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Streamflow and Water-Quality Monitoring in Support of Watershed Model Development, Potomac River Basin

Attachment 1

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A Cooperative Project between the U.S. Geological Survey and the Maryland Department of the Environment

Summary

Problem. The National Water-Quality Assessment (NAWQA) Program, Potomac River Basin study unit (1992-95), indicated that elevated concentrations of nitrogen and phosphorus in surface and ground water in the Potomac basin often result from human activities such as manure and fertilizer application. The monitoring program proposed here is designed to support development of a watershed model of the basin that may be used to assess the effects of point and nonpoint nutrient and sediment sources on water quality in the Potomac River.

Objectives. The U.S. Geological Survey (USGS) has responsibility for four objectives in an overall monitoring program designed to support the development and calibration of a watershed model for the Potomac River Basin: restart and operate two currently-inactive continuous stream-gaging stations; establish nine new water-quality monitoring stations; plan, coordinate, and oversee sample collection, using USGS and Maryland Department of the Environment (MDE) staff; and manage all data and plan and oversee quality assurance.

Benefits. Historical data, data collected by MDE at numerous sites, and data collected through this study will provide information necessary for the development and calibration of an HSPF (Hydrologic Simulation Program-FORTRAN) model of the Potomac River Basin, which in turn can be used as necessary input for a water-quality model to be developed by MDE. The calibrated watershed and estuarine water-quality model of the Potomac River Basin will allow resource managers to simulate large-scale effects of land-use changes and best management practices on water quality. The proposed study also meets several goals of the USGS Water Resources Division (WRD).

Approach and methods. Candidate sites for monitoring were chosen based on existing information and modeling needs. Those sites without adequate historical water-quality data were then prioritized to arrive at proposed monitoring sites. Sites within the Coastal Plain were considered the highest priority. Integrator sites in subunits with none were give high priority, as were sites within any given subunit that could act as indicators of a particularly important land use. The nine highest-priority sites are chosen for the proposed monitoring effort; of these, two require restart of an inactive gage. Automatic samplers will be installed at all feasible sites to collect storm samples; regular baseflow and high-flow samples will also be collected. All samples will be collected using NAWQA protocols and analyzed for nutrients at the National Water-Quality Laboratory (NWQL) in Denver; sediment analyses will be done at the USGS Iowa District Sediment Laboratory.

Problem

The Potomac River Basin encompasses 38,000 square kilometers (14,670 square miles) in four states and the District of Columbia. As a hydrological unit, it includes a complex assemblage of topography, from the Appalachian Plateau to the Coastal Plain, and land uses, including major agricultural, forested, and urban and suburban areas. Surface waters of the Potomac River are the subject of investigation by a number of state and federal agencies; in particular, MDE is interested in quantifying nutrient sources and loadings within the Potomac River Basin as part of regulatory and voluntary efforts needed to restore or protect water quality.

In the Potomac River Basin, the quality of streams and ground water is affected by a number of natural and human processes. Major types of chemicals found in waters in the basin include nutrients (predominantly nitrogen and phosphorus), trace metals, pesticides, chlorinated industrial compounds, and volatile organic compounds (VOCs; Ator et al., 1998). Nutrients (as well as pesticides) are of particular interest to environmental managers within the basin. Although the nutrients nitrogen and phosphorus occur naturally and are essential for plant and animal growth, excessive nutrients in water can adversely affect human health and the environment.

> *The Potomac River is one of more than fifty USGS National Water-Quality Assessment Program (NAWQA) Study Units. As such, a significant body of data and scientific understanding exists, and continues to be developed, for the basin. Major NAWQA findings that emerged during the last intensive study phase (1992-95) indicated that elevated concentrations of nitrogen and phosphorus in surface and ground water in the Potomac basin often result from human activities such as manure and fertilizer application (Ator et al., 1998).*

The amount and timing of nutrient, sediment, and other inputs to the main stem of the Potomac River depend on a number of factors, including:

1. hydrological conditions and the mechanisms active in moving water through the basin;
2. the type of sources of those water constituents, either natural (e.g., atmospheric inputs) or anthropogenic (e.g., manure or fertilizer application);
3. the distribution of those various sources (for example, surface versus subsurface sources, point versus nonpoint sources, or proximity to major tributaries); and
4. any processes that might modify their quantity as they are transported through the system, either as ground water or surface water.

For example, organic nitrogen and phosphorus concentrations are typically low within the basin, except in streams during high flow; streams draining agricultural areas yield the greatest quantities of nitrogen, while streams draining agricultural and urban areas yield the greatest quantities of phosphorus (Ator et al., 1998). Hydrological and water-quality models exist that provide a framework for understanding the relationships among important hydrological, biogeochemical, and land-use variables.

> *MDE, in conjunction with USGS and the Interstate Commission on the Potomac River Basin (ICPRB), have determined that a watershed model of the basin may be needed to assess the effects of point and nonpoint nutrient and sediment sources on water quality in the Potomac River. The monitoring program proposed here is designed to support this modeling effort.*

Objectives

The USGS has responsibility for four objectives in the overall monitoring program:

1. Restart two inactive stream gaging stations. Collect stage data for the period of the study (October 2000–September 2002) according to standard USGS protocols and develop a rating curve for continuous discharge determination.

2. Establish nine new water-quality monitoring stations. Maintain and collect and analyze samples at seven of those stations, according to the methods described below, for a period of 18 months (January 2001–June 2002).

3. Plan, coordinate, and provide oversight for sample collection at remaining two sites by MDE staff.

4. Manage data collected at all nine sites. Plan and provide oversight for quality assurance and quality control for field monitoring at all sites.

These objectives contribute to a data-collection program that will support the development and calibration of a watershed model for the Potomac River Basin. Also supporting a watershed model for the Potomac River Basin is an extensive monitoring program being conducted by MDE in parallel with the monitoring proposed in this study. The MDE program consists of streamflow and water-quality monitoring on a regularly scheduled basis at more than 50 stream sites throughout the Potomac Basin. MDE's regularly scheduled sampling, plus the baseflow and stormflow sampling at nine sites as part of this proposed study, will provide a comprehensive data set with which to develop, calibrate, and verify a watershed model of the Potomac River Basin.

Benefits

Data collected as described in this proposal, combined with existing data from other USGS studies and historical and ongoing monitoring by MDE and the Maryland Department of Natural Resources (DNR), will provide information necessary for the development and calibration of an HSPF model of the Potomac River Basin, which in turn can be used as necessary input for a water-quality model to be developed by MDE. The calibrated watershed and estuarine water-quality model of the Potomac River Basin will allow resource managers to simulate large-scale effects of land-use changes and best management practices on water-quality.

The proposed study meets several goals of the Water Resources Division (WRD) of the USGS, by: 1) advancing knowledge of the regional hydrological system; 2) providing water-resources information that will be used by multiple parties for planning and operational purposes; and 3) contributing data to national databases that will be used to advance the understanding of regional and temporal variations in hydrological conditions.

Study Area and Existing Information

In 1991, the USGS began a comprehensive assessment of water-quality conditions in the Potomac River Basin as part of the NAWQA Program. The results of this study, as well as numerous other USGS and other studies, have been compiled in a number of reports that provide a portion of the information needs for a proposed modeling effort. The monitoring plan proposed here will make use of this existing data, as well as historical and ongoing data collected by MDE, DNR, and other agencies.

The Potomac River Basin has an area of 38,000 square kilometers in four states and the District of Columbia (39% in Virginia, 26% in Maryland, <24% in West Virginia, <11% in Pennsylvania, and <0.5% in DC). The Potomac River and its tributaries traverse a number of physiographic provinces, from the elevated headwaters of the North Branch within the Appalachian Plateau through the Valley and Ridge and Piedmont Provinces to the Coastal Plain. The general northeast-southwest strike of the physiographic provinces, and underlying geology, is reflected in the important boundary (fall line) between the relatively flat sediments of the Coastal Plain and the older igneous and metamorphic rocks of the Appalachian Mountains and adjacent Valley and Ridge and Piedmont.

