Herring Run Watershed

Stream Assessment and Restoration Concept Plan

Final Report

July 2004





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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1.0 INTRODUCTION

1.1 BACKGROUND AND PROBLEM STATEMENT

In February of 2003, the City of Baltimore began an assessment of the mainstem channel and tributaries of the Herring Run watershed within the City limits. This project, the Herring Run Watershed Stream Assessment and Restoration Concept Plan, called for a geomorphologic survey of approximately 18.4 miles of streams to identify and assess existing conditions, prioritize reaches for restoration, and prescribe specific approaches for several priority reaches.

The Herring Run watershed is under constant pressure from urban influences, which threaten existing physical conditions and habitat values of the creek. Compared with streams in less densely populated rural areas of Maryland, much of the stream is in poor physical condition. Many portions of Herring Run are undergoing changes with adverse consequences to the watershed at large. These problems are driven by encroaching urban infrastructure, poor riparian buffers, and local bank erosion.

1.2 PROJECT GOALS AND SCOPE OF REPORT

It is the intent of this Stream Assessment and Restoration Concept Plan to provide some general approaches to both 1) protecting existing stream and riparian areas and 2) ameliorating those reaches that show the most degraded conditions. Stable, healthy portions of the creek are critical for preservation given their natural tolerance to flood effects, resilience against bank erosion, and high habitat value. Furthermore, maintaining these conditions ultimately maintains good water quality conditions in the Herring Run watershed and the Chesapeake Bay itself. Of equal importance is improving those areas that pose the greatest water quality problems, thereby preventing additional deleterious channel adjustments and management costs down the road.

Specifically, the Herring Run Stream Assessment and Restoration Concept Plan was developed with the following objectives in mind:

- To conduct a thorough "fluvial audit" of the stream network to identify and assess existing geomorphic conditions and identify problem areas on a relative basis.
- To develop stream bank stabilization and riparian corridor recommendations that would improve physical and habitat conditions in Herring Run and decrease delivery of fine sediment to Herring Run and ultimately the Chesapeake Bay.
- To produce GIS coverages summarizing existing conditions to inform and/or guide future restoration planning in a consistent format.

The Restoration Concept Plan followed several stages of development. First, existing conditions were qualitatively and systematically documented by Biohabitats scientists, who walked the approximately 18 miles of the Herring Run drainage network within the City limits. Next, the information was synthesized to rank problematic reaches. Finally, for several of the most impacted reaches, restoration concepts were developed to improve unstable portions of the channel.

This report is conceptual in nature and is not intended to be exhaustive in its methods, content, or recommendations. Ultimately, however, the information presented within this report is intended to assist agencies and landowners' consultants in the planning and conceptual design of water quality improvement projects, including stream stabilization and riparian revegetation projects. For example, if a landowner pursues the stabilization of a bank as recommended in the concept plan, implementation of the structure may require additional field investigations, detailed design drawings, and permits from multiple agencies.

1.3 Location of Study Area and Watershed Characterization

Herring Run is a highly urbanized stream that discharges into the Back River before reaching the Chesapeake Bay east of Baltimore City. This study concerns the portion of Herring Run and its major tributaries that lie within the City limits (Figure 1.0). Herring Run drains an approximately 31 mi^2 area (to the Back River confluence) of the Chesapeake Bay watershed. Headwaters originate outside the northeastern limits of the City of Baltimore. There are five major branches in the drainage network of Herring

INSERT FIGURE 1.0

Run: Chinquapin Run, West Branch, Moores Run, Biddison Run, and Armistead Tributary. Each branch comprises over 1 mile of the total network length (Table 1.0).

Table 1.0 Lengths of Key Stream Reaches

Stream Reach	Length	
	Linear Feet	Miles
Herring Run: Mainstem and Unnamed Tributaries	44,329	8.40
West Branch	9,772	1.85
Chinquapin Run	13,956	2.64
Moores Run	13,095	2.48
Biddison Run	9,123	1.73
Armistead Tributary	6,977	1.32
Total	97,252	18.42

The Herring Run watershed lies at the interface of the Middle Atlantic Piedmont and Coastal Plain physiographic provinces. The landscape within the Herring Run watershed within the City limits in relatively flat with low, broad rolling hills. There exists a patchwork of land use, riparian conditions, and associated stream conditions through the Herring Run watershed within Baltimore City limits. The remaining riparian areas include a diversity of forest types from early- and mid-successional deciduous forests dominated by Eastern hardwoods. Deer browse is generally minimal due to proximity to roadways, residences, and commercial activity. Invasive species are numerous and extensive in the riparian areas surrounding the creeks.

1.4 ANTHROPOGENIC IMPACTS TO STREAMS

Changes in land use within a watershed, such as through residential development, can and most often *do* result in negative impacts to water quality, stability of stream channels, and habitat within a watershed and to receiving bodies of water. As land is deforested for development, the magnitude and frequency of stormwater runoff (nonpoint source runoff) increase and higher pollutant loads are delivered downstream. Pollutant loads can include sediment, nutrients, and heavy metals.

The changes in the runoff regime that are associated primarily with nonpoint source runoff also result in stream channel adjustments to accommodate the increases in flow, including channel bank erosion and channel bed incision. Aquatic habitat is impaired as a result of the decline in water quality and stream channel condition. Riparian conditions are often impaired as well, including the reduction or elimination of forest buffer along stream channels and increases in invasive species among the plant communities in these disturbed areas. These impacts to the riparian condition result in aquatic and terrestrial habitat loss, reduction in the filtering capacity of pollutants along these streamside zones, and increased stream channel erosion as a result of the loss of root mass from woody material.

While there are no datasets available which track physical adjustments of Herring Run with incremental development in the watershed, it is likely that some such changes have occurred. It is also common that stream adjustment lags behind physical changes in the supply of sediment and water to the channel. Therefore, it is possible that the creek has not fully achieved a new geometry that can convey this altered flow regime and the sediment supplied to the channel giving the existing conditions in the watershed. If this is the case, additional channel changes can be expected in the future as the creek continues to adjust, and additionally if future land use changes in the watershed induce more change. For these reasons, it is important to continue to observe the physical condition of Herring Run in the future and address any critical problems promptly as they are identified.

2.0 METHODS

Preparation of this Stream Assessment and Restoration Concept Plan required two main avenues for methodology: cruised reach assessment and ranking of reach data. Ultimately the two methods provided a database for description of the existing conditions of the reaches and ranking them.

2.1 CRUISED REACH ASSESSMENT

The cruised reach assessment was conducted to 1) familiarize the team with the conditions of the watershed, and 2) identify problem areas within evaluated reaches. Cruised reach assessment began with the development of field data collection sheets. The creation of field data collection sheets was intended to provide a consistent means of evaluating individual reaches along the Herring Run watershed. The consistency stems from the use of field data sheet collection sheets that include a standard set of parameters to be evaluated for each reach. Summarization of the collected information allows both a broad-brush characterization of the existing conditions of the channel and riparian area of each reach, and also a more detailed comparison between reaches for ranking of their potential for restorative measures (see Section 2.2).

Prior to conducting the field campaign, Biohabitats' staff visited portions of the Herring Run watershed to observe a "sampling" of conditions to help direct the development of the field data collection sheets. Based on observation during this field work, Biohabitats determined the type of parameters that would be necessary for data collection.

It was determined that no standardized, preexisting field data collection forms fit particularly well with anticipated needs. The creation of field assessment sheets for data collection, therefore, drew from several available stream data collection formats, including the USDA NRCS's Stream Visual Assessment Protocol (1998) and Maryland's Stream Corridor Assessment Survey (2001), but also included additional elements. An example of the final developed data collection sheet is shown in Appendix A. Sheet 1 was used to record channel type, substrate, gradient, and channel morphology information. Sheet 2 included descriptions of culverts, outfalls and exposed pipes, as well as Bank Erosion Hazard Index (BEHI) information. Parameters evaluated on Sheet 3 could be assigned an arbitrary level between 1 to 10 with an associated description (these values underwent weighting in the later ranking process and do not themselves represent point values). This allowed an evaluator to record subtle differences between reaches (in up to 10 levels) and reduced the potential for low and high scores to be damped out later during the ranking process.

Stream scientists then conducted a “cruised” survey of the mainstem and the major tributaries of the Herring Run watershed within the City limits. “Cruising” consisted of a team of two environmental scientists walking the length of the stream and recording channel morphology, disturbance, stability, and habitat parameters on the data collection sheets.

There was no predetermined limit to reach lengths. Instead, reach boundary breaks were predicated only upon a distinct change in Rosgen channel type classification (Rosgen, 1996). Additional factors that determined reach breaks included one or more of the following: 1) dramatic and consistent changes in stream morphology, bank condition, and/or riparian condition, and 2) locations of roadway crossings, tributary confluences, culverts, and/or outfalls. Because Herring Run includes mostly B and C type channel and similar stability problems occur in most reaches, reach lengths were quite protracted. Of the 24 reaches that were identified, reach lengths range from approximately 1,275 to 7,560 feet, with an average length of 4,050 feet.

For each reach, one set of observations was recorded. Listed below are the specific parameters that were evaluated during the field survey (also see Appendix A). Asterisks indicate those parameters later used to develop the ranking system and are described in more detail in Section 2.2. At least one surveyed cross section was also conducted along each reach to refine stream type determination and quantify representative channel dimensions.

