COMMONWEALTH OF VIRGINIA

Department of Environmental Quality
Water Division
Larry G. Lawson, P.E., Director

SUBJECT: Guidance Memo No. 03-2012
HSPF Model Calibration and Verification for Bacteria TMDLs

TO: Regional Directors

FROM: Larry G. Lawson, P.E., Director

COPIES: TMDL staff, Alan Pollock, Jack Frye (VADCR)

DATE: September 3, 2003

Summary:

This document provides guidance to DEQ TMDL staff and TMDL contractors on certain model calibration and verification procedures for bacteria TMDL development in free-flowing streams using HSPF-based models. Specifically, this guidance addresses modeling time step, model calibration and verification output functions, calibration parameters and presentation of modeling results. It does not address general HSPF modeling procedures because these are described in detail in other manuals and technical support documents (USEPA, 1993; USEPA, 2000; USEPA, 2001). Comments received from the DEQ Academic Advisory Committee regarding modeling issues were considered in the development of this guidance memorandum and incorporated where appropriate.

Electronic Copy:

An electronic copy of this guidance in PDF format is available for staff internally on DEQNET, and for the general public on DEQ's website at: http://www.deq.state.va.us/water/.

Contact information:

If you have any questions on this guidance document, please contact Ms. Jutta Schneider, TMDL Modeling Coordinator, Watershed Programs Section, at (804) 698-4099 or jschneider@deq.state.va.us.

Disclaimer:

This document is provided as guidance and, as such, sets forth standard operating procedures for the agency. However, it does not mandate any particular method nor does it prohibit any particular method for the analysis of data, establishment of a wasteload allocation, or establishment of a permit limit. If alternative proposals are made, such proposals should be reviewed and accepted or denied based on their technical adequacy and compliance with appropriate laws and regulations.

HSPF Model Calibration and Verification for Bacteria TMDLs

Background:

TMDL development for impaired waters is a priority of the Division of Water Programs Coordination. According to the 1998 303(d) list of impaired waters, a large majority of the Commonwealth's impaired waters are impaired due to non-attainment of the primary contact recreation use, as evidenced by high violations of the fecal coliform water quality criterion. From 1999 to 2002, EPA approved 38 fecal coliform TMDLs submitted by the Commonwealth in accordance with the requirements of the 1999 Federal Consent Decree. The modeling procedures employed in the development of these TMDLs varied widely, due to both an evolving body of knowledge pertaining to bacteria model development as well as contractor preferences. In order to introduce more consistency into the TMDL development process, this guidance document lays out the standard operating procedures to be used for the development of bacteria TMDLs for a May 1, 2004 EPA submittal date and beyond, including TMDLs currently under development.

Additionally, the Commonwealth has adopted *E. coli* as the new bacterial indicator in freshwater water bodies. The new indicator was approved by the State Water Control Board in its May 6, 2002 meeting and became effective on January 15, 2003. A copy of the new criteria is attached as Appendix A. DEQ and DCR have developed and submitted to EPA a letter outlining Virginia's approach to transition to the new indicator. The letter is incorporated into this guidance and attached as Appendix B. In summary, all bacteria TMDLs developed for submittal under the 2004 requirements must address the *E. coli* indicator as the water quality target. If fewer than 12 *E. coli* data points are available for the impaired segment, the TMDL must also address the revised fecal coliform criteria.

Modeling Calibration and Verification Procedures:

Hydrology Calibration

HSPEXP is the preferrable tool to be used in the hydrologic calibration process, however, other decision support software such as PEST is also acceptable. In the preparation of each bacteria TMDL's hydrology calibration, the following procedures should be followed as much as possible. Alternative procedures that are being considered should be submitted in writing to the DEQ CO TMDL modeling coordinator and to the appropriate DEQ regional TMDL staff prior to initiating the modeling process. A justification and detailed description of the alternative procedure will be essential for the review process.

1. General information: The TMDL report should include a description of the procedures used in developing the weather data input file, including filling in missing data and dis-aggregating daily data to hourly data. Where applicable, a table showing the weather stations used to develop the weather data file should be provided. Also, the TMDL report should include a table showing the channel characteristics used in the model. Appendix C contains examples of appropriate formats.

2. Time step: The hydrology calibration should be run on an hourly time step.

3. Representation of point sources: The hydrology calibration must consider flow contributed by permitted point sources in the watershed.

4. Output function: The output function for HSPF-based hydrology models should be the daily average flow, in cubic feet per second (cfs).

5. Calibration parameters: The parameters used in model development should fall within the range of possible values, and preferrably the range of most commonly used values specified in the HSPF manual. Appendix D presents some of the final calibration parameters that have been used in the Commonwealth.

6. Presentation of results: The results of the hydrology calibration and, where applicable, verification should be presented as described in the following paragraphs. For each graph and table described below Appendix E contains sample formats that should be used for the presentation of results.
   a) For each calibration station, calibration and verification time series showing observed and modeled average daily flow data for simulation period, typical hydrologic year, and a specific storm should be prepared. If possible, precipitation data should be included on each figure.
   b) For each calibration station, cumulative frequency curves showing observed and modeled data for the calibration and verification time periods should be presented.
   c) For both calibration and verification time periods, a summary statistics table should be prepared comparing modeled and observed flow for total annual runoff, total of highest 10% flows, total of lowest 50% flows, total winter (Dec-Feb) runoff, total summer (Jun-Aug) runoff (all in inches). Error statistics should be calculated and compared to the quality criteria specified in HSPEXP. A coefficient of determination (r^2 value) for observed vs. modeled flow should be calculated for both calibration and verification simulation periods.
   d) On an average annual basis for both calibration and verification periods, flow partitioning between total annual runoff, surface runoff, interflow, and baseflow (all in inches), and the baseflow index (in % of baseflow to total flow) should be presented in a table.
   e) The final calibration parameters should be presented in tabular format as shown in Appendix D. At a minimum, the table should include: % imp, AGWETP, AGWRC, BASETP, DEEPFR, INFILT, INTFW, IRC, KVARY, LZETP, LZSN, UZSN. For parameters varying by subwatershed and/or land use, a parameter range covering the entire watershed can be presented in the body of the report but values for each sub-watershed and land use should be provided in the appendix section.
   f) Additional information should be presented as appendices.

