Benchmark Report for the EPA BASINS Decision Support Tool

The BASINS Decision Support Tool has been developed by the U.S. Environmental Protection Agency to simulate watershed pollution and to identify sources of nonpoint pollution.

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1.0 EXECUTIVE SUMMARY

NASA developed a partnership with the Environmental Protection Agency (EPA) to investigate the feasibility of using NASA data and data products to improve EPA's capability to model watershed nonpoint source pollution. The EPA is responsible for protecting various bodies of water in the U.S.. The primary guideline for EPA's mandate is the Clean Water Act of 1972 (Federal Water Pollution Control Act, 1972). One of the regulations spelled out in this Act is that EPA must track the Total Maximum Daily load (TMDL) for any watershed. In short, the TMDL defines the amount of pollution that can be carried by water before it is determined to be "polluted". The problem of nonpoint source pollution is a spatially and temporally complex issue. There are essentially two ways for EPA to do this: one is through in-stream measurements and sampling, and two, through modeling the streams response to storm runoff and pollution loadings. The first option would be prohibitively expensive and impractical for the entire U.S.. The modeling approach is the only practical solution. To do this, EPA developed the BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) (USEPA, 2001) decision support tool. The models in BASINS currently rely on point-based meteorological and pollution measurements. This study focused on HSPF, an hourly precipitation-runoff simulation model. Our premise is that by incorporating NASA remote-sensing data, many of the critical input variables to BASINS can be improved spatially. Using satellite gridded data and data products for model inputs might enhance BASINS output results, thereby leading to better decisions regarding water quality, leading to improved management of the nation's water resources.

Seven watersheds within the Chesapeake Bay drainage basin with different topographic and land cover/land use characteristics had been selected for this project. Each study watershed was chosen to represent specific topographic and land cover/land use characteristics. Taken in total, the sample of watersheds provided a wide range of soils, geology, land cover/land use and topography.

The most important conclusion from this study is that the NASA developed data assimilation precipitation products will result in improved model performance. Attempts to use data assimilation ET products did not show a measurable improvement in model performance. The recommendation culminating from this study is that NASA and EPA work together to add the capability for using the data assimilation precipitation products to the EPA hand books of procedures. This process has been initiated. Thus, any group interested in using BASINS to estimate TMDLs, would have an alternative method for estimating precipitation inputs. This will be especially valuable for cases where the nearest weather station is some 10s of kilometers outside of the watershed. This should also expand the potential use of BASIINS to parts of the United States and the world where good meteorological data are lacking.

An additional conclusion is for the EPA to evaluate the findings from the Wisconsin group to see how some of the forest disturbance metrics could be adapted into a parameterization scheme so that HSPF could respond to different forest species and the health of the forests.

2.0 INTRODUCTION

2.1 NASA, ESE, ESA and Application Mission Traceability

The NASA vision and mission statements include a clear focus on the Earth and life on Earth. NASA seeks to improve life on Earth by enabling people to use measurements of our home planet in valuable ways to manage our natural resources. NASA's Earth Science Division has primary responsibility for two Agency-wide, Earth oriented themes in the NASA strategic plan: Earth system science and Earth science applications. In serving these themes, the Division works with its domestic and international partners to provide accurate, objective scientific data and analysis to advance our understanding of Earth system processes and to help policy makers and citizens achieve economic growth and effective, responsible stewardship of Earth's resources.

The Earth Science Applications Program has as its primary goal to extend the benefits of NASA's Earth science to the broader community. To do this, NASA has identified twelve applications of national priority of which water resources is one. The Water Resources Program Element extends products derived from Earth science information, models, technology and other capabilities into partners' decision support tools to help them meet their water management responsibilities and mandates to support water resource managers. The general areas related to water availability and quality include:

- Estimating water storage – snowpack, soil moisture, aquifer volumes
- Modeling and predicting water fluxes - evapotranspiration, rain, runoff
- Water quality – turbidity, temperature, modeling nonpoint source pollution

It is in response to this last item, nonpoint source pollution, that NASA is partnering with the Environmental Protection Agency (EPA) to investigate the feasibility of using NASA data and data products to improve EPA's capability to model watershed nonpoint source pollution. The EPA is responsible for protecting various bodies of water in the U.S.. The primary guideline for EPA's mandate is the Clean Water Act of 1972 (Federal Water Pollution Control Act, 1972). One of the regulations spelled out in this Act is that EPA must track the Total Maximum Daily load (TMDL) for any watershed. In short, the TMDL defines the amount of pollution that can be carried by water before it is determined to be "polluted". There are essentially two ways for EPA to do this: one is through in-stream measurements and sampling, and two, through modeling the streams response to storm runoff and pollution loadings. The first option would be prohibitively expensive and impractical for the entire U.S.. The modeling approach is the only practical solution. To do this, EPA developed the BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) (USEPA, 2001) decision support tool.

The problem of nonpoint source pollution is a spatially and temporally complex issue. To overcome these shortcomings, the EPA has developed a suit of models to simulate streamflow and nonpoint pollution loadings. The models in BASINS currently rely on point-based meteorological and pollution measurements. Our premise is that by incorporating NASA remote-sensing data, many of the critical input variables to BASINS can be improved spatially. Satellite gridded data and data products might enhance BASINS output results, thereby leading to better decisions regarding water quality, leading to improved management of the nation's water resources. This goal complements the NASA Mission Statement "To understand and protect our home planet..." and NASA's Vision "to improve life here..."

2.2 The BASINS DST

Ideally, one would like to monitor water quality at numerous locations within a watershed on a periodic basis to assess fluctuations in water quality under different flow and seasonal conditions and assist in the identification of pollution sources. Unfortunately, all states lack the resources to assess and protect water bodies with monitoring data alone. To overcome this shortcoming, the EPA has developed a modeling system for performing watershed and water quality studies. BASINS (USEPA, 2001) is a multipurpose environmental analysis system to assist regional, state and local agencies in their assessment obligations. BASINS was developed to meet three objectives:

1. To facilitate examination of environmental information
2. To support analysis of environmental systems
3. To provide a framework for examining management alternatives

BASINS is configured to support environmental and ecological studies in a watershed context. BASINS is also configured to develop TMDLs for water bodies that are not meeting water quality standards. Section 303(d) of the Clean Water Act requires states to develop TMDLs for water bodies that are not meeting applicable water quality standards. Developing TMDLs requires a watershed-based approach that integrates both point and nonpoint sources.

BASINS includes a suite of models designed to model meteorological conditions, flow across watersheds, and ultimately pollutant transport. The systems overview for BASINS is illustrated in Figure 1. The results produced by the models enable more accurate understanding of conditions leading to excessive TMDL values. BASINS includes hydrologic and pollutant fate and transport models that simulate streamflow and runoff from the land surface (nonpoint sources).

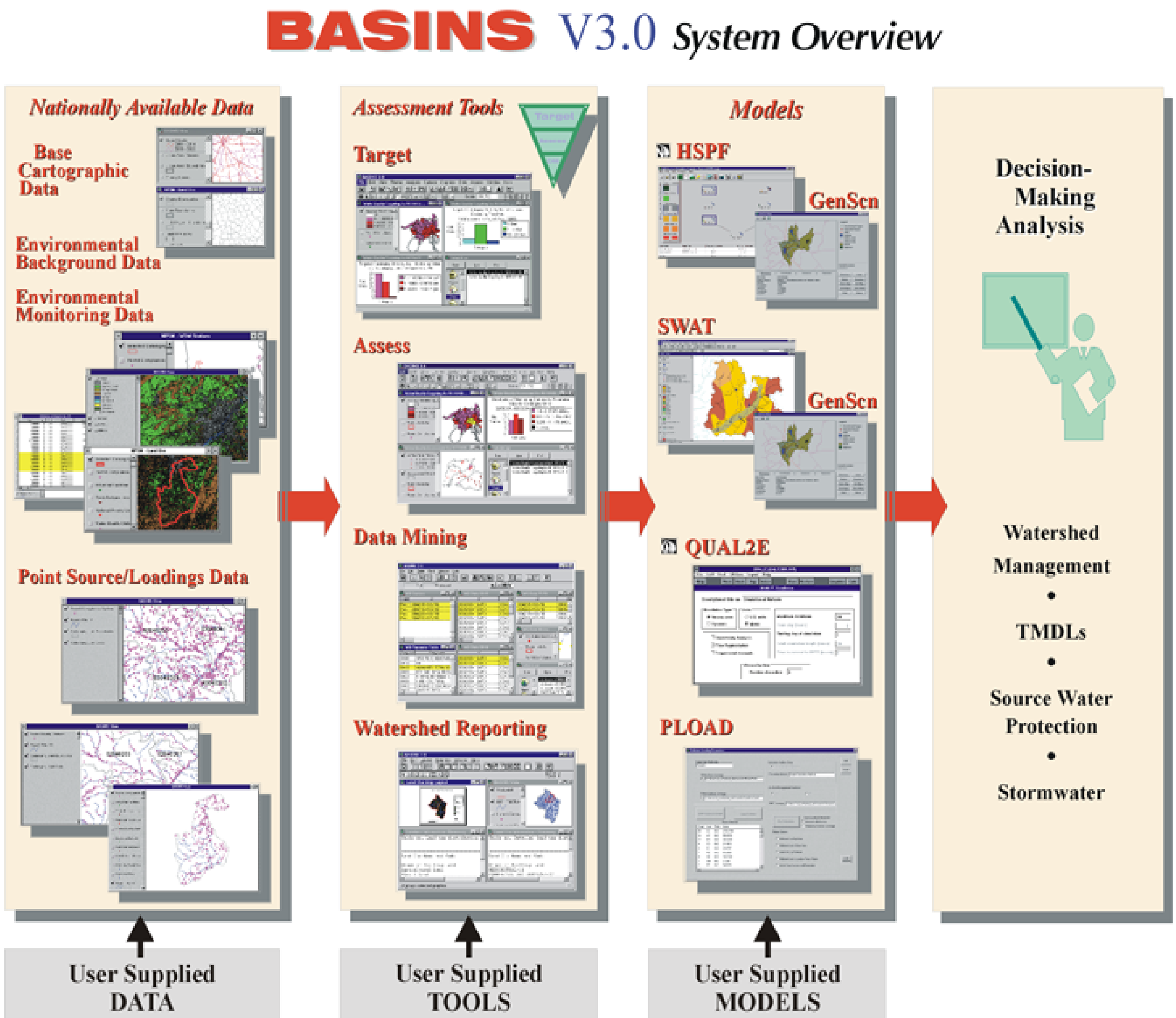

Figure 1: BASINS operational overview.

Accuracy in modeling streamflow and runoff is essential for estimating water quality and establishing TMDLs at locations within a watershed. Quantitative measures or estimates of streamflow are needed to define concentrations of water quality constituents. In order to simulate streamflow in a watershed, EPA has sponsored the development of a continuous hydrologic simulation model known as HSPF (Hydrologic Simulation Program – FORTRAN) (Donigian et al., 1995 and Bicknell et al., 1997). HSPF simulates nonpoint source runoff and pollution loadings, combines these with point source contributions, and performs flow and water quality routings in the watershed channels.

The Evaluation Report (NASA, 2007) defines the steps taken and the justification for choosing HSPF as the DST for this Benchmark study. The key to the BASINS suite of models is the Hydrological Simulation Program - Fortran (HSPF), which calculates daily stream flow rates and the corresponding pollutant concentrations at the watershed outlet.

HSPF does not perform well when adequate spatial input and watershed data are not readily available.

2.3 Systems Engineering Approach

The Earth Science Applications program's approach to extend the benefits of Earth science observations and predictions to decision-support tools is based on fundamental system engineering principles. Figure 2 illustrates the architecture underlying the activities of the Earth Science Applications program. To the right, partner agencies own, develop and operate decision support tools to carry out their water management mandates. On the left, NASA extends the observations, model predictions, and computational techniques from its Earth science research to support its partners.

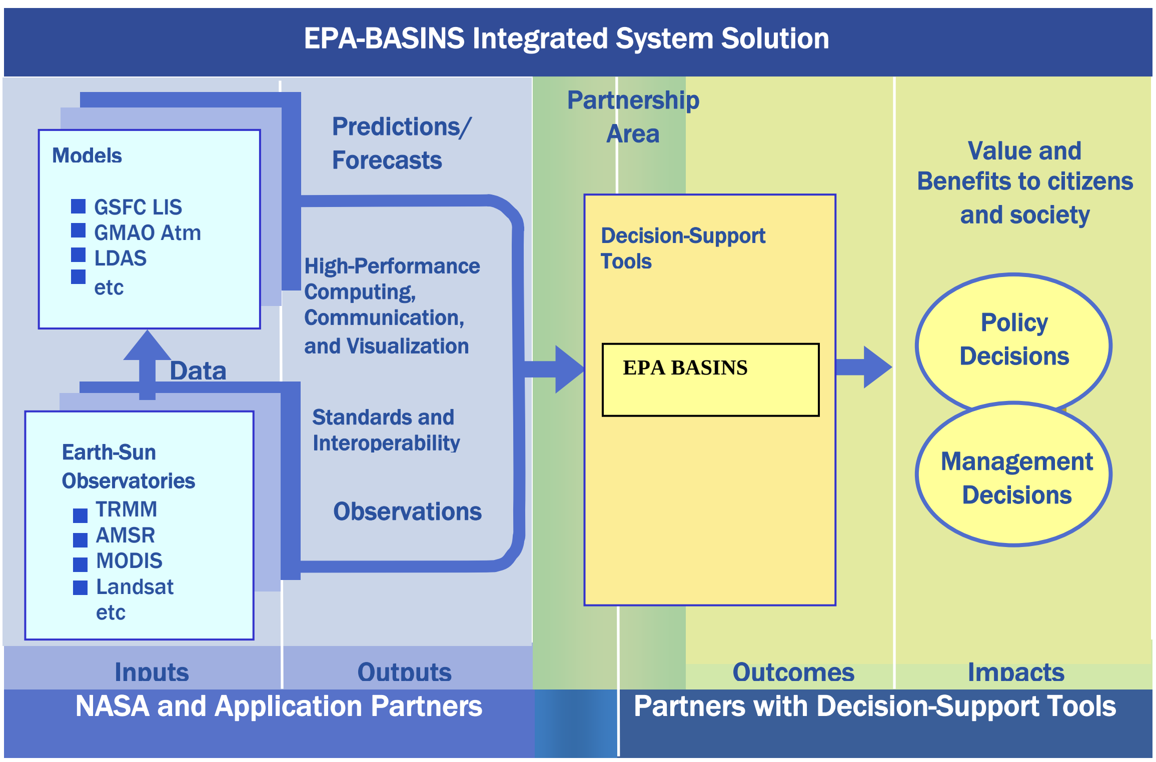

Figure 2. Illustration of the systems engineering architecture underlying the activities of the Earth Science Applications Program and its specific application to the EPA BASINS Decision Support Tool.

The systems engineering approach involves the four steps of ***evaluation, validation, verification and benchmarking*** to test the utility of NASA Earth science data for improving the performance of EPA's watershed and water quality decision support tools. The emphasis of this report is to evaluate the use of NASA data products through study of the EPA BASINS Decision Support Tool (DST). The benefit to EPA would be the adaptation and inclusion of state-of-the-art Earth systems data and data products into watershed assessment while a benefit for NASA benefit would stem from continuing its mission "to understand and protect our home planet."

The major emphasis is the use of NASA products to estimate important model parameters (e.g., land use, buffer zones, etc.), improve forcing functions (e.g., precipitation, evaporation, etc.) and provide initial conditions (e.g., soil moisture, snow cover, etc.) to improve the performance and accuracy of BASINS. The ***evaluation*** step in this process was to assess BASINS inputs and outputs. Next, NASA modeling and remote sensing products were matched against the existing inputs to BASINS.

Following this initial evaluation, the most promising NASA data products were chosen to be substituted into BASINS one at a time to test for improvements in HSPF-simulated stream flow. The process of ingesting NASA data to BASINS constituted the second step of the systems engineering approach. This ***Verification and Validation*** phase involved the development of techniques for using NASA data in BASINS. Also, the ***baseline*** data has been defined and ***benchmark*** metrics have been developed within this phase.

The third and final phase in the systems engineering process, the ***benchmarking*** phase, included the results of testing each NASA input separately against the established baseline in phase 2. Also, the ***benchmarking*** phase described the processes necessary to integrate results of this effort into everyday BASINS use at the EPA and partner level.

An anticipated outcome of this project was the determination of optimal data sets for use with watershed assessment tools. A key part of the ***benchmarking*** procedure is comparisons of results using EPA traditional data and configurations versus those with NASA data and to document the improvements with quantitative measures against the baseline results.

2.4 Purpose of Report

The purpose of this report is to document the entire process of the investigation. This is simply keeping with good practice. However, more importantly, this report is intended to provide comprehensive results for the partnering agency, EPA. The report provides details of the study process and the results in quantifying metrics so as to enable EPA to make decisions on whether or not to implement improvements to their BASINS system.

3.0 SUMMARY OF SYSTEMS ENGINEERING ACTIVITIES

3.1 DST Evaluation

The BASINS system combines six components to provide the range of tools needed for performing watershed and water quality analysis. These interrelated components can be summarized as follows:

1. National environmental data bases (basic cartographic data, environmental background and monitoring data, point sources/loading data)
2. Assessment tools (TARGET {broad based, preliminary conclusions}, ASSESS {status of specific stream reaches and evaluate the need for source characterization and cause-effect relationships} and Data Mining)
3. Utilities (a series of tools for managing data, delineating sub-watersheds, reclassification of data and overlaying data)
4. Watershed characterization reports (point sources, land use, topography, etc.)
5. Water quality stream models (QUAL2E)
6. Watershed models (HSPF, SWAT, PLOAD)

The decision was made to evaluate the EPA models (5&6 above) to select the optimal opportunities for infusing NASA data and data products with the hope of improving the usefulness and performance of the EPA BASINS system.

QUAL2E is a one dimensional model that analyzes the fate and transport of pollutants selected stream reaches. QUAL2E is best used where you are concerned *with a Dissolved Oxygen (DO) endpoint in an effluent dominated system and can accept the steady state assumptions.* The details and scale of this model eliminated it from further consideration for NASA contributions. Our focus then concentrated on the three watershed models.

In considering what strengths a potential NASA contribution could make to improving the application of BASINS to different physiographic regions, we focused on the spatial and temporal characteristics of remote sensing data and data products. EPA considered a continuous simulation model to be critical for a realistic representation of watershed processes. A continuation simulation model automatically takes into consideration the serial correlation present in flows and other variables, as well as the cross-correlations between measured variables. Based on this criterion, we eliminated PLOAD and SWAT from consideration. PLOAD is a simple watershed model that is based on annual precipitation, land use and Best Management Practices (BMP). PLOAD can be used when you want *estimates of annual and seasonal loading to drive simple eutrophication models.* SWAT is a daily time step model that can predict the effects of land use management and can be used where there are *no nearby meteorological stations with hourly data and where there is no nearby gauged watershed.*

The process of elimination and the matching of NASA capabilities and BASINS needs has led us to focus on the Hydrologic Simulation Program – FORTRAN (HSPF) Donigian et al., 1995 and Bicknell et al., 1997) model. HSPF simulates the hydrology and associated water quality processes on pervious and impervious land surfaces and in streams and well mixed impoundments. HSPF is a lumped parameter, continuous streamflow simulation model based on the Stanford Watershed Model (SWM), the first real watershed model performed on a digital computer. The model requires land use, channel reach, and meteorological data and information on expected pollutants. HSPF is designed to interact with BASINS utilities and data sets to facilitate the extraction of appropriate information and the preparation of model input files. HSPF can be run on a single watershed or a system of multiply connected sub-watersheds that have been delineated using the BASINS "Watershed Delineation" tool and GIS elevation datasets such as the Digital Elevation Model (DEM) provided by USGS. Generally, spatial variability within a large watershed is dealt with by subdividing the watershed into sub-watersheds. In doing this one then must select parameters for each sub-watershed to reflect the spatial heterogeneity.

3.2 Implementation

In choosing to work with HSPF, we realized that the NASA impact could be derived from all three potential areas in which NASA data and science products may be used to improve the BASINS model performance. These include:

- Improved input data sets (i.e., land use, buffer zones, from satellite imagery, etc.)
- Improved forcing (i.e., spatially distributed precipitation, evaporation, wind, solar radiation, etc. derived from data assimilation)
- Improved initial conditions (i.e., snow cover, soil moisture, from data assimilation products, etc.)

