SECTION 8. HYDROLOGY SIMULATION AND CALIBRATION

Contents

Figures

Tables

SECTION 8. HYDROLOGY SIMULATION AND CALIBRATION

8.1 Introduction

Hydrologic processes in the watershed are simulated using HSPF (Bicknell et al. 1997; 2001; Donigian et al. 1984; Johanson et al. 1980). The PWATER module is used to simulate processes such as interception storage, evapotranspiration, infiltration, and surface water and groundwater runoff response on pervious land uses. The IWATER module is used to simulate interception storage, evaporation, and surface water runoff response on different types of impervious land uses. Each major land use type is parameterized separately so that the hydrology simulation is sensitive to changes in land use.

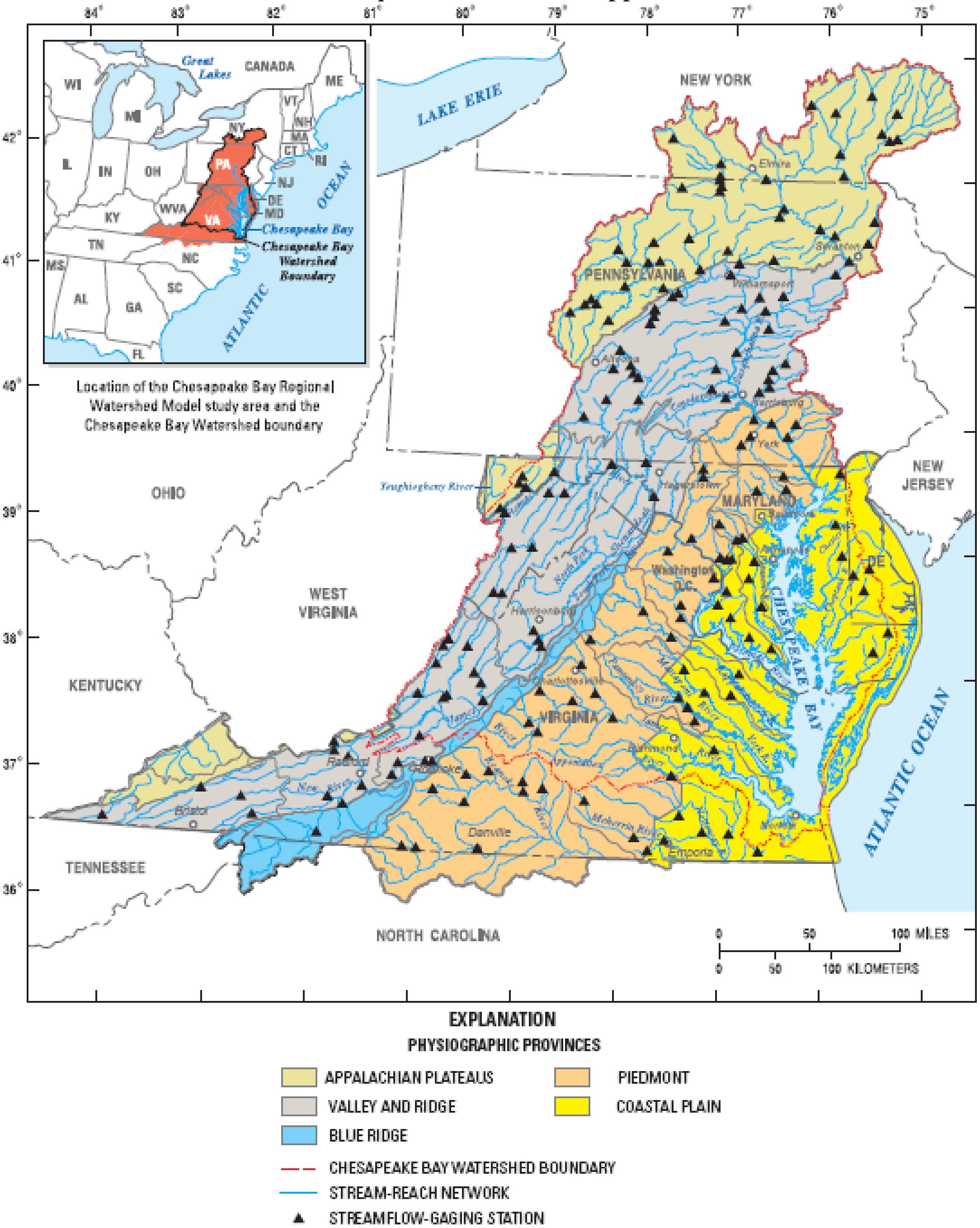
The HYDR module is used for hydrologic simulation in the rivers and reservoirs. The HYDR module uses a mass balance approach based on a stage-volume-discharge relationship for each river reach. For further details on the structure of the HSPF model, see Bicknell et al. (2001).

HSPF requires that each simulated river reach or reservoir have a defined stage-volume-area-discharge relationship. That relationship is represented as a table rather than an analytic function. The HSPF term for the table is an FTABLE. FTABLEs for the Phase 5.3 Model were generated throughout the watershed by a study (Moyer and Bennett 2007) that related watershed size to stream characteristics for a given physiographic region. In reservoirs, those relationships did not hold, so additional work was done to determine the appropriate stage-volume-discharge relationship for 42 of the largest reservoirs in the Chesapeake watershed.

Observed flow data from USGS gauging stations were used to calibrate the model at 287 stations in the Phase 5.3 model domain, including 222 in the Chesapeake Bay watershed. Informed by previous HSPF automated hydrology calibrations (Flynn et al. 1995) an automated calibration method was developed and implemented to arrive at a repeatable calibration, to ensure that all areas of the watershed were treated equally, and to handle the complexity of the simulation. The automated calibration method was applied primarily to parameters governing the hydrology simulation on pervious land. Outside the FTABLEs, only a few model parameters are used for the reaches. Most of those, such as reach length and change in elevation, are determined by GIS. With the few exceptions detailed in Section 8.7, no reach parameters were set by calibration.

8.2 Development of the Stage-Volume-Area-Discharge Tables (FTABLEs) for Non-Reservoir River Reaches

Moyer and Bennett (2007) found that the parameters necessary to calculate the values in an FTABLE for river reaches can be inferred from measurable variables having to do with the size of the watershed, the length of the river reach, the physiographic province, and stream cross-section parameters. The watershed size and geology were known for each of the 739 simulated river reaches. However, the stream cross-sectional geometry was known only at the flow gauging stations (Figure 8-1). Equations relating the stream cross-sectional geometry to the watershed size were developed for each physiographic province using 240 selected flow gauging stations. Figure 8-2 shows the relationship between watershed size and bankfull stage for each major physiographic province in the Chesapeake watershed. Similar analyses were done for bankfull width and bottom width. Those equations were then applied for all simulated reaches.



Source: Moyer and Bennett 2007

Figure 8-1. Physiographic provinces represented and streamflow-gaging stations used in HSPF FTABLE development in the Phase 5.3 Community Watershed Model.

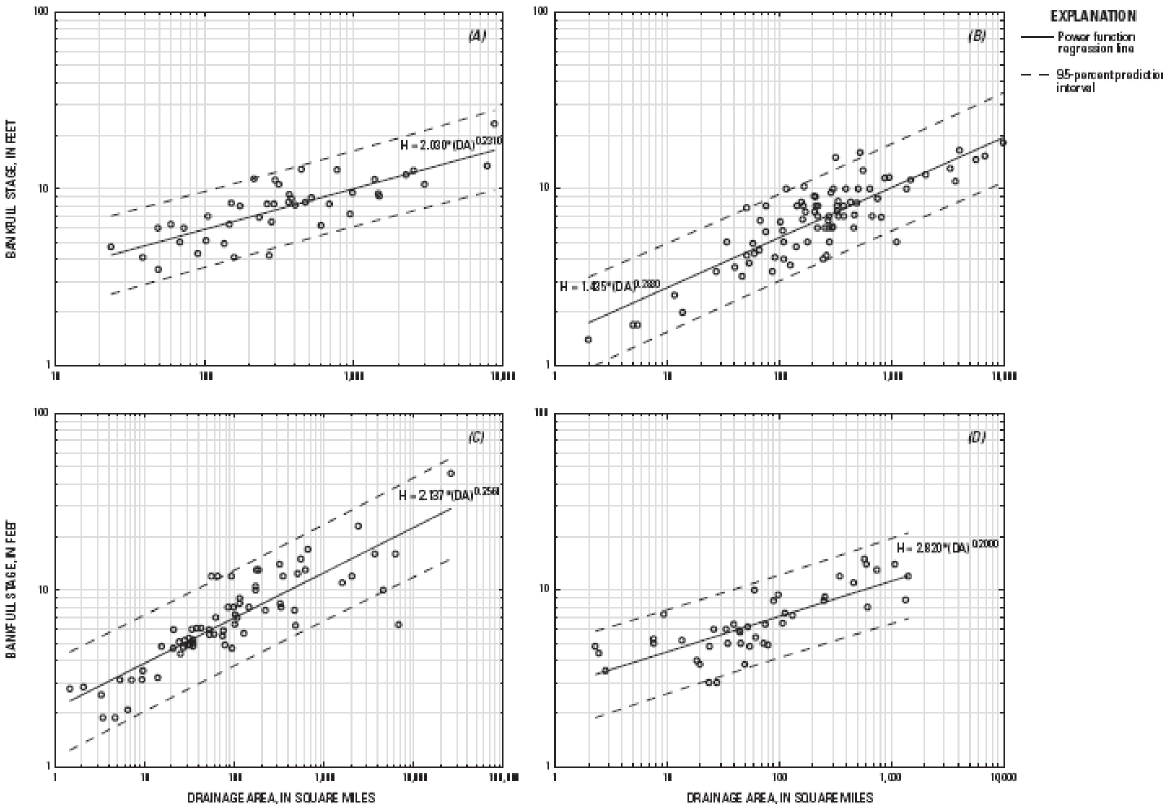


Figure 8-2. Relation of Bankfull stage to basin drainage area for streamflow-gaging stations in the (A) Appalachian Plateaus, (B) Valley and Ridge, (C) Piedmont, and (D) Coastal Plain physiographic provinces.

Floodplain slope, channel slope, and reach length were determined through GIS analysis of elevation data. Manning's *n* was estimated through field observation in some cases and derived through Manning's equation in others. The XSECT program was used to generate FTABLEs using the above parameters. For a full discussion, see Moyer and Bennett 2007.

8.3 Development of the Stage-Volume-Area-Discharge Tables (FTABLEs) for Reservoirs

Reservoirs violate the assumptions of channel flow, on which the rest of the model FTABLEs were based. They also change watershed hydrology and sediment and nutrient transport by adding significant storage volume and retention time to river segments. Consequently, the decision was made to explicitly simulate important reservoirs in the watershed model area with the use of special reservoir FTABLEs.

An FTABLE for a reservoir works similarly to a channel FTABLE in HSPF. Columns in the FTABLEs represent, from left to right, stage, surface area, volume, and discharge. In some reservoirs, additional columns represent alternate stage-discharge relationships because of reservoir management.

In this section, reservoir characteristics are presented in brief, and the process by which available data on reservoir geometry and flow characteristics were used to create reservoir FTABLEs is described. The generation of FTABLEs for reservoirs where geometry or flow data is unavailable is also discussed.

8.3.1 Reservoir Selection

Many reservoirs were considered for inclusion within the Phase 5.3 Watershed Model. However, only reservoirs that were on simulated river reaches and were primarily used for power generation and water supply were ultimately represented. The primary source of reservoir information for the selection process included the National Inventory of Dams (NID) from the U.S. Army Corps of Engineers (http://crunch.tec.army.mil/nidpublic/webpages/nid.cfm). The NID data were supplemented by other available USGS information, such as the Summary of Selected Characteristics of Large Reservoirs (http://water.usgs.gov/GIS/metadata/usgswrd/XML/reservoir.xml).

That initial list of reservoirs selected for FTABLE development was later refined as data-collection efforts began and the potential effects of particular reservoirs on watershed hydrology were better understood. A few reservoirs were removed from the list or combined with nearby reservoirs for the purposes of FTABLE development. Ultimately, 42 FTABLEs were used to simulate reservoirs or reservoir systems in the Phase 5.3 Watershed Model (Table 8-1).

