MIDDLE AND UPPER RAPPAHANNOCK RIVER BASIN, VA
RAINFALL, STREAM, AND
WATER QUALITY GAUGING ANALYSIS

Prepared by:
U.S. Army Corps of Engineers
Norfolk District
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EXECUTIVE SUMMARY

This report was prepared by the United States Army Corps of Engineers (USACE) Norfolk District in partnership with the Virginia Department of Conservation and Recreation (VA DCR). The study was conducted under the authority of Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251), as amended which authorizes the Secretary of the Army, acting through the Chief of Engineers, to assist states and localities in the preparation of comprehensive plans for development, utilization, and conservation of water related land resources.

The purpose of the Middle and Upper Rappahannock River Basin Rainfall, Stream and Water Quality Gauging Analysis is to provide recommendations and supporting information for additional real-time, continuous gauge locations in the river basin. The study included a major outreach effort spurred by three separate study meetings, held in Fredericksburg, VA. The meetings included local stakeholders and technical experts throughout the region, to review existing programs and prompt discussion. Major existing gauge and monitoring programs of the National Weather Service (NWS), United States Geological Survey (USGS), Virginia Department of Emergency Management (VDEM), and Virginia Department of Environmental Quality (VA DEQ) were presented by agency staff at the first two meetings. USACE staff also attended meetings of the Rappahannock River Basin Commission (and Technical Committee) and the Rappahannock-Rapidan Regional Commission and Land Use and Environmental Committee Meeting, and USACE staff contacted over one hundred individuals in the basin, as well as, ensured responses and conducted follow-up contact with representatives from each locality in the study area. Additionally, USACE staff researched existing background information regarding rainfall, stream, and water quality gauging programs and local plans applicable to the study area.

Currently, there are 24 rainfall, 11 stream, and 0 water quality real-time, continuous active gauges located within the study area. As a result of this analysis, an additional 13 rainfall and 7 real-time continuous stream gauges have been identified and proposed as top priorities for consideration to add to the existing basin gauge network. An additional 27 real-time continuous water quality gauges were identified and priorities for installation of these gauges are developed into three separate alternatives in this analysis. All coordination, research, and analysis which lead to the identified gauge locations for the middle and upper portions of the basin are documented in this report, as well as the final results of the proposed gauge locations.

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303(d) – list of impaired and threatened waters
AWOS – Automated Weather Observing System
AHPS – Advanced Hydrologic Prediction Service
BMP – Best Management Practice
CFR – Code of Federal Regulations
CFS – Cubic Feet per Second
COOP – Cooperative
CSA – Cost Share Agreement
CWA – Clean Water Act
DMA – Disaster Mitigation Act
DO – Dissolved Oxygen
EMAP – Environmental Monitoring and Assessment Program
EPA – Environmental Protection Agency
FMA – Flood Mitigation Assistance
GIS – Geographic Information System
GWRC – George Washington Regional Council
HMA – Hazard Mitigation Assistance
HMGP – Hazard Mitigation Grant Program
HSPF – Hydrologic Simulation Program - Fortran
HUC 8 – eight digit Hydraulic Unit Code
HUC 12 – twelve digit Hydraulic Unit Code
IFLOWS – Integrated Flood Observation and Warning System
Level I Data – data not approved by VA DEQ for assessment
Level II Data – data partially approved by VA DEQ for assessment
Level II Data – data approved by VA DEQ for assessment
MS4 – municipal separate storm sewer system
NARS – National Aquatic Resource Survey
NASQAN – National Stream Quality Accounting Network
NAWQA – National Water-Quality Assessment program
NID – National Inventory of Dams
NOAA – National Oceanic and Atmospheric Administration
NPEDS – National Pollutant Elimination Discharge System
NPS – National Park Service
NSIP – National Streamflow Information Program
NWIS – National Water Information System
NWQMC – National Water Information System
NWS – National Weather Service
PAS – Planning Assistance to States

PDC – Planning District Commission
PDM – Pre-Disaster Mitigation grant program
PPM – Parts Per Million
PPB – Parts Per Billion
QA/QC – Quality Assurance / Quality Control
RRBC – Rappahannock River Basin Commission
RFC – Repetitive Flood Claims grant program
SRL – Sever Repetitive Loss grant program
STORET – STORage and RETrieval data wharehouse
SWCD – Soil and Water Conservation District
TP – Total Phosphorus
TMDL – Total Maximum Daily Load
TMDL IP – Total Maximum Daily Load Implementation Plan
TN – Total Nitrogen
TSS – Total Suspended Sediment
USACE – United States Army Corps of Engineers
USGS – United States Geological Survey
VA DCR – Virginia Deparment of Conservation and Recreation
VA DEQ – Virginia Department of Environmental Quality
VA DGIF – Virginia Department of Game and Inland Fisheries
VA SAS – Virginia Save Our Streams Program
VDEM – Virginia Department of Emergency Management
VDF – Virginia Department of Forestry
VDH – Virginia Department of Health
VDOT – Virginia Department of Transportation
VECOS – Virginia Estuarine and Coastal Observing System
VEGIS – Virginia Environmental Geographical Information Systems
VIMS – Virginia Institute of Marine Science
VPEDS – Virginia Pollutant Elimination Discharge System
VSMP – Virginia Stormwater Management Program permit
VWMC – Virginia Water Monitoring Council
WQP – Water Quality Portal
WWTP – Wastewater Treatment Plant
WTP – Water Treatment Plant

1.0 BACKGROUND AND STUDY COORDINATION

The Middle and Upper Rappahannock River Basin Rainfall, Stream, and Water Quality Gauging Analysis officially commenced on August 24th, 2012 with a cost sharing agreement between the U.S. Army Corps of Engineers (USACE) Norfolk District and Virginia Department of Conservation and Recreation (VA DCR). As the study focus is the middle and upper portions of the Rappahannock River Basin (RRB), the Rappahannock River Basin Commission and commission staff are active participants in this study. The scope of the study includes the communities of the middle portion of the basin: City of Fredericksburg, Stafford County, and Spotsylvania County; and the communities of the upper basin: Culpeper County, Fauquier County, Greene County, Madison County, Orange County, and Rappahannock County.

Table 1.1 – Localities Included in Scope of Study

Locality	Percent of Land Area in Basin
Culpeper County	100
Fauquier County	44
City of Fredericksburg	100
Greene County	41
Madison County	100
Orange County	56
Rappahannock County	100
Spotsylvania County	23
Stafford County	29

This study was spurred from the Chowan River Basin, VA, Rainfall and Stream Gauging Analysis completed by USACE Norfolk District in 2009, with on-going implementation by the responsible agencies. The Chowan River Basin study focused on the development of an 'integrated flood warning system,' which included recommendations for locations and generalized cost estimates, for seven real-time continuous stream gauges and upgrades to four rain gauges to continuous and real-time reporting. The Rappahannock River Basin Gauging Analysis will vary greatly from this study due to the overwhelming need for water quality information, in addition to flood warning gauge needs.

1.1 Study Objectives

The objective of the Middle and Upper Rappahannock River Basin Gauging Analysis is to conclude what the needs for additional data collection are in the basin and where additional long-term real-time continuous gauges can be located to solve these needs. Additionally, coordination and research conducted for this study promotes collaboration for a holistic understanding of the current status of data collection in the basin and opportunities for improvement.

1.2 Rappahannock River Basin Background Information

The Rappahannock River Basin includes the land and water drainage area that flows to the Rappahannock River, Figure 1.1, and is approximately 2,715 square miles. The basin includes all or part of the counties of Albemarle (small upper portion of perennial streams), Caroline, Essex, Fauquier, Greene, King George, Lancaster, Madison, Middlesex, Northumberland, Orange, Rappahannock, Richmond, Spotsylvania, Stafford, and Westmoreland. The City of Fredericksburg and a number of towns also share the basin. The Rappahannock River Basin is represented by eight digit Hydraulic Unit Codes (HUC-8) 02080103 for the upper basin and 02080104 for the lower basin.

The waterway begins as streams flowing from the eastern slopes of the Blue Ridge Mountains. The southern streams form the Rapidan River, while the Rappahannock River forms in the northern streams of the basin. The Rapidan meets the Rappahannock just west of Fredericksburg, where Culpeper, Stafford, and Spotsylvania counties share borders. The river at Fredericksburg travels through the fall line geologic formation, characterized by rocks and rapids. East of Fredericksburg, the Rappahannock enters the coastal plain, where the waters receive tidal influences from the Chesapeake Bay. The river continues to widen and becomes increasingly brackish as it flows east toward Stingray Point and Windmill Point where it meets the Chesapeake Bay (USACE 2000).

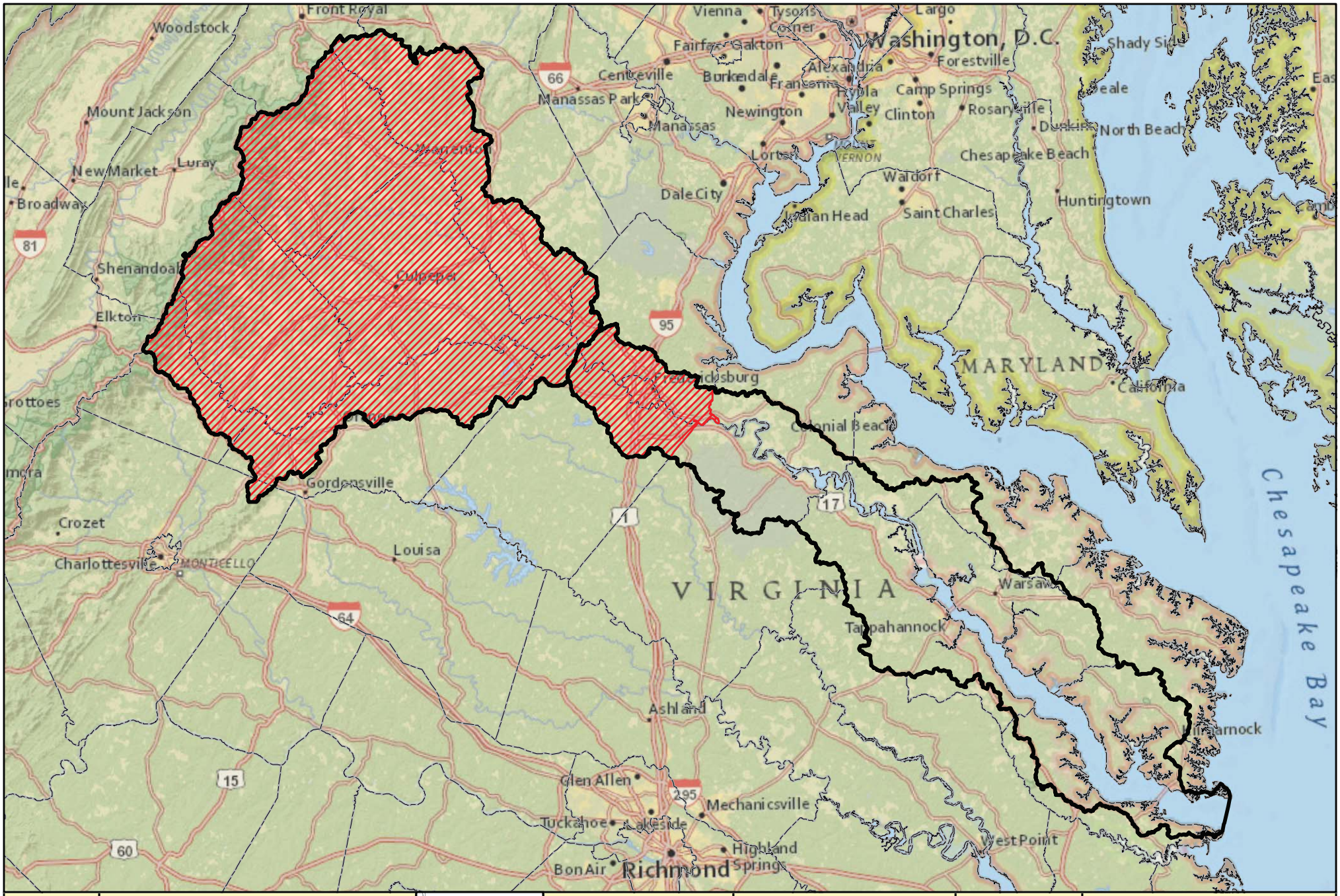
<u>Flooding</u>

The middle and upper portions of the Rappahannock River Basin have experienced rainfall type flooding events on a recurring basis. Listed below are the top ten flooding events and any additional flooding events from the past ten years from existing gauges at the upper portion of the basin, at Remington, and in the middle portion of the basin, just above the City of Fredericksburg.

Upper Rappahannock River, Stream Gauge at Remington (#01664000)

Reference Datum: Gauge Height 0 referenced at 252.53 ft (NGVD 29)
Flood Stages:

- Major Flood Stage: 25 ft
- Moderate Flood Stage: 20 ft
- Flood Stage: 15 ft
- Action Stage: 12 ft



US Army Corps of Engineers
Norfolk District

Rappahannock River Basin Study Area Overview

Figure 1.1

0 4 8 16 Miles

Study Area
Rappahannock River Basin
County Boundary

Projection:
Virginia State Plane
North Zone - NAD 83
U.S. Survey Feet

Basemap:
Esri ArcGIS Online
National Geographic

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Map File: 4a_Rap_River_Basin_Overview.mxd
Map Date: 09 January 2013

Historical Crests:

(1) 30.00 ft on 10/16/1942
(2) 29.20 ft on 04/26/1937
(3) 26.70 ft on 06/02/1889
(4) 24.82 ft on 06/22/1972 (Hurricane Agnes)
(5) 24.04 ft on 09/07/1996 (Hurricane Fran)
(6) 23.52 ft on 08/18/1955 (Hurricane Connie and Diane)
(7) 21.97 ft on 10/10/1976
(8) 21.96 ft on 03/05/1993
(9) 21.21 ft on 02/15/1984
(10) 21.05 ft on 01/20/1996

Crests since 2002:
(1) 19.06 ft on 04/17/2011
(2) 18.76 ft on 12/11/2003
(3) 18.09 ft on 03/14/2010
(4) 17.96 ft on 01/26/2010
(5) 17.93 ft on 09/24/2003
(6) 17.05 ft on 05/12/2008
(7) 16.30 ft on 03/11/2011
(8) 15.95 ft on 03/21/2003
(9) 15.80 ft on 11/30/2005
(10) 15.52 ft on 02/23/2003

Middle Rappahannock River, Stream Gauge above Fredericksburg (# 01668000)

Reference Datum: Gauge Height 0 referenced at 70 ft (NGVD 29)
Flood Stages:

Major Flood Stage: 23 ft
Moderate Flood Stage: 16 ft
Flood Stage: 13 ft
Action Stage: 10 ft

Historical Crests:
(1) 25.90 ft on 10/16/1942
(2) 25.14 ft on 04/26/1937
(3) 22.56 ft on 06/22/1972 (Hurricane Agnes)
(4) 17.97 ft on 09/07/1996 (Hurricane Fran)
(5) 17.14 ft on 06/28/1995

(6) 17.00 ft on 08/19/1955 (Hurricane Connie and Diane)
(7) 16.50 ft on 09/13/1924
(8) 15.54 ft on 03/05/1993
(9) 15.10 ft on 10/01/1924
(10) 15.03 ft on 05/06/1989

Crests since 2002:
(1) 12.69 ft on 12/11/2003
(2) 12.53 ft on 09/20/2003
(3) 11.81 ft on 01/26/2010
(4) 11.73 ft on 01/15/2005
(5) 11.10 ft on 05/12/2008
(6) 10.88 ft on 03/07/2011
(7) 10.77 ft on 03/11/2011

It should be noted that although the top ten flooding events for each gauge station have not occurred in the last ten years, the flood stage and moderate stage events that have occurred in the last ten years have still caused damages to the communities of the basin. The most recent severe flood in 1995 and 1996, had severe impacts on the upper basin. For the June 1995 flood, one reference states that a storm produced almost 20 inches of rain in the southwestern part of Madison County in less than 12 hours (McNaught).

