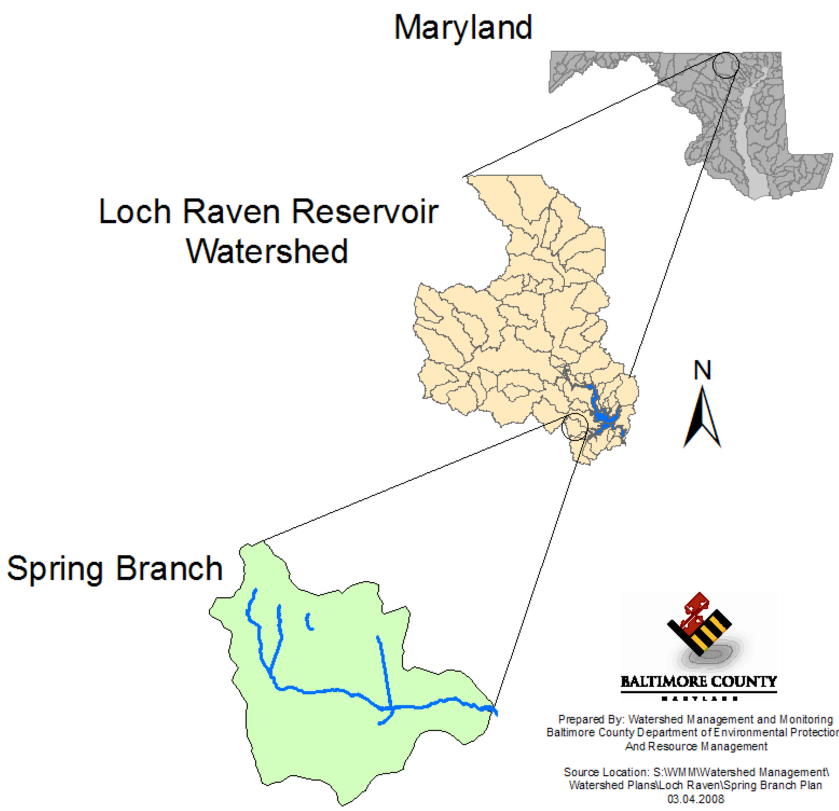
Spring Branch Subwatershed -
Small Watershed Action Plan

(Addendum to the Water Quality Management Plan for Loch Raven Watershed)

Volume 1



Prepared by

Baltimore County

Department of Environmental Protection and Resource Management

401 Bosley Avenue, Suite 416, Towson, MD 21204

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CHAPTER 1

INTRODUCTION

1.1 Project History and Background

The Baltimore County Department of Environmental Protection and Resource Management (DEPRM) initiated the Spring Branch Small Watershed Action Plan in 2008 in response to US Environmental Protection Agency comments regarding the Loch Raven Plan inadequacy in meeting the EPA generated A through I criteria for watershed planning. This plan follows in the footsteps of prior and continuing efforts to address the environmental conditions of the Loch Raven Reservoir watershed. The previous and continuing efforts include:

- Reservoir Management Agreement (1979 through 2005)
- Water Quality Management Plan for Loch Raven Watershed (1997)
- Source Water Assessment (2004)

Reservoir Management Agreement

Loch Raven Reservoir is one of three reservoirs in the Baltimore Metropolitan System serving 1.8 million people. Spring Branch is one of the subwatersheds within the Loch Raven Reservoir watershed that drains directly to the reservoir. The Loch Raven reservoir is owned and operated by Baltimore City. As a result of algae blooms within the reservoirs in the 1970s, a Reservoir Management Agreement was signed in 1979. The first Reservoir Watershed Management Agreement was signed by Carroll County, Baltimore City, and Baltimore County, in a coordinated effort to mitigate emerging pollution problems and establish the basis for continual water quality improvement in the reservoirs. In 1984, 1990, and 2005 the Reservoir Management Agreement was updated and re-signed by the cooperating jurisdictions and agencies. The updates strengthened the declarations within the Agreement. The primary goals of the Agreement are the reduction of phosphorus inputs to the reservoirs to prevent algal blooms and the resultant degradation of water quality, and the reduction of sediment input to the reservoirs to maintain capacity. The agreement sets up a Reservoir Technical Group to develop and implement a Reservoir Watershed Action Strategy. The Technical Group is composed of representatives of the jurisdictions and agencies signing the Agreement and is facilitated and coordinated by the Baltimore Metropolitan Council. The text of the latest agreement can be found at:

http://www.baltometro.org/RWP/ReservoirAgreement2005.pdf

The Reservoir Action Strategy can be found at:

http://www.baltometro.org/RWP/RWPActionStrategy2005.pdf

The website also contains updates on the status of the implementation of the Action Strategies.

Water Quality Management Plan for Loch Raven Watershed

Tetra Tech, Inc. developed the Water Quality Management Plan for Loch Raven Watershed in 1997 under contract to Baltimore County Department of Environmental Protection and Resource Management. The plan included the development of a pollutant load model using the EPA Storm Water Management Model (SWMM) for the entire watershed, stream stability assessments (based on case study areas), overall watershed characterization, a management planning analysis, and the development of management planning areas and management actions. Due to the size of the Loch Raven watershed (~140,000 acres) and limitation on funding availability, a case study approach was taken for the stream stability assessment, while the balance of the analysis was conducted watershed wide. Fourteen subwatersheds out of 46 subwatersheds were selected for the stream stability assessment. The selected subwatersheds provided a representation of the distribution of the land use within the Loch Raven Reservoir watershed and included subwatersheds dominated by urban, suburban, agricultural, and forest land uses. The Spring Branch subwatershed was not selected for inclusion in the case study assessments, as the stream had already been selected for a stream restoration project and a detailed assessment of the stream had already been completed (see Appendix F, *Spring Branch Stream Restoration – Conceptual Plan Report* (Biohabitats, 1995)).

Source Water Assessment

A Source Water Assessment was conducted by Maryland Department of the Environment to meet the requirements of Section 1453 of the Safe Drinking Water Amendments of 1996. This assessment found that nitrates were the most common pollutants found in groundwater supplies. Urban development and agricultural activities were the most common sources of contaminants. Agricultural land contributed nutrients and microbial pathogens. Runoff from urban land contributed excessive sediment and deicing compounds.

1.2 Spring Branch Subwatershed Watershed Overview

The Spring Branch is a 1,005-acre subwatershed located in the Loch Raven Reservoir watershed (Basin No. 02130805), which in turn is located in the Gunpowder River Basin (Figure 1-1). The Spring Branch subwatershed is in the Piedmont region of Maryland. The subwatershed drains directly to southwestern portion of the Loch Raven Reservoir. It was primarily developed in the 1950-1970 time period and predates the environmental regulations that are currently in place. The controlled storm water discharge resulted in severe stream erosion within the subwatershed.

Prior to 1980, to address the problems in Spring Branch, Baltimore County straightened, and channelized Spring Branch to maximize land for development and to divert stormwater. Sizing of many bridges and culverts frequently did not account for flows during large storms, subsequently causing backwater effects and flooding. Sewer lines were installed in the stream valleys for gravity flow and ease of construction. Structures were built close to stream banks without accounting for water level increases during large storms, and storm drains linked impervious surfaces directly to streams. The removal of vegetative buffer areas and development of vast areas of impervious surface compounded adverse effects on this stream. At the time, there was little understanding of the influence these practices would have on long-term stream stability and water quality.

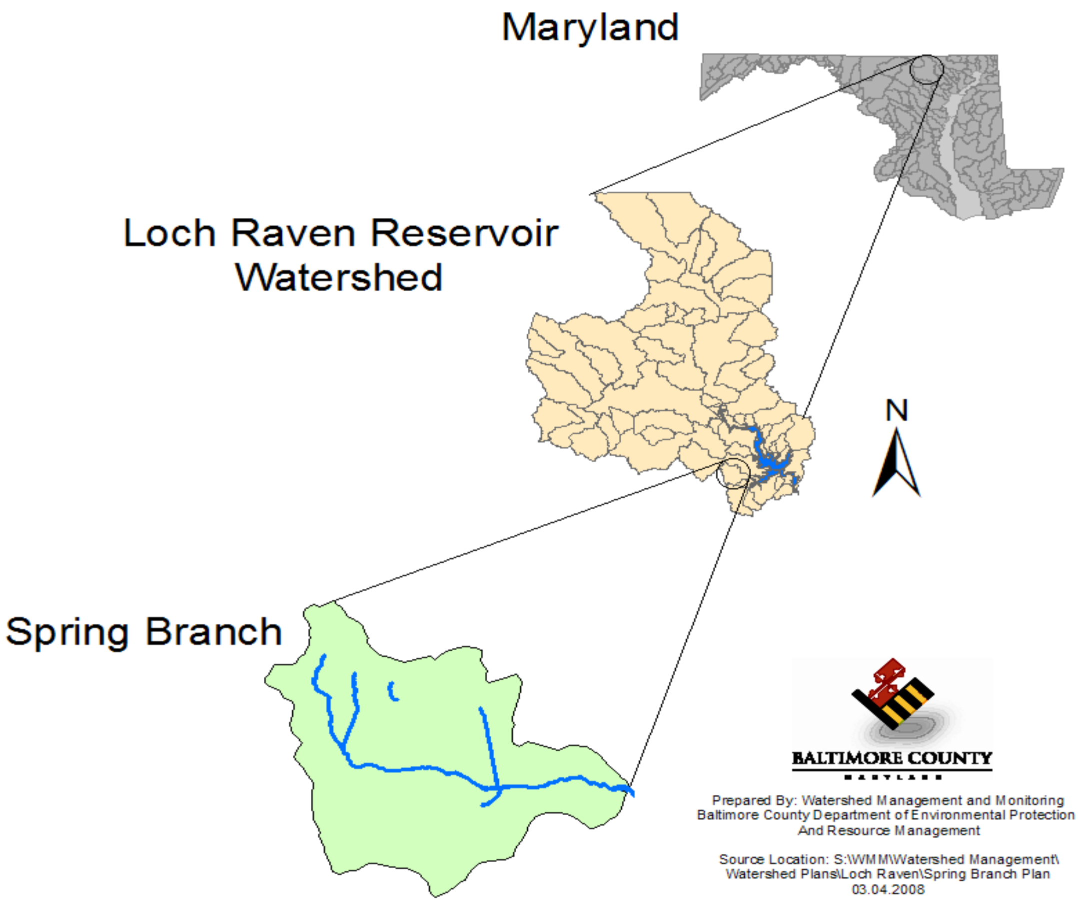

Figure 1-1: Location of the Spring Branch Subwatershed.

1.3 Document Organization

This plan is organized in five chapters. Chapter 1 presents a short overview of previous planning efforts and a brief description of the subwatershed.

Chapter 2 presents a characterization of the subwatershed, including a GIS analysis of the landscape features, a summary of existing data, and a pollutant loading analysis based on the Loch Raven Total Maximum Daily Load for Phosphorus and Sediment.

Chapter 3 presents the overall subwatershed goals and objectives, stakeholder outreach, and education efforts.

Chapter 4 summarizes the plan for restoration of the Spring Branch subwatershed.

A series of appendices provides additional detailed information used in the development and support for the Spring Branch Small Watershed Action Plan (SWAP). These appendices include:

- Appendix A – A description on how the Spring Branch SWAP process meets the US Environmental Protection Agencies A through I Criteria for watershed planning.
- Appendix B1 – Public Outreach.
- Appendix B2 - Public Response and Technology Transfer.
- Appendix C – A copy of the Chesapeake Bay Program – Best Management Practice pollutant load reduction credits.

In addition, a second volume of appendices of supporting documentation on the condition of the Loch Raven Reservoir watershed is provided. This second volume includes:

- Appendix D – *Spring Branch Stream Restoration – Conceptual Plan Report* (Biohabitats, 1995)
- Appendix E – *Lower Spring Branch – Preliminary Assessment Analysis Report* (Biohabitats, 2005)
- Appendix F – *Lower Spring Branch – Concept Report* (Biohabitats, 2006)
- Appendix G – *Total Maximum Daily Loads of Phosphorus and Sediments for Loch Raven Reservoir and Total Maximum Daily Loads of Phosphorus for Prettyboy Reservoir, Baltimore, Carroll and Harford Counties, Maryland* (MDE 2007)

Chapter 2

Characterization

2.1 Introduction

The physical aspects of a watershed provide the background and context for the associated biological and hydrological processes, as well as for the development that takes place on the land at the hands of man. In this chapter, we will describe both the natural physical context and the human use and present state of the land in the Spring Branch subwatershed. Included in this chapter will be a summary of water quality and living resources.

The Spring Branch subwatershed lies mainly within the Piedmont Region of Maryland. The natural Piedmont landscape is characterized by rolling hills, extensive forests, thick soils on deeply weathered crystalline bedrock, and abundant forest litter that minimizes overland flow.

This chapter will be presented in five parts: the first will document the natural background state of the natural resources of the basin (Section 2.2), the second will describe the present state of the landscape as it is now, after several centuries of human modification (2.3), the third will present the monitoring data available for Spring Branch (2.4), the fourth will discuss the 303(d) listings and the TMDLs applicable to Spring Branch (2.5), and the last section will present the Spring Branch pollutant loading analysis (2.6).

2.2 The Natural Landscape

The natural landscape includes many factors that provide the background context and foundation for land use. Among the factors are the physiographic province, the underlying geology and the surface soils, the climate that effects the formation and erosion of soils, the stream drainage system, and the forest and wetland cover.

2.2.1 Climate

The climate of the region can be characterized as a humid continental climate, with four distinct seasons modified by the proximity of the Chesapeake Bay and Atlantic Ocean (DEPRM, 2000). Rainfall is evenly distributed through all months of the year, with most months averaging between 3.0 and 3.5 inches per month. Storms in the fall, winter, and early spring tend to be of longer duration and lesser intensity than summer storms, which are often convective in nature with scattered high-intensity storm cells. The average annual rainfall, as measured at the

Westminster Police barracks, is ~44 inches per year. The average annual snowfall is approximately 21 inches, with the majority of accumulation in December, January, and February.

The climate of a region affects the rate and form of soil formation and erosion patterns, and, by interacting with the underlying geology, influences the stream drainage network pattern and the resulting topography. Climate also affects the distribution and composition of the flora and fauna of the aquatic and terrestrial ecosystems.

2.2.2 Location and Physiogeographic Province

The Spring Branch subwatershed is located in the Cockeysville area to the west of the Loch Raven Reservoir. The Spring Branch subwatershed lies mainly within the Piedmont Physiographic Province, with the lower portion overlapped by geological formations more typical of the Coastal Plain Physiographic Province. The highest point of the subwatershed, located just south of Padonia Road, is 536 feet in elevation. The lowest point in the watershed is located Spring Branch discharges to the reservoir, which is 242 feet in elevation. The Piedmont Physiographic Province is characterized by rolling hills of varying steepness dissected by streams that occur in dendritic drainage patterns.

2.2.3 Geology

The headwaters of Spring Branch subwatershed are located at the top of a geological feature known as the Texas Dome. This is an area of local uplifting characterized by a relatively flat top and steep sides. The geological formations of the Spring Branch subwatershed are shown in Figure 2-2, with the acres and percentage of each geological type shown in Table 2-1. These formations affect the chemical composition of surface and groundwater, as well as the recharge rate to groundwater. They are also key to soil formation. As such, the geology is closely correlated with water quality in pristine systems, and affects the buffering of pollution to stream systems in developed areas.

Table 2-1: Spring Branch Geology

Geology	Physiographic Province	Acres	Percent
Cockeysville Marble	Piedmont	442	44.0
Baltimore Gneiss	Piedmont	224	22.2
Setters Gneiss	Piedmont	17	1.7
Patuxent Formation	Coastal Plain	323	32.1
Total		**1006**	**100.0**

Cockeysville marble underlies 44% of the Spring Branch subwatershed. This rock type provides buffering capacity and due to solution of the bedrock generally provides a greater infiltration capacity for the overlying soil. Approximately a quarter of the underlying bedrock is gneiss. This bedrock type is metamorphic. The density and distribution of cracks in this rock type control the amount of water holding capacity of the bedrock. This may be limited. The Patuxent Formation, an unconsolidated formation, underlies one-third of the subwatershed. This unconsolidated formation is associated with the Coastal Plain Physiographic Province. At this location we have the interface of the Coastal Plain with the Piedmont, where the unconsolidated sediments of the Coastal Plain overlap the bedrock formations of the Piedmont.

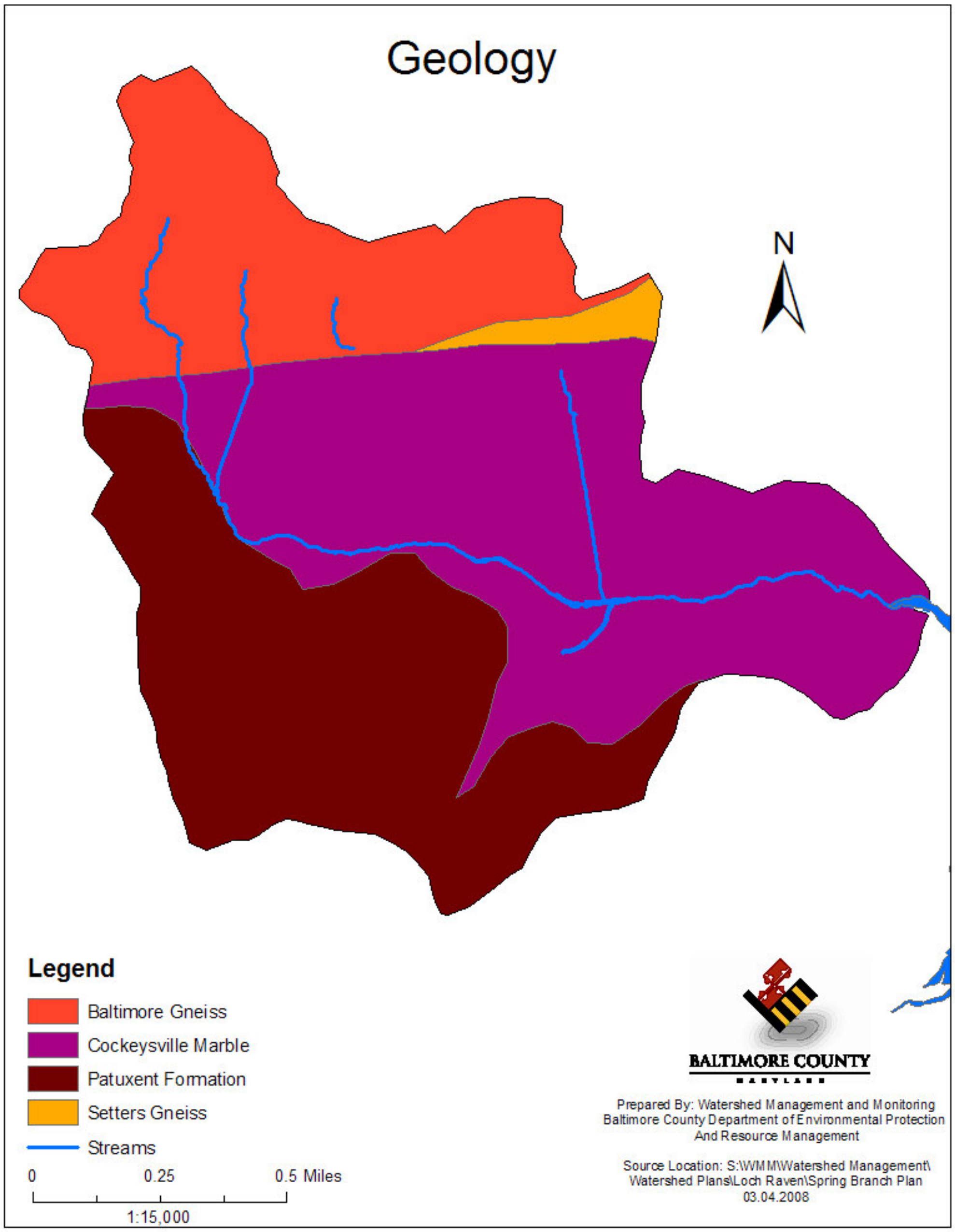

Figure 2-2: Spring Branch Subwatershed Geology

2.2.4 Topography

The shape of the land, including its steepness and degree of concavity, affect surface water flows and soil erosion, as well as the suitability for development. The Piedmont Region is characterized by rolling hills of varying steepness. Steep slopes are more prone to overland flow and soil erosion, and therefore have a greater potential for generation of pollutants. Table 2-2 displays the results for Spring Branch based on the Baltimore County Soil Survey. Figure 2-2 displays the distribution of the slope categories.

Table 2-2: Spring Branch Topography

Slope Category	Slope Range	Acres	Percent
a	0-3%	154	15.3
b	3-8%	362	36.0
c	8-15%	362	36.0
d	15-25%	103	10.2
e	>25%	25	2.5
Total		**1006**	**100**

The Spring Branch subwatershed is characterized by moderate to steep slopes thoughout most of the subwatershed. A band of high to very high slopes occurs in the upper portion of the subwatershed (Figure 2-2). This is a result of the uplifting associated with the Texas Dome geological feature. The top of the dome (above the band of steep slopes) is relatively flat, as is the base of the dome. The steeper slopes in the upper portion of the watershed provide additional energy to the stream flow due to the steeper nature of the stream channel. This can result in greater erosion of the channel after development has occurred.

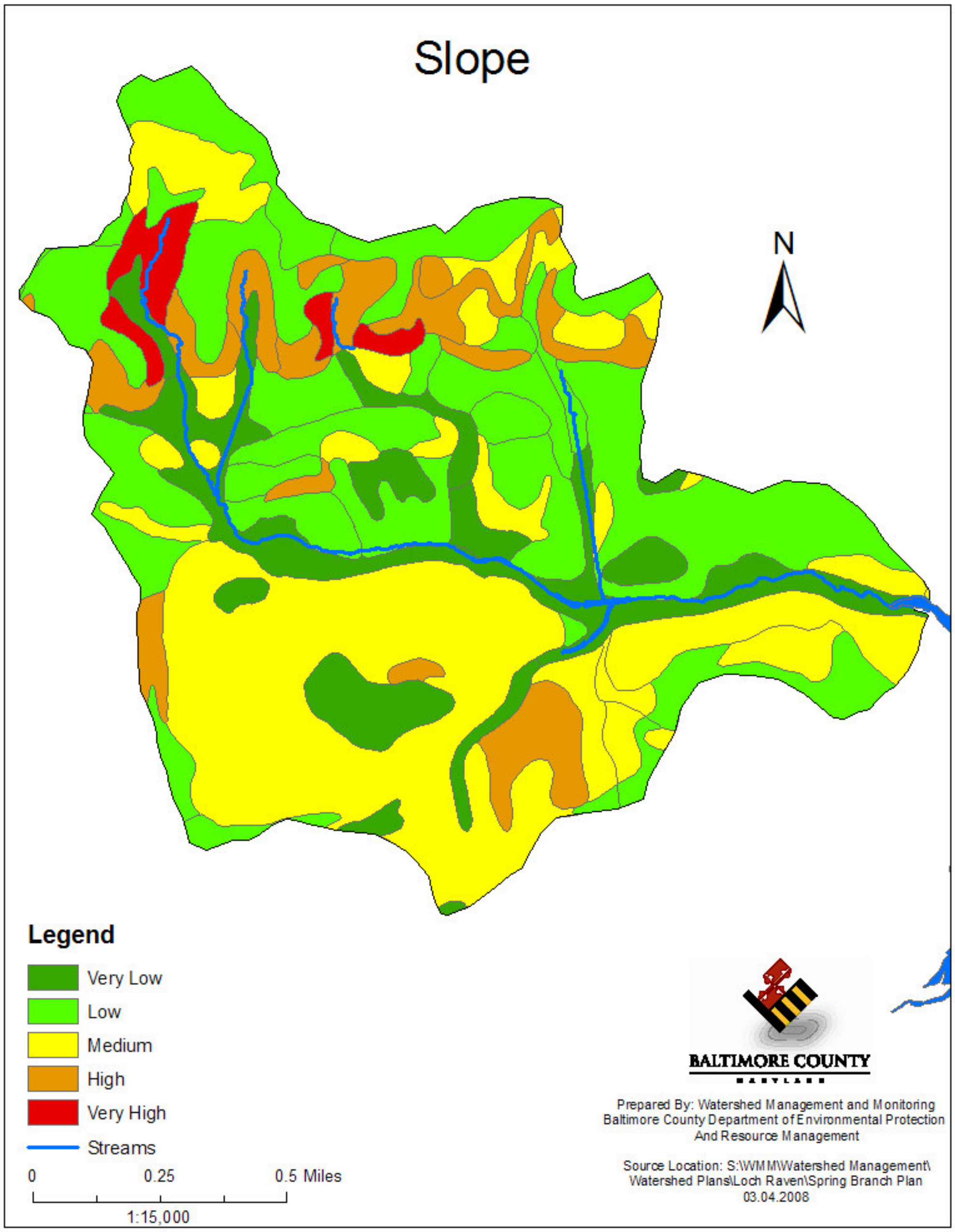

Figure 2-2. Spring branch Subwatershed Topography

2.2.5 Soils

Soil type and moisture conditions greatly affect how land may be used and the potential for vegetation and habitat on the land. Soil conditions are also one determining factor for water quality and quantity in streams and rivers. Soils are an important factor to consider in targeting projects aimed at improving water quality or habitat.

2.2.5.1 Hydrologic Soil Groups

The Natural Resource Conservation Service (USDA) classifies soils into four Hydrologic Soil Groups (HSG) based on the soil's runoff potential. Runoff potential is the opposite of infiltration capacity; soils with high infiltration capacity will have low runoff potential, and vice versa. The four Hydrologic Soils Groups are A, B, C and D, where A's generally have the smallest runoff potential and D's the greatest. Soils with low runoff potential will be less prone to erosion, and their higher infiltration rates result in faster flow-through of precipitation to groundwater. However, alluvial soils are often found to be susceptible to erosion.

Details of the hydrological soils classification can be found in 'Urban Hydrology for Small Watersheds' published by the Engineering Division of the Natural Resource Conservation Service, United States Department of Agriculture, Technical Release–55.

Group A is composed of sand, loamy sand or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well-to excessively drained sands or gravels and have a high rate of water transmission.

Group B is silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures.

Group C soils are sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water, and the soils have moderately fine to fine structure.

Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. This Hydrologic Soil Group (HSG) has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils lying over nearly impervious material.

Spring Branch subwatershed hydrologic soil group distribution is displayed in Figure 2-3 and in Table 2-3. Spring Branch soils are dominated by soil types that provide high to moderate infiltration rates. The low to very low infiltration rates are associated with soils that lie along the stream system where the high water table limits infiltration rates.

Table 2-3: Spring Branch Hydrologic Soil Groups

Hydrologic Soil Group	Infiltration Rate	Acres	Percent
A	High	271	27.0
B	Moderate	560	55.6
C	Low	70	7.0
D	Very Low	105	10.4
Total		**1,006**	**100.0**

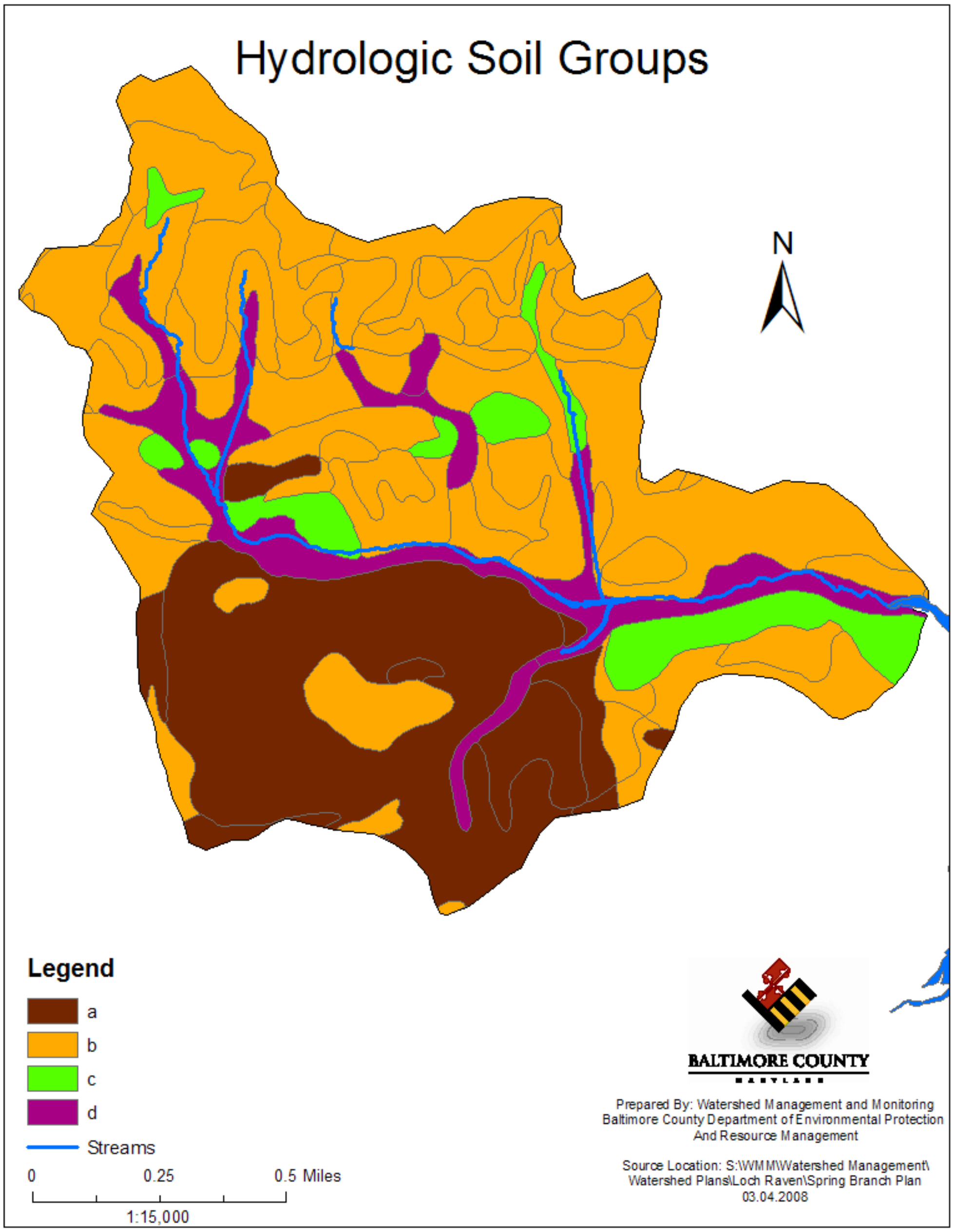

Figure 2-3. Spring Branch Subwatershed - Hydrological Soil Groups

2.2.5.2 Soil Erodibility

The erodibility of the soil is its intrinsic susceptibility to erosion. It is one factor (known as the K factor) in the Universal Soil Loss Equation, which estimates the rate of erosion at an actual site. Erodibility is based on the physical and chemical properties of the soil, which determine how strongly soil particles cohere with one another. Figure 2-4 shows soil erodibility in the Spring Branch subwatershed, and Table 2-4 is the summary erodibility factor. Low erodibility is defined as a K factor <0.24, medium is K between 0.24 and 0.32, and high is K>0.32. These classes are based on groupings in the data that resulted in three classes. They also represent the breaks used in the Baltimore County *Steep Slopes and Erodible Soils Analysis* for determining riparian buffer widths.

Spring Branch is characterized by soils that are either highly or moderately erodible. The highly erodible soils are located along the stream channel and along the face of the Texas dome.

Table 2-4: Spring Branch Erodibility

K Factor	Erodibility Category	Acres	Percent
.01 - 0.24	Low	52	5.1
0.25 - 0.32	Medium	694	69.0
>0.32	High	260	25.9
Total		**1006**	**100.0**

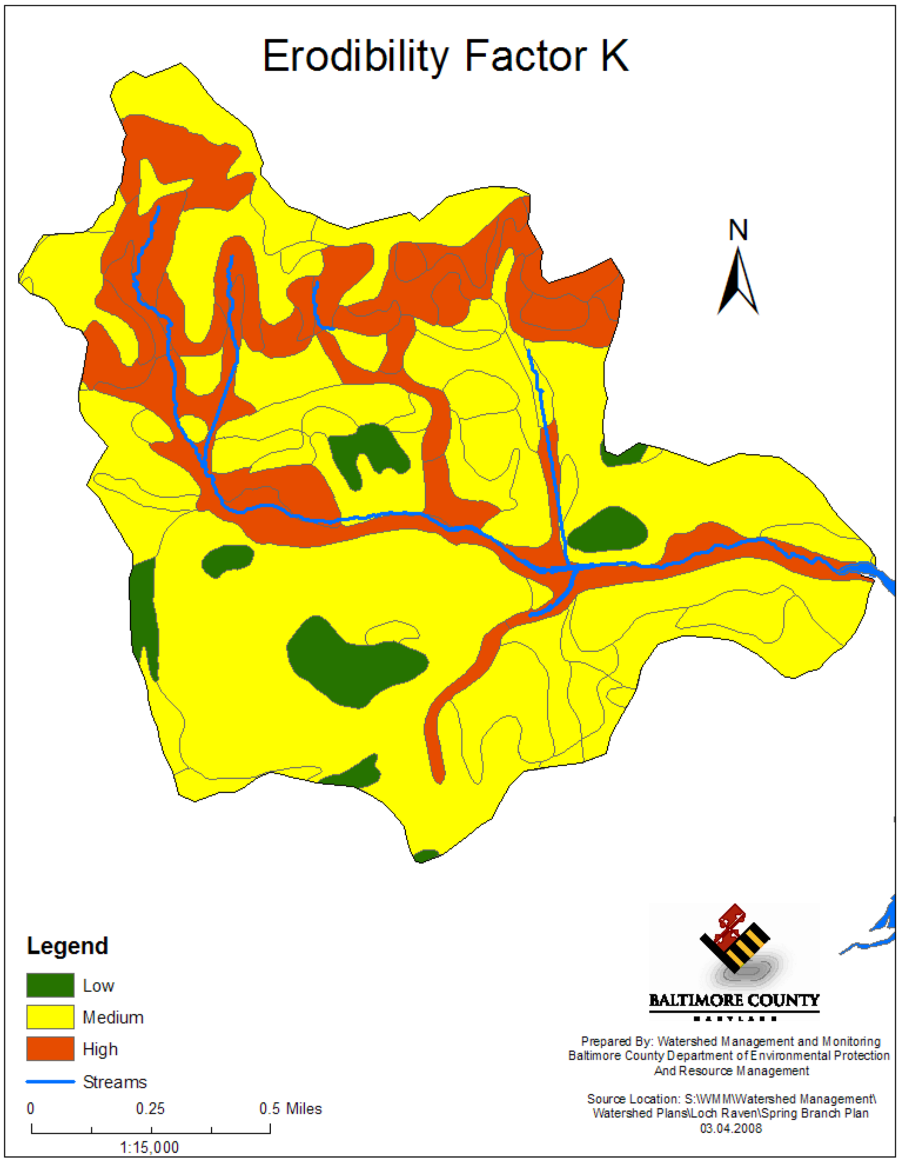

Figure 2-4. Soil Erodibility based on the K factor

2.2.6 Stream Systems

Stream systems are a watershed's circulatory system, and the most visible attribute of the hydrological cycle. Streams are the flowing surface waters, and are distinct from both groundwater and standing surface water (such as lakes), though they are connected with both of them. The stream system is an intrinsic part of the landscape, and closely reflects conditions on the land. Streams are a fundamental natural resource, with myriad benefits for plants, animals, and humans. Maintaining a healthy stream system is a priority for many individuals and organizations, and requires ensuring that stream flows and water quality closely mimic the conditions found in un-impacted watersheds.

The Spring Branch subwatershed has 3.96 miles of stream channel. This results in stream density (miles of stream/square miles of drainage area) of 2.52. Compared to Other Piedmont streams this stream density is low and indicates that some of the stream channel has either been buried or the hydrology has been altered in such a fashion that perennial baseflow is not supported in the remaining channel. The last is evident in the southern portion of the subwatershed where a concrete swale has replaced the stream channel and is dry except during storm events. In order to address the erosion in the mainstem of Spring Branch, concrete had been installed in previous years. Prior to the restoration much of the concrete had deteriorated with increased erosion.

2.3 The Human Modified Landscape

The natural landscape has been modified for human use over time. The intensity of this modification has increased, starting with the colonization of Maryland in the 1600s. This modification has resulted in environmental impacts to both the terrestrial and aquatic ecosystems. This section will provide a characterization of the human modified landscape and will explain how that modification is associated with impacts on the natural ecosystem. The characterization will progress from the general characteristics of land use and land cover to specific human impacts including impervious cover, drinking water and wastewater, storm water systems, discharge permits, zoning, and build-out analysis.

2.3.1 Land Use

Based on MDP 2002 GIS land use data, the Spring Branch subwatershed is predominately urban in nature. Table 2-5 tabulates the acreage by land use category, while Figure 2-5 displays the distribution within the subwatershed.

Table 2-5: Spring Branch Land Use

Land Use Category	Land Use Description	Acres	Percent
11	Low Density Residential	332	33.0
12	Medium Density Residential	551	54.8
13	High Density Residential	37	3.7
16	Institutional	18	1.7
41-43	Forest	67	6.7
Total		**1,005**	**99.9**

As can be seen from Table 2-5 the majority of Spring Branch is residential (91.5%) of varying degrees of density, but the bulk of the residential in is the medium density residential category. Forest cover accounts for only 6.7% of the land use, with the majority in the lower portion of the watershed. Forest cover is underestimated based on the land use. There exists an extensive canopy cover as can be seen in Figure 2-6.

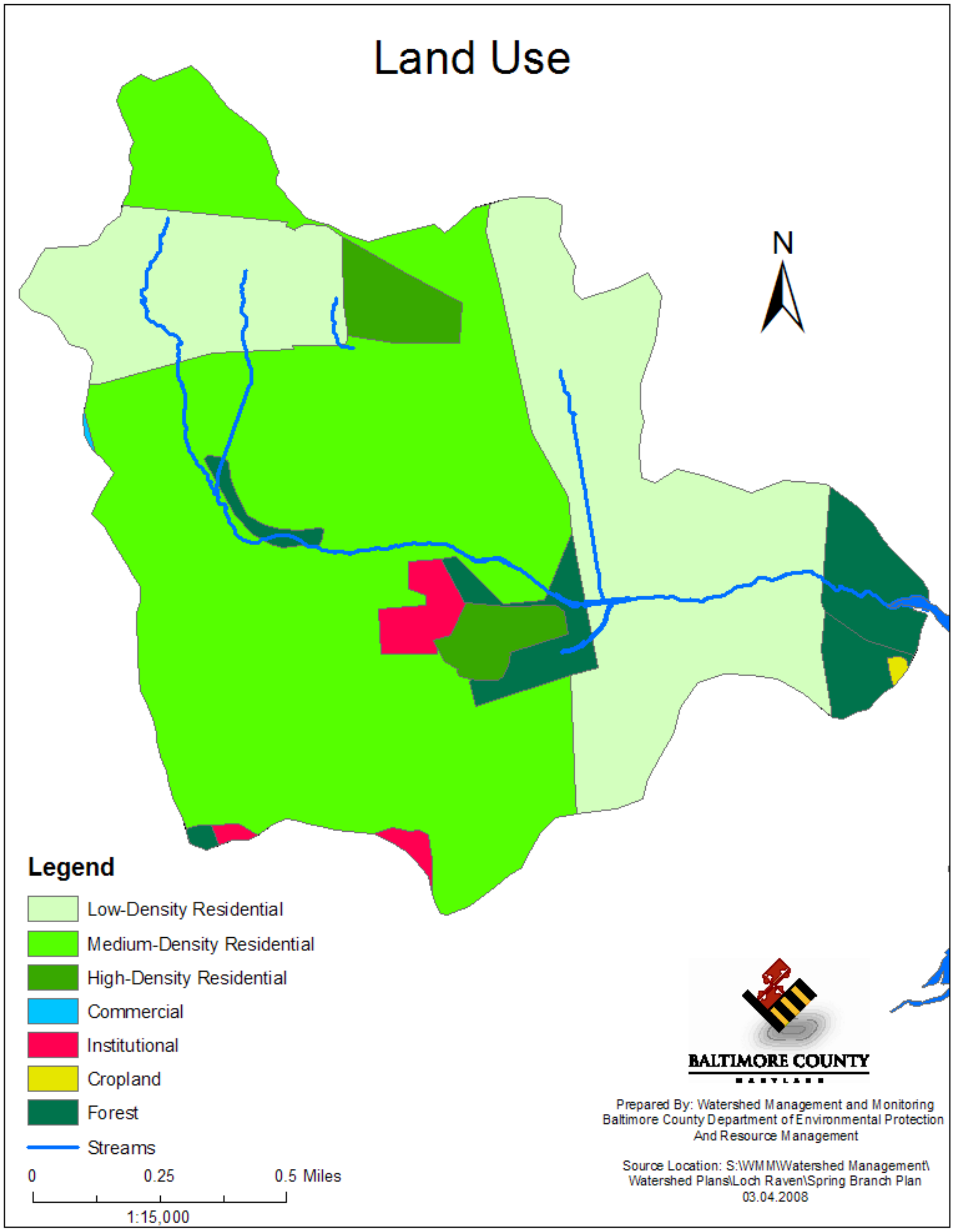

Figure 2-5. Spring Branch Subwatershed – Land Use

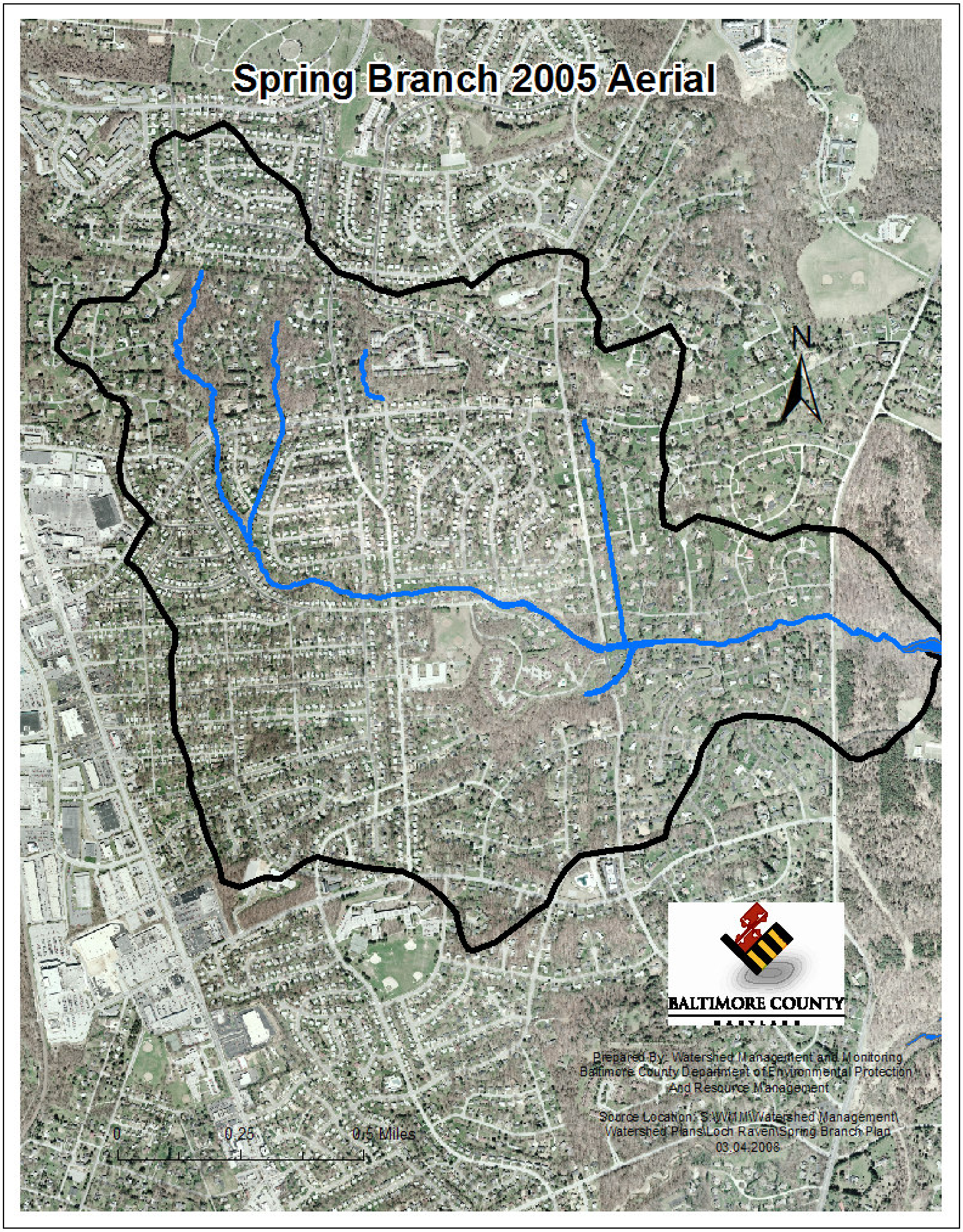

Figure 2-6: Spring Branch Aerial

Land use has pronounced impacts on water quality and habitat. A forested watershed diminishes erosion, absorbs nutrients and slows the flow of water into streams. Roads, parking areas, and roofs are collectively called impervious surface. Impervious surfaces block the natural seepage of rain into the ground. Unlike many natural surfaces, impervious surfaces typically concentrate stormwater runoff, accelerate flow rates, and direct stormwater to the nearest stream. This can cause bank erosion and destruction of in-stream and riparian habitat. Watersheds with small amounts of impervious surface tend to have better water quality in local streams than watersheds with greater amounts of impervious surface.

2.3.2 Impervious Surfaces

To derive estimates of impervious surface acreages in the Spring Branch subwatershed a GIS analysis using the digitized 'footprint' of impervious surfaces based on the interpretation of aerial photographs from 1997 was used. Two data layers were created, one that displays roadways and parking lots, and a second that displays buildings, including sheds and detached garages. Sidewalks and driveways were not captured as part of either GIS data layer, therefore, the impervious cover estimate will be a little lower than the actual impervious cover. Table 2-6 shows acreages covered by buildings and roads, while Figure 2-7 displays the distribution.

Table 2-6: Spring Branch Impervious Cover

Category	Acres	Percent
Roads	94.6	9.4
Buildings	92.8	9.2
Total	**187.4**	**18.6**

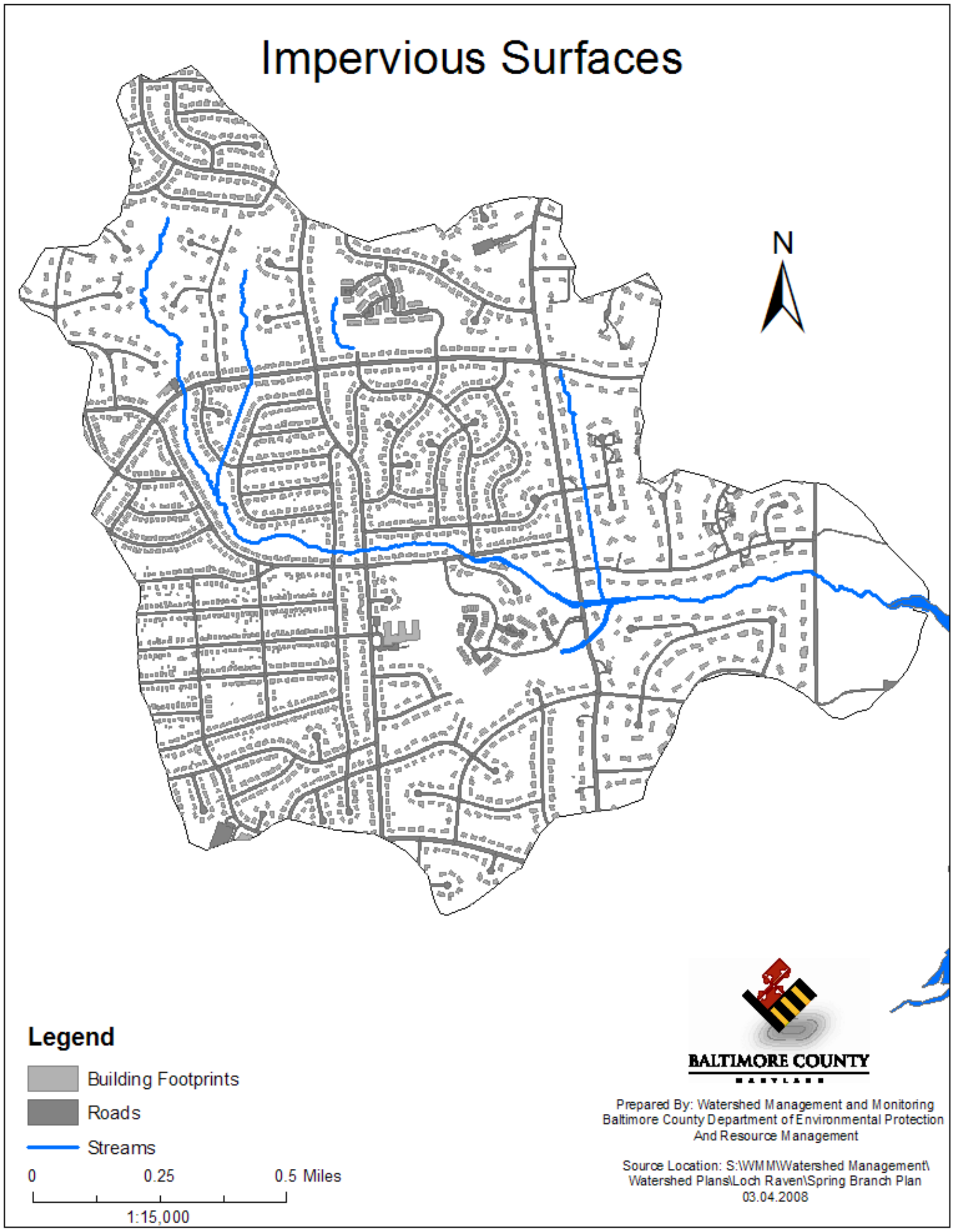

Figure 2-7: Spring Branch Impervious Cover

2.3.3 Wastewater

Wastewater created through human use must be treated and disposed. This may be accomplished in two ways, either through on-site individual wastewater treatment systems (septic systems) or through public conveyance to a municipal wastewater treatment plant. Residential wastewater consists of all of the water that is typically used by residents, including wash water, bathing water, human waste, and any other rinse water (paint brush, floor washing, etc). Spring Branch is entirely served by public sewer.

A public sewer system conveys wastewater from individual residences or businesses to a facility that treats the wastewater prior to discharge. The system itself consists of the building sewer and cleanouts on individually owned properties. The individual landowner is responsible for the maintenance of this part of the system. The part of the system that is in the public right-of-way is owned and maintained by the local government. The public system consists of the gravity piping system, access manholes, pumping stations, and force mains.

Environmental impacts associated with the public sewer system are usually the result of sewage overflows. These overflows usually result from blockages within the sewage system, pumping station failures, infiltration or exfiltration of sewage effluent due to sewer line deterioration/failure. The environmental impacts themselves include high Biological Oxygen Demand, nutrients, bacteria, and turbidity.

Within Spring Branch subwatershed there are 22.8 miles of public gravity sewer lines and 0.67 miles of force mains. The locations of these lines are displayed in Figure 2-8. While many of the lines are located in the street right-of-way, there are also lines that parallel the streams system. The lines adjacent to streams are subject of exposure and damage from stream erosion. Prior to the Phase I – Spring Branch stream restoration project, a number of lateral lines were exposed by stream erosion and were leaking sewage into the stream channel. A review of our Sanitary Sewer Overflow (SSO) database indicted that no sanitary sewer overflows occurred in Spring Branch in the time period of 2001 through 2007.

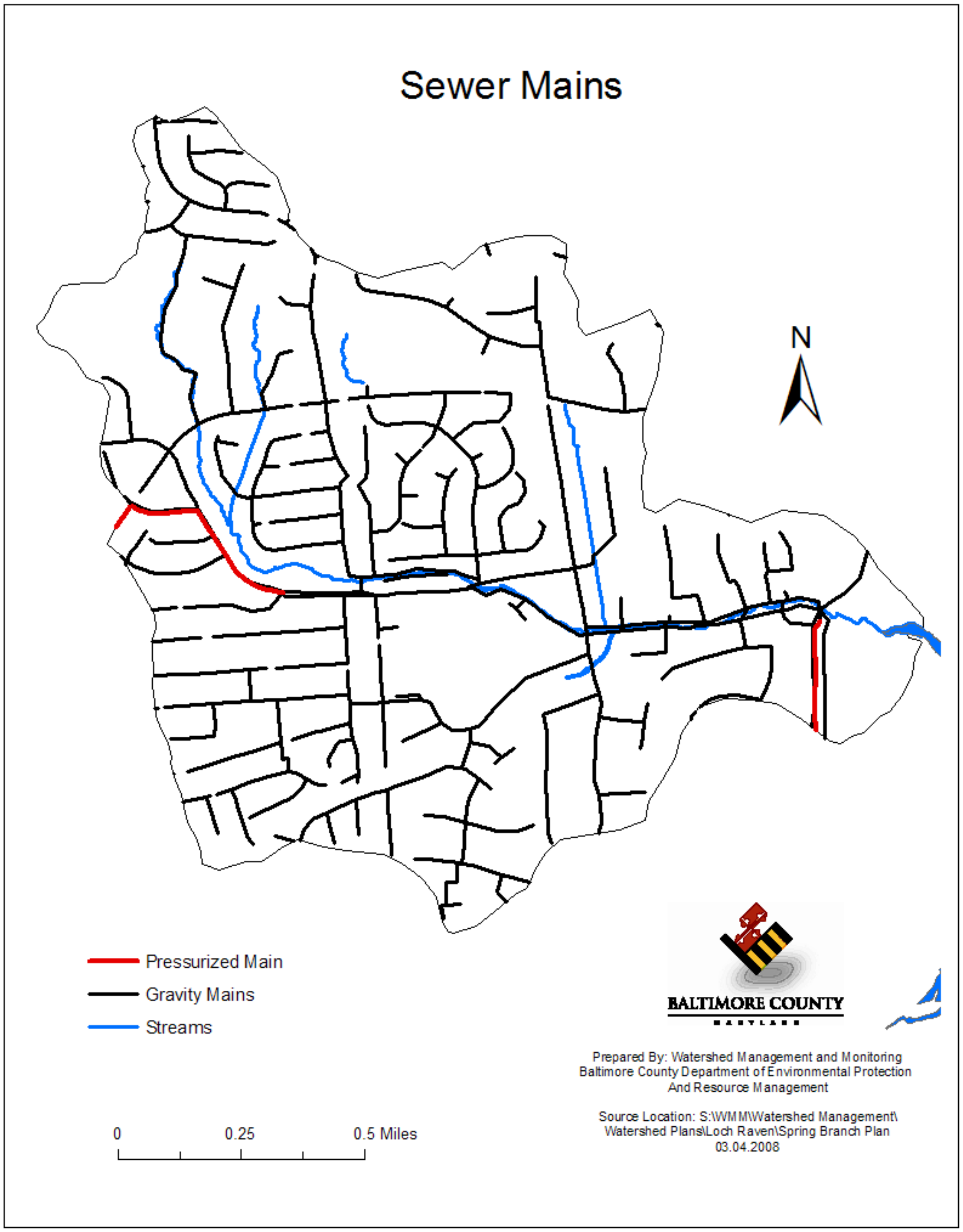

Figure 2-8: Spring Branch Subwatershed Public Sanitary Sewer Line Locations

2.3.4 Stormwater

Stormwater consists of the surface and shallow subsurface water that runs off during and immediately after storm events. Impervious surfaces placed in a watershed increase the amount of runoff that makes its way to the streams. Soil characteristics and slope as well as the amount and intensity of rainfall affect the amount of runoff water. Stormwater can carry pollutants from impervious surfaces and agricultural operations into the streams. The increase in the amount of runoff due to impervious surfaces (high) and agricultural operations (moderate) typically results in stream erosion that destroys natural habitat and impairs natural ecological function of the stream.

The storm drainage system consists of either, curb and gutter, with associated inlets and piping system, or drainage swales. The function of either system is to remove water quickly from roadways to prevent flooding and other potentially hazardous situations. However, the environmental impact from the two types of systems is different. The curb and gutter system with inlets, piping and storm drain outfalls removes water quickly from impervious surfaces and routes that water to low spots in the topography, usually directly to the nearest stream. This type of system delivers not only increased volumes of water, but untreated pollutants associated with impervious surfaces. Drainage swales (road side ditches) do not move the water as efficiently as curb and gutter systems. Therefore, the water is slowed somewhat prior to entering the stream. The drainage swales also allow some infiltration into the soil, thus reducing the amount of water eventually delivered. The infiltration and the slower movement of water also provide some filtering of pollutants. The majority of the storm drainage systems within the Spring Branch subwatershed fall into the curb and gutter category.

Starting in the mid-1980s, stormwater management was required by Maryland Department of the Environment for new development to control the quantity of runoff. The State's stormwater management regulations evolved from the initial requirement for control of water quantity to including water quality control in the early 1990s. In 2000 a new stormwater design manual was released by MDE requiring additional water quality and quantity controls along with stormwater management for large-lot subdivisions.

There are a variety of types of stormwater management facilities that have different pollutant removal capabilities. The initial dry pond design for water quantity management has the lowest pollutant-removal efficiency, while those facilities that infiltrate or otherwise filter the water have among the highest pollutant-removal capabilities.

Table 2-7 characterizes the storm drain system within the Spring Branch subwatershed, while Table 2-8 summarizes the information the stormwater management facilities present in the subwatershed. Figure 2-9 shows the distribution of both the storm drain system and the stormwater management facilities.

Table 2-7: Spring Branch Storm Drainage System Characteristics

	Major >36" Diameter	Minor <36" Diameter	Total
Number of outfalls	9	41	50
Number of inlets	40	151	191
Length of Storm Drain (feet)	7,565	19,335	26,900
Acres	329	282	611

Drainage to the storm drain system covers 61% of the subwatershed drainage area. This storm drain conveyance provides fast delivery of runoff to the stream during storm events resulting in a quick response to the stream system.

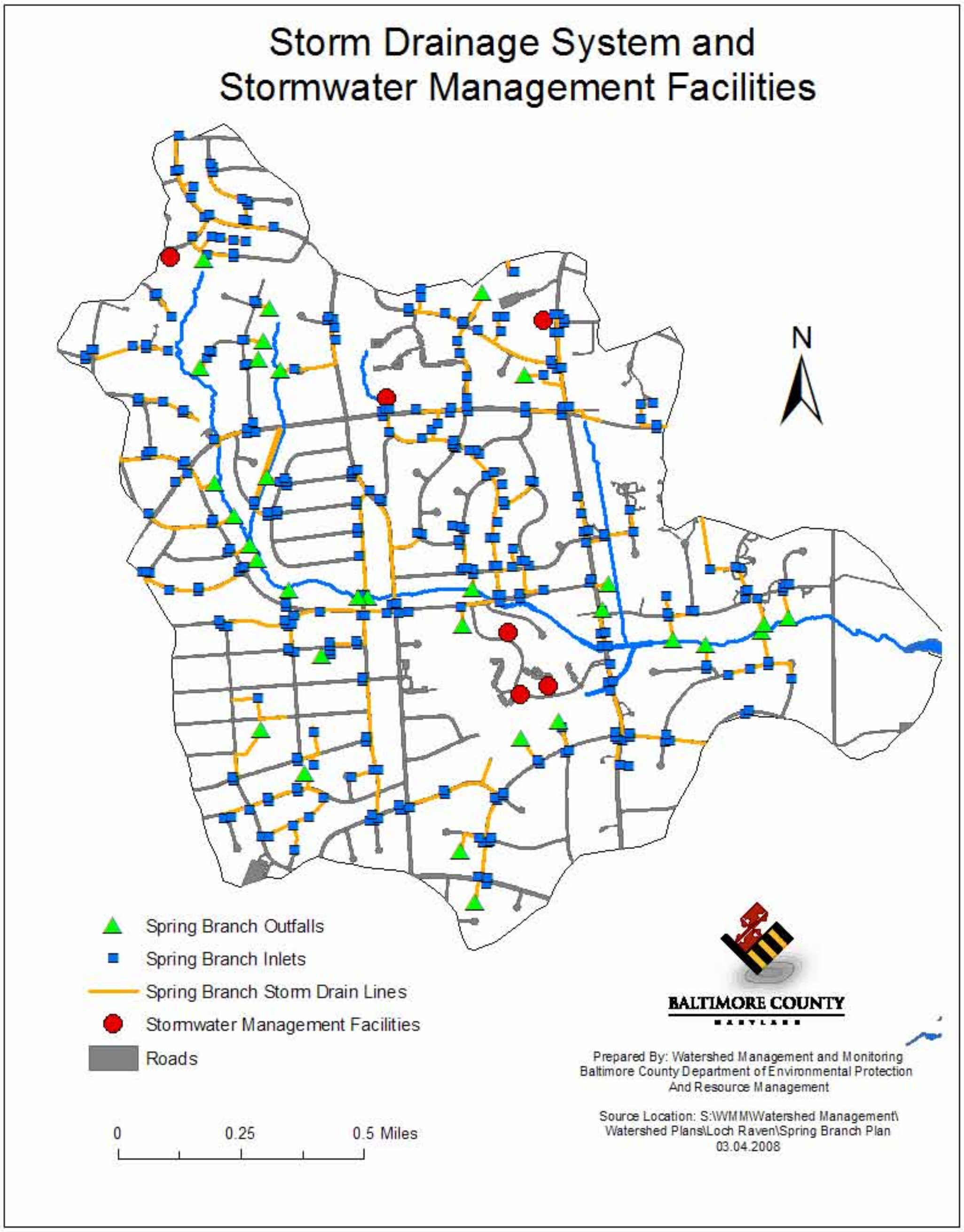

Figure 2-9: Spring Branch Subwatershed Storm Drain System and Stormwater Management

Table 2-8: Spring Branch Stormwater Management Facilities

Storm Water Structure Number	Structure Type	Drainage Area	Ownership	Year Approved
138	Dry Pond	11.43	Private	1981
956	Underground Storage	3.65	Private	1977
957	Underground Storage	2.81	Private	1977
958	Underground Storage	2.80	Private	1977
1020	Dry Pond	6.81	Public	1991
2880	Wet Pond (Retrofit)	45.37	Public	1996
		72.87		

Only 7.2% of watershed area is served by stormwater management. This is reflective of the fact that the majority of development in the subwatershed occurred prior to the implementation of stormwater management requirements. In fact, some of the earliest stormwater management facilities installed occur in this subwaterhsed. The wet pond, which serves 45.37 acres was installed as part of the Spring Branch Restoration – Phase I.

2.3.5 Zoning and Build-Out

"Zoning is the legal mechanism by which county government is able, for the sake of protecting the public health, safety, morals, and/or general welfare, to limit an owner's right to use privately-owned land." (Baltimore County Office of Planning, 2003). Zoning therefore controls the development patterns that occur over time. Build-out is the analysis of the number of residential units that could be built in a given area, based on the current zoning. Build-out looks at the existing development and, based on the density (allowable housing units), attempts to determine how many more residential units can be built in the future. This analysis is conducted to estimate the potential future impacts due to urban development.

Historical Development

Using the tax parcel Geographic Information System data layer, the decade of lot improvement can be determined. Table 2-9 presents the information on when residential development occurred in Spring Branch and Figure 2-10 displays the distribution of residential development by decade.

Table 2-9: Spring Branch Historical Development Patterns

Decade of Development	Number of Residential Units	Percent
<1930's	5	0.2
1930's	4	0.2
1940's	67	3.3
1950's	984	48.6
1960's	608	30.0
1970's	201	10.0
1980's	144	7.1
1990's	10	0.5
2000's	2	0.1
	2,025	**100**

As can be seen from Table 2-9, the majority of the residential development in Spring Branch occurred in the 1950's and 1960's with 79% of the development occurring in those two decades. The 1970's experienced a decrease in residential development with only 201 units built.

Stormwater management requirements were mandated in 1984. The last two decades have seen limited development within the subwatershed with the addition of only 12 more houses.

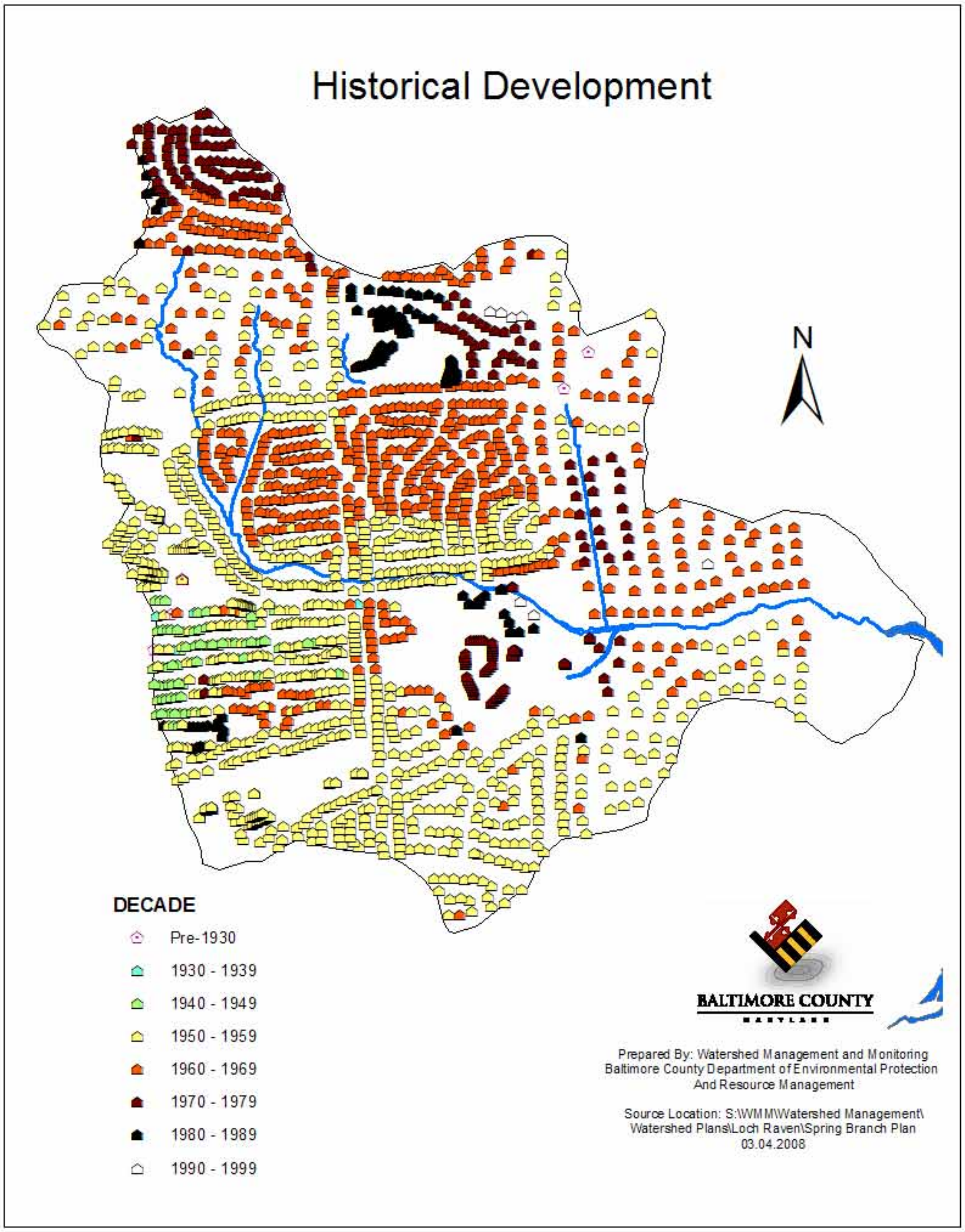

Figure 2-10: Spring Branch Historical Development

Zoning

The zoning for the Spring Branch subwatershed is strictly residential with varying allowable densities. Table 2-10 presents the acreage by zoning category and the number of allowable residential units based on the acreage. Figure 2-11 displays the distribution of the zoning categories.

Table 2-10: Spring Branch Zoning

Zoning Category	Allowable Density	Acres	Percent	Number of Allowable units
DR1	1 unit per acre	226.4	22.5	226
DR2	2 units per acre	254.4	25.3	508
DR3.5	3.5 units per acre	284.5	28.5	995
DR5.5	5.5 units per acre	193.8	19.3	1065
RC7	1 unit per 25 acres	46.3	4.6	1
		1,005.4	**100**	**2,795**

Approximately 52% of the subwatershed is zoned for low density residential (DR1, DR2, RC7), while the balance is zoned for medium density residential (DR3.5, DR5.5). A comparison with Table 2-9 on historical development would indicate thatan additional 773 residential units can be developed within the subwatershed.

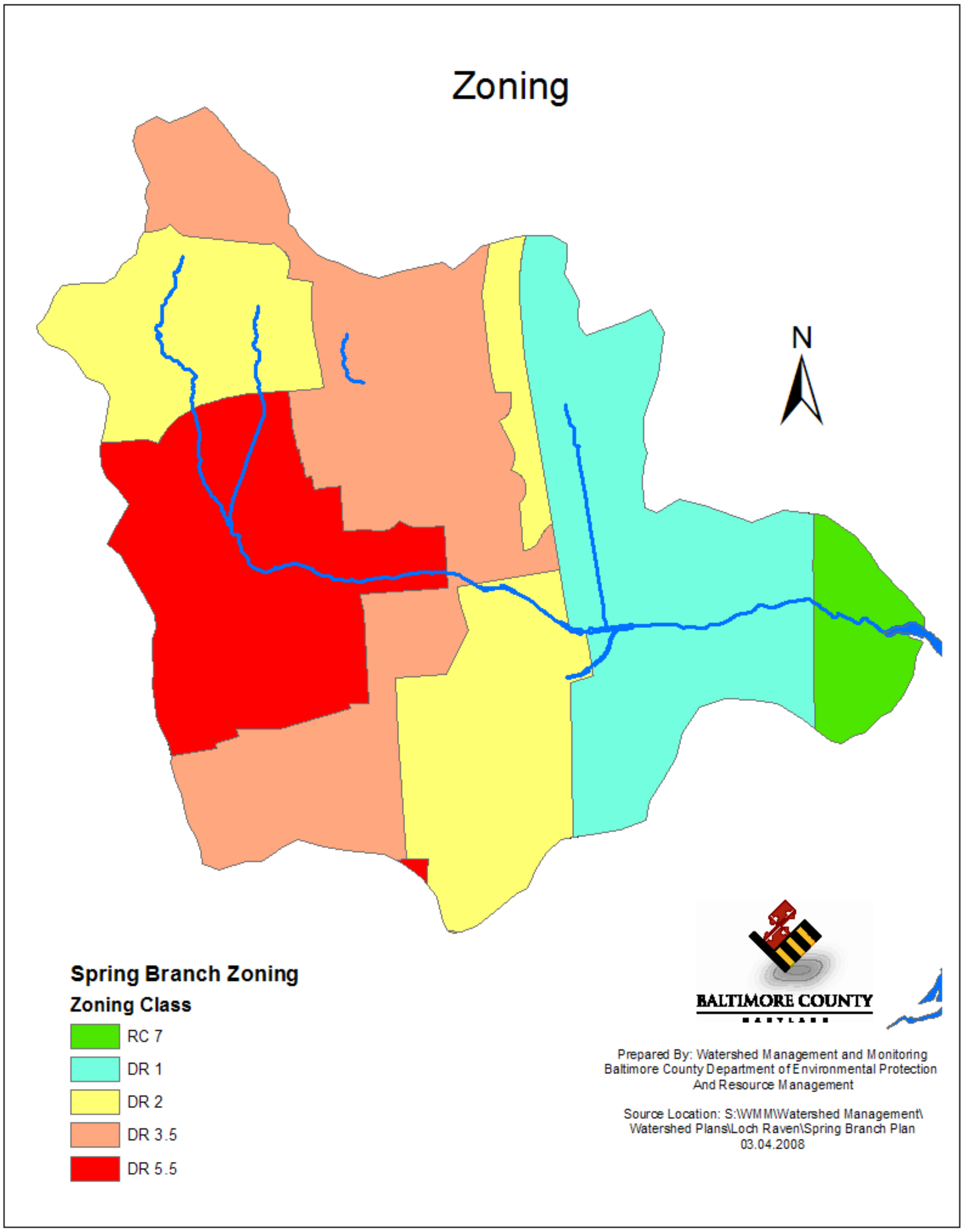

Figure 2-11. Zoning in the Spring Branch Subwatershed

Subwatershed Build-Out

The watershed build out analysis for the Spring Branch subwatershed was conducted using the zoning data layer and the parcel tax assessment data layer to identify improved properties. The maximum legal density was used to assess the number of potential new residential units for properties that have already been improved, (but are below full density) and for un-improved properties. The publicly owned land and roadways were excluded from the analysis, as these lands will not be developed. The results are displayed in Table 2-11.

Table 2-11: Spring Branch Build-Out Analysis

Zoning Category	Acres	Built Acres	Public Lands & Roads	Acres Available for New Development	Number of Allowable units	Number of Built Units	Potential Number of New Units	Minor Sub Units	Total New Units
DR1	226	189	18	19	226	203	20	1	21
DR2	254	192	23	36	508	365	72	0	72
DR3.5	285	199	46	40	995	805	140	27	167
DR5.5	194	143	32	19	1065	647	107	18	125
RC7	46	0	46	0	1	0	0	0	0
	1,005	**723**	**165**	**114**	**2,795**	**2,020**	**339**	**46**	**385**

There were a few improved lots that were above the allowable zoning density. If these lots were to be subdivided a total of an additional 46 units could be developed (Table 2-11, Minor Sub column). After removing the acreage of public lands and roadways, only 114 acres are available for new development. While the zoning would indicate that a total of 2,795 residential units could be built (an additional 773 units over the existing 2,022 existing units), this analysis indicates that only 385 more units could be developed within the subwatershed. However, based on the trend exhibited under the historical development discussion, it is anticipated that any new residential development will be limited.

2.4 Monitoring Data

Monitoring within the Spring Branch subwatershed commenced in 2004 as part of our NPDES MS4 Permit application. At that time it consisted of storm event chemical monitoring only. In 2005 the chemical monitoring continued under our first 5-year NPDES-MS4 Permit. The site had been selected based on the stream having been selected for a stream restoration project. The chemical monitoring took place at an outfall located at the headwaters of the stream and in-stream just prior to Potspring Road. This was also the extent of the stream restoration project. Additional chemical monitoring was conducted in the adjacent Long Quarter Branch subwatershed; again with a headwater storm drain outfall monitoring location and an in-stream monitoring location. This permitted a paired watershed, up-stream down-stream, before-after, comparison to determine the pollutant load reductions. The biological and geomorphological monitoring did not commence prior to the stream restoration project. Thus all of the results are post restoration only, from 1999 through 2005.

This section will summarize the monitoring information on Spring Branch in relation to the stream restoration project. New pollutant load reductions will be calculated using more recent chemical data (Section 2.4.1). The success of stream restoration in improving the biological community will be assessed (2.4.2) and the stability of the stream channel post restoration will analyzed (2.4.3).

2.4.1 Chemical Monitoring

The chemical data for Spring Branch was analyzed to determine both the short term and longer-term pollutant load reduction due to stream restoration. The Spring Branch stream restoration was constructed between late September 2006 and the end of February 2006. The chemical data was divided into three groups; before stream restoration (March 1995 - September 1996), immediate post restoration (June 2007 – February 2001), and more recent data (April 2004 – May 2005). Previous analysis had included the results from a paired watershed (Long Quarter Branch). Since comparable data for Long Quarter Branch were not available for the more recent time period only the Spring Branch data was used for the comparisons of pollutant load reduction. The Spring Branch monitoring locations are shown in Figure 2-12.

The analysis included the creation of linear regression equations based on the $\log_{10}$ transformations of the discharge, suspended sediment, and nutrient data. This resulted in the development of a linear regression equation for each pollutant and each time period. The equations are presented in Table 2-12. The data points and the regressions are shown in Figures 2-13 (Total Suspended Solids), 2-14 (Total Nitrogen), and 2-15 (Total Phosphorus). Each Figure displays three graphs representing the three time periods used in the analysis (pre-restoration, immediate post-restoration, and seven years port-restoration).

Table 2-12: Regression Equations Relationship Between Discharge (CFS) and Pollutant Concentrations

Time Period	Total Suspended Solids	Total Nitrogen	Total Phosphorus
1995 – 1996	.4141 + 1.211*(logCFS)	.5621 - .1079*(logCFS)	-1.0016 + .3705*(logCFS)
1997 – 2001	.5454 + 0.5998*(logCFS)	.3877 - .0808*(logCFS)	-1.3768 + .3233*(logCFS)
2004 – 2005	-.0647 + 1.0448*(logCFS)	.3187 - .0434*(logCFS)	-1.5049 + .7061*(logCFS)

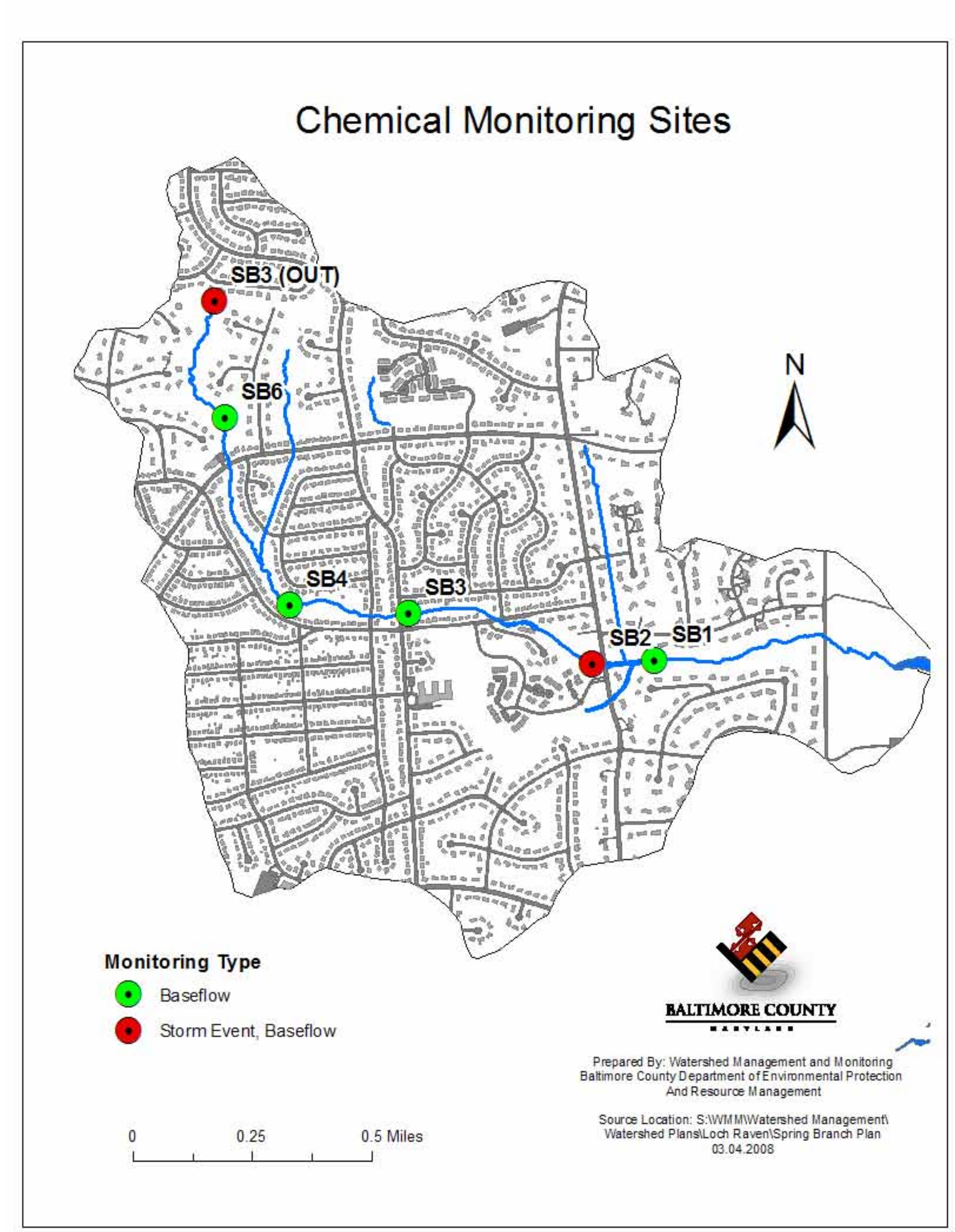

Figure 2-12: Spring Branch Monitoring Locations

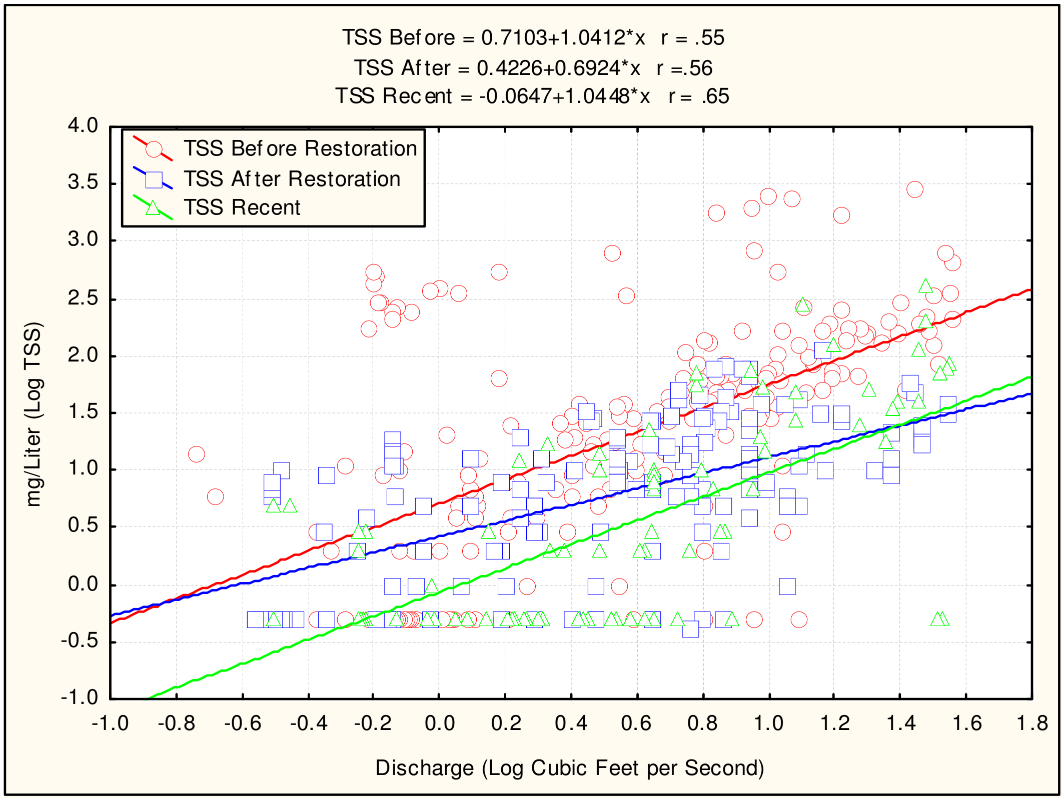

Figure 2-13: Total Suspended Solids (TSS) Data and Regressions for the Three Time Periods.

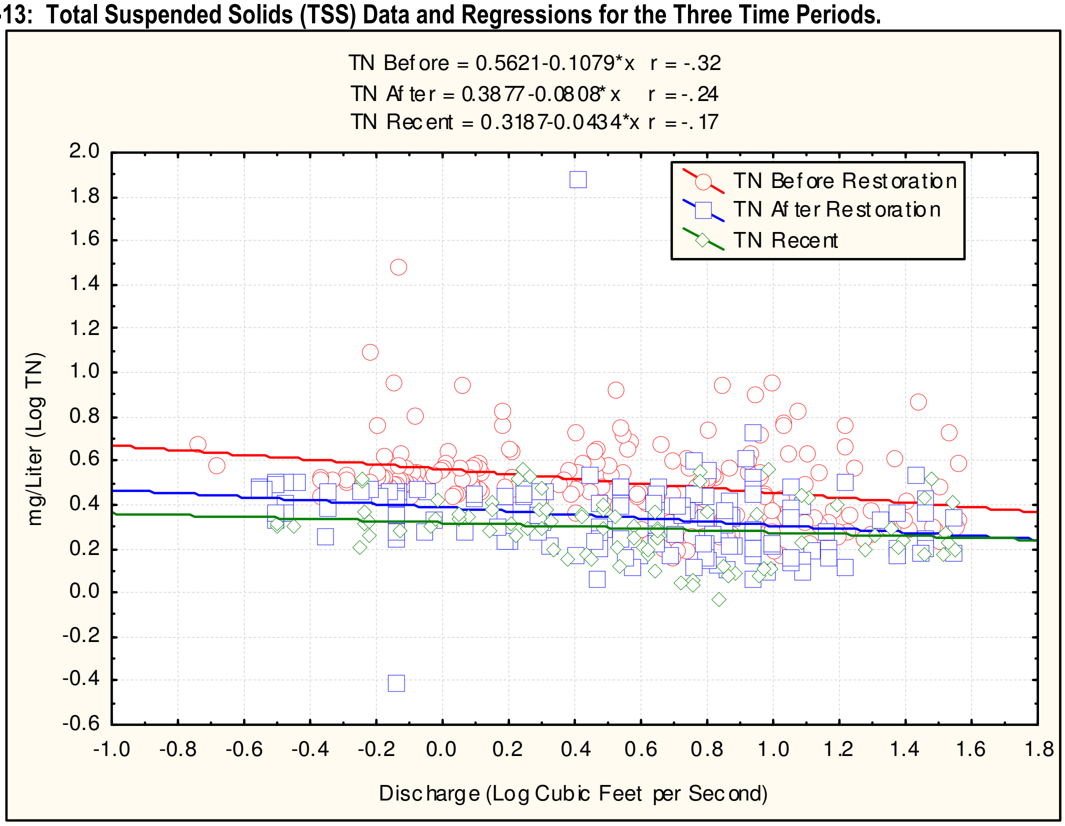

Figure 2-15: Total Nitrogen (TN) Data and Regressions for the Three Time Periods

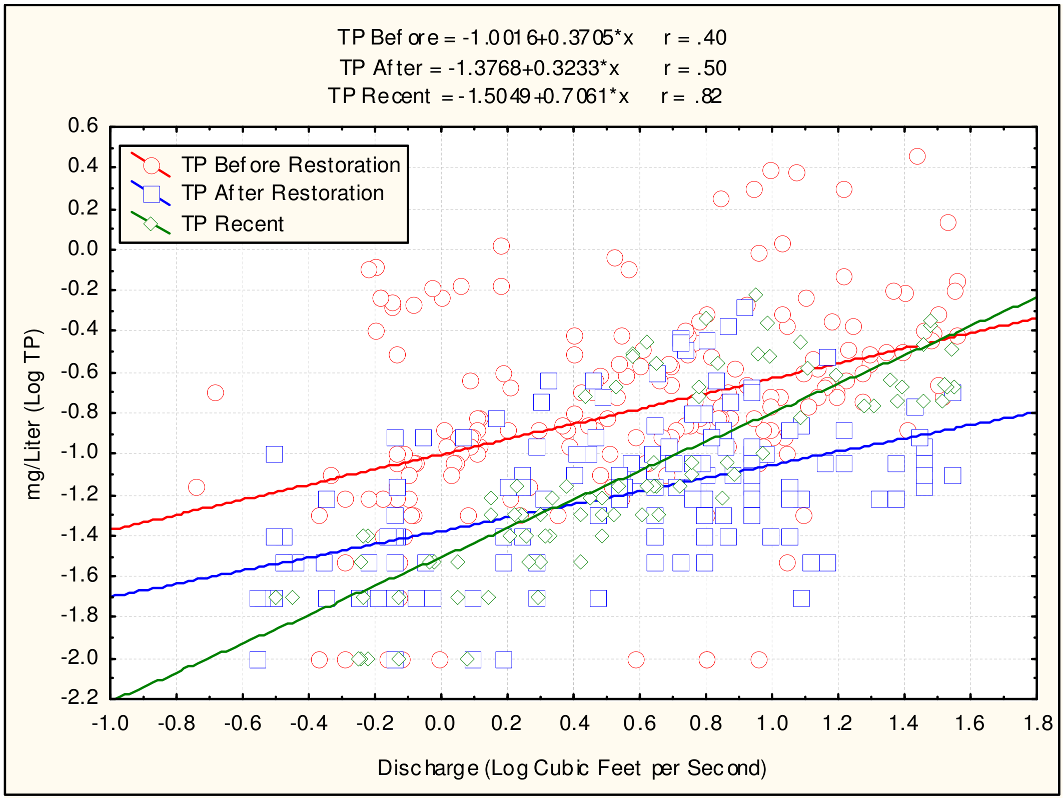

Figure 2-14: Total Phosphorus (TP) Data and Regressions for the Three Time Periods.

A water level sensor was installed in Spring Branch and a rating curve was developed from in-stream discharge measurements made with a pygmy meter. The only period of record for which good data was derived was from July 28, 1999 through March 31, 2001. Data was recorded at 10 minute intervals through this time period result in >73,000 individual discharge readings. The regression equations determined above, relating pollutant concentration to discharge, were used to determine the pollutant concentration for each 10-minute interval. From this data the load was calculated for each 10-minute interval using the following formula:

$P_L = (P_C * .000008345) * (CFS * 448.8 * 10)$, where

P_L = Pollutant Load,
P_C = Pollutant Concentration,
.000008345 = Conversion factor to convert mg/L to pounds per gallon,
CFS = Cubic feet per second,
448.8 = Conversion factor to convert cubic feet per second to gallons per minute
10 = number of minutes in the interval.

The results obtained by the above formula were standardized to both an annual pollutant load for the drainage area and an annual pollutant load per acre. The reduction in the pollutant load due to stream restoration was then calculated on both a percent reduction for the drainage area to the restored stream and on a linear foot of stream reduction. The per linear foot of the stream restoration pollutant load reduction was used previously and is the current standard used by the Chesapeake Bay Program for pollutant load credits for stream restoration. The results are shown in Table 2-13.

Table 2-13: Pollutant Load Reductions Due to Stream Restoration

Monitoring Period	Annual Drainage Area Load	Annual per Acre Load	% Pollutant Load Reduction	Pollutant Reduction/Linear Foot	CBP Credit
Total Suspended Solids					
Before	44,237	92.0			
After	9,382	19.5	78.8 %	3.49	2.55
7 Years After	7,505	15.6	83.0 %	3.67	
Total Nitrogen					
Before	5,393	11.2			
After	3,629	7.5	33.0%	.176	.02
7 Years After	3,127	6.5	42.0 %	.227	
Total Phosphorus					
Before	203.9	0.42			
After	81.2	0.17	59.5%	.0123	.0035
7 Years After	114.2	0.24	42.9%	.0090	

The differences between the Chesapeake Bay Program credit and the calculations presented here are due to several factors.

- In the original calculations, a non-linear estimation procedure on untransformed data was used to determine the pollutant loads. That procedure was forced to go through the origin to remove negative pollutant concentrations. With these calculations, the data were $\log_{10}$ transformed to enable a linear regression procedure to be preformed. This procedure automatically results in no negative concentrations.
- To account for differences in the range of range of discharge measured during the three period. The 2004-2005 data highest discharge measurement was 35.48 cfs. This was used as the cutoff for developing the regression equations for the other two periods. The water level sensor record was analyzed and it was found to have only 0.04% of the records above 36 cfs. In the original analysis no provision was made to ensure that the data spanned the same range.
- In the initial analysis an adjustment was made to the original pollutant load reduction determination using the results from the headwater outfall and the Long Quarter Branch in-stream monitoring site. No such adjustment was made in this analysis, as there was no data for the Long Quarter Branch in-stream monitoring site.

As with all effectiveness studies of Best Management Practices, additional studies are necessary to determine the range of effectiveness of stream restoration for pollutant load reduction. However, on the basis of this single study, urban stream restoration provides an effective mechanism to address the reductions necessary to meet the Total Maximum Daily Loads and Chesapeake Bay Program – Tributary Strategies requirements.

Mean EMC concentration were calculated for the 1995-2000 time period for Total Suspended Solids, Total Nitrogen, Total Phosphorus, and metals (Cd, Cu, Zn, Pb). The results are displayed in Figure 2-16. In the case of TSS, TN, and TP there was a clear decrease in the mean EMC's after stream restoration compared to prior to restoration, while for metals the pattern is not as clear-cut.

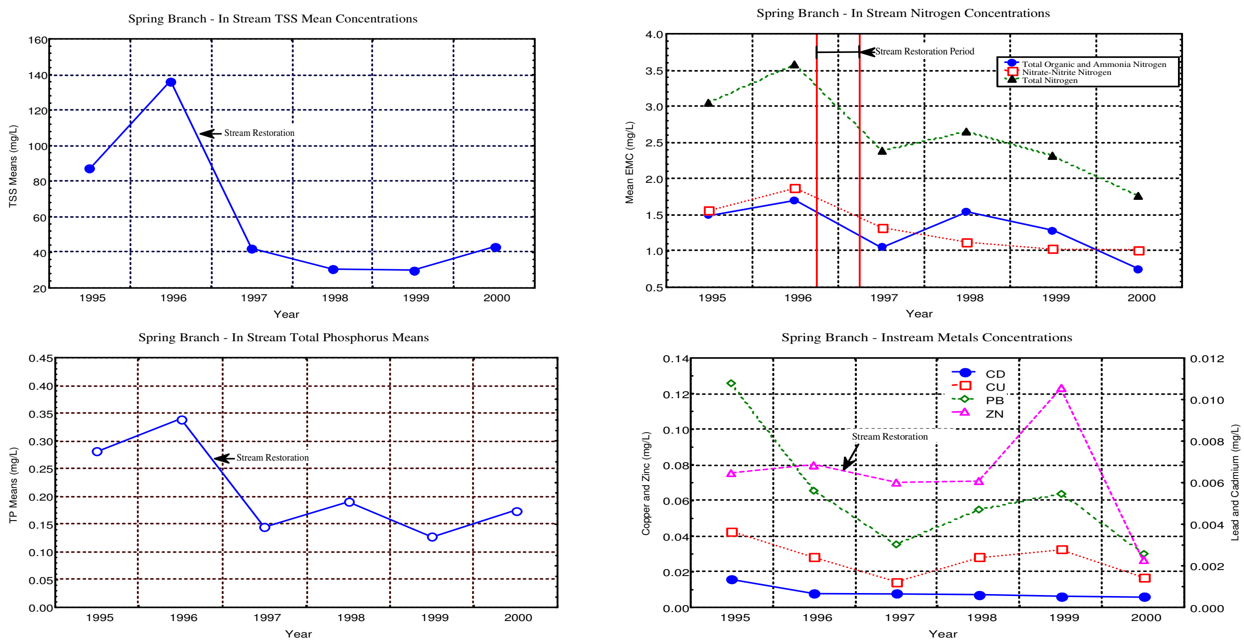

Figure 2-16: Yearly mean EMCs for the Spring Branch in-stream monitoring site.

Baseflow analysis

In 1999, a baseflow analysis was conducted to look at nitrate/nitrite concentrations changes longitudinally as one proceeded down stream. A total of five sites within Spring Branch were sampled on ten different dates. An adjacent subwatershed (Merryman's Branch) was sampled to provide an outside reference point. The results are displayed in Figure 2-17.

As can be seen from Figure 2-17, the concentration of nitrate/nitrite nitrogen decreased downstream in almost every sampling period. There are several possibilities for the decrease:

- the processing of nitrate within the stream system by uptake and denitrification resulted in a decrease in concentration;
- the addition of flow to the stream from storm drain outfalls that flow during dry weather and/or the input of groundwater into the stream channel have lower concentrations that result in a dilution of the nitrate/nitrite nitrogen concentration.

Due to staffing limitations, the determination of which mechanism is resulting in lower nitrate/nitrite nitrogen concentrations was not made. The Merryman's Branch subwatershed site results indicate that the concentration of nitrite/nitrite nitrogen was lower for each sampling date. Merryman's Branch has high-density urban residential development in the headwaters, but the lower half is forested and in pasture. As with the Spring Branch sites the much lower Merryman's Branch concentrations could be due to either processing of nitrogen within the stream channel or dilution by input of lower concentration groundwater.

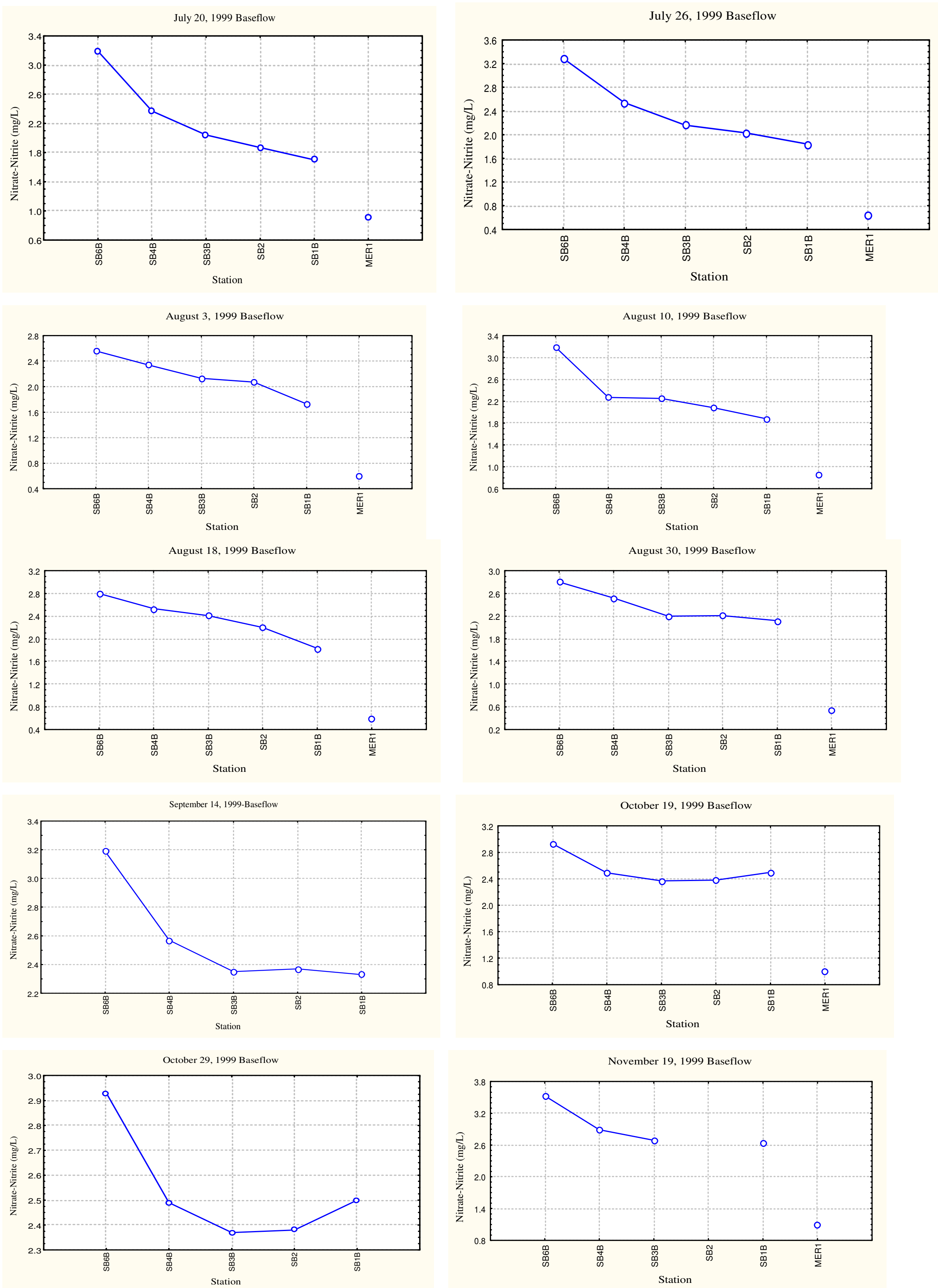

Figure 2-17: Longitudinal Spring Branch Stream profiles for nitrate-nitrite nitrogen concentrations

2.4.2 Biological Monitoring

The focus of the Spring Branch biological monitoring project was on improvements in the benthic macroinvertebrate community as a result of the stream restoration that was completed in February 1997. The research design includes three stations within the restoration area, one site below the restoration area and a reference site in Merryman's Branch (Figure 2-12). Samples have been collected since the spring of 1997 until the spring of 2005. Until Fall 2003 sampling was conducted using a Surber sampler with three replicates collected at each riffle station. For the Fall 2003 monitoring and subsequent monitoring seasons sampling was conducted using the MBSS sampling protocols using a D-net. One D-net sample was collected at each of the monitoring sites, where previously three replicate Surber samples were collected. This change was necessitated by the amount of staff time needed to sort each individual Surber sample. Greater detail on the research design has been included in earlier reports. The results for the time period of 2001 through 2005 are displayed graphically in Figure 2-18 and 2-19.