Table 8-1. Major reservoirs represented in the Phase 5.3 Watershed Model

RESEVOIR NAME	ABBR.	RIVER SEGMENT	MAJOR BASIN	F-TABLE TYPE
Brasfield	BRAS	JA5_7480_0001	James River	Simple
Brighton	BRIG	XU2_4070_4330	Patuxent River	Varying
Alvin R. Bush	BUSH	SW3_1130_1390	Susquehanna River	Simple
Chickahominy	CHIK	JB3_7053_0001	James River	Simple
Claytor	CLAY	NR6_8500_7820	New River	Varying
Conowingo	CONO	SL9_2720_0001	Susquehanna River	Simple
Cowanesque	COWA	SU2_0741_0690	Susquehanna River	Special
Curwensville	CURW	SW4_1860_1720	Susquehanna River	Varying
Deep Creek	DEEP	GY0_4240_3951	Youghiogheny River	Simple
Diascund Creek	DIAS	JB0_7052_0001	James River	Simple
T. Nelson Elliott	ELLI	PL0_5141_5140	Potomac River	Simple
East Sydney	ESYD	SU2_0291_0320	Susquehanna River	Varying
John W. Flannagan	FLAN	BS4_8540_8441	Big Sandy River	Varying
Gathright	GATH	JU3_6900_6950	James River	Varying
Holtwood	HOLT	SL9_2700_2720	Susquehanna River	Simple
Hyco	HYCO	OD2_8920_8830	Roanoke River	Varying
John H. Kerr	KERR	OR7_8470_8490	Roanoke River	Varying
Leesville/Smith Mtn.	LEES	OR4_8271_8120	Roanoke River	Simple
Liberty	LIBE	WM0_3881_3880	Western Shore	Simple
Little Creek	LITL	JB0_7051_0001	James River	Simple
Loch Raven	LOCH	WU3_3480_3481	Western Shore	Simple
Marburg	MARB	SL0_2831_2830	Susquehanna River	Simple
Mead	MEAD	JB1_8090_0001	James River	Simple
North Anna	NANN	YP2_6390_6330	York River	Simple
Otsego	OTSE	SU2_0030_0140	Susquehanna River	Varying
Philpott	PHIL	OD2_8560_8630	Roanoke River	Varying
Prettyboy	PRET	WU0_3021_3020	Western Shore	Simple
Jennings Randolph	RAND	PU3_4450_4440	Potomac River	Varying
Raystown	RAYS	SJ4_2360_2340	Susquehanna River	Varying
Rocky Gorge	ROCK	XU2_4330_4480	Patuxent River	Simple
Safe Harbor	SAFE	SL9_2520_2700	Susquehanna River	Simple
Savage River	SAVA	PU1_4190_4300	Potomac River	Varying
Foster Joseph Sayers	SAYE	SW3_1690_1660	Susquehanna River	Special
South Rivanna	SRIV	JL2_6441_6520	James River	Simple
George B. Stevenson	STEV	SW3_1091_1380	Susquehanna River	Simple
Stony River	STON	PU1_4840_4760	Potomac River	Simple
Swift Creek	SWIF	JA0_7291_7290	James River	Simple
Tioga	TIOG	SU3_0831_0790	Susquehanna River	Simple
Upper Occoquan	UOCC	PL3_5250_0001	Potomac River	Simple
Warrior Ridge	WARR	SJ4_2060_2010	Susquehanna River	Varying
Western Branch	WBRA	JB2_7800_0001	James River	Simple
Whitney Point	WHIT	SU3_0240_0350	Susquehanna River	Varying

Reservoir outside of Chesapeake Bay Watershed (shaded rows)

8.3.2 FTABLE Development

In general, FTABLEs were developed with data collected in consultation with reservoir operators. Of the 42 FTABLEs developed, 30 were created at least in part from such operational data. However, the reservoirs are managed for a variety of purposes, and their management often varies seasonally, so creating simple stage-discharge relationships often required substantial interpretation of available stage-discharge data. Furthermore, available data were often supplemented with estimates to fill in portions of the FTABLEs for which data were not available.

Frequent manual control of reservoir output by reservoir operators was difficult to represent in the Phase 5.3 Watershed Model with simple stage-discharge curves, because manual operations often result in inconsistent relations between stage and discharge for a reservoir. For example, in a reservoir managed for flood control, the relation of stage to discharge during fall drawdown could be quite different from the relation of stage to discharge during flood attenuation in the spring season. The relative complexity of a reservoir's operation affected the amount of interpretation and simplification required for developing the FTABLE for that reservoir. Of course, variations in reservoir operations over periods of different amounts of rainfall and runoff further complicated interpretive efforts. Given those considerations, the goal of the FTABLE development was the accurate simulation of reservoir operations rather than strict physical representation of reservoir dimensions.

For the most part, the FTABLEs created from operational data were constructed from available information about reservoir dimensions, approximation and simplification of years of available stage-discharge data, and varying amounts of available information about reservoir operations. The operations of the reservoirs were classified into several groups for the purposes of FTABLE generation. Groups of reservoirs with similar characteristics are discussed in Sections 8.3.2.1, 8.3.2.2, and 8.3.2.3. Notes on individual reservoirs are included in Appendix 8.A.

Three of the reservoir FTABLEs were carried over from earlier versions of the Watershed Model and were not constructed using the methods described in this report. Those three are the major Susquehanna reservoirs of Conowingo, Holtwood, and Safe Harbor.

For nine of the reservoirs modeled, operational data were not available, and the reservoirs were represented with FTABLEs developed for other reservoirs with similar characteristics. In some cases, those proxy FTABLEs were modified from the original versions, but several of the proxy FTABLEs are identical to those developed for other reservoirs.

Consistent Management

Most reservoirs in the study are managed to maintain or approximate a single target level. Consequently, they are represented in the model with a single table relating water level to surface area, volume, and discharge. Some could be run-of-the-river reservoirs, which are subject to very little management of water storage, release, or spill. In any case, the FTABLE represents a simplification of reservoir operations to a single stage-discharge relationship without substantial variation based on season or year. Of the 42 reservoirs simulated for the Phase 5.3 Watershed Model, 25 are represented by simple FTABLEs (see Table 8-1).

Variable Management

Some reservoirs are managed with more than one target level for the level of the impounded pool. Target pool levels vary with time, and can depend on seasonal flood management, power generations schedules, or a mix of these and other considerations. Different target levels require different stage-discharge relationships, and the stage-discharge relationship can vary depending on whether the reservoir is being filled or drawn down under varying input conditions. During a period of reservoir filling or drawdown from one target level of pool impoundment to another, the relations between reservoir level, surface area, and volume are constant, but the varying stage-discharge relationship is represented in the FTABLE with a separate discharge column for each seasonal management infill or drawdown period. In some cases, depending on the data available to characterize the reservoir operating rules, an abrupt change occurs from one stage-discharge relationship to the next. For others, however, the transition between the various stage-discharge relationships is managed by incorporating linear transition periods of varying lengths. Those transition periods are incorporated into the model programming, so they are not represented in the FTABLEs, but notation is made with the FTABLEs indicating the existence and duration of the transition periods. Of the 42 simulated reservoirs, 15 are represented with seasonal FTABLEs, with or without transitional periods (see Table 8-1).

Special Cases

For a few reservoirs, changes in reservoir operation during the period represented by the model required special changes in the FTABLE. For the Cowanesque Reservoir, the single target level changed in 1990, so there is one stage-discharge relation for the period before 1990, and another stage-discharge relation for the period after 1990. The Foster Joseph Sayers Reservoir was managed with three seasonal levels (with transition) before 1994 and with two seasonal levels (with transition) after 1994, and those different stage-discharge relations are simulated with separate FTABLEs for the two time periods.

The Conowingo Reservoir, which is the terminal reservoir on the Susquehanna, is managed to optimize power generation at peak demand periods among other considerations. Flows are lower on weekends than mid-week. A model of reservoir output based on reservoir input and the day of the week generates the time series output from the Conowingo.

8.3.3 Results of the reservoir simulation.

To test the utility of adding reservoirs to the simulation, an uncalibrated development version of the Phase 5.3 Model was run with and without reservoir simulations, and the results were compared to observed data. The average increase in Nash-Sutcliffe Efficiency, or, hereafter, just *efficiency* (Beven 2001), for all reservoir-affected monitoring stations was 0.16 in absolute terms and 0.26 when comparing the Nash-Sutcliffe Efficiency of the logarithm of flow.

The effect on the skill of nutrient and sediment simulation was not specifically tested, but it is clear that reservoirs have a large effect on nutrient delivery.

8.4 Calibrated Hydrologic Parameters

The PWATER module simulates pervious land hydrology in HSPF using approximately 20 parameters, some of which can vary monthly. The hydrology simulation is sensitive to the values of only a few parameters. Lumb et al. (1994) developed an expert system for calibrating HSPF and find a set of sensitive parameters. Doherty and Johnston (2003) using automated calibration methods, found a similar set of sensitive HSPF hydrology simulation parameters. A sensitivity test on the Phase 5 Watershed Model confirmed those findings. Table 8-2 lists the key hydrologic parameters that were calibrated and their range of values used in Phase 5.3. Other parameters were set with default values or on the basis of information derived by GIS. Default values and permitted range were largely based on BASINS Technical Note 6 on parameterization (USEPA 2000).

Table 8-2. Key hydrology calibration parameters

Parameter	Description	Permitted range
LAND_EVAP	PET adjustment (similar to pan evaporation coefficient)	0.75–1.25
INFILT	Infiltration rate	0.0125–0.25
LZSN	Lower zone soil moisture storage index	8.0–12.0
AGWR	Baseflow recession coefficient	0.92–0.995
INTFW	Ratio of interflow to surface runoff	1.0–5.0
IRC	Interflow recession coefficient	0.3–0.85
AGWTP	Evapotranspiration from groundwater storage	0.0001–0.3

The upper zone soil moisture storage index (UZSN) was set as a fixed fraction of the lower zone soil moisture storage index (LZSN) as recommended in USEPA 2000. Table 8-3 gives the ratio between UZSN and LZSN for each land use.

Table 8-3. Ratio of UZSN to LZSN by land use

Land use	Forest	Crop	Grass, pasture, hay	Pervious urban
UZSN: LZSN	0.12	0.14	0.1	0.1

Also as recommended in USEPA 2000, UZSN was allowed to vary monthly for cropland, to better represent how storage is affected by the crop growth cycle. Table 8-4 gives the ratio of the monthly UZSN to its maximum value.

Table 8-4. Fraction of maximum crop UZSN

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fraction	0.6	0.6	0.6	0.6	0.6	0.7	0.95	1.0	1.0	0.8	0.7	0.65

As shown in Table 8-2, seven parameters were calibrated for hydrology. The parameters varied spatially in that unique values were found for each of the 308 land segments depending on the fit of the simulated flows to observed flows in downstream gages. Section 8.6 deals with that process in detail. Because each land segment was composed of 21 separate pervious land uses, not enough information was in the calibration data set to calibrate each land use in each land segment individually. To deal with that issue, the parameter values for other land uses were specified by four master land uses: forest; crop; pervious urban; and grass, pasture, and hay. Parameters for the four master land uses were, in turn, specified as a fixed ratio of the crop land use. Table 8-5 gives the ratio between the values of the parameters for the crop and other master land uses.

Table 8-5. Ratio of hydrology parameters to their values for cropland by land use

Land use	INFILT	LZSN	AGWR	INTFW	IRC	AGWETP
Forest	1.6	1.0	1.0	1.25	1.0	6.0
Grasses	1.5	1.0	1.0	1.0	1.0	1.5
Pervious Urban	0.8	1.0	1.0	1.0	1.0	2.0

8.5 Observed Data

Observed flow data were compiled from USGS gaging stations at the 287 stations in the Phase 5.3 Model domain that had at least 3 years of flow data and are on a river designated as having an average flow greater than 50 cubic feet per second. Those stations are shown in Figure 8-3 below and listed in Appendix 8.B.

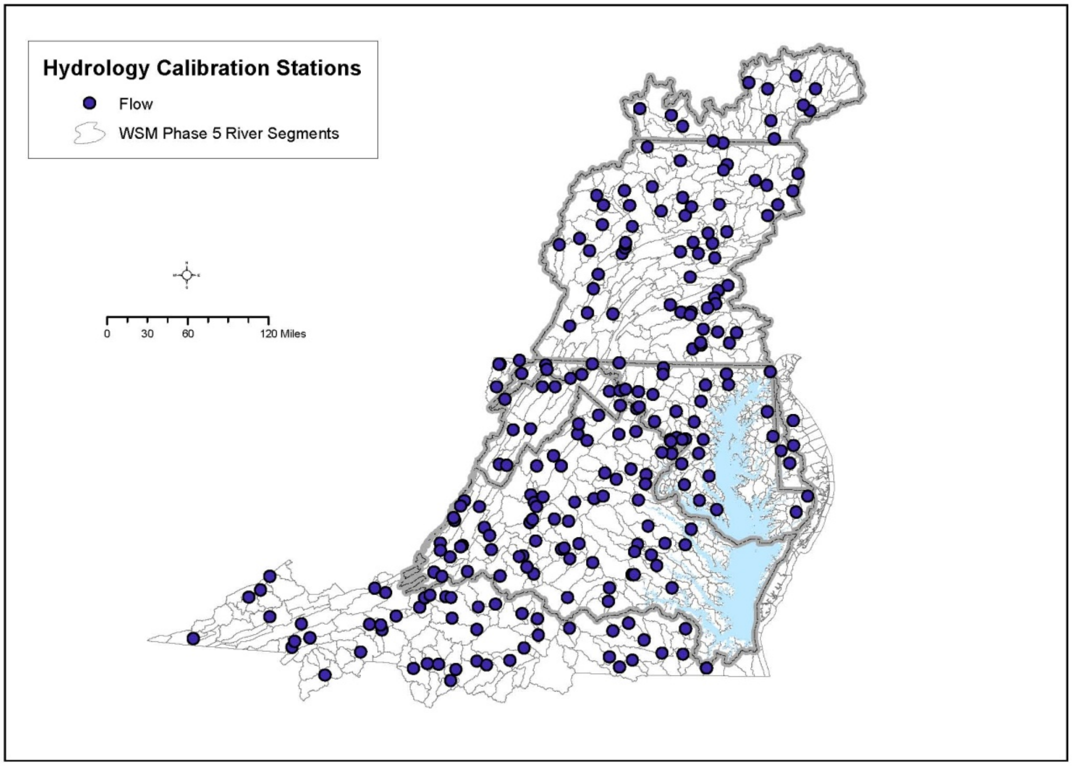


Figure 8-3. USGS flow gaging stations used in the Phase 5.3 Watershed Model calibration.

