where a tank overflows with rainwater or where a portion of drainfield malfunctions. Thus a malfunction percentage can be introduced into the model for either whole or part of the modeling period. If the malfunction percentage is 10%, the steady state concentration in segment 1 is achieved in 10-15 days as 48,270 MPN/100mL (Figure 34). Additionally, bacteria concentration in the opposite end of the canal (Segment 3) is predicted to exhibit concentrations higher than state standards.

For selected subdivisions, a second scenario was modeled to evaluate an intermittent point source. This scenario represents a short-duration septic system discharge into the cove water, as may be expected from a failure resulting from an overloaded system on laundry day once per week. This event was estimated as a 33.3 gallon discharge of raw sewage into the canal, which is also consistent with 4 hours (or 1/6 of a day's effluent) for one residential household. A maximum predicted canal/cove concentration of approximately 500 MPN/100mL is predicted by the Oak Trail Shores model, with concentration exceeding the stakeholder goal of 53 MPN/100ml in segment 1 for a duration of 3.5 days following the one-time discharge in segment 1 (Figure 35).

Model results at this location indicate that a local concentration far in excess of the state water quality standards (geometric mean of 126 MPN/100mL) can be achieved with only one residence continuously discharging all sewage directly to the canal (Figure 33). In addition, intermittent, short duration discharges from a single residence can result in locally-high bacteria concentrations that exceed stakeholder goals (Figure 35). Results across all modeled subdivisions (see Appendix E) are consistent with these general conclusions.

Considering bacteria monitoring does not indicate concentrations as high or as persistent as those predicted by the continuous discharge scenario, a continuous and complete septic system malfunction is not likely a typical failure mode in this area. Rather, order-of-magnitude comparisons of data and model predictions indicate that a more typical failure mode is one that is intermittent (occurs only under certain high-stress conditions, e.g., during a large family gathering), a failure mode that is incomplete (only a small proportion of sewage is emitted) and/or a combination of intermittent/incomplete failures by one or more systems.

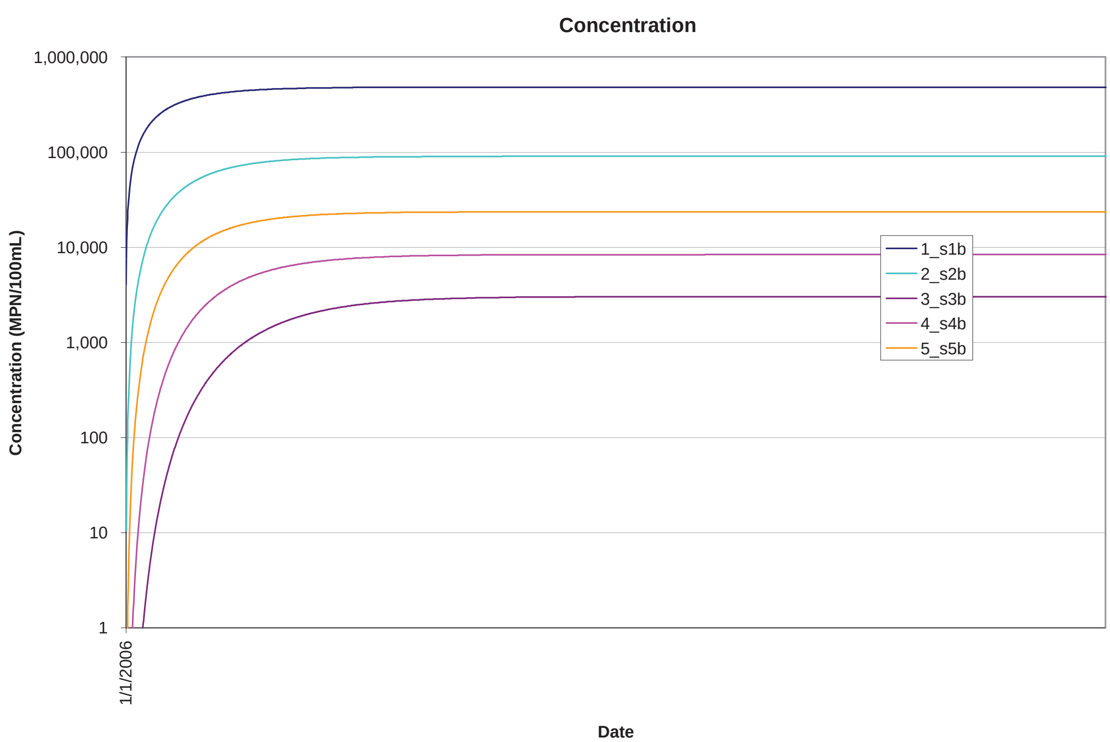


Figure 33. Bacteria concentration for each segment for continuous direct discharge scenario (1 residence)

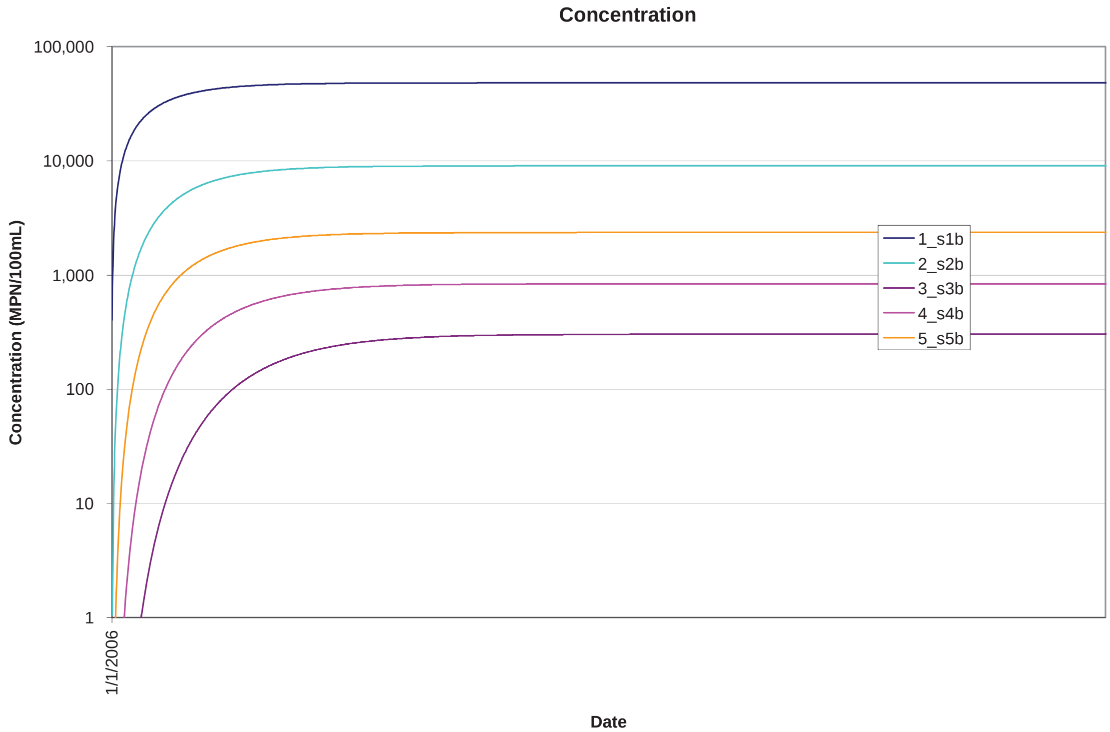


Figure 34. Bacteria concentration for each segment for continuous discharge with 10% malfunction percentage (1 residence)

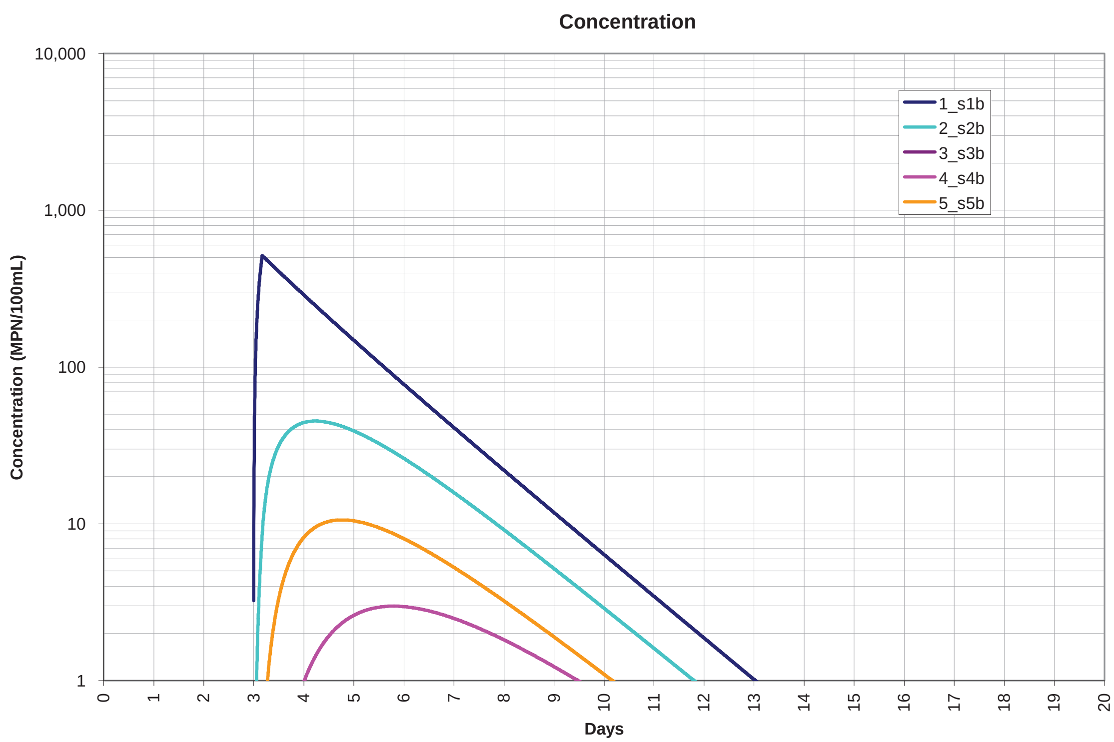


Figure 35. Bacteria concentration by segment for intermittent, one-time point discharge (1 residence)

4.8.2.2 Lake-source of Bacteria Scenario

This modeling scenario tests the hypothesis that high bacteria concentrations in the main body of Lake Granbury can cause high bacteria concentrations in the coves. Historically, bacteria concentration at long-term lake monitoring locations has been well below the state standard. The maximum values recorded at the three long-term stations were evaluated to develop an unlikely scenario that concentration in the lake could be 300 MPN/100mL. Using this concentration as a lake boundary condition in selected lake/cove models can test how bacteria may travel through natural dispersion processes from the lake into the upper reaches of the coves.

Given sustained conditions (more than 4 days) of high-concentration bacteria in the lake, concentration in Oak Trail Shores canal segments located away from the lake may get as high as the stakeholder goal of 53 MPN/100mL (Figure 36). For the selected canals evaluated, lake waters are not considered a likely source of bacteria within distal ends of canals.

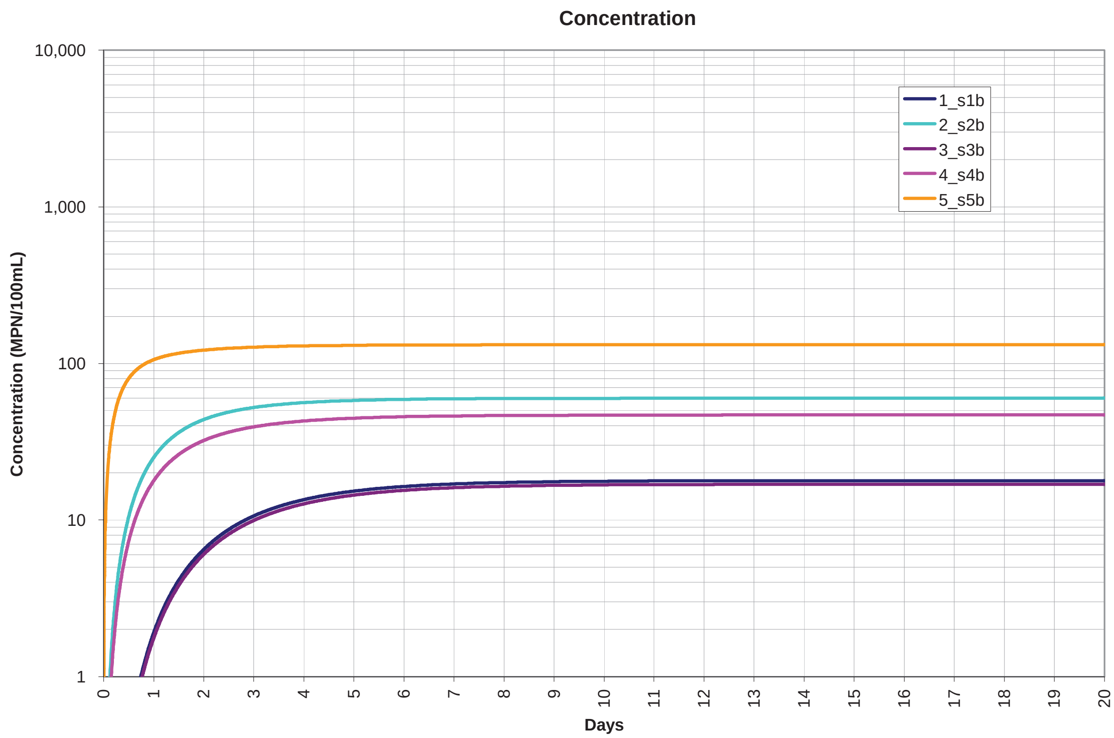


Figure 36. Bacteria concentration by segment in Oak Trail Shores- Lake Granbury as bacteria source

4.8.2.3 Nonpoint Source Surface Runoff Scenario

To evaluate how bacteria concentration in the canal may be tied to non-point source pollution and upper-watershed sources resulting from rainfall events, a time-series model scenario was developed for each subdivision for the period July 2002 through July 2008. Bacteria concentration in runoff water is assumed to be the only bacteria source for this scenario. Methods used to determine bacteria load are described below. Development of this time-series model based upon precipitation events observed near the study area allows comparison to observed monitoring data.

Surface runoff is estimated using the SCS curve number procedure (Neitsch 2002). The SCS runoff equation is an empirical model that was developed to provide a consistent basis for estimating the amounts of runoff under varying land use and soil types.

$$Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)} \qquad \text{Equation 2}$$

Where
Q_{surf} – Accumulated runoff or rainfall excess (mm H_2O)
R_{day} – Rainfall depth for the day (mm H_2O)
I_a – Initial abstractions which includes surface storage, interception and infiltration prior to runoff (mm H_2O)
S – Retention parameter (mm H_2O), approximately $I_a = 0.2S$

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \qquad (4.3)$$

CN – curve number for the day

CN is a function of the soil's permeability, land use and antecedent soil water condition. For Lake Granbury residential district, the average lot size is 1/8 acre or less, average percent impervious area is 65% and hydrologic soil is regarded as group C or D (high runoff potential). Thus a curve number $CN = 90$ is used for surface runoff calculation.

Runoff on a particular day occurs only when the depth of rainfall exceeds the initial abstractions, $R_{day} > I_a$. For Lake Granbury in this study, it is estimated runoff occurs when $R_{day} > 0.22$ inch.

The one day rainfall is expressed as a 6 hour hyetograph. As an example, a 0.5 inch rainfall hyetograph is shown in Figure 37 (Williams-Sether 2004). Historical precipitation data for Lake Granbury is available from 1985 to date, enough for the modeling period of July 2002 to July 2008.

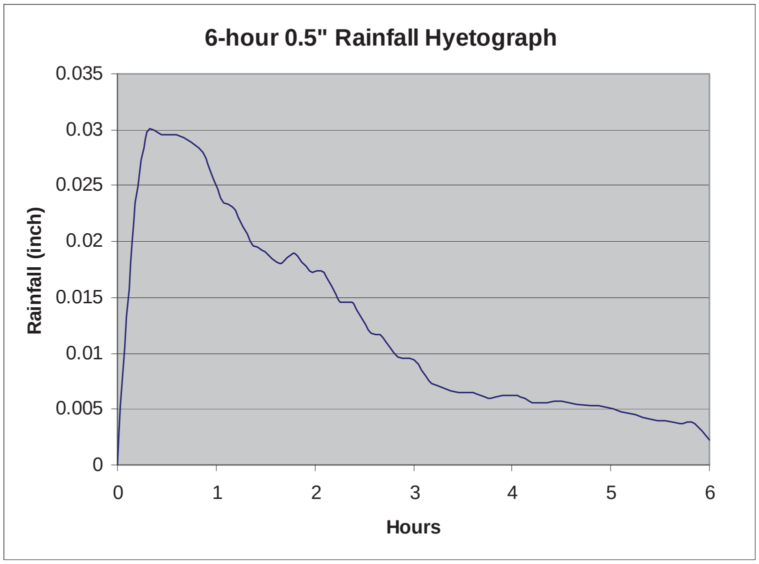


Figure 37. Hyetograph of a conceptual 6 hours 0.5" rainfall

As explained in Equation 2, accumulated runoff or rainfall is expressed in the format of precipitation depth. Therefore, the watershed area needs to be determined to calculate the runoff discharge in volume. Multiplication of precipitation depth and watershed area gives the value of runoff discharges in L/day. In this way, runoff non-point source load series were developed and applied to the water quality model.

To illustrate an example, three micro-watersheds exist near the Oak Trail Shores canal system (Figure 38), which are numbered as Watershed 1 (red polygon), 2 (yellow polygon) and 3 (green polygon). The respective areas for Watersheds 1, 2, and 3 are 110 acres, 76 acres and 58 acres.

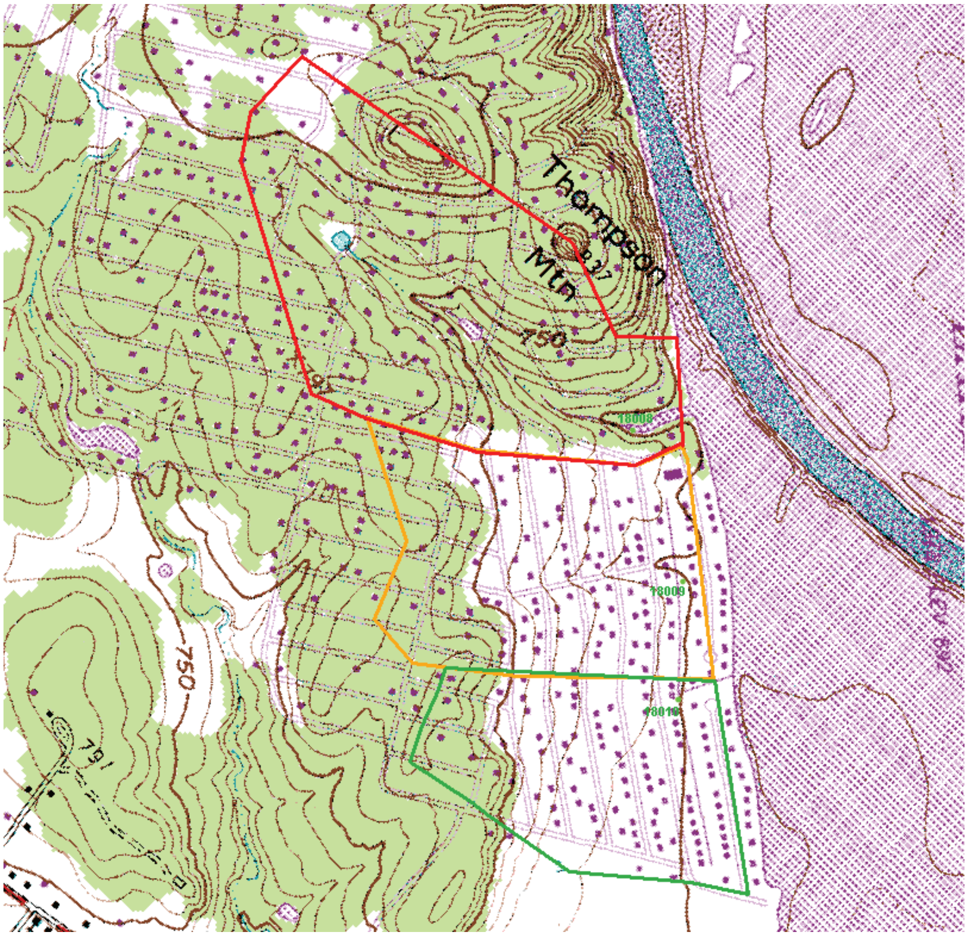


Figure 38. Micro-Watersheds at Oak Trail Shores

Because of drainage patterns observed on-site, runoff flows for Watershed 2 and 3 were applied to segment 1 and segment 3 as non-point source flow, with runoff *E. coli* concentration of 11,233.6 MPN/100ml at the same time periods of rainfall events. Resultant predicted bacteria concentration in Oak Trail Shores is shown in Figure 39 along with bacteria *E. coli* concentration monitoring data.

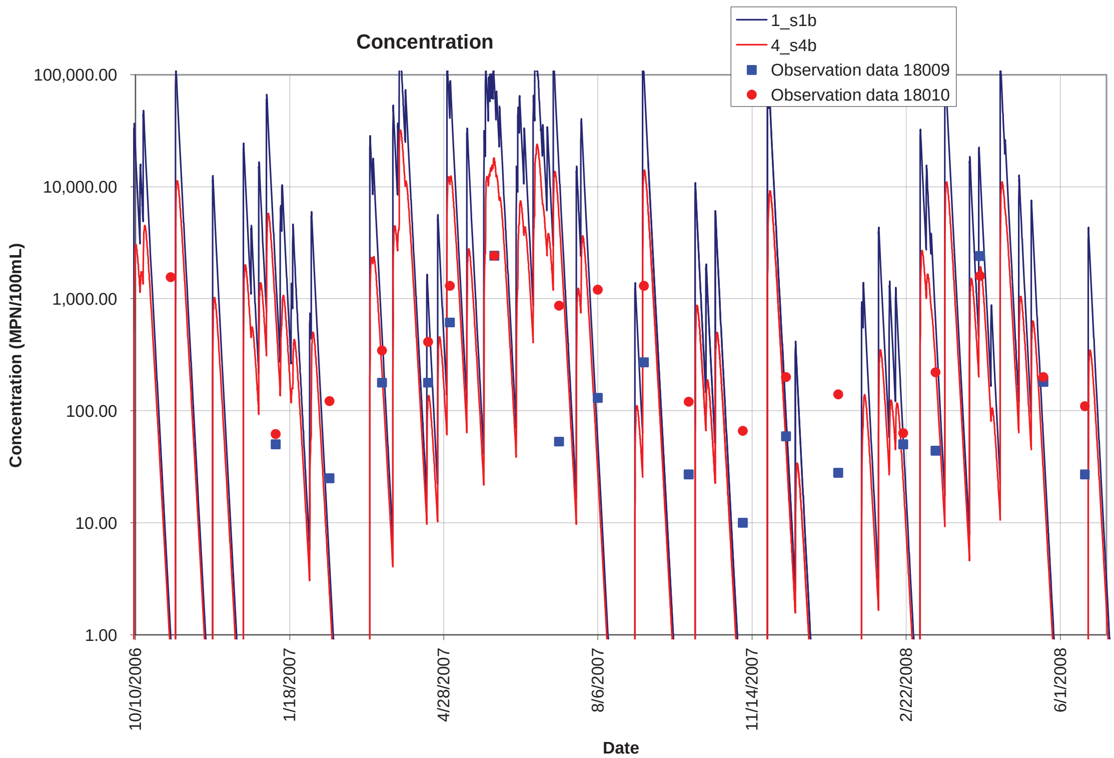


Figure 39. Predicted bacteria concentration from assumed potential non-point sources at Oak Trail Shores canal

Evaluation of time-series runoff-based model predictions was conducted by comparing bacteria predictions with observed data in coincident spatial-temporal locations. Both visual, graphical comparisons and residual analysis were used to estimate the degree of correspondence between runoff-based bacteria predictions and observations.

Figure 39 illustrates the graphical depiction of bacteria concentration modeling results at Oak Trail Shores for model segments coincident with monitoring locations. The modeling results graphics for all 10 subdivisions are shown in Appendix E. While the figures illustrate correspondence between observed values and model prediction values, the graphics provide only qualitative comparisons.

Additional quantitative validation was conducted through residual analysis. Residual analysis is performed to evaluate differences between model predictions and field observations. Residuals were calculated between on-site observed bacteria concentration and model predicted bacteria concentration within a window of time. Recognizing that analysis of bacteria field samples limited the upper *E. coli* concentration reported to 2,420 MPN/100mL (or, to a reporting value of >2,420 MPN/100mL) and the lower reporting value to <1 MPN/100mL, an alternative residual analysis was conducted by evaluating the differences "horizontally" on the time axis. For each observed bacteria concentration, a horizontal (time axis) check was performed to determine when the model prediction catches the same concentration with the smallest backward-looking time difference. This time difference was recorded for each observed data point and plotted on the residual graph (e.g., Figure 40). Given uncertainty in timing of rainfall events, only model results before the monitoring time or within 1 day following were compared. Model output greater than one day after a monitoring observation is not coincident.

Residual plots of non-point source loads from Oak Trail Shores are shown in Figure 40 and Figure 41. The time difference between monitoring bacteria concentration at station 18009 and the model predicted bacteria level in segment 1 is illustrated in Figure 40. The time difference between monitoring bacteria concentration at station 18010 and the model predicted bacteria level in segment 4 is plotted in Figure 41.

The plots are indicators of correspondence between runoff-induced model predictions and observed bacteria concentration, and provide indication of the degree of correspondence between rainfall-induced events and observed high bacteria concentration. The highest observed concentration events in the Oak Trail Shores area do correspond to predicted rainfall-induced non-point source loadings (Figure 40 and Figure 41). Lower persistent bacterial levels (< 250 MPN/100mL) in this area are evident at times more removed from runoff events indicating other bacteria factors exist nearer to the canal water body like intermittent discharge of systems (e.g. Figure 35) or pets.

For comparison to the Oak Trail Shores example, Sky Harbor station 18014 more strongly indicates a relationship between runoff and observed concentration (Figure 42). With one exception, all high bacteria events >150 MPN/100mL occur within 3 days of a model-derived, runoff-induced bacteria model prediction and concentrations remain low without runoff events. Conversely, the Port Ridglea East example (Figure 43) illustrates little correspondence to the runoff event model, indicating that the source of bacteria is less keyed to rainfall/runoff processes and more keyed to local, direct sources.

A range of results were observed for other subdivisions, as presented in Appendix E.

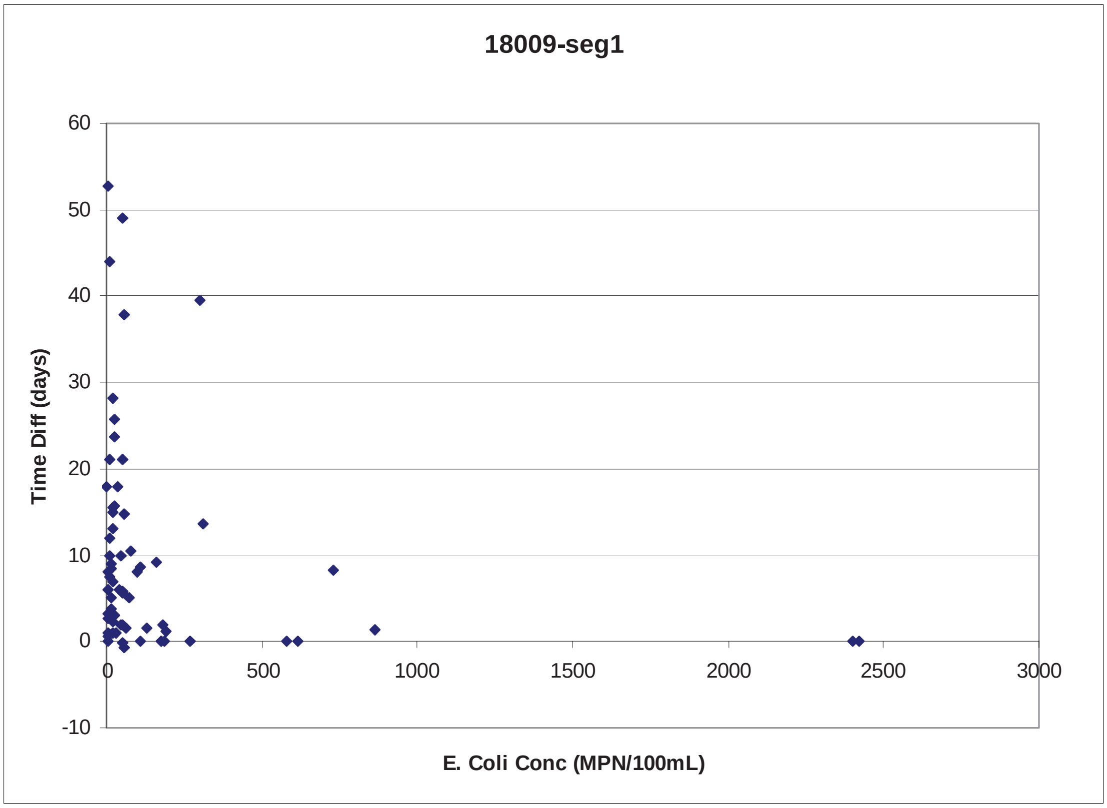


Figure 40. Residual plot for monitoring station 18009 at Oak Trail Shores

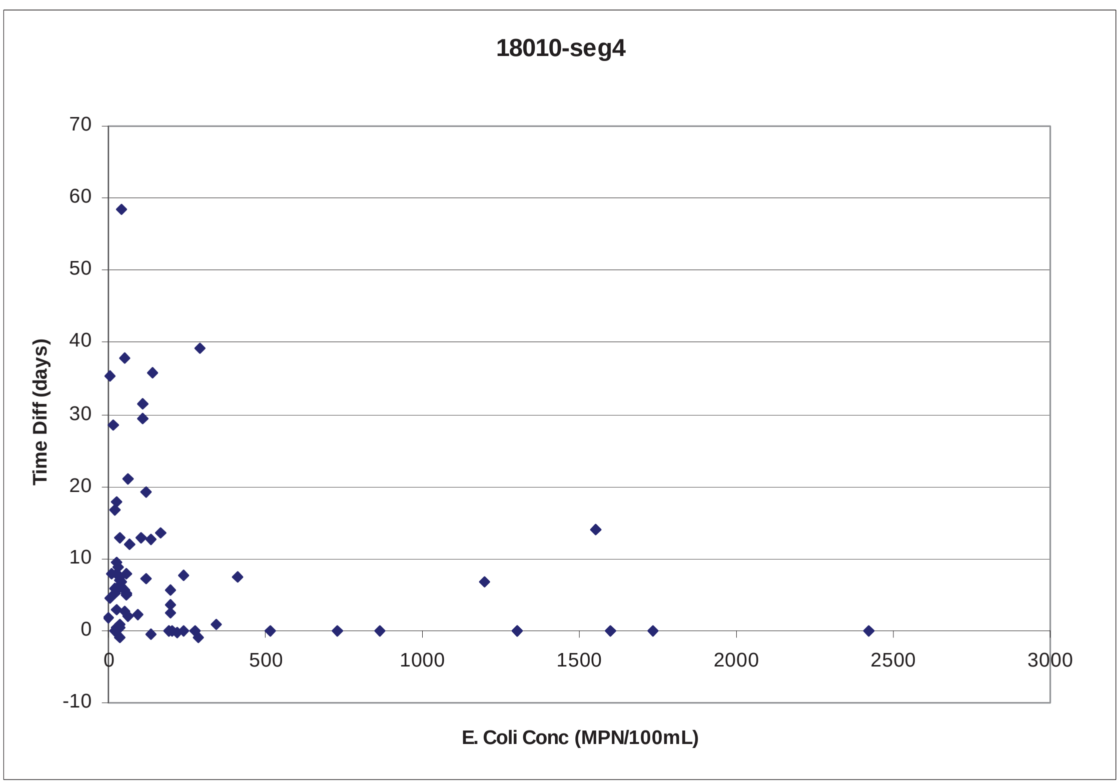


Figure 41. Residual plot for monitoring station 18010 at Oak Trail Shores

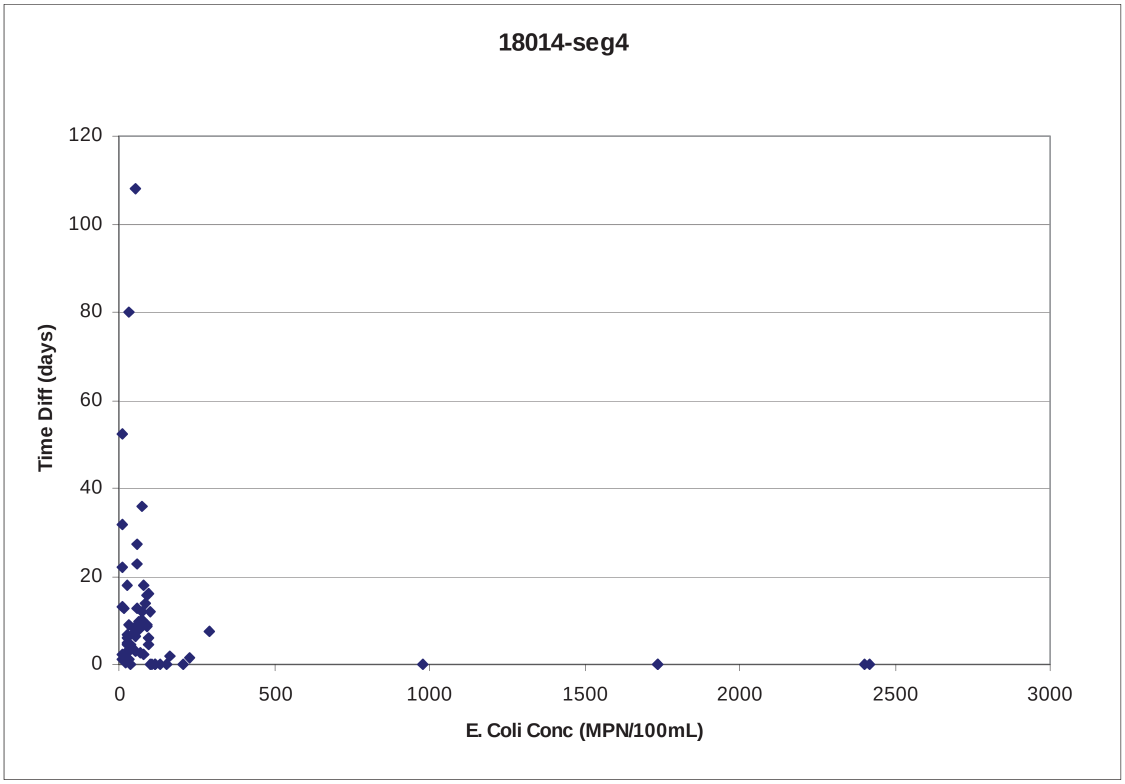


Figure 42. Residual plot for monitoring station 18014 at Sky Harbor

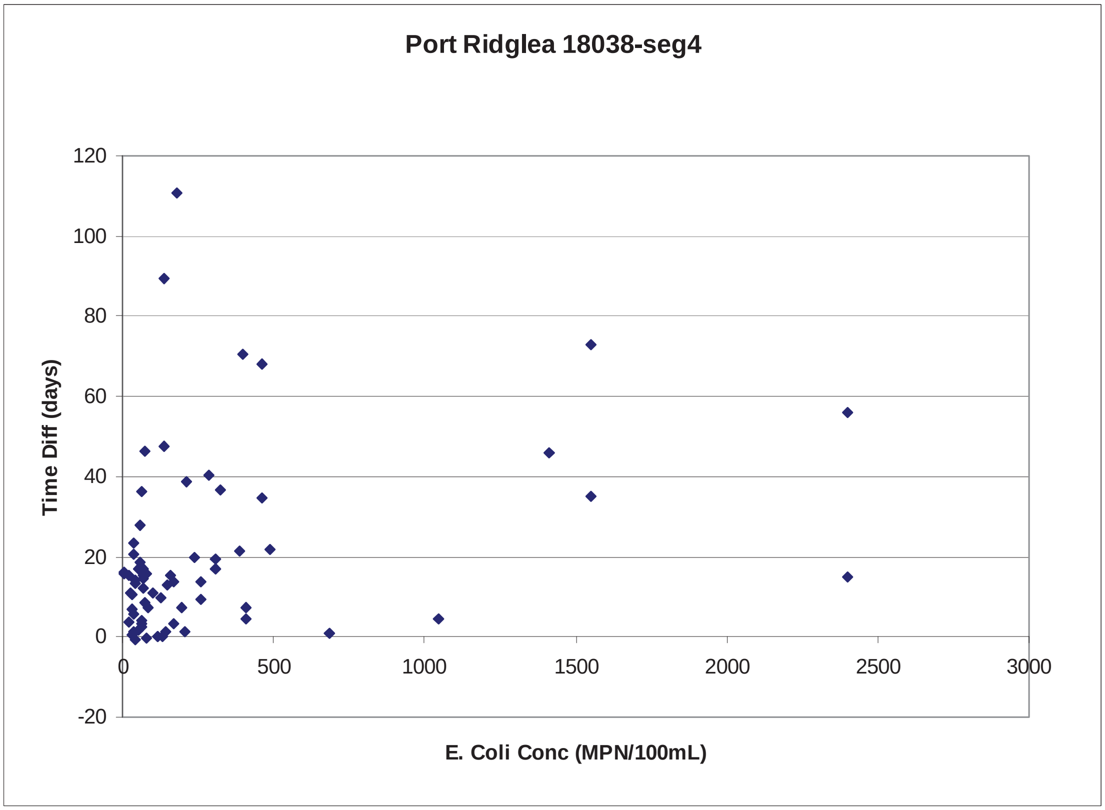


Figure 43. Residual plot for monitoring station 18038 at Port Ridglea East

4.9 MOST LIKELY BACTERIA SOURCES: COMBINED WATERSHED AND LAKE/COVE MODELING

The modeling results of both watershed potential loading models and lake/cove water quality models are combined and aggregated in this section to investigate the most likely bacteria sources for the 12 modeled subdivision areas and the three streams. Based upon these findings, possible best management practices can be identified and recommended for each of these locations.

4.9.1 Most Likely Bacteria Sources

Using the lake/cove models, most likely bacteria sources were identified by evaluating loading schema to determine which scenarios most likely resulted in the observed measurement concentrations of bacteria (Table 21). These scenarios considered the contributing watershed size, rainfall events, and cove geometries. The loading scenarios considered near-canal sources discharging waste to the canals ("Near-canal/septic") or a generic non-point source ("NPS") urban bacteria loading within the watershed away from the canal waterbody. Some canal water bodies exhibit correspondence to both loading scenarios; like Oak Trail Shores that exhibits both a strong correspondence of high bacteria levels to precipitation events (noted as NPS) while lower background bacteria levels are persistent even without antecedent rainfall (noted as Near-canal/Septic). The lake/cove modeling source evaluation does not differentiate the species of potential sources, but does provide information on near-canal sources vs. more distant watershed sources that require a rainfall event to transport bacteria to the canals.

Table 21. Most Likely Bacteria Sources identified by lake/cove modeling scenarios

Subdivision	Most likely sources
Rolling Hills Shores	Near-canal/Septic + NPS
Arrowhead Shores	Near-canal/Septic + NPS
Oak Trail Shores	Near-canal/Septic + NPS
Sky Harbor	NPS
Nassau Bay II	Near-canal/Septic + NPS
Waters Edge	No problem exhibited; NPS
Ports O' Call	Near-canal/Septic
Indian Harbor Cove	Near-canal/Septic
Indian Harbor Canal	Near-canal/Septic + NPS
Port Ridglea East	Near-canal/Septic
Blue Water Shores	Near-canal/Septic

Using the watershed SELECT model, area-weighted potential bacteria watershed loads were ranked for several watershed sources of bacteria, including cattle, deer, feral hogs, pets and septic system malfunction, for each studied subdivision (Table 22). This ranking was based on relative load magnitude from each potential source influencing the watershed(s) and the source species likely to be present within the watershed.

Table 22. Most Likely Bacteria Sources identified by watershed modeling of potential sources

Area	Most likely sources
Rolling Hills Shores	62% Septic, 38% Cattle, <1% Pets,<1%Deer
Arrowhead Shores	99% Septic, <1% Pets, <1% Deer
Oak Trail Shores	54% Septic, 46% Pets
Sky Harbor	82% Cattle, 13% Septic, 4% Pets, 2% Feral Hog
Nassau Bay II	98% Septic, 2% Pets
Waters Edge	Very low potential; Pets
Ports O' Call	>99% Septic, <1% Pets
Indian Harbor Cove	99% Septic, 1% Pets
Indian Harbor Canal	98% Septic, 2% Pets
Port Ridglea East	>99% Septic, <1% Pets
Blue Water Shores	Pets
Long Creek - Watershed	<98% Cattle, 2% Feral Hog, <1% Pets, <1% Deer
Long Creek - Cove	>99% Septic, <1% Pets
Walnut Creek	96% Cattle, 2% Feral Pets, <1% Pets, <1% Deer
McCarthy Branch	94% Cattle, 3.5% Pets, 2% Feral Hog, <1% Septic

Combining both the watershed and cove modeling approaches (Table 23) provides greater insight into the most likely sources using a multi-pronged approach to source identification. The benefit of combining these approaches is we can evaluate the types of loading scenarios occurring, relate them to monitoring data and consider watershed characteristics to further evaluate relative contributions of particular sources to the total pollutant loads.

Table 23. Model results to evaluate most likely potential sources by subdivision studied.

Subdivision	Most likely potential sources	
	Lake/cove model	Watershed model
Rolling Hills Shores	Near-canal/Septic + NPS	Septic, Cattle, Dogs, Deer
Arrowhead Shores	Near-canal/Septic + NPS	Septic, Dogs, Deer
Oak Trail Shores	Near-canal/Septic + NPS	Septic, Dogs
Sky Harbor	NPS	Cattle, Septic, Dogs, Feral hogs
Nassau Bay II	Near-canal/Septic + NPS	Septic, Dogs, Feral hogs
Waters Edge	No problem exhibited; NPS	Very low potential; Dogs
Ports O' Call	Near-canal/Septic	Septic, Dogs
Indian Harbor Cove	Near-canal/Septic	Septic, Dogs
Indian Harbor Canal	Near-canal/Septic + NPS	Septic, Dogs
Port Ridglea East	Near-canal/Septic	Septic, Dogs
Blue Water Shores	Near-canal/Septic	Dogs
Long Creek - Watershed		Cattle, Feral hogs, Dogs, Deer
Long Creek – Cove		Septic, Dogs
Walnut Creek		Cattle, Feral hogs, Dogs, Deer
McCarthy Branch		Cattle, Dogs, Feral hogs, Septic

4.9.1.1 Rolling Hills Shores

Malfunctioning holding tanks are a potential persistent source of bacteria in the coves of this subdivision; however, watershed sources, particularly livestock, are indicated as a significant potential source contributed from the upper watershed. Enforcement actions and typical septic system configurations do not rule out septic discharges as a potential source. The cove modeling schemes indicate that both continuous near-canal and runoff-event non-point source contributions do relate to the observed concentration data. Thus both models and anecdotal evidence suggests that septage is the largest contributing source followed by either livestock or wildlife from the upper watershed after runoff events.

4.9.1.2 Arrowhead Shores

The contributing watershed for the Arrowhead Shores subdivision is small. The model results indicate near-canal/septic and NPS contributions to bacteria. Since the watershed contributing to the canal in this area is small, the contributions are likely from septic systems proximal to the canal or from localized NPS (dogs, deer or other wildlife).

4.9.1.3 Oak Trail Shores

The fit of the canal model with monitoring data suggests that highest bacteria loading occurs during rainfall events; however, persistent elevated background levels also exist between rainfall events. The most likely sources are pets and OWTF/septic malfunctions. The location of malfunctioning septic contributions, whether in the watershed or adjacent to the canals, is not known.

4.9.1.4 Sky Harbor

The Sky Harbor subdivision is characterized by high population density areas with localized watersheds near the finger canals; however, less populated, large rural watersheds also drain to the main canal system. The models evaluations indicate watershed non-point sources such as livestock and wildlife appear most likely. Cattle, pets, septic, and feral hogs all have high potential for contributing NPS bacteria loadings.

4.9.1.5 Nassau Bay II

The Nassau Bay II subdivision has a small contributing watershed. The canal model indicates localized NPS or pipe leakage are the most likely sources. Further, the model indicates continuous direct discharge from residence is not the bacteria source in this area since direct discharge scenario predicts an *E. coli* concentration much higher than observed concentrations, even with discharge from just one residence. The watershed model identified the most likely sources as septic effluent, dogs, and feral hogs.

4.9.1.6 Waters Edge

No problems exhibited. This subdivision has a small contributing watershed. Direct discharge (WWTP), leaking collection system pipes, or local non-point source (pets, runoff from yards adjacent to canal) would be the most likely potential sources if a problem were to exist.

4.9.1.7 Ports O' Call/Indian Harbor

The Ports O' Call and Indian Harbor subdivisions have small watersheds comprised of residential lots adjacent to the canal water bodies. The sources of bacteria found in the canals are most likely from direct discharge (septic) or localized non-point sources (pets, runoff from yards adjacent to canal).

4.9.1.8 Port Ridglea

The Port Ridglea subdivision has small localized watersheds with some off-site runoff that enters the canals. Direct discharge from septic systems is the most likely potential source, based upon the lake/cove model since high persistent bacteria values are exhibited in absence of rainfall events. The high density of residences also indicates potential for local non-point source runoff from pet waste contributed from yards adjacent to canal. Ducks and geese in specific areas have been reported in high numbers by residents, although waterfowl count studies by BRA and TPWD did not indicate sufficient numbers of fowl to cause a problem. Though a fowl source was not modeled, the anecdotal evidence suggests management measures to address waterfowl would be beneficial.

4.9.1.9 Blue Water Shores

Blue Water Shores subdivision exhibits a small contributing watershed and residences in the area are served by a sewage collection and treatment facility. Based upon the watershed modeling, the most likely source of bacteria is from local non-point source runoff from high-density, high impervious cover yards adjacent to canal, most likely from pet waste. There is not evidence of WWTP pipe leakage, but this potential source should be investigated in further detail, given the persistence of elevated bacteria levels in absence of rainfall events.

4.9.1.10 Long Creek

Due to elevated bacteria concentrations observed at station 20220 after the start of the bacteria assessment modeling studies, the stakeholders requested further investigation of potential sources for the Long Creek Watershed. It should be noted that the Long Creek watershed does not actually include the Long Creek subdivision located downstream of the monitoring station. The stakeholders indicated that migratory water fowl congregate in adjacent headwaters of the lake. While migratory birds are not included in the models, this could be a major source of contribution during migratory season but fowl counts by BRA and TPWD did not indicate sufficient numbers to be of concern. The watershed modeling exercise indicates livestock (modeled as cattle though could be from some other type of livestock) and wildlife (primarily feral hogs and deer) as the most likely potential sources of bacteria contributing to Long Creek.

Bacteria from human activities (septic and pets) is not considered likely due to the relatively small number of residences, distance from the streams, and size of properties.

4.9.1.11 Walnut Creek

Bacteria concentration measurements at station 20229 in Lake Granbury at the mouth of Walnut Creek indicate rising bacteria concentrations that have exceeded the stakeholder goal of 53 MPN/100 mL. This noted rise in bacteria compelled the stakeholders to request further investigation into the Walnut Creek Watershed potential sources of bacteria. The Walnut Creek Watershed can be divided into four subwatersheds: Walnut Creek above the confluence with Ike Branch, the McCarthy Branch, the Ike Branch, and Walnut Creek near the DeCordova subdivision. Several pond structures exist along the McCarthy Branch reach near the confluence with Walnut Creek near the lake as well as near the creek further up in the watershed and on the golf course. These pond structures are observed to host water fowl, a potential localized source of nonpoint source pollution. Watershed contributions are likely from some type of livestock (modeled here as cattle) in upper watershed, from dogs from the DeCordova and Acton Meadows subdivisions, and feral hogs attracted to the undeveloped land and water features in these watersheds.

4.10 SUMMARY OF BACTERIA SOURCE IDENTIFICATION EFFORTS

Stakeholders and cooperators applied a multi-pronged approach in evaluating potential bacteria sources. Current and historical data indicates differences in bacteria trends for different areas across the Lake Granbury watershed (Table 1, Figure 5 and EC 2009), and investigation of spatial patterns in land use indicates a range watershed sizes and land uses for areas with elevated bacteria concentrations (Figure 9 through Figure 11). To dissect likely potential causes of elevated bacteria across the spectrum of unique areas, and to provide information to feed forward into the decision-making process, stakeholders and cooperators conducted many site-specific studies, including (1) on-site data collection; (2) bacterial source tracking studies; (3) SELECT watershed modeling bacteria assessment; and (4) lake/cove modeling within affected water bodies.

The results of the watershed efforts and the lake/cove modeling efforts were chosen to be used as basis for identification of bacteria sources. The Stakeholders carefully considered the results of site-specific bacterial source tracking (BST) studies, but decided further development of BST methodologies would be warranted before BST results could be used.

The SELECT watershed watershed modeling approach identifies potential bacteria loading across a range of sub-watersheds considering soils, slope, land use and bacteria source species. This approach was used to identify areas of high bacteria contribution potential, and to identify what sources of bacteria (e.g., human/ossf, pets or wildlife) are most suspect within each area.

Waterbody modeling within the lake/cove waters allowed evaluation of how different potential sources could affect the magnitude and timing of bacteria concentration in the water body. Considering each area’s cove/canal geometry and watershed hydrology in response to localized rainfall events, the lake/cove models helped identify whether distant upper watershed sources (e.g., wildlife or urban sources transported via runoff) or nearby watershed sources (e.g., direct discharge of residential sewage from septic/OSSF systems) were most likely to produce bacteria concentrations similar to concentrations reported in monitoring data.

From the multi-pronged approach, specific results were developed to indicate the most likely source of bacteria for each area around the lake. These results were fed forward into evaluation and identification of appropriate management measure priorities for the Lake Granbury WPP watershed.

5.0 MANAGEMENT MEASURES

Management measures can be defined as activities that are implemented within the watershed to support or achieve the goals of the WPP. Both structural and non-structural activities can achieve goals, including educational programs, inspection programs, land management programs, livestock fencing, catchment basins, construction projects or other behaviors.

As part of the WPP process for submission of plans to the EPA, an evaluation of all possible management measures is necessary to allow identification of most practicable measures for the site-specific watershed area. The analysis of management measure alternatives described in this report addresses three elements of the EPA's Nine Element WPP:

2. Estimate load reductions with each alternative
3. Proposed management measures
4. Technical and financial assistance needs

The Lake Granbury stakeholder group evaluated many possible management measures and, based upon that evaluation, recommended and prioritized measures they felt could achieve their goals. The recommendations include both a suite of lake-wide measures and a suite of site-specific measures tailored to reduce bacteria levels within particular subdivisions and small sub-watersheds.

Presented in later sections of this chapter are descriptions of structural and non-structural management measures, the criteria used to evaluate the alternative measures, and the location-specific recommendations. Technical and financial assistance needs are discussed at the end of this chapter.

5.1 PRIORITY MANAGEMENT MEASURES

In February 2009, the Lake Granbury WPP Best Management Practice (BMP) Work Group identified potential management measures to address bacteria pollution in lake and canal waters. Through a series of four stakeholder meetings held between June and September 2009, a suite of management measure alternatives, specific to each area of concern, were presented to the stakeholders. Stakeholders provided comments and guidance through this series of meetings leading to development of a final set of management measure alternatives presented to the stakeholder group in October 2009. Based upon stakeholder evaluation and input on the final set of alternatives, the following list of management measures represents stakeholder priorities, in order of priority:

1. **Watershed coordinator**
    a. A watershed coordinator should oversee implementation of this WPP; the coordinator should be capable of identifying funding sources, summarizing monitoring, coordinating with local entities and assembling the stakeholders, as necessary.

2. **Regional wastewater collection and treatment**

   a. The stakeholder group is in support of regional wastewater treatment options over on-site sewage facilities (septic systems) for areas surrounding Lake Granbury and within Hood County.
   b. Implementation of the Port Ridglea East collection system is a particular priority, given that infrastructure extensions are currently in-process.

3. **Pursue funding for all management measure alternatives**
   a. Funding for Community education programs
      i. One full-time position within Hood County for an education coordinator
      ii. Monitoring education effectiveness: Follow up surveys after education is complete to determine effectiveness in achieving goals (e.g., did homeowners discover need for repairs and/or perform maintenance?)
   b. Funding for Regional wastewater collection and treatment infrastructure
      i. Funding availability for area sewer service providers (AMUD, C.O. Granbury, etc.)
         1. TWDB
         2. ORCA
         3. EPA, TCEQ, etc.
   c. Funding availability for Oak Trail Shores alterations
         1. Drainage re-routing
         2. Dredging and opening additional outlets
   d. Funding availability for Sky Harbor catchment basins

4. **Implementation of Community Education and Management**
   a. Implement Lake Granbury WPP Educational Workplan
   b. Educate on existing NRCS programs to maximize implementation
      i. Area conservation plans
      ii. Small-acreage landowner plans
   c. Educational focus areas
      i. Urban – Septic and Pets
         1. Rolling Hills Shores
         2. Port Ridglea East
         3. Oak Trail Shores Home Owners Association (HOA) area (includes surrounding areas, Lake Granbury Estates)
         4. DeCordova Estates (Pet education)
      ii. Agricultural and/or small acreage land-owners
         1. Sky Harbor
         2. Long Creek
         3. Walnut Creek
      iii. Water fowl feeding education

5. **Support record keeping activities to assist Hood County Health District ensure compliance with existing health codes**
   a. Support routine and scheduled maintenance activity (e.g., pump-out) record keeping, enforcement or ordnances, particularly in Rolling Hills Shores where holding tanks are common

   b. Maintain database of Health District inspections and activities to assess linkage between activities and bacteria improvement

6. **Support development of HOA rules requiring all new development or expansion projects to consult with Hood County health department in advance of HOA approval**

7. **Implement regional wastewater collection and treatment –priority areas, in order of importance**
   a. Port Ridglea East (PRE) with surrounding areas – improvements are in-process for PRE
   b. Oak Trail Shores HOA area (OTS) – existing infrastructure is nearby
   c. Sky Harbor – existing infrastructure is nearby
   d. Indian Harbor and surrounding areas (Ports O' Call) – no existing treatment facilities are near
   e. Areas surrounding Port Ridglea East, including Port Ridglea West, Nassau Bay II, Sandy Beach, Holiday Estates
   f. Blue Water Shores
   g. +/-100 homes to the east of DeCordova Estates near Lusk Branch
   h. Rolling Hills Shores (RHS) and areas between RHS and OTS

8. **Improve cove circulation**
   a. Indian Harbor – install a circulation pump/fountain
   b. Oak Trail Shores HOA area – subdivision drainage re-routing and/or construction of an additional canal connection to the lake
   c. Sky Harbor – circulation, existing irrigation pumps discharging back into canal

5.2 IDENTIFYING ALL POSSIBLE MANAGEMENT MEASURES

A special workshop for brainstorming potential BMPs in the lake watershed was held in February 2009 by the Lake Granbury WPP BMP Work Group. The outcome of this workshop was a list of possible management measures that were to be evaluated (Table 24 and Table 25) for each area. The technical evaluation provided information on factors including cost and effectiveness that led to the stakeholder priority recommendations described in the previous section.

Whether arising from point or non-point sources, bacteria survival depends on moisture, temperature, pH and availability of nutrients, among other factors. Management measures, sometimes called Best Management Practices (BMPs), should be effective and practical means of preventing or reducing bacteria from entering water bodies. Non-structural measures may include public education programs, septic system maintenance, pet waste management and livestock manure management. Structural management measures may include constructed wetlands, buffers, sand filters, infiltration trenches, livestock fencing and municipal infrastructure. Implementation of structural measures clearly requires considerable planning and resources; therefore, non-structural measures may be the most practical and near-term approaches to achieve bacteria goals.

Table 24. Site Specific Non-Structural Management Measures Identified at BMP Workshop

Location	Septic Maintenance and Education for Local and Neighboring Communities (including Graywater)	Septic Management (records, inpsectors)	Urban Education on Fertilizer Application and Products	Pet Waste Education	Area Conservation Plan and Education for Ranchette/small acreage land owners	Livestock/Range Management Education	Feral Hog Education Program/ County-wide bounty program	Waterfowl Breeding Control Program/ Deter Bird Roosting Under Bridges	Waterfowl and Wildlife Feeding Ordinances and Education	Waterfowl Breeding Control Program	Collection System Sewage Lines- Maintenance and Repairs
Rolling Hills Shores	x	x		x		x			x		
Long Creek	x			x	x	x		x	x	x	
Oak Trail Shores	x	x		x					x		
Sky Harbor	x			x	x	x			x		
Nassau Bay II	x		x	x					x		
Waters Edge			x	x					x		
Indian Harbor	x		x	x					x		
Port Ridglea East	x		x	x	x				x		
Blue Water	x			x					x		x
Lake-Wide	x		x	x		x	x	x	x		

Table 25. Site Specific Structural Management Measures Identified at BMP Workshop

Location	Septic Cluster Systems	Septic System Replacement	Septic Maintenance Pump-out pilot program	Local Centralized Wastewater Treatment-Independent	Local Centralized Wastewater Treatment-Aggregate	Regional Wastewater Treatment	Cove Dyanmics: Dredge, Fill	Drainage Re-route	Cove Circulation Systems (Fountains, etc)	Catchment Basin	Property Buy Out	Filter Strips for Livestock
Rolling Hills Shores	x	x		x	x	x	x				x	
Long Creek	x	x		x	x	x						x
Oak Trail Shores	x	x		x	x	x	x	x				
Sky Harbor	+	+		x	x	x			x	x		
Nassau Bay II				x	x	x						
Waters Edge						x						
Indian Harbor				x	x	x			x			
Port Ridglea East	+	+	x	x	x	x			x			
Blue Water												
Lake-Wide						x						x

x Requested BMP Investigation
\+ Additional EC Analysis

5.3 NON-STRUCTURAL MANAGEMENT MEASURES

5.3.1 Watershed coordinator

The stakeholder group expressed a desire to have a full-time Lake Granbury WPP Watershed Coordinator which will work side-by-side with the stakeholders to implement the recommended management measures in the Lake Granbury WPP. This person's role would be to coordinate efforts of the stakeholder group and community decision-makers, as well as to keep main priorities of the WPP in the forefront of planning efforts and public awareness. Specific tasks expected of the watershed coordinator are outlined below.

- Project Administration including project oversight; quarterly progress reports to TCEQ and Stakeholders; project administration; project fact sheet; and annual report article.
- Stakeholder Group Facilitation to include coordinating meetings; update Lake Granbury WPP Webpage with Agendas, Meeting Materials and Minutes; engage stakeholders; and maintain stakeholder list and general public notification list.
- Resource Identification, Grant Writing, Funding Requests and Procurement of Services to include identify resources; assist stakeholders in grant writing and preparing funding requests; assist stakeholders in procurement of services; and track implementation of construction-based management measures as outlined in the WPP.
- Local Orders, Ordinances and Homeowner's Association Regulations to include drafting and presenting a County Order and City Ordinances prohibiting the feeding of wildlife and waterfowl within one mile of the reservoir; recommend Homeowner's Association Regulations regarding OSSF expansions; and track implementation of Local Orders, Ordinances and Homeowner's Association Regulations.

5.3.2 Public Education Programs

Public awareness of the importance of bacteria level control is important for the water quality management in Lake Granbury area. Educated residents are more concerned about the water quality condition, are aware of their personal responsibilities and are more willing to help on funding initiatives or field study participation. A comprehensive, detailed summary of watershed education and outreach programs is provided in a separate section of this watershed protection plan. The vision of the stakeholders is to have a dedicated education coordinator for Hood County and the Lake Granbury watershed who can participate in implementation of the education program. The Education Coordinator will develop, track the implementation, and evaluate the effectiveness of the education plan management measure requested by the Stakeholder's as well as publicize the WPP efforts.

For other areas in Texas, bacteria-targeted educational programs similar to those outlined in the Lake Granbury Education and Outreach Plan (see Section 6.0) have been shown to be very effective. For example, 100% of individuals responding to post-course surveys indicate an increase in knowledge of septic system operation. Of those respondents, 54% to 65% indicate willingness to change practices that include performing regular septic system maintenance, particularly to aerobic disinfection units (TAES 2009). While literature or studies are not available to translate educational effectiveness to load reduction effectiveness, it is anticipated that educational programs will provide load reductions in two ways: (1) through actual load reductions realized through increased efforts to repair and maintain OSSF systems, and (2) through increased awareness and participation in associated strategies that manage and reduce bacteria loading (e.g., pet waste or livestock manure management programs).

5.3.3 Septic System Maintenance and Record-keeping

Septic system malfunction is a major potential source of bacteria within the coves of Lake Granbury. By maintaining a septic system regularly and repairing problems as they are discovered, likelihood of malfunction and contamination to receiving waters is less likely. Routine maintenance also extends the longevity of the septic system, reducing costly repairs or replacements.

In practice, septic system management includes routine septic inspections and pump-outs. Conventional septic tanks should be inspected every three years and pumped as needed, or when the tank solids level increases to about 1/3 filled. The inspection and service records can be tracked and reported, particularly in areas with holding tanks requiring frequent pump-outs (this may be weekly pump-outs for full-time residents). A requirement for permit holders to maintain and annually submit pump-out records would promote compliance with existing regulations.

The most significant constraint for this measure would be the limited staff available through the local health departments to perform routine inspections for all systems within the watershed .

5.3.4 Pet Waste Management

Unlike other bacteria sources, pet waste can be simply and economically managed by individual residents. This measure conveys the importance of cleaning up after pets and ensuring proper disposal of pet wastes through the distribution of marketing materials such as signs, radio and TV advertisements, and mail outs.

5.3.5 Livestock Manure Management

Livestock manure, particularly from cattle populations, are a significant source of bacteria and in some areas can be a significant source to Lake Granbury. Runoff from barnyards or livestock areas may have the highest potential of any agricultural operations to contaminate waterbodies. Moreover, livestock access to streams results in direct discharge of bacteria into water. An additional potential source is runoff from fields where manure is applied as fertilizer. The proper collection, storage, transportation, and application of animal waste can significantly reduce potential bacteria contamination.

Agencies such as the local Texas AgriLife Extension agent, NRCS, and SWCD already have programs established to work with individuals to develop conservation plans and seek cost share funding. The Texas Farm Bureau currently maintains a website dedicated to sharing information and providing links to these publicly available resources. The biggest challenge is motivating landowners to voluntarily seek available help. This will be addressed in the Lake Granbury watershed through the educational programs recommended by the stakeholders.

5.3.6 Other Watershed Management Approaches

Several other management options were proposed by the Work Group including education on fertilizers and pesticide applications; discouraging waterfowl and other wildlife feeding in the watershed, wildlife control programs such as feral hog bounties; education for property owners of small acreage plots as well as "ranchette" conservation practices; and range management education and incentives for large acreage lands with agricultural practices. The combined effect of implementing these suggestions across the lake and surrounding watershed are anticipated to reduce the bacteria contributions to the lake. In addition, many of these practices will also reduce nutrient contributions arising from the same sources.

5.4 STRUCTURAL MANAGEMENT MEASURES

5.4.1 Septic Replacement

This management measure consisted of replacing aging septic systems, which would minimize potential for bacteria transfer to water bodies. The average life span of a septic system is approximately 20 years and many near-lake subdivisions were established over 25 years ago. Replacement of the drain field is likely required if the system has not been maintained properly over time (e.g., pumped every 3-5 years). Additionally, the design of most existing systems in the area would not meet current standards and all repairs, revisions or replacements must meet current standards.

In the Lake Granbury area, the typical onsite sewage facility consists of a conventional septic tank and drain field. Typically, the soil types in most areas surrounding the lake are not suitable for conventional systems so alternative treatment systems, such as aerobic tanks with drip emitters, would need to be installed if these communities remain on individual OSSFs/OWTFs. More suitable alternative treatment systems are often more expensive than conventional systems and may be a financial burden on the economically disadvantaged citizens in these communities. Because of awareness and collaboration among WPP stakeholders, grant assistance was provided by the Texas Department of Rural Affairs (formerly the Office of Rural and Community Development, ORCA) at the outset of this WPP process. The grant was for replacement of malfunctioning septic systems owned by disadvantaged citizens within the project area.

5.4.2 Local Collection Systems

Another measure that minimizes bacteria transfer to water bodies is installation of community-wide sewage collection systems.

Service pipes for sewage collection are either designed for gravity flow or under low pressure. Gravity lines require a positive slope and are the most efficient collection system. However, gravity collection is less suitable in areas with hilly terrain, negligible slope, within the floodplain or where the water table is high. Given all of these conditions in the vicinity of Lake Granbury, a low pressure system is most appropriate in most areas. Low pressure lines require a grinder pump & water-tight small diameter pipes that minimize wet weather peak flows. The use of small diameter pipe at shallow depths minimizes installation costs. An efficient combination of low pressure and gravity collection could be utilized in some areas where appropriate.

For planning-level conceptual design of the collection systems for areas near Lake Granbury, the maximum assumed total dynamic head allowable is 185 feet, wastewater discharge rate for each residence of 200 gallons per day, and one grinder pump per connection (for low pressure lines). Lift stations to deliver waste to off-site Waste Water Treatment Plants (WWTP) are sized per TCEQ regulations for peak design flows.

Once collected, two options were considered for treatment of waste. Construction of a small local package plant may be an efficient option for communities distant from existing treatment infrastructure. For communities near existing or proposed regional treatment facilities, construction of trunk lines and lift stations from the community to the facility may be more efficient and preferred.

5.4.3 Local Centralized Wastewater Treatment

Treatment of waste collected from a small community or subdivision may be handled by a nearby package plant or mini-wastewater plant. These plants are defined as facilities which treat up to 0.5 MGD. These plants are generally steel or concrete construction, depending on anticipated life-cycle need. Steel construction is typically less expensive and has an approximate 20-year lifespan whereas concrete construction has a longer lifespan but is more expensive. This option may be appropriate for communities located long distances away from existing infrastructure or where other physical and economic limitations exist. Stakeholders indicated that vigilant maintenance and operation of these types of small facilities is imperative to reduce threats to the lake if a malfunction were to occur.

5.4.4 Regionalized Wastewater Treatment

Several WWTPs already exist in the Lake Granbury area that could potentially provide treatment capacity to additional communities needing service. The active sewer utilities in Hood County include:

- Acton MUD
- Aqua Texas, Inc.
- City of Cresson (proposed)
- City of Granbury
- Fall Creek Utility Company, Inc.
- Laguna Vista LTD
- Texas H2O, Inc.

Two entities, the City of Granbury and Acton Municipal Utility District (AMUD), currently have additional capacity and/or plans to add future capacity that may help fulfill needs to the Lake Granbury area. In addition to their existing facilities with permitted waste treatment capacity of 2.0 MGD, the City of Granbury (2009) is developing plans for a 10 MGD plant north of Granbury. AMUD has existing treatment capacity on the southeast side of the lake and is currently developing plans to add capacity. Additionally, AMUD has a sewer Certificate of Convenience and Necessity (CCN) on the south west side of the lake so may be able to provide sewer service to that area if funding for infrastructure construction is available and attractive.

5.4.5 Cove/Canal Dynamics

The stakeholders expressed interest in evaluating the effects of construction projects involving modification of existing canal systems that would improve the cove water exchange dynamics. The concept is to improve water movement through coves to decrease stagnant water, encourage “flushing” of pollutants, and improve cove aesthetics. Modification projects could include partial filling or dredging (or some combination of both), or creation of additional connections to the lake to physically change the cove designs.

Some concerns related to the “fill” option are reduction in water frontage, flood zone impacts need to be considered per NFIP Rules, and permitting requirements per USACE 404 and TCEQ 401 Water Quality Certifications. Considerations for the “dredge” option include increasing the depth or water frontage, sediment removal and continued maintenance cycles.

5.4.6 Cove Circulation Systems

To promote water movement and decrease stagnation within canal water bodies, cove circulation systems could be constructed to improve water quality. These systems typically consist of floating water fountains, aeration systems, or more complex systems incorporating pipe network and water intake-discharge components.

A floating fountain feature, the cheapest option, would provide improved circulation to only a small area of the cove near the water surface. This would improve the oxygen in the immediate vicinity of the fountain but not provide any movement or flushing out of pollutants. An aeration system would be comprised of a compressor at the bottom of cove, creating air bubbles and is effective for increasing dissolved oxygen and improving circulation for a larger area than a simple water fountain. These options are not anticipated to provide significant reduction in bacteria levels.

A water intake-discharge system would convey water from the lake and discharge at the head of the canal/cove promoting circulation and flushing. This option requires a more complex design, and more expensive equipment, but could reduce bacteria concentrations in the canals by dilution with low-bacteria concentration lake water.

5.4.7 Off-site Drainage Bypass

Drainage patterns can be modified to redirect runoff away from the canals and coves. This may prevent pollutant loading from pesticides, pet waste, etc. Modifications may include adjustment of infrastructure (swales, culverts, storm drains, etc.) to re-direct the path of stormwater with associated pollutants.

5.4.8 Catchment Basin

Catchment basins are a type of structural management measure to “catch” and temporarily store runoff from the watershed before discharging to the coves or lake. Wet ponds, a type of catchment basin, can be highly effective at reducing both bacteria and nutrient loads if properly designed and maintained. Wet ponds treat runoff constituents by allowing solids to settle and through biological uptake from plants.

5.4.9 Vegetative Filter Strips

A vegetative filter strip (VFS) is an area of vegetation that is intentionally planted to help remove sediment and pollutants from storm water runoff. Engineered strips of vegetation slow and filter runoff allowing plant uptake of nutrients. Similar to sediment capture, bacteria is also trapped by settling allowing exposure and sunlight to facilitate the die-off rate.

5.5 CRITERIA FOR EVALUATING ALTERNATIVES

The stakeholders evaluated all management measure alternatives using four criteria to prioritize and select area-specific best management measures. These criteria included each measure's potential to reduce pollution; time to implement; annualized cost per residence (including O&M); and site-specific feasibility considering constraints.

Funding is not included as a criterion for choosing appropriate management measures but was recognized as one of the most important considerations when it comes to actual on-the-ground implementation. Ability to fund projects will become the primary factor in determining which stakeholder-determined priority management measures become implemented.

5.5.1 Pollutant Reduction Potential

The percent reduction of bacteria level was evaluated using the Lake Granbury models as appropriate for each management measure. For predicting the change in concentration of bacteria considering cove interactions, the lake modeling tools were utilized. Where changes in pollutant source loading were predicted, the results from the watershed modeling tools were utilized. Where these models were not appropriate for determining the effectiveness of management measures and expected reductions, assumptions were based upon researched literature values specific to each management measure.

The current WPP goal is to obtain water quality at or below 53 MPN/100 mL geometric mean concentrations for *E. coli* bacteria. This goal is much more conservative than the state standard of 126 MPN/100 mL and promotes increased recreational health and overall health of the waterbodies. Unfortunately there are limitations in predicting the reductions of concentrations based on model results, and evaluation of model predictions against the numerical goal is challenging. For example, the watershed model determines the total potential bacteria colonies on the land surface on a given day. Logic suggests that a reduction in this total load will result in a reduction in the amount of bacteria transporting into the water body; however, this is not a direct 1:1 reduction in concentration since this would depend upon the size and timing of rainfall events as well as understanding more precisely the die-off mechanisms of the bacteria as they move from one environment (in fecal matter on the land surface) to another (overland runoff and eventually the larger cove waterbody).

The lake modeling tools can predict the expected change in concentration for a given event and change of scenario such as modifying the cove dynamics. The limitation of these models is that they are based upon literature values for input bacteria load but do not account for the variability of bacteria load according to storm event magnitude. Thus these tools are helpful for determining the change of concentration in the cove for constant source concentrations but evaluation of variable bacteria loading is challenging.

Despite the limits of the model predictions, these tools can effectively evaluate which management measures would have the greatest potential for bacteria reduction and ability to achieve stakeholder goals. An example evaluation matrix for possible management measures for the Oak Trail Shores subdivision is provided in Table 26.

5.5.2 Cost of Management Measures

The Lake Granbury WPP Financial Workgroup was formed to evaluate the economic assessment conducted by the project team. Composed of stakeholders or their designees, work group the stakeholders appointed members whom they felt had appropriate experience with finance, economics and proposed management measures. The Financial Work Group met to discuss and evaluate the BRA and EC project team's proposed economic analysis method and assumptions. The Work Group approved the project team's assumptions and approach to estimating costs, as outlined below.

A robust economic model must consider varying cost parameters such as initial capital investment, operation and maintenance costs, interest, and financing. The Equivalent Annual Cost (EAC) method considers these varying parameters in calculating the per-year cost of owning an asset over its entire lifespan (Equation 3). EAC is a common method for comparing alternatives using present value to consider different life cycles, different initial capital, and different O&M expenses (Figure 44).

EAC = Capital Cost * Annuity Factor + Net Present Value of O&M Equation 3

Where:

Annuity Factor = $r * (1+r)^t / [(1+r)^t - 1]$

r = weighted cost of capital (interest rate)

t = lifespan in years of capital project

The cost of management measures is determined through a series of conceptual designs and assumptions. For example, conceptual collection system layouts were developed for each of the subdivisions; capital cost estimates were developed from materials estimates considering sewer line lengths, preliminary sizes, manhole spacing, lift station sizing and other factors as appropriate. Land costs were estimated where right-of-way or facility construction was anticipated and professional costs were included as associated with design, administration and permitting. A contingency factor was also added to account for unanticipated costs that may arise during a less conceptual design process or during construction.

Operations and maintenance (O&M) costs were developed and applied annually considering life cycle of system components (e.g., grinder pump replacement interval), by industry standard estimates or by estimates provided by stakeholders. Similarly, sources of capital costs included information provided by local entities (particularly City of Granbury and AMUD), recent experience in Texas and a materials and labor cost estimating tool RS Means. Appropriate area-specific adjustments were applied for the project area within Texas.

All cost estimates were based upon 2008 averages. Given the fluctuation and adjustment of financial markets in 2009, significant uncertainty may exist in carrying absolute costs forward into the future. However, since nearly all sectors were affected by the fluctuations, it is anticipated that relative future costs will remain similar to relative 2008 costs.

Finance costs were not included because of uncertainty related to methods of financing projects. Some areas with greatest needs may qualify for grants, low-interest or no-interest government loans. Other areas may need to finance projects entirely based upon tax or bond revenue.

Assumptions specific to each area and each management measure alternative are provided in Appendix F.

To consider economies of scale, the total EAC for each management measure was divided by the number of homes it would benefit. This step allowed for consideration and comparison among different areas having different home densities.

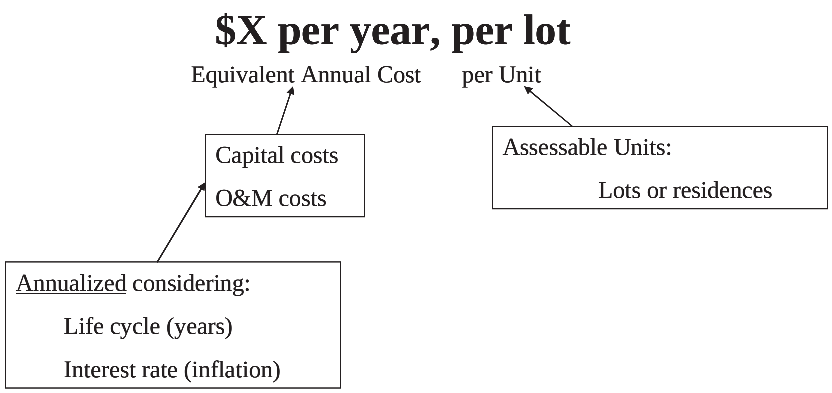


Figure 44. Diagram of Equivalent Annual Cost Inputs

The conceptual nature of these cost estimates and the economic instability in 2009 led to uncertainty in future capital costs and finance rates in comparison to historical costs and rates. To keep focus on relative comparative costs between alternative management measures, the EAC is presented as an annualized cost index (Figure 45). The index allows comparison of costs among alternatives (e.g., how much more expensive is one alternative than another) without focus on absolute costs or out-of-pocket dollars. While stakeholders did express considerable interest in absolute anticipated costs, they understood how planning-level conceptual cost estimates are less accurate than an on-the-ground construction bid for a project ready to break ground. So rather than focusing on absolute costs for this planning-level evaluation, the stakeholder group chose to focus on relative costs. The Financial Work Group agreed that the project team's approach to relative cost was suitable for their comparative purposes.

$$COST\_INDEX = \frac{[alternative\_\mathrm{cost}]}{[\mathrm{max}imum\_\mathrm{cost}]}$$

Figure 45. Cost Index

5.5.3 Time to Implement

An important consideration for planning management measures is the amount of time required to fully implement the measure to achieve full expected bacteria reduction. Depending upon the complexity of the alternative, the evaluation and decision-making steps alone can take considerable time, potentially years. For major projects like construction of multi-million dollar waste treatment facilities, involved parties must formalize agreements to move forward with a particular alternative, conduct conceptual preliminary planning, land acquisition, seek funding, obtain funding, and pursue inter-local agreements to move forward. Permitting (e.g., such as establishing CCN boundaries for new utilities or NPDES permitting) and full engineering designs must be pursued prior to the start of construction.

This factor was used to identify and consider how complex infrastructure may take years to implement, whereas educational measures or placement of a simple water fountain may become implemented in less than a year.

5.5.4 Constraints and Other Considerations

Throughout the management measures analysis, the feasibility of each measure was considered for each specific site. This evaluation criterion was qualitative which allows stakeholders to address items not easily quantified in other categories. Active participation of stakeholders allowed identification of constraints affecting particular areas. Some examples of design constraints and considerations include compatibility with existing capital improvement plans; compatibility with local ordinances; floodplain considerations; discharge permitting; and navigability within the cove/canal systems.

5.6 SELECTION OF MANAGEMENT MEASURES

This section presents for one area, Oak Trail Shores, an example of how the stakeholders evaluated, selected and prioritized management measures appropriate for including in this WPP. A similar process was completed for each of the remaining areas; corresponding detail for remaining areas is included in Appendix F.

Numerous management approaches were considered for the Oak Trail Shores area because of the complicated interaction of drainage patterns, lot density, development patterns and subdivision age. Other subdivision areas exhibit different characteristics than Oak Trail Shores; this generally resulted in fewer management measures being evaluated for the other areas.

A matrix table summarizing the four major evaluation criteria (i.e., bacteria reduction, time to implementation, cost index and constraints) was developed (Table 26). The list of alternatives was sorted first according to bacteria reduction potential, then according to cost index, then according to implementation time. Additional considerations and constraints were discussed as they related to feasibility of implementation. Bacteria reduction associated with educational programs was not quantified in this exercise; however, all stakeholders are in strong support of educational initiatives. While stakeholders anticipate load reductions based upon studies showing the effectiveness of related educational programs in changing public practices (e.g., TAES 2009), their expectation of the magnitude of load reduction is realistic in that anticipated education-based reductions are not as high as those anticipated from structural measures.

Stakeholders compared and considered management measure alternatives, giving higher priority to measures targeting reductions in source bacteria (e.g., sewage collection systems). Lower priority was given to measures targeting infrastructure changes resulting in reduced bacteria concentrations without reducing source bacteria (e.g., re-routing stormwater drainage, or increasing circulation within cove water bodies).

Significant input was provided by HOA members in this area resulting in additional management measures being considered and incorporated into the priority list. A priority should be to promote HOA regulations requiring, prior to HOA approval, health department approval of plans to increase the size of any existing dwelling.

While priority management measures for each area were not explicitly identified, discussion and evaluation of area-specific alternatives, in conjunction with identification of priority areas, led to development of the list of regional priorities in Section 5.1.

Table 26. Example matrix of alternative management measures, Oak Trail Shores Subdivision

Area	BMP Alternative		% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Oak Trail Shores 1,653 units	Cove Dynamics:	Dredge, Add Outlet	65%	2-5 yrs	0.84	1.29	Does not address source(s);
	Regional Wastewater Treatment (include neighboring areas)		54%	10-15 yrs	0.26	0.48	
	Local Centralized Wastewater Treatment - Aggregate		54%	5-10 yrs	0.33	0.62	
	Regional Wastewater Treatment		54%	10-15 yrs	0.35	0.66	
	Local Centralized Wastewater Treatment - Independent		54%	2-5 yrs	0.38	0.71	
	Drainage Re-route		51%	<1 yr	0.07	0.14	
	Septic System Replacement	Section 1	41%	<1 yr	0.38	0.94	
		Section 3			0.73	1.81	
		Section 2			0.50	1.24	
	Cove Circulation: Intake/Discharge		39%	1-2 yrs	0.20	0.51	Infrastructure may impede navigation; Does not address source(s)
	Cove Dynamics:	Dredge	30%	1-2 yrs	0.57	1.91	Does not address source(s)
	Septic Maintenance and Education			<1 yr			
	Pet Waste Education			<1 yr			
	Septic Management (records, inspectors)			1-2 yrs			
	Waterfowl and Wildlife Feeding Ordinances			1-2 yrs			

5.7 SELECTION OF PRIORITY AREAS

Recognizing that resources may not be available to implement management measures for all of the areas in the near timeframe, the stakeholders prioritized which areas they felt should be addressed first (Table 27). Prioritization of areas was based largely upon existing bacteria levels in comparison to the identified goal of 53 MPN/100mL. Additional consideration was given to areas located near existing facilities capable of satisfying needs, or to subdivision groups that could benefit from economies of scale.

For example, Indian Harbor is not the top priority despite the highest bacteria levels. The most likely source of bacteria is from septic systems, so a collection system and treatment plant would provide the best potential reduction in bacteria; however, treatment facilities would need to be developed for this area since none currently exist or are proximal. Adjacent areas (Ports O' Call and Rough Creek Cove) should be considered during development of plans for new facilities, so are at the same priority level.

In contrast, higher priority areas currently have plans under way to provide service (Port Ridglea East) or have near-by existing sewer lines with sufficient capacity (Oak Trail Shores and Sky Harbor). In addition, both Oak Trail Shores and Sky Harbor areas have multiple potential bacteria source mechanisms that may require multiple management measures to address; these areas may take more work and resources to achieve improvements than Indian Harbor.

Acton Municipal Utility District (AMUD) provided the following information in consideration of prioritizing efforts: For each of the last 3 years, AMUD has filed an IUP with the TWDB under the CWSRF to provide first time sewer service for residents of Port Ridglea East, Port Ridglea West, Nassau Bay II and Holiday Estates – all within a single project. Just as Ports O' Call and Rough Creek Cove have been tied closely with Indian Harbor in this table due to their close proximity to each other, the Nassau Bay II, Holiday Estates, Sandy Beach and Port Ridglea West should be tied closely with PRE. Receiving facilities are already in close proximity to this area, a concept plan with related costs has been developed, and the project could move quickly given adequate funding.

5.8 SOURCES OF FUNDING

Successful implementation of management measures outlined in the Lake Granbury Watershed Protection Plan is dependent on acquisition of funding. Some high priority measures will require significant funding for both initial implementation as well as future sustainability. Other management measures may only need minor adjustments to current activities. Traditionally, funding is available at the federal, state and local levels of government. Creative approaches to satisfying funding requirements (e.g., matching) will be needed. A number of potential funding sources should be investigated; a collection of some potential funding avenues are provided in Appendix G.
The stakeholder group was provided with information on several relevant programs. Staff from state and federal funding agencies made presentations during stakeholder wpp meetings.

Table 27. Priority areas and bacteria concentrations (geomean in MPN/100mL)

Area	E. coli Range (MPN/ 100mL)	Geometric Mean (MPN/ 100mL	% Samples Above 53	% Samples Above 126	% Samples Above 394	Stake-holder Priority*
Port Ridglea East	1 - >2420	73	58%	31%	10%	1
Oak Trail Shores	1 - >2420	70	50%	34%	17%	2
Sky Harbor	1 - 24000	63	50%	29%	14%	3
Indian Harbor	1 - >2420	71	55%	29%	11%	4
Ports O' Call	1 - 170	9	10%	2%	0%	4
Rough Creek Cove	1 - 249	8	9%	4%	0%	4
Nassau Bay II	1 - 921	27	36%	16%	3%	5
Port Ridglea West	1 - 1120	26	28%	14%	5%	5
Holiday Estates	1 - >2420	25	32%	17%	2%	5
Blue Water Shores	1 - >2420	37	36%	23%	9%	6
Walnut Creek	7 - >2400	124		48%	20%	7
Rolling Hills Shores	1 - >2420	27	35%	24%	13%	8
Arrowhead Shores	1 - 1733	14	19%	8%	5%	8
Canyon Creek Cove	1 - 2400	8	9%	5%	6%	
Waters Edge	1 - 1986	17	22%	10%	3%	
Mallard Pointe	1 - 410	9	16%	11%	2%	
Long Creek	10 - 24000	156		43%	25%	
Strouds Creek	8 - >2400	105		34%	20%	
Rucker Creek	5 - 6100	100		36%	23%	
Robinson Creek	4 - >2400	76		30%	16%	
Lambert Branch	1 - 1600	22	29%	11%	4%	
Brazos River at Lake Country Acres	1 - 8665	28		25%	20%	
Lake Granbury at Business 377	1 - 1400	6	7%	4%	1%	
Lake Granbury at 51	1 - 2400	5	8%	7%	2%	
Lake Granbury Dam	1 - 326	2	2%	2%	0%	

Data through May 2010
*Ranking per October 2009 Stakeholder Meeting

Table 288. *E. coli* Reductions Needed by Area to Meet Stakeholder Goals

Area	% *E. coli* Reduction
Port Ridglea East	27
Oak Trail Shores	24
Sky Harbor	16
Indian Harbor	24
Walnut Creek	57
Long Creek	66
Strouds Creek	49
Rucker Creek	47
Robinson Creek	30

USDA Rural Development has a Hood County specialist. Rural Development offers infrastructure (collection and treatment facilities) funding in two general classes: low interest loans and grants for small municipalities, and low interest loans and grants for qualifying individual low-income homeowners.

USDA Natural Resources Conservation Service (NRCS) also has a Hood County representative. The NRCS works with voluntary individuals and can provide technical assistance and in some cases cost-sharing. The EQIP program may provide funding to landowners for management of grazing lands and the WIP program may provide funding to landowners for management of wildlife areas. These programs generally apply to rural, rather than residential, areas; however, groups of landowners may choose to band together to collectively manage a number of small properties.

The Texas Department of Rural Affairs offers grants to city or county entities for community development projects like installation of water and sewer services, or related infrastructure. Funding is also available for low to moderate income areas for residential repairs or upgrades of treatment systems and yard lines.

The Texas Water Development Board (TWDB) has a number of low-interest loan programs for infrastructure development programs through the Clean Water State Revolving Fund (CWSRF).

In addition to local matching funds as required by some of the federal and state programs, local communities may also have the ability to independently fund some implementation strategies. The local city, county, and other jurisdictional districts have more flexibility and can be creative in their approaches for funding. Additionally, local funding can be quicker to acquire and would not have outside competition for funding.

5.9 POTENTIAL FUNDING NEEDS AND SOURCES

The primary management measure recommended by the LGWPPSC to eliminate bacteria sources impacting the canals of Lake Granbury is the long-term development of a regional wastewater collection system. The LGWPPSC feels this is best way to protect the lake into the future and to eliminate the concern of fecal contamination in the canals. This is an ambitious goal that will take many years to implement and will require extensive funding assistance to local communities and service providers from both state and federal sources. Some areas close to existing infrastructure, like Port Ridglea East, can be served in the near term but others, due to cost, terrain, remote citing, size of potential service area and/or lack of existing, nearby infrastructure may take up to 20 years to develop and fund.

Sewage treatment will most likely be provided by the City of Granbury, in the central and northern portion of the lake and the southern portion will most likely be serviced by AMUD. However, given the large potential service areas both the City of Granbury and AMUD will need significant financial assistance to expand their existing wastewater treatment systems to service lakeside communities. This assumption regarding most likely providers is based on the locations of existing sewage treatment facilities, sewage collection lines and existing Certificates of Convenience and Necessity for sewage service and in no way requires the City of Granbury or

AMUD to provide these services. Other existing or new entities may be able to provide effective wastewater treatment to lakeside communities in priority areas.

Based upon all of the assumptions and estimates described in other sections of this report, the aggregate capital cost of implementing wastewater collection and treatment infrastructure to serve approximately 4,200 lots located within priority areas is estimated at $59 million. To include areas adjacent to or between priority service areas (as would be anticipated to occur to take advantage of economies of scale), increases the total capital cost to an estimated $107 million and serves approximately 9,700 households.

Another strategy evaluated but rejected by the stakeholders was replacement of existing OSSF systems with new OSSF systems. The aggregated cost to replace 2,500 existing systems in all priority areas (considering characteristics unique within each area) is estimated at approximately $38,000,000. Additionally, the actual ability to replace all existing OSSF systems is highly limited in many areas due soil characteristics and lot sizes that are not compliant with current state regulations and local orders and ordinances. Stakeholders felt that strategies to provide collection and treatment services to priority areas would be more effective than replacement strategies at providing long-term reductions to bacteria loading. The preferred collection and treatment strategies more efficiently accommodate future growth anticipated in these priority areas and, because of increased operational oversight, are less likely to exhibit problems throughout the infrastructure life cycle.

These estimated costs represent an aggregation of several component projects in priority areas; it is anticipated that several different applications would be necessary to encompass all priority communities. Each estimated capital cost represents providing new sewer service to areas currently served by on-site sewage facilities (OSSFs), and also represents regionalization of treatment facilities to the extent evaluated in this report. If options representing construction of a number of smaller facilities (e.g., a package plant near Rolling Hills Shores [RHS] in lieu of connecting to RHS to City of Granbury service) are implemented then costs are anticipated to be higher.

Possible funding sources for these infrastructure projects include USDA Rural Development and programs through TWDB including CWSRF and Rural Water Assistance Fund (RWAF). For particular priority areas that may meet stringent, competitive criteria, possible funding sources may also include Community Development Block Grants from Texas Department of Rural Affairs and TWDB Economically Distressed Area Program (EDAP).

Other management measures target installation of structural best management practices within the watershed to control non-point pollution. An estimated cost of both vegetative filter strips (RHS) and improvements to drainage infrastructure (OTS) is $175,000. Additional estimated cost to construct all identified catchment basins is $5.2 million dollars. Funds to address non-point source pollution through these management measures may be sourced from federal 319h funding. EPA Targeted Watersheds Grant Program funding may also be available for projects meeting award criteria.

Watershed coordination and educational measure costs are estimated to be at least $350,000 dollars over the first 3 years; these first three years would be used to investigate and secure grant or loan funding as well as implement the educational plan. The federal 319h program is anticipated to be a partner source of funding for watershed coordination and education. For watershed coordination, the EPA Environmental Justice Small Grants Program may be another source of funding. For educational programs, the EPA Targeted Watersheds Grant Program funding may also be available. Educational measures may increase awareness and participation in programs that assist land-owner initiated measures like EQIP; this program may assist land owners to recover some costs of installing structural measures to control non-point source pollution (e.g., like catchment basins) in rural areas of the watershed.

Aggregated, estimated capital costs are summarized in Table along with potential funding partner source or sources, anticipating that local funding sources may not be available to cover all costs. It is important to note that these estimated capital costs are aggregated, meaning that the costs of many component projects are lumped together; the size, cost and timing of individual projects represent fractions of the total estimated capital costs shown. Requests for specific projects and amounts will be made as specific management measures are designed and engineered. Figure 46 provides a hypothetical funding needs schedule to implement the stakeholder recommended management measures.

One potential funding avenue would be to revisit the concept of the Lake Granbury Water Quality District (discussed on page 8). Due to failure of local voters to confirm the taxing district in 2002, stakeholders were reluctant to pursue this option for funding at this time. However, they did request to revisit the issue in five years and amend the WPP accordingly, if obtaining funding assistance through the sources discussed above is unsuccessful.

Table 29. Aggregated potential funding program needs

Management measure	Aggregated estimated capital cost of component measures, as noted	Potential non-local partner funding program(s)
Capital wastewater infrastructure		
Sewer service to 13 priority areas (4,200 households)	$59,000,000	CWSRF, Rural Development
Sewer service to 13 priority + adjacent areas (9,700 households)	$107,000,000	CWSRF, Rural Development
Non-point source structural measures		
OTS - surface drainage infrastructure	$170,000	319h
RHS - catchment basin	$1,100,000	319h, EQIP
Sky Harbor - catchment basins	$3,850,000	319h, EQIP
Walnut Creek - catchment basin	$226,000	319h
Non-point source non-structural measures		
OSSF pump-out and records keeping		319h
Watershed coordination and education		
Watershed coordination (first 3 years)	$200,000	319h
Education programs (first 3 years)	$150,000	319h

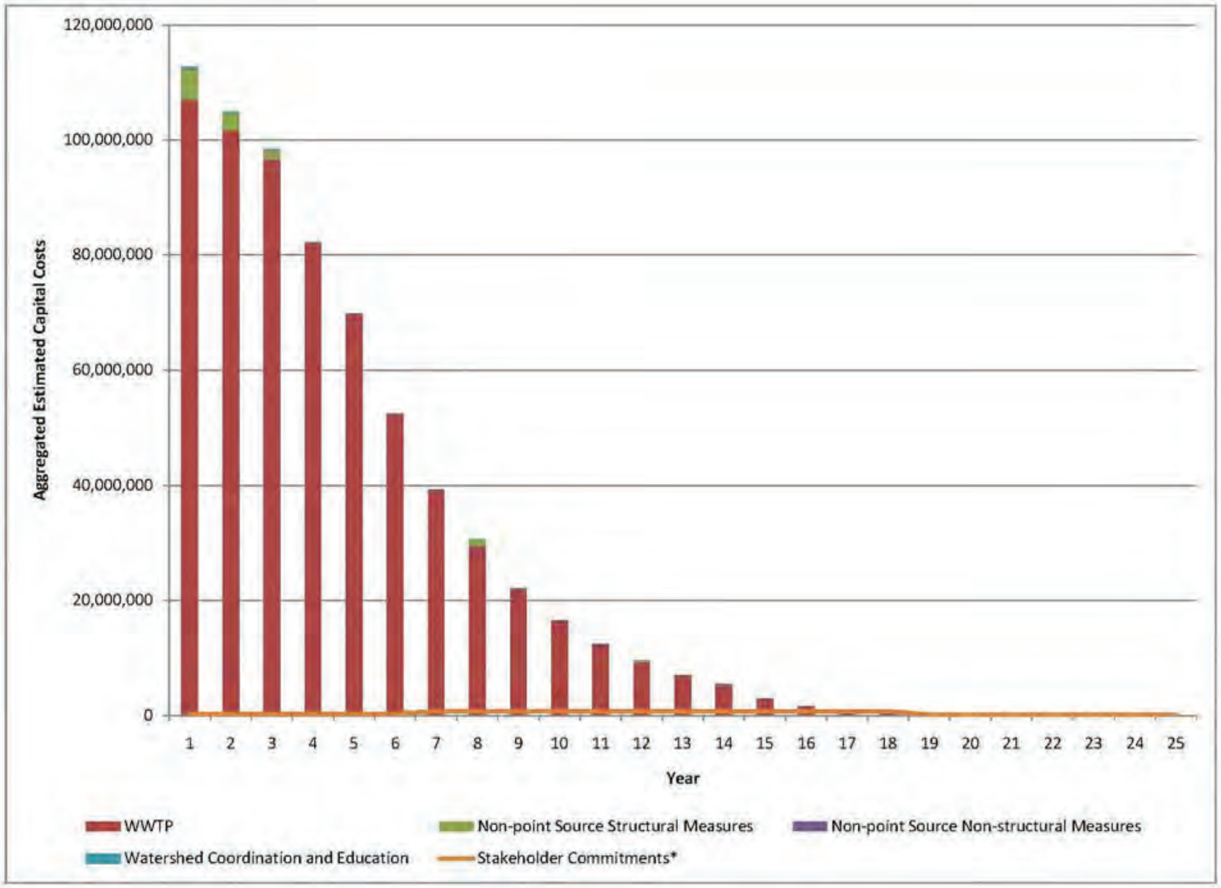


Figure 46. Hypothetical Funding Needs and Firm Stakeholder Commitments for Implementation of Management Measures

*additional stakeholder commitments have been made but are dependent on receipt of grants and/or low-interest loans, on bond issuance and are not reflected in this chart

6.0 EDUCATION AND OUTREACH

Education and Outreach activities supporting the Lake Granbury Watershed Protection Plan have been a collaborative effort between the Brazos River Authority (BRA), and Texas AgriLife Research and Extension (AgriLife).

6.1 ON-GOING OUTREACH AND EDUCATION EFFORTS

The Education and Outreach work group was charged with the task of defining methods to 1) increase public awareness about water quality issues and planning and implementation efforts in the watershed, and 2) motivate individual actions to improve water quality in the Lake Granbury. The Lake Granbury Watershed Protection Plan, Education and Outreach Plan is attached in Appendix H.

To engage stakeholders and to support development of the watershed protection plan, a suite of outreach strategies have beed used to inform the local community about water quality issues and the Lake Granbury Watershed Protection Plan development. Ongoing outreach and education efforts have maintained public involvement in the process and continue to increase awareness of the program and its goals throughout the watershed. Resources and activities that have been utilized in this effort include the following:

6.1.1 Project Websites

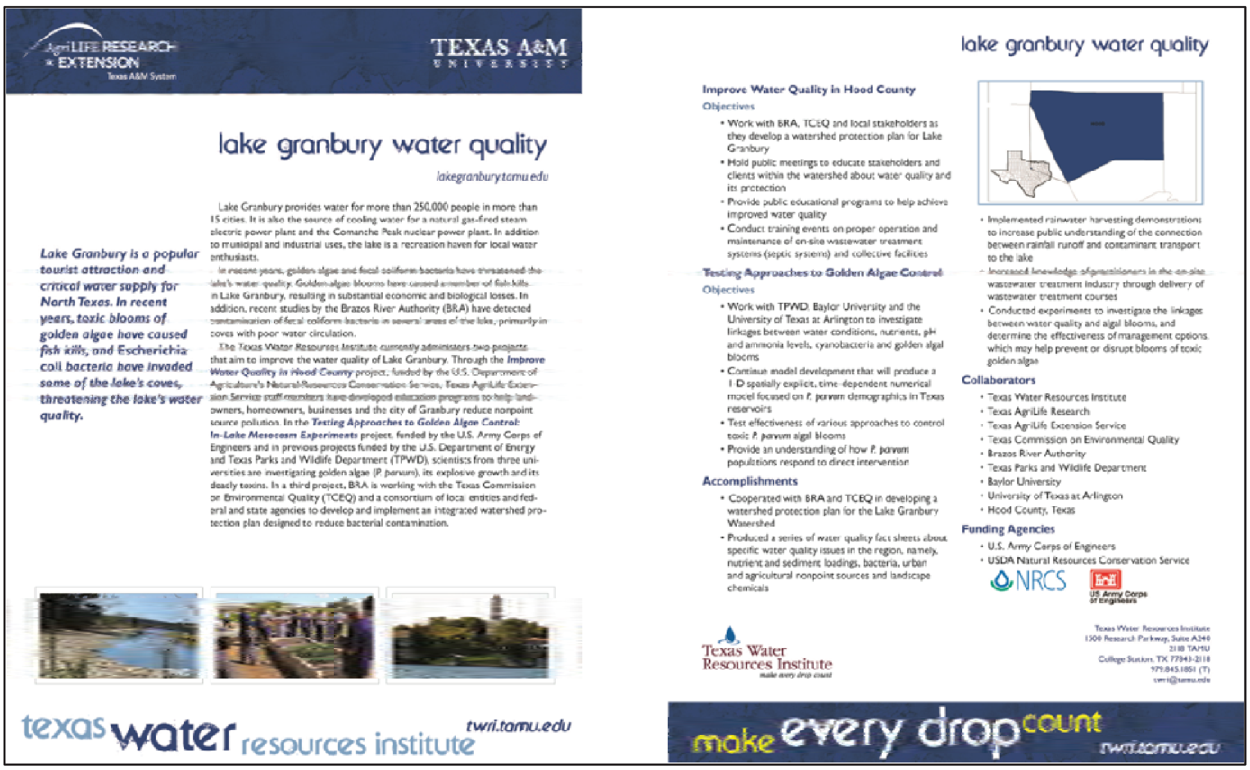
Two, linked project websites were created to provide easy access to project related information. The Lake Granbury Watershed Protection Plan website (http://www.brazos.org/gbWPP.asp) is maintained by the BRA and includes information on the technical aspects of the project including: a general problem description, the project work plan, stakeholder meeting agendas, stakeholder meeting minutes, presentations to the stakeholders group, a calendar of stakeholder events, and status reports. A Lake Granbury Water Quality website (http://twri.tamu.edu/programs/lake-granbury-water-quality) is also maintained by TWRI. The site includes information on water quality education, fact sheets on numerous water quality issues impacting bacteria levels on Lake Granbury, and information on golden algae research on Lake Granbury.

6.1.2 Fact Sheet

The Lake Granbury Water Quality Fact Sheet was developed as a 2-page information marketing tool to support and facilitate participation in the planning process (Figure 47). It has been distributed in the watershed via electronic mail, at stakeholder meetings and at community events. The fact sheet is also available at the Hood County Extension Office and on the Lake Granbury Water Quality website. Update versions will continue to be created as needed to provide new information about programs and accomplishments resulting from project implementation.

6.1.3 News Releases

Both the BRA and AgriLife have created and submitted news releases to numerous local media outlets, including the local newspapers and television stations. Submission of information articles to local news media regarding the Lake Granbury WPP, Lake Granbury water quality, and other environmental issues impacting the lake is on-going. Additional public information articles will be developed and submitted to key outlets to announce the completion of the watershed plan and to encourage stakeholder involvement in the implementation process. Table 30 summarizes the list of related news releases.



AgriLife Research & Extension
Texas A&M System

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lake granbury water quality

lakegranbury.tamu.edu

Lake Granbury is a popular tourist attraction and critical water supply for North Texas. In recent years, toxic blooms of golden algae have caused fish kills, and Escherichia coli bacteria have invaded some of the lake's coves, threatening the lake's water quality.

Lake Granbury provides water for more than 250,000 people in more than 15 cities. It is also the source of cooling water for a natural gas-fired steam electric power plant and the Comanche Peak nuclear power plant. In addition to municipal and industrial uses, the lake is a recreation haven for local water enthusiasts.

In recent years, golden algae and fecal coliform bacteria have threatened the lake's water quality. Golden algae blooms have caused a number of fish kills in Lake Granbury, resulting in substantial economic and biological losses. In addition, recent studies by the Brazos River Authority (BRA) have detected contamination of fecal coliform bacteria in several areas of the lake, primarily in coves with poor water circulation.

The Texas Water Resources Institute currently administers two projects that aim to improve the water quality of Lake Granbury. Through the ***Improve Water Quality in Hood County*** project, funded by the U.S. Department of Agriculture's Natural Resources Conservation Service, Texas AgriLife Extension Service staff members have developed education programs to help landowners, homeowners, businesses and the city of Granbury reduce nonpoint source pollution. In the ***Testing Approaches to Golden Algae Control: In-Lake Mesocosm Experiments*** project, funded by the U.S. Army Corps of Engineers and in previous projects funded by the U.S. Department of Energy and Texas Parks and Wildlife Department (TPWD), scientists from three universities are investigating golden algae (*P. parvum*), its explosive growth and its deadly toxins. In a third project, BRA is working with the Texas Commission on Environmental Quality (TCEQ) and a consortium of local entities and federal and state agencies to develop and implement an integrated watershed protection plan designed to reduce bacterial contamination.

texas water resources institute twri.tamu.edu

lake granbury water quality

Improve Water Quality in Hood County

Objectives

- Work with BRA, TCEQ and local stakeholders as they develop a watershed protection plan for Lake Granbury
- Hold public meetings to educate stakeholders and clients within the watershed about water quality and its protection
- Provide public educational programs to help achieve improved water quality
- Conduct training events on proper operation and maintenance of on-site wastewater treatment systems (septic systems) and collective facilities

Testing Approaches to Golden Algae Control

Objectives

- Work with TPWD, Baylor University and the University of Texas at Arlington to investigate linkages between water conditions, nutrients, pH and ammonia levels, cyanobacteria and golden algal blooms
- Continue model development that will produce a 1-D spatially explicit, time-dependent numerical model focused on *P. parvum* demographics in Texas reservoirs
- Test effectiveness of various approaches to control toxic *P. parvum* algal blooms
- Provide an understanding of how *P. parvum* populations respond to direct intervention

Accomplishments

- Cooperated with BRA and TCEQ in developing a watershed protection plan for the Lake Granbury Watershed
- Produced a series of water quality fact sheets about specific water quality issues in the region, namely, nutrient and sediment loadings, bacteria, urban and agricultural nonpoint sources and landscape chemicals
- Implemented rainwater harvesting demonstrations to increase public understanding of the connection between rainfall runoff and contaminant transport to the lake
- Increased knowledge of practitioners in the on-site wastewater treatment industry through delivery of wastewater treatment courses
- Conducted experiments to investigate the linkages between water quality and algal blooms, and determine the effectiveness of management options which may help prevent or disrupt blooms of toxic golden algae

Collaborators

- Texas Water Resources Institute
- Texas AgriLife Research
- Texas AgriLife Extension Service
- Texas Commission on Environmental Quality
- Brazos River Authority
- Texas Parks and Wildlife Department
- Baylor University
- University of Texas at Arlington
- Hood County, Texas

Funding Agencies

- U.S. Army Corps of Engineers
- USDA Natural Resources Conservation Service

NRCS
US Army Corps of Engineers

Texas Water Resources Institute
make every drop count

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make every drop count twri.tamu.edu

Figure 47. Lake Granbury Water Quality Fact Sheet

Table 30. News Releases Related to Lake Granbury Water Quality

Year	Organization	Title
2010	BRA	Texas Lake and River Swimmers Reminded of Potential Health Risks
2009	AgriLife	On-site Wastewater System Management
2009	AgriLife	Pet Waste Management
2009	AgriLife	Management of Wildlife on Your Property
2009	AgriLife	Proper Lawn Maintenance
2009	BRA	Beware of Hazards Due to Low Lake Levels
2008	BRA	Lake and River Swimmers Should be Aware of Potential Health Risks
2008	BRA	Proper Disposal Can Keep Your Money from Going Down the Drain
2008	BRA	BRA to Conduct Dye-Based Flow Studies
2008	BRA	Brazos River Authority to Hold Lake Granbury Open House
2008	BRA	Dye-based Water Flow Study will Begin at Lake Granbury
2007	BRA	Brazos River Authority to Begin Lake Granbury Cleanup
2007	BRA	Lake Granbury Dye Testing
2007	BRA	The Brazos River Authority Advises Lake and River Swimmers of a Potential Health Risk
2007	BRA	Bacteria Levels Return to Normal in Most Parts of the Basin
2007	BRA	Clear Skies Don’t Guarantee Risk Free Recreation
2007	BRA	Lake Granbury Public Boat Ramps Reopen to the Public
2007	BRA	Texas Parks and Wildlife Closes Access to Lake Granbury
2007	BRA	What Should I Know After a Flood
2006	BRA	Brazos River Authority and TCEQ Fly the Rivers

6.1.4 Newsletter Articles

Lake Granbury Watershed Protection Plan articles, as well as, informational articles regarding general water quality and environmental issues have been written for the “The Brazos Basin” newsletter which is prepared and disseminated by the BRA. The newsletter is distributed quarterly via email to all Authority customers and lakeside residents and is available on the BRA website.

Table 31. Newsletter Articles

Year	Title
2010	Easing the Brazos’ Salt Water Woes
2010	Taming a River: Calming the Flood Prone Brazos River
2010	Water School: School is in Session
2010	How do you Dispose of Hazardous Waste?
2010	Invasion of the Mollusks
2010	Monitoring the Brazos
2010	Staying Informed on the River
2010	The Backbone of our Water Supply
2010	Water: Not Just for Drinking
2010	Planning for Water in Texas
2010	Community Works to Remove Lake Pollutant
2010	Brazos River Authority to Begin Lake Granbury Cleanup
2009	What Happens After you Flush?
2009	Flood Control vs. Water Supply vs. Recreation
2009	Keeping the Brazos Clean
2009	Conservation Important for Fall Gardening
2009	Will we have Enough Water?
2009	Nuisance Water Plants

2009	Recreation on the Brazos River
2009	Teaching Kids About Water
2009	Texas: The State of Flowing Water
2009	Preparing for a Potentially Extended Drought
2008	Don't Let your Trash Go Down the Drain
2008	Drought Easing in the Basin
2008	Make your Fall Garden Flourish
2008	Controlling Nuisance Wildlife
2008	Texas Aquatic Plants can be a Beautiful Nuisance
2008	Texas Tough Landscapes through Xeriscaping
2008	Keeping Your Lakes Clean
2008	Time to Take Care of our Lakes and Rivers
2007	Protecting Water for our Future
2007	Yuck! Why does the Water Taste Funny?

6.1.5 Watershed Tour

A watershed tour was organized upon request of the Lake Granbury Watershed Protection Plan Stakeholders Group to provide an overview of the current characteristics and conditions across the watershed. The tour was conducted on June 23, 2009. Information was provided on urban, agricultural and industrial activities and issues and water quality monitoring efforts in the watershed.

6.1.6 Outreach at Local Events

Local public events such as the Rotary Club meetings, Chamber of Commerce meetings, homeowner's association meetings, were used as venues for presentations and/or distribution of education and information resources. Depending on the event maps, displays, fact sheets and handouts addressing the plan and water quality issues were disseminated and will continue to be disseminated. Events attended are listed in Table 32.

6.1.7 Texas Watershed Stewards

Texas Watershed Stewards is a science-based watershed education program designed to help citizens identify and take action to address local water quality impairments. A Texas Watershed Stewards workshop was held in Hood County on June 30, 2009

6.1.8 Targeted Outreach Efforts

AgriLife staff organized as series of events targeted at specific groups or addressing specific water quality topics related to Lake Granbury. A summary of Targete Outreach Efforts is presented in Table 32. Topics presented include:

Table 32. Outreach at Local Events

Year	Organization	Event/Group Meeting
2010	BRA	Pecan Plantation Men's Breakfast Club
2009	BRA	Hood County Law Enforcement Environmental School
2009	BRA	Lake Granbury Waterfront Owner's Association
2009	AgriLife	Hood County Fair
2009	AgriLife	Granbury Birthday Bash
2009	AgriLife	Local Television Station - discuss watershed management, bacterial sources, and BMPs
2009	AgriLife	Pecan Plantation Men's Breakfast Club
2008	BRA	Lake Granbury Open House
2008	BRA	2nd Grade Class at Acton Elementary School
2008	BRA	5th Grade Class at Oakwood Intermediate School
2008	BRA	Granbury Rotary Club
2008	BRA	3rd Grade Class at Acton Elementary School
2008	BRA	5th Grade Class at Oakwood Intermediate School
2007	AgriLife	Oak Trail Shores Homeowner's Association
2007	BRA	AquaSmart at all Granbury ISD Elementary, Intermediate and Middle Schools
2007	BRA	Hood County Chapter of Master Gardeners
2007	BRA	Hood/Somervell County Chapter of Master Naturalists

Advanced On-site Wastewater Treatment Systems for Practitioners
Hood County wastewater practitioners participated in a training program describing the use of advanced treatment units to remove contaminants of concern from the wastewater.

Septic System Maintenance for Homeowners
Four workshops have been conducted for homeowners. These trainings targeted concern areas identified in WPP. The program focused on key aspects of operation, maintenance and repair that are important for homeowners.

These trainings have been extremely successful in motivating homeowner's to perform maintenance on their systems. After a training targeted at the communities on the northwest shore of the lake, one community had a homeowner's, who lived on the worst canal in the development perform maintenance on their system. Since that time bacteria concentrations in the canal have been dramatically reduced.

Future training events will be conducted in other priority areas as needed and where additional funding is available.

Pet Waste Management
AgriLife staff worked with the North Central Texas Council of Governments to create a Public Service Announcement on Pet Waste Management, a source of bacterial contamination especially for areas adjacent to the lake. The PSA was run on local television and radio stations.

Non-Point Sources of Pollution
AgriLife personnel prepared radio news pieces on non-point sources of pollution, which was run on local radio stations.

Bacterial Impairment of the Lake

AgriLife personnel prepared radio news pieces on bacterial impairment of the lake, which was run on local radio stations/

Septic System Health
AgriLife personnel prepared radio news pieces on septic system health, which was run on local radio stations.

Rainwater Harvesting Education
The topic of rainwater harvesting was used to convey messages about water and stormwater management, pollution control and the importance of educating others. The course as comprised of both classroom instruction and field demonstrations. During the course, participants were able to help in the installation of rainwater harvesting systems that became part of a demonstration site located near the Extension office. These systems are a stormwater management BMP that teaches basic hydrology and water management. Many participants increased their water literacy through implementing a rainwater harvesting project. They learned about the quantity of water running off a surface and the contaminants that can be absorbed by the water as it runs across a surface. They learned how the volume of water generated during a rainfall event is quantified. In addition, the amount available for capture from a specific size surface was calculated. Ultimately, the participants learned valuable information that will assist them in making informed decisions regarding management and protection of critical water resources

Table 33. Targeted Outreach Efforts

Year	Topic
2010	2 - Basic Septic System Maintenance Programs
2009	Rainwaterharvesting
2009	2- Basic Septic System Maintenance Programs
2009	Advanced On-Site Wastewater Treatment Systems – for Practitioners
2009	Stormwater Management in the Home Landscape
2009	Health and Maintenance of your Aerobic Treatment System
2009	Wastewater Practitioners Training
2008	Pet Waste Management
2008	Small Acreage Land Management
2007	2- Basic Septic System Maintenance Programs
2007	Priority Groundwater Management Areas
2007	Septic System Installer Training

6.1.9 Printed and Distributed Fact Sheets

In order to facilitate dissemination of information and educational materials Texas AgriLife Extension personnel developed multiple fact sheets that were printed and distributed to homeowners, at local events and during targeted training sessions.

1. Fecal Coliform Contamination and Sources,
2. Collective Wastewater Treatment Systems,
3. Pet Waste Management,
4. Graywater Use and Water Quality
5. Nutrient and Sediment loading,
6. Landscape Chemicals, and Management Practices to Minimize Loadings
7. What is the Fate of Your Rainfall;
    a. What is the Fate of Your Rainfall: Leader Guide;

   b. What is the Fate of Your Rainfall: Flip Chart; Lawn Fertilization and Environmental Impacts;

8. Living on the Water's Edge.
9. Agricultural BMPs
10. Bacteria and Nutrients
11. Golden Algae
12. In Home Water Conservation
13. Pollution
14. Rainwater Harvesting
15. Uran BMPs
16. Water Conscious Landscapes
17. Water Testinf
18. Watersheds,
19. On-Site Wastewater Treatment – Selecting and Permitting,
20. On-Site Wastewater Treatment – Alternative Collection Systems,
21. On-Site Wastewater Treatment – Homeowner's Guide to Evaluating Service Contracts,
22. On-Site Wastewater Treatment – Soil Particle Analysis Procedure,
23. On-Site Wastewater Treatment – Graywater,
24. On-Site Wastewater Treatment – Septic Tank/Soil Absorption Fields,
25. On-Site Wastewater Treatment – Evaoptranspitation Beds,
26. On-Site Wastewater Treatment – Low-Pressure Dosing,
27. On-Site Wastewater Treatment - Subsurface Drip Distribution,
28. On-Site Wastewater Treatment – Aerobic Treatment Units,
29. On-Site Wastewater Treatment – Spray Distribution Systems,
30. On-Site Wastewater Treatment – Table Chlorination,
31. On-Site Wastewater Treatment - Operation and Maintenance,
32. On-Site Wastewater Treatment – Mound Systems, and
33. On-Site Wastewater Treatment – Liquid Chlorination.

The education programs provided through this project will and have lead to changes in behavior and have created a sense of ownership of Lake Granbury. This sense of ownership will lead to improved water quality. BRA and AgriLife will continue to work together to develop and present information on how to protect and improve water quality.

7.0 WATERSHED MILESTONES

7.1 MEASURABLE MILESTONES

Due to the dynamic nature of watersheds and the countless variables governing landscape processes across scales of time and space, some uncertainty is to be expected when a Watershed Protection Plan is developed and implemented. As the recommended restoration measures of the Lake Granbury Watershed Protection Plan are put into action, it will be necessary to track the water quality response over time and make any needed adjustments to the implementation strategy. As efforts continue, incorporation of new data will improve the understanding of watershed conditions and will drive a more efficient implementation process.

Adaptive management will allow initial results to guide future restoration strategies as stakeholders learn through experience. By tracking water quality trends, stakeholders will be able to evaluate whether plan execution is successful and will determine the need for new action or refocusing of existing programs (Table 34). This adaptive approach relies on constant input of watershed information and the establishment of intermediate and final water quality targets. Stakeholders plan to have bi-annual meetings to discuss implementation progress and strategies. Additionally, stakeholders have requested a full review with the potential to revise and modify the WPP once every five years, in case redirection or alternative management measures need to be included.

Table 34. Adaptive Management Review Schedule

Year	Review Type
2011	Bi-annual Stakeholder Review of Implementation Status
2012	Bi-annual Stakeholder Review of Implementation Status
2013	Bi-annual Stakeholder Review of Implementation Status
2014	Bi-annual Stakeholder Review of Implementation Status
2015	Revise WPP if Stakeholders Determine Necessary
2016	Bi-annual Stakeholder Review of Implementation Status
2017	Bi-annual Stakeholder Review of Implementation Status
2018	Bi-annual Stakeholder Review of Implementation Status
2019	Bi-annual Stakeholder Review of Implementation Status
2020	Revise WPP if Stakeholders Determine Necessary
2021	Bi-annual Stakeholder Review of Implementation Status
2022	Bi-annual Stakeholder Review of Implementation Status
2023	Bi-annual Stakeholder Review of Implementation Status
2024	Bi-annual Stakeholder Review of Implementation Status
2025	Revise WPP if Stakeholders Determine Necessary

Pollutant concentration targets were developed based on complete implementation of the Watershed Protection Plan and assume full accomplishment of pollutant load reductions by the end of the 20-year project period (Tables 35). While some of the less complex management measures recommended here will be relatively simple to implement early in the process, implementation of other measures will require more time, energy, and funding. For this reason, reductions in pollutant loads and associated concentrations initially may be gradual. However, it can be assumed that reductions in the loading of bacteria and nutrients will be tied to the implementation of management measures throughout the watershed. Thus, these projected pollutant targets will serve as benchmarks of progress, indicating the need to maintain or adjust 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.

Milestones relate to achievement of bacteria goals in priority areas. Milestones consider timing and implementation of management measures in important areas. Short-term and long-term checkpoints in time may be used to indicate progress towards implementation, used to indicate level of effectiveness of implemented management measures, and may relate to implementation of additional measures if needed. It is understood that bacteria reductions are not achievable in all years. Other measures of progress and success in achieving stakeholder goals may include active pursuit of funding for priority management measures and enactment of HOA rules or local ordinances.

Table 35. *E. coli* bacteria targets at selected intervals through implementation.

Year	Oak Trail Shores	Sky Harbor	Port Ridglea East	Indian Harbor	Long Creek	Walnut Creek
2011	70	63	73	71	156	124
2015	65	55	65	60	100	100
2020	60	53	60	55	75	75
2025	53	53	53	53	53	53

7.2 SCHEDULE FOR IMPLEMENTATION

Implementation of management measures will generally commence in order of stakeholder-identified priority for each area; however, implementing many measures depends upon securing appropriate resources which may become available.

Implementation of some of the recommended management measures is already being undertaken by stakeholders. Because of awareness and collaboration among WPP stakeholders, grant assistance has been provided by the Texas Department of Rural Affairs (formerly the Office of Rural and Community Development, ORCA to the Hood County Health Department for replacement of 25 malfunctioning septic systems owned by disadvantaged citizens within the project area.

For each of the last 3 years, AMUD has filed an Intended Use Plan with the TWDB under the CWSRF to provide first time sewer service for residents of Port Ridglea East, Port Ridglea West, Nassau Bay II and Holiday Estates – all within a single project. Unfortunately, AMUD was not successful in receiving funding for the entire project but has secured funding to extend a sewer main into the area. This extension will be the first step in connecting these areas to the AMUD collection and treatment system.

Texas AgriLife Research and Extension continues to put on educational events in Hood County. These trainings have been extremely successful in motivating homeowner's to alter their behavior regarding property management. In late September, after a septic system maintenance training targeted at the communities on the northwest shore of the lake, Oak Trail Shores had a homeowner who lived on the worst canal in the development perform maintenance on their system. Since that time bacteria concentrations in the canal have been dramatically reduced and

AgriLife hopes to use this example to encourage more homeowner's around the lake to perform routine maintenance on their systems.

This schedule is developed considering year 1 begins in late 2011, with the exception of implementation projects already under way, after final approval of this WPP document.

7.2.1 Implementation of education and non-structural management measures

Lake-wide educational measures, commencing within the first year and continuing into the future, will be open to any community member within the area covered by this WPP (Table 36). Where resources are limited, educational and advertising focus will be directed towards priority areas.

Years 1 and 2

- Funding should be pursued for a dedicated Watershed Coordinator to help stakeholders implement strategies and identify funding as well as coordinate and facilitate stakeholder involvement and decision making.
- Funding should be pursued to develop, implement and continue the educational components, including post-education follow-up surveys. Educational programs should begin in year 1, and may include a dedicated Education Coordinator staff member.
- Educational programs are developed for water fowl and wildlife feeding.
- Adopt/update county order to require pump-out records be submitted annually to the Hood County Health District for all holding tanks in the Lake Granbury flood plain.
- Health District can establish and maintain a database of inspections and activities.
- Funding should be pursued to implement structural management measures.

Long-termContinue education efforts and pursuit of funding until goals are achieved.

7.2.2 Implementation of structural management measures

Management measures resulting in structural improvements (e.g, construction projects like installation of sewage collection systems, watershed best management practices, drainage projects, etc.) will be implemented as funding becomes available for each measure. Table 36 presents a schedule for implementation based on permitting and construction timelines regardless of funding needs. This schedule may need to be adjusted based on the status of funding for different projects. Beginning immediately within the first year, funding will be investigated according to stakeholder-identified priority areas and priority management measures. While it is not anticipated that the schedule of implementation of management measures will strictly follow the order of priorities, it is anticipated that the priorities will be used as a guide identifying funding opportunities for measures having the best value in terms of efficiency in achievement of bacteria goals.

Table 36. Implementation Schedule for Educational and Non-Structural Management Measures

Management Measure	Number Events per Year				
	Year				
	1	2	3	4	5+
Stakeholder Meetings	2	2	2		
Executive Committee Meetings	12	12	12		
Update Lake Granbury WPP Web-page	2	2	2		
Bi-monthly Email Newsletter	6	6	6		
Maintain Stakeholder List and General Public Notification List	2	2	2		
Track Implementation of Non-Point Source Management Measures	4	4	4		
Identification of Funding Sources linked to each non-point source management measures	1	1	1		
Assist Stakeholders in Grant Writing and Preparing Funding Requests	2	2	2		
Train Stakeholders to Find and Apply for Funding	4	4	4		
Evaluate Watershed Knowledge and Awareness	1				
County Order Requiring Special Data Submittals to the Hood County Health Department for residents in the 100-yr Floodplain in Rolling Hills Shores	1				
County Order Prohibiting Feeding of Wildlife within 1 mile of Lake Granbury	1				
Outreach to Local Governments	4				
Outreach to Homeowners Associations	5	5			
Develop Educational Program and Materials for Home Inspectors	1				
Develop Educational Program and Materials for Wildlife/Waterfowl	1				
Deliver Educational Programs	24	24	24		
Track Implementation of Education and Outreach Management Measures	4	4	4		
Evaluate Targeted Outreach Effectiveness	4	4	4		
Press Releases	4	4	4		
Public Service Announcements	4	4	4		
Maintenance of Hood County Health Department OSSF Database	4	4	4		
Area Conservation Plans for Long Creek Microwatershed		1	1	1	1
Area Conservation Plans for WalnutCreek Microwatershed	1	1	1	1	1

7.2.3 Implementation of structural management measures

Management measures resulting in structural improvements (e.g, construction projects like installation of sewage collection systems, watershed best management practices, drainage projects, etc.) will be implemented as funding becomes available for each measure. Table 37 presents a schedule for implementation based on permitting and construction timelines regardless of funding needs. This schedule may need to be adjusted based on the status of funding for different projects. Beginning immediately within the first year, funding will be investigated according to stakeholder-identified priority areas and priority management measures. While it is not anticipated that the schedule of implementation of management measures will strictly follow the order of priorities, it is anticipated that the priorities will be used as a guide identifying funding opportunities for measures having the best value in terms of efficiency in achievement of bacteria goals.

