U.S. Fish & Wildlife Service

Western Coastal Plain Reference Reach Survey

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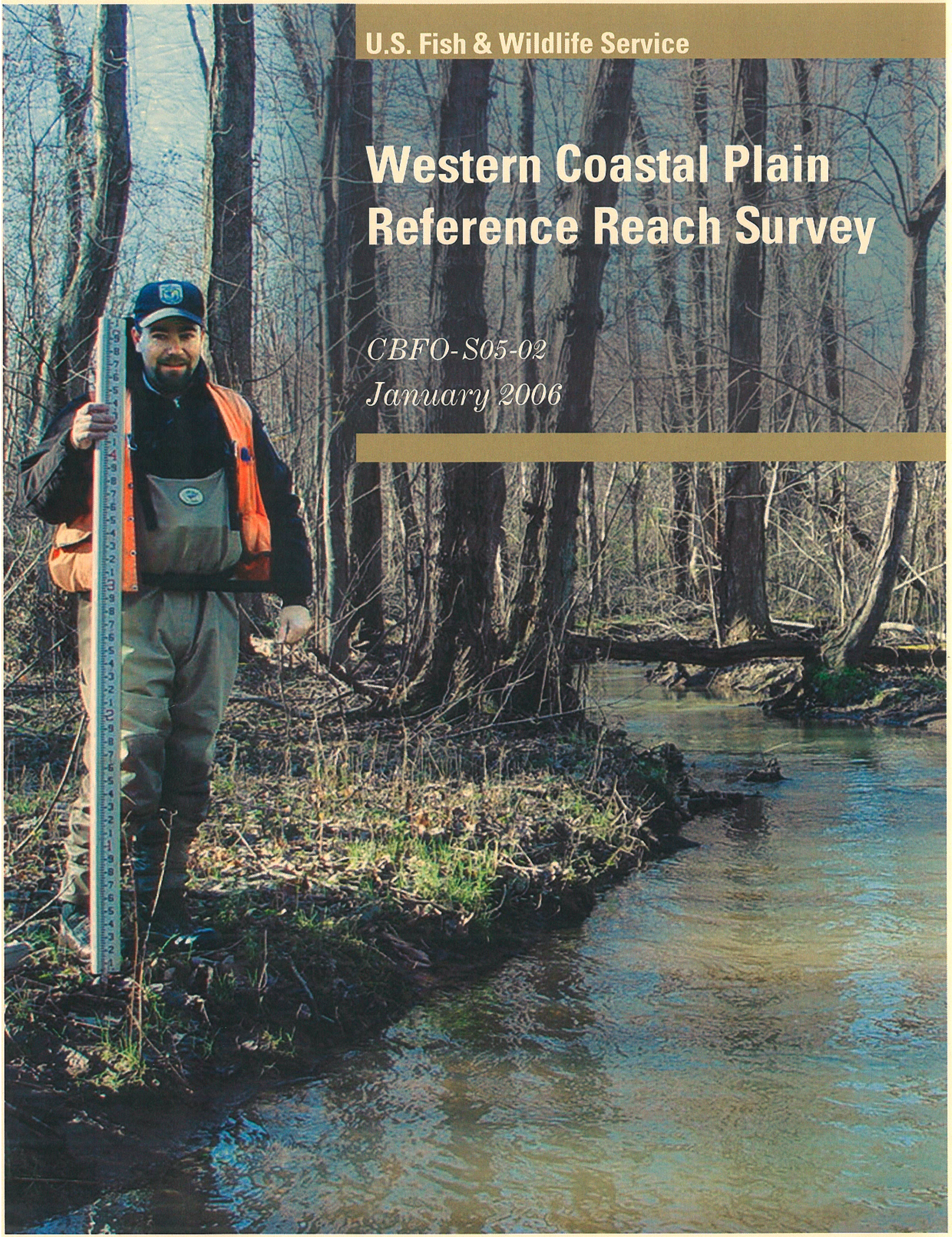

WESTERN COASTAL PLAIN REFERENCE REACH SURVEY

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Stream Habitat Assessment and Restoration Program
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office

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I. INTRODUCTION

The Anne Arundel County Office of Environmental and Cultural Resources (County) and the U.S. Fish and Wildlife Service (Service) - Chesapeake Bay Field Office entered into a cooperative agreement (Agreement # 1902-5041) to collaborate on projects that advance the understanding of streams and stream processes in the Western Coastal Plain. This information will assist the County in stream management and restoration, and foster a better management of County stream resources. The assessment work described in this report is the first collaborative effort between the Service and the County.