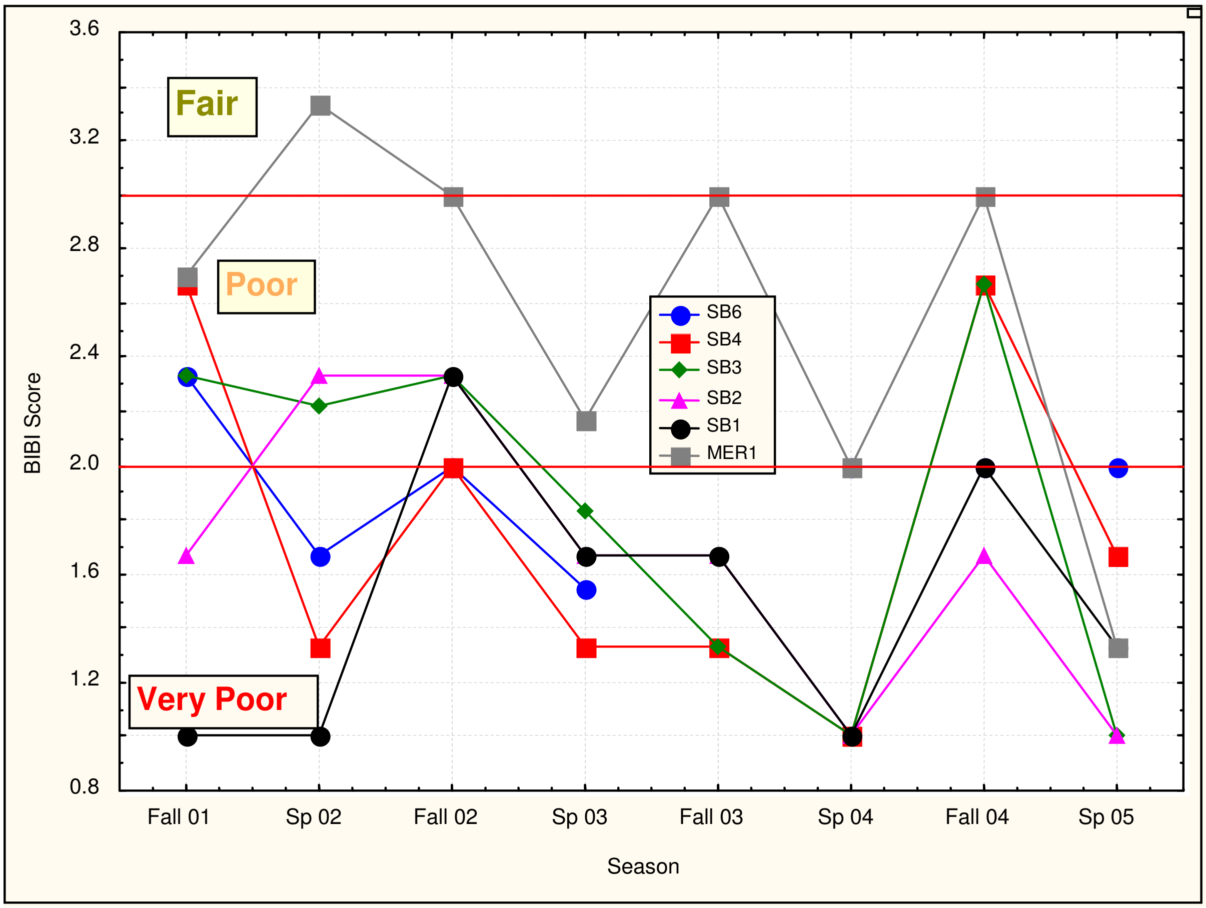

Figure 2-18: Spring Branch BIBI Scores, Site by Season.

Figure 2-18 shows BIBI results for each station by the sampling season. The figure shows that there is no consistent pattern of improvement at any of the sites. Merryman's Branch, the reference site is the only site to achieve a fain rating during the monitoring period, but even that site had excursions into poor ratings. The drought of 2001 and 2002 followed by the third wettest year on record in 2003 could have masked any recovery in the biological community due to stream restoration. The samples from the spring of 2005 were all in the very poor range.

Figure 2-19 displays the changes at each site over the sampling period. SB1, the site below the restored reach was consistently rated as very poor by the BIBI scores. Sites within the restored reach ranged from poor to very poor, but scored better than SB1 with the exception of spring 2003. Merryman's Branch was rated higher during most seasons, but was below SB6 in the fall of 2001.

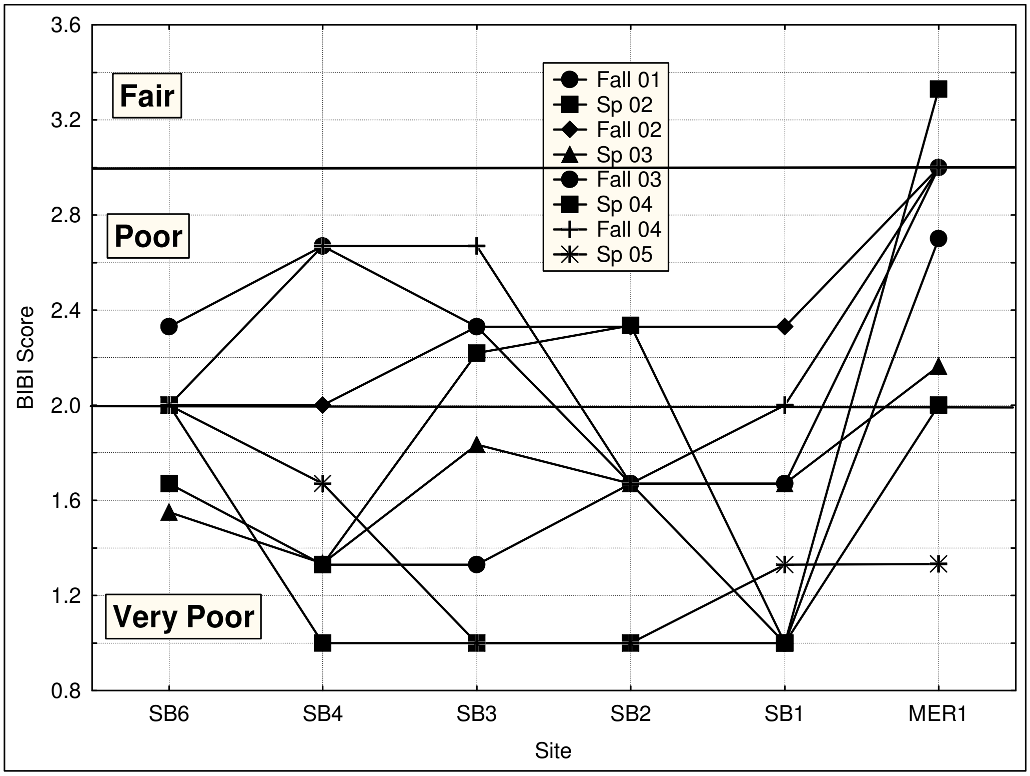

Figure 2-19: Spring Branch BIBI Scores, Season by Site.

The biological monitoring of Spring Branch did not indicate any improvement in the biological community due to stream restoration, although any improvement may have been masked by the extreme conditions experienced during the monitoring period.

2.4.3 Geomorphological Monitoring

Baltimore County DEPRM completed a stream restoration design and construction project on Spring Branch in Timonium, Maryland in March 1997. The stream was severely eroded and eroding due to urbanization in its 481-acre watershed, constructed mostly in the 1960's. The over 10,000 foot long project incorporated natural stream channel geometry design parameters and soil bioengineering approaches. After construction was complete, DEPRM retained Biohabitats, Inc., the design firm, to provide stream channel geometry monitoring for two years following construction to monitor the stability and success of the project. The findings of the first two years of monitoring were that the channel is stable overall even though some erosion and aggradation had occurred. This amount of erosion and aggradation was considered to be within the range of normality for a stable channel. In their report, Biohabitats stated, "More than half of the cross sections monitored at the site have experienced almost no change in geometry". Additionally, the profile data shows that the streambed has maintained its design geometry. Furthermore, the channel has not shown any serious erosion of the banks indicating any changes in the pattern of the stream which would lead to any future property loss."

Subsequent to the first two years, DEPRM staff conducted geomorphological monitoring in April, 2001, March, 2003, April, 2004, and January, 2005. In 2001 three of the 14 monumented cross sections used in the first two years monitoring period were located and surveyed. They are CX3, CX11, and CX12 located above Timonium Road, above Green Drive, and below Green Drive respectively. In 2003, 2004 and 2005 CX# 3, CX# 5, CX# 8, CX# 11, and CX # 13 were found and surveyed. The cross sections proceed in a downstream direction beginning with CX # 3 above Timonium Road, except CX#5 is on a tributary to Spring Branch above Hollowbrook Rd.

In addition to the above cross sections, three longitudinal profiles approximately 300 feet long each were surveyed in 2003, 2004, and 2005. Profile #1 corresponds roughly to Biohabitat's Profile #1 and passes through a step/pool sequence ending just above Timonium Road. Profile # 2 is in the vicinity of Biohabitat's Profiles #3 and #4 sequence and passes through CX8, and Profile #3 is in the vicinity of Biohabitat's Profile #5 and passes through CX13 and a riffle pool sequence. The beginning and end points of Biohabitat's original profiles could not be located, however these re-runs should include much of the same stream areas.

Table 2-14 quantifies the degree of cutting and filling of cross sections CX #3, CX #5, CX #8, CX #11, and CX #13 for the periods of 1999 – 2005 and 2004 – 2005. The values are in cubic feet based on an assumed one-foot wide width along the cross section.

Table 2-14: Spring Branch Cross Sections 3, 5, 8, 11, & 13 - Cut and Fill for Two Time Periods

CX 3: Change (cu ft)	Period: 2004 – 2005	Period 1999 – 2005
Total Cut (negative value)	-3.3	-3.1
Total Fill	2.7	1.5
Total Change	6	4.6
Net Change	-0.6	-1.6
CX 5: Change (cu ft)	**Period: 2004 – 2005**	**Period 1999 – 2005**
Total Cut (negative value)	-0.3	-1.6
Total Fill	1.8	0.5
Total Change	2.1	2.1
Net Change	1.5	-1.2
CX 8: Change (cu ft)	**Period: 2004 – 2005**	**Period 1999 – 2005**
Total Cut (negative value)	-0.5	0
Total Fill	3.1	7.5
Total Change	3.6	7.5
Net Change	2.6	7.5
CX 11: Change (cu ft)	**Period: 2004 – 2005**	**Period 1999 - 2005**
Total Cut (negative value)	- 1.3	-0.2
Total Fill	2.2	5
Total Change	3.5	5.2
Net Change	0.9	4.8
CX 13: Change (cu ft)	**Period: 2004 – 2005**	**Period 1999 - 2005**
Total Cut (negative value)	-5.5	-8.6
Total Fill	2	9.5
Total Change	7.5	18.2
Net Change	-3.5	0.9

Upon examination of these values, a trend is evident going from upstream to downstream sections. The net change was positive (deposition) during the 1999 – 2005 time period for the lower cross sections in contrast to a net degradation in the upstream CX3 and tributary cross section CX5. This primarily reflects levee build up - especially for CX 13. Although CX13 shows the greatest net cut of the sections for the recent year, this section has undergone the most total change due to reshaping its channel effectively making it deeper and more narrow including the levee (bank shoulder) buildup. It is also apparent that the greatest total changes for the cross sections occurred in the years prior to 2005. The data indicates that the stream restoration of Spring Branch has resulted in a stable stream channel that has undergone minor adjustments. Furthermore, the stream was subjected to a record rainfall year including tropical storm "Isabele" in 2003 and held up well.

2.5 303(d) List of Impaired Waters and Total Maximum Daily Load (TMDL)

The Loch Raven Reservoir watershed does not attain the full extent of its designated uses as defined in Maryland water quality regulations. These areas, known as "impaired waters", are tracked by MDE under Section 303(d) requirements of the Federal Clean Water Act.

Maryland Department of the Environment uses the 303(d) list of impaired waters to determine the need for establishing Total Maximum Daily Loads (TMDLs). A TMDL is the maximum amount of pollutant a given waterbody can assimilate and still meet the standards for its designated use. A waterbody may have multiple impairments and multiple TMDLs to address them. MDE is responsible for establishing TMDLs.

In general, TMDLs have two key parts:

1- Maximum pollutant load that the water can accept while still allowing the waterbody to meet its intended use.

2- Allocation of the maximum pollutant load to point and nonpoint pollutant sources in the watershed.

The list of impairments for waterbodies and any associated total maximum daily loads in the Loch Raven Reservoir watershed are summarized below. More information on the 303(d) list can be found at: http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/index_new.asp

A new listing of impaired waterbodies will be prepared in 2008. The current impairment listings for the Loch Raven Reservoir watershed include:

- Methylmercury
- Sediment
- Nutrients
- Biological Community

2.5.1 Methylmercury

The State's 303(d) list in 2002 included listings for mercury contamination for Loch Raven Reservoir and the other two Baltimore-area reservoirs. The entire Loch Raven Reservoir watershed was listed. The listings were based on observed mercury content in fish tissue and on a recent change in the EPA methodology for calculating the risk associated with human consumption of contaminated fish. Total Maximum Daily Loads (TMDLs) have been completed for all three reservoirs and submitted to EPA for approval. EPA granted approval in August 2004.

As part of this effort, MDE submitted a TMDL for mercury for Loch Raven Reservoir watershed of 196.6 grams per year. Although TMDLs as originally defined explicitly call for daily loads, many agencies estimate allowable loads on a per-year basis, rather than a daily basis. This load was primarily allocated to "load" or non-point sources (180.9 grams per year). With MDE's preparation of this TMDL, Loch Raven Reservoir watershed was placed on the Category 4A list for mercury, the list of impaired water bodies for which TMDLs have been completed. Since the primary source of mercury pollution in the watershed is atmospheric deposition from sources outside the watershed (especially from coal-fired electric power generating plants), this characterization and the SWAP will not further address this contaminant. The TMDL for Methylmercury may be viewed at: http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/ApprovedFinalTMDL/TMDL_final_lochraven_Hg.asp .

2.5.2 Biological

The 2006, 303(d) list includes Loch Raven Reservoir watershed as being biologically impaired. These listings result from Maryland Biological Stream Survey (MBSS) 2000-2004 data.

The current method that MDE uses to list streams for biological impairment allows for entire 12-digit watersheds to be listed based on one sample with low biological integrity (either fish or macro-invertebrates). MDE is considering revising this standard, and works with local authorities to verify if such listings are based on systemic biological problems associated with particular pollutants, or if there are other causes. In the latter case, the water body could potentially be taken off the impaired list. As part of the revised standard, streams and 12-digit watersheds with only one sample with a low index of biological integrity could be targeted with a more intense monitoring effort to verify if the impaired listing is justified.

2.5.3 *Nutrients and Sediment*

The 303(d) list for 1996 included the entire Maryland portion of Loch Raven Reservoir watershed as being "impaired" due to elevated concentrations of nutrients and for sediment. While nitrogen levels are elevated in the Loch Raven Reservoir, the primary nutrient of concern is phosphorous, due to its significant connection with chlorophyll a levels in the reservoir.

For the Loch Raven Reservoir Watershed, in 2006 MDE submitted to the EPA a Total Maximum Daily Load for phosphorous of 54,941 pounds per year; this represents a 50% reduction from 1997 levels. This load was allocated as follows: 30,184 pounds were allocated to non-point sources (55%) and 22,010 were allocated to point sources (40%), with an additional allocation of 2,747 pounds as a margin of safety (5%).

The sediment impairment listing is due to the infilling of the reservoir with remediation intended to extend the length of time before the reservoir fills in. The sediment Total Maximum Daily Load for sediment is 28,925 tons/year. This load was allocated as follows: 27,715 tons were allocated to non-point sources (96%) and 1,201 tons were allocated to point sources (4%), with the margin of safety implicit in the modeling. This represents a 25% reduction from the baseline sediment load.

The scenario run by Maryland Department of the Environment projected a 15% reduction in Total Phosphorus from developed lands and a 0% reduction for sediment. These will be the initial targets for meeting the urban land reductions for the Loch Raven TMDL.

EPA granted approval of the nutrient TMDL in March of 2007. The TMDL may be viewed at:

http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/ApprovedFinalTMDL/TMDL_final_gunpowder_P_sed.asp#TMDL_Loch_Raven_Reservoir

2.6 Spring Branch Pollutant Load Analysis

In order to scale the Loch Raven Reservoir watershed Total Maximum Daily Load to the Spring Branch subwatershed and to compare loading results derived from other modeling methodologies and monitoring data, a series of analyses were performed. The modeling methodologies that were compared included:

- The Maryland Department of the Environment – Total Maximum Daily Load analysis using the HSPF model.
- The Chesapeake Bay Program – Watershed Model using the HSPF model.
- The Loch Raven Water Quality Management Plan – pollutant loading analysis using the SWMM model.
- The Baltimore County Department of Environmental Protection – land use pollutant load simple model.
- The Baltimore County Department of Environmental Protection – monitoring results for Spring Branch subwatershed.

With the exception of the Spring Branch monitoring results, the analysis was performed using a spreadsheet with either per acre loading for impervious cover and urban pervious cover (MDE-TMDL, CBP-Watershed models) or per acre loading based on land use (Loch Raven – SWMM, DEPRM – Simple Model). The results of the analysis are displayed in Table 2-15.

Table 2-15: Spring Branch Subwatershed – Pollutant Load Analysis

	MDE TMDL (HSPF)	CBP (HSPF)	Loch Raven SWMM	DEPRM	SB Monitoring
TP – Annual Load	645	1,681	695	526	422.1
TP Load/Acre	0.64	1.67	0.69	0.52	0.42
Sediment – Annual Load	111,765	461,937	186,104	134,284	92,460
Sediment Load/Acre	111	460	185	134	92
TN – Annual Load	4,436	15,424	7,132	5,566	11,256
TN Load/Acre	4.41	15.35	7.10	5.54	11.2

As can be seen from Table 2-15, the Chesapeake Bay Program – Watershed Model consistently calculates higher loads for each of the three constituents analyzed, while the monitoring resulted in the lowest loads for Total Phosphorus and Sediment and somewhat higher loads for Total Nitrogen compared to the other calculation methods. Since meeting the Total Maximum Daily Load reductions is one of the primary goals in the development of Small Watershed Action Plans, the pollutant loads derived from the MDE-TMDL model will serve as the base for determining the necessary load reductions. As indicated in Section 2.5 the scenario run by MDE for meeting the TMDL load reduction assumes a 15% reduction in Total Phosphorus from urban lands and no reduction in sediment.

An analysis of the completed Phase I Spring Branch restoration and the designed restoration for Phase II was conducted to determine if the target load reductions will be met. Phase I included the installation of a stormwater wet pond at the headwaters of the stream system and restoration of 10,000 linear feet of stream channel. Included with the restoration of the stream channel was planting of 7.1 acres of riparian buffer, and installation of velocity dissipaters at the storm drain outfalls along the stream. Phase II includes the restoration of an additional 2,500 linear feet of eroded stream channel. In order to calculate the pollutant removal form the stormwater management facilities installed as part of development and the wet pond installed as part of the restoration project, the drainage areas were calculated. Using the loading rates for impervious cover and urban pervious cover derived from the MDE – TMDL model the load to each facility was calculated. The load reduction efficiency was determined using the Chesapeake Bay Program Best Management Practice efficiency table (Appendix C). The loads to the facilities were then reduced by the efficiency. The results are displayed in Table 2-16 in the second and third lines (SWM Removal, Phase I Wet Pond Retrofit). For the load reduction due to the stream restoration the results from the Spring Branch – Phase I study were used. A mean per linear foot load reduction for each constituent was derived by averaging the short term post restoration monitoring and the longer term post restoration monitoring (Table 2-13 above). This resulted in the following reduction numbers:

- Total Suspended Solids – 3.58 pounds per liner foot of restoration
- Total Phosphorus – 0.0107 pounds per linear foot of restoration
- Total Nitrogen – 0.202 pounds per linear foot of restoration

The results are displayed in Table 2-16. As can be seen from the table, the percent reductions of Total Phosphorus and Sediment exceed the targets set by the MDE scenario for meeting the TMDL for Loch Raven Reservoir watershed.

Table 2-16: Spring Branch Restoration – Pollutant Load Reduction

	Total Phosphorus	Sediment	Total Nitrogen
TMDL Load	645	111,765	4436
SWM Removal	1.8	306	5.7
Phase I Wet Pond Retrofit	14.5	4,036	55.9
Phase I Stream Restoration	107.0	35,800	2,020.0
Phase II Stream Restoration	26.8	8,950	505.0
Total Pollutant Removal	150.1	49,092	2,586.6
% Removal	**23.3%**	**43.9%**	**58.3%**

CHAPTER 3

SUBWATERSHED GOALS AND STAKEHOLDER OUTREACH

3.1 Subwatershed Goals

The Baltimore County Stream Restoration Program prioritizes projects, in part, by evaluating opportunities identified in the watershed plans. The Spring Branch Restoration project was selected prior to the completion of the Loch Raven Watershed Plan so the site was selected based on a watershed approach and systematic assessment to address the severity of problems and restoration goals. Restoration priority was further determined by several factors, including (1) benefit of the project to overall watershed health, (2) restoration sustainability and availability of easements, (3) stakeholder input and concerns, (4) protection of existing infrastructure (roads, bridges, utilities), and (5) estimated restoration cost.

Baltimore County Department of Environmental Protection and Resource Management (DEPRM) evaluated the entire length of Spring Branch and initiated the Phase I Spring Branch Stream Restoration Project in 1993. This project was selected to be the pilot project for stream restoration in Baltimore County. The consultant team was selected in late 1993 and the conceptual design was initiated in 1994. The project was selected for the following reasons:

- Numerous stream erosion complaints dating back 10-15 years
- Significant loss of private property.
- Exposed sanitary sewer line repeatedly repaired by DPW
- Water quality degradation - biological monitoring station indicated poor conditions
- Reservoir Management Agreement - Goal to reduce sediment and phosphorus loadings
- Typical urban residential stream - no buffers, development encroachment, attempts to stabilize banks by citizens with yard debris.
- Sedimentation from stream bank and channel erosion due to uncontrolled stormwater runoff and encroachment.
- Drains to Loch Raven Watershed – Drinking water reservoir for Baltimore Metropolitan Area.

Due to the importance of the Loch Raven Reservoir as a public drinking water supply and natural trout habitat, streams which drain to the reservoir have been designated a top priority for stream restoration. The goals of the restoration project include:

- Restore steam channel stability
- Reduce sediment loading to the Reservoir
- Improve water quality to Spring Branch and to Loch Raven
- Eliminate repeated sewer lateral breaks
- Provide community education and participation
- Establish buffers (mowed yards to trees)
- Eliminate loss of property

Baltimore County has an ambitious plan to restore streams throughout the entire County. Spring Branch was selected as the pilot project to combine many innovative techniques along the 2 miles of stream and provide immediate water quality benefits to the Reservoir. This project received a *Community Innovation Award* in 1997 from the Chesapeake Local Government Advisory Committee. Baltimore County was selected for its contribution and commitment to the protection and restoration of streams, rivers, and the Chesapeake Bay through the implementation of the Spring Branch Stream Restoration Project.

As Spring Branch Project was initiated prior to the preparation of the Loch Raven Watershed Water Quality Management Plan, 1997, the Plan excludes the Spring Branch Watershed as a potential restoration area.

Total Maximum Daily Load for Nutrients and Sediment

With the development of the Total Maximum Daily Load (approved by EPA March, 2007) for nutrient and sediment pollution to the Loch Raven Reservoir, the additional goal of improving water quality to meet the pollutant load reduction targets was incorporated. The TMDL (*Total Maximum Daily Loads of Phosphorus and Sediments for Loch Raven Reservoir and Total Maximum Daily Loads of Phosphorus for Prettyboy Reservoir, Baltimore, Carroll and Harford Counties, Maryland*) developed by Maryland Department of the Environment (MDE) can be found in Volume 2, Appendix G.

Briefly, this TMDL found that Total Phosphorus needed to be reduced by 50% to meet water quality standards for dissolved oxygen and chlorophyll *a* in the Loch Raven reservoir. The scenario developed included a 15% reduction of Total Phosphorus and no sediment reduction from developed lands. The model indicated that changes in the nitrogen load would not result in changes in the dissolved oxygen and chlorophyll *a*. The sediment reduction is based on the preservation of reservoir volume for drinking water. It is anticipated that restoration projects that address phosphorus will also address sediment.

The opportunities for restoration of urbanized and the cost can severely limit the extent that pollutant load reductions can be met by urban restoration. When those opportunities present themselves, and when stakeholder support is present, Baltimore County, to the extent that funding is available, avails themselves of the opportunity. Spring Branch subwatershed presents such an opportunity. The entire subwatershed will be addressed between the completed Phase I restoration, and the Phase II restoration currently designed and designated for construction in the summer of 2008.

3.2 Spring Branch Watershed Restoration – Stakeholder Outreach

Baltimore County works to identify and develop rapport among individuals and organizations directly and indirectly affected by restoration efforts. The Stream Restoration Program has benefited from fostering partnerships with a wide array of stakeholders, including: residential, commercial, and industrial property owners; local and regional non-profit organizations, research institutions, and conservation groups; and government agencies with vested interest as regulatory bodies or policy-makers. State and federal agencies, community associations, and environmental advocacy groups have proven instrumental in efforts to inform, guide and support DEPRM's restoration goals.

During both Phases of the planning and design of the Spring Branch Restoration Projects, community meetings were held and on-going communication was conducted throughout each milestone to ensure stakeholder understanding and support. Several permanent easements were secured along Phase I to permit construction activities and to allow monitoring and maintenance. One big challenge was educating property owners about the importance of maintaining vegetative buffers along streams. Since many residents prefer the neat appearance of a well-manicured lawn, it is sometimes difficult to convince property owners that riparian vegetation is necessary for the stability and health of the stream. DEPRM worked with property owners to establish native plantings that require minimum maintenance and provide aesthetic benefits.

For Phase I of the Spring Branch Restoration, DEPRM conducted a public outreach program to inform and educate local citizens and affected homeowners about the project. This effort included a homeowner survey, stream tours, community meetings, mailings, newspaper articles, and stream walks. An educational video was prepared, displays of the project were featured at local festivals, and newspaper articles were published on the project. DEPRM has conducted numerous demonstration tours of the project to further assist in transfer of the technology to others. Local support and valuable input were received from citizens. Examples of the letters to residences and of public information prepared and distributed is included in Appendix B1 and B2.

For Phase II an initial community meeting was conducted to explain the project and to engage the property owners in the importance of the restoration project. Preliminary plans were discussed and one-on-one meetings were conducted with several property owners. Several access agreements have been secured and the community has been advised of the status of the project.

CHAPTER 4

RESTORATION STRATEGIES

4.1 Overview

Project Description

Both phases of Spring Branch restoration address impacts of urbanization, including a flashy flow regime, rapid erosion, declining ecological function, failing infrastructure, poor water quality and property damage. The existing conditions in the watershed included primarily medium density residential land uses with an imperviousness of approximately 20%.

Restoration includes the establishment of a stable planform by adjusting sinuosity and armoring stream banks at key locations, water quality improvement with storm drain retrofits, reconnection of the stream to the floodplain, and re-establishment of the riparian/wetland ecosystem. In addition to these objectives, Phase I included infrastructure improvements including concrete channel removal, and sanitary sewer stabilization. As well as storm drain retrofits, including a 4-cell headwater-settling basin. The location of the Phase I and Phase II restoration projects is depicted in Figure 4-1. The total cost of design and construction of Phase I was $2.25 million and Phase II is estimated to be $1.3 million.

Restoration Strategies

This urban stream has experienced severe bank erosion and instability due to extensive development in the 1,005-acre watershed, which occurred during the 1950's and 1960's prior to stormwater management regulations. Based on pre-restoration monitoring results, a significant amount of sediment and associated phosphorus was being carried down Spring Branch each year. Since the stream drains directly into the Loch Raven Reservoir, a source of drinking water for 1.8 million users in the Baltimore metropolitan region, the effects of sediment and pollutant transport into this impoundment and the Chesapeake Bay extended well beyond the stream itself.

In early 1997 the Baltimore County Department of Environmental Protection and Resource Management (DEPRM) completed the restoration of approximate two miles of Spring Branch (Phase I) along with the creation of associated wetlands and construction of storm drain outfall retrofits to provide storm flow attenuation and water quality enhancement. In 2008, the Lower Spring Branch Stream Restoration Project (Phase II) will be completed. Phase II will restore approximately 2,500 linear feet of Spring Branch between Dulaney Valley Road and Pot Spring Road by creating a stable channel using natural stabilization techniques.

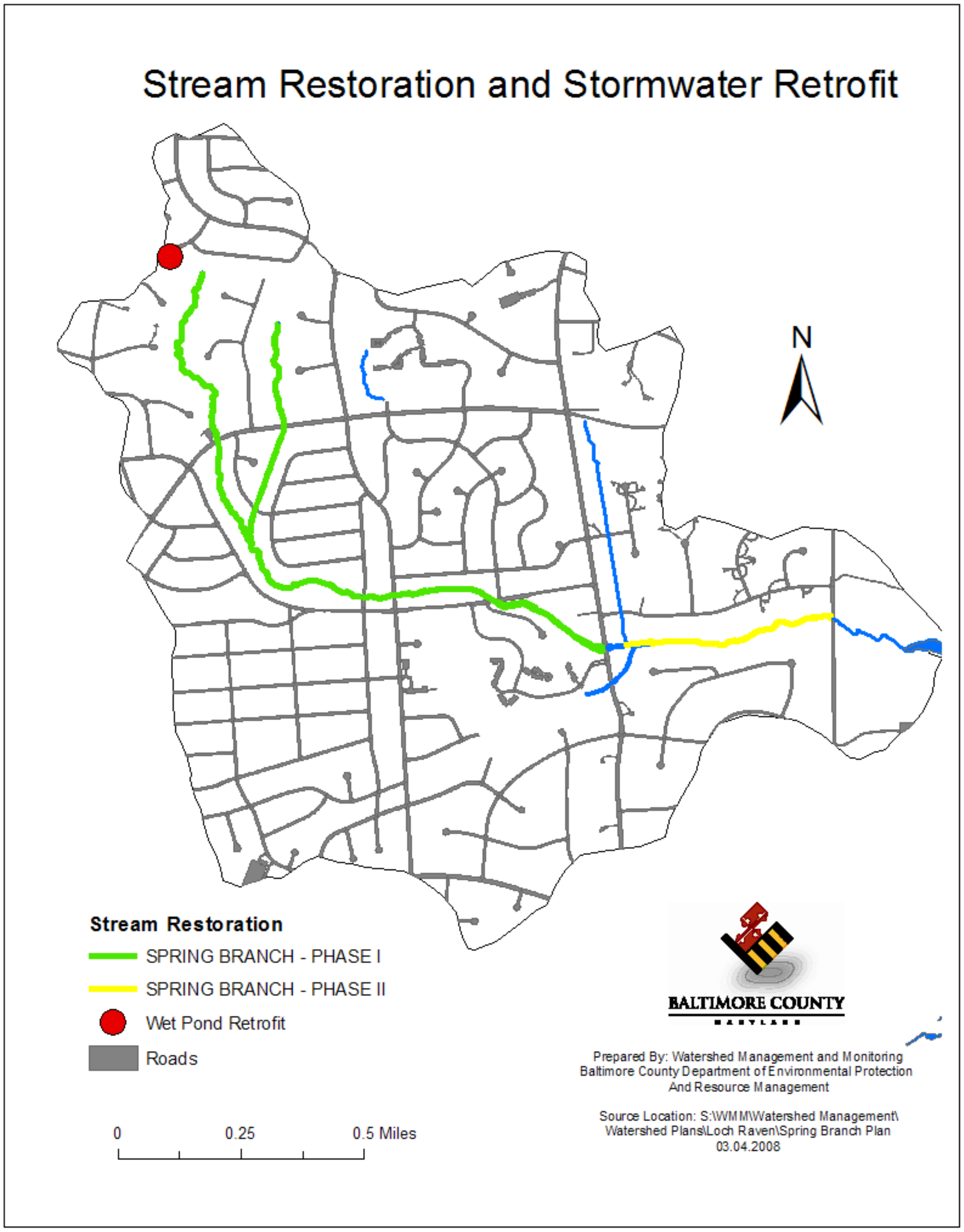

Figure 4-1: Spring Branch Subwatershed Restoration Projects

4.2 Phase I – Spring Branch Stream Restoration Project

Phase I of Spring Branch is located in a heavily developed headwater area. The typical problems of stream buffer removal, flashy flow regime, and floodplain encroachment were evident. Two sections of failed concrete and multiple sewer line crossings disrupted ecological connectivity. The system had severely eroding banks due to structural failures and the clear water discharge from the high percentage of imperviousness in the watershed.

Spring Branch was an unstable stream with a steep gradient, dropping over 180 feet in two miles of length. The channel passed through confined areas of residential development and had evolved from a quiet brook into an eroded chasm 30 feet wide and up to 15 feet deep. Adjacent homeowners were experiencing flooding, loss of streamside property and depreciation of property values due to reduced aesthetics, habitat, and safety hazards. The stream had been channelized and straightened over the years with areas of no vegetation along the banks.

Recognizing that outdated traditional stream improvements such as channelization, lining the stream with concrete, and doing piecemeal repairs do not work, DEPRM elected to apply a relatively new design approach that accommodates the natural forces and processes of streams.

The design process utilized applied fluvial geomorphologic principles along with hydraulic engineering. Features such as step-pools, meander patterns and flood plains were incorporated into the new channel of Spring Branch. Following construction-grading, the new stream channel and other disturbed areas were stabilized using bio-engineering techniques incorporating natural materials such as boulders, tree root wads, and live fascines to provide soil and channel stability. As a result, a channel geometry and sinuosity was created that is consistent with streams of Maryland's Piedmont Plateau.

The Spring Branch initiative was an integration of related projects that included, in addition to the stormwater management retrofits, the relocation of an exposed sanitary sewer line and the removal of 1740 feet of concrete lined channels. The stormwater retrofit was comprised of a 4-cell detention and settling basin to treat the runoff from the headwaters of the drainage area. Maryland Small Creeks and Estuary funding was utilized for this water quality retrofit. The retrofit was planted with wetland vegetation and riparian vegetation around the entire site. Each storm drain outfall was incorporated into the design and the construction included rock lined step pools to dissipate energy at the end of pipe.

To prevent erosion and provide aquatic habitat benefits, various soil and bioengineering techniques were applied to stabilize the stream banks. Live facines, brush mattresses and live branch layers were employed to provide a natural appearance and effective stabilization, Reforestation of twelve acres of disturbed areas with a variety of native trees and shrubs was completed in conformance with the County's Forest Conservation Act. Developer fee-in lieu-of mitigation funds were utilized for the plantings.

4.3 Phase II – Spring Branch Stream Restoration Project

The Lower Spring Branch project study area is located between Pot Spring and Dulaney Valley Road and includes 80 feet of an intermittent concrete-lined tributary. The study reach is approximately 2,600 feet long and receives water from a 1.58 square mile watershed. This project will extend the 1997 restored reach of Spring Branch to Dulaney Valley Road.

The impacts to the lower portion of the stream include channelization, concrete armoring, and stormwater runoff from residential development. This has resulted in considerable bank erosion, generally along the left bank, as the stream flows through the neighborhood and persistent flooding at the downstream end of the project area. Prior to the 1980s, Lower Spring Branch was straightened, channelized, and armored to maximize land for development and to divert stormwater. Sizing of the culvert at Dulaney Road did not account for flows during large storms, subsequently causing backwater effects and flooding. Sewer lines are installed in the stream valleys adjacent to the stream. The removal of vegetative buffer areas and development of vast areas of impervious surface compounded adverse effects on this stream.

4.4 Results And Benefits

The stream restoration involves several techniques including bioengineering (live fascines, live branch layering and native planting), bank stabilization (root wads, rock toe protection) and in-stream structures (vortex rock weirs, step pools). Stabilizing the channel geometry, providing bank protection and recreating stream, wetland and floodplain areas along this degraded stream system will address the need for habitat regarding species of concern. The proposed channel reconfiguration provides a more heterogeneous and stable substrate, thereby increasing the diversity and abundance of aquatic insects. The creation of pools and riffles will provide habitat and cover for adult fish as well as spawning and nursery areas for some of those species.

The improvements to Spring Branch will benefit the species of concern, such as anadromous fish and waterfowl. With the implementation of this stream/riparian restoration project several important functions can be restored in the watershed.

For Baltimore County, the Spring Branch is a landmark pilot project utilizing innovative restoration approaches. This project was the first stream restoration project in Baltimore County and was completed in 1997. The success of this project gave DEPRM the confidence that the natural channel design approach can be used successfully for other stream restoration projects implemented through the County's Capital Improvement Program.

When Phase II is complete, over 14,000 linear feet of stream will be restored. This project will focus on the diverse role freshwater stream systems play in maintaining suitable habitat for the living resources of the Chesapeake Bay.

Based on the pollutant load reduction analysis in Chapter 2 (Section 2.6). The combined pollutant load reduction for Phase I and Phase II will be ~23% for total phosphorus, ~44% for sediment and ~58% to nitrogen.

4.5 Monitoring

A ten-year monitoring program was implemented on Phase I to measure the stability of the stream channel. Water quality monitoring was also conducted to measure changes in pollutant loading from storm flows, as well as, biological monitoring (Chapter 2, Section 2.4). The new stream channel has withstood several large storms (during and post construction), and the sediment loading appears to be greatly reduced in and along the streambed. Improved habitat and aquatic resources are expected to occur over time. Citizen and landowner response has been very positive to date.

A physical monitoring program will be implemented for Phase II that will include surveyed monumented stream cross sections, survey of longitudinal profile, evaluation of structures, bed and bank stability assessment and sediment transport functions. The water quality analysis for Phase II will be limited to biological monitoring of the benthic macroinvertebrate community of the restored stream section, with both upstream and downstream monitoring, and an outside reference site located at Merryman's Branch.

APPENDIX A

US ENVIRONMENTAL PROTECTION AGENCY

A THROUGH I CRITERIA FOR WATERSHED PLANNING

This appendix will provide information on how the development of the Spring Branch Subwatershed Small Watershed Action Plan addresses the US Environmental Protection Agency (EPA) A through I criteria for watershed planning. It will serve as a guide to the location within the document, including the appendices, where each criteria is addressed.

a. An identification of the causes and sources or groups of sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan), as discussed in item (b) below. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed (e.g., X number of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded streambank needing remediation).

Loch Raven Reservoir watershed is listed by the Maryland Department of the Environment (MDE) as being impaired by nutrients, bacteria, methyl-mercury in fish tissue, and stream biology is impaired. The Spring Branch subwatershed is located within the Loch Raven Reservoir watershed. MDE has prepared Total Maximum Daily Loads (TMDL) for nutrients and methyl-mercury. The TMDL for methyl-mercury identifies the source as air bourn mercury from power plant emissions outside of the Spring Branch subwatershed planning area. The TMDL for nutrients identified phosphorus as the limiting nutrient for improvements in the reservoir water quality. The model broke down the pollutant sources between point sources (wastewater treatment plant discharges and urban stormwater), non-point sources (agricultural sources and forest), and stream channel scour. The agricultural sources were divided into various agricultural operation categories. The TMDL document is included in Volume 2 – Appendix G, as support for the phosphorus load reductions necessary to achieve water quality standards within the Loch Raven Reservoir, of which Spring Branch is a part. EPA approved the TMDL in March 2007.

In order to refine the estimates of phosphorus loads for the Spring Branch subwatershed, an analysis was conducted based on the per-acre loading rates developed in the TMDL model, the Chesapeake Bay Program watershed model, the Loch Raven SWMM model, the DEPRM simple model, and Spring Branch monitoring data. This data is presented in Chapter 2.6.

Additional information was analyzed to refine specific sources of impairment. This information is presented in Chapter 2.

b. An estimate of the load reductions expected for the management measures described under paragraph (c) below (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time). Estimates should be provided at the same level as in item (a) above (e.g., the total load reduction expected for dairy cattle feedlots; row crops; or eroded streambanks.

Expected phosphorus load reductions were based on the EPA - Chesapeake Bay Program load reduction criteria used in their Phase 5 model for the water quality impairments of the tidal Chesapeake Bay. These load reductions are presented in Appendix C. The estimate of pollutant reduction for stream restoration was based on the re-analysis of the Spring Branch data presented in Chapter 2.4 Using the information in Appendix C, and the reanalysis of the Spring Branch stream restoration data, the phosphorus load reductions for the various actions were calculated and presented in Chapter 2, Table 2-16.

c. A description of the NPS management measures that will need to be implemented to achieve the load reductions estimated under paragraph (b) above (as well as to achieve other watershed goals identified in this watershed-based plan), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.

The management measures that will need to be implemented to meet the pollutant load reductions detailed in the TMDL (Appendix G) and analyzed specifically for Spring Branch, Chapter 2.6. Chapter 2.6 details the pollutant reductions that will be achieved through implementation of the Spring Branch – Phase I and Phase II restoration. The reductions achieved are above the scenario developed through the TMDL. This will help develop a credit for pollutant load reduction in subwatersheds that have limited restoration potential.

d. An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and the authorities that will be relied upon, to implement this plan. As sources of funding, States should consider the use of their 319 programs, State Revolving Funds, USDA's Environmental Quality Incentives Program and Conservation Reserve Program, and other relevant Federal, State, local and private funds that may be available to assist in implementing this plan.

The costs for Spring Branch Phase I and Phase II Restoration are presented in Chapter 4.

e. An information/education component that will be used to enhance public understanding of the project and encourage their earl and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented.

The educational activities to enhance public understanding and encourage participation in restoration implementation planning and the installation of best management practices are detailed in Exhibits A and B.

f. A schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious.

Spring Branch Restoration- Phase I was completed in 1997. Spring Branch Restoration – Phase II is due for construction the summer of 2008. With the completion of these two phases, the restoration of Spring Branch will be complete. Educational activities identified for all of Loch Raven Reservoir watershed will continue. Some of these activities will reach Spring Branch residents.

g. A description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented.

Interim, measurable milestones are not needed for this subwatershed, as the restoration will be complete with the implementation of Phase II.

h. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards, and, if not, the criteria for determining whether this watershed-based plan needs to be revised or, if a NPDES TMDL has been established, whether the NPS TMDL needs to be revised.

The load reductions due to the restoration activities will be calculated via a spreadsheet using the EPA Chesapeake Bay Program – Best Management Practice Pollutant Reduction Efficiencies. These efficiencies will be used in conjunction with the implementation tracking to calculate the load reductions being achieved. The efficiencies used will be modified based on any modifications of the EPA Chesapeake Bay Program efficiencies. The efficiency for stream restoration pollutant load reduction is based on the re-analysis of the Spring Branch monitoring data; detailed in Chapter 2.4.

i. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (h) immediately above.

Chapter 4 details the monitoring that will occur to evaluate the effectiveness of implementation of Phase II. Phase I was extensively monitored for stream stability, pollutant load reduction, and aquatic biological community improvement.

APPENDIX B1

PUBLIC OUTREACH

- **Homeowner Survey**
- **Stream Tour Agenda**
- **Public Information Meeting Notices**
- **Power Point Presentation for Public Meeting**

SPRING BRANCH NEEDS YOUR HELP FOR EARTH MONTH, 1994

THE BALTIMORE COUNTY CITIZENS
FOR STREAM
RESTORATION CAMPAIGN
WILL BE CONDUCTING A SURVEY OF THE
ALMOST 2000 HOMES IN THE
SPRING BRANCH WATERSHED DURING APRIL.
HELP US FIND OUT WHAT THE COMMUNITY KNOWS ABO
WATER QUALITY ISSUES

Baltimore County
Citizens for Stream Restoration Campaign

Restoring the Past, Preserving the Future

JOIN US
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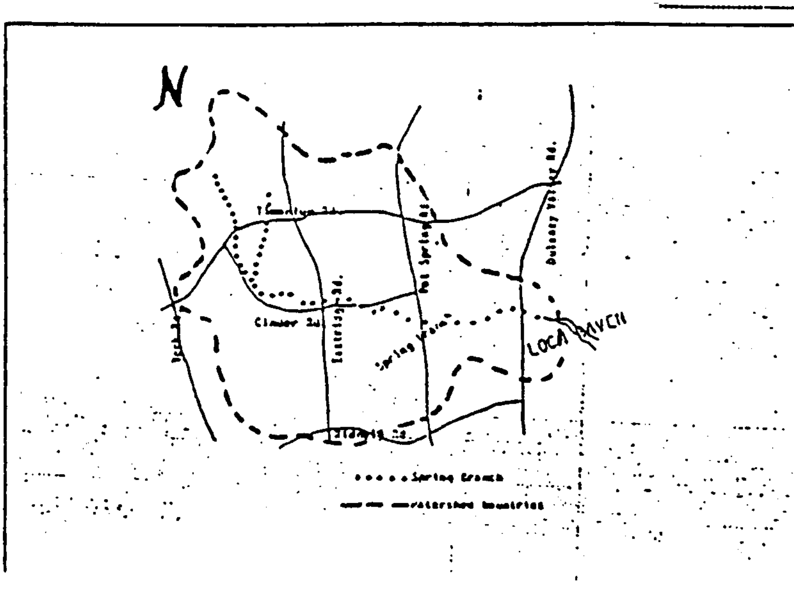
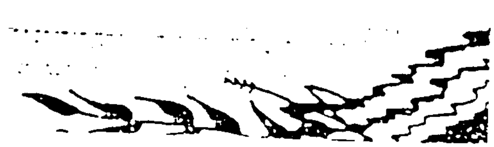
TIMONIUM U. M.
CHURCH
2300 POT SPRING RD.
NOON - 2:00 PM
TO VOLUNTEER CALL
TERRY LEHR
MARYLAND SAVE OUR
STREAMS
969-0087



Maryland Save Our Streams



Save Our Streams
258 Scotts Manor Drive * Glen Burnie, Md 21061
(410)969-0084 or (800)448-5826

Spring Branch Watershed Household Survey

Draft Report

November 1, 1994

Prepared for the:

Baltimore County Citizens for Stream Restoration Campaign

Contents:

This is a draft report. Comments on content, representation, etc. are encouraged.

DRAFT

SPRING BRANCH SURVEY
REPORT

The Spring Branch watershed is located in the Timonium area of Baltimore County, and is part of the Loch Raven Reservoir. In co-operation with DEPRM, SOS developed a forty-eight question survey about the daily routines in and around the house that can affect the water quality of Spring Branch. This survey form was distributed by community volunteers, in the watershed, beginning April, 1994.

There are about 1996 homes located in this watershed. The area was divided into 11 turfs. Seven of the turfs were distributed, and one volunteer was given an area along Gateswood Rd. and Chapelwood Lane '(adjacent to the waterway) that was a combination of two turfs. Two other sections of turfs were distributed by staff and volunteers from McDonough School. Of the 2200 surveys printed, about 1500 were handed out to volunteers to be distributed in the community. The survey area with houses directly located adjacent to the waterway was a priority to be covered. Many of the volunteers were not able to fill their commitments due to scheduling problems (softball, soccer, vacation, work) and weather conditions were some of the reasons given.

Only one turf "3" was completely covered. Turf "8" was returned with only 1 survey completed, due to work problems, one volunteer would not respond to any correspondence with staff, and the volunteer teams from turfs "6&7" and "2" mailed surveys to the SOS offices, that were not received by staff.

Eighty-seven responses were received, which is about a 4.5% of population return. On the back of the survey questionnaire, residents were asked to mark where they lived in the watershed. Thirteen surveys do not response to this section. Dividing the area map into 16 sections (see map), the response was the majority from section 6 (41), and from section 10 (12). These adjacent turf areas are along Eastridge Rd., and Timonium Rd. Sections 2, 7, 13, and 14 had two responses, while sections 1, 8, and 9 has one response each. No response was marked for sections 1, 4, 5, 13, 15, and 16. Forty-six of the survey participants gave their name, address, and phone number on the questionnaire.

Of the 87 survey responses, based on repondent's report 52 were from houses 1/4 mile or less from the waterway and 17 were between 1/4 to 1/2 mile. This is because the houses directly adjacent to the waterway were a priority.

According to the responses received, the majority of the households have lived in the Spring Branch watershed for over twenty years and consist of two members. Only one household had six or more occupants.

The majority of the responses (41) to the questionnaire stated that they had no conception of what Spring Branch's water quality might be, while 17 perceived it to be fair, six poor, and eight did not response. There were no excellent responses.

As to the major causes of the pollution to the waterway, 21 gave no response, while some had multiple selections. Mud, solids/sediments and junk/trash were both selected 17 times, while toxics,poisons and animal waste, nutrients each were felt to be the major pollutant on 11 questionnaires. Three residents selected other pollutants such as lawn clippings, leaves, and branches as the cause.

As to the heating methods for the houses in the watershed that responded, only one was heated by oil, while the rest where gas or electric. The lone oil tank reported in the survey was located in the basement of the building. There was no fireplace or woodstove responses to the question reported.

Fifty of the responses stated that they owned two transportation vehicles, 16 had one vehicle, 15 had three, three had four vehicles, and two gave no response.

Several questionnaires has several responses to the question as to where these vehicles were parked. The largest response was in the driveway (69), while 24 selected garage kept, 18 times street was selected, carport once and one resident did not respond.

The survey responses were 28 stated yes, 27 no to the question do they wash their own vehicles. Only 7 responded yes that they knew where the nearest oil/antifreeze collection center was, fifty stated no they didn't, while 14 did not answer the question.

Even through only 7 stated yes that they knew were the collection center was, there were additional answers as to where it was located. Twenty-seven gave a location. Twelve stated the Texas Landfill, 11 Cockeysville, four the service station (one named Citco), and one each for the dealer, Glen Burnie, the County yard, and Hi Gear Auto.

Of the 86 survey received, 72 households do not change their own oil or antifreeze, 2 did not respond, and 12 stated yes they do. There were 16 responses that the used oil/antifreeze was taken to the collection center, which was the only response to the question.

Forty nine homes that answered the survey do not use a professional lawn service, while 38 do. One survey did not have a response. The services brought from the lawn service was stated to be 28 for cutting grass, 12 trim work, 24 for chemical treatment (one respond stated it was an organic service and another stated only natural product service provided), for fertilization 21 (two responds stated it was an organic service and another stated only natural product service provided), while 43 failed to respond to the question. The chemical treatment services were stated to be 21 seasonally, twice annually, and one monthly. The fertilization treatment was recorded as 16 seasonally, 3 annually, and none monthly.

Thirty households responded no they did not maintain a vegetable/flower garden, while 11 did, but there were additional answers to the size of a garden. Sixteen gardens were listed to less then 100 square feet, 14 from 100 to 200 square feet, and 6 from 400 to 800 square feet. Nineteen responses were they did not know the square footage, while 8 did not response.

A large percentage of the responses (59) stated that they used commercial fertilizer, 27 natural, organic alternatives, 3 commercial chemicals, five none, and 12 did not response.
As to how often the gardens were fertilized, 23 responses were for seasonally treatment, 21 annually, 5 monthly,4 never, once twice a year, and 18 had no response. There was no weekly treatments reported. The chemical treatment to the gardens were reported to be 49 never, 11 seasonally, 4 annually, and 3 occasionally. There was no monthly or weekly treatments reported, while 22 did not answer this question.

Multiple responses were received to the question about there being trees, shrubs or ground covering plants on the lawns of the responses. Eighty-six reported trees, 83 had shrubs, 58 ground covering plants, and one reported yard of grape vines. As to how much lawn residents would be willing to landscape, 25 reported over 20 %, 19 between 10-20%, 18 less than 10%, 5 none, and 20 did not response.

In respond to a series of questions related to lawn care practices the follow answers were received: as to the question about if the lawns were watered regularly, 56 stated no, 26 yes, 1 was watered by rain, and three did not respond; 56 lawns have their walkways edged, 25 do not, 2 do occasionally, and 5 had no response; while 45 stated they do not have a mulching mower, 35 do, while 7 did not respond. Multiple methods were listed by the residents on several surveys regarding how grass, leaves, and shrub clippings were reported to be disposed of. Their responses were: 44 in the trash/landfill, 24 stated a compost pile, 13 by a lawn service, 3 along the stream bank, 2 no response, and 7 had other methods (such as mulch, leave in woods or on lawn). No responses were for placing in the stream or in the storm drain.

In regards to pest control problems, 39 survey responds were that they do it themselves, 28 use a professional/commercial service, 3 stated nothing is done, and 13 did not respond to the question. The pests reported were mostly household insects and hornets/wasps, followed by termites, ants, gypsy moths, beetles, mosquitoes, rodents, slugs, fleas, tent caterpillar, and aphids. Twenty-nine surveys stated no problem, and 9 did not answer. Sixty-three of the surveys reported they had not used a professional pest control service in the last three years, and only 22 reported yes. One survey had a none respond tabulated.

Fifty of the received questionnaires reported that there was a sump pump at the residence. As to how often these pumps discharge, 7 were reported to work seasonally, 7 never, 4 daily, 1 weekly, where 5 were listed other. This includes 1 seldom, 1 only 2 to 3 times a year, 1 when it rains, and two broken or not plugged in. Sixteen residents did not know how often the pump worked. Twenty-four sump pumps were reported to discharge to the lawn, eight to the curb, 2 to the driveway, 12 unknowns, and 7 no responses. There were 38 houses reported not to have a sump pump, while only 1 no response was received.

Forty-one of the responses received stated that there were no water conservation fixtures in the home, while 31 sated yes to the question. Nine residents did not know, while there were 7 no answers.

As to having a pool at the property, 64 responds were negative, and only 12 did have a pool. There were 11 none responses to this question. The break down of the reported pools were 8 in-ground, 3 above ground, and 1 no respond. The sizes of the pools varied. One was given as an 18 x 31 ft. pool, while each following listed gallon size was reported once: 100, 1500, 1700, 10000, 25000, 28000, 35000, 40000, and 44000. One did not know and 1 no respond were reported. Ten of the pool owners do not use a professional service, and only 2 reported uses a service. While only 2 of the pools were heated, one by gas and one solar energy, and one no response. The pools filter types were listed 1 cartridge, 5 sand, 2 DE, 1 earth and three didn't know what type of filter.

As to the number of answers to having a spa or hot tub, there were 3 possible answers, 62 no, and 22 no reponses. All 3 of the reported hot tubs were heated by electric, while 2 used a cartridge filter, and 1 owner didn't know what type of filtering system was used. The backwash flow was listed to be into the lawn by 2 residents, and again one didn't know where the backwash went.

Seventy-two households reported that they do recycle, 14 do not, and one stated "sometimes". As if the negative responses would participate in curbside recycling, when it is avaiable in their area, 14 stated yes, 3 no, 2 didn't know, and one respond "more often". As to the recycling center currently used, it was recorded as Cockeysville 19, the Texas landfill 16, County paper pick-up 14, Reynolds Aluminuim 2, and one each for Towson-Parkville Recycling Center and Baltimore Recycling Center. One resident didn't know, and 11 gave no response to the question.

A large number (52) replied that they use "environmently friendly" products or home remedies in or around their homes. To this question, 19 replied no, while 17 did not reponse. Sixty-nine of the received completed surveys households, stated that they would use the most environmentally safe products if readily available. Several responses clarified their answer that if the products were as effective, not exclusively and "I think so". Sixteen responses were recorded a Don't know and there were 10 no responses. One of the no reponses questioned for what uses would the products be.

There is an inconsistence in the number of responses to certain questions, such as know collection center, size of gardens, used of chemical and fertilizer treatments. This may be confusion on the responses due to the wording of the question. It is possible that many residents confused the questions about the gardens with lawns, including care, services and treatments.

Possible activities that could be used as a follow-up to this suvey are several education campaigns. It appears there is a need for more knowledge about disposal of grass and lawn clippings. Two survey responses were onto the stream bank. During meetings and conversations with watershed residents during this project, several beleived placing lawn waste on the stream banks stablized them. Residents should be aware that a small amount of leaves are natural in the waterway, but excessive material degrades the water quality. There are many residents that need more information about the avaiable recycling stations in the area. One response was Glen Burnie to the nearest oil/antifreeze collection center. Hopefully, stream walks can be organized to make the watershed citizens more aware of stream ecology. It must be cautioned that many of the residents may be older, and accessiability to the stream should be an easier pathway, or other methods used.

SPRING BRANCH STREAM TOUR

Saturday, March 25, 1995

AGENDA

10:00-10:15 AM	Registration	
10:15-10:30 AM	Introduction	Rebecca Pitt, Save Our Streams
10:30-10:45 AM	Video - "Restoring the Past, Preserving the Future"	
10:45-11:15 AM	DEPRM's Restoration Plans; Spring Branch Watershed	Don Outen, DEPRM
11:15-11:30 AM	BREAK	
11:30-1:30 PM	Tour of Spring Branch	Don Outen/Candy Szabad, DEPRM
30-1:45 PM	Where Do We Go From Here?	Suzi Wong, Save Our Streams
:45-2:00 PM	Wrap Up/Return to School	

SPRING BRANCH STREAM TOUR

with
BALTIMORE COUNTY
DEPARTMENT OF ENVIRONMENTAL PROTECTION AND RESOURCE MANAGEMENT (DEPRM)

JOIN US ON A TOUR OF SEVERAL SECTIONS OF THE RESTORED STREAM

SATURDAY MAY 16, 1998
10:00 AM

MEET AT ST TIMOTHY LUTHERAN CHURCH PARKING LOT

100 E. TIMONIUM ROAD

PLEASE WEAR APPROPRIATE CLOTHING AND BOOTS FOR WALKING IN AND AROUND THE STREAM

FOR MORE INFORMATION PLEASE CONTACT
JO OWEN 410-252-5515 OR CANDY SZABAD (DEPRM) 410-887-2904

RAIN DATE FOR <u>HEAVY</u> RAIN ONLY - MAY 23RD PLEASE CALL TO CONFIRM

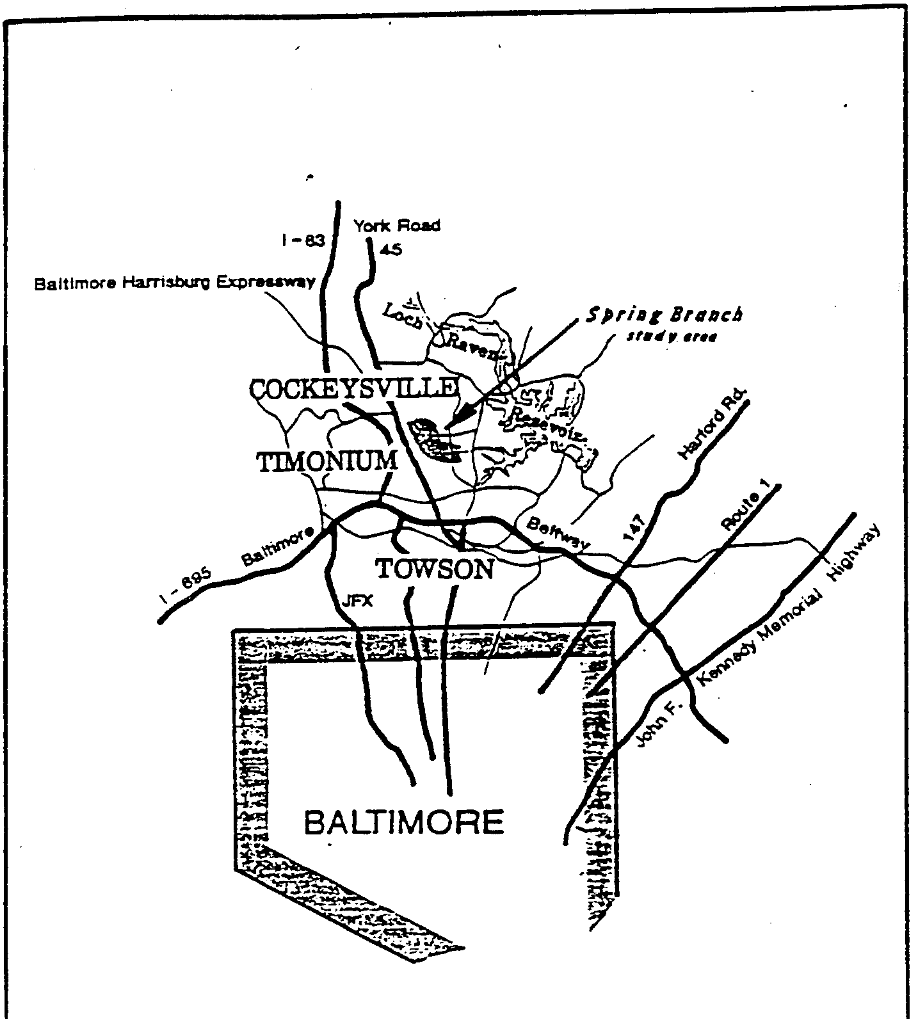
PRESS RELEASE

IMMEDIATE RELEASE FEBRUARY 26, 1996

The Baltimore County Department of Environmental Protection and Resource Management is conducting a public meeting on Wednesday, March 27, 1996 to discuss the proposed stream restoration improvements to Spring Branch in Timonium. The meeting will be held in the cafeteria of Dulaney High School at 7:30pm.

All property owners adjacent to the stream are urged to attend.

For further information please call the Department of Environmental Protection and Resource Management at 887-2904.



SPRING BRANCH STREAM RESTORATION PROJECT

The Baltimore County Department of Environmental Protection and Resource Management is conducting a public meeting on Wednesday, March 27, 1996 to discuss the proposed stream restoration improvements to Spring Branch in Timonium. The meeting will be held in the cafeteria of Dulaney High School at 7:30pm. All property owners adjacent to the stream are urged to attend. For further information please call the Department of Environmental Protection and Resource Management at 887-2904.

March 7, 1996

Dear Property Owner:

Baltimore County is proposing improvements to the stream and/or County onwed land adjacent to your property. This stream, known as Spring Branch, is a tributary to the Loch Raven Reservoir. The Department of Environmental Protection and Resource Management would like you to attend the following informational community meeting:

DATE: MARCH 27, 1996

TIME: 7:30 PM

PLACE: DULANEY HIGH SCHOOL CAFETERIA

Baltimore County representatives will present the proposed improvements to Spring Branch and answer any questions you may have.

Should you have any questions, please call Candace Szabad or Chin Y. Lien of my staff at 887-2904.

Very truly yours,

Donald C. Outen, A.I.C.P.
Bureau Chief
Bureau of Water Quality and
Resource Management

DCO:jj

Baltimore County
Department of Environmental Protection
and Resource Management

Office of the Director
401 Bosley Avenue, Suite 416
Towson, Maryland 21204
(410) 887-3733
Fax: (410) 887-4804

August 15, 1996

Dear Spring Branch Property Owner:

The long awaited construction of the stream restoration project on Spring Branch is scheduled to begin. The County's contractor, the firm of Coastal Design and Construction, Inc., will begin to work in the stream in the next couple of weeks.

We appreciate your continued cooperation and patience on this extremely complex project.

Should you have any questions, please call Candace Szabad or Chin Y. Lien of my staff at 887-2904.

Very truly yours,

George G. Perdikakis
Director

GGP:cs

Baltimore County
Department of Environmental Protection
and Resource Management

Bureau of Engineering Services
401 Bosley Avenue, Suite 416
Towson, Maryland 21204
(410) 887-3768
Fax: (410) 887-4804

September 24, 1996

DEAR SPRING BRANCH PROPERTY OWNER:

As you are aware, the Spring Branch Stream Restoration Project is underway. Your property is located adjacent to the proposed restoration work. The work area has been or will soon be located with wooden stakes with pink ribbon labeled LOD (Limit of Disturbance). These stakes also mark the location of the property line. If you have any structures or landscape features located on County property (between the LOD stake and the stream), you may want to remove those items as soon as possible. Any items within the work area may be subject for removal. Any items left within the work area are done so at your own risk.

If you have any questions, please contact Candace L. Szabad of the Department of Environmental Protection and Resource Management at 887-2904.

Sincerely,

Chin Y. Lien, P. E., Supervisor
Capital Improvements Section
Bureau of Resource Management
and Engineering Services

CYL:cs

May 30, 1997

DEAR SPRING BRANCH PROPERTY OWNER

The construction activity in Spring Branch has now been completed. I would like to take this opportunity to thank each of you for your interest and patience during the construction of this important stream restoration project. This Department will be monitoring the success of this project throughout the year

I would like to remind you to dispose of your grass clippings and other yard waste properly and not to dispose of any yard waste in the stream or on the banks. It is crucial to the success of the project to ***keep all yard waste out of the stream and off the banks***. The banks of the stream have been planted with variety of trees and shrubs and a mix of seed. To ensure proper growth, please ***do not mow*** these areas.

Once again, thank you for your cooperation and I hope that you are pleased with the results of the restoration effort.

Very truly yours,

George G. Perdikakis
Director

GGP:cs

Spring Branch Stream Restoration

- Naturalized channel
- Stable slopes
- Stream improvement
  - water quality
  - habitat
  - asthetics

Spring Branch Stream Restoration

- Type of Work Effort
  - Grading
    - Dirt Removal
    - Sculpting New Channel
  - Stabilization
    - Reseeding
    - Naturalized Landscape
    - Sod and Lawn Replacement

Spring Branch Stream Restoration

- Bioengineering Methods:
  - Root Wads
  - Rock Toe protection
  - Live Fascines
  - Coir Fiber Role
  - Live Branch Layering
  - Live Brush Matress
  - Native Plant Seeding

Spring Branch Stream Restoration

- Stream Construction Methodology
  - Disturb Small areas of the channel
  - Proceed Section at a time
  - Minimize Disturbance to Private Property
  - Limit Disturbed area to <1,000 feet of channel at a time.
  - Limit Construction Access
  - Protect Existing Landscape.

Spring Branch Stream Restoration

- Will the entire channel be disturbed?
  - No!
- Will all the trees be removed?
  - No!
- What will happen on my property?
  - Probably Nothing!

APPENDIX B2

PUBLIC RESPONSE AND TECHNOLOGY TRANSFER

- **Letters from Local Citizens**
- **Letters from Firms**
- **Script for Video**
- **Newspaper Articles**

FILE

February 0, 1997

Mr. Chin Y. Lien, P.E., Supervisor
Capital Improvements Section
Bureau of Resource Management
and Engineering Services
401 Bosley Avenue, Suite 416
Towson, MD 21204

Mr Lien,

The neighbors of Coldbrook Road wish to express their thanks and appreciation for the team of engineers and workers that dealt with the Spring Branch restoration project (tracking# 199661250). You, and especially M's Candace Szabad, were most helpful, and patient in responding to the questions and concerns which many of us had during the restoration period. M's Szabad was quick to respond to issues, and was very cooperative in dealing with requests for assistance.

The project appears to be completed in the Coldbrook Road area. For the most part, the neighbors of Coldbrook generally like the finished work. With the plantings installed by the County, and the property grading which took place, all of us anticipate seeing a more beautiful and natural setting along the Spring Branch stream.

Please express our thanks to the various work crews that participated in this project.

[illegible]
217 Coldbrook Road
Mr. & Mrs George [illegible] 214 Coldbrook Road
[illegible] 225 Coldbrook Rd
[illegible] & MRS MICHAEL J NEWLOVE 122 SPRINGSIDE DR
Mr and Mrs Laurence Townsley
213 Coldbrook Road Timonium 21093
[illegible] 215 Coldbrook Rd Timonium

F I

Post-it™ routing request pad 7664

ROUTING - REQUEST

	To
READ	GGP ✓
HANDLE	ATLV ✓
APPROVE	CLS ✓
FORWARD	A copy of this letter to
RETURN	be placed in Candy's

J. R. ZARFOSS
207 COLDBROOK RD.
TIMONIUM MD 21093

BUREAU OF WATER QUALITY AND RESOURCE MGMT.
401 BOSLEY AVE. SUITE 416
TOWSON MD. 21204

REFERENCE - SPRING BRANCH RESTORATION, 19966125O
ATTN: CHIN Y. LIEN, SUPERVISOR CAPITAL IMPROVEMENT

DEAR MR. LIEN,

I WISH TO COMMEND YOU AND THE PROJECT TEAM FOR AN EXCELLENT PRESENTATION. AS YOU CAN SEE BY THE ENCLOSED LETTER I FULLY SUPPORT THE PLANNED ACTIVITY.

ALSO, I WOULD LIKE TO REMIND YOU OF THE POSSIBILITY OF A LEAKING SANITARY SEWER BEHIND 206 AND 208 CINDER RD. MANY YEARS AGO ERROSION ALLOWED THE STREAM BANK TO SLIP CAUSING THE SEWER PIPE TO SAG AND LEAK. THE BACK FILL AND RIP RAP FIX HAVE NOW SLIPPED AGAIN AND THERE IS OCCASIONAL EVIDENCE OF RAW SEWAGE LEAKING INTO THE STREAM.

PLEASE EXTEND MY THANKS TO THE TEAM AND CONGRATULATIONS ON A FINE PRESENTATION. I WISH YOU COMPLETE SUCCESS.

VERY TRULY YOURS,

J. R. Zarfoss, P.E.

J. R. ZARFOSS
207 COLDBROOK RD
TIMONIUM, MD 21093

U.S. ARMY CORPS. OF ENGINEERS, BALTO DISTRICT
P.O. BOX 1715
BALTIMORE MARYLAND 21203-1715

REFERENCE
SPRING BRANCH STREAM RESTORATION 96-61250-1
ATTN: MR. D.W. ROESKE, CHIEF REGULATORY BRANC

DEAR MR. ROESKE,

I ATTENDED A TEAM PRESENTATION OF THE PROJECT TO RESTORE SPRING BRANCH ON MARCH 27 AND WAS IMPRESSED BY THE THOROUGHNESS AND ATTENTION TO DETAIL. I HAVE LIVED ADJOINING THE STREAM FOR 38 YEARS AND THEIR DEFINITION OF THE PROBLEM APPEARS TO ME TO BE ON TARGET. THE EXAMPLES OF PRIOR WORK AND THEIR CONFIDENCE THAT THE PROPOSED SOLUTIONS ARE CORRECT FOR THIS SITUATION CONVINCED ME THAT THE PROJECT SHOULD RECEIVE THE SUPPOR OF THE COMMUNITY. I BELIEVE THE PROJECT IS WORTHY OF YOUR APPROVAL.

THANK YOU FOR YOUR CONSIDERATION.

J.R. Zarfoss, P.E.

C.C. C.Y. LIEN ✓

144 Greenmeadow Drive
Timonium, Maryland 21093

March 11, 1997

The Honorable C.A. "Dutch" Ruppersberger
Baltimore County Executive
400 Washington Avenue
Towson, Maryland 21204

Dear Dutch:

Just wanted to let you know how thrilled I am with the outcome of Spring Branch so far and apologize for being so remiss in thanking you.

I really appreciate you getting the "ball rolling" last year
I think everyone who has been involved has done a great job!

I would like to commend George Perdikakis, Candy Szabad, Tom Vidmar, and of course, Doug Riley, for all of the time and effort they have put into this restoration project of Spring Branch. They couldn't have been more helpful, cooperative and informative through out these past few months. They are great people and I would think that you would be proud to know they are on your Baltimore County "team"!

I am really looking forward to the arrival of spring so I can the new trees and greenery on my new "waterfront property"!

I assume by now that you are off of the crutches and are moving along rather rapidly. Once again, thanks for your input and am looking forward to seeing you sometime in the near future.

Sincerely,

Mary Lee

Mary Lee Sas

MLS:m

If you need any help when campaigning begins, do not hesitate to give me a call.

cc Tara Oursler
Bob Barrett

March 28, 1996

Baltimore County
Dept. of Environment Protection
and Resource Management

Attn: Candace Szabad

Dear M's Szabad,

My wife and I attended the community meeting on March 27, at Dulaney High School, regarding the restoration of the Spring Branch tributary. I talked with other home owners after the meeting about the issue, and, with only one exception, heard only favorable comments for the plan. Additionally, everyone said the presentation was clearly made, easy to understand, and that the question and answer period went rather well, also.

Good Job.

Now - let's get the bids in and move on this project

Yours truly,

Bruce Numbers

BRUCE NUMBERS
217 COLDBROOK ROAD
TIMONIUM, MD. 21093

BRUCE NUMBERS, M.S.
SUITE 209C (410) 764-4210
6776 REISTERSTOWN ROAD
BALTIMORE, MD 21215

RECEIVED
APR 1 - 1996
DEPRM
CAPITAL IMPROVEMENTS

144 Greenmeadow Drive
Timonium, Maryland 21093

March 11, 1997

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Baltimore County Executive
400 Washington Avenue
Towson, Maryland 21204

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Sincerely,

Mary Lee

Mary Lee Sas

MLS:m

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bc Tara Oursler
Bob Barrett

THE COX COMPANY
Planners · Landscape Architects
Civil Engineers · Urban Designers

FEB

January 27, 1997

Ms. Candace Szabad
Baltimore County Department of Environmental Protection
and Resource Management
401 Bosley Avenue, Suite 416
Towson, Maryland 21204

Dear Candace,

Thank you for your tour of the Spring Branch Stream Restoration Project this past Wednesday, and for fielding our inquiries related to stream restoration. The Spring Branch project was exemplary, and incorporated many of the bio-engineering techniques we had hoped to see. Having the opportunity to view a recent installation was important to our understanding of the construction details and their specific applications.

As we mentioned, the local restoration project we have undertaken has many streamside situations similar to Spring Branch, and we plan to incorporat bio-engineering techniques into the plan. We are convinced of their environmental suitability, and excited about the prospects for Rock Creek.

We would like to plan a visit to Spring Branch again once the installation has been through a growing season, and so will contact you perhaps in late summer. We would also be interested in the availability of the video being produced detailing the bio-engineering approach used for Spring Branch.

We wish you the best in your work on future projects, and thank you once again for meeting with us.

Sincerely,

Linda Winecoff

Linda Winecoff

Fred Missel

804 · 295 · 7131
220 East High Street
Charlottesville, Virginia 22902

CHESAPEAKE BAY LOCAL GOVERNMENT ADVISORY COMMITTEE

416 GOLDSBOROUGH STREET
EASTON, MARYLAND 21601-3611
(410) 822-9630 (800) 446-5422
(410) 820-5039 (Fax)

October 13, 1997

Mr. George Perdikakas
Director, DEPRM
401 Bosley Avenue, Suite 416
Towson, MD 21204

Dear Mr. Perdikakas,

On behalf of the Chesapeake Bay Local Government Advisory Committee (LGAC), am pleased to inform you that Baltimore County is a 1997 recipient of a Local Government Advisory Committee's *Award for Community Innovation*. Congratulations! Your project indeed makes a worthwhile contribution to the protection and restoration of the Chesapeake Bay, its rivers, and streams.

This year, eight communities are receiving Awards:
Stormwater Management Program, Hanover County, VA
Oyster Gardening, Tidewater RC&D, VA
Targets of Opportunity, City of Alexandria, VA
"Ecowise Program", Montgomery County, MD
Emergent Grass Re-Vegetation Program, Anne Arundel County, MD
Spring Branch Restoration Project, Baltimore County, MD
Spring Meadow Recreational Parcel, South Middleton Township, PA
Lititz Run Watershed Alliance, Lititz, PA

In recognition of your effort, I would like to invite a representative from your office to attend the next LGAC meeting at which time the award will be presented. The meeting will take place on November 20 in Annapolis, MD. Please contact LGAC staff at (800) 446-5422 with the name(s) of your representative and for information on the location of the meeting.

Congratulations and thank you for your involvement in the protection and restoration of the Chesapeake Bay! I look forward to presenting Baltimore County with its award on November 20.

With warm regards,

Russell Pettyjohn

Russell Pettyjohn, Chair
Local Government Advisory Committee
Mayor, Lititz Borough, PA

cc Eldon Gemmill

SUMMARY SHEET

Project: **Spring Branch Stream Restoration and Water Quality Retrofit**

Agency: Baltimore County Department of Environmental Protection and Resource Management (DEPRM) - Director: George Perdikakas

Objectives: Create a stable flow regime; correct severe bank erosion and a stable, self sustaining stream channel; improve habitat and aquatic resources; reduce flooding, property damage and safety hazards; reduce pollutant loading to the reservoir and the Chesapeake Bay

Project Management: Candace Szabad-Project Manager; Chin Lien-Supervisor, Capital Improvements Section

Location: Timonium, Baltimore County, Maryland

Watershed: Loch Raven - Gunpowder Falls Watershed ; Tributary to Loch Raven Reservoir;

Drainage Area: 481 acres; Landuse is primarily small lot residential

A. 10,541 linear feet of stream restoration
B. Retrofit-creation of three shallow marsh basins, encasement of an exposed sanitary sewer line, removal of concrete channel bottom and realignment of storm drain outfall.

Stream Restoration: $2.25 million
Water Quality Retrofits: $208,000

Funding: Baltimore County Bonds, Maryland MDE Small Creeks & Estuaries Grant; MDE Stormwater cost share

Time Lines: Concept Plan: Spring 1992; Design 1994-1996; Construction: Fall 1996-Spring 1997; Monitoring: Five years planned beginning Fall 1997

Status: Construction -completed; monitoring - ongoing

Public Awareness & Education:

SOS meeting & field tour; one large community meeting; one-on-one property owner visits; mailings; video; newspaper articles; homeowner survey

Stream Restoration in Maryland Using Natural Geometry Approaches

Keith Bowers
Biohabitats, Inc., 15 West Aylesbury Road Timonium, MD
(410-337-3659)
Fax (410-583-5678)

Urbanization, flood control, land clearing, and agricultural practices have extensively degraded and disturbed aquatic systems throughout the Northeast. In particular, urban development has a profound impact on stream hydrology, morphology, water quality, and biodiversity. The state of Maryland, recognizing the inseparable link between ecologically stable tributary streams and a healthy Chesapeake Bay, is striving for a comprehensive strategy to restore the tributaries of the Chesapeake Bay watershed.

Baltimore County has embarked on one of the most ambitious stream restoration programs in the Eastern U.S. to date. One of the highlights of their program is the restoration of Spring Branch which is located in the Piedmont Plateau physiographic province and drains nearly 500 acres to the Loch Raven Reservoir, a valuable drinking supply for the Baltimore Metropolitan Region. Over the last 50 years, the Spring Branch watershed has undergone intensive development. Today, the landscape is blanketed by many clone-like single-family homes on 1/4 to 1/2 acre lots serviced by standard curb and gutter roads. Impervious surfaces account for more than 50 percent of the watershed and due to the age of the development, stormwater management is absent, quite typical of the Northeastern suburban landscape.

Stormwater runoff is conveyed underground through storm drains, discharging directly into Spring Branch. On average, 25 percent of the area contributing stormwater runoff enters the stream via overland flow (non-point sources) and 75 percent via storm drain inputs (point sources). The large percentage attributable to point sources suggests that the rate of storm runoff entering the stream channel can be generally described by short, rapid peak hydrographs. These commonly called "pulse inputs" tend to discharge storm water into the stream channel more rapidly and with a greater intensity than streams dominated by forested watersheds.

Anthropogenic influences in the watershed and to the channel are evident in the degraded physical appearance of the stream system. The channel has been enlarged through episodes of downcutting, lateral erosion, and aggradation. Both base and storm flows typically occur so as to maintain or reach an equilibrium that is in synchrony with watershed inputs.

The predominant component affecting channel morphology is the desychro- nized, point source flow regime associated with seasonal storm events. Although not a direct influence on the existing channel structure, the broadened channel and eroding streambanks which are remnant features from earlier perturbations, inherently affect the overall stability of the stream system. Erosion from rushing storm water has carved a gorge 30 feet across and up to 15 feet deep in Spring Branch. One long-time resident recently explained that twenty years ago, a person could "hop" across this channel.

Recognizing the need to protect water quality and aquatic biodiversity, Baltimore County retained Biohabitats to assess approximately two miles of Spring Branch and develop a management plan to restore a stable stream channel geometry, enhance water quality, and re-establish aquatic habitat.

In 1994, we began a two-year process of assessing the physical and biological conditions of Spring Branch. Using an applied fluvial geomorphological approach, Spring Branch was classified according to channel geometry relationships using the Rosgen Stream Classification system. This stream classification system establishes predictable, morphologic stream types based on the following variables: bankfull width to depth ratios, entrenchment, channel gradient, sinuosity, and sediment grain size. Stream classifications are predictable since these variables are interrelated; fluvial processes and channel morphology (i.e., pattern, profile, and dimension) evolve concurrently, resulting in a natural channel geometry that can be classified or recreated in restoration design. These components are integral to creating a stable stream channel in equilibrium with the surrounding lands, and facilitates the restoration of lotic aquatic life. This means of rehabilitation can be used on streams and rivers for various purposes, such as the stabilization of an eroding stream bank or a total channel and floodplain reconstruction.

From the classification information, Biohabitats then characterized stream channel cross sections, profile, and plan geometry. Stream substrate was characterized using the Wolman

(continued on page 3)

SER Northeast Group Sponsoring Wetlands Restoration Conference

The SER's Northeast Group is supporting the Association of Massachusetts Wetland Scientists and New England Chapter of the Society for Wetland Scientists, together with the Rhode Island Association of Wetland Scientists, in holding a Wetland Restoration Conference focusing on forested wetlands, scheduled fof March 15th. The conference agenda promises to be a very exciting day at the Holiday Inn in Boxborough, MA (northeastern MA, directly off I-495 and in close proximity to several ski areas) with a very resonable registration fee which includes coffee, danish and a full lunch! The conference format and content will consist of specific topics, nuts and bolts discussions on vegetation, soils, microtopography, and hydrology in New England but applicable to other regions, too. The discussions will include information on both success and failures, providing insight on the dos and don'ts of restoration. Register early, as seating is limited! Please see the attached registration form on page 5 for further information. Hope to see you there!

Rebounding Rockfish

Fish surveys conducted by Maryland's Department of Natural Resources (MDNR) of several major Chesapeake Bay rivers during 1996 have revealed record numbers of young-of-the-year (YOY) striped bass *(Morone americana)*.signaling a continued successful restoration of this prized gamefish. Chesapeake Bay has long been known as a principal East Coast spawning and nursery area of the striped bass or rockfish", although Bay rockfish stocks plummeted during the late

(continued on page 6)

Pebble Count: streambank erosion was measured and rated: and dominant stream discharges were both field measured and collaborated with engineering hydrologic and hydraulic modeling performed by our sub-consultant KCI Technologies, Inc.

After conducting the field and assessment phases of the project, we concluded that Spring Branch had desychronized, point source flow regimes; severe bank instability and subsequent erosion; failing or threatened infrastructures; lack of a vegetated riparian buffer; and poor land use practices in and adjacent to the stream. Despite the urban nature of the watershed, we also predicted that the recovery potential for this system would be high if the stream was given some effective assistance. We recommended that restoration efforts focus on restoring a stable channel morphology and correcting bank erosion. A wide array of solutions and techniques was presented focusing on a comprehensive restoration approach that targeted overall stream health.

Because stream systems are so intimately tied to physical, biological, and chemical processes that occur throughout a watershed, stream restoration, defined as a return to an original condition, is a complex and difficult task. Most so-called "stream restoration" projects are more properly considered attempts to rehabilitate selected sections of riverine systems to a predetermined structure and function.

Past restoration efforts have often focused on enhancing aquatic habitat without significant regard to stream hydrology on morphology. The majority of these projects eventually fail and many do not function as originally intended. What is needed is a comprehensive, holistic approach to stream rehabilitation that incorporates fluvial geomorphologic principles, natural stream dynamics, and applied ecology. This holistic approach to stream restoration has many benefits, including replication of natural hydrologic and ecological cycles, enhancement of riparian and in-stream aquatic habitat, improved aesthetics, long-term sustainability, and significant cost savings over most structural solutions.

Baltimore County agreed and approved work to begin preparation of final design and construction plans for the restoration of the entire two miles of Spring Branch study reach. In general, Biohabitats' approach to stream restoration combines the disciplines of fluvial geomorphology, civil engineering, and applied ecology. Our approach depends on accurate identification of stream classification type, an understanding of hydrologic actions within the watershed and their effects on a stream channel, and clearly defined restoration goals. Although we utilize accepted hydrologic and hydraulic models and equations to determine stream discharges, water surface profiles and shear stress, our experience shows that accurate field observations of channel characteristics are required to accurately calibrate and corroborate modeling output.

Conventional practice suggests that the critical discharge for re-establishing a stream channel is the bankfull discharge. This discharge at a 1 to 2-year recurrence interval will occur more frequently as the watershed becomes more urbanized with increased impervious area. Therefore, Biohabitats calibrates and corroborates hydrologic modeling outputs with field measurements to ensure that reliable channel conveyances are used to predict and design a restored channel geometry.

Using ratios and measurements from reference stable stream reaches, hydraulic and hydrologic modeling, and design parameters developed from years of research by Dave Rosgen from Colorado, we set out to meet our objectives. Our design was constrained by many factors, including a 50-foot wide easement, sanitary sewer lines running the length of the project, large trees, overhead electric, telephone and cable television wires, 16 storm drain outfalls, existing concrete lined channels, and a skeptical neighboring community.

(continued on page 4)

The best approach moderating the flow regime was to reduce velocity and time of concentration of storm flows delivered to the channel. The place to achieve these objectives is essentially throughout the watershed. however, due to the built-out nature of the watershed, this was infeasible without disrupting existing land use, roadway, and storm drain networks.

Although generally less effective, flow regimes were slightly moderated through retrofit activities in the stream valley and stream channel, including :

- Create A/B step pool morphologies as the outfall channel
- Create plunge pools below pipe outfalls
- Place rip-rap in outfall channels and downstream of culverts
- Create catch basins to attenuate flow

The other approach for ameliorating the storm flow pulse regime was to provide floodplain access for bankfull discharges. This approach involved creating flood prone areas in sections of the channel that are currently entrenched by altering channel geometry. Channel reconfiguration typically involves modifying the cross-sectional and meander geometry to provide a more stable, efficient morphology and maintain stream habitat. In some cases, reconfiguration may involve creating an entirely new morphology, or correcting specific variable(s) that may not be in balance with the operation of the channel and flow regime. Channel modifications must reflect and be consistent with valley features, watershed inputs, adjacent land uses, and base and storm flows. For Spring Branch. this generally involved changing overly widened and entrenched sections of the channel so that they would allow bankfull discharge to enter a floodplain area.

In many cases, channel modification design efforts consisted of "tweaking" various aspects of the current geometry in order to facilitate natural recovery efforts already underway. In other locales, a new channel and floodplain were designed to efficiently transport bed load and sediment load, and withstand storm flows. Sinuosity, bankfull width and depth. and entrenchment relationships of stable step-pool and pool-riffle morphologies were used as design references.

Once a stream cross section. profile, and pattern were designed, our attention turned to developing stream stabilization measures that not only supported natural stream geometry objectives but also provided aquatic habitat benefits. The use of innovative soil bioengineering techniques for stream rehabilitation support and compliment a holistic restoration approach such as Spring Branch. Various soil bioengineering techniques were applied to stabilize streambanks, augment aquatic habitat, and enhance biodiversity in Spring Branch including vortex rock weirs, root wad revetments, gravel riffles, step pools, meander bend pools, live fascines, live brush mattresses, live branch layering, and live joint planting.

Several meetings were held with the neighborhood community to explain stream ecology, and restoration concepts, construction logistics, and maintenance activities. Additionally, we asked for community input for certain design parameters including selection of riparian plantings. These meetings turned out to be a great success and generated overwhelming community support. Similarly, both federal and state regulatory agencies gave full support to the efforts.

In the summer of 1996, work began on the Spring Branch restoration. Coastal Design and Construction from Norfolk, Virginia was the successful contractor. Biohabitats was retained to provide construction review and observation, inspection, troubleshooting. preparation of As-Built construction drawings, and survey permanent cross sections for long-term monitoring. Site construction is expected to be completed by the end of January 1997.

It is interesting to note that the project has undergone three "bankfull" rain events since September, truly testing the design. Even though these events slowed construction progress. the storms turned out to be very beneficial from a design standpoint. We were able to observe how the new stream channel functioned during high flow events and were able to modify certain construction techniques to improve the overall design.

Overall costs associated with the restoration effort were high due to limited construction access and tight working conditions. A composite cost including assessment, design, permitting, construction procurement, construction. and a one-year plant material warranty amounted to S200 per linear foot. Other projects we have been working on range in cost between S25 and S150 per linear foot. depending on the extent of the restoration and site constraints.

Baltimore County has six similar projects in the design phase and expects stream restoration to be a major focus of its capital improvements budget for some time to come. Biohabitats is currently working on at least 16 stream restoration projects for local, state, and federal agencies throughout the Northeast and Ohio River Valley.

In conclusion, a holistic, ecologically sensitive approach to stream restoration has many benefits. including replication of the natural hydrological and ecological cycles. enhancement of riparian and in-stream aquatic habitat, improved aesthetics, and significant cost savings over structural solutions. Biohabitats' objective is to create a stream system that is hydrologically stable, ecologically dynamic, and biologically diverse.

SPRING BRANCH VIDEO TEXT

Title: "Spring Branch: Restoring a Neighborhood Stream"

Introduction to Spring Branch
Connection to Loch Raven Reservoir
Problems and Causes
Priority for Stream Restoration
Goals
Stream Restoration Approach
Stream Restoration Design Plan
Construction
The Completed Project/Benefits Gained
The Citizen's Role

TEXT

Spring Branch is an urban stream which has experienced severe bank erosion and instability for many years.

Spring Branch is located in the Timonium area of Baltimore County flowing generally eastward 2.84 miles from Timonium to the Loch Raven Reservoir.

The Loch Raven Reservoir is a source of drinking water for 1.5 million people in the Baltimore metropolitan region and part of the Chesapeake Bay watershed.

Stream erosion and urban stormwater runoff in Spring Branch have contributed sediment and nutrient pollutants to Loch Raven.

Since Spring Branch drains to the Loch Raven Reservoir, it is a high priority for water quality improvements.

The watershed of Spring Branch consists of many land use types including residential homes, schools, stores and other businesses, industry, roads and parking lots

Stormwater runoff over these land use types carry nutrients, toxic materials and sediment into the stream.

The following stream problems are found in many urban/suburban stream settings:

- Streambank and channel erosion. Sediment entering the stream increases turbidity, decreases reservoir water storage capacity, and smothers animal life

- Degraded water quality. Nutrients and toxins wash off lawns and home landscapes and into local streams. Water flowing over paved walkways, driveways and parking lots carries pollutants. Runoff carries loose soil, fertilizer, pesticides and oily residues into storm drains and streams. Grass clippings and other yard wastes wash into storm drains, drainage ditches, and streams adding too many nutrients and toxins to the water. Toxins kill fish and other life. Nutrient over-enrichment promotes the over-growth of algae, resulting in unpleasant odors in drinking water. As algae die and decay, water is robbed of vital dissolved oxygen, causing a dieback of life in the water.

- Stressed streamside ecosystem. There is no vegetated streamside protective buffer zone and no tree cover. Grass is mowed up to the edge of the stream.

These problems are caused by:

- Actions on the land that contribute pollutants (nutrients, sediment, and toxins) to the water. People do not know how everyday actions at home affect the water in the neighborhood stream.

- Uncontrolled stormwater runoff from the large amount of paved surfaces in the watershed.

Baltimore County has designated the tributaries of Loch Raven, including Spring Branch, as a priority for stream restoration.

This priority is an overall commitment to protect water quality in the streams feeding the drinking water reservoir.

Baltimore County's goals in the stream restoration of Spring Branch were to stabilize the channel and reduce erosion, which will result in the improvement of water quality, and habitat.

To reach these goals, Baltimore County selected an approach that attempted to restore a natural stream channel by using native and natural materials such as tree root wads, logs, boulders, and live branch cuttings.

Native trees, shrubs, and ground covers were selected to establish a protective stream buffer on the land adjacent to the stream. The stream and buffer areas were surveyed and a detailed engineering plan was developed.

Community meetings were held to inform and educate the citizens living in the watershed.

Several property owners adjacent to the stream were contacted to cooperate in allowing construction equipment across their property in order to reach the stream

Once design plans were completed and permitted by the Federal, State and Local agencies, the County advertised for construction bids.

After an approved construction firm was selected, the project was underway.

The construction crews began the project in September of 1996.

The first task was to build the access roads to allow equipment to reach the stream.

During construction, the water flowing in the stream was pumped around the work area.

The crews then built the new channel as the equipment worked its way upstream or downstream.

The equipment operators and construction crews reconfigured the channel shape and size and installed the required bank protection measures and slope control features.

Pools and riffles were built in the new streambed. These features, in several locations replaced concrete channels that had been constructed years ago.

The rebuilt stream consist of a combination of sinuous or curved channels and rock step pools.

Once the proper shape, size and pattern was constructed, the bank protection measures were installed.

To prevent streambank erosion and provide aquatic habitat benefits, the following measures were used in Spring Branch

Root Wads - Root wads are the root fan of a tree with approximately 10' to 12' of the trunk attached. The trunk is inserted into the bank so the fan is against the streambank. Root wads protect the streambank from erosion while providing habitat for fish and other riparian critters. Once the streambanks are planted with riparian vegetation, the root wads blend in with the vegetation and provide a very natural looking stable streambank. In several places root wads could not be used due to the proximity of utility lines. In these instances, rock boulders were placed along the streambank to provide erosion protection.

Vortex Rock Weirs - This structure is installed to create grade control and prevent the stream from downcutting. The weirs also increase the depth of the stream which provided for an efficient transport of sediments. The structure is designed to allow the energy from the stream flow to be concentrated in the center of the stream. This keeps the stress off of the banks which will prevent erosion.

2 Step Pools - Step pools are rock structures that were placed in the steeper sections of Spring Branch. These structures dissipate energy from stormwater runoff as the water cascades over the rocks.

3 Bioengineering - Various soil bioengineering techniques were applied to stabilize the streambanks. These include live fascines, live brush mattresses, and live branch layering

The live fascines consist of Willow and Dogwood stems and branches. They were tied together in long bundles and placed along the toe of the streambank. Live fascines provide excellent erosion control protection.

The live brush mattresses also consist of Willow and Dogwood stem and branches, but are placed in a crisscross pattern on the slope of the streambank to provide erosion protection from stormwater runoff.

The live branch layering was used on the streambanks in several locations to provide erosion control

The live plantings are an excellent stabilization technique along streambanks. Slopes are stabilized quickly and the vegetation provides a cost effective approach while providing a natural and pleasing appearance.

4. Riparian Buffer Plantings - The area adjacent to the stream was planted with trees and shrubs and a mix of forbs and grasses. All of the vegetation utilized is native to the region and this particular watershed

The vegetation selected is primarily drought tolerant and disease resistant. Vegetation was planted on County property approximately 25 feet on both sides of the stream. This vegetated buffer is critical to the success of the stream restoration project.

Stream buffers provide significant water quality and wildlife benefits, as well as enhance the natural features of the community. The root system of the vegetation will assist in controlling streambank erosion, stormwater runoff and will reduce the amount of sediments and nutrients entering the stream.

The benefits of the Spring Branch project are many.

