JAMES MIERTSCHIN & ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERING
P.O. BOX 162305 ◦ AUSTIN, TEXAS 78716-2305 ◦ (512) 327-2708

20 November 2006

Mr. Kerry Niemann, Project Manager
TMDL, Strategic Assessment Division
Texas Commission on Environmental Quality
Post Office Box 13087
Austin, Texas 78711-3087

RE: Final Report, Modeling Report for Fecal Coliform TMDL Development for Peach Creek, Segment 1803C
Project Area 2 - Basin Groups D & E Bacteria Impairments
Contract No. 582-2-44841
Work Order No.5 (582-2-44841-05)

Dear Mr. Niemann:

We are submitting a final modeling report for the Peach Creek TMDL for the subject project. We are providing two bound paper copies and a digital copy. The report describes bacteria modeling activities, including model setup, calibration, and allocations for Segment 1803C, Peach Creek. The final report contains revisions pursuant to comments by TCEQ that were provided via letter dated 21 February 2006. A tabulation of comments and responses is also provided.

This report represents a final deliverable under Task 3.5 of Work Order 5.

If you have any questions, please do not hesitate to call me at (512) 327-2708.

Yours truly,

JAMES MIERTSCHIN & ASSOCIATES, INC.

James Miertschin, PE, PhD

TX201106.WPD

FINAL MODELING REPORT
FOR FECAL COLIFORM TMDL
(TOTAL MAXIMUM DAILY LOAD) DEVELOPMENT
FOR PEACH CREEK, SEGMENT 1803C

PROJECT AREA 2 - BASIN GROUPS D & E BACTERIA IMPAIRMENTS
WORK ORDER #5

Prepared For:

TMDL Unit
Texas Commission on Environmental Quality
Post Office Box 13087 MC 203
Austin, Texas 78711-3087

November 2006

JAMES MIERTSCHIN & ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERING
P.O. BOX 162305 • AUSTIN, TEXAS 78716-2305 • (512) 327-2708

JAMES MIERTSCHIN & ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERING
P.O. BOX 162305 • AUSTIN, TEXAS 78716-2305 • (512) 327-2708

FINAL MODELING REPORT FOR FECAL COLIFORM TMDL (TOTAL MAXIMUM DAILY LOAD) DEVELOPMENT FOR PEACH CREEK, SEGMENT 1803C

PROJECT AREA 2 - BASIN GROUPS D & E BACTERIA IMPAIRMENTS
WORK ORDER #5

Prepared for:

TMDL Unit
Texas Commission on Environmental Quality
Post Office Box 13087
Austin, Texas 78711-3087

Prepared by:

James Miertschin & Associates, Inc.

November 2006

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 BACKGROUND

Section 303(d) of the Federal Clean Water Act and U.S. Environmental Protection Agency (EPA) regulation 40 CFR 130.7 require states to identify waterbodies that do not meet, or are not expected to meet, applicable water quality standards. The compilation of subject waterbodies is known as the 303(d) list. Each state must assign priorities to waterbodies on the list, in order to schedule development of total maximum daily loads (TMDL). The TMDL is an allocation of point and nonpoint source pollutant loadings that will enable the waterbody to meet water quality standards.

The Texas Commission on Environmental Quality (TCEQ), formerly Texas Natural Resource Conservation Commission (TNRCC), is responsible for the monitoring and assessment of water quality to evaluate compliance with State water quality standards. Pursuant to the Clean Water Act, one of the areas of TCEQ responsibility is the development of the 303(d) list for Texas and subsequent development of TMDLs.

Peach Creek, Segment 1803C, was included on the Texas 303(d) list for the year 2000 developed by the TCEQ (TNRCC, 2000a). Peach Creek was listed for elevated levels of bacterial indicators for pathogens and nonsupport of contact recreation use.

The TCEQ has retained James Miertschin & Associates, Inc. (JMA) to provide support for data analysis, mathematical modeling of water quality, TMDL development, and report preparation. Previous work efforts involved the compilation and assessment of historical water quality data for bacterial indicators on the study segments, followed by the development of monitoring plans for supplemental data collection, and execution of supplemental data collection activities.

1.2 GENERAL TMDL APPROACH

The essence of a TMDL has been described by the EPA as follows (Perciasepe, 1997):

> States identify specific waters where problems exist or are expected; States set priorities; States allocate pollutant loadings among point and nonpoint sources; and EPA approves State actions or acts in lieu of the State if necessary. Point and nonpoint sources then reduce pollutants to achieve the pollutant loadings established by the TMDL through a wide variety of Federal, State, Tribal, and local authorities, programs, and initiatives.

EPA has required States to develop an appropriate schedule for establishment of TMDLs for all waters on the most recent 303(d) list, beginning with the 1998 list. Subsequent to the establishment of TMDLs for a waterbody, it is the implementation of the prescribed pollutant loading allocations that will actually accomplish improvement in water quality. The potential ramifications of establishment of a TMDL are significant for both point and nonpoint sources. Permit effluent limits for point sources must be consistent with the TMDL load allocation. Implementation of load allocations for nonpoint sources may involve individual landowners or public and private entities.

Examples offered for implementation of nonpoint load allocations include incentive-based approaches and local regulations or ordinances related to zoning, land use, and storm water runoff (Perciasepe, 1997).

The EPA Region 6 office has prepared guidance for the conduct of a TMDL study (EPA, 1997). The general approach involves definition of the problem, identification of contributing pollutant sources, and allocation of loadings from the sources. The approach incorporates eight elements, as described below:

1. Problem definition: Pollutant of concern, pollutant sources, waterbody characteristics, and applicable water quality standards are identified.

2. Endpoint identification: The desired endpoint or measurable goal is identified.

3. Source analysis: The type, magnitude, and location of sources of pollutant loading are determined.

4. Linkage between sources and receiving water: The cause and effect linkage between the pollutant source and the endpoint is analyzed over an appropriate range of conditions, and the assimilative capacity of the waterbody is determined. Monitoring and water quality modeling are used to establish the linkage.

5. Margin of safety: A margin of safety is incorporated into the analysis to account for uncertainty. This can take the form of conservative modeling assumptions or specification of a supplemental loading.

6. Loading allocation: Recommendations for loading allocations to all known or suspected point and nonpoint sources are developed.

7. Public participation.

8. Implementation and reasonable assurances.

For TMDLs in Texas, the TCEQ will have the initial approval authority. The TCEQ developed guidance for TMDLs that incorporates the key elements from EPA guidance (TNRCC, 1999). The TCEQ's outline includes the following steps for TMDL development:

1. Water quality target identification: apply existing numeric water quality criterion from Texas Surface Water Quality Standards; develop additional targets; or, modify existing designated uses or water quality criteria.

2. Assess current watershed and water quality conditions: use available data or collect additional data.

3. Analyze pollutant sources (point, non-point, background, atmospheric): identify the location and types of sources; pollutant load from each source.

4. Allocate pollutant loads: allocate to point, non-point, and natural background sources; include margin of safety.

The present study was conducted to conform to both EPA and TCEQ guidance regarding the content of the TMDL study.

1.3 OBJECTIVES

The objectives of the present study address key tasks of the TMDL development project for Peach Creek. Specific objectives include the following:

a) Development of a water quality model for simulation of bacteria in the study segment;

b) Development of loading allocations for achievement of water quality objectives and definition of the TMDL.

The scope of the present study was based upon application of the Hydrologic Simulation Program - Fortran (HSPF) model for simulation of the watershed and receiving stream. In preparation for the modeling analysis, field data collection was conducted to obtain site-specific water quality and hydrographic data. Historical flow and water quality data were also employed in the study. The available databases were used for calibration of the models, and the models were applied for a determination of loading allocation.

1.4 DESIGNATED USES AND APPLICABLE WATER QUALITY STANDARDS

1.4.1 Applicable Criteria

The most recent Texas Surface Water Quality Standards include criteria for *E. coli* and fecal coliform bacteria for each classified stream segment in the State (TNRCC, 2000b). The preferred indicator for freshwater is *E. coli*, but fecal coliform can still be used as an alternative indicator during the transition period to the new indicator. For saltwater, the new indicator is Enterococci bacteria. These bacteria all serve as indicators of the potential presence of pathogenic organisms. Classified segments are designated as either contact recreation or non-contact recreation waters.

For contact recreation waters, the *E. coli* counts should not exceed 126 colonies/100 mL, or, alternately, the fecal coliform content should not exceed 200 colonies per 100 mL, both expressed as geometric means. In addition, the *E. coli* content should not equal or exceed 394 colonies/100 mL, or, alternately, the fecal coliform content should not equal or exceed 400 colonies per 100 mL, in a single sample.

For non-contact recreation waters, the *E. coli* content should not exceed 605 colonies/100 mL, or, the fecal coliform content should not exceed 2,000 colonies per 100 mL, expressed as a geometric mean. In addition, the fecal coliform content should not equal or exceed 4,000 colonies per 100 mL in a single sample.

1.4.2 Assessment Guidance

The TCEQ has published guidance for assessment of impairment based upon bacterial indicators. The most recent TCEQ assessment methodology is described in the document "Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data, 2002" (TNRCC, 2001). This guidance document was based upon use of the Texas Surface Water Quality Standards that were adopted by the TNRCC in July 2000, but have not yet been approved by the US EPA. This latest methodology was used in the development of the draft 2002 305(b) list. In a previous phase of study, the JMA project team conducted an assessment of historical data based upon application of this most recent guidance, as directed by the TCEQ TMDL program (JMA and PES, 2002a, 2002b).

Exceedances for Partial Support and Non-support of Uses

The TCEQ has devised a procedure based upon the binomial method to estimate the probability of committing Type I and Type II classification errors for support of uses. With this method, the minimum number of required exceedances has been calculated for different sample sizes to determine if uses are fully supported, partially supported, or not supported. For contact recreation use evaluation, there is no designation of partial support. There are only classifications of fully supporting or not supporting. For example, with a sample size of 10 samples, 5 exceedances are required to classify a segment as not supporting, using the binomial method. The number of exceedances varies with sample size, as described in tabular form in the guidance document.

There are also exceedance requirements established to determine if there are "primary concerns." These concerns are also based upon the binomial method. Primary concerns are further subdivided into "Tier 1 concerns" and "Tier 2 concerns". Tier 1 concerns are defined for sample sizes of 4-9, while Tier 2 concerns are defined for sample sizes of 10 or greater. For example, with a sample size of 7 samples, three exceedances are required for a Tier 1 concern. With a sample size of 10 samples, three exceedances are required for a Tier 2 concern. The number of exceedances varies with sample size, as described in tabular form in the guidance document.

Flow Conditions

Samples in freshwater streams should be collected when stream flow is equal to or greater than the seven-day, two-year low flow (7Q2) condition. The data may include samples collected under high-flow runoff conditions.

The TCEQ has also developed guidance for appropriate flow conditions in small unclassified streams. For perennial streams, the contact recreation use is evaluated using data collected when the flow is equal to or greater than the 7Q2 flow or 0.1 cfs. For intermittent streams and intermittent streams with perennial pools, the bacterial indicator criteria apply at all times.

Assessment for Use Support

Contact recreation use support is evaluated based upon analysis of fecal coliform, *E. coli* (in freshwater), or Enterococci (in tidal waters) data. The typical available data base consists of samples collected at routine biannual, quarterly, or monthly frequencies. For this type of routine data, assessment screening levels for single samples are set as 400 colonies/100 mL for fecal coliform, 394 colonies/100 mL for *E. coli*, and 89 colonies/100 mL for Enterococci. Geometric means are also included in the assessment protocol as follows: fecal coliform 200 colonies/100 mL, *E. coli* 126 colonies/100 mL, and Enterococci 35 colonies/100 mL. According to the TCEQ guidance document, the preferred indicator is *E. coli* in freshwater, and data for this indicator should be used when data for fecal coliform is also available.

For 10 or more samples, support of the contact recreation use is defined as "fully supporting" where the geometric mean is less than the criterion and 25% of the time, or less, concentrations exceed the single sample criterion at a frequency commensurate with the binomial method. The assessment is defined as "not supporting" where the geometric average exceeds the criterion or greater than 25% of all samples collected exceed the single sample criterion, with the required number of exceedances described by the binomial method. A "primary concern" can also be identified for the bacterial indicator data. A "Tier 2 primary concern" is designated where greater than 25% of all samples exceed the single sample criterion, at a frequency in accordance with the binomial method.

Procedures are modified for data sets of 4 to 9 samples. The contact recreation use is not assessed as either "fully supporting" or "not supporting" for small sample sets. However, a "Tier 1 primary concern" is assigned where the long-term geometric mean exceeds the criterion, or, greater than 25% of the time, concentrations exceed the single sample criterion at a frequency determined by the binomial method.

1.5 FECAL COLIFORM BACTERIA MONITORING AND ASSESSMENT

Historical water quality data were available for both *E. coli* and fecal coliform indicator bacteria at one monitoring station on Peach Creek.

A prior study described assessment of water quality conditions in Peach Creek, based upon application of available water quality data from a five-year period (JMA, 2002a). The available data (1996-2001) for bacterial indicators were analyzed using TCEQ Year 2002 guidance methodology. Results for the assessment of the bacteria data are summarized in the following table. The data were assessed with respect to support of the contact recreation use.

WATERBODY	STATUS
Peach Creek, Segment 1803C	"not supporting" based on fecal coliform for lower 25 miles of segment

In this context, "not supporting" denotes that the water quality data indicates exceedance of applicable criteria and therefore the contact recreation use is not supported. Peach Creek, Segment 1803C, was determined to be "not supporting" based on fecal coliform data. In this early assessment, the stream was also assessed based upon *E. coli* data and found to be "fully supporting." However, additional *E. coli* monitoring (2001-2004) has indicated that the stream is no longer in compliance with the *E. coli* criteria. A more thorough presentation of these data is included in Sections 3.2 and 3.3.

2.0 WATERSHED CHARACTERIZATION

2.1 WATERSHED BOUNDARIES

The Peach Creek Basin, covering 484.8 square miles (310,275 acres), is located in the south central portion of Texas, as shown in Figure 2-1. The basin is located between San Antonio and Houston along the I-10 corridor. Peach Creek is a tributary of the Guadalupe River. The two largest municipalities located within the watershed are Flatonia and Waelder. Their populations were 1,377 and 947, respectively, in the year 2000 (US Census, 2006). The Peach Creek watershed encompasses portions of Gonzales, Caldwell, Bastrop, Fayette, and Lavaca Counties.

2.2 STREAM NETWORK

The stream originates in Bastrop County and flows southward toward the Guadalupe River. Major tributaries include Five Mile Creek, Sandy Fork Creek, and Denton Creek. The length of Peach Creek is 66 miles, and there are approximately 77 miles of tributaries. Peach Creek drops in elevation from its headwaters by approximately 300 feet.

2.3 TOPOGRAPHY AND LAND RESOURCES

The topography of the Peach Creek Basin consists primarily of gently rolling hills. The elevations typically range from 250 to 600 feet above mean sea level. Most of the study area watershed is located within Gonzales County. Major land-resource areas include the Texas Claypan Prairie of the Post Oak Belt, the Southern Blackland Prairie, and the Northern Rio Grande Plain.

Typical vegetation includes post oak savannah with tall grasses, post oak, and blackjack oak in the Texas Claypan areas; mesquite, prickly pear, brush, and low-growing grasses of the Northern Rio Grande Plain; and live oaks, pecan, and walnut in the southern Blackland Prairie.

2.4 CLIMATE

The Gulf of Mexico is the principal source of moisture that drives precipitation in the study area. The amount of precipitation that falls is influenced by the distance from the Gulf of Mexico and by topography. The study area is located primarily within the South Central Texas climatic division.

The climate of the region is classified as humid subtropical. Summers are usually hot and humid, while winters are often mild and dry. The hot weather is rather persistent from late May through September, accompanied by prevailing southeasterly winds. There is little change in the day-to-day summer weather except for the occasional thunderstorm, which produces much of the annual precipitation within the region. The cool season, beginning about the first of November and extending through March, is typically the driest season of the year as well. Winters are typically short and mild, with most of the precipitation falling as drizzle or light rain.