7. Paired watershed approach: Stream gages do not exist on all impaired water bodies. In some cases, the use of a surrogate station will be necessary. The following paragraphs describe the supporting documentation that should be provided in using this approach. The fecal coliform TMDLs for Naked Creek, Holmans Creek and Dodd Creek, among others, were developed using the paired watershed approach. They can be found at **http://www.deq.state.va.us/tmdl/tmdlrpts.html**

   a) The gaged watershed must be comparable to the ungaged watershed in size, land use, slope, soils and geology. A table presenting data on these five factors for both watersheds should be prepared.
   b) After the surrogate hydrology model has been calibrated, the same data as described above must be provided.
   c) There must be a clear description of the parameterization process for the ungaged watershed. Any changes to the calibrated parameters must be well documented and

justified.

d) Tables showing flow partitioning and final model parameters for the ungaged stream must be provided.

Water Quality Calibration

In the preparation of each bacteria TMDL's water quality calibration, the following procedures should be followed as much as possible. Alternative procedures that are being considered should be submitted in writing to the DEQ CO TMDL modeling coordinator and to the appropriate DEQ regional TMDL staff prior to initiating the modeling process. A justification and detailed description of the alternative procedure will be essential for the review process.

1. Time step: Bacteria models should be run on an hourly time step.

2. Representation of point sources: The water quality calibration must include the average discharge conditions contributed by permitted point sources in the watershed.

3. Output function: The output function for HSPF-based bacteria models should be the daily average bacteria concentration, in counts/100mL. As stated in the HSPF manual (USEPA, 1993), the term "average" or "mean" for an output time series "is taken in a wide sense and includes any value assumed to be representative of behavior of the time series over the time step…". Based on this definition, and considering the variability in bacteria data, each daily average value is assumed to represent a daily sample within the definition of the State's water quality standard.

   If the bacteria model is developed for fecal coliform, an additional output series for *E. coli* must be created to allow the development of an *E. coli* TMDL. DEQ monitoring staff has developed the following translator function to translate fecal coliform data into *E. coli* data (see Appendix B for additional detail on the translator):

   $$\log_2 EC\ (cfu/100\ mL) = -0.0172 + 0.91905 * \log_2 FC\ (cfu/100\ mL)$$

4. Geometric mean calculation: The geometric mean should be calculated on the last day of each calendar month using the daily average values for the respective number of days within that calendar month. For example, a 31-day geometric mean should be calculated for January, a 28-day or 29-day geometric mean for February and a 30-day geometric mean for April.

5. Calibration parameters: For reference, Appendix D contains some of the final calibration parameters that have been used in fecal coliform TMDLs in Virginia. No *E. coli* models have yet been developed in Virginia.

6. Use of BST data: It is expected that all future bacteria TMDLs will have 12 or more data points for BST analysis. On an average annual basis at the TMDL compliance point (i.e. the ambient monitoring station used to determine impairment), the % contribution from the major source categories to the total in-stream load should be consistent with the % signature from each major source category in the observed BST results. Serious discrepancies between fecal bacteria concentrations predicted by BST and HSPF should be investigated. In case of serious discrepancies, best professional judgment and common sense should be used to make final decisions because of known uncertainties with both BST and HSPF.

7. Presentation of results: The results of the water quality calibration should be presented as described in the following paragraphs. For each graph and table described below Appendix F contains sample formats that should be used for the presentation of results.
   a) For each calibration station, calibration time series showing observed and modeled daily bacteria data for the simulation period should be prepared. If possible, precipitation data should be included on each figure. Data should be presented for both fecal coliform and *E. coli* calibration time series after application of the *E. coli* translator.
   b) For each calibration station, one geometric mean value for the entire simulation period should be calculated and compared to the geometric mean of all observed data collected during the simulation period.
   c) An analysis of % violation of the instantaneous as well as the geometric mean (where available) water quality standards should be prepared for modeled and observed bacteria data. The modeled data should be consistent with the observed data set.
   d) If possible, a coefficient of determination (r^2) for observed vs. modeled concentrations should be calculated.
   g) The final calibration parameters should be presented in tabular format as shown in Appendix D. At a minimum, the table should include: WSQOP, IOQC, AOQC, SQO, POTFW, POTFS, FSTDEC, and THFST. For parameters varying by subwatershed and/or land use, a parameter range covering the entire watershed can be presented in the body of the report but values for each sub-watershed and land use should be provided in the appendix section.
   e) Additional information should be presented as appendices.

8. The following general guidelines should be followed as well:
   - During calibration, the frequency of simulated daily fecal coliform values above detection limit should be equal to or slightly greater that the fraction of observed values that exceed the upper detection limit. Similarly, if there is a lower detection limit, the frequency of simulated values below the detection limit should be approximately equal to the frequency of measured values below the lower detection limit.
   - Simulated concentrations should be at or above high truncated concentrations and at or below minimum concentration values during visual calibration.
   - Truncated data should not be assumed to be the maximum or minimum concentrations. They should be viewed as minimum concentrations for high concentration periods and the maximum concentrations for low concentration periods during calibration.
   - Until data become available that provides evidence to the contrary, fecal coliform concentrations predicted by HSPF during recession limbs should be assumed valid.
   - Until research is done to better describe the equilibrium between free and sediment adsorbed fecal coliform and die-off rates for fecal coliform in sediment, fecal coliform should continue to be modeled using the presently used free bacteria (dissolved) approach.
   - Until research is conducted to measure bacterial concentrations in interflow, interflow concentrations should be assumed to be 50% larger than estimated groundwater concentrations.

Appendix A – Bacteria Criteria Effective January 15, 2003

Revised Bacteria Criteria, as published in the Virginia Register
Volume 18, Issue 20 (June 17, 2002)

9 VAC 25-260-170. Bacteria; other waters.

A. In surface waters, except shellfish waters and certain waters identified in subsection B of this section, the following criteria shall apply to protect primary contact recreational uses:
   1. Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection have a minimum of 12 data points or after June 30, 2008, whichever comes first.