General

- Main Rosgen stream type
- Secondary stream types
- Bed material sizes present
- Estimated median grain size
- Bedrock control of bed*
- Bedrock control of banks*
- Channel slope (estimated)
- Sinuosity (estimated)
- Bankfull indicators
- Bankfull channel dimensions
- Surrounding land uses

Channel Disturbance

- Culvert
- Outfalls
- Direct human channel impacts
- Bridges
- Exposed pipes

Channel Stability Parameters

- Overall channel conditions*
- Degree of channel incision*
- Bed stability*
- Bank stability*
- Bank Erosion Hazard Index (BEHI) measurements*

Habitat Parameters

- Riparian invasive plant species*
- Canopy cover*
- Nutrient enrichment

- Width of riparian zone*
- Terrestrial habitat/riparian composition*
- Riffle embeddedness*
- Barriers to fish movement*
- Instream fish cover*
- Pools*
- Insect/Invertebrate habitat*
- Degree of human intervention*

Other parameters, such as drainage area to individual reaches, were measured from maps in the office. Digital photographs were also taken at each culvert, outfall, and exposed pipe to help record existing reach conditions.

Observations recorded on data sheets were summarized in a series of tables (Appendix B). The database can be queried by GIS for any parameter(s) of interest, and can be expanded as additional observations and data are collected in the watershed.

2.2 REACH RANKING

Ranking of the field observations assisted in: 1) prioritizing the need of specific restoration approaches (e.g., bank stabilization and riparian revegetation), 2) identifying common findings between ranking parameters as a means of verification of priority areas 3) highlighting strengths and shortcomings for identifying the most appropriate parameters, and 4) developing the Restoration Concept Plan to establish and prioritize suitable management approaches by reach.

After completion of the field work, stream scientists identified those variables that they observed to be most indicative of channel problems and that would assist in stratifying the reaches into priority categories for restoration techniques. A ranking system was developed to identify those reaches appropriate for channel restoration and riparian revegetation. Primary factors used to rank channel problems were grouped into two broad categories: 1) channel stability, and 2) habitat conditions. (There are strong connections and overlap between the factors; however, this organization allows for some useful generalizations.) Additional information was used to provide detail and support for these rankings in later recommendations.

Next, a point-based ranking system was imposed for each parameter. This involved the assignment of a point value to each reach parameter based on field observations. The maximum number of points possible for a selected parameter is based on the relative importance of that parameter to the overall reach ranking. Specifically, the breakdown of possible points awarded for each parameter was based on 1) professional judgment of the significance of different levels (e.g., what should be the difference in ranking points between a $>12 mi^2$ and 8-12 mi^2 drainage area?) and 2) the need to better differentiate between reaches by imposing weighting factors to increase the point spread within an individual parameter (e.g., how many more ranking points should a good rating of “9” versus “8” be worth for the parameter “canopy cover?”).

After the initial rankings were completed, scientists revisited a subset of reaches with high, average, and low rankings to verify that the ranking system successfully compared and contrasted the existing conditions of the study reaches in a comprehensive manner. Minor revisions were then made to the ranking system. Table 2.1 and 2.2 broadly indicate how points were assigned to each reach based on the recorded level of each parameter and the percentage of channel length that fell into each category. A more comprehensive table showing the weighting factors and the range of points assigned to each parameter of each reach is included in Appendix C.

It should be noted that the rating point cutoffs are subjective and suit the purposes of this study in that they exaggerate the differences between reaches and cumulatively assess physical function. This approach helped develop a relative *prioritization of problems* on a reach basis. These were checked with professional judgment to assess appropriateness of these rankings, and were found to capture the range of noted conditions.

Table 2.0 Primary Factors Used in the Channel Stability Ranking and Results on Reach Basis.

Parameter	Level of Parameter	Rating Points Assigned to Level*	Reaches at Given Level of Parameter	
			Stream Length (mi)	Percent Length (%)
*Maximum 100 rating points possible. Higher scores indicate better conditions and/or lesser need for restoration based on parameter.				
Drainage Area to Reach	>12 mi^2	10	5.8	31.4
	8-12 mi^2	8	2.8	15.4
	4-8 mi^2	4	2.3	12.4
	2-4 mi^2	2	3.2	17.5
	0-2 mi^2	0	4.3	23.3
		Total	**18.4**	**100.0**
Overall Channel Condition	Excellent	20	0.0	0.0
	Good	8-14.4	6.8	36.9
	Fair	2.6-5.2	7.7	42.0
	Poor	0	3.9	21.1
		Total	**18.4**	**100.0**
Bed Stability	Likely Stable	10	14.6	79.0
	Possibly Stable	9	3.0	16.3
	Indeterminate	8	0.0	0.0
	Aggrading	0	0.0	0.0
	Degrading	0	0.9	4.6
		Total	**18.4**	**100.0**
Bedrock Control of Bed	Yes: Pervasive	10	1.8	9.9
	Yes: Moderate	8	3.8	20.6
	Yes: Local	4	3.5	18.9
	No	0	9.3	50.6
		Total	**18.4**	**100.0**
Bank Stability	Excellent	20	2.3	12.5
	Good	8-14.4	8.4	45.6
	Fair	2.6-5.2	7.7	42.0
	Poor	0	0.0	0.0
		Total	**18.4**	**100.0**
BEHI	<10% High and	0	9.4	51.0
	25% >High ≥ 50%	-5	4.8	25.9
	≥ 25 % High	-10	4.3	23.1
		Total	**18.4**	**100.0**
Bedrock Control of Banks	Yes: Pervasive	10	2.2	11.9
	Yes: Moderate	6	1.6	8.5
	Yes: Local	2	3.6	19.7
	No	0	11.0	59.9
			18.4	**100.0**
Degree of	Excellent	20	0.0	0.0

Parameter	Level of Parameter	Rating Points Assigned to Level*	Reaches at Given Level of Parameter	
			Stream Length (mi)	Percent Length (%)
	Good	11.2-14.4	3.2	17.3
	Fair	5.2-7.8	7.5	40.8
	Poor	2-3	5.2	28.1
	Very Poor	0	2.5	13.7
		Total	**18.4**	**100.0**

Table 2.1 Primary Factors Used in the Habitat Ranking.

Parameter	Level of Parameter	Rating Points Assigned to Level*	Reaches at Given Level of Parameter	
			Stream Length (mi)	Percent Length (%)
***Maximum 100 rating points possible. Higher scores indicate better conditions and/or lesser need for restoration based on parameter.**				
Riparian Zone: Left	Excellent	14	4.8	26.3
	Good	10	8.0	43.4
	Fair	5	3.9	21.1
	Poor	1	1.3	7.1
	Very Poor	0	0.4	2.1
		Total	**18.4**	**100.0**
Riparian Zone: Right	Excellent	14	3.4	18.7
	Good	10	9.1	49.4
	Fair	5	3.9	21.1
	Poor	1	1.6	8.6
	Very Poor	0	0.4	2.1
		Total	**18.4**	**100.0**
Terrestrial Habitat	Excellent	8	9.6	52.0
	Good	6	5.4	29.1
	Fair	4	0.8	4.5
	Poor	1	2.3	12.3
	Very Poor	0	0.4	2.1
		Total	**18.4**	**100.0**
Riparian Invasives	Excellent	8	0.0	0.0
	Good	6	4.1	22.1
	Fair	4	6.4	34.7
	Poor	1	7.4	40.2
	Very Poor	0	0.6	3.0
		Total	**18.4**	**100.0**
Canopy Cover	Excellent	8	0.0	0.0
	Good	6	9.1	49.2
	Fair	4	6.0	32.5

Parameter	Level of Parameter	Rating Points Assigned to Level*	Reaches at Given Level of Parameter	
			Stream Length (mi)	Percent Length (%)
	Poor	1	2.1	11.6
	Very Poor	0	1.2	6.7
		Total	**18.4**	**100.0**
Riffle Embeddedness	Excellent	8	3.3	18.1
	Good	6	7.8	42.5
	Fair	4	3.6	19.6
	Poor	1	3.1	16.6
	Very Poor	0	0.6	3.1
		Total	**18.4**	**100.0**
Barriers to Fish Movement	Excellent	8	2.1	11.4
	Good	6	4.0	22.0
	Fair	4	1.2	6.7
	Poor	1	3.1	17.0
	Very Poor	0	7.9	43.0
			18.4	**100.0**
Instream Fish Cover	Excellent	8	0.0	0.0
	Good	6	4.2	24.0
	Fair	4	11.4	62.0
	Poor	1	2.0	10.9
	Very Poor	0	0.6	3.0
		Total	**18.4**	**100.0**
Pools	Excellent	8	2.7	23.8
	Good	4	0.6	5.7
	Fair	1	3.0	26.9
	Poor	0	1.4	12.2
		Total	**18.4**	**100.0**
Insect/Invertebrate Habitat	Excellent	8	5.0	26.9
	Good	6	10.4	56.7
	Fair	4	2.5	13.4
	Poor	1	0.6	3.0
			18.4	**100.0**
Human Intervention	Excellent	8	0.0	0.0
	Good	4	5.9	32.2
	Fair	1	7.7	41.9
	Poor	0	4.8	25.9
		Total	**18.4**	**100.0**

2.2.1 Channel Stability Parameters

For the ranking of channel stability, eight parameters were selected: 1) drainage area to the reach, 2) overall channel condition, 3) bed stability, 4) bedrock control of bed, 5) bank stability, 6) Bank Erosion Hazard Index (BEHI), 7) bedrock control of banks, and 8) degree of channel incision. Below is a brief description of these parameters and there relative importance in the channel stability ranking.