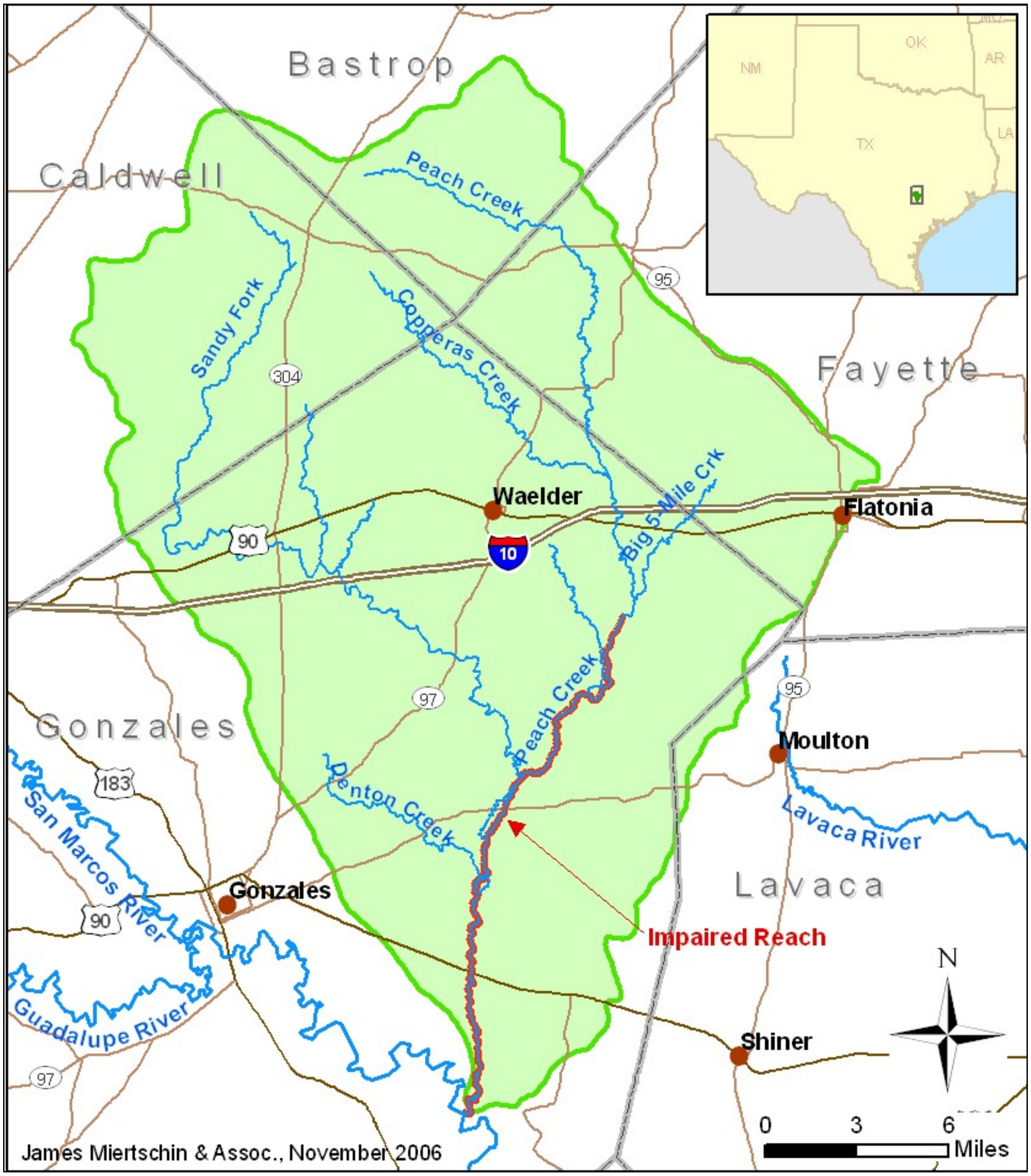

Figure 2-1 Peach Creek Basin

The climate is dominated by proximity to the Gulf of Mexico and characterized by prevailing southeasterly winds. During the long humid summers, high daytime temperatures are common in the study area. Although mean annual temperatures are basically uniform throughout the region, there are some marked seasonal variations, which lead to widely varied values for annual net lake surface evaporation.

As with the rest of the interior of the State, maximum precipitation periods in the study area are typically late spring (May) and early autumn (September). Winter and summer periods are typically low precipitation periods. The maximum precipitation period in May is driven by the buildup of water vapor from the Gulf of Mexico from the prevailing winds from the south. Precipitation is caused by late season cold air migrations, warm season thunderstorms, and spring low pressure troughs. In September, cold air converges with moisture-laden southerly winds and late season convective thunderstorms drive the precipitation. It is also not unusual for hurricanes to effect rainfall in the early autumn period. Summer drought conditions are common in the study area, due to strong high pressure cells that result in lengthy dry spells. Mean annual precipitation in the watershed ranges from 34 to 37 inches per year.

Precipitation data employed in the present study were obtained from the National Weather Service. Records of daily rainfall for the National Weather Service co-op stations in Jeddo, Flatonia, and Gonzales were the primary source of data for modeling. The data from these daily rainfall stations were disaggregated using hourly rainfall data, primarily from gages in Austin, San Antonio, and Victoria (based on proximity and availability of data).

2.5 ECONOMY

The study watershed includes the corners of Gonzales, Caldwell, Fayette and Bastrop Counties, with the Gonzales County portion being by far the largest. Flatonia, located partially within the study watershed in Fayette County, is the largest city in the study area and has a population of 1,377 (year 2000) (US Census, 2006). Waelder, located in the center of the watershed in Gonzales County, has a population of 947 (year 2000). The total population of the study area was estimated by intersecting “block-group” level census data with the watershed boundaries inside a GIS. Based on these data, the estimated population of the study area was 5,214 in 1990 and 6,812 in 2000.

Agribusiness is probably the most important component of the local economy. Poultry and cattle are the primary types of livestock raised in the watershed. The majority of the farmland in the study area is used as rangeland for the raising of livestock. Harvested crops, such as grains and pecans, are grown in a small portion of the region’s farmland (TSHA, 2001; USDA, 2002).

Other natural resources in the region include clay, sand, and gravel mines; oil and gas production; and uranium production.

2.6 GEOLOGY AND HYDROGEOLOGY

Tertiary period geologic formations underlie the Peach Creek watershed. These formations typically consist of sandstones formed through fluvial processes. The formations dip gently toward the Gulf of Mexico.

Groundwater in the area is primarily associated with the Queen City and Carrizo-Wilcox aquifer systems. The Queen City Aquifer underlies most of the watershed. The outcrop zone of this aquifer includes the portions of the watershed inside Bastrop, Caldwell, and northwestern Gonzales County. The aquifer is made up of sand and loose sandstone and is usually less than 500 feet in thickness. The Carrizo-Wilcox Aquifer downdip zone underlies the Queen City Aquifer throughout most of the study watershed. The thickness of sand and gravel layers in the Carrizo-Wilcox aquifer range from less than 200 feet to 3,000 feet in thickness (Ashworth, 1995).

2.7 SOILS

Soil conditions vary significantly throughout the study area. Gonzales County, alone, includes over 75 different soil types and 19 underlying geological formations, making it the most diverse county of the state (TSHA, 2001). Soils in the study area can range from clays to sands and typically have moderate to low permeability.

2.8 LAND USE

Land use in the Peach Creek watershed is dominated by farms and ranches located on forested and rangeland areas. There are also some concentrated animal feeding operations located within the watershed. Land use data for the watersheds were based on the United States Geological Survey National Land Cover Dataset (USGS NLCD). Derived from the early to mid-1990s Landsat Thematic Mapper satellite data, the NLCD is a land cover classification scheme applied consistently over the United States. The spatial resolution of the data is 30 meters and mapped in the Albers Conic Equal Area projection, NAD 83. Land use for the watershed is shown in Figure 2-2.

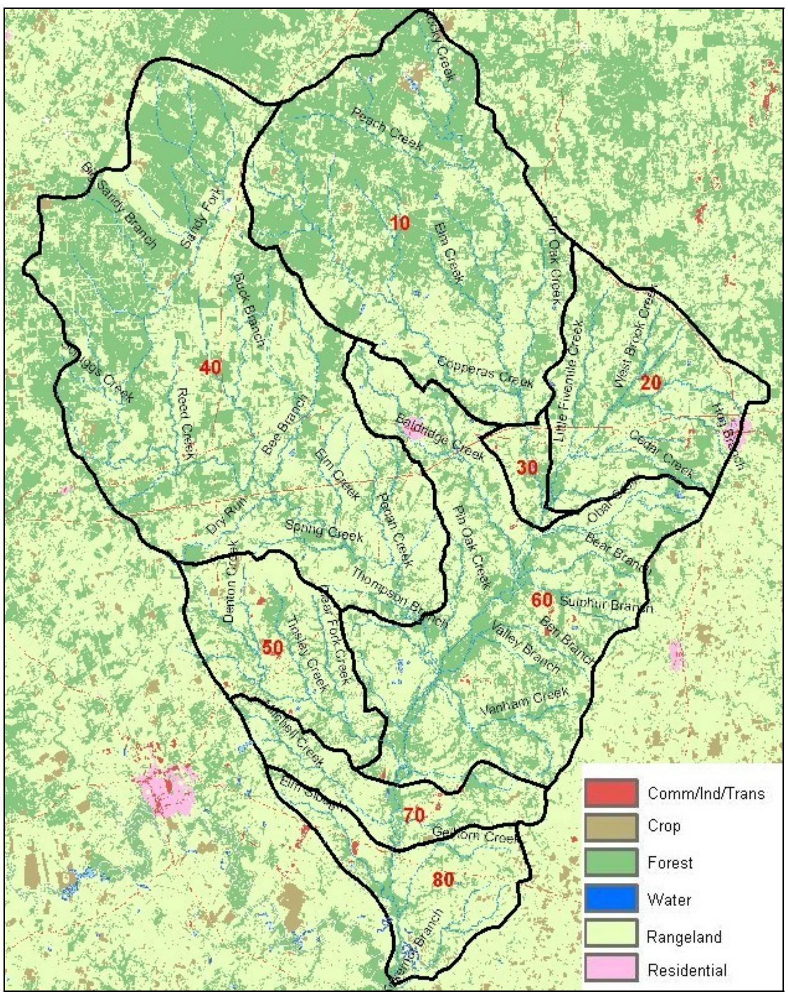

Figure 2-2 Peach Creek Land Cover

3.0 TMDL ENDPOINT AND WATER QUALITY SUMMARY

3.1 ENDPOINT DETERMINATION FOR BACTERIA

Peach Creek, Segment 1803C, was listed as impaired due to *E. coli* or fecal coliform bacteria on the Texas 2000 303(d) list of impaired waters, based upon monitoring conducted from October 1996 to November 2001. Elevated levels of *E. coli* and fecal coliform bacteria were documented at the water quality monitoring station located at CR 353 on Peach Creek during the assessment time period. It was determined, as a result, that Peach Creek did not support the contact recreation use designation.

TMDL development requires the identification of a numeric endpoint that will allow for the attainment of designated uses and water quality criteria. Instream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementation of load reductions specified in the TMDL. For the Peach Creek TMDL, the applicable endpoint can be determined directly from the Texas surface water quality standards. The current water quality standards specify criteria for dual indicator bacteria. For fecal coliform bacteria, the criteria include a geometric mean concentration of 200 org/100 mL, with a single grab sample limitation of 400 org/100 mL to support the contact recreation use designation. For *E. coli* bacteria, the criteria specify a geometric mean concentration of 126 org/100 mL, with a single grab sample limitation of 394 org/100 mL.

The geometric mean for fecal coliform bacteria was employed as the principal endpoint for the present TMDL determination. Application of the geometric mean is facilitated because of the availability of continuous simulation modeling results for mean daily bacteria concentrations. Fecal coliform was selected as the principal constituent for the analysis, since most of the available literature regarding sources is based upon fecal coliform, rather than *E. coli*. However, the final allocation will also be assessed with respect to *E. coli*.

3.2 MONITORING STATIONS

Fecal coliform and *E. coli* bacteria data have been collected by various entities, including the GBRA and TCEQ, at several monitoring stations on Peach Creek. Supplemental data were collected in 2003 and 2004 in conjunction with the present study. Monitoring site locations for Peach Creek are shown in Figure 3-1. Fecal coliform and *E. coli* data collected on Peach Creek are summarized in Table 3-1. The table includes the number of samples that exceeded the grab sample criterion and the geometric mean of all of the samples.

Table 3-1 Bacteria Data Collected on Peach Creek, 1996-2004

TCEQ Station	Location	*E. coli*			Fecal Coliform		
		No. Samples	No. Exceed	Geomean (org/100mL)	No. Samples	No. Exceed	Geomean (org/100mL)
14937	CR 353	112	29	184	67	21	259
17935	FM 397	8	1	188	4	0	157
17934	FM 1680	9	1	115	5	2	244
17933	US 90	9	3	172	5	2	322

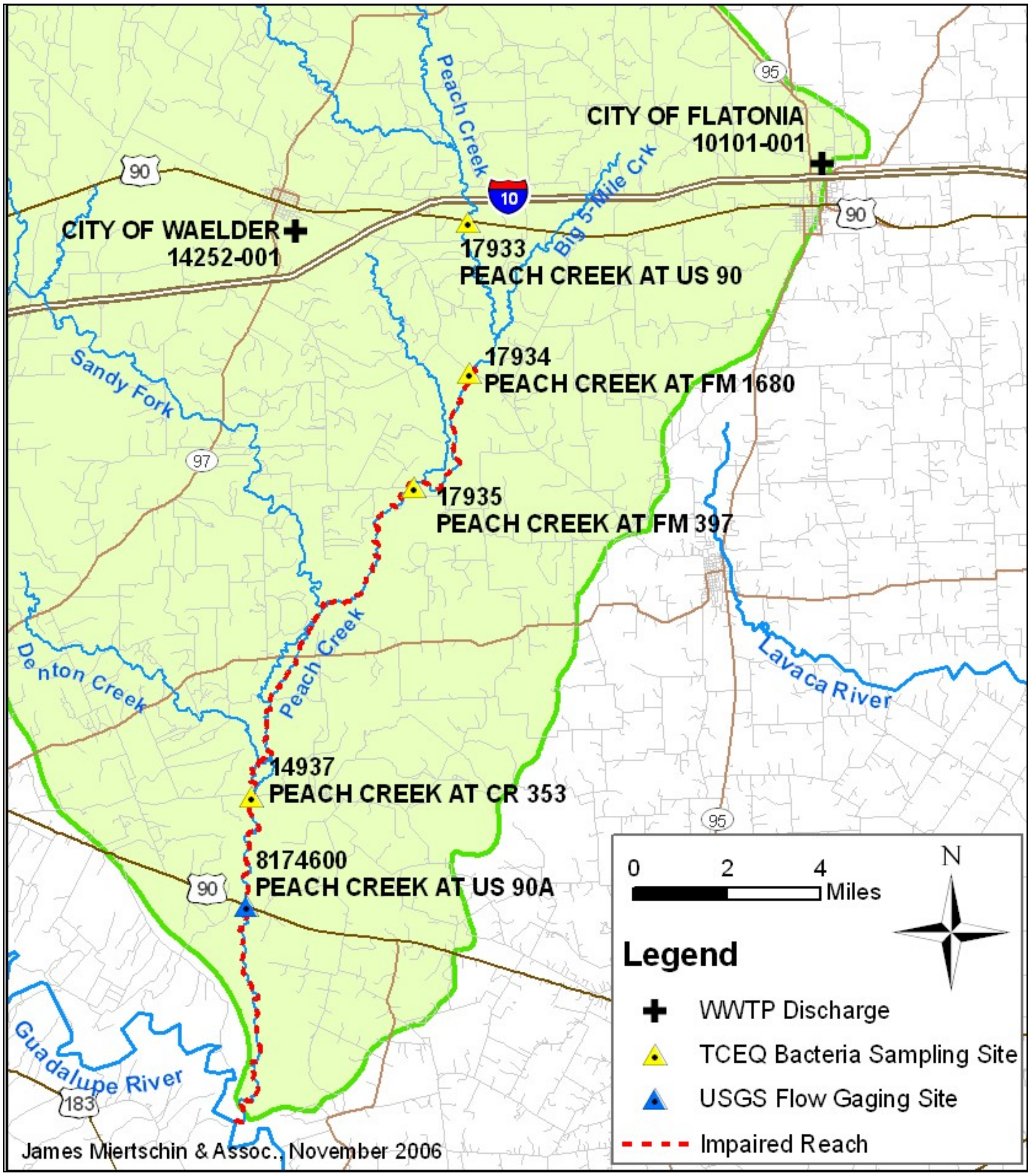

Figure 3-1 Peach Creek Sampling Stations

3.3 WATER QUALITY SUMMARY

To summarize the water quality on Peach Creek, the single station with the majority of available data was selected for presentation in this section of the report to illustrate typical conditions. Fecal coliform bacteria monitoring data for Peach Creek St. 14937 at CR 353 for the period 1996-2003 are displayed in Figure 3-2. A plot of *E. coli* bacteria concentrations for the same station is displayed in Figure 3-3 for the years 1996-2004. Also, shown are flow records for the USGS gage at US 90 (#08174600), which was inactive prior to October of 2000. Data analysis in a previous study showed no apparent seasonal trends or numerical relationships with flow (JMA and PES, 2002b). It was observed, however, that higher counts are typically associated with runoff conditions.