<u>Years 1 and 2</u>

- Funding opportunities should be pursued for structural implementation measures, with concentration given to priority areas.
- Funding opportunities should be pursued specifically for priority areas, to allow for mid-term implementation.
    - Port Ridglea East
    - Oak Trail Shores
    - Sky Harbor
- Conduct field evaluation to identify or rule out sources of bacteria near Blue Water Shores.

<u>Years 3 through 5</u>

- Implementation of structural measures in priority area Port Ridglea East to compliment existing funded measures.
- Outline a plan for implementation of structural measures in priority areas surrounding Oak Trail Shores and priority areas surrounding Indian Harbor. The plan should identify responsible or sponsoring entities (e.g., utility district, non-profit corporation or private corporation) and should include preliminary drawings, specifications and cost estimates as appropriate. Pursue funding for these plans.
- Implementation of range and acreage landowner management initiatives, particularly in Sky Harbor, Long Creek and Walnut Creek watersheds.

<u>Long-term</u>

- Continue pursuit of funding for any un-implemented measures.
- Implementation of structural measures in areas surrounding Port Ridglea East.
- Implement sewage collection and treatment in all priority areas.

Hypothetical load reductions and concentration reductions of *E. coli* in coves of Lake Granbury that can be expected as a result of full implementation of the Lake Granbury Watershed Protection Plan are presented in Figures 48 and 49. Precise estimates of attainable load reductions are difficult to determine and may change over time due to significant changes in land use and pollutant sources. Additionally, estimates of implementation costs for the recommended management measures have been calculated and a tentative schedule has been developed, assuming funding will be available at each critical step of the implementation process. These estimates can be used to demonstrate expected improvement toward target water quality goals for the watershed and what reductions can be anticipated with each expenditure and type of management measure implemented (Figure 50). With active stakeholder engagement and participation in plan implementation and continued support from cooperating groups and agencies, the activities outlined here will make significant progress toward improving and protecting water quality in Lake Granbury and its coves.

Table 37. Implementation Schedule for Structural Management Measures

Management Measure	Number Implemented Year			Equivalent Annual Cost Index	Cost/Reduction Benefit Ratio
	1-5	5-10	10+		
Regional Wastewater Treatment and Collection – Port Ridglea East	1	3		0.65	0.66
Regional Wastewater Treatment and Collection – Port Ridglea West, Nassau Bay II, Sandy Beach, and Holiday Estates		1	3	0.65	0.66
Cove Circulation for Sky Harbor	5			0.25	0.64
Cove Circulation for Indian Harbor		5		0.21	0.65
Cove Circulation for Blue Water Shores		5		0.20	0.54
Regional Wastewater Treatment and Collection – Sky Harbor		1		0.30	2.37
Catchment Basins for Sky Harbor/Bee Creek Watershed	1			0.82	1.25
Catchment Basins Walnut Creek Watershed		1		0.16	7.88
Catchment Basins Rolling Hills Shores			1		
Drainage Re-Routing Oak Trail Shores	1	1	1	0.07	0.14
Dredge Coves in Oak Trail Shores		1		0.84	1.29
Dredge Coves in Rolling Hills Shores			1	0.91	1.06
Dredge Coves in Blue Water Shores		1		0.96	2.13
Vegetative Filter Strips for Rolling Hills Shores	1	1	1	0.05	0.90
Regional Wastewater Treatment and Collection – Long Creek		1	1	0.59	0.59
Regional Wastewater Treatment and Collection – Arrowhead Shores			1	0.26	0.42
Regional Wastewater Treatment and Collection – Oak Trail Shores			1	0.26	0.48
Regional Wastewater Treatment and Collection – Rolling Hills Shores			1	0.26	0.42
Regional Wastewater Treatment and Collection - Indian Harbor			1	0.60	0.61

7.3 IMPLEMENTATION MONITORING PLAN AND ADAPTIVE MANAGEMENT

Twice every year, stakeholders will have the opportunity to provide input on the achievement of milestones. At each input opportunity, the stakeholders will evaluate achievement and adapt the plan. Stakeholders could choose to re-evaluate the list of priority areas, re-evaluate priority management measures (including consideration of additional measures) and/or re-evaluate the bacteria goal.

Throughout the year, it is anticipated that the Watershed Coordinator will provide updates to the stakeholders on relevant stakeholder activities, provide quarterly updates and maintain a website. The Watershed Coordinator will work with the Executive Committee on a more frequent basis to assist with the implementation of recommended management measures.

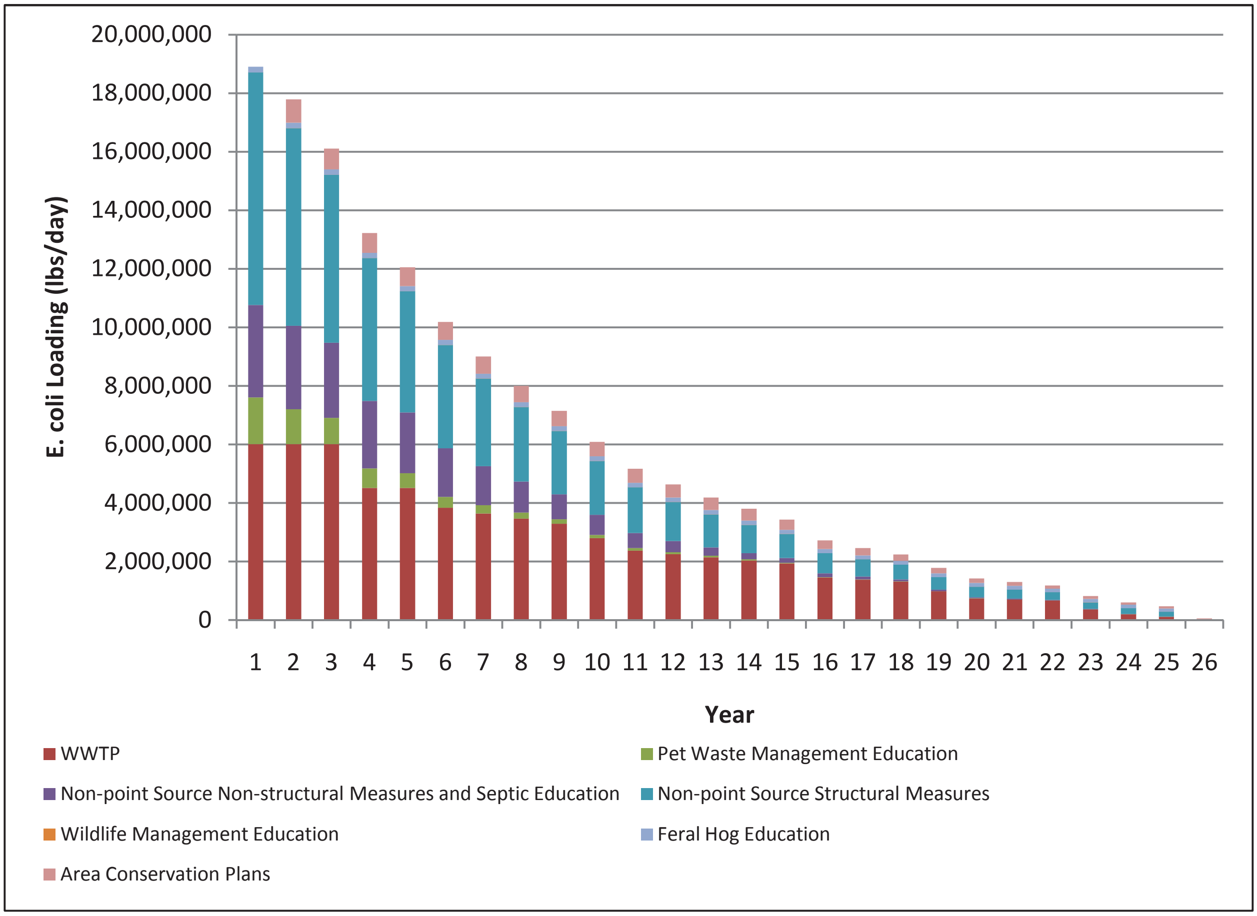

Figure 48. Hypothetical *E. coli* Loading and Reductions Due to Management Measure Implementation

7.3.1 Implementation Monitoring Plan

Watershed and landscape processes are dynamic and variable across scales of time and space, so some uncertainty is to be expected when a Watershed Protection Plan is developed and implemented. As the management measures recommended in the Lake Granbury Watershed Protection Plan become implemented and water quality response is tracked, strategies may need to be adapted to help achieve goals. Adaptive management will allow initial results to guide stakeholders in making informed decisions on future restoration strategies; those adaptions may include new action or refocusing of existing programs.

The purpose of this water quality monitoring plan is to outline the monitoring strategy that will be used to track water quality conditions through the implementation of the Lake Granbury WPP. The goal of this monitoring plan is to provide a means to document water quality improvements in Lake Granbury and its adjacent canals as a result of implementation of recommended management measures.

While some of the less complex management measures recommended here will be relatively simple to implement early in the process, full implementation of the management measures will require more time, energy and funding. For this reason, reductions in pollutant loads and concentrations initially may be gradual since reductions are assumed to be tied to the implementation of management measures throughout the watershed.

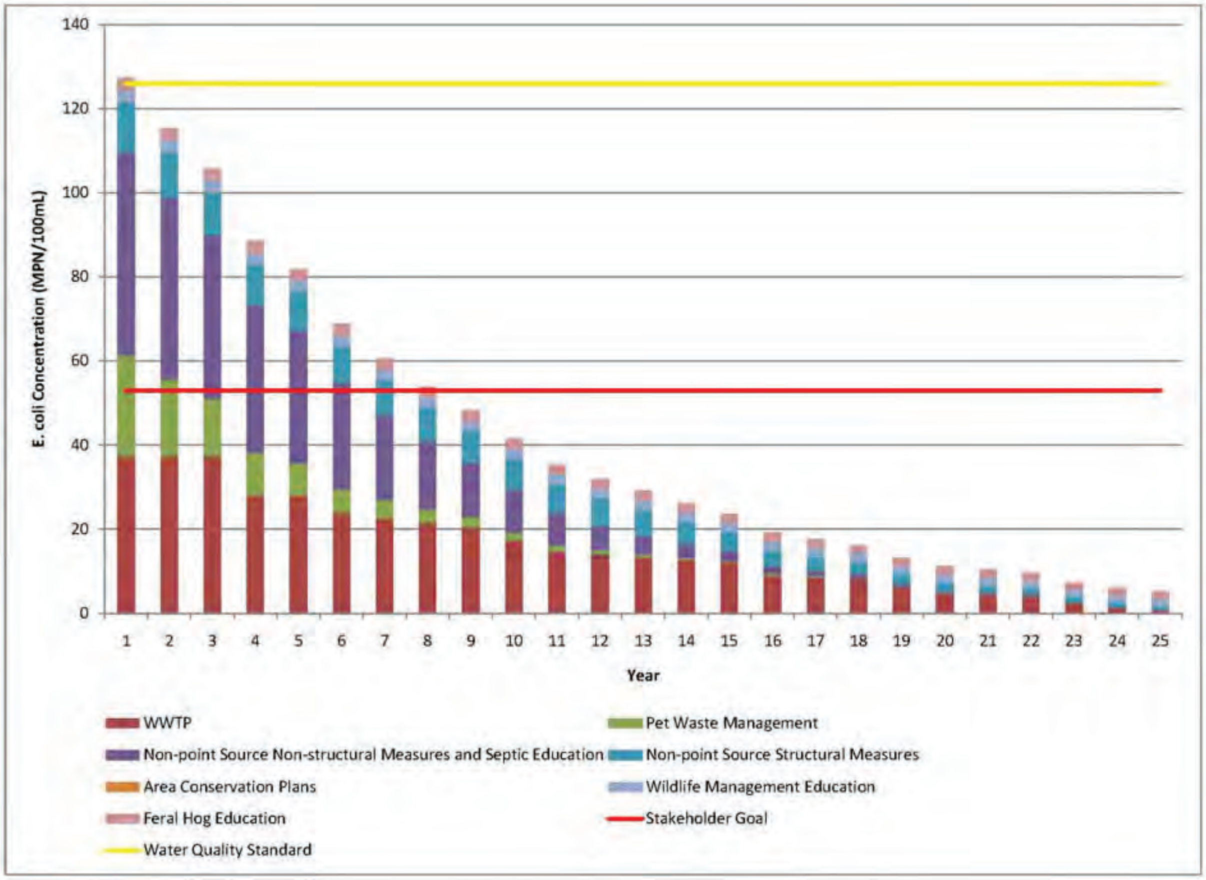

Figure 49. Hypothetical *E. coli* Concentration Reductions Due to Management Measure Implementation

Because most of the construction-based management measures require design, engineering and then construction, these will be long-term multiyear implementation projects. Some of the construction-based management measures, such as the Port Ridglea East sewer expansion, are only waiting funding to implement; therefore, success could be observed here rather quickly if funding is attained. The construction-based management measures related to eliminating the aging OSSFs/OWTFs and replacing them with regionalized wastewater treatment are estimated to reduce bacteria loading into the canals of Lake Granbury from 62 to 99%. The construction-based management measures related to altering drainage patterns and cove dynamics are estimated to reduce bacteria loading or concentrations into the canals by 30 to 60%.

To assess bacteria trends, water quality data will be compiled and a 7-year geometric mean for *E. coli* bacteria will be computed every six months to examine trends in the main body and the coves. Additionally, parameters including, but not limited to, dissolved oxygen, water temperature and nutrients will also be evaluated by the stakeholder committee every six months. These values will be compared to historical data to (1) determine the effectiveness of monitoring measures in reducing bacteria concentrations, (2) determine achievement of stakeholder goals and (3) determine the need to adjust implementation.

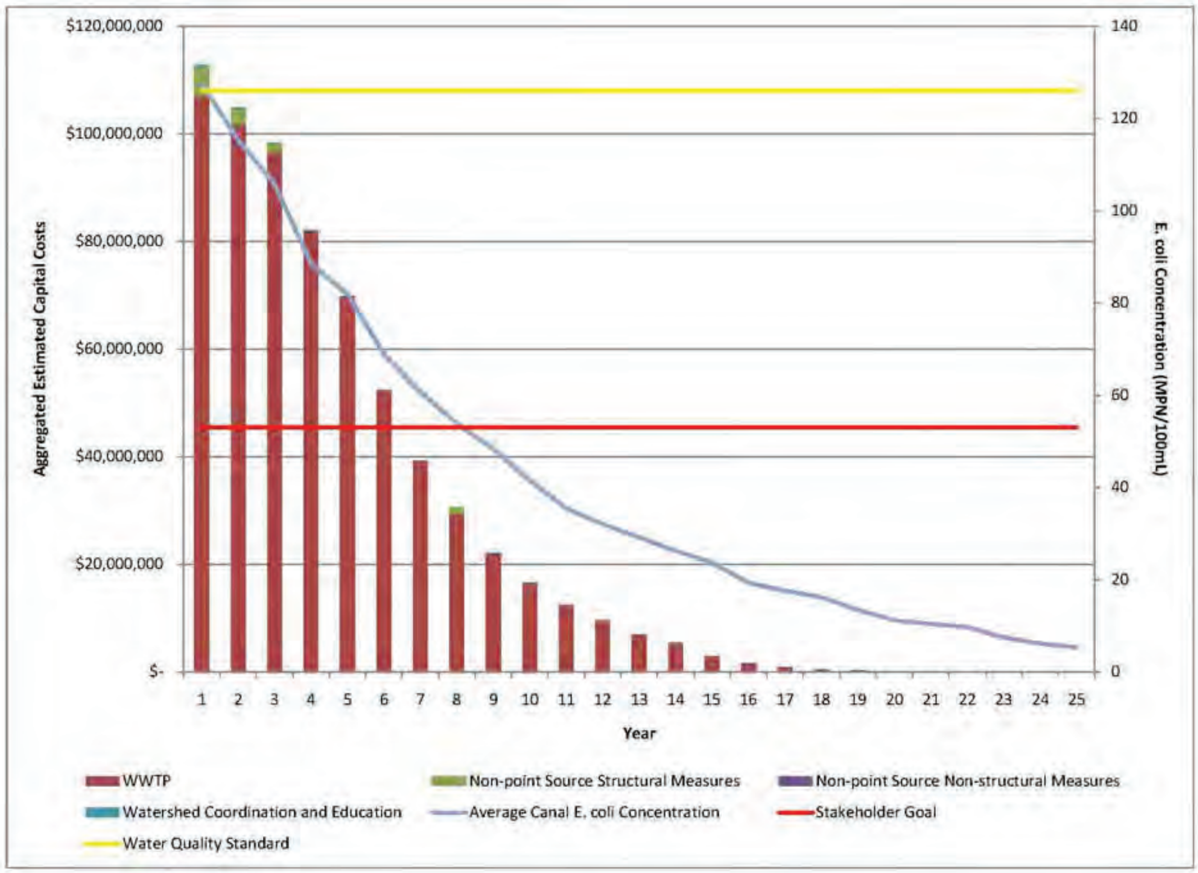

Figure 50. Hypothetical Funding Needs for Implementation of Management Measure and Hypothetical *E. coli* Concentration Reductions in the Canals of Lake Granbury as Management Measures are Implemented

Current water quality monitoring efforts in the watershed consists of existing long-term monitoring sites on the main body of the reservoir, plus monitoring of 38 canals and 6 tributary streams. As funding is being sought and design, engineering and construction plans are being developed for implementation measures, interim-baseline monitoring will consist of monthly monitoring of three sites on the main body of the lake, eight cove sites in the most problematic areas and five tributary streams (Table 38 and Figure 51).

Though not all of these measures coincide with current impairments or concerns, continued monitoring for a wide array of parameters will detect the development of additional water quality problems, in addition to measuring progress towards the WPP water quality goal.

As construction-based management measures are implemented, the number of monitoring sites in the affected area will be increased to include all impacted coves in the area for a two-year period to assess the effectiveness of the management measure in reducing bacteria concentrations.

An example of increased monitoring efforts is the Port Ridglea East area. Currently, Acton Municipal Utility District (AMUD) is working on a five-phase project to connect the area to its wastewater collection and treatment system. Phase 1 is currently funded and being constructed and will extend a necessary sewer main to the area. Once complete a limited number of households will be connected to the new sewer main. When this phase of the project is complete the BRA will increase its monitoring in the area of Port Ridglea East affected by this upgrade to document if the implementation and removal of OSSFs improved water quality. BRA will add an additional monitoring site on the canal that will be affected and will collect monthly data at this site for a two-year period (Figure 52). As the project moves through all five phases the BRA will continue to adjust and increase monitoring in the affected areas of Port Ridglea East.

However, AMUD is pursuing funding for phases 2-5 in one large block. If successful in obtaining funding for the remaining phases at one time, AMUD will disregard the phased approach and construct and implement the project in its entirety. If this occurs, Figure 53, reveals how the BRA would adjust its Interim Monitoring Plan for Port Ridglea East once construction is completed for two years to document success.

Assessment of interim and implementation monitoring data will occur on three levels. In the first level of assessment each individual canal will be assessed to show improvement, this will be particularly valuable to show improvements in areas where regional wastewater treatment expansions projects will be phased over a long period of time. The individual canals in the immediate vicinity of the improvement will most likely show water quality improvement before the entire community or larger area of the lake.

The next assessment level will be by community or tributary; here the data from all of the canals in a community will be composited into one data set to assess the overall water quality for the canals in the community. This will hopefully assess both the effectiveness of education programs in altering land management practices by lakeside residents and the long-term, community-wide impact of the implementation of larger management measures. For the tributaries, this level of assessment will allow us to determine the effectiveness of agricultural management measures such as the development and implementation of area conservation plans and individual property water quality management plans.

The final assessment level will be the mainbody of the lake. However, this level of assessment may be of little value in determining the effectiveness of management measure implementation aimed at rectifying water quality concerns in the canals and tributaries. Historically, while the canals and tributaries have shown varying levels of water quality impairment, the mainbody of lake has never indicated a concern for elevated bacteria concentrations.

Table 38. Monitoring Sites, Parameters and Annual Monitoring Frequency for Interim-Baseline Monitoring

Site Description	Station ID	E. coli	N)$_3$	PO_4	Cl^-	SO_4	Temperature	Conductivity	Dissolved Oxygen	pH	Salinity
Lake Granbury Near Dam	11860	12	12	12	12	12	12	12	12	12	12
Lake Granbury Upstream of Business US 377	20307	12	12	12	12	12	12	12	12	12	12
Lake Granbury at FM 51	11862	12	12	12	12	12	12	12	12	12	12
Unnamed canal at the low-water crossing on Bedford Drive	18004	12	12	12	12	12	12	12	12	12	12
Unnamed canal at 3709 Greenbrook Drive	18010	12	12	12	12	12	12	12	12	12	12
Unnamed canal east of the intersection of Apollo Court and Sky Harbour Drive	18015	12	12	12	12	12	12	12	12	12	12
Unnamed canal east-southeast of intersection of Hartwood Drive and East Fernwood Court	18038	12	12	12	12	12	12	12	12	12	12
Unnamed canal west of the intersection of Kruse Court at Blue Water Circle	18741	12	12	12	12	12	12	12	12	12	12
Unnamed canal northwest of the intersection of Mallard Way and Mallard Court	18018	12	12	12	12	12	12	12	12	12	12
Unnamed canal north east of the intersection of Dakota Trail and Conejos Court	20216	12	12	12	12	12	12	12	12	12	12
Contrary Creek	20218	12	12	12	12	12	12	12	12	12	12
Long Creek	20220	12	12	12	12	12	12	12	12	12	12
Robinson Creek	20227	12	12	12	12	12	12	12	12	12	12
Strouds Creek	20228	12	12	12	12	12	12	12	12	12	12
Walnut Creek	20229	12	12	12	12	12	12	12	12	12	12
Brazos River at Turkey Creek Confluence	20230	12	12	12	12	12	12	12	12	12	12

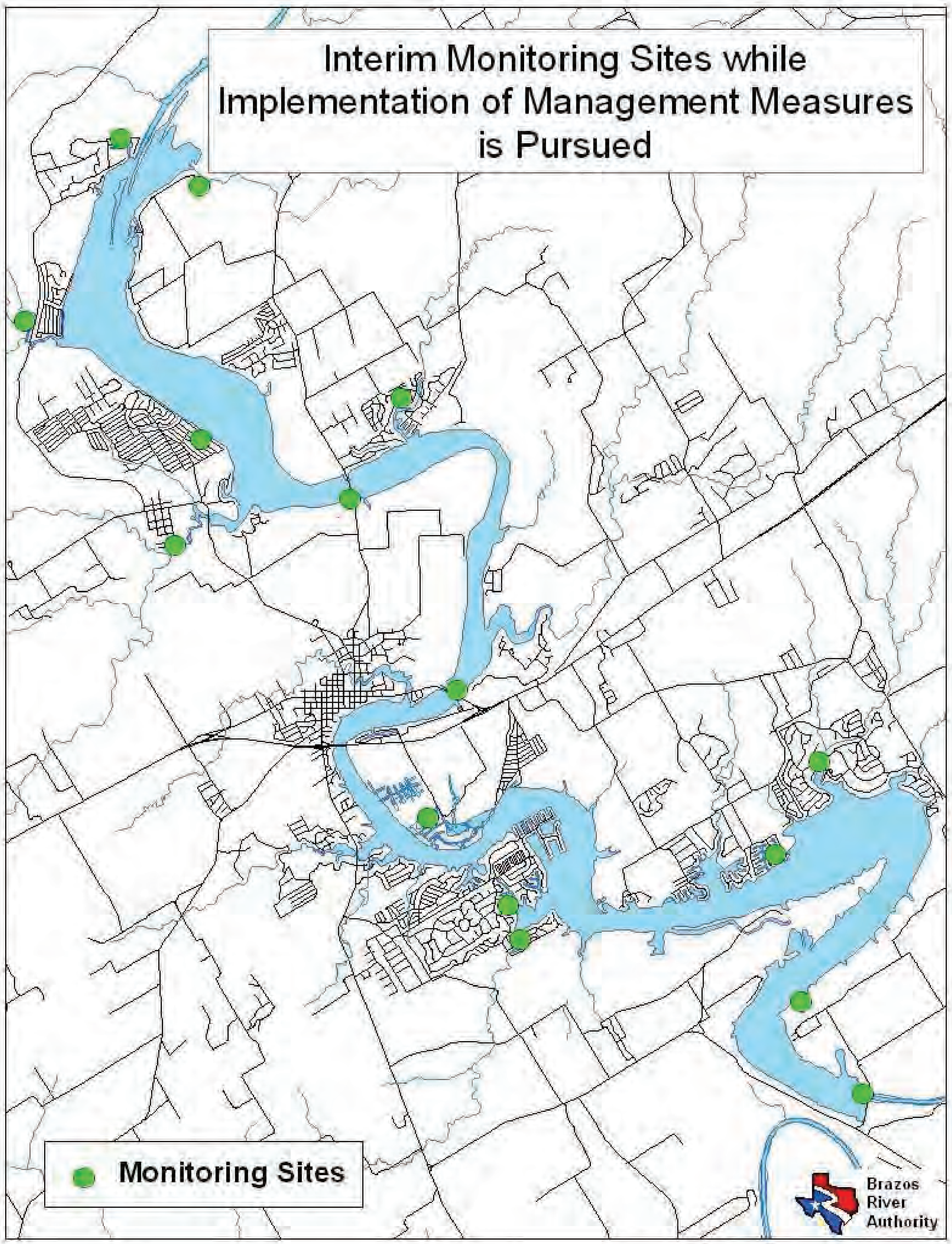

Figure 51. Interim monitoring sites

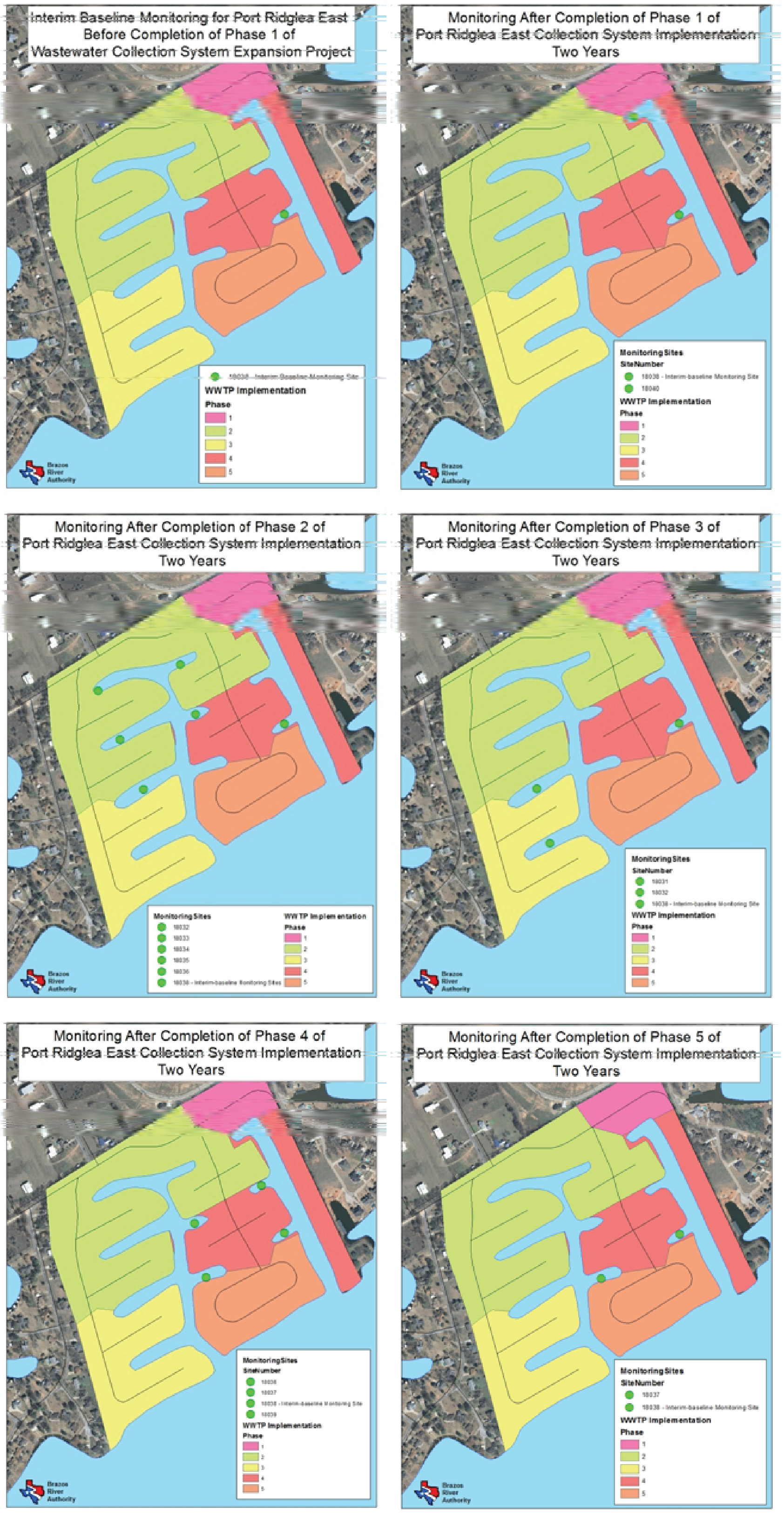

Figure 52. Hypothetical adjustments to Interim Monitoring Plan as wastewater collection management measure is implemented in Port Ridglea East.

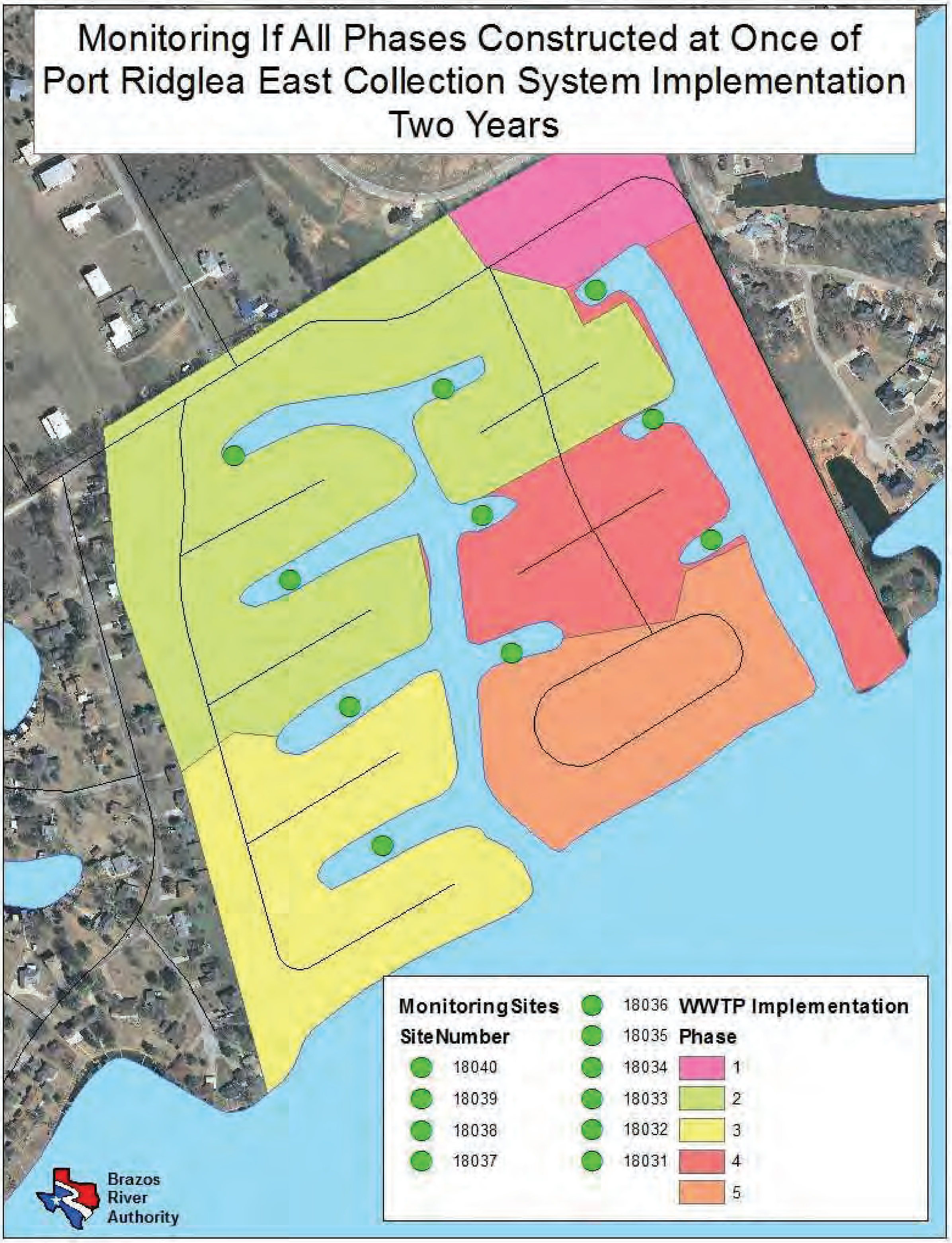

Figure 53. Implementation monitoring if all phases of WWTP expansion implemented at once.

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A.0 APPENDIX A: STAKEHOLDER GROUP BY-LAWS

Lake Granbury
Watershed Protection Plan
STAKEHOLDERS GROUP

BYLAWS

Adopted

March 24, 2006

Table of Contents

ARTICLE I. ORGANIZATION

Section 1. Organization Name
The official name of this organization shall be the "Lake Granbury Watershed Protection Plan Stakeholders Group" (Stakeholder Group).

Section 2. Establishment and Purpose
The STAKEHOLDER GROUP was established by appointment of an initial coordination of Federal and State legislative staff, Texas Commission on Environmental Quality (TCEQ) staff, and Brazos River Authority (Authority) staff. The purpose of the STAKEHOLDER GROUP shall be to provide regional input into the Lake Granbury Watershed Protection Plan (WPP).

Section 3. Principal Administrative Office
The principal administrative office of the STAKEHOLDER GROUP shall be the principal business offices of the Authority. The Watershed Coordinator shall be the principal point of contact at the Authority.

Section 4. Responsibilities
The STAKEHOLDER GROUP shall have the responsibility for providing input and information with respect to selecting, designing, and implementing water quality management measures. Foremost among those responsibilities shall be identification of areas with the greatest concerns, making recommendations for additional monitoring, and selecting Best Management Practices (BMPs).

ARTICLE II. VOTING MEMBERSHIP

Section 1. Initial Composition
The initial voting members of the STAKEHOLDER GROUP were selected by the initial coordinating body. Member groups were selected to ensure adequate and balanced representation of the interests of individuals and entities that have a vested interest in the waters of Lake Granbury or directly affected by project outcome or decisions, including the general public, associations, government, industry, fee payers, and other interested parties.

The entity or stakeholder group that has been asked to participate shall appoint an individual to be their designated representative.

Section 2. Voting Membership
The current voting membership of the STAKEHOLDER GROUP shall include adequate and balanced representation of the interests of individuals and entities that have a vested interest in

the waters of Lake Granbury and other interests determined by the STAKEHOLDER GROUP. The voting membership of the STAKEHOLDER GROUP may also include persons added or removed as provided under this Article and Article III. The voting membership of the STAKEHOLDER GROUP shall not exceed 25 members.

Section 3. Terms of Office

All voting member groups are considered to be permanent members for the duration of the project. Anticipated project duration is from November 21, 2005 through August 31, 2009.

If a designated representative is unable to serve for the duration of the project, the entity or stakeholder group that the individual represents will be asked to appoint a new individual to represent their interests.

Section 4. Conditions of Membership

In order to be eligible for voting membership on the STAKEHOLDER GROUP, a person at the time of taking office must represent the group for which a member is sought, be willing to participate in the WPP process, and abide by these Bylaws. The individual voting member cannot select his/her replacement. Replacement must be chosen by the entity from which membership is sought.

Section 5. Attendance

All members shall make a good faith effort to attend all STAKEHOLDER GROUP meetings. Records of attendance shall be kept by the Authority at all STAKEHOLDER GROUP meetings. Voting members must attend at least one-half of the sum of all meetings during a calendar year. Voting members of the STAKEHOLDER GROUP who have excessive absences shall be subject to removal from membership under Section 7 of this Article. Representation by a designated alternate pursuant to Article V does not excuse a member's absence.

Section 6. Code of Conduct

Members and designated alternates of the STAKEHOLDER GROUP shall ethically conduct the business of the STAKEHOLDER GROUP and shall avoid any form or appearance of a conflict of interest, real or apparent.

Potential conflicts of interest shall be clearly stated by the voting member or designated alternate prior to any deliberation or action on an item with which the voting member or designated alternate may be in conflict. Where the potential conflict is restricted to a divisible portion of an item, the Facilitator may divide the agenda item into parts, at the Facilitator’s discretion, for deliberation and voting purposes. An abstention from participation in deliberations, decisions, or voting and the reasons therefore shall be noted in the minutes.

The fact that a member is also an employee or public official of an entity which has some relationship, direct or indirect, with the STAKEHOLDER GROUP (e.g., County Judge, Mayor, City Manager, Water District or River Authority member or employee), shall not disqualify such person from voting membership and full participation. These Bylaws recognize that such circumstances will probably arise in the very nature of the work and the legal structure of the STAKEHOLDER GROUP and that it is appropriate to expressly recognize such facts.

Section 7. Removal of Voting Members

The following shall constitute grounds for removal of a voting member:

a. excessive absenteeism as defined under Section 5 of this Article determined by the STAKEHOLDER GROUP;
b. resignation;
c. change in status so that the member no longer represents the interest he or she was selected to represent;
d. failure to abide by the Code of Conduct provisions set forth under Section 6 of this Article;
e. falsifying documents or information presented to the STAKEHOLDER GROUP;
f. any other serious violation of these Bylaws as may be determined by the voting members; or
g. The voting member's designated alternate fails to abide by the Code of Conduct provisions set forth under Section 6 of this Article.

ARTICLE III. SELECTION OF ADDITIONAL GROUPS TO THE VOTING MEMBERSHIP

Section 1. Timing

No later than 30 calendar days prior to the next meeting, a voting member shall submit to the Watershed Coordinator a written proposal for consideration of an additional group and a written request that the item be added to the next meetings agenda.

Section 2. Proposal Requirements

Such proposals shall identify the particular interest group for which the nomination is sought and supporting documentation of need for this group to be represented.

Section 3. Vote Required

The voting members shall make a decision for the addition of a group by a two-thirds vote of the voting membership when a quorum is present.

Section 4. Membership Criteria

In the consideration of new groups, the Voting Membership shall strive to achieve geographic, ethnic, and gender diversity.

ARTICLE IV. DESIGNATED ALTERNATES

Each voting member shall designate an alternate to represent him/her when he/she is unable to attend a meeting or hearing. Each voting member must notify the Watershed Coordinator in writing a designated alternate.

The designated alternate shall enjoy the same voting privileges and shall be bound by the same duties, terms, and conditions as the member they represent, except as otherwise provided in these Bylaws.

ARTICLE V. MEETINGS

Section 1. Public Participation
All meetings of the STAKEHOLDER GROUP shall be open to the public. All actions of the STAKEHOLDER GROUP shall be deliberated and undertaken in open meeting. Copies of all materials presented or discussed during meeting shall be made available for public inspection.

Section 2. Regular Meetings
At least one regular meeting of the STAKEHOLDER GROUP shall be held each quarter of each year. The Watershed Coordinator shall insure that an advance notice for regular meetings will be provided to the Voting Membership of the STAKEHOLDER GROUP.

Section 3. Special Meetings
A simple majority of the total Voting Membership of the STAKEHOLDER GROUP may call special meetings of the STAKEHOLDER GROUP. The Watershed Coordinator shall insure that advance notice is provided to the Voting Membership of the STAKEHOLDER GROUP.

Section 4. Agenda
The Watershed Coordinator of the STAKEHOLDER GROUP shall insure that an agenda is prepared for all meetings. Items shall be placed on the agenda as deemed necessary by the Watershed Coordinator or the TCEQ. Copies of the agenda and all supporting information shall be made available for public inspection.

Section 5. Quorum
A quorum of the STAKEHOLDER GROUP shall be a simple majority of the Voting Membership. At least a quorum shall be necessary to conduct any business of the STAKEHOLDER GROUP. However, if a quorum cannot be gathered or a decision cannot be

reached and a critical deliverable is due, the Watershed Coordinator will move forward in consultation with TCEQ to complete the deliverable.

ARTICLE VI. MAKING DECISIONS

Section 1. Applicability; No Written Proxies
Written proxies shall not be allowed in any decision-making by the STAKEHOLDER GROUP. However, designated alternates shall be allowed to participate in decision making as set forth in these Bylaws.

Section 2. Decision-Making Process
The STAKEHOLDER GROUP shall make decisions and take action by a vote of a simple majority of the Voting Membership when a quorum is present, unless otherwise specified in these Bylaws. However, if a quorum cannot be gathered or a decision cannot be reached and a critical deliverable is due, the Watershed Coordinator will move forward in consultation with TCEQ to complete the deliverable.

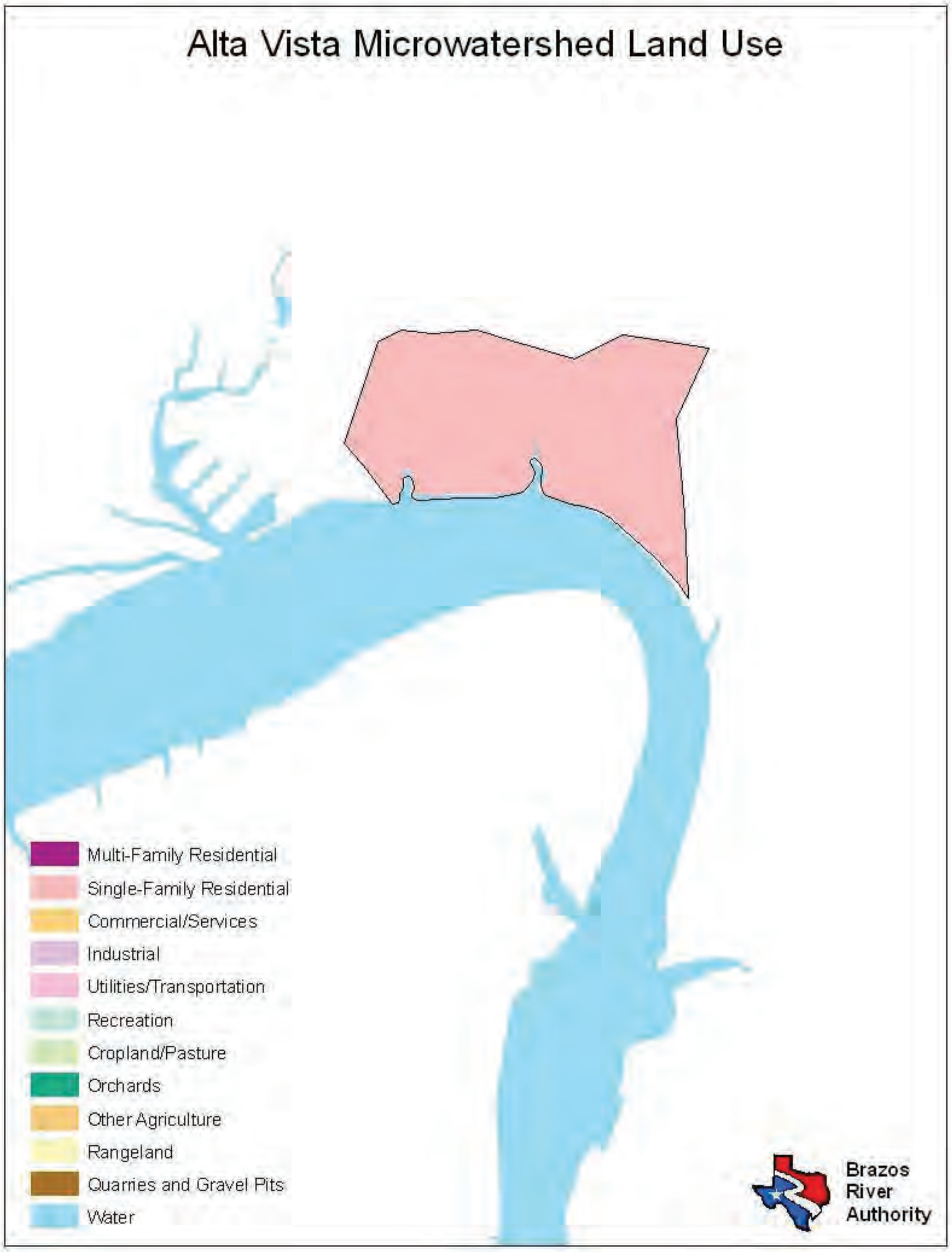
ARTICLE VII. COMPENSATION

Members of the STAKEHOLDER GROUP are not to be compensated for their services by the State of Texas.

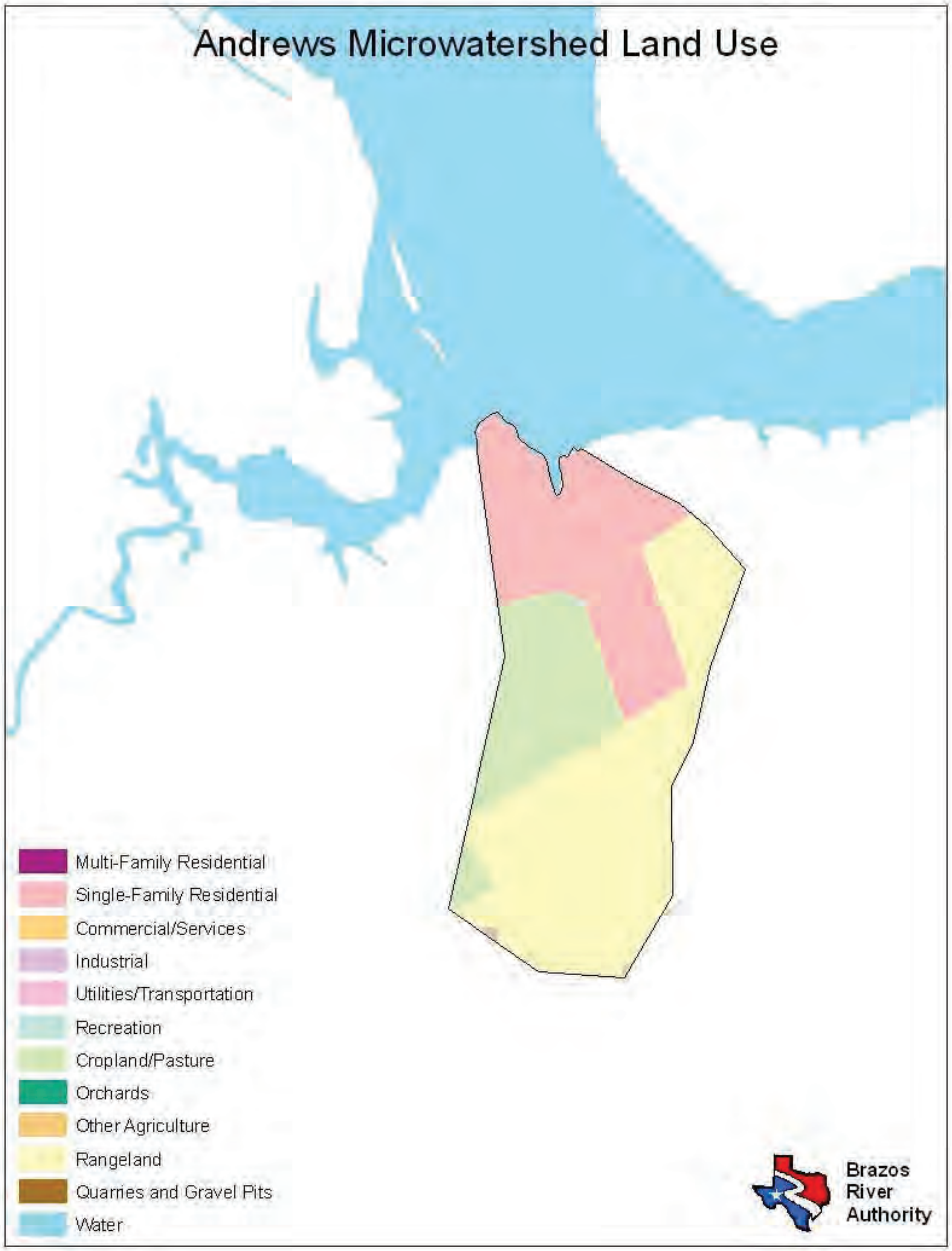
ARTICLE VIII. ADOPTING AND AMENDING THE BYLAWS

These Bylaws shall have full force and effect upon approval and adoption by the voting members of the STAKEHOLDER GROUP. The voting members shall adopt these Bylaws and any amendments thereto by a two-thirds vote of the voting membership when a quorum is present.

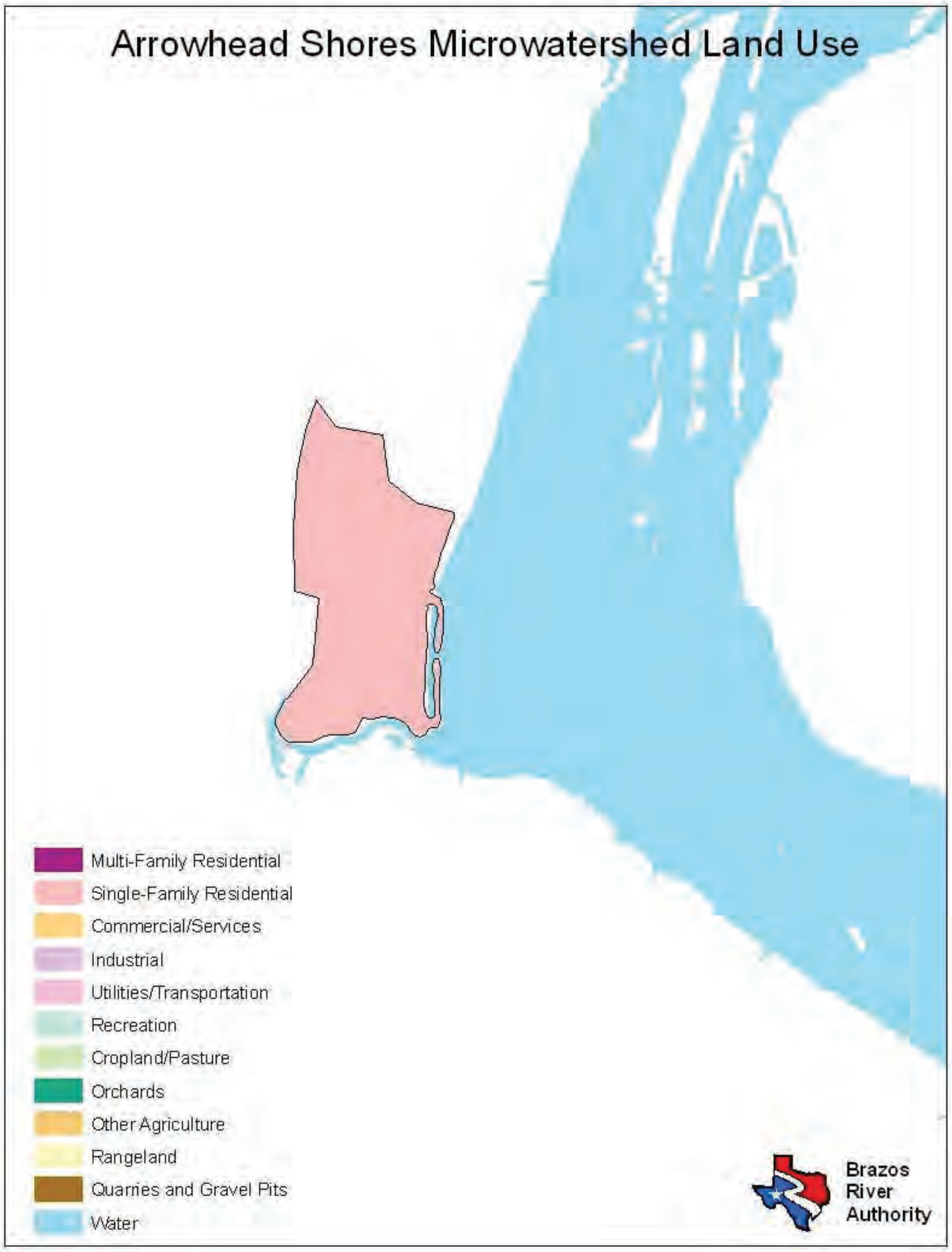
B.0 APPENDIX B: LAND USE SUMMARY



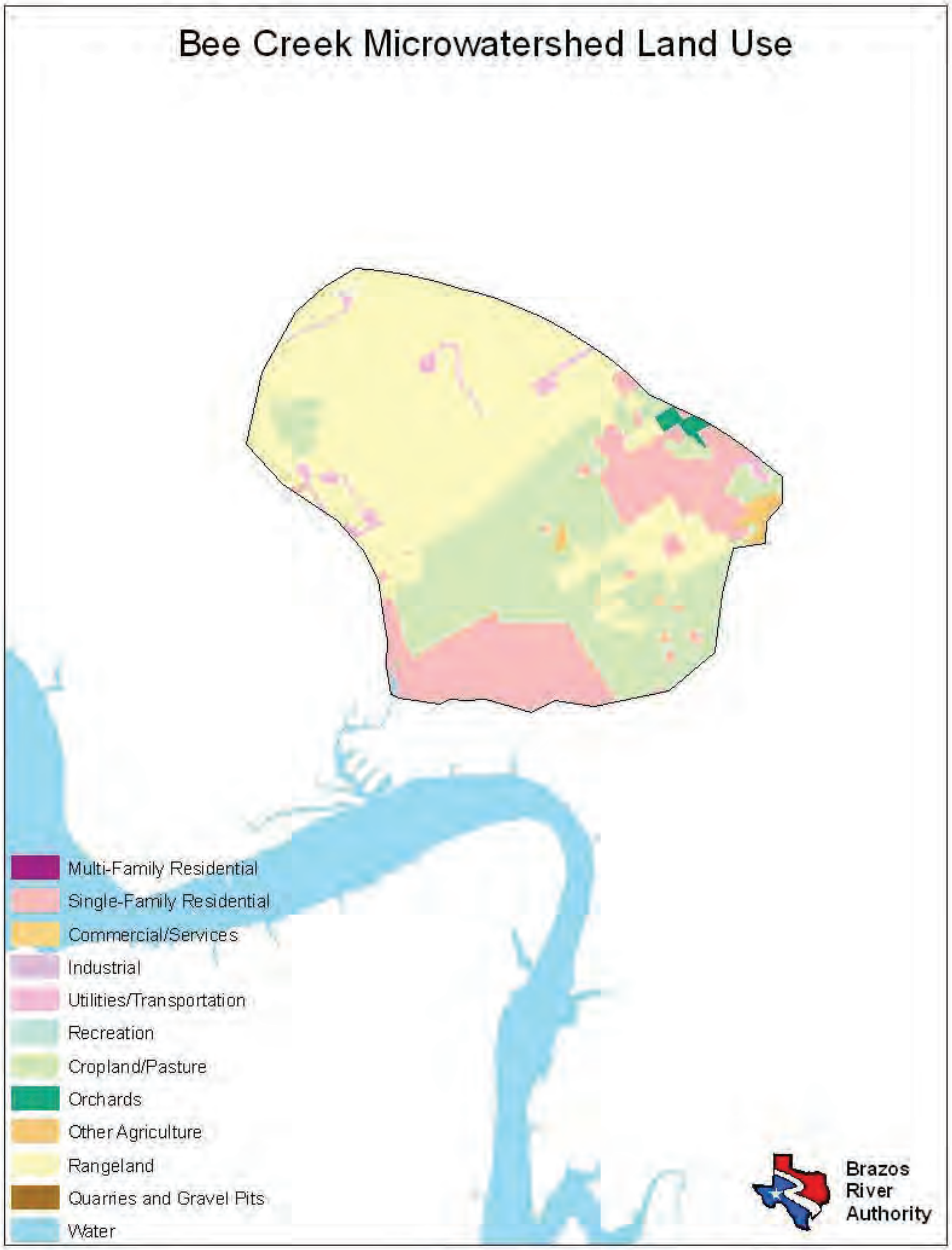
Land Use	Percent by Microwatershed
Single Family Residential	99%
Water	1%



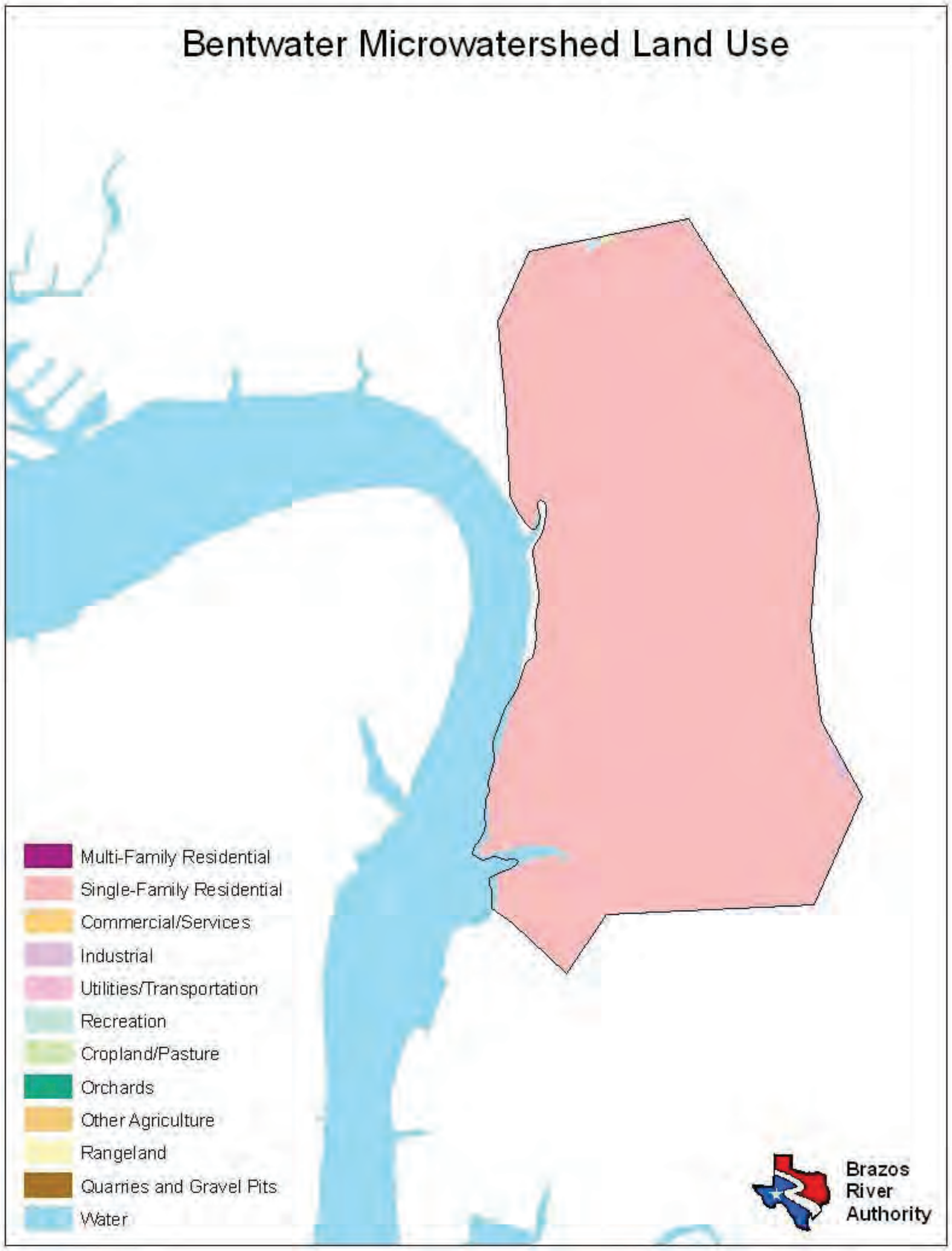
Land Use	Percent by Microwatershed
Single Family Residential	31%
Cropland/Pasture	20%
Rangeland	49%
Water	<1%



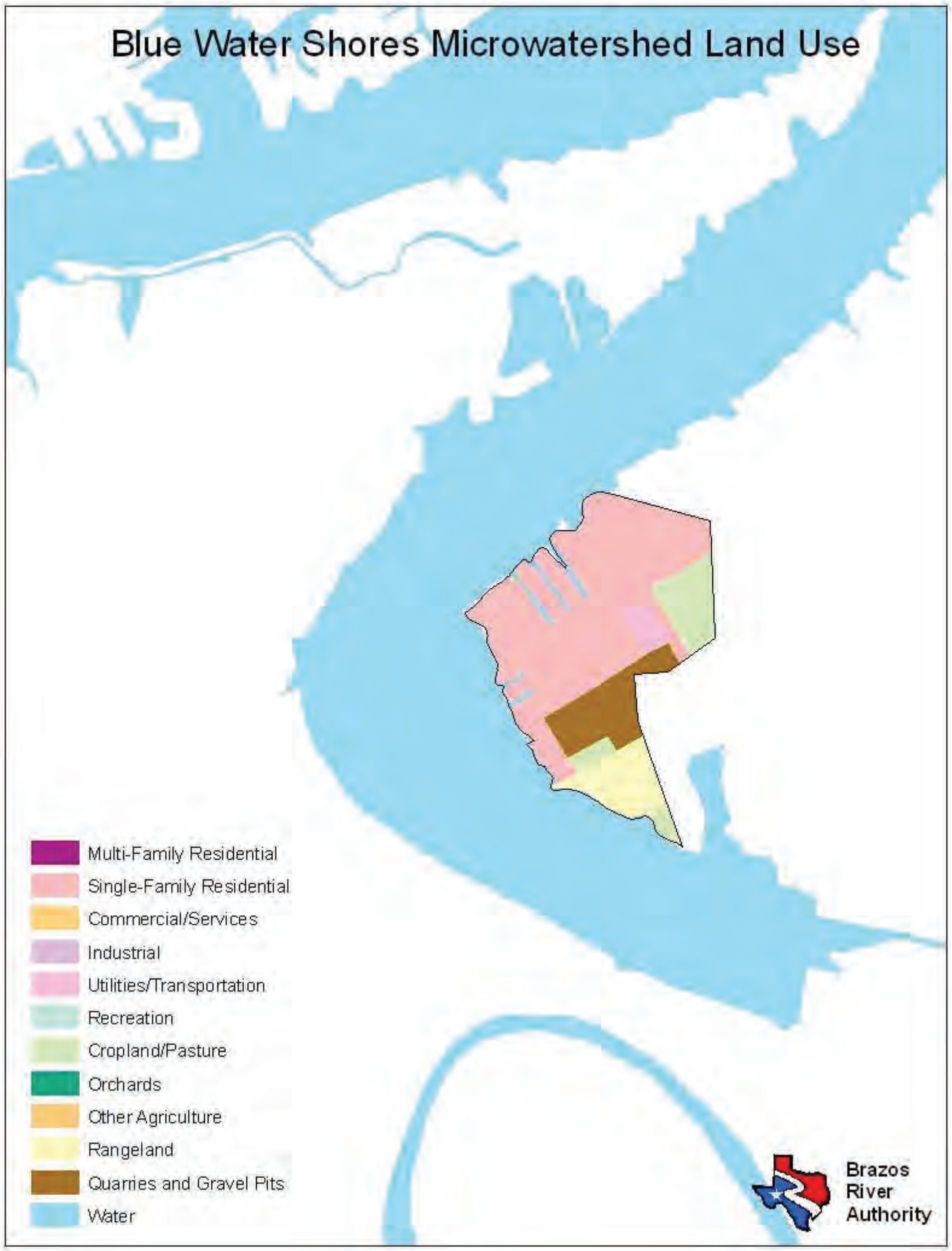
Land Use	Percent by Microwatershed
Single Family Residential	99%
Water	<1%



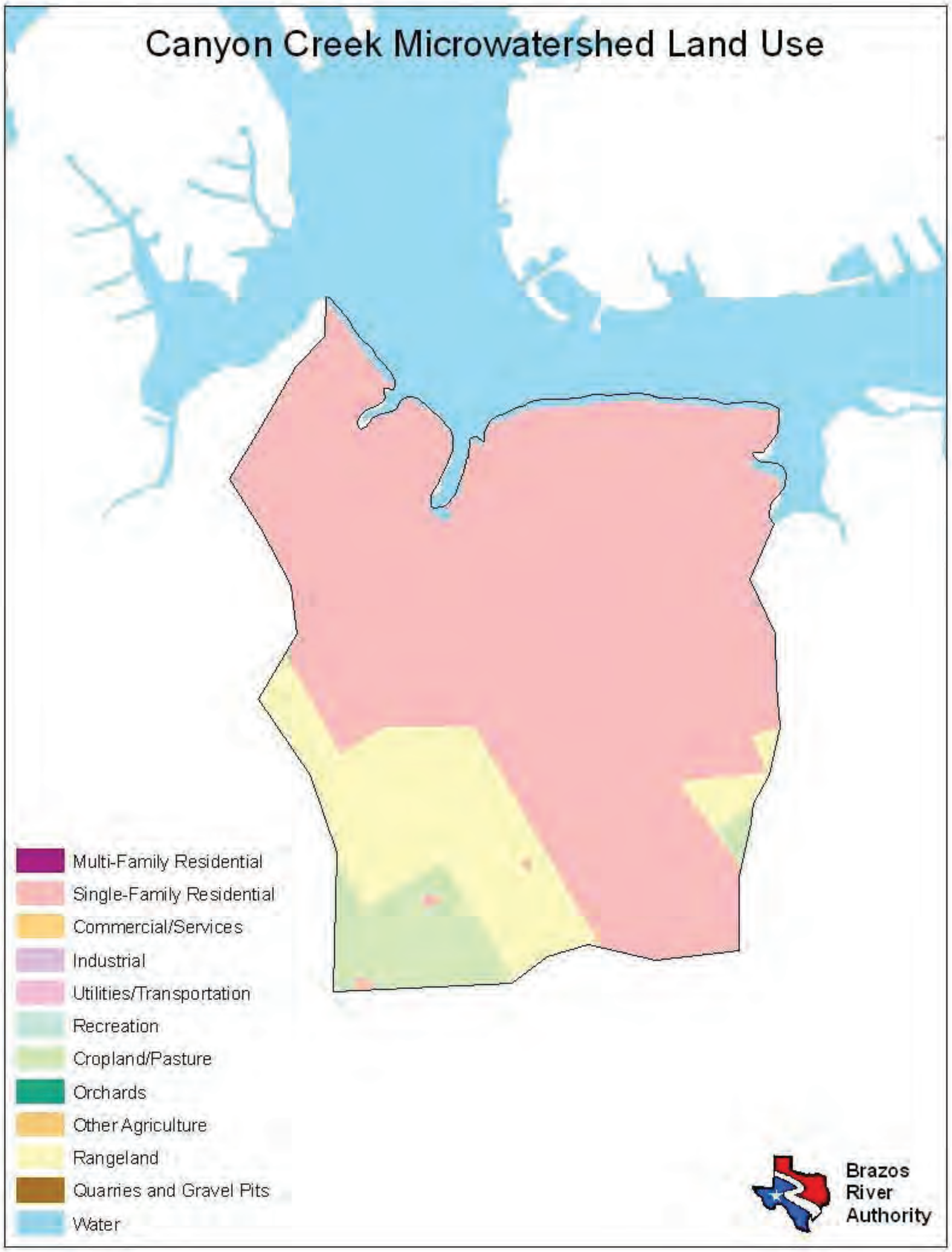
Land Use	Percent by Microwatershed
Single Family Residential	19%
Utilities/Transportation	2%
Cropland/Pasture	29%
Orchards	<1%
Rangeland	49%
Water	<1%



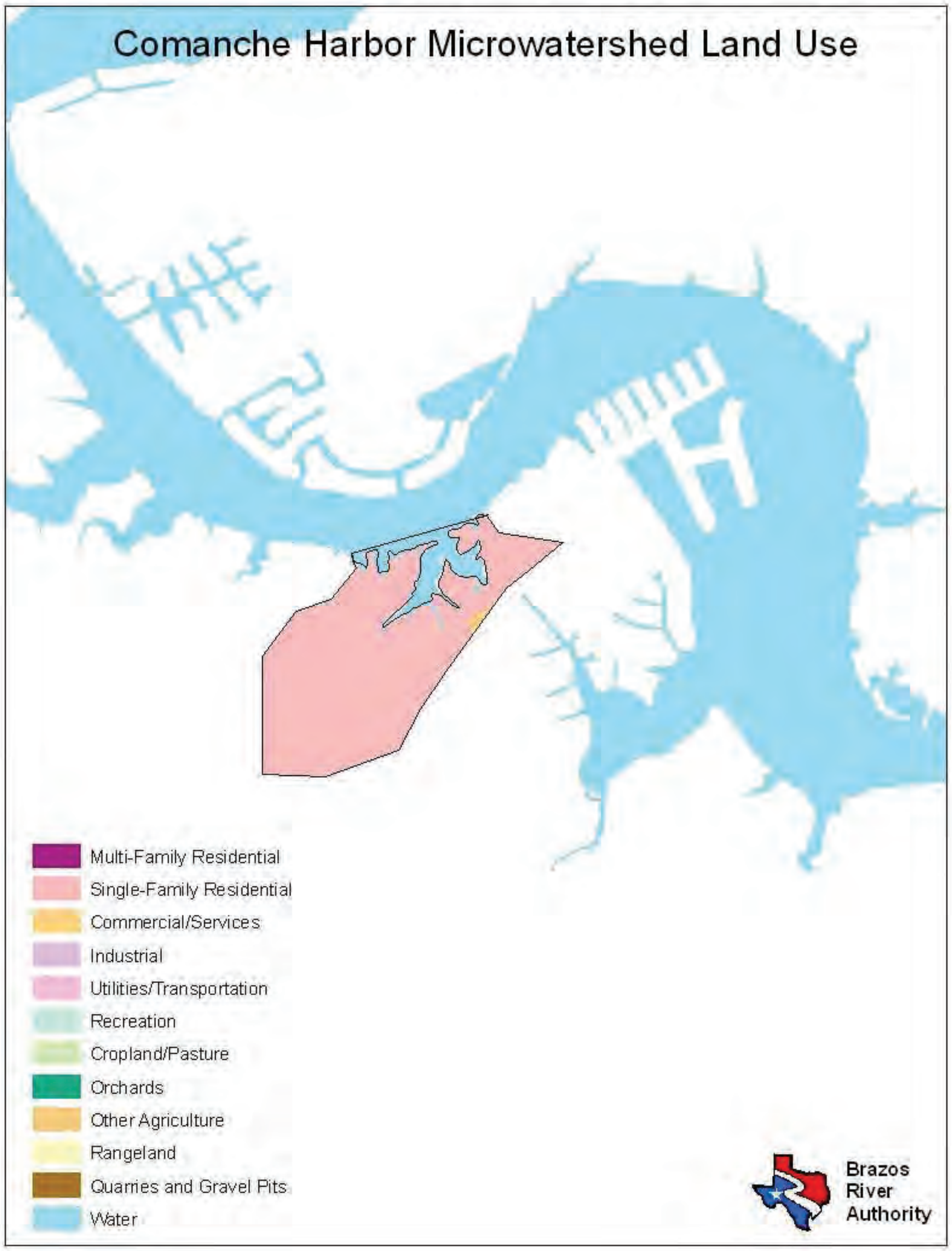
Land Use	Percent by Microwatershed
Single Family Residential	99%
Industrial	<1%
Cropland/Pasture	<1%
Water	<1%



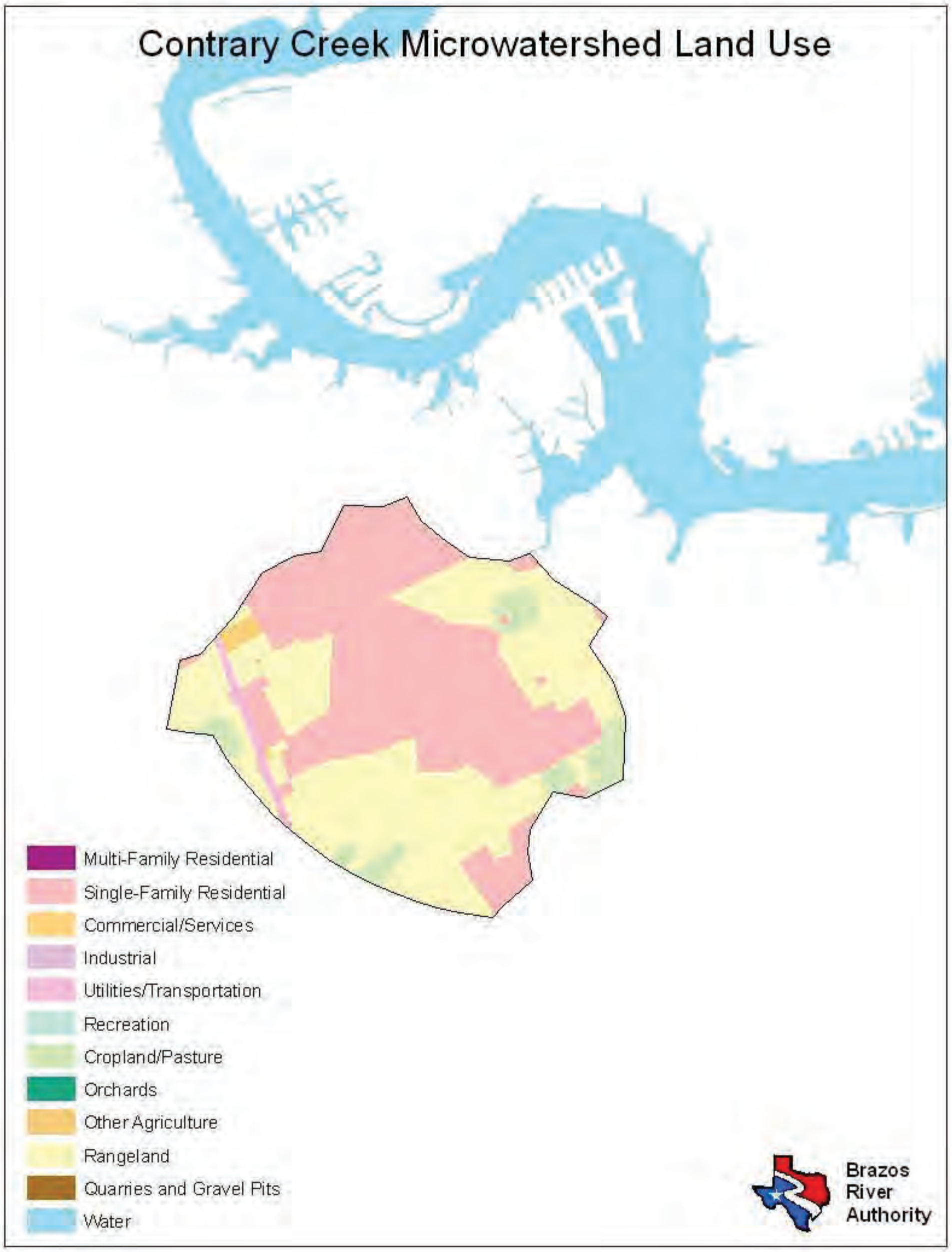
Land Use	Percent by Microwatershed
Single Family Residential	63%
Utilities/Transportation	2%
Cropland/Pasture	11%
Rangeland	9%
Quarries and Gravel Pits	12%
Water	3%



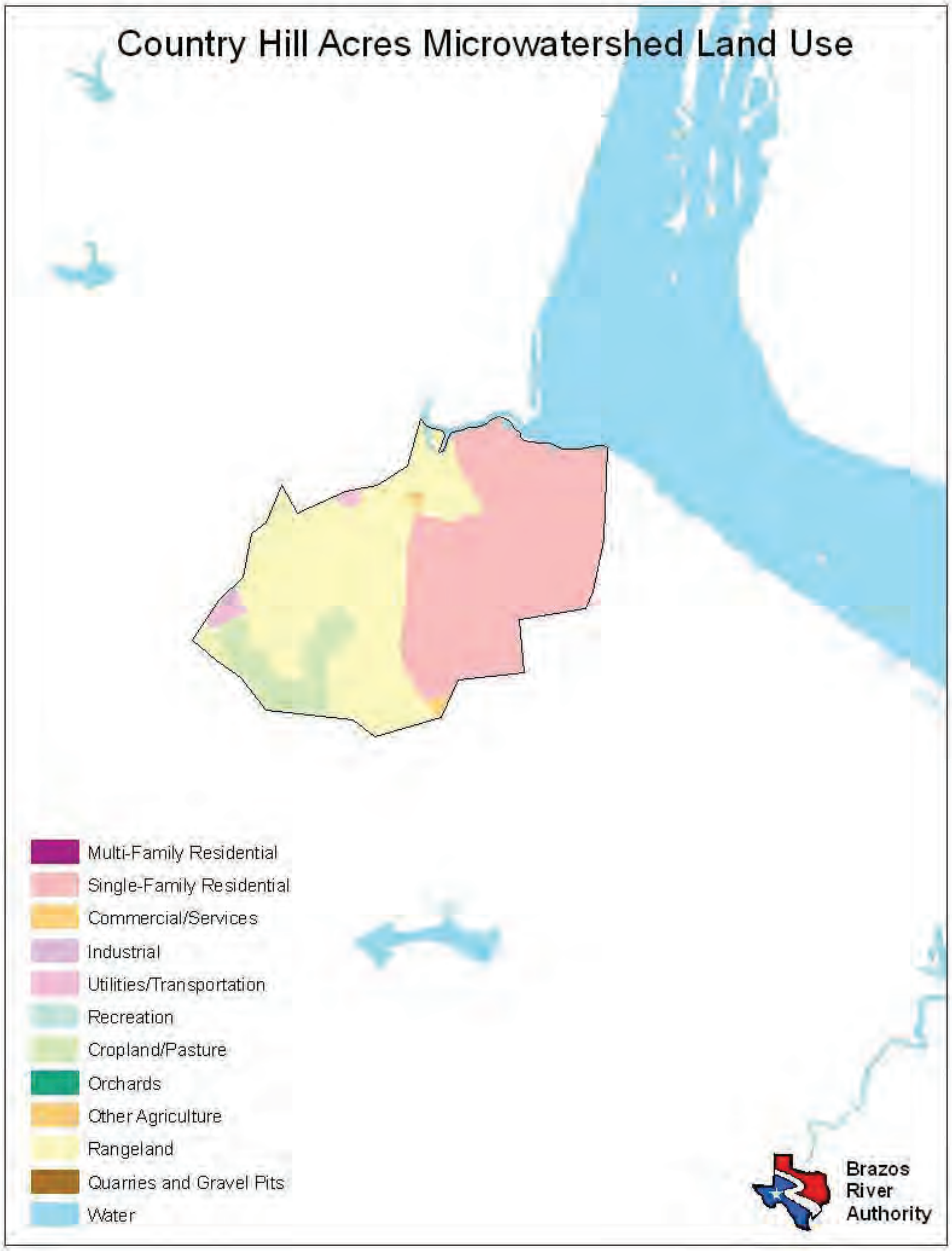
Land Use	Percent by Microwatershed
Single Family Residential	76%
Cropland/Pasture	6%
Rangeland	16%
Water	1%



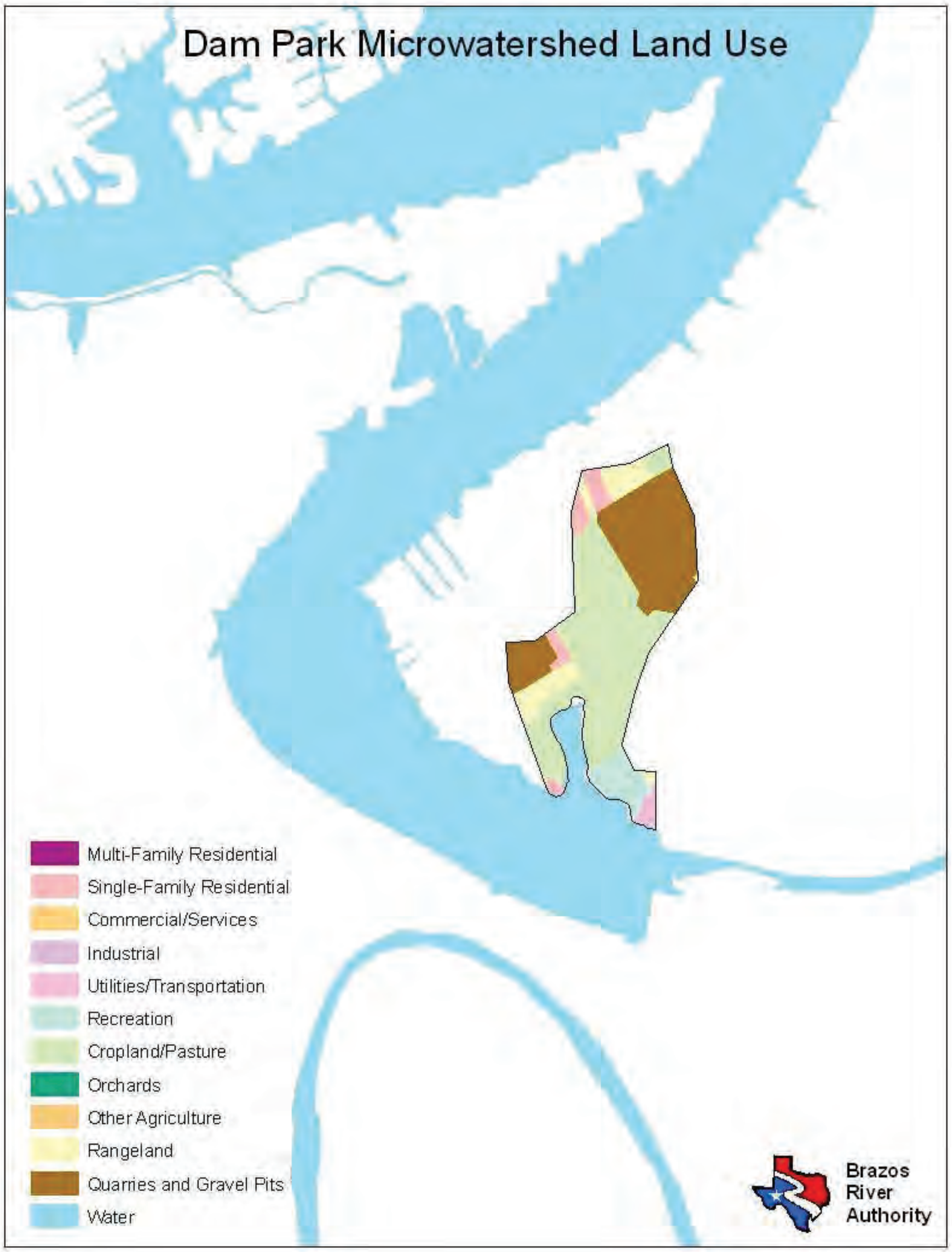
Land Use	Percent by Microwatershed
Single Family Residential	97%
Commercial/Services	<1%
Water	2%



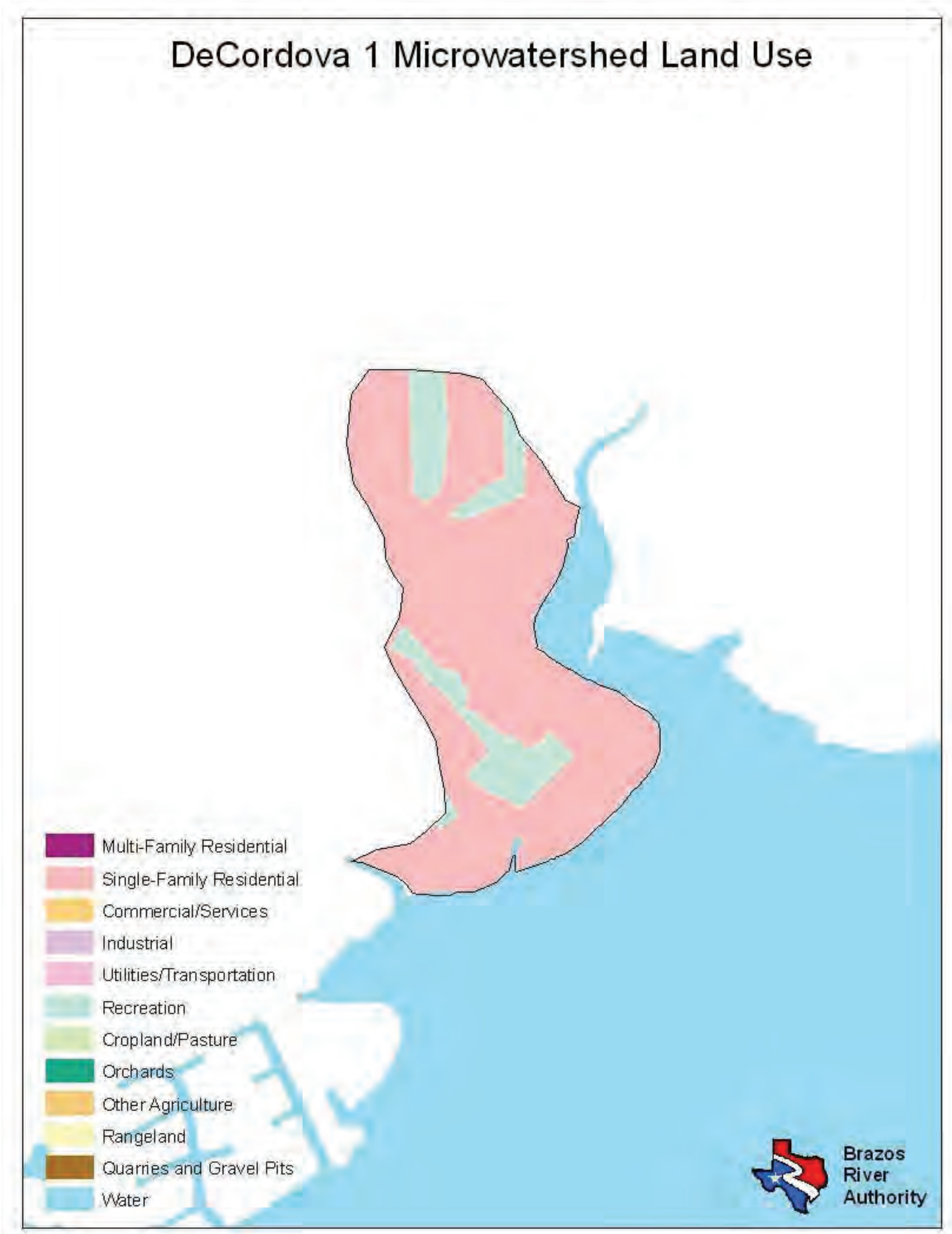
Land Use	Percent by Microwatershed
Single Family Residential	47%
Commercial/Services	<1%
Utilities/Transportation	1%
Cropland/Pasture	6%
Rangeland	45%



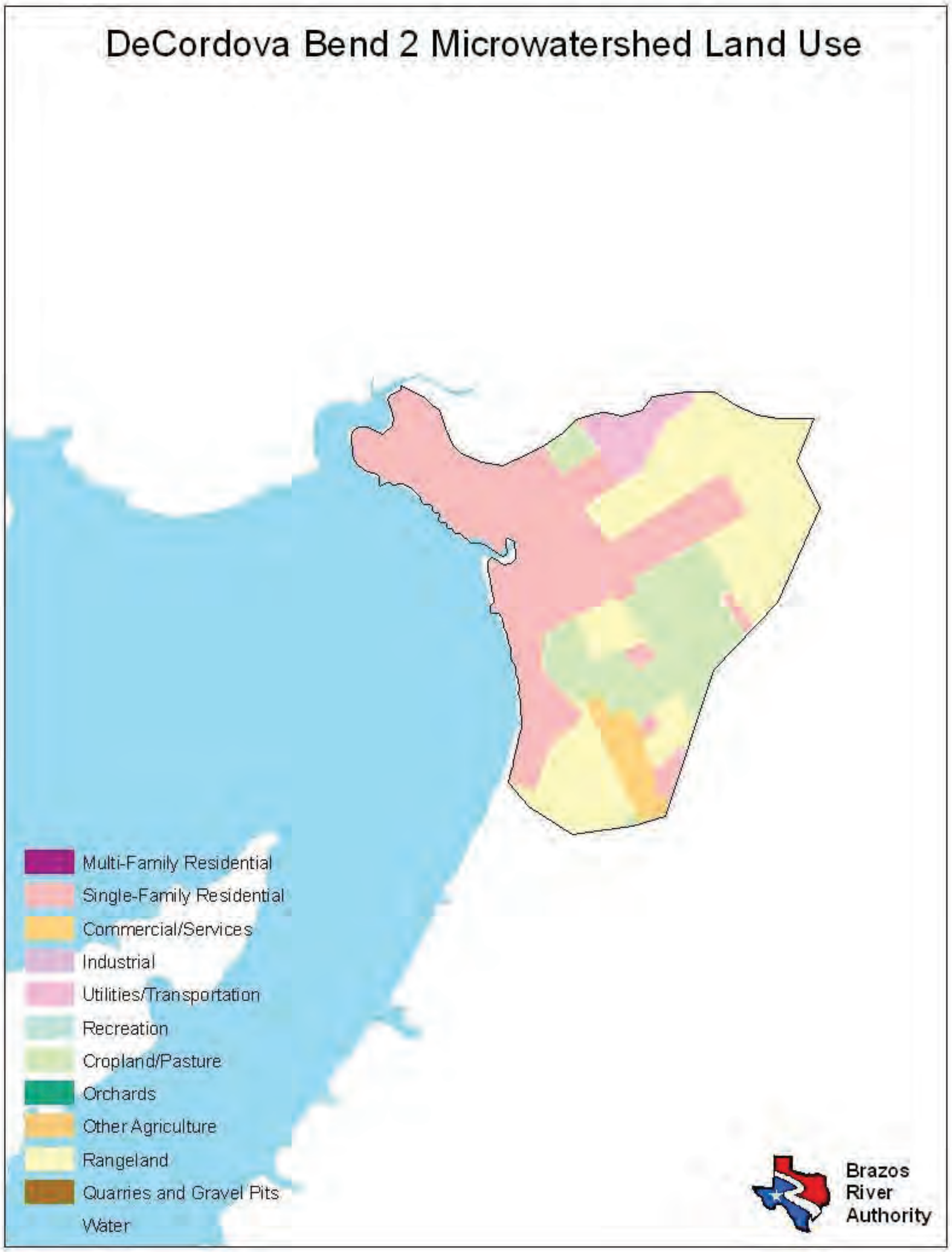
Land Use	Percent by Microwatershed
Single Family Residential	46%
Commercial/Services	<1%
Utilities/Transportation	1%
Cropland/Pasture	8%
Rangeland	43%
Water	<1%



Land Use	Percent by Microwatershed
Single Family Residential	6%
Utilities/Transportation	1%
Recreation	6%
Cropland/Pasture	46%
Rangeland	10%
Quarries and Gravel Pits	31%
Water	<1%

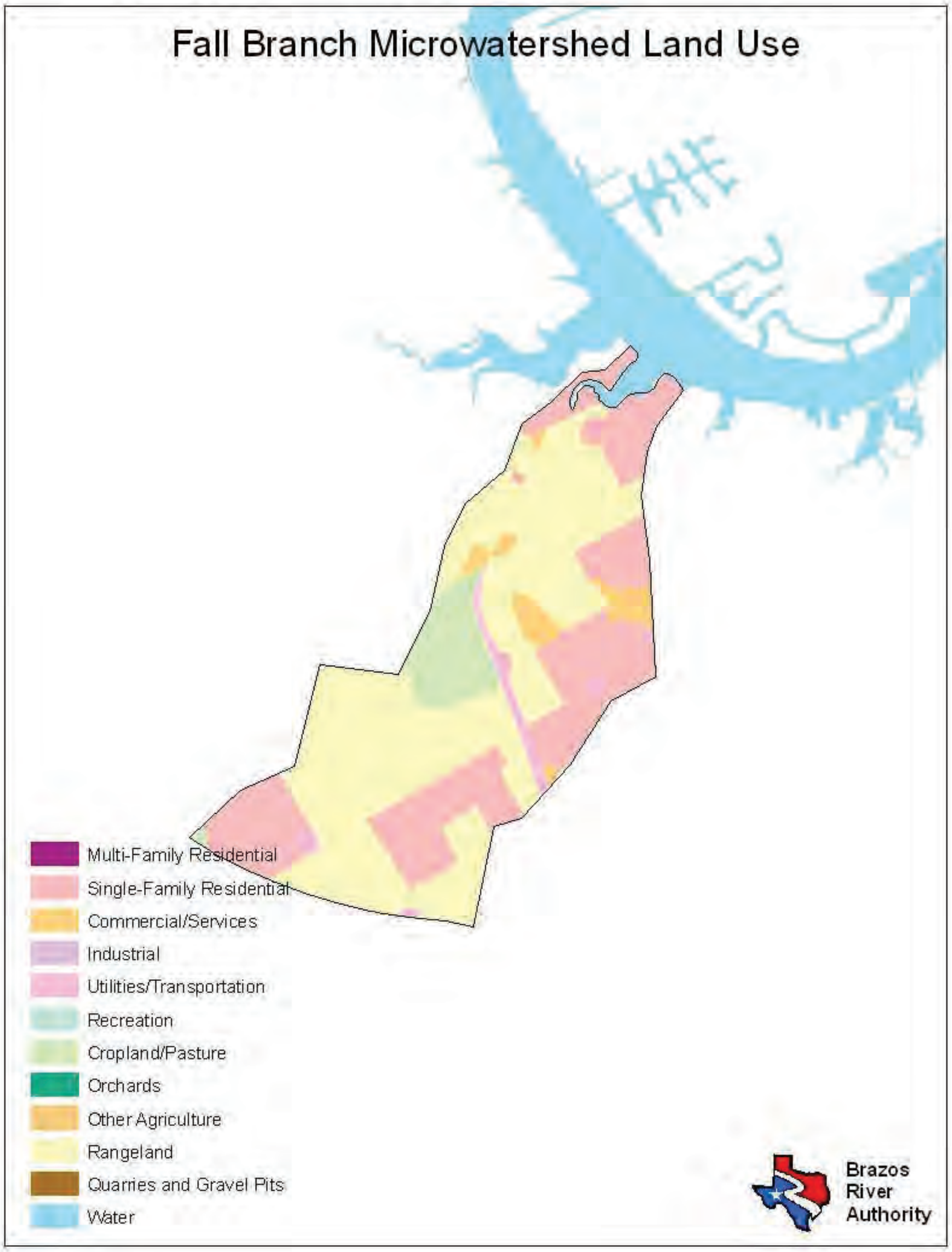


Land Use	Percent by Microwatershed
Single Family Residential	84%
Recreation	15%
Water	<1%

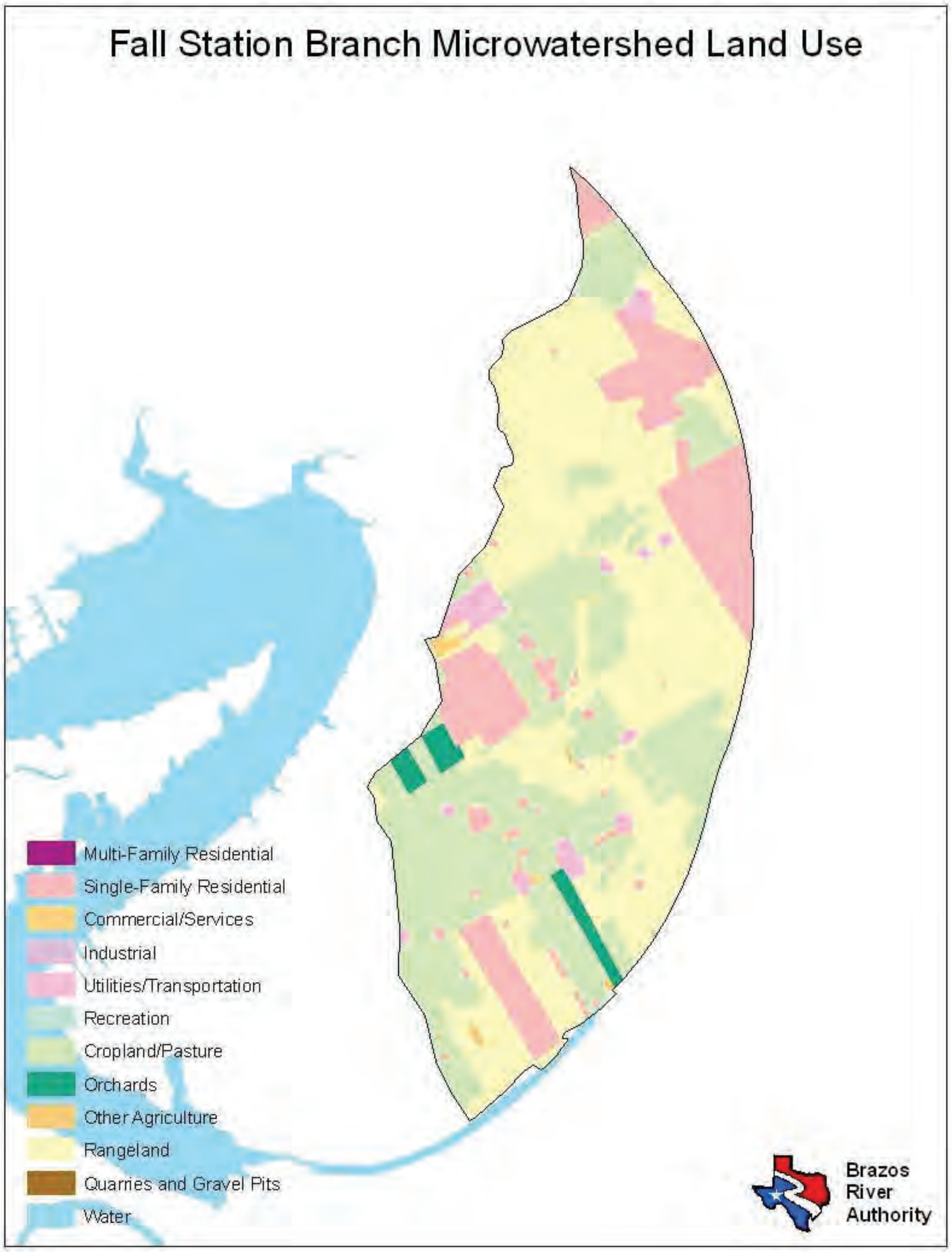


Land Use	Percent by Microwatershed
Single Family Residential	40%
Commercial/Services	4%
Utilities/Transportation	4%
Cropland/Pasture	18%
Rangeland	10%
Quarries and Gravel Pits	34%
Water	<1%

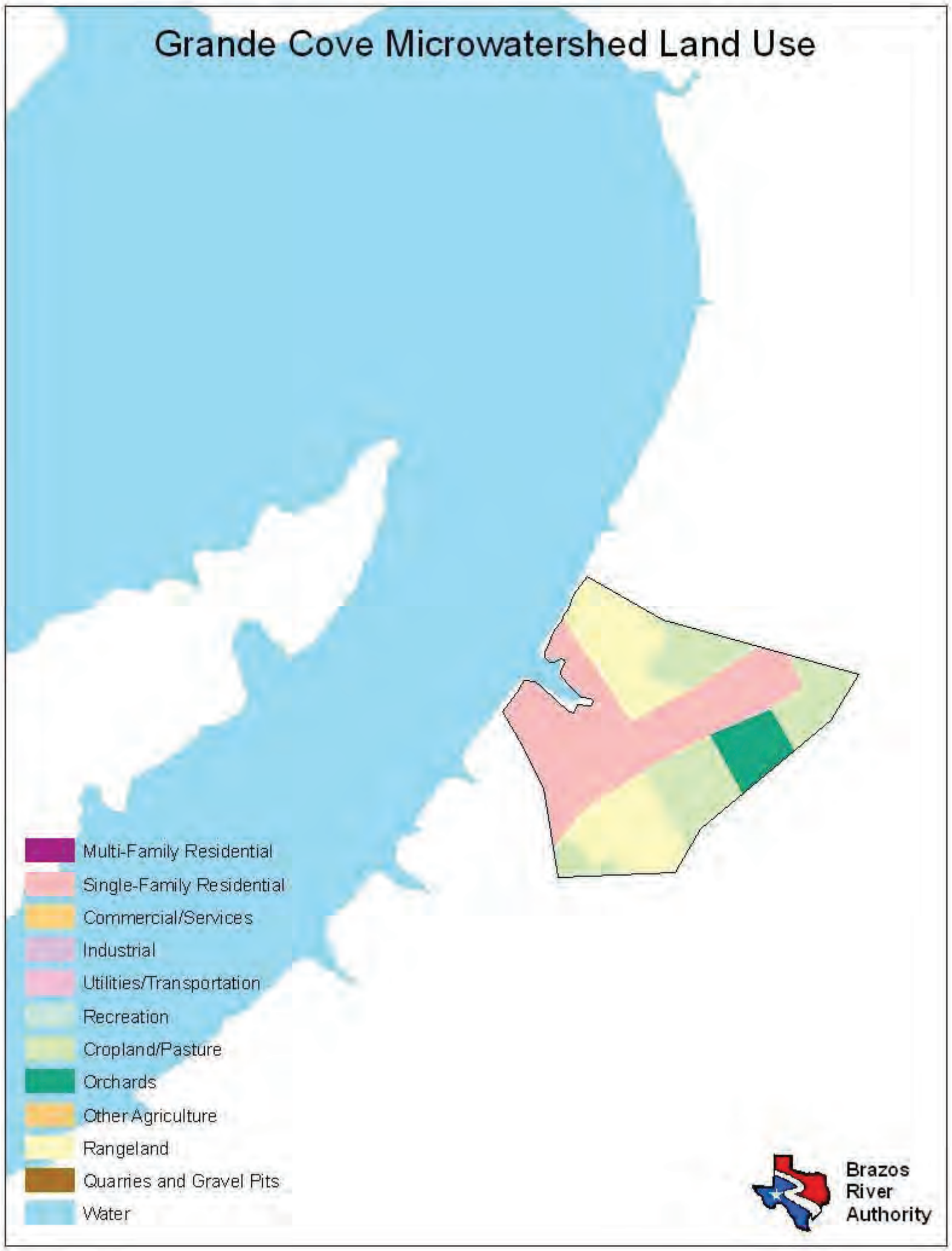
Land Use	Percent by Microwatershed
Single Family Residential	22%
Cropland/Pasture	72%
Rangeland	4%
Water	2%



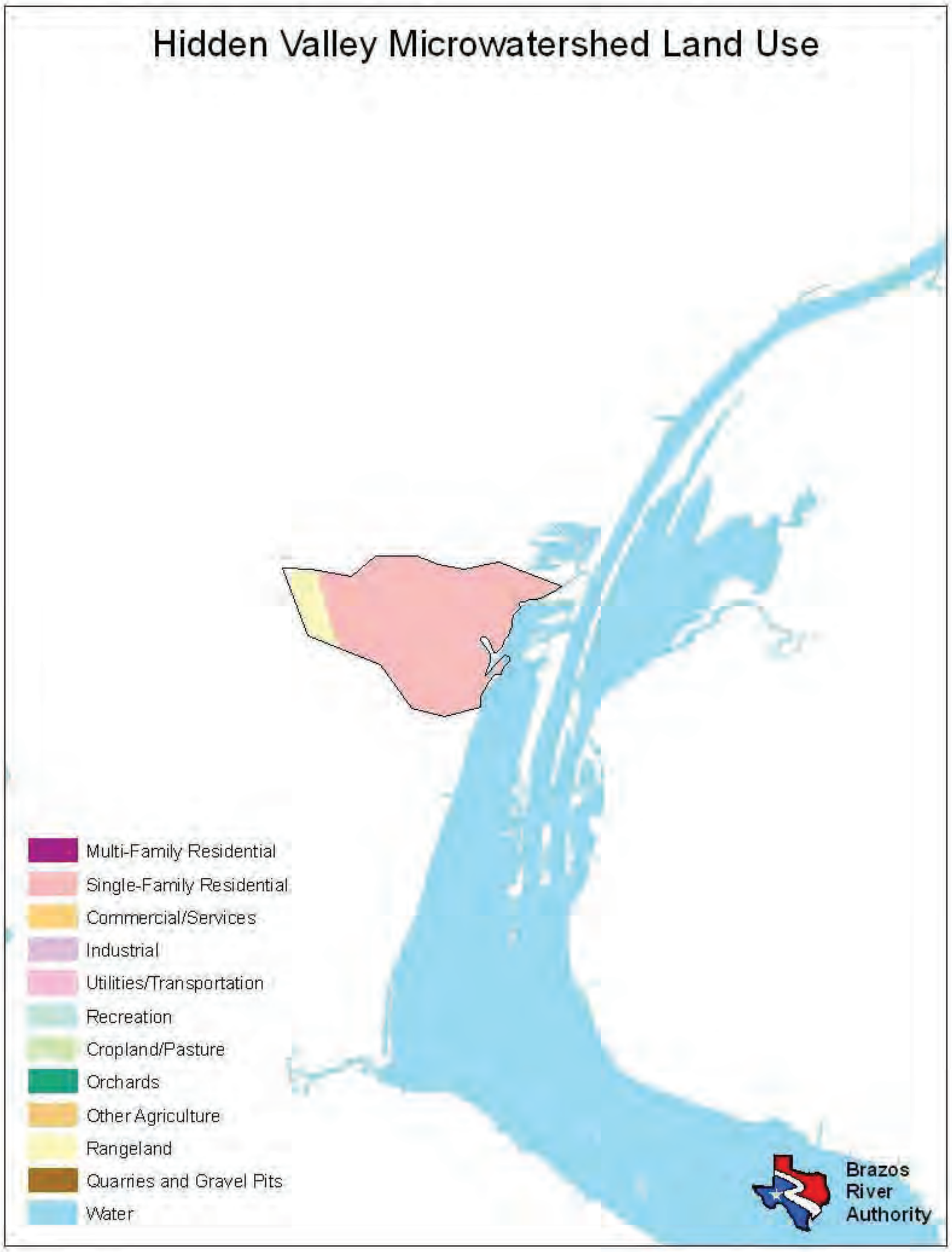
Land Use	Percent by Microwatershed
Single Family Residential	33%
Commercial/Services	4%
Utilities/Transportation	2%
Cropland/Pasture	7%
Rangeland	54%
Water	<1%



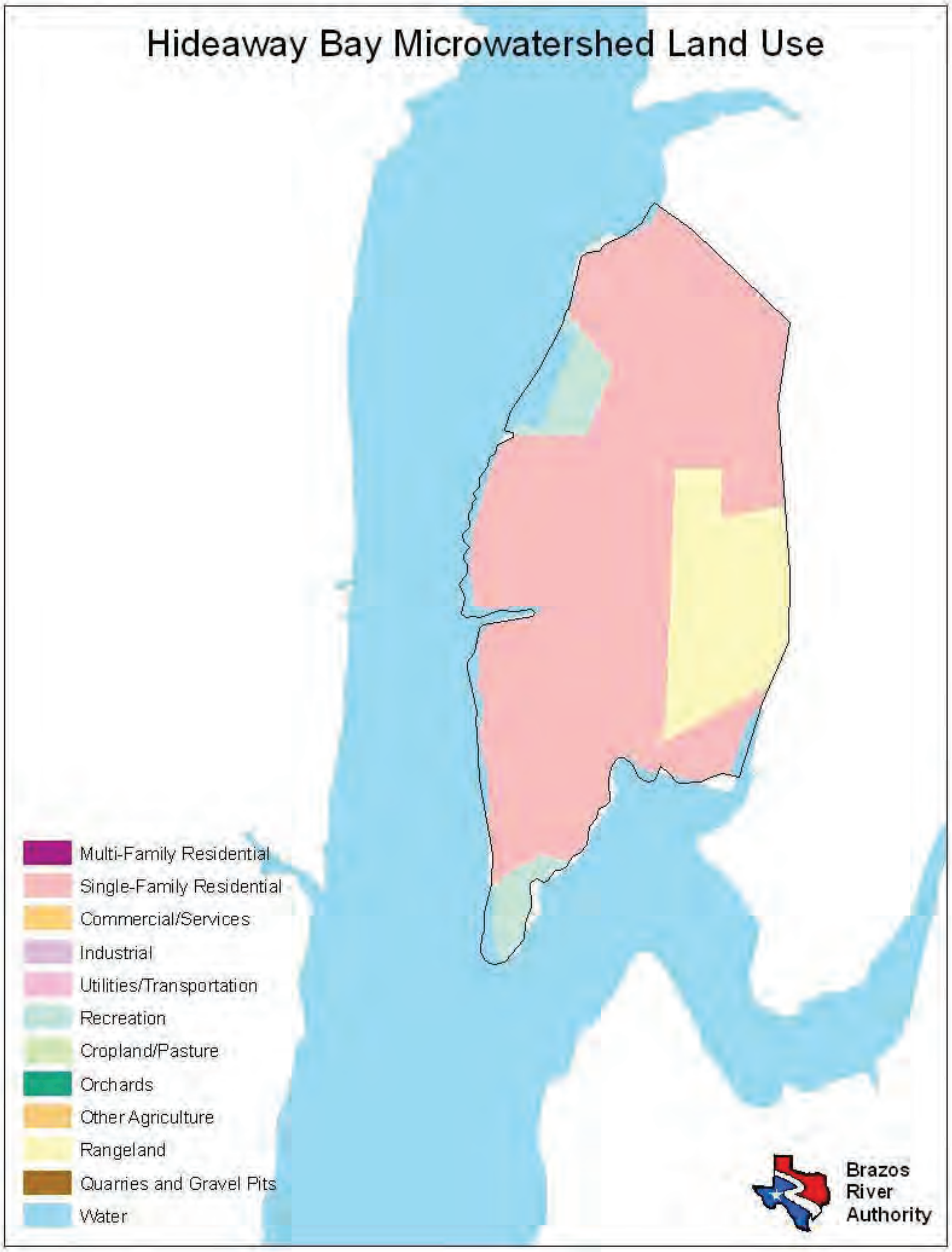
Land Use	Percent by Microwatershed
Single Family Residential	17%
Commercial/Services	<1%
Utilities/Transportation	2%
Cropland/Pasture	35%
Orchard	2%
Rangeland	43%
Water	<1%



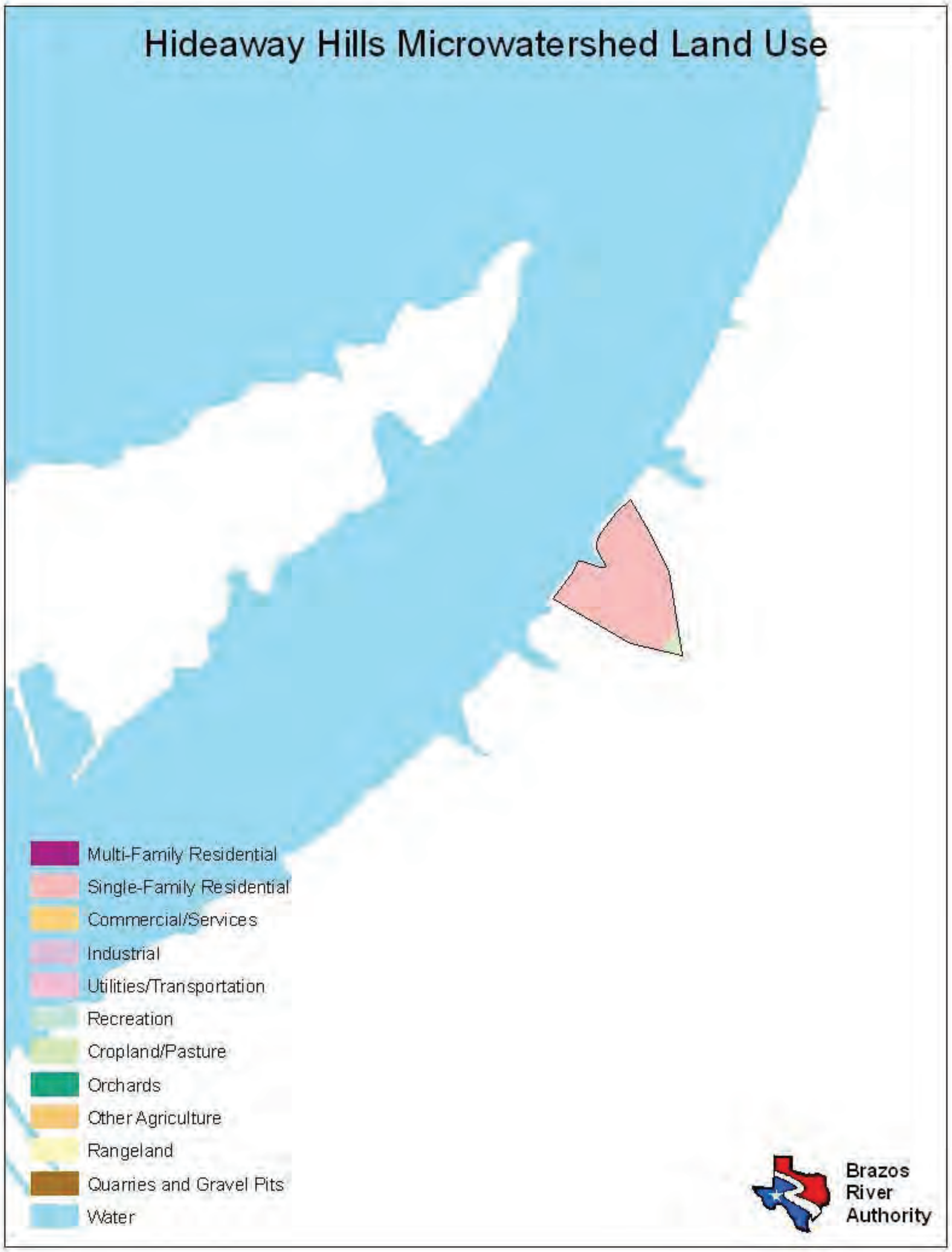
Land Use	Percent by Microwatershed
Single Family Residential	40%
Cropland/Pasture	26%
Orchard	6%
Rangeland	27%
Water	<1%



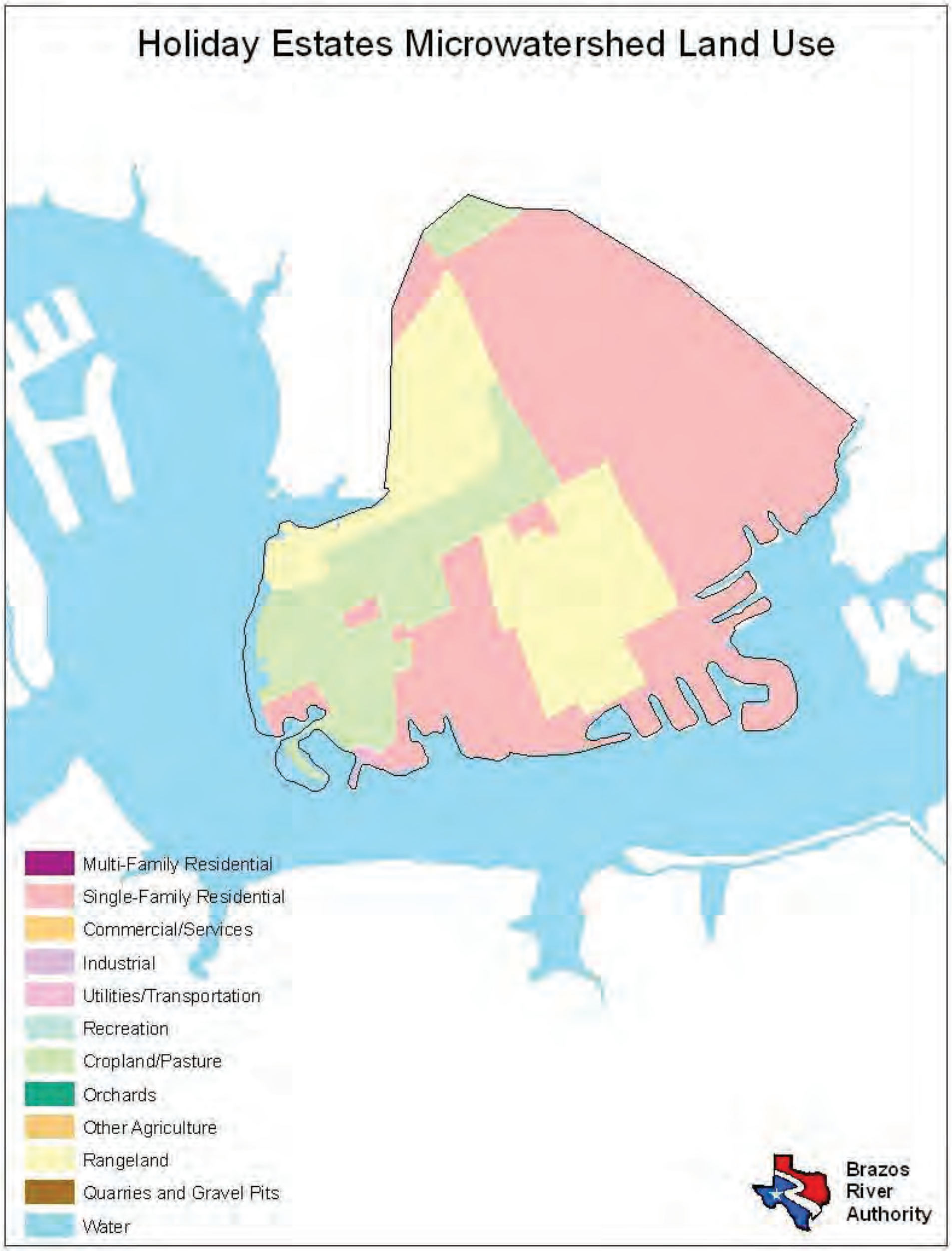
Land Use	Percent by Microwatershed
Single Family Residential	91%
Rangeland	8%
Water	<1%



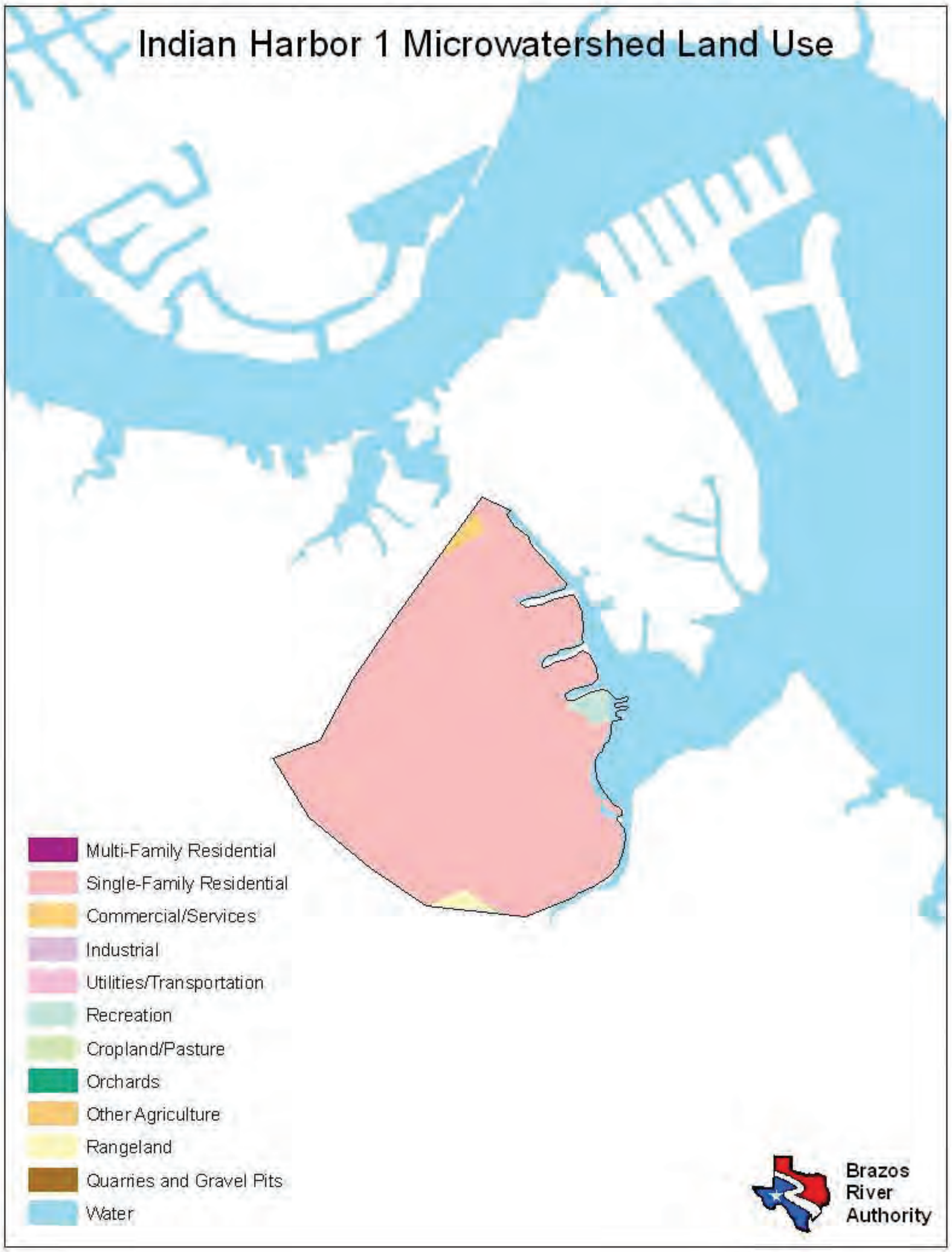
Land Use	Percent by Microwatershed
Single Family Residential	75%
Recreational	5%
Rangeland	15 %
Water	<1%