Drainage Area to Reach

The drainage area to each reach is incorporated in the ranking system to distinguish between relatively smaller and larger streams. The intent of including drainage area is to place additional emphasis on taking action in smaller streams, since they are source areas in terms of sediment and water (hydrology) and therefore have consequences to downstream reaches. In additional, stream rehabilitation in smaller streams is more cost effective, since more techniques are generally available for use and require less spatially extensive coverage. Up to 10 points (out of 100 total possible) are assigned to each reach's ranking based on drainage area.

Overall Channel Condition

The parameter "overall channel condition" is worth up to 20 points in the ranking. This parameter was intended to be a catch-all index of the channel condition resulting from the *interaction* of individual factors such as bank stability, natural character, bed stability, and the degree of channel recovery from past activities.

Bed Stability

Bed stability is included in the ranking since it can generate significant sediment yields and can have deleterious consequences to banks and water quality. Field indicators of degradation (progressive downcutting of the channel into its deposits) include the presence of a knickpoint, lack of depositional features, undercutting at the toe of slope, and irregular claypan bed topography. Field indicators of aggradation (chronic deposition of sediment on the bed) include depositional features such as midchannel bars, a relative abundance of fine sediment along the bed, and, in many cases, associated bank erosion. Bed stability is worth up to 10 points in the ranking.

Bedrock Control of Bed

Bedrock plays an important role in stream processes of Herring Run and the resulting planform and cross-sectional pattern. Bedrock outcrops occur intermittently along the bed and banks of the creek and subsequently protect these locations from erosion. For this reason, the degree of bedrock control is included as a ranking parameter worth up to 10 points. The degree of bedrock control was assessed in the field based simply on the relative abundance of bedrock outcropping along the bed and banks of a reach.

Bank Stability

Bank stability was assessed as an index of the overall severity of bank erosion and sediment supplied to the channel. Assessment of bank erosion was based on factors such as streambank angle and shape, undercutting of root masses, exposed roots, lack of surficial protection (e.g., by vegetation), evidence of recent soil removal and slumping, and active erosion processes such as dry ravel. Field observations suggested that bank stability is especially important in distinguishing restoration potential on a reach basis, and is therefore worth up to 20 points in the channel stability ranking.

Bank Erosion Hazard Index

Developed by Rosgen (1996), Bank Erosion Hazard Index (BEHI) scores provide an indicator of the extent of any local, extreme bank erosion processes. Representative BEHI measurements were used to identify the percentage of banks in each reach with low up to extreme erosion hazards. BEHI scores are based on such factors as streambank angle, root density, bank height versus bankfull depth, and the amount of surficial protection. In contrast to other parameters, BEHI is scored as a subtractive factor, such that up to 10 points are deducted due to poor BEHI ratings.

Bedrock Control of Banks

Bedrock plays an important role in stream processes of Herring Run and the resulting planform and cross-sectional pattern. Bedrock outcrops occur intermittently along the bed and banks of the creek and subsequently protect these locations from erosion. For this reason, the degree of bedrock control is included as a ranking parameter worth up to

10 points. The degree of bedrock control was assessed in the field based simply on the relative abundance of bedrock outcropping along the bed and banks of a reach.

Degree of Channel Incision

Assessment of channel incision provides an index of how impacted a reach is from past management activities. The level of channel incision was evaluated by comparing the elevation of bankfull relative to the elevation of the adjacent floodplain. For those reaches with significant incision, floodplain vegetation is separated from the water table and does not interact with lower flows. Instead shear stresses are exerted directly along the bed and lower banks with little protection from plant roots. In many cases of significant channel incision, channels are unable to "self-recover." For this reason, as many as 20 points are awarded for this parameter within the ranking system.

2.2.2 Habitat Parameters

Eleven parameters were identified as essential to defining the quality and quantity of in-stream and riparian habitat: 1) width of left riparian zone, 2) width of right riparian zone, 3) terrestrial habitat, 4) riparian invasives, 5) canopy cover, 6) riffle embeddedness, 7) barriers to fish migration, 8) in-stream fish cover, 9) pools, 10) insect/invertebrate habitat, and 11) human intervention.

Even though it has dire consequences to in-stream habitat and water quality, nutrient enrichment was not included in the habitat ranking. Field observations suggested that nutrient enrichment was most strongly linked to recent sewage leaks, and was therefore too transient spatially (depending on local breaks and follow-up maintenance) to be indicative of longer term reach conditions. Although nutrient enrichment is not included in the reach rankings, it remains a critical factor in stream health.

Riparian Zone Width: Left and Right

Riparian width is an indicator of both the bank stability afforded by vegetation and available sediment trapping function. Riparian areas also provide important habitat and nutrient processing. The forested riparian buffer width was estimated in the field based on average reach conditions for each bank. Because the natural landscape is forested, riparian areas consisting of only lawns and other such grasses were considered to have no effective width. Given the high variability in riparian zone widths between reaches and the strong potential for revegetation in sparse areas, this parameter is weighted strongly, with up to 28 points possible (out of 100 total possible) between both banks.

Terrestrial Habitat

The number of layers present in the riparian zone (e.g., trees, shrubs, and herbaceous species) affects the health, integrity and habitat complexity of terrestrial areas. Up to 8 points are awarded to the habitat ranking based on terrestrial habitat. This factor is scored independently of the density of riparian invasives, which is considered as a separate parameter.

Riparian Invasives

Invasive species are both widespread and dense throughout the majority of the Herring Run watershed. Because they displace native plants, reduce food and shelter for native wildlife, eliminate host plants of native insects, and compete for native pollinators, riparian invasives can greatly impact riparian health. Along many reaches of Herring Run, riparian invasives are spreading rapidly and threatening to produce a riparian monoculture (single plant species), which has little ecological value. Up to 8 points are awarded for the level of riparian invasives in the ranking system.

Canopy Cover

Canopy cover provides a good integrator of riparian width, canopy height, canopy density, and stream shading. In many cases reduced canopy cover corresponds to those areas with extensive human intervention, particularly residential and industrial development. Up to 8 points are assigned to the canopy cover component of the habitat ranking.

Riffle Embeddedness

Riffle embeddedness, the degree to which riffle areas were buried by fine sediment, is a good indicator of sediment supply delivered to a reach. High riffle embeddedness can be problematic to fish, benthic organisms, and other aquatic species. Reaches are assigned up to 8 points based on riffle embeddedness.

Barriers to Fish Movement

Since they limit the movement and/or migration of fish through the stream network, barriers to fish movement were included in the ranking. Depending on the number and severity of barriers along an individual reach, up to 8 points are awarded for this parameter.

Instream Fish Cover

Complex in-stream habitat provides important refugia to fish. The following items were noted as providing instream fish cover and are collectively worth up to 8 points in the ranking: logs/large woody debris, deep pools, overhanging vegetation, boulders/cobbles, riffles, undercut banks, thick root mats, dense macrophyte beds, and isolated/backwater pools.

Pools

Pools also provide important refugia for aquatic species. The abundance and depth of pools was evaluated as an additional important aspect of in-stream habitat, and comprise up to 8 points in the habitat ranking of each reach.

Insect/Invertebrate Habitat

Insect and invertebrate habitat was qualitatively assessed for each reach based on the presence of fine woody debris, submerged logs, leaf packs, undercut banks, cobbles, boulders, and coarse gravel. Reaches with these features receive up to 8 points in the habitat ranking.

Human Intervention

The degree of human intervention was assessed to determine the extent of natural channel function remaining along each reach. Up to 8 points are assigned for this parameter. Those reaches with extensive bank and bed protection, culverts and/or utilities lines, and persistent evidence of straightening were recorded as having high human intervention. Those areas in which significant channel recovery had occurred or the channel boundaries were primarily natural received higher (better) human intervention scores.

3.0 FIELD RESULTS AND RANKING

3.1 CRUISED REACH ASSESSMENT

Results of the cruised reach assessment are summarized in Appendix B. Not surprisingly, results from the reaches are highly variable and difficult to generalize across the watershed. Most reaches, however, are coarse-bedded C type streams with relatively low sinuosity. Approximately half of the reaches are influenced by localized bedrock outcrops. Residential and forest are the most common adjacent land uses. When comparing results among all twenty-four reaches, no reach has overwhelming "good" or "poor" conditions. Instead, each reach shows a complicated combination of factors. Results shown in Appendix B should be referred to for the most complete picture of each reach.

3.2 REACH RANKING

Figures 3.0 and 3.1 illustrate the priority of restoration based upon channel stability versus habitat, respectively, as a result of the ranking system. Figure 3.2 shows the *overall* need for restoration, and considers both existing channel stability and habitat attributes on a reach basis. Ranking scores associated with these priority designations are summarized below in Table 3.0.

Generally speaking, tributaries have a significantly higher priority for restoration rather than mainstem reaches of Herring Run. Main reasons for this difference probably stem from several factors: 1) low order (smaller) streams are generally source areas for sediment and more readily display erosional problems, whereas higher order (larger) streams are transport areas that respond to upstream input of high sediment loads, and 2) there are more parklands adjacent to the mainstem Herring Run than tributary areas, which allow more beneficial channel-floodplain interactions and more extensive riparian areas.

For each of the eight channel stability and the eleven parameter used in the ranking system, the detailed ranking results are summarized in Appendix C. Specific activities for revegetation and stream restoration are discussed more in Section 4.0.

