DESIGN UPDATE OF THE ANNE ARUNDEL COUNTY BIOLOGICAL MONITORING PROGRAM

Prepared for

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Background

In 2003, Anne Arundel County initiated the design of a Countywide Biological Monitoring Program (Program) (Hill and Stribling 2004). From 2004 to 2013, the County implemented the Program in two, five-year sampling Rounds, which provided a statistically robust baseline assessment of the County's non-tidal streams. Over the ten years of program implementation, significant changes in the regulatory environment have occurred associated mostly with the County's NPDES municipal separate storm sewer system (MS4) compliance, especially in addressing Total Maximum Daily Loads (TMDLs) implementation. To meet these and other challenges, the County has revised the Program to increase its robustness and utility through the following efforts:

- Ensuring all regulatory requirements are met
- Enhancing the existing program to the latest scientific standards
- Increasing the efficiency and cost-effectiveness of the program
- Integrating the program with other watershed management and MS4 monitoring

The County, its consultants, and a Technical Review Committee (TRC) comprised of experts in stream and watershed assessment evaluated the following potential changes to the program in order to meet the County's current goals. This report details the specific analyses conducted and the changes adopted.

1. Redesign the biological survey to address trends in condition, provide a more even geographic coverage, and reduce local variability

2. Change to a more detailed stream network with implications for survey design and comparability with previous rounds

3. Combine the monitoring in the biological survey with monitoring in the watershed assessments using representative analysis

4. Add additional MBSS or other parameters (e.g., fish, amphibian, geomorphic, and water quality parameters) to the biological survey

5. Improve stressor identification at local scales

6. Redevelop IBIs or reference conditions to characterize the more detailed County stream network

7. Expand monitoring to include tidal waters

The report includes discussion of both planned changes to the current program (survey revisions) and potential future changes that cannot be implemented at this time.

Summary of Design Changes

1. Institute a partial replacement survey design that includes 50% fixed sites from previous rounds and 50% new random sites in each watershed (primary sampling unit or PSU)

2. Reduce the number of sites to be sampled in each watershed from 10 to 8 based on power analysis that used more data and showed less variability in western Coastal Plain reference streams

3. Add sampling on smaller streams (using the more detailed stream network developed by Anne Arundel County that more than triples the number of stream miles) as separate stratum, therefore, increasing the number of sites per watershed two-fold

4. Add sampling for the following components using Maryland Biological Stream Survey (MBSS) methods:

   - Larger suite of water quality parameters (from 5 to 18 parameters total)
   - Fish assemblages
   - Crayfish and mussel species
   - Amphibians, reptiles, and vernal pools in the riparian area

5. Develop a new Benthic Index of Biotic Integrity (B-IBI) for small streams that will be added with the more detailed County stream network

1 Redesign biological survey to address trends in condition, provide a more even geographic coverage, and reduce local variability

Currently, Anne Arundel County samples approximately 240 stream sites (75-m segments) over a 5-year round, countywide. Ten sites each are randomly allocated among the 24 watershed primary sampling units (PSUs). Within each PSU, sites are allocated by stream order in proportion to their occurrence. Round 1 was conducted during 2004-2008; Round 2 covered 2009-2013. Going forward, the biological survey design could be modified to provide better trend detection, a more even geographic coverage, or less local variability. The incremental benefits of each modification and implications for comparability with past data are described below.

1.1 Design options for improving trend detection

The current survey design provides trend detection through comparison of area wide estimates among rounds. There are three options for improving trend detection by reducing the among site variability that comes with selecting new random sites each round.

- Creating a fixed site network (either of reference condition or of a gradient of condition) in addition to the random survey
- Partial replacement design (combination of random and fixed sites selected each round)
- Using only repeats of sampled sites going forward (i.e., repeating sites sampled in earlier rounds)

The TRC supported the idea of fixed sites to detect trends over time. There was no consensus on whether this network should be included in the countywide design or separate. The pros and cons of the three options are as follows:

<u>Fixed site network separate from the random survey</u>. The MBSS currently maintains a sentinel site network of 29 sites identified as among the least disturbed and most protected in the state. These sites were selected from random sites previously sampled by the MBSS. The goal of this network is to evaluate changes resulting from natural factors (e.g., weather and climate change) as opposed to changes from local anthropogenic stressors. Currently the MBSS sentinel site network includes seven western Coastal Plain sites (none in Anne Arundel County), which should be adequate for determining trends in least disturbed sites. A network of sentinel sites that addresses the gradient of disturbance would be an extensive and expensive addition to the Program. Since the number of sites in the current Program is the minimum required for adequate power, a separate fixed-site network of any size would entail additional costs in the number of sites in the network.

<u>Partial replacement design</u>. This is a hybrid design where the next round of sampling includes both repeat sampling of sites sampled in previous rounds and new random sites selected for the next round. This design improves trend detection by reducing the among site variability by the proportion of repeat sites. The inclusion of new random sites ensures that assessments continue to approximate area wide conditions and are not overly constrained to the subset of sites selected originally. Sampling theory (e.g., Cochran 1977) indicates that a design using 25-50% repeat sites is the ideal balance of trend detection and representative assessment.

Conversion to fixed-site network. In this design, all sites sampled in subsequent rounds would be repeat sites selected from previously sampled random sites, creating a fixed site network going forward. This greatly reduces the among-site variability by eliminating new random sites (Naiman et al. 2001); however, the lack of new random sites reduces our confidence that the original set of random sites is representative of overall conditions over time. The MBSS is currently employing this design for its Round 4 because the focus of Round 4 is trends detection rather than additional condition assessment.

1.2 Evaluate adding stratification using smaller watersheds to provide more even geographic coverage

Random sampling creates a more variable density of sample sites across the landscape than grid sampling, but is easier to implement and analyze than grid sampling, especially over a stream network. A more even distribution of sample sites along a stream network can be obtained by allocating sites to smaller strata, such as subwatersheds. For Anne Arundel County, sample sites could be allocated to subwatersheds smaller than the current 24 watersheds sampled as PSUs to more evenly distribute the sites. Estimates of stream condition would not be calculated for the subwatershed strata, as each would contain too few sites (unless sampling effort was increased). Estimates would require calculation of stream miles by each subwatershed to properly weight the stream values.

Figure 1-1 illustrates that the distribution of Anne Arundel County random sites for both rounds provides generally good coverage of all parts of the County. In addition, as future rounds of random sampling are completed, the areas without samples will become fewer.

Of greatest concern, however, is whether the areas without sites are caused by the absence of sampling permissions, which can bias the assessment when the sites denied permission are different from the sites sampled. Table 1-1 shows that very few sites were denied permission in the monitoring program years of 2004-2013—only 44 sites were denied permission compared to the 480 sampled (9.2%). The new County requirement to obtain active permissions will likely increase the number of sites that cannot be sampled, so the distribution of non-permission sites among land use types should be evaluated in the future to identify any potential bias.

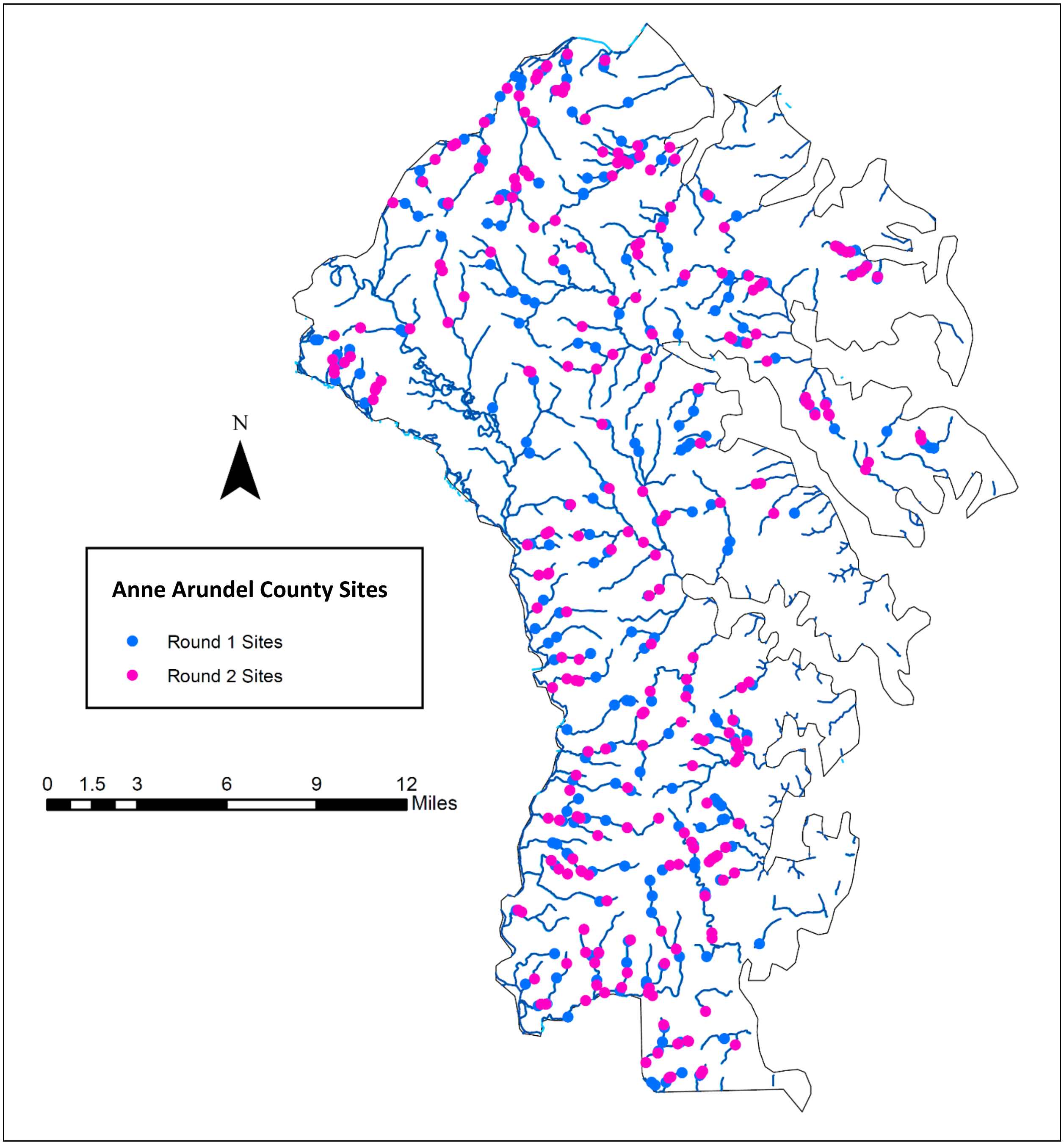

Figure 1-1. The distribution of random sites sampled during Rounds 1 and 2 of the Program, indicating generally good coverage of all parts of the County. The unsampled area along the central, western boundary of the county is Fort George G. Meade.

Table 1-1. Number of sites where permissions were denied by year and watershed, for the years 2004-2013		
Year	**Number of Sites with Permissions Denied**	**Watershed**
2004	0	None
2005	0	None
2006	1	Hall Creek
2007	1	Piney Run
	2	Little Patuxent River
2008	1	Cabin Branch
	3	Rhode River
2009	1	Lower North River
	1	West River
	5	Rock Branch
2010	1	Stony Creek
	1	Sawmill Creek
	2	Herring Bay
	1	Middle Patuxent River
	3	Ferry Branch
2011	1	Bodkin Creek
	1	Upper Magothy River
2012	9	Rhode River
	2	Hall Creek
2013	1	Cabin Branch
	1	Lower Magothy River
	2	Stocketts Run
	4	Lyons Creek

1.3 Evaluate adding stratification by stream type (e.g., braided/wetland or slope, stream order or size, geology, ephemeral versus perennial if more detailed stream network is used), using analysis of MBSS data for western Coastal Plain

More important than stratifying the survey for more even geographic coverage is the issue of stratifying to address naturally different stream types, i.e., stream types for which the reference condition should be different. One of the challenges of large-area biological surveys is to develop and apply indicators of stream condition that are both practical and realistic—given that every stream is, in some sense, unique. The MBSS carefully considered the number of strata needed for the statewide survey and developed indicators for reference conditions in each of three geographic strata: Highlands, Eastern Piedmont, and Coastal Plain. However, the number of MBSS strata was limited by resources and practicality; finer strata would be beneficial but would provide only diminishing returns on the investment for a statewide survey.

All Anne Arundel County streams fall within the MBSS Coastal Plain stratum. Additional strata of stream types would undoubtedly be beneficial, though they would not necessarily exceed the costs required in indicator development and additional sampling. The finer differences in the geology of Anne Arundel County streams are not well enough known to warrant developing different reference conditions. Therefore, additional stratification would be limited to an evaluation of whether natural biological conditions vary with size or slope of streams in Anne Arundel County as described in Section 6.