Appendix 8.B lists several river segments as having stations that are not part of the physical segmentation. Those virtual segments, known as confluence segments, are created when a gauging station is just downstream of a confluence. The confluence station is not representative of any of the upstream segments nor is it representative of the outlet of the downstream segment. It represents the addition of all upstream segments. In such a case, a confluence segment is generated. The confluence river segment name has the same first nine characters of the downstream segment name, but it ends in *0003*. The model postprocessor calculates the addition of the upstream segment and stores the output under the confluence river segment name for comparison against the observed data.

8.6 Calibration

8.6.1 Introduction

An automated calibration procedure was developed and implemented to iteratively adjust hydrologic parameter values on the basis of the agreement of simulated and observed hydrograph statistics at calibration stations. The procedure was primarily developed in 2004 but was modified as late as 2008 in response to input from stakeholders.

Automated calibration of HSPF and other watershed models is a growing practice as computing power increases. The literature gives a number of implementations of the parameter estimation software, PEST (e.g., Doherty and Johnston 2003). A PEST calibration is a full implementation of a gradient-based optimization, which requires many function evaluations during each iteration to calculate the derivatives of the objective function with respect to each variable. A function evaluation in the Phase 5.3 Model would require a full run of the model, which takes approximately 12 hours on a single processor, making full gradient-based optimization infeasible given the number of parameters to optimize.

The automated calibration used for the Phase 5.3 Watershed Model is similar to those methods with two very significant differences. First, the derivatives of the parameters with respect to the objective are fixed for the entire process on the basis of an initial sensitivity analysis. Fixing the derivatives speeds up the optimization by orders of magnitude; however, it can be used only when parameters are reasonably uncorrelated. Low values of sensitivity were selected to reduce oscillation of parameters during the calibration process. Second, the procedure simultaneously optimizes multiple calibration objectives rather than a single objective. Each parameter type was assigned to optimize a single calibration objective.

Santhi et al. (2008) is another example of calibration using defined sensitivities and a limited objective function.

8.6.2 Calibration Statistics

Sensitivity tests were performed where the parameters described in Section 8.4 were perturbed and the distribution of responses across all simulated rivers was recorded.

Examination of the response of the simulated hydrograph to parameter modification yielded a set of statistics appropriate for use in calibration. A well-performing statistic was sensitive primarily to a single calibrated parameter described in Section 8.4 and had a relatively narrow range of sensitivity. After many such trials, a set of statistics was selected that (1) describes the entire hydrograph, (2) creates a 1:1 relationship between calibration parameters and response variables, and (3) reacts in a predictable manner to upstream parameter modification.

A set of statistics that describes the entire hydrograph is presented below. The statistics were then used individually or combined to meet the requirements (2) and (3) above. The relationship between statistics and parameters is described in Section 8.6.3.

For the derivations below,

- s = simulated.
- o = observed.
- Summer months are June, July, August.
- Winter months are December, January, February.
- Stormflow and baseflow are determined by hydrograph separation using the USGS PART program.
- All values of simulated and observed are paired. That is, values are used in calculations only for days in which both simulated and observed values are available.

The names of derived statistics here are not necessarily meant to be universal, but rather specific to the Phase 5.3 application.

Bias represents the simulated agreement with overall water balance. It is calculated as relative bias, with zero bias being perfect agreement

$$Bias = \frac{\sum_{All} s - \sum_{All} o}{\sum_{All} o}$$

Wbias is the bias for the paired simulated and observed values in winter months only, calculated as above.

Sbias is the bias for the paired simulated and observed values in summer months only, calculated as above.

Bbias is the bias for the paired simulated and observed values during base flow only, calculated as above.

Pbias is the bias for the paired simulated and observed values of peak flows, calculated as above. Paired peak flows were found by determining the 50 highest peaks for the simulated and observed data and including in the analysis only those that fell on the same day. Peaks were defined as days in which the flow was greater than both the preceding and following days.

VPbias is the bias in the volume of the storms related to the paired peaks. Volume is calculated by adding storm flow preceding and following the peak that does not include a return to baseflow or another peak.

BaveRI is the ratio of the simulated and observed average recession indices for baseflow. The recession index is the flow at day *n+1* divided by the flow at day *n*. The average recession index is the average of all daily indices that can be calculated from the paired simulated and observed baseflow data. BaveRI is the ratio of the simulated average to the observed average with unity being perfect agreement.

QaveRI is the same as BaveRI, but for storm flow rater than baseflow.

Wstat is an index of the winter bias normalized for the total bias. It is calculated as (*Wbias* + 1) / (*Bias* + 1). Unity is perfect agreement.

Sstat is an index of the summer bias normalized for total bias. It is calculated in the same manner as *Wstat*.

Bstat is an index of the base flow bias normalized for total bias. It is calculated in the same manner as *Wstat*.

Together, those statistics measure how well the simulation is capturing the properties of the observed flows.

8.6.3 Calibration Procedure and Parameter Sensitivities

During the automated calibration, each calibrated land parameter was linked to the statistics described in Section 8.6.2, calculated for relevant gages. The Watershed Model was run once with default parameters, and the above statistics were calculated at each gaging station. Using the update multipliers described below, each parameter was updated to a new value. The model was then run again with the new parameters. The process was completed 10 times with the hydrograph statistics and model efficiencies calculated at each step.

As described above, sensitivity distributions between parameters and statistics were found by experimentation. Using those distributions and a trial-and-error method, update multipliers were found that generally converged in six to eight iterations, did not induce parameter oscillation, and achieved a high average model efficiency. The final update multipliers are in Table 8-6 below:

Most of the linkages between parameters and statistics are obvious. Clearly, the overall water balance could be adjusted by changing LAND_EVAP to increase or decrease PET. Similarly, INFILT, IRC, AGWR, and INTFW are conceptualized within HSPF to control the exact processes that the statistics are measuring. Less obvious is the fact that LZSN could adjust the ratio of winter to summer flows. Storage in the lower zone, however, is predominately a function of season, in which water is stored in the lower zone during wetter periods in winter and spring, and evaporated in the summer. If winter flows are too high, relative to summer flows, storage can be increased.

Table 8-6. Update rules for calibration of hydrology parameters

Parameter	Statistic	Update multiplier
LAND_EVAP	Bias	2 / (2 –Bias)
LZSN	Wstat, Sstat	(2.5 – Sstat / Wstat) / 1.5
INFILT	Bstat	1 / Bstat
IRC	QaveRI	2 / (1 + QaveRI)
AGWR	BaveRI	2 / (1 + BaveRI)
INTFW	Pbias, Vpbias	Pbias × Vpbias > 0 => 1 + max(Pbias, Vpbias) / 2 Pbias × Vpbias < 0 => 1.0

8.6.4 Connection of Land Segments to Relevant Stations

Four issues arose in linking land segment parameters to relevant flow gauging stations. (1) Given the segmentation scheme with separate, overlapping land and river segments, many land segments that were in more than one non-overlapping watersheds; (2) land segments could drain to multiple nested downstream stations; (3) reservoirs regulated flow and disturbed the relationship between parameters and statistic; and (4) some land segments did not drain to any calibration stations.

The first two issues are solved with the same technique. The *importance* of a land segment to a flow gage is defined here as the percent of the total flow gage drainage that is within that land segment. The importance of each flow gage is calculated with respect to a land segment. The results are scaled so that they add to 100 percent. If the lowest importance is less than 10 percent, the lowest importance is ignored, and the results are again rescaled to 100 percent. That process is repeated until no importances are lower than 10 percent. The parameter adjustments that would be determined by each flow gage are then scaled by the importance of that flow gage.

An example helps to explain the procedure. Suppose land segment A drains to stream gages X, Y, and Z. Segment A makes up 100 percent of X, 50 percent of Y, and 10 percent of Z. The relative importance of A to X is 100 / (100 + 50 + 10) or 62.5 percent, the importance of A to Y = 31.25 percent, the importance of A to Z is 6.25 percent. Z is below the 10 percent threshold, so it is dropped, and the ratios are calculated as 66.7 percent for X and 33.3 percent for Y. Land segment A takes 66.7 percent of the recommended update multiplier from river gage X and 33.3 percent of the recommended update multiplier from river gage Y.

Generally, flow gauging stations with more than 50 percent of the upstream watershed passing through a reservoir were removed from the automated calibration and in those cases the calibration rested on other stations that were unaffected by reservoir influences.

As with the update multipliers, variants of the above procedures were investigated. The process that optimized average model efficiency was retained.

Parameters for land segments with no downstream gages, primarily in the coastal plain, are set equal to similar land segments that were judged to be the best match. The criteria are proximity, similarity, and the degree to which the similar segment is well-calibrated. That last criterion is based on the maximum raw importance score. Table 8-7 shows which calibrated land segments were assigned to segments without downstream reaches.

Table 8-7. Assignment of *no gage* land segments to *similar* land segments

No Gage	Similar		No Gage	Similar		No Gage	Similar		No Gage	Similar
A10003	A10001		A37185	A37145		A51133	A51193		A51685	A51059
A24019	A24045		A51001	A24047		A51199	A51181		A51700	A51181
A24029	A24035		A51013	A51059		A51520	A51191		A51710	A51181
A24039	A24047		A51073	A51057		A51550	A51181		A51735	A51181
A24041	A24011		A51095	A51181		A51570	A51181		A51740	A51181
A24510	A24005		A51099	A51057		A51620	A51175		A51750	A51121
A37001	A37033		A51103	A51193		A51650	A51181		A51810	A51181
A37077	A37145		A51115	A51057		A51670	A51181		A51830	A51181
A37135	A37145		A51119	A51057		A51683	A51059		B51035	A51141
A37181	A37145		A51131	A24047						

8.6.5 Calibration of Snow Parameters

The snow simulation in HSPF is based on an energy balance. Precipitation falling at less than 32 degrees Fahrenheit adds to the snow pack. Snow pack decreases because of sublimation, and melting from energy inputs from rain, shortwave radiation, longwave radiation, and the transfer of heat from the ground and air. The sensitive parameters are those related to the heat transfer from the ground and air. A simple trial and error procedure found that the optimal model efficiencies were found for the Potomac and Susquehanna rivers when the atmospheric heat flux coefficient, CCFAC, was minimized and the ground heat coefficient, MGMELT, was maximized.

8.7 Special Cases

8.7.1 Hurricane Isabel

The simulation of tropical storm Isabel around September 20, 2003 was inaccurate in the Rappahannock, with the simulated peak flow much higher than the observed peak. The over-simulation caused mass balance problems with the estuarine hydrodynamic model of the Chesapeake. Adjustments were made to the FTABLEs in the Rappahannock to increase the floodplain volume, which brought down the simulated peaks. Those adjustments affected only storms with return frequencies over approximately 2 years.

8.7.2 Big Melt

Around January 7–9, 1996, three successive snow storms created a snow pack of 3 to 4 feet in many areas of the Susquehanna and Potomac drainages. One week later, warm air climbed over a cold air mass creating a warming event and rain storm of approximately 2 to 3 inches. That caused a very high flows and flooding in the Susquehanna and Potomac. For an entertaining historical account, see: http://www.erh.noaa.gov/lwx/Historic_Events/md-winter.html.

A large ice dam at Harrisburg has often been offered as the cause of the massive flows in the Susquehanna. The ice dam was simulated, but it did not offer much improvement in the simulation. It was noted that the flows were greatly underestimated during the event but steadily overestimated in the spring melt; therefore, the melting caused by the rain was suspected. The temperature of the precipitation was increased by 10 degrees Celsius for a group of counties in the path of the storm. The increase was found by trial and error to produce the greatest increase in efficiency for the simulation of 1996 hydrology overall. Figure 8-4 is a histogram of change in model efficiency for all flow stations in 1996 after making the change. There was widespread improvement of the simulation. The many stations that are unchanged are outside the Potomac and Susquehanna basins.

8.7.3 Hurricane Juan

The remnants of Hurricane Juan settled over the upper Potomac watershed in November of 1985, dropping large amounts of rain on the watershed and producing extremely high flows. The initial calibration was unable to match the flows. Several fixes were tried.

The first was to calibrate by hand to that storm, and then see if that can inform a modified calibration method. That was unsuccessful because the storm peak was unattainable by any attempted parameter set.