   2. E. Coli and enterococci bacteria per 100 ml of water shall not exceed the following:

	Geometric Mean[1]	Single Sample Maximum[2]
Fresh		
E. coli[3]	126	235
Saltwater and Transition Zone		
Enterococci	35	104

[1] For two or more samples taken during any calendar month
[2] No single sample maximum for enterococci and E. coli shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in fresh and 0.7 shall be used as the log standard deviation in saltwater and transition zone. Values shown are based on a log standard deviation of 0.4 in freshwater and 0.7 in saltwater.
[3] See 9 VAC 25-260-140 C for fresh water and transition zone delineation.

B. Notwithstanding the above, all sewage discharges shall be disinfected to achieve the applicable bacteria concentrations in subdivision A2 of this section prior to discharge. However, the board, with the advice of the State Department of Health, may determine that reduced or no disinfection of a discharge is appropriate on a seasonal or year-round basis. In making such a determination, the board shall consider the designated uses of these waters and the seasonal nature of those uses. Such determinations will be made during the process of approving, issuing or reissuing the discharge permit and shall be in conformance with a board-approved site-specific use-attainability analysis performed by the permittee. When making a case-by-case determination concerning the appropriate level of disinfection for sewage discharges into these waters, the board shall provide a 45-day public notice period and opportunity for a public hearing.

Appendix B – Procedure for Implementing the New Bacteria Criteria in Virginia's TMDL Program

October 23, 2002

Mr. Thomas Henry
Water Protection Division
USEPA REGION 3 - 3WP13
1650 Arch Street
Philadelphia, PA 19103-2029

Dear Mr. Henry:

This letter is to describe the approach that DEQ and DCR staff have developed to address the transition from fecal coliform (FC) to *E. coli* (EC) as a bacteriological indicator in fresh water.

1. Based on a review of available data and comments from microbiologists, statisticians and modelers (see attachment 1), 493 paired data sets for *E. coli* and fecal coliform from DEQ's statewide monitoring network were used to develop a statewide regression model between FC and EC. The regression model was developed to allow FC data to be translated into EC data during the state's transition period between the two indicators. The regression model is defined as follows:

$\log_2 EC = -0.0172 + 0.91905 * \log_2 FC$

The data used to develop the regression model, the statistical software output and a conversion tool from fecal coliform to *E. coli* are provided to you on the enclosed CD.

2. A comparison with regionally grouped data resulted in reasonable approximations up to 100,000 FC #/100 mL (see attachment 2). The statewide regression model is therefore considered appropriate for use in TMDL studies throughout the state.

3. For bacteria TMDLs due to be submitted as part of Virginia's 2004 TMDL commitment, the TMDL endpoint will be based on the new criteria as described in the final regulation published in the Virginia Register on June 17, 2002. For *E. coli*, the applicable single sample maximum criterion should be 235 #/100 mL. This value is subject to revision, pending the issuance of agency guidance for developing single sample maxima based on site-specific data.
Tom Henry

The translator should be applied where needed 1) to extend the monitored FC data set for modeling and load duration TMDLs, and 2) to translate FC model output time series into EC time series in order to determine whether the EC WQS will be met under the TMDL allocation scenario. Attachment 3 contains a flow chart outlining the process for determining the applicable TMDL endpoints based on availability of EC data.

4. The Commonwealth is currently evaluating its options with respect to already completed and approved TMDLs.

I trust that you will find the described approach satisfactory. If you have any questions or need additional information, please contact me or Mr. Charles Martin at (804) 698-4462.

Sincerely,

Alan Pollock
Office of Water Quality Programs

Attachments

Cc: Charles Martin, VADEQ
Jack Frye, VADCR
file

Attachment 1 – Review of Comments

Transition to new bacteria indicator for bacteria TMDLs – Review of Comments

This review of comments presents the results from DEQ's request for comments regarding the transition from the current fecal coliform bacteria criteria to the new E. coli criteria in freshwaters of the Commonwealth. As described in DEQ's memorandum dated July 22, 2002, EPA has proposed that a fecal coliform to E. coli translator should be used "to insure that the allocations will attain the future bacteriological standard". EPA also proposed using such a translator to extend the E. coli data set used for TMDL development.

Following the TMDL committee meeting on July 19, 2002, DEQ requested Drs. Chuck Hagedorn and Bruce Wiggins, both microbiologists, Dr. Eric Smith, a statistician, and Dr. Gene Yagow, a TMDL developer, to evaluate four options for such a translator. Additional comments were provide by Dr. Mike Scanlan and Ron Phillips, both with VADEQ. The evaluators' responses are summarized in the table provided below. A review of the evaluators' assessments revealed the following:

- Of the four options, Options 1 and 4 were most favored by the reviewers. Option 1 uses a large statewide data set while Option 4's benefit is its localized (but smaller) data set. Option 1 can also be implemented quickly and will require less resources than Option 4. The reviewers suggested an improved regression model using the statewide data set, but allowing for site-specific modifications if the local data warrant or require it.

- Option 2, while easily understood and presentable to the public, was not generally favored. It was not considered sufficiently developed and the ratio between EC and FC has been shown to vary. Also, that option presents EC and FC ratios based on a single agar plate. This method is not compatible with the analytical techniques used in the ambient monitoring program.

- Option 3 was generally dismissed because it is not based on an observed relationship between actual data.

At the TMDL committee meeting on August 9, 2002, it was decided to refine the statewide regression model by including all available data, adding site and region codes to allow data grouping, and developing linear regressions (EC vs. FC) on log-transformed data. It was also agreed to further discuss the application of such a translator in the case of already completed TMDLs, as proposed by EPA.