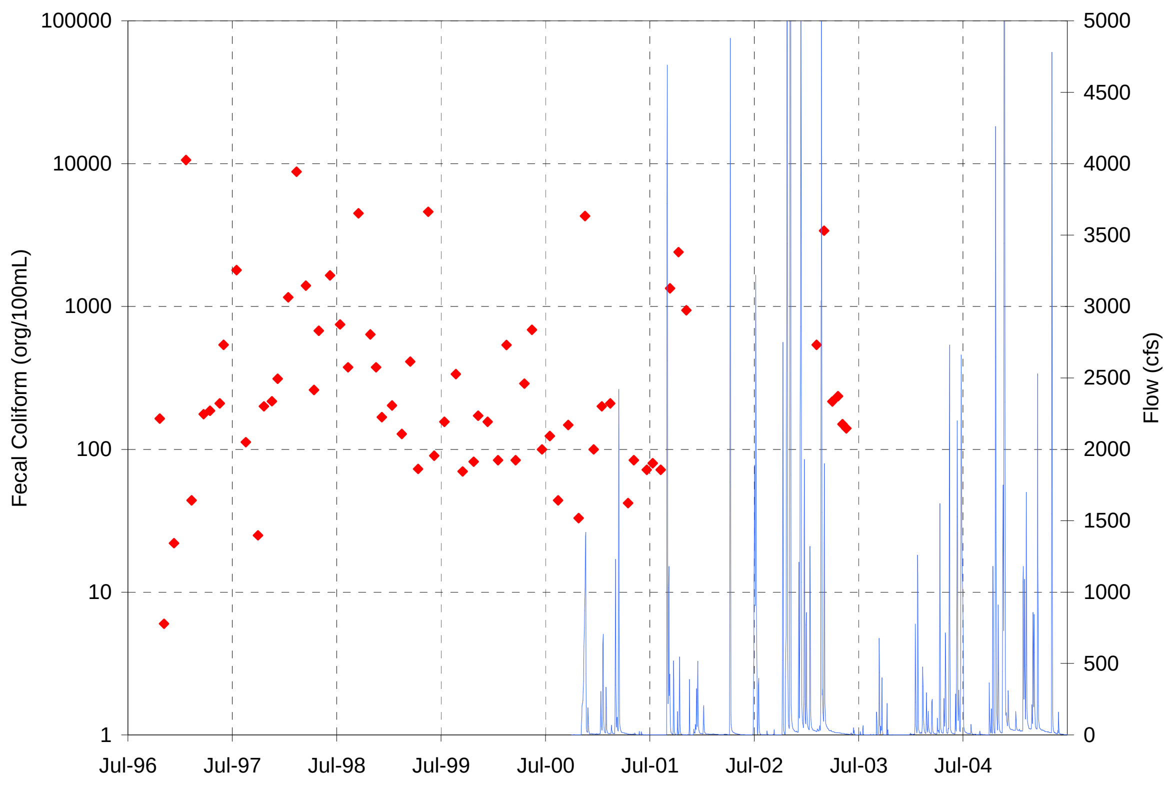

Figure 3-2 Fecal Coliform Monitoring Data for Peach Crk at CR 353, 1996-2004

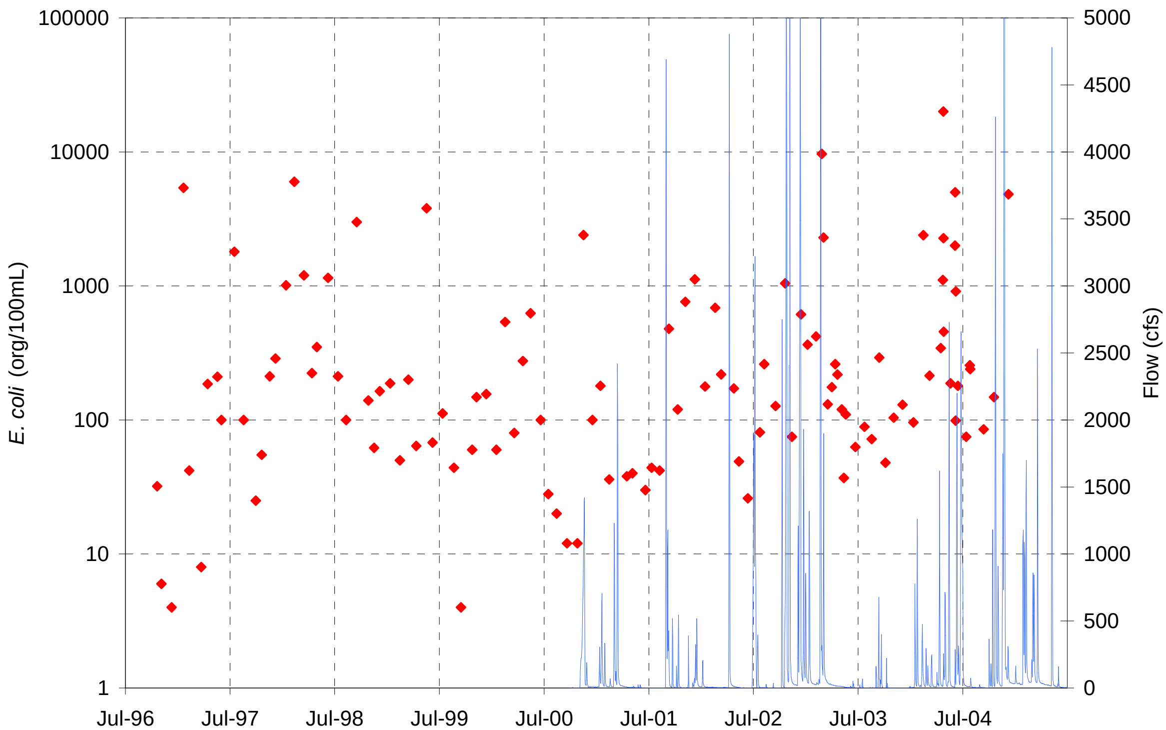

Figure 3-3 *E. coli* Monitoring Data for Peach Crk at CR 353, 1996-2004

4.0 SOURCE CHARACTERIZATION AND ASSESSMENT

The TMDL development described in this report included examination of all potential sources of bacteria loading in the Peach Creek watershed. The potential sources include both point and non-point sources. The source assessment was used as the basis of model development and the analysis of TMDL allocation scenarios. To characterize and evaluate the sources, a variety of information was employed, including agricultural and land use information, water quality monitoring and point source data, past TMDL studies, literature sources, and input from state and local management agencies. This section documents the available information and its interpretation. Procedures and assumptions used in estimating fecal coliform bacteria loads for representation in the model are discussed in the following Section 5.0.

4.1 ASSESSMENT OF POINT SOURCES

Point sources, such as municipal wastewater treatment plants (WWTPs), can contribute fecal coliform bacteria loads to surface water streams through effluent discharges. These point sources are permitted through the Texas Pollutant Discharge Elimination System (TPDES) program that is managed by the TCEQ. Five active permitted point sources have been identified in the Peach Creek watershed, as listed in Table 4-1. The locations of these point sources are shown in Figure 4-1.

Table 4-1 Point Sources

PERMITTEE	TCEQ Permit #
City of Waelder – WWTP (0.12 MGD)	14252
City of Flatonia – WWTP (0.25 MGD)	10101
Southern Clay Products, Inc. - US 90 clay mine	1925
Southern Clay Products, Inc. - Elm Grove clay mine	3405
Aqua WSC - Delhi iron removal plant	14361

There are two point sources located in the study watershed that may contribute fecal coliform: the City of Flatonia and the City of Waelder wastewater treatment plants (WWTPs). Permitted point sources that process wastewater associated with fecal matter are typically required to provide disinfection. Both the Flatonia and Waelder wastewater treatment facilities include facultative lagoon systems. These treatment facilities do not include chemical disinfection processes. Instead, a substantial reduction in bacteria is achieved via provision of 21 days of detention time within the pond system, during which bacteria are eliminated by solar radiation and other natural processes. This type of pond system is usually required to monitor effluent for fecal coliform. At the Waelder Plant, effluent fecal coliform levels must be measured once each month, but there is no maximum discharge concentration stipulated by the permit. At the Flatonia Plant, fecal coliform samples must be collected five times each week and the average value may not exceed 200 org/100mL, according to the facility's permit.

The wastewater treatment plants for the cities in the Peach Creek watershed have been in operation for a number of years. Records for these municipal outfalls were obtained from TCEQ and the municipalities.

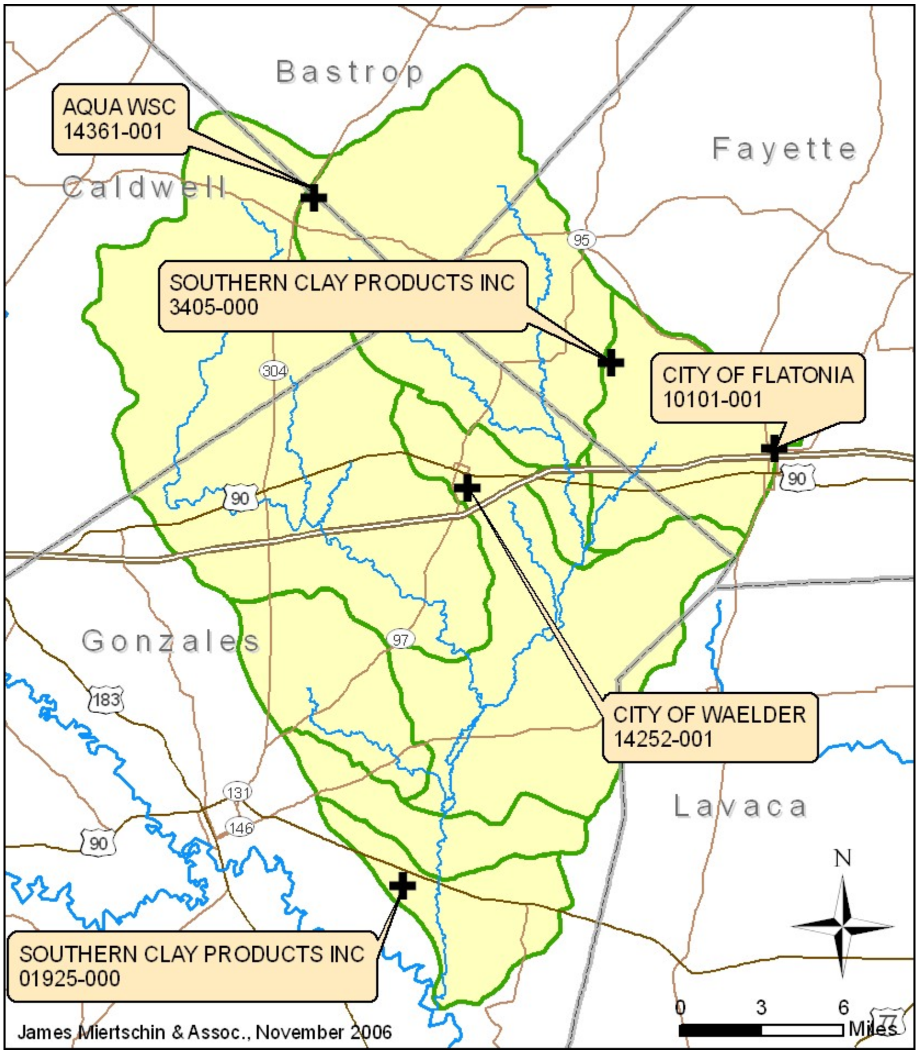

Figure 4-1 Point Source Locations

4.2 ASSESSMENT OF NON-POINT SOURCES

In the Peach Creek watershed, both urban and rural non-point sources of fecal coliform bacteria were considered in the present analysis. The Texas 303(d) list for 2000 identifies unknown point and nonpoint sources as the primary sources of pathogens in the subject watershed. Sources included in the present analysis include septic systems, wildlife, livestock, and general urban runoff. The representation of the following sources in the model is described in Section 5.0.

4.2.1 Failing Septic Systems

Private residential sewage treatment systems (septic systems) typically consist of one or more septic tanks and a drainage or distribution field. Household waste flows into the septic tank, where solids settle out. The liquid portion of the waste flows to the distribution system which may consist of perforated pipes buried in a soil or gravel bed. Effluent in the bed may move vertically to groundwater, laterally to surface water, or upward to the ground surface. As it moves, the majority of the liquid portion is consumed by evapotranspiration of vegetation planted on top of the distribution field or adjacent to it. Properly designed, installed, and functioning septic systems would be expected to contribute virtually no fecal coliform to surface waters. The principal removal mechanism for the fecal coliform would be die-off as the liquid moves through the soil. Various studies have attempted to quantify the transport and delivery of bacteria in effluent from septic systems. For example, it has been reported that less than 0.01% of fecal coliform originating in the household waste moves farther than 6.5 feet downgradient from the drainfield (Weiskel, 1996).

A septic system failure can occur via two mechanisms. First, drainfield failures, broken pipes, or overloading could result in uncontrolled, direct discharges to the streams. Such failures would not be expected to be common in the study watershed, but they could occur in reaches with older homes located near a watercourse or in remote areas. As a second mechanism, an overloaded drainfield could experience surfacing of effluent, and the pollutants would then be available for accumulation on the ground surface and subsequent washoff under runoff conditions.

The number of septic systems in the study area was estimated using information from the 1990 U.S. Census, which included a question regarding the means of household sewage disposal (US Census, 2006). Unfortunately, this question was not posed in the 2000 Census. Based on the 1990 data, the number of septic systems (and other non-sewered systems) in the study area was estimated by intersecting the geographic census block-groups with the study area watershed. The spatial distribution of these systems is shown in Figure 7. From 1990 to 2000, the total number of septic systems was estimated to have increased from 1,694 to 2,202 (based on population growth). Table 4-2 shows the estimated number of septic systems, by subbasin, for the year 2000.

Generally, only septic systems near streams have a high likelihood of contributing bacteria to the surface water. For this study, a riparian corridor of 300 feet (total width) was applied to all perennial streams in the study area. Of these systems, only a small percentage would be expected to be failing. According to a report by Reed, Stowe, and Yank (2001), about 12% of the septic systems in the study area are chronically malfunctioning. For this analysis, only the potential direct discharges from failing septic systems were considered in the model. Fecal coliform loadings were calculated based upon a septic system fecal density of 10,000 org/100 mL (EPA, 2000). According to US Census data, the average household in the study area includes about 2.7 people.

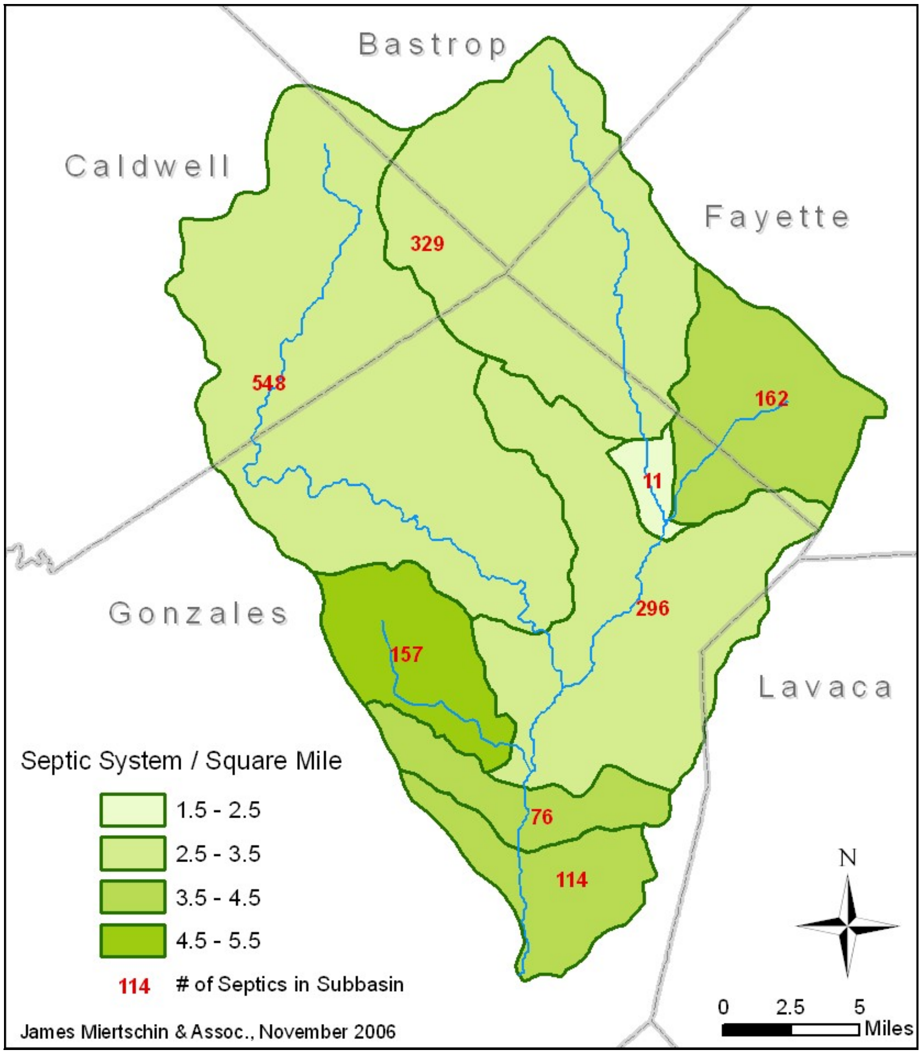

Figure 4-2 Sewage Disposal by Subwatershed

Table 4-2 Septic Systems by Subwatershed, 2000

Subbasin #	Septic Systems, Total	Septic Systems, Near-stream	% Failure	Failing Septic Systems, Near-stream
10	428	6	12.0%	0.7
20	211	5	12.0%	0.6
30	14	1	12.0%	0.1
40	712	12	12.0%	1.4
50	204	6	12.0%	0.7
60	385	5	12.0%	0.6
70	99	1	12.0%	0.1
80	149	2	12.0%	0.2
Total	2202	38	-	4.4

4.2.2 Livestock

Livestock population estimates for Gonzales, Fayette, Caldwell, and Bastrop Counties were based upon the 2002 Agricultural Census and TCEQ and Texas State Soil & Water Conservation Board (TSSWCB) registration records. The types of livestock explicitly included in the present analysis were cattle, horses/donkeys, sheep/goats, hogs, and chickens. The census data were used to determine the density of livestock (except chickens) for each county; then the watershed totals were obtained based upon the representative county areas associated with the watershed. Data for chickens were obtained from TCEQ and TSSWCB registration records. Animal population estimates are presented in Table 4-3. Other types of livestock had small populations compared to the major livestock species listed above, and therefore, the fecal loads from these other animal groups were assumed to be negligible.

Table 4-3 Livestock Population Estimates for the Peach Creek Watershed

Animal Type	Number of Animals
Cattle & Calves	65,457
Swine	629
Sheep	546
Horses & Donkeys	1,346
Chickens	8,527,610

Fecal coliform bacteria produced by livestock can enter surface waters through several pathways: washoff of waste deposited on the land surface, washoff of concentrated waste from land application sites, direct deposition of waste material in the stream, and potential discharges from animal confinement areas or waste handling systems. The present analysis included dairy cattle within confined animal feeding operations as well as mechanisms of deposition of waste from grazing animals and the potential direct discharge of fecal material to the streams.