- Reduce nutrient and sediment loads to the Loch Raven Reservoir.
- A stable stream channel
- Restore eroded stream banks
- Protect adjacent property
- Increase riparian habitat
- Improve aesthetics - A natural looking environment
- Improve water quality in our drinking water supply.
- Improve aquatic life

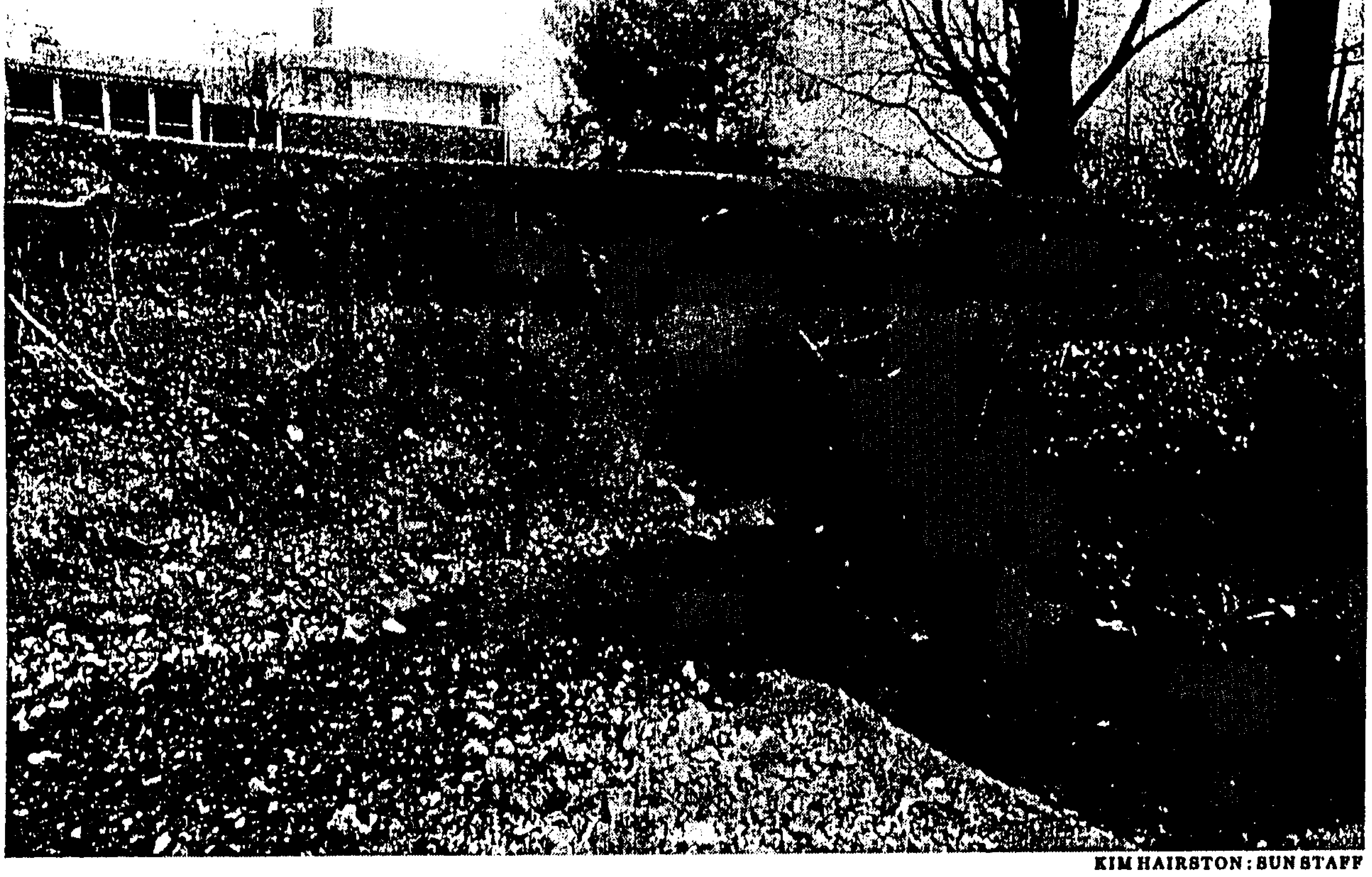
The actions of the citizens is very important to the future success of the project.

- Keep trash and grass clippings and ward waste out of the stream
- Don't use pesticides and fertilize within 75' of the stream
- Don't mow the vegetated stream side buffer zone
- Don't over fertilize

Plant more trees, shrubs and ground cover

- Divert downspouts to vegetated areas so the water can infiltrate into the ground.

BALTO SUN 3/27/96



KIM HAIRSTON : SUN STAFF

Growing gap: *Surging water at the junction of Spring Branch and a tributary has caused serious erosion of lawns at Springside Drive. A meeting tonight will discuss a plan to re-create a natural meandering.*

Effort launched to tame stream in Timonium, restore meandering

Patchwork straightening of Spring Branch leads to destructive torrents

By SHERIDAN LYONS
SUN STAFF

Residents along a Timonium stream are skeptical — but hopeful — that a trickle-turned-torrent behind their homes can be tamed by an ambitious plan to restore it to a natural state.

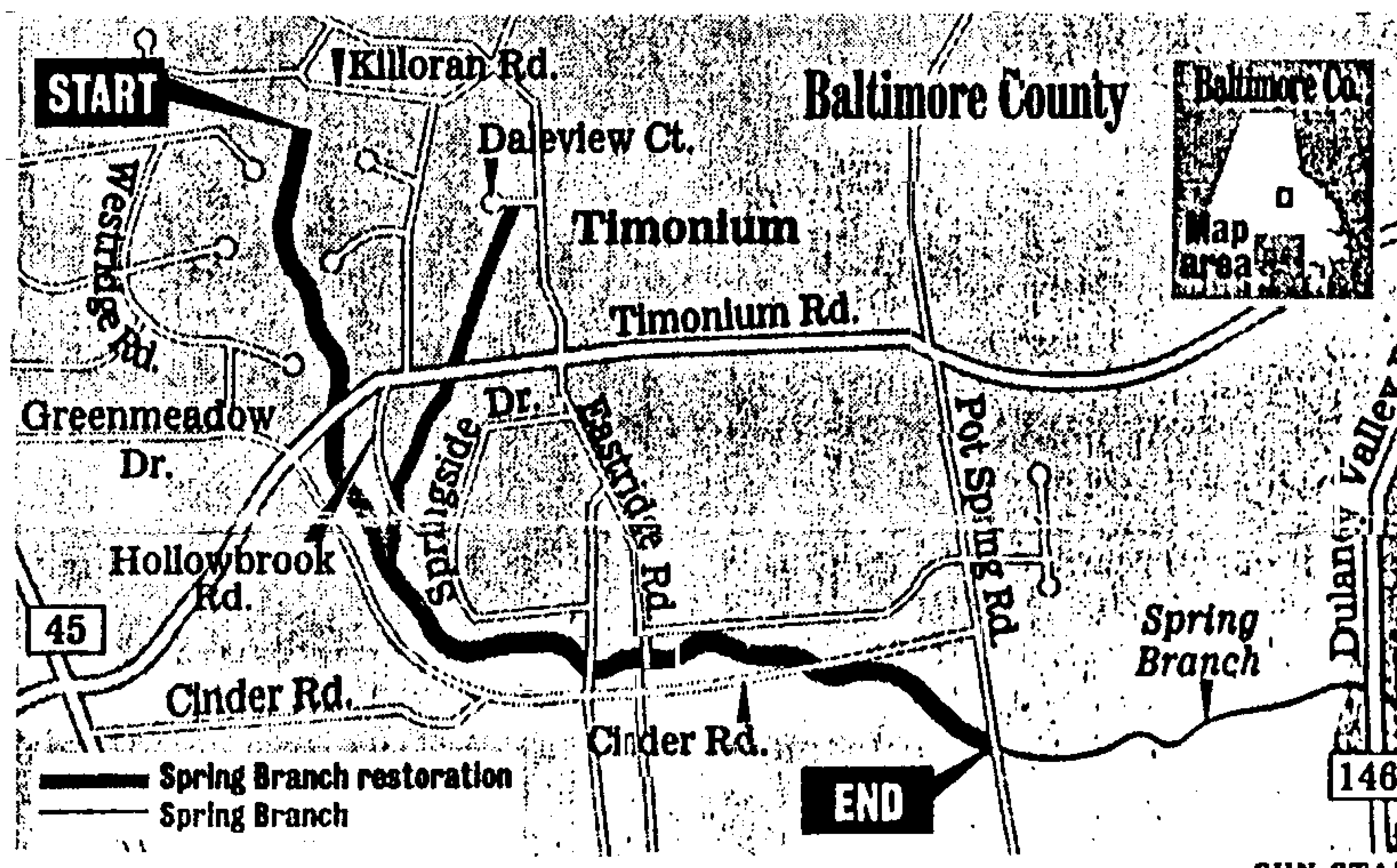
In a $500,000 project jointly funded by the state and county, the natural meander of Spring Branch would be restored. Boulders and tree stumps would replace concrete chutes and years of patchwork repairs along a two-mile section.

Plans for the stream — which begins north of Timonium Road and flows south, then east beside Cinder Road and into Loch Raven Reservoir — will be explained at a meeting at 7:30 tonight at Dulaney High School held by the county Department of Environmental Protection and Resource Management.

The four-month project, planned to start in June, would begin near Killoran Road and end at Pot Spring Road and Deer Fox Lane, passing about 150 homes along Spring Branch and an unnamed tributary. These two streams meet south of Hollowbrook Road, between Springside and Greenmeadow drives — creating the most troublesome section.

At this junction, erosion from rushing storm water has carved a gorge about 10 feet deep and 15 feet across, and torn away chunks of lawn — along with shrubs and trees. Pieces of fence and oil drums lie among chunks of concrete that bear witness to previous, unsuccessful repairs.

On Springside Drive, Chandler and Betty Freund and Richard and Mary Ann Brown recalled moving in about 30 years ago, when their children could walk down a gradual slope at the rear of their properties and hop across the creek.



SUN STAFF

"It was a trickle, less than 1 foot wide and 6 inches deep, when we moved here — 33 years ago this April," Mrs. Freund said.

Daniel Freeman, an engineer who moved in about three years ago, expressed concern about safety because water undercuts the stream bank behind his property, leaving dangerous overhangs.

"Our bank's probably the worst one," Mr. Freeman said. "A few years ago, we had a 6- to 8-foot section drop all at once off the yard."

Mr. Brown met John J. Smialkowski Sr. of Greenmeadow Drive as they commiserated over the widening gap between their two back yards, and tried to get the county to act. Mr. Smialkowski has been writing to his councilman since 1991 and went door to door with a petition about the problem several years ago.

Although reluctant to get his hopes up, Mr. Smialkowski said, "It's gotten worse. Whatever they can do to prevent it, I'm for it. I think it's a good idea not to use concrete, to keep the regular habitat."

Candace L. Szabad, a county natural resources specialist, said several concrete channels would be removed in an attempt to get the streambed's depth and width back to a natural proportion. Storm water drains from as far north as Padonia Road, she explained, "and when it rains and all that water hits that concrete, it's like a flume there where it hits that bend."

She explained that the artificial straightening of the stream in years past increased the velocity of the water, unlike "a natural meander which slows the stream," she said.

In addition to restoring that meander, she said, a series of step pools will be created for the water flowing down the slope, and trees and shrubs will be planted to help stabilize the banks.

One who disagrees with the plan is Robert Johnson, who has lived for 25 years north of Hollowbrook Road, where manicured lawns slope gradually to one of the straight concrete chutes. He said he plans to attend the meeting and denounce the plan as "a waste of money."

Ms. Szabad said six similar projects are in the design stage. The most ambitious is White Marsh Run, including the main, north and south forks.

Lawsuits allege builders deny access to disabled

Housing laws ignored in area, Balto. group says

By DENNIS O'BRIEN
SUN STAFF

tion of the finer points of the fair housing law to know that this is a problem," said Mr. Levy as his wheelchair rested in the street, several steps below the Lions Gate sales office.

Mr. Levy said amendments to

by county building officials, who enforce housing codes.

"If the builder's architect and the county inspector review the plans and agree they're in compliance, we're not in a position to dispute that," said Steven Koren, de-

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By THOMAS W. WA
AND C. FRASER SM
SUN STAFF

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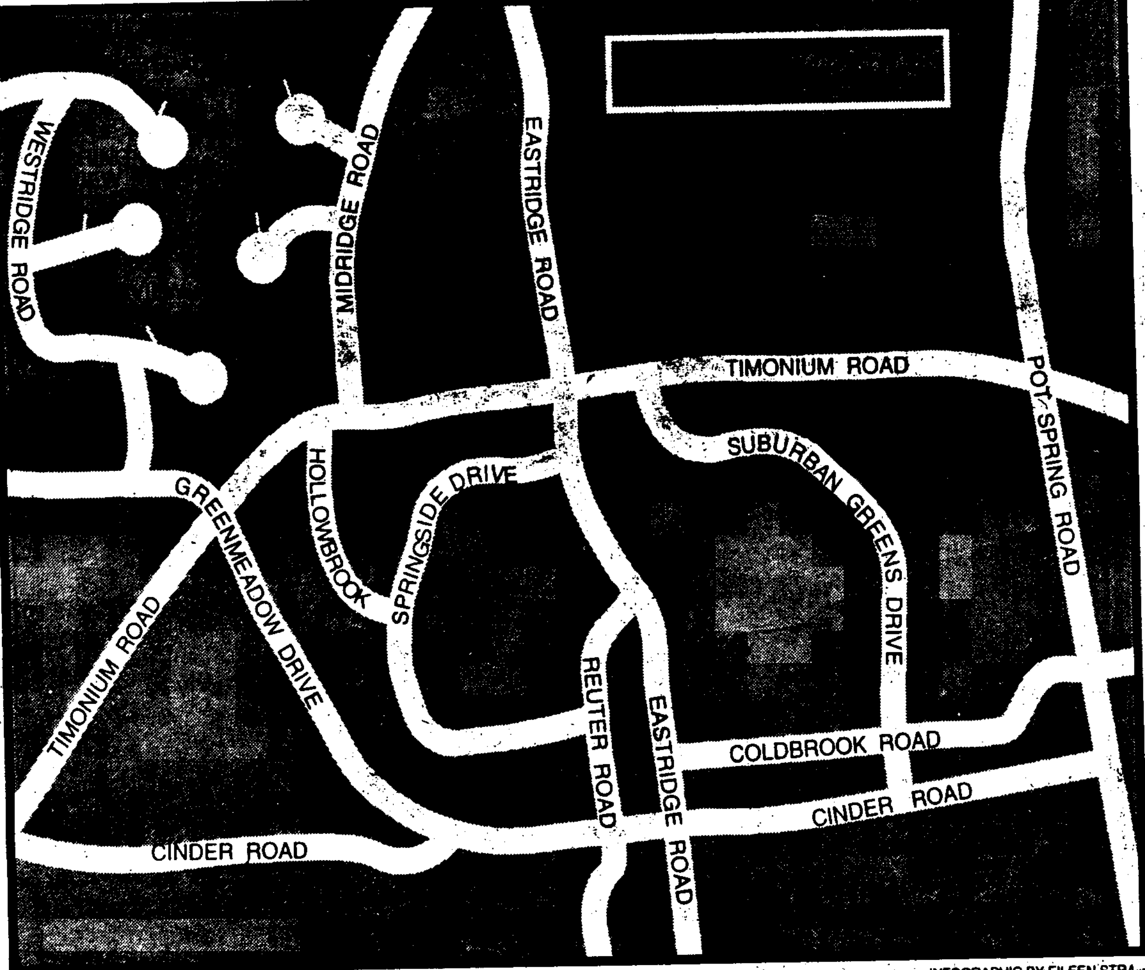
SPRING CLEANING

Spring Branch, a Loch Raven Reservoir tributary, runs through Timonium



SOURCE: BALTIMORE COUNTY DEPARTMENT OF ENVIRONMENTAL MANAGEMENT & RES RCE PROTECTION

INFOGRAPHIC BY EILEEN STRA

County planning to restore stream

BY LONI INGRAHAM

Spring is a time of restoration but the restoration of Spring Branch won't begin until mid-June.

Meanwhile, Baltimore County's Department of Environmental Protection and Resource Management is asking for cooperation from adjacent property owners to get the job done more efficiently, quickly and cheaply.

Time and circumstance have forced this Timonium tributary of Loch Raven Reservoir to wander from its original course to the point where it is eating away adjacent private properties, according DEPRM.

"There are 10-foot vertical undercuts in some places," says Chin Lien, supervisor for the department's capital improvements section.

The branch is a hodgepodge of temporary repairs and measures that have caused problems rather than solved them.

The Spring Branch project, which will cost at least $500,000 and take at least four months, will begin in mid-June, assuming the county can get the permits required by the state and federal government, Lien says.

The work, which involves a two-mile stretch of the branch from just below between Killoran Road to the culvert crossing for Pot Spring Road, should restore the branch to its original channel.

The result should be a stream that can handle the flow of water as well as support a wildlife habitat, he says.

During a public meeting Wednesday, March 27 at 7:30 p.m. in the Dulaney High School cafeteria, DEPRM officials will present their plan for the restoration in detail.

They are hoping that residents who live next to the stream will attend because they want residents will to the contractor permission to gain access to the stream bed via private property.

They are also seeking easements for grading, for the planting of trees — "for whatever needs to be done," says Lien.

The job still can be done without the permission of adjacent property-owners, "but we prefer to have their permission," says Lien. "Without it, the work could be more difficult. I will take more time and escalate the cost."

For further information, call DEPRM on 887-2904.

3/20/96 TOWSON TIMES

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Vol. 2, No. 5 November 1992

Spring Branch Creek Is Headache For Neighbors

by Diane Carliner

To hear Dorothy and John Smialkowski tell it, what once were the bonnie banks of Spring Branch Creek in the Yorkshire section of Timonium have become a raging headache.

"It used to be a little leap," said Dorothy, as she looked down upon the rims of earth that have separated to a distance of eight feet over 15 or 20 years.

Dorothy also said that the creek, which flows past her back yard, "sounds like a river" in a hard rain. She described the problem a neighbor had when his basement flooded six times. Then she pointed to the runoff ditch, constructed by the county at the edge of her property, which contributes to the overflow of the creek by funneling to it water collected from the street.

"I'm afraid my grandchildren can fall in," said her husband John, who is known as an activist on the subject of the stream.

"What concerns the neighborhood," he said, "is that the monies were there. No one knew the money was taken for other projects. The stream is above the Loch Raven Reservoir and contaminates it. What could be a more important priority?"

Both Smialkowski and Harold Thompson, VP of the Yorkshire Community Association, said that through the years, there has been a lot of passing the buck. If a tree fell, the county would say it was the responsibility of the Balto. Gas and Electric Co. BG&E said the cable company should take care of it, and the cable company said the county should take care of it.

(photo courtesy of John Smialkowski)

Flooding in Spring Branch Creek causes erosion. Here a bankside tree has fallen into a resident's fence.

According to the Smialkowskis, neighbors have sighted large rodents, an infestation of insects caused by unsanitary conditions, and floodwaters that almost reach back doors.

See Creek, p. 16

What's Inside?

Creek (continued from p. 1)

"I haven't had much to do with politics, but I'm getting a taste of it," said John. He added that it was "highly unusual" and welcome when he called the county last month to complain about a fallen tree and someone came to remove it within a week.

Funding

Thompson also said he was curious about where the money went that was allocated for correcting erosion, flooding, and pest problems caused by the creek in its present condition. He said that 40 to 45 homes have been affected, and that although there has been a lot of talk and sympathy coming from the county, he is still waiting for action.

Both Smialkowski and Thompson are aware that the difficulties existed long before the current budget crunch. Problems with the creek continued to build through the low-keyed Donald P. Hutchinson administration and the extravagant years of 1986-90 when former County Executive Dennis F. Rasmussen spent millions refurbishing the county courthouse, including sandblasting, tearing out grey marble walls and replacing them with red marble, digging up the courthouse lawn three times, curving straight cement walkways, and ordering the planting of exotic and expensive blooms.

Although the county now has severe financial constraints due to the cutoff of large amounts of state funding, Councilman Doug Riley (R4), who was first elected to the County Council two years ago, said, "I'd really like to do something about it [the creek]. There is still money for this project."

Work Planned

Donald Outen, Bureau Chief of Water Quality and Resource Management, said that work should begin on the project no later than June of 1993, and that a very rough advance notice cost estimate would be $1/2 million. The project will take two to three years to complete.

"I hope the restoration of Spring Branch Creek will be a prime example of the new methods of stream restoration. As the county is at the leading edge of new technology concerning waterway improvement programs, we are proceeding in the most effective manner.

"To be most effective, the work on the Essex creeks, which lead into the Chesapeake Bay and which were started some time ago, must be completed in sequence before we can start work on Spring Branch Creek. Approximately 37% cutbacks in state funding both this year and last have contributed to delays, and we want to make sure that when using the new, environmentally sensitive, more natural, more ecological and more cost-effective methods, that everything is done properly," said Outen.

Both Kathleen Beadell, President of the Yorkshire Community Assoc., and Harold Thompson, VP, warn neighbors not to put any grass clippings, leaves, branches, or anything into the stream, as dumping will cause jamming, flooding, and ultimately more erosion.

"I believe Roger Hayden and the county Dept. of Environmental Protection and Resource Management (DEPRM), truly care about this issue and will do whatever they can to help," said Beadell. "I hope Councilman Riley and DEPRM officials will come to our meeting on Nov. 17." #

Wetlands Engineering & River Restoration Conference 1998

ABSTRACT

Major Points of Interest

- Urban stream restoration using natural stream geometry approaches
- soil bioengineering to stabilize stream banks
- design issues in an urban environment
- construction management
- post construction monitoring

Please consider this paper for the planned technical session on River Restoration; Rehabilitation of Urban Rivers, Streams, and Waterways

Spring Branch Stream Restoration - Using Natural Stream Geometry Approaches (Maryland),

J. Keith Bowers, Biohabitats, Inc., 15 W. Aylesbury Road, Timonium, Maryland, 21093 (410)337-3659 e-mail: biohabitat.com

Urbanization, flood control, land clearing, and agriculture practices have extensively degraded and disturbed aquatic systems throughout the Northeast. In particular, urban development profoundly impacts the hydrology, morphology, water quality, and biodiversity of streams. Maryland, recognizing the connection between healthy streams and a healthy Chesapeake Bay, developed a comprehensive strategy to restore the tributaries of the Chesapeake Bay watershed.

Baltimore County has embarked on one of the most ambitious stream restoration programs to date. The restoration of Spring Branch is a hallmark of their program. Located in the piedmont plateau physiographic province, Spring Branch drains approximately 489 acres to the Loch Raven reservoir, one of several drinking supply reservoirs for the Baltimore metropolitan region.

Recognizing the need to protect water quality and aquatic biodiversity, Baltimore County retained Biohabitats to assess approximately two miles of Spring Branch and develop a plan to restore a stable stream channel geometry, enhance water quality, and reestablish an aquatic habitat. In 1994, we began a two-year process of assessing the physical and biological conditions of Spring Branch. Using an applied fluvial geomorphologic approach, we classified Spring Branch according to channel geometry relationships (Rosgen Stream Classification system). After conducting the field and assessment phases of the project, we concluded that Spring Branch had desychronized, point source flow regimes; severe bank instability and subsequent erosion; failing or threatened infrastructures; lack of a riparian buffer; and poor land use practices in and adjacent to the stream. Despite the urban nature of the watershed, we believed that the recovery potential for this system was high, if the stream was given some assistance. We recommended that restoration efforts focus on restoring a stable channel morphology and correcting bank erosion. We presented a wide array of solutions and techniques, however, a comprehensive restoration approach that targeted the overall health of the stream system was selected as the preferred restoration strategy. In general, our approach to stream restoration combines the disciplines of fluvial geomorphology, civil engineering, and applied ecology. Using ratios and measurements from reference stable stream reaches, hydraulic and hydrologic modeling, and design parameters developed from years of research, principles, and theories reported by Ingles, 1942; Leopold and Wolman, 1957; Langbein and Leopold, 1966; Leopold, Wolman, and Miller, 1964; and Rosgen, 1994 among others, we set out to meet our objectives.

Once a stable stream cross section, profile, and pattern were designed, our attention turned toward developing stream stabilization measures that not only supported natural stream geometry objectives but also provided aquatic habitat benefits. The use of innovative soil bioengineering techniques for stream rehabilitation support and compliment a holistic restoration approach such as Spring Branch.

A holistic, ecologically sensitive approach to stream restoration has many benefits, including replication of natural hydrological and ecological cycles, enhancement of riparian and in-stream aquatic habitat, improved aesthetics, and significant cost savings over structural solutions. Our objective is to create a stream system that is hydrologically stable, ecologically dynamic, and biologically diverse.

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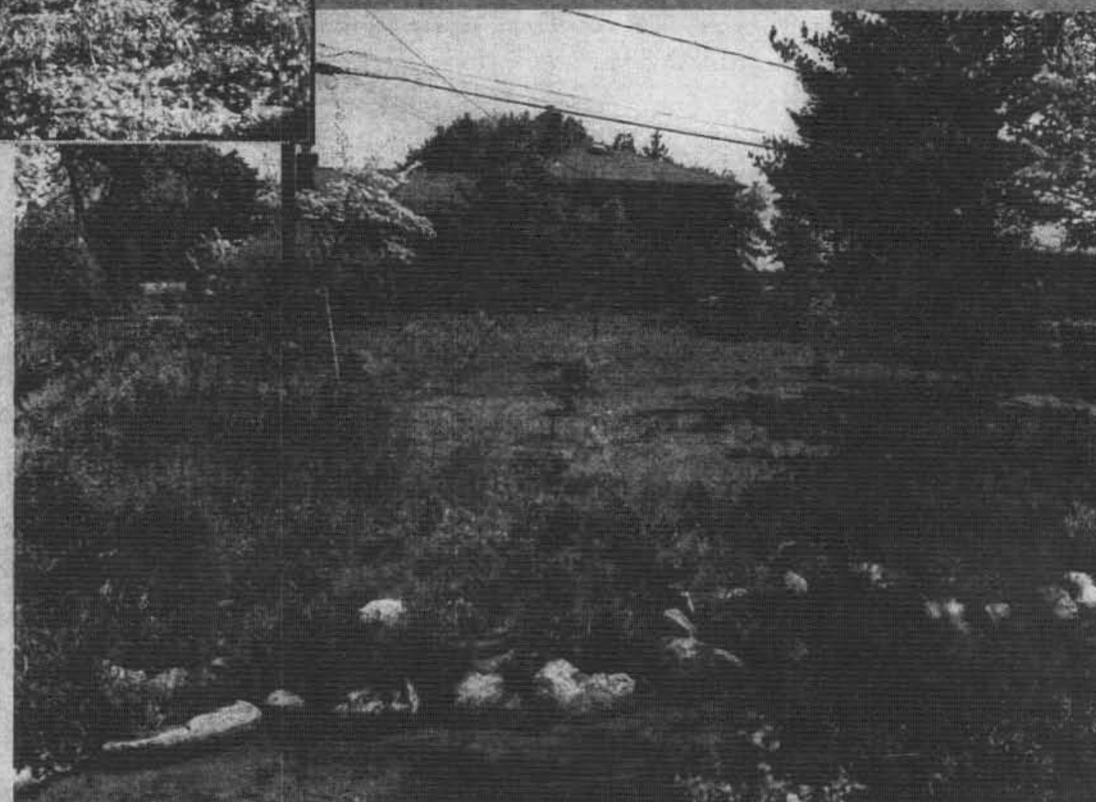
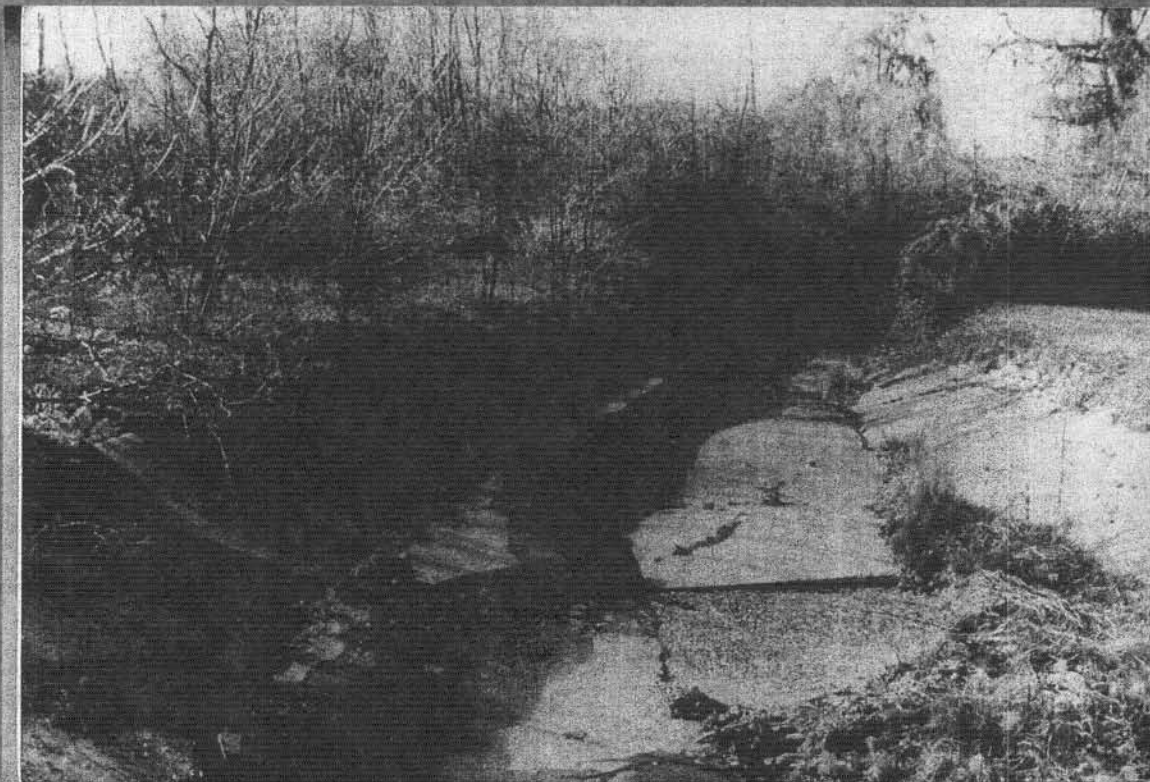
SPRING BRANCH

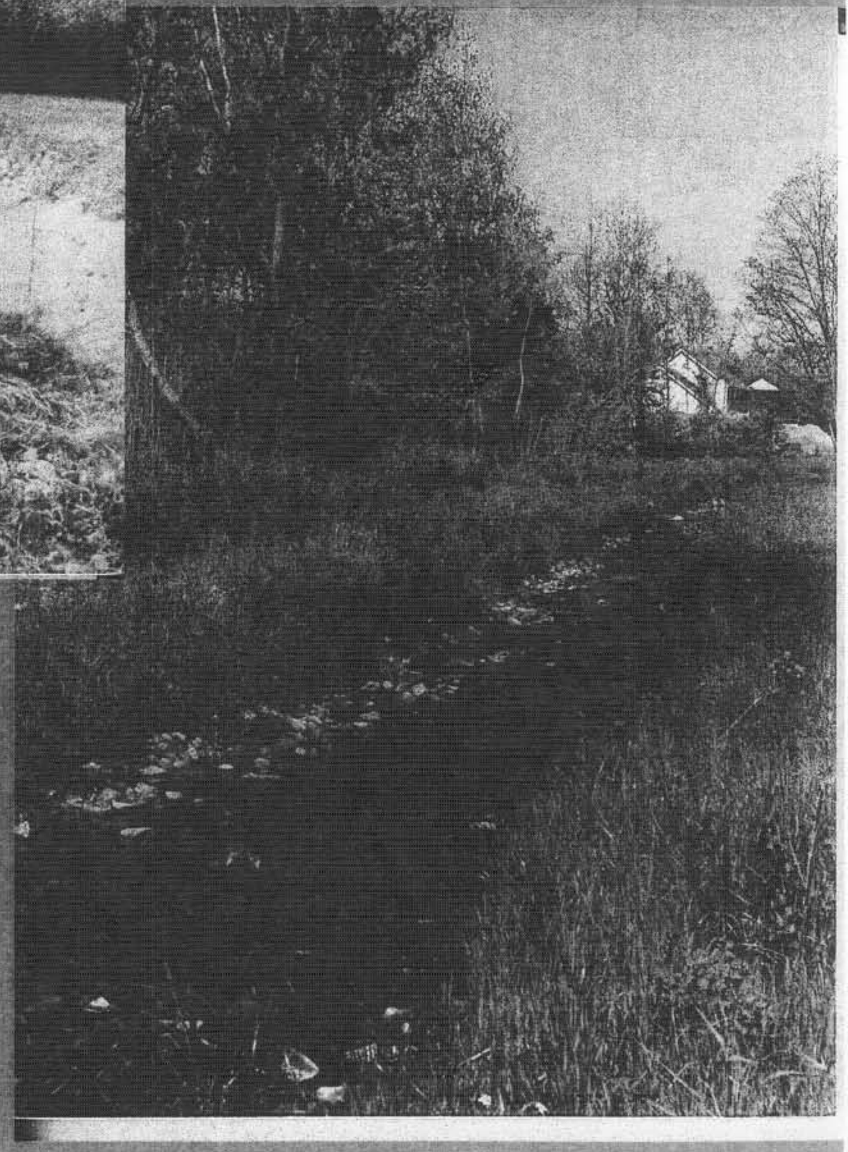


MAIN STEM AT
CONFLUENCE

BEFORE AND AFTER

SPRING BRANCH

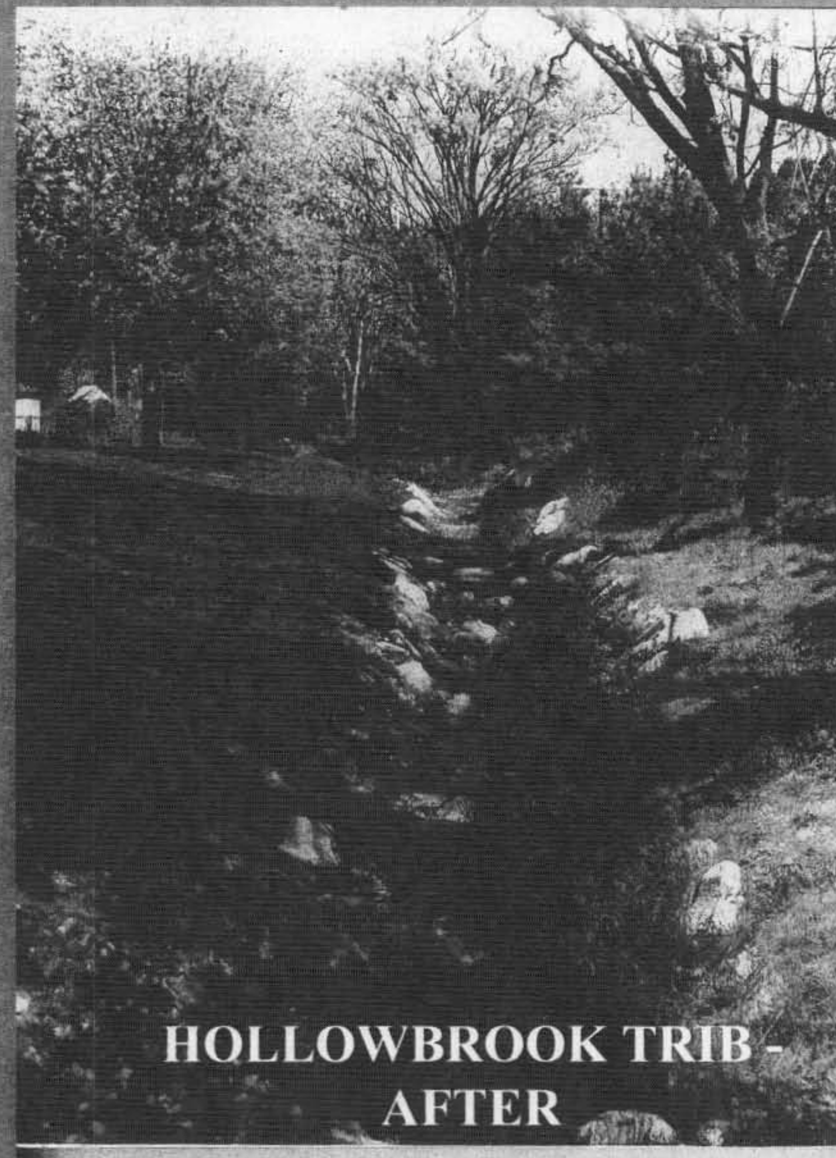




MAIN STEM AT POT SPRING ROAD

BEFORE AND AFTER

SPRING BRANCH



APPENDIX C

CHESAPEAKE BAY PROGRAM POLLUTANT LOAD REDUCTION EFFICIENCIES

Table 1: Nonpoint Source Best Management Practices that have been Peer-Reviewed and CBP-Approved for Phase 5.0 of the Chesapeake Bay Program Watershed Model
Revised 1/12/06

Agricultural BMPs	***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***
Riparian Forest Buffers and Wetland Restoration - Agriculture[1]:	Landuse conversion + efficiency	Efficiency applied to 4 upland acres	Efficiency applied to 2 upland acres	Efficiency applied to 2 upland acres
Coastal Plain Lowlands	Efficiency	25%	75%	75%
Coastal Plain Dissected Uplands	Efficiency	40%	75%	75%
Coastal Plain Uplands	Efficiency	83%	69%	69%
Piedmont Crystalline	Efficiency	60%	60%	60%
Blue Ridge	Efficiency	45%	50%	50%
Mesozoic Lowlands	Efficiency	70%	70%	70%
Piedmont Carbonate	Efficiency	45%	50%	50%
Valley and Ridge Carbonate	Efficiency	45%	50%	50%
Valley and Ridge Siliciclastic	Efficiency	55%	65%	65%
Appalachian Plateau Siliciclastic	Efficiency	60%	60%	60%
Riparian Grass Buffers - Agriculture:	Landuse conversion + efficiency	Efficiency applied to 4 upland acres	Efficiency applied to 2 upland acres	Efficiency applied to 2 upland acres
Coastal Plain Lowlands	Efficiency	17%	75%	75%
Coastal Plain Dissected Uplands	Efficiency	27%	75%	75%
Coastal Plain Uplands	Efficiency	57%	69%	69%
Piedmont Crystalline	Efficiency	41%	60%	60%
Blue Ridge	Efficiency	31%	50%	50%
Mesozoic Lowlands	Efficiency	48%	70%	70%
Piedmont Carbonate	Efficiency	31%	50%	50%
Valley and Ridge Carbonate	Efficiency	31%	50%	50%
Valley and Ridge Siliciclastic	Efficiency	37%	65%	65%
Appalachian Plateau Siliciclastic	Efficiency	41%	60%	60%

[1] These peer-reviewed BMP efficiencies and/or landuse conversions will be refined with more recent data for use in Phase 5.0 of the Chesapeake Bay Program Watershed Model based on results of the EPA CBPO FY2006 BMP Literature Synthesis project. Estimated Completion Date: TBD.

Agricultural BMPs (continued)	How Credited	TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
Conservation Plans - Agriculture[1] (Solely structural practices such as installation of grass waterways in areas with concentrated flow, terraces, diversions, drop structures, etc.):	Efficiency			
Conservation Plans on Conventional-Till	Efficiency	8%	15%	25%
Conservation Plans on Conservation-Till and Hay	Efficiency	3%	5%	8%
Conservation Plans on Pasture	Efficiency	5%	10%	14%
Cover Crops[1]:	Efficiency			
Cereal Cover Crops on Conventional-Till:	Efficiency			
Early-Planting - Up to 7 days prior to published first frost date	Efficiency	45%	15%	20%
Late-Planting - Up to 7 after published first frost date	Efficiency	30%	7%	10%
Cereal Cover Crops on Conservation-Till:	Efficiency			
Early-Planting - Up to 7 days prior to published first frost date	Efficiency	45%	0%	0%
Late-Planting - Up to 7 after published first frost date	Efficiency	30%	0%	0%
Commodity Cereal Cover Crops / Small Grain Enhancement on Conventional-Till:	Efficiency			
Early-Planting - Up to 7 days prior to published first frost date	Efficiency	25%	0%	0%
Late-Planting - Up to 7 after published first frost date	Efficiency	17%	0%	0%
Commodity Cereal Cover Crops / Small Grain Enhancement on Conservation-Till:	Efficiency			
Early-Planting - Up to 7 days prior to published first frost date	Efficiency	25%	0%	0%
Late-Planting - Up to 7 after prior to published first frost date	Efficiency	17%	0%	0%
Off-stream Watering with Stream Fencing (Pasture)	Efficiency	60%	60%	75%
Off-stream Watering without Fencing (Pasture)	Efficiency	30%	30%	38%
Off-stream Watering with Stream Fencing and Rotational Grazing (Pasture)	Efficiency	20%	20%	40%

[1] These peer-reviewed BMP efficiencies and/or landuse conversions will be refined with more recent data for use in Phase 5.0 of the Chesapeake Bay Program Watershed Model based on results of the EPA CBPO FY2006 BMP Literature Synthesis project. Estimated Completion Date: TBD.

Agricultural BMPs (continued)	How Credited	TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
Animal Waste Management Systems - Applied to model manure acre where 1 manure acre = runoff from 145 animal units:	Reduction in manure acres			
Livestock Systems	Reduction in manure acres	100%	100%	N/A
Poultry Systems	Reduction in manure acres	100%	100%	N/A
Barnyard Runoff Control / Loafing Lot Management	Reduction in manure acres	100%	100%	N/A
Conservation-Tillage[1]	Landuse conversion	N/A	N/A	N/A
Land Retirement - Agriculture	Landuse conversion	N/A	N/A	N/A
Tree Planting - Agriculture	Landuse conversion	N/A	N/A	N/A
Carbon Sequestration / Alternative Crops	Landuse conversion	N/A	N/A	N/A
Nutrient Management Plan Implementation - Agriculture	Built into simulation	135% of modeled crop uptake	135% of modeled crop uptake	N/A
Enhanced Nutrient Management Plan Implementation – Agriculture[1]	Built into simulation	115% of modeled crop uptake	115% of modeled crop uptake	N/A
Alternative Uses of Manure / Manure Transport	Built into preprocessing	Reduction in nutrient mass applied to cropland	Reduction in nutrient mass applied to cropland	N/A
Poultry Phytase	Built into preprocessing	N/A	Reduction in nutrient mass applied to cropland	N/A

[1] These peer-reviewed BMP efficiencies and/or landuse conversions will be refined with more recent data for use in Phase 5.0 of the Chesapeake Bay Program Watershed Model based on results of the EPA CBPO FY2006 BMP Literature Synthesis project. Estimated Completion Date: TBD.

Agricultural BMPs (continued)	***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***
Dairy Precision Feeding / and Forage Management[1]	Built into preprocessing	Reduction in nutrient mass applied to cropland	Reduction in nutrient mass applied to cropland	N/A
Swine Phytase	Built into preprocessing	N/A	Reduction in nutrient mass applied to cropland	N/A
Continuous No-Till:				
Below Fall Line	Efficiency	10%	20%	70%
Above Fall Line	Efficiency	15%	40%	70%
Water Control Structures	Efficiency	33%	N/A	N/A
Urban and Mixed Open BMPs				
Stormwater Management::	Efficiency			
Wet Ponds and Wetlands[1]	Efficiency	30%	50%	80%
Dry Detention Ponds and Hydrodynamic Structures[1]	Efficiency	5%	10%	10%
Dry Extended Detention Ponds[1]	Efficiency	30%	20%	60%
Infiltration Practices	Efficiency	50%	70%	90%
Filtering Practices	Efficiency	40%	60%	85%
Erosion and Sediment Control[1]	Efficiency	33%	50%	50%
Urban and Mixed Open BMPs (continued)	***How Credited***	***TN Reduction***	***TP Reduction***	***SED Reduction***

[1] These peer-reviewed BMP efficiencies and/or landuse conversions will be refined with more recent data for use in Phase 5.0 of the Chesapeake Bay Program Watershed Model based on results of the EPA CBPO FY2006 BMP Literature Synthesis project. Estimated Completion Date: TBD.

		Efficiency	***Efficiency***	***Efficiency***
Nutrient Management (Urban)	Efficiency	17%	22%	N/A
Nutrient Management (Mixed Open)	Efficiency	17%	22%	N/A
Abandoned Mine Reclamation	Landuse change converted to efficiency	Varies by model segment	Varies by model segment	Varies by model segment
Riparian Forest Buffers – Urban and Mixed Open	Landuse conversion + efficiency	25%	50%	50%
Wetland Restoration – Urban and Mixed Open	Landuse conversion	N/A	N/A	N/A
Stream Restoration – Urban and Mixed Open[1]	Load reduction converted to efficiency	0.02 lbs/ft	0.0035 lbs/ft	2.55 lbs/ft
Impervious Surface and Urban Growth Reduction / Forest Conservation	Landuse conversion	N/A	N/A	N/A
Tree Planting – Urban and Mixed Open	Landuse conversion	N/A	N/A	N/A
Resource and Septic BMPs				
Forest Harvesting Practices[1]	Efficiency	50%	50%	50%
Septic Denitrification	Efficiency	50%	N/A	N/A
Septic Pumping	Efficiency	5%	N/A	N/A
Septic Connections / Hook-ups	Removal of systems	N/A	N/A	N/A

[1] These peer-reviewed BMP efficiencies and/or landuse conversions will be refined with more recent data for use in Phase 5.0 of the Chesapeake Bay Program Watershed Model based on results of the EPA CBPO FY2006 BMP Literature Synthesis project. Estimated Completion Date: TBD.

Table 2: Nonpoint Source Best Management Practices Requiring Additional Peer-Review for Phase 5.0 of the Chesapeake Bay Watershed Model Revised 1/12/06

(Note: Credit and Efficiencies are listed in parenthesis since they have not received formal peer review)

Agricultural BMPs Requiring Peer Review	***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***	***CBP Lead Status Estimated Completion Date***
Precision Agriculture	(Built into simulation)	N/A	N/A	N/A	Tributary Strategy Workgroup EPA CBPO FY2006 BMP Literature Synthesis project will determine efficiency for Phase 5.0 Completion Date: TBD Delaware Maryland Agribusiness Association plans to work with CBPO to provide tracking data for this BMP.
Manure Additives	TBD	TBD	TBD	TBD	Agriculture Nutrient Reduction Workgroup TBD TBD
Ammonia Emission Reductions	(Built into preprocessing)	(Reduction in ammonia deposition)	N/A	N/A	Tributary Strategy Workgroup EPA CBPO FY2006 BMP Literature Synthesis project will determine efficiency Completion Date: TBD
Precision Grazing	Efficiency	(25%)	(25%)	(25%)	Agriculture Nutrient Reduction Workgroup Tributary Strategy Workgroup EPA CBPO FY2006 BMP Literature Synthesis project will determine efficiency Completion Date: TBD
Mortality Composters	Efficiency	(14%)	(14%)	N/A	Tributary Strategy Workgroup EPA CBPO 2006/2007 project will determine efficiency June 2008
Horse Pasture Management	Efficiency	(20%)	(20%)	(40%)	Tributary Strategy Workgroup EPA CBPO FY2006 BMP Literature Synthesis project will determine efficiency Completion Date: TBD

Agricultural BMPs Requiring Peer Review (continued)	***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***	***CBP Lead Status Estimated Completion Date***
Non-Urban Stream Restoration	Load reduction converted to efficiency				
Non-Urban Stream Restoration on Conventional-Till and Pasture	Load reduction converted to efficiency	(0.026 lbs/ft)	(0.0046 lbs/ft)	(3.32 lbs/ft)	Tributary Strategy Workgroup EPA CBPO FY2006 BMP Literature Synthesis project will determine efficiency Completion Date: TBD
Non-Urban Stream Restoration on Conservation-Till, Hay	Load reduction converted to efficiency	(0.02 lbs/ft)	(0.0035 lbs/ft)	(2.55 lbs/ft)	Tributary Strategy Workgroup EPA CBPO FY2006 BMP Literature Synthesis project will determine efficiency Completion Date: TBD
Urban and Mixed Open BMPs Requiring Peer Review					
Non-Urban Stream Restoration on Mixed Open	Load reduction converted to efficiency	(0.02 lbs/ft)	(0.0035 lbs/ft)	(2.55 lbs/ft)	Tributary Strategy Workgroup EPA CBPO FY2006 BMP Literature Synthesis project will determine efficiency Completion Date: TBD
Dirt & Gravel Road Erosion & Sediment Control on Mixed Open	Load reduction converted to efficiency	(0.02 lbs/ft)	(0.0035 lbs/ft)	(2.55 lbs/ft)	Tributary Strategy Workgroup EPA CBPO FY2006 BMP Literature Synthesis project will determine efficiency Completion Date: TBD
Roadway Systems	TBD	TBD	TBD	TBD	Urban Stormwater Workgroup (USWG) USWG will meet with Departments of Transportation to identify roadway BMPs and efficiencies TBD
Urban Street Sweeping and Catch Basin Inserts	Efficiency	(10%)	(10%)	(10%)	Urban Stormwater Workgroup EPA CBPO street sweeping project will provide efficiency recommendations for the Urban Stormwater Workgroup review in Fall 2007

Urban and Mixed Open BMPs Requiring Peer Review (continued)	How Credited	TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency	CBP Lead Status Estimated Completion Date
Riparian Grass Buffers – Urban and Mixed Open	TBD	TBD	TBD	TBD	TBD
Resource BMPs Requiring Peer Review					
Non-Urban Stream Restoration on Forest	Load reduction converted to efficiency	(0.02 lbs/ft)	(0.0035 lbs/ft)	(2.55 lbs/ft)	Tributary Strategy Workgroup EPA CBPO FY2006 BMP Literature Synthesis project will determine efficiency Completion Date: TBD
Dirt & Gravel Road Erosion & Sediment Control on Forest	Load reduction converted to efficiency	(0.02 lbs/ft)	(0.0035 lbs/ft)	(2.55 lbs/ft)	Tributary Strategy Workgroup EPA CBPO FY2006 BMP Literature Synthesis project will determine efficiency Completion Date: TBD
Voluntary Air Emission Controls within Jurisdictions (Utility, Industrial, and Mobile)	Built into preprocessing	(Reduction in nitrogen species deposition)	N/A	N/A	Nutrient Subcommittee TBD TBD

Table 3: Nonpoint Source Best Management Practices that have been Peer Reviewed and CBP Approved for the Chesapeake Bay Water Quality Model
Revised 1/12/06

Shoreline BMPs	How Credited	TN Reduction Efficiency	TP Reduction Efficiency	SED Reduction Efficiency
Structural Tidal Shoreline Erosion Control	Water Quality Model	N/A	N/A	N/A
Non-Structural Tidal Shoreline Erosion Control	Water Quality Model	N/A	N/A	N/A

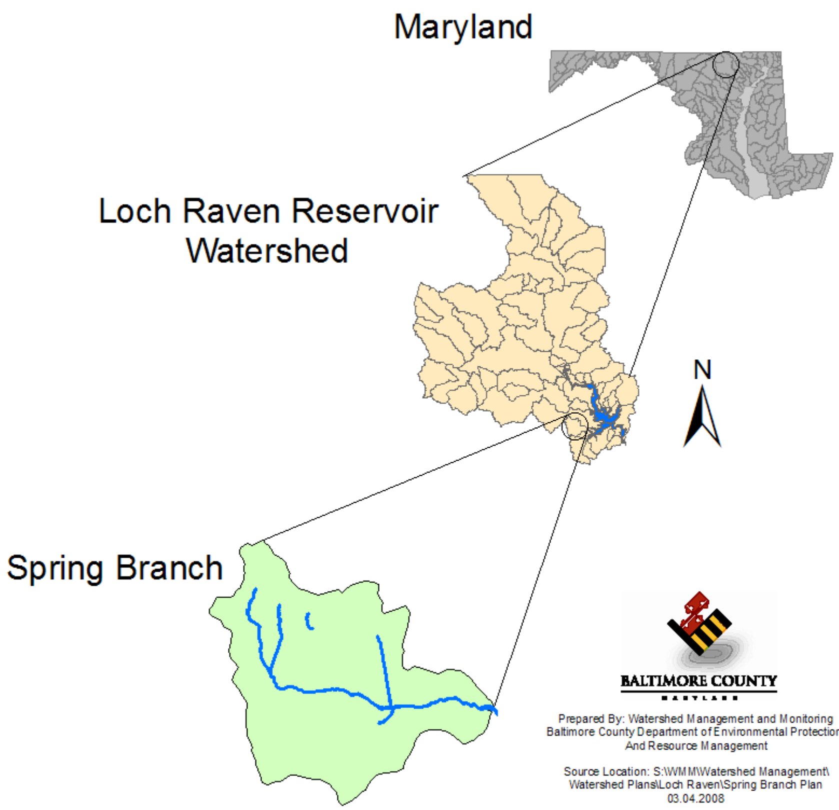
Table 4: Nonpoint Source Best Management Practices Requiring Additional Peer Review for the Chesapeake Bay Water Quality Model
Revised 1/12/06

Resource BMPs	***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***	***CBP Lead Status Estimated Completion Date***
Coastal Floodplain Flooding	TBD	TBD	TBD	TBD	Sediment Workgroup TBD TBD
SAV Planting and Preservation	Water Quality Model	TBD	TBD	TBD	Living Resources Subcommittee TBD TBD
Oyster Reef Restoration and Shellfish Aquaculture	Water Quality Model	TBD	TBD	TBD	TBD TBD TBD
Structural Shoreline Erosion Controls:					Sediment Workgroup TBD TBD
Shoreline hardening	Water Quality Model	TBD	TBD	TBD	Sediment Workgroup TBD TBD
Resource BMPs (continued)	***How Credited***	***TN Reduction Efficiency***	***TP Reduction Efficiency***	***SED Reduction Efficiency***	***CBP Lead Status Estimated Completion Date***
Off-shore breakwater	Water Quality Model	TBD	TBD	TBD	Sediment Workgroup TBD TBD
Headland control	Water Quality Model	TBD	TBD	TBD	Sediment Workgroup TBD TBD
Breakwater systems	Water Quality Model	TBD	TBD	TBD	Sediment Workgroup TBD TBD

Spring Branch Subwatershed - Small Watershed Action Plan

(Addendum to the Water Quality Management Plan for Loch Raven Watershed)

Volume 2: Appendices D Through G



Prepared by

Baltimore County

Department of Environmental Protection and Resource Management

401 Bosley Avenue, Suite 416, Towson, MD 21204

March 17, 2008

Spring Branch Subwatershed Small Watershed Action Plan
Volume 2: Appendices D Through G

APPENDIX D

Spring Branch Stream Restoration – Conceptual Plan Report

(Biohabitats, 1995)

Baltimore County

Spring Branch Stream Restoration

Job No. 21-7-10

Conceptual Plan Report

January 27, 1995

Baltimore County

Spring Branch Stream Restoration Project

Conceptual Plan Report

Job Order 21-7-10

Prepared by:

Prime Consultant:

Biohabitats, Inc.
303 Allegheny Avenue
Towson, Maryland 21204

Subconsultants:

KCI Technologies, Inc.
10 North Park Drive
Hunt Valley, Maryland 21030

Envirens, Inc.
P.O. Box 299
Freeland, Maryland 21053

January 27, 1995

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1.0 INTRODUCTION

1.0 INTRODUCTION

1.1 Background

Recognizing the need to protect its aquatic resources and respond to public concerns, the Baltimore County Department of Environmental Protection and Resource Management, Capital Improvement Section (DEPRM CIS) initiated restoration efforts for Spring Branch. The Spring Branch Restoration Project is funded jointly by DEPRM and the Maryland Department of the Environment (MDE), Nonpoint Source Capital Projects Program.

DEPRM-CIS contracted Biohabitats, Inc. and its subconsultants - KCI Technologies, Inc. and Envirens, Inc., to analyze the stream system, develop feasible restoration strategies, and provide final design services for approved restoration solutions. This *Conceptual Plan Report* contains the results of the analysis and preliminary restoration solutions.

1.2 Goals and Objectives

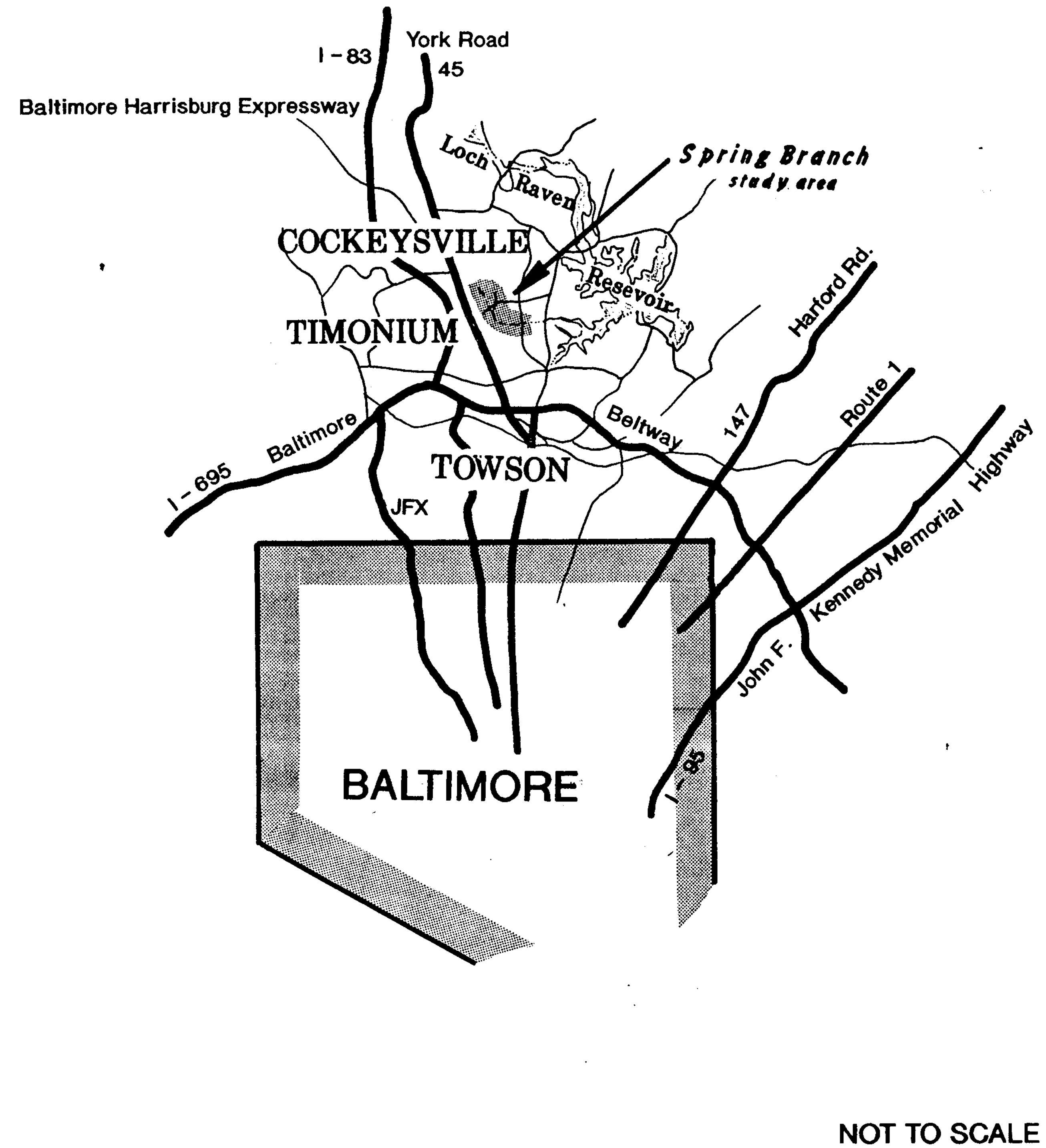
Spring Branch, a tributary stream to Loch Raven Reservoir, is located in Timonium, Maryland (refer to Figure 1.1 Project Location). The stream system has been heavily manipulated as a result of urbanization of the watershed and is currently in a degraded physical condition.

Effective and successful stream restoration projects depend upon a thorough understanding of fluvial geomorphologic processes and clear, achievable restoration goals. The County's primary focus for restoration is to improve channel stability. Upon completing the assessment of current conditions, the Team refined this goal to specifically address creation of a stable flow regime and correct severe bank erosion problems.

1.3 Report Structure

This report is part of a package of information pertaining to the Spring Branch Stream Restoration Project. The *Conceptual Plan Report* describes methods of evaluation used in analyzing the stream system (Section 2.0). Existing conditions and problems in the watershed and channel are identified in Section 3.0. Restoration strategies, techniques, preferred solutions, and associated costs are presented in Section 4.0. Section 5.0 discusses operation, maintenance, and monitoring issues associated with restoration solutions. Field data and photographs are includes in appendices to the report. Existing conditions and restoration solutions are illustrated on the Spring Branch Restoration Plans that accompany this report.

A detailed Hydrology and Hydraulics (H&H) Report has been prepared by KCI Technologies, Inc, and is submitted under separate cover. A synopsis of the detailed H&H report in included in this *Conceptual Plan Report*.



KCI TECHNOLOGIES

ENVIRENS, INC

Biohabitats

Figure 1.1

VICINITY MAP

2.0 METHODS

2.0 METHODS OF EVALUATION

Baseline conditions for Spring Branch were developed through a combination of field investigation, map, photographic, and literature review. The following section outlines the methodologies used to collect data, perform the field-run survey, analyze existing stream conditions, perform hydrologic and hydraulic analyses.

2.1 Data review

Prior to conducting field investigations, the following map and report data was evaluated:

- Hydrologic and hydraulic reports (Maryland Engineering and Surveying, 1981; Purdum & Jeschke, 1985).
- As-built stream improvement construction drawings
- Baltimore County sanitary sewer and storm drain construction drawings
- USGS discharge data
- Baltimore County 1" = 200' topography (photogrammetry)
- Soils, geology, wetlands maps
- Baltimore County and commercially available aerial photography (Air Photographics, 1993)
- Property and utility right-of-way (ROW) maps

2.2 Field Run Survey

The following features were more specifically located and recorded via standard land survey techniques:

- Approximately 6,700 linear feet of stream channel centerline from Killoran Road to Cinder Road
- 100 foot cross-sections (50' either side of stream centerline)
- Relocate original 1981 H&H sections and add sections between original H&H sections at approximately 100 foot intervals along the stream length
- Topographic survey around storm drain outlet pipes

- Inverts of pipes and box culverts
- Location of observed utilities
- Wetland boundaries
- Lowest point of entry survey

2.3 Wetlands

Wetland and Waters of the United States determinations were performed in June of 1994 by DEPRM EIRD personnel. Wetlands were delineated and flagged in the field using criteria mandated in the Corps of Engineers 1987 delineation manual. The boundary was surveyed and wetland flag locations are shown on the Spring Branch Restoration Existing Conditions Maps accompanying this report. Wetland report documentation and jurisdictional boundary validation is beyond the scope of this study and will be performed by DEPRM.

2.4 Stream Conditions

Physical stream conditions were documented through field reconnaissance, map, and photographic review.

Stream channels were assessed using the procedures and methodologies for fluvial geomorphological analysis as outlined in "A Classification for Natural River Systems" (Rosgen, 1993). The stream channels were walked and the location of instream and riparian features were photodocumented and recorded using a hip chain. Features included:

- Bankfull width/depth
- Channel slope
- Hydraulic geometry
- Sinuosity
- Debris dams
- Bank erosion
- Meander/belt width radius
- Pool/Riffle sequences
- Entrenchment
- Storm drain outfalls
- Riparian vegetation
- Channel bars
- Riparian vegetation
- Channel improvements

The Rosgen Channel Classification System was used to categorize the main branch and tributary into major natural channel types on the basis of morphological features of stream channel and valley. Key variables used in the Rosgen Classification analysis are presented in Table 2.1.

Table 2.1 Rosgen Stream Classification Parameters

Channel Type	Channel Gradient	Width/Depth Ratio	Sinuosity	Entrenchment Ratio
A	4 to 10%	< 12	Low (< 1.2)	1 to 1.4
B	2 to 4%	> 12	Moderate (> 1.2)	1.41 to 2.2
C	< 1%	> 12	High (> 1.4)	> 2.2
D	1 to 2%	> 50	Unstable	> 2.2
E	< 2%	< 12	Very High (> 1.4)	> 2.2
F	< 2%	> 12	Moderate - High (> 1.4)	1 to 1.4
G	2 to 4%	< 12	Moderate (> 1.2)	1 to 1.4

Figure 2.1 Stream Channel Types, illustrates typical plan and cross sectional characteristics of the seven major streams types.

Each major stream type was further classified based upon the dominance of the

particle size of the bed material:

1 - Bedrock	4 - Gravel
2 - Boulder	5 - Sand
3 - Cobble	6 - Silt

The Wolman Pebble Count Method was used to determine dominant particle size of the bed material.

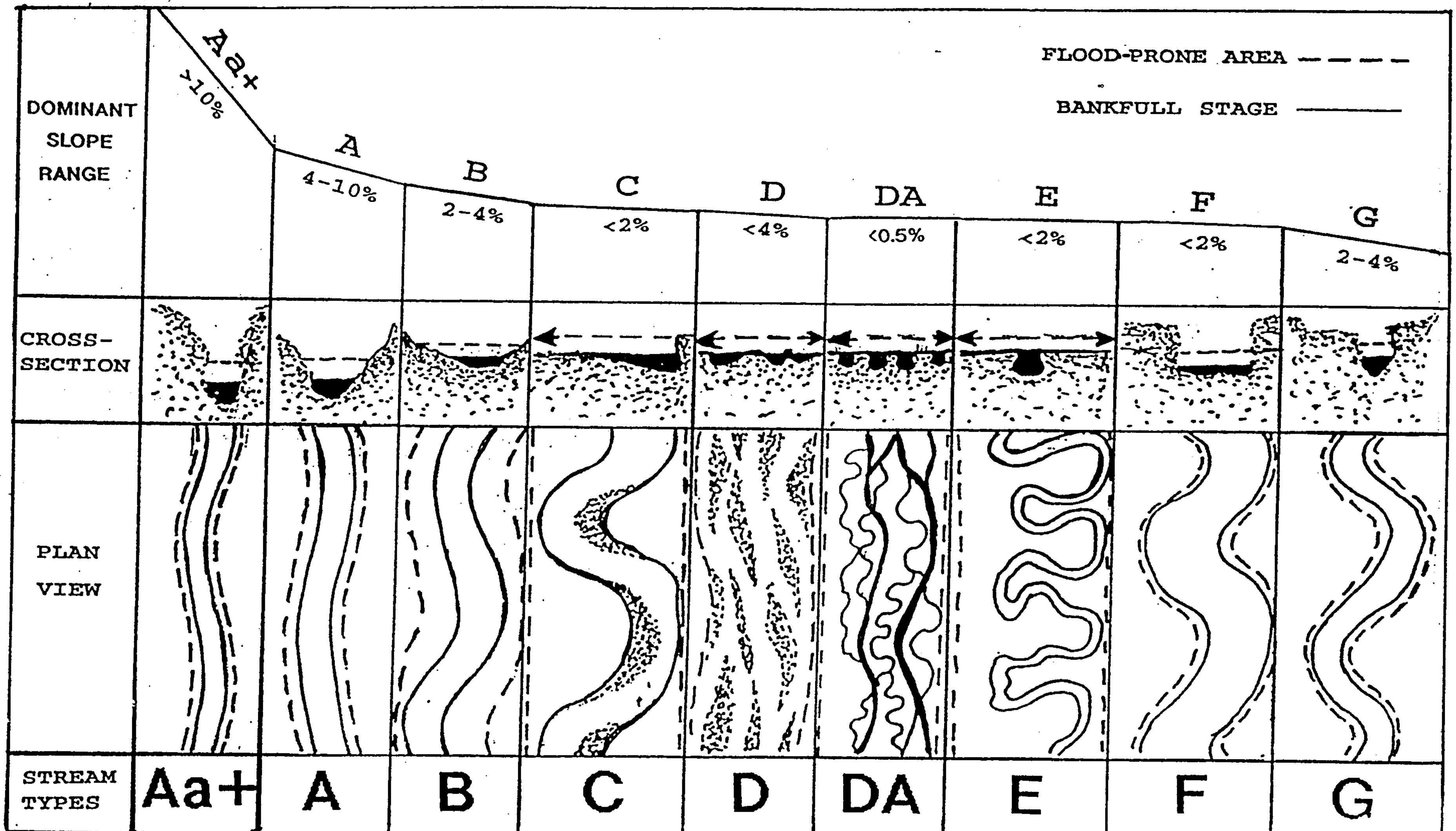


Figure 2.1

SOURCE: ROSGEN, 1993

STREAM CHANNEL TYPES

The classification process was initiated by walking the entire stream valley in both upstream and downstream directions and then separating the stream into discrete reaches that were initially determined by visual observation of changes in valley landforms, slope, and channel appearance. Initial reach lengths included a minimum of 20 channel widths or 2 complete cycles (wavelengths). Field measurements were then conducted within these reaches to collect data on stream entrenchment, sinuosity, bankfull discharge width and depth, channel slope and substrate materials. Rosgen classification parameters were applied to the field data.

It was noted that individual variables for each reach did not fit consistently with variable values for a given channel classification. The most notably inconsistent variable was channel sinuosity. In almost every reach, it is low even in areas of gentle gradients. Most reaches are also entrenched. The data suggested that the channel was in an unnatural/hybrid morphology or in the process of evolving towards a more natural different channel type. The data was compared with surveyed cross sectional geometry and preliminary channel type designations were made.

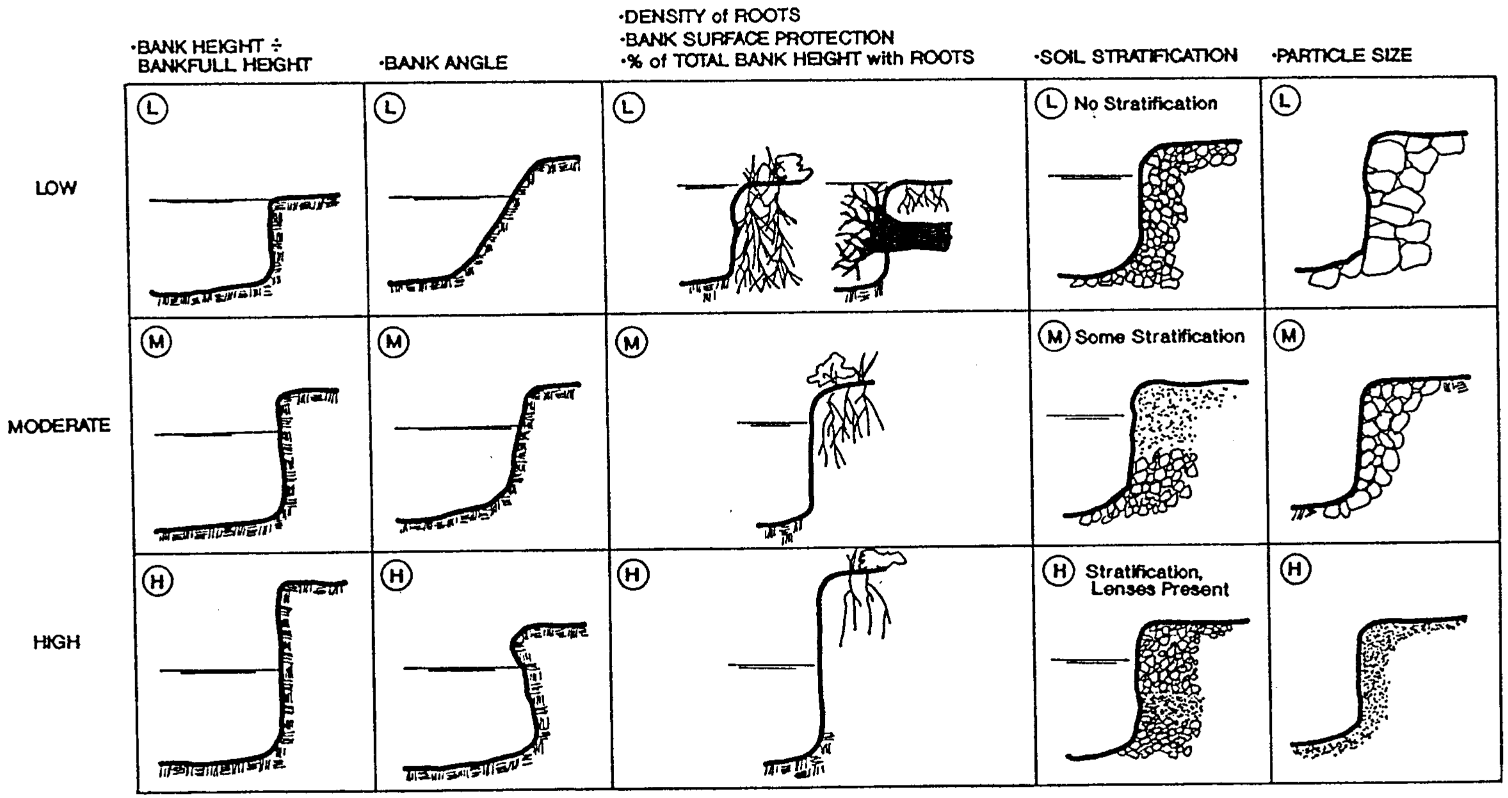
An additional field visit was conducted to confirm and refine the preliminary classifications. In areas where measurements were not classically conforming to Rosgen channel parameters, or the data fell within the overlap range for entrenchment, width/depth, or sinuosity, channel designations were made based upon plan and cross-sectional appearance of the channel and best professional judgement. In several areas, original reach classifications were subdivided into reaches that include less than two complete wavelength cycles or areas of discretely different set of channel conditions contained within a larger uniform reach length.

The stream was photographed at the starting and end point the study area, upstream and downstream of and specific in-channel features. Thirty-five millimeter color slide film was used. Representative slides were selected and developed as color photographs. Appendix A contains color photographs of examples of channel types, problem areas of interest, bank erosion, and outfall conditions.

Recent black and white aerial photography at an approximate scale of 1" = 200' was used to review the valley morphology, relative orientation of development features, sinuosity pattern and landcover conditions.

Stream channel banks and outfall areas were assessed to identify areas of top of bank, toe, and full bank erosion. A visual assessment of bank conditions was performed using stream bank erodibilty factors and erosion potential ratings after Pfankuch (1975) and Rosgen (1993) and are shown in detail in Figure 2.2. - Bank Erodibility Factors. Field data sheets documenting bank erosion are contained in Appendix E - Field Data Sheets.

Field sketches were also developed on-site to map stream geometries, bar and bed features, bank conditions and riparian zone features.



SOURCE: ROSGEN, 1993

NOT TO SCALE

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Figure 2.2
BANK EROSION FACTORS

2.5 Hydrology and Hydraulics

A detailed description of the methods used in performing the hydrology and hydraulics analyses are described in greater detail in the Spring Branch Hydrology and Hydraulics (H&H) Report submitted under seperate cover and accompanying this report. The methods contained in this section are meant to provide a brief overview of the analyses.

The purpose of the hydrologic and hydraulic study of Spring Branch was to establish bankfull, 2-, 10-, 25-, 50-, and 100-year flow rates and water surface elevations for existing and proposed (with restoration scenarios) conditions. Two previous studies involving the Spring Branch watershed were obtained and used to determine existing hydrologic conditions. A watershed drainage study was performed for Spring Branch in 1981 by Maryland Surveying and Engineering Co., Inc. The purpose of the study was to establish 100-year floodplain limits for ultimate land uses and solve potential flood drainage problems. The 1981 study included a hydrologic analysis of the watershed using TR-20, however, the flow rates determined are no longer valid because sheet flow lengths of up to 500 feet were used in the time of concentration calculations. The backup data for the time of concentration calculations were not available, therefore, the TR-20 model could not be revised without substantial effort which was beyond the scope of this report. A HEC-2 model was also used to compute 100-year storm water surface elevations and determine the limits of the 100-year floodplain.

In 1985, a study of the Gunpowder Falls watershed was completed by Purdum and Jeschke, Inc. and approved by WRA. The Spring Branch watershed was delineated as a subarea of the Gunpowder Falls watershed. The results of this study included flow rates obtained using TR-20 at several cross-sections along Spring Branch. Although the scope of the Gunpowder Falls watershed study is much broader than the current Spring Branch study, the flow rates established during the Gunpowder Falls study are sufficient for the use in the current study. Permission to use the established flow rates has been granted by Baltimore County (John Maple, Department of Public Works - Bureau of Engineering) and is presently being requested from WRA.

Several new design study points were introduced in this study that were not included in the Purdum and Jeschke report. Since a comprehensive TR-20 subarea analysis is beyond the scope of this project, U.S.G.S. regression equations were used to translate known flow rates upstream to design study points without TR-20 established flow rates. This procedure is only valid when the drainage area for the translated flow rate is within 50 percent of the drainage area of the known flow rate in accordance with Characteristics of Stream Flow in Maryland (USGS, 1983). This method was used along the main stem up to the confluence with the tributary. The flow rates for the tributary and main stem upstream of the confluence were then subdivided using the ratio of 100-year flow rates developed in the 1981 Spring Branch Study.

The Army Corps of Engineers' HEC -2 computer program version 4.6.2, dated May, 1991 was the floodplain hydraulic model used in the study. The program has many capabilities including: computing water surface profiles for steady gradually varied flow in natural or man made channels; subcritical and supercritical flow profiles; considers and computes the effects of various obstructions such as bridges, culverts, weirs and structures in the floodplain; evaluates floodway encroachments and designates flood hazard zones; and can assess the effects of channel improvements and levees on water surface profiles. The computational procedure, known as the Standard Step Method, is based on the solution of the one-dimensional energy equation with energy loss due to friction evaluated in Manning's equation.

The basic HEC-2 model is approximately 8200 feet in length including the main stem and tributary. The model begins 485 feet downstream of the Cinder Road box culvert and extends upstream through culverts at East Ridge Road, Reuter Road and Timonium Road to a storm drain outfall structure south of Killoran Road. The tributary extends from a point along the main stem midway between Reuter Road and Timonium Road, through Hollowbrook Road culvert to Timonium Road. Cross- sections were field surveyed at the original (1981) locations and additional cross-sections were taken as needed so that the reach length between each cross-section was approximately 50 feet. Roughness coefficients used in the HEC-2 model were assigned based on field investigations and engineering judgement, following guidelines established by Chow (Open Channel Hydraulics, 1959). The model was developed and run separately for both sub-critical and super-critical flow types so that the actual flow regime could be established for each reach of the stream channel.

The bankfull discharge was estimated by calibrating the HEC-2 model with field measurements of bankfull depth and bankfull width. The bankfull depth was measured at several cross sections along the stream channel. The field measured water surface elevation was then calculated by adding the bankfull depth to the surveyed stream invert at the cross section. The HEC-2 model was calibrated by varying the flow rate (bankfull discharge) until the water surface elevation computed by the model closely resembled the field measured water surface elevation.

Each culvert was analyzed separately using a combination of techniques including FHWA's HY-8 computer program, Bureau of Public Roads Charts, and the Direct Step Method. The tailwater elevation for each culvert was first established using the HEC-2 model. The type of culvert flow was determined and the headwater elevation was then computed using the most appropriate method for that flow type.

2.6 Storm Sewer Relocation

The purpose of the utility relocation plan for the project is to review and evaluate the existing conditions of the sanitary lateral connection serving Stratford Lot #32, 108 Westdale Court. The site was field reviewed and survey data was obtained to establish the location and critical elevations of the sanitary lateral. Baltimore County record drawing 65-159 was used in conjunction with the field survey to develop the base sheet required for the evaluation.

The evaluation and design criteria for the sanitary lateral relocation is based on the latest edition of the Baltimore County Design Manual; Standard Specifications and Details for Construction; and all laws, codes and Maryland Department of the Environment regulations that pertain.

2.7 Storm Drain Retrofit

The purpose of the storm drain outfall retrofit is to develop non-structural methods within the natural stream valley which will maximize the stormwater management benefit downstream of the outfall and provide a distinct sampling point for future monitoring. The benefit of quantity management is the reduction in peak storm flows and discharge velocities through energy dissipation and flow attenuation. The effect of quality management is the removal of point source and non-point source pollutants attributable to the development of the watershed.

Typically, stormwater management facilities are incorporated within the design of a proposed development. In this case, where the development was designed and built prior to the promulgation of stormwater management regulations, the design becomes intricate and is dependent on the various site constraints. Since there is no available land within the watershed to provide stormwater management facilities, one alternative is to provide the facilities at the outfall. Prior to the design of the stormwater management facility, data was gathered on the site in order to appropriately chose the best method of treatment. The data that was gathered and its source are as follows:

Data Description	Source
Contributing Watershed Area	Balt. Co. Photogrammetry Maps
Watershed Land Use	Balt. Co. Photogrammetry Maps
Storm Drain System	Balt. Co. Record Drawings
Outfall Location Area	Field Survey/Site Inspection
Stream Channel Geometry/Slope	Field Survey/Site Inspection
Watershed Pollutant Export	Stormwater Sampling

Current stormwater management regulations require quantity and quality management of storm water runoff. Quantity management of increased run-off is required so that pre-development peak discharge rates are not exceeded, thus preventing accelerated channel erosion. Quality management is required for the treatment of the first one-half inch of stormwater runoff from impervious surfaces prior to delivery of that runoff to the naturally occurring aquatic system. This reduces the delivery of sediments, heavy metals, hydrocarbons, fertilizers, and other pollutants to State and Federal waters. Standard design techniques for quantity and quality management involve the temporary storage and gradual release of storm runoff, however, the impoundment of naturally occurring stream systems is generally not acceptable.

Since the development of Best Management Practices (BMP's) for the management of storm water runoff, an abundance of laws, regulations, and policies have been adopted, at both the local and state level, to encourage or mandate the use of urban BMP's. Several of these references were developed by the Maryland Department of the Environment (MDE) and the Maryland Water Resources Administration (WRA). Although a majority of these guidelines address the use of BMP's for new developments, the basis of these guidelines can be used for existing developments such as this.

The findings of the storm drain retrofit study and recommendations are located in Section 4.2.5 of this report.

3.0 EXISTING CONDITIONS

3.0 EXISTING CONDITIONS

This section of the report documents physical features and existing conditions within the Spring Branch study area. Physical and hydrologic characteristics of the watershed are described. Morphological channel types are identified and stream conditions are discussed in terms of channel type and stability. Existing features are depicted on the Spring Branch Restoration Plans - Existing Conditions Maps accompanying this report.

3.1 Study Area

The project is located several miles north of Towson, Maryland in the Timonium area of Baltimore County. The study area includes the Spring Branch main channel between Killoran and Cinder Roads and an unnamed tributary stream (hereafter referred to as the Hollowbrook tributary) between Timonium Road and its confluence with Spring Branch. The study area also includes a corridor approximately 100 feet wide centered around each stream channel's centerline. See Figure 3.1 for a map of the study area.

The study area was divided into four geographic sectors for reference and mapping purposes. These sectors are:

KT Sector - Killoran Road to Timonium Road
TCf Sector - Timonium Road to Hollowbrook tributary confluence
CfR Sector - Channel confluences to Reuter Road
RC Sector - Reuter Road to Cinder Road

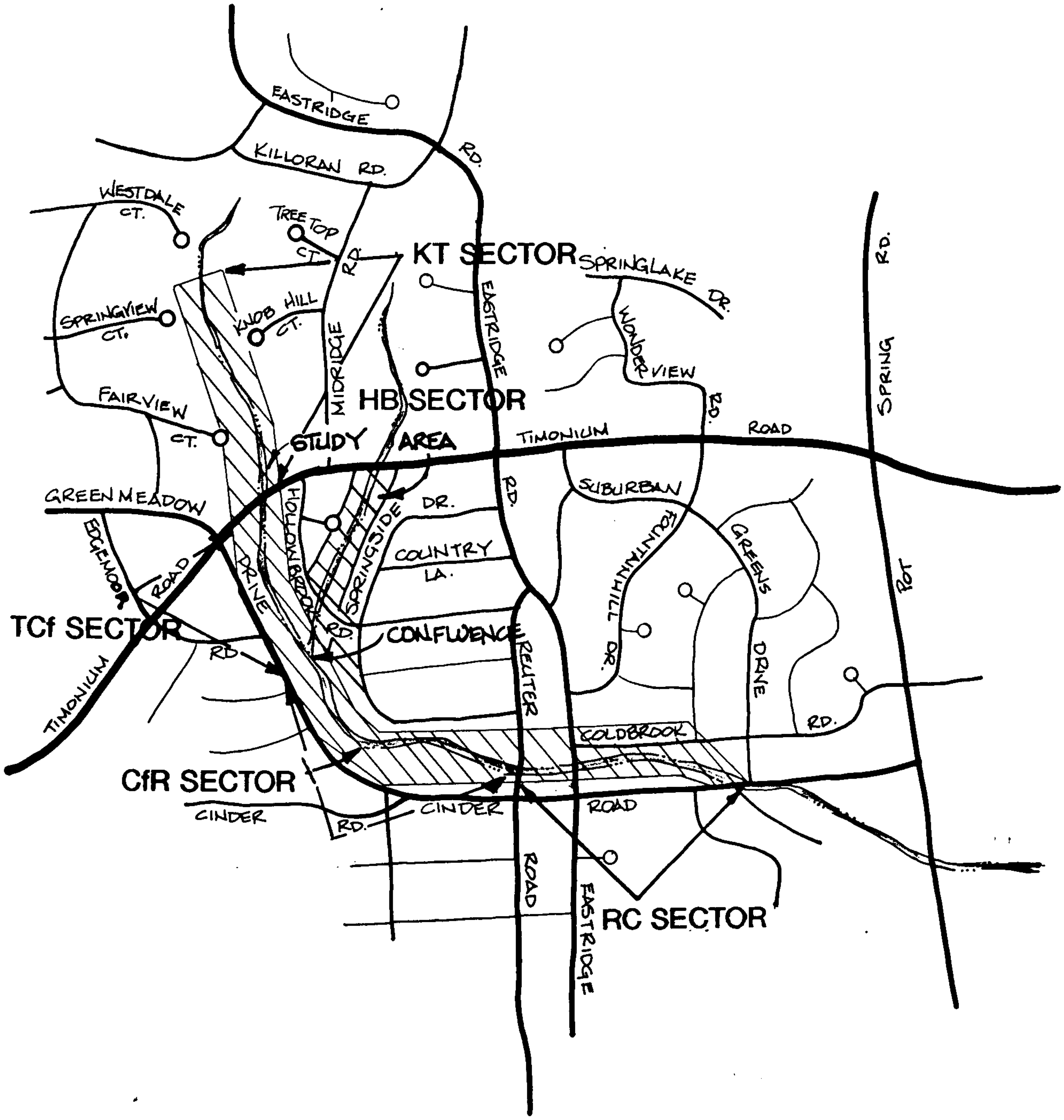

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Figure 3.1

STUDY AREA

3.2 Watershed Characteristics

3.2.1 Physiography, Topography and Geology

Spring Branch is located in Maryland's Piedmont Plateau physiographic province. The piedmont consists of mid-elevation rolling terrain over a diverse geology of igneous, metamorphic and sedimentary gneiss with an extensive network of anastomosing tributaries draining the watershed through valleys of more erodible parent material.

Underlying geologic formations include the streaked-augen member of the Baltimore Gneiss above Timonium Road, metalimestone member of the Cockeysville Marble, and Quaternary alluvium in the stream valley (Crowley and Cleaves, 1974). The geologic contact zone corresponds with the Timonium Road stream crossing. Bedrock is exposed in several locations, most predominantly in the KT sector and also in the TCf sector between traverse points 27 and 28. The geology forms a complex structure of tilted, folded, and faulted rocks that are deeply weathered and overlain with a residual layer of soil and saprolite that ranges between in 5 and 20 feet thick.

Soils within the study area consist of the Manor-Glenelg and the Baltimore-Conestoga-Hagerstown associations (USDA, 1976). Association boundaries correspond with the geologic contact between the Baltimore Gneiss and Cockeysville Marble (Manor-Glenelg association occurs north of Timonium Road).

Dominant soil series throughout the study area are Alluvial land in the immediate stream valley, Manor, Glenelg, Baile, Baltimore, and Joppa soil series. Brief descriptions of these soil series are provided.

<u>Alluvial Land</u>

This soil group consists of sediments that are deposited on the stream valley floor, channel, and flood plains. The material is unconsolidated and consists of range of particle sizes including gravel, sand, silt and clay. Parent material for these soils originates off site and typically expresses a mixture of the upstream geology and soils.

Manor Soils

The Manor soils are rather shallow, excessively drained soils with a weakly developed subsoil. The soils are developed from materials weathered from rather hard slatey schist or soft micaceous schist. The severely eroded channery silt loams have lost most to all original surface soil and bedrock is often exposed in deep gullies. All Manor soils are considered highly erodible. Units include MdE and channery loam (McD3).

Glenelg Soil

The Glenelg soils are shallow to moderately deep, well drained soils that are developed from materials weathered from mica schist, granitized schist, or gneiss. They have a well developed, textured subsoil that is substantially finer than the surface soil. Some of the severely eroded channery silt loams have lost most to all original surface soil and bedrock is often exposed in gullies. All Glenelg soils are considered highly erodible. Units include loam (GcC2).

Baile Soils

The Baile soils are deep, poorly drained soils that are developed in local alluvium and partly in materials weathered from micaceous rock. They are found in upland depressions near the heads of drains and at the foot of slopes adjacent to minor drainage ways. The subsoil is gray, mottled clay loam that is sticky and plastic. These soils have a low erodibility rate. Units include silt loam (BaA). Baile soils are mapped adjacent to the stream for most of the KT sector. Non-tidal wetlands, springs, and seeps are sporadically present in this sector.

Baltimore Soils

The Baltimore soils are deep, well-drained soils that developed in deposits of weathered micaceous colluvium over material weathered in place from marble or dolomite. The subsoil is mainly a red gravelly clay loam that is sticky and plastic. The top portion of the subsoil is a thin layer of yellowish-red clay loam with a few rounded pebbles. Baltimore soils are considered moderately erodible. Units include silt loam (BmB2 and BmC2).

Joppa Soils

The Joppa soils are rather deep, excessively drained soils that developed in old sandy and highly gravelly deposits. The upper portion of the subsoil is a yellowish-red gravelly sandy loam, while the lower portion is a reddish-brown gravelly sandy loam. The Joppa soils are considered moderately erodible. Units include gravelly sandy loams (JpB and JpC2).

Topography within the study area is variable. Elevations range from 480 feet at the storm drain outfall at Killoran Road to 296 feet downstream at the Cinder Road culvert. This decrease in elevation throughout the length of the study area occurs in a series of "steps", (e.g, alternating steep and level areas) rather than a uniform, gradual decrease in elevation.

The KT sector is moderately to steeply sloping in the headwater areas above Timonium Road. Individual reaches of this sector have gradients that range between 1.5 and 7%. Valley width is relatively narrow below the Killoran Road outfall and broadens between traverse points 7 and 10, narrowing again below traverse point 7 down to the Timonium road culvert.

The TCf sector is overall more moderately sloping than the KT sector. Slopes range between 2 and 5% with alternating level and moderately sloping areas. The stream valley morphology has been historically altered through mass grading associated with development during the 1960's and is broad and moderately sloping.

The CfR sector contrasts from the previous sectors in that it is gently and uniformly sloping. Gradients range between 1 and 2%. The channel itself is somewhat incised and at a lower elevation than the adjacent valley floor. As with the TCf sector, valley morphology has been leveled through mass grading associated with the construction of development; it is broad and gently sloping.

The RC sector is morphologically very similar to the CfR sector. Slopes range between 1 and 3% with the steeper portions near Cinder Road.

3.2.2 Watershed Hydrology and Hydraulics

Approximately 489 acres drains to the study area and includes the headwaters of the Spring Branch watershed. The stream's headwaters originate above Killoran Road and have been enclosed in the storm drain system. Open channel flow begins at a 42 inch pipe outfall below Killoran Road.

The portion of the Spring Branch Watershed analyzed in this study has been fully developed since the late

1960's. The drainage area to the downstream study point is comprised almost entirely of single family residences with an average lot size between 1/4 acre and 1/2 acre. This land use equates to a percent impervious area of approximately 30 to 35 percent in accordance with SCS Urban Hydrology for Small Watersheds (TR-55). No future development is planned or anticipated.

The net effect to a natural stream system due to a residential development such as this is a series of changes to the stream hydrology. These changes are summarized as follows:

Increase in peak discharges
Increase in volume of stormwater runoff
Increase in frequency and severity of flooding
Increase in runoff velocity
Decrease of time of concentration
Decrease in base flow during dry periods

3.3 Stream Channel Conditions

This section discusses channel classification, morphology, hydrology and hydraulics, and evaluates the overall conditions and forces that shape and affect the current structure of the stream system. Also included in this section is a discussion of the existing conditions at the broken sewer lateral and storm drain outfall retrofit study.

3.3.1 Channel Classification and Morphology

A number of stream channel types occur within study area and vary based upon physical changes in landform and flow inputs to the system. These types include A, B, C, F, and G classifications. The predominant channel types are G and F morphologies. F and G type channels are entrenched systems which have a low to moderate gradient (2-4%), moderate sinuosity, and moderate to high width-depth ratios. F and G streams are generally entrenched to such a degree that the bankfull flows and higher flood flows are contained within the channel and therefore, do not have access to a traditional wide floodplain for volume storage, energy dissipation, and sediment deposition. Consequently, storm flow velocities tend to be high within the channel itself which can result in a significant increase in bank erosion and channel depositional features. This situation is clearly expressed in the Spring Branch system.

Many of the F and G reaches contain sections where characteristics of B and C morphologies have developed within the confines of the enlarged channel. These areas were not specifically broken out as channel types as they often did not maintain uninterrupted B/C form over several wavelength cycles. Many of these F and G reaches have characteristics, and may be remnants of, B and C morphologies.

A, B, and C type morphologies are also present, though they occur less frequently throughout the study area and are of relatively short length compared to the F and G channel types. A/B morphologies are moderate to steeply sloping channels that are somewhat entrenched and have a low to moderate sinuosity. Broad, flat floodprone areas are generally not associated with A/B morphologies. C channel morphologies have a low gradient, low entrenchment, high sinuosity, and develop within broad, relatively flat valleys. Features such as point bars and pool riffle sequences are common in C type channels.

Two areas were designated as "atypical" channel morphologies because they have been substantially altered and do not conform with the natural morphological classifications of the Rosgen system. These reaches include the concrete channelized portion of the Hollowbrook tributary above Hollowbrook Road and a gabioned section of the stream extending from the Folkstone Drive outfall to the Cinder Road culvert.

Reach breakouts and classification variables are shown on the Existing Conditions Maps accompanying this report. Representative field surveyed cross-sections are shown in Appendix C.

3.3.2 Channel Hydrology and Hydraulics

There is a measurable dry-weather base flow in the stream which is supported by groundwater seeps and spring heads. This base flow appears relatively low in contrast to the current size of the stream channel.

The low base flow can be attributed to reduced infiltration and ground water recharge within the watershed as a result of development. Additional flow during storm events enters the stream channel as stormwater runoff from a combination of overland flow and storm drain outfalls. On average, 25 percent of the area contributing stormwater runoff enters the stream via overland flow (non-point source) and 75 percent via storm drain inputs (point source).

The large percentage of drainage area attributable to point sources suggests that the rate of storm runoff entering the stream channel can be described with short, rapid peak hydrographs. These commonly called "pulse inputs" tend to discharge storm water into the stream channel sooner and with higher intensity than conditions prior to development. The resulting stream bank erosion at the outfall points due to this phenomenon is clearly visible in several areas along the course of Spring Branch.

The 1.5 to 2-year storm event controls the shape and form of natural stream channels. The bankfull discharge calibration for Spring Branch resulted in bankfull discharges ranging from 20 cfs at the downstream design point to 7 cfs within the tributary subarea. These flow rates are estimated to be lower than the 1-year design storm flow rates indicating that the stream reaches bank full stage several times per year. Watershed development tends to increase the frequency and magnitude of bankfull flooding. These bankfull floods are erosive in nature and result in an increase in the potential for stream bank and channel erosion. The extensive bank erosion and undercutting visible throughout Spring Branch supports these conclusions.

From the results of the HEC-2 analysis, it was determined that the stream channel is hydraulically steep (supercritical flow regime) throughout the majority of the study limits. The exceptions to this were at the culverts. The culverts created the affect of a backwater causing sub-critical flow for several sections upstream of the culverts up to the point where the super-critical flow profile intersected the profile of the backwater curve. A hydraulic jump is assumed to occur in the vicinity of this intersection.

The 100-year floodplain, determined by the HEC-2 model, extends into the back yard lawns of several lots that border the stream. This occurs primarily along the lower reaches of the stream, south of Timonium

Road. Along the upper reaches, north of Timonium Road, the stream channel is incised, the banks are steep and the 100-year flood remains within the stream channel. This behavior is typical for a stream in the super-critical flow regime.

The results of the hydrology and hydraulics analyses are described in greater detail in a separate H&H Report (KCI, 1995). The report was developed to establish benchmark water surface elevations with which to compare the effects of the stream restoration alternatives. The report will be submitted to WRA along with an application for a Waterway Construction Permit.

Problem assessment

Anthropogenic influences in the watershed and on the channel are clearly expressed in the degraded physical appearance of the stream system. The channel has been enlarged through episodes of downcutting, lateral erosion, and aggradation.

Following is a brief summary of known past actions that have shaped the channel's current morphology and stability pattern:

- Deforestation to accommodate agricultural activities (date of initiation unknown).
- Area cropped and grazed through the late 1950's.
- Rapid urbanization of the watershed in the 1960's increasing impervious surface and altering planform of the watershed (e.g., topography, drainage network, and floodplain morphology).
- Alteration of groundwater and surface water flow regimes; specifically a shift from predominantly non-point to a point source discharge regime.
- Stream channelization to maximize residential land use and contain flood flows with the channel.
- Riparian buffer eliminated and converted to lawn.
- Sewers installed adjacent to stream.
- Bank stabilization methods using gabions, culverts, rip-rap, concrete walls.

With the exception of deforestation and agricultural activities, most of these influences occurred within the past 30 years. Although these influences continue to affect the stream, the major channel response and subsequent adjustments likely occurred during a concentrated period of time in the early 1960s.

The predominant influence affecting and maintaining current channel morphology is the desychronized, point source flow regime associated with storm events. Although not a direct influence on the current channel form, the enlarged channel and eroding stream banks which are remnant features from earlier perturbations, are none the less a problem associated with the overall stability of the stream system.

Flow regime

Surface flow patterns within the stream are extremely variable and reflect the watershed's high degree of imperviousness, lack of stormwater quantity management, and concentrated flow inputs. Base flows are reduced (low) during non-storm event periods and storm flows are characterized as "flashy" in that there is a dramatic rise and fall of discharge in response to storm events.

As previously mentioned in Section 3.0, point source discharges (storm drains) and increased flow velocities through box culverts result in erratic and localized high energy flow regimes. Storm drain inputs occur every 200 to 500 feet throughout the entire system. Drainage to and discharge from each outfall is variable. These "pulses", in conjunction with changing valley conditions, are most likely responsible for the frequent changes in channel morphology. More stable channel morphologies (e.g., B and C) tend to occur 200-300 feet downstream from a point source input suggesting a more stable flow regime has been established in the channel.

The bankfull discharge is associated with flows generated by nine month to one year storms -- equal to one to two inches of rainfall over a 24 hour period. Rainfall data (see Appendix E) for the Towson area from March through September, 1994, indicates that there were 10 storm events during this period in which one to two inches of rainfall occurred. This indicates that bankfull events probably occur frequently during the year, and consequently affect channel morphology on a frequent basis. This indication is supported by observational changes in channel morphology during field visits in July, October, and December.

Bank Erosion

There is extensive bank erosion throughout the course of Spring Branch. Causes of erosion include:

- Slopes adjustments (e.g., slumping) of the enlarged channel banks.
- Lack of riparian cover to ameliorate overland flow.
- Active toe erosion associated with base and storm flows.

Channel banks are high with steep bank angles, a result of deliberate channelization or the channel enlargement response to perturbations in the watershed. Rosgen (1993) has developed a relationship between the bank height to bankfull height ratio and erosion potential (refer to Figure 3.2). Applying this relationship to measurements of bank conditions made in the field, the majority of the channel banks area rated as having a very high to

extreme potential for erosion. In most cases the bank erosion is a predominantly the result of slumping and lack of riparian cover. Figure 3.3 illustrates a typical sequence of channel bank adjustment following channel enlargement. Spring Branch exhibits all stages of channel adjustment at various different locations; however stages 3 and 4 are most representative of current conditions.