1.4 Confirm/revise the number of sites per PSU that are needed to maintain the ability to detect 30% change, 80% of time, with 95% confidence (currently 10 sites per PSU). This will depend on whether the strata are being used for assessment or more even geographic coverage.

The original stream survey design for Round 1 of the Anne Arundel County biological monitoring program was based on power analysis that determined that 10 random sites per PSU would detect a 30% change in IBI scores, 80% of the time, with 95% confidence. Like the MBSS, this power analysis was based on the variability in "reference and similar" site IBI results found in the MBSS data from 1995-1997. Both power analyses at that time determined that 10 sites per PSU would achieve the desired power.

A new power analysis with the same 30-80-95 objective was completed using all MBSS sites sampled through 2014. The many more sites available also allowed us to use only true reference sites for this new power analysis (290 for Coastal Plain and 137 for Western Coastal Plain), rather than including the "similar" sites (i.e., sites did not fully meet the reference threshold) that were used in the original analysis to increase the number of sites for analysis. The number of available reference sites also allowed us to determine the variability (and power) in sampled sites for two different categories of Coastal Plain sites relevant to Anne Arundel County: (1) all MBSS Coastal Plain reference sites and (2) MBSS western Coastal Plain sites. In each analysis, only the most recent sampling at each site was used to eliminate pseudoreplication. This new power analysis indicates that less than 10 sites per PSU will meet the 30-80-95 objective (see Figure 1-2). Nine (9) sites per PSU are indicated by the entire Coastal Plain data, while 7 sites are indicated by the western Coastal Plain data. A second power analysis was completed on 31 "surrogate reference" sites in Anne Arundel County, since only 7 true reference sites occur in the county. A criterion of greater than 60% forest cover at the site was used to define these surrogate references, though it should be noted that most of these sites have stressors present that prevent them from being true reference sites (resulting in greater than natural variability). This power analysis indicates that 10 sites are needed to meet the 30-80-95 objective (see Figure 1-3). Based on the quality of the reference sites (i.e., closeness to natural variability) and geography similar to Anne Arundel County, we conclude that the western Coastal Plain power analysis is likely to be the most accurate (i.e., 7 sites meet the 30-80-95 objective), but choose to use 8 sites as a conservative number for survey design.

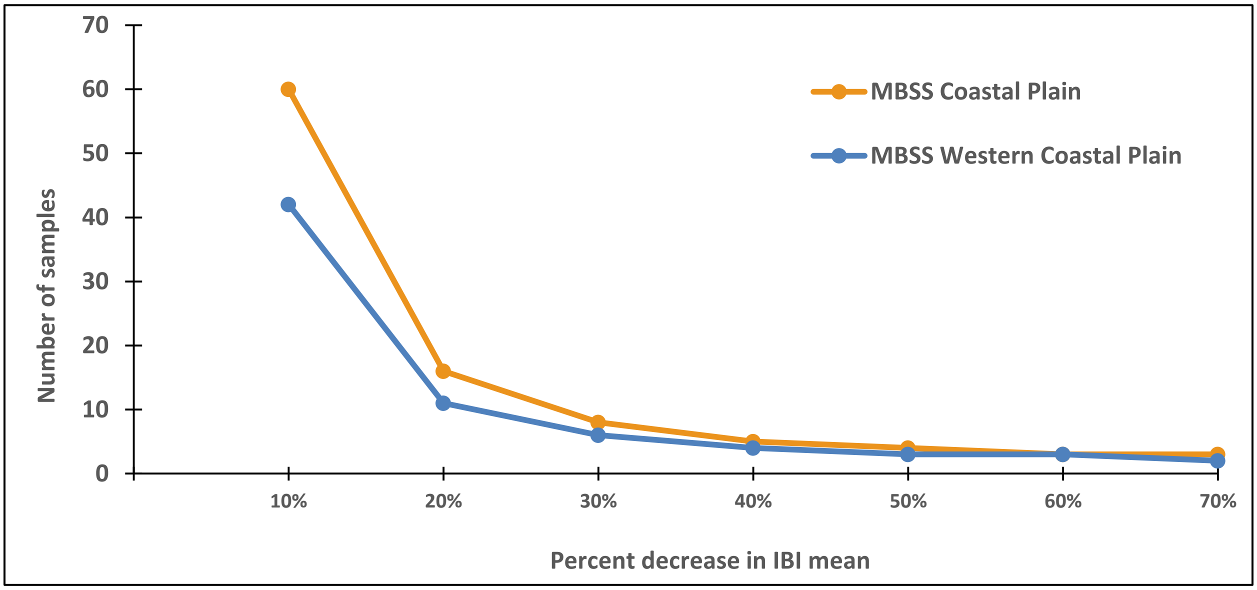

Figure 1-2. Power analysis of MBSS reference site data (for 290 Coastal Plain sites and 137 Western Coastal Plain sites relevant to Anne Arundel County) showing the number of sites per PSU that are needed to detect a 30% change in IBI scores, 80% of the time, with 95% confidence.

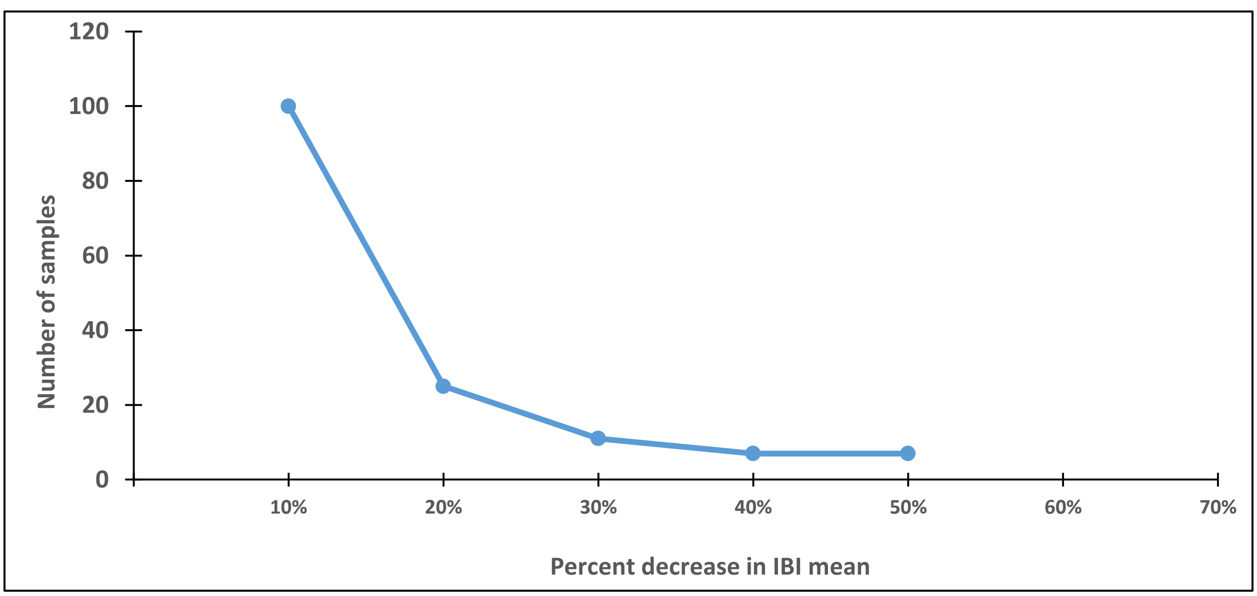

Figure 1-3. Power analysis of 31"surrogate reference" Anne Arundel site data (based on 60% or greater forest cover) showing the number of sites per PSU that are needed to detect a 30% change in IBI scores, 80% of the time, with 95% confidence.

SURVEY REVISION

Anne Arundel County will revise the survey design to include partial replacement of random sites with repeat sites from previous rounds. Specifically, two sites in each Round 3 PSU will be randomly chosen from the 10 Round 1 sites, and two sites would be randomly chosen from the 10 Round 2 sites; the remaining four sites (as dictated by the new power analysis) in each watershed would be new, randomly selected sites. This will achieve an ideal balance of 50% fixed and 50% random sites in the round. Future rounds would retain the same fixed sites (for optimal trend detection) and select new random sites each round.

The revised design would retain the proportional allocation to stream order (1st, 2nd, and 3rd). The allocation in proportion to the number of stream miles in each stream order retains the assumption that sites are selected within watersheds in a simple random manner, without the need for weighting by stream order. The repeat sites will be selected at random and the new random sites chosen from each stream order as needed to retain the proportional allocation to the extent practical. Selected sites may deviate from the exact stream order proportions because of small numbers of stream miles in a stream order, but will remain randomly selected sites.

Calculations of areawide condition (equations used to determine significant differences in IBIs) will remain the same. Comparisons of areawide change over time will be more precise because among site variability will be less, i.e., the power analysis using only random sites is conservative for this design. The replacement of fixed sites that are unavailable owing to lack of permissions or access, with random sites will only have a small effect on reducing the ability to detect trends. Comparisons of change in the fixed sites alone will have the greatest power.

Modifying the survey design to include allocation of sites by subwatershed strata for more even geography is not warranted, given the fairly even distribution of random sites which will increase with future rounds.

As described in Section 2, the survey will also be revised to include the additional stratum of small streams on the more detailed County stream network, so that areawide condition assessments can be conducted for both small and large streams, separately, within each watershed. This requires that the number of sampling sites be increased proportionally. Therefore, as the number of sampling units will be increased from 24 watersheds to 48 categories of watershed-specific small streams and watershed-specific large streams, the number of sites that must be sampled to retain the same power will double from 8x24 or 192 sites to 8x48 or 384 total sites (compared to the 240 sites sampled in each of Rounds 1 and 2).

2 Change to a more detailed stream network with implications for survey design and comparability with previous rounds

Currently, Anne Arundel County uses the National Hydrography Dataset (NHD) at the 1:100,000 scale to identify and assess streams in the biological sampling program. The County is also developing a field-verified stream map from its watershed assessments that is finer than the topographic 1:24,000-scale map. This more detailed stream network map is complete for about 80% of the county and will be finalized when the remaining watershed assessments are completed. This map is derived from field investigations by a variety of consultants and includes some variability in the extent of the stream network by watershed. It should be noted, however, that no map is a perfect representation of on-the-ground features, and this more detailed map better captures the true stream network than previous maps.

The importance of these small streams is evidenced by the continued debate on the breadth of "Waters of the United States (WOTUS)" as summarized in Meyer et al. (2003) and U.S. EPA (2015a). The new federal rule on WOTUS mandates inclusion of smaller waterbodies in protection efforts. In addition, using the more detailed map is important for understanding the continuity of the stream network, even if some small streams are not sampled (Matt Baker, TRC).

While the benefits of sampling at this finer scale are considerable, the costs and complications are significant:

- The more detailed stream network will need to be quality assured and it will not have the attributes and modeling capability of the NHD.
- It will be more likely that many of these streams will be dry at the time of sampling, especially those streams designated as ephemeral or intermittent. While all the streams smaller than the 1:100,000-scale network are included in this sampling design, the County could choose to delete those stream segments designated as ephemeral or intermittent from the more detailed County stream layer. This would reduce the number of new small streams added by about one-third.
- To allow backward comparison of stream assessments, the number of sample sites will be twice that of a single stratum (in this case, two strata of 8 sites each in each watershed per the new power analysis, so 1.6 times more sites than sampled in Rounds 1 and 2)
- A new B-IBI for these smaller streams will need to be developed, as it is very likely that natural differences dictate a separate reference condition (see Section 6)

2.1 Stream miles that would be added to the monitoring program by converting to the more detailed County stream network

Figure 2-1 shows the extent of the more detailed stream network overlain on the current 1:100,000-scale network. The 1:100,000-scale map includes 422 stream miles; the more detailed Anne Arundel County map includes 1,448 stream miles. Note that 5% more small streams may be added with completion of the remaining watershed assessments (as about 20% more stream miles than the planimetric base map are added in the field verification), resulting in about