During the first intensive phase of Potomac NAWQA, physiography and geology were determined to be the two most influential natural factors affecting water quality in the basin, and their combination was used to define eight subunits[1] (Figure 1). Land use was considered to be the most influential human factor influencing water quality in the basin (Figure 2, Table 1).

Subunit	Area, in square km	Major land use, in percentage of subunit area		
		Forest	Agriculture	Urban
Appalachian Plateau	1710	83	10	2
Valley and Ridge	13,090	82	15	2
Great Valley (Carbonate/Noncarbonate)	8170	29	58	12
Blue Ridge	2380	82	13	4
Piedmont/Triassic Lowlands	7225	30	43	25
Coastal Plain	5450	34	13	25

Table 1. Selected information about Potomac River Basin NAWQA subunits. Sources: Gerhart and Brakebill, 1996; Vogelmann et al., 1997.

As of water year 1998, there are 74 active USGS stream gages in the Potomac River Basin; records from approximately 56 inactive (or other) gages are also available. Water-quality data are available from a number of sources. **For the purposes of this study we have considered only those sources and data that: 1) can be used to estimate an annual load (for any of total nitrogen, total phosphorus, or sediment), that is, that involve simultaneous continuous flow measurement; 2) were from the period 1980–2000; and 3) included adequate provision for quality assurance.**

Approach

The steps taken to arrive at a list of proposed sites for monitoring was as follows:

1. Existing data were compiled (see previous section).

2. Available data-collection sites (including active and inactive gage sites, with or without water-quality sampling) were grouped by subunit (Table 1).

[1] For this proposal, the Great Valley Carbonate and Great Valley Noncarbonate subunits have been combined, as have the Piedmont and Triassic Lowlands. The Blue Ridge, although included in the discussion and analysis and listed in Table 1, is not considered as a separate subunit requiring additional monitoring, but as forested portions of the adjacent Piedmont and Great Valley subunits.

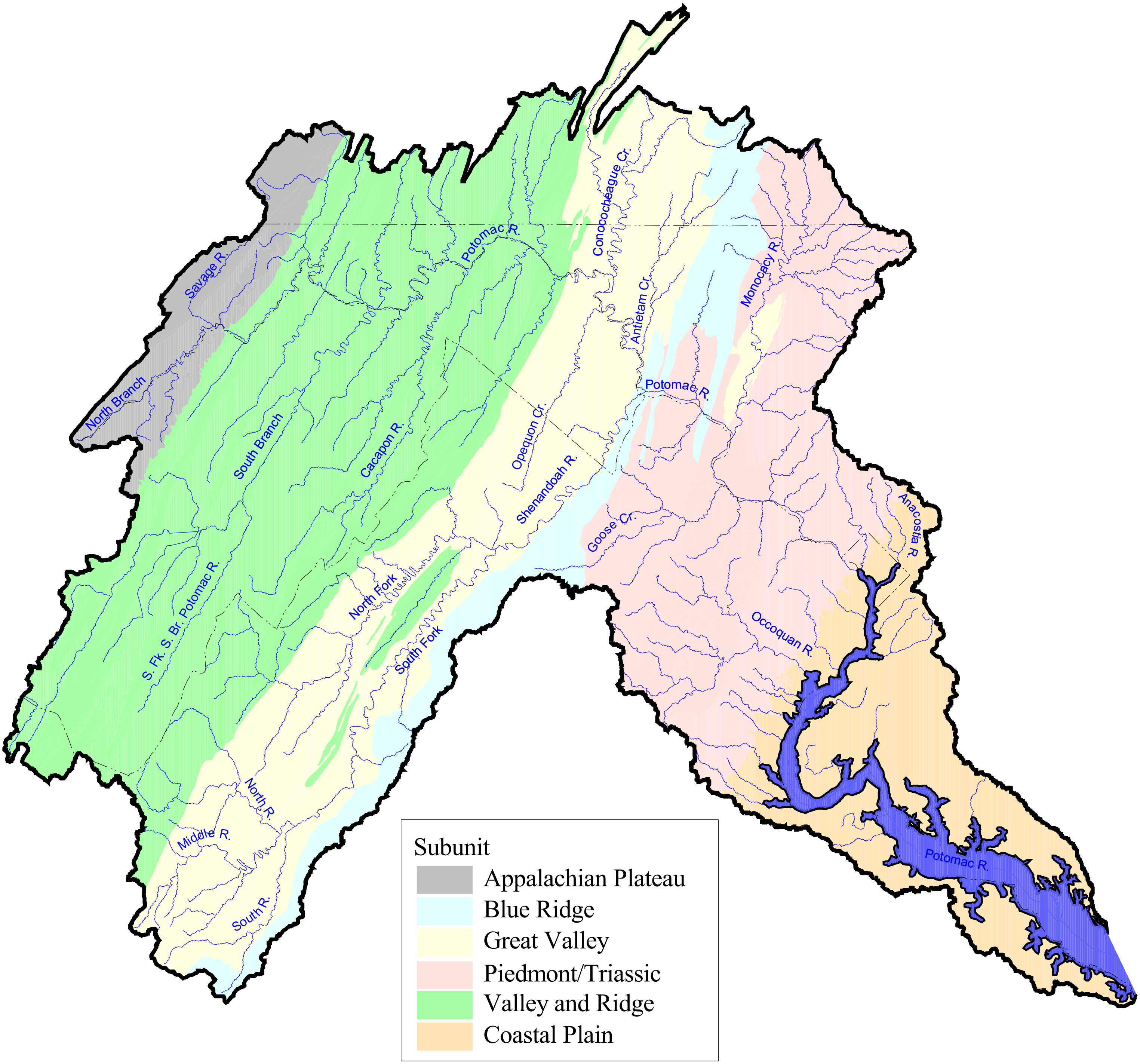

Figure 1. Map of the study region showing geologic-physiographic subunits and major streams and rivers. Source: Gerhart and Brakebill, 1996.