Improved input datasets can take the form of GIS datasets currently available to BASINS from many sources, including the National Elevation Dataset (Gesch et al., 2002), the National Land Cover Dataset (Vogelman et al., 2001), and the STATSGO soils database (USDA, 1993). However, numerous alternative data sets exist, including digital elevation data from the Shuttle Radar Topography Mission (SRTM, e.g., Smith and Sandwell, 2003), soil properties maps (e.g., Hargrove and Luxmoore, 1998), ecoregion delineations (Hargrove and Hoffman, 2004), as well as detailed land use and land cover maps with more hydrologically meaningful categories, such as impervious surface area (e.g., Civco et al., 2002; Wang and Zhang, 2004; and Jantz et al., 2004) or MODIS-derived measures of vegetation cover and phenology (Hansen et al., 2002; Zhang et al., 2003; and Ni-Meister and Tomita, 2005).

Many of these data sets – especially those related to land cover – are expected to provide more accurate representations of the surface properties within watersheds. Specifically, the dynamic characterization of land cover through time will be an improvement over static classifications. Likewise, the assessment of total imperviousness within a watershed (where every pixel exhibits a range of imperviousness) will be more useful than the simple quantification of pixel area mapped as an impervious class (e.g., "urban or built-up" in the Anderson Level II scheme (Anderson et al., 1976).

The introduction of improved parameterization for land cover/land use (lc/lu) was to be performed by the Wisconsin group. The goal was to see if up to date and seasonal measures of lc/lu would provide more realistic characterization of the actual watershed conditions than using a static lc/lu measure dating to 1991.

Improved forcings for HSPF will focus on improving the accuracy of meteorological data at appropriate temporal and spatial resolutions to ensure the quality of the modeling results. Typically hourly station data maintained by NOAA or other organizations is used in HSPF modeling. However, there are many instances in which there are no nearby meteorological data available from ground-based stations for a watershed of interest. In such instances, estimates are usually made by using data from the closest stations. Meteorological data plays a crucial role in simulating stream flow and runoff, which in turn have a significant impact in estimating total pollutant loads and developing TMDLs. Having accurate hourly meteorological data on a relatively small spatial scale could improve HSPF modeling efforts by decreasing modeling uncertainty, increasing the accuracy of TMDL estimates, and allowing for modeling on smaller scales. More local scale modeling could lead to more efficient placement of Best Management Practices (BMPs) used to control nonpoint source pollution, thereby providing better water quality results at lower costs.

Both the Hunter and GSFC groups worked on evaluating the impact of improved forcings. The goal here was to evaluate the impact of LDAS and LIS developed precipitation and ET inputs of HSPF performance. Hunter attempted to use both precipitation and ET as improved inputs to the model while the GSFC group concentrated on precipitation alone.

Improved initial conditions involve quantifying the hydrologic status of the watershed at the beginning of the simulation run. Typically these would include variables such as soil moisture, snowpack volume and water content and impoundment levels. Soil moisture is a product derived from data assimilation and in the future from direct satellite measurements. However, it cannot be used to improve HSPF because the soil moisture related parameters in HSPF are simply parameters and are not based on actual levels of soil moisture. However, snow products from data assimilation and satellites have the potential for significant improvements in simulating runoff from snowmelt or rain on snow events.

Given the fact that HSPF is a lumped model that is highly parameterized, there is no direct relationship between model parameters and actual measurements in the field. For example, Upper Zone Soil Moisture, in HSPF, is a model fitting parameter and not a physical state variable. Because of this we saw no way to use NASA model or measurement derived data to improve model performance.

3.3 DST Verification and Validation

Seven watersheds within the Chesapeake Bay drainage basin with different topographic and land cover/land use characteristics have been selected for this project. Figure 3 shows the location of the study watersheds within the greater Chesapeake drainage basin. Our general approach was to *Verify* our results on one watershed and to work out the procedures for inputing the NASA data and data products with this chosen watershed. These procedures were then used to analyze the impacts of NASA inputs for all of the watersheds. The *Verification* watershed is the Patuxent watershed between Washington and Baltimore. This is an area that has experienced typical nonpoint source pollution problems, including runoff from agricultural lands, conversion of agricultural and forested areas to urban and suburban use, and runoff from impervious areas. EPA has already set up the HSPF and BASINS modeling systems for use in this area. The *verification* step involved comparisons of the HSPF model output with the measured flow and this also established the *baseline* for the future *benchmarking.* The comparisons involved graphical plots of annual and storm hydrographs and statistical measures of the differences between the model produced and measured streamflow.

The output from this system has been compared to measured stream flow and water quality parameter concentrations at various points in the watershed and the results are not particularly good. Our plan was to incrementally force the HSPF model with improved input data from the LIS to see if we can improve the fit between measured and model derived results. We also planned to do similar experiments with improved parameters and improved initial conditions. After seeing which forcings, parameters and initial conditions improve the HSPF/BASINS results we planned to experiment with combinations of these.

We then *validated* our procedures by running similar experiments on the other chosen watersheds within the Chesapeake Bay watershed. The final *verification and validation* step was making the enhanced version of HSPF available for demonstration using operational NASA data and data products. The last step is the *benchmarking* and documentation of the performance of the enhanced DSS (in this case, HSPF) by assessing its performance and comparing results with the *baseline.*

4.0 BENCHMARKING

4.1 Overview of Operational Environment

The EPA's Office of Water and NASA's Earth Science Enterprise (ESE) entered into a Memorandum of Understanding (MOU) in 2003 to study the use of NASA remote sensing and modeling information to support EPA's water-related programs. Within this framework, NASA/GSFC and EPA developed a project plan (NASA, 2004) under NASA Water Management to study the use of NASA data to improve EPA's water quality program. The unique capabilities provided by NASA satellite remote sensing and modeling have significant potential to address critical deficiencies for EPA modeling of spatially and temporally variable nonpoint source pollution. This project attempts to leverage the large investment in ESE data to a federal agency with national applications that may provide a significant return for policy making on water quality affecting people's every day lives. A recent Gallup News Service Poll (Saad, 2002) reported the top three out of ten environmental concerns of Americans involve water quality.

This project is based on needs documented in the Memorandum of Understanding between NASA and The Environmental Protection Agency for Cooperation in Water, Coastal and Earth Sciences. In this document, NASA agrees to:

1. Support EPA science and technology research, development, transfer, utilization, and commercial efforts within the Research, Economics and Education Mission Area as agreed upon by providing technical expertise

for performance, planning, review, or consultation in areas of mutual interest, subject to program priorities and budget constraints.

2. Assist EPA through collaborations to evaluate, verify, validate, and benchmark practical uses of NASA-sponsored observations from remote sensing systems and predictions from scientific research and modeling through the NASA Earth Sciences Enterprise (ESE).

NASA and EPA have identified ten areas of shared goals for improving decision making, policy, and management through beneficial and appropriate use of Earth science data and modeling. Of these ten areas, at least eight are natural extensions of ongoing research and capabilities within the Hydrological Sciences Branch at GSFC. Further collaborations for this project are currently being developed with groups at SSC and several universities that have demonstrated expertise in one or more of these areas. The combined NASA and EPA teams have identified the highest priority area for possible improvement through the use of NASA Earth science technology as being related to nonpoint source pollution. Details of this collaboration are in the NASA approved project plan, "Water Management Plan: Nonpoint Source Pollution, 2004" (http://aiwg.gsfc.nasa.gov/esappdocs/progplans/water_ver1-1.pdf).

As a result of the MOU between NASA HQ, NASA/GSFC along with the EPA Office of Water prepared a five year project plan (NASA, 2004), "BASINS: Nonpoint Source Water Quality" including work with the University of Maryland Center for Environmental Studies and Hunter College that was approved by NASA HQ. NASA/GSFC received funding in 2004 to work with the EPA to further develop relationships and start work. Thus far, the time invested by NASA/GSFC with the EPA has been on study site selections, training, model calibration, and preliminary evaluation studies described in this document.

Hunter College, CUNY. (PI, Wenge Ni- Meister) Dr. Ni-Meister has significant Land Data Assimilation System (LDAS), data assimilation, and remote sensing expertise to study effects of NASA MODIS and LDAS products on BASINS. This coupled with their strong department work on GIS should enable a thorough analysis of test watersheds using LDAS and satellite data such as from MODIS. Shihyan Lee has run the HSPF model and used PEST for calibration.

University of Wisconsin, Madison. (PI, Phil Townsend) Dr Townsend has been a leader in research on watershed water quality and use of remote sensing data to establish relationships to land cover/land use. Brenden??

Chesapeake Bay Program, Annapolis Maryland, Gary Shenk (Chesapeake Bay Program (CBP) Office) and Angelica L. Gutiérrez-Magness (UMCP/USGS). EPA and CBP will help coordinate the selection of test sites and watersheds. They will coordinate and provide assistance with setting up HSPF and performing calibrations. Shenk and Gutiérrez-Magness will provide the CBP phase 5 version of HSPF code and sample datasets for the applications team. They will work closely with the team in all phases and will participate in informal meetings and quarterly reporting periods.

NASA/GSFC – David Toll (NASA/GSFC) is the Team Leader with assistance from Edwin Engman. GSFC is responsible for coordination of activities between groups. GSFC is also the lead group evaluating NASA LIS precipitation in to BASINS. Joe Nigro provides GIS expertise and conducts the BASINS-HSPF runs.

4.2 Benchmarking Activities

Planning and Design: The general approach used in this study was to establish a *baseline* condition in which HSPF was run to mimic as closely as possible what EPA or a contractor would do to estimate TMDLs for a watershed. The project selected two precipitation products and an evapotranspiration product as the NASA inputs to evaluate whether or not these inputs could improve the performance of the HSPF for the selected watersheds. Each of these were used to replace the nearest station values used in the *baseline* model runs. Improvements, if any, were indicated by an improvement by the suite of statistical measures used in BASINS.

Study Watershed Selection: Seven watersheds within the Chesapeake Bay drainage basin with different topographic and land cover/land use characteristics have been selected for this project. Figure 3 shows the location of the study watersheds within the greater Chesapeake drainage basin. Figures 4 illustrate the land cover/land use for each study basin and list the areas, elevations ranges and details of the nearest weather station.

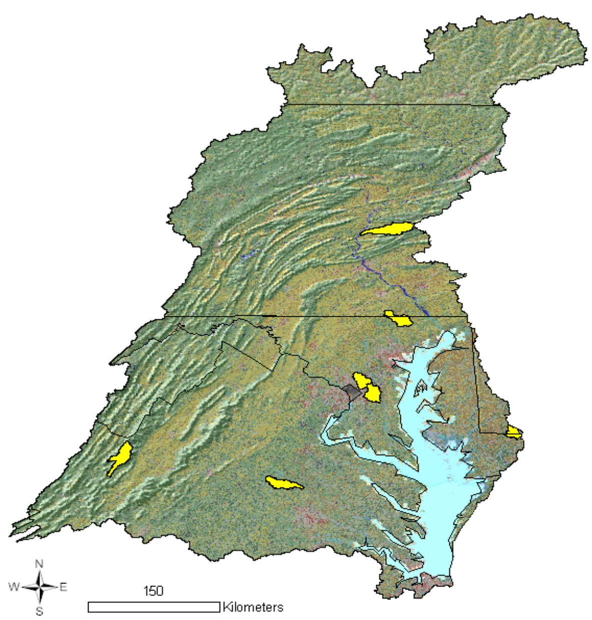

Figure 3. Location of study watersheds within the Chesapeake Bay basin.

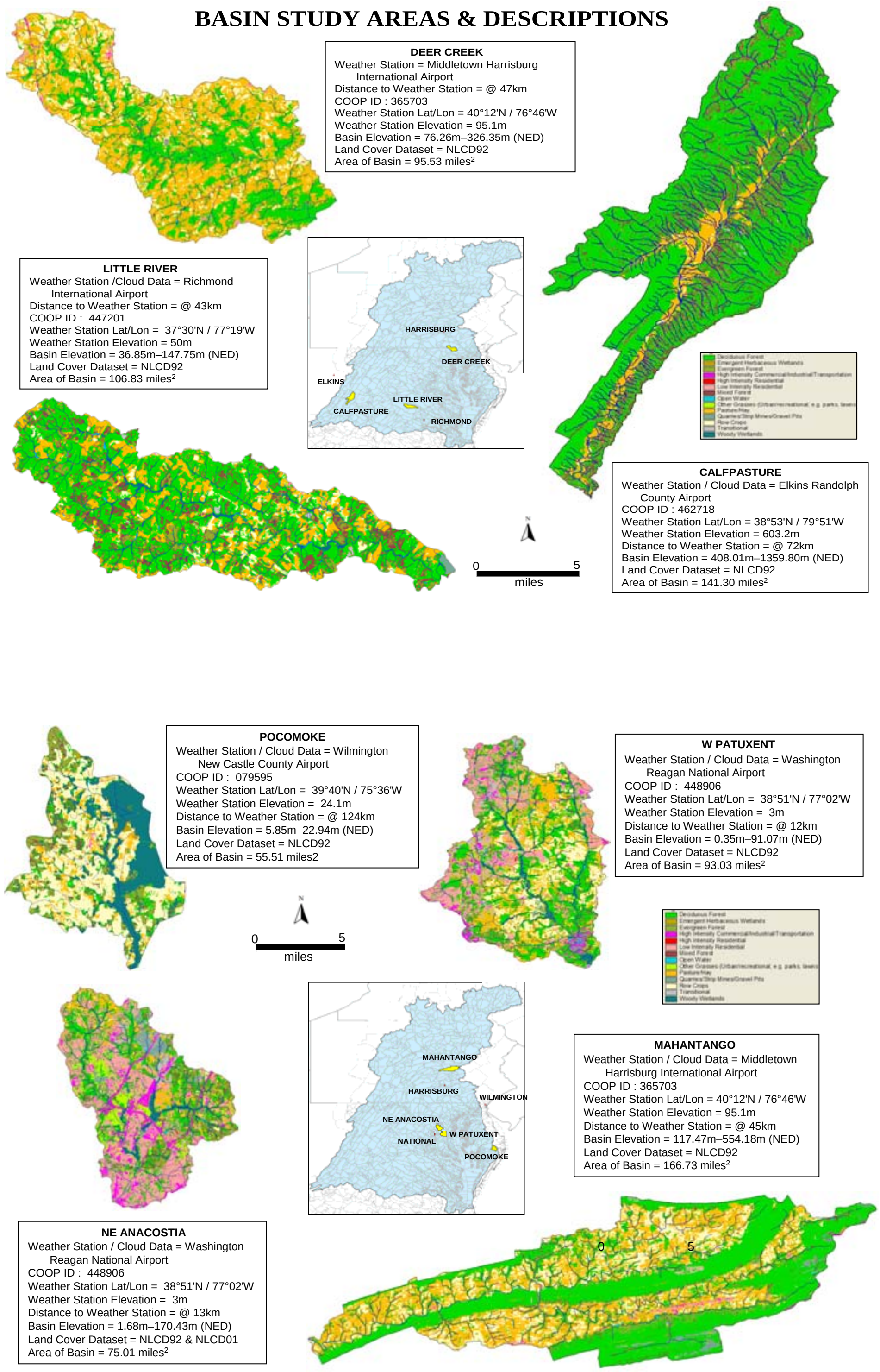

Figure 4. Physical characteristics of watersheds chosen for the study.

Each study watershed was chosen to represent specific topographic and land cover/land use characteristics. Taken in total, the sample of watersheds provided a wide range of land cover/land use and topographic variety.

<u>Methods and Metric</u>s: The first step in our study was to establish ***default*** model runs for each of the selected watersheds. The ***default*** runs were conducted so as to mirror what the EPA or a contractor would do if they were establishing TMDLs for a selected watershed. In the GSFC case, this involved using the Chesapeake Bay Program calibration values and using meteorological data from the nearest weather station. The ***default*** model runs established the ***baseline*** against which future model runs using NASA data inputs would be compared to see if any improvement in model performance was achieved. In the Hunter case, a similar strategy was followed except that the calibration values were derived from an automatic parameter estimation technique.
Our general approach was to ***Verify*** our results on each watershed and to work out the procedures for inputting the NASA data and data products with each chosen watershed. These procedures were then be used to analyze the impacts of NASA inputs to all of the watersheds. The first ***Verification*** watershed is the Patuxent watershed between Washington and Baltimore. This is an area that is experiencing typical nonpoint source pollution problems, including runoff from agricultural lands, conversion of agricultural and forested areas to urban and suburban use, and runoff from impervious areas. EPA has already set up the HSPF and BASINS modeling systems for use in this area. The ***verification*** step involved comparisons of the HSPF model output with the measured flow and this established the ***baseline benchmark.*** The comparisons involved graphical plots of annual and storm hydrographs and statistical measures of the differences between the model produced and measured streamflow. The ***verification*** results are shown as the ***default*** data in the following results tables.

The procedures were then ***validated*** by running similar experiments on the other chosen watersheds within the Chesapeake Bay watershed. The final ***verification and validation*** step made the enhanced version of HSPF available for demonstration using operational NASA data and data products. The last step was the ***benchmarking*** and documentation of the performance of the enhanced DSS (in this case, HSPF) by assessing its performance and comparing results with the ***baseline.***
The BASINS system includes several statistics for evaluating how well the model runs compare to the measured data. These include ***a correlation coefficient, a coefficient of determination, a percent mean error, a mean absolute error, a RMS error, the Nash-Sutcliff model fit efficiency, and the Nash-Sutcliffe absolute difference.*** Our ***benchmarking*** concentrated on the ***correlation coefficient*** and the ***Nash-Sutcliff statistic.***

4.3 Preparatory Activities

<u>Calibration Strategies:</u> The project used two different approaches to deal with the selection of HSPF calibration values. HSPF a conceptual model and its parameters often do not have simple relationships with field measurements. Calibration in HSPF is a must step. Although studies have shown that HSPF often yield superior results over other

hydrologic models (Johnson et al., 2003, Nasr et al., 2007), adequate calibrations have been the key for HSPF accurate model predictions. The calibration process in HSPF commonly involves subjective parameter fitting, which is time consuming, not reproducible, requires expert knowledge of the region's meteorology and hydrology properties as well as experience using HSPF. However, in some cases calibration values are established for a watershed or a region such as the Chesapeake Bay Watershed for use without subjective parameter fitting.

In this study, the calibration strategy is adopted from HSPF calibration guide line published by the EPA (US EPA 2000). Parameters representing the watershed's geographical properties, (e.g. slope) are not calibrated, instead values derived through the application of GIS methodologies were used for running the model . Parameters representing hydrologic process related parameters on pervious surfaces including LZSN, INFILT, AGWETP, CEPSC, UZSN, INTFW, IRC, NSUR and LZETP are potential parameters for calibration. Additional non-pervious land segment parameters, NSUR, RETSC, were calibrated for NE Anacostia because of its large urban area. Parameters related with interaction with deep aquifer, (BASETP, DEEPFR) were set to zero since this activity is unlikely in this region, and he detail domains used for each calibration parameter are listed in table 3. this setting is consistent with Chesapeake Bay Program's (CBP) calibration parameters.

Table 3. HSPF calibration parameters and their domains

Parameter	Unit	Range	Parameter	Unit	Range
LZSN	inch	3.5 - 15	UZSN	inch	0.2 - 2
INFILT	inch	0.03 - 0.3	NSUR	inch	0.1 - 0.5
AGWRC	1/day	0.9 - 0.99	INTFW	inch	1.5 - 6
AGWETP	1/day	0 - 0.15	IRC	inch	0.3 - 0.85
CEPSC		0 - 0.25	LZETP		0.3 - 0.9

1. GSFC Approach   The baseline or default runs were implemented in two different ways that match as closely as possible the procedures that EPA would use for establishing TMDLs for these seven watersheds. In the first case GSFC used HSPF calibration values established for the watersheds within the Chesapeake Bay watershed. The Chesapeake Bay Program had established calibration values based on average county soils, topography and land use for each county in the basin. Figure 5 illustrates the location of the study watersheds and the counties chosen for the calibration values. Watersheds that covered more than one county used the averages of the pertinent county values. No attempt was made to improve the hydrograph fitting through manual calibration. Our thinking was that the CBP parameters were quite good and that any improvement (if any) through use of the NASA forcing data would be evident without further calibration.

