TRAIL CREEK ESCHERICHIA COLI TMDL REPORT

PREPARED FOR:

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
OFFICE OF WATER QUALITY
2525 NORTH SHADELAND AVENUE
INDIANAPOLIS, INDIANA 46219

PREPARED BY:

TRIAD ENGINEERING INCORPORATED
325 EAST CHICAGO STREET
MILWAUKEE, WI 53202

In association with

HYDROQUAL, INC.
1200 MACARTHUR BLVD
MAWWAH, NJ 07430

and

T N & ASSOCIATES, INC.
1033 N. MAYFAIR ROAD
WAUWATOSA, WI 53226

TRIAD ENGINEERING INCORPORATED
PROJECT NO. I023557

DECEMBER 2003

TRAIL CREEK ESCHERICHIA COLI TMDL REPORT

PREPARED FOR:

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
OFFICE OF WATER QUALITY
2525 NORTH SHADELAND AVENUE
INDIANAPOLIS, INDIANA 46219

TRIAD ENGINEERING INCORPORATED
PROJECT NO. I023557

DECEMBER 2003

Tina A. Reese	Andrew J. Thuman, P.E.
Project Manager	Water Quality Modeler

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

GENERAL INFORMATION
TRAIL CREEK ESCHERICHIA COLI TMDL REPORT

SITE NAME:	Trail Creek Watershed
ARN NO.:	A305-1-01-276-1-0
303d ID No:	#37, 14 digit HUC 04040001070030
GENERAL LOCATION:	Michigan City, Indiana
REGULATORY CONTACT:	Ms. Jennifer Hutchison
MAILING ADDRESS:	Indiana Department of Environmental Management Office of Water Quality 100 North Senate Avenue P.O. Box 6015 (Shadeland) Indianapolis, IN 46206
TELEPHONE:	(317)-308-3142
FACSIMILE:	(317)-308-3219
EMAIL:	jhutchis@dem.state.in.us
CONSULTANTS:	Triad Engineering Incorporated
ADDRESS:	325 East Chicago Street Milwaukee, WI 53202
CONTACTS:	Ms. Tina A. Reese/Project Manager Mr. Willie Gonwa/Quality Assurance Manager
TELEPHONE: FACSIMILE: EMAIL:	(414) 291-8840 (414) 291-8841 tina.reese@triadengineering.com willie.gonwa@triadengineering.com
	Mr. Andrew J. Thuman, P.E./Water Quality Modeler (HydroQual, Inc.)
TELEPHONE: FACSIMILE: EMAIL:	(201) 529-5151 (201) 529-5728 athuman@hydroqual.com

LIST OF ACRONYMS

BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BMP	best management practices
BOD_u	Ultimate Biochemical Oxygen Demand
CDs	Compact Disks
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu/100 mL	colony forming units per 100 milliliter
cm	centimeters
COOPID	Cooperative ID
CSO	combined sewer overflow
DMR	Discharge Monitoring Report
E	East
E. coli	Escherichia coli
ERM	Environmental Resources Management
ESRI	Environmental Systems Research Institute
ET	evapotranspiration
EUTRO	WASP Model for dissolved oxygen and eutrophication
FOCS	Field Office Computing System
GIS	Geographic Information System
g/m^3-day	gallons per cubic meter per day
GPS	Global Positioning System
GWLF	General Water Loading Functions
ha	hectacres
hr	hour
HydroQual	HydroQual, Inc.
IAC	Indiana Administrative Code
IDEM	Indiana Department of Environmental Management
LA	Load Allocation for non-point sources
LTCP	Long Term Control Plan
OWQ	Office of Water Quality
M	main
m/day	meters per day
m^2/day	meters per day
mg	million gallons
mgd	million gallons per day
mg/L	milligrams per liter
MHP	Mobile Home Park
mL	milliliters
MOS	margin of safety
NIRPC	Northwestern Indiana Regional Planning Commission
NOAA	National Oceanic and Atmospheric Administration
NCDC	National Climatic Data Center
No.	number
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service

PCBs	polychlorinated biphenyls
PCS	Permit Compliance System
SSURGO	Soil Survey Geographic
STORET	Storage and Retrieval System
TMDL	total maximum daily load
TN	T N & Associates, Inc.
Triad	Triad Engineering Incorporated
USDA	United States Department of Agriculture
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WASP	Water Quality Analysis Simulation Program
W	West
WLA	Wasteload Allocation for Point Sources
WWTP	Waste Water Treatment Plant

EXECUTIVE SUMMARY

A Total Maximum Daily Load (TMDL) is the total pollutant load from point and nonpoint sources that a water body can assimilate while maintaining its designated use (water quality standards). It also includes an appropriate margin of safety and is expressed below:

$$TMDL = \sum WLA + \sum LA + MOS$$

where: WLA – Wasteload allocation for point sources;
LA – Load allocation for nonpoint sources; and
MOS – Margin of safety (implicit or explicit).

The focus of the TMDL is the reduction of pollutant inputs to a level (or "load") that fully supports the designated use of a given water body. The mechanisms (implementation plan) used to address water quality problems after the TMDL is developed can include a combination of Best Management Practices (BMPs) and/or effluent limits and monitoring required through National Pollutant Discharge Elimination System (NPDES) permits.

Trail Creek has been identified through the 303 (d) listing process as being impaired for the parameter of concern Escherichia Coli (*E. coli).* As a result, the Indiana Department of Environmental Management (IDEM) is required to establish a TMDL generating process and implementation procedure that follows the federal guidelines and regulations.

As required by the USEPA, TMDL projects must identify a quantifiable water quality target for each constituent that causes a body of water to appear on the State of Indiana's 1998 and 2002 303(d) Impaired Waterbodies List (ID#37, 14 digit HUC 04040001070030). The bacterial water quality targets established by the Indiana Water Pollution Control Board (327 IAC 2-1-6 Section 6(d)) for *E. coli* are that concentrations shall not exceed 125 cfu/100 ml as a geometric mean based on not less than five samples equally spaced over a 30-day period nor exceed 235 cfu/100 ml in any one sample in a 30-day period. These water quality standards also include policies regarding the State nondegradation policy applicable to all surface waters of the State (327 IAC 2-1-2). For all waters of the state, existing beneficial uses shall be maintained and protected. No degradation of water quality shall be permitted which would interfere with or become injurious to existing and potential uses.

Potential *E. coli* sources in the Trail Creek watershed originate from both point and nonpoint sources under both dry and wet weather conditions. There are four permitted point sources in the watershed, which include the J.B Gifford Wastewater Treatment Plant (Michigan City), Friendly Acres Mobile Home Park, Autumn Creek Mobile Home Park, and Indian Springs Subdivision. Michigan City does have two combined sewer overflow (CSO) points. However, the City has implemented a *Long Term CSO Control Plan* that includes sewer separation to reduce combined sewers in the District's service areas. The LTCP has been reviewed by IDEM, and Michigan City is currently in the process of responding to their comments. These point source permits require that effluent disinfection occurs during the recreational season (April to October) and year 2000 Discharge Monitoring Reports (DMR) records indicate that each of these point sources are meeting their permit requirements. Therefore, point sources in the Trail Creek watershed are not considered a significant source of *E. coli*.

Nonpoint sources in the watershed are varied and include: agricultural field drainage and runoff, cattle/steer grazing (both in fields and in the creek), failing septic systems, illicit connections and/or urban storm water runoff. These nonpoint sources are a function of rainfall, land use and soil type, but also operate on a relatively continuous basis as exhibited by the observed consistent high levels of *E. coli* throughout the watershed. These more continuous nonpoint sources may be due to cattle/steer grazing in the creek, failing septic systems in close proximity to the creek and/or direct illicit discharges to the creek.

Linking these point and nonpoint source *E. coli* loads was completed with the Trail Creek watershed model, which describes the *E. coli* cause (loads) and effect (concentrations) relationships in the watershed. These cause and effect relationships occur during both dry and wet weather conditions. Development of the TMDL is defined by continued control of point sources (IDEM permitting) and control of nonpoint sources through storm water management plans, best management plans (BMPs) and local cooperation in controlling these sources with the assistance of State watershed grants.

The Trail Creek Watershed model reasonably reproduced observed creek flow and *E. coli* concentrations given the limitations present in both the flow and *E. coli* databases. Although the models are not rigorously calibrated due to lack of acceptable flow and *E. coli* data, the models can be used to assess current conditions and to develop allocation and implementation strategies for Trail Creek. That is, the GWLF and WASP6 models were developed with the best information available at this time and the development of point source wasteload allocations (WLA) and nonpoint source load allocations (LA) for the Trail Creek *E. coli* TMDL is practical and supported by the available data.

Based on the source assessment and watershed modeling, *E. coli* levels in Trail Creek are present during both dry and wet weather conditions and, therefore, low-flow critical conditions are not necessarily appropriate for developing the TMDL. In order to meet the TMDL target concentrations (125 and 235 cfu/100mL), continued operation of the four point sources in the watershed in accordance with their IDEM NPDES permits (125 cfu/100mL monthly geometric mean and 235 cfu/100mL daily maximum) at their permitted effluent flow will meet the WLA component of the *E. coli* TMDL for Trail Creek. Similarly, nonpoint sources in the watershed will need to meet the TMDL target concentrations (125 and 235 cfu/100mL) in order for Trail Creek to be in compliance with State *E. coli* standards.

The required MOS is incorporated into the TMDL analysis implicitly. TMDL rules allow for an explicit Margin of Safety (MOS) (i.e., expressed in the TMDL as a portion of the allocations) or an implicit MOS (i.e., incorporated through conservative assumptions in the analysis). The implicit MOS was used because the die-off rate of *E. coli* was assigned as zero for the allocation model calculations.

In order to investigate the effectiveness of the allocations in meeting the Trail Creek TMDL, continued monitoring in the watershed for *E. coli* is recommended. The monitoring program should be designed to provide good spatial coverage of the watershed, but also be aimed at obtaining data during dry and wet weather conditions. In addition, storm event monitoring should also be completed to better define nonpoint source loadings in the watershed. For the permitted point sources in the watershed, IDEM NPDES permitting and monitoring requirements will provide the necessary reasonable assurance that these sources are not contributing to violations of State *E. coli* standards. For the nonpoint sources, State storm water regulations and land application permits should also provide necessary reasonable assurance for these potential types of nonpoint sources. The other nonpoint sources will need to be monitored locally for implementation of BMPs or in providing access to watershed grants to assist in reducing nonpoint sources to meet the LA developed under this TMDL.

Section 1.0
INTRODUCTION

Triad Engineering Incorporated (Triad), in association with HydroQual, Inc. (HydroQual) and T N & Associates, Inc. (TN), was retained by the Indiana Department of Environmental Management's (IDEM's) Office of Water Quality (OWQ) to provide technical services related to *Escherichia coli (E. coli)* Total Maximum Daily Load (TMDL) development and implementation planning for the Trail Creek watershed (303d ID# 37; 14 digit HUC 04040001070030).

Pursuant to Section 303(d) of the federal Clean Water Act and the U.S. Environmental Protection Agency (USEPA) Water Quality Planning and Management regulations (40 CFR Part 130), states are required to identify waterbodies that do not meet established water quality standards (USEPA, 2001). Watersheds draining to the Great Lakes must also comply with the Great Lakes Initiative (USEPA, 1995), which is an agreement between the USEPA and the Great Lakes states establishing a comprehensive plan (*Final Water Quality Guidance for the Great Lakes System*) to restore the health of the Great Lakes by setting water quality standards for 29 pollutants, including bioaccumulative chemicals of concern, and prohibiting the use of mixing zones for these toxic chemicals. TMDLs must be developed for the Trail Creek watershed and best management practices (BMPs) and other actions implemented in order to bring the waterbodies into compliance. At that time, delisting procedures can be initiated.

A TMDL is the total pollutant load from point and nonpoint sources that a water body can assimilate while maintaining its designated use (water quality standards). It also includes an appropriate margin of safety and is expressed below:

$$TMDL = \sum WLA + \sum LA + MOS$$

where: WLA – Wasteload allocation for point sources;
LA – Load allocation for nonpoint sources; and
MOS – Margin of safety (implicit or explicit).

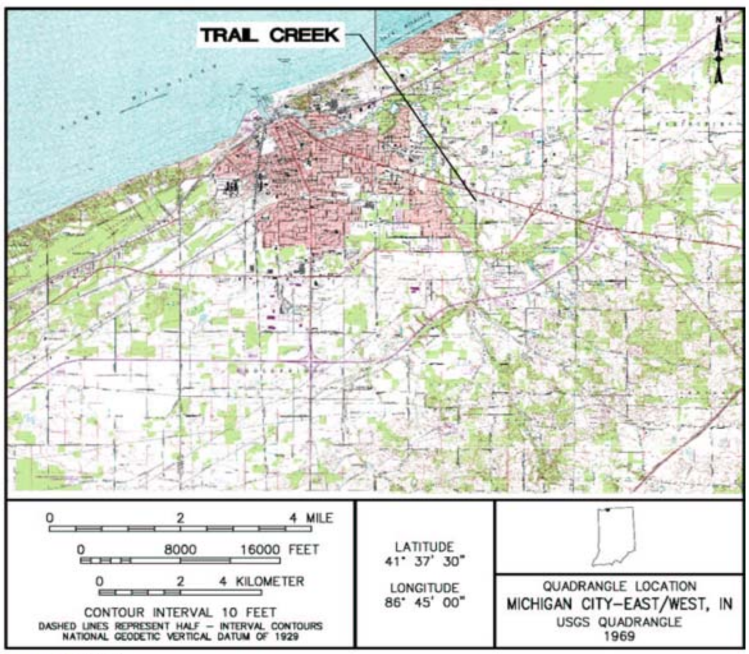
The focus of the TMDL is the reduction of pollutant inputs to a level (or "load") that fully supports the designated use of a given water body. The mechanisms (implementation plan) used to address water quality problems after the TMDL is developed can include a combination of BMPs and/or effluent limits and monitoring required through NPDES permits.

Trail Creek has been identified through the 303 (d) listing process as being impaired for the parameter of concern *E. coli.* As a result, the IDEM is required to establish a TMDL generating process and implementation procedure that follows the federal guidelines and regulations.

Section 2.0
BACKGROUND INFORMATION

2.1 SETTING AND LAND USE

The Trail Creek watershed in LaPorte County (Figure 2-1) is located within the Lake Michigan Basin in northwestern Indiana, one of 12 major watersheds or groups of watersheds entirely or partially within Indiana. According to IDEM (2000), each of the 43 miles of Lake Michigan shoreline within the Lake Michigan Basin fully supports aquatic life. However, the shoreline only partially supports recreational uses due to periodic beach closings caused by elevated levels of *E. coli* bacteria, such as at Michigan City's lakefront park and marina where Trail Creek discharges into Lake Michigan.



TRIAD ENGINEERING INCORPORATED

FIGURE 1
SITE LOCATION AND LOCAL TOPOGRAPHY

The watersheds along the Indiana shore of Lake Michigan include a combination of dense-to-moderate residential, various levels of industrial, major shipping, and recreational land use as well as open water esturarian wetlands (*i.e.*, the Indiana Dunes State Park and the Indiana Dunes National Lakeshore). The Trail Creek watershed (Figure 2-2; approximately 37,824 acres) is comprised of three sub-watersheds (the Main, East, and West Branches) that include various percentages of developed, agricultural, forested, water (reservoir), and transitional (*e.g.*, forested/agricultural grading into developed, quarries) land uses. The estimated sizes (in acres) and percentages of land use for each Trail Creek sub-watershed are detailed in Table 2-1 below.

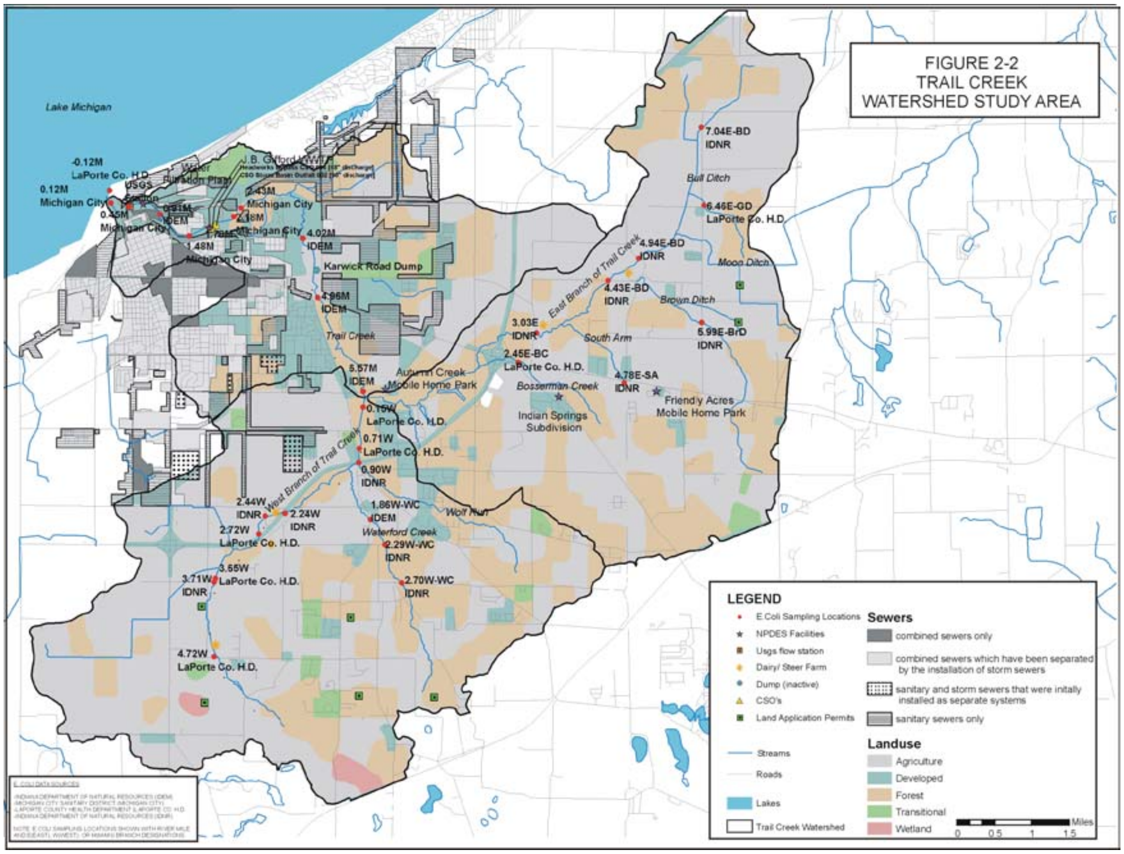


Table 2-1 Land Use in the Trail Creek Watershed

SUB-WATERSHED (total acres)	Agriculture acres / % land use	Forest acres / % land use	Transitional acres / % land use	Developed acres / % land use
East Branch (13,875)	8,115 / 58.4%	4,987 / 35.9%	89 / 0.64%	684 / 4.9%
Main Branch (8,595)	2,311 / 26.9%	1,853 / 21.6%	358 / 4.2%	4,072 / 47.4%
West Branch (15,194)	9,205 / 60.6%	4,126 / 27.6%	398 / 2.62%	1,465 / 9.6%

2.2 GENERAL CHARACTERISTICS OF THE TRAIL CREEK WATERSHED

The Trail Creek watershed drains approximately 59.1 square miles within LaPorte County (NIRPC, 1993) and has numerous, relatively small tributaries, lake and pond overflow, and spring source headwaters. Tributaries include Waterford Creek and Wolf Run in the West Branch and Bull Ditch, Brown Ditch, South Arm, Bosserman Creek, and Moon Ditch in the East Branch. Contributing lakes include Dingler Lake, Ohms Lake, and Browdy Lake. According to the Northwestern Indiana Regional Planning Commission (NIRPC, 1993), Trail Creek flows through 14.5 linear miles, has a hydraulic gradient of 6.4 feet per mile upstream from Springland Avenue in Michigan City, and is one of the few streams in Indiana that drain into Lake Michigan.

As stated in NIRPC (1993), soils within the Trail Creek basin are comprised of mostly loose sandy soils of beach deposit of eolian origin to sandy and loamy soils of lacustrine origin. As a result of their high sand content, basin soils are highly transmissive with good drainage despite nearly level to flat topography with slopes ranging between 0 and 2% (United States Department of Agriculture, 1978). The dominant soil types directly adjacent to Trail Creek include sandy/silty clay, sandy silt, or sandy loam, which are poorly to moderately well-drained soils (NIRPC, 1993).

At one time, there were approximately 5,400 acres of wetlands present within the Trail Creek watershed with 4% being water bodies (NIRPC, 1993). Wetlands provide flood control and maintain water quality. Over the last 10 years, the disappearance of wetlands as a result of development, agriculture, and/or reclassification has become a national trend. Trail Creek is also designated a salmonid stream, and, therefore, requires a more stringent set of water quality standards than for general use streams (NIRPC, 1993).

Trail Creek stream flow (based on U.S. Geological Survey measurements near the Trail Creek discharge to Lake Michigan [Gage No. 04095300]; Hydrologic Unit Code 04040001) ranged between approximately 84 and 294 cubic feet per second (cfs) in 1998 with an average of 131 cfs; between 67 and 318 cfs in 1999 with an average of 125 cfs; between 45 and 396 cfs in 2000 with an average of 114 cfs; and between approximately 34 and 144 cfs in 2001 with an average of 93 cfs.

Trail Creek is subject to frequent flow reversals at the mouth due to the natural seiche action of Lake Michigan (NIRPC, 1993). The flow reversals result in water level fluctuations of one to two inches according to Environmental Resources Management (ERM, 1992). Based on written correspondence with the U.S. Geological Survey (USGS, 2002), the backwater effect from Lake Michigan might extend at least 2 miles upstream due to the channel thalweg gradient being so gradual. In addition, the backwater effect from Lake Michigan may not be affected by lake level. Flow reversals may extend some distance upstream also.

2.3 PRESENT AND FUTURE GROWTH TRENDS IN AREA

Based on U.S. Census Bureau data (2000), the population of Michigan City is 32,900 and has decreased 3.2 % from 1990 to 2000. The population of the Town of Trail Creek is 2,296 and has decreased 7% from 1990 to 2000. The population of LaPorte County has increased 2.8% from 107,066 in 1990 to 110,106 in 2000. For the purposes of this study, the population within the Trail Creek watershed is assumed to remain relatively constant in the near future.

2.4 POLLUTANTS OF CONCERN AND LIST STATUS

According to the NIRPC (1993), Trail Creek has historically been associated with numerous water quality problems caused by inadequately treated sewage, combined sewer overflows (CSOs), industrial discharges, and chemical spills, which have also resulted in periodic fish kills. Trail Creek sampling for bacterial contamination has typically been performed by IDEM, the LaPorte County Health Department, and the Michigan City Sanitary District. In general, water quality data provided by these agencies from 1998 through 2001 show increasing *E. coli* concentrations ranging between 0.5 and 15,000 colony forming units per 100 milliliters (cfu/100 mL) in 1998 (average of 765 cfu/100 mL), 0.5 and 15,000 cfu/100 mL in 1999 (average of 839 cfu/100 mL), 0.5 and 29,000 cfu/100 mL in 2000 (average of 1,233 cfu/100mL), and 120 and 203,000 cfu/100 mL in 2001 (average of 6,642 cfu/100mL). The bacterial water quality target established by the Indiana Water Pollution Control Board (327 IAC 2-1-6 Section 6(d)) for *E. coli* is 125 cfu/100 mL as a geometric mean based on not less than five samples equally spaced over a 30-day period and 235 cfu/100 mL in any one sample in a 30-day period.

Section 303(d) of the Clean Water Act requires states to identify waters that do not or are not expected to meet applicable water quality standards with federal technology based standards alone. States are also required to develop a priority ranking for these waters taking into account the severity of the pollution and the designated uses of the waters. Once the listing and ranking of the waters is completed, the states are required to develop TMDLs for these waters in order to achieve compliance with the water quality standards. Trail Creek was included in IDEM's *2002 303(d) List of Impaired Waterbodies with 15 Year Schedule* (original order) with a priority (List# 37, 14 digit HUC 04040001070030) and severity (medium) ranking for the parameters of concern polychlorinated biphenyls (PCBs) and mercury (fish consumption advisory for both; air pollution is suspected source), cyanide, and *E. coli*. This TMDL addresses the E.Coli impairment for Trail Creek only and impairments caused by other parameters will be completed at a later date. Indiana's 2002 303(d) list was approved by the U.S. EPA on September 30, 2003.

Trail Creek was originally listed with a TMDL Development Schedule between the years 2000 and 2004. Recent IDEM guidance (IDEM, 2002) indicates a 2003 final TMDL date. The TMDL Development Schedule corresponds with IDEM's basin-rotation monitoring schedule to take advantage of all available resources for TMDL development. Listed dates are suggestions based on current water quality monitoring strategy and may change depending on public input, available resources, or as different methods for TMDL development are perfected.

Section 3.0
APPLICABLE WATER QUALITY STANDARDS AND TARGETS

As required by the USEPA, TMDL projects must identify a quantifiable water quality target for each constituent that causes a body of water to appear on the State of Indiana's 303(d) Impaired Waterbodies List. Identifying a water quality target for a specific water body will depend on the nature of impairment and applicable water quality standards. The following applicable uses may apply for the Trail Creek watershed as designated by the Indiana Water Pollution Control Board (327 IAC 2-1-3):

- Surface waters of the State are designated for full-body contact recreation during the recreation season (April through October);

- All waters, except limited use waters, will be capable of supporting a well-balanced, warm water aquatic community;

As this TMDL addresses E. Coli impairments only, the bacterial water quality targets established by the Indiana Water Pollution Control Board (327 IAC 2-1-6 Section 6(d)) for *E. coli* using membrane filter count are the following numeric standards:

- Concentrations shall not exceed 125 cfu/100 ml as a geometric mean based on not less than five samples equally spaced over a 30-day period nor exceed 235 cfu/100 ml in any one sample in a 30-day period.

These water quality standards also include policies regarding the State nondegradation policy applicable to all surface waters of the State (327 IAC 2-1-2) as follows:

- For all waters of the state, existing beneficial uses shall be maintained and protected. No degradation of water quality shall be permitted which would interfere with or become injurious to existing and potential uses; and

- All waters whose existing quality exceeds the standards as of February 17, 1977, shall be maintained in their present high quality unless it is demonstrated that limited degradation of such waters is justifiable based on necessary economic or social factors and will not interfere with any beneficial uses.

Section 4.0
SOURCE IDENTIFICATION

4.1 INFORMATION SOURCES

Existing sources of water quality data were assembled and stored in Microsoft Access for use in the desktop geographic information system (GIS) and mapping software ArcView 8.3 (ESRI, 2003), which provided data visualization, query, analysis and integration along with the ability to create an edit geographic data.

Existing sources of water quality data were obtained from a variety of sources and included the following.

- USEPA's Storage and Retrieval System (STORET),
- USGS databases,
- IDEM OWQ,
- Michigan City Wastewater Treatment Plant (WWTP), and
- Interagency Task Force on *E.coli* - The Interagency Task Force data was a compilation of data collected by the IDEM, the LaPorte County Health Department, and the Michigan City Sanitary District.

A pollutant source inventory was compiled and included data obtained from federal, state and local databases. The source inventory is summarized below and includes:

- IDEM OWQ – NPDES permitted facilities, solid waste permitted facilities, landfill permits, permitted solid waste compost facilities, land application permits and various reports and studies (*Trail Creek Watershed Management Plan* and *Water Quality Assessment for the Development of TMDLs for E.coli and Cyanide in Trail Creek, Michigan City, LaPorte County*),
- USEPA - Permit Compliance System (PCS) database, and Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) BASINS,
- United States Fish and Wildlife - Wildlife population estimates,
- LaPorte County Health Department - Onsite sewage disposal permits and septic system information, sewage handling permits, biosolids use facilities permits and the Final Report; *Town of Trail Creek Sanitary Survey*, and
- Michigan City Sanitary District – Drawings of the Michigan City sewer collection system, precipitation, outfall location and other related data,

Watershed characteristics were compiled from the following databases:

- USGS hydrologic and stream flow gauging data,
- USGS daily mean flow data for Trail Creek stations 4095380 (1994-2001) and 4095300 (1969-1994),
- LaPorte County Water Resources website, http://pasture.ecn.purdue.edu/~frankenb/watershed/county/laporte/index.html;
- National Resource Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database - Soil survey information, and
- NIRPC - Existing GIS data layer coverage, subject listings and related internet sites, http://www.iun.edu/~lib/GIS_resources.htm. Access for geographic data and services through a global network of publishers is found using the link http://www.geographynetwork.com/home.html.

Agricultural and urban best management practices (BMP) utilized in the watershed were also researched and included the following:

- Agricultural Best Management Practices (BMP) information was obtained from the federal NRCS Field Office Computing System (FOCS) and the State Agricultural BMP Tracking Program, as well as local Soil and Water Conservation District personnel. IDEM OWQ also provided data regarding their Nutrient Management Plan.
- Urban BMP Information was obtained from existing community storm water management programs and ordinances, including location and type of permitted storm water management facilities; municipal Phase I/II storm water permits; and identification of subdivisions constructed prior to adoption of local ordinances.

A detailed listing of sources for water quality data, pollutant source inventory, watershed characteristics and BMPs is documented in the Trail Creek Data Report (Triad, 2002). Based on analyses of this data, potential sources of E. Coli loading to Trail Creek are related to:

- NPDES permitted facilities;
- Failing or improperly operated septic systems;
- Cattle grazing and deposition of fecal matter both on the fields and directly to the Creek;
- Urban storm water runoff; and
- Illegal sewer connections to stormwater or drainage systems.

To the extent feasible, data are correlated to Global Positioning System (GPS) coordinates and conform to IDEM OWQ GPS procedures and requirements.

Section 5.0
POLLUTANT LOAD MODELING

Watershed modeling is the quantitative component of a TMDL. The watershed model couples a landside and receiving stream model, which was utilized to determine the response of a system to a causative factor, such as point or nonpoint source loadings and the subsequent instream concentrations. These quantitative modeling frameworks are useful tools for assessing the instream environmental conditions due to point and nonpoint source discharges, as well as to assess the role of remedial programs aimed at correcting environmental pollution problems. The tasks associated with watershed modeling in Trail Creek included: the assessment of current conditions and estimating *E. coli* concentrations contributed from various sources within the watershed; reproducing existing or past watershed conditions (model calibration and validation) and determining the Trail Creek watershed TMDL; projecting future conditions due to *E. coli* bacteria load reduction measures; and evaluating the value of alternative *E. coli* bacteria loading scenarios or assessing the effectiveness of BMPs.

5.1 MODELING OBJECTIVES

The Trail Creek Watershed model needed to be capable of analyzing watershed runoff, associated *E. coli* loadings and the ultimate fate and transport of *E. coli* in the receiving waters of the watershed. This capability was required to provide IDEM with a technically defensible watershed model for:

- Identifying the loading capacity of Trail Creek for *E. coli* bacteria at critical environmental conditions;
- Identifying cause and effect relationships between sources and Trail Creek *E. coli* levels for determining attainment with State water quality standards;
- Developing, testing and evaluating potential *E. coli* allocations, which includes wasteload allocations (WLA) for point sources, load allocations for nonpoint sources (LA) and an appropriate margin of safety (MOS);
- Testing and evaluating implementation alternatives compatible with the State's NPDES Permitting and Compliance Programs.

The selected watershed model General Water Loading Functions (GWLF) and receiving water model Water Quality Analysis Simulation Program (WASP) were both chosen to provide the necessary components to properly represent *E. coli* loading and fate and transport in the Trail Creek watershed. That is, the models were capable of relating rainfall runoff and groundwater sources (nonpoint sources), point sources and instream fate and transport to *E. coli* levels in the Trail Creek watershed (cause and effect relationships). After calibration, the models were suitable for determining the loading capacity of Trail Creek for developing load allocations and testing implementation alternatives, which will be useful in State permitting and compliance programs.

5.2 TRAIL CREEK WATERSHED MODEL

The Trail Creek watershed model is based on two public domain models: a watershed model BasinSim 1.0 (GWLF), and a receiving water quality model WASP6. BasinSim 1.0 is a product of National Oceanic and Atmospheric Administration (NOAA) and WASP6 is distributed by the USEPA. BasinSim 1.0 was used to compute time variable runoff quantity in the Trail Creek watershed due to factors such as rainfall, land use/cover and soil type. The WASP6 model was used to simulate water quality in the major branches of the watershed due to watershed loadings, dilution and chemical/physical/biological reactions. The calculated runoff flow from the BasinSim 1.0 model was used as input into the WASP6 model to perform water transport calculations. The Trail Creek watershed was divided into three sub-watersheds: an East Branch, West Branch, and Main Branch. The BasinSim 1.0 model simulates daily stream flows in the three sub-watersheds with the calculated total sub-watershed flow distributed evenly along the branch length as the runoff inflow in the WASP6 model.

In an effort to identify a time period for the model calibration, a summary table of annual average flow, total annual rainfall, and *E. coli* concentration data from 1998 to 2001 is presented in Table 5-1. Year 2000 was selected as the calibration year because there were more sampling stations and samples of *E. coli* data for this year than the other 3 years. However, since the BasinSim 1.0 model uses a hydrologic year, which starts in April, the watershed landside model was applied from April 1999 to March 2001. Runoff flow output for the year 2000 was then extracted and input into the WASP6 model to simulate time and spatially variable instream *E. coli* concentration for the year 2000.

Table 5-1
SUMMARY OF AVAILABLE DATA FOR YEAR 1998 – 2001

Year	Annual Average Flow (cfs)	Annual Total Rain Fall (inches)	No. of *E. coli* Sampling Stations	No. of *E. coli* Samples
1993[1]	109	39.95	NA	NA
1998[2]	63	28.96	10	368
1999[2]	62	25.39	7	215
2000[2]	56	29.92	27	457
2001[2]	47	34.55	11	168

1 USGS flow from discontinued upstream gage No. 04095300 and adjusted rainfall from NCDC City of LaPorte gage
2 Adjusted USGS flow from current harbor gage No. 04095380 and rainfall from Michigan City WWTP

5.2.1 BasinSIM (GWLF) Model

BasinSim 1.0 is a Windows based simulation system that uses the Generalized Watershed Loading Functions (GWLF) model. The GWLF model is a mid-range watershed model that is more detailed than empirical export coefficient approaches (e.g., unit area loadings) but less complex than mechanistic (mass balance) simulation models. GWLF simulates the hydrologic cycle in a watershed, predicting streamflow based on precipitation, evapotranspiration, land use and soil characteristics. Streamflow consists of runoff and discharge from groundwater. The Natural Resource Conservation Service Curve Number Equation was used to calculate watershed runoff quantity and groundwater discharge was determined from a watershed water balance. GWLF can also predict nutrient loads from surface runoff, groundwater, point sources, and septic systems with the hydrologic cycle and input loading functions. In the application of the model to the Trail Creek watershed, only the hydrologic component was used and the computed runoff quantity was coupled with an assigned *E. coli* concentration to generate bacteria loads for the instream water quality model, WASP6.

The GWLF model computes runoff using the following equation:

$$Q_{kt} = \frac{(R_t + M_t - 0.2 * DS_{kt})^2}{R_t + M_t + 0.8 * DS_{kt}}$$

where R_t and M_t are rainfall and snowmelt on day t. The detention parameter DS_{kt} is determined from the curve number CN_{kt} from source area k on day t:

$$DS_{kt} = \frac{2540}{CN_{kt}} - 25.4$$

Groundwater discharge was obtained from a lumped parameter watershed water balance. Daily water balances were calculated for unsaturated and shallow saturated zones. Infiltration to the unsaturated and shallow saturated zones equals the excess, if any, of rainfall and snowmelt less runoff and evapotranspiration. Percolation occurs when the unsaturated zone water exceeds field capacity. The shallow saturated zone was modeled as a linear groundwater reservoir. Figure 5-1 presents the water balance components.