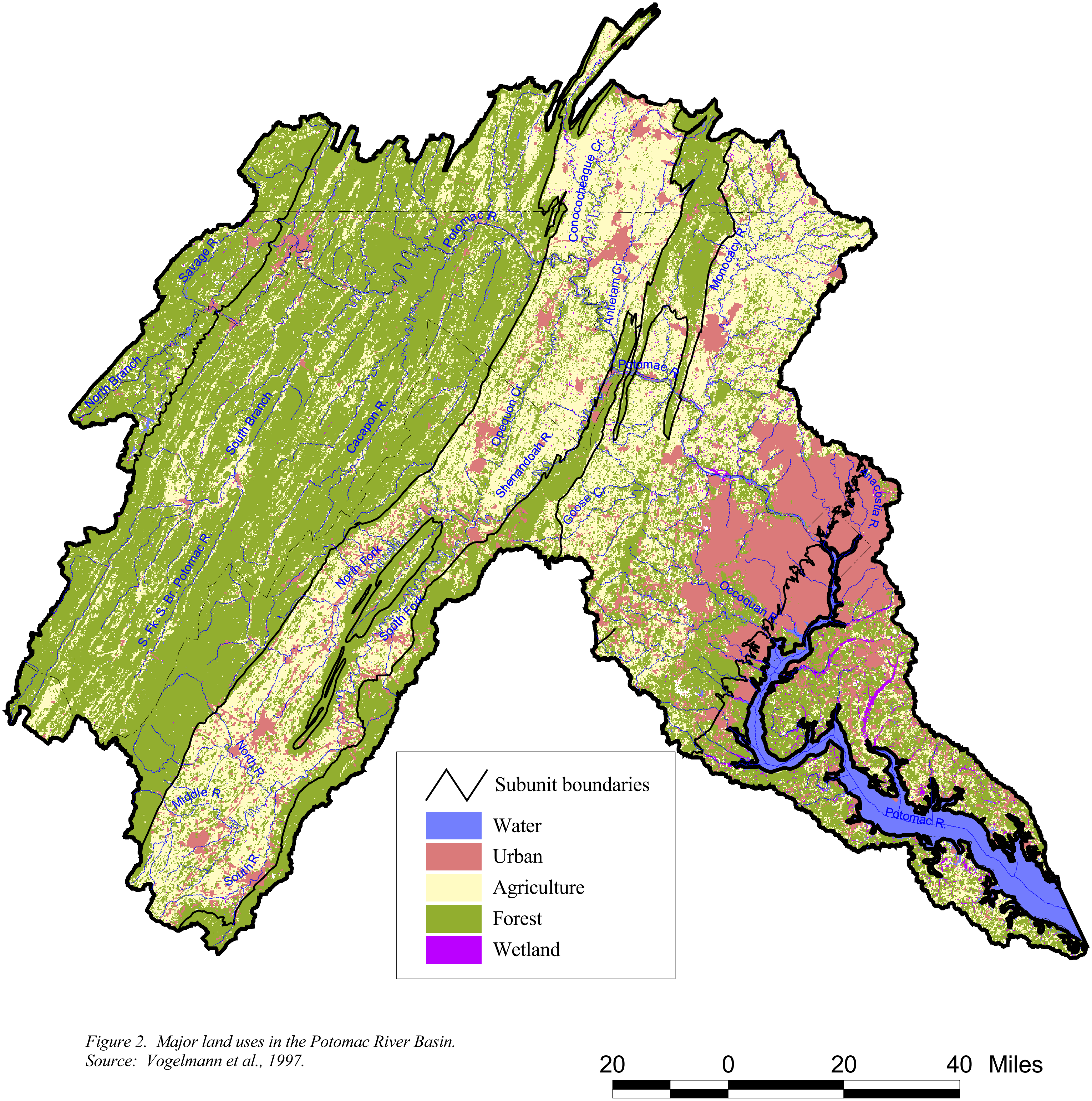

Figure 2. Major land uses in the Potomac River Basin.
Source: Vogelmann et al., 1997.

3. Within each subunit, candidate sites were classified according to their utility as: a) integrator sites; or b) indicator sites, that may be used to calibrate or verify the model for particular land uses within a subunit.

4. Candidate sites were prioritized for proposed monitoring.

Compilation of existing data

Water-quality site information was compiled into a single GIS coverage from the following sources (there is some overlap between different sources):

- Potomac NAWQA "fixed" sites (Gerhart and Brakebill, 1996): 11 sites
- Sites adopted by SPARROW (SPAtially-Referenced Regression On Watershed attributes), Version 2 (1992 time period, S. Preston, personal comm., 2000): 40 sites
- Sites adopted by SPARROW, Version 1 (1987 time period, Brakebill and Preston, 1999): 34 sites
- Sites currently monitored by MDE: 27 sites, not all of which coincide with an active stream gage
- DNR "Core" monitoring sites: 36 sites, not all of which coincide with an active stream gage

A second coverage was created of catchments delineated from both active and inactive gages. **These two coverages, catchment boundaries with gages and water-quality monitoring sites, could be combined interactively within a GIS framework with base maps including hydrography, point sources, subunits, and land use.**

Grouping by subunit and classification

Catchments were examined within each individual subunit in order to identify those that could be used first as *integrators*—sites that drain large areas and that represent the combined effects of all natural and anthropogenic water-quality factors in the particular subunits they drain. At least one integrator site was selected for each of the five main subunits. A total of twelve possible integrator sites were identified; of these, eleven had active stream gages and eight had adequate water-quality data available for modeling purposes (using criteria described in previous section).

Additional sites were chosen within each subunit as *indicators*—sites that drain relatively homogenous catchments. The intention in choosing this suite of sites is to provide information necessary to calibrate or verify the watershed model for a particular land use within each subunit. The goal was to identify small to intermediate size catchments (although a lower size limit was maintained to avoid some issues of scale dependence and sampling logistics) with a single predominant land use or characteristic land-use combination. This exercise produced twenty additional sites, of which three had inactive gages and ten had adequate water-quality data available for modeling purposes.

Finally, five sites on the main stem of the Potomac River were selected primarily for use as calibration or verification points for in-stream routing and process modeling. All 37 selected sites are listed in Table 2; additional information summarizing the number, type, and timing of water-quality analyses are presented in Appendix 1. Sites with an inactive gage ("Gage Reactivation"), and without adequate water-quality data ("New Sampling") are indicated in the last two columns of Table 2. Fifteen sites are considered candidates for new or reactivated monitoring.

Basic goals in choosing and prioritizing sites were as follows: to choose sites that could serve primarily as calibration points for an HSPF model; to choose sites that maximized diversity of monitored land uses; and to choose sites that could allow for, or create, nesting of monitoring data.

Site Prioritization

A number of factors were considered in prioritizing the fifteen candidate sites for monitoring. These are listed below, in the approximate order of relative importance in determining the final ranking:

A. **Sites on the Coastal Plain were considered the highest priority.** The initial phase of Potomac NAWQA emphasized the catchment above Chain Bridge (01646580); therefore, relatively little information exists and the proposed additional monitoring would benefit the second phase of NAWQA. This subunit is also prioritized because of its proximity to the Lower Potomac, which is of interest to MDE.

B. **Other subunits were prioritized such that priority decreased from east to west.** Candidate sites within other subunits were prioritized as follows, from highest to lowest, based on data availability, relative size, and relative amount of agriculture and urban areas: Piedmont, Great Valley, Valley and Ridge, Appalachian Plateau.

C. **Integrator sites in subunits with few or none were given high priority.** Most subunits included a number of possible existing integrator sites; the Coastal Plain was an exception.

D. **Sites within any given subunit that could act as indicators of a particularly important land use, or one about which little or no information exists, were considered high priorities.** An example would be Abrams Creek near Winchester, Virginia, which represents an urban indicator catchment in the Great Valley. Conversely, candidate sites that duplicated existing or other candidates' sites attributes were reprioritized. One goal was to maximize the benefit gained from additional sampling, by maximizing site type diversity.

E. **Sites already part of MDE's monitoring effort in western Maryland were considered to be a high priority.** These sites were considered good candidates for collaborative effort between MDE and USGS, and have an initial and ongoing record.

F. **Sites were considered high priority that helped meet USGS-WRD goals.**

G. **Sites close to the main stem Potomac were give higher priority than distal, headwater sites.** Recent work using SPARROW (Alexander et al., 2000) indicates that proximity of sources (of nitrogen) to large streams and rivers is an important determinant of nitrogen delivery to a terminal water body, such as an estuary. Longer travel times and instream processing can remove nitrogen originating in headwaters before reaching terminal water bodies.

Each site was scored for each of these factors on a scale of 0 to 10 (A and B, and C and D, were combined), and then a weighted average determined. The scores, chosen weights, and resultant prioritization of the fifteen sites are presented in Table 3. Figures 3 and 4 show the location of these sites and their associated drainage areas, as well as the other sites that may be used for the Potomac watershed model development.

Nine highest-priority sites are chosen for the proposed monitoring effort; of these, two require construction of a new gage at an inactive site (Appendix 2). Data to be collected at these sites over the course of the project are believed to be essential to accurately model watershed hydrological and water-quality processes in the Potomac River Basin.