Many stream restoration practitioners in the Mid-Atlantic are using a natural channel design approach. There are a variety of ways in which one can execute these kinds of projects (Skidmore et al., 2001). Typically, successful implementation of this approach requires information about the parameters associated with creating the stability of a desired stream state. This desired state can be determined by performing detailed survey work on a seemingly stable stream reach co-located in the same watershed as the project reach. The information is then used as a template to develop a new pattern, profile and dimension for the restored reach.

This approach can be somewhat problematic if no stable stream reaches exist in a watershed of interest. In addition, for projects of limited physical scope, like bridge replacement or repair or storm drain outfall rehabilitation, an evaluation of the upstream channel conditions is typically beyond the project budget. Another way to obtain this information is to collect detailed data on a set of streams that have physical stability and that are located in similar hydrologic and geologic conditions. After detailed measurements on the reach of interest are collected, a variety of dimensionless relationships can be developed with the information.

The information collected during this project may help describe the potential characteristics of a stable stream type commonly found in Anne Arundel County and within the greater Western Coastal Plain: the Rosgen E channel. Recent work by the County in the Severn River watershed found that approximately 35 percent of all reaches evaluated were classified as E streams (AAC 2005).

This report presents the data collected for five reference reach surveys in the Maryland Western Coastal Plain. The data includes reference reach data and a coarse woody debris assessment.

II. METHODOLOGY

The methodology section includes brief descriptions of methods the Service and County used to complete the survey. Those descriptions include office site selection, field reconnaissance site visits, field data collection, data entry, and data processing.

A. Site Selection

1. Selection Criteria and Procedures

Site selection was conducted using both office and field evaluations. The Service and the County conducted a comprehensive in-office investigation of potential sites within and outside the County using the following general criteria:

- Perennial flow
- Dominated by storm flow runoff
- Nontidal
- Non-urban (Forest cover > 50%)
- Single thread channel with natural features (pools, riffles, runs, etc.)
- Watershed soils, geology, and topography representative of Anne Arundel County
- Upstream drainage area between 1 and 20 square miles
- Rosgen C and E stream types

County staff conducted a variety of GIS-based evaluations of potential study sites. The County's stream reach layer was overlaid upon 2000 aerial photography, after which a reconnaissance survey of potential sites was performed. Potential reaches were selected by the absence of developed land and the dominance in the upstream drainage area. Because of the distribution of development in the County, most of the potential sites were located in the southern and western areas of the County, where the majority of undeveloped and agricultural land is located. Sites with drainage areas less than 0.1 sq. mi. were excluded from further consideration. Reaches in sites larger than 0.1 sq. mi. were then subjected to Rosgen Level I classification using digital topographic data. Reaches characterized as stable during Level I classification were considered for additional consideration, as described in the next section. This approach generated four sites, outside of Anne Arundel County, considered suitable for field reconnaissance.

Additional County office assessment work involved using data derived from a recent watershed study conducted in the Severn River. This study was performed as part of the County's development of a GIS-based watershed assessment and management procedure called the Watershed Management Tool (WMT). As part of this study, a stream walk that included a habitat and infrastructure evaluation along with extensive Rosgen Level I and II classifications were performed. All this information, along with a variety of other data, was compiled in a spatial database created for the Severn River. County staff used this information to search for potential sites in the Severn River using the following criteria:

- Rosgen C or E channel
- Habitat condition score of good
- Biological condition score of good
- ≥50% forest cover or ≤10% impervious cover in drainage area
- Minimal infrastructure impacts

Using these criteria, 31 sites were generated for evaluation and field reconnaissance. The Service and County visited six of these sites.

The Service consulted with the Maryland Department of Natural Resources (DNR) to use data collected during the Maryland Biological Stream Survey (MBSS) to identify potential reference sites. Specifically, reaches called Sentinel Sites are selected using a tiered system of land use and water quality conditions coupled with high quality biological communities (Prochaska 2005). These sites are repeatedly surveyed to assess biological and habitat conditions. For this survey, an assumption was made that high quality biological conditions would be associated with geomorphic stability. Using this information, 42 potential sites were identified.