The lack of riparian cover and the heavily maintained (mowed) land uses within the County storm drainage reservation and resident's back yards exacerbates the natural slope adjustment processes of the enlarged channel. From observations of land use, it appears adjacent residents have included the County easement as part of their property and mow and maintain it

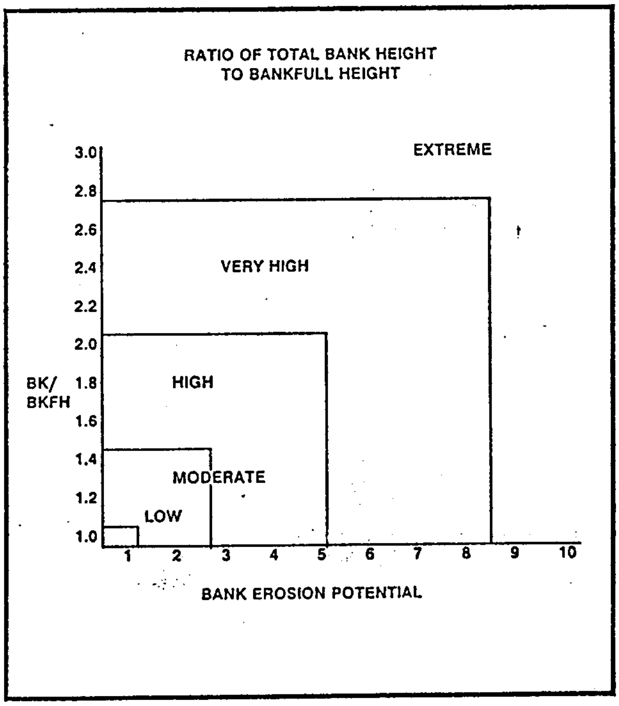


FIGURE 3.2 - EROSION POTENTIAL RATINGS

accordingly. Conversely, overland flow rates are accelerated due to the low roughness coefficient and lack of a fibrous root system to assist in holding soil in place.

Localized problems

In addition to stream wide problems, there are also localized problem areas associated with failing infrastructures, debris dams, and disjunct and improperly installed bank stabilization measures. Several problem areas are described below:

Failing Infrastructures

An existing sanitary lateral connection serving Stratford Lot #32, 108 Westdale Court, is located between sanitary manholes 34857 and 34858. This sanitary lateral connection is an aerial crossing which impedes the stream flow by catching storm debris. The force of the stream acting on the lateral connection has caused several pipe joints to open, resulting in sanitary discharge to the stream. Temporary shoring of this line is required to eliminate the discharge. Permanent solutions are proposed in Section 4.0.

There are also several exposed manholes that are located in or immediately adjacent to the active channel. As

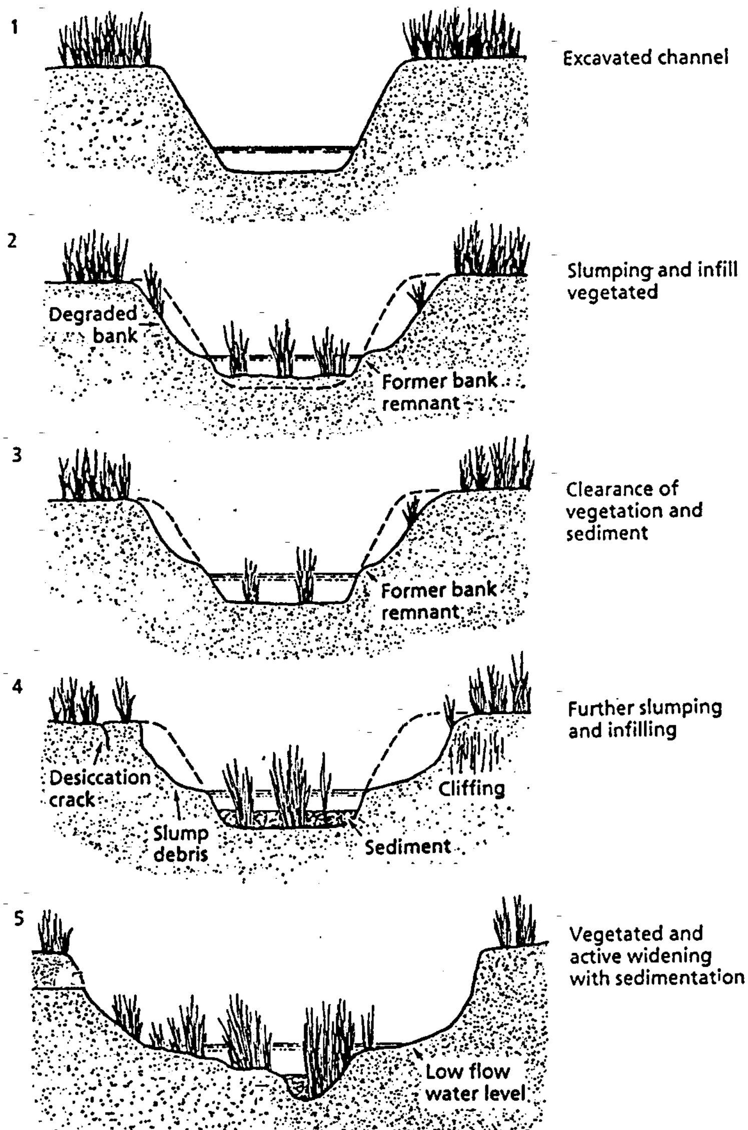


Figure 3.3 Sequence of Channel Changes (Whitlow & Grady, 1989)

erosion continues, or lateral migration of the stream continues, these structures may become compromised. Most of the box culverts seem to be maintaining structural integrity however the angle at which flow enter the Timonium Road culvert has shifted against the left bank and severe bank erosion is occurring just above the wing wall. Many of the storm drain outfalls have been undercut and those with concrete aprons or outfall channels have failed or will do so in the foreseeable future.

Storm drain outfall

The 42" RCCP outfall is the discharge point of a storm drain system which conveys runoff from a drainage area of approximately 50 acres. The 42" outfall pipe extends from Killoran Road, between 2 residences along a County easement, and discharges at the headwaters of Spring Branch. At the end of the pipe is a concrete headwall and concrete channel. The foot and the sides of the concrete channel have been greatly eroded creating a plunge pool for approximately 20 feet. Additional erosion is present around the headwall due to the concentration of overland flow from the backyards of the adjacent residences.

This section of stream channel is characterized by a deep, well defined channel with little sinuosity. The channel invert is relatively steep in slope averaging 6 to 7 percent. Although the plunge pool tends to reduce the discharge velocities immediately downstream of the headwall, the headwall and the limits of the plunge pool are still susceptible to further erosion. Immediately downstream of the plunge pool, where the slope of the stream channel is steep, the flow velocities return to values with high erosion potential. The stream channel however, seems stable due to the presence of medium to large rock and boulders lining the stream channel invert.

There is a defined terrace on both sides of the stream channel. The terraces are moderately sloped and are well established with woodland forest. Despite the presence of a terrace, it is evident from field investigations that it is rarely used as a floodplain and that the stream flow remains within the limits of the stream channel for most storm events. This observation is supported by the HEC-2 model. The results of the HEC-2 model shows that none of the storm events modeled utilize the floodplain. Since a majority of the urban pollutants get washed out during the early stages of most storm events, designated as "first flush", it is unlikely that the floodplain, as it currently exists, provides any water quality benefit.

Additional site constraints include the location of public utilities. Immediately east of the headwall is a sanitary sewer manhole and a utility pole supporting overhead power lines.

Samples of the storm drain effluent were taken during three different storm events during the months of June and July 1994. Several urban pollutants were tested for from the effluent. The pollutants and their average event mean concentration (EMC) for the three storm events are as shown below. In 1980-1981, EPA conducted a Nationwide Urban Runoff Program (NURP) Project for the Washington, D.C. area. This project established average pollutant concentrations for "New Suburban" sites. These average pollutant concentrations are shown below for comparison.

Event	Date	Duration	Precipitation
1	June 21	75 minutes	0.51 inches
2	June 30	85 minutes	0.04 inches
3	July 26	90 minutes	0.30 inches

	Pollutant Concentration (ppm)			
Pollutant	Event 1	Event 2	Event 3	Nurp Study
Total Suspended Solids	320	56.9	82.3	N/A
Total Solids	639	486	173.5	N/A
Total Nitrogen	7.22	13.3	2.25	2.00
Total Phosphorous	0.77	0.40	0.24	0.26
Cadmium	0.01	0.00	0.00	N/A
Copper	0.04	0.12	0.03	N/A
Lead	0.05	0.01	0.02	0.02
Zinc	0.17	0.19	0.06	0.04
BOD	28.8	9.53	8.81	5.1
COD	236	65.97	29.1	35.6
Chlorine	8.42	120	8.04	N/A
FOG's	---	2.64	0.05	N/A

The average EMC values from the NURP study were obtained from "Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMP's" (Schueler, 1987).

It is unknown whether there were additional storm events in between the sampled events. Without additional information such as this, it is difficult to reach any definitive conclusions other than it appears the EMC's are on average higher than the average EMC's developed during the NURP study. It is clear that the pollutants are present in the runoff and at concentrations sufficient to warrant the consideration of a stormwater management facility somewhere within the study area.

Debris Dams

Several significant debris dams occur throughout the system. They are a result of:

- Fallen trees blocking flow in the channel
- Yard waste (grass/shrub clippings, leaves) dumped in the channel or on banks
- Failed structural bank repair measures (concrete, stone, sand bags, sheet metal, etc.) that have disintegrated and washed into the active channel

Debris dams can have dramatic effects on channel geometry in streams with a high sediment transport and no access to an active floodplain to deposit materials. The debris dams effectively slow storm and base flow velocities causing the high sediment and bedloads to drop out up and down stream of the blockage. The combination of debris and depositional materials are often large enough to cause stream flow to be diverted, which, in turn, causes changes in meander patterns and erosion of the bank and floodplain. Similar effects of debris dams can be found throughout the course of Spring Branch.

4.0 RESTORATION CONCEPTS

4.0 RESTORATION CONCEPTS

The following section identifies various restoration strategies and their associated opportunities and constraints. The restoration concept focuses on improving the physical structure, stability, and function of the stream system. Specific goals, strategic approach, alternatives, and specific enhancement techniques are identified.

Restoration concepts were developed after completion of the channel classification and problem assessment. Several in-house work sessions were conducted with the Team to develop goals, strategic approach, alternatives, and construction techniques. A field session was also held after the work-sessions to verify and refine restoration concepts.

4.1 Restoration Goals

As discussed previously in Section 3.3.2, Spring Branch is in an unstable and inefficient state of equilibrium. Desynchronized storm flow regimes are responsible for maintaining current channel morphology more than any other influence operating on the system. A secondary problem is extensive bank erosion. Although rather a symptom than a cause, bank erosion is resulting in the public perception that private property is being lost. However, the facts indicate that it is County storm drainage easement that is being eroded instead of private property. In addition, continuing bank erosion impairs water quality, increases sediment loads delivered to Loch Raven Reservoir, affects stream biota, and may initiate alterations in channel morphology in the future. Therefore, stream restoration goals were developed to address storm pulse flows and stream bank erosion.

Restoration goals are as follows:

- *To create a stable, self-maintaining channel and a stable discharge flow regime*

- *To reduce bank erosion.*

Other restoration goals, such as water quality, flood attenuation and habitat improvement are not the focus of conceptual stream restoration design efforts in Spring Branch, but will occur as a result of achieving the primary restoration goal.

4.2 Conceptual Design Alternatives

A sound stream restoration philosophy is one that advocates addressing watershed inputs to the system first and foremost. Once these inputs are addressed, channel modification is a more effective alternative. Channel modifications are performed for the following reasons:

- Accelerate the stream's natural recovery processes;
- Correct or prevent severe problems or threats to safety (e.g. flooding), ecosystem health, or property loss;
- It is not possible to correct inputs to the system outside of the channel.

In order to successfully restore the Spring Branch system to a more efficient and stable equilibrium it is necessary to correct or modify many of the influences that are concurrently acting on the system. These include moderating flow regimes including point source and overland flow, reshaping fluvial geometry, stabilizing banks, and modifying adjacent land use.

The conceptual restoration strategies have been developed from two basic approaches:

1) A No Build Alternative, which evaluates the pros and cons of leaving the system as is; and

2) Proposed Alternatives which aims to ameliorate the "pulse" flow regime and stabilize eroding banks.

4.2.1 No-build Alternative

The no-build alternative assumes no further man-made changes in the watershed or to the stream channel. It also assumes that inputs to the system will not change (e.g., no more development in the watershed or direct actions proposed in the channel) and that the current input regime has functioning as described for the past 20+ years. No-build predictions are extrapolated from the affects of past known events, channel evolutionary models, and current geomorphology and fluvial characteristics.

Selection of the no-build alternative will likely result in the following stream conditions in over the next several decades:

- The channel will continue to be affected by storm flow pulses of differing magnitude and frequency. Which, depending on the magnitude and frequency of storm events, may result in further downcutting, lateral erosion, and aggradation of the channel. This will continue to maintain a negative feedback loop on channel morphology maintenance. An inefficient flow regime will continue to operate; one that is unable to move sediment and bedload efficiently during base flow and contains erosive energy regimes during annual storm or more frequent bankfull storm events. Stable channel morphologies in equilibrium with inputs may never totally evolve since storm flow pulses are inconsistent and a function of precipitation patterns.

- If stream bank instability continues, stable morphologies, such as C's, may eventually evolve to F's and D's. B channel types may evolve to G's. However, this evolution is dependant on the magnitude and frequency of storm flow pulses, climate and time.

- Bank erosion will naturally continue until a more moderate angle of repose is established, bank height to bankfull height ratios are substantially decreased, vegetation is established on bank faces, and the overall roughness coefficient of adjacent land use is increased.

- Utilities such as exposed manholes, trunk and lateral sewers, and overhead power lines, continue to be exposed, undermined, and eventually damaged.

  The County storm drainage reservation easement will continue to erode, the stream may begin to migrate outside of the easement, thereby causing increased property loss.

  Headward erosion will continue to undermine culverts and headwalls, eventually threatening the integrity of these structures.

  Yard wastes dumped in the channel and unauthorized bank repair measures will continue to contribute to debris dams and localized areas of disturbed channel morphology.

4.2.2 Proposed Alternatives

Urbanized streams are complex, disturbed systems with an array of problems that often require several restoration measures applied in tandem to successfully restore the system to a more healthy state. This alternative uses a "menu" approach to zero in on specific reaches or localized problem areas and offer an array of solutions. The menu approach is preferable over the single-theme alternative approach. For that reason, it provides many restoration options while allowing the County to customize the restoration effort based upon severity of the problem and fiscal capability. Although a variety of alternatives are offered, the overall restoration approach remains consistent:

- *To create a stable, self-maintaining channel and a stable discharge flow regime.*

- *To reduce bank erosion.*

These goals are achieved by proposing restoration techniques designed to:

1) ameliorate the flow regime;
2) create natural, more stable channel morphologies; and
3) stabilize eroding banks.

The goals are not necessarily independent of each other and in some areas must function together as a collective restoration unit.

The following section briefly describes proposed restoration methods and includes recommendations for preferred solutions. Proposed restoration methods are mapped on the Spring Branch Preliminary Concept Design Plans accompanying this report. Details showing individual restoration techniques are contained in Appendix B.

Flow Regime Modification

The best approach to moderating the flow regime is to reduce velocity and prolong time of concentration of storm flows delivered to the channel. The ideal place to achieve these objectives is throughout the watershed. However, due to the built out nature of the watershed, this is not feasible without disrupting current land use, roadway, and storm drain networks

Though less effective, flow regimes can be slightly moderated through retrofit activities in the stream valley and stream channel. Retrofit methods include modifying storm drain outfalls and culverts. Storm drain outfalls and box culverts can be modified by lengthening the distance between the end of pipe and channel interface and/or increasing the roughness coefficient of outfall channels and culvert apron interfaces with the natural channel. Specific techniques could include:

- Create A/B step pool morphologies as the outfall channel
- Create plunge pools below pipe outfalls
- Place rip-rap in outfall channels and downstream of culverts
- Create catch basins to attenuate flow

Another approach for ameliorating the storm flow pulse regime is to provide floodplain access for bankfull discharges. This approach involves creating flood prone areas in sections of the channel that are currently entrenched by altering channel geometry. Channel geometry modification is also proposed as a means for creating stable, self maintaining morphologies and flow competence. The approach is described below.

over ?

Channel Reconfiguration

Channel reconfiguration typically involves modifying the cross-sectional and meander geometry to provide a more stable, efficient morphology and to maintain competence of the stream. In some cases reconfiguration may involve creating an entirely new morphology, or correcting a specific variable(s) that may be out of balance with the operation of the channel and flow regime. The channel modifications must reflect and be consistent with, valley features, watershed inputs, adjacent land uses, and base and storm flows.

For Spring Branch this generally encompasses changing overwidened and entrenched sections of the channel from G and F morphologies, to B or C type channels that will provide bankfull discharge access to a floodplain and flood prone area. The proper morphologies will be selected based upon reach slope, W/D ratios, sinuosity, bankfull depth and width, discharge volume, and spacing between storm drain inputs.

B and C channel types are proposed because they work most efficiently with the existing valley form. They are probably the historical channel morphologies (pre-residential development) based upon review and analysis of 1952 aerial photography, original stream geometry depicted on 1950s storm drain, water, and sewer construction drawings and professional judgement.

In many cases, channel modification efforts will consist of "tweaking" various aspects of the current geometry in order to facilitate natural recovery efforts already underway. In other locales, a new channel and floodplain may be designed to efficiently transport bedload, sediment load, and withstand storm flows. Sinuosity, bankfull width and depth, and entrenchment relationships of stable B and C reach morphologies will be used as a design reference when developing new channel dimensions. An example of a proposed restoration technique for channel geometry modification is provided below:

Location KT-11 (Refer to Sheet 6 of 9, Preliminary Restoration Concept Plans):

Existing G:		Proposed B:	
ER:	1.2	ER:	1.8
W/D:	20	W/D:	20
Sin:	1.15	Sin:	1.3
Slope:	3.0%	Slope:	3.0%

Entrenchment will be reduced by increasing the flood prone area width (FPAw) and the bankfull width (BFw) correspondingly:

	Existing G:	Proposed B:
FPAw:	$\frac{5.0'}{4.1'} = 1.2$	$\frac{8.0'}{4.4'} = 1.8$
BFw:		

Increases in sinuosity will occur by increasing amplitude, increasing belt width and/or decreasing meander length. Meander width ratios (belt width/bankfull width and meander ratios (belt width to meander width) will be limited to the maximum widths of the storm drainage reservation easement. It is unlikely, that highly sinuous channel morphology will be necessary to create stable morphologies; however the system as a whole can benefit from an increase in sinuosity and preliminary computations indicate that there is sufficient area within the channel and County easement. Where channel gradients are moderate to steep and the easement is narrow, step pool channels will be created. Channel modifications also include bank stabilization measures where required.

Natural materials required for the channel reconfiguration process (e.g. logs, rootwads, and coarse particle size material (gravel, cobbles, boulders), are found throughout the study area, particularly the KT sector. If on site material is of suitable size and integrity, it will be used during the construction process.

Bank Stabilization

Bank erosion could be corrected by two approaches; modifying channel banks; and by establishing a densely vegetated riparian buffer within the storm drainage reservation easement and beyond if possible.

There are three different methods that could be applied to modify the channel banks:

- Structural - application of materials such as rip-rap, gabions, retaining walls etc. to hold the bank in place. These methods are suitable for addressing mass wasting situations or where toe and full bank face erosion conditions occur.

- Non-structural - uses vegetation to stabilize eroding slopes. This method works best on moderately sloping banks (maximum 2:1 slope) or conditions where surficial or top of bank erosion occurs.

- Bioengineering - These measures rely predominantly on the combination of plant material and rock to control erosion and stabilize slopes. It is suitable for treating toe, top of bank, and full bank erosion situations. Specific techniques include the use of rootwads, branch packing, brush mattresses and crib walls, coconut rolls, and coir fabric. Recommended plant species for bioengineering are shown in Appendix D.

Riparian buffer establishment is highly recommended throughout the study area. Buffer establishment will involve reestablishment or supplemental plantings of native trees, shrubs, and groundcover throughout the storm drainage reservation easement. Native plant species that are adapted to the soils in each sector and have dense above ground mass and fibrous roots are recommended. Recommended plant species for riparian buffer establishment are shown in Appendix D

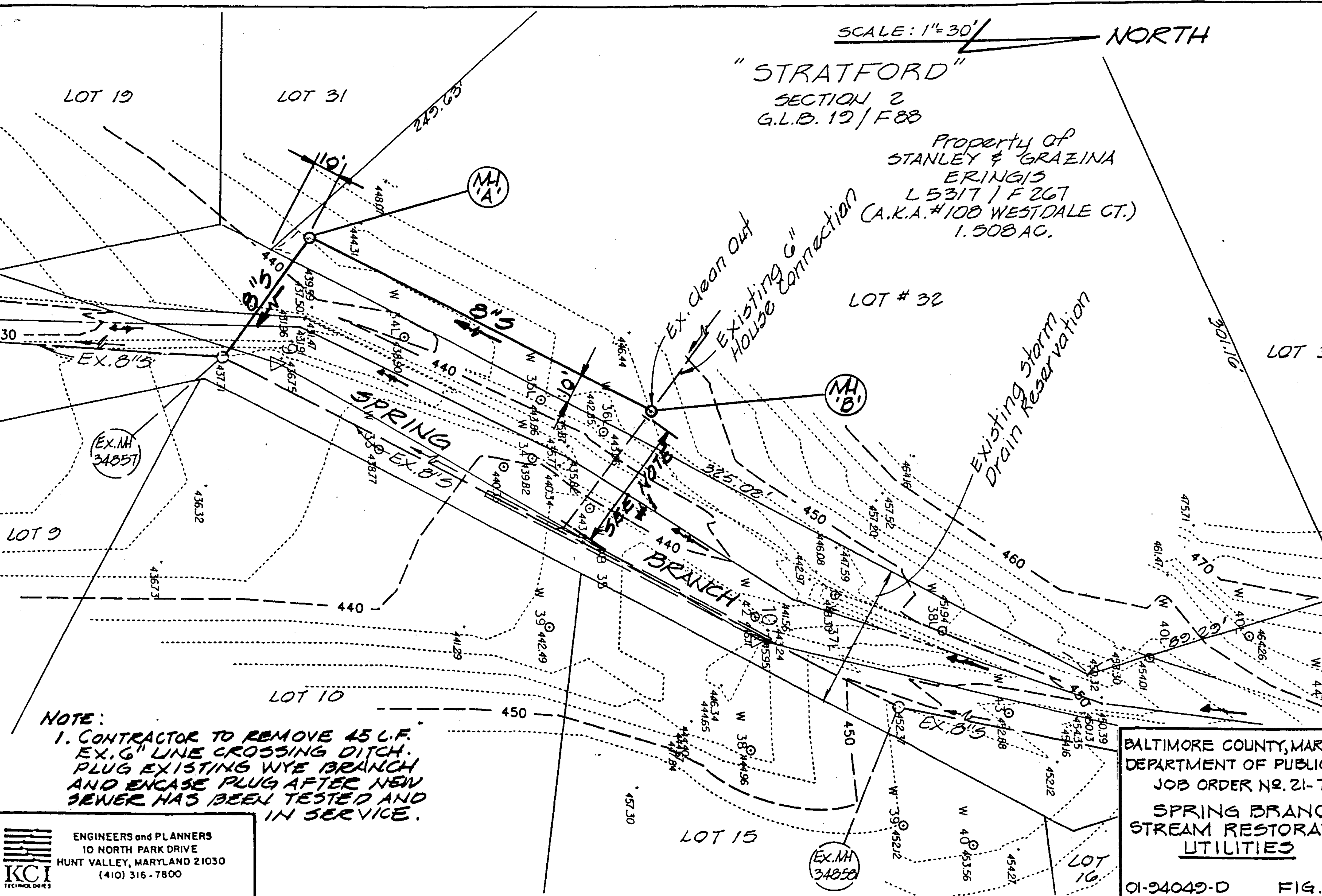
Where bank stabilization is not a high priority, steep slopes occur, and the easement width is narrow (e.g., the RC sector), buffer establishment may be more effective if the tops of banks are terraced and then planted. A community wide education program on the benefits of establishing and maintaining a buffer should be established. Adjacent home owners should be encouraged to plant the rear of their lots in recommended plant species.

Additional techniques that may assist bank stabilization efforts include debris dam removal and selective tree cutting. Large debris dams formed by trees, construction materials, or dumped refuse should be removed from the channel. Consideration should be given to removing depositional material in mid-channel and side bar locations if hydraulic computations indicate that the excess materials force the stream into disequilibrium. Excess material on point bars should be removed or reshaped to maintain the elevation of the bar at an appropriate bankfull discharge elevation.

Selective tree cutting involves identifying live or dead trees on the active bank face that are in danger of being undermined and are accelerating bank erosion. These trees are already leaning at a steep angle over the channel and the root fan is often undercut and exposed. The trunk can be cut at the base, close to the root fan and the trunk and upper branches are removed. This substantially reduces stress on the bank and keeps the stream bank intact.

Broken sewer lateral

Temporary shoring of the lateral should be performed immediately to eliminate further waste discharge into the stream. A permanent solution should be coordinated with stream restoration activities. Two approaches for correcting the broken sewer lateral have been submitted to DEPRM and DPW for review. These include encasing the lateral in concrete or relocating the lateral at the clean out and reconnecting to the main trunk line at Manhole 34857. The County has indicated that relocation is the preferred approach. A preliminary relocation design is shown in Figure 4.1.



NOTE:

1. CONTRACTOR TO REMOVE 45 L.F. EX. 6" LINE CROSSING DITCH. PLUG EXISTING WYE BRANCH AND ENCASE PLUG AFTER NEW SEWER HAS BEEN TESTED AND IN SERVICE.

KCI TECHNOLOGIES
ENGINEERS and PLANNERS
10 NORTH PARK DRIVE
HUNT VALLEY, MARYLAND 21030
(410) 316-7800

BALTIMORE COUNTY, MAR
DEPARTMENT OF PUBLIC
JOB ORDER NO. 21-
SPRING BRANC
STREAM RESTORAT
UTILITIES

01-94049-D FIG.

4.2.3 Proposed Alternatives Hydrology and Hydraulics

The hydrology and the hydraulics of the Spring Branch may be affected by the restoration design in two ways. First, the flow rates may be reduced from the affects of flow attenuation and desynchronization of multiple hydrograph peaks. Second, the hydraulic characteristics of the flow through the cross sections (i.e. water surface elevation, flow area, velocity) may be affected by the changes in cross section geometry, stream channel sinuosity, and roughness coefficient. The actual effect on the hydrology and hydraulics can not be quantitatively determined prior to final design of the restoration work. However, certain predictions can be made based on the design concept presented herein.

In regard to the hydrology impacts, it is unlikely that there will be a substantial reduction in flow rates throughout the system. Flow attenuation is directly associated with the amount of floodplain storage utilized. Since the existing stream channel is relatively steep and the channel is deeply entrenched, there is very little floodplain storage currently being utilized. Where possible, morphologies such as Bc or C type channels should be created to provide the bankfull discharge with access to a flood plain.

In regard to the hydraulic impacts, there will be a change of unknown magnitude at all of the locations where the cross section or stream channel geometry is changed. A widening of the cross section will cause a decrease in the water surface elevation. Conversely, a constriction of the cross section will cause an increase in the water surface elevation. The result of bank stabilization is an increase in the roughness coefficient causing a increase in the water surface elevation and a decrease in velocity. Finally, the result of increasing the sinuosity is a gradual reduction in the channel slope. This will tend to increase the water surface elevations and reduce the flow velocities.

The hydrologic and hydraulic affects stated above are only generalities based on the best judgement of fluvial systems professionals. A final H&H report will be prepared after completion of the final restoration design. The report will summarize the actual impacts to the flow regime at each cross section as a result of the proposed restoration alternative. ?

4.2.4 Preferred Alternatives

The Proposed Alternatives provide a variety of solutions and techniques to restore Spring Branch. This allows Baltimore County some flexibility in implementing the restoration in several ways:

- The County has the option to immediately address localized or high priority problems such as the broken sewer lateral, impending property loss from bank erosion, or failing/threatened infrastructures.

- Multiple problem areas of similar magnitude and cause can have different restoration techniques applied which can then be monitored to determine which ones perform best or are most cost effective.

- Certain aspects of the overall restoration strategy may be completed in stages if there are fiscal constraints.

The most effective approach to restoring Spring Branch is a comprehensive one that treats the entire system. Channel geometry modification, in conjunction with the pulse input retrofits, is the preferred approach. It is unlikely that the stream will be able to develop a more stable equilibrium without some degree of modification. This conclusion is based on the assumption that system inputs have been relatively static over the past 30+ years and the channel has not achieved a stable channel morphology. Channel modification is a better long term solution in that the system will be able to "maintain itself" with competence. Channel geometry modification also plays a significant role in cumulatively moderating the storm flow pulse regime.

At a minimum, the storm drain outfalls and culverts should be retrofit to ease stress on the downstream channel. Though it is acknowledged that significant reductions in pulse inputs are not likely, incremental increases or decreases to channel flow are logarithmic and cumulative. The riparian buffer reestablishment should also be performed and expanded to include private property and any available open space in the watershed.

The second preferred alternative is to perform broad scale bank stabilization throughout the system. This also should be performed in conjunction with retrofits of the storm drains/culverts and riparian buffer establishment. It would prevent further loss of County and private property, but it is unlikely that it will assist the channel in reaching a more stable state.

Bioengineering techniques, where feasible are recommended over structural techniques. Bioengineering offers strong protection against accelerated and high storm flows which can occur within the system. Storm flows associated with larger events must still be confined within a relatively narrow valley, due to the close proximity of the development and deeply incised nature of the system. Therefore the stream valley will have to be well armored to withstand large storm events to avoid accelerated erosion and property damage. Biogeoengineering solutions provide more natural habitat, are more aesthetically pleasing, and generally more cost effective.

4.2.5 Storm Drain Retrofit

In an attempt to provide additional water quality and quantity control for the upper reaches of the study area, a potential retrofit below the 42 inch storm drain outfall south of Killoran Road was investigated. The outfall carries an unmeasurable base flow (most likely from groundwater seepage) and stormwater discharges from a 50 acre drainage area comprised of medium density residential land use. The intentions of the proposed retrofit is to increase water quantity and quality controls within this reach yet retain the integrity of the existing stream channel and associated riparian zones.

An analysis of the outfall region and receiving stream corridor revealed numerous constraints in accomplishing the intended goal. To achieve measurable water quality improvements for this area (assuming 0.5 inch runoff from a 30% impervious watershed), a storage area with an approximate capacity of 27,000 ft^3 would be required. Extensive grading and loss of stream channel and riparian areas required to accommodate this storage make this option infeasible. Other potential alternatives to increase storage within this reach include off-channel diversions, floodplain grading and/or in-stream weir construction. The existing stream and valley morphology, however, preclude the incorporation of any of these options for water quantity/quality control. The primary limiting factor is stream and valley slope which is estimated to be 6-8 percent within this segment. The high gradient and large substrate is typical of "A" channels under the Rosgen Stream Classification System (Rosgen, 1994). Available storage areas (floodplains) are not typical of "A" stream types. The amount of potential water storage from in-stream weirs and off-channel diversions is also limited because of the steep valley and in-stream gradient.

Additional constraints below the outfall include sanitary sewer, power utility poles, and a number of large trees within close proximity to stream banks. Removal and/or relocation of these features would be necessary if extensive grading is undertaken.

In-stream restoration improvements (i.e. step-pool structures, bank stabilization, thalweg confinement, etc.) and stabilization of the existing scour pool below the outfall may improve water quality conditions though the net impact of the improvements will likely be immeasurable.

Due to the limitations present below the outfall, it is recommended that other areas downstream with more suitable gradients and accessible floodplains be investigated for potential water quality and quantity control measures.

5.0 PRELIMINARY RESTORATION COSTS

5.0 RESTORATION COSTS

A preliminary engineers cost estimate has been prepared to assess the costs and benefits associated with the System Recovery alternatives. The preliminary engineers cost estimate, arranged by stream sector (i.e. RC, CfR, etc.), provides unit costs for both the preferred approach and second alternative restoration concept.

An engineers cost estimate for the No-build Alternative was not prepared. However, based on the geomorphological condition of the current stream channel, Baltimore County will encounter future costs associated with maintenance of storm drains and road culverts, debris removal, erosion and sediment control, and possible easement acquisition. Costs associated with these items will vary based on the County's desire and fiscal ability to permanently correct the problem or apply a "quick fix".

The unit prices for the cost estimate were obtained from the following sources:

- Means Sitework & Landscape Cost Data
- Kerr's Cost Data for Landscape Construction
- Maryland State Highway Administration Bid Tabulations and Engineers Cost Estimates
- Biohabitats' historical cost data

5.1 Assumptions

Because this is a preliminary cost estimate based on conceptual solutions, several assumptions were made in order to develop a consistent and reliable estimate. Assumptions include:

1. All unit costs include material constructed and in place.

2. A "Grading" category with "Hour" units was established for modification and creation of new channel morphology and geometry. It is assumed that this operation will encompass excavation, grading, and filling all within and immediately adjacent to the channel. Unit cost assumes 2 pieces of equipment, 2 operators, and 1 laborer.

3. "Rip rap" includes a combination of both MSHA Class I and Class II stone based on the MSHA Standard Specifications for Construction and Materials, October 1993.

4. "Class 2 Excavation" is based on the MSHA Standard Specifications for Construction and Materials,

October 1993. The unit cost for Class 2 Excavation assumes that the contractor can balance the cut and fill on site.

5. "Bioengineering Bank Stabilization" includes any one of the measures listed in the report.

6. "Revegetation channel slopes" assumes a mix of bare root and container grown shrubs 12-24" planted 8' on-center and the area seeded with a native riparian grass and forb seed mix within the channel. Riparian reforestation is calculated separately (see # 7 below).

7. For areas designated to modify and create new channel morphology and geometry it was assumed that an average of one-half the channel length required to complete bank stabilization (1/2 bioengineering and 1/2 revegetation) and rip rap toe protection.

8. Contractors "Mobilization" is based on 10% of the total quantities cost.

9. "Erosion and Sediment Control" is based on 15% of the total quantities cost. It is anticipated that E&S control will consist of completing the construction in segments that allow the contractor to divert the clean water around the construction site during the construction process. E&S controls will most likely consist of stabilized construction entrance, silt fence, and stream diversion measures.

10. A 10% contingency, based on the total quantities cost, is added to cover miscellaneous and unforseen items including construction access and private property restoration.

The estimates do not include the following:

1. Baltimore County contractor procurement and contract administration time.
2. Permit application fees and regulatory permitting time.
3. Public hearings, presentations and notices.
4. Unforseen regulatory permit special conditions.
5. Easement or property acquisitions costs

5.2 Preliminary Cost Estimates

The following preliminary engineers cost estimates are arranged by stream sector (i.e. RC, CfR, etc.), provides unit costs for both the preferred approach and second alternative restoration concept. Also included is a preliminary cost estimate for riparian reforestation.

Riparian reforestation is highly recommended for both alternatives and has been estimated as a separate component. Riparian reforestation assumes that the County Easement will be planted to achieve a density of 435 woody trees and shrubs per acre (Bare root/containerized; 2-6' height). For estimating purposes, it is assumed that 20% of the areas calculated for riparian reforestation already contain woody trees and shrubs. It is also assumed that riparian reforestation will not require mobilization, erosion and sediment control, and contingency monies. Riparian reforestation is estimated as follows:

Stream Reach	Acreage	(X 80%)	Unit Cost	Total Cost
KT	0.7	0.6	$ 9,000	$ 5,400
	3.6	2.9	$ 9,000	$ 26,100
HB	1.2	0.9	$ 9,000	$ 8,100
CfR	3.3	2.6	$ 9,000	$ 23,400
RC	1.9	1.6	$ 9,000	$ 14,400
TOTAL	**10.7**	**8.6**		$ 77,400

STREAM SECTOR - KT Preferred Alternative

Quantities

Item	Units	Unit Price	1	2	3	4	5	6	7	8	9	10	11	12	Total Quantities	Cost
Est. Length			N/A	102	210'	340'	N/A	380'	312'	50'	90'	288'	192'	25'		
Av. Channel Hgt.			N/A	3'	3'	4'	N/A	2'	3'	2'	2'	3'	4'	2'		
Remove & Dispose of Debris and Trash	TONS	80.00										1			1	80.00
Remove & Dispose of Concrete	TONS	150.00													0	0.00
Excavation	CY	10.00						170		70					240	2,400.00
Grading	HRS	160.00	40	10	21	34		76	31	18	18	28	19	8	303	48,480.00
Class I/II Rip Rap	TONS	23.00		18	5	85		9	8	5	5	7	5	2	149	3,427.00
Geotextile Fabric	SY	1.60		70						25					95	152.00
Rock/Concrete Weir Structure	EA	1500.00													0	0.00
Bioengineering Bank Stabilization	SY	40.00		8	18	75		21	26	4	2	24	21	2	201	8,040.00
Revegeate Channel Slopes (shrubs and groundcover)	SY	15.00		8	118	75		21	26	4	2	24	21	2	301	4,515.00

Subtotal	67,094.00
5% Mobilization	3,354.70
15% Erosion & Sediment Control	10,064.10
10% Contingency	6,709.40
TOTAL COST	87,222.20

STREAM SECTOR - TCF Preferred Alternative

Item	Units	Unit Price	1	2	3	4	5	6	7	8	9	10	Total Quantities	Cost
			Quantities											
Est. Length			N/A	240'	70'	10'	40'	250'	40'	300'	50'	N/A		
Av. Channel Hgt.			N/A	3'	3'	N/A	5'	4'	3'	4'	2'	N/A		
Remove & Dispose of Debris and Trash	TONS	80.00											0	0.00
Remove & Dispose of Concrete	TONS	150.00				2							2	300.00
Excavation	CY	10.00										3080	3080	30,800.00
Grading	HRS	160.00	16	24	7	16		25	4	30	5		127	20,320.00
Class I/II Rip Rap	TONS	23.00	5	12		4		12	2	15	5		55	1,265.00
Geotextile Fabric	SY	1.60	65										65	104.00
Rock/Concrete Weir Structure	EA	1500.00											0	0.00
Bioengineering Bank Stabilization	SY	40.00		40	23	2	44	55	13	66	10		253	10,120.00
Revegeate Channel Slopes	SY	15.00		40	23			55	13	66			197	2,955.00
Subtotal														65,864.00
5% Mobilization														3,293.20
15% Erosion & Sediment Control														9,879.60
10% Contingency														6,586.40
TOTAL COST														85,623.20

STREAM SECTOR - HB Preferred Alternative

			Quantities					
	Est. Length		860'	320'	20'	100'		
	Av. Channel Hgt.		2'	6'	6'	6'		
Item	Units	Unit Price	1	2	3	4	Total Quantities	Cost
Remove & Dispose of Debris and Trash	TONS	80.00					0	0.00
Remove & Dispose of Concrete	TONS	150.00	95			10	105	15,750.00
Excavation	CY	10.00					0	0.00
Grading	HRS	160.00	86	32			118	18,880.00
Class I/II Rip Rap	TONS	23.00	32	16	6		54	1,242.00
Geotextile Fabric	SY	1.60			45		45	72.00
Rock/Concrete Weir Structure	EA	1500.00					0	0.00
Bioengineering Bank Stabilization	SY	40.00	50	106	13	130	299	11,960.00
Revegeate Channel Slopes	SY	15.00	150	106	13		269	4,035.00

Subtotal	51,939.00
5% Mobilization	2,596.95
15% Erosion & Sediment Control	7,790.85
10% Contingency	5,193.90
TOTAL COST	67,520.70

STREAM SECTOR - CFR Preferred Alternative

			Quantities								
	Est. Length		335'	30'	45'	180'	240'	310'	30'		
	Av. Channel Hgt.		6'	6'	4'	12'	8'	5'	4'		
Item	Units	Unit Price	1	2	3	4	5	6	7	Total Quantities	Cost
Remove & Dispose of Debris and Trash	TONS	80.00				2				2	160.00
Remove & Dispose of Concrete	TONS	150.00								0	0.00
Excavation	CY	10.00								0	0.00
Grading	HRS	160.00	34	8	8			31	8	89	14,240.00
Class I/II Rip Rap	TONS	23.00	17	3	4	9	12	16	2	63	1,449.00
Geotextile Fabric	SY	1.60								0	0.00
Rock/Concrete Weir Structure	EA	1500.00								0	0.00
Bioengineering Bank Stabilization	SY	40.00	111	20	20	580	426	86	7	1250	50,000.00
Revegeate Channel Slopes	SY	15.00	111					86	7	204	3,060.00
							Subtotal				68,909.00
							5% Mobilization				3,445.45
							15% Erosion & Sediment Contr				10,336.35
							10% Contingency				6,890.90
							TOTAL COST				89,581.70

STREAM SECTOR - RC Preferred Alternative

Item	Units	Unit Price	1	2	3	4	5	6	7	8	9	10	11	Total Quantities	Cost
Est. Length			20'	90'	120'	N/A	160'	110'	600'	N/A	75'	30'	125'		
Av. Channel Hgt.			5'	5'	4'	N/A	5'	6'	4'	N/A	5'	3'	N/A		
Remove & Dispose of Debris and Trash	TONS	80.00												0	0.00
Remove & Dispose of Concrete	TONS	150.00			9			12		2	5			28	4,200.00
Excavation	CY	10.00			30									30	300.00
Grading	HRS	160.00			16				60			6		82	13,120.00
Class I/II Rip Rap	TONS	23.00	5	4	6				30			3		48	1,104.00
Geotextile Fabric	SY	1.60	85											85	136.00
Rock/Concrete Weir Structure	EA	1500.00												0	0.00
Bioengineering Bank Stabilization	SY	40.00	22	50	53		88	74			42	10		339	13,560.00
Revegeate Channel Slopes Stabilization	SY	15.00							266					266	3,990.00
Repair Gabions	SY	35.00											55	55	1,925.00
Subtotal															38,335.00
5% Mobilization															1,916.75
15% Erosion & Sediment Control															5,750.25
10% Contingency															3,833.50
TOTAL COST															49,835.50

STEAM SECTOR - KT 2nd Alternative

			Quantities													
	Est. Length		N/A	102	210'	340'	N/A	380'	312'	50'	90'	288'	192'	25'		
	Av. Channel Hgt.		N/A	3'	3'	4'	N/A	2'	3'	2'	2'	3'	4'	2'		
Item	Units	Unit Price	1	2	3	4	5	6	7	8	9	10	11	12	Total Quantities	Cost
Remove & Dispose of Debris and Trash	TONS	80.00												0.5	0.5	40.00
Remove & Dispose of Concrete	TONS	150.00													0	0.00
Excavation	CY	10.00								45					45	450.00
Grading	HRS	160.00						38		5	8	28		8	87	13,920.00
Class I/II Rip Rap	TONS	23.00		6		1		10	2	3	5	15		5	47	1,081.00
Geotextile Fabric	SY	1.60												45	45	72.00
Rock/Concrete Weir Structure	EA	1500.00		1											1	1,500.00
Bioengineering Bank Stabilization	SY	40.00			70	150		42	208	6	4		170		650	26,000.00
Revegeate Channel Slopes (shrubs and groundcover)	SY	15.00			70	150		42		6					268	4,020.00

Subtotal	47,083.00
5% Mobilization	2,354.15
15% Erosion & Sediment Control	7,062.45
10% Contingency	4,708.30
TOTAL COST	61,207.90

STREAM SECTOR - TCF 2nd Alternative

			Quantities										
Est. Length			n/a	240'	70'	10'	40'	250'	40'	300'	50'		
Av. Channel Hgt.			n/a	3'	3'	n/a	5'	4'	3'	4'	2'		
Item	Units	Unit Price	1	2	3	4	5	6	7	8	9	Total Quantities	Cost
Remove & Dispose of Debris and Trash	TONS	80.00										0	0.00
Remove & Dispose of Concrete	TONS	150.00										0	0.00
Excavation	CY	10.00										0	0.00
Grading	HRS	160.00							8		10	18	2,880.00
Class I/II Rip Rap	TONS	23.00					60		5		5	70	1,610.00
Geotextile Fabric	SY	1.60										0	0.00
Rock/Concrete Weir Structure	EA	1500.00										0	0.00
Bioengineering Bank Stabilization	SY	40.00	80					222	13	266	10	591	23,640.00
Revegeate Channel Slopes	SY	15.00	80									80	1,200.00

Subtotal	29,330.00
5% Mobilization	1,466.50
15% Erosion & Sediment Control	4,399.50
10% Contingency	2,933.00
TOTAL COST	38,129.00

STREAM SECTOR - HB 2nd Alternative

			Quantities					
	Est. Length		860'	320'	20'	100'		
	Av. Channel Hgt.		2'	6'	6'	6'		
Item	Units	Unit Price	1	2	3	4	Total Quantities	Cost
Remove & Dispose of Debris and Trash	TONS	80.00					0	0.00
Remove & Dispose of Concrete	TONS	150.00					0	0.00
Excavation	CY	10.00					0	0.00
Grading	HRS	160.00					0	0.00
Class I/II Rip Rap	TONS	23.00					0	0.00
Geotextile Fabric	SY	1.60					0	0.00
Rock/Concrete Weir Structure	EA	1500.00					0	0.00
Bioengineering Bank Stabilization	SY	40.00		426			426	17,040.00
Revegeate Channel Slopes	SY	15.00					0	0.00
			Subtotal					17,040.00
			5% Mobilization					852.00
			15% Erosion & Sediment Control					2,556.00
			10% Contingency					1,704.00
			TOTAL COST					22,152.00

STREAM SECTOR - CFR 2nd Alternative

			Quantities								
	Est. Length		335'	30'	45'	180'	240'	310'	30'		
	Av. Channel Hgt.		6'	6'	4'	12'	8'	5'	4'		
Item	Units	Unit Price	1	2	3	4	5	6	7	Total Quantities	Cost
Remove & Dispose of Debris and Trash	TONS	80.00								0	0.00
Remove & Dispose of Concrete	TONS	150.00								0	0.00
Excavation	CY	10.00					570			570	5,700.00
Grading	HRS	160.00		8	8	18			8	42	6,720.00
Class I/II Rip Rap	TONS	23.00	8	4	4	9	12		4	41	943.00
Geotextile Fabric	SY	1.60		35	35				35	105	168.00
Rock/Concrete Weir Structure	EA	1500.00								0	0.00
Bioengineering Bank Stabilization	SY	40.00	223	20	20	120	426	344	7	1160	46,400.00
Revegeate Channel Slopes	SY	15.00	223			120				343	5,145.00

Subtotal	65,076.00
5% Mobilization	3,253.80
15% Erosion & Sediment Contr	9,761.40
10% Contingency	6,507.60
TOTAL COST	84,598.80

STREAM SECTOR - RC 2nd Alternative

			Quantities												
	Est. Length		20'	90'	120'	N/A	160'	110'	600'	n/a	75'	30'	125'		
	Av. Channel Hgt.		5'	5'	4'	N/A	5'	6'	4'	n/a	5'	3'	n/a		
Item	Units	Unit Price	1	2	3	4	5	6	7	8	9	10	11	Total Quantities	Cost
Remove & Dispose of Debris and Trash	TONS	80.00												0	0.00
Remove & Dispose of Concrete	TONS	150.00											110	110	16,500.00
Excavation	CY	10.00												0	0.00
Grading	HRS	160.00										6	12	18	2,880.00
Class I/II Rip Rap	TONS	23.00			6			5			4	5	6	26	598.00
Geotextile Fabric	SY	1.60												0	0.00
Rock/Concrete Weir Structure	EA	1500.00												0	0.00
Bioengineering Bank Stabilization	SY	40.00										5		5	200.00
Revegeate Channel Slopes (shrubs and groundcover)	SY	15.00			53			73	530		42	5	42	745	11,175.00
Repair Gabions	SY													0	0.00

Subtotal	31,353.00
5% Mobilization	1,567.65
15% Erosion & Sediment Control	4,702.95
10% Contingency	3,135.30
TOTAL COST	40,758.90

5.3 Cost/Benefit Analysis

A summary and discussion of the individual cost estimates are provided below.

Stream Reach	Preferred Alternative	PER LF	2nd Alternative	PER LF
KT	87,222.00	43..85	61,207.00	30.77
	85,623.00	85..62	38,129.00	38.12
HB	65,520.00	50..40	22,152.00	17.04
	89,581.00	76..56	84,598.00	72.30
RC	49,835.00	37.47	40,758.00	30.64
SUB-TOTAL	**377,782.00**		**246,846.00**	
R.Refor.	77,400.00		77,400.00	
TOTAL	**455,182.00**		**324,246.00**	

Preferred Alternative Cost Analysis

Based on an estimated 6,790 linear feet of stream and storm drain outfall tributaries, the preferred alternative is estimated to cost approximately \$ 55.00 per linear foot of stream without riparian reforestation and approximately \$ 67.00 per linear foot with riparian reforestation.

Reaches KT, TCf, and CfR represent 70% of the total estimated costs. Reach HB represents only 17% of the costs. Approximate 30% of the total costs are associated with grading for channel modification and realignment and 27% of the costs are affiliated with bioengineering bank stabilization.

Approximately 50% of the cost associated with Reach TCf is related to restoration alternative #10, excavation of the confluence to create addition flood storage. Costs associated with this measure may be substantial reduced once a final grading plan is developed and off site disposal areas are investigated. The major costs associated with Reach HB are associated with the removal of the existing concrete channel. Close to 56% of the costs associated with Reach CfR are attributed to the bioengineering measures required to stabilize 8' - 15' channel banks midway between the confluence and Reuter Road. Primary costs associated with Reach RC include grading and bioengineering stabilization of banks 4' - 8' in height.

Riparian reforestation represents approximately 17% of the total cost of the preferred alternative.

2nd Alternative Cost Analysis

Based on an estimated 6,790 linear feet of stream and storm drain outfall tributaries, the 2nd alternative is estimated to cost approximately $ 36.35 per linear foot of stream without riparian reforestation and approximately $ 47.75 per linear foot with riparian reforestation.

Reach CfR represents 34% of the sub-total estimated costs. Reach HB represents only 9% of these costs. Only 10% of the sub-total costs are associated with grading for channel modification and realignment while 50% of the costs are affiliated with bioengineering bank stabilization. All of the costs associated with Reach HB are for bioengineering bank stabilization.

Riparian reforestation represents approximately 24% of the total cost of the preferred alternative.

Preferred Alternative vs 2nd Alternative

The preferred alternative costs approximately 1.4 times the cost of the 2nd alternative
($ 128,434). The primary reasons for the difference in costs include the excavation and creation of a active floodplain at the confluence of Spring Branch and the HB tributary and channel geometry modification and realignment associated with the preferred alternative. The 2nd alternative includes substantially more bioengineering bank stabilization then the preferred alternative.

6.0 IMPLEMENTATION

6.0 IMPLEMENTATION

This section addresses implementation procedures for pre-construction and construction phase measures, operations and maintenance, and monitoring.

6.1 Sequence of Operations

The overall success of restoration is dependent on implementing various elements of the program in the proper order and according to the plans and specifications. The following section outlines pre-construction and construction measures required to ensure the success of the restoration project.

Preconstruction

Stream restoration projects rely heavily on thorough site preparation, marking of features in the field, and constant supervision of the construction process. Prior to construction, it will be necessary to flag and locate certain features, (i.e. debris/log jams, concrete walls, etc.) as these may be difficult to accurately locate on a plan. It may also be necessary to make minor adjustments to the plan during the construction process as field conditions warrant. Therefore it is strongly recommended that the construction process be supervised by a Restoration Ecologist experienced in stream restoration design and implementation.

Construction

The following is the construction sequence for the Spring Branch Stream Restoration project:

- Install sediment and erosion control.
- Clear and grub. Remove debris.
- Excavate and grade.
- Install stabilization and in-channel measures/structures.
- Clean up.
- Remove sediment and erosion control.

Timing of the installation is critical. If at all possible, construction should be avoided during stream closure dates (October 1 through April 30) and convectional storm patterns of the late summer. However, where bioengineering methods are used for stream bank stabilization, plant material must be installed during their dormant stage (December 1 through March 30). The restoration project that includes the use of bioengineering necessitates obtaining a Waterway Construction Permit Waiver for construction activities during the stream closure period. It is also important to install vegetation (other than bioengineering plant material) in the earlier part of the growing season to promote optimal growth and coverage as quickly as possible.

Material removal can be accomplished in a variety of ways. Small debris dams, lawn wastes and sediment deposits can be removed by hand or with the use of small hydraulic dredge. Use of heavy equipment such as bobcats and backhoes may be necessary to accomplish debris removal, channel modification and bank stabilization. Hydraulic cranes may be necessary to remove large sections of concrete. Regularly scheduled debris removal can be a relatively low cost maintenance technique, accomplished by neighborhood groups and volunteers and monitored by resource agency personnel. Neighborhood groups can also be used for planting and maintaining buffers and streambanks. In general, stream restoration jobs should be staffed with an adequate number of experienced personnel to accomplish the job as quickly as possible to avoid prolonged disturbance of the channel and exposure to high flows from storm runoff.

An erosion and sediment control plan (E&S) should be prepared specifying and illustrating devices to be employed for channel modification and bank stabilization. The E&S devices should be selected and designed according to current industry standards and technology. Control devices should be maintained throughout construction and for approximately one year after.

As-built construction drawings should be created upon completion of the construction process. These drawings document the finished conditions and any adjustments to the original design made during installation. The As-built drawings will also serve as baseline conditions for post construction monitoring of the success of the project.

6.2 Operations and Maintenance

The preliminary Operations and Maintenance Plan (O&M) provides guidelines for procedures to operate and maintain the restoration project. These procedures are designed to achieve project objectives, through timely and cost effective techniques, and can be easily implemented by trained personnel. The operations and maintenance plan should be arranged to take place throughout the year, ensuring that all tasks are completed during the most favorable time of the year.

Three primary O&M procedures have been identified:

- Maintenance of In-Channel Structures
- Maintenance of Stabilization Structures
- Maintenance of Plant Species

The following sections describe specific O&M procedures and scheduling.

Maintenance of In-Channel Structures

Regular inspection of habitat structures is essential to ensure that the structures are in place and functioning properly. Structures associated with plunge pools, step pools, and channel constrictors should be inspected each spring and fall. Any damage or movement of material should be repaired immediately to prevent loss of the structure, a reduction in function, or undesirable channel modifications. Minor reconfiguration and realignment of certain structures, over a period of time, may be necessary to ensure the ultimate success of the project.

Maintenance of Bank Stabilization Structures

Similar to In-Channel Structures, bank stabilization structures should also be regularly inspected to ensure that the structures are in place and functioning properly. Riprap toe protection, root wads, live fascines, and live branch packing should be examined on a semi-annual basis. Undermining, increased erosion noted downstream, plant mortality, and structural integrity should all be inspected and in-kind repairs made as soon as possible. Minor reconfiguration and realignment of certain structures, over a period of time, may be necessary to ensure the ultimate success of the project.

Maintenance of Plant Species

Plant material should be inspected annually in the early spring. Maintenance of plant material may consist of the following:

- Replace and remove dead and diseased plant material
- Removal of unwanted, non-native invasive species (weed control)
- Pruning of woody plant material for rejuvenation and maximum density
- Fertilization
- Replace plant material damaged by storm events
- Removal or pruning to correct damage from wildlife predation
- Watering
- Removal of trash and debris to prevent smothering

It is recommended that O&M procedures be performed for a minimum of five years, and optimally for the life of the project. O&M procedures will require routine attention as well as specific attention following storm events, extreme weather, and vandalism.

6.3 Monitoring

A Monitoring Program is necessary to measure the success of the restoration plan. In addition, project monitoring will provide information needed to diagnose problems resulting from the design and construction of the project. This information can then be used to develop restoration contingency plans and facilitate the design and construction of future restoration projects with similar objectives and site conditions.
The monitoring program should address the following key elements to document preconstruction, construction, and post construction project conditions:

- Update databases with any change in land use within the watershed.
- Establish permanent cross sections to measure channel response to changes in the watershed and as a result of the proposed restoration. Permanent cross sections should also be established several hundred feet below the limits of the restoration project to observe any channel changes downstream of the project limits. Re-measure cross sectional data annually or after a major storm event such as a 50 year storm. Resurvey the stream centerline after five years to identify changes in meander geometry.
- Monitor base and storm flow on an annual basis to refine discharge data and energy regimes.
- Inspect structures on a semi-annual basis and immediately following storm events of the two year discharge or greater magnitude. Repair or remove damaged structures immediately.
- Vegetation survival, distribution patterns, and density should be measured annually in April.

Evaluation of monitoring data should be performed by experienced personnel with an understanding of fluvial geomorphology and stream restoration methodologies. The monitoring program should be conducted for a minimum period of five years starting with the completion of construction.

7.0 CONCLUSION

7.1 Summary

After conducting the field and assessment phases of the project, the Team has concluded that the Spring Branch stream system does not maintain an inefficient state of equilibrium. Problems associated with the system include:

- Desychronized, point source flow regimes;
- Severe bank instability and subsequent erosion;
- Failing or threatened infrastructures;
- Lack of riparian buffer;
- Poor land use practices in and adjacent to the stream;

Despite the urban nature of the watershed, the recovery potential for this system is high if the stream is given some assistance. Restoration efforts focus on stabilizing channel morphologies and flow regime, and correcting bank erosion. A wide array of solutions and techniques have been presented. However a comprehensive restoration approach that addressed the overall health of the system is preferred, rather than treatment of individual "symptoms".

7.2 Recommendations

Following are critical factors or additional actions that will ensure and enhance the success of the restoration efforts:

- At a minimum, retrofit all storm drain outfalls to ameliorate the point source pulse inputs. Without this effort, the system has no chance of recovery or maintenance of stable morphologies and energy regimes.

- Convert the County Storm Drainage Reservation into a riparian buffer and discontinue all maintained and residential land use activities in this easement. Encourage riparian buffer reestablishment on private property and reforestation of open space within the watershed.

- Continue and accelerate educational efforts on good stewardship practices for members of the community, particularly those who reside immediately adjacent to the stream channel.

  Explore opportunities for establishing community compost areas for disposal of yard waste. Possible locations throughout the watershed include the church on Timonium Road, the water tower property in the Stratford subdivision, open space at the confluence of Spring Branch and the Hollowbrook Tributary, expanded areas of the Storm Drainage Reservation above Reuter Road.

DEPRM CIS is willing to undertake the restoration of a degraded and urbanized stream system, an ambitious undertaking for which it should be commended. This project clearly demonstrates Baltimore County's commitment to protecting and restoring its natural resources.

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BIBLIOGRAPHY

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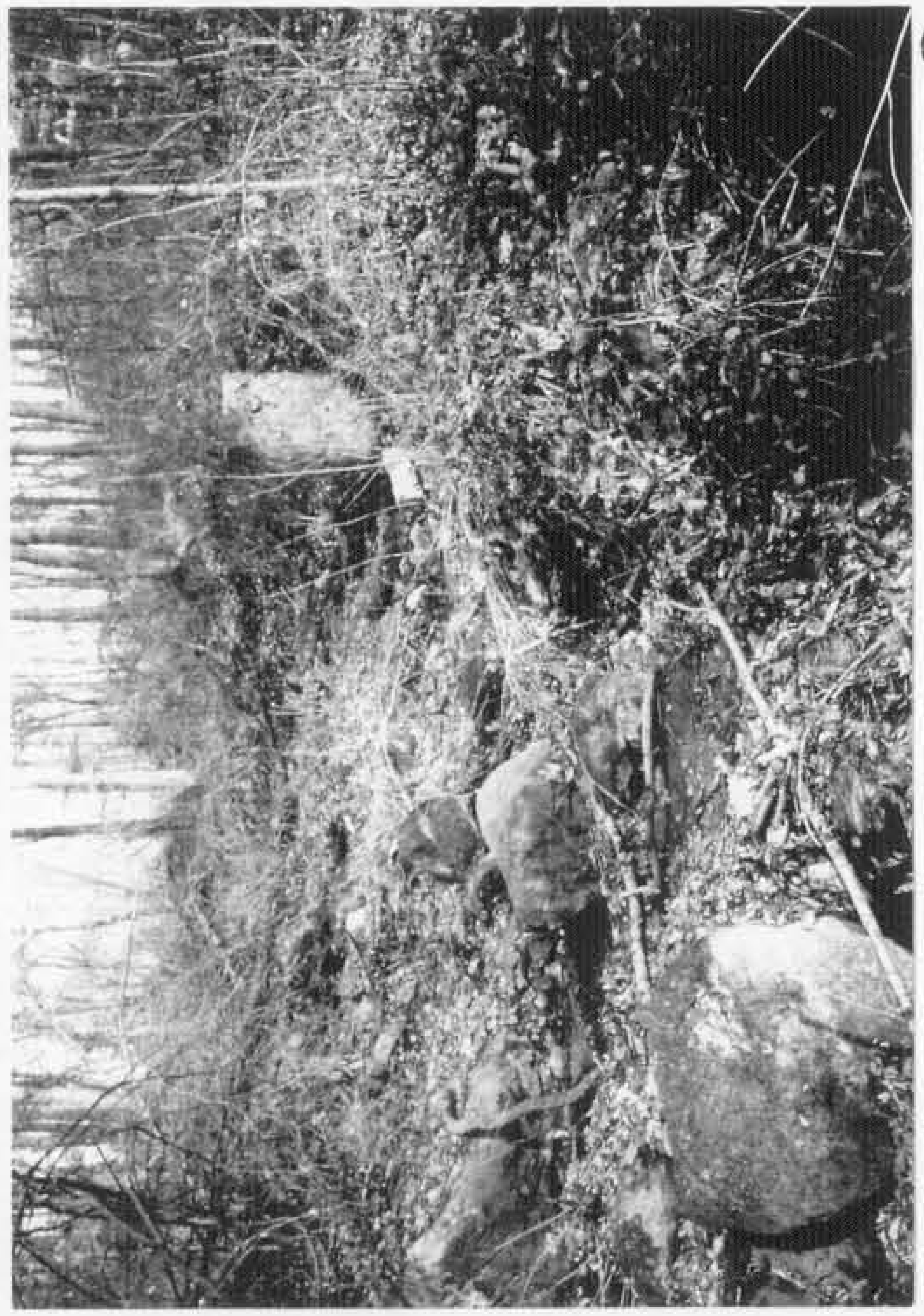

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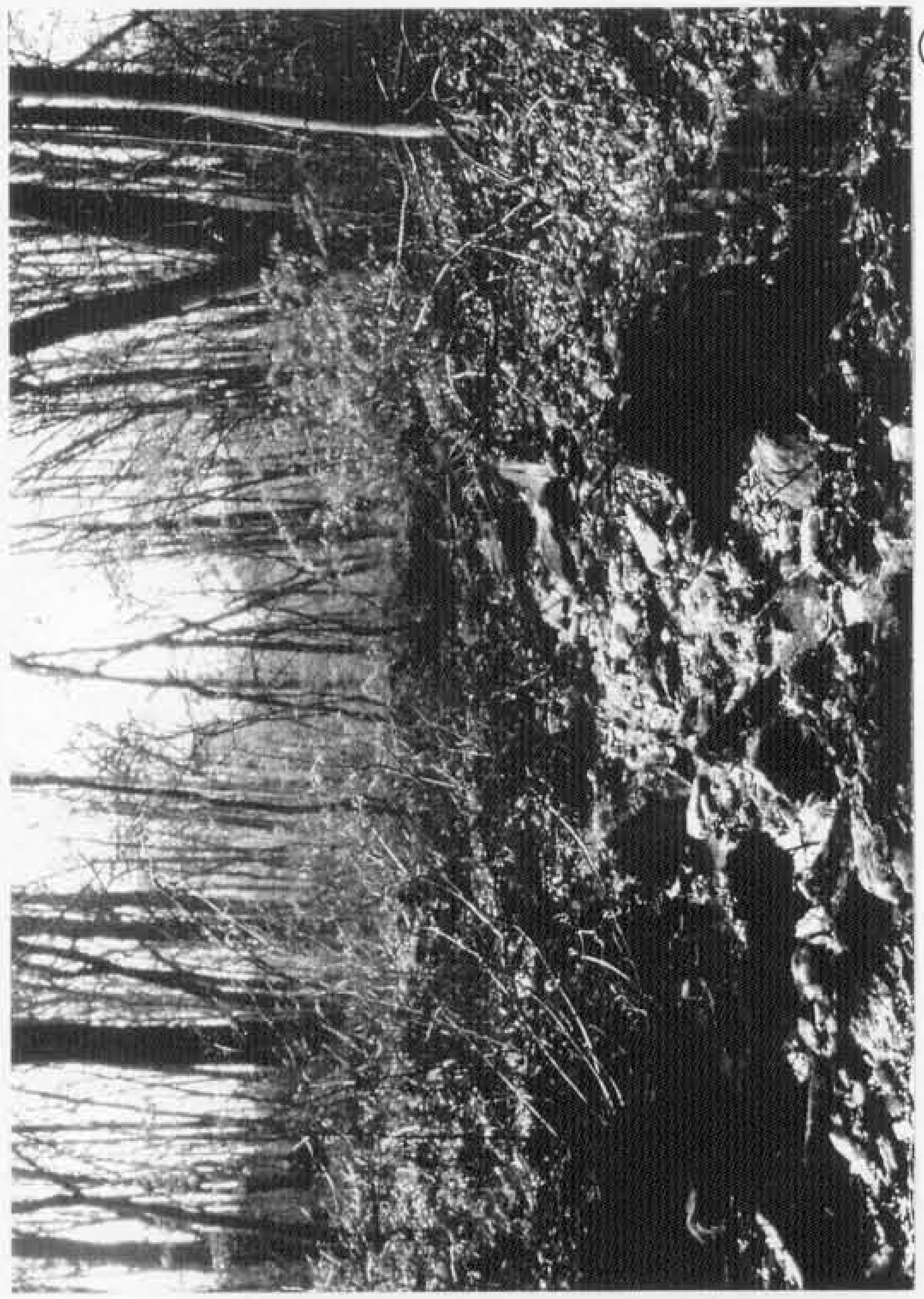

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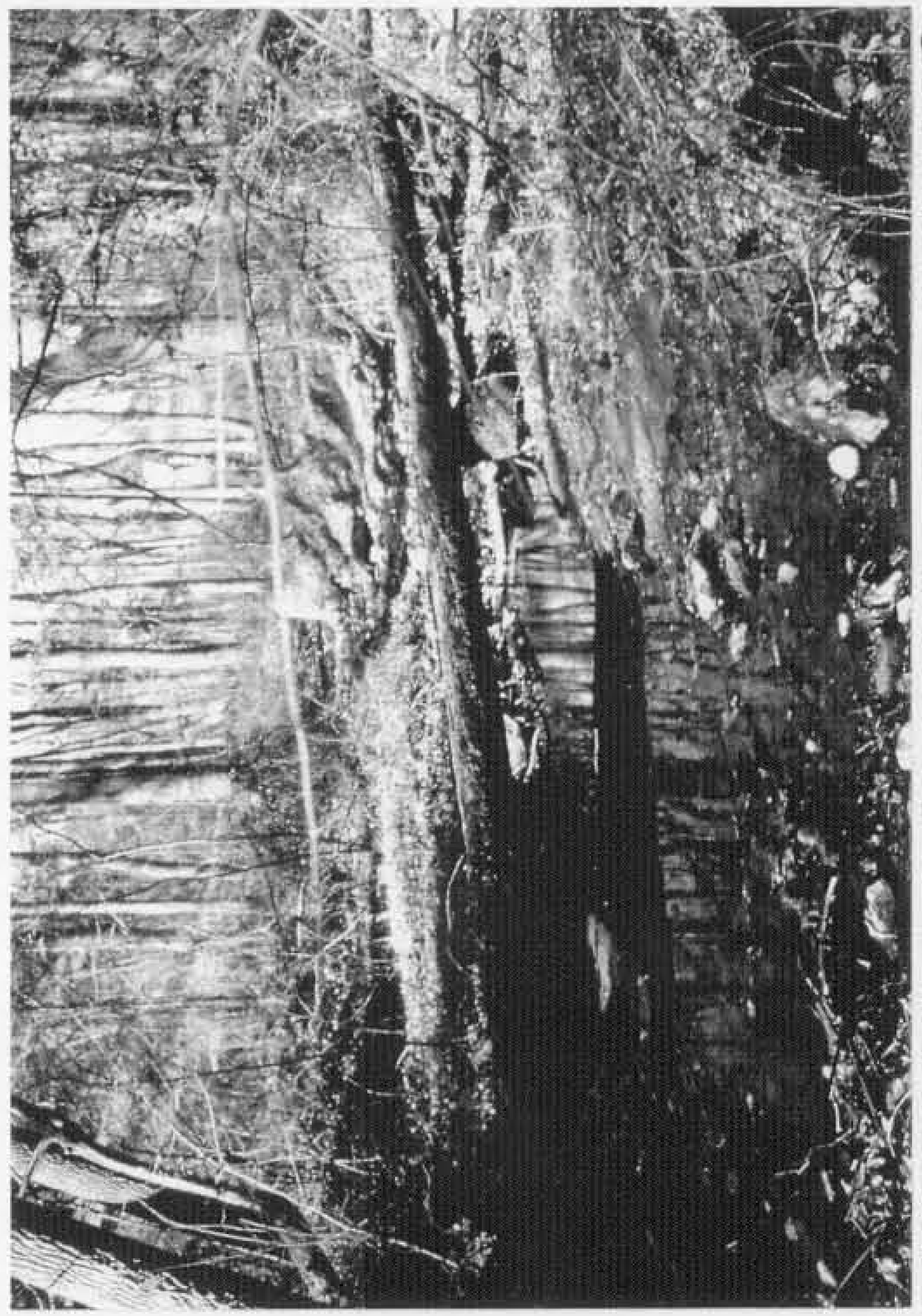

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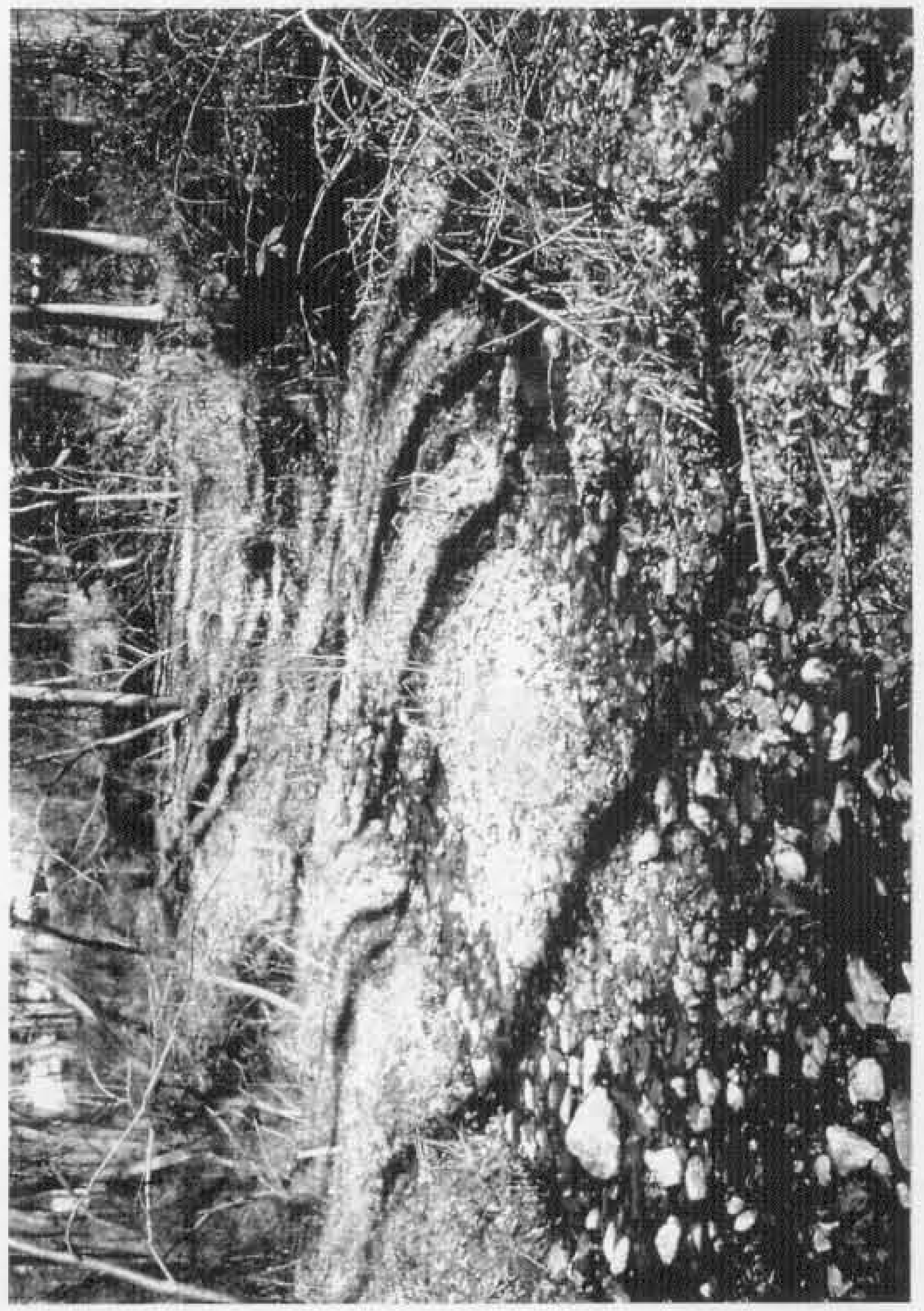

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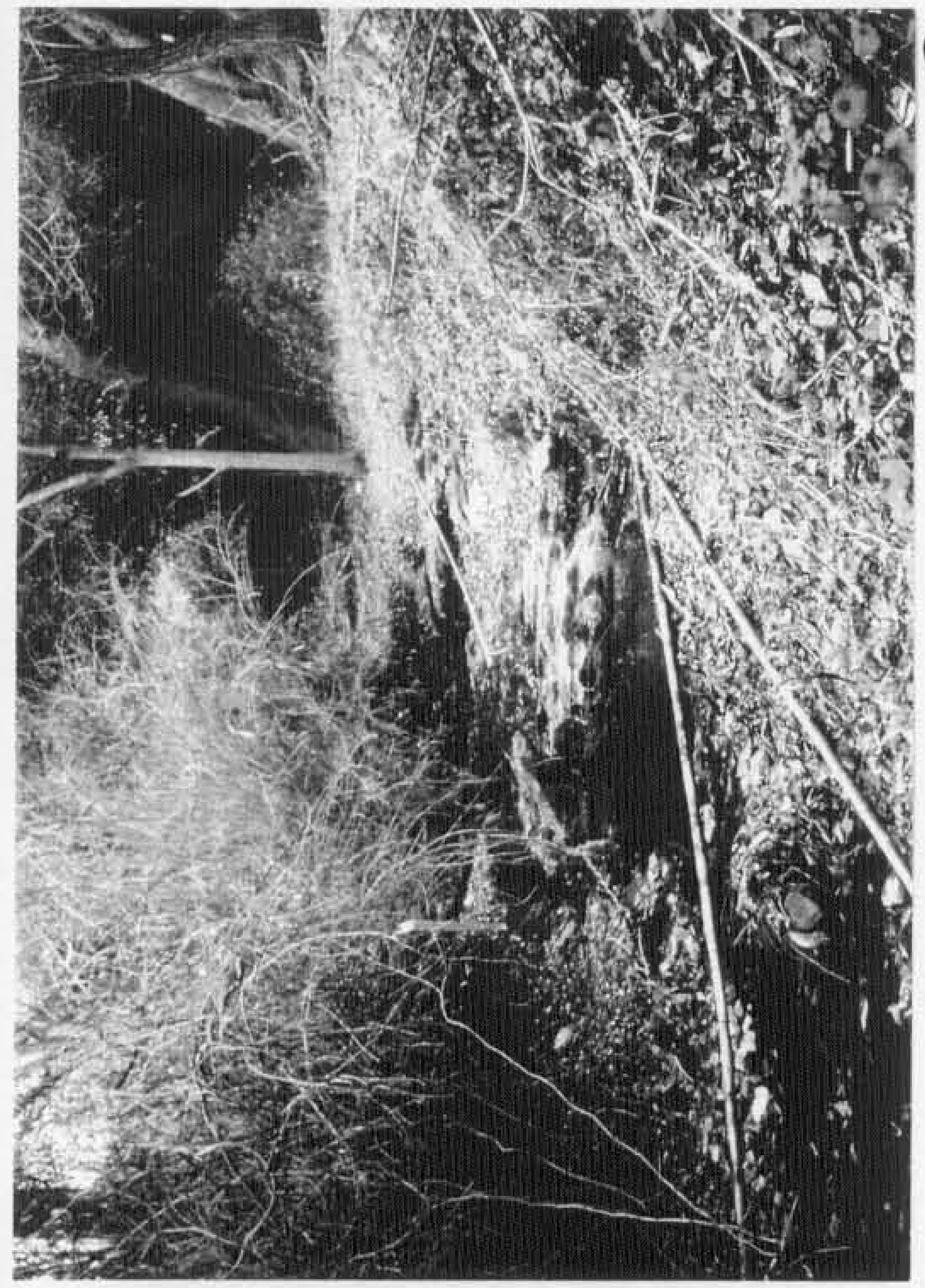


1. KILLORAN ROAD - TIMONIUM ROAD SECTOR AT TRAVERSE POINT 10 (G).

2. KILLORAN ROAD - TIMONIUM ROAD SECTOR BELOW KILLORAN ROAD OUTFALL (F).

3. KILLORAN ROAD - TIMONIUM ROAD SECTOR UPSTREAM FROM TRAVERSE POINT 4 (F).

4. KILLORAN ROAD - TIMONIUM ROAD SECTOR BETWEEN TRAVERSE POINTS 3 & 4. NOTE MID-CHANNEL BAR (C).

5. TIMONIUM ROAD - CONFLUENCE SECTOR AT TRAVERSE POINT 29 (C).

6. TIMONIUM ROAD - CONFLUENCE SECTOR ABOVE TRAVERSE POINT 27 (B1).

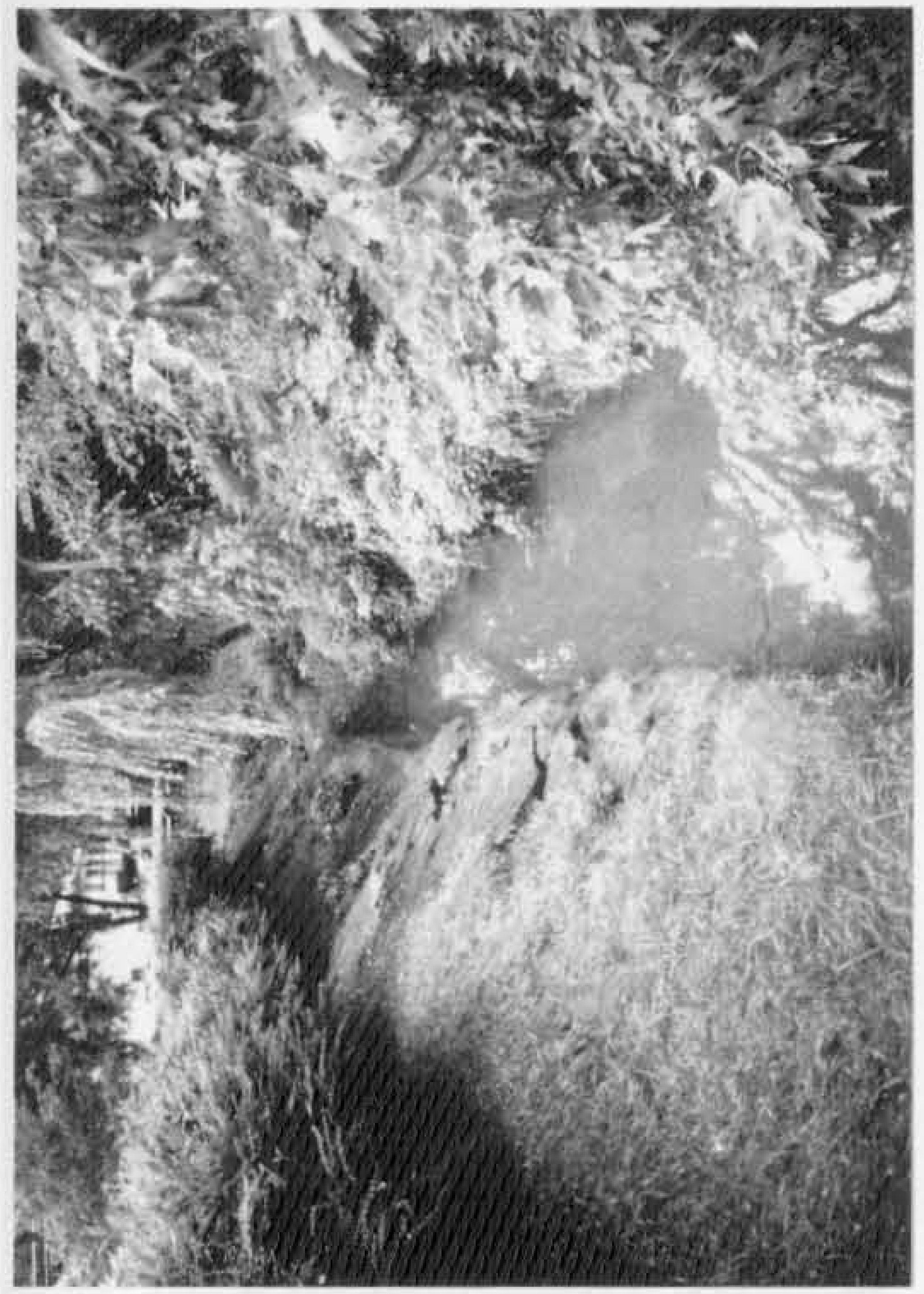
CHANNEL TYPES

1


2


3


4


5


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1. CONFLUENCE - REUTER ROAD SECTOR BELOW HATHAWAY ROAD OUTFALL (G).

2. CONFLUENCE - REUTER ROAD SECTOR DOWNSTREAM OF TRAVERSE POINT 35 (C).

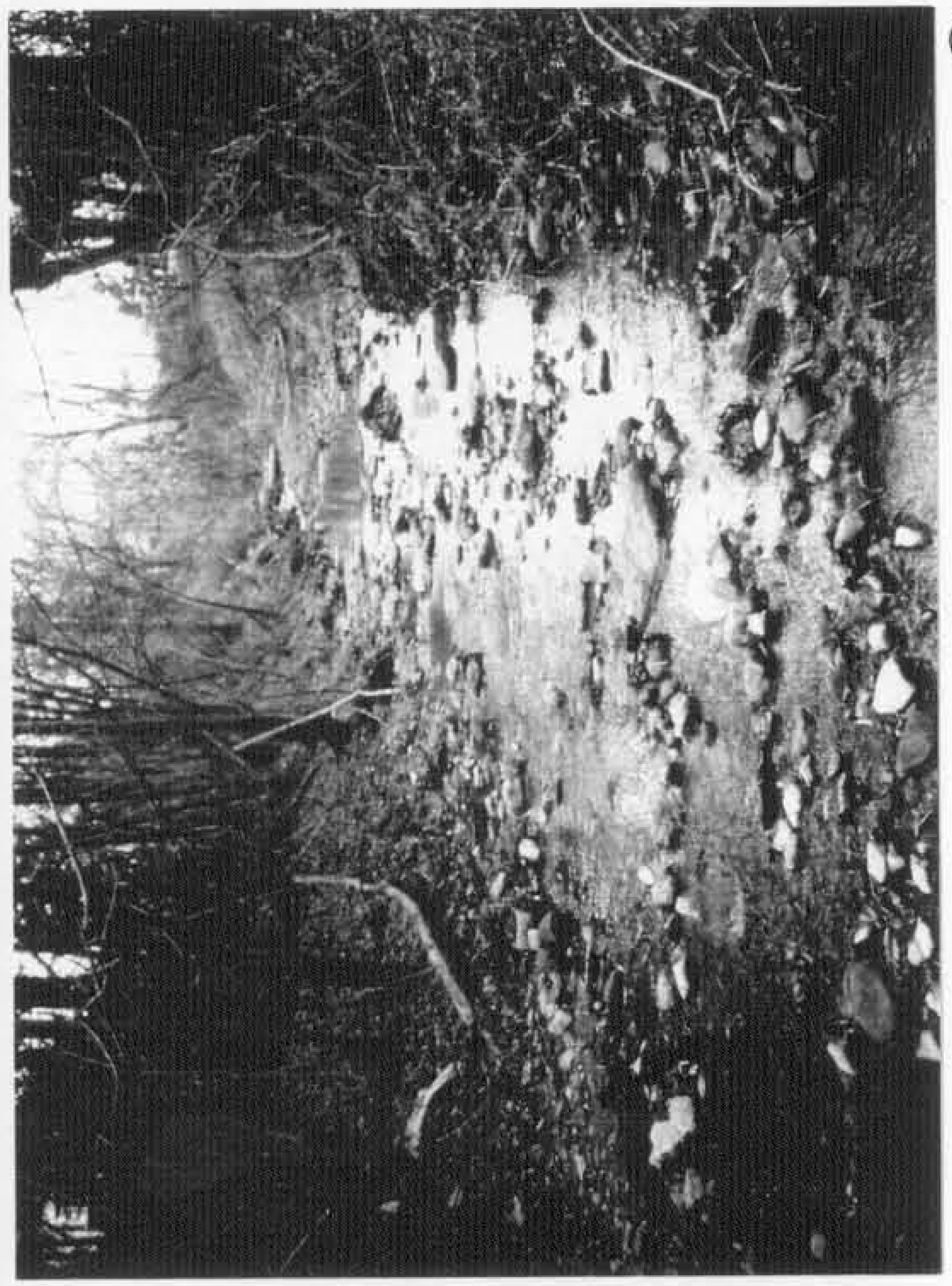
3. CONFLUENCE - REUTER ROAD SECTOR NEAR TRAVERSE POINT 38 (C).

4. CONFLUENCE - REUTER ROAD SECTOR BETWEEN TRAVERSE POINTS 36 & 37 (F).

5. REUTER ROAD - CINDER ROAD SECTOR UPSTREAM VIEW BETWEEN REUTER AND EASTRIDGE ROADS. (C)

6. REUTER ROAD CULVERT. (F)

CHANNEL TYPES

1


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1. REUTER ROAD - CINDER ROAD SECTOR AT TRAVERSE POINT 46 (F).

2. REUTER ROAD - CINDER ROAD SECTOR BELOW EASTRIDGE ROAD CULVERT (F).

3. HOLLOWBROOK TRIBUTARY AT CONFLUENCE WITH MAIN STEM.

4. REUTER ROAD - CINDER ROAD SECTOR AT TRAVERSE POINTS 48 & 47 (ATYPICAL/GABIONS).

5. HOLLOWBROOK TRIBUTARY AT HOLLOWBROOK ROAD CULVERT. (G)

6. HOLLOWBROOK TRIBUTARY CONCRETE FLUME. (ATYPICAL)

CHANNEL TYPES

1


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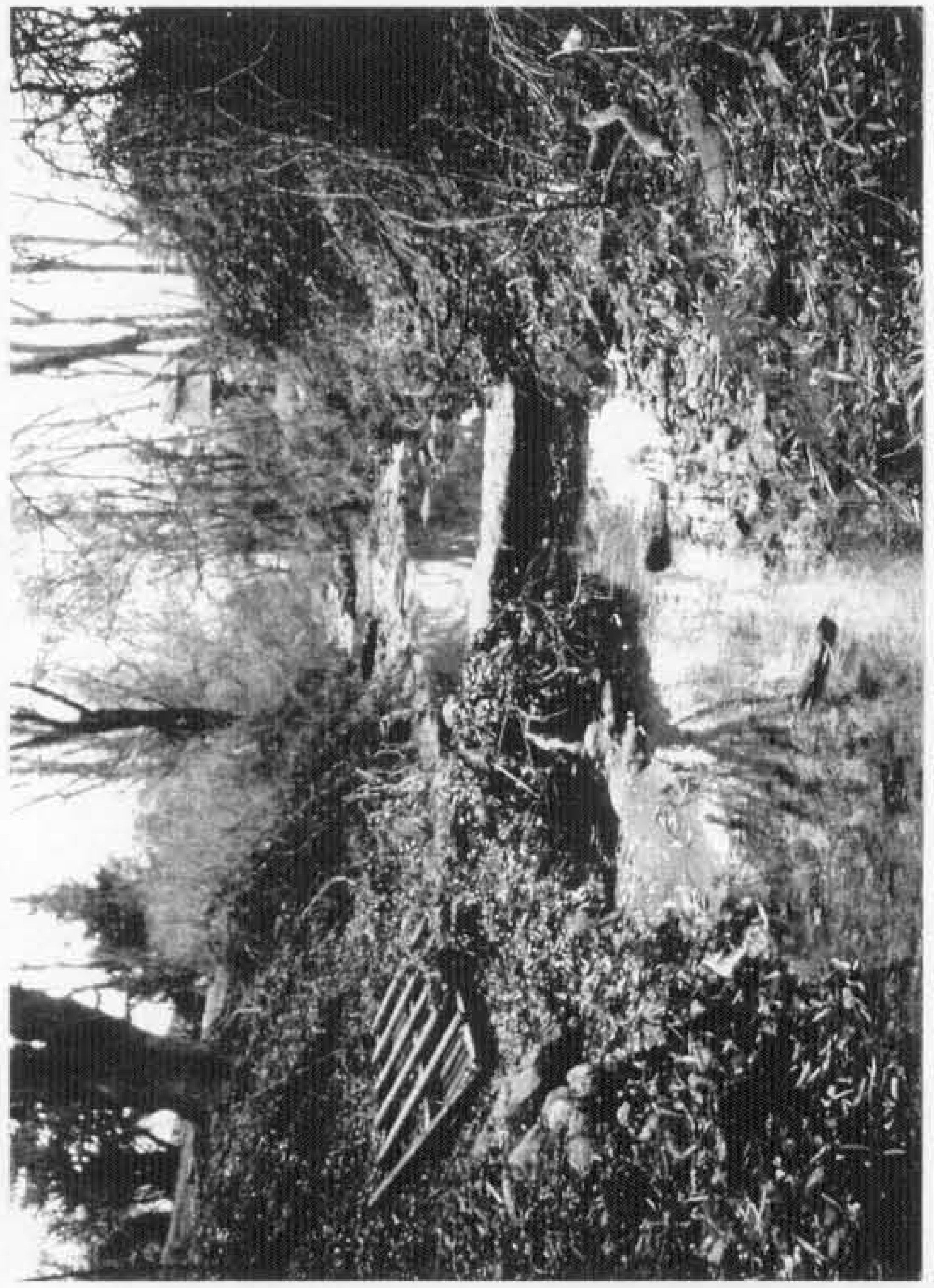

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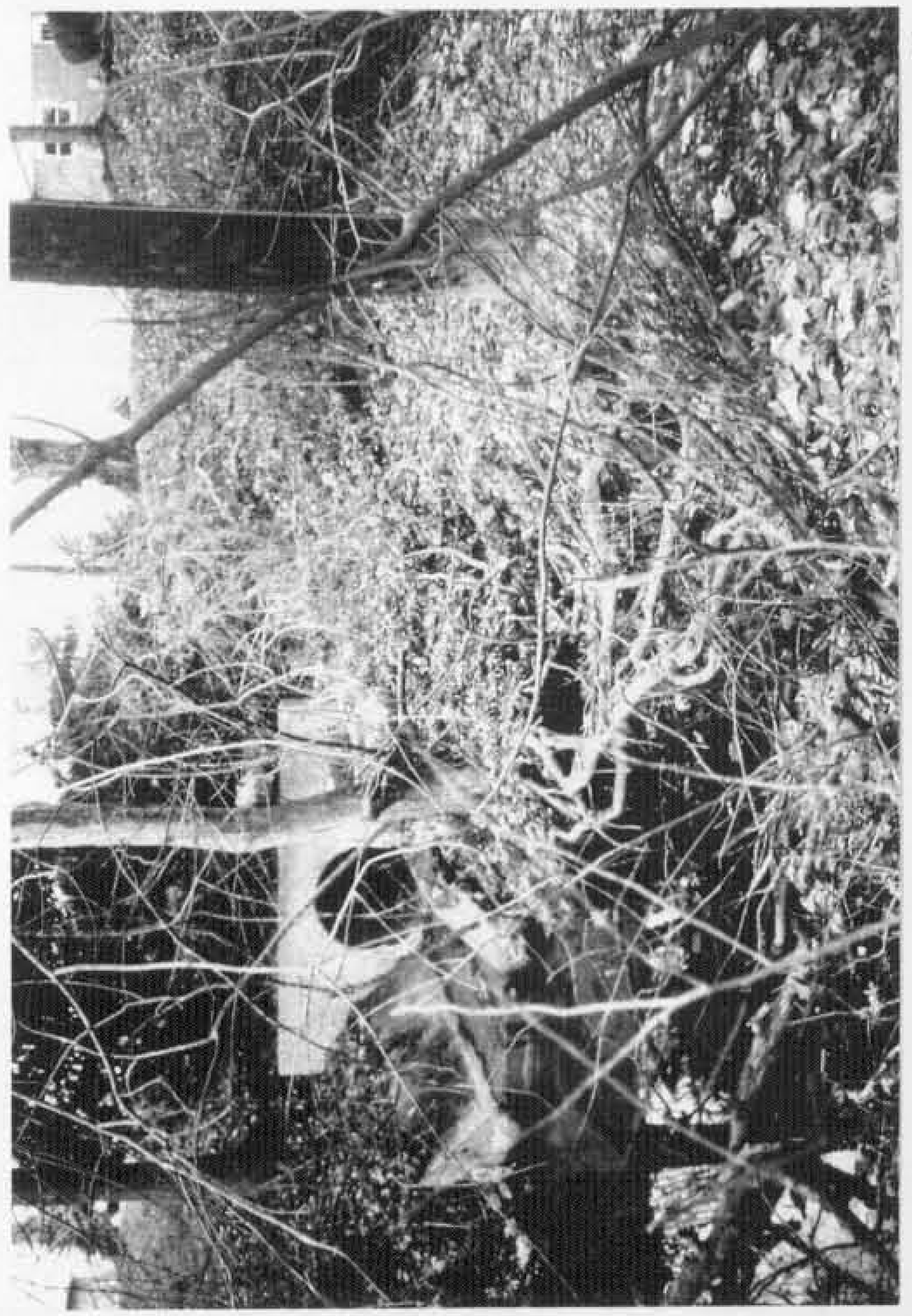

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6


1. CONCENTRATED OVERLAND FLOW ABOVE KILLORAN ROAD OUTFALL.

2. EXPOSED SEWER TRUNK LINE CROSSING IN REUTER ROAD - CINDER ROAD SECTOR ABOVE TRAVERSE POINT 46.

3. BROKEN SEWER LATERAL IN KILLORAN ROAD - TIMONIUM ROAD SECTOR.

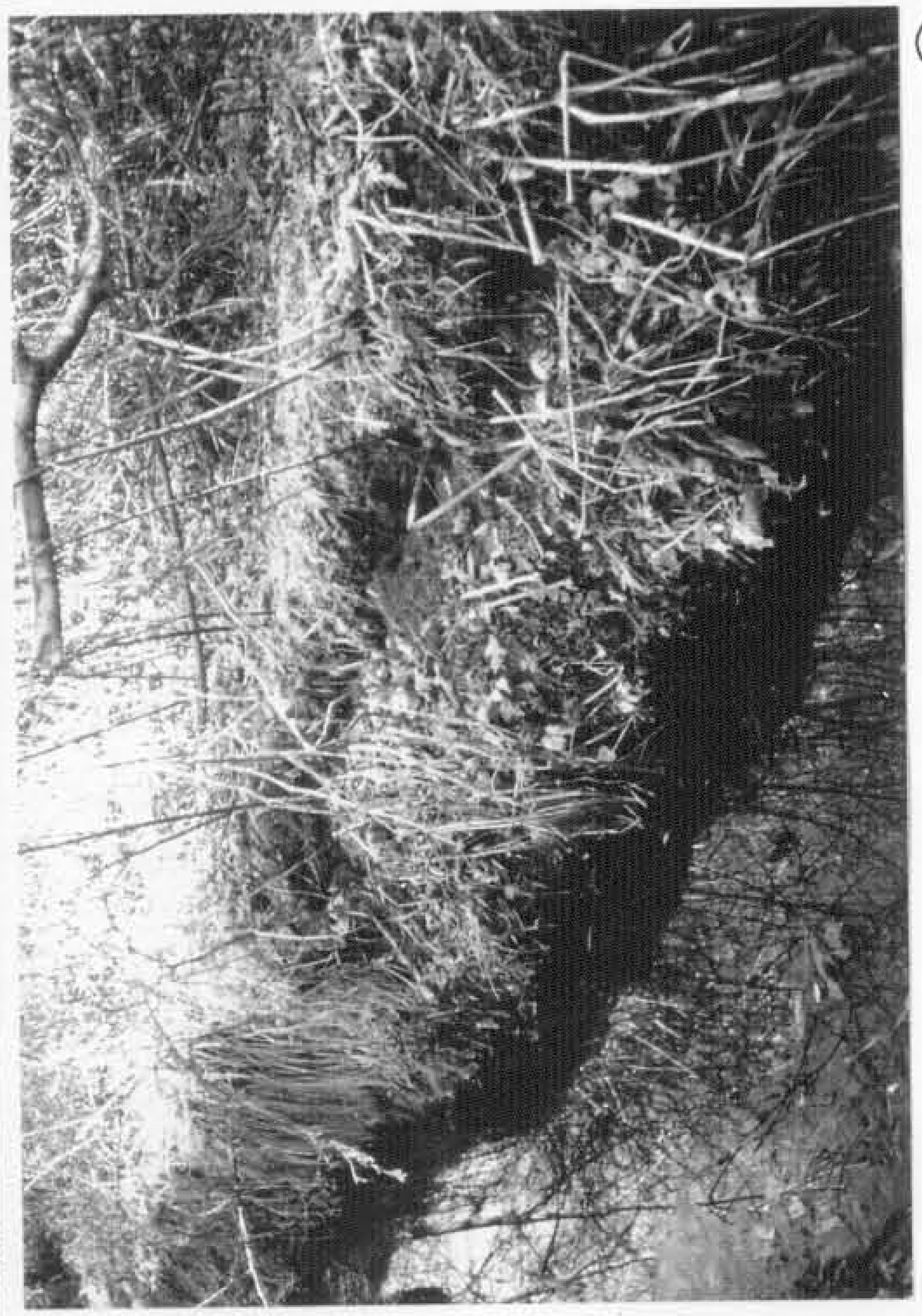
4. EROSION AT KILLORAN ROAD OUTFALL.