Station ID	Station Name	Subunit	Site Type	Gage Reactivation	New Sampling
01595200	Stony River nr Mount Storm, WV	AP	Mining		
01596500	Savage River nr Barton, MD	AP	Forest		X
01599000	Georges Creek at Franklin, MD	AP	Urban		
01603000	North Branch Potomac River nr Cumberland, MD	AP	Integrator		
01608000	South Fork S. Branch Potomac River nr Moorefield, WV	VR	Ag(poultry)/Forest		
01608500	South Branch Potomac River nr Springfield, WV	VR	Integrator		
01609000	Town Creek nr Oldtown, MD	VR	Forest/Ag	X	X
01610000	Potomac River at Paw Paw, WV	Main	Main		
01610155	Sideling Hill Creek nr Bellegrove, MD	VR	Forest		X
01611500	Cacapon River nr Great Cacapon, WV	VR	Integrator		X
01613000	Potomac River at Hancock, MD	Main	Main		
01613545	Licking Creek nr Pecktonville, MD	VR	Integrator	X	X
01614500	Conococheague Creek at Fairview, MD	GV	Integrator		
01616000	Abrams Creek nr Winchester, VA	GV	Urban	X	X
01617800	Marsh Run at Grimes, MD	GV	Ag		X
01618000	Potomac River at Shepherdstown, WV	Main	Main		X
01619500	Antietam Creek nr Sharpsburg, MD	GV	Integrator		
01620500	North River nr Stokesville, VA	VR	Forest		X
01621050	Muddy Creek at Mt. Clinton, VA	GV	Ag(crop)		
01624800	Christians Creek nr Fishersville, VA	GV	Ag(poultry)		
01631000	South Fork Shenandoah River at Front Royal, VA	GV	Integrator		
01634000	North Fork Shenandoah River nr Strasburg, VA	GV	Integrator		
01635500	Passage Creek nr Bucktown, VA	VR	Ag(non-poultry)/Forest		
01636500	Shenandoah River at Millville, WV	GV	Integrator		
01638480	Catoctin Creek at Taylorstown, VA	PD	Ag(low-intensity)		
01638500	Potomac River at Point of Rocks, MD	Main	Main		
01639000	Monocacy River at Bridgeport, MD	PD	Ag/Urban		
01643000	Monocacy River at Jug Bridge nr Frederick, MD	PD	Integrator		
01644000	Goose Creek nr Leesburg, VA	PD	Integrator		X
01646580	Potomac River at Chain Bridge at Washington, DC	Main	Main		
01649500	Northeast Branch Anacostia River at Riverdale, MD	CP	Urban		
01653600	Piscataway Creek at Piscataway, MD	CP	Urban		X
01654000	Accotink Creek nr Annandale, VA	PD	Urban		
01658000	Mattawoman Creek nr Pomonkey, MD	CP	Urban	X	X
01660920	Zekiah Swamp Run nr Newtown, MD	CP	Integrator		X
01661050	St. Clement Creek nr Clements, MD	CP	Ag/Forest		X
01661500	St. Marys River at Great Mills, MD	CP	Ag/Forest		X

Table 2. Candidate sites for Potomac River watershed modeling effort. (CP – Coastal Plain; PD – Piedmont; GV – Great Valley; VR – Valley and Ridge; AP – Appalachian Plateau; Main – Potomac main stem; Ag – agriculture.)

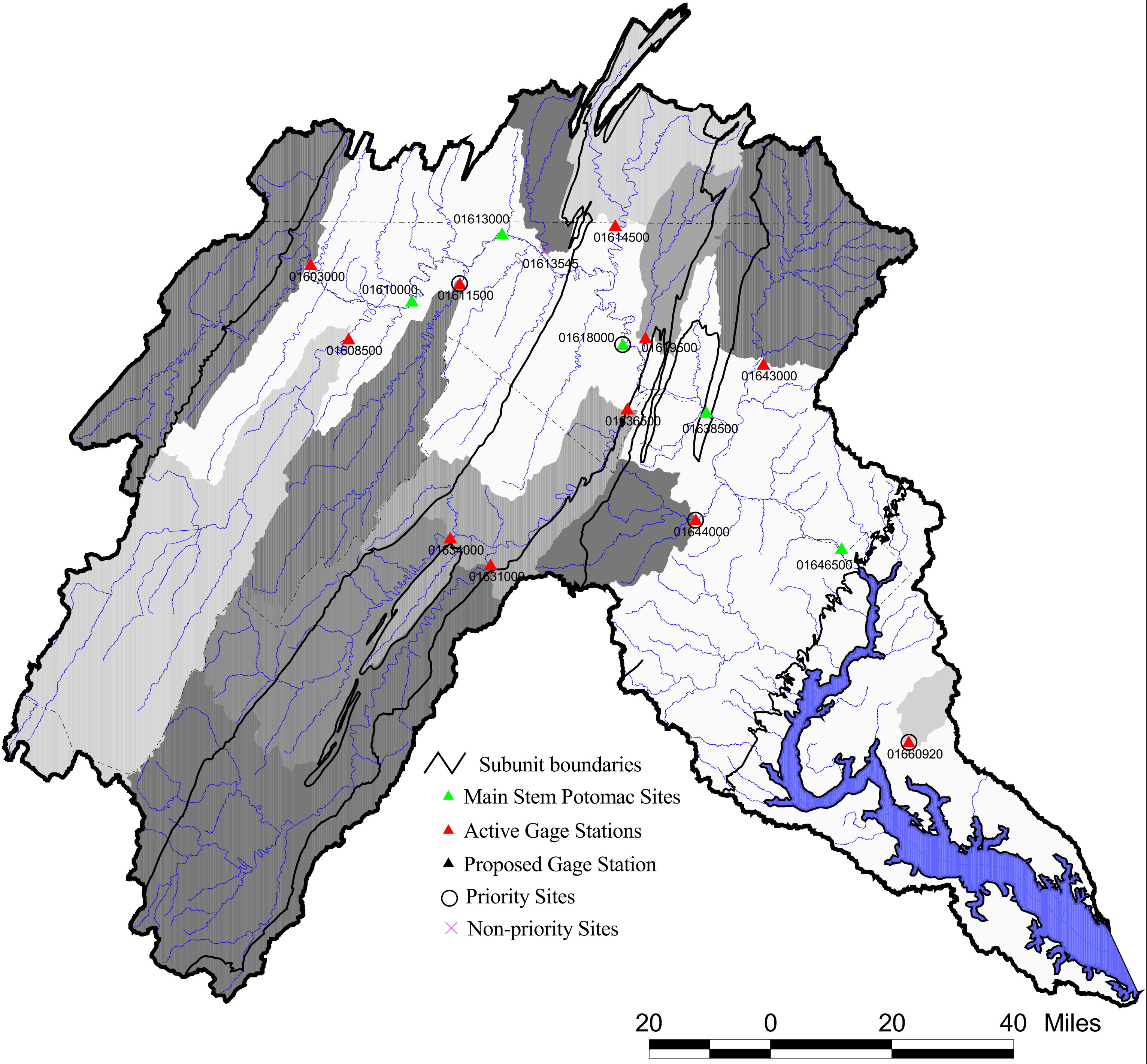

Figure 3. Catchments draining to selected integrator sites.