Table 1: Comment Summary (Yagow, Hagedorn, Wiggins, Smith, Scanlan, Phillips*)*

	Option 1: Based on counts from separate E. coli/FC analyses	Option 2: based on counts from combined E. coli/FC analyses	Option 3: based on EPA bacteria criteria	Option 4: To be based on counts from separate E. coli/FC analyses
Positive	- most scientifically valid - largest # samples - statistically based - good choice as long as data set is suitable	- easy to present to public - easy to understand by public - suitable if E. coli (EC) is determined from same plate as fecal coliform (FC)	- easy to present to public - easy to understand by public - adequate - simplest, most defendable if underlying data set is appropriate	- **site-specific data generally preferred by public** - data collection is already planned
Negative	- most difficult to explain - not suitable for data above/below DL - not based on local data - uses only data from lower concentration range	- conflict with Option 3 - %age is in conflict with Mountain Run study (38-47%) - VT and JMU work not suitable for use - VT data from source, not water samples	- conflict with Option 2 - simplistic, no observed data - less desirable than 1 and 4 due to variability in EC/FC ratio - lower than observed - higher than observed	- few data points - limited data range
Suggestions	→ use with Option 4 to cross-validate → use linear regression of log of counts → remove outliers → expand data set			→ use with Option 1 as cross-validation → use as refinement to Option 1, 2 or 3 → expand data set

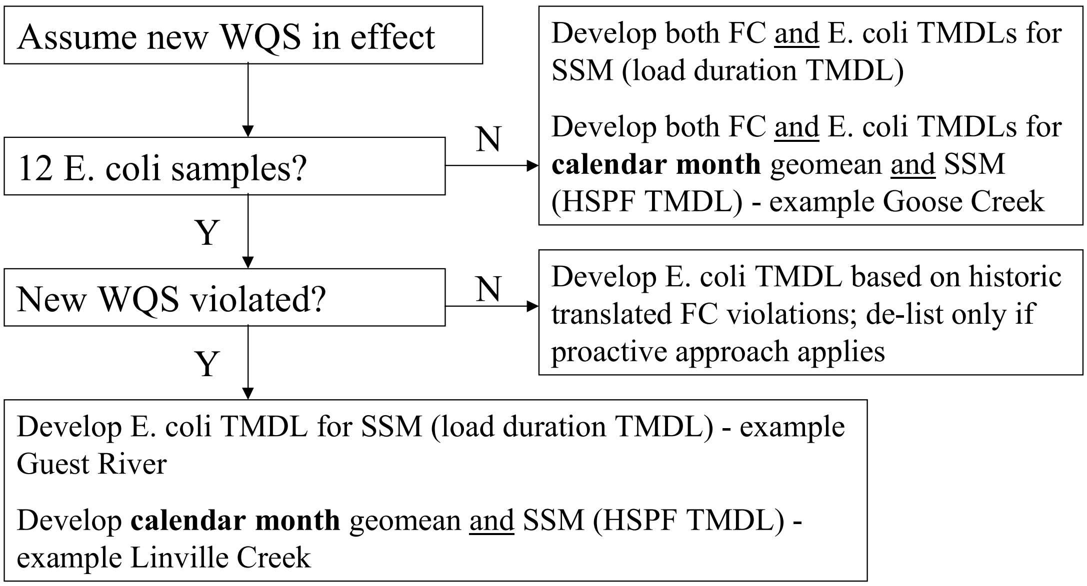
Note: Conflicting comments reflect the opinions of the various commenters

Attachment 2 – Regional Translator Comparison

FC conc	Resulting EC conc for			
	Statewide N = 493	02070005 N = 175	03010101 N = 122	05050001 N = 39
10	8	8	8	9
	0.00%	0.00%	0.00%	-12.50%
100	68	69	69	70
	0.00%	-1.47%	-1.47%	2.94%
190	123	124	124	123
	0.00%	-0.81%	-0.81%	0.00%
200	129	130	129	129
	0.00%	-0.78%	0.00%	0.00%
400	243	245	243	237
	0.00%	-0.82%	0%	2.47%
1,000	565	564	561	530
	0.00%	0.18%	0.71%	6.19%
2,000	1,068	1,061	1,055	975
	0.00%	0.66%	1.22%	8.71%
10,000	4,688	4,600	4,573	4,011
	0.00%	1.88%	2.45%	14.44%
100,000	38,911	37,503	37,281	30,332
	0.00%	3.62%	4.19%	22.05%

% indicates statewide result compared to regional result

Proposed Implementation of New Bacteria Indicators for 2004 Bacteria TMDLs



Implementation of New Bacteria Indicators for 2004 Bacteria TMDLs - Goose Creek

- HSPF modeling TMDL
- Draft Oct 02, final Dec 02
- No E. coli data
- Assume new WQS in effect
  - develop FC TMDL <u>and</u> E. coli TMDL
  - address both calendar month geometric mean and single sample maximum criteria
  - use implicit MOS
  - WLA: should reflect both criteria

Implementation of New Bacteria Indicators for 2004 Bacteria TMDLs - Linville Creek

- HSPF modeling TMDL
- Draft Nov 02, final Dec 02
- >12 E. coli data
- Assume new WQS in effect
  - develop E. coli TMDL only
  - address both calendar month geometric mean and single sample maximum criteria
  - use implicit MOS
  - WLA: should reflect both criteria

Implementation of New Bacteria Indicators for 2004 Bacteria TMDLs - Guest River

- Load Duration TMDL
- Draft Sept 03, final Dec 03
- 12 E. coli data
- Assume new WQS in effect
  - develop E. coli TMDL
  - address single sample maximum criterion only
  - use implicit MOS
  - WLA: should reflect SSM criterion

Appendix C – Sample formats for weather station and stream channel information

Table xx. Weather Stations Used To Fill Missing Daily Data and to Dissagregate Daily Data to Hourly Values

Station	Coop ID	Missing Data Fill Order	Dissaggregation Selection Order
The Plains	448396	Mt. Weather Reagan National	The Plains Reagan National Piedmont Star Tannery
Mt. Weather	445851	The Plains Regan National	The Plains Reagan National Piedmont Star Tannery
Lincoln	444909	The Plains Mt. Weather Dulles Reagan National	The Plains Reagan National Piedmont Star Tannery
Dulles	448903	Reagan National	Reagan National The Plains Piedmont Star Tannery