Table 3.0 Results of Channel Stability, Habitat, and Total Rankings

	Channel Stability		Habitat		Channel Stability + Habitat	
	Ranking Score	Reach	Ranking Score	Reach	Ranking Score	Reach
Poorer Conditions	-0.5	O	18.0	R	39.6	E
↑	1.6	L	20.0	B2	41.5	O
	6.6	E	25.0	K	52.0	B2
	10.8	P	33.0	E	55.6	L
	16.1	W	35.0	J2	61.0	R
	25.2	U	35.0	S	66.1	W
	29.8	A	42.0	O	67.8	P
	32.0	B2	45.0	B	71.5	K
	33.8	B	49.0	T	77.9	S
	34.4	T	50.0	W	78.8	B
	35.7	D	53.0	D	83.4	T
	40.0	V	53.0	V	86.2	U
	40.9	G	54.0	C	86.8	A
	42.6	Q	54.0	G	87.6	J2
	42.9	S	54.0	L	88.7	D
	43.0	R	54.0	M	93.0	V
	45.0	M	55.0	Q	94.9	G
	46.5	K	56.0	I	97.6	Q
	52.6	I	57.0	A	99.0	M
	52.6	J2	57.0	P	108.6	I
↓	54.3	C	58.0	H	108.3	C
	59.2	F	61.0	U	125.2	F
Better	69.3	J	66.0	F	135.3	J
Conditions	78.4	H	66.0	J	136.4	H
Average	**37.2**		**47.9**		**85.1**	

3.3 APPLICATION OF REACH RANKINGS

The reach ranking results are intended to provide a stand-alone assessment of the need for stream restoration on a reach basis, *given observed physical and habitat conditions in the watershed*. It is anticipated that the selection of reaches for future restoration activities will rely on the results presented in this Stream Assessment and Restoration Concept

Plan. However, additional factors would also be considered for the final selection of reaches for restoration activities. These factors could include 1) internal priorities within the City, 2) available funding, and 3) connectivity between reaches for the purposes of further prioritization. These factors are described further below.

Internal priorities of the City for stream restoration activities may also be affected by specific threats to infrastructure (e.g., bridge abutment scour, exposed pipes, etc.), community feedback (e.g., concentrations of complaints by homeowners), and other ongoing City projects that could be combined with stream restoration work (e.g., stormwater detention projects, park improvements, urban BMPs). Addressing these types of concerns *in conjunction with* undertaking stream restoration will be a cost-effective approach that will factor into decision-making. Available funding will pose limits on the overall size and scope of any such project.

For several reasons, reach connectivity will be an additional important factor in selection of reaches for restoration activities. First, for example, if a reach is assigned a "very high" priority for channel stability restoration and it is located immediately upstream of a reach with good channel stability and/or aquatic habitat, it may be especially important to restore the upstream reach to protect the downstream reach. Specific examples of this include: (1) Reach D (high priority ranking for restoration in Figure 3.2), which feeds into Reach F (low priority) and Reach G (moderate priority), and (2) Reaches A (high priority), B (high priority), B2 (very high priority), and E (very high priority), which feed into Reaches C (moderate priority) and Reach H (low priority).

In addition, by lumping several reaches together with varying priority rankings, a longer, more comprehensive restoration design could be developed between reaches with varying priority rankings. Finally, given that construction costs generally decrease on a linear foot basis due to an "economy of scale" effect, maximizing project length may be an important strategy for the City. For example, the restoration of reaches B2 and/or E could also consider including Reaches B, A, and E to be more comprehensive, effective, and cost-effective.

INSERT FIGURE 3.0

INSERT FIGURE 3.1

INSERT FIGURE 3.2

4.0 STREAM RESTORATION TECHNIQUES

Herring Run is a disturbed system with complex hydrologic, sedimentological, and vegetative conditions. With such a broad array of existing conditions, numerous restoration measures should be applied in concert to successfully restore the system to a stable condition. Restoration measures should exploit both opportunities and work around constraints to allow implementation and effectiveness.

Based on results from this ranking, internal priorities within the City, and contiguity of reaches, the City of Baltimore selected Biddison Run (Reaches O and P) and Moores Run (Reaches T and U) for the development of restoration reaches. Restoration concepts for these four reaches are described in Section 4.0. Additional reaches may be added in the future as more funding becomes available.

The primary purpose for restoring Biddison and Moores Run is to correct and prevent severe degradation of the channel and to promote/improve the health of the surrounding ecosystem. Recommended *structural* strategies include measures like stabilizing channel invert elevations with grade control and channel banks with revetments. *Non-structural* techniques include regrading and vegetating banks, or the use of soil bioengineering techniques. Additionally, invasive species management and repairs to infrastructure would improve watershed and stream conditions. Benefits of these types of restoration approaches may include:

- Acceleration of the stream's natural recovery processes,
- Correct or prevention of severe problems or threats to infrastructure, ecosystem health, or property, and
- Improvements to the channel when it is not possible to correct inputs to the system outside of the channel.

4.1 OPPORTUNITIES AND CONSTRAINTS

General opportunities and constraints posed by this project are outlined below. Site constraints have been taken into account in each concept design. As the project progresses, more specific items may be identified and designs can be adjusted accordingly.

Opportunities

- Removal of non-native, invasive species in the adjacent floodplain before the percent cover of invasive species inhibits native species
- Improvement of channel-floodplain interaction by reshaping channel geometry
- Improvement of aquatic and terrestrial habitats
- Spot stabilization of bank erosion using natural materials for bank protection, soil bioengineering, or other means
- Improvement of water quality via reduction in bed and bank erosion
- Improved channel and floodplain aesthetics

Constraints

- Existing utilities (sewer and water pipes, electric lines)
- Existing roads and culverts
- Existing trees that should be retained
- Easement and access (property ownership, stakeholder participation)
- Regulatory requirements (including City, County, State, and Federal)
- Existing and future hydrologic conditions
- Economic considerations, including design and construction costs versus available resources
- Public concerns

Access

Implementation of conceptual designs may require access to the stream by large equipment for removal of soil and replacement with restoration materials. Access to the site could be obtained by numerous ways from nearby residential roads. There are several alternative access points to the stream channel that should result in the least amount of disturbance.

4.2 SPECIFIC RESTORATION STRATEGIES

The following strategies are recommended for use in the restoration of Biddison and Moores Run based on existing conditions, opportunities, and constraints. Individual strategies and the location of their application were determined based on existing stream conditions identified during additional site visits. For example, bank stabilization measures recommended for Biddison and Moores Run vary based on the extent, type, and severity of the erosion, and include non-structural and structural approaches.

Strategies described below are not necessarily mutually exclusive and are used in a complementary fashion throughout the design concepts to produce a comprehensive restoration plan. Specific information about where these measures are recommended is included in Section 5.0 and in Appendices D (Reach O), E (Reach P), F (Reach T), and G (Reach U).

4.2.1 Stabilize Banks Non-Structurally

Bank regrading should be performed to adjust the bank angle and increase the stream's access to its floodplain. This both reduces the erosive power of the stream and provides water to floodplain wetland areas. This method works best where there are minimal lateral constraints. Three types of bank grading are proposed for Moores Run and Biddison Run: regrading of the entire bank, regrading the top of the bank, and grading a bench in the banks. Soil bioengineering can also be used as natural bank stabilization.

Regrade Banks

General regrading of existing banks is proposed for areas with severe bank erosion and adequate right-of-way and involves the shaping of banks to a more stable slope. In areas where the channel is relocated, regrading of the old banks to a more stable slope also will prevent further erosion.

Regrade Top of Banks

Some areas of the restoration reaches have a stable toe of slope with large trees growing at the bottom of the bank, but also have steep, bare upper banks that restrict the channel-floodplain interaction. At these locations, the top of the banks should be graded back at a gentle slope, low enough to allow for overbank flooding while maintaining essential tree cover and root cohesion.

Grade Bench

The grading of banks to form a bench will be used in areas where the surrounding topography does not allow for large scale grading but floodplain area should be increased. A stable stream geometry will be established through the formation of a low bench, which will alleviate shear stresses during high flow events.

Soil Bioengineering

One suite of methods that includes natural inert and planting materials—soil bioengineering—is appropriate wherever bank instability exists, there is sufficient space from the stream to allow regrading to a less steep slope (~1.5H:1V) and sufficient lighting conditions for plant growth. This approach is suitable for treating toe, top of bank, and full bank erosion situations. The installation of soil bioengineering is recommended for areas in Moores and Biddison Run and can include a variety of innovative planting techniques, including live branch layering, brush mattresses, and planted crib walls, which encourage rapid plant growth and slope stability. Soil bioengineering helps speed the bank stabilization process by adding the sediment holding capacity of fast growing shrub roots. These structures also improve habitat by providing shade and organic material to the stream.

4.2.2 Stabilize Banks Structurally

Where inadequate right-of-way, extensive tree removal at the top of bank prohibits regrading of the banks, and banks are steep (>2:1 slope), more structural strategies are needed to stabilize banks. Application of materials to the toe of slope or the full bank is needed to hold the bank in place.

Toe of Slope Stabilization

In some areas, erosion is severe along only the toe of slope or a very low bank.

Stabilization of the bank toe may consist of the installation of boulder or log structures in the lower bank. This toe protection will prevent further erosion along the base of the bank and reduce the potential for further upper bank erosion and slumping.