Additionally, the Service and the County each considered potential sites identified by other agencies either in previous assessments or current work.

2. Reconnaissance Site Visit

The Service conducted a reconnaissance visit of over 50 potential sites to determine site suitability for inclusion. The parameters included site conditions (alteration, dams, headcuts, etc.), bank conditions, stream features (pools, riffles, runs), width/depth ratio, incision, entrenchment, and Rosgen stream type. The Service used this information to determine vertical and lateral stability. Unstable sites were excluded from the survey.

For those sites not eliminated, the Service walked the reaches to locate a consistent geomorphic feature throughout the reach to identify bankfull. The Service compared the bankfull cross-sectional area, width, and mean depth of a measured cross section to the predicted values of the Coastal Plain regional curve (McCandless 2003). The comparison allowed the Service to validate the field determined bankfull.

B. Field Data Collection

The Service conducted a Rosgen Level II and partial Level III assessments to survey the selected reference reaches. The Rosgen Level II assessment describes, in detail, the existing morphological characteristics of a stream. The Service also used this information to classify the sites using the Rosgen Classification System (Rosgen 1994).

The Rosgen Stream Classification system uses specific bankfull channel characteristics such as width, depth, cross-sectional area, entrenchment, sinuosity, water surface slope, and substrate composition to categorize streams into set groups which share similar fluvial geomorphic relationships.

The Service used the Rosgen Level III assessment to predict and monitor potential lateral adjustment (*e.g.,* bank erosion). The Service and the County will use this data to predict bank erosion as part of other stream projects. Furthermore, the data may be combined with other bank erosion monitoring projects conducted by the Service.

The Service walked the reach and flagged the stream facet features (*i.e.,* pools, runs, and riffles) while conducting bank erosion hazard index (BEHI), near bank shear stress (NBSS), and a Pfankuch channel stability procedure as part of the Level III assessment. The Service conducted the BEHIs and NBSS at all sites prior to the full survey to determine the range of bank stability conditions present amongst all of the sites. At least one monumented cross section was measured for each BEHI and NBSS condition existing amongst the sites. This enabled the Service to determine the minimum number of monumented cross sections for each site, thereby reducing the level of effort associated with the project. The monumented cross sections were used to validate bank stability predictions. The Service also developed a site map sketch for each reach showing locations of BEHIs, NBSS, rebar benchmarks, cross sections, and adjacent landuses.

The Service conducted a total station survey generally following established protocols (McCandless and Everett 2002) to characterize the stream dimension, pattern, and profile.

Specifically, the Service used the following steps at each survey site:

1. The Service placed rebar monuments at each endpoint of the classification cross section and the erosion cross sections. Cross-section surveys note the elevations for the following features: top and ground surface at monuments, slope breaks, bankfull indicator, water surface at the edge of water, thalweg, and several points across the floodplain including the flood-prone elevation points.
2. The Service installed rebar toe pins on one or both banks and measured bank profiles at all monumented cross sections.
3. At each monumented cross section, the Service took digital photographs upstream, downstream, and at both banks. The Service took additional digital photographs to document the condition of the reference reach.
4. For the longitudinal profile, the survey stationing included the flagged stream features, depths at the mid-point of features, bankfull indicators, points of maximum pool depths, and surveyed cross section locations. At each station, the Service measured the elevations corresponding to top of the lowest bank, bankfull indicator (if present), water surface, and thalweg. The Service placed rebar monuments at the endpoints of the longitudinal survey.
5. The Service characterized the substrate composition of the riffle or run using a modified Wolman pebble count. This pebble count was located in the same location as the Rosgen classification cross section or the cross section that best characterized the hydraulic features of the reach.
6. If the survey reach had depositional bars, the Service sampled the bar using protocols established by Rosgen (Rosgen 2003).
7. For classification purposes, the Service conducted a modified Wolman pebble count in the reach to characterize the substrate composition.
8. Because coarse woody debris (CWD) represents a critical habitat component of Coastal Plain streams, the Service measured CWD using a method adapted from other workers (Robinson and Beschta 1990).