Grazing animals contribute fecal coliform bacteria to the land surface that is subsequently available for washoff to surface waters during storm events. The mechanism for the contribution is shown schematically in Figure 4-3. Thus, in the present analysis, deposition of waste from cattle, horses/donkeys, sheep/goats, and hogs onto the land surface was considered. It was assumed that grazing animals deposited waste on forest and rangeland land use categories.

Non-grazing animals considered in the present analysis were chickens in various types of production facilities. The chickens are confined in covered facilities where they are grown or employed in egg-laying. Chicken litter (waste) is collected in the various facilities. In the smaller growing operations, litter is generally scraped and typically stockpiled before it is land applied on waste application fields. In the egg-laying facilities, litter is scraped or washed to lagoons for storage and treatment, after which lagoon wastewater is land-applied via sprinkler irrigation. Thus, the litter from the chicken facilities is ultimately applied in solid or liquid form to waste application fields (WAFs). Once applied to the WAFs, the waste is subject to washoff from the land surface under runoff conditions.

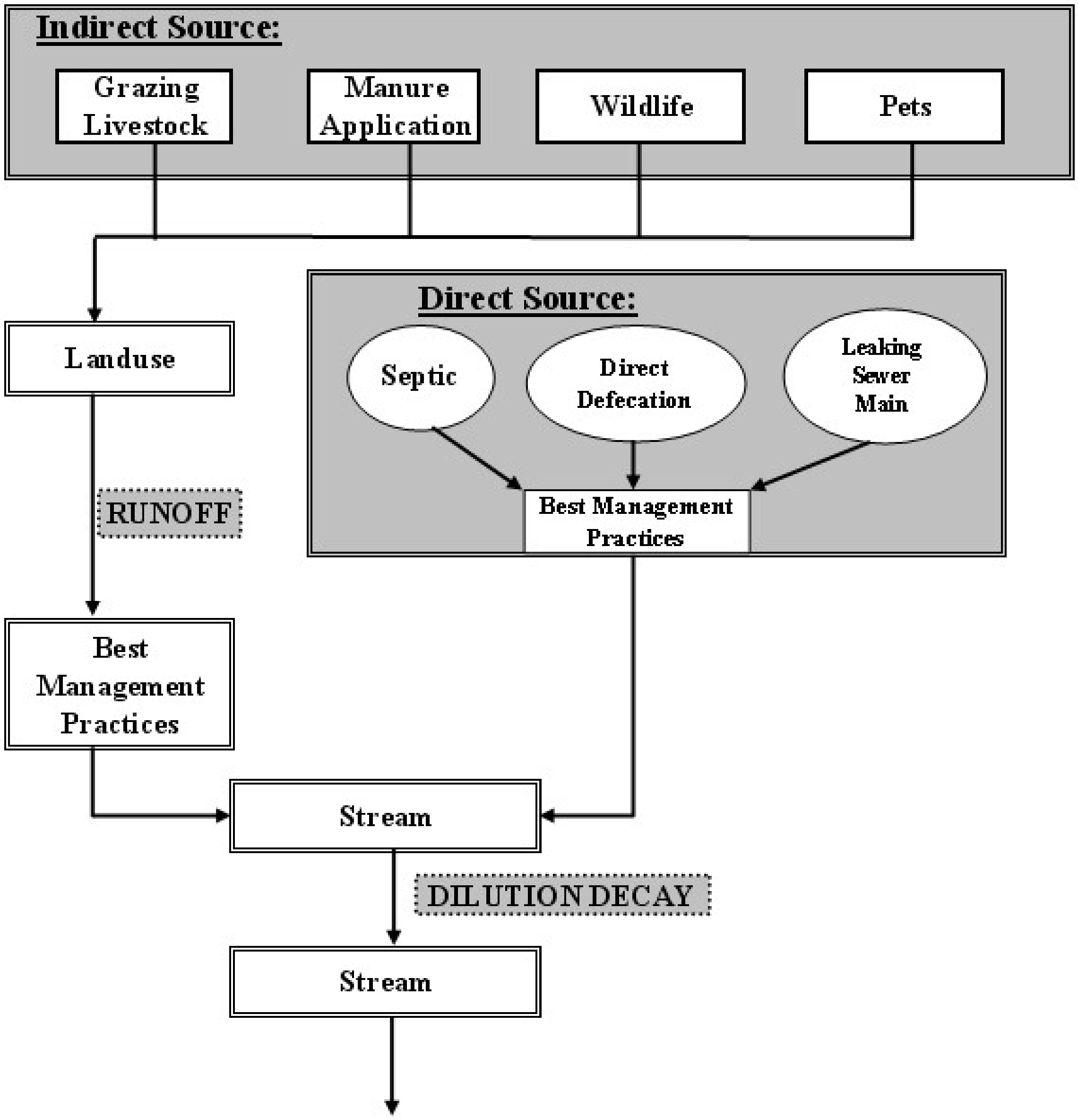

Figure 4-3 Mechanism of Fecal Coliform Nonpoint Source Accumulation

Direct contributions from livestock into the stream were also considered in the present analysis. It was assumed that cattle and horses spent a small fraction of their time directly in the stream and therefore the potential exists for direct deposition. Other livestock, sheep/goats and hogs, were assumed to deposit all feces on pasture and forested areas. The amount of time that cattle and horses spend in direct contact with the stream depends upon the time of year and the availability of stream access and non-stream watering facilities. For the present analysis, the time spent was assumed to be related to mean monthly water temperature, with higher usage in warmer weather. Data for direct contact with the stream are shown in Table 4-4. These percentages indicate the assumed portion of time that a livestock animal spends directly in the stream, compared to the total time that the animal spends in the riparian area. To establish a reference point, it was assumed that animals spend 1% of their time in the stream in the coolest warm-season month of November. Time in the stream was then proportionally varied according to mean water temperature. For colder months, it was assumed that there was essentially no time spent in the stream.

Table 4-4 Direct Animal Contact with Stream

Month	Cattle and Horses Grazing Time Spent in Streams
January	0%
February	0%
March	1.03%
April	1.14%
May	1.26%
June	1.36%
July	1.40%
August	1.40%
September	1.32%
October	1.18%
November	1.0%
December	0%

Fecal coliform bacteria production rates for livestock are displayed in Table 4-5. For the present study, all of the data regarding manure production rates and fecal coliform density were based upon values from literature, as reported in the EPA Bacterial Indicator Tool (EPA, 2000).

Table 4-5 Fecal Coliform Bacteria Production Rates for Livestock and Wildlife

Animal	Fecal Coliform (count/animal/day)
Dairy Cow	1.01×10^{11}
Beef Cow	1.04×10^{11}
Hog	1.08×10^{10}
Sheep	1.20×10^{10}
Horse	4.20×10^{8}
Chicken	1.36×10^{8}
Turkey	9.30×10^{7}
Duck	2.43×10^{9}
Opossums	1.25×10^{8}
Deer	5.00×10^{8}
Feral Hogs	1.08×10^{10}
Raccoon	1.25×10^{8}

4.2.3 Wildlife

The predominant wildlife species considered in the modeling analysis were determined by wildlife biologists on the project team based on their experience, literature (Davis and Schmidly, 1994; TPWD, 2004), site visits, and consultation with Texas Parks and Wildlife Department staff (Cain, 2004). The key species included deer, raccoons, opossums, feral hogs, and ducks/geese. Of course, there are numerous other species of animals that inhabit the watershed, but the species selected in the present analysis were chosen based upon population and fecal production potential.

The population of each wildlife species was developed using estimated population densities per square mile of habitat and the total area of suitable habitat available in each subwatershed. The total wildlife inventory is shown in Table 4-6.

Table 4-6 Inventory of Wildlife

Animal	Number
Ducks	125
Deer	4,732
Raccoons	18,927
Opossums	75,707
Feral Hogs	9,463

This inventory of wildlife populations can be applied to develop initial estimates of bacteria loading in the watershed. Exact counts are not available for any of the species in the watershed. Even if exact numbers for deer, raccoons, etc. were available, there will always be some species of wildlife animals that are not specifically counted, such as mice, sparrows, and many more. To support water quality modeling, a general estimate of the overall load contribution from wildlife is needed. Since wildlife populations cannot be precisely known, all loading parameters that represent wildlife are subject to adjustment in the model calibration process.

As with livestock, there are two mechanisms considered for bacteria loadings from wildlife to be transported to the stream segment. First, wildlife deposit waste on land surfaces that accumulates and is subsequently available for washoff with runoff. Second, wildlife may deposit waste directly into the stream.

For specification of the number of animals that may be engaged in direct deposition to the stream, the area of a riparian habitat corridor approximately 300 feet in width was calculated, and the prescribed animal density was applied to this riparian area in order to provide an initial estimate of the near-stream populations. Then, a small fraction of this population was assumed to directly deposit waste in the stream. A seasonal component for the frequency of wildlife visitation to the stream was developed as a function of mean ambient water temperature, with the assumption that water visitation would be more likely under warm-weather conditions, similar to the livestock approach described previously.

Fecal coliform bacteria production rates for wildlife in the Peach Creek watershed are shown in the above Table 4-5. For the present study, all of the data regarding fecal production rates and fecal coliform density was based upon values reported in the EPA Bacterial Indicator Tool (EPA, 2000).

4.2.4 Urban Loadings

Some of the study area is comprised of the urban landscape of residential, commercial, and industrial areas. While the initial estimates of bacteria mass loadings for non-urban land use areas were developed based upon an inventory of septic systems, livestock, and wildlife, the myriad of sources in the urban areas were represented by typical loading rates from literature sources (EPA, 2000). These generalized urban loading rates thus represent bacteria loadings that may be derived from urban wildlife, pets, septic system failures, sewer system leaks, discharges of varied nature and composition, and any other sources that may be present. The specific factors employed in the present analysis for the initial urban loading estimates are summarized in Table 4-7.

Table 4-7 Typical Bacteria Loading Rates from Urban Land Uses

Land Use	*Median FC count/acre/day*
Road	2.00×10^5
Commercial	6.21×10^6
Single family low density	1.03×10^7
Single family high density	1.66×10^7
Multifamily residential	2.33×10^7

5.0 WATERSHED MODELING

Establishing the relationship between instream water quality targets and the source loadings of bacteria is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. The link can be established through a variety of techniques, ranging from qualitative assumptions based on scientific principles to sophisticated mathematical modeling techniques. In the development of a TMDL for the impaired reach of Peach Creek, the relationship was defined through computer modeling based upon data collected throughout the watershed. Monitored flow and water quality data were used to verify that the relationships developed through modeling were accurate. In this section, the selection of modeling tools, setup, and model application are discussed.

5.1 MODELING FRAMEWORK SELECTION

The US EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) system Version 3.1 (EPA, 2004) and the Hydrologic Simulation Program - Fortran (HSPF) water quality model were selected as the modeling framework to simulate existing conditions and to perform TMDL allocations. BASINS is a multipurpose environmental analysis system for use in performing watershed and water quality-based studies in a wide variety of areas. BASINS includes a geographic information system (GIS) for integration of landscape information, including land uses, monitoring stations, point source locations, and watershed delineation. The HSPF model is a continuous simulation model for watershed hydrology and water quality. The model can account for both point source loadings and non-point source loadings in the watershed. HSPF includes simulation of the receiving stream that receives mass loadings from the watershed. The features of HSPF that led to its selection are summarized below:

- Full capabilities for long-term simulation of hydrologic response
- Full capabilities for simulation of dynamic mass transport from the watershed surface
- Adaptability to urban and non-urban land uses
- Built-in receiving water module with instream source/sink terms
- Successful application to bacteria TMDLs demonstrated throughout the country.

The HSPF model is comprehensive in its treatment of the watershed. Land surfaces are simulated as either pervious or impervious land segments, labeled as PERLNDs and IMPLNDs, respectively. The model is driven by input of precipitation data. Runoff in response to rainfall is generated on the surfaces of the PERLNDs and IMPLNDs. Pollutant mass is also generated on these land surfaces and is available to be washed off by the runoff. The runoff volume and the pollutant mass volume are transported to the nearest channel, referred to as a RCHRES. Segmentation of the receiving stream is constructed as a series of RCHRES segments, with each transporting flow and mass to the next downstream segment, in the same configuration as the real stream segments in the physical world.

5.2 MODEL SETUP

The Peach Creek watershed was subdivided into several subwatersheds to adequately represent the spatial variation in fecal coliform sources, watershed characteristics, hydrology, and the location of water quality monitoring and streamflow gaging stations.

BASINS provides standard 8-digit Hydrologic Unit Code (HUC) boundaries developed by the USGS. The Peach Creek watershed boundary exists within HUC #12100202. This watershed was segmented to delineate the hydrologically connected subwatershed boundaries. These subwatersheds were delineated by using 1:250,000-scale USGS quad sheets and the digital elevation model (DEM) provided with the BASINS program. The Peach Creek watershed was subdivided into 8 subwatersheds, including distinct subwatersheds for Big Five-Mile Creek, Denton Creek, and Sandy Fork, as shown in Figure 5-1. The spatial division of the watershed into subwatershed allows for a more refined representation of pollutant sources and a more realistic description of hydrologic factors in the watershed. A hydraulic reach, Reach 61, was also included in the model to represent the confluence of Denton and Peach Creeks. This reach has no associated subbasin area. A schematic of the model network developed in BASINS is shown in Figure 5-2.

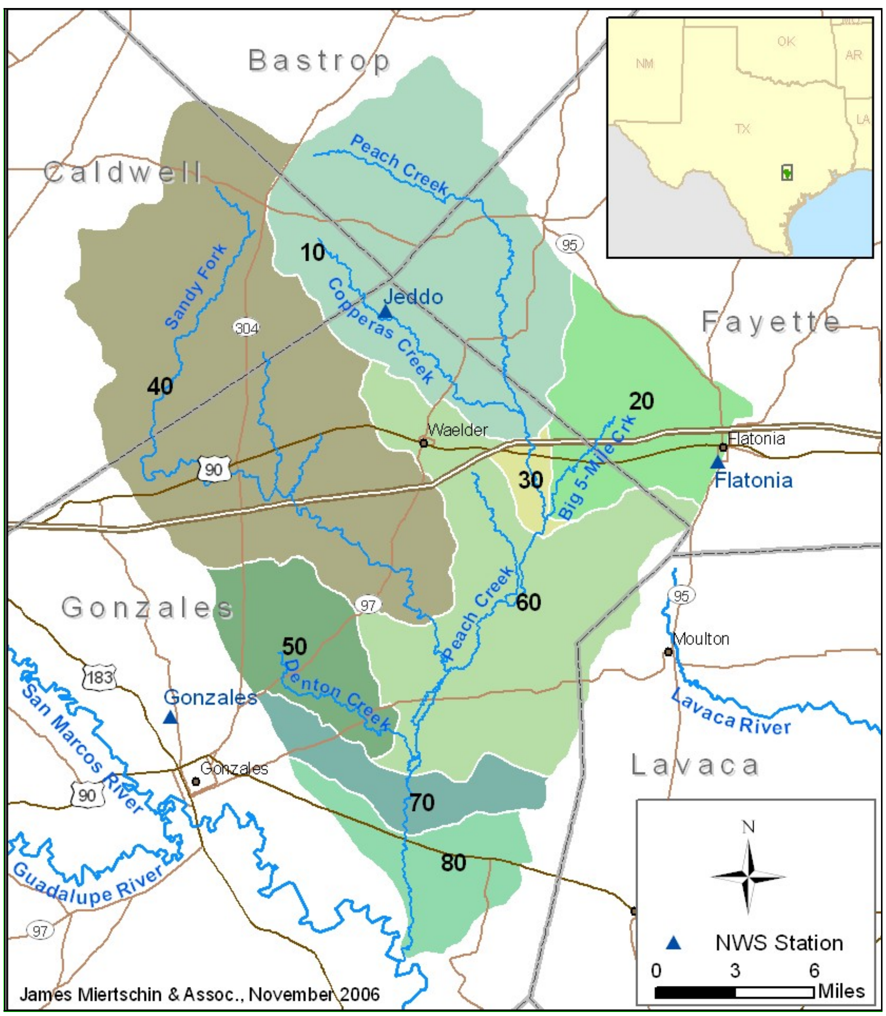

Figure 5-1 Peach Creek Subwatersheds and Rain Gages

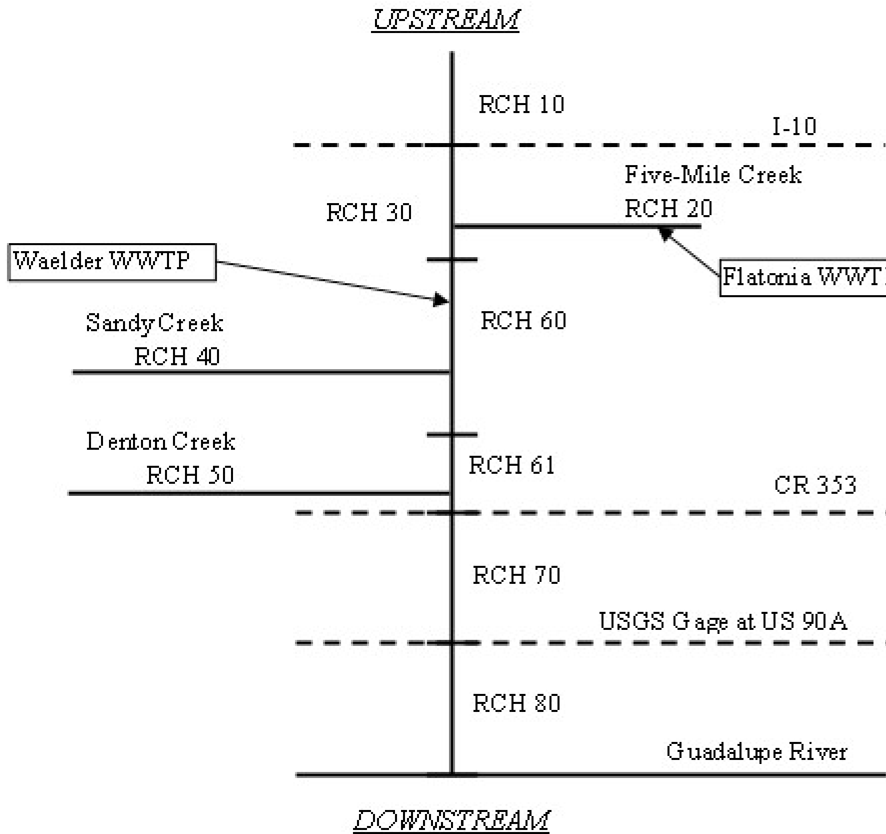

Figure 5-2 Schematic of Peach Creek

Land use in the watershed was based on the USGS National Land Cover Dataset (NLCD) found in BASINS. Derived from the early to mid-1990s Landsat Thematic Mapper satellite data, the National Land Cover Data (NLCD) is a land cover classification scheme applied consistently over the United States. The spatial resolution of the data is 30 meters. Table 5-1 shows land use coverages provided by NLCD and the consolidated land use list employed in the present study.