Water balances for the unsaturated and shallow saturated zones are:

$$U_{t+1} = U_t + R_t + M_t - Q_t - E_t - PC_t$$
$$S_{t+1} = S_t + PC_t - G_t - D_t$$

In these equations, U_t and S_t are the unsaturated and shallow saturated zone soil moistures at the beginning of day t and R_t, M_t, Q_t, E_t, PC_t, G_t, and D_t are rainfall, snowmelt, watershed runoff, evapotranspiration, percolation into the shallow saturated zone, groundwater discharge into the stream and seepage flow to the deep saturated zone, respectively, on day t.

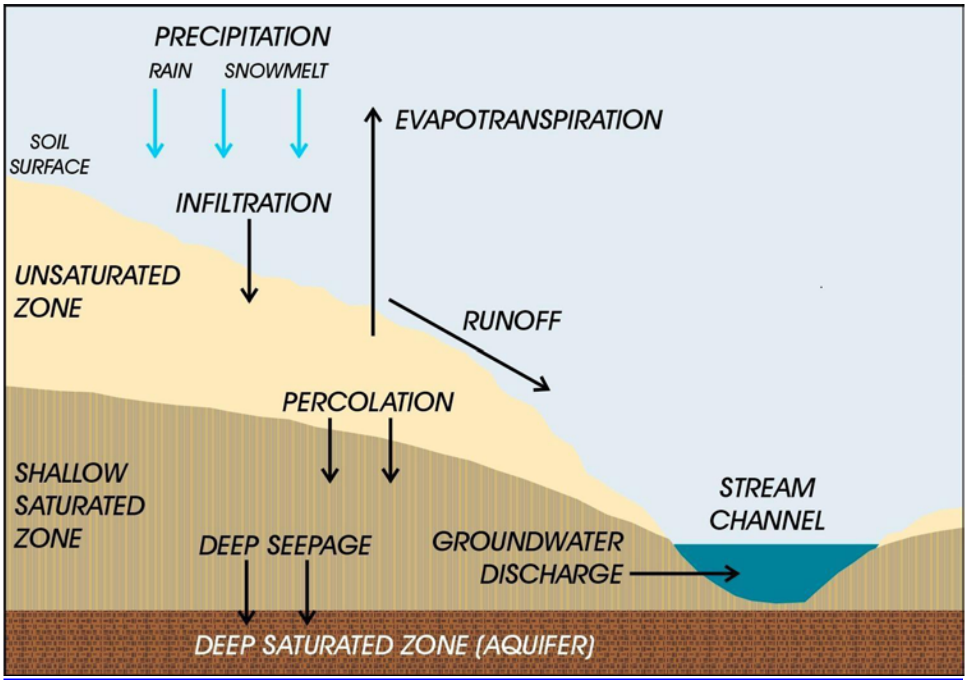


Figure 5-1. GWLF Model Water Balance

Model Inputs

There are three basic input files required to run BasinSim: a weather file, transport file, and nutrient file. Weather and transport files were created according to the observed data in the Trail Creek to simulate the hydrologic cycle. The nutrient file was not used because *E. coli* is being simulated and concentrations were assigned to the calculated GWLF runoff to develop the runoff (NPS) loads for the WASP6 model.

<u>Weather Data File</u>

The weather data file consisted of daily air temperature and precipitation for Trail Creek. This data was obtained from the National Climatic Data Center (NCDC) for a weather station in the City of LaPorte (COOPID No. 124837) for April 1, 1992 to March 31, 1994 and from the Michigan City Wastewater Treatment Plant Weather Data CDs from April 1, 1999 to March 31, 2001. Figure 5-2 and 5-3 present the air temperature and rainfall used as model input for the two separate calibration and validation periods.

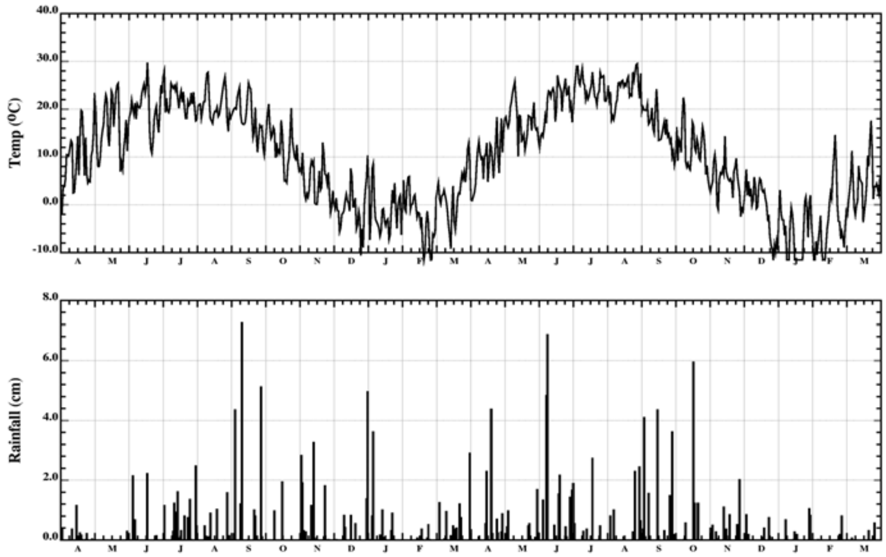


Figure 5-2. Trail Creek Daily Temperature and Rainfall Data, April 1992 - March 1994

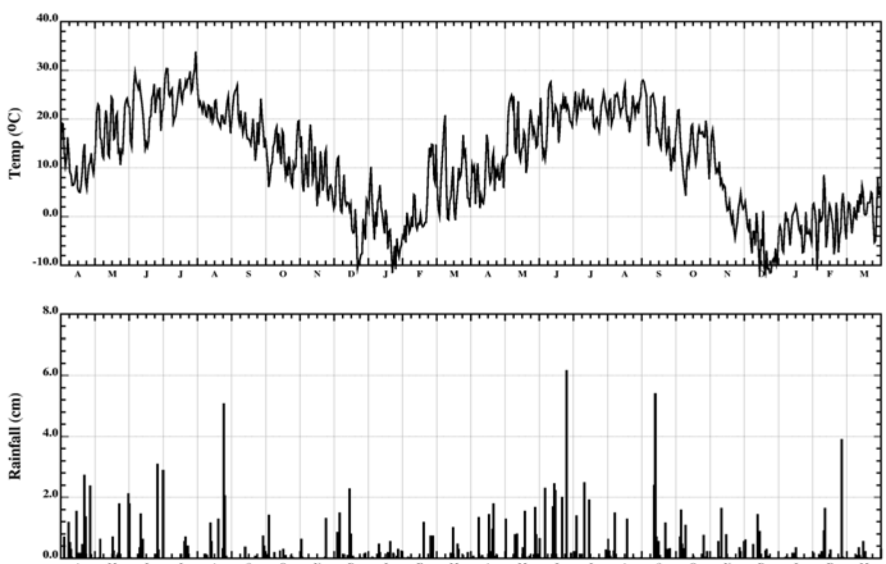


Figure 5-3. Trail Creek Daily Temperature and Rainfall Data, April 1999 - March 2001

Transport Data File

There are three transport data files for the three sub-watersheds. The transport data file included parameters such as land use types and areas, runoff curve numbers, erosion product (K*LS*C*P) for each runoff source, groundwater recession and seepage coefficients, the available water capacity of the unsaturated zone, the sediment delivery ratio, monthly values for evapotranspiration cover factors, average daylight hours, growing season indicators and rainfall erosivity coefficients. The erosion product parameters from the Universal Soil Loss Equation along with the table and equation numbers form the BasinSim GWLF manual for typical values are presented below:

K – Soil erodibility factor (Table B-10);
LS – Calculated parameter as a function of slope length and percent slope (Equations B-6 and B-7);
C – Cover and management factor (Table B-11 and B-12); and
P – Supporting practice factor (Table B-13).

Land Use Types (Runoff Sources)

The runoff sources (same as land use types) in Trail Creek were classified as agriculture, forest, transitional, and developed. Figure 2-1 presents the land use types for the Trail Creek watersheds. The east and West Branch sub-watersheds are mainly forest and agriculture, and the Main Branch sub-watershed is mainly developed area.

Areas

Areas in hectares for each runoff source (land use) for the three sub-watersheds were calculated for the Trail Creek watershed from land use files downloaded from the Lake RIM website. The detailed land use categories obtained from the website were modified and grouped into five general land use categories (developed, agriculture, forest, transitional and water) .

Runoff Curve Numbers

Runoff curve numbers proportionally determines the runoff amount. Usually runoff in urban areas is higher than that in forest and farm areas. Runoff curve numbers are given in the BasinSim GWLF manual Appendix B-2 to B-5 for different land use/cover and soil hydrologic group combinations. The land use and soil hydrologic group information for the Trail Creek watershed were obtained from the USEPA Basins database. The curve numbers were calculated for each land use type for the three sub-watersheds by grouping different land use and soil hydrologic group combinations and a weighted average was performed for each land use type within each sub-watershed. Table 5-2 presents the area and runoff curve numbers for each of the three sub-watersheds used for the calibration and validation periods.

Table 5-2 RUNOFF CURVE NUMBERS USED IN THE GWLF MODEL											
Main Branch	**Land Use**	**Area (ha)**	**Curve No.**	**East Branch**	**Land Use**	**Area (ha)**	**Curve No.**	**West Branch**	**Land Use**	**Area (ha)**	**Curve No.**
	Agriculture	935	61		Agriculture	3284	61		Agriculture	3725	61
	Forest	750	30		Forest	2018	30		Forest	1670	30
	Transitional	145	59		Transitional	36	59		Transitional	161	59
	Developed	1648	83		Developed	277	83		Developed	593	83

*Erosion Product K*LS*C*P*

K, LS, C, P are the standard values for soil erodibility, topographical, cover and management, and supporting practice factors for soil loss calculations. Because nutrients are not modeled in the landside model for Trail Creek, this product was not essential in simulating hydrologic cycles in the Trail Creek watershed model for *E. coli*.

Groundwater Recession and Seepage Coefficient

The recession coefficient was estimated from streamflow records at the upstream gage (No. 04095300) in the year 1993 during four hydrograph recessions between March and May. The calculated recession coefficients were: 0.25 for March 23-27, 0.27 for April 1-5, 0.43 for April 20-24 and 0.21 for May 5-9. All of these calculated recession coefficients had correlation coefficients (r) greater than 0.94. An average groundwater recession value of 0.3 was assigned for the east, west and Main Branches for the GWLF model calibration and validation. The seepage coefficient was adjusted during the calibration to match the observed flow data and a final value of zero was used, which indicates that no rainfall was lost to deep aquifer storage.

Initial Unsaturated and Saturated Storage, Initial Snow Cover, Unsaturated Water Capacity

The initial conditions for unsaturated storage, saturated storage and snow were set to default values given in the manual, which do not affect the year 1993 calibration and 2000 validation. The default value for initial unsaturated and saturated storage was set at 10 cm and initial snow cover was set at 0 cm. The unsaturated water capacity was set at 15 cm based on the calibration to 1993 and validation to 2000.

Sediment Delivery Ratio

The sediment delivery ratio is required in the transport file for the calculation of sediment output. It is calculated in the GWLF model based on the area of the watershed although unused because of the current application to *E. coli*.

Monthly Evapotranspiration Cover Factors

The evapotranspiration (ET) cover coefficient is the ratio of water loss by evapotranspiration from ground and plants compared to what would be lost by evaporation from an equal area of standing water. ET cover coefficients vary by land use type and time period within the growing season. Typical values are between 0 (for impervious surfaces) and 1 (water). Monthly averages weighted by land use percentages were required in the transport data file for the entire watershed. The coefficients were obtained from Appendix B-6 to B-8 in the GWLF manual and the final calibration values are presented in Table 5-3. Calibration of the ET coefficients was based on reproducing the observed creek flows (peak and base) with the GWLF model. The original ET coefficients (area weighted) from the GWLF manual were 0.25/0.59 (dormant/growing season) for the Main Branch, 0.30/0.96 for the East Branch, and 0.29/0.90 for the West Branch.

Table 5-3
EVAPOTRANSPIRATION COVER COEFFICIENTS USED IN GWLF MODEL

	Month	ET Cover Coeff		Month	ET Cover Coeff		Month	ET Cover Coeff
Main Branch	Apr	0.7	**East Branch**	Apr	1.0	**West Branch**	Apr	1.0
	May	0.7		May	1.0		May	1.0
	Jun	0.7		Jun	1.0		Jun	1.0
	Jul	0.7		Jul	1.0		Jul	1.0
	Aug	0.7		Aug	1.0		Aug	1.0
	Sept	0.7		Sept	1.0		Sept	1.0
	Oct	0.7		Oct	1.0		Oct	1.0
	Nov	0.4		Nov	0.5		Nov	0.5
	Dec	0.4		Dec	0.5		Dec	0.5
	Jan	0.4		Jan	0.5		Jan	0.5
	Feb	0.4		Feb	0.5		Feb	0.5
	Mar	0.4		Mar	0.5		Mar	0.5

Average Daylight Hours

Monthly daylight hours were obtained from Table B-9 in the GWLF manual with the latitude of Trail Creek as 42 degrees north and are presented in Table 5-4.

Table 5-4
AVERAGE DAYLIGHT HOURS USED IN GWLF MODEL

Month	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Daylight Hours	13.1	14.3	15	14.6	13.6	12.3	10.9	9.7	9.0	9.3	10.4	11.7

Growing Season Indicator

Growing season indicators were estimated based on typical planting periods in northern Indiana obtained from Purdue University and USDA on-line information. April through October was assigned 1 indicating the growing season and November through April as 0 indicating the dormant season.

Rainfall Erosivity Coefficient

Rainfall erosivity is a coefficient in soil erosion. Since sediment in the Trail Creek watershed was not modeled, this parameter was not essential for the streamflow calculation. It was estimated from Table B-14 in the GWLF manual based on the erosivity zone of Trail Creek, which is zone 15 according to Figure B-1 in the GWLF manual.

<u>Nutrient Data File</u>

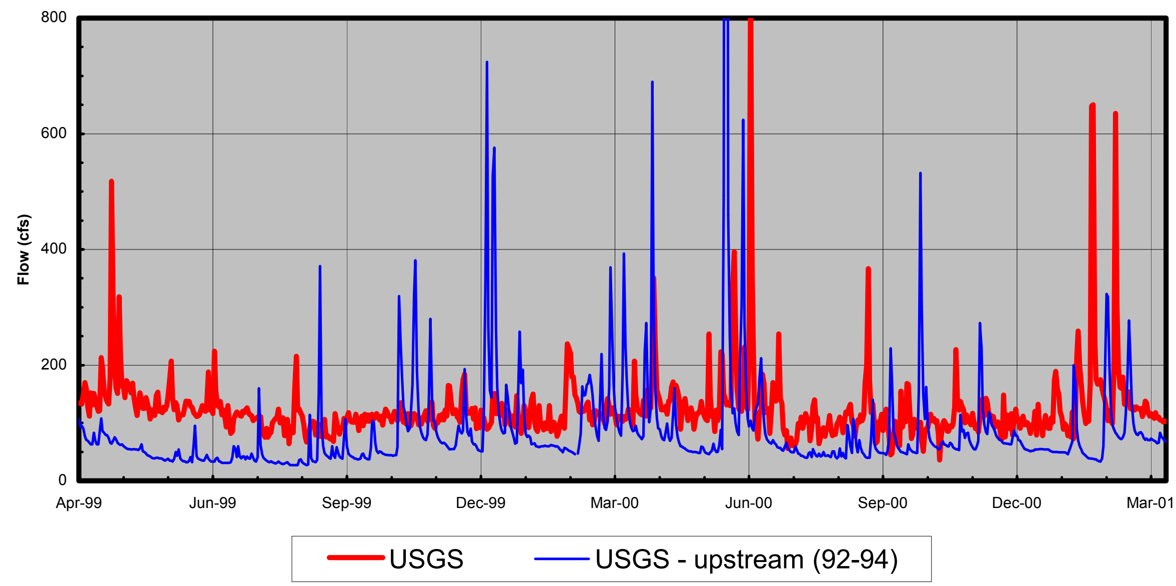
The nutrient data file was not used in streamflow calculations, but is a required input as part of the BasinSim 1.0 input files, even though nutrients are not modeled in this application for the Trail Creek TMDL. The Trail Creek watershed nutrient data file was created according to the required input format but without estimating model-specific coefficients and parameters because nutrients were not modeled for the Trail Creek Watershed *E. coli* TMDL. This input file did not effect the calculations of runoff flow and, therefore, the input values assigned did not affect the model output of runoff flow.

Model Calibration

The current flow gage in the Trail Creek watershed is located in Michigan City Harbor (No. 04095380), which is affected by water levels in Lake Michigan. That is, measured river flows at this gage can be less than or equal to zero depending on water levels in the lake. This complication limited the use of this flow gage for GWLF runoff calibration in the year 2000. Historically, there was an upstream flow gage at Michigan City (No. 04095300), which was not influenced by the lake, but this gage was discontinued in 1994. In order to calibrate the GWLF model, the model was calibrated to a period from April 1, 1992 to March 31, 1994 for the 1993 annual cycle using the upstream gage and then the calibration parameters obtained were used to calculate runoff for the 2000 modeling period (April 1, 1999 to March 31, 2001). This process was necessary to determine the GWLF model calibration coefficients from a flow record that was not influenced by Lake Michigan water levels.

Calibration and validation of the GWLF model was to stream flow for the two periods discussed above: 1993 and 2000. Figure 5-4 presents the comparison of USGS flow data at the mouth of the creek (active) and at Springland Avenue (retired). Although the time of the data is different because the gage station at Springland Avenue was discontinued in 1994, the magnitude of the flow at the two stations indicates that the measurements at the mouth of Trail Creek are indeed influenced by the lake and are typically greater. To compare the model results with the active gage data at the mouth of Trail Creek for the validation to year 2000, some kind of flow adjustment was needed. This adjustment factor was based on comparing the flow from the retired gage before the active gage began. The retired gage flow on September 30, 1994 was 36 cfs and the active gage flow was 103 cfs on October 1, 1994, which is a difference of 67 cfs. An adjustment flow of 65 cfs is used to adjust the active gage data for comparison with the model results.

Figure 5-4. Comparison of USGS Flows at the Mouth of Trail Creek and at Springland Avenue



Figures 5-5a through 5-5e present the GWLF runoff calibration results and Figures 5-6a through 5-6e present the validation results. The first figure in each set contains the GWLF calculated flows (blue line) and observed USGS flows (red line), the second through fourth presents the GWLF calculated flows for the west, east and main watersheds, and a bar chart of GWLF calculated and observed monthly runoff volumes.