Install Revetment

Where erosion is severe along the full height of a steep bank, a revetment may be necessary. Advantages of revetment installation include dramatically reduced erosion, tree fall, channel widening and migration. Revetments function by protecting streams from high shear stresses, deflecting flow, and providing long term (>10 years) stabilization while vegetation takes hold. More natural bank stabilization methods such as rootwad and log revetments should be used in areas where possible, to maintain aesthetic and habitat benefits. For example, the placement of riprap is not considered a type of revetment consistent with this Restoration Concept Plan.

4.2.3 Stabilize Channel Structurally

Where the channel bed is vulnerable to additional downcutting, structural stabilization is recommended using either a discrete grade control structure or a more protracted sequence of step pools.

Install Grade Control

Where the channel bed is actively incising or headcuts exist, bed stabilization measures are recommended. This usually involves installation of structures along the existing grade of the bed to hold that elevation. A common bed stabilization structure that would work well in Herring Run is the rock cross vane. Water is redirected away from the bank by the two “arms” of the rock cross vane and flows over large midchannel rocks that prevent channel downcutting. Cross section modification should be done in conjunction with bed stabilization so that erosion problems are not shifted to the stream banks.

Install Step Pools

The installation of step pools is suited to unstable, short, and steep sections of channel where B type channel geometry predominates. The installation of a series of rock pool structures will stabilize the channel bed through preventing bed scour and downcutting. Step pools can provide a controlled change in elevation over the length of the treated reach, preventing erosion in areas of high slope. Step pools can also be used to transition flows more gradually from an outfall to eliminate apron scour or fish migration barriers. Step pools also provide a more natural stabilized channel where culverts are to be removed.

4.2.4 Realign & Relocate Channel

In some cases, it may be best to reconfigure the channel rather than restore the channel in its current location. Although intensive, this type of channel restoration is often most effective because it addresses stability problems holistically via the channel cross-sectional geometry, planform pattern, and profile. For example, rather than installing bank protection along the outside of a tight bend, it may promote greater long-term stability to increase the radius of curvature by realigning and reshaping the channel.

Channel reconfiguration typically involves providing a more stable, efficient morphology and to maintain sediment transport through the stream. Channel modifications must reflect and be consistent with valley features (i.e. width and slope), watershed inputs, adjacent land uses, and storm flows. In some areas, there may be limitations to this type of activity, given bedrock outcrops, infrastructure, or private property limitations.

A preliminary evaluation of field data revealed seven portions of Biddison Run, and six portions of Moores Run that are potential stream realignment and relocation areas. Channel realignment and relocation is recommended only intermittently for portions of these reaches due to construction and maintenance costs, and the amount of disturbance that occurs to existing natural habitat.

4.2.5 Enhance Riparian Areas

Where riparian areas are narrow, overcome by invasive species, or have altered hydrology, a suite of approaches can be used to improve riparian conditions along Biddison and Moores Run.

Reforest Riparian Areas

An evaluation of the existing land use within the Biddison and Moores Run watersheds revealed very few areas available for reforestation. However, those lands adjacent to the creek, that are not developed and are currently unforested, are priority reforestation sites. Generally, reaches surrounding these potential reforestation sites had corresponding low existing habitat values.

Reforestation that occurs adjacent to the channel will provide wetland habitat and other associated benefits: cooler temperatures, rainfall interception, reduced runoff, reduced sediment load, reduced discharge velocities, increased groundwater recharge, increased species diversity and habitat, and improved air quality and aesthetics.

Manage Invasive Species

Maintaining a healthy riparian plant community along Biddison and Moores Run will retain biodiversity and support a healthy stream ecosystem. Invasive species provide little value to native animals that depend on native species for habitat and/or food. Because of this threat to the biodiversity of native communities, an invasive species management plan would assist natural succession within the riparian buffer through decreasing possible further impacts of invasive species. An invasive species management plan will require, at a minimum, a three-year commitment to ensure success.

Field observations suggest that invasives are a pervasive problem throughout the four reaches. For this reason and to keep graphics uncluttered, discrete areas recommended for invasives control areas are *not* mapped in Appendices D through G. Ultimately, management of invasives is needed along *all* of Biddison and Moores

Run. Although a detailed mapping of specific invasive species was not completed for Biddison and Moores Run, Japanese honeysuckle (*Lonicera japonica*) and Japanese knotweed (*Polygonum cuspidatum*) are the prevalent invasive species observed during the field reconnaissance. Both species are non-native, which further compromises riparian habitat. In many areas, knotweed, due to its aggressive nature, has already out-competed native vegetation. Additional invasive species noted include multiflora rose (*Rosa multiflora*, non-native), English ivy (*Hedera helix*, non-native), greenbrier (*Smilax rotundifolia*, native), clematis (*Clematis sp.*), and grape (*Vitis sp.*).

Although invasive species management is recommended for all areas, such a widespread implementation is probably unrealistic (on the basis of cost). Therefore, planting plans for all implemented restoration efforts, including bank regrading and channel realignment, should complement the invasive species management plan by recommending appropriate native planting to supplement areas where invasives have been eliminated. This will ensure that some problem areas are addressed, if not along the full reach lengths.

Create/Enhance Riparian Wetlands

Land currently available for reforestation located adjacent to the channel is also ideal for wetland creation. Wetland creation adjacent to the channel is best suited to those areas where stream relocation and realignment are suitable. Because stream relocation and realignment typically involve large quantities of grading, replanting the disturbed areas can be customized to create specific habitats. Wetlands, a rich habitat that relies on saturated soils and vegetation adapted to these conditions could be created concurrently with channel relocation and realignment. Therefore, the best opportunities for wetland creation are adjacent to those channels that are also suitable relocation /realignment sites.

Further investigation of all potential restoration and realignment sites should include the following: rainfall data collection and evaluation, runoff calculations, soils investigation, water budget, native species investigation, and groundwater monitoring. Ideally, groundwater levels for all potential wetland creation sites should be monitored to determine their suitability prior to design. Advantages of wetland creation are groundwater recharge, increased habitat, increased plant and animal species diversity, and improved water quality.

Enhance Riparian Outfall

They are several concrete-lined storm drain outfall conveyance channels that could be eradicated for wetland enhancement purposes. These lined channels were intended to rapidly divert flow from the outfall directly to the channel. However, stormwater could instead be redirected into the adjacent broad, wooded areas to create forested wetlands or vernal pools to enhance water quality and riparian habitat.

4.2.6 Remove Channel Impediments

In some locations along Biddison and Moores Run, hardened structures along the bed and banks are restrictive to aquatic species and limit habitat opportunities. To enhance aquatic and riparian habitat, the removal of several fish barriers and once concrete bank revetment is recommended.

Remove Fish Barrier

Large structures or facilities within the channel interrupt natural flow patterns and alter the hydrology and hydraulics of the stream in which they are present. These structures may also pose a significant obstacle to the natural movement of fish within the stream. There are several locations where either man-made or channel-formed obstructions impede fish passage, particularly at road crossing culvert aprons and exposed sanitary lines. These obstructions can lead to a series of channel changes including bank and bed erosion. It should be noted that careful evaluation of all environmental costs and benefits, specifically habitat and any potential historical significance associated with each structure must be taken into consideration.

Remove Concrete Revetment

Near the upstream end of Reach T, an extensive concrete bank revetment has contributed to adjacent bed scour and bank erosion across the stream. A softer approach such as minor regrading with planting and/or soil bioengineering would help improve stability and habitat through this section.

4.2.7 Maintain Infrastructure

The repair of outfalls and sewer lines is important to preventing drainage problems, localized erosion, and improving water quality.

Repair Outfalls

The outfall pipes of Baltimore City's stormwater drainage system can sustain damage where they enter the stream. Much of the damage noted on Moores and Biddison Run is related to the scouring of soil from the banks surrounding the outfall pipe and headwall. This scour generally leads to the detachment of the end section of pipe and headwall from the bank. Repair of these damaged stormwater outfall pipes would involve the stabilization of the bank and/or redirect flow away from the bank.

Repair Sewer lines

There are several locations along both Moores and Biddison Run where, at the time of the cruised reach assessment, portions of the City's sanitary lines were in disrepair and leaking sewage material along the channel. Repairs at these locations, if not already complete, are critical to reducing nutrient enrichment and improving water quality and instream habitat.

4.2.8 Install Trash Rack

Debris, or trash, is abundant along the bed and banks of both Biddison and Moores Run. The installation of trash racks could decrease the delivery of debris to the stream network. Reductions in trash include reestablishing natural flow patterns, decreasing nutrient levels, improving water quality, and improving habitat for macroinvertebrate and aquatic vegetation species. Manual removal (e.g., community stream cleanups) would also help eliminate trash already introduced to streams. Other techniques that would prevent additional litter inputs include additional public education discouraging littering, littering enforcement, regular street sweeping, and recycling opportunities.

4.3 LAND MANAGEMENT STRATEGIES

Although not expressly part of this Stream Assessment and Restoration Concept Plan, land management strategies would also benefit the watershed particularly with *preventative*, rather than reactive, measures.

Developed land management strategies include nonstructural approaches such as 1) preservation of natural areas and open space (and riparian buffer enhancement described above), 2) reduction in impervious surfaces, 3) drainage structure maintenance, and 4) public awareness and education. These applications are effective means of reducing the amount and impacts of nonpoint source pollution, and improving habitat.