Multiple land use types were represented in the model. The five fundamental land use types included rangeland, forested land, crop/pastureland, residential land, and commercial/industrial land. Each land use type could have both PERLND and IMPLND segments. With each PERLND and IMPLND type were associated specific hydrologic and mass loading parameters. Some of the parameters were developed from site-specific data sources, while others were developed via the calibration of the model. An inventory of the various land use types and the area of each type within each subwatershed is displayed in Table 5-2 for the Peach Creek watershed.

Table 5-1 Land Use Coverages used in Model

Consolidated Land Uses	BASINS Land Uses
Residential	Low Intensity Residential
	High Intensity Residential
Commercial/Industrial	Commercial/Industrial/Transportation
	Quarries/Strip Mines/Gravel Pits
Rangeland	Bare Rock/Sand/Clay
	Deciduous Shrubland
	Grassland/Herbaceous
	Pasture/Hay
	Other Grasses (Urban/recreational)
	Emergent Herbaceous Wetlands
Forest	Deciduous Forest
	Evergreen Forest
	Mixed Forest
	Woody Wetlands
Crop	Planted/Cultivated (orchards, vineyards, groves)
	Row Crops
	Small Grains

Table 5-2 Various Land Use Types and Areas for the Peach Creek Watershed

Land Use Type	Area	% of Total
Forest	118,932	38.3%
Crop/Pastureland	4,739	1.5%
Rangeland	184,181	59.4%
Residential	554	0.2%
Comm/Ind/Trans	1,869	0.6%
Total	310,275	100%

5.3 SOURCE REPRESENTATION

Both point and nonpoint sources were represented in the model. Point sources were added to the model as time-series of pollutant (bacteria) and flow inputs to the stream. Land-based nonpoint sources were represented in the model through an accumulation of pollutant mass on the land surface, where some portion is available for washoff and transport with runoff. The amount of accumulation and availability for transport vary with land use type. The model allows for a maximum accumulation to be specified.

Some nonpoint sources, rather than being land-based, were represented in the model as being deposited directly to the receiving stream, for example defecation by animals directly to a stream. These sources were labeled as "direct sources" in the model, and they were modeled in a manner similar to point sources. As such, they do not require a runoff event for delivery to the stream.

5.3.1 Point Sources

Existing point sources were explicitly included in the model. In the Peach Creek watershed, these point sources consisted of two municipal wastewater treatment facilities. Discharge and fecal coliform sampling records for the Flatonia and Waelder outfalls during the simulation period were obtained from the TCEQ and the municipalities. Based on the available records, a time series for daily discharge flow and fecal coliform concentration was synthesized for each municipal point source. For the Flatonia and Waelder wastewater treatment plants, the median effluent concentrations, based on the synthesized time series, were found to be 10 and 63 org/100mL, respectively.

5.3.2 Failing Septic Systems

The total number of septic systems in the watershed was estimated from available US Census data. A nominal assumed failure rate of 12% was applied, as discussed in Section 4.2.1. For this analysis, only the potential direct discharges from failing septic systems were considered in the model. Fecal coliform loadings were calculated based upon the fecal density of septic effluent and the flow from a household assuming a population of 2.7 persons per household.

The approach represents a method to incorporate explicitly bacteria loadings from failing septic systems into the modeling analysis. The precise number of actual failures and their loadings within the study area is unknown, and no data base is available to accurately quantify this mechanism. Instead, the present approach provided an input to the model, which could be adjusted via the calibration process, to account for some measure of loadings from this particular potential source of bacteria.

5.3.3 Livestock

Fecal coliform bacteria produced by livestock can enter surface waters through several pathways: washoff of waste deposited on the land surface, washoff of concentrated waste from land application sites, direct deposition of waste material in the stream, and potential discharges from animal confinement areas or waste handling systems. Each of these pathways can be accounted for in the model. The population of each livestock species considered in the modeling analysis was distributed among subwatersheds based upon the total area of forest and rangeland in each subwatershed. This livestock inventory was shown in Table 4-3.

Grazing animals contribute fecal coliform bacteria to the land surface that is subsequently available for washoff to surface waters during storm events. The inventory of livestock animals and their waste loadings was analyzed using a modification of the EPA's Bacterial Indicator Tool (EPA, 2000). This spreadsheet tool includes the necessary specifications of waste generation, fecal coliform density, and bacteria counts per animal unit for calculation of loads. It enables calculation of loading parameters that can be applied as initial estimates in the modeling analysis, specifically, fecal coliform accumulation rates (in count/acre/day) and the maximum accumulation (in count/acre).

Chicken populations for each subwatershed were estimated from data provided by the TCEQ and Gonzales County Soil and Water Conservation District. The populations were assigned to one of two land use categories in the model, namely, WAF1 and WAF2. WAF1 represents land surfaces that receive litter applications. WAF2 represents land surfaces that receive sprinkler waste application.

Direct contributions from livestock were also included as inputs in the modeling analysis. It was assumed that grazing cattle and horses spent a small fraction of their time directly in the stream and therefore the potential exists for direct deposition. Other livestock, sheep/goats and hogs, were assumed to deposit all feces on pasture and forested areas. The potential direct contribution was estimated for each subwatershed using the parameters contained in the Bacterial Indicator Tool spreadsheet. Results from this analysis were provided in terms of direct bacteria loadings (in counts/day) per stream segment. The analysis also enables calculation of the associated flow rate from these direct animal contributions, but this flow rate was not included in the hydrologic balance of the present analysis because of its extremely small size.

5.3.4 Wildlife

Wildlife species explicitly included for initial estimates of bacteria loading in the modeling analysis included deer, raccoons, opossums, feral hogs, and ducks/geese. The population of each wildlife species was developed using estimated population densities per square mile of habitat and the total area of suitable habitat available in each subwatershed. This wildlife inventory was shown in Table 4-6. As with livestock, there are two mechanisms considered for bacteria loadings from wildlife to be transported to the stream segment. First, wildlife deposit waste on land surfaces that accumulates and is subsequently available for washoff with runoff. Second, wildlife may deposit waste directly into the stream.

Wildlife loadings were calculated within the framework of the modified EPA Bacterial Indicator Tool (EPA, 2000), in a manner analogous to that applied for livestock. For specification of the number of animals that may be engaged in direct deposition to the stream, the area of a riparian habitat corridor approximately 300 feet in width was calculated, and the prescribed animal density was applied to this riparian area in order to provide an initial estimate of the near-stream populations. Then, a small fraction of this population was assumed to directly deposit waste in the stream. A seasonal component for the frequency of wildlife visitation to the stream was developed as a function of mean ambient water temperature, with the assumption that water visitation would be more likely under warm-weather conditions.

5.3.5 Urban Loadings

Some of the study area is comprised of the urban landscape of residential, commercial, and industrial areas. While the initial estimates of bacteria mass loadings for non-urban land use areas were developed based upon an inventory of septic systems, livestock, and wildlife, the myriad of sources in the urban areas were represented by typical loading rates from literature sources (EPA, 2000). These loading rates provided an initial estimate, and the final specification of loading parameters was derived via calibration exercises. These generalized urban loading rates thus represent bacteria loadings that may be derived from urban wildlife, pets, septic system failures, sewer system leaks, discharges of varied nature and composition, and any other sources that may be present.

5.3.6 Incorporation of Sources in the Model

The preceding representations of bacteria sources were incorporated in various ways into the modeling framework. There were five fundamental categories of loads in the analysis:

- Point source loads
- Septic loads
- Direct source loads
- Land-based washoff loads

Point Source Loads

The category of point source loads is represented in the model in a straightforward manner. A time series of daily flow and bacteria for each point source was developed and these sources are then input directly into the specific RCHRES where each is situated. The bacteria loading time series is provided in units of org/day, and is input into the model in units of 10^6 org/hr. This source is a continuously discharging source of bacteria that occurs on a daily basis. As described previously, the point source component consists of a routine daily discharge load along with a synthesized overflow load. The routine point source load occurs daily with no association with rainfall runoff, therefore it is a source of bacteria under all stream flow conditions. Conversely, the overflow point source load occurs sporadically under conditions of high rainfall only.

Septic Loads

The category of septic loads is represented in the model as a continuous daily discharge of bacteria in each reach, similar to the point source mechanism. Because the flow contribution is negligibly small, only the bacteria contribution is represented in a time series. The septic loading time series is provided in units of org/day. The septic load category discharges with no association with rainfall runoff events, therefore it is a source of bacteria under all stream flow conditions.

Direct Source Loads

The direct source category captures bacteria loadings that are discharged to the stream on a continuous basis, with no association with rainfall runoff. The loading time series was provided in units of org/day. A time series for direct source bacteria discharge was developed for each reach, based upon assumptions described previously for direct wildlife and livestock deposition to the stream. Because the flow contribution is negligibly small, only the bacteria contribution was represented in a time series. These time series values were applied as initial estimates only, and factors were applied to adjust the direct source values up or down in the calibration process. The direct source category was the primary source variable that was adjusted in the model calibration process to achieve an acceptable water quality calibration under baseflow conditions in the receiving stream. With this procedure, the initial estimates based upon presumed animal populations were not critical to the analysis. Even though the initial estimates were developed based upon presumed direct animal defecation, this category of direct source loads would also capture any other continuous daily releases of bacteria that may be occurring in the stream but that are difficult to quantify. For example, in some locations, leaking sewer mains could contribute a steady source of bacteria to the stream that would constitute a direct source component.

Land-Based Washoff Loads

The land-based washoff loads are expected to be the source of the largest quantity of bacteria. As the category name implies, these loads represent bacteria that are deposited on the land surface and are subsequently washed off the land surface to the receiving stream under conditions of rainfall runoff. As such, loads from this category exert an influence on instream bacteria concentrations primarily under runoff and high flow conditions, and they would not be expected to be a substantial contributor to instream bacteria on a daily basis.

The land-based washoff loads are formulated as loading rates of bacteria to the land surface on a daily basis, along with a limit on the total amount of bacteria that can be stored on the land surface at any point in time. Initial estimates (starting values) for these loading rates were developed based upon assumptions related to wildlife and livestock populations that were described previously. However, these loading rates were ultimately set based upon adjustments during the model calibration process. Therefore, the initial assumptions regarding animal populations were not critical to the process, serving only to establish a hypothetical loading rate based upon assumed population numbers.

5.4 STREAM CHARACTERISTICS

Application of the HSPF model requires that stream reaches be represented by constant characteristics that relate flow rate, surface area, depth, and volume. Each reach also is described by a unique length, slope, and Manning's "n" coefficient for resistance to flow. The length and slope were obtained from digital elevation records based upon 7.5 minute USGS topographic maps, as well as from observations from paper copies of the same maps. Manning's *n* was estimated based upon literature values.

The hydraulic function tables (F-tables) used in HSPF describe the relationship among flow rate, surface area, depth, and volume in each stream reach. The flow and geometry relationships were developed based upon available physical data from USGS streamflow gaging records. These records were analyzed to develop a typical cross section and relationships at the gaging station location, then the data were extrapolated upstream and downstream to provide coverage of the entire reach. This extrapolation was based on the overall slope of the stream channel in each subwatershed, but the F-tables were modified on a reach-by-reach basis in recognition of other available data, such as field measurements of cross sections and observations of channel characteristics.

5.5 SELECTION OF REPRESENTATIVE MODELING PERIOD

The selection of a representative modeling period was based upon the availability of stream flow and water quality data and the need to represent critical hydrological conditions. With respect to streamflow data, records for Peach Creek were available from October 2000 to the present. The most comprehensive time period for reported fecal coliform concentrations consists of the period from 1996 to the present. Some data are available prior to that time, however, it was assumed that the more recent data would be more representative of current water quality conditions. Since flow data was the limiting factor, the period selected for hydrologic calibration encompassed the years 2001 through 2004. Application of a five-year hydrologic calibration period is generally recommended for application of the HSPF model, but in the present case with the lack of streamflow data, a four-year calibration period is the best option. This modeling period has good availability of streamflow data, and it incorporates numerous wet, dry, and average flow conditions that typically occur in the study area.

A separate validation period for model hydrologic response was not examined due to the limited availability of streamflow data at the USGS gage at US 90A. For the same reason, a separate validation period for the model water quality response was not examined.

5.6 MODEL CALIBRATION PROCESS

In order to develop a representative linkage between the sources and the instream water quality response in the Peach Creek watershed, model parameters were adjusted to accurately represent hydrology and streamflow as well as fecal coliform bacteria loading and instream concentrations. Hydrologic parameters in the model were set and adjusted based upon available soils, land use, and topographic data. Bacteria loading parameters in the model were based upon the linkages with the various explicit and implicit sources described previously.

5.6.1 Hydrologic Calibration

Hydrologic calibration entails adjustment of pertinent model parameters in order to achieve agreement between simulated streamflow rates and observed streamflow rates. Ideally, a stream to be modeled will have one or more continuous streamflow gaging stations with long-term records available. These records would supply the data base of observed flows for a specific location within the stream segment.

There were several model parameters that were adjusted to achieve hydrologic calibration. Key parameters included the following:

LZETP - evapotranspiration from the root zone
AGWRC - recession rate for groundwater
IRC - recession rate for interflow
LSUR - length of overland flow plane
UZSN - soil moisture storage in the upper zone
LZSN - soil moisture storage in the lower zone
CEPSC - interception storage on pervious surfaces
INFILT - infiltration capacity of the soil
INTFW - soil water contributing to interflow
DEEPFRC - loss to lower groundwater storage
RETSC - interception storage on impervious surfaces

For Peach Creek, continuous streamflow records are available at the USGS monitoring station no. 08174600, located at US 90A, near the terminus of the stream study segment. Mean daily streamflow records for this station were obtained for application to the modeling analysis.

The hydrologic calibration for Peach Creek focused upon quantitative comparison between simulated streamflow and observed streamflow at the location of the US 90A USGS gaging station. In the Peach Creek model, this location corresponds to RCHRES 70. For the present analysis, the calibration period encompassed the years 2001 through 2004, with the year 2000 included as a ramp-up period. Results for the entire calibration period are displayed in Figure 5-3. This figure shows simulated flow and observed flow as a function of time.

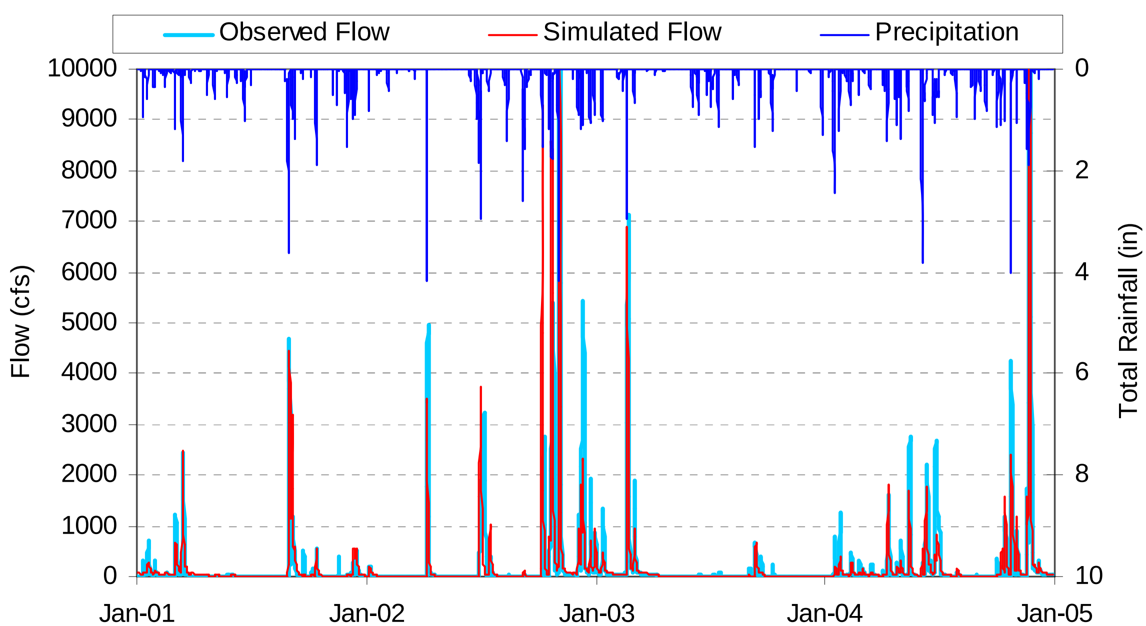

Figure 5-3 Hydrologic Calibration for Peach Crk at US 90A, 2001-2004

To provide some additional visual resolution, results are also presented for each individual simulation year in Figures 5-4 through 5-7. Precipitation records for the gage at Gonzales (see Figure 5-1) are also shown in these figures.