Figure 5-5a. Trail Creek Watershed GWLF Model Calibration Results

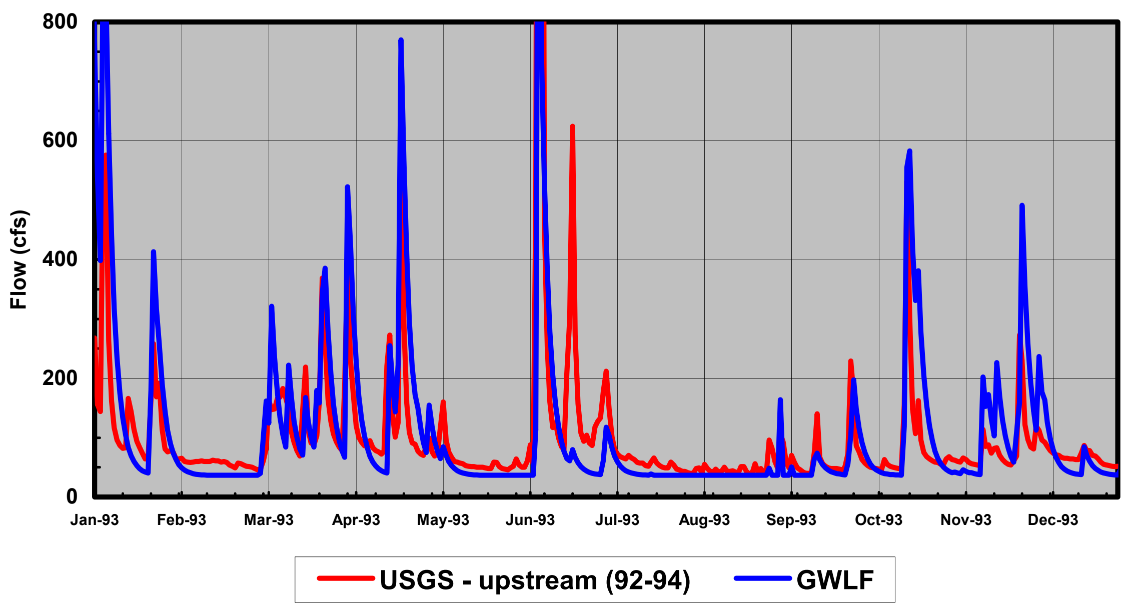


Figure 5-5b. Trail Creek Watershed GWLF Model Calibration Results - West Branch

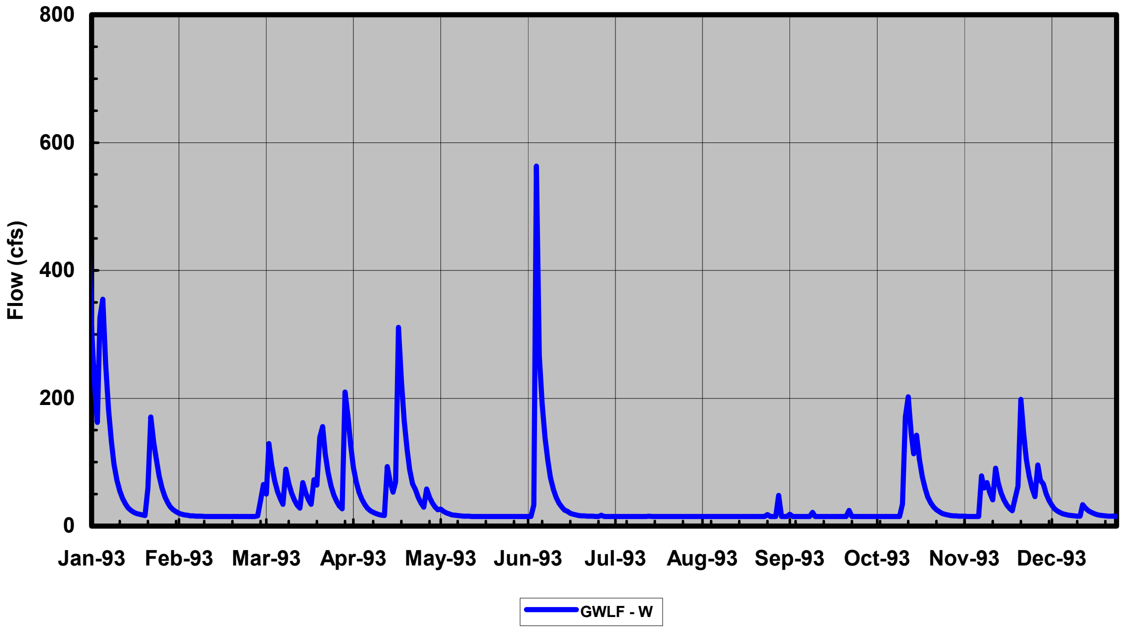


Figure 5-5c. Trail Creek Watershed GWLF Model Calibration Results - East Branch

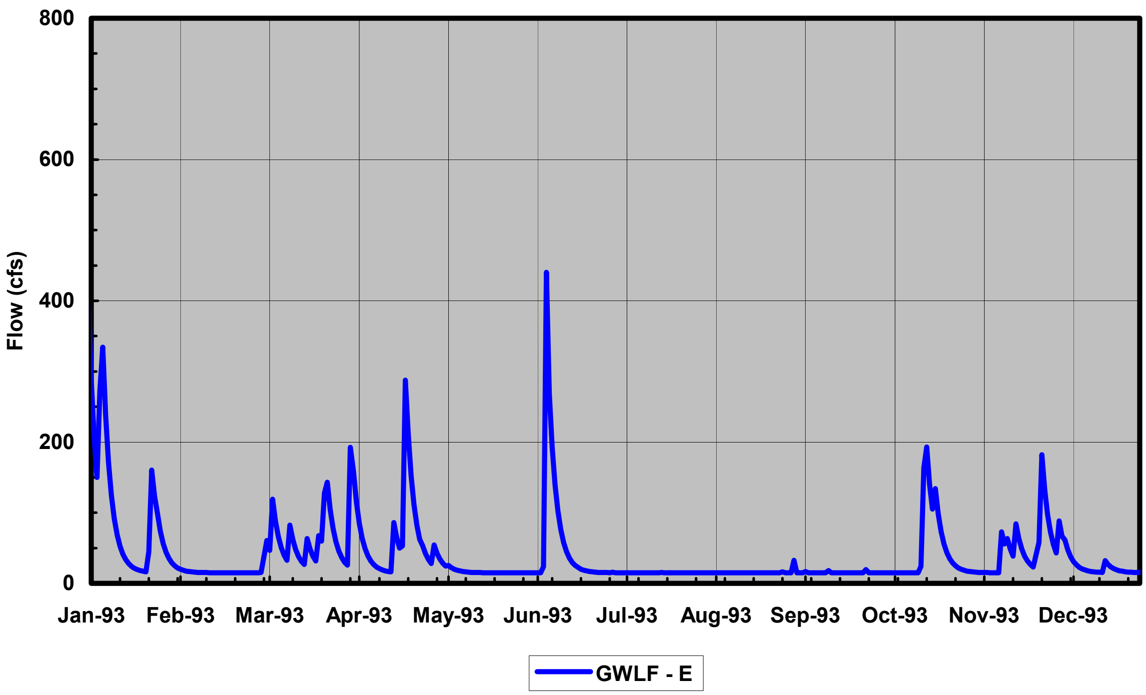


Figure 5-5d. Trail Creek Watershed GWLF Model Calibration Results - Main Branch

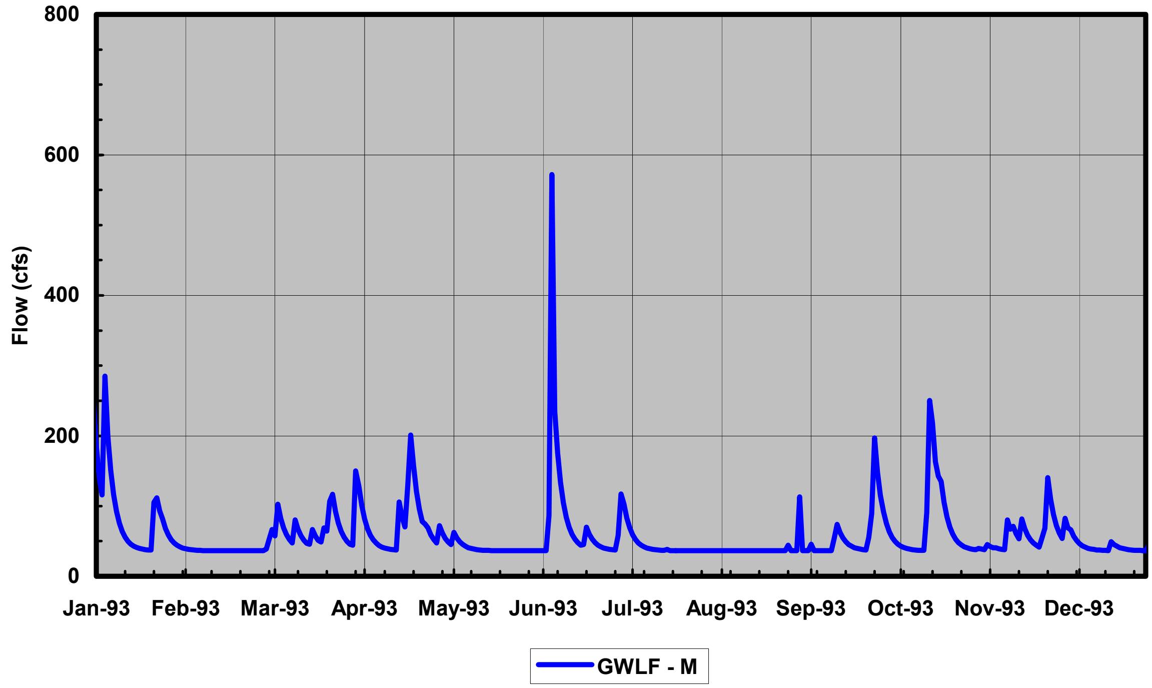


Figure 5-5e. Trail Creek Watershed GWLF Model Calibration Monthly Summary

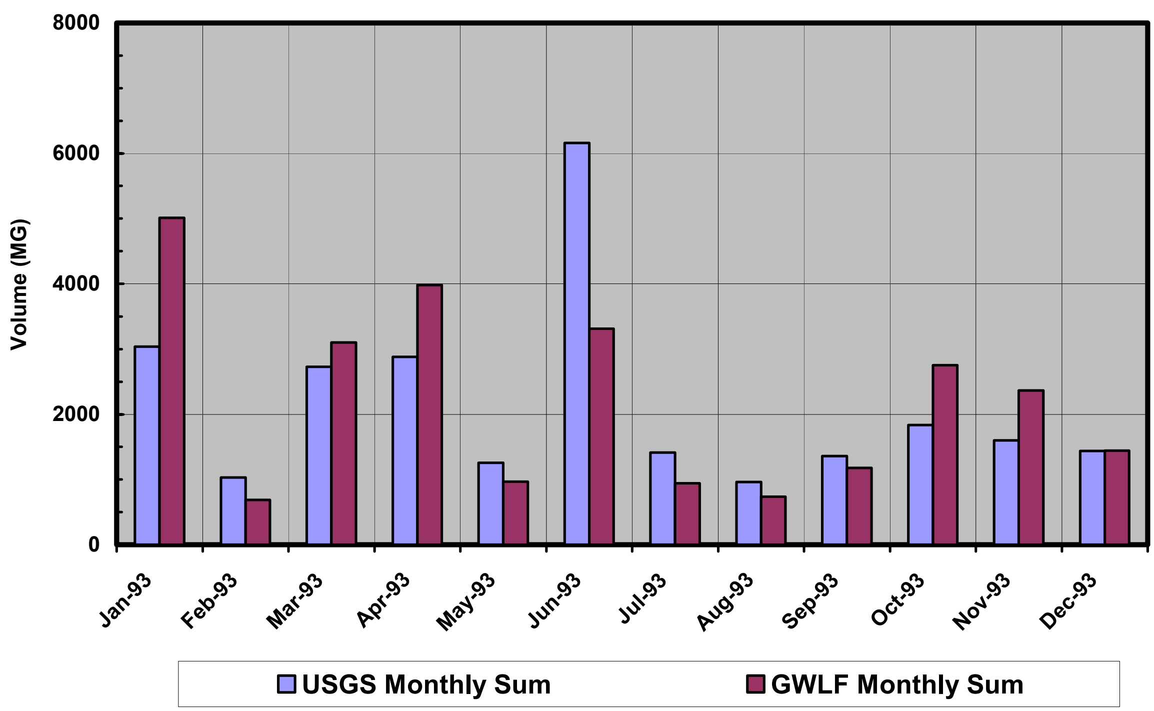


Figure 5-6a. Trail Creek Watershed GWLF Model Validation Results

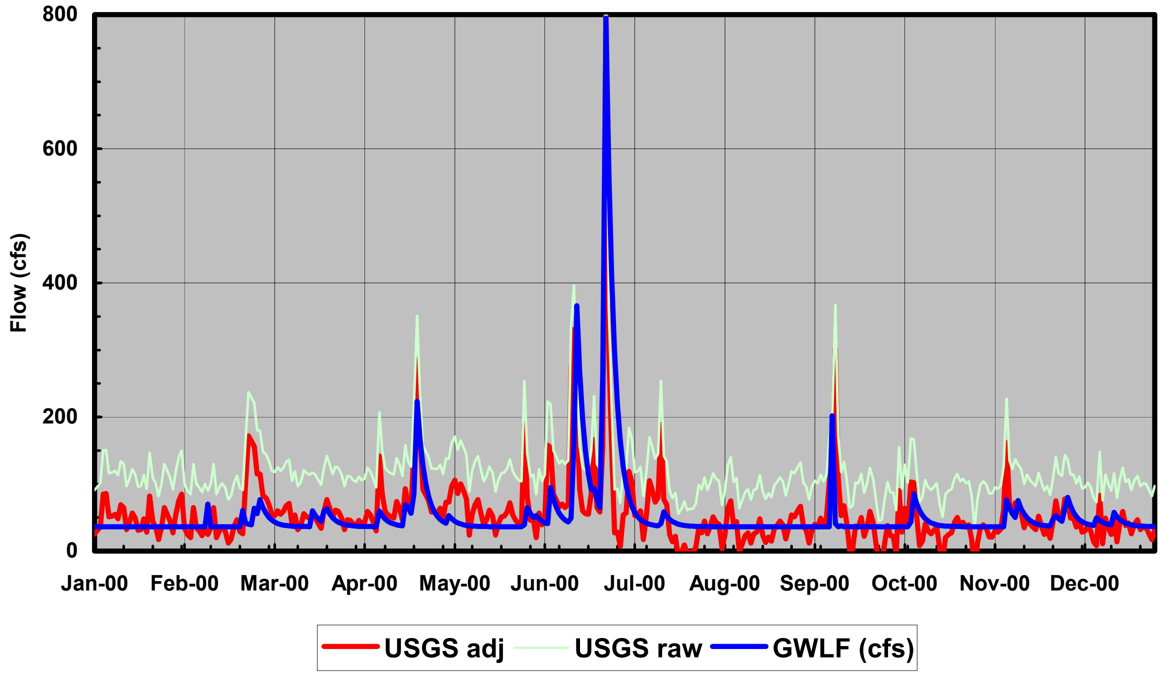


Figure 5-6b. Trail Creek Watershed GWLF Model Validation Results - West Branch

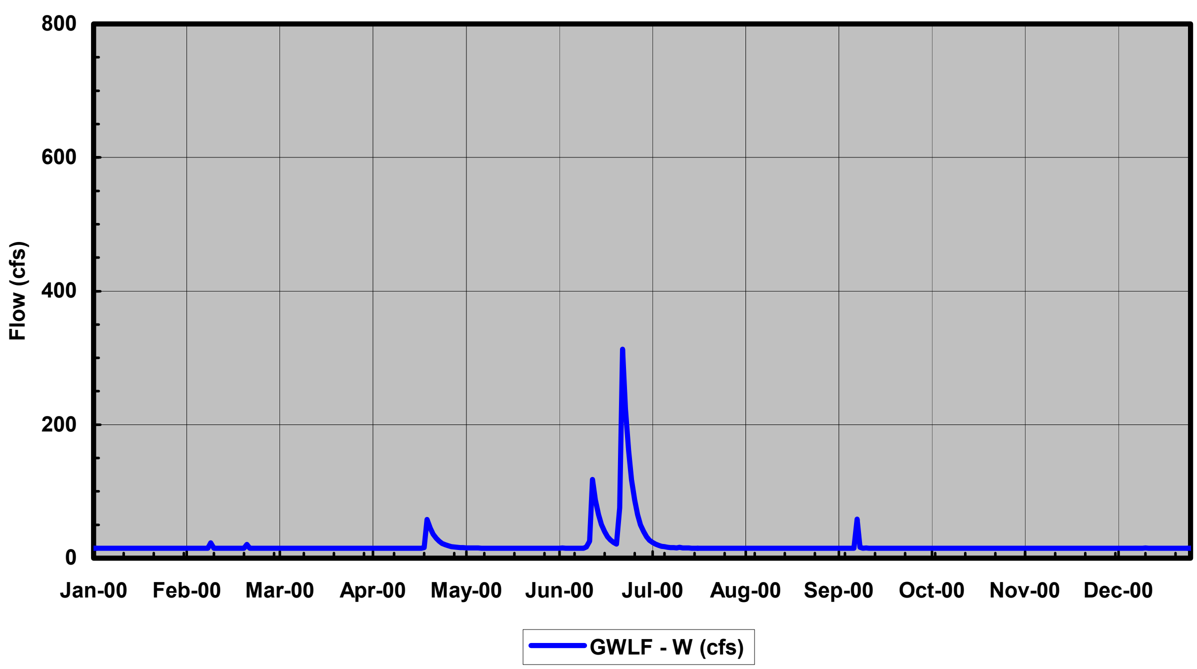


Figure 5-6c. Trail Creek Watershed GWLF Model Validation Results - East Branch

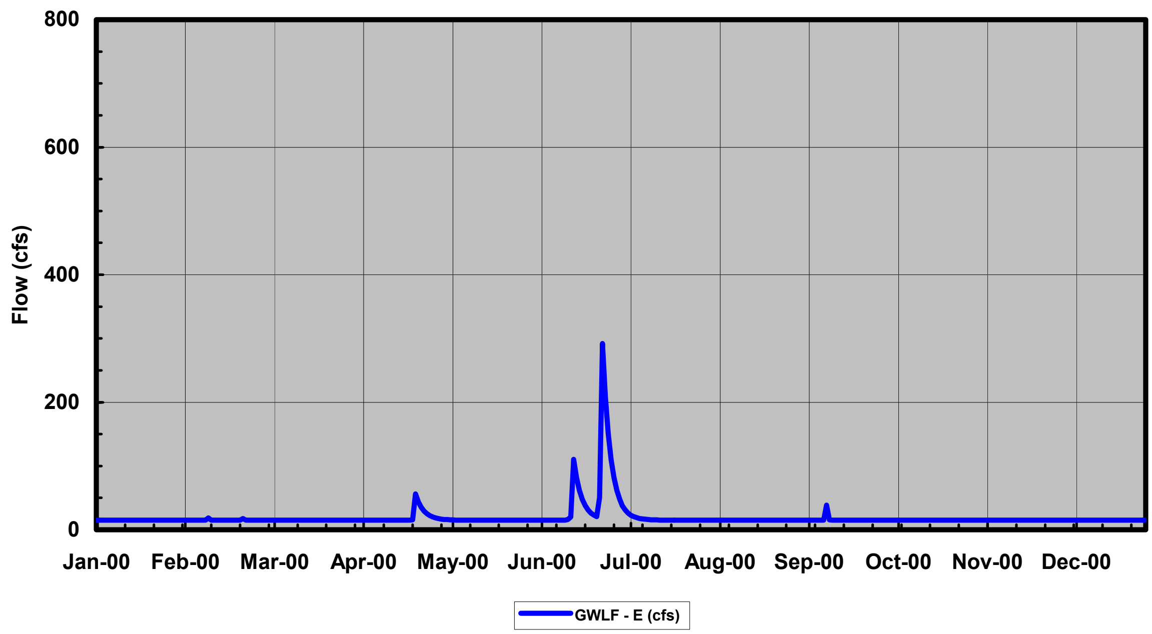


Figure 5-6d. Trail Creek Watershed GWLF Model Validation Results - Main Branch

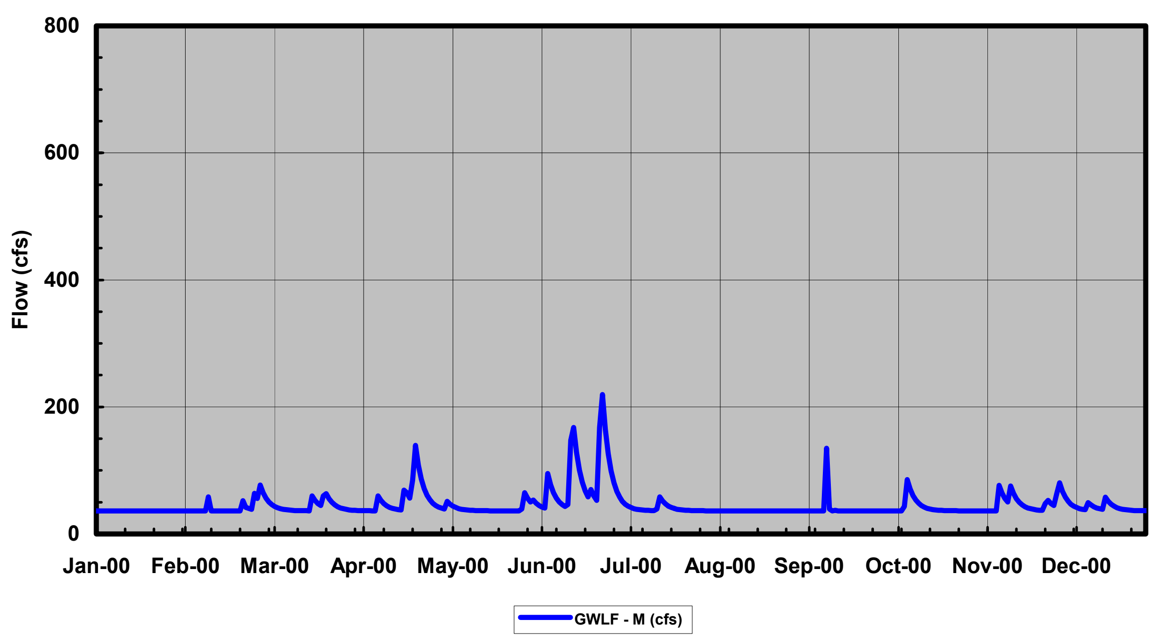
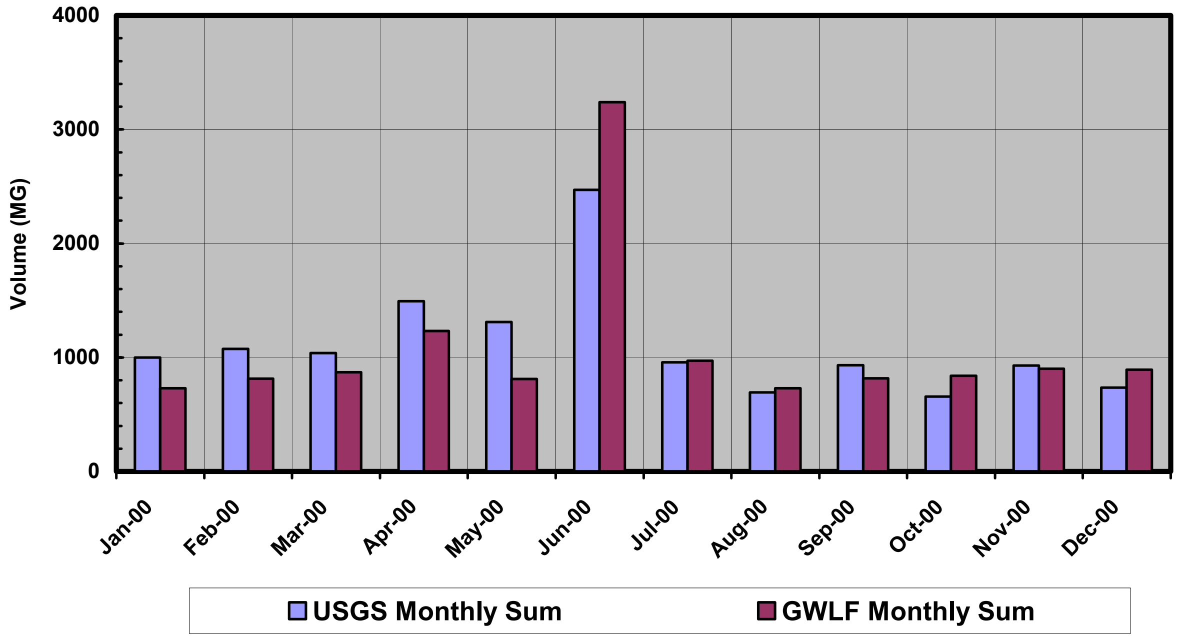


Figure 5-6e. Trail Creek Watershed GWLF Model Validation Monthly Summary



As presented in the previous figures, the model captures the peaks and has the same patterns as observed in the data although the proper magnitude is not always obtained, which may be due to local weather patterns not reflected in the rainfall data used for both the model calibration and validation. A base groundwater flow was assigned in the model based on the calibration for the East and West Branches of 15 cfs for both the 1993 and 2000 modeling periods. This was necessary because the GWLF model assumption of a simple lumped parameter groundwater model results in model flow calculations during periods of minimal rainfall as near zero. As discussed above, the 2000 flow data available to validate the GWLF model is not ideal due to the lake influence and calibration to this data may not result in the best agreement. Use of the year 2000 flow data from the harbor was necessary because the year 2000 was selected to calibrate the WASP6 model based on the best *E. coli* data availability as discussed in Section 4.0. Overall the GWLF model reasonably reproduced the observed creek flows in 1993 and 2000. That is, the calculated GWLF flows reasonably reproduced the observed hydrographs in 1993 and 2000 for peak and base flows in addition to the recession of flows after storm events. Table 5-5a and 5-5b summarize monthly and annual runoff volumes from the GWLF model and the USGS flow data for the years 1993 and 2000. Although the month-to-month volume comparisons were not always similar, annual runoff volumes were within less than 4% of the observed volumes for both 1993 and 2000.

Table 5-5a Comparison of Monthly and Annual Volumes of the Model and Data in 1993													
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Annual**
Model (MG)	4776	665	3136	4001	917	3315	942	737	1223	2722	2464	1331	26230
Data (MG)	3037	1029	2727	2879	1256	6162	1411	963	1359	1835	1602	1438	25698

Table 5-5b Comparison of Monthly and Annual Volumes of the Model and Data in 2000													
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Annual**
Model (MG)	729	828	858	1239	810	3347	854	729	817	839	911	884	12845
Data (MG)	998	1075	1040	1494	1310	2471	957	692	933	657	929	735	13292

5.2.2 WASP6 Model

Instream *E. coli* concentrations in Trail Creek were simulated with WASP6 for the year 2000 using the runoff flows computed with the calibrated and validated GWLF model. However the WASP6 model was not validated with an additional dataset as was the GWLF model. Although validation of the WASP6 model was not completed, the time-variable calibration of the model for the year 2000 encompassed a wide range of runoff events and, therefore, the model was well tested for a variety of runoff conditions.

WASP6 is an enhanced Windows version of the USEPA Water Quality Analysis Simulation Program (WASP). The time-varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange are present in the basic program. Stream flow was assigned based on the computed GWLF runoff and groundwater flows. The three reaches in the Trail Creek watershed were segmented for application of the WASP6 model with length, width, and depth assigned for each model segment. Segment length is assigned to maintain model stability and minimize numerical dispersion. The water quality component of the WASP6 model includes bacteria die-off as a function of temperature as the main loss rate with loading sources from runoff (NPS) loadings and point sources. Time-variable output from the model is compared with the observed watershed data for calibration to the instream *E. coli* concentrations.

Water Quality State Variables

The EUTRO model, a eutrophication model within the WASP6 model, was used to calculate *E. coli* concentrations in Trail Creek. This modeling component contains nine systems: Inorganic and organic forms of nitrogen and phosphorus, phytoplankton, ultimate BOD (BODu) and salinity (tracer). For Trail Creek, the ultimate BOD system was used to model *E. coli* with the other systems not simulated and set at constant values so as not to interfere with the *E. coli* calculations in the BODu system. Salinity was kept in the model as a tracer to check on mass balances, which was completed by assigning a constant value of 100 to all boundary and initial conditions, and all sources. Results from this test indicated that the model was maintaining mass balances in all model segments throughout the entire simulation period. The general mass balance equation used in the model to solve the state variable in each segment is:

$$\frac{\partial C}{\partial t} = -\frac{\partial}{\partial x}(U_x C) - \frac{\partial}{\partial y}(U_y C) - \frac{\partial}{\partial z}(U_z C) + \frac{\partial}{\partial x}(E_x \frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(E_y \frac{\partial C}{\partial y}) + \frac{\partial}{\partial z}(E_z \frac{\partial C}{\partial z}) + S_L + S_B + S_K$$

where:

C =	concentration of the water quality constituent, mg/L;
t =	time, days;
U_x, U_y, U_z =	longitudinal, lateral, and vertical advective velocities, m/day;
E_x, E_y, E_z =	longitudinal, lateral, and vertical diffusion coefficients, m^2/day;
S_L =	direct and diffuse loading rate, g/m^3-day;
S_b =	boundary loading rate (including upstream, downstream, benthic, and atmospheric), g/m^3-day; and
S_K =	total kinetic transformation rate; positive is source, negative is sink, g/m^3-day.

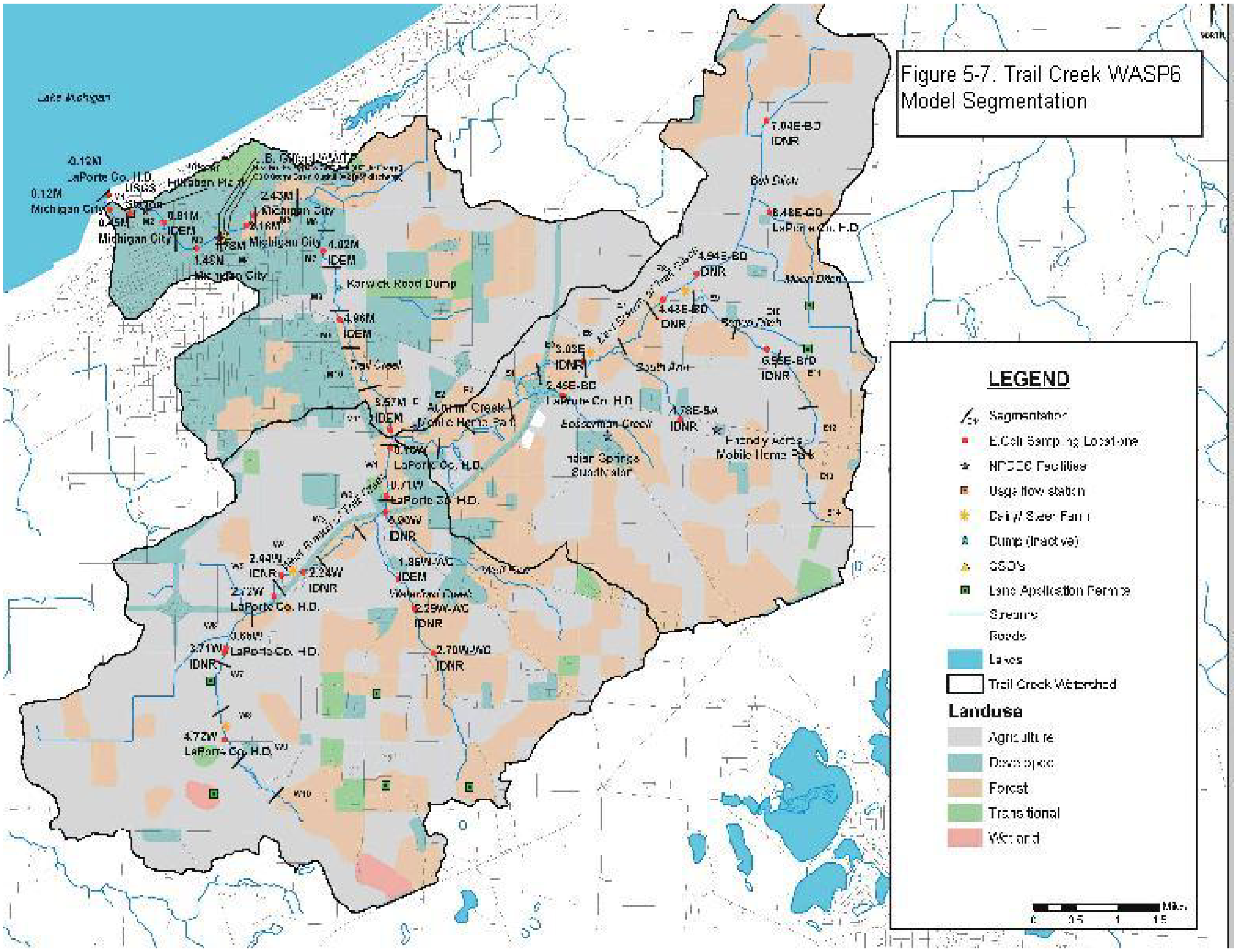
WASP6 is a multi-dimensional model and was applied with one surface water segment only (one-dimensional) for the Trail Creek watershed. In this application, advection is the only transport process for the variables with dispersion considered negligible.

Model Input

The WASP6 model requires input for initial conditions, streamflow, point and nonpoint source loads, boundary conditions, segments characteristics (including river geometry, parameter specification), temperature time functions, integration time step, and print intervals.

Model Segmentation

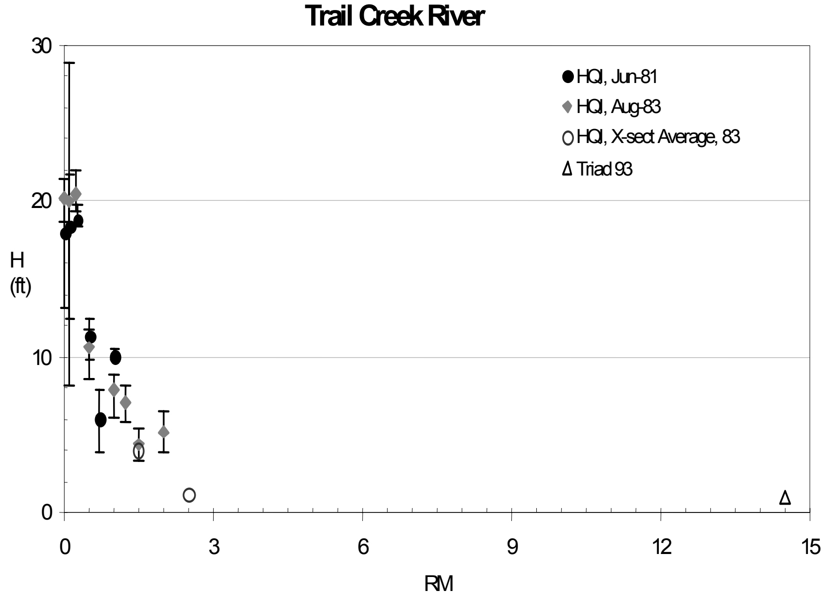
The model is divided into 36 segments. Figure 5-7 presents the segmentation of the model, and the length of each segment. Segmentation starts from the mouth of the creek, going upstream along the Main Stem (segments M1 through M12), then splits at the junction of the west (W1 to W10) and East Branches (E1 to E14). Each of the segments is about one kilometer long. Segments M1 and M2 are set at 0.8 and 1.2 kilometers, respectively, because the geometry near the mouth of the creek changes rapidly around 0.8 kilometers from the mouth.



Creek Geometry

The model required segment volume, velocity, and depth for each segment. Segment volume was the product of segment length, width, and depth. Estimation of segment width and depth was based on geometry studies performed earlier (HydroQual, 1984; NIRPC, 1993) and/or from USGS maps. The HydroQual surveys were completed in 1981 and 1983, and the Trail Creek Watershed Plan completed in 1993. These surveys provide depth and width information for some locations in the Creek. In addition, more general width information is obtained by estimating stream width from USGS topographical maps. Figure 5-8 presents the depth and width data from the surveys and USGS maps. Depth and width averages were taken from the different geometry data sources for different sections of the creek and assigned to the segments. Most of the data obtained are for the downstream portion of the Main Branch, and only one data point in the West Branch was available. Upstream in the West Branch, a minimum width of 5 feet and depth of 0.5 ft was assigned. Due to lack of information, geometry of the East Branch was set to have the same values as the West Branch. Wherever there is lack of data for segments, linear interpolation was performed based on the river miles of each segment.

Streamflow



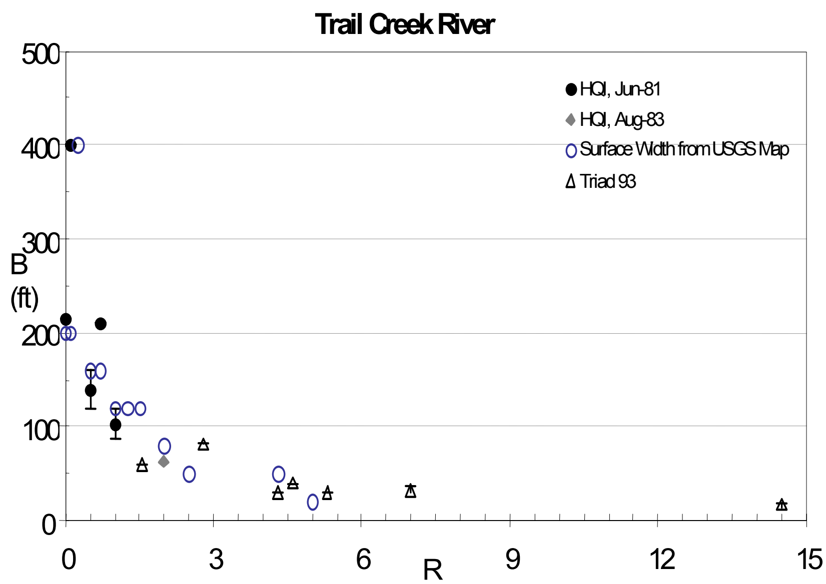


Figure 5-8. Trail Creek Geometry Data

Streamflow

Runoff inflow into each WASP6 segment was obtained by distributing the GWLF runoff flows from the East and West Branch sub-watersheds and Main Branch watershed into the East and West Branches and Main Branch of the creek, respectively. Besides the runoff flow from the GWLF output, an upstream boundary flow of 15 cubic feet per second (cfs) was assigned to upstream of the East and West Branches that represents a minimum base groundwater flow based on the GWLF calibration and validation. This base flow was determined from calibration of the GWLF model to dry weather conditions for the 1993 period and validated through GWLF application to dry weather conditions for the 2000 period.

Besides the runoff inflow and boundary flow, there are also some incoming flows from municipal WWTP discharges. These include Michigan City Sanitary Station, Friendly Acres Mobile Home Park (MHP), Autumn Creek Mobile Home, and Indian Springs Subdivision. The data source for these flows is discharge monitoring reports (DMRs) data for the year 2000.

Point Source Loads

Point sources of *E. coli* into Trail Creek mainly come from municipal discharges, including Michigan City Sanitary Station, Friendly Acres MHP, Autumn Creek MHP, and Indian Springs Subdivision. Michigan City does have two combined sewer overflows (CSO) points but there were no reported events in 2000. CSO events in Michigan City have improved significantly since 1990 (Table 5-6) and currently the City is implementing a Long Term CSO Control Plan that was submitted to IDEM for approval on April 24, 2002, which includes sewer separation to reduce combined sewers in the District's service areas. It is anticipated that IDEM will provide Michigan City with final comments on the LTCP by mid-December 2003. Consequently, CSOs are not considered a source, and therefore no WLA has been assigned to them.

Table 5-6
MICHIGAN CITY SANITARY DISTRICT CSO HISTORY

Year	Number of Annual CSO Overflows (Outfall 002)
1990	47
1991	24
1992	2
1993	32
1994	3
1995	0
1996	19
1997	14
1998	1
1999	0
2000	0
2001	1

DMR data provided monthly flow for these point sources but *E. coli* concentrations for only the Sanitary Station. Average effluent flow for the year 2000 was 4.8 million gallons per day (MGD) for the Sanitary Station, 0.015 MGD for Friendly Acres MHP, 0.010 MGD for Autumn Creek MHP, and 0.018 MGD for Indian Springs Subdivision. Average *E. coli* levels from the Sanitary Station during 2000 ranged from 2 to 23 #/100ml (7 month average of 12 #/100mL) with maximum levels ranging from 6 to 200 #/100mL during the months of April through October. In addition, disinfection at these wastewater treatment plants (WWTP) occurs during the months of April through October, which coincides with the State *E. coli* standard being applied during these months. For the WWTPs where no *E. coli* information was available, the Sanitary Station average *E. coli* level of 12 #/100mL was used during the months of April through October. It was assumed that 2 orders of magnitude bacterial kill is achieved with disinfection and, therefore, for the months when disinfection at the WWTPs is not occurring (November through March), *E. coli* levels were assigned 2 orders of magnitude greater than during the disinfection months (i.e., 1,200 #/100mL). Typical percent removal of bacteria during the disinfection process of treated wastewater is 98-99% (Metcalf & Eddy, 1991) or greater, which would result in non-disinfection *E. coli* levels of approximately 1,200 #/100mL or lower. In addition, in the USEPA document *Municipal Wastewater Disinfection* (1986), initial *E. coli* levels before disinfection at secondary treatment ranged from 10^3-10^5 #/100mL. Although there is a range in *E. coli* levels before disinfection, this assumption did not affect model calculations during the important recreational season (March to October) when the WWTPs are disinfecting to *E. coli* levels well below 100 #/100mL. Table 5-7 presents the *E. coli* point source loads for the year 2000 used in the water quality modeling.

Table 5-7
POINT SOURCE *E. COLI* LOADS (#/DAY) IN 2000

Month	Michigan City Sanitary Station	Friendly Acres MHP	Autumn Creek MHP	Indian Springs Subdivision	
Jan	1.77×10^{11}	6.81×10^{8}	4.04×10^{8}	6.81×10^{8}	
Feb	1.77×10^{11}	6.81×10^{8}	4.04×10^{8}	8.18×10^{8}	
Mar	1.82×10^{11}	6.81×10^{8}	4.50×10^{8}	8.63×10^{8}	
Apr	9.46×10^{8}	6.81×10^{6}	4.59×10^{6}	9.54×10^{6}	
May	4.25×10^{9}	6.81×10^{6}	4.36×10^{6}	7.72×10^{6}	
Jun	5.57×10^{9}	6.81×10^{6}	5.54×10^{6}	9.08×10^{6}	
Jul	3.23×10^{9}	6.81×10^{6}	5.90×10^{6}	5.00×10^{6}	8.63×10^{6}
Aug	1.70×10^{9}	6.81×10^{6}	4.09×10^{6}	4.09×10^{6}	8.63×10^{6}
Sep	3.86×10^{8}	6.81×10^{6}	5.00×10^{6}	5.45×10^{6}	7.72×10^{6}
Oct	1.42×10^{9}	6.81×10^{6}	7.27×10^{6}	4.09×10^{6}	5.90×10^{6}
Nov	1.82×10^{11}	6.81×10^{8}	5.90×10^{8}	4.54×10^{8}	7.72×10^{8}
Dec	1.77×10^{11}	6.81×10^{8}	5.45×10^{8}	6.36×10^{8}	7.27×10^{8}

Nonpoint Source Loads

WASP6 has an optional nonpoint source linkage option. Nonpoint source loads were calculated daily for each segment as the product of the GWLF runoff flow and *E. coli* concentration in each segment. GWLF runoff flow was distributed evenly for the segments in each branch. For example, each of the 10 segments in the West Branch has a runoff flow equal to one tenth of the GWLF runoff flow for the West Branch sub-watershed. *E. coli* concentrations in the runoff were estimated from the Trail Creek *E. coli* survey data at upstream stations that reflected land use types associated with agriculture and forested areas. Measurements at stations in the agricultural and forested area of the West and East Branches (4.72W and 6.46E-GD) were chosen to represent the runoff concentrations in these sub-watersheds. Since *E. coli* concentrations were usually positively related to river flow, correlation analyses were performed on *E. coli* concentrations at these stations versus flow at the active USGS gaging station. Figure 5-9 presents the *E. coli* and flow correlation for the sampling stations.

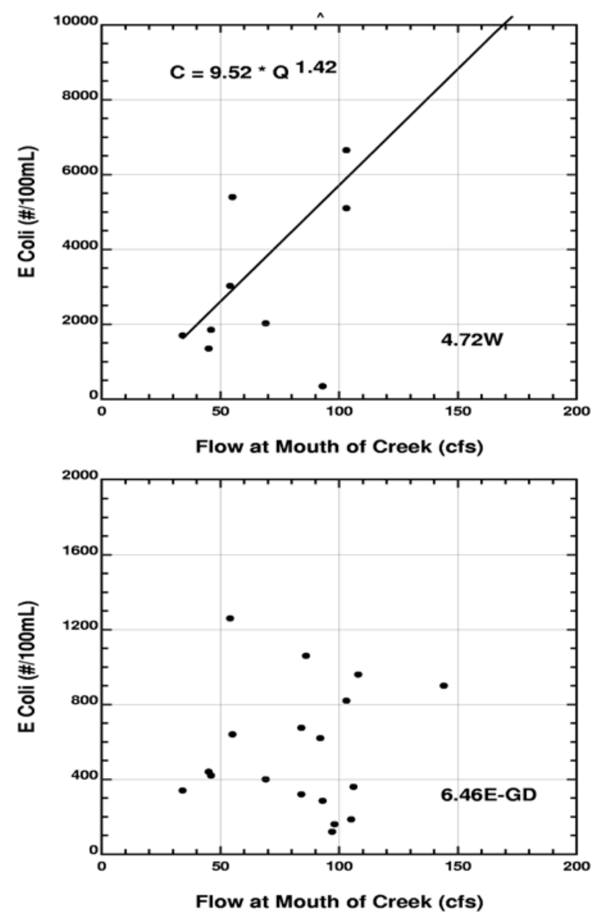


Figure 5-9. E. Coli Data and Flow Correlation

The data at station 4.72W indicated a positive correlation while the data at station 6.46E-GD suggests a random pattern not related to river flow. The equation developed for station 4.72W ($E.\ Coli = 9.52 \times Flow^{1.42}$) and USGS flow at the active gaging station were applied to derive the *E. coli* concentrations in year 2000 for the WASP6 model input for the West Branch. For the East Branch, the observed data distribution as represented by the median and variation of the data were used to develop random *E. coli* daily concentrations for the year 2000. This random distribution was developed to maintain the same distribution observed in the data, which is presented in Figure 5-10.

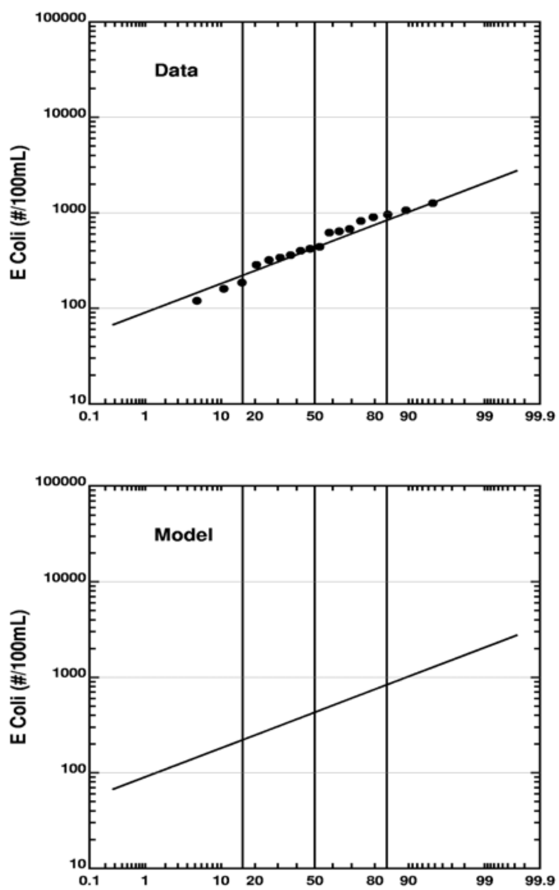


Figure 5-10. E. Coli Data and Model Distribution for Station 6.46E-GD

These generated *E. coli* concentrations for the West and East Branches were coupled with the GWLF runoff flows to generate nonpoint source loads into the WASP6 model. For the Main Branch, an *E. coli* concentration of 25,000 #/100mL was assigned to calculate the runoff load. This *E. coli* value is within the range for urban storm water runoff, which can range from approximately 100 to 250,000 #/100mL, but was also based on reproducing observed *E. coli* levels in the Main Branch when upstream (east and West Branch) loadings were minimal. Table 5-8 presents the nonpoint source *E. coli* loads for the calibration period.

Table 5-8
NONPOINT SOURCE *E. COLI* LOADS (#/DAY) IN 2000

Month	East Branch	West Branch	Main Branch	Groundwater Base flow	Total
Jan	0.00	0.00	0.00	7.34×10^{10}	7.34×10^{10}
Feb	1.49×10^{9}	6.61×10^{10}	3.91×10^{12}	7.34×10^{10}	4.05×10^{12}
Mar	0.00	0.00	4.30×10^{12}	7.34×10^{10}	4.37×10^{12}
Apr	5.49×10^{10}	1.12×10^{12}	1.10×10^{13}	2.20×10^{11}	1.24×10^{13}
May	1.83×10^{9}	3.15×10^{10}	2.33×10^{12}	3.67×10^{11}	2.73×10^{12}
Jun	7.56×10^{11}	9.49×10^{12}	3.01×10^{13}	3.67×10^{11}	4.07×10^{13}
Jul	8.91×10^{10}	8.25×10^{11}	2.90×10^{12}	3.67×10^{11}	4.18×10^{12}
Aug	7.81×10^{5}	1.04×10^{7}	3.36×10^{9}	3.67×10^{11}	3.70×10^{11}
Sep	6.74×10^{9}	3.65×10^{11}	2.09×10^{12}	2.20×10^{11}	2.68×10^{12}
Oct	2.49×10^{4}	7.79×10^{5}	3.36×10^{12}	7.34×10^{10}	3.44×10^{12}
Nov	0.00	0.00	6.21×10^{12}	7.34×10^{10}	6.28×10^{12}
Dec	1.02×10^{7}	4.73×10^{8}	4.97×10^{12}	7.34×10^{10}	5.05×10^{12}

Boundary Conditions

Boundary conditions for *E. coli* at the most upstream segment in the East and West Branches were assigned a nominal value between 100 and 500 #/100mL to reflect background loadings with associated groundwater base flow and other unidentified inputs. The base flow represents the minimum groundwater flow input to the Creek during dry weather conditions. The months of October through March were assigned a value of 100 #/100mL, April and September were assigned 300 #/100mL, and May through August were assigned 500 #/100mL. These boundary condition values were based on calibration of the WASP6 model to downstream locations and also based on observed *E. coli* levels at upstream stations in the East and West Branches during dry weather conditions.

Initial Conditions

Initial conditions are usually not critical if data is not available at the beginning of the model simulation because the assigned values quickly equilibrate to levels that represent the loading and transport conditions in the model for systems with very short residence time, as is the case in Trail Creek. Initial conditions are more important in system with long residence time (e.g., lakes or estuaries) where the initial assignment may have an impact on the model calculations. Consequently an initial condition of 100 #/100mL was assigned.

Temperature Time Functions

The time functions in the *E. coli* model were three temperature functions for the three branches. The temperature data is from the IDEM *E. coli* sampling database and monthly averages were assigned in the three branches based on the observed data.

Constants

The only constants used in the model were the die-off rate for *E. coli* and the temperature adjustment coefficient for the decay. The most commonly used approach in modeling bacteria disappearance is a simple first-order reaction equation:

$$\frac{dC}{dt} = -kC \quad \text{or} \quad C(t) = C_0 e^{-kt}$$

where:

C = *E. coli* concentration, #/100mL;
C_0 = initial *E. coli* concentration, #/100mL;
C(t) = *E. coli* concentration at time t, #/100mL;
k = *E. coli* die-off rate at ambient temperature, day^{-1}; and
t = exposure time, days.

Factors affecting *E. coli* die-off rates can be physical, physicochemical, and biochemical-biological, such as solar radiation, temperature, sedimentation, nutrient deficiencies, predation, pH, and/or chemical toxicity. Among all the factors, temperature is probably the most generally influential factor modifying all other factors (Bowie, G. L. etc, 1985). The equation for temperature correction for the decay rate, k, in the WASP6 model is the following:

$$k = k_{20}\theta^{T-20}$$

where:

k_{20} = die-off rate at 20°C; and
θ = temperature correction factor.

Typical ranges for the *E Coli* die-off rate ranges from 0.005 hr^{-1} (0.12/day) in the Tennessee River (deep system) in the summer to 1.1 hr^{-1} (26/day) in the Glatt River (Bowie, G. L. etc, 1985). An *E. coli* die-off rate of 1.5/day and typical temperature correction factor (θ) of 1.07 was used for the model calibration. The die-off rate and temperature correction factor, model input requirements were assigned based on literature reported ranges and modeling studies in similar watersheds.

Model Calibration

Figures 5-11a through 5-11h present the WASP6 model time series results as compared to observed data for the year 2000 on both an arithmetic and logarithmic scale for *E. coli*. The black line in these figures represents the WASP6 daily output and the observed values are presented as filled black circles.