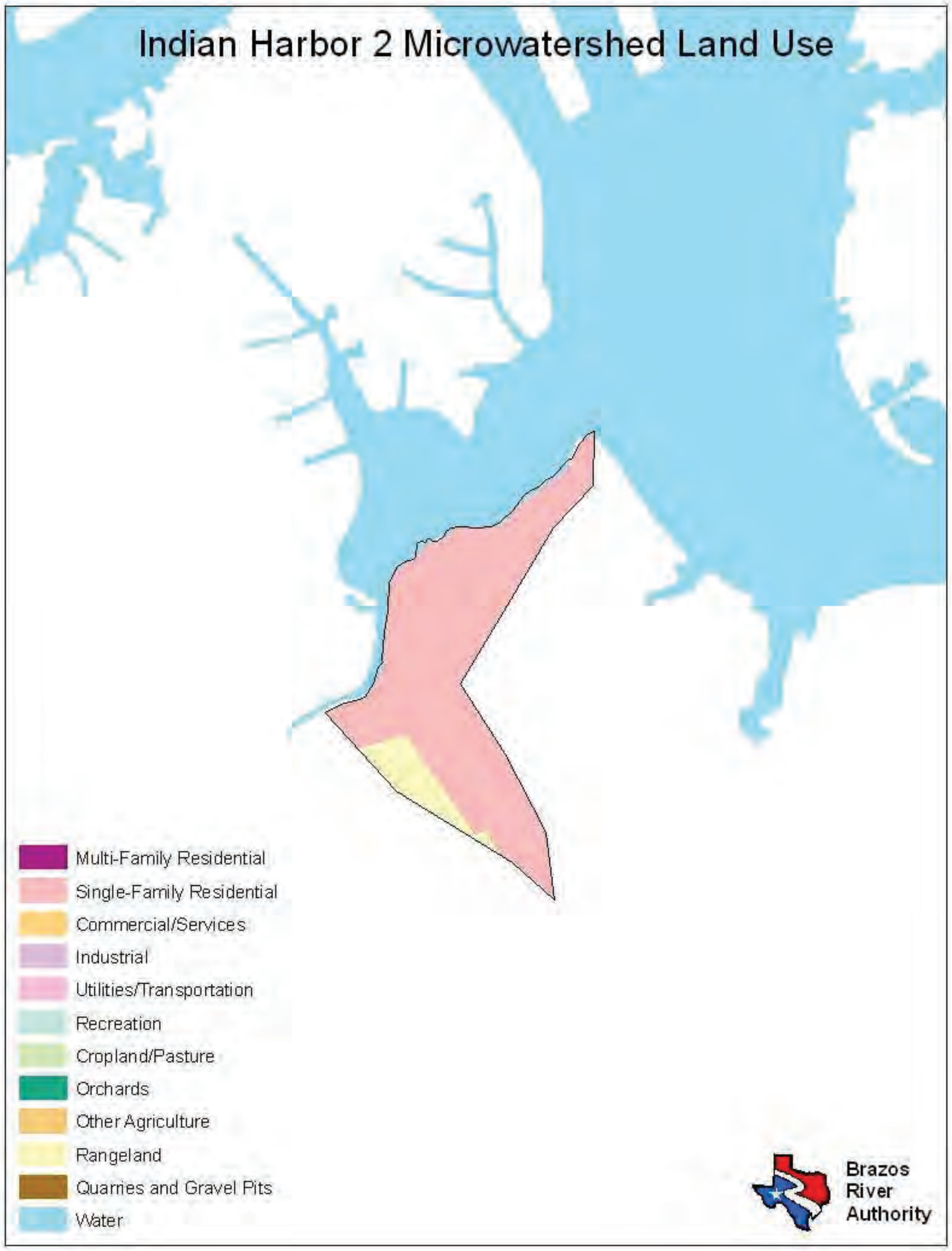
Land Use	Percent by Microwatershed
Single Family Residential	97%
Copland/Pasture	3%
Water	<1%



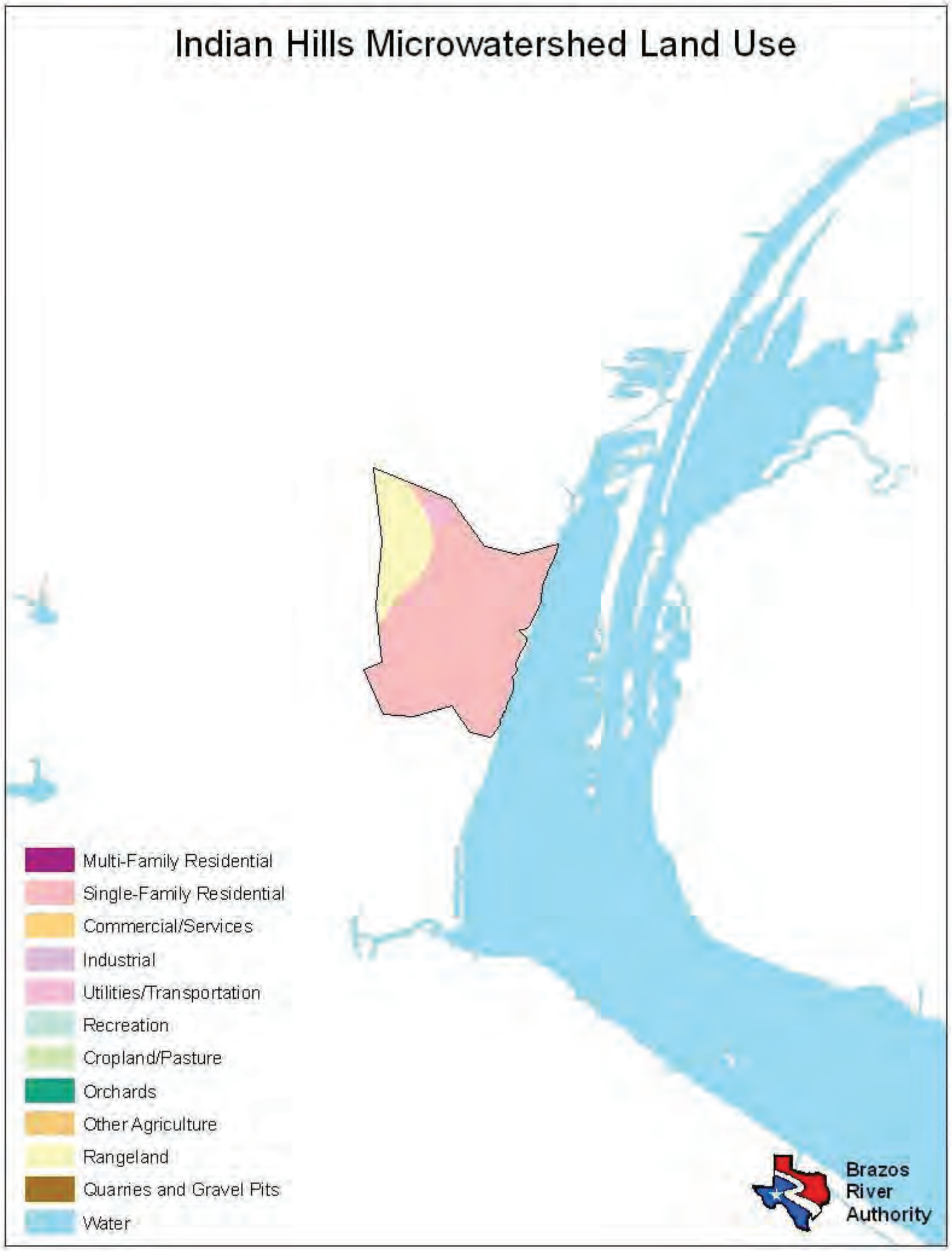
Land Use	Percent by Microwatershed
Single Family Residential	57%
Cropland/Pasture	17%
Rangeland	24 %
Water	2%



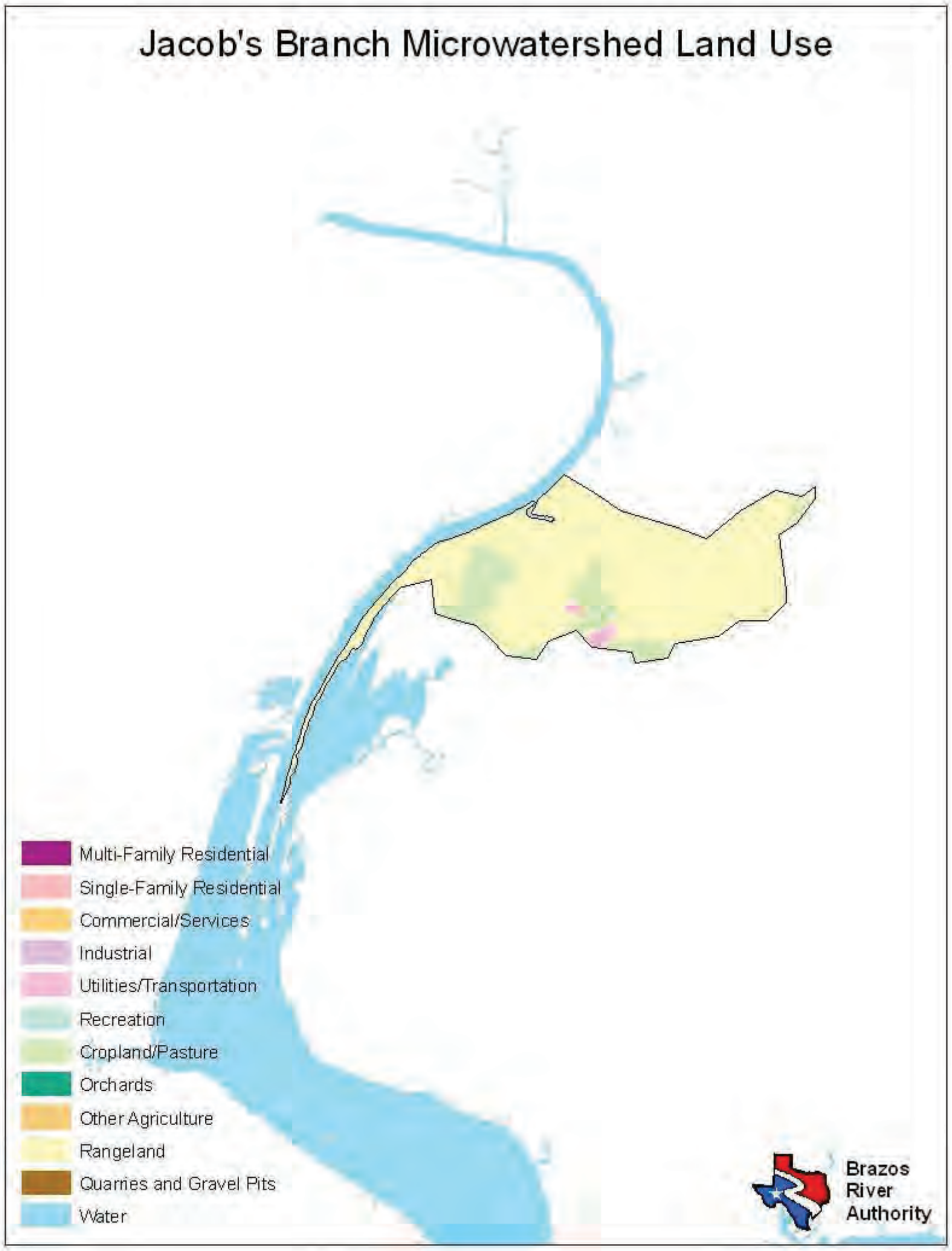
Land Use	Percent by Microwatershed
Single Family Residential	89%
Commercial/Services	<1%
Recreation	1
Rangeland	<1%
Water	1%



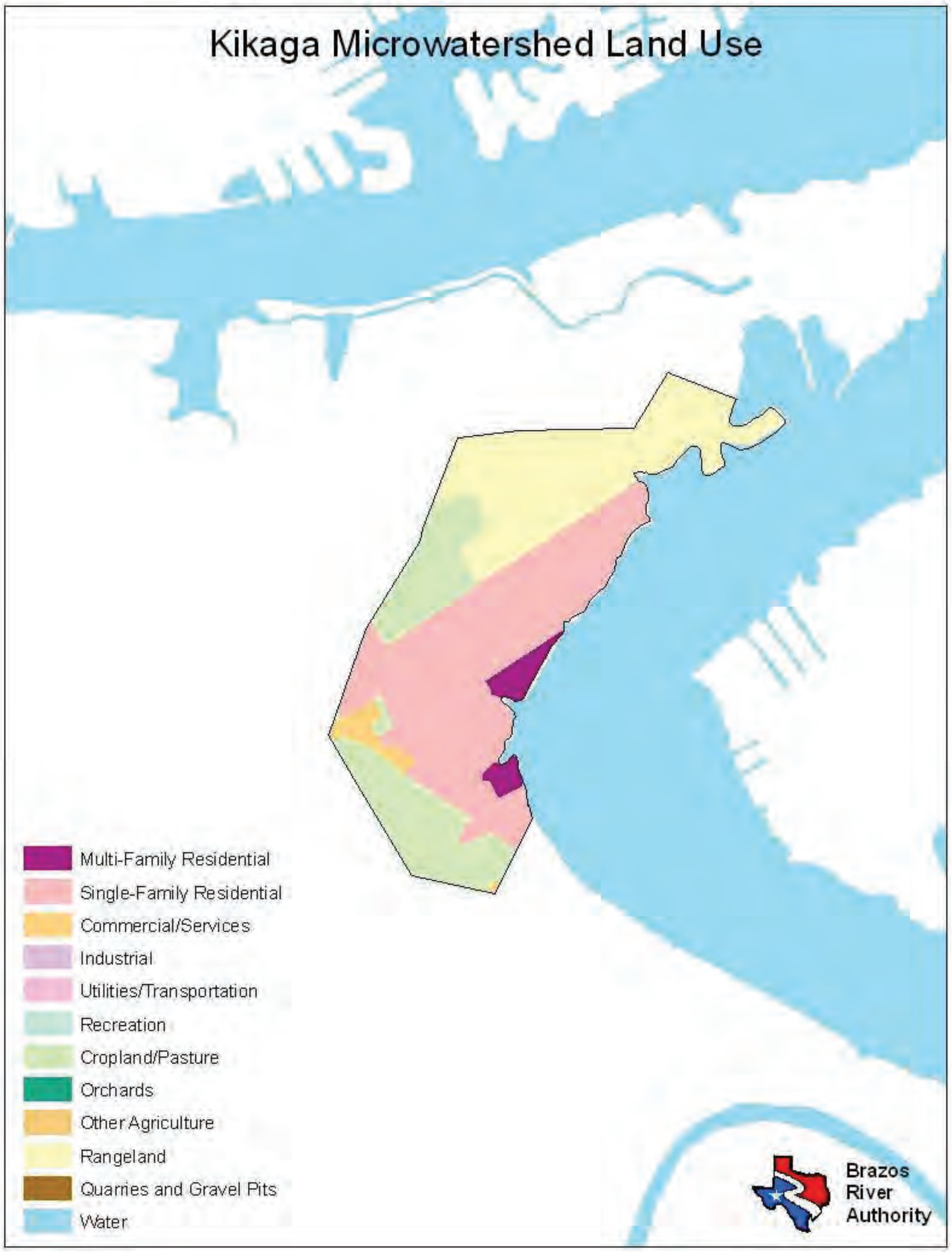
Land Use	Percent by Microwatershed
Single Family Residential	89%
Rangeland	9%
Water	1%



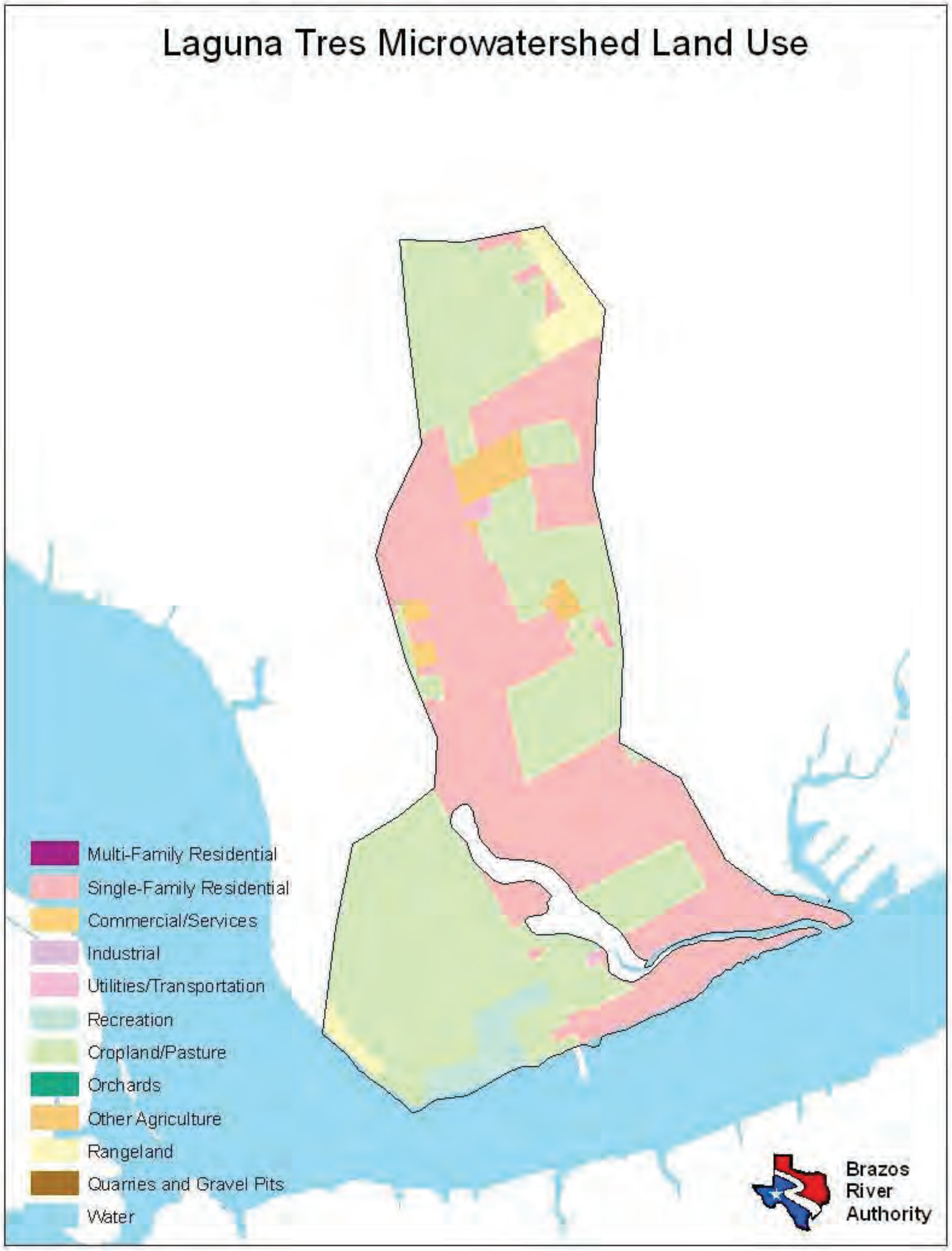
Land Use	Percent by Microwatershed
Single Family Residential	81%
Commercial/Services	2%
Rangeland	18
Water	<1%



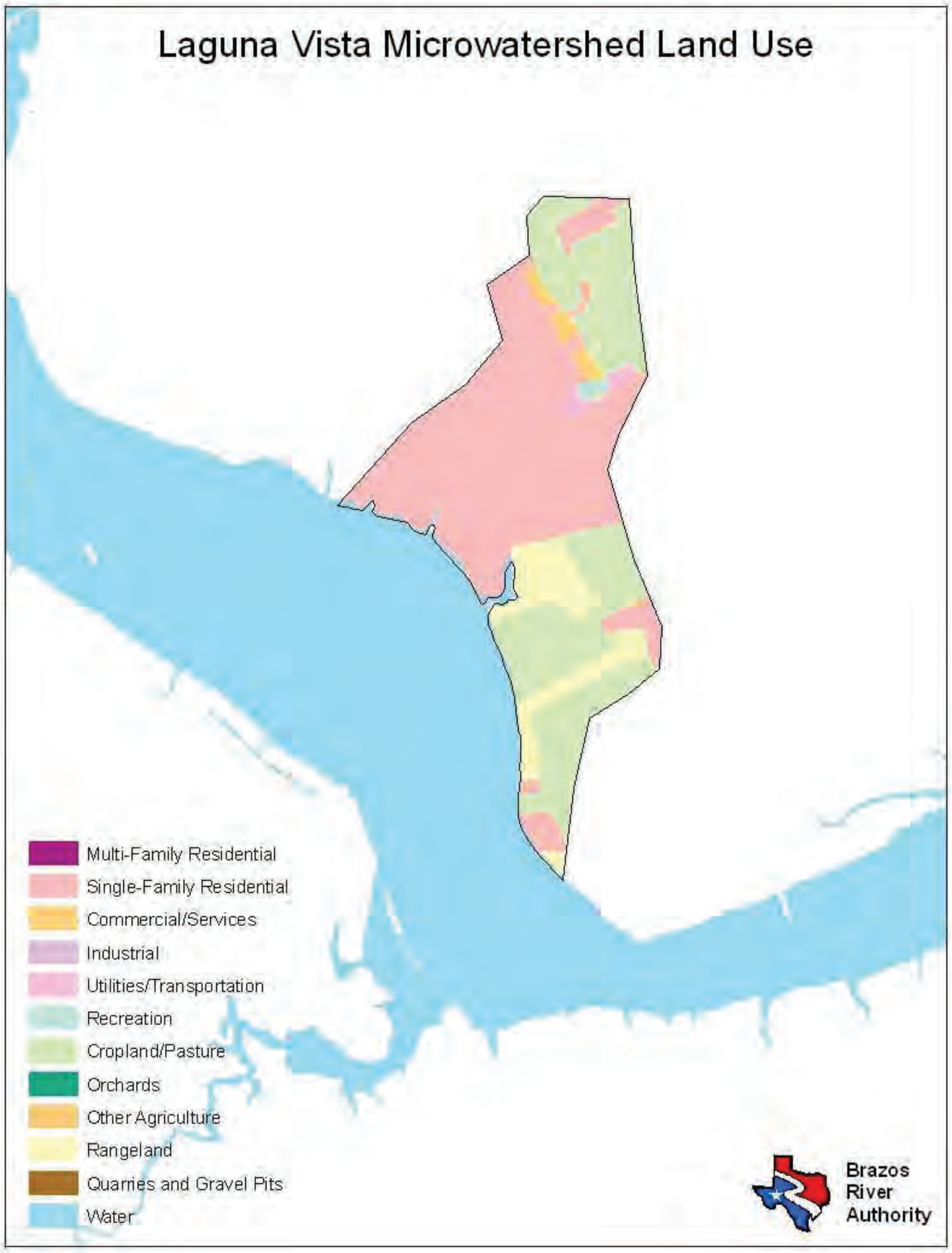
Land Use	Percent by Microwatershed
Single Family Residential	<1%
Industrial	<1%
Utilities/Transportation	1%
Cropland/Pasture	15%
Rangeland	82%
Water	<1%



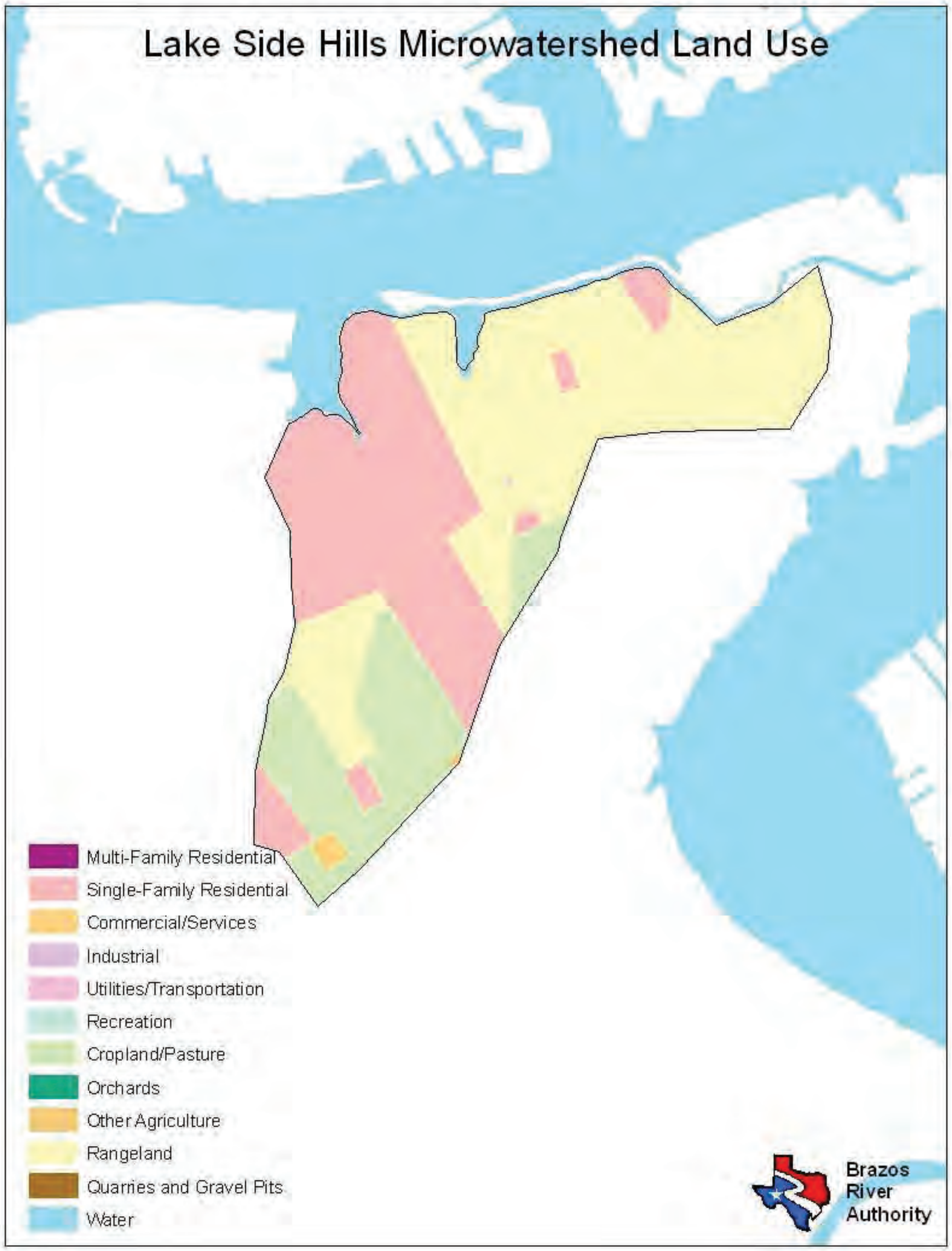
Land Use	Percent by Microwatershed
Multi-Family Residential	3%
Single Family Residential	43%
Commercial/Services	2%
Cropland/Pasture	22%
Rangeland	30%
Water	<1%



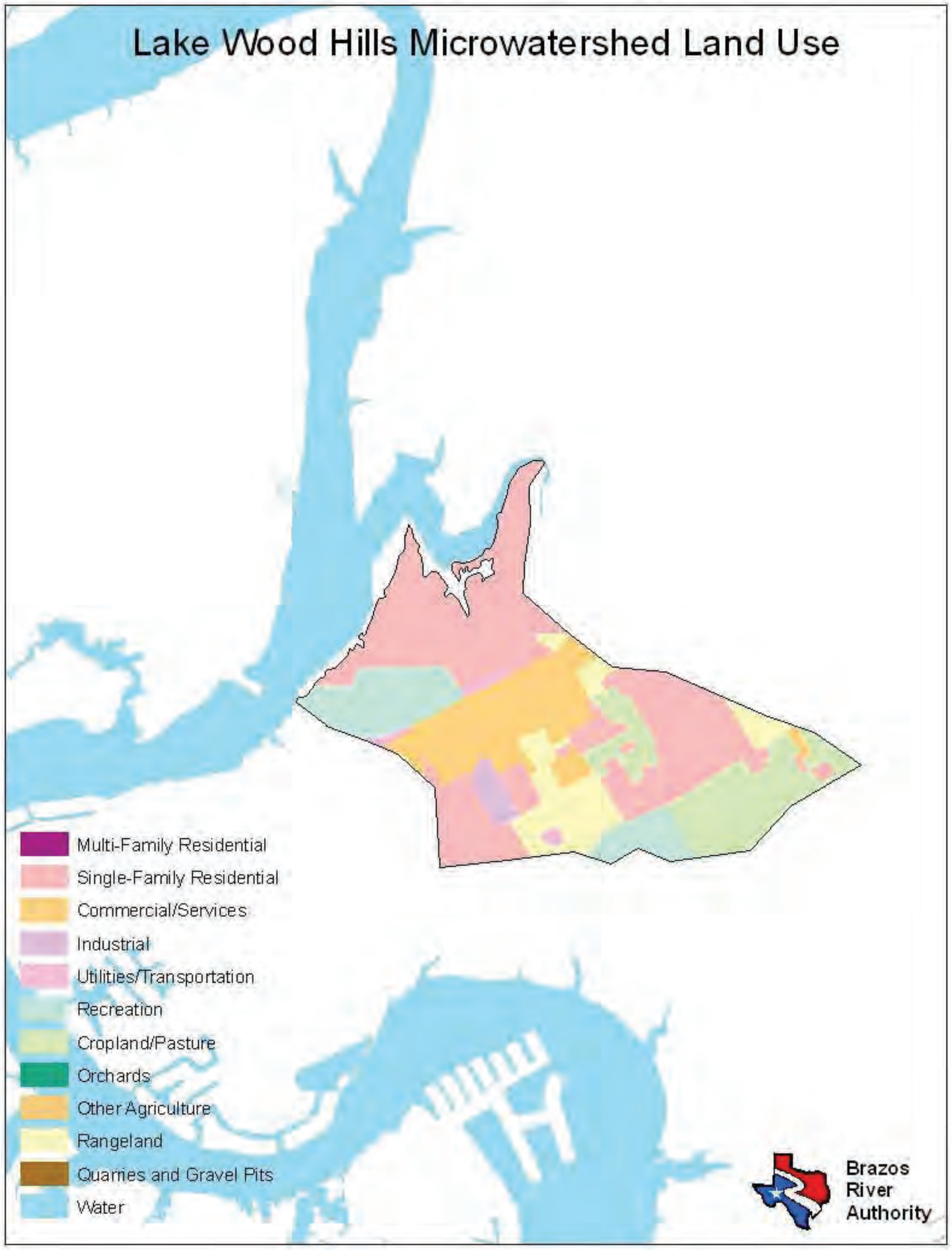
Land Use	Percent by Microwatershed
Single Family Residential	42%
Commercial/Services	<1%
Utilities/Transportation	<1%
Cropland/Pasture	48%
Other Agriculture	2%
Rangeland	3%
Water	<1%



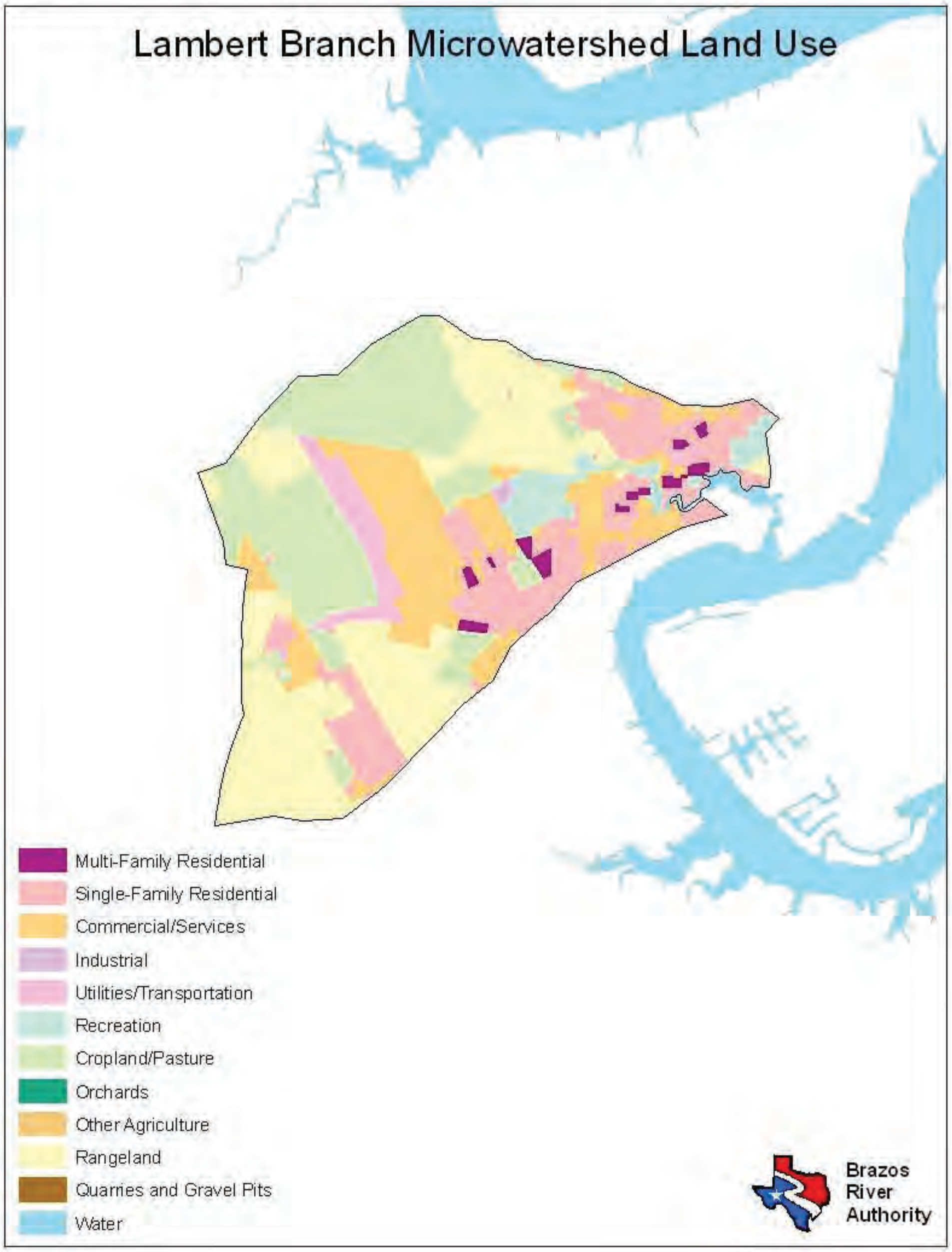
Land Use	Percent by Microwatershed
Single Family Residential	52%
Commercial/Services	2%
Utilities/Transportation	<1%
Recreation	<1%
Cropland/Pasture	34%
Rangeland	10%
Water	1%



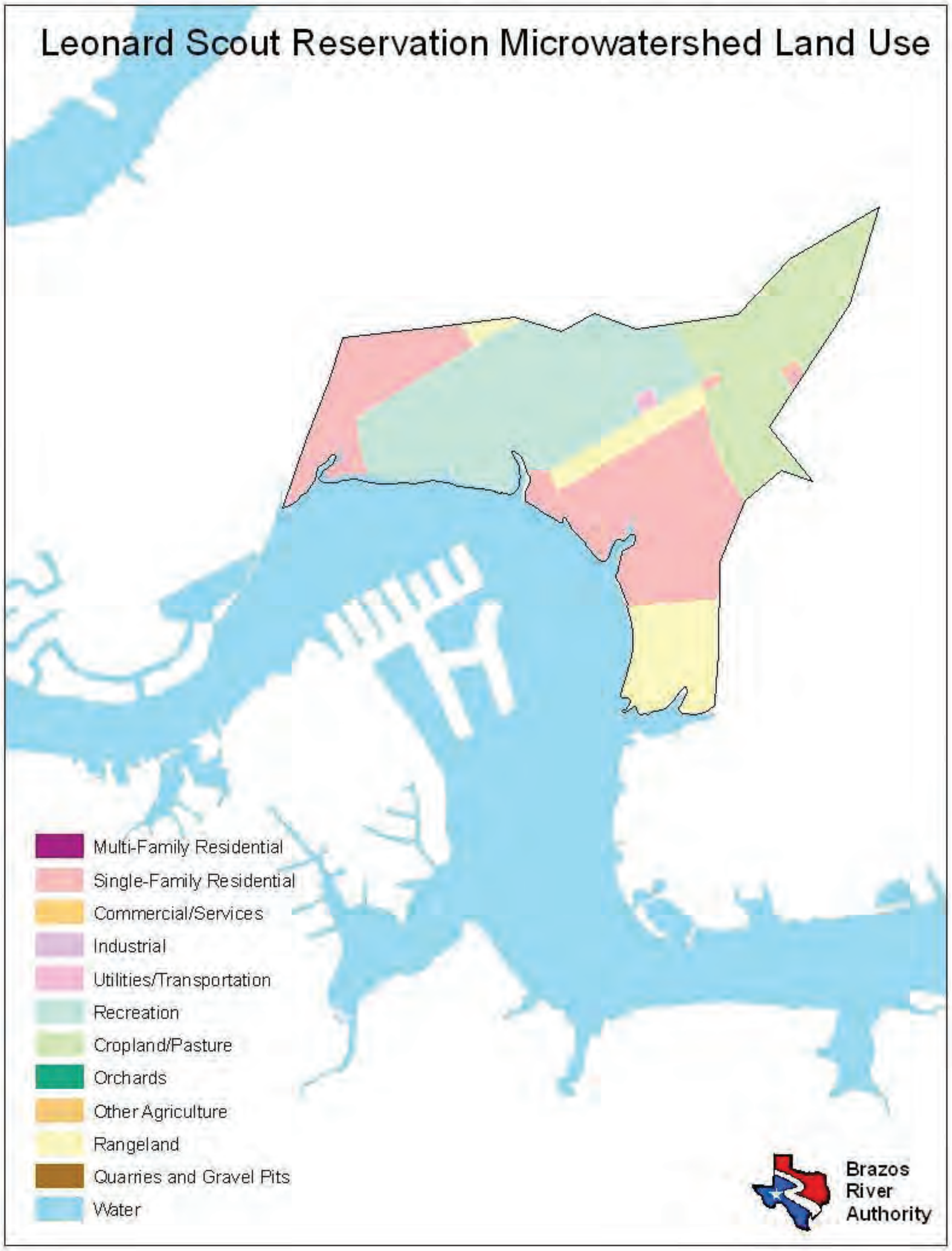
Land Use	Percent by Microwatershed
Single Family Residential	35%
Commercial/Services	<1%
Cropland/Pasture	18%
Rangeland	46%
Water	<1%



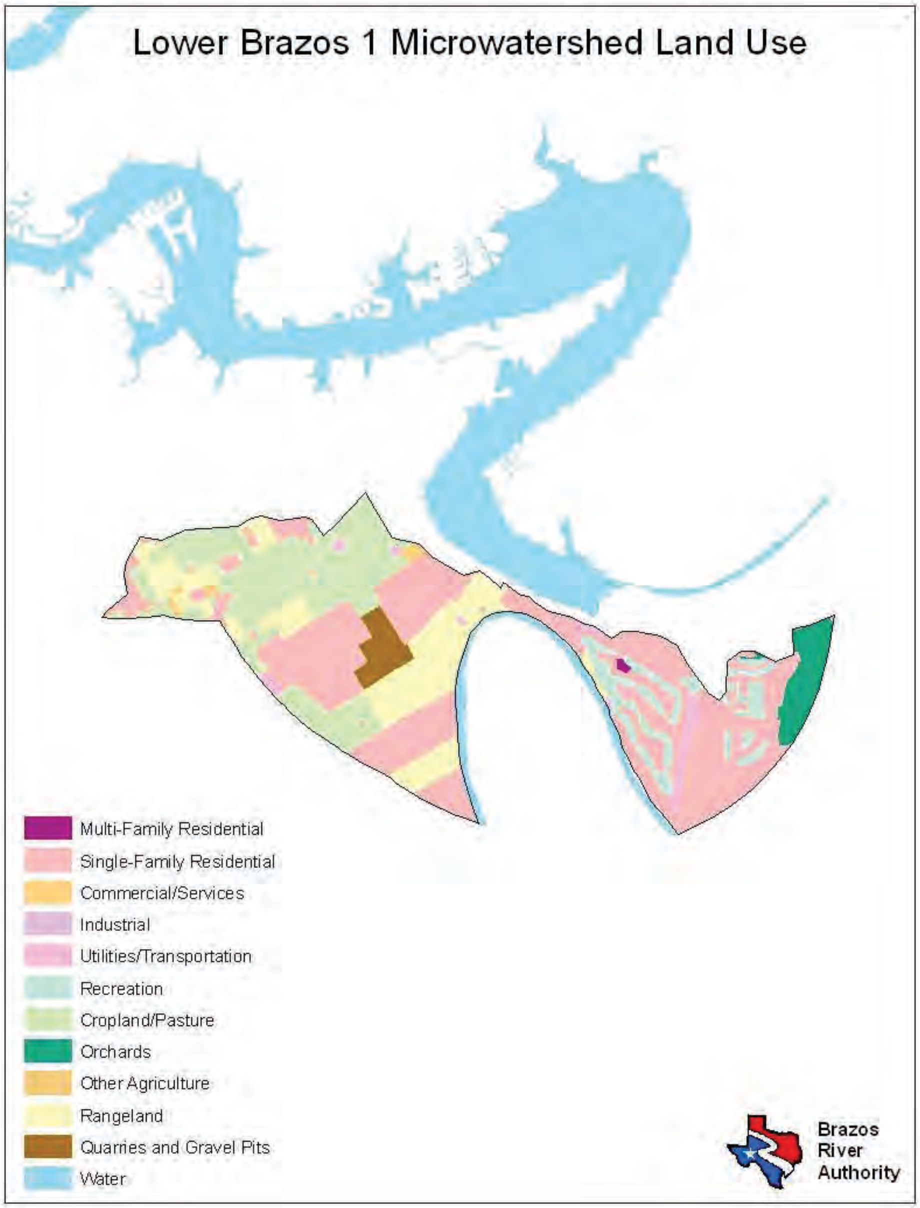
Land Use	Percent by Microwatershed
Single Family Residential	45%
Commercial/Services	16%
Industrial	2%
Utilities/Transportation	1%
Recreation	12%
Cropland/Pasture	14%
Rangeland	10%
Water	<1%



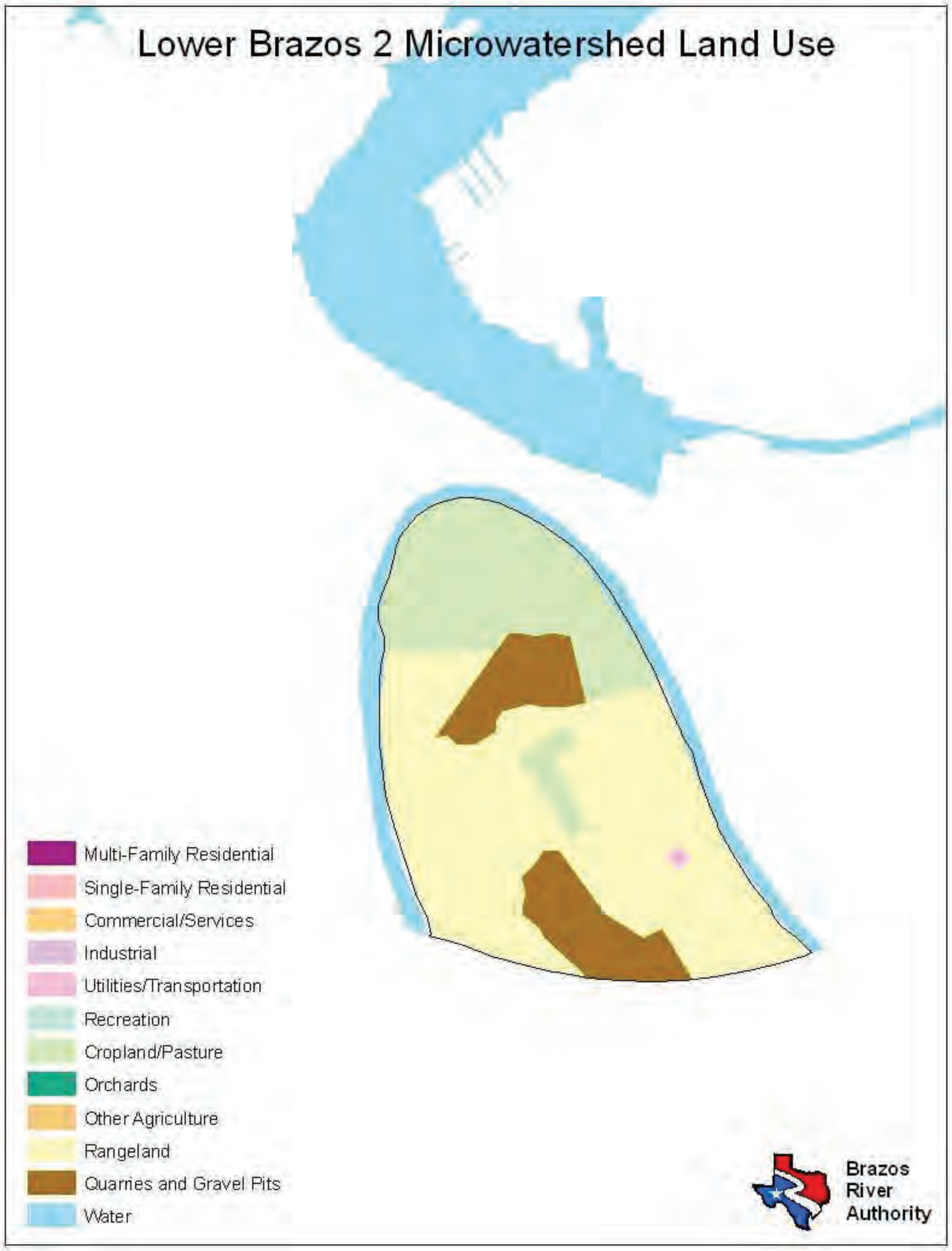
Land Use	Percent by Microwatershed
Multi-Family Residential	1%
Single Family Residential	18%
Commercial/Services	18%
Industrial	<1%
Utilities/Transportation	4%
Recreation	4%
Cropland/Pasture	26%
Rangeland	29%
Water	<1%



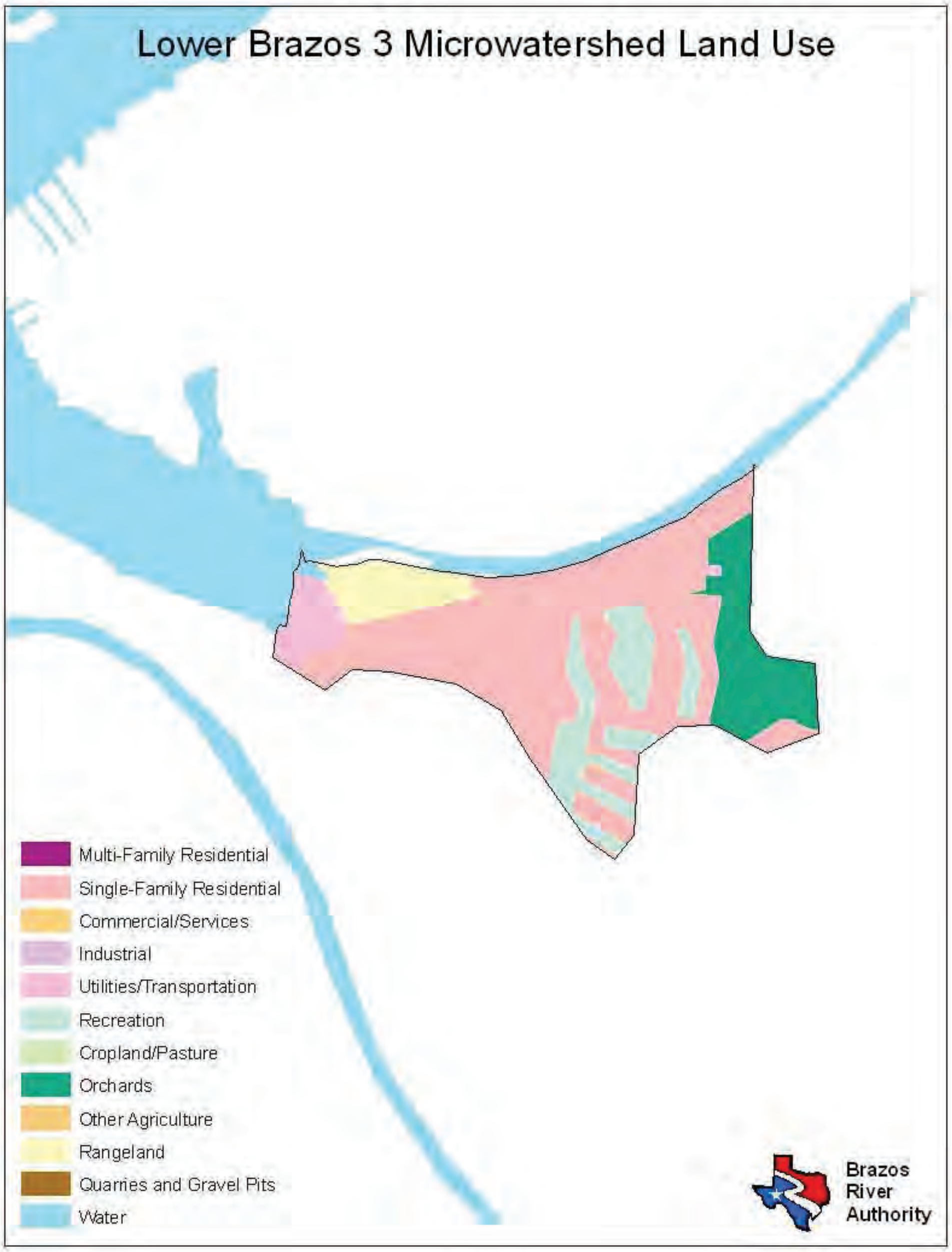
Land Use	Percent by Microwatershed
Single Family Residential	32%
Utilities/Transportation	<1%
Recreation	33%
Cropland/Pasture	20%
Rangeland	13%
Water	1%



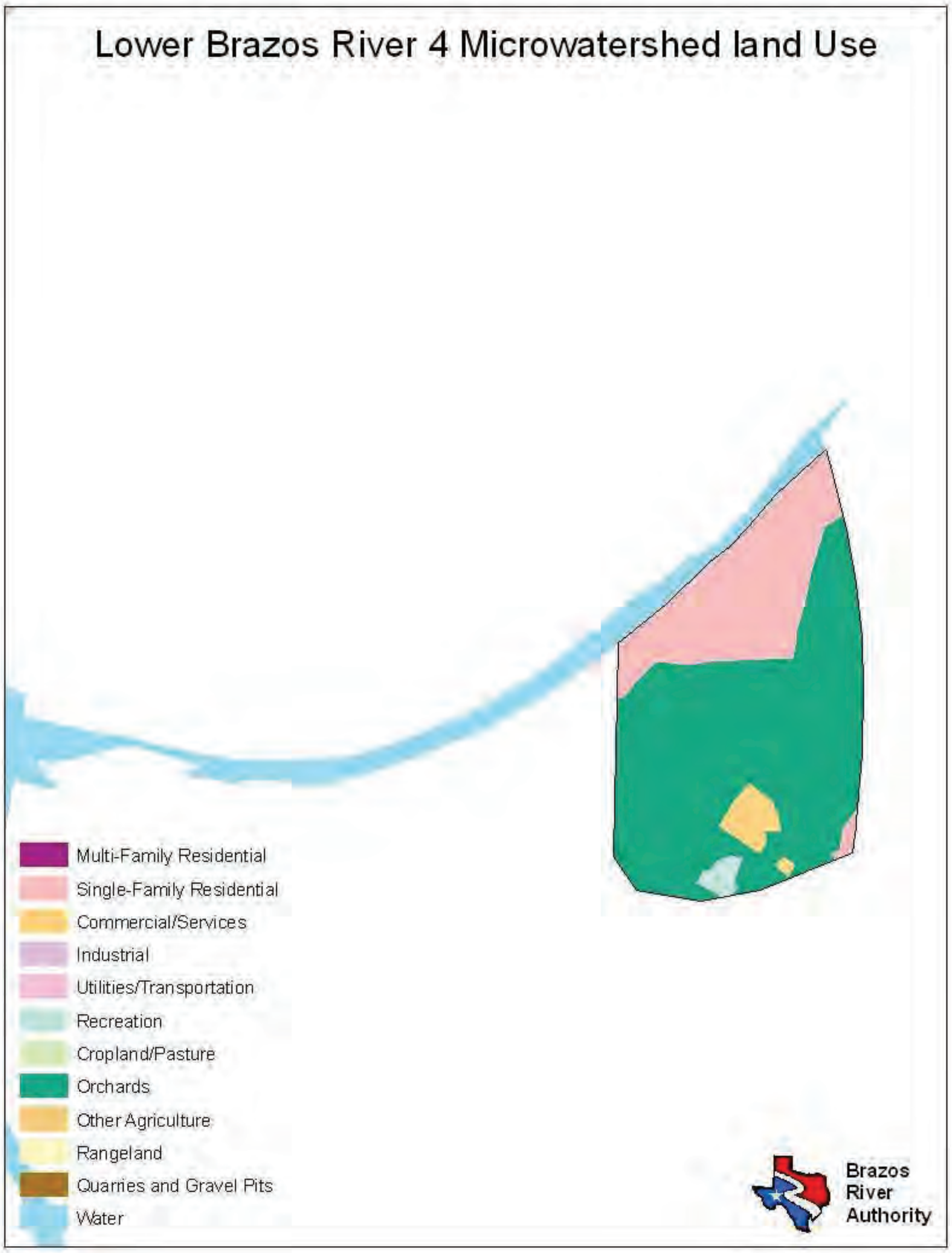
Land Use	Percent by Microwatershed
Multi-Family Residential	<1%
Single Family Residential	46%
Commercial/Services	<1%
Utilities/Transportation	2%
Recreation	6%
Cropland/Pasture	22%
Orchard	4%
Rangeland	16%
Quarries and Gravel Pits	3%
Water	<1%



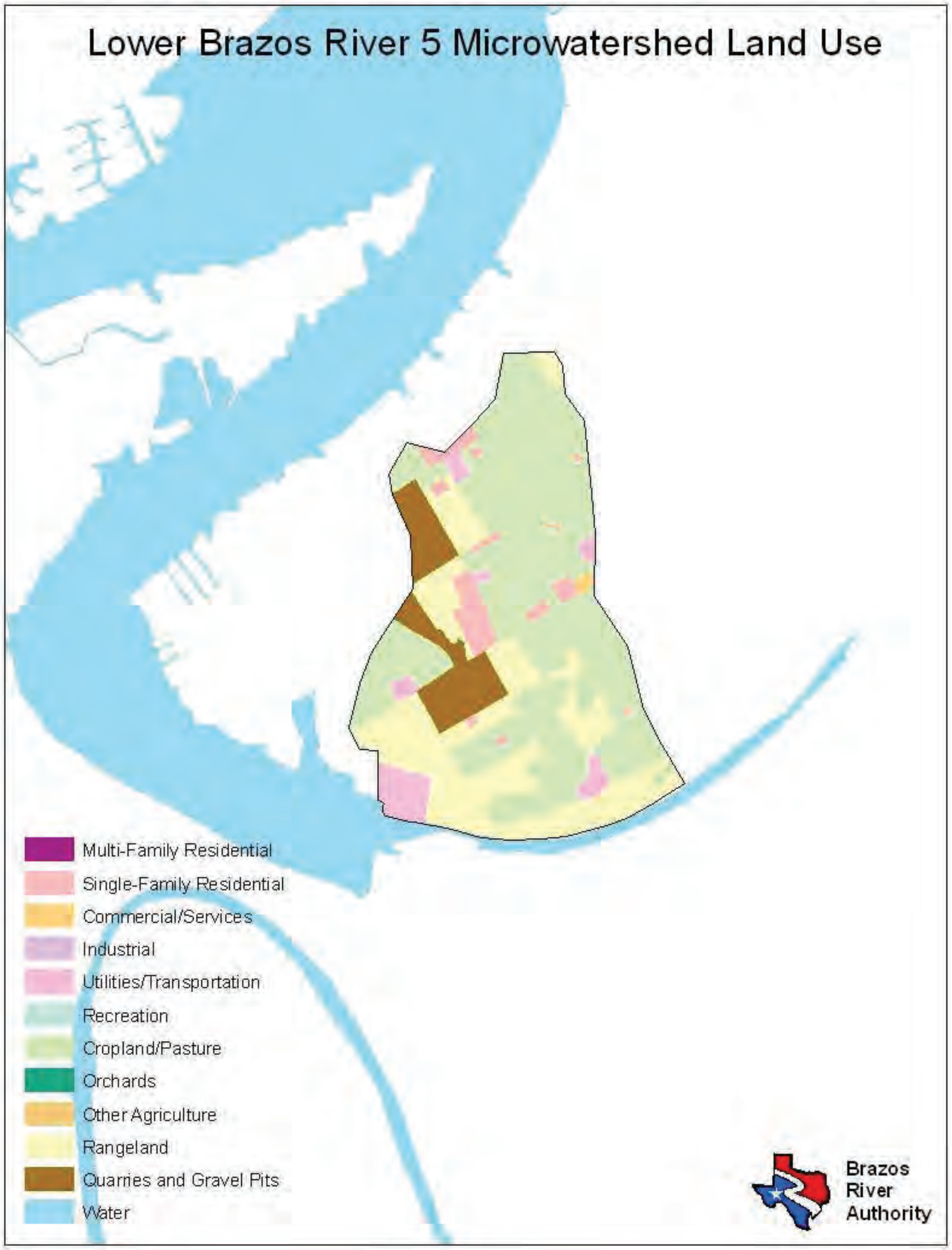
Land Use	Percent by Microwatershed
Utilities/Transportation	<1%
Cropland/Pasture	26%
Rangeland	58%
Quarries and Gravel Pits	14%
Water	<1%



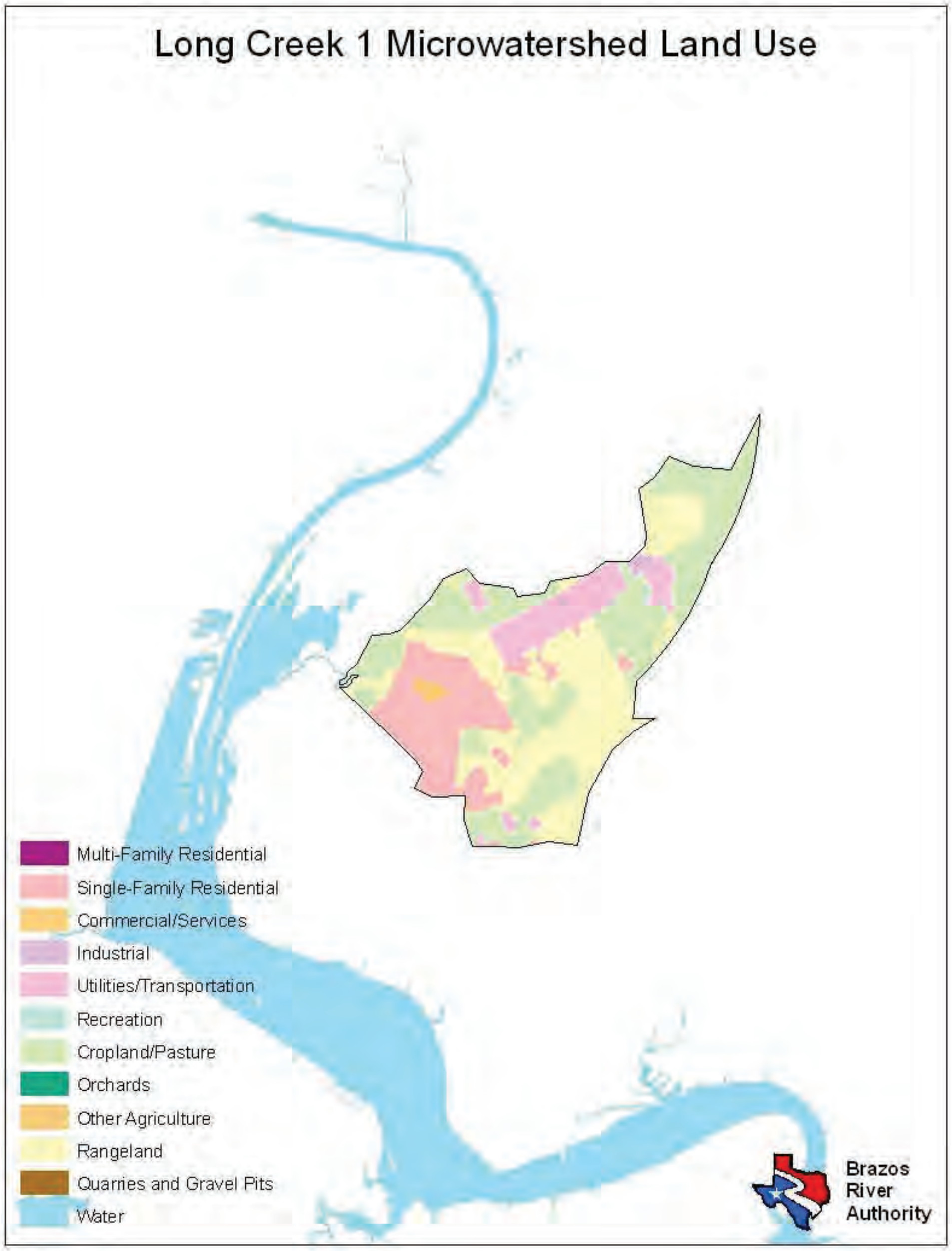
Land Use	Percent by Microwatershed
Single Family Residential	60%
Utilities/Transportation	5%
Recreation	13%
Orchard	14%
Rangeland	7%
Water	<1%



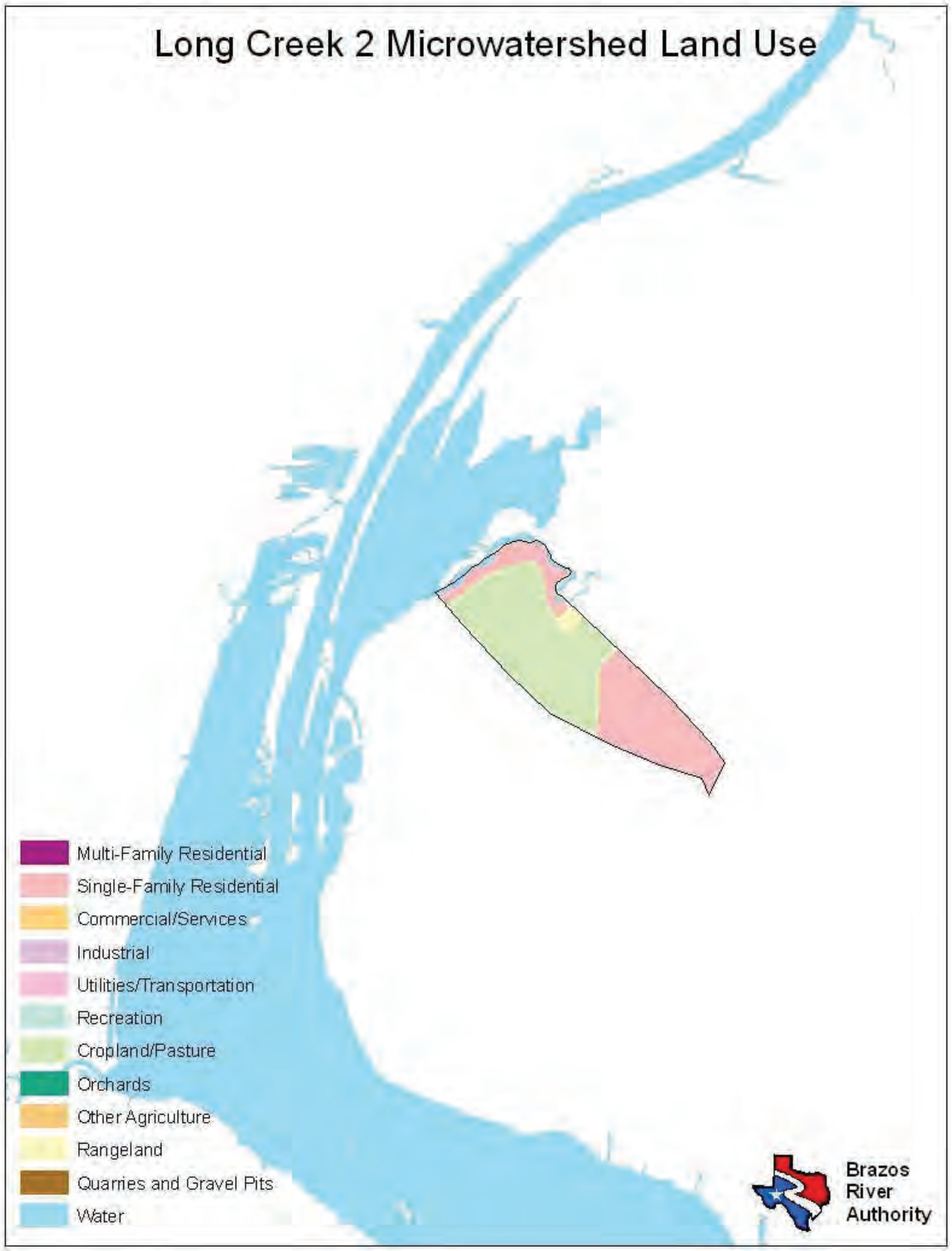
Land Use	Percent by Microwatershed
Single Family Residential	27%
Commercial/Services	3%
Recreation	1%
Orchard	68%
Water	<1%



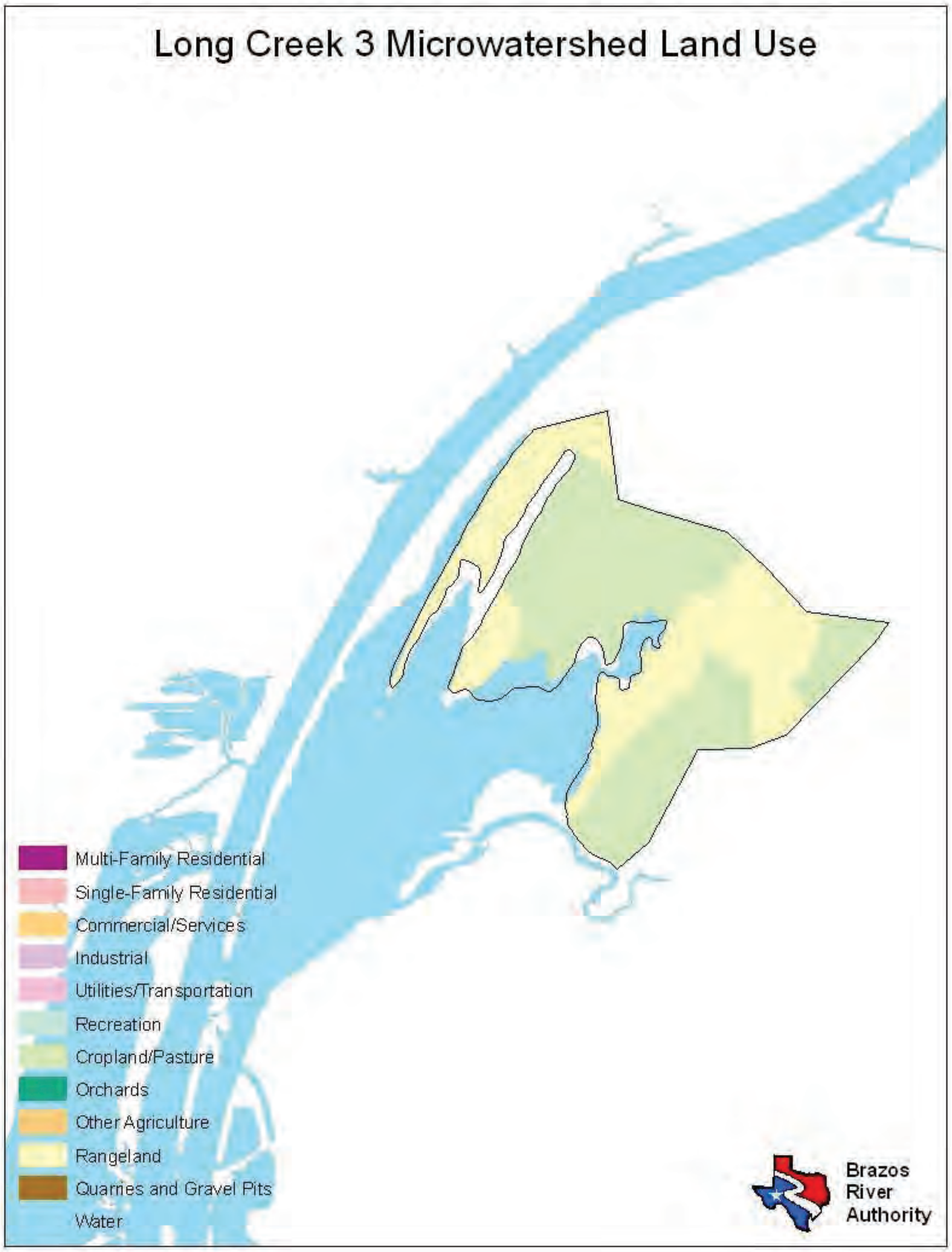
Land Use	Percent by Microwatershed
Single Family Residential	5%
Commercial/Services	<1%
Utilities/Transportation	5%
Recreation	<1%
Cropland/Pasture	53%
Rangeland	28%
Quarries and Gravel Pits	9%
Water	<1%



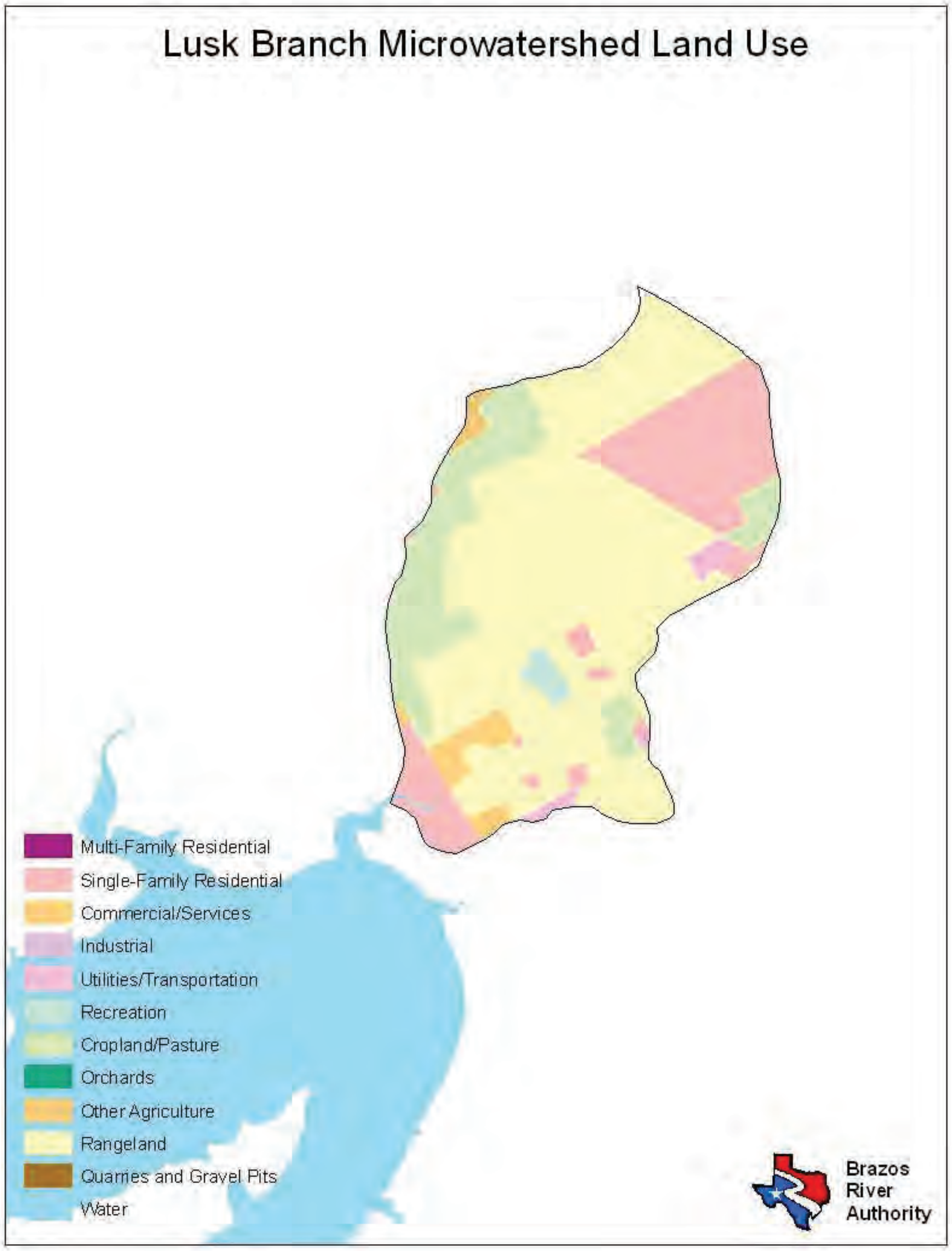
Land Use	Percent by Microwatershed
Single Family Residential	19%
Commercial/Services	<1%
Industrial	<1%
Utilities/Transportation	10%
Cropland/Pasture	36%
Other Agriculture	<1%
Rangeland	33%
Water	<1%



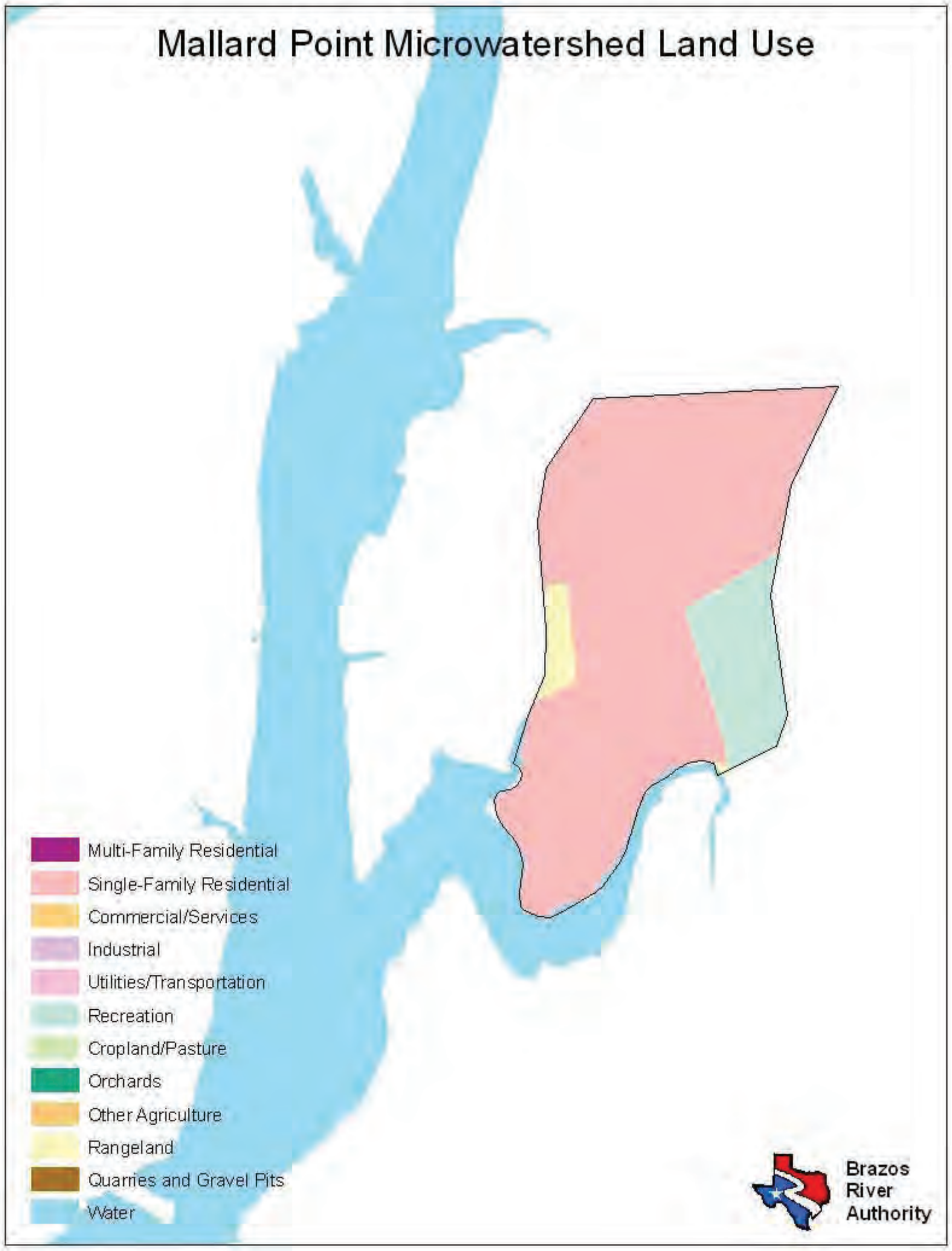
Land Use	Percent by Microwatershed
Single Family Residential	44%
Cropland/Pasture	53%
Rangeland	2%
Water	1%



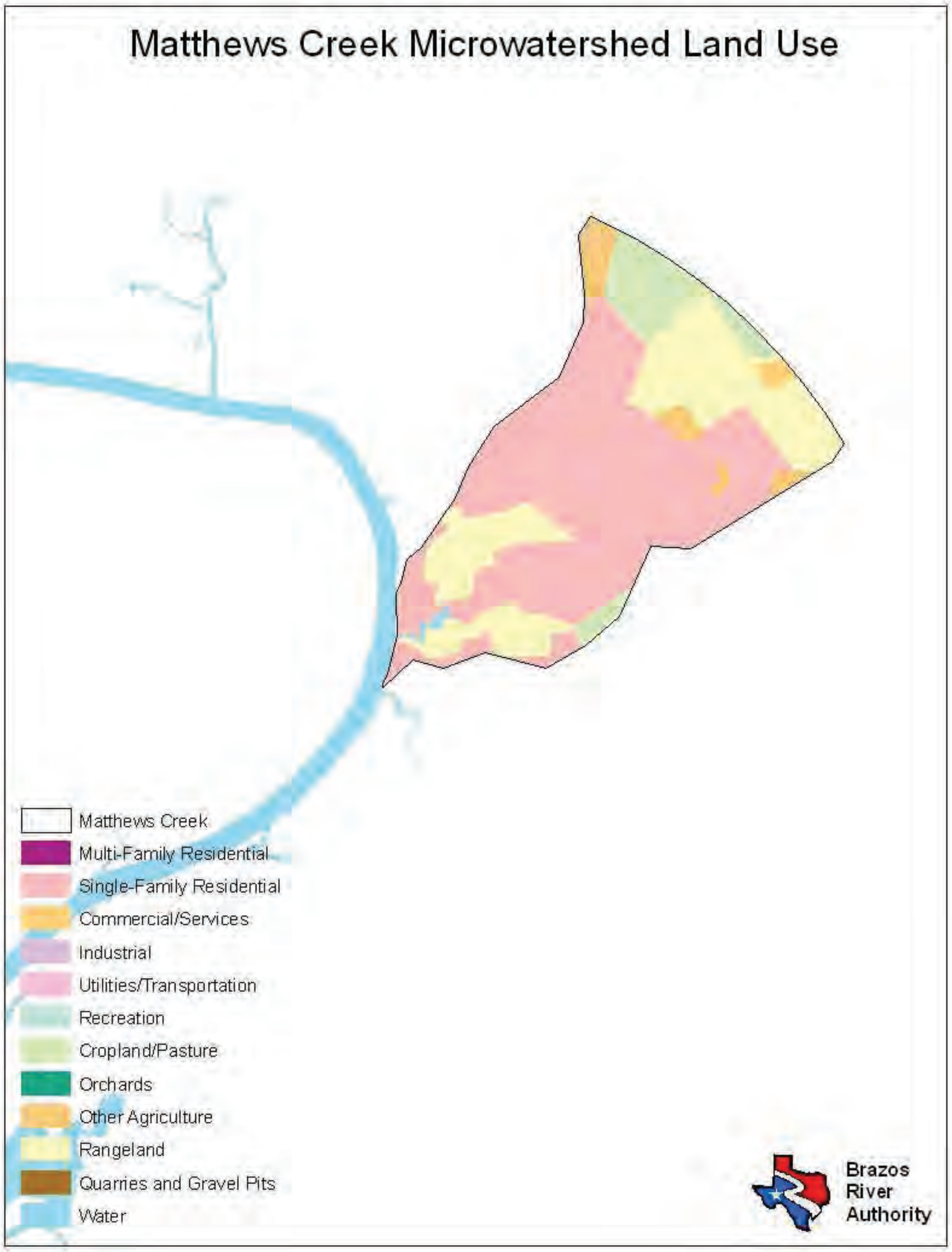
Land Use	Percent by Microwatershed
Cropland/Pasture	55%
Rangeland	40%
Water	4%



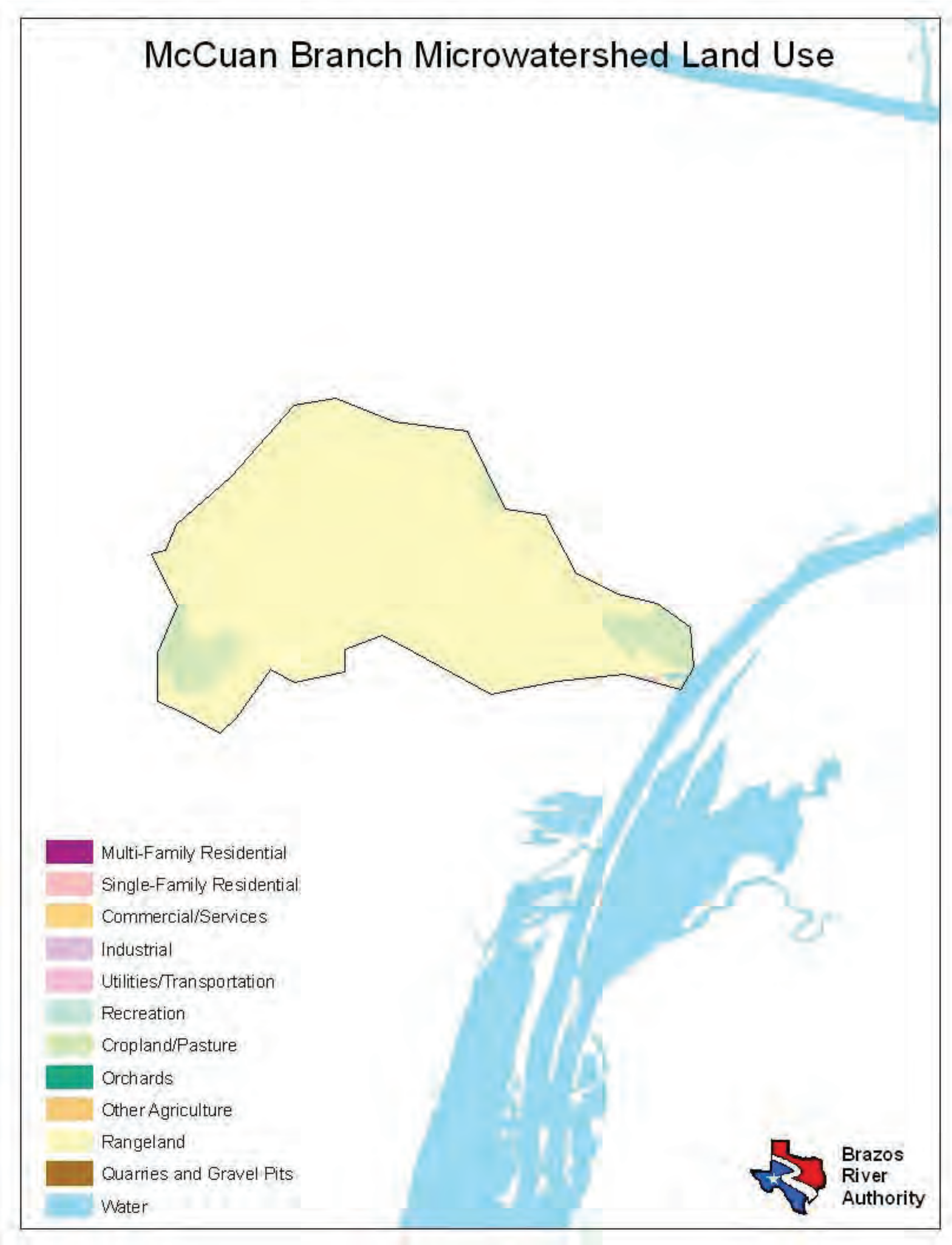
Land Use	Percent by Microwatershed
Single Family Residential	19%
Commercial/Services	3%
Utilities/Transportation	1%
Recreation	1%
Cropland/Pasture	15%
Rangeland	60%
Water	<1%



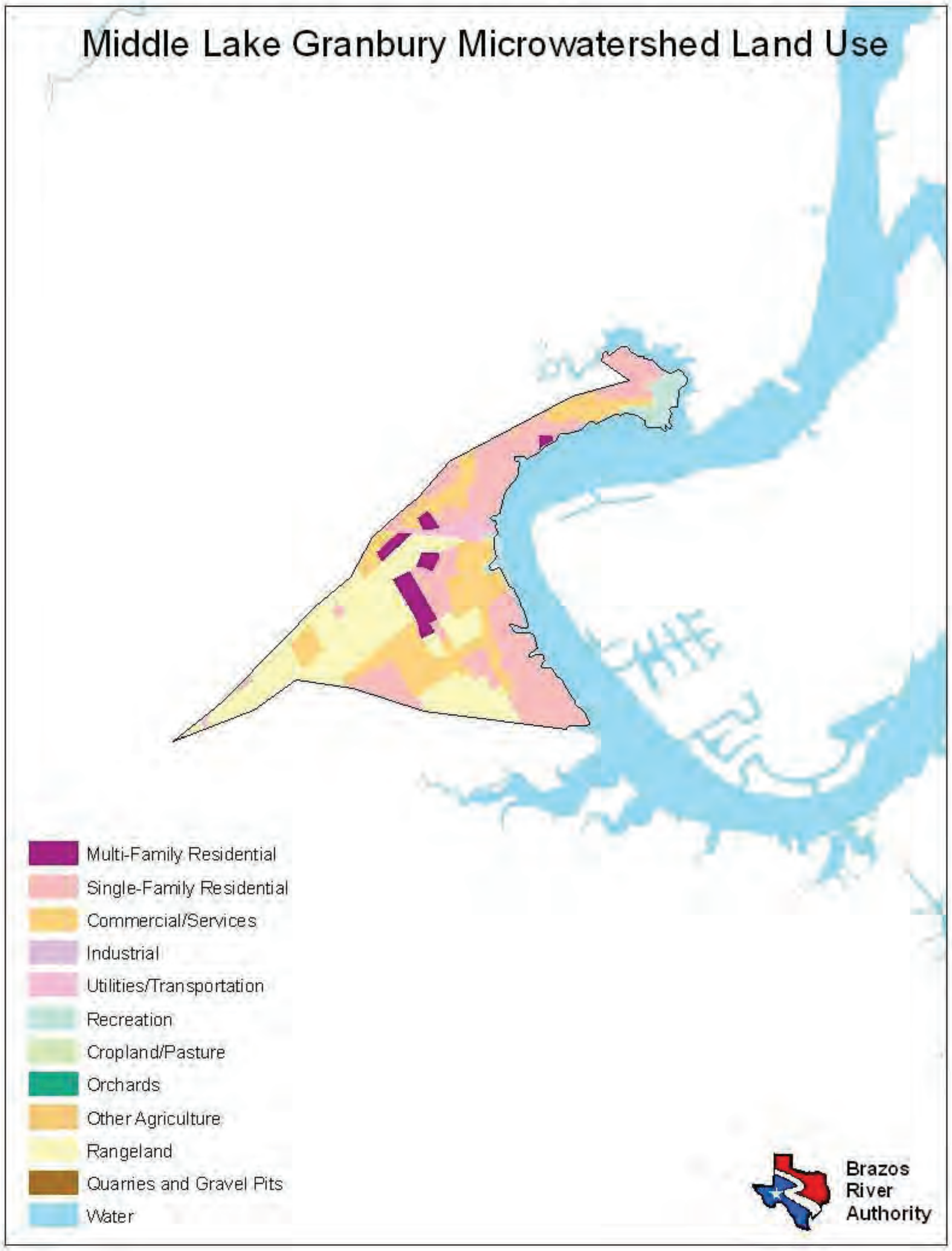
Land Use	Percent by Microwatershed
Single Family Residential	84%
Recreation	12%
Rangeland	3%
Water	<1%



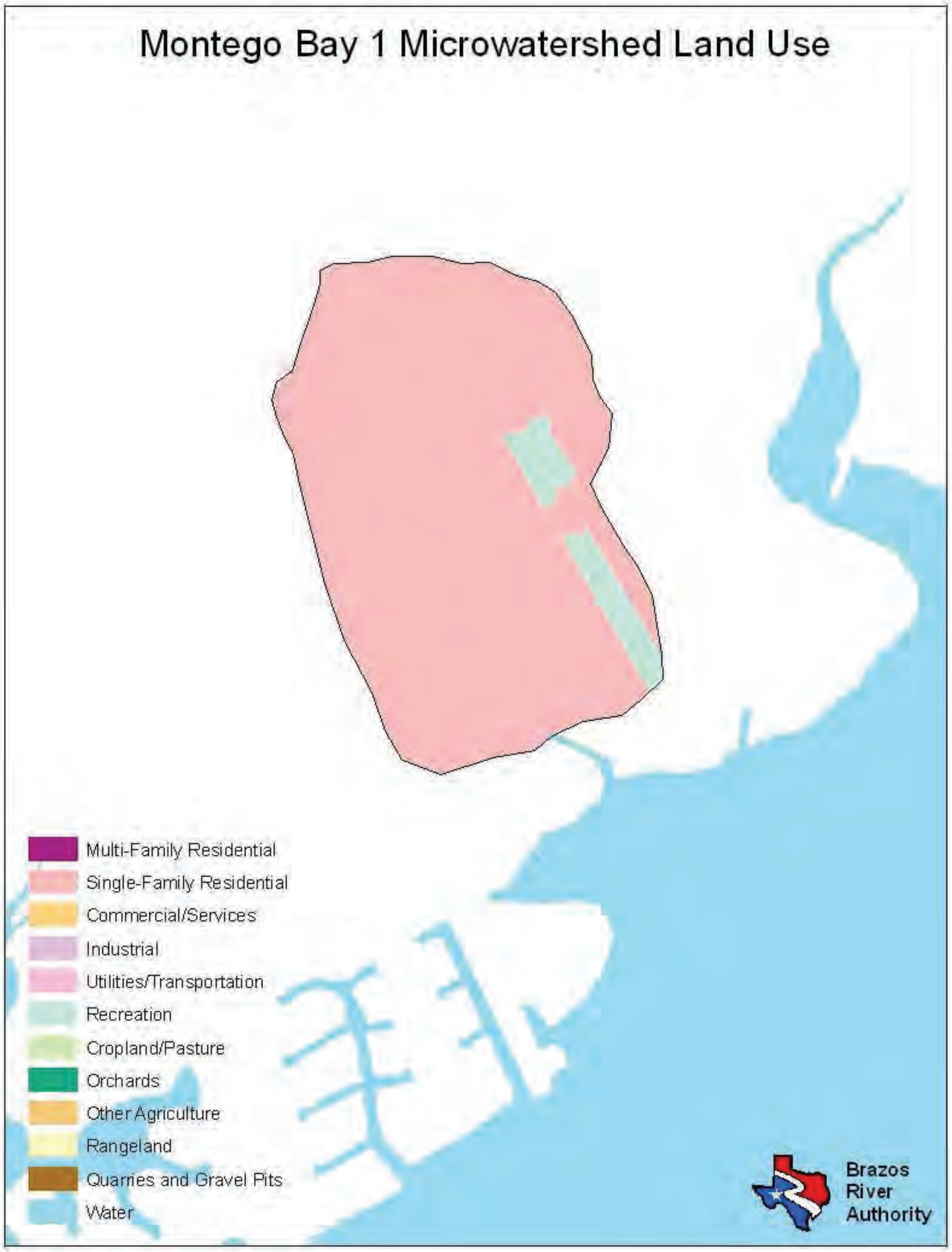
Land Use	Percent by Microwatershed
Single Family Residential	58%
Commercial/Services	<1%
Cropland/Pasture	9%
Other Agriculture	4%
Rangeland	28%
Water	<1%



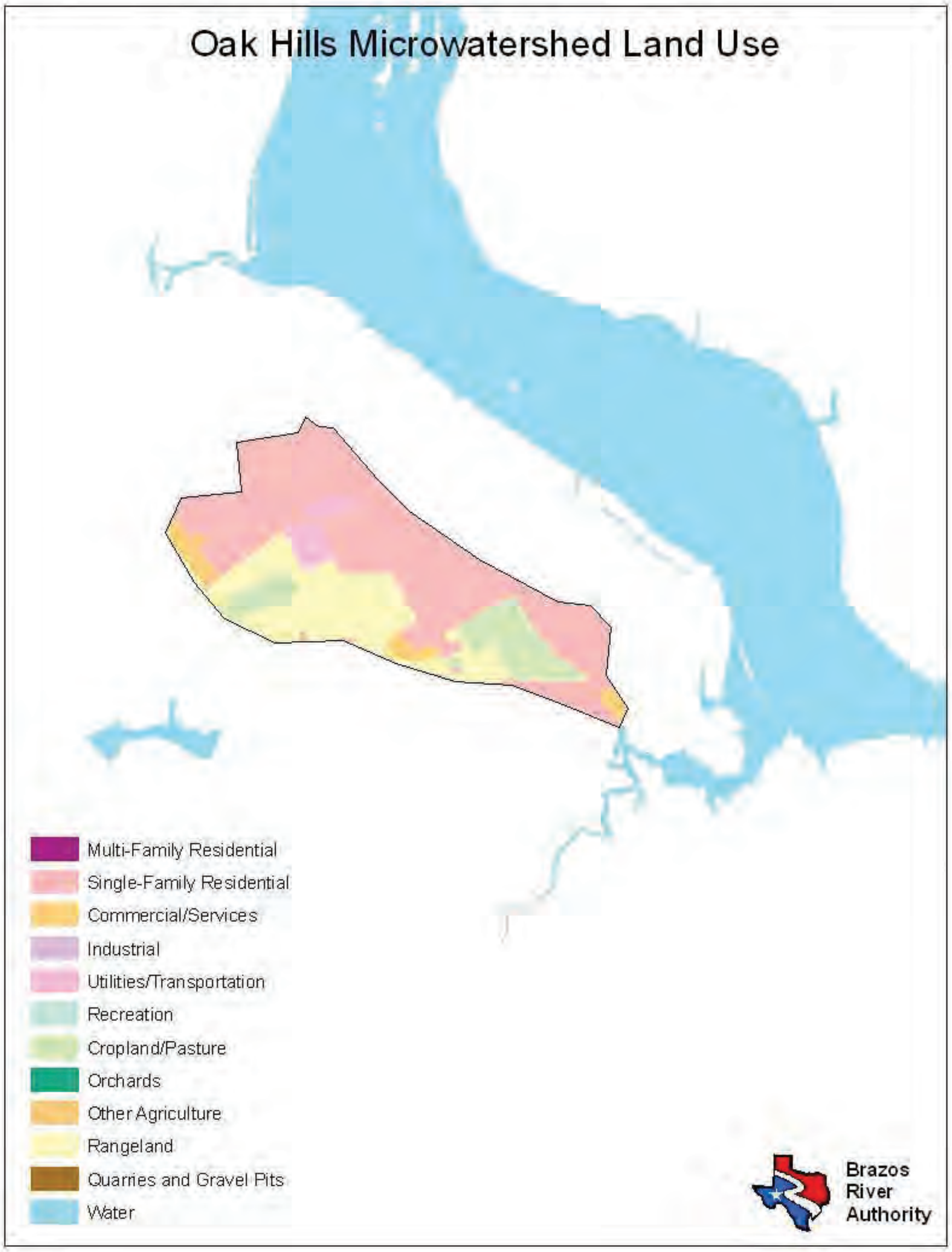
Land Use	Percent by Microwatershed
Utilities/Transportation	<1%%
Cropland/Pasture	8%
Rangeland	92%
Water	<1%



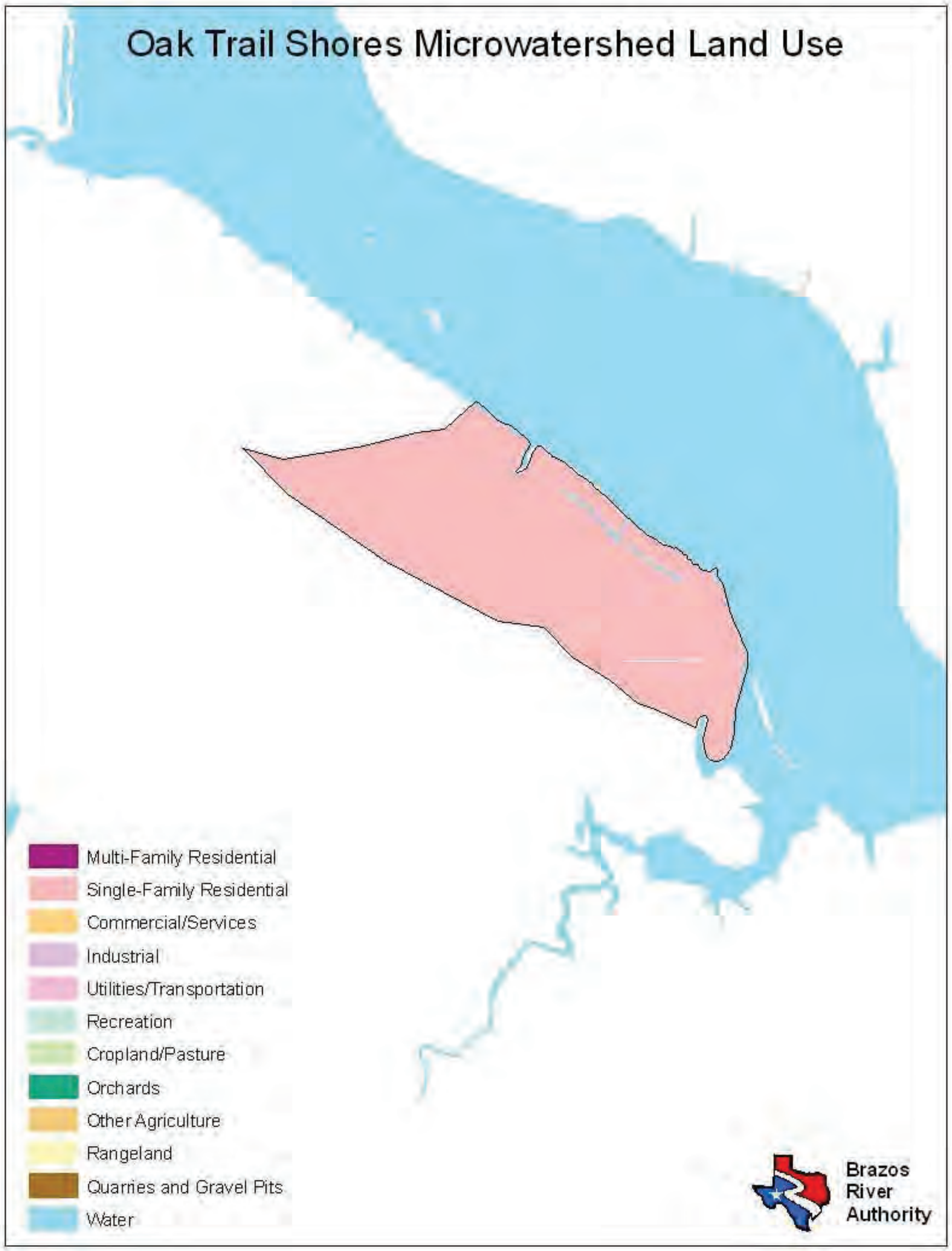
Land Use	Percent by Microwatershed
Multi-Family Residential	4%
Single Family Residential	34%
Commercial/Services	25%
Utilities/Transportation	2%
Recreation	3%
Cropland/Pasture	<1%
Rangeland	31%
Water	<1%



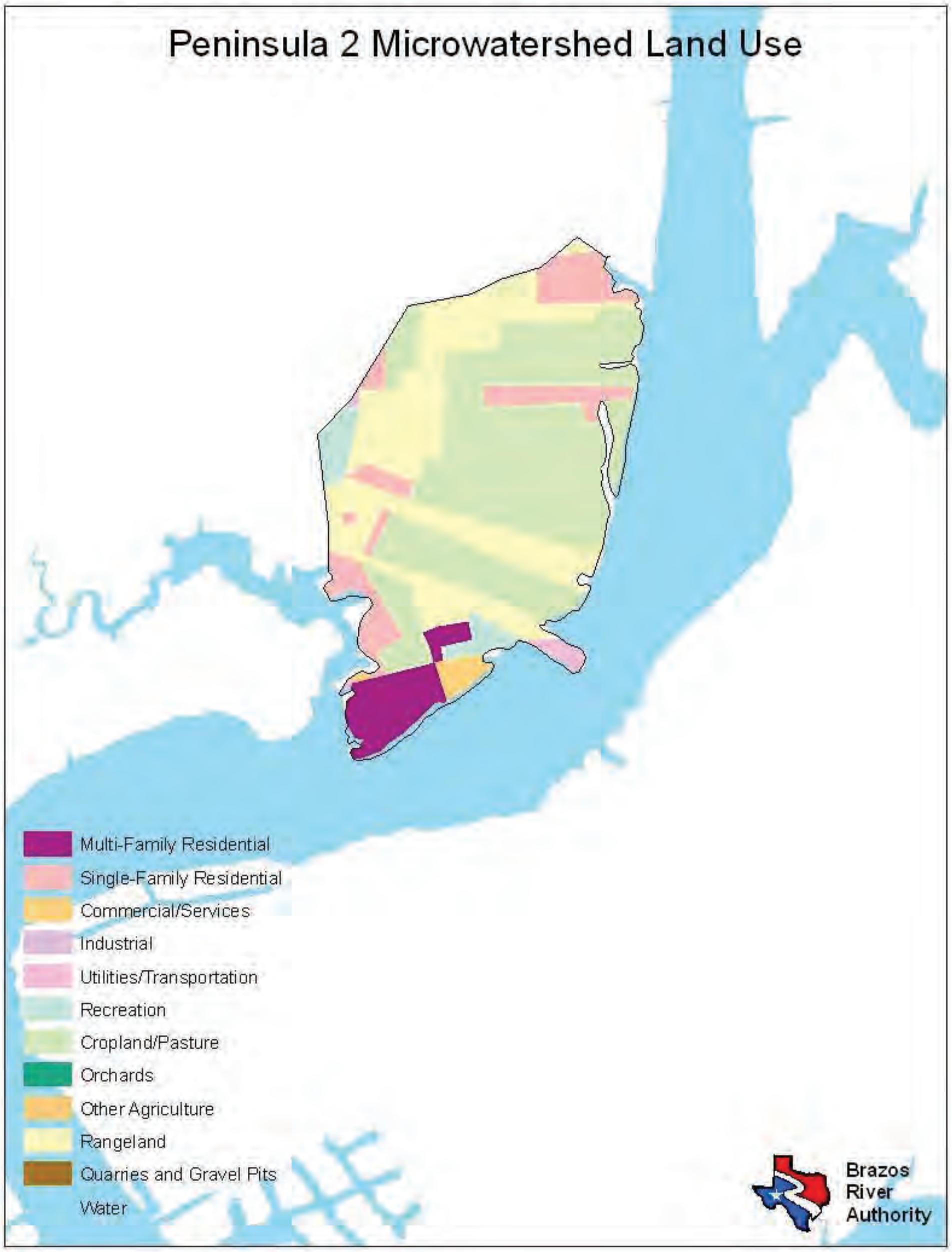
Land Use	Percent by Microwatershed
Single Family Residential	95%
Recreation	5%
Water	<1%



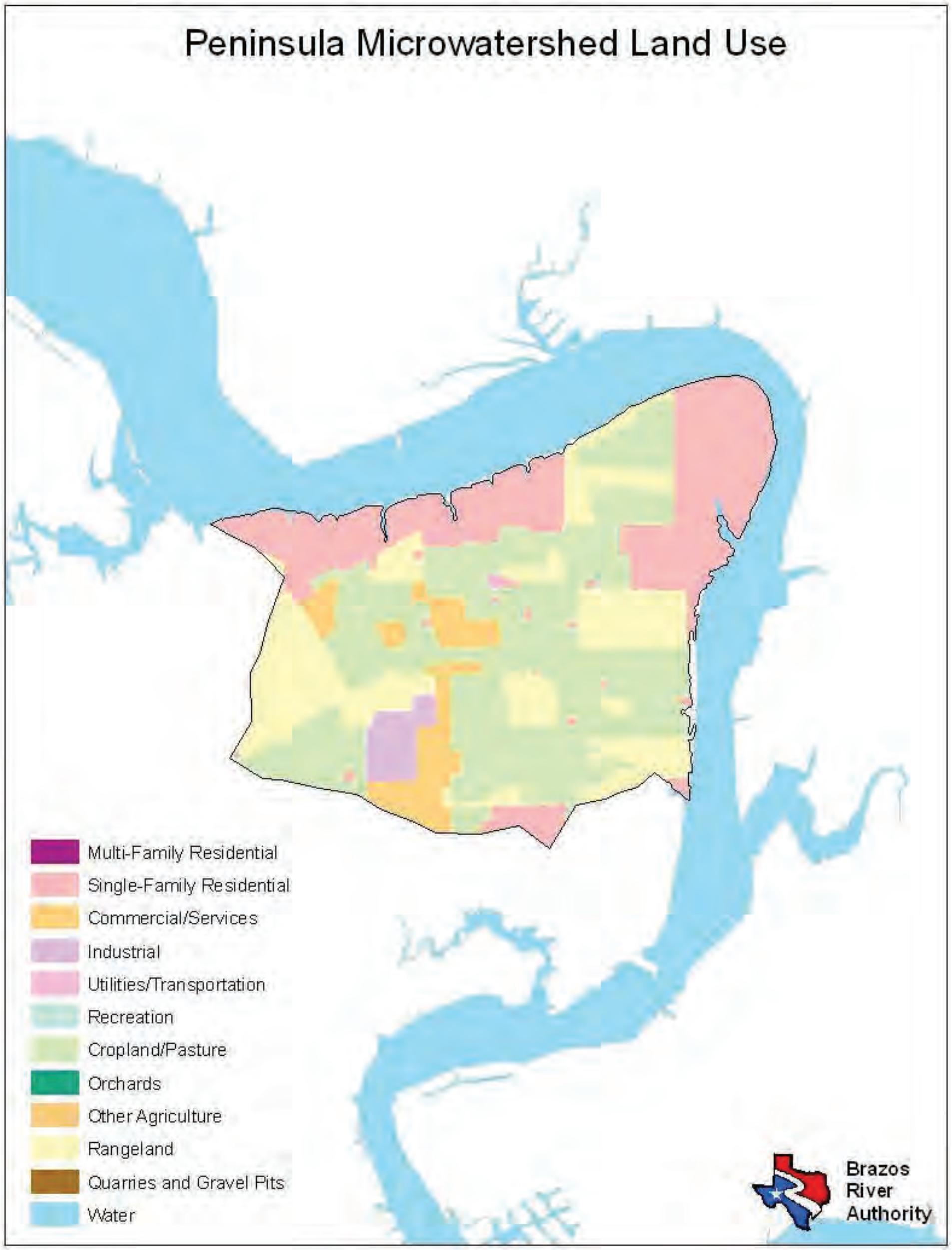
Land Use	Percent by Microwatershed
Single Family Residential	58%
Commercial/Services	4%
Industrial	3%
Cropland/Pasture	10%
Rangeland	24%



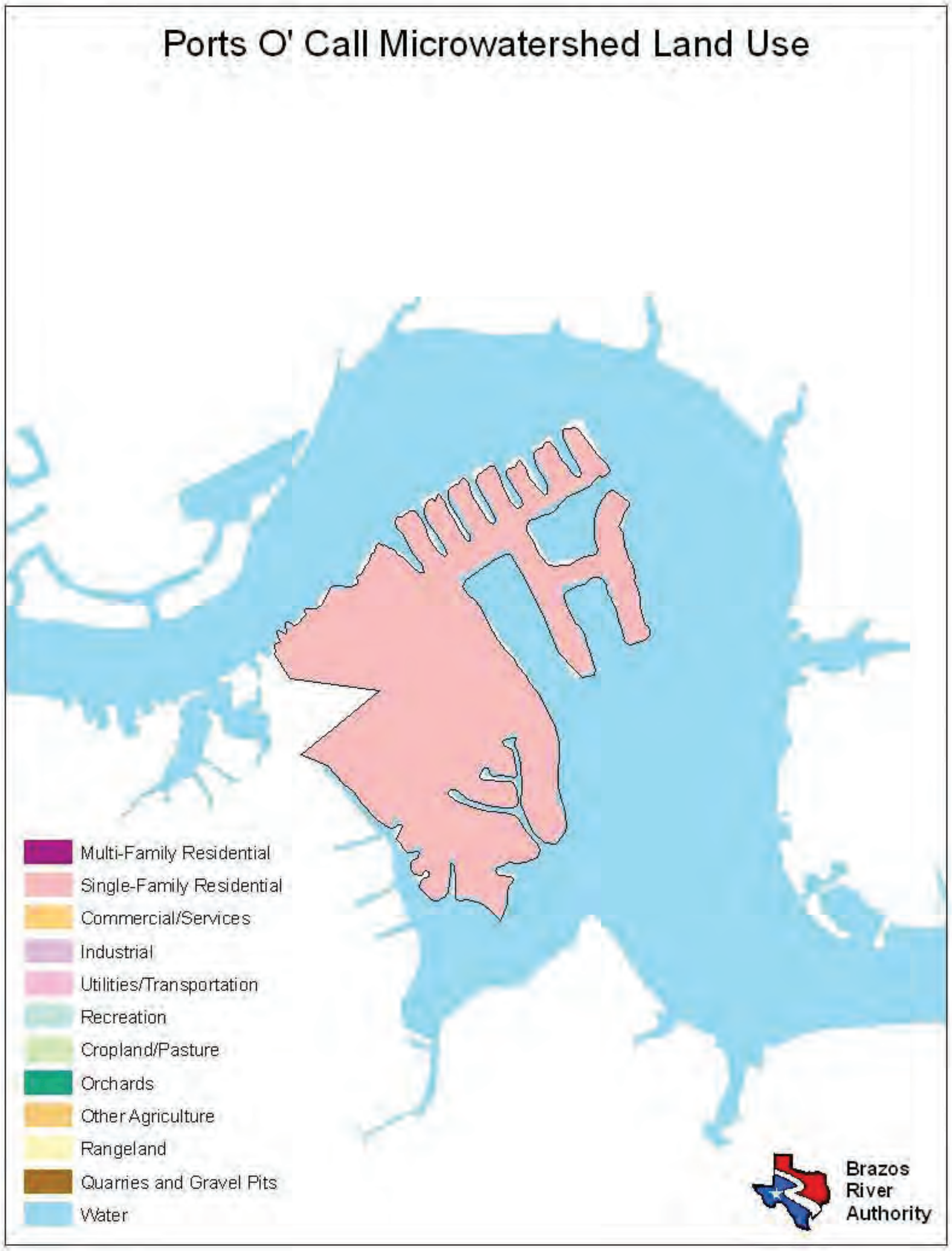
Land Use	Percent by Microwatershed
Single Family Residential	98%
Water	2%



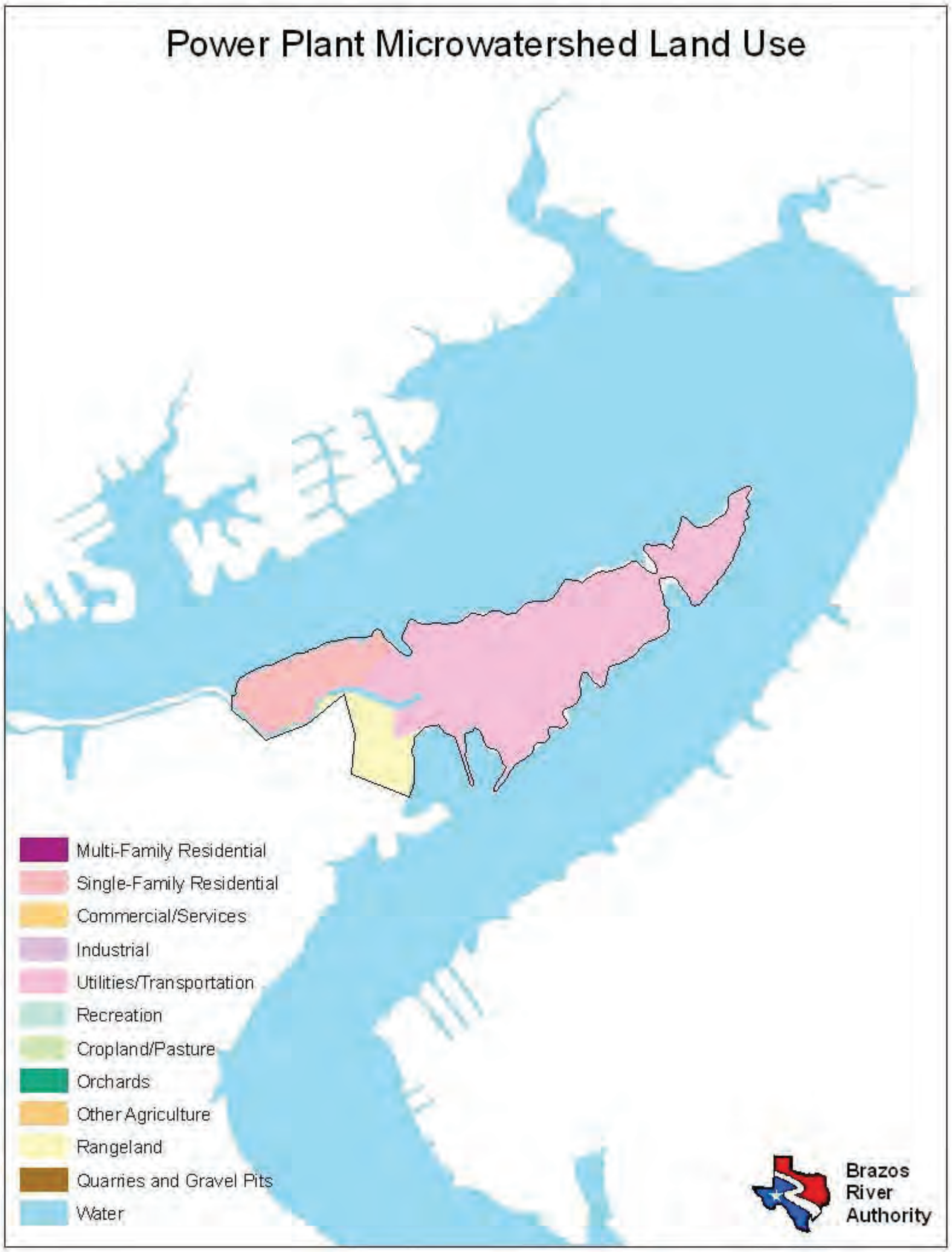
Land Use	Percent by Microwatershed
Multi-Family Residential	6%
Single Family Residential	12%
Commercial/Services	2%
Utilities/Transportation	1%
Recreation	3%
Cropland/Pasture	45%
Rangeland	28%
Water	1%



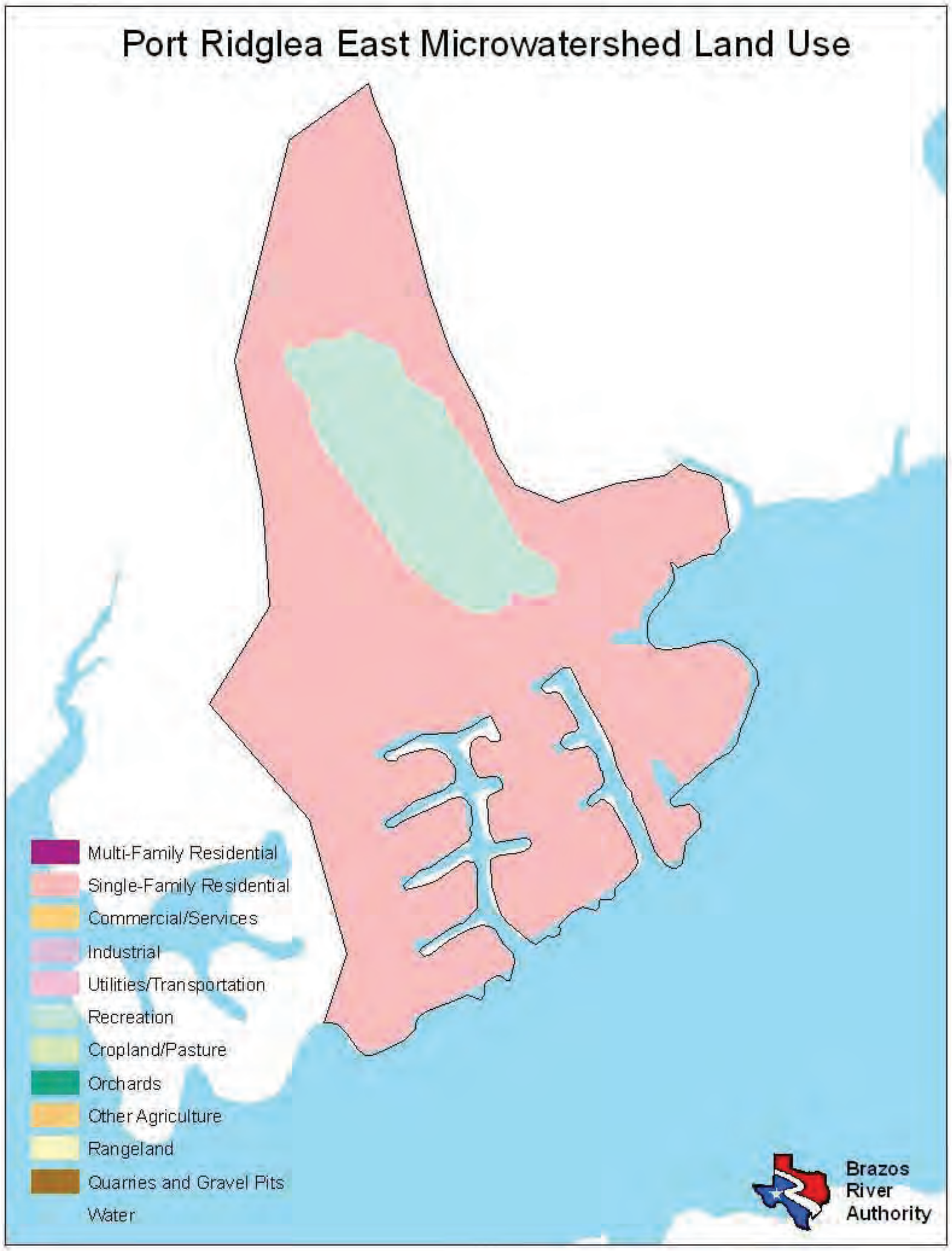
Land Use	Percent by Microwatershed
Single Family Residential	26%
Commercial/Services	7%
Industrial	3%
Utilities/Transportation	<1%
Cropland/Pasture	41%
Rangeland	22%
Water	<1%



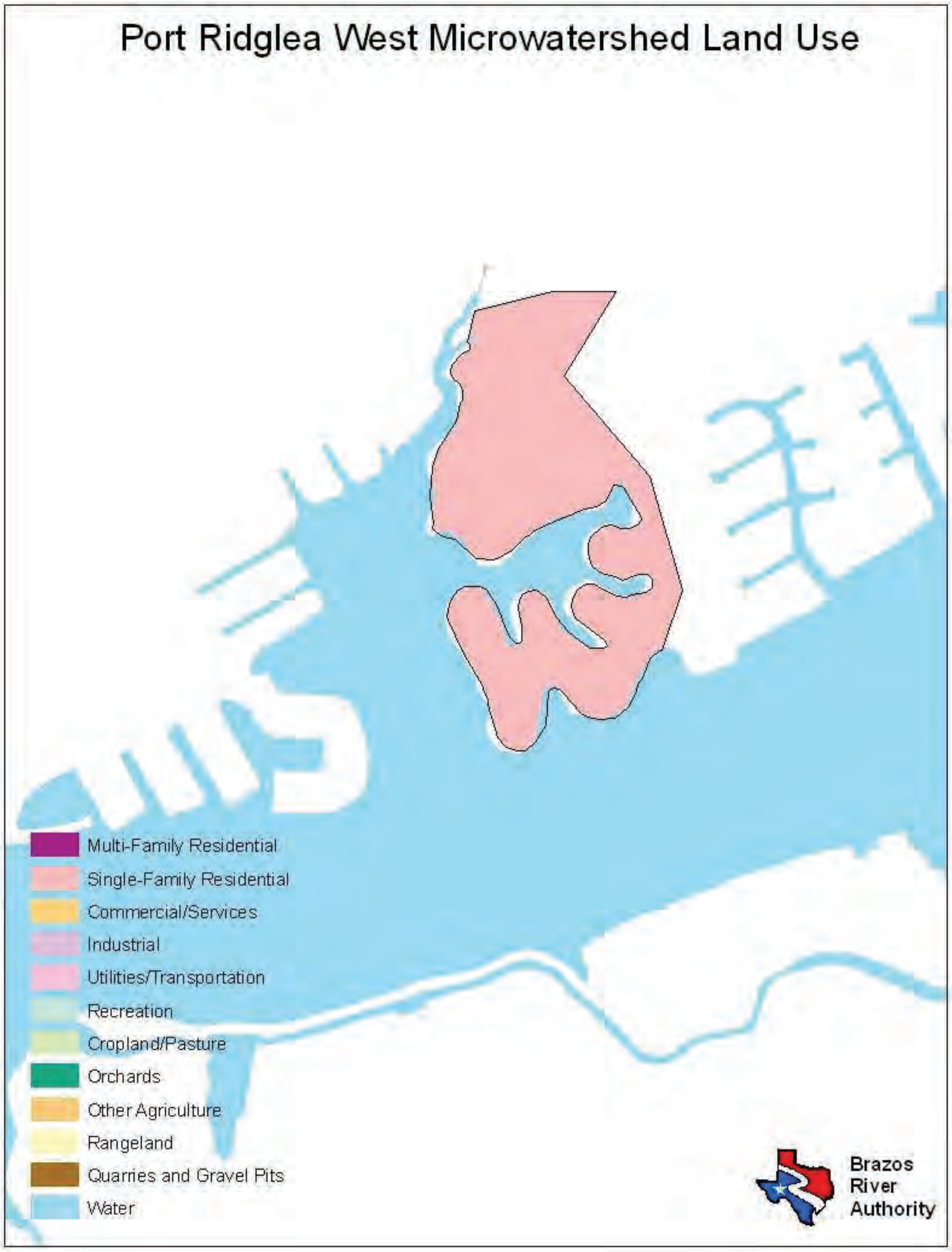
Land Use	Percent by Microwatershed
Single Family Residential	96%
Water	4%



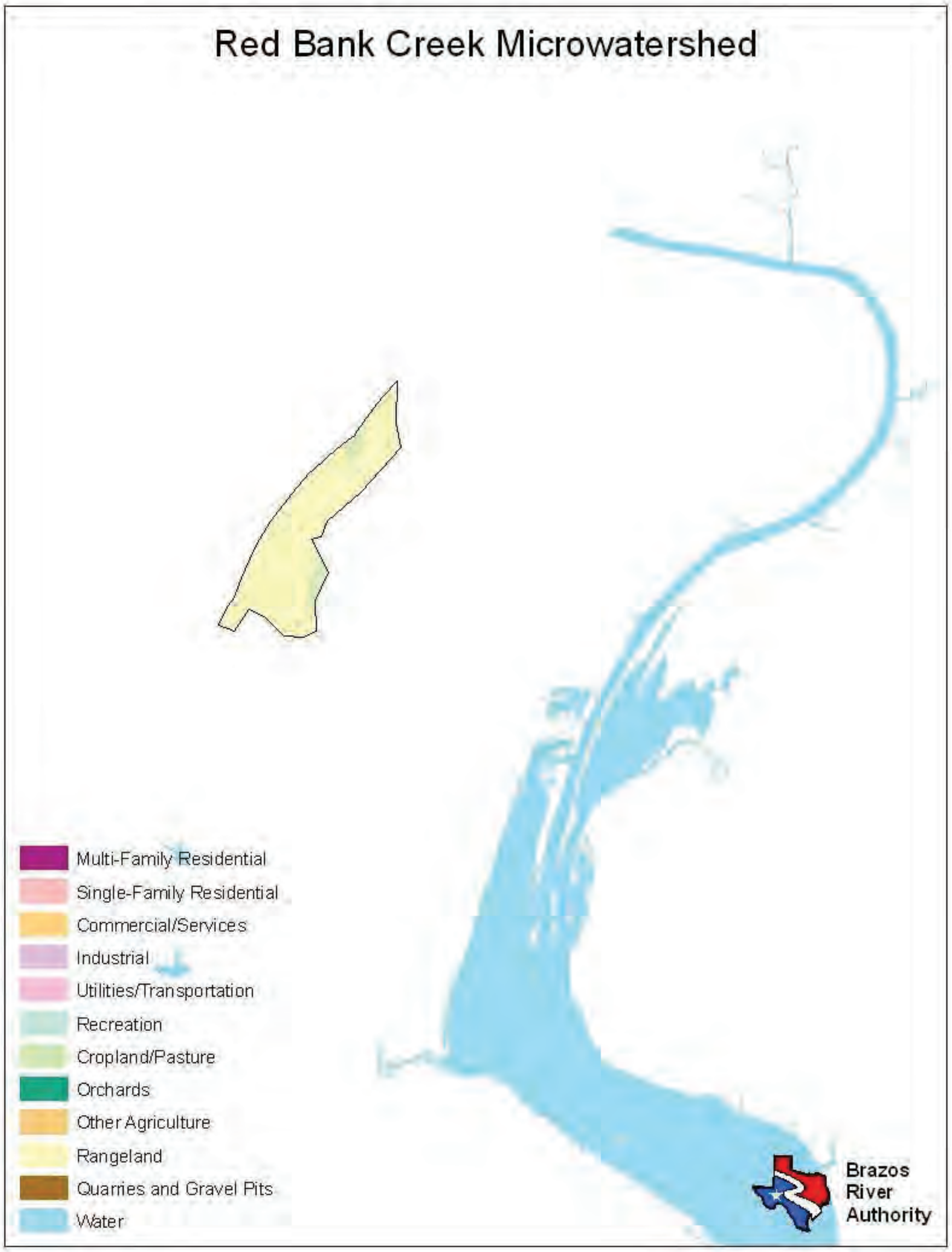
Land Use	Percent by Microwatershed
Single Family Residential	15%
Utilities/Transportation	71%
Rangeland	10%
Water	4%