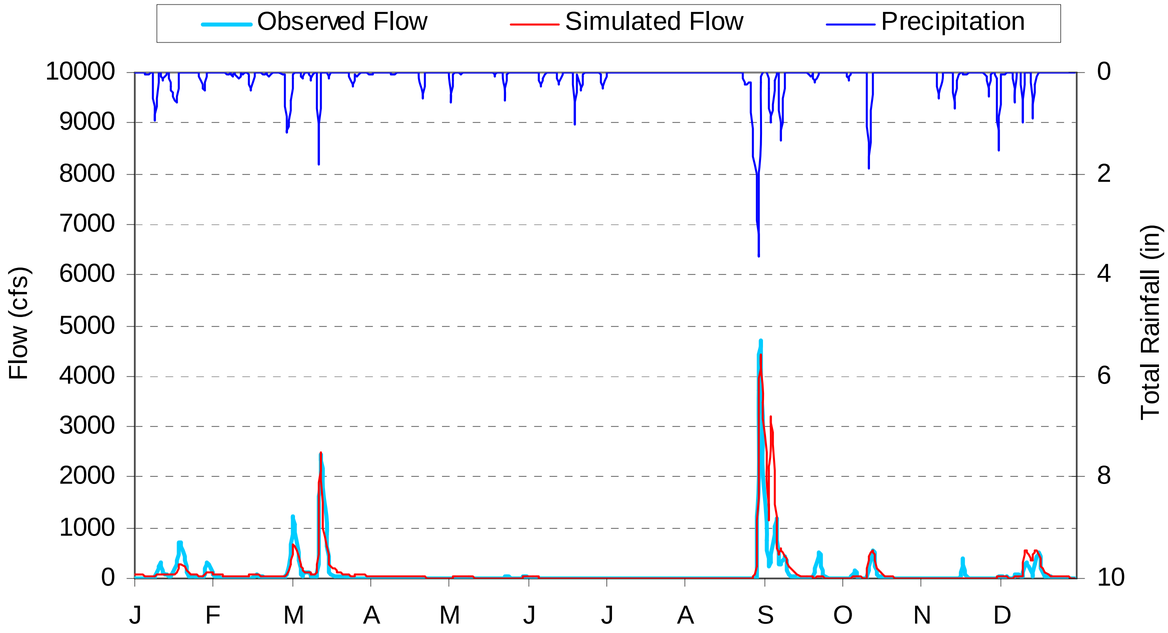

Figure 5-4 Hydrologic Calibration for Peach Crk at US 90A, 2001

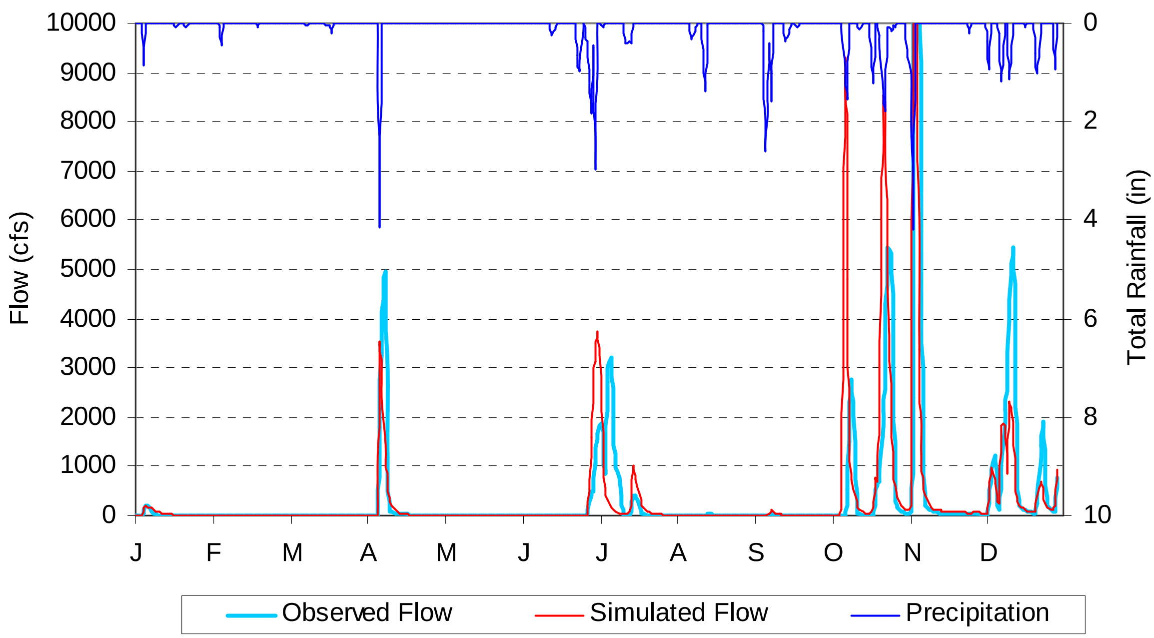

Figure 5-5 Hydrologic Calibration for Peach Crk at US 90A, 2002

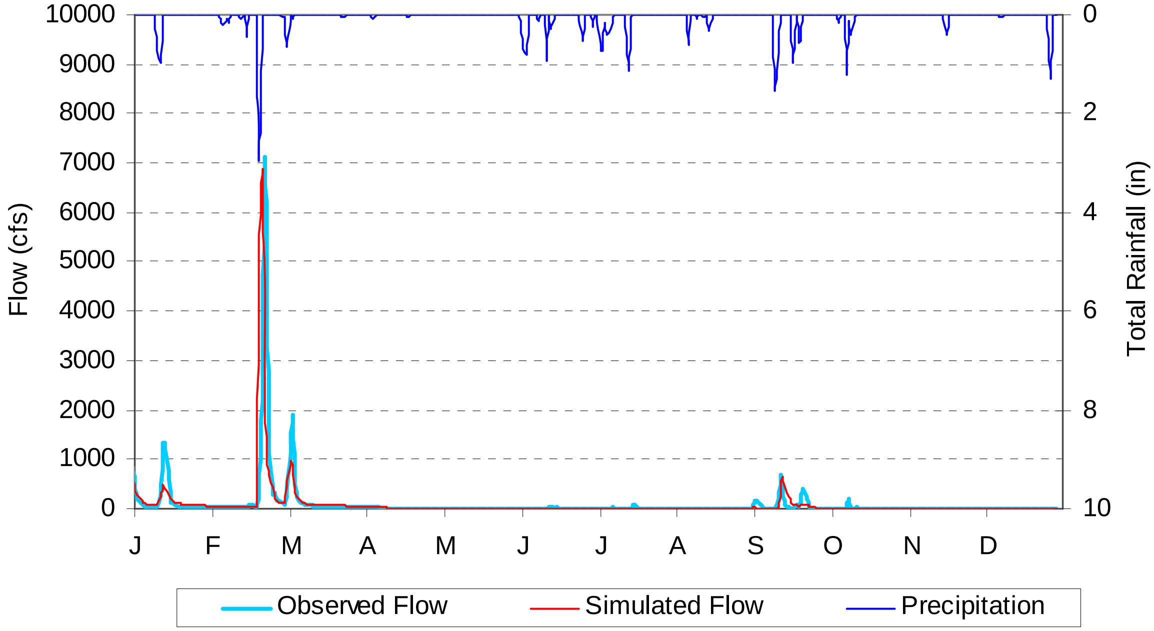

Figure 5-6 Hydrologic Calibration for Peach Crk at US 90A, 2003

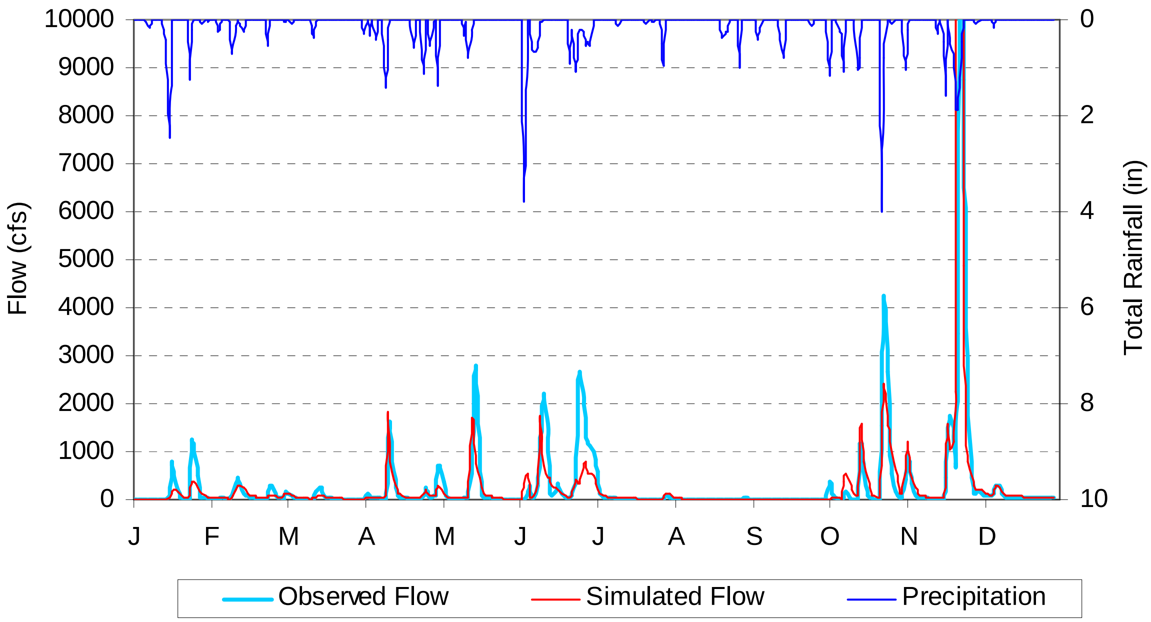

Figure 5-7 Hydrologic Calibration for Peach Crk at US 90A, 2004

Calibration statistics are summarized in Table 5-3 for Peach Creek. The statistics demonstrate that errors are generally below 20%, which indicates that the hydrologic calibration has been successfully achieved. A flow duration curve for Peach Creek is shown in Figure 5-8. A comparison of the observed and simulated average monthly runoff is presented in Figure 5-9.

Table 5-3 Hydrologic Calibration Statistics for Peach Crk at US 90A, 2001-2004

Annual Averages	Simulated	Observed	Error
Total flow (in/yr)	6.80	6.39	6%
Highest 10% of flows (in/yr)	5.72	5.65	1%
Storm flow (in/yr)	4.46	3.93	13%
Storm peaks (cfs)	8,316	7,107	17%
Summer flow (in/yr)	1.23	1.28	-4%
Winter flow (in/yr)	3.45	3.3	5%
Summer storm flow (in/yr)	0.62	0.61	2%
Winter storm flow (in/yr)	2.70	2.52	7%

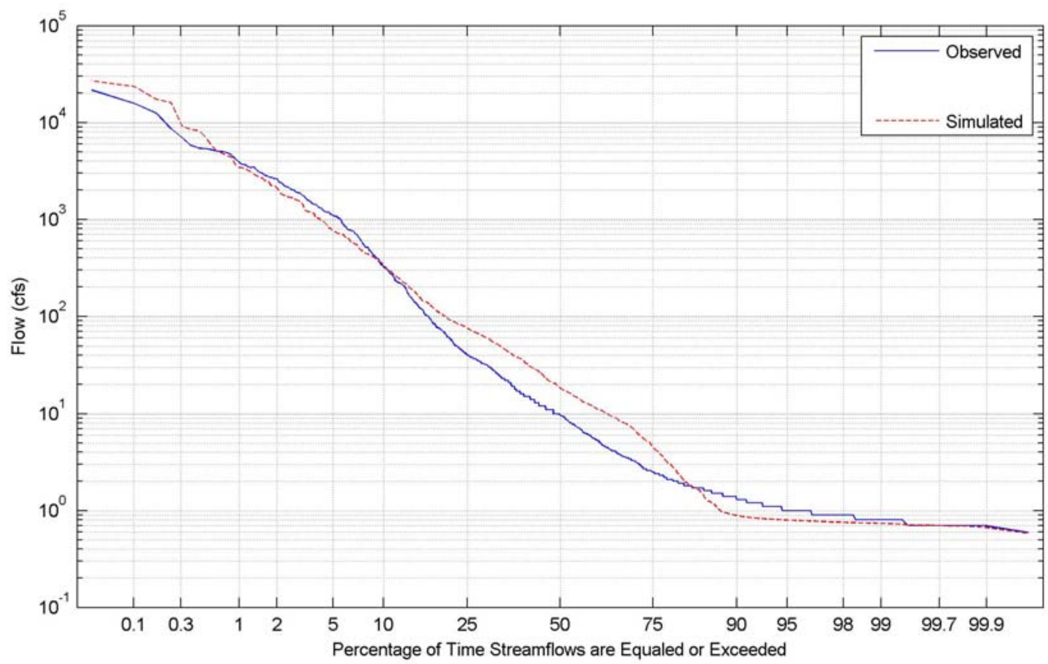

Figure 5-8 Flow Duration plot for Peach Crk at US 90A, 2001-2004

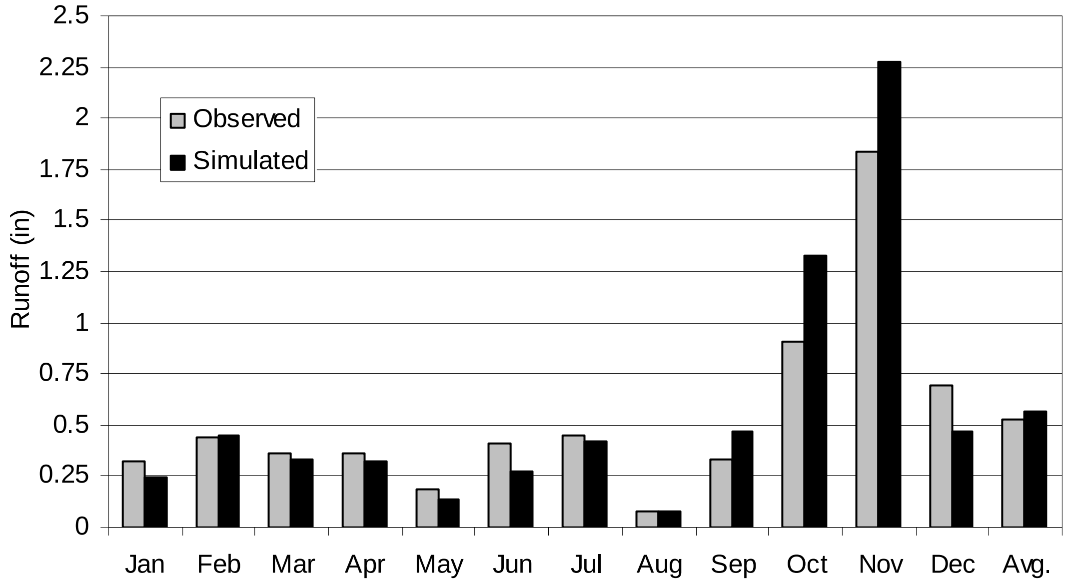

Figure 5-9 Average Monthly Runoff for Peach Crk at US 90A, 2001-2004

5.6.2 Water Quality Calibration

Compared to the hydrologic calibration, water quality calibration is considerably more challenging. For hydrologic calibration, ample observed data is often available for the stream segment, typically consisting of continuous records of mean daily streamflow. By contrast, water quality calibration usually has to proceed with limited sets of observed data, and the data that is available typically consists of sporadically collected grab samples that each represent a single point in time.

For the present evaluation, the available water quality data set is limited. There is only a single water quality monitoring station with substantial available fecal coliform data on Peach Creek, so the spatial extent of data is limited. The frequency of data collection at the main water quality site, Station No. 14937 at CR 353, has historically been steady. And as is the case with almost all bacteria data bases, the available fecal coliform data set consists of grab samples that provide an instantaneous measurement of instream concentration, rather than a daily mean or an event mean concentration. Fecal coliform measurements exhibit a high degree of variability and an acceptable laboratory precision test may encompass as much as 1-log of variability (ten times greater to one-tenth of actual value). Despite these potential difficulties, the available bacteria data set for the study area is sufficient to accomplish the study objectives and it is comparable to data sets that have been successfully employed in other TMDL determinations.

The water quality calibration for Peach Creek was conducted using available fecal coliform data for the period 2001 - 2004. Most of the available data originated from routine agency monitoring programs. Additional monitoring of bacteria concentrations was conducted in 2003 and 2004 in conjunction with the present study. The available data sets were examined closely for input to the model calibration process. This available water quality data base represents the site-specific data that is available for calibration of the model. Many of the bacterial loading parameters and variables in the modeling analysis are based upon assumptions and best professional judgment, but the measured values of fecal coliform bacteria concentrations within Peach Creek provide the test for the validity of the multiple assumptions.