The second was to assume that above a certain size storm, the rain gages were unreliable and that any storm above a certain level should be increased across the board. This was somewhat consistent with the report of several gage stations were knocked offline during this 100 year storm. Several attempts were made, but they tended to make the rest of the simulation overestimate output and not increase the 1985 storm substantially.

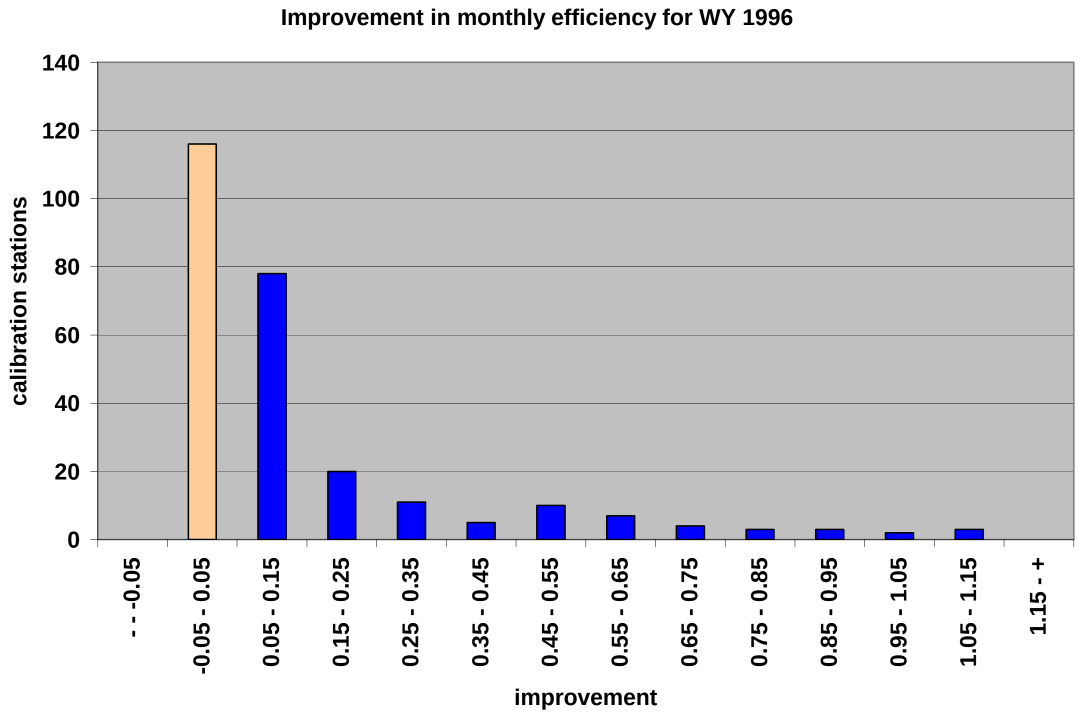


Figure 8-4. Flow model efficiency improvement from increased rainfall temperature.

The Modeling Subcommittee, in October 2004, decided that the storm was not well characterized in the rain gage information or the rainfall model and the rainfall was increased to provide the volume of water needed to improve calibration at flow monitoring stations.

8.8 Hydrology Calibration Results

As previously noted in this section, the hydrology calibration procedure is a method of automatically adjusting land hydrologic parameters using information from downstream river flow gages. The calibration runs for 10 iterations at which point the model is considered calibrated.

Figures 8-5, 8-6, and 8-7 above show the progress made in optimizing various calibration metrics over iterations. Figure 8-5 shows various statistics with an ideal value of 1.0. Those cover winter, summer, baseflow, stormflow, and recession indices. Generally they converge to within 5 percent of the ideal value. Figure 8-6 shows total bias and storm bias. Again, they converge to within 5 percent. Figure 8-7 shows different model efficiency measures. The efficiency of daily flows has a median value of greater than 0.6, while the efficiency of the logs is 0.7 and the efficiency of monthly flows nearly 0.85. It is important to note that the efficiency was not part of the objective function in calibration, yet the overall model statistic improves along with the calibrated statistic. It reaches its maximum value after approximately 5 iterations, implying that while the individual calibration statistics are still improving after 10 iterations, the overall agreement with data is not changing. Therefore, 10 iterations is a reasonable end point.

Many high biases and low efficiencies are associated with reaches with reservoirs and impoundments. Reservoirs and impoundments are difficult to simulate daily. Rather than using observed outflows or estimating outflows from observed parameters like surface elevation, the Phase 5.3 Model uses idealized operating rules to simulate outflows from reservoirs. This was done so the model could simulate management scenarios that changed flow rates.

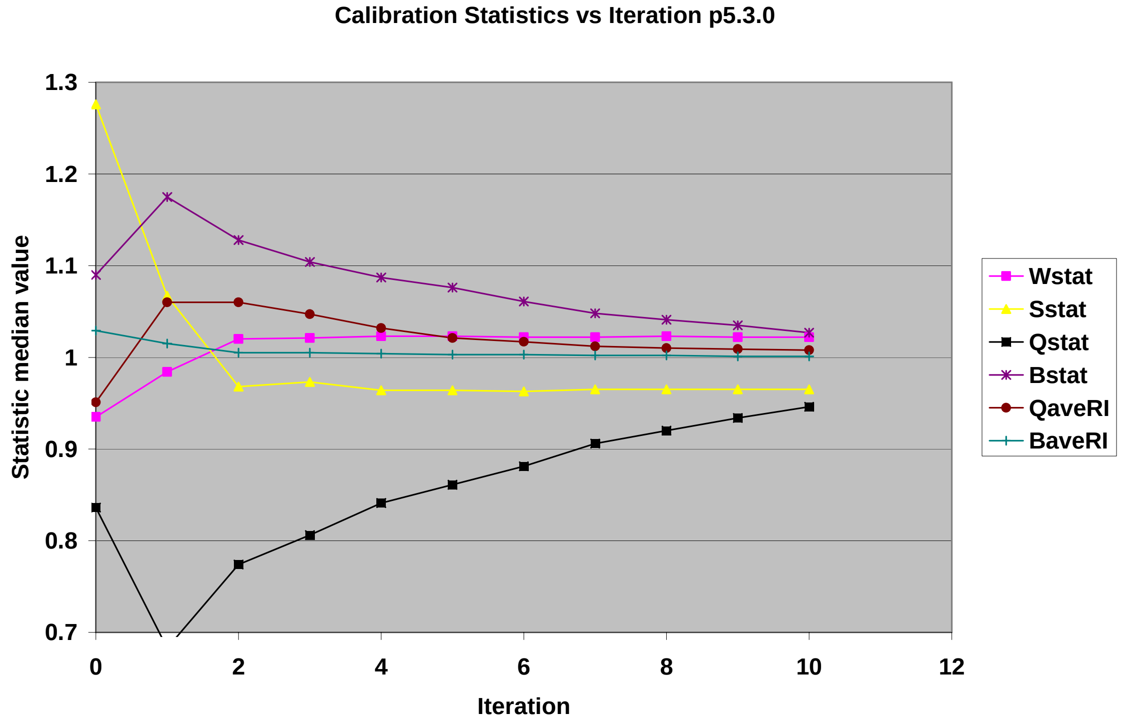


Figure 8-5. Calibration iterative improvement in calibration statistics. Ideal is 1.0.

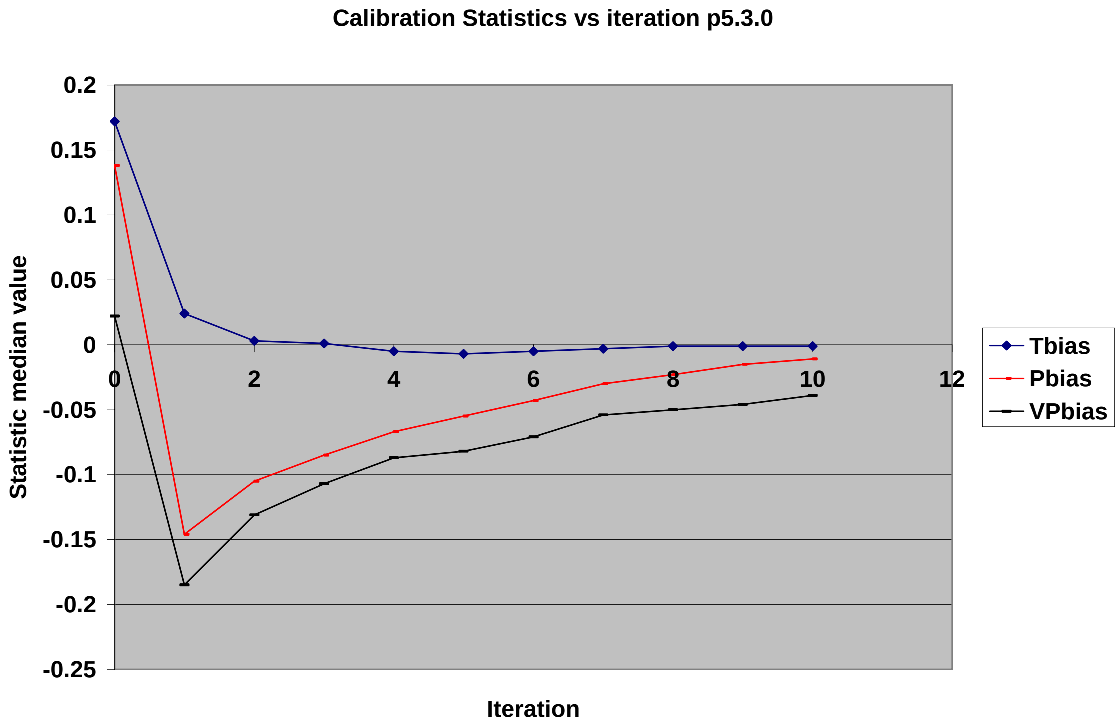


Figure 8-6. Iterative improvement in calibration statistics. Ideal is 0.

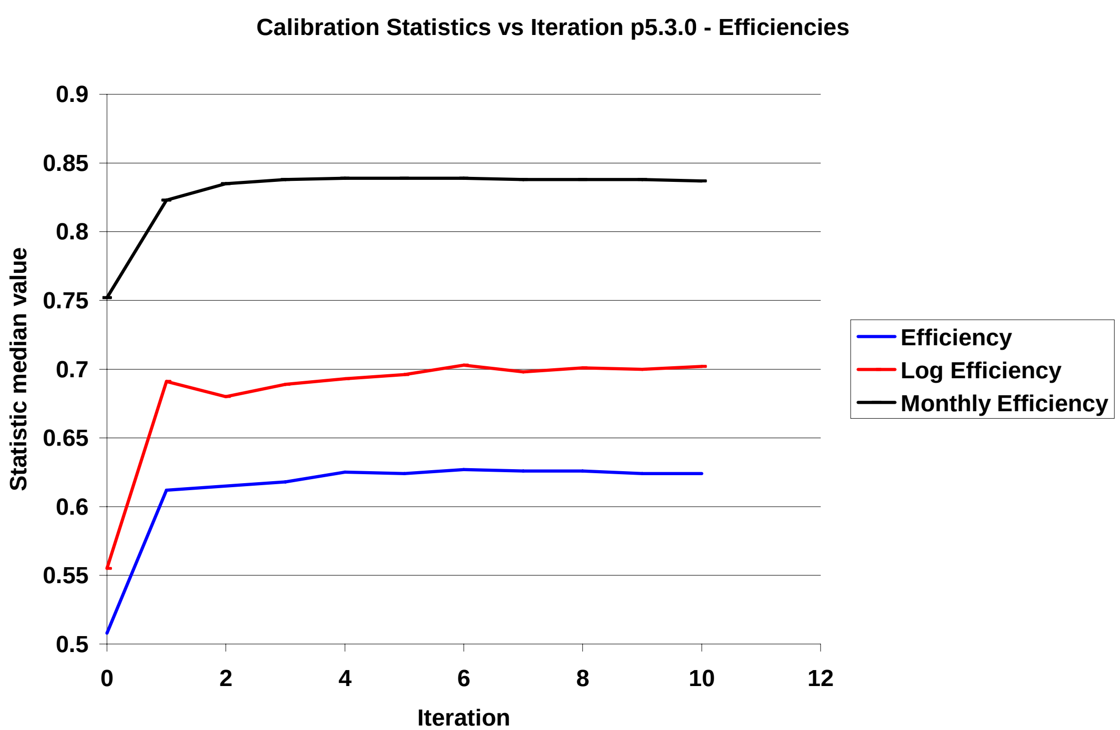


Figure 8-7. Iterative improvement in model efficiencies. Ideal is 1.0.

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Errata Revision February 24, 2011

Appendix A. Notes on Individual Reservoirs

BRAS – JA5_7480_0001 – Brasfield
(James River Basin; Appomattox River)

Brasfield Dam impounds Lake Chesdin on the Appomattox River in Chesterfield and Dinwiddie counties, Virginia. The gravity dam was completed in 1968 and is owned by STS Hydropower. The lake is managed primarily for water supply purposes.