Water Quality

The Rappahannock River Basin lies within the Chesapeake Bay watershed, which is listed as impaired under the Clean Water Act since 1998. In December 2010, the Environmental Protection Agency established a Total Maximum Daily Load (TMDL) for the Chesapeake Bay, establishing load limits, and required reductions from current estimated pollutant loads of nitrogen, phosphorus and total suspended solids (sediment). The TMDL further provides limits for the three pollutants assigned to each contributing watershed, the upper Rappahannock (ending before the City of Fredericksburg) and the lower Rappahannock (from just above the City of Fredericksburg to the entrance of the Bay). However, the Rappahannock River Basin also has several local TMDLs established that requires more complete water quality data records for water quality to effectively plan and implement Best Management Practices (BMPs) to meet the regulatory requirements.

According to the EPA's TMDL web-page, since October 1st 1995 the lower Rappahannock River Basin has 51 TMDLs developed for various tributaries for the pollutants of fecal coliform, pathogens, ammonia, e. coli (Escherichia coli), enterococcus bacteria, fecal, total nitrogen (total kjehldahl nitrogen), and total residual chlorine. The upper Rappahannock River Basin has 42

TMDLs identified for the pollutants of ammonia, e coli, fecal coliform, benthic, copper, DDT, dissolved oxygen, endrin, and total nitrogen. A review of the most recent TMDL Implementation Plans developed and TMDL Reports at the local level will be addressed in Section 3.0, Problems and Opportunities, of this report.

1.3 Study Coordination

Due to some of the key information from this study being developed from coordination and communication with study participants from private firms, local groups, or local, state and Federal governments or agencies, documentation of correspondence and study progression is important to ensure all efforts and background information gathered to develop gauge locations can be used for related future work without duplication of efforts. Over the course of this analysis, a list of over fifty professional contacts was developed from the individuals that participated and provided input. In addition to the meetings listed in the following section, USACE staff presented the status of this analysis to the Rappahannock River Basin Commission quarterly meetings throughout this study effort.

June 27th, 2012 Rappahannock River Basin Commission Technical Committee

USACE representatives attended the Rappahannock River Basin Commission (RRBC) Technical Committee meeting in Fredericksburg, VA, on June 27th, 2012. During the meeting, USACE presented the study scope of work and requested input to suggested study participants. From this meeting, follow-up correspondence, and existing contacts for agency technical experts, USACE Norfolk District was able to develop an invitation list of well over one hundred participants, including local stakeholders, technical experts from private firms and local groups, and local, state and Federal agencies. In addition, the established RRBC Technical Committee contact list and the Rappahannock-Rapidan Regional Commission Land Use and Environmental Committee contact list were included.

August 2nd, 2012 Study Information Meeting

The invitation list of over one hundred local stakeholders and technical experts was used to form this meeting. Additionally, specific agencies of interest due to their monitoring programs: Virginia Department of Environmental Quality (VA DEQ), Virginia Department of Emergency Management (VDEM), National Weather Services (NWS), and United States Geological Survey (USGS) were in attendance. These agencies made presentations for their specific programs and missions at the first and second study meeting. The first meeting included presentations on Chowan River Basin Rainfall and Stream Gauging Analysis study process and the proposed scope of study for the Rappahannock River Basin Stream, Rainfall, and Water Quality Gaging

Analysis. A NWS representative presented on existing rain gauges in the basin and data gaps identified from a recent storm event. A USGS representative presented on USGS and VA DEQ stream flow data collection programs. Following the presentations, an open discussion on current gauging needs in the basin was facilitated to mold the scope of the RRB Gauging Analysis. The agenda along with the presentations and sign-in sheet for this meeting are located in Appendix A.

The initial invitation list was reduced to fifty local stakeholders and technical experts for future correspondence to include initial attendees and those who responded with interest in the study. The contact list was updated as needed to include additional parties identified as the study developed.

August 24, 2012 Cost Sharing Agreement Execution

The Middle and Upper Rappahannock River Basin Rainfall, Stream, and Water Quality Gauging Analysis officially commenced on August 24th, 2012 with a Cost Sharing Agreement (CSA) between the U.S. Army Corps of Engineers (USACE) Norfolk District and Virginia Department of Conservation and Recreation (VA DCR). A representative from VA DCR was assigned to the study from the Floodplain Management and Dam Safety Branch. The CSA is located in Appendix A.

September 18th, 2012 Study Meeting

The September 18th Meeting was announced upon the execution of the CSA. The purpose of the September 18th meeting was to allow the remaining agencies who participate in this type of data collection to present on their programs. A VDEM representative presented on the Integrated Flood Observation and Warning System (IFLOWS) program, and how to use and access the IFLOWS webpage. Additional information is located in the Section 2.0, Existing Gauges and Monitoring. A VA DEQ representative presented on VA DEQ water quality monitoring programs and monitored locations, the presentations along with the agenda and sign-in sheet are located in Appendix A. Following the presentations the meeting attendees participated in an initial data gathering exercise by marking-up maps with proposed gauge locations. In Section 4.0, the initial list of identified gauge locations lists the source that provided each location, the September 18th Study Meeting is listed as a source.

At this meeting the possibility of including ground water data collection needs was considered. However due to the intricacy of ground water monitoring with the limitations on the timeline and funding for the existing study, ground water monitoring could not be pursued further under this CSA. A ground water monitoring analysis is suggested for a future study, and can be

accomplished on a cost-shared basis under the Norfolk District PAS Program under a new CSA, provided Federal funding is available.

This meeting established the beginning of data collection for the study. A follow-up email containing background information on existing gauge or monitoring locations was sent to the study contact list requesting information on proposed gauge locations or information on existing stormwater management or floodplain management issues that would benefit from additional gauge data.

October 24th, 2012 Rappahannock River Basin Commission Technical Committee Meeting

In order to expedite the data gathering process, USACE attended the October 24th Rappahannock River Basin Commission Technical Committee Meeting to gather additional information for gauge locations and suggestions of other methods or contacts to collect this data. At this meeting it was suggested that USACE attend the November 15th Rappahannock-Rapidan Regional Commission Land Use and Environmental Committee Meeting to reach out to localities of the upper portion of the basin.

November 15th, 2012 Rappahannock-Rapidan Regional Commission Land Use and Environmental Committee Meeting

USACE attended the November 15th Land Use and Environmental Committee Meeting to remind communities and other stakeholders in the study area of the need for input of where the localities would like stream, rainfall, and water quality gauges. Several locations were collected at the meeting and the contact list for the study was extended.

February 5, 2013 Final Study Meeting

The purpose of the final study meeting is to review the results of the data collection, proposed gauge locations and the priority of the proposed gauges suggested in the draft report. A discussion of the draft report distribution and comment deadline was also presented. Several suggestions to improve the gauging analysis were considered and made before distributing the draft report for review.

Other Coordination

Throughout the study, USACE coordinated with technical experts from USGS, NWS, VDEM, and VA DEQ for information on their programs and technical information about gauges. This study would not have been possible without the contributions and cooperation of the representatives from these agencies. Stakeholders from private sector and local groups also

provided invaluable input, in addition to the staff of each locality. A list of participating members can be found in Appendix A. Every locality in the basin was informed of the study and contacted for study input. Responses can be found in Appendix C, Comments from Local Agencies, Local Groups, and Local Governments.

The final draft review and distributions schedule is presented in the table below.

Table 1.2 – Draft Report Review

Date	Action
February 11, 2013	Draft Report Distributed for Review
April 19, 2013	Report Finalized

2.0 EXISTING GAUGES OR MONITORING

The search for existing gauges and monitoring programs is a large challenge for this study. Current data collection is proprietary and differs between organizations and programs. Additionally, some data collection programs are only for a few samples, or short periods of time, while others are on-going and have long period of record. Also, the quality control or quality assurance of data from different sources varies, which causes the allowed uses for the collected data to vary.

The identified programs presented below are gathered through research and outreach to different agencies. The following sections outline the major programs collecting data in the basin, under agencies of United States Geological Survey (USGS), Virginia Department of Environmental Quality (VA DEQ), Virginia Department of Emergency Management (VDEM), National Weather Service (NWS), and several other programs from the Virginia Water Monitoring Council (VWMC), Environmental Protection Agency (EPA), National Park Service (NPS), Virginia Department of Health (VDH), Virginia Institute of Marine Science (VIMS), and citizen monitoring through Virginia Save Our Streams (VA SOS).

Additionally, many small programs involving field measurements for rain, stream flow, and water quality also exist, but are not documented below. Some examples include monitoring done for specific sites, such as water supply reservoirs, wastewater effluent, construction sites and irregular monitoring done for short term studies. Although this type of data can be useful, it is not considered in this study, as the goal of this study involves proposing long term real-time continuous rainfall, stream, or water quality gauges needed to fill large data gaps.

2.1 United States Geological Survey (USGS)

Stream Gauges

The United States Geological Survey (USGS) currently operates over 9,600 active stream gauges across the United States. For most of these gauges, USGS has partnered with more than 800 Federal, state, and local agencies through the Federal-State Cooperative Water Program (Water Coop Program) to provide funding to operate stream gauging stations. In Virginia, the cooperative effort includes data collection and gauging station maintenance by the VA-DEQ for a significant portion of the stream flow monitoring network. In the Rappahannock River basin, 5 of the 8 real-time continuous stream flow monitoring stations are maintained by the VA DEQ (Table 2.1). Stream discharge data collected by the VA DEQ from these sites are provided to the USGS for access via the NWIS network. The current active, real-time USGS and VA DEQ stream flow gauging stations within the Rappahannock River Basin can be accessed from the USGS Surface-Water Data from the Nation web-page. A map with USGS and VA DEQ stream

gauge locations can be found in Appendix B, the following table list eight active gauges in the basin:

Table 2.1 – USGS and VA DEQ Continuous Real-Time Stream Gauges

Station Number	Station Name	Managed By:
01662800	Battle Run Near Laurel Mills	VA DEQ
01663500	Hazel River at Rixeyville	USGS
01664000	Rappahannock River at Remington	USGS
01665500	Rapidan River near Ruckersville	VA DEQ
01666500	Robinson River near Locust Dale	VA DEQ
01667500	Rapidan River near Culpepper	VA DEQ
01668000	Rappahannock River near Fredericksburg	USGS
01669000	Piscataway Creek near Tappahannock*	VA DEQ

*Piscataway Creek near Tappahannock Station is in the lower basin. USGS defines the basin by the two HUC codes, instead of three parts. For the purpose of this study the Rappahannock River near Fredericksburg Station is considered the middle basin, although it is a part of the lower HUC code.

These real-time gauges display current conditions based on the most recent data from on-site automated recording equipment, which provide measures at a fixed interval from 6 minutes to 60 minutes and usually transmits the data hourly. The raw data produced by these gauges is provisional, but is analyzed for quality control, including verification with field measurements, and the reviewed data is marked as accepted or verified data for the records.

In addition to the currently operating gauges within the Rappahannock River Basin, the USGS National Streamflow Information Program (NSIP) indicates the goals and stream gauges likely to be funded by the agency in the future. The NSIP was initiated in 2003 in order to modernize USGS stream gauging programs. This program was developed in response to concerns about a decrease in the number of operating stream gauges, decreased funding through partnerships in the Water Coop Program, and increasing demand for stream flow information. The program operates on five goals: (1) stable stream gauge network (2) improved delivery of stream flow data to users (3) regional assessments of stream flow characteristics (4) expanded data collection during floods and droughts (5) research and development. The NSIP 2012 plan suggests the following gauges in the Rappahannock River Basin:

Table 2.2 – NSIP 2012 Plan Suggested Gauges

Station Number	Station Name
01669500	Dragon Swamp Near Church View*
01665000	Mountain Run Near Culpeper*
01667000	Rapidan River at Rapidan*
01663500	Hazel River at Rixeyville
01664000	Rappahannock River at Remington
01667500	Rapidan River near Culpepper
01668000	Rappahannock River near Fredericksburg

* Dragon Swamp, Mountain Run, and Rapidan River stream gauges are currently inactive. Additionally, Dragon Swamp Near Church View is located in the lower basin.

These gauges are a part of the Federal goals for stream gauges identified for 2012. The NSIP would provide full funding, without partnership, to operate all of these gauges if the program were fully funded. In 2011, the NSIP was funded $27.7M, operation of the complete program would require $117 M. Funding for the program since initial discussion in 1998 has been below 2011 levels (Norris).

Water Quality Gauges and Monitoring

Water quality data can also be collected through Federal-State Cooperative Water Program (Water Coop Program), however there are several other programs presented on USGS web-page for water quality data collection: the National Water-Quality Assessment program (NAWQA) and the National Stream Quality Accounting Network (NASQAN). These are displayed through the National Water Information System (NWIS) and the Water Quality Watch – Continuous Real-Time Water Quality of Surface Water in the United States.

The Water Quality Watch webpage has no real-time continuous sites in the Rappahannock River Basin currently. However, a real-time continuous gauge was located on a buoy at the stream flow station Rappahannock River near Fredericksburg, VA, Station 01668000, from March 2004 to May 2008. This gauge was damaged during a storm, and is no longer in operation.

The current water quality monitoring stations sampled by USGS in the Rappahannock River Basin are funded by both VA DEQ (with the USGS Water Coop Program) and the EPA. During the past five years, EPA provided additional funding to VA DEQ and the USGS to expand water-quality monitoring stations in the Rappahannock River Basin and other Chesapeake Bay Watersheds in Virginia. The current monitoring being conducted by USGS in the watershed is the result of this expansion, but no further expansion or funding is expected from VA DEQ and the EPA. These stations have 20 water-quality samples per year collected (consisting of 12 scheduled monthly samples and 8 targeted storm flow samples) at the following 3 stations:

1. Rappahannock River near Fredericksburg (USGS Station ID 01668000)
2. Rapidan River near Culpeper (USGS Station ID 01667500)
3. Rappahannock River at Remington (USGS Station ID 01664000)

From these samples they are able to compute nutrient and sediment loads and determine long-term trends at each of these 3 locations. The water quality information from these sampling sites can be found on the webpage for each related stream gauge station or collectively from the NWIS mapper webpage.