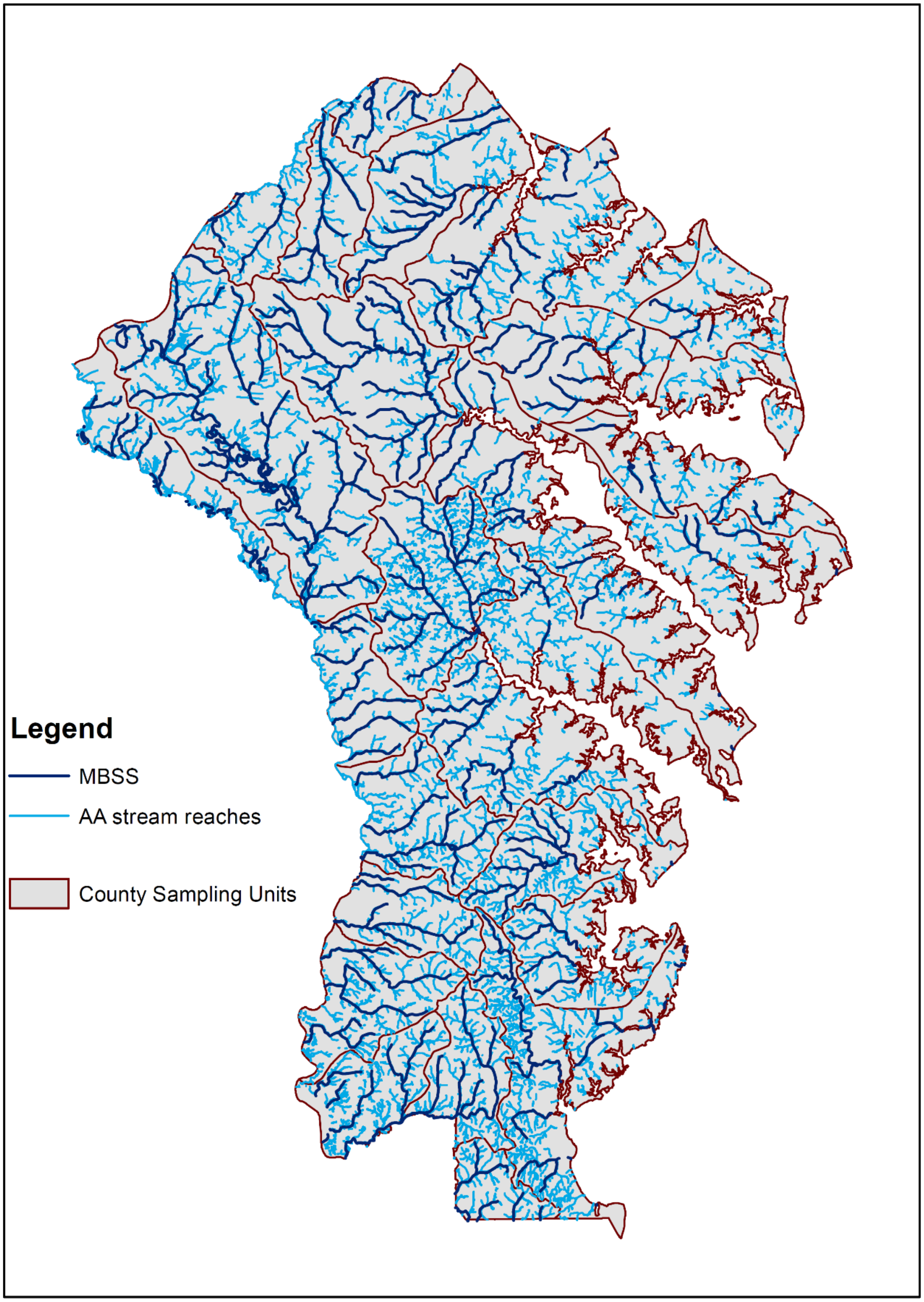

Figure 2-1. Comparison of the more detailed County stream network (not yet complete) and current 1:100,000-scale stream network, showing an increase from 422 to 1,448 stream miles.

1,500 stream miles. While there are some 1:100,000-scale stream reaches that do not appear on the more detailed stream network, the vast majority of the difference are the additional stream miles on the more detailed network compared to the current 1:100,000-scale network. Analysis done on the MBSS 100,000-scale stream network compared to the 1:24,000-scale network used by Montgomery County (Roth et al. 2002; Volstad et al. 2003) revealed that 4% of total stream miles were only on the 1:100,000-scale while 60% were only on the 1:24,000-scale (with 36% common to both maps).

The additional stream miles on the more detailed County stream network constitutes an approximately 250% increase in the number of stream miles (3.5 times more stream miles). These new stream reaches are, by definition, nearly all smaller in Strahler order and size of the catchments that drain to them.

2.2 Increase in sites needed to maintain 30-80-95 power (currently 10 per PSU) for comparing back to subset of larger 1:100,000-scale streams from previous rounds

The new power analysis completed for this project is described in Section 1.4. It concludes that eight sites per PSU will meet the 30-80-95 objective (see Figure 1-2). Section 1 also notes that eight sites per PSU will be needed for each population of streams to be assessed.

A key aspect of adding more, smaller stream miles to the survey design by switching to the more detailed County stream network is the need to continue to compare only the streams on the 1:100,000-scale network in future rounds with the results of Rounds 1 and 2. It is not statistically valid to compare the complete new stream network to Rounds 1 and 2, because the new network comprises a different population of streams, one that includes smaller streams not sampled in Rounds 1 and 2. Therefore, to retain the 30-80-95 power goal, eight random sites must continue to be sampled on the 1:100,000-scale stream network in future rounds. To attain an assessment of the smaller streams (those on more detailed map but not on the 1:100,000-scale map), another eight random sites per PSU must be sampled in future rounds.

We considered whether the smaller streams added from the more detailed County stream network would be more naturally variable and require more sites to be sampled to attain the same 30-80-95 power goal. To evaluate this, we conducted a power analysis of 31 MBSS reference sites that are small streams (draining catchments of less than 575 acres) sampled in the Western Coastal Plain. The 575-acre threshold represents the smallest 50% of streams in Anne Arundel County. This analysis indicates that these smaller streams are significantly less variable than all Western Coastal Plain reference sites, so that sampling more than eight sites per stratum are not needed (see Figure 2-2). Therefore, to obtain the desired 30-80-95 power with the more detailed Anne Arundel County stream network, the number of sites sampled would double from 192 to 384.

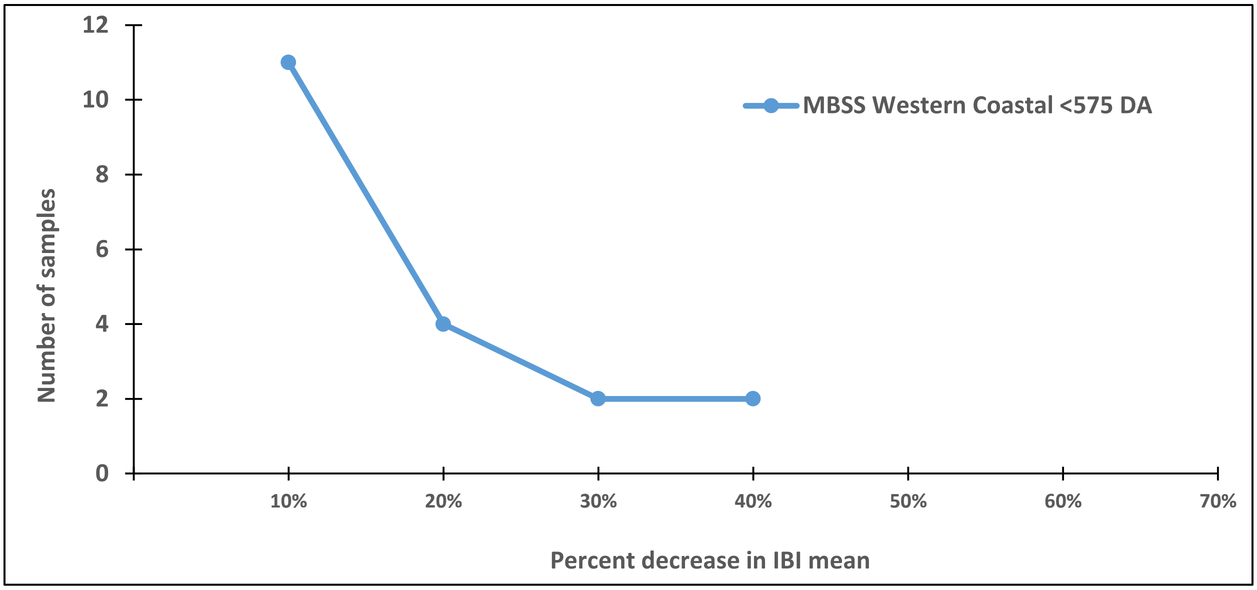

Figure 2-2. Power analysis of 31 MBSS reference small stream sites (draining catchments of less than 575 acres) sampled in the Western Coastal Plain., showing the number of sites per PSU that are needed to detect a 30% change in IBI scores, 80% of the time, with 95% confidence.

2.3 Evaluate stream size differences in B-IBI that might indicate the need for a new B-IBI for smaller streams added with more detailed County map (e.g., identify variation in metric scores at reference sites with different drainage areas)

In addition to the need to sample more sites when converting to the more detailed County stream network, the appropriateness of using the existing indicators (i.e., the MBSS Benthic Index of Biotic Integrity or B-IBI) on smaller streams must be considered.

The exact comparison of B-IBI differences between the 1:100,000-scale stream network and the more detailed stream network cannot be calculated because no sampling has been done on the smaller streams. As a surrogate, we looked at the analysis in Section 6 where Figure 6-6 shows the difference in mean B-IBI scores for county streams draining small (< 575 ac) versus large (> 575 ac) catchments. This difference would be greater, and perhaps much greater, when considering the smaller streams on the more detailed stream network. Some of the streams on the more detailed stream network are ephemeral and intermittent, and have significantly different ecological character.

Another critical concern with converting the sampling frame to the more detailed Anne Arundel County stream network is the need to quality assure and finalize the network. At present, there are inconsistencies in the density of streams identified in different watersheds (perhaps an effect of different sampling teams under the watershed management program), as well as the attributes ascribed to each stream reach. This is a substantial effort for any new sampling frame.

SURVEY REVISION

Anne Arundel County will use the more detailed stream network to assess watershed conditions in Round 3 and future rounds. The survey will treat the larger streams (from 1:100,000-scale map) as one stratum and the smaller streams (occurring on the more detailed map but not on 1:100,000-scale map) as a second stratum within each watershed. The survey will sample eight sites per stratum (as indicated by the new power analysis), equaling 16 sites in each of the 24 PSUs, so that both larger and smaller stream populations can be compared across all rounds where they were sampled. The County will attempt to develop a small-stream B-IBI using appropriate small-stream reference conditions. Note that this will increase the overall sampling effort for the Program from the current level of 240 sites per round (10 per PSU) to 384 sites (16 per PSU).

3 Combine the monitoring in the biological survey with monitoring in the watershed assessments using representative analysis

The County has assessed the biological condition (among other factors) of streams under a watershed management program that targets stream sites on downstream and mid-watershed reaches. In contrast, the Program monitors randomly selected stream sites stratified by watershed and stream size over multiple rounds. Because the watershed management program assessments are nearly complete, the biological monitoring program will not be revised to address integrating these targeted and random assessments.

Nonetheless, it is valuable to compare the biological condition results obtained by both work efforts. Figure 3-1 shows the percentage of sites scoring less than 3 on the Benthic Index of Biotic Integrity (B-IBI) within each of the 24 PSUs in the Program. A score of less than 3 indicates the site has a degraded biological condition (i.e., is rated Poor or Very Poor). The percentage of random (Round 1 and Round 2) sites is a valid estimate of the percentage of degraded stream miles in the PSU; the percentage of targeted sites may not be unbiased but may, nonetheless, produce similar results. The results show that, in one-third of the assessed watersheds, the percentage of degraded targeted sites fell between the percentages of degraded random sites in the two different random rounds. Where the targeted sites percentages were different, they were nearly equally higher (in six watersheds) or lower (in six watersheds). This indicates that the targeted biological assessments are not producing an identifiable bias in the results by watershed. In general, the extent of difference in the percentage of degraded targeted sites was similar to the difference between the two random site rounds, which can be attributed to temporal effects such as weather.