(1) Notes indicate that the project was waiting on data from STS Hydropower at the time of the initial delivery (11/03/03) of reservoir FTABLEs to the Chesapeake Bay Program (CBP). The notes also indicate that no close proxies were available but that the FTABLE from Raystown (RAYS, SJ4_2360_2340) would be used temporarily.

(2) Project notes indicate that a simple (single) FTABLE was received on 12/16/03. The source of the data used to generate the table is unknown, but this does not appear to be a proxy table copied from another reservoir.

BRIG – XU2_4070_4330 – Brighton
(Patuxent River Basin; above Bowie, Maryland)

Brighton Dam impounds Tridelphia Reservoir on the Patuxent River in Montgomery County, Maryland. It is a buttress dam completed in 1943 and owned by Alternative Energy Associates, Ltd. The reservoir is managed for hydroelectric power generation and water supply.

(1) Project notes indicate that no contacts and no data were available for this reservoir as of 11/03/03 and suggest a size-based proxy could be used for the FTABLE.

(2) Later, updated note indicates that the FTABLE from Western Branch (WBRA, JB2_7800_0001) should be used as a proxy for Brighton.

(3) An e-mail from 7/21/04 indicates that stage/discharge data had been acquired for Brighton from the dam operator, but files containing the data have not been found.

(4) The FTABLE in the CBP files used in the model (1/18/07) has clearly been modified from the East Sydney (ESYD, SU2_0292_0320) FTABLE, with one season added. The Brighton FTABLE now has three seasons with transition periods.

BUSH – SW3_1130_1390 – Alvin R. Bush
(Susquehanna River Basin; West Branch Susquehanna River)

Alvin R. Bush Dam impounds Kettle Creek Lake on Kettle Creek in Clinton County, Pennsylvania. It is an earth dam completed in 1962 and operated by the Baltimore District of the U.S. Army Corps of Engineers. The reservoir is managed for flood control and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

CLAY – NR6_8500_7820 – Claytor
(New River Basin)

Claytor Lake is impounded by a dam on the New River in Pulaski County, Virginia. The concrete gravity dam was completed in 1939 and is owned and operated by Appalachian Power Company. The reservoir is managed for hydroelectric power generation, water supply, and recreation.

(1) Project notes on 11/03/03 indicate this is a large reservoir outside the Bay watershed in Virginia and its owner/operator, Appalachian Power Co., had been contacted at that time, but no data were yet available.

(2) Project notes indicate that a simple (single) FTABLE was received on 12/16/03. The source of the data used to generate the table is unknown, but it does not appear to be a proxy table copied from another reservoir. Other notes and conversations indicate that data had been received from reservoir/dam operators, and this FTABLE was probably generated from those data.

(3) An internal e-mail on 12/16/03 indicates that the FTABLE used at that time contained a single, simple stage-discharge relationship.

(4) The final FTABLEs used had two seasonally variable stage-discharge relationships with a transition period between them.

CONO – SL9_2720_0001 – Conowingo
(Susquehanna River Basin; Lower Susquehanna River below West Branch confluence, not including the Juniata River)

Conowingo Lake is impounded by a dam on the Susquehanna River in Harford County, Maryland. The concrete gravity dam was completed in 1928 and is owned and operated by Susquehanna Power Company and Philadelphia Electric Company. The reservoir is managed for hydroelectric power generation, water supply, and recreation.

(1) FTABLE was not developed by Virginia Water Science Center for this terminal Susquehanna dam/reservoir. It was prepared and calibrated by the U.S. Environmental Protection Agency (EPA) CBP staff using a simple stage-discharge relationship.

COWA – SU2_0741_0690 – Cowanesque
(Susquehanna River Basin; Upper Susquehanna River, above the confluence with West Branch)

Cowanesque Lake is impounded by a dam on the Cowanesque River in Tioga County, Pennsylvania. The earth and rockfill dam was completed in 1980 and is operated by the Baltimore District of the U.S. Army Corps of Engineers. The reservoir is managed for flood control and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship developed from data acquired from dam/reservoir managers.

CURW – SW4_1860_1720 – Curwensville
(Susquehanna River; West Branch Susquehanna River)

Curwensville Lake is impounded by a dam on the West Branch of the Susquehanna River in Clearfield County, Pennsylvania. The earth dam was completed in 1965 and is operated by the Baltimore District of the U.S. Army Corps of Engineers. The reservoir is managed for flood control and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship developed from data acquired from dam/reservoir managers.

DEEP – GY0_4240_3951 – Deep Creek
(Youghiogheny River Basin)

The Deep Creek Reservoir is impounded by a dam on Deep Creek in Garrett County, Maryland. The earth dam was completed in 1925 and is owned and operated by the Pennsylvania Electric Company. The reservoir is managed for hydroelectric power generation and recreation.

(1) Project notes indicate that contacts and FTABLE data were not available for this reservoir in western Maryland outside the Bay watershed. Pennsylvania Electric is mentioned as a possible contact.

(2) In a later, undated note, the simple, standard FTABLE from Swift Creek (SWIF, JA0_7291_7290) was suggested as a size-based proxy.

(3) The FTABLE in use in the model (1/18/07) is an exact copy of the Swift Creek (SWIF, JA0_7291_7290) FTABLE which is a simple stage-discharge relationship.

ELLI – PL0_5141_5140 – T. Nelson Elliott
(Potomac River Basin; Lower Potomac River below Chain Bridge)

Broad Run Reservoir is impounded by the T. Nelson Elliott Dam on Broad Run (Occoquan River) in Prince William County, Virginia. The gravity dam was completed in 1968 and is operated by the city of Manassas. The reservoir is managed for hydroelectric power generation and water supply.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

ESYD – SU2_0291_0320 – East Sidney
(Susquehanna River Basin; Upper Susquehanna River above confluence with West Branch)

The East Sydney Dam impounds a reservoir on Ouleout Creek in Otsego County, New York. The earth gravity dam was completed in 1950 and is operated by the Baltimore District of the U.S. Army Corps of Engineers. The reservoir is managed for flood control and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. Two season FTABLEs with transition periods were developed from data acquired from dam/reservoir managers.

FLAN – BS4_8540_8441 – John W. Flannagan
(Big Sandy River Basin)

The John W. Flannagan Dam impounds a reservoir on the Pound River in Dickenson County, Virginia. The earth dam was completed in 1963 and is operated by the Huntington West Virginia District of the U.S. Army Corps of Engineers. The reservoir is managed for flood control, recreation, water supply, and fish and wildlife.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. Two season FTABLEs with transition periods were developed from data acquired from dam/reservoir managers.

GATH – JU3_6900_6950 – Gathright
(James River Basin; Upper James River, above Maury confluence)

The Gathright Dam impounds Lake Moomaw on the Jackson River in Alleghany County, Virginia. The earth and rockfill dam was completed in 1978 and is operated by the Norfolk District of the U.S. Army Corps of Engineers. The reservoir is managed for flood control and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. The complex, seven-season FTABLE with transition periods between seasons was developed from data acquired from dam/reservoir managers.

HOLT – SL9_2700_2720 – Holtwood
(Susquehanna River Basin; Lower Susquehanna River below West Branch confluence, not including the Juniata River)

The Holtwood or McCalls Ferry Dam impounds a reservoir on the lower Susquehanna River in Lancaster County, Pennsylvania. The concrete gravity dam was completed in 1910 and is operated by the Pennsylvania Power and Light Corporation. The reservoir is managed for hydroelectric power generation and recreation.

(1) FTABLE was not developed by Virginia Water Science Center for this terminal Susquehanna dam/reservoir. It was prepared and calibrated by EPA CBP staff as a simple stage-discharge relationship.

HYCO – OD2_8920_8830 – Lake Hyco
(Roanoke River Basin, Dan River)

Lake Hyco is impounded by a dam on the Hyco River in Person County, North Carolina, in the Roanoke River watershed. The earth gravity dam was completed in 1963 and is operated by Carolina Power and Light. The lake is managed as a cooling reservoir for an electrical generation plant and for recreation.

(1) Project notes indicate that no contacts and no data are available for the reservoir as of 11/03/03.

(2) Later, undated note indicates that the FTABLE from Philpott (PHIL, OD2_8560_8630) should be used as a proxy for Hyco.

(3) The FTABLE in the CBP files used in the model (1/18/07) is a copy of the FTABLE from Jennings Randolph (RAND, PU3_4450_4440), with changes to the discharges and the timing of the transitions. The FTABLE now has three seasons, with a transition period between only one of the seasons.

KERR– OR7_8470_8490 – John H. Kerr
(Roanoke River Basin; not including the Dan River)

The John H. Kerr reservoir is impounded by a dam on the Roanoke River in Mecklenburg County, Virginia. The earth gravity dam was completed in 1953 and is operated by the Wilmington District of the U.S. Army Corps of Engineers. The reservoir is managed for water supply and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A two-season FTABLE with transition periods between seasons was developed from data acquired from dam/reservoir managers.

LEES – OR4_8271_8120 – Leesville
(Roanoke River Basin; not including the Dan River)

The Leesville Dam impounds a reservoir on the Roanoke River in Campbell and Pittsylvania counties, Virginia. The concrete gravity dam was completed in 1963 and is owned and operated by Appalachian Power Company. The reservoir is managed for hydroelectric power generation.

(1) Project notes on 11/03/03 indicate the importance of the large reservoir outside the Bay watershed in Virginia. Owner/operator Appalachian Power Co. had been contacted at that time, but no data were yet available. Notes suggested the use of the FTABLE from Raystown (RAYS, SJ4_2360_2340) as a proxy for both the Leesville and Smith Mountain reservoirs.

(2) Project notes indicate that a simple (single) FTABLE was received on 12/16/03. The source of the data used to generate the table is unknown, but it does not appear to be a proxy table copied from another reservoir. Other notes and conversations indicate that the FTABLE was probably generated from data received from the reservoir operators.

(3) On the basis of project notes and e-mails, the FTABLE in use in the model (1/18/07) is a combined FTABLE developed from data for the Leesville and Smith Mountain reservoirs. Thus, a new unique reach code has been assigned. According to a 12/29/03 e-mail from Alan Simpson to the CBP, a fixed volume and area representing the Smith Mountain reservoir was added to the Leesville areas and volumes. The Leesville stage/discharge relationship was used. The same e-mail indicates that the new OR4_8271_8120 reach combines three former reach segments: Leesville (8270), Smith Mountain (7940), and an uncalibrated portion of the Pig River (8390) between Leesville and the next upstream gage. This is a simple FTABLE with no seasonal changes.

LIBE – WM0_3881_3880 – Liberty
(Western Shore of Chesapeake Bay; Middle Western Shore, including the Patapsco and Back rivers)

Liberty Reservoir is impounded by a dam on the North Branch of the Patapsco River in Baltimore County, Maryland. The gravity dam was completed in 1953 and is owned and operated by the Baltimore City Department of Public Works. The reservoir is managed for water supply and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

LOCH – WU3_3480_3481 – Loch Raven
(Western Shore of Chesapeake Bay; Upper Western Shore)

Lock Raven Reservoir is impounded by a dam on the Gunpowder River in Baltimore County, Maryland. The gravity dam was completed in 1923 and is owned and operated by the Baltimore City Department of Public Works. The reservoir is managed for water supply and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

MARB – SL0_2831_2830 – Lake Marburg
(Susquehanna River Basin; Lower Susquehanna River below West Branch confluence, not including the Juniata River)

Lake Marburg is impounded by a dam on the West Branch of Codorus Creek in York County, Pennsylvania. The earth dam was completed in 1967 and is owned and operated by the P.H. Glatfelter Company. The reservoir is managed for water supply and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

MEAD – JB1_8090_0001 – Lake Mead
(James River Basin; James River below Richmond, not including the Appomattox River)

Lake Mead is impounded by a dam on the Nansemond River in Suffolk City, Virginia. The gravity dam was completed in 1959 and is owned and operated by the city of Portsmouth Department of Utilities. The reservoir is managed for water supply.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

NANN – YP2_6390_6330 – North Anna
(York River Basin; Pamunkey River)

Lake Anna is impounded by a dam on the North Anna River in Spotsylvania County, Virginia. The earth gravity dam was completed in 1972 and is owned and operated by the Virginia Dominion Power Company. The reservoir is managed hydroelectric power generation, flood control, and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.
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OTSE – SU2_0030_0140 – Otsego Lake
(Susquehanna River Basin; Upper Susquehanna River, above confluence with West Branch)

Otsego Lake is impounded by a dam on the Susquehanna River in Otsego County, New York. The buttress dam was completed in 1900 and is owned and operated by the village of Cooperstown, New York. The reservoir is managed for water supply and recreation.

(1) Project notes on 11/03/03 identify the reservoir owner as the city of Cooperstown, New York, but state that no contacts had been made.

(2) A later project note suggests that the FTABLE from East Sydney (ESYD, SU2_0292_0320) should be used as a proxy for the Otsego FTABLE.