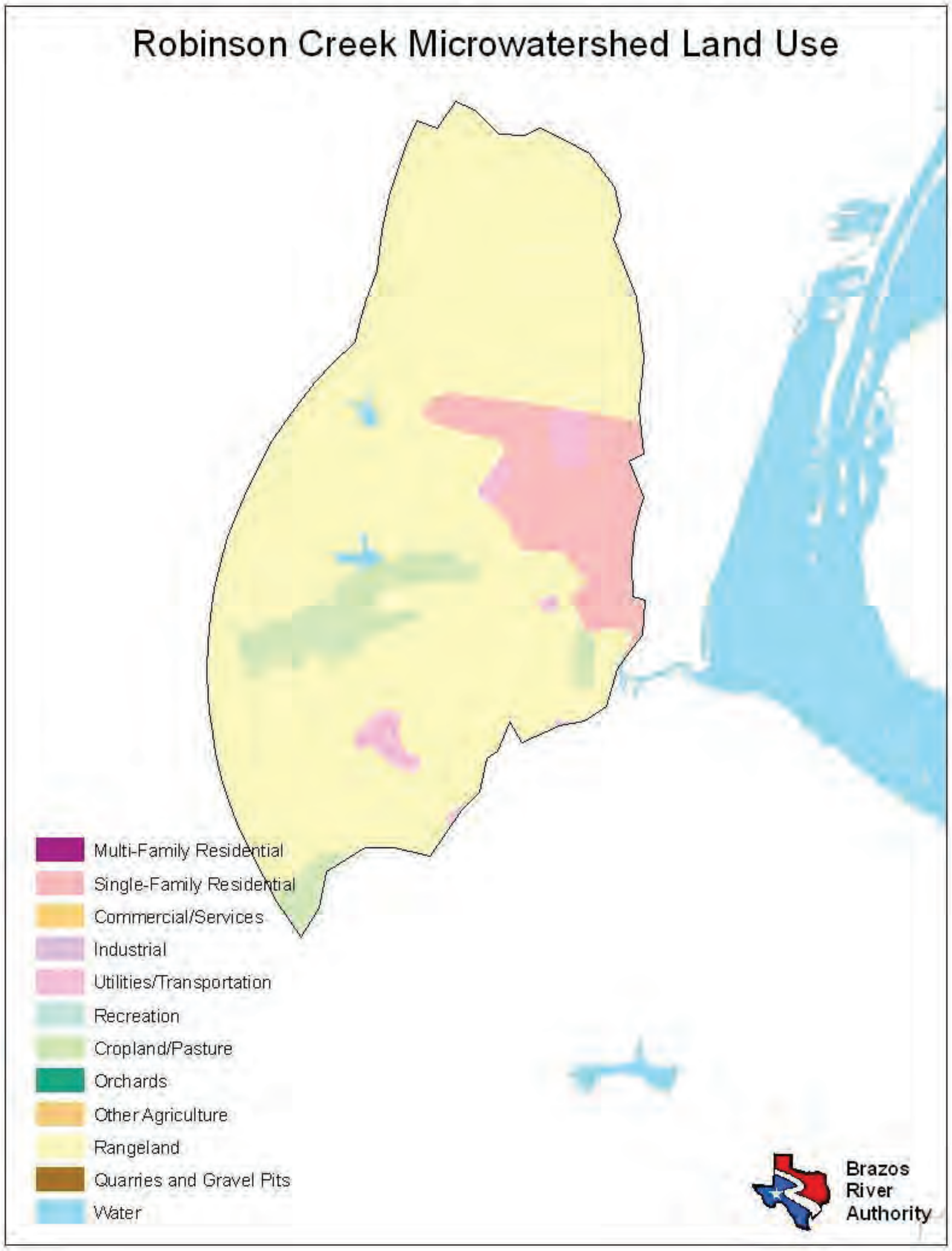
Land Use	Percent by Microwatershed
Single Family Residential	84%
Recreation	13%
Water	2%



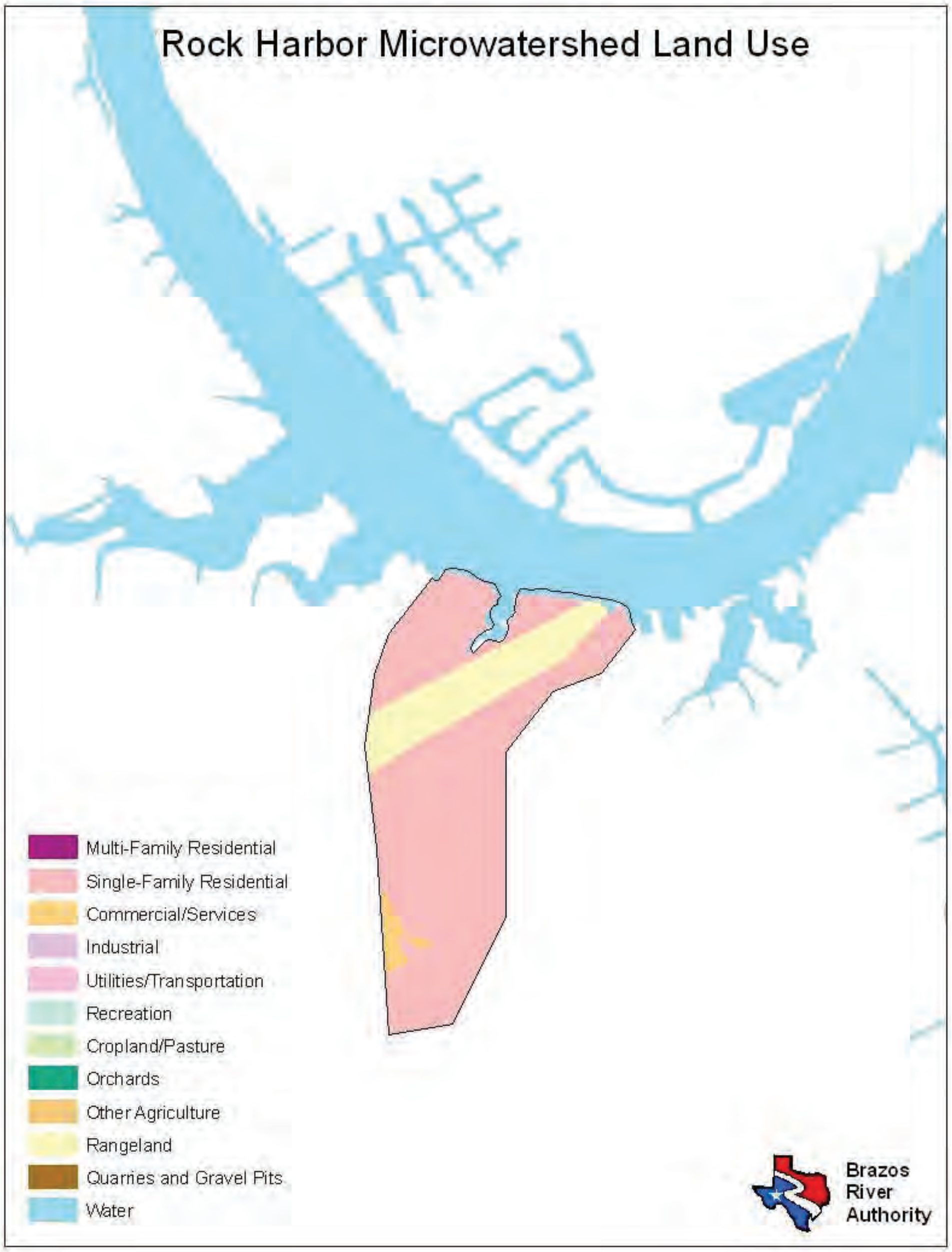
Land Use	Percent by Microwatershed
Single Family Residential	98%
Water	2%



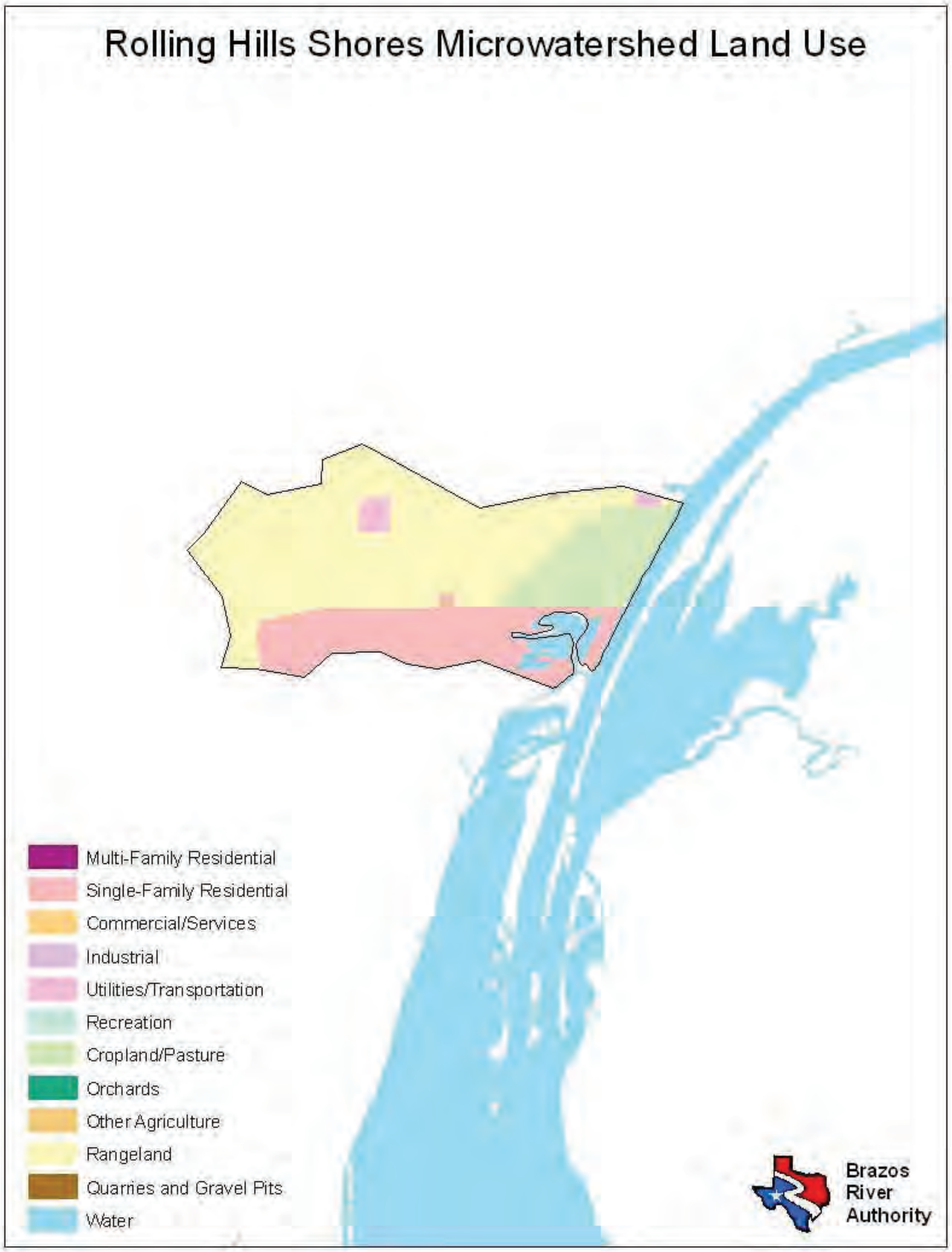
Land Use	Percent by Microwatershed
Single Family Residential	<1%
Cropland/Pasture	7%
Rangeland	93%



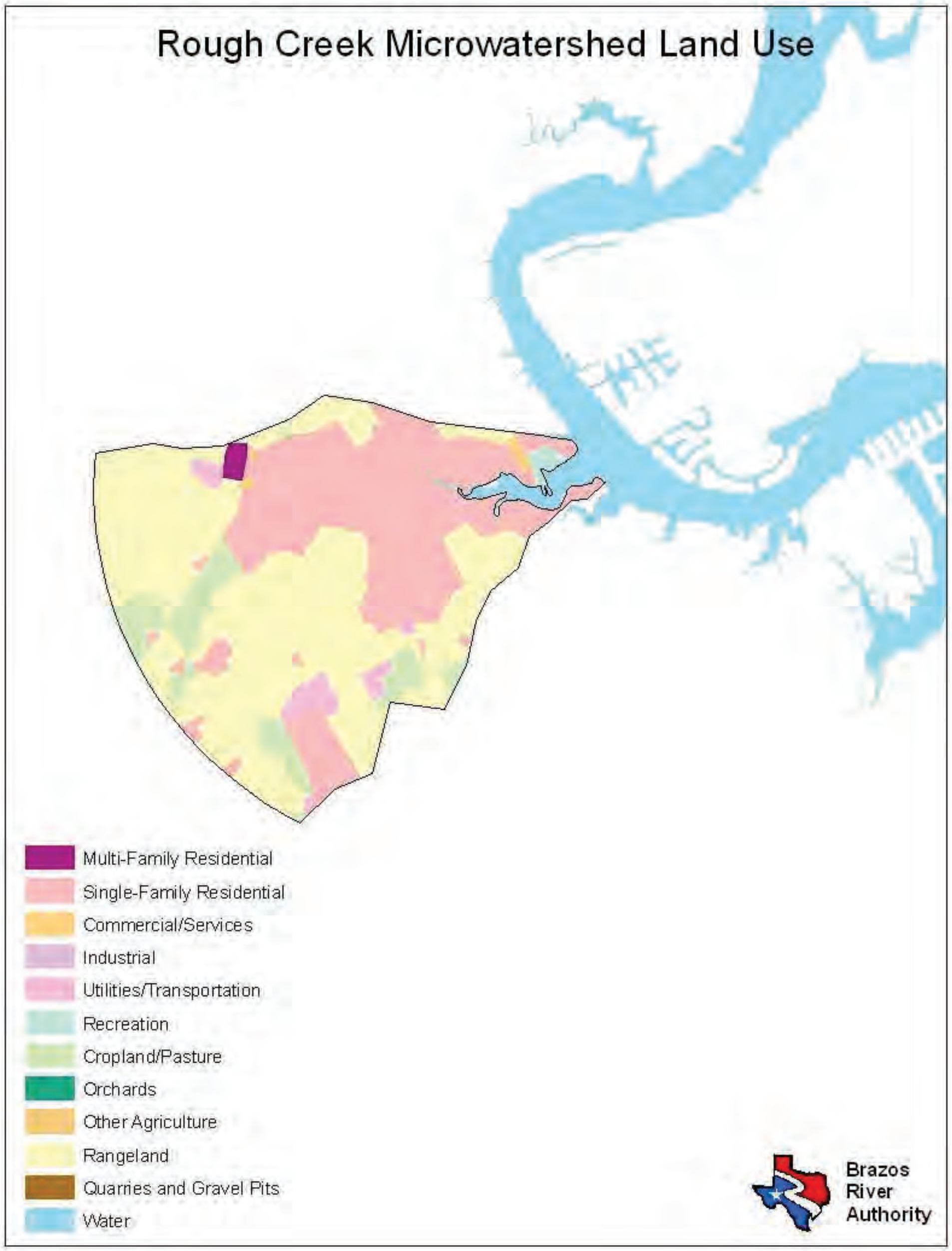
Land Use	Percent by Microwatershed
Single Family Residential	11%
Utilities/Transportation	2%
Cropland/Pasture	7%
Rangeland	80%
Water	<1%



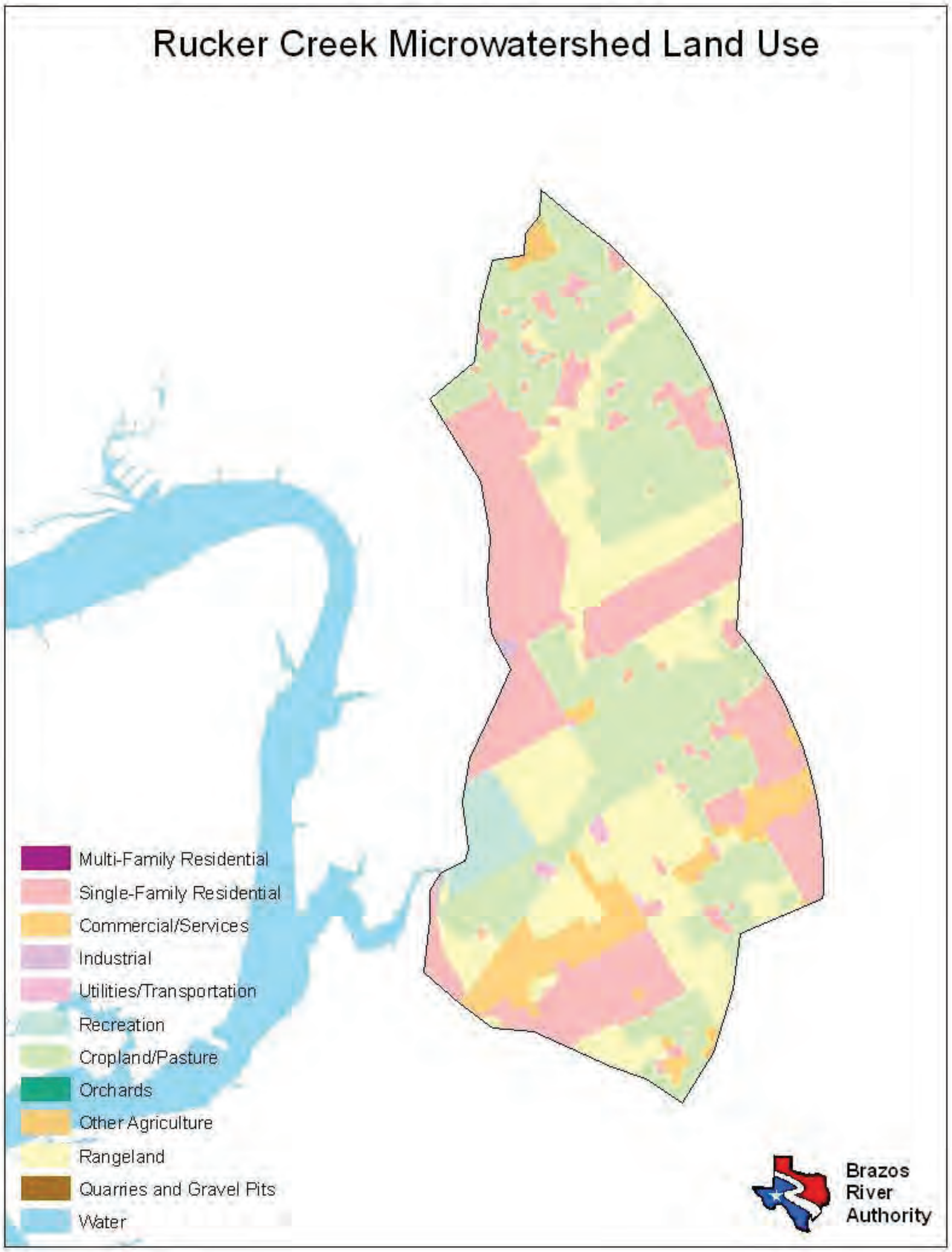
Land Use	Percent by Microwatershed
Single Family Residential	78%
Commercial/Services	2%
Rangeland	18%
Water	2%



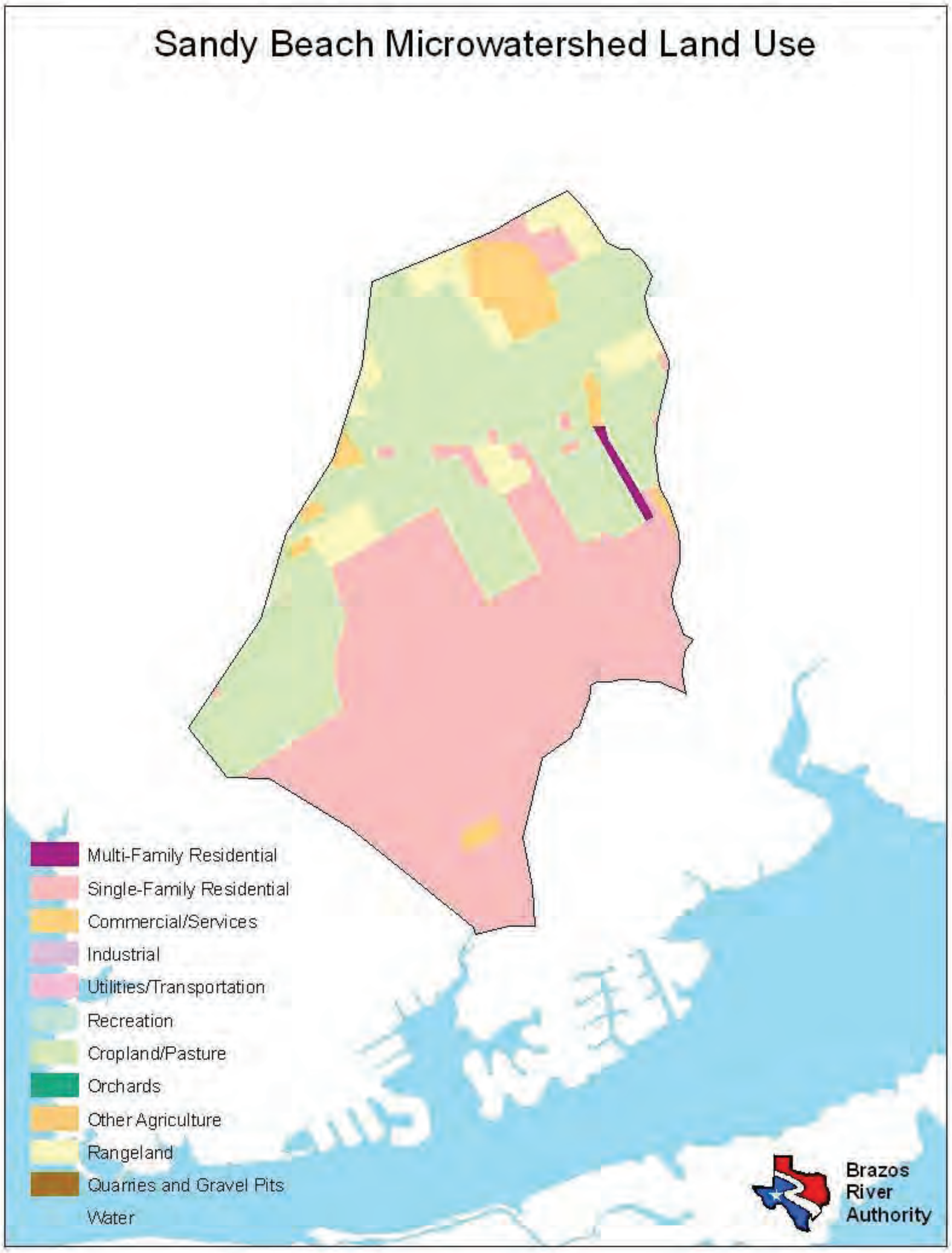
Land Use	Percent by Microwatershed
Single Family Residential	23%
Utilities/Transportation	2%
Cropland/Pasture	14%
Rangeland	58%
Water	3%



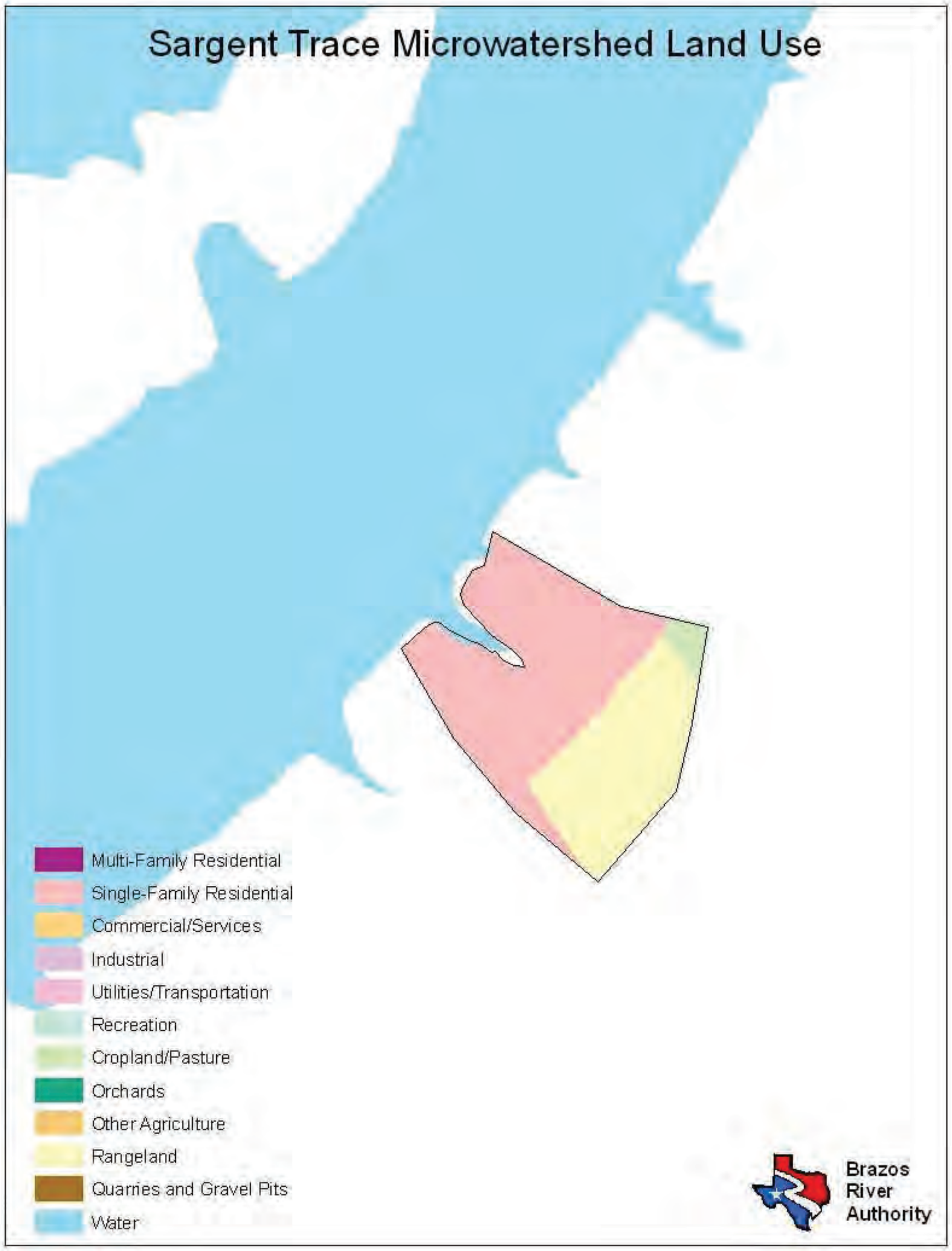
Land Use	Percent by Microwatershed
Multi-Family Residential	<1%
Single Family Residential	36%
Commercial/Services	<1%
Utilities/Transportation	3%
Recreation	<1%
Cropland/Pasture	7%
Rangeland	52%
Water	<1%



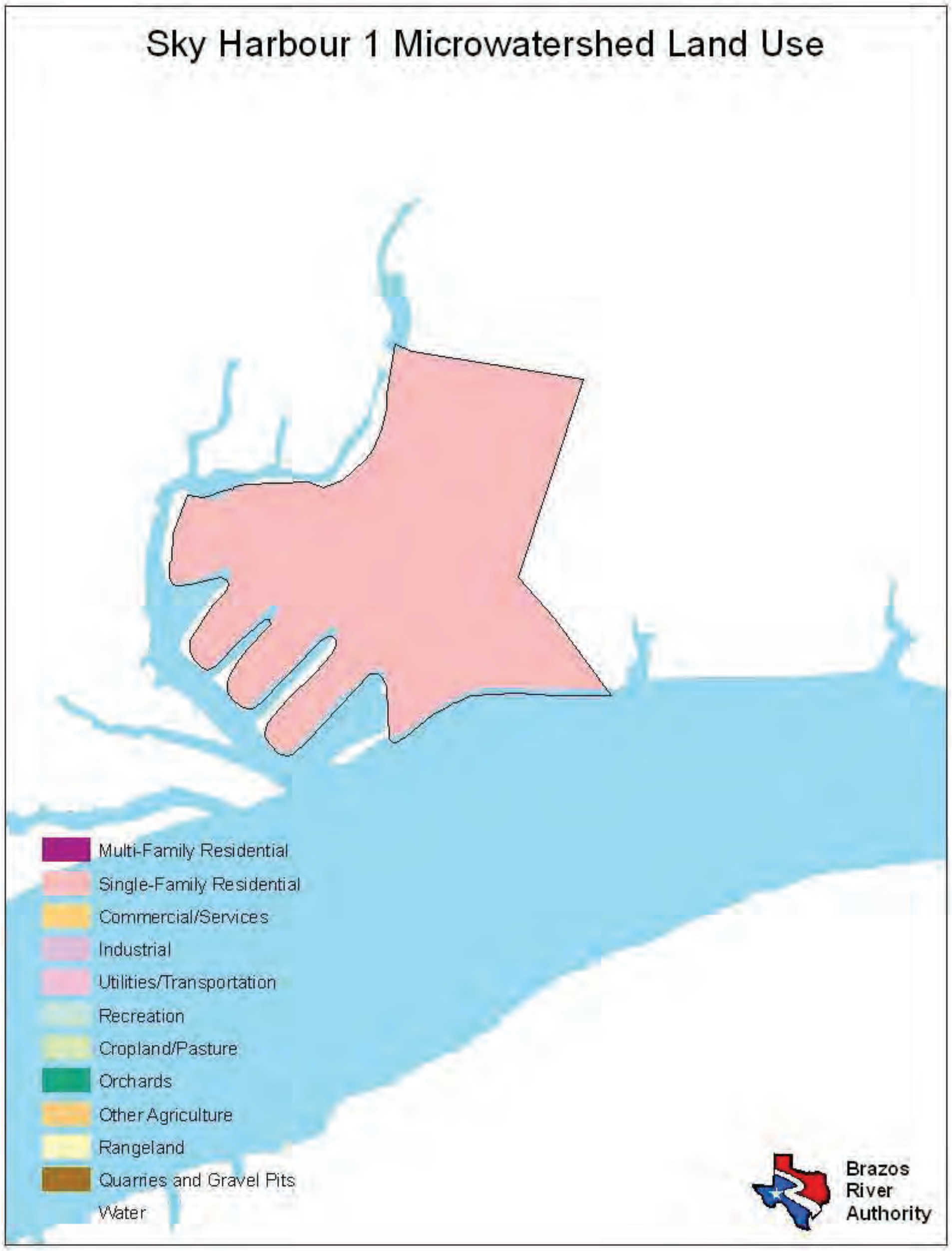
Land Use	Percent by Microwatershed
Single Family Residential	29%
Commercial/Services	7%
Industrial	<1%
Utilities/Transportation	<1%
Recreation	3%
Cropland/Pasture	36%
Other Agriculture	<1%
Rangeland	24%
Water	<1%



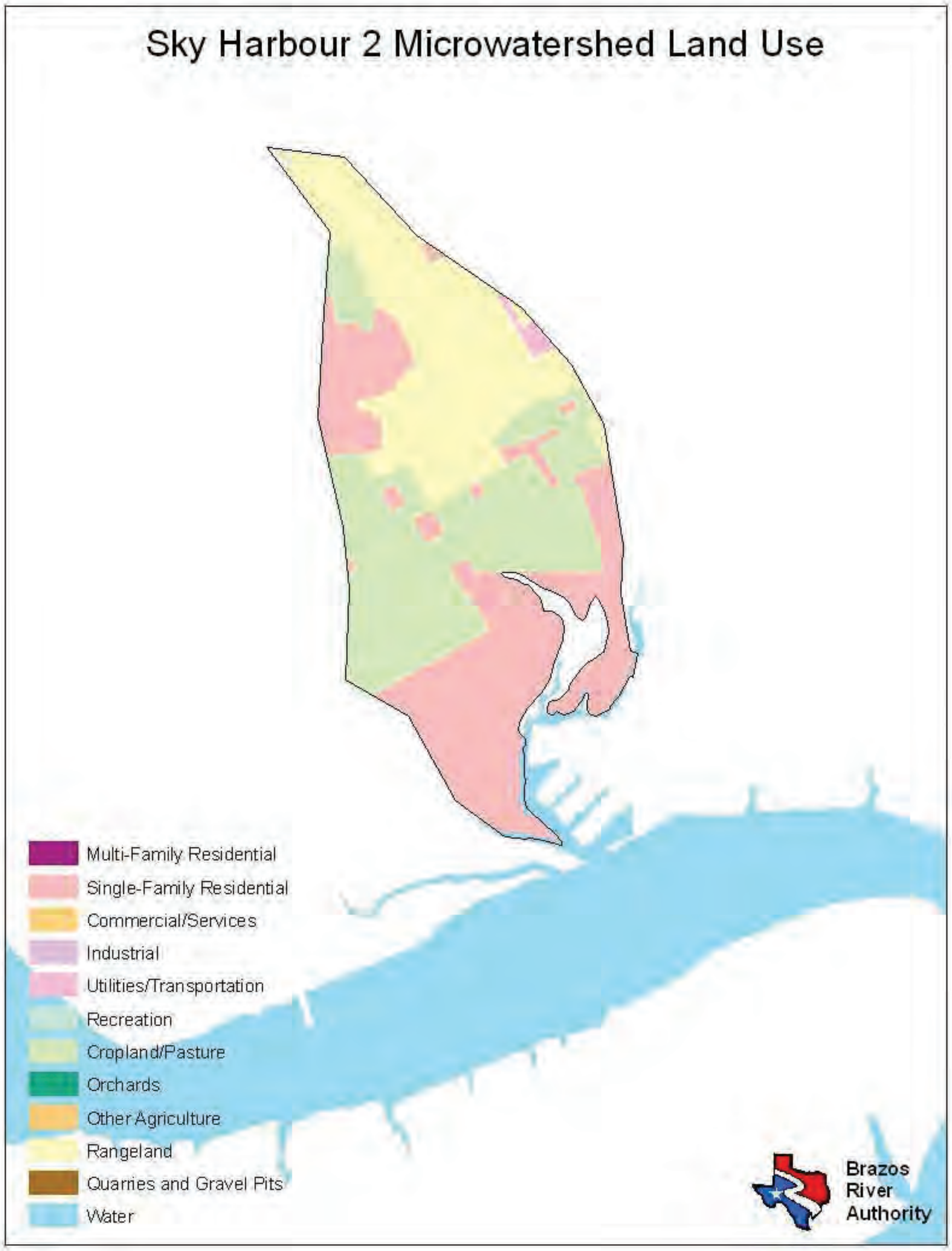
Land Use	Percent by Microwatershed
Multi-Family Residential	<1%
Single Family Residential	49%
Commercial/Services	5%
Cropland/Pasture	40%
Rangeland	6%



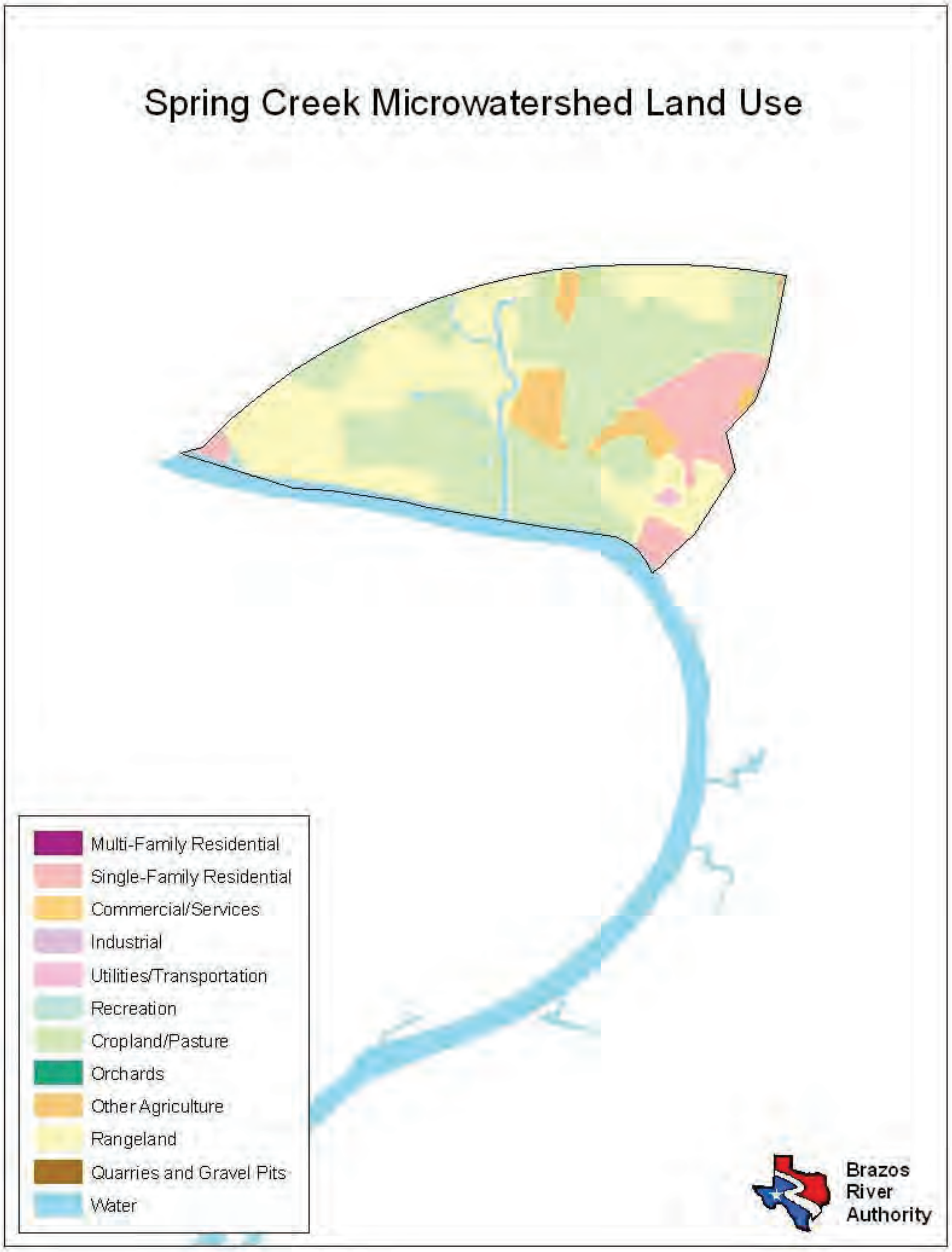
Land Use	Percent by Microwatershed
Single Family Residential	61%
Cropland/Pasture	3%
Rangeland	36%



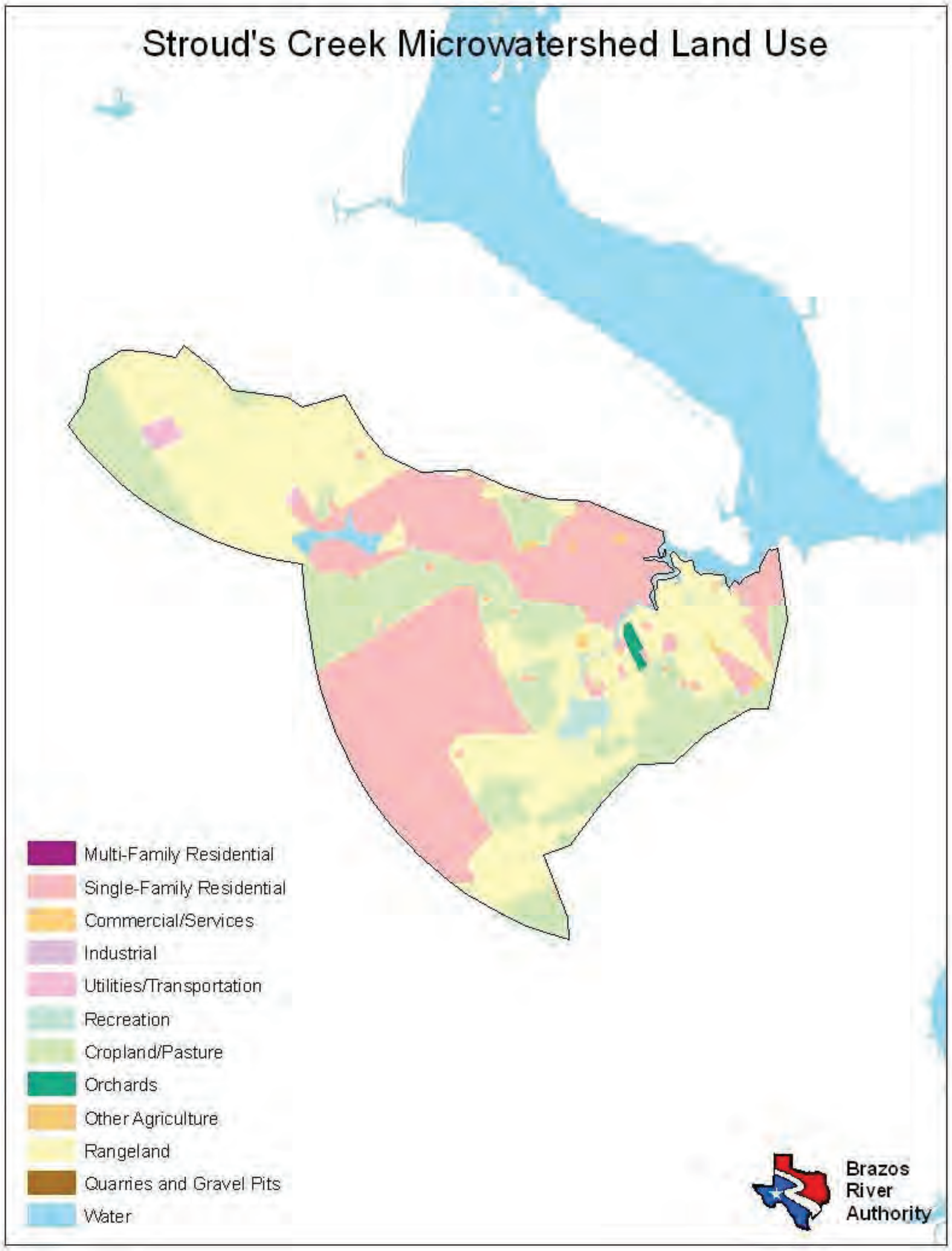
Land Use	Percent by Microwatershed
Single Family Residential	97%
Water	3%



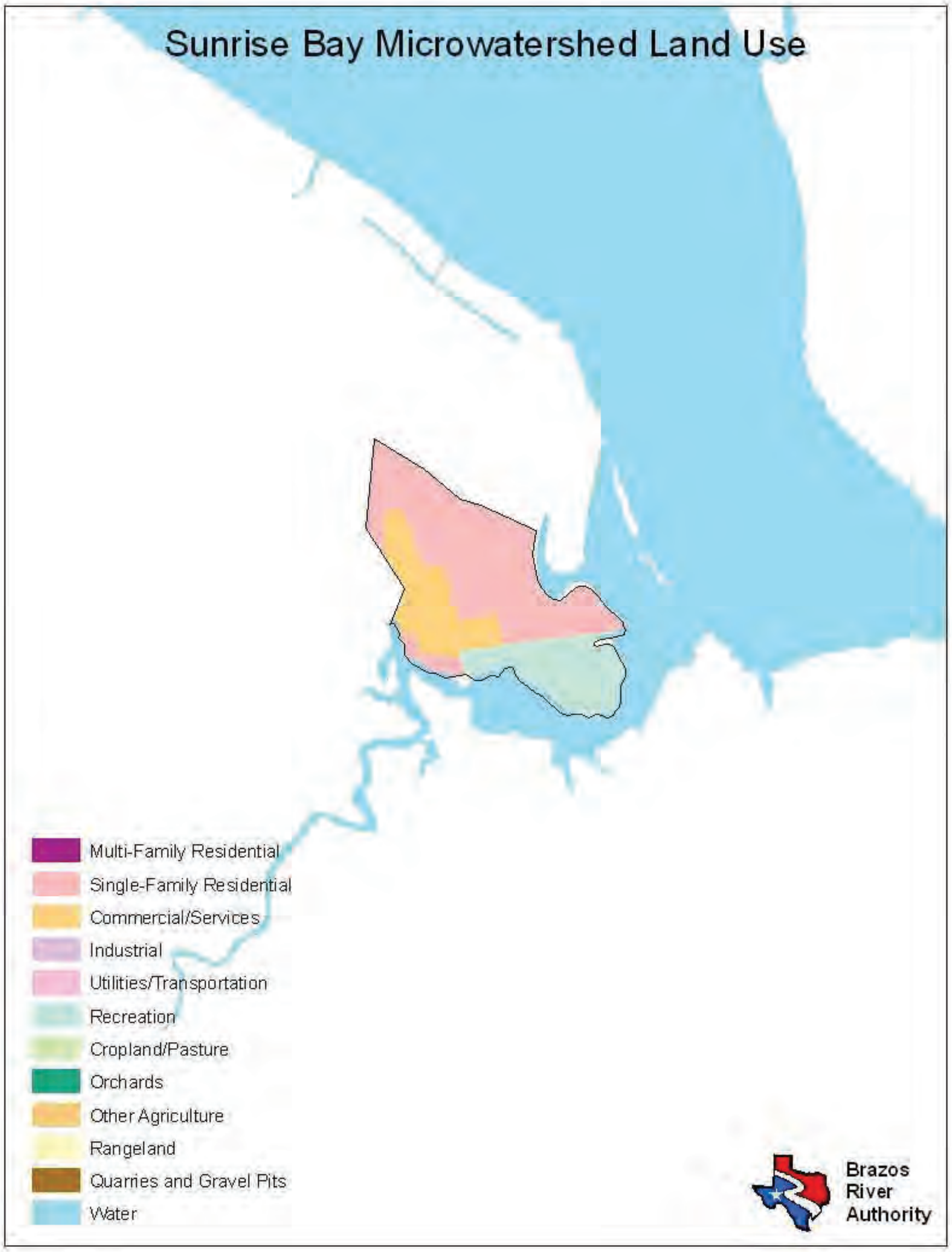
Land Use	Percent by Microwatershed
Single Family Residential	36%
Utilities/Transportation	<1%
Cropland/Pasture	33%
Rangeland	30%
Water	<1%



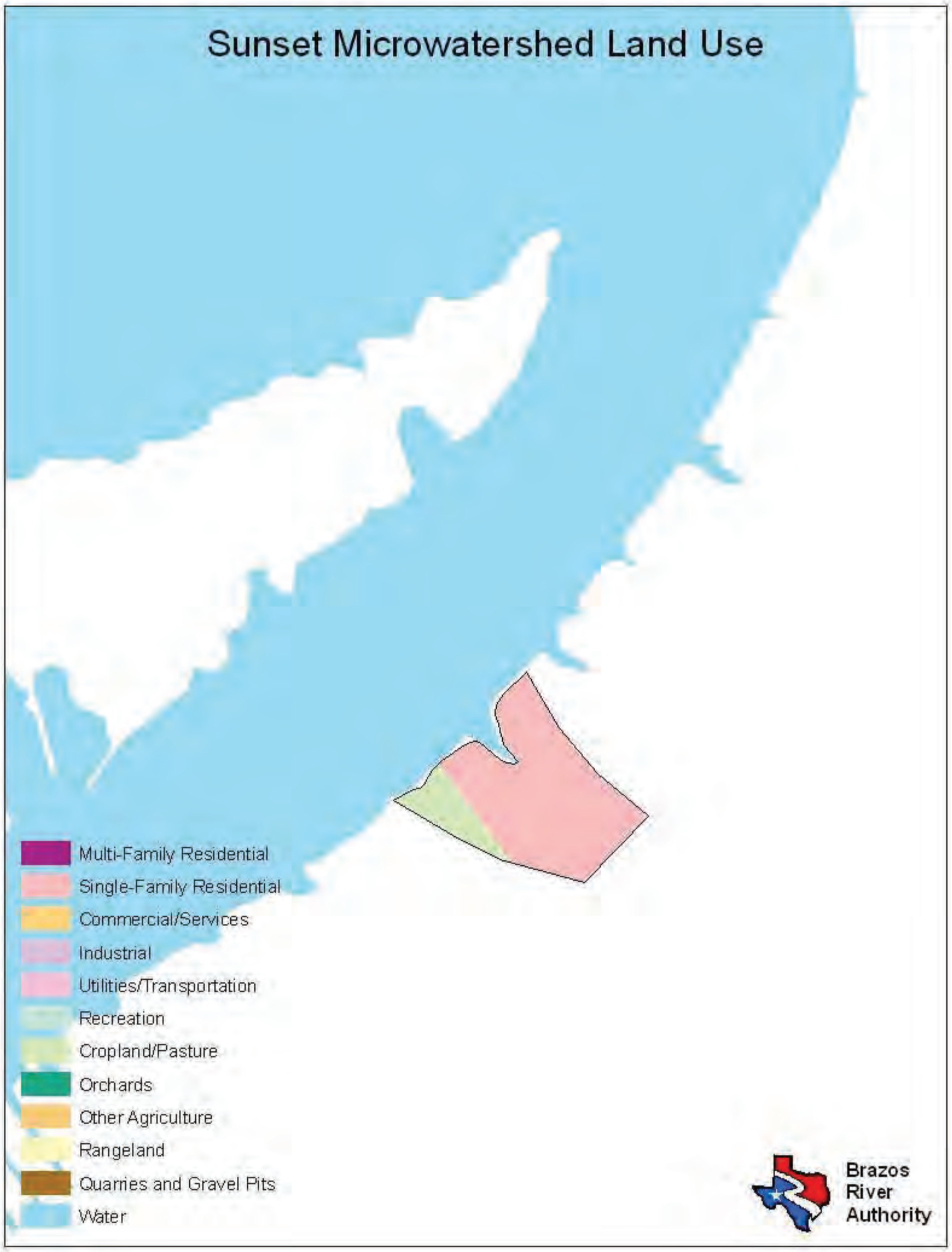
Land Use	Percent by Microwatershed
Single Family Residential	10%
Utilities/Transportation	<1%
Recreation	<1%
Cropland/Pasture	45%
Other Agriculture	6%
Rangeland	35%
Water	3%



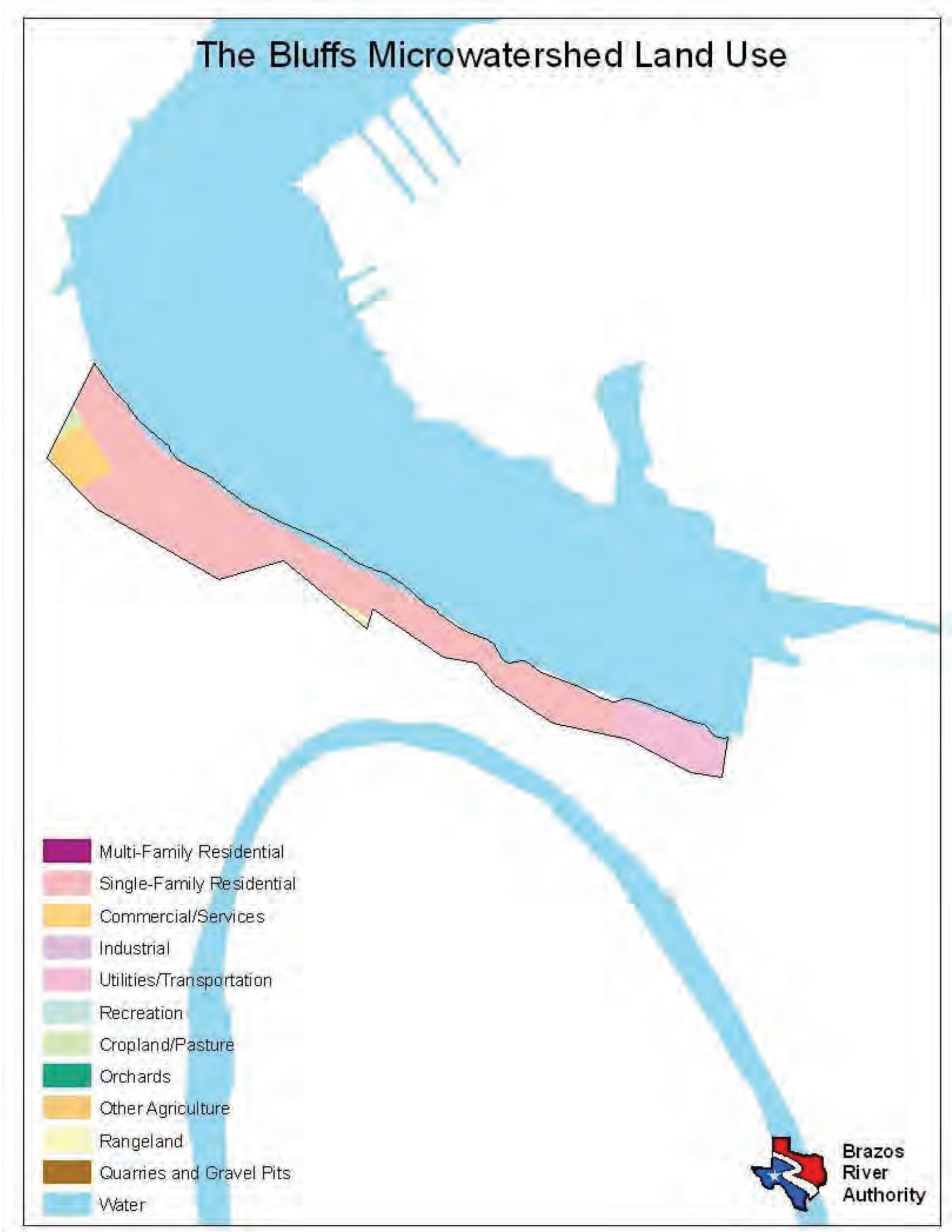
Land Use	Percent by Microwatershed
Single Family Residential	36%
Commercial/Services	<1%
Utilities/Transportation	<1%
Recreation	<1%
Cropland/Pasture	23%
Orchards	<1%
Rangeland	37%
Water	<1%



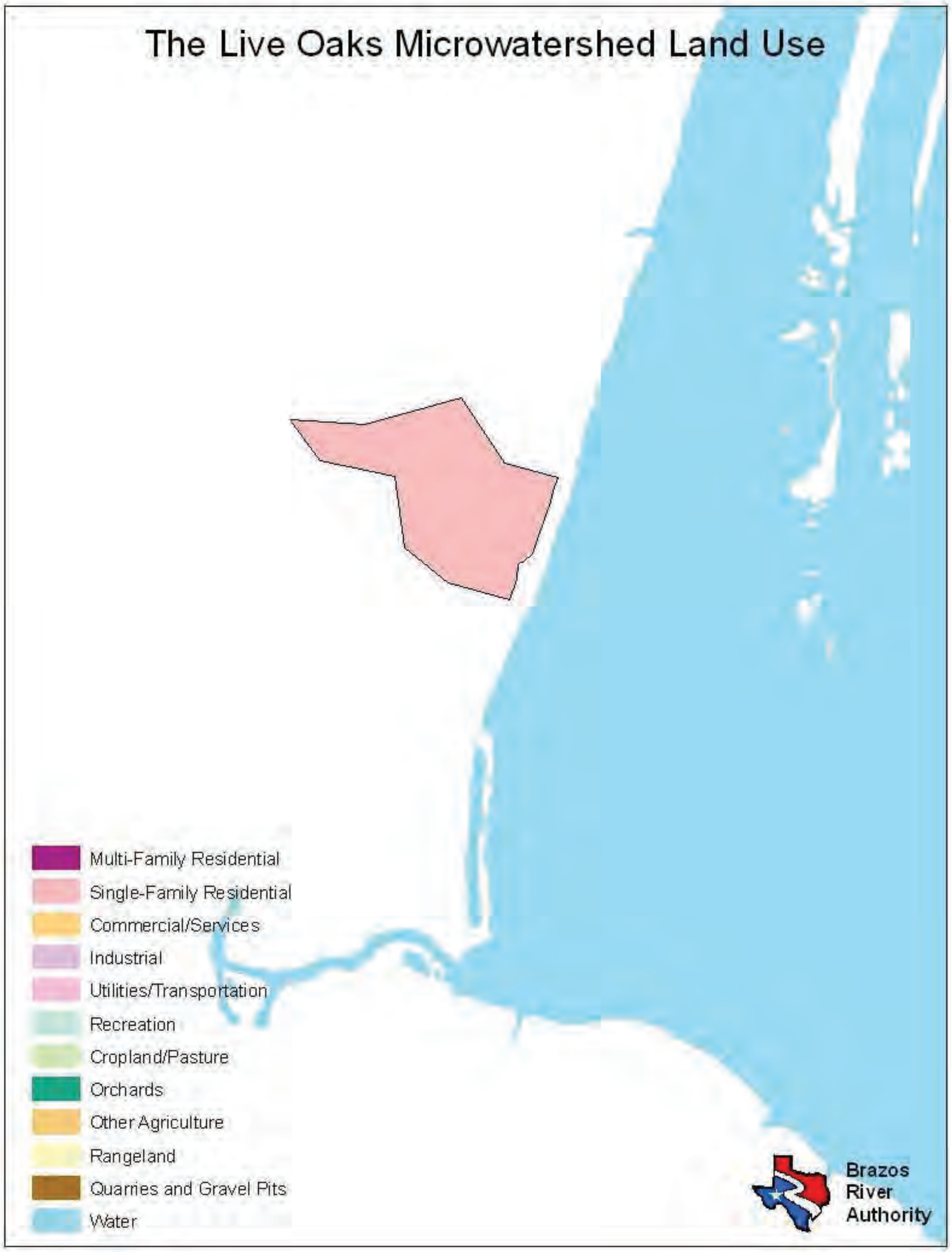
Land Use	Percent by Microwatershed
Single Family Residential	56%
Commercial/Services	20%
Recreation	21%
Water	3%



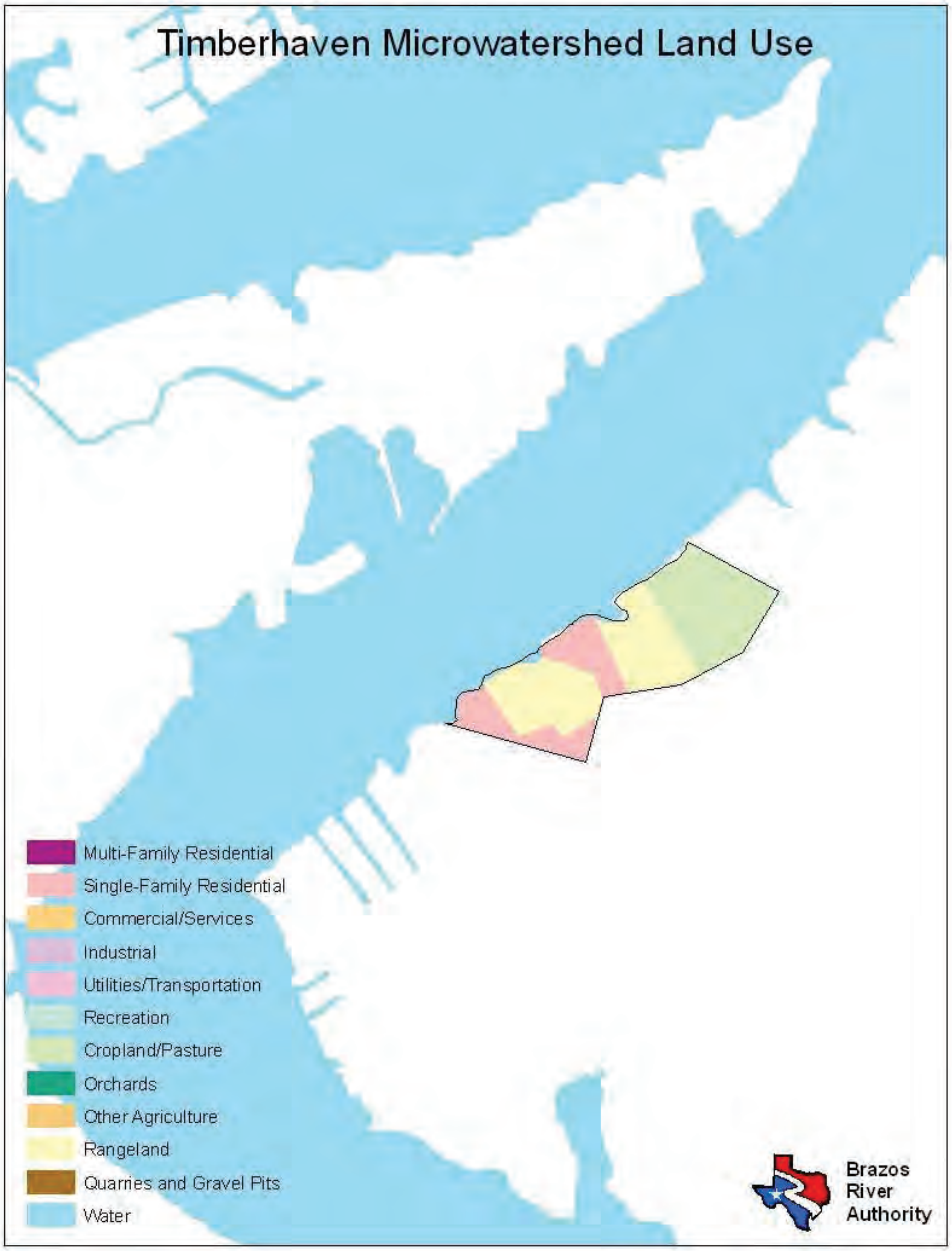
Land Use	Percent by Microwatershed
Single Family Residential	85%
Cropland/Pasture	15%
Water	<1%



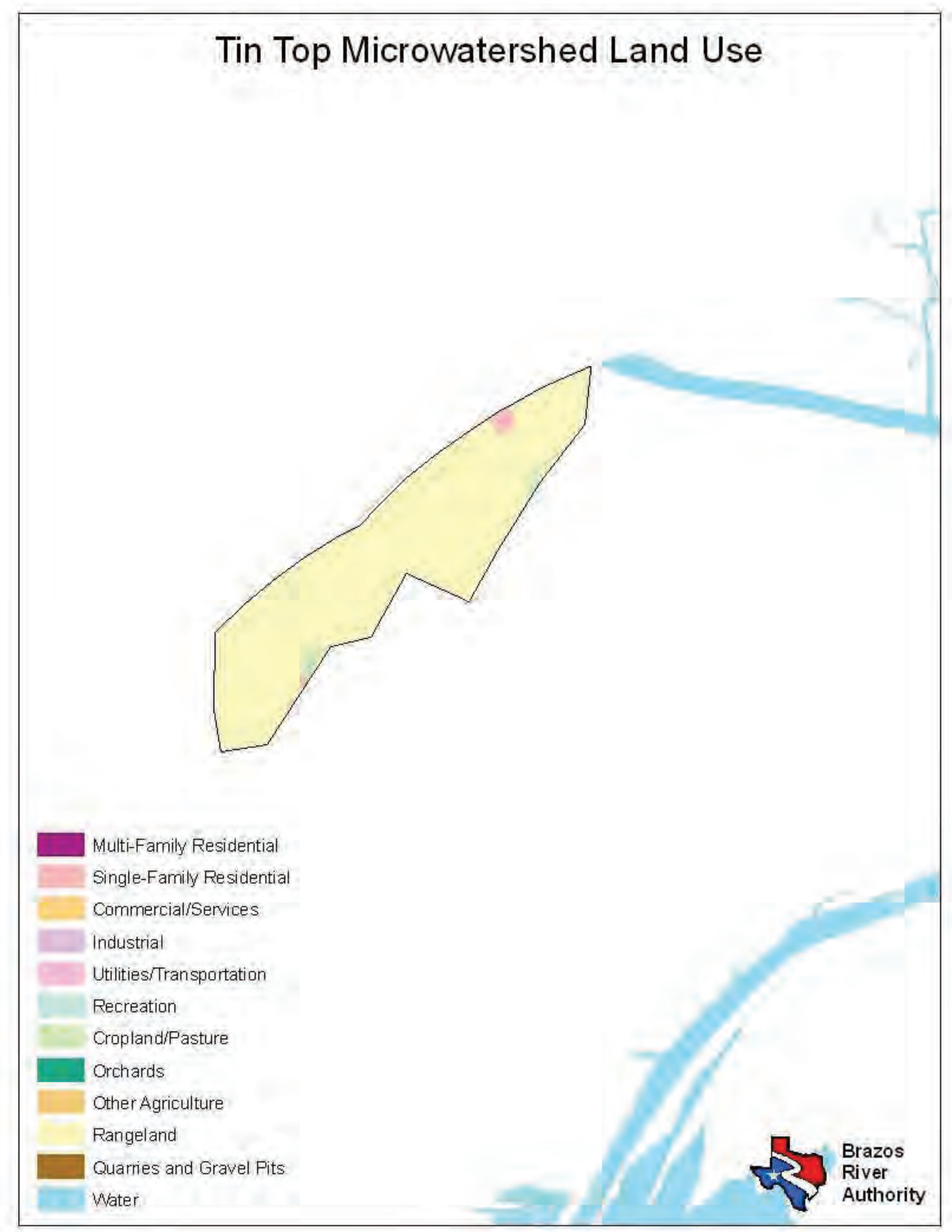
Land Use	Percent by Microwatershed
Single Family Residential	76%
Commercial/Services	6%
Utilities/Transportation	11%
Cropland/Pasture	<1%
Rangeland	<1%
Water	5%



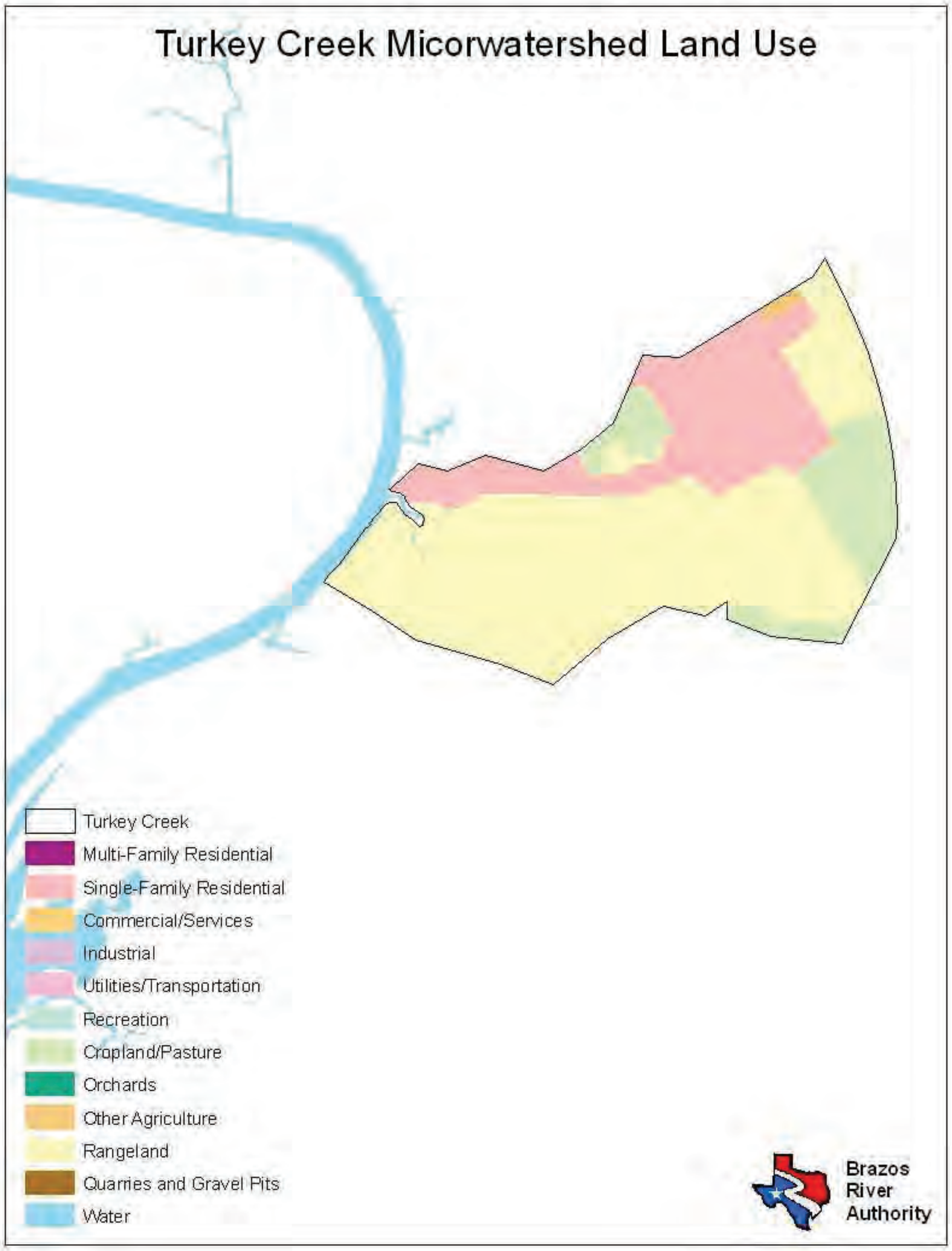
Land Use	Percent by Microwatershed
Single Family Residential	100%



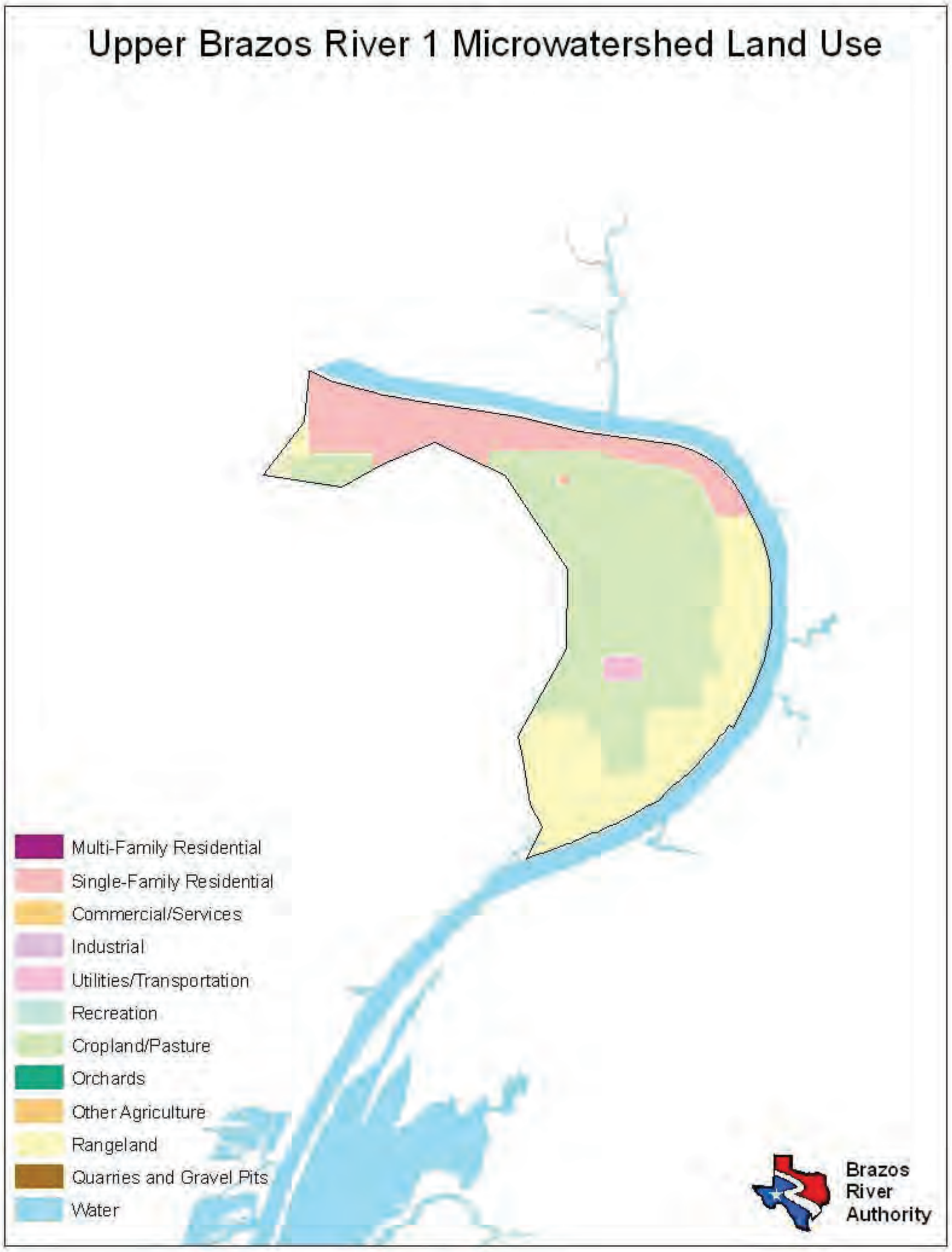
Land Use	Percent by Microwatershed
Single Family Residential	24%
Cropland/Pasture	32%
Rangeland	42%
Water	2%



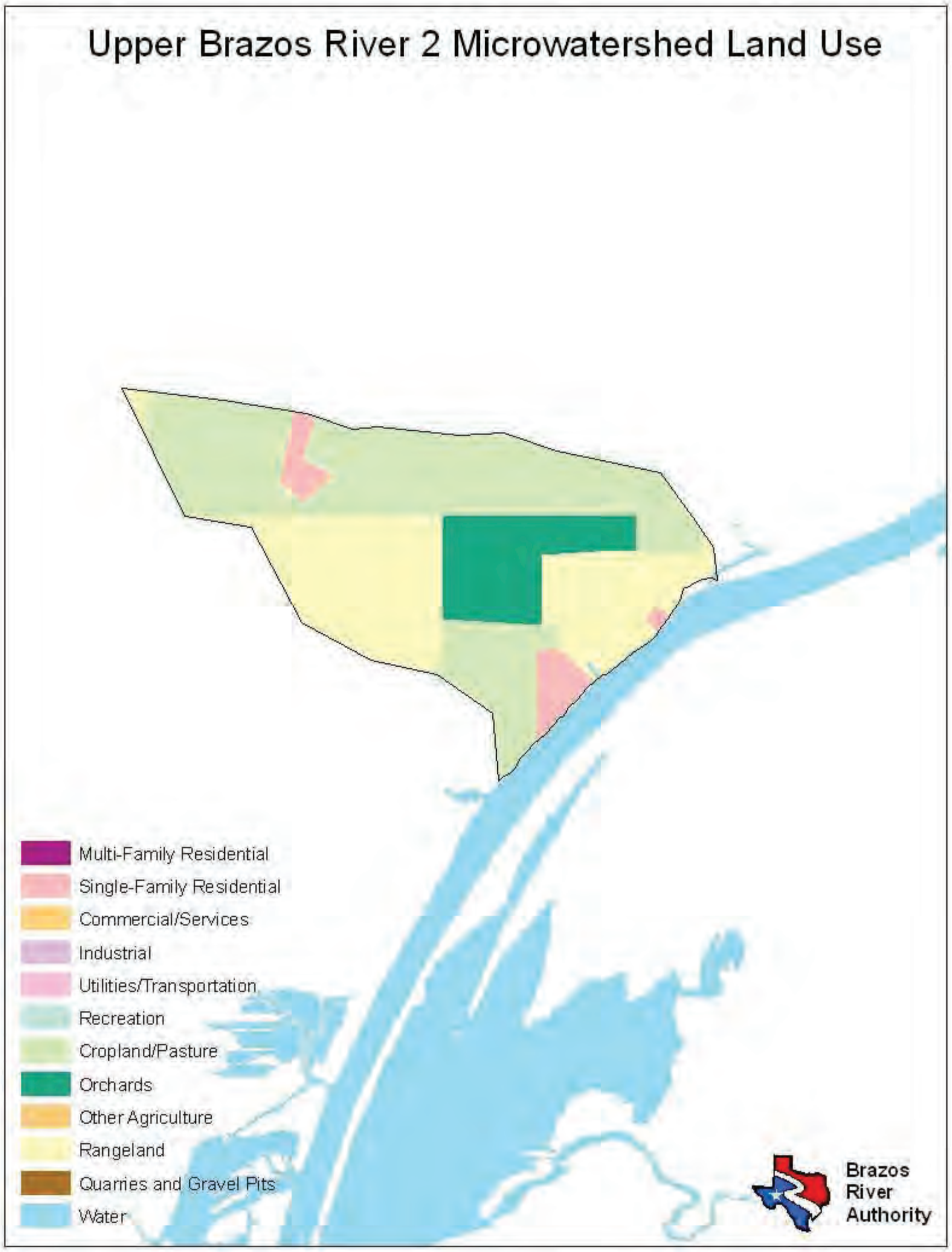
Land Use	Percent by Microwatershed
Single Family Residential	1%
Cropland/Pasture	2%
Rangeland	97%



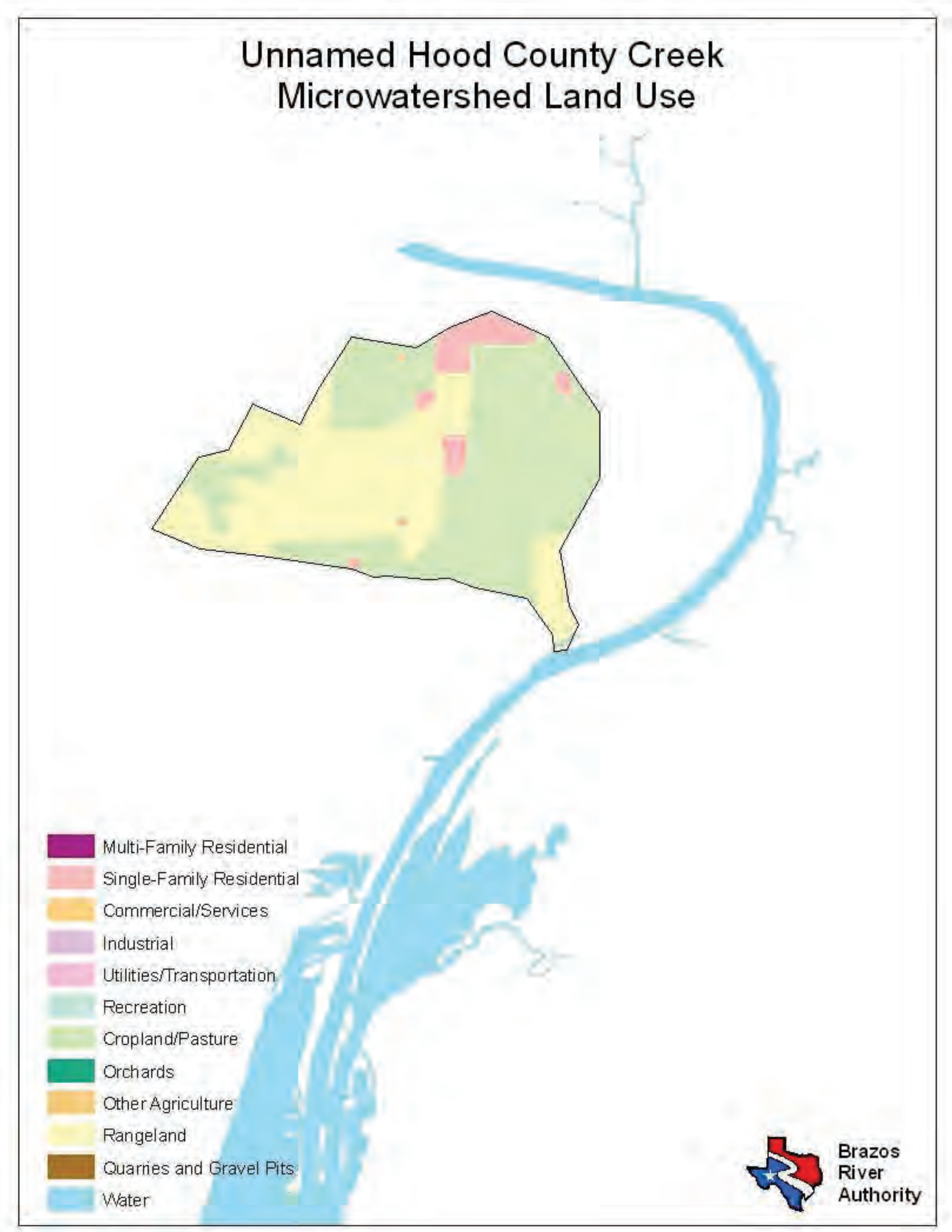
Land Use	Percent by Microwatershed
Single Family Residential	25%
Cropland/Pasture	13%
Other Agriculture	<1%
Rangeland	62%
Water	<1%



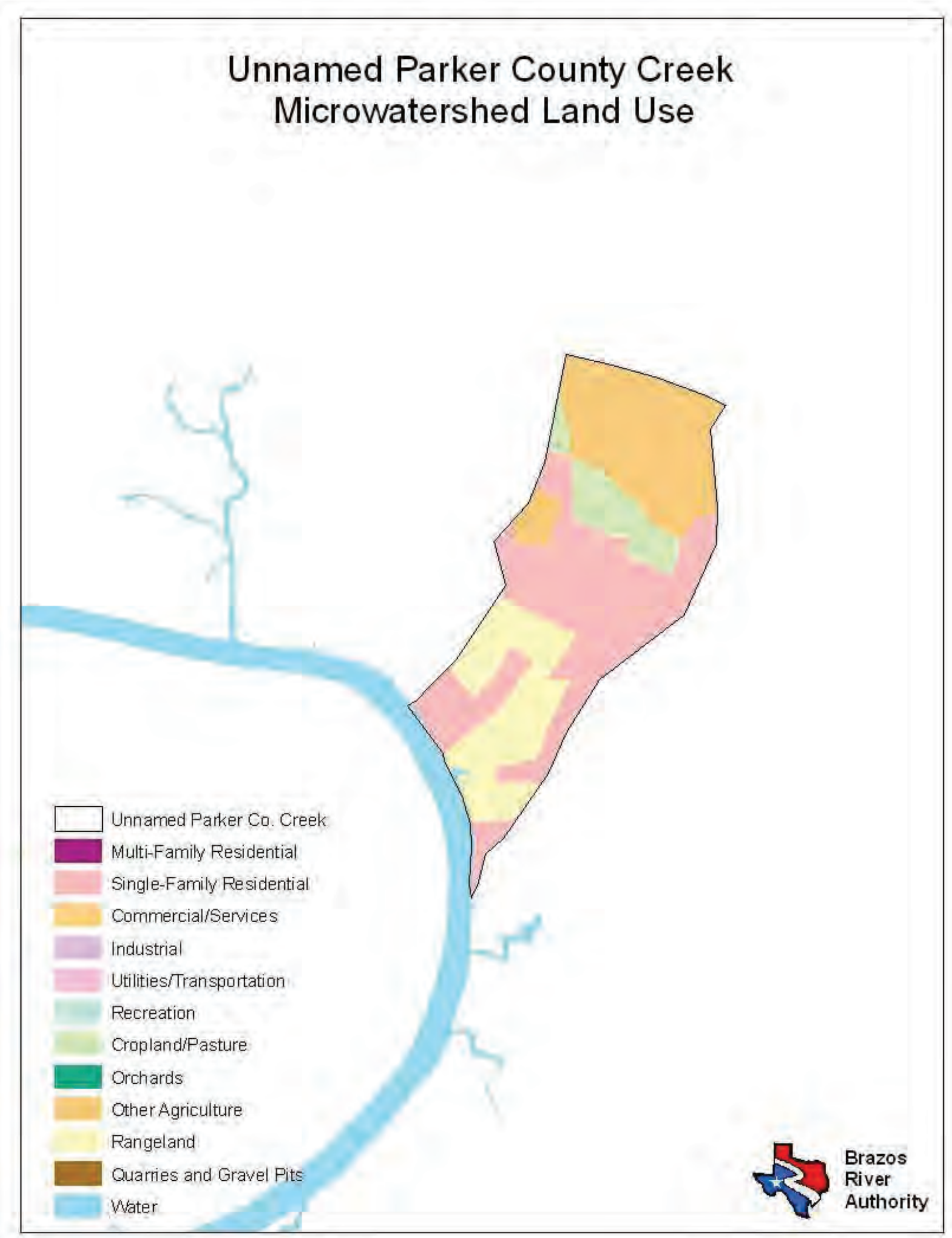
Land Use	Percent by Microwatershed
Single Family Residential	20%
Utilities/Transportation	1%
Cropland/Pasture	50%
Rangeland	29%
Water	<1%



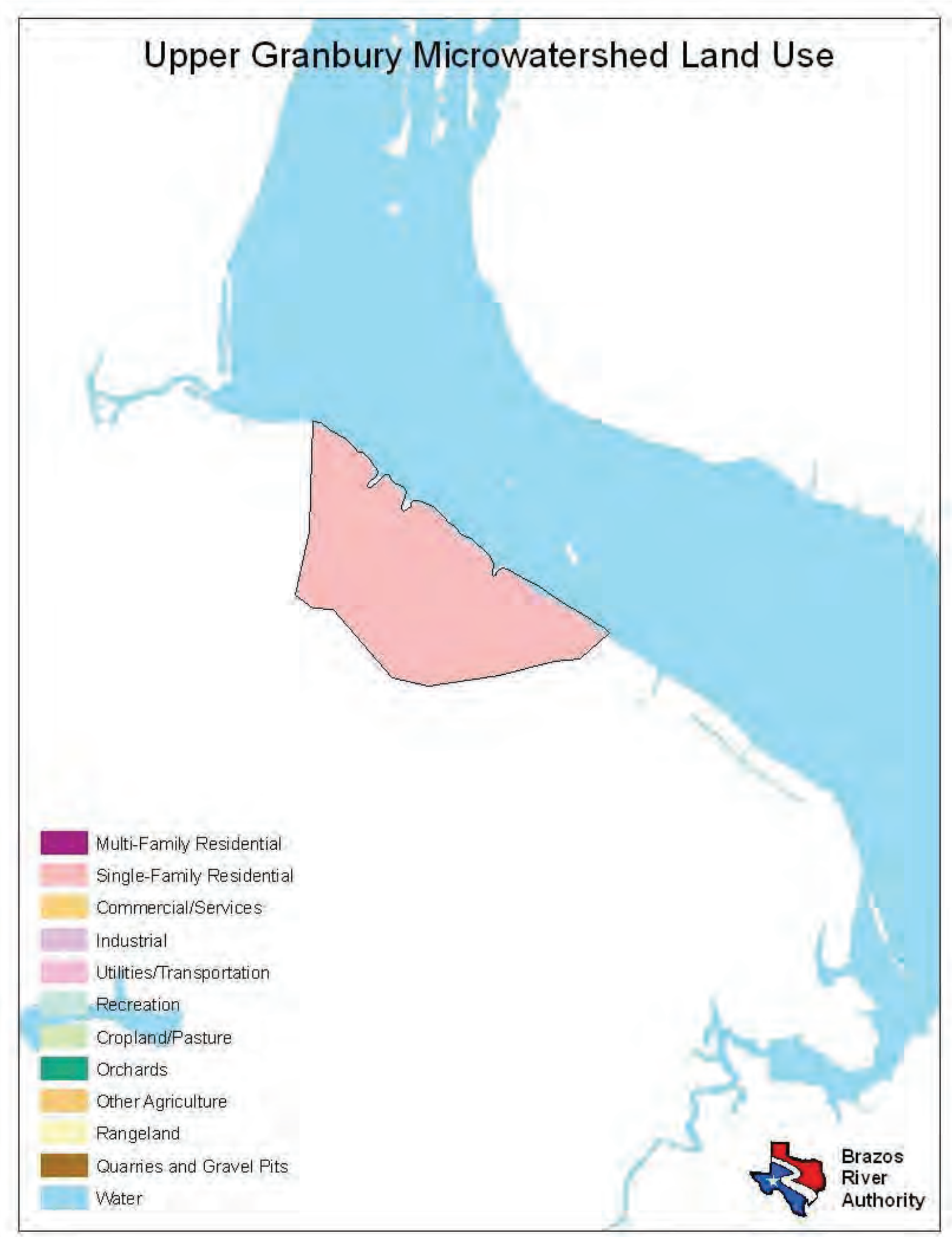
Land Use	Percent by Microwatershed
Single Family Residential	5%
Cropland/Pasture	48%
Orchards	12%
Rangeland	34%
Water	<1%



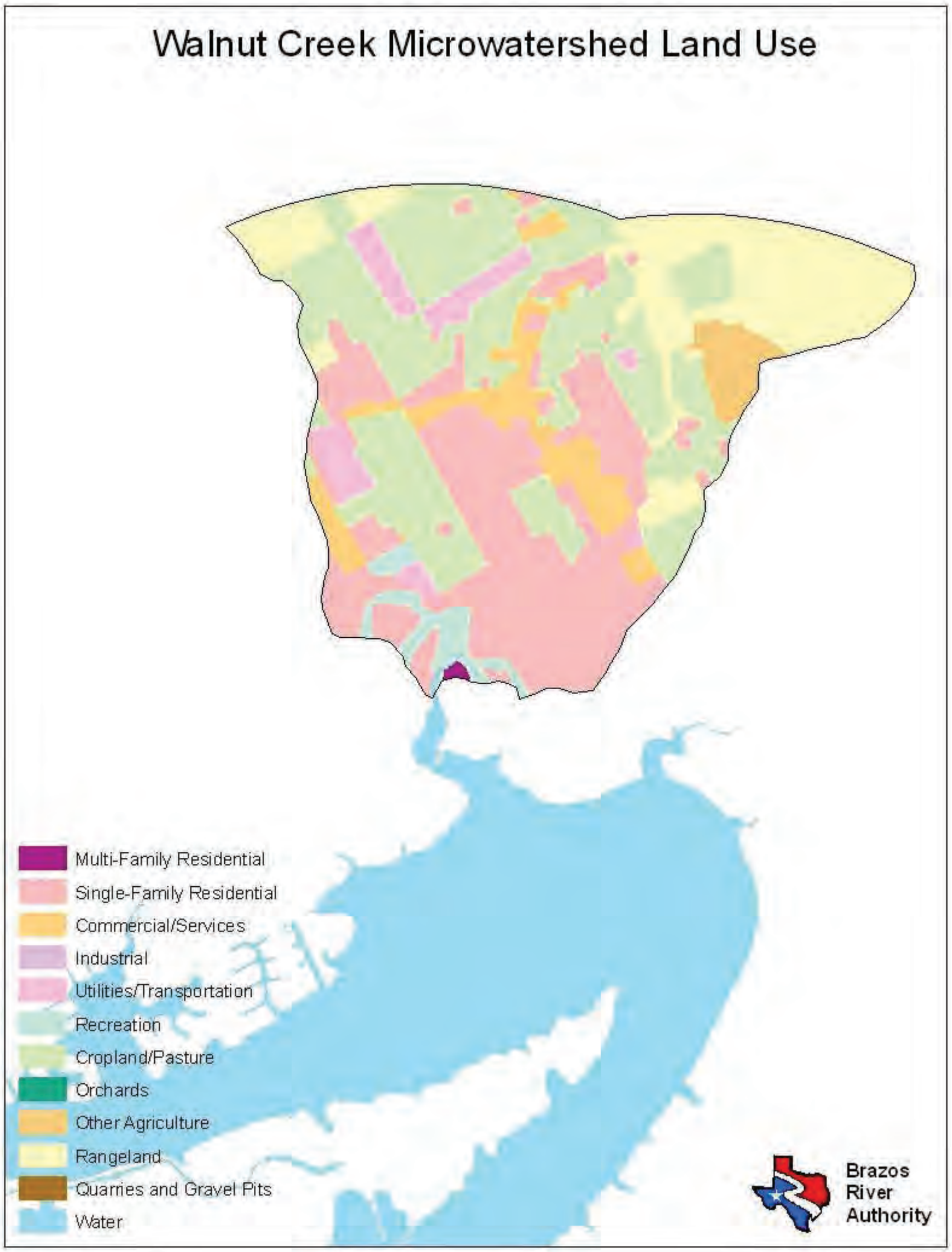
Land Use	Percent by Microwatershed
Single Family Residential	5%
Cropland/Pasture	53%
Rangeland	40%
Water	<1%



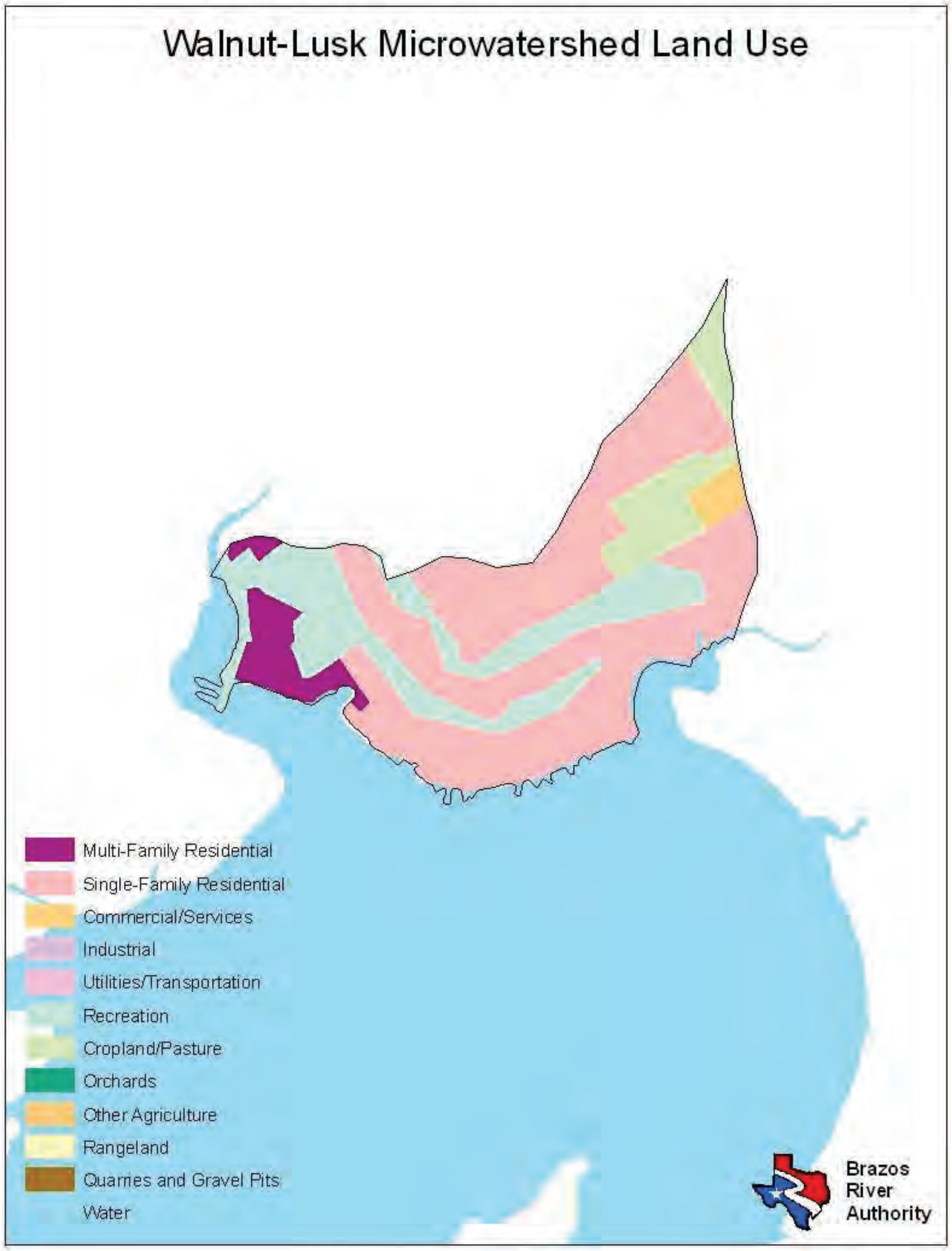
Land Use	Percent by Microwatershed
Single Family Residential	43%
Cropland/Pasture	8%
Other Agriculture	28%
Rangeland	20%
Water	<1%



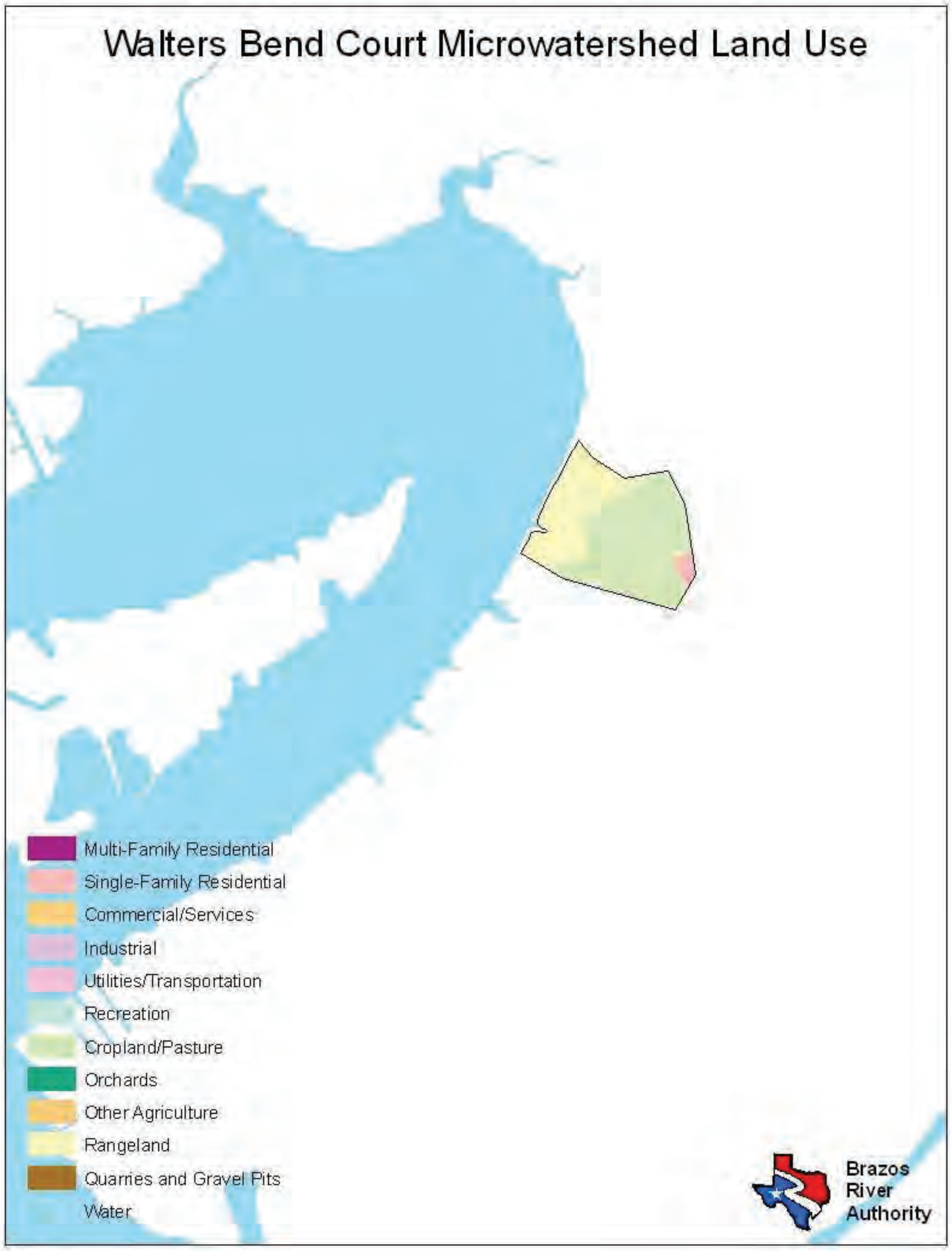
Land Use	Percent by Microwatershed
Single Family Residential	98%
Water	2%



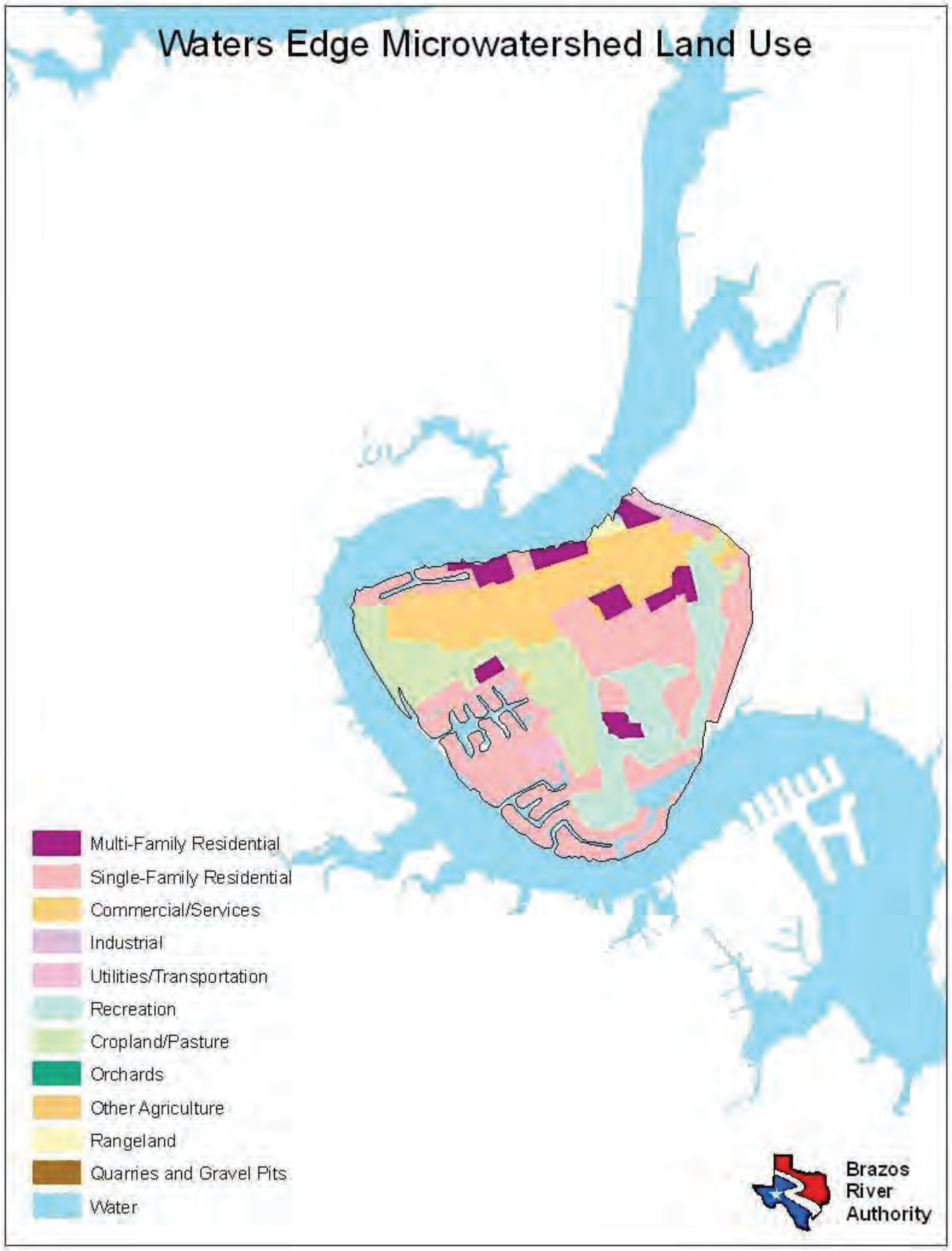
Land Use	Percent by Microwatershed
Multi-Family Residential	<1%
Single Family Residential	33%
Commercial/Services	8%
Utilities/Transportation	5%
Recreation	3%
Cropland/Pasture	34%
Rangeland	18%
Water	<1%



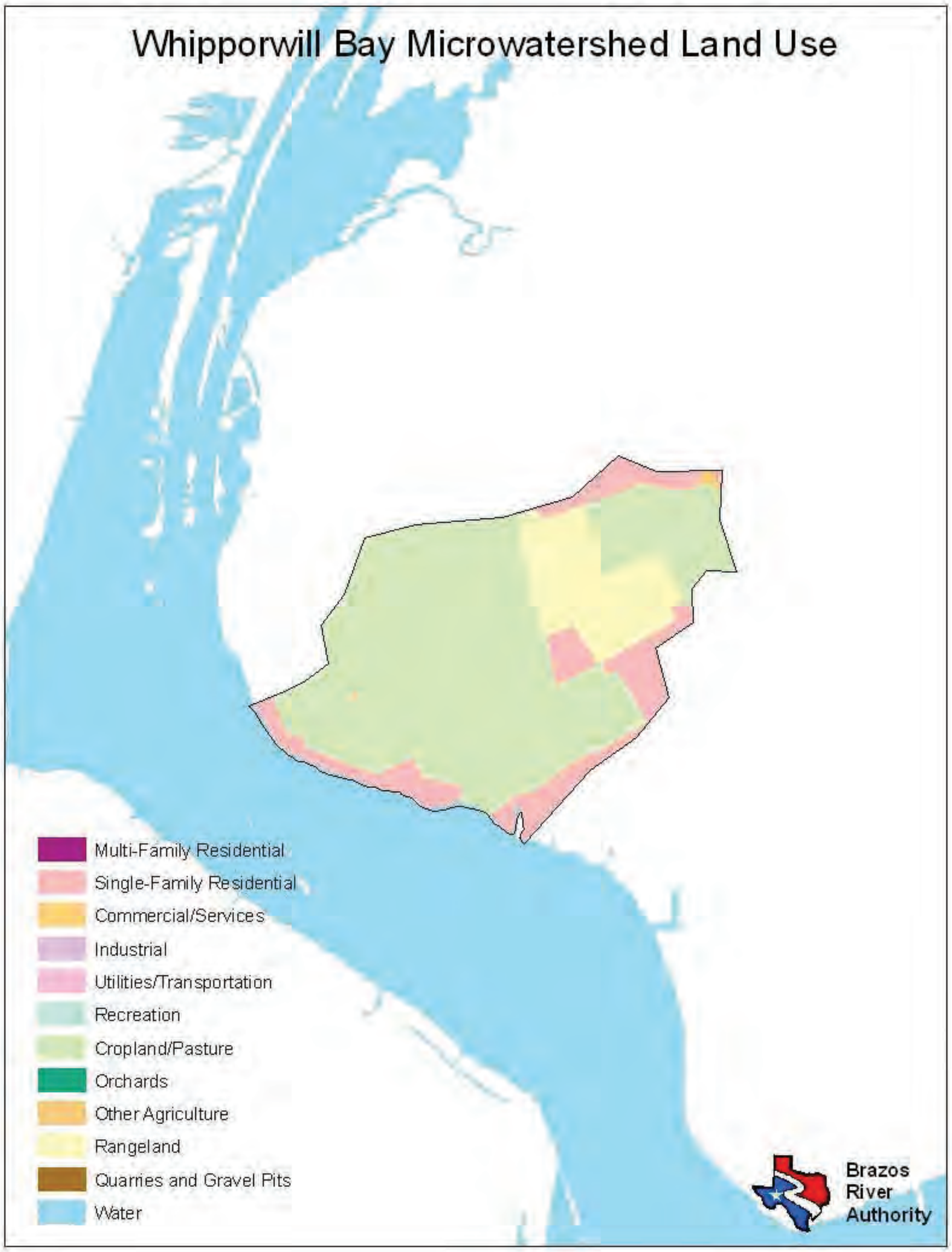
Land Use	Percent by Microwatershed
Multi-Family Residential	6%
Single Family Residential	59%
Commercial/Services	2%
Recreation	22%
Cropland/Pasture	8%
Water	2%



Land Use	Percent by Microwatershed
Single Family Residential	4%
Cropland/Pasture	62%
Rangeland	35%



Land Use	Percent by Microwatershed
Multi-Family Residential	6%
Single Family Residential	39%
Commercial/Services	20%
Utilities/Transportation	2%
Recreation	14%
Cropland/Pasture	15%
Rangeland	<1%
Water	4%



Land Use	Percent by Microwatershed
Single Family Residential	16%
Commercial/Services	<1%
Cropland/Pasture	69%
Rangeland	14%
Water	<1%

C.0 APPENDIX C: DATA COLLECTION

C.1 Dye circulation/dispersion studies

Espey Consultants, Inc. (EC) performed a circulation study February 18 through 22, 2008. The purpose of the circulation study is to develop field data from which to calculate dispersion coefficients in tested coves. The circulation study was performed by releasing predetermined volumes of 20% solution of Rhodamine WT (RWT 20%) dye in several canal systems within Lake Granbury.

The specific cove systems characterized by this field test were Oak Trail Shores, Rolling Hills Shores, Sky Harbor, Port Ridglea East, Waters Edge, Indian Harbor, and Ports O' Call subdivisions. Each canal system was revisited multiple times to measure the concentration of the dye using a Turner Designs 10-AU fluorometer with flow through cell and pump. The pump intake was located 1.0 – 1.5 feet below the water surface, and the pump discharge was located on the opposite side of the boat.

Circulation patterns, and therefore circulation studies, are sensitive to wind, flow and lake recreation in the study area. Inflows to and outflows from the lake were relatively low and decreasing during the period of the study (60 to 120 cfs). A temporary wind station was set up to collect wind data on-site during the study. Boat traffic inside the canals can potentially impact circulation dye studies, but boat traffic was negligible. Three boaters were spotted throughout the entire study period with only one boat spotted in a canal. Disruption due to survey boat velocity was minimized by traveling at low velocity with a small trolling motor to reduce the impact of data collection on the natural water circulation.