4.3.1 Preservation of Existing Forested Areas

Although not widespread in the Herring Run watershed, existing forests are extremely valuable habitat. Throughout existing developed lands and for future development in the Herring Run subwatershed, it is recommended that native plant communities and forest be preserved wherever feasible. These areas should be protected and managed, if necessary, to preserve the small amount of forested riparian buffer present surrounding both Biddison and Moores Run. This is particularly important where unique natural areas are located, such as large contiguous tracts of forestland, meadow areas, broad riparian zones, etc.

The benefits of riparian buffer preservation include improved pollution removal, runoff infiltration, stream shading, channel stability, and aquatic and terrestrial habitat. A continuous riparian corridor should be maintained or established with adequate width that is in keeping with natural stream processes at a site. (For example, meandering channels may need a wider riparian zone than step-pool channels). In no case should the riparian width be less than adequate to provide a minimum level of shading and organic debris recruitment to the stream. Educational/informational signage, creating small parks or designated green space, and installing fences or prohibiting access in areas where the riparian area has been disturbed are additional strategies to help preserve existing forests.

4.3.2 Reduction of Impervious Surfaces

Stream channels within the Biddison Run and Moores Run watersheds have responded to high density development and increased runoff through downcutting and overwidening in an attempt to accommodate higher flows. Since there is little land available for reforestation or to protect from becoming developed, the amount of existing impervious surfaces should be reduced. Examples of strategies to reduce the amount of existing impervious surfaces and/or the amount of runoff include:

- √ Stormwater management basins – both wet/dry ponds have the ability to collect storm flow, hold water temporarily and release water to a stream at a constant rate. Disadvantages of basins are finding the available land to build them and the associated maintenance over many years. In areas where additional development is still possible, or re-development may occur, stormwater management ponds are a suitable method to reduce runoff. Planned species selection for vegetating the pond perimeter, banks, and edges may also help reduce nutrients delivered to streams. Similarly, in areas where adequate space is not available, grass swales can be used to increase infiltration while decreasing the velocity of runoff prior to delivering it to the streams.

- √ Bioretention – bioretention facilities are similar to stormwater management ponds in their function, but differ since they are much better suited for small areas. Bioretention facilities can be installed next to parking lots, curbs, major roads, etc. to immediately catch runoff, filter sediment and allow rainwater to infiltrate back into the groundwater table. These facilities are well suited to the Biddison and Moores Run watersheds because the majority of the watershed is already developed, available space is limited, and the size and shape of bioretention facilities are extremely adaptable.

- √ Parking Lot Island Installation and Plantings – parking lot islands can be installed and planted within large paved areas to create less contiguous impervious surfaces. Islands can be depressed to catch stormwater and planted to provide water quality benefits, shade and aesthetic value. Often, planted parking lot islands can serve dual purposes and provide water quality benefits if they are also bioretention facilities. At a minimum, efforts should aim to steady the existing percent impervious surfaces associated with parking lots. When and if the opportunity arises, unnecessarily paved and oversized parking lots could be converted to have smaller spaces and contain islands to create less contiguous paved surfaces. Parking lots and other paved right-of-ways should also be evaluated when adding or relocating utilities. To fully utilize existing paved surfaces instead of creating new impervious surfaces utilities could be located underneath existing pavement.

4.3.3 Appropriate Road and Culvert Maintenance

Managing existing infrastructure is an important component in protecting channels within the Biddison and Moores Run watersheds. A drainage structure not functioning properly can affect receiving culverts, pipes, manmade ditches, and channels. Malfunctioning culverts and ditches can lead to increased erosion and scour and flooding. Maintenance in these areas includes removal of debris, spot stabilization of eroding areas, assessment of vegetation to determine appropriateness and erosion resistance, and assessment of ditch lining adequacy. By maintaining those drainage structures already present in the watershed, many potentially serious erosion problems will be prevented.

Often inappropriately sized culverts or poorly stabilized roads will impact a channel through eroding the bed and banks. Bed scour may cause a headcut or knickpoint that is capable of migrating upstream. A headcut or knickpoint will continue to scour the bed and deepen the channel as it moves upstream until it is inhibited by a natural bed formation or man-made structure resistant to erosion. Although the headcut or knickpoint may have stopped migrating, it is still present in the channel and if channel conditions change may begin to migrate again.

4.3.4 Public Education

Public education provides opportunities to relate the importance of stream habitat and stability and to influence and/or change the behavior of residents. Public education begins with public involvement. One principle avenue for educating residents is through forming local watershed groups. Local watershed groups are most effective when strong, mutually beneficial relationships are established early between the volunteers and local government agencies. Fortunately, the Herring Run Watershed Association is already effective in coordinating many efforts within the watershed. The Herring Run Watershed Association and volunteers communicate and work together to educate neighbors through activities such as stream clean-ups, revegetating stream banks, long-term monitoring, and publishing articles in the local newspaper(s), among many other activities.

5.0 REACH RESTORATION CONCEPTS

The following section briefly describes the recommended restoration approaches for the four distinctive reaches. These proposed restoration concepts are also depicted on the foldouts in the Appendix D, E, F, and G of this report. Photographs of many of the problems within these reaches are included in Appendix H. Preliminary cost estimates for the reaches are included in Appendix I.

5.1 RESTORATION CONCEPTS FOR REACH O, BIDDISON RUN

Of the 24 reaches delineated and evaluated, Reach O received the lowest (poorest) ranking for channel stability and fell within the lower third for habitat. Bank instability is widespread, resulting in the delivery of fine sediment to the bed and high riffle embeddedness. In many locations, the channel is widening at the base of the banks, causing bank materials to slough off into the channel. Bank erosion is especially pronounced in the more sinuous sections, where the radius of curvature is too tight for the size of the channel. In some areas, artificial bank protection is providing short-term defense from bank failure.

The majority of the channel has incised historically, also contributing to bank erosion processes. Some signs of ongoing bed degradation appear at the upstream end of the reach. Bedrock outcrops are minor and weathered (saprolitic), so they do not affect channel dynamics or restrict bed degradation.

Instream habitat and riparian areas are relatively intact, and appear to be of less concern than channel stability problems. However, invasive riparian species are abundant and cover the majority of riparian areas. Multiple sewage leaks were identified during the cruised reach assessment, and are elevating nutrient levels. In addition, multiple fish barriers are present, but are not easily remedied. Trash is a significant and pervasive problem throughout the stream corridor.

STA 93+39 – STA 79+00 (Sipple Avenue to arbitrary station):

- Installation of trash collection structure at the culvert outfall of Biddison Run on the south side of Sipple Avenue at STA 93+39.

- Channel realignment from STA 91+75 to STA 88+00 to alleviate bank erosion on the right bank and exposure of sanitary line. Filling of the abandoned channel and regrading of the steep eroded banks of the old channel.
- Riparian forest buffer enhancement along the left bank from STA 93+39 to STA 88+25 and along the right bank from STA 90+00 to STA 80+50.
- Installation of grade control structures at STA 84+25 and STA 80+75 to stabilize the downcutting of channel bed.
- Reduction of left bank slope from STA 80+50 to STA 79+25 using bank grading.
- Stabilization of toe of slope and stabilize the toe of slope on the right bank from STA 80+50 to STA 79+50.

STA 79+00 – STA 63+00 (arbitrary station to Goodnow Road):

- Channel realignment from STA 78+75 to STA 73+00 to alleviate severe bank erosion on the right bank. Filling and enhancement of the abandoned channel and grading of the steep eroded banks of the old channel.
- Riparian forest buffer replanting and enhancement along both banks of the realigned channel from STA 78+75 to STA 72+25.
- Localized bank stabilization with sections of revetments and bank grading from STA 72+50 to 70+00.
- Repair of stormwater outfall on left bank at STA 71+00.
- Floodplain wetland enhancement on left bank floodplain from STA 69+00-64+00. Removal of three concrete troughs across the floodplain at STAs 68+25, 67+75, and 63+25 to redirect stormflow into the floodplain wetland.
- Localized left bank grading from STA 68+75 to STA 68+35.
- Repair of sanitary line and stabilization of bank with toe protection from STA 67+50 to 65+75.
- Channel realignment from STA 64+25 to STA 63+00 to alleviate severe bank erosion. Filling and enhancement of the abandoned channel.

Access:

- From the south side of Sipple Avenue at STA 93+39 on the left bank.
- From the driveway of a private apartment complex around STA 80+50 on the right bank.
- From powerline right-of-way connecting Goodnow Road to STA 72+50.
- From established access road from Goodnow Road at STA 64+50.

5.2 RESTORATION CONCEPTS FOR REACH P, BIDDISON RUN

Reach P received the fourth poorest rating for channel stability, but scored relatively well with respect to habitat. Bank stability problems are extremely spatially variable. The majority of the channel is moderately incised, which has led to oversteepened banks and reduced function of the floodplain. Bank erosion is especially severe along the outside perimeter of meander bends.

In the upper portions of the reach from Sinclair Lane to Moravia Park Drive, the reach displays depositional patterns suggestive of a highly mobile bed, but these processes are neither chronic nor problematic (and cause only local transient aggradation). As a result, restoration techniques in this reach are generally not extensive and instead involve minimal channel work. There are several sections in particular (e.g., STA 32+00 to STA 30+00) where the channel is extremely dynamic due to frequency sediment transport and debris jams fed by treefall. Again, significant restoration measures are not proposed because there is adequate lateral space to prevent any threat to nearby infrastructure. Banks in these areas are also relatively low (e.g., 1 to 4 feet), which further reduces erosion potential and allows for more frequent inundation of the floodplain.