The NAWQA program began in 1991, and the program strives to establish a baseline understanding of water quality conditions in the nation's river basins. The program only focuses on 51 basins picked to cover a variety of hydrologic and ecological resources, critical sources of contaminants from agricultural, urban or natural sources, and a high percentage of the population that is served by municipal water supply and irrigated agriculture. This program does not cover the Rappahannock River Basin.

The NASQAN was initiated in 1973, but according to USGS its objectives have changed several times. Now the NASQAN goal is to report on the concentrations and loads of selected constituents delivered by major rivers to the coastal waters of the US and selected inland sub-basins in priority river basins to determine the sources and relative yields of constituents within these basins. The only NASQAN station that provides information for Virginia is on the border of Virginia and Washington D.C. on the Potomac River, outside of the Rappahannock River Basin.

Additionally, some USGS water quality data provided to the National Water Quality Monitoring Council (NWQMC) is displayed on the Water Quality Portal (WQP) in cooperation with the USGS National Water Information System (NWIS) and EPA STOrage and RETrieval (STORET) Data Warehouse. The EPA STORET Data Warehouse contains water quality monitoring data collected by water resource management groups across the country, see EPA program information under Section 2.5, Other.

2.2 National Weather Service (NWS)

Rain Gauges

The National Weather Service (NWS), an agency of the National Oceanic and Atmospheric Administration (NOAA), primarily uses USGS and VA DEQ stream gauges for stream flow predictions and in the Rappahannock River Basin the NWS uses VDEM IFLOWS program, NWS Automated Weather Observing Systems (AWOS), or NWS Individual Cooperative (COOP) Observers rain gauges as sources for rainfall data. The COOP program, founded in

1890, collects data from more than 11,000 volunteers across the country. Types of meteorological information collected manually or by automated equipment at each COOP site may vary. A map with COOP program rain gauges is located in the Appendix B, these locations were provided by NWS staff in September 2012. Predictions from the National Weather Services are displayed in their online system Advanced Hydrologic Prediction Service (AHPS).

2.3 Virginia Department of Emergency Management (VDEM)

Stream and Rain Gauges

The Virginia Department of Emergency Management (VDEM) manages the Virginia Integrated Flood Observation and Warning System (IFLOWS), a joint venture between VDEM, the NWS, and local jurisdictions. The IFLOWS program has evolved on a national level since the late 1970s, and today includes 250 computers with 1500 sensors in 12 states. The current IFLOWS program for Virginia consists of 35 jurisdictions, in the western areas of the state, with 282 rain sensors and 80 stream sensors. The rain and stream sensors report continuously in real-time, data uploaded in 15 minute increments, and can be viewed on the Virginia IFLOWS webpage. A map of current rain and stream gauges in the Rappahannock River Basin can be found in Appendix B and was provided by VDEM staff in September 2012. The map shows the rain gauges are located mostly in the Western part of the basin. Also, it is important to note that IFLOWS stream gauges report stage readings and have not been calibrated to the associated flow rate (a rating curve has not been developed for these sites). The IFLOWS network has its own quality control process since it is primarily used for predicting floods and monitoring active flooding.

2.4 Virginia Department of Environmental Quality (VA DEQ)

Water Quality Monitoring

The Virginia Department of Environmental Quality (VA DEQ) conducts water quality monitoring with field samples, in addition to managing five stream flow gauges in the basin, as discussed in Section 2.1. This is the largest source of water quality data for the Rappahannock River Basin. VA DEQ staff monitors over 1,000 locations across the state of Virginia. According to VA DEQ staff, the water quality monitoring program is re-evaluated on an annual basis to adjust resources to the needs required for 303(d) streams and TMDL Implementation Plans, as well as, several stations that are monitored on a permanent basis to provide a longer record of data. The sites that have monitoring data, whether a single sample or have been sampled often, from the VA DEQ program since 2000 are shown in a map in Appendix B. The dataset presented in this map was provided by VA DEQ staff in September 2012.

As symbolized in the map legend, Trend and Chesapeake Bay Non-Tidal stations are well established with long period of record, while other monitoring sites have a variable record. More information about each site is presented with a map key in Appendix B. VA DEQ also supports citizen monitoring and their web-pages contains guides on how citizen monitoring can be completed, as well as, information on grant opportunities to fund local groups to perform monitoring. The site also contains information on how citizen monitoring can be used to support TMDL, 303(d) streams, for education and outreach, or for suggestions for future areas to monitor.

When VA DEQ staff sample at a monitoring site, they first "perform on-the-spot field tests for dissolved oxygen, pH, temperature, salinity, and additional indications of water quality. Samples from the mud at the bottom of lakes and rivers also are tested for the presence of pesticides and other harmful compounds." Additionally, "These water samples are shipped to a state laboratory for chemical and bacterial tests. The samples are tested for levels of nutrients, solids, bacteria associated with human and animal wastes, toxic metals, some pesticides and harmful organic compounds." Results of VA DEQ water quality monitoring can be found in GIS format on their webpage (VEGIS).

2.5 Other

The Virginia Water Monitoring Council (VWMC)

The Virginia Water Monitoring Council was established in 1999, to coordinate water quality monitoring activities in the state of Virginia. The council consists of over 500 members from academia, citizen groups and other nonprofits, consulting firms, industry, and the community, local and regional governments, Virginia government agencies, and multi-state and Federal government agencies. The council has a steering committee in which representatives from VA DEQ and USGS participate on a permanent basis.

Environmental Protection Agency (EPA) National Aquatic Resource Surveys (NARS)

EPA publishes water quality data on the EPA STORET Data Warehouse web-page, as Section 2.1 discussed. This site contains data from the EPA's Environmental Monitoring and Assessment Program (EMAP), which is now the National Aquatic Resource Survey (NARS), from 2004 to 2009 for the upper basin and 1993 to 2002 and 2005 to 2006 for the lower basin. The National Aquatic Resource Surveys provide for random sampling designed to provide regional and national estimates of the condition of the national aquatic resources.

National Park Service (NPS) Water Resources Division

The National Park Service (NPS) Water Resources Division collects water quality data through partnership with USGS for Shenandoah National Park, Fredericksburg-Spotsylvania National Battlefield Park, and Fredericksburg National Cemetery. This data has been used for past projects that have developed the acidification vulnerability of the park and also reported on the effects of human activities and recreational use on bacteria concentrations in streams. Data records collected by the NPS Water Resources Division for both the lower and upper basin are located on the EPA STORET site.

Virginia Department of Health (VDH)

The Virginia Department of Health monitors water quality at beaches and for drinking water, including groundwater well information. There are no beaches in this study area. Drinking water provided by waterworks companies have required testing by VDH, which far exceeds the accuracy a water quality gauge could provide. Additionally, ground water health for some areas are provided on the VDH web-page, but as discussed in Section 1.2, Study Coordination, ground water is outside of the scope of work, but should be investigated further in the future.

The Virginia Institute of Marine Science (VIMS) Virginia Estuarine and Coastal Observing System (VECOS)

The VIMS VECOS provides water quality data sampled in the Chesapeake Bay and some tributaries. The data is developed from mapping, continuous measurements, and long term sampling. There are several locations in the lower basin, but there are no sites in this study area as the program focuses on the Chesapeake Bay.

The Virginia Save Our Streams (VA SOS)

VA SOS program monitors water quality by volunteers from different organizations who may be funded by the Virginia Citizen Water Quality Monitoring Program passed in 2002, amended in 2007 and requires a quality assurance plan for the data. The program has over 700 data archives available from their web-page for the Modified Method (Rocky Bottom) Data Entry Form, which determines the benthic community health in higher gradient streams. Additionally, from Chapter 3 of the *Draft 2012 305(b)/303(d) Water Quality Assessment Integrated Report*, through VA SOS 2,652 water quality samples for level I, partially approved by VA DEQ, or level II, approved by VA DEQ, have been taken at 106 different sites by various environmental groups in the Rappahannock River Basin. The VA SOS is in conjunction with the citizen monitoring discussed in the VA DEQ Water Quality monitoring section above.

3.0 PROBLEMS AND OPPORTUNITIES

In order to develop both proposed locations for stream, rainfall, or water quality gauges and justification for these gauges this study contacted local stakeholders and technical experts, and also researched any existing information or reports which could suggest or identify gauging needs and locations. Existing information considered, in addition to the agency programs discussed above, include dam locations, 303 (d) Impaired Streams, and Virginia Pollution Elimination Discharge System (VPEDS) permitting. Existing reports considered include Local Hazard Mitigation Plans, TMDL Implementation Plans or Proposed Plans, and Local Water Supply Plans.

Information collected through coordination with agencies, local groups, or local governments is provided in the Appendix C, and all suggestions are included in developing proposed gauge locations and prioritization. This is further explained in Section 4.0, Proposed Gauges, It is important to recognize each locality within the study area was contacted and given a chance to participate in this study, furthermore, additional coordination was conducted to ensure each locality had at least one representative respond with proposed gauge locations or that no additional information is needed for that locality.

3.1 Dams

There are two dam inventories considered in this study, both with different requirements for which dams are included, these are the USACE National Inventory of Dams (NID) and the VA DCR Dam Inventory. Both Inventories are displayed on a map in Appendix B; generally the inventory by VA DCR includes all of the dams in USACE NID and additional smaller impoundments. Additional information on what size dams are in each of these inventories can be found on the respective web-pages for each program. It is important to consider dams in the gauging analysis for two reasons. First, dams pose a safety risk for the potential of dam breach or break that can cause flooding downstream. However, gauges placed for monitoring dam safety is not considered in this study since VA DCR is currently working on developing a DamWatch program developed by USEngineering Solutions. According to the company:

> "USEngineering Solutions has developed the DamWatch(r) dam-monitoring software application to enable dam owners and dam safety professionals to proactively monitor, in real-time, their valuable infrastructure so they can better prevent and protect against hazardous, costly, and potentially catastrophic events.
>
> DamWatch collects and processes real-time data at regular intervals from weather and hydrologic sources, meters and gauges, and other sensing devices. Data comparisons are then performed against internal dam databases to alert, when appropriate, essential

personnel via any electronic medium (cell phones, pagers, email, fax, etc.) when dams are experiencing a dangerous or critical event. DamWatch can also be utilized as a hands-on training and scenario tool for emergency preparedness because of the application's archiving and event simulation capabilities."

Secondly, dams can control the amount of flow going into the receiving stream and will affect where stream gauges and water quality gauges should be located. Therefore dams should be a consideration in gauge placement even though there is not a need for gauges to specifically monitor dams at this time.

3.2 Hazard Mitigation Plans

Hazard mitigation plans are prepared for jurisdictions or multi-jurisdictional areas to assist state or local governments in identifying and preparing for natural hazards. They are required by the Robert T. Stafford Relief and Emergency Assistance Act amended, by Section 322 of the Disaster Mitigation Act of 2000 (DMA 2000), which addresses the requirements for mitigation planning at state and local levels; and further outlined by the National Flood Insurance Act of 1969, as amended by the National Flood Insurance Act of 2004. FEMA implements various hazard mitigation planning provisions through regulation 44 Code of Federal Regulations (CFR) Part 201, Mitigation Planning. Also, 44 CFR Part 201.6 requires a jurisdiction to adopt a hazard mitigation plan to be eligible for Hazard Mitigation Assistance (HMA) which includes: Hazard Mitigation Grant Program (HMGP), Pre-Disaster Mitigation (PDM), Flood Mitigation Assistance (FMA), Repetitive Flood Claims (RFC) and Severe Repetitive Loss (SRL) grant funding. Further explanation of mitigation assistance can be found in FEMA's Local Multi-Hazard Mitigation Planning Guidance, published July 1, 2008.

Each plan for the communities in the Rappahannock River Basin is multi-jurisdictional and managed by the representative Planning District Commission (PDC). The state of Virginia is broken down into 21 planning districts, which are chartered as a political subdivision of the state under the Regional Cooperation Act. The PDC boundaries are political and do not follow the Rappahannock River Basin boundaries. More information about Virginia PDC, including a map of PDC boundaries, is available from the Virginia Association of Planning District Commissions (VA PDC) web-page: www.vapdc.org.

The plans which cover the Rappahannock River Basin contain background information about what storm events have affected the area, however, most information is general and list when disasters were declared and not details about particular problem areas or high water marks which would be useful for the gauging analysis. The most relevant information provided in these plans include that two of three plans that cover the upper and middle Rappahannock River Basin list

improved monitoring capabilities as a mitigation strategy. The following is a summary of relevant information from each plan:

George Washington Regional Commission Hazard Mitigation Plan, March 2012 (Covers the Middle Basin – Stafford and Spotsylvania Counties and the City of Fredericksburg)

- Page 318 - GWRC Mitigation Strategies – Flood Gauge Installed on Rappahannock River by the City of Fredericksburg – It is recommended to establish an early warning system, such as river gauging and flood warning systems, for jurisdictions in the GWRC region that can provide event-distinct information to citizens and businesses.

Rappahannock-Rapidan Multi-Jurisdictional Hazard Mitigation Plan, 2012 Update (Covers most of the Upper Rappahannock River Basin – Counties of Culpeper, Fauquier, Madison, Orange, and Rappahannock, and the towns of Culpeper, Madison, Orange, Remington, and Warrenton)

- Appendix A: Page 2 – Region Wide Project 13, improved water monitoring capabilities along major rivers in the region (including additional monitor stations and improved data tracking capabilities)
- Appendix C: Page 29 – IFLOWs rain gauge to be used for early warning systems.

Thomas Jefferson Planning District Commission Regional Natural Hazard Mitigation Plan, 2012 Update (Covers Greene County)

- No suggestions developed from the review of this plan.

3.3 VPDES Permit Locations

The Virginia Pollutant Discharge Elimination System (VPDES) program is managed by the Virginia Department of Environmental Quality. The VPDES program is the state administration of the required NPDES permit system, established in 1972, which require permits for any point source discharges to waters of the United States. Permits are issued to wastewater dischargers setting effluent limits and monitoring and reporting requirements. See Appendix B for a Map of the Individual Permits and detailed tables with individual and general permits in the basin provided by VA DEQ in November 2012. Generally, the permit locations were not used in the analysis, exceptions include if specific discharge points were identified by local stakeholders as areas where stream gauge and water quality gauge could be helpful. In order to maintain a permit for a larger facility, such as a waste water treatment effluent, specific site monitoring is already required and managed with the VPDES Permit program. However, the data collected for compliance with various wastewater treatment plant (WWTP) permits could be coordinated and used in conjunction with continuous data collected by proposed water quality gauges.

