# Total Maximum Daily Loads of Fecal Coliform
# for Church Creek in the Little Choptank River Basin
# in Dorchester County, Maryland

# FINAL

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FINAL

**Table of Contents**

FINAL

## List of Figures

## List of Tables

Church Creek (Little Choptank River) TMDL Fecal Coliform
Document version: September 28, 2004

**List of Abbreviations**

BMP         Best Management Practice
CAFO        Confined Animal Feeding Operations
cfs         Cubic Feet per Second
CFR         Code of Federal Regulations
COMAR       Code of Maryland Regulations
CSO         Combined Sewer Overflow
CWA         Clean Water Act
CWP         Center for Watershed Protection
EPA         Environmental Protection Agency
FA          Future Allocation
GIS         Geographic Information System
LA          Load Allocation
LMM         Long-term Moving Median
MACS        Maryland Agricultural Cost Share Program
MASS        Maryland Agricultural Statistic Service
MDE         Maryland Department of the Environment
MDP         Maryland Department of Planning
ml          Milliliter(s)
MOS         Margin of Safety
MPN         Most Probable Number
MRLC        Multi-Resolution Land Cover
MSSCC       Maryland State's Soil Conservation Committee
NPDES       National Pollutant Discharge Elimination System
NSSP        National Shellfish Sanitation Program
RID         MDE Restricted Area Identification
SSO         Sanitary Sewer Overflows
$T^{-1}$       per Tidal Cycle
TARSA       Technical and Regulatory Services Administration
TMDL        Total Maximum Daily Load
USGS        United States Geological Survey
WQIA        Water Quality Improvement Act
WLA         Wasteload Allocation
WQLS        Water Quality Limited Segment
WWTP        Waste Water Treatment Plant

**EXECUTIVE SUMMARY**

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

The Little Choptank River (basin number 02-13-04-02) was identified on the 1996 303(d) list submitted to the EPA by MDE as being impaired by nutrients and fecal coliform in the tidal portions. On the draft 2004 303(d) List, Church Creek was identified as restricted shellfish harvesting area. This document proposes to establish Total Maximum Daily Loads (TMDL) of fecal coliform in Church Creek. Church Creek is located on the northeast shoreline of the Little Choptank River watershed (basin number 02-13-04-02) which drains directly to the Chesapeake Bay. Church Creek is impaired by levels of bacteria exceeding Maryland's water quality standards for fecal coliform, which has resulted in closure of the area to shellfish harvesting. Fecal coliform is an indicator organism used in water quality monitoring in shellfish waters to indicate fresh sources of pollution from human waste. When the water quality standard for fecal coliform in shellfish waters is exceeded, waters are closed to shellfish harvesting to protect human health due to the potential risk from consuming raw molluscan shellfish from sewage contaminated waters. The water quality goal of this TMDL is to reduce high fecal coliform concentrations at a level at which the designated uses for Church Creek will be met. The nutrient impairments within the Little Choptank River basin will be addressed at a future date.

A variety of data at the watershed scale, including shoreline sanitary survey data, was used to identify potential fecal coliform contributions. The potential fecal coliform contributions were estimated using Geographic Information Systems (GIS) data coverage including land use, septic distribution, property, and stream data, concurrently with local agriculture census data. There is no permitted point source facility in the Church Creek watershed. From these estimates, the major contributions of fecal coliform load are nonpoint sources, including livestock, wildlife, pets, and failing septic systems. Estimated sources will be revisited once laboratory analysis, using bacteria source tracking, is completed.

A steady state tidal prism model was used to estimate current fecal coliform load based on volume and concentration, and to establish an allowable load for Church Creek. The tidal prism model incorporates both influences of freshwater discharge and tidal flushing, which represents the hydrodynamics of Church Creek. The load is then allocated to sources (human, livestock, pets, and wildlife) by determining the proportional contribution of each source based on animal/source density per land use acre times the fecal coliform production.

One of the critical tasks for this TMDL is to determine current loads from all potential sources in the watershed. The procedure needs to account for temporal variability caused by the seasonal variation and the wet-dry hydrological conditions. In order to accomplish this, data available

Church Creek (Little Choptank River) TMDL Fecal Coliform
Document version: September 28, 2004

from the most recent five-year period (i.e., 1999-2003) were used to calculate a median and 90th percentile. These results were then used to estimate the current load condition. The allowable loads for Church Creek were then computed using both the median water quality standard for shellfish harvesting of 14 Most Probable Number (MPN)/100ml and the 90th percentile standard of 49 MPN/100ml. An implicit Margin of Safety (MOS) was incorporated in the analysis to account for uncertainty. The TMDLs developed for Church Creek for fecal coliform median load and 90th percentile load are as follows:

The median load of fecal coliform TMDL $= 1.15 \times 10^{11}$ counts per day
The 90th percentile load of fecal coliform TMDL $= 4.01 \times 10^{11}$ counts per day

For the Church Creek restricted shellfish harvesting area, the 90th percentile criterion requires the greatest reduction. Therefore, the source reduction scenario is developed based on the 90th percentile load TMDL. The source contributions estimated from the watershed analysis were used to determine the percent contribution for each source. The percent distributions of these sources were used to partition the source allocation that would meet water quality standards at Church Creek. The reduction for each source was calculated based on differences of the current loads and the allowable loads. The reductions needed in the Church Creek restricted shellfish harvesting area to meet the shellfish criteria and the load allocations required to meet the TMDLs are shown in the table below.

| RID | Source | Current Load Distribution (% of Total) | Required Reduction | TMDL Load Allocation (% of Total) |
|---|---|---|---|---|
| Church Creek | | | |
| 39G | Total | 100.0% | 69.1% | 100.0% |
| | Wildlife | 82.7% | 63.7% | 97.2% |
| | Human | 0.3% | 95.0% | 0.1% |
| | Pets | 14.2% | 95.0% | 2.3% |
| | Livestock | 2.8% | 95.0% | 0.4% |

Once the U.S. Environmental Protection Agency (EPA) has approved a TMDL, and it is known what measures must be taken to reduce pollution levels, implementation of best management practices (BMPs) is expected to take place. The Maryland Department of the Environment (MDE) intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality, with consideration given to ease of implementation and cost. To confirm the bacteria source allocations, MDE is conducting a one-year bacteria source tracking (BST) study for Church Creek restricted shellfish harvesting area identified in this report. There is an ongoing effort for continued monitoring by MDE's Shellfish Certification Division.

## 1.0    INTRODUCTION

Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each State to develop a Total Maximum Daily Load (TMDL) for each impaired water quality limited segment (WQLS) on the Section 303(d) list, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty.  A TMDL reflects the total pollutant loading of the impairing substance a water body can receive and still meet water quality standards.

TMDLs are established to achieve and maintain water quality standards.  A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use.  Designated uses include activities such as swimming, drinking water supply, and shellfish propagation and harvest.  Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

The Little Choptank River (basin number 02-13-04-02) was identified on the 1996 303(d) list submitted to the EPA by MDE as being impaired by nutrients and fecal coliform in the tidal portions. On the draft 2004 303(d) List, Church Creek was identified as restricted shellfish harvesting area. This document proposes to establish TMDLs of fecal coliform in Church Creek within the Little Choptank River basin.  The nutrient impairments within the Little Choptank River basin will be addressed at a future date.

In both the 1996 and 1998 Maryland 303(d) lists of impaired water bodies, many 8-digit watersheds were identified as being impaired since these water bodies are closed to shellfish harvesting due to elevated fecal coliform concentrations.  Monitoring is ongoing in shellfish areas, and openings and closings occur routinely.  The draft 2004 303(d) List indicates currently restricted shellfish harvesting areas within an 8-digit watershed that require TMDLs.

Fecal coliform are found in the intestinal tract of humans and other warm-blooded animals.  Few fecal coliform are pathogenic; however, the presence elevated levels of of fecal coliform in shellfish waters indicates recent sources of pollution.  Some common waterborne diseases associated with the consumption of raw clams and oysters harvested from polluted waters include viral and bacterial gastroenteritis and hepatitis A.  Fecal coliform may occur in surface waters from point and nonpoint sources.

## 2.0    SETTING AND WATER QUALITY DESCRIPTION

### 2.1    General Setting

Church Creek is situated approximately 16 km upriver from the mouth of the Little Choptank River along its southwest shoreline. Little Choptank River is located on Maryland's eastern shore and is about 19.2 km long.  Shellfish waters in the Little Choptank River extend from its headwaters to the mouth of the river where it discharges into the Chesapeake Bay.

FINAL

Church Creek, designated as restricted area (RID) 39G, drains south to the Little Choptank River, as shown in Figure 2.1.1. The drainage basin for Church Creek is approximately 4.5 km in the north-south direction by 0.5 km in the east-west direction with a drainage area of approximately 2,905 acres (11.8 km$^2$). The watershed consists of fine textured to medium textured soils. The thick beds of silt, or silt-clay loam, are characteristic of the area. Soils mainly consist of silt (42.9%), sand (37.6%), and clay (19.5%) (USDA, 1995). The topography of the watershed is generally level, and the majority of the area near the receiving waters consists of low-lying land with high runoff. Church Creek itself has a mean water volume of 1,165,792 cubic meters and mean water depth of 0.87 m. The dominant tide in this region is the lunar semi-diurnal (M$_2$) tide with a tidal range of 0.5 m and tidal period of 12.42 hours. The 2000 Maryland Department of Planning (MDP) land use/land cover data shows that the watershed can be characterized as rural. The land use percentage distribution for Church Creek is shown in Table 2.1.1, and spatial distributions for each land use are shown in Figure 2.1.3.