Sections of Reach P downstream of Moravia Park Road include more significant channel stability problems, which necessitate the use of more extensive approaches, such as channel realignment, extensive bank regrading, and installation of step pools.

At least one leaking sewer line was noted during the cruised reach assessment, but other leaks may have been contributing to the smelly, gray streamflow. Several fish migration barriers exist due to steep drops from culvert outfalls or gabion revetments, and could be remedied using the techniques described below.

STA 56+50 – STA 29+25 (Sinclair Lane to Moravia Park Drive):

- Removal of a barrier to fish passage at the culvert crossing of Sinclair Lane over Biddison Run at STA 56+50.
- Channel realignment from STA 56+25 to STA 55+00 to alleviate bank erosion on the right bank. Regrade the eroded banks of the old channel.
- Repair of sanitary line at the top of slope at STA 51+50.
- Installation of grade control structure at STA 50+75 to stabilize the downcutting of channel bed. Stabilize erosion of the right bank upstream of the grade control through channel bank grading from STA 51+50 to STA 50+75.
- Floodplain wetland enhancement on left bank floodplain from STA 47+50 to STA 43+65. Removal of invasive plant species to be included.
- Stabilization of localized bank erosion with soil bioengineering on the right bank from STA 46+65 to STA 46+10, and both banks from STA 44+00 to STA 42+50.
- Installation of grade control structures at STA 42+25 and STA 38+75 to stabilize downcutting of the channel bed.
- Channel realignment from STA 38+75 to STA 36+75 to alleviate severe bank erosion on the left bank. Filling of the abandoned channel and grading of the steep eroded banks of the old channel to reduce further erosion.
- Stabilization of localized bank erosion using soil bioengineering on the right bank from STA 33+25 to 32+10.
- Grading of right bank to increase high water flows through the right cell of the Moravia Park crossing culvert at STA 30+00.

STA 29+25 – STA 17+50 (Moravia Park Drive to Moravia Road):

- Removal of a barrier to fish passage at the culvert crossing of Moravia Park Drive over Biddison Run at STA 29+00 through removal of concrete apron and raising of stream invert.

- Installation of a series of step pool structures from STA 29+00 to STA 24+25 to raise invert and prevent additional channel downcutting. Application of soil bioengineering to stabilize steep, confined banks.
- Repair of stormwater outfall on left bank at STA 24+75.
- Channel realignment from STA 24+25 to STA 18+50 to alleviate severe right bank erosion threatening Moravia Road. Filling of the abandoned channel and grading of the steep eroded banks of the old channel to prevent further erosion.
- Riparian forest buffer replanting and enhancement along both banks of the realigned channel from STA 24+25 to STA 18+50.
- Repair of stormwater outfall on the right bank at STA 20+00.

STA 17+50 – STA 0+00 (Moravia Road to confluence with Herring Run):

- Channel realignment from STA 16+00 to STA 12+00 to alleviate bank erosion on the left bank. Filling and regrading of the eroded banks of the old channel.
- Repair of stormwater outfall on the left bank at STA 15+00.
- Removal of a barrier to fish passage at the culvert crossing of an access road over Biddison Run at STA 11+00 through removal of concrete apron and raising of stream invert.
- Installation of revetment on the left bank at STA 11+00 to STA 10+65 just downstream of the access road crossing to relieve localized bank erosion.
- Stabilization of localized bank erosion on the left bank from STA 10+35 to 9+25 through bank grading.
- Removal of large metal culverts and other debris from the stream channel at STA 9+00.
- Installation of a series of step pool structures from STA 9+50 to STA 8+75 to serve as grade control structures to prevent the downcutting of channel bed and account for drop through area of removed culverts.
- Grading of both banks from STA 5+80 to STA 2+00 to form a bench creating accessible floodplain and stabilizing channel morphology.

- Installation of a series of step pool structures from STA 1+75 to STA 0+50 to serve as grade control structures to preventing the downcutting of channel bed and allow for fish passage. (This may require localized removal of gabions.)

Access:

- From powerline right-of-way connecting Truesdale Avenue to STA 43+00 on the right bank of Biddison Run.
- From parking lot on the north side of Frankford Avenue at STA 19+00 on the left bank just east of Moravia Road.
- From the driveway of the City of Baltimore Department of Public Works refuse facility on the west side of Moravia Road at STA 11+00 on the right bank of Biddison Run.

5.3 RESTORATION CONCEPTS FOR REACH T, MOORES RUN

Reach T ranks in the lowest (poorest) half of the 24 reaches in terms of channel stability and habitat. Most significant problems include moderate channel incision, localized bank erosion problems, the presence of artificial embankments, and inadequate riparian buffer widths.

Creative approaches to bank regrading (e.g., grading back just the top of banks in some areas) could significantly improve the function of the floodplain. Beneficial attributes of the existing channel include the lack of fine sediment in riffles and the lack of barriers to fish movement.

STA 90+36 – STA 57+25 (Evanshire Avenue to Radecke Avenue):

- Channel realignment from STA 90+25 to STA 88+25 to alleviate bank erosion on the right bank. Fill and regrade the eroded banks of the old channel.
- Installation of trash collection structure at the culvert outfall of Moores Run on the south side of Hamilton Avenue at STA 85+50.
- Removal of concrete channel on left bank from STA 85+50 to STA 82+25.
- Installation of toe protection from STA 85+50 to 83+50 to alleviate bank erosion.

- Stabilization of bank erosion using toe protection and bank grading on the right bank from STA 85+25 to STA 82+25.
- Channel realignment from STA 82+75 to STA 79+75 to alleviate bed downcutting and prevent erosion on the right bank.
- Filling of the old channel from STA 83+25 and STA 80+35.
- Riparian forest buffer planting and enhancement along the left bank of the realigned channel from STA 85+00 to STA 78+00.
- Installation of toe protection from STA 81+25 to STA 80+15 to protect eroding bank.
- Riparian forest buffer planting and enhancement along the left bank from STA 76+00 to STA 74+00.
- Repair of stormwater outfall on the left bank at STA 74+00.
- Riparian forest buffer planting and enhancement along the right bank from STA 74+25 to STA 69+00.
- Repair of stormwater outfall on the right bank at STA 70+60.
- Stabilization of localized bank erosion using soil bioengineering on the right bank from STA 69+25 to STA 68+90.
- Grading of the top of the right bank from STA 74+25 to STA 69+00 to create an accessible floodplain and stabilize the channel morphology.
- Installation of trash collection structure at the stormwater outfall at STA 66+00 along the left bank of Moores Run west of Moores Run Drive.
- Riparian forest buffer planting and enhancement along the right bank from STA 66+00 to STA 64+00.
- Floodplain wetland creation on right bank floodplain from STA 64+00 to STA 63+00 by redirecting stormflow into the floodplain wetland from stormwater outfall.
- Riparian forest buffer planting and enhancement along the right bank from STA 63+00 to STA 57+25.
- Stabilization of bank erosion on the right bank from STA 63+00 to 61+50 through bank grading and toe of bank protection.

Access:

- From open space/park east of Evanshire Avenue at STA 90+00.

- From private property on the south side of Hamilton Avenue at STA 84+00 on the left bank.
- From Denview Way on the east side of Moores Run at STA 69+50.

5.4 RESTORATION CONCEPTS FOR REACH U, MOORES RUN

Reach U ranks in the poorest quarter of the 24 reaches rated in terms of channel stability, but received the third best habitat ranking. As a result, restoration concepts below focus mostly on unstable sections of the reach along with significant habitat enhancement opportunities.

Because the lower portion of the reach downstream of 27+00 is surrounded by forest, this section is somewhat more capable of "self recovery" and allows more opportunities for channel realignment rather than structural approaches to remedy severe bank erosion. Because of the extensive riparian width through this section, eradication of invasive species should be less of a priority, as compared to more discrete riparian zones along other reaches.

STA 56+75 – STA 27+00 (Radecke Avenue to Todd Way):

- Stabilization of bank erosion on the right bank from STA 56+75 to STA 54+50 through bank grading.
- Riparian forest buffer planting and enhancement along the left bank from STA 55+00 to STA 52+00.
- Stabilization of left bank from STA 52+00 to STA 51+00 and stabilization of right bank from STA 52+00 to STA 50+50 with soil bioengineering where Moores Run passes through power line right-of-way. The establishment of low growing riparian shrubs will reduce maintenance of the right-of-way.
- Floodplain wetland enhancement on right bank floodplain from STA 49+00 to STA 47+50, including the redirection of flow from adjacent outfall into floodplain wetland.
- Installation of trash collection structure at the stormwater outfall on the left bank at STA 47+00 of Moores Run just south of the Cedonia Avenue crossing.

- Riparian forest buffer planting and enhancement along the left bank from STA 47+00 to STA 36+50.
- Stabilization of the left bank with soil bioengineering from STA 45+85 to 44+50.
- Grading of the top of the right bank from STA 42+65 to STA 35+75 to create an accessible floodplain and stabilize the channel morphology.
- Riparian forest buffer planting and enhancement along the right bank from STA 42+65 to STA 27+00.
- Stabilization of erosion along the left bank using toe protection from STA 35+25 to STA 32+25 and soil bioengineering from STA 32+85 to STA 31+50.
- Channel realignment from STA 32+35 to STA 28+50 to alleviate bed downcutting and prevent erosion on the right bank.
- Floodplain wetland creation on right bank floodplain from STA 31+25 to STA 29+35 in the abandoned channel.