3.4 303(d) and TMDL Development and Implementation Plans

According to the *Draft 2012 305(b)/303(d) Water Quality Assessment Integrated Report*: Section 303(d) of the Clean Water Act and the Environmental Protection Agency's regulation 40 CFR, Section 130.7 (d) requires each state to submit a Total Maximum Daily Load (TMDL) Priority List to EPA on April 1 of even numbered years. In order to accomplish this, VA DEQ must perform and assessment of streams in Virginia to determine if they must be added to the Federally mandated 303(d) impaired stream list. It is important to note that not all streams have been through this evaluation to be considered impaired or not impaired. If the streams/stream segments are added to the 303 (d) list, they then require the development of a Total Maximum Daily Load in order to reduce the pollutants. The Total Maximum Daily Load reductions are accomplished through the development of a TMDL Implementation Plan, which proposes mitigation strategies to improve water quality for the impaired stream segment. Typically, to assess the condition of a stream VA DEQ uses trend stations, over a 20 year period of record of monthly monitoring that includes: bacteria, total suspended solids, total nitrogen, and total phosphorus. This data is submitted to an EPA approved quality assurance/quality control process. Citizen monitoring data can also be useful to track improvements in water quality due to TMDLs, but does not go through a QA/QC process approved to be used for 303(d) assessments. The *Draft 2012 305(b)/303(d) Water Quality Assessment Integrated Report* provides detailed information on the monitoring datasets considered for use and current 303(d) and TMDL status. An important item to note about VA DEQ monitoring is the trend stations must be associated with a USGS stream flow gauge, therefore additional stream flow gauges could allow for additional opportunities for monitoring. A map of the current 303 (d) stream segments in Virginia is located in Appendix B.

The following is a review of the recent TMDL Implementation Plans and TMDL Reports for any information pertaining to data collection needs completed for the study area:

<u>Upper Hazel River Bacteria Total Maximum Daily Load Implementation Plan</u>

- Page 23 - The plan identifies control measures to reduce bacteria. These measures are implemented throughout the Upper Hazel River Basin, and therefore do not pinpoint a specific area where a gauge would be helpful for monitoring.
- Page 33 – The plan identifies VA DEQ monitoring stations in the Upper Hazel River Basin. There are four Trend stations that will be permanently monitored. Three additional watershed stations, which are sampled twelve times over a two year period, rotated in a six year cycle. Additionally, there is one TMDL IP monitoring station which is created to track the progress of this implementation plan and is sampled over other month during the year. The impaired portions of this watershed include the Hughes,

Hazel and Rush Rivers. The Hughes and Hazel River have long term trend stations; however the Rush River is only monitored by the TMDL IP station, but is the smallest sub-watershed in the Upper Hazel River Watershed.

Little Dark Run and Robinson River Bacteria Total Maximum Daily Load Implementation Plan

- Page 19 - The plan identifies control measures to reduce bacteria. These measures are spread out and implemented on large portions of the Little Dark Run and Robinson River Basins, and therefore do not pinpoint a specific area where a gauge would be helpful for monitoring.
- Page 32 – The plan identifies VA DEQ monitoring stations in the Little Dark Run and Robinson River Basins. There are two Trend stations that will be permanently monitored. Three additional Watershed Stations, which are sampled twelve times over a two year period, rotated in a six year cycle. The impaired portions of this watershed include a small portion of the Upper Robinson River, Little Dark Run, and the portion of the Lower Robinson River leading to the confluence. The Trend Stations are located in the middle of the Robinson River Basin and near the confluence on the Robinson River.

Craig Run, Browns Run, and Marsh Run Bacteria Total Maximum Daily Load Implementation Plan

- Page 19 - The plan identifies control measures to reduce bacteria. These measures are spread out and implemented on large portions of the Craig Run, Browns Run, and Marsh Run Basins, and therefore do not pinpoint a specific area where a gauge would be helpful for monitoring.
- Page 31 – The plan identifies VA DEQ monitoring stations in the Craig Run, Browns Run, and Marsh Run Basins. There are no Trend stations in the segments of impaired stream. However, there are five VA DEQ Watershed Stations which are sampled twelve times over a two year period, rotated in a six year cycle. The plan also suggests citizen monitoring to continue at a station from the John Marshall Soil and Water Conservation District on Marsh Run.

Bacteria Total Maximum Daily Load Development for the Rappahannock River Basin

- This plan is applicable to portions of the Hughes River, two segments of the Hazel River, Rush River, three segments of the Rappahannock River, Craig Run, and Browns Run.
- The plan models water quality, the fate and transport of fecal coliform bacteria, through the Hydrologic Simulation Program – Fortran (HSPF).
- Page 2-4 – There is at least one VA DEQ station on each impaired stream segment. (For more details compare 303(d) map and VA DEQ station map included in this report).

- Page 4-30 – The VA DEQ stations on each impaired segment are used for water quality calibration and validation. The report adds: "It should be noted that each observed bacteria concentration datum represents a "snapshot" resulting from the examination of one grab sample, while the modeled data represents a continuous time series of bacteria concentration. Uncertainty exists in the stream condition the grab sample represents. For example, was the sample taken as the bacteria concentration was increasing or decreasing in the stream? The short-period fluctuations in modeled bacteria concentration represent the variability within daily concentrations associated with wildlife, livestock, and straight pipe direct deposition distribution across each day." However, the simulation results produced acceptable results using this data.

Bacteria Total Maximum Daily Load Development for the Rapidan River Basin

- This plan is applicable to portions of Marsh Run, Blue Run, two segments of the Rapidan River, Unnamed Tributary to the Rapidan River, and Cedar Run.
- The plan models water quality, the fate and transport of fecal coliform bacteria, through the Hydrologic Simulation Program – Fortran (HSPF).
- Page 2-4 – There is at least one VA DEQ station on each impaired stream segment. (For more details compare 303(d) map and VA DEQ station map included in this report).
- Page 4-29 – Similar to the Bacterial TMDL IP for the Rappahannock River Basin, this plan also mentions that VA DEQ stations are used for calibration and validation and only represent a "snapshot" in time. However, the simulation results for the Rapidan River basin were also acceptable using this data.

3.5 Water Supply Plans

All water supply plans for each jurisdiction in the study area were reviewed. Water supply plans typically use one or two stream gauges and a rain gauge to estimate water availability. Additional rain and stream gauges could allow for more accurate water supply predictions on a local basis. The following sections provide information from the water supply plans considered in this analysis.

Fauquier County Regional Water Supply Plan

- Page 23 – "Surface Water Resources Objective SW5 (Monitoring): Work with DEQ, USGS, JMSWCD, and citizen volunteers to establish and maintain a monitoring program for County streams that can be used to gage changes through time and that is accessible to the public."
- Page 68 – "The USGS in partnership with VA DEQ collects real-time water flow data using stationary stream gauging stations placed throughout the state. There are two

continuously monitored stations, by USGS in partnership with VA DEQ, within Fauquier County: Cedar Run near Catlett, Virginia and the Rappahannock River near Remington, Virginia (USGS 2011). The Cedar Run station was established in order to measure discharge in cubic feet per second (CFS) in 1950. […] Between 1968 and 2008 water quality analysis was done on samples collected from this station during 19 discrete sampling events. Because of the infrequency of the sampling events, it is difficult to extrapolate any long term trends from the data collected."

- Page 111 – "Stream flows-USGS stream flow gages located in discrete locations (Remington, Cedar Run, Goose Creek) throughout the County will be identified in order to monitor the water level within the stream and compare it with historic data available through the USGS."

<u>The Water Supply Plan for Rappahannock County and the Town of Washington</u>

- Page 45 – Two stream flow gauges are used in the water supply analysis:
    - Hazel River at Rixeyville, Gauge Number 01663500, 59 years of record
    - Battle Run, Gauge Number 01662800, 46 years of record
    - Page 49 – "These gauges are critical resources in evaluating the hydrologic conditions within the County."
    - Page 87 – "Under no circumstances should these gaging stations be discontinued."
- Page 46 – "The second analytical challenge is that determining the value for MAP (Mean Annual Precipitation) is complicated due to the fact that rainfall amounts can vary widely across the County. Much of this variability can be attributed to the "Shadow" effects of the Blue Ridge Mountains and to the mountains and valleys within the County. While there is a gauge in Sperryville, it is unlikely to be representative for the county as a whole. It is quite common, for example, that Sperryville can experience a significant rainfall even while other parts of the County receive no rain at all. Likewise, the southern part of the County can experience rainfall while the upland areas, including Sperryville, receive little or no rain."
- Page 86 – "More locally focused monitoring and record keeping and evaluation of needs should be undertaken in order to refine both drought response planning and to assist local users in the county. The data generated here in the headwaters will also provide a regional early warning system to support more measured and better-timed responses in localities in the downstream reaches of the Rappahannock River Basin and in the flatter down gradient portions of the fractured rock aquifers of the Piedmont."
- Page 87 – Needs:
    - Monitor flows from springs and identify their capture zones.

- Develop a set of meteorological monitoring stations that will be able to track precipitation on at least an hourly basis to identify rainfall patterns, temperatures, wind speeds, and snowfall.

Water Supply Plan Stafford County, Virginia

- Drought analysis does require looking at the stream flows in the Rappahannock River, however specific gauging site used is not listed. One proposed alternative in the plan suggest that Stafford County could fill future water supply needs with storage reservoirs filled with pumped water from the Rappahannock
- The proposed Rocky Pen Run Reservoir, which will be an impoundment by the construction of dam upstream of the mouth of Rocky Pen Run, north of the Rappahannock River in Stafford County, is currently under construction.

Regional Water Supply Plan for Greene County, Virginia, and Town of Standardsville

- A proposed reservoir, White Run Reservoir, is currently under permit review. White Run Reservoir will pump surface water from the tributary of White Run of the Rapidan River.

Other plans reviewed, but no pertinent information obtained:

- Regional Water Supply Plan for Town of Culpeper, Virginia and Culpeper County, Virginia
- Spotsylvania County, Virginia and City of Fredericksburg Regional Water Supply Plan
- Regional Water Supply Plan, Town and County of Madison, Virginia
- Orange County Water Supply Plan

4.0 PROPOSED GAUGES

4.1 Identified Locations

The following is a list of identified locations for rainfall, stream or water quality gauges that have been developed from coordination with local stakeholders, technical experts, and the background researched from the previous sections. Refer to the comments located in Appendix C from all agencies or other groups involved in the study effort for the source of most of the identified gauge locations and reasoning.

Table 4.1 Identified Locations

Id	Issue	Location Description	Type	Source of Information
1	Need real time rain gauge for flooding predictions.	At stream gauge, Battle Run near Laurel Mills, VA	New Rain Gauge	VDEM, Sept 18 Meeting
2	Real time stream and rain gauges to predict flooding in the Mountain Run Area, NWS documents reports of flooding on Oct 2, 2012.	At historic stream gauge Mountain Run near Culpeper, VA	New Rain Gauge, New Stream Gauge	NWS, Sept 18 Meeting and Nov 15 Meeting
3	Real time rain gauge for flooding predictions.	At stream gauge Rapidan River near Culpeper, VA	New Rain Gauge, Water Quality Gauge	VDEM, Sept 18 Meeting
4	Real time stream and rain gauges to predict flooding, also water quality monitoring mainly to build baseline data from an agricultural and forestry portion of the watershed.	Rappahannock River at Route 211 Bridge, at historic stream gauge Rappahannock River near Warrenton, VA	New Rain Gauge, New Stream Gauge, Water Quality	Sept 18 Meeting and Fauquier, J.M. SWCD
5	Extreme need for rain gauge east of Ruckersville, real time stream and rain gauges to predict flooding.	Locust Grove, Route 3, Germanna Hwy, crossing of Rapidan River	New Rain Gauge, New Stream Gauge, Water Quality	VDEM, NWS, Sept 18 Meeting and Nov 15 Meeting
7	Real time stream and rain gauges to predict flooding.	Confluence of Mountain Run and Flat Run	New Rain Gauge, New Stream Gauge	VDEM, Sept 18 Meeting

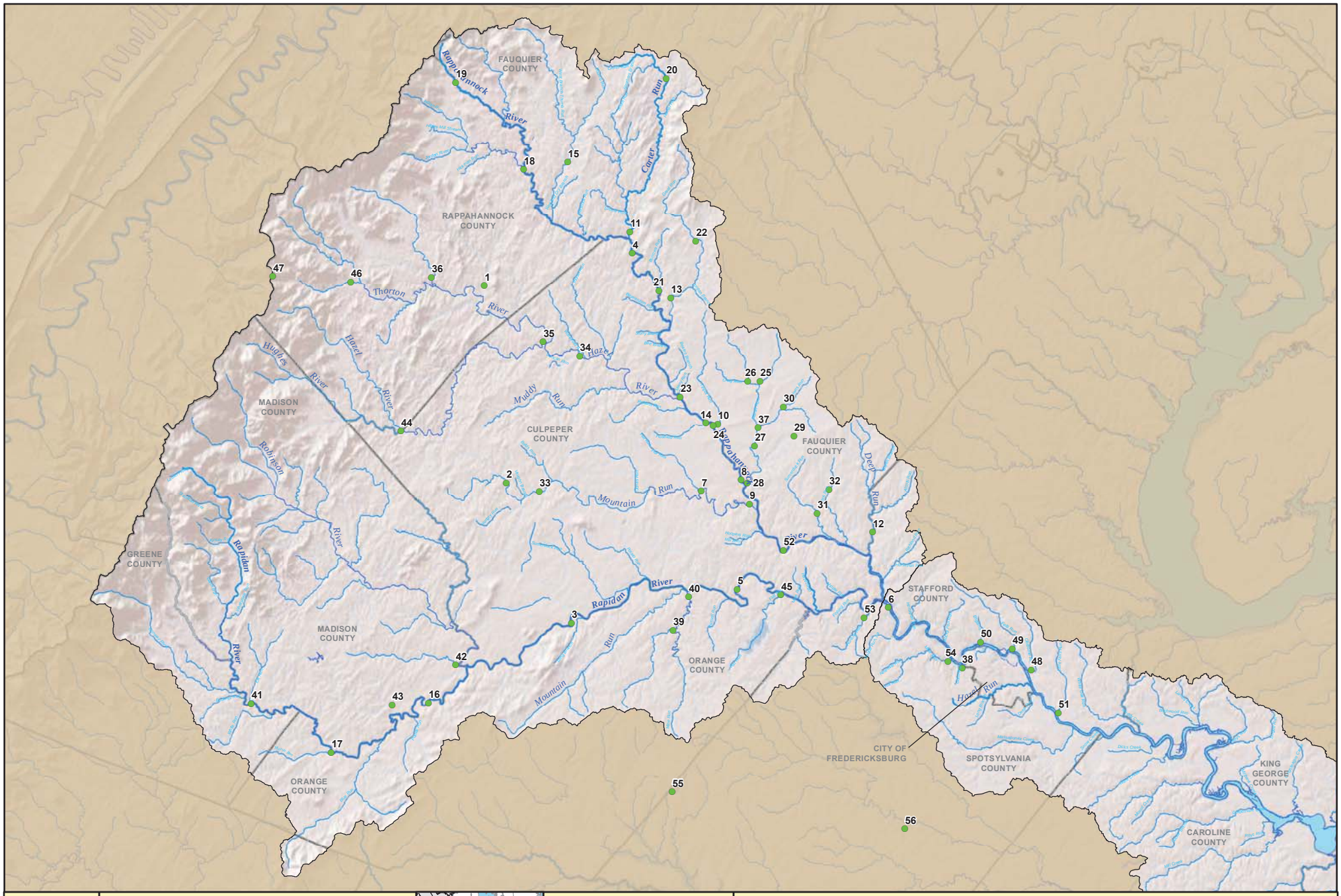
6	Real time stream and rain gauges to predict flooding.	Upriver from Fredericksburg, below the confluence of Rappahannock and Rapidan River, VDEM priority for additional stream gauge	New Rain Gauge, New Stream Gauge	VDEM, NWS, Sept 18 Meeting and Nov 15 Meeting
8	Real time stream and rain gauges to predict flooding, NWS documents reports of flooding on Oct 2, 2012.	Rappahannock River at Route 620 Bridge	New Rain Gauge, New Stream Gauge, Water Quality	Sept 18 Meeting and Fauquier, J.M. SWCD
9	Need for water quality data.	On Mountain Run before confluence with Rappahannock River or at confluence	Water Quality Gauge	Sept 18 Meeting and Fauquier, J.M. SWCD
10	Frequent local flooding and water quality gauge downstream of Remington WWTP, Water Quality for Mountain Run.	Tin Pot Run at Remington, Route 651 Bridge	New Rain Gauge, Water Quality	Nov 15 Meeting and Fauquier, J.M. SWCD and VA DEQ Priority
11	Need for water quality data.	Carters Run at Route 688	Water Quality Gauge	Nov 15 Meeting and Fauquier, J.M. SWCD
12	Need for water quality data.	Deep Run at Route 17	Water Quality Gauge	Nov 15 Meeting and Fauquier, J.M. SWCD
13	Downstream of Warrenton WWTP, plus some stormwater discharge from Warrenton, downstream of Warrenton Training Center.	Great Run at Opal Road, Route 687	Water Quality Gauge	Nov 15 Meeting and Fauquier, J.M. SWCD
14	Need for water quality and rainfall data, upstream of Remington stormwater discharge and WWTP discharge.	Major Outfall, at DEQ Non-tidal station, 3-RTP 147.49, 3-RAP030.21, and USGS Remington Stream Gauge	New Rain Gauge, Water Quality Gauge	Nov 15 Meeting and Fauquier, J.M. SWCD
15	Need for water quality data.	Thumb Run at Route 688, Leeds Manor Rd	Water Quality Gauge	Nov 15 Meeting and Fauquier, J.M. SWCD