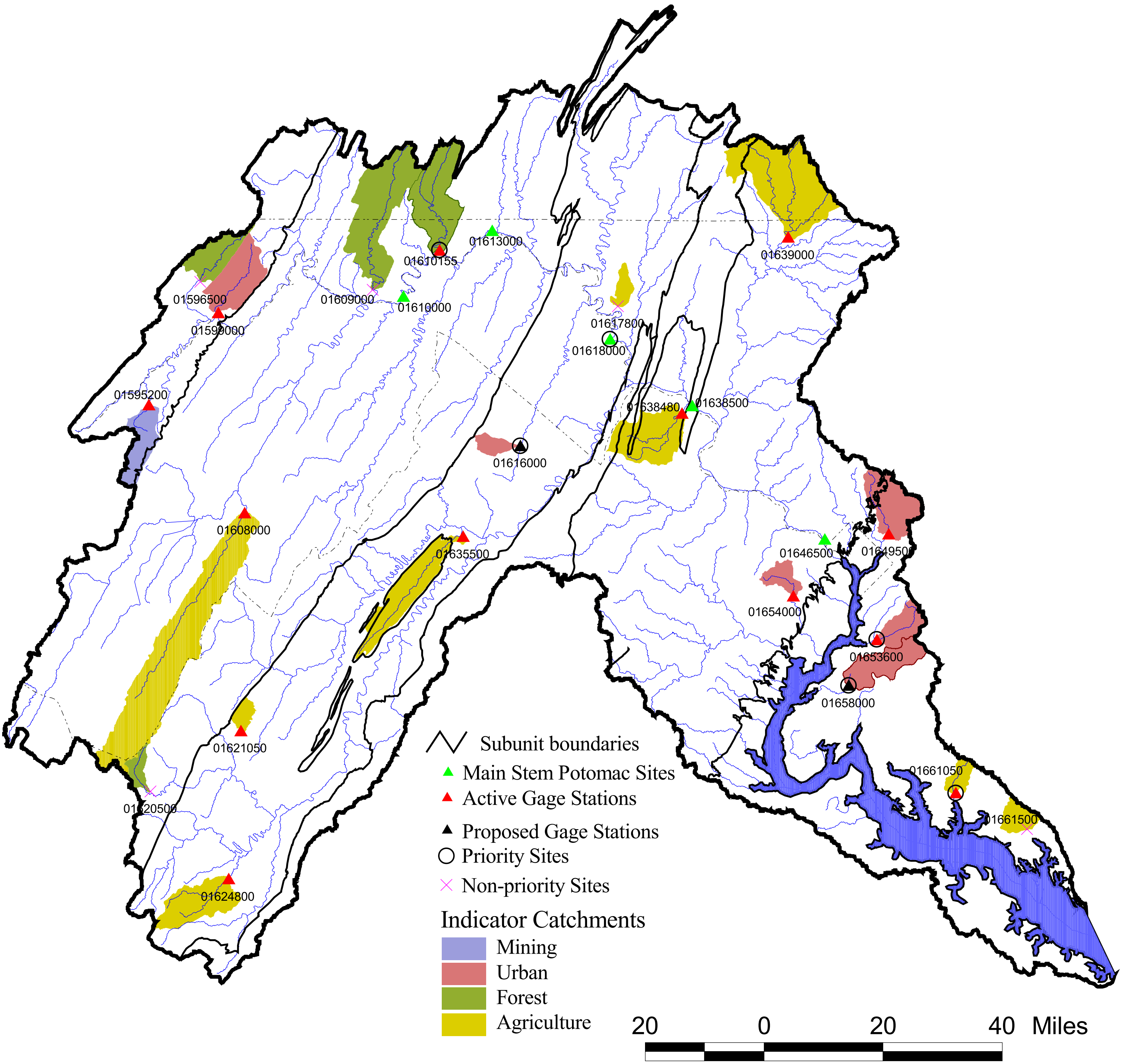

Figure 4. Catchments chosen as indicators for particular land uses within each subunit.

Station ID	Station Name	A/B	C/D	E	F	G	Weighted Score
01660920	Zekiah Swamp Run nr Newtown, MD	10	10	0	10	10	8.0
01644000	Goose Creek nr Leesburg, VA	8	10	0	10	5	6.9
01618000	Potomac River at Shepherdstown, WV	6	10	0	10	10	6.8
01658000	Mattawoman Creek nr Pomonkey, MD	10	5	0	10	10	6.5
01653600	Piscataway Creek at Piscataway, MD	10	5	0	5	10	6.0
01661050	St. Clement Creek nr Clements, MD	10	5	0	5	10	6.0
01616000	Abrams Creek nr Winchester, VA	6	10	0	10	0	5.8
01610155	Sideling Hill Creek nr Bellegrove, MD	4	5	10	0	10	5.7
01611500	Cacapon River nr Great Cacapon, WV	4	5	10	0	10	5.7
01609000	Town Creek nr Oldtown, MD	4	0	10	0	10	4.2
01613545	Licking Creek nr Pecktonville, MD	4	0	10	0	10	4.2
01661500	St. Marys River at Great Mills, MD	10	0	0	0	10	4.0
01617800	Marsh Run at Grimes, MD	6	0	0	0	10	2.8
01620500	North River nr Stokesville, VA	4	5	0	0	0	2.7
01596500	Savage River nr Barton, MD	2	5	0	0	5	2.6
	Weight:	0.3	0.3	0.2	0.1	0.1	

Table 3. Prioritization of sites for Potomac River watershed modeling effort. The top nine sites are considered "priority" sites for proposed monitoring. Key:

A *Sites on the Coastal Plain were considered the highest priority.*
B *Other subunits were prioritized such that priority decreased from east to west.*
C *Integrator sites in subunits with few or none were give high priority.*
D *Sites within any given subunit that could act as indicators of a particularly important land use, or one about which little or no information exists, were considered high priorities.*
E *Sites already part of MDE's monitoring effort in western Maryland were considered to be a high priority.*
F *Sites were considered high priority that helped meet WRD or NAWQA program goals.*
G *Sites close to the main stem Potomac were give higher priority than distal, headwater sites.*

Methods

Streamflow

Stream-gaging stations will be reconstructed at two sites. At the remainder of the sites listed in Table 2 that might be used in developing and calibrating a Potomac River watershed model, the USGS currently operates gages as part of other ongoing projects. All permits and access agreements required for gage reactivation will be the responsibility of USGS. At all stations, stream stage will be recorded every 15 minutes and stored in an electronic data logger. Streamflow will be determined from stage data by use of a stage-discharge rating developed for each site using methods described by Rantz et al. (1982). Development of the rating will be the responsibility of USGS and will proceed as rapidly as possible so that the rating can be used to program operation of the automatic samplers (described below). A modem and telephone line will be installed at each of the proposed priority monitoring sites to provide real-time remote access to stage, precipitation, and automatic sampler data. Real-time data will be needed to monitor storms and coordinate the field effort.

Water-quality sampling and analysis

Samples for water-quality analysis will be collected using both manual field-sampling methods (following NAWQA protocols; Shelton, 1994), and automatic samplers (where feasible). Automatic samplers cannot be used at all nine priority sites. For those sites that will be sampled using automatic samplers, shelters will be constructed to house water-sampling and stage-recording equipment. Automatic water-sampling equipment will consist of a portable, refrigerated, self-contained unit (for example, ISCO, American Sigma, or equivalent) capable of collecting a minimum of 12 discrete 1-L samples. The sampler will be equipped with a pressure transducer to measure fluid pressure (stage) and a data logger. Sample collection will be initiated by a rise in stream stage above a specified stage and will proceed at intervals based on flow increments at rated sites, or based on changes in stream stage. Sampling will proceed throughout the event, although not all samples may be analyzed for any given storm. Rather, samples will be selected for analysis on the basis of their timing relative to the rise, peak, and recession of the storm hydrograph.

The sampler intake will be positioned using methods described by Edwards and Glysson (1988) to maximize intake efficiency. The point sampling required for an automatic sampler is biased for streams that are not well mixed. For the purposes of the proposed study, all small streams are assumed to be well mixed. For larger streams and rivers, which are unlikely to be well mixed, simultaneous automatic and manual cross-sectional sampling will be used to calibrate each automatic sampler for the mean concentration in the flow.

Coordination of sampling events and sampling frequency

Storm samples - USGS will select storms targeted for sampling and appropriately program the automatic sampler. USGS will collect storm samples and maintain the samplers. After the storm event, USGS will review the hydrograph and select samples to be analyzed.