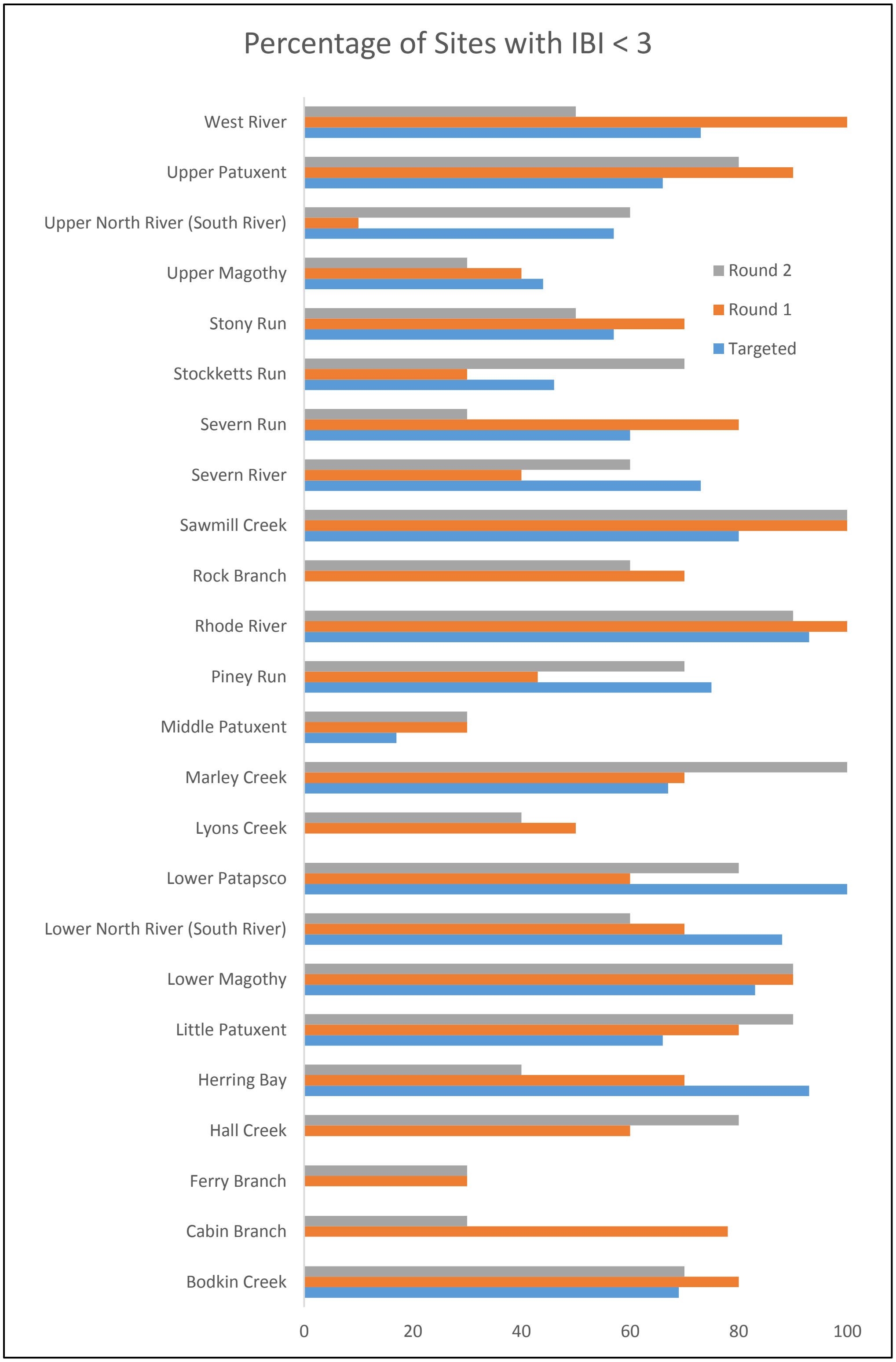

Figure 3-1. Percentage of sites scoring less than 3 on the Benthic Index of Biotic Integrity (B-IBI) within each of the Program's 24 PSUs from two random rounds of sampling (Round 1 and Round 2) and one targeted (non-random) program of sampling

Should the County wish to combine the results of the random (probability-based) and targeted (non-probability-based) sites in the future, this may be possible through representativeness analysis. A summary of this approach is provided below.

3.1 Summarize the literature on using non-random “found” samples to augment random surveys

A common problem that plagues long-term water quality monitoring programs is the change of survey structure and data collected over time as various monitoring programs can develop, diminish, or abruptly change over time. Often researchers are left with the challenge of how to link “found” data, or data from a nonprobability-based survey, with observations from a true statistical sample (p-sample) and attempt to retain the advantages for estimation inherent in the statistical sample. Overton et al. (1993) proposes a framework to integrate probability sampling and found samples by grouping found data into similar subsets. Two methods for integrating found data are outlined—a pseudo-random approach and a calibration approach.

The pseudo-random approach is taken when the variables of interest have been measured in both the found data and the random (p-sample) dataset, so that combined they increase the effective sample size. For pseudo-random approach, the p-samples are stratified into homogenous subsets that represent corresponding subpopulations. Found samples then are assigned to the p-sample subsets and are assumed to be representative of the corresponding subunits. The calibration method is used when the found sample contributes information that is unique and has not been measured in the p-sample. This approach requires the development a predictor equation. This equation estimates the variable of interest from a regression based on the characteristics of the p-sample sites. These estimations of the variable of interest can then be used to supplement the p-sample dataset.

Through this data supplementing approach, Overton et al. (1993) report a decrease in the standard error of the parameter estimates and an increase in precision when the found sites were assumed representative of the assigned subpopulations. Importantly, Overton highlights the most important use of found data, the ability to extend inferences to attributes not available in the p-sample.

For creating successful long-term monitoring studies, Overton and Stehman (1996) suggest design strategies that allow for adaptations to changes while maintaining capacity to detect trends over time. Three primary sampling features that they emphasize are (1) subpopulation estimation, (2) post-stratification from conditional design, and (3) sample restructuring. In addition, Overton and Stehman warn against using data from complex designs where the designs limit the data’s suitability for other studies.

SURVEY REVISION

Because the watershed management program assessments are nearly complete, the biological monitoring program will not be revised to address integrating these targeted and random assessments. Should the County wish to combine the results of the Program and the targeted watershed management program sites in the future, the Overton approach can be used.

4 Add additional MBSS or other parameters (e.g., fish, geomorphic, and water quality parameters) to the biological survey

Although the Program was patterned after the MBSS in 2003 and revised in 2009, the MBSS has evolved during this time, as have the County goals, especially related to TMDLs. Currently the Program samples for five water quality parameters, benthic macroinvertebrates, and five physical and geomorphic parameters.

4.1 Water quality – Anne Arundel County currently only samples for dissolved oxygen, pH, temperature, specific conductance, and turbidity as part of the biological monitoring program.

The County will add sampling for additional water quality parameters to improve detection of local stressors, especially those related to TMDLs, and to comport with Federal and State monitoring programs. Of particular interest are total nitrogen, which is a better indicator of condition during baseflow monitoring than total phosphorus, which is bound to sediments that move in storm flows (Don Weller, SERC, TRC), and chloride which will soon become a water quality standard in Maryland (Matt Stover, TRC). Chloride from road salt is an emerging major stressor to streams for which EPA has established a new benchmark for drinking water standards in the Coastal Plain of 250 mg/L. Scott Stranko and Ray Morgan stated that Tim Fox of MDE has a method for determining the proportions of different constituents such as chloride in the ion matrix when at least one ion is measured along with conductivity (which is already sampled by the County). The TRC considered a phased approach that would only monitor additional parameters where conductivity is high, but the County determined that 93% of all sites sampled in Rounds 1 and 2 had conductivity values above 100 µS/cm and that more than 40% of sites had values above 250 µS/cm. Therefore, the County will add a standard suite of the nutrient and metals parameters typical of other monitoring programs. Sampling for pesticides will not be conducted as laboratory analysis was judged too expensive the Program to implement. Oil and grease is another useful parameter, but only when sampled in storm flows, which are not captured by the Program. The TRC also agreed that sampling for bacteria is of limited value without microbial source tracking (MST) to differentiate between human, pet, livestock, and wildlife sources; MST techniques are becoming increasingly accurate but were considered too expensive for a the Program to implement.

Table 4-1 lists the parameters sampled by the MBSS and some other Maryland counties. The prices shown are those charged by the UMCES-Appalachian Laboratory. Different prices may be available from different vendors. A per sample processing fee is typically an additional cost charged by analytical laboratories.

Table 4-1. Per site cost for chemical parameters sampled by MBSS and certain Maryland Counties (Katie Kline, UMCES-Appalachian Laboratory). The 48 sites/year annual cost is comparable to the size of the current annual chemistry monitoring conducted by the County.		
Parameter	**Cost per Sample**	**Cost per year (assuming 48 sites/year)**
Turbidity	$5.00	$240.00
Total Nitrogen	$14.00	$672.00
Total Phosphorus	$14.00	$672.00
Ammonia-N	$7.00	$336.00
TKN (calculated)	$0.00	$0.00
Nitrate-Nitrogen	$15.00	$720.00
Nitrite-Nitrogen	$10.00	$480.00
Dissolved Organic Carbon	$15.00	$720.00
Orthophosphate	$15.00	$720.00
Total Organic Carbon	$10.00	$480.00
Copper	$12.00	$576.00
Lead	$12.00	$576.00
Zinc	$12.00	$576.00
Chloride	$15.00	$720.00
TOTAL	**$156.00**	**$7488.00**

4.2 Geomorphology – Anne Arundel County currently performs a Rosgen Level II geomorphic assessment, including a qualitative physical habitat assessment (0-20 scale), modified Wolman pebble count, stream cross section, water surface slope, and reach sinuosity measurements. Maryland DNR has recently developed geomorphic methods for MBSS core sampling (less intensive) and Trust Fund sampling (more intensive). Research on the relationships between geomorphologic and biological results is still inconclusive.

Attempts to correlate biological condition (B-IBI) in County streams with current geomorphology results (Rosgen Level 2 assessments) have met with very limited success (Chris Victoria, Anne Arundel County, TRC). To date, few strong relationships between geomorphic parameters and biology have been demonstrated; however, a useful metric may remain to be discovered somewhere between the coarse level perspective that humans see and the fine level that benthic invertebrates see (Scott Lowe, TRC). In addition, geomorphology is context dependent, meaning that (1) geomorphology may not be a controlling factor when degraded water quality is present and (2) Coastal Plain streams are relatively homogeneous in their geomorphic characteristics.

While the exact magnitude of influence varies, it is clear that the physical characteristics of stream channels influence the biological community found in these systems (see, for example, Myers and Resh 2000 or Schwartz and Herricks 2008). Consequently, it is important to have some understanding of these variables in a biological monitoring program beyond qualitative habitat assessments like those of the RBP or MPHI.

The MBSS has initiated geomorphic assessments for Round 4 sampling begun in 2014. Investigations into MBSS biology-geomorphology relationships are only recently underway, but indicate that substrate assessments may improve on previous correlations. Upon completion of the analysis from MBSS Round 4 analyses, the MBSS will continue to monitor the most promising geomorphology parameters in future years.

Given the TRC was not able to propose a geomorphic assessment method with a stronger relationship to overall biological condition, the County will continue Rosgen Level II assessments and participate in further analysis with MBSS before other parameters are added.

4.3 Fish, Amphibians, or Other Organisms – The County does not currently sample fish or amphibians as part of the program, but believes that these organisms may be good indicators for wetland-stream complexes within the county. Round 4 of the MBSS is sampling for salamanders and hopes to apply a streamside salamander IBI, though likely not in the Coastal Plain. MBSS also samples other herpetofauna, crayfish, mussels, and vernal pools.

Fish. Sampling stream fishes is an important part of assessing and restoring watershed health (Scott Stranko, TRC). They are the component of stream biota of most interest to the public, both commercially and aesthetically. The electrofishing technique employed by the MBSS gives a nearly complete census of the community which allows for robust estimates of the density and abundance of individual species, estimates that are not obtainable under current sampling methods for benthic macroinvertebrates. These estimates can be useful for identifying species that are common, rare, or in need of conservation measures to secure populations within the County. Accurate abundance and distribution information is particularly useful for managing recreational fishes in the County, such as various perch, bass, pickerel, and trout. Also, the distribution of American eel is of special importance for its commercial value and influence on stream communities.

Additional benefits of including fish sampling in the Program are the ability to detect non-native and invasive fishes, stressors related to fish health, and barriers to movement. By sampling for fish, the County will be able to detect and track the spread of invasive species within the county. Some of the species with the potential to affect County stream communities are the northern snakehead, blue catfish, and oriental weather loach. Fish sampling can also monitor stream conditions using long-lived fish, such as suckers and catfish that can live for 10 or more years. Long-lived species also develop fish tumors that can help identify potential stressors. A Countywide survey of fish would also identify gaps in stream connectivity, because, unlike stream invertebrates that have winged adult dispersal, fish rely upon stream connectivity to disperse and found populations in un-colonized streams.

Analysis of MBSS datasets has found low correlations between benthic invertebrate IBI scores and fish IBI scores, which likely indicates that these two indices of biological condition are responding to different environmental stressors and habitats. This is similar to findings in other regions that fish metrics tend to respond to reach-scale, geomorphology, and water chemistry effects, while macroinvertebrate metrics tend to respond to larger-scale land use effects (Johnson and Ringler 2014). By assessing both fish and macroinvertebrate conditions, the County will obtain a more complete picture of watershed health and will be able to identify and react to wider range of environmental conditions (Freund and Petty 2007).

The cost of adding fish sampling using the MBSS methods will likely be about $4,500 per site (Stranko, Maryland DNR, TRC).