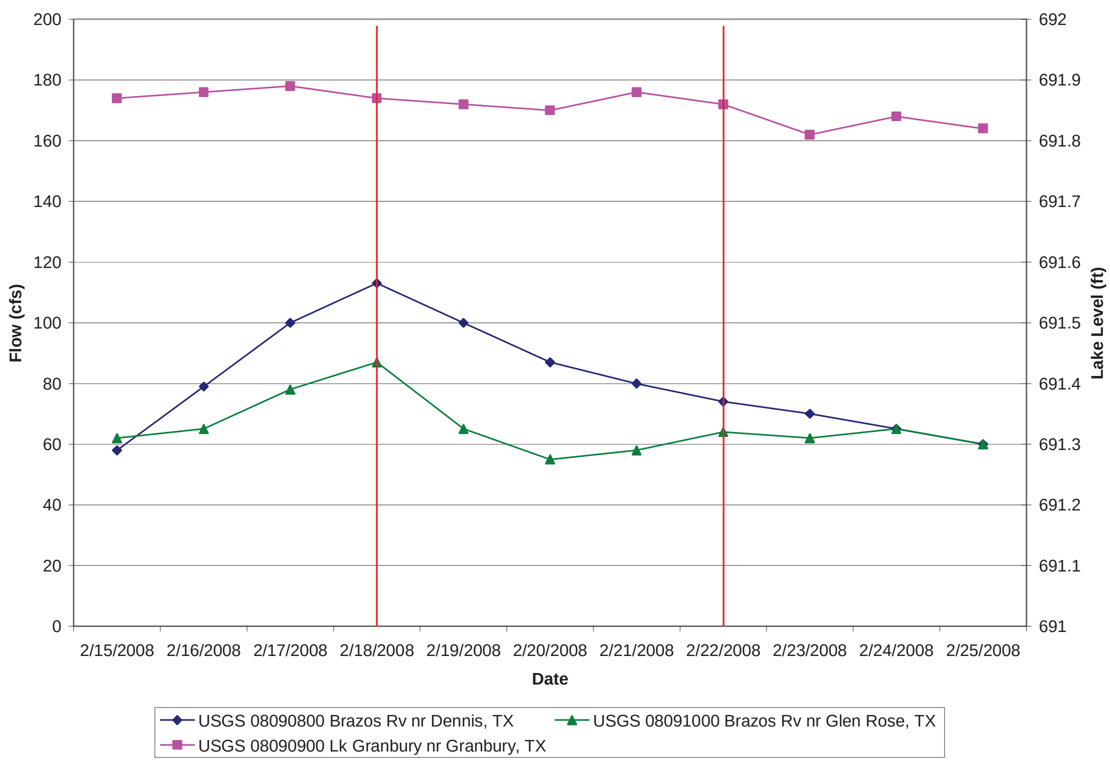


Figure C.1Stream Flow

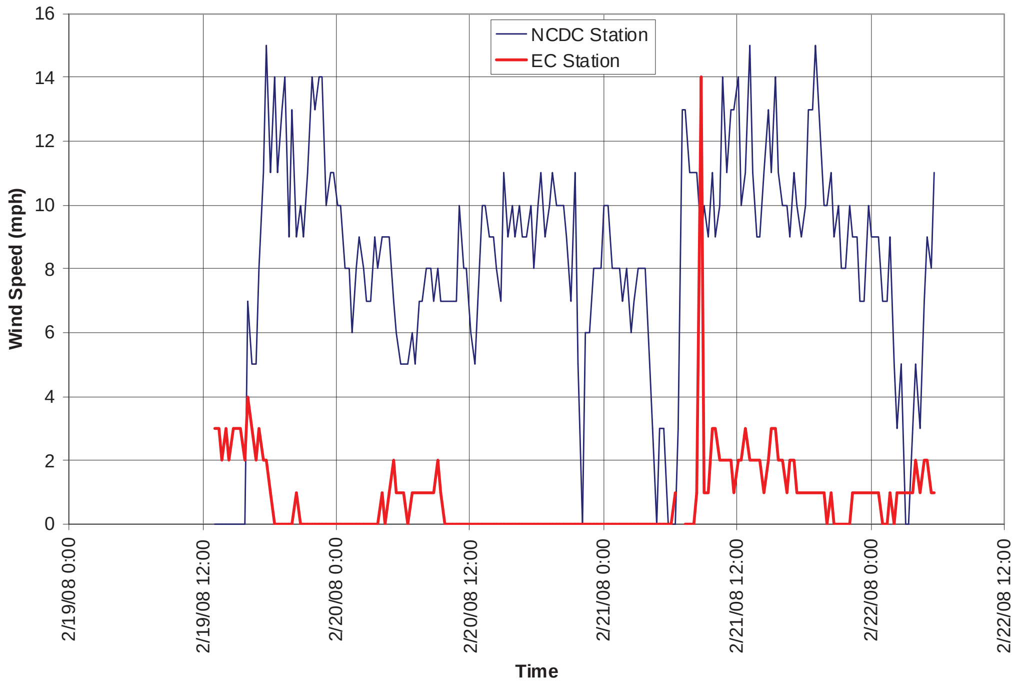


Figure C.2 EC weather station wind data and NCDC wind data comparison

Figure C.3 Weather station

C.1.1 Circulation: Oak Trail Shores

Figure C.4 and Figure C.5 RWT 20% released in canal

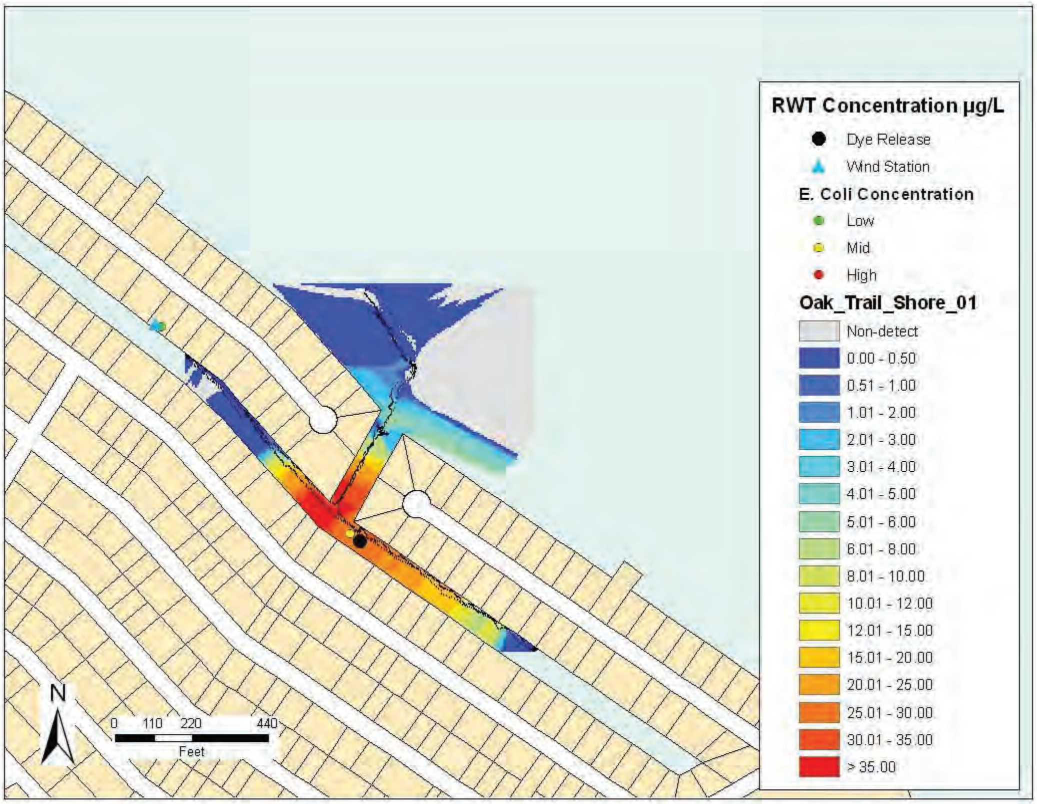


Figure C.6 Oak Trail Shores 02-19-2008 16:26 – 17:19, Hours since dye release: 3

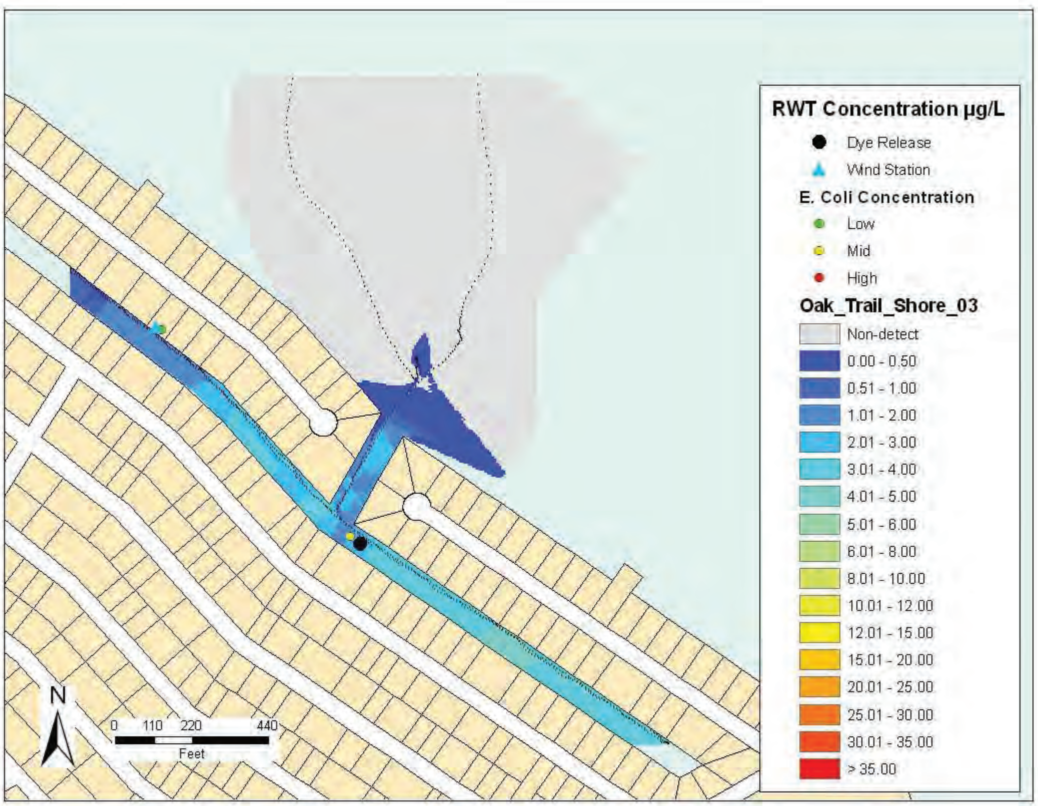


Figure C.7 Oak Trail Shores 02-20-2008 16:15 – 17:30, Hours since dye release: 27

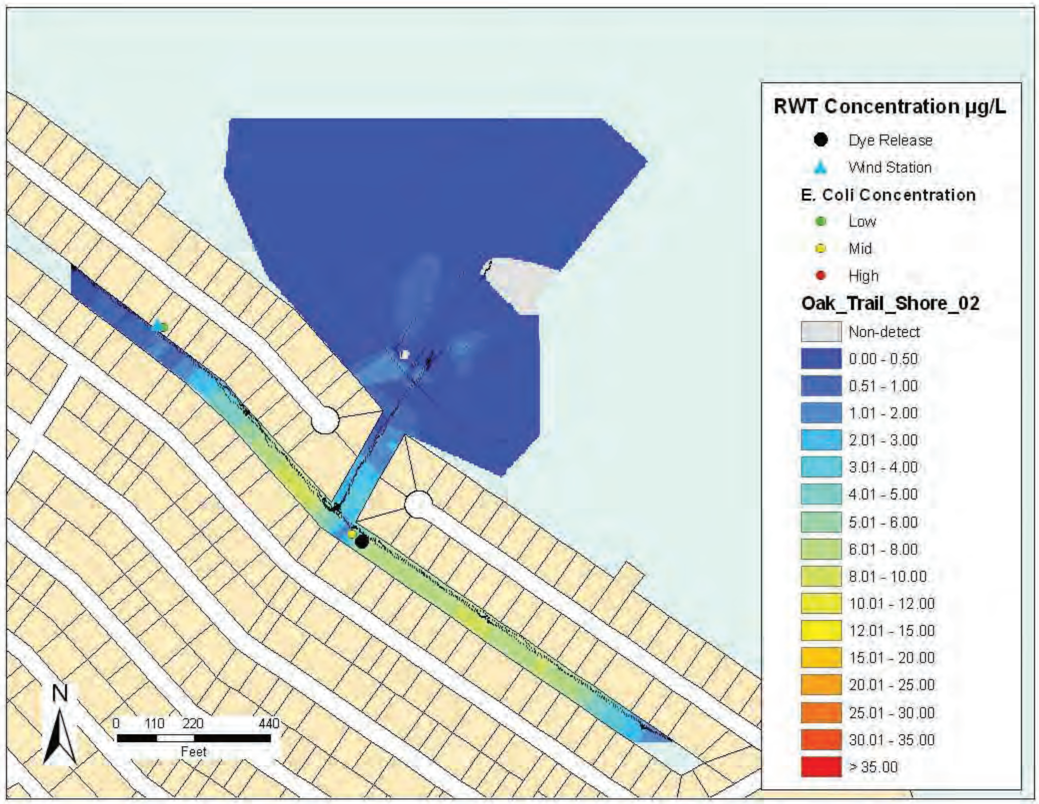


Figure C.8 Oak Trail Shores 02-22-2008 13:48 – 14:19, Hours since dye release: 72

C.1.2 Circulation: Sky Harbor


Figure C.9 and Figure 2.C.10 RWT 20% dye release at Sky Harbor

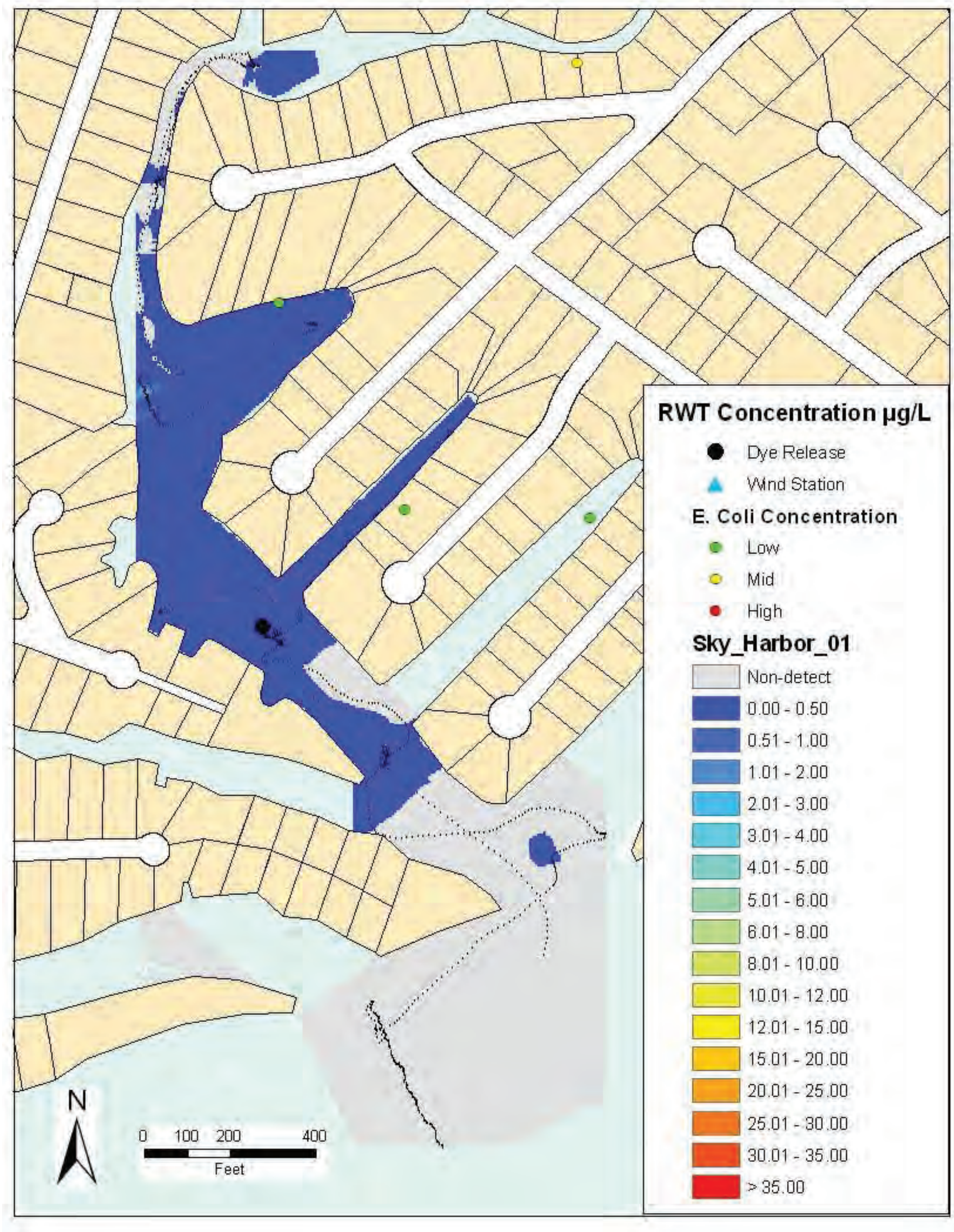


Figure C.11 Sky Harbor 02-20-2008 07:43 – 08:37 Hours since release: 16

C.1.3 Circulation: Port Ridglea East

Figure C.12 RWT 20% dye release at Port Ridglea East

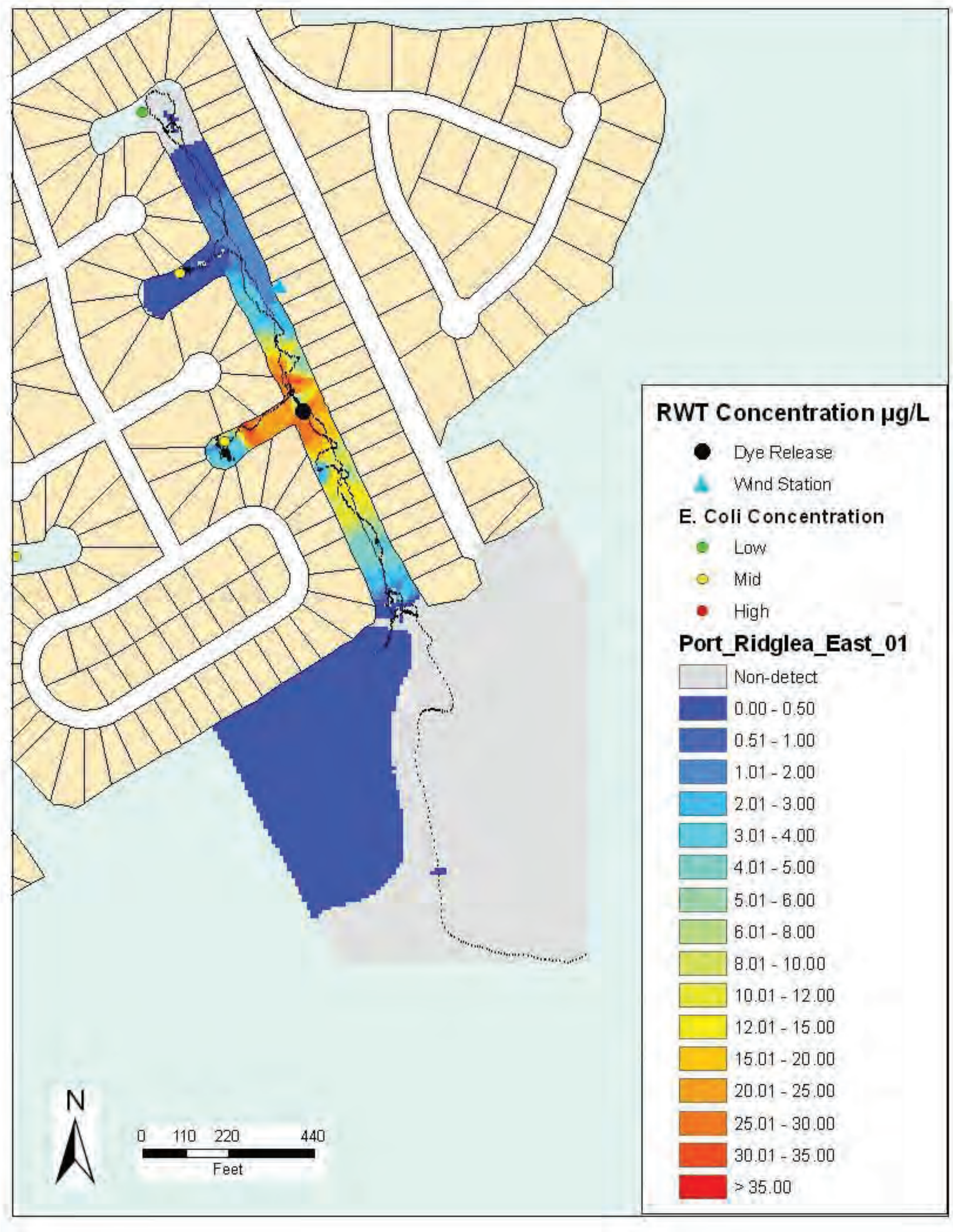


Figure C.13 Port Ridglea East 02-21-2008 14:13 – 15:22, Hours since dye release: 3

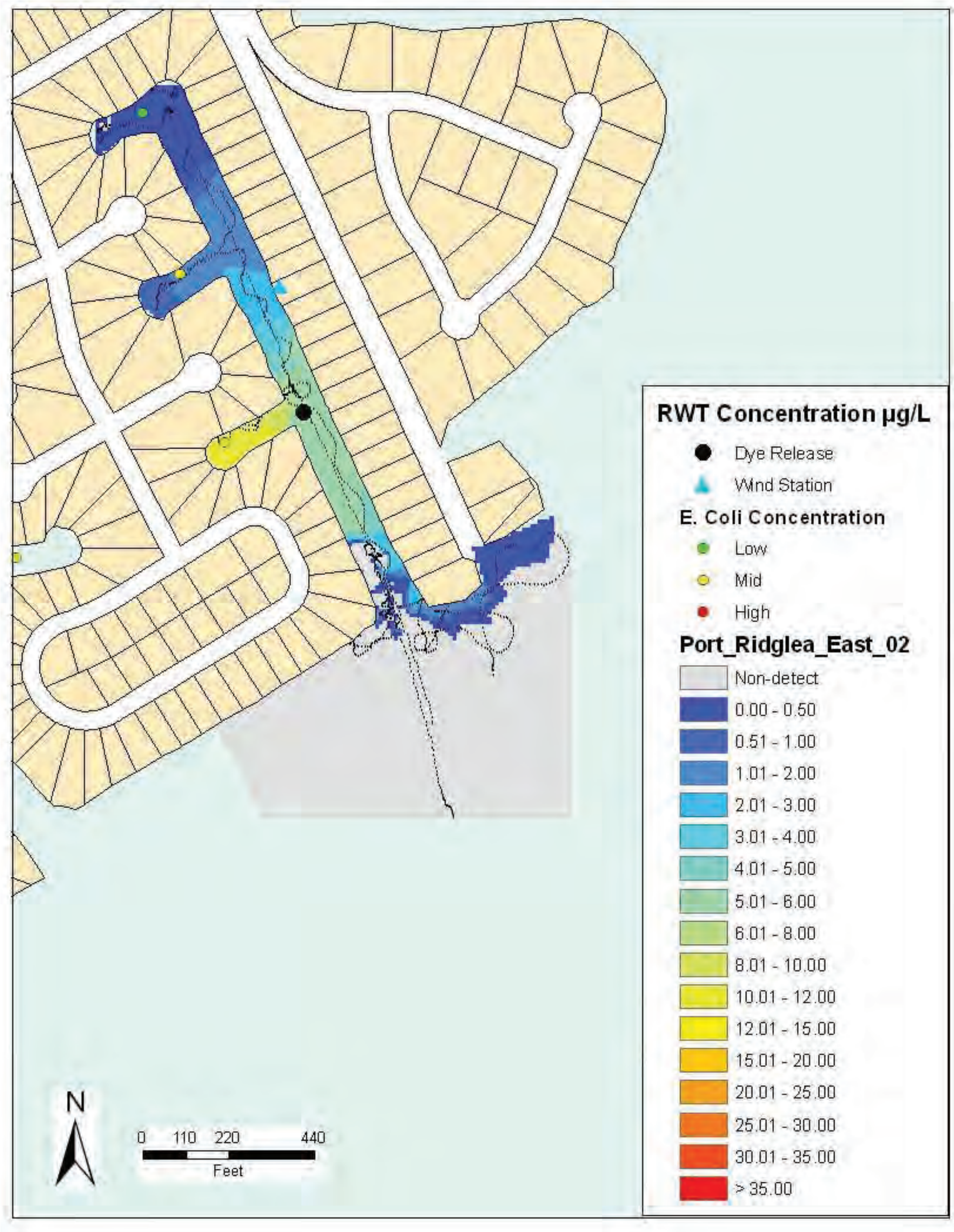


Figure C.14 Port Ridglea East 02-22-2008 09:16 – 10:15, Hours since dye release: 22

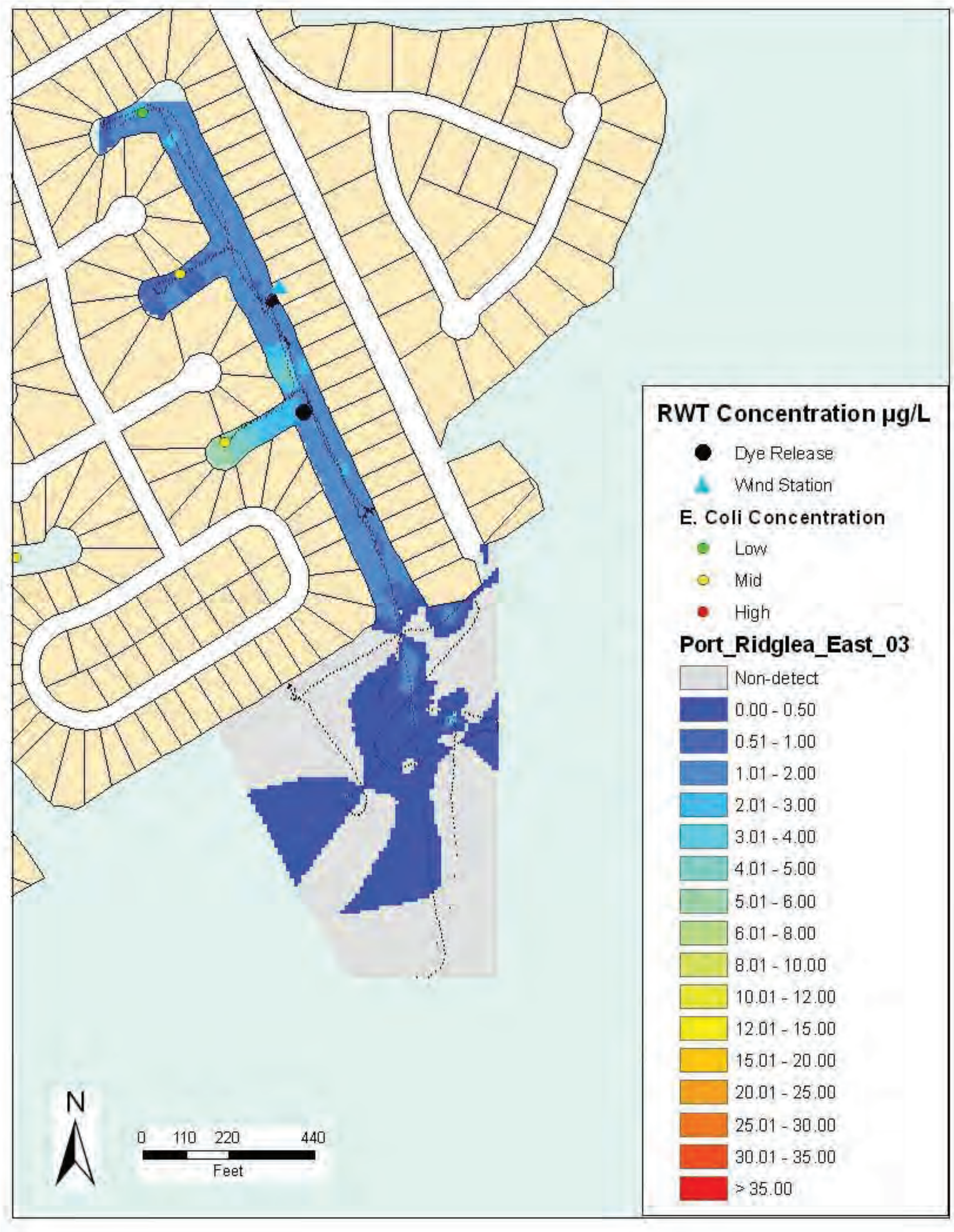


Figure C.15 Port Ridglea East 02-22-2008 16:53 – 17:51, Hours since dye release: 30

C.1.4 Circulation: Waters Edge

Figure C.16 and Figure C.17 RWT 20% dye release at Water's Edge

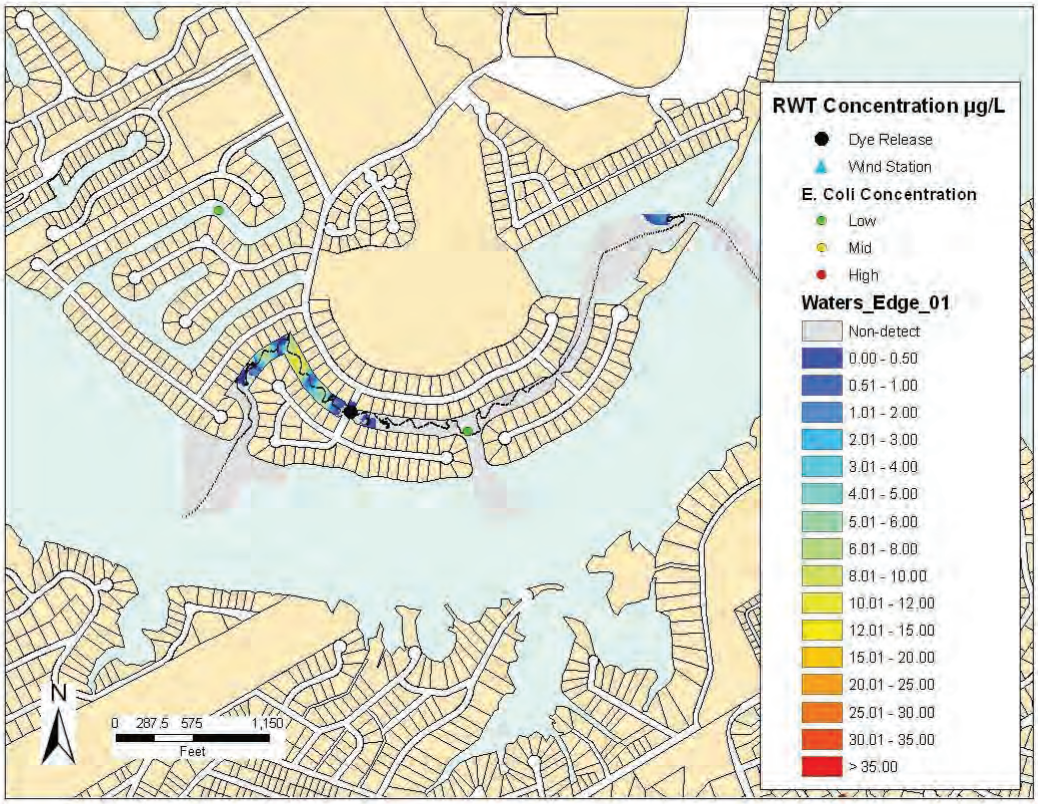


Figure C.18 Waters Edge 02-21-2008 16:54 – 18:03, Hours since dye release: 4

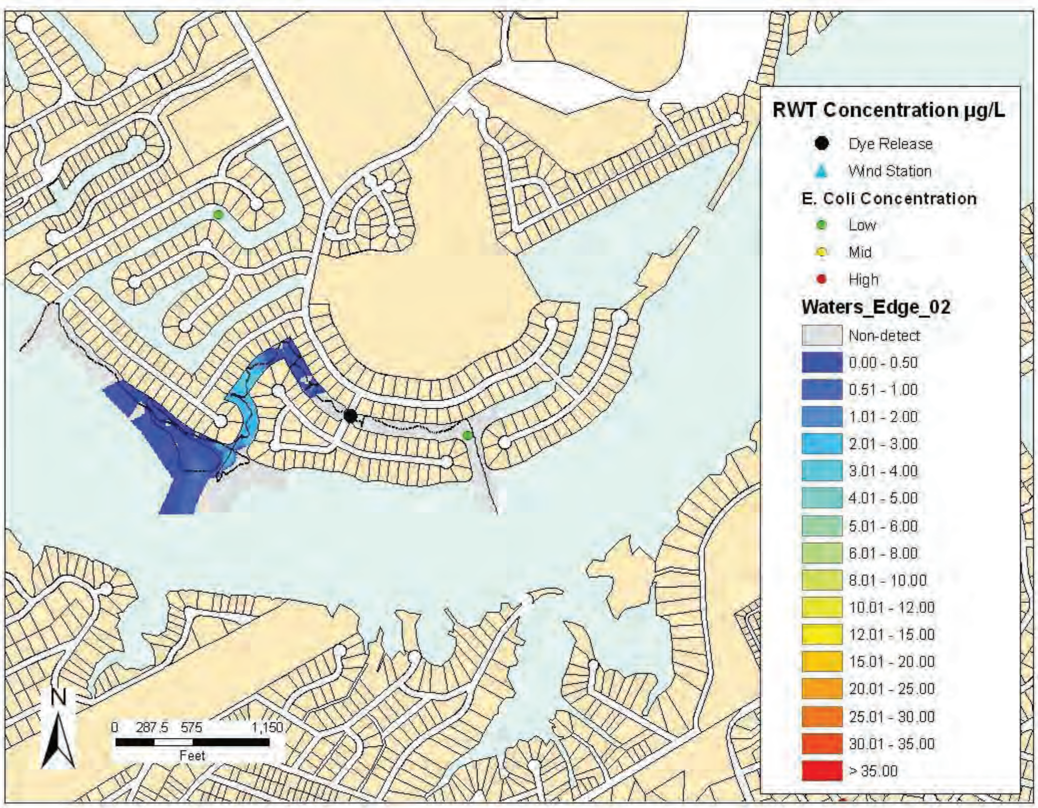


Figure C.19 Waters Edge 02-22-2008 12:07 – 13:13, Hours since dye release: 23

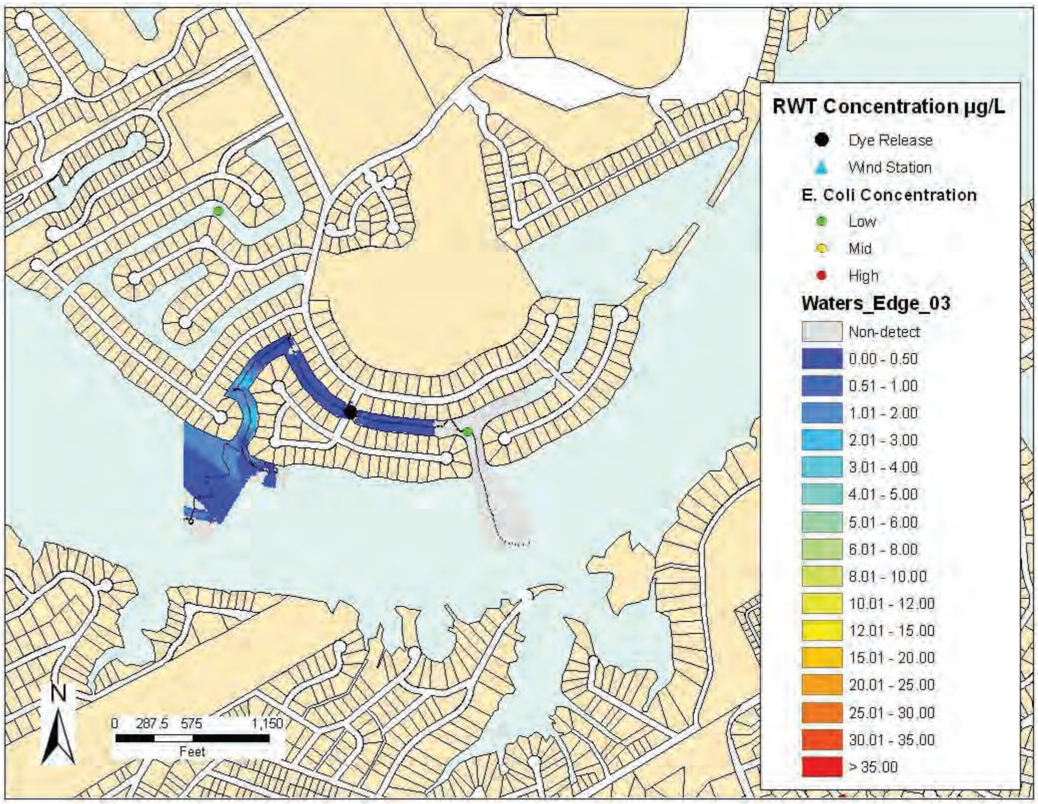


Figure C.20 Waters Edge 02-22-2008 15:23 – 15:47, Hours since dye release: 26

C.1.5 Circulation: Ports O' Call

Figure C.21 and Figure C.22 RWT 20% dye release at Ports O Call

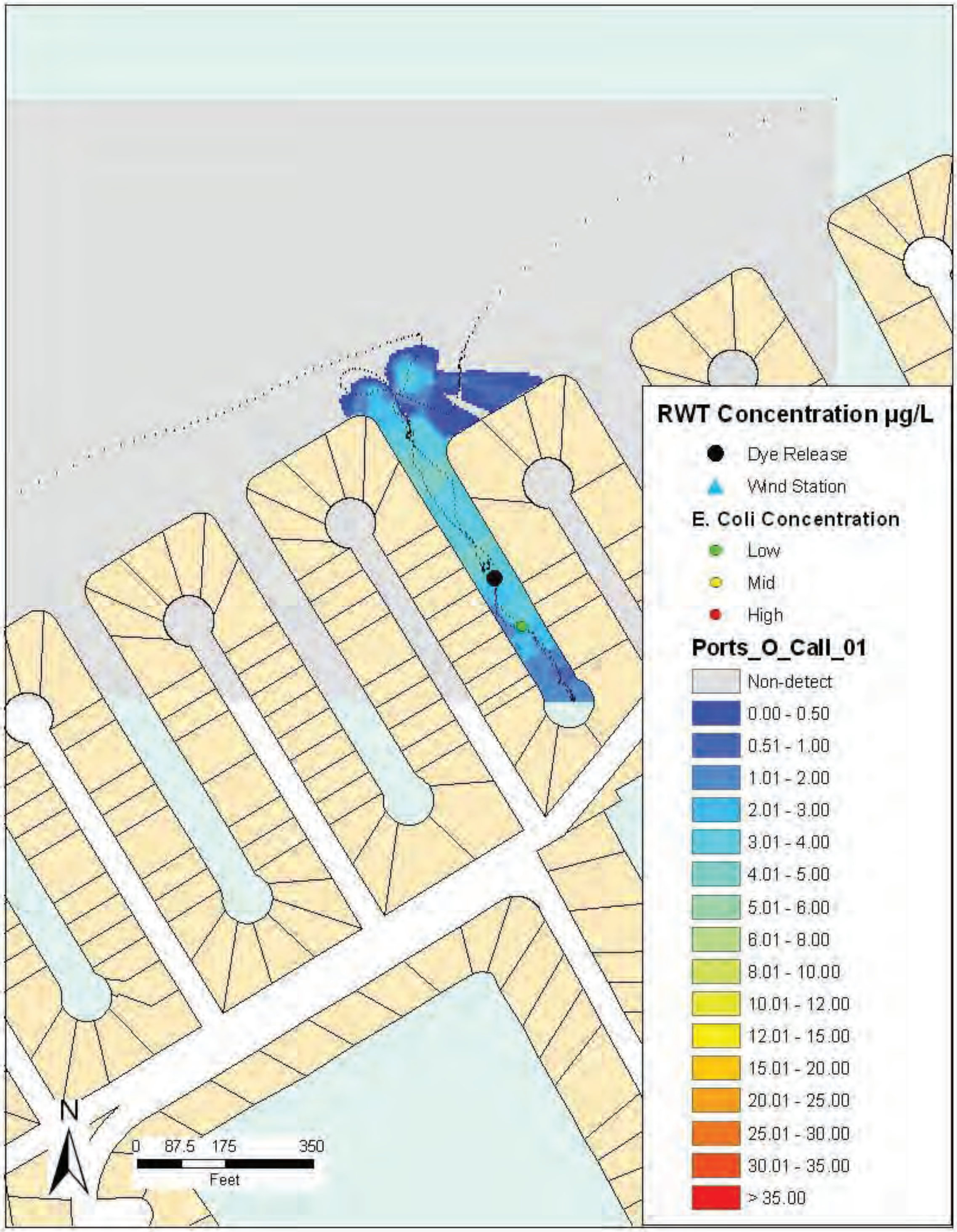


Figure C.23 Ports O Call 02-21-2008 16:29 – 16:46, Hours since dye release: 4

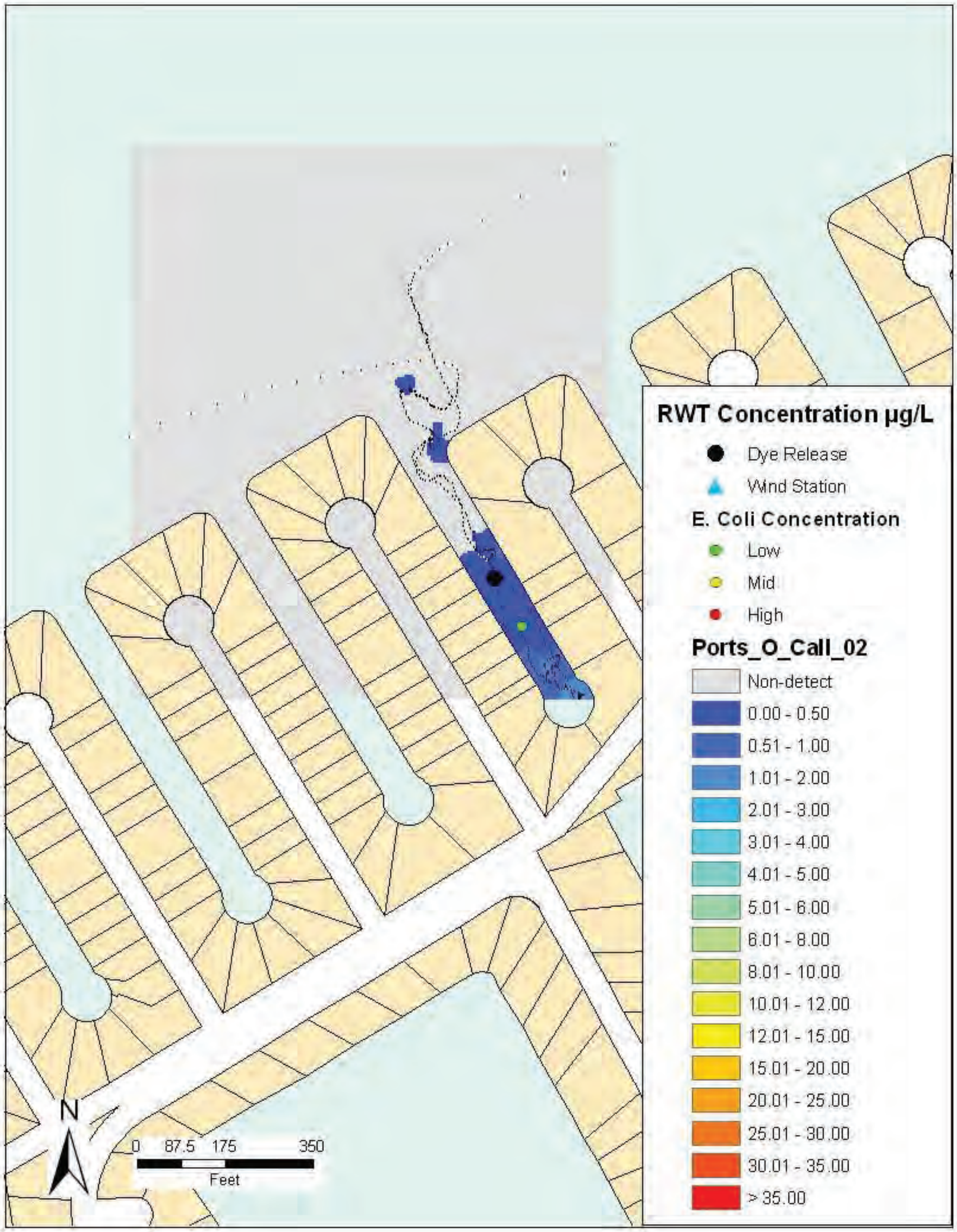


Figure C.24 Ports O Call 02-22-2008 11:42 – 12:01, Hours since dye release: 23

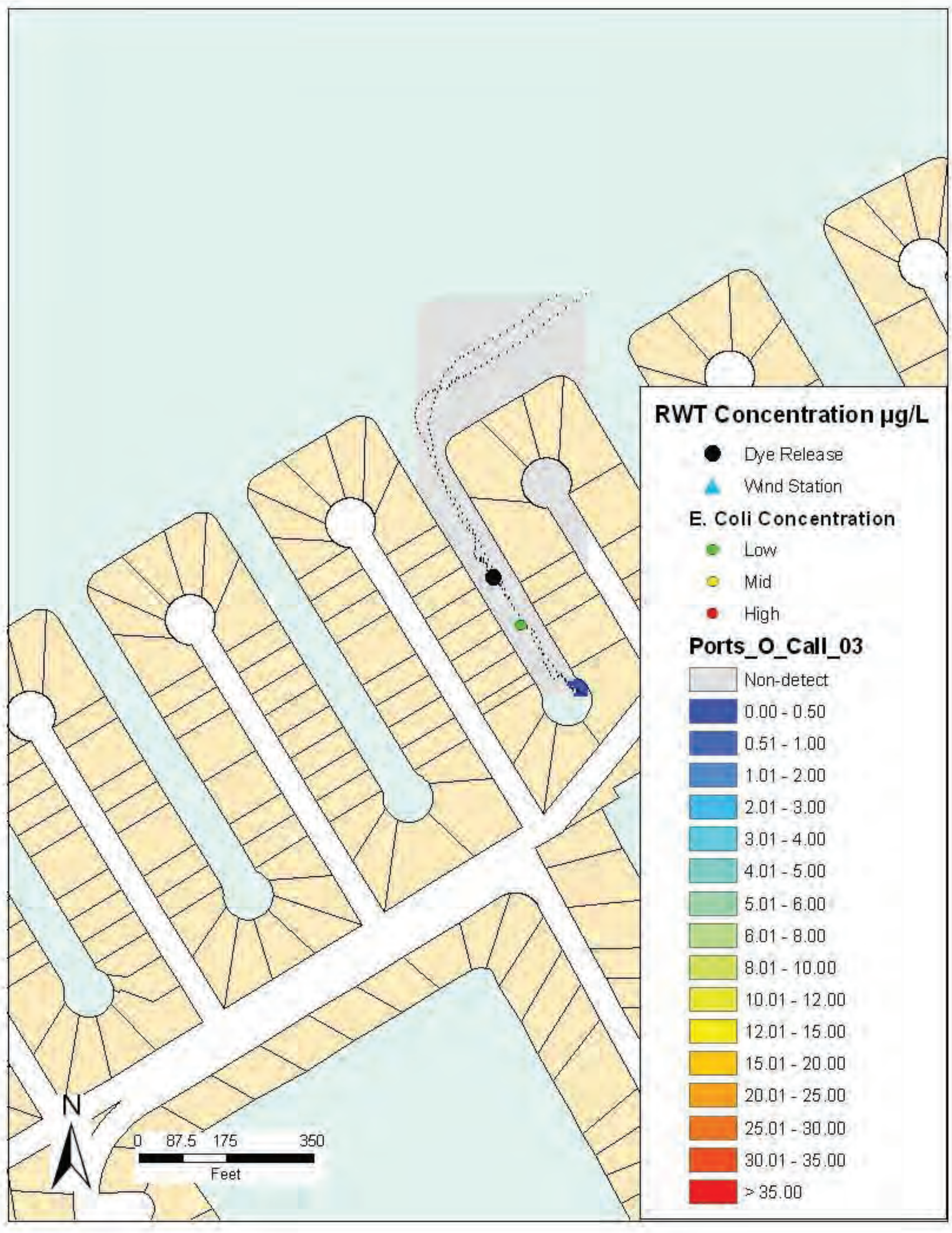


Figure C.25 Ports O Call 02-22-2008 16:02 – 16:10, Hours since dye release: 28

C.1.6 Circulation: Indian Harbor (lagoon)


Figure C.26 and Figure C.27 RWT 20% dye release at Indian Harbor

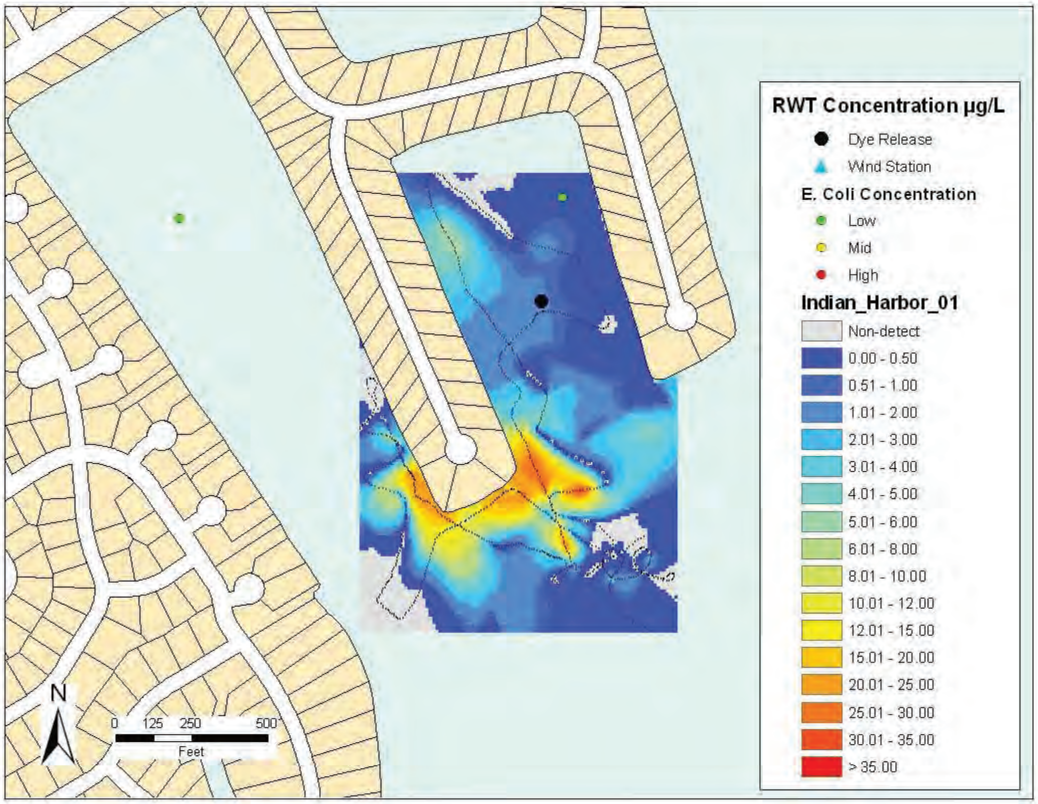


Figure C.28 Indian Harbor 02-21-2008 15:56 – 16:22, Hours since dye release: 4

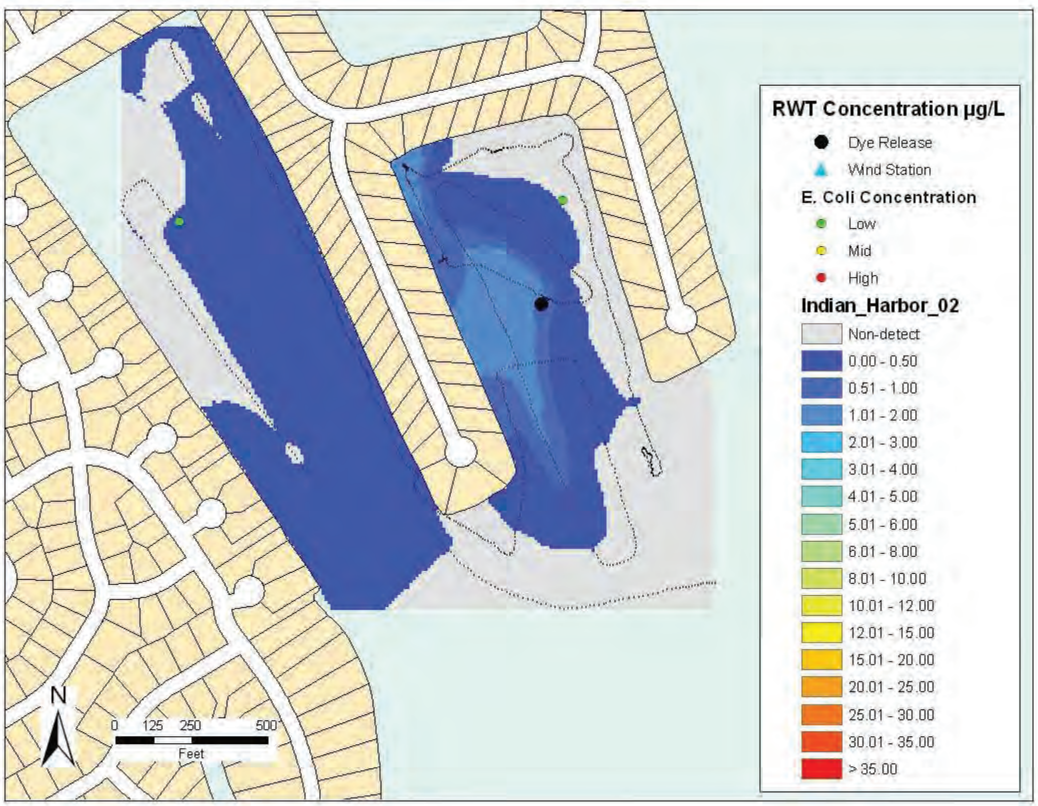


Figure C.29 Indian Harbor 02-22-2008 10:29 – 11:34, Hours since dye release: 23

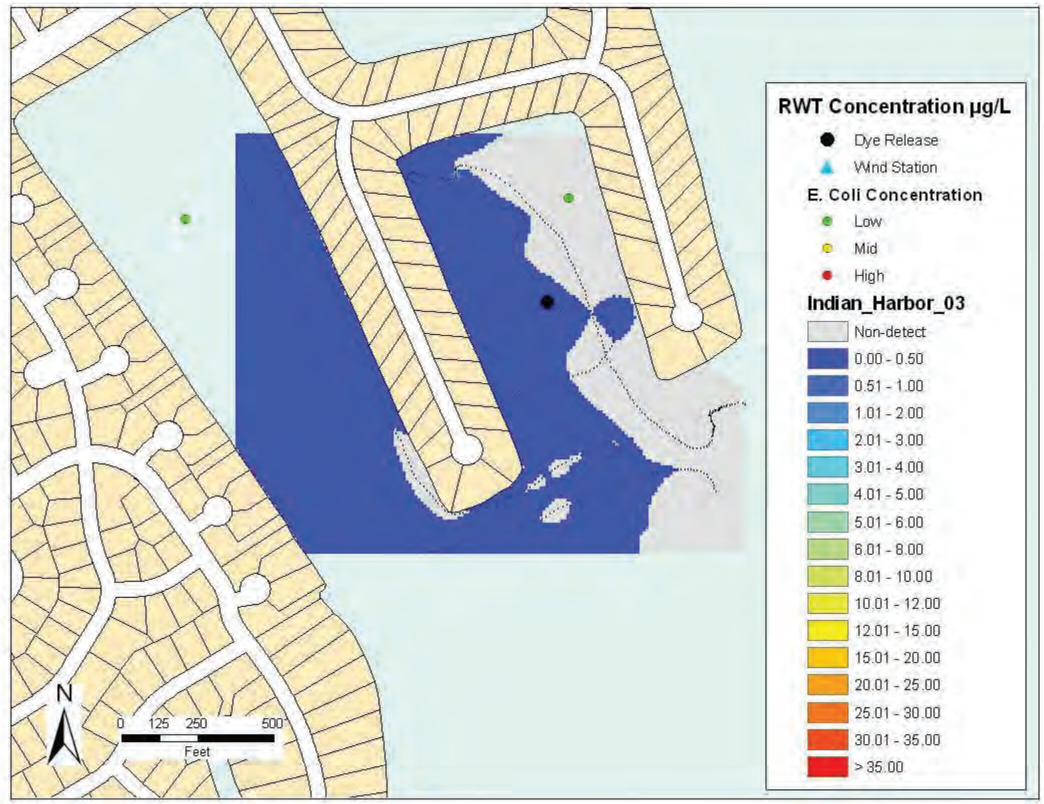


Figure C.30 Indian Harbor 02-22-2008 16:22 – 16:46, Hours since dye release: 28

C.1.7 Circulation: Rolling Hills Shore

EC attempted to access Rolling Hills Shores canal system via boat on February 19, 2008. However, the channel into the canal was too shallow for entry. Due to the inaccessibility of the site, a circulation study was not conducted.

C.1.8 Circulation: Summary

Ward (1985) performed a dye study for Texas bays, and methods used for that study were adopted to calculate the dispersion coefficients for Lake Granbury. The calculated dispersion coefficients are listed in Table C-1. The parameters for unvisited canals were estimated according to canals with similar conditions where data was available.

Table C-1. Calculated Dispersion coefficients

Subdivision	Dispersion Coefficients (m2/s)
Indian Harbor	0.02
Oak Trail Shores	0.1
Port Ridglea East	0.125
Ports O' Call	0.09
Sky Harbor	0.18
Waters Edge	0.08

C.2 Septic system leakage dye study

Table C-2 Breakdown of contacts for septic study

Subdivision	Letters	Subdivision	Phone Calls
Oak Trail Shores	161	Oak Trail Shores	85
Rolling Hills Shores	78	Rolling Hills Shores	52
Port Ridglea	238	Port Ridglea	167
Sky Harbor	313	Sky Harbor	237
Total	790	Total	541

The number of responses, including both willing and non-willing participants, as well as the number of residents actually visited in each subdivision are listed in Table C-3. These are also illustrated in Figure C.31to Figure C.34for all four subdivisions.

Table C-3 Residents Responses for septic study

Subdivision	Responses		Actually Visited
	Yes	No	
Oak Trail Shores	5	14	3
Rolling Hills Shores	1	6	0
Port Ridglea	35	24	PRE 18/ PRW 8
Sky Harbor	34	16	15
Total	75	60	44
	135		

Figure C.31Septic Study statistics in Oak Trail Shores

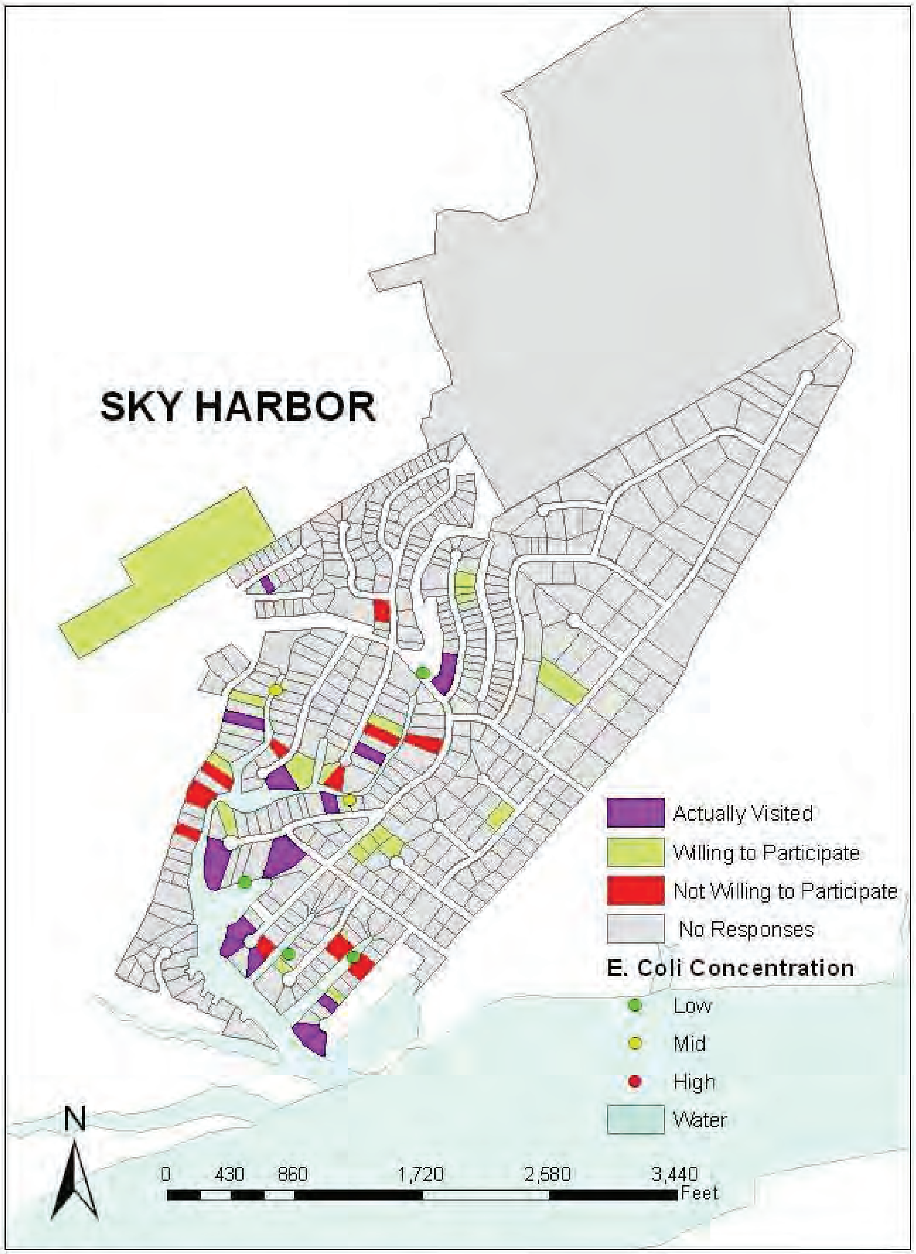


Figure C.32 Septic Study statistics in Sky Harbor

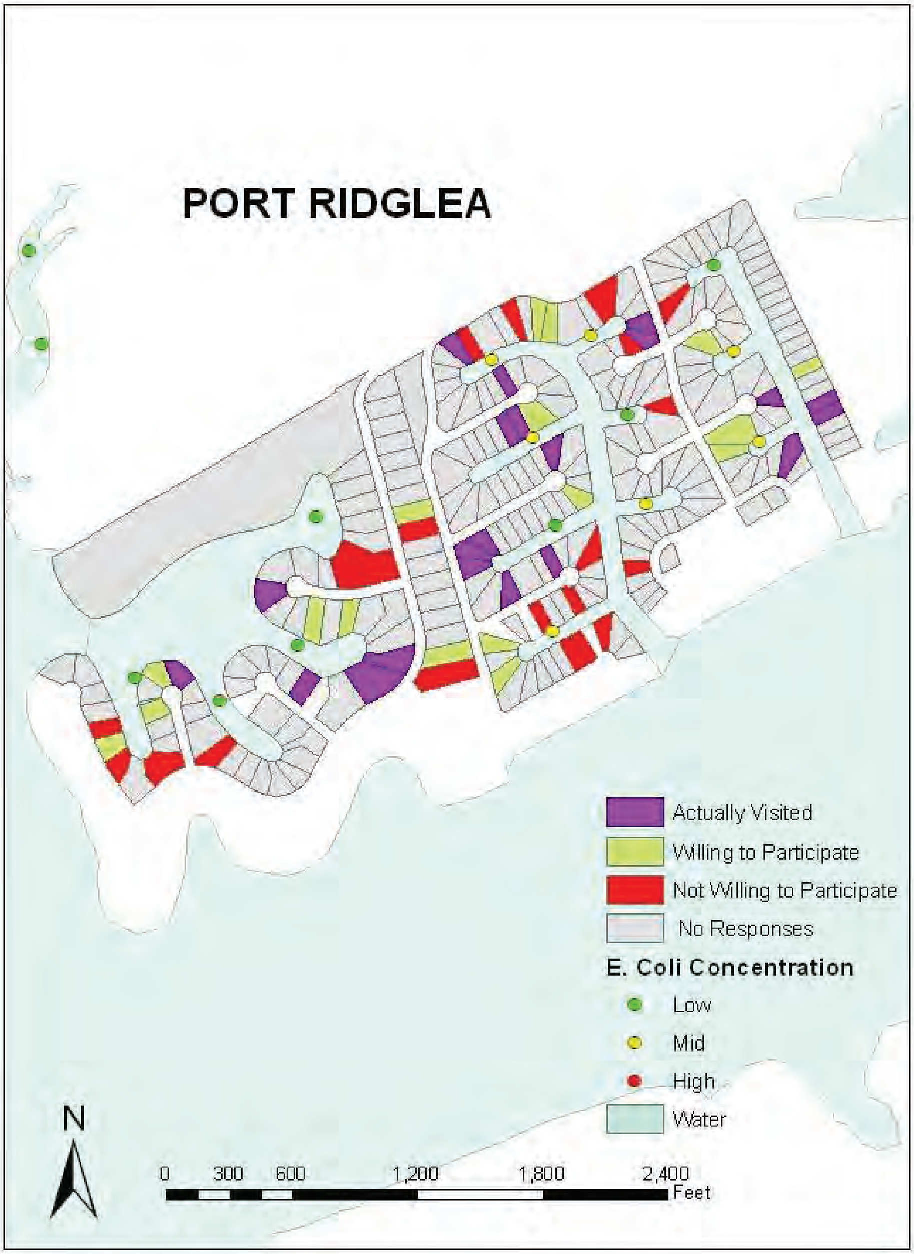


Figure C.33 Septic Study statistics in Port Ridglea

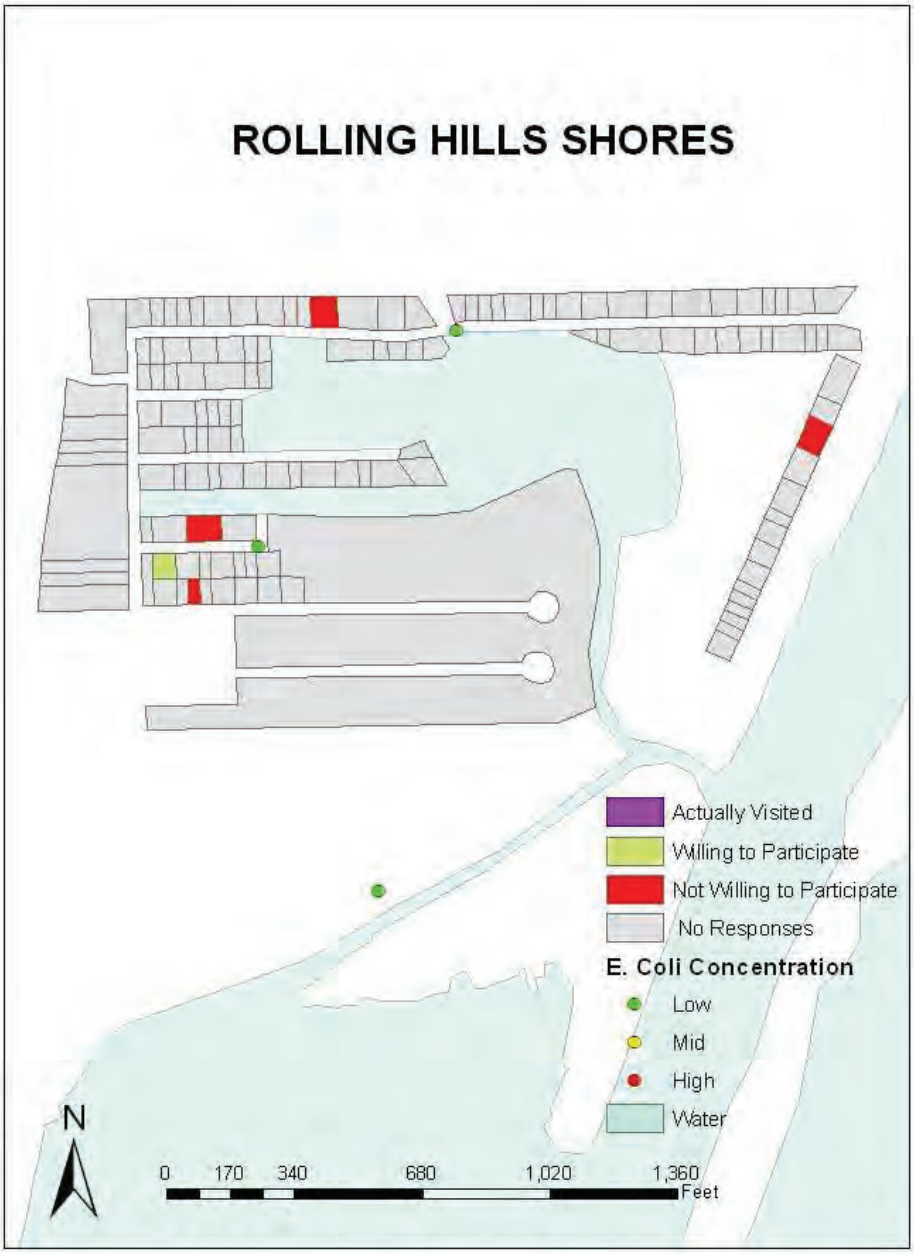


Figure C.34 Septic Study statistics in Rolling Hills Shores

D.0 APPENDIX D: SELECT MODEL SETUP AND RESULTS

D.1 SELECT Assumptions and Setup

SELECT estimated potential *E. coli* load resulting from cattle, deer, feral hogs, pets, malfunctioning OWTS, and Waste-Water Treatment Plants. The default fecal production rates are the highest from the range of values provided in the EPA Protocol for Developing Pathogen TMDLs (USEPA, 2001) for all *E. coli* sources in the Lake Granbury Watershed (Table D-1). Default values for *E. coli* concentrations were used for all sources except malfunctiong OWTS due to the stakeholder resolutions on raw sewage effluent. Additionally, stakeholders resolved using a Fecal coliform to E. coli conversion of 0.7 based on local data observations.

Table D-1 Calculation of *E. coli* Loads from Source Populations.

Source	Calculation
Cattle	$E.coli = \#Cattle * 10 * 10^{10}\, cfu/day * 0.7$
Deer	$E.coli = \#Deer * 3.5 * 10^{8}\, cfu/day * 0.7$
Feral Hogs	$E.coli = \#Feralhogs * 1.1 * 10^{10}\, cfu/day * 0.7$
Dogs	$E.coli = \#Households * \frac{0.8 dogs}{Household} * 5 * 10^{9}\, cfu/day * 0.7$
Malfunctioning OWTS	$E.coli = \#OWTSs * MalfunctionRate * \frac{9.554x10^{6}\, cfu}{100 mL} * \frac{200 gal}{household/day} * \frac{3785.4 mL}{gal} * 0.7 * 0.133$
WWTP	$E.coli = PermittedMGD * \frac{126 cfu}{100 mL} * \frac{10^{6}\, gal}{MGD} * \frac{3785.4 mL}{gal}$

<u>Livestock</u>

All livestock populations are determined from the 2007 National Agricultural Statistics Service (NASS) inventory on a per county basis. The cattle populations for Hood and Parker counties were 30,265 and 62,793 cattle, respectively. The cattle population was distributed uniformly on grasslands and pasture/hay since cattle graze mainly on these land uses.

<u>Wildlife</u>

SELECT attempts to account for wildlife contributions by distributing population estimates across suitable habitats as determined by consultation with wildlife experts. The first step in calculating wildlife pollutant loading is to identify the types of wildlife most likely contributing the most significant amounts of pollution and ignore the sources that only minimally contribute. This was achieved by consulting wildlife experts such as the Texas Parks and Wildlife Department (TPWD) and thorough literature review. It is also important to identify the land use classifications wildlife prefer/need for survival, along with population estimates. Many agencies such as the TPWD have published studies that address these issues. Currently, SELECT provides the option to evaluate pollutant loading of *E. coli* from deer, feral hogs, and two other generic sources.

The population density of 13.25 deer/1000 acre is estimated from the Lockwood (2000) report. This report was a study the Texas Parks and Wildlife Department (TPWD) performed to track white tail deer populations. The deer population density was determined as the average of Resource Management Unit (RMU) 22 and RMU 24 for the Lake Granbury Watershed. It was assumed that deer roam in forests and shrubland. The model also assumes the deer need continuous suitable habitat of at least 20 acres. Urban areas, as defined in the shapefile from the 2000 US Census, were removed from the suitable habitat.

A regional population density of 4 hogs/km^2 (Teague, 2007) results in an estimated feral hog population of 4,166 hogs in the entire Lake Granbury Watershed. This population was redistributed within a 100 m buffer of the streams and restricted to undeveloped land use classifications.

<u>On-site Wastewater Treatment Systems (OWTSs)</u>

Another need for bacteria load assessment is an improved understanding of when OWTSs malfunction, how much these systems contribute to contamination, and how to reasonably predict such occurrences. For evaluating the potential *E. coli* loading from malfunctioning OWTSs a new approach different from Teague (2007) was developed. Clark et al. (2001) indicated that the age of OWTS, soil condition, and vicinity to water bodies have the greatest influence on contamination due to OWTSs. Methods for developing a sewage pollution risk assessment have been developed and were used as a guideline (Kenway and Irvine, 2001). Combining this methodology for OWTS risk assessment with soil landscape mapping can assess the individual system contribution to the cumulative risk of sewage pollution (Chapman et al., 2004). The primary function of SELECT is to provide a total potential *E. coli* loading available on the land surface before fate and transport mechanisms are incorporated. Therefore, the distance component when predicting contribution from malfunctioning OWTSs is not included in the load assessment.

This method was developed based on the age of subdivisions and the OWTS absorption field limitation ratings (slight, moderate, and severe) provided with National Resource Conservation Service (NRCS) SSURGO soils data (USDA-NRCS, 2004). The user inputs the appropriate OWTS shapefile and indicates the 'fields' within the attribute table containing the number of permits and the average estimated age of the subdivision/OWTSs in each polygon. The number of systems contributing to potential is determined from the number of permitted homes on OWTSs multiplied by the expected percent malfunction. The percent malfunction is a reclassification of the OWTS suitability rating for a given area. The suitability rating is calculated as:

$$SuitabilityRating = 0.7 \times SoilRate + 0.3 \times AgeRate \quad (3.1)$$

The program creates an age rating for the OWTS shapefile (Table D-2), and a soil rating based on the SSURGO soil limitation ratings of severely limited (3), somewhat limited (2), and slightly limited (1). The NRCS limitation ratings are based on geophysical factors such as soil classification, depth to bedrock, and slope (Table D-3). The soil file with the suitability rating is intersected with the age rate and then weighted with 70% to soil rate and 30% to the age rating to create a new OWTS malfunction index. This weighting scheme is based on the assumption that soil treatment capability has the greatest role in contribution, followed by malfunction due to limited maintenance (related to age of system) (Lesikar, 2007). Areas missing soil or age information are assigned index ratings of -99. In this case the higher the suitability rating, the less effluent the system can treat. A malfunction index based on the suitability rating is converted to a raster file and then reclassified into percent malfunctioning (contributing to load potential) (Table D-4). After determining the number of homes contributing, a flow rate (gal / household × day), effluent rate (cfu/100 mL), and necessary conversion factors are applied to estimate the potential *E. coli* loading in cfu/day.

OWTS information was obtained from county permit records (Hood County Appraisal District). The assumption of 200 gal/household-day is based on the adopted stakeholder resolutions. SSURGO soil shapefiles for each county and the associated soil properties tables were obtained from the NRCS Soil Datamart. In addition, after further discussion and comparisons with cove modeling results it was decided to incorporate a correction factor for the likeliness for a given system to fail on a given day. It is assumed that a higher loading (which would lead to overflow of the system) occurs approximately four times every month so on a given day each system has a 4/30 or 13.3% chance of overflow.

Table D-2 Age Rating for Subdivisions in Lake Granbury Watershed to Calculate OWTS Index.

Age (years)	Age Rate
0 – 15	1
16 – 30	2
> 30	3
No Data	-99

Table D-3 Interpretative Soil Properties and Limitation Classes for Septic Tank Soil Absorption Suitability (Source: SCS, 1986).

Interpretive Soil Property	Limitation Class		
	Slight	Moderate	Severe
Total Subsidence (cm)	--	--	>60
Flooding	None	Rare	Common
Bedrock Depth (m)	> 1.8	1-1.8	< 1
Cemented Pan Depth (m)	> 1.8	1-1.8	< 1
Free Water Occurrence (m)	> 1.8	1-1.8	< 1
Saturated Hydraulic Conductivity (μm/s)			
Minimum 0.6 to 1.5 m[a]	10-40	4-10	< 4
Maximum 0.6 to 1 m[a]			> 40
Slope (Pct)	< 8	8-15	> 15
Fragments > 75 mm[b]	< 25	25-50	> 50
Downslope Movement			[c]
Ice Melt Pitting			[c]
Permafrost			[d]

[a]0.6 to 1.5 m pertains to percolation rate; 0.6 to 1 m pertains to filtration capacity
[b]Weighted average to 1 m.
[c]Rate severe if occurs.
[d]Rate severe if occurs above a variable critical depth (see discussion of the interpretive soil property).

Table D-4 OWTS Index Reclassification to Percent Malfunction used in determining OWTS Malfunction Rates in Lake Granbury Watershed.

Index	Percent Malfunction
< 0	8
0 - 1.5	5
1.5 - 2.5	10
2.5 – 3	15

Pets

Generally, dogs are the primary pet allowed to defecate outside the home and most often the defecated waste is not cleaned up. Cats and other pets are primarily kept in homes and waste disposed of directly to solid waste management so these contributions will be neglected. The assumption of a constant 0.8 dogs per home for Texas (AVMA, 2002) is an adjustable model parameter included in SELECT. The program creates a raster that represents the number of homes from the census block demographics table joined to the census block shapefile. Again the program applies the fecal production rate and then aggregates the potential load to zones of interest. Census block shapefiles are needed for each county. The associated census block demographics table for the state of Texas is indicated in the GUI as well as the appropriate field for the number of homes in each census block.

Wastewater Treatment Plants (WWTPs)

To assess point sources SELECT evaluates the contribution from Wastewater Treatment Plants (WWTPs). Within the GUI, the user indicates the shapefile with the permitted outfall locations ensuring unrelated outfalls (i.e. cooling plants or any other non-pathogenic discharges) removed. The file should include permitted discharges in the units of millions of gallons per day (MGD) as a field within the shapefile. The default (adjustable within the GUI) value of 126 cfu/100 mL effluent standard is assumed. The loading is calculated by simply multiplying the effluent by the discharge and applying conversion factors to determine the loading in cfu/day. For this study, wastewater outfall locations were obtained from TCEQ GIS files. The permitted flows were obtained from the EPA Envirofacts Data Warehouse (USEPA, 2006).

Once all individual source inputs are selected and fed into the model a summation from all sources is carried out. Thus, potential loading for the Lake Granbury watershed was spatially distributed.

D.2 SELECT Results

D.2.1 Large Lake Granbury watershed

Potential *E. coli* loadings from livestock, wildlife, and domestic sources in the Lake Granbury Watershed were calculated by SELECT. The loadings from the individual sources were combined and aggregated on a subwatershed basis and then divided by the area of the subwatersheds to produce the area weighted potential loading (Figure D.1). The potential loading component of SELECT can help identify source contributions spatially distributed across the watershed. However, this is only a daily snapshot of the amount of *E. coli* potentially present in the watershed. The Pollutant Connectivity Factor (PCF) applied weighting to important fate and transport factors such as runoff capabilities and travel distance to provide helpful information to determine whether *E. coli* from various sources potentially contaminate the waterbodies. For the Lake Granbury Watershed, PCF analyses was based on applying multiple weighting schemes (Table D-5) and then ranking the subwatersheds (Figure D.3) for potential water quality problems due to bacteria.

Table D-5 Weighting Scheme for Sensitivity Analyses of Pollutant, Runoff, and Distance Indicators for determining the Pollutant Connectivity Factor (PCF).

Trial Number	W_p	W_r	W_d
1	5	3	2
2	5	2	3
3	4	4	2
4	4	3	3
5	4	2	4
6	3	5	2
7	3	4	3
8	3	3	4
9	3	2	5
10	2	5	3
11	2	4	4
12	2	3	5
13	3.33	3.33	3.33

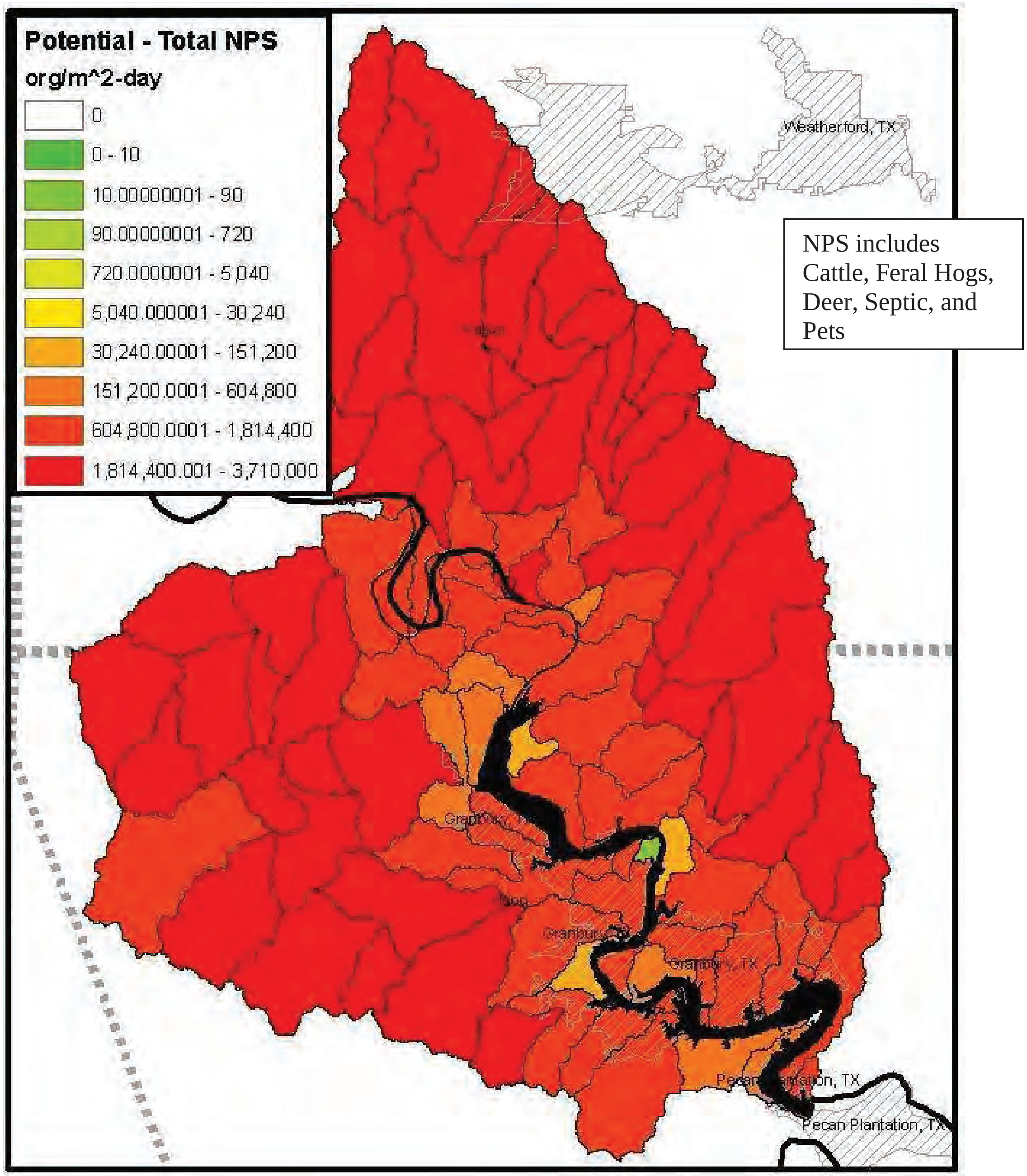


Figure D.1Total Potential Non-Point Source (NPS) *E. coli* Load from All Sources in Lake Granbury Watershed.

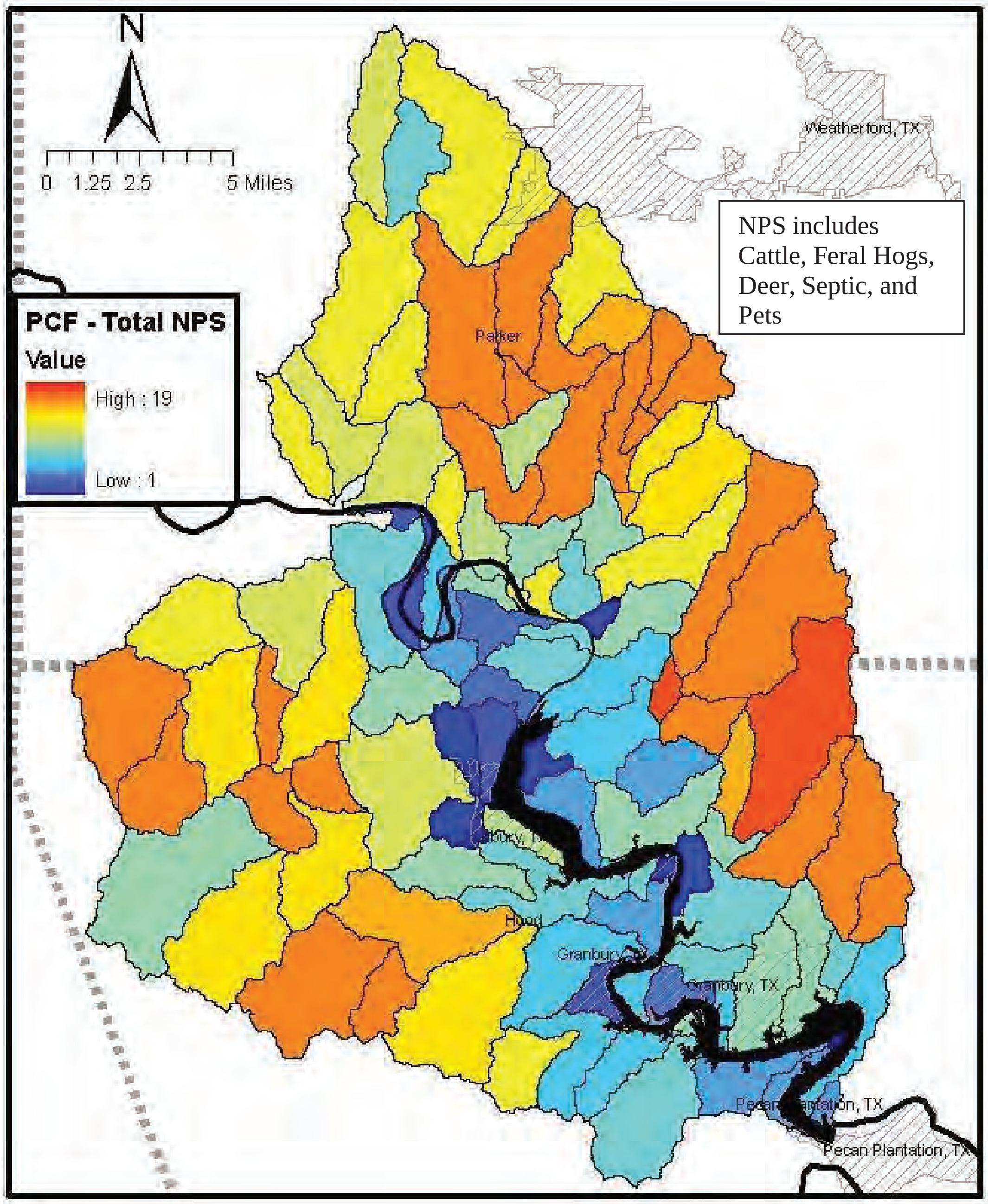
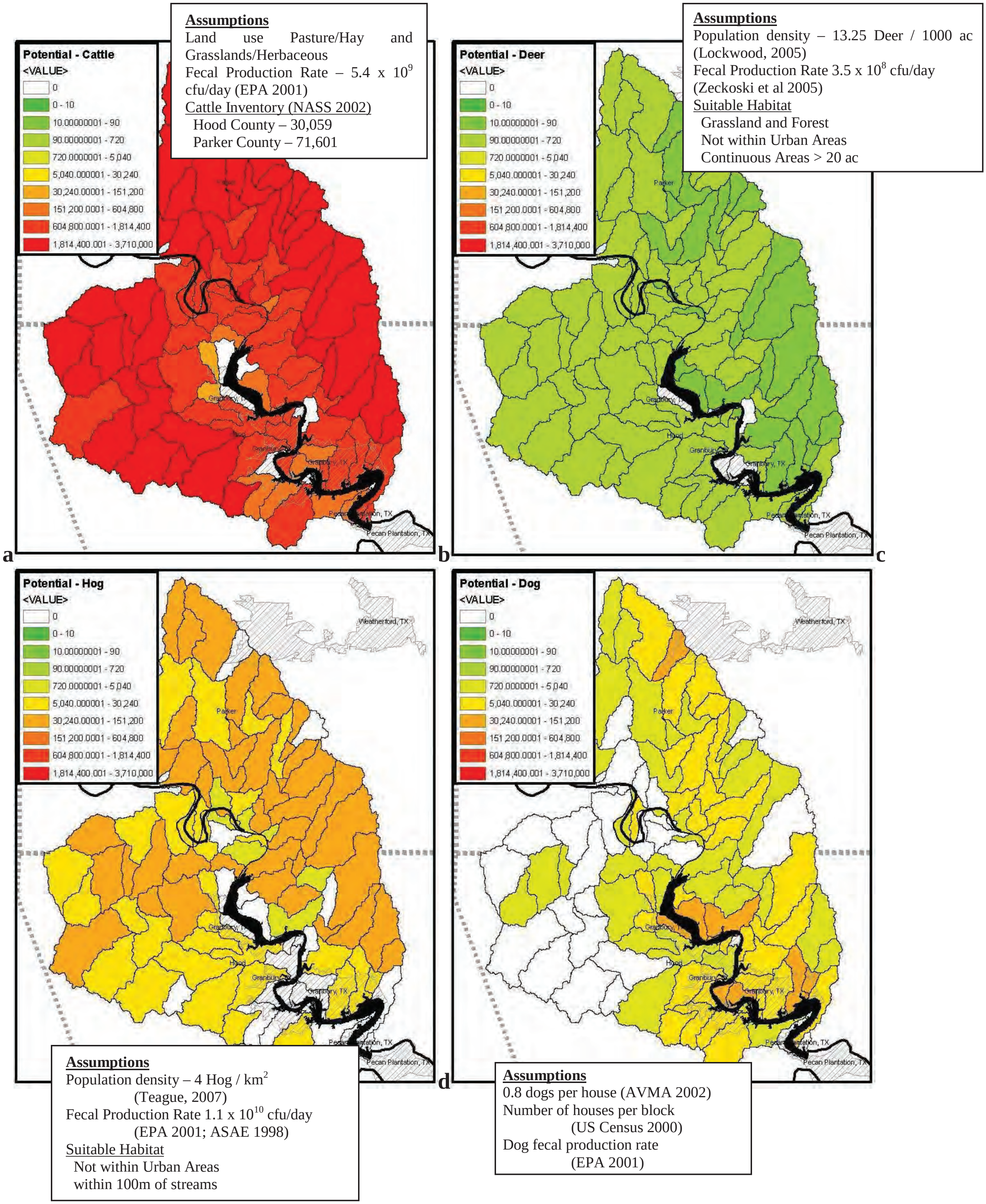


Figure D.2 Pollutant Connectivity Factor for Total Non-Point Source (NPS) *E. coli* Potential Load Determined by Ranked Subwatersheds Averaged over Multiple Weighting Scenarios.

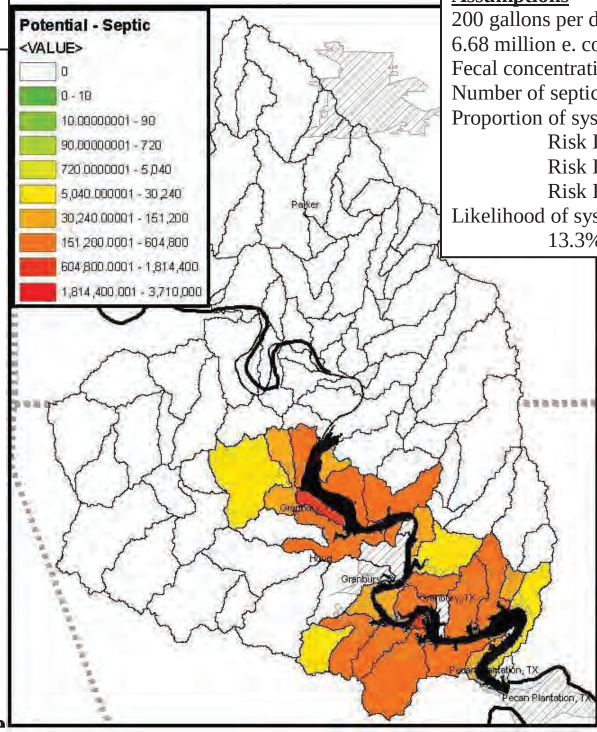
Daily Potential *E. coli* Loading in Lake Granbury Watershed

The potential *E. coli* loading can be broken into two classes for analyses; non-point and point sources.



Potential = Potential Load in organisms per day per m^2

Potential = Potential Load in organisms per day per m^2



Assumptions
200 gallons per day per system
6.68 million e. coli MPN/100mL
Fecal concentration in sewage (EPA 2001)
Number of septic systems per area
Proportion of systems failing (Septic Index)
Risk Level 1 – 5%
Risk Level 2 – 10%
Risk Level 3 – 15%
Likelihood of systems failing on a given day
13.3% = 4 days per month

e

Figure D.3 Area Weighted Potential *E. coli* Load (organisms/day-m^2) in Lake Granbury Watershed Resulting from Various Non-Point Sources: a) Cattle, b) Deer, c) Feral Hogs, d) Pets , and e) On-site Wastewater Treatment Systems (OWTS)

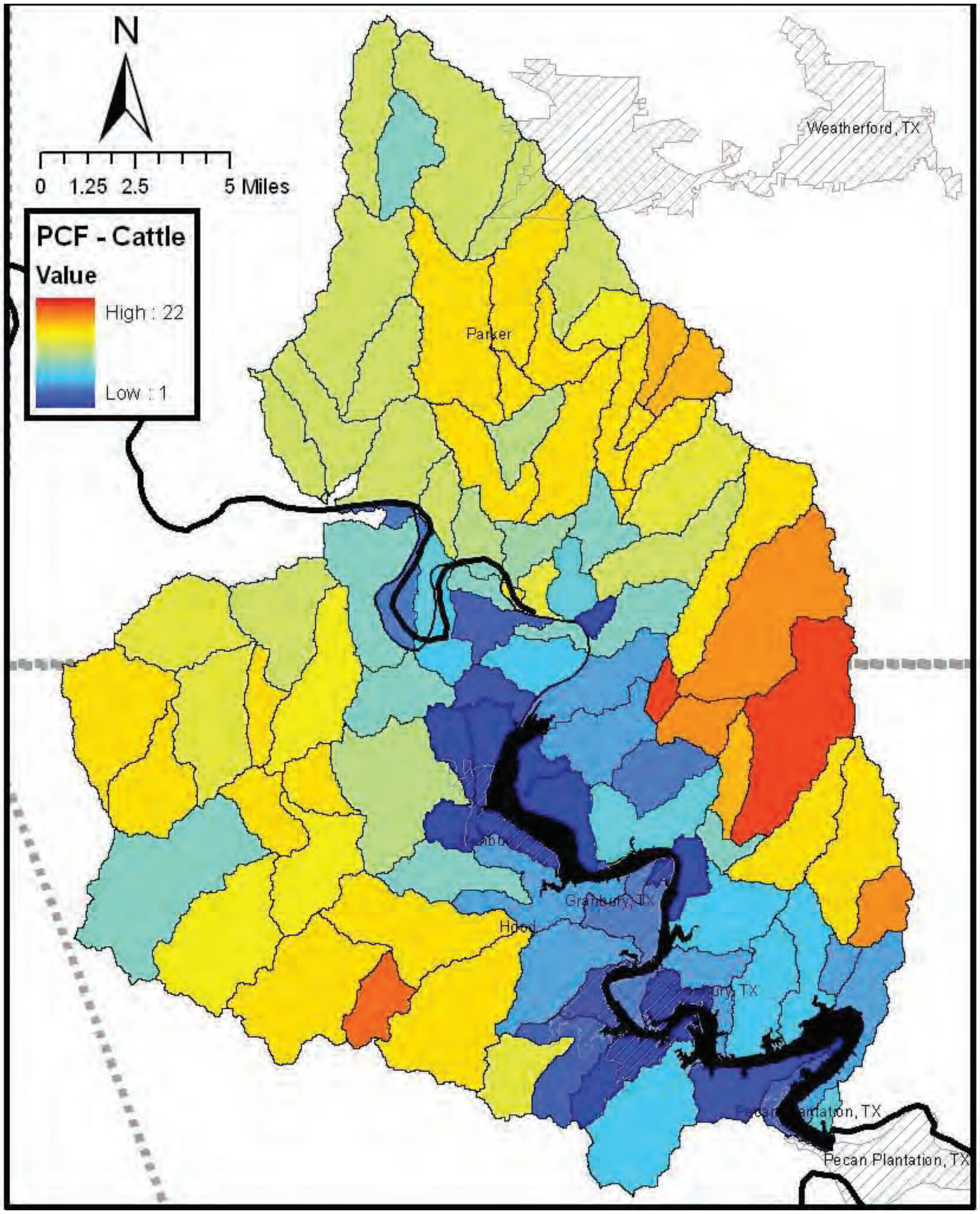


Figure D.4 Ranked PCF for Area Weighted Cattle Potential *E. coli* Loading

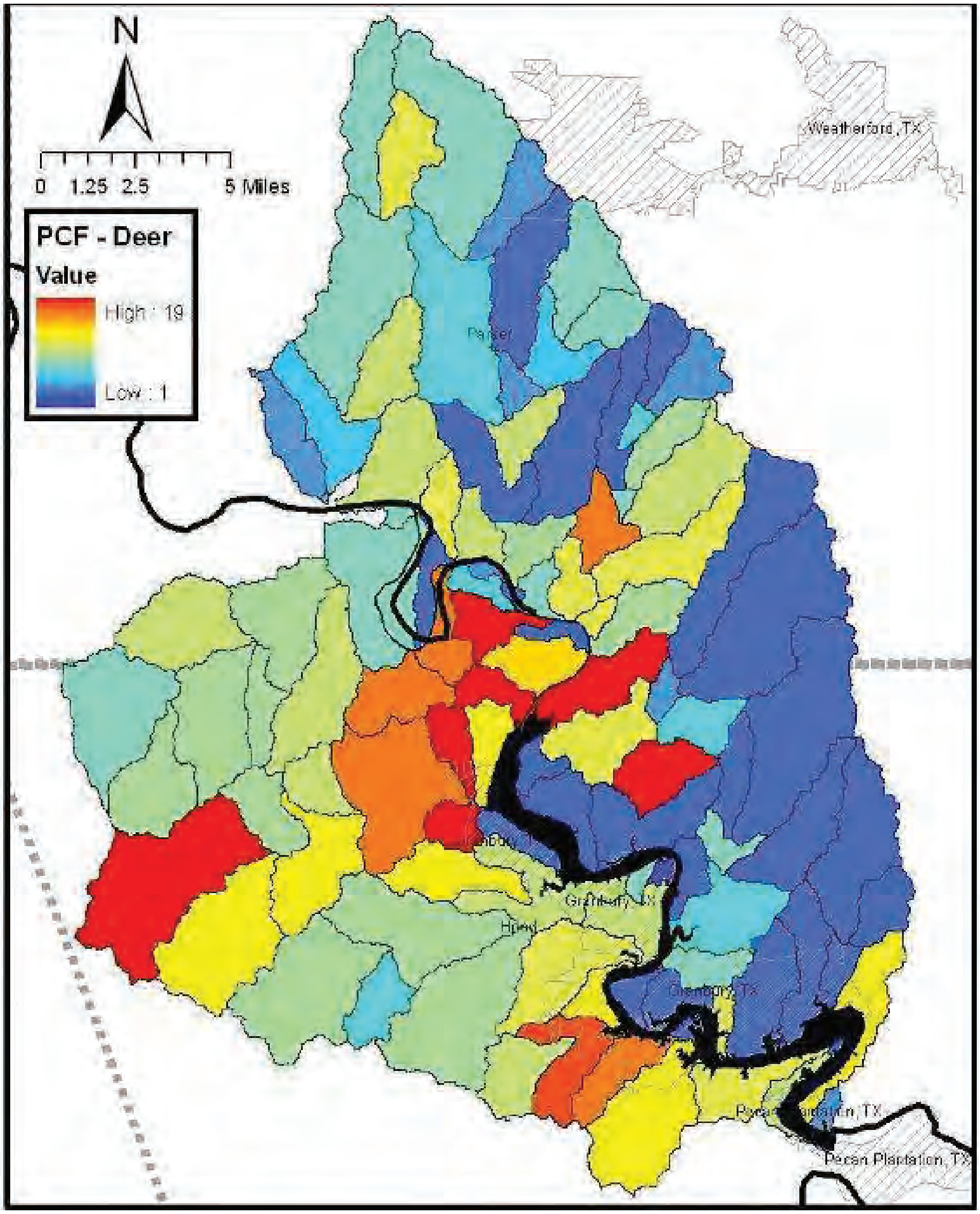


Figure D.5 Ranked PCF for Area Weighted Deer Potential *E. coli* Loading

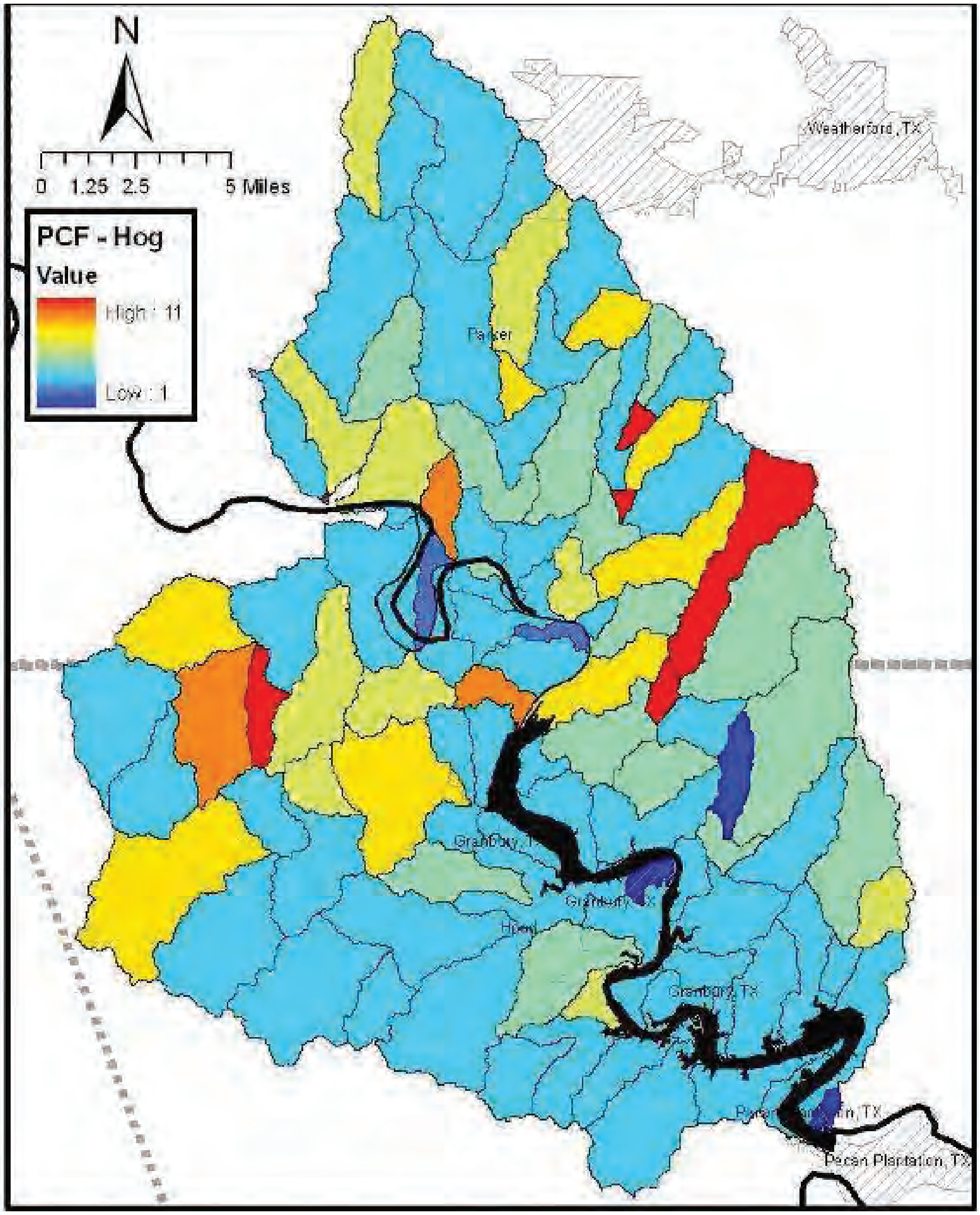


Figure D.6 Ranked PCF for Area Weighted Feral Hog Potential *E. coli* Loading

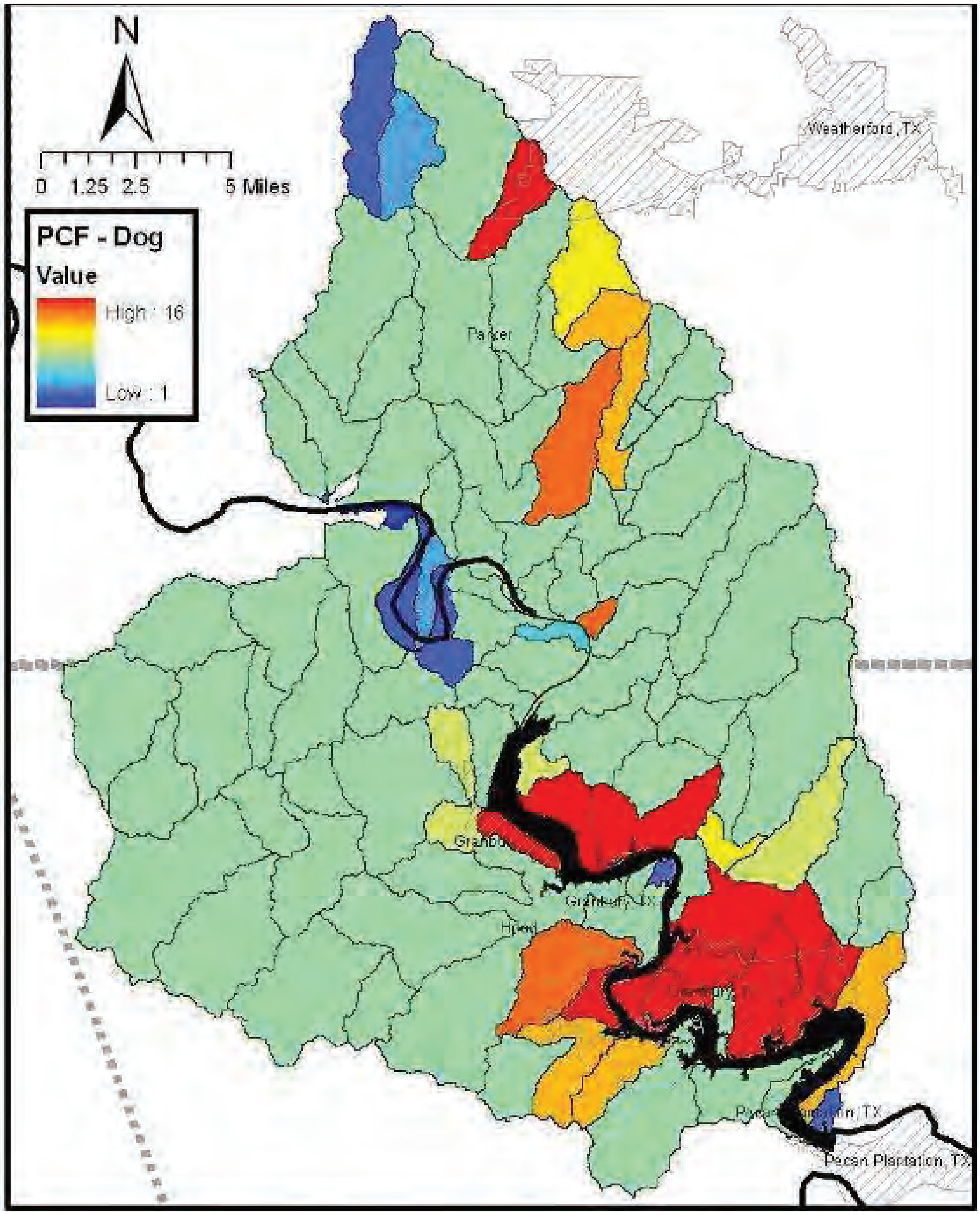


Figure D.7 Ranked PCF for Area Weighted Dog Potential *E. coli* Loading

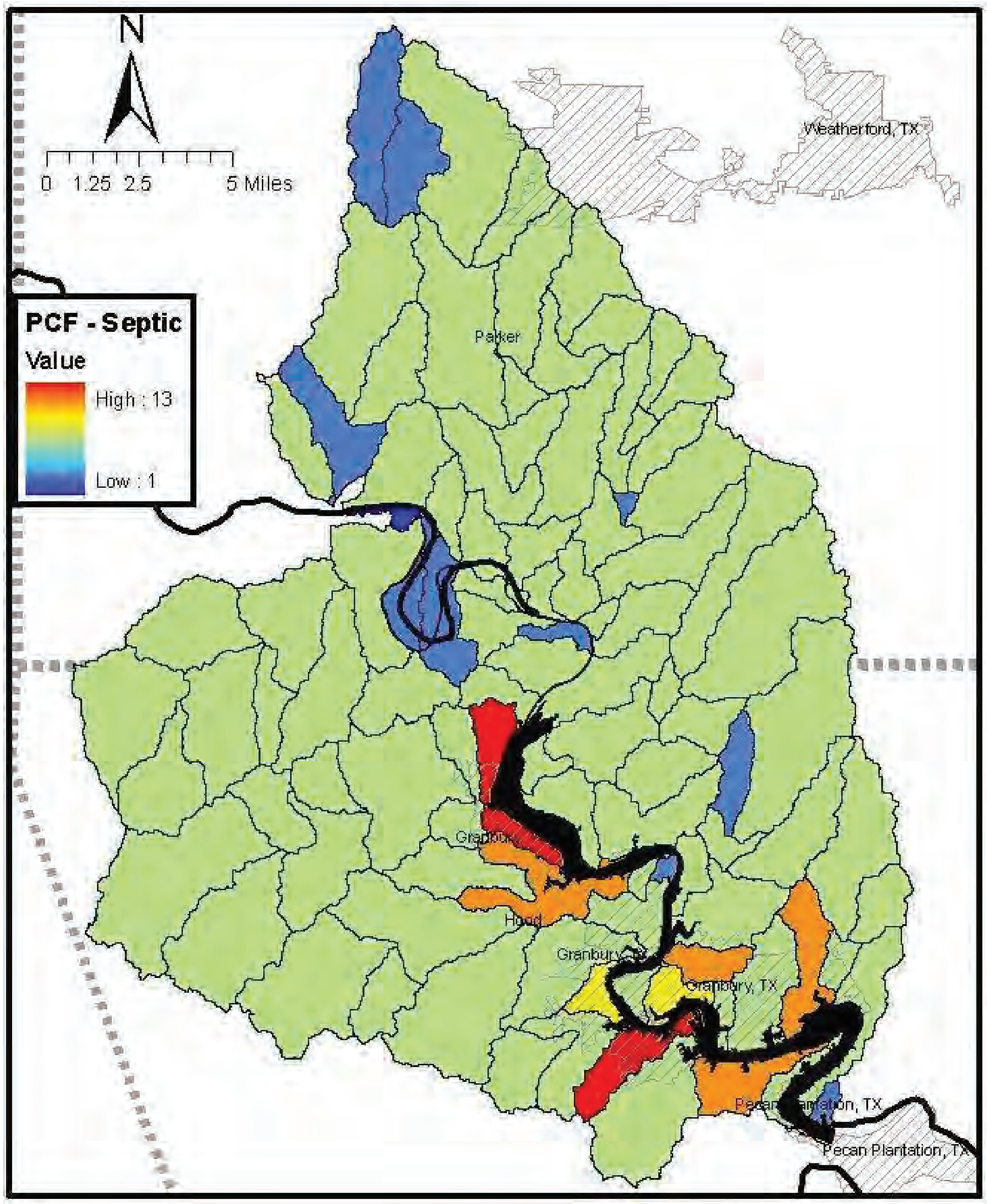


Figure D.8 Ranked PCF for Area Weighted Septic Potential *E. coli* Loading

Non-Point Sources

High potential *E. coli* load resulting from cattle (Figure D.3a) occurs in the northern-most subwatersheds as well as in subwatersheds on the Eastern side of the watershed near the Hood and Parker County lines. These subwatersheds have a landscape dominated by grasslands with a mixture of pasture/hay. The watersheds closest to Caddo Lake have lower loads mainly due to higher human population. During a runoff event the highest ranked PCF 'hot spots' are the most likely to significantly contribute to contamination in the waterbodies. The subwatersheds with high potential loads and closest to the lake were determined to be the highest ranked, by PCF, areas likely to be contributing to contamination in the waterbodies (Figure D.4). The highest average PCF ranking occurs in the eastern portion of the basin near the Hood and Parker County lines about 5 miles away from Lake Granbury.

The highest potential *E. coli* loading resulting from deer (Figure D.3b) can be seen in the northern and western portions of the watershed where human population is less dense and large areas of contiguous forested lands are found. The second highest group of potential loading tends to have significant amounts of forests but these areas are more scattered and broken up by streams and intermixed with open range and grass lands. The southern half of the watershed generally has lower potential loads resulting from deer mainly due to the influence of higher human populations. When these loads are compared with the PCF ranking (Figure D.5), it is evident the most influence from deer can be found in the subwatersheds just north of Lake Granbury and in the far Western portions of the basin with the least influence in the southeast portions of the basin.

The areas with high feral hog potential are similarly characterized as with the deer population except the feral hogs are distributed in more areas of the watershed and concentrated along stream corridors. The feral hog *E. coli* potential is insignificant in the urban areas along Lake Granbury and in the southern portion of the watershed due to the highly developed land classifications in these regions. This is further emphasized in the PCF ranking for feral hogs (Figure D.6).

Potential *E. coli* loading resulting from malfunctioning OWTSs (Figure D.3c) was calculated for Hood County only where descriptive permit data was gathered to create a spatial subdivision OWTS file by the Brazos River Authority from the Hood County Appraisal District. This information has not been gathered for Parker County. This does not pose a significant problem since the northern portion of the watershed in Parker County is much further from the waterbodies of concern. In addition, the only areas with significant populations are on the north-eastern edge of the watershed where the populations are quite dense and most likely on combined sewer networks. Subwatersheds located across the main section of Lake Granbury on the eastern shoreline have the highest potential *E. coli* loads resulting from malfunctioning OWTSs (Figure D.8). These areas are characterized by significant developed, low intensity landuse classification which generally includes single-family housing units, as well as significantly developed, medium and high intensity, land use which includes single-family housing units with higher percent impervious land cover and areas where people reside or work in high numbers. The second highest potential loading group is located west of the lake and characterized by residential development scattered amongst undeveloped grasslands, forests, and pastures.

The potential *E. coli* loading resulting from pets (Figure D.3d) is highest in the northern-most portion of the watershed, along the southeastern edge, and in subwatersheds around Lake Granbury. This is explained by significant low and medium intensity developments within these subwatersheds and the direct relationship between household densities and pet density. These are popular residential areas because of the lake in the southern portion of the watershed and the close proximity to the Fort Worth metropolitan area in the northeast.

Point Sources

There are seven wastewater treatment plant facilities operating within the watershed (Figure D.9). These facilities contribute large amounts of treated effluents and could impact the environment if improper/inefficient treatment of wastewater were to occur. When localities are considering consolidating on-site wastewater treatment systems into municipal sewage systems, the local officials should take into account the amount of pollutants, such as *E. coli* and nutrients, that would be discharged as a direct point source (with virtually zero travel time or attenuation) if maintained improperly.

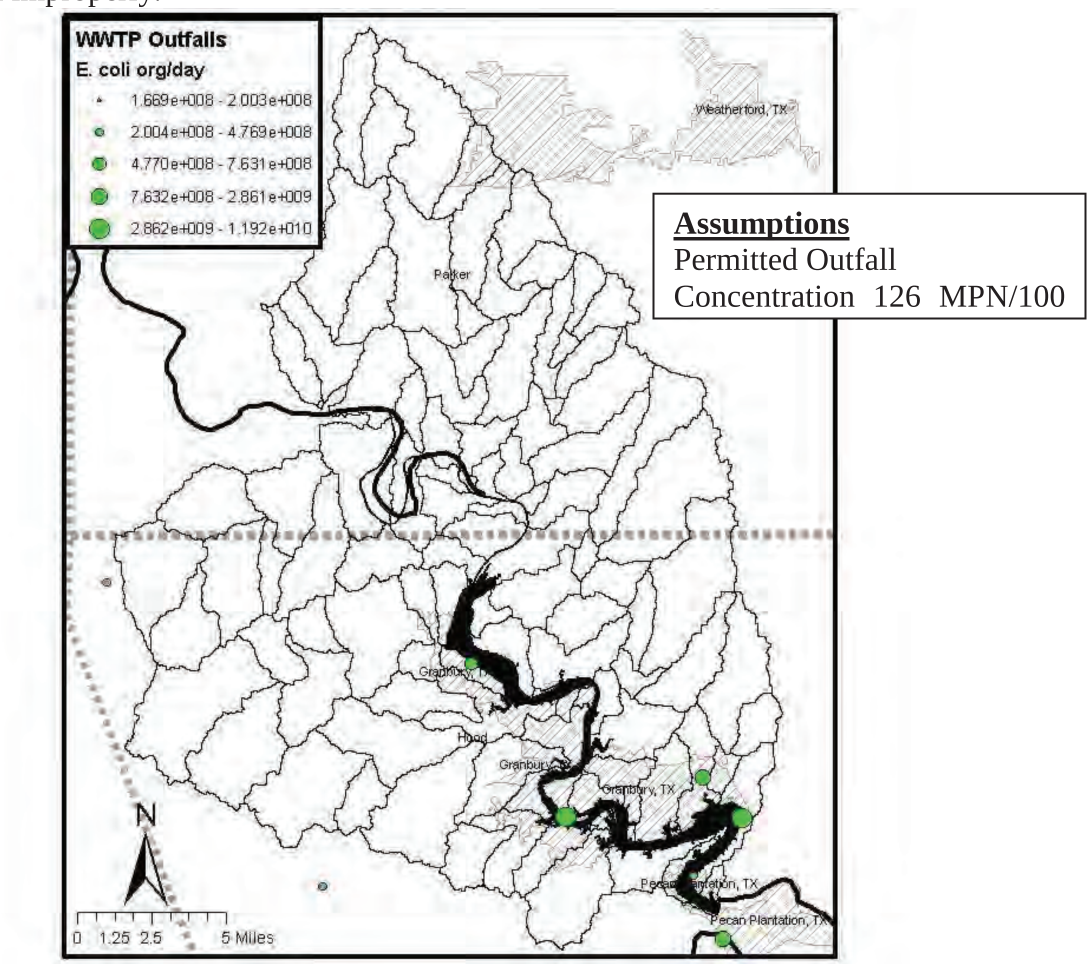


Figure D.9 Potential *E. coli* Loading from Wastewater Treatment Plants.

<u>Combined Loading from All Sources</u>

The SELECT results including the PCF analysis indicate that across the entire watershed cattle is the largest contributor to *E. coli* loading followed by deer, pets, OWTS, and then WWTPs (Figure D.3 through Figure D.9). Comparing the SELECT results with actual *E. coli* concentrations measured at water quality monitoring stations indicates that malfunctioning OWTS are potentially a major concern followed by pets. Currently, bacterial water quality is not monitored where SELECT predicts high potential *E. coli* loads in the broader Lake Granbury Watershed (Figure D.3 through Figure D.8).

D.2.2 Modeling Results for Micro-watersheds of Priority Areas

Potential *E. coli* loadings for Micro-watersheds (Figure D.10 and Figure D.11) in Lake Granbury subdivisions were calculated by SELECT following the same assumptions as in the larger Lake Granbury Watershed analyses. Bacteria loads from livestock (cattle), wildlife (deer and feral hogs) and domestic sources (septic systems and other OWTSs and pets) were calculated individually and combined and aggregated on micro-watershed basis. The potential loading component of SELECT can help identify source contributions spatially distributed across the watershed. However, this is only a snapshot of the amount of *E. coli* present in the area. The Pollutant Connectivity Factor (PCF) applied weighting to important fate and transport factors such as runoff capabilities and travel distance to provide qualitative information to determine whether *E. coli* from various sources potentially contaminate the waterbodies. It should be noted that PCF is comparative only with the particular source of interest and is not meant for comparative use between sources as magnitude of potential bacterial loading is normalized in each case individually. The difference in magnitudes will be similar to those seen in the larger watersheds potential loading.

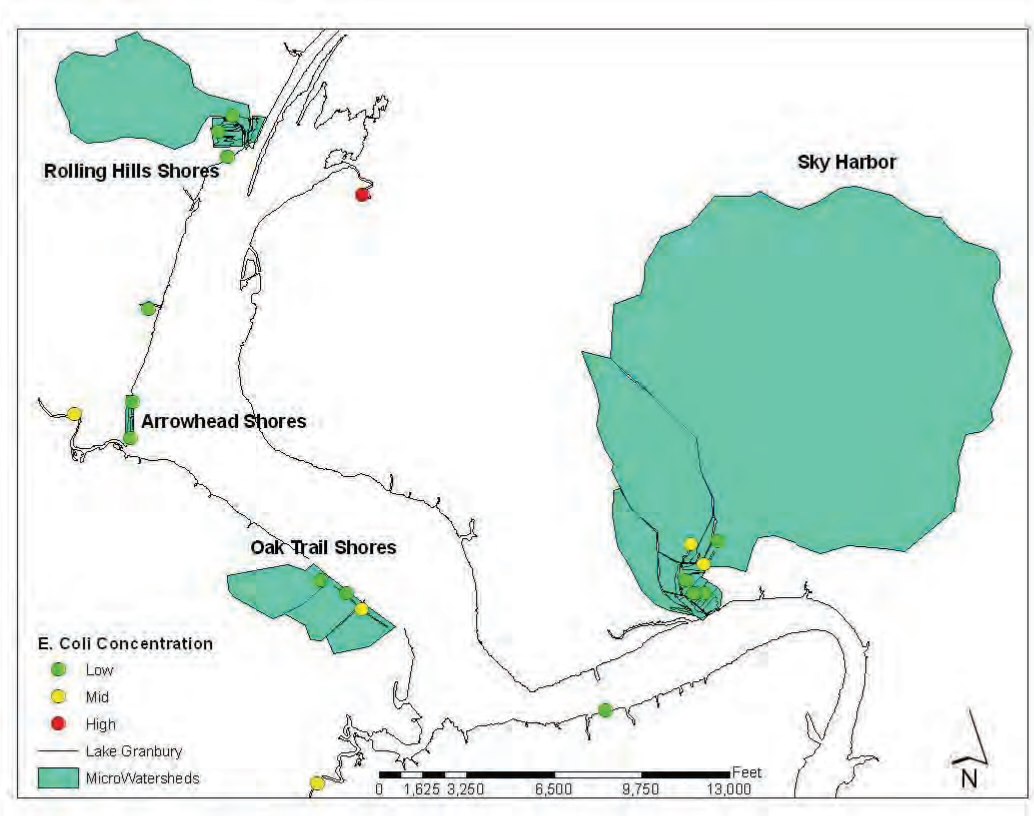


Figure D.10 Lake Granbury Micro-watersheds (Northern Portion of Lake)

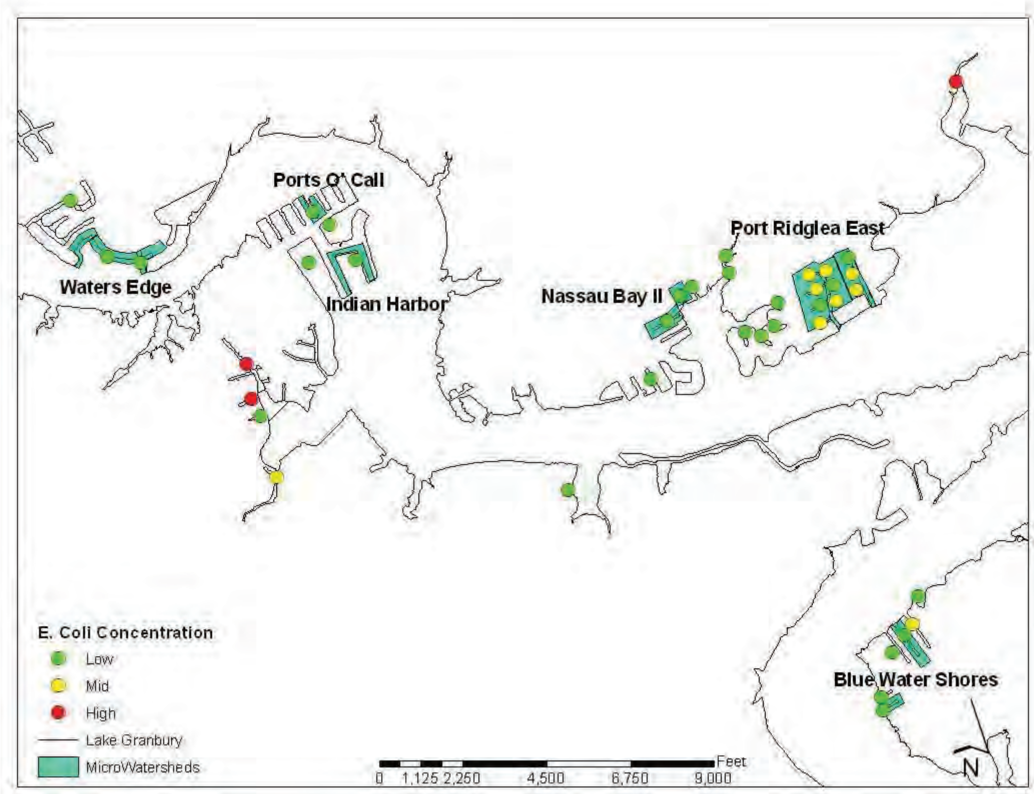


Figure D.11 Lake Granbury Micro-watersheds (Southern Portion of Lake)

<u>Non-Point Sources</u>
Only non-point sources were evaluated for the micro-watershed modeling since the WWTP point sources will be identical to those described previously in the large watershed modeling section of this report.

High potential *E. coli* load resulting from cattle Figure D.13 occurs in the microwatersheds around the Sky Harbor subdivision (Figure D.10). These micro-watersheds have a relatively larger landscape dominated by grasslands with a mixture of pasture/hay. The other small micro-watersheds have negligible cattle loads mainly due to the urban landscape and high population. During a runoff event the highest ranked PCF 'hot spots' are the most likely to significantly contribute to contamination in the waterbodies. The highest average PCF ranking was in Sky Harbor subdivision (Figure D.12).

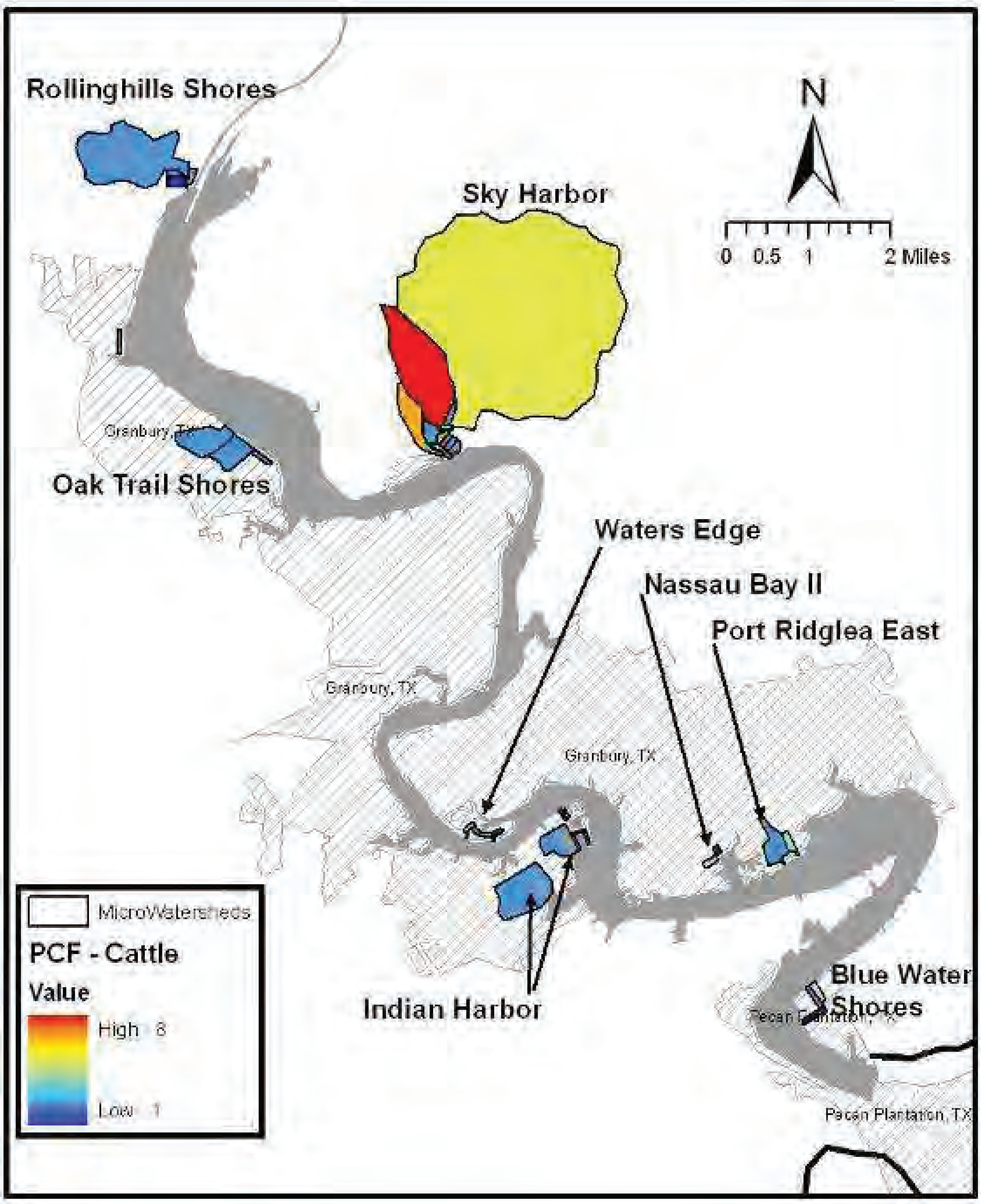


Figure D.12 PCF Ranking of Microwatersheds from Area Weighted Potential E. coli Loading from Cattle

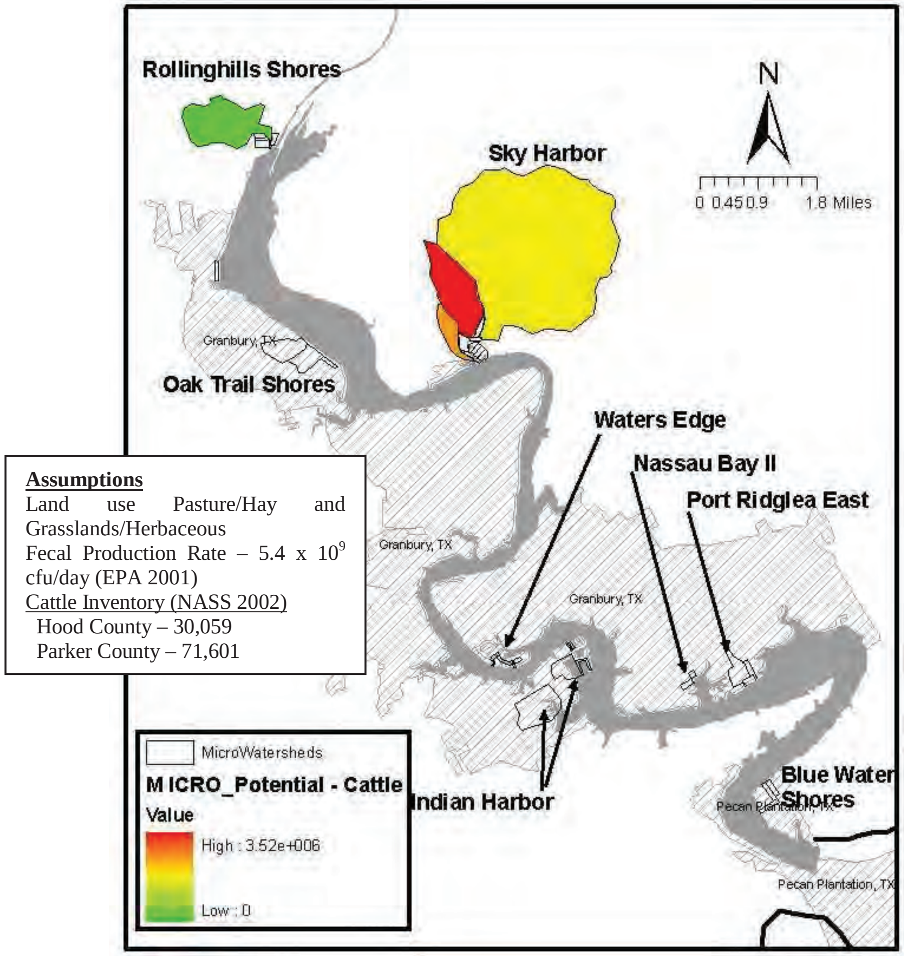


Figure D.13 Area Weighted Potential E. coli Loading from Cattle

The highest potential *E. coli* loading resulting from deer (Figure D.14 and Figure D.15) can be seen in the Rolling Hills Shores micro-watershed where human population is less dense and forest landuse is the dominant landscape. The small watersheds around urban subdivisions have lower potential loads resulting from deer mainly due to the influence of higher human populations. When these loads are compared with the PCF ranking, Rolling Hills Shores was among the areas of high concern. Following Rolling Hills Shores for concern due to deer contributions are the micro-watersheds around the Sky Harbor subdivision which is also characterized by less development and some forested areas.