Baseflow and high-flow grab samples - USGS will select dates for baseflow and high-flow grab samples. Discharge will be measured at the time of sample collection for the high-flow samples.

Sampling time period - USGS will begin manual monthly sample collection at the seven presently gaged sites in October 2000. Automatic sample collection will begin in January 2001. Sampling will end in June 2002; the minimum sampling period will be 18 months. It is expected that sampling will continue at each of the nine sites for three months following the end of this sampling period (i.e., July–September 2002) under the auspices of the NAWQA Program.

Sampling frequency - USGS will collect and analyze samples at a rate of approximately 24–36 samples per water year from each site. In addition, 2–4 samples per year will be required for quality assurance and quality control. Another 9 samples will be collected in order to calibrate the automatic sampler (as discussed below). This will result in 48–69 samples over an 18-month sampling period.

Sampling and analytical methods for nutrients

Samples are collected using equal-discharge integrated sampling techniques and composited in a churn splitter or a cone splitter. Samples for whole-water analysis are collected directly from the splitting device and are fixed with concentrated sulfuric acid (1 mL/125 mL of sample). Samples for dissolved phase constituents are collected with a peristaltic pump from the splitting device and filtered in line with a 0.45 mm polycarbonate capsule filter. Samples are shipped on ice overnight to the NWQL in Denver, Colorado, and are analyzed within 5 days of arrival. Nitrogen and phosphorus are analyzed by colorimetric methods using air-segmented continuous-flow analyzers (Alpkem Corp. Clackamas, Ore.), operated with pecked sampling and bubble-gated detectors (Patton and Wade, 1997). Kjeldahl nitrogen and phosphorus (Watstore codes 00666, 00625, 00625, and 00671) are predigested batch-wise using a Tecator Digestion System 40, model 1016 block digester (Patton and Truit, 1992). USGS analytical methods with approximately equivalent USEPA methods and method reporting limits are listed in Table 4 (Patton and Truitt, 1992; Fishman, 1993). All NWQL laboratory methods are documented and verified for bias, accuracy, and precision with standard reference materials and participation in the USGS Office of Water Quality sample-testing program (Maloney et al., 1994; Pritt and Raese, 1995). Field blanks and field replicates are also collected to monitor bias and precision in all aspects of data collection.

USGS Watstore Code	Constituent	USGS Method	USEPA Method	Method Reporting Limit
00010	Water Temperature (°Celsius)	NA	NA	0.5
00300	Dissolved Oxygen (mg/L)	NA	NA	0.5
00095	Specific Conductance (µS/cm)	NA	NA	0.1
00400	pH	NA	NA	0.1
00078	Secchi Depth (meters)	NA	NA	0.1 m
80156	Suspended Sediment (mg/L)	NA	NA	1
00666	Soluble Phosphorus (mg/L as P)	I-2610-91	365.4	0.006
00625	Total Kjeldahl Nitrogen (mg/L as N)	I-4515-91	351.2	0.10
00665	Total Phosphorus (mg/L as P)	I-4610-91	365.4	0.008
00623	Soluble Kjeldahl Nitrogen (mg/L as N)	I-2515-91	351.2	0.10
00671	Orthophosphate (mg/L as P)	I-2601-90	365.1	0.010
00613	Nitrite (mg/L as N)	I-2545-90	353.2	0.010
00631	Nitrite + Nitrate (mg/L as N)	I-2545-90	353.2	0.050
00608	Ammonium (mg/L as N)	I-2522-90	350.1	0.02

Table 4. Methods for field parameters, suspended sediment, and schedule S2702 (USGS-NAWQA schedule for nutrients). (NA – not applicable.)

Field Methods

Field measurements will be made at the same time that samples are collected for nutrient analysis. Specific conductance, pH, dissolved oxygen, and water temperature will be determined with a calibrated YSI 6600-0 multimeter or with a WTW multimeter. Methods for field analysis are documented in the USGS National Field Manual (Wilde and others, 1998).

Sample analysis, quality assurance, and quality control

All chemical analyses will be done at the National Water-Quality Laboratory in Denver, CO. Suspended-sediment analyses (including total suspended sediment concentration, or TSS; sand-fine fractionation; and size distribution analysis of the fine fraction at 0.002 mm, 0.004 mm, and 0.016 mm) will be done at the USGS Iowa District Sediment laboratory. One-third of the samples will be selected and analyzed for the full suite of sediment measures, while two-thirds will be analyzed only for TSS. The decision to perform the full suite of analyses, rather than only TSS, will depend on basin size and characteristics, how samples were obtained (samples from the automatic sampler will tend to be biased), what type of event (large storms will be prioritized), and other factors.

USGS will provide quality assurance and quality control oversight for water-quality samples. The primary quality-assurance objectives will be to control bias due to equipment contamination and poor sampler-intake efficiency, evaluate sample collection techniques and potential problems with laboratory performance, and estimate data precision. Due to a limited number of samples being collected, meaningful quality assurance through statistical process control is not possible. Quality-assurance procedures for sample collection will consist of using appropriate equipment cleaning and sample-collection techniques prescribed by Wood and Harr (1990) and Edwards and Glysson (1988) and submitting quality-control samples.

Quality-control samples will consist of equipment blanks, field blanks, and field-split duplicates. Equipment blanks will provide data on sample contamination. Field blanks will provide data on contamination due to sample handling. Blank samples will consist of certified inorganic-free water and will be collected with automatic samplers *in situ* and after at least one storm sample has been collected. Duplicates will be split in the field from one automatic sample. Field-split duplicate storm samples will provide a measure of analytical precision on environmental samples.

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Appendix 1: Available Water-Quality Analyses

Station ID		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
01595200	TN	0	0	0	0	0	0	0	–	0	0	0	–	–	–	–	–	–
	TP	0	0	0	0	0	0	0	–	0	0	0	–	–	–	–	–	–
	SS	6	1	0	0	0	0	0	–	0	0	0	–	–	–	–	–	–
	TSS	0	0	0	0	0	0	0	–	0	0	0	–	–	–	–	–	–
01599000	TN	0	0	0	0	0	0	11	10	10	11	10	9	9	11	12	12	12
	TP	23	23	23	23	23	17	9	9	10	11	10	12	8	12	12	12	12
	SS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TSS	12	11	10	12	11	12	11	11	12	11	11	11	12	11	11	12	12
01603000	TN	0	0	0	0	0	0	0	0	–	–	–	–	0	0	0	–	–
	TP	15	14	14	12	12	8	0	0	–	–	–	–	0	18	10	–	–
	SS	12	1	0	0	0	0	0	0	–	–	–	–	0	18	0	–	–
	TSS	0	9	12	9	11	9	0	0	–	–	–	–	0	0	0	–	–
01608000	TN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–
	TP	0	0	0	0	0	0	0	0	0	0	0	0	0	20	25	14	–
	SS	0	0	0	0	0	0	0	0	0	0	0	0	0	20	11	14	–
	TSS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	2	–
01608500	TN	0	0	0	0	–	–	–	–	–	–	–	–	–	0	0	0	0
	TP	0	0	0	0	–	–	–	–	–	–	–	–	–	20	21	14	2
	SS	1	1	0	0	–	–	–	–	–	–	–	–	–	20	21	14	2
	TSS	0	0	0	0	–	–	–	–	–	–	–	–	–	0	0	0	0
01610000	TN	0	0	0	0	0	0	11	10	11	10	10	11	10	10	12	10	12
	TP	23	22	23	24	22	18	9	6	11	10	9	11	10	12	12	10	12
	SS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TSS	12	10	12	12	11	10	11	11	12	11	9	10	11	10	12	9	12
01613000	TN	0	0	0	0	0	0	12	11	10	10	11	11	9	12	12	12	12
	TP	0	8	11	13	12	10	12	12	10	10	10	12	9	12	12	12	12
	SS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TSS	0	8	11	13	12	10	12	11	11	12	12	12	12	12	12	12	12
01614500	TN	0	0	0	0	0	0	12	11	11	9	10	11	10	12	12	12	11
	TP	8	12	12	10	11	11	13	12	11	10	10	12	12	36	31	95	191
	SS	0	0	0	0	0	0	0	0	0	0	0	0	0	24	9	19	92
	TSS	7	8	10	10	11	10	12	11	12	12	12	12	12	12	12	12	11
01619500	TN	0	0	0	0	0	0	12	11	11	10	12	13	11	12	11	11	11
	TP	8	12	13	13	12	12	14	12	12	10	9	13	11	11	13	12	12
	SS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	TSS	7	8	11	13	12	12	12	11	12	11	12	14	12	12	12	12	12
01621050	TN	–	–	–	–	–	–	–	–	–	–	–	–	–	31	11	6	–
	TP	–	–	–	–	–	–	–	–	–	–	–	–	–	31	11	6	–
	SS	–	–	–	–	–	–	–	–	–	–	–	–	–	29	9	4	–
	TSS	–	–	–	–	–	–	–	–	–	–	–	–	–	0	0	0	–
01624800	TN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TP	10	11	9	11	8	8	13	10	7	4	6	10	12	12	11	12	12
	SS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TSS	10	11	9	11	8	11	13	10	7	6	6	10	12	12	12	12	12