Amphibians and Reptiles. The Stream Salamander Index of Biotic Integrity (SS-IBI) is the latest biological indicator developed by the MBSS (Southerland et al. 2004). Stream salamander sampling in underway as part of Round 4 of the MBSS and results will be used to validate the SS-IBI so that it can be used in Round 4 reporting. It is anticipated that MBSS will not apply the SS-IBI to Coastal Plain streams, because the number of species and abundance of individual salamanders are too low for effective IBI development.

The MBSS has sampled all amphibians and reptiles using either incidental or areawide searches of the riparian area during the four rounds of the MBSS. There is an increasing relationship between the number of amphibian and reptile species found at each site and B-IBI scores in Anne Arundel County (Figure 4-1). Table 4-2 and Figure 4-2 show the number of each species of amphibian and reptile sampled in Anne Arundel County by the MBSS from 1995-2013.

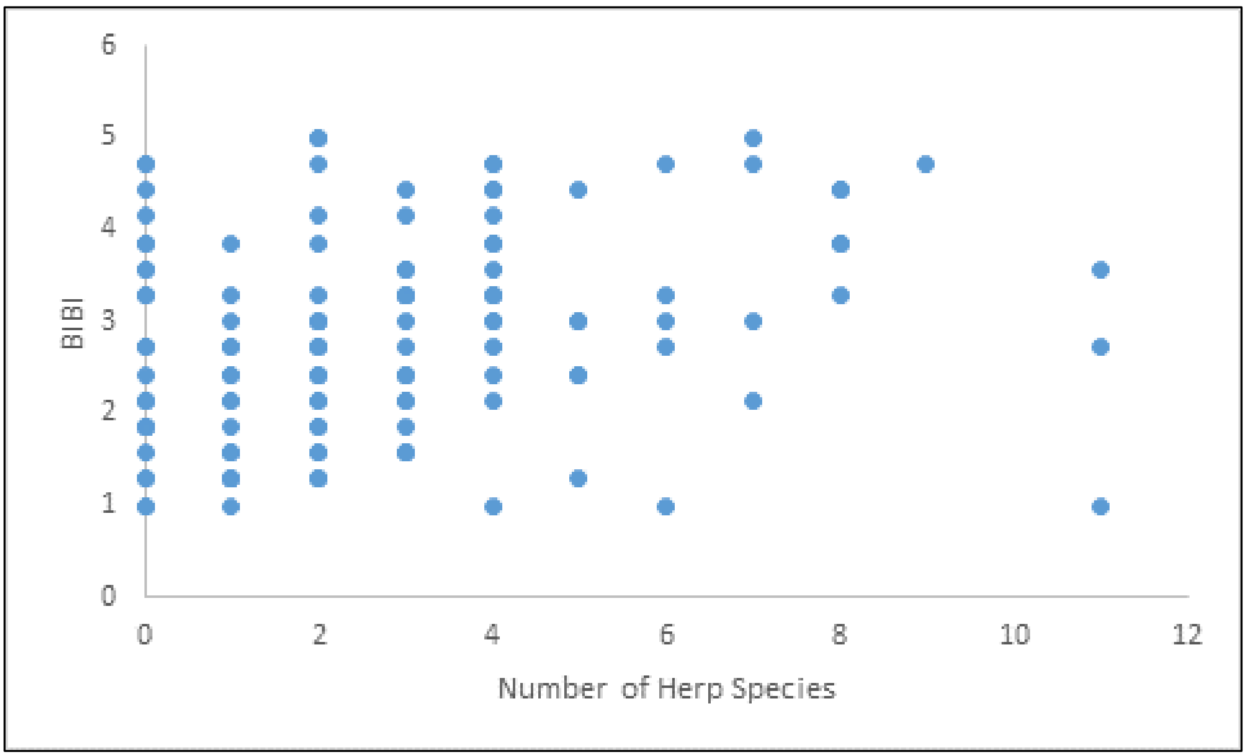

Figure 4-1. Relationship between B-IBI and number of amphibian and reptile species sampled at MBSS sites in Anne Arundel County from 1995-2013

Table 4-2. Amphibian and reptile species in Anne Arundel County found by the MBSS from 1995-2013

Amphibian and Reptile Species	Number of Occurrences
American Bullfrog	58
Broad-Headed Skink	1
Common Five-Lined Skink	10
Cope's Gray Treefrog	4
Eastern American Toad	20
Eastern Box Turtle	16
Eastern Cricket Frog	11
Eastern Gartersnake	2
Eastern Mud Salamander	1
Eastern Painted Turtle	1
Eastern Red-Backed Salamander	2
Eastern Smooth Earthsnake	1
Eastern Snapping Turtle	6
Eastern Wormsnake	2
Fowler's Toad	11
Gray Treefrog	6
Marbled Salamander	1
Northern Dusky Salamander	2
Northern Green Frog	104
Northern Red Salamander	2
Northern Red-Bellied Snake	1
Northern Ring-Necked Snake	3
Northern Spring Peeper	17
Northern Two-Lined Salamander	38
Northern Water Snake	5
Pickerel Frog	51
Queen Snake	2
Red-Spotted Newt	3
Ring-Necked Snake	1
Southern Leopard Frog	13
Spotted Salamander	3
Stinkpot	3
Wood Frog	8

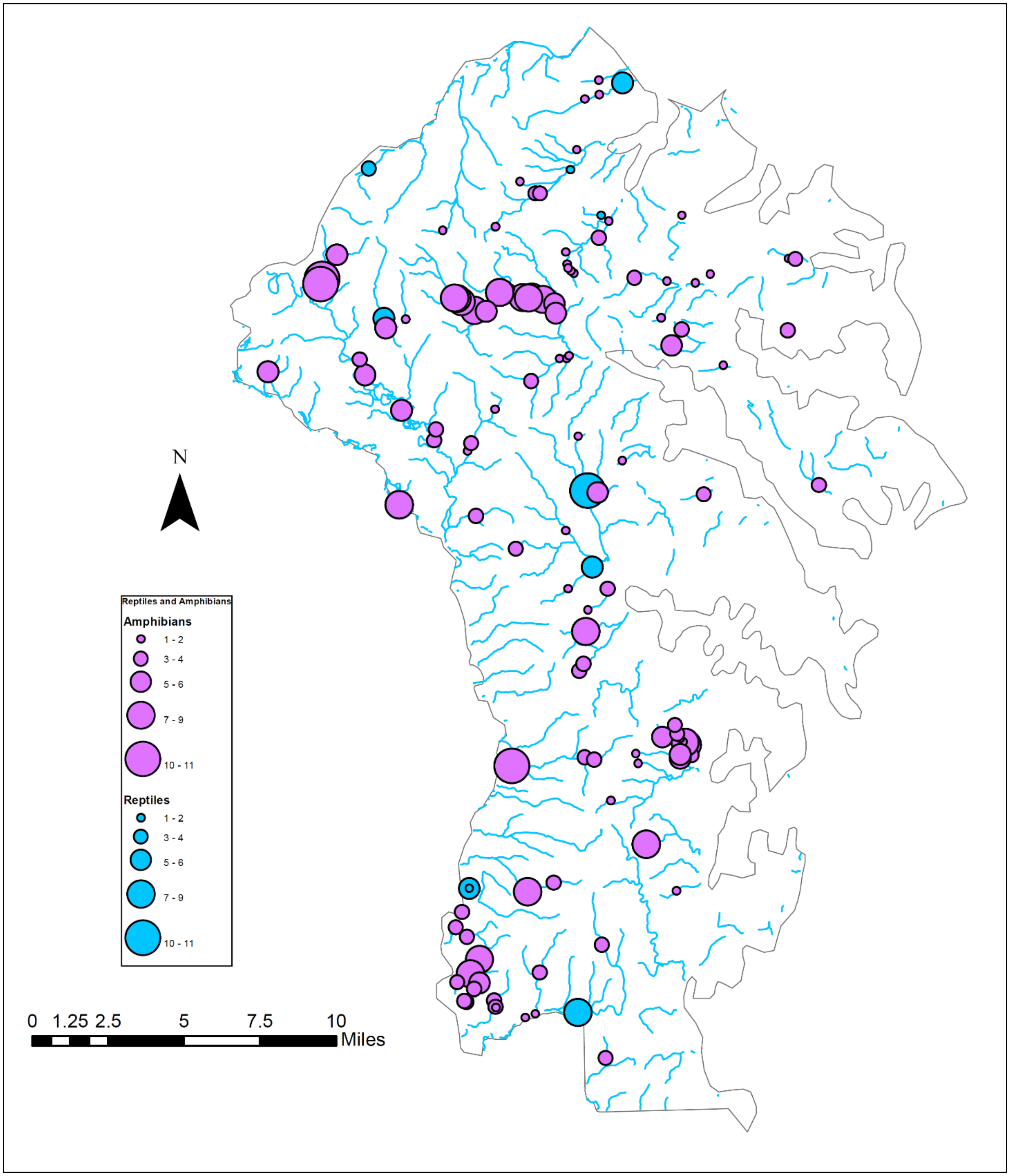

Figure 4-2. Locations of MBSS sites where amphibians and reptiles were found by the MBSS in 1995-2013. Size of circle indicates number of species.

The cost of the adding herpetofauna to the county survey is variable. Under current MBSS protocols for Round 4, herpetofauna searches last up to 60 minutes.

Crayfish and Mussels. The MBSS has also sampled crayfish and mussels for periods of the MBSS. Table 4-3 and Figure 4-2 show the number of each species of crayfish and mussels sampled in the County by the MBSS from 1995-2013 (2007-2013 for crayfish). Only 10 sites recorded mussels, eight of which were the non-native Asian clam. Crayfish were more common, totaling 34 records, only five of which were non-native.

Table 4-3. Crayfish and mussel species in Anne Arundel County found by the MBSS from 1995-2013 (2007-2013 for crayfish).

Crayfish Taxa	Number of Occurrences
Devil Crayfish	15
Eastern Crayfish	14
Virile Crayfish	4
White River Crayfish	1
Mussel Taxa	**Number of Occurrences**
Alewife Floater	1
Asian Clam	8
Eastern Floater	1

Vernal pools. Vernal pools are seasonal habitats for aquatic species including mole salamanders, wood frogs, fairy shrimp, and others. These pools are depressions in the landscape that fill with water during the fall and winter months, but which become dry over the summer. The inability of fish populations to survive in vernal pools makes them important for species that cannot survive in aquatic habitats with fish. While vernal pools are found throughout the landscape, many are found in the floodplains surrounding streams.

The MBSS has been sampling for vernal pools at their stream sites since 2007. All vernal pools observed in the 50-m riparian area are measured and recorded. A total of 23 vernal pools have been found in Anne Arundel County at 17 MBSS sites (some sites had more than one vernal pool). Figure 4-4 shows the number and location of vernal pools in the County by the MBSS from 2007-2013.

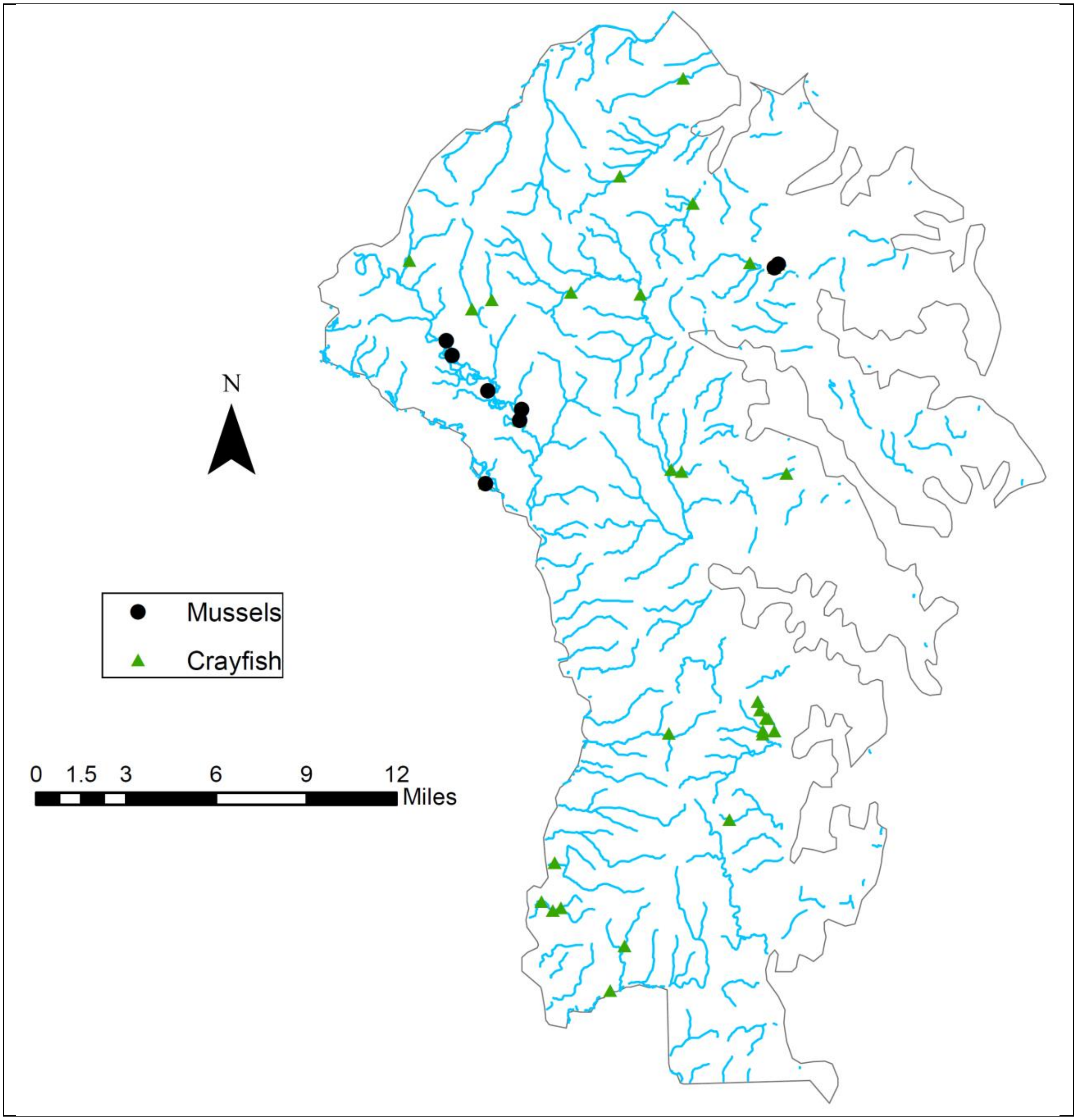

Figure 4-3. Crayfish and mussel species in Anne Arundel County found by the MBSS from 1995-2013 (2007-2013 for crayfish).