16	Need for stream flow and water quality data.	Water intake just about Route 15, need for Stream Gauge	New Stream Gauge, Water Quality Gauge	Nov 15 Meeting
17	Need for water quality data.	Greene County, below Rapidan, near Ruckersville	Water Quality Gauge	Nov 15 Meeting
18	Stream gauge to capture flow from Jordan River, at Crest Hill Road or below. Baseline data needed from a mainly agricultural and forestry portion of the watershed.	Rappahannock River, confluence of Jordan and Rappahannock Rivers, Rt 647 Crest Hill Road Bridge	New Stream Gauge, Water Quality Gauge	NWS, Fauquier, J.M. SWCD
19	Baseline data needed from a mainly agricultural and forestry portion of the watershed. Baseline flow data needed for water supply.	Rappahannock River at Route 635 Bridge	New Stream Gauge, Water Quality Gauge	Fauquier, J.M. SWCD, Tim Bondelid Consulting Engineer
20	Downstream of Marshall WWTP.	Carter Run at 719 Bridge	Water Quality Gauge	Fauquier, J.M. SWCD
21	Downstream of two golf courses and discharge point from Fauquier Springs Country Club WWTP.	Rappahannock River at Route 802 Bridge	Water Quality Gauge	Fauquier, J.M. SWCD
22	Downstream of Warrenton WWTP, plus some stormwater discharge from Warrenton, downstream of Warrenton Training Center.	Great Run at Route 802 Bridge	Water Quality Gauge	Fauquier, J.M. SWCD
23	Need for water quality data.	Confluence of Hazel River and Rappahannock River	Water Quality Gauge	Fauquier, J.M. SWCD
24	Water Quality Gauge to have a comparison with Hazel River and Rappahannock water quality gauge, to measure effects of the Remginton stormwater and WWTP.	Confluence of Tinpot Run and Rappahannock River	Water Quality Gauge	Fauquier, J.M. SWCD
25	Water Quality downstream of Bealeton and Midland Service Districts and Airport Industrial Park, Water Quality Gauge for Craigs Run (303 d stream with no long term monitoring).	Marsh Run at Route 17 Bridge	Water Quality Gauge	Fauquier, J.M. SWCD, and Craigs Run TMDL IP

26	Local flooding due to constriction of floodplain by railroad bridge. Water Quality Gauge for Craigs Run (303 d stream with no long term monitoring).	Craig Run and Bowen Run confluence at Route 656 Bridge. Downstream of Bealeton Service District	New Rain Gauge, New Stream Gauge	Fauquier, J.M. SWCD, and Craigs Run TMDL IP
27	Need for water quality data.	Marsh Run at Route 668 (Savannah Branch Rd) Bridge	Water Quality Gauge	Fauquier, J.M. SWCD and Marsh Run TMDL IP
28	Background data for a largely agricultural watershed. Bottom of watershed for Marsh Run, 303(d) impaired, which has no long term monitoring.	Marsh Run at Route 651 (Germanna Bridge Quad) Bridge	Water Quality Gauge	Fauquier, J.M. SWCD
29	Downstream of large subdivision with online pond.	Harpers Run at Route 17 Bridge	Water Quality Gauge	Fauquier, J.M. SWCD
30	Background data from a largely agricultural watershed.	Browns Run at Route 17 Bridge	Water Quality Gauge	Fauquier, J.M. SWCD
31	Background data from a largely agricultural watershed.	Sumerduck Run at Route 651 Bridge	Water Quality Gauge	Fauquier, J.M. SWCD
32	Background data from a largely agricultural watershed.	Rock Run at Route 17 Bridge.	Water Quality Gauge	Fauquier, J.M. SWCD
33	Stream flow data needed downstream of Lake Pelham Dam.	Downstream of Lake Pelham Dam.	New Rain Gauge, New Stream Gauge	VDEM, Town of Culpepper
34	Need for water quality data.	Bottom of Hazel River Watershed	Water Quality Gauge	Culpepper County
35	Need for water quality data.	Thorton River at Hazel River, Butler store road and Monument Mills Road, for TMDL and water supply planning	New Rain Gauge, New Stream Gauge, Water Quality	Culpepper County, Culpepper SWCD
36	Need for water quality data.	Bottom of Rush River Watershed	Water Quality Gauge	Upper Hazel River TMDL IP, Culpepper SWCD

37	Need for water quality data.	Bottom of Browns Run Watershed	Water Quality Gauge	Browns Run TMDL IP
38	Need for water quality data for Rappahannock River at Fredericksburg, only previous continuous water quality gauge was located here, but has been washed out by a storm. City of Fredericksburg would like to capture water quality runoff from the City.	5 miles upstream of I-95, near Motts Run, to be installed at the intake structure for the City of Fredericksburg	Water Quality Gauge	USGS, City of Fredericksburg
39	Need for water quality data for 303(d) stream with TMDL that drains a large portion of Orange County.	At bottom of Mine Run watershed.	Water Quality Gauge	Culpepper SWCD, Orange County
40	Need for water quality data for 303(d) stream with TMDL that drains a large portion of Orange County.	At the bottom of Mountain Run watershed, drains in Rapidan, in Orange County.	Water Quality Gauge	Culpepper SWCD, Orange County
41	Need for stream flow and water quality data, to support water intake site for Rapidan Service Authority and support TMDL IP for 303(d) portions of Rapidan.	Rapidan River at Route 29	New Stream Gauge, Water Quality Gauge	Culpepper SWCD
42	Need for rainfall, stream flow, and water quality data for Robinson River at route 614. Robinson river is a major tributary of the Rapidan. Robinson river is undergoing a TMDL effort.	Robinson River at Route 614	New Rain Gauge, New Stream Gauge, Water Quality	Culpepper SWCD, Orange County
43	Need for water quality data for Beautiful Run at Route 620, a 303(d) stream.	Beautiful Run at Route 620	Water Quality Gauge	Culpepper SWCD
44	Need for water quality data.	Bottom of Hughes River Watershed	Water Quality Gauge	Culpepper SWCD
45	Need for water quality data.	At bottom of Flat Run Watershed	Water Quality Gauge	Orange County
46	Stream flow and rainfall data on South Fork of the Thorton, Sperryville, several homes and business, some in 1 % annual	South fork of Thornton River, at Rt 522 Bridge, Sperryville	New Rain Gauge, New Stream	Rappahannock County

	chance flood plain.		Gauge	
47	Need for rainfall data in the Park near the headwaters of South Fork of the Thorton, flooding can be caused by heavy rain on snowpack. This is helpful for flooding related issues, but also for drought monitoring.	Headwaters of the South fork of the Thornton River, at Route 211 and the Park entrance	New Rain Gauge	Rappahannock County
48	Need for water quality data for urbanized area and 303(d) stream - Claiborne Run	At bottom of Clairborne Run Watershed	Water Quality Gauge	Stafford County
49	Need for water quality data.	At bottom of Falls Run Watershed	Water Quality Gauge	Stafford County
50	Need for water quality data.	At bottom of England Run Watershed	Water Quality Gauge	Stafford County
51	Need for water quality data.	At bottom of Little Falls Run.	Water Quality Gauge	Stafford County
52	Need for rainfall and stream flow data for flood warning.	At Rappahannock River Kemper's Ford or Richardsville	New Rain Gauge, New Stream Gauge	NWS, VDEM
53	Need for rainfall data for flood warning.	Hunington Run	New Rain Gauge	NWS
54	Need for rainfall data.	Motts Run	New Rain Gauge	VDEM
55	Need for rainfall data (outside of basin, but rain information could provide warnings to basin area).	Po River USGS Gauge	New Rain Gauge	VDEM
56	Need for rainfall data (outside of basin, but rain information could provide warnings to basin area).	Partlow USGS Gauge	New Rain Gauge	VDEM
57	Need for rainfall data (outside of basin, but rain information could provide warnings to basin area).	North Anna River, or close to this area	New Rain Gauge	VDEM



US Army Corps of Engineers
Norfolk District

Figure 4.1
Identified Gauge Locations

0 9,500 19,000 38,000 Feet

1:500,000

Legend

Identified Gauge Locations

Overall there are 57 new gauge sites recommended. Of the 57 sites there are 22 new rain gauges (3 located outside of the border of the basin needed for flood warnings), 17 new stream gauges (for purposes other than WQ), and 43 new water quality gauges (which will also require a stream gauge not listed). The total combinations of each are as follows:

- Rain Only - 6
- Rain and Stream - 8
- Rain and Water Quality - 3
- Rain and Stream and Water Quality - 5
- Stream and Water Quality - 4
- Water Quality Only - 31

4.2 Analysis

The 57 recommended gauge sites are analyzed to determine funding priorities. Opportunities for funding installation will only allow for one or a few gauges at a time due to the cost and continuing operation and maintenance cost. Only the top priority gauges should be the focus when pursuing initial funding sources for installation. Other gauge locations can be considered in the future when funding opportunities are available. The analysis criterion is created based off of comments provided by local stakeholders and technical experts. The list of identified gauges has been developed from August 2012 to January 2013 and locations can be expected to change some over time. This analysis criterion could be used to re-prioritize a revised list of suggested gauge locations in the future.

The first step in the analysis is to group together gauge recommendations that are close to one another, and can serve the same or similar purpose. To combine sites, some sites need to be deleted, while others need to be shifted slightly. Combined sites will contain the notes and contributing organization from all original sites. Additionally, smaller tributaries with more than one stream or water quality gauge recommended are reduced to one gauging site. By combining and removing multiple gauges and reducing the number of recommended gauge sites on smaller tributaries only 32 identified gauge sites remain. If a gauge site was combined or removed from consideration the site was attributed with a YES in the ESRI ArcGIS shapefile of all gauge locations and the reason why it is combined or removed, see Appendix C, proposed gauge location map key of the shapefile attribute table for all gauge locations.

The following chart shows the process used to rank the remaining gauge sites. The sections following the chart provide further details on each step of the gauging analysis.