Table xx. Channel Characteristics For Calculating F-tables

Segment	Length (mi.)	Upstream Elevation (ft)	Downstream Elevation (ft)	Bottom Channel Width (ft)	Top Channel Width (ft)	Depth (ft)	Flood Plain Slope	Channel Manning's N	Flood Plain Manning's N
40	2.5	283	203	27	33	5	0.035	0.045	0.06
100	3	350	283	27	33	4.7	0.025	0.045	0.06
130	6.16	300	270	23	66	3.5	0.053	0.045	0.065
140	12.18	700	300	23	66	3.5	0.036	0.045	0.065
150	4.69	300	250	51	62	5.9	0.023	0.045	0.065
160	17.40	600	300	43	47	4.8	0.039	0.045	0.065
170	4.52	310	280	23	66	3.5	0.058	0.045	0.065
180	16.40	600	310	23	66	3.5	0.032	0.045	0.065
200	13.43	600	320	30	35	3	0.044	0.045	0.065
220	14.84	900	380	33.3	50	3.3	0.052	0.045	0.065
230	1.4	366	350	27	33	4.5	0.025	0.045	0.06
240	3.3	480	366	15	25	4	0.03	0.045	0.06
250	3.6	520	366	15	25	4	0.03	0.045	0.06

Appendix D - Final Hydrology and Water Quality Calibration Parameters for Selected Virginia TMDLs

Table xx. Calibrated Hydrology and Water Quality Parameters

Parameter	Definition	Units	Final Naked Creek TMDL	Final Gills Creek TMDL	Final Thumb Run TMDL	Final Dodd Creek TMDL	Final Goose Creek TMDL	Function of…
FOREST	Fraction forest cover	none	1.0 forest, 0.0 other	0.0	0-0.5	0.0, 1.0	0	Forest cover
LZSN	Lower zone nominal soil moisture storage	inches	6-7[1]	15.0	2.8	0.9-1.0	3-9.5	Soil properties
INFILT	Index to infiltration capacity	in/hr	0.05-0.08[1]	0.059-0.262	0.22	0.14-0.17	0.046-0.187	Soil and cover condition
LSUR	Length of overland flow	feet	300	15-1260	300.0	200	300-500	Topography
SLSUR	Slope of overland flowplane	none	0.03-0.10[1]	0.0001-0.173	0.0084	0.02	0.032-0.129	Determined by GIS
KVARY	Groundwater recession variable	1/in	0	0.0	0.0	0.0	0	Calibrate
AGWRC	Base groundwater recession	none	0.98	0.98	0.94	0.95	0.890-0.986	Calibrate
PETMAX	Temp below which ET is reduced	Deg. F	40	40.0	40.0	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	Deg. F	35	35.0	35.0	35	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	none	2	2.0	2.0	2	2	Soil properties
INFILD	Ratio of max/mean infiltration capacities	none	2	2.0	2.0	2	2	Soil properties
DEEPFR	Fraction of GW inflow to deep recharge	none	0.19	0.1	0.3	0.00	0.0	Geology
BASETP	Fraction of remain ET from baseflow	none	0.05	0.03-0.05	0.035	0.03	0.02	Riparian vegetation
AGWETP	Fraction of remain ET from active GW	none	0	0.00	0.0	0.0	0	Marsh/wetlands ET
CEPSC	Interception storage capacity	inches	monthly[1]	0.000-0.375	0.06-0.16	Monthly[1]	0-0.1	Vegetation
UZSN	Upper zone nominal soil moisture storage	inches	0.2-0.7[1]	0.313-3.300	0.18	1.3-1.6	0.9900-0.7301	Soil properties
NSUR	Manning'n (roughness)	none	0.2-0.25[1]	0.048-0.576	0.2-0.35	0.25	0.3-0.4	Land use, surface condition
INTFW	Interflow/surface runoff partition parameter	none	1.1	2.0	1.0	1.0	0.34-2.80	Soils, topography, land use
IRC	Interflow recession parameter	none	0.6	0.55-0.70	0.3	0.3	0.5-0.67	Soils, topography, land use
LZETP	Lower zone ET parameter	none	monthly[1]	0.189-0.930	0.1-0.7	Monthly[1]	0.01-0.99	Vegetation
SQO	Initial storage of constituent	#/ac					2E+5-5E+9	
POTFW	Washoff potency factor	#/ton	NOT SIMULATED					
POTFS	Scour potency factor	#/ton						

[1] Varies with land use

Parameter	Definition	Units	Final Naked Creek TMDL	Final Gills Creek TMDL	Final Thumb Run TMDL	Final Dodd Creek TMDL	Final Goose Creek TMDL	Function of…
ACQOP	Rate of accumulation of constituent	#/day	monthly[1]	49.0E+06-9.0E+10	3E+6-9E+9	7.6E7-2E10	76E+06-86E09	Calculated From Source Assessment
SQOLIM	Maximum accumulation of constituent	#	9x ACQOP	1.0E+08-17.0E+12	9*ACQOP	1E8 to 3E10	61E07-78E10	Calculated From Source Assessment
WSQOP	Wash-off rate	in/hr	1.5	0.3-0.9	0.6	0.70-1.5	0.3-2.0	Land use
IOQC	Constituent conc. In interflow	#/ft3	4248	1.0E+02-9.0E+04	1416	1416	0	
AOQC	Constituent conc. In active groundwater	#/ft3	4248	0.0	283.2	283	0	
LSUR	Length of overland flow	Feet	220-250[1]	15-1260	100.0	200	300-500	Topography
SLSUR	Slope of overland flowplane	none	0.03-0.07[1]	0.0001-0.173	0.01	0.02	0.05-0.18	Topography
NSUR	Mannings'n (roughness)	none	0.10	0.048-0.576	0.1	0.25	0.1	Land use, surface condition
RETSC	Retention/interception storage capacity	inches	0.065	0.001-0.05	0.065	-	0.065	Land use, surface condition
PETMAX	Temp below which ET is reduced	deg. F	40	40.0	40.0	40	40	Climate, vegetation
KS	Weighting factor for hydraulic routing		0.5	0.5	0.5	0.5	0.5	
FSTDEC	First order decay rate of the constituent	1/day	1.15	0.25-1.00	1.15	1.15	0.1-2.5	
THFST	Temperature correction coeff. For FSTDEC		1.05	1.07	1.05	1.07	1.05	