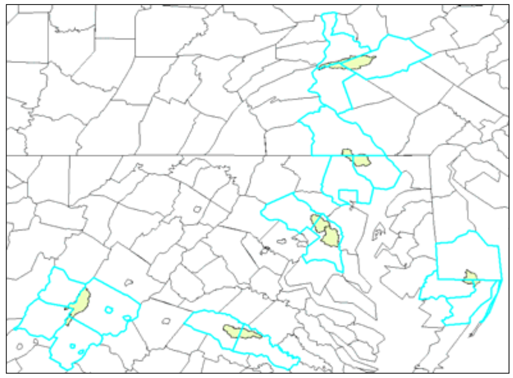

Figure 5. Counties used to establish the baseline calibration for HSPF.

2. HUNTER Approach This approach used an automatic procedure for estimating the calibration values. This method known as PEST (Doherty, 2001) provided an alternative way of calibration by calculating the model errors gradient from the current parameter values' differential. The model errors are calculated by a set of objective functions which are based on the principle of the weighted least-squares (Carroll and Ruppert, 1988), with different weights assigned for each objective function. To find the global minimum for the objective functions (model errors), an iterative process based on the nonlinear estimation technique known as the Gauss-Marquardt-Levenberg (Levenberg, 1944) and (Marquardt, 1963) method was applied to adjust parameters within preset ranges. The Gauss-Marquardt-Levenberg technique is based on the linearization of the relation between model parameters and model predictions at the beginning of all iterations. This process can be automatic therefore the results can be reproduced. In this study, the latest version of PEST (version 11, Doherty 2004) was used as the tool for automatic calibration.

The uneven flow volume distribution results In the model calibration not being a straight forward process. It is common for the flow in the studied area having 1-2 order higher in magnitude than base flow; however, its duration is much shorter than low flow. The peak flows will likely dominating the calibration process if commonly used single root-mean-squared-error (RMSE) method is used. To remediate the peak flow domination, an inverse weight by flow volume can be applied to set the equal weight on daily flow errors. This type of objective function will likely produce the best fit (correlation coefficient); however it could be far worse in predicting peak flows and maintaining overall water balance. This is because the dominating factors had a shift from peak flow to lower flow days because their overwhelming numbers. To better capture hydrologic characteristics, three objective functions, naming mFlow, mVol and mTime, were used. A fourth objective function (mET) was added for HSPF runs involving NASA ET. Each objective function was designed to target specific flow characteristics.

mFlow is calculated as the error between daily observed and simulated flow with a weight as the inverse of observed flow to normalize the error among high and low flow days. Since storm events are short, the purpose of this component is to focus on calibrating base or low flow. MVol is calculated as the error between monthly observed and simulated flow, with a weight set as the inverse of square root of observed flow. This component is set to balance the monthly water budget which also impacts overall water balance. MTime is calculated as the error between the percentages in flow duration (percent flow days in certain flow volume range). This component is often associated with peak and overall flow volume. In this study, it is calculated at 5% flow duration interval. mET is calculated as the error between NASA ET and HSPF simulated actual ET (SAET). This component is used for model runs involving NASA ET, which served a mean to match HSPF SAET to NASA ET and have nothing to do with stream flow. More detail on the purpose of mET will be discussed later.

An important part of automatic calibration is choosing the initial condition and selecting a reasonable domain for each calibrating parameter. The CBP calibrated the HSPF model in many of its watersheds, and maintain a HSPF parameter dataset at county level, which is slightly larger then our basins. Therefore, we estimated the initial condition for each watershed from the closest CBP calibration parameters in that area. The values of parameters during the calibration were constrained by the highest and lowest possible values that can be found in the whole CBP calibration parameters set, which means the parameters are in the reasonable range for the region's climate and hydrologic properties.

As stated earlier, three objective functions (four for NASA ET runs) are used during the calibration; each is calculated differently and with its own purpose. The ultimate goal was to make each components contribute approximately equally at the end of calibration. The reason for doing this is to get the best general fit since this study did not aim at any specific application. Besides the weights associated with each member within the same objective function, a second weight function was applied to each function to adjust the relative importance among them. The group weight function was then adjusted iteratively until equal contribution from each objective function was achieved.

<u>Subdividing Watersheds:</u>   Each selected watershed had to be subdivided into subwatersheds that approximated the grid square for input (precipitation or ET) of the grid based NASA data. Within BASINS the process of watershed subdivision is known as ***segmentation.*** ***Segmentation*** allows the modeler to develop sub-areas of the watershed with uniform parameters and meteorological inputs that are connected by a reach network.   This step was done by overlaying the watershed with the LDAS or LIS grid, and identifying a point on the boundary of the grid where an outflowing stream crossed it. The BASINS Automatic Watershed Delineation tool was then used to set up the HSPF to accept the gridded NASA input data. Figure 6 illustrates this process for the NLDAS 1/8 degree data and the Stage IV 4 km data.

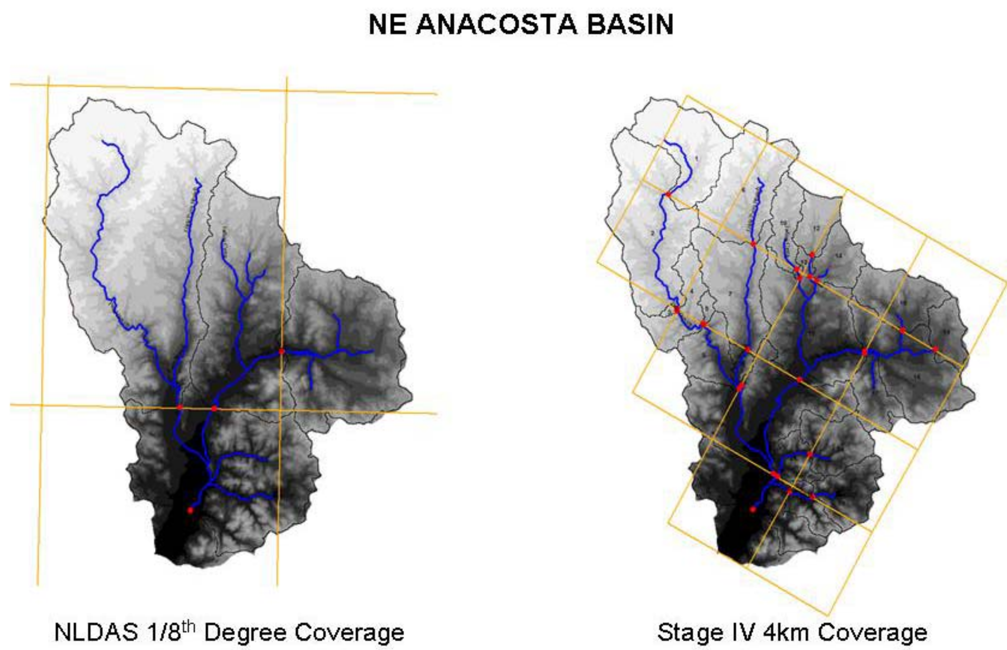

Figure 6. Illustration of how the gridded LDAS and Stage IV data overlaid the watersheds and outlets (red points) were assigned based on the interaction of stream and grid boundary.

<u>Data Collection</u> The watersheds chosen all had continuous stream flow measurements for the period of 2001 to 2004. This period was selected to match the LDAS and LIS records that were readily available for abstracting the NASA data contributions.

LDAS (Land Data Assimilation System) ingests satellite- and ground-based observational products as data for parameterizing, forcing, constraining, and evaluating a suite of sophisticated land surface models (LSMs), in order to generate optimal fields of land surface states (e.g., soil moisture, snow water storage, soil temperature) and fluxes (e.g., evapotranspiration, runoff, sensible heat flux) (Rodell et al., 2004a). The software, which has been streamlined and parallelized by the Land Information System (LIS) sister project (Kumar et al., 2005), drives multiple, offline (not coupled to the atmosphere) land surface models, executes globally at high resolutions (2.5° to 1 km), and is capable of producing results in near-real time.

<u>Forcing Data</u> Three forcings developed from the NASA data assimilation products were used. Each is described briefly as follows:

1. LDAS 1/8 degree precipitation: Hourly observation based precipitation data were derived from a combination of daily National Center for Environmental Prediction Climate Prediction Center (CPC) gauged-based precipitation analyses and hourly National Weather Service Doppler radar-based (WSR-88D)

precipitation analyses, where in the hourly radar-based analyses are used to temporally disaggregate the daily CPC values.

2. Stage IV 4 km precipitation: The hourly 4km precipitation values have been derived by the NOAA River Forecast Center Multisensor Precipitation Estimator (MPE). This product is generated at NCEP directly from radar and gauged data. These data are preliminary estimates of what one can expect in the future LIS precipitation products that would include TRMM and other satellite inputs.
3. NOAH ET values: The community NOAH Land Surface Model (LSM) is a stand alone, 1-Dimensional model which can be executed either coupled or uncoupled modes. NOAH uses a linearized, non-iterative surface energy budget, the Jarvis-Steward "big-leaf" canopy conductance for different land-use classes, and treats multiple soil layers through soil moisture diffusion and soil heat transfer for different soil textures (Chen et al, 1996, Ek et al, 2003).

Goodness of fit statistics were produced for four different scenarios: 1. The annual hydrograph, 2. An extended period of low flow (little or no precipitation), 3. A period of high flows that included several storms, and 4. A short period around individual summer (presumably convective storms).

Analysis and Findings – Improved Forcing - Precipitation The GSFC results for each scenario are presented in Appendices I – III. Three different flow conditions were analyzed for each study basin. First, the annual hydrographs were calculated for each year using the ***default*** and improved forcings. Subsequently, some low flow periods were subjectively selected and several summer storms were also selected for each watershed. In these tables, the ***default*** statistics represent use of the nearest weather station data. The NLDAS $1/8^{th}$ statistics represent the results from the NASA derived precipitation data but for a subdivided watershed to correspond to the $1/8^{th}$ degree grid. The Stage IV statistics represent the results from using the Stage IV rainfall data but for a subdivided watershed corresponding to a 4 km grid. In the GSFC results the same calibration values used for the ***default*** runs were used for the NLDAS and Stage IV runs. The best performing statistics are highlighted with a red box. It can be seen that in almost every event and almost every scenario that either the NLDAS or the Stage IV precipitation dramatically improved HSPF model performance. In most cases there is little to choose between the NLDAS and Stage IV precipitation results. Both improved HSPF performance but neither one was consistently better then the other.

Analysis and Findings – Improved Forcing – Evapotranspiration The Hunter results where LDAS modeled ET was substituted for the HSPF derived ET values are shown in Appendices IV-VI. These results show very little, if any, improvement in the overall statistics when using the LDAS modeled ET in place of the HSPF derived ET. In a number of cases use of the LDAS ET actually resulted in worse statistics than with the default run. In the case of the Hunter results, the model was calibrated using PEST for the default runs and the NLDAS and Stage IV runs. Thus the model was recalibrated for each run. The Hunter and GSFC results were very similar for the improved precipitation forcings from LDAS and Stage IV data. This was true for the GSFC approach that held the calibration parameters constant and for the Hunter approach that recalibrated each run with PEST.

Analysis and Findings – Improved Parameterization – Land Cover Attempts to update land cover parameters with annual and seasonal land cover delineations were not successful. The research leading up to this strategy illustrated a strong relationship between land cover changes and nitrate in the streams. Unfortunately, BASINS version 3.0 has only three land cover classes and there was no basis for changing the forest land cover parameterization short of outright guessing. Within the forest cover classification there is no way to differentiate among species, leaf-on, leaf-off conditions or cases of partial defoliation due to disease or drought. Thus there was no defensible strategy for infusing the NASA improved land cover information into the BASINS version 3.0 HSPF.

Fortunately, the Wisconsin group has performed some very interesting research on the effects of land cover changes on water quality. These results have potentially major impacts on how Version 4.0 of BASINS might be used to examine changes in water quality associated with seasonal as well as long term land cover/land use changes. These results are summarized in section 5.0.

Lessons Learned In retrospect, one would have to conclude that use of the HSPF watershed model limited our ability to really test the potential of NASA data and data products for improving model performance. The lumped nature of HSPF and its reliance on fitting calibration parameters are its principal weaknesses.

The lumped nature of HSPF is inherently incompatible with NASA data which are grid based and spatially distributed. For example, this eliminated the possibility of trying to use improved satellite derived landuse/land cover data to spatially represent the true conditions within the watershed. HSPF, being a lumped model means that within the watershed or subwatershed the model parameters are uniform and unable to represent normal spatial heterogeneity.

Although many of the model parameters would appear to have a physical significance (Upper Zone Storage – UZSN, INFILT, etc..) they are, in reality, simple fitting parameters. The advantage of a model with many fitting parameters is that if one has good streamflow and meteorological data, one can eventually produce a very good fit to the measured data. The disadvantage is that since these parameters do not represent real hydrologic states or variables, one has no capability to see if substituting real states (i.e., soil moisture) or variables (i.e., ET) would improve model performance.

This being said, the major lesson learned is that use of NASA derived precipitation data does improve model performance in a significant way. This should not be surprising; after all, precipitation is the major driver of the rainfall-runoff process and a more accurate estimate will result in improved simulation results, even for a lumped model. The important result from this study is that EPA now has an alternative for developing the precipitation data other then from the nearest meteorological station, which may be many kilometers away.

5.0 EFFECTS OF SEASONAL LAND COVER CHANGES ON WATER QUALITY

Forest disturbances such as the conversion of land to agriculture or pasture, logging, or defoliation by the gypsy moth larvae (*Lymantria dispar)* can lead to significant and consequential increases in the concentration of nitrogen (N) in receiving streams and downstream estuaries (Likens et al. 1970, Swank et al. 1981, Eshleman et al. 1998, Williams et al. 2005). Satellite-based remote sensing has proven to be an effective tool for monitoring such disturbances and predicting their effects on the loading of N to streams (Townsend et al. 2004, McNeil et al. 2007). In order to guide future integration of such remote sensing measurements into the BASINS/HSPF modeling framework, we conducted a benchmarking study comparing the abilities of several widely-used remote sensing metrics of land cover and forest disturbance for predicting the concentration of N in streams draining mixed land cover watersheds undergoing varying degrees of forest disturbance.

We studied two different forest disturbance events (primarily logging and gypsy moth defoliation) that occurred in central Appalachian headwater catchments of the Potomac River. The watersheds within these catchments are on average 85% forested, but the percentage of cleared lands (pasture, agriculture, low-density residential) ranges from 0.1 to 69 percent. The first forest disturbance event occurred in the summers of 2000 and 2001 within the Fifteenmile Creek (FMC) catchment, and the second occurred in the summer of 2006 within the Savage River (SR) catchment. During baseflow conditions in the spring following each disturbance event (April 2001 and 2002 in FMC, May 2007 in SR), we conducted a survey of stream water nitrate (NO_3^-) concentrations in randomly selected watersheds within each catchment. For each disturbance event, we evaluated the ability of different remote sensing metrics of land cover and disturbance (independent variables) to predict spatial variability in the stream water NO_3^- measurements (dependent variable).

We evaluated land cover metrics derived from the 2001 National Land Cover Dataset (Homer et al. 2007). The categorical NLCD data are the standard inputs to BASINS and HSPF model analyses, and thus provided the baseline for our benchmarking study. We reclassified the categorical NLCD data to obtain watershed average measures of (1) percent non-forest area, (2) a net nitrification index, (3) an N retention index, and (4) an N output index. We calculated the latter three indices using land-cover specific HSPF calibrated parameters developed for till soils in the Ipswich River watershed of Massachusetts (Filoso et al. 2004). We also calculated watershed averages of the two continuous NLCD metrics: percent canopy cover and percent impervious surface.

We evaluated satellite-based remote sensing metrics derived from NASA’s Landsat and MODIS instruments. These metrics characterized the spatial pattern of disturbance intensity using four different approaches: (1) single date, (2) inter-annual change detection using one “reference” year relative to the disturbance year, (3) phenologic change detection using pre- and post-disturbance images within a year, and (4) integrated annual phenology metrics. Availability of Landsat data enabled us to apply the single date approach, as well as the inter-annual change detection approach. For both approaches we evaluated the NDVI, NDII, and Tasseled Cap Brightness, Greenness, and Wetness indices, as well as the "disturbance index" that summarizes the three tasseled cap indices (Healey et al. 2005). We also evaluated a change vector approach that summarizes the magnitude and direction of inter-annual change in dimensions defined by the three tasseled cap indices (Townsend et al. 2004). From the MODIS imagery, we used imagery from before the gypsy moth defoliation and during the defoliation to detect the within-year phenologic change caused by disturbance. We used three MODIS data sources: daily data, 8-day composite data, and the 16-day EVI product. Finally, we also evaluated the integrated measures of annual phenology derived from MODIS data. For comparison to the stream water nitrate data available for each watershed, we summarized the higher resolution Landsat data by calculating the average of all forested pixels in each watershed. In order to retain the maximum number of pixels in the study watersheds, we did not mask out non-forest pixels in the analysis with the coarser-resolution MODIS data.

Stream water nitrate concentrations ranged from 0.16 mg/L to 1.35 mg/L (mean = 0.53 mg/L, 1σ = 0.27 mg/L) in the 40 watersheds of the May 2007 SR survey, and ranged from 0.002 mg/L to 0.93 mg/L (mean = 0.23 mg/L, 1σ = 0.21 mg/L) in the 31 watersheds of the April 2001 FMC surveys. Our "baseline" benchmark data of the categorical NLCD land cover metrics showed a poor ability to predict spatial variability of nitrate concentrations in either catchment (Table 1). Similarly, the continuous NLCD measurements of percent impervious surfaces and percent canopy cover also showed poor predictive ability (Table 4). Reclassifying the NLCD categorical data with the calibrated HSPF model parameters from Filoso et al. (2004) did not improve these results (Table 1). While previous BASINS/HSPF modeling analyses have highlighted a strong relationship between land cover (particularly the percent non-forest area of a watershed) and spatial variability in nitrogen export (Williams et al. 2005), we suggest that the small percentages of non-forest land cover types in our study catchments emphasized the importance of forest disturbance processes, and precluded our ability to find direct relationships among land cover and watershed N export.

The remote sensing metrics of forest disturbance strongly differed in their abilities to predict spatial variability in stream water nitrate concentrations (Table 1). The integrated annual phenology metrics obtained from the MODIS for North American Carbon Program were the least successful group of metrics, as the spatial patterns in all tested metrics (i.e. green-up, brown down, large integral, small integral, and season length) had no significant relation to the spatial pattern of stream water N (Table 1). The Landsat single-image metrics also showed a low predictive ability of stream water nitrate (Table 1). The addition of a reference image and use of a change detection approach dramatically increased the ability to use Landsat and MODIS remote sensing data to predict spatial patterns of stream water N loading. As we have found previously (Townsend et al. 2004, McNeil et al. 2007), the ability to detect increases in the nitrate concentration of stream waters was based on detecting disturbance-induced decreases in the greenness and wetness components of forest canopies. In particular, the Δ NDII, a close correlate of canopy moisture content (Jackson et al. 2004), was generally stronger than Δ tasseled cap indices and Δ NDVI or Δ EVI. This result was not surprising in light of the fact that greenness measures (e.g. NDVI) can saturate in dense canopies, and thus may lose precision in discriminating the effects of small amounts of forest disturbance. In contrast, canopy water content based metrics such as NDII scale linearly with total canopy mass, and thus can capture subtle disturbance-induced changes to the canopy. The strong linkage among canopy cover and stream water N loading was further indicated by our multiple regression analyses where a portion of the residuals about the relationship with Landsat Δ NDII could be explained by the NLCD measure of percent canopy cover. These two canopy cover metrics combined to predict 58% of the spatial variability in nitrate concentrations within streams of the FMC catchment (Table 3).

Collectively, we suggest that these results reinforce the idea that the loss of forest canopy structure and function, either through increased non-forest land cover fraction (Williams et al. 2005), logging (Likens et al. 1970), or subtle insect defoliation or drought events (Townsend et al. 2004, McNeil et al. 2007) is mechanistically linked to decreased watershed retention of N. Accordingly, we suggest that modeling canopy cover in a continuous and dynamic fashion would greatly enhance the precision and accuracy of predictions obtained from the BASINS/HSPF model, especially in largely forested watersheds. In particular, our results show promise for using the 2001 NLCD percent canopy cover land cover metric in tandem with repeat MODIS- or Landsat-based NDII measurements that can account for the important forest disturbance-induced effects on stream water N concentrations.