(3) E-mails from January 2004 indicate contact with a researcher at the State University of New York at Oneonta who had data on the hydrology of Otsego Lake. Conversations with Alan Simpson in February 2007 revealed that Alan had worked with data from Otsego to generate an FTABLE.

(4) The FTABLE for Ostego in CBP model files (01/17/07) is an exact copy of the East Sydney FTABLE. It has two seasonal stage/discharge relationships with a transition period between them.

PHIL – OD2_8560_8630 – Philpott
(Roanoke River Basin; Dan River)

Philpott Reservoir is impounded by a dam on the Smith River in Henry County, Virginia. The gravity dam was completed in 1953 and is operated by the Wilmington District of the U.S. Army Corps of Engineers. The reservoir is managed for hydroelectric power generation, recreation, water supply, and fish and wildlife.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. Developed from data acquired from dam/reservoir managers.

(2) This was originally described in project notes as a two-season FTABLE with short seasons and long transitional periods between the seasons. However, the FTABLE found in the CBP files on 1/18/07 describes two stage-discharge relationships, with the first in effect on weekdays and the second in effect on weekends.

PRET – WU0_3021_3020 – Prettyboy
(Western Shore of Chesapeake Bay; Upper Western Shore)

Prettyboy Reservoir is impounded by a dam on the Gunpowder River in Baltimore County, Maryland. The gravity dam was completed in 1936 and is owned and operated by the Baltimore City Department of Public Works. The reservoir is managed for water supply and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

RAND– PU3_4450_4440 – Jennings Randolph
(Potomac River Basin; Upper Potomac River, above Shenandoah confluence)

Jennings Randolph Lake, also known as Bloomington Lake, is impounded by a dam on the North Branch of the Potomac River in Garrett County, Maryland, and Mineral County, West Virginia. The earth and rockfill dam was completed in 1981 and is operated by the Baltimore District of the U.S. Army Corps of Engineers. The reservoir is managed for flood control and stormwater management, water supply, and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. Developed from data acquired from dam/reservoir managers. It is a three-season FTABLE with transitional periods between two of the three seasons.

RAYS – SJ4_2360_2340 – Raystown
(Susquehanna River Basin; Juniata River)

Raystown Lake is impounded by a dam on the Raystown Branch of the Juniata River in Huntingdon County, Pennsylvania. The earth and rockfill dam was completed in 1973 and is operated by the Baltimore District of the U.S. Army Corps of Engineers. The reservoir is managed for flood control, stormwater management, and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. Developed from data acquired from dam/reservoir managers. It is a two-season FTABLE with transitional periods between the seasons.

ROCK – XU2_4330_4480 – Rocky Gorge
(Patuxent River Basin; Patuxent River above Bowie, Maryland)

Rocky Gorge Dam, also known as Duckett Dam, impounds a reservoir on the Patuxent River in Prince George's County, Maryland. The concrete buttress dam was completed in 1953 and is owned and operated by the Washington Suburban Sanitary Commission. The reservoir is managed for water supply and recreation.

(1) Notes indicate that the project had received data to create a single FTABLE at the time of the initial delivery (11/03/03) of reservoir FTABLEs to the CBP.

(2) A later, undated note indicates that the FTABLE from East Sydney (ESYD, SU2_0291_0320) would be used as a size-based proxy.

(3) The FTABLE in the CBP files used in the model (1/18/07) does not appear to be a proxy from any other reservoir, and was likely developed from reservoir data, but the source of that data is unknown. Simple stage-discharge relationship.

SAFE – SL9_2520_2700 – Safe Harbor
(Susquehanna River Basin; Lower Susquehanna River below West Branch confluence, not including the Juniata River)

Safe Harbor Dam impounds a reservoir on the Susquehanna River in Lancaster County, Pennsylvania. The gravity dam was completed in 1930 and is owned and operated by the Safe Harbor Water Power Commission. The reservoir is managed for hydroelectric power generation, recreation, and water supply.

(1) FTABLE was not developed by Virginia Water Science Center for this terminal Susquehanna dam/reservoir. It was prepared and calibrated by EPA CBP staff. Simple stage-discharge relationship.

SAVA – PU1_4190_4300 – Savage River
(Potomac River Basin; Upper Potomac River, above the Shenandoah confluence)

Savage River Dam impounds a reservoir on the Savage River in Garrett County, Maryland. The earth and rockfill dam was completed in 1952 and is owned and operated by the Upper Potomac River Commission. The reservoir is managed water supply, flood control, and stormwater management.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. Developed from data acquired from dam/reservoir managers. It is a two-season FTABLE with transitional periods between the seasons.

SAYE – SW3_1690_1660 – Foster Joseph Sayers
(Susquehanna River Basin; West Branch Susquehanna River)

Foster Joseph Sayers Dam impounds a reservoir on Bald Eagle Creek in Centre County, Pennsylvania. The earth dam was completed in 1969 and is operated by the Baltimore District of the U.S. Army Corps of Engineers. The reservoir is managed for flood control, stormwater management, and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. Developed from data acquired from dam/reservoir managers. Two separate FTABLE files appear to be in use by the CBP. Before July, 1994, this is modeled as a three-season FTABLE (SW3_1690_2222) with transitional periods between the seasons. After July, 1994, the reservoir is modeled with a two-season FTABLE (SW3_1690_1660), also with transitional periods.

SMIT – OR4_7940_8270 – Smith Mountain
(Roanoke River Basin; not including the Dan River)

Smith Mountain Lake is impounded by a dam on the Roanoke River in Bedford County, Virginia. The arch dam was completed in 1963 and is owned and operated by Appalachian Power Company. The reservoir is managed for hydroelectric power generation and recreation.

(1) Data from this reservoir was combined with that from the nearby Leesville reservoir to generate a single FTABLE representing the joint operations of both. Thus, there is no FTABLE with this reach code. For information on the development of the FTABLE, see notes on Leesville (LEES, OR4_8271_8120).

SRIV – JL2_6441_6520 – South Rivanna
(James River Basin; Lower James River, below the Maury River confluence, above Richmond, Virginia)

The South Rivanna Reservoir is impounded by a dam on the South Fork of the Rivanna River in Albemarle County, Virginia. The gravity dam was completed in 1966 and is owned and operated by the Rivanna Water and Sewer Authority. The reservoir is managed for water supply and hydroelectric power generation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

STEV – SW3_1091_1380 – George B. Stevenson
(Susquehanna River Basin; West Branch Susquehanna River)

George B. Stevenson Reservoir is impounded by a dam on First Fork of Sinnemahoning Creek in Cameron County, Pennsylvania. The earth dam was completed in 1956 and is owned and operated by the Pennsylvania Department of Natural Resources Bureau of State Parks. The reservoir is managed for flood control, stormwater management, and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

STON – PU1_4840_4760 – Stony River
(Potomac River Basin; Upper Potomac River, above the Shenandoah confluence)

The Stony River Dam and Mt. Storm Power Station Dams impound two reservoirs near each other on the Stony River in Grant County, West Virginia. The upstream Stony River Reservoir is owned by Westvaco and was used to control water flow for a paper pulp mill. The downstream Mt. Storm Lake is owned and operated by Dominion Energy as cooling water for a coal-fired power-generation facility. The reservoirs are simulated together for the watershed model.

(1) Notes indicate that no contacts and no data were available for the reservoir at the time of the initial delivery (11/03/03) of reservoir FTABLEs to the CBP. They suggest developing a size-based proxy.

(2) A later, undated note indicates that the FTABLE from Swift Creek (SWIF, JAO_7291_7290) would be used as a size-based proxy.

(3) The FTABLE in the CBP files used in the model (1/18/07) is an exact copy of the Swift Creek (SWIF, JAO_7291_7290) FTABLE. It is based on a simple stage-discharge relationship.

SWIF – JA0_7291_7290 – Swift Creek
(James River Basin; Appomattox River)

Swift Creek Reservoir is impounded by a dam on Swift Creek in Chesterfield County, Virginia. The earth dam was completed in 1965 and is owned and operated by Chesterfield County. The reservoir is managed for water supply and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

TIOG – SU3_0831_0790 – Tioga
(Susquehanna River Basin; Upper Susquehanna River, above the confluence with West Branch)

Tioga Lake is impounded by a dam on the Tioga River in Tioga County, Pennsylvania. The earth and rock-fill dam was completed in 1979 and is operated by the Baltimore District of the U.S. Army Corps of Engineers. The reservoir is managed for flood control, stormwater management, and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. Developed from data acquired from dam/reservoir managers. The FTABLE resulted from the combination of the joined Tioga and Hammond reservoirs, which are operated together.

UOCC– PL0_5250_0001 – Upper Occoquan
(Potomac River Basin; Lower Potomac River, below Chain Bridge)

The Occoquan Reservoir is impounded by a dam on the Occoquan River in Fairfax County, Virginia. The dam was completed in 1976 and is owned and operated by the Upper Occoquan Sewage Authority.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

WARR – SJ4_2060_2010 – Warrior Ridge
(Susquehanna River Basin; Juniata River)

Warrior Ridge Dam impounds a reservoir on the Juniata River in Huntingdon County, Pennsylvania. The buttress dam was completed in 1906 and is owned and operated by the American Hydro Power Partners. The reservoir is managed for hydroelectric power generation.

(1) Notes indicate that the project was waiting on data from American Hydropower at the time of the initial delivery (11/03/03) of reservoir FTABLEs to the CBP.

(2) A later, undated note indicates that no close proxies were available but that the FTABLE from Raystown (RAYS, SJ4_2360_2340) would be used temporarily.

(3) The FTABLE in the CBP files used in the model (1/18/07) has been slightly modified from the Raystown (RAYS, SJ4_2360_2340) FTABLE. Like the Raystown FTABLE, it has two seasons with no transition period.

WBRA – JB2_7800_0001 – Western Branch
(James River Basin; James River below Richmond, not including the Appomattox River)

Western Branch Reservoir is impounded by a dam the Western Branch of the Nansemond River in Suffolk City, Virginia. The earth dam was completed in 1963 and is owned and operated by the city of Norfolk Department of Utilities. The reservoir is managed for water supply and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

WHIT – SU3_0240_0350 – Whitney Point
(Susquehanna River Basin; Upper Susquehanna River, above the confluence with West Branch)

Whitney Point dam impounds a reservoir on the Otselic River in Broome County, New York. The earth dam was completed in 1942 and is operated by the Baltimore District of the U.S. Army Corps of Engineers. The reservoir is managed for flood control, stormwater management, and recreation.

(1) FTABLE delivered from Virginia Water Science Center to CBP on 11/03/03. A simple stage-discharge relationship was developed from data acquired from dam/reservoir managers.

Appendix B. USGS Stations Used in the Hydrology Calibration of Phase 5.3.0

River Segment	Station ID	Station Name
BS1_8730_8540	03208950	CRANES NEST RIVER NEAR CLINTWOOD, VA
BS3_8350_8330	03207800	LEVISA FORK AT BIG ROCK, VA
BS4_8440_0003	03208500	RUSSELL FORK AT HAYSI, VA
BS4_8540_8441	03209000	POUND RIVER BELOW FLANNAGAN DAM NEAR HAYSI, VA
DE0_3791_0001	01483700	ST JONES RIVER AT DOVER, DE
DE0_4231_0001	01484100	BEAVERDAM BRANCH AT HOUSTON, DE
EL0_4562_0003	01487000	NANTICOKE RIVER NEAR BRIDGEVILLE, DE
EL1_5430_0001	01485500	NASSAWANGO CREEK NEAR SNOW HILL, MD
EL2_4400_4590	01488500	MARSHYHOPE CREEK NEAR ADAMSVILLE, DE
EL2_5110_5270	01485000	POCOMOKE RIVER NEAR WILLARDS, MD
EM2_3980_0001	01491000	CHOPTANK RIVER NEAR GREENSBORO, MD
EU0_3830_0001	01493000	UNICORN BRANCH NEAR MILLINGTON, MD
EU1_2650_0001	01495000	BIG ELK CREEK AT ELK MILLS, MD
GY0_3800_3801	03078000	CASSELMAN RIVER AT GRANTSVILLE, MD
GY0_3950_3952	03076600	BEAR CREEK AT FRIENDSVILLE, MD
GY0_3951_3952	03076500	YOUGHIOGHENY RIVER AT FRIENDSVILLE, MD
GY0_4532_0003	03075500	YOUGHIOGHENY RIVER NEAR OAKLAND, MD
JA1_7600_7570	02041000	DEEP CREEK NEAR MANNBORO, VA
JA2_7550_7280	02039500	APPOMATTOX RIVER AT FARMVILLE, VA
JA4_7280_7340	02040000	APPOMATTOX RIVER AT MATTOAX, VA
JA5_7480_0001	02041650	APPOMATTOX RIVER AT MATOACA, VA
JB3_6820_7053	02042500	CHICKAHOMINY RIVER NEAR PROVIDENCE FORGE, VA
JL1_6560_6440	02031000	MECHUMS RIVER NEAR WHITE HALL, VA
JL1_6760_6910	02030000	HARDWARE RIVER BL BRIERY RUN NR SCOTTSVILLE, VA
JL1_6770_6850	02028500	ROCKFISH RIVER NEAR GREENFIELD, VA
JL1_6940_7200	02027000	TYE RIVER NEAR LOVINGSTON, VA
JL1_7080_7190	02027500	PINEY RIVER AT PINEY RIVER, VA
JL2_6240_6520	02032680	N F RIVANNA RIVER NEAR PROFFIT, VA
JL2_6441_6520	02032515	S F RIVANNA RIVER NEAR CHARLOTTESVILLE, VA
JL2_7110_7120	02030500	SLATE RIVER NEAR ARVONIA, VA
JL2_7240_7350	02027800	BUFFALO RIVER NEAR TYE RIVER, VA
JL4_6520_6710	02034000	RIVANNA RIVER AT PALMYRA, VA
JL6_6890_6990	02029000	JAMES RIVER AT SCOTTSVILLE, VA
JL6_7160_7440	02025500	JAMES RIVER AT HOLCOMB ROCK, VA
JL6_7430_7320	02026000	JAMES RIVER AT BENT CREEK, VA
JL7_6800_7070	02037000	JAMES RIVER AND KANAWHA CANAL NEAR RICHMOND, VA
JL7_7100_7030	02035000	JAMES RIVER AT CARTERSVILLE, VA
JU1_6290_6590	02011460	BACK CREEK NEAR SUNRISE, VA
JU1_6300_6650	02015700	BULLPASTURE RIVER AT WILLIAMSVILLE, VA
JU1_6590_6600	02011470	BACK CREEK AT SUNRISE, VA
JU1_7630_7490	02017500	JOHNS CREEK AT NEW CASTLE, VA
JU1_7750_7560	02018500	CATAWBA CREEK NEAR CATAWBA, VA
JU2_6410_6640	02020500	CALFPASTURE RIVER ABOVE MILL CREEK AT GOSHEN, VA
JU2_6600_6810	02011500	BACK CREEK NEAR MOUNTAIN GROVE, VA
JU2_7140_7330	02013000	DUNLAP CREEK NEAR COVINGTON, VA