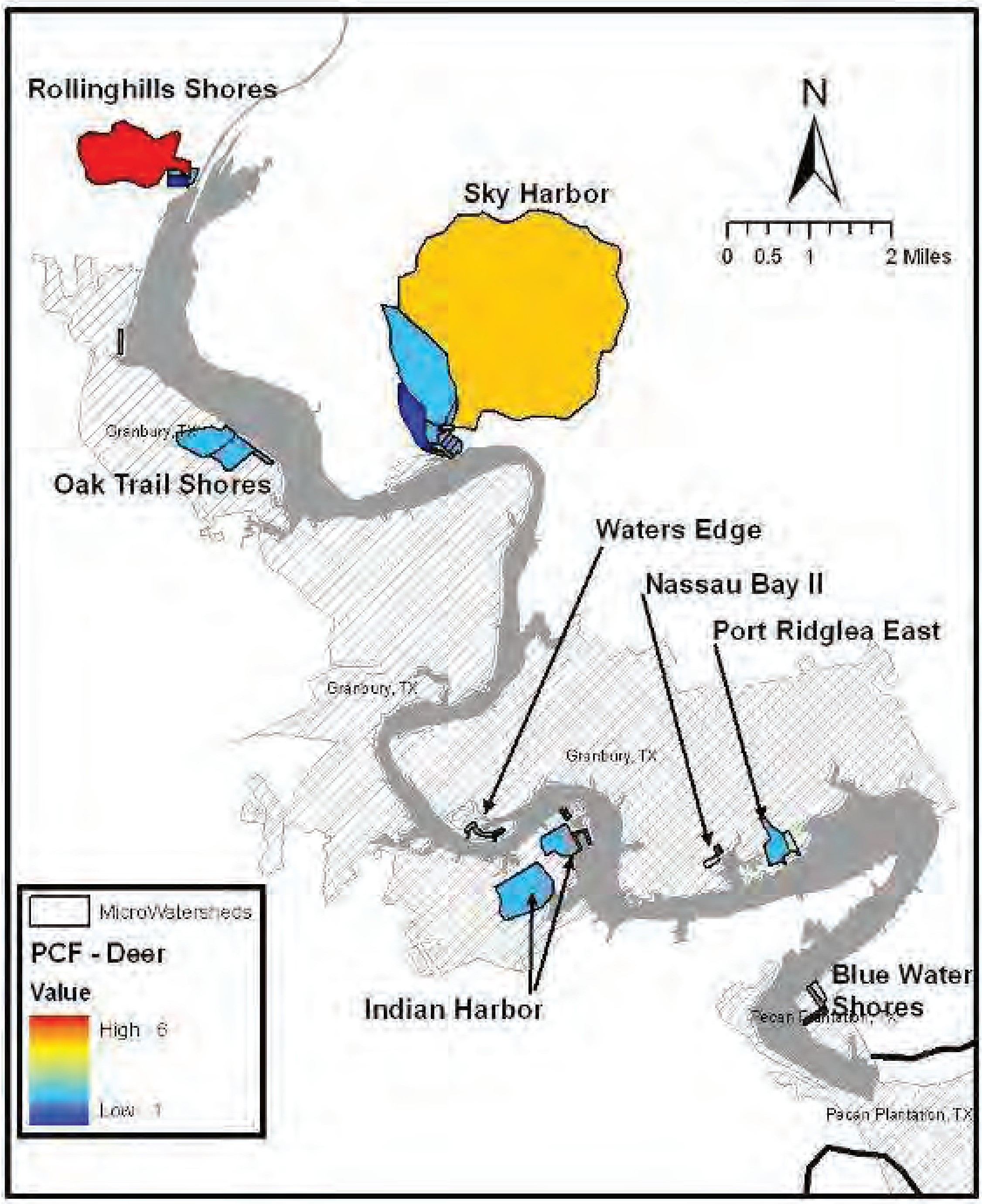


Figure D.14 PCF Ranking of Microwatersheds from Area Weighted Potential E. coli Loading from Deer

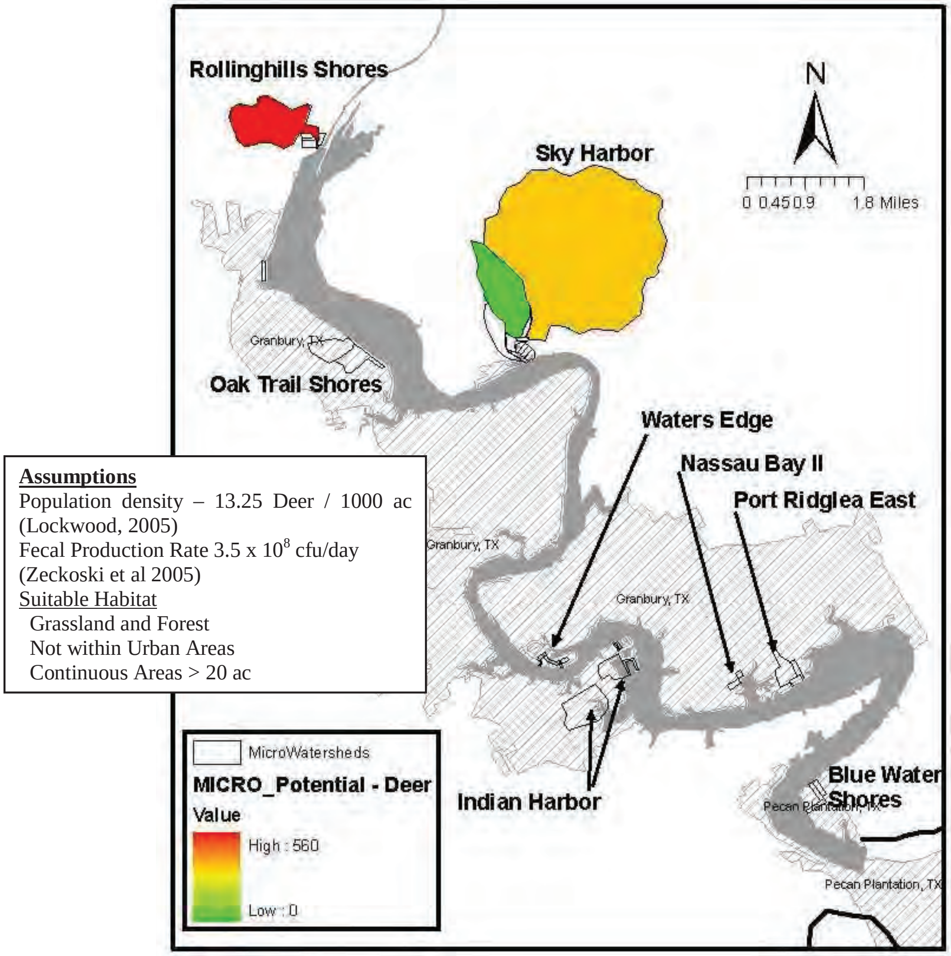


Figure D.15 Area Weighted Potential E. coli Loading from Deer

Potential *E. coli* loading from feral hogs (Figure D.16 and Figure D.17) would most likely be contributed in Sky Harbor but is very unlikely due to the high human population and relative closeness to higher human populated areas. Overall, for these subdivisions feral hogs have very low potential *E. coli* load contributions.

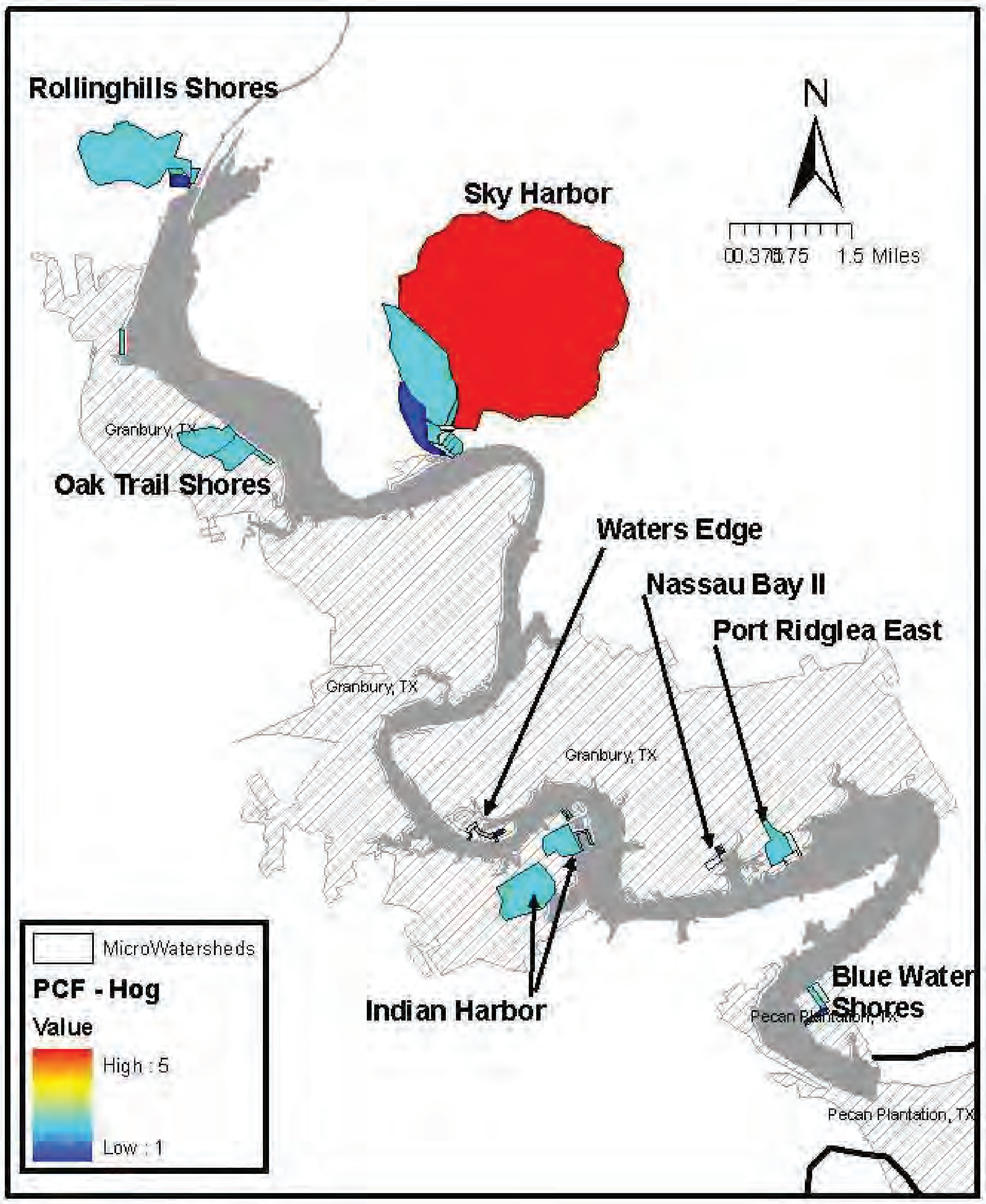


Figure D.16 PCF Ranking of Microwatersheds from Area Weighted Potential E. coli Loading from Feral Hogs

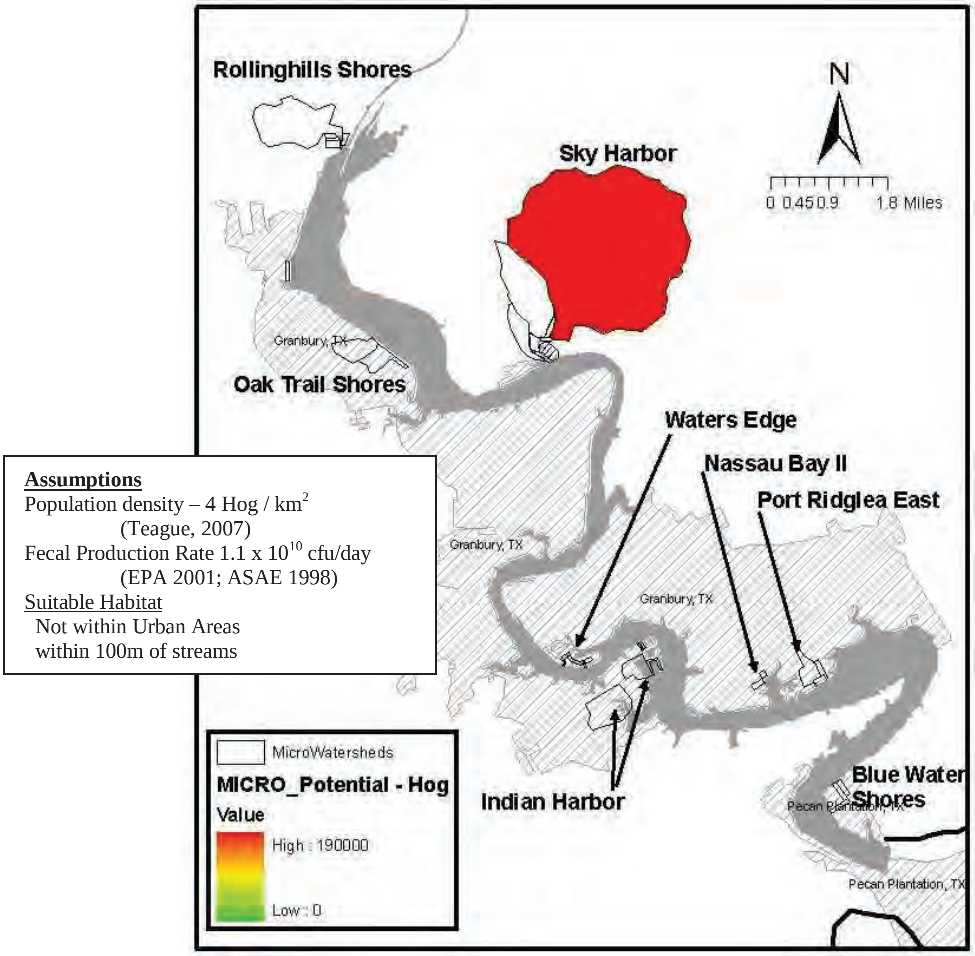


Figure D.17 Area Weighted Potential E. coli Loading from Feral Hogs

Potential *E. coli* loading resulting from malfunctioning septic systems (Figure D.17) was highest around small micro-watershed areas at Oak Trail shores, Ports O' Call, Indian Harbor and Port Ridglea East. These micro-watersheds were characterized by significant developed, high intensity landuse classification which generally included single-family housing units with higher percent impervious land cover and areas where people reside or work in high numbers. The areas potentially contributing significant *E. coli* loadings resulting from malfunctioning OWTSs a high PCF ranking of three to ten (Figure D.18).

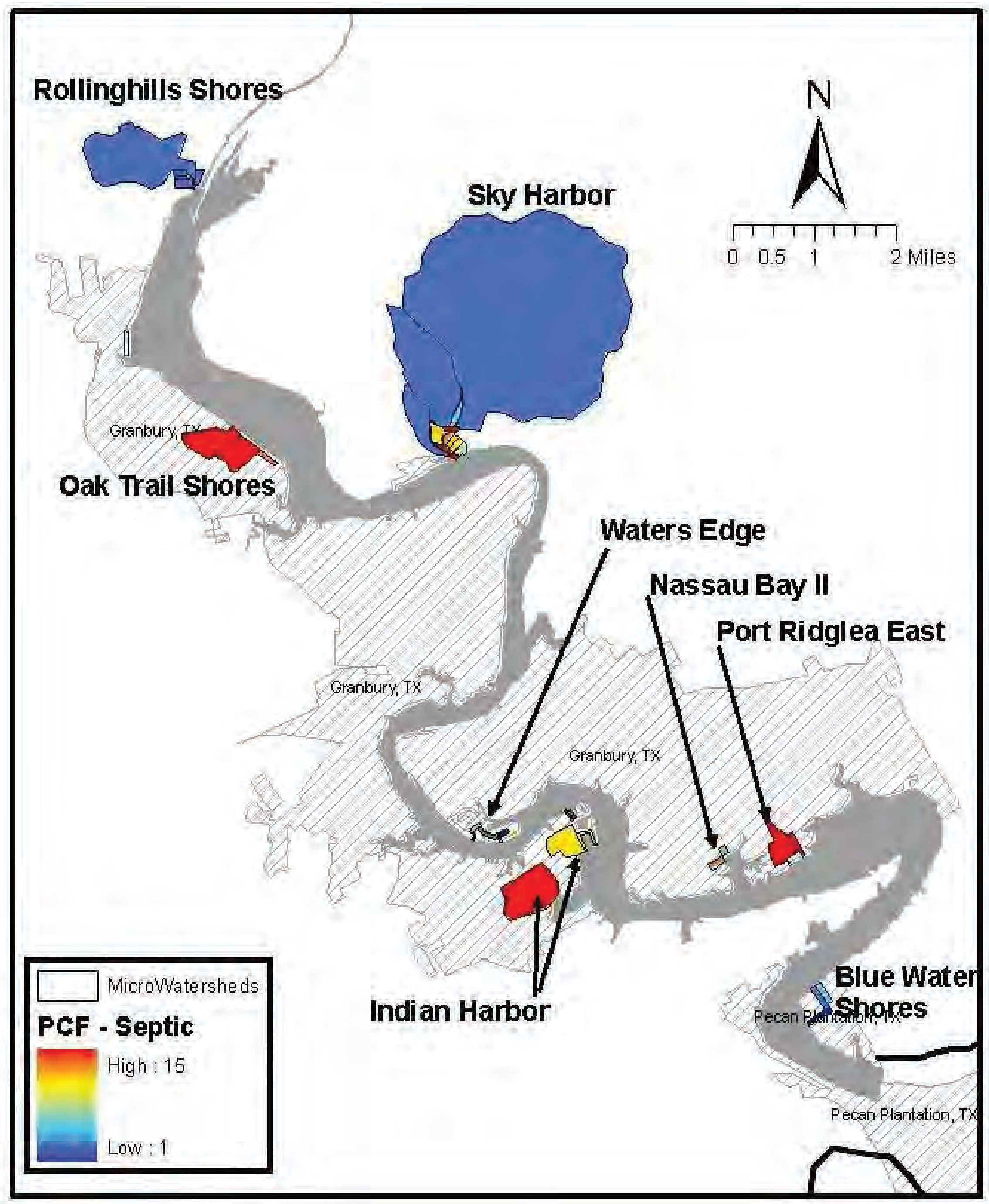


Figure D.18 PCF Ranking of Microwatersheds from Area Weighted Potential E. coli Loading from Malfunctioning Septic Systems

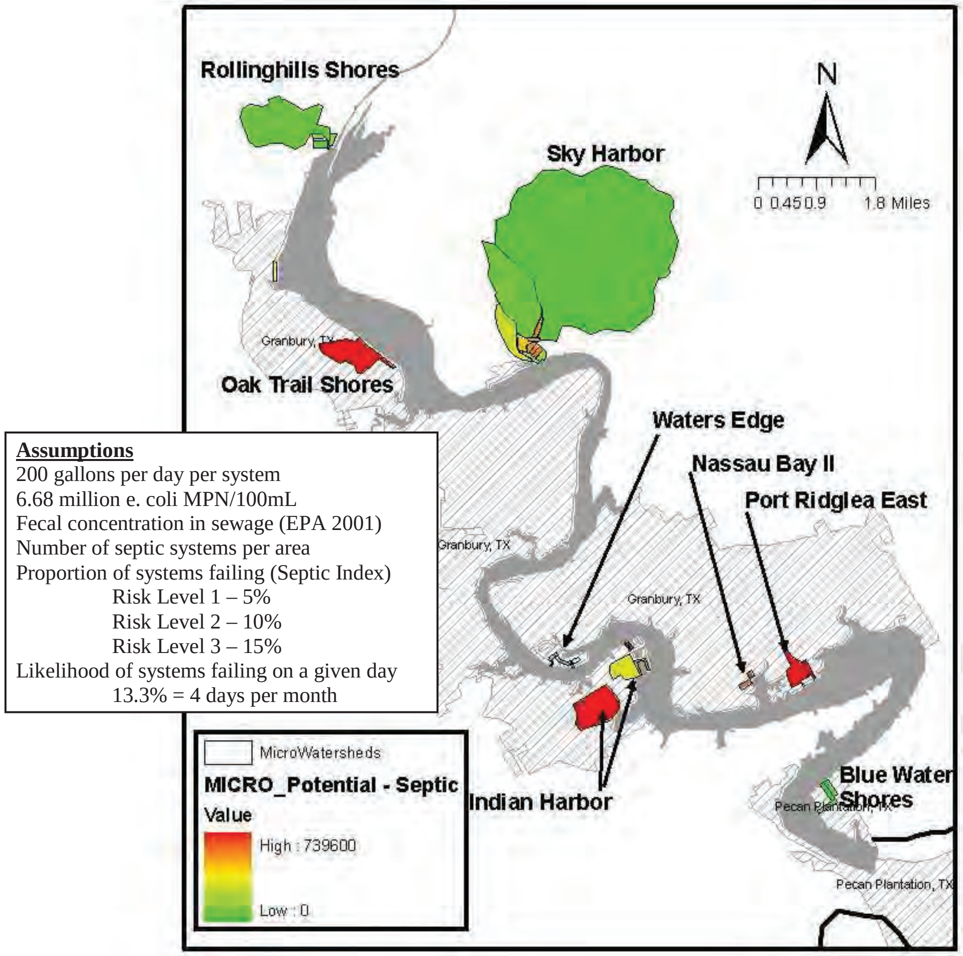


Figure D.19 Area Weighted Potential E. coli Loading from Malfunctiong Septic Systems

The potential *E. coli* loading resulting from pets (Figure D.21) is highest in micro-watersheds at Oak Trail Shores and Sky Harbor. Also it should be noted that there is some loading in all of the subdivisions. This is explained by housing developments within these subdivisions. These are popular residential areas because of the lake in the southern portion of the watershed. The micro-watersheds with highest potential *E. coli* load resulting from pets are ranked using the average PCF over several weighting schemes as high (Figure D.21).

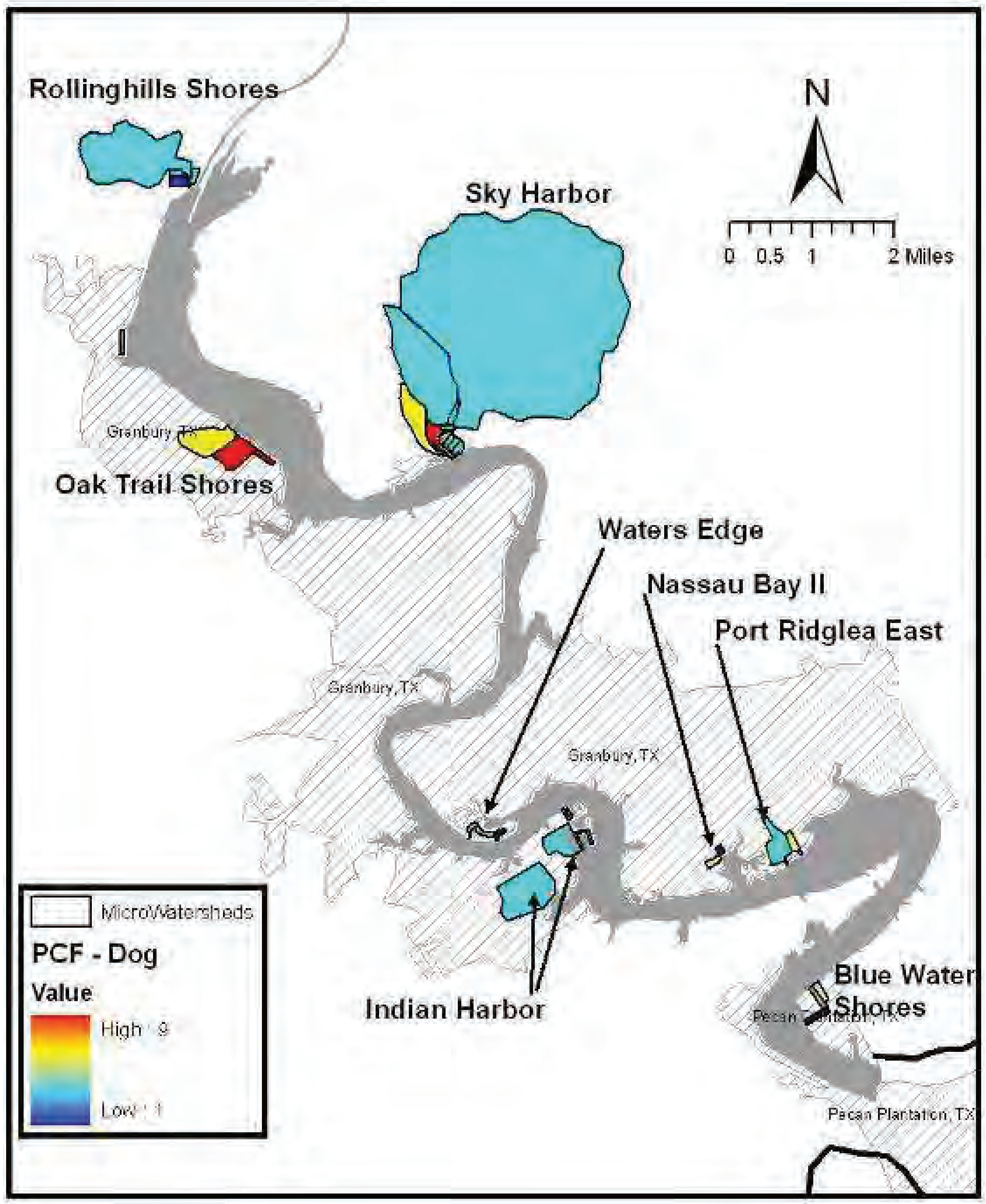


Figure D.20 PCF Ranking of Microwatersheds from Area Weighted Potential E. coli Loading from Dogs

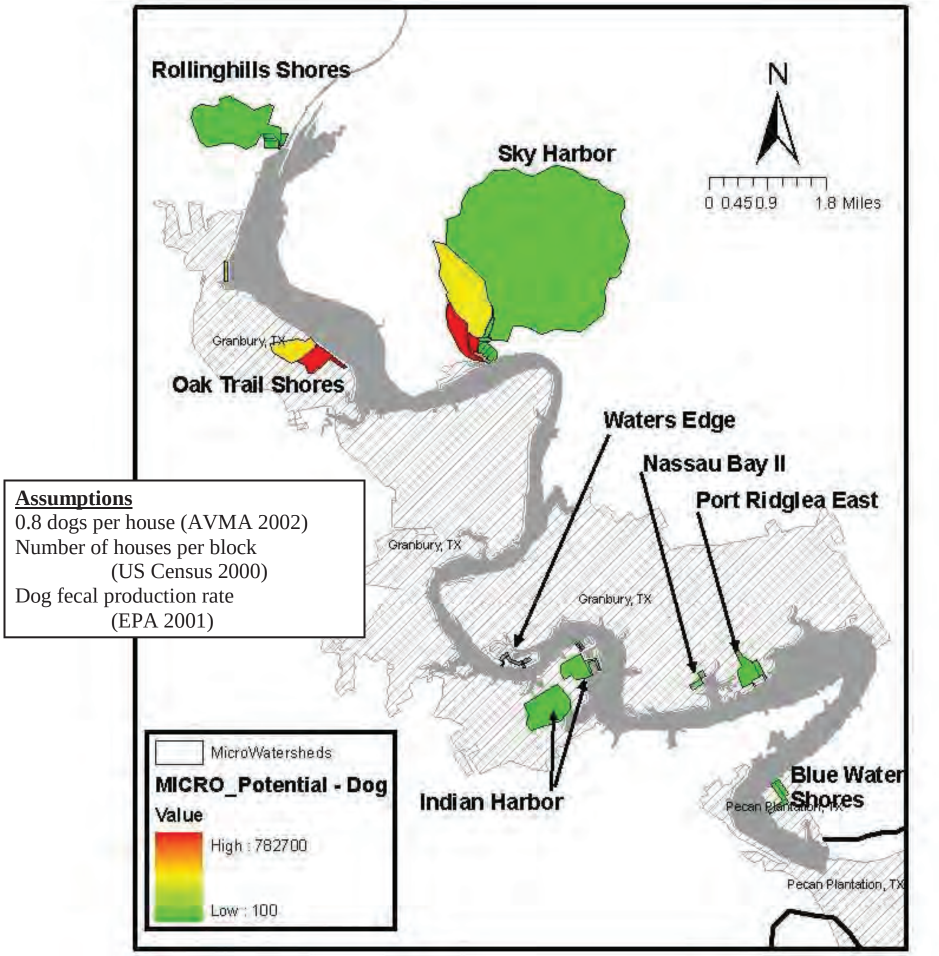


Figure D.21 Area Weighted Potential E. coli Loading from Dogs

<u>Combined Loading from All Non-Point Sources</u>

The highest total non-point source *E. coli* loads (Figure D.23) occur in micro-watersheds around Sky Harbor and Rolling Hills Shores. These subdivision watersheds have land uses appropriate for cattle and deer. Hence, it can be concluded that major *E. coli* contributors in these micro-watersheds are cattle and deer. It should also be pointed out that all of the microwatersheds had similar total potential loadings per area even though the source composition is slightly different for each micro-watershed.

The SELECT results including the PCF analysis of the microwatersheds indicates the highest concern for contributing *E. coli* to the waterbodies is in Sky Harbor and portions of Port Ridglea East (Figure D.22). For Sky Harbor BMP efforts should focus on controlling wildlife and livestock access to waterways. In Port Ridglea East either more education about maintaining properly functioning OWTSs or the consolidation into municipal sewage collection system are options to be considered due to the high possibility of malfunctioning OWTS contributions.

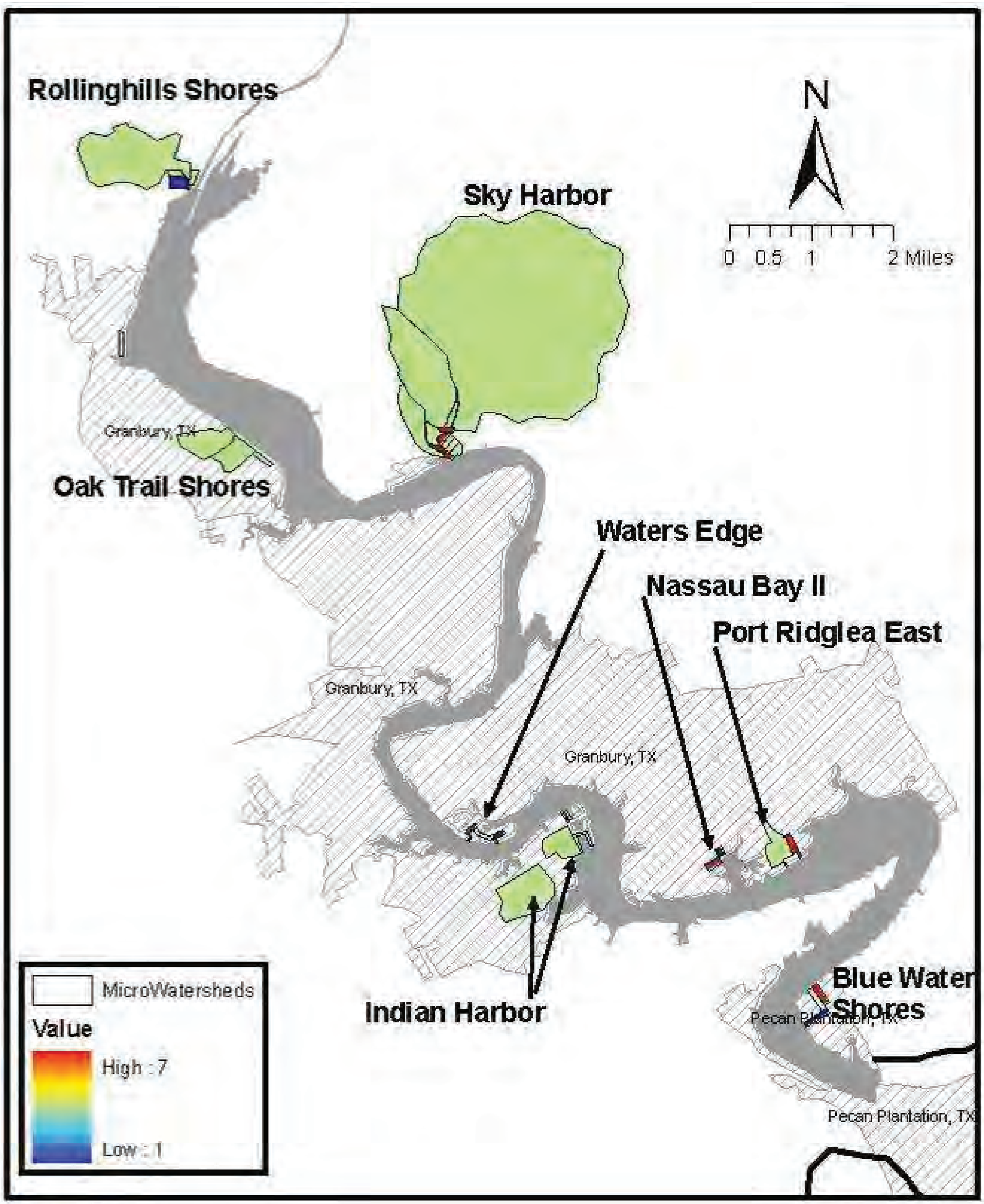


Figure D.22 PCF Ranking of Microwatersheds from Area Weighted Potential E. coli Loading from Non-point Sources

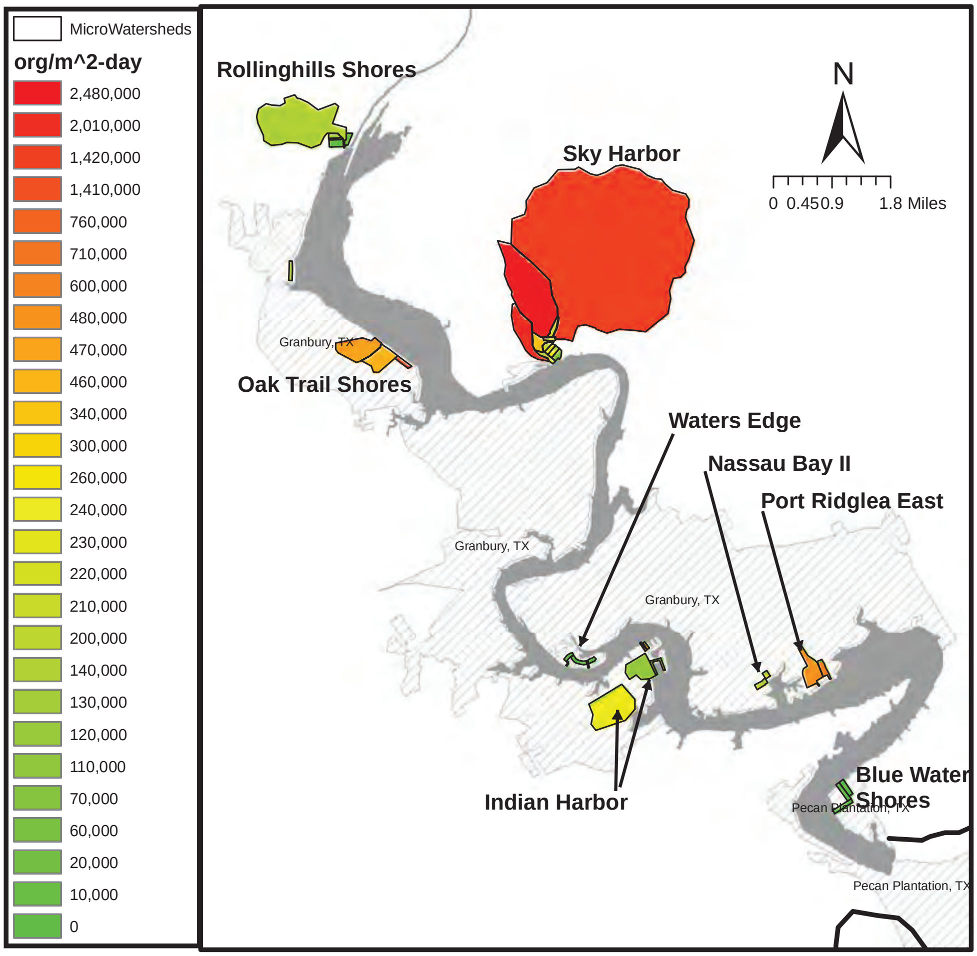


Figure D.23 Area Weighted Potential E. coli Loading from Non-point Sources

<u>Point Sources</u>

There are five wastewater treatment plant facilities operating within the greater Lake Granbury watershed (Figure D.9). The highest *E. coli* loading occurs upstream of the Blue Water Shores watershed followed by the Waters Edge watershed. These facilities contribute large amounts of treated effluents and could impact the environment if improper/inefficient treatment of wastewater were to occur. When localities are considering consolidating on-site wastewater treatment systems into municipal sewage systems, the local officials should take into account the amount of pollutants, such as *E. coli* and nutrients, that would be discharged as a direct point source (with virtually zero travel time or attenuation) if municipal systems are managed improperly.

D.3 Watershed Modeling Summary

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) was developed and automated to characterize the production of pathogens from various pollutant sources across a watershed. SELECT was applied to the greater Lake Granbury Watershed in Texas as well as for the micro-watersheds of particular subdivisions along the lake.

When potential *E. coli* loads simulated by SELECT are combined with the PCF module, decision makers can identify *E. coli* sources and areas of potential concern in a watershed. This will ultimately help decision makers choose cost effective BMPs to alleviate contamination issues in an impaired watershed. Once BMPs have been chosen, PCF analysis can be performed in order to determine the spatially explicit locations to implement source specific BMPs. The PCF results can also be used to determine the locations for water quality monitoring. Ideally, these locations should be in potential *E. coli* contributing areas and in areas where BMPs have been implemented to measure the success of the *E. coli* load reductions.

It is very possible that the water quality data will indicate a different scenario than the simulated loads using SELECT. In this case a more thorough investigation is imperative. It will be necessary to apply a more specific hydrologic simulation model to investigate pollutant loads reaching the lake waterbodies and canals.

D.4 Watershed Modeling References

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E.0 APPENDIX E: COVE AND CANAL MODELING, SETUP AND RESULTS

E.1 Methodology

Time-series mass balance models were developed for 10 representative subdivisions to address statkeholder concerns:

- Rolling Hills Shores
- Arrowhead Shores
- Oak Trail Shores
- Ports O' Call
- Indian Harbor
- Nassau Bay
- Sky Harbor
- Port Ridglea East
- Blue Water Shores
- Waters Edge

Model results for each subdivision are presented in this appendix. A description of the scenarios and interpretive methods is provided in the WPP document.

E.2 Lake modeling Results

E.2.1 Rolling Hills Shores

The cove/canals connected to Rolling Hills Shores were subdivided into five segments (Figure E.1) for bacteria modeling. The contributing micro-watersheds (Figure E.2) are generally composed of shorelines adjacent to each segment, except segment 5 which includes a larger watershed contribution from undeveloped land.

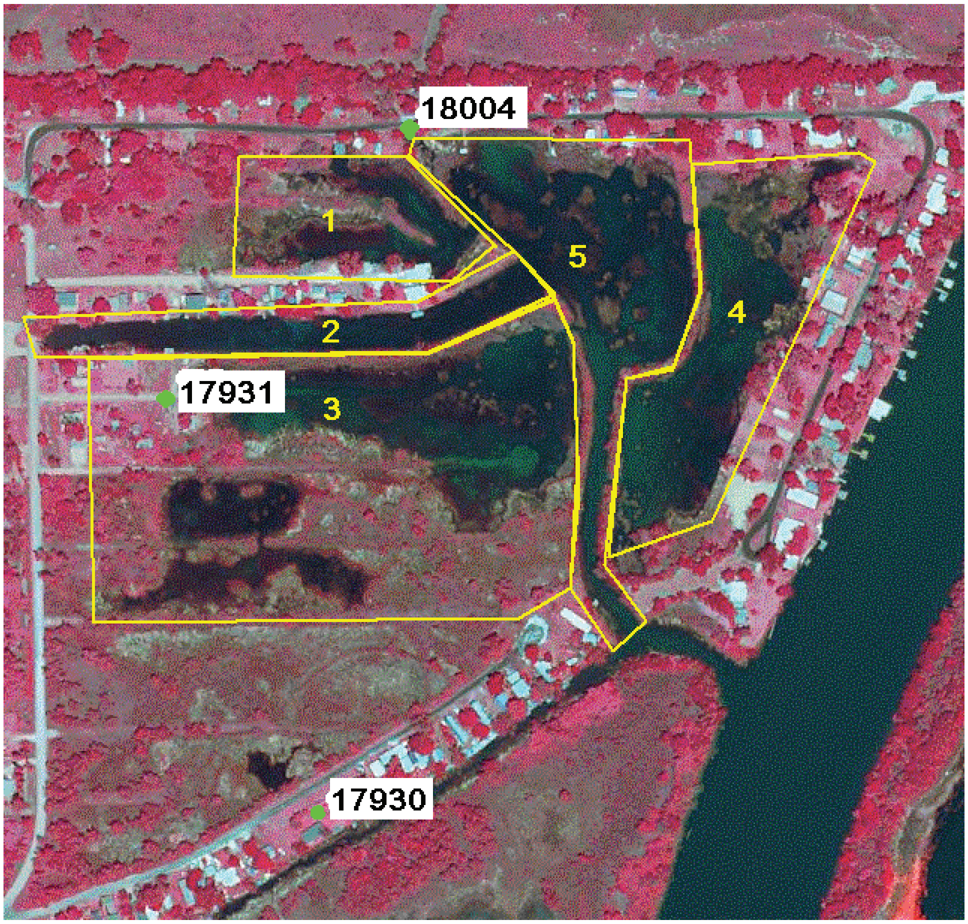


Figure E.1Canal Segmentation for Rolling Hills Shores

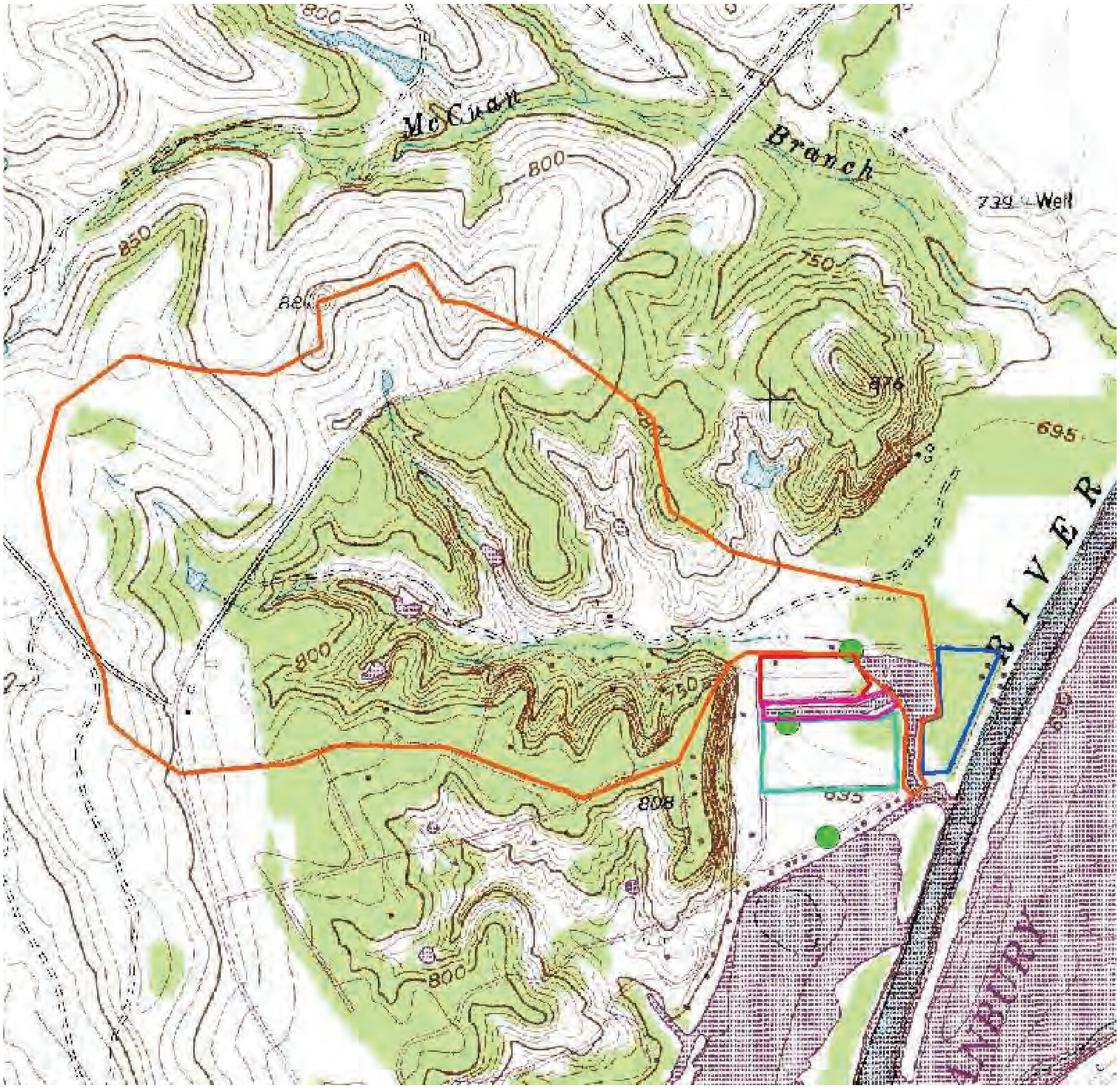
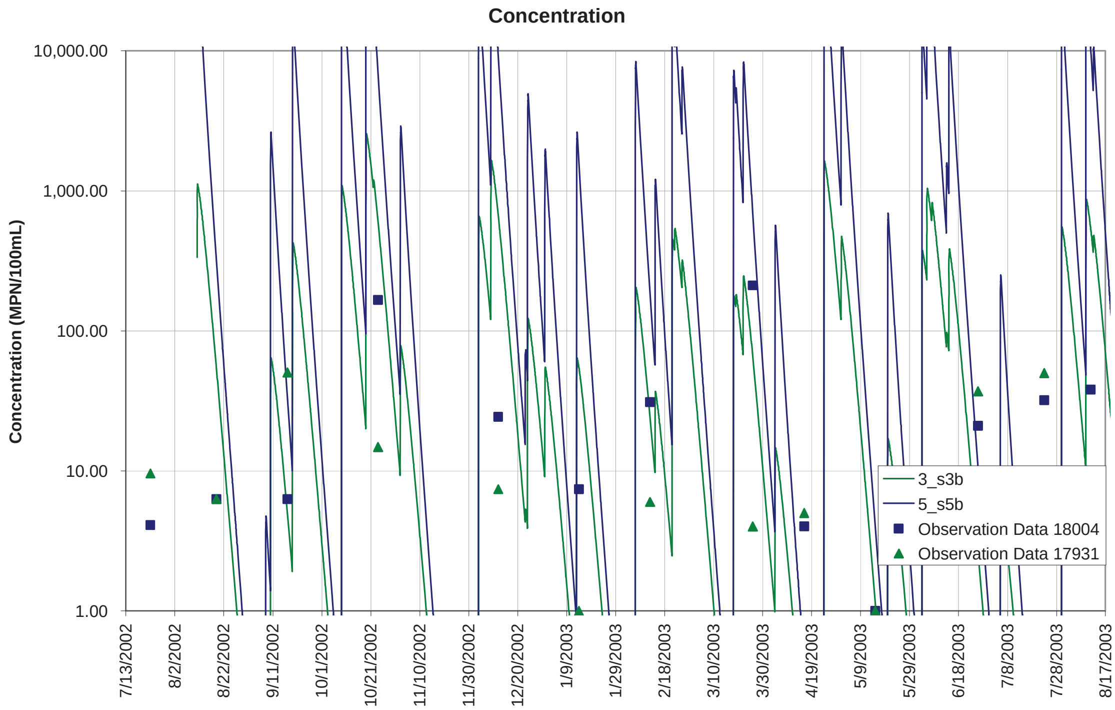


Figure E.2. Microwatershed Delineation for Rolling Hills Shores canals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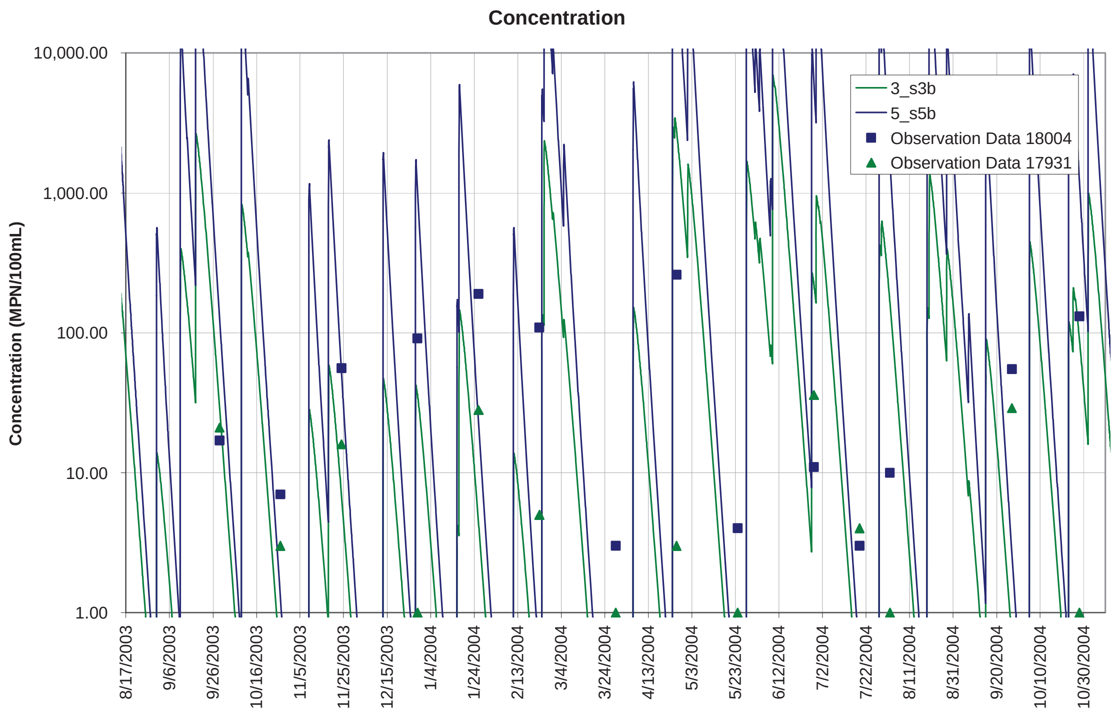
Observation Data 18004
Observation Data 17931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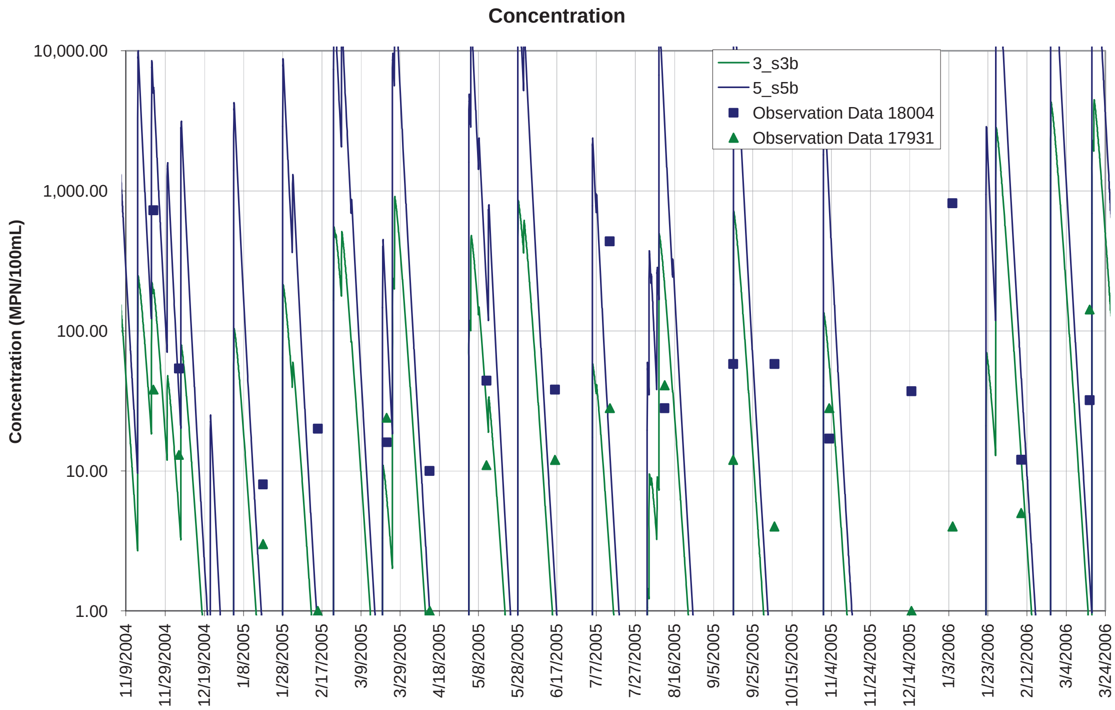
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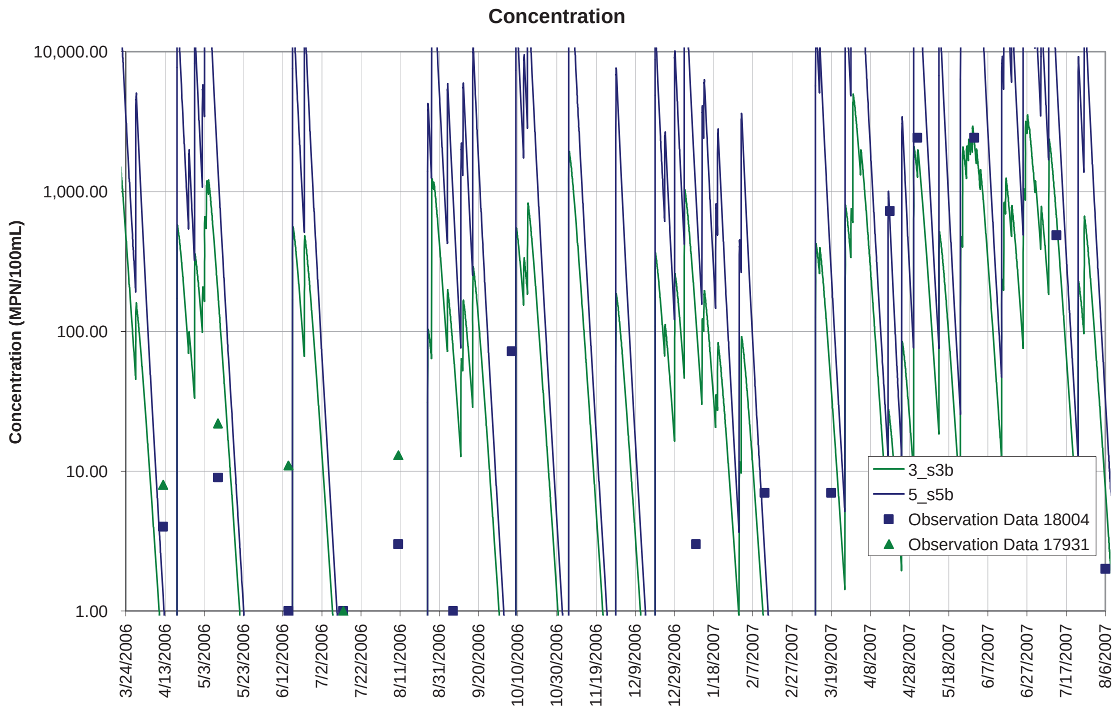
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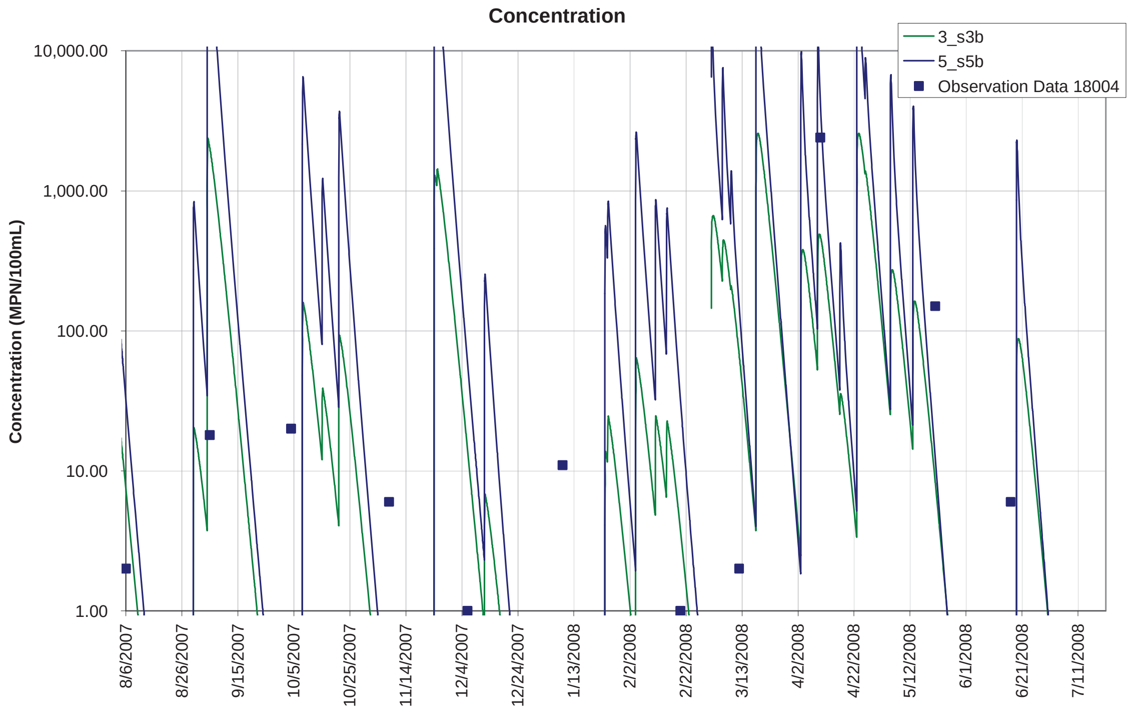


Figure E.3 Runoff model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Stations 18004 and 17931 located within the Rolling Hills Shores Canals

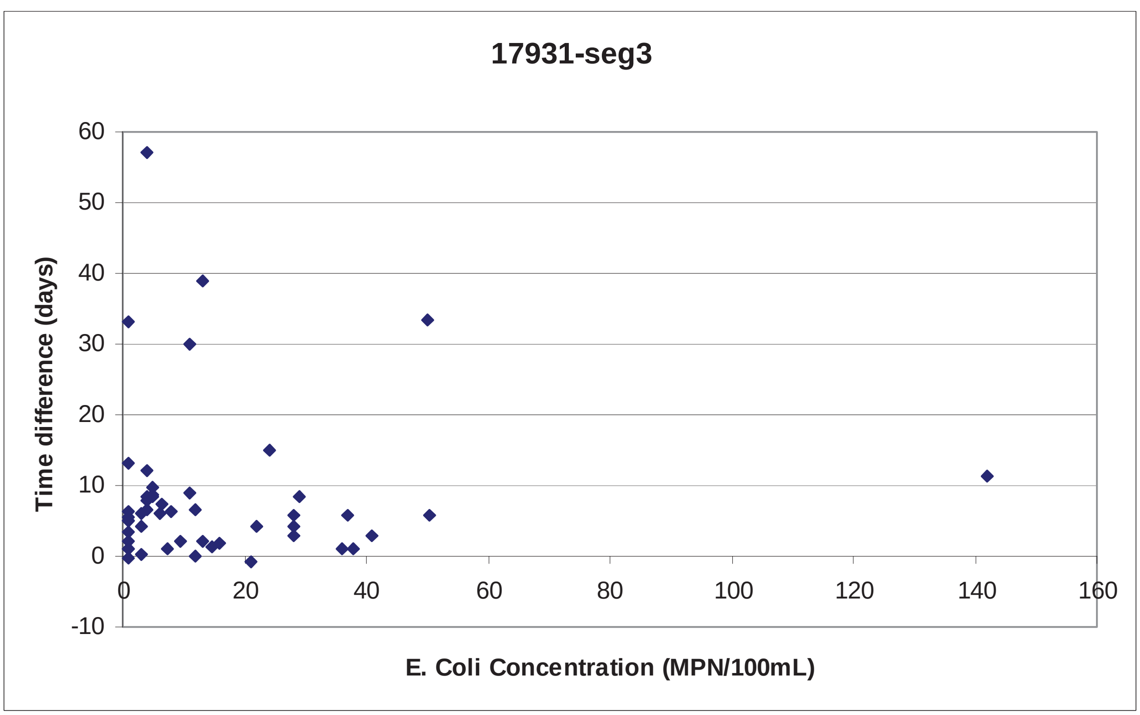


Figure E.4 Residual Plot for Station 17931 located within the Rolling Hills Shores Canals

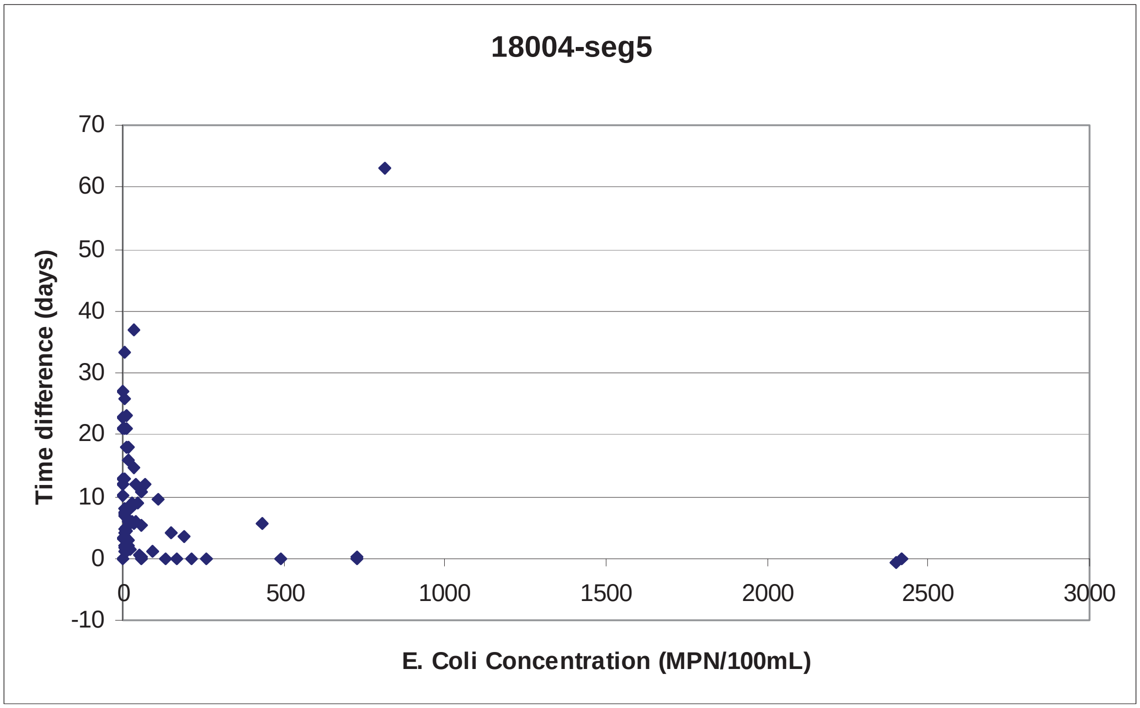


Figure E.5 Residual Plot for Station 18004 located within the Rolling Hills Shores Canals

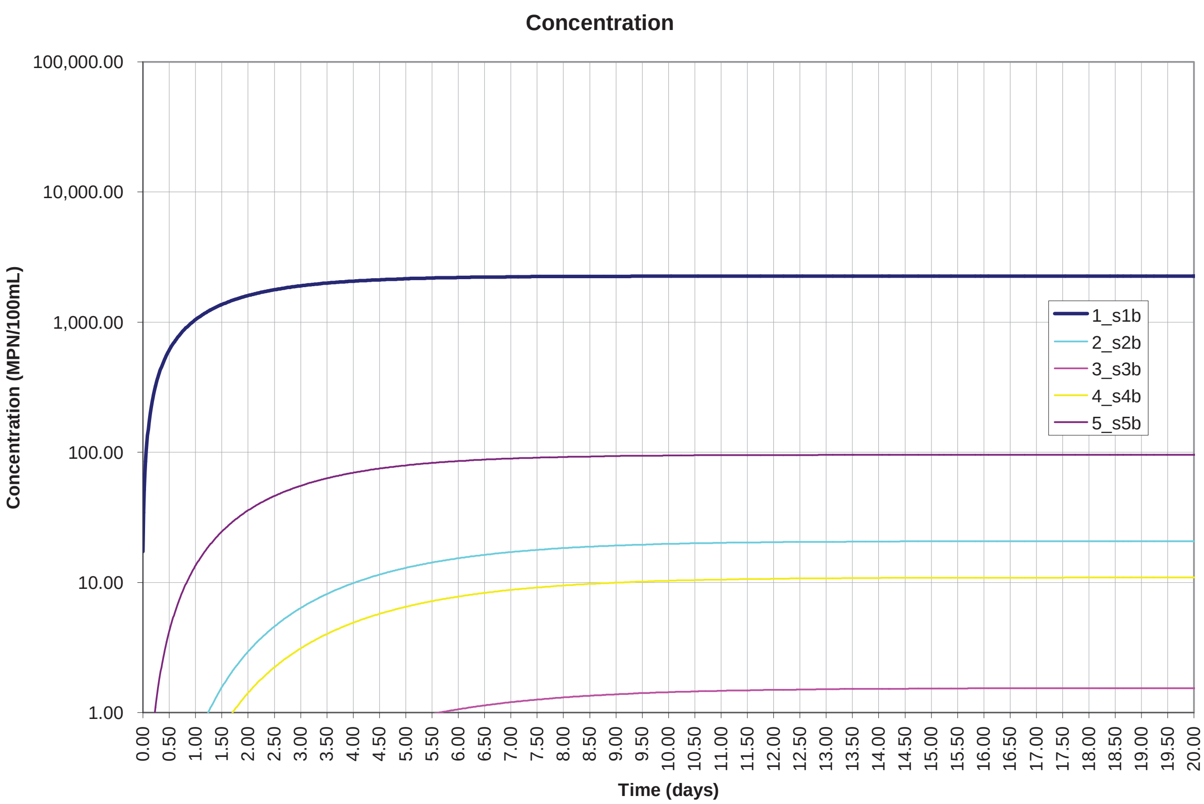


Figure E.6 Modeled Continuous Direct Discharge (septic) for Rolling Hills Shores

E.2.2 Arrowhead Shores

Model segmentation was conducted according to flow directions and canal geometry. The Arrowhead Shores canal system is divided into five segments as shown in Figure E.7. Mass balance using Equation E-1 is calculated for each segment in the spreadsheet model. The flow directions are: 1→2, 2→5, 3→4, 4→5, 5→lake. The microwatershed for this canal system is isolated to a small region immediately adjacent to the canal (Figure E.8).

Figure E.7 Canal Segmentation for Modeling Arrowhead Shores

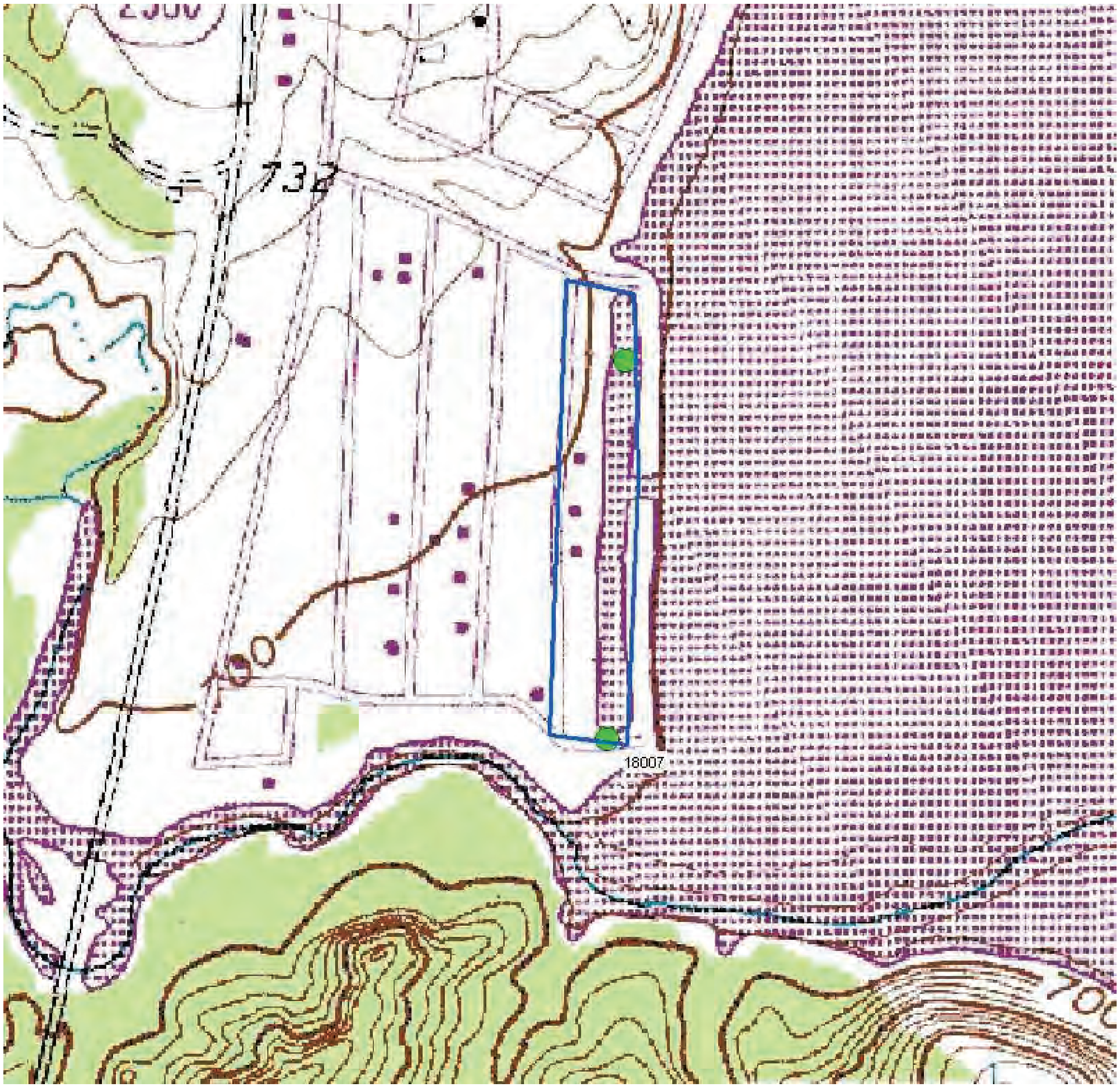
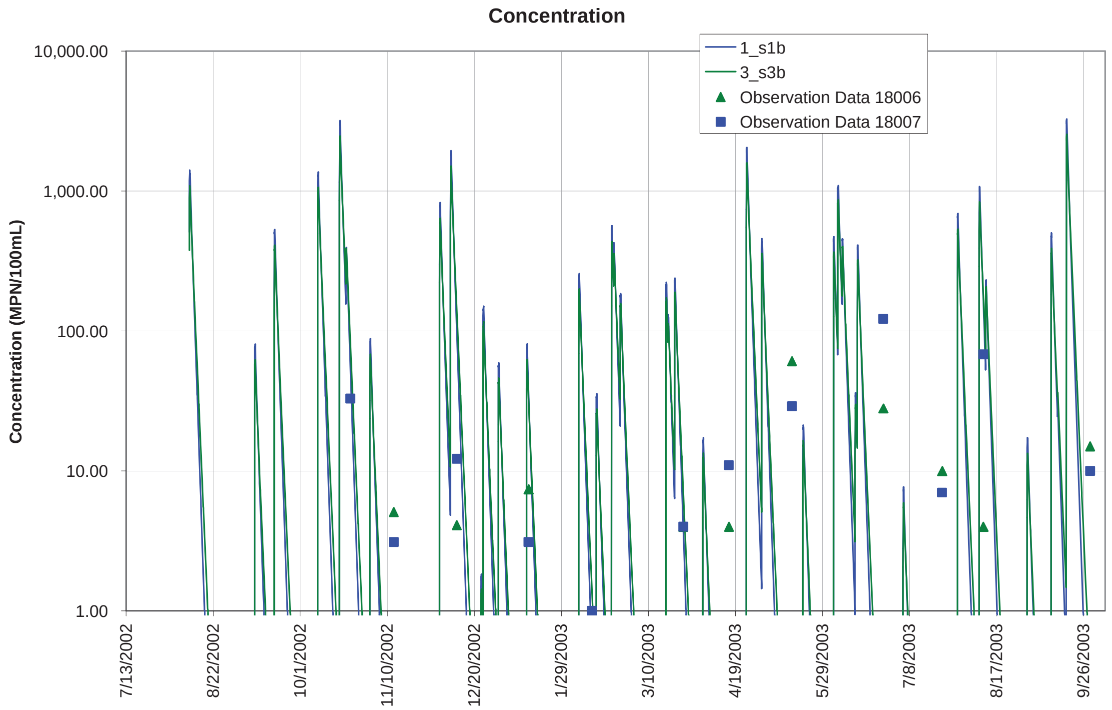


Figure E.8 Microwatershed Delineation for Arrowhead Shores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Observation Data 18006
Observation Data 18007
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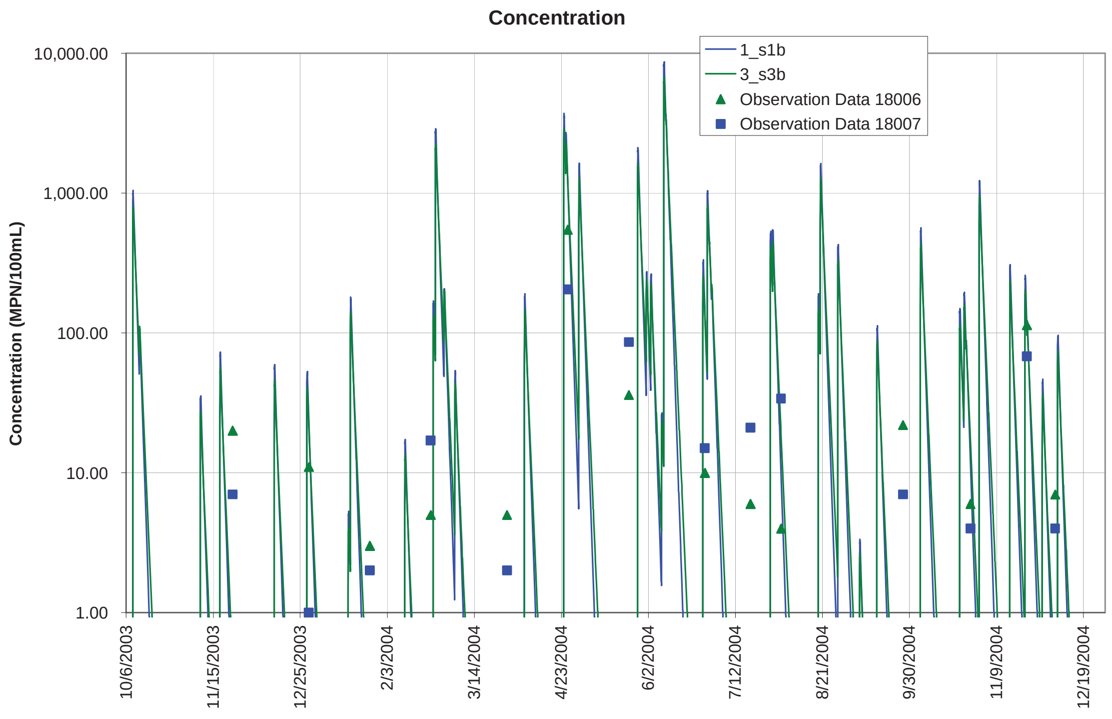
4/19/2003
5/29/2003
7/8/2003
8/17/2003
9/26/2003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3_s3b
Observation Data 18006
Observation Data 18007
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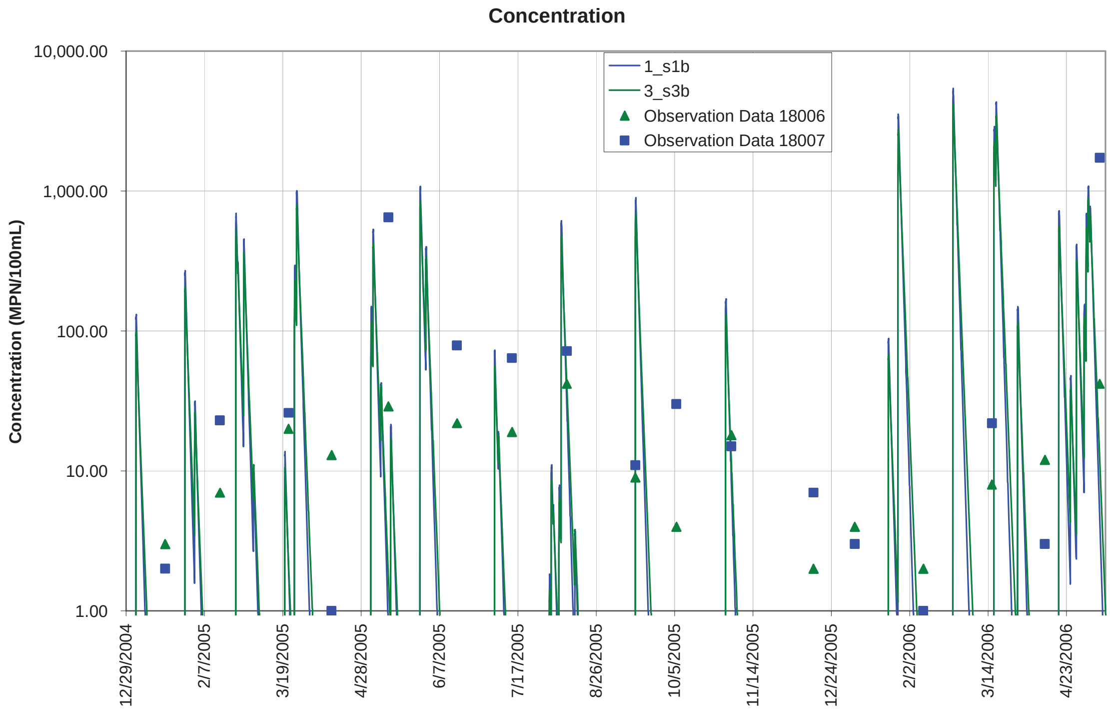
100.00
10.00
1.00
10/6/2003
11/15/2003
12/25/2003
2/3/2004
3/14/2004
4/23/2004
6/2/2004
7/12/2004
8/21/2004
9/30/2004
11/9/2004
12/19/2004


Concentration
Concentration (MPN/100mL)
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1,000.00
100.00
10.00
1.00
1_s1b
3_s3b
Observation Data 18006
Observation Data 18007
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2/7/2005
3/19/2005
4/28/2005
6/7/2005
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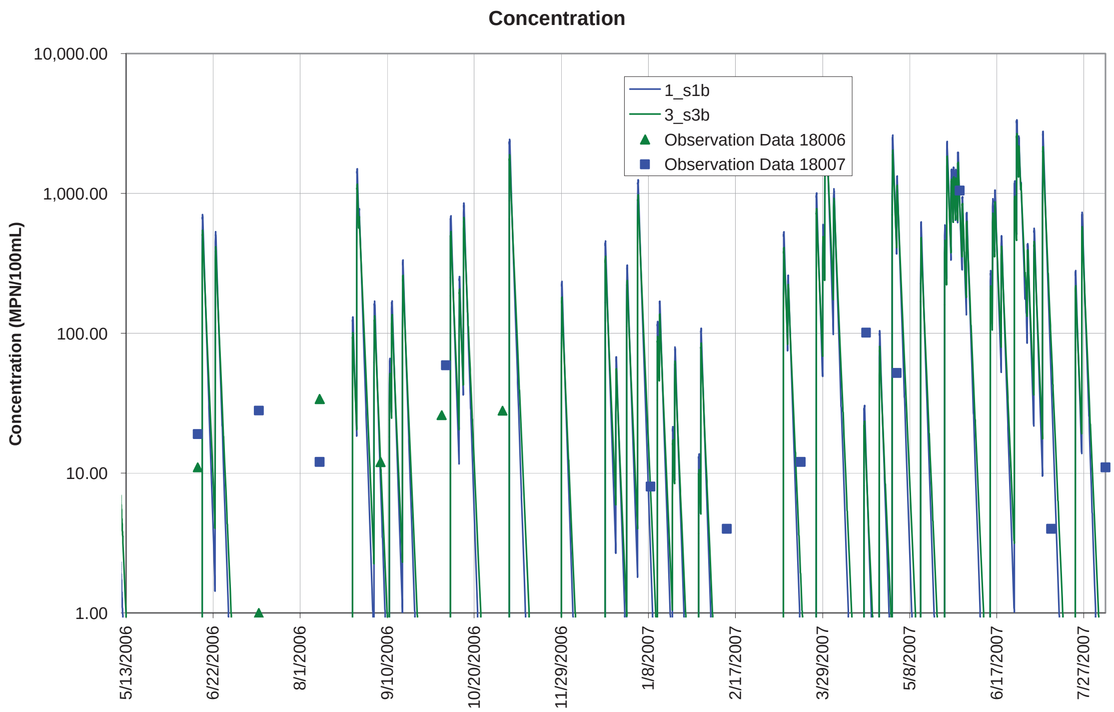
3/14/2006
4/23/2006


Concentration
Concentration (MPN/100mL)
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1,000.00
100.00
10.00
1.00
1_s1b
3_s3b
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Observation Data 18007
5/13/2006
6/22/2006
8/1/2006
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6/17/2007
7/27/2007

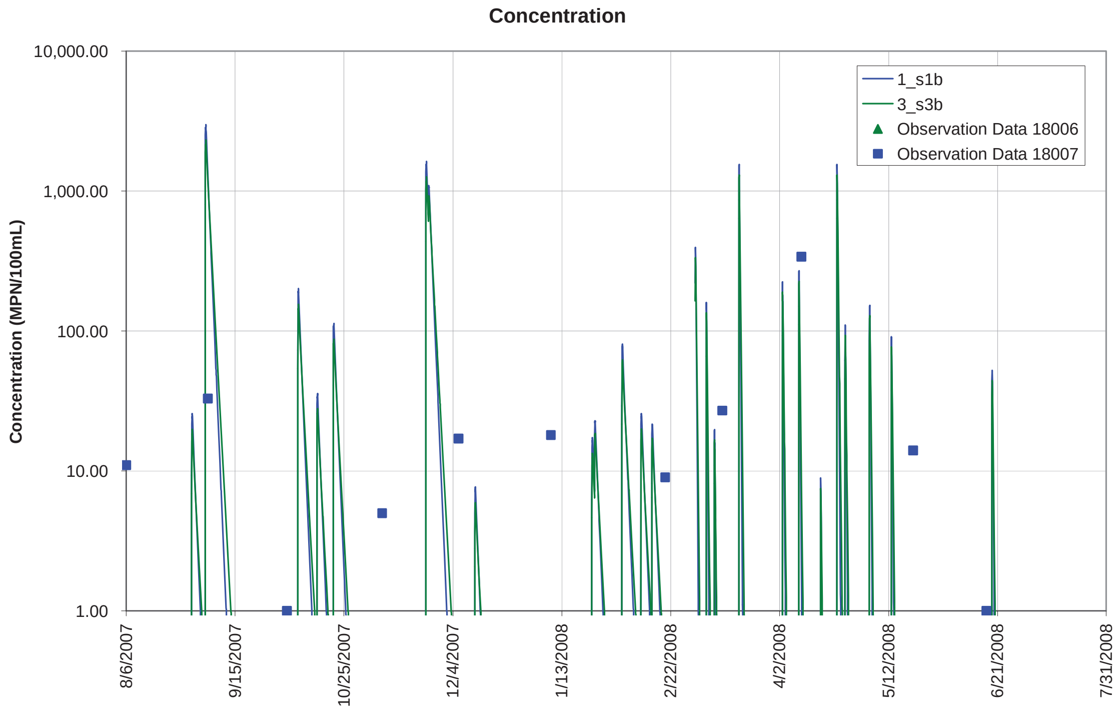


Figure E.9 Runoff model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Stations 18006 and 18007 located within the Arrowhead Shores Canals

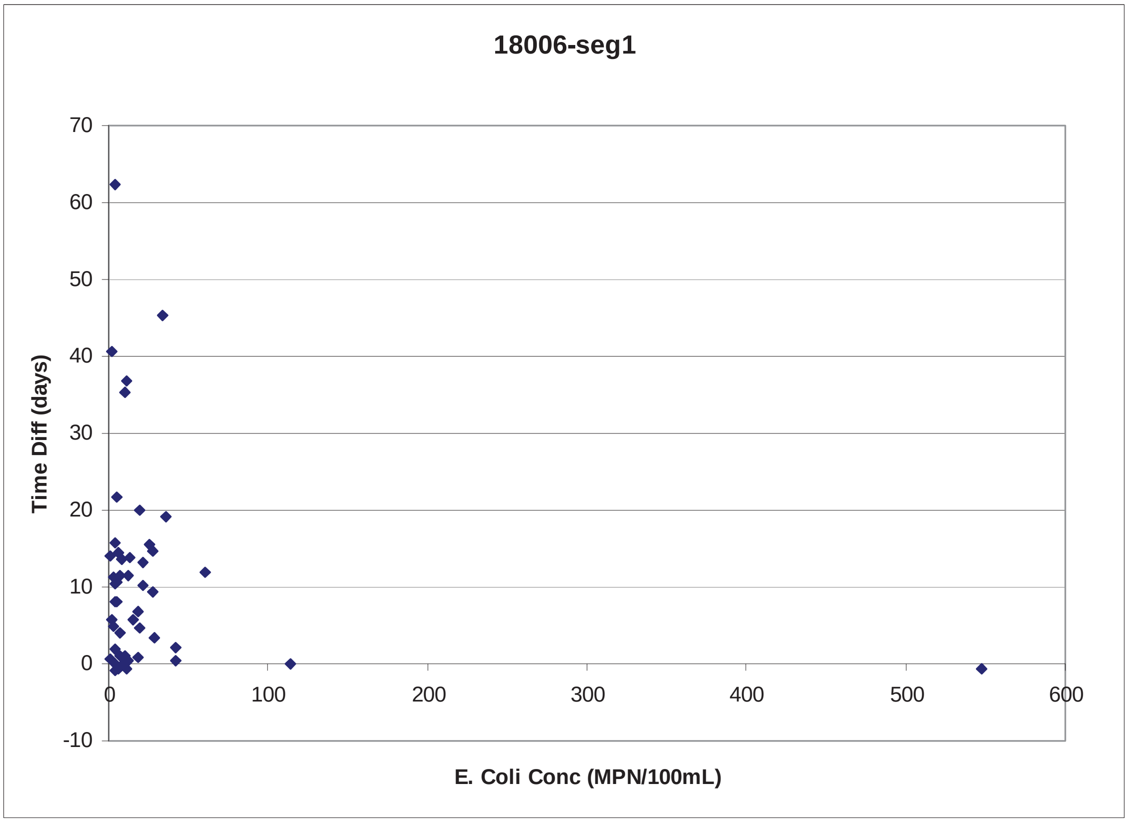


Figure E.10 Residual Plot for Station 18006 located within the Arrowhead Shores Canals

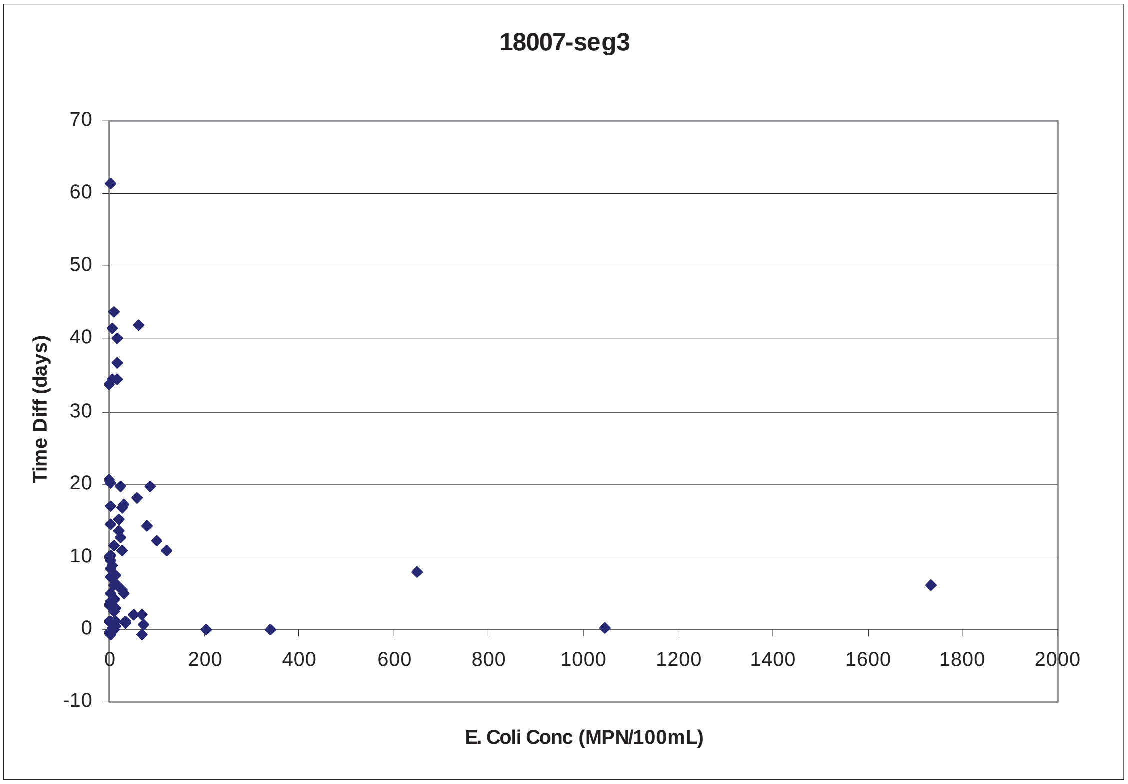


Figure E.11 Residual Plot for Station 18007 located within the Arrowhead Shores Canals

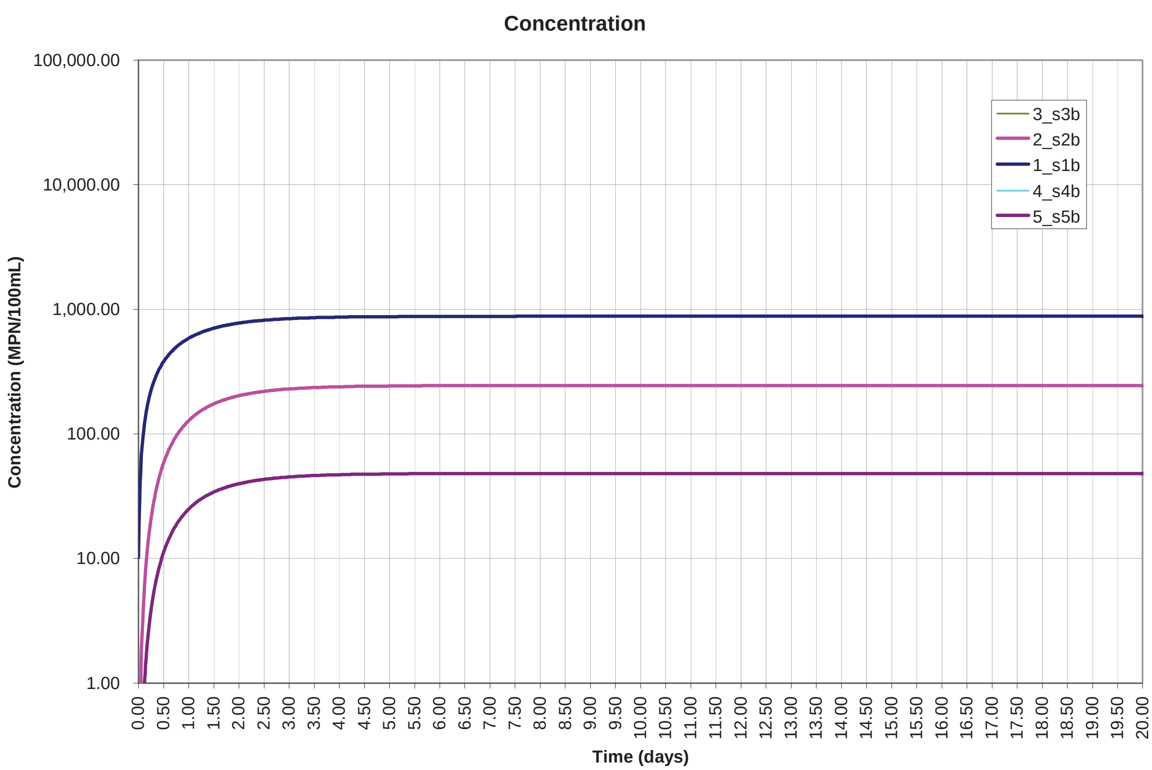


Figure E.12 Modeled Continuous Direct Discharge (septic) in Arrowhead Shores

E.2.3 Oak Trail Shores

Model segmentation was conducted according to flow directions and canal geometry. The Oak Trail Shores canal system is divided into five segments as shown in Figure E.13. Mass balance using Equation E-1 is calculated for each segment in the spreadsheet model. The flow directions are: 1→2, 2→5, 3→4, 4→5, 5→lake. Approximate dimensions and volumes of each segment are tabulated in Table E-1 for Oak Trail Shores.

Table E-1. Dimensions and Volumes for each segment in Oak Trail Shores

Segment	1	2	3	4	5
Length (m)	169.3	161.6	173.7	183.7	107.3
Width (m)	8.9	9.5	9.8	9.8	9.2
Depth (ft)	3.4	3.4	3.7	3.7	4.5
Depth (m)	1.04	1.04	1.13	1.13	1.37
Volume (m^3)	1561	1591	1920	2030	1354
Volume (L)	1561496	1590958	1919741	2030261	1353989

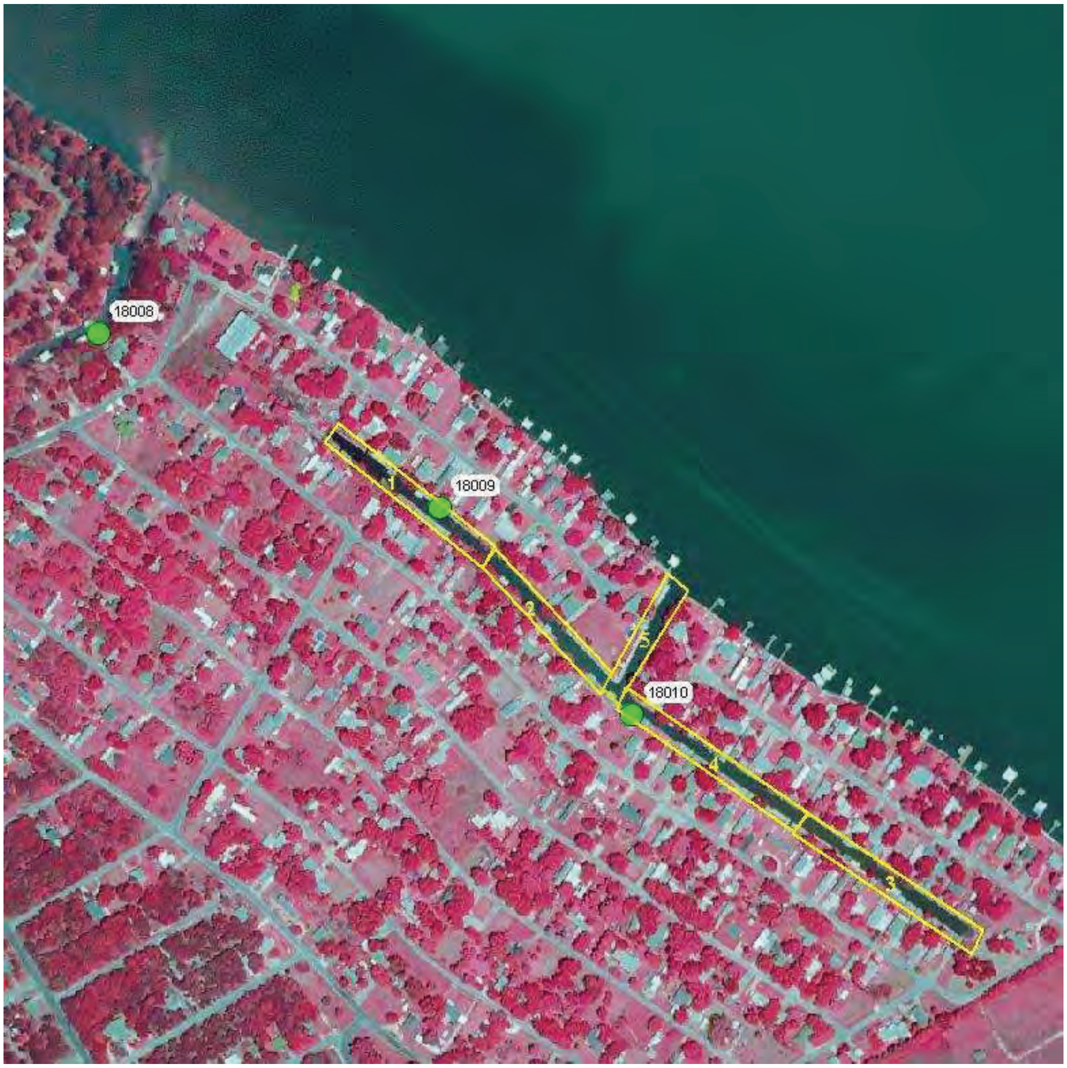


Figure E.13 Canal Segmentation for Modeling Oak Trail Shores

There are three micro-watersheds around the Oak Trail Shores canal system (Figure E.14), which are numbered as Watershed 1 (red polygon), 2 (yellow polygon) and 3 (green polygon). The respective areas for Watersheds 1, 2, and 3 are 110 acres, 76 acres and 58 acres.

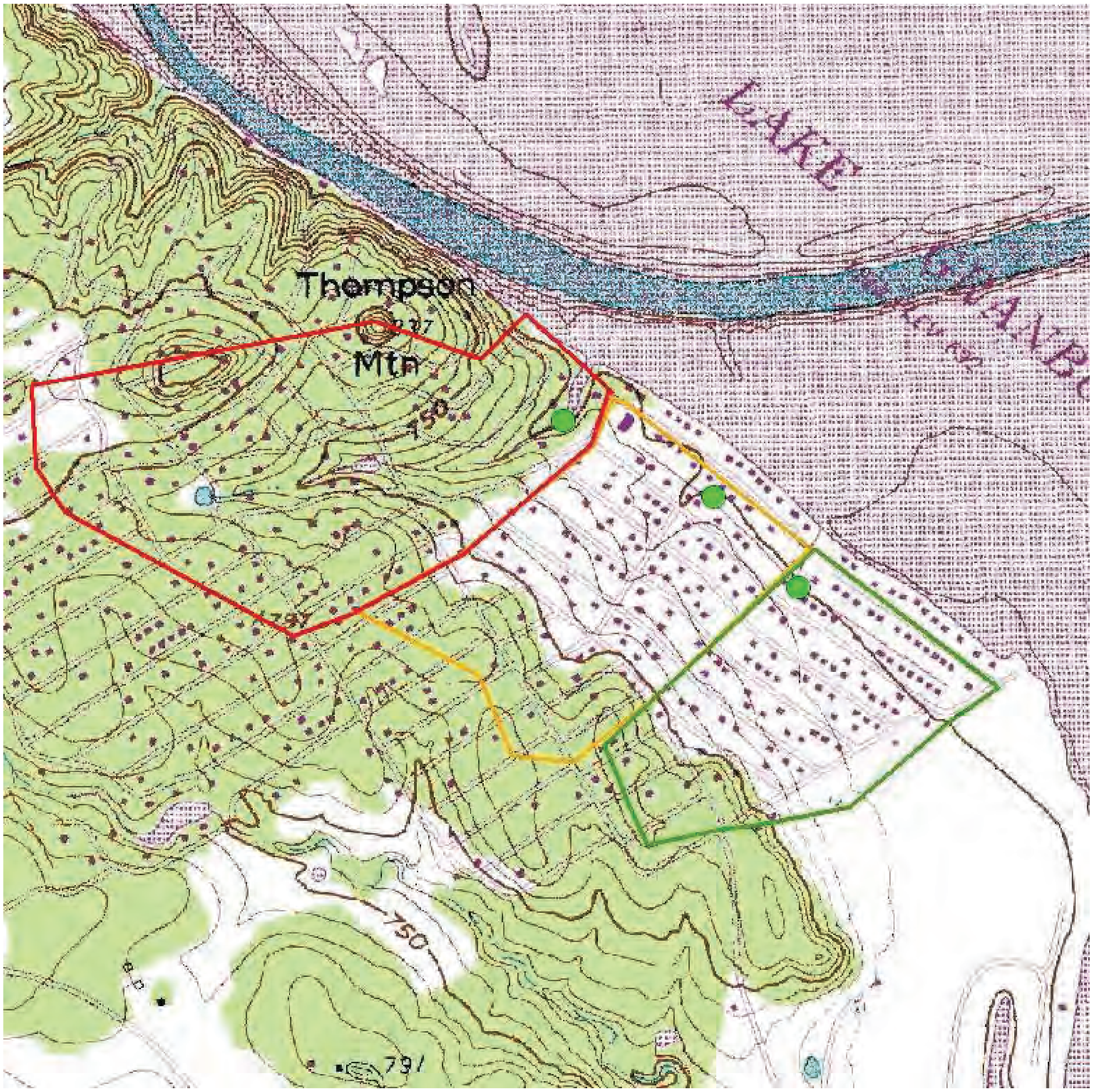
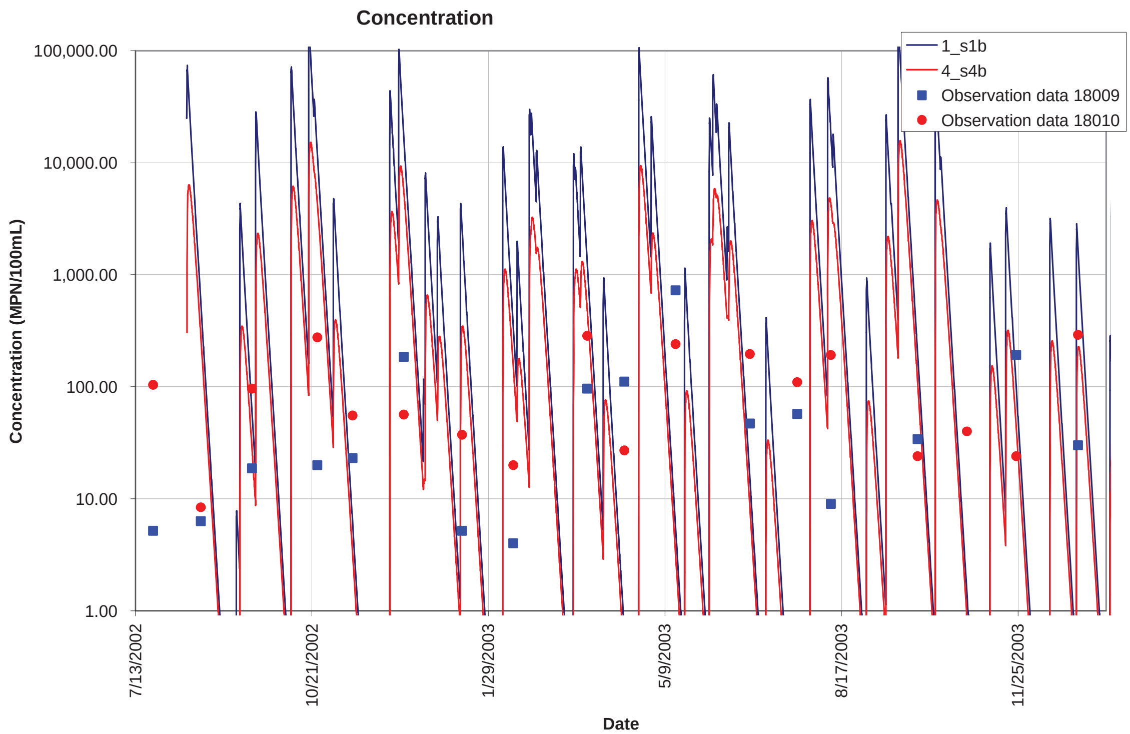


Figure E.14 Microwatershed Delineation for Oak Trail Shores

Residual plots of non-point source loads from Oak Trail Shores are shown in Figure E.19 and Figure E.20. The time difference between monitoring bacteria concentration at station 18009 and the model predicted bacteria level in segment 1 is illustrated in Figure E.15. The time difference between monitoring bacteria concentration at station 18010 and the model predicted bacteria level in segment 4 is also plotted in Figure E.15.

The plots are indicators of correspondence between model outputs and observed bacteria concentration. High bacteria concentration in the Oak Trail Shores area correspond to predicted rainfall-induced non-point source loadings (such as area-wide septic system malfunction and pets), while lower background bacterial levels were from other sources (potentially from septic failures or pets adjacent to the canal).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4_s4b
Observation data 18009
Observation data 18010
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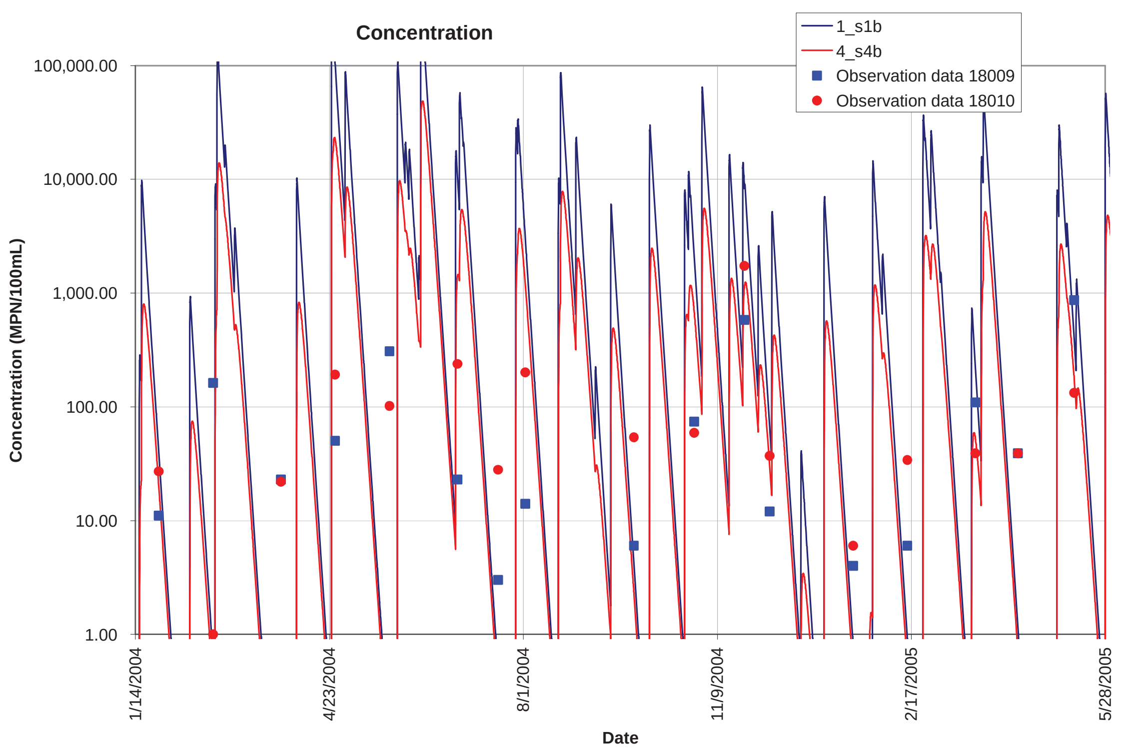
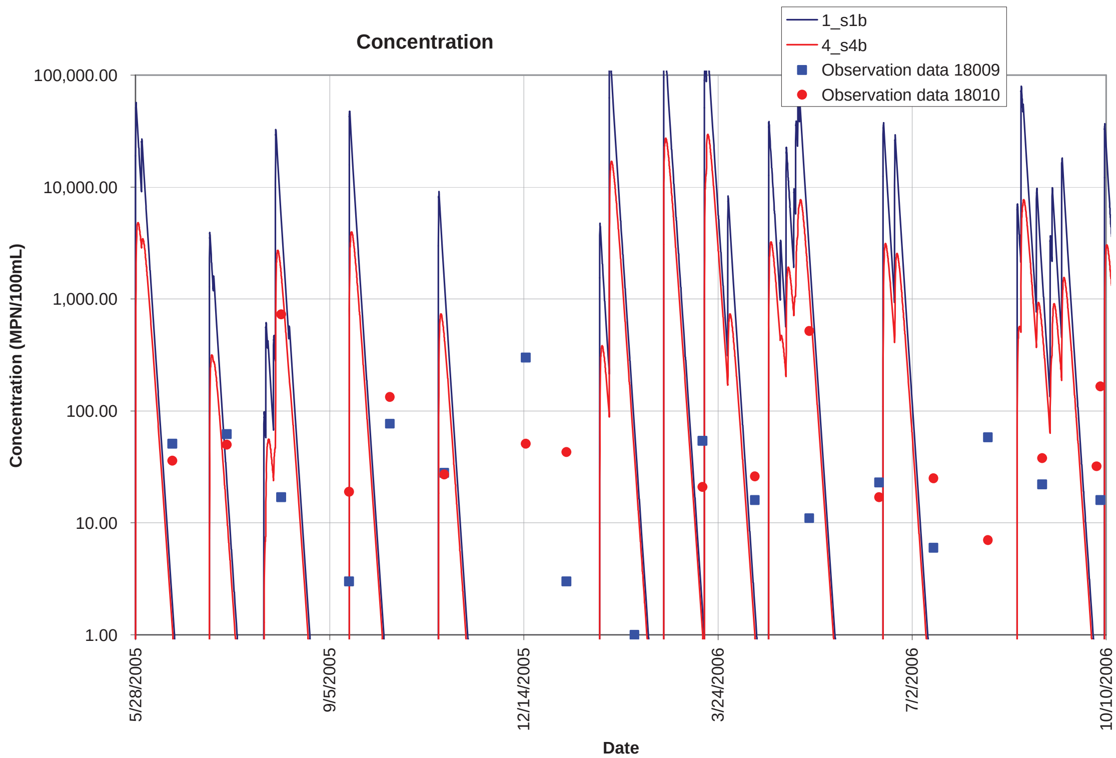
10,000.00
1,000.00
100.00
10.00
1.00
Concentration (MPN/100mL)
7/13/2002
10/21/2002
1/29/2003
5/9/2003
8/17/2003
11/25/2003
Date


Concentration
1_s1b
4_s4b
Observation data 18009
Observation data 18010
100,000.00
10,000.00
1,000.00
100.00
10.00
1.00
Concentration (MPN/100mL)
1/14/2004
4/23/2004
8/1/2004
11/9/2004
2/17/2005
5/28/2005
Date



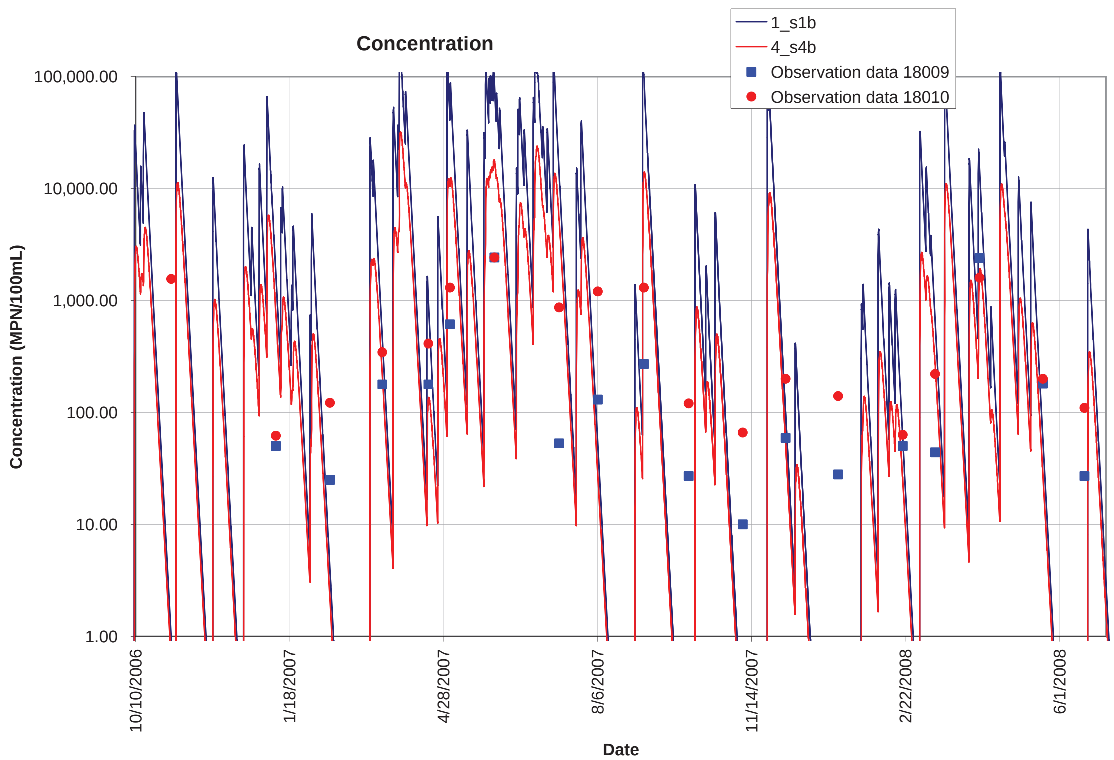


Figure E.15 Runoff Model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Stations 18009 and 18010 located within the Oak Trail Shores Canals

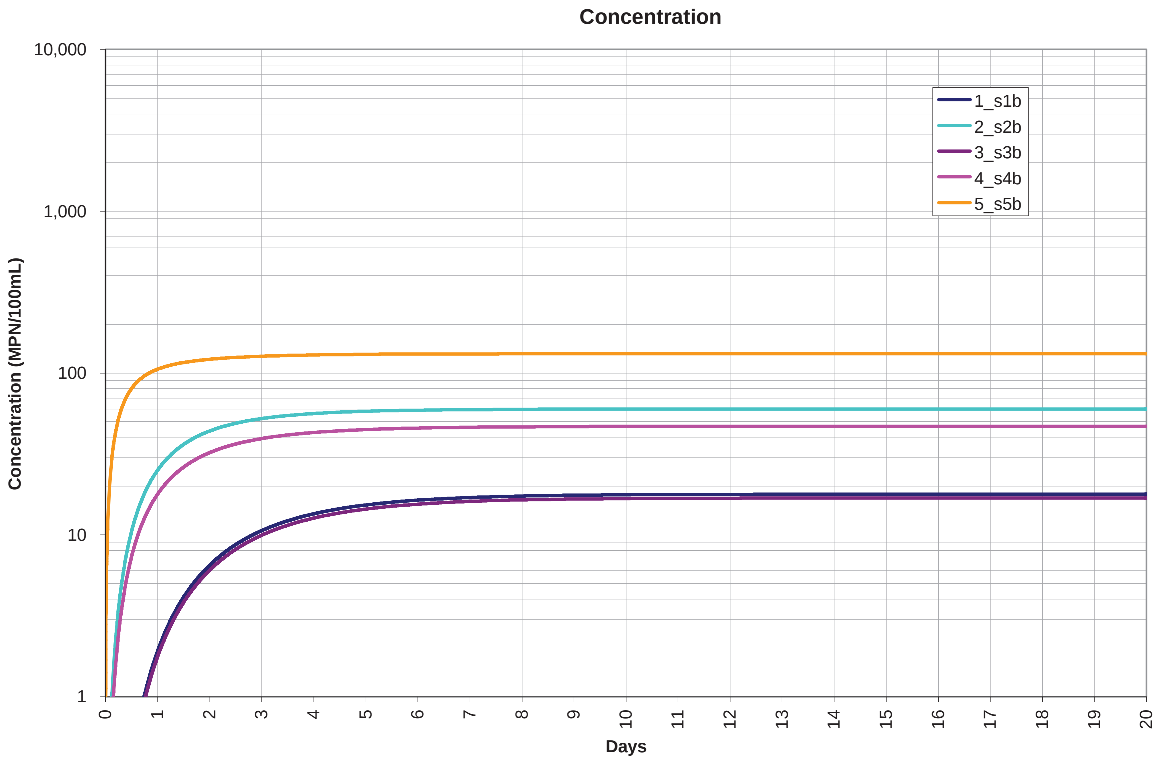


Figure E.16 Modeled Lake Boundary Condition for Oak Trail Shores Canals

The Oak Trail Shores canal was modeled with 1 residence discharging continuously to segment 1 (Figure E.17), the steady state concentration in segment 1 after 10-15 days is predicted at about 482,700 MPN/100mL. If the malfunction percentage is 10%, the steady state concentration in segment 1 is achieved in 10-15 days as 48,270 MPN/100mL.

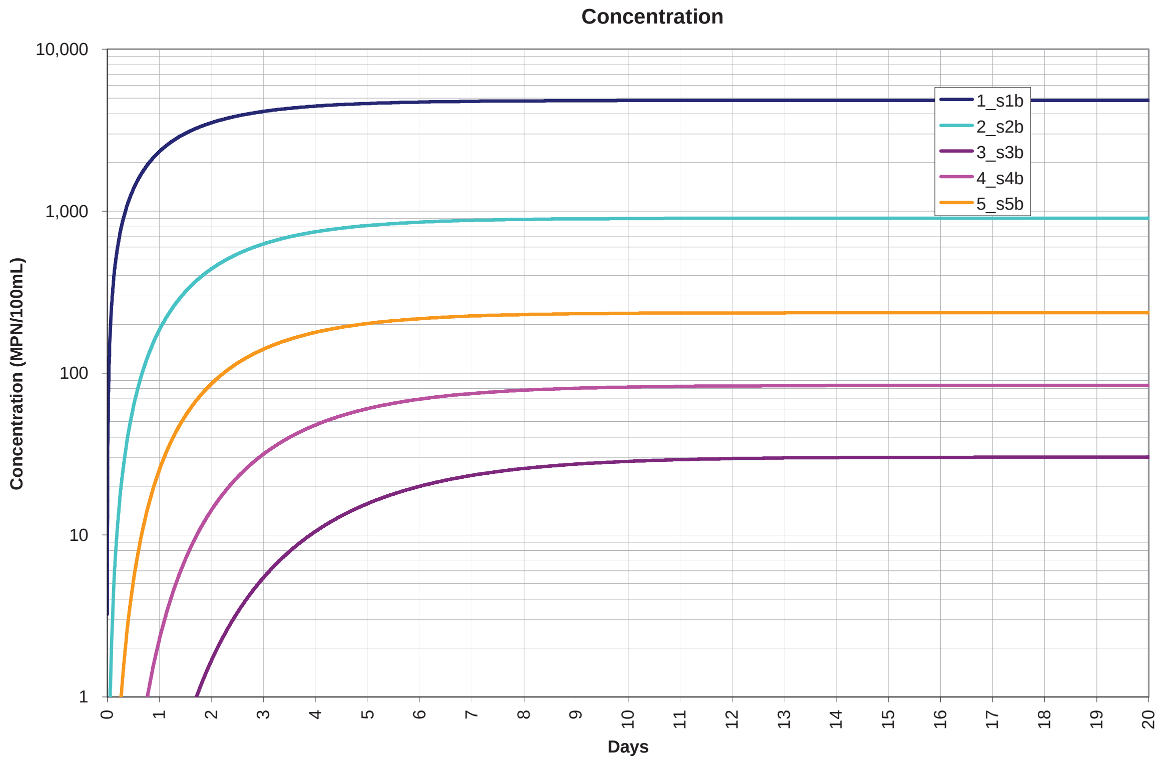


Figure E.17 Modeled Continuous Direct Discharge (septic) in Oak Trail Shores Canals

Another scenario was modeled to evaluate an intermittent point source. This scenario represents a short-duration septic system discharge into the cove water, as exhibited by a 33.3 gallon discharge of raw sewage into the canal. This load is consistent with 4 hours (or 1/6 of a day's effluent) for one residential household. A maximum concentration of approximately 500 MPN/100mL is predicted by the Oak Trail Shores model, with concentration staying above the stakeholder goal of 53 MPN/100ml for 3.5 days following the one-time discharge (Figure E.18).

Model results at this location indicate that a local concentration far in excess of the state water quality standards (geometric mean of 126 MPN/100mL) can be achieved with only one residence continuously discharging all sewage directly to the canal. In addition, short duration discharges from a single residence can result in locally-high bacteria concentrations.

Considering bacteria monitoring does not indicate high concentrations as high as those predicted by this scenario, a continuous and complete septic system malfunction is not likely a typical failure mode in this area. Rather, order-of-magnitude comparisons of data and model predictions indicate that a more typical failure mode is one that is intermittent (occurs only under certain high-stress conditions, e.g., during a large family gathering), a failure mode that is incomplete (only a small proportion of sewage is emitted) and/or a combination of intermittent/incomplete failures by one or more systems.

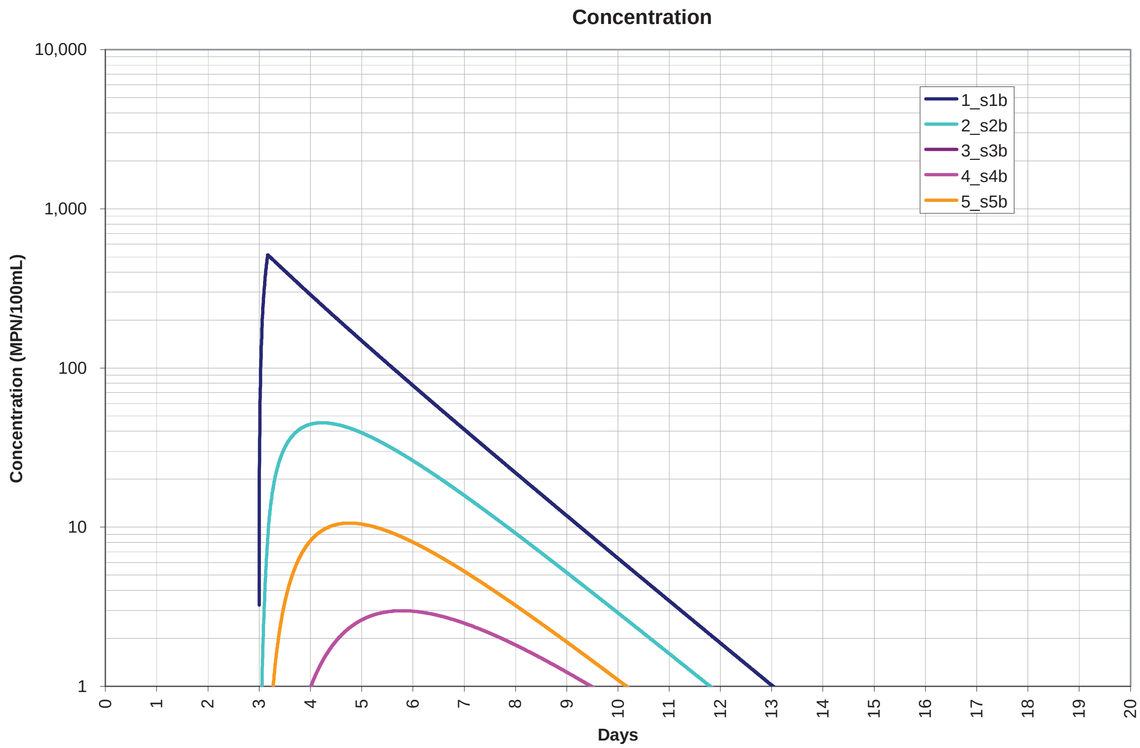


Figure E.18 Modeled Intermittent Direct Discharge (septic overload) in Oak Trail Shores Canals

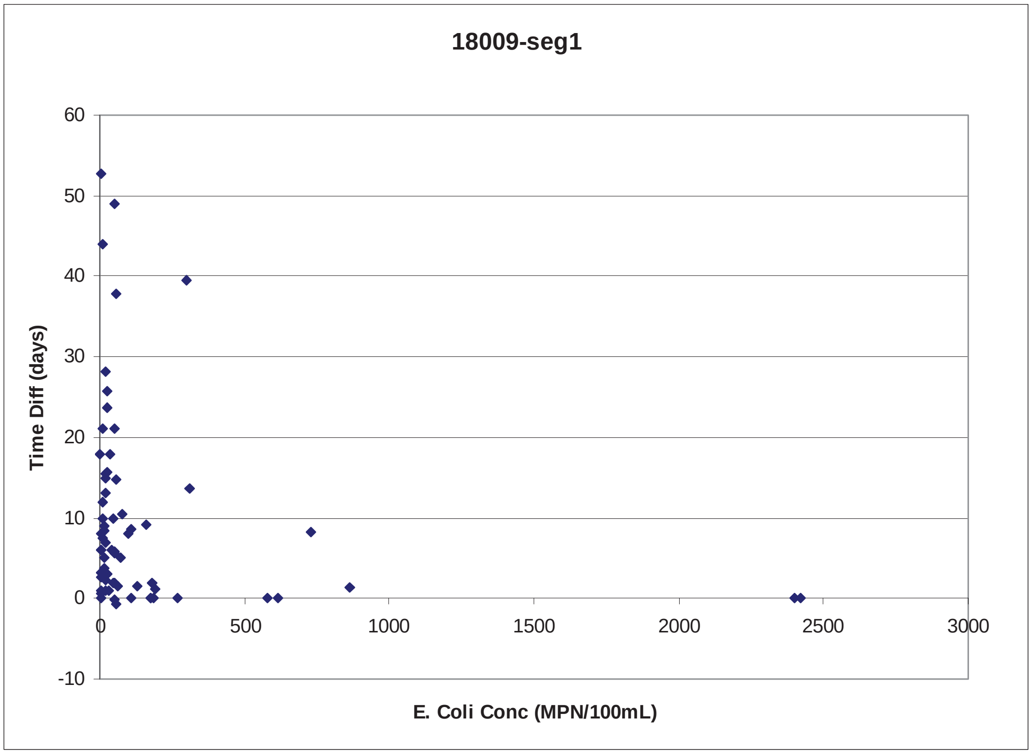


Figure E.19 Residual Plot for Station 18009 located within the Oak Trail Shores Canals

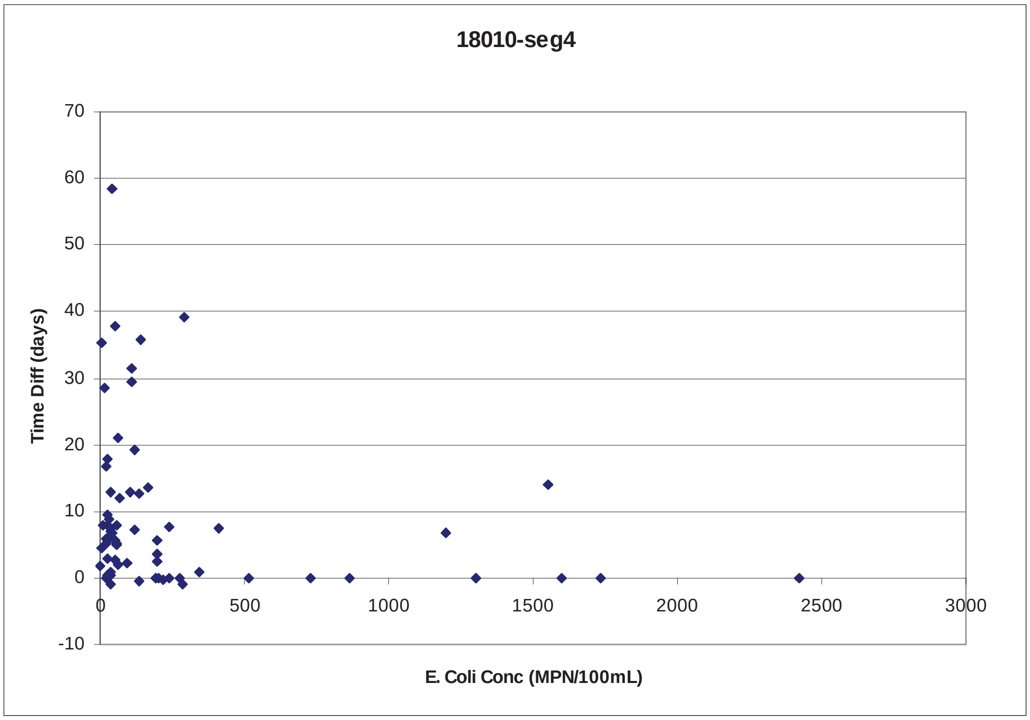


Figure E.20 Residual Plot for Station 18010 located within the Oak Trail Shores Canals

E.2.4 Sky Harbor

The Sky Harbor canal system was broken into 11 segments for the mass balance model. The flow direction is 1→4, 2→4. 3→4, 4→6, 5→6, 6→11, 7→11, 8→11, 9→11, 10→11, 11→lake. Mass balance using Equation E-1 is calculated for each segment in the spreadsheet model. Approximate dimensions and volumes of each segment are provided in Table E-2.