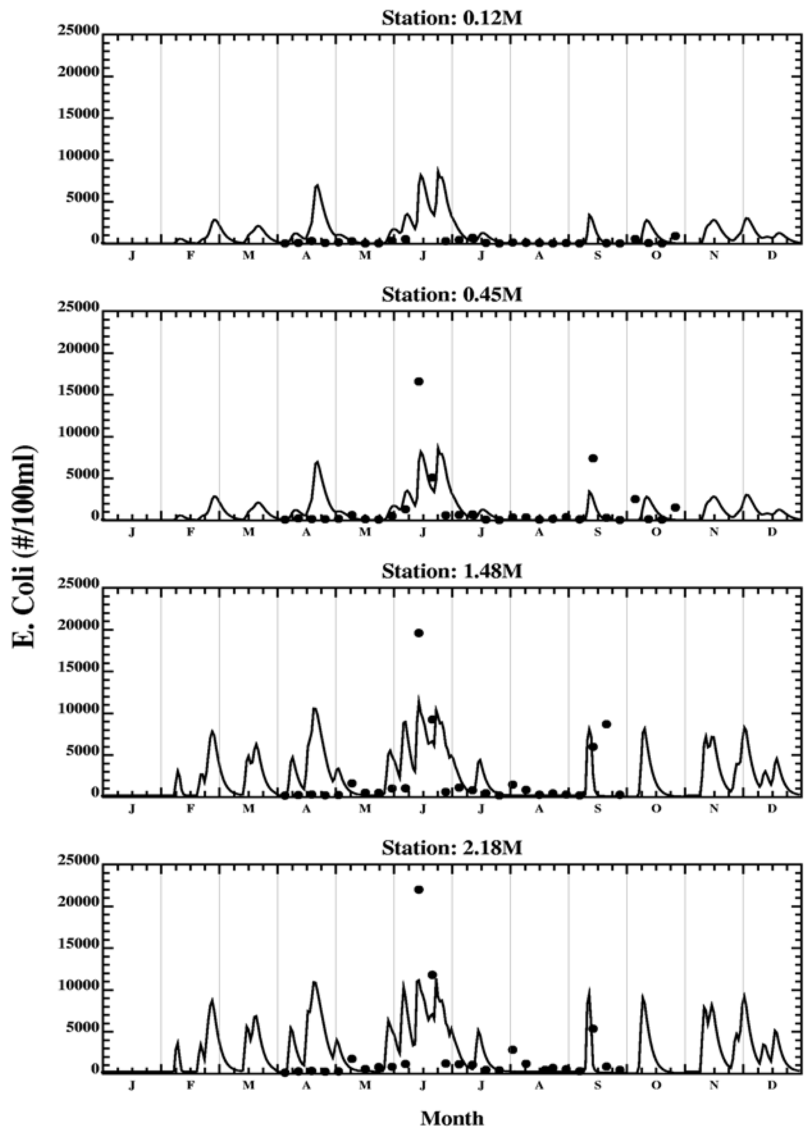


Figure 5-11a. Trail Creek E Coli Model and Data Comparison, Year 2000

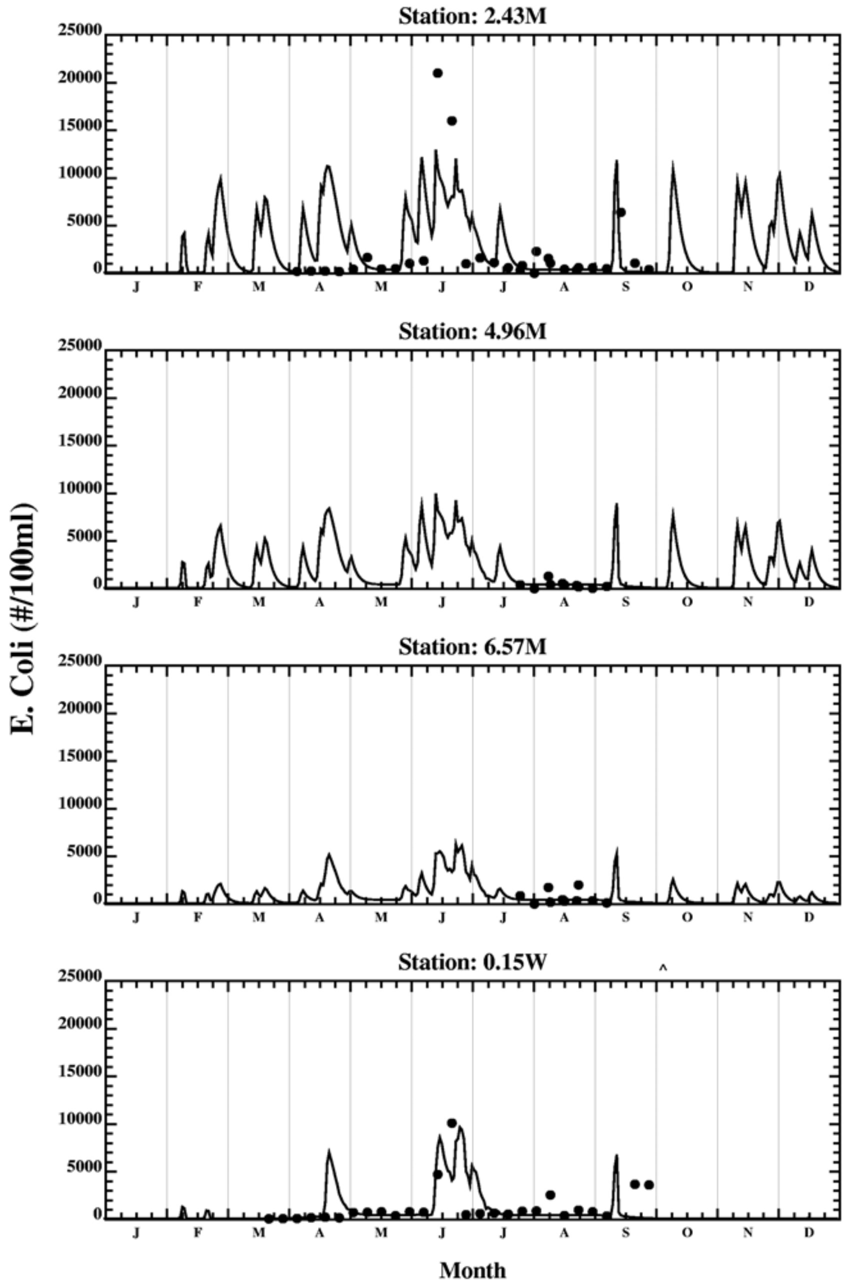


Figure 5-11b. Trail Creek E Coli Model and Data Comparison, Year 2000

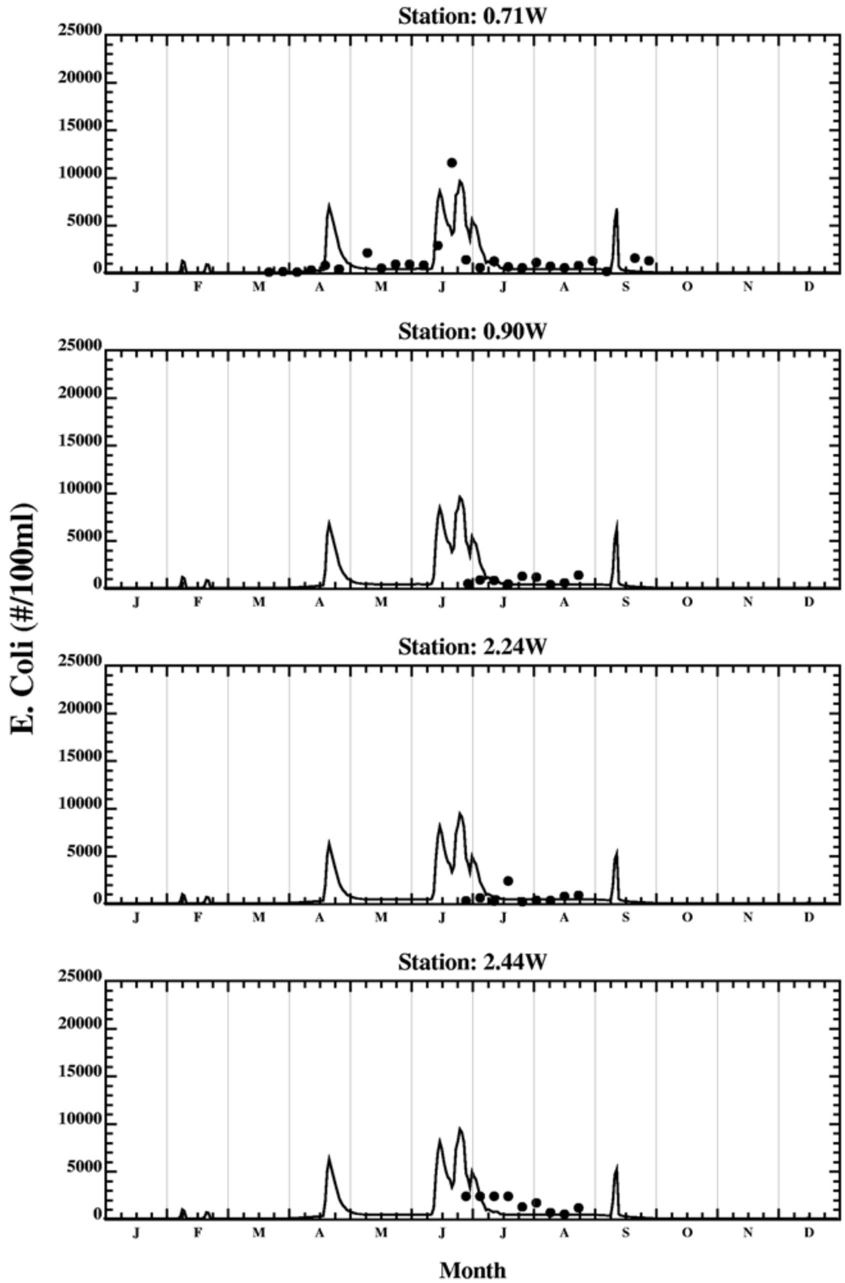


Figure 5-11c. Trail Creek E Coli Model and Data Comparison, Year 2000

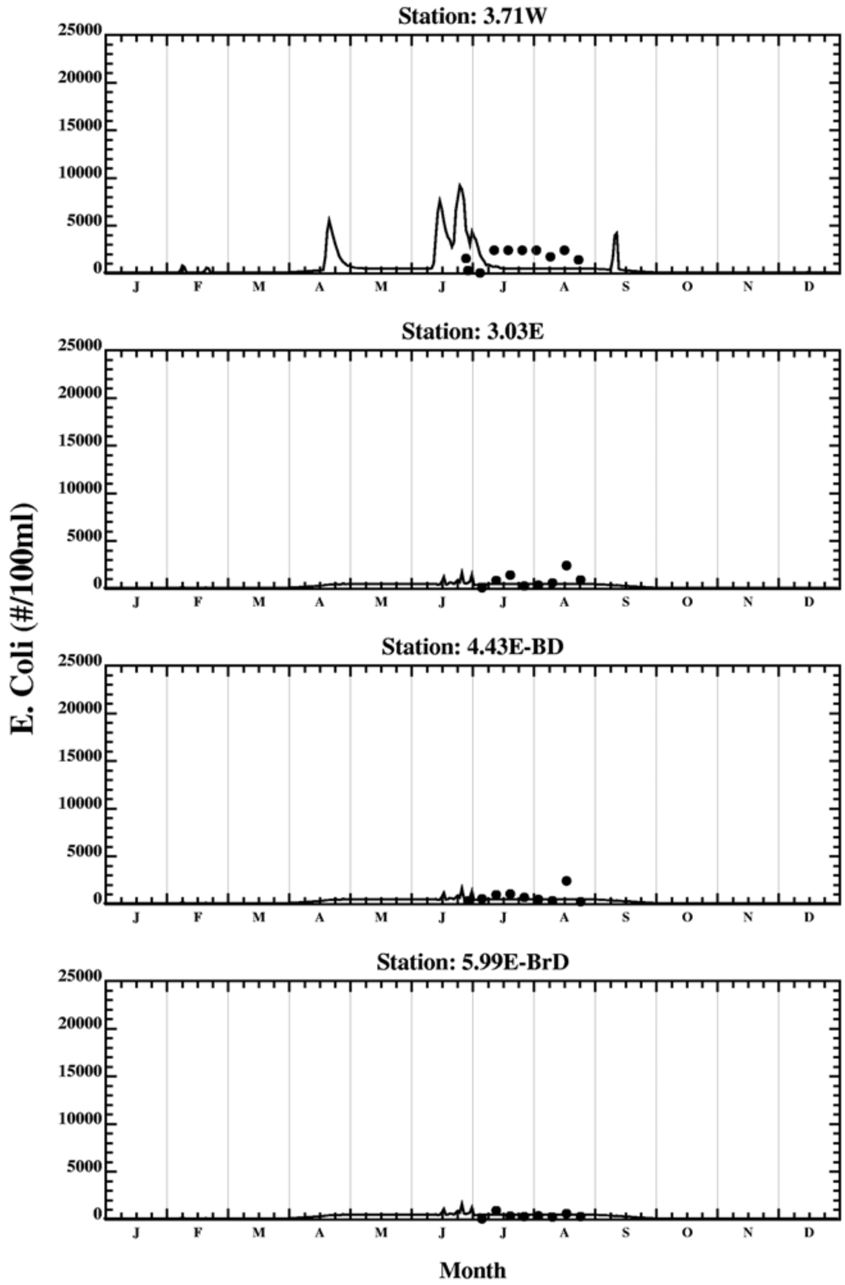


Figure 5-11d. Trail Creek E Coli Model and Data Comparison, Year 2000

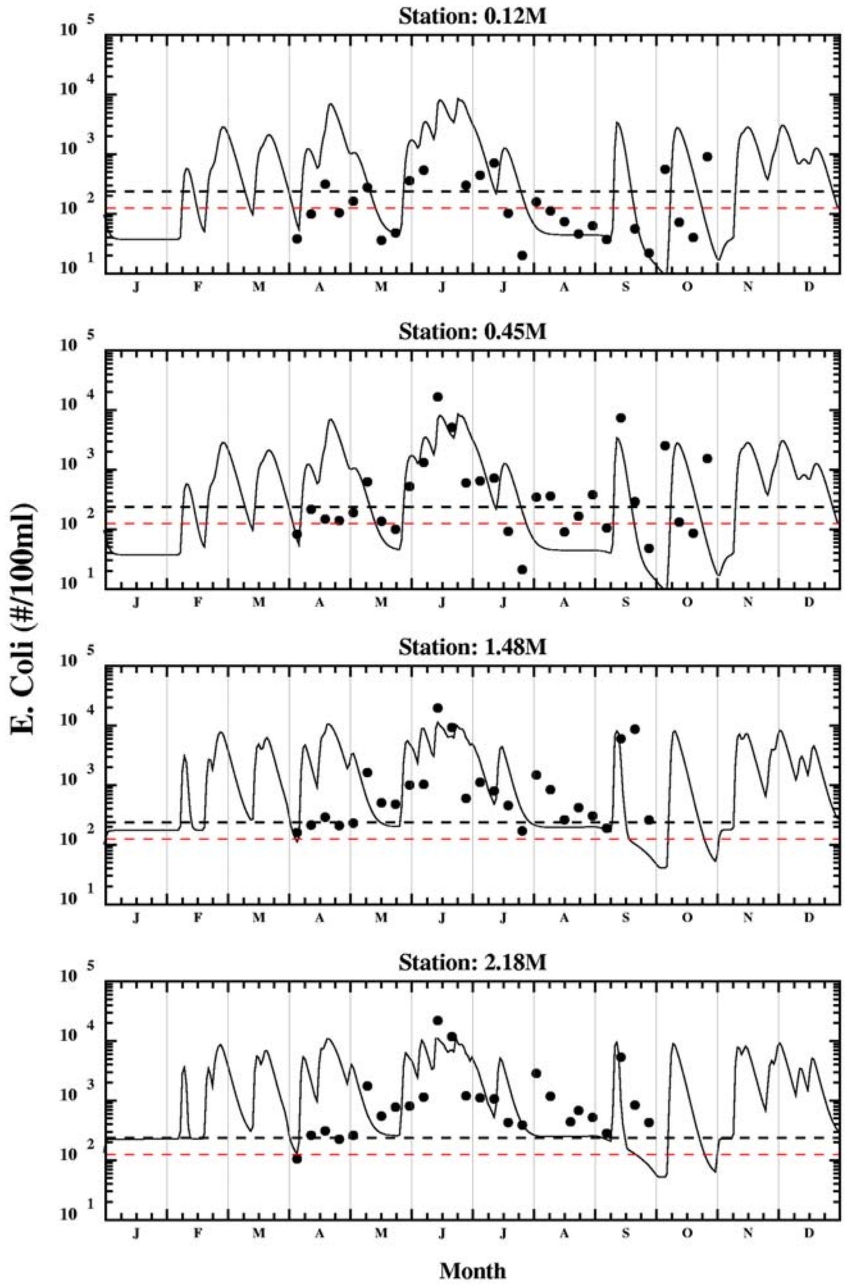


Figure 5-11e. Trail Creek E Coli Model and Data Comparison, Year 2000

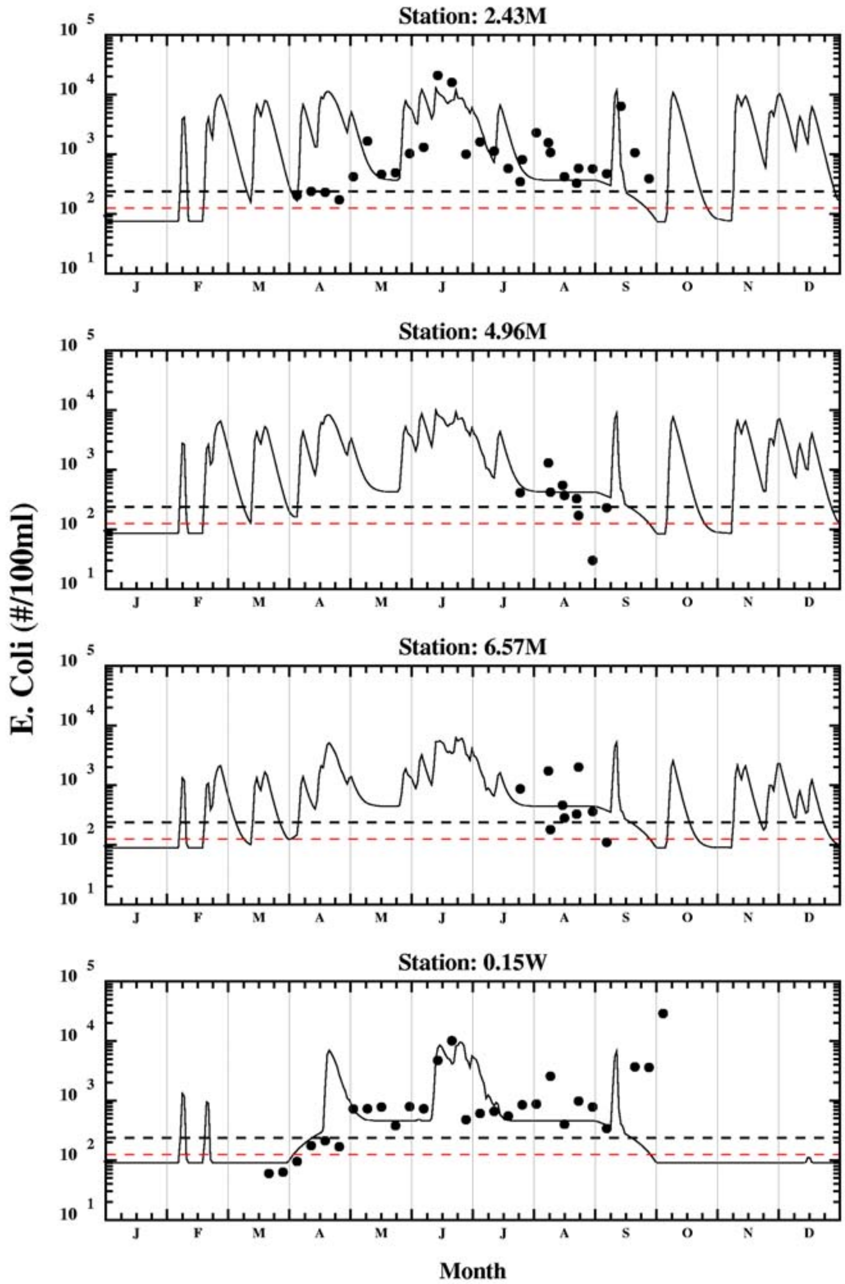


Figure 5-11f. Trail Creek E Coli Model and Data Comparison, Year 2000

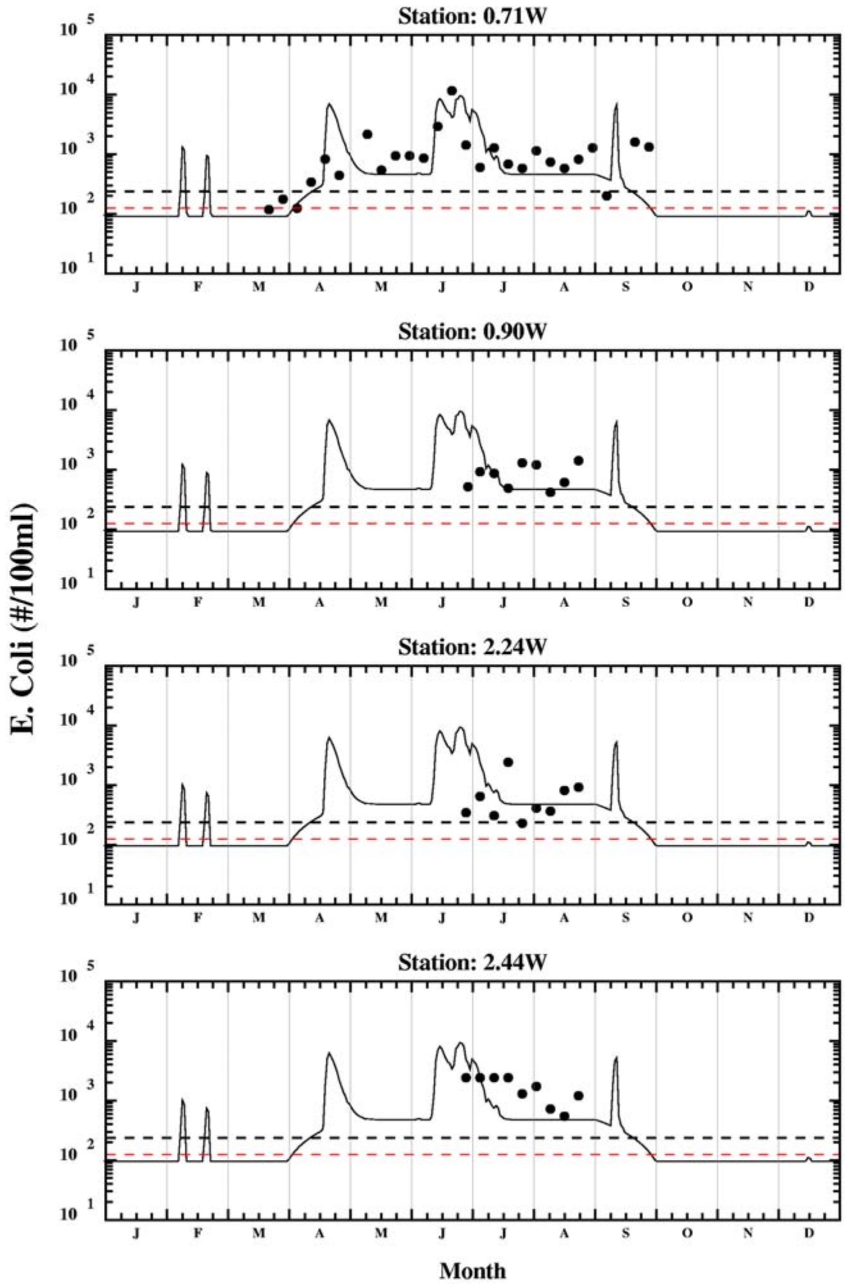


Figure 5-11g. Trail Creek E Coli Model and Data Comparison, Year 2000

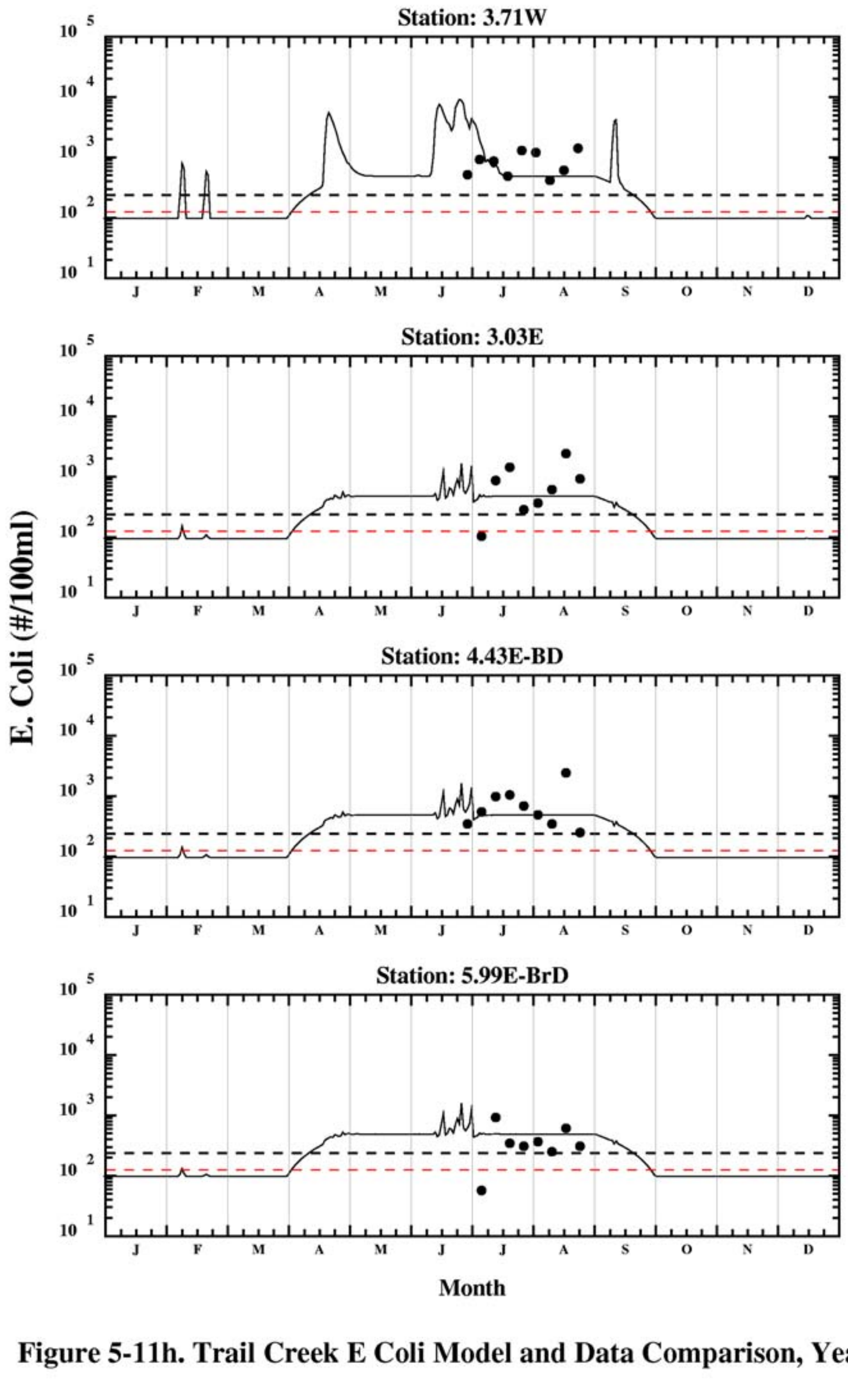


Figure 5-11h. Trail Creek E Coli Model and Data Comparison, Year 2000

There were a number of rainfall events occurring in the year 2000, but most of the samples were collected before or after the events and, therefore, little data was available during a storm event to properly test the model. This sampling artifact is presented in Figures 5-12a and 5-12b for the model and data comparisons in June and September when significant rainfall occurred.

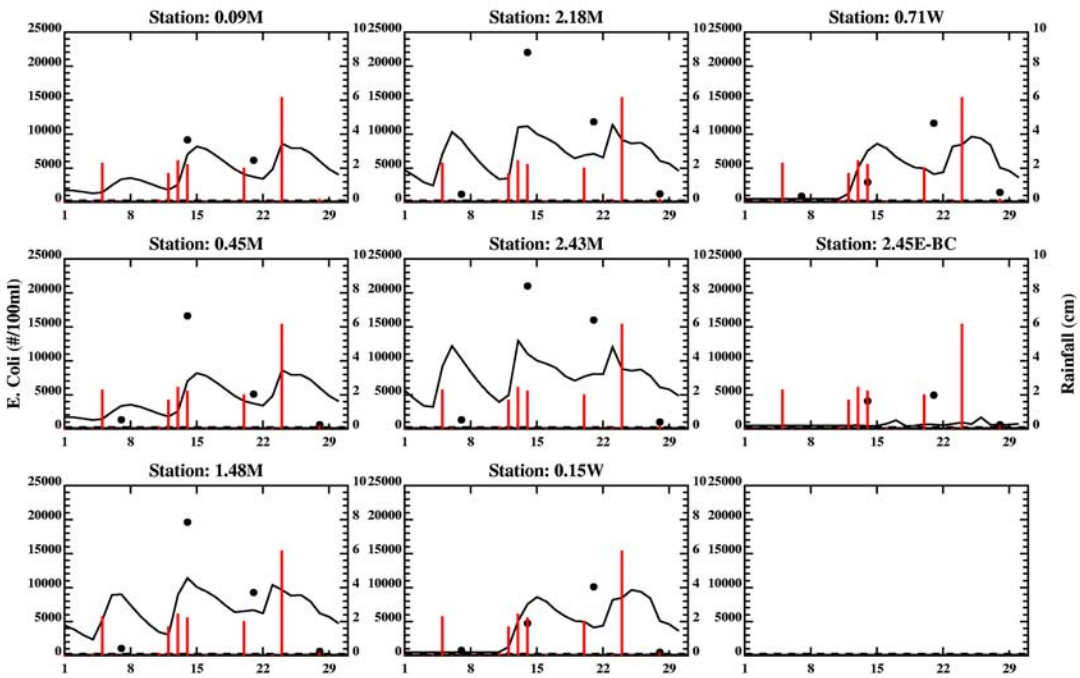


Figure 5-12a. Trail Creek E. Coli Model, Data and Rainfall, June 2000

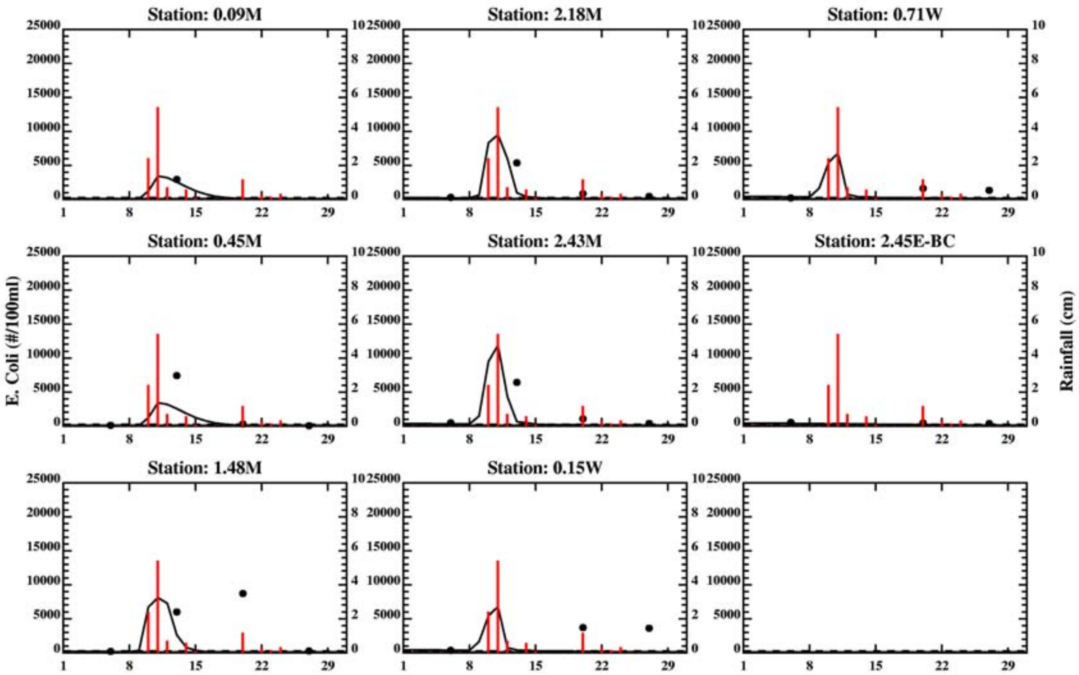


Figure 5-12b. Trail Creek E. Coli Model, Data and Rainfall, September 2000

Observed data near the mouth of the creek were typically lower than the WASP6 results but this is most likely due to additional dilution of the creek from Lake Michigan not represented in the model. Also, the model did not reproduce some of the higher observed values in June in the Main Branch but this may suggest that there is a missing *E. coli* source entering the creek, as these high values are not observed upstream. In general, the WASP6 model reasonably reproduced the observed data in the East, West and Main Branches given the limitations in the sampling for *E. coli* in Trail Creek.

There were a few sampling events that came closer to capturing a storm event and these are presented in Figures 5-12a and 5-12b for June and September, respectively. These figures present the observed *E. coli* data, WASP6 model output and rainfall data for the months of June and September at a number of stations in Trail Creek. These figures highlight the typical creek sampling before and after storms and also that the model does capture these non-storm periods fairly well. The storm event in the middle of June was not completely reproduced by the WASP6 model but this may be due to a missing source as discussed above. The storm events in September were better reproduced by the model and, therefore, highlight that the model is capable of representing *E. coli* levels in Trail Creek.

Another way to compare model output with observed data is through comparison of probability distributions. This type of comparison highlights whether the model reproduces the observed variation observed in the data. Figures 5-13a and 5-13b present the model calculated and observed probability distributions of *E. coli* concentrations at various stations in the East, West and Main Branches of Trail Creek. In order to generate the model distributions, model output was extracted during the months when sampling occurred at the respective monitoring stations. In general, the model calculated median and variation compared fairly well with the observed data indicating that although exact timing may not be reproduced in the model, the observed variation is reproduced at most stations.