Table 4. Predictive abilities of remotely-sensed land cover (NLCD) and forest disturbance metrics for assessing spatial variation in spring baseflow nitrate concentrations within watersheds of the Savage River and Fifteenmile Creek headwater catchments of the Potomac River. Tabled values are R^2 from regressions. Non-statistically significant results ($p > 0.05$) are denoted by (NS), *bold italics* indicate $p < 0.001$.

		Savage River (n = 40 watersheds)	Fifteenmile Creek (n = 35 watersheds)
NLCD categorical data (reclassified)		NS	NS
NLCD continuous metrics (% impervious, % canopy cover)		NS	NS
Landsat single-date	Tass. Cap Brightness	NS	NS
	Tass. Cap Greenness	0.10	NS
	Tass. Cap Wetness	0.17	0.12
	Tass. Cap DI	0.12	0.09
	NDVI	NS	NS
	NDII	0.11	NS
Landsat inter-annual change detection	Δ Tass. Cap Brightness	NS	NS
	Δ Tass. Cap Greenness	***0.29***	***0.23***
	Δ Tass. Cap Wetness	***0.27***	***0.25***
	Δ Tass. Cap DI	***0.20***	***0.30***
	Δ Tass. Cap change vector (θ angle + magnitude)	***0.30***	***0.59***
	Δ NDVI	0.17	***0.35***
	Δ NDII	***0.28***	***0.44***
MODIS daily images	Δ EVI	***0.23***	***0.31***
	Δ NDII	***0.25***	***0.45***
MODIS 8-day composite images	Δ EVI	***0.48***	***0.48***
	Δ NDII	***0.48***	***0.32***
MODIS 16-day Veg. Index Product (Δ EVI)		***0.49***	***0.34***
MODIS for NACP Phenology Product (Small integral under EVI phenology curve)		NS	NS
Multiple Regression Landsat ΔNDII + NLCD % canopy cover		NLCD % canopy cover not significant	***0.58***

6.0 BENCHMARKING GAPS

The major benchmarking gap would be choice of a suitable model for examining all of the potential NASA contributions (see the discussion above under lessons learned). The benchmarking process appears to be a valid technique for documenting any improvements that NASA data could make to an existing DST.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The most important conclusion from this study is that the NASA developed data assimilation precipitation products will result in improved model performance.

The recommendation culminating from this study is that NASA and EPA work together to add this capability to the EPA hand books of procedures. Thus, any group interested in using BASINS to estimate TMDLs, would have an alternative method for estimating precipitation inputs. This will be especially valuable for cases where the nearest weather station is some 10s of kilometers outside of the watershed. This should also expand the potential use of BASINS to parts of the world where good meteorological data are lacking.

An additional conclusion is for the EPA to evaluate the findings from the Wisconsin group to see how some of the forest disturbance metrics could be adapted into a parameterization scheme so that HSPF could respond to different forest species and the health of the forests.

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9.0 ABBREVIATIONS AND ACRONYMS

ALI	Advanced Land Imager
AMSR-E	Advanced Microwave Scanning Radiometer-EOS
ArcView	ESRI GUI-based GIS
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BMP	Best Management Practices

BRDF	Bidirectional Reflectance Distribution Function
CBP	Chesapeake Bay Program
CUNY	City University of New York
DEM	Digital Elevation Model
DO	Dissolved Oxygen
DSS	Decision Support System
DST	Decision Support Tool
EO-1	NASA's Earth Observing-1 satellite
EOS	NASA's Earth Observing System
EPA	U.S. Environmental Protection Agency
ESE	NASA's Earth Science Enterprise
ESRI	Environmental Systems Research Institute, Inc.
ET	Evapotranspiration
FPAR	Fraction of Photosynthetically Active Radiation
FSL	NOAA's Forecast Systems Laboratory
GAPP	NOAA's GEWEX Americas Prediction Project
GEWEX	Global Energy and Water Cycle Experiment
GIS	Geographic Information System
GMAO	NASA's Global Modeling and Assimilation Office
GPM	NASA's Global Precipitation Measurement Mission
GSFC	NASA's Goddard Space Flight Center
HQ	NASA Headquarters
HSPF	Hydrological Simulation Program - FORTRAN
IGBP	International Geosphere-Biosphere Programme
LAI	Leaf Area Index
LDAS	Land Data Assimilation System
LIS	Land Information System
LSM	Land Surface Model
MODIS	Moderate Resolution Imaging Spectroradiometer
MOU	Memorandum of Understanding
MVI	Modified Vegetation Index
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NDVI	Normalized Difference Vegetation Index
NEXRAD	NOAA's Next Generation Doppler Radar
NLDAS	North American Land Data Assimilation System
NOAA	National Oceanic and Atmospheric Administration
PEST	Parameter Estimation and tool for model calibration
PI	Principal Investigator
PLOAD	BASINS Pollutant Loading Application
Pot. ET	Potential Evapotranspiration
QUAL2E	Enhanced Stream Water Quality Model
RUC	Rapid Update Cycle model
SRTM	Shuttle Radar Topography Mission
SSC	NASA's Stennis Space Center
STATSGO	State Soil Geographic Database

SWAT	Soil and Water Assessment Tool
SWIR	Short Wavelength Infrared
SWM	Stanford Watershed Model
TIR	Thermal Infrared
TM	Landsat Thematic Mapper
TMDL	Total Maximum Daily Load
TRMM	Tropical Rainfall Measuring Mission
U Wind	East-West component of wind vector
UMCES	University of Maryland Center for Environmental Science
UMCP	University of Maryland, College Park
UMD	The University of Maryland
USGAO	U.S. Government Accountability Office
USGS	U.S. Geological Survey
V Wind	North-South component of wind vector
V&V	Verification and Validation
VNIR	Visible and Near Infrared

APPENDIX I – GSFC ANNUAL RESULTS

Annual Results

● = best statistic

CALFPASTURE

	Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
2001							
Default Calibrated	0.40	0.16	11.54	97.50	187.14	0.15	0.11
NLDAS 1/8th Calibrated ●	0.75	0.57	-41.87	56.75	159.19	0.39	0.48
Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
2002							
Default Calibrated	0.48	0.23	13.62	118.12	224.27	0.22	0.14
NLDAS 1/8th Calibrated ●	0.60	0.36	-54.16	79.92	215.08	0.28	0.42
Stage IV Calibrated ●	0.63	0.40	-110.75	83.32	225.51	0.21	0.40
2003							
Default Calibrated	0.54	0.29	-69.28	205.01	430.16	0.09	0.28
NLDAS 1/8th Calibrated ●	0.72	0.52	-13.26	202.52	348.75	0.40	0.29
Stage IV Calibrated ●	0.81	0.66	-75.11	207.42	412.60	0.16	0.27
2004							
Default Calibrated	0.19	0.04	22.69	183.85	415.66	0.01	-0.10
NLDAS 1/8th Calibrated ●	0.58	0.34	-12.96	107.72	352.59	0.29	0.35
Stage IV Calibrated	0.50	0.25	-116.39	114.40	409.41	0.04	0.31

DEER CREEK

	Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
2001							
Default Calibrated ●	0.83	0.68	-98.82	38.63	54.42	0.21	0.06
NLDAS 1/8th Calibrated ●	0.90	0.81	-80.09	34.03	46.21	-0.40	0.18
Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
2002							
Default Calibrated ●	0.79	0.62	-9.59	19.22	30.84	0.60	0.37
NLDAS 1/8th Calibrated	0.78	0.61	14.68	26.65	60.22	0.54	0.13
Stage IV Calibrated	0.70	0.50	-26.25	26.61	51.95	-0.12	0.13
2003							
Default Calibrated	0.60	0.37	-55.44	84.83	153.33	0.11	0.11
NLDAS 1/8th Calibrated ●	0.81	0.65	-24.40	63.42	108.46	0.53	0.34
Stage IV Calibrated	0.77	0.59	-27.93	58.38	115.61	0.50	0.39
2004							
Default Calibrated	0.39	0.15	-44.94	104.65	223.59	-0.92	-0.31
NLDAS 1/8th Calibrated	0.71	0.50	-53.23	74.38	132.83	-0.43	0.07
Stage IV Calibrated ●	0.74	0.55	-42.81	65.19	125.20	0.40	0.18

LITTLE RIVER

	Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
2001							
Default Calibrated	NA	NA	NA	NA	NA	NA	NA
NLDAS 1/8th Calibrated	NA	NA	NA	NA	NA	NA	NA
Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
2002							
Default Calibrated	0.75	0.56	-26.30	20.64	43.73	0.51	0.40
NLDAS 1/8th Calibrated ●	0.79	0.62	-14.04	20.29	38.89	0.61	0.41
Stage IV Calibrated	0.43	0.19	-16.14	25.26	75.96	-0.49	0.26
2003							
Default Calibrated	0.36	0.13	12.65	151.70	387.62	-1.04	0.06
NLDAS 1/8th Calibrated ●	0.51	0.26	11.25	114.76	294.05	-0.17	0.29
Stage IV Calibrated	0.41	0.17	9.81	136.20	340.56	-0.58	0.15
2004							
Default Calibrated	0.22	0.05	34.51	134.00	321.50	-6.86	-0.97
NLDAS 1/8th Calibrated ●	0.59	0.35	-0.75	66.94	105.55	0.15	0.02
Stage IV Calibrated	0.50	0.25	-12.69	59.65	124.17	-0.17	0.12

MAHANTANGO

	Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
2001							
Default Calibrated	0.77	0.59	-62.13	67.60	99.46	0.46	0.33
NLDAS 1/8th Calibrated	0.85	0.72	-127.84	77.34	134.97	0.00	0.24
Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
2002							
Default Calibrated	0.81	0.65	-37.52	68.42	137.10	0.58	0.50
NLDAS 1/8th Calibrated	0.64	0.41	-109.56	105.41	201.77	0.09	0.24
Stage IV Calibrated	0.80	0.65	-90.22	87.93	173.03	0.33	0.36
2003							
Default Calibrated	0.46	0.22	-48.68	207.13	388.99	0.12	0.24
NLDAS 1/8th Calibrated	0.75	0.56	-115.75	238.80	423.24	-0.05	0.12
Stage IV Calibrated	0.70	0.50	-95.22	204.17	386.77	0.13	0.25
2004							
Default Calibrated	0.85	0.73	-38.32	165.96	455.30	0.57	0.23
NLDAS 1/8th Calibrated	0.94	0.89	-104.46	184.56	521.03	0.44	0.15
Stage IV Calibrated	0.95	0.91	-90.14	161.12	469.51	0.54	0.26

NE ANACOSTIA

	Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
2001							
Default Calibrated	0.60	0.37	-123.97	45.42	148.81	0.26	0.28
NLDAS 1/8th Calibrated	0.81	0.66	-76.35	35.85	99.20	0.47	0.43
Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
2002							
Default Calibrated	0.78	0.61	-58.68	32.70	78.00	0.56	0.45
NLDAS 1/8th Calibrated	0.87	0.75	-28.75	26.64	64.88	0.69	0.55
Stage IV Calibrated	0.70	0.49	-35.76	32.85	88.95	0.43	0.45
2003							
Default Calibrated	0.83	0.68	-36.02	92.67	203.40	0.65	0.47
NLDAS 1/8th Calibrated	0.80	0.65	-26.50	81.73	220.32	0.59	0.53
Stage IV Calibrated	0.88	0.78	-33.67	84.29	193.22	0.68	0.52
2004							
Default Calibrated	0.60	0.36	-41.20	59.00	180.42	0.32	0.37
NLDAS 1/8th Calibrated	0.58	0.34	-70.67	54.60	187.11	0.27	0.42
Stage IV Calibrated	0.84	0.71	-32.87	54.60	133.40	0.63	0.59

POCOMOKE

	Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
2001							
Default Calibrated	0.58	0.34	-56.93	30.10	62.80	0.27	0.39
NLDAS 1/8th Calibrated	0.76	0.58	-46.28	29.77	59.03	0.35	0.39
Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
2002							
Default Calibrated	0.59	0.35	-138.98	43.21	86.37	0.06	0.26
NLDAS 1/8th Calibrated	0.72	0.52	-81.25	34.79	79.46	0.20	0.40
Stage IV Calibrated	0.77	0.59	-258.35	45.86	91.10	-0.05	0.21
2003							
Default Calibrated	0.20	0.04	-83.85	99.84	178.04	-0.29	0.10
NLDAS 1/8th Calibrated	0.68	0.46	-77.27	82.04	146.10	0.13	0.27
Stage IV Calibrated	0.62	0.38	-150.00	98.12	166.25	-0.13	0.13
2004							
Default Calibrated	0.04	0.00	0.53	73.12	132.97	-0.54	-0.13
NLDAS 1/8th Calibrated	0.82	0.68	-32.50	43.03	89.45	0.30	0.32
Stage IV Calibrated	0.80	0.65	-60.15	43.05	92.33	0.26	0.32

WB PATUXENT

	Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
2001							
Default Calibrated ●	0.73	0.53	-64.37	46.69	94.61	0.17	0.32
NLDAS 1/8th Calibrated ●	0.71	0.50	-35.42	30.22	75.96	0.46	0.48
Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
2002							
Default Calibrated ●	0.79	0.63	-38.30	31.36	68.42	0.50	0.37
NLDAS 1/8th Calibrated	0.74	0.55	8.52	32.11	76.37	0.38	0.42
Stage IV Calibrated	0.62	0.38	-39.39	32.99	86.65	0.20	0.41
2003							
Default Calibrated	0.72	0.52	-22.76	81.50	179.41	0.48	0.38
NLDAS 1/8th Calibrated	0.62	0.38	10.62	97.89	258.01	-0.08	0.35
Stage IV Calibrated ●	0.76	0.58	-19.28	76.69	164.35	0.56	0.49
2004							
Default Calibrated	0.64	0.41	-18.15	60.18	129.46	0.35	0.31
NLDAS 1/8th Calibrated	0.59	0.34	-6.66	58.99	165.02	-0.05	0.30
Stage IV Calibrated ●	0.81	0.66	-37.52	46.48	108.94	0.54	0.45

APPENDIX II – GSFC LOW FLOW RESULTS

Calfpasture Low Flow Period Results

● = best statistic

Low Flow Period		Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Jul 20 - Jul 25, 2001	Default Calibrated	0.95	0.9	96.54	160.75	160.97	-15043.7	-140.82
	● NLDAS 1/8th Calibrated	1	0.99	74.07	16.48	16.75	-161.93	-13.53
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Sep 19 - Sep 24, 2001	Default Calibrated	0.72	0.52	89.48	44.92	44.95	-19925.74	-154.54
	● NLDAS 1/8th Calibrated	0.95	0.9	28.03	2.06	2.34	-52.96	-6.12
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Nov 15 - Nov 24, 2001	Default Calibrated	0.02	0	61.84	7.55	7.6	-9015.39	-164
	● NLDAS 1/8th Calibrated	0.46	0.21	-463.93	3.83	3.84	-2301.15	-106.13
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Jan 3 - Jan 18, 2002	Default Calibrated	-0.21	0.04	76.33	33.26	34.43	-1826.2	-47.91
	● NLDAS 1/8th Calibrated	0.44	0.2	49.18	9.98	10.29	-162.26	-13.69
	● Stage IV Calibrated	0.29	0.08	27.55	3.92	4.35	-28.18	-4.77
Jun 29 - Jul 9, 2002	● Default Calibrated	0.96	0.91	95.86	107.26	108	-10812.75	-124.07
	NLDAS 1/8th Calibrated	0.94	0.89	67.19	9.49	10.46	-100.43	-10.07
	● Stage IV Calibrated	0.95	0.9	57.5	6.27	7.09	-45.64	-6.3
Aug 23 - Sep 15, 2002	● Default Calibrated	0.88	0.77	96.48	42.39	44.72	-4855.41	-74.66
	NLDAS 1/8th Calibrated	0.79	0.62	55.19	1.96	2.7	-16.69	-2.5
	● Stage IV Calibrated	0.48	0.23	-44.29	1.02	1.17	-2.32	-0.83
Jan 20 - Feb 17, 2003	Default Calibrated	-0.05	0	77.22	148.19	166.69	-194.58	-13.72
	NLDAS 1/8th Calibrated	-0.02	0	83.88	227.5	332.47	-777.09	-21.6
	● Stage IV Calibrated	0.66	0.43	61.83	70.83	71.73	-35.22	-6.03
Aug 24 - Sep 2, 2003	● Default Calibrated	-0.48	0.24	60.12	49.15	52.55	-135.46	-12.97
	NLDAS 1/8th Calibrated	0.88	0.78	78.2	116.96	117.05	-675.9	-32.24
	● Stage IV Calibrated	0.93	0.87	71.64	82.35	82.43	-334.72	-22.44
Oct 18 - Nov 5, 2003	● Default Calibrated	0.72	0.52	22.65	23.22	26.07	-1.54	-0.66
	NLDAS 1/8th Calibrated	0.65	0.42	49.39	77.41	78.45	-22.02	-4.53
	Stage IV Calibrated	0.56	0.31	30.09	34.14	36.77	-4.06	-1.46
Jan 1 - Feb 4, 2004	Default Calibrated	0.11	0.01	63.7	144.45	149	-18.69	-3.99
	NLDAS 1/8th Calibrated	0.09	0.01	61.31	130.42	140.33	-16.47	-3.5
	● Stage IV Calibrated	0.97	0.93	32.78	40.14	41.68	-0.54	-0.39
Jul 25 - Aug 5, 2004	Default Calibrated	0.19	0.04	88.04	185.2	188.81	-1108.28	-37.09
	NLDAS 1/8th Calibrated	0.96	0.92	47.86	23.1	23.16	-15.69	-3.75
	● Stage IV Calibrated	0.99	0.98	1.56	1.23	1.43	0.94	0.74
Aug 15 - Sep 7, 2004	Default Calibrated	0.85	0.72	84.52	96.89	98.34	-178.01	0.25
	NLDAS 1/8th Calibrated	0.91	0.82	29.81	7.6	8.99	-0.5	0.94
	● Stage IV Calibrated	0.95	0.91	-33.41	4.45	5.45	0.45	0.97