The population of available fecal coliform measurements was analyzed to provide information that might establish approximate calibration targets for the stream. At any one monitoring station, the available data set typically consists of a set of grab samples that were collected under a range of streamflow conditions and that exhibit a substantial range of values. There is no significant mathematical relationship between streamflow rate and concentration. However, intuition would suggest and observations do indicate that there is some correspondence of higher bacteria concentrations with elevated streamflow rates. This correspondence was analyzed for the bacteria data set at the key monitoring station. Attendant streamflow and antecedent streamflow was analyzed for individual data points and each point was classified as either baseflow or runoff related. Statistical analysis of the baseflow and runoff data sets was conducted to define median values, 90^{th} percentile values, and 10^{th} percentile values for each population. While these statistics on the limited historical data base provided guidance, the primary calibration benchmark was the achievement of a reasonable visual conformance between simulated and observed fecal coliform values.

Calibration of the Peach Creek model entailed adjustment of bacteria-related parameters to achieve agreement of the simulated model results with observed fecal coliform measurements. Several parameters were available for adjustment in the model. To achieve calibration under baseflow conditions, adjustment was made to parameters that represent continuous discharges and are not dependent upon transport via runoff mechanisms. For the present analysis, the primary parameter that was adjusted was the magnitude of loading derived from the category of direct sources. The direct sources category nominally includes contributions of fecal coliform from direct deposition from wildlife or livestock, but this type of continuous source could also include contributions of fecal coliform from failing septic systems and leaking wastewater collection system infrastructure. This direct source category could also represent other mechanisms that are difficult to quantify explicitly, including resuspension of bacteria associated with sediment and illicit discharges.

Calibration under runoff conditions was achieved through adjustment of parameters that relate to washoff of bacteria from land surfaces. The accumulation rate of bacteria on land surfaces (ACQOP) and the maximum accumulation (SQOLIM) were adjusted to render either more or less bacterial mass available for washoff. These bacterial accumulation rates represent the contributions from wildlife, livestock, and general urban loadings to the land surfaces in the watershed. The rate of surface runoff that will remove 90% of stored fecal coliform (WSQOP) was adjusted, which effects the proclivity for washoff to occur.

The final values for ACQOP and SQOLIM established in the calibration are shown in Table 5-4. Uniform values of ACQOP and SQOLIM were applied to all of the land use categories in the subwatersheds in the present study.

Table 5-4 ACQOP and SQOLIM Loading Rates

Description	ACQOP (10^6 counts/ac/d)	SQOLIM (10^6 counts/ac)
Forest	600	4,200
Cropland	300	2,100
Rangeland	600	4,200
Residential Pervious	5,000	35,000
Comm/Ind Pervious	3,000	21,000
Res. Impervious	2,500	17,500
Comm/Ind Impervious	1,500	10,500
WAF1	820 - 8,170	5,740 - 57,190
WAF2	1,530 - 1,920	10,710 - 13,440

Figure 5-10 shows the results of the calibration as simulated fecal coliform at CR 353. The simulated results display good visual agreement with the available fecal coliform data. Note that the simulated fecal coliform values are mean daily concentrations, while plotted observed concentrations are instantaneous grab measurements. It would be unrealistic to expect simulated mean daily fecal coliform concentrations to match precisely observed grab sample concentrations. The degree of correspondence between simulated and observed values is similar to standards of performance exhibited in other TMDL determinations for bacteria. Comparison of baseflow and runoff population median concentrations for simulated results versus observations is summarized in Table 5-5. The calibration results shown in Table 5-5 indicate that the modeled concentrations correspond reasonably well to the observed fecal coliform values.

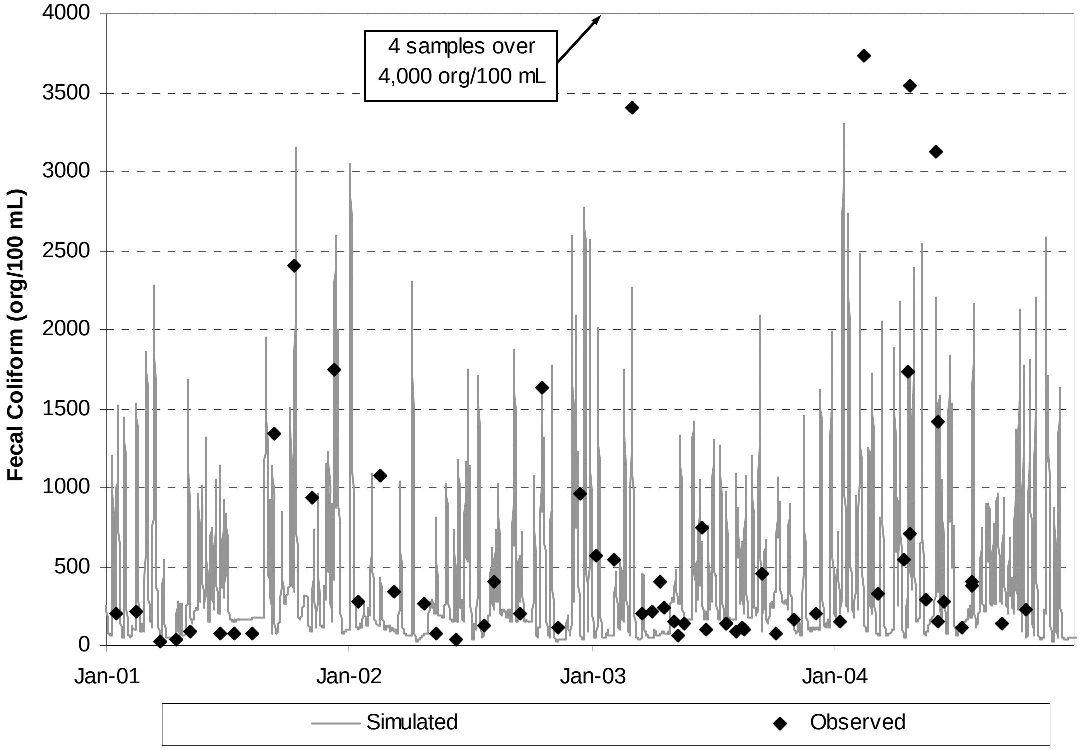

Figure 5-10 Water Quality Calibration for Peach Creek at CR 353, 2001-2004

Table 5-5 Comparison of Observed and Simulated Fecal Coliform Concentrations

Flow Condition	Concentrations (org/100mL)			
	Observed			Simulated
	10th Percentile	Median	90th Percentile	Median
Baseflow	72	157	474	155
Runoff	439	1682	8544	785

One additional check of the reasonableness of the water quality calibration was performed. A specific reach was selected and the model simulated bacterial loads emanating from each land use category were inventoried. These loads were then applied to the annual runoff volume emanating from each land use category in order to calculate an average annual runoff concentration. Reach 20 was selected for this analysis in the present study. The typical annual average runoff fecal coliform concentrations that were simulated in the modeling analysis for Reach 20 are displayed in Table 5-6. These simulated concentrations appear reasonable based upon best professional judgment. To obtain an additional perspective, the simulated values can be compared to ranges of typical concentrations reported in the literature, as shown in Table 5-7. It is apparent for this comparison that the fecal coliform concentrations simulated in the model are within the range of values reported from other studies.

Table 5-6 Typical Fecal Coliform Washoff Concentrations in Model (Reach 20)

Land Use	Concentration (org/100 mL)
Forest	2,192
Cropland	1,124
Rangeland	2,189
Residential	18,201
Comm/Ind	10,924
WAF1	2,989
WAF2	5,564
Residential Imp.	8,809
Comm/Ind Imp.	5,222

Table 5-7 Typical Fecal Coliform Washoff Concentrations in Other Studies

Land Use	Concentration (org/100 mL)
Forest	200 - 50,000
Cropland	200 - 10,000
Rangeland	200 - 50,000
Residential	5,000 - 50,000
Comm/Ind	5,000 - 50,000
WAF1	10,000 - 100,000
WAF2	10,000 - 100,000
Residential Imp.	5,000 - 50,000
Comm/Ind Imp.	5,000 - 50,000

The typical bacteria concentration ranges reported in Table 5-7 were derived from a variety of sources. The concentrations characteristic of urban land uses were based largely upon available bacteria data collected in two Texas cities, Austin and San Antonio, along with national-level data (Glick, 2005; Miller, 2005; EPA, 1986). Bacteria data for agricultural related land uses were derived from numerous available reports and studies from across the country that investigated bacteria concentrations in runoff from specific land use types (see for example, Baxter-Potter and Gilliland, 1988; Buckhouse and Gifford, 1976; Doran and Linn, 1979; Drapcho and Hubbs, 2003; Edwards, et al, 2000; Edwards, et al, 1997; Inamdar, et al, 2002; Kress and Gifford, 1984; Mau and Pope, 1999; Moore, et al, 1989; Ockerman, 2002; Robbins, et al, 1972; Selvakumar and Borst, 2004; Smith and Douglas, 1973; Thelin and Gifford, 1983; Weidner, et al, 1969). Most of these studies examined bacteria runoff from grazed pastures and agricultural operations and the effects of factors such as loading rate, time, rainfall intensity, and distance. Though these various agricultural studies were located at various places throughout the country, it is expected that bacteria transport and processes resident within the Peach Creek watershed would be generally similar.

In many water quality modeling studies, calibration exercises are followed by a validation exercise, which typically entails exercise of the calibrated model and comparison to an independent set of observed measurements. This type of exercise is particularly valuable when two distinct set of observed conditions are present, for example, when simulating a dissolved oxygen sag below a wastewater discharge under first warm-weather, then cold-weather conditions, or under two distinctly different streamflow regimes. For the present analysis of bacteria concentrations, there does not exist a distinct set of observed data that reflect conditions that are not already embodied within the calibration data set. It was more important to apply the complete contemporary available bacteria data set to the calibration exercise, in order to have the greatest confidence in the calibration results.

The bacterial loads associated with the model calibration can be readily examined in terms of load originating from the land use categories and point sources embodied in the analysis. The simulated annual average loads entering Peach Creek and its tributaries are compared graphically in Figure 5-11 and are tabulated in the subsequent Table 6-1. The loads shown are the total loads that enter the stream, and do not account for decay that occurs as the bacteria travel downstream.

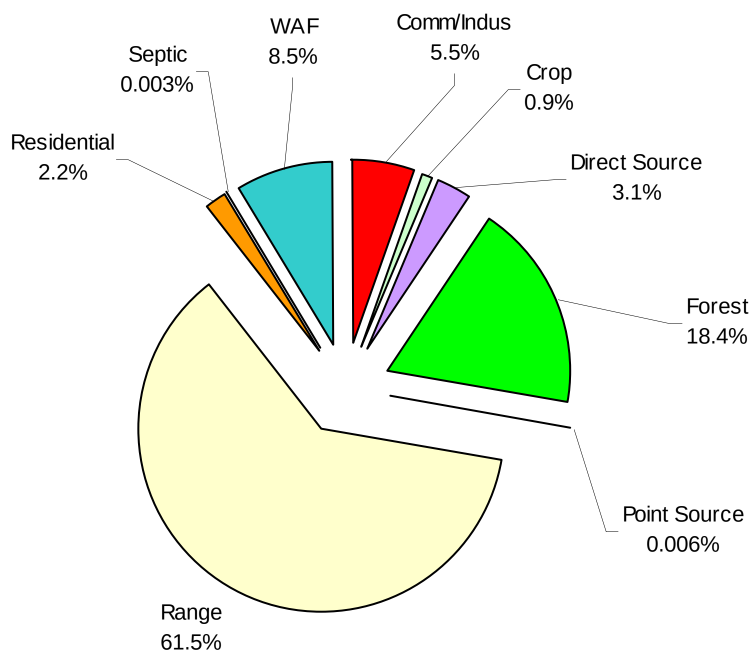

Figure 5-11 Comparison of Fecal Coliform Sources for Peach Creek

For the study reach, it is apparent that the largest presumed source of fecal coliform bacteria is rangeland. This is attributable to the fact that rangeland is the largest land use category in terms of acreage, and it is the recipient of bacterial deposition from wildlife and livestock. The next largest contribution is estimated to be forest, and the third largest source is shown to be the category of waste application fields. The urban areas and WAFs have relatively small acreages but their assumed loading parameters are relatively large. Loads from point sources and septic systems are not zero, but are small enough to be negligible in this comparison.

Now that the calibration of the water quality model is complete, it may be instructive to put in perspective some of the initial assumptions. Preceding sections described the development of initial estimates of livestock and wildlife populations by subwatershed. This was followed by calculation of the potential fecal coliform contributions from each source based upon application of literature values for mass of fecal material and bacterial density. These source representations were employed to develop initial values of ACQOP and SQOLIM for input into the modeling analysis. These initial values should be considered to represent the potential loading parameter values that are based upon numerous assumptions. The initial values of ACQOP and SQOLIM underwent substantial adjustment during the process of model calibration. Typically, the initial values to establish loading parameters were reduced substantially to achieve model calibration. The exception to this trend was the adjustment of urban land use contributions. These areal loading rates were increased substantially in the calibration process. So, this discussion should illustrate that the model calibration is not directly related to the initial assumptions on animal counts. Even if the initial counts were substantially revised, it would not necessarily affect the ultimate calibration of the model.

6.0 TMDL METHODOLOGY

6.1 TMDL CALCULATION

Total maximum daily loads (TMDLs) are the sum of the individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background conditions, and a margin of safety (MOS). The TMDL equation is written as follows:

TMDL = WLA + LA + MOS

The TMDL defines the total amount of a pollutant that can be assimilated by the receiving waterbody while still achieving water quality standards. For fecal coliform bacteria, TMDLs are expressed in terms of bacteria counts or resulting concentration. The WLA portion of this equation is the total loading assigned to traditional point sources, such as domestic wastewater treatment plants. The LA portion of this equation represents the loading assigned to nonpoint sources, which would include washoff from land surfaces, direct deposition from animals, and leaking septic systems or collection system mains. The MOS is the portion of the loading that is assigned to represent any uncertainty in the data and the modeling process.

The TMDL target was established as a fecal coliform geometric mean value of 200 org/100 mL, based on the bacteria criteria specified in the Texas Water Quality Standards. An explicit MOS of 5 percent was employed in the TMDL calculations. This 5 percent MOS amounts to 10 org/100 mL, referencing the geometric mean criterion. Application of the model to the TMDL determination then was based on achievement of compliance with an instream geometric mean of 190 org/100 mL. In addition to the explicit MOS, implicit MOS factors were also incorporated into the TMDL development process through the use of conservative model assumptions.

The HSPF model was developed for the study area and was employed to simulate instream bacterial counts for the period 2001 through 2004. For TMDL determinations, the model was applied to simulate various allocation scenarios that could result in partial attainment or full attainment of water quality standards.

6.2 CRITICAL CONDITIONS

The HSPF model is a continuous simulation model that has been successfully applied to bacteria TMDLs throughout the country. For the present analysis, simulations were conducted for the period 2001 - 2004. The water quality model accounts for seasonal affects by including temporal variations in climatic patterns, groundwater releases, water temperature, and loading rates for some of the bacteria sources. Climatic variations have the greatest influence on bacteria levels in the streams, with periods of chronic wet weather typically resulting in the highest average bacteria concentrations. Through simulation of this multi-year period, a wide range of potential hydrologic conditions are explicitly considered in development of the TMDL.

6.3 SEASONALITY

As discussed in the previous section, seasonal variation was explicitly included in the modeling approach for TMDL determination. Application of the continuous simulation model over a multi-year period ensured that all potential seasonal effects were considered.

6.4 FUTURE GROWTH

In many cases, future growth can conceivably impact TMDL allocation scenarios if associated with increased point source loads or increased nonpoint source loads. Point source loads can change if existing point sources are expanded, for example, a municipal wastewater treatment plant is expanded to handle increased wastewater flows. Point source loads can also change from addition of new point sources, such as new wastewater treatment plants. In the present analysis, future growth in point sources is not expected to have a deleterious effect upon bacterial concentrations because of the assumption that disinfection will be required prior to discharge and the resulting loads will be too small to be significant.

Future growth can also conceivably affect nonpoint sources as land use coverages change in the watersheds. For example, forest land may be converted to residential land. Such changes are expected to be minimal in the present study area, due to the largely rural character of the watershed. The watershed is expected to retain its rural characteristic for a long term planning period.

6.5 REQUIRED LOADING REDUCTIONS

The existing average annual bacterial loads entering Peach Creek and its tributaries were estimated based on the calibrated model results, and are displayed in Table 6-1. Loads, presented as organisms per year, are tabulated for each source category and for each stream reach. The loads shown are the total loads that enter the stream, and do not account for decay that occurs as the bacteria travel downstream.

Several scenarios for best management practices (BMP) application were examined in order to assess options for loading allocation scenarios for the watershed. The scenarios constitute different percent removals applied as BMPs to the bacteria loads that emanate from the watershed and contribute to Peach Creek. In the model, this was accomplished for washoff-based loadings by application of a module that allows specification of a percent of load removal by land use category. Other direct sources of loadings were adjusted in the model with appropriate multipliers to effect reductions. The percent removals are in terms of the load that emanates from the source and that subsequently reaches the stream. Three scenarios were selected for presentation in this report. The BMP-A and BMP-B scenarios represent 50% and 30% reductions, respectively, applied to washoff sources, direct NPS, and point sources. The BMP-C scenario is the same as the BMP-A scenario, except that no reductions are required for point sources. Table 6-2 summarizes the frequency of criteria exceedance under these scenarios.