1 varies with land use

Appendix E – Sample Formats for Presentation of Hydrology Calibration Results

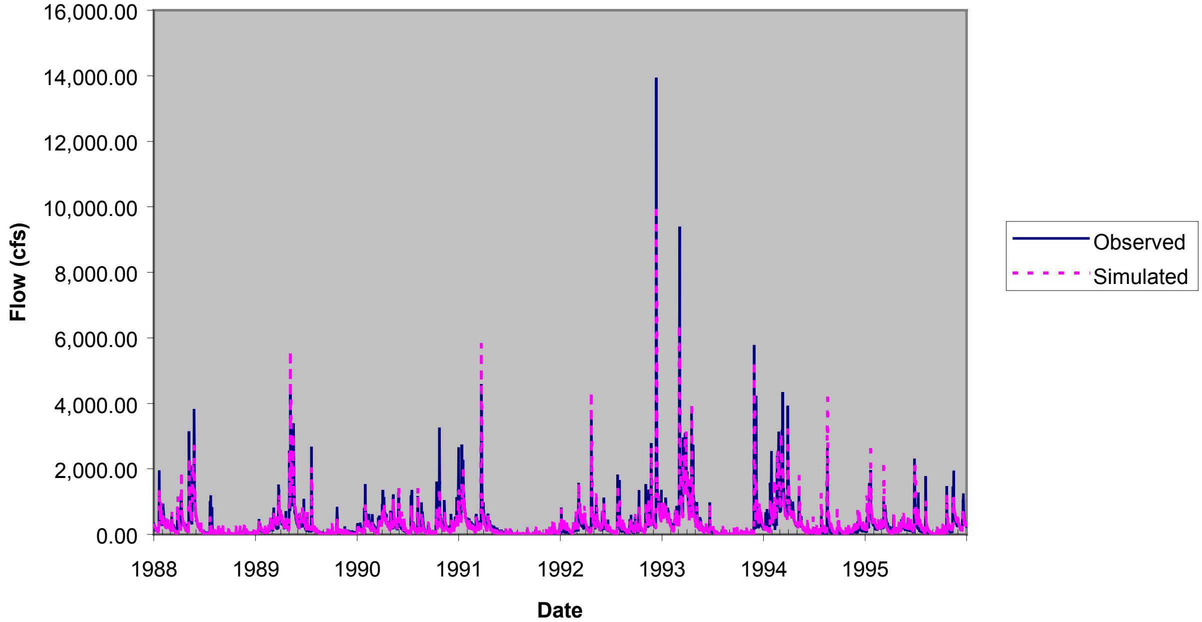


Figure zz. Simulated and Observed Flow, Goose Creek Near Leesburg - Calibration Period