5. DEBRIS DAM IN CONFLUENCE - REUTER ROAD SECTOR ABOVE TRAVERSE POINT 35.

6. FAILED CONCRETE BANK REPAIR ABOVE EASTRIDGE ROAD CULVERT.

PROBLEM AREAS OF INTEREST

1



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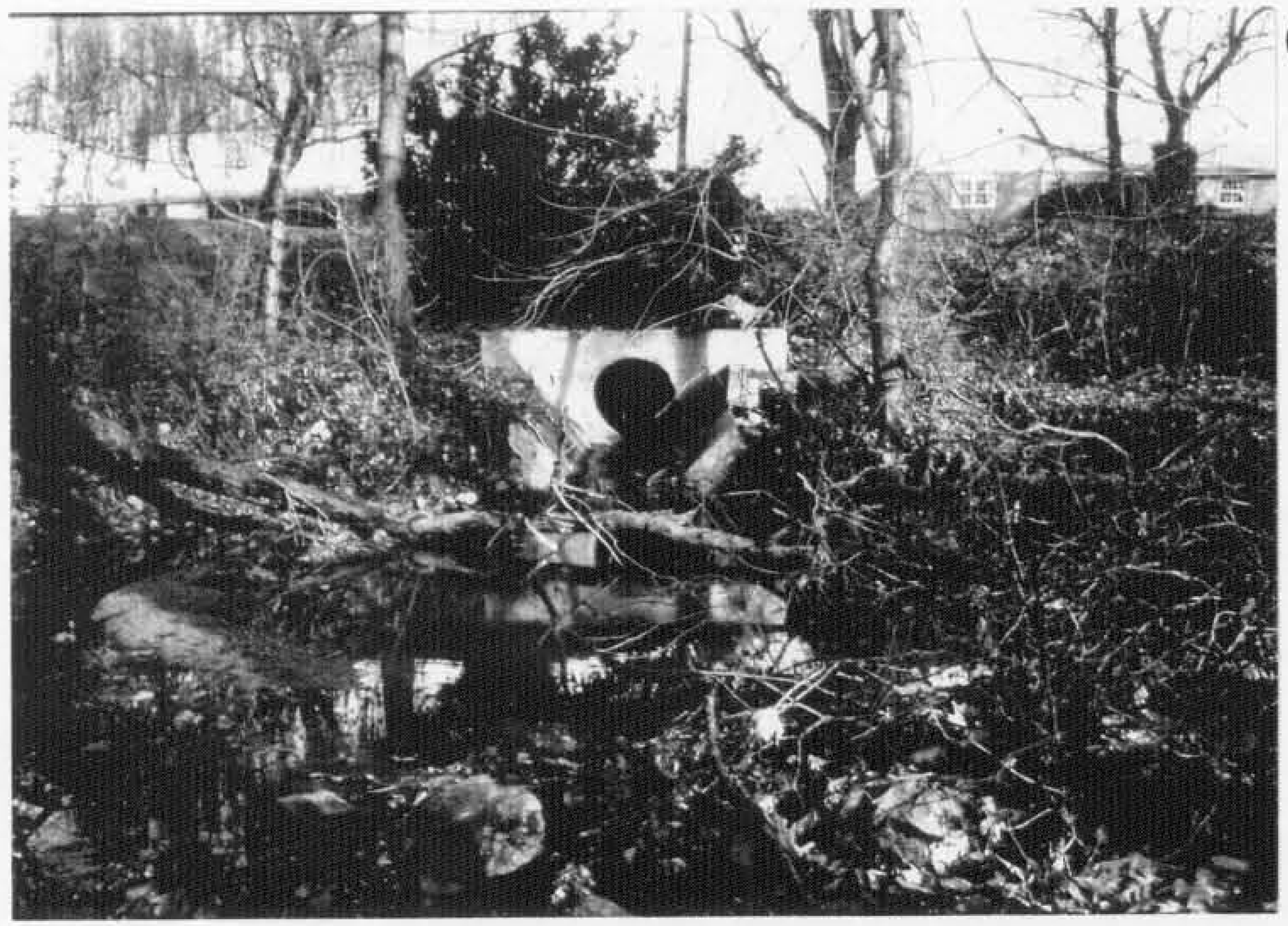
1. RIGHT BANK OF HOLLOWBROOK TRIBUTARY.
2. RIGHT BANK OF THE REUTER ROAD - CINDER ROAD SECTOR.
3. KILLORAN ROAD - TIMONIUM ROAD SECTOR, OPPOSITE TRAVERSE POINT 9.
4. LEFT BANK BELOW EASTRIDGE ROAD.
5. LEFT BANK BELOW REUTER ROAD CULVERT.
6. RIGHT BANK AT AND BELOW SPRINGSIDE DRIVE PIPE OUTFALL.

BANK EROSION EXAMPLES

①

②

③



④

⑤

1. [illegible]

2. GERARD AVENUE

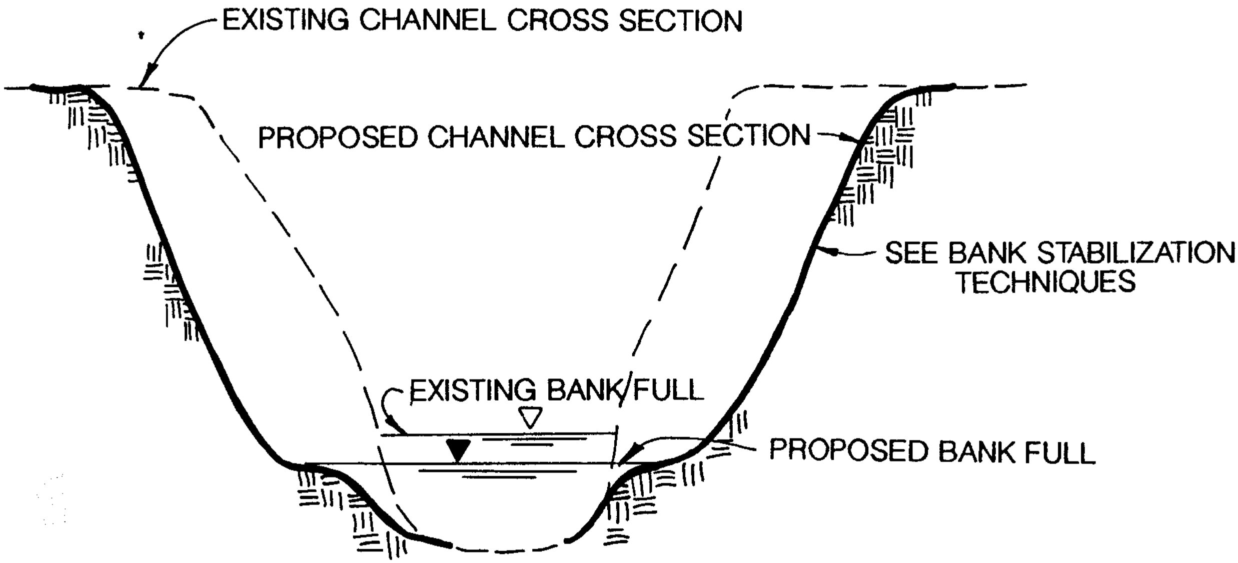
3. GREENMEADOW DRIVE

4. KILLORAN ROAD

5. FOLKSTONE DRIVE
   AT COLDBROOK ROAD

OUTFALL CONDITIONS

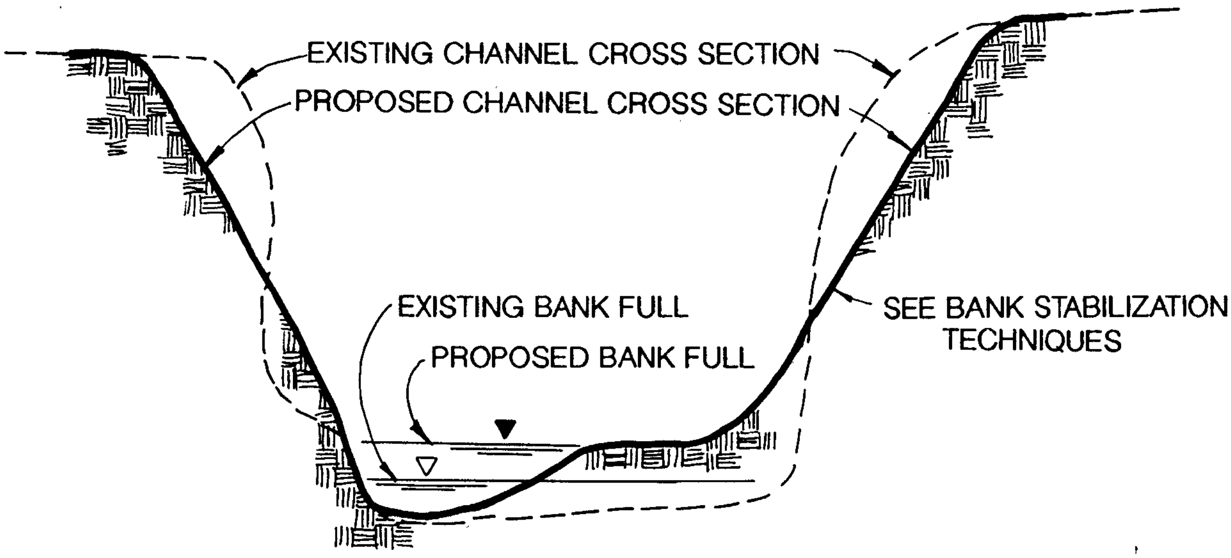
APPENDIX B: TYPICAL DETAILS - PROPOSED RESTORATION TECHNIQUES



CHANNEL GEOMETRY MODIFICATION

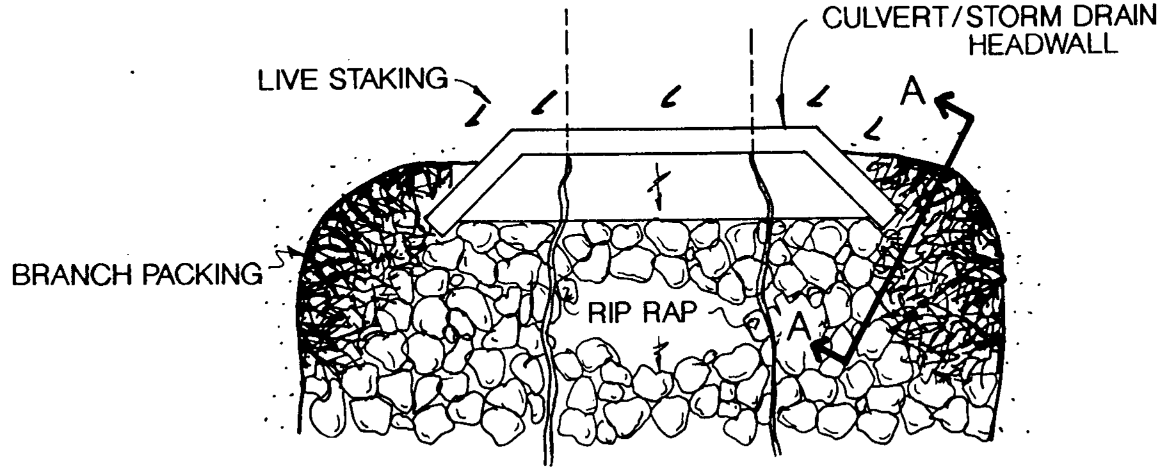
"B" WITHIN A "G"

NTS

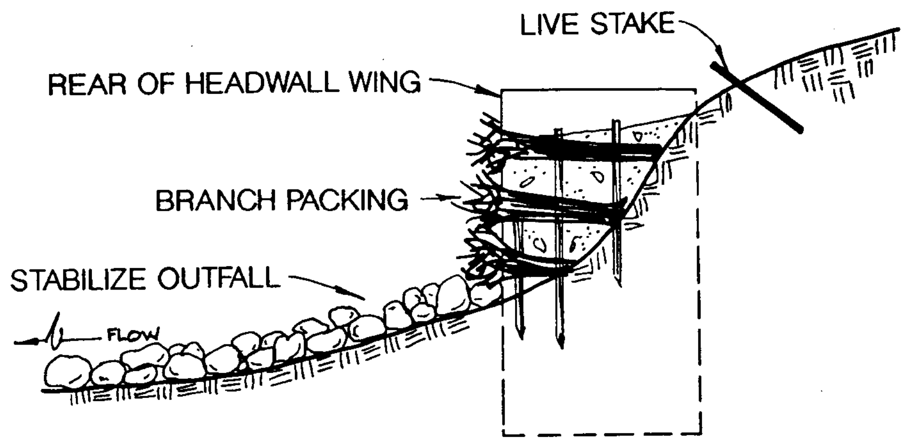


CHANNEL GEOMETRY MODIFICATION
"C" WITHIN AN "F"

NTS

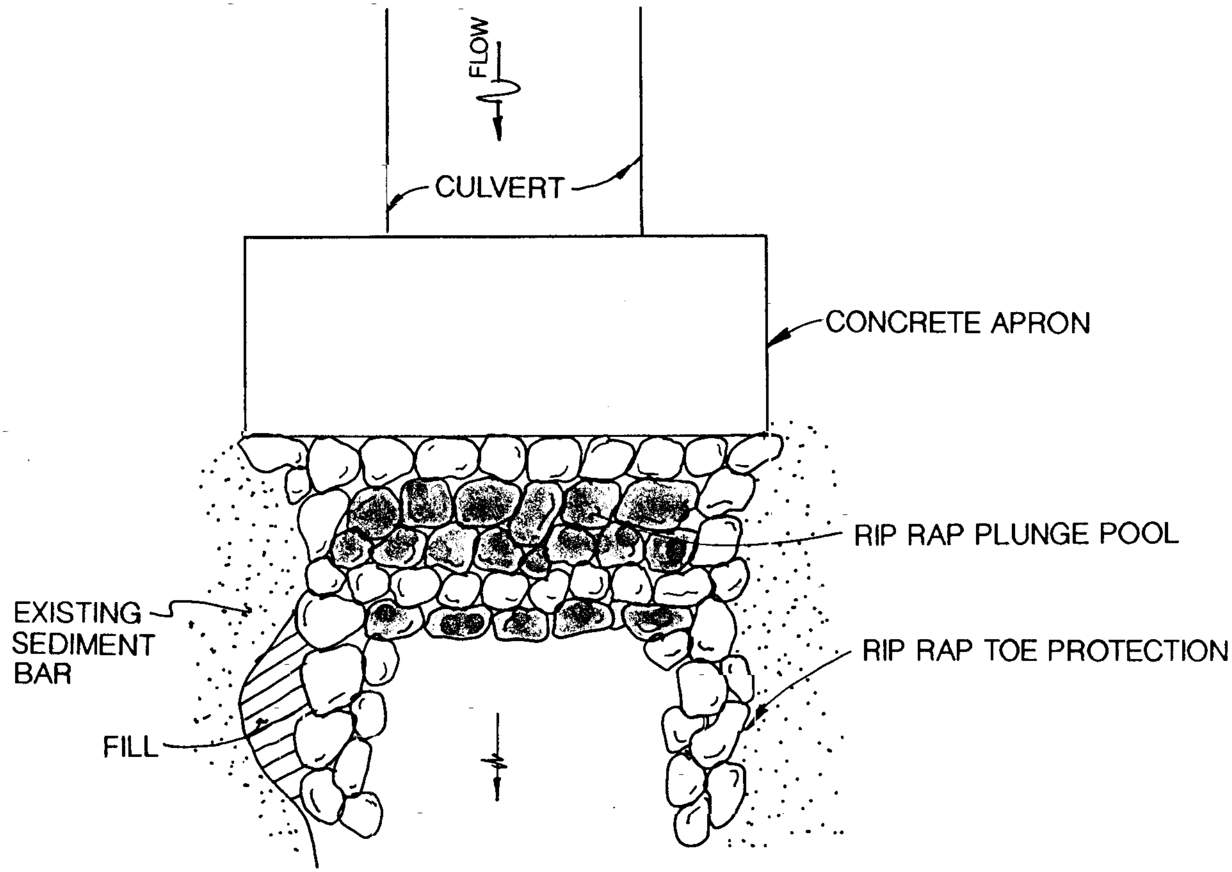


PLAN
NTS

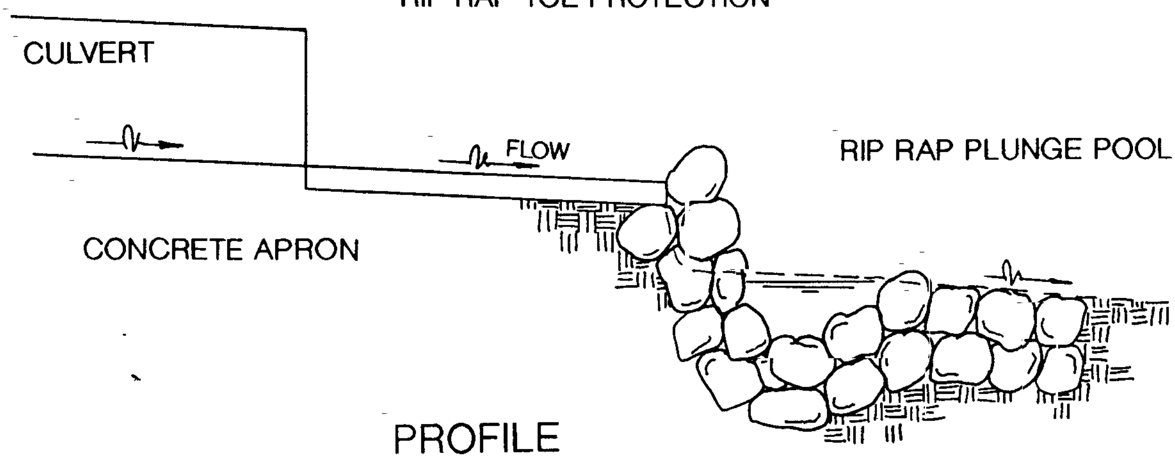


SECTION A – A
NTS

CULVERT/STORM DRAIN HEADWALL
BRANCH PACKING/BRANCH LAYERING
NTS



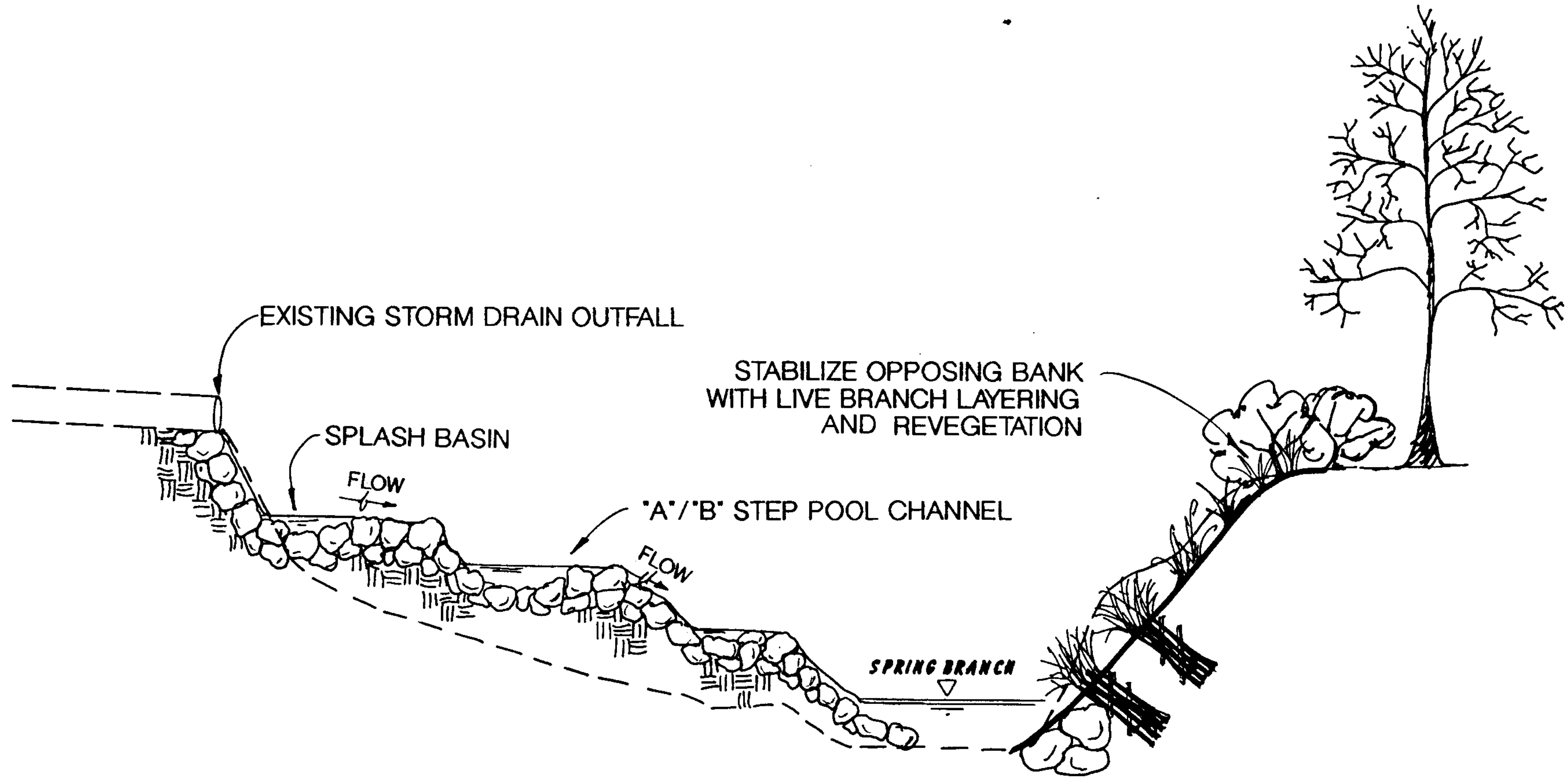
RIP RAP TOE PROTECTION



PROFILE

CULVERT OUTFALL RETROFIT

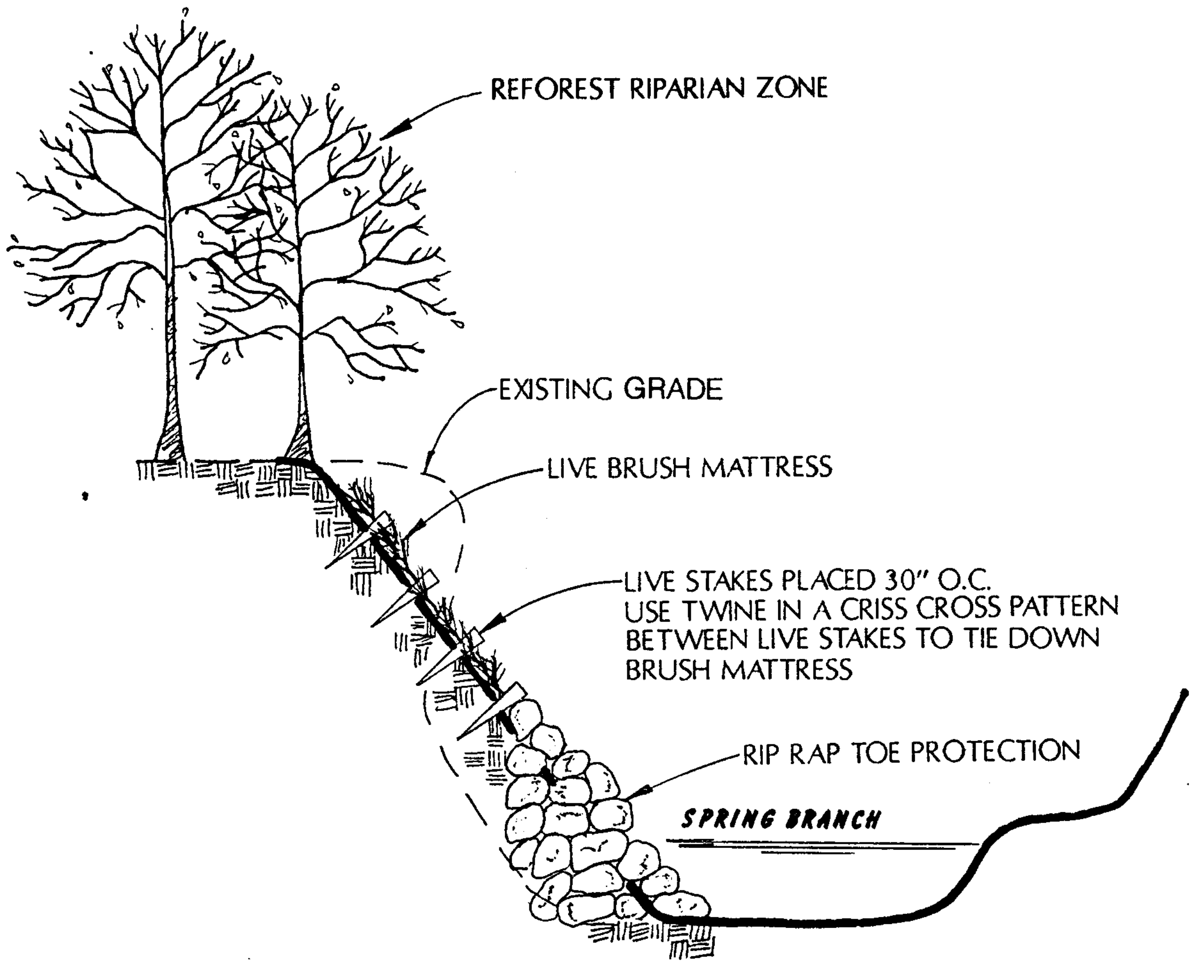
NTS



STORM DRAIN OUTFALL RETROFIT

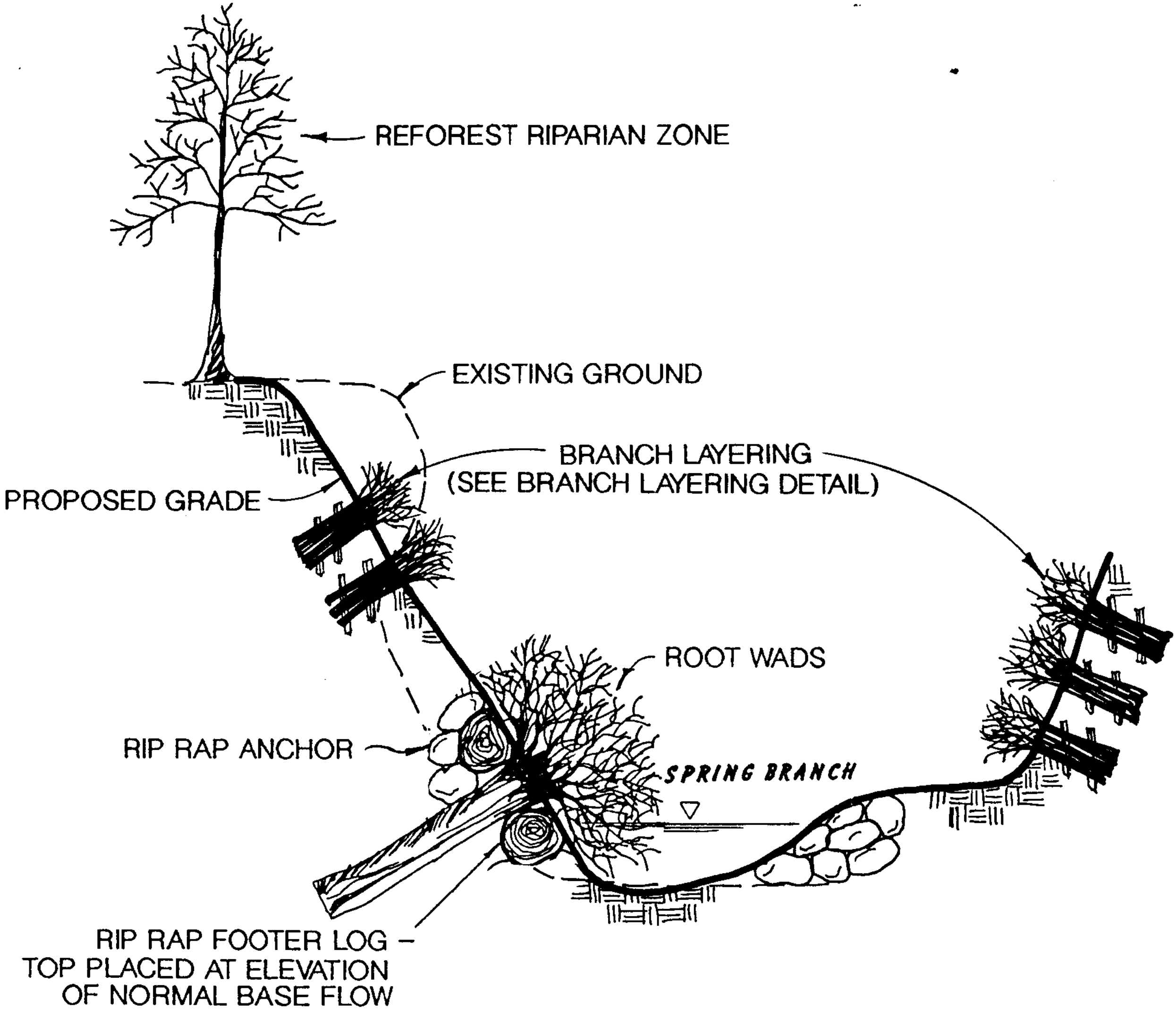
PROFILE

NTS



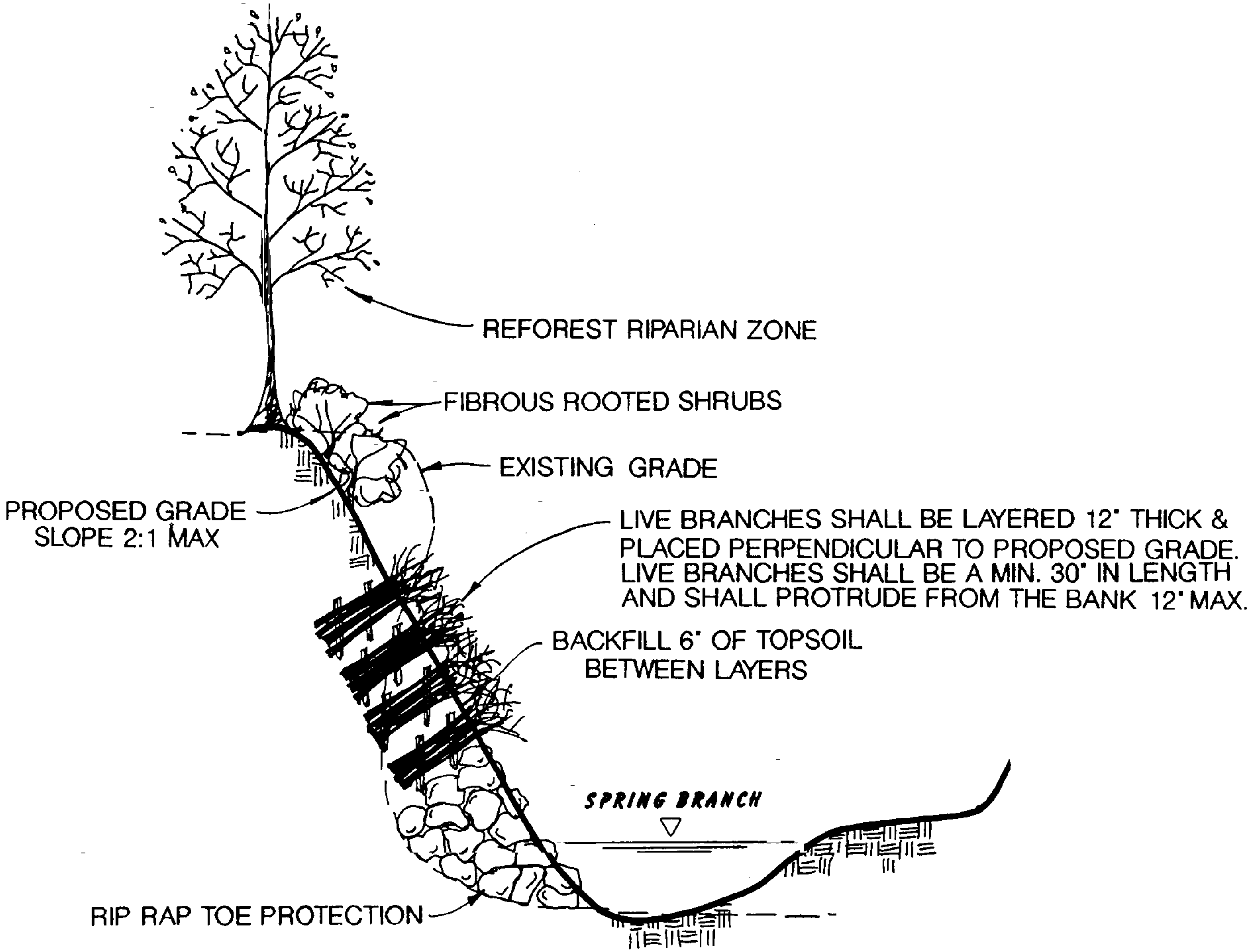
LIVE BRUSH MATTRESS

NTS



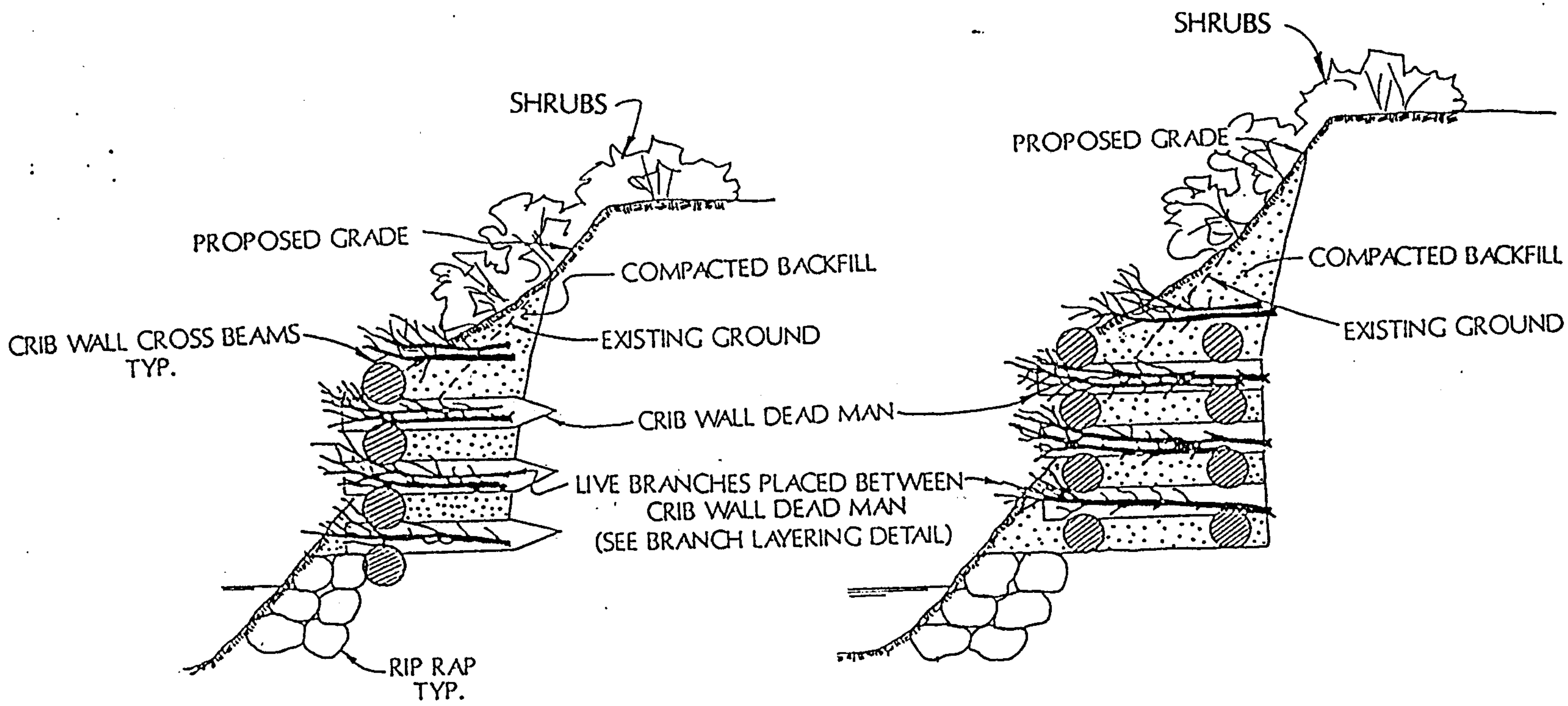
ROOT WAD WITH BRANCH LAYERING

NTS



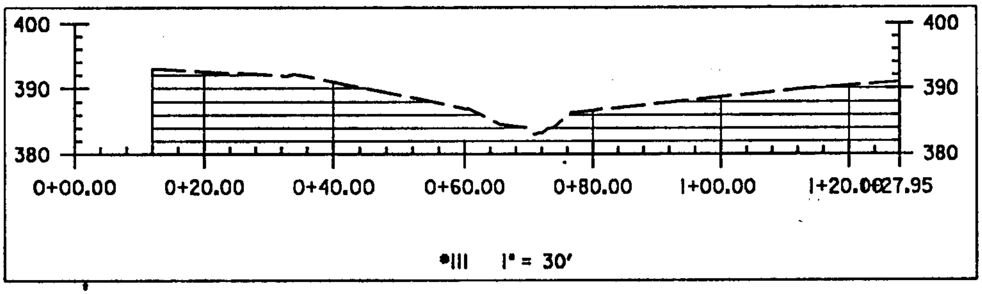
BRANCH LAYERING WITH RIP RAP TOE

NTS



LIVE CRIB WALL W/LIVE BRANCH LAYERING NTS

APPENDIX C: SELECT FIELD SURVEYED CROSS SECTIONS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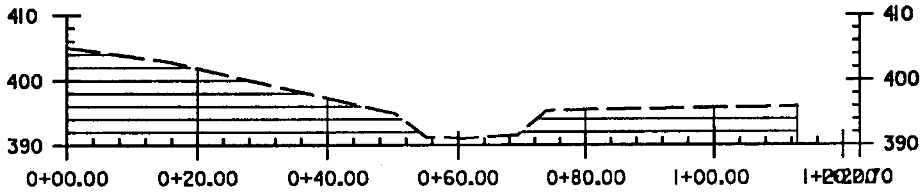
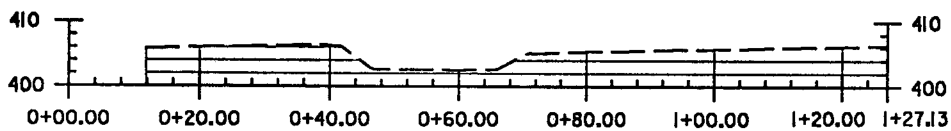
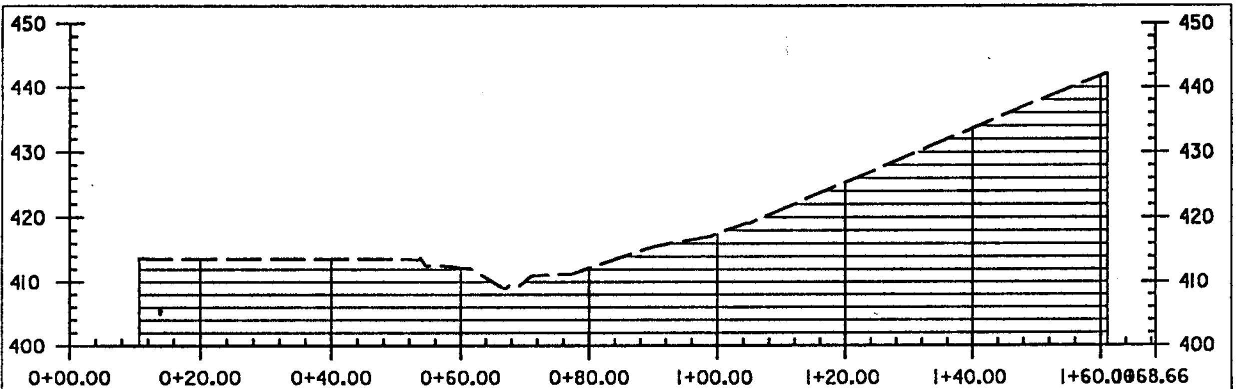
380
400
390
380
0+00.00
0+20.00
0+40.00
0+60.00
0+80.00
1+00.00
1+20.00
127.95
*III 1" = 30'



*115.1 1" = 30'


410
400
410
400
0+00.00
0+20.00
0+40.00
0+60.00
0+80.00
1+00.00
1+20.00
1+27.13

#117 1" = 30'



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430
420
410
400
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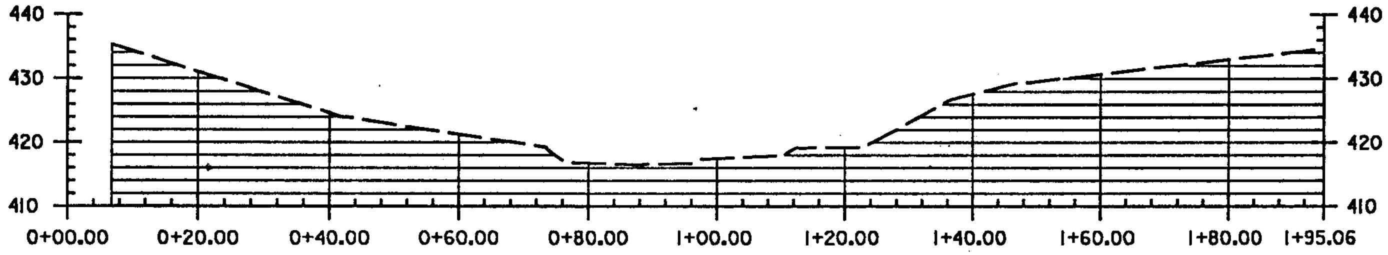
0+20.00
0+40.00
0+60.00
0+80.00
1+00.00
1+20.00
1+40.00
1+60.0068.66

*119.1 1" = 30'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1+00.00
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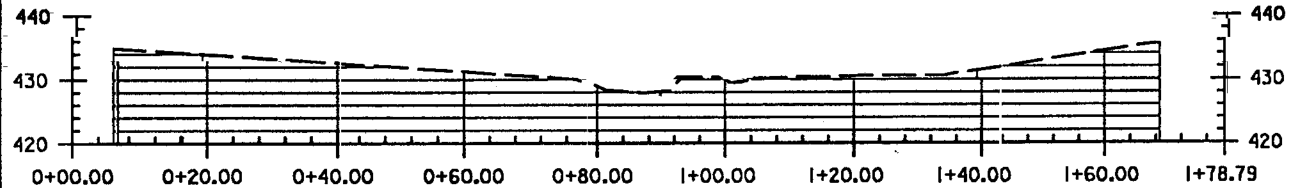
1+40.00
1+60.00
1+80.00
1+95.06
440
430
420
410

#119.3 1" = 30'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430
420
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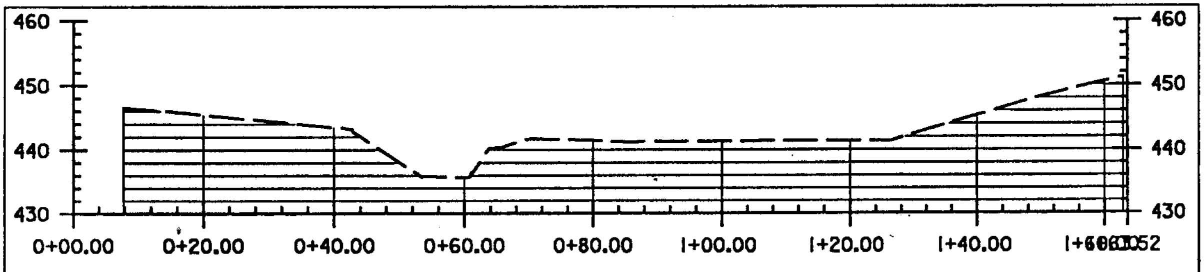
0+20.00
0+40.00
0+60.00
0+80.00
1+00.00
1+20.00
1+40.00
1+60.00
1+78.79

*122 1" = 30'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450
440
430
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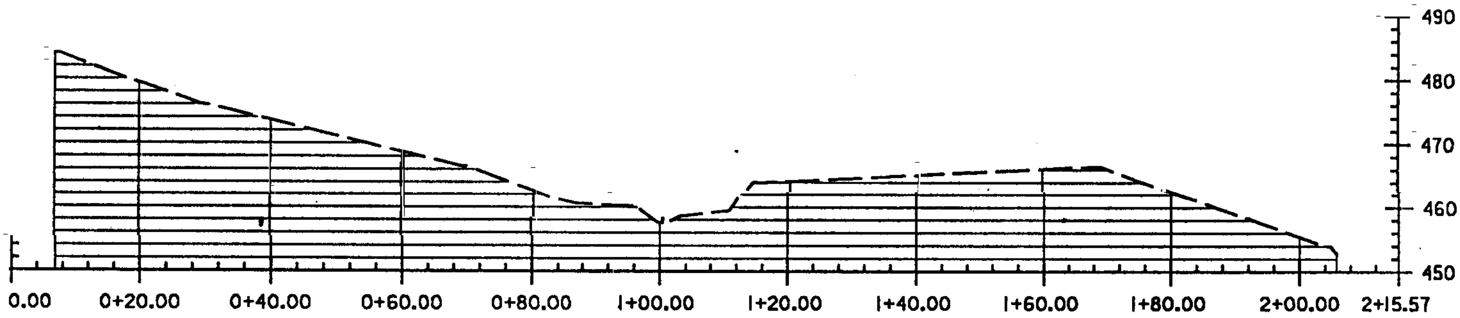
0+20.00
0+40.00
0+60.00
0+80.00
1+00.00
1+20.00
1+40.00

#125 1" = 30'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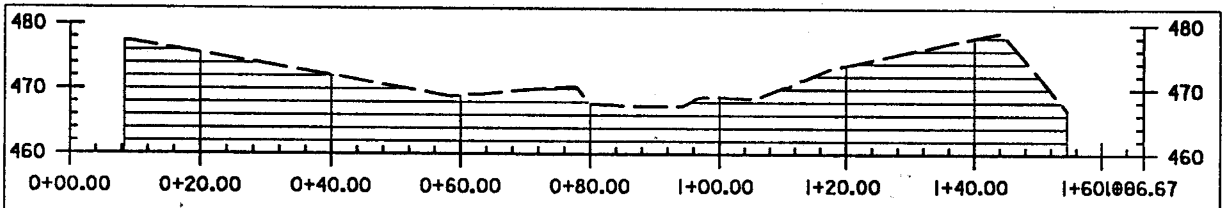
480
470
460
450
0.00
0+20.00
0+40.00
0+60.00
0+80.00
1+00.00
1+20.00
1+40.00
1+60.00
1+80.00
2+00.00
2+15.57

*128 1" = 30'



480
470
460
0+00.00
0+20.00
0+40.00
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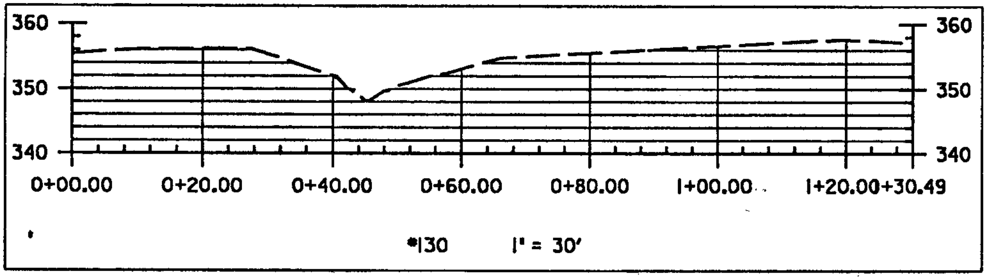
0+80.00
1+00.00
1+20.00
1+40.00
1+601#86.67
480
470
460

#129 1" = 30'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340
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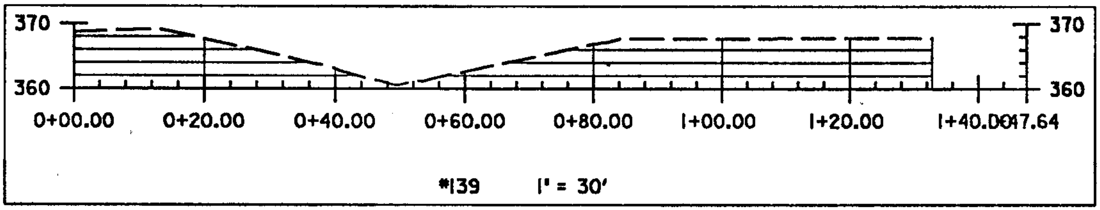
0+80.00
1+00.00
1+20.00
+30.49
*130
1" = 30'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360
370
360
0+00.00
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0+40.00
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0+80.00
1+00.00
1+20.00
1+40.0047.64
#139
1" = 30'

APPENDIX D: RECOMMENDED PLANT LIST

RECOMMENDED PLANT SPECIES FOR BIOENGINEERING

Scientific Name	Common Name
TREES:	
Betula nigra	River birch
Cornus alternifolia	Alternate-leaved dogwood
Salix nigra	Black willow
SHRUBS:	
Alnus serrulata	Common/smooth or brookside alder
Cornus amomum	Silky dogwood
Cornus sericea/stolonifera	Red twig dogwood
Hamamelis virginiana	Witchhazel
Salix discolor	Glaucous Willow
Salix caroliniana	Ward's willow
Salix humilis	Upland willow
Salix interior	Sandbar willow
Salix sericea	Silky willow
Viburnum dentatum	Arrowwood viburnum
Viburnum prunifolium	Blackhaw viburnum

RECOMMENDED PLANT SPECIES FOR RIPARIAN REESTABLISHMENT

Scientific Name	Common Name
TREES:	
Acer rubrum	Red maple
Acer saccharum	Sugar maple
Acer saccharinum	Silver maple
Amelanchier canadensis	Shadblow serviceberry
Betula nigra	River birch
Carpinus caroliniana	American hornbeam
Carya glabra	Pignut hickory
Carya ovata	Shagbark hickory
Carya toméntosa	Mockernut hickory
Celtis occidentalis	Hackberry
Cercis canadensis	Eastern redbud
Cornus alternifolia	Alternate-leaved dogwood
Cornus florida	Flowering dogwood
Fagus grandifolia	American beech
Fraxinus pennsylvanica	Green ash
Ilex opaca	American holly
Juglans nigra	Black walnut
Juniperus virginana	N. red cedar
Liquidambar styraciflua	Sweet gum
Liriodendron tulipifera	Tulip poplar/yellow poplar
Malus 'Zumi'	Flowering crab apple
Nyssa sylvatica	Black gum
Pinus strobus	White pine
Pinus virginiana	Virginia pine
Platanus occidentalis	Sycamore
Populus deltoides	Cottonwood
Prunus serotina	Black cherry
Quercus acutissima	Sawtooth oak
Quercus alba	White oak
Quercus bicolor	Swamp white oak
Quercus borealis/rubra	Northern red oak
Quercus falcata	S. red oak
Quercus palustris	Pin oak
Quercus phellos	Willow oak
Quercus prinus	Chestnut oak
Salix nigra	Black willow
Sassafras albidum	Common sassafras
Tsuga canadensis	Canada hemlock
Ulmus rubra	Slippery elm

RECOMMENDED PLANT SPECIES FOR RIPARIAN REESTABLISHMENT

Scientific Name	Common Name
SHRUBS:	
Alnus serrulata	Common/smooth or brookside alder
Amelanchier canadensis	Serviceberry/shadblow/juneberry
Aronia arbutifolia	Red chokeberry
Aronia melanocarpa	Black chokeberry
Cephalanthus occidentalis	Buttonbush
Clethra alnifolia	Summersweet/sweet pepperbush
Cornus amomum	Silky dogwood
Cornus racemosa	Gray dogwood
Cornus sericea/stolonifera	Red twig dogwood
Corylus americana	Hazelnut
Hamamelis virginiana	Witchhazel
Ilex glabra	Inkberry
Ilex verticillata	Winterberry
Itea virginica	Virginia sweetspire
Kalmia latifolia	Mountain laurel
Lindera benzoin	Spicebush
Rhododendron nudiflorum	Pinxter-flower azalea
Rhododendron viscosum	Swamp azalea
Salix discolor	Glaucous Willow
Salix caroliniana	Ward's willow
Salix humilis	Upland willow
Salix interior	Sandbar willow
Salix sericea	Silky willow
Sambucus canadensis	American elderberry
Spirea alba	Narrowleaf meadowsweet spirea
Spirea tomentosa	Hardhack spirea
Vaccinium angustifolium	Lowbush blueberry
Vaccinium corymbosum	Highbush blueberry
Viburnum acerifolium	Maple-leaf viburnum
Viburnum cassinoides	Witherod viburnum or N. wild raisin
Viburnum dentatum	Arrowwood viburnum
Viburnum nudum	Possumhaw or southern wild raisin
Viburnum prunifolium	Blackhaw viburnum
Viburnum trilobum	American cranberry bush
FERNS:	
Onoclea sensibilis	Sensitive fern
Osmunda cinnamomea	Cinnamon fern
Osmunda regalis	Royal fern
Polystichum acrostichoides	Christmas fern
Thelypteris noveboracensis	New York fern

RECOMMENDED PLANT SPECIES FOR RIPARIAN REESTABLISHMENT

Scientific Name	Common Name
GRAMINOIDS:	
Acorus calamus	Sweetflag
Andropogon gerardii	Big bluestem
Andropogon virginicus	Broomsedge
Carex lurida	Lurid sedge
Carex stricta	Tussock sedge
Carex vulpinoidea	Fox sedge
Eliocharis palustris	Creeping spike rush
Leerzia oryzoides	Rice cutgrass
Panicum virgatum	Switchgrass
Schizachyrium scoparium	Little bluestem
Scirpus americanus/pungens	Common three-square
Scirpus cyperinus	Wool grass
Scirpus validus	Soft-stem bulrush
Sorghastrum nutans	Indian grass
FORBS:	
Alisma plantago-aquatica	Water plantain
Asclepias incarnata	Swamp milkweed
Aster novae-angliae	New England aster
Aster novi-belgii	New York aster
Aster puniceous	Purple-stem aster
Chelone glabra	Turtlehead
Cimicifuga racemosa	Black snakeroot
Eupatorium fistulosum	Joe-pye weed
Eupatorium perfoliatum	Boneset
Impatiens capensis (I. bifloral)	Jewelweed
Iris pseudacorus	Yellow iris
Iris versicolor	Blue flag iris
Lobelia cardinalis	Cardinal flower
Lobelia siphilitica	Great blue lobelia
Podophyllum peltatum	Mayapple
Polygonatum biflorum	Solomon's seal
Mimulus ringens	Monkey flower
Mitchella repens	Partridgeberry
Sanguinaria canadensis	Bloodroot
Saururus cernuus	Lizard's tail
Smilacina racemosa	False Solomon's seal
Sparganium amercanum	Eastern burreed
Sparganium eurycarpum	Giant burreed
Symplocarpus foetidus	Skunk-cabbage
Verbena hastata	Blue vervain
Vernonia noveboracensis	New York ironweed

APPENDIX E: FIELD DATA SHEETS

STREAM INVENTORY

STREAM INVENTORY

Date 8/17/94 Stream Name

Field Investigator(s) KP, RP BH Project Name/No.

Section/Area A-B Weather ___rain ___rain 24 ___rain 48 ___rain >48

Notes: Lower end near Tennision

Level #1 Broad Characterization (Field data sheet)

	③ A, lower	② B, middle at sewer	① C, above sewer	04
+ BF width (BFW)	18' 1.5" = 18.13'	6.0'	7.3'	12
BF depth* (BFD)	—	—	—	8
Mean BFD	0.73'	0.50'	0.48'	.5
Max. depth @ BF	16.25"	11.75"	11.25"	.8
Max. depth x 2 = FPA (elev)	32.50"	23.5"	22.5"	1.6'
FPA width	21'	15.8'	13.2'	10'
FPA/BFW = ER	21/18.13 = $\boxed{1.16}$	$\boxed{2.6}$	$\boxed{1.8}$	
BF width (BFW)	18.13'	6.0	7.3	
Mean BFD	0.73'	0.5	0.48	
BFW/MBFD = W/D	$\boxed{24.83}$	$\boxed{12}$	$\boxed{15.2}$	20
Channel slope	3%	3.5%	6%	
Meander belt width				
Bankfull width				
Meander BW/BFW =				
Meander Width Ratio				

* Use back or X-section sheet to calculate.

\+ measurements taken at cross-over reach.

STREAM INVENTORY

Date 8/17/94 Stream Name ______
Field Investigator(s) KP, RP BH Project Name/No. ______
Section/Area C-B Weather ___rain ___rain 24 ___rain 48 ___rain >48
Notes: ______

Level #1 Broad Characterization (Field data sheet) (see next sheet for 5.

	[illegible] 4 A1 (B3)	6 A2 [illegible] (D2)	2 A3 above [illegible] (B1)	
+ BF width (BFW)	7'2"	9'5"	6.3'	
BF depth* (BFD)	—	—	—	
Mean BFD	.55'	.88'	0.31'	
Max. depth @ BF	13.0	16.5	7.5"	
Max. depth x 2 = FPA (elev)	26.0	33.0	15.0"	
FPA width	13'0"	15'6.5"	8.4'	
FPA/BFW = ER	13.0'/7.16' = $\boxed{1.82}$	15.54'/9.42 = $\boxed{1.64}$	8.4/6.3 = $\boxed{1.33}$	
BF width (BFW)	7.16'	9.42'	6.3'	
Mean BFD	.55'	.88'	0.31'	
BFW/MBFD = W/D	$\boxed{13.0'}$	$\boxed{10.7'}$	$\boxed{20}$	
Channel slope	5%	3%	3.2%	
Meander belt width				
Bankfull width				
Meander BW/BFW =				
Meander Width Ratio				

* use back or X-section sheet to calculate.
+ measurements taken at cross-over reach.

Reach C-B

STREAM INVENTORY

Date 8-24-94 Stream Name
Field Investigator(s) EP + JB BH Project Name/No.
Section/Area C-B Weather __rain __rain 24 __rain 48 __rain >48
Notes: Bamboo - bedrock

Level #1 Broad Characterization (Field data sheet)

	5 · B1			
+ BF width (BFW)	3.9'			
BF depth* (BFD)	—			
Mean BFD	0.33'			
Max. depth @ BF	5.75"			
Max. depth x 2 = FPA	11.5			
FPA width (elev)	9.9'			
FPA/BFW = ER	9.9/3.9 = 2.5			
BF width (BFW)	3.9			
Mean BFD	0.33			
BFW/MBFD = W/D	11.8'			
Channel slope				
Meander belt width				
Bankfull width				
Meander BW/BFW =				
Meander Width Ratio				

* use back or X-section sheet to calculate.
\+ measurements taken at cross-over reach.

STREAM INVENTORY

Date 8/17/94 Stream Name
Field Investigator(s) KP, RP BH Project Name/No.
Section/Area C1-C Weather __rain__rain 24__rain 48__rain >48
Notes:

Level #1 Broad Characterization (Field data sheet)

	(9) A1 area below channel	(8) B2 area before confluence		
+ BF width (BFW)	4'8" = 4.6'	6'3.5" = 6.29'		
BF depth* (BFD)	—	—		
Mean BFD	7.9"	5.39"		
Max. depth @ BF	11.0"	9.75"		
Max. depth x 2 = FPA (elev)	22.0"	19.5"		
FPA width	8'6.5" = 8.54	8'3.5" = 8.29'		
FPA/BFW = ER	8.54/4.6 = $\boxed{1.86}$	8.29/6.29 = $\boxed{1.32}$		
BF width (BFW)	4.6'	6.29'		
Mean BFD	7.9" = 0.66'	5.39" = 0.45'		
BFW/MBFD = W/D	4.6/0.66 = $\boxed{6.97'}$	6.29/0.45 = $\boxed{13.98'}$		
Channel slope				
Meander belt width				
Bankfull width				
Meander BW/BFW =				
Meander Width Ratio				

* use back or X-section sheet to calculate.
+ measurements taken at cross-over reach.

STREAM INVENTORY

Date 8-18 Stream Name

Field Investigator(s) RP-KP BH Project Name/No.

Section/Area D - C (Reentre to Confluence) Weather ___rain___rain 24___rain 48___rain >48

Notes: (May be part of "C" reach)

Level #1 Broad Characterization (Field data sheet)

	D, 10			
+ BF width (BFW)	18.0'			
BF depth* (BFD)	—			
Mean BFD	0.75'			
Max. depth @ BF	15.5"			
Max. depth X 2 = FPA	31.0"			
FPA width (elv.)	22.3'			
FPA/BFW = ER	22.3/18.0 = $\boxed{1.24}$			
BF width (BFW)	18.0'			
Mean BFD	0.75'			
BFW/MBFD = W/D	$\boxed{24}$			
Channel slope	2.5%			
Meander belt width				
Bankfull width				
Meander BW/BFW =				
Meander Width Ratio				

* Use back or X-section sheet to calculate.

\+ measurements taken at cross-over reach.

STREAM INVENTORY

Date 8·18 Stream Name

Field Investigator(s) RP/KP BH Project Name/No.

Section/Area D-C (Rentre - Confluence) Weather __rain__rain 24__rain 48__rain >48

Notes:

Level #1 Broad Characterization (Field data sheet)

	C_1 (12)	C_2 (11)		
BF width (BFW) +	15.95'	15.25		
BF depth* (BFD)	—	—		
Mean BFD	0.68'	1.03'		
Max. depth @ BF	13.0"	20"		
Max. depth X 2 = FPA (elev)	26.0"	40"		
FPA width	17.9'	18.5'		
FPA/BFW = ER	17.9/15.95 = 1.12	18.5/15.25 = 1.21		
BF width (BFW)	15.95	15.25		
Mean BFD	0.68	1.03		
BFW/MBFD = W/D	23.46	14.8		
Channel slope	~2.5%	2%		
Meander belt width				
Bankfull width				
Meander BW/BFW =				
Meander Width Ratio				

* use back or X-section sheet to calculate.

\+ measurements taken at cross-over reach.

STREAM INVENTORY

Date 8-18 Stream Name
Field Investigator(s) KP, KP BH Project Name/No.
Section/Area D-C (Reentr - Confluence) Weather __rain __rain 24 __rain 48 __rain >48
Notes:

Level #1 Broad Characterization (Field data sheet)

	B1 (13)	B2 (14)	B3 (15)	
+ BF width (BFW)	14.4'	13.45'	15.3'	
BF depth* (BFD)	—	—	—	—
Mean BFD	1.0'	.72'	0.48'	
Max. depth @ BF	16.0"	13.0"	10.0"	
Max. depth X 2 = FPA (elev)	32.0"	26.0"	20.0"	
FPA width	20.25'	19.6	17.5'	
FPA/BFW = ER	20.25/14.4 = 1.41	19.6/13.45 = 1.46	17.5/15.3 = 1.14	
BF width (BFW)	14.4'	13.45'	15.3'	
Mean BFD	1.0'	.72'	0.48'	
BFW/MBFD = W/D	14.4'	18.68	31.87	
Channel slope	~2.0% ±	2.0% ±	2.0% ±	
Meander belt width				
Bankfull width				
Meander BW/BFW =				
Meander Width Ratio				

* Use back or X-section sheet to calculate.
\+ measurements taken at cross-over reach.

STREAM INVENTORY

Date 8-18-94 Stream Name

Field Investigator(s) CP / RP BH Project Name/No.

Section/Area D-C (Eastridge - Renter Rd) Weather __rain __rain 24 __rain 48 __rain >48

Notes:

Level #1 Broad Characterization (Field data sheet)

	A_1 17	16 A_2		
+ BF width (BFW)	8.3'	7.7'		
BF depth* (BFD)	—	—		
Mean BFD	0.88'	1.27'		
Max. depth @ BF	16.5"	22.75"		
Max. depth × 2 = FPA (elev)	33.0"	45.5"		
FPA width	16.2'	14.15'		
FPA/BFW = ER	16.2/8.3' = $\boxed{1.95}$	14.15/7.7 = $\boxed{1.84}$		
BF width (BFW)	8.3'	7.7'		
Mean BFD	0.88'	1.27'		
BFW/MBFD = W/D	$\boxed{9.43'}$	$\boxed{6.1'}$		
Channel slope	~1.4%	1.4%		
Meander belt width				
Bankfull width				
Meander BW/BFW =				
Meander Width Ratio				

* Use back or X-section sheet to calculate.

\+ measurements taken at cross-over reach.

STREAM INVENTORY

Date 8.18.94 Stream Name
Field Investigator(s) KD RP BH Project Name/No.
Section/Area E-D (SubGreen Eastridge Rd) Weather ___rain___rain 24___rain 48___rain >48
Notes:

Level #1 Broad Characterization (Field data sheet) Δ97, Sec 64

X-section	A1 19	A2 18	* A3 (Gabion) 20	
+ BF width (BFW)	13.3'	13.0'	4.2' 21"	22
BF depth* (BFD)	—	—	— 9.83"	—
Mean BFD	0.52'	0.64'	0.82'	
Max. depth @ BF	8.5"	10.5"	14.25"	
Max. depth X 2 = FPA (elev)	17.0"	21	28.5"	
FPA width	15.5'	16.75'	10.9'	
FPA/BFW = ER	15.5'/13.3' = 1.17	16.75/13.0 = 1.29'	10.9/4.2 = 2.6'	
BF width (BFW)	13.3'	13.0'	4.2'	
Mean BFD	0.52'	0.64'	0.82'	
BFW/MBFD = W/D	25.6	20.3	* 5.12	
Channel slope	~3.5%	1.5	1.5	
Meander belt width				
Bankfull width				
Meander BW/BFW =				
Meander Width Ratio				

* Use back or X-section sheet to calculate.
\+ measurements taken at cross-over reach.

STREAM INVENTORY

Date 8-24-94 Stream Name
Field Investigator(s) KP & JB BH Project Name/No.
Section/Area (A1 - B1) - not in study area Weather ___rain ___rain 24 ___rain 48 ___rain >48
Notes: Middle

Level #1 Broad Characterization (Field data sheet)

	X,			
+ BF width (BFW)	6.2'			
BF depth* (BFD)	—			
Mean BFD	0.23'			
Max. depth @ BF	4.25"			
Max. depth X 2 = FPA (elev)	8.5"			
FPA width	8.0'			
FPA/BFW = ER	8.0/6.2 = 1.29			
BF width (BFW)	6.2'			
Mean BFD	0.23'			
BFW/MBFD = W/D	26.95			
Channel slope:	3%			
Sin	low - mod (est.)			
Meander belt width				
Bankfull width				
Meander BW/BFW =				
Meander Width Ratio				

* use back or X-section sheet to calculate.
+ measurements taken at cross-over reach.

PEBBLE COUNT/DOMINANT PARTICLE SIZE

SECTION A, -F

Reach A1 to B-1

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count ⁚. = 3 , ⊠ = 9	Tot. No.	% of Tot.	Cum %
Less .062		Silt/Clay			5	4.5	4.5%
.062-.125		Very Fine	SAND		3	2.7	7.2
.125-.25		Fine	SAND		5	4.5	11.7
.25 -.50		Medium	SAND		8	7.2	18.9
.50 -1.0		Coarse	SAND		11	9.9	28.8
1.0 -2.0		Very Coarse	SAND		2	1.8	26.1% 30.6
2.0 -4.0		Very Fine	GRAVEL		6	5.4	36
4.0 -8.0		Fine	GRAVEL		6	5.4	41.4
8.0 -16	.08-0.6	Medium	GRAVEL		3	2.7	44.1
16 -32	0.6-1.3	Coarse	GRAVEL		9	8.1	52.2
32- 64	1.3-2.5	Very Coarse	GRAVEL		9	8.1	29.7% 60.3
64-128	2.5-5.0	Small	COBBLE		12	10.8	71.1
128-256	5-10	Large	COBBLE		22	19.8	30.6% 90.9
256-512	10-20	Small	BOULDERS		5	4.5	95.4
512-1024	20-40	Medium	BOULDERS		2	1.8	97.2
1024-2048	40-80	Large	BOULDERS		2	1.8	99
2048-4096	80-160	Very Large	BOULDERS		1	.9	9% 99.9
		Total Number of Samples....			111		

GRAVEL/ COBBLE (3)

PHOTOGRAPHIC NOTES: Photographer________________ Date__/__

Exp.No.	Speed	f #	Subject

Section A -

REACH 1 (Below outfall at headwaters)

POOL

~~HHH~~ ~~HHH~~ ~~HHH~~ ~~HHH~~ I

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count :.= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %	
Less .062		Silt/Clay		:.	3	2.3	2.3%	
.062-.125		Very Fine	SAND	.	1	.7	3.0	
.125-.25		Fine	SAND	::	4	3	6.0	
.25 - .50		Medium	SAND	:.	3	2.3	8.3	
.50 - 1.0		Coarse	SAND	:.	3	2.3	10.6	
1.0 - 2.0		Very Coarse	SAND		Ø	Ø	8.3%	10.6
2.0 - 4.0		Very Fine	GRAVEL	..	2	1.5		12.1
4.0 - 8.0		Fine	GRAVEL	⊠	10	7.6		19.7
8.0 - 16	.08-0.6	Medium	GRAVEL	⊠	9	6.9		26.6
16 - 32	0.6-1.3	Coarse	GRAVEL	⊠⊠	19	14.5		41.1
32- 64	1.3-2.5	Very Coarse	GRAVEL	⊠⊠::	24	18.3	48.8%	59.4 GRAVEL
64-128	2.5-5.0	Small	COBBLE	⊠⊠:	22	16.7		76.1
128-256	5-10	Large	COBBLE	⊠::	14	10.7	27.4%	86.8
256-512	10-20	Small	BOULDERS	⊠::	14	10.7		97.5
512-1024	20-40	Medium	BOULDERS	:.	3	2.3		99.8
1024-2048	40-80	Large	BOULDERS		Ø	Ø		
2048-4096	80-160	Very Large	BOULDERS		Ø	Ø	13%	
				Total Number of Samples....	131			

PHOTOGRAPHIC NOTES: Photographer__________ Date__/__

Exp.No.	Speed	f #	Subject

REACH 2

POOL

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count :.= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %	
Less .062		Silt/Clay			Ø	Ø	Ø	
.062-.125		Very Fine	SAND		2	1.6	1.6	
.125-.25		Fine	SAND		Ø	Ø	[illegible]	
.25-.50		Medium	SAND		3	2.5	4.1	
.50-1.0		Coarse	SAND		12	10	14.1	
1.0-2.0		Very Coarse	SAND		4	3.3	17.4	
2.0-4.0		Very Fine	GRAVEL		4	3.3	20.7	
4.0-8.0		Fine	GRAVEL		7	5.9	26.6	
8.0-16	.08-0.6	Medium	GRAVEL		9	7.5	34.1	
16-32	0.6-1.3	Coarse	GRAVEL		15	12.6	46.7	
32-64	1.3-2.5	Very Coarse	GRAVEL		15	12.6	41.9% 59.3	GRAVEL
64-128	2.5-5.0	Small	COBBLE		15	12.6	71.9	
128-256	5-10	Large	COBBLE		26	21.8	34.4% 93.7	
256-512	10-20	Small	BOULDERS		6	5	98.7	
512-1024	20-40	Medium	BOULDERS		1	.8	99.5	
1024-2048	40-80	Large	BOULDERS		Ø			
2048-4096	80-160	Very Large	BOULDERS		Ø		5.8%	
Total Number of Samples....					119			

PHOTOGRAPHIC NOTES: Photographer__________ Date__/__

Exp.No.	Speed	f #	Subject

REACH 3

POOL 35

PEBBLE COUNT

Size Range Metric-mm	Inches	Class Name		Dot & Dash Count :.= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %	
Less .062		Silt/Clay			3	2	2%	
.062-.125		Very Fine	SAND		7	4.8	6.8	
.125-.25		Fine	SAND		8	5.5	12.3	
.25 -.50		Medium	SAND		10	6.9	19.1	
.50 -1.0		Coarse	SAND		10	6.9	26.0	
1.0 -2.0		Very Coarse	SAND		3	2	26.1%	28.0
2.0 -4.0		Very Fine	GRAVEL		3	2		30.0
4.0 -8.0		Fine	GRAVEL		4	2.8		32.8
8.0 -16	.08-0.6	Medium	GRAVEL		10	6.9		39.7
16 -32	0.6-1.3	Coarse	GRAVEL		24	16.5		56.2
32- 64	1.3-2.5	Very Coarse	GRAVEL		25	17.2	45.4%	73.4 GRAVEL
64-128	2.5-5.0	Small	COBBLE		25	17.2		90.6
128-256	5-10	Large	COBBLE		10	6.9	24.1%	97.5
256-512	10-20	Small	BOULDERS		1	.7		98.2
512-1024	20-40	Medium	BOULDERS		Ø	Ø		
1024-2048	40-80	Large	BOULDERS		2	1.3		99.5
2048-4096	80-160	Very Large	BOULDERS		Ø	Ø	2%	
				Total Number of Samples....	145			

PHOTOGRAPHIC NOTES: Photographer__________ Date __/__

Exp.No.	Speed	f #	Subject

REACH 4

RIFF | POOL
16

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count :.= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %		
Less .062		Silt/Clay			2	1.6	1.6%		
.062-.125		Very Fine	SAND		4	3.2	4.8		
.125-.25		Fine	SAND		12	9.6	14.4		
.25-.50		Medium	SAND		5	4	18.4		
.50-1.0		Coarse	SAND		7	5.6	24.0		
1.0-2.0		Very Coarse	SAND		Ø	Ø	22.4%		
2.0-4.0		Very Fine	GRAVEL		6	4.8	28.8		
4.0-8.0		Fine	GRAVEL		5	4	32.8		
8.0-16	.08-0.6	Medium	GRAVEL		8	6.4	39.2		
16-32	0.6-1.3	Coarse	GRAVEL		7	5.6	44.8		
32-64	1.3-2.5	Very Coarse	GRAVEL		31	25	45.8%	69.8	GRAVEL
64-128	2.5-5.0	Small	COBBLE		23	18.5	88.3		
128-256	5-10	Large	COBBLE		11	8.8	27.3%	97.1	
256-512	10-20	Small	BOULDERS		2	1.6		98.7	
512-1024	20-40	Medium	BOULDERS		Ø	Ø			
1024-2048	40-80	Large	BOULDERS		1	.8		99.5	
2048-4096	80-160	Very Large	BOULDERS		Ø	Ø	2.4%		

Total Number of Samples.... 124

PHOTOGRAPHIC NOTES: Photographer________ Date __/__

Exp.No.	Speed	f #	Subject

REACH 5

25 POOL

RIFF
13
9
15
31
16
53
17
70

47

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count :.= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %		
Less .062		Silt/Clay			Ø	Ø	Ø%		
.062-.125		Very Fine	SAND		7	5.5	5.5		
.125-.25		Fine	SAND		13	10.3	15.8		
.25-.50		Medium	SAND		5	3.9	19.7		
.50-1.0		Coarse	SAND		13	10.3	30.0		
1.0-2.0		Very Coarse	SAND		9	7.1	37.1%	37.	
2.0-4.0		Very Fine	GRAVEL		8	6.3	43.4		
4.0-8.0		Fine	GRAVEL		11	8.7	52.1		
8.0-16	.08-0.6	Medium	GRAVEL		2	1.6	53.7		
16-32	0.6-1.3	Coarse	GRAVEL		13	10.3	64.0		
32-64	1.3-2.5	Very Coarse	GRAVEL		19	15	41.9%	79.0	GRAVEL
64-128	2.5-5.0	Small	COBBLE		11	8.7	87.7		
128-256	5-10	Large	COBBLE		9	7.1	15.8%	94.8	
256-512	10-20	Small	BOULDERS		4	3.2	98.0		
512-1024	20-40	Medium	BOULDERS		1	.8	98.8		
1024-2048	40-80	Large	BOULDERS		Ø	Ø			
2048-4096	80-160	Very Large	BOULDERS		1	.8	4.8%	99.6	

Total Number of Samples.... 126

PHOTOGRAPHIC NOTES: Photographer__________ Date__/__

Exp.No.	Speed	f #	Subject

REACH 5 → 6

RIFF:
11
11 22
22
12
34
21
55
15
70

POOL
25

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count :.= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %	
Less .062		Silt/Clay			Ø	Ø	Ø	
.062-.125		Very Fine	SAND		2	1.4	1.4	
.125-.25		Fine	SAND		5	3.6	5.0	
.25-.50		Medium	SAND		11	7.9	12.9	
.50-1.0		Coarse	SAND		15	10.8	23.7	
1.0-2.0		Very Coarse	SAND		2	1.4	25.1%	25.1
2.0-4.0		Very Fine	GRAVEL		4	2.9	28.0	
4.0-8.0		Fine	GRAVEL		9	6.5	34.5	
8.0-16	.08-0.6	Medium	GRAVEL		9	6.5	41.0	
16-32	0.6-1.3	Coarse	GRAVEL		20	14.4	55.4	
32-64	1.3-2.5	Very Coarse	GRAVEL		26	18.7	49.%	74.1 GRAVEL
64-128	2.5-5.0	Small	COBBLE		22	15.8	89.9	
128-256	5-10	Large	COBBLE		9	6.5	22.3%	96.4
256-512	10-20	Small	BOULDERS		1	.7	97.1	
512-1024	20-40	Medium	BOULDERS		Ø	Ø		
1024-2048	40-80	Large	BOULDERS		2	1.4	98.5	
2048-4096	80-160	Very Large	BOULDERS		2	1.4	3.5%	99.9
		Total Number of Samples....			139			

PHOTOGRAPHIC NOTES: Photographer________________ Date__/__

Exp.No.	Speed	f #	Subject

SECTION G1 - A

RIFF ~~29~~ 57 14 71

POOL

H

REACH 7

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count : .= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %
Less .062		Silt/Clay			2	1.6	1.6%
.062-.125		Very Fine	SAND		6	5	2.1
.125-.25		Fine	SAND		4	3.3	5.4
.25-.50		Medium	SAND		7	5.9	11.3
.50-1.0		Coarse	SAND		8	6.7	18.0
1.0-2.0		Very Coarse	SAND		2	1.6	22.5% 19.6
2.0-4.0		Very Fine	GRAVEL		3	2.5	22.1
4.0-8.0		Fine	GRAVEL		7	5.9	28.0
8.0-16	.08-0.6	Medium	GRAVEL		5	4.2	32.2
16-32	0.6-1.3	Coarse	GRAVEL		28	23.5	55.7
32-64	1.3-2.5	Very Coarse	GRAVEL		28	23.5	59.6% 79.2 GRAVEL
64-128	2.5-5.0	Small	COBBLE		14	11.8	91.0
128-256	5-10	Large	COBBLE		5	4.2	16% 95.2
256-512	10-20	Small	BOULDERS				
512-1024	20-40	Medium	BOULDERS				
1024-2048	40-80	Large	BOULDERS				
2048-4096	80-160	Very Large	BOULDERS				∅

Total Number of Samples.... 119

PHOTOGRAPHIC NOTES: Photographer________ Date __/__

Exp.No.	Speed	f #	Subject

(8)

Reach : #1 : Suburban Green to Riprap (...

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count :.= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %	
Less .062		Silt/Clay			1	.3	.83%	
.062-.125		Very Fine	SAND		3	2.5	3.3	
.125-.25		Fine	SAND		9	7.5	10.8	
.25-.50		Medium	SAND		6	5	15.8	
.50-1.0		Coarse	SAND		15	12.5	28.3	
1.0-2.0		Very Coarse	SAND		6	5	32.5%	33.3
2.0-4.0		Very Fine	GRAVEL		12	10		43.3
4.0-8.0		Fine	GRAVEL		10	8.3		51.6
8.0-16	.08-0.6	Medium	GRAVEL		9	7.5		59.1
16-32	0.6-1.3	Coarse	GRAVEL		11	9.2	6[illegible]	
32-64	1.3-2.5	Very Coarse	GRAVEL		20	17	52%	85.3 GRAVEL (4)
64-128	2.5-5.0	Small	COBBLE		15	12.5		97.8
128-256	5-10	Large	COBBLE		3	2.5	15%	100.3
256-512	10-20	Small	BOULDERS					
512-1024	20-40	Medium	BOULDERS					
1024-2048	40-80	Large	BOULDERS					
2048-4096	80-160	Very Large	BOULDERS				∅	

Total Number of Samples.... 120

PHOTOGRAPHIC NOTES: Photographer ____________ Date __/__

Exp.No.	Speed	f #	Subject

Note: Riprap slope's ...ble

Reach #2: Above Gabions to Check Dam
Key/R = 10-90 ?

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count :.= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %	
Less .062		Silt/Clay			Ø		Ø	
.062-.125		Very Fine	SAND		Ø	Ø		
.125-.25		Fine	SAND		4	3.8	3.8	
.25-.50		Medium	SAND		6	5.8	9.6	
.50-1.0		Coarse	SAND		14	13.6	23.2	
1.0-2.0		Very Coarse	SAND		1	1	24.2%	
2.0-4.0		Very Fine	GRAVEL		Ø	Ø		
4.0-8.0		Fine	GRAVEL		3	2.9	27.1	
8.0-16	.08-0.6	Medium	GRAVEL		5	4.9	32.0	
16-32	0.6-1.3	Coarse	GRAVEL		16	15.5	47.5	GRAVEL (4)
32-64	1.3-2.5	Very Coarse	GRAVEL		24	23	46.3% 70.5	
64-128	2.5-5.0	Small	COBBLE		22	21	91.5	
128-256	5-10	Large	COBBLE		5	4.9	25.9% 96.4	
256-512	10-20	Small	BOULDERS		3	2.9	99.3	
512-1024	20-40	Medium	BOULDERS					
1024-2048	40-80	Large	BOULDERS					
2048-4096	80-160	Very Large	BOULDERS				2.9%	
		Total Number of Samples....			103			

PHOTOGRAPHIC NOTES: Photographer__________ Date __/__

Exp.No.	Speed	f #	Subject

Note still riprap

Reach 3: 40/60 pool riffle

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count : . = 3 , ⊠ = 9	Tot. No.	% of Tot.	Cum %	
Less .062		Silt/Clay			1	.9	.9%	
.062-.125		Very Fine	SAND		Ø	Ø		
.125-.25		Fine	SAND		2	1.9	2.8	
.25-.50		Medium	SAND		4	3.7	6.5	
.50-1.0		Coarse	SAND		9	8.4	14.9	
1.0-2.0		Very Coarse	SAND		4	3.7	17.7% 18.6	
2.0-4.0		Very Fine	GRAVEL		2	1.9	20.5	
4.0-8.0		Fine	GRAVEL		8	7.4	27.9	
8.0-16	.08-0.6	Medium	GRAVEL		15	14	41.9	
16-32	0.6-1.3	Coarse	GRAVEL		28	26	67.9	
32-64	1.3-2.5	Very Coarse	GRAVEL		20	18.7	68% 86.6	GRAVEL (4)
64-128	2.5-5.0	Small	COBBLE		10	9.3	95.9	
128-256	5-10	Large	COBBLE		4	3.7	13% 99.6	
256-512	10-20	Small	BOULDERS					
512-1024	20-40	Medium	BOULDERS					
1024-2048	40-80	Large	BOULDERS					
2048-4096	80-160	Very Large	BOULDERS				0%	

Total Number of Samples.... 107

PHOTOGRAPHIC NOTES: Photographer________ Date __/__

Exp.No.	Speed	f #	Subject

Note: concrete on left bank

Reach 4 : 30-70

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count :.= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %	
Less .062		Silt/Clay			1	.1	.1%	
.062-.125		Very Fine	SAND		Ø			
.125-.25		Fine	SAND		1	1	2	
.25-.50		Medium	SAND		6	5.7	7.7	
.50-1.0		Coarse	SAND		7	6.6	14.3	
1.0-2.0		Very Coarse	SAND		2	1.9	15.2%	16.2
2.0-4.0		Very Fine	GRAVEL		3	2.9	19.1	
4.0-8.0		Fine	GRAVEL		2	1.9	21.0	
8.0-16	.08-0.6	Medium	GRAVEL		5	4.8	25.8	
16-32	0.6-1.3	Coarse	GRAVEL		26	25	50.8	
32-64	1.3-2.5	Very Coarse	GRAVEL		41	39	73.6%	89.8 GRAVEL (4)
64-128	2.5-5.0	Small	COBBLE		7	6.6	96.4	
128-256	5-10	Large	COBBLE		2	1.9	8.5%	98.3
256-512	10-20	Small	BOULDERS		2	1.9		100.2
512-1024	20-40	Medium	BOULDERS					
1024-2048	40-80	Large	BOULDERS					
2048-4096	80-160	Very Large	BOULDERS				1.9%	
		Total Number of Samples....			105			

PHOTOGRAPHIC NOTES: Photographer________ Date__/__

Exp.No.	Speed	f #	Subject

Note: was split to 30-70 + 50-50 previously, but not in this data set

Reach 5 : 50 - 50   Between Eastridge + Router.

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count :.= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %	
Less .062		Silt/Clay			4	3.8	3.8%	
.062-.125		Very Fine	SAND		Ø	Ø		
.125-.25		Fine	SAND		2	1.9	5.7	
.25-.50		Medium	SAND		Ø	Ø		
.50-1.0		Coarse	SAND		15	14.3	20.0	
1.0-2.0		Very Coarse	SAND		5	4.7	20.9%	24.7
2.0-4.0		Very Fine	GRAVEL		7	6.6	31.3	
4.0-8.0		Fine	GRAVEL		9	8.5	39.8	
8.0-16	.08-0.6	Medium	GRAVEL		13	12.4	53.2	
16-32	0.6-1.3	Coarse	GRAVEL		20	19	72.2	
32-64	1.3-2.5	Very Coarse	GRAVEL		8	7.6	54.1%	79.8 GRAVEL (4)
64-128	2.5-5.0	Small	COBBLE		12	11	90.8	
128-256	5-10	Large	COBBLE		9	8.5	19.5%	99.3
256-512	10-20	Small	BOULDERS		1	.9	100.2	
512-1024	20-40	Medium	BOULDERS					
1024-2048	40-80	Large	BOULDERS					
2048-4096	80-160	Very Large	BOULDERS				.9%	

Total Number of Samples.... 105

PHOTOGRAPHIC NOTES: Photographer__________ Date__/__

Exp.No.	Speed	f #	Subject

Reach 6 : Above Rueter Rd 50-50

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count :.= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %	
Less .062		Silt/Clay			Ø		Ø	
.062-.125		Very Fine	SAND		Ø	Ø		
.125-.25		Fine	SAND		3	2.6	2.6	
.25-.50		Medium	SAND		7	6.2	8.8	
.50-1.0		Coarse	SAND		21	18.6	27.4	
1.0-2.0		Very Coarse	SAND		11	9.7	37.1%	37,1
2.0-4.0		Very Fine	GRAVEL		10	8.8	45.9	
4.0-8.0		Fine	GRAVEL		9	7.9	53.8	
8.0-16	:08-0.6	Medium	GRAVEL		12	10.6	64.4	
16-32	0.6-1.3	Coarse	GRAVEL		17	15	79.4	
32-64	1.3-2.5	Very Coarse	GRAVEL		15	13.3	55.6%	92.7 GRAVEL (4)
64-128	2.5-5.0	Small	COBBLE		2	1.7	94.4	
128-256	5-10	Large	COBBLE		4	3.5	5.2%	97.9
256-512	10-20	Small	BOULDERS		2	1.7	99.6	
512-1024	20-40	Medium	BOULDERS					
1024-2048	40-80	Large	BOULDERS					
2048-4096	80-160	Very Large	BOULDERS				1.7%	

Total Number of Samples.... 113

PHOTOGRAPHIC NOTES: Photographer______________ Date__/__

Exp.No.	Speed	f #	Subject

#7 40-60 Below Confluence

PEBBLE COUNT

Size Range Metric-mm	Size Range Inches	Class Name		Dot & Dash Count :.= 3 , ⊠= 9	Tot. No.	% of Tot.	Cum %
Less .062		Silt/Clay			1	.8	.8%
.062-.125		Very Fine	SAND		3	2.5	3.3
.125-.25		Fine	SAND		5	4.2	7.5
.25-.50		Medium	SAND		6	5	12.5
.50-1.0		Coarse	SAND		16	13.5	26
1.0-2.0		Very Coarse	SAND		4	3.3	28.5% 29.3
2.0-4.0		Very Fine	GRAVEL		10	8.5	3
4.0-8.0		Fine	GRAVEL		4	3.4	41.2
8.0-16	.08-0.6	Medium	GRAVEL		7	5.9	47.1
16-32	0.6-1.3	Coarse	GRAVEL		15	12.7	5
32-64	1.3-2.5	Very Coarse	GRAVEL		22	18.6	49.1% 78.4 GRAVEL (4)
64-128	2.5-5.0	Small	COBBLE		21	17.8	96.2
128-256	5-10	Large	COBBLE		4	3.4	21.2% 99.6
256-512	10-20	Small	BOULDERS				
512-1024	20-40	Medium	BOULDERS				
1024-2048	40-80	Large	BOULDERS				
2048-4096	80-160	Very Large	BOULDERS				0%

Total Number of Samples.... 118 118

PHOTOGRAPHIC NOTES: Photographer__________ Date__/__

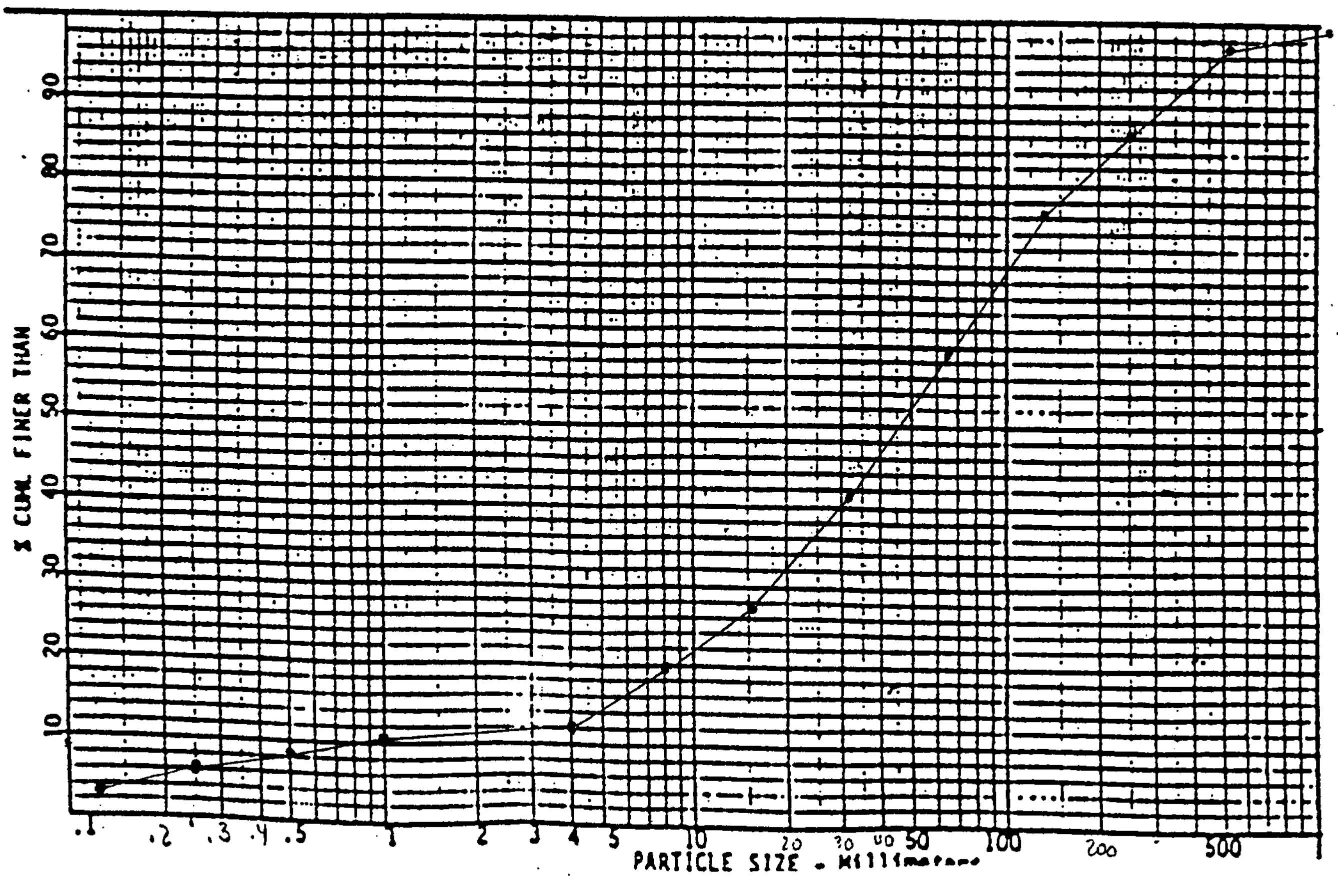
Exp.No.	Speed	f #	Subject

PEBBLE COU

ite __/__/__ Party: ________ rshd: ________

Site/Reach: REACH 1 (BELOW OUTFALL AT HEADWATERS)

Metric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
Less- .062		SILT/CLAY													
.062- .125		Vry FINE	SANDS												
.125- .25		FINE													
.25 - .50		MEDIUM													
.50 - 1.0		COARSE													
1.0 - 2	.04 - .08	Vry CRSE													
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE													
6 - 8	.24 - .31														
8 - 12	.31 - .47	MEDIUM													
12 - 16	.47 - .63														
16 - 24	.63 - .94	COARSE													
24 - 32	.94 - 1.26														
32 - 48	1.26- 1.9	Vry CRSE													
48 - 64	1.9 - 2.5														
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0														
128 - 192	5.0 - 7.6	LARGE													
192 - 256	7.6 - 10														
256 - 384	10 - 15	SMALL	BOULDERS												
384 - 512	15 - 20														
512 - 1024	20 - 40	MEDIUM													
1024 - 2048	40 - 80	LARGE													
2048 - 4096	80 - 160	Vry LRGE													
Count Note: 3=∴ 9=⊠				Totals....				Totals....				Totals....			



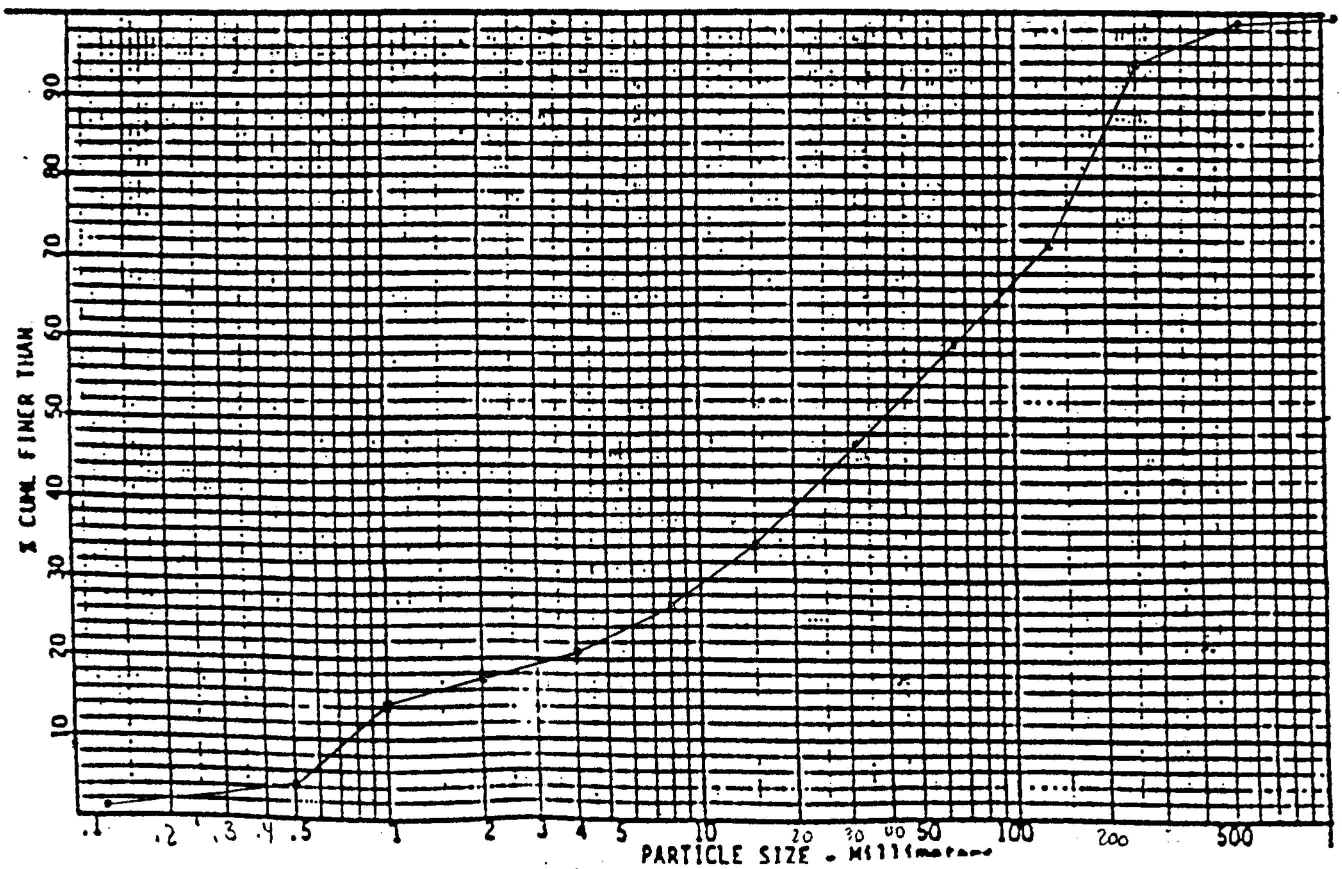
NORTHWEST

PEBBLE COU

ate __/__/__ Party:__________ rshd:__________

Site/Reach: REACH 2

Metric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
Less- .062		SILT/CLAY													
.062- .125		Vry FINE	SANDS												
.125- .25		FINE	SANDS												
.25 - .50		MEDIUM	SANDS												
.50 - 1.0		COARSE	SANDS												
1.0 - 2	.04 - .08	Vry CRSE	SANDS												
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE	GRAVELS												
6 - 8	.24 - .31	FINE	GRAVELS												
8 - 12	.31 - .47	MEDIUM	GRAVELS												
12 - 16	.47 - .63	MEDIUM	GRAVELS												
16 - 24	.63 - .94	COARSE	GRAVELS												
24 - 32	.94 - 1.26	COARSE	GRAVELS												
32 - 48	1.26- 1.9	Vry CRSE	GRAVELS												
48 - 64	1.9 - 2.5	Vry CRSE	GRAVELS												
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0	SMALL	COBBLES												
128 - 192	5.0 - 7.6	LARGE	COBBLES												
192 - 256	7.6 - 10	LARGE	COBBLES												
256 - 384	10 - 15	SMALL	BOULDERS												
384 - 512	15 - 20	SMALL	BOULDERS												
512 - 1024	20 - 40	MEDIUM	BOULDERS												
1024 - 2048	40 - 80	LARGE	BOULDERS												
2048 - 4096	80 - 160	Vry LRGE	BOULDERS												
Count Note: 3=:· 9= ⌧				Totals....				Totals....				Totals....			