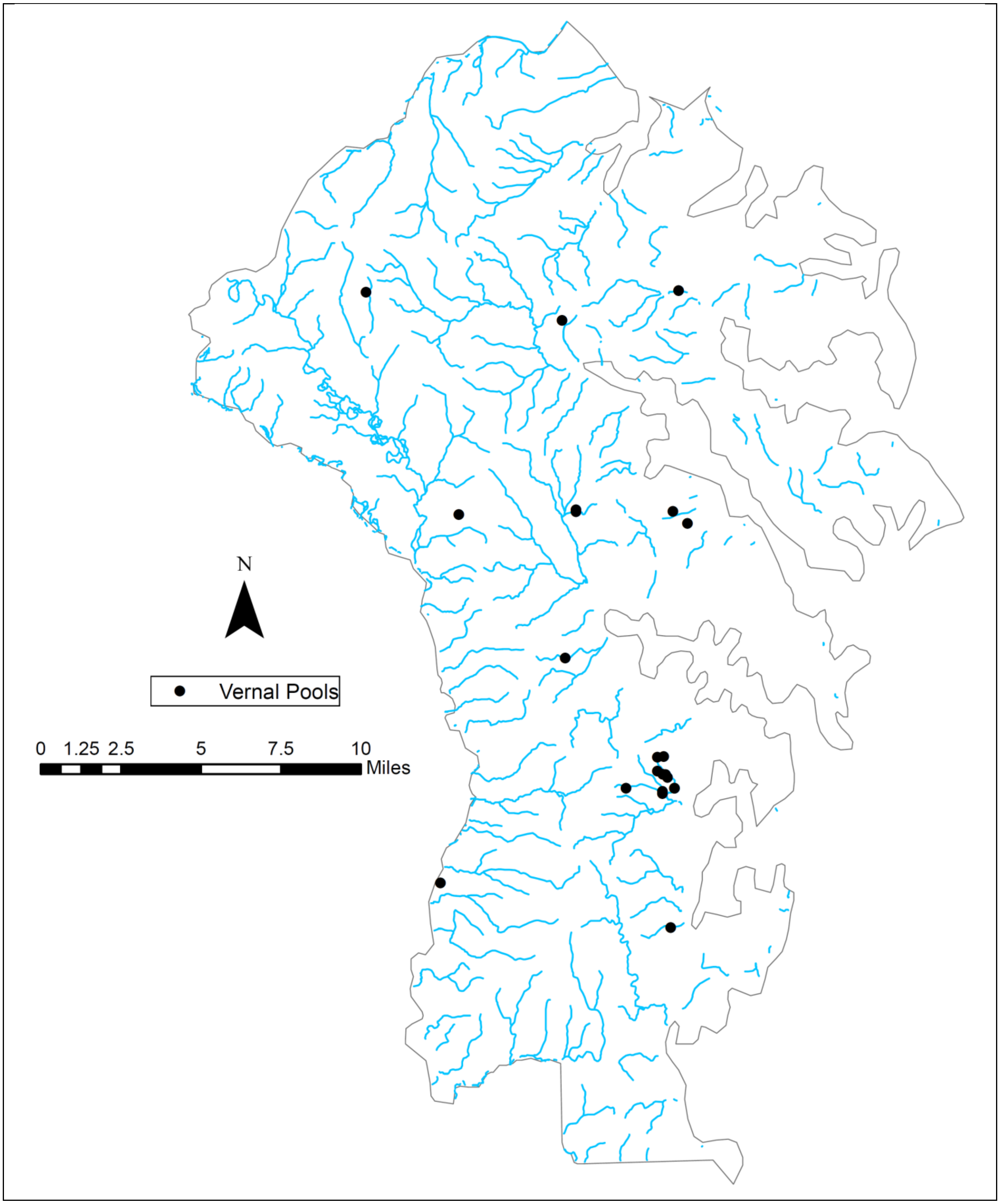

Figure 4-4. Vernal pools in Anne Arundel County found by the MBSS from 2007-2013

Periphyton. DNR has sampled for periphyton using EPA protocols (standard area scrape from in-situ rocks) at 50 sites over two years. Periphyton is also sampled in the EPA National Surveys. Periphyton have also been monitored by others for acid mine drainage, nutrient criteria, and identifying sensitive taxa. Attempts to use periphyton in nutrient criteria have been problematic, owing to variability and confounding factors such as shading (Matt Stover, TRC). While periphyton sampling is promising, especially as an additional indicator for nutrients which are subject to regulation in County TMDLs, the County and TRC decided to wait to adopt periphyton until locally validated indicators are available from another source.

SURVEY REVISION

The County will add the standard suite of the nutrient and metal parameters (addressing most TMDLs) typical of other monitoring programs, by sampling for the MBSS parameters in Table 4-1. This would include chloride, but not pesticides or bacteria.

Given the current uncertainty associated with geomorphology-biology relationships, but recognizing the need to continue trying to characterize such relationships, the County will not change its geomorphology sampling. Rosgen Level II assessments will continue in Round 3. The County will participate in further analysis with MBSS to determine if other parameters should be added. At that time, the County would continue the Rosgen Level II assessments for at least one additional year at sites that were sampled previously to (1) evaluate change over time and (2) investigate relationships between the Rosgen and new MBSS geomorphology parameters.

The County will add fish sampling as the best means of improving assessments of ecological condition of County streams. The County will adopt the MBSS electrofishing protocols at estimated cost of $4,500 per site.

The County will also add sampling for crayfish and mussels using MBSS protocols. The County will not add stream salamander sampling using the MBSS protocols as stream salamander communities in the Coastal Plain are depauperate compared to other parts of the state (MBSS SS-IBI will not apply to Coastal Plain streams). The County will also add herpetofauna searches and vernal pool sampling within the 50-m riparian area using MBSS methods. This sampling will improve the assessment of floodplain ecosystems and add more components of biodiversity to produce a more holistic ecosystem assessment.

5 Improve stressor identification at local scales

Assessment efforts like the Program and MBSS can produce robust characterizations of stressor extent and severity at the large watershed scale, depending on the parameters sampled. Stressor identification at finer scales, however, is needed for management decisions.

The County investigated four issues related to stressor identification: increase in sample parameters related to stressors, intensification of sampling in target areas, extrapolation of MS4 pollutant load monitoring to other areas, and effect of legacy land use.

5.1 Additional sample parameters

The County will add the MBSS suite of water chemistry parameters to Program as described in Section 4.1. These parameters will be used to flag potential stressors (where parameter values exceed a threshold of concern) for more intensive study. Typically, diagnosis of stressors affecting streams requires a specific "detective" method such as the U.S. EPA Causal Analysis Diagnosis Decision Information System (EPA 2015b).

5.2 Intensification of random samples in certain areas of the County

The TRC concluded that targeted sampling for stressors is more effective than intensifying random samples, so intensification of the survey design will not be implemented. One program enhancement that might provide information of the effects of stressors Countywide is the monitoring of fixed (or sentinel) sites along a gradient of imperviousness. This "sentinel" network would not evaluate the effect on annual variation in weather (or climate change) on reference sites, but would rather improve our understanding of how development (and correlated stressors) affect stream condition. This enhancement will not be pursued at this time, but may be investigated as combined activity with other counties or the State.

5.3 Evaluate which countywide biological survey parameters should be included in restoration and stressor monitoring to study possible surrogate parameters for intensive monitoring

The County already conducts restoration monitoring related to TMDL and other concerns and requirements. As stated above, targeted sampling for stressors is more effective than intensifying random samples, so intensification or stratification of the survey design for stressor identification will not be implemented. However, there are potential benefits of measuring the parameters sampled in the random survey as part of the intensive site monitoring for pollutant reduction performance and TMDL compliance. By doing this, it may be possible to identify relationships between random survey parameters and pollutant performance. One example relationship might be between simple geomorphological measurements and sediment reduction. Such relationships could be used to extrapolate pollutant reduction to larger areas where only random survey parameters were sampled.

5.4 Legacy impacts from previous land uses

Legacy land use is an important topic for interpreting monitoring results and determining the limits of restoration potential in Anne Arundel County. Harding et al. (1998) and Maloney and Weller (2011) describe and quantify the effects of legacy land use, including potential differentiation of biogeography (latitude) versus land use (elevation) effects. The TRC concluded that legacy impacts from previous land uses are another issue better addressed through targeted site monitoring. As with the gradient of impervious monitoring, this study could be undertaken in conjunction with other counties or the State and would not be a core component of the Program.

SURVEY REVISION

As described above, Anne Arundel County will add the MBSS water chemistry parameters to (1) flag potential stressors at random sites for further investigation and (2) provide estimates of stressor extent and intensity at the PSU scale.

The County will not implement a network of fixed sites along a gradient of imperviousness to better understand how development affects streams. This may be pursued in the future as a combined activity with other counties or the State, but would not be a core component of the Program.

The County will not intensify the random survey in presumed areas of high stressors, but rather add the parameters measured in the random survey (e.g., MBSS parameters) to all intensive stressor and restoration monitoring (if not already included), so that lessons learned in restoration monitoring can be applied to interpretation of the Program data.

6 Redevelop IBIs or reference conditions to address County stream types

While the Coastal Plain B-IBI is generally an effective indicator of stream condition throughout the Coastal Plain landscapes of the State, local environmental settings in Anne Arundel County can influence natural reference conditions. This is especially important at finer scale assessments. Streams near the Fall Line, such as the northwest part of the County, may have natural Piedmont characteristics. Small streams, which will become more numerous as the Program potentially incorporates the County stream network into the sampling effort, have different natural conditions than larger streams. Low-relief streams, in general, take on more anastomosed (braided) forms that have ecological implications and may justify different reference conditions.

Two kinds of analysis were performed to determine how stream conditions vary naturally based on (1) region (eastern vs. western shore), (2) size (drainage area), or (3) slope (gradient):

- comparisons of B-IBI scores at MBSS reference sites
- comparisons of B-IBI scores at Anne Arundel County sites with upstream catchments that are at least 60% forested.

The forested Anne Arundel County sites are surrogate reference sites since the parameters needed to apply MBSS reference criteria were not sampled.

Figure 6-1 shows that the distribution of stream sizes in Anne Arundel County has no distinct break point between large and small sizes with 90% of sites draining less than 5,000 acres and 50% draining less than 575 acres. Figure 6-2 also shows that the distribution of stream gradients in Anne Arundel County has no distinct break point between low and high gradient, with 90% of sites having gradients of less than 1% (with gradient calculated as rise over run distance, as a percentage)) and 50% of sites having gradients of less than 0.6%.