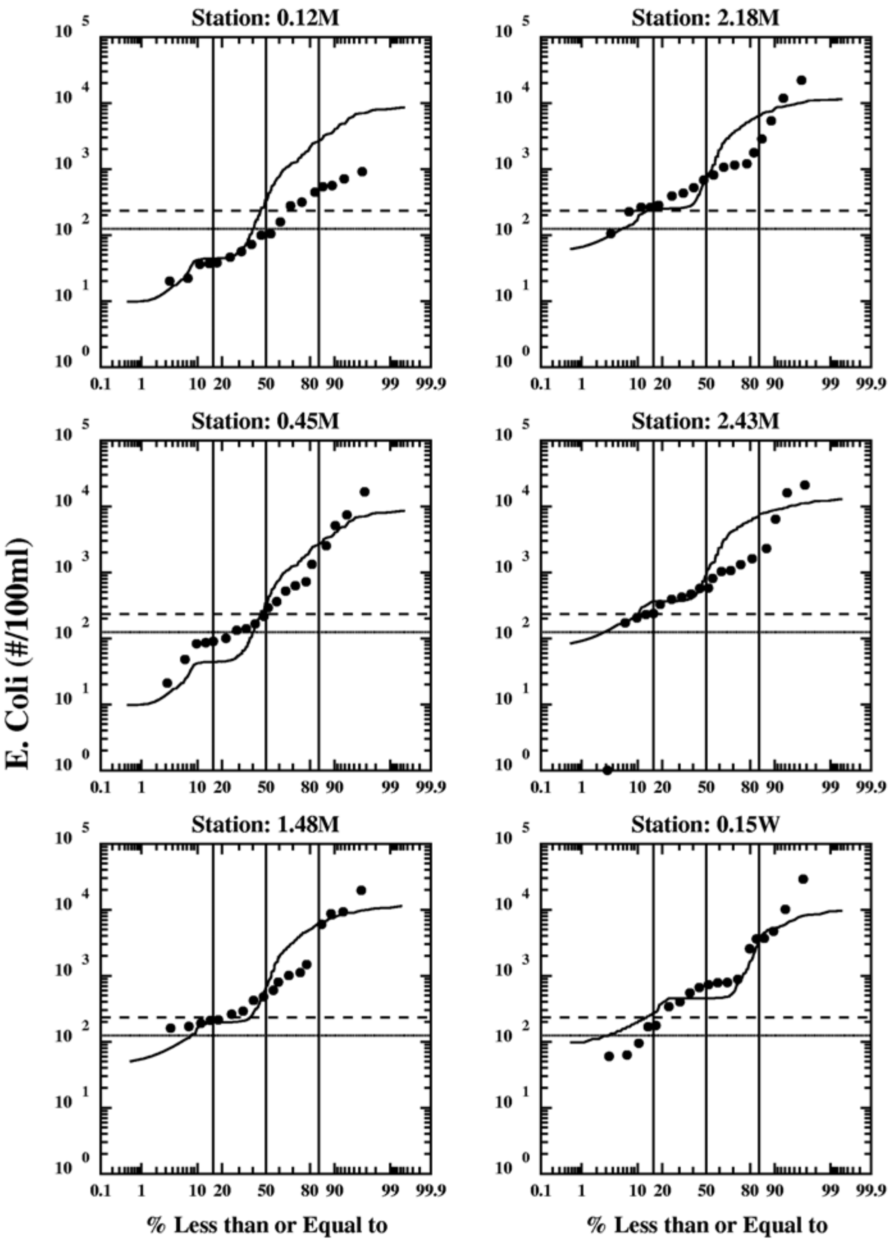


Figure 5-13a. Trail Creek E. Coli Model and Data Probability Plots, 2000

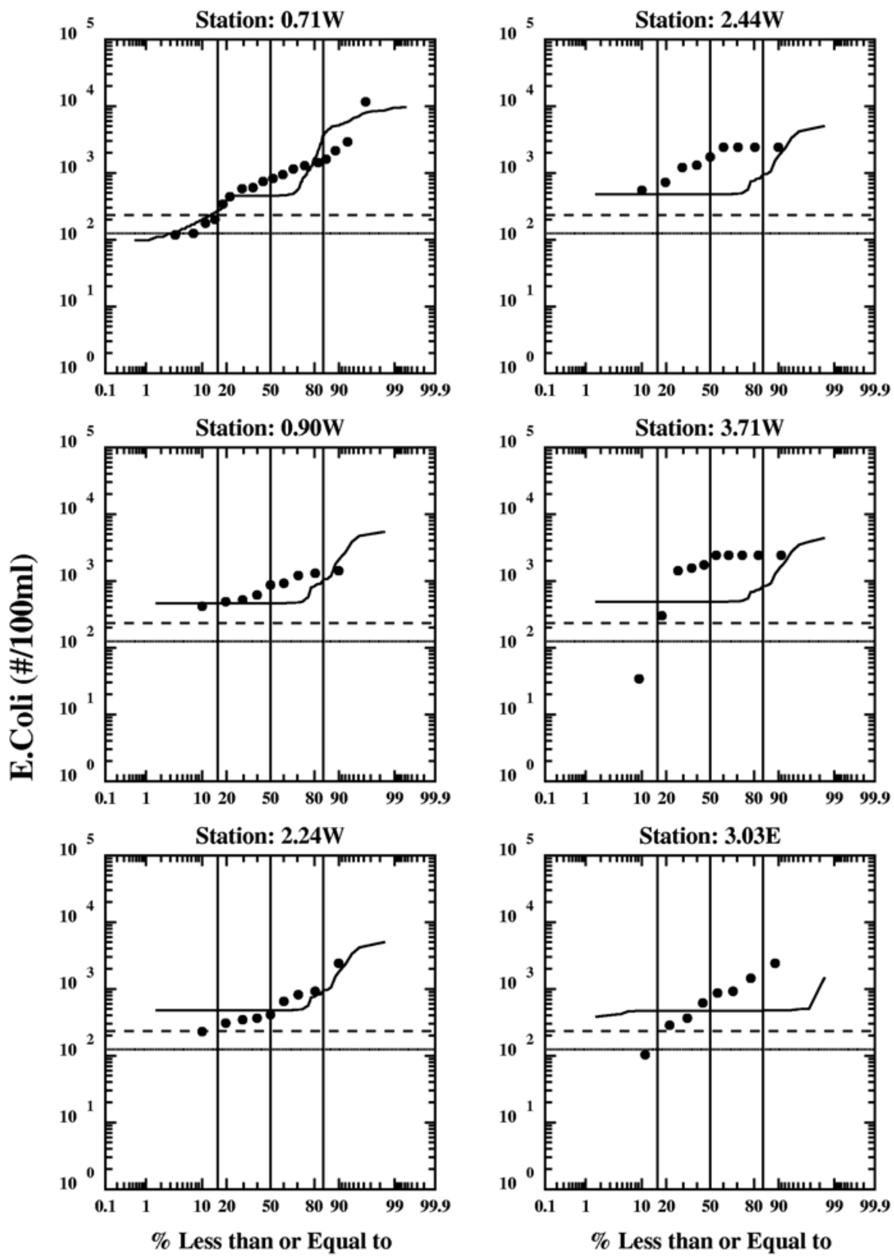


Figure 5-13b. Trail Creek E. Coli Model and Data Probability Plots, 2000

Model Sensitivity

In order to investigate the sensitivity to the Main Branch *E. coli* runoff concentrations, two additional model runs were completed. These sensitivities were chosen because the Main Branch runoff concentration was partially estimated from observed data in the watershed and typical urban storm water runoff concentrations can vary over orders of magnitude. Two sensitivities were completed for a Main Branch runoff concentration of 10,000 #/100mL and 50,000 #/100mL, the figures of which are contained in Appendices 1 and 2, respectively. In general, these figures highlight the importance of the urban storm water runoff concentration on the calculated *E. coli* concentrations in the Main Branch of Trail Creek. The higher runoff concentration (50,000 #/100mL) improves the model fit of the observed data in June but also causes higher calculated concentrations than observed during other times of the year. The opposite is true for the lower runoff concentration (10,000 #/100mL). These results indicate that better definition of *E. coli* concentration from urban storm water runoff for the Main Branch of Trail Creek should be investigated.

5.3 CONCLUSIONS

The Trail Creek Watershed model reasonably reproduced observed creek flow and *E. coli* concentrations given the limitations present in both the flow and *E. coli* databases. Although the models are not rigorously calibrated due a lack of acceptable flow and *E. coli* data, the models can be used to assess current conditions and to develop allocation and implementation strategies for Trail Creek. That is, the GWLF and WASP6 models were developed with the best information available at this time and the development of point source wasteload allocations (WLA) and nonpoint source load allocations (LA) for the Trail Creek *E. coli* TMDL is practical and supported by the available data.

APPENDIX 1

MAIN BRANCH RUNOFF SENSITIVITY
(10,000 #/100mL)

APPENDIX 2

MAIN BRANCH RUNOFF SENSITIVITY
(50,000 #/100mL)

Section 6.0
TMDL LOAD ALLOCATION

A TMDL is the maximum loading of a pollutant that a waterbody can assimilate and still meet State water quality standards. The numeric targets for the Trail Creek *E. coli* TMDL are a monthly geometric mean standard of 125 cfu/100mL and a maximum daily standard of 235 cfu/100mL. Typically, loading assessments are completed at critical waterbody conditions (e.g., point source WLA are typically completed at low-flow, summer conditions). Based on the source assessment and watershed modeling, *E. coli* levels in Trail Creek are present during both dry and wet weather conditions and, therefore, low-flow critical conditions are not necessarily appropriate for developing the TMDL. The critical conditions for determining the *E. coli* TMDL are varied and the year 2000 modeling period was used, which represents a range of both dry and wet weather conditions. In addition, seasonality must be incorporated into the TMDL and this is accomplished with the year 2000 modeling period, which ranges from January to December 2000 (winter, spring, summer and fall).

TMDLs for most pollutants are developed on a mass loading basis (e.g., BOD allocations to point and nonpoint sources in units of pounds/day). For *E. coli*, a mass loading approach is not suitable and, therefore, a concentration based approach is used as recommended by the USEPA (USEPA, 2001). This concept is presented below as stated in the USEPA document *"Protocol for Developing Pathogen TMDLs"*.

> "For most pollutants, TMDLs are expressed on a mass loading basis (e.g., pounds per day). For fecal indicators, however, TMDLs can be expressed in terms of organism counts (or resulting concentration), in accordance with 40 CFR 130.2(i): 'TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure,' and NPDES regulations at 40 CFR 122.45(f): 'All pollutants limited in permits shall have limitations … expressed in terms of mass except … pollutants which cannot appropriately be expressed by mass.' "

Therefore, the Trail Creek TMDL was developed on a concentration basis so that *E. coli* levels throughout the watershed will meet the State monthly geometric mean standard of 125 #/100mL and maximum daily standard of 235 cfu/100mL.

In order to meet the TMDL concentrations (125 and 235 cfu/100mL), continued operation of the four point sources in the watershed in accordance with their IDEM NPDES permits (125 cfu/100mL monthly geometric mean and 235 cfu/100mL daily maximum) at their permitted effluent flow will meet the WLA component of the *E. coli* TMDL for Trail Creek. The permitted flow for the Michigan City Sanitary Station is 12 MGD, for Friendly Acres Mobile Home Park is 0.015 MGD, for Autumn Creek Mobile Home Park is 0.010 MGD, and for Indian Springs Subdivision is 0.018 MGD. Any violations of their permits and, therefore, violation of the TMDL will be handled through IDEM permitting groups and DMR reporting requirements. Typically, these point sources operate at *E. coli* levels less than the TMDL concentrations and, therefore, will provide an additional level of protection. Continued efforts by the Michigan City Sanitary District to implement their LTCP will minimize and eventually eliminate CSO discharges of *E. coli* to Trail Creek. The LTCP has been reviewed by IDEM, and Michigan City is currently in the process of responding to their comments.

Similarly, nonpoint sources in the watershed will need to meet the TMDL concentrations (125 and 235 cfu/100mL) in order for Trail Creek to be in compliance with State *E. coli* standards. Since nonpoint source loads are rainfall runoff driven, an initial estimate of the nonpoint source LA component of the TMDL was assigned a runoff concentration of *E. coli* at the maximum daily standard of 235 cfu/100mL. The base flow LA component of the nonpoint sources (i.e., the continuous loading component) was assigned an *E. coli* concentration of 125 cfu/100mL. The resulting instream *E. coli* concentrations due to the WLA and LA described above is presented in Figures 6-1a through d, which present the resulting *E. coli* concentrations at the calibration stations in the Main, West and East Branches of Trail Creek.

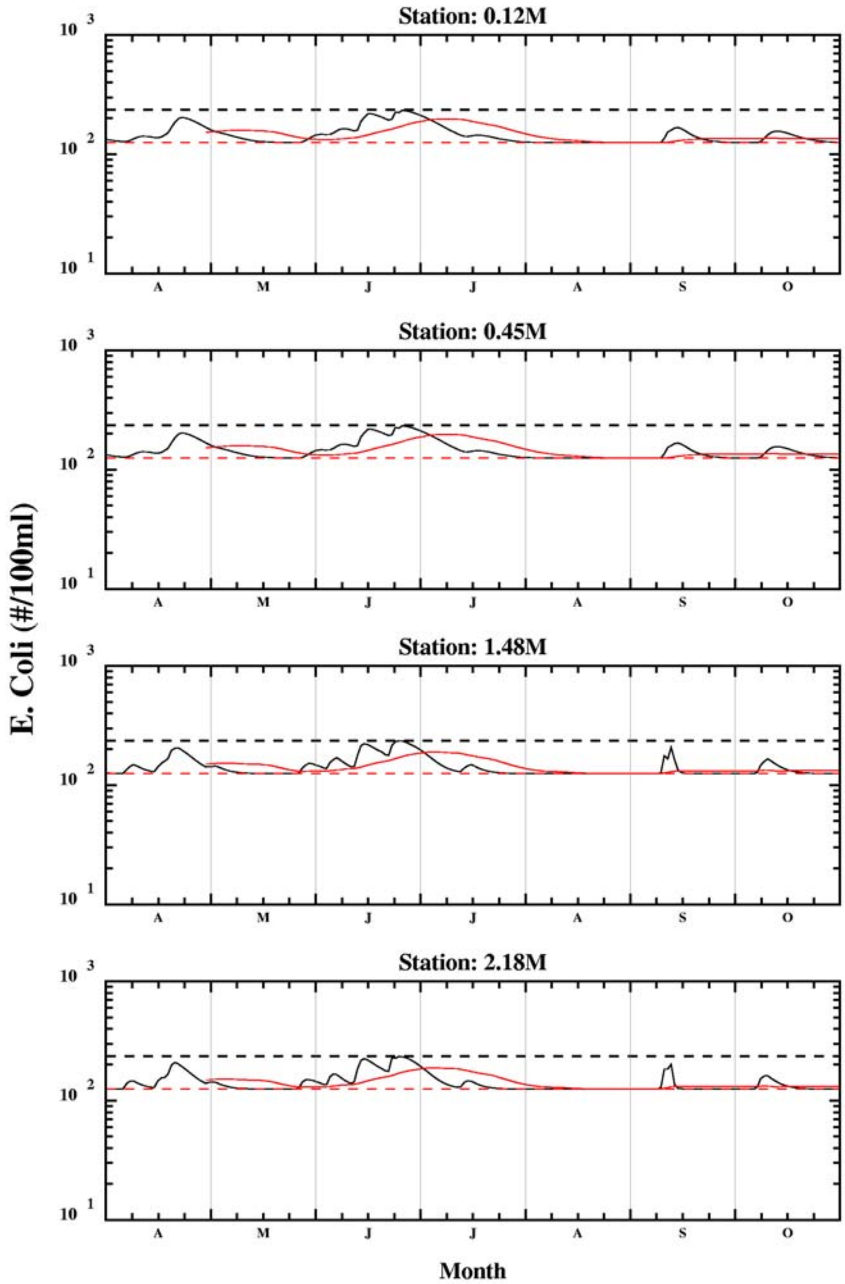


Figure 6-1a. Trail Creek E Coli Model and Data Comparison, Year 2000

(Max STD   Geo Mean STD   Daily Model Output   30-day Geo Mean of Model Output)

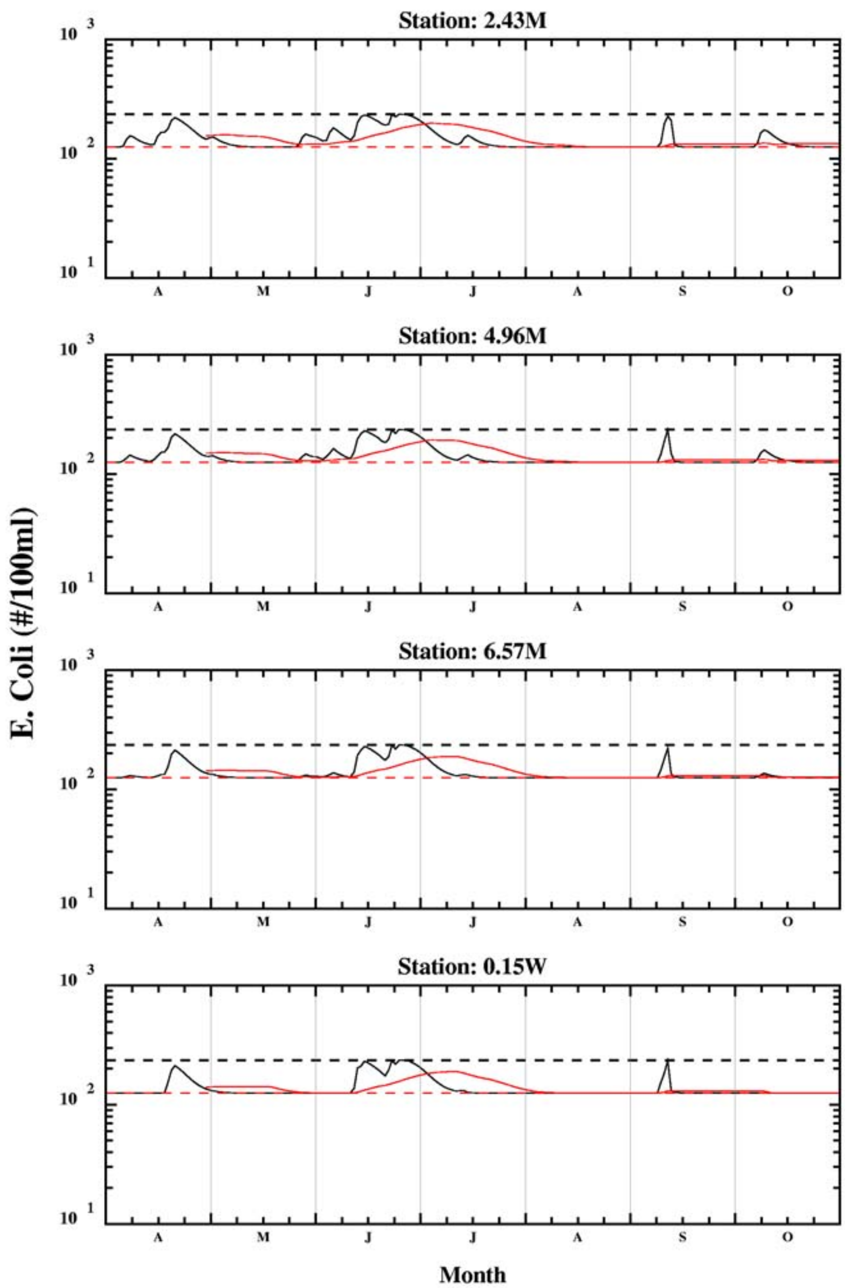


Figure 6-1b. Trail Creek E Coli Model and Data Comparison, Year 2000

(Max STD — Geo Mean STD — Daily Model Output — 30-day Geo Mean of Model Output)

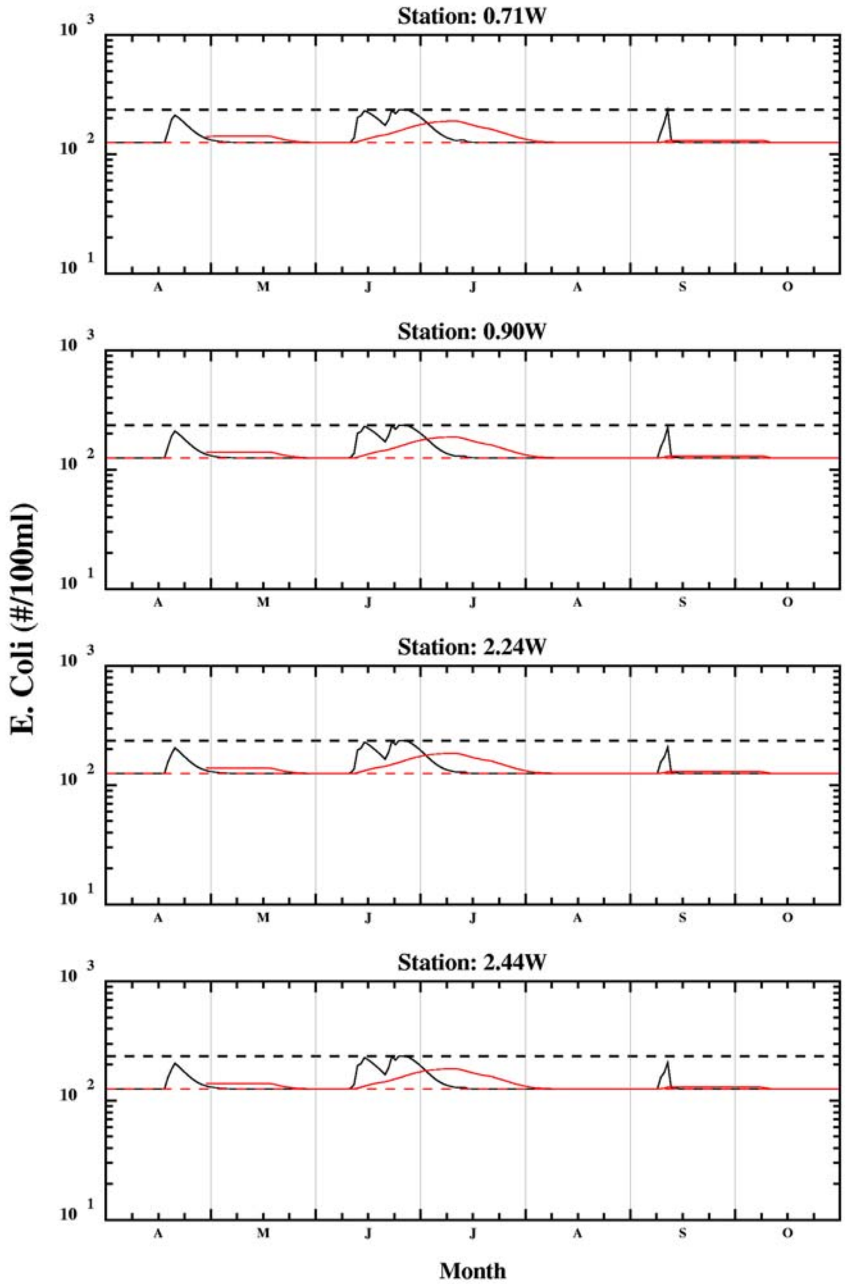


Figure 6-1c. Trail Creek E Coli Model and Data Comparison, Year 2000

(Max STD — Geo Mean STD — Daily Model Output — 30-day Geo Mean of Model Output)

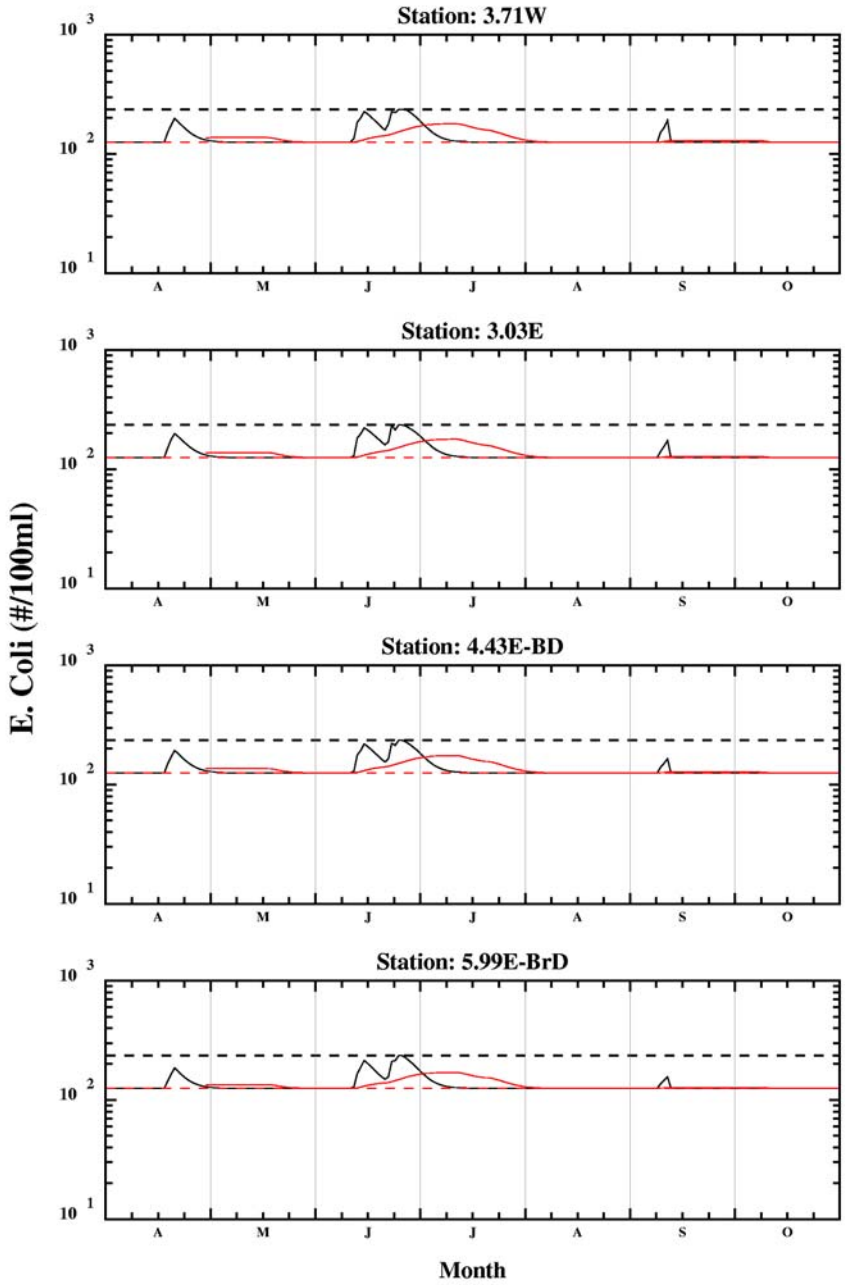


Figure 6-1d. Trail Creek E Coli Model and Data Comparison, Year 2000
(Max STD Geo Mean STD Daily Model Output 30-day Geo Mean of Model Output)

As presented, the maximum daily *E. coli* standard of 235 cfu/100mL is attained with these load allocations but the monthly geometric mean standard is still violated at a number of stations.

An additional (final) LA was developed that assigned a nonpoint source runoff E. Coli concentration of 125 cfu/100mL. The resulting calculated instream E. Coli concentrations for this additional LA is presented in Figures 6-2a through 6-2d and represents the final E. Coli LA for Trail Creek.

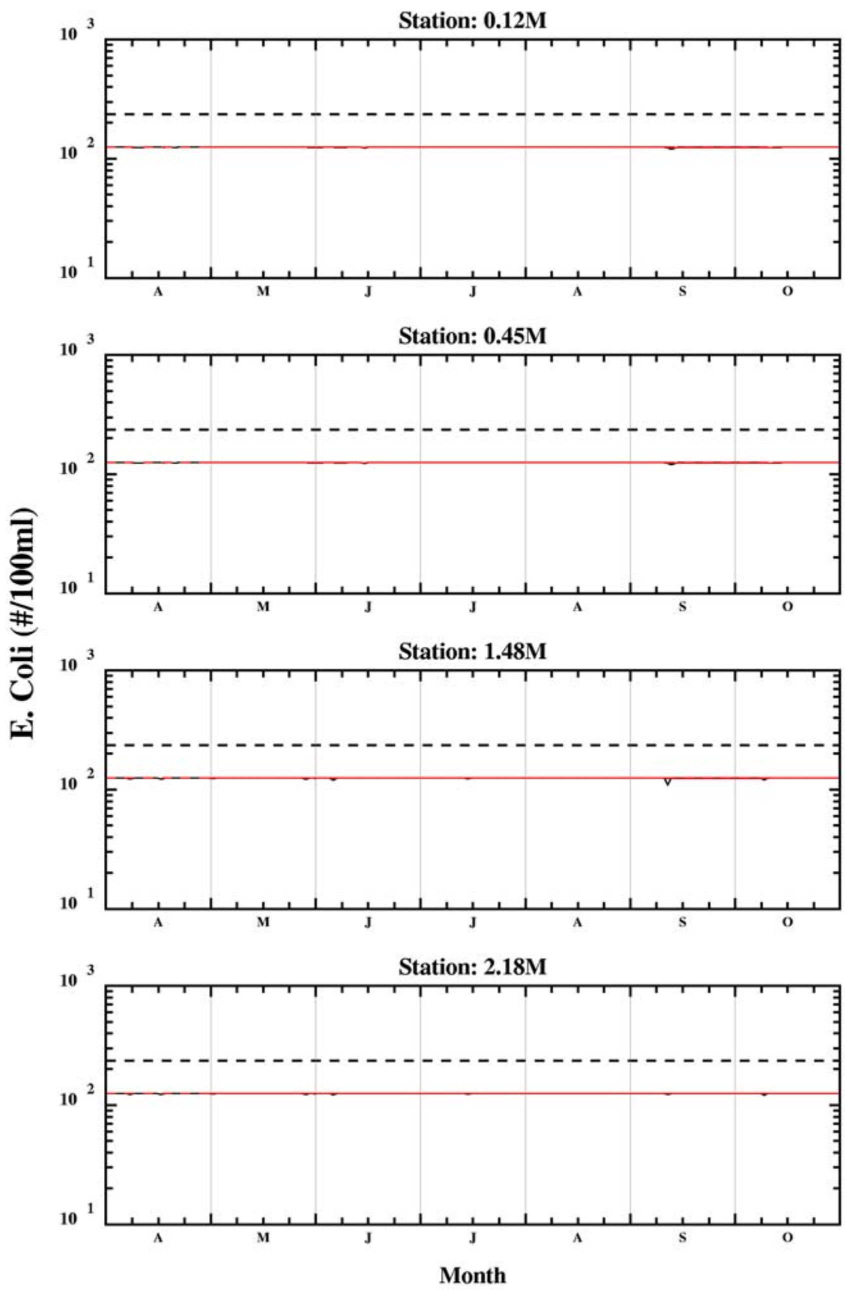


Figure 6-2a. Trail Creek E Coli Model and Data Comparison, Year 2000

(— — Max STD — — Geo Mean STD —— Daily Model Output —— 30-day Geo Mean of Model Output)

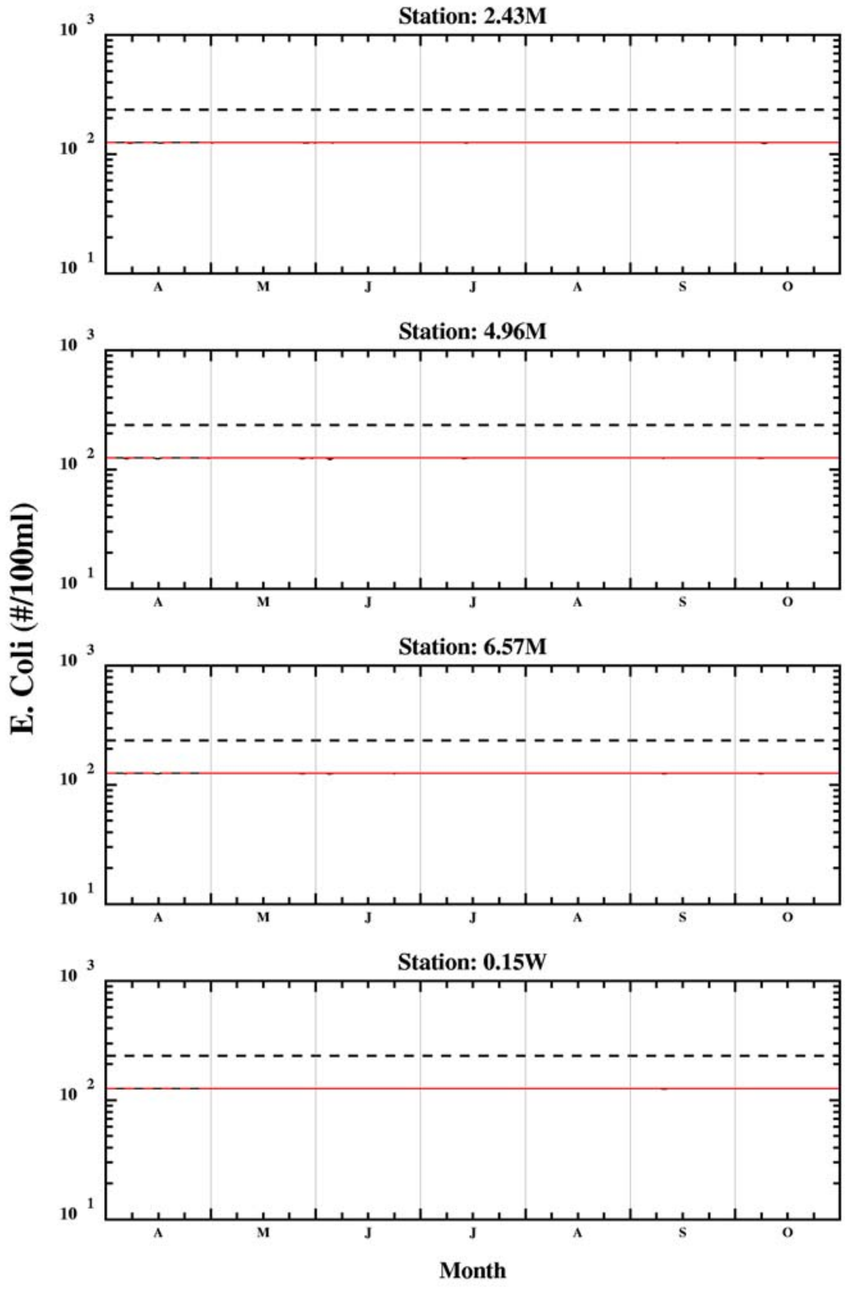


Figure 6-2b. Trail Creek E Coli Model and Data Comparison, Year 2000

(— — Max STD — — Geo Mean STD —— Daily Model Output —— 30-day Geo Mean of Model Output)

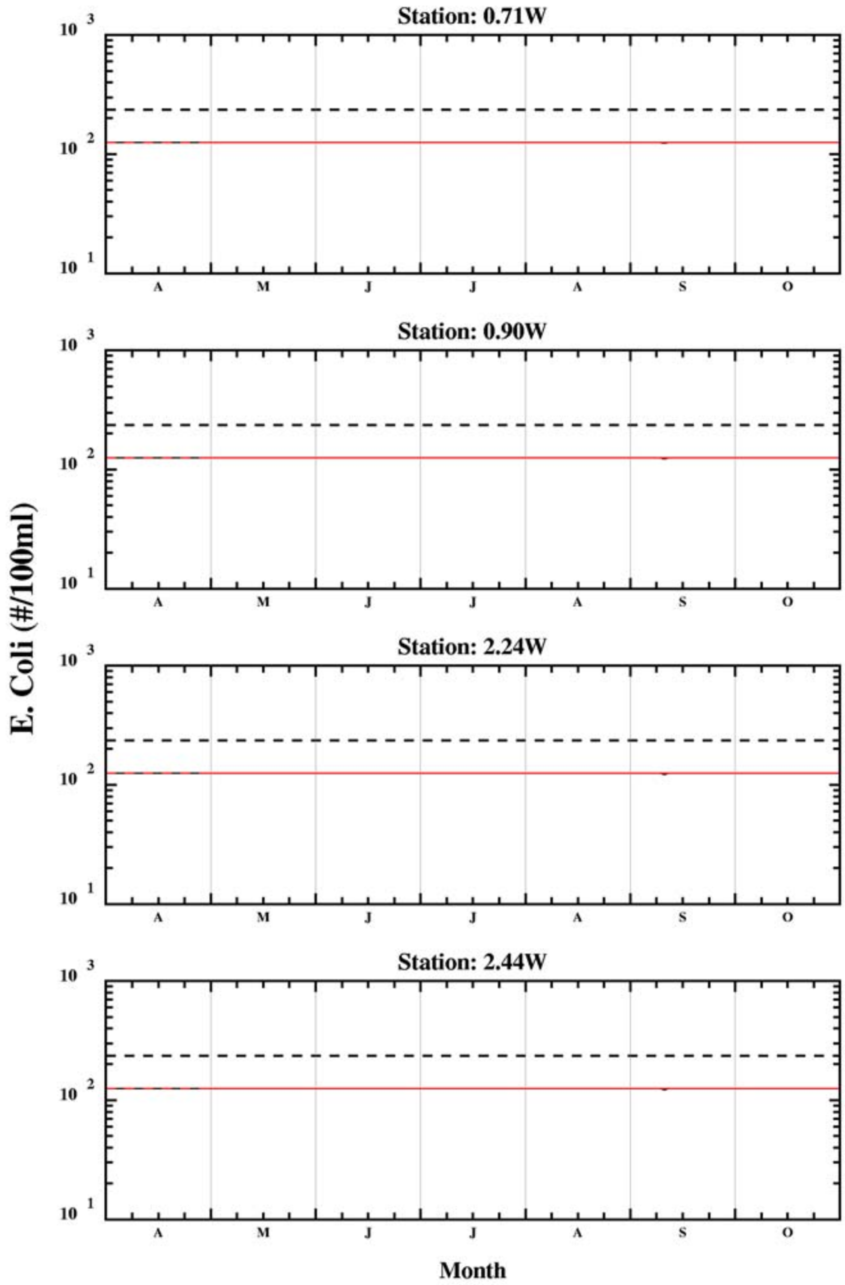


Figure 6-2c. Trail Creek E Coli Model and Data Comparison, Year 2000

(Max STD Geo Mean STD Daily Model Output 30-day Geo Mean of Model Output)

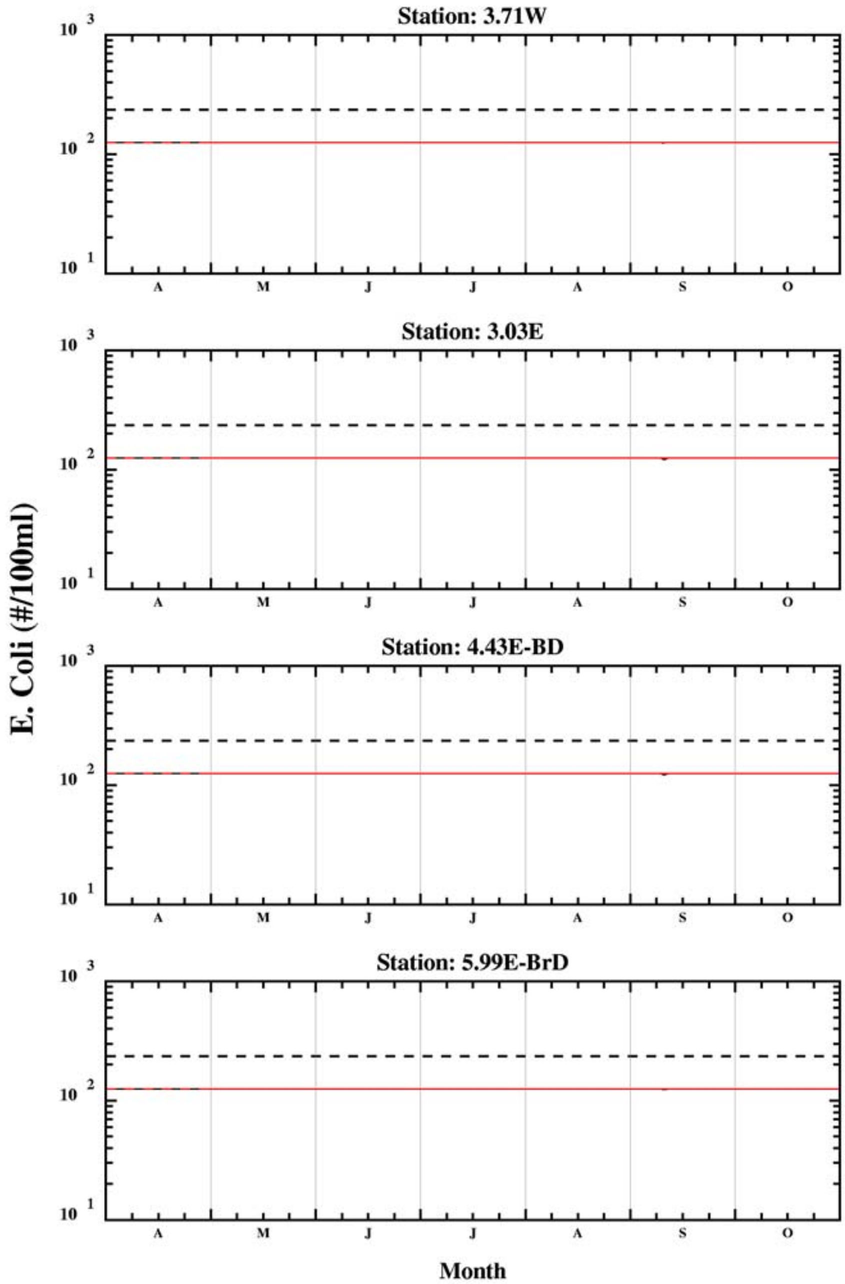


Figure 6-2d. Trail Creek E Coli Model and Data Comparison, Year 2000

(Max STD — Geo Mean STD — Daily Model Output — 30-day Geo Mean of Model Output)

The resulting TMDL for this additional LA results in attainment of both the daily maximum and monthly geometric mean standards in Trail Creek. This final TMDL requires an *E. coli* nonpoint source LA of 125 cfu/100mL for all sources. Tables 6-1 and 6-2 present the final WLA and LA in counts/day that meet the TMDL concentrations of a monthly geometric mean of 125 cfu/100mL and daily maximum of 235 cfu/100mL during the recreational season of April to October. A summary of the total WLA and LA for the final TMDL is presented in Table 6-3.