River Segment	Station ID	Station Name
JU2_7450_7360	02014000	POTTS CREEK NEAR COVINGTON, VA
JU3_6380_6900	02011400	JACKSON RIVER NEAR BACOVA, VA
JU3_6640_6790	02021500	MAURY RIVER AT ROCKBRIDGE BATHS, VA
JU3_6650_7300	02016000	COWPASTURE RIVER NEAR CLIFTON FORGE, VA
JU3_6900_6950	02011800	JACKSON RIVER BL GATHRIGHT DAM NR HOT SPGS, VA
JU3_7490_7400	02018000	CRAIG CREEK AT PARR, VA
JU4_7260_0003	02024000	MAURY RIVER NEAR BUENA VISTA, VA
JU4_7330_0003	02013100	JACKSON RIVER BL DUNLAP CREEK AT COVINGTON, VA
JU5_7300_0003	02016500	JAMES RIVER AT LICK RUN, VA
JU5_7500_7420	02019500	JAMES RIVER AT BUCHANAN, VA
MN0_8300_0001	02043500	CYPRESS SWAMP AT CYPRESS CHAPEL, VA
MN1_7990_8100	02051000	NORTH MEHERRIN RIVER NEAR LUNENBURG, VA
MN2_7720_7830	02046000	STONY CREEK NEAR DINWIDDIE, VA
MN2_8530_8510	02052500	FOUNTAINS CREEK NEAR BRINK, VA
MN3_7540_7680	02047500	BLACKWATER RIVER NEAR DENDRON, VA
MN3_7770_7930	02044500	NOTTOWAY RIVER NEAR RAWLINGS, VA
MN3_7930_8010	02045500	NOTTOWAY RIVER NEAR STONY CREEK, VA
MN3_8190_8260	02051500	MEHERRIN RIVER NEARLAWRENCEVILLE, VA
MN4_8080_8110	02049500	BLACKWATER RIVER NEAR FRANKLIN, VA
MN4_8260_8400	02052000	MEHERRIN RIVER AT EMPORIA, VA
MN5_8161_0003	02047000	NOTTOWAY RIVER NEAR SEBRELL, VA
NR2_8210_8180	03175500	WOLF CREEK NEAR NARROWS, VA
NR2_8600_8700	03167000	REED CREEK AT GRAHAMS FORGE, VA
NR3_8290_8170	03173000	WALKER CREEK AT BANE, VA
NR3_8420_8430	03170000	LITTLE RIVER AT GRAYSONTOWN, VA
NR3_8690_8500	03167500	BIG REED ISLAND CREEK NEAR ALLISONIA, VA
NR3_9310_9240	03161000	SOUTH FORK NEW RIVER NEAR JEFFERSON, NC
NR5_8870_0003	03164000	NEW RIVER NEAR GALAX, VA
NR6_7820_0003	03171000	NEW RIVER AT RADFORD, VA
NR6_8051_8000	03176500	NEW RIVER AT GLEN LYN, VA
NR6_8500_0003	03168000	NEW RIVER AT ALLISONIA, VA
OD1_8910_8930	02069700	SOUTH MAYO RIVER NEAR NETTLERIDGE, VA
OD2_8560_8630	02072000	SMITH RIVER NEAR PHILPOTT, VA
OD2_8670_8890	02074500	SANDY RIVER NEAR DANVILLE, VA
OD2_8830_8710	02077500	HYCO RIVER NEAR DENNISTON, VA
OD2_8840_9020	02068500	DAN RIVER NEAR FRANCISCO, NC
OD2_8920_8830	02077303	HYCO R BL ABAY D NR MCGEHEES MILL, NC
OD3_8340_8520	02077000	BANISTER RIVER AT HALIFAX, VA
OD3_8630_8720	02072500	SMITH RIVER AT BASSETT, VA
OD3_8720_8900	02074000	SMITH RIVER AT EDEN, NC
OD3_8850_8931	02070000	NORTH MAYO RIVER NEAR SPENCER, VA
OD4_9140_8990	02071000	DAN RIVER NEAR WENTWORTH, NC
OD5_8770_0003	02075000	DAN RIVER AT DANVILLE, VA
OD5_8780_8660	02075500	DAN RIVER AT PACES, VA
OR1_7700_7980	02065500	CUB CREEK AT PHENIX, VA
OR1_8280_8020	02053800	S F ROANOKE RIVER NEAR SHAWSVILLE, VA
OR1_8320_8271	02056900	BLACKWATER RIVER NEAR ROCKY MOUNT, VA
OR2_7610_7780	02061500	BIG OTTER RIVER NEAR EVINGTON, VA
OR2_7650_8070	02059500	GOOSE CREEK NEAR HUDDLESTON, VA

River Segment	Station ID	Station Name
OR2_7670_7840	02064000	FALLING RIVER NEAR NARUNA, VA
OR2_7900_7740	02055000	ROANOKE RIVER AT ROANOKE, VA
OR2_8020_8130	02054500	ROANOKE RIVER AT LAFAYETTE, VA
OR2_8130_7900	02054530	ROANOKE RIVER AT GLENVAR, VA
OR2_8460_8271	02058400	PIGG RIVER NEAR SANDY LEVEL, VA
OR3_7740_8271	02056000	ROANOKE RIVER AT NIAGARA, VA
OR4_8120_7890	02060500	ROANOKE RIVER AT ALTAVISTA, VA
OR5_7890_7970	02062500	ROANOKE (STAUNTON) RIVER AT BROOKNEAL, VA
OR5_8200_8370	02066000	ROANOKE (STAUNTON) RIVER AT RANDOLPH, VA
PL0_4510_0001	01651000	NW BRANCH ANACOSTIA RIVER NEAR HYATTSVILLE, MD
PL0_5000_0001	01653000	CAMERON RUN AT ALEXANDRIA, VA
PL0_5010_5130	01654000	ACCOTINK CREEK NEAR ANNANDALE, VA
PL0_5070_0001	01653600	PISCATAWAY CREEK AT PISCATAWAY, MD
PL0_5540_5490	01658500	S F QUANTICO CREEK NEAR INDEPENDENT HILL, VA
PL0_5730_5690	01660400	AQUIA CREEK NEAR GARRISONVILLE, VA
PL0_5750_0001	01661050	ST CLEMENT CREEK NEAR CLEMENTS, MD
PL1_4460_4780	01648000	ROCK CREEK AT SHERRILL DRIVE WASHINGTON, DC
PL1_4540_0001	01649500	NORTH EAST BRANCH ANACOSTIA RIVER AT RIVERDALE, MD
PL1_5230_0001	01658000	MATTAWOMAN CREEK NEAR POMONKEY, MD
PL1_5370_5470	01656000	CEDAR RUN NEAR CATLETT, VA
PL1_5910_0001	01661500	ST MARYS RIVER AT GREAT MILLS, MD
PL2_5300_5630	01660920	ZEKIAH SWAMP RUN NEAR NEWTOWN, MD
PM1_3120_3400	01639500	BIG PIPE CREEK AT BRUCEVILLE, MD
PM1_3510_4000	01637500	CATOCTIN CREEK NEAR MIDDLETOWN, MD
PM1_4250_4500	01645000	SENECA CREEK AT DAWSONVILLE, MD
PM1_4430_4200	01638480	CATOCTIN CREEK AT TAYLORSTOWN, VA
PM2_2860_3040	01639000	MONOCACY RIVER AT BRIDGEPORT, MD
PM2_4860_4670	01643700	GOOSE CREEK NEAR MIDDLEBURG, VA
PM3_4670_4660	01644000	GOOSE CREEK NEAR LEESBURG, VA
PM4_4040_0003	01643000	MONOCACY RIVER AT JUG BRIDGE NEAR FREDERICK, MD
PM7_4200_0003	01638500	POTOMAC RIVER AT POINT OF ROCKS, MD
PM7_4820_0001	01646500	POTOMAC RIVER NEAR WASH, DC LITTLE FALLS PUMP STA
PS0_6150_6160	01621410	BLACKS RUN AT RT 726 AT HARRISONBURG, VA
PS1_4790_4830	01634500	CEDAR CREEK NEAR WINCHESTER, VA
PS2_5550_5560	01632000	N F SHENANDOAH RIVER AT COOTES STORE, VA
PS2_5560_5100	01633000	N F SHENANDOAH RIVER AT MOUNT JACKSON, VA
PS2_6490_6420	01627500	SOUTH RIVER AT HARRISTON, VA
PS2_6660_6490	01626850	SOUTH RIVER NEAR DOOMS, VA
PS2_6730_6660	01626000	SOUTH RIVER NEAR WAYNESBORO, VA
PS3_5100_5080	01634000	N F SHENANDOAH RIVER NEAR STRASBURG, VA
PS3_6161_6280	01622000	NORTH RIVER NEAR BURKETOWN, VA
PS3_6460_6230	01625000	MIDDLE RIVER NEAR GROTTOES, VA
PS4_5840_5240	01629500	S F SHENANDOAH RIVER NEAR LURAY, VA
PS4_6360_5840	01628500	S F SHENANDOAH RIVER NEAR LYNNWOOD, VA
PS5_4380_4370	01636500	SHENANDOAH RIVER AT MILLVILLE, WV
PS5_5240_5200	01631000	S F SHENANDOAH RIVER AT FRONT ROYAL, VA
PU0_6080_5620	01605500	SOUTH BRANCH POTOMAC RIVER AT FRANKLIN, WV
PU1_3100_3690	01610155	SIDELING HILL CREEK NEAR BELLEGROVE, MD
PU1_3850_4190	01596500	SAVAGE RIVER NEAR BARTON, MD