## 2.2    Water Quality Characterization

MDE's Shellfish Certification Program is responsible for classifying shellfish harvesting waters to ensure oysters and clams are safe for human consumption. MDE adheres to the requirements of the National Shellfish Sanitation Program (NSSP), with oversight by the U.S. Food and Drug Administration. MDE conducts shoreline surveys and collects routine bacteria water quality samples in the shellfish-growing areas of Maryland. These data are used to determine if the water quality criterai are being met. If the water quality criteria are exceeded, the shellfish areas are closed to harvesting and the designated use is not being achieved.

MDE's Shellfish Certification Division has monitored shellfish growing regions throughout Maryland for the past several decades. Church Creek has only one measurement station within its basin: Station 10-07-704. Its location is shown in Table 2.2.1 and Figure 2.2.1. Observations recorded during the period 1999-2003 are shown in Figure 2.2.2. In general, based on Statewide shellfish monitoring data, fecal coliform concentrations are higher in the headwaters.
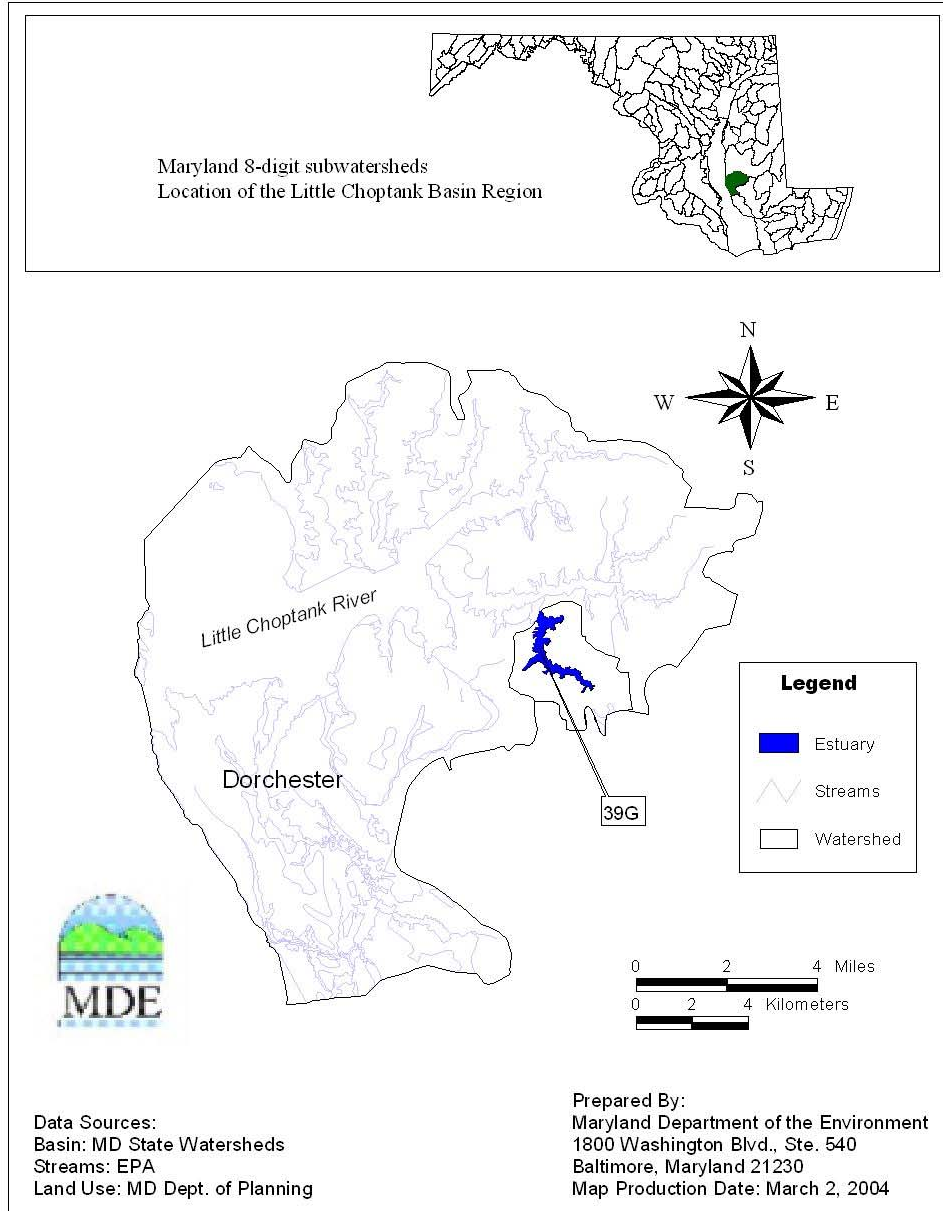
**Figure 2.1.1: Location Map of the Church Creek Basin (RID 39G)**

**Table 2.1.1:  Land Use Percentage Distribution for Church Creek (RID 39G)**

| Land Type | Acreage | Percentage |
|---|---|---|
| Urban | 513.6 | 17.7 |
| Forest | 866.6 | 29.8 |
| Agriculture | 1160.4 | 39.9 |
| Wetlands | 30.3 | 1.0 |
| Water | 334.4 | 11.5 |
| | | |
| **Totals** | **2905.2** | **100.0** |
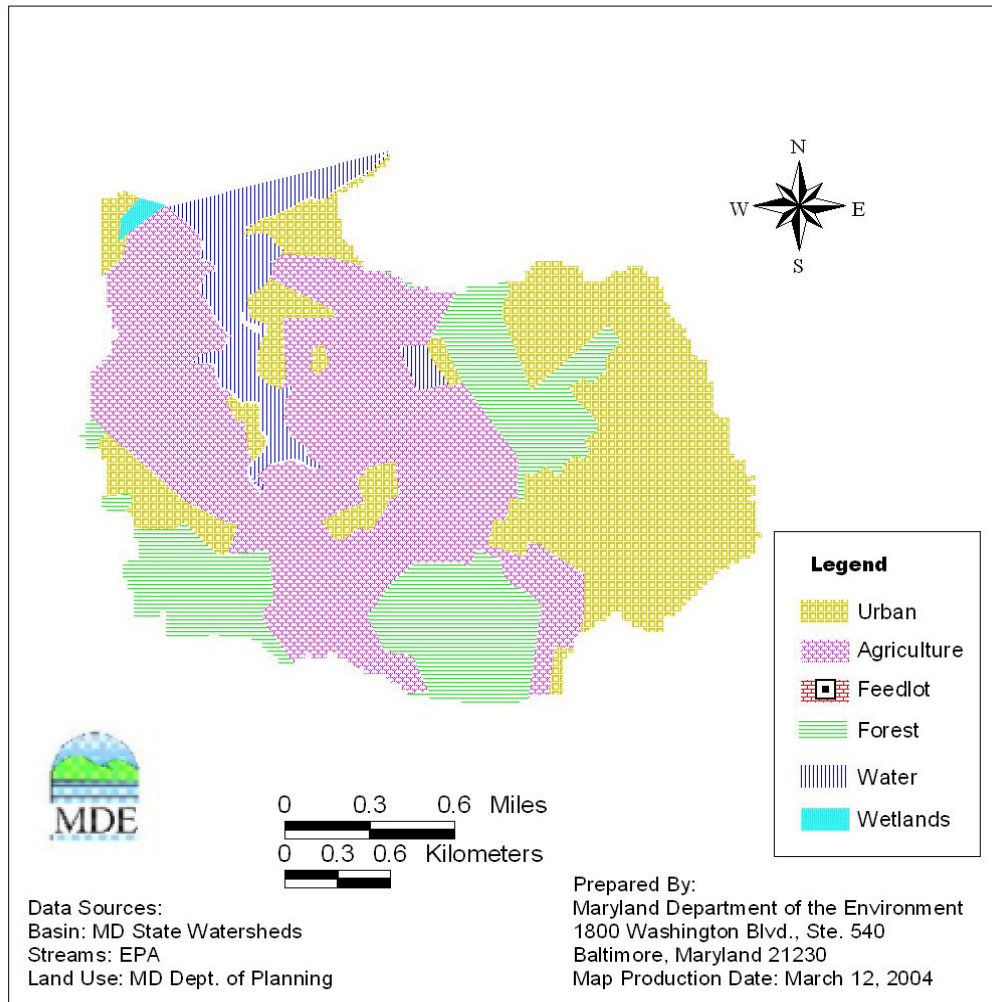


**Figure 2.1.2:  Land Use in Church Creek Basin (RID 39G)**

**Table 2.2.1: Locations of Shellfish Monitoring Station in Church Creek**

| Shellfish Monitoring Station | Obs. Period | Total Obs. | LATITUDE Deg-min-sec | LONGITUDE Deg-min-sec |
|---|---|---|---|---|
| 10-07-704 | 1999-2003 | 59 | 38 31 13.0 | 76 10 32.0 |