Deer Creek Low Flow Period Results

● = best statistic

Low Flow Period		Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Jul 14 - Aug 9, 2001	Default Calibrated	0.31	0.1	-147.71	24.49	24.86	-46.14	-7.03
	● NLDAS 1/8th Calibrated	0.77	0.6	-81.35	18.43	18.82	-26.02	-5.04
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Aug 26 - Sep 8, 2001	Default Calibrated	0.94	0.89	-137.23	19.34	19.41	-32.07	-5.46
	● NLDAS 1/8th Calibrated	0.97	0.95	-129.14	18.84	18.9	-30.38	-5.28
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Oct 19 - Nov 25, 2001	● Default Calibrated	0.44	0.19	-367.56	24.95	25.09	-141.88	-20.09
	● NLDAS 1/8th Calibrated	0.28	0.08	-237.17	22.32	22.63	-115.29	-17.88
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Feb 14 - Mar 2, 2002	Default Calibrated	0.73	0.53	-134.89	19.19	19.27	-260.85	-17.73
	● NLDAS 1/8th Calibrated	0.74	0.54	-113.19	17.74	17.86	-223.76	-16.33
	● Stage IV Calibrated	0.79	0.63	-746.86	29.47	29.48	-611.42	-27.77
Jun 22 - Jul 9, 2002	Default Calibrated	0.93	0.86	32.51	9.26	9.41	-4.51	-1.67
	● NLDAS 1/8th Calibrated	0.98	0.95	27.95	7.46	7.59	-2.59	-1.15
	● Stage IV Calibrated	0.98	0.96	-10.64	1.86	2.03	0.74	0.47
Aug 9 - 22, 2002	● Default Calibrated	0.47	0.22	13.77	1.2	1.96	-0.14	0.94
	● NLDAS 1/8th Calibrated	0.99	0.98	30.83	2.97	2.99	-1.65	0.86
	● Stage IV Calibrated	0.99	0.98	33.6	3.38	3.38	-2.4	0.84
Jan 12 - Feb 15, 2003	● Default Calibrated	0.77	0.59	8.95	14.78	17.31	-0.37	-0.22
	NLDAS 1/8th Calibrated	0.75	0.56	16.37	21.59	24.97	-1.84	-0.78
	● Stage IV Calibrated	0.79	0.62	15.15	19.36	22.23	-1.25	-0.6
Apr 29 - May 8, 2003	Default Calibrated	0.7	0.49	-26.96	27.29	27.76	-22.9	-4.35
	NLDAS 1/8th Calibrated	0.78	0.61	-36.67	34.48	34.94	-36.84	-5.76
	● Stage IV Calibrated	0.9	0.82	-22.24	23.38	23.71	-16.43	-3.59
Aug 20 - Sep 1, 2003	Default Calibrated	-0.02	0	-38.03	34.46	34.96	-14.97	-3.62
	NLDAS 1/8th Calibrated	0.75	0.56	-60.53	39.74	40.2	-20.12	-4.33
	● Stage IV Calibrated	0.96	0.92	-29.71	24.14	24.26	-6.69	-2.23
Jan 1 - Feb 2, 2004	● Default Calibrated	0.63	0.39	-65.56	74.47	76.25	-21.92	-5.2
	● NLDAS 1/8th Calibrated	0.53	0.29	-32.88	49.31	52.25	-9.76	-3.1
	● Stage IV Calibrated	0.5	0.25	-22.98	38.19	40.77	-5.55	-3.18
Mar 23 - 31, 2004	● Default Calibrated	0.9	0.81	-84.84	60.02	60.1	-174.22	-14.58
	● NLDAS 1/8th Calibrated	0.9	0.81	-68.28	53.06	53.21	-136.35	-12.78
	● Stage IV Calibrated	0.44	0.19	-25.88	30.19	31.64	-47.56	-6.84
Aug 14 - Sep 17, 2004	Default Calibrated	0.34	0.11	19.91	45.15	142.75	-66.99	-2.02
	● NLDAS 1/8th Calibrated	0.93	0.86	-17.15	18.48	22.28	-0.66	-0.23
	● Stage IV Calibrated	0.95	0.9	-35.91	26.91	28.07	-1.63	-0.8

Little River Low Flow Period Results

● = best statistic

Low Flow Period		Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Jun 2- 15, 2002	Default Calibrated	0.2	0.04	76.65	10.51	10.66	-133.24	-12.9
	● NLDAS 1/8th Calibrated	0.61	0.37	73.36	8.81	8.99	-94.61	-10.65
	● Stage IV Calibrated	0.7	0.48	91.38	33.93	86.83	-8913.44	-43.87
Aug 1 - 23, 2002	Default Calibrated	0.53	0.28	-45.74	0.17	0.2	-0.66	-0.26
	● NLDAS 1/8th Calibrated	0.78	0.6	82.19	1.43	2.39	-227.28	-9.69
	Stage IV Calibrated	0.57	0.32	-14.25	0.2	0.23	-1.2	-0.52
Sep 10 - Oct 10, 2002	Default Calibrated	0.58	0.33	93.82	7.6	8.02	-1134.52	-37.7
	● NLDAS 1/8th Calibrated	0.86	0.73	93.58	7.3	7.49	-991.16	-197.36
	● Stage IV Calibrated	0.42	0.18	90.41	4.72	5.84	-601.29	-23.04
Jan 7 - Feb 14, 2003	● Default Calibrated	0.71	0.5	8.86	14.52	16.34	0.4	0.22
	NLDAS 1/8th Calibrated	0.64	0.41	26.27	21.69	26.14	-0.52	-0.16
	Stage IV Calibrated	0.66	0.44	16.55	16.89	19.01	0.19	0.09
Aug 1 - Sep 12, 2003	Default Calibrated	0.68	0.46	81.8	141.64	197.5	-73.38	-6.5
	● NLDAS 1/8th Calibrated	0.72	0.52	51.43	33.54	39.5	-1.98	0.78
	● Stage IV Calibrated	0.67	0.45	46.57	29.32	41.61	-2.3	-0.55
Oct 3 - 14, 2003	● Default Calibrated	0.93	0.86	40.6	26.31	26.68	-8.41	-2.76
	● NLDAS 1/8th Calibrated	0.93	0.87	38.96	24.58	24.91	-7.21	-2.51
	● Stage IV Calibrated	0.92	0.85	27.43	14.55	14.97	-1.97	-1.08
Feb 17 - Mar 15, 2004	● Default Calibrated	0.84	0.71	-199	65.84	66.23	-25.15	-4.76
	NLDAS 1/8th Calibrated	0.84	0.7	-135.52	56.93	57.37	-18.62	-3.98
	● Stage IV Calibrated	0.89	0.79	-132.71	56.42	56.72	-18.18	-3.94
Jul 1 - Jul 14, 2004	Default Calibrated	0.61	0.37	82.91	114.69	137.53	-1302.1	-36.3
	NLDAS 1/8th Calibrated	0.67	0.45	67.71	49.57	52.98	-192.41	-15.14
	● Stage IV Calibrated	0.7	0.49	31.71	10.98	11.54	-8.17	-2.58
Aug 21 - Sep 7, 2004	● Default Calibrated	0.68	0.47	67.62	69.03	75.28	-91.16	-10.6
	● NLDAS 1/8th Calibrated	0.6	0.36	32.48	15.9	17.86	-4.19	-1.67
	Stage IV Calibrated	0.42	0.18	49.23	32.06	36.74	-20.95	-4.39

Mahantango Low Flow Period Results

● = best statistic

Low Flow Period		Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Jan 1 - 18, 2001	Default Calibrated	0.72	0.52	43.04	62.26	68.72	-65.2	-8.17
	● NLDAS 1/8th Calibrated	0.84	0.7	-71.57	34.37	34.84	-16.01	-4.05
	Stage IV Calibrated	NA	NA		NA	NA	NA	NA
Aug 23 - 31, 2001	Default Calibrated	0.81	0.66	-129.83	15.57	15.73	-19.2	-3.74
	● NLDAS 1/8th Calibrated	0.85	0.72	4.42	2	2.49	0.49	0.39
	Stage IV Calibrated	NA	NA		NA	NA	NA	NA
Oct 25 - Nov 24, 2001	● Default Calibrated	0.9	0.8	-641.06	16.97	17.06	-121.95	-11.88
	● NLDAS 1/8th Calibrated	0.82	0.67	23.79	6.12	6.93	-19.27	-3.65
	Stage IV Calibrated	NA	NA		NA	NA	NA	NA
Feb 1 - Mar 2, 2002	● Default Calibrated	0.76	0.57	-68.45	31.28	34.74	-1.54	-0.74
	● NLDAS 1/8th Calibrated	0.96	0.92	-82.19	34.72	38.78	-2.16	-0.93
	Stage IV Calibrated	0.81	0.65	-166.23	48.06	50.05	-4.26	-1.68
Jul 23 - Aug 7, 2002	Default Calibrated	0.16	0.03	-527.27	15.03	16.2	-6.12	-1.73
	NLDAS 1/8th Calibrated	0.84	0.7	58.52	25.22	25.7	-16.92	-3.59
	● Stage IV Calibrated	0.89	0.8	-178.32	11.45	11.78	-2.76	-1.08
Aug 20 - Sep 8, 2002	● Default Calibrated	0.69	0.47	-120.21	7.28	7.69	-8.12	-2.32
	NLDAS 1/8th Calibrated	0.54	0.29	47.01	11.84	12.34	-22.5	-4.39
	Stage IV Calibrated	0.36	0.13	-372.81	10.52	10.88	-17.27	-3.79
Jan 18 - 31, 2003	● Default Calibrated	0.14	0.02	16.98	41.09	51.28	-19.21	-3.34
	● NLDAS 1/8th Calibrated	0.11	0.01	21.47	35.94	38.78	-10.56	-2.79
	● Stage IV Calibrated	0.13	0.02	-95.83	64.32	66.95	-33.45	-5.78
Feb 9 - 22, 2003	● Default Calibrated	-0.53	0.28	81.07	353.24	478.42	-5025.49	-60.88
	● NLDAS 1/8th Calibrated	0.38	0.14	60.93	128.63	153.84	-518.73	-21.51
	● Stage IV Calibrated	-0.29	0.09	50.89	89.82	134.78	-397.91	-14.72
May 10 - 24, 2003	Default Calibrated	0.62	0.39	40.63	72.45	74.08	-37.66	0.75
	● NLDAS 1/8th Calibrated	0.18	0.03	9.74	14.59	18.12	-1.31	0.95
	● Stage IV Calibrated	0.83	0.68	-409.71	758.26	877.69	-1.91	0.89
Jan 21 - Feb 3, 2004	● Default Calibrated	-0.35	0.12	19.93	39.04	54.49	-6.85	-1.35
	● NLDAS 1/8th Calibrated	0.05	0	16.51	31.22	38.06	-2.83	-0.87
	● Stage IV Calibrated	0.16	0.03	-23.59	32.59	36.79	-2.58	-0.96
Jul 3 - Jul 11, 2004	Default Calibrated	0.93	0.87	-42.72	22.42	23.44	-4.69	-1.77
	NLDAS 1/8th Calibrated	0.77	0.6	16.38	14.67	16.13	-1.7	-0.81
	● Stage IV Calibrated	0.96	0.91	-21.24	13.12	13.44	-0.87	-0.62
Aug 21 - Sep 17, 2004	● Default Calibrated	0.98	0.96	45.85	96.9	172.14	-3.2	-0.69
	NLDAS 1/8th Calibrated	0.85	0.73	12.53	57.16	73.85	0.23	0
	● Stage IV Calibrated	0.95	0.91	-65.28	45.92	73.22	0.24	0.2

NE Anacostia Low Flow Period Results

● = best statistic

Low Flow Period		Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Apr 18 - May 11, 2001	● Default Calibrated	1	1	-86.9	13.77	13.82	-1.2	-0.91
	● NLDAS 1/8th Calibrated	0.99	0.98	-29.83	7.01	8.26	0.21	0.03
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Oct 7 - 13, 2001	Default Calibrated	0.81	0.65	-434.3	11.38	11.38	-452.61	-38.8
	● NLDAS 1/8th Calibrated	0.82	0.67	-359.16	10.95	10.96	-419.19	-37.33
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Nov 3 - 8, 2001	● Default Calibrated	0	0	-2704.1	15.43	15.43	1	0
	● NLDAS 1/8th Calibrated	0	0	-4784.81	15.67	15.67	1	0
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Feb 9 - 20, 2002	Default Calibrated	0.92	0.85	-681.93	15.84	15.86	-138.34	-14.4
	● NLDAS 1/8th Calibrated	0.93	0.87	-335.84	14	14.01	-107.66	-12.61
	Stage IV Calibrated	0.89	0.79	-1147.76	16.71	16.74	-154.14	-15.25
Aug 7 - 22, 2002	Default Calibrated	0.87	0.76	-443.58	4.17	4.63	-2.62	-1.49
	● NLDAS 1/8th Calibrated	0.49	0.24	-51.92	2.43	2.91	-0.43	-0.46
	● Stage IV Calibrated	0.98	0.97	-373.82	4.03	4.35	-2.21	-1.41
Oct 19 - 24, 2002	● Default Calibrated	0.93	0.87	-22.14	3.23	3.76	-0.05	-0.16
	● NLDAS 1/8th Calibrated	0.94	0.88	31.42	8.17	8.27	-4.08	-1.94
	Stage IV Calibrated	-0.15	0.02	53.35	20.39	21.69	-33.91	-6.33
Jan 10 - 26, 2003	● Default Calibrated	0.83	0.69	-90.09	21.72	22.83	-4.76	-2.18
	NLDAS 1/8th Calibrated	0.81	0.66	38.92	29.2	33.11	-11.66	-3.28
	Stage IV Calibrated	0.78	0.62	39.43	29.84	32.39	-11.11	-3.36
Apr 14 - 24, 2003	● Default Calibrated	0.95	0.9	-27.31	13.3	13.72	-1.02	0.32
	● NLDAS 1/8th Calibrated	0.83	0.69	-0.97	5.9	8.2	0.28	0.26
	● Stage IV Calibrated	0.97	0.94	-20.18	11.61	12.54	-0.69	0.09
Sep 5 - 11, 2003	Default Calibrated	0.93	0.86	-103.45	20.85	22.77	-2.23	-1.21
	● NLDAS 1/8th Calibrated	0.98	0.95	-21.96	7.38	8.67	0.53	0.22
	Stage IV Calibrated	0.91	0.83	-98.87	20.38	22.51	-2.16	-1.16
Feb 12 - Mar 1, 2004	Default Calibrated	0.89	0.8	-32.64	16.05	17.8	-0.11	-0.3
	● NLDAS 1/8th Calibrated	0.9	0.81	-25.99	13.85	15.57	0.15	-0.12
	Stage IV Calibrated	0.83	0.68	-5.14	8.56	10.77	0.59	0.31
Mar 19 - 24, 2004	Default Calibrated	0.95	0.9	-48.4	21.31	22.26	-4.7	-1.78
	NLDAS 1/8th Calibrated	0.97	0.93	-33.57	16.5	17.23	-2.41	-1.15
	● Stage IV Calibrated	0.98	0.96	-34.19	14.78	15.03	-1.6	-0.93
Aug 19 - Sep 3, 2004	Default Calibrated	0.9	0.81	33.17	14.67	20.59	-10.58	-2.01
	NLDAS 1/8th Calibrated	0.71	0.51	-49.19	10.53	11.06	-2.34	-1.16
	● Stage IV Calibrated	0.98	0.96	2.51	4.26	4.85	0.36	0.13

Pocomoke Low Flow Period Results

● = best statistic

Low Flow Period		Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Jan 1 - 14, 2001	● Default Calibrated	0.66	0.43	-0.31	1.3	1.54	0.37	0.17
	● NLDAS 1/8th Calibrated	0.92	0.86	-36.03	5.62	5.68	-7.63	-2.6
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Oct 31 - Nov 6, 2001	Default Calibrated	-0.27	0.08	-25.18	1.78	2.07	-4.07	-1.29
	● NLDAS 1/8th Calibrated	0.94	0.88	-0.4	0.44	0.51	0.7	0.43
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Dec 3 - 6, 2001	● Default Calibrated	-0.58	0.33	-23.16	1.17	1.18	-736.55	-30.2
	● NLDAS 1/8th Calibrated	0.06	0	-80.19	2.77	2.77	-4098.39	-72.87
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Feb 23 - Mar 2, 2002	Default Calibrated	0.18	0.03	-60.67	5.62	5.65	-87.91	-11.8
	● NLDAS 1/8th Calibrated	0.86	0.74	-45.83	4.68	4.68	-60.07	-9.71
	Stage IV Calibrated	0.76	0.58	-255.24	10.69	10.7	-317.38	-23.43
Jul 7 - 13, 2002	Default Calibrated	0.38	0.14	77.71	18.97	19.02	-2014.16	-48.9
	● NLDAS 1/8th Calibrated	0.99	0.97	67.6	11.36	11.38	-719.66	-28.92
	● Stage IV Calibrated	0.97	0.95	46.62	4.75	4.78	-126.25	-11.49
Aug 8 - 23, 2002	Default Calibrated	0.88	0.77	75.2	5.95	5.98	-196.46	-16.2
	● NLDAS 1/8th Calibrated	0.96	0.93	67.57	4.09	4.14	-93.47	-10.85
	● Stage IV Calibrated	0.95	0.9	30.27	0.85	0.9	-3.49	-1.47
Jan 5 - 30, 2003	● Default Calibrated	0.95	0.91	-2.08	11.54	15.11	0.6	0.41
	● NLDAS 1/8th Calibrated	0.95	0.9	-15.34	9.99	16.04	0.54	0.49
	Stage IV Calibrated	0.93	0.87	-131.39	35.8	40.78	-1.94	-0.84
Jul 17 - Aug 4, 2003	Default Calibrated	0.96	0.93	65.71	42.16	42.23	-97.48	-1.16
	NLDAS 1/8th Calibrated	0.89	0.8	60.55	33.77	33.82	-62.18	0.06
	● Stage IV Calibrated	0.98	0.96	52.26	24.09	24.15	-31.22	0.21
Oct 1 - 14, 2003	● Default Calibrated	0.97	0.94	5.35	5.51	6.14	0.62	0.34
	● NLDAS 1/8th Calibrated	0.96	0.92	2.79	3.84	4.5	0.79	0.54
	Stage IV Calibrated	0.96	0.91	-11.96	4.96	6.92	0.51	0.4
Feb 23 - Mar 5, 2004	● Default Calibrated	0.98	0.97	-37.04	16.8	18.8	-1.85	-0.76
	● NLDAS 1/8th Calibrated	0.98	0.97	-35.04	16.13	17.35	-1.42	-0.69
	● Stage IV Calibrated	0.98	0.97	-75.51	26.75	27.78	-5.22	-1.81
Jul 1 - 12, 2004	Default Calibrated	-0.2	0.04	85.38	60.73	62.21	-4397.39	-71.9
	● NLDAS 1/8th Calibrated	0.98	0.95	62.81	17.57	17.72	-355.91	-20.09
	● Stage IV Calibrated	0.98	0.96	54.74	12.58	12.71	-182.71	-14.09
Sep 4 - 14, 2004	Default Calibrated	0.94	0.89	38.69	17.16	17.35	-11.95	-3.12
	● NLDAS 1/8th Calibrated	1	1	51.89	29.32	29.34	-36.04	-6.04
	● Stage IV Calibrated	1	1	34.9	14.57	14.59	-8.16	-2.5

WB Patuxent Low Flow Period Results

● = best statistic

Low Flow Period		Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Oct 3 - 5, 2001	Default Calibrated	0.98	0.95	46.42	9.53	9.53	-135.33	-13.3
	● NLDAS 1/8th Calibrated	1	0.99	14.98	1.94	1.98	-4.88	-1.9
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Oct 8 - 14, 2001	● Default Calibrated	-0.59	0.34	57.14	11.92	12.02	-3650.39	-72.06
	● NLDAS 1/8th Calibrated	-0.26	0.07	-12.98	1.45	1.69	-70.97	-7.84
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Dec 2 - 7, 2001	● Default Calibrated	0.06	0	-61.71	5.09	5.16	-119.01	-10.45
	● NLDAS 1/8th Calibrated	0.18	0.03	-323.04	10.18	10.21	-467.75	-21.91
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Jun 21 - 27, 2002	Default Calibrated	-0.1	0.01	71.81	17.18	17.64	-68.66	-9.41
	● NLDAS 1/8th Calibrated	0.98	0.95	57.66	9.18	9.2	-17.94	-4.57
	● Stage IV Calibrated	0.98	0.96	23.73	2.1	2.17	-0.06	-0.28
Aug 8 - 27, 2002	Default Calibrated	0.29	0.08	77.4	7.24	7.35	-34.95	-7.42
	NLDAS 1/8th Calibrated	0.2	0.04	30.59	1.81	2.21	-2.24	-1.11
	● Stage IV Calibrated	0.33	0.11	-17.74	1.12	1.63	-0.76	-0.3
Oct 19 - 25, 2002	Default Calibrated	-0.14	0.02	44.53	14.16	16.48	-4.82	-1.65
	NLDAS 1/8th Calibrated	0.71	0.51	66.92	34.69	35.09	-25.37	-5.49
	● Stage IV Calibrated	0.97	0.93	41.75	12.29	12.54	-2.37	-1.3
Jan 5 - Feb 14, 2003	● Default Calibrated	0.6	0.36	13.45	22.24	28.6	0.24	0.033
	NLDAS 1/8th Calibrated	0.81	0.65	39.57	42.27	56.85	-1.99	-0.97
	● Stage IV Calibrated	0.9	0.81	39.9	43.02	48.2	-1.15	-1
Apr 19 - 25, 2003	Default Calibrated	0.58	0.34	30.86	33.67	34.66	-10.72	-2.9
	● NLDAS 1/8th Calibrated	0.89	0.79	-29.84	17.34	17.95	-2.14	-1
	● Stage IV Calibrated	0.99	0.98	-52.17	26.04	26.19	-5.69	-2.01
Sep 29 - Oct 14, 2003	Default Calibrated	0.62	0.39	55.94	59.44	60.4	-27.11	-5.89
	NLDAS 1/8th Calibrated	0.87	0.75	29.7	19.93	24.59	-3.66	-1.31
	● Stage IV Calibrated	0.96	0.92	21.77	14.3	17.86	-1.46	-0.66
Feb 15 - Mar 5, 2004	● Default Calibrated	0.83	0.69	17.58	17.56	18.75	-1.82	-0.99
	● NLDAS 1/8th Calibrated	0.91	0.83	-67.72	33.23	34.16	-8.36	-2.75
	Stage IV Calibrated	0.85	0.73	-34.35	21.04	23.54	-3.45	-1.38
May 19 - 25, 2004	Default Calibrated	0.47	0.22	33.77	23.31	24.87	-6.18	-1.8
	● NLDAS 1/8th Calibrated	0.65	0.43	-4.56	11.55	12.25	-0.74	-0.39
	● Stage IV Calibrated	0.94	0.89	-40.08	13.08	13.44	-1.1	-0.57
Aug 23 - Sep 8, 2004	Default Calibrated	0.93	0.87	68.98	52.32	52.38	-90.41	-10.93
	● NLDAS 1/8th Calibrated	0.97	0.94	-19.22	3.84	4.59	0.3	0.12
	● Stage IV Calibrated	0.99	0.98	17.26	6.07	7.82	-1.04	-0.38