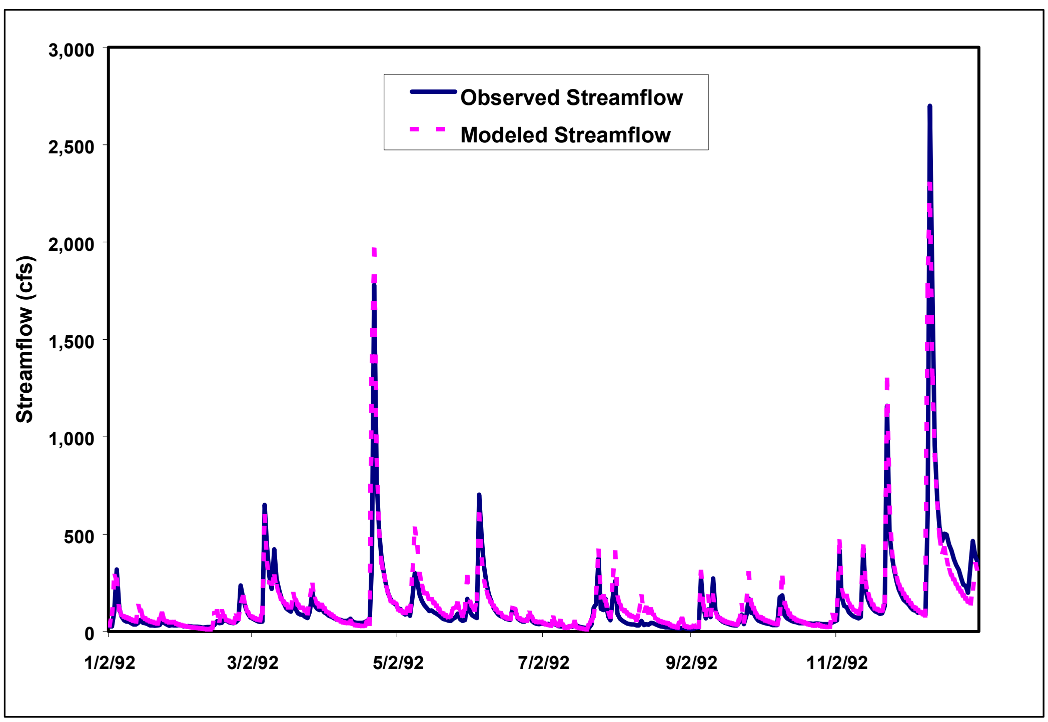


Figure zz: Observed and simulated streamflow at Middleburg gage for 1990

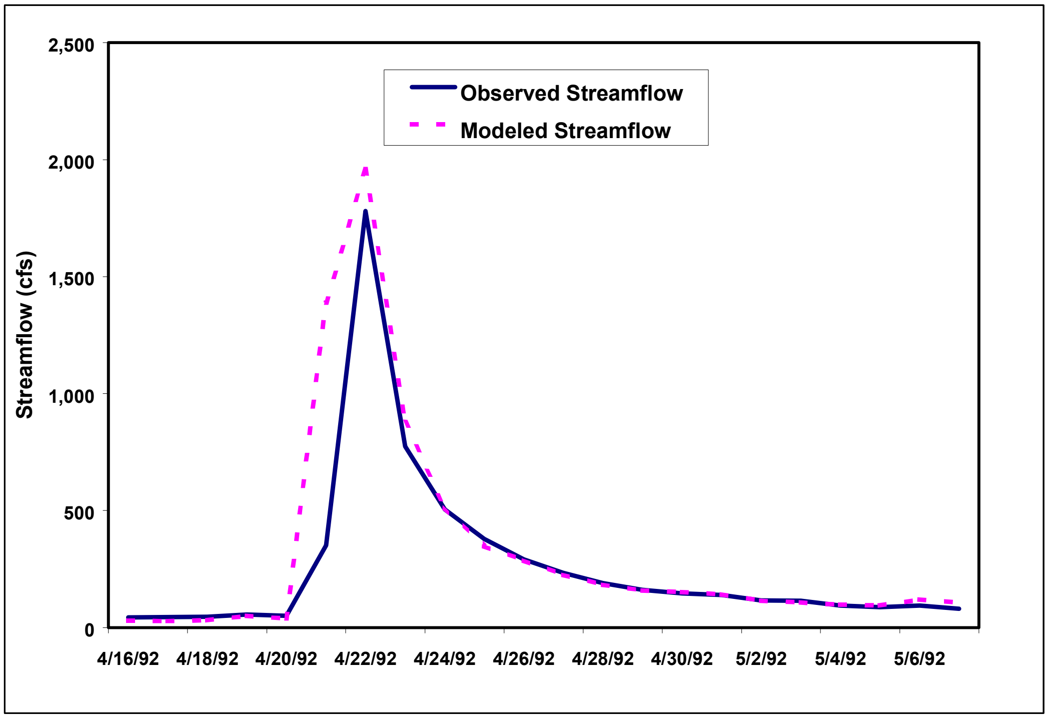


Figure zz: Observed and modeled streamflow at Middleburg gage for a typical storm event

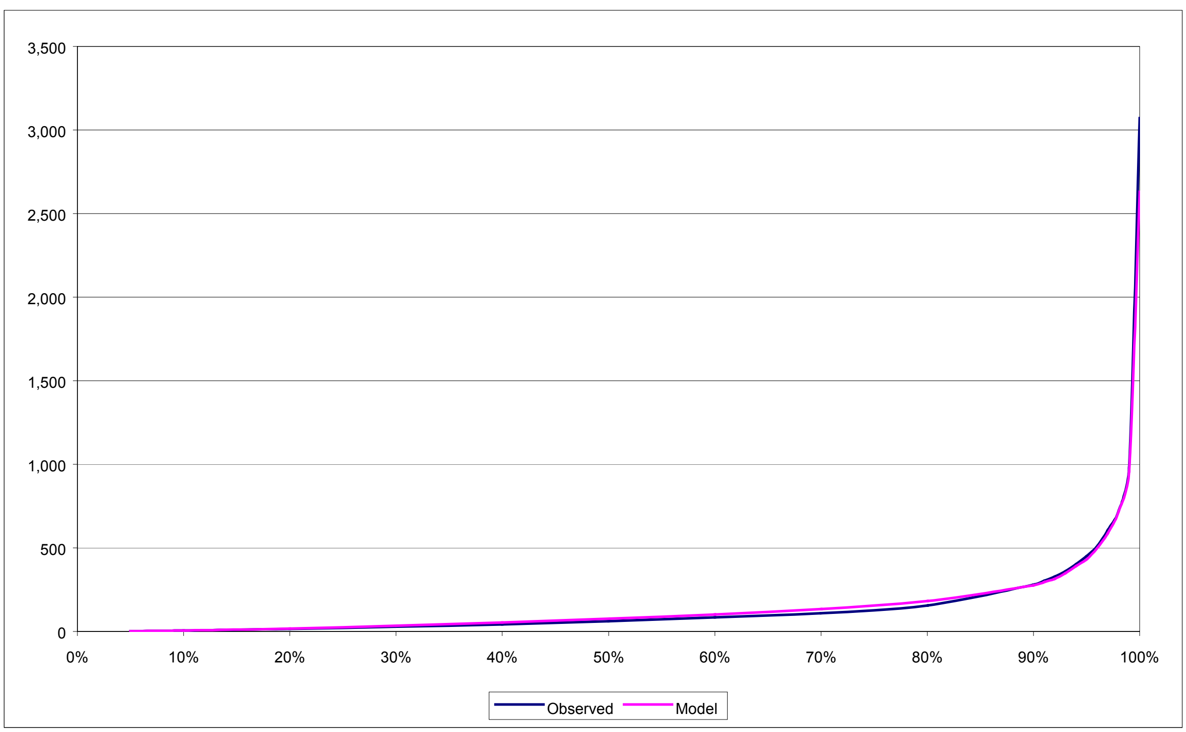


Figure zz: Cumulative distribution of observed and simulated flows at Goose Creek near Middleburg, calibration period (1988-1995)

Table xx: Summary statistics for hydrology calibration at Middleburg

	Observed	Simulated	Error	Criterion
Total Volume (in)	13.3	14.3	+7.0	±10%
Volume Highest 10% Flows (in)	6.4	6.3	-3.0	±15%
Volume Lowest 50% Flows (in)	1.3	1.6	+20.0	±10%
Spring Flow Volume (in)	4.1	3.9	-4.0	±10%
Summer Flow Volume (in)	3.8	3.8	-2.0	±10%
Fall Flow Volume (in)	3.0	3.7	+22.0	±10%
Winter Flow Volume (in)	2.4	2.9	+22.0	±10%
Groundwater Recession Coefficient	0.95	0.93	-2.0	±10%
Coefficient of Determination r^2	0.79			

Table xx: Summary statistics for hydrology verification at Middleburg

	Observed	Simulated	Error	Criterion
Total Volume (in)	34	37	+9.0	±10%
Volume Highest 10% Flows (in)	11	12	+13	±15%
Volume Lowest 50% Flows (in)	7.4	7.7	+3.0	±10%
Spring Flow Volume (in)	7.1	7.4	+5.0	±10%
Summer Flow Volume (in)	4.8	6.8	+42	±10%
Fall Flow Volume (in)	8.6	9.6	+11	±10%
Winter Flow Volume (in)	14	13	-3.0	±10%
Groundwater Recession Coefficient	0.96	0.93	-3.0	±10%
Coefficient of Determination r^2	0.88			

Table xx: Simulated average annual runoff, interflow, and baseflow

Average Annual Flow	Goose Creek Near Middleburg (210)	
	Calibration	Verification
Runoff (in)	3.7 (26%)	8.7 (26%)
Interflow (in)	1.6 (11%)	5.1 (15%)
Baseflow (in)	9.0 (63%)	20.2 (59%)
Total (in)	14.3 (100%)	34.0 (100%)
Baseflow Index	0.63	0.59

Table xx. Sensitivity Analysis: Variation in Coefficient of Determination With Respect to Variation in Parameters For Simulation Period 1988-2001

Parameter	Coefficient of Determination	
	+10% change in parameter	-10% change in parameter
INFILT	0.79	0.78
LZSN	0.78	0.79
UZSN	0.79	0.79
IRC	0.78	0.79
AGWRC	0.74	0.78
INTFW	0.79	0.78
LZETP	0.79	0.78
Calibrated Parameters 0.79		

Appendix F - Sample Formats for Presentation of Water Quality Calibration Results.