**Figure 2.2.1: Shellfish Monitoring Station in Church Creek**

**Figure 2.2.2: Observed Fecal Coliform Concentration at Station 10-07-704**

### 2.3 Water Quality Impairment

The Maryland water quality standards Surface Water Use Designation for these restricted shellfish harvesting areas is Use II - Shellfish Harvesting Waters (Code of Maryland Regulations COMAR 26.08.02.08E). The Little Choptank River (basin number 02-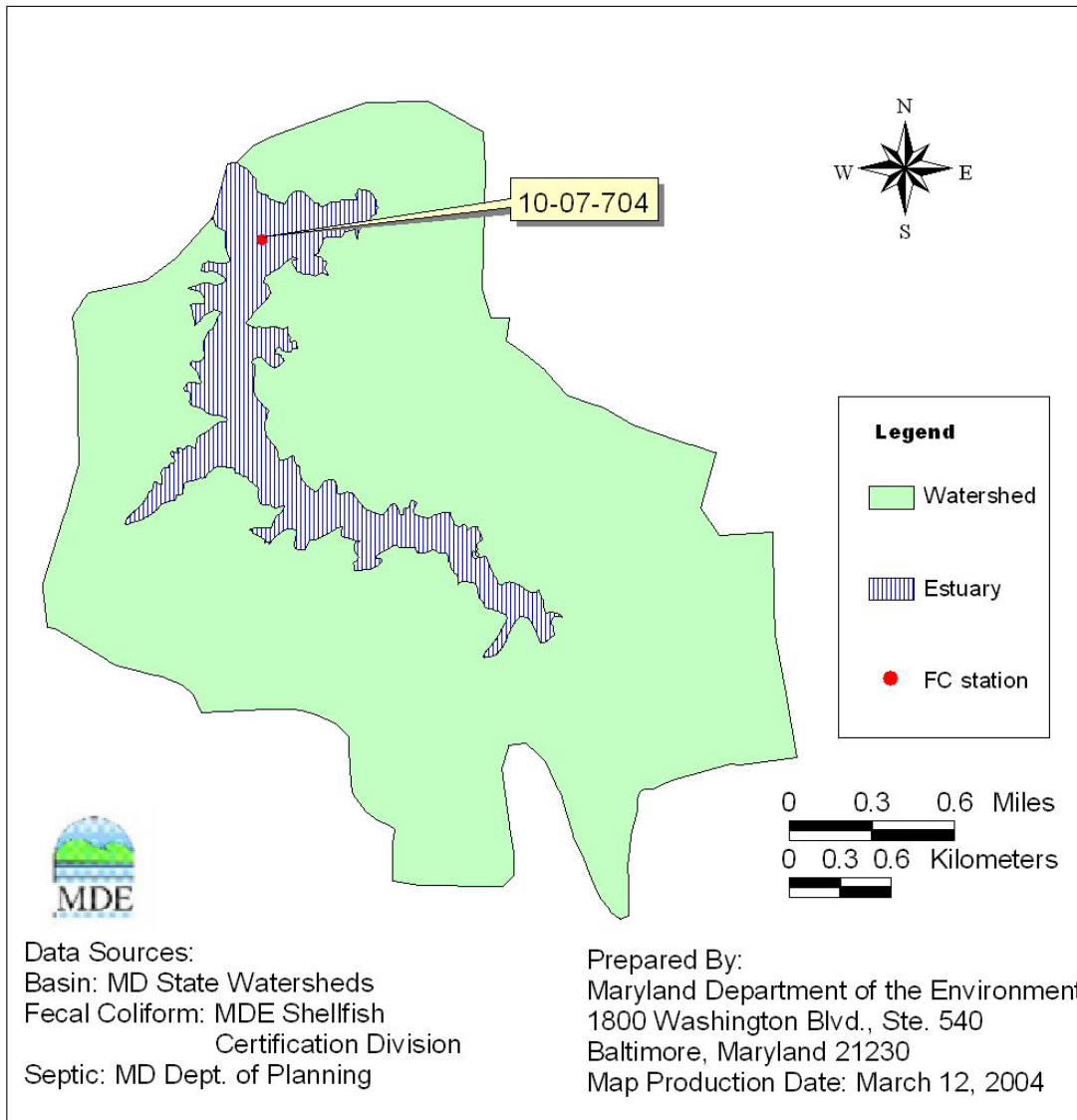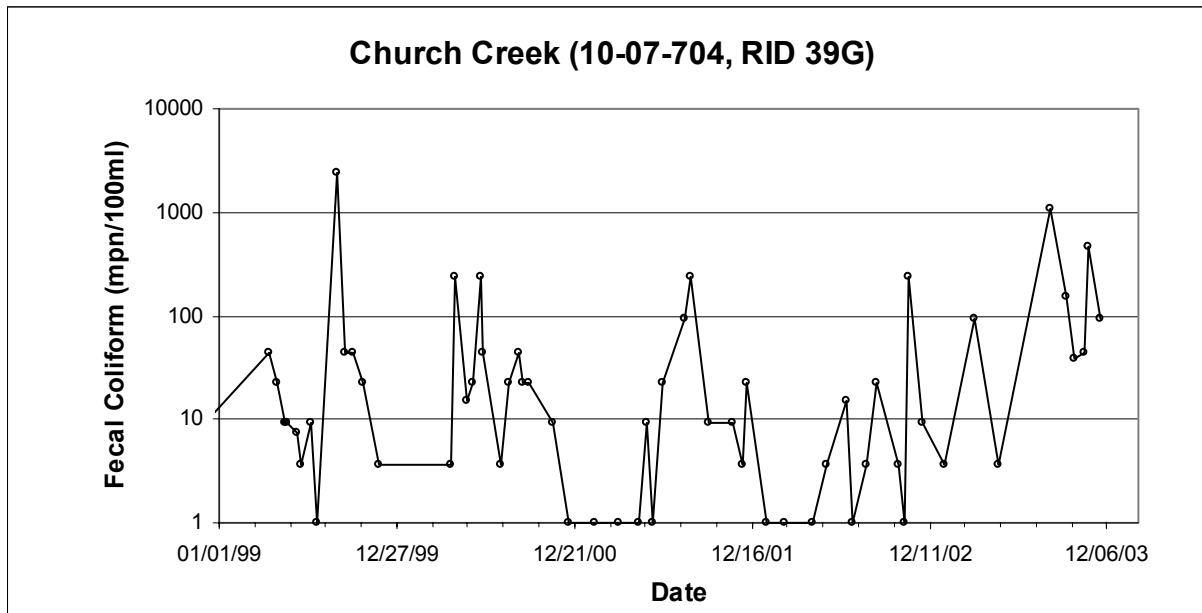13-04-02) has been included on the draft 2004 Integrated 303(d) List as impaired for fecal coliform. Church Creek, located along the northeast shoreline of the Little Choptank River, is identified as areas in this basin that do not meet shellfish water quality standards. Shellfish harvesting waters are classified as *Use II*. Waters within this classification, according to the Code of Maryland Regulation (COMAR) Section 26.08.02.03-3C (criteria for Use II waters - shellfish harvesting), **"means that the median fecal coliform MPN of at least 30 water sample results taken over a three year period to incorporate inter-annual variability shall not exceed 14 per 100 milliliters, and**

**(i) In areas affected by point source discharges, not more than 10 percent of the samples shall exceed an MPN of 43 per 100 ml for a five tube decimal dilution test or 49 MPN per 100 ml for a three tube decimal dilution test; or**

**(ii) In other areas, the 90th percentile of water sample results shall not exceed an MPN of 43 per 100 ml for a five tube decimal dilution test or 49 MPN per 100 ml for a three tube decimal dilution test."**

For this report, the monitoring data averaging period was based on a combination of management objectives and monitoring data requirements for determination of shellfish harvesting area water quality standards attainment. The averaging period for the monitoring data required least 30 samples and used all data within the most recent five year period.

Church Creek (Little Choptank River) TMDL Fecal Coliform
Document version: September 28, 2004

The water quality impairment was assessed using the median and 90th percentile concentrations. Descriptive statistics of the monitoring data and the water quality criterion are shown in Table 2.3.1.

**Table 2.3.1:  Church Creek Shellfish Monitoring Station (1999-2003) - Median and 90th Percentile**

| RID | Area Name | Station | Median | | 90th Percentile | |
|---|---|---|---|---|---|---|
| | | | Monitoring Data | Criterion | Monitoring Data | Criterion |
| | | | MPN/100ml | MPN/100ml | MPN/100ml | MPN/100ml |
| 39G | Church Creek | 10-07-704 | 9.1 | 14 | 158.5 | 49 |

## 2.4     Nonpoint Source Assessment

**Nonpoint Source Assessment**

Nonpoint sources of fecal coliform bacteria do not have one discharge point but occur over the entire length of a stream or waterbody.  There are many types of nonpoint sources in watersheds discharging to the restricted shellfish harvesting areas.  The possible introductions of fecal coliform bacteria to the land surface are through the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife.  As the runoff occurs during rain events, surface runoff transports water and fecal coliform over the land surface and discharges to the restricted shellfish harvesting area.  The deposition of non-human fecal coliform directly to the restricted shellfish area occurs when livestock or wildlife have direct access to the waterbody.  Nonpoint source contributions to the bacterial levels from human activities generally arise from failing septic systems and their associated drain fields as well as through pollution from recreation vessel discharges.  The transport of fecal coliform from land surface to the restricted shellfish harvesting area is dictated by the hydrology, soil type, land use, and topography of the watershed.

The complete distributions of these source loads are also listed in Tables 2.4.1, along with counts/day for each loading.  Details of the source estimate procedure can be found in Appendix B.  The Bacteria Source Tracking (BST) data will be used to further confirm the source distribution when it becomes available.