The required MOS is incorporated into the TMDL analysis implicitly. TMDL rules allow for an explicit MOS (i.e., expressed in the TMDL as a portion of the allocations) or an implicit MOS (i.e., incorporated through conservative assumptions in the analysis). The implicit MOS was used because a conservative die-off rate was assigned as zero for the allocation model allocations, which accounts for uncertainty in the model. That is, the calibration and validation modeling was completed using E. Coli die-off rate of 1.5/day and the MOS was incorporated into the TMDL by using a die-off rate of zero for all the model allocation runs.

Table 6-1. Point Source *E. coli* WLA (cfu/day)

Month	Mich. City Sanitary Station	Friendly Acres MHP	Autumn Creek MHP	Indian Springs Subdivision
Apr	5.68×10^{10}	6.81×10^{8}	1.18×10^{8}	1.18×10^{8}
May	5.68×10^{10}	6.81×10^{8}	1.18×10^{8}	1.18×10^{8}
Jun	5.68×10^{10}	6.81×10^{8}	1.18×10^{8}	1.18×10^{8}
Jul	5.68×10^{10}	6.81×10^{8}	1.18×10^{8}	1.18×10^{8}
Aug	5.68×10^{10}	6.81×10^{8}	1.18×10^{8}	1.18×10^{8}
Sep	5.68×10^{10}	6.81×10^{8}	1.18×10^{8}	1.18×10^{8}
Oct	5.68×10^{10}	6.81×10^{8}	1.18×10^{8}	1.18×10^{8}

Table 6-2. Nonpoint Source *E. coli* LA (cfu/day)

Month	East Branch	West Branch	Main Branch	Baseflow	Total
Apr	1.36×10^{10}	1.42×10^{10}	5.50×10^{10}	9.18×10^{10}	1.75×10^{11}
May	3.38×10^{8}	3.98×10^{8}	1.17×10^{10}	9.18×10^{10}	1.04×10^{11}
Jun	1.18×10^{11}	1.30×10^{11}	1.51×10^{11}	9.18×10^{10}	4.91×10^{11}
Jul	1.08×10^{10}	1.16×10^{10}	1.45×10^{10}	9.18×10^{10}	1.29×10^{11}
Aug	1.69×10^{5}	1.82×10^{5}	1.68×10^{7}	9.18×10^{10}	9.18×10^{10}
Sep	2.49×10^{9}	4.57×10^{9}	1.04×10^{10}	9.18×10^{10}	1.09×10^{11}
Oct	4.53×10^{3}	9.73×10^{3}	1.68×10^{10}	9.18×10^{10}	1.09×10^{11}

Table 6-3. Trail Creek TMDL *E. coli* WLA & LA (cfu/day)			
Month	**Total WLA**	**Total LA**	**TMDL**
Apr	5.72×10^{10}	1.75×10^{11}	2.32×10^{11}
May	5.72×10^{10}	1.04×10^{11}	1.61×10^{11}
Jun	5.72×10^{10}	4.91×10^{11}	5.48×10^{11}
Jul	5.72×10^{10}	1.29×10^{11}	1.86×10^{11}
Aug	5.72×10^{10}	9.18×10^{10}	1.49×10^{11}
Sep	5.72×10^{10}	1.09×10^{11}	1.66×10^{11}
Oct	5.72×10^{10}	1.09×10^{11}	1.66×10^{11}

Monitoring and Reasonable Assurance

In order to investigate the effectiveness of the allocations in meeting the Trail Creek TMDL continued monitoring in the watershed for *E. coli* is recommended. The monitoring program should be designed to provide good spatial coverage of the watershed but also be aimed at obtaining data during dry and wet weather conditions. In addition, storm event monitoring should also be completed to better define nonpoint source loadings in the watershed.

For the permitted point sources in the watershed, IDEM NPDES permitting and monitoring requirements will provide the necessary reasonable assurance that these sources are not contributing to violations of State *E. coli* standards. For the nonpoint sources, State storm water regulations and land application permits should also provide these necessary reasonable assurance for these potential types of nonpoint sources. The other nonpoint sources will need to be monitored locally for implementation of BMPs or in providing access to watershed grants to assist in reducing nonpoint sources to meet the LA developed under this TMDL. The Unity/Michigan City Sanitary District has received a 319 grant for use in the Trail Creek E. Coli TMDL.

The only monitoring currently performed in the Trail Creek watershed is conducted by the Michigan City Sanitary District. The Sanitary District monitors *E. coli*, water temperature, flow and precipitation on a weekly basis at one location upstream and one location downstream of the WWTP outfall, as well as the plant effluent. In addition, IDEM will conduct water quality monitoring in the Trail Creek watershed, as part of their Basin Rotation Monitoring program, in 2005.

The Michigan City Sanitary District has received funding from the IDEM Section 319 Grant Program to update the Trail Creek Watershed Plan. One of the major objectives of the proposed Trail Creek Watershed Plan is to develop specific goals, strategies and actions that will eventually lead to a reduction of *E. coli* concentrations in Trail Creek.

Section 7.0
PUBLIC PARTICIPATION

7.1 PUBLIC MEETINGS

To date, IDEM has held four public meetings to present information on the TMDL process and to provide periodic updates on the milestones reached in the Trail Creek TMDL development. Information such as data sources, source assessment, model introduction and the draft TMDL for Trail Creek were presented. The public meetings were held on July 25, 2002; October 23, 2002, March 19, 2003 and September 15, 2003.

IDEM invited all stakeholders in the Trail Creek watershed, as well as many major environmental groups and concerned citizens.

Section 8.0
LIMITATIONS

The Trail Creek *E.coli* TMDL study was performed in accordance with generally accepted practices for the environmental consulting profession, undertaking similar studies at the same time and in the same geographical area as the work conducted by Triad. Triad observed the degree of care and skill that are generally exercised by the profession under similar circumstances and conditions. No other warranty is expressed or implied.

Triad's observations, findings, and opinions should not be considered as scientific certainties, but only as opinion based upon our professional judgment concerning the significance of the data gathered during the course of this investigation. Specifically, Triad does not and cannot represent that the watershed has characteristics or other latent conditions beyond that observed or evaluated by Triad during the course of the investigation. Additionally, due to limitations of the investigation/evaluation process and the necessary use of data furnished by others, Triad and its associates cannot assume liability if actual conditions differ from the information presented in this report.

This report and the findings contained herein shall not, in whole or in part, be disseminated nor used by any other party, in whole or in part, as such action may result in inaccuracies and/or misrepresentations concerning the information obtained by Triad.

Section 9.0
REFERENCES

Bowie G. L., Mills W. B., Porcella D. B., Campbell C. L., Pagenkopf J. R., Rupp G. L., Johnson K. M., Chan P. W. H., Gherini S. A., Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling, Second Edition, EPA 600-3-85-040, June 1985.

Dai T., Wetzel R. L., Christensen T. R. L., Lewis E. A., BasinSim 1.0, User's Guide, April 12, 2002.

Environmental Systems Research Institute, Inc., 1999, *ArcView GIS 3.2*, Redlands, CA

Environmental Systems Research Institute, Inc., 2003, *ArcView GIS 8.3*, Redlands, CA

HydroQual Inc., Trail Creek Wasteload allocation Study, March 1984.

Indiana Department of Environmental Management, 1999, *TMDL Guidelines*, Office of Water Quality, final draft, revised August 30, 1999.

Indiana Department of Environmental Management, 2000, *Indiana State of the Environment Report*, Office of Water Management, www.state.in.us/idem/soe/2000report/water.pdf.

Indiana Department of Environmental Management, 2002, *Total Maximum Daily Load Program Strategy*, Office of Water Quality, January 23, http://www.in.gov/idem/water/assessbr/toxchem/webtmdlg.pdf.

Environmental Resources Management - North Central, 1992, *Waste, Inc. Site Remedial Investigation Report*.

Metcalf & Eddy, 1991, Wastewater Engineering: Treatment, Disposal and Reuse, Third Edition. McGraw-Hill, Inc.

Michigan City Wastewater Treatment Plant, Weather Data CDs.

Northwestern Indiana Regional Planning Commission, Trail Creek Watershed Management Plan, September 30, 1993.

Northwestern Indiana Regional Planning Commission, 1993, *Trail Creek Watershed Management Plan*, September 30.

Triad Engineering Incorporated, *E. coli* TMDL for the Trail Creek Watershed, Watershed and Water Quality Modeling/Analytical Framework Report, March 25, 2003.

Triad Engineering Incorporated, *E. coli* TMDL for the Trail Creek Watershed, Source Identification and Assessment Report, February 4, 2003.

Triad Engineering Incorporated, *E. coli* TMDL for the Trail Creek Watershed, Trail Creek Allocation Report, September 2003.

Triad Engineering Incorporated, *E. coli* TMDL for the Trail Creek Watershed, Watershed and Water Quality Modeling Analytical Report, September 2003.

Triad Engineering Incorporated, *E. coli* TMDL for the Trail Creek Watershed, Trail Creek Data Report, December 10, 2002.

United States Census Bureau, 2000, *United States Census 2000*, http://www.census.gov/main/www/cen2000.html.

United States Department of Agriculture, Soil Conversation Service, 1978, *Soil Survey of LaPorte County, Indiana*.

United States Environmental Protection Agency, 1995, *Final Water Quality Guidance for the Great Lakes System,* Final Rule, Federal Register, EPA 820/Z-95-001, March 23.

United States Environmental Protection Agency, 2001, Protocol for Developing Pathogen TMDLs, First Edition, EPA 841-R-00-002, January, www.epa.gov/owow/tmdl/pathogen_all.pdf

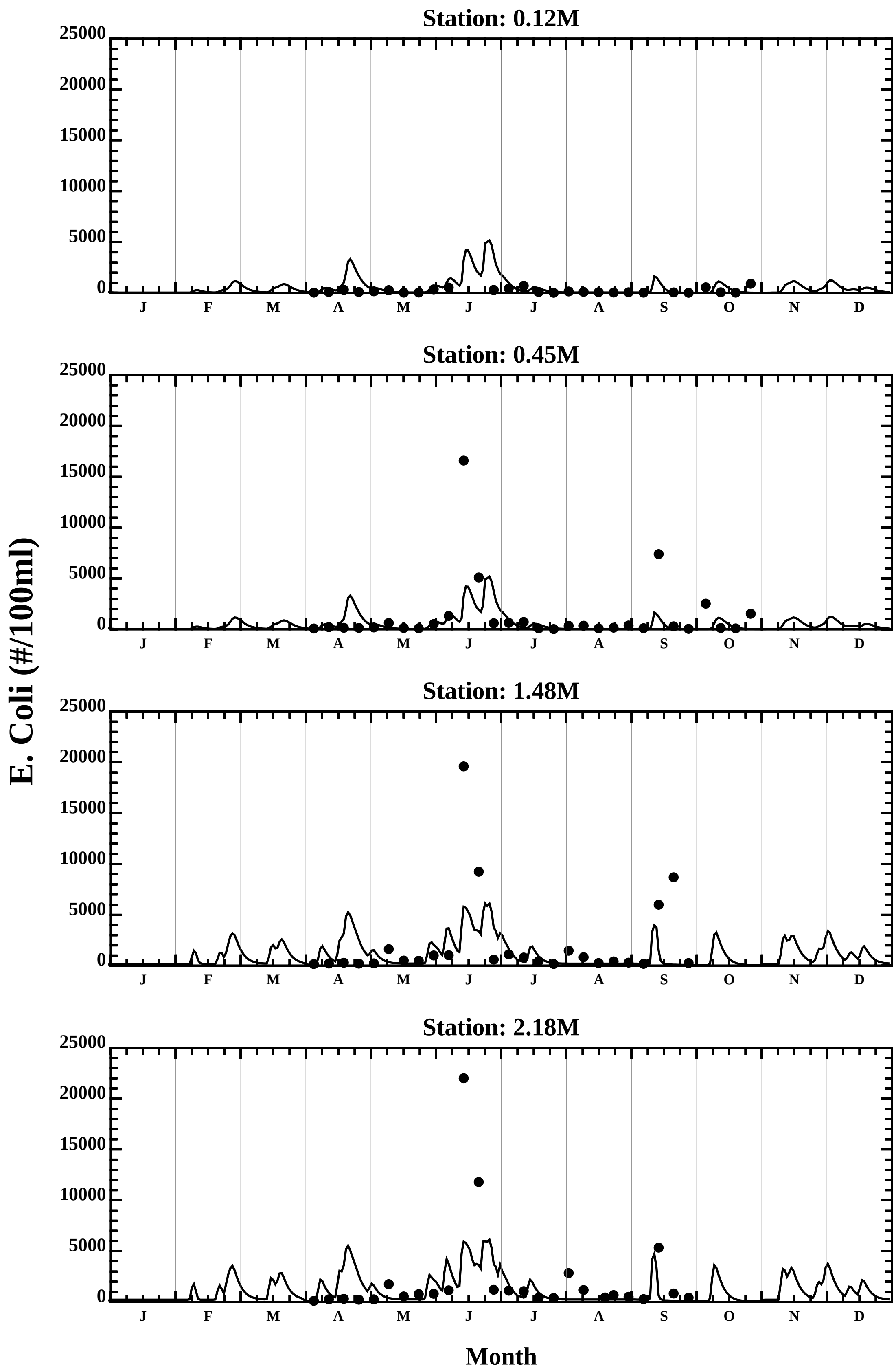
United States Environmental Protection Agency, 2001. Protocol for Developing Pathogen TMDLs. United States Environmental Protection Agency, 841-R-00-002

United States Environmental Protection Agency, 1986, Design Manual: Municipal Wastewater Disinfection. Office of Research and Development. EPA/625/1-86/021.

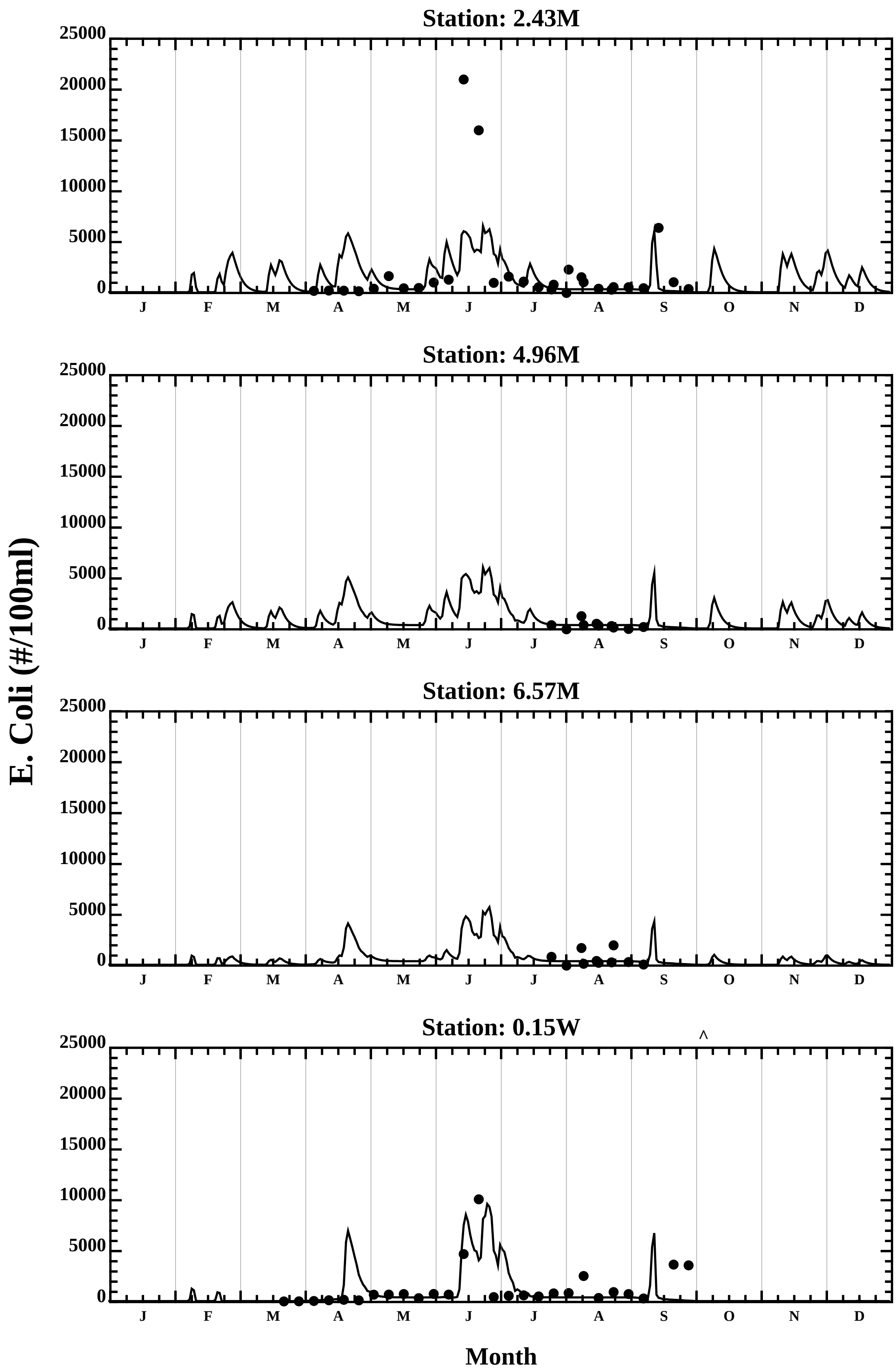
United States Environmental Protection Agency, BASINS CD, Version 3, Region 5, EPA-823-C-01-005, June 2001.

United States Geological Survey, 2002, Email correspondence from Mr. Scott Morlock, Water Resources Division, Indianapolis, Indiana, December 18. Triad Engineering Incorporated, 2003, Watershed and Water Quality Modeling/Analytical Report, September 2003.

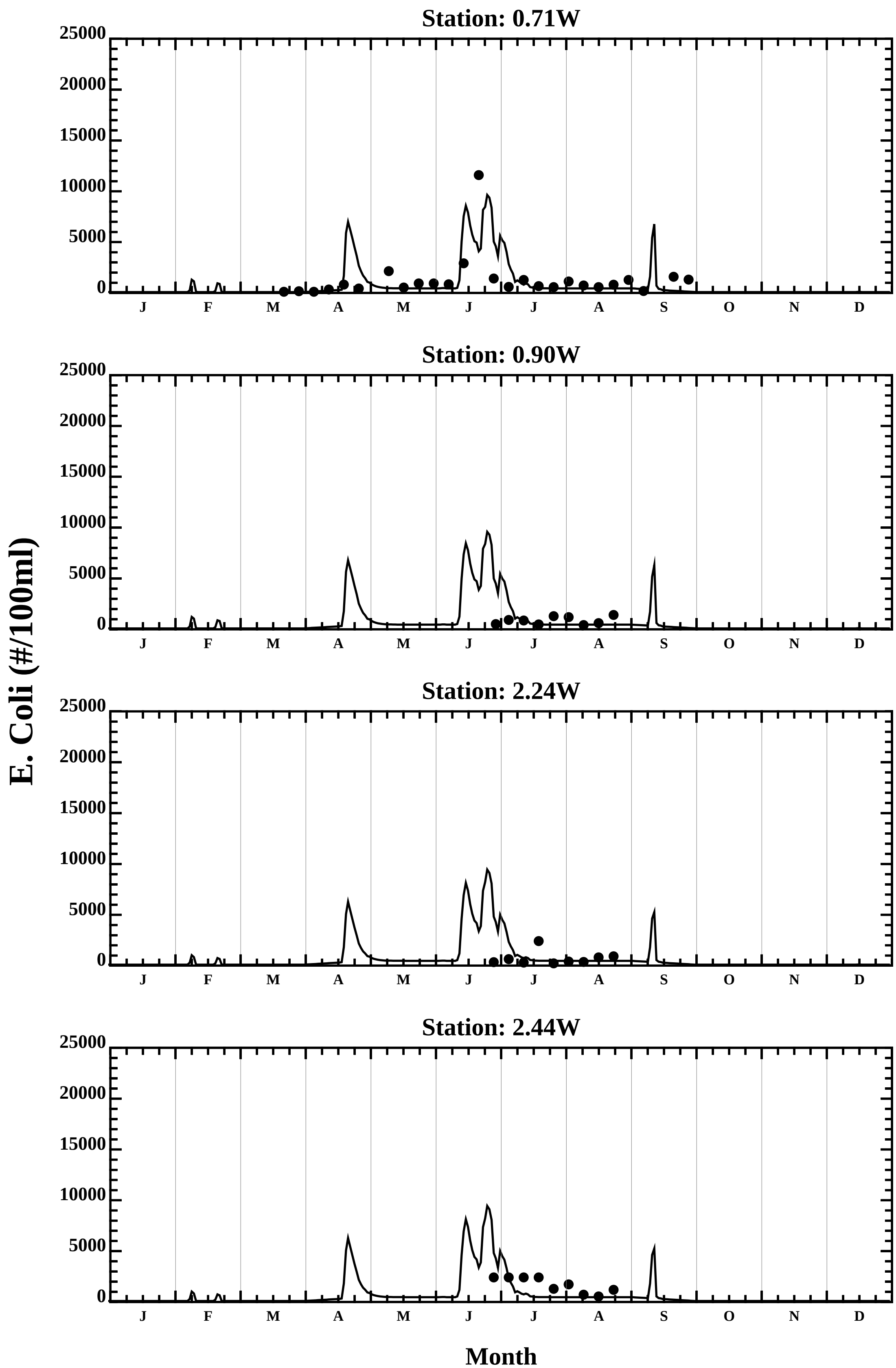
Wool T. A., Ambrose R. B., Martin J. L., Comer E. A., Water Quality Analysis Simulation Program (WASP6), User's Manual, Version 6.



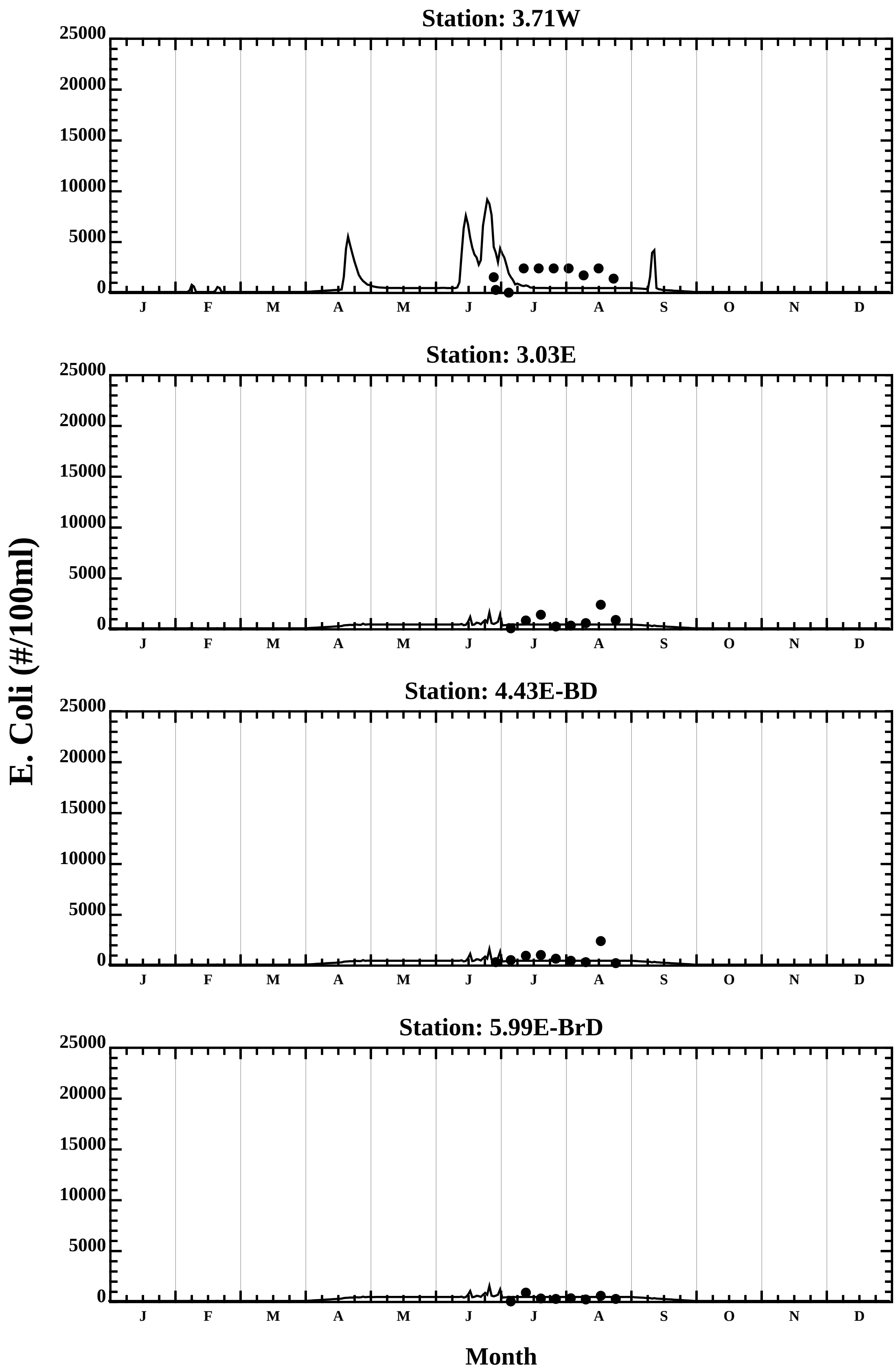
Appendix 1A. Trail Creek E Coli Model and Data Comparison, Year 2000



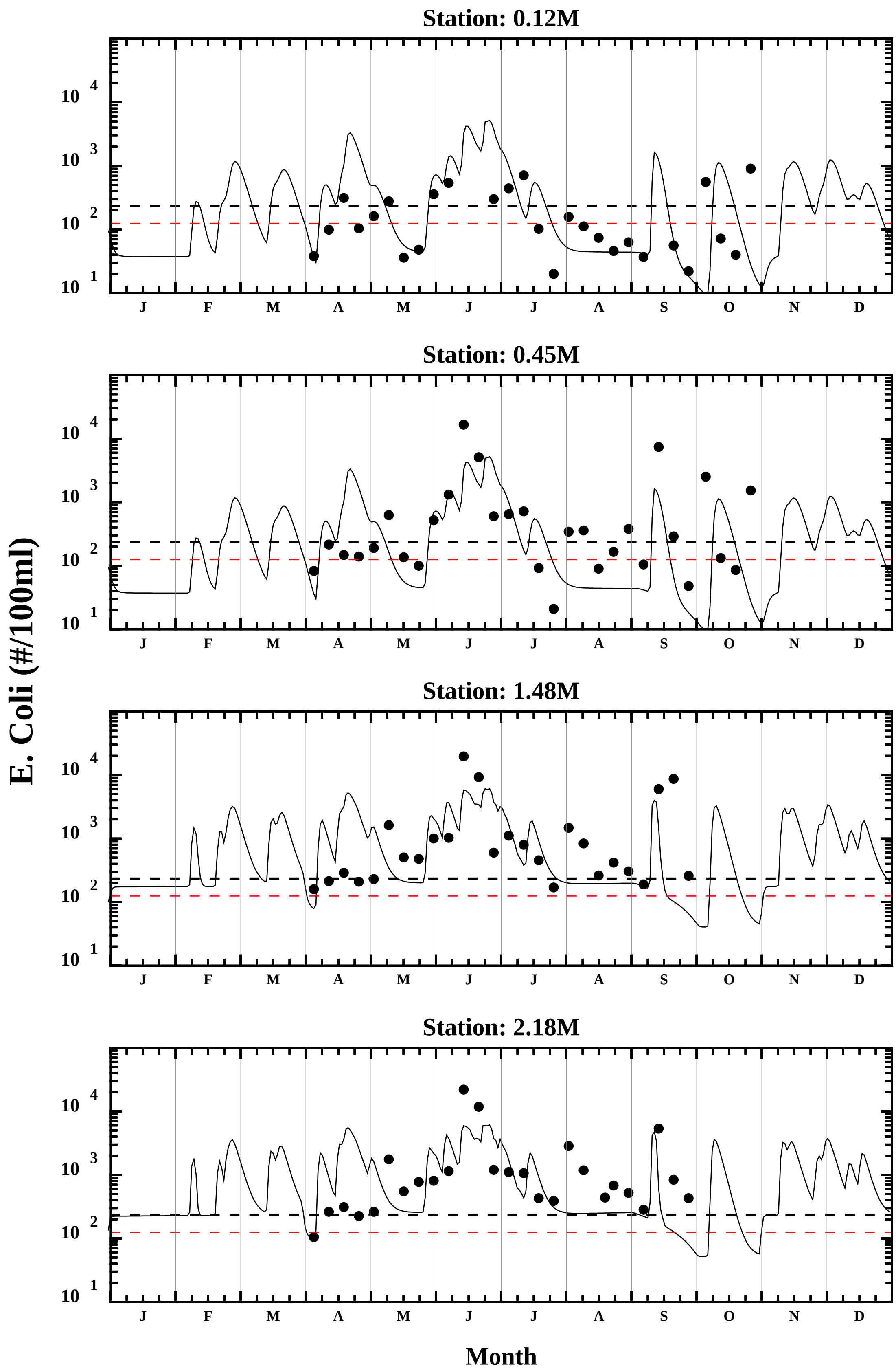
Appendix 1A. Trail Creek E Coli Model and Data Comparison, Year 2000