Table 5. Number of water-quality analyses available by station ID, calendar year, and type of analysis (TN - total nitrogen; TP - total phosphorus; SS - suspended sediment; TSS - total suspended solids; "–" - no data collected that year).

Station ID		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
01631000	TN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	16
	TP	8	11	9	12	10	6	13	12	6	4	7	11	12	12	14	11	30
	SS	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	15
	TSS	8	11	9	12	10	12	13	12	7	4	5	9	11	12	12	12	12
01634000	TN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	15
	TP	7	11	9	11	8	8	14	8	4	5	5	12	12	12	14	11	31
	SS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	17
	TSS	8	11	9	11	8	12	14	8	4	5	5	8	11	12	12	12	12
01635500	TN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TP	8	11	8	11	9	8	14	8	4	5	5	10	12	12	12	11	12
	SS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TSS	8	11	8	11	9	12	14	8	4	5	4	10	11	12	12	12	12
01636500	TN	9	6	5	6	6	7	6	5	5	0	1	6	3	0	0	0	0
	TP	10	6	5	6	6	7	6	5	5	1	6	12	8	38	24	8	6
	SS	7	6	5	6	6	7	6	6	5	1	8	12	10	34	18	4	6
	TSS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01638480	TN	–	–	–	–	–	–	–	–	–	–	–	–	–	0	5	0	–
	TP	–	–	–	–	–	–	–	–	–	–	–	–	–	8	17	3	–
	SS	–	–	–	–	–	–	–	–	–	–	–	–	–	9	9	2	–
	TSS	–	–	–	–	–	–	–	–	–	–	–	–	–	0	0	0	–
01638500	TN	0	0	0	0	0	0	11	11	11	11	11	12	11	11	12	11	12
	TP	13	12	12	12	10	13	10	12	9	11	10	13	11	11	12	11	12
	SS	0	0	3	1	6	1	1	1	1	1	0	0	2	0	0	0	0
	TSS	7	8	11	12	10	13	12	11	12	12	12	14	12	12	12	11	12
01639000	TN	0	0	1	1	0	0	11	11	12	18	130	25	55	11	11	12	11
	TP	7	10	12	13	12	11	12	11	12	18	179	39	101	242	85	84	17
	SS	0	0	0	0	0	0	0	0	0	8	85	24	34	36	51	5	6
	TSS	7	10	10	11	12	11	12	11	12	11	12	14	12	12	12	12	11
01643000	TN	0	0	1	1	0	–	–	0	0	–	0	1	0	0	0	0	0
(01643020)[2]	TP	1	4	3	2	0	–	–	0	0	–	0	2	0	18	19	2	6
	SS	0	1	0	1	2	–	–	2	1	–	8	4	10	18	16	0	6
	TSS	0	0	0	0	0	–	–	0	0	–	0	0	0	0	0	0	0
01646580	TN	50	75	5	6	6	10	12	12	9	14	19	6	6	19	49	41	9
	TP	50	76	5	6	6	10	13	12	11	14	20	19	13	38	63	46	13
	SS	81	84	6	6	6	8	11	12	11	14	22	17	16	36	17	8	14
	TSS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	33	0
01649500	TN	–	–	–	–	–	0	0	0	0	0	0	0	0	0	0	–	–
	TP	–	–	–	–	–	1	0	0	0	0	0	13	26	16	15	–	–
	SS	–	–	–	–	–	0	0	0	0	0	0	0	0	0	0	–	–
	TSS	–	–	–	–	–	14	19	20	19	20	20	14	30	16	15	–	–
01654000	TN	–	–	–	–	–	–	–	–	–	–	–	–	–	0	17	0	–
	TP	–	–	–	–	–	–	–	–	–	–	–	–	–	8	42	10	–
	SS	–	–	–	–	–	–	–	–	–	–	–	–	–	8	25	10	–
	TSS	–	–	–	–	–	–	–	–	–	–	–	–	–	0	0	0	–

Table 5 (continued).

[2] The water-quality site associated with gage site 01643000, Monocacy River at Jug Bridge nr Frederick, MD, is 01643020, Monocacy River at Reichs Ford Bridge nr Frederick, MD.

Appendix 2: Priority Site Information

A number of additional considerations went into choosing the nine priority monitoring sites. In addition, specific site characteristics may influence the nature of the monitoring strategy at certain sites. This information is provided below. The nine priority sites and their associated catchments are shown in Figure 5; site monitoring and other site and catchment characteristics are summarized in Tables 6 and 7.

Station ID	Station Name	Subunit	Site Type	Gage Reactivation	Sampling Lead
01660920	Zekiah Swamp Run nr Newtown, MD	CP	Integrator	No	USGS-MD
01644000	Goose Creek nr Leesburg, VA	PD	Integrator	No	USGS-VA
01618000	Potomac River at Shepherdstown, WV	Main	Main	No	MDE
01658000	Mattawoman Creek nr Pomonkey, MD	CP	Urban	Yes	USGS-MD
01653600	Piscataway Creek at Piscataway, MD	CP	Urban	No	USGS-MD
01661050	St. Clement Creek nr Clements, MD	CP	Ag/Forest	No	USGS-MD
01616000	Abrams Creek nr Winchester, VA	GV	Urban	Yes	USGS-VA
01610155	Sideling Hill Creek nr Bellegrove, MD	VR	Forest	No	MDE
01611500	Cacapon River nr Great Cacapon, WV	VR	Integrator	No	USGS-WVA

Table 6. Priority site monitoring characteristics. (CP – Coastal Plain; PD – Piedmont; GV – Great Valley; VR – Valley and Ridge; Main – Potomac main stem; Ag – agriculture.)