FIGURE 4.2 PROCESS FLOW CHART OF ANALYSIS CRITERIA

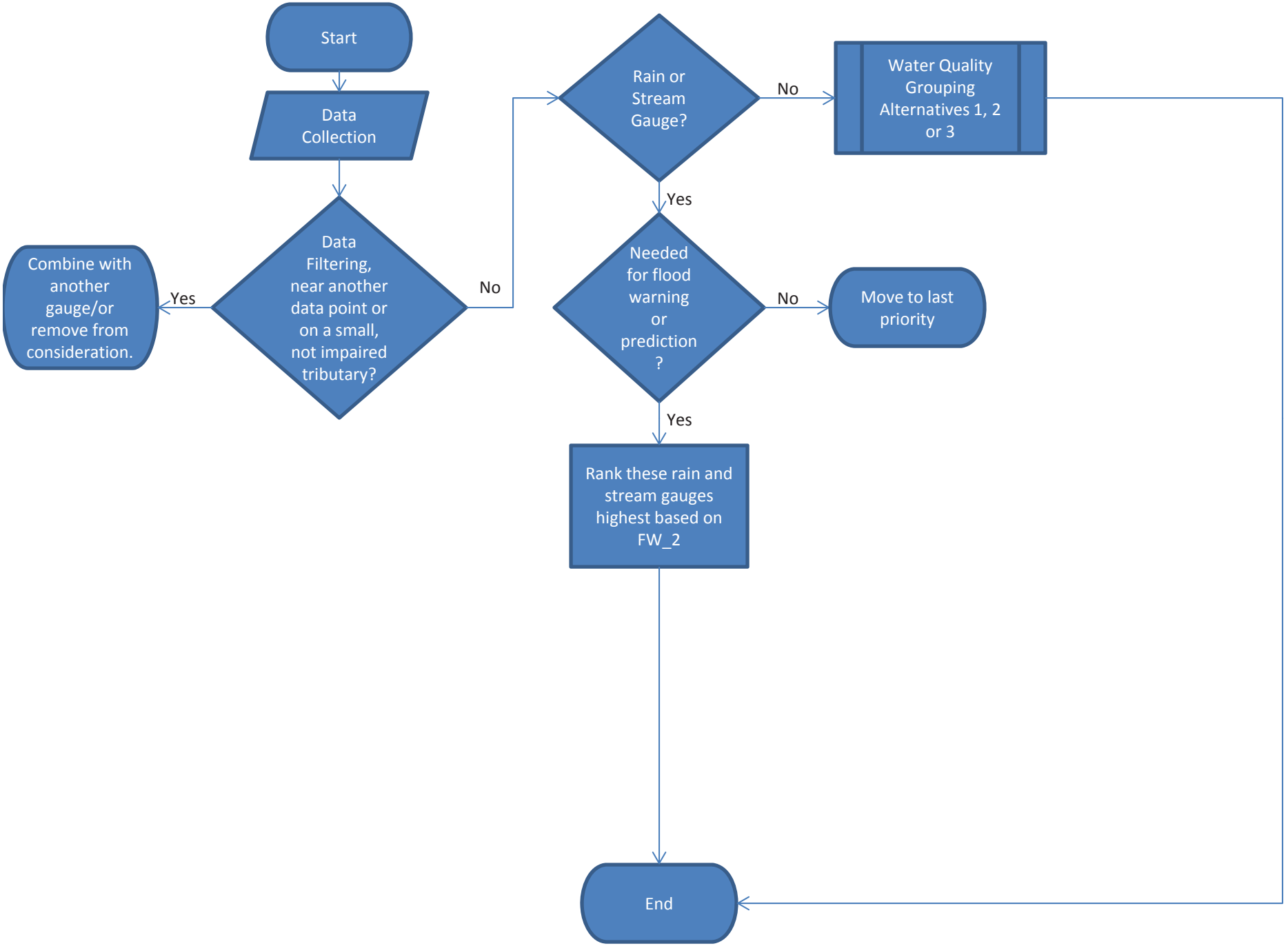
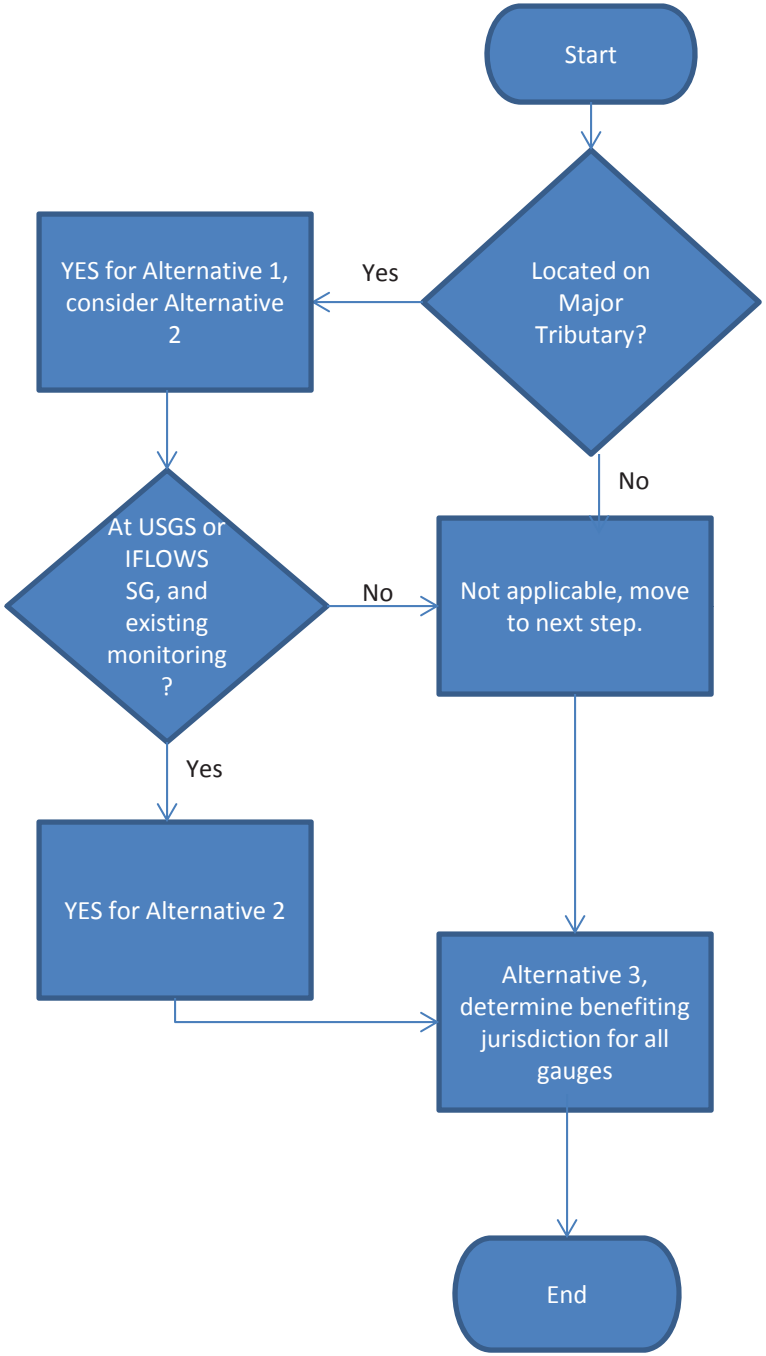


FIGURE 4.2, CONTINUED, PROCESS FLOW CHART OF WATER QUALITY ALTERNATIVES



Rain and Stream Gauges

Rain and stream gauge sites requested for flood prediction and warnings or water supply are considered separately from water quality gauges in developing the priorities for sites. Flood warning is a life safety issue and should be given top priority to ensure adequate prediction capability for forecasters.

FW_1. Rain and stream gauges needed for flood prediction and warning. (YES = go to FW_2, NO = move to end of rain and stream gauge recommendations)

FW_2. Review comments to rank rain and stream gauges needed for flood prediction and warning. Rain gauges to be added to existing stream gauges should be ranked high. Second, stream or rain gauges recommended by multiple parties should be ranked high. Rain gauges should be distributed to provide adequate coverage to all areas of the basin, considering the topography, to include the mountainous areas in the northwest portion of the basin, and its effects on the movement of storms through the region. Also, recommended stream gauges should be as uniformly distributed throughout the stream network of the basin as possible with existing gauges, understanding that more gauges are needed on larger tributaries where there are more effects. Overlay proposed gauge stations with both the VA DCR Dam Inventory and the NID. Remove from consideration gauge locations that would monitor already regulated flow. Additionally, VA DCR is working on creating a DamWatch program for dam safety monitoring; therefore gauges for dam sites are not recommended in this analysis. (Rank gauges from high to low, these will be the highest priority gauges).

The following table is the ranking for rain and stream gauges:

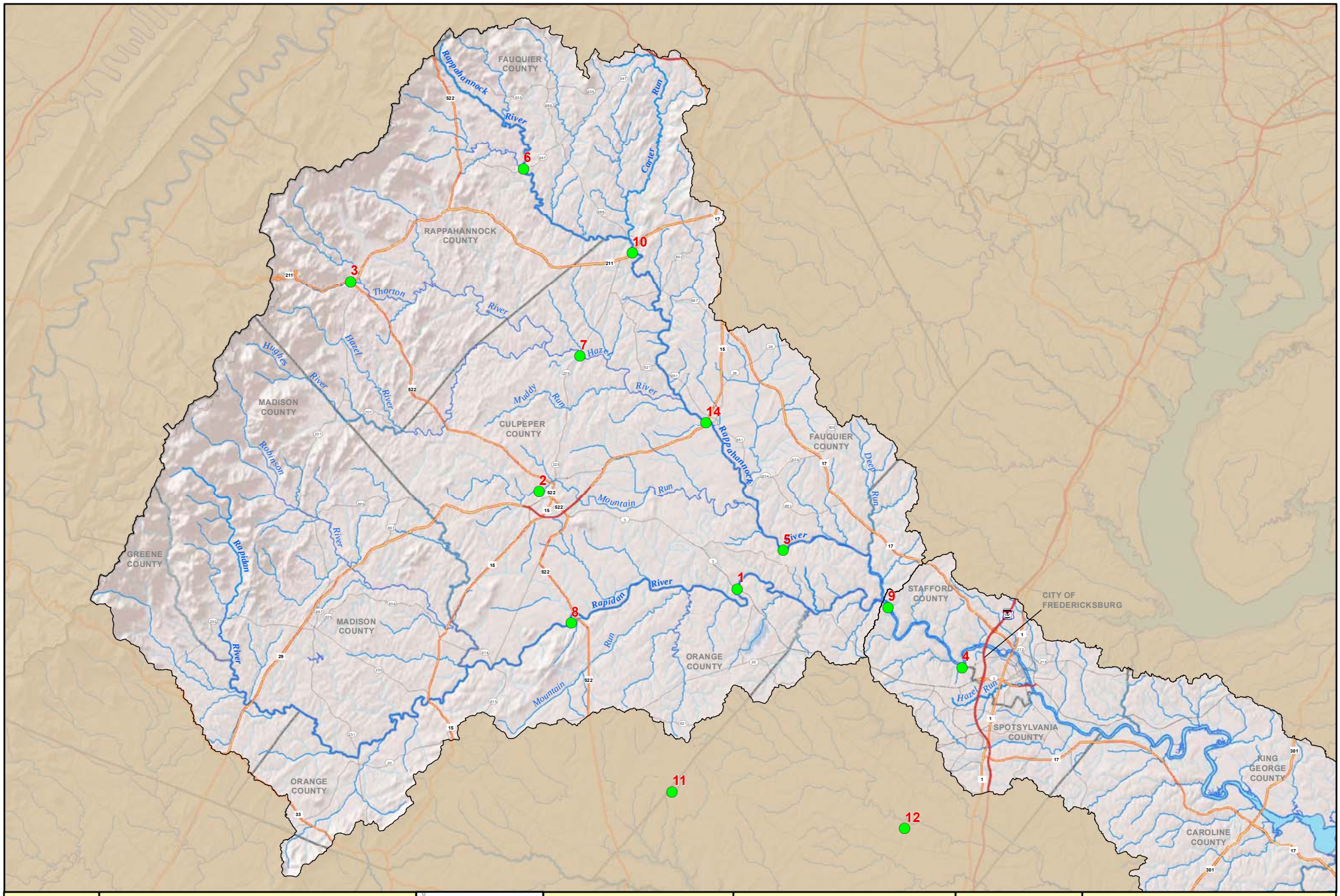
Table 4.2 Final Priority List of Proposed Gauge Locations for Rain and Stream Gauges

Priority	Id	Issue	Location Description	Type	Source of Information
1	5	Extreme need for rain gauge east of Ruckersville, real time stream and rain gauges to predict flooding.	Locust Grove, Route 3, Germanna Hwy, crossing of Rapidan River	New Rain Gauge, New Stream Gauge, (Water Quality)	VDEM, NWS, Sept 18 Meeting, Nov 15 Meeting, and Orange County
2	33	Stream gauge downstream of Lake Pelham Dam. Real time stream and rain gauges to predict flooding in the	Downstream of Lake Pelham Dam	New Rain Gauge, New Stream Gauge	VDEM, Town of Culpepper, NWS, Sept 18 Meeting and Nov 15 Meeting

		Mountain Run Area, NWS documents reports of flooding on Oct 2, 2012.			
3	46	Need for rainfall and stream flow information on South Fork of the Thorton, Sperryville, several homes in business, some in 1 % annual chance flood plain.	South fork of Thornton River, at Rt 522 Bridge, Sperryville	New Rain Gauge, New Stream Gauge	Rappahannock County
4	38	Need for rainfall data.	5 miles upstream of I-95, near Motts Run, to be installed at the intake structure for the City of Fredericksburg	New Rain Gauge, (Water Quality)	USGS, City of Fredericksburg, VDEM
5	52	Need for rainfall data.	At Rappahannock River Kemper's Ford or Richardsville	New Rain Gauge, New Stream Gauge, (Water Quality)	NWS, VDEM
6	18	Need for stream flow information from Jordan River.	Rappahannock River, confluence of Jordan and Rappahannock Rivers, Rt 647 Crest Hill Road Bridge	New Stream Gauge, (Water Quality Gauge)	NWS, Fauquier, J.M. SWCD, Tim Bondelid Consulting Engineer
7	34	Need for rainfall data.	Bottom of Hazel River Watershed	New Rain Gauge, (Water Quality Gauge)	Culpepper County, VDEM Sept 18 Meeting
8	3	Need for rainfall data.	At stream gauge Rapidan River near Culpeper, VA	New Rain Gauge, (Water Quality Gauge)	VDEM, Sept 18 Meeting
9	6	Need for rainfall and stream flow information for flood warning.	Upriver from Fredericksburg, below the confluence of Rappahannock and Rapidan River, VDEM priority for additional stream gauge	New Rain Gauge, New Stream Gauge, (Water Quality)	VDEM, NWS, Sept 18 Meeting and Nov 15 Meeting

10	4	Need for real time rainfall, stream flow for flood warning.	Rappahannock River at Route 211 Bridge, at historic stream gauge Rappahannock River near Warrenton, VA	New Rain Gauge, New Stream Gauge, (Water Quality)	Sept 18 Meeting and Fauquier, J.M. SWCD
11	55	Need for rainfall data (outside of basin, but rain information could provide warnings to basin area).	Po River USGS Gauge	New Rain Gauge	VDEM
12	56	Need for rainfall data (outside of basin, but rain information could provide warnings to basin area).	Partlow USGS Gauge	New Rain Gauge	VDEM
13	57	Need for rainfall data (outside of basin, but rain information could provide warnings to basin area).	North Anna River, or close to this area	New Rain Gauge	VDEM
14	14	Need for rainfall data.	Major Outfall, at DEQ Non-tidal station, 3-RTP 147.49, 3-RAP030.21, and USGS Remington Stream Gauge	New Rain Gauge, (Water Quality Gauge)	Nov 15 Meeting and Fauquier, J.M. SWCD

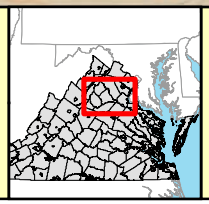
The following page shows Figure 4.3, Prioritized Rain and Stream Gauge Sites.



US Army Corps of Engineers
Norfolk District

Rappahannock River Basin Gauging Analysis

Figure 4.3
Prioritized Rain and Stream Gauges



0 2 4 8 Miles

1:500,000

Proposed Gauge Location
Rappahannock River Basin
County Boundary

Projection:
Virginia State Plane
North Zone - NAD 83
U.S. Survey Feet

Basemap:
Esri ArcGIS Online
World Shaded Relief

Project Manager: Holly Carpenter
E-mail: Holly.A.Carpenter@usace.army.mil
Phone: (757) 201-7825
Fax: (757) 201-7646

Map Date: 11 February 2013

Water Quality Gauges

Water quality gauges are not individually ranked, but are grouped into three alternatives based on the level of detail and applicability of each recommended water quality gauge site.

WQ_ALT1. Alternative 1: Recommend quality gauging sites for major rivers and tributaries to develop an overall picture of pollutants for the study area. (ALT1 = YES).

WQ_ALT2. Alternative 2: Recommend water quality gauging sites for major rivers and tributaries to develop an overall picture of pollutants for the study area, but reduce to those easiest to install and most cost effective due to existing monitoring and stream gauges, while still maintaining a dispersed network to represent the basin. (ALT2 = YES).

WQ_ALT3. Alternative 3: Consider specific water quality gauging sites for each jurisdiction. (ALT3 = add name of localities benefiting from each water quality gauging site).

Considerations used in the water quality analysis:

Pollutant: The desired pollutant to measure at each water quality site is added for the remaining 27 water quality sites after being removed or combined as discussed above. The desired pollutant to be measured is determined from the VA DEQ 303(d) riverine assessment shapefile and additional pollutants of TN, TP, and TSS are considered for stations on the major tributaries as these pollutants have TMDLs imposed for the entire Rappahannock River Basin as it is a tributary of the Chesapeake Bay. The following pollutants or impairment causes are identified for gauging sites in the study area: Total Nitrogen (TN), Total Phosphorus (TP), Total Suspended Sediment (TSS), Benthic-Macro invertebrate Bioassessments, Escherichia coli (E-coli), PCB in Fish Tissue, pH, Mercury in Fish Tissue, Dissolved Oxygen (DO), Water Temperature, and Fecal Coliform.