**Table 2.4.1: Distribution of Fecal Coliform Source Loads in the Church Creek Basin**

| Fecal Coliform Source | Loading Counts/day | Loading Percent |
|---|---|---|
| Livestock | 1.22E+10 | 2.8% |
| Pets | 6.32E+10 | 14.2% |
| Human | 1.45E+09 | 0.3% |
| Wildlife | 3.68E+11 | 82.7% |
| Total | 4.45E+11 | 100.0% |

**Point Source Assessment**

There are no permitted point source facilities discharging directly into Church Creek watershed, based on the point source permitting information.

## 3.0 TARGETED WATER QUALITY GOAL

The overall objective of the fecal coliform TMDLs established in this document is to establish the loading caps needed to assure attainment of water quality standards in the restricted shellfish harvesting areas. These standards are described fully in Section 2.3 Water Quality Impairment.

## 4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

### 4.1 Overview

This section documents detailed fecal coliform TMDL and source allocation developments for Church Creek. The required load reduction was determined based on the most recent five-year data spanning the years 1999 to 2003. The TMDL is presented as counts/day. The second section describes the analysis framework for simulating fecal coliform concentration in Church Creek. The third section addresses the critical period. The fourth section presents the TMDL calculation. The fifth section discusses TMDL loading caps. The sixth section presents the load allocation. The margin of safety is discussed in Section 4.7. Finally, the variables of the equation are combined in a summary accounting of the TMDL.

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality criteria, in this case Maryland's water quality criteria for shellfish waters. It is also important to note that the TMDLs presented herein are not literal daily limits. These loads are based on an averaging period that is defined by the water quality criteria (i.e. at least 30 samples). The averaging period used for development of these TMDLs requires at least 30 samples and uses the most recent 5 year period of data.

TMDLs are comprised of the sum of individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. The TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody, and in the scientific and technical understanding of water quality in natural systems. In addition, the TMDL may include a future allocation (FA) when necessary. Conceptually, this definition is denoted by the equation:

$$TMDL = WLAs + LAs + MOS + FA$$

## 4.2    Analysis Framework

In general, tidal waters are exchanged through their connecting boundaries. The tide and amount of freshwater discharging into the restricted shellfish harvesting areas are the dominant influences on the transport of fecal coliform. The methodology used assumes that freshwater input, tidal range, and the first-order decay of fecal coliform are all constant. The decay rate is a lumped parameter, which is the net loss due to solar radiation, temperature, salinity, settling, resuspension, and shellfish filtering. The TMDL is calculated based on the steady state tidal prism model. Compared to the volumetric method (EPA Shellfish Workshop, 2002), the steady state tidal prism model provides improvements incorporating the influences of tidal induced transport, freshwater, and decay of fecal coliform in the restricted shellfish harvesting areas. A detailed description of the model is presented in Appendix A.

The most recent five-year median and $90^{th}$ percentile concentrations were used to estimate the current loads. Using the steady state tidal prism model, the loads can be estimated according to the equation as follows (see also Appendix A):

$$L = [C(Q_b + kV) - Q_0 C_0] \times Cf \tag{1}$$

where:
$L$ = fecal coliform load (counts per day)
$C$ = fecal coliform concentration (MPN /100ml) of embayment
$Q_b$ = the quantity of mixed water that leaves the embayment on the ebb tide that did not enter the embayment on the previous flood tide ($m^3$ per tidal cycle)
$k$ = the fecal coliform decay rate ($T^{-1}$)
$V$ = the mean volume of the embayment ($m^3$)
$Q_0$ = the quantity of water that enters the embayment on the flood tide through the ocean boundary that did not flow out of the embayment on the previous ebb tide ($m^3$ per tidal cycle)
$C_0$ = the fecal coliform concentration (MPN/100ml) at the oceanside boundary
$Cf$ = the unit conversion factor.

$Q_b$ and $Q_0$ are estimated based on the steady state condition as follows:

$$Q_b = Q_0 + Q_f$$

where $Q_f$ is mean freshwater discharge during the tidal cycle

$$Q_0 = \beta Q_T$$

where $\beta$ is an exchange ratio and $Q_T$ is the total ocean water entering the bay on the flood tide, which is calculated based on tidal range. The dominant tide in this region is the lunar semi-diurnal ($M_2$) tide with a tidal period of 12.42 hours; therefore, the $M_2$ tide is used for the representative tidal cycle. In general, the exchange ratio varies from 0.3 to 0.7, based on the previous model tests in Virginia coastal embayments (Kuo et al., 1998; Shen et al., 2002). The observed salinity data were also used to estimate the exchange ratio. The estimated values range from 0.3-0.8; therefore, a value of 0.5 is used for the exchange ratio. The stream flow used for the estimation of $Q_f$ was based on the flows of the U.S. Geological Survey (USGS) gage # 02060006, located nearby in Calvert County, MD. The average long-term flow for this USGS gage (i.e., 4.99 cfs) was adjusted by the ratio of the drainage basin area of Church Creek to that of the gage (2905.3 acres to 4307.5 acres, or 0.674) to derive an estimate of the long-term flow for Church Creek ( 3.36 cfs).

### 4.3 Critical Condition and Seasonality

The EPA Code of Federal Regulations (40 CFR 130.7(c)(1)) requires TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The critical condition accounts for the hydrologic variation in the watershed over many sampling years whereas the critical period is the condition under which a waterbody is the most likely to violate the water quality standard(s).

The 90th percentile concentration is the concentration exceeded only 10% of the time. Since data collected during the most recent five-year period was used to calculate the 90th percentile, the critical condition is implicitly included in the value of the 90th percentile. Given the length of the monitoring record used and the limited applicability of best management practices to extreme conditions, the 90th percentile is utilized instead of the absolute maximum.

A comparison of the median values and the 90th percentile values against the water quality criteria determines which represents the more critical condition or higher percent reduction. If the median values dictate the higher reduction, this suggests that, on average, water sample counts are very high with limited variation around the mean. If the 90th percentile criterion requires a higher reduction, this suggests an occurrence of the high fecal coliform due to the variation of hydrological conditions.

Similar to the critical condition, seasonality is also implicitly included in the analysis due the averaging required in the water quality standards. It is possible that during colder season the bacteria levels will be less however this is not always true when reviewing monitoring data. The shellfish monitoring program uses a systematic random sampling design which was developed to cover inter-annual variability.

### 4.4    TMDL Computation

According to the water quality standard for fecal coliform in shellfish waters, computation of a TMDL requires analyses of both the median and 90th percentile. These analyses are described below.

For the load analyses, the most recent 5-year period of monitoring data (at least 30 samples), specifically fecal coliform concentrations were used to estimate the current loads. This was conducted for median and for 90th percentile conditions. There is only a single measurement station in Church Creek (i.e., Station 10-07-704). For this reason, the most recent five-year median and 90th percentile values from this station was served as both the restricted shellfish harvesting area concentration and boundary condition.

The allowable load is calculated using the water quality criteria of a median of 14 MPN/100ml and a 90th percentile of 49 MPN/100ml. The load reductions needed for the attainment of the criteria is determined by subtracting the allowable loads from the current loads. The TMDL calculations are presented in Appendix A. The calculated results are listed in Tables 4.4.1 and Table 4.4.2.

**Table 4.4.1:  Median Loading Analysis of Current Load and Estimated Load Reduction**

| Area | Mean Volume | Fecal Coliform Concentration Median | Decay Rate per tidal cycle | Estimated Residence Time day | Current Load counts/day | Allowable Load counts/day | Required Percent Reduction (%) |
|---|---|---|---|---|---|---|---|
| | m³ | MPN/100mL | | | | | |
| Church Creek | 1165792 | 9.1 | 0.36 | 1.8 | 7.455E+10 | 1.147E+11 | 0.00 |

**Table 4.4.2:  90th Percentile Analysis of Current Load and Estimated Load Reduction**

| Area | Mean Volume | Fecal Coliform Concentration 90th percentile | Decay Rate per tidal cycle | Estimated Residence Time day | Current Load Counts/day | Allowable Load counts/day | Required Percent Reduction (%) |
|---|---|---|---|---|---|---|---|
| | M³ | MPN/100mL | | | | | |
| Church Creek | 1165792 | 158.5 | 0.36 | 1.8 | 1.298E+12 | 4.014E+11 | 69.09 |

## 4.5     TMDL Loading Caps

This section presents the TMDL for the median and the 90th percentile conditions.  Seasonal variability is addressed implicitly through the interpretation of the water quality standards. The TMDLs for Church Creek are as follows:

The median load of fecal coliform TMDL  $= 1.15 \times 10^{11}$ counts per day
The 90th percentile of fecal coliform TMDL $= 4.01 \times 10^{11}$ counts per day

The greater reduction required when comparing the median and the 90th percentile results (see Tables 4.4.1 and 4.4.2), was used for source allocation.  It is also important to note that the TMDLs presented herein are not literal daily limits.  These loads are based on an averaging period that is defined by the water quality criteria (i.e. at least 30 samples).  The averaging period used for development of these TMDLs is five years.

## 4.6     Load Allocation

The allocations described in this section demonstrate how the TMDL can be implemented to achieve water quality standards. However, the State reserves the right to revise these allocations provided the allocations are consistent with the achievement of water quality standards.