STA 27+00 – STA 0+00 (Todd Way to confluence with Herring Run):

- Riparian forest buffer planting and enhancement along the right bank from STA 21+25 to STA 20+00.
- Channel realignment from STA 21+15 to STA 17+25 to alleviate bank erosion on the right bank.
- Floodplain wetland creation on right bank floodplain from STA 20+25 to STA 18+25 in the abandoned channel.
- Repair of stormwater outfall on the right bank at STA 18+25.
- Stabilization of the outfall along the right bank at STA 19+00.
- Stabilization of bank erosion on the left bank from STA 16+35 to STA 15+00 through bank grading.
- Stabilization of bank erosion on the right bank from STA 14+85 to STA 15+35 though bank regrading.
- Channel realignment from STA 14+65 to STA 11+75 and STA 10+00 to STA 5+00 to create a more stable geometry and alleviate bank erosion, including filling of abandoned channel adjacent to channel realignment.

- Riparian forest buffer planting and enhancement along the right bank from STA 12+25 to STA 10+50.
- Stabilization of the stormwater outfall channel from the outfall to its confluence with Moores Run using soil bioengineering on the right floodplain at STA 8+75 and STA 3+00.
- Installation of revetment on the right bank from STA 1+75 to 1+00 to relieve localized bank erosion.

Access:

- From powerline right-of-way connecting Cedonia Avenue to STA 51+50 on the left bank of Moores Run.
- From the open space/park on the west side of Cedgate Road at STA 44+00 on the left bank of Moores Run.
- From the open space/park on the east side of Denview Way from STA 44+00 to STA 27+00 on the right bank of Moores Run.
- From the open space/park on the east side of Relcrest Road from STA 20+00 to STA 9+00 on the right bank of Moores Run.

5.5 Cost Estimates of Restoration Concepts

Appendix I contains preliminary cost estimates for the construction of each of the reach restoration concepts described above. The cost estimates are based on the conceptual level of the proposed designs; therefore, they should be considered as first-order estimates of expected construction costs. For each reach, a twenty percent contingency cost is included to account for uncertainties in the cost estimate. The repair of sewer lines is not included in the cost estimates.

The cost estimates assume that all recommended measures will be implemented on a reach basis. If instead portions of a restoration concept were excluded, the cost estimate would be reduced but not necessarily in a proportional fashion (e.g., such as on the basis of linear feet). Conversely, if two contiguous reaches were constructed under the same contract and timeframe (e.g., Reaches O and P), there would likely be an “economy of scale" effect such that actual construction costs would be less than the sum of the estimated construction costs for each reach. Since implementation of the proposed restoration concepts is unlikely to occur within the next year, Appendix I also shows projected costs for the next 3 years assuming a 3% annual rate of inflation.

In the process of developing more detailed construction documents to restore Reaches O, P, T, and U, the cost estimate should be revised to more accurately reflect the extent and character of the proposed restoration techniques.

6.0 REFERENCES

Maryland Department of Natural Resources (2001). Stream Corridor Assessment Survey, SCA Survey Protocols, Watershed Restoration Division, Chesapeake & Coastal Watershed Services, September.

Rosgen, D., 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

USDA NRCS, 1998. Stream Visual Assessment Protocol. National Water and Climate Center, Technical Note 99-1.

APPENDIX A

CRUISED REACH
DATA COLLECTION SHEETS

APPENDIX B

CRUISED REACH DATA SUMMARY AND BEHI RESULTS

APPENDIX C

REACH RANKING SYSTEM

APPENDIX D

REACH O

RESTORATION CONCEPT DESIGN

APPENDIX E

REACH P

RESTORATION CONCEPT DESIGN

APPENDIX F

REACH T

RESTORATION CONCEPT DESIGN

APPENDIX G

REACH U
RESTORATION CONCEPT DESIGN

APPENDIX H

PHOTOGRAPHS OF PROBLEM AREAS
ALONG REACHES O, P, T, AND U

APPENDIX I

PRELIMINARY COST ESTIMATE FOR CONCEPT DESIGNS

PRELIMINARY CONSTRUCTION COST ESTIMATE

HERRING RUN WATERSHED

STREAM ASSESSMENT AND RESTORATION CONCEPT PLAN

ITEM	ITEM DESCRIPTION	QUANTITY				UNIT	UNIT COST	TOTAL COST			
		REACH O	REACH P	REACH T	REACH U			REACH O	REACH P	REACH T	REACH U
1	Mobilization	1	1	1	1	LS	$20,000.00	$20,000.00	$20,000.00	$20,000.00	$20,000.00
2	Construction Stakeout	1	1	1	1	LS	$20,000.00	$20,000.00	$20,000.00	$20,000.00	$20,000.00
3	Erosion and Sediment Control (includes BOF, silt fence)	1	1	1	1	LS	$10,000.00	$10,000.00	$10,000.00	$10,000.00	$10,000.00
4	Stabilized Contruction Entrance	1	3	2	3	EA	$1,500.00	$1,500.00	$4,500.00	$3,000.00	$4,500.00
5	Clearing & Grubbing (includes tree removal)	1	1	1	1	LS	$20,000.00	$20,000.00	$20,000.00	$20,000.00	$20,000.00
6	Pump Around - Maintenance of Stream Flow	1	1	1	1	LS	$20,000.00	$20,000.00	$20,000.00	$20,000.00	$20,000.00
7	Salvaging and/or Furnishing and Placing Topsoil										
	Salvaging and Placing Topsoil	16,350	10,018	10,187	21,483	SY	$2.50	$40,875.00	$25,045.00	$25,467.50	$53,707.50
	Furnishing and Placing Topsoil	5,450	3,339	3,396	7,161	SY	$4.00	$21,800.00	$13,356.00	$13,584.00	$28,644.00
8	Channel or Stream Change Excavation (Excess)										
	Realign & Relocate Channel	6,050	3,986	5,056	11,688	CY	$25.00	$151,250.00	$99,650.00	$126,400.00	$292,200.00
	Regrade Banks	1,269	1,081	1,500	1,611	CY	$25.00	$31,725.00	$27,025.00	$37,500.00	$40,275.00
	Grade Top of Slope	0	0	2,000	2,519	CY	$25.00	$0.00	$0.00	$50,000.00	$62,975.00
	Grade Bench	0	1,333	0	0	CY	$25.00	$0.00	$33,325.00	$0.00	$0.00
	Create/Enhance Riparian Wetland	1,050	537	192	659	CY	$25.00	$26,250.00	$13,425.00	$4,800.00	$16,475.00
9	Revetment										
	Stabilize Toe of Slope (assume boulder toe protection)	50	0	217	151	TON	$85.00	$4,250.00	$0.00	$18,445.00	$12,835.00
	Install Revetment (assume boulder bank protection)	81	15	0	38	TON	$85.00	$6,885.00	$1,275.00	$0.00	$3,230.00
10	Install Grade Control (assume rock cross vane)	2	3	0	0	EA	$3,625.00	$7,250.00	$10,875.00	$0.00	$0.00
11	Step/Pool	0	2,795	0	0	TON	$85.00	$0.00	$237,575.00	$0.00	$0.00
12	Soil Bioengineering (includes associated earthwork)	0	1,545	25	1,200	LF	$18.00	$0.00	$27,810.00	$450.00	$21,600.00
13	Remove Concrete Channel (Enhance Riparian Outfall) or Revetment	14.6	0	80.4	0	CY	$50.00	$730.00	$0.00	$4,020.00	$0.00
14	Remove Fish Barrier (those not addressed by step pools)	0	2	0	0	EA	$5,000.00	$0.00	$10,000.00	$0.00	$0.00
15	Repair Outfalls	1	3	2	1	EA	$5,000.00	$5,000.00	$15,000.00	$10,000.00	$5,000.00
16	Manage Invasive Species	2.8	5.2	3.1	5.2	AC	$15,000.00	$42,000.00	$78,000.00	$46,500.00	$78,000.00
17	Planting Trees & Shrubs with Permanent Seeding	5.8	3.5	3	6.7	AC	$30,000.00	$174,000.00	$105,000.00	$90,000.00	$201,000.00
18	Trash Rack	1	0	2	1	EA	$2,000.00	$2,000.00	$0.00	$4,000.00	$2,000.00
19	Stream Restoration Certification As-Built	1	1	1	1	LS	$25,000.00	$25,000.00	$25,000.00	$25,000.00	$25,000.00
20	Temporary Seeding	1	1	1	1	LS	$5,000.00	$5,000.00	$5,000.00	$5,000.00	$5,000.00
	SUBTOTAL							**$635,515.00**	**$821,861.00**	**$554,166.50**	**$942,441.50**
	20% Contingency							$127,103.00	$164,372.20	$110,833.30	$188,488.30
	TOTAL (July 2004)							**$762,618.00**	**$986,233.20**	**$664,999.80**	**$1,130,929.80**
					REACH LENGTH (LF)			3039	5700	3336	5700
					COST/LF			$250.94	$173.02	$199.34	$198.41

CALCULATION OF TOTAL GIVEN ASSUMED ANNUAL INFLATION OF 3%

2004	**$762,618.00**	**$986,233.20**	**$664,999.80**	**$1,130,929.80**
2005	$785,496.54	$1,015,820.20	$684,949.79	$1,164,857.69
2006	$809,061.44	$1,046,294.80	$705,498.29	$1,199,803.42
2007	$833,333.28	$1,077,683.65	$726,663.24	$1,235,797.53
2008	$858,333.28	$1,110,014.16	$748,463.13	$1,272,871.45

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