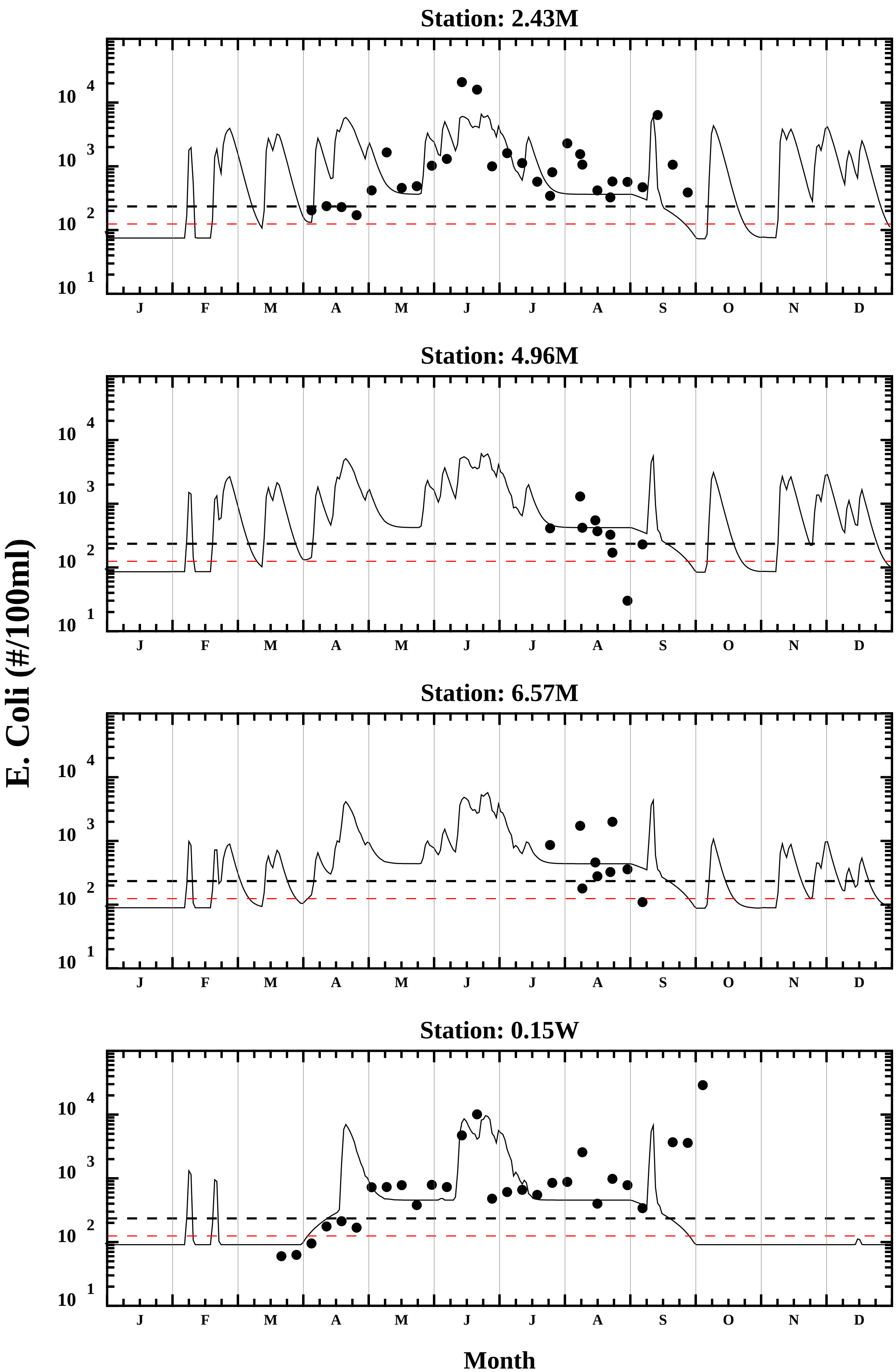
Appendix 1A. Trail Creek E Coli Model and Data Comparison, Year 2000



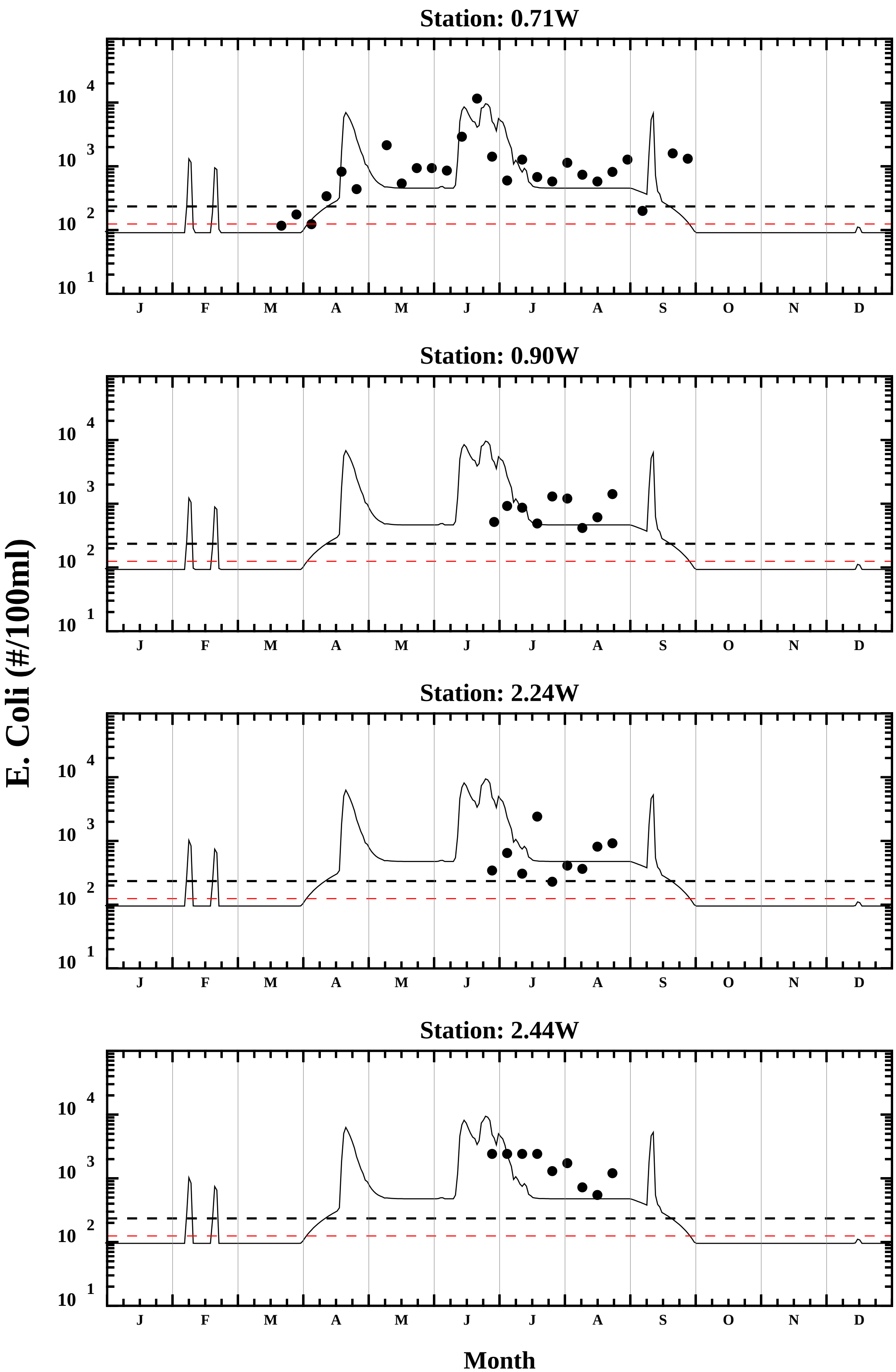
Appendix 1A. Trail Creek E Coli Model and Data Comparison, Year 2000



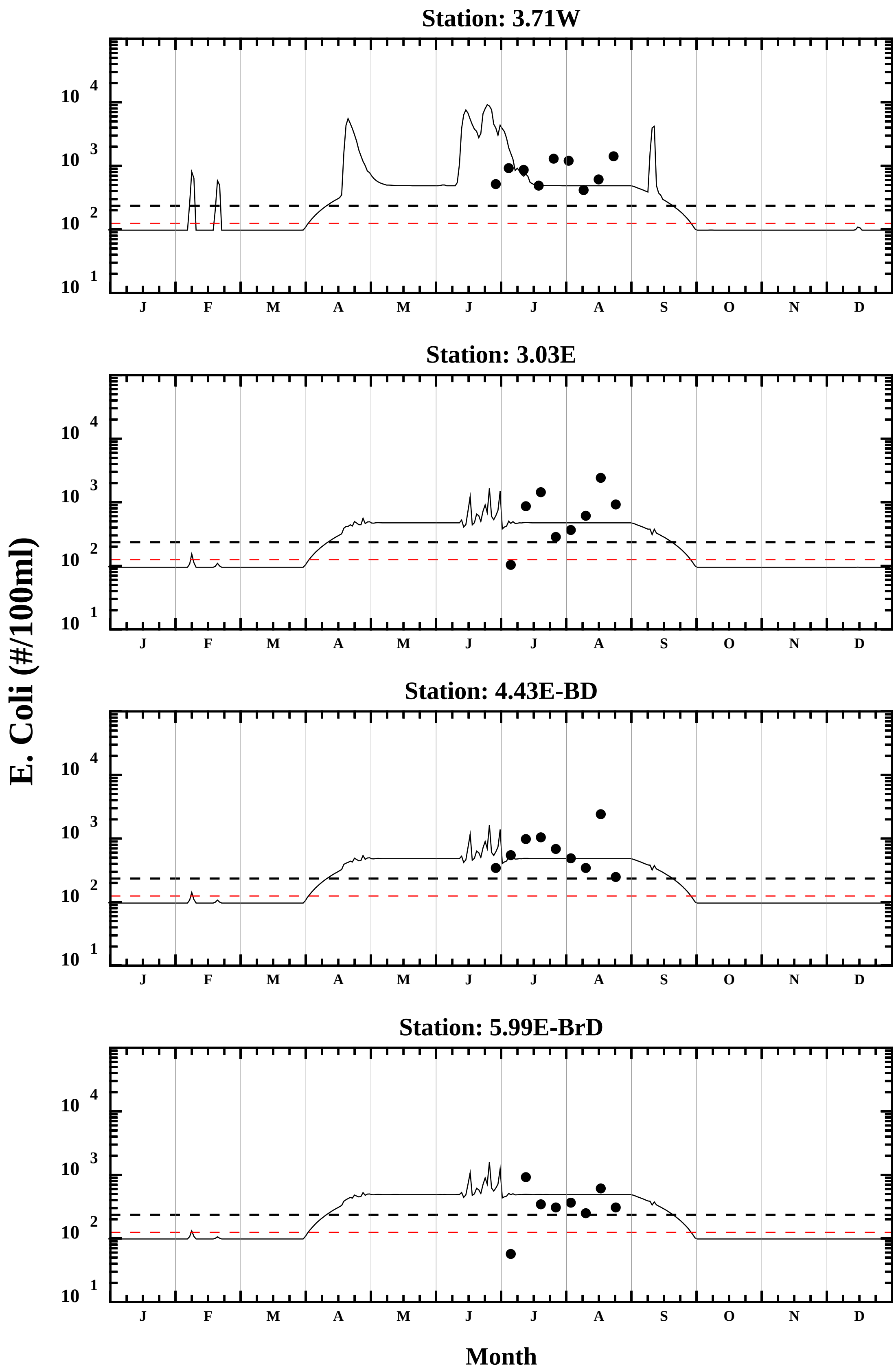
Appendix 1A. Trail Creek E Coli Model and Data Comparison, Year 2000



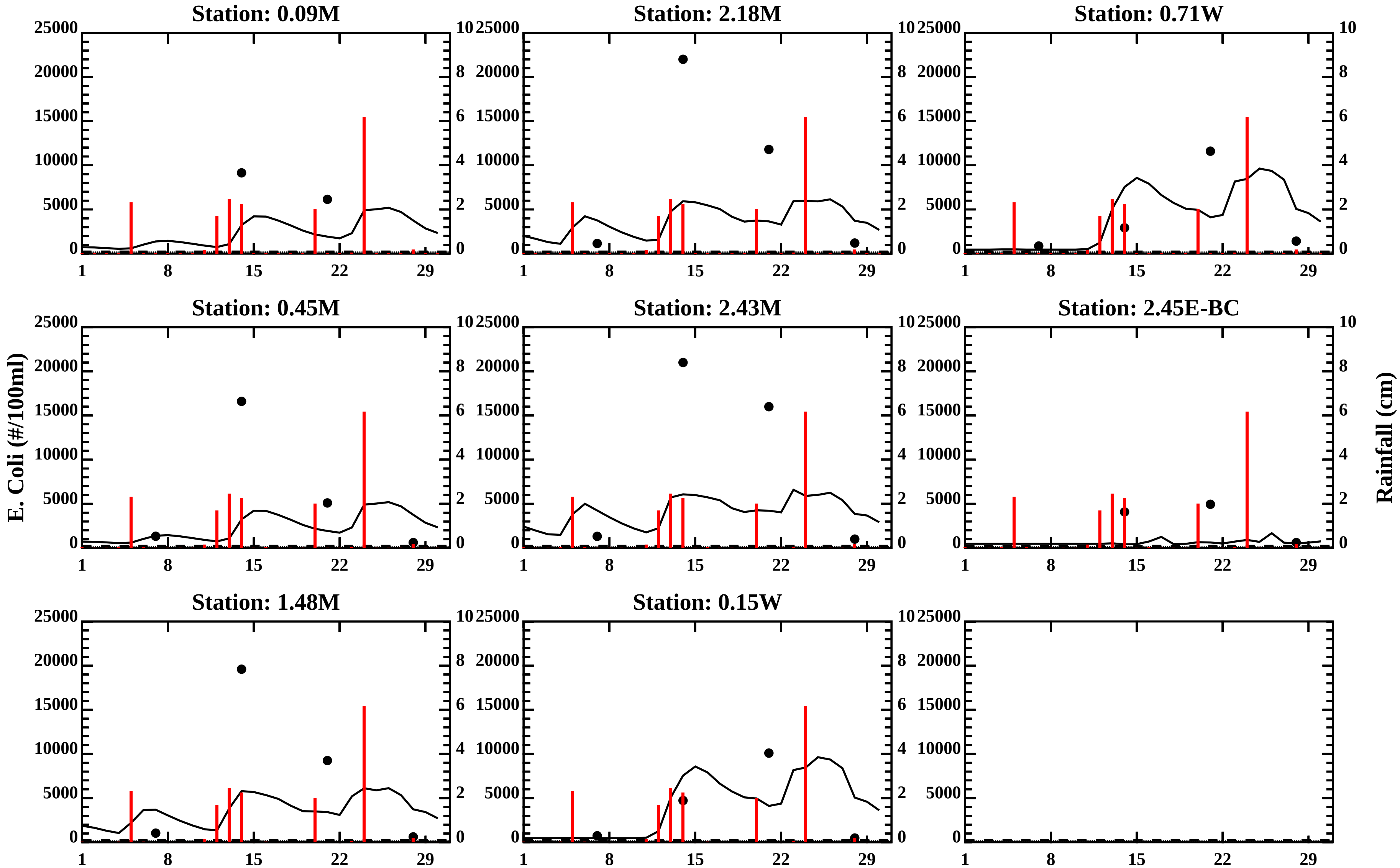
Appendix 1A. Trail Creek E Coli Model and Data Comparison, Year 2000



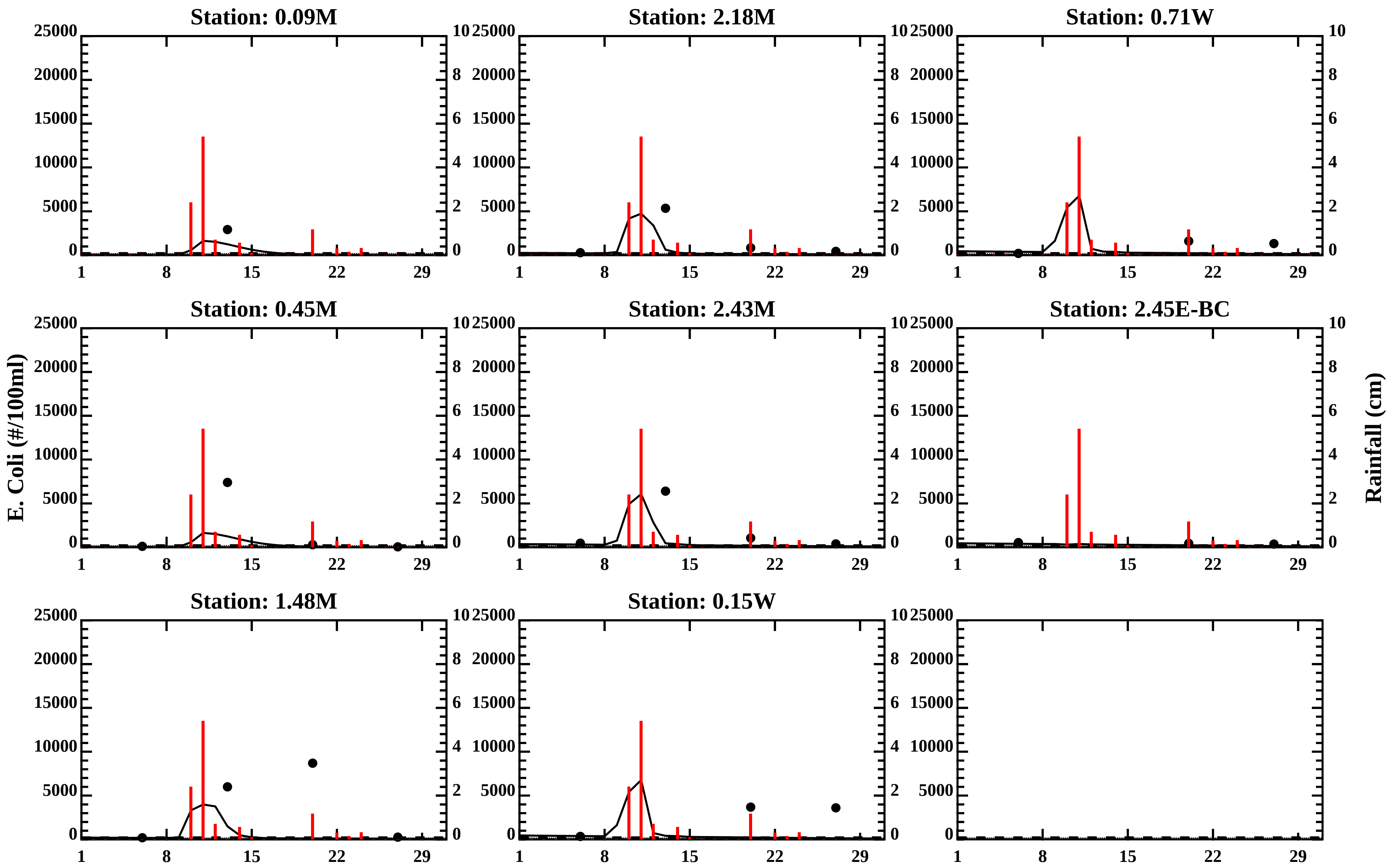
Appendix 1A. Trail Creek E Coli Model and Data Comparison, Year 2000



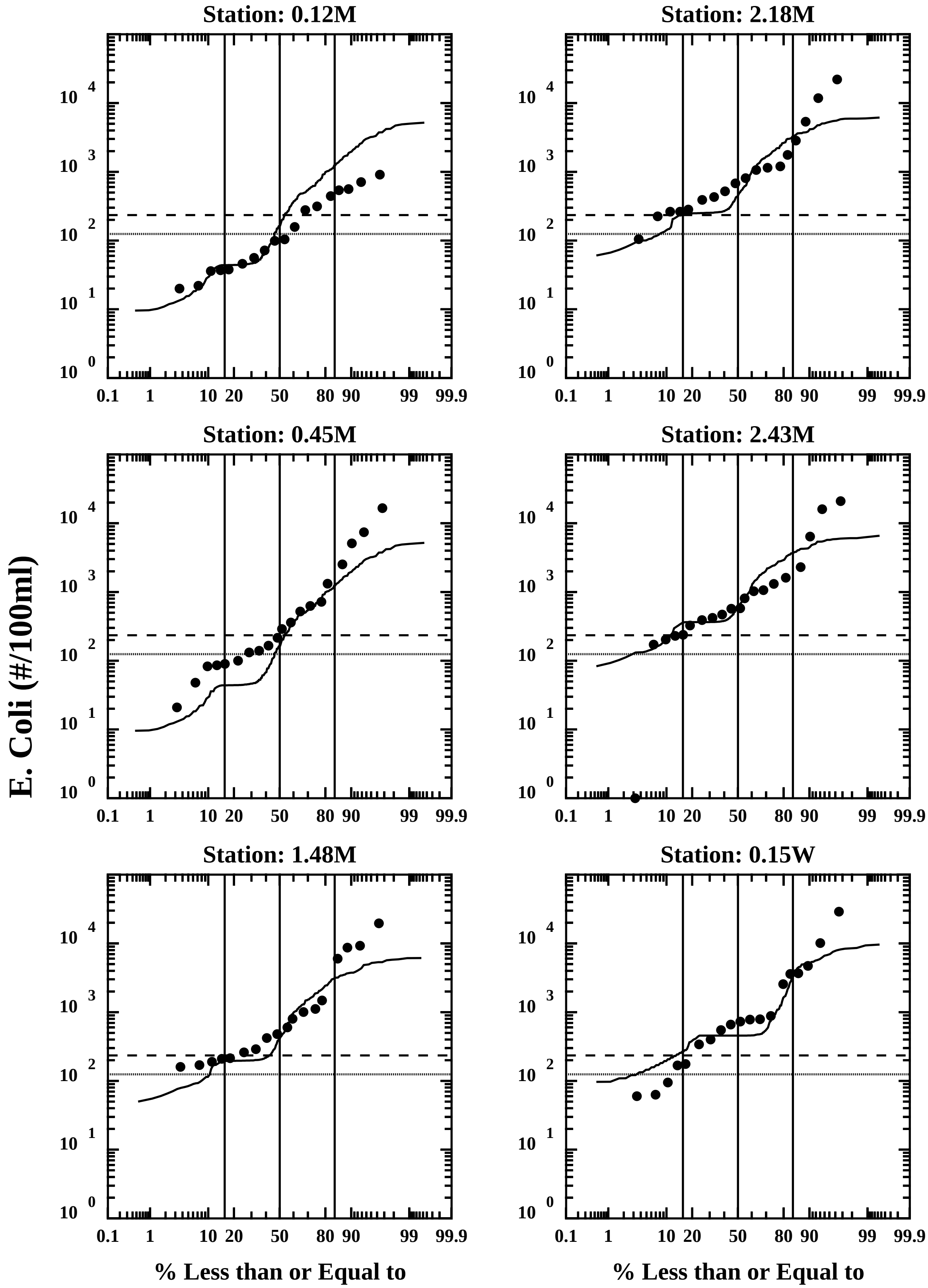
Appendix 1A. Trail Creek E Coli Model and Data Comparison, Year 2000



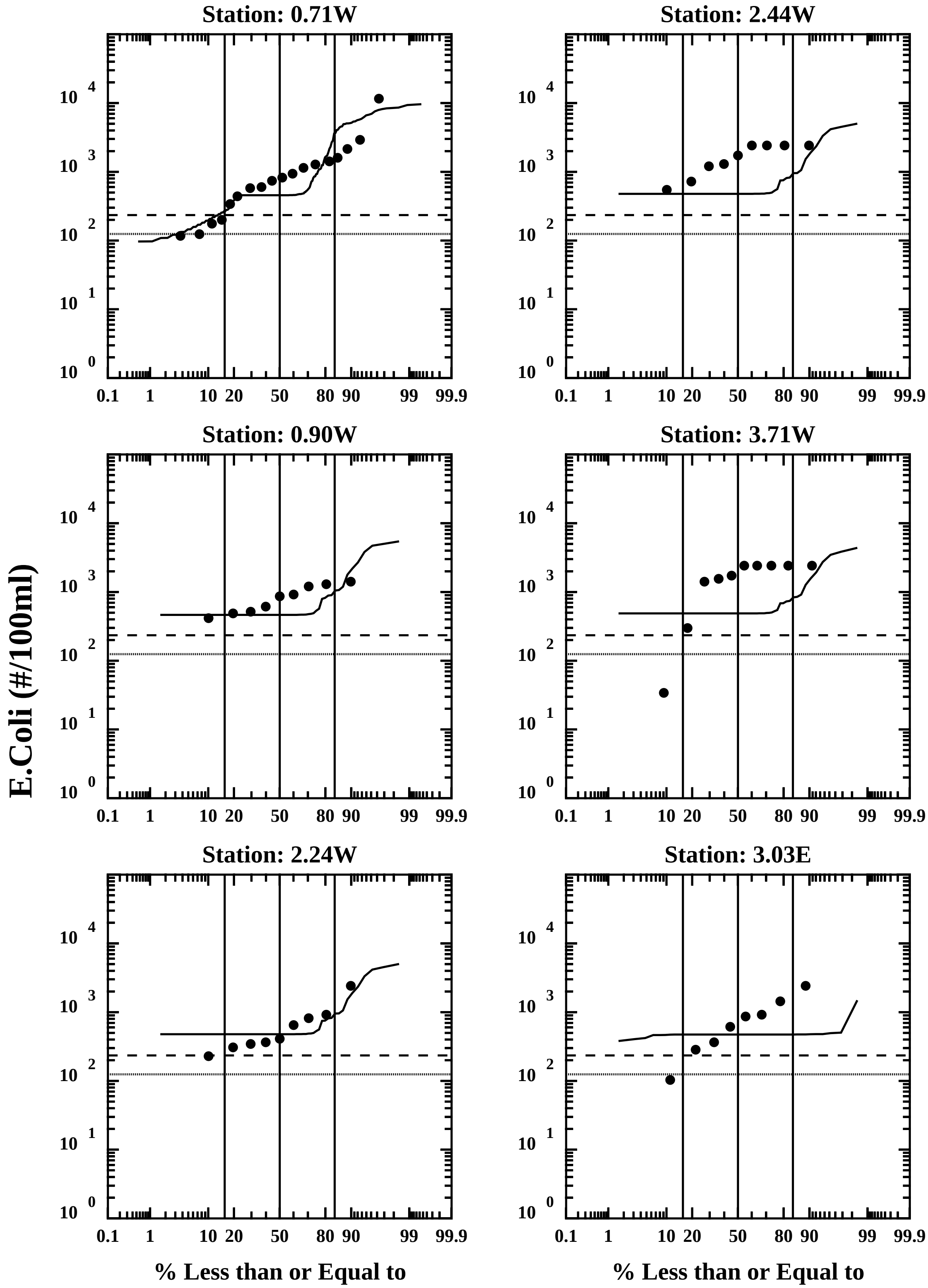
Appendix 1B. Trail Creek E. Coli Model, Data and Rainfall, June 2000



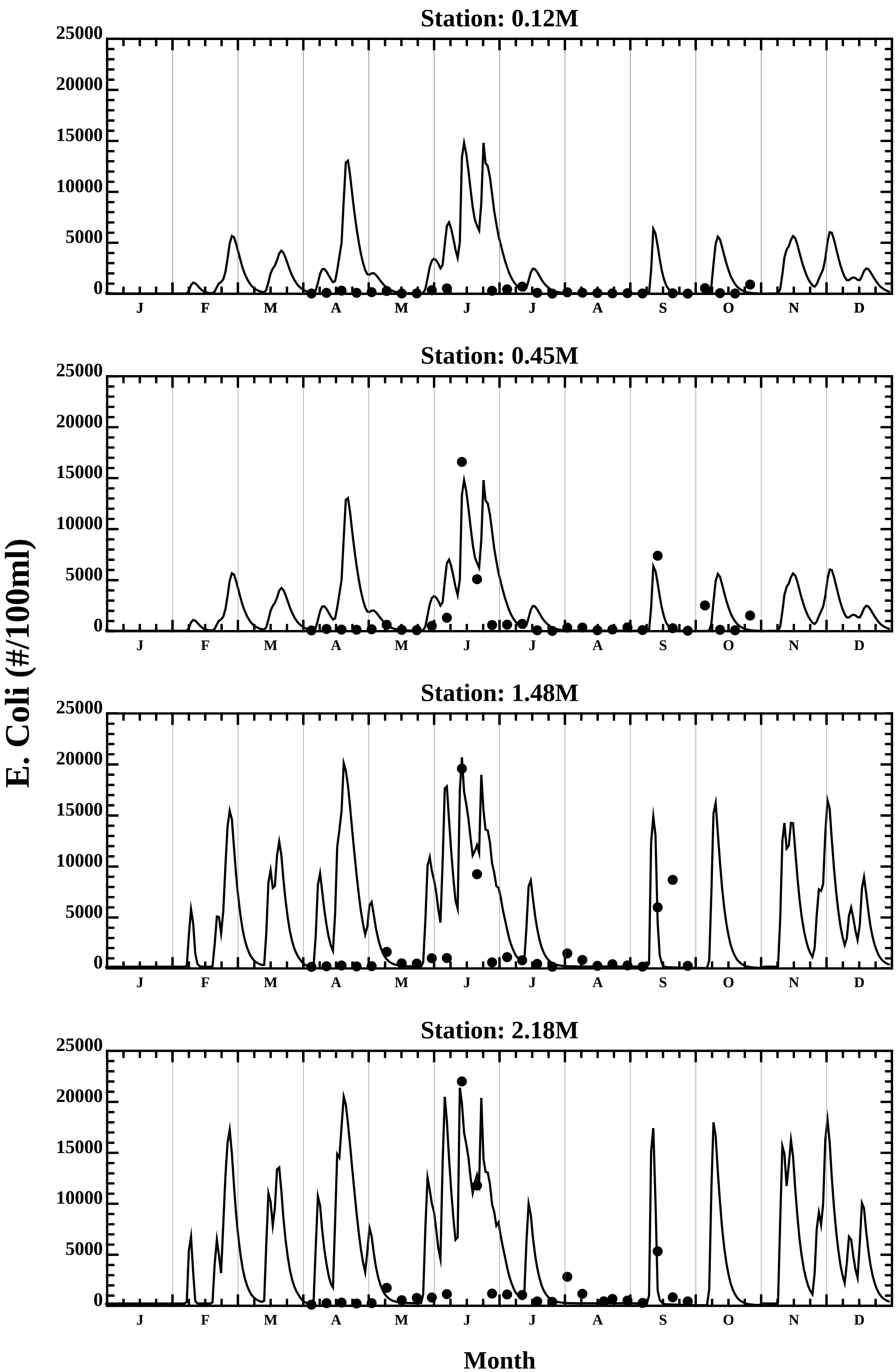
Appendix 1B. Trail Creek E. Coli Model, Data and Rainfall, September 2000



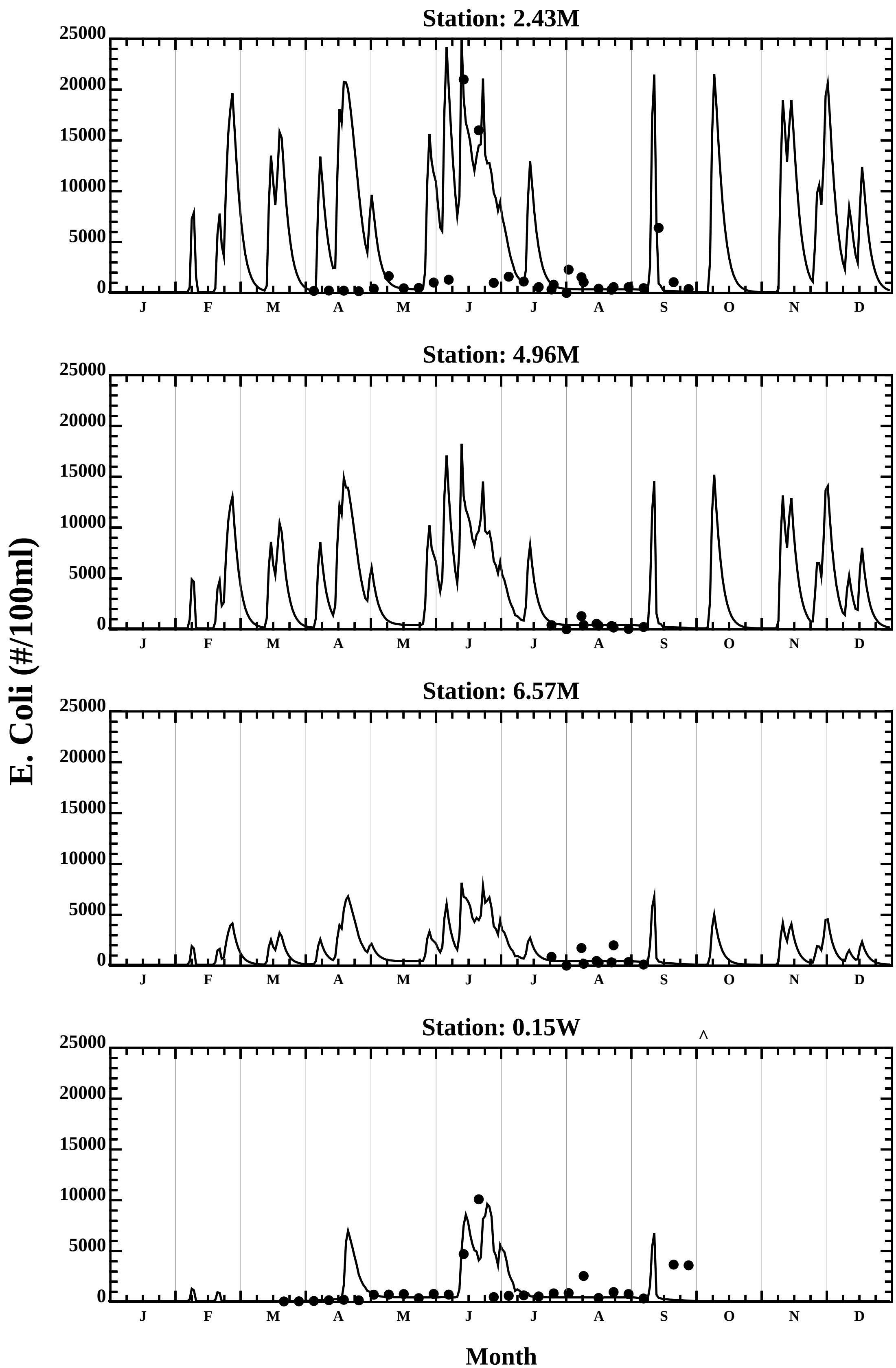
Appendix 1C. Trail Creek E. Coli Model and Data Probability Plots, 2000



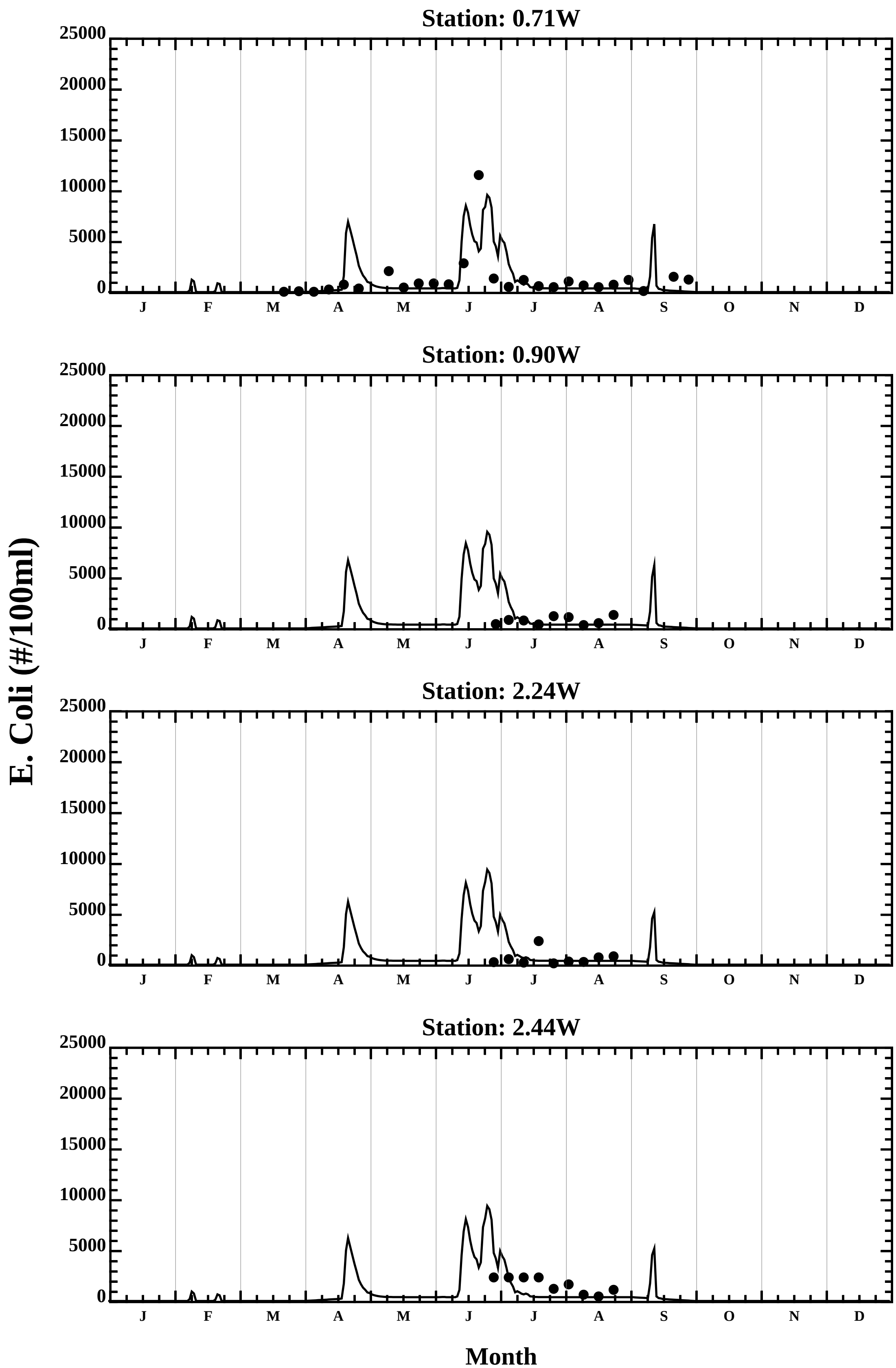
Appendix 1C. Trail Creek E. Coli Model and Data Probability Plots, 2000