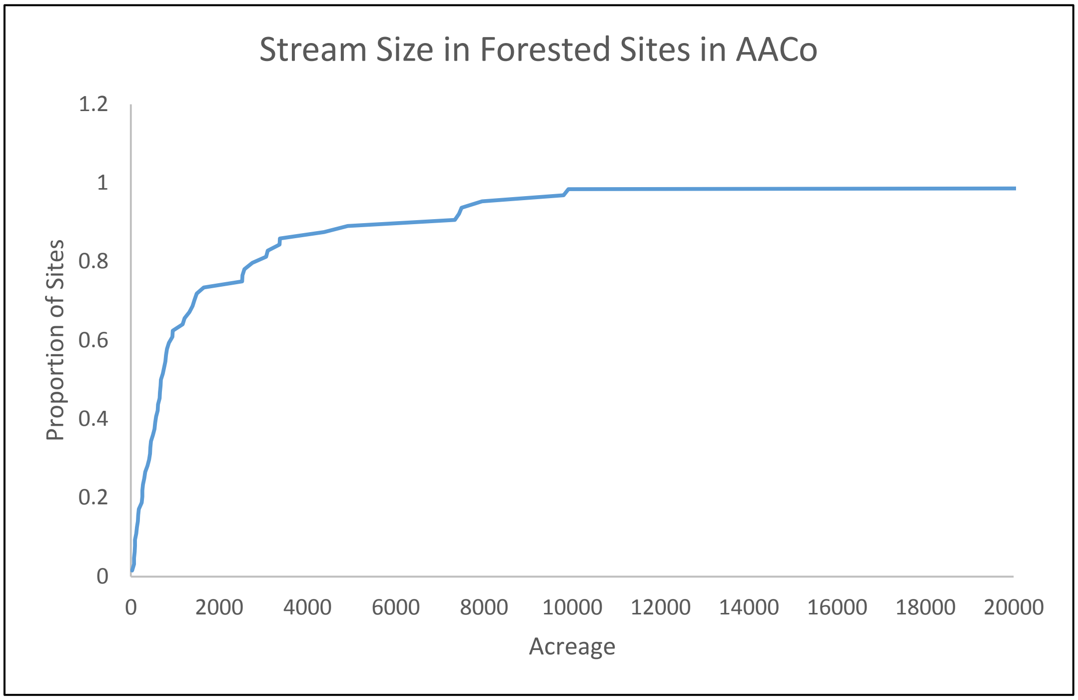

Figure 6-1. Distribution of stream sizes in Anne Arundel County showing that 90% of sites drain less than 5,000 acres and 50% drain less than 575 acres

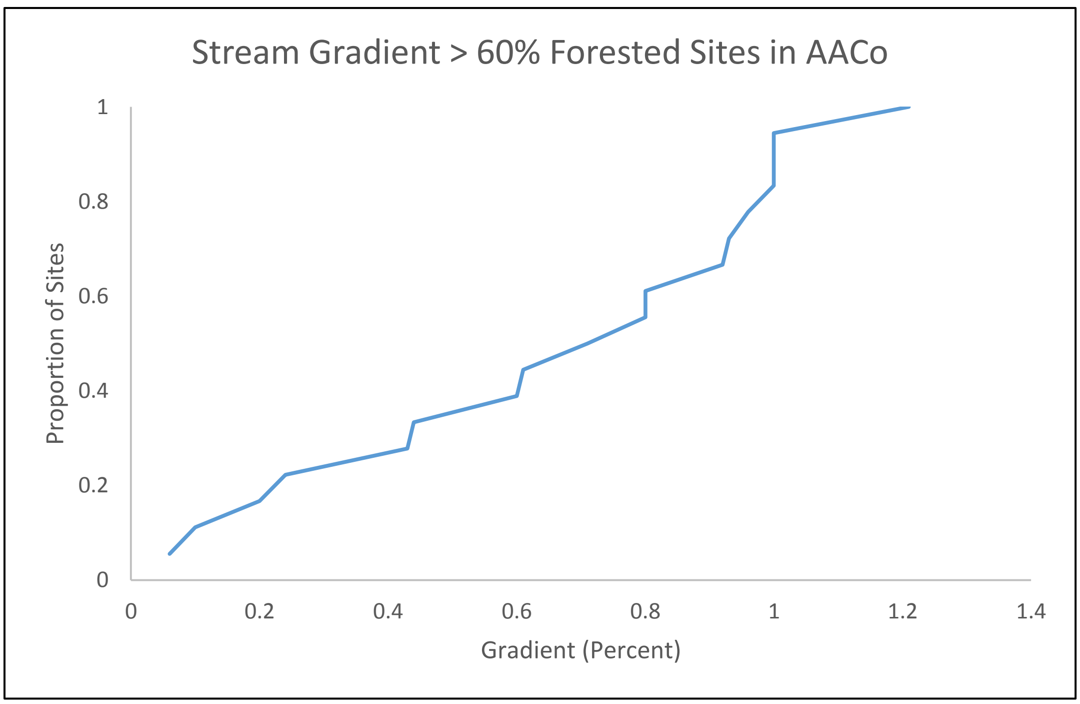

Figure 6-2. Distribution of stream gradients in Anne Arundel County showing that 90% of sites have gradients of less than 1% and 50% of sites have gradients of less than 0.6%

6.1 Are MBSS B-IBI results different between the western and eastern Coastal Plain (CP) which have a single MBSS B-IBI?

All MBSS reference sites in the Coastal Plain were assigned either to the western or eastern shore and the distribution of the B-IBI was investigated using box plots. The difference in the B-IBI scores for all sites was not significant (Figure 6-3), indicating that a separate western Coastal Plain B-IBI does not need to be developed.

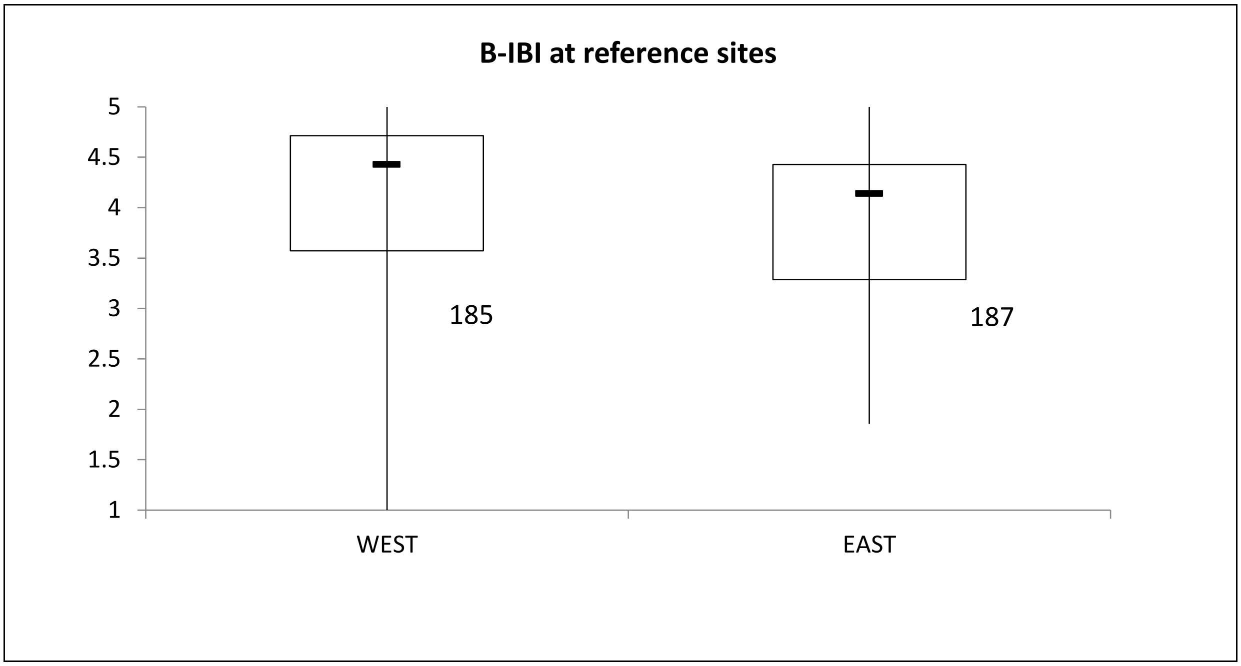

Figure 6-3. Comparison of B-IBI scores at MBSS reference sites in western and eastern Coastal Plain

Next we compared B-IBI scores at MBSS reference sites in the entire western Coastal Plain to those found in Anne Arundel County alone (Figure 6-4). In this case, there was a difference, though it was not statistically significant, as there were only seven MBSS reference sites in Anne Arundel County, including one with a B-IBI score of 1.00. Therefore we also compared western Coastal Plain and Anne Arundel B-IBI scores using surrogate reference sites based on 60% forested catchments (Figure 6-5). This comparison indicates that Anne Arundel surrogate reference sites have significantly lower B-IBIs than surrogate reference sites in the entire western Coastal Plain (not unexpected as these surrogate sites are not true reference sites).

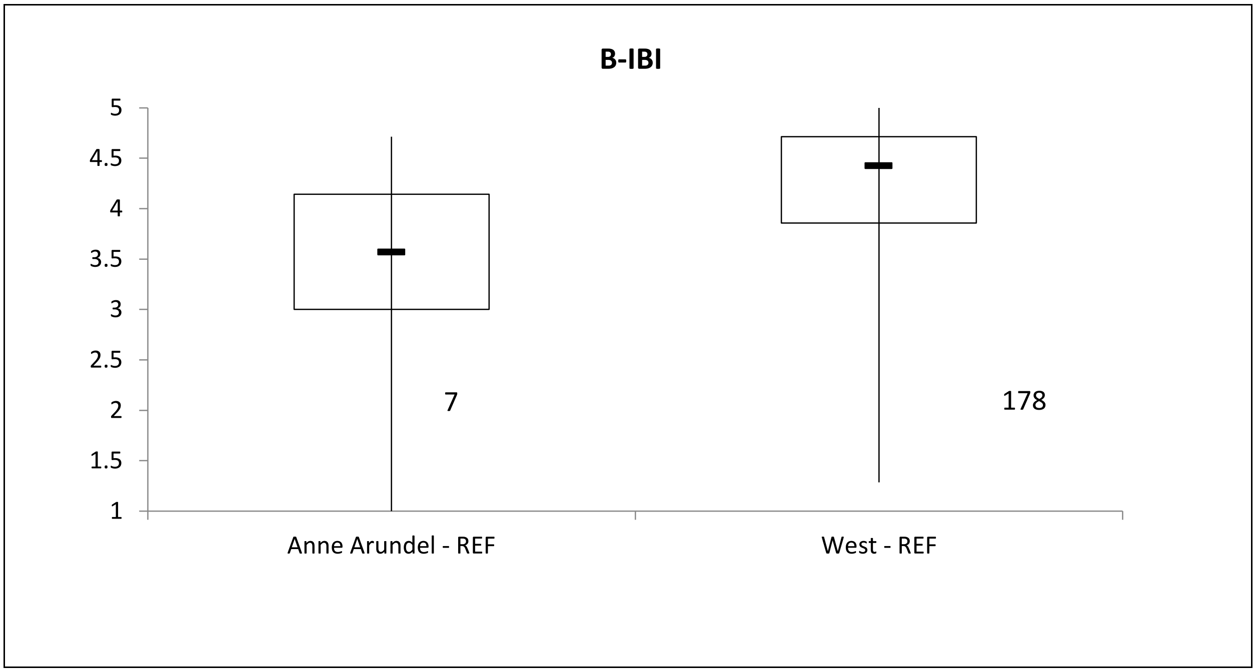

Figure 6-4. Comparison of B-IBI scores at MBSS reference sites in Anne Arundel County and the entire western Coastal Plain, which suggests a difference but is not statistically significant (may be driven by single outlier with B-IBI of 1.0)

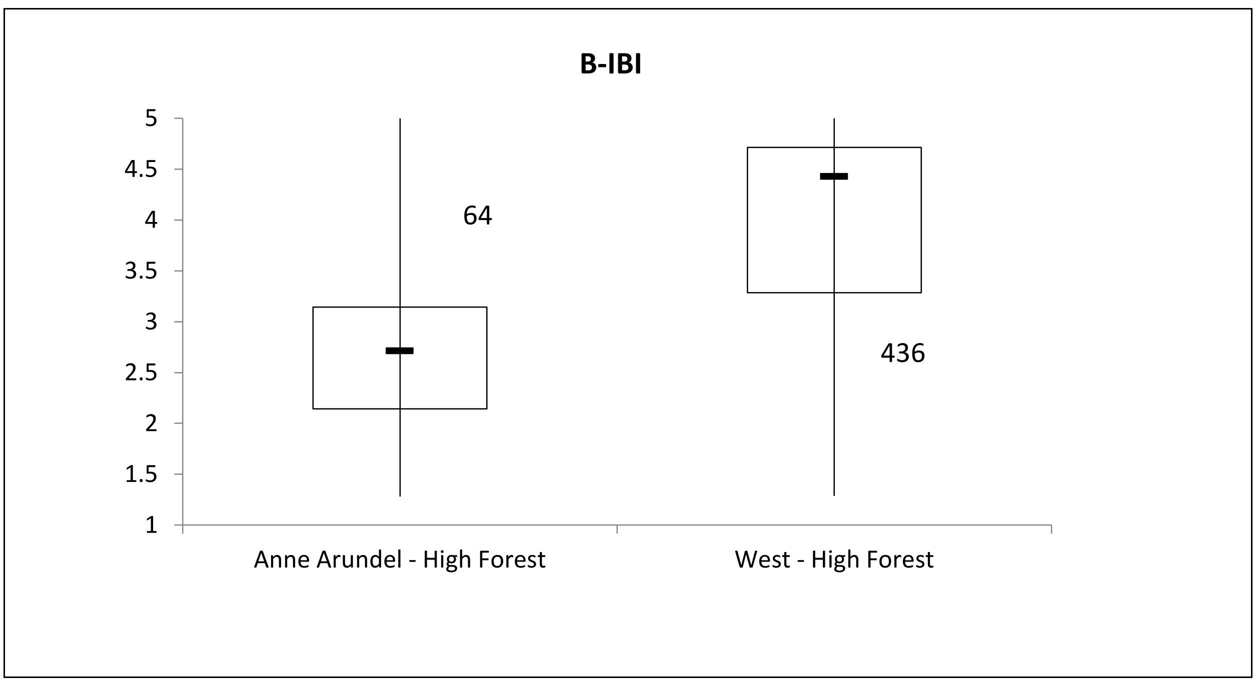

Figure 6-5. Comparison of B-IBI scores at surrogate (60% forested catchment sites) reference sites in Anne Arundel County and the entire western Coastal Plain, which is significantly different ($p < 0.001$). This may indicate that water quality or other non-land use stressors are degrading forested Anne Arundel streams.