APPENDIX III – GSFC STORM FLOW RESULTS

CONVECTIVE STORM PERIOD FLOW RESULTS

● = best statistic

CALFPASTURE - Convective Storms		Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
TWO DAYS BEFORE/AFTER STORM								
Jun 29-Jul 3, 2001: precipitation = 0.97 inches	Default Calibrated	-0.74	0.55	92.43	139.12	140.26	-18916.21	-157.18
storm occurred Jul 1, 2001 (h17-h20)	● NLDAS 1/8th Calibrated	0.96	0.92	79.37	43.86	43.87	-1849.68	-48.84
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Jul 8-12, 2002: precipitation = 0.98 inches	Default Calibrated	0.14	0.02	94.54	255.88	-378.81	-378.81	-21.07
storm occurred Jul 10, 2002 (h0-h2)	● NLDAS 1/8th Calibrated	0.86	0.73	26.84	9.08	10.33	0.61	0.23
	● Stage IV Calibrated	0.83	0.69	-14.17	8	11.95	0.48	0.29
Aug 9-13, 2003: precipitation = 0.76 inches	Default Calibrated	0.64	0.41	-160.88	177.76	271.59	-0.61	0.12
storm occurred Aug 11, 2003 (h17-h18)	● NLDAS 1/8th Calibrated	0.82	0.68	-16.63	163.69	192.01	0.2	0.19
	● Stage IV Calibrated	0.91	0.82	-49.75	171.07	222.42	-0.08	0.15
Jul 8-12, 2004: precipitation = 0.89 inches	Default Calibrated	-0.25	0.06	23.48	185.94	205.05	-0.07	-0.17
storm occurred Jul 10, 2004 (h11)	● NLDAS 1/8th Calibrated	0.79	0.62	-58.67	124.13	-0.03	-0.03	0.22
	● Stage IV Calibrated	0.93	0.86	-169.2	109.2	214.08	-0.16	0.31
DEER CREEK - Convective Storms								
TWO DAYS BEFORE/AFTER STORM								
Aug 1-5, 2001: precipitation = 1.16 inches	Default Calibrated	0.47	0.22	-120.41	20.98	21.88	-180.28	-15.4
storm occurred Aug 3, 2001 (h19-h21)	● NLDAS 1/8th Calibrated	0.74	0.55	-21	-120.72	21.03	-166.57	-15.42
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Aug 1-5, 2002: precipitation = 0.6 inches	Default Calibrated	0.15	0.02	-101.6	12.48	21.33	-0.49	0.14
storm occurred Aug 3, 2002 (h15-h17)	NLDAS 1/8th Calibrated	0.84	0.71	-57.75	11.09	18	-0.06	0.24
	● Stage IV Calibrated	0.96	0.92	-31.42	7.24	12.39	0.5	0.5
Jul 20-24, 2003: precipitation = 1.38 inches	Default Calibrated	0.64	0.4	32.81	115.99	150.82	-16.15	-2.32
storm occurred Jul 22, 2003 (h17-h18)	● NLDAS 1/8th Calibrated	0.96	0.92	-80.24	73.19	76.63	-3.43	-1.1
	● Stage IV Calibrated	0.97	0.94	-110.27	86.22	91.15	-5.26	-1.47
Aug 20-22, 2004: precipitation = 1.2 inches	Default Calibrated	0.06	0	74.58	346.24	481.09	-26704.66	-128.88
storm occurred Aug 20, 2004 (h23)	● NLDAS 1/8th Calibrated	0.65	0.43	-3.01	4.14	4.72	-1.57	-0.5
	Stage IV Calibrated	-0.26	0.07	-26.62	24.81	25.15	-71.99	-8.29
LITTLE RIVER - Convective Storms								
TWO DAYS BEFORE/AFTER STORM								
May 30-Jun 3, 2001: precipitation = 2.05 inches	Default Calibrated	NA	NA	NA	NA	NA	NA	NA
storm occurred Jun 1, 2001 (h15-h18)	NLDAS 1/8th Calibrated	NA	NA	NA	NA	NA	NA	NA
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Jul 18-22, 2003: precipitation = 1.38 inches	Default Calibrated	-0.05	0	63.5	110.81	226.46	-123.79	-1.22
storm occurred Jul 20, 2003 (h15-h16)	● NLDAS 1/8th Calibrated	-0.46	0.21	27.53	26.57	33.82	-1.78	0.47
	● Stage IV Calibrated	0.71	0.5	52.15	68.43	112.02	-29.54	-0.37
Jun 8-12, 2004: precipitation = 2.70 inches	● Default Calibrated	0.71	0.5	69.97	199.14	501.43	-36.61	-11.03
storm occurred Jun 10, 2004 (h0-h3)	NLDAS 1/8th Calibrated	-0.29	0.08	75.07	115.62	162.83	-994.21	-0.55
	● Stage IV Calibrated	-0.22	0.05	42.31	28.16	34.45	-43.55	0.62
Sep 6-10, 2004: precipitation = 2.55 inches	● Default Calibrated	0.99	0.97	30.25	97.13	157.2	0.5	0.45
storm occurred Sep 8, 2004 (h21-h23)	● NLDAS 1/8th Calibrated	1	1	-66.06	97.31	143.22	0.58	0.45
	Stage IV Calibrated	0.27	0.07	54.45	309.04	577.18	-5.75	-0.73
MAHANTANGO - Convective Storms								
TWO DAYS BEFORE/AFTER STORM								
Sep 22-26, 2001: precipitation = 1.06 inches	Default Calibrated	0.91	0.82	-976.14	105.95	154.83	-0.61	0.03
storm occurred Sep 24, 2001 (h18-h19)	● NLDAS 1/8th Calibrated	0.95	0.9	-181.43	79.09	130.95	-0.15	0.28
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Sep 20-24, 2002: precipitation = 1.02 inches	● Default Calibrated	1	1	-554.48	38.63	46.34	-0.96	-0.19
storm occurred Sep 22, 2002 (h21-h23)	● NLDAS 1/8th Calibrated	0.97	0.95	-45.06	20.36	27.6	0.31	0.37
	Stage IV Calibrated	0.94	0.88	-139.07	26.53	34.82	-0.11	0.18
Jul 20-24, 2003: precipitation = 1.38 inches	● Default Calibrated	0.58	0.34	10.34	167.45	255.86	0.09	0.24
storm occurred Jul 22, 2003 (h17-h18)	NLDAS 1/8th Calibrated	0.8	0.64	-122.68	228.86	311.99	-0.36	-0.03
	● Stage IV Calibrated	0.94	0.88	-148.01	201	294.43	-0.21	0.09
Aug 18-22, 2004: precipitation = 1.2 inches	● Default Calibrated	0.99	0.97	53.64	244.56	355.36	-6.66	-0.95
storm occurred Aug 20, 2004 (h23)	● NLDAS 1/8th Calibrated	0.92	0.85	-42.25	100.46	131.43	-0.05	0.2
	Stage IV Calibrated	0.97	0.94	-102.17	106.84	144.36	-0.26	0.15

CONVECTIVE STORM PERIOD FLOW RESULTS

● = best statistic

		Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
NE ANACOSTIA - Convective Storms								
TWO DAYS BEFORE/AFTER STORM								
Jun 14-18, 2001: precipitation = 0.96	Default Calibrated	0.97	0.94	33.59	71.44	125.05	-0.57	0.08
storm occurred Jun 16, 2001 (h13)	● NLDAS 1/8th Calibrated	0.98	0.96	-42.66	46.66	67.59	0.54	0.4
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Jun 11-15, 2002: precipitation = 1.52	Default Calibrated	0.62	0.39	75.89	127.2	243.85	-146.39	-5.51
storm occurred Jun 13, 2002 (h14)	NLDAS 1/8th Calibrated	0.4	0.16	65.98	70.59	95.2	-21.46	-2.62
	● Stage IV Calibrated	0.9	0.81	-33.41	9.12	12.84	0.59	0.53
Aug 24-28, 2003: precipitation = 0.93	● Default Calibrated	0.8	0.64	-10.54	58.57	71.77	0.4	0.32
storm occurred Aug 26, 2003 (h16)	● NLDAS 1/8th Calibrated	0.96	0.93	-112.55	63.97	85.9	0.15	0.26
	Stage IV Calibrated	0.9	0.81	-192.67	79.52	103.77	-0.25	0.09
Aug 10-14, 2004: precipitation = 2.11	Default Calibrated	0.92	0.85	59.04	336.79	590.59	-12.47	-1.47
storm occurred Aug 12, 2004 (h16-h17)	NLDAS 1/8th Calibrated	0.98	0.96	-154.59	130.43	173.95	-0.17	0.04
	● Stage IV Calibrated	0.99	0.98	-29.91	49.45	65.78	0.83	0.64
POCOMOKE - Convective Storms								
TWO DAYS BEFORE/AFTER STORMS								
Sep 2-6, 2001: precipitation = 0.99 inches	● Default Calibrated	-0.56	0.31	-12.02	2.63	3.39	-4.76	-1.18
storm occurred Sep 4, 2001 (h17)	● NLDAS 1/8th Calibrated	0.99	0.99	50.66	20.53	20.53	-209.81	-16.12
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Jul 7-11, 2002: precipitation = 0.96 inches	Default Calibrated	-0.26	0.07	77.21	19.24	19.31	-6954.74	-104
storm occurred Jul 9, 2002 (h19-h22)	NLDAS 1/8th Calibrated	0.96	0.93	67.32	11.7	11.71	-2556.44	-62.59
	● Stage IV Calibrated	0.98	0.96	46.61	4.96	4.98	-461.58	-25.85
Aug 28-Sep 1, 2003: precipitation = 0.80 inches	Default Calibrated	0.92	0.85	13.8	10.46	11.12	-0.08	-0.01
storm occurred Aug 30, 2003 (h14-h15)	● NLDAS 1/8th Calibrated	0.98	0.96	10.18	8.09	8.55	0.36	0.22
	● Stage IV Calibrated	0.93	0.87	9.22	7.89	8.37	0.39	0.24
Jul 5-9, 2004: precipitation = 1.87 inches	Default Calibrated	-0.47	0.22	85.6	60.04	60.59	-16385.46	-166
storm occurred Jul 7, 2004 (h16-h18)	NLDAS 1/8th Calibrated	0.92	0.84	62.39	16.76	16.81	-1260.38	-45.56
	● Stage IV Calibrated	0.93	0.87	54.28	11.99	12.04	-646.48	-32.28
WB PATUXENT - Convective Storms		Corr. Coefficient	Coeff. of Determination	% Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
TWO DAYS BEFORE/AFTER STORM								
Jun 15-19, 2001: precipitation = 1.05 inches	Default Calibrated	0.53	0.28	10.51	44	58.37	-0.13	0.1
storm occurred Jun 17, 2001 (h12-h14)	● NLDAS 1/8th Calibrated	0.67	0.45	-8.8	28.34	41.47	0.43	0.42
	Stage IV Calibrated	NA	NA	NA	NA	NA	NA	NA
Jun 11-15, 2002: precipitation = 1.82 inches	Default Calibrated	0.5	0.25	67.85	52.94	74.32	-19.97	-2.69
storm occurred Jun 13, 2002 (h11-h15)	NLDAS 1/8th Calibrated	0.67	0.45	52.38	27.59	36.37	-4.02	-0.92
	● Stage IV Calibrated	0.94	0.88	-42.69	7.5	10.32	0.6	0.48
Aug 24-28, 2003: precipitation = 0.93 inches	Default Calibrated	0.53	0.28	26.52	64.4	67.83	0.07	-0.02
storm occurred Aug 26, 2003 (h16)	● NLDAS 1/8th Calibrated	0.83	0.7	-38.89	39.62	58.3	0.31	0.38
	● Stage IV Calibrated	0.98	0.96	-143.45	51.62	73.75	-0.1	0.19
Aug 10-14, 2004: precipitation = 2.43 inches	Default Calibrated	0.68	0.47	34.26	105.05	182.28	-0.32	0.12
storm occurred Aug 12, 2004 (h16-h20)	NLDAS 1/8th Calibrated	0.79	0.62	-98.99	106.6	165.28	-0.09	0.11
	● Stage IV Calibrated	0.87	0.76	-27.54	71.77	89.47	0.68	0.4

APPENDIX IV – HUNTER ANNUAL RESULTS

Annual Results

● = best statistic

CALFPASTURE

		Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)
2001						
Default Calibrated		0.52	-28.40	75.12	182.97	0.24
NLDAS 1/8th Precipitation	●	0.83	-40.88	49.01	135.53	**0.58**
NLDAS 1/8th ET		0.36	48.41	125.62	277.78	-0.74
NLDAS 1/8th Precipitation & ET	●	**0.85**	-34.27	57.16	137.46	0.57
2002						
Default Calibrated		0.65	21.22	73.73	176.05	0.39
NLDAS 1/8th Precipitation	●	**0.82**	-23.83	53.57	140.39	**0.61**
NLDAS 1/8th ET		0.59	76.82	107.98	257.29	-0.31
NLDAS 1/8th Precipitation & ET		0.76		56.36	162.92	0.47
2003						
Default Calibrated		0.51	-53	70.39	426.55	0.11
NLDAS 1/8th Precipitation	●	**0.81**	-5.93	46.62	270.64	**0.64**
NLDAS 1/8th ET		0.57	-48.87	68.51	402.84	0.21
NLDAS 1/8th Precipitation & ET		0.78	-8.89	48.35	291.51	0.58
2004						
Default Calibrated		0.25	6.79	87.50	424.42	-0.03
NLDAS 1/8th Precipitation	●	**0.79**	-3.22	49.33	262.93	**0.60**
NLDAS 1/8th ET		0.22	24.79	105.79	468.13	-0.26
NLDAS 1/8th Precipitation & ET		0.68	-14.16	62.08	307.94	0.46

DEER CREEK

		Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)
2001						
Default Calibrated	●	**0.78**	-42.86	42.90	56.56	0.19
NLDAS 1/8th Precipitation		0.73	-36.47	39.89	54.30	0.25
NLDAS 1/8th ET		0.72	-46.32	47.83	60.61	0.07
NLDAS 1/8th Precipitation & ET	●	0.76	-29.20	36.76	47.79	**0.42**
2002						
Default Calibrated		0.64	81.89	92.22	56.27	-1.20
NLDAS 1/8th Precipitation	●	**0.74**	43.12	63.02	35.94	**0.10**
NLDAS 1/8th ET		0.63	81.56	95.33	56.87	-1.25
NLDAS 1/8th Precipitation & ET		0.72	62.04	81.01	54.95	-1.10
2003						
Default Calibrated		0.57	-7.09	31.88	121.76	0.31
NLDAS 1/8th Precipitation	●	**0.79**	1.75	24.57	92.39	**0.60**
NLDAS 1/8th ET		0.45	-12.75	32.73	133.69	0.17
NLDAS 1/8th Precipitation & ET		0.72	-3.22	29.42	105.91	0.48
2004						
Default Calibrated		0.32	-5.42	54.31	202.67	-0.57
NLDAS 1/8th Precipitation	●	**0.70**	-9.51	28.15	116.36	**0.48**
NLDAS 1/8th ET		0.27	-20.11	48.11	164.50	-0.04
NLDAS 1/8th Precipitation & ET		0.65	-12.15	36.54	127.3	0.38

LITTLE RIVER

		Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)
2002						
Default Calibrated		0.75	3.55	64.07	34.85	0.56
NLDAS 1/8th Precipitation	●	0.89	-8.57	56.30	24.80	**0.78**
NLDAS 1/8th ET		0.79	-36.69	55.67	39.70	0.43
NLDAS 1/8th Precipitation & ET	●	**0.90**	-8.63	53.82	25.25	0.77
2003						
Default Calibrated		0.52	-23.17	58.96	225.93	0.24
NLDAS 1/8th Precipitation		0.68	2.33	43.48	198.34	0.42
NLDAS 1/8th ET		0.51	-9.55	60.48	223.95	0.26
NLDAS 1/8th Precipitation & ET	●	**0.70**	5.29	41.20	193.96	**0.44**
2004						
Default Calibrated		0.13	13.94	95.71	190.10	-1.75
NLDAS 1/8th Precipitation		0.63	-2.75	58.54	98.20	0.27
NLDAS 1/8th ET		0.13	33.06	105.40	233.36	-3.14
NLDAS 1/8th Precipitation & ET	●	**0.74**	-20.86	46.11	80.92	**0.5**

MAHANTANGO

		Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)
2001						
Default Calibrated	●	**0.81**	-32.01	47.25	95.49	**0.53**
NLDAS 1/8th Precipitation		0.72	-15.40	47.66	104.38	0.44
NLDAS 1/8th ET		0.70	-11.29	50.79	106.51	0.41
NLDAS 1/8th Precipitation & ET		0.72	-13.79	48.28	104.52	0.44
2002						
Default Calibrated	●	**0.85**	14.67	37.74	93.81	0.70
NLDAS 1/8th Precipitation		0.80	16.72	43.63	117.41	0.53
NLDAS 1/8th ET	●	**0.85**	8.72	35.37	92.92	**0.71**
NLDAS 1/8th Precipitation & ET		0.76	7.25	49.88	118.75	0.52
2003						
Default Calibrated		0.44	-11.47	53.72	341.06	0.16
NLDAS 1/8th Precipitation	●	**0.82**	-7.07	34.82	219.45	0.65
NLDAS 1/8th ET		0.41	-9.32	56.32	350.84	0.11
NLDAS 1/8th Precipitation & ET	●	**0.82**	-2.01	35.82	211.78	**0.68**
2004						
Default Calibrated		0.73	1.02	69.58	483.48	0.52
NLDAS 1/8th Precipitation		0.91	-7.82	38.52	317.37	0.79
NLDAS 1/8th ET		0.76	-1.78	71.84	455.96	0.57
NLDAS 1/8th Precipitation & ET	●	**0.93**	-4.43	44.7	275.92	**0.84**

NE ANACOSTIA

		Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)
2001						
Default Calibrated		0.68	-12.04	50.53	104.47	0.45
NLDAS 1/8th Precipitation		0.79	-16.00	50.19	87.08	0.62
NLDAS 1/8th ET	●	**0.80**	-9.53	51.16	85.22	**0.64**
NLDAS 1/8th Precipitation & ET	●	**0.80**	-8.09	52.37	85.73	0.63
2002						
Default Calibrated		0.8	24.24	56.1	70.6	0.52
NLDAS 1/8th Precipitation	●	**0.86**	33.10	59.90	62.66	0.62
NLDAS 1/8th ET		0.79	16.98	59.16	72.61	0.49
NLDAS 1/8th Precipitation & ET	●	0.85	18.21	55.16	60.23	**0.65**
2003						
Default Calibrated	●	0.85	-7.32	42.81	181.57	**0.73**
NLDAS 1/8th Precipitation		0.85	-11.35	37.96	186.23	0.71
NLDAS 1/8th ET		0.85	-10.08	43.25	185.01	0.71
NLDAS 1/8th Precipitation & ET	●	**0.87**	-13.02	36.39	180.31	**0.73**
2004						
Default Calibrated	●	**0.65**	-9.10	52.31	176.42	0.35
NLDAS 1/8th Precipitation		0.61	-22.02	46.90	176.22	0.35
NLDAS 1/8th ET		0.64	-14.69	52.89	174.56	0.36
NLDAS 1/8th Precipitation & ET	●	**0.65**	-26.18	47.45	169.48	**0.4**