C. Data Entry and Processing

The Service entered the data in Terramodel, RIVERMorph, and excel spreadsheets. The

Service used Terramodel, a survey program, to reduce the total station survey data. Cross sections, longitudinal profile, and plan form geometry were derived from the Terramodel data. The Service then entered the data into RIVERMorph, software that allows the user to enter data for one or many sites into one project file for processing and analysis. BEHI, Pfankuch, and summary data were entered into Excel spreadsheets. GISHYDRO was used to determine the drainage area and land use values for each site. Appendixes A to E provide the data collected for each site.

III. RESULTS

A. Site Selection

The Service conducted reconnaissance visits at more than 50 potential sites at various locations within the Western Coastal Plain physiographic province. The Service and the County expanded the survey area outside of Anne Arundel County after conducting initial reconnaissance visits to the selected potential sites in Anne Arundel County after not finding enough suitable sites for inclusion. The Service eliminated many potential sites due to the effects of agriculture, forestry, and development. The majority of potential reference reach sites were excluded due to alterations and stream channel instabilities. The Service excluded 20 potential sites because of widespread vertical or lateral instability. Three sites were excluded due to extensive beaver activity, two because of Rosgen stream type, and two sites because access was denied. At the end of the reconnaissance visits, the Service and the County identified five sites for inclusion in the survey (Figure 1).

B. Watershed Descriptions

The five sites selected for the survey are located in the Western Coastal Plain of Maryland. Drainage basin sizes range from 0.52 to 8.73 square miles (sq. mi.) (Table 1). Percent impervious ranged from 0.5 – 7.9 percent. The watersheds of the five sites were predominately forested with values ranging from 54 – 93 percent, with remaining land uses being agriculture and small amounts of urban.

Table 1. Site location summary for survey reaches.

Site	County	Drainage Area (sq. mi.)	River Basin	Rosgen Stream Type	Stream Order
Unnamed tributary to Severn River	Anne Arundel	0.73	Severn	E5	1
Unnamed tributary to Zekiah Swamp	Charles	0.52	Potomac	E4	1
Hilton Run	St. Mary’s	2.40	Potomac	E4	2
Plum Point Creek	Calvert	3.96	Chesapeake Bay	E6	2
St. Mary’s River	St. Mary’s	8.73	Potomac	E5	3