6.2 Evaluate differences in MBSS B-IBI data by stream type (e.g., braided/wetland or slope, stream order or size, geology) for western Coastal Plain

To determine whether County streams of different sizes or gradients vary naturally in biological condition, we calculated the mean B-IBIs for each size and gradient class using surrogate reference sites based on sites draining catchments with at least 60% forest land use. These reference sites represent the top 20% of sites sampled by the County in terms of natural (forested) land use. It was necessary to use this surrogate approach because the sampling data from the Program do not include all the attributes needed to define reference using MBSS reference criteria and there are only seven MBSS-sampled references in the County.

Figure 6-6 shows that B-IBI scores for smaller Anne Arundel County streams (draining less than 575 ac) are significantly lower than scores for larger streams (draining more than 575 ac).

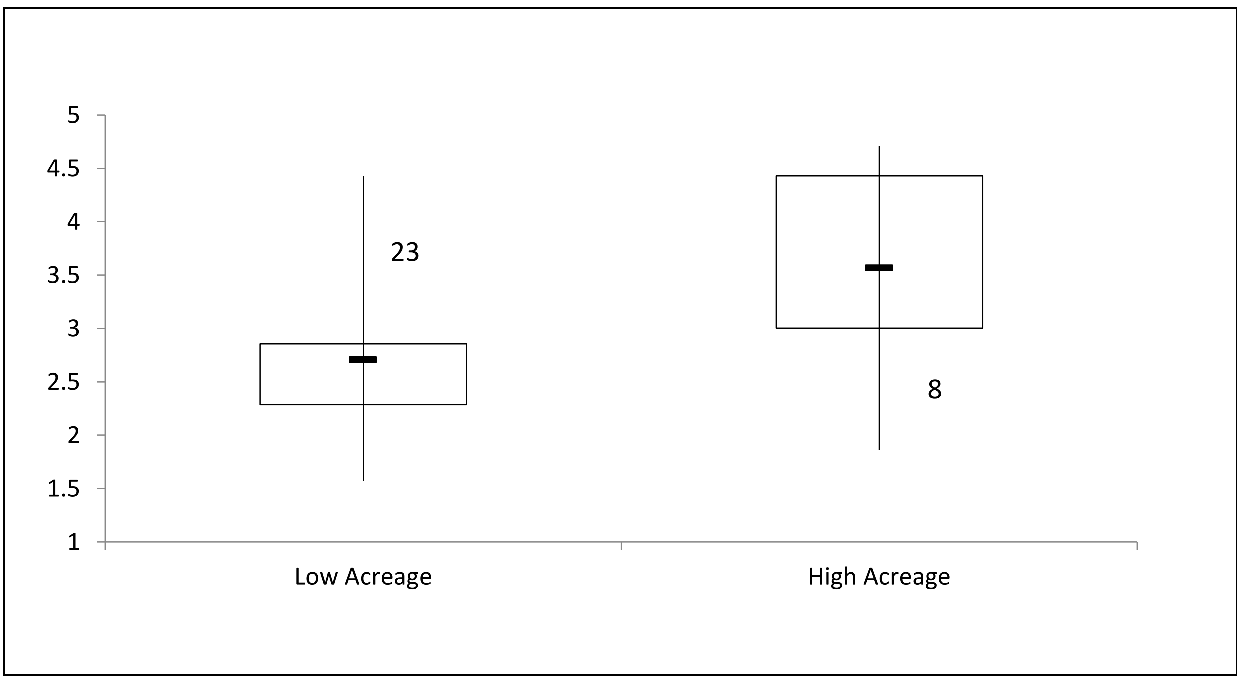

Figure 6-6. Comparison of B-IBI scores of small (draining < 575 ac) and large Anne Arundel County streams using surrogate (60% forested catchment sites) reference sites, which is significantly different ($p < 0.02$)

Figure 6-7 shows that B-IBI scores are not significantly different between low (< 0.6) gradient and high gradient County streams.

These results indicate that natural stream conditions likely differ among small and large County streams, but not among low and high gradient streams. It is possible that the low gradient cutoff for analysis did not capture wetland-type streams, which should be analyzed separately.

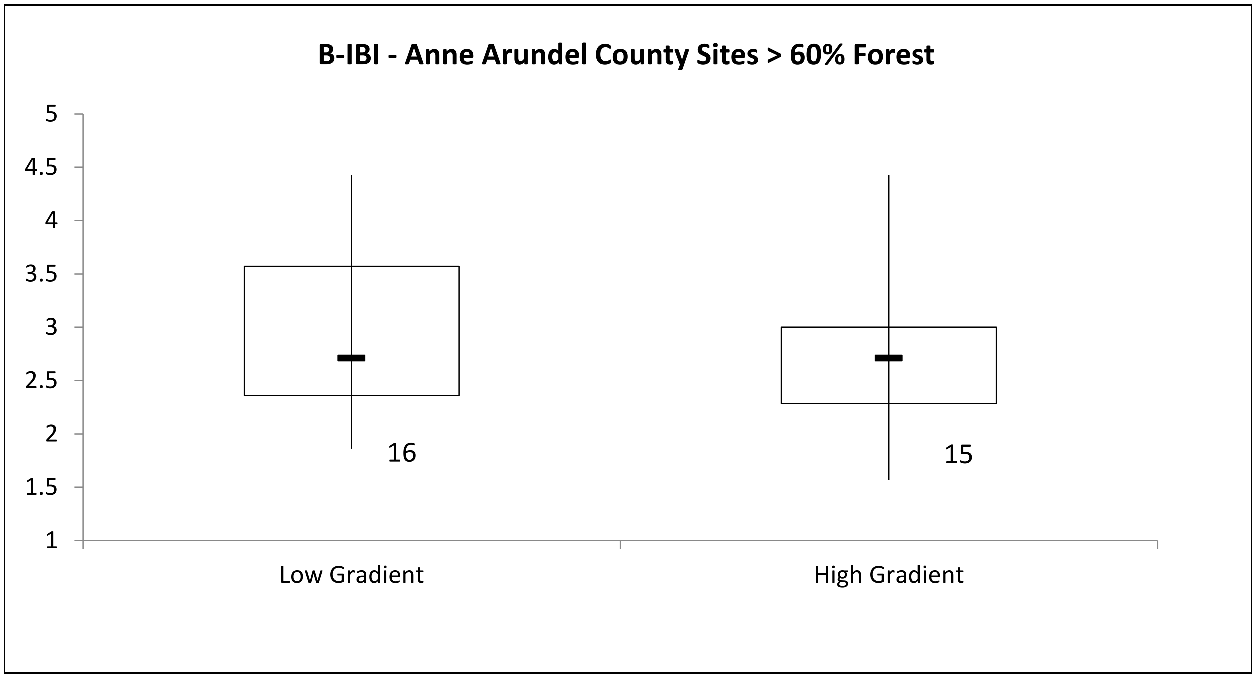

Figure 6-7. Comparison of B-IBI scores between low (< 0.6) gradient and high gradient Anne Arundel County streams, using surrogate (60% forested catchment sites) reference sites, which is not significantly different (16 low gradient, 15 high gradient sites)

Natural variation may extend to the interaction of size and gradient (e.g., four potential types of streams) with the relevant types in County being low gradient-large streams and low gradient-small wetlands (Matt Baker, TRC). Different land uses may confound the ability to distinguish these stream types, especially given the greater development found in coastal watersheds.

6.3 Evaluate stream size differences in B-IBI and component metrics that might indicate the need for new B-IBI for smaller streams added with the more detailed County stream network (e.g., identify variation in metric scores at reference sites with different drainage areas)

As described in Section 2.3, it is not possible to evaluate the difference in B-IBI scores between streams on the 1:100,000-scale map versus the more detailed County map, because the smaller streams on the County map have not been formally sampled in the Program. Nonetheless, the comparison of B-IBI scores in the larger and smaller sampled streams (< 575 ac on the 1:100,000-scale map) shown above indicates that inclusion of even smaller streams from the more detailed stream network would certainly require development of a new “small stream” B-IBI.

Both small streams and direct drainage streams typically have depauperate fish assemblages, because of their isolation and propensity to go dry (Scott Stranko, TRC). Therefore, the County will not sample for fish in the smaller streams, so only a new B-IBI will be developed.

6.4 Describe implications of implementing a new B-IBI for (1) affecting only the smaller streams added with the more detailed stream network and (2) affecting all sites which would complicate backward comparisons (though new B-IBIs could be calculated on old data)

Developing and implementing a small stream B-IBI for streams only present on the more detailed County stream network would not affect calculating areawide stream condition as this new B-IBI would be comparable to the existing B-IBI (albeit with different reference conditions). Countywide and watershed-wide stream conditions can be reported for small streams, large streams, and combined.

Backward comparison of stream condition, however, can only be done between the large streams on the 1:100,000-scale stream network. Including the smaller streams would result in comparing different populations of streams and might lead to erroneous results (e.g., showing a change in improvement in stream conditions overall when in reality the result was caused by adding in small streams in better condition, or conversely showing a decline in overall conditions if adding streams in worse condition). Going forward, the combined condition of small and large streams can be reported, but should include a caveat about comparing this result with previous rounds that only include larger streams.

RECOMMENDATION: Analyses indicate that streams in Anne Arundel County may differ naturally from streams in the entire western Coastal Plain (though the western and eastern Coastal Plain streams do not differ significantly based on MBSS data). Stream biological conditions in the County may naturally vary with size (catchment area) but not with slope (gradient), though wetland streams were not assessed directly.

These results indicate that development of new B-IBIs to address both regional and stream size differences would provide more accurate assessments of County stream condition. Therefore, a new B-IBI will be developed for the smaller streams that would be added by sampling on the more detailed County stream network. Because fish assemblages are generally depauperate in the smallest streams, sampling for fish in streams only on the more detailed stream network will not be conducted. Therefore, a new small stream Fish IBI will not be needed.

Development of the new B-IBI for smaller streams will require sampling of small streams outside of the random survey in Round 3. Because reference streams in Anne Arundel County are so uncommon, and therefore unlikely to be sampled randomly, the minimum 10 and ideally 40 reference sites needed for B-IBI development will be identified using GIS analysis. Once candidate reference sites are identified, they will be added to the sample sites for Round 3 to obtain information on stressors needed to confirm that they meet reference site criteria. Should distinct reference conditions be identified within the small stream references sites (e.g., between wetland streams in low gradients and gully streams in high gradients), more than one B-IBI should be developed.

7 Expand monitoring to include tidal waters

The County has a wealth of tidal waters that are not currently monitored as part of the Program. In the past, Maryland DNR has been interested in developing methods for integrating the tidal and non-tidal monitoring of the state, specifically for "filling the gap" between those programs in freshwater tidal and nearshore shallows. Baltimore County has recently incorporated tidal sampling into their biological monitoring program, allocating one-third of the sampling effort to tidal waters using the protocols of Chesapeake Bay Long-Term Benthic monitoring program. A similar sampling effort could be designed for Anne Arundel County in the future.

RECOMMENDATION: Add a tidal component to the Anne Arundel County biological program monitoring program in the future when budget is available.

8 References

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