Table E-2. Dimensions and Volumes for each segment in Sky Harbor

Segment	1	2	3	4	5	6
Length (m)	223.0	96.3	245.0	292.0	130.0	389.0
Width (m)	6.1	12.6	13.5	19.6	42.0	39.0
Depth (ft)	4.5	7.3	6.7	8.3	9.0	9.0
Depth (m)	1.37	2.23	2.04	2.53	2.74	2.74
Volume (m3)	1,865.79	2,699.82	6,754.44	14,478.78	14,977.87	41,617.09
Volume (L)	1,865,787	2,699,819	6,754,444	14,478,780	14,977,872	41,617,087

Segment	7	8	9	10	11
Length (m)	187.0	251.5	232.0	305.4	320.0
Width (m)	17.6	20.1	71.5	16.9	62.0
Depth (ft)	5.3	7.0	9.8	10.9	11.0
Depth (m)	1.62	2.13	2.99	3.32	3.35
Volume (m3)	5,316.74	10,785.67	49,549.02	17,147.36	66,519.55
Volume (L)	5,316,736	10,785,668	49,549,020	17,147,357	66,519,552

Figure E.21 Canal Segmentation for Modeling Sky Harbor

There are several small micro-watersheds near canal segments 5, 7, 8, and 9 and larger micro-watersheds for the other canals.

High bacteria concentration correspond to predicted rainfall-induced non-point source loadings. This is expected since these canals are influenced by larger watersheds

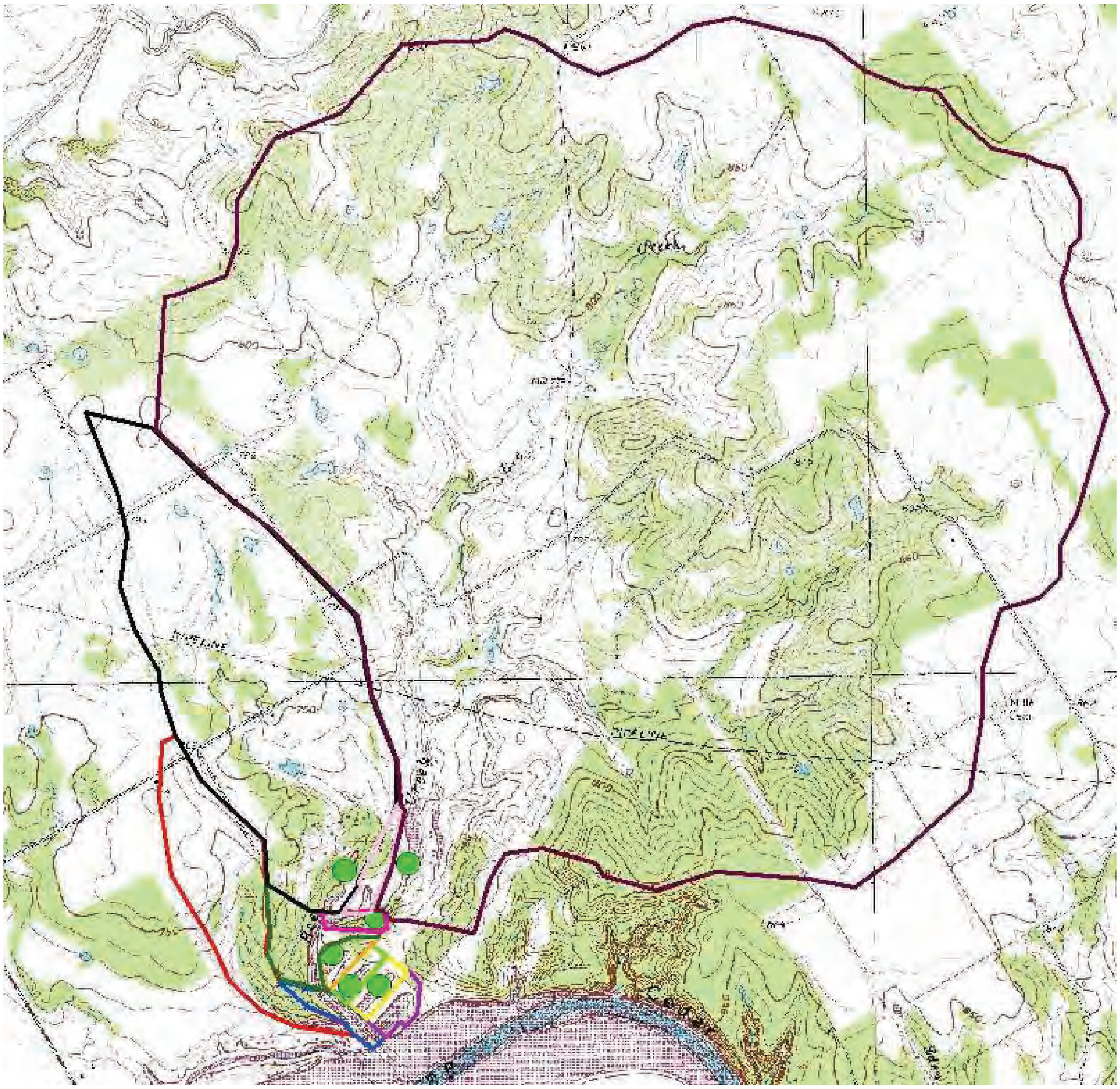
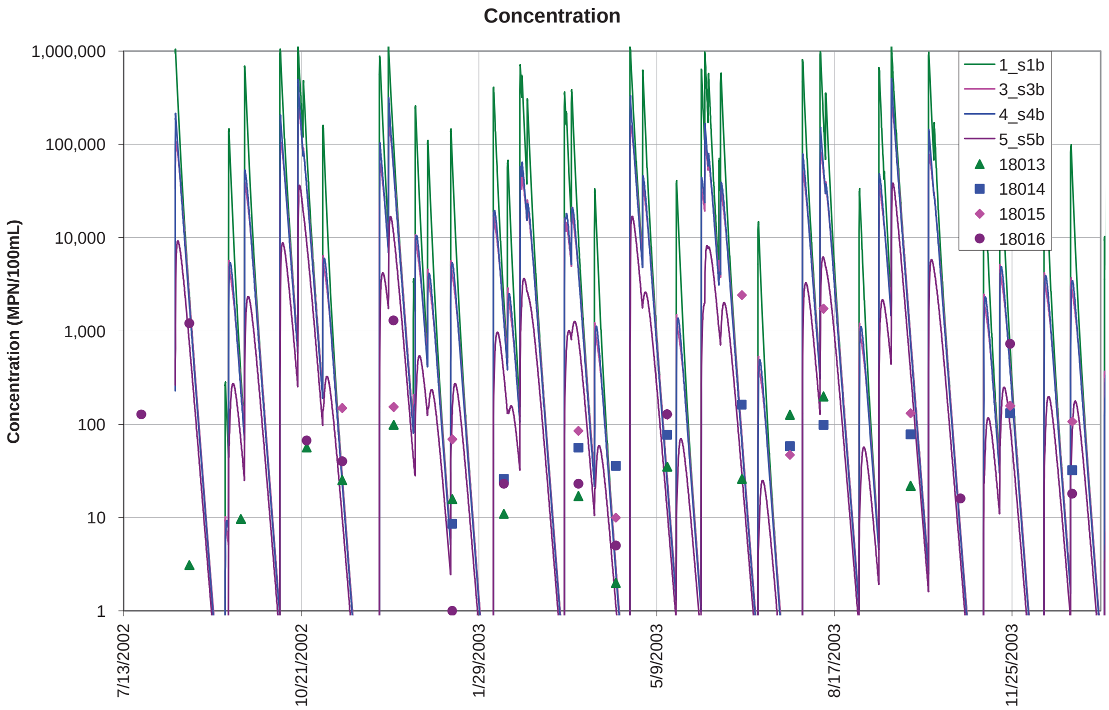


Figure E.22 Microwatershed Delineation for Sky Harbor


Concentration
Concentration (MPN/100mL)
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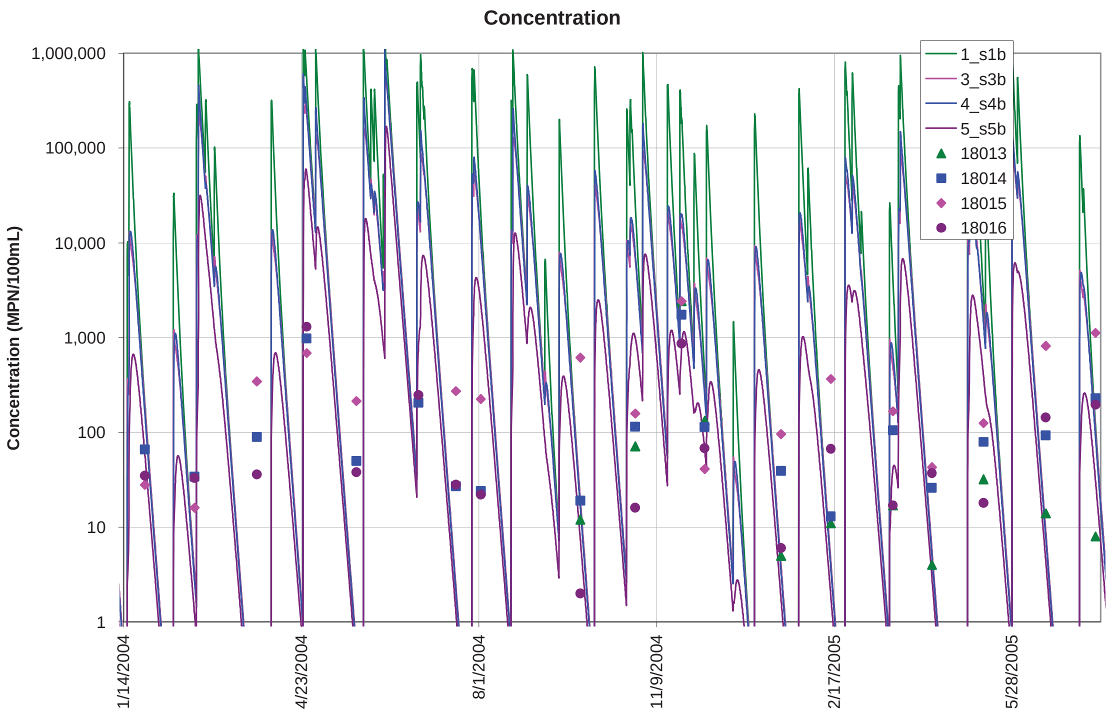
100,000
10,000
1,000
100
10
1
7/13/2002
10/21/2002
1/29/2003
5/9/2003
8/17/2003
11/25/2003
1_s1b
3_s3b
4_s4b
5_s5b
18013
18014
18015
18016


Concentration
Concentration (MPN/100mL)
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100,000
10,000
1,000
100
10
1
1/14/2004
4/23/2004
8/1/2004
11/9/2004
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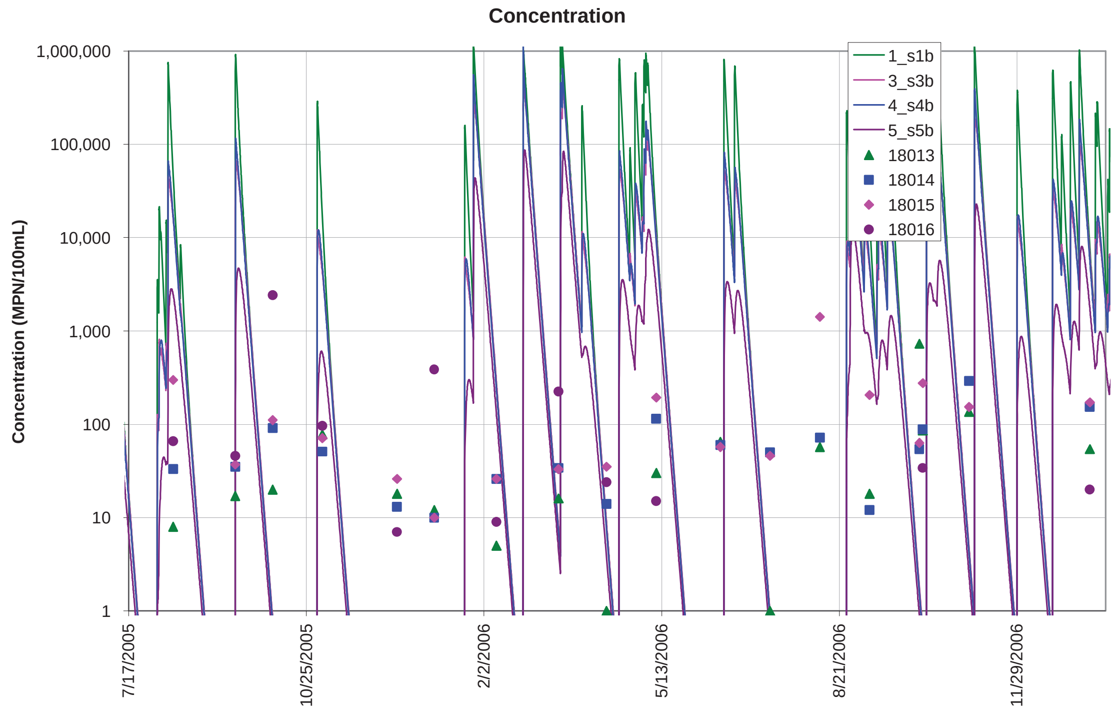
18014
18015
18016



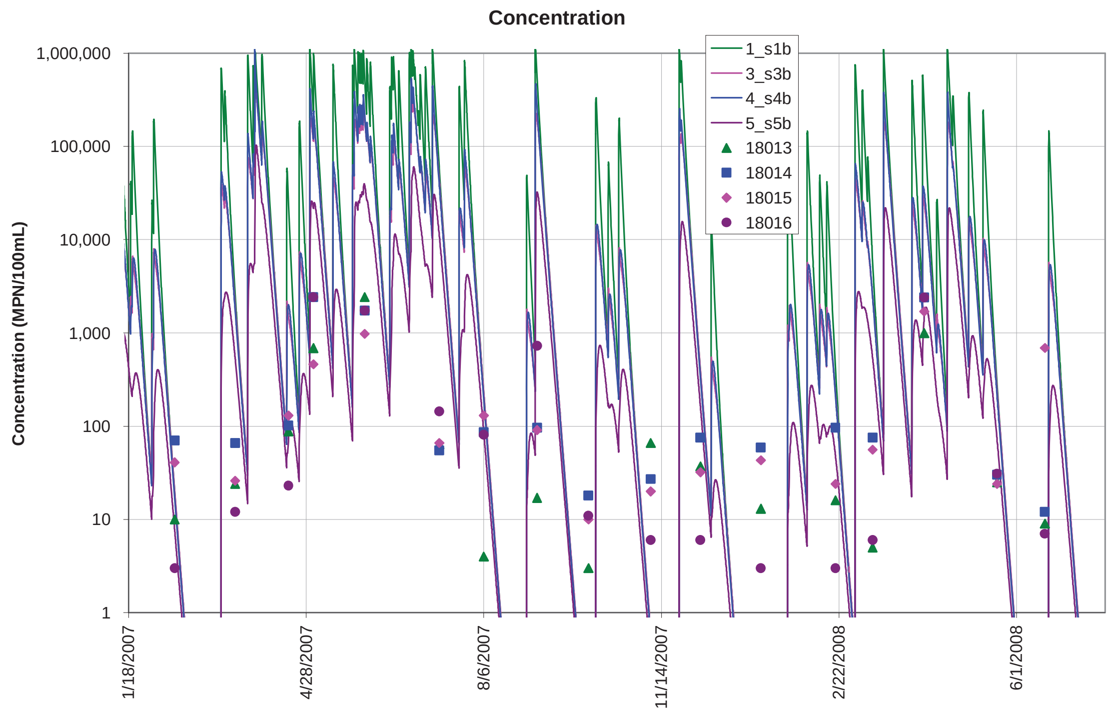


Figure E.23 Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Stations 18013, 18014, 18015, and 18016 located within the Sky Harbor Canals

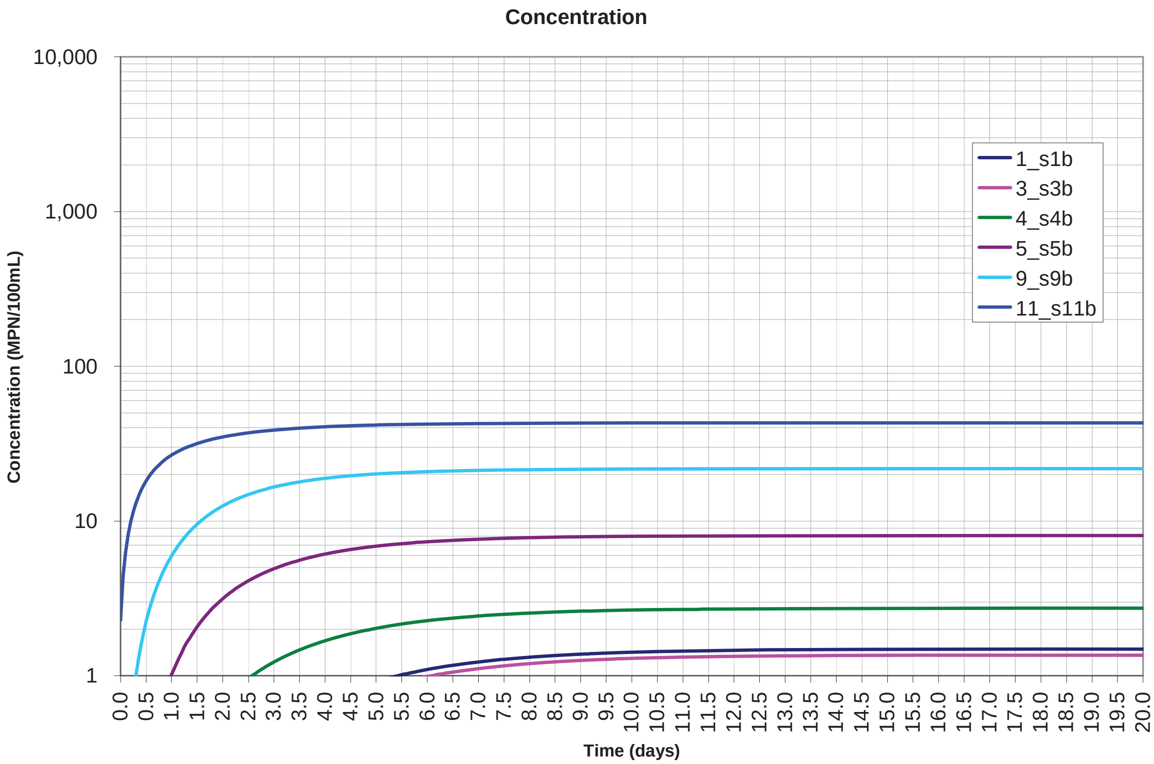


Figure E.24 Modeled Lake Boundary Condition for the Sky Harbor Canals

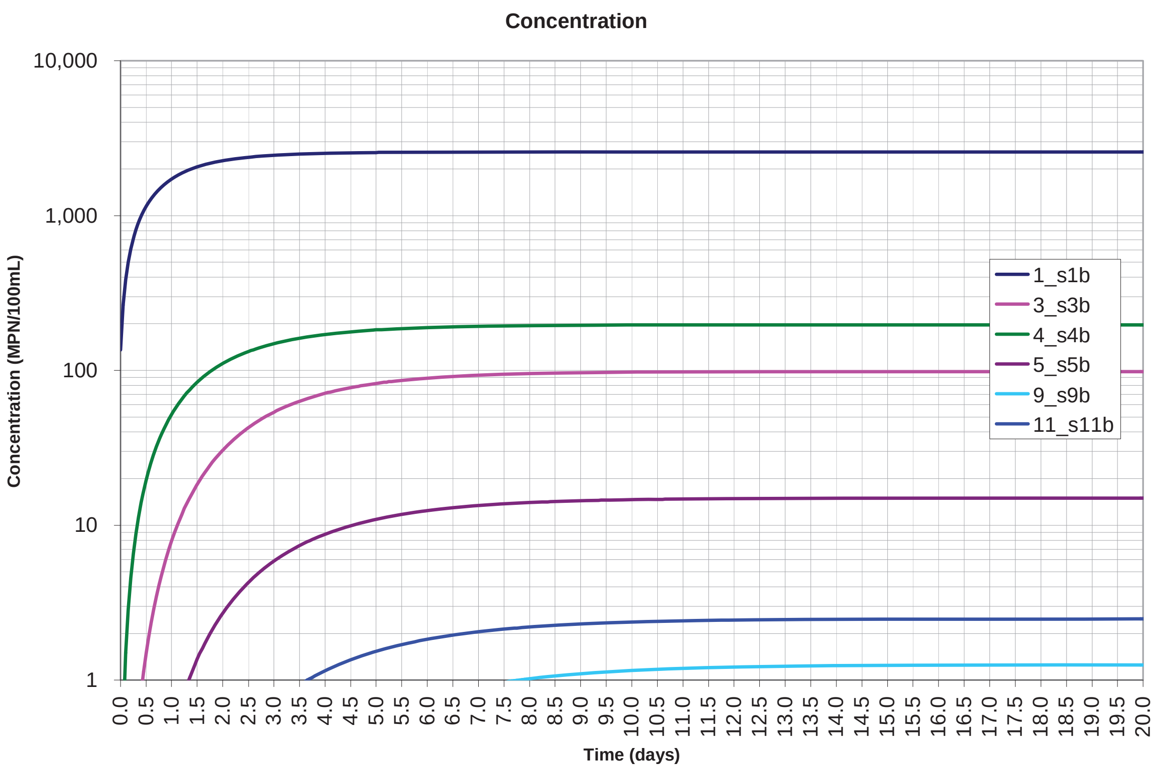


Figure E.25 Modeled Continuous Direct Discharge (septic) in the Sky Harbor Canals

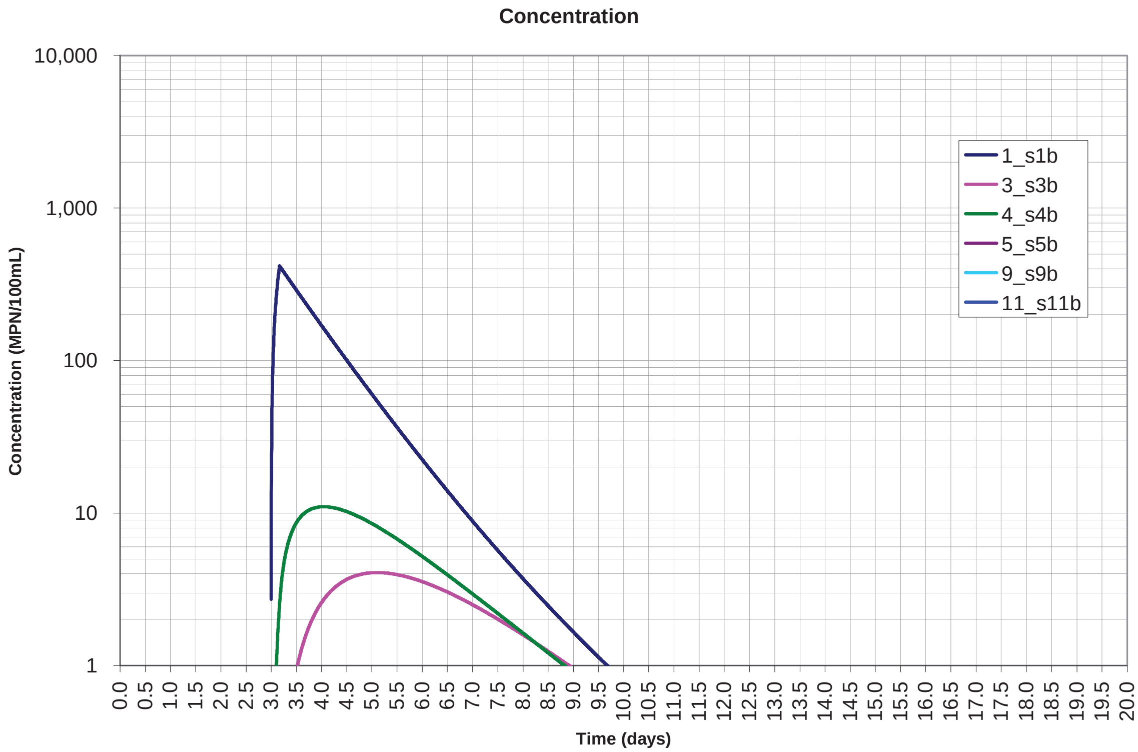


Figure E.26 Modeled Intermittent Direct Discharge (septic overload) in the Sky Harbor Canals

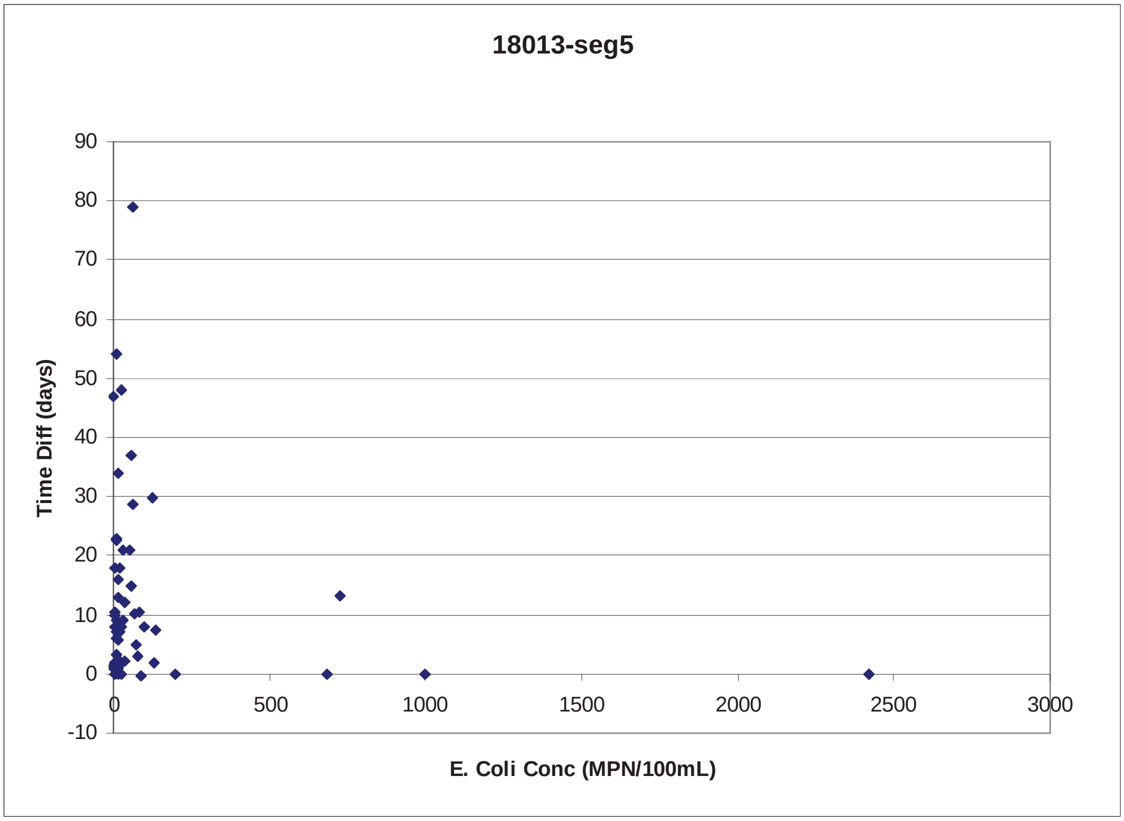


Figure E.27 Residual Plot for Station 18013 located within the Sky Harbor Canals

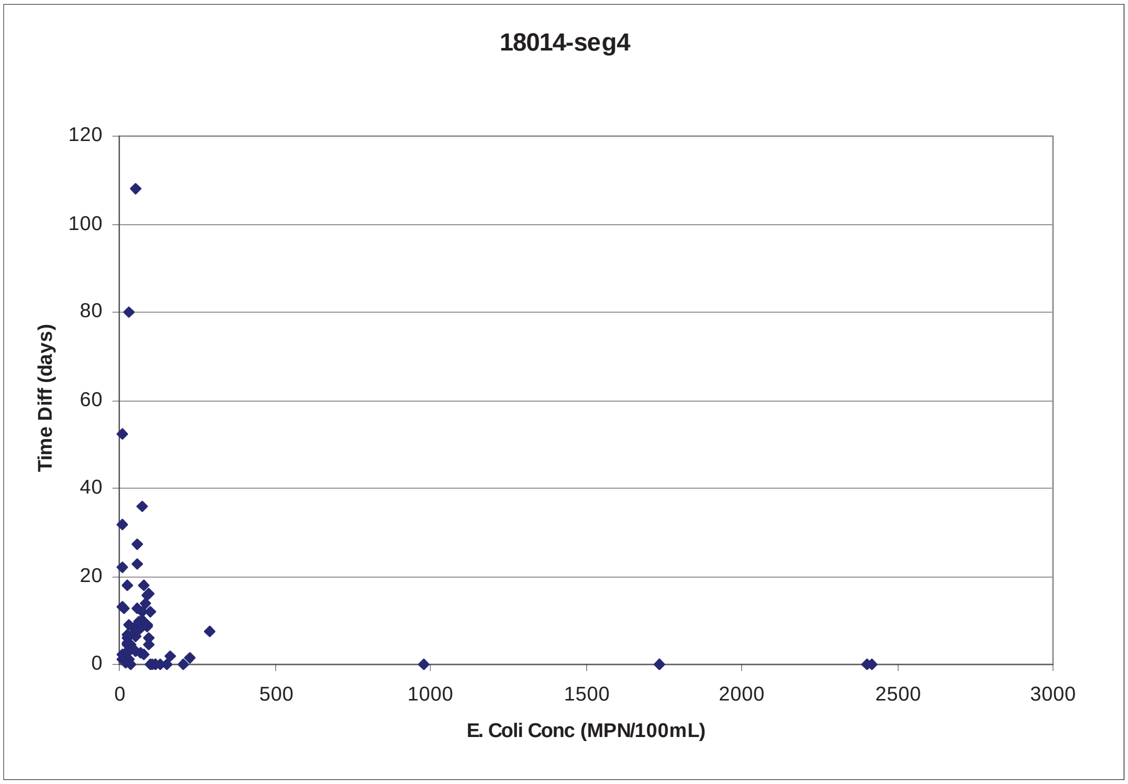


Figure E.28 Residual Plot for Station 18014 located within the Sky Harbor Canals

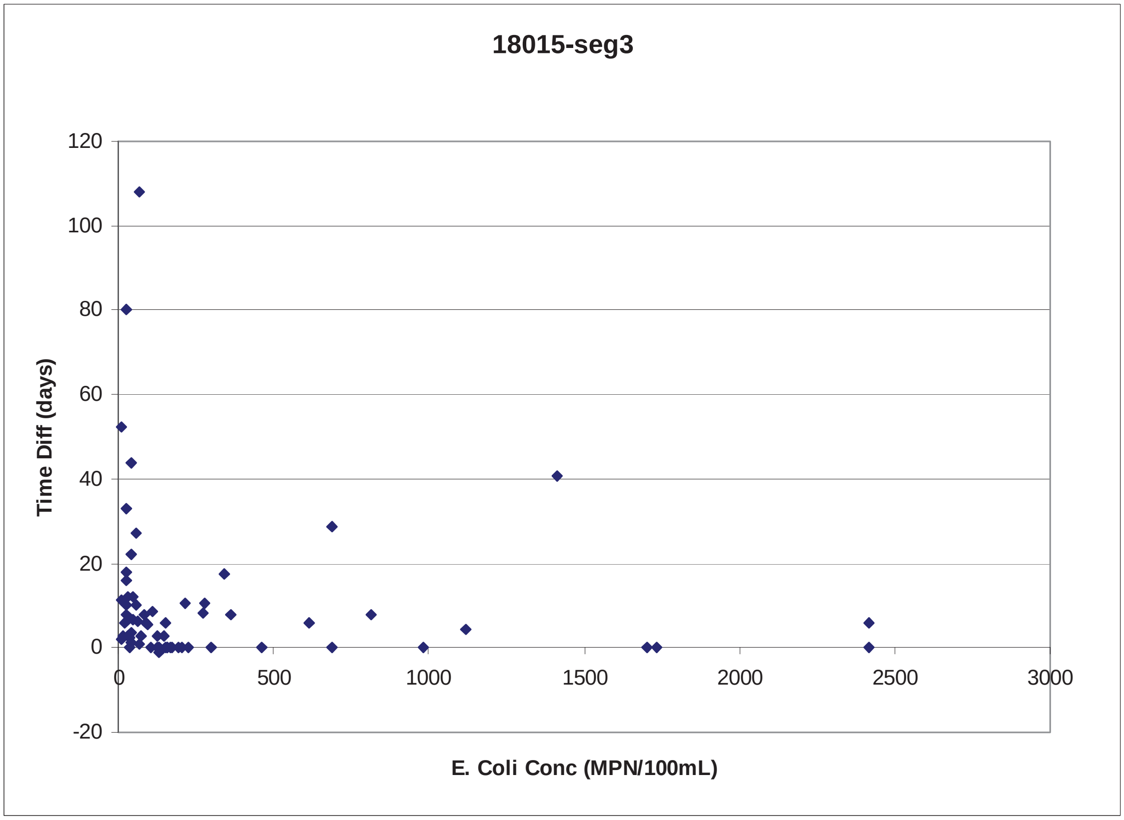


Figure E.29 Residual Plot for Station 18015 located within the Sky Harbor Canals

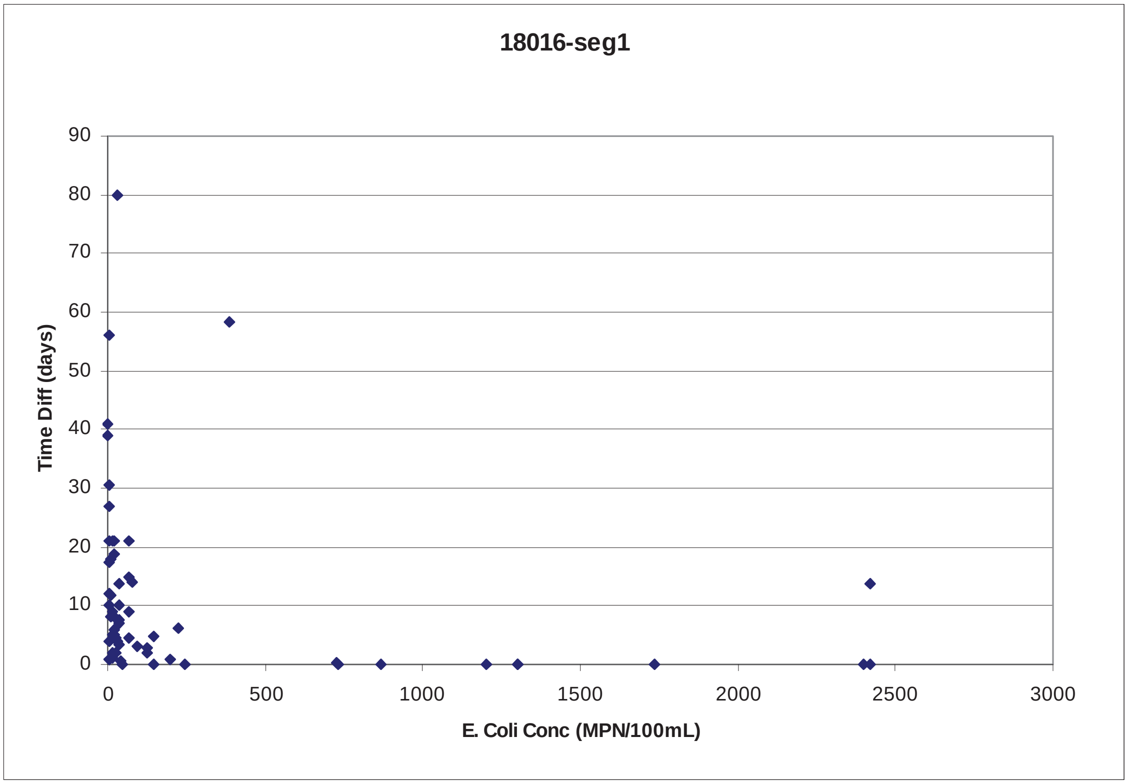


Figure E.30 Residual Plot for Station 18016 located within the Sky Harbor Canals

E.2.5 Nassau Bay II

Model segmentation was conducted according to flow directions and canal geometry. The Nassau Bay II canal that was modeled is divided into three segments as shown in Figure E.31. Mass balance using Equation E-1 is calculated for each segment in the spreadsheet model. The flow directions are: 1→2, 2→3, 3→lake. The contributing microwatershed (Figure E.32) is very localized to the neighboring residences

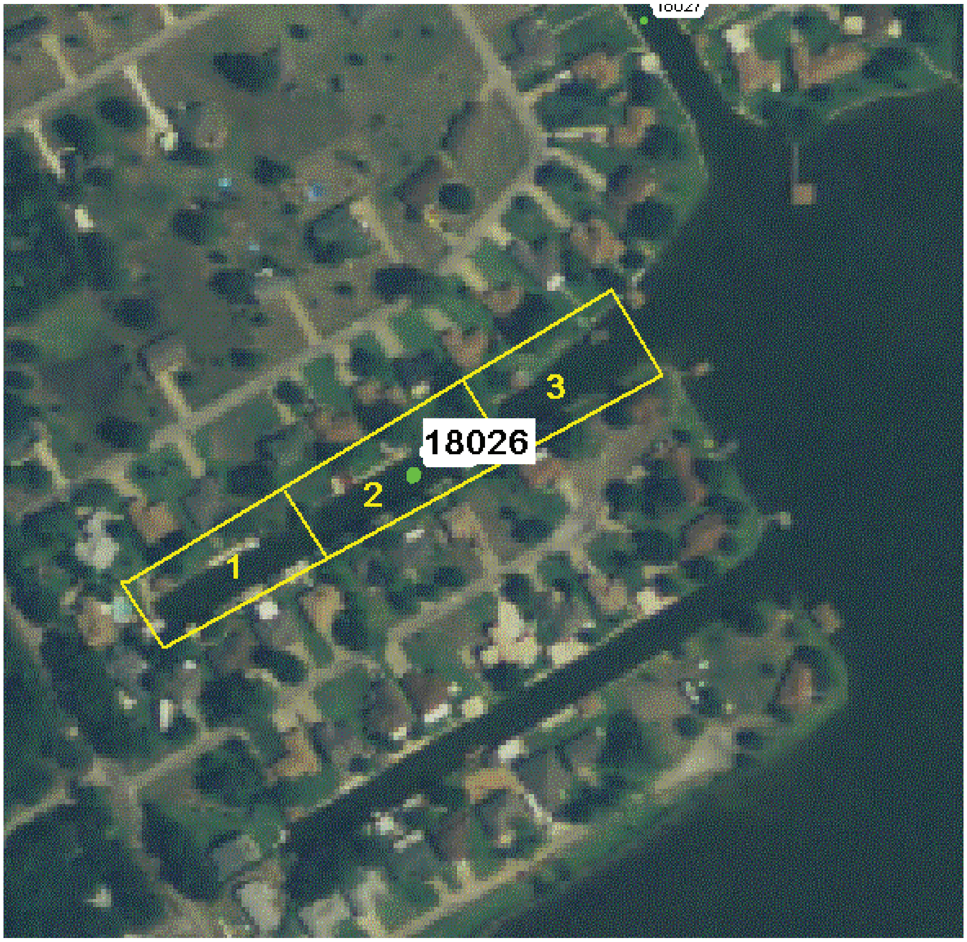


Figure E.31 Canal Segmentation for Modeling Nassau Bay II

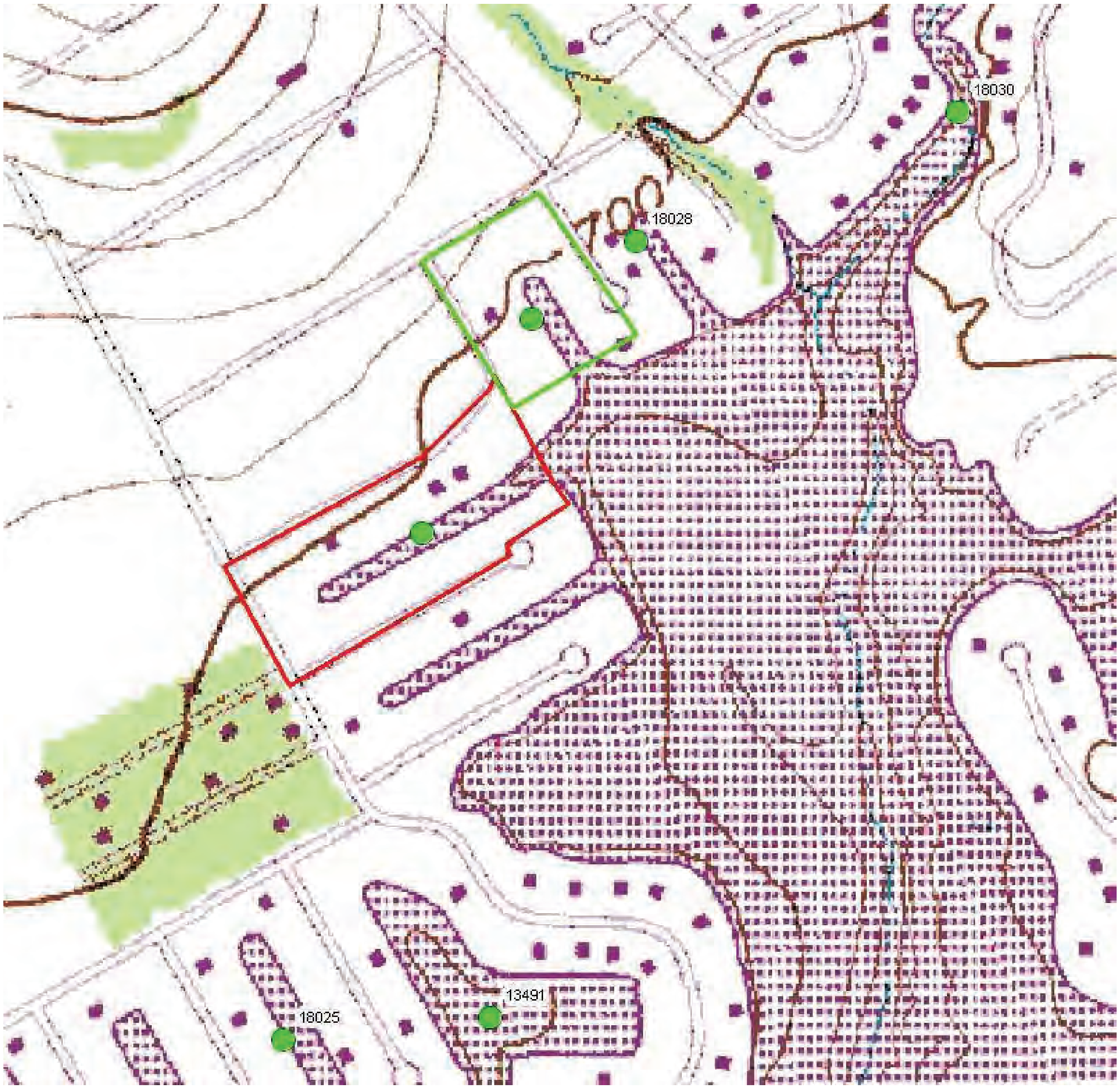
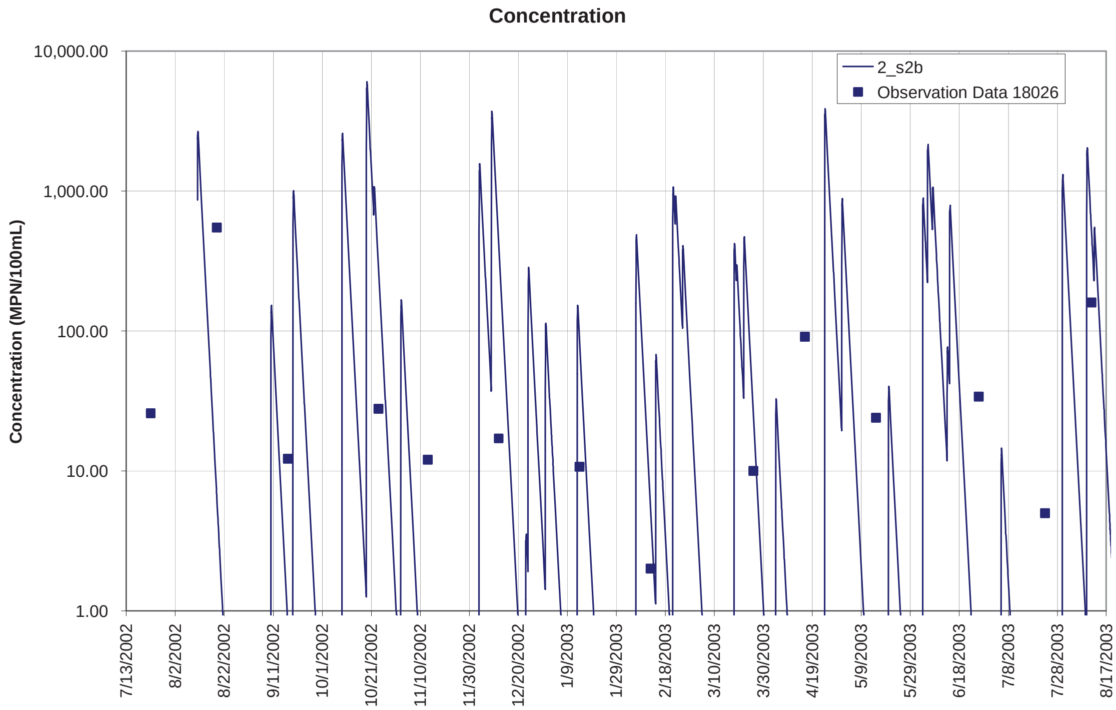


Figure E.32 Microwatershed Delineation for Nassau Bay II



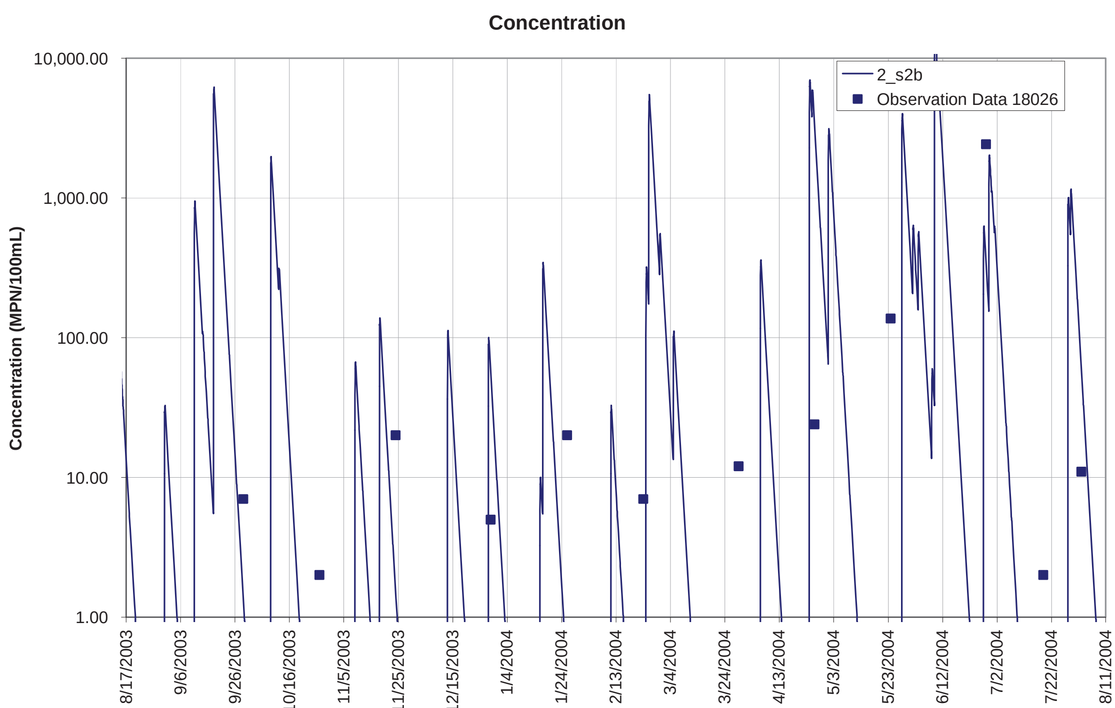


Figure E.33 Runoff models: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Station 18026 located within the Nassau Bay II Canals

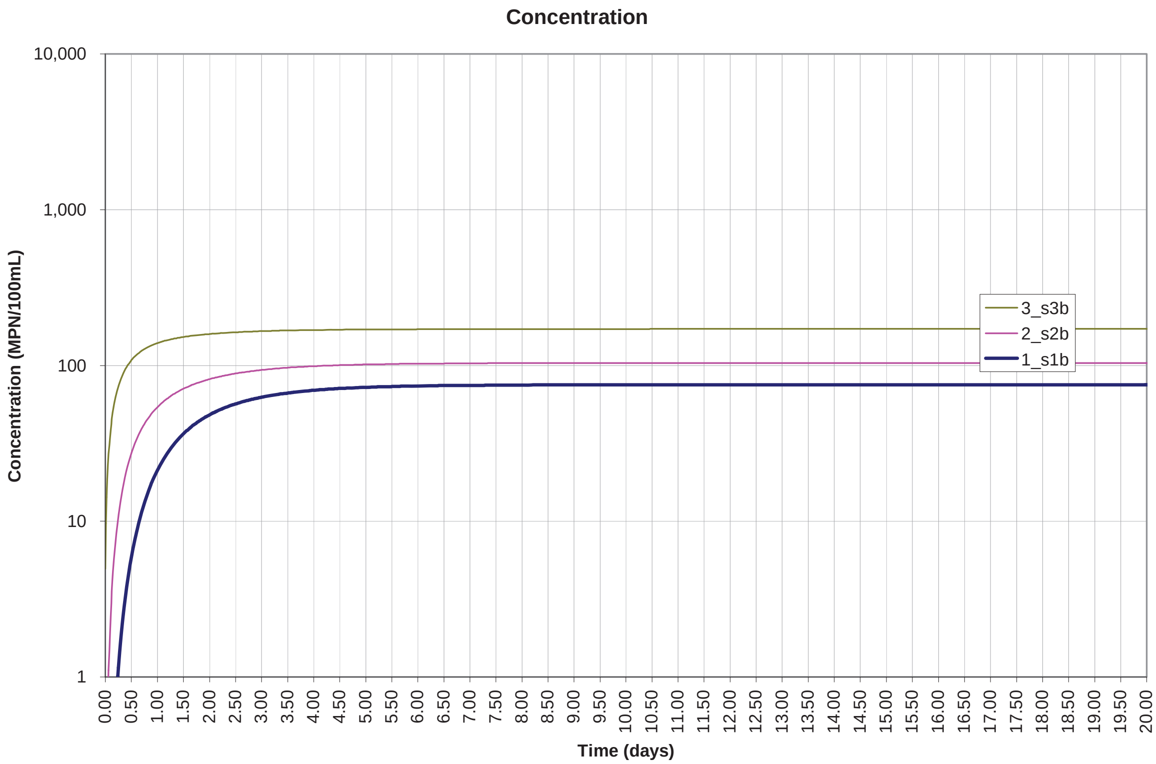


Figure E.34 Modeled Lake Boundary Condition for the Nassau Bay II Canals

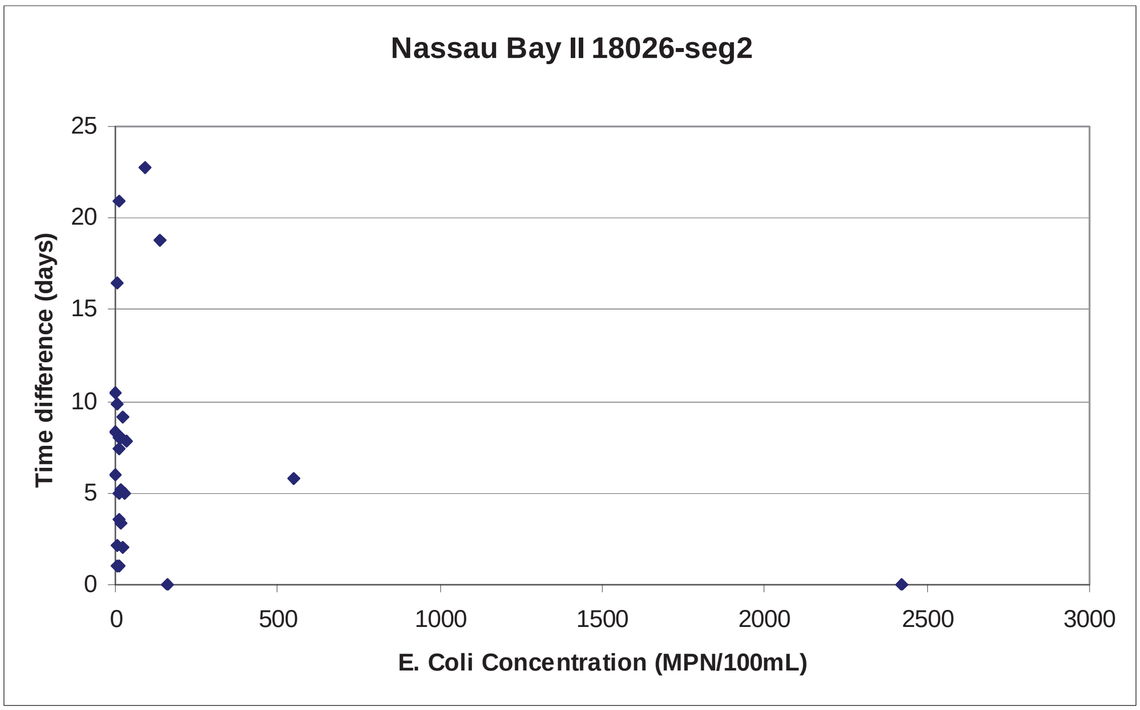


Figure E.35 Residual Plot for Station 18016 located within the Sky Harbor Canals

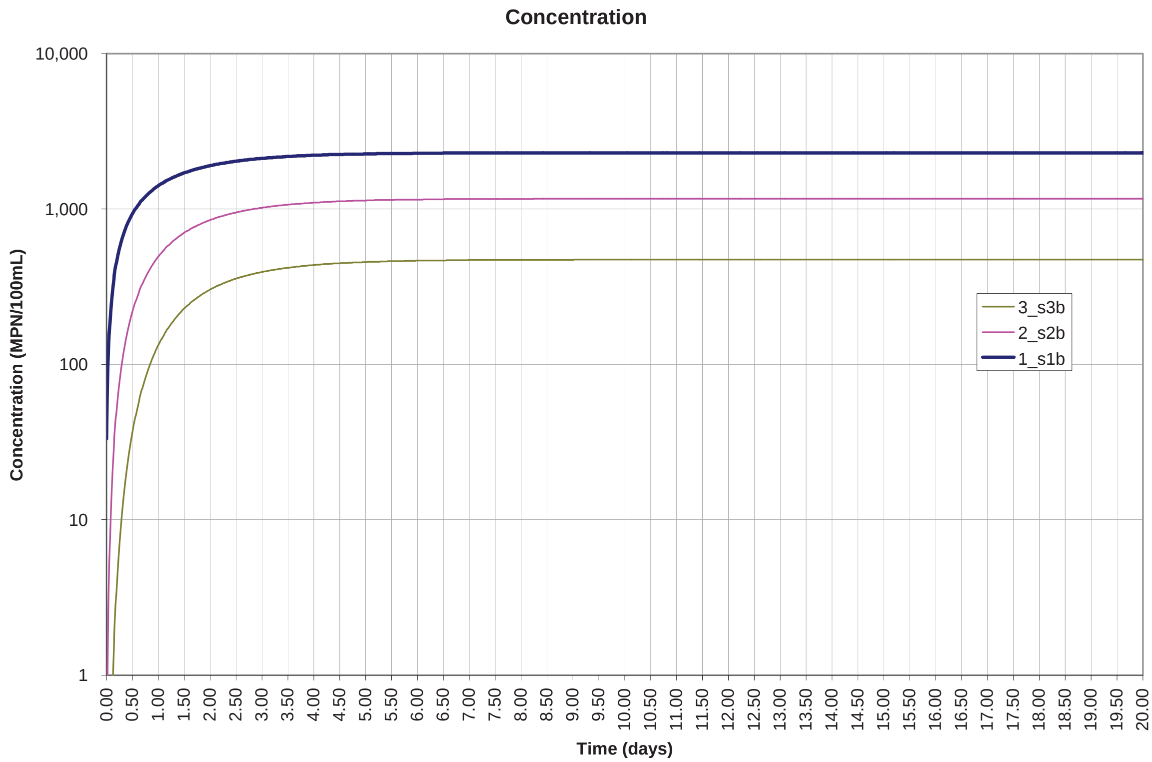


Figure E.36 Modeled Continuous Direct Discharge (septic) for Nassau Bay II canals

E.2.6 Waters Edge

The Water's Edge subdivision has two separate canal systems, Part I and Part II (Figure E.37). Part I was segmented into eight sections for the mass balance model. The direction of flow for Part I is from segment 1→2, 2→3, 3→4. 4→8, 6→7, 5→7, 7→8, 8→lake. Part II has two segments connected to the lake and the movement of water is from lake→segment 4→2, 2→3, 1→3, 3→lake.

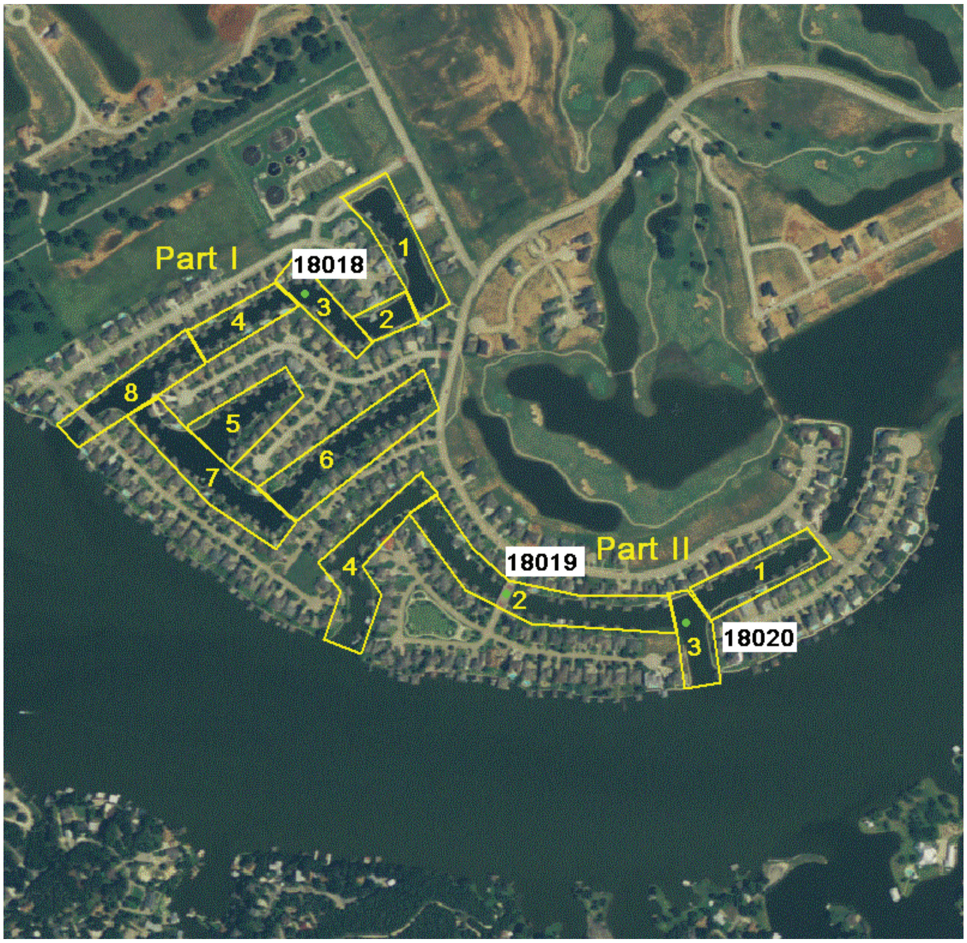


Figure E.37 Canal Segmentation for Modeling Water's Edge

The microwatersheds for Part II of Waters Edge is very isolated to the residential lots adjacent to the canals (Figure E.38).

Figure E.38 Microwatershed Delineation for Waters Edge

The model predicted no significant concerns for water quality impairment due to bacteria from runoff sources. Further, the only potential source of bacteria would be a localized nonpoint source such as pets.

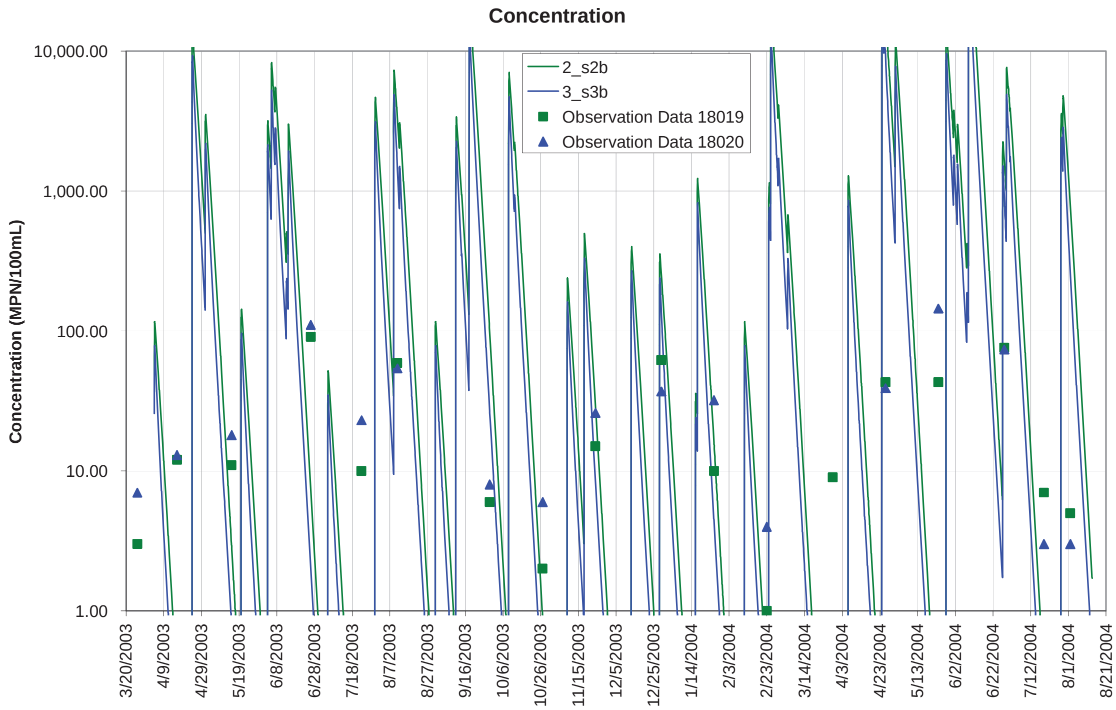


Figure E.39 Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Stations 18019 and 18020 located within the Water's Edge Canals

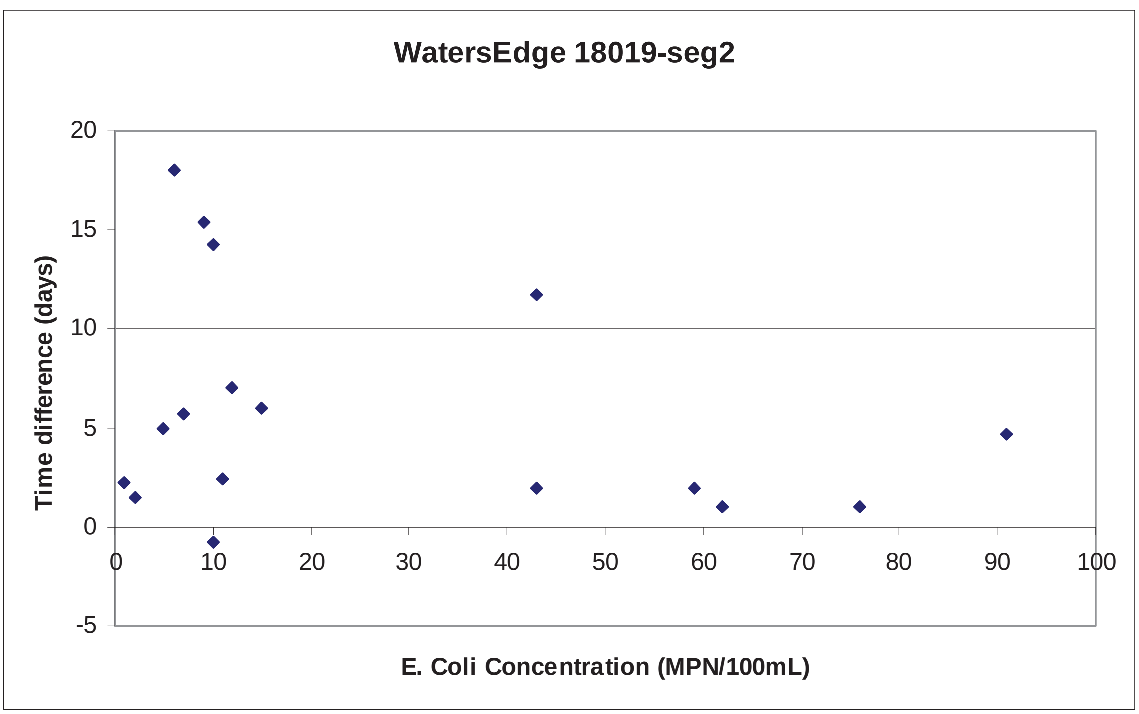


Figure E.40 Residual Plot for Station 18019 located within the Water's Edge Canals

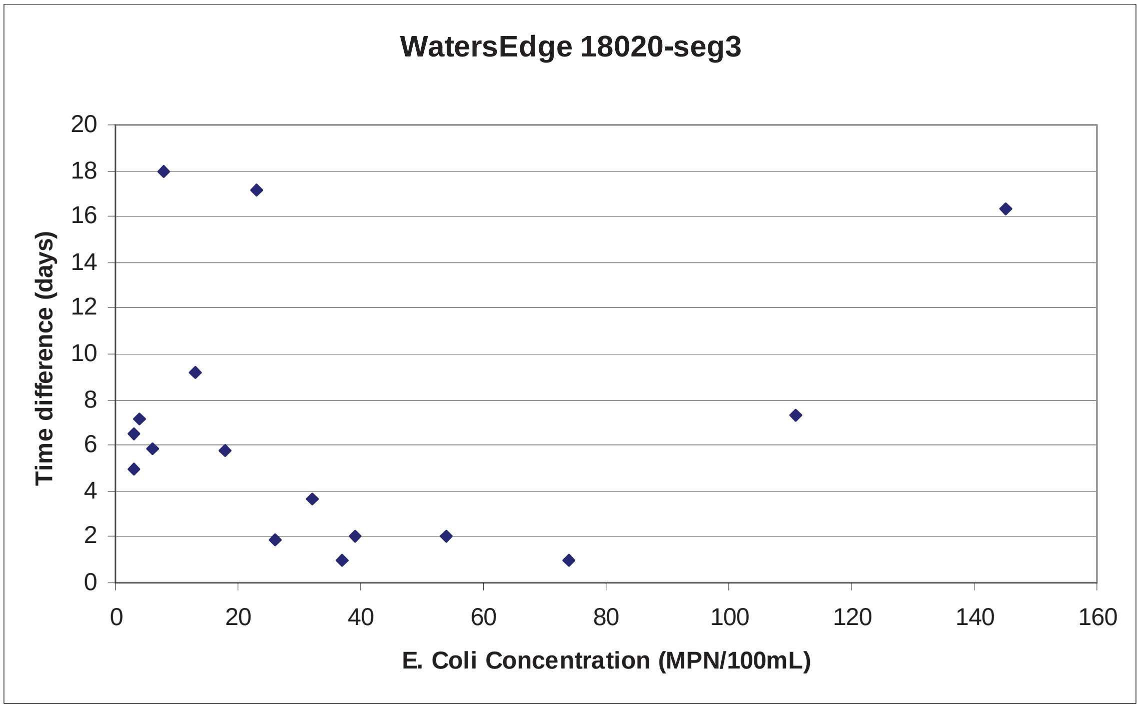


Figure E.41 Residual Plot for Station 18020 located within the Water's Edge Canals

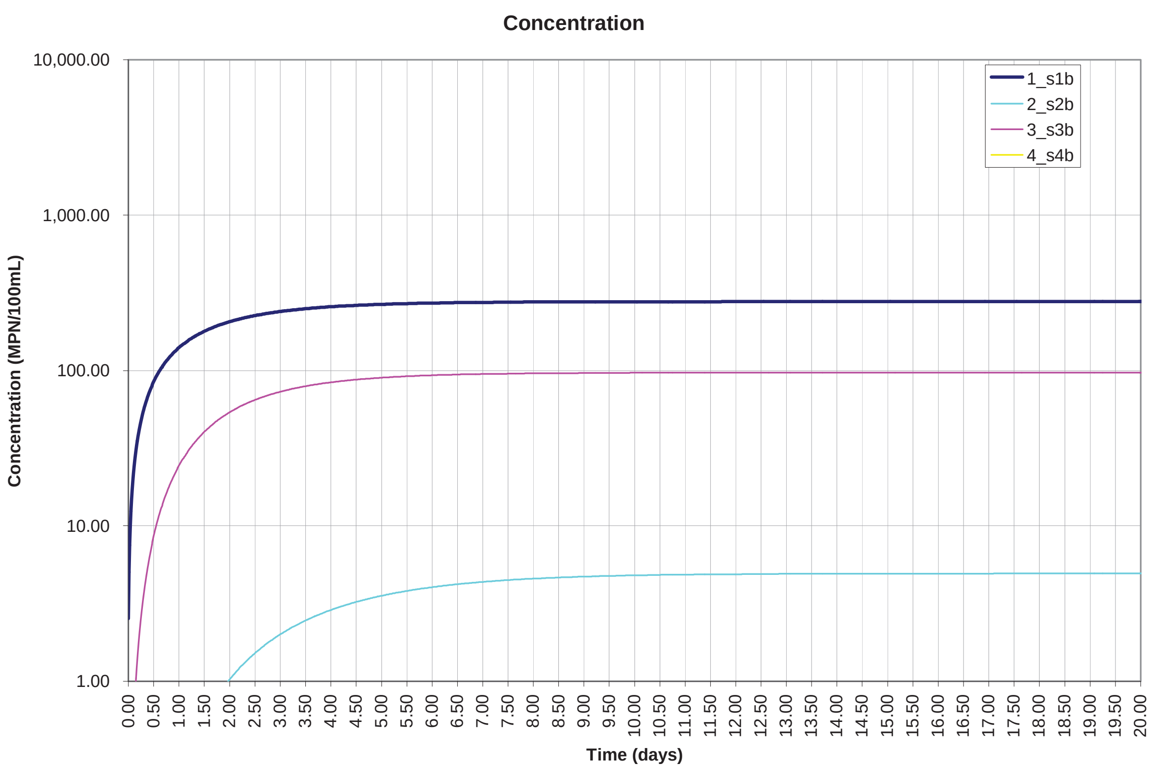


Figure E.42 Continuous Direct Discharge Water's Edge

E.2.7 Ports O' Call

The Ports O' Call subdivision has several canals. The canal monitored by station 18021 was divided into three segments for modeling the mass balance (Figure E.43). Again, this canal system has a very isolated microwatershed consisting of the residential lots immediately adjacent to the canal (Figure E.44).

Figure E.43 Canal Segmentation for Modeling Ports O' Call

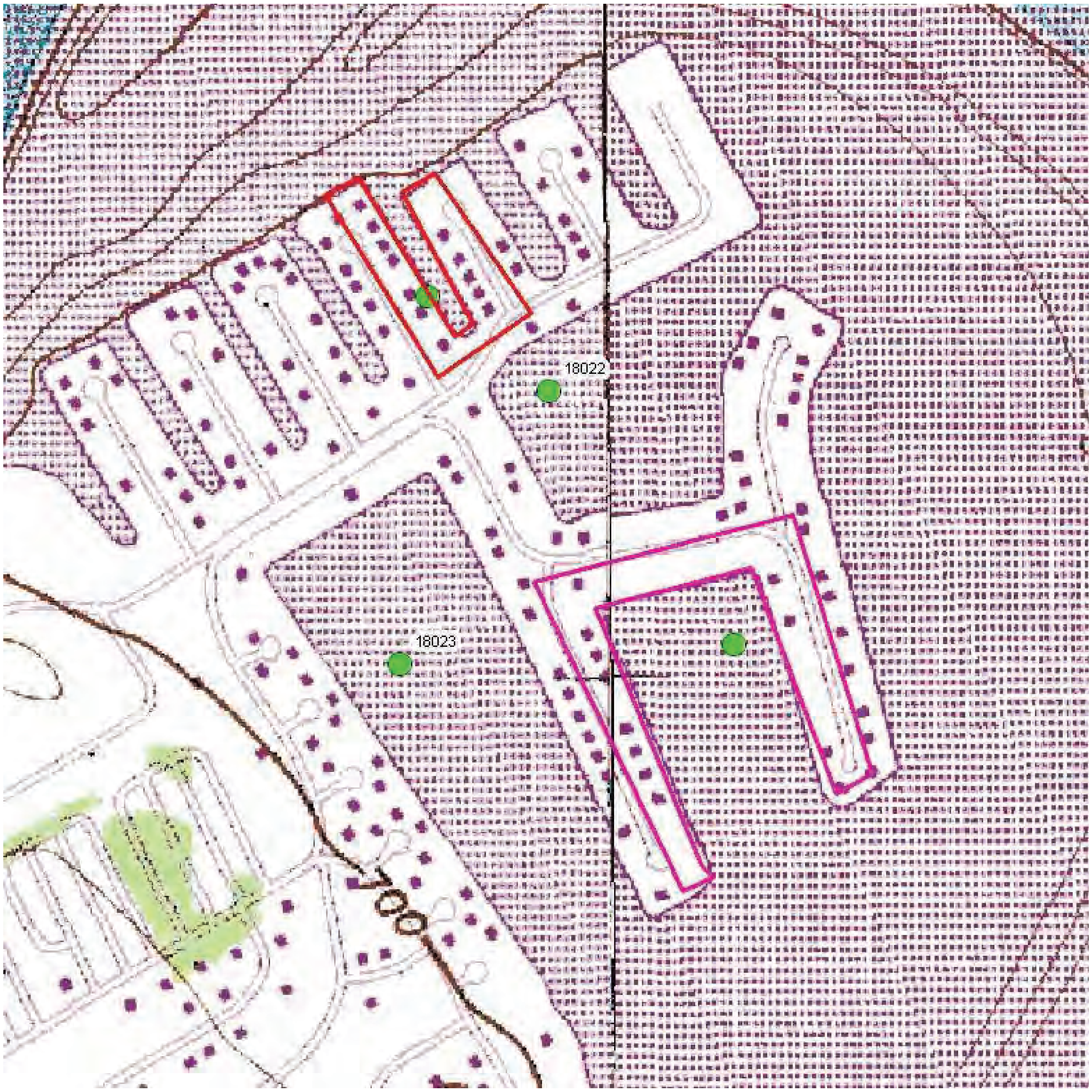
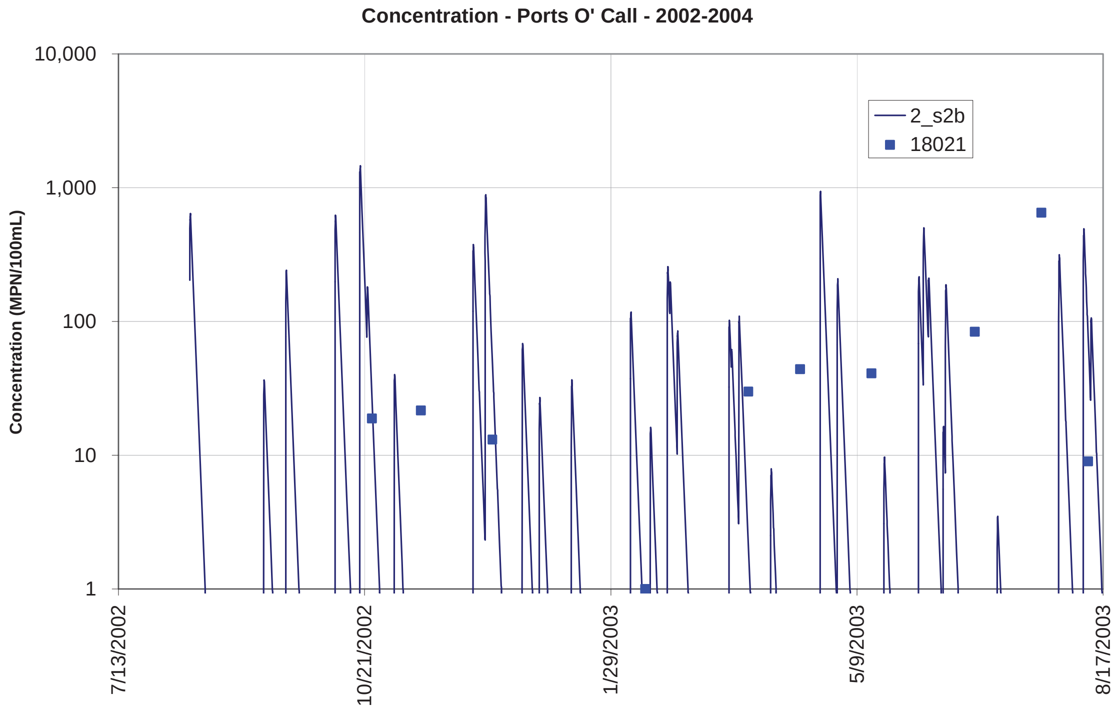


Figure E.44 Microwatershed Delineation for Ports O' Call and Indian Harbor



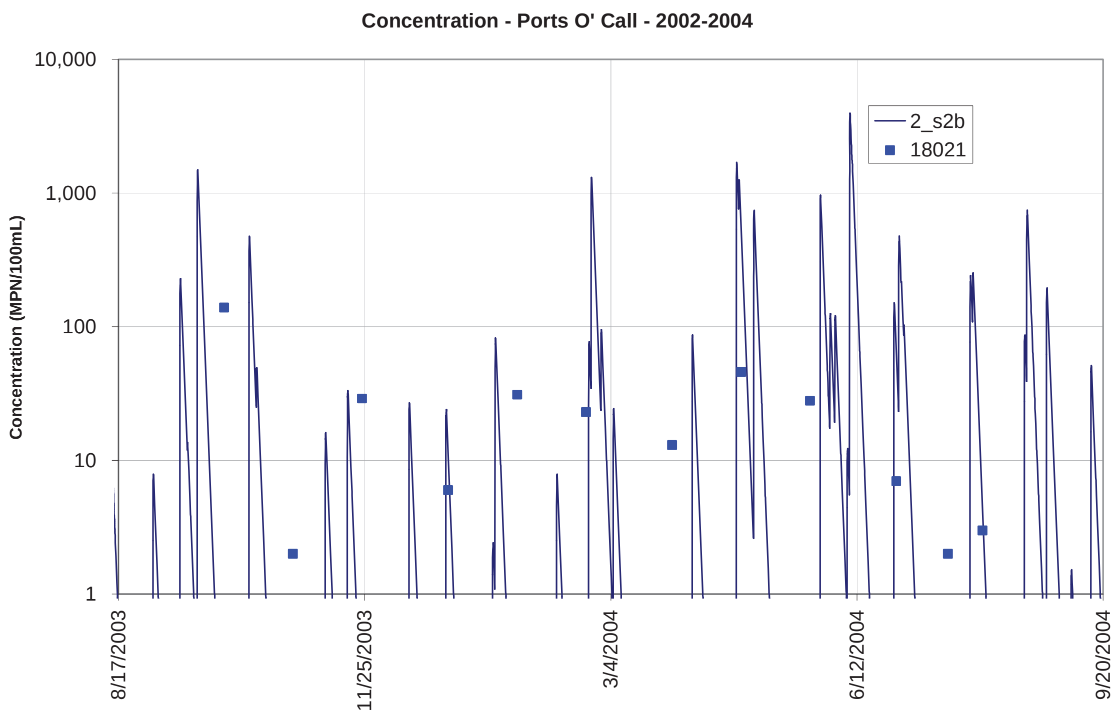


Figure E.45 Runoff model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Station 18021 located within the Ports O' Call Canal

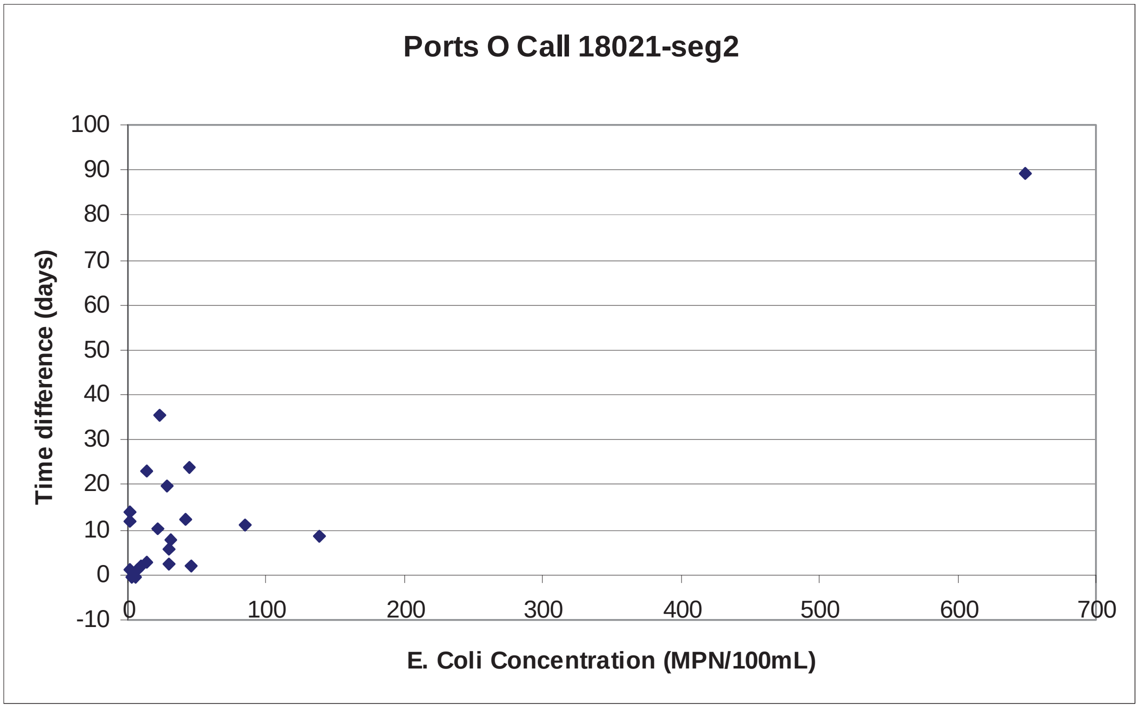


Figure E.46 Residual Plot for Station 18021 located within the modeled Ports O' Call canal

E.2.8 Indian Harbor

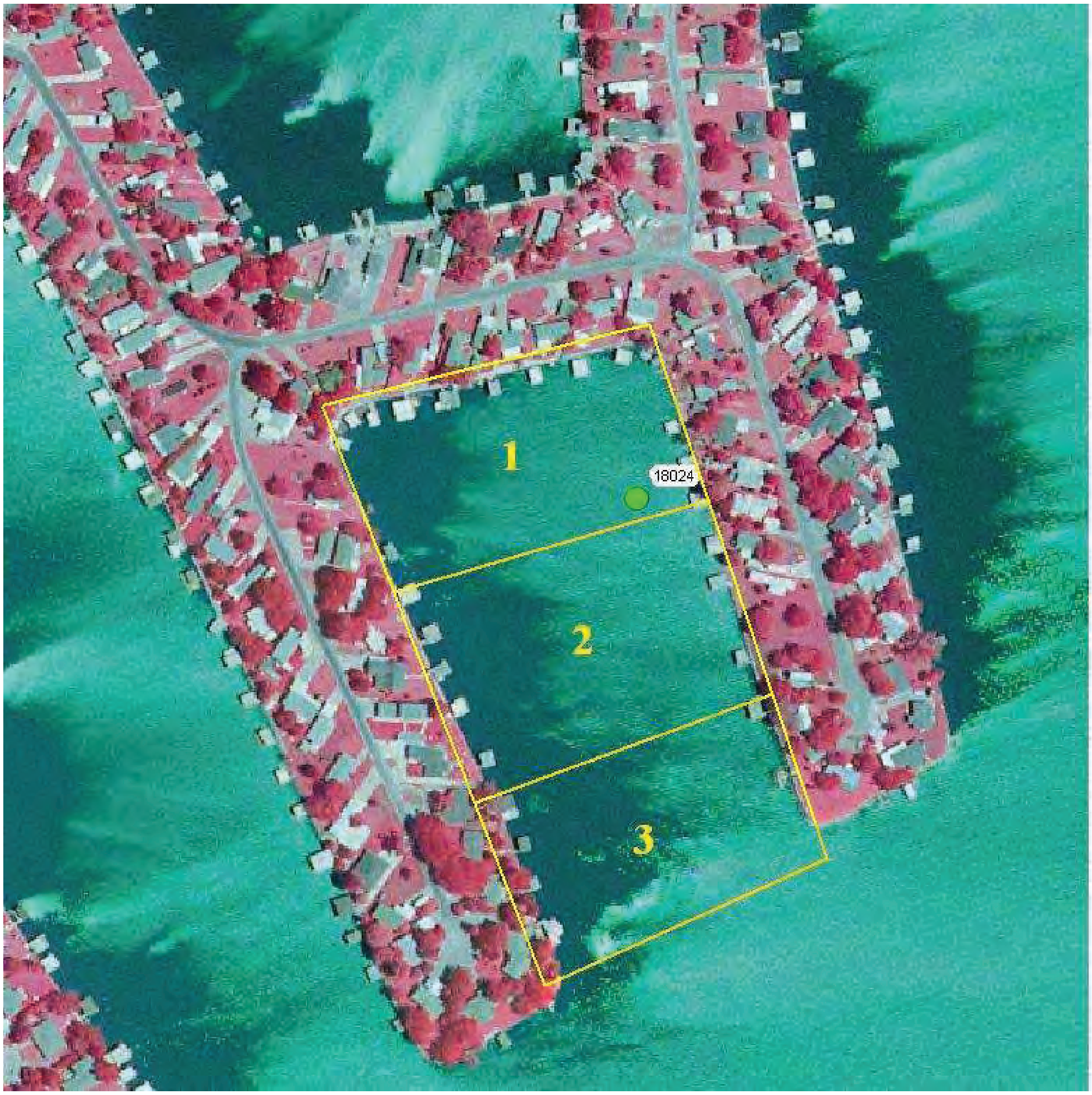


Figure E.47 Cove Segmentation for Modeling Indian Harbor

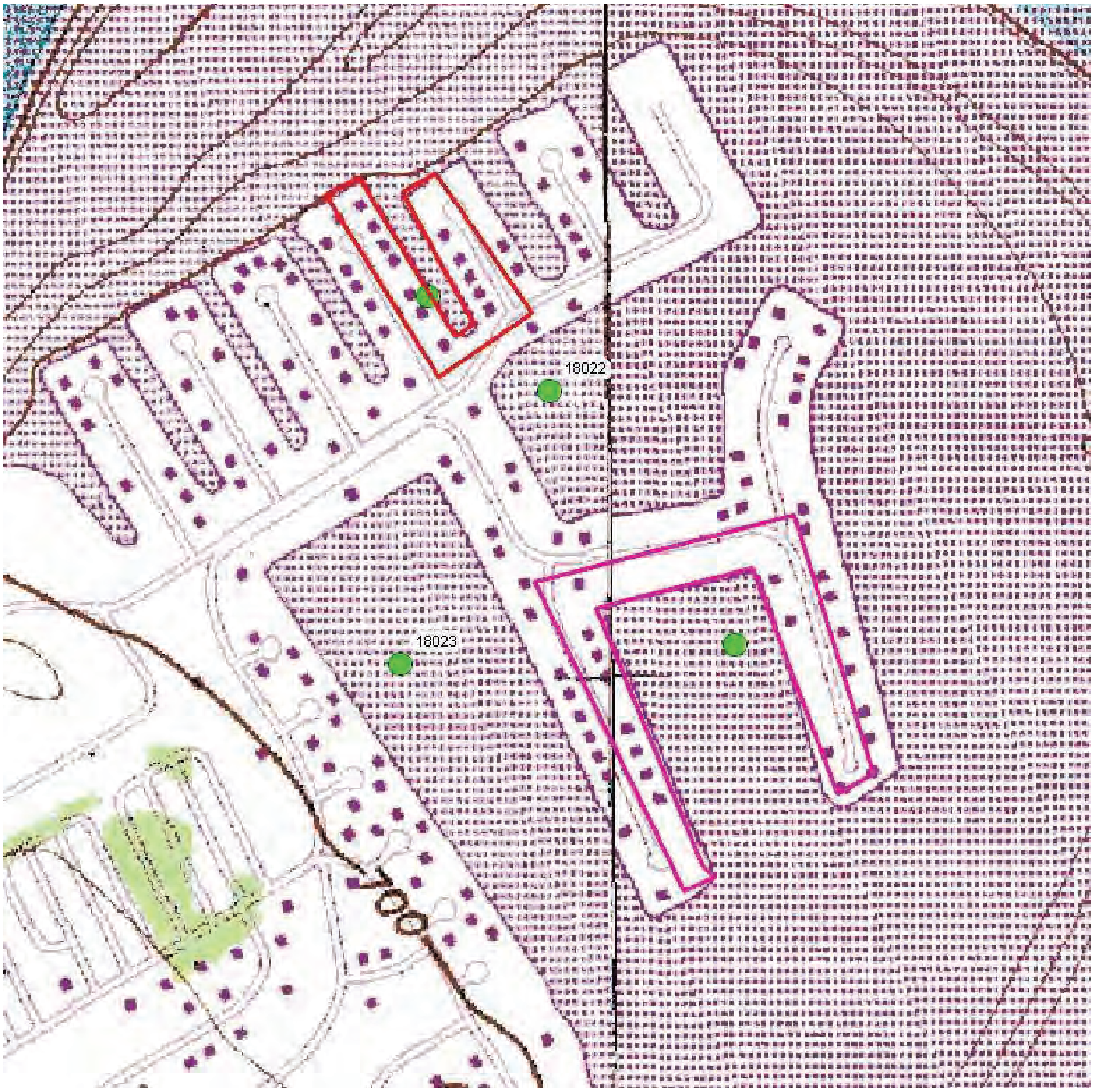
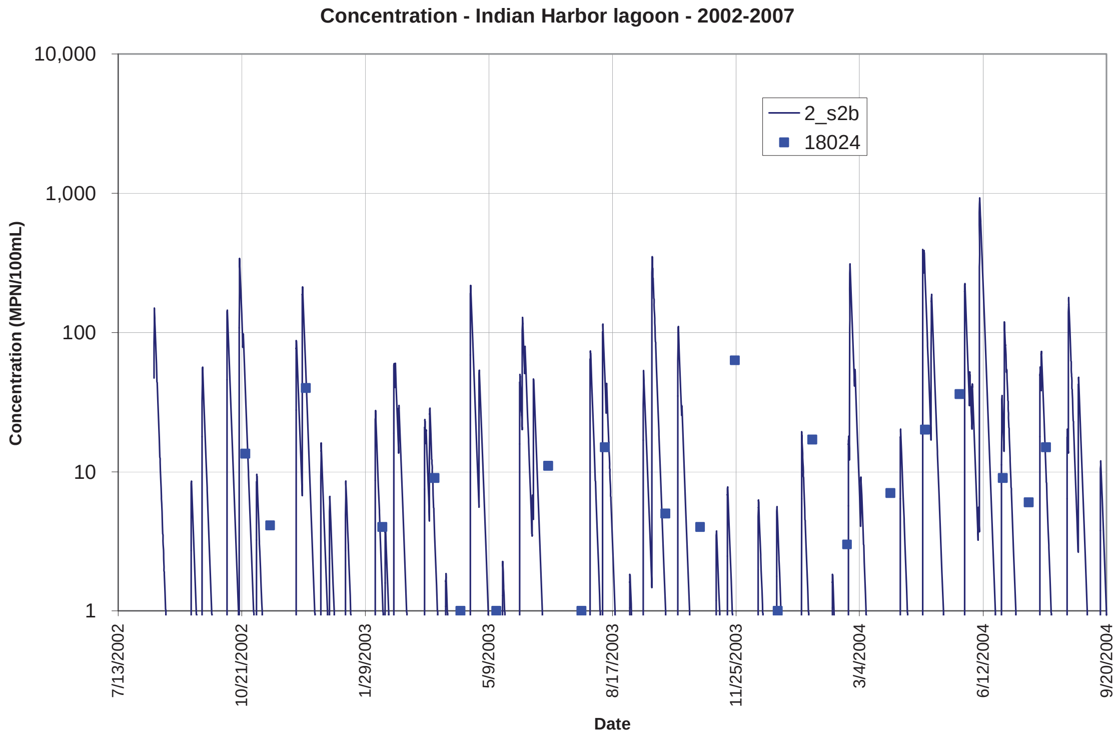


Figure E.48 Microwatershed Delineation for Ports O'Call and Indian Harbor



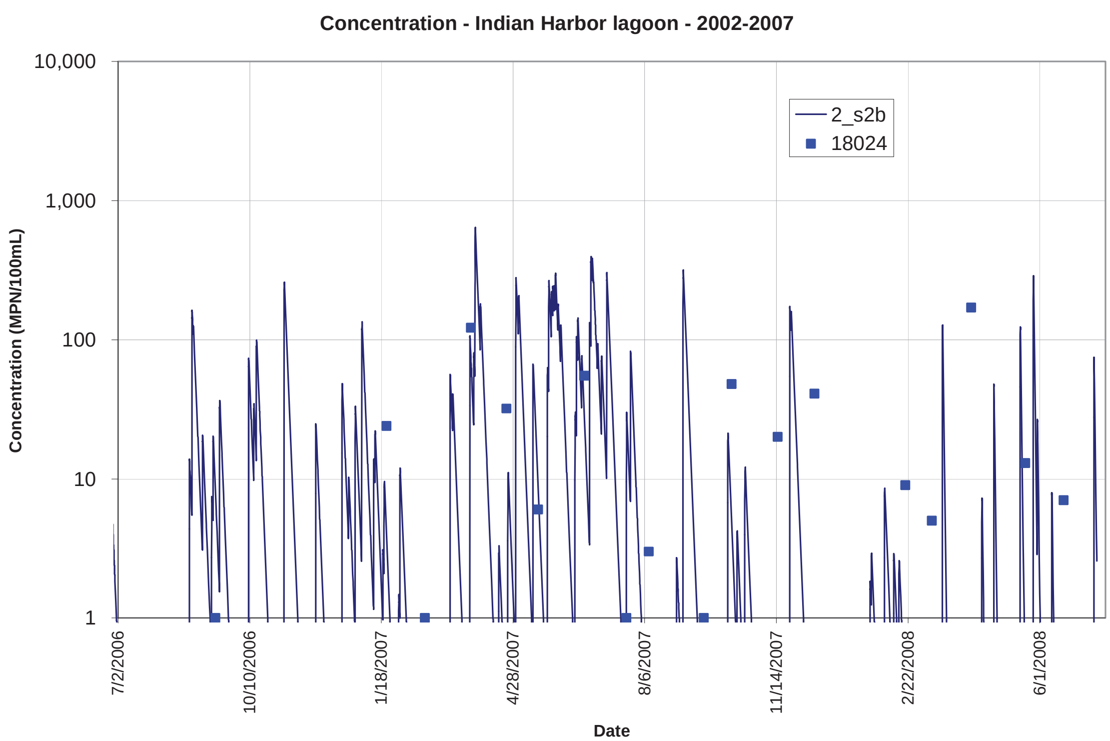


Figure E.49 Runoff model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Station 18024 located within the Indian Harbor Cove area

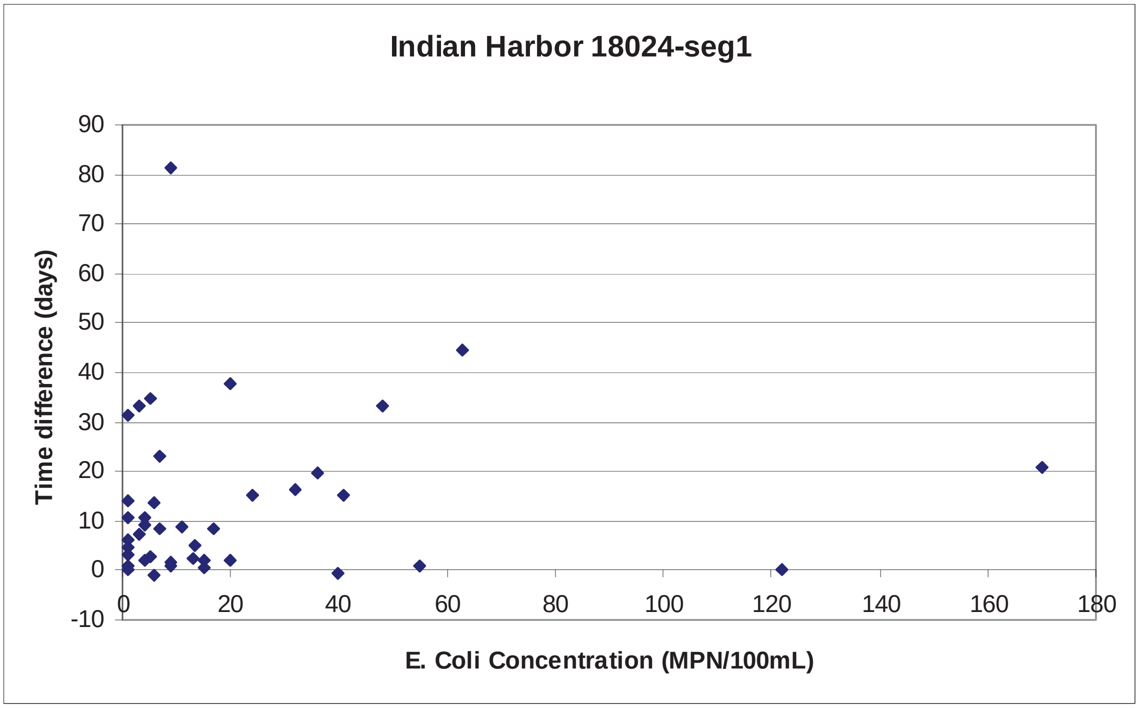


Figure E.50 Residual Plot for Station 18024 located within the Indian Harbor Cove area

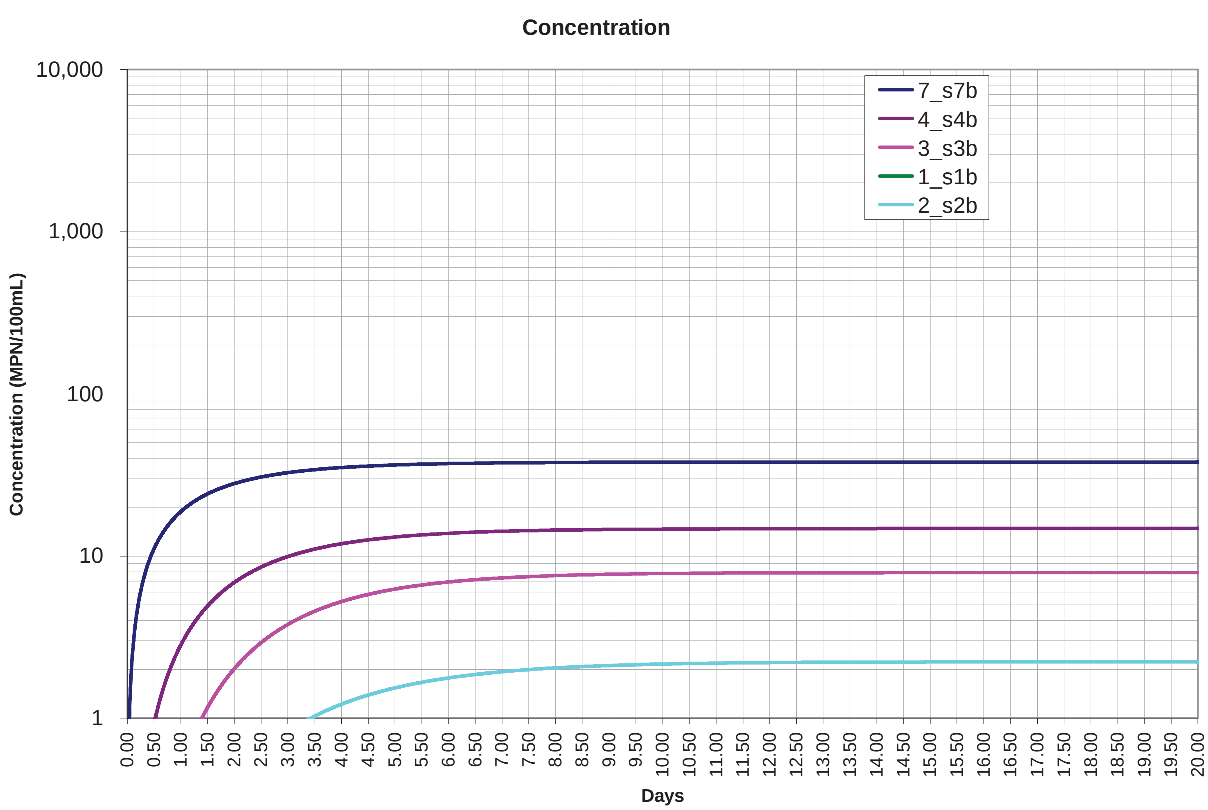


Figure E.51 Lake as source Boundary Condition for the Indian Harbor Cove area

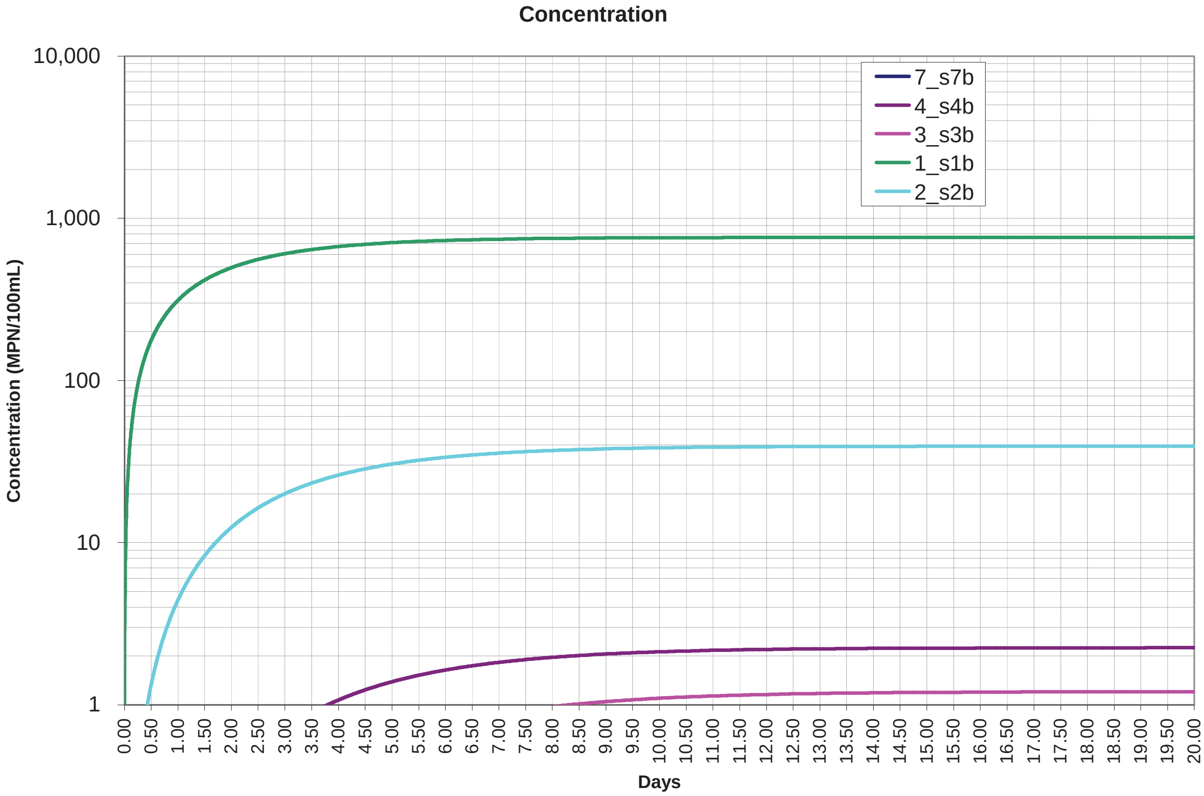


Figure E.52 Modeled Continuous Direct Discharge (septic) in the Indian Harbor Cove area

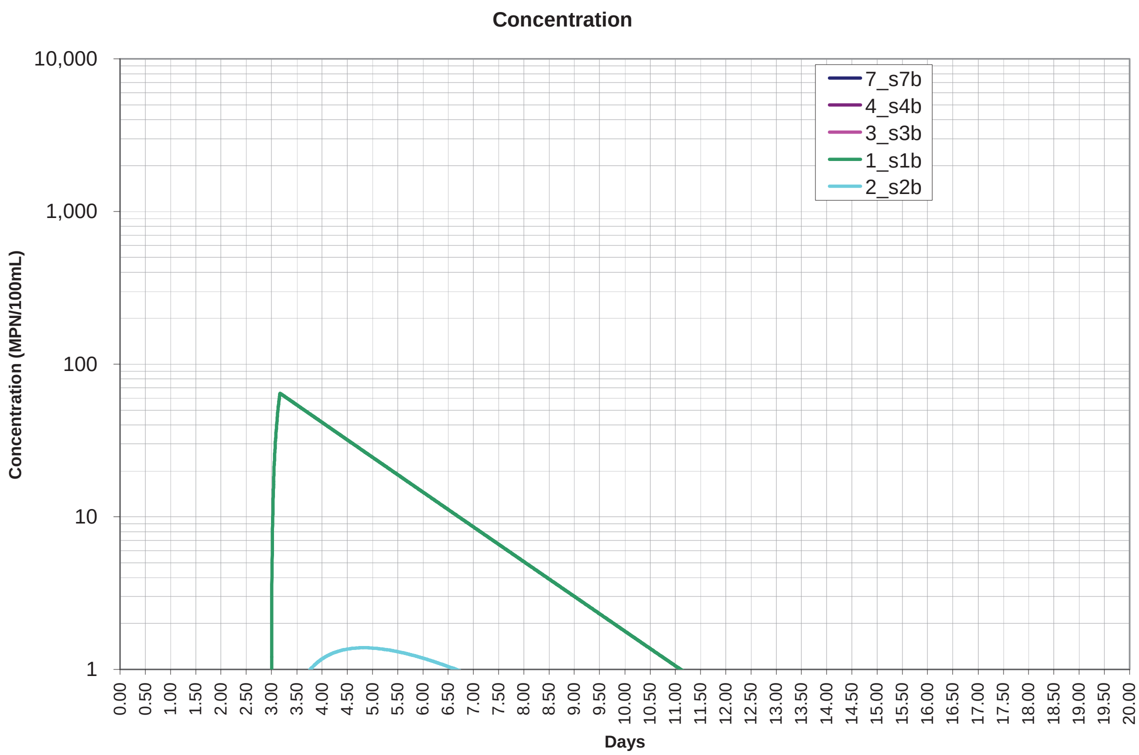


Figure E.53 Intermittent Direct Discharge (septic overload) in the Indian Harbor cove area

E.2.9 Port Ridglea

Figure E.54 Canal Segmentation for Modeling Port Ridgelea

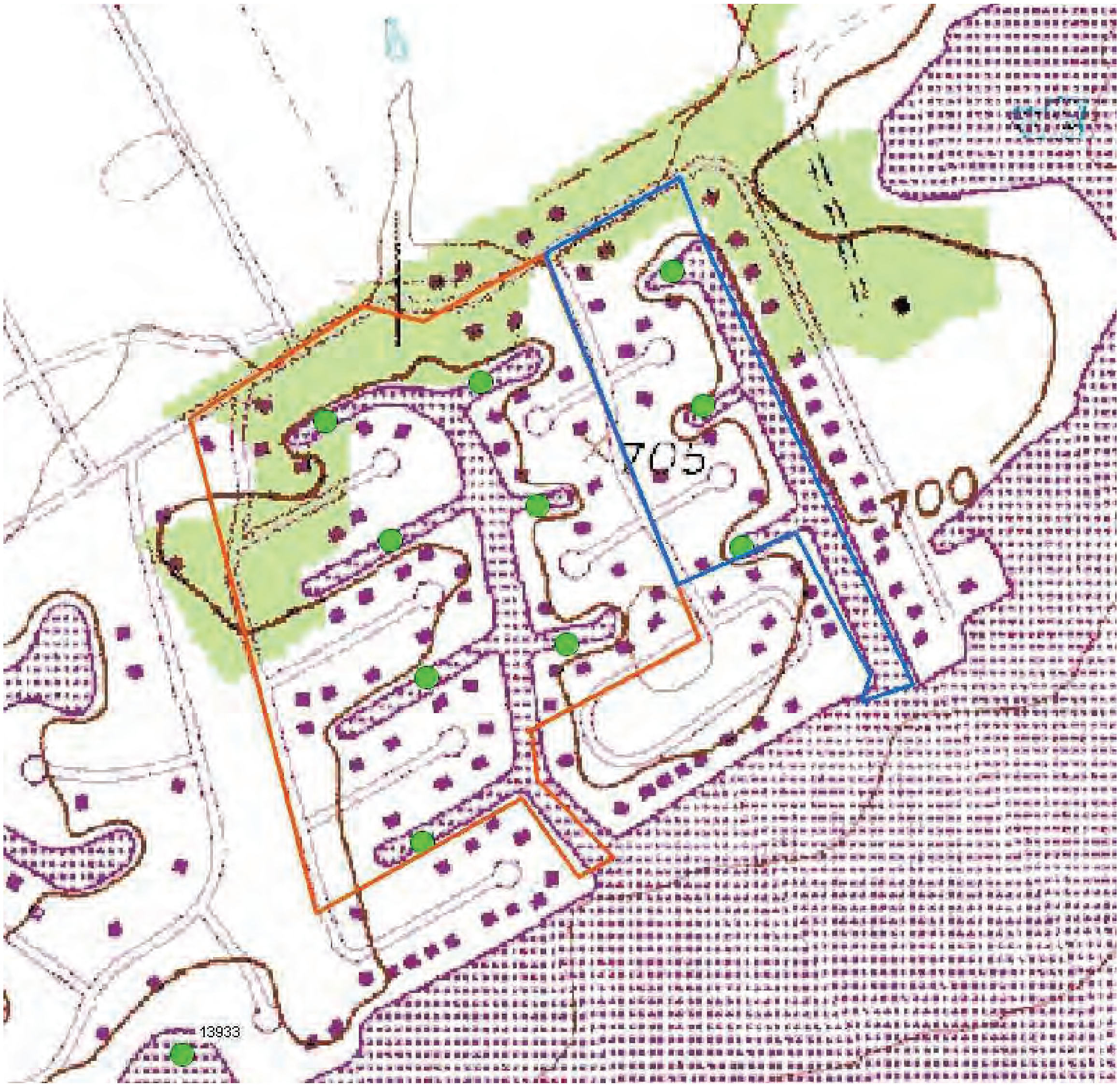
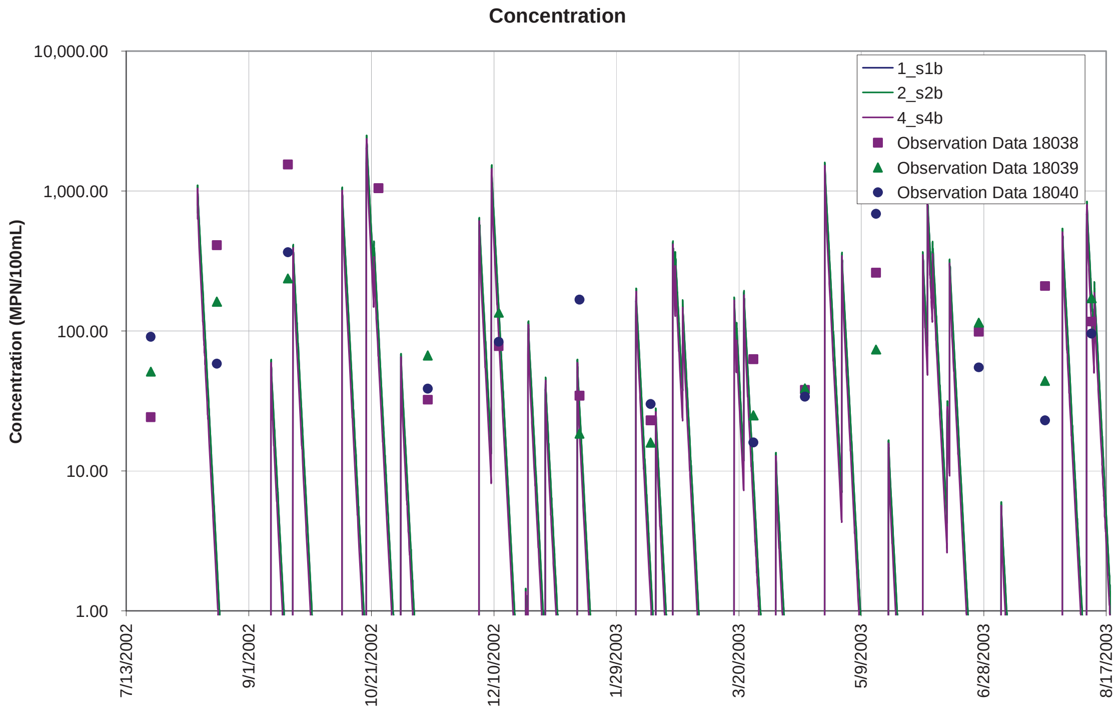


Figure E.55 Microwatershed Delineation for Port Ridglea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10,000.00
1,000.00
100.00
10.00
1.00
Concentration (MPN/100mL)
1_s1b
2_s2b
4_s4b
Observation Data 18038
Observation Data 18039
Observation Data 18040
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1/29/2003
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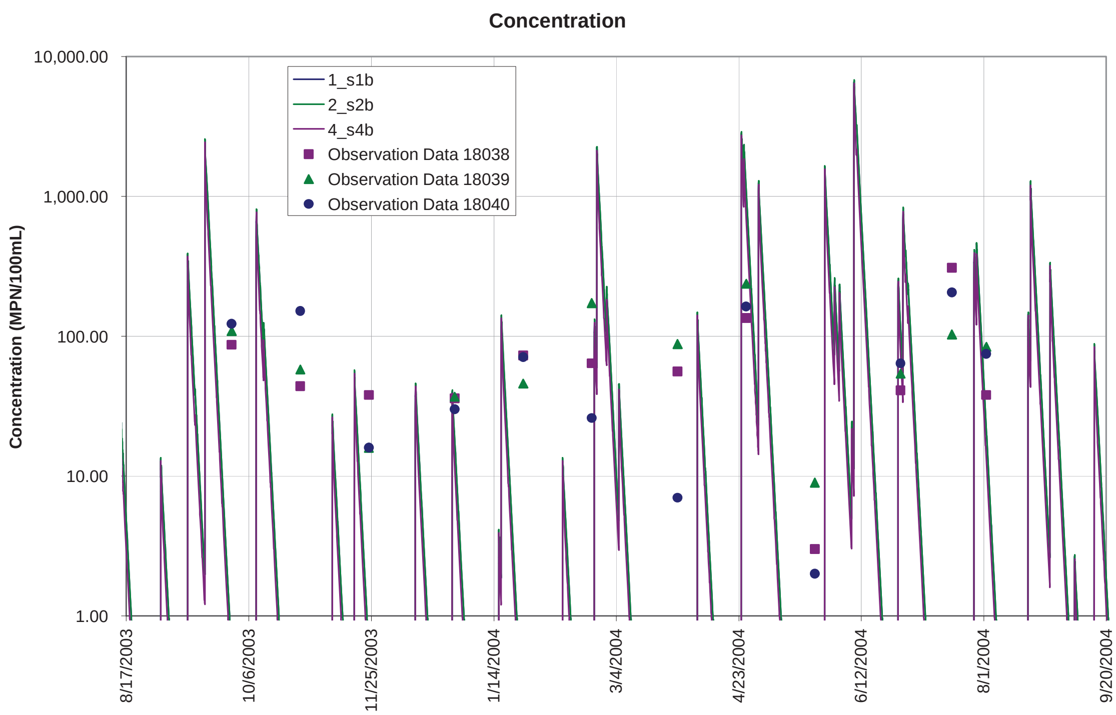
5/9/2003
6/28/2003
8/17/2003


Concentration
10,000.00
1,000.00
100.00
10.00
1.00
Concentration (MPN/100mL)
1_s1b
2_s2b
4_s4b
Observation Data 18038
Observation Data 18039
Observation Data 18040
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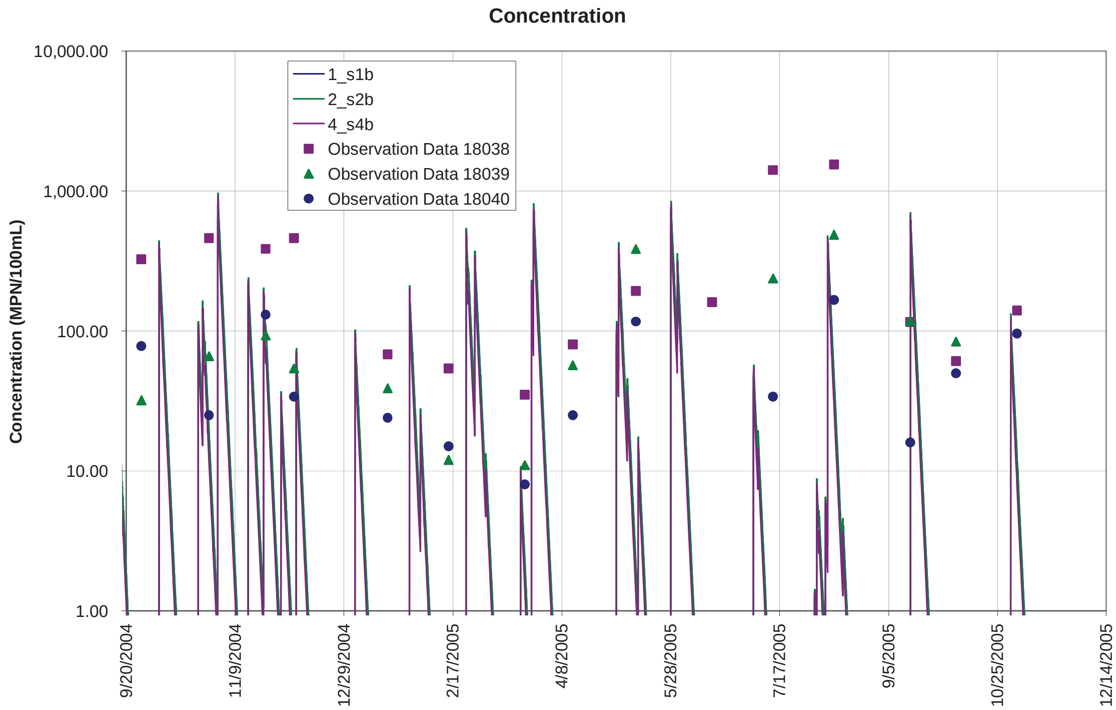
11/25/2003
1/14/2004
3/4/2004
4/23/2004
6/12/2004
8/1/2004
9/20/2004


Concentration
Concentration (MPN/100mL)
10,000.00
1,000.00
100.00
10.00
1.00
1_s1b
2_s2b
4_s4b
Observation Data 18038
Observation Data 18039
Observation Data 18040
9/20/2004
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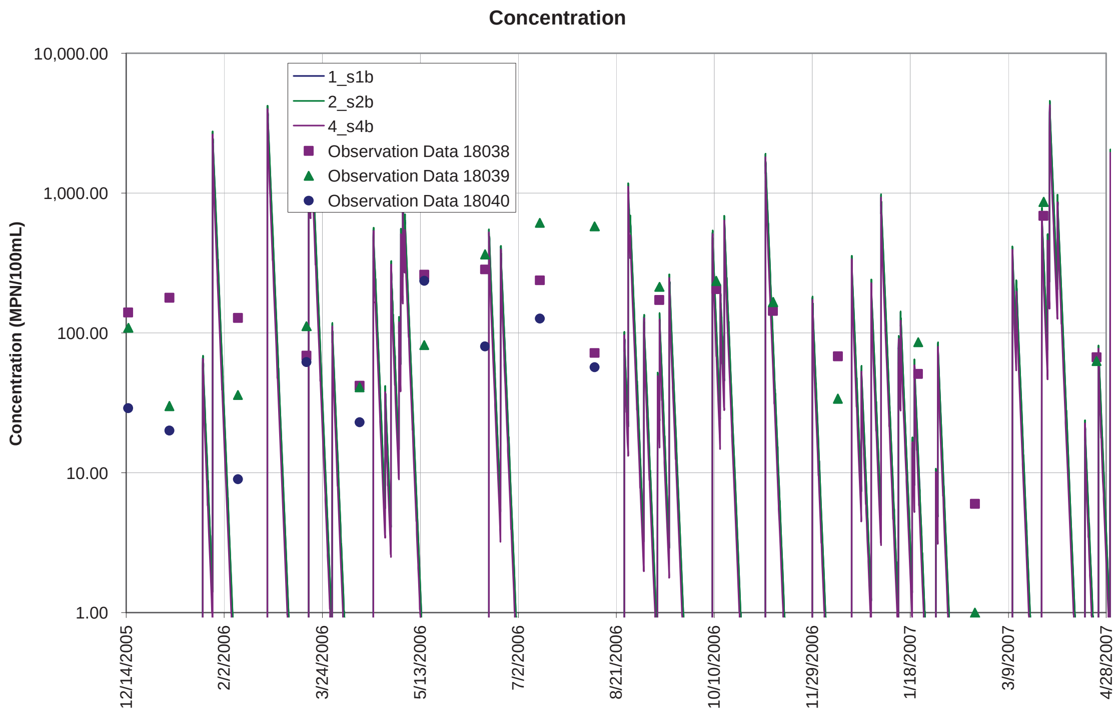
10/25/2005
12/14/2005