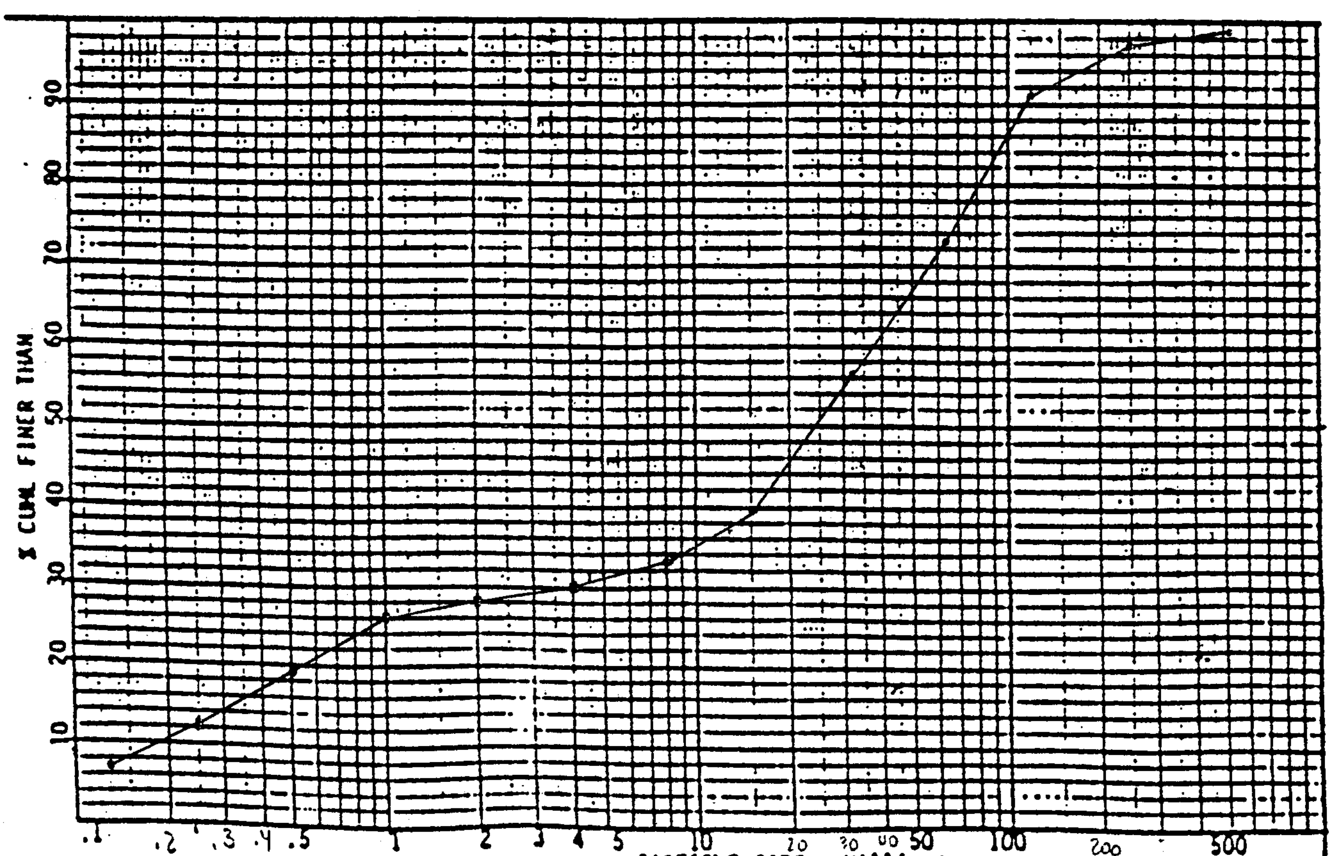
NORTHWEST

PEBBLE COU

ate __/__/__ Party:________ rshd:________

Site/Reach: REACH 3

Metric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
Less- .062		SILT/CLAY													
.062- .125		Vry FINE	SANDS												
.125- .25		FINE													
.25 - .50		MEDIUM													
.50 - 1.0		COARSE													
1.0 - 2	.04 - .08	Vry CRSE													
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE													
6 - 8	.24 - .31														
8 - 12	.31 - .47	MEDIUM													
12 - 16	.47 - .63														
16 - 24	.63 - .94	COARSE													
24 - 32	.94 - 1.26														
32 - 48	1.26- 1.9	Vry CRSE													
48 - 64	1.9 - 2.5														
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0														
128 - 192	5.0 - 7.6	LARGE													
192 - 256	7.6 - 10														
256 - 384	10 - 15	SMALL	BOULDERS												
384 - 512	15 - 20														
512 - 1024	20 - 40	MEDIUM													
1024 - 2048	40 - 80	LARGE													
2048 - 4096	80 - 160	Vry LRGE													
Count Note: 3=:· 9=				Totals....				Totals....				Totals....			



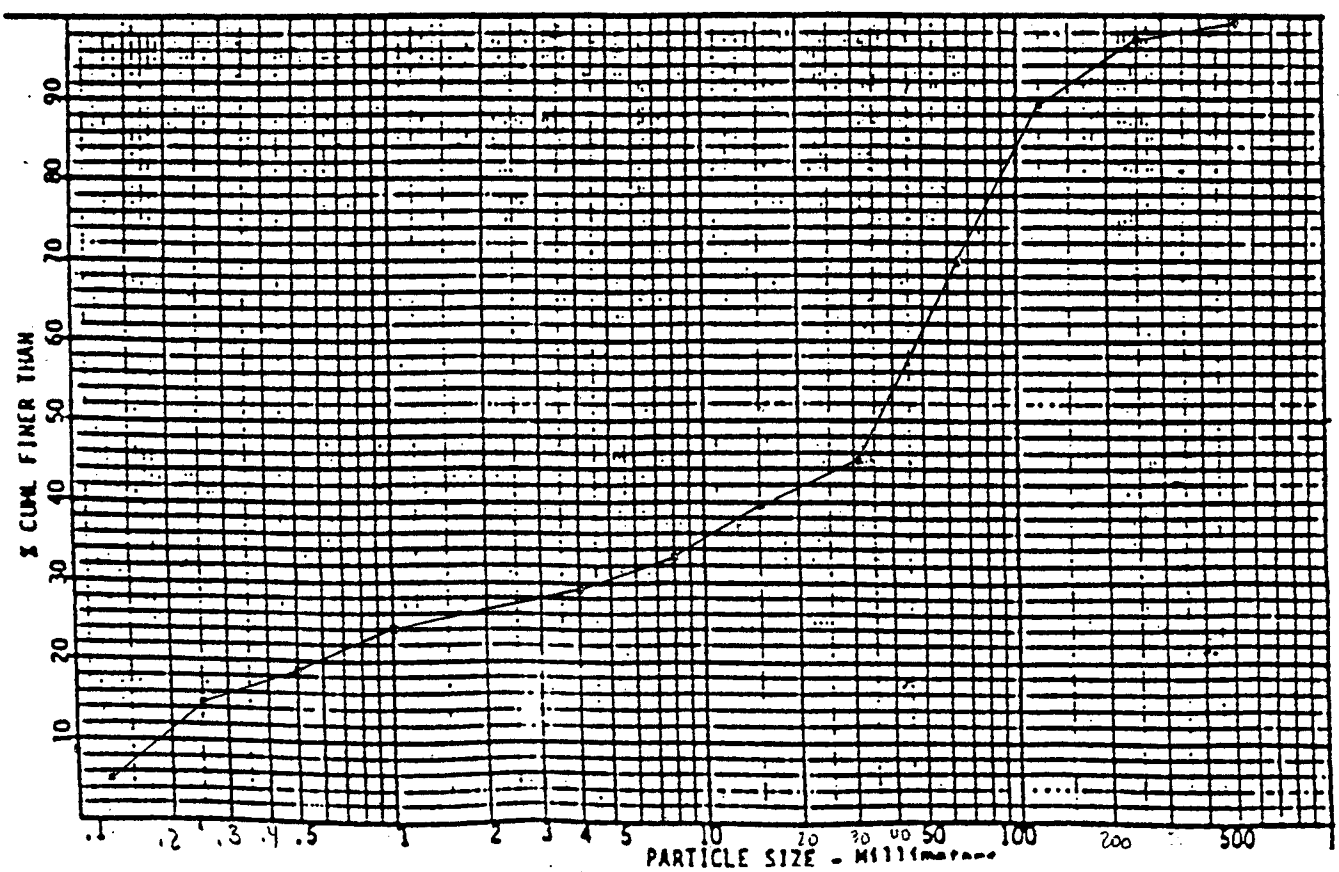
NORTHWEST

PEBBLE CO

Date ___/___/___ Party:__________________ Wshd:______________

Site/Reach: REACH 4

Metric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tnt	%Cum	Item Count	Tot#	%Tnt	%Cum
Less- .062		SILT/CLAY													
.062- .125		Vry FINE	SANDS												
.125- .25		FINE	SANDS												
.25 - .50		MEDIUM	SANDS												
.50 - 1.0		COARSE	SANDS												
1.0 - 2	.04 - .08	Vry CRSE	SANDS												
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE	GRAVELS												
6 - 8	.24 - .31	FINE	GRAVELS												
8 - 12	.31 - .47	MEDIUM	GRAVELS												
12 - 16	.47 - .63	MEDIUM	GRAVELS												
16 - 24	.63 - .94	COARSE	GRAVELS												
24 - 32	.94 - 1.26	COARSE	GRAVELS												
32 - 48	1.26- 1.9	Vry CRSE	GRAVELS												
48 - 64	1.9 - 2.5	Vry CRSE	GRAVELS												
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0	SMALL	COBBLES												
128 - 192	5.0 - 7.6	LARGE	COBBLES												
192 - 256	7.6 - 10	LARGE	COBBLES												
256 - 384	10 - 15	SMALL	BOULDERS												
384 - 512	15 - 20	SMALL	BOULDERS												
512 - 1024	20 - 40	MEDIUM	BOULDERS												
1024 - 2048	40 - 80	LARGE	BOULDERS												
2048 - 4096	80 - 160	Vry LRGE	BOULDERS												
Count Note: 3=∴ 9=⊠				Totals....				Totals....				Totals....			



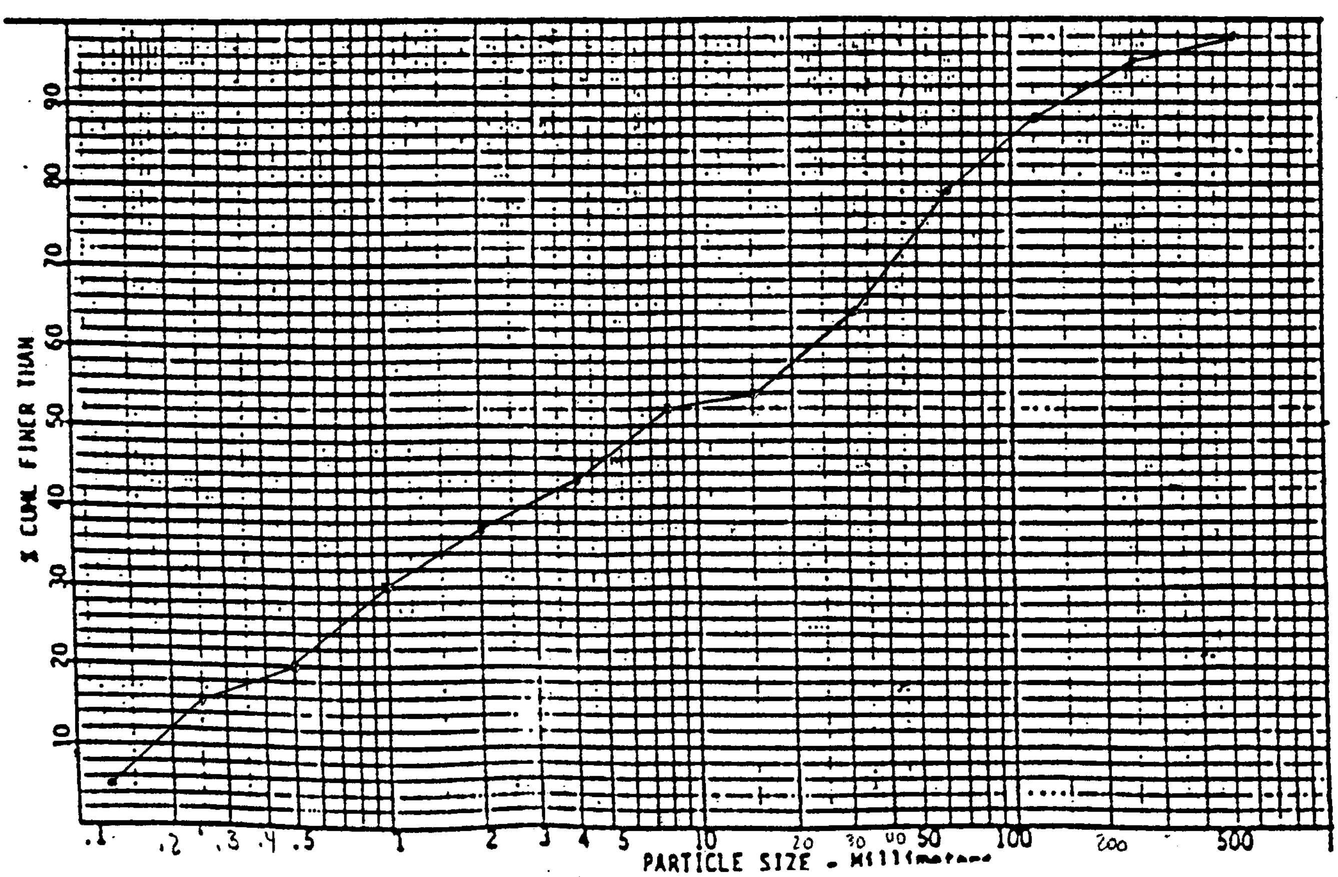
NORTHWEST

PEBBLE COU

ite___/___/___ Party:________________ ...snd:__________

Site/Reach: REACH 5

Metric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
Less- .062		SILT/CLAY													
.062- .125		Vry FINE	SANDS												
.125- .25		FINE													
.25 - .50		MEDIUM													
.50 - 1.0		COARSE													
1.0 - 2	.04 - .08	Vry CRSE													
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE													
6 - 8	.24 - .31														
8 - 12	.31 - .47	MEDIUM													
12 - 16	.47 - .63														
16 - 24	.63 - .94	COARSE													
24 - 32	.94 - 1.26														
32 - 48	1.26- 1.9	Vry CRSE													
48 - 64	1.9 - 2.5														
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0														
128 - 192	5.0 - 7.6	LARGE													
192 - 256	7.6 - 10														
256 - 384	10 - 15	SMALL	BOULDERS												
384 - 512	15 - 20														
512 - 1024	20 - 40	MEDIUM													
1024 - 2048	40 - 80	LARGE													
2048 - 4096	80 - 160	Vry LRGE													
Count Note: 3=∴ 9=⊠			Totals....					Totals....				Totals....			



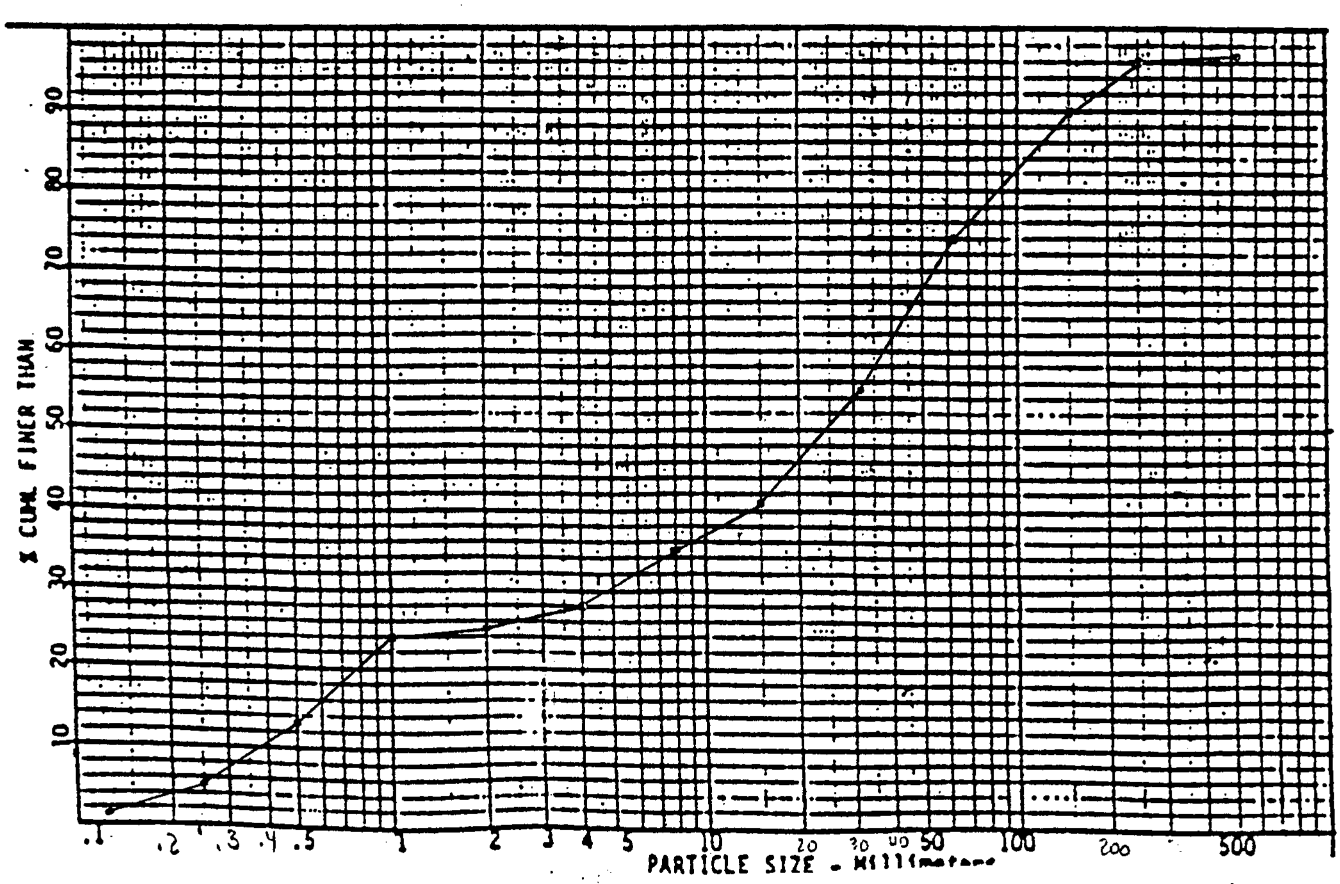
NORTHWEST

PEBBLE CO

Date ___/___/___ Party:__________ Xsnd:__________

Site/Reach: REACH 6

Metric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
Less - .062		SILT/CLAY													
.062 - .125		Vry FINE	SANDS												
.125 - .25		FINE	SANDS												
.25 - .50		MEDIUM	SANDS												
.50 - 1.0		COARSE	SANDS												
1.0 - 2	.04 - .08	Vry CRSE	SANDS												
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE	GRAVELS												
6 - 8	.24 - .31	FINE	GRAVELS												
8 - 12	.31 - .47	MEDIUM	GRAVELS												
12 - 16	.47 - .63	MEDIUM	GRAVELS												
16 - 24	.63 - .94	COARSE	GRAVELS												
24 - 32	.94 - 1.26	COARSE	GRAVELS												
32 - 48	1.26 - 1.9	Vry CRSE	GRAVELS												
48 - 64	1.9 - 2.5	Vry CRSE	GRAVELS												
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0	SMALL	COBBLES												
128 - 192	5.0 - 7.6	LARGE	COBBLES												
192 - 256	7.6 - 10	LARGE	COBBLES												
256 - 384	10 - 15	SMALL	BOULDERS												
384 - 512	15 - 20	SMALL	BOULDERS												
512 - 1024	20 - 40	MEDIUM	BOULDERS												
1024 - 2048	40 - 80	LARGE	BOULDERS												
2048 - 4096	80 - 160	Vry LRGE	BOULDERS												
Count Note: 3=::' 9=⊠				Totals....				Totals....				Totals....			



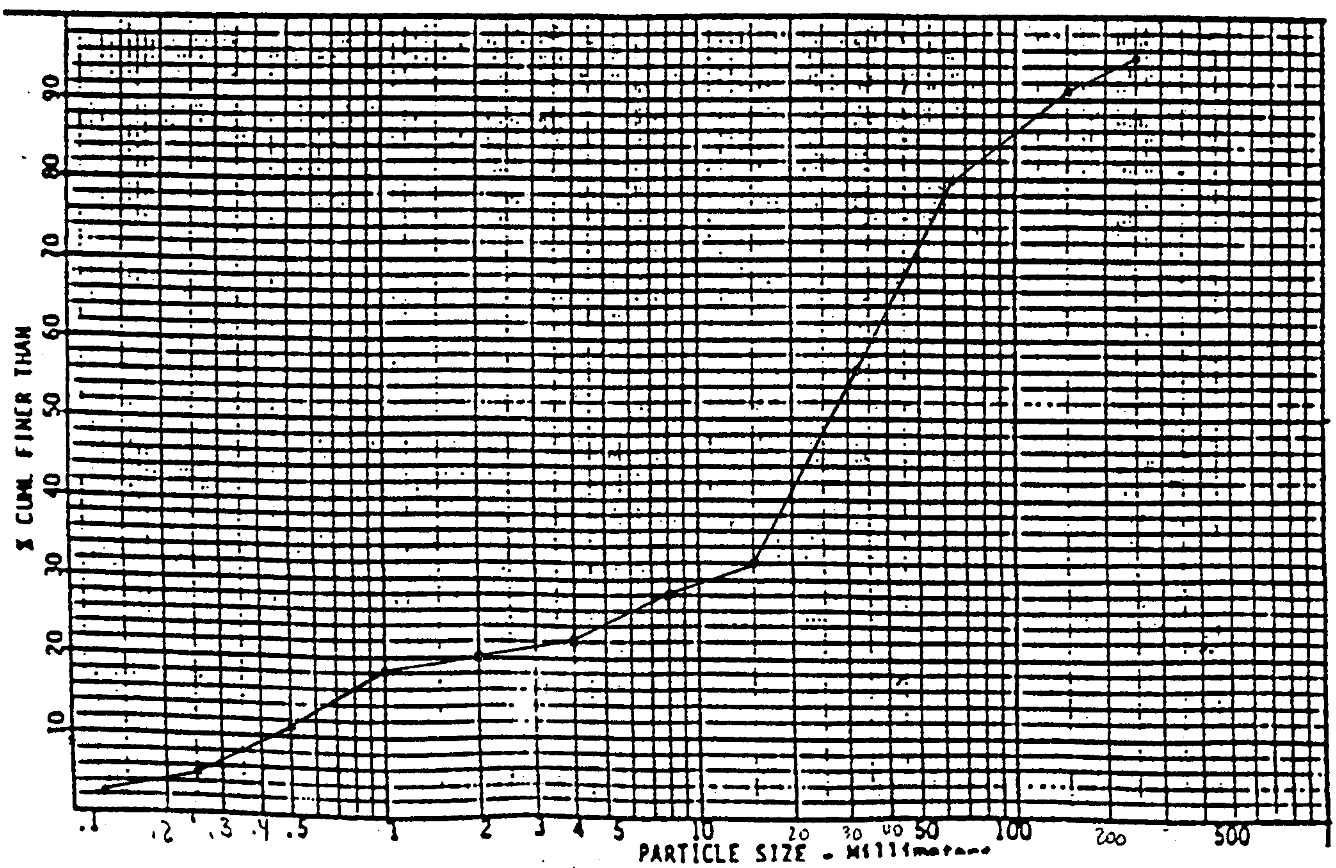
NORTHWEST

PEBBLE COU

ate___/___/___ Party:__________ __rshd:__________

Site/Reach: REACH 7

Metric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
Less- .062		SILT/CLAY													
.062- .125		Vry FINE	SANDS												
.125- .25		FINE	SANDS												
.25 - .50		MEDIUM	SANDS												
.50 - 1.0		COARSE	SANDS												
1.0 - 2	.04 - .08	Vry CRSE	SANDS												
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE	GRAVELS												
6 - 8	.24 - .31	FINE	GRAVELS												
8 - 12	.31 - .47	MEDIUM	GRAVELS												
12 - 16	.47 - .63	MEDIUM	GRAVELS												
16 - 24	.63 - .94	COARSE	GRAVELS												
24 - 32	.94 - 1.26	COARSE	GRAVELS												
32 - 48	1.26- 1.9	Vry CRSE	GRAVELS												
48 - 64	1.9 - 2.5	Vry CRSE	GRAVELS												
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0	SMALL	COBBLES												
128 - 192	5.0 - 7.6	LARGE	COBBLES												
192 - 256	7.6 - 10	LARGE	COBBLES												
256 - 384	10 - 15	SMALL	BOULDERS												
384 - 512	15 - 20	SMALL	BOULDERS												
512 - 1024	20 - 40	MEDIUM	BOULDERS												
1024 - 2048	40 - 80	LARGE	BOULDERS												
2048 - 4096	80 - 160	Vry LRGE	BOULDERS												
Count Note: 3=∴ 9=⊠				Totals....				Totals....				Totals....			



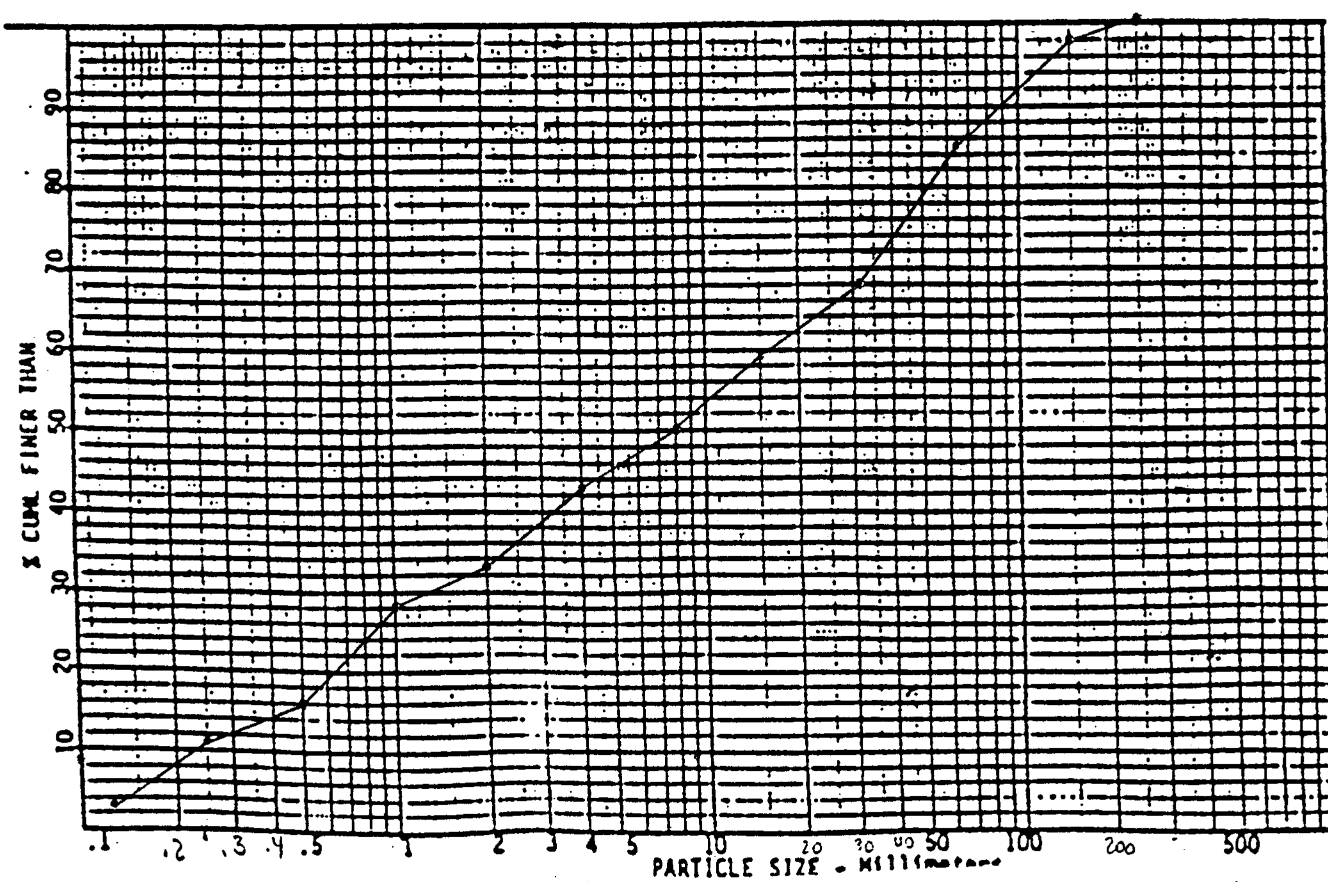
NORTHWEST

PEBBLE COU

ate ___/___/___ Party: __________ shd: __________

Site/Reach: Reach 1 (Suburban Green to Riprap)

Metric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
Less - .062		SILT/CLAY													
.062 - .125		Vry FINE	SANDS												
.125 - .25		FINE	SANDS												
.25 - .50		MEDIUM	SANDS												
.50 - 1.0		COARSE	SANDS												
1.0 - 2	.04 - .08	Vry CRSE	SANDS												
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE	GRAVELS												
6 - 8	.24 - .31	FINE	GRAVELS												
8 - 12	.31 - .47	MEDIUM	GRAVELS												
12 - 16	.47 - .63	MEDIUM	GRAVELS												
16 - 24	.63 - .94	COARSE	GRAVELS												
24 - 32	.94 - 1.26	COARSE	GRAVELS												
32 - 48	1.26 - 1.9	Vry CRSE	GRAVELS												
48 - 64	1.9 - 2.5	Vry CRSE	GRAVELS												
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0	SMALL	COBBLES												
128 - 192	5.0 - 7.6	LARGE	COBBLES												
192 - 256	7.6 - 10	LARGE	COBBLES												
256 - 384	10 - 15	SMALL	BOULDERS												
384 - 512	15 - 20	SMALL	BOULDERS												
512 - 1024	20 - 40	MEDIUM	BOULDERS												
1024 - 2048	40 - 80	LARGE	BOULDERS												
2048 - 4096	80 - 160	Vry LRGE	BOULDERS												
Count Note: [illegible]				Totals....				Totals....				Totals....			



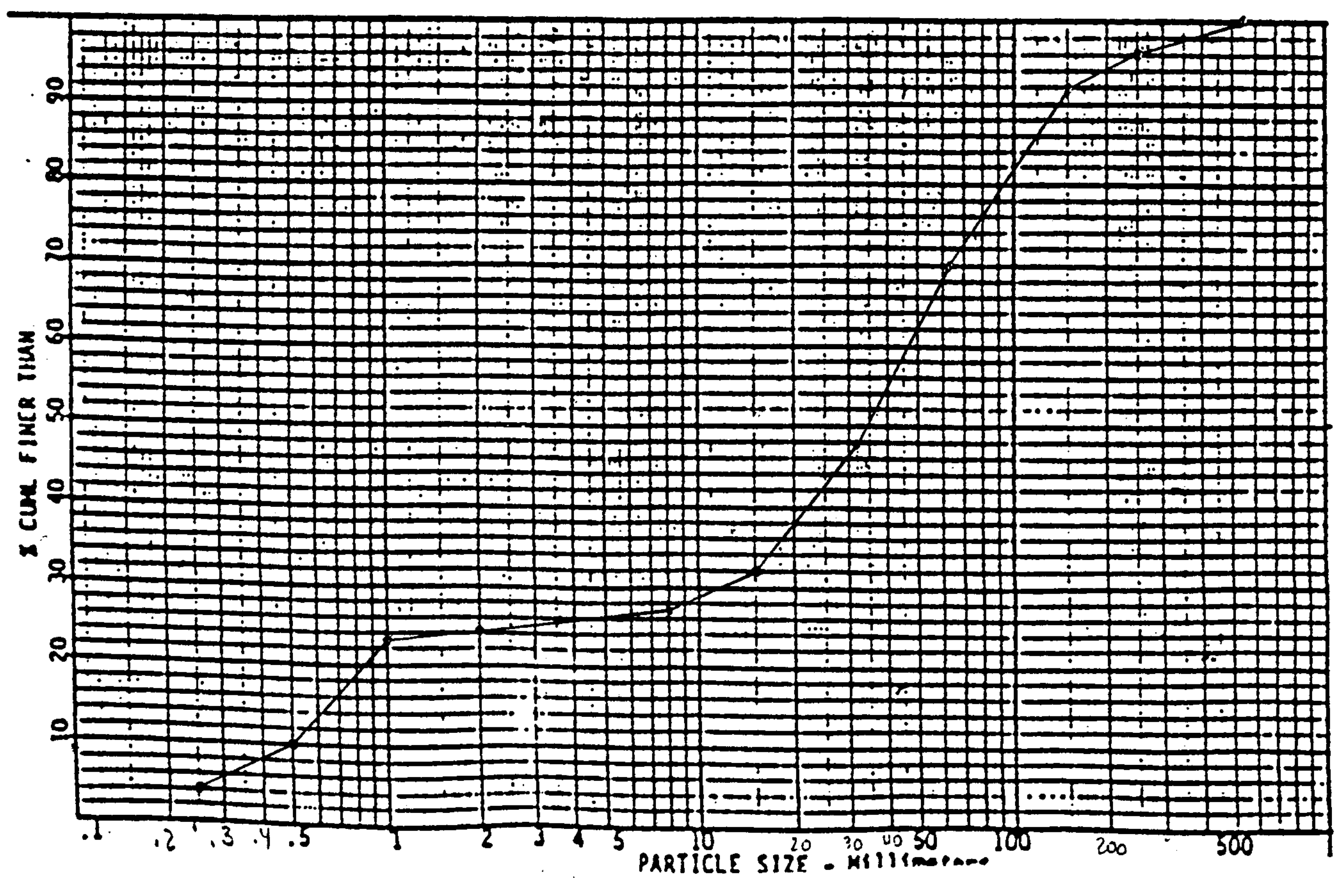
NORTHWEST

PEBBLE COU

ate __/__/__ Party: __________ Wshd: __________

Site/Reach: Reach 2 (Above Gabions to Check Dam)

Metric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
Less- .062		SILT/CLAY													
.062- .125		Vry FINE	SANDS												
.125- .25		FINE													
.25 - .50		MEDIUM													
.50 - 1.0		COARSE													
1.0 - 2	.04 - .08	Vry CRSE													
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE													
6 - 8	.24 - .31														
8 - 12	.31 - .47	MEDIUM													
12 - 16	.47 - .63														
16 - 24	.63 - .94	COARSE													
24 - 32	.94 - 1.26														
32 - 48	1.26- 1.9	Vry CRSE													
48 - 64	1.9 - 2.5														
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0														
128 - 192	5.0 - 7.6	LARGE													
192 - 256	7.6 - 10														
256 - 384	10 - 15	SMALL	BOULDERS												
384 - 512	15 - 20														
512 - 1024	20 - 40	MEDIUM													
1024 - 2048	40 - 80	LARGE													
2048 - 4096	80 - 160	Vry LRGE													
Count Note: 3=∴ 9=⊠				Totals....				Totals....				Totals....			



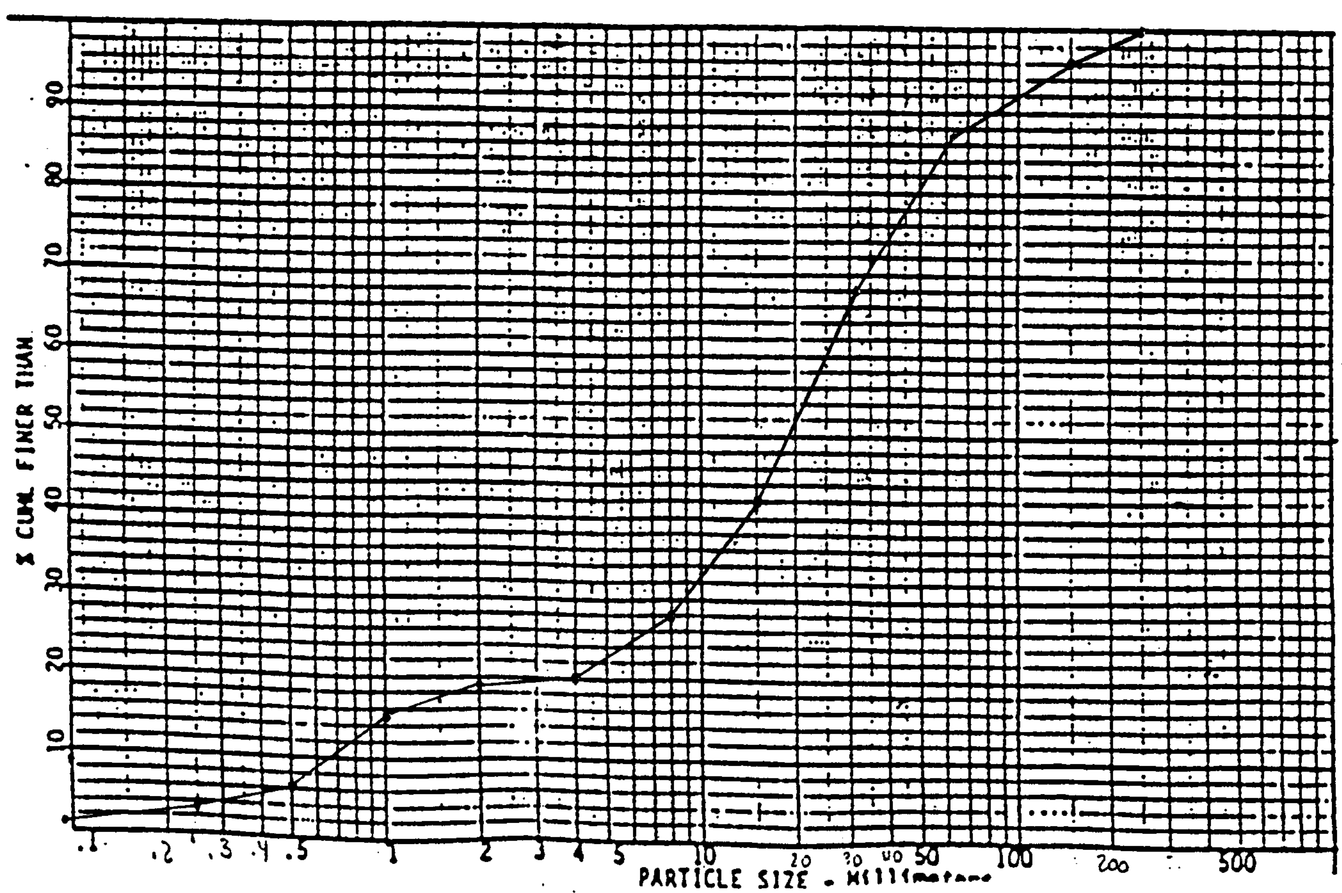
NORTHWEST

PEBBLE COUNT

0 e__/__/__ Party:________ nd:________

Site/Reach: REACH 3 40/60

tric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
ss- .062		SILT/CLAY													
.062- .125		Vry FINE	SANDS												
25- .25		FINE													
5 - .50		MEDIUM													
.50 - 1.0		COARSE													
0 - 2	.04 - .08	Vry CRSE													
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE													
6 - 8	.24 - .31														
8 - 12	.31 - .47	MEDIUM													
12 - 16	.47 - .63														
16 - 24	.63 - .94	COARSE													
24 - 32	.94 - 1.26														
32 - 48	1.26- 1.9	Vry CRSE													
45 - 64	1.9 - 2.5														
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0														
28 - 192	5.0 - 7.6	LARGE													
192 - 256	7.6 - 10														
256 - 384	10 - 15	SMALL	BOULDERS												
84 - 512	15 - 20														
512 - 1024	20 - 40	MEDIUM													
1024 - 2048	40 - 80	LARGE													
48 - 4096	80 - 160	Vry LRGE													
Count Note: 3=:· 9= ⊠			Totals....					Totals....				Totals....			



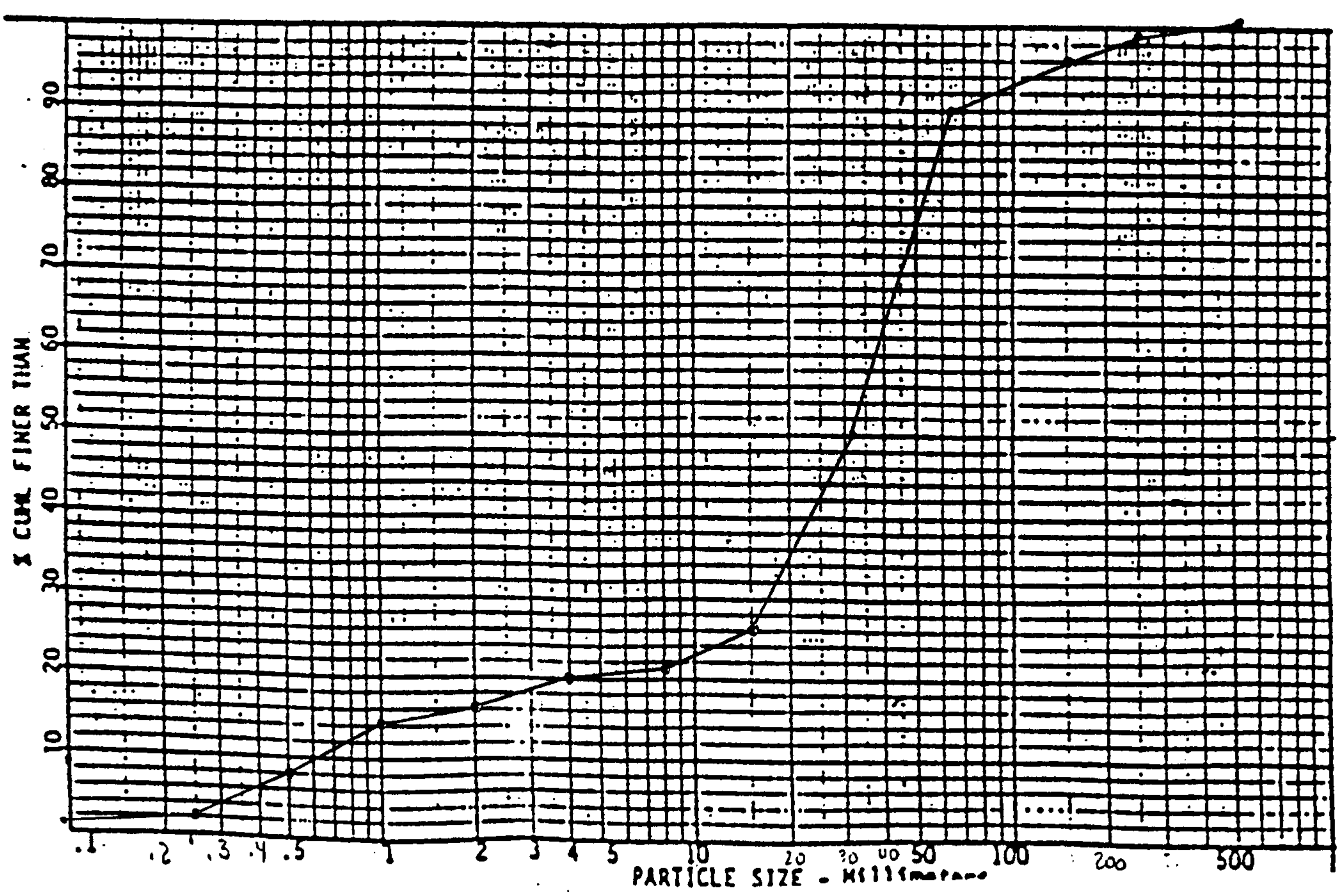
NORTHWEST

PEBBLE COUNT

D e__/__/__ Party:____________ nd:____________

Site/Reach: REACH 4 30 – 70

tric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
ss- .062		SILT/CLAY													
.062- .125		Vry FINE	SANDS												
.25- .25		FINE	SANDS												
5 - .50		MEDIUM	SANDS												
.50 - 1.0		COARSE	SANDS												
.0 - 2	.04 - .08	Vry CRSE	SANDS												
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE	GRAVELS												
6 - 8	.24 - .31	FINE	GRAVELS												
8 - 12	.31 - .47	MEDIUM	GRAVELS												
12 - 16	.47 - .63	MEDIUM	GRAVELS												
16 - 24	.63 - .94	COARSE	GRAVELS												
24 - 32	.94 - 1.26	COARSE	GRAVELS												
32 - 48	1.26- 1.9	Vry CRSE	GRAVELS												
48 - 64	1.9 - 2.5	Vry CRSE	GRAVELS												
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0	SMALL	COBBLES												
28 - 192	5.0 - 7.6	LARGE	COBBLES												
192 - 256	7.6 - 10	LARGE	COBBLES												
256 - 384	10 - 15	SMALL	BOULDERS												
84 - 512	15 - 20	SMALL	BOULDERS												
512 - 1024	20 - 40	MEDIUM	BOULDERS												
024 - 2048	40 - 80	LARGE	BOULDERS												
48 - 4096	80 - 160	Vry LRGE	BOULDERS												
Count Note: 3=∴ 9= ⊠				Totals....				Totals....				Totals....			



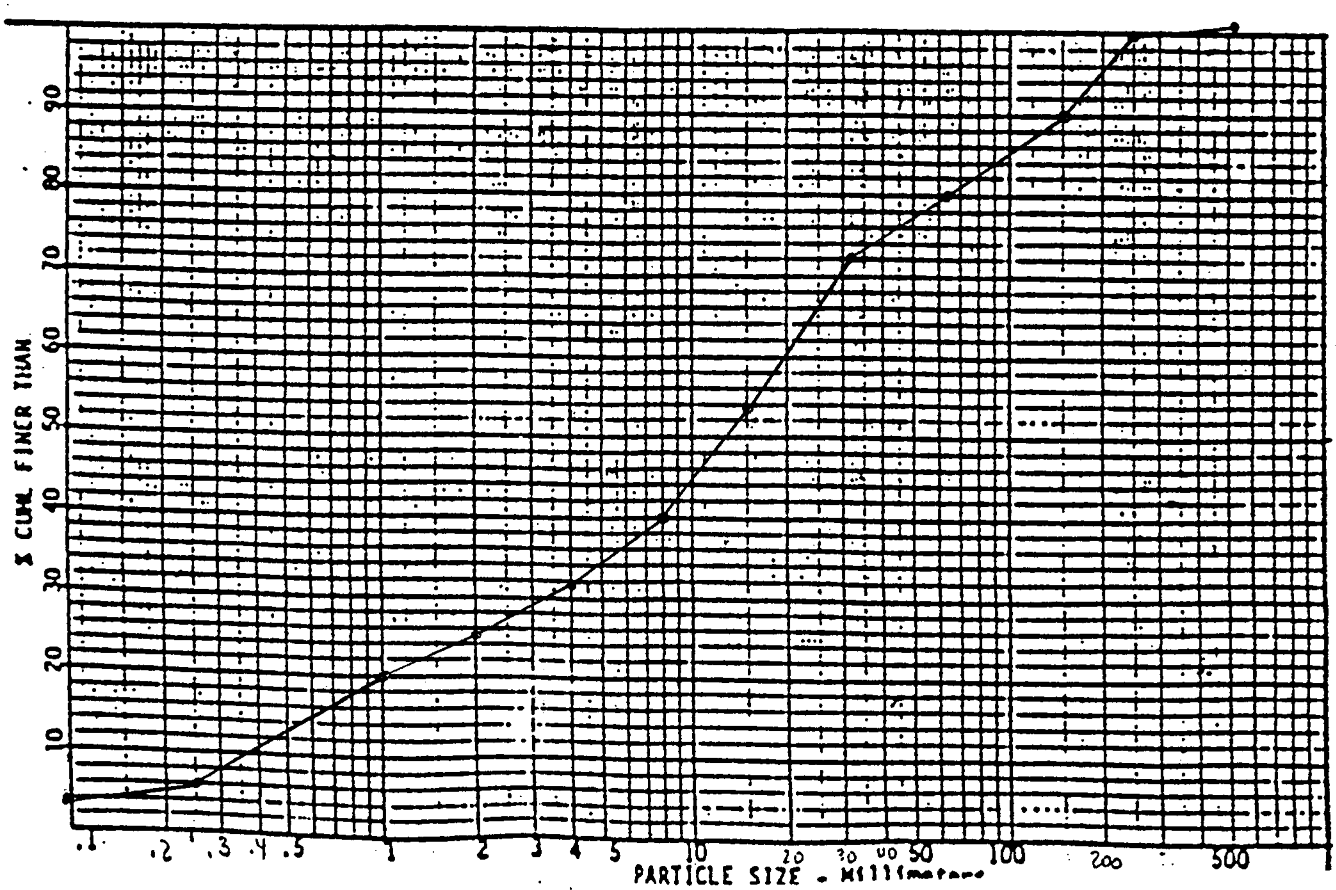
NORTHWEST

PEBBLE COUNT

e__/__/__ Party:________ End:________

Site/Reach: Reach 5 50-50

Metric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
ss- .062		SILT/CLAY													
.062- .125		Vry FINE	SANDS												
.25- .25		FINE	SANDS												
.5 - .50		MEDIUM	SANDS												
.50 - 1.0		COARSE	SANDS												
0 - 2	.04 - .08	Vry CRSE	SANDS												
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE	GRAVELS												
6 - 8	.24 - .31	FINE	GRAVELS												
8 - 12	.31 - .47	MEDIUM	GRAVELS												
12 - 16	.47 - .63	MEDIUM	GRAVELS												
16 - 24	.63 - .94	COARSE	GRAVELS												
24 - 32	.94 - 1.26	COARSE	GRAVELS												
32 - 48	1.26- 1.9	Vry CRSE	GRAVELS												
45 - 64	1.9 - 2.5	Vry CRSE	GRAVELS												
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0	SMALL	COBBLES												
28 - 192	5.0 - 7.6	LARGE	COBBLES												
192 - 256	7.6 - 10	LARGE	COBBLES												
256 - 384	10 - 15	SMALL	BOULDERS												
84 - 512	15 - 20	SMALL	BOULDERS												
512 - 1024	20 - 40	MEDIUM	BOULDERS												
24 - 2048	40 - 80	LARGE	BOULDERS												
48 - 4096	80 - 160	Vry LRGE	BOULDERS												
Count Note: 3=:' 9=⌘				Totals....				Totals....				Totals....			



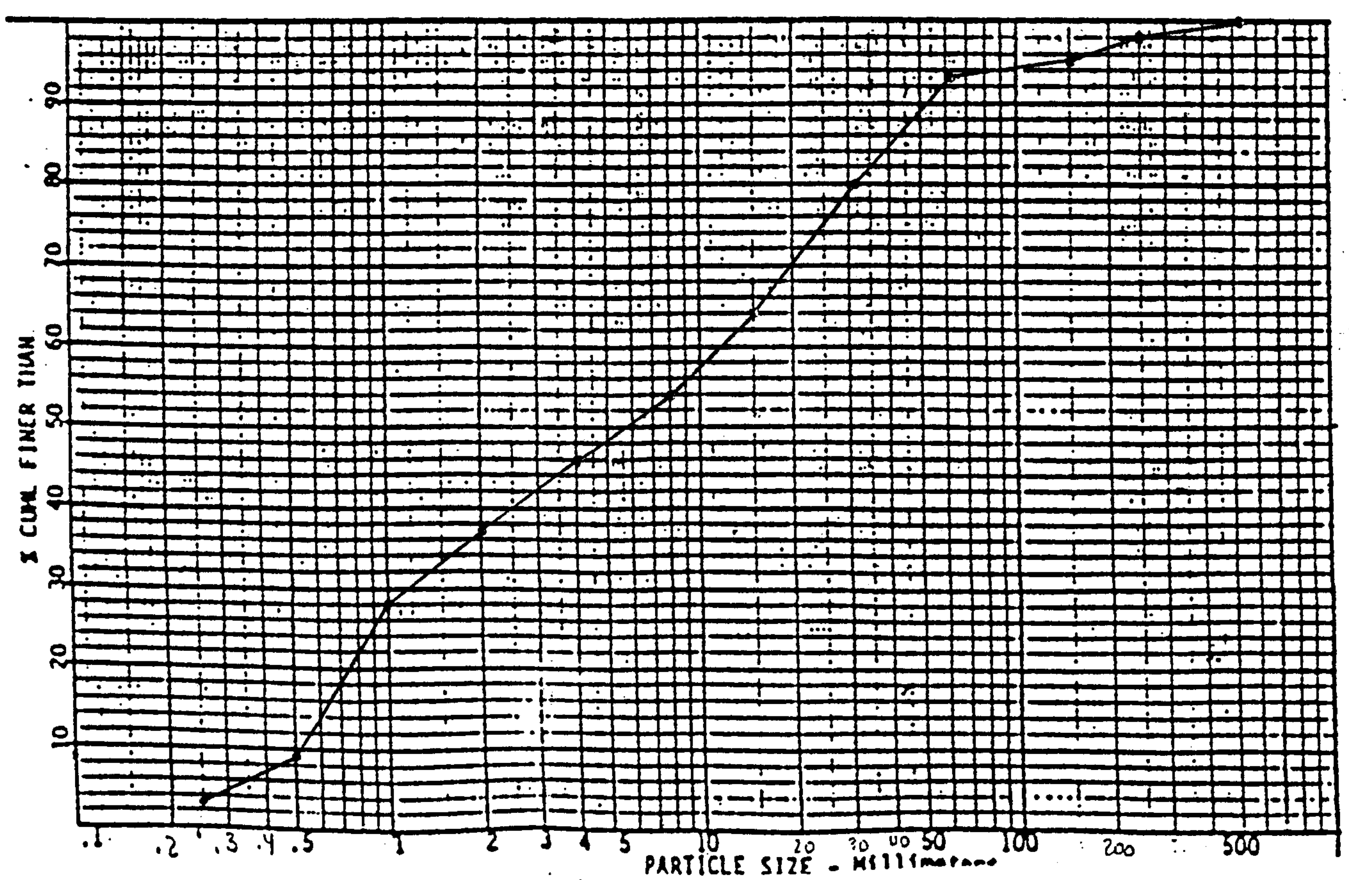
NORTHWEST

PEBBLE COUNT

Date: __/__/__ Party: __________ W d: __________

Site/Reach: REACH 6 (ABOVE REUTER RD. 50-50)

Metric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
Less - .062		SILT/CLAY													
.062 - .125		Vry FINE	SANDS												
.125 - .25		FINE													
.25 - .50		MEDIUM													
.50 - 1.0		COARSE													
1.0 - 2	.04 - .08	Vry CRSE													
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE													
6 - 8	.24 - .31														
8 - 12	.31 - .47	MEDIUM													
12 - 16	.47 - .63														
16 - 24	.63 - .94	COARSE													
24 - 32	.94 - 1.26														
32 - 48	1.26 - 1.9	Vry CRSE													
48 - 64	1.9 - 2.5														
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0														
128 - 192	5.0 - 7.6	LARGE													
192 - 256	7.6 - 10														
256 - 384	10 - 15	SMALL	BOULDERS												
384 - 512	15 - 20														
512 - 1024	20 - 40	MEDIUM													
1024 - 2048	40 - 80	LARGE													
2048 - 4096	80 - 160	Vry LRGE													
Count Note: 3=:· 9=⌧				Totals....				Totals....				Totals....			



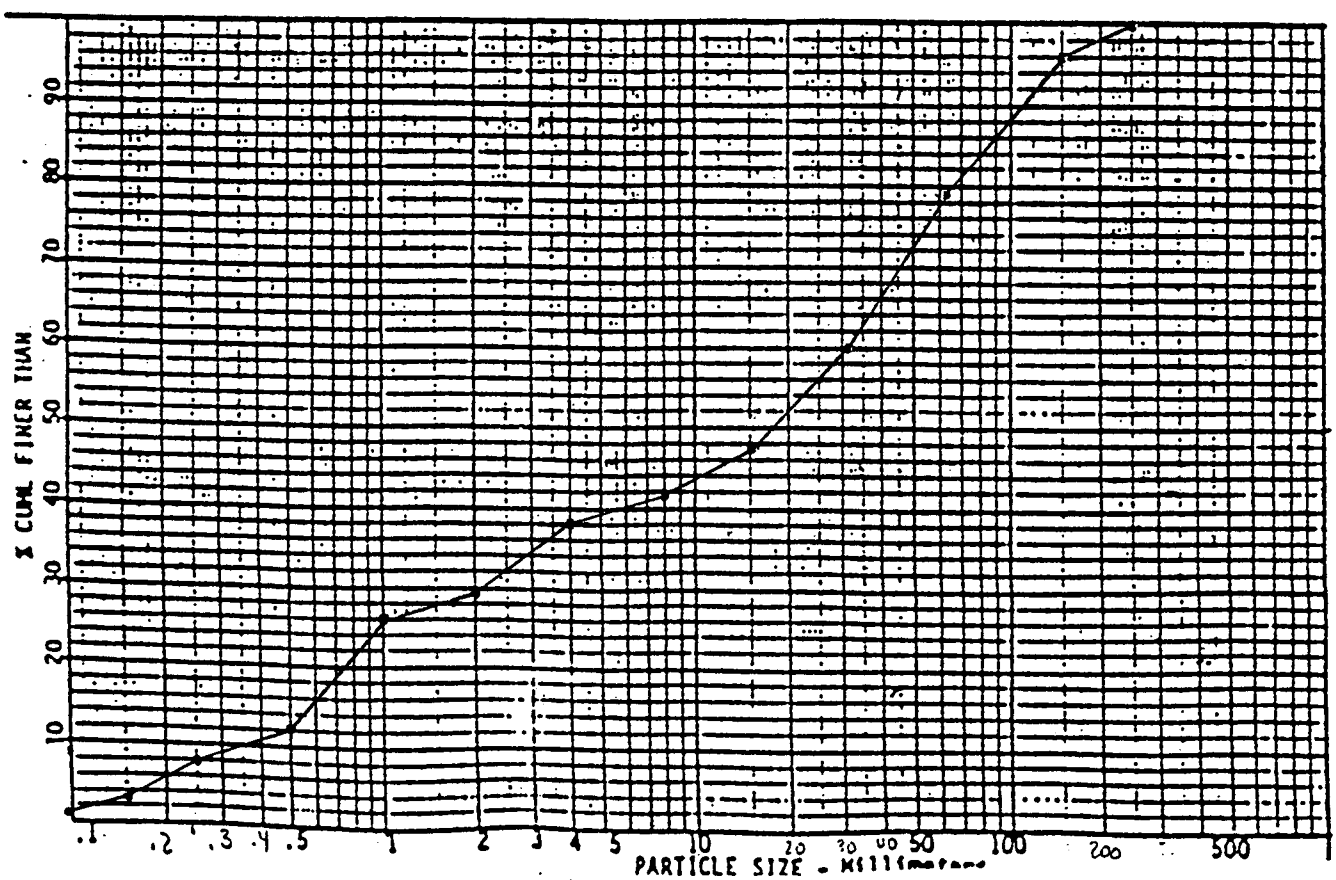
NORTHWEST

PEBBLE COUNT

D. e__/__/__ Party:________ W d:________

Site/Reach: REACH 7 40-60 (BELOW CONFLUENCE)

tric mm	Inches	Particle		Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum	Item Count	Tot#	%Tot	%Cum
ss- .062		SILT/CLAY													
.062- .125		Vry FINE	SANDS												
25- .25		FINE	SANDS												
5 - .50		MEDIUM	SANDS												
.50 - 1.0		COARSE	SANDS												
0 - 2	.04 - .08	Vry CRSE	SANDS												
2 - 4	.08 - .16	Vry FINE	GRAVELS												
4 - 6	.16 - .24	FINE	GRAVELS												
6 - 8	.24 - .31	FINE	GRAVELS												
8 - 12	.31 - .47	MEDIUM	GRAVELS												
12 - 16	.47 - .63	MEDIUM	GRAVELS												
16 - 24	.63 - .94	COARSE	GRAVELS												
24 - 32	.94 - 1.26	COARSE	GRAVELS												
32 - 48	1.26- 1.9	Vry CRSE	GRAVELS												
48 - 64	1.9 - 2.5	Vry CRSE	GRAVELS												
64 - 96	2.5 - 3.8	SMALL	COBBLES												
96 - 128	3.8 - 5.0	SMALL	COBBLES												
28 - 192	5.0 - 7.6	LARGE	COBBLES												
192 - 256	7.6 - 10	LARGE	COBBLES												
256 - 384	10 - 15	SMALL	BOULDERS												
84 - 512	15 - 20	SMALL	BOULDERS												
512 - 1024	20 - 40	MEDIUM	BOULDERS												
1024 - 2048	40 - 80	LARGE	BOULDERS												
48 - 4096	80 - 160	Vry LRGE	BOULDERS												
Count Note: 3=:· 9= ⌘				Totals....				Totals....				Totals....			



NORTHWEST

STREAM BANK EROSION ASSESSMENT

STRE[illegible]BANK EROSION ASSESSMENT

Date: Dec 28 1994
Project Name/Number: Spring Branch
Investigators: SB
Weather/Comments: Fair, 50's - No significant precip for 72 hrs
Stream Segment Location: Main Branch - confluence to Timonium Road + trib @ confluence w/ main channel to hollow brook RD.
Soil Types % of site: ________ Hydric: Yes____ No____
Slope Average: ________

Riparian Vegetation:
1. Rock_____% 2. Bare Soil_____% 3. Annuals/Forbs_____% 4. Perennial Grass_____% 5. Sod Grass_____% 6. Low Brush_____% 7. High Brush_____% 8. Conifer Trees_____% 9. Deciduous Trees_____% 10. Wetlands_____% 11. Exposed Root Materials_____%
Adjacent Land Use/Cover Type: ________

Legend:

L - Low Potential
M - Moderate "
H - High "
PS - Particle size
CC - Canopy Closure
BH/BFH - Bank Height/Bankfull Height ratio
BA - Bank Angle
BSP - Bank Surface Protection
SS- Soil Stratification
R - right bank (looking upstream)
L - left bank

Note places for survey re TOB + toe

Distinguish between T.O.B & Toe erosion

ADD photo locations to map (ALT / EX COND)

Location	Bh/Bfh	BA	BSP	SS	PS	CC	COMMENTS
△24-△25 L	5'/6"	M-H	H-M	M-H	H	10-30%	50% - variable CC
△24-△25 R	8'/6"	M-H	H-M	M-H	H	10%	top bank - very open good for bio eng
△25-△26 L	4.5/5-6'	H	H	H	H	50%	
" " R	1.5-2'/6"	M-H	L-M	M-H	H	50	60% > actively [illegible] look @ class [illegible]
△26-△27 R	2'/6"	L-M	L-M	M-H	H	30"	some isolated areas of higher erosion
" " L	4-5'/6"	M-H	M-H	M-H	H	30	
△27-28 R	1-2'/6"	L	L	L	L	10-30	bedrock, [illegible], willow
" " L	3-5'/6"	H-L	H-L	L	H	30-70	
△28-29 L	2-3'/6"	L-M	L	M-H	M-H	30-70	
" " R	2-3'/6"	L-M	L-M	M	M	40	
△29-30-L	5-6'/6"	M-H	M-H	M-H	H	20	1/2 of reach is bad rating - are 1/2 is low ero for high E
" " R	5'/6"	M-H	H	M	H	10	top of bank erosion
△30-31-L	4-5'	M-H	M	M	H	30	Some bedrock
" " R	"	"	"	"	"	"	~~Some rip~~
△31-32 L	2-5'/6"	L-M	L-M			50-70	rip-rap (random)
" " R	"	L-M	L-M			"	
TRIB confluence to H3	8-9'/5'	M	H	M-H	H	40%	top bank erosion - some rip-rap has been periodically placed
" " " L	5-6'/5'	M	M	M	H	40%	some rip-rap spotty
H3 - Light pole	1.5'/6"	M-H	L-M	*	*	10	actively sloughing @ top
" " " L	"	"	"	"	"	0	
Light pole to Culvert	8'/6"	M	H	H	H	10-70	toe & top bank erosion
	4-5'/6"	L-M	L	M-H	H	70%	near culvert 8'/6" ratings change to: M-H, M-H,

STREAM BANK EROSION ASSESSMENT

Date:______________________________

Project Name/Number:______________________________

Investigators:______________________________

Weather/Comments:______________________________

Stream Segment Location:______________________________

Soil Types % of site:______________________________ Hydric: Yes____ No____

Slope Average:__________________

Riparian Vegetation:

1. Rock_____% 2. Bare Soil_____% 3. Annuals/Forbs_____% 4. Perennial Grass_____% 5. Sod Grass_____% 6. Low Brush_____% 7. High Brush_____% 8. Conifer Trees_____% 9. Deciduous Trees_____% 10. Wetlands_____% 11.

Exposed Root Materials______%

Adjacent Land Use/Cover Type:______________________________

Legend:

L - Low Potential
M - Moderate "
H - High "
PS - Particle size
CC - Canopy Closure

BH/BFH - Bank Height/Bankfull Height ratio
BA - Bank Angle
BSP - Bank Surface Protection
SS- Soil Stratification

top

Location	Bh/Bfh	BA	BSP	SS	PS	CC	COMMENTS
Δ5 - Δ6 L	5'	H	H	L	H	50-60	alternates high & low erosion w/ meanders
" " , R	4'	M-H	M-H	L	H	60	see map - avg measurements
Δ6 - MH toe L	1'/4"	L	L	M	M	50-60	bars
Δ6 - MH R	3'/4'	H	M-H	M-H	M	50	actively undercut
MH - Δ7 L	4'/4"	M-H	H	M-H	H	50	
MH - Δ L R	25'/4"	L	L	~	~	20	
Δ7 L	10'/6"	H	H	M	H	40	bedrock - right near champion beech - overland flow contribut
Δ7 - just above SD	5-10/	M-H	H	M	H	30	
" " R	2-3'/	L	L	M		30	
above SD - Δ8 L	3/4"	L	L	M	M		
" "	2'/6"	M	M-H	H	H	30-40	
Δ8 - Δ9 L	5-6'	M	M	M	H	30	G channel trib enters left side bar top of bank trib is undercut
R	5-6'	M	M	M	H	30	
Δ9 - L							toe severely
L							toe

STREAMBANK EROSION ASSESSMENT

Date:___
Project Name/Number:___
Investigators:___
Weather/Comments:___
Stream Segment Location:___
Soil Types % of site:___ Hydric: Yes___ No___
Slope Average:___
Riparian Vegetation:
1. Rock___% 2. Bare Soil___% 3. Annuals/Forbs___% 4. Perennial Grass___% 5. Sod Grass___% 6. Low Brush___% 7. High Brush___% 8. Conifer Trees___% 9. Deciduous Trees___% 10. Wetlands___% 11. Exposed Root Materials___%
Adjacent Land Use/Cover Type: ___

Legend:

L - Low Potential
M - Moderate "
H - High "
PS - Particle size
CC - Canopy Closure

BH/BFH - Bank Height/Bankfull Height ratio
BA - Bank Angle
BSP - Bank Surface Protection
SS- Soil Stratification

Location	Bh/Bfh	BA	BSP	SS	PS	CC	COMMENTS
confluence — 1st house dow	6-8'/4"	M-H	H	M-H	H	30-40%	
SD - △24 L	10-12'/6"	H	H	M-H	H	30-40%	
SD- △24 R	2'/6"	L	L	M-H	H	10%	only midway to △24 – then doubcut/severe erosion
△1 — 1st house backyard R	6'/4"	H	H	M-H	H	0-10%	
△1 — church Pkg lot L	1'/3-4"	L	L	M-H	H	50	bar
△2 - ~1st house L	4.5'/6"	M-H	H	H	H	50	toe & top of bank ≤ bedrock
" " R	4'/6"	L-M	L-M	H	H	50	bedrock outcrops
1st house - △3 L	2'/6"	L-	L	M-H	H	50	bed rock outcrops
" " R	3'/NA	M-H	M-H	M-H	H	40	bar is active flow bank - old bank top of bank erosion calc what is valid
△3 - Sec 116 L	1-3'/3-4'	L-H	L-H	H	H	50	rather [illegible] because bank heights
" " R	1-3'/"	"	"	"	"	"	
114 - △4 L	1'/6"	L	L	M-H	M	40	
" " R	"	L	L	M-H	M	40	eroding face of midchannel bar
△4 - MH R	1-2'/6"	L	L	M	M+	50	
△" " L	2-3'	L-M	L-M	M	M+	50	
MH - △5 R	3'/6"	L-	L	M	M	40-50	bar material build up behind MH & bank scour here
MH - △5 L	4'/6"	H	H	M	M	40-50	[illegible] for high E portion

94001.01
EX COND TECH

STREAM BANK EROSION ASSESSMENT

Date: 12/20/94
Project Name/Number: 94001.01
Investigators: SYB
Weather/Comments: Clear 40's - no precip past 72 hrs
Stream Segment Location: Reuter - Eastridge, above Reuter
Soil Types % of site: ______ Hydric: Yes___ No___
Slope Average: ______
Riparian Vegetation:
1. Rock___% 2. Bare Soil___% 3. Annuals/Forbs___% 4. Perennial Grass___% 5. Sod Grass___% 6. Low Brush___% 7. High Brush___% 8. Conifer Trees___% 9. Deciduous Trees___% 10. Wetlands___% 11.
Exposed Root Materials___%
Adjacent Land Use/Cover Type: ______

Legend:

L - Low Potential
M - Moderate "
H - High "
PS - Particle size
CC - Canopy Closure

BH/BFH - Bank Height/Bankfull Height ratio
BA - Bank Angle
BSP - Bank Surface Protection
SS- Soil Stratification

total veg - use soil survey

Location	Bh/Bfh	BA	BSP	SS	PS	CC	COMMENTS
R42-41 Eastridge-Reuter	2'/7"	L	L	*	*	<30%	
R-T41-40	6'/8"	H	H	H	H	10%	Severely eroded
L-T42-41	5'/	L	L	L	*	0%	concrete
L-T41-40	2-3/7"	M	M	L	H	30%	
Reuter ↑ L - 2nd house	5-6'/6"	M	M-L	M	H	10%	some rip-rap - up to culvert to 2nd house
Reuter ↑R - 2nd house	5-6/6"	L-M	L-M	M	H	30%	
Reuter ↑L 2-7	1.5'/5"	L	L	M	H	50%	old & new bars
Reuter ↑R2	2-3/6"	L	L	M	H	30-50	open area behind house in Reuter
△38-36 R	7'/6-8'	M-L	M-L	M	H	10-30	very clear order! alternating terraces
△38-36 L	3-4/6-8'	L	L-M	L-M	M	30-40%	
△36 - up 4 houses L	7-8'/8'	M	M-H	M	M-H	30-40%	
△36 - up 4 houses R	6'/8"	M	M	M	M	10-30	
last location to △35 - L	8'/8"	H	M-H	M-H	H	30%	
" " R	3'/6'/8½"	L/M	L/M-H	M-H	H	30%-40%	probably a morph change of this
△35 - SD R	5'/½"	M-H	M-H	M-H	H	30-40	
△35 - SD L	12'/6-8'	M-H	H	M-H	H	30	
SDL-SDR R							top of bank is severely eroded bare-face slopes
SDL-SDR - L							

SD = Storm drain

RAINFALL DATA

TOWSON

STATION (Climatological) (River Station, if different)	MONTH	19	WS FORM B-91 (7-89)
Environmental Technologies Group	3	94	U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL WEATHER SERVICE
STATE: Maryland — COUNTY: Baltimore	RIVER		
TIME (local) OF OBSERVATION RIVER — TEMP. — PRECIPITATION	STANDARD TIME IN USE		
TYPE OF RIVER GAGE — ELEVATION OF RIVER GAGE ZERO Ft. — FLOOD STAGE Ft.	NORMAL POOL STAGE Ft.		

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

TEMPERATURE F. (24 HRS. ENDING AT OBSERVATION) — PRECIPITATION (24-HR AMOUNTS; At Ob.) — Draw a straight line (——) through hours precipitation was observed, and a waved line (~~~) through hours precipitation probably occurred unobserved. A.M. NOON P.M. — WEATHER (Calendar Day): Mark 'X' for all types occurring each day. — RIVER STAGE — REMARKS (Special observations, etc.)

DATE	MAX.	MIN.	AT OBSN.	Rain, melted snow, etc. (Ins. and hundredths)	Snow, ice pellets (ins. and tenths)	Snow, ice pellets, hail, ice on ground (ins.)	Fog	Ice Pellets	Glaze	Thunder	Hail	Damaging Winds	Time of observation if different from above	CONDITION	GAGE READING AT ___ A.M.	TENDENCY	REMARKS
1	29	33	31	.09	M	M											[illegible]
2	33	18	33	.49	M												[illegible] Sgt.
3	39	36	38	.12	M												[illegible]
4	49	21	44	.68		M											
5	48	28	45	.13		0											[illegible] Officer
6	48	42	44	0.15													[illegible]
7	61	26	59	0.15													[illegible] Sgt.
8	58	26	44	0.06													[illegible] Sgt.
9	44	27	31	.07													[illegible] Sgt.
10	46	42	43	.14													[illegible]
11	44	30	42	.55													[illegible] Sgt.
12	48	26	44	.05													[illegible] Soper, Officer
13	59	39	49	.01													[illegible], Officer
14	59	49	50	.00													[illegible]
15	57	48	51	.00													[illegible] Sgt.
16	32	59	33	.00													[illegible]
17	39	35	37	0													S/O [illegible]
18	[illegible]8	36	38	.05													
19	49	40	36	.04													Officer [illegible]
20	58	49	57	.00													Officer [illegible]
21	59	56	58	.16													Off. [illegible]
22				*													
23				*													
24	79	46	68	V.14													
25	68	46	50	.30													[illegible] Sgt.
26	51	31	45	.50													[illegible] Officer
27				*													
28	52	37	47	V1.04													[illegible] Sgt.
29	52	47	49	0.59													[illegible]
30	53	34	50	0.05													[illegible]
31	58	51	57	0.06													[illegible]
SUM			SUM														

CHECK BAR (For wire-weight) NORMAL CK. BAR — READING — DATE

OBSERVER

SUPERVISING OFFICE

STATION INDEX NO 18 8877 6

CONDITION OF RIVER AT GAGE

A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage
F. Shore ice.
G. Floating ice.
H. Pool stage.

Punched 77690

TOWSON

X

WS FORM B-91
(7-89)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATION (Climatological) (River Station, if different): ENVIRONMENTAL TECHNOLOGIES GROUP
MONTH: 4 19 94
STATE: MARYLAND
COUNTY: BALTIMORE
RIVER:
TIME (local) OF OBSERVATION RIVER: ~~1730~~ 18→
TEMP.: —
PRECIPITATION: —
STANDARD TIME IN USE: EST/DST
TYPE OF RIVER GAGE:
ELEVATION OF RIVER GAGE ZERO: Ft.
FLOOD STAGE: Ft.
NORMAL POOL STAGE: Ft.

DATE	TEMPERATURE F. 24 HRS. ENDING AT OBSERVATION MAX.	MIN.	AT OBSN.	PRECIPITATION 24-HR AMOUNTS Rain, melted snow, etc. (ins. and hundredths)	Snow, ice pellets, (ins. and tenths)	At Ob. Snow, ice pellets, hail, ice on ground (ins.)	WEATHER	RIVER STAGE	REMARKS (Special observations, etc.)
1	57	58	60	Ø					[illegible]
2	62	49	52	.05					[illegible]
3									[illegible]
4	73	38	59	.05					[illegible]
5	68	67	65	.Ø					[illegible]
6	67	44	64	.67					[illegible]
7	61	45	52	.20					[illegible]
8	57	33	35	.Ø					[illegible]
9	55	51	49	.01					Officer [illegible]
10	105	38	63	.81					Officer [illegible]
11	65	44	58	.17					[illegible]
12	59	44	51	.02					[illegible]
13	68	67	46	.38					[illegible]
14	77	46	73	.15					[illegible]
15	[illegible]	[illegible]	[illegible]	.15					[illegible]
16	80	63	64	.15					OFFICER JOHN A DRAPER
17	80	63	75	.19					OFFICER JOHN A DRAPER
18	80	41	42	Ø					[illegible]
19	83	42	82	1.0					[illegible]
20	83	68	66	Ø					[illegible]
21	68	49	64	0					[illegible]
22	[illegible]	[illegible]	[illegible]	0					
23	95	50	66	0					Officer [illegible]
24	80	40	77	0					Officer [illegible]
25	67	58	55	0					[illegible]
26	66	59	80	0					[illegible]
27	82	51	76	0.09					[illegible]
28	75	53	72	0					[illegible]
29	78	62	64	0					[illegible]
30	75	54	72	0.1					Officer [illegible]
31									
SUM			SUM						

WEATHER (Calendar Day): Mark 'X' for all types occurring each day. Fog | Ice Pellets | Glaze | Thunder | Hail | Damaging Winds

Time of observation if different from above

RIVER STAGE: CONDITION | GAGE READING AT ___ A.M. | TENDENCY

PRECIPITATION: Draw a straight line (——) through hours precipitation was observed, and a waved line (〰) through hours precipitation probably occurred unobserved. A.M. 1 2 3 4 5 6 7 8 9 10 11 NOON P.M. 1 2 3 4 5 6 7 8 9 10 11

CHECK BAR (For wire-weight) NORMAL CK. BAR
READING | DATE

CONDITION OF RIVER AT GAGE

A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage
F. Shore ice.
G. Floating ice.
H. Pool stage.

OBSERVER

SUPERVISING OFFICE

STATION INDEX NO. 18 8877 6

TOWSON

WS FORM B-91
(7-89)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATION (Climatological): ENVIRONMENTAL TECHNOLOGIES GROUP, INC. (River Station, if different)
MONTH: 5 19 94
STATE: MARYLAND COUNTY: BALTIMORE RIVER:
TIME (local) OF OBSERVATION RIVER: ~~1730~~ 18 TEMP. – PRECIPITATION – STANDARD TIME IN USE: DST
TYPE OF RIVER GAGE: ELEVATION OF RIVER GAGE ZERO: Ft. FLOOD STAGE: Ft. NORMAL POOL STAGE: Ft.

DATE	TEMPERATURE F. 24 HRS. ENDING AT OBSERVATION MAX.	MIN.	AT OBSN.	PRECIPITATION 24-HR AMOUNTS Rain, melted snow, etc. (ins. and hundredths)	Snow, ice pellets (ins. and tenths)	At Ob. Snow, ice pellets, hail, ice on ground (ins.)	WEATHER (Calendar Day) Fog	Ice Pellets	Glaze	Thunder	Hail	Damaging Winds	Time of observation if different from above	RIVER STAGE CONDITION	GAGE READING AT ___ A.M.	TENDENCY	REMARKS (Special observations, etc.)
1																	
2	65	41	61														Sgt. [illegible]
3	62	45	60	0													S/o Mitchell
4	59	48	51	.60													S/o Mitchell
5	72	48	71	0.13													
6	74	45	70	0													
7	71	43	50	1.30													
8	71	49	58	0.86													
9																	
10	74	52	68	1.60													Sgt. [illegible]
11	74	49	71	0.00													Sgt. [illegible]
12	73	54	61	0.35													Sgt. [illegible]
13	68	42	67	0.01													Sgt. [illegible]
14	72	41	69	.01													[illegible]
15	83	52	78	.01													Pt Fire [illegible]
16	85	65	70	.70													Sgt. [illegible]
17	70	54	63	0													S/o Mitchell
18	70	46	60	.03													S/o White
19	62	46	56	.03													Sgt. [illegible]
20	56	46	57	.00													S/o White
21	77	42	77	.12													S/o White
22	84	42	84	.00													S/o White
23	90	42	88	.00													Sgt. [illegible]
24	59	41	53	.00													Sgt. [illegible]
25	58	42	65	1.00													Sgt. [illegible]
26	82	38	65	0.05													S/o Kelvin D. Collins
27	66	38	65	0.55													S/o Kelvin D. Collins
28	70	37	70	0.00													S/o Kelvin D. Collins
29	78	37	76	0.00													S/o Kelvin D. Collins
30																	
31	56	36	50	0.0													Sgt. [illegible]
SUM			SUM				Fog	Ice Pel.	Glaze	Thund.	Hail	Dam. Winds					

PRECIPITATION: Draw a straight line (——) through hours precipitation was observed, and a waved line (~~~) through hours precipitation probably occurred unobserved. A.M. 1 2 3 4 5 6 7 8 9 10 11 NOON P.M. 1 2 3 4 5 6 7 8 9 10 11

CHECK BAR (For wire-weight) NORMAL CK. BAR
READING | DATE

CONDITION OF RIVER AT GAGE
A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage
F. Shore ice.
G. Floating ice.
H. Pool stage.

OBSERVER

SUPERVISING OFFICE

STATION INDEX NO
18 8877 6

TOWSON

STATION (Climatological) (River Station, if different)	MONTH	19	WS FORM B-91 (7-89)
Environmental Technologies Group	June	94	

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATE	COUNTY	RIVER
Maryland	Balt'more County	

TIME (local) OF OBSERVATION RIVER	TEMP.	PRECIPITATION	STANDARD TIME IN USE
5 PM	5 PM		E

TYPE OF RIVER GAGE	ELEVATION OF RIVER GAGE ZERO	FLOOD STAGE	NORMAL POOL STAGE
—	— Ft.	— Ft.	— Ft.

TEMPERATURE F. — 24 HRS. ENDING AT OBSERVATION

PRECIPITATION — 24-HR AMOUNTS / At Ob. — Draw a straight line (——) through hours precipitation was observed, and a waved line (~~~~) through hours precipitation probably occurred unobserved. A.M. NOON P.M.

WEATHER (Calendar Day) — Mark 'X' for all types occurring each day.

DATE	MAX.	MIN.	AT OBSN.	Rain, melted snow, etc. (ins. and hundredths)	Snow, ice pellets, (ins. and tenths)	Snow, ice pellets, hail, ice on ground (ins.)	Fog	Ice Pellets	Glaze	Thunder	Hail	Damaging Winds	Time of observation if different from above	CONDITION	GAGE READING AT ___ A.M.	TENDENCY	REMARKS (Special observations, etc.,)
1	56	50	72	0.0													Sgt. [illegible]
2	87	55	71	0.0													Sgt. [illegible]
3	78	49	77	0.0													Sgt. [illegible]
4	82	76	78	0.0													S/O Kelvin D. Collins
5	80	75	77	0.0													S/O White
6	86	52	83	0.0													Sgt. [illegible]
7	92	53	91	0.0													Sgt. [illegible]
8	79	72	75	0.0													S/O Kelvin D. Collins
9	78	51	78	0.0													Sgt. [illegible]
10	86	53	83	0.0													Sgt. [illegible]
11	82	54	67	.14													S/O White
12	84°	55	84°	.02													S/O White
13	90	56	88	0.0													Sgt. [illegible]
14	95	91	93	0													S/O [illegible]
15	97	56	91	0													Sgt. [illegible]
16	93	78	86	0.10													Sgt. [illegible]
17	88°	55	85	00													S/O White
18	[illegible]	[illegible]	[illegible]	[illegible]													
19	90	55	89	0.0													Office Snyder
20	96	81	87	00													S/O White [illegible]
21	90	73	90	0.0													Sgt. [illegible]
22	90°	86°	88°	0.18													S/O Kelvin D. Collins
23	89°	71°	88°	.01													S/O White [illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]													
25	90	80	83	.09													Office Snyder
26	90	80	85	.08													Office Snyder
27	91	70	82	.108													Sgt. [illegible]
28	85	66	84	.09													Sgt. [illegible]
29	89	66	87	.02													S/O White
30	88°	70°	74°	0.30													S/O Kelvin D. Collins
31																	
SUM			SUM				Fog	Ice Pel.	Glaze	Thund.	Hail	Dam. Winds					

CHECK BAR (For wire-weight) NORMAL CK. BAR

READING	DATE

OBSERVER

SUPERVISING OFFICE

STATION INDEX NO. 18 8877 6

CONDITION OF RIVER AT GAGE

A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage
F. Shore ice.
G. Floating ice.
H. Pool stage.

WS FORM B-91
(7-89)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

TOWSON

OR X

STATION (Climatological): Environmental Technologies Group (River Station, if different)
MONTH: July 19 94
STATE: Maryland
COUNTY: Baltimore County
RIVER:
TIME (local) OF OBSERVATION RIVER: 5 P.M
TEMP.: 5 PM
PRECIPITATION: 17
STANDARD TIME IN USE: D/S
TYPE OF RIVER GAGE: —
ELEVATION OF RIVER GAGE ZERO: Ft.
FLOOD STAGE: — Ft.
NORMAL POOL STAGE: — Ft.

DATE	TEMPERATURE F. 24 HRS. ENDING AT OBSERVATION MAX.	MIN.	AT OBSN.	PRECIPITATION 24-HR AMOUNTS Rain, melted snow, etc. (ins. and hundredths)	Snow, ice pellets (ins. and tenths)	At Ob. Snow, ice pellets, hail, ice on ground (ins.)	WEATHER (Calendar Day) Fog	Ice Pellets	Glaze	Thunder	Hail	Damaging Winds	Time of observation if different from above	RIVER STAGE CONDITION	GAGE READING AT — A.M.	TENDENCY	REMARKS (Special observations, etc.)
1	55	65	55	0.0													Sgt. [illegible]
2	90	89	90	0.0													S/O Shelby
3	78°	76	77	0.0													S/O Shelby
4	86	84	85	.11													S/O Shelby
5	55	66	86	.09													Sgt. [illegible]
6	95°	89°	92°	0.0													S/O Kelvin D. Collins
7	93	67	90	0.03													Sgt. [illegible]
8	96	69	96	.04													S/O White, Jason
9	92	90	91	.02													S/O Shelby
10	88	86	87	.03													S/O Shelby
11	88	62	81	0.00													Sgt. [illegible]
12	58	62	57	0.00													Sgt. [illegible]
13	94°	89°	92°	0.00													S/O Kelvin D. Collins
14	92	86°	89	.00													S/O White
15	92	65	91	.52													S/O White
16	88	85	87	.05													S/O Shelby
17	88	73	75	.03													S/O Shelby
18	87°	81°	84°	0.12													S/O Kelvin D. Collins
19	80	67	88	.10													S. White
20	89°	78°	91°	0.0													S/O Kelvin D. Collins
21	92°	75°	78°	1.45													S/O Kelvin D. Collins
22	89	69	88	.00													S/O White
23	88	81	82	.21													S/O Shelby
24	90	86	88	.21													S/O Shelby
25	90°	71°	75°	0.31													S/O Kelvin D. Collins
26	85	66	73	.10													S/O White
27	80°	76°	79°	0.10													S/O Kelvin D. Collins
28	79	64	77	.89													S/O White
29	85	64	81	.0													Sgt. [illegible]
30	86	83	86	.02													S/O Shelby
31	87	80	81	.03													S/O Shelby
SUM			SUM				Fog	Ice Pel.	Glaze	Thund.	Hail	Dam. Winds					

CHECK BAR (For wire-weight) NORMAL CK. BAR

READING	DATE

CONDITION OF RIVER AT GAGE

A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage
F. Shore ice.
G. Floating ice.
H. Pool stage.

OBSERVER

SUPERVISING OFFICE

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— TOWSON

WS FORM B-91 (7-89)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATION (Climatological): ~~ENVIRONMENTAL TECHNOLOGIES GROUP~~ (River Station, if different)
MONTH: AUG. 19 94
STATE: MARYLAND COUNTY: BALTIMORE CO. RIVER:
TIME (local) OF OBSERVATION RIVER: 1700 HRS TEMP.: 1700 HRS PRECIPITATION: 1700 HRS STANDARD TIME IN USE: D/S
TYPE OF RIVER GAGE: ELEVATION OF RIVER GAGE ZERO: Ft. FLOOD STAGE: Ft. NORMAL POOL STAGE: Ft.

DATE	TEMPERATURE F. 24 HRS. ENDING AT OBSERVATION MAX.	MIN.	AT OBSN.	PRECIPITATION 24-HR AMOUNTS Rain, melted snow, etc. (ins. and hundredths)	Snow, ice pellets (ins. and tenths)	At Ob. Snow, ice pellets, hail, ice on ground (ins.)	WEATHER	RIVER STAGE	REMARKS (Special observations, etc.)
1	86	64	85	.05					Sgt. Sanders
2	85	65	74	.07					S/O White
3	89	65	85	.05					Sgt. ~~S~~
4	90	65	88	.03					S/O White
5	88	66	71	.22					Sgt. Sanders
6	97	73	76	.01					S/O Shelby
7	74	75	78	.01					S/O Shelby
8	81	52	[illegible]	.00					S/O White
9	53	52	52	.01					S/O White
10	53	52	52	.00					Sgt. Sanders
11	83	53	81	.00					S/O White
12	85	53	85	.28					
13	91	86	90	.01					S/O Shelby
14	85	82	84	.14					S/O Shelby
15	84	54	75	1.03					S/O White
16	78	54	70	.00					Sgt. Sanders
17	77	54	77	.65					S/O White
18	77	54	71	.15					Sgt. Sanders
19	84	54	81	.01					S/O White
20	85	83	85	.01					S/O Shelby
21	80	69	80	1.5					S/O Shelby
22	80	62	71	2.01					S/O White
23	76	56	76	.00					Sgt. Sanders
24	79	55	78	.00					Sandra Wallace
25	80	78	70	.00					S/- Wallace
26	87	81	84	1.35					S/- Wallace
27	86	83	85	1.35					S/O Shelby
28	86	84	86	1.34					S/O Shelby
29	86	85	75	1.55					S/- Wallace
30	79	56	77	1.54					S/O White
31	65	80	82	.00					S/- Wallace
SUM			SUM						

PRECIPITATION: Draw a straight line (——) through hours precipitation was observed, and a waved line (〰) through hours precipitation probably occurred unobserved. A.M. NOON P.M. 1 2 3 4 5 6 7 8 9 10 11

WEATHER (Calendar Day): Mark 'X' for all types occurring each day. Fog, Ice Pellets, Glaze, Thunder, Hail, Damaging Winds. Time of observation if different from above.

RIVER STAGE: CONDITION, GAGE READING AT ___ A.M., TENDENCY

CHECK BAR (For wire-weight) NORMAL CK. BAR
READING | DATE

CONDITION OF RIVER AT GAGE
A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage
F. Shore ice.
G. Floating ice.
H. Pool stage.

OBSERVER

SUPERVISING OFFICE

STATION INDEX NO. 18 8877 6

(Towson)

WS FORM B-91 (7-89)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATION (Climatological): Environmental Technologies Group Inc (River Station, if different)
MONTH: Sept. 19 94
STATE: Maryland
COUNTY: Baltimore Co.
RIVER:
TIME (local) OF OBSERVATION RIVER: 1700 Hrs.
TEMP.: 1700 Hrs
PRECIPITATION: 1700 Hrs.
STANDARD TIME IN USE: D/S
TYPE OF RIVER GAGE:
ELEVATION OF RIVER GAGE ZERO: Ft.
FLOOD STAGE: Ft.
NORMAL POOL STAGE: Ft.

TEMPERATURE F. (24 HRS. ENDING AT OBSERVATION) · PRECIPITATION (24-HR AMOUNTS; At Ob.) · WEATHER (Calendar Day): Mark 'X' for all types occurring each day. · RIVER STAGE

Draw a straight line (——) through hours precipitation was observed, and a waved line (~~~) through hours precipitation probably occurred unobserved. (A.M. 1–11, NOON, P.M. 1–11)

DATE	MAX.	MIN.	AT OBSN.	Rain, melted snow, etc. (ins. and hundredths)	Snow, ice pellets, (ins. and tenths)	Snow, ice pellets, hail, ice on ground (ins.)	Fog	Ice Pellets	Glaze	Thunder	Hail	Damaging Winds	Time of observation if different from above	CONDITION	GAGE READING AT ___ A.M.	TENDENCY	REMARKS (Special observations, etc.)
1	83	71	74	00													S/ Wallace
2	75	69	70	00													S/ Wallace
3	75	54	69	03													Officer Sonya Draper
4	75	57	67	03													Officer Sonya Draper
5	74	52	71	.03													Lt. Jonathan Sanders
6	78	73	75	00													S/ Wallace
7	80	75	78	00													S/ Wallace
8	81	60	78	.03													[illegible]
9	83	70	73	.02													S/O [illegible]
10	79	76	78	0.0													S/O Shelby
11	75	70	74	0.0													S/O Shelby
12	76	73	75	0.0													S/O White
13	85	82	84	0.0													S/ Wallace
14	89	84	87	0.0													Lt. [illegible]
15	87	77	80	.06													S/O White
16	81°	78°	80°	.07													S/O Kelvin D. Collins
17	82	75	80	.02													Officer [illegible]
18	70	61	66	.14													Officer [illegible]
19	76	51	76	.13													Lt. [illegible]
20	78°	74°	76°	.02													S/O Kelvin D. Collins
21	78	70	80	00													S/ Wallace
22	78°	71	76°	.15													S/O Kelvin D. Collins
23	[illegible]	58	68	1.70													Lt. Jonathan Sanders
24	71	69	70	.02													S/O Shelby
25	78	75	77	.01													S/O Shelby
26	78	63	75	.19													S/O White
27	78	56	69	.65													S/O White
28	80	65	65	0.60													S/ Wallace
29	70°	65°	68°	0.87													S/O Kelvin D. Collins
30	75°	52°	76°	0.10													S/O Kelvin D. Collins
31																	
SUM			SUM														

CHECK BAR (For wire-weight) NORMAL CK. BAR — READING | DATE

CONDITION OF RIVER AT GAGE
A. Obstructed by rough ice.
B. Frozen, but open at gage.
C. Upper surface of smooth ice.
D. Ice gorge above gage.
E. Ice gorge below gage
F. Shore ice.
G. Floating ice.
H. Pool stage.

OBSERVER

SUPERVISING OFFICE

STATION INDEX NO. 18 8877 6

BALTIMORE COUNTY MARYLAND

LOWER SPRING BRANCH

Concept Report

MAY 2006

Biohabitats
Incorporated

LOWER SPRING BRANCH

Concept Report

May 2006

Prepared For:

Baltimore County Department of Environmental Protection and Resource Management
401 Bosley Avenue
Towson, MD 21204

Prepared by:

Biohabitats, Inc.
The Stables Building
2081 Clipper Park Road
Baltimore, MD 21211

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APPENDICES

1.0 INTRODUCTION

Spring Branch is a headwater stream that originates south of Padonia Road in Timonium and flows generally southeast to Loch Raven Reservoir. It is one of several tributaries that feed Loch Raven Reservoir, which is an impounded section of the Gunpowder River. In 1993 Biohabitats was contracted by Baltimore County DEPRM to design and oversee the restoration of the section of Spring Branch between Killoran Road and Pot Spring Road. The construction of the upper section of Spring Branch was completed in 1996.

The Lower Spring Branch project study area is located between Pot Spring Road and Dulaney Valley Road and has been described in detail in the *Lower Spring Branch Preliminary Assessment and Analysis Report* (Biohabitats, Inc. December 2005). The preliminary assessment report includes description of the study area, preliminary hydrologic and hydraulic analyses, and a range of potential alternatives to restore this impacted stream. The report found that the Lower Spring Branch channel suffers from impacts associated with concrete armoring and development within the watershed. These impacts include, fish blockages, riparian clearing, and severe bank erosion and meander migration associated with heightened storm flows. To correct these impacts and restore Lower Spring Branch, the Baltimore County Department of Environmental Protection and Resource Management (DEPRM) has approved the suggested preferred restoration alternative from the preliminary assessment report and requested further development of the preferred alternative into a restoration concept design. The preferred alternative included removing all of the concrete channel armoring within the project limits, minor remeandering of the channel, raising the bed elevation in specific areas, and regrading a floodplain bench and providing bank stabilization.

Here we present the Lower Spring Branch Concept Report. This document and the accompanying Concept Plans have been completed to provide DEPRM with the rationale and general framework for the design of the Lower Spring Branch restoration. This report describes the methods, field activities and results of the geomorphologic assessment of the study area and reference reaches, base flow and bankfull discharge calculations, hydrologic and hydraulic analyses, wetland delineation, and soil samples. Using this data we have begun the 30% concept design for the stream. Within the attached initial concept we have provided

- the survey baseline
- proposed stream planform alignment
- location of cross sections
- location of restoration measures
- location of wetlands
- approximate location of existing utilities
- property information
- typical details (cross sections and treatments)

In this design we will capitalize on opportunities to create a stable, more natural channel and riparian corridor, as well as in-stream habitat enhancement. In turn, the natural character of the stream will be re-established. This will help improve the quality of life in the surrounding community by providing a natural riparian corridor where a concrete channel and degraded reach currently exist.

2.0 ASSESSMENT APPROACH

Conditions of Lower Spring Branch were documented through field investigation and review of existing documents, electronic files, and aerial photographs pertinent to the study area. This section outlines the approach used to collect data, perform the field survey, and create a preliminary hydrologic and hydraulic model.

2.1 Reach Characteristics

Biohabitats surveyed six representative cross sections using standard land survey techniques. Cross sections were positioned at riffles and typified representative reaches of the channel based upon valley landforms, channel slope, and channel appearance. At each cross section, the local thalweg profile and bankfull elevation were surveyed. In addition, a 100-particle Wolman pebble count was conducted at each cross section to characterize bed material and associated channel roughness (Wolman, 1954). Each pebble count was conducted within the riffle at the chosen cross section. From the survey data, field data, and base map, the following parameters were calculated

- Bankfull width/depth
- Entrenchment
- Channel slope
- Median grain size ("D50")

These parameters and other geomorphologic conditions were analyzed using the system outlined in Rosgen (1994). The Rosgen classification system was used to categorize the stream channel into major, natural channel types. These channel types are determined on the basis of existing morphological features of the stream channel and valley (Table 2.0).

Each stream reach identified in the field was further classified based upon the median particle size of the bed material. Numbers through 6 correspond to different sediment size ranges as follows:

- Bedrock
2 - Boulder
3 - Cobble
4 - Gravel
5 - Sand
6 - Silt

Table 2.1 Rosgen Stream Classification Parameters*

Channel Type	Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Gradient
A	< 1.4	< 12	Low (< 1.2)	4 to 10%
B	1.4 to 2.2	> 12	Moderate (> 1.2)	2 to 4%
C	> 2.2	> 12	Moderate to High (> 1.2)	< 2%
D	N/A	> 40	Very Low (<<1.2)	< 2%
E	> 2.2	< 12	High (> 1.5)	< 2%
F	< 1.4	> 12	Moderate (> 1.2)	< 2%
G	< 1.4	< 12	Moderate (> 1.2)	2 to 4%

*Adapted from Rosgen, 1994 and Rosgen, 1996.