River Segment	Station ID	Station Name
PU1_4190_4300	01597500	SAVAGE RIV BL SAVAGE RIV DAM NEAR BLOOMINGTON, MD
PU1_4840_4760	01595200	STONY RIVER NEAR MOUNT STORM,WV
PU2_3090_4050	01619500	ANTIETAM CREEK NEAR SHARPSBURG, MD
PU2_4220_3900	01616500	OPEQUON CREEK NEAR MARTINSBURG, WV
PU2_4360_4160	01604500	PATTERSON CREEK NEAR HEADSVILLE, WV
PU2_4720_4750	01595000	NORTH BRANCH POTOMAC RIVER AT STEYER, MD
PU2_4730_4220	01615000	OPEQUON CREEK NEAR BERRYVILLE, VA
PU2_5190_4310	01608000	SO FK SOUTH BRANCH POTOMAC R NR MOOREFIELD, WV
PU2_6050_5190	01607500	SO FK SO BR POTOMAC R AT BRANDYWINE, WV
PU3_3290_3390	01614500	CONOCOCHEAGUE CREEK AT FAIRVIEW, MD
PU3_3680_3890	01601500	WILLS CREEK NEAR CUMBERLAND, MD
PU3_3860_3610	01611500	CACAPON RIVER NEAR GREAT CACAPON, WV
PU4_3890_3990	01603000	NORTH BRANCH POTOMAC RIVER NEAR CUMBERLAND, MD
PU4_4310_4210	01608500	SOUTH BRANCH POTOMAC RIVER NEAR SPRINGFIELD, WV
PU4_4440_0003	01598500	NORTH BRANCH POTOMAC RIVER AT LUKE, MD
PU4_5050_0003	01606500	SO. BRANCH POTOMAC RIVER NR PETERSBURG, WV
PU6_3610_3530	01613000	POTOMAC RIVER AT HANCOCK, MD
PU6_3752_4080	01618000	POTOMAC RIVER AT SHEPHERDSTOWN, WV
PU6_4020_3870	01610000	POTOMAC RIVER AT PAW PAW, WV
RL0_6540_0001	01669000	PISCATAWAY CREEK NEAR TAPPAHANNOCK, VA
RL1_6180_0001	01668500	CAT POINT CREEK NEAR MONTROSS, VA
RU2_5940_6200	01666500	ROBINSON RIVER NEAR LOCUST DALE, VA
RU2_6090_6220	01665500	RAPIDAN RIVER NEAR RUCKERSVILLE, VA
RU3_5610_0003	01663500	HAZEL RIVER AT RIXEYVILLE, VA
RU3_6170_6040	01667500	RAPIDAN RIVER NEAR CULPEPER, VA
RU4_5640_0003	01664000	RAPPAHANNOCK RIVER AT REMINGTON, VA
RU5_6030_0001	01668000	RAPPAHANNOCK RIVER NEAR FREDERICKSBURG, VA
SJ2_2530_2820	01560000	DUNNING CREEK AT BELDEN, PA
SJ2_2580_2500	01564500	AUGHWICK CREEK NEAR THREE SPRINGS, PA
SJ3_2040_1980	01558000	LITTLE JUNIATA RIVER AT SPRUCE CREEK, PA
SJ3_2250_2230	01556000	FRANKSTOWN BR JUNIATA RIVER AT WILLIAMSBURG, PA
SJ4_2060_2010	01559000	JUNIATA RIVER AT HUNTINGDON, PA
SJ4_2360_2340	01563200	RAYS BR JUNIATA R BLW RAYS DAM NR HUNTINGDON, PA.
SJ4_2660_2360	01562000	RAYSTOWN BRANCH JUNIATA RIVER AT SAXTON, PA
SJ5_2210_2320	01563500	JUNIATA RIVER AT MAPLETON DEPOT, PA
SJ6_2130_0003	01567000	JUNIATA RIVER AT NEWPORT, PA
SL0_2180_2220	01573160	QUITTAPAHILLA CREEK NEAR BELLEGROVE, PA
SL1_1730_1700	01554500	SHAMOKIN CREEK NEAR SHAMOKIN, PA
SL1_2390_2420	01576540	MILL CREEK AT ESHELMAN MILL ROAD NEAR LYNDON, PA
SL1_2770_2730	01575000	SOUTH BRANCH CODORUS CREEK NEAR YORK, PA
SL1_2830_2760	01574500	CODORUS CREEK AT SPRING GROVE, PA
SL2_1810_2030	01555500	EAST MAHANTANGO CREEK NEAR DALMATIA, PA
SL2_1850_1990	01572025	SWATARA CREEK NEAR PINE GROVE, PA
SL2_1990_2070	01572190	SWATARA CREEK NEAR INWOOD, PA
SL2_2910_3060	01580000	DEER CREEK AT ROCKS, MD
SL3_1710_1740	01555000	PENNS CREEK AT PENNS CREEK, PA
SL3_2290_2260	01568000	SHERMAN CREEK AT SHERMANS DALE, PA
SL3_2350_2470	01576500	CONESTOGA RIVER AT LANCASTER, PA
SL3_2400_2440	01571500	YELLOW BREECHES CREEK NEAR CAMP HILL, PA

River Segment	Station ID	Station Name
SL3_2420_2700	01576754	CONESTOGA RIVER AT CONESTOGA, PA
SL3_2460_2430	01574000	WEST CONEWAGO CREEK NEAR MANCHESTER, PA
SL3_2730_2550	01575500	CODORUS CREEK NEAR YORK, PA
SL4_2090_2100	01573000	SWATARA CREEK AT HARPER TAVERN, PA
SL4_2140_2240	01573560	SWATARA CREEK NEAR HERSHEY, PA
SL4_2370_2330	01570000	CONODOGUINET CREEK NEAR HOGESTOWN, PA
SL8_1760_1780	01554000	SUSQUEHANNA RIVER AT SUNBURY, PA
SL9_2270_0003	01570500	SUSQUEHANNA RIVER AT HARRISBURG, PA
SL9_2490_2520	01576000	SUSQUEHANNA RIVER AT MARIETTA, PA
SL9_2720_0001	01578310	SUSQUEHANNA RIVER AT CONOWINGO, MD
SU1_0080_0210	01502000	BUTTERNUT CREEK AT MORRIS NY
SU1_0820_0740	01518862	COWANESQUE RIVER AT WESTFIELD, PA
SU2_0110_0240	01510000	OTSELIC RIVER AT CINCINNATUS NY
SU2_0291_0320	01500000	OULEOUT CREEK AT EAST SIDNEY NY
SU2_0510_0570	01524500	CANISTEO R BELOW CANACADEA CR @ HORNELL NY
SU2_0670_0810	01534300	LACKAWANNA RIVER NEAR FOREST CITY, PA.
SU2_0741_0690	01520000	COWANESQUE RIVER NR LAWRENCEVILLE, PA
SU2_0900_0870	01532000	TOWANDA CREEK NEAR MONROETON, PA
SU2_0920_0830	01516350	TIOGA RIVER NEAR MANSFIELD, PA
SU3_0090_0170	01505000	CHENANGO RIVER AT SHERBURNE NY
SU3_0370_0490	01529500	COHOCTON RIVER NEAR CAMPBELL NY
SU3_0710_0910	01534000	TUNKHANNOCK CREEK NEAR TUNKHANNOCK, PA
SU3_0790_0770	01518700	TIOGA RIVER AT TIOGA JUNCTION, PA
SU3_0810_0970	01534500	LACKAWANNA RIVER AT ARCHBALD, PA.
SU3_0831_0790	01518000	TIOGA RIVER AT TIOGA, PA
SU3_0970_1120	01536000	LACKAWANNA RIVER AT OLD FORGE, PA.
SU3_1310_1280	01539000	FISHING CREEK NEAR BLOOMSBURG, PA.
SU4_0260_0003	01509000	TIOUGHNIOGA RIVER AT CORTLAND NY
SU4_0300_0310	01502500	UNADILLA RIVER AT ROCKDALE NY
SU4_0690_0650	01520500	TIOGA RIVER AT LINDLEY NY
SU5_0340_0310	01500500	SUSQUEHANNA RIVER AT UNADILLA NY
SU5_0420_0003	01512500	CHENANGO RIVER NEAR CHENANGO FORKS NY
SU5_0530_0003	01529950	CHEMUNG RIVER AT CORNING NY
SU5_0610_0600	01531000	CHEMUNG RIVER AT CHEMUNG NY
SU5_0650_0003	01526500	TIOGA RIVER NEAR ERWINS NY
SU6_0480_0520	01503000	SUSQUEHANNA RIVER AT CONKLIN NY
SU7_0720_0003	01515000	SUSQUEHANNA RIVER NEAR WAVERLY NY
SU7_0850_0730	01531500	SUSQUEHANNA RIVER AT TOWANDA, PA
SU7_0960_0003	01533400	SUSQUEHANNA RIVER AT MESHOPPEN, PA
SU7_1120_1140	01536500	SUSQUEHANNA RIVER AT WILKES-BARRE, PA
SU8_1610_1530	01540500	SUSQUEHANNA RIVER AT DANVILLE, PA
SW0_1520_1600	01547950	BEECH CREEK AT MONUMENT, PA
SW1_1180_1190	01552500	MUNCY CREEK NEAR SONESTOWN, PA
SW1_1450_1510	01553700	CHILLISQUAQUE CREEK AT WASHINGTONVILLE, PA
SW1_1830_1690	01547100	SPRING CREEK AT MILESBURG, PA
SW1_1890_1830	01546500	SPRING CREEK NEAR AXEMANN, PA.
SW1_1910_1890	01546400	SPRING CREEK AT HOUSERVILLE, PA
SW2_1100_1130	01544500	KETTLE CREEK AT CROSS FORK, PA
SW3_1040_1220	01550000	LYCOMING CREEK NEAR TROUT RUN, PA

River Segment	Station ID	Station Name
SW3_1091_1380	01544000	F FORK SINNEMAHONING CR NR SINNEMAHONING, PA
SW3_1130_1390	01545000	KETTLE CREEK NEAR WESTPORT, PA
SW3_1270_1370	01543000	DRIFTWOOD BR SINNEMAHONING CR AT STERLING RUN, PA
SW3_1580_0003	01548005	BALD EAGLE CREEK NEAR BEECH CREEK STATION, PA
SW3_1690_0003	01547200	BALD EAGLE CREEK BL SPRING CREEK AT MILESBURG, PA
SW3_1690_1660	01547500	BALD EAGLE CREEK AT BLANCHARD, PA
SW3_1870_1800	01541500	CLEARFIELD CREEK AT DIMELING, PA
SW3_1920_1750	01542000	MOSHANNON CREEK AT OSCEOLA MILLS, PA.
SW4_1110_1150	01548500	PINE CREEK AT CEDAR RUN, PA
SW4_1260_0003	01552000	LOYALSOCK CREEK AT LOYALSOCKVILLE, PA
SW4_1430_1490	01543500	SINNEMAHONING CREEK AT SINNEMAHONING, PA
SW4_1720_1650	01541303	WEST BRANCH SUSQUEHANNA RIVER AT HYDE, PA
SW4_1860_1720	01541200	WB SUSQUEHANNA RIVER NEAR CURWENSVILLE, PA
SW4_1940_1860	01541000	WEST BRANCH SUSQUEHANNA RIVER AT BOWER, PA
SW5_1350_0003	01549700	PINE CREEK BL L PINE CREEK NEAR WATERVILLE, PA
SW5_1540_0003	01542500	WB SUSQUEHANNA RIVER AT KARTHAUS, PA
SW6_1330_1230	01545500	WEST BRANCH SUSQUEHANNA RIVER AT RENOVO, PA
SW7_1320_0003	01551500	WB SUSQUEHANNA RIVER AT WILLIAMSPORT, PA
SW7_1640_0003	01553500	WEST BRANCH SUSQUEHANNA RIVER AT LEWISBURG, PA
TU2_8790_9070	03475000	M F HOLSTON RIVER NEAR MEADOWVIEW, VA
TU2_8950_9040	03471500	S F HOLSTON RIVER AT RIVERSIDE NR CHILHOWIE, VA
TU3_8650_8800	03488000	N F HOLSTON RIVER NEAR SALTVILLE, VA
TU3_9180_0003	03473000	S F HOLSTON RIVER NEAR DAMASCUS, VA
TU3_9230_9260	03531500	POWELL RIVER NEAR JONESVILLE, VA
TU4_8680_8810	03524000	CLINCH RIVER AT CLEVELAND, VA
TU5_9280_0003	03527000	CLINCH RIVER AT SPEERS FERRY, VA
WM1_3660_3910	01589300	GWYNNS FALLS AT VILLA NOVA, MD
WM3_3880_4060	01589000	PATAPSCO RIVER AT HOLLOFIELD, MD
WU1_3240_3331	01581700	WINTERS RUN NEAR BENSON, MD
WU1_3350_3490	01583500	WESTERN RUN AT WESTERN RUN, MD
WU2_3020_3320	01582500	GUNPOWDER FALLS AT GLENCOE, MD
XL0_5320_0001	01594670	HUNTING CREEK NEAR HUNTINGTOWN, MD
XL1_4690_0001	01594526	WESTERN BRANCH AT UPPER MARLBORO MD
XU0_4130_4070	01591000	PATUXENT RIVER NEAR UNITY, MD
XU2_4070_4330	01591610	PATUXENT RIVER BELOW BRIGHTON DAM NEAR BRIGHTON,MD
XU2_4270_0003	01594000	LITTLE PATUXENT RIVER AT SAVAGE, MD
XU2_4330_4480	01592500	PATUXENT R NR LAUREL, MD
XU3_4650_0001	01594440	PATUXENT RIVER NEAR BOWIE, MD
YM2_6120_6430	01674000	MATTAPONI RIVER NEAR BOWLING GREEN, VA
YM4_6620_0003	01674500	MATTAPONI RIVER NEAR BEULAHVILLE, VA
YP0_6860_6840	01673550	TOTOPOTOMOY CREEK NEAR STUDLEY, VA
YP1_6570_6680	01671100	LITTLE RIVER NEAR DOSWELL, VA
YP2_6390_6330	01670400	NORTH ANNA RIVER NEAR PARTLOW, VA
YP3_6330_6700	01671020	NORTH ANNA RIVER AT HART CORNER NEAR DOSWELL, VA
YP3_6470_6690	01672500	SOUTH ANNA RIVER NEAR ASHLAND, VA
YP4_6720_6750	01673000	PAMUNKEY RIVER NEAR HANOVER, VA