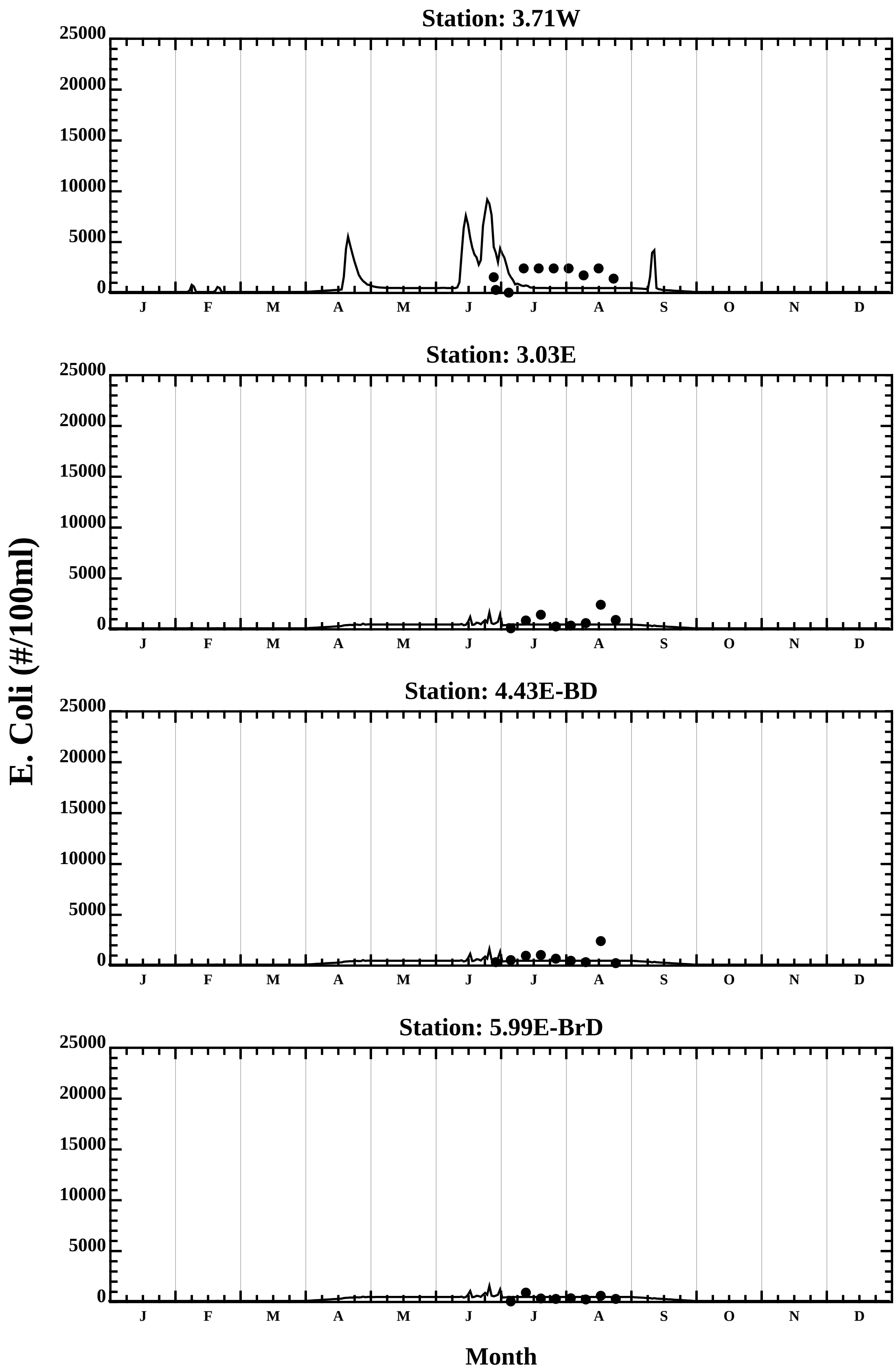
Appendix 2A. Trail Creek E Coli Model and Data Comparison, Year 2000



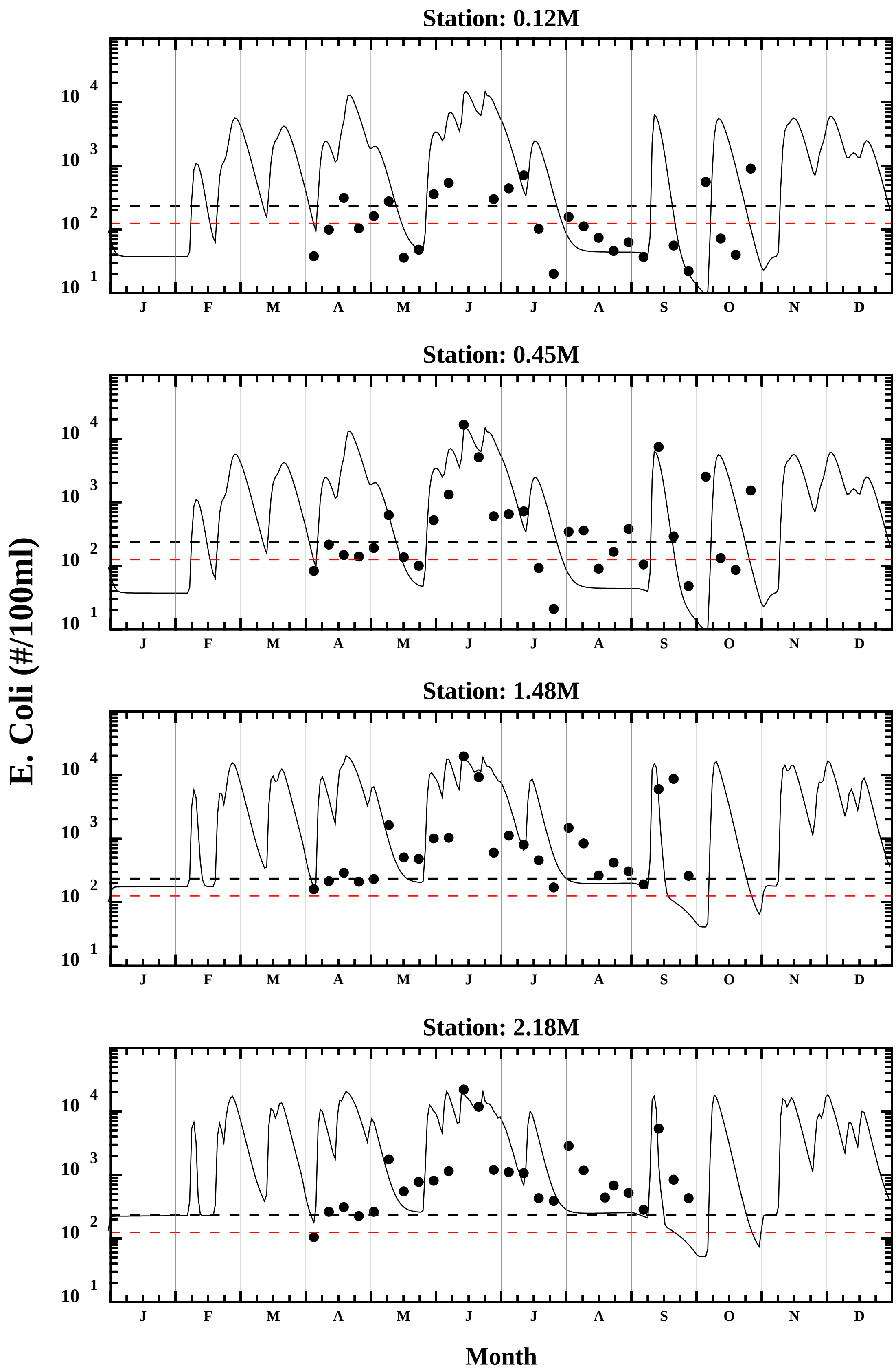
Appendix 2A. Trail Creek E Coli Model and Data Comparison, Year 2000



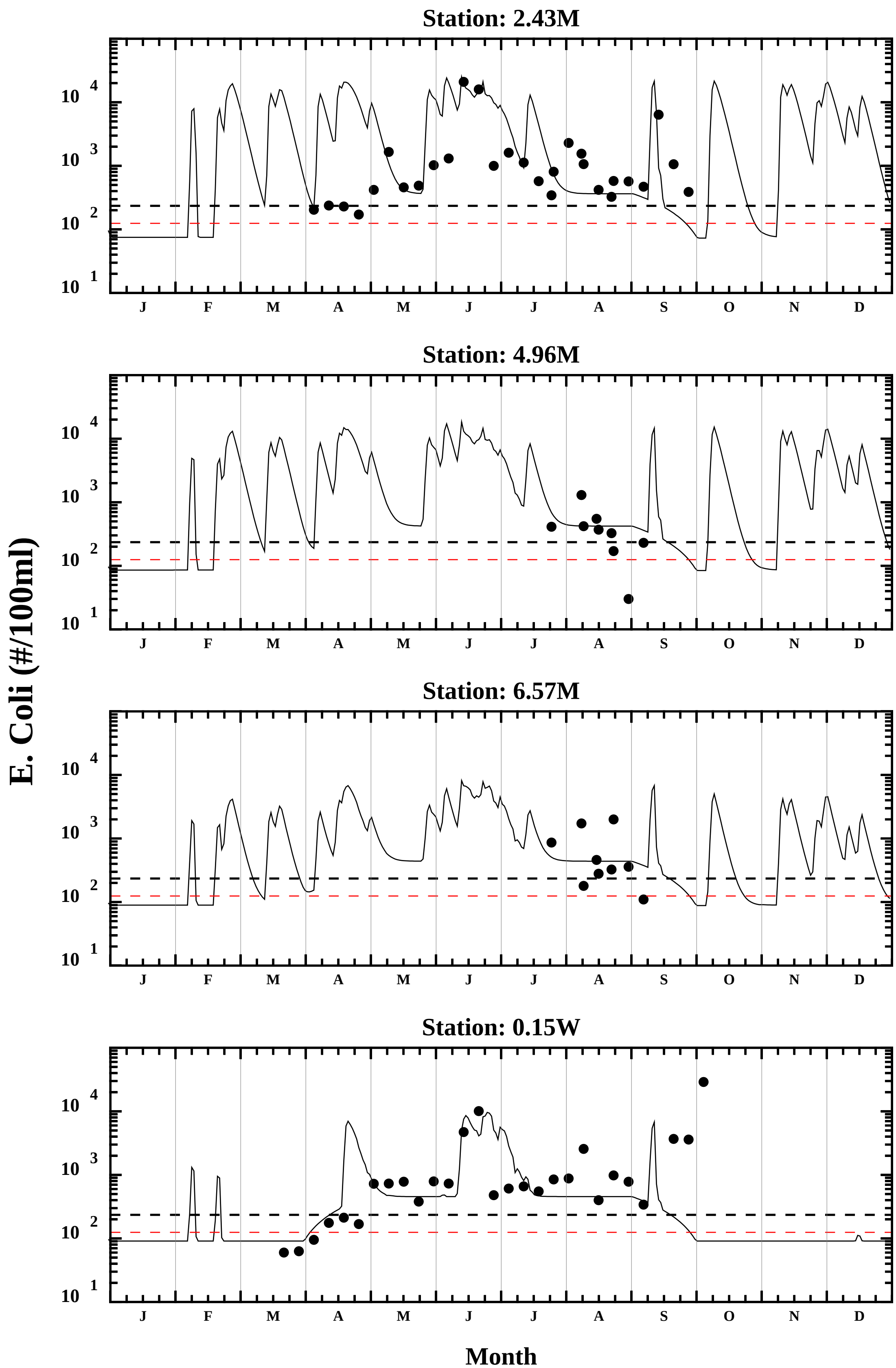
Appendix 2A. Trail Creek E Coli Model and Data Comparison, Year 2000



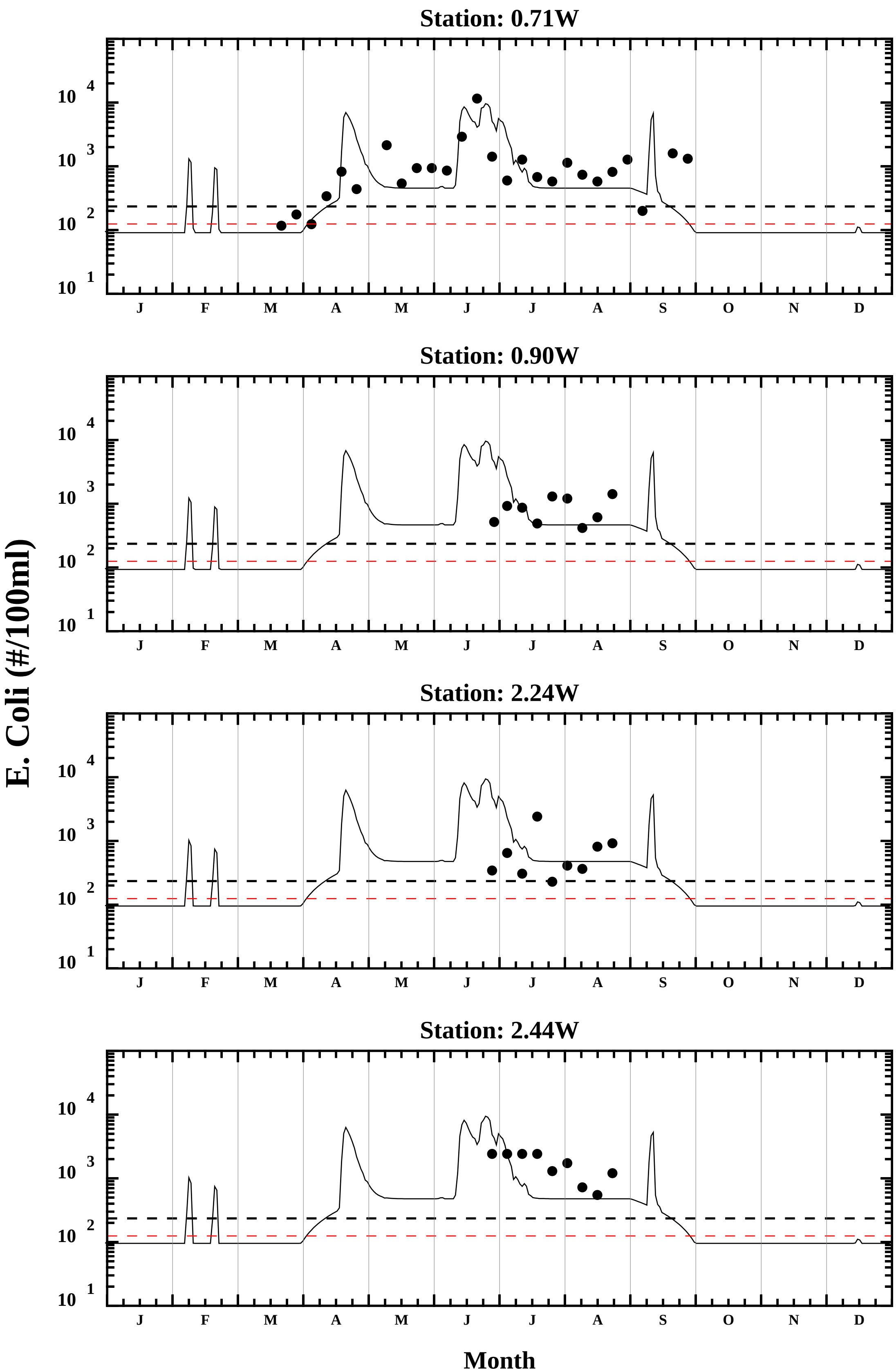
Appendix 2A. Trail Creek E Coli Model and Data Comparison, Year 2000



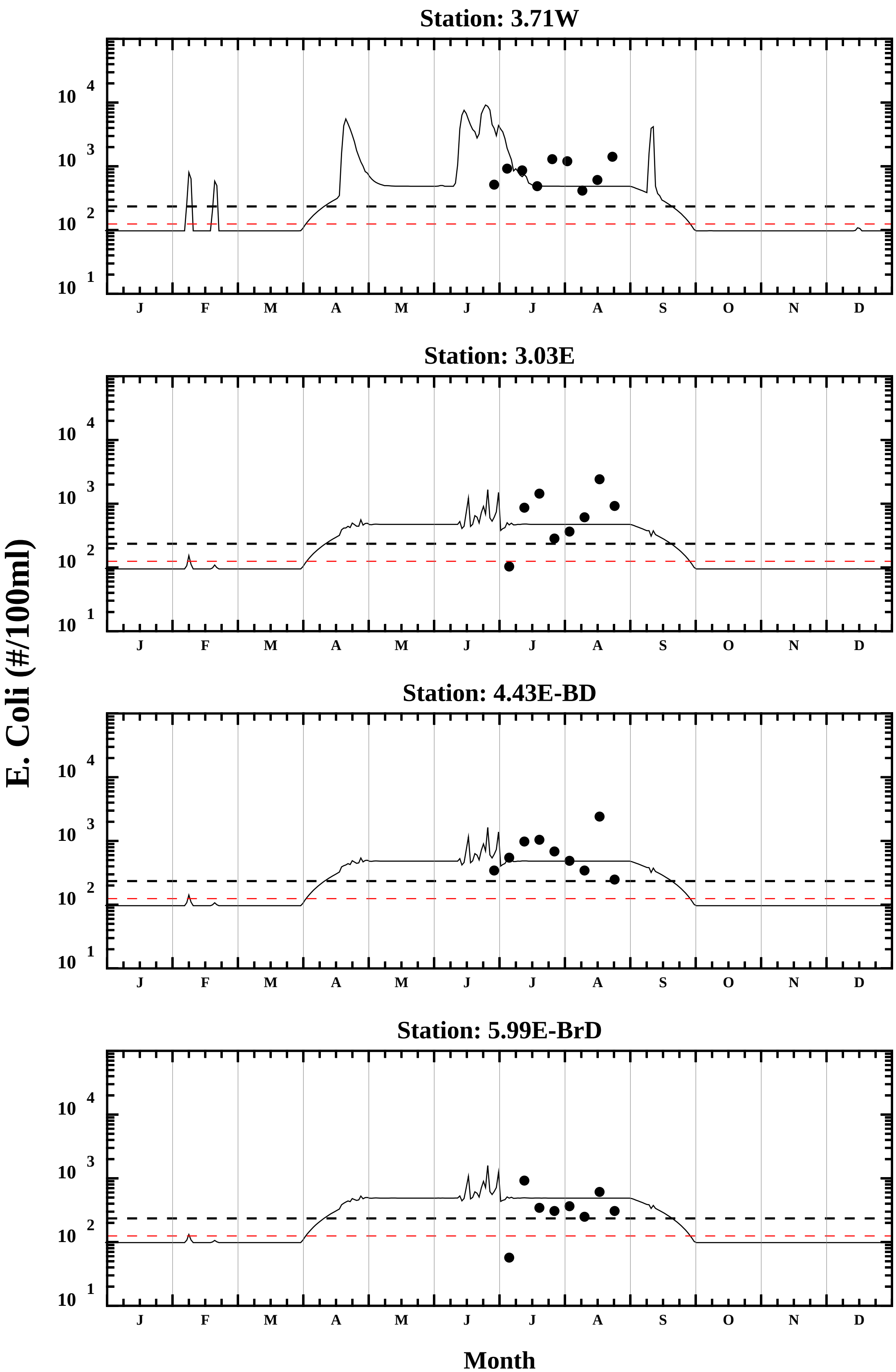
Appendix 2A. Trail Creek E Coli Model and Data Comparison, Year 2000



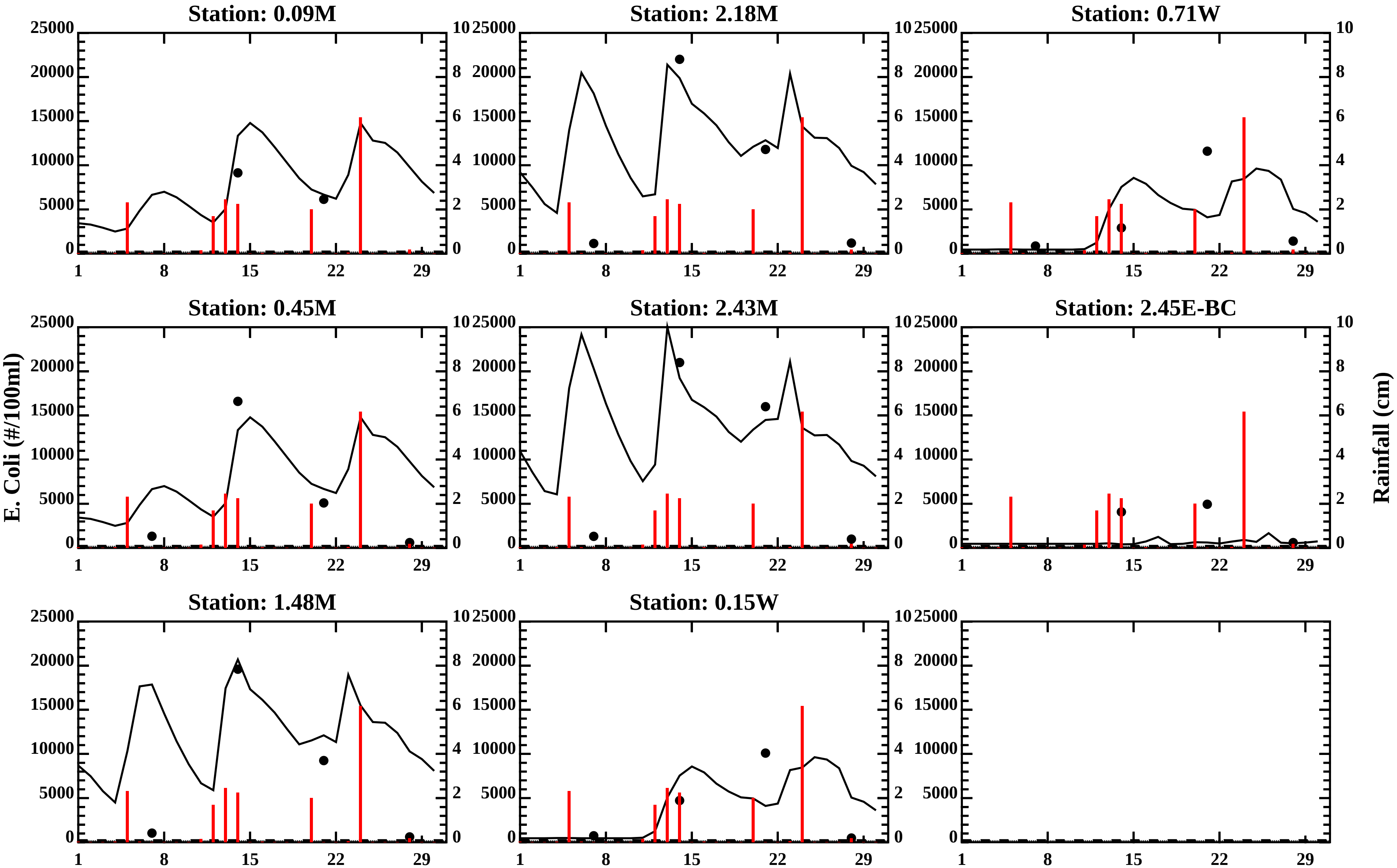
Appendix 2A. Trail Creek E Coli Model and Data Comparison, Year 2000



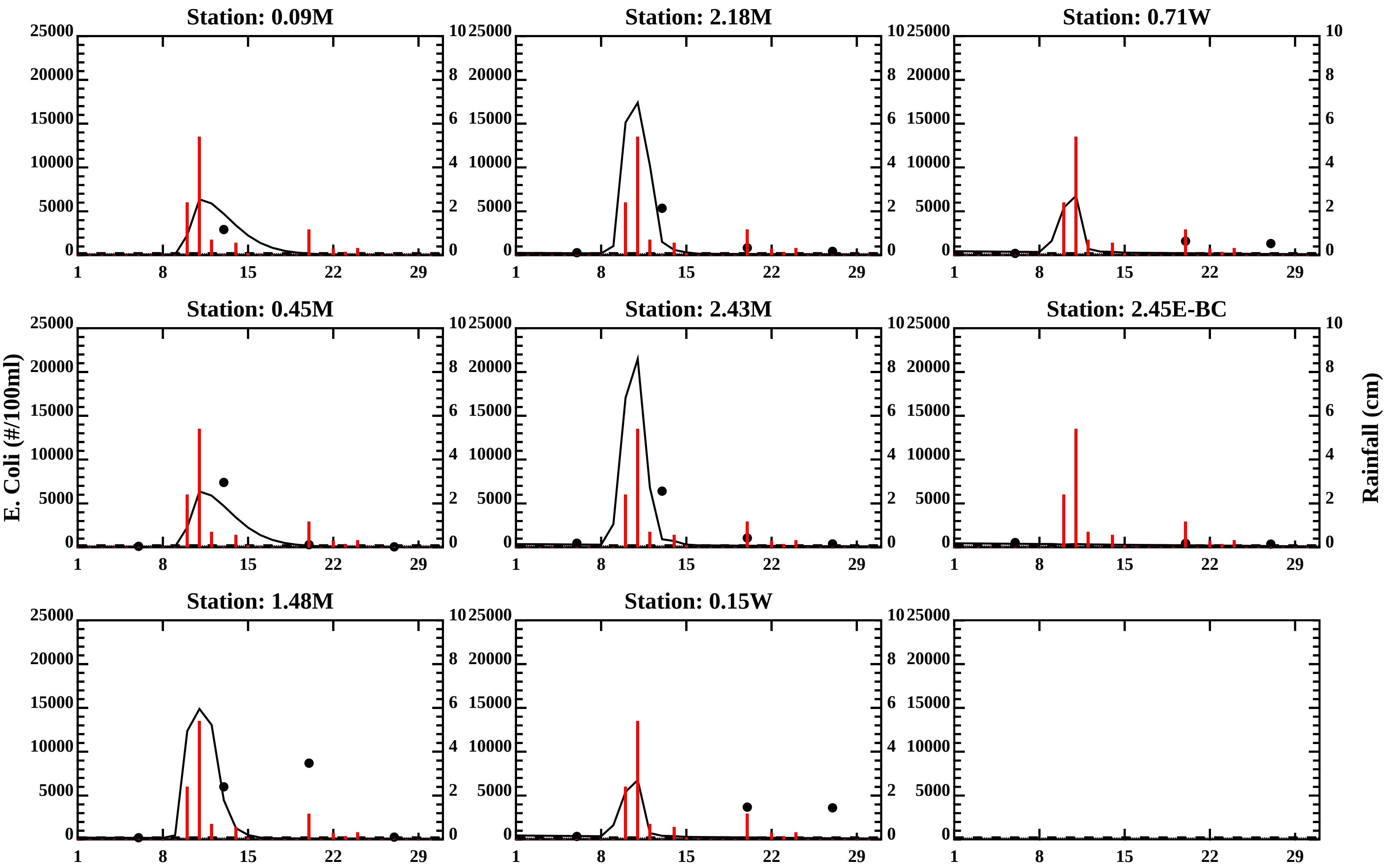
Appendix 2A. Trail Creek E Coli Model and Data Comparison, Year 2000



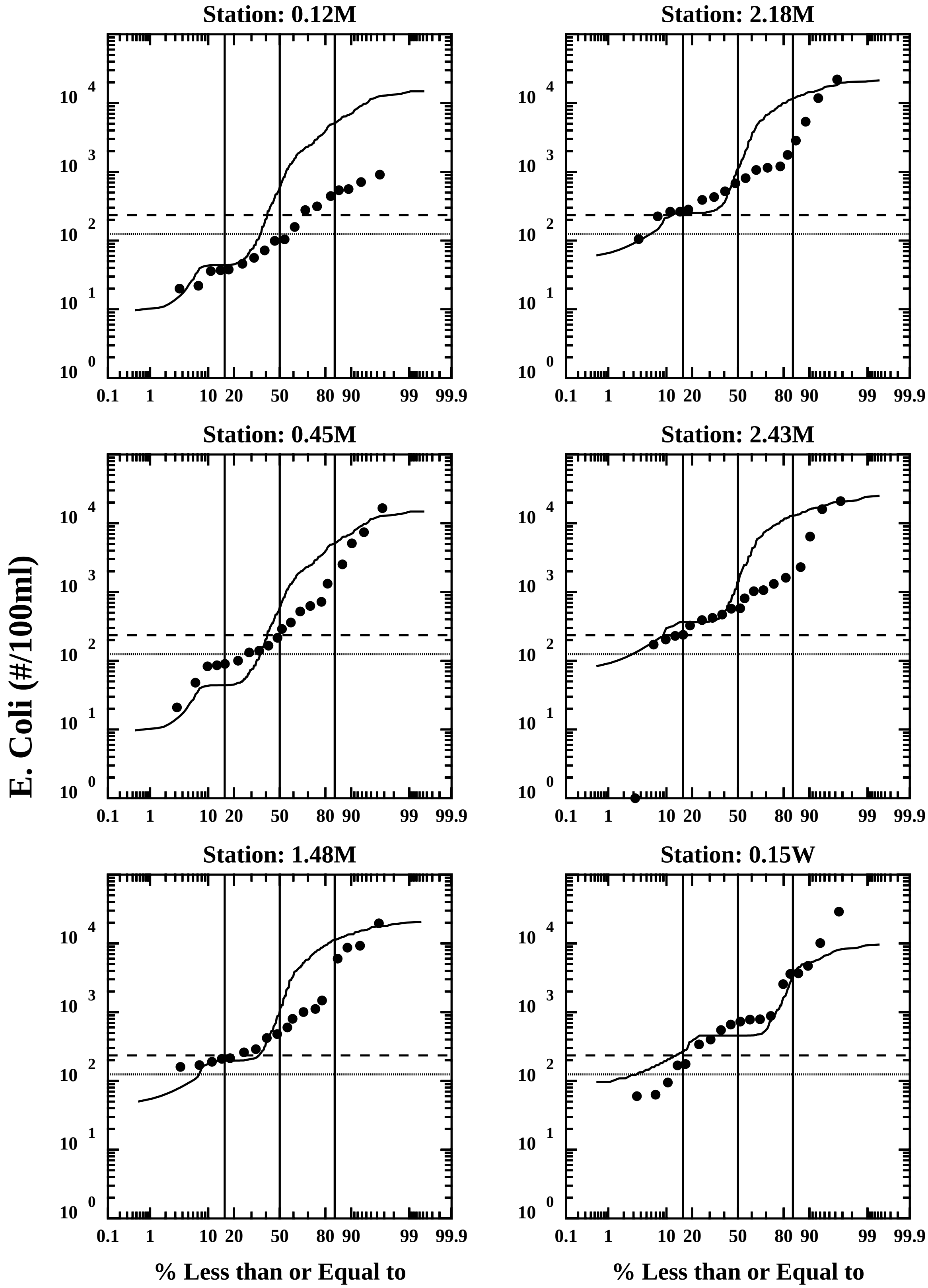
Appendix 2A. Trail Creek E Coli Model and Data Comparison, Year 2000



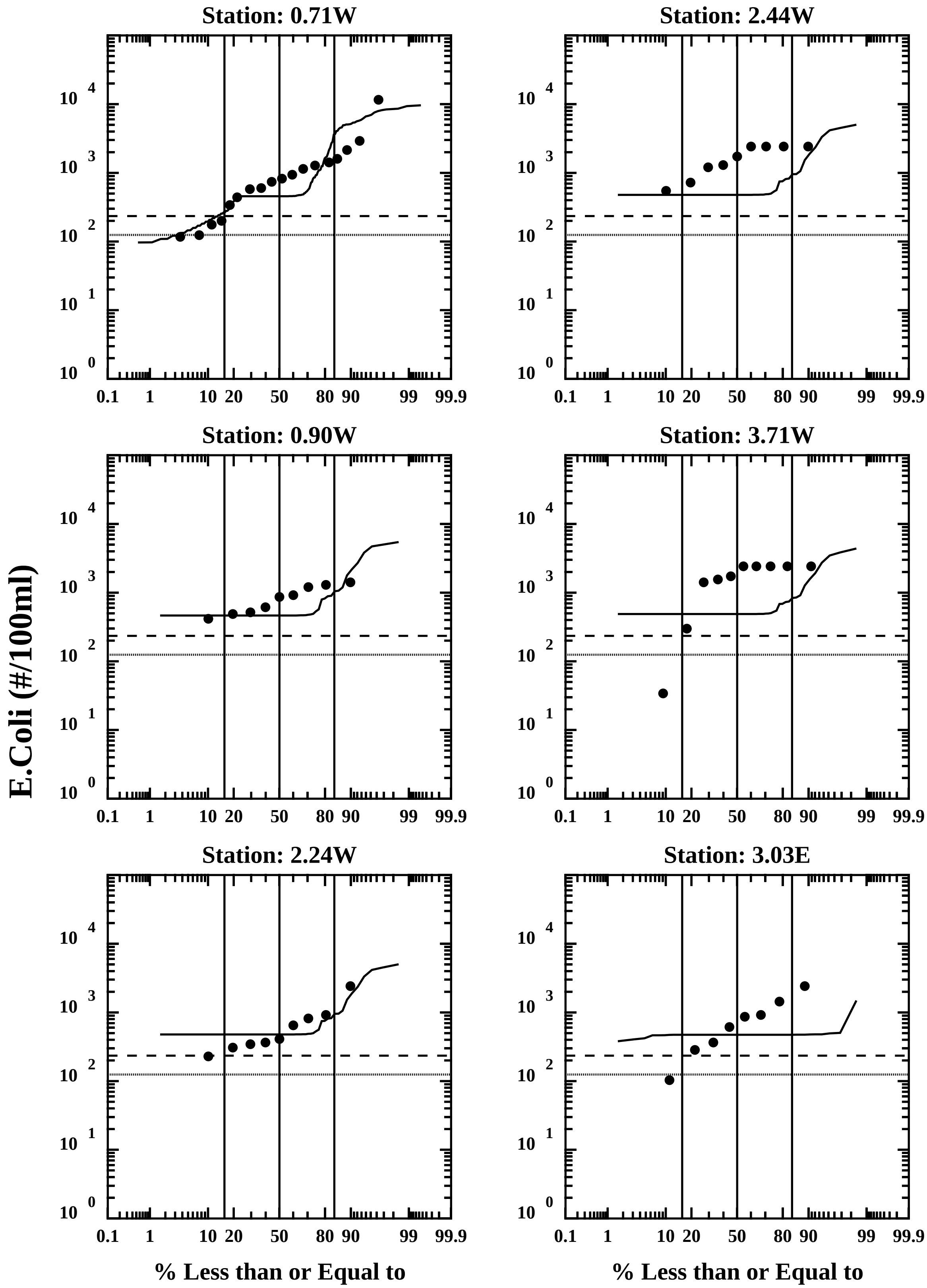
Appendix 2B. Trail Creek E. Coli Model, Data and Rainfall, June 2000



Appendix 2B. Trail Creek E. Coli Model, Data and Rainfall, September 2000



Appendix 2C. Trail Creek E. Coli Model and Data Probability Plots, 2000



Appendix 2C. Trail Creek E. Coli Model and Data Probability Plots, 2000