Field measurements taken at each cross section were then compared with the parameters in the Rosgen classification system to determine channel type. The Rosgen classification system generally applies to channels that are in a state of "dynamic equilibrium". It should be noted that Spring Branch is actively adjusting, as evidenced by eroding banks, channel down-cutting, and meander migration. Channel adjustments like those seen in Lower Spring Branch are most often a result of changes in surrounding land use including increased development in a watershed. The increased frequency and volume of floodflows associated with development are able to erode and transport channel bed and bank materials more frequently and in greater volumes. Depending on the interactions between the altered hydrology, sediment supply, and channel materials, net channel adjustments may occur in the form of bed degradation (vertical adjustment in the form of down-cutting or incision), channel widening, and/or lateral adjustment in the channel cross section. Although channel adjustments may be difficult to predict, the channel will ultimately evolve into one of the stable Rosgen stream types of a dimension that is able to withstand the altered sediment and flow regime.

Altered reaches and actively adjusting reaches, are often in transition between Rosgen stream types. For reaches where stream morphology did not match a Rosgen stream type, best professional judgment was used to assign a stream type to indicate direction of change that best reflected stream conditions. Additionally, for stream sections that have been highly modified such as concrete lined reaches, channel morphology does not coincide with a single stream type.

2.2 REFERENCE REACH ASSESSMENT

Reference reaches are control streams with similar physical properties, fewer impacts, and greater stability compared to the reach to be restored. The restoration of Lower Spring Branch required data from key morphologic features of a stable reference reach as an example of attainable stream conditions. Within stable natural channels there are close correlations between all aspects of the channel morphology. Therefore, morphologic relationships derived from stable channels (reference reaches) can be scaled to determine the design parameters of the reach to be restored

Many local channels have the correct slope and valley type and could potentially make good reference reaches for Lower Spring Branch. However, most have suffered the same impacts from development and are in similar degraded condition.

The reference reach search began within the Jones Falls watershed, then moved to the Gunpowder watershed. Two potential reference streams were evaluated outside of the immediate watershed These are the North Branch of Jones Falls, and Baisman Run. Both reaches were deemed to be impacted either by straightening or sedimentation, or not of the appropriate stream or valley type. The focus turned to the Spring Branch watershed with the premise that the constraints posed by private property, utilities, and an altered flow regime will require a stable reference reach located in an impacted watershed. Therefore, a reference reach selected from one of the previously restored reaches upstream of the current study area would make an ideal candidate. Construction of the upstream portion of Spring Branch was completed in 1996. Many of these reaches have developed stable geometry over the past ten years and make excellent analogues for the design of the new channel

Three stable reference reaches were located. The field activities were based on the same standard land survey techniques as in section 2.1 above, where additional survey points were recorded along the longitudinal profile to capture key features including maximum pool depth, pool length, and riffle, run and glide slopes. Along with the riffle cross sections, pool cross sections were also surveyed within in the reference reaches. The collected data were analyzed using the system outlined in Rosgen, (1994) and the key features were used for creating dimensionless ratios that can be scaled to design the typical cross section and profile for each reach (Sections 3.2 and 4.1).

2.3 WATERSHED HYDROLOGY

The peak discharge for the Lower Spring Branch study area watershed was estimated using a combination of GIS software (Arcview 3.2 and ArcGIS 8.3, ESRI, 1999) and standard hydrologic models including, HEC-HMS 3.0 (USACE, 2003), TR-55 (USDA, 1986), TauDEM (Tarboton et al., 2005), and a previous hydrologic model of Spring Branch conducted by Maryland Surveying and Engineering Co., Inc. (MSE) in 1981. Varying type-II 24 hour storm events were used to determine peak discharges for the 1-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year flood events.

The Lower Spring Branch watershed was delineated by interpolating a Digital Elevation Model (DEM) from a 2-foot contour GIS layer provided by Baltimore County using ArcGIS 8.3. The watershed was divided into seven sub-basins by importing the layer into TauDEM and Arcview 8.3 programs and run through preprocessing routines to determine exact watershed and sub-basin boundaries (Figure 2.1).

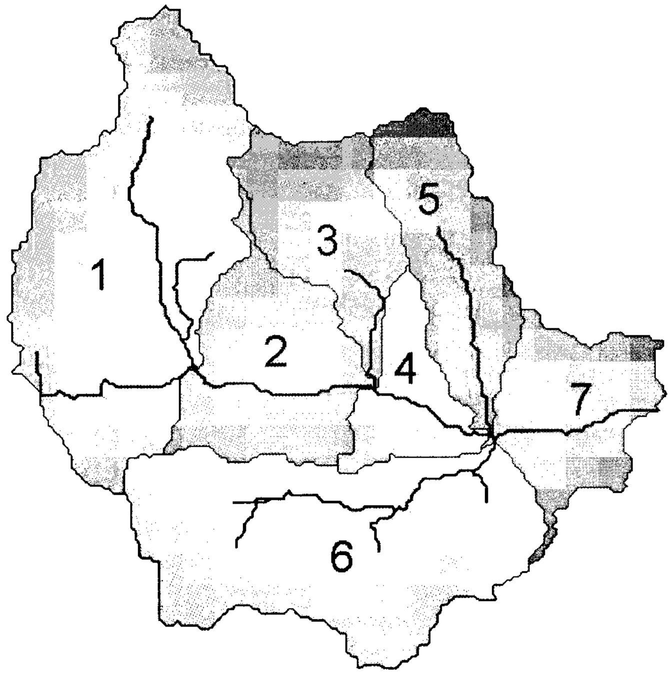

Figure 2.1. Spring Branch Sub-basin Watershed Map.

Runoff curve (CN) numbers and times of concentration (Tc) were obtained from MSE, Inc. (1981). Where the MSE model had 13 sub-basins, the Biohabitats' model contained seven. A weighted average based on area was used to obtain Tc values where multiple subbasins in the MSE model made up a single subbasin in the Biohabitats model.

Slope and reach lengths were obtained from the TauDEM GIS preprocessing routines. For each reach in the study area, Muskingum – Cunge routing method was used and the Soil Conservation Service method was used to model each sub-basin using HEC-HMS.

2.4 BANKFULL DISCHARGE, BACKGROUND AND ESTIMATION

The development of a natural channel design often uses as its foundation a single flow value to provide needed channel capacity while promoting long-term channel stability. The single flow value approach stems from different geomorphic concepts including, *dominant discharge*, *effective discharge*, and bankfull discharge. Many river restoration designs have drawn from the concept of a *dominant discharge*—a steady flow value that would theoretically form the same channel size and shape as the full range of natural flow magnitudes and frequencies experienced by the natural channel (Doyle et al. 1999).

The *effective discharge*, or the discharge that over time transports most sediment, has been increasingly used as a measurable and defensible approach to identifying a single-value flow that does the majority of geomorphic work. The effective discharge corresponds to the peak volume of sediment transported, such that effective discharge is the maximum possible product of the frequency of flow occurrence and the amount of sediment transported by a flow event (Wolman and Miller 1960) By coupling detailed flow and sediment transport data, an effective discharge can be calculated and applied to stream restoration design. Furthermore, in temperate climates, effective discharges correlate well with flows of moderate frequency (e.g., 1.5- to 2-year flood event). The results imply that more frequent storms ultimately drive the dominant geomorphic form of alluvial rivers. The effective discharge approach has considerable merit, because it is physically based and accounts for sediment supply.

Wolman and Miller (1960) further suggested that the morphology of alluvial channels adjusts to convey the dominant discharge, thus suggesting that effective discharge will be similar to bankfull discharge for alluvial channels in equilibrium. The identification of bankfull discharge is easily estimated and widely accepted as an alternative to effective discharge calculation Studies have documented significant correlations between the bankfull and effective discharges (Andrews, 1980; Andrews & Nankervis, 1995), as well as one and two order(s) of magnitude discrepancies (Pickup & Warner, 1976; Doyle et al., 1999). Therefore, limitations of the bankfull method must be considered prior to application of results. In addition, ongoing bank erosion and occasional bedrock outcrops obscure bankfull indicators.

During the field activities of Sections 2.1 and 2.2 above, bankfull elevations were identified by Biohabitats personnel at all surveyed cross sections. Since much of the channel is unstable, bankfull indicators were not easily identified in the restoration reach, however, prominent and consistent bankfull indicators were recorded in the reference reaches. Bankfull elevations at all cross sections were derived from all available indications including depositional features, changes in bank angle, vegetation, scour lines and storm debris lines. Bankfull elevations at the concrete reaches were estimated from the observed water elevation during a storm on October 8, 2005. Bankfull discharge was estimated by solving the Manning equation for discharge given the bankfull elevation, local channel geometry, slope, and roughness. Channel roughness, represented by Manning's "n", was approximated using the standard references Chow (1959) and Barnes (1967).

2.5 DESIGN DISCHARGE DETERMINATION

In addition to the field based discharge estimates, bankfull discharges were also estimated using available Baltimore County regression relationships (Baltimore County DEPRM, 1999). Five urban (>20% impervious area) and five rural gages, were used by the County to develop the regressions.

Predicted bankfull discharges were also calculated using regression relationships created by the Maryland Geological Survey (MGS, Carpenter, 1983) and the U.S. Geological Survey (USGS, Dillow, 1996). In addition, bankfull estimates were calculated from a regression relationship created by the U.S. Fish and Wildlife Service (McCandless and Everett, 2002) and another by the USGS and Pennsylvania Department of Environmental Protection (Cinotto, 2003).

2.6 CHANNEL HYDRAULICS

The HEC-RAS model (USACE, 2001) was used to predict resulting water surface elevations along the channel system for flood discharges obtained from the HEC-HMS analysis. Topographic survey provided by Century Engineering, Inc. was used to generate channel geometry using the Hydrologic Engineering Center's Geo-River Analysis System (HEC-GeoRAS, Version 3.1)—an extension designed to process geospatial data for easy import into HEC-RAS. Cross sections were "cut" within HEC Geo-RAS between Pot Spring Road and Dulaney Valley Road along the Mainstem, Tributary A and Tributary B. HEC-GeoRAS was used to generate geometric data input for existing conditions of Lower Spring Branch. The resulting geometry files were then imported into HEC-RAS to run the full hydraulic analysis.

Upon completion of the existing conditions hydraulic model, a proposed conditions model was created by superimposing the design typical cross sections at the appropriate design inverts and tying in the cross sections to existing topography by hand. Comparison of the existing channel condition to the proposed design cross section was used to determine how the project will affect channel hydraulics, and the resulting water surface elevations. Revisions to the proposed cross sections may be necessary through the design process as utilities information further dictates the development of the grading plan

2.7 WETLAND DELINEATION AND RIPARIAN VEGETATION

On November 17, 2005 two Biohabitats personnel experienced in wetland delineations visited the site to evaluate the restoration area for the presence of wetlands, identify riparian vegetation and to collect soil samples for laboratory analysis The wetland delineation and riparian vegetation assessment aids the design process by determining the existing resources that may be impacted by the restoration construction. The plant community along the stream was evaluated for dominance by plants with hydrophytic status of Facultative (FAC), Facultative-Wetland (FACW) and/or Obligate Wetland (OBL) according to Reed (1988). In addition, soils in the project area were evaluated for hydric properties to a depth of 18 inches using a sharpshooter spade. Evidence of wetland hydrology was also evaluated. This evaluation was performed in accordance with the 1987 Army Corps of Engineers Wetlands Delineation Manual (Technical Report 87-1

3.0 EXISTING CONDITIONS

This section contains the results of the geomorphologic classification, reference reach assessment, HEC-HMS model and comparison to past studies and regional regressions, as well as channel hydraulics, wetland delineation and riparian vegetation composition, and soils data. Appendix A contains computational sheets for the surveyed cross sections. Appendix B contains the computational sheets for the reference reach. Appendix C contains the morphological variables recorded at the reference reaches. Appendix D contains the results of the Hydraulic model. Appendix E contains field wetland delineation sheets, and Appendix F contains the computational sheets for the proposed cross sections.

3.1 CHANNEL CLASSIFICATION CHARACTERISTICS

'he qualitative physical attributes of the channel and riparian area within each reach have been described in detail in the *Lower Spring Branch Preliminary Assessment Analysis Report* (Biohabitats, Inc. December, 2005). This section provides a brief descriptive summary of each reach and the results of the morphological assessment and channel classification (Table 3 The results of the morphological assessment from each reach were analyzed according to Rosgen (1994) and each reach was categorized according to stream type. Where stream morphology deviated from the Rosgen stream types best professional judgment was used to assign Rosgen stream types and indicate direction of change that best reflected stream conditions.

Reach 1 is a trapezoidal concrete channel that begins at the downstream side of the Pot Spring Road double box culvert and extends approximately 450 feet to the end of the concrete (Table 3.1). The entrenchment ratio is 2.21 making it "slightly entrenched" and the approximate bankfull width is 21.65 feet (difficult to determine in a concrete channel). This reach was channelized in the early 1970's to accommodate underground sanitary sewer lines and overhead utility lines on the south bank, and residential properties along both banks.

Table 3.1. Summary of Stream Reach Characteristics within Lower Spring Branch.

Reach	Reach Length (ft)	Slope	D50, D84 (mm)	Width/Depth Ratio	Entrenchment	Bankfull Width (ft)	Avg. Bankfull Depth (ft)	Bankfull Area (ft^2)	Rosgen Stream Type	General Conditions
1	450	1.06%	N/A	12.82	2.21	21.65[1]	1.69[1]	36.56[1]	N/A	Concrete trapezoidal channel Riparian area is mostly maintained lawn
Tributary B	100	1.98%	N/A	9.95	3.22	12.31[1]	1.24	15.25	N/A	• Concrete trapezoidal channel • Riparian area is mostly maintained lawn
2	415	1.43%	33.71, 113.21	20.58	1.42	35.72	1.74	61.99	F4	• Large (2.0') drop at upstream end of reach • Evident bank erosion on the north bank • Long cobble riffles and shallow pools
3	650	0.61%	56, 114.29	13.0	1.34	32.71	2.52	82..30	B4c	• Bedrock and boulders prominent in channel • Appears most entrenched with steep banks on both sides of channel
4		0.79%	37.6, 77.71	19.04	2.37	29.15	1.53	44.64	C4	• Bank erosion on most outside meander bends • Substrate changes to coarse gravel, sand, and hardpan • Potential flooding of adjacent homes

Estimated from water surface elevation recorded on 10/8/05.

Reach 2 begins at a shallow plunge pool at the end of the Reach 1 concrete channel and extends approximately 415 feet to where the channel becomes more incised and lined with boulders. This reach has flat, extended riffles with a few shallow pools. Much of the north bank of this reach is a four to six foot eroding vertical wall, while the south bank is more gently sloping. The entrenchment ratio is 1.42 making it "moderately entrenched" and a very high width depth ratio of 20.58. The approximate bankfull width is 35.72 feet (Table 3.1). The channel here is classified as a Rosgen F4 stream type. Rosgen "F" stream types are entrenched, high width/depth ratio channels occurring in gentle terrain. The banks within these reaches are often eroding unless they have been stabilized. The ranges of morphological parameters for this stream type can be reviewed in Table 2.0. These channels have an extreme sensitivity to disturbance, poor natural recovery potential, and very high sediment supply (Rosgen, 1996).

Reach 3 begins where the Spring Branch channel becomes more incised and flows through numerous boulders and bedrock outcrops. This reach is confined by the steep valley slope along the south bank, boulders within the channel, and a sanitary sewer line that runs parallel to, and near the thalweg invert for approximately 90 feet. Large boulders and exposed bedrock outcrops provide stable channel substrate through the mid section of this reach. They also help maintain the deep pools. At the top of the north bank, the riparian area flattens sharply and is composed of a few trees scattered within maintained residential lots. With an entrenchment ratio of 1.34, reach is considered "entrenched" (Table 3.1). The bankfull width is 32.71 feet. The higher entrenchment dictates that it be classified as a Rosgen B4c type channel. This category is reserved for channels that exhibit typical Rosgen "B" characteristics, but with a lower slope (Rosgen, 1994). The sinuosity of "B" channels is usually controlled by the steep valley side slopes. In this case the local confinement and entrenchment from development and utilities is what helps maintain the "B" channel characteristics.

Reach 4 begins where the floodplain and channel widen, the stream begins to meander, and the substrate changes to fine sand, gravel, and small cobble. The reach extends approximately 980 feet to the end of the study area at Dulaney Valley Road (Table 3.1). Both the north and south banks within this reach are vertical and eroding along many of the outside meander bends. Here the channel may be attempting to widen in response to frequent storm flows. Within the channel, there are relatively short, somewhat embedded riffles and larger deep pools (>3ft) with clay and hardpan substrate. The entrenchment ratio is 2.37 making it "slightly entrenched" and the approximate bankfull width is 29.15 feet (Table 3.1). This reach is classified as a Rosgen C4 stream type. The Rosgen "C" type channel is a slightly entrenched, meandering, riffle/pool dominated channel with a well vegetated riparian corridor (Rosgen, 1994). Although this reach lacks the sinuosity typically expressed in a "C" channel, it is only slightly entrenched, and exhibits riffles, pools, and point bars associated with a "C" channel. It is highly likely that if this reach were left untouched, it would expand its beltwidth into a typical "C" channel.

Tributary A enters Spring Branch from the north approximately 200 feet downstream from Pot Spring Road. The area of interest on Tributary A extends from the Chapelwood Lane culvert to the confluence with Spring Branch. The channel is approximately 8 feet wide at the top of bank and has several areas of bank erosion along. It is lined by maintained residential yards on both banks. Although this Tributary is small, it appears to be a perennial stream. Due to time and scope constraints, no formal geomorphic classification was conducted on this reach.

Tributary B enters Spring Branch from the south approximately 340 feet downstream of Pot Spring Road. It is a 14 foot wide (at the top of bank) trapezoidal concrete channel that carries no baseflow much of the year. It was constructed at the same time as the concrete armoring of Spring Branch. The slope within the downstream 100 feet of this reach is nearly 2% (Table 3.1). The entrenchment ratio is 3.22 making it "slightly entrenched" and the approximate bankfull width is 12.31 feet (difficult to determine in a concrete channel). This concrete channel does not appropriately fit into a Rosgen stream type.

REFERENCE REACH DATA

Three reference reaches were identified in the previously restored reach of Spring Branch and their geomorphic variables were measured. Reference Reach A is located downstream of Cinder Road and has a slope 1.1% (Table 3.2). Reference Reach B is located upstream of Pot Spring Road and reference Reach C is located downstream of Eastridge Road. Their slopes are 2.1% and 0.77%, respectively.

Table 3.2. Evaluated Reference Reaches.

Evaluated Stream	Location	Slope	Stream Condition
Spring Branch Reach A	Downstream of Cinder Road	1.1%	Stable C morphology with stable steps, riffles, and pools
Spring Branch Reach B	Upstream of Pot Spring Road	2.1%	Stable B morphology with stable steps, riffles, and pools
Spring Branch Reach C	Downstream of Eastridge Road	0.77%	Stable Bc morphology with stable steps, riffles, and pools

Dimensionless ratios for the three Reference reaches were computed from the geomorphic data collected and presented in Appendix B. The ratios of relevance have been separated according to specific channel features and will be used for designing the typical cross sections and profile of each reach (Table 3.3). The primary dimensionless ratios of interest in developing cross sections are width to mean depth ratio and entrenchment ratio. Using these ratios as limiting factors for the design cross section ensures that channel dimensions are preserved between the reference and design reaches. Ratios were not developed for meander pattern or sinuosity. The constraints imposed by existing utilities and easements preclude designing a natural meander pattern. Where curves are proposed in the channel, their radii have been approximated using the proposed bankfull width according to the formula: Radius of Curvature = 2.5-3.2*Bankfull Width (Leopold, 1994).

Table 3.3. Dimensionless Ratios Derived from Each Reference Reach.

Ratio	Reference Reach A	Reference Reach B	Reference Reach C
Rosgen Classification	C	B	Bc
Riffle Cross section			
Width to mean depth (W_{Bkf}/ d)	26.5	17	14.5
Entrenchment ratio ($W_{2*Bkf\ max}$ / W_{Bkf})	1.8	1.9	1.6
Pool Cross Section			
Pool width to riffle width (W_P / W_{Bkf})	0.97	1.16	1.34
Max Pool Depth to Max Riffle Depth (D_{Pmax}/$D_{Bkf\ max}$)	3.32	1.6	1.53
Pool Area to Riffle Area (A_p / A_R)	3.52	1.45	1.83
Profile			
Pool Slope to Reach Slope (S_P / S_{Reach})	0.45	0.20	0.79
Glide Slope to Reach Slope (S_G / S_{Reach})	9.05	0.67	3.91
Run Slope to Reach Slope (S_{Run} / S_{Reach})	4.65	2.13	2.16
Riffle Slope to Reach Slope (S_{Rif} / S_{Reach})	1.45	1.92	1.00
Pool Length to Riffle width (L_P to W_{Bkf})	3.98	2.88	1.02
Pool Spacing to Riffle width (L_{P-P} to W_{Bkf})	10.36	6.18	4.02

3.3 WATERSHED HYDROLOGY

The HEC-HMS model was developed for existing land use conditions and soil types in the study area. Storm discharges were evaluated for the seven sub-basins within the watershed (Figure 2.0). The calculations of drainage area, time of concentration, and curve numbers were performed by MSE, Inc. (1981) for each sub-basin used in the model. Final input parameters can be located therein. The discharges of concern along the Spring Branch Channel are at Pot Spring Road, Tributary A, Tributary B, and at Dulaney Valley Road (Table 3.4). The sub-basins 1 through 4 were used to describe the discharge at Pot Spring Road, sub-basin 5 for Tributary A, sub-basin 6 for Tributary B, and the downstream end of sub-basin 7 for the discharge at Dulaney Valley Road (Figure 2.0).

Table 3.4. Biohabitats HEC-HMS and MSE, Inc. Modeled Discharges.

		Pot Spring Road	**Tributary A**	**Tributary B**	**Dulaney Valley Road**
	Drainage Area (sq.mi)	0.87	0.16	0.41	1.58
Storm Event	24hr. Rainfall (inches)		Peak Discharge (cfs)		
1-Year	2.6	359.01	31.74	128.87	516.7
2-Year	3.2	595.11	67.91	228.16	893.57
5-Year	4.2	1044.88	143.83	421.94	1604.31
10-Year	5.1	1485.11	223.7	614.79	2321.34
25-Year	5.5	1686.22	261.55	704.36	2681.32
50-Year	6.3	2104.77	340.53	889.01	3401.45
100-Year	7.1	2529.08	422.96	1079.98	4144.83

Predicted peak discharges ranged from 359.01 Cubic Feet per Second (CFS) for a 1-year storm event to 2529 CFS for the 100-year event at Pot Spring Road (Table 3.4). The discharges predicted for Tributary A ranged from 31.74 CFS for the 1-year event to 422.96 CFS, for the 100-year event. Discharges from Tributary B ranged from 128.87 CFS for the 1-year event to 1079.98 CFS for the 100-year event. Discharges at Dulaney Valley Road ranged from 516.7 CFS to 4144.83 CFS for the 1-year and 100-year storm events, respectively

Comparison of the discharges predicted for the downstream end of the study area at Dulaney Valley Road show that the HEC-HMS results are moderately high (Table 3.5). Modeled peak 2-year discharges are nearly two times as high as those predicted by Purdum & Jeske (1985) and four times as high as those predicted by the MGS (Dillow, 1996) regression. This discrepancy appears to decrease slightly with increasing storm events. The discharge values for all of the studies on Lower Spring Branch were high compared to the MGS and USGS regressions. It should be noted that these regressions use values from many rural stations and may not compare well to discharges modeled for the more urbanized Spring Branch. Although higher compared to previous studies, the values calculated using HEC-HMS appear to be useful for our study.

Table 3.5. Predicted Peak Discharges at the Downstream End of the Study Area at Dulaney Valley Road

Recurrence Interval of Storm Event (yr)	Biohabitats Predicted Peak Discharge (cfs) HEC-HMS (MSE, Inc 1981)	Purdum & Jeske (1985) TR-20	MCS Predicted Peak Discharge (cfs)[1]	USGS Predicted Peak Discharge (cfs)[2]
1	516.7	n/a	n/a	n/a
2	893.57	482	207.6	293.4
5	1604.31	973	386.3	565.6
10	2321.34	1496	558.6	822.6
25	2681.32	1805	863.7	1238.8
50	3401.45	2258	1167.7	1615.8
100	4144.83	2866	1554.2	2055.6

[1] Carpenter, 1983
[2] Dillow, 1996

3.4 Bankfull Discharge

Field determined bankfull discharge estimates are based on measurements taken between September 2005 and January 2006. Bankfull elevations at all cross sections were derived from all available indications including depositional features, changes in bank angle, vegetation, scour lines and storm debris lines. Bankfull elevations at the concrete reaches were estimated from the observed water elevation during a single storm event on October 8, 2005 (Table 3.6, Reach 1 XS2, and Tributary B). In the project reach, much of the channel is unstable, therefore bankfull indicators were not easily identified. However, in the reference reaches, two consistent and distinct bank features were easily identified. These were recorded as "high bankfull" and "low bankfull", respectively (Table 3.6). The low bankfull discharge was calculated from the small channel that has naturally formed within the restored section of Spring Branch. The high bankfull discharge was calculated from a stable high bench that corresponds to the designed bankfull elevation

Table 3.6. A list of Field-based Bankfull Discharges (cfs).

Stream Reach	Location	Drainage Area (sq mi)	Bankfull Discharge
Reach 1	Concrete section DS Pot Spring Road	0.87	
Tributary B	Concrete tributary from the South	0.41	302.6
Reach 1 XS2	End of the mainstem concrete section	1.44	952.4
Reach 2	Down stream of the concrete	1.44	443.8
Reach 3	Incised boulder reach.	1.58	471.9
Reach 4	Upstream of Dulaney Valley Road	1.58	240.5
Reference Reach A High BKF	Riffle downstream of Cinder Road	0.6	53.2
Reference Reach A Low BKF	Riffle downstream of Cinder Road	0.6	134.7
Reference Reach B High BKF	Riffle upstream of Pot Spring Road	0.87	375.1
Reference Reach B Low BKF	Riffle upstream of Pot Spring Road	0.87	129.5
Reference Reach C High BKF	Riffle downstream of Eastridge Road	0.5	117.9
Reference Reach C Low BKF	Riffle downstream of Eastridge Road	0.5	35.74

Among the bankfull discharge estimates, the discharges from the concrete reaches may be discarded as outliers since the discharge was estimated from the water surface during only one storm event (Table 3.6). Also, bankfull indicators from the single point bar in Reach 4 are poor. The bar did not have a consistent feature the clearly indicated the bankfull elevation. This suggests that the field selection of the bankfull elevation was too low. However the results from the "high bankfull discharges" of the reference reaches, and the bankfull discharges calculated for Reaches 2 and 3 appear to correspond well with their respective drainage areas and each other. These appear to be the strongest candidates for determining a design discharge both upstream and downstream of Tributaries A and B.

3.5 SELECTION OF THE DESIGN DISCHARGE

Results from the regional regressions in comparison to the field based bankfull discharges and the HEC-HMS model are wide ranging, however important patterns can be extracted from the values which point to a realistic design discharge (Figure 3.1). A group of the field based estimates appear to correspond well with the Dillow (1996) and Carpenter (1983) regressions. However, the regression results are based on a two-year discharge. This is likely not the return interval that corresponds to the bankfull indicators in the more urbanized conditions of Lower Spring Branch.

As previously noted, the best bankfull indicators were located on the reference reaches and within Reaches 2 and 3. The field based discharge values calculated for these reaches fall in line with the DEPRM Urban (1999) regression; however, the drainage areas used for the regression are out of the range of the drainage area of our study (Figure 3.1). More support for these values can be found in the results of the 1-year discharge from the HEC-HMS model. The high bankfull discharge calculated for reference Reach B (375.1 CFS) near Pot Spring Road corresponds very well with the value retuned for the HEC-HMS model (359 CFS) at the same location (Tables 3.3 and 3.5). In addition, the value (516 CFS) modeled for the downstream end of the site at Dulaney Valley Road corresponds well with the bankfull measurements for Reaches 2 and 3 (443.8 and 471.9 respectively).

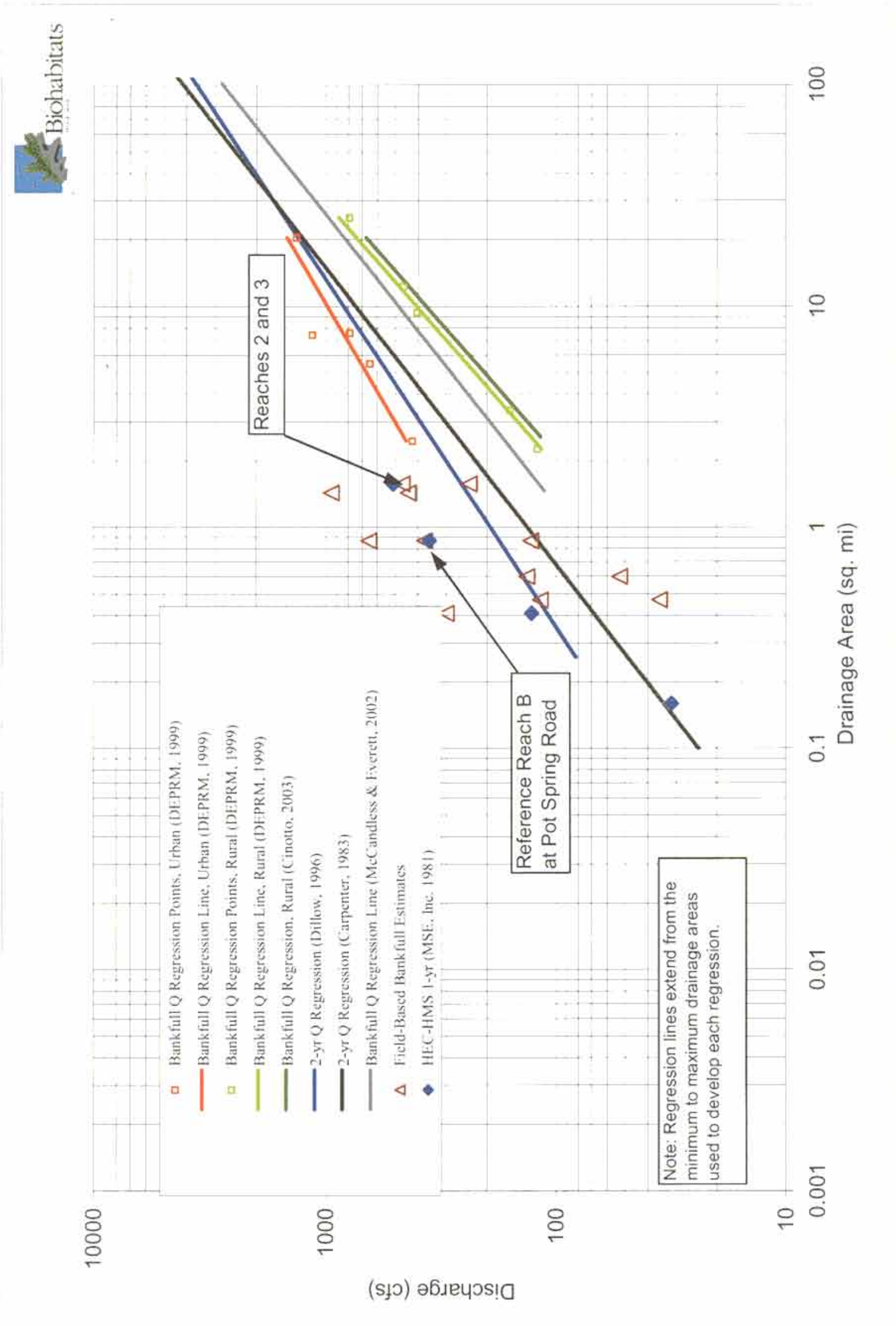

Figure 3.1. Comparison of Field Bankfull Estimates, HEC-HMS Results, and Regional Regressions.

From these relationships we propose a high bankfull design discharge of 360 CFS from Pot Spring Road to Tributary A and a design high bankfull discharge of 520CFS from Tributary A to Dulaney Valley Road (Table 3.7). The comparison of the field based, and HEC-HMS discharge estimates indicate that the model is a good indicator of the bankfull discharge. Therefore the 1-year HEC-HMS discharge estimates will be used for Tributaries A and B.

As previously reported, a naturally formed low bankfull discharge bench was consistently observed in the reference reaches. This bench has apparently formed from a discharge much lower compared to the high bankfull indicators. The consistency of this feature cannot be ignored. Therefore, we propose designing an additional low bankfull discharge channel that corresponds to the feature observed in the reference reach. The reference reach data indicate that the low bankfull discharge is approximately 1/3 of the high bankfull discharge (Table 3.6). From this we propose a design discharge for the low bankfull channel of 130CFS near Pot Spring Road and 180 CFS from Tributary A to Dulaney Valley Road (Table 3.7).

Table 3.7. Proposed Design Discharges for Lower Spring Branch.

Stream Reach	Low Bankfull Design Discharge (CFS)	High Bankfull Design Discharge (CFS)
Pot Spring Road to Tributary A	130	360
Tributary A	N/A	32
Tributary B	N/A	130
Tributary A to Dulaney Valley Road	180	520

The channel to be designed from the discharges reported above should consist of a low discharge channel nested within a larger bankfull channel. This nested channel system will convey the baseflow discharges and discharges resulting from smaller storm events, while also effectively conveying bankfull discharges, and larger events. The nested channel will also improve local hydrology by reconnecting the stream to a small, but active floodplain bench.

3.6 CHANNEL HYDRAULICS

HEC-RAS was used to model the water surface elevation for the 100-year discharge of the existing and proposed channel alignment for the study area (Table 3.8). The proposed typical cross sections used to model Reaches 1 through 4, Tributary A, and Tributary B are located in Appendix D. Each cross section name refers to the distance of each cross section upstream from the end of its reach. More accurate cross sections will be modeled when the site grading has been designed

Reach	Cross Section	Water Surface Elevation (ft) Existing	Proposed	Change
Tributary A	314	277.93	277.01	0.92
Tributary A	258	277.40	276.42	0.98
Tributary A	172	275.62	275.8	-0.18
Tributary B	394	277.31	277.92	0.61
Tributary B	291	275.25	275.92	0.67
Tributary B	167	273.28	274.15	0.87
Reach 1	2602	273.39	275.41	2.02
Upper Reach 2	1939	267.83	268.16	0.33
Lower Reach 2	1554	267.94	268.25	0.31
Upper Reach 3	1038	261.48	262.55	1.07
Lower Reach 3	749	262.57	261.87	-0.7
Reach 4	258	262.29	261.83	-0.46

Table 3.8. Comparison of Existing and Proposed 100-year Flood water surface elevations.

The cross sections for Tributary A were widened above the bankfull elevation in an attempt to maintain or reduce the 100-year flood. However, our results indicate that the water surface elevations for the cross section furthest upstream increase the elevation of the 100-year event approximately one foot, while the third cross section decreased by 0.18 feet. More analysis is needed for Tributary A to determine if the first two cross sections can be feasibly altered to contain the 100-year flood

In Tributary B the water surface elevation for the proposed cross section increased an average of 0.72 feet above the existing 100-year flood elevation (Table 3.8). The existing channel is concrete. When the model is run using a channel with natural bed material, the roughness increases significantly and results in a corresponding increase in the water surface elevation. Without further analysis it is difficult to determine if a cross section can be designed to lower the proposed water surface elevation within the limits of the drainage and utility easement.

Sixteen existing and proposed cross sections were compared on the mainstem of Lower Spring Branch. All but four of the proposed cross sections, produced water surface elevations lower than the existing 100-year elevations. Representative cross sections from Reaches 3 and 4 (258 and 749) indicated a decrease in the water surface elevation (Table 3.8). Cross sections that indicated an increase in the proposed 100-year water surface elevation were located just below Pot Spring Road (2602) and within Reaches 2 and 3 (1939, 1554, and 1038). The observed increase in the 100-year water elevation in proposed cross sections in Reaches 2 and 3 may be mitigated through additional floodplain grading to be added in the next design submission.

The proposed cross section at station 2602 witnessed a two foot increase in water surface elevation (Table 3.8). The channel at Pot Spring road is composed of concrete. When the model is run using the proposed channel with natural bed material, the roughness increases significantly and results in a corresponding increase in the water surface elevation. At this time, it does not appear that additional floodplain grading will reduce the large increase in water surface elevation at this cross section. More analysis will be required to determine the best option for this cross section.

3.7 WETLAND DELINEATION, RIPARIAN VEGETATION, AND SOILS

The plant community along the stream was evaluated for dominance by plants with hydrophytic status of Facultative (FAC), Facultative-Wetland (FACW) and/or Obligate Wetland (OBL) according to Reed (1988). In addition, soils in the project area were evaluated for hydric properties to a depth of 18 inches using a sharpshooter spade. Evidence of wetland hydrology was also evaluated.

3.7.1 Wetland Distribution and Characterization

While the majority of the project area is not wetland, as described in the 'Upland Characterization' section below, two minor wetland areas were observed.

Wetland Area covers 0.021 acres and is located in and adjacent to an alluvial bar which formed inside the concrete channel at the upstream end of the project area. This area is dominated by black walnut, (*Juglans nigra*), black willow (*Salix nigra*), and boxelder, (*Acer negundo*) (Table 3.9).

The hydrology of this wetland is based on frequent inundation associated with 'in-channel' water level fluctuation as well as the 'dam' effect this alluvial 'mound' has had on adjacent lateral surface drainage into the concrete channel.

Table 3.9 Vegetation Identified within Wetland Area 1

Species (Common, *Scientific*)	Status	Native/Non-Native/Invasive
black walnut, *Juglans nigra*	FACU	Native
black willow, *Salix nigra*	FACW	Native
boxelder maple, *Acer negundo*	FAC	Native
sycamore, *Platanus occidentalis*	FACW	Native
Norway maple, *Acer platanoides*	FACU	Non-Native, Invasive
multiflora rose, *Rosa multiflora*	FACU	Non-Native, Invasive
goldenrod, *Solidago* spp.	UNK	Native
honeysuckle vine, *Lonicera japonica*	FAC-	Non-Native, Invasive
ivy, *Hedera helix*	FACU	Non-Native, Invasive
oriental bittersweet, *Celastrus orbiculatus*	FACU	Non-Native, Invasive
watercress, *Nasturium officinale*	OBL	Native
cattail, *Typha latifolia*	OBL	Native, Invasive

The soils of this area were difficult to sample and characterize due to their coarse texture and shallowness. However, surface loamy sand soils were characterized with a color of 10YR3/2. Deeper samples were more difficult to find and sample and were characterized as sand with a color of 10YR6/4. The relative lack of fines and the presumed long term saturation of the coarse alluvium explain the absence of the gleying and other hydric soil indicators.

Wetland Area 2 covers 0.032 acres and is associated with the man-made pond and its outlet channel on the south terrace near Reach 2. The pond appeared to be approximately 3-ft deep with vertical rock walls and approximately 1 ft of water depth. A small (i.e. less than 1 ft wide) drainage channel conveyed the seepage from this pond into the stream. The pond and the outlet channel were identified as wetlands. The wetland plant community along the fringes of the pond and drainage channel included soft rush (*Juncus effuses*), jewelweed (*Impatiens capensis*), and honeysuckle vine (*Lonicera japonica*) (Table 3.10).

The hydrology of this wetland was based on perennial groundwater discharge associated with the excavated pond. The hydrology was limited to the pond bottom and the narrow outlet channel.

Table 3.10 Vegetation Identified within Wetland Area 2.

Species (Common, *Scientific*)	Status	Native/Non-Native/Invasive
soft rush, *Juncus effusus*	FACW	Native
jewelweed, *Impatiens capensis*	FACW	Native
honeysuckle vine, *Lonicera japonica*	FAC-	Non-Native, Invasive
fowl manna grass, Glyceria striata	FACW	Native
watercress, *Nasturium officinale*	OBL	Native
privet, *Ligustrum japonicum*	FACU	Non-Native, Invasive

The soils of the channel and the pond were characterized as 10YR6/4 sand loam with oxidized rhizospheres. It was clear from the presence of erosion control material (i.e., ½ inch polyethelene grid associated with excelsior matting) associated with the channel that the observed conditions were recent.

The wetlands delineated and evaluated for the stream restoration project are not significant natural areas providing critical wetland functions. Both identified wetland areas occur in man-made features. However, both wetland areas are regulated features which will require submittal of a Joint Federal State Permit Application. Similarly, the stream is regulated as a Water of the US, and will require the same permit application. The regulated activities likely to be required for the project include: temporary and permanent modification of the floodplain; excavation and filling or grading in the floodplain, wetlands and stream; and similar activities in the stream and wetland buffer.

3.7.2 Upland Characterization

While most of the floodplain is maintained as grass, many of the trees and shrubs remaining in the floodplain or riparian area are species typical of forested wetlands. Many other species present are not wetland adapted or are non-native. Common species observed were black walnut and boxelder (Table 3.11).

Table 3.11 Vegetation Identified within the Lower Spring Branch Upland Area.

Species (Common, *Scientific*)	Status	Native/Non-Native/Invasive
black walnut, *Juglans nigra*	FACU	Native
white pine, *Pinus strobus*	FACU	Native
black willow, *Salix nigra*	FACW	Native
boxelder maple, *Acer negundo*	FAC	Native
sycamore, *Platanus occidentalis*	FACW	Native
norway maple, *Acer platanoides*	FACU	Non-Native, Invasive
tulip poplar, *Lireodendron tulipifera*	FACU	Native
red Maple, *Acer rubrum*	FAC	Native
multiflora rose, *Rosa multiflora*	FACU	Non-Native, Invasive
privet, *Ligustrum japonicum.*	FACU	Non-Native, Invasive
honeysuckle vine, *Lonicera japonica*	FAC-	Non-Native, Invasive
ivy, *Hedera helix*	FACU	Non-Native, Invasive
oriental bittersweet, *Celastrus orbiculatus*	FACU	Non-Native, Invasive

3.7.3 Soils

The soils in the project area can be characterized as a disturbed urban sandy loam complex. None of the sampled soil horizons exhibited undisturbed hydric soil characteristics. Generally, the soils examined presented chromas brighter than the chroma 2 threshold (e.g., 10YR6/4). Much of the surficial soil included evidence of fill (e.g., gravel, brick fragments) and a disturbed soil structure (i.e., no well defined A, B, and C horizons) likely associated with historic construction in the floodplain (e.g., sanitary sewer alignments, stream improvements).

3.7.4 Hydrology

No groundwater was encountered in any of the soil pits even though several were within 3 ft of the stream channel and others were in localized depressions. It appears that the incised channel and the presence of a well bedded sanitary sewer alignment in the floodplain, have the effect of lowering the groundwater and minimizing this source of hydrology. Similarly, overbank flooding is not of sufficient frequency or duration to support a wetland hydrology in this project vicinity. In addition, the texture of the floodplain soil ranged from sandy loam to loamy sand, allowing surface waters associated with precipitation or overbank flooding to infiltrate relatively quickly.

4.0 CONCEPT DESIGN DEVELOPMENT

Using the data gathered in the field, modeling, and other computational activities, a concept design has been developed that uses the stable qualities of the upstream restored channel, and considers the existing conditions and constraints within the project reach. The design concept is generally based on the nested channel with a vegetated bench as observed in the reference reaches.

This nested channel system will convey the baseflow discharges and discharges resulting from smaller storm events, while also effectively conveying bankfull discharges, and larger events. The nested channel will also improve local hydrology by reconnecting the stream to a small, but active floodplain bench.

4.1 DESIGN RATIONALE

The design reaches through Lower Spring Branch were identified by new discharge inputs, or by vertical containment and lateral constraints. Significant discharge inputs occur at Tributaries A and B and hydraulic controls for the mainstem are:

1 The culvert at Pot Spring Road
2) Bed rock within the channel at the top of Reach 3
3) The culvert at Dulaney Valley Road

The upstream hydraulic control for Tributary A is the culvert at Chapelwood Lane and the upstream hydraulic control for Tributary B is the existing invert of the channel at its upstream extent. Six design reaches were established according to their slope and relative discharge (Table 4.1). Each design reach was assigned a reference reach based on slope similarity. Design Reach 2 is downstream of Tributaries A and B, and is separated from Reach 1 based on the added discharge of these streams. No reference reach slope has been assigned to Reach 3 since a high/steep south bank, bedrock channel and sanitary sewer crossing, preclude significantly altering the existing channel geometry.

Cross section dimensions and profile feature distribution for each design reach were determined from the dimensionless ratios of the corresponding reference reach. The primary dimensionless ratios of interest are width to mean depth ratio and entrenchment ratio. Using these ratios as limiting factors for the design cross section ensured that channel dimensions were preserved between the reference and design reaches. Ratios were not developed for meander pattern or sinuosity. The constraints imposed by existing utilities and easements preclude designing a natural meander pattern. Where curves are proposed in the channel, their radii have been approximated from the proposed bankfull width using the formula: Radius of Curvature = 2.5-3.2*Bankfull Width. Proposed typical riffle cross sections were designed using variables calculated from the dimensionless ratios (Table 4.2). The design variables represent a range that was applied to the design of each cross section. Therefore the dimensions of the proposed channel cross section may not exactly match the design variables presented in Table 4.2. Typical riffle cross sections for the design are graphically presented in Appendix F

Table 4.1. Design Reaches and Assigned Reference Reaches.

Design Reach	Design Slope	Assigned Reference Reach	Reference Reach Slope
Reach 1	1.1%	Reach A	1.1%
Reach 2	1.1%	Reach A	1.1%
Reach 3	0.5%	Reach C	0.77%
Reach 4	0.7%	Reach C	0.77%
Tributary A	1.1%	Reach A	1.1%
Tributary B	1.9%	Reach B	2.1%

With the proposed cross sections designed, Biohabitats used dimensions from the low bankfull, nested channel to establish a range of acceptable design variables for the stream profile (Table 4.2). The stream profile will be provided in the next submittal. We do not anticipate altering the profile or alignment within Reach 3 where bedrock dominates the channel and a sewer line crosses nearly parallel to the existing channel alignment. All of the values appear usefull in the design, however, each one will be critically analyzed during the creation of the final cross section and profile design

Table 4.2. Variables to be used in The Lower Spring Branch Design.

Variable	Reach 1		Reach 2		Reach 3		Reach 4		Trib A	Trib B
	Low BKF	High BKF	Low BKF	High BKF	Low BKF	High BKF	Low BKF	High BKF	BKF	BKF
Riffle Cross section										
W_{Bkf}	28'	41'	32'	41.5'	24'	40.4'	24'	46'	14'	20'
$D_{Bkf\,max}$	1.6'	2.5'	1.9'	2.8'	2.1'	3.8'	2.0'	3.5'	1.1'	1.6'
A_R (sf)	29.2	61.6	39.54	73.4	39.2	93.4	39.4	90.5	10.2	22.1
W_{Bkf} / d	27	27.4	25.5	23.5	14.8	17.5	14.6	23.2	19.1	18.0
ER	1.72	>2.2	1.5	>2.2	1.76	1.5	2.5	>2.2	2.12	1.97
Pool Cross Section										
W_P	27.2'	39.8'	31'	40.3'	32.2'	54.2'	32.2'	62'	13.6'	23.2'
D_{Pmax}	5.3'	8.3'	6.3'	9.3'	3.2'	5.8'	3.1'	5.4'	3.6'	2.6'
A_p(sf)	103	216.8	139.2	258.4	71.7	170.9	72.1	165.6	35.9	32.0
Profile										
S_P	.005		.005		existing		.006		.005	.004
S_G	.103		.103		existing		.029		.103	.012
S_{Run}	.053		.053		existing		.016		.053	.04
S_{Rif}	.016		.016		existing		.0075		.016	.036
L_P	111.4'		127.4'		existing		24.5'		55.7'	57.6'
$L_{P\text{-}P}$	290.1'		331.5'		existing		96.5'		145.0'	123.6'

W_{Bkf} = Bankfull Width
$D_{Bkf\,max}$ = Max Bankfull Depth
A_R (sf) = Riffle Cross Sectional Area (sq. feet)
W_P = Wetted Perimeter
D_{Pmax} = Max Pool Depth
A_p (sf) = Pool Cross Sectional Area (sq. feet)
S_P = Pool Slope
S_G = Glide Slope
S_{Run} = Run Slope
S_{Rif} = Riffle slope
L_p = Pool Length
$L_{P\text{-}P}$ = Pool-to-pool spacing

4.2 DESIGN DESCRIPTION

All of the concrete in Reach 1 will be removed beginning approximately 55 feet down stream of Pot Spring Road and moderately meandering nested channel will be constructed with additional floodplain grading accommodate higher flows. Although this channel will exhibit a mild meander pattern, the local channel profile, will be dictated more by grade control structures than by meander geometry and a "Bc" type channel will be designed.

Similarly to Reach 1, Reach 2 will be constructed as a moderately meandering nested channel with the location of riffles and pools dictated by grade controls such as cross vanes and step/riffle structures. It may be necessary to raise the bed elevation of the upstream end of this reach, one-to-two feet to tie-in with the downstream bed elevation of Reach 1. Depending on ultimate channel profile and the size and condition of the concrete rubble obtained from demolishing the concrete channel; it may be feasible to use this material as base fill in this reach.

Reach 3 will generally follow the existing alignment. This reach constrained by the steep valley slope along the south bank, boulders within the channel, and a sanitary sewer line that runs parallel to, and near the thalweg invert for approximately 90 feet. Therefore, the reference reach profile ratios will not be directly applied to this reach. However, the cross section variables have been adhered to in the proposed channel (Table 4.2, Appendix F). Here the north bank will be graded to a more stable slope and stabilized with structural protection where necessary. Step grade controls may be provided to protect the existing sanitary sewer crossing, and to enhance the existing pool habitat.

In Reach 4 a moderately meandering nested channel will be constructed with additional floodplain grading to accommodate higher flows. This reach will exhibit a riffle/pool pattern as seen in "C" channels. Although the sinuosity and beltwidth will be low for a "C" channel of this size, the riffles and pools can be structurally maintained with cross vanes and step/riffle structures. Some structural bank stabilization will be required where an existing sanitary sewer line is currently exposed at the channel invert.

The concrete will be removed from the downstream end of Tributary A, and the eroding banks will be regraded to stable angles. Step/riffle structures will be installed to prevent headcuts from forming in the channel between Spring Branch and Chapelwood Lane. Also an additional step structure may be downstream of where this tributary crosses a sewer line before the confluence with Spring Branch.

The concrete will be removed within the downstream 80 feet of Tributary B and it will be constructed as a step/riffle channel to tie in with Reach 1

The bank stabilization and grade control structures described above may be enhanced by installing rootwads in pool areas for in-stream habitat and soil bioengineering (live branch layering or live stakes) for added stabilization. Proposed pools that occur on meanders or after cross vanes appear to be ideal for installing rootwads, however, rootwads should be installed where there is adequate floodplain relief above the structure. When floodplain grading is established in the next submittal a more accurate depiction of root wad locations will be indicated on the drawings. Additionally, the banks along Tributary A and in Reaches 1, 2, and 4 structural stabilization may be enhanced with bioengineering. Here live branch layering, or live stakes will be installed around the ends of step/riffle structures, or at the ends of cross vanes. Also, where pools occur in straight reaches, soil bioengineering may be adequate to maintain stable banks.

In the proposed nested channel, bank stabilization, bioengineering, and cross vanes should be placed at the elevation of the low bankfull channel. This ensures that they are at the proper elevation to maintain stability as well as provide in-stream habitat. It is anticipated that the bench between the low bankfull and high bankfull channels will be inundated numerous times during a given year. To prevent the stream from cutting around the ends of stabilization structures boulder cut-off sills will be installed on the bench of the nested channel. Also smaller shrub vegetation and heavy erosion control matting should be installed to prevent erosion from occurring on the bench before the vegetation becomes established.

It is anticipated that shear stress will be greatest in the low bankfull channel. Currently the substrate in the Lower Spring Branch channel is composed of small cobble, gravel and sand, which is easily mobilized during storm events. It will be necessary to construct the low bankfull cross section with cobble material that will not be mobilized during bankfull events, while allowing smaller material mobilized from upstream to move through the system. Within the high bankfull channel and on the bench between the high and low bankfull channels it is anticipated that shear stress will be lower. Therefore, a material similar to the existing channel material may be used to create a stable bench The stability of this bench will be increased with the materials described in the previous paragraph.

The channel restoration and stabilization measures listed above will also include riparian reforestation within the entire stream reservation. Shrubs and herbaceous vegetation only will be planted directly over existing sanitary sewer lines.

5.0 IMPLEMENTATION

The success of the Lower Spring Branch restoration is dependent on implementing all elements of the design in the proper order and according to the plans and specifications. The following section outlines pre-construction and construction measures required to ensure the success of the restoration project.

5.1 PERMITTING

The restoration of Lower Spring Branch will require compliance with Baltimore County, State, and Federal regulatory requirements. The proposed concept will have temporary impacts to wetlands within the stream corridor. The wetlands delineated and evaluated for the stream restoration project are not significant natural areas providing critical wetland values. Both identified wetland areas occur in man-made features. However, both wetland areas are regulated features which will require submittal of a Joint Federal State Permit Application. Similarly, the stream is regulated as a Water of the US, and will require the same permit application. The regulated activities likely to be required for the project include: temporary and permanent modification of the floodplain; excavation and filling or grading in the floodplain, wetlands and stream; and similar activities in the stream and wetland buffer.

5.2 PRE-CONSTRUCTION

Restoration projects rely heavily on thorough site preparation, marking features in the field, and supervision of the construction process by an experienced professional. Prior to construction, it will be necessary to locate and flag certain features with easily visible survey flagging or spray paint. Features that require marking or flagging prior to construction consist of:

- limits of disturbance (including all wetlands not to be disturbed)
- existing sanitary and storm sanitary sewer laterals
- existing electric and water lines
- trees to be preserved
- property lines

Trees within the limits of grading that meet the specifications for root wads, will be identified and uniquely marked for use in these structures. The same marking will apply for other natural materials commonly found in the study area such as large rocks or boulders (in Reach 3) that may be used for stream bank stabilization and in-stream grade control

In addition to marking specific features, it is the responsibility of Baltimore County to conduct land owner notification, public meetings, and easement acquisitions that may be required for the project.

5.3 CONSTRUCTION

Construction should be avoided during any stream closure dates. As a tributary to Loch Raven Reservoir in the Gunpowder River watershed, Lower Spring Branch is classified as Use III-P Waters (Natural Trout Waters and Public Water Supply) according to the Code of Maryland Regulations (26.08.02.08). Among other considerations, this requires that in-stream work be excluded between October 1 through April 30.

The following is a proposed construction sequence for work conducted within the Lower Spring Branch Study Area:

Construction stake-out including the limits of disturbance by a qualified land surveyor.

2. Flag underground utilities.

3 Mark trees to be saved and mark trees and boulders to be used in the restoration.

4. Hold a pre-construction meeting on-site with contractor, Baltimore County officials, and the restoration engineer.

5 Install sediment and erosion control devices

6. Install construction entrance/s.

Have the sediment and erosion control devices inspected and approved.

8 Clear and grub.

9 Salvage rootwads and boulders suitable for in-stream structures

10. Excavate and grade proposed channel modifications.

1 Install stabilization, in-channel measures/structures, and bioengineering.

12. Stabilize banks and all disturbed areas (plant material such as live stakes, etc., seeding &

matting, etc.).

13. Install trees and shrubs
14 Remove sediment and erosion control devices.

When soil bioengineering methods are used for stream bank stabilization, plant material must be installed during their dormant stage (December 1 through March 15). It is also advisable to install vegetation (other than soil bioengineering plant material) and seed disturbed areas in the earlier part of the growing season (April-May) to promote optimal growth and quick coverage.

It may be necessary to make minor adjustments to the final design plan as field conditions warrant. Therefore, it is strongly recommended that a restoration engineer experienced in stream restoration design and implementation conduct inspections during the construction process. If changes to the design are deemed necessary during construction, they will first be approved by DEPRM, then directed and recorded by the restoration engineer. All adjustments to the final design will be recorded on the "field" plan set and in the construction log. A memo describing all of the design adjustments for the restoration will be submitted to DEPRM at the completion of construction.

5.4 AS-BUILT DOCUMENTATION

Upon the completion of construction an additional site survey will be conducted by the land surveyor that conducted the original topographic survey and construction stakeout. From this survey as-built construction drawings will be created. These drawings document the finished conditions and any adjustments to the original design made during installation. The as-built drawings will also serve as baseline conditions for post construction monitoring of the success of the project.

5.5 MONITORING

A Technical Monitoring Program is necessary to measure the success of the restoration. The technical monitoring program should begin after the completion of the restoration and continue for three years. Monitoring will provide information needed to track natural adjustments within the restored channel. This information can then be used to ensure that the long term goals of the restoration were met and to facilitate the design and construction of future restoration projects with similar objectives and site conditions.

The Technical Monitoring Program should address the following key elements to document post construction project conditions:

- Update databases with any change in land use within the watershed
- Establish permanent cross sections to measure channel changes and project success. Permanent cross sections should also be established several hundred feet below the limits of the restoration project to observe any channel changes downstream. Re-survey the cross sections annually.
- Re-survey the stream thalweg annually to identify changes in meander geometry and bed profile.
- Inspect structures on a semi-annual basis and immediately following storm events producing bankfull discharge or greater magnitude. Repair or remove damaged structures immediately
- Establish baseline habitat and water quality information. In-stream and riparian habitat should be qualitatively evaluated pre- and post construction for the monitoring period.
- Install scour chains to record sediment accumulation and scoring, and bank pins to record bank erosion and deposition.
- Evaluate vegetation survival, distribution patterns, and density, annually during the growing season.
- Evaluate invasive species abundance within the restored area and implement a management strategy as necessary.

The evaluation of the monitoring data should be performed by personnel experienced in stream geomorphic assessments.

5.6 MAINTENANCE

A maintenance program provides guidelines for procedures to operate and maintain the restoration project and should be part of the final design plans. These procedures are designed to achieve project objectives, through timely and cost effective techniques, and can be easily implemented

The primary maintenance procedures include maintenance of structures and stream alignment, and maintenance of plantings. The maintenance program should be performed for a minimum of five years after project completion.

5.6.1 Maintenance of Structures and Channel Alignment

All in-stream and bank stabilization structures should be inspected after bankfull and larger flow events, or semi-annually at a minimum. Any significant damage or movement of material should be repaired immediately to prevent failure or loss of the structure, or undesirable channel modifications. Small debris dams and sediment deposits may also be removed if they appear to harm the integrity of structures. Minor reconfiguration and realignment of certain structures may be necessary to ensure the ultimate success of the project.

Maintenance of Installed Vegetation

Plant material should be inspected according to the warranty provided by the landscaping contractor. Maintenance of plant material may consist of the following:

- replace and remove dead and diseased plant material
- removal of unwanted, non-native invasive species (weed control)
- pruning of woody plant material for rejuvenation and maximum density
- replace plant material damaged by storm events

Many non-native and invasive species have the ability to colonize quickly and out-compete native woody and herbaceous species. It is important to monitor the presence and or expansion of these plants after the restoration to make sure that they do not overtake more desirable native species. Should invasive species become problematic, an invasive species plan should be implemented to control the spread of invasives and allow the newly established native plants to flourish

6.0 CONCEPT COSTS

A preliminary cost estimate of $ 692,624.86 was prepared for the preferred design alternative in the preliminary assessment report (Biohabitats, Inc. December 2005). This estimate has been re-evaluated to give a better estimate of the construction costs. Changes to the original estimate include added line items for mobilization, stabilized construction entrances, erosion and sediment control, pump-around, and more accurate estimates for in-stream and bank stabilization structures (Table 6.1). In addition, the unit prices have been adjusted from recent project bid tabulations, engineers cost estimates and Biohabitats' historical cost data.

This concept cost estimate is based on several assumptions:

1. All unit costs include material constructed and in place.
2. Grading, excavation and fill quantities were estimated by comparing existing and proposed cross sections.
3. Native plantings assumed revegetation of the entire stream reservation. Changes will occur as the grading plan becomes more definite.
4. Boulder bank protection would be required where meanders are in the vicinity of sanitary sewer lines. Other meanders would be stabilized with boulder toe and/or bioengineering.
5. Grade control structures (cross vanes and/or steps) would be required immediately downstream of sanitary sewer line crossings to prevent incision.
6. Erosion and Sediment control will consist of completing the construction in segments that allow the contractor to divert the clean water around the construction site during the construction process. E&S controls will most likely consist of stabilized construction entrances and silt fence.
7. A 15% contingency, based on the total quantities cost, is added to cover miscellaneous and unforeseen items including private property restoration or repair.

The updated concept cost estimate is $917,366.50 (Table 6.1).

Table 6.1. Estimated Construction Costs for the Lower Spring Branch Restoration.

Item No.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Mobilization	1	LS	$20,000.00	$20,000.00
2	Stabilized Construction Entrance	2	EA	$1,800.00	$3,600.00
3	Silt Fence	500	LF	$3.00	$1,500.00
4	Orange Safety Fence	5,200	LF	$3.00	$15,600.00
5	Pump-around/Stream flow diversion	1	LS	$15,000.00	$15,000.00
6	Coir matting	6,000	SY	$4.00	$24,000.00
7	Clearing and Grubbing	1	LS	$10,000.00	$10,000.00
8	Concrete Removal	886	CY	$150.00	$132,900.00
9	Salvaging and/or furnishing and Placing Topsoil at 6" depth	4,000	SY	$15.00	$60,000.00
10	Channel or Stream Excavation	980	CY	$15.00	$14,700.00
11	Salvaging and Placing Fill Material	750	CY	$7.00	$5,250.00
12	Boulder Toe	441	TON	$80.00	$35,280.00
13	Boulder Bank Protection	1200	TON	$80.00	$96,000.00
14	Furnishing and Placing Riffle Material, depth varies	4433	SY	$30.00	$132,990.00
15	Step	15	EA	$2,000.00	$30,000.00
16	Step Riffle	2	EA	$2,500.00	$5,000.00
17	Rock Cross Vane	2	EA	$3,000.00	$6,000.00
18	Rootwad Habitat Structure	4	EA	$1,800.00	$7,200.00
19	Live Branch Layering	405	LF	$30.00	$12,150.00
20	Planting Trees and Shrubs - Riparian Forest Zone 1				
	Trees 5'-6' Container	1,516	EA	$55.00	$83,380.00
	Trees 3'-4' Container	970	EA	$40.00	$38,800.00
	Shrubs & Vines	1,110	EA	$20.00	$22,200.00
21	Herbaceous Permanent Seeding - Zones 1-2				
	Riparian Forest Zone 1 - Grasses (Seeded)	218,000	SF	$0.12	$26,160.00
	SUBTOTAL				**$797,710.00**
	15% Contingency				**$119,656.50**
	TOTAL				**$917,366.50**

7.0 SUMMARY

Lower Spring Branch has been impacted by channelization, armoring, stormwater runoff, erosion, and riparian clearing. Although it maintains good perennial baseflow, the stream is subjected to extremely high discharges during storm events.

The design parameters presented in the previous sections are based on accurate field measurements and calculations, and sound analytical design techniques. In this concept Biohabitats has proposed a channel design that is similar to the stable upstream channel. By using this as the basis for our design we have proposed a stable, slightly meandering, nested channel through much of the stream reach.

The locations and elevations of underground sanitary sewer lines have imposed some minor constraints to the stream geometry. Their elevations will be considered in the next submittal and will dictate the final stream profile and geometry. In the design of the high bankfull channel Biohabitats has attempted to stay within the limits of the stream reservation. A grading plan has not been created as part of this submittal. Some above-bank grading will be necessary beyond the existing stream reservation, into the drainage and utility easement. The extent of this grading will become more evident in the future development of the design.

9.0 REFERENCES

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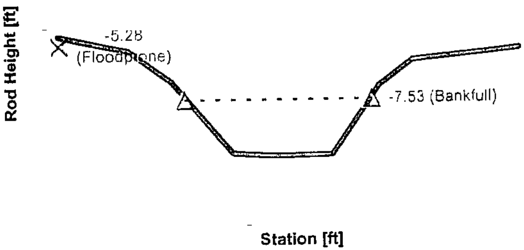
PROJECT REACH CROSS SECTIONS

APPENDIX A

Biohabitats

Lower Spring Branch
Xsection #1



bf max depth:	2.25 ft	
bf avg depth:	1.69 ft	
entrenchment:	2.21	
width/depth ratio:	12.82	
hydraulic radius:	1.66 ft	
bankfull discharge:	656.42 ft^3/s	17.95 ft/s
floodprone discharge:	2,172.32 ft^3/s	
Avg. shear stress at bankfull stage:	1.101 lb/ft^2	

Benchmark Elevation		*Bankfull Rod Height [ft]*	7.53	measured wat	
Benchmark Rod Height		*channel slope*	1.06%		
		manning's 'n'	0.012	(concrete channel)	

Floodprone	-5.28
Rod Height [ft]	= (2 · max depth $_{bf}$)

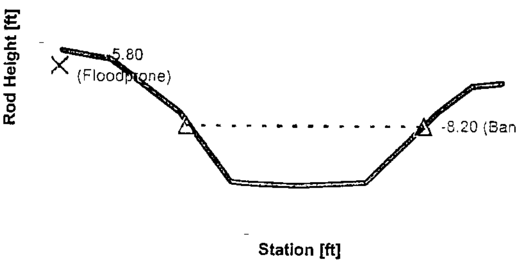
			Bankfull			*Floodprone*		
Station [ft]	*Rod Height [ft]*	*Negative Rod Height [ft]*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*
Total			**21.97 ft**	**36.56 ft^2**	**21.65 ft**	**49.32 ft**	**103.60 ft^2**	**47.77 ft**
	4.85	-4.85						
	5.45	-5.45				2.27 ft	0.19 ft^2	2.27 ft
	6.74	-6.74				5.16 ft	4.08 ft^2	5.00 ft
20	9.67	-9.67	5.54 ft	5.78 ft^2	5.40 ft	7.59 ft	20.48 ft^2	7.00 ft
20.9	9.7	-9.70	0.90 ft	1.94 ft^2	0.90 ft	0.90 ft	3.96 ft^2	0.90 ft
24	9.77	-9.77	3.10 ft	6.84 ft^2	3.10 ft	3.10 ft	13.81 ft^2	3.10 ft
26.5	9.78	-9.78	2.50 ft	5.61 ft^2	2.50 ft	2.50 ft	11.24 ft^2	2.50 ft
31.5	9.74	-9.74	5.00 ft	11.15 ft^2	5.00 ft	5.00 ft	22.40 ft^2	5.00 ft
37	6.98	-6.98	4.93 ft	5.25 ft^2	4.75 ft	6.15 ft	16.94 ft^2	5.50 ft
41	5.95	-5.95				4.13 ft	4.74 ft^2	4.00 ft
50	5.65	-5.65				9.00 ft	4.68 ft^2	9.00 ft
53.5	5.53	-5.53				3.50 ft	1.09 ft^2	3.50 ft

Ineffective Flow

ver 1.4

Biohabitats

Lower Spring Branch
Xsection #2B



bf max depth:	2.40 ft	
bf avg depth:	1.82 ft	
entrenchment:	1.61	
width/depth ratio:	15.24	
hydraulic radius:	1.80 ft	
bankfull discharge:	952.42 ft³/s	18.91 ft/s
floodprone discharge:	3,539.53 ft³/s	
Avg. shear stress at bankfull stage:	1.190 lb/ft²	

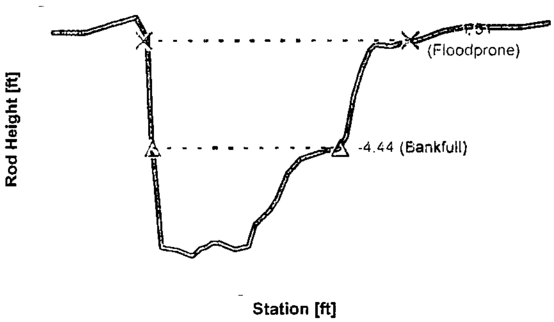
Benchmark Elevation		*Bankfull Rod Height [ft]*	8.20	measured wat	Floodprone Rod Height [ft] -5.80 = (2 · max depth $_{bf}$)
Benchmark Rod Height		*channel slope*	1.06%		
		manning's 'n'	0.012	(concrete channel)	

			Bankfull			Floodprone			
Station [ft]	*Rod Height [ft]*	*Negative Rod Height [ft]*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	Ineffective Flow
Total			**28.00 ft**	**50.37 ft²**	**27.71 ft**	**45.86 ft**	**134.88 ft²**	**44.53 ft**	
[illegible]	[illegible]	-5.15							☐
	5.5	-5.50							☐
	63	-7.63				7.11 ft	6.43 ft²	7.03 ft	☐
	45	-10.45	5.29 ft	5.76 ft²	5.12 ft	6.63 ft	19.44 ft²	6.00 ft	☐
		-10.52	1.50 ft	3.43 ft²	1.50 ft	1.50 ft	7.03 ft²	1.50 ft	☐
		-10.60	6.10 ft	14.40 ft²	6.10 ft	6.10 ft	29.04 ft²	6.10 ft	☐
	[illegible]		5.90 ft	13.92 ft²	5.90 ft	5.90 ft	28.08 ft²	5.90 ft	☐
35.7	10.47	-10.47	2.20 ft	5.05 ft²	2.20 ft	2.20 ft	10.33 ft²	2.20 ft	☐
44	7.63	-7.63	7.01 ft	7.81 ft²	6.89 ft	8.77 ft	26.98 ft²	8.30 ft	☐
48	6.55	-6.55				4.14 ft	5.16 ft²	4.00 ft	☐
	6.42	-6.42				3.50 ft	2.40 ft²	3.50 ft	☐

Biohabitats

Lower Spring Branch
Xsection #3

Field 1.xls]



bf max depth:	2.93 ft	
bf avg depth:	1.74 ft	
entrenchment:	1.42	
width/depth ratio:	20.58	
hydraulic radius:	1.67 ft	
bankfull discharge:	443.80 ft³/s	7.16 ft/s
floodprone discharge:	2,014.50 ft³/s	
Avg. shear stress at bankfull stage:	1.489 lb/ft²	

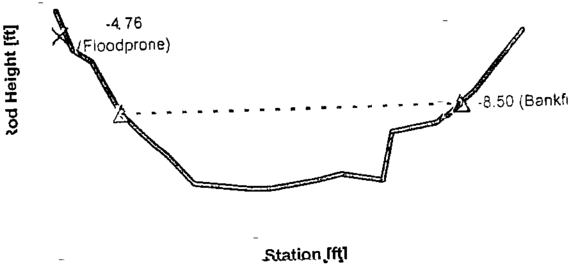
Benchmark Elevation		*Bankfull Rod Height [ft]*	4.44
Benchmark Rod Height		*channel slope*	1.43%
		manning's 'n'	0.035

Floodprone Rod Height [ft]	-1.51 = (2 · max depth $_{bf}$)

			Bankfull			Floodprone			
Station [ft]	*Rod Height [ft]*	*Negative Rod Height [ft]*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	Ineffective Flow
Total			***37.18 ft***	***61.99 ft²***	***35.72 ft***	***54.16 ft***	***178.61 ft²***	***50.77 ft***	
	[illegible]	-1.27							
		-1.27							
		-0.84							
		-1.40							
8.5	4	-4.07				2.67 ft	2.56 ft²	2.00 ft	
	5	-5.54	1.33 ft	0.62 ft²	1.13 ft	1.78 ft	3.30 ft²	1.00 ft	
	7	-7.13	1.88 ft	1.90 ft²	1.00 ft	1.88 ft	4.83 ft²	1.00 ft	
		-7.20	3.00 ft	8.18 ft²	3.00 ft	3.00 ft	16.97 ft²	3.00 ft	
6.4		-7.37	2.90 ft	8.25 ft²	2.90 ft	2.90 ft	16.75 ft²	2.90 ft	
7.9		-7.17	1.51 ft	4.25 ft²	1.50 ft	1.51 ft	8.64 ft²	1.50 ft	
		-7.11	1.10 ft	2.97 ft²	1.10 ft	1.10 ft	6.19 ft²	1.10 ft	
30.1	7.01	-7.01	1.10 ft	2.88 ft²	1.10 ft	1.10 ft	6.11 ft²	1.10 ft	
31.5		-7.00	1.40 ft	3.59 ft²	1.40 ft	1.40 ft	7.69 ft²	1.40 ft	
32.8		-7.09	1.30 ft	3.39 ft²	1.30 ft	1.30 ft	7.20 ft²	1.30 ft	
34.5	7.18	-7.18	1.70 ft	4.58 ft²	1.70 ft	1.70 ft	9.56 ft²	1.70 ft	
37.1	7.1	-7.10	2.60 ft	7.02 ft²	2.60 ft	2.60 ft	14.64 ft²	2.60 ft	
38.4	6.51	-6.51	1.43 ft	3.07 ft²	1.30 ft	1.43 ft	6.88 ft²	1.30 ft	
41.2	6.11	-6.11	2.83 ft	5.24 ft²	2.80 ft	2.83 ft	13.44 ft²	2.80 ft	
42.5	5.81	-5.81	1.33 ft	1.98 ft²	1.30 ft	1.33 ft	5.78 ft²	1.30 ft	
44.5	5.12	-5.12	2.12 ft	2.05 ft²	2.00 ft	2.12 ft	7.91 ft²	2.00 ft	
46.8	4.73	-4.73	2.33 ft	1.12 ft²	2.30 ft	2.33 ft	7.85 ft²	2.30 ft	
51.5	4.5	-4.50	4.71 ft	0.82 ft²	4.70 ft	4.71 ft	14.59 ft²	4.70 ft	
54	4.46	-4.46	2.50 ft	0.10 ft²	2.50 ft	2.50 ft	7.43 ft²	2.50 ft	
55.5	4.12	-4.12	0.09 ft	0.00 ft²	0.09 ft	1.54 ft	4.17 ft²	1.50 ft	
57	2.96	-2.96				1.90 ft	3.05 ft²	1.50 ft	
58.5	2.23	-2.23				1.67 ft	1.63 ft²	1.50 ft	
60	1.75	-1.75				1.57 ft	0.72 ft²	1.50 ft	
61		-1.60				1.01 ft	0.16 ft²	1.00 ft	
64		-1.65				3.00 ft	0.34 ft²	3.00 ft	
67.5		-1.50				3.27 ft	0.23 ft²	3.27 ft	
69	1.49	-1.49							
74	1.23	-1.23							
79	1.109	-1.11							
84	1.14	-1.14							
89	1.13	-1.13							
94	1.02	-1.02							

Biohabitats

Lower Spring Branch
Xsection #4



bf max depth:	3.74 ft
bf avg depth:	2.52 ft
entrenchment:	1.34
width/depth ratio:	13.00
hydraulic radius:	2.36 ft
bankfull discharge:	471.87 ft³/s
floodprone discharge:	2,031.47 ft³/s
Avg. shear stress at bankfull stage:	0.900 lb/ft²

5.73 ft/

Floodprone Rod Height [ft]	-4.76 = (2 · max depth $_{bf}$)

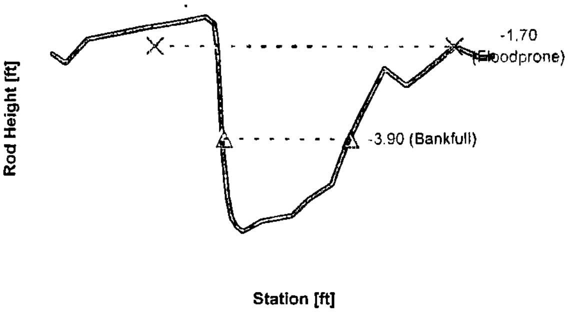
Benchmark Elevation	
Benchmark Rod Height	

Bankfull Rod Height [ft]	8.50
channel slope	0.61%
manning's 'n'	0.036

			Bankfull			*Floodprone*			*Ineffective Flow*
Station [ft]	*Rod Height [ft]*	*Negative Rod Height [ft]*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	
Total			***34.92 ft***	***82.30 ft²***	***32.71 ft***	***48.58 ft***	***225.49 ft²***	***43.98 ft***	☐
	3.52	-3.52				0.77 ft	0.20 ft²	0.68 ft	☐
	5.36	-5.36				1.90 ft	1.64 ft²	1.80 ft	☐
		-5.98				3.68 ft	6.67 ft²	2.70 ft	☐
		-8.48				3.33 ft	13.32 ft²	3.00 ft	☐
	9.92	-9.92	3.28 ft	2.25 ft²	3.17 ft	1.52 ft	7.64 ft²	1.40 ft	☐
10.40	10.52	-10.52	1.52 ft	2.41 ft²	1.40 ft	2.86 ft	16.13 ft²	2.50 ft	☐
12.90	11.90	-11.90	2.86 ft	6.78 ft²	2.50 ft	5.61 ft	40.94 ft²	5.60 ft	☐
18.50	12.24	-12.24	5.61 ft	19.99 ft²	5.60 ft	1.90 ft	14.19 ft²	1.90 ft	☐
20.40	12.22	-12.22	1.90 ft	7.09 ft²	1.90 ft	4.31 ft	31.39 ft²	4.30 ft	☐
24.70	11.90	-11.90	4.31 ft	15.31 ft²	4.30 ft	2.31 ft	16.12 ft²	2.30 ft	☐
27.00	11.64	-11.64	2.31 ft	7.52 ft²	2.30 ft	4.02 ft	28.24 ft²	4.00 ft	☐
31.00	12.00	-12.00	4.02 ft	13.28 ft²	4.00 ft	2.51 ft	6.09 ft²	1.00 ft	☐
32.00	9.70	-9.70	2.51 ft	2.35 ft²	1.00 ft	4.32 ft	20.47 ft²	4.30 ft	☐
36.30	9.34	-9.34	4.32 ft	4.39 ft²	4.30 ft	3.98 ft	14.25 ft²	3.70 ft	☐
40.00	7.88	-7.88	2.29 ft	0.94 ft²	2.24 ft	5.57 ft	8.21 ft²	4.80 ft	☐
44.80	5.06	-5.06							

Biohabitats

Lower Spring Branch
Xsection #5



bf max depth:	2.20 ft	
bf avg depth:	1.53 ft	
entrenchment:	2.37	
width/depth ratio:	19.04	
hydraulic radius:	1.49 ft	
bankfull discharge:	240.48 ft³/s	5.39 ft/s
floodprone discharge:	824.82 ft³/s	
Avg. shear stress at bankfull stage:	0.732 lb/ft²	

Benchmark Elevation	*Bankfull Rod Height [ft]*	3.90
Benchmark Rod Height	*channel slope*	0.79%
	manning's 'n'	0.032

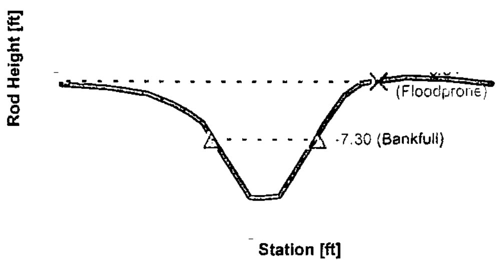
Floodprone Rod Height [ft]	-1.70
	= (2 · max depth $_{bf}$)

Station [ft]	Rod Height [ft]	Negative Rod Height [ft]	Bankfull Wetted Perimeter	Bankfull Cross Sectional Area	Bankfull Top Width	Floodprone Wetted Perimeter	Floodprone Cross Sectional Area	Floodprone Top Width	Ineffective Flow
Total			**30.02 ft**	**44.64 ft²**	**29.15 ft**	**71.47 ft**	**132.29 ft²**	**69.08 ft**	
	1.88	-1.88							☐
3	2.09	-2.09				3.01 ft	0.85 ft²	3.00 ft	☐
8	1.52	-1.52				3.44 ft	0.67 ft²	3.44 ft	☐
20	1.26	-1.26							☐
30	1.09	-1.09							☐
35	0.99	-0.99							☐
37	1.15	-1.15							☐
37.8	1.81	-1.81				0.17 ft	0.01 ft²	0.16 ft	☐
39.1	4.07	-4.07	0.20 ft	0.01 ft²	0.16 ft	2.61 ft	1.61 ft²	1.30 ft	☐
40.3	5.28	-5.28	1.70 ft	0.93 ft²	1.20 ft	1.70 ft	3.57 ft²	1.20 ft	☐
41.2	5.77	-5.77	1.02 ft	1.46 ft²	0.90 ft	1.02 ft	3.44 ft²	0.90 ft	☐
42.5	6	-6.00	1.32 ft	2.58 ft²	1.30 ft	1.32 ft	5.44 ft²	1.30 ft	☐
43.8	6.1	-6.10	1.30 ft	2.79 ft²	1.30 ft	1.30 ft	5.65 ft²	1.30 ft	☐
48	5.85	-5.85	4.21 ft	8.72 ft²	4.20 ft	4.21 ft	17.96 ft²	4.20 ft	☐
55	5.72	-5.72	7.00 ft	13.20 ft²	7.00 ft	7.00 ft	28.60 ft²	7.00 ft	☐
58.9	5.33	-5.33	3.92 ft	6.34 ft²	3.90 ft	3.92 ft	14.92 ft²	3.90 ft	☐
64.1	4.98	-4.98	5.21 ft	6.53 ft²	5.20 ft	5.21 ft	17.97 ft²	5.20 ft	☐
66	4.43	-4.43	1.98 ft	1.53 ft²	1.90 ft	1.98 ft	5.71 ft²	1.90 ft	☐
68	3.92	-3.92	2.06 ft	0.55 ft²	2.00 ft	2.06 ft	4.95 ft²	2.00 ft	☐
71	3.25	-3.25	0.09 ft	0.00 ft²	0.09 ft	3.07 ft	5.66 ft²	3.00 ft	☐
76	2.22	-2.22				5.10 ft	5.18 ft²	5.00 ft	☐
81	2.62	-2.62				5.02 ft	3.60 ft²	5.00 ft	☑
85	2.3	-2.30				4.01 ft	3.04 ft²	4.00 ft	☑
92	1.69	-1.69				6.91 ft	2.07 ft²	6.90 ft	☑
98	1.96	-1.96				5.78 ft	0.75 ft²	5.78 ft	☑
100	1.95	-1.95				2.00 ft	0.51 ft²	2.00 ft	☑
100.6	1.91	-1.91				0.60 ft	0.14 ft²	0.60 ft	☑

ver 1.4

Lower Spring Branch
Xsection Trib B (Dry Concrete Channel)

Sheets



bf max depth:	1.96 ft	
bf avg depth:	1.24 ft	
entrenchment:	3.22	
width/depth ratio:	9.95	
hydraulic radius:	1.21 ft	
bankfull discharge:	302.56 ft³/s	19.84 ft/s
floodprone discharge:	1,062.27 ft³/s	
Avg. shear stress at bankfull stage:	1.496 lb/ft²	

Benchmark Elevation	*Bankfull Rod Height [ft]*	7.30	measured wat	Floodprone Rod Height [ft] -5.34 = (2 · max depth $_{bf}$)
Benchmark Rod Height	*channel slope*	1.98%		
	manning's 'n'	0.012	(concrete channel)	

			Bankfull			*Floodprone*		
Station [ft]	*Rod Height [ft]*	*Negative Rod Height [ft]*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*
Total			***12.60 ft***	***15.25 ft²***	***12.31 ft***	***41.12 ft***	***52.00 ft²***	***39.71 ft***
	5.42	-5.42						
	5.51	-5.51				5.00 ft	0.63 ft²	5.00 ft
		-5.72				5.00 ft	1.38 ft²	5.00 ft
		-6.07				3.02 ft	1.67 ft²	3.00 ft
15	6.39	-6.39				2.03 ft	1.78 ft²	2.00 ft
16.5	6.71	-6.71				1.53 ft	1.82 ft²	1.50 ft
22	9.24	-9.24	4.64 ft	4.36 ft²	4.50 ft	6.05 ft	14.49 ft²	5.50 ft
23.5	9.26	-9.26	1.50 ft	2.93 ft²	1.50 ft	1.50 ft	5.87 ft²	1.50 ft
25.5	9.2	-9.20	2.00 ft	3.86 ft²	2.00 ft	2.00 ft	7.78 ft²	2.00 ft
30.7	6.75	-6.75	4.46 ft	4.10 ft²	4.32 ft	5.75 ft	13.70 ft²	5.20 ft
33	5.81	-5.81				2.48 ft	2.16 ft²	2.30 ft
35	5.4	-5.40				2.04 ft	0.53 ft²	2.00 ft
40	5.21	-5.21				1.58 ft	0.05 ft²	1.58 ft
45	5.28	-5.28						
50	5.44	-5.44				3.13 ft	0.16 ft²	3.13 ft

Ineffective Flow

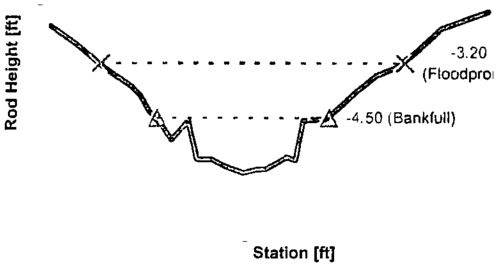
REFERENCE REACH CROSS SECTIONS

APPENDIX B

ver 1.4

Biohabitats

Lower Spring Branch
Reference Reach A Riffle



bf max depth:	1.30 ft	
bf avg depth:	0.74 ft	
entrenchment:	1.77	
width/depth ratio:	26.45	
hydraulic radius:	0.71 ft	
bankfull discharge:	53.19 ft³/s	3.64 ft/s
floodprone discharge:	272.16 ft³/s	
Avg. shear stress at bankfull stage:	0.511 lb/ft²	

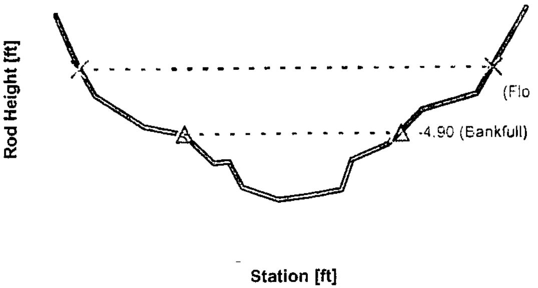
Benchmark Elevation		*Bankfull Rod Height [ft]*	4.50
Benchmark Rod Height		*channel slope*	1.15%
		manning's 'n'	0.035

Floodprone	-3.20
Rod Height [ft]	= (2 · max depth $_{bf}$)

			Bankfull			*Floodprone*			
Station [ft]	*Rod Height [ft]*	*Negative Rod Height [ft]*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	Ineffective Flow
Total			***20.57 ft***	***14.62 ft²***	***19.67 ft***	***35.90 ft***	***48.67 ft²***	***34.73 ft***	
		-2.31							
		-2.75							
		-3.22				0.12 ft	0.00 ft²	t	
		-3.75				3.54 ft	1.00 ft²	t	
		-3.95				1.02 ft	0.65 ft²	t	
		-4.32				1.07 ft	0.94 ft²	t	
			0.96 ft	0.10 ft²	0.95 ft	1.75 ft	2.24 ft²	t	
		-5.00	0.94 ft	0.32 ft²	0.90 ft	0.94 ft	1.49 ft²	t	
		-4.55	1.95 ft	0.52 ft²	1.90 ft	1.95 ft	2.99 ft²	t	
		-5.47	1.36 ft	0.51 ft²	1.00 ft	1.36 ft	1.81 ft²	t	
		-5.48	1.70 ft	1.66 ft²	1.70 ft	1.70 ft	3.87 ft²	t	
		-5.65	1.61 ft	1.70 ft²	1.60 ft	1.61 ft	3.78 ft²	t	
	5.8	-5.80	2.01 ft	2.45 ft²	2.00 ft	2.01 ft	5.05 ft²	t	
	5.72	-5.72	1.50 ft	1.89 ft²	1.50 ft	1.50 ft	3.84 ft²	t	
24.	5.71	-5.71	1.10 ft	1.34 ft²	1.10 ft	1.10 ft	2.77 ft²	t	
	5.59	-5.59	1.11 ft	1.27 ft²	1.10 ft	1.11 ft	2.69 ft²	t	
	5.43	-5.43	1.31 ft	1.31 ft²	1.30 ft	1.31 ft	3.00 ft²	t	
	5.5	-5.50	1.00 ft	0.97 ft²	1.00 ft	1.00 ft	2.27 ft²	t	
	4.56	-4.56	1.30 ft	0.48 ft²	0.90 ft	1.30 ft	1.65 ft²	t	
	4.52	-4.52	2.60 ft	0.10 ft²	2.60 ft	2.60 ft	3.48 ft²	t	
33.2	4.22	-4.22	0.12 ft	0.00 ft²	0.11 ft	1.73 ft	1.99 ft²	t	
34.9	3.89	-3.89				1.73 ft	1.45 ft²	t	
37.3	3.5	-3.50				2.43 ft	1.19 ft²	t	
39.8	3.29	-3.29				2.51 ft	0.49 ft²	t	
	2.92	-2.92				0.52 ft	0.02 ft²	t	
	2.38	-2.38							
	1.98	-1.98							

Biohabitats

Ref Reach B
LOW BKF



bf max depth:	1.81 ft
bf avg depth:	1.09 ft
entrenchment:	1.92
width/depth ratio:	16.98
hydraulic radius:	1.06 ft
bankfull discharge:	129.51 ft³/s
floodprone discharge:	704.54 ft³/s
Avg. shear stress at bankfull stage:	1.453 lb/ft²

Benchmark Elevation	*Bankfull Rod Height [ft]*	-4.90
		4.90
Benchmark Rod Height	*bf channel slope*	2.20%
	manning's 'n'	0.036

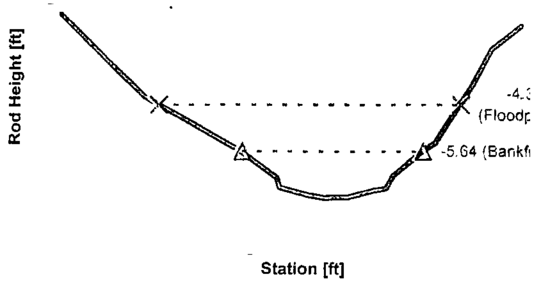
Floodprone	-3.09
Rod Height [ft]	= (2 · depth $_{bf}$)

			Bankfull			*Floodprone*		
Station [ft]	*Rod Height [ft]*	*Negative Rod Height [ft]*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*
Total			***19.20 ft***	***20.32 ft²***	***18.57 ft***	***36.67 ft***	***72.71 ft²***	***35.58 ft***
0.4	.58	-1.58						
	[illegible]	-2.76						
		-3.31				1.43 ft	0.49 ft²	1.36 ft
		-4.68				4.29 ft	4.85 ft²	4.20 ft
		-4.90				3.41 ft	5.78 ft²	3.40 ft
		-5.70	2.72 ft	1.07 ft²	2.68 ft	2.72 ft	5.75 ft²	2.60 ft
		-5.66	1.30 ft	1.01 ft²	1.30 ft	1.30 ft	3.37 ft²	1.30 ft
16.5		-6.27	1.39 ft	1.34 ft²	1.20 ft	1.39 ft	3.51 ft²	1.20 ft
19.6		-6.71	3.12 ft	5.08 ft²	3.10 ft	3.12 ft	10.70 ft²	3.10 ft
		-6.60	2.60 ft	4.56 ft²	2.60 ft	2.60 ft	9.27 ft²	2.60 ft
		-6.45	2.80 ft	4.55 ft²	2.80 ft	2.80 ft	9.62 ft²	2.80 ft
25.9	5.62	-5.62	1.22 ft	1.02 ft²	0.90 ft	1.22 ft	2.65 ft²	0.90 ft
29	5.18	-5.18	3.13 ft	1.55 ft²	3.10 ft	3.13 ft	7.16 ft²	3.10 ft
31.9	4.24	-4.24	0.91 ft	0.13 ft²	0.89 ft	3.05 ft	4.70 ft²	2.90 ft
36.6	3.8	-3.80				4.72 ft	4.37 ft²	4.70 ft
40.9	1.44	-1.44				1.48 ft	0.50 ft²	1.41 ft

ver 1.4

Biohabitats

Lower Spring Branch
Xsection C Riffle



bf max depth:	1.26 ft
bf avg depth:	0.83 ft
entrenchment:	1.66
width/depth ratio:	14.47
hydraulic radius:	0.81 ft
bankfull discharge:	35.74 ft³/s 3.56 ft/s
floodprone discharge:	159.93 ft³/s
Avg. shear stress at bankfull stage:	0.392 lb/ft²

Benchmark Elevation		*Bankfull Rod Height [ft]*	5.64
Benchmark Rod Height		*channel slope*	0.78%
		manning's 'n'	0.032

Floodprone Rod Height [ft]	-4.38 = (2 · max depth $_{bf}$)

			Bankfull			Floodprone		
Station [ft]	*Rod Height [ft]*	*Negative Rod Height [ft]*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*
Total			***12.39 ft***	***10.03 ft²***	***12.05 ft***	***20.78 ft***	***30.31 ft²***	***20.05 ft***
		-1.93						
		-4.14						
		-4.73				1.58 ft	0.27 ft²	1.57 ft
						4.00 ft	3.14 ft²	3.90 ft
			2.40 ft	0.83 ft²	2.37 ft	2.40 ft	3.70 ft²	2.30 ft
			0.33 ft	0.17 ft²	0.20 ft	0.33 ft	0.42 ft²	0.20 ft
			1.91 ft	2.03 ft²	1.90 ft	1.91 ft	4.43 ft²	1.90 ft
			1.10 ft	1.34 ft²	1.10 ft	1.10 ft	2.73 ft²	1.10 ft
			0.50 ft	0.63 ft²	0.50 ft	0.50 ft	1.26 ft²	0.50 ft
			1.00 ft	1.24 ft²	1.00 ft	1.00 ft	2.50 ft²	1.00 ft
.7			1.71 ft	1.94 ft²	1.70 ft	1.71 ft	4.08 ft²	1.70 ft
.5	6.6	-6.64	0.80 ft	0.82 ft²	0.80 ft	0.80 ft	1.83 ft²	0.80 ft
	6.2	-6.28	0.62 ft	0.41 ft²	0.50 ft	0.62 ft	1.04 ft²	0.50 ft
24		-5.61	2.01 ft	0.63 ft²	1.98 ft	2.11 ft	3.13 ft²	2.00 ft
24.8	5.3	-5.39				0.83 ft	0.90 ft²	0.80 ft
27.2	3.8	-3.86				1.88 ft	0.90 ft²	1.78 ft
		-2.86						
		-2.23						

Ineffective Flow

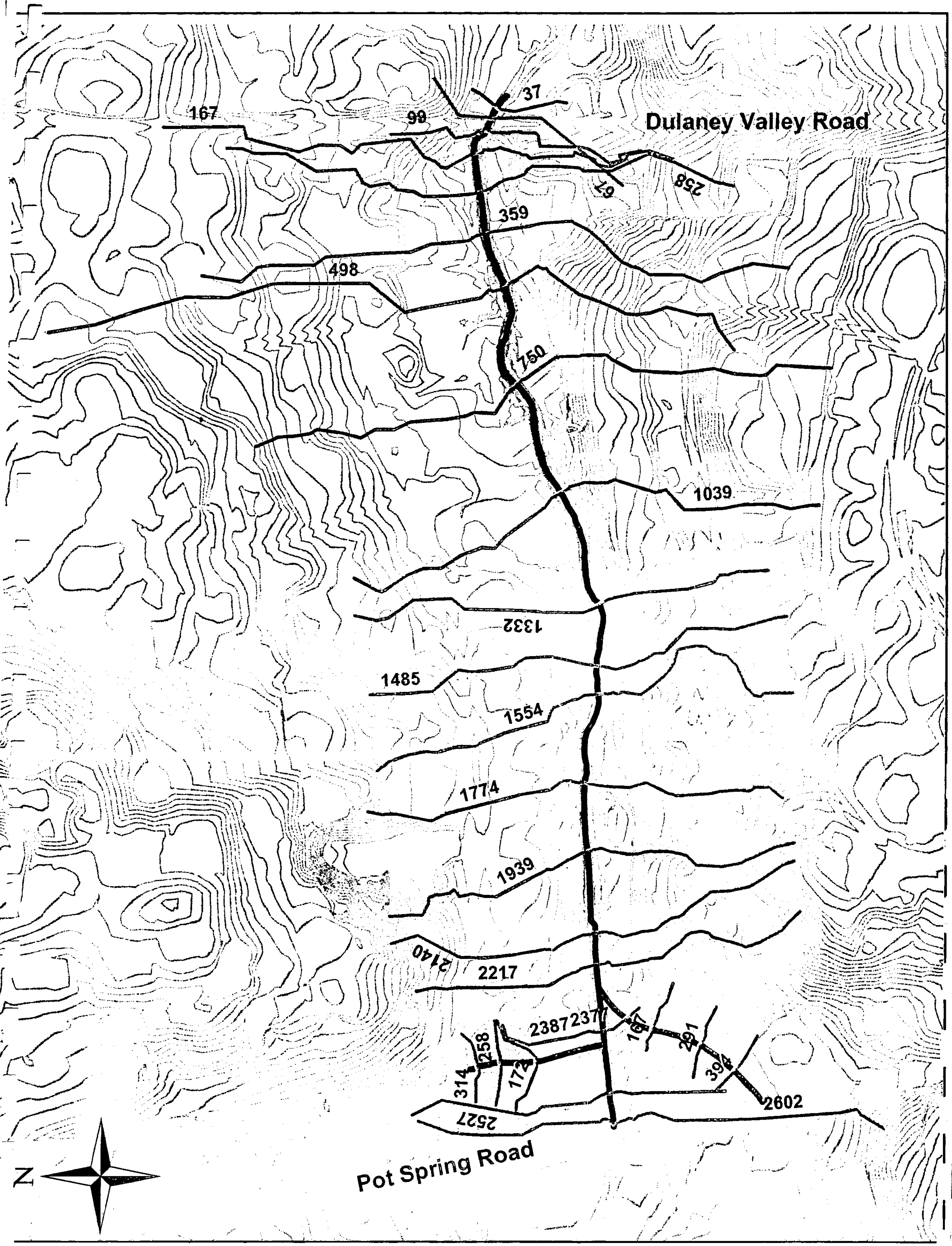
GEOMORPHIC DATA COLLECTED FROM THE REFERENCE REACHES