Source reductions were assigned by first managing controllable sources (human, livestock and pets) and then determining if the TMDL could be achieved.  If the total required reduction was not achieved then the wildlife source was then reduced.  Given the non-point source characteristics of the wildlife contribution, it was assumed that best management practices applied to controllable sources may also reduced some wildlife sources contributing to the restricted shellfish harvesting area.  Based on these assumptions, the source allocation for  the watershed  for each of the major source categories is estimated.  Results are presented in Table 4.6.1.

**Table 4.6.1.  Load Allocation and Reductions**

| RID | Source | Current Load Distribution (% of Total) | Required Reduction | TMDL Load Allocation (% of Total) |
|---|---|---|---|---|
| | | Church Creek | | |
| | Total | 100.0% | 69.1% | 100.0% |
| | Wildlife | 82.7% | 63.7% | 97.2% |
| 39G | Human | 0.3% | 95.0% | 0.1% |
| | Pets | 14.2% | 95.0% | 2.3% |
| | Livestock | 2.8% | 95.0% | 0.4% |

### 4.7     Margin of Safety

A Margin of Safety (MOS) is required as part of a TMDL in recognition of many uncertainties in the understanding and simulation of water quality in natural systems.  For example, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural water bodies.  The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection.

For TMDL development, the MOS needs to be incorporated to account for uncertainty due to model parameter selection.  Based on previous analysis (VIMS, 2004), it was determined that the most sensitive parameter is the decay rate.  The value of the decay rate varies from 0.7 to 3.0 per day in salt water (Mancini, 1978; Thomann and Mueller, 1987).  A decay rate of 0.7 per day was used as a conservative estimate in the TMDL calculation.  Further literature review supports this assumption as a conservative estimate of the decay rate (MDE, 2004).  Therefore, the MOS is implicitly included in the calculation.

### 4.8     Summary of Total Maximum Daily Loads

Since there are no permitted point sources in the watershed, all allocations are to nonpoint sources.   The TMDLs are summarized as follows:

The median TMDL (counts per day):

| **TMDL** | **=** | **LA** | **+** | **WLA** | **+** | **FA** | **+** | **MOS** |
|---|---|---|---|---|---|---|---|---|
| $1.15 \times 10^{11}$ | = | $1.15 \times 10^{11}$ | + | N/A | + | N/A | + | **Implicit** |

The 90th percentile TMDL (counts per day):

| **TMDL** | **=** | **LA** | **+** | **WLA** | **+** | **FA** | **+** | **MOS** |
|---|---|---|---|---|---|---|---|---|
| $4.01 \times 10^{11}$ | = | $4.01 \times 10^{11}$ | + | N/A | + | N/A | + | **Implicit** |

Where:

TMDL = Total Maximum Daily Load
LA     = Load Allocation (Nonpoint Source)
WLA   = Waste Load Allocation (Point Source)
FA      = Future Allocation
MOS   = Margin of Safety

## 5.0     ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the fecal coliform TMDL will be achieved and maintained.  The appropriate measures to reduce pollution levels in the impaired segments include, where appropriate, the use of better treatment technology or installation of best management practices (BMPs).  Details of these methods are to be described in the implementation plan.

In general, MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality, with consideration given to ease of implementation and cost.  The iterative implementation of BMPs in the watershed has several benefits: tracking of water quality improvements following BMP implementation through follow-up stream monitoring; providing a mechanism for developing public support through periodic updates on BMP implementation; and helping to ensure that the most cost-effective practices are implemented first.

Potential funding sources for implementation include the Maryland's Agricultural Cost Share Program (MACS) which provides grants to farmers to help protect natural resources and the Environmental Quality and Incentives Program which focuses on implementing conservation practices and BMPs on land involved with livestock and production.  Additional funding available for local governments include the State Water Quality Revolving Loan Fun and the Stormwater Pollution Cost Share Program.  Details of these programs and additional funding sources can be found at http://www.dnr.state.md.us/bay/services/summaries.html.

Regulatory enforcement of potential bacteria sources may include MDE's routine sanitary surveys of shellfish growing areas and through National Pollutant Discharge Elimination System (NPDES) permitting activities such as concentrated animal feeding operations (CAFOs).  Though not directly linked, it is assumed that the nutrient management plans from the Water Quality Improvement Act of 1998 (WQIA) will have some reduction of bacteria from manure application practices.

As part of Maryland's commitment to the NSSP, MDE will continue to monitor shellfish waters and classify harvesting areas.  Those waters meeting shellfish water quality standards may be reclassified as open to harvesting and can serve to track the effectiveness of TMDL implementation and water quality improvements.  Additional monitoring will also include bacteria source tracking and will be used to confirm the source estimates presented in this document.  Bacteria source tracking will be completed according to MDE's schedule posted on MDE's website, http://www.mde.state.md.us:8001/assets/document/BST_schedule.pdf.

Implementation and Wildlife Sources

It is expected that in some waters for which TMDLs will be developed, the bacteria source analysis will indicate that after controls are in place for all anthropogenic sources, the waterbody does not meet water quality standards.  However, neither the State of Maryland, nor EPA is

proposing the elimination of wildlife to allow for the attainment of water quality standards. This is considered to be an impracticable and undesirable action. While managing the overpopulation of wildlife remains and option for state and local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

After developing and implementing, to the maximum extent possible, a reduction goal based on the anthropogenic sources identified in the TMDL, Maryland is considering the following TMDL strategy to address wildlife issues. It is possible that implementation to reduce the nonpoint controllable sources may also reduce some wildlife inputs to the shellfish waters. Following this first implementation stage, MDE would re-assess the water quality to determine if the designated use is being achieved. If the water quality standards are not being attained, then MDE would consider developing either a risk based adjusted water quality assessment or a Use Attainability Analysis to reflect the presence of naturally high bacteria levels from uncontrollable sources.

## 6.0    PUBLIC PARTICIPATION

Public notification of the State's intent to address the bacteria listing was conducted in a variety of ways. Identified stakeholders (including local government contacts, tributary team chairs, and interested parties) were formally notified of MDE's intent to develop bacteria TMDLs in March 2004.

Following this initial contact, these stakeholders were again notified on June 23, 2004 when the document began Interagency Review. The document went through a public comment period from August 10, 2004 to September 8, 2004 where the document was placed in the Dorchester County Library, MDE's website and notices were published in the Daily Banner. Following the public comment period, comments were reviewed and addressed through a comment response document. The documents were then submitted to EPA Region III at which time stakeholders were notified of this action. Once the document was approved by EPA Region III, stakeholders were notified of the action and the finalized document was posted on MDE's website.

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## Appendix A

**Tidal Prism Model**

A detailed description of the tidal flushing model is presented in this section. It is assumed that a single volume can represent a water body, and that the pollutant is well mixed in the water body system, as shown in Figure A-1.

The mass balance of water can be written as follows (Guo and Lordi, 2000):

$$\frac{dV}{dT} = (Q_0 - Q_b + Q_f) \tag{1}$$

where $Q_0$ is the quantity of water that enters the embayment on the flood tide through the ocean boundary ($m^3T^{-1}$); $Q_b$ is the quantity of mixed water that leaves the bay on the ebb tide that did not enter the bay on the previous flood tide ($m^3$ per tidal cycle); $Q_f$ is total freshwater input over the tidal cycle ($m^3$); $V$ is the volume of the bay ($m^3$); $T$ is the dominant tidal period (hours).

It is further assumed that $Q_0$ is the pure ocean water that did not flow out of the embayment on the previous ebb tide, and that $Q_b$ is the embayment water that did not enter into the system on the previous flood tide. The mass balance for the fecal coliform can then be written as follows:

$$\frac{dVC}{dT} = Q_0 C_0 - Q_b C + L_f + L_l - kVC \tag{2}$$

where $L_f$ is the loading from upstream; $L_l$ is the additional loading from the local area within the tidal cycle, $k$ is the fecal coliform decay rate (or a damped parameter for the net loss of fecal coliform), $C$ is fecal coliform concentration in the embayment, and $C_0$ is the fecal coliform concentration from outside the embayment.

In a steady-state condition, the mass balance equations for the water and the fecal coliform concentration can be written as follows:

$$Q_b = Q_0 + Q_f \tag{3}$$

$$Q_b C + kVC = Q_0 C_0 + L_f + L_l \tag{4}$$

The fecal coliform concentration in the embayment can be calculated as follows:

$$C = \frac{Q_0 C_0 + L_f + L_l}{Q_b + kV} \tag{5}$$

FINAL

From Equation (4), assuming $L_f + L_l = Load_t$ and letting $C_c$ be the criterion of fecal coliform in the embayment, the loading capacity can be estimated as:

$$Load_T = C_c(Q_b + kV) - Q_0 C_0 \qquad (6)$$

The daily load can be estimated based on the dominant tidal period in the area. For the upper Chesapeake Bay the dominant tide is lunar semi-diurnal ($M_2$) tide with a tidal period of 12.42 hours. If fecal coliform concentration is in MPN/100ml, the daily load (counts day$^{-1}$) can be estimated as:

$$Load = Load_T \times \frac{24}{12.42} \times 10000 \qquad (7)$$

In practice, one may not know $Q_0$ *a priori*. Instead, one is given the tidal range of the tidal embayment. From that, $Q_T$, the total ocean water entering the bay on the flood tide, can be calculated. From this, $Q_0$, the volume of new ocean water entering the embayment on the flood tide can be determined by the use of the ocean tidal exchange ratio β as:

$$Q_0 = \beta Q_T \qquad (8)$$

where β is the exchange ratio and $Q_T$ is the total ocean water entering the bay on the flood tide. The exchange ratio can be estimated from salinity data (Fischer et al., 1979):

$$\beta = \frac{S_f - S_e}{S_0 - S_e} \qquad (9)$$

where $S_f$ is the average salinity of ocean water entering the bay on the flood tide, $S_e$ is the average salinity of the bay water leaving the bay, and $S_0$ is the salinity at the ocean side. The numerical value of β is usually smaller than 1, and it represents the fraction of new ocean water entering the embayment. Once $Q_0$ is known, then $Q_b$ can be calculated from equation (3).