Concentration
Concentration (MPN/100mL)
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1,000.00
100.00
10.00
1.00
1_s1b
2_s2b
4_s4b
Observation Data 18038
Observation Data 18039
Observation Data 18040
12/14/2005
2/2/2006
3/24/2006
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3/9/2007
4/28/2007

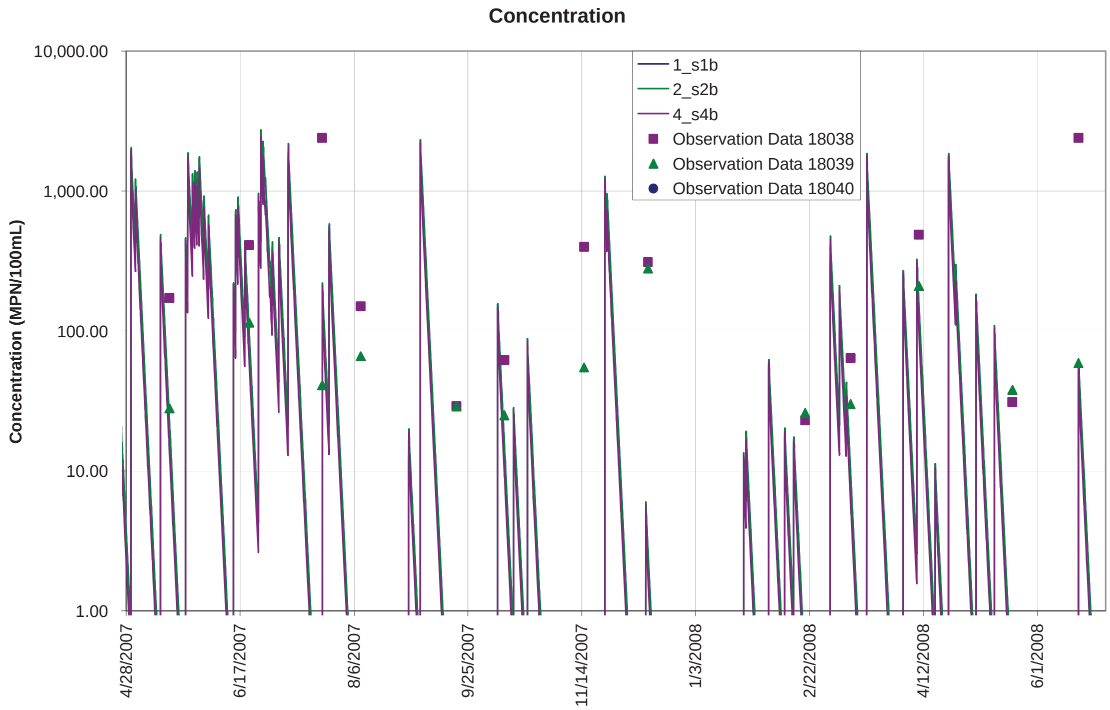


Figure E.56 Runoff model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Stations 18036, 18039, and 18040 located within the Port Ridglea Canals

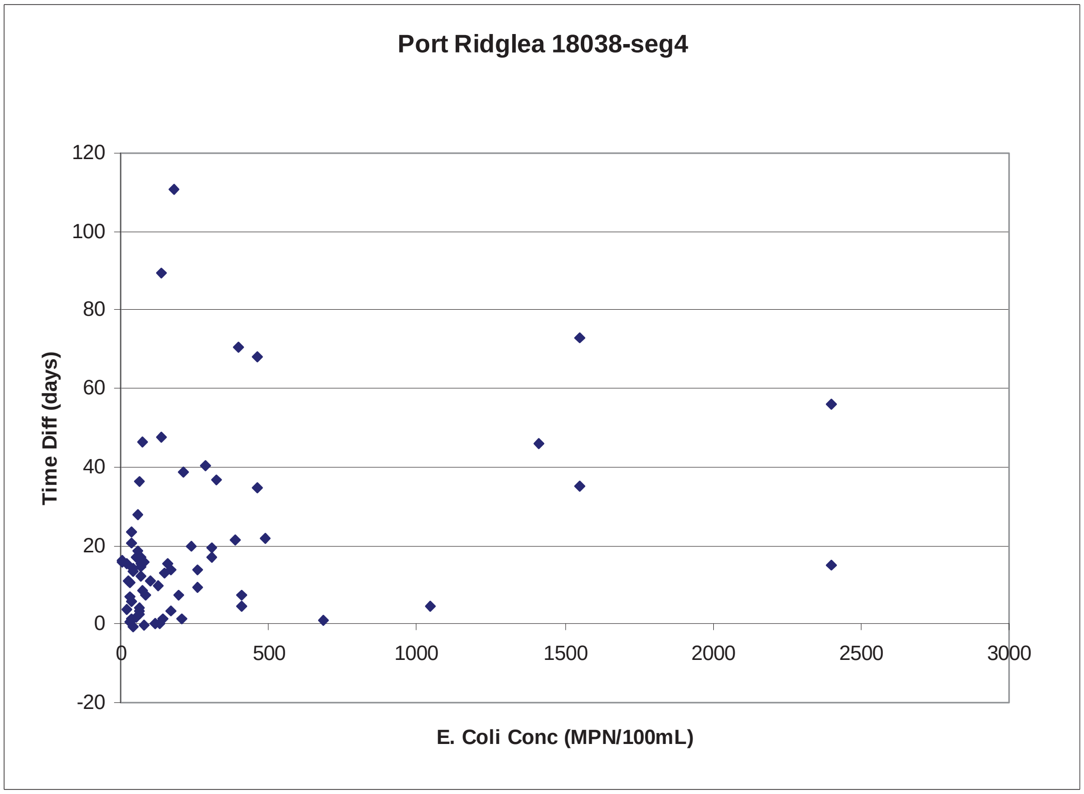


Figure E.57 Residual Plot for Station 18038 located within the Port Ridglea Canals

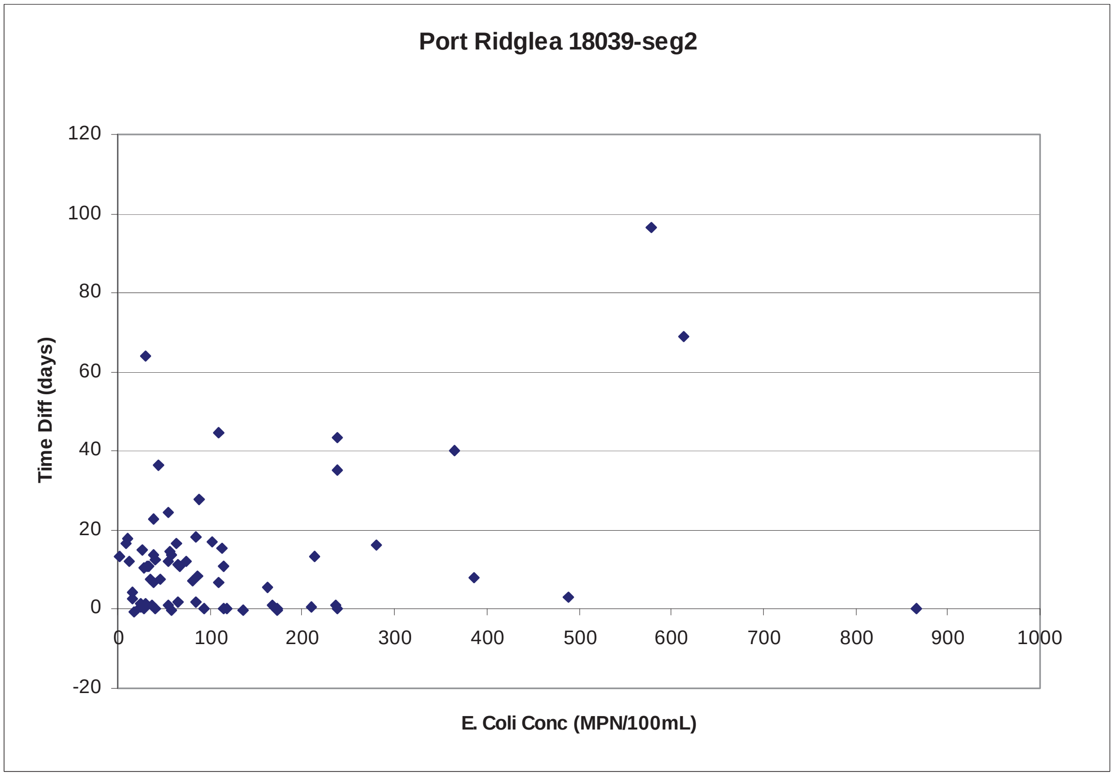


Figure E.58 Residual Plot for Station 18039 located within the Port Ridglea Canals

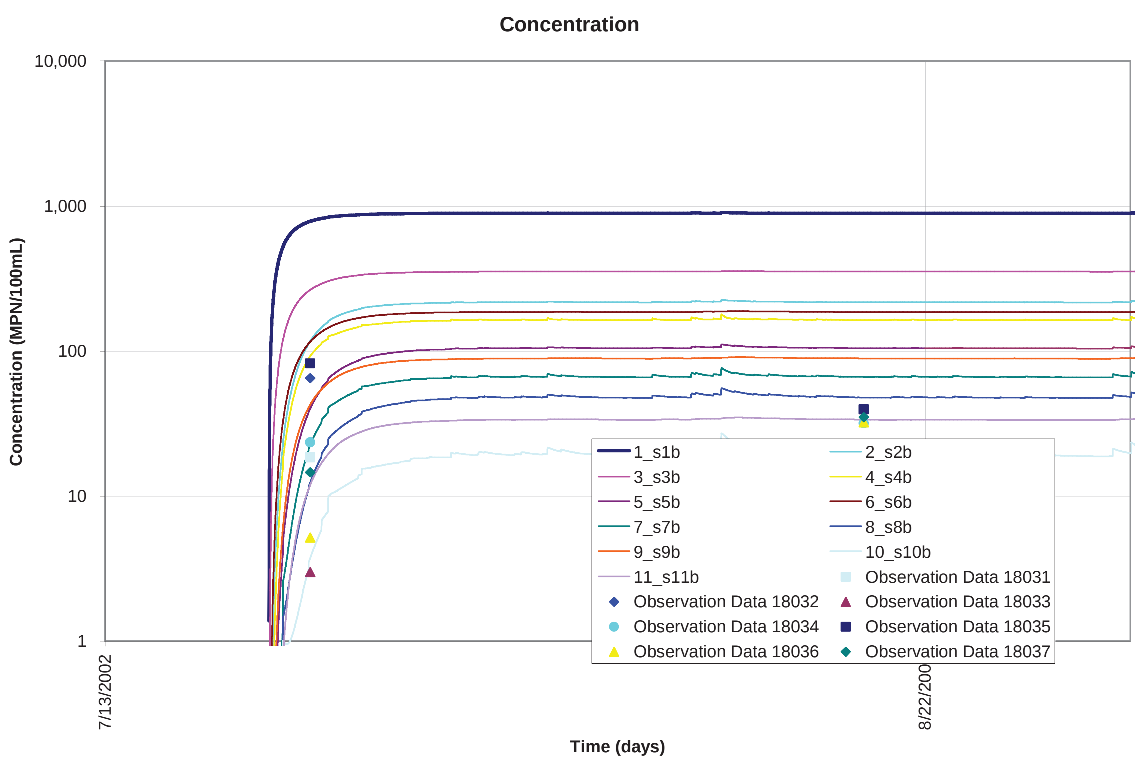


Figure E.59 Modeled Continuous Direct Discharge (septic) in Port Ridglea Canals

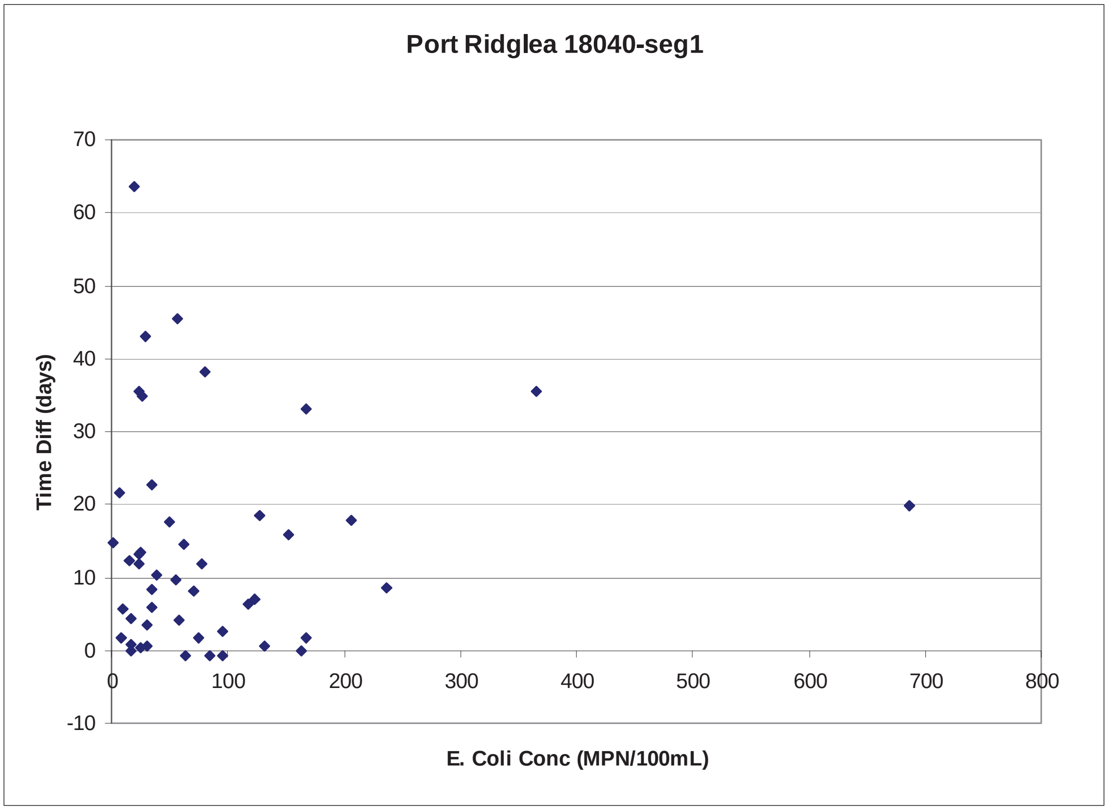


Figure E.60 Residual Plot for Station 18040 located within the Port Ridglea Canals

E.2.10 Blue Water Shores

Figure E.61 Canal Segmentation for Modeling Blue Water Shores

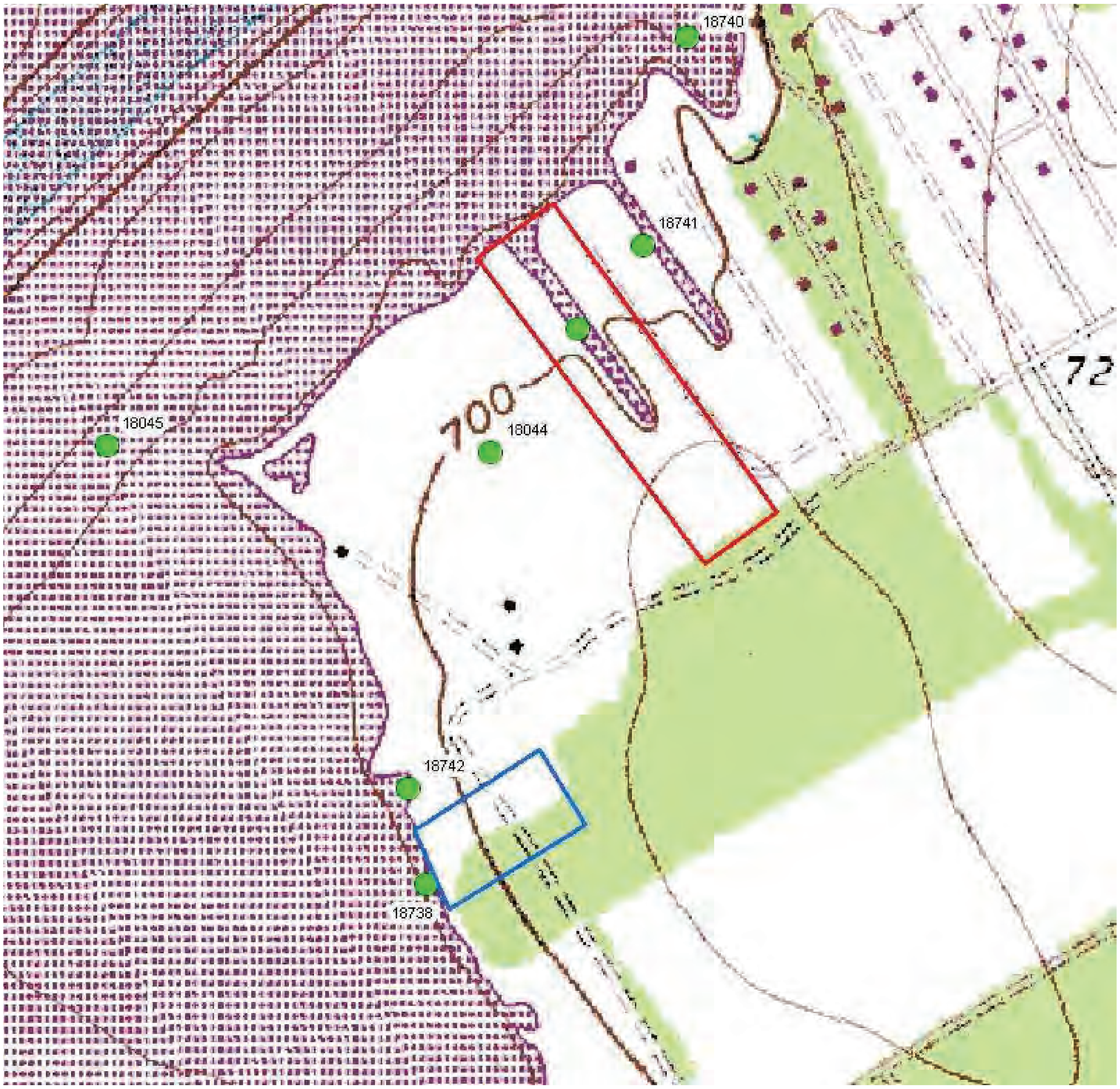
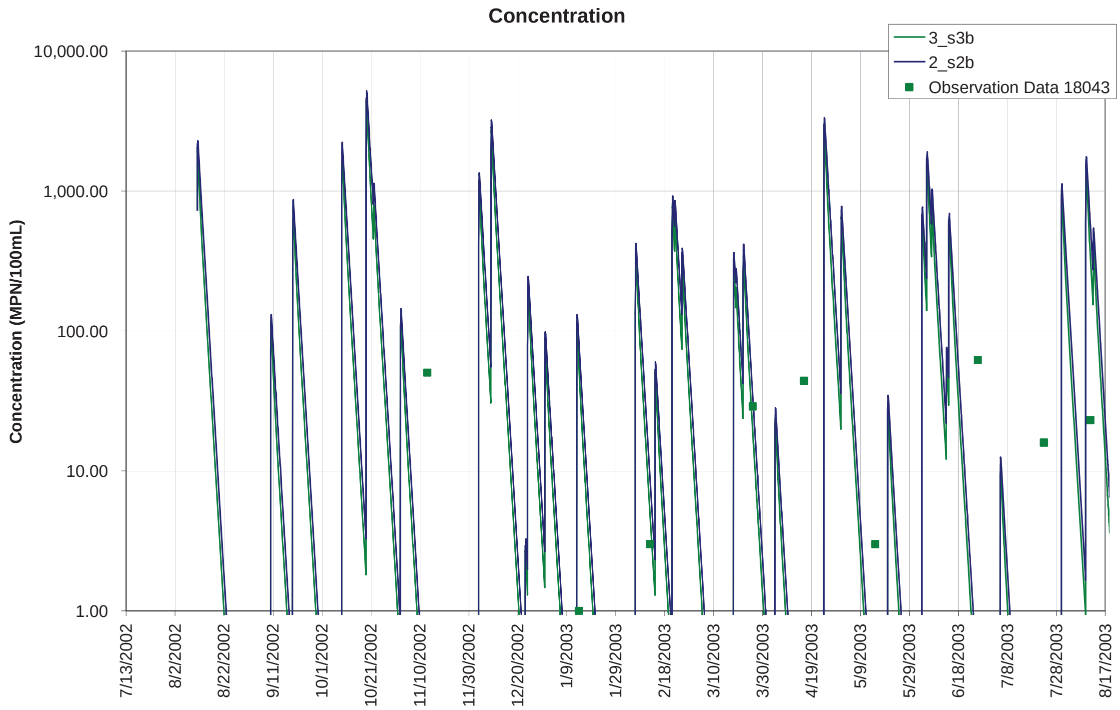


Figure E.62 Microwatershed Delineation for Blue Water Shores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2_s2b
Observation Data 18043
Concentration (MPN/100mL)
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100.00
10.00
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9/11/2002
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11/10/2002
11/30/2002
12/20/2002
1/9/2003
1/29/2003
2/18/2003
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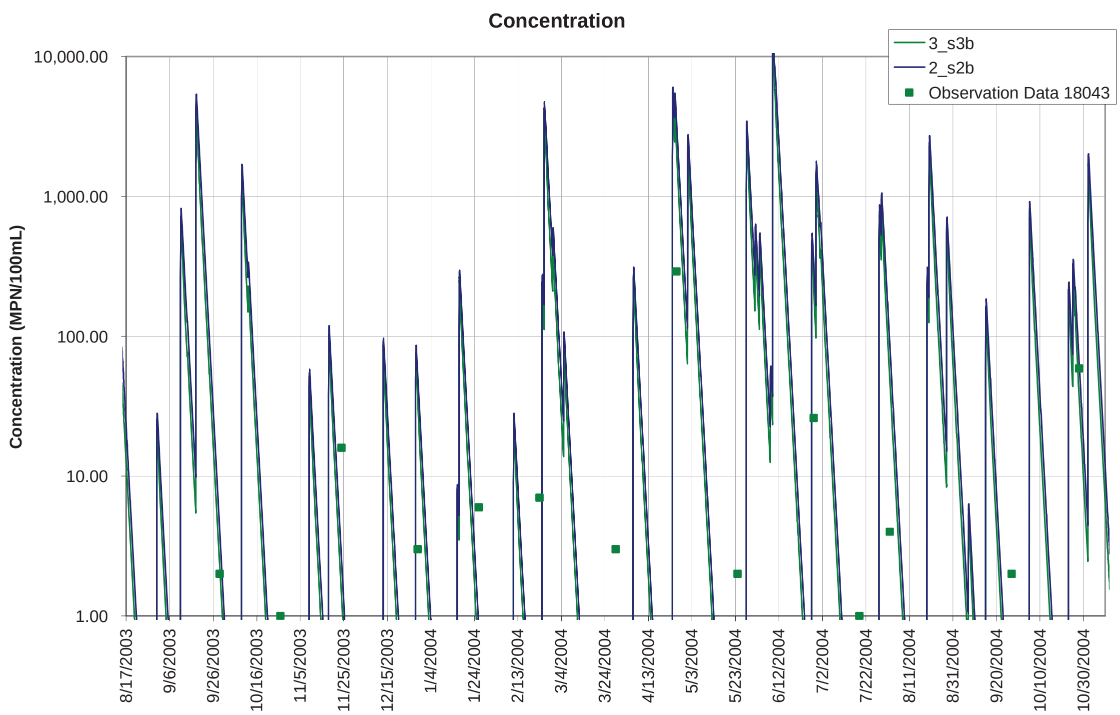
7/28/2003
8/17/2003


Concentration
3_s3b
2_s2b
Observation Data 18043
Concentration (MPN/100mL)
10,000.00
1,000.00
100.00
10.00
1.00
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10/16/2003
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11/25/2003
12/15/2003
1/4/2004
1/24/2004
2/13/2004
3/4/2004
3/24/2004
4/13/2004
5/3/2004
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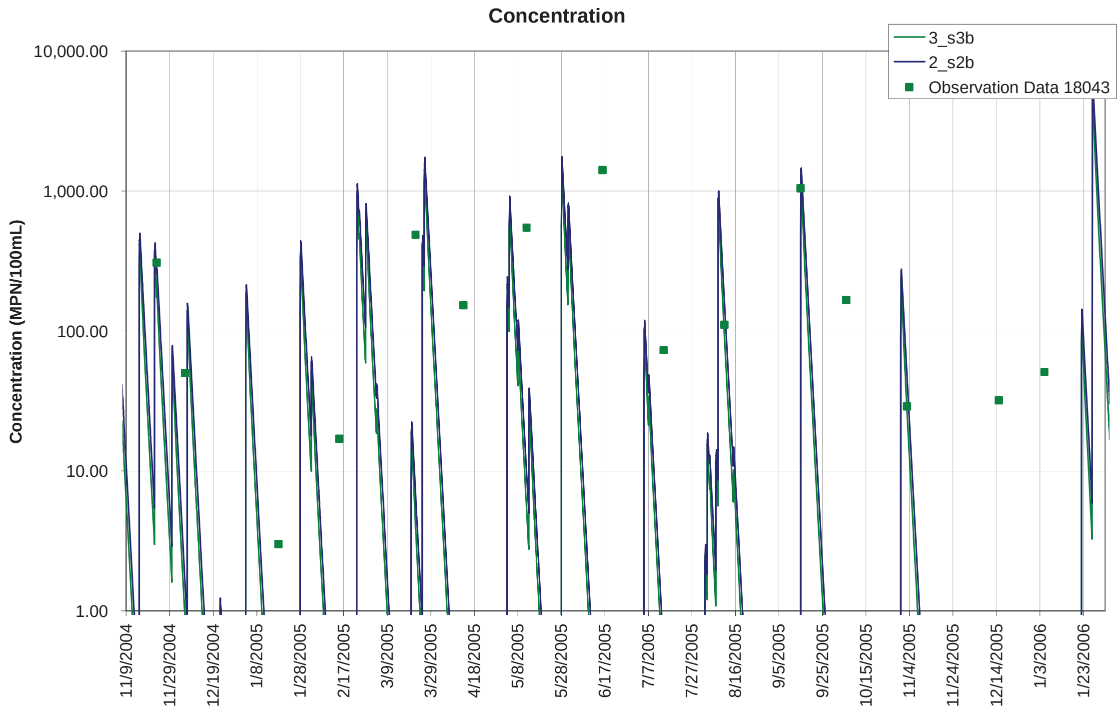
10/10/2004
10/30/2004



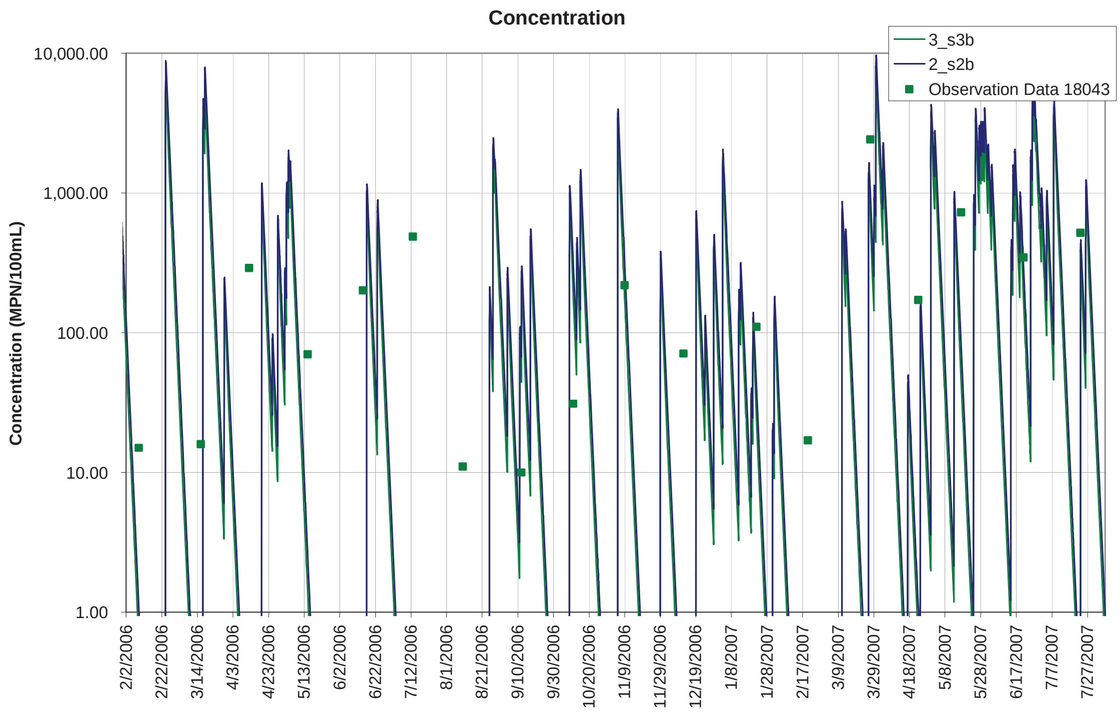


Figure E.63 Runof model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Station 18043 located within the Blue Water Shores Canal

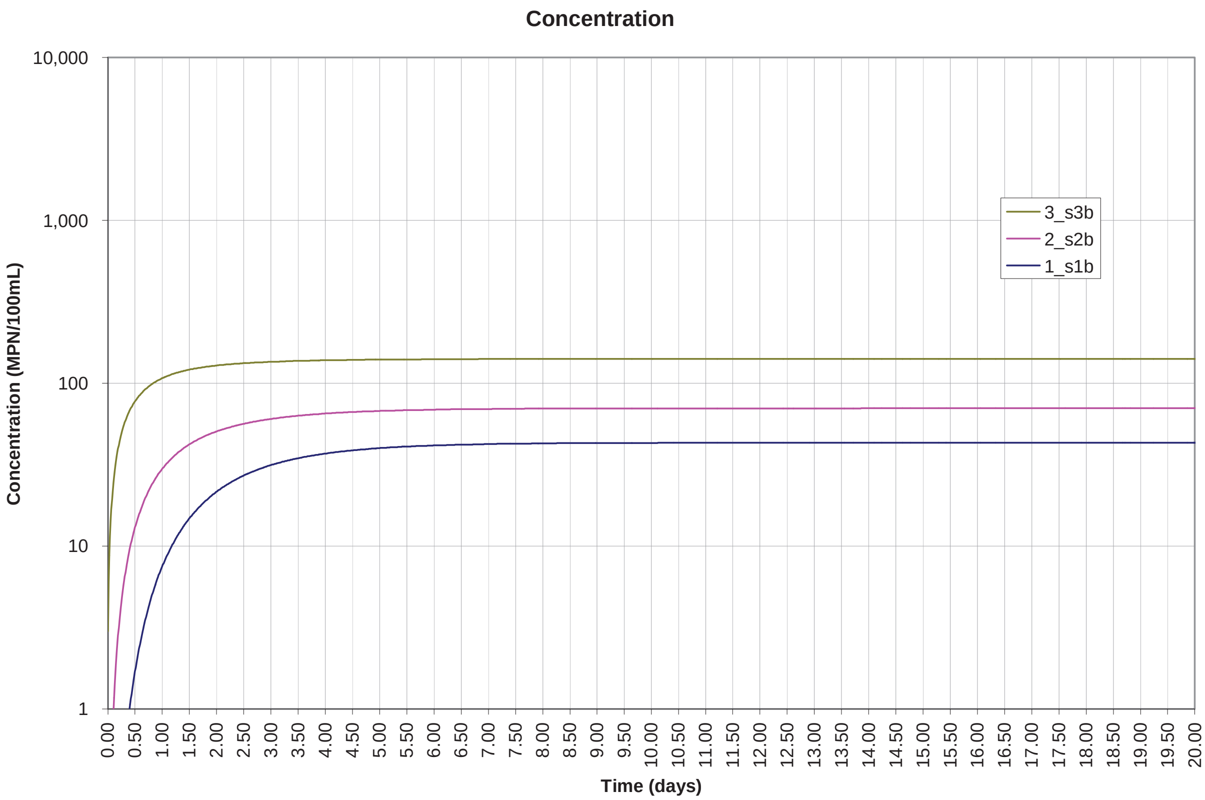


Figure E.64 Modeled Lake Boundary Condition for Blue Water Shores

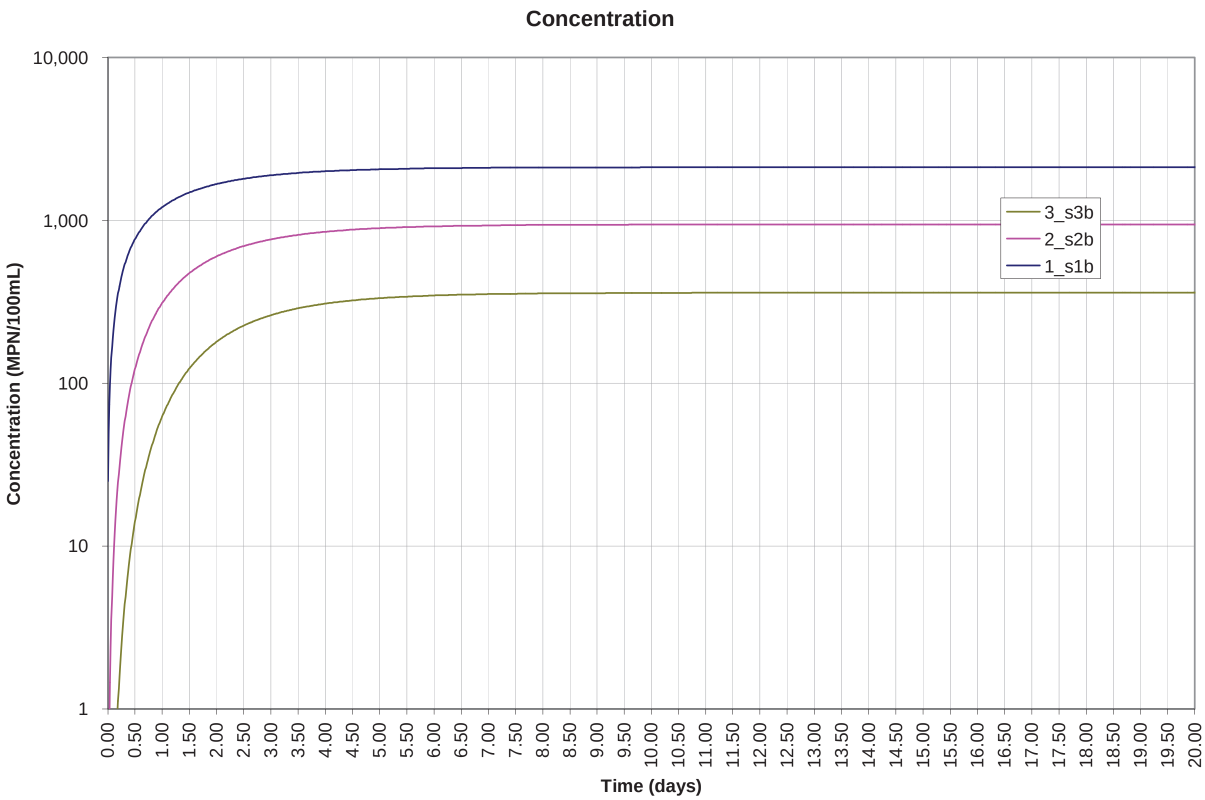


Figure E.65 Modeled Continuous Direct Discharge (septic) in the Blue Water Shores Canal

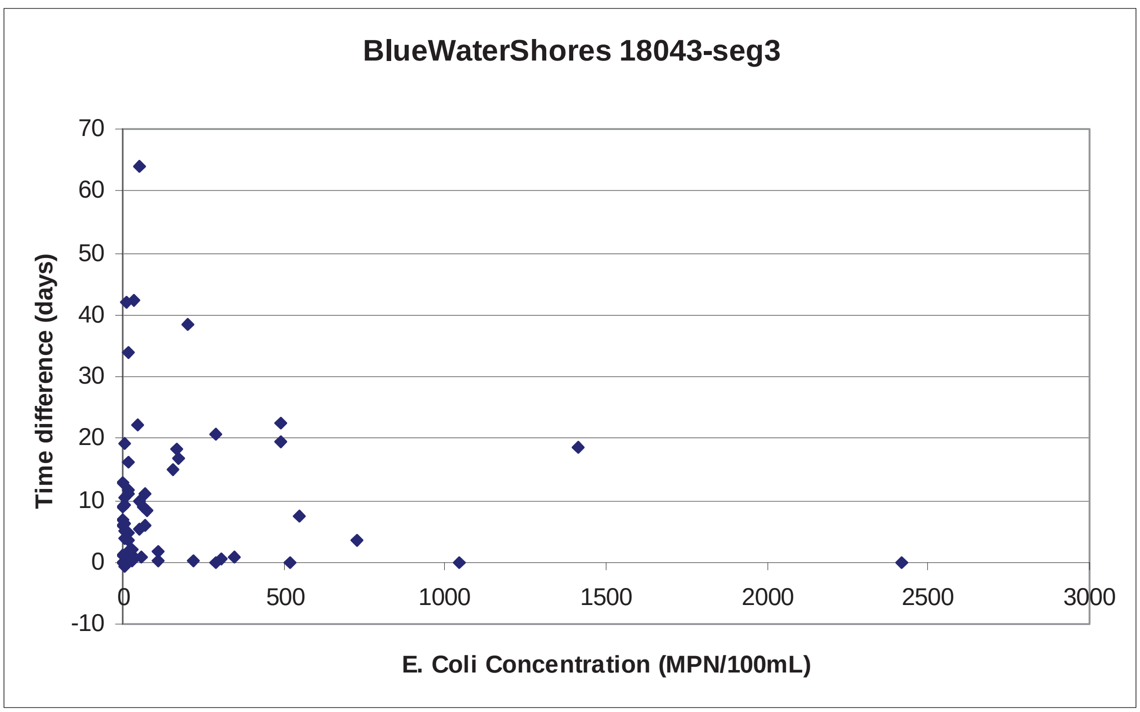


Figure E.66 Residual Plot for Station 18043 located within the Blue Water Shores Canal

F.0 APPENDIX F – MANAGEMENT MEASURES EVALUATION

F.1 Management Measures Assumptions and Summary Sheets

Alternative Name:	Septic Replacement
Description:	Replacement of old and malfunctioning On-site Sewage Facilities (OSSFs) with new units that meet current standards.
Pollutant Addressed:	Bacteria
Conceptual Design Assumptions:	
Soil Suitability	SSURGO Soil Survey for Hood County. Depth to Bed Rock, Minimum Depth to Restrictive Layer
Applicable Treatment Methods	30 TAC §285.91 Table 13 Pretreatment Method: Septic or Aerobic Treatment Disposal Method: Drainfield, Drip Emmitters, Spray Distribution, or Leaching Chambers
Required Area for Disposal	30 TAC §285 Design Discharge 240 gpd/system Soil Absorption 0.2 to 0.38 gpd/sq-ft (sandy clay to sand) Application Rate Irrigation 0.064 Absorptive Rate 0.2 gpd/sq-ft for Drip Emitters and Leaching Chambers *1200 ft^2 for Conventional Drainfield (not in clays), drip emitters, and leaching chambers (not in clays, some reduction allowed for water saving devices)* *3750 ft^2 for Spray Application*
Capital Cost Assumptions:	*Source: Austin Water Utility*
Construction Cost	Cost to install pretreatment tanks and related necessary components. Cost to install disposal field and all necessary components.
Land Costs	Appraisal Value of average lot if more area needed and available for disposal fields. Did not apply in all cases.
Design & Administrative	Estimated - engineering judgement. Assumed $2,500 per system, regardless of type.
Contingency	none included
O&M Cost Assumptions:	*Source: Austin Water Utility* Periodic pumping of tanks, both aerobic and septic Maintenance contracts required for spray application and holding tanks Electrical use for spray application and drip emitters Additional equipment and repairs for spray application and drip emitters
Equivalent Annual Cost Analysis:	
Lifespan Assumption:	25 years
Interest Rate Assumption:	10% Weighted cost of capital, assuming return to inflationary trend within 5 years
Equivalent Annual Cost Index:	Ratio of Equivalent Annual Cost for this alternative compared to the maximum Equivalent Annual Cost of all alternatives considered for the specific subdivision.
Percent Pollutant Reduction:	
Watershed Model	75% of septic potential removed Resultant %reduction of bacteria for watershed considering all sources

Alternative Name:	OSSF (Septic) Replacement				
Alternative ID:	~~Rolling Hills Shores – Downhill Along Cove~~	Rolling Hills Shores - Uphill	Oak Trail Shores Section 1	Oak Trail Shores Section 2	Oak Trail Shores Section 3
Conceptual Design Assumptions:					
Average Lot Size	~~< 6,000 ft^2~~	0.75 acres	14,000 ft^2	10,000 ft^2	10,000 ft^2
Soil Suitability	~~Null, In floodplain~~	Some areas have adequate depth to bedrock and restrictive layer for conventional septic tank/drainfield systems.	Significant areas have adequate depth to bedrock and restrictive layer for conventional septic tank/drainfield systems.	Depth to bedrock and restrictive layer as well as proximity to canals makes poor suitability for conventional systems.	Significant areas have adequate depth to bedrock and restrictive layer for conventional septic tank/drainfield systems in northwest portion, remaining soils not suitable for conventional system.
Applicable Treatment Methods	~~Holding tanks~~	Assume 1/2 can utilize conventional systems, remaining half spray distribution with pretreatment.	Conventional Septic Tank and Drainfield	septic tanks with Spray Distribution aerobic tanks with Drip Emitters	conventional septic/drainfield in NW septic tanks with Spray Distribution aerobic tanks with Drip Emitters septic tanks with leaching chambers
Required Area for Disposal	~~N/A – Waste must be pumped and trucked off-site~~	Conventional Drainfield 1200 ft^2 Spray Distribution 4404 ft^2	Conventional Drainfield 1200 ft^2	Spray Distribution 4404 ft^2 Drip Emitters 1200 ft^2	Conventional Drainfield 1200 ft^2 Spray Distribution 4404 ft^2 Drip Emitters 1200 ft^2 Leaching Chambers 1200 ft^2
Capital Costs:		average (assuming 1/2 spray, 1/2 drainfield)		average (assuming 1/2 spray, 1/2 drip emitter)	average (assuming 1/2 spray, 1/4 conventional, 1/8 drip emitters, 1/8 leaching chambers)
Construction Cost	~~holding tank~~	septic; aerobic tanks drainfield spray application;	septic tank drainfield	septic; aerobic tanks spray application; drip emitter field	septic; aerobic tanks drainfield; spray application; drip emitter field; leaching chamber field
Land Costs	~~None~~ ~~Some permitting fees may apply. Not included here.~~	None	None	None	None
Annual O&M Costs:	~~Pumping and trucking (annual)~~	average (assuming 1/2 spray, 1/2 drip emitters) Periodic pumping of tanks, both aerobic and septic Maintenance contracts required for spray application Electrical use for spray application Additional equipment and repairs for spray application	Periodic pumping of septic tanks	average (assuming 1/2 spray, 1/2 drip emitter) Periodic pumping of aerobic and septic tanks Maintenance contracts required for spray application and drip emitters Electrical use for spray application and drip emitters Additional equipment and repairs for spray application and drip emitters	average (assuming 1/2 spray, 1/4 conventional, 1/8 drip emitters, 1/8 leaching chambers) Periodic pumping of aerobic and septic tanks Maintenance contracts required for spray application and drip emitters Electrical use for spray application and drip emitters Additional equipment and repairs for spray application and drip emitters
Equivalent Annual Cost Analysis:					
Equivalent Annual Cost Index:		0.49	0.38	0.73	0.50
Percent Pollutant Reduction:		46%	41% Sections not modeled separately.		

Alternative Name:	OSSF (Septic) Replacement		
Alternative ID:	Long Creek	Sky Harbor	Port Ridglea East
Conceptual Design Assumptions:			
Average Lot Size	26,000 ft^2	15,250 ft^2	10,900 ft^2
Soil Suitability	Depth to bedrock and restrictive layer as well as proximity to canals makes poor suitability for conventional systems.	Significant land could be suitable for conventional drainfields	"Null" for both depth to bedrock and depth to restrictive layer Septic tank absorption field suitability "Very Limited"
Applicable Treatment Methods	septic or aerobic tanks with Spray Distribution aerobic tanks with drip emitters	Assume 1/4 can utilize conventional systems, half spray distribution (septic or aerobic tanks), 1/8 drip emitters (aerobic tanks), 1/8 leaching chambers (septic)	Replace conventional systems with aerobic tanks with drip emitters
Required Area for Disposal	Spray Distribution 4404 ft^2 Drip Emitters 1200 ft^2	Conventional Drainfield 1200 ft^2 Spray Distribution 4404 ft^2 Drip Emitters 1200 ft^2 Leaching Chambers 1200 ft^2	Drip Emitters 1200 ft^2
Capital Costs:	average (assuming 1/2 spray, 1/2 drip emitter)	average (assuming 1/2 spray, 1/4 septic/drainfield, 1/8 drip emitter, 1/8 leaching chamber)	assuming all drip emitters with aerobic pretreatment
Construction Cost	septic; aerobic tanks spray application; drip emitter field	septic; aerobic tanks drainfield; spray application; drip emitter field; leaching chamber field	aerobic tanks drip emitter field
Land Costs	None	None	None
Annual O&M Costs:	average (assuming 1/2 spray, 1/2 drip emitter)	average (assuming 1/2 spray, 1/4 septic/drainfield, 1/8 drip emitter, 1/8 leaching chamber)	assuming all drip emitters with aerobic pretreatment
	Periodic pumping of aerobic and septic tanks	Periodic pumping of aerobic and septic tanks	Periodic pumping of aerobic tank
	Maintenance contracts required for spray application and drip emitters	Maintenance contracts required for spray application and drip emitters	Maintenance contracts required for drip emitters
	Electrical use for spray application and drip emitters	Electrical use for spray application and drip emitters	Electrical use for drip emitters
	Additional equipment and repairs for spray application and drip emitters	Additional equipment and repairs for spray application and drip emitters	Additional equipment and repairs for drip emitters
Equivalent Annual Cost Analysis:			
Equivalent Annual Cost Index:	0.80	0.57	1.00
Percent Pollutant Reduction:	Negligible watershed reduction.	9%	75%

Alternative Name:	Low Pressure Wastewater Collection System
Description:	Removal of OSSFs, replacement with low pressure collection system
Pollutant Addressed:	Bacteria
Conceptual Design Assumptions:	LP collection system per vendor design guidelines; TCEQ Chap. 217; SDR-21 pressure class PVC
	200 gal/connection/day
	30 Amp/240V dedicated circuit available at each site
	Assumed TDH (Total Dynamic Head) <185'; design goal is operating pressure below 60 psi.
	Average flowrate at each pump set at 11 gpm.
	Lines to be installed in existing ROW; infrequent conflicts with other utilities, driveways, mailboxes, etc.
	Relief valve assemblies not included (no analysis done to determine need)
	Easements required from service tap to grinder pump would be granted at no cost
	Capacities and costs assume service to each platted lot, whether occupied or not.
	Lift station capacity determined by peak flows (TCEQ CH 217, Subchap B).
Capital Cost Assumptions:	
Construction Cost	LP system includes: grinder pump/tank (station); control panel; lateral assembly; saddle tap to main; bedding material; force main; asphalt repair
	3-phase power is assumed to be available at lift station and plant sites
Design & Administrative	Engineering, Surveying, Permitting, Construction Administration, Contract Administration Total 20% (added to construction cost)
Contingency	Given multiple uncertainties at this stage, 20% assumed and added to construction cost.
O&M Cost Assumptions:	
	Maintenance will be performed under contract, monthly fee assessed
	Pump equipment replacement at year 10, partial equipment (other than pump) replacement at year 21
	Power cost calculated at $0.11/kWh and +/- 9 kWh/month
Equivalent Annual Cost Analysis:	
Lifespan Assumption:	25 years
Interest Rate Assumption:	10% Weighted cost of capital assuming inflationary trend
Equivalent Annual Cost Index:	Ratio of Equivalent Annual Cost for this alternative compared to the maximum Equivalent Annual Cost of all alternatives.

Alternative Name:	Mixed Collection System: Gravity and Low Pressure
Description:	Removal of OSSFs, replacement with mixed low pressure and gravity collection system
Pollutant addressed:	Bacteria
Conceptual Design Assumptions:	LP collection system per vendor design guidelines; TCEQ Chap. 217; SDR-21 pressure class PVC
	200 gal/connection/day
	30 Amp/240V dedicated circuit available at each site
	Assumed TDH <185'; design goal is operating pressure below 60 psi.
	Average flowrate at each pump set at 11 gpm.
	Lines to be installed in existing ROW; infrequent conflicts with other utilities, driveways, mailboxes, etc.
	Relief valve assemblies not included (no analysis done to determine need)
	Easements required from service tap to grinder pump would be granted at no cost
	Capacities and costs assume service to occupied lots only.
	Lift station capacity determined by peak flows (TCEQ CH 217, Subch B).
Capital Cost Assumptions:	
Construction Cost	LP system includes: grinder pump/tank (station); control panel; lateral assembly; saddle tap to main; bedding material; force main; asphalt repair
	8" PVC Gravity main assumed; slope assumed consistent with surface grade; concrete 4' dia manholes assumed at change in direction and every 400'
	3-phase power is assumed to be available at lift station and plant sites
Design & Administrative	Engineering, Surveying, Permitting, Construction Administration, Contract Administration Total 20% (added to construction cost)
Contingency	Given multiple uncertainties at this stage, 20% assumed and added to construction cost.
O&M Cost Assumptions:	Maintenance will be performed under contract/monthly fee assessed
	Pump equipment replacement at year 10, partial equipment (other than pump) replacement at year 21
	Power cost calculated at $0.11/kWh and +/- 9 kWh/month
Equivalent Annual Cost Analysis:	
Lifespan Assumption:	25 years
Interest Rate Assumption:	10%
	Weighted cost of capital assuming inflationary trend
Equivalent Annual Cost Index:	Ratio of Equivalent Annual Cost for this alternative compared to the maximum Equivalent Annual Cost of all alternatives.

Alternative Name:	Local Wastewater Treatment (Package Plant/MiniWastewater)
Description:	Removal of OSSFs, replacement with a collection system to a package treatment plant
Pollutant Addressed:	Bacteria
Conceptual Design Assumptions:	Serves an individual subdivision or an aggregation of subdivisions Collection by low pressure or mixed system Treats up to 0.5 MGD 200 gal/connection/day Plant capacity determined by permitted flows (TCEQ CH 217, Subchapter B). Steel construction Plant location not tied to specific property, but "prototypical, neutral property" based on total dynamic head pumping limits Assumed treatment limits: CBOD-10, TSS-15, NH3-2, DO-4, P-2 Treated wastewater discharged into lake, or immediate tributary to lake after disinfection
Capital Cost Assumptions:	
Construction Cost	3-phase power is assumed to be available at lift station and plant sites Wastewater Treatment Plant is assumed to be steel package plant with limits as described above. Price includes sitework/yardwork/electrical and foundation.
Land Costs	Purchase of land for plant site assumed at 3 times taxroll appraised value due to limitations on pumping (total dynamic head) that will restrict site selection (ie. lack of substitutability).
Design & Administrative	Engineering, Surveying, Permitting, Construction Administration, Contract Administration Total 20% (added to construction cost)
Contingency	Given multiple uncertainties at this stage, 20% assumed and added to construction cost.
O&M Cost Assumptions:	Includes labor, chemicals/materials, equipment replacement Power cost calculated at $0.11/kWh and +/- 9 kWh/month Maintenance will be performed under contract/monthly fee assessed
Equivalent Annual Cost Analysis:	
Lifespan Assumption:	25 years
Interest Rate Assumption:	10% Weighted cost of capital assuming inflationary trend
Equivalent Annual Cost Index:	Ratio of Equivalent Annual Cost for this alternative compared to the maximum Equivalent Annual Cost of all alternatives.

Alternative ID:	RHS-LP-Local	RHS FP-LP-Local
Alternative Name:	Rolling Hills Shores, Low Pressure System, Local Treatment	Rolling Hills Shores Floodplain, Low Pressure System, Local Treatment
Service Area	Rolling Hills Shores and Hidden Valley Estates	Residences in floodplain in Rolling Hills Shores
Collection		
Number of Connections	299 (103 residences and 196 non-floodplain lots)	103
Lift Station	Not considered to be required for chosen treatment site.	Not considered to be required for chosen treatment site.
Wastewater Treatment		
Treatment Facility	Package Plant	Package Plant
Treatment Flows	0.09 MGD	0.03 MGD
Equivalent Annual Cost Index:	0.64	0.65
Pollutant Percent Reduction:	62%	62%

Alternative ID:	OTS-LP-Local	LC-LP-Local
Alternative Name:	Oak Trail Shores, Low Pressure System, Local Treatment	Long Creek, Low Pressure System, Local Treatment
Service Area	Oak Trail Shores	Long Creek
Collection		
Number of Connections	1985	95
Lift Station	Assumed flow from 875 connections to be lifted: 1.05 MGD, 3,300 ft force main	Not considered to be required for chosen treatment site.
Wastewater Treatment		
Treatment Facility	Package Plant	Package Plant
Treatment Flows	0.596 MGD	0.03 MGD
Equivalent Annual Cost Index:	0.55	0.59
Pollutant Percent Reduction:	54%	100%

Alternative ID:	SH-LP-Local	~~IH-LP-Local~~
Alternative Name:	Sky Harbor, Low Pressure, Local Treatment	~~Indian Harbor, Low Pressure, Local Treatment~~
Service Area	Sky Harbor	~~Indian Harbor~~
Collection		
Number of Connections	629	~~1909~~
Lift Station	Assumed flow from 215 connections lifted: 0.258 MGD, 5,250 ft force main	~~Assumed flow from 790 connections lifted: 0.948 MGD, 6,000 ft force main~~
Wastewater Treatment		
Treatment Facility	Package Plant	~~Package Plant~~
Treatment Flows	0.189 MGD	~~0.573 MGD~~
Equivalent Annual Cost Index:	0.42	~~0.25~~
Pollutant Percent Reduction:	13%	~~100%~~

Alternative ID:	~~NB II-LP-Local~~	~~PRE-LP-Local~~
Alternative Name:	~~Nassau Bay II, Low Pressure, Local Treatment~~	~~Port Ridglea East-Low Pressure-Local Treatment~~
Service Area	~~Nassau Bay II~~	~~Port Ridglea East~~
Collection		
Number of Connections	~~123~~	~~248~~
Lift Station	~~Not considered to be required for chosen treatment site.~~	~~Not considered to be required for chosen treatment site.~~
Wastewater Treatment		
Treatment Facility	~~Package Plant~~	~~Package Plant~~
Treatment Flows	~~0.037 MGD~~	~~0.074 MGD~~
Equivalent Annual Cost Index:	~~0.28~~	~~0.28~~
Pollutant Percent Reduction:	~~98%~~	~~100%~~

Alternative ID:	RHS-Mixed-Local	OTS-Mixed-Local	SH-Mixed-Local
Alternative Name:	Rolling Hills Shores, Mixed Collection, Local Treatment	Oak Trail Shores, Mixed Collection, Local Treatment	Sky Harbor, Mixed Collection, Local Treatment
Service Area	Rolling Hills Shores and Hidden Valley Estates	Oak Trail Shores	Sky Harbor
Collection			
Number of Connections	299 (103 residences and 196 non-floodplain lots)	1985	629
Low Pressure Connections	288	849	215
Gravity Connections	11	1136	414
Lift Station	Not considered to be required for chosen treatment site.	Lift flow from 849 connections: 1.36 MGD, 3,300 ft force main	Lift flow from 215 connections: 0.258 MGD, 1,800 ft force main
Force Main			
Wastewater Treatment			
Treatment Facility	Package Plant	Package Plant	Package Plant
Treatment Flows	0.09 MGD	0.596 MGD	0.189 MGD
Equivalent Annual Cost Index:	0.67	0.38	0.42
Pollutant Percent Reduction:	62%	54%	13%

Alternative ID:	~~IH-Mixed-Local~~	~~NB-II-Mixed-Local~~
Alternative Name:	~~Indian Harbor, Mixed Collection, Local Treatment~~	~~Nassau Bay II, Mixed Collection, Local Treatment~~
Service Area	~~Indian Harbor~~	~~Nassau Bay II~~
Collection		
Number of Connections	~~1909~~	~~123~~
Low Pressure Connections	~~1119~~	~~65~~
Gravity Connections	~~790~~	~~58~~
Lift Station	~~Lift flow from 989 connections: 1.187 MGD, 6,000 ft force main~~	~~Lift flow from 123 connections: 0.148 MGD, 4,150 ft force main.~~
Force Main		
Wastewater Treatment		
Treatment Facility	~~Package Plant~~	~~Package Plant~~
Treatment Flows	~~0.573 MGD~~	~~0.037 MGD~~
Equivalent Annual Cost Index:	~~0.24~~	~~0.34~~
Pollutant Percent Reduction:	~~0.997~~	~~0.982~~

Alternative ID:	RHS & OTS_Local_Treatment	RHS to OTS_Local_Treatment	NB2 & PRE_Local_Treatment	NB2 to PRE_Local_Treatment
Alternative Name:				
Service Area	Rolling Hills Shores, Hidden Valley Estates, and Oak Trail Shores	Rolling Hills Shores, Hidden Valley Estates, The Cliffs of Lake Granbury, Indian Hills, The Live Oaks, Lake Granbury Harbor, Arrowhead Shores, Lake Granbury Estates, Country Hill Acres, Oak Trail Acres, Oak Hills, Oak Trail Shores	Nassau Bay II and Port Ridglea East	Nassau Bay II, Nassau Bay, Sandy Beach, Wildwood, Holiday Estates, Summerland, Port Ridglea, Port Ridglea East, Sierra Blanca, Oak Grove Farm, Sierra, Lake at Timber Cove, Timber Cove, Montego Bay
Collection				
Number of Connections	2,284	5,404	359	1,251
Low Pressure Connections	1,137	2,929	359	1,251
Gravity Connections	1,147	2,475	0	0
Lift Station	Assume 2 required.	Assume 4 required.	Assume 0 required.	Assume 2 required.
Force Main	5.2 miles	5.2 miles	None required.	2 miles
Wastewater Treatment				
Treatment Facility	Package Plant	Package Plant	Package Plant	Package Plant
Treatment Flows	0.69 MGD	1.74 MGD	0.43 MGD	1.0 MGD
Equivalent Annual Cost Index:	0.56	0.33	0.65	0.54
Pollutant Percent Reduction:	Equals human (septic) contribution from both areas	Equals human (septic) contribution from all areas	Equals human (septic) contribution from both areas	Equals human (septic) contribution from all areas

Alternative Name: Regional Wastewater Treatment

Description: Removal of OSSFs with a collection system to a regional wastewater treatment plant; Service for subdivisions along Lake Granbury not provided by centralized wastewater treatment

Pollutant Addressed: Bacteria

Conceptual Design Assumptions:

Serves residents along Lake Granbury without centralized wastewater treatment

Subdivisions/local entities provide wastewater collection and tie into extended trunklines to reach City of Granbury's proposed 10 MGD plant north of Granbury or Acton MUD's existing plant on east side of lake.

Collection by low pressure or mixed system

200 gal/connection/day used to determine treatment flows

Lift station location not set to specific property, but governed by total dynamic head (TDH) limits

Package plants constructed for interim treatment may be converted to lift stations to tie into regional plants

Assumed treatment limits: CBOD-10, TSS-15, NH3-2, DO-4, P-2

Treated wastewater discharged into lake, or immediate tributary to lake after disinfection

Capital Cost Assumptions:

Construction Cost

Collection system not included; determined separately.

3-phase power is assumed to be available at lift station and plant sites

Wastewater treatment plant cost assumes concrete facilities, sitework, yardwork, electrical and foundation.

Land Costs

Purchase of land for plant site assumed at 3 times taxroll appraised value due to limitations on TDH that will restrict site selection (ie. lack of substitutability).

Design & Administrative

Engineering, Surveying, Permitting, Construction Administration, Contract Administration Total 20% (added to construction cost)

Contingency

Given multiple uncertainties at this stage, 20% assumed and added to construction cost.

O&M Cost Assumptions:

Includes labor, chemicals/materials, equipment replacement

Maintenance will be performed under contract/monthly fee assessed

Power cost calculated at $0.11/kWh and +/- 9 kWh/month

Equivalent Annual Cost Analysis:

Lifespan Assumption: 50 years

Interest Rate Assumption: 10%
Weighted cost of capital assuming inflationary trend

Equivalent Annual Cost Index: Ratio of Equivalent Annual Cost for this alternative compared to the maximum Equivalent Annual Cost of all alternatives.

Alternative ID:	RHS & OTS_Regional	RHS to OTS_Regional	Sky Harbor_Regional
Alternative Name:			
Service Area	Rolling Hills Shores, Hidden Valley Estates, and Oak Trail Shores	Rolling Hills Shores, Hidden Valley Estates, The Cliffs of Lake Granbury, Indian Hills, The Live Oaks, Lake Granbury Harbor, Arrowhead Shores, Lake Granbury Estates, Country Hill Acres, Oak Trail Acres, Oak Hills, Oak Trail Shores	Sky Harbor
Collection			
Number of Connections	2,284	5,404	629
Low Pressure Connections	1,137	2,929	242
Gravity Connections	1,147	2,475	387
Lift Station	Assume 2 required.	Assume 4 required.	Assume 1 required.
Force Main	2.5 miles	2.5 miles	0.61 miles
Wastewater Treatment			
Treatment FacilityDestination	City of Granbury	City of Granbury	City of Granbury SE WWTP
Treatment Flows ($3/Gallon Capital Recovery)	0.69 MGD	1.74 MGD	0.75 MGD
Connection Fee (each)			
Equivalent Annual Cost Index:	0.35	0.26	0.30
Pollutant Percent Reduction:	Equals human (septic) contribution from all areas	Equals human (septic) contribution from all areas	Equals human (septic) contribution from all areas

Alternative ID: **Alternative Name:**	NB2 & PRE_Regional	NB2 to PRE_Regional	Indian Harbor_Regional	Indian Harbor & neighbors_Regional
Service Area	Nassau Bay II and Port Ridglea East	Nassau Bay II, Nassau Bay, Sandy Beach, Wildwood, Holiday Estates, Summerland, Port Ridgle, Port Ridglea East, Sierra Blanca, Oak Grove Farm, Sierra, Lake at Timber Cove, Timber Cove, Montego Bay	Indian Harbor	Indian Harbor, Ports O'Call, Island Village, Comanche Harbor, Comanche Point, The Hills of Granbury, Knob Hill, Mountain View
Collection				
Number of Connections	359	1,251	1,243	2,788
Low Pressure Connections	359	1,251	477	781
Gravity Connections	0	0	766	2,007
Lift Station	Assume 1 required.	Assume 3 required.	Assume 1 required.	Assume 1 required.
Force Main	3 miles	3 miles	1.36 miles	1.36 miles
Wastewater Treatment				
Treatment FacilityDestination	Acton MUD DeCordova	Acton MUD DeCordova	Acton MUD New Facility	Acton MUD New Facility
Treatment Flows ($3/Gallon Capital Recovery)	0.43 MGD	1.0 MGD	1.49 MGD	3.35 MGD
Connection Fee (each)	$3,143	$3,143	$3,143	$3,143
Equivalent Annual Cost Index:	0.65	0.54	0.70	0.60
Pollutant Percent Reduction:	Equals human (septic) contribution from all areas	Equals human (septic) contribution from all areas	Equals human (septic) contribution from all areas	Equals human (septic) contribution from all areas

Alternative Name:	Cove Dynamics: Dredge and Fill
Description:	Improve water movement through coves to encourage "flushing" of pollutants
Pollutant Addressed:	Bacteria
Conceptual Design Assumptions:	
Dredge	Dredging or deepening a channel increases the volume of water in the canal allowing more dilution and provides a path for improved conveyance to the main lake body. Dredge method assumed as excavation from a small barge. Dredged material hauled off-site, up to 10 miles.
Partial Fill	The cove/canal is partial filled. Areas of water in sections of the canal/cove are replaced with earthen material, reducing the path of runoff to exit. This requires acquiring and hauling suitable PI material for backfill and compaction. Backfill elevation is assumed as one foot greater than the average water depth. Backfill would be level with ground. Backfill is graded to drain.
Partial Fill with Dredge	The cove/canal is partially filled. The channel is dredged in the remaining open sections.
Partial Fill with Dredge and additional outlet (s)	The cove/canal is partially filled, an additional outlet to cove/canal is created, and a channel is dredged in the remaining open sections.
Complete Fill	The cove/canal is completely filled with soil, eliminating the water way.
Capital Cost Assumptions:	
Construction Cost	Fill materials (soils) hauled from offsite where net fill required. Assumed 10 mi round trip.
	Includes dredge, fill placement, compaction, and dewatering.
	Outlet construction requires land acquisition, land clear and grub, pavement removal, excavation, culvert, backfill and compaction, road repair.
Land Costs	Purchase of land for outlet(s) at taxroll appraised value
	Lease of land for temporary spoils disposal and dewatering.
Design & Administrative	Engineering, Surveying, Permitting, Construction Administration, Contract Administration Total 20%
	Permitting costs associated with dredging and filling within waterway not included (e.g., USACE Section 404)
Contingency	Given multiple uncertainties at this stage, 20% assumed.
O&M Cost Assumptions:	
Dredge	Assumed maintenance dredging every 5 years
Partial Fill	N/A
Partial Fill with Dredge	Assumed maintenance dredging every 5 years
Partial Fill with Dredge and construct additional outlet (s)	Includes culvert maintenance, bank stabilization, guard rails; Assume maintenance dredging within 5 years
Complete Fill	N/A
Equivalent Annual Cost Analysis:	
Lifespan Assumption:	
Dredge	5 years
Partial Fill	75 years
Partial Fill with Dredge	10 years
Partial Fill with Dredge and additional outlet (s)	10 years
Complete Fill	100 years
Interest Rate Assumption:	10%
	Weighted cost of capital assuming inflationary trend
Equivalent Annual Cost Index:	Ratio of Equivalent Annual Cost for this alternative compared to the maximum Equivalent Annual Cost of all alternatives.

Alternative ID:	RHS-Fill	RHS-Partial Fill	RHS- Dredge	RHS -Dredge&PartialFill
Alternative Name:	Fill	Partial Fill	Dredge	Dredge and Partial Fill
Service Area	Rolling Hills Shores	Rolling Hills Shores	Rolling Hills Shores	Rolling Hills Shores
Construction Details and Assumptions:				
	Fill entire cove, assume 4' fill depth	Fill sections of cove, assume 4' fill depth	Dredge channel in cove from lake to shore	Dredge channel in cove from lake to shore
	Haul 223,574 cy of fill material to site	Haul 187,800 cy of fill material to site	Dredged Channel dimensions: 3' depth, 20' width, 1190' length	Dredged channel dimensions: 3' depth, 20' width, 1190' length
			Dredge method: excavation from a barge	Dredge method: excavation from a barge
			Haul 2,644 cy dredge spoils from site	Haul 2,644 cy dredge spoils from site
			Purchase 1 acre spoils site for dredge spoils	Fill sections of cove,assume 4 ft fill depth
				Haul 187,800 cy of fill material to site
				Purchase 1 acre spoils site for dredge spoils
Equivalent Annual Cost Index:	0.62	0.53	0.28	0.76
Pollutant Percent Reduction:	N/A	0%	4%	0

Alternative ID:	RHS -Dredge&PartialFill&Outlet	BWS-Dredge 1	BWS-Dredge 2
Alternative Name:	Dredge, Partial Fill and Outlet	Dredge to 6ft	Dredge to 8ft
Service Area	Rolling Hills Shores	Blue Water Shores	Blue Water Shores
Construction Details and Assumptions:			
	Dredge channel in cove from lake to shore	Dredge channel in cove from lake to shore	Dredge channel in cove from lake to shore
	Dredged channel dimensions: 3’ depth, 20’ width, 1940 ft length	Dredged channel dimensions: 2’ depth, 71’ width, 1000 ft length	Dredged channel dimensions: 4’ depth, 71’ width, 1000 ft length
	Dredge method: excavation from a barge	Dredge method: excavation from a barge	Dredge method: excavation from a barge
	Fill sections of cove, assume 4 ft fill depth	Haul 5,260 cy dredge spoils from site	Haul 10,519 cy dredge spoils from site
	Haul 187,800 cy of fill material to site	Purchase 1 acre spoils site for dredge spoils	Purchase 1 acre spoils site for dredge spoils
	Outlet: Excavate channel: 20' width, 300' length, 5' depth		
	Remove road, place culvert, repair road, land acquistion		
	Haul 5,422 cy dredge and excavated spoils from site		
	Purchase 1 acre spoils site for dredge spoils		
Equivalent Annual Cost Index:	0.91		
Pollutant Percent Reduction:	86%	30%	45%

Alternative ID:	~~OTS-Fill~~	~~OTS-Partial Fill~~	~~OTS- Dredge~~	~~OTS-Dredge&Outlet~~
Alternative Name:	~~Fill~~	~~Partial Fill~~	~~Dredge~~	~~Dredge and Outlet~~
Service Area	~~Oak Trail Shores~~	~~Oak Trail Shores~~	~~Oak Trail Shores~~	~~Oak Trail Shores~~
Construction Details and Assumptions:				
	~~Fill entire cove, 3-5' fill depth~~	~~Partial fill of cove, 3-5' fill depth~~	~~Dredge channel in cove from lake to shore~~	~~Dredge channel in cove from lake to shore~~
	~~Haul 20,132 cy of fill material to site~~	~~Haul 7,780 cy of fill material to site~~	~~Dredged channel dimensions: 3' depth, 20' width, 1,245' length~~	~~Dredged channel dimensions: 3' depth, 20' width, 1,245' length~~
			~~Haul 6,260 cy of fill material to site~~	~~Haul 6,260 cy of fill material to site~~
			~~Purchase 1 acre spoils site for dredge spoils~~	~~Outlets: Excavate north and south outlets: 25' width, 4' depth, 921' total length~~
				~~Remove road, place culvert, repair road, land acquistion for both outlets~~
				~~Haul 9,415 cy dredge and excavation spoils from site~~
				~~Purchase 1 acre spoils site for dredge spoils~~
Equivalent Annual Cost Index:	~~0.01~~	~~0.01~~	~~0.99~~	~~0.35~~
Pollutant Percent Reduction:	~~N/A~~	~~0%~~	~~30%~~	~~65%~~

Alternative Name:	Cove Circulation - Intake-Discharge Circulation System
Description:	Water circulation in cove is increased by pumping water from lake to top of cove fingers, reducing stagnation and bacteria accumulation.
Pollutant Addressed:	Bacteria
Conceptual Design Assumptions:	
	Submersible pumps intake water and discharge at the end of canals. Sediment intake is reduced by a pump filter.
	Pumps work at 70% efficiency. Pumps is sized to circulate cove volume.
	PVC pipes with mechanical restraining joints convey water from pumps and discharge at top of cove. Pipes lay at the bottom of lake.
	Discharge is dissiapated with a control device.
Capital Cost Assumptions:	
Construction Cost	Includes pump, pump filter, intake station frame, pump electrical system, and pvc pipes with mechanical restraining joints
Land Costs	None
Design & Administrative	Engineering, Surveying, Permitting, Construction Administration, Contract Administration Total 20% (added to construction cost)
Contingency	Given multiple uncertainties at this stage, 20% assumed and added to construction cost.
O&M Cost Assumptions:	
	Includes bi-weekly backflushing of filter media, pump repair, pipe repair, labor, and materials/incidental supplies
	Power cost calculated at $0.11/kWh and +/- 9 kWh/month
Equivalent Annual Cost Analysis:	
Lifespan Assumption:	15 years
Interest Rate Assumption:	10%
	Weighted cost of capital assuming inflationary trend
Equivalent Annual Cost Index:	
	Ratio of Equivalent Annual Cost for this alternative compared to the maximum Equivalent Annual Cost of all alternatives.

Alternative ID:	PRE Circulation	SH Circulation	IH Circulation
Alternative Name:	Intake-Discharge Circulation System	Intake-Discharge Circulation System	Intake-Discharge Circulation System
Service Area	Port Ridgle East	Sky Harbor	Indian Harbor
Construction Details and Assumptions:			
Conveyance	6" to 18" diameter PVC pipes, 7010 LF	12" to 24" diameter PVC pipes, 5591 LF	9" to 24" diameter PVC pipes, 5060 LF
	Pipe velocity 3-6 fps	Pipe velocity 3-6 fps	Pipe velocity 3-6 fps
Pump	18 hp pump (west section) and 10 hp pump (east section)	64 hp pump	27 hp pump
	System sized for 4 day water turnover rate.	System sized for 4 day water turnover rate.	System sized for 4 day water turnover rate.
Equivalent Annual Cost Index:	0.30	0.25	0.21
Pollutant Percent Reduction:	30%	39%	33%

Alternative ID:	BWS Circulation	OTS Circulation
Alternative Name:	Intake-Discharge Circulation System	Intake-Discharge Circulation System
Service Area	Blue Water Shores	Oak Trail Shores
Construction Details and Assumptions:		
Conveyance	6" diameter PVC pipe, 955 LF	6" diameter PVC pipes, 2571 LF
	Pipe velocity 3-6 fps	Pipe velocity 3-6 fps
Pump	4 hp pump	6 hp pump
	System sized for 4 day water turnover rate.	System sized for 4 day water turnover rate.
Equivalent Annual Cost Index:	0.20	0.20
Pollutant Percent Reduction:	38%	39%

Alternative Name:	Offsite Drainage Bypass
Description:	Pet/wildlife waste and pesticides on ground surface are picked up in rainfall runoff. Direct surface run-off away from cove by providing an channel to intercept runoff from uphill and force to drain at location away from cove.
Pollutant Addressed:	Bacteria
Conceptual Design Assumptions:	
	Drainage ditch is a v-shaped channel constructed along the road (in the easement) and toward the lake, as best suited by topography.
	Drainage ditch is sized to convey runoff from frequent rainfall events (up to the 5 year event). Channel size limited by available land. Small diameter drainage pipes is required to provide conveyance under driveways.
	Culverts are required to provide conveyance under roads.
Capital Cost Assumptions:	
Construction Cost	Channel excavation and 10 mile haul
	Install driveway pipes and repair driveways; assume 1 driveway per lot; assume driveway width less than 30 ft (30 ft drainage pipe length)
	Remove road, install culvert, repair road; assume 30 ft culvert length
	Seeding
Design & Administrative	Engineering, Surveying, Permitting, Construction Administration, Contract Administration Total 20% (added to construction cost)
Contingency	Given multiple uncertainties at this stage, 20% assumed and added to construction cost.
O&M Cost Assumptions:	
	Sediment maintenance every 3 years, 3x/year mowing, culvert and drainage pipe cleanout
Equivalent Annual Cost Analysis:	
Lifespan Assumption:	50 years
Interest Rate Assumption:	10%
	Weighted cost of capital assuming inflationary trend
Equivalent Annual Cost Index:	Ratio of Equivalent Annual Cost for this alternative compared to the maximum Equivalent Annual Cost of all alternatives.

Alternative Name:	Wet Ponds
Description:	Wet ponds capture and detain runoff before reaching Lake Granbury coves/canals to allow for settlement of pollutants, wet plant uptake and microbiological degradation.
Pollutant Addressed:	Bacteria
Conceptual Design Assumptions:	
	Implement water quality controls to treat watersheds draining to the pollutated areas of the lake. Large watersheds may require several controls in series.
	Pond design based on TCEQ Wet Basin guidelines: removal of 80% of total suspended solids (TSS). Assumed natural areas/landscaped areas have a runoff coefficient of 0.03.
	Sediment forebay holds 15-25% of permanent pool volume and at least 3 ft deep. Water quality volume based on average annual rainfall of 33 inches. Permanent pool volume is 1.2 times the water quality volume. Permanent pool average depth of 4 to 6 ft. Outflow structure drains the water quality volume in a minimium of 24 hours.
	Wet ponds are shallow ponds effective in removing pollutants for drainage areas between 10 acre to 640 acres through settling and biological uptake by plants. Appropriate for drainage areas where a continual or nearly continual base flow is present to sustain vegetation growth. Make up water must be provided if no continuous flow is available.
Capital Cost Assumptions:	
Construction Cost	Includes general allowances for mobilization, staging, testing; clear and grub land, excavation, haul (10 mi round trip), vegetation/planting allowance, erosion/sedimentation controls, maintenance items (concrete pads, driveway apron), outfall weir/structure and misc. drainage appurtances.
Land Costs	Two times the appraised value due to site specific locations
Design & Administrative	Engineering, Surveying, Permitting, Construction Administration, Contract Administration Total 20% (added to construction cost)
Contingency	Given multiple uncertainties at this stage, 20% assumed and added to construction cost.
O&M Cost Assumptions:	
	Remove sediment accumulation every 20 years
	Maintenance every 5 to 7 years or when 50% of forebay capacity is silted
	Annual cost of routine maintenance is approx 3% of construction cost
Equivalent Annual Cost Analysis:	
Lifespan Assumption:	25 years
Interest Rate Assumption:	10%
	Weighted cost of capital assuming return to inflationary trend within 5 years
Equivalent Annual Cost Index:	Ratio of Equivalent Annual Cost for this alternative compared to the maximum Equivalent Annual Cost of all alternatives.

Alternative ID:	SH-Wet Ponds	RHS-Wet Ponds	Walnut Creek - Detention Ponds	OTS-Drainage Bypass	RHS-Property Buyout
Alternative Name:	Catchment Basins	Catchment Basins	Catchment Basins	OffSite Drainage Bypass	Property Buyout
Service Area	Sky Harbor	Rolling Hills Shores	Walnut Creek	Oak Trails Shores	Rolling Hills Shores
Construction Details and Assumptions:	Twelve ponds, sizes range from 0.5 to 2.5 acres, with assumed 3ft depth. Location of ponds determined by topography and a drainage limit of 640 acres. Ponds may require make up water source if not continious flow available. Ponds designed to remove 80% TSS			V-shaped channel along the east side of Green Brook St 12.5 ft top width, and 2 ft depth, 3:1 (H:V) side slopes Outfalls to north and south of canal Contains runoff from the 2-year and 5-year rainfall events	213 lots identified within the 100-yr floodplain
Equivalent Annual Cost Index:	0.82	0.32	0.16	0.07	0.35
Pollutant Percent Reduction:	65%			51%	62%

F.2 Management Measures Evaluation Matrices Summarized by Area

Area	BMP Alternative	% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Lake Wide	Regional Wastewater Treatment	varies	10-15 yrs	varies	varies	
	Vegetative Filter Strips		<1 yr			
	Septic Maintenance and Education		<1 yr			
	Urban Education on Fertilizer Application		1-2 yrs			
	Pet Waste Education		<1 yr			
	Livestock/Range Management Education		1-2 yrs			
	Feral Hog Education Program/Bounty		2-5 yrs			
	Waterfowl Breeding Control Program		1-2 yrs			
	Waterfowl and Wildlife Feeding Ordinances		1-2 yrs			

Area	BMP Alternative	% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Long Creek and **Long Creek Subdivision** 95 units	Local Centralized Wastewater Treatment - Independent[1]	*99%*	2-5 yrs	0.59	0.59	Subdivision below monitoring point
	Regional Wastewater Treatment[1]	*99%*	10-15 yrs			Inefficient considering distance and number of lots
	Septic System Replacement[1]	*75%*	<1 yr	0.80	1.06	Subdivision below monitoring point
	Vegetative Filter Strips		<1 yr			Site specific
	Septic Maintenance and Education		<1 yr			
	Pet Waste Education		<1 yr			
	Area Conservation Plan and Education for small acreage land owners		2-5 yrs			
	Livestock/Range Management Education		1-2 yrs			
	Waterfowl Breeding Control Program		1-2 yrs			
	Waterfowl and Wildlife Feeding Ordinances		1-2 yrs			

1 - *Long Creek Subdivision Only, does not consider upper watershed*

Area	BMP Alternative	% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Rolling Hills Shores 196 uphill + 103 floodplain units	Cove Dynamics: Dredge, Partial Fill, Add Outlet	86%	2-5 yrs	0.91	1.06	Does not address source(s)
	Regional Wastewater Treatment (include neighboring areas)	62%	10-15 yrs	0.26	0.42	
	Local Centralized Wastewater Treatment-Aggregate	62%	5-10 yrs	0.33	0.54	
	Property Buy-Out	62%	1-2 yrs	0.35	0.57	Removal of tanks
	Regional Wastewater Treatment	62%	10-15 yrs	0.35	0.57	
	Local Centralized Wastewater Treatment - Independent	62%	2-5 yrs	0.67	1.08	
	Septic System Replacement Uphill	46%	<1 yr	0.49	1.06	future repairs
	Catchment for Upper Watershed	30%	2-5 yrs	0.32	1.07	
	Vegetative Filter Strips	5%	<1 yr	0.05	0.90	
	Cove Dynamics: Dredge	4%	1-2 yrs	0.28	6.99	Does not address source(s)
	Cove Dynamics: Partial Fill	0%	1-2 yrs	0.53	-	Does not address source(s)
	Cove Dynamics: Fill	-	1-2 yrs	0.62	-	Does not address source(s)
	Cove Dynamics: Partial Fill & Dredge	0%	2-5 yrs	0.76	-	Does not address source(s)
	Septic Maintenance and Education		<1 yr			
	Pet Waste Education		<1 yr			
	Septic Management (records, inspectors)		1-2 yrs			
	Livestock/Range Management Education		1-2 yrs			
	Waterfowl Breeding Control Program		1-2 yrs			

Area	BMP Alternative	% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Arrowhead Shores 354 units	Regional Wastewater Treatment (include neighboring areas)	99%	10-15 yrs	0.26		
	Septic Maintenance and Education		<1 yr			
	Pet Waste Education		<1 yr			
	Urban Education on Fertilizer Application		1-2 yrs			
	Waterfowl and Wildlife Feeding Ordinances		1-2 yrs			

Area	BMP Alternative		% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Oak Trail Shores 1,653 units	Cove Dynamics:	Dredge, Add Outlet	65%	2-5 yrs	0.84	1.29	Does not address source(s);
	Regional Wastewater Treatment (include neighboring areas)		54%	10-15 yrs	0.26	0.48	
	Local Centralized Wastewater Treatment - Aggregate		54%	5-10 yrs	0.33	0.62	
	Regional Wastewater Treatment		54%	10-15 yrs	0.35	0.66	
	Local Centralized Wastewater Treatment - Independent		54%	2-5 yrs	0.38	0.71	
	Drainage Re-route		51%	<1 yr	0.07	0.14	
	Septic System Replacement	Section 1	41%	<1 yr	0.38	0.94	
		Section 3			0.73	1.81	
		Section 2			0.50	1.24	
	Cove Circulation: Intake/Discharge		39%	1-2 yrs	0.20	0.51	Infrastructure may impede navigation; Does not address source(s)
	Cove Dynamics:	Dredge	30%	1-2 yrs	0.57	1.91	Does not address source(s)
	Septic Maintenance and Education			<1 yr			
	Pet Waste Education			<1 yr			
	Septic Management (records, inspectors)			1-2 yrs			
	Waterfowl and Wildlife Feeding Ordinances			1-2 yrs			

Area	BMP Alternative	% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Sky Harbor 629 units	Catchment Basins	65%	2-5 yrs	0.82	1.25	
	Cove Circulation Systems (Fountains, etc)	39%	1-2 yrs	0.25	0.64	May impede navigation
	Regional Wastewater Treatment	13%	10-15 yrs	0.30	2.37	
	Local Centralized Wastewater Treatment - Independent	13%	2-5 yrs	0.42	3.33	
	Septic System Replacement	9%	<1 yr	0.57	6.03	
	Septic Maintenance and Education		<1 yr			
	Pet Waste Education		<1 yr			
	Livestock/Range Management Education		1-2 yrs			
	Waterfowl and Wildlife Feeding Ordinances		1-2 yrs			
	Area Conservation Plan and Education for small acreage land owners		2-5 yrs			

Area	BMP Alternative	% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Water's Edge	Urban Education on Fertilizer Application		1-2 yrs			
	Pet Waste Education		<1 yr			
	Waterfowl and Wildlife Feeding Ordinances		1-2 yrs			

Area	BMP Alternative	% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Indian Harbor 1,243 units	Regional Wastewater Treatment	99%	10-15 yrs	0.60	0.61	
	Cove Circulation Systems (Fountains, etc)	33%	1-2 yrs	0.21	0.65	May impede navigation
	Septic Maintenance and Education		<1 yr			
	Pet Waste Education		<1 yr			
	Urban Education on Fertilizer Application		1-2 yrs			
	Waterfowl and Wildlife Feeding Ordinances		1-2 yrs			

Area	BMP Alternative	% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Nassau Bay II 123 units	Regional Wastewater Treatment	98%	10-15 yrs	0.54	0.55	
	Regional Wastewater Treatment (include neighboring areas)	98%	10-15 yrs	0.65	0.66	
	Septic Maintenance and Education		<1 yr			
	Pet Waste Education		<1 yr			
	Urban Education on Fertilizer Application		1-2 yrs			
	Waterfowl and Wildlife Feeding Ordinances		1-2 yrs			

Area	BMP Alternative	% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Port Ridglea East 236 units	Regional Wastewater Treatment (include neighboring areas)	99%	10-15 yrs	0.54	0.54	
	Regional Wastewater Treatment	99%	10-15 yrs	0.65	0.65	
	Septic System Replacement	75%	<1 yr	1.00	1.34	Small lots, large number of homes with waterfront property
	Cove Circulation Systems (Fountains, etc)	30%	1-2 yrs	0.30	1.00	Navigation
	Septic Maintenance Pump-out pilot program		<1 yr			
	Septic Maintenance and Education		<1 yr			
	Pet Waste Education		<1 yr			
	Urban Education on Fertilizer Application		1-2 yrs			
	Waterfowl and Wildlife Feeding Ordinances		1-2 yrs			
	Area Conservation Plan and Education for small acreage land owners		2-5 yrs			

Area	BMP Alternative	% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Walnut Creek and **DeCordova Estates** 1,573 units	Catchment Basin	2%	2-5 yrs	0.16	7.88	Work with golf course to redesign pond features; may not address source(s)
	Vegetative Filter Strips		<1 yr			Site specific
	Septic Maintenance and Education		<1 yr			
	Pet Waste Education		<1 yr			
	Area Conservation Plan and Education for small acreage land owners		2-5 yrs			
	Livestock/Range Management Education		1-2 yrs			
	Feral Hog Education Program/Bounty		2-5 yrs			

Area	BMP Alternative		% Reduction Bacteria	Time to Implement	Equivalent Annual Cost index	Cost/ Reduction Ratio	Feasibility (Constraints/ Considerations)
Blue Water Shores 357 units	Cove Dynamics:	Dredge 8 ft	45%	1-2 yrs	0.96	2.13	
	Cove Circulation System: Intake/Discharge		38%	1-2 yrs	0.20	0.54	
	Cove Dynamics:	Dredge 6ft	30%	1-2 yrs	0.50	1.68	
	Septic Maintenance and Education (Neighboring Communities)			<1 yr			
	Pet Waste Education			<1 yr			
	Waterfowl and Wildlife Feeding Ordinances			1-2 yrs			
	Collection System Sewage Line - Maintenance			1-2 yrs			

G.0 APPENDIX G: POTENTIAL FUNDING SOURCES

G.1 U. S. Department of Agriculture - Rural Development

Water and Environmental Programs
Water and Environmental Programs (WEP) provides loans, grants and loan guarantees for drinking water, sanitary sewer, solid waste and storm drainage facilities in rural areas and cities and towns of 10,000 or less. Public bodies, non-profit organizations and recognized Indian tribes may qualify for assistance. WEP also makes grants to nonprofit organizations to provide technical assistance and training to assist rural communities with their water, wastewater, and solid waste problems.

Texas USDA-Rural Development Community Facilities Loans
Community Programs can guarantee loans to develop essential community facilities in rural areas and towns of up to 20,000 in population. Loans and guarantees are available to public entities such as municipalities, counties, and special-purpose districts, as well as to non-profit corporations and tribal governments. Loan funds may be used to construct, enlarge, or improve community facilities for health care, public safety, and public services. This can include costs to acquire land needed for a facility, pay necessary professional fees, and purchase equipment required for its operation.

G.2 Texas Water Development Board (TWDB)

Development Fund
The Development Fund II program, administered by the TWDB, includes state loans (does not receive Federal subsidies) for water supply, water quality enhancement, flood control and municipal solid waste. This Development Fund II serves the purposes previously served by Development Fund (Development Fund I), but separates the State Loan Program from the State Participation Program and the Economically Distressed Areas Program components. The Development Fund II enables the Board to fund multiple eligible components in one loan to borrowers, e.g., if an applicant applies for funding of water and wastewater components, this is done with one loan. Financial assistance for Wastewater (Water Quality Enhancement Purposes) may include acquisitions and improvements or construction of wastewater facilities such as sewer treatment plants and collection systems. Nonpoint Source pollution abatement is also eligible. Development of new municipal solid waste disposal facilities can also be funded. Eligible applicants include political subdivisions, districts, water supply corporations and access is on a first-come, first-serve basis.

Economically Distressed Areas Program
The Economically Distressed Areas Program provides financial assistance in the form of a grant, a loan, or a combination grant/loan to bring water and wastewater services to areas where the present water and wastewater facilities are inadequate to meet the minimal needs of residents. The program includes measures to prevent future substandard development.
Eligible Applicants include all political subdivisions, including cities, counties, water districts, and non-profit water supply corporations. An economically distressed area is one which has a

median household income that is not greater than 75% of the median state household income. An eligible economically distressed area is an area in which:

1. The water supply or wastewater systems are inadequate to meet minimal needs of residential users;
2. The financial resources are inadequate to provide services to meet those needs; and
3. There was an established residential subdivision on or prior to June 1, 2005.

State Participation Program

Generally, the State Participation Program enables the Texas Water Development Board (TWDB) to assume a temporary ownership interest in a regional project when the local sponsors are unable to assume debt for the optimally sized facility. The TWDB may acquire ownership interest in the water rights or a co-ownership interest of the property and treatment works. The loan repayments that would have been required, if the assistance had been from a loan, are deferred. Ultimately, however, the cost of the funding is repaid to the TWDB based upon purchase payments, which allow the TWDB to recover its principal and interest costs and issuance expenses, etc., but on a deferred timetable.

The intent of this program is to allow for optimization of regional projects through limited State participation where the benefits can be documented, and such development is unaffordable without State participation. The goal is to allow for the "Right Sizing" of projects in consideration of future growth. The program recognizes two types of State Participation Projects those that create a new supply of water and those that do not.

- Eligible Applicants – Political Subdivisions. Districts, water supply corporations
- Access/Eligibility – first-come, first-served; no PDF; Funs Excess CAP (Up to 50%); findings
- Approximate Funds Available - $25 million/year

Clean Water State Revolving Fund (CWSRF)

The Clean Water State Revolving Fund (CWSRF) provides loans at interest rates lower than the market to political subdivisions with the authority to own and operate a wastewater system. Loans can be used for planning, design, and construction of wastewater treatment facilities, wastewater recycling and reuse facilities, collection systems, stormwater pollution control projects. They can also be used for implementation of nonpoint source pollution control projects. The CWSRF also includes Federal (Tier III) and Disadvantaged Communities funds that provide even lower interest rates for those meeting the respective criteria.

Rural Water Assistance Fund (RWAF)

The RWAF program is designed to assist small rural water utilities to obtain low cost financing for water or water-related projects. The TWDB offers attractive interest rate loans with short and long-term finance options at tax exempt rates. Funding through this program gives an added benefit to Nonprofit Water Supply Corporations by making construction purchases qualify for a sales tax exemption.
Access/Eligibility – Service area of 10,000 or less in population or a county in which no urban area exceeds 50,000 in population

G.3 Texas Department of Rural Affairs

Community Development Block Grant

Every year, the US Department of Housing and Urban Development provides federal Community Development Block Grant (CDBG) funds directly to states, which, in turn, provide the funds to small, rural cities with populations less than 50,000, and to counties that have a non-metropolitan population under 200,000 and are not eligible for direct funding from HUD. These small communities are called "non-entitlement" areas because they must apply for CDBG dollars through Texas Department of Rural Affairs (TDRA). Funded activities include sanitary sewer systems, clean drinking water, disaster relief and urgent need projects, housing, drainage and flood control, passable streets, economic development, community centers, and other related activities. In fiscal year 2009, TDRA received $73,017,739 from HUD for the administration of the state's CDBG non-entitlement program.

Small Towns Environment Program

Communities may apply for the Texas STEP Program by invitation from Texas Department of Rural Affairs (TDRA) only. The Texas STEP approach to solving water and sewer needs recognizes affordability factors related to the construction and operations/maintenance of the necessary water or sewer improvements and then initiates a local focus of control based on the capacity and readiness of the community’s residents to solve the problem through self-help. By utilizing the community’s own resources (human, material and financial), the necessary water or sewer construction costs, engineering costs, and related administration costs can be reduced significantly from the cost for the installation of the same improvements through conventional construction methods.

CDBG staff will provide guidance, assistance, and support to community leaders and residents willing to use self-help to solve their water and sewer problems.

Texas Capital Fund Main Street Improvements Program

The Texas Capital Fund (TCF) Main Street Program fosters the economic development in downtown areas by providing financial assistance to non-entitlement cities for public improvements. The program funds are a part of the United States Department of Housing and Urban Development (HUD) Community Development Block Grant (CDBG) Program and matching funds are required.

Texas Capital Fund Infrastructure Development Program

The Texas Capital Fund Infrastructure Development Program is an economic development tool designed to provide financial resources to non-entitlement communities. Funds from this program can be utilized for public infrastructure needed to assist a business which commits to create and/or retain permanent jobs, primarily for low and moderate income persons. This program encourages new business development and expansions. Awards may be provided for construction of a wide variety of public infrastructure including measures proposed in the LG WPP such as water and sewer, purchase of real estate related to infrastructure, drainage channels and ponds, and engineering fees. Businesses or individuals may not directly submit applications. Projects must demonstrate project feasibility and financial capability. Matching funds are required.

G.4 Environmental Protection Agency

A variety of grants are available through the EPA. Some of the available programs are described below.

Targeted Watersheds Grant Program
The Targeted Watersheds Grant program is designed to encourage successful community-based approaches and management techniques to protect and restore the nation's watersheds. Implementation Grant projects that have been funded thus far focus on a broad array of methods for addressing watershed concerns including water quality trading, agricultural best management practices, wetland and riparian restoration, nutrient management, fish habitat restoration and public outreach and education.

EPA expects to announce a Request for Proposals (RFP) early in 2010 that will be for Targeted Watersheds Grants for Capacity Building in Urban Watersheds. Anticipated federal funding under the competition is approximately $600,000 for FY 2010. In addition to supporting on-the-ground watershed projects through Targeted Watersheds Grants (TWG) Implementation Grants, the TWG program also supports the development and dissemination of tools, training, and technical assistance to strengthen the effectiveness of community-based partnerships working across the country to achieve clean water goals. The goal of the capacity building component of the Targeted Watersheds Grant program is to assist local watershed organizations across the country to develop and successfully implement watershed plans. TWG Capacity Building grants will assist local watershed organizations to better address water resource issues.

Pollution Prevention Incentives for States
Under CFDA 66.708, EPA has approximately $5 million to support pollution prevention grants in FY 2010 through the **Pollution Prevention (P2) and Pollution Prevention Information Network (PPIN)** grant programs. Eligible applicants include the 50 States, the District of Columbia, the U.S. Virgin Islands, the Commonwealth of Puerto Rico, any territory or possession of the U.S., any agency or instrumentality of a State including State colleges or universities, and Federally-recognized Tribes and Intertribal Consortia that meet the requirements for treatment in a manner similar to a State as described in 40 CFR 35.663. P2 Grant recipients must provide at least a 50 percent match of the total allowable project cost by the time of award to be considered eligible to receive funding.

The PPIN grants focus on providing P2 information services that: increase awareness of P2 approaches and practices; and support the adoption and implementation of P2 practices. The Request for proposals (RFP) asks for proposals that address: identified audience needs for P2 information and assistance; and measure changes in awareness, knowledge, or adoption of P2 plans and practices. The PPIN competition awards about $800,000 annually to promote quality P2 information services, references and training that is shared nationally. The Regional centers receiving these grants have developed their own organization called the Pollution Prevention Resource Exchange (P2Rx).

Under CFDA 66.717, EPA has approximately $1.4 million to support the **Source Reduction Assistance and the Pollution Prevention Information Network Centers grant programs**. Eligible applicants include the fifty States, the District of Columbia, the United States Virgin

Islands, the Commonwealth of Puerto Rico, any territory or possession of the United States, local governments, city or township governments, independent school districts, incorporated non-profit organizations (other than institutions of higher education), public and private institutions of higher education, community-based grassroots organizations, and Indian Tribes and Intertribal Consortia. EPA requires the applicant to provide a minimum 5% match, as part of the total allowable project cost, in order to receive an award.

Environmental Justice Small Grants Program
The EPA Environmental Justice Small Grants Program (EJSG) supports community based organizations addressing local environmental and public health issues by building collaborative partnerships. Successful collaborative partnerships involve not only well-designed strategic plans to build, maintain and sustain the partnerships, but also to work towards addressing the local environmental and public health issues. The EPA EJSG Program is a national program with the total funding available for awards under this solicitation at $1,000,000. EPA anticipates awarding approximately 40 grants in the amount of $25,000 each.

Section 106 State Water Pollution Control Grants
Section 106 of the Clean Water Act authorizes EPA to provide federal assistance to states and interstate agencies to establish and implement ongoing water pollution control programs. Prevention and control measures supported by State Water Quality Management programs include permitting, pollution control activities, surveillance, monitoring, and enforcement; advice and assistance to local agencies; and the provision of training and public information. The Water Pollution Control Program is helping to foster a watershed protection approach at the state level by looking at states' water quality problems holistically, and targeting the use of limited finances available for effective program management.

Section 319(h) Federal Clean Water Act
Under Section 319, states, territories and tribes receive grant money from the USEPA that supports a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, demonstration projects and monitoring to assess the success of specific nonpoint source implementation projects. If a state’s funding plan is consistent with grant eligibility requirements and procedures, EPA then awards the funds to the state. In Texas, Clean Water Act Section 319(h) funds are provided only to both the TSSWCB and the TCEQ to implement their approved nonpoint source management programs. The Brazos River Authority has applied for 319(h) funds administered through TCEQ to support implementation of select management measures from the Lake Granbury WPP, specifically targeted at hiring a watershed coordinator.

G.5 U. S. Department of Agriculture – Natural Resource Conservation Service (NRCS)

Watershed Protection and Flood Prevention Program
Summary – This program provides technical and financial assistance to address resource and related economic problems on a watershed basis. Projects related to watershed protection, flood prevention, water supply, water quality, erosion and sediment control, wetland creation and restoration, fish and wildlife habitat enhancement, and public recreation are eligible for

assistance. Technical and financial assistance is also available for planning and installation of works improvement to protect, develop and use land and water resources in small watersheds.

Funding – typical awards range from $3,500,000 to $5,000,000
Local Match – none noted

Watershed Operations is a voluntary program which provides assistance to sponsoring local organizations of authorized watershed projects, planned and approved under the authority of the Watershed Protection and Flood Prevention Act of 1954 (P.L. 83-566), and 11 designated watershed authorized by the Flood Control Act of 1944 (P.L. 78-534). NRCS provides technical and financial assistance to States, local governments and Tribes (project sponsors) to implement authorized watershed project plans for the purpose of watershed protection; flood mitigation; water quality improvements; soil erosion reduction; rural, municipal and industrial water supply; irrigation water management; sediment control; fish and wildlife enhancement; and wetlands and wetland function creation and restoration.

Project sponsors are provided assistance in installing planned land treatment measures when plans are approved. Surveys and investigations are made and detailed designs, specifications, and engineering cost estimates are prepared for construction of structural measures. Areas where sponsors need to obtain land rights, easements, and rights-of-way are delineated. Technical assistance is also furnished to landowners and operators to accelerate planning and application of needed conservation measures on their individual land units.

Resource Conservation and Development Program
The purpose of the Resource Conservation and Development (RC&D) program is to accelerate the conservation, development and utilization of natural resources, improve the general level of economic activity, and to enhance the environment and standard of living in designated RC&D areas. It improves the capability of State, tribal and local units of government and local nonprofit organizations in rural areas to plan, develop and carry out programs for resource conservation and development. The program also establishes or improves coordination systems in rural areas. Current program objectives focus on improvement of quality of life achieved through natural resources conservation and community development which leads to sustainable communities, prudent use (development), and the management and conservation of natural resources. RC&D areas are locally sponsored areas designated by the Secretary of Agriculture for RC&D technical and financial assistance program funds.
Funding – in FY 2009 Texas was awarded $2,486,594
Local Match –
http://www.nrcs.usda.gov/programs/rcd/

Environmental Quality Incentives Program (EQIP)
EQIP offers contracts with a minimum term that ends one year after the implementation of the last scheduled practices and a maximum term of ten years. These contracts provide financial assistance to implement conservation practices. Owners of land in agricultural production or persons who are engaged in livestock or agricultural production on eligible land may participate in the EQIP program. Program practices and activities are carried out according to an EQIP program plan of operations developed in conjunction with the producer that identifies the

appropriate conservation practice or measures needed to address the resource concerns. The practices are subject to NRCS technical standards adapted for local conditions.

EQIP provides payments up to 75 percent of the incurred costs and income foregone of certain conservation practices and activities. However certain historically underserved producers (Limited resource farmers/ranchers, beginning farmers/ranchers, socially disadvantaged producers) may be eligible for payments up to 90 percent of the estimated incurred costs and income foregone. Farmers and ranchers may elect to use a certified Technical Service Provider (TSP) for technical assistance needed for certain eligible activities and services. The new Farm Bill established a new payment limitation for individuals or legal entity participants who may not receive, directly or indirectly, payments that, in the aggregate, exceed $300,000 for all program contracts entered during any six year period. Projects determined as having special environmental significance may, with approval of the NRCS Chief, have the payment limitation raised to a maximum of $450,000.

G.6 Texas Commission on Environmental Quality (TCEQ)

Texas Clean Rivers Program (CRP)
The Texas Clean Rivers Program (CRP) is a statewide program for water quality monitoring, assessment, and public outreach funded by state fees. The CRP is a partnership between TCEQ and 15 agencies who all work to promote improving water quality in river basins across the state. The CRP coordinates the efforts of diverse organizations, both locally and regionally, by providing a framework and forum for managing water quality issues within a river basin.

The Clean Rivers Program coordinates watershed management with both the Nonpoint Source Program and the Total Maximum Daily Load Program for which the TCEQ and the Texas State Soil and Water Conservation Board (TSSWCB) are responsible. The TCEQ is the lead agency for preventing and abating nonpoint source pollution from urban and other nonagricultural sources. The TSSWCB fulfills those responsibilities for agricultural and forestry lands. Both agencies administer grant funds that may be used to prevent or reduce nonpoint source pollution.

CRP funds are used to promote watershed planning and quality assured water quality data. The LG WPP will continue to employ this resource to support surface water quality monitoring in the watershed.

Supplemental Environmental Project Program
A Supplemental Environmental Project (SEP) is a means for directing fines, fees, and penalties for environmental violations toward environmentally beneficial uses. Through a SEP, a respondent in an enforcement matter can choose to invest penalty dollars in improving the environment, rather than paying into the Texas General Revenue Fund.

The Texas Assoc. of Resource Conservation & Development Areas (RC&D) is funded through SEP funds. Through this is a project (Project 8) specifically for Water or Wastewater Assistance. Through this project the RC&D shall repair or replace failing water systems or on-site wastewater systems for low-income homeowners. RC&D shall use SEP Funds to pay for the labor and materials costs related to repairing or replacing the failing systems. The recipients will not be charged for the cost of replacing or repairing the failing systems. RC&D shall use a consistent and documented system for determining eligible participants. Funding through this source may be pursued to replace failing on-site wastewater systems in areas where connecting to a collection system may not be feasible in the near future due to physical location and/or economic constraints.

More information about RC&D may be viewed at
http://www.texasrcd.org/about_rcd.htm.

Benefit: Protect water sources for drinking, recreation and wildlife from contamination from the failing systems; protect public health from contaminated drinking water supplies.
Minimum Contribution: $2,000
Eligible Counties: Statewide

G.7 Texas State Soil and Water Conservation Board (TSSWCB)

Water Quality Management Plan (WQMP) Program
In addition to the Texas Clean Rivers Program and administering 319(h) funds for agricultural non-point source pollution, the TSSWCB provides the Water Quality Management Plan (WQMP) program. The purpose of WQMPs is to implement pollution prevention or abatement practices. A site specific WQMP is developed and approved by soil and water conservation districts for agricultural or silvicultural lands. The plan includes appropriate land treatment practices, production practices, management measures, technologies or combinations thereof.

In accordance with the Lake Granbury WPP, individual large acreage land owners will be encouraged to obtain WQMPs by working with the local soil and water conservation district (SWCD). There is no charge for development of a WQMP; however, there may be costs for implementing certain practices required in the WQMP, for which there may be financial assistance available.

G.8 Environmental Finance Center at University of New Mexico

The New Mexico Environmental Finance Center (NMEFC) is a program of the Institute of Engineering Research and Applications (IERA) at New Mexico Institute of Mining and Technology and is dedicated to helping state, local, and tribal governments with the "how to pay" issues of environmental compliance and regulation. The NM EFC was established to assist the states of EPA Region 6 (New Mexico, Texas, Oklahoma, Arkansas, and Louisiana) and the first emphasis of the EFC was public private partnerships. The NM EFC work includes public private partnerships, water system capacity development, source water protection, tribal water system compliance, tribal operator certification, water regionalization, drought preparedness planning, arsenic rule compliance, leak detection, and asset management.

http://nmefc.nmt.edu/home.php

G.9 Department of Commerce – Economic Development Administration

Grants for Public Works and Economic Development Facilities

EDA provides Public Works investments to support rehabilitation construction of essential public infrastructure and development facilities necessary to generate higher-skill, higher-wage jobs and private investment. Characteristic projects include investments in facilities such as water and sewer systems, industrial access roads, industrial and business parks, port facilities, rail spurs, skill-training facilities, business incubator facilities, brown-field redevelopment, eco-industrial facilities, and telecommunications and broadband infrastructure improvements necessary for business creation, retention and expansion. A project must be located in or benefit a region that, on the date EDA receives an application for investment assistance, satisfies one or more of the economic distress criteria set forth in 13 CFR 301.3(a).

Funding – FY 08 $169,919,000; FY 09 est $129,280,000; The average size of a Public Works investment in FY 2008 was $1.32 million.

Local match – The EDA generally requires a 50% match for grants. In-kind contributions may be included in the match requirement. An applicant can request a waiver or reduction of the non-Federal share, based on criteria established in EDA regulations.

More info – http://www.cfda.gov/public/viewprog.asp?progid=167

Other Department of Commerce – Economic Development Administration

EDA oversees three (National, Local and University Center) types of *technical assistance* to promote economic development and alleviate under-employment and unemployment in distressed areas. EDA also has the *Economic Adjustment Assistance* program to assist State and local interests design and implement strategies to adjust or bring about change to an economy. The EDA generally requires a 50% match for grants.

G.10 Texas Department of Agriculture

Rural Municipal Finance Program

The Texas Agricultural Finance Authority (TAFA) provides financial assistance through loan guarantees to lenders for eligible applicants who wish to establish or enhance their farm and/or ranch operation or establish an agriculture-related business. Funds must be used to improve or assist in the economic development of the rural area such as: Purchase of real estate, construction of buildings and site improvements, equipment, water and wastewater systems, and municipal infrastructure projects. Eligible applicants include city and county governments; economic development corporations; hospital districts; rail districts; utility districts; special districts; agricultural districts; and private water and wastewater corporations.

G.11 State of Texas Office of the Governor

Texas Enterprise Fund

The Texas Enterprise Fund was established in 2003 (and reauthorized in 2005) to allow the state to respond quickly and aggressively to opportunities to bring jobs and employers to Texas. The funds are used primarily to attract new business to the state or assist with the substantial expansion of an existing business as part of a competitive recruitment situation. Funds are also appropriated for a variety of economic development projects, including infrastructure development, community development, job training programs and business incentives, as well as to attract technology and biotechnology businesses and support university research.

To be eligible for Texas Enterprise Fund support, a project must demonstrate a significant return on the state's investment and strong local support. The review process will consider a variety of factors associated with each project, including job creation and wages, capital investment, the financial strength of the applicant, the applicant's business history, analysis of the relevant business sector, and public and private sector financial support. Before funds can be awarded, the Governor, Lieutenant Governor and Speaker must unanimously agree to support the use of the Texas Enterprise Fund for each specific project.

H.0 APPENDIX H: EDUCATION AND OUTREACH PLAN

The Lake Granbury Education & Outreach Work Group follows the U.S. Environmental Protection Agency's "Getting in Step" program to construct the education and outreach component of the Lake Granbury Watershed Protection Plan. The program is designed to aid in the process of developing a comprehensive strategy to increase public awareness and participation, as well as encourage local stewardship. The program steps are:

1. Define goals and objectives
2. Identify target audience
3. Determine message
4. Packaged materials
5. Distribute educational material and message
6. Evaluation

H.1 Driving Forces, Goals and Objectives

The **driving force** for the development of the Lake Granbury Education and Outreach campaign is that Lake Granbury is identified as a priority watershed for restoration. The **goal** of Lake Granbury educational program is to share information regarding the status of Lake Granbury, future condition scenarios recognizing that the activities of people living in the watershed and around the lake will help dictate the future water quality within the lake. An educational program will utilize key messages to empower residents to accept information describing the status of the lake and implement best management practices on their property to limit availability and transport of contaminants to the lake.

Objectives:

- Increase public awareness regarding water quality around Lake Granbury.
- Increase natural resource literacy among residents of Lake Granbury.
- Identify groups within the watershed conducting environmental education programs.
- In cooperation with other Lake Granbury work groups develop educational strategies consistent with the Lake Granbury WPP priorities to increase awareness of contaminant sources and best management practices to limit contaminants from reaching the lake.
- Identify and pursue sources of funding for water quality education and outreach.

H.2 Identifying and Analyzing Target Audiences

People's actions will define the long-term water quality status in the lake. A variety of audiences will be targeted during the educational program to disseminate and share information with the public. Many people and organizations are already involved and instrumental in development of this WPP; their continued collaboration and influence will be key in future efforts to identify and educate appropriate audiences.

- Agricultural Producers
  - Ranchers

    - Wildlife Managers
- Small acreage landowners
- Sportsmen
- Ecotourism:
    - Bird watching
    - Boating
    - Swimming
    - Marinas
    - Camping
    - Bed and Breakfast
- Youth
- Gardeners and Homeowners
    - OSSF Owners
    - Pet Owners
- Greenspace management:
    - Landscapers
    - Golf course managers
    - Parks and Recreation Staff
- Influential people and organizations
    - Elected officials such as county judges, county commissioners, city mayors and council members, state legislature or congressional representatives.
    - Civic organizations such as the Rotary and Lions Clubs, Junior League, Knights of Columbus.
    - Media personnel
    - City managers
    - Chamber of commerce
    - Business and community leaders
    - Water supply corporations
    - Realtors

H.3 Message Development and Delivery

These messages address the overall education and outreach objectives. They emphasize the value of the natural resources associated with Lake Granbury, along with its problems and the measures that can bring about solutions. Materials will be developed that are consistent with the Lake Granbury WPP priorities; particular educational activities will be targeted in areas identified as most in need (e.g., pet waste education in dense subdivisions near the water or small acreage land management in upper watershed areas).

Messages defining the **value** of the natural resources include:

- Property values surrounding the lake will be maintained by having an aesthetically pleasing lake.
- Lake Granbury is a valuable water supply for local residents
- Depressed property values and sales tax revenue losses from decreased ecotourism will impact availability of county services or require increased taxing to maintain services.

- Implementing low impact development practices can improve local beautification, scenic value and quality of life in the region.

Messages defining the **problems** include**:**

- What is the Lake Granbury watershed?
- What is the current water quality situation in Lake Granbury?
- Contaminants of concern for the lake
    - Bacteria
- Trash, pet waste and malfunctioning septic systems are impacting ecosystem.

Messages defining the recommended **solutions** include:

- Improved agricultural management designed to diminish pollutants from ranching in the watershed will reduce pollutant loading to Lake Granbury
- Improved urban stormwater management designed to diminish pollutants (bacteria) from urban areas flowing into our streams, creeks and rivers and eventually into the lake
- Enhanced wastewater infrastructure for individuals, municipalities and rural communities in the watershed will reduce pollutants in Lake Granbury
- Water quality monitoring to evaluate the condition of Lake Granbury and to gain additional knowledge of the pollutant sources and water quality problems will help target load reduction measures
- Improved wildlife and pet waste management designed to decrease fecal contamination of the watershed
- Improved stormwater management will decrease pollution in the lake

Messages defining what **individuals can do to help** include:

- Find out where you live in relation to the Lake Granbury Watershed
- Become familiar with the Lake Granbury Watershed
- Ask your county and city elected officials to address pollution issues within your community
- Ask your county and city elected officials for recycling options in counties that have not yet adopted these practices
- Support local efforts to repair or replace outdated wastewater treatment facilities and infrastructure.
- Volunteer for environmental projects in your community, such as local trash cleanups and habitat restoration.
- Adopt a zero tolerance attitude toward littering, a potential source of pollution
- Install and incorporate a rainwater harvesting system at your home or business to reduce stormwater, a potential source of pollution and erosion
- Volunteer for, or encourage storm drain labeling in your community
- Utilize proper livestock, pet and wildlife waste management

H.4 The Lake Granbury Education and Outreach Plan

To implement the educational and outreach plan, seven strategies will be pursued.

Strategy 1 – Establish a Brand

Strategy 2 – Deliver Basic Facts about Lake Granbury

Objectives:

- Distribute the basic facts about Lake Granbury to targeted audiences.
- Develop campaign brochures that include numerous photographs, illustrations, simple graphics, maps and easy reading text.
- Develop different presentations for targeted audiences.
- Create fact sheets and FAQs (Frequently Asked Questions).
- Produce a video.

Strategy 3 – Increase Awareness and Community Involvement in Lake Granbury Watershed Protection Plan

Objectives:

- Raise awareness of the Lake Granbury Watershed Protection Plan by utilizing television, radio, signs and targeted advertising strategies.
- Seek grants to develop and distribute television advertisements.
- Seek out and collaborate with other groups developing environmental PSA's.
- Work to have roadway signage to indicate the presence of Lake Granbury.
- Work with communities within the watershed to label storm drains to increase awareness between storm water and pollution.
- Use many different methods of both direct and indirect education to reach all groups within Lake Granbury through:
    - Direct Educational Methods:
        - Presentations at local meetings
        - Booth at local community activities
        - Hosting specific meetings, workshops, conferences.
        - Direct post card or letter to people
        - Electronic mailed letter
        - Site visit to local property
        - Construct demonstrations of recommended best management practices.
        - Tours of best management practice demonstrations.
        - Informational promotional/specialty items.
    - Methods of In-Direct Mass Education
        - Articles in newspaper, newsletter, blog,
        - Public service announcements implemented through radio or television.
        - Mailings through utilities mailings such as water bill
        - Educational displays at local businesses frequented by the target audience.
        - Educational trailers at local movie theatres.

Strategy 4 – Develop Partnerships for Message Distribution

Objectives:

- Develop partnership with business, community based organizations and Non-Governmental Agencies (NGO's) supporting environmental education and conservation programs for message distribution including:
  - Agricultural Producers
    - Farm Bureau
  - Small Acreage Landowners
    - Local Soil and Water Conservation District
    - Natural Resources Conservation Service District Office
    - Texas Department of Agriculture
    - Texas AgriLife Extension Service
  - Sportsmen
    - Bass Anglers Sportsmen Society (B.A.S.S.)
    - Texas Trophy Hunters Association
    - Texas State Rifle Association (TSRA)
    - Ducks Unlimited
    - North Central Texas Safari Club
    - Texas Chapter of American Fisheries
  - Ecotourism Vendors
    - Chamber of Commerce's
    - Convention and Visitor's Bureau
    - Marinas
    - Lodging
  - Schools and Educational Organizations
    - 4-H
    - FFA
    - Girl Scouts
    - Boy Scouts
    - School Carnivals and Community Festivals
    - Teachers
  - Homeowners
    - Master Gardeners
    - Master Naturalists
    - Homeowners Associations
    - Church Organizations
  - Greenspace Management
    - Landscapers
    - Golf Course Managers
    - Parks and Recreation Staff
  - Environmental Groups
    - Texas Wildlife Association
    - Granbury Friends to Animals
    - Keep Texas Beautiful
    - Sierra Club
    - BRCC

  - Influential People and Organizations
    - Elected officials such as county judges, county commissioners, city mayors and council members, state legislature or congressional representatives.
    - Civic organizations such as the Rotary and Lions Clubs, Junior League, Knights of Columbus.
    - Media personnel
    - City managers
    - Chamber of Commerce
    - Business and community leaders
    - Water supply corporations
    - Clergymen or women
    - Realtors
- Develop an outreach campaign targeting local businesses and community based organizations to:
  - Inform them of Lake Granbury Watershed Protection Plan
  - Inform them how the water quality problems associated with Lake Granbury will impact them.
  - Give them ways they can aid both personally or professionally, while stressing their venue being a point of distribution for information on the LGWPP.

Strategy 5 – Create Micro-campaigns for Specific Target Audiences

1. Micro-campaign Target Audience A: Agricultural Producers
   Objectives:
   - Promote conservation programs sponsored by NRCS, S&WCD and other organizations that provide technical assistance and funding for the implementation of conservation measure and practices
   - Construct BMP demonstrations as a learning tool
   - Utilize fact sheets, presentations and other information to educate agricultural producers on:
     - Agricultural BMPs
     - Cost and Benefits of implementing BMPs
     - Stocking rates and overgrazing
     - Runoff Management

   Through the following avenues:
     - Texas AgriLife Extension Service sponsored events and field days
     - NRCS and S&WCD Mail outs
     - Texas AgriLife Extension Service Newsletters
     - Ranch and Rural Magazine
     - Country World News

2. Micro-campaign Target Audience B: Small Acreage Landowners
   Objectives:

- Promote conservation programs sponsored by NRCS, S&WCD and other organizations that provide technical assistance and funding for the implementation of conservation measure and practices
- Construct BMP demonstrations as a learning tool
- Utilize fact sheets, presentations and other information to educate small acreage landowners on:
    - Land stewardship
    - Onsite wastewater treatment system maintenance
    - Stocking rates and overgrazing
    - Pond management
    - Pasture planting

3. Micro-campaign Target Audience C: Sportsmen
   Objectives:
    - Distribute brochures at local fishing support businesses such as bait stores, marinas, sporting goods stores, fishing guide businesses, boat dealerships, etc.
    - Include a specific task that the fisherman can do to help do their part to improve water quality on Lake Granbury.
    - Organize a fishing tournament on Lake Granbury and distribute fact sheets to each fisherman with their entry.
    - Organize fisherman for clean up days.

4. Micro-campaign Target Audience D: Ecotourism Vendors
   Objectives:
    - Compile and keep a current database of ecotourism vendors
    - Host an informational reception or luncheon for the vendors, including a presentation and invitation to participate in efforts to improve the water quality while participating in the ensuring the future of their livelihoods'.
    - Include vendors in group emails and in updates from the Lake Granbury Watershed Protection Plan.
    - Plan follow-up or semi-annual gatherings for the group to discuss the progress and environmental concerns.

5. Micro-campaign Target Audience E: Schools and Educational Organizations
   Objectives:
    - Identify all after-school programs including:
        - Learning Centers
        - Private After-School Care
        - School Extracurricular Programs (i.e. Rodeo Club, Science Club, etc.)
    - Work with BRA, BRCC and other local organizations to create a youth-based learning curriculum for Lake Granbury.
    - Art contest with High School art students to develop a unique logo for the stakeholder group
    - Use schools as a distribution point for basic information about Lake Granbury to distribute to the families of school children through "back-pack stuffers".

- Reach out to area science teachers through the regional education service center to provide basic information on Lake Granbury Watershed Protection Plan and offer suggestions for school projects they can incorporate into their lessons to raise interest among students in their role in helping the Lake Granbury Watershed.
- Use Stream Trailers, rainfall simulator, rainwater harvesting table top display, enviroscape, dual flush toilet as hands-on visual teaching tools to raise interest and awareness of Lake Granbury's current and future condition.

6. Micro-campaign Target Audience F: Gardeners/Homeowners
   Objectives:
   - Promote neighborhood association recognition for environmentally friendly landscaping.
   - Target education within priority areas
     - Utilize fact sheets, presentations and other information to educate homeowners on:
     - Rainwater harvesting
     - Stormwater management
     - Pet waste management
     - Urban landscape management
     - Onsite wastewater treatment system
     - Gray water management
     - Grass clipping/leaf disposal

     Through the following avenues:
     - HOA's and other local meetings
     - Utility bill mailings
     - Tax Bills
     - Water supply corporations
     - Master Gardener programs.

7. Micro-campaign Target Audience G: Greenspace Management
   Objectives:
   - Develop demonstrations of BMPs for visual reference of practices that demonstrate the effectiveness of reducing runoff and pollution transport
   - Develop a listing of stormwater control and green infrastructure measures developers can use and implement into designing a new neighborhood

8. Micro-campaign Target Audience H: Influential People and Organizations
   Objectives:
   - Seek frequent media contact through
     - Newspapers: Hood County News
     - Press Releases
     - TV News: Channel 5 and 11
     - BRCC
     - Chamber of Commerce: Listing of Events
     - Radio: KPIR 1420 AM – The Pirate
     - Utility bill stuffers or direct message printing

Strategy 6 – Establish a Practice of Ongoing Campaign Evaluation

Education effectiveness will be assessed throughout the Education Program. Evaluation instruments will be circulated before and after select events to assess the effectiveness of tools, outreach and presentations in convincing participants to make lifestyle changes that will benefit the watershed. Additionally, a survey instrument will be circulated annually to the Lake Granbury Watershed Stakeholders Group to assess their satisfaction with the campaign and to solicit inputs for improvements. A database of attendees of outreach events will be developed and those attendees will be surveyed six months after the event to determine whether attendees modified their lifestyle as a result of the information provided during the event. The Outreach Campaign will be continually evaluated and suggestions from stakeholders and attendees will be incorporated to make the campaign more effective.

Strategy 7 – Collaborate with Governmental Agencies Offering Environmental E&O

Groups to Collaborate with**:**

- United States Environmental Protection Agency (EPA)
- United States Department of Agriculture – Natural Resource Conservation Service (USDA-NRCS)
- Texas Commission on Environmental Quality (TCEQ)
    - TMDL Outreach Project
    - Clean Texas Greenscapes
- Texas State Soil and Water Conservation Board (TSSWCB)
- Texas Department of Agriculture (TDA)
    - Stop the Drop
- Texas Water Development Board
    - The Water Smart Campaign
- Texas Parks and Wildlife Department (TPWD)
- Brazos River Authority (BRA)
- North-Central Texas Council of Government (NCTCOG)
- Soil and Water Conservation Districts (SWCD)
- Texas AgriLife Extension Service
- Texas AgriLife Research
- Water Wise Council of Texas
- National Association of Conservation Districts (NACD)