Table 6-1 Existing Fecal Coliform Loads for Peach Creek

Indirect (Washoff) Sources (org/yr)							
Subbasin	Comm/ Indust	Crop	Forest	Range	Resi- dential	WAF	Total
10	4.6E+12	1.0E+13	2.1E+14	4.7E+14	3.3E+12	1.2E+13	7.2E+14
20	5.2E+13	1.2E+12	7.0E+13	2.6E+14	4.0E+13	1.4E+13	4.4E+14
30	9.5E+12	5.1E+11	8.5E+12	3.9E+13	-	-	5.7E+13
40	7.8E+13	1.3E+13	2.7E+14	8.1E+14	3.2E+10	1.3E+14	1.3E+15
50	2.1E+13	2.9E+12	2.2E+13	1.6E+14	-	7.8E+13	2.8E+14
60	3.8E+13	3.6E+12	1.5E+14	5.8E+14	4.7E+13	1.9E+13	8.4E+14
61	-	-	-	-	-	-	0.0E+00
70	1.0E+13	1.6E+12	1.6E+13	1.1E+14	-	-	1.4E+14
80	1.8E+13	3.2E+12	1.5E+13	1.3E+14	-	9.6E+13	2.6E+14
Total	2.3E+14	3.6E+13	7.7E+14	2.6E+15	9.0E+13	3.5E+14	4.0E+15

Direct Discharge Sources (org/yr)				
Subbasin	Direct NPS	Point Source	Septic	Total
10	8.9E+12	-	1.9E+10	8.9E+12
20	2.5E+13	1.9E+11	1.4E+10	2.5E+13
30	9.8E+12	-	2.5E+09	9.8E+12
40	1.9E+13	-	3.6E+10	1.9E+13
50	7.6E+12	-	1.8E+10	7.6E+12
60	3.9E+13	5.9E+10	1.5E+10	3.9E+13
61	1.8E+12	-	7.0E+08	1.8E+12
70	5.5E+12	-	3.1E+09	5.5E+12
80	1.1E+13	-	7.1E+09	1.1E+13
Total	1.3E+14	2.5E+11	1.2E+11	1.3E+14

Table 6-2 Existing and Load Reduction Scenario Results

Scenario	91-Day Mean Excursions (2001-2004)			
	190 org/100mL		200 org/100mL	
	# days	% days	# days	% days
Existing	1020	74.4%	975	71.1%
BMP-A (50% reduction in washoff NPS, direct NPS, and point source)	0	0.0%	0	0.0%
BMP-B (30% reduction in washoff NPS, direct NPS, and point source)	499	36.4%	379	27.6%
BMP-C (50% reduction in washoff NPS and direct NPS)	0	0.0%	0	0.0%

In Table 6-2 are displayed the number of days of exceedance of the 91-day criteria associated with each control scenario. Columns are provided for the number of days that a concentration of 190 org/100mL is exceeded (the criterion with the MOS), as well as the number of days of exceedance of the actual fecal coliform criterion of 200 org/100mL. Recall that the total simulation period was

2001 through 2004 for the BMP control scenarios. The number of days of exceedance provides an indication of the extent of time that the criteria are not met with each scenario.

The results of the various BMP application scenarios can also be viewed graphically. Model output can be plotted to display differences between the existing conditions and the allocation conditions. For this purpose, the daily calculation of the 91-day geometric mean bacteria concentration is employed. These data are shown, for the existing and BMP scenarios, in Figure 6-1, for the key water quality station at CR 353 (Reach 61 in the model). Note that no results are presented prior to April of 2001, because 91 days of preceding data are required in order to calculate the geometric mean. Also, note that BMP-A and BMP-C are plotted as the same line, because the results of these scenarios are virtually identical. Based upon these results, the reductions included in the BMP-C scenario will be recommended to achieve compliance with the objectives of the TMDL.

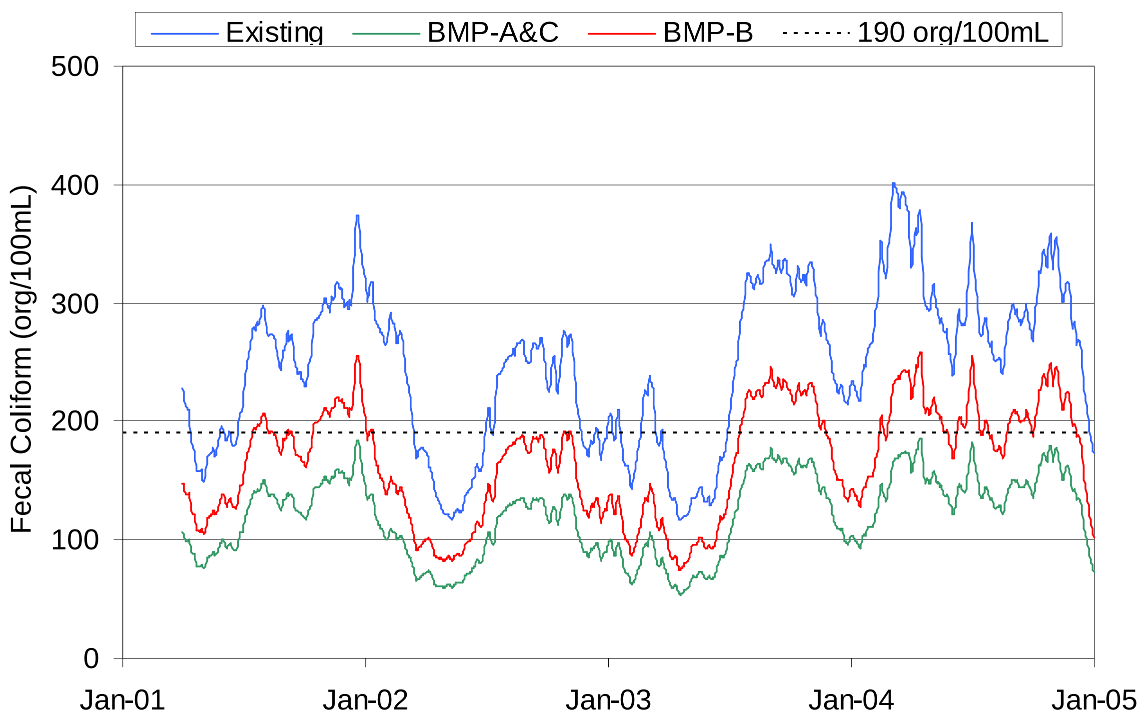

Figure 6-1 Fecal Coliform Results for BMP Scenarios at CR 353

6.6 WASTELOAD ALLOCATIONS

In the Peach Creek watershed, there are two potentially significant point source discharges in existence. These sources are the Flatonia and Waelder wastewater treatment plants (WWTPs). Both of these facilities utilize facultative lagoons to achieve wastewater disinfection. Instead of a chemical disinfection process, substantial reduction in bacteria numbers is achieved via provision of 21 days of detention time within the pond system, during which bacteria are eliminated by solar radiation and other natural processes. These types of treatment facilities may not be able to provide sufficient hydraulic retention time under conditions of rainfall-induced peak flows, therefore, there is no mechanism to control the concentration of bacteria that might be discharged. Self-reporting monitoring data for this facility does indicate that fecal coliform bacteria are discharged.

Based on self-reported data, the bacteria loads leaving the wastewater treatment facilities are negligible compared to the much larger nonpoint sources. The point source loads account for just 0.006% of the total annual average stream load, and just 0.2% of directly discharging loads (non-washoff loads). Furthermore, the bacteria concentrations measured in the effluent from these facilities are typically well below the primary contact bacteria criteria. For these reasons, no reduction in point source loading has been prescribed.

Table 6-3 WLAs for Point Source Fecal Coliform Loads in Peach Creek

Point Source	Existing Load (org/yr)	% Reduction	WLA (org/yr)
City of Flatonia WWTP	1.90E+11	0	1.90E+11
City of Waelder WWTP	5.90E+10	0	5.90E+10
		Total WLA (org/yr) =	2.49E+11

6.7 LOAD ALLOCATIONS

Load allocations for nonpoint sources include land-based washoff loadings and direct discharge nonpoint source loadings. The land-based loadings originate via washoff of bacteria from land surfaces in the watersheds of the impaired reach under rainfall runoff conditions. The direct discharge nonpoint source loadings represent direct deposition from animals (including wildlife, livestock, and pets), and potentially leaking wastewater collection mains.

The load allocation component of the TMDL incorporates background loadings within the impaired reach, which include aspects of both the land-based source loadings and the direct source loadings. Specifically, the background load from wildlife is included as deposition of bacteria onto land surfaces that is subject to subsequent washoff under rainfall runoff conditions, and as direct deposition into receiving streams.

The LA is determined as shown in Table 6-4. Here, existing loads and allocated loads are inventoried. The total load allocation (LA) for nonpoint sources is shown in the table. This total load allocation was the result of summation of the various individual load allocations, based on hypothetical removals applied to corresponding existing loads.

Table 6-4 LAs for NPS Fecal Coliform Loads in Peach Creek

Nonpoint Source	Existing Load (org/yr)	% Reduction	LA (org/yr)
Washoff NPS	4.04E+15	50	2.02E+15
Direct Discharge NPS	1.28E+14	50	6.40E+13
Septic NPS	1.16E+11	0	1.16E+11
		Total LA (org/yr) =	2.08E+15

As with the point source control measures, the selection of BMP control measures to address reductions in loading from nonpoint sources will be developed during the implementation phase of the TMDL with participation from stakeholders. For washoff sources, the different land use categories will dictate the most promising BMPs for both urban and non-urban areas. In this analysis, the 50% reduction in washoff nonpoint sources has been applied to the entire watershed, irrespective of land use. During the TMDL implementation phase, stakeholders will have the option to prescribe different percent reductions to different types of land uses, so long as these various reductions result in an overall washoff load reduction of at least 50%.

The category of septic loads is modeled separately from the direct nonpoint category, but they are both similar in that they represent sources of bacteria that are discharged continuously to the stream and that are not associated with rainfall runoff. Based on the estimation of septic loads performed in this study, these septic loads are expected to be negligible when compared to direct nonpoint loads. However, if during implementation, significant septic loads are discovered and reduced, then this reduction could be considered part of the required direct nonpoint source reduction.

6.8 TMDL SUMMARY

The TMDL was developed to achieve compliance with the Texas Water Quality standard for fecal coliform of 200 org/100 mL as a geometric mean value. Table 6-5 summarizes the allocations of the TMDL for fecal coliform for Peach Creek. The WLA includes all of the allocated point source discharges. The LA is comprised of the allocated washoff sources, direct discharge sources, and various background sources. The MOS is calculated as 5 percent of the TMDL.

Table 6-5 Summary of Fecal Coliform TMDL for Impaired Reach

	TMDL (org/yr)	WLA (org/yr)	LA (org/yr)	MOS (org/yr)
Peach Creek	2.19E+15	2.49E+11	2.084E+15	1.10E+14

In order to achieve the bacteria TMDL for Peach Creek, reductions in washoff loadings from land use areas will be required, along with reductions in direct nonpoint sources, as described in detail in the preceding sections.

The proposed TMDL for fecal coliform is also protective for Texas water quality criteria for *E. coli*. Analysis of historical water quality data for the Peach Creek study area revealed that the ratio of *E. coli* to fecal coliform is variable, but the least-squares best fit value is a ratio of 0.64. Therefore, development of a TMDL to achieve compliance with a fecal coliform concentration of 190 org/100 mL should be protective down to an *E. coli* concentration of 190 times 0.64, or, 121.6 org/100 mL. This is below the corresponding *E. coli* of 126 org/100 mL as a geometric mean. Table 6-6 summarizes the TMDL results for *E. coli*.

Table 6-6 Summary of *E. coli* TMDL for Impaired Reach

	TMDL (org/yr)	WLA (org/yr)	LA (org/yr)	MOS (org/yr)
Peach Creek	1.38E+15	1.59E+11	1.334E+15	4.83E+13

7.0 REFERENCES

Ashworth, J., J. Hopkins. 1995. Report 345: Aquifers of Texas. Texas Water Development Board. Austin, Texas.

Baxter-Potter, W.R. and M.W.Gilliland. 1988. Bacterial Pollution in Runoff from Agricultural Lands. J.of the Am Water Res Assoc. Vol 17, No. 1

Brazos River Watershed Information Center. http://wqweb.brazos.org/ Retrieved January 2006.

Buckhouse, J.C. and G.F. Gifford. 1976. Water Quality Implications of Cattle Grazing on Semiarid Watershed in Southeastern Utah. J. Of Rangeland Man. Vol. 29, No. 2

Cain, A. 2004. Personal communication, District Biologist, TPWD

Davis, W.B. and D.J. Schmidly. 1994. The Mammals of Texas. TPWD Nongame and Urban Program

Doran, J.W. and D.M. Linn. 1979. Bacteriological Quality of Runoff Water from Pastureland. Applied and Envir. Microb. May.

Drapcho, C.M and A.K.B. Hubbs. 2003. Fecal Coliform Concentration in Runoff from Fields with Applied Dairy Manure. La Water Resources Inst.

Edwards, D.R., B.T.Larson, and T.T.Lim. 2000. Runoff Nutrient and Fecal Coliform Content from Cattle Manure Application to Fescue Plots. J.of the Am Water Res Assoc. Vol 36, No. 4

Edwards, D.R., M.S.Coyne, P.F.Vendrell, T.C.Daniel, P.A.Moore, and J.F. Murdoch. 1997. Fecal Coliform and Streptococcus concentrations in Runoff from Grazed Pastures in Northwest Arkansas. J.of the Am Water Res. Assoc, Vol. 32, No. 2

EPA. 1986. Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality, EPA 440/5-87-001

EPA. 1997. TMDL Regional Guidance. Region 6, 9 Sep 1997. Dallas, TX.

EPA. 2000. Bacterial Indicator Tool: User's Guide. EPA-823-B-01-003. Office of Water. Washington, D.C.

EPA. 2004. Better Assessment Science Integrating Point and Nonpoint Sources. BASINS v.3.1. EPA-823-C-04-004. Office of Water. Washington, D.C.

Glick. R. 2005. City of Austin Stormwater Data, 1984-2004, unpublished data. COA Watershed Protection Dept.

Inamdar, S.P., S. Mostaghimi, M.N. Cook, K.M. Brannan, and P.W. McClellan. 2002. A Long-Term, Watershed-Scale, Evaluation of the Impacts of Animal Waste BMPs. J.of the Am.Water Res Assoc, Vol.38, No.3.

JMA and PES. 2002a. Historical Water Quality Data Assessment, Project Area 2 - Basins Groups D &E Bacteria Impairments. Report to TNRCC TMDL Strategic Assessment Division

JMA and PES. 2002b. Supplemental Report, Historical Water Quality Data Assessment, Project Area 2 - Basins Groups D & E Bacteria Impairments. Report to TNRCC TMDL Strategic Assessment Division

Kress, M. And G.F. Gifford. 1984. Fecal Coliform Release from Cattle Fecal Deposits. Wat. Res. Bull. Vol. 20, No. 1.

Mau, D.P, and L.M. Pope. 1999. Occurrence of Fecal Coliform Bacteria in the Cheney Reservoir Watershed, South-Central Kansas, 1996-1998. USGS, Fact Sheet 170-99

Miller, M. 2005. City of San Antonio Stormwater Data, 2000-2004. Unpublished data. SAWS

Moore, J.A., J.D. Smyth, E.S. Baker, J.R. Miner, and D.C. Moffitt. 1989. Modeling Bacteria Movement in Livestock Manure Systems. ASAE. Vol. 32, No. 3.

Ockerman, D.J. 2002. Hydrologic Conditions and Quality of Rainfall and Storm Runoff in Agricultural and Rangeland Areas in San Patricio County, Texas, 2000-2001. USGS, Open File Report 02-291

Perciasepe, Robert. 1997. Memorandum: New Policies for Establishing and Implementing Total Maximum Daily Loads (TMDLs). Office of Water, Washington, D.C.

Reed Stowe and Yanke. 2001. Study to determine the magnitude of, and reasons for, chronically malfunctioning on-site sewage facility systems in Texas. Austin, Texas.

Robbins, J.W.D., D.H. Howells, and G.J. Kriz. 1972. Stream Pollution from Animal Production Units. J.WPCF. Vol. 44, No.8

Selvakumar, A. And M. Borst. 2004. Land Use and Seasonal Effects on Urban Stormwater Runoff Microorganism Concentrations. ASCE, World Water Congress

Smith, J.H. and C.L. Douglas. 1973. Microbiological Quality of Surface Drainage Water from Three Small Irrigated Watersheds in southern Idaho. J.of Env.Qual. Vol 2, No. 1

Thelin, R. And G.F. Gifford. 1983. Fecal Coliform Release Patterns from Fecal Material of Cattle. J.of Env. Qual., Vol. 12, No. 1

TNRCC. 1999. TMDL Guidance Document. TMDL Team, Water Quality Division.

TNRCC. 2000a. Draft 2000 303(d) list.

TNRCC. 2000b. Texas Surface Water Quality Standards. 30 TAC 307.1-307.10.

TNRCC. 2001. Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data

TPWD. 2004. Online white-tailed deer population data.

TSHA. 2001. The Handbook of Texas Online: Kerr County. Texas State Historical Association. http://www.tsha.utexas.edu/handbook/online/

US Census. 2006. US Census Bureau online data for 1990, 2000.

USDA. 2002. Census of Agriculture, County Data.

Weidner, R.B., A.G. Christianson, S.R. Weibel, and G.G. Robeck. 1969. Rural Runoff as a Factor in Stream Pollution. J.WPCF, Vol. 41, No.3, Part 1

Weiskel, Peter K., B. L. Howes, G. R. Heufelder. 1996. Coliform Contamination of a Coastal Embayment: Sources and Transport Patheways. *Environmental Science and Technolog*y. 30:1872-1881.