The residence time, $T_L$, is an estimate of time required to replace the existing pollutant concentration in a system; it can be calculated as follows:

$$T_L = \frac{V_b}{Q_b} \qquad (10)$$

where $V_b$ is mean volume of the embayment. From the definition, the denominator can either be $Q_T$ or $Q_b$. However, using $Q_T$ assumes that the ocean water enters into the embayment during the flood tide is 100% new, whereas using $Q_b$ takes into consideration that a portion of water is not entirely new. It can be shown that the latter is more realistic. If $Q_b$ is used in the residence time calculation, it will result in a longer time scale than if $Q_T$ is used (Ketchum, 1951; Guo and Lordi, 2000).
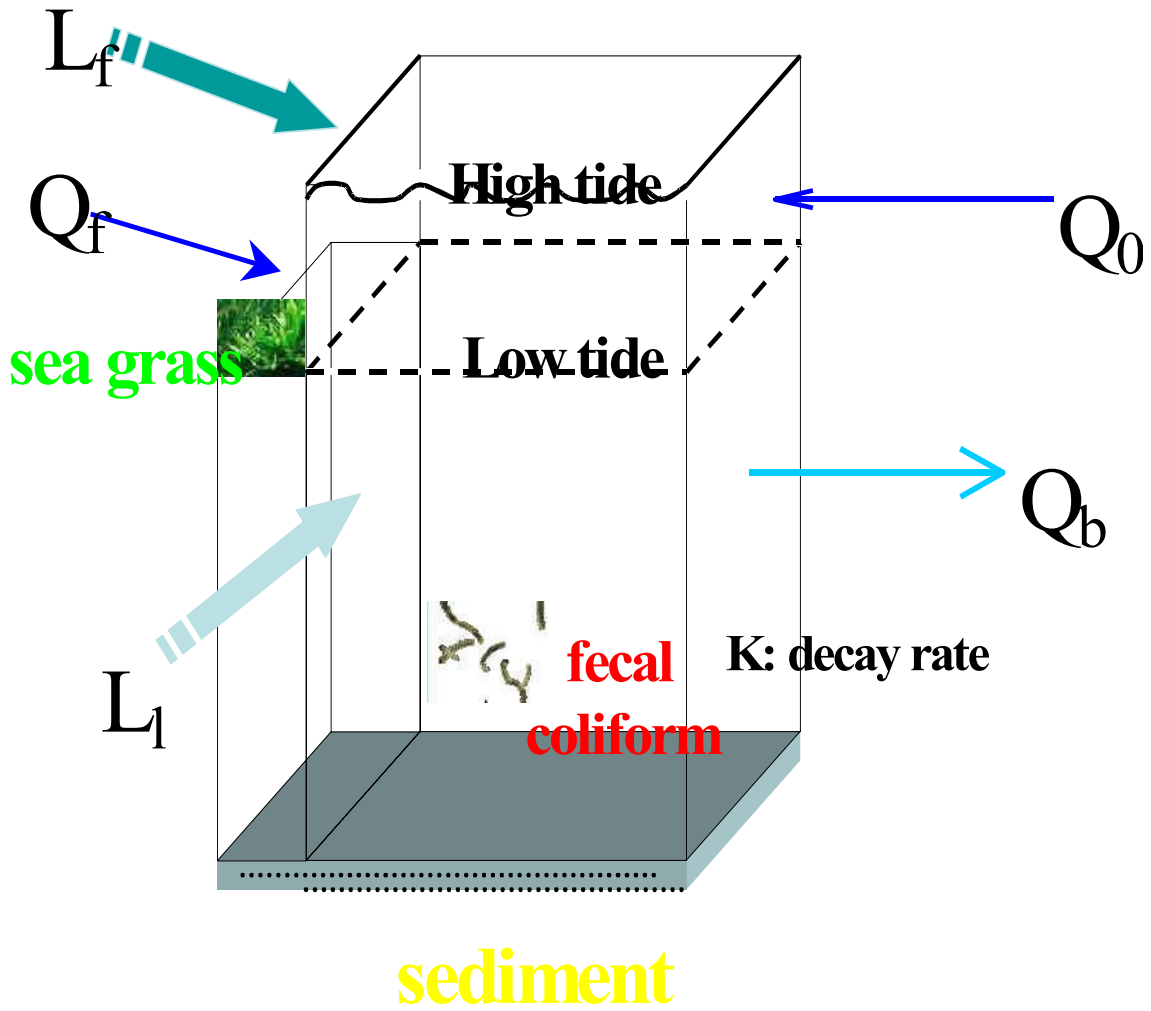
$L_f$

$Q_f$

sea grass

High tide

Low tide

$Q_0$

$Q_b$

fecal coliform

K: decay rate

$L_l$

sediment

Figure A-1: The schematic diagram for the tidal prism model

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**A Tidal Prism Model Calculation for Church Creek (RID 39G)**

Case I: The most recent 5-year fecal coliform median concentration is used.

The median load calculation is illustrated as follows:

$V$ = Mean volume of the embayment = 1165792.2($m^3$)
$k$ = Fecal coliform decay rate = 0.36($T^{-1}$)
$Q_f$ = Freshwater discharge
    = 3.3645 cfs = 3.3645 × 0.0283×86400×12.42÷24 = 4257.3 ($m^3T^{-1}$)
$Q_0$ = 334462.2 ($m^3T^{-1}$)
$Q_b$ = 338719.5 ($m^3 T^{-1}$)
$C_c$ = water quality criterion = 14 MPN/100ml
$C$ = current fecal coliform 5-year median concentration = 9.1 (MPN/100ml)
$C_0$ = fecal coliform 5-year median outside of the embayment = 9.1 (MPN/100ml)
$T$ = tidal cycle = 12.42 hours
$Cf$ = the unit conversion factor

For allowable calculation, $C_c$ is used as fecal coliform concentration (i.e., 14 MPN/100ml). The fecal coliform concentration at the outside of the embayment also uses 14 MPN/100ml. The allowable load is calculated as follows:

Allowable Load =
$Load = [C_c(Q_b+kV) - Q_0C_0] \times Cf$
    = [14× (338719.5 +0.36×1165792.2) - 334462.2× 14] ×24÷12.42×10000
    = $1.147×10^{11}$

For the current load estimation, the most recent five-year median fecal coliform concentration is used for the calculation. The current load is calculated as follows:

Current condition =
$Load = [C(Q_b + kV) - Q_0C_0] \times Cf$
[(9.1) × (338719.5 +0.36×1165792.2) - 334462.2 × (9.1)] ×24÷12.42×10000
= $7.455×10^{10}$

The load reduction is estimated as follows:

$$\text{Load Reduction} = \frac{\text{Current Load} - \text{Allowable Load}}{\text{Current Load}} \times 100\%$$

$$\text{Load Reduction} = \frac{7.455×10^{10} - 1.147×10^{11}}{7.455×10^{10}} = 0\%$$

**A Tidal Prism Model Calculation for Church Creek (con't.)**

Case II: The most recent 5-year fecal coliform 90th percentile concentration is used.

The 90th percentile load calculation is illustrated as follows:

$V$ = Mean volume of the embayment = 1165792.2 $(m^3)$
$k$ = Fecal coliform decay rate = 0.36 $(T^{-1})$
$Q_f$= Freshwater discharge
    = 3.3645 cfs = $3.3645 \times 0.0283 \times 86400 \times 12.42 \div 24 = 4257.3$ $(m^3T^{-1})$
$Q_0 = 334462.2$ $(m^3T^{-1})$
$Q_b = 338719.5$ $(m^3\ T^{-1})$
$C_c$ = water quality standard = 49 MPN/100ml
$C$ = current fecal coliform 5-year 90th percentile concentration = 158.5 (MPN/100ml)
$C_0$ = fecal coliform 5-year 90th percentile at the outside of the embayment
    = 158.5 (MPN/100ml)
$T$ = tidal cycle = 12.42 hours
$Cf$ = the unit conversion factor

For allowable calculation, $C_c$ is used as fecal coliform concentration (i.e., 49 MPN/100ml). The fecal coliform concentration at the outside of the embayment also uses 49 MPN/100ml. The allowable load is calculated as follows:

Allowable Load =
$Load = [C_c(Q_b + kV) - Q_0C_0] \times Cf$
$= [49 \times (338719.5 + 0.36 \times 1165792.2) - 334462.2 \times 49] \times 24 \div 12.42 \times 10000$
$= 4.014 \times 10^{11}$

For the current load estimation, the most recent five-year 90th percentile fecal coliform concentration is used for the calculation. The current load is calculated as follows:

Current condition =
$Load = [C(Q_b + kV) - Q_0C_0] \times Cf$
$[(158.5) \times (338719.5 + 0.36 \times 1165792.2) - 334462.2 \times (158.5)] \times 24 \div 12.42 \times 10000$
$= 1.298 \times 10^{12}$

The load reduction is estimated as follows:

$$\textbf{Load Reduction} = \frac{\textbf{Current Load} - \textbf{Allowable Load}}{\textbf{Current Load}} \times 100\%$$

$$\text{Load Reduction} = \frac{1.298 \times 10^{12} - 4.014 \times 10^{11}}{1.298 \times 10^{12}} = 69.09\%$$

## Appendix B

**Nonpoint Source Assessment**

Nonpoint sources of fecal coliform bacteria do not have one discharge point but occur over the entire length of a stream or waterbody. There are many types of nonpoint sources in watersheds discharging to the restricted shellfish harvesting areas. The possible introductions of fecal coliform bacteria to the land surface are through the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife. As the runoff occurs during rain events, surface runoff transports water and fecal coliform over the land surface and discharges to the restricted shellfish harvesting area. The deposition of non-human fecal coliform directly to the restricted shellfish area occurs when livestock or wildlife have direct access to the waterbody. Nonpoint source contributions to the bacterial levels from human activities generally arise from failing septic systems and their associated drain fields as well as through pollution from recreation vessel discharges. The transport of fecal coliform from land surface to the restricted shellfish harvesting area is dictated by the hydrology, soil type, land use, and topography of the watershed.

In order to determine the sources of fecal coliform contribution and reduction needed to achieve water quality criteria, and to allocate fecal coliform load among these sources, it is necessary to identify all existing sources. The nonpoint source assessment was conducted using available data collected in the watershed. Multiple data sources were used to determine the potential sources of the fecal coliform load from the watershed. The data used for source assessment are:

1. Land use data of 2000 Maryland Department of Planning (MDP) land use/land cover data
2. Livestock inventory by 8-digit Hydrologic Unit Code (Maryland States Soil Conservation Committee (MSSCC); USDA, 1997; MASS, 2002a; MASS, 2002b; Brodie and Lawrence, 1996)
3. GIS 2000 Census of Human population (MDP)
4. Pet survey results from The Center for Watershed Protection (Swann, 1999)
5. Fecal coliform monitoring data (MDE Shellfish Certification Division)
6. The shoreline sanitary survey data (MDE Shellfish Certification Division)
7. Stream GIS coverage (EPA, 1994)
8. Septic GIS Coverage (MDP, 2003)
9. Wildlife population (Maryland DNR, 2003)

In the Little Choptank River basin, wildlife contributions, both mammalian and avian, are natural conditions and may represent a background level of bacterial loading. Livestock contributions, such as those from mammalian and avian livestock, mainly result from surface runoff. Pet contributions usually occur through runoff from streets and land. Since there are no direct point source discharges to the embayment and there is a lack of information available for the discharge from boats, it is assumed that human loading results from failures in septic waste treatment systems. The major nonpoint source contributions assessed for restricted shellfish areas in the Little Choptank River are summarized in Table B-1. The potential nonpoint sources were grouped into four categories: wildlife; human; pets; and livestock. Due to insufficient data

sources, the source assessment method does not account for boat discharge, resuspension from bottom sediment, and the potential for regrowth of fecal coliform in the embayment.

### Table B-1:  Summary of Nonpoint Sources

| Category | Source |
|---|---|
| Wildlife | Beaver, deer, goose, duck, muskrat, raccoon and wild turkey |
| Human | Septic |
| Pets | Dog |
| Livestock | cattle, sheep, chicken, and horse |

## A.      Wildlife Contributions

In general it is assumed that the wildlife species existent in the watershed include beaver, deer, goose, duck, muskrat, raccoon and wild turkey.  Fecal coliform from wildlife can be from excretion on land that is subject to runoff or direct deposition into the stream. Wildlife populations within the watershed were estimated based on a combination of information from the Maryland DNR Wildlife and Heritage Service and from habitat information listed in Virginia bacteria TMDL report (VA DEQ, 2002).  Habitat density results were reviewed by the Maryland Department of Natural Resources, and are listed in Table B-2.

### Table B-2:  Wildlife Habitat and Densities

| Wildlife Type | Population Density | Habitat Requirements |
|---|---|---|
| Beaver[1] | 4.8 animals/ mile of stream | Tidal and non-tidal regions |
| Deer[2] | 0.047 animals/acre | Entire watershed |
| Goose[2] | 0.087 animals/acre | Entire watershed |
| Duck[2] | 0.039 animals/acre | Entire watershed |
| Muskrat[1] | 2.75 animals/acre | Within 66 feet of streams and ponds |
| Raccoon[1] | 0.07 animals/acre | Within 600 feet of streams and ponds |
| Wild Turkey[1] | 0.01 animals/acre | Entire watershed excluding farmsteads and urban |

[1] VA DEQ (2002); [2] MD DNR (2003)

The habitat areas for each species were determined using ArcView GIS with the 2000 MDP land use data and EPA reach coverage in the watershed.  The GIS tool was applied to the land use coverage to create a habitat area according to Table B-2.  For the deer, goose and duck estimates the entire watershed was used because the density estimates were developed using watershed area as the ratio estimator. Wildlife populations were obtained by applying assumed wildlife densities to these extracted areas.  The populations of the wildlife were obtained by applying density factors to estimated habitat areas.  The fecal coliform contributions were estimated based on the estimated number of wildlife and fecal coliform production rates, which is listed in Table B-3.  To obtain the total wildlife contribution, population density is multiplied by the applicable acreage or stream mile and that product is multiplied by fecal coliform production rates for each animal.

**Table B-3: Wildlife Fecal Coliform Production Rates**

| Source | Fecal Coliform Production (counts/animal/day) |
|---|---|
| Beaver[1] | 2.50E+08 |
| Deer[1] | 5.00E+08 |
| Goose[2] | 2.43E+09 |
| Duck[1] | 2.43E+09 |
| Muskrat[3] | 3.40E+07 |
| Raccoon[3] | 1.00E+09 |
| Wild turkey[4] | 9.30E+07 |

[1]USEPA (2000); [2]Use duck rate (USEPA, 2000);
[3]Kator and Rhodes (1996); [4]ASAE (1998)

## B.    Human Contributions

Human loading can result from failures in septic waste treatment systems or through pollution from recreation vessel discharges in the identified restricted shellfish harvesting areas. Since the majority of the area near the receiving waters consists of low-lying, poorly drained land, it is assumed that the failing of a septic system is a direct load contribution from humans. The estimation of human contribution is based on human population, properties, the number of septic systems in the watershed, and an estimated septic system failure rate.

The human population and the number of households were estimated from the GIS 2000 Census Block that includes the Church Creek watershed. Since the Church Creek subwatershed is a sub-area of the Census Block, the GIS tool was used to extract the areas from the 2000 Census Block within the subwatershed of Church Creek. The percentage of the subwatershed area relative to the total area of the 2000 Census Block was calculated. This percentage was applied to partition the total census block population and number of households to proportion the population within the area of the subwatershed. The results are shown in Table B-4, along with the total census block number of septic systems for this area.

**Table B-4: Proportional Population, Households, Septics and Sewer Coverage in the Church Creek Basin**

| RID | Area Name | Proportional Population | Proportional Septic Systems | Proportional Households | Public Sewer |
|---|---|---|---|---|---|
| 39G | Church Creek | 305 | 249 | 134 | Partial |

The distribution of septic systems in the Church Creek Basin is shown in Figure B-1. Based on GIS property coverage, a point is assumed to represent a septic system. The total number of septic systems in the watershed can be estimated based on total points in the GIS property coverage. The estimated total number of septic systems exceeds the estimated number of households in the area; therefore, the estimated number of households is used as the total septic in the area.

It is assumed that the human contribution is attributed to septic systems. The human contribution to the restricted shellfish harvesting areas was calculated using the number of septic systems, the average number of people using the septic systems, and the failure rate of the septic systems. The estimated fecal coliform loading from humans is calculated as follows:

$$Load = P \ S \ F_r \ C \ Q \ C_V$$

Where
P = number of people per septic system
S = number of septic systems in the restricted area
$F_r$ = failure rate of septic systems
C = fecal coliform concentration of wastewater
Q = daily discharge of wastewater per person
$C_V$ = unit conversion factor (37.854)