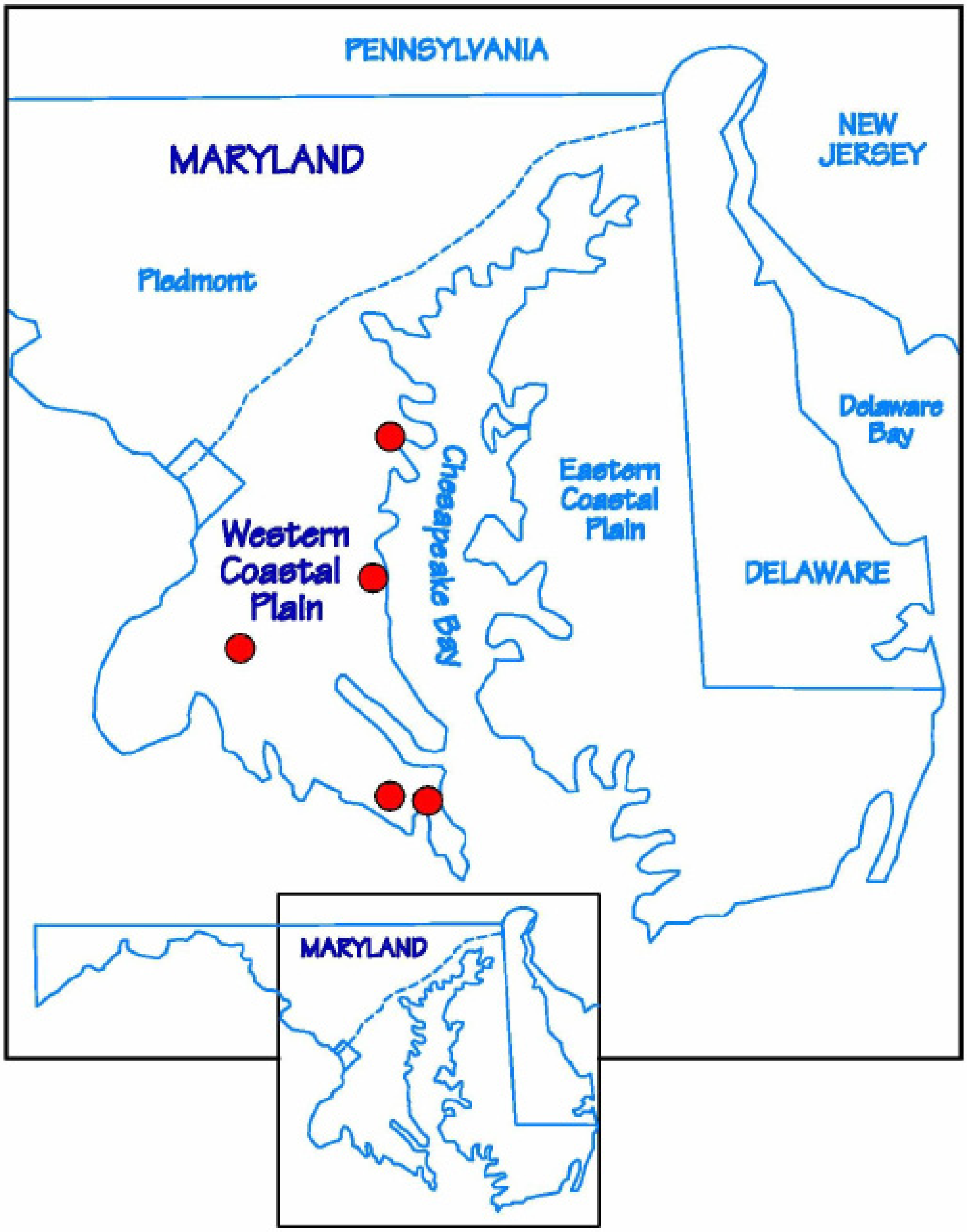

Figure 1. Survey site locations in the Western Coastal Plain, Maryland.

Underlying the watershed of unnamed tributary to Zekiah Swamp Run are soils in the Beltsville, Gravelly Land, and Bourne series. Beltsville soils are moderately drained, nearly level to moderately sloping that are located on uplands. Gravelly Land series are steep gravelly deposits that may have once been Aura or Croom soils, but have been severely eroded and cannot be identified. The Bourne series are moderately well drained soils that are gently to moderately sloping and found mainly on broad ridgetops. In addition to those series, the Bibb series consisting of poorly drained, nearly level soils are found on the floodplains (U.S. Department of Agriculture-Soil Conservation Service (USDA-SCS) 1974).

The St. Mary's River and Hilton Run watersheds consist of mainly Beltsville, Croom, and Bibb soils. Beltsville soils are moderately drained, nearly level to moderately sloping that are located on uplands. The Croom series are upland soils that are well drained and found on level to strongly sloping land. The floodplains consist of Bibb soils, which are poorly drained and level to nearly level (USDA-SCS 1978).

The Plum Point Creek watershed has soils in the Sassafras, Westphalia, and mixed alluvial series. Both the Sassafras and Westphalia series are deep well drained upland soils. The mixed alluvial soils consist of material deposited on the floodplains from the uplands. They are wet poorly drained soils with materials that range from sand and gravel to silt and clay (USDA-SCS 1971).

Unnamed Tributary to Severn Run watershed consists of Evesboro, Rumford, and Sassafras soils. The Evesboro Series are very deep, well drained to excessively drained soils. Rumford soils are deep somewhat excessively drained soils. Both series are sandy upland soils. The Sassafras Series are deep well drained upland soils. The floodplains consist of Bibb soils, which are poorly drained and level to nearly level (USDA-SCS 1973).

The soils for the sites included in the survey are representative of the soils found in Anne Arundel County. Soils in the county range from nearly level to very steep. They consist of unconsolidated deposits of silt, sand, gravel, and clay. Drainage rates range from well drained to poorly drained soils. The well drained soils are located on the uplands, with the poorly drained soils located on the floodplains (USDA-SCS 1973).

C. Reference Reach Summary Data

The Service developed summary data consisting of numerous channel values of dimension, pattern, profile, and bed materials (Appendix A - E). Dimensionless ratios were derived for each site using the bankfull width of the channel at the classification riffle cross section. The dimensionless ratios allow the data development using dimension, pattern, and profile values for restoration designs with the bankfull width of the new channel.