			Major land use, in percentage of catchment area				
Station ID	Station Name	Area, km^2	Urban	Agriculture	Forest	Wetland	Water/Barren
01660920	Zekiah Swamp Run nr Newtown, MD	208	22.6	18.4	**45.8**	11.1	2.1
01644000	Goose Creek nr Leesburg, VA	856	4.7	**54.7**	40.2	0.1	0.2
01618000	Potomac River at Shepherdstown, WV	15,419	2.9	23.0	**72.3**	0.3	1.5
01658000	Mattawoman Creek nr Pomonkey, MD	148	31.7	12.9	**44.7**	8.7	1.9
01653600	Piscataway Creek at Piscataway, MD	93	**55.1**	10.8	27.6	5.2	1.2
01661050	St. Clement Creek nr Clements, MD	47	18.3	29.4	**47.2**	5.0	0.2
01616000	Abrams Creek nr Winchester, VA	44	**50.8**	29.6	18.2	0.2	1.1
01610155	Sideling Hill Creek nr Bellegrove, MD	268	0.9	21.5	**76.1**	0.3	1.1
01611500	Cacapon River nr Great Cacapon, WV	1,751	0.5	12.8	**85.7**	0.1	1.0

Table 7. Catchment characteristics for the nine priority monitoring sites. Predominant land use indicated in bold. Source: Vogelmann et al., 1997.

Zekiah Swamp Run nr Newtown, MD (01660920). This site is considered high priority for a number of reasons, such as its location within the Coastal Plain and relatively large size. The site has an active stream gage. Because of the nature of the channel, it is unlikely that an automatic sampler can be used, requiring additional field trips to sample storms. However, due to the large fraction of wetlands within the catchment (Table 7), recession is relatively slow, which should lessen the difficulty in sampling stormflow. Sampling at this site can begin October 1, 2000.

Goose Creek nr Leesburg, VA (01644000). This site provides a critical integrator in the Piedmont. The site has an active stream gage. An automatic sampler will be installed in the fall of 2000. Manual sampling at this site can begin October 1, 2000, with automatic sampling beginning January 1, 2001.

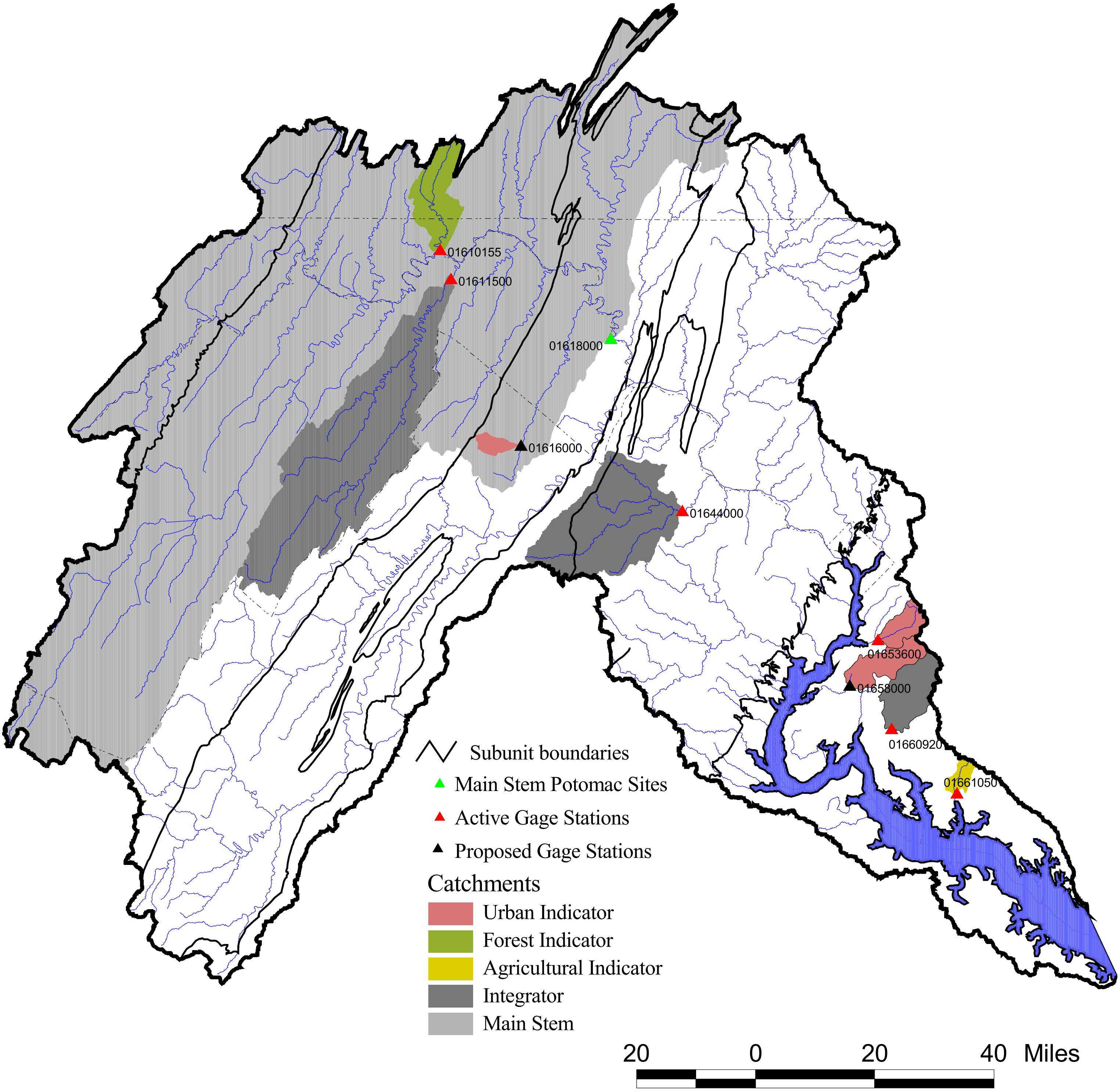

Figure 5. Priority sites.

Potomac River at Shepherdstown, WV (01618000). This site is the sole main stem Potomac site considered in the proposed monitoring plan. The site will have an active stream gage by October 1, 2000; at present, stage is only being recorded above 5 feet. Due to the size of the channel, an automatic sampler will not be used; additional field effort will be required to sample at this site as a result. This is one of two sites that will be the responsibility of MDE staff to help maintain and sample. Manual sampling at this site can begin on or before October 1, 2000.

Mattawoman Creek nr Pomonkey, MD (01658000). Mattawoman Creek is one of two important urban indicators in the Coastal Plain. The site will require reactivation of a stream gage (a stream gage existed at the site between 1949 and 1972). An automatic sampler will also be installed in the fall of 2000. Automatic sampling at this site will begin January 1, 2001.

Piscataway Creek at Piscataway, MD (01653600). This site is the second important urban indicator in the Coastal Plain. The site has an active stream gage. An automatic sampler will also be installed in the fall of 2000. Manual sampling at this site can begin October 1, 2000, with automatic sampling beginning January 1, 2001.

St. Clement Creek nr Clements, MD (01661050). The fourth proposed priority monitoring site in the Coastal Plain, St. Clement Creek is an Agriculture/Forest indicator near the downstream end of the Potomac River Basin. The site has an active stream gage. An automatic sampler will also be installed in the fall of 2000. Manual sampling at this site can begin October 1, 2000, with automatic sampling beginning January 1, 2001.

Abrams Creek nr Winchester, VA (01616000). Abrams Creek is an ideal urban indicator in the Great Valley. The site will require reactivation of a stream gage (a stream gage existed at the site between 1949 and 1960, and again between 1979 and 1994). An automatic sampler will also be installed in the fall of 2000. Automatic sampling at this site will begin January 1, 2001.

Sideling Hill Creek nr Bellegrove, MD (01610155). The site has an active stream gage. An automatic sampler will also be installed in the fall of 2000. This is one of two sites that will be the responsibility of MDE staff to help maintain and sample. Manual sampling at this site can begin on or before October 1, 2000, with automatic sampling beginning January 1, 2001.

Cacapon River nr Great Cacapon, WV (01611500). This site drains a significant land area (1,751 km^2) that has little historical water-quality data. The site has an active stream gage. Due to the size of the channel, an automatic sampler will not be used; additional field effort will be required to sample at this site as a result. Difficulties in sampling high flow may require additional planning and consideration early in the project.