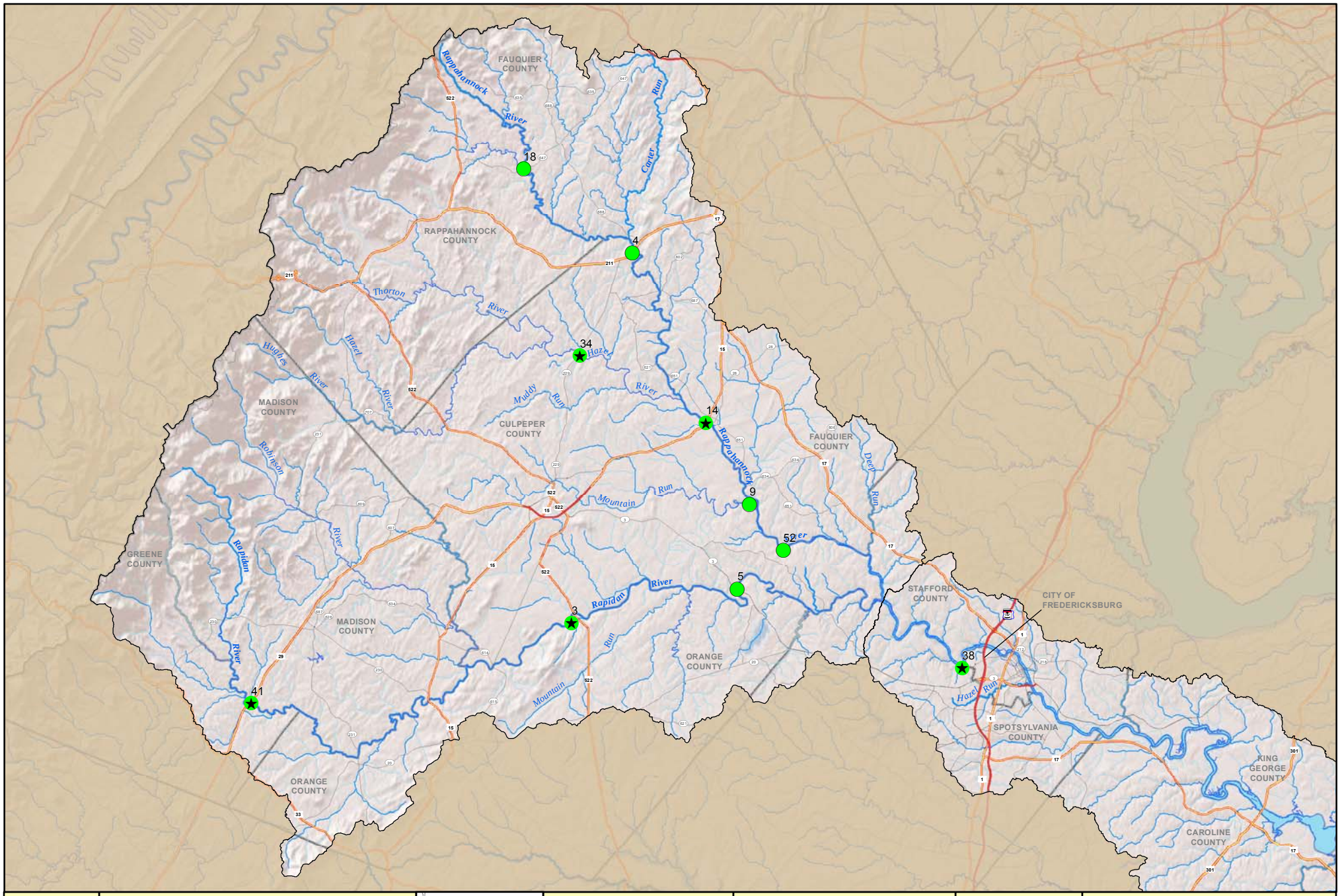
Existing Monitoring: In order to leverage existing resources, water quality gauge sites are easiest to add to locations that have long term monitoring already being funded and conducted by VA DEQ (trend or non-tidal stations) or USGS. (Exist_Mon =YES).

Existing Stream Gauge: In order to leverage existing resources, water quality gauge sites are easiest to add to existing real-time continuous water quality gauging sites of USGS and VA DEQ or IFLOWS. Of these, locations of USGS gauges are easier to utilize due to existing rating curve developed and regular field work required for rating curve development. Additionally, a secondary consideration can include where stream gauges are recommended from this study for reasons other than water quality. (ExistSG = USGS, IFLOWS, or Proposed).

Table 4.3 Alternative 1 and Alternative 2 Recommendations

Id	Problem Location	Organization	Pollutant	Existing Monitoring	Existing Stream Gauge	Alt. 1	Alt. 2
3	At stream gauge Rapidan River near Culpeper, VA.	VDEM, Sept 18 Meeting	TN, TP, TSS, E-coli, Fecal Coliform, Benthic-Macro invertebrate Bioassessments	YES	USGS	YES	YES
4	Rappahannock River at Route 211 Bridge, at historic stream gauge Rappahannock River near Warrenton, VA.	Sept 18 Meeting and Fauquier, J.M. SWCD	TN, TP, TSS, E-coli		PROPOSED	YES	
5	Locust Grove, Route 3, Germanna Hwy, crossing of Rapidan River.	VDEM, NWS, Sept 18 Meeting, Nov 15 Meeting, and Orange County	TN, TP, TSS, E-coli, Fecal Coliform, Benthic-Macro invertebrate Bioassessments		PROPOSED	YES	
9	On Mountain Run before confluence with Rappahannock River or at confluence.	Sept 18 Meeting and Fauquier, J.M. SWCD	E-coli, PCB in Fish Tissue, Benthic Macroinvertebrate Bioassessments	YES		YES	
14	Major outfall, at VA DEQ non-tidal station, 3-RTP 147.49, 3-RAP030.21, and USGS Remington Stream Gauge.	Nov 15 Meeting and Fauquier, J.M. SWCD	TN, TP, TSS, E-coli, Benthic-Macroinvertebrate Bioassessments, Water Temperature	YES	USGS	YES	YES
18	Rappahannock River, confluence of Jordan and Rappahannock Rivers, Route 647 Crest Hill Road Bridge.	NWS, Fauquier, J.M. SWCD, Tim Bondelid Consulting Engineer	TN, TP, TSS, E-coli	YES	PROPOSED	YES	
34	Bottom of Hazel River Watershed.	Culpepper County, VDEM Sept 18 Meeting	E-coli, Water Temperature	YES	USGS	YES	YES
38	5 miles upstream of I-95, near Motts Run, to be installed at the intake structure for the City of	USGS, City of Fredericksburg, VDEM	TN, TP, TSS, Benthic-Macro invertebrate Bioassessments, E-coli, PCB in Fish Tissue, pH, Mercury	YES	USGS	YES	YES

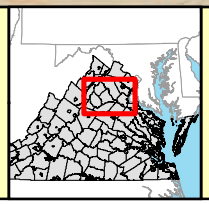
	Fredericksburg.		in Fish Tissue, DO, Water Temperature, Fecal Coliform				
41	Rapidan River at Route 29.	Culpepper SWCD	TN, TP, TSS, Benthic-Macro invertebrate Bioassessments	YES	USGS	YES	YES
52	At Rappahannock River Kemper's Ford or Richardsville.	NWS, VDEM	TN, TP, TSS, E-coli, Benthic-Macroinvertebrate Bioassessments, Water Temperature, DO, PCB in Fish Tissue		PROPOSED	YES	



Rappahannock River Basin Gauging Analysis

Figure 4.4 Water Quality Gauge
Proposed Locations
Alternative 1 and Alternative 2

US Army Corps of Engineers
Norfolk District



0 2 4 8 Miles

1:500,000

- Alt. 1 Only
- Alt. 1 and Alt. 2
- Rappahannock River Basin
- County Boundary

Projection:
Virginia State Plane
North Zone - NAD 83
U.S. Survey Feet

Basemap:
Esri ArcGIS Online
World Shaded Relief

Project Manager: Holly Carpenter
E-mail: Holly.A.Carpenter@usace.army.mil
Phone: (757) 201-7825

Map Date: 11 February 2013

Table 4.4 Alternative 3,
All Proposed Water Quality Gauges Grouped by Benefiting Jurisdiction

Id	Problem Location	Organization	Alt. 1	Alt. 2	Pollutant	Existing Monitoring	Existing Stream Gauge	Alternative 3								
								Culpeper	Fauquier	Fredericksburg	Greene	Madison	Orange	Rappahannock	Spotsylvania	Stafford
3	At stream gauge Rapidan River near Culpeper, VA.	VDEM, Sept 18 Meeting	**YES**	**YES**	**TN, TP, TSS, E-coli, Fecal Coliform, Benthic-Macro invertebrate Bioassessments**	**YES**	**USGS**	**X**			**X**	**X**	**X**			
4	Rappahannock River at Route 211 Bridge, at historic stream gauge Rappahannock River near Warrenton, VA.	Sept 18 Meeting and Fauquier, J.M. SWCD	**YES**		**TN, TP, TSS, E-coli**		**PROPOSED**	**X**	**X**					**X**		
5	Locust Grove, Route 3, Germanna Hwy, crossing of Rapidan River.	VDEM, NWS, Sept 18 Meeting, Nov 15 Meeting, and Orange County	**YES**		**TN, TP, TSS, E-coli, Fecal Coliform, Benthic-Macro invertebrate Bioassessments**		**PROPOSED**	**X**					**X**			

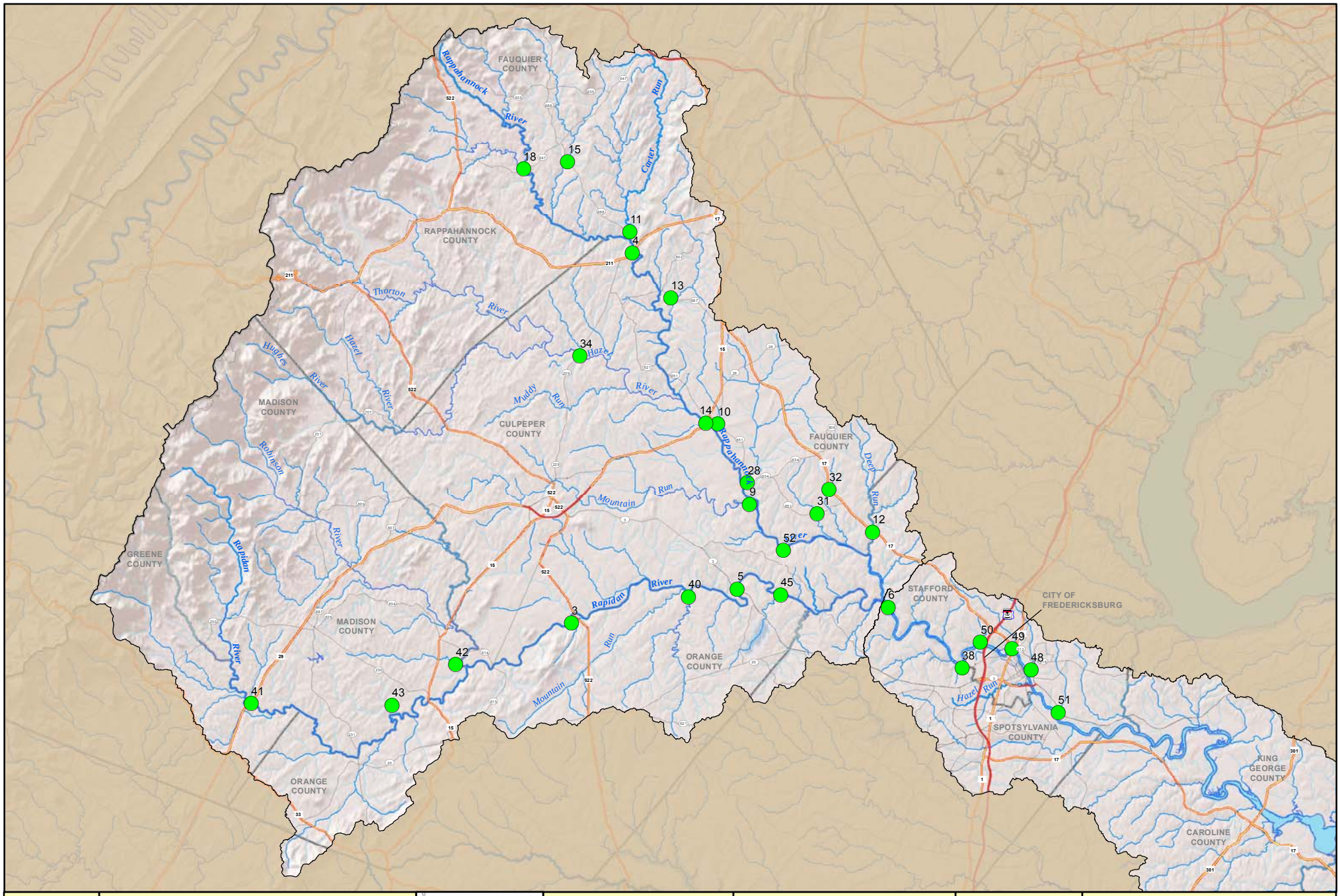
6	Upriver from Fredericksburg, below the confluence of Rappahannock and Rapidan River, VDEM priority for additional stream gauge.	VDEM, NWS, Sept 18 Meeting and Nov 15 Meeting			**TN, TP, TSS, Benthic-Macro invertebrate Bioassessments, E-coli, PCB in Fish Tissue, pH, Mercury in Fish Tissue, DO, Water Temperature, Fecal Coliform**			**X**	**X**	**X**			**X**		**X**	**X**
9	Mountain Run before confluence with Rappahannock River or at confluence.	Sept 18 Meeting and Fauquier, J.M. SWCD	**YES**		**E-coli, PCB in Fish Tissue, Benthic Macroinvertebrates Bioassessments**	**YES**		**X**								
10	Tin Pot Run at Remington, Route 651 Bridge.	Nov 15 Meeting and Fauquier, J.M. SWCD and VA DEQ Priority			**E-coli**				**X**							
11	Carters Run at Route 688.	Nov 15 Meeting and Fauquier, J.M. SWCD			**E-coli**				**X**							
12	Deep Run at Route 17.	Nov 15 Meeting and Fauquier, J.M. SWCD			**E-coli, Fecal Coliform**	**YES**			**X**							**X**