IV. DISCUSSION

A. Dimensionless Ratios

Not surprisingly, the stream dimensionless ratios have a fairly narrow range given that all sites are Rosgen E stream types. The width/depth ratio on average is 9.03 (Table 2) with the stream cross section having a "v" rather than "u" shape for all sites except Plum Point Creek, an E6 Rosgen stream type, which had a more "u" shaped channel due to a mostly clay bed. Because the sites are fairly small (less than 10 sq. mi.), and have low width/depth ratios, the pool widths are not significantly greater than the riffle or run widths, although overall pool area was slightly greater, and average pool depth almost twice that of the riffle or run. There was little difference between run and glide depths overall (Table 2).

Table 2. Dimensionless Ratios - Cross Section. E Streams - Maryland Western Coastal Plain

RATIO	RANGE			AVERAGE
Width/Depth	5.73	to	12.83	9.03
$Width_{pool}/Width_{bkf}$	0.76	to	1.66	1.11
$Area_{pool}/Area_{bkf}$	0.86	to	2.11	1.30
Riffle $Depth_{max}$/Riffle $Depth_{bkf}$	1.05	to	1.88	1.44
Pool $Depth_{max}$/Riffle $Depth_{bkf}$	1.52	to	3.12	2.10
Run $Depth_{max}$/Riffle $Depth_{bkf}$	1.21	to	2.25	1.57
Glide $Depth_{max}$/Riffle $Depth_{bkf}$	1.21	to	2.09	1.54

The slope range for the survey sites was very slight (0.0022 – 0.0066) (Table 3), similar to measurements made for the regional curve development in the Maryland Coastal Plain (McCandless 2003). For many sites, wood was responsible for increasing riffle or run slopes. On average, the riffles were 1.4 times steeper than the average water surface slope with the pool slopes about half of the average slope. At all sites, at least 50 percent of the reach was represented by pools (run, glide, and pool), with four of the five sites having pool features representing greater than 72 percent of the site.

Glide and run slopes had the greatest variability in range of measurements. However, on average, these features are slightly less steep than the average water surface slope, which is typical for stable streams. The variability in the range of slopes can be partially explained based on the variability of bed features associated with sand bed streams. Sand bed streams can form eight distinctively different bed features depending upon flow conditions, specifically sub-critical, critical, and super critical flows (Gordon, 1992 *et al.*). During sub-critical flows, ripple and ripple/dune patterns form on the streambed. During critical flows, dunes, washed-out dunes, and plane bed patterns form on the streambed. During super critical flows, standing waves, antidunes, and chute and pool patterns form on the streambed. Each of these sand bed features have unique characteristics that are directly related to glide and run slopes. However, it is difficult to develop potential relationships between the ranges of slope measurements with only glide and run data from five sites. Additional glide and run data could possibly assist in developing the relationships.

Table 3. **Dimensionless Ratios - Profile.** E Streams - Maryland Western Coastal Plain				
RATIO	**RANGE**			**AVERAGE**
Riffle Slope/Average Water Surface Slope	0.78	to	3.00	1.65
Pool Slope/Average Water Surface Slope	0.07	to	1.01	0.48
Run Slope/Average Water Surface Slope	0.04	to	4.58	0.85
Glide Slope/Average Water Surface Slope	0.04	to	1.82	0.64

The streams were fairly sinuous and met criteria for Rosgen E stream types (Rosgen 1994), although all sites were located in mature forest with dense root mass along the banks (Table 4). This is likely a factor in the low radius of curvature to bankfull width (average 1.92), as the bends typically had dense root mats from trees or from woody shrubs. Williams (1986) reports and average radius of curvature of 2.43, with one-third of the sites less than 2.0. The meander length ratio to bankfull width ranged from 3.5 to 13.5 with and average of 7.58. Williams (1986) reports an average of 7.5 and Leopold and Wolman is slightly higher at 10.0 (1960). The meander width ratios, or belt width to bankfull width was also low for these sites (2.2 – 12.9). The range found in the Western Coastal Plain for Rosgen E stream types with a drainage area of 3 to 45 sq. mi., was 11 – 37, with an average of 21 (McCandless 2003 – drainage area limits of 0.3 to 89.7 sq. mi.). Rosgen reports a range of 20 – 40, with an average of 24 for E stream types (Rosgen 1996).