POCOMOKE

		Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)
2001						
Default Calibrated		0.47	-22.84	62.14	74.20	0.02
NLDAS 1/8th Precipitation	●	**0.88**	1.96	36.30	39.49	**0.72**
NLDAS 1/8th ET		0.49	-16.20	62.53	74.57	0.01
NLDAS 1/8th Precipitation & ET		0.81	4.94	44.79	47.92	0.59
2002						
Default Calibrated		0.51	-14.82	65.52	75.62	0.25
NLDAS 1/8th Precipitation	●	**0.87**	29.61	52.91	48.40	**0.69**
NLDAS 1/8th ET		0.61	-5.16	65.00	69.21	0.37
NLDAS 1/8th Precipitation & ET		0.85	24.36	48.84	50.19	0.67
2003						
Default Calibrated		0.38	-21.85	59.74	143.13	-0.03
NLDAS 1/8th Precipitation	●	**0.91**	-20.61	32.39	68.70	**0.76**
NLDAS 1/8th ET		0.39	-24.90	59.35	140.88	0.00
NLDAS 1/8th Precipitation & ET		0.90	-22.85	31.91	77.60	0.70
2004						
Default Calibrated		0.14	35.03	107.26	138.96	-0.69
NLDAS 1/8th Precipitation	●	**0.85**	-6.68	44.35	56.45	**0.72**
NLDAS 1/8th ET		0.16	19.05	94.21	130.18	-0.48
NLDAS 1/8th Precipitation & ET		0.81	-15.34	46.11	64.49	0.64

WB PATUXENT

	Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)
2001					
Default Calibrated	0.77	-23.24	41.50	72.81	0.54
NLDAS 1/8th Precipitation	0.77	-17.36	41.14	69.83	0.58
NLDAS 1/8th ET	0.78	-9.12	43.86	67.92	0.60
NLDAS 1/8th Precipitation & ET	0.76	-14.87	45.02	70.71	0.56
2002					
Default Calibrated	0.82	18.27	55.04	46.86	0.64
NLDAS 1/8th Precipitation	0.83	-0.67	47.49	44.43	0.68
NLDAS 1/8th ET	0.80	11.60	55.58	47.91	0.63
NLDAS 1/8th Precipitation & ET	0.82	0.61	51.20	45.46	0.66
2003					
Default Calibrated	0.81	0.29	36.36	145.95	0.66
NLDAS 1/8th Precipitation	0.80	3.95	36.35	152.51	0.63
NLDAS 1/8th ET	0.83	-4.68	35.62	141.55	0.68
NLDAS 1/8th Precipitation & ET	0.82	2.02	35.24	141.86	0.68
2004					
Default Calibrated	0.71	-19.37	43.96	115.15	0.49
NLDAS 1/8th Precipitation	0.81	-8.81	35.49	94.09	0.66
NLDAS 1/8th ET	0.61	-23.54	48.91	130.66	0.34
NLDAS 1/8th Precipitation & ET	0.71	-3.55	47.32	123.83	0.41

APPENDIX V – HUNTER LOW FLOW RESULTS

Calfpasture Low Flow Period Results

● = best statistic

Low Flow Period			Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Jul 20 - 25, 2001	Default Calibrated	●	0.99	988.27	988.27	58.61	-1993.62	-49.29
	NLDAS 1/8th Precipitation	●	0.97	126.29	126.29	7.35	-30.33	-5.43
	NLDAS 1/8th ET	●	0.99	2917.79	2917.79	189.29	-20803.15	-147.46
	NLDAS 1/8th Precipitation & ET	●	0.99	280.07	280.07	16.69	-160.79	-13.25
Sep 19 - 24, 2001	Default Calibrated	●	0.95	52.99	52.99	3.34	-109.09	-8.69
	NLDAS 1/8th Precipitation	●	0.91	26.44	26.44	1.85	-32.7	-3.84
	NLDAS 1/8th ET	●	0.95	-35.26	35.71	2.51	-61.16	-5.53
	NLDAS 1/8th Precipitation & ET		0.85	123.04	123.04	6.6	-428.98	-21.5
Nov 15 - 24, 2001	Default Calibrated		0.04	-83.69	83.69	4.03	-2531.64	-59.94
	NLDAS 1/8th Precipitation		0.36	-90.04	90.04	4.2	-2752.18	-64.56
	NLDAS 1/8th ET		0.16	-89.3	89.3	4.25	-2826.97	-64.02
	NLDAS 1/8th Precipitation & ET	●	0.58	-81.64	81.64	3.81	-2269.95	-58.44
Jan 3 - 18, 2002	Default Calibrated		0.01	18.48	48.29	5.63	-47.91	-6.33
	NLDAS 1/8th Precipitation	●	0.67	-29.13	29.13	3.44	-17.3	-3.42
	NLDAS 1/8th ET		-0.13	101.83	121.1	15.91	-389.18	-17.37
	NLDAS 1/8th Precipitation & ET		0.66	-35.07	35.07	4.01	-23.8	-4.32
Jun 29 - Jul 9, 2002	Default Calibrated	●	0.99	332.25	332.25	15.78	-229.75	-16.96
	NLDAS 1/8th Precipitation		0.96	231.3	231.3	10.95	-110.12	-11.5
	NLDAS 1/8th ET		0.94	258.74	258.74	13.87	-177.35	-12.98
	NLDAS 1/8th Precipitation & ET	●	0.97	134.57	134.57	6.56	-38.94	-6.27
Aug 23 - Sep 15, 2002	Default Calibrated		0.59	257.51	257.51	5.75	-79.29	-6.12
	NLDAS 1/8th Precipitation		0.76	237.17	237.17	4.31	-44.03	-5.55
	NLDAS 1/8th ET		0.57	214.21	258.45	6.37	-97.54	-6.14
	NLDAS 1/8th Precipitation & ET	●	0.78	182.76	182.76	3.57	-29.99	-4.05
Jan 20 - Feb 17, 2003	Default Calibrated		-0.15	406.35	406.35	289.84	-590.35	-16.64
	NLDAS 1/8th Precipitation		-0.32	313.34	313.34	179.98	-227.02	-12.6
	NLDAS 1/8th ET		-0.11	200.24	241.01	279.64	-549.46	-9.46
	NLDAS 1/8th Precipitation & ET	●	-0.06	109.22	109.22	66.75	-30.37	-3.74
Aug 24 - Sep 2, 2003	Default Calibrated	●	-0.68	-73.97	73.97	26.43	-33.5	-5.85
	NLDAS 1/8th Precipitation		0.86	145.15	145.15	47.41	-110.03	-12.44
	NLDAS 1/8th ET		-0.48	91.74	143.43	116.81	-673.14	-12.28
	NLDAS 1/8th Precipitation & ET	●	0.93	163.86	163.86	54.19	-144.1	-14.18
Oct 18 - Nov 5, 2003	Default Calibrated	●	0.94	-49.44	49.44	39.97	-4.98	-1.8
	NLDAS 1/8th Precipitation		0.56	-19.94	20.15	21.63	-0.75	-0.14
	NLDAS 1/8th ET	●	0.94	-42.61	42.61	34.25	-3.39	-1.41
	NLDAS 1/8th Precipitation & ET	●	0.74	-9.65	13.35	13.6	0.31	0.24
Jan 1 - Feb 4, 2004	Default Calibrated		0.13	201.91	201.91	182.46	-28.53	-4.74
	NLDAS 1/8th Precipitation		-0.1	61.41	63.51	97.37	-7.41	-0.81
	NLDAS 1/8th ET		0.08	73.64	93.14	103.85	-8.56	-1.65
	NLDAS 1/8th Precipitation & ET	●	0.79	-12.8	20.72	23.24	0.52	0.41
Jul 25 - Aug 5, 2004	Default Calibrated		0.04	304.01	304.01	87.46	-237.01	-14.74
	NLDAS 1/8th Precipitation	●	0.91	-1.64	11.6	3.57	0.6	0.4
	NLDAS 1/8th ET		0.27	1630.93	1630.93	541.32	-9116.59	-83.44
	NLDAS 1/8th Precipitation & ET		0.96	30.25	30.25	7.81	-0.9	-0.57
Aug 15 - Sep 7, 2004	Default Calibrated	●	0.87	-0.72	14.78	3.68	0.75	0.53
	NLDAS 1/8th Precipitation		0.94	-12.56	16.15	3.78	0.74	0.49
	NLDAS 1/8th ET		0.94	14.95	45.88	9.14	-0.55	-0.45
	NLDAS 1/8th Precipitation & ET	●	0.98	135.87	135.87	30.29	-15.98	-3.29

Deer Creek Low Flow Period Results

● = best statistic

Low Flow Period			Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Jul 14 - Aug 9, 2001	Default Calibrated		0.55	-27.95	28.68	12.25	-10.45	-2.86
	NLDAS 1/8th Precipitation	●	0.76	15.65	17.42	8.49	-4.5	-1.35
	NLDAS 1/8th ET		0.21	-25.49	29.32	13.33	-12.56	-2.95
	NLDAS 1/8th Precipitation & ET		0.72	22.98	23.67	11.05	-8.32	-2.19
Aug 26 - Sep 08, 2001	Default Calibrated		0.89	-9.81	9.81	3.61	-0.15	-0.09
	NLDAS 1/8th Precipitation		0.97	-6.62	6.62	2.51	0.45	0.26
	NLDAS 1/8th ET		0.94	15.57	15.72	6.03	-2.19	-0.75
	NLDAS 1/8th Precipitation & ET	●	0.98	-1.59	2.2	1.03	0.91	0.76
Oct 19 - Nov 25, 2001	Default Calibrated	●	0.3	-47.93	47.93	16.55	-61.21	-11.86
	NLDAS 1/8th Precipitation		0.24	-43.72	43.72	14.68	-47.92	-10.73
	NLDAS 1/8th ET	●	0.3	-56.29	56.44	19.61	-86.33	-14.14
	NLDAS 1/8th Precipitation & ET	●	0.24	-40.18	40.18	13.51	-40.45	-9.78
Feb 14 - Mar 2, 2002	Default Calibrated	●	0.74	-11.41	14.62	5.79	-22.63	-3.77
	NLDAS 1/8th Precipitation	●	0.77	-21.62	21.62	7.42	-37.84	-6.05
	NLDAS 1/8th ET		0.74	-41.97	41.97	14.72	-151.68	-12.69
	NLDAS 1/8th Precipitation & ET		0.75	-24.75	24.75	8.47	-49.55	-7.07
Jun 22 - Jul 9, 2002	Default Calibrated	●	0.94	162.35	162.35	31.59	-61.13	-8
	NLDAS 1/8th Precipitation	●	0.98	182.06	182.06	35.11	-75.75	-9.09
	NLDAS 1/8th ET		0.91	206.64	206.64	40.66	-101.91	-10.45
	NLDAS 1/8th Precipitation & ET	●	0.98	195.7	195.7	37.7	-87.5	-9.84
Aug 9 - Aug 22, 2002	Default Calibrated	●	0.26	234.36	234.36	15.85	-73.47	-8.8
	NLDAS 1/8th Precipitation	●	0.99	332.87	332.87	22.24	-145.61	-12.91
	NLDAS 1/8th ET		0.62	252.85	252.85	17.07	-85.41	-9.57
	NLDAS 1/8th Precipitation & ET	●	0.99	303.66	303.66	20.27	-120.76	-11.69
Jan 12 - Feb 15, 2003	Default Calibrated		0.76	32	33.21	40.58	-6.51	-1.77
	NLDAS 1/8th Precipitation		0.74	43.99	43.99	46.81	-8.99	-2.67
	NLDAS 1/8th ET	●	0.68	-4.99	20.54	25.93	-2.07	-0.71
	NLDAS 1/8th Precipitation & ET	●	0.79	19.25	21.01	24.95	-1.84	-0.75
Apr 29 - May 8, 2003	Default Calibrated		0.48	-0.51	6.49	9.82	-1.99	-0.63
	NLDAS 1/8th Precipitation	●	0.9	-2.47	4.99	7.12	-0.57	-0.26
	NLDAS 1/8th ET		0.29	-2.16	7.64	11.8	-3.32	-0.92
	NLDAS 1/8th Precipitation & ET		0.85	-16.36	16.36	21.28	-13.04	-3.12
Aug 20 - Sep 1, 2003	Default Calibrated		0.52	30.43	30.82	41.32	-21.31	-3.36
	NLDAS 1/8th Precipitation	●	0.75	8.79	9.05	10.95	-0.57	-0.28
	NLDAS 1/8th ET		0.72	61.59	61.59	65.91	-55.75	-7.71
	NLDAS 1/8th Precipitation & ET	●	0.94	22.07	22.07	24.5	-6.84	-2.12
Jan 1 - Feb 2, 2004	Default Calibrated		0.62	-25.73	25.81	52.92	-10.04	-3.04
	NLDAS 1/8th Precipitation	●	0.56	-10.12	14.03	29.5	-2.43	-1.2
	NLDAS 1/8th ET		0.65	-45.06	45.06	86.3	-28.35	-6.05
	NLDAS 1/8th Precipitation & ET	●	0.89	-31.62	31.62	59.93	-13.15	-3.95
Mar 23 - 31, 2004	Default Calibrated		0.89	-34.47	34.47	45.69	-100.26	-10.7
	NLDAS 1/8th Precipitation	●	0.88	-19.07	19.07	25.69	-31.02	-5.47
	NLDAS 1/8th ET		0.9	-41.48	41.48	54.57	-143.43	-13.08
	NLDAS 1/8th Precipitation & ET	●	0.91	-33.4	33.4	43.74	-91.8	-10.34
Aug 14 - Sep 17, 2004	Default Calibrated		0.46	99.48	99.48	168.17	-93.36	-5.54
	NLDAS 1/8th Precipitation	●	0.92	42.15	42.59	60.59	-11.25	-1.8
	NLDAS 1/8th ET		0.74	82.65	82.65	95.45	-29.4	-4.43
	NLDAS 1/8th Precipitation & ET	●	0.94	56.09	56.28	71.34	-15.98	-2.7

Little River Low Flow Period Results

● = best statistic

Low Flow Period		Best	Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Jun 2 - 15, 2002	Default Calibrated		-0.36	123.86	167.43	6.36	-46.83	-6.08
	NLDAS 1/8th Precipitation		0.49	270.95	270.95	8.94	-93.47	-10.45
	NLDAS 1/8th ET		-0.11	19.16	74.28	2.62	-7.13	-2.14
	NLDAS 1/8th Precipitation & ET	●	0.54	18.87	49.96	1.92	-3.38	-1.11
Aug 1 - 23, 2002	Default Calibrated	●	0.71	-57.38	67.99	0.24	-1.26	-0.56
	NLDAS 1/8th Precipitation	●	0.58	-51.59	58.39	0.21	-0.78	-0.34
	NLDAS 1/8th ET		0.53	-52.22	73.7	0.26	-1.66	-0.7
	NLDAS 1/8th Precipitation & ET		0.35	-62.1	90.61	0.35	-4	-1.08
Sep 10 - Oct 10, 2002	Default Calibrated		0.51	1134.34	1137.28	7.18	-909.04	-27.96
	NLDAS 1/8th Precipitation	●	0.86	446.12	446.12	2.88	-145.98	-10.36
	NLDAS 1/8th ET		0.55	1011.13	1011.4	6.06	-646.8	-24.75
	NLDAS 1/8th Precipitation & ET	●	0.86	483.52	486.97	3.17	-176.01	-11.4
Jan 7 - Feb 14, 2003	Default Calibrated		0.86	-21.58	23.65	16.33	0.41	0.35
	NLDAS 1/8th Precipitation		0.7	-0.14	26.47	16.92	0.36	0.27
	NLDAS 1/8th ET	●	0.88	-21.35	22.63	14.96	0.5	0.38
	NLDAS 1/8th Precipitation & ET		0.81	27.71	37.57	21.95	-0.07	-0.03
Aug 1 - Sep 12, 2003	Default Calibrated		0.65	357.55	357.55	155.91	-45.35	-4.97
	NLDAS 1/8th Precipitation	●	0.77	72.91	74.03	31.1	-0.84	-0.24
	NLDAS 1/8th ET		0.73	433.49	433.49	173.72	-56.55	-6.24
	NLDAS 1/8th Precipitation & ET		0.76	53.61	61	23.07	-0.01	-0.02
Oct 3 - Oct 14, 2003	Default Calibrated	●	0.99	27.13	41.59	21.98	-5.39	-1.29
	NLDAS 1/8th Precipitation	●	0.96	35.97	35.97	15.14	-2.03	-0.98
	NLDAS 1/8th ET		0.97	123.16	123.16	59.56	-45.94	-5.77
	NLDAS 1/8th Precipitation & ET		0.98	61.89	61.89	27.49	-9	-2.4
Feb 17 - Mar 15, 2004	Default Calibrated		0.46	-82.95	82.95	83.1	-40.16	-6.18
	NLDAS 1/8th Precipitation	●	0.94	-60.29	60.29	59.81	-20.32	-4.22
	NLDAS 1/8th ET		0.63	-71.48	71.48	71.74	-29.67	-5.19
	NLDAS 1/8th Precipitation & ET		0.93	-60.78	60.78	60.33	-20.7	-4.26
Jul 1 - Jul 14, 2004	Default Calibrated	●	0.92	421.95	421.95	105.54	-766.34	-31.48
	NLDAS 1/8th Precipitation		0.8	219.27	219.27	60.83	-253.91	-15.88
	NLDAS 1/8th ET		0.91	376.25	376.25	91	-569.52	-27.96
	NLDAS 1/8th Precipitation & ET	●	0.9	99.24	99.24	26.44	-47.15	-6.64
Aug 21 - Sep 7, 2004	Default Calibrated		0.08	1288.88	1288.88	568.27	-5250.12	-70.52
	NLDAS 1/8th Precipitation		0.43	-3.32	24.4	11.17	-1.03	-0.35
	NLDAS 1/8th ET		0.01	1739.18	1739.18	743.05	-8976.98	-95.51
	NLDAS 1/8th Precipitation & ET	●	0.74	16.46	22.69	9.79	-0.56	-0.26