13	Great Run at Opal Road, Route 687.	Nov 15 Meeting and Fauquier, J.M. SWCD			**E-coli, Benthic-Macroinvertebrate Bioassessments**				**X**							
14	Major Outfall, at DEQ Non-tidal station, 3-RTP 147.49, 3-RAP030.21, and USGS Remington Stream Gauge.	Nov 15 Meeting and Fauquier, J.M. SWCD	**YES**	**YES**	**TN, TP, TSS, E-coli, Benthic-Macroinvertebrate Bioassessments, Water Temperature**	**YES**	**USGS**	**X**	**X**							
15	Thumb Run at Route 688, Leeds Manor Rd.	Nov 15 Meeting and Fauquier, J.M. SWCD			**E-coli**				**X**							
18	Rappahannock River, confluence of Jordan and Rappahannock Rivers, Rt 647 Crest Hill Road Bridge.	NWS, Fauquier, J.M. SWCD, Tim Bondelid Consulting Engineer	**YES**		**TN, TP, TSS, E-coli**	**YES**	**PROPOSED**		**X**						**X**	
28	Marsh Run at Route 651 Bridge.	Fauquier, J.M. SWCD			**E-coli, DO**				**X**							
31	Sumerduck Run at Route 651 Bridge.	Fauquier, J.M. SWCD			**E-coli**				**X**							

32	Rock Run at Route 17 Bridge.	Fauquier, J.M. SWCD			**None Identified**				**X**							
34	Bottom of Hazel River Watershed.	Culpepper County, VDEM Sept 18 Meeting	**YES**	**YES**	**E-coli, Water Temperature**	**YES**	**USGS**	**X**								
38	5 miles upstream of I-95, near Motts Run, to be installed at the intake structure for the City of Fredericksburg.	USGS, City of Fredericksburg, VDEM	**YES**	**YES**	**TN, TP, TSS, Benthic-Macro invertebrate Bioassessments, E-coli, PCB in Fish Tissue, pH, Mercury in Fish Tissue, DO, Water Temperature, Fecal Coliform**	**YES**	**USGS**	**X**	**X**	**X**			**X**		**X**	**X**
40	At the bottom of Mountain Run Watershed, drains in Rapidan, in Orange County.	Culpepper SWCD, Orange County			**E-coli**								**X**			
41	Rapidan River at Route 29.	Culpepper SWCD	**YES**	**YES**	**TN, TP, TSS, Benthic-Macro invertebrate Bioassessments**	**YES**	**USGS**				**X**	**X**	**X**			

42	Robinson River at Route 614.	Culpepper SWCD, Orange County			**E-coli**							**X**					
43	Beautiful Run at Route 620.	Culpepper SWCD			**E-coli**							**X**					
45	At bottom of Flat Run Watershed.	Orange County			**None Identified**								**X**				
48	At bottom of Claiborne Run Watershed.	Stafford County			**E-coli, PCB in Fish Tissue**												**X**
49	At bottom of Falls Run Watershed.	Stafford County			**None Identified**												**X**
50	At bottom of England Run Watershed.	Stafford County			**None Identified**												**X**
51	At bottom of Little Falls Run.	Stafford County			**None Identified**												**X**

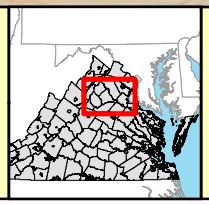
52	At Rappahannock River Kemper's Ford or Richardsville	NWS, VDEM	**YES**		**TN, TP, TSS, E-coli, Benthic-Macroinvertebrate Bioassessments, Water Temperature, DO, PCB in Fish Tissue**		**PROPOSED**	**X**	**X**							



Rappahannock River Basin Gauging Analysis

Figure 4.5 Water Quality Gauge
Proposed Locations
Alternative 3 (All Locations)

US Army Corps of Engineers
Norfolk District



0 2 4 8 Miles

1:500,000

Proposed Gauges

Rappahannock River Basin

County Boundary

Projection:
Virginia State Plane
North Zone - NAD 83
U.S. Survey Feet

Basemap:
Esri ArcGIS Online
World Shaded Relief

Project Manager: Holly Carpenter
E-mail: Holly.A.Carpenter@usace.army.mil
Phone: (757) 201-7825

Map Date: 11 February 2013

4.3 Funding Gauge Installation and Operation and Maintenance

The Chowan River Basin Gauging Analysis, discussed in the introduction of this report, is in the process of installing rain and stream gauges for emergency management or flood warning purposes. The rain gauges to be installed in the Chowan River Basin will be complete by the National Weather Service; installation was estimated to cost $75,000 for upgrades to four existing rain gauges to real time and the new gauge system will have minimal operation and maintenance cost. The stream gauges proposed to be installed, and operated and maintained by the USGS Water Coop Program, discussed in Section 2.1 USGS Gauge and Monitoring Programs, on a fifty-fifty cost share basis with a local sponsor. Installation cost estimated to be $160,000 for seven real-time continuous stream gauges, with an annual maintenance cost of $96,800. Funding for NWS and USGS programs is limited and it may not be available for the proposed gauges needed in the Rappahannock River Basin. Additionally, it has been noted that if funding is available for gauge installation under the USGS Water Coop Program, it may be on a higher cost share for the locality. Currently, the highest cost share rate on an existing project in Virginia under the Water Coop Program is around 30% Federal funding.

According to USGS staff, a new individual stream gauge with transmitter (continuous real time stream gauge to measure stage and produce flow parameters and includes any permitting) will cost $17,000 for locations in Virginia. The exception to this is tidal gauges which can cost more, however no tidal gauges are recommended in this study. The operation and maintenance cost for a new stream gauge of this type is approximately $15,000 per year. Stream gauges that include monitoring for water quality parameters, with one sample each month and eight targeted storm samples per year, will cost $35,000 per stream gauge site to operate and maintain. Additionally, adding water quality equipment to produce real-time continuous water quality data cost $12,000 for the monitoring sonde and additional $6,000 for other equipment and installation materials ($18,000 in addition to the stream gauge cost). In order to operate and maintain a water quality gauge and perform the monitoring, one sample each month and 8 targeted storm samples per year to establish relationships between measure and desired parameters, the cost is around $50,000 to $60,000 per site. This cost includes any lab analysis needed for the water quality data, however sites maintained by VA DEQ may cost a little less since VA DEQ performs water quality tests at their own lab facility. All of these costs are for installation, and operation and maintenance of a single gauge, grouping gauges together can decrease operation and maintenance cost. The decrease could come from reduced travel time of agency personal to perform monitoring and maintenance of gauges in the same area.

According to VDEM staff, the IFLOWS program will usually install both a rain and stream gauge on one site and the typical installation costs of the program are about $20,000, including the cost of the transmitter needed for real-time data reporting. The IFLOWS program typically obtains a land-owners agreement to place a gauge on the site. This agreement is not binding and

enforceable by law, like an easement, but the program does not pay any fees to the landowner. However, if a gauge is to be located on VDOT property, such as from a bridge, coordination and a permit from VDOT must be obtained first. Typically the state of Virginia will fund the operation and maintenance of gauges in the IFLOWS program after installation. There are a few exceptions where gauges have been included in the IFLOWS program, but operation and maintenance cost are paid by the locality. Examples include gauges in the Cities of Franklin and Richmond, and Rockingham County. These communities used Hazard Mitigation Grant Program (HMGP) funds to pay for installation, but operate and maintain the gauges themselves.

There are other means of funding gauges that can be considered. VDEM staff has provided information about how the IFLOWS program has increased their gauging network in the last few years. The IFLOWS program has taken advantage of available grants, such as HMGP funds for gauge installation.

Table 4.5 Summary of Cost Estimates

Item	**Type**	**Cost ($1000)**	**Agency**
Stream Gauge	Installation	$17	USGS
	O&M	$15	USGS
	O&M with monitoring	$35	USGS
Water Quality Gauge	Installation	$36	USGS
	O&M with monitoring	$50-$60	USGS
Stream and Rain Gauge at one site	Installation	$20	VDEM

A list of possible funding source for installation and operation and maintenance is presented in the following table:

Table 4.6 – Possible Funding Sources

Program	**Agency**	**Type of Gauge/Comments**
Chesapeake Bay Program Grant Funds	EPA (CWA)	Water Quality, installation (funding through this program in the near future is unlikely since funds for improving the stream gauge network and existing water quality monitoring have been recently provided), cost share
Water Quality Improvement Act	EPA (CWA)	Water Quality, installation
Hazard Mitigation Grant Program (HMGP)	FEMA	Rain, Stream Gauges (flood mitigation), installation
Pre-Disaster Mitigation Grant Program (PDM)	FEMA	Rain, Stream Gauges (flood mitigation), installation
Water Coop Program	USGS	All, installation and O&M, cost-share, limited funding each year
COOP	NWS	Rain, installation and O&M
IFLOWS Program	VDEM	Rain, Stream Gauges (flood mitigation), installation and O&M
Section 319 Base Funds	EPA (CWA)	Water Quality, up to 20% of base funding for the program may be used for planning and assessment activities to solve non-point source problems
Chesapeake Bay Stewardship Fund	National Fish and Wildlife Foundation (NFWF)	Water Quality - planning, research and monitoring listed as a key strategy

SECTION 5.0 CONCLUSIONS

The Middle and Upper Rappahannock River Basin Rainfall, Stream, and Water Quality Gauging study, conducted by the United States Army Corps of Engineers (USACE), Norfolk District, from August 2012 through April 2013, identifies where all regular existing monitoring for rainfall, stream flow, and water quality in the Rappahannock River Basin and suggests where additional real-time continuous rainfall, stream and water quality gauges are needed in the river basin. This report makes recommendations for the priorities of installation and also identifies funding options for installation. The study process included coordination through several meetings with local stakeholders and agency technical experts to provide input for where flooding problems or water quality issues exist and where additional real-time continuous gauges can provide additional data to evaluate these issues.

Real-time continuous rain and stream gauges were identified by local stakeholders, to include emergency managers and planners (who also have an interest in water supply), and agency representatives from the Virginia Department of Emergency Management (VDEM) and the National Weather Service (NWS). The middle areas of the basin are currently lacking in adequate coverage for rain gauges and several tributaries and upper portions of the main streams, the Rappahannock River and Rapidan River, are currently lacking in stream flow information. During this evaluation a few areas were identified as having regular flooding and existing reports of the Hazard Mitigation Plans and Water Supply Plans were reviewed. Recommendations for 13 new real-time continuous rainfall gauges and 7 new real-time continuous stream gauges were made in the conclusion of this analysis. These gauges were also prioritized based on the number of parties that identified the need and the reasons for the need, with flood warning for life safety as the top priority. Installation of any of the proposed real-time, continuous rainfall and stream gauges will lead to a more complete flood warning system for the basin and provide additional information which can be used for water supply planning or in conjunction with water-quality sampling. Additionally, real-time continuous rain and stream gauges allow for development of better planning information, for example in the future this data could be used in conjunction with high resolution topography to produce real-time flood inundation mapping.

There are currently no real-time continuous water quality gauges in the Rappahannock River Basin. The issues that lead to recommendations of new real-time continuous water quality gauges in the basin were spurred by a variety of objectives. There are many specific needs for water-quality data, to address effectiveness or Best Management Practices (BMPs) toward achieving Total Maximum Daily Load (TMDL) limits. However, since there are no existing real-time continuous water quality gauges in the basin the recommended plan forward from this gauging analysis is to install real-time continuous water quality gauges on the main stems and tributaries of the upper and middle basin to provide an overall picture of water quality parameters from the Chesapeake Bay TMDL, which provide limits for Total Phosphorus (TP),

Total Nitrogen (TN), and Total Suspended Sediment (TSS) for the Rappahannock River Basin as a whole. In order to reduce cost from operation and maintenance and field sampling required to produce information from real-time continuous water quality gauges, the gauges are recommended to be placed at existing United States Geological Survey (USGS) or Virginia Department of Environmental Quality (VA DEQ) real-time continuous stream gauges and where existing long-term monitoring is being conducted by USGS or VA DEQ. This plan is Alternative 2, described in more detail in Section 4.0, Proposed Gauges, of this report.

The recommendations for water quality gauges were based off of coordination with local stakeholders, including government officials and local environmental groups, and from input of the leading agencies for water quality monitoring in Virginia, in particular USGS and VA DEQ. The results of this analysis identified need for 27 real-time continuous water quality gauges (Alternative 3), but recommended five gauges as the first priority (Alternative 2). Installation of these five gauges will provide an overview picture of water quality in the basin. Due to the cost of real-time continuous water quality gauges, installation of gauges identified only as a part of Alternative 3, which have interest at a more localized level, will probably need to be championed by the local government or group who indicated need for these gauges. Additionally, Alternative 2 recommends placement of five real-time continuous water quality gauges, however if there is funding opportunity for only one or two gauges, the water quality gauge downstream of the confluence of the Rappahannock and Rapidan rivers should be considered first priority. Second priorities would include water quality gauges upstream of the confluence on each the Rappahannock and Rapidan rivers. The installation of any real-time continuous water quality gauge will provide data that can be used to monitor the effectiveness of upstream BMPs and be used as more accurate input and calibration of water quality parameters in water quality models that describe the basin. The current water quality data is from field sampling, which only produces a snap shot in time of the water quality parameters, therefore the addition of continuous data will provide more accuracy by providing values for water quality parameters in all conditions.

For future installation of the recommended real-time continuous rainfall, stream, and water quality gauges the most likely funding option includes local partnerships to cost share with the Virginia Department of Emergency Management (VDEM) for additional real-time continuous stream and rain gauges for flood warning purposes and local and/or state partnerships to cost share with the United States Geological Survey (USGS) for real-time continuous water-quality gauges, and possibly associated stream gauges, needed for development of water quality parameters. It is noted that funding is limited, particularly Federal funding for the USGS programs. There are also several grant programs worth considering. The Hazard Mitigation Grant Program (HMGP) has served as a source of funding for past installation of real-time continuous rain and stream gauges in the VDEM IFLOWs program, but is only available when a state of emergency is declared in Virginia. Most grant programs available that pertain to water

quality only provide funding for implementation of BMPs and not for planning and monitoring items such as water-quality gauges. Additional funding opportunities are listed in Section 4.0, Proposed Gauges, section of this report.

In order for real-time continuous rainfall, stream, and water quality gauges to be added to the current network of gauges and monitoring within the Rappahannock River Basin, collaboration and leveraging of resources on the local, state, and Federal levels will need to be obtained. This report should serve as starting point for this effort. While this report presents a large number of proposed locations for real-time continuous rainfall, stream, and water quality gauges; it is important to focus on the most immediate needs. There is an immediate need for additional rainfall gauges to support a more complete flood warning system in the basin, this should be considered as first priority. Second priorities include additional stream gauges that will supplement the flood warning systems, assist in water supply planning, and can provide flow data for water quality monitoring or future gauges. Additional future consideration should be given to installation of real-time continuous water quality gauges to provide more accurate and continuous data for water quality parameters. Finally, it should also be noted that as time passes and before funds are expended on gauges, there should be a re-evaluation of the recommended gauge priorities based on any updated information to ensure the priorities recommended in this report will meet the data needs of the Rappahannock River Basin at that time and in the future. Overall this gauging analysis study displays that there is a need for additional gauge data and installation of any of the recommended real-time continuous rainfall, stream, and water quality gauges will provide for an increase in information for planning and response purposes in the Rappahannock River Basin.

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