Table 4. Dimensionless Ratios - Pattern. E Streams - Maryland Western Coastal Plain				
RATIO	**RANGE**			**AVERAGE**
Sinuosity	1.33	to	1.60	1.42
Meander Length/$Width_{bkf}$	3.53	to	13.50	7.58
Radius of Curvature/$Width_{bkf}$	1.00	to	4.61	1.92
Beltwidth/$Width_{bkf}$	2.20	to	12.90	5.03
Pool to Pool Spacing/$Width_{bkf}$	2.49	to	15.56	5.80
Pool Length/$Width_{bkf}$	1.41	to	7.25	3.35

B. Coarse Woody Debris

The Service conducted a coarse woody debris (CWD) survey to characterize the size, orientation, location, and influence of CWD on pool formation for all the survey sites. The Service did not conduct a detailed analysis to determine the influence of CWD on the development and maintenance of channel dimension, pattern, and profile. The Service used a method developed by Robinson and Beschta (1990). The survey method worked fairly well in characterizing the CWD with exception to the minimum size threshold. The method has a minimum size threshold of 0.65 feet in diameter. There was a significant number of CWD below this threshold existing within the survey sites and we believe that these CWD had an influence on channel characteristics. Therefore, we recommend lowering the minimum size threshold for future CWD surveys.

Some sites had noticeably more CWD debris (Hilton Run – 8 pieces and St. Mary's – 10 pieces) than other sites (UT Zekiah Swamp Run – 3 pieces, Plum Point – 3 pieces, and UT Severn Run – 1 piece). A majority of the CWD were located in pools (76 percent) with a few located in riffles (13 percent) and runs (12 percent). Eighty percent of the CWD were within the active channel and the remaining 20 percent were on the streambanks. Their orientation to flow was fairly equal with 52 percent perpendicular to flow and 48 percent parallel to flow. Grouped versus ungrouped was also fairly equal with 60 percent being ungrouped and 40 percent grouped. The size of CWD ranged from 0.5 feet (ft) to 1.6 ft in diameter with a median of 0.9 feet and 4.2 ft to 70 ft in length with a median of 15 feet. Only one piece of CWD provided grade control and only 2 percent had some influence on pool formation.

C. Bankfull Discharge

The Service calculated bankfull discharge and Manning's "n" by using various roughness models. Limerinos (1970), Leopold (1964), and the Continuity Equation (discharge = cross section area x velocity) best predicted Manning's "n" values similar to the values calculated for the regional curve development in the Maryland Coastal Plain (McCandless 2003). The Manning's "n" by stream type did not predict "n" values close to the Maryland Coastal Plain values. This is mostly likely because the Manning's "n" by stream type was developed from large rivers and all of the reference sites are not large rivers. The Service calculated Manning's "n" values for the reference sites by averaging the Manning's "n" values calculated from Limerinos, Leopold, and Continuity Equation (Table 5). The Maryland Coastal Plain Manning's "n" values calculated for Western Coastal Plain streams ranged from 0.023 to 0.50, with a median of 0.030. Plum Point is the only site which the Manning's "n" value is outside of the range associated with the Maryland Coastal Plain values. Plum Point has a clay streambed while all of the Maryland Coastal Plain sites were either sand or gravel bed streams. Therefore, the Manning's "n" should be lower for Plum Point.

Table 5. Bankfull Discharge, Velocity and Manning's "n"

Reference Site	Bankfull Discharge (cfs)	Bankfull Velocity (ft/sec)	Manning's "n"
UT Severn Run	5.84	2.18	0.030
UT Zekiah Swamp Run	24.60	3.68	0.025
Hilton Run	64.80	3.54	0.027
Plum Point Creek	73.54	4.78	0.015
St. Marys	155.03	4.19	0.024

The velocities calculated for the reference reaches also compared well with the velocities reported in the Maryland Coastal Plain report. The Maryland Coastal Plain velocities calculated for Western Coastal Plain streams ranged from 2.25 feet per second (ft/sec) to 4.54 ft/sec, with a median of 2.87 ft/sec.

All of the bankfull discharges calculated for the reference reaches, except for one, compared well with the bankfull discharges reported in the Maryland Coastal Plain report (Figure 2). The bankfull discharge calculated for UT Severn Run is significantly lower than the bankfull discharge versus drainage area relationship shown in the Maryland Coastal Plain report. UT Severn Run has a small watershed drainage area (0.73 sq. mi.) with a large wetland complex located at the headwaters of the watershed. This large wetland complex significantly influences the amount of storm runoff flow that reaches UT Severn Run. As a result, UT Severn Run receives a much smaller portion of the storm runoff flows and thus has a lower bankfull discharge.