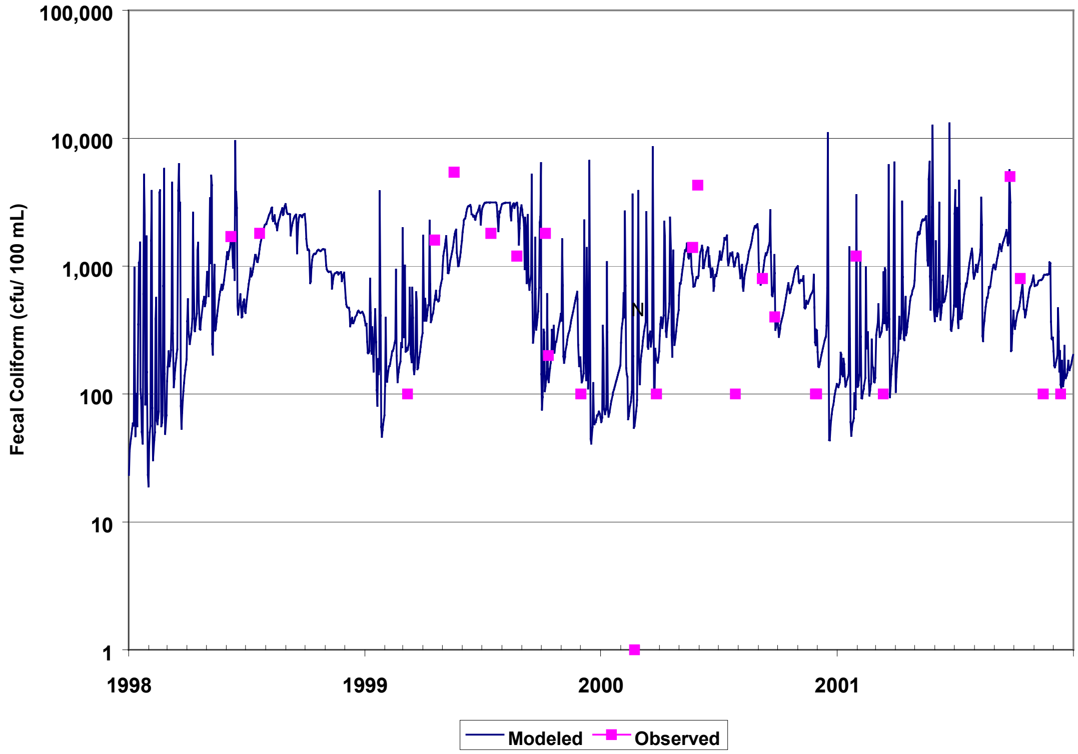


Figure zz. Simulated and Observed Fecal Coliform Concentration North Fork Goose Creek Verification Scenario

Table xx: Observed and Simulated Geometric Mean Fecal Coliform Concentration Over the Simulation Period (1992-2001)

Segment	Station ID	Watershed	Geometric Mean (cfu/100 mL) Observed	Modeled
20	1AGOO002.38	Lower Goose Creek	198.28	376.49
30	1ATUS000.37	Tuscarora Creek	215.02	234.15
100	1ASYC002.03	Sycolin Creek	261.20	293.07
140	1ANOG005.69	North Fork Goose Creek	371.84	636.81
160	1ALIV004.78	Little River	523.50	560.61
180	1ABEC004.76	Beaverdam Creek	345.87	515.28
190	1AGOO022.44	Middle Goose Creek	168.01	349.95
200	1ACRM001.20	Cromwells Run	344.09	348.59
230	1ASYC004.93	Sycolin Creek	689.98	624.01
240	1ASFS000.28	South Fork Sycolin Creek	461.69	440.05
250	1ASYC007.43	Sycolin Creek	233.24	617.46

Table xx: Observed and simulated exceedance rates of the 1,000 cfu/100 ml instantaneous fecal coliform standard

Segment	Watershed	Rate of Exceedance	
		Observed	Simulated
20	Lower Goose Creek	0.10	0.11
30	Tuscarora Creek	0.11	0.11
100	Sycolin Creek	0.2	0.2
140	North Fork Goose Creek	0.33	0.37
160	Little River	0.27	0.3
180	Beaverdam Creek	0.27	0.29
190	Middle Goose Creek	0.9	0.9
200	Cromwells Run	0.24	0.22
230	Sycolin Creek	0.4	0.35
240	South Fork Sycolin Creek	0.27	0.26
250	Sycolin Creek	0.17	0.32

Table xx. Sensitivity Analysis: Change in Violation Rate From 20% Change in Calibration Parameter Values

	WSQOP		FSTDEC		VOLUME	
Segment #	+20%	-20%	+20%	-20%	+20%	-20%
20	-0.01	+0.01	-0.03	+0.06	-0.01	0
30	0	+0.01	-0.01	+0.02	-0.01	+0.02
100	-0.01	0	-0.05	+0.05	-0.04	+0.02
140	-0.01	+0.01	-0.04	+0.04	-0.02	+0.02
160	-0.01	+0.01	-0.02	+0.02	-0.01	+0.01
180	0	+0.01	-0.05	+0.08	-0.02	+0.04
190	0	0	-0.03	+0.05	-0.03	+0.03
200	-0.01	0	-0.01	+0.01	-0.01	0
230	-0.01	+0.01	-0.02	+0.02	-0.02	+0.01
240	0	+0.01	-0.01	+0.02	-0.01	+0.02
250	0	+0.01	-0.01	+0.04	-0.02	+0.02