Mahantango Low Flow Period Results

● = best statistic

Low Flow Period		Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Jan 1 - 18, 2001	Default Calibrated	0.95	-71.01	71.01	58.57	-47.07	-7.59
	NLDAS 1/8th Precipitation	0.96	-73.54	73.54	60.64	-50.54	-7.9
	NLDAS 1/8th ET ●	0.97	-79.67	79.67	65.67	-59.44	-8.64
	NLDAS 1/8th Precipitation & ET ●	0.96	-69.37	69.37	57.26	-44.95	-7.39
Aug 23 - 31, 2001	Default Calibrated	-0.25	46.46	46.46	16.84	-22.15	-2.9
	NLDAS 1/8th Precipitation	0.72	-27.57	28.24	8.32	-4.66	-1.37
	NLDAS 1/8th ET ●	0.67	-7.78	14.31	4.48	-0.64	-0.2
	NLDAS 1/8th Precipitation & ET ●	0.82	-16.04	17.75	5.49	-1.46	-0.49
Oct 25 - Nov 24, 2001	Default Calibrated ●	0.9	-44.73	54.85	11.69	-56.74	-7.17
	NLDAS 1/8th Precipitation	0.88	-42.84	53.03	11.49	-54.77	-6.9
	NLDAS 1/8th ET	0.87	100.65	100.65	24.86	-260.19	-13.98
	NLDAS 1/8th Precipitation & ET ●	0.89	-35.38	52.48	11.28	-52.76	-6.81
Feb 1 - Mar 2, 2002	Default Calibrated	0.73	-15	38.75	32.84	-1.27	-0.66
	NLDAS 1/8th Precipitation ●	0.94	-22.37	26.02	21.47	0.03	-0.11
	NLDAS 1/8th ET ●	0.77	-21.52	23.78	22.77	-0.09	-0.02
	NLDAS 1/8th Precipitation & ET	0.93	-29.51	32.09	25.05	-0.32	-0.37
Jul 23 - Aug 7, 2002	Default Calibrated	-0.16	130.69	130.69	31.54	-25.99	-3.25
	NLDAS 1/8th Precipitation ●	0.64	59.83	60.58	19.7	-9.53	-0.97
	NLDAS 1/8th ET ●	0	39.52	61.11	19.62	-9.45	-0.99
	NLDAS 1/8th Precipitation & ET ●	0.66	71.07	71.48	21.69	-11.76	-1.32
Aug 20 - Sep 8, 2002	Default Calibrated	0.27	381.78	381.78	57	-500.36	-22.21
	NLDAS 1/8th Precipitation ●	0.53	63.74	73.8	13.96	-29.09	-3.49
	NLDAS 1/8th ET	0.16	127.78	127.78	24.81	-93.96	-6.77
	NLDAS 1/8th Precipitation & ET ●	0.48	-18.57	57.06	8.81	-10.97	-2.47
Jan 18 - 31, 2003	Default Calibrated ●	0.23	-20.81	28.19	43.64	-13.64	-2.9
	NLDAS 1/8th Precipitation	0.18	-15.86	24.57	41.48	-12.23	-2.4
	NLDAS 1/8th ET ●	0.12	-5.82	19.04	31.32	-6.54	-1.64
	NLDAS 1/8th Precipitation & ET	0.13	-32.98	34.35	52.39	-20.09	-3.76
Feb 9 - 22, 2003	Default Calibrated	-0.29	433.63	433.63	475.9	-4972.77	-61.61
	NLDAS 1/8th Precipitation ●	0.58	81.01	81.02	103.9	-236.08	-10.7
	NLDAS 1/8th ET	-0.29	255.79	255.79	297.03	-1936.52	-35.93
	NLDAS 1/8th Precipitation & ET ●	0.51	10.21	45.59	66.12	-95.02	-5.58
May 10 - 24, 2003	Default Calibrated	0.37	82.32	82.32	94.31	-61.64	-7.61
	NLDAS 1/8th Precipitation ●	-0.07	-10.49	32.11	47.42	-14.84	-2.36
	NLDAS 1/8th ET ●	0.75	112.16	112.16	124.23	-107.7	-10.73
	NLDAS 1/8th Precipitation & ET	0.07	13.5	32.29	56.66	-21.61	-2.38
Jan 21 - Feb 3, 2004	Default Calibrated ●	0.71	-20.05	21.43	43.42	-3.99	-0.94
	NLDAS 1/8th Precipitation ●	0.82	-27.67	27.67	47.13	-4.88	-1.51
	NLDAS 1/8th ET	0.73	-36.26	36.26	58.47	-8.04	-2.29
	NLDAS 1/8th Precipitation & ET ●	0.82	-46.85	46.85	72.95	-13.08	-3.25
Jul 3 - 11, 2004	Default Calibrated	0.11	20.51	31.42	31.87	-9.52	-1.91
	NLDAS 1/8th Precipitation ●	0.59	-10.97	16.87	14.08	-1.05	-0.56
	NLDAS 1/8th ET	0.29	14.03	22.68	25.86	-5.93	-1.1
	NLDAS 1/8th Precipitation & ET	0.56	9.97	12.06	14.8	-1.27	-0.12
Aug 21 - Sep 17, 2004	Default Calibrated ●	0.97	206.56	206.56	362.12	-17.59	-3.11
	NLDAS 1/8th Precipitation ●	0.88	50.63	51.85	71.81	0.27	-0.03
	NLDAS 1/8th ET	0.87	226.46	226.46	480.78	-31.77	-3.5
	NLDAS 1/8th Precipitation & ET	0.88	88.47	88.47	119.14	-1.01	-0.76

NE Anacostia Low Flow Period Results

● = best statistic

Low Flow Period			Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Apr 18 - May 11, 2001	Default Calibrated	●	**0.98**	10.87	12.14	6.34	0.54	0.5
	NLDAS 1/8th Precipitation	●	**0.98**	2.11	4.19	2.13	**0.95**	**0.83**
	NLDAS 1/8th ET		0.97	10.95	11.95	3.95	0.82	0.51
	NLDAS 1/8th Precipitation & ET		0.97	10.95	11.95	3.95	0.82	0.51
Oct 7 - 13, 2001	Default Calibrated	●	**0.85**	22.14	22.14	3.48	-41.46	-9.85
	NLDAS 1/8th Precipitation	●	0.84	-3.67	3.96	0.68	**-0.64**	**-0.94**
	NLDAS 1/8th ET		0.82	136.78	136.78	19.24	-1294.85	-66.02
	NLDAS 1/8th Precipitation & ET		0.81	207.78	207.78	29.29	-3000.85	-100.81
Nov 3 - 8, 2001	Default Calibrated		0	-46.15	46.15	7.41	-Inf	-Inf
	NLDAS 1/8th Precipitation		0	-52.22	52.22	8.37	-Inf	-Inf
	NLDAS 1/8th ET		0	-5.71	6.58	1.26	-Inf	-Inf
	NLDAS 1/8th Precipitation & ET		0	-11.6	11.6	2.19	-Inf	-Inf
Feb 9 - 20, 2002	Default Calibrated	●	**0.93**	-33.11	33.11	6.07	**-19.39**	**-4.85**
	NLDAS 1/8th Precipitation	●	**0.93**	-39.02	39.02	7.11	-26.97	-5.9
	NLDAS 1/8th ET	●	**0.93**	-68.01	68.01	12.37	-83.76	-11.02
	NLDAS 1/8th Precipitation & ET	●	**0.93**	-53.67	53.67	9.76	-51.79	-8.49
Aug 7 - 22, 2002	Default Calibrated	●	**0.85**	76.08	76.96	4.09	**-1.83**	**-1.35**
	NLDAS 1/8th Precipitation		0.69	223.15	223.15	11.53	-21.5	-5.82
	NLDAS 1/8th ET		0.83	156.1	156.1	8.08	-10.06	-3.77
	NLDAS 1/8th Precipitation & ET		0.65	132.45	132.45	7.02	-7.35	-3.05
Oct 19 - 24, 2002	Default Calibrated		0.93	122.4	122.4	21.87	-34.51	-6.86
	NLDAS 1/8th Precipitation	●	**0.94**	87.68	87.68	15.74	-17.39	-4.63
	NLDAS 1/8th ET		0.93	107.17	107.17	19.2	-26.36	-5.88
	NLDAS 1/8th Precipitation & ET	●	0.93	52.94	52.94	9.61	**-5.86**	**-2.4**
Jan 10 - 26, 2003	Default Calibrated		0.79	65.01	65.01	30.83	-9.98	-3.36
	NLDAS 1/8th Precipitation		0.78	58.61	58.61	27.53	-7.75	-2.93
	NLDAS 1/8th ET		0.78	37.63	37.63	18.35	-2.89	-1.52
	NLDAS 1/8th Precipitation & ET	●	**0.81**	29.93	29.93	15.6	**-1.81**	**-1.01**
Apr 14 - 24, 2003	Default Calibrated		0.44	3.55	11.5	10.8	-0.25	0.07
	NLDAS 1/8th Precipitation		0.23	11.48	16.72	19.45	-3.06	-0.36
	NLDAS 1/8th ET	●	**0.55**	-4.36	10.51	9.07	**0.12**	**0.15**
	NLDAS 1/8th Precipitation & ET		0.45	4.15	10.88	12.51	-0.68	0.12
Sep 5 - 11, 2003	Default Calibrated		0.95	-28.09	28.09	14.82	-0.37	-0.22
	NLDAS 1/8th Precipitation	●	**1**	-6.87	9.48	6.87	**0.71**	**0.59**
	NLDAS 1/8th ET		0.95	-7.44	13.67	9.66	0.42	0.41
	NLDAS 1/8th Precipitation & ET		0.99	27.39	27.39	11.54	0.17	-0.19
Feb 12 - Mar 1, 2004	Default Calibrated	●	0.89	-25.91	25.91	19.35	**-0.31**	**-0.36**
	NLDAS 1/8th Precipitation		0.88	-35.67	35.67	26.23	-1.41	-0.87
	NLDAS 1/8th ET		0.89	-31.14	31.14	22.69	-0.81	-0.63
	NLDAS 1/8th Precipitation & ET	●	**0.91**	-52.2	52.2	35.7	-3.47	-1.73
Mar 19 - 24, 2004	Default Calibrated		0.91	-14.31	40.64	25.63	-6.55	-2.07
	NLDAS 1/8th Precipitation		0.91	-19.22	38.36	22.89	-5.02	-1.9
	NLDAS 1/8th ET		0.91	-31.84	40.18	23.78	-5.5	-2.04
	NLDAS 1/8th Precipitation & ET	●	**0.92**	-32.15	32.97	20.85	**-4**	**-1.49**
Aug 19 - Sep 3, 2004	Default Calibrated	●	**0.78**	74.05	74.05	27.68	-19.92	-3.48
	NLDAS 1/8th Precipitation	●	0.32	15.77	21.14	10.15	**-1.82**	**-0.28**
	NLDAS 1/8th ET		0.74	111.54	111.54	35.93	-34.26	-5.75
	NLDAS 1/8th Precipitation & ET		0.38	43.59	43.59	17.11	-6.99	-1.64

Pocomoke Low Flow Period Results

● = best statistic

Low Flow Period			Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Jan 1 - 14, 2001	Default Calibrated	●	0.94	-63.88	63.88	13.57	-48.25	-7.68
	NLDAS 1/8th Precipitation		0.05	-55.08	55.08	11.92	-36.97	-6.48
	NLDAS 1/8th ET	●	0.9	-19.16	19.16	4.2	-3.71	-1.6
	NLDAS 1/8th Precipitation & ET		0.79	-55.46	55.46	11.85	-36.52	-6.54
Oct 31 - Nov 6, 2001	Default Calibrated		0.97	-66.28	66.28	5.91	-40.46	-6.53
	NLDAS 1/8th Precipitation	●	0.98	-64.48	64.48	5.73	-38.03	-6.33
	NLDAS 1/8th ET		0.96	-36.32	36.32	3.27	-11.66	-3.13
	NLDAS 1/8th Precipitation & ET	●	0.96	-20.38	20.38	1.89	-3.23	-1.32
Dec 3 - 6, 2001	Default Calibrated	●	0.23	-34.3	34.3	2.15	-2459.22	-55.94
	NLDAS 1/8th Precipitation		0.22	-62.87	62.87	3.92	-8191.31	-103.36
	NLDAS 1/8th ET		0.37	72.57	72.57	4.81	-12353.63	-119.47
	NLDAS 1/8th Precipitation & ET	●	0.39	-41.63	41.63	2.6	-3596.39	-68.11
Feb 23 - Mar 2, 2002	Default Calibrated		0.81	-41.46	41.46	6.18	-105.4	-13.1
	NLDAS 1/8th Precipitation	●	0.83	-28.66	28.66	4.36	-51.85	-8.74
	NLDAS 1/8th ET		0.12	-24.79	24.79	3.84	-40.12	-7.43
	NLDAS 1/8th Precipitation & ET	●	0.72	-21.18	21.18	3.22	-27.81	-6.2
Jul 7 - 13, 2002	Default Calibrated		-0.03	351.46	351.46	19.25	-2061.51	-49.39
	NLDAS 1/8th Precipitation		-0.59	4.81	12.44	0.79	-2.46	-0.78
	NLDAS 1/8th ET		-0.69	179	179	10.16	-573.83	-24.67
	NLDAS 1/8th Precipitation & ET	●	0.96	-8.74	8.74	0.49	-0.35	-0.25
Aug 8 - 23, 2002	Default Calibrated	●	0.97	93.7	93.7	1.93	-19.67	-4.33
	NLDAS 1/8th Precipitation	●	0.97	217.6	217.6	4.61	-116.44	-11.37
	NLDAS 1/8th ET	●	0.95	35.9	35.9	0.73	-1.97	-1.04
	NLDAS 1/8th Precipitation & ET		0.96	42.4	42.4	0.97	-4.18	-1.41
Jan 5 - 30, 2003	Default Calibrated	●	0.99	6.05	14.35	11.57	0.76	0.53
	NLDAS 1/8th Precipitation		0.88	-40.94	41.28	28.26	-0.41	-0.34
	NLDAS 1/8th ET	●	0.99	8.32	16.37	14.41	0.63	0.47
	NLDAS 1/8th Precipitation & ET		0.98	-30.46	30.46	19.69	0.31	0.01
Jul 17 - Aug 4, 2003	Default Calibrated	●	0.98	18.95	19.67	5.84	-0.89	-0.25
	NLDAS 1/8th Precipitation		-0.2	100.94	101.17	26.44	-37.62	-5.41
	NLDAS 1/8th ET		0.94	-32.53	32.53	7.31	-1.95	-1.06
	NLDAS 1/8th Precipitation & ET		-0.3	19.32	34.16	10.38	-4.95	-1.16
Oct 1 - 14, 2003	Default Calibrated	●	1	31.26	36.71	23.02	-4.4	-1.02
	NLDAS 1/8th Precipitation		0.98	-54.69	54.69	25.43	-5.59	-2.01
	NLDAS 1/8th ET		0.99	27.07	34.69	21.16	-3.56	-0.91
	NLDAS 1/8th Precipitation & ET	●	0.99	-18.25	19.09	9.79	0.02	-0.05
Feb 23 - Mar 5, 2004	Default Calibrated		0.99	-58.73	58.73	36.89	-9.96	-2.83
	NLDAS 1/8th Precipitation		0.99	-78.92	78.92	49.53	-18.76	-4.15
	NLDAS 1/8th ET	●	0.99	-57.39	57.39	35.99	-9.43	-2.74
	NLDAS 1/8th Precipitation & ET	●	1	-63.21	63.21	39.87	-11.81	-3.12
Jul 1 - 12, 2004	Default Calibrated		-0.64	780.27	780.27	98.09	-10931.87	-96.38
	NLDAS 1/8th Precipitation	●	0.67	-15.26	20.11	2.28	-4.91	-1.51
	NLDAS 1/8th ET		-0.65	684.67	684.67	90.18	-9240.99	-84.45
	NLDAS 1/8th Precipitation & ET		0.21	-18.24	31.27	3.59	-13.65	-2.9
Sep 4 - Sep 14, 2004	Default Calibrated	●	1	-22.36	22.36	6.26	-0.68	-0.46
	NLDAS 1/8th Precipitation		0.94	-26.32	28.94	8.26	-1.94	-0.89
	NLDAS 1/8th ET	●	0.96	-1.17	4.88	1.55	0.9	0.68
	NLDAS 1/8th Precipitation & ET		0.97	19.43	19.43	7.15	-1.2	-0.27

WB Patuxent Low Flow Period Results

● = best statistic

Low Flow Period			Correlation Coefficient	Percent Mean Error	Mean Absolute Error	RMS Error	Model Fit Efficiency (NS)	NS Absolute Difference
Oct 3 - 5, 2001	Default Calibrated	●	**1**	19.39	19.39	2.17	**-6.05**	**-2.2**
	NLDAS 1/8th Precipitation	●	**1**	57.08	57.08	6.28	-58.14	-8.42
	NLDAS 1/8th ET	●	**1**	134.11	134.11	14.8	-327.5	-21.13
	NLDAS 1/8th Precipitation & ET	●	**1**	75.16	75.16	8.3	-102.43	-11.4
Oct 8 - Oct 14, 2001	Default Calibrated	●	-0.57	16.88	24.87	2.67	**-179.72**	**-12.62**
	NLDAS 1/8th Precipitation		-0.59	64.81	64.81	6.1	-939.21	-34.5
	NLDAS 1/8th ET	●	**-0.48**	130.17	130.17	11.99	-3632.88	-70.3
	NLDAS 1/8th Precipitation & ET		-0.5	53.34	53.34	5.21	-685.38	-28.22
Dec 2 - 7, 2001	Default Calibrated	●	**0.22**	-86.95	86.95	11.61	-605.82	-25.09
	NLDAS 1/8th Precipitation		0.19	-75.66	75.66	10.11	-458.66	-21.7
	NLDAS 1/8th ET		0.09	-72.81	72.81	9.74	-425.98	-20.84
	NLDAS 1/8th Precipitation & ET	●	0.2	-64.36	64.36	8.62	**-333.72**	**-18.31**
Jun 21 - 27, 2002	Default Calibrated		0.8	249.59	249.59	17.34	-66.28	-9.21
	NLDAS 1/8th Precipitation	●	0.96	108.01	108.01	7.32	**-10.98**	**-3.42**
	NLDAS 1/8th ET		0.88	317.18	317.18	21.9	-106.3	-11.97
	NLDAS 1/8th Precipitation & ET	●	**0.98**	143.18	143.18	9.68	-19.99	-4.85
Aug 8 - 27, 2002	Default Calibrated		0.2	-23.71	70.06	1.98	-1.61	-0.72
	NLDAS 1/8th Precipitation	●	**0.44**	-96.15	96.15	2.33	-2.6	-1.37
	NLDAS 1/8th ET	●	0.13	-13.56	57.05	1.72	**-0.97**	**-0.4**
	NLDAS 1/8th Precipitation & ET		0.16	109.62	134.55	3.42	-6.78	-2.31
Oct 19 - 25, 2002	Default Calibrated	●	**0.87**	286.19	286.19	49.32	-51.08	-8.18
	NLDAS 1/8th Precipitation	●	0.26	97.51	97.51	18.23	**-6.11**	**-2.13**
	NLDAS 1/8th ET		0.73	222.29	222.29	38.45	-30.67	-6.13
	NLDAS 1/8th Precipitation & ET		0.79	133.21	133.21	23.24	-10.57	-3.27
Jan 5 - Feb 14, 2003	Default Calibrated		0.81	52.02	52.04	53.31	-1.63	-0.56
	NLDAS 1/8th Precipitation		0.58	66.37	66.37	55.92	-1.89	-0.99
	NLDAS 1/8th ET	●	**0.89**	28.56	32.96	32.29	0.04	0.01
	NLDAS 1/8th Precipitation & ET	●	0.84	12.04	23.88	25.73	**0.39**	**0.28**
Aprl 19 - 25, 2003	Default Calibrated		0.69	-22.23	22.23	18.41	-2.31	-0.94
	NLDAS 1/8th Precipitation	●	0.56	2.65	7.8	8.69	**0.26**	**0.32**
	NLDAS 1/8th ET		0.71	-10.42	11.84	10.59	-0.09	-0.03
	NLDAS 1/8th Precipitation & ET	●	**0.87**	-22.54	22.54	17.76	-2.08	-0.96
Sep 29 - Oct 14, 2003	Default Calibrated		0.83	52.51	53.01	31.56	-6.68	-1.87
	NLDAS 1/8th Precipitation	●	0.41	30.71	30.71	23.47	**-3.25**	**-0.66**
	NLDAS 1/8th ET		0.86	68.1	68.1	36.91	-9.5	-2.69
	NLDAS 1/8th Precipitation & ET	●	**0.89**	51.45	51.45	29.6	-5.75	-1.79
Feb 15 - Mar 5, 2004	Default Calibrated		0.95	-43.44	43.44	35.96	-9.38	-3.04
	NLDAS 1/8th Precipitation	●	0.92	-28.21	28.21	24.04	**-3.64**	**-1.62**
	NLDAS 1/8th ET		0.96	-45.74	45.74	37.82	-10.48	-3.25
	NLDAS 1/8th Precipitation & ET	●	**0.97**	-56.06	56.06	46.22	-16.14	-4.21
May 29 - 25, 2004	Default Calibrated		0.13	-17.18	27.78	13.31	-1.06	-0.53
	NLDAS 1/8th Precipitation		0.02	28.86	35.91	27.07	-7.5	-0.97
	NLDAS 1/8th ET	●	0.21	-13.87	24.6	12.1	**-0.7**	**-0.35**
	NLDAS 1/8th Precipitation & ET	●	**0.71**	51.53	51.53	32.8	-11.48	-1.83
Aug 23 - Sep 8, 2004	Default Calibrated	●	**0.99**	95.09	95.09	26.12	-21.72	-4.1
	NLDAS 1/8th Precipitation	●	0.95	23.83	23.83	5.87	**-0.15**	**-0.28**
	NLDAS 1/8th ET	●	**0.99**	118.35	118.35	30.58	-30.16	-5.35
	NLDAS 1/8th Precipitation & ET		0.98	14.04	20.45	6.1	-0.24	-0.1