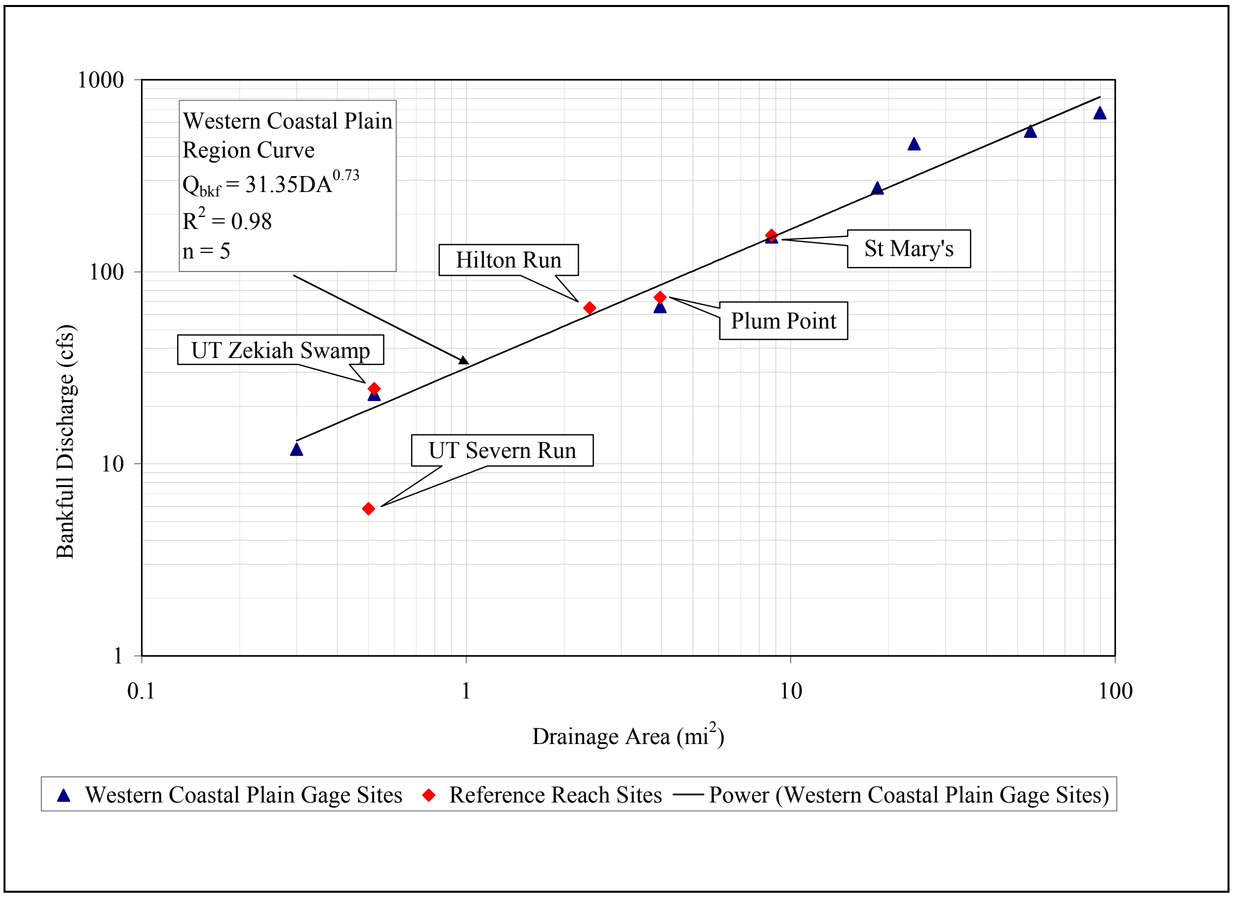

Figure 2. Discharge versus Drainage Area

V. CONCLUSION

The Service and the County will continue to seek potential sites using the four methods described in Section II Task A, as well as several additional methods. Expansion of the data set would potentially allow inclusion of additional Rosgen stream types and selection of additional sites that encompass a wider range of watershed sizes. These sites represent conditions that are found in mature forested, although not pristine, conditions. In using this information for design, practitioners must consider specific site conditions accordingly. This information allows a framework for comparison against design ratios with specific site conditions.

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