The number of people using each septic system is estimated by the ratio of the population to the number of septic systems. According to shoreline sanitary survey data in the Little Choptank River watershed, an estimated failing rate of 3 % was used to estimate the total number of failing septic systems. This rate is in the same range as that in the upper Chesapeake Bay (De Walle, 1981; EPA Stormwater Management Center). It was assumed that wastewater for each person was 70 gallons per day with a fecal coliform concentration of $1 \times 10^5$ most probable number (MPN)/100ml. The estimated load due to failures of septic systems is about 2%.
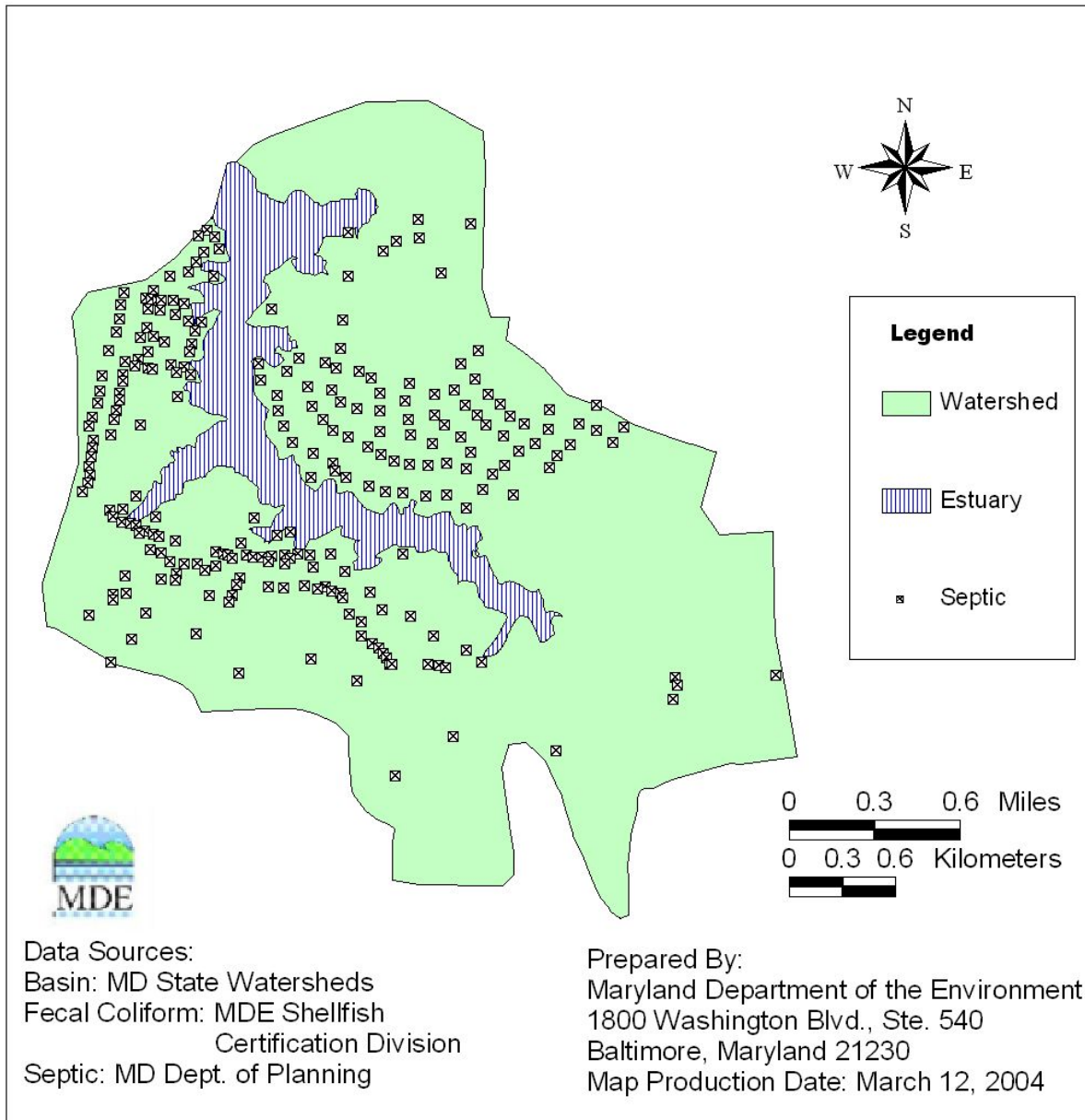
**Figure B-1: Distribution of Septic Systems in the Church Creek Basin**

## C.    Pet Contributions

Pet contributions usually occur through runoff from either an urban or a low-density residential area.  Dogs are the only domestic pets assumed to contribute fecal coliform.  Dog license information can be obtained from the county, however, these data will not include feral or unlicensed pets.  This is likely to cause an underestimation of the total population.  Therefore, the dog population around Church Creek was estimated based on the number of households (see Table B-4).  According to a survey conducted by the Center for Watershed Protection of Chesapeake Bay residents, about 41% of the households own a dog.  Of these dog owners, only about 56% walk their dogs, and of that group only 59% clean up most of the time (i.e., 41% do not).  The estimated total load available for wash off is 23% (i.e., 56%×41%). The fecal coliform contribution from the dog population was estimated using a production rate of $5 \times 10^9$ counts/dog/day (EPA, 2000).   Using the estimated populations from Table B-4, estimated fecal coliform loading from dogs is calculated as follows:

$$LOADING_{dog} = P \ R_1 \ R_2 \ R_3 \ PR_{dog}$$

where:
P = number of households in Church Creek area
$R_1$ = ratio of dogs per household in this region
$R_2$ = percent of owners that walk their dogs
$R_3$ = percent of walked dogs contributing fecal matter
$PR_{dog}$ = average fecal coliform production rate for dogs

## D.    Livestock Contributions

The fecal coliform contribution from livestock is through the manure spreading processes and direct deposition during grazing.  This contribution was estimated based on land use data and the Maryland livestock census data  (Brodie and Lawrence, 1996; USDA, 1997; MASS, 2002).  Animal ratio estimators for the 8-digit watersheds were developed based on the finest resolution of animal counts available – statewide, region or county.  These Maryland 8-digit watershed livestock animal counts were then proportioned to the sub-watersheds using the procedure outlined in Figure B-2.  The fecal coliform load was estimated based on the total number of livestock and the fecal coliform production rates.
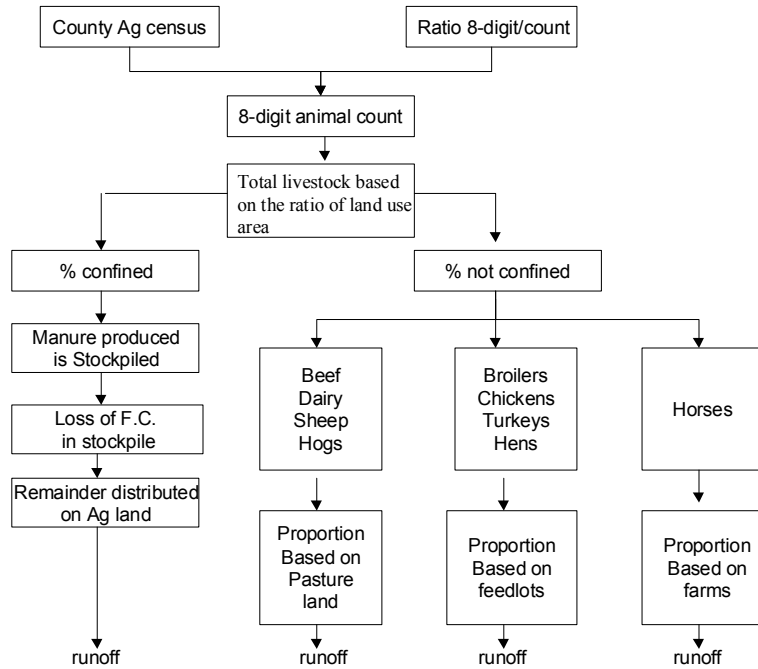
**Figure B-2: Diagram to Illustrate Procedure Used to Estimate Fecal Coliform Production from Estimated Livestock Population**

Fecal coliform production rates used to estimate loading are listed in Table B-5. The estimated fecal coliform produced by animals was divided into manure spreading and direct deposition, depending on the percent of time they were confined. The percent of time livestock was confined is listed in Table B-6. The estimated percentage of manure available for wash off is about 40% (VIMS, 2004). For chickens, however, only about 10% is available for wash off (Woods, 2004). Therefore, fecal coliform decay is also considered in the estimation of fecal coliform production. The percent of fecal coliform available for wash off from manure spreading in the field is also listed in Table B-6.

**Table B-5: Livestock Fecal Coliform Production Rates**

| Source | Fecal Coliform Production (counts/animal/day) |
|---|---|
| Dairy | 1.01E+11 |
| Beef | 1.20E+10 |
| Horses | 4.20E+08 |
| Sheep | 1.20E+10 |
| Broilers | 1.36E+08 |
| Turkeys | 9.30E+07 |
| Chickens | 1.36E+08 |
| Layers | 1.36E+08 |
| Hogs | 1.08E+10 |

US EPA (2000)

**Table B-6: Percent of Time Livestock is Confined**

| Livestock | Percent of time confined | Percent Manure Available For Wash off |
|---|---|---|
| Dairy | 80.0% | 40.0% |
| Beef | 20.0% | 40.0% |
| Horses | 50.0% | 40.0% |
| Sheep | 50.0% | 40.0% |
| Broilers | 85.0% | 10.0% |
| Turkeys | 85.0% | 10.0% |
| Chickens | 85.0% | 10.0% |
| Layers | 85.0% | 10.0% |
| Hogs | 100.0% | 40.0% |

US EPA (1996); Woods (2004)

## E. Nonpoint Source Summary

The distribution of these non-point source loads is listed in Table 2.4.7, along with counts/day for each loading. The BST data will be used to further confirm the source distribution when it becomes available.

**Table B-7:  Distribution of Fecal Coliform Source Loads in the Church Creek Basin**

| Fecal Coliform Source | Loading Counts/day | Loading Percent |
|---|---|---|
| Livestock | 1.22E+10 | 2.8% |
| Pets | 6.32E+10 | 14.2% |
| Human | 1.45E+09 | 0.3% |
| Wildlife | 3.68E+11 | 82.7% |
| Total | 4.45E+11 | 100.0% |