APPENDIX C

Lower Spring Branch (05015.01)							
Spring Branch Reference Reach A, B, C		2/16/2006		A	B	C	
			Reach BKF Slope	0.0115	0.0219	0.00776	
Spring Branch: Vortex Weir	n	Reach A	Reach C	Reach B	Reach B	Mean	Units
Mean Bankfull Depth	1	1.1	-	-	-	1.1	ft
Maximum Bankfull Depth	1	1.5	-	-	-	1.5	ft
Bankfull Width	1	15.5	-	-	-	15.5	ft
X/S Area	1	17.4	-	-	-	17.4	ft^2
W/D	1	13.8	-	-	-	13.8	n/a
Entrenchment Ratio	1	2.4	-	-	-	2.4	n/a
Weir Slope	4	0.118	0.016	0.098	0.023	0.064	ft/ft
Weir Length	4	4.400	6.700	5.700	7.300	6.0	
RATIO W_{bkf}/(mean D_{bkf})	1	13.85	-	-	-	13.85	n/a
RATIO W_{bkf}/(max D_{bkf})	1	10.34	-	-	-	10.34	n/a
RATIO (max Dbkf)/(mean Dbkf)	1	1.34	-	-	-	1.34	n/a
Spring Branch: Riffle	n	Reach A	Reach B	Reach C	Reach B	Mean	
Mean Bankfull Depth	3	0.7	1.1	1.0	-	0.9	ft
Maximum Bankfull Depth	3	1.3	1.8	1.5	-	1.6	ft
Bankfull Width	3	19.6	18.6	14.1	-	17.4	ft
X/S Area	3	14.6	20.3	13.6	-	16.2	ft^2
W/D	3	26.5	17.0	14.5	-	19.3	n/a
Entrenchment Ratio	3	1.8	1.9	1.6	-	1.8	n/a
RATIO W_{bkf}/(mean D_{bkf})	3	26.49	17.04	14.51	-	18.66	n/a
RATIO W_{bkf}/(max D_{bkf})	3	15.08	10.26	9.14	-	11.23	n/a
RATIO (max Dbkf)/(mean Dbkf)	3	1.76	1.66	1.59	-	1.66	ft/ft
Riffle slope	4	0.0167	0.0420	0.0220	0.0290	0.0274	ft/ft
Riffle length	4	127.0	66.0	38.0	45.5	69.1	ft
Spring Branch: Pool	n	Reach A	Reach B	Reach B	-	Mean	
Mean Bankfull Depth	3	2.7	1.4	1.3	-	1.8	ft
Maximum Bankfull Depth	3	4.3	2.9	2.4	-	3.2	ft
Bankfull Width	3	19.0	21.5	18.8	-	19.8	ft
X/S Area	3	51.5	29.4	24.9	-	35.3	ft^2
W/D	3	7.0	15.7	14.2	-	12.3	n/a
Pool facet slope (Run)	3	0.054	0.047	0.0473	-	0.049	ft/ft
Pool facet slope (Glide)	3	0.104	0.015	0.0857	-	0.068	ft/ft
Entrenchment Ratio	3	2.2	2.4	1.5	-	2.0	n/a
RATIO W_{bkf}/(mean D_{bkf})	3	0.37	0.73	0.76	-	0.62	n/a
RATIO W_{bkf}/(max D_{bkf})	3	0.14	0.53	0.57	-	0.35	n/a
RATIO (max Dbkf)/(mean Dbkf)	3	2.71	1.37	1.32	-	1.78	n/a
Pool slope	3	0.0051	0.004	0.01736	-	0.0	ft/ft
RATIO pool slope/reach slope	3	0.4461	0.196	0.793	-	0.478	n/a
Pool length	3	78.0	53.5	14.4	-	48.6	ft
General		Reach A	Reach B	Reach B	Reach C	Mean	
Pool to Pool Spacing (Dmax to Dmax)		203	114.7	56.6	-	124.8	ft
Reach Length		334	265.4	265.4	73	234.45	ft
Reach Slope		**0.0115**	**0.0219**	**0.0219**	**0.00776**	0.015765	ft/ft
Pool Length		78	53.5	14.4	35	45.225	ft
Glide Length		27	25	7	16	18.75	ft
Riffle Length		127	66	45.5	38	69.125	ft
Run Length		51	21	7.4	6	21.35	ft
Water Surface Slope		0.01	0.021	0.021	0.0118	0.01595	ft
Est. Discharge BKF		53.19	129.5	129.5	53.38	91.3925	cfs
RATIO Pool Length/Reach Slope		6782.61	2442.92	657.53	4510.31	3598.3	n/a
RATIO Glide Length/Reach Slope		2347.83	1141.55	319.63	2061.86	1467.7	n/a
RATIO Riffle Length/Reach Slope		11043.48	3013.70	2077.63	4896.91	5257.9	n/a
RATIO Run Length/Reach Slope		4434.78	958.90	337.90	773.20	1626.2	n/a
RATIO Mean Pool Depth/Mean Riffle Depth		3.66	1.26	1.36	-	2.1	n/a
RATIO Pool BKF Width/ Riffle BKF Width		0.97	1.16	1.34	-	1.2	n/a
RATIO Pool Area/Riffle Area		3.52	1.45	1.83	-	2.3	n/a
RATIO Pool DMax/Mean DBKF		5.84	2.66	2.42	-	3.6	n/a
RATIO Pool DMax/Max DBKF		3.32	1.60	1.53	-	2.2	n/a
RATIO Pool Slope/Avg Water Surface Slope		0.51	0.20	0.83	-	0.5	n/a
RATIO Glide Slope / Avg Water Surface Slope		10.41	0.70	4.08	-	5.1	n/a
RATIO Riffle Slope/Avg Water Surface Slope		1.67	2.00	1.05	2.46	1.8	n/a
RATIO Run slope/Avg water surface slope		5.35	2.22	2.25	-	3.3	n/a
RATIO Pool Length/Width BKF		3.98	2.88	1.02	-	2.6	n/a
RATIO Pool to Pool Spacing/Width BKF		10.36	6.18	4.02	-	6.9	n/a
RATIO Pool slope/reach slope		0.45	0.20	0.79	-	0.5	n/a
RATIO Glide slope/reach slope		9.05	0.67	3.91	-	4.5	n/a
RATIO Riffle slope/reach slope		1.45	1.92	1.00	3.74	2.0	n/a
RATIO Run slope/reach slope		4.65	2.13	2.16	-	3.0	n/a

RESULTS OF THE HYDRAULIC MODELING

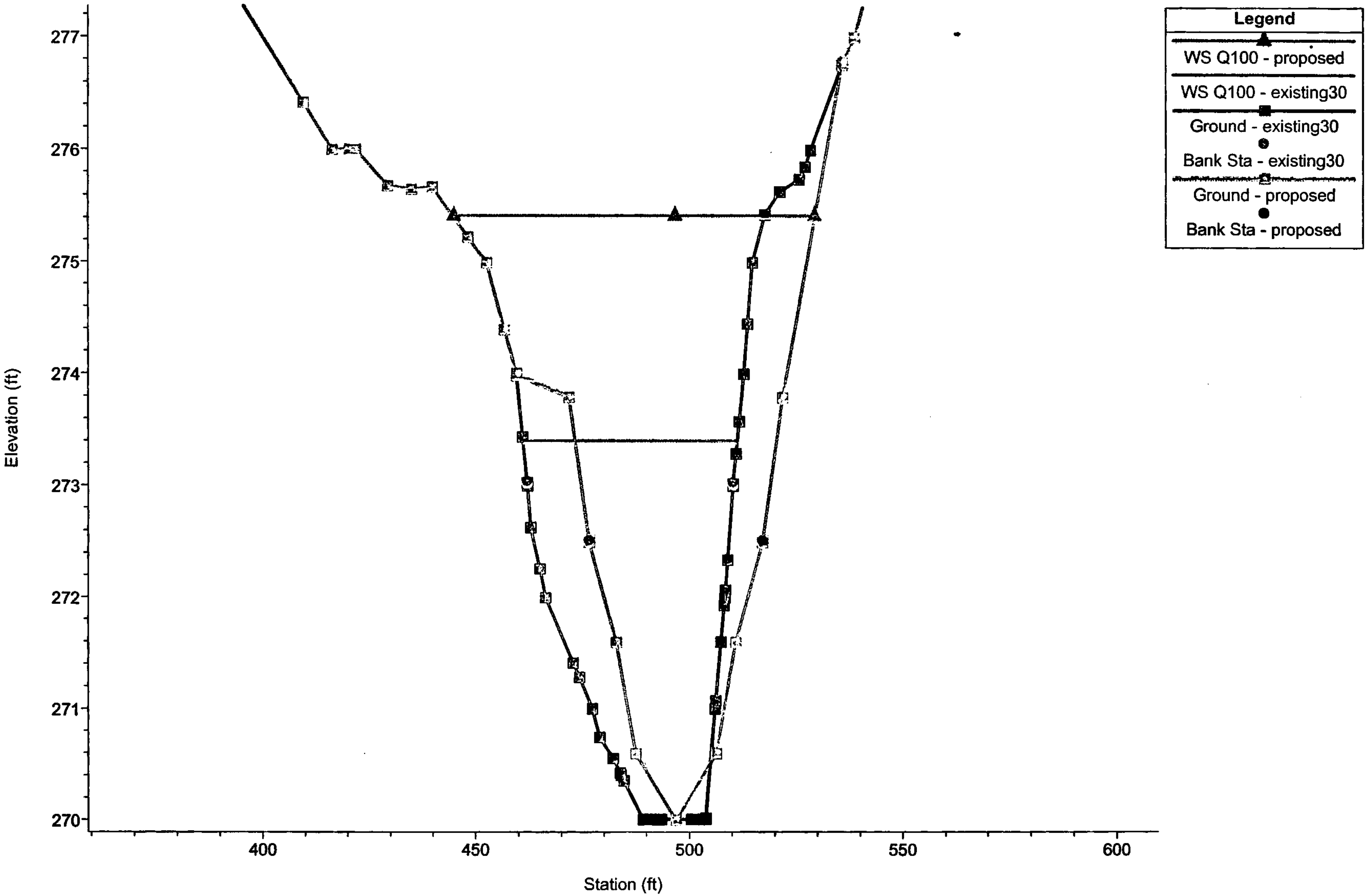
APPENDIX D



Dulaney Valley Road
37
99
167
67
258
359
498
750
1039
1332
1485
1554
1774
1939
2140
2217
2387
2377
167
291
39
258
314
172
2527
2602
Pot Spring Road
N

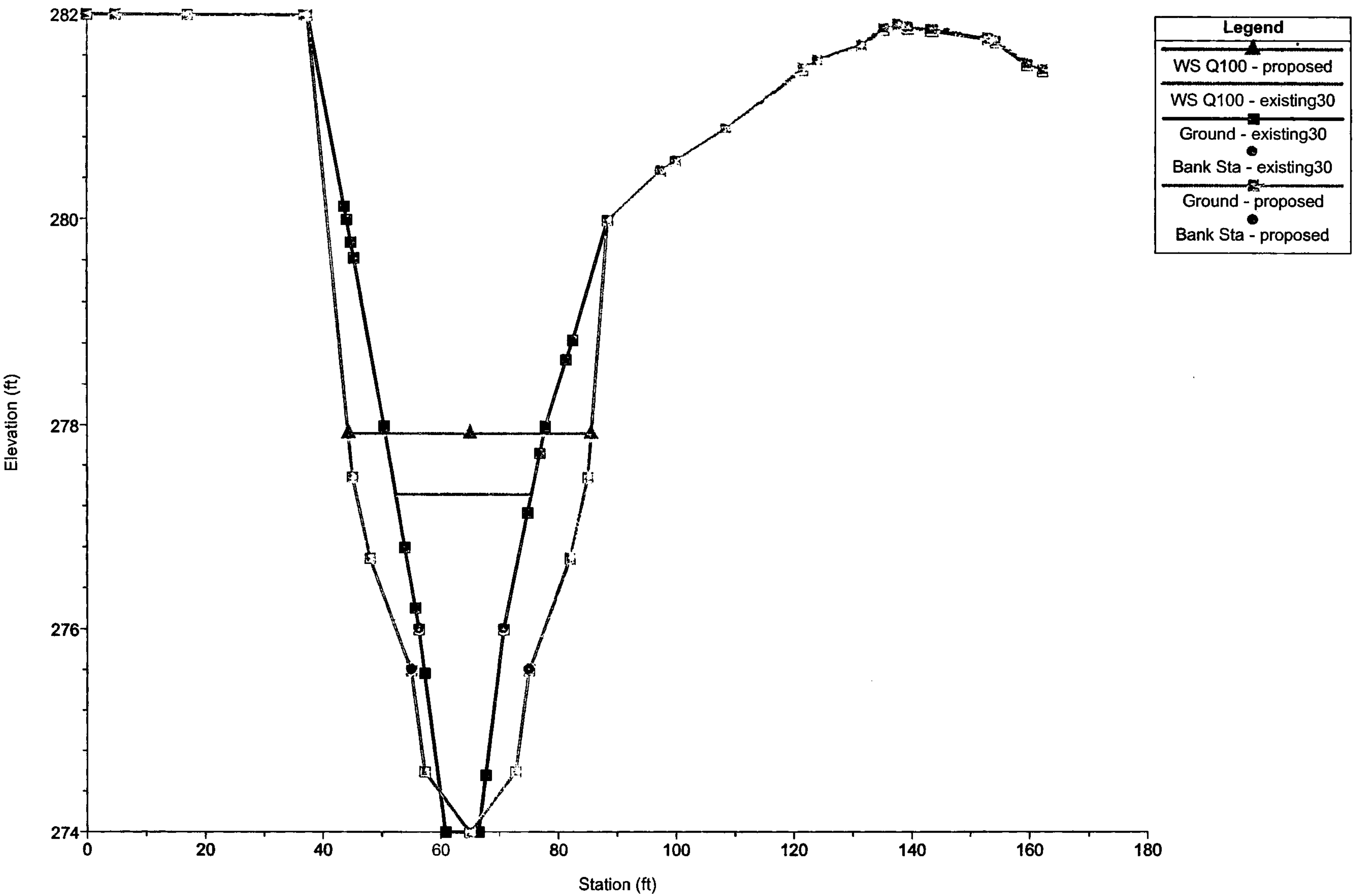
Lower Spring Branch 100-YR WS Comparison

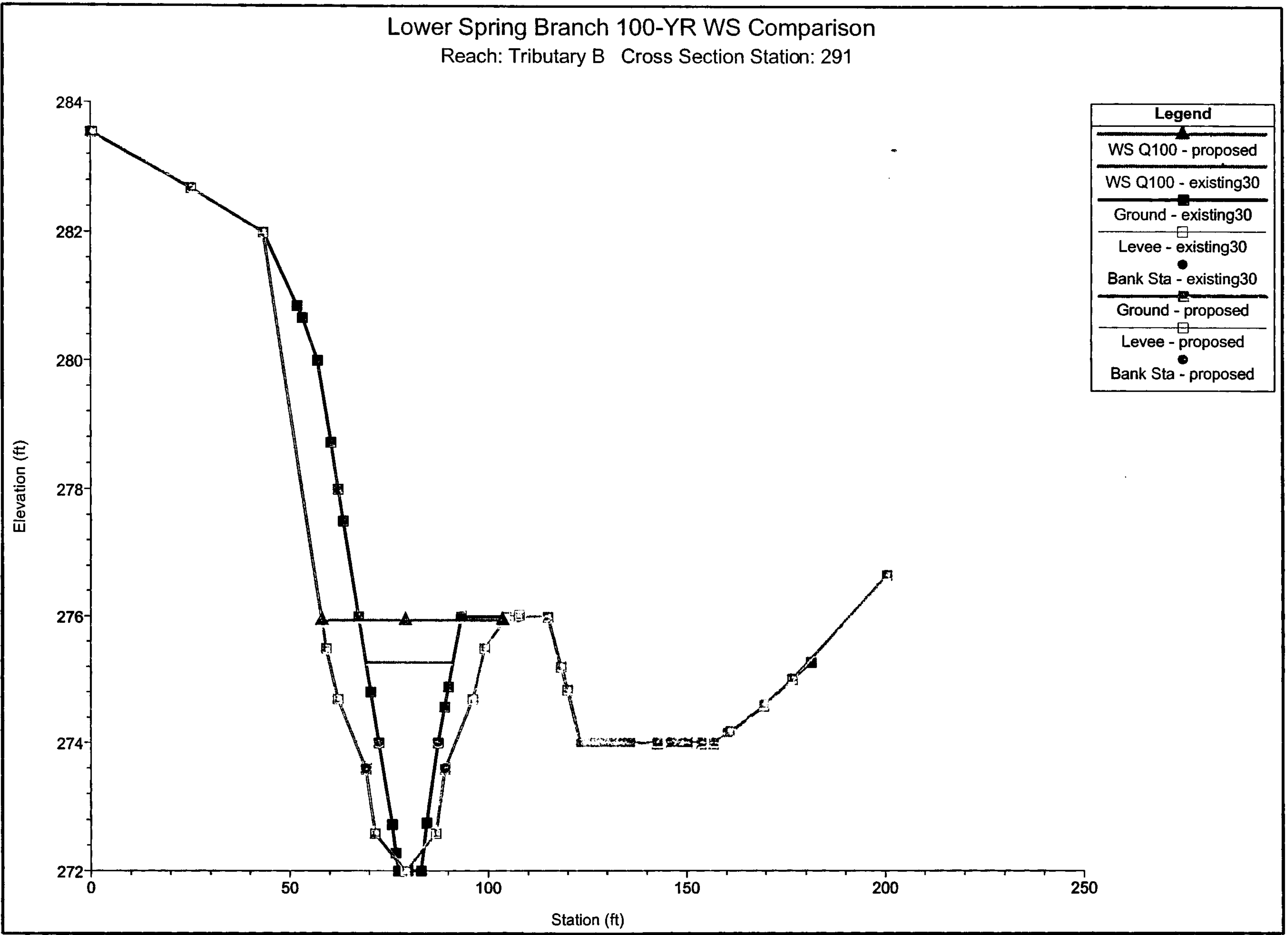
Reach: Mainstem   Cross Section Station: 2602



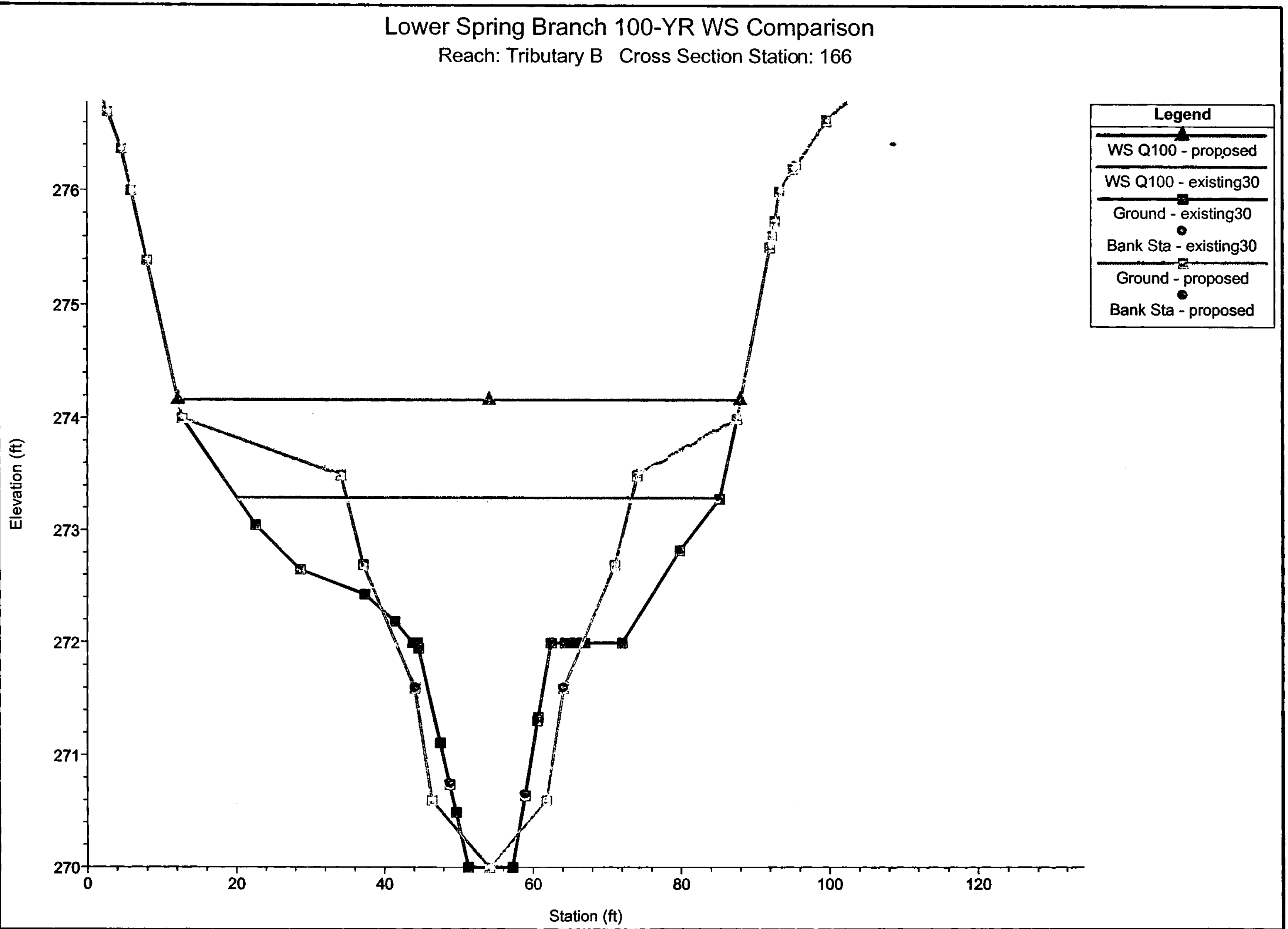
Lower Spring Branch 100-YR WS Comparison

Reach: Tributary B   Cross Section Station: 394

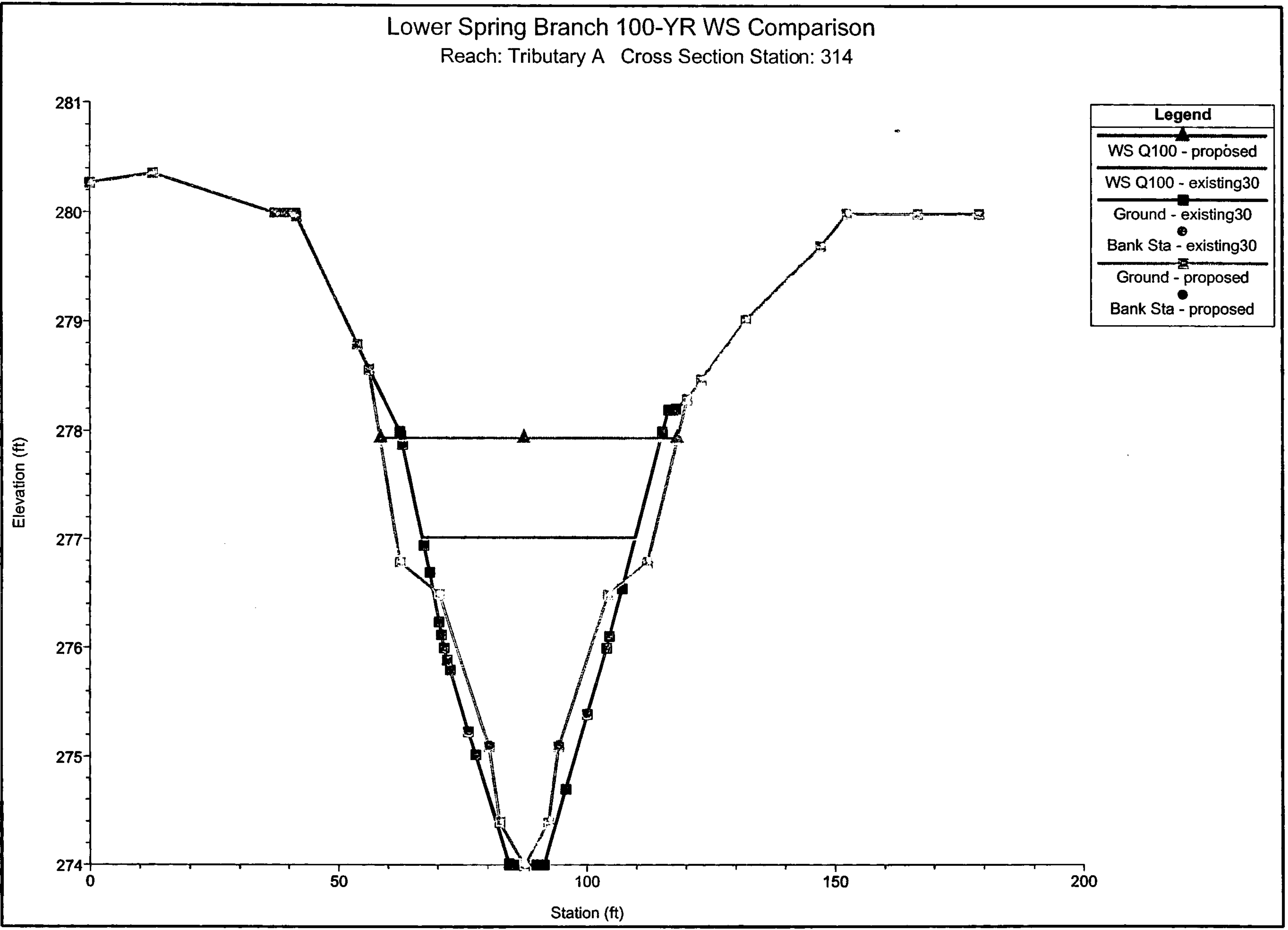




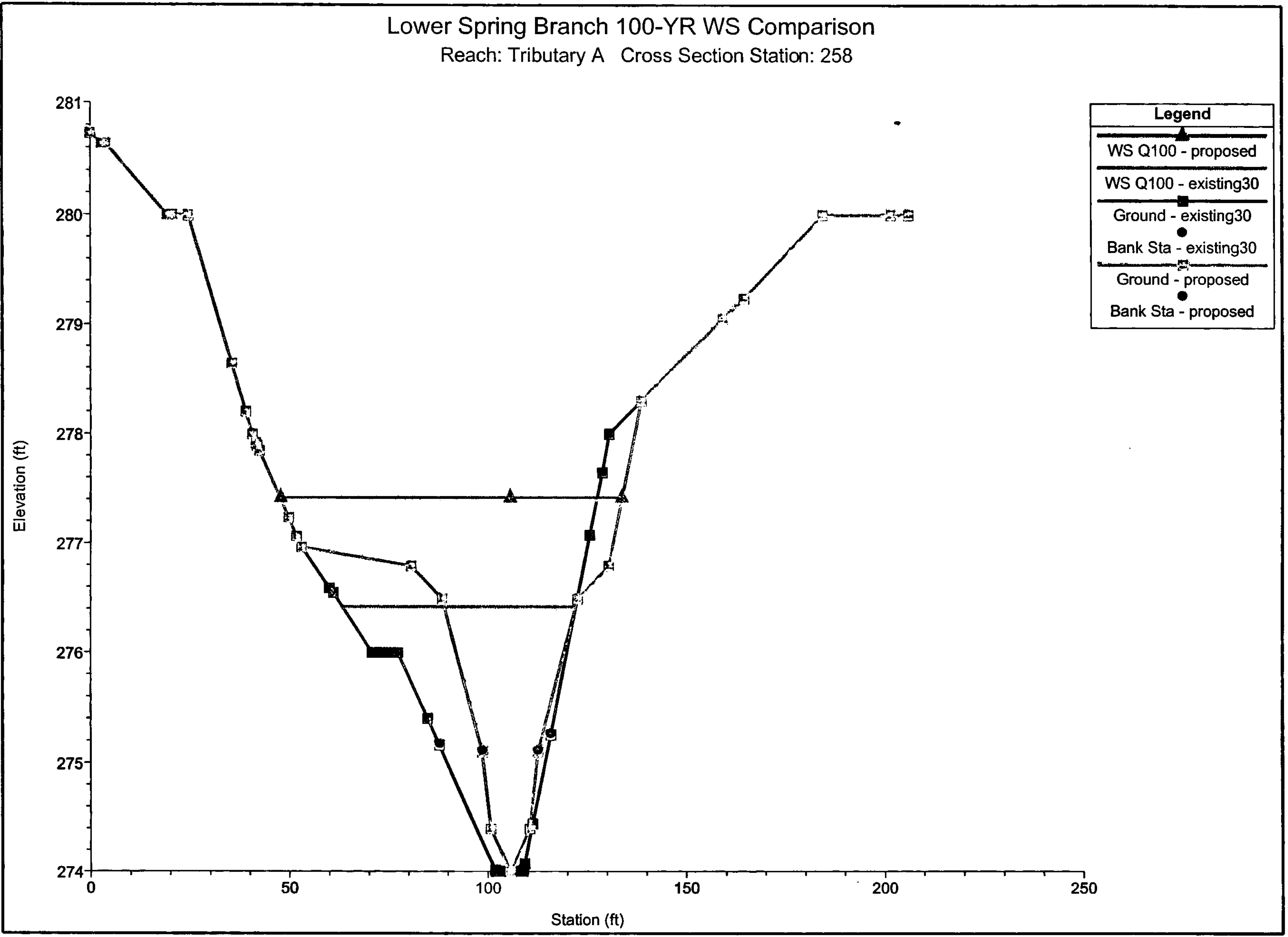
Lower Spring Branch 100-YR WS Comparison
Reach: Tributary B   Cross Section Station: 291
Legend
WS Q100 - proposed
WS Q100 - existing30
Ground - existing30
Levee - existing30
Bank Sta - existing30
Ground - proposed
Levee - proposed
Bank Sta - proposed
Elevation (ft)
284
282
280
278
276
274
272
Station (ft)
0
50
100
150
200
250



Lower Spring Branch 100-YR WS Comparison
Reach: Tributary B   Cross Section Station: 166
Legend
WS Q100 - proposed
WS Q100 - existing30
Ground - existing30
Bank Sta - existing30
Ground - proposed
Bank Sta - proposed
Elevation (ft)
Station (ft)
270
271
272
273
274
275
276
0
20
40
60
80
100
120



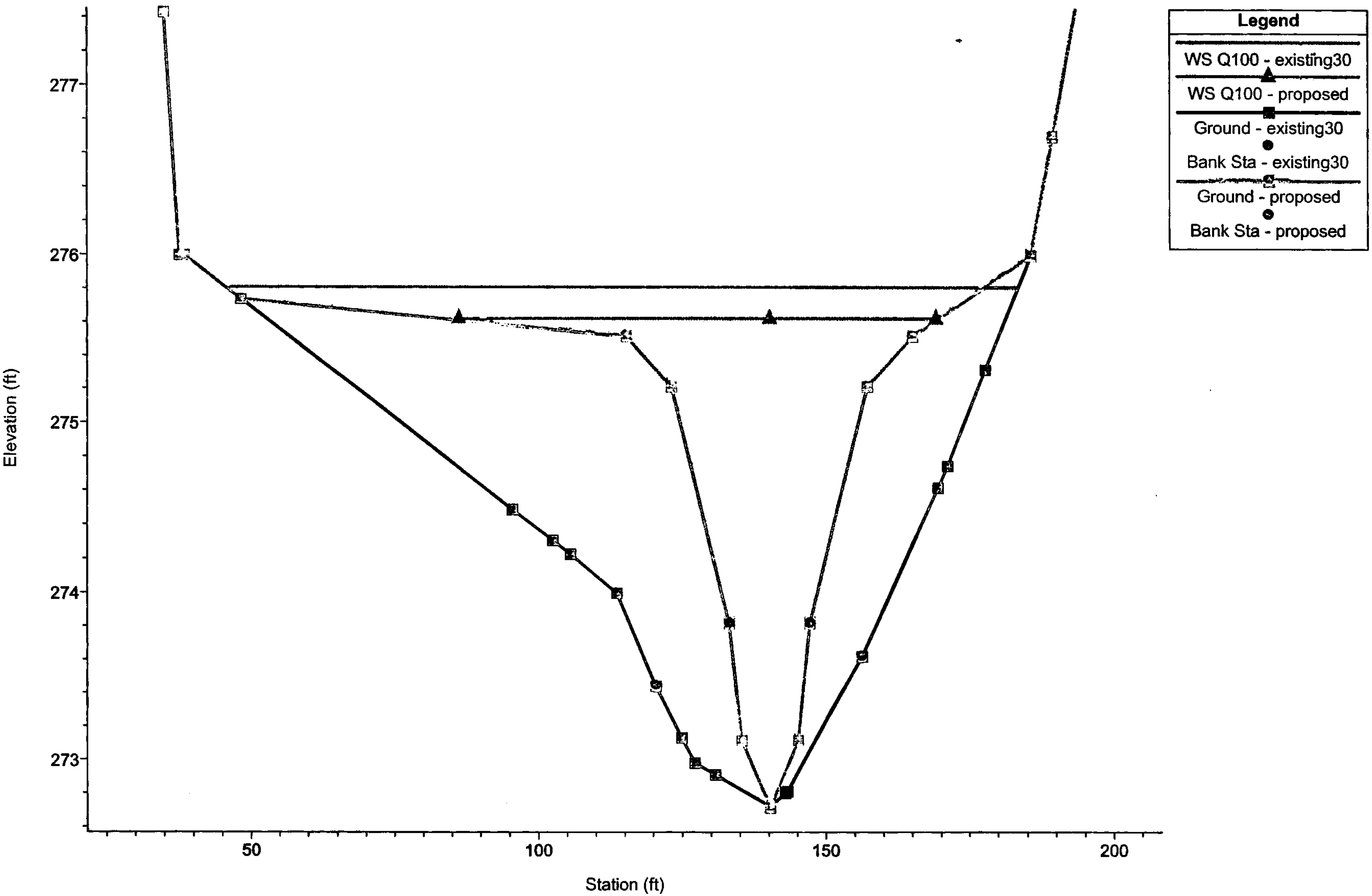
Lower Spring Branch 100-YR WS Comparison
Reach: Tributary A Cross Section Station: 314
Elevation (ft)
Station (ft)
281
280
279
278
277
276
275
274
0
50
100
150
200
Legend
WS Q100 - proposed
WS Q100 - existing30
Ground - existing30
Bank Sta - existing30
Ground - proposed
Bank Sta - proposed

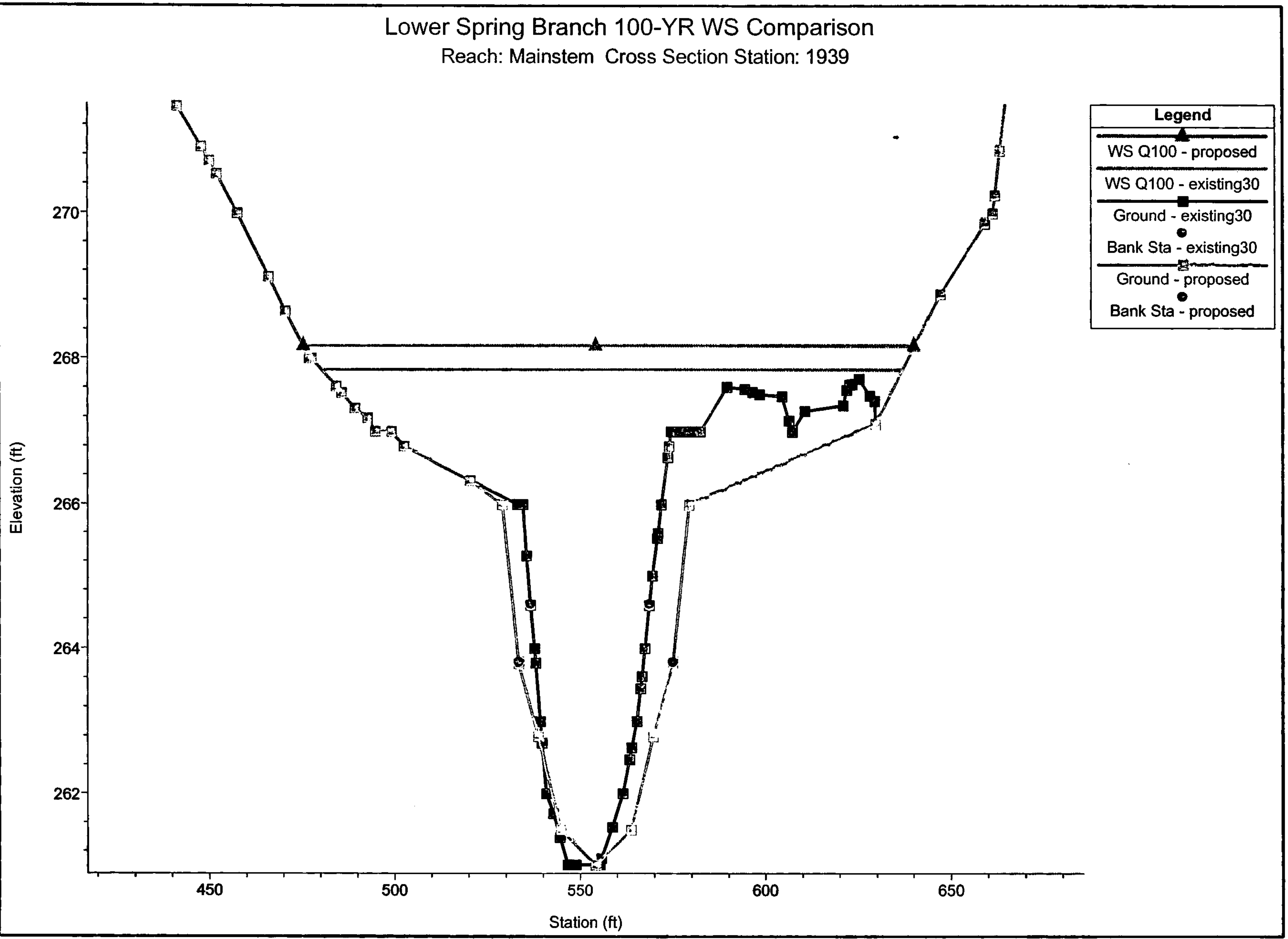


Lower Spring Branch 100-YR WS Comparison
Reach: Tributary A   Cross Section Station: 258
Legend
WS Q100 - proposed
WS Q100 - existing30
Ground - existing30
Bank Sta - existing30
Ground - proposed
Bank Sta - proposed
Elevation (ft)
Station (ft)
281
280
279
278
277
276
275
274
0
50
100
150
200
250

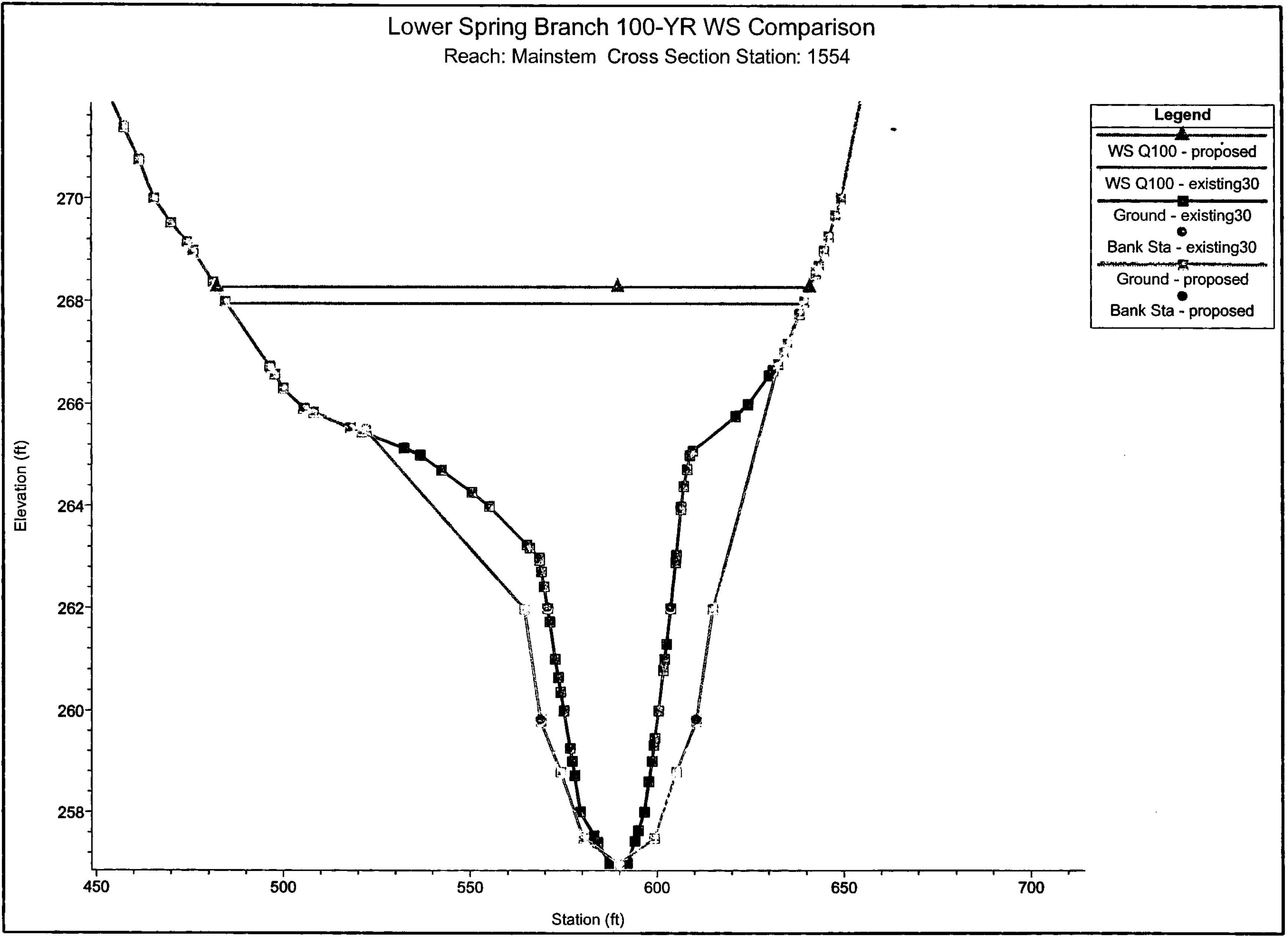
Lower Spring Branch 100-YR WS Comparison

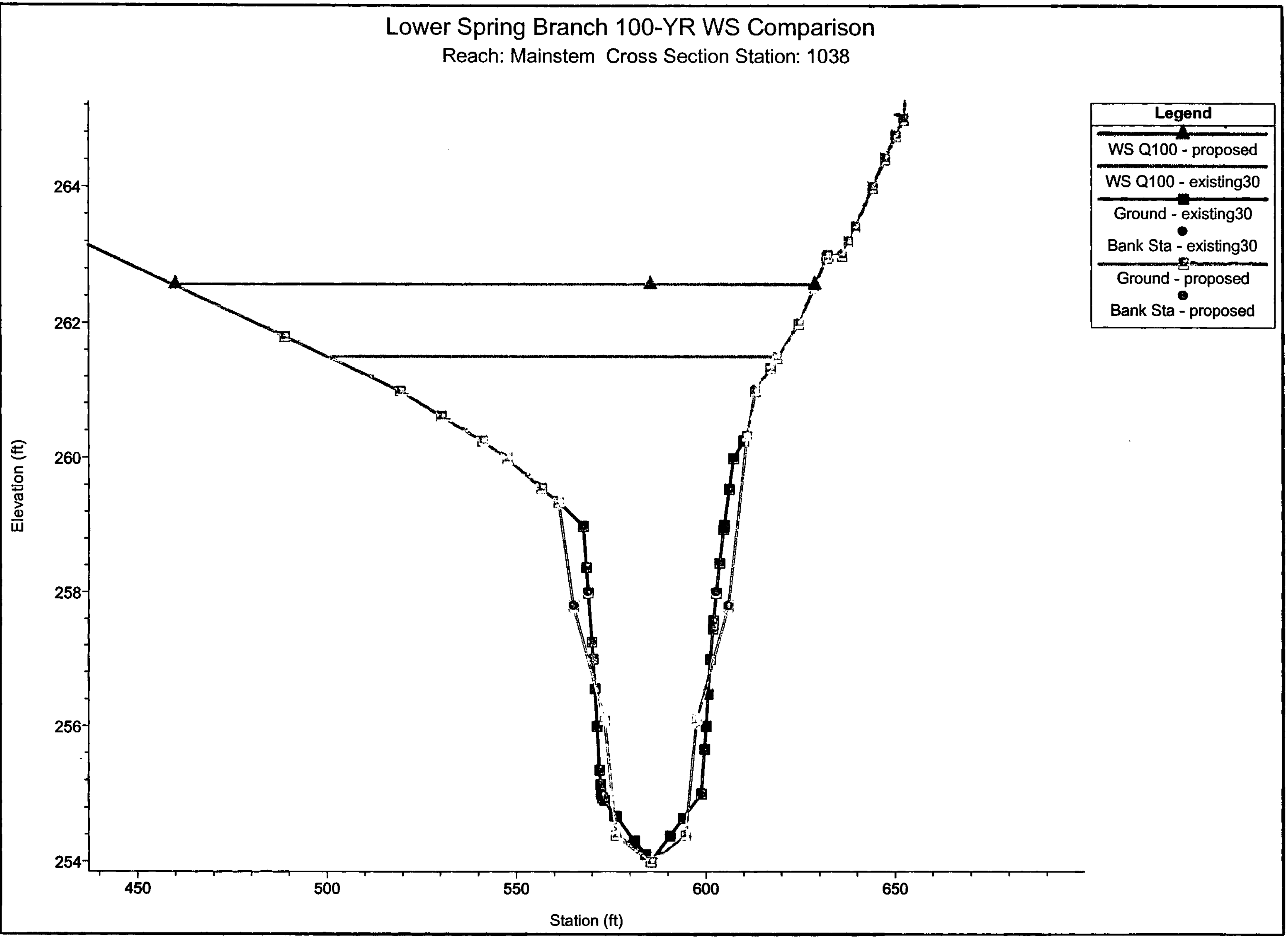
Reach: Tributary A   Cross Section Station: 172

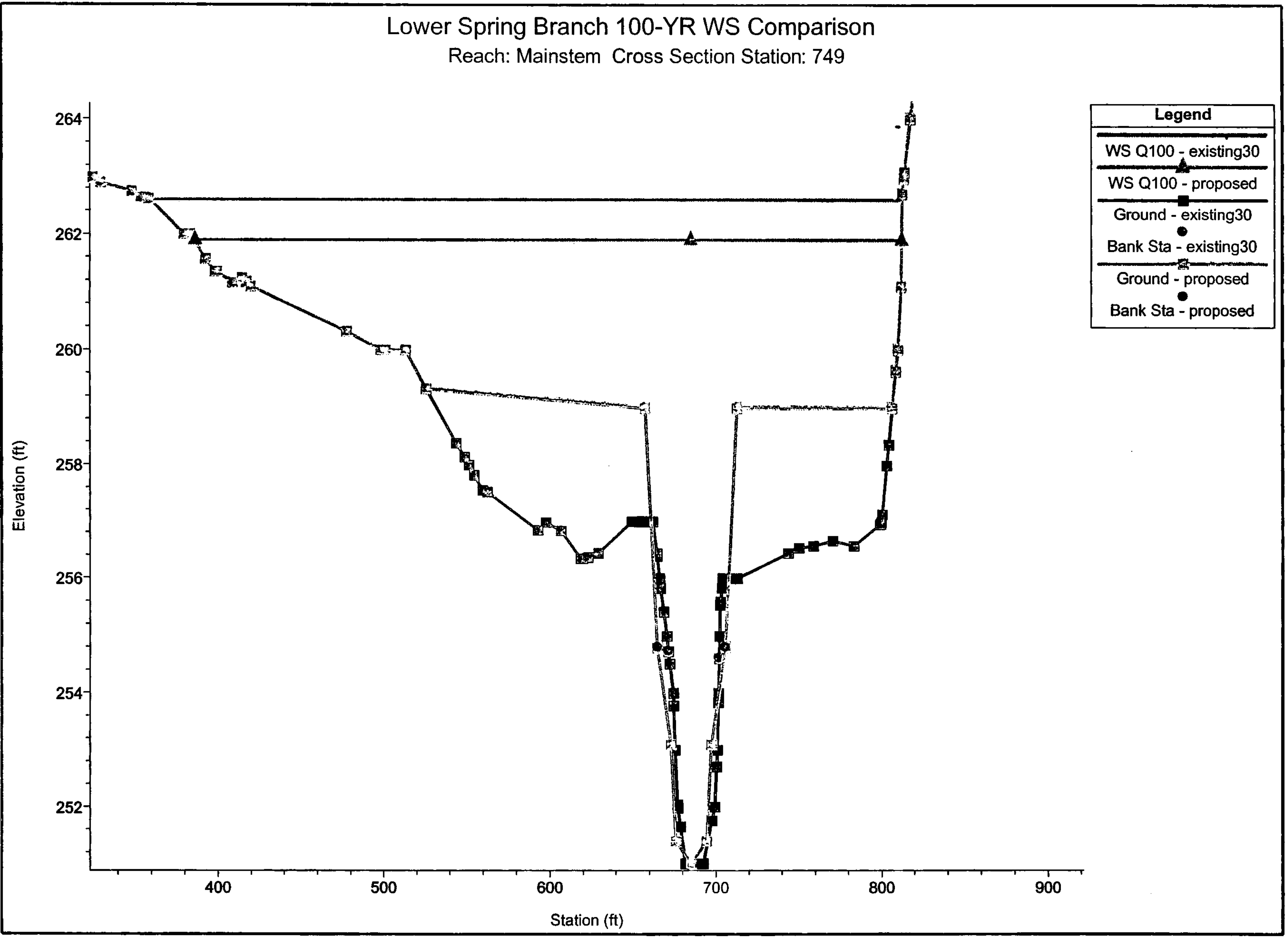


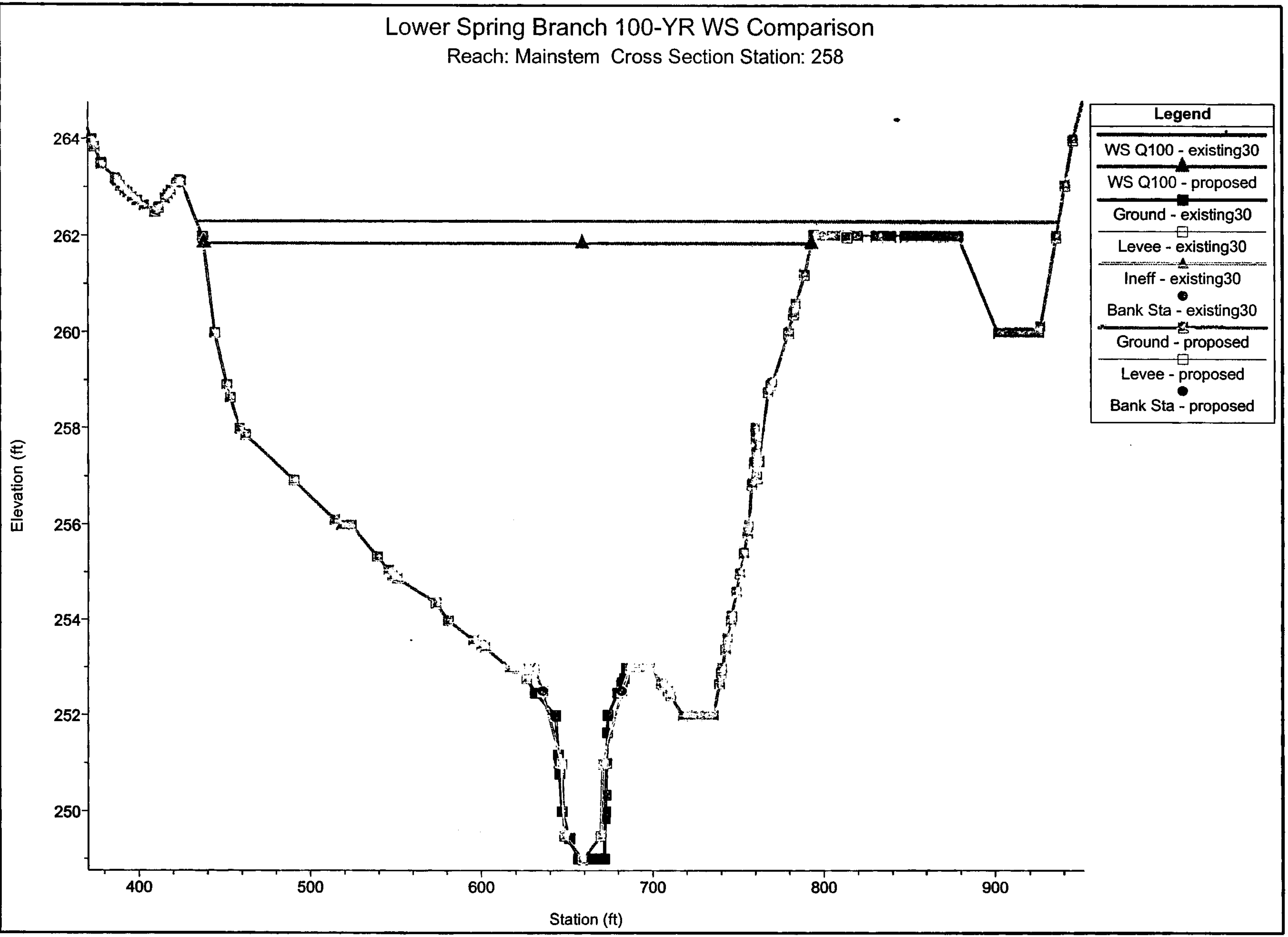


Lower Spring Branch 100-YR WS Comparison
Reach: Mainstem Cross Section Station: 1939
Legend
WS Q100 - proposed
WS Q100 - existing30
Ground - existing30
Bank Sta - existing30
Ground - proposed
Bank Sta - proposed
Elevation (ft)
270
268
266
264
262
Station (ft)
450
500
550
600
650


Lower Spring Branch 100-YR WS Comparison
Reach: Mainstem Cross Section Station: 1554
Elevation (ft)
270
268
266
264
262
260
258
450
500
550
600
650
700
Station (ft)
Legend
WS Q100 - proposed
WS Q100 - existing30
Ground - existing30
Bank Sta - existing30
Ground - proposed
Bank Sta - proposed


Lower Spring Branch 100-YR WS Comparison
Reach: Mainstem Cross Section Station: 1038
Legend
WS Q100 - proposed
WS Q100 - existing30
Ground - existing30
Bank Sta - existing30
Ground - proposed
Bank Sta - proposed
Elevation (ft)
264
262
260
258
256
254
450
500
550
600
650
Station (ft)


Lower Spring Branch 100-YR WS Comparison
Reach: Mainstem Cross Section Station: 749
Elevation (ft)
264
262
260
258
256
254
252
Station (ft)
400
500
600
700
800
900
Legend
WS Q100 - existing30
WS Q100 - proposed
Ground - existing30
Bank Sta - existing30
Ground - proposed
Bank Sta - proposed



Lower Spring Branch 100-YR WS Comparison
Reach: Mainstem Cross Section Station: 258
Elevation (ft)
264
262
260
258
256
254
252
250
Station (ft)
400
500
600
700
800
900
Legend
WS Q100 - existing30
WS Q100 - proposed
Ground - existing30
Levee - existing30
Ineff - existing30
Bank Sta - existing30
Ground - proposed
Levee - proposed
Bank Sta - proposed

WETLAND DETERMINATION DATA FORMS

APPENDIX E

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: [illegible]	Date: 11/17/05
Applicant/Owner: [illegible]	County: [illegible]
Investigator: [illegible]	State: [illegible]
Do Normal Circumstances exist on the site? Yes (No)	Community ID: 1
Is the site significantly disturbed (Atypical Situation)? Yes (No)	Transect ID:
Is the area a potential Problem Area? Yes (No) (If needed, explain on reverse.)	Plot ID:

Wetlands – [illegible] – Flags WL-1-7

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. [illegible] (D)	H	OBL	9. Norway maple	C	FACU
2. Typha latifolia (D)	H	OBL	10. English ivy	V	FACU
3. Multiflora rose	S	FACU	11. Solidago sp.	H	[illegible]
4. Lonicera japonica	V	FAC-	12. Oriental bittersweet	V	[illegible]
5. black walnut	C	[illegible]	13.		
6. black willow	C	FACW	14.		
7. [illegible]	C	FAC+	15.		
8. Sycamore	C	FACW	16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-). 5/7 ≈ 70%

Remarks: excluding non-native invasives

HYDROLOGY

___ Recorded Data (Describe in Remarks):
___ Stream, Lake, or Tide Gauge
___ Aerial Photographs
___ Other
✓ No Recorded Data Available

Field Observations:

Depth of Surface Water: ______ (in.)

Depth to Free Water in Pit: ______ (in.)

Depth to Saturated Soil: 0 (in.)

Wetland Hydrology Indicators:

Primary Indicators:
___ Inundated
✓ Saturated in Upper 12 Inches
✓ Water Marks
___ Drift Lines
✓ Sediment Deposits
___ Drainage Patterns in Wetlands

Secondary Indicators (2 or more required):
___ Oxidized Root Channels in Upper 12 Inches
___ Water-Stained Leaves
___ Local Soil Survey Data
___ FAC-Neutral Test
___ Other (Explain in Remarks)

Remarks: frequent inundation by stream – [illegible] in flooding

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: Springs Ranch	Date: 1/17/05
Applicant/Owner: Balt Co	County: Balt
Investigator: TMD	State: MD
Do Normal Circumstances exist on the site? Yes **No**	Community ID: 2
Is the site significantly disturbed (Atypical Situation)? Yes **No**	Transect ID:
Is the area a potential Problem Area? Yes **No** (If needed, explain on reverse.)	Plot ID:

Wetland 2 - Outlet channel from pond - Flags 1-[illegible]

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. Juncus effusus	H	FACW	9.		
2. Impatiens capensis	H	FACW	10.		
3. Lonicera japonica	V	FAC-	11.		
4. Privet	S	FACU	12.		
5. Watercress	H	OBL	13.		
6. [illegible] grass	H	FACW	14.		
7.			15.		
8.			16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-). 4/6 = 67%

Remarks:

HYDROLOGY

___ Recorded Data (Describe in Remarks):
___ Stream, Lake, or Tide Gauge
___ Aerial Photographs
___ Other
✓ No Recorded Data Available

Field Observations:

Depth of Surface Water: 0 - 6 (in.)

Depth to Free Water in Pit: ______ (in.)

Depth to Saturated Soil: ______ (in.)

Wetland Hydrology Indicators:

Primary Indicators:
✓ Inundated
✓ Saturated in Upper 12 Inches
✓ Water Marks
___ Drift Lines
___ Sediment Deposits
___ Drainage Patterns in Wetlands

Secondary Indicators (2 or more required):
✓ Oxidized Root Channels in Upper 12 Inches
___ Water-Stained Leaves
___ Local Soil Survey Data
___ FAC-Neutral Test
___ Other (Explain in Remarks)

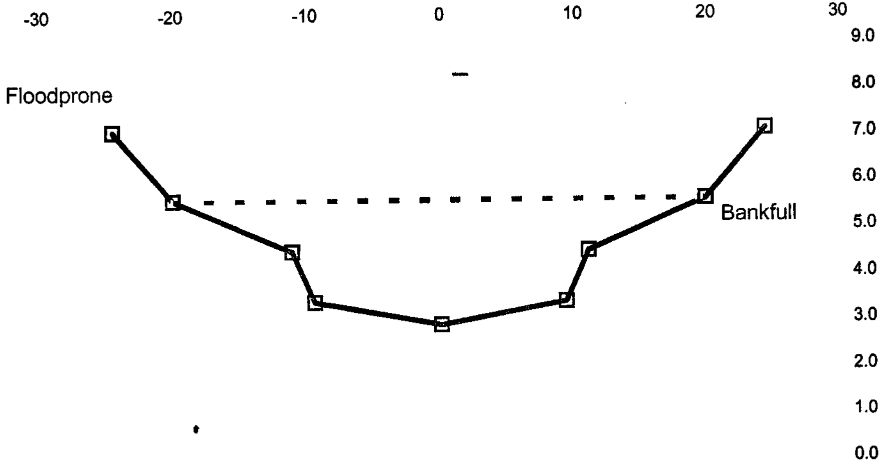
Remarks: outlet from pond

PROPOSED RIFFLE CROSS SECTIONS

APPENDIX F

Reach 1 High BKF

UPS Trib A&B Bc Channel



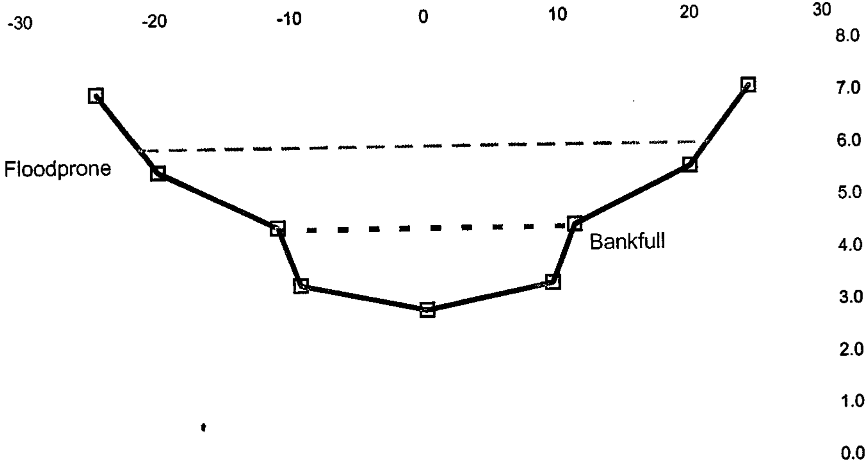
	Bankfull	Floodprone
Max Depth	2.70 ft.	5.40 ft.
Manning's 'n'	0.035	0.060
slope	1.14%	n/a
Q	367.04 ft³/s	1946.43 ft³/s
V_{avg}	5.98 ft/s	9.98 ft/s
R_h	1.51	0.28
Entenchment	1.34	n/a
W/D Ratio	25.82	n/a
Avg. Depth	1.54 ft	3.66 ft
Avg. Shear	1.08 lbs/ft²	

1

Increment change	*offset*	*elevation*	Bankfull *Wetted Perimeter*	Bankfull *Cross Sectional Area*	Bankfull *Top Width*	Floodprone *Wetted Perimeter*	Floodprone *Cross Sectional Area*	Floodprone *Top Width*
			40.61 ft	**61.34 ft²**	**39.80 ft**	**54.84 ft**	**195.10 ft²**	**53.30 ft**
0.1	-24.4	7.1	0.00 ft	0.00 ft	0.00 ft	4.74 ft	8.77 ft	4.50 ft
	-19.9	5.6	0.00 ft	0.00 ft²	0.00 ft	4.74 ft	8.77	4.50 ft
side slope	-11.1	4.5	8.87 ft	4.84 ft²	8.80 ft	8.87 ft	28.59	8.80 ft
1.55:1	-9.4	3.4	2.02 ft	2.80 ft²	1.70 ft	2.02 ft	7.39	1.70 ft
65%	0.0	2.9	9.41 ft	23.03 ft²	9.40 ft	9.41 ft	48.40	9.40 ft
	9.4	3.4	9.41 ft	23.03 ft²	9.40 ft	9.41 ft	48.40	9.40 ft
	11.1	4.5	2.02 ft	2.80 ft²	1.70 ft	2.02 ft	7.39	1.70 ft
	19.9	5.6	8.87 ft	4.84 ft²	8.80 ft	8.87 ft	28.59	8.80 ft
	24.4	7.1	0.00 ft	0.00 ft²	0.00 ft	4.74 ft	8.77	4.50 ft

Reach 1 Low BKF

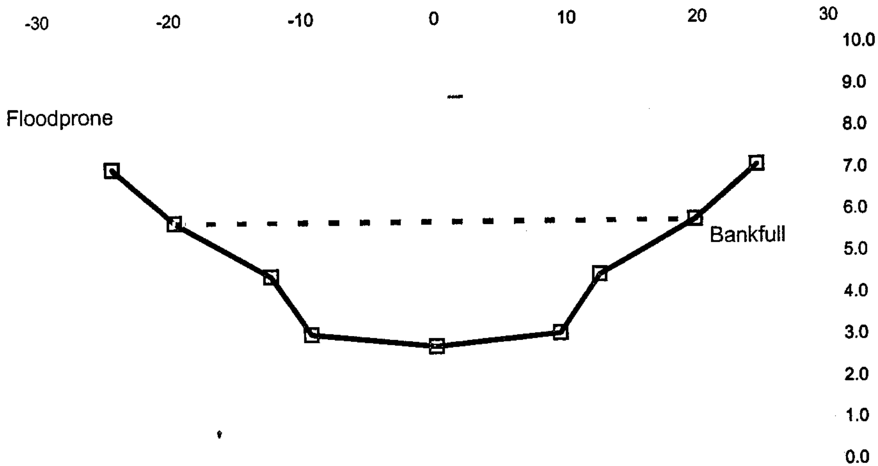
UPS Trib A&B Bc Channel



	Bankfull	Floodprone
Max Depth	1.57 ft.	3.15 ft.
Manning's 'n'	0.035	0.060
slope	1.14%	n/a
Q	134.58 ft³/s	389.48 ft³/s
V_{avg}	5.05 ft/s	4.87 ft/s
R_h	1.17	0.56
Entenchment	1.98	n/a
W/D Ratio	18.35	n/a
Avg. Depth	1.21 ft	1.83 ft
Avg. Shear	0.83 lbs/ft²	

Increment change: 1	offset	elevation	Bankfull: Wetted Perimeter	Bankfull: Cross Sectional Area	Bankfull: Top Width	Floodprone: Wetted Perimeter	Floodprone: Cross Sectional Area	Floodprone: Top Width
			22.78 ft	26.66 ft²	22.12 ft	44.85 ft	80.03 ft²	43.82 ft
0.1	-24.4	7.1	0.00 ft	0.00 ft	0.00 ft	1.41 ft	0.30 ft	1.34 ft
	-19.9	5.6	0.00 ft	0.00 ft²	0.00 ft	1.41 ft	0.30	1.34 ft
side slope	-11.1	4.5	0.00 ft	0.00 ft²	0.00 ft	8.87 ft	8.77	8.80 ft
1.55:1	-9.4	3.4	1.98 ft	0.89 ft²	1.66 ft	2.02 ft	3.56	1.70 ft
65%	0.0	2.9	9.41 ft	12.44 ft²	9.40 ft	9.41 ft	27.23	9.40 ft
	9.4	3.4	9.41 ft	12.44 ft²	9.40 ft	9.41 ft	27.23	9.40 ft
	11.1	4.5	1.98 ft	0.89 ft²	1.66 ft	2.02 ft	3.56	1.70 ft
	19.9	5.6	0.00 ft	0.00 ft²	0.00 ft	8.87 ft	8.77	8.80 ft
	24.4	7.1	0.00 ft	0.00 ft²	0.00 ft	1.41 ft	0.30	1.34 ft

Reach 2 High BKF
UPS Trib A&B Bc Channel

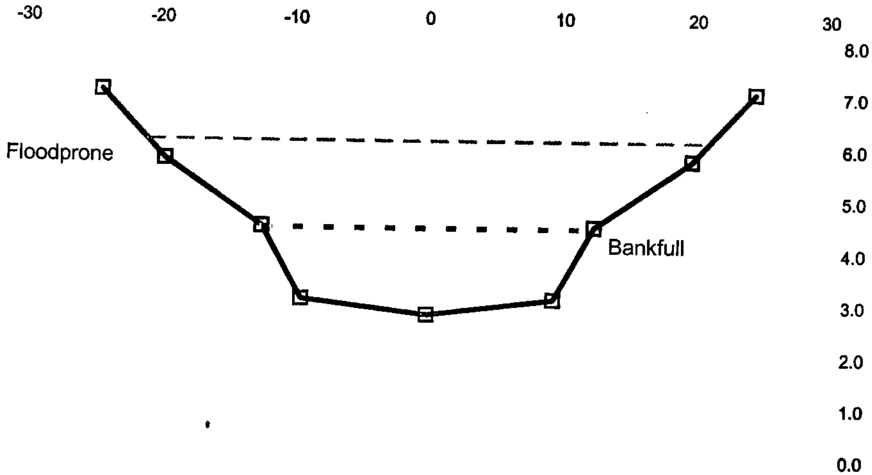


	Bankfull	Floodprone
Max Depth	2.99 ft.	5.97 ft.
Manning's 'n'	0.035	0.060
slope	1.14%	n/a
Q	512.34 ft³/s	2386.38 ft³/s
V_{avg}	6.87 ft/s	10.61 ft/s
R_h	1.86	0.24
Entenchment	1.36	n/a
W/D Ratio	20.67	n/a
Avg. Depth	1.90 ft	4.21 ft
Avg. Shear	1.32 lbs/ft²	

1			Bankfull			Floodprone		
Increment change	*offset*	*elevation*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*
			40.11 ft	**74.56 ft²**	**39.25 ft**	**54.89 ft**	**225.02 ft²**	**53.50 ft**
0.1	-24.4	7.1	0.00 ft	0.00 ft	0.00 ft	4.88 ft	10.92 ft	4.70 ft
	-19.7	5.8	0.00 ft	0.00 ft²	0.00 ft	4.88 ft	10.92	4.70 ft
side slope	-12.4	4.5	7.34 ft	4.65 ft²	7.23 ft	7.41 ft	26.46	7.30 ft
2.14:1	-9.4	3.1	3.31 ft	5.96 ft²	3.00 ft	3.31 ft	14.92	3.00 ft
47%	0.0	2.8	9.40 ft	26.67 ft²	9.40 ft	9.40 ft	54.75	9.40 ft
	9.4	3.1	9.40 ft	26.67 ft²	9.40 ft	9.40 ft	54.75	9.40 ft
	12.4	4.5	3.31 ft	5.96 ft²	3.00 ft	3.31 ft	14.92	3.00 ft
	19.7	5.8	7.34 ft	4.65 ft²	7.23 ft	7.41 ft	26.46	7.30 ft
	24.4	7.1	0.00 ft	0.00 ft²	0.00 ft	4.88 ft	10.92	4.70 ft

Reach 2 Low BKF

UPS Trib A&B Bc Channel



	Bankfull	Floodprone
Max Depth	1.68 ft.	3.36 ft.
Manning's 'n'	0.035	0.060
slope	1.14%	n/a
Q	177.53 ft³/s	493.25 ft³/s
V_{avg}	5.40 ft/s	5.48 ft/s
R_h	1.30	0.49
Entenchment	1.75	n/a
W/D Ratio	18.60	n/a
Avg. Depth	1.33 ft	2.08 ft
Avg. Shear	0.92 lbs/ft²	

Increment change	offset	elevation	Bankfull Wetted Perimeter	Bankfull Cross Sectional Area	Bankfull Top Width	Floodprone Wetted Perimeter	Floodprone Cross Sectional Area	Floodprone Top Width
1			**25.34 ft**	**32.85 ft²**	**24.71 ft**	**44.31 ft**	**89.97 ft²**	**43.31 ft**
0.1	-24.4	7.1	0.00 ft	0.00 ft	0.00 ft	1.35 ft	0.23 ft	1.30 ft
	-19.7	5.8	0.00 ft	0.00 ft²	0.00 ft	1.35 ft	0.23	1.30 ft
side slope	-12.4	4.5	0.00 ft	0.00 ft²	0.00 ft	7.41 ft	7.38	7.30 ft
2.14:1	-9.4	3.1	3.26 ft	2.04 ft²	2.96 ft	3.31 ft	7.08	3.00 ft
47%	0.0	2.8	9.40 ft	14.38 ft²	9.40 ft	9.40 ft	30.18	9.40 ft
	9.4	3.1	9.40 ft	14.38 ft²	9.40 ft	9.40 ft	30.18	9.40 ft
	12.4	4.5	3.26 ft	2.04 ft²	2.96 ft	3.31 ft	7.08	3.00 ft
	19.7	5.8	0.00 ft	0.00 ft²	0.00 ft	7.41 ft	7.38	7.30 ft
	24.4	7.1	0.00 ft	0.00 ft²	0.00 ft	1.35 ft	0.23	1.30 ft

Biohabitats
Incorporated

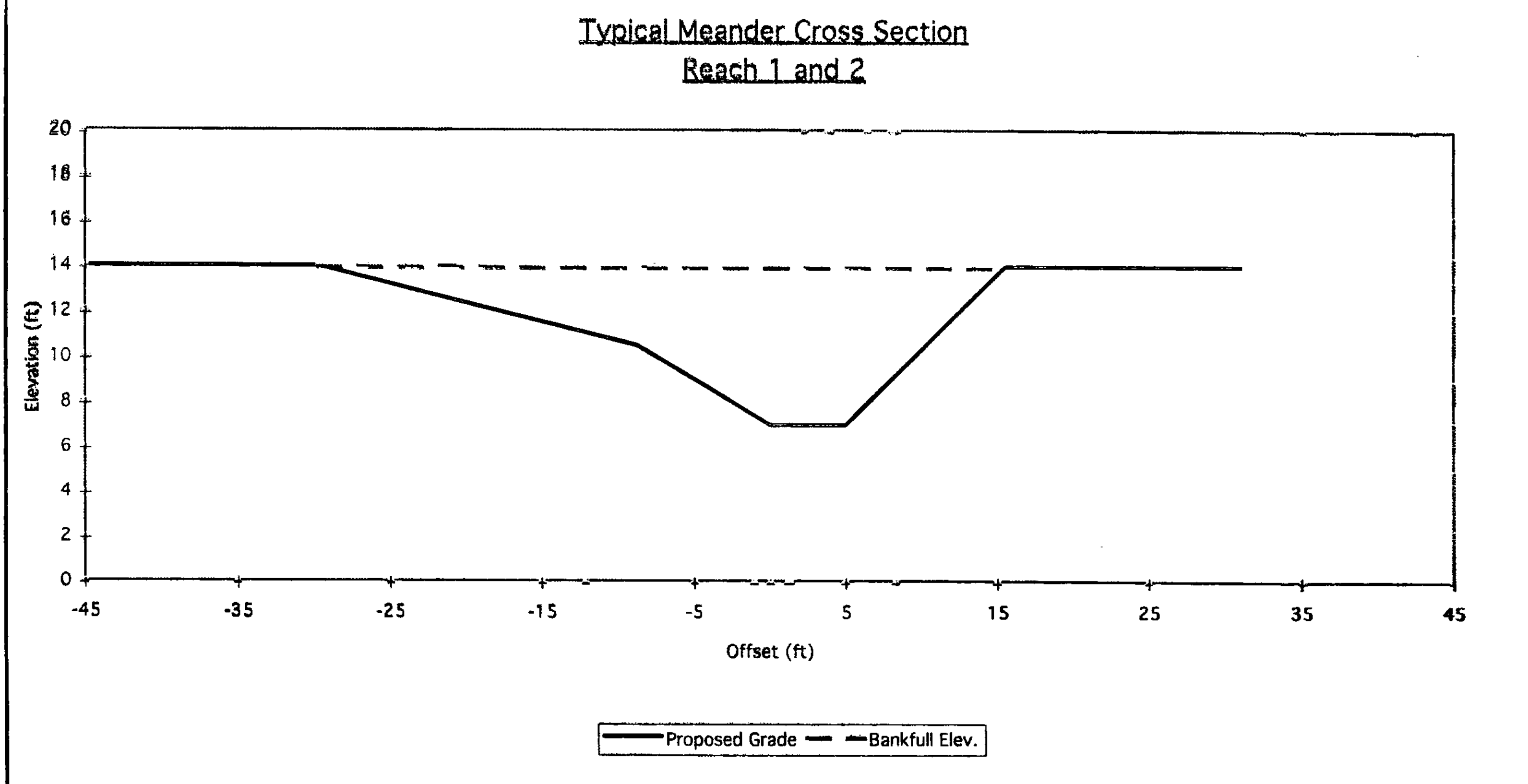
Project Name:	Lower Spring Branch
Biohabitats Project No. :	5015.01
Date:	2/13/2006
Prepared by:	PK
Cross Section Identification:	Reach 1-2

Meander Channel Elevation and Offset Nodes

Feature	Offset	Elevation
Floodprone left	-44.625	14.0
Bankfull Left	-29.75	14.0
Bar to Pool	-8.75	10.5
Thalweg	0	7.0
Pool	5	7.0
Bankfull Right	15.5	14.0
Floodprone right	31	14

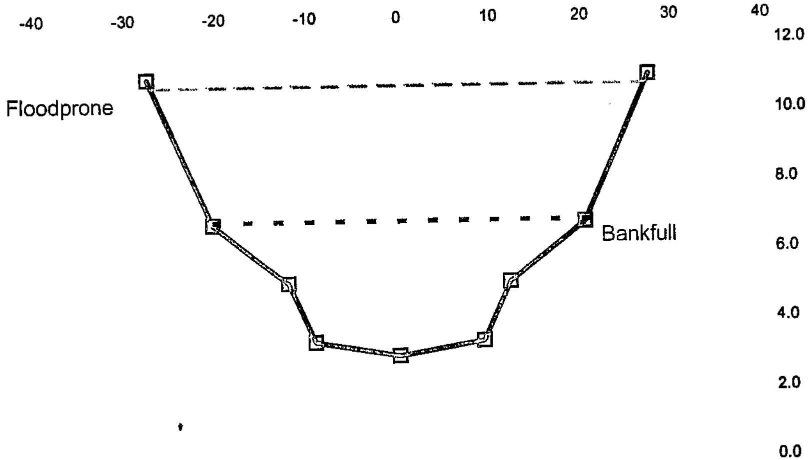
Meander Channel Dimensions

		Ratio to Riffle
Meander Width	45.3 ft	3.38
Wetted Perimeter	48.3 ft	2.49
Hydraulic Radius	3.2 ft	1.29
Area	154.4 ft^2	3.21
Max Pool Depth	7.0 ft	1
Bar Slope	6.0:1	
Bar Toe Slope	2.5:1	
Outer Bank Angle	1.50:1	



Reach 3 High BKF

DS Trib A&B Bc Channel Entrei



	Bankfull	Floodprone
Max Depth	3.88 ft.	7.76 ft.
Manning's 'n'	0.035	0.060
slope	0.50%	n/a
Q	517.65 ft³/s	1983.43 ft³/s
V_{avg}	5.26 ft/s	6.69 ft/s
R_h	2.31	0.22
Entenchment	1.48	n/a
W/D Ratio	17.26	n/a
Avg. Depth	2.39 ft	4.87 ft
Avg. Shear	0.72 lbs/ft²	

1			Bankfull			Floodprone		
Increment change	*offset*	*elevation*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*
			42.55 ft	**98.36 ft²**	**41.20 ft**	**65.40 ft**	**296.29 ft²**	**60.87 ft**
0.1	-27.5	11.0	0.15 ft	0.01 ft	0.13 ft	7.77 ft	13.23 ft	6.69 ft
	-20.4	6.8	0.15 ft	0.01 ft²	0.13 ft	7.77 ft	13.23	6.69 ft
side slope	-12.1	5.1	8.47 ft	7.71 ft²	8.30 ft	8.47 ft	39.90	8.30 ft
1.71:1	-9.2	3.4	3.36 ft	7.62 ft²	2.90 ft	3.36 ft	18.87	2.90 ft
59%	0.0	3.0	9.21 ft	33.84 ft²	9.20 ft	9.21 ft	69.52	9.20 ft
	9.2	3.4	9.21 ft	33.84 ft²	9.20 ft	9.21 ft	69.52	9.20 ft
	12.1	5.1	3.36 ft	7.62 ft²	2.90 ft	3.36 ft	18.87	2.90 ft
	20.4	6.8	8.47 ft	7.71 ft²	8.30 ft	8.47 ft	39.90	8.30 ft
	27.5	11.0	0.15 ft	0.01 ft²	0.13 ft	7.77 ft	13.23	6.69 ft

Project Name: Lower Spring Branch
Biohabitats Project No.: 5015.01
Date: 2/13/2006
Prepared by: PK
Cross Section Identification: Reach 3
Reach 3

Stream Design Worksheet

Biohabitats Incorporated

Input Variables

Mannings "n" of channel =	0.03	
Mannings "n" of floodplain =	0.06	
Equivalent "n" for flood flows =	0.03	
Channel Slope =	0.005	
Design B.F. Discharge =	520	[cfs]
Bankfull Elevation =	6.5	[ft]
Floodprone Elevation =	9.0	[ft]
Bankfull Width =	35	[ft]
Floodprone Width =	52	[ft]

Calculated Quantities

Cross Section Area =	76.6	[sq. ft.]
Wetted Perimeter =	25.5	[ft]
Hydraulic Radius =	3.00	[ft]
Bankfull Discharge =	**560**	**[cfs]**
F.P. XSEC Area =	192.6	[sq. ft.]
F.P. Wetted Perimeter =	55	[ft]
F.P. Hydraulic Radius =	3.51	[ft]
Floodprone Discharge =	1815	[cfs]
Average Depth =	2.19	[ft]
W/D Ratio =	16	
Entrenchment Ratio =	1.5	
Shear Stress =	0.94	[lb/sq.ft.]
D84=	62	[mm]

Relevant Equations

Continuity Equation:

$$Q = V \times A$$

Manning's Equation:

$$Q = 1.49\frac{A}{n}(R)^{\frac{2}{3}}(S)^{\frac{1}{2}}:$$

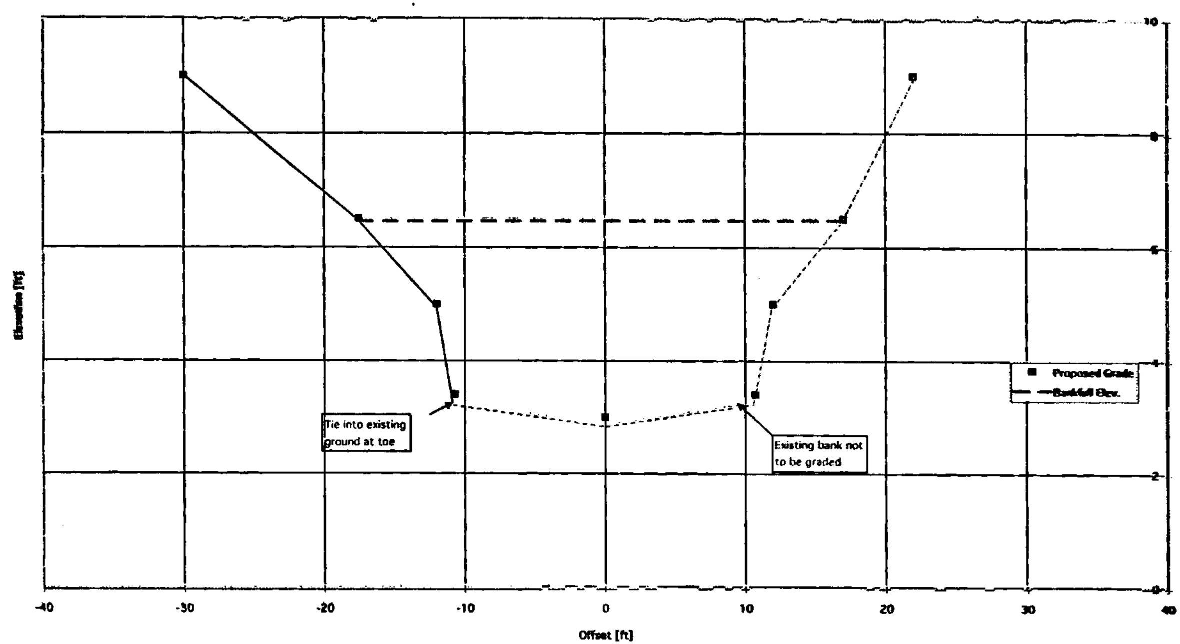
$$\tau_o = \rho g R S$$

Cross Section Points			Bankfull Channel Calculations			
Feature	Offset	Elevation		Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
Floodprone	-30	9.0				
	-17.5	6.5	bank slope			
Bankfull	-12	5.0	0.8	2.99		2.06
	-10.7	3.4		35.31		10.71
Max Depth	0	3.0	2.0	35.31		10.71
	10.7	3.4		2.99		2.06
Bankfull	12	5.0				
	17	6.5				
Floodprone	22	9.0	Total Area =	76.6	Wet Perimeter =	25.54

Floodprone Channel Calculations

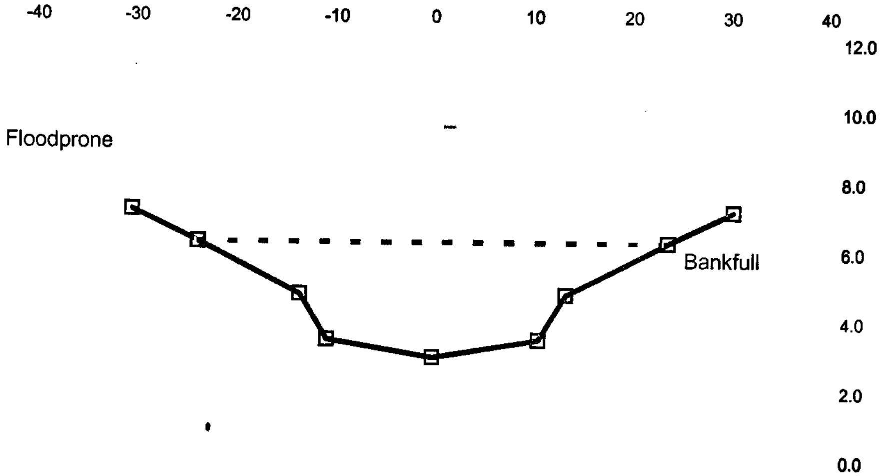
	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
	15.625		12.75
lA.fp	17.875	lP.fp	5.70
	6.24		2.06
	62.06		10.71
	62.06		10.71
	6.24		2.06
rA.fp	16.25	rP.fp	5.22
	6.25		5.59
Total Area =	192.6	Wet Perimeter =	54.80

Typical Riffle Cross Section



Reach 4 High BKF

DS Near Dulaney Valley C Channel

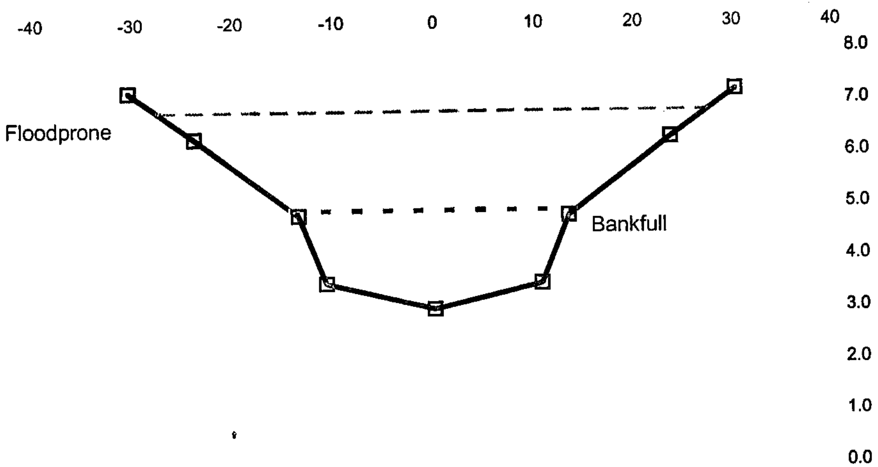


	Bankfull	Floodprone
Max Depth	3.31 ft.	6.62 ft.
Manning's 'n'	0.035	0.060
slope	0.75%	n/a
Q	527.58 ft³/s	2774.26 ft³/s
V_{avg}	5.69 ft/s	9.05 ft/s
R_h	1.92	0.22
Entenchment	1.41	n/a
W/D Ratio	24.43	n/a
Avg. Depth	1.95 ft	4.56 ft
Avg. Shear	0.90 lbs/ft²	

1			Bankfull			Floodprone		
Increment change	offset	elevation	Wetted Perimeter	Cross Sectional Area	Top Width	Wetted Perimeter	Cross Sectional Area	Top Width
			48.45 ft	**92.79 ft²**	**47.61 ft**	**68.22 ft**	**306.48 ft²**	**67.20 ft**
0.1	-30.3	7.2	0.07 ft	0.00 ft	0.07 ft	6.66 ft	18.94 ft	6.60 ft
	-23.7	6.3	0.07 ft	0.00 ft²	0.07 ft	6.66 ft	18.94	6.60 ft
side slope	-13.4	4.8	10.41 ft	7.82 ft²	10.30 ft	10.41 ft	41.91	10.30 ft
2.08:1	-10.7	3.5	3.00 ft	5.83 ft²	2.70 ft	3.00 ft	14.77	2.70 ft
48%	0.0	3.0	10.71 ft	32.74 ft²	10.70 ft	10.71 ft	68.15	10.70 ft
	10.7	3.5	10.71 ft	32.74 ft²	10.70 ft	10.71 ft	68.15	10.70 ft
	13.4	4.8	3.00 ft	5.83 ft²	2.70 ft	3.00 ft	14.77	2.70 ft
	23.7	6.3	10.41 ft	7.82 ft²	10.30 ft	10.41 ft	41.91	10.30 ft
	30.3	7.2	0.07 ft	0.00 ft²	0.07 ft	6.66 ft	18.94	6.60 ft

Reach 4 Low BKF

DS Near Dulaney Valley C Channel



	Bankfull	Floodprone
Max Depth	1.91 ft.	3.81 ft.
Manning's 'n'	0.035	0.060
slope	0.75%	n/a
Q	180.27 ft^3/s	505.48 ft^3/s
V_{avg}	4.55 ft/s	4.23 ft/s
R_h	1.37	0.50
Entenchment	2.08	n/a
W/D Ratio	20.17	n/a
Avg. Depth	1.40 ft	2.04 ft
Avg. Shear	0.64 lbs/ft^2	

			Bankfull			***Floodprone***		
1			***Wetted Perimeter***	***Cross Sectional Area***	***Top Width***	***Wetted Perimeter***	***Cross Sectional Area***	***Top Width***
Increment change	***offset***	***elevation***	**28.90 ft**	**39.62 ft^2**	**28.27 ft**	**59.64 ft**	**119.57 ft^2**	**58.70 ft**
0.1	-30.3	7.2	0.00 ft	0.00 ft	0.00 ft	3.80 ft	0.97 ft	3.77 ft
	-23.7	6.3	0.00 ft	0.00 ft^2	0.00 ft	3.80 ft	0.97	3.77 ft
side slope	-13.4	4.8	0.74 ft	0.04 ft^2	0.73 ft	10.41 ft	13.01	10.30 ft
2.08:1	-10.7	3.5	3.00 ft	2.04 ft^2	2.70 ft	3.00 ft	7.19	2.70 ft
48%	0.0	3.0	10.71 ft	17.73 ft^2	10.70 ft	10.71 ft	38.13	10.70 ft
	10.7	3.5	10.71 ft	17.73 ft^2	10.70 ft	10.71 ft	38.13	10.70 ft
	13.4	4.8	3.00 ft	2.04 ft^2	2.70 ft	3.00 ft	7.19	2.70 ft
	23.7	6.3	0.74 ft	0.04 ft^2	0.73 ft	10.41 ft	13.01	10.30 ft
	30.3	7.2	0.00 ft	0.00 ft^2	0.00 ft	3.80 ft	0.97	3.77 ft

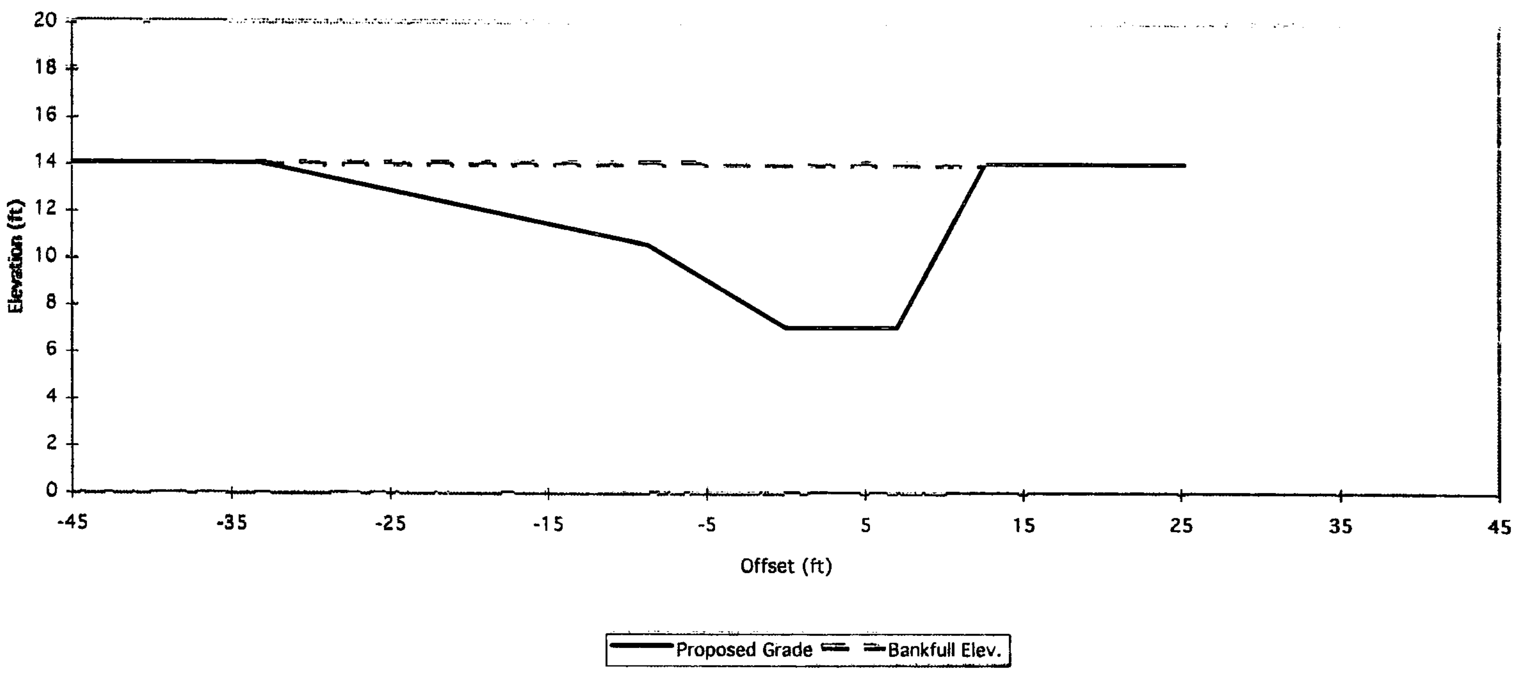
Biohabitats Incorporated

Project Name:	Lower Spring Branch
Biohabitats Project No. :	5015.01
Date:	2/13/2006
Prepared by:	PK
Cross Section Identification:	Reach 4

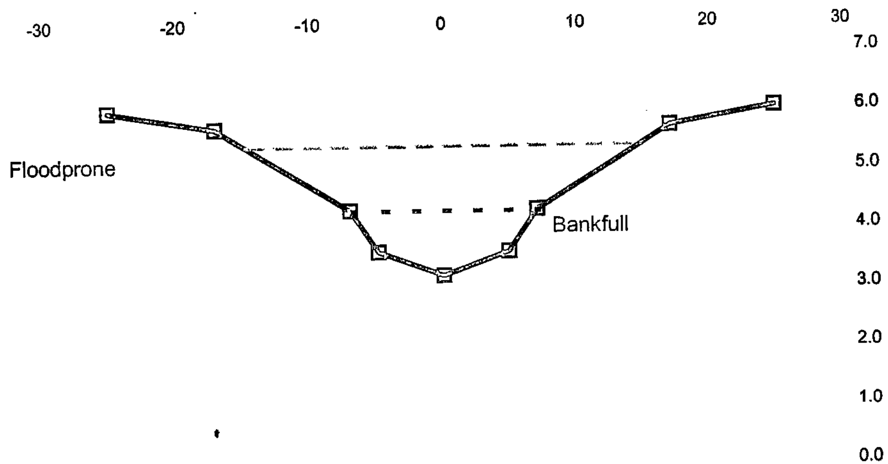
Meander Channel Elevation and Offset Nodes		
Feature	Offset	Elevation
Floodprone left	-49.875	14.0
Bankfull Left	-33.25	14.0
Bar to Pool	-8.75	10.5
Thalweg	0	7.0
Pool	7	7.0
Bankfull Right	12.6	14.0
Floodprone right	25.2	14

Meander Channel Dimensions		
		Ratio to Riffle
Meander Width	45.9 ft	3.42
Wetted Perimeter	50.1 ft	2.59
Hydraulic Radius	3.1 ft	1.27
Area	157.4 ft^2	3.27
Max Pool Depth	7.0 ft	1
Bar Slope	7.0:1	
Bar Toe Slope	2.5:1	
Outer Bank Angle	.80:1	

Typical Meander Cross Section
Reach 4



Trib A Channel



	Bankfull	Floodprone
Max Depth	1.09 ft.	2.19 ft.
Manning's 'n'	0.035	0.060
slope	1.14%	n/a
Q	37.19 ft^3/s	120.19 ft^3/s
V_{avg}	3.64 ft/s	3.54 ft/s
R_h	0.72	0.88
Entenchment	2.12	n/a
W/D Ratio	19.11	n/a
Avg. Depth	0.73 ft	1.15 ft
Avg. Shear	0.51 lbs/ft^2	

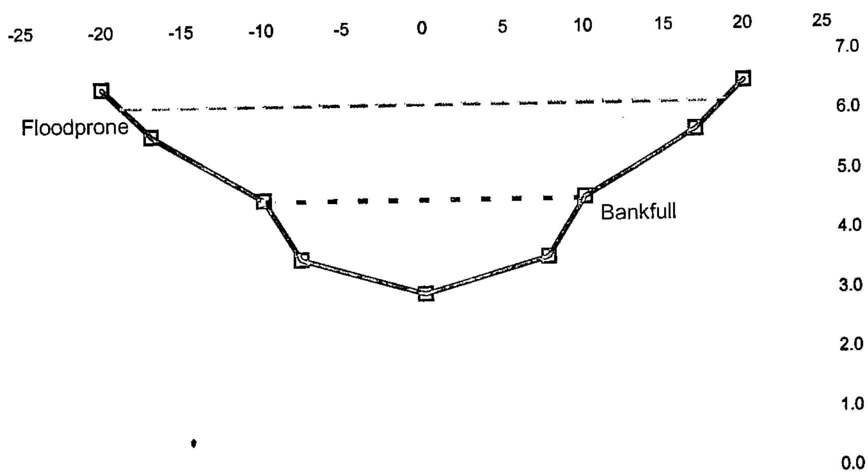
1

Increment change
0.1

side slope
3.00:1
33%

		Bankfull			Floodprone		
offset	*elevation*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*
		14.22 ft	**10.21 ft^2**	**13.96 ft**	**29.96 ft**	**33.98 ft^2**	**29.54 ft**
-24.9	6.0	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft	0.00 ft
-17.0	5.7	0.00 ft	0.00 ft^2	0.00 ft	0.00 ft	0.00	0.00 ft
-7.0	4.3	0.00 ft	0.00 ft^2	0.00 ft	7.85 ft	4.23	7.77 ft
-4.9	3.6	2.19 ft	0.72 ft^2	2.08 ft	2.21 ft	3.02	2.10 ft
0.0	3.2	4.92 ft	4.38 ft^2	4.90 ft	4.92 ft	9.74	4.90 ft
4.9	3.6	4.92 ft	4.38 ft^2	4.90 ft	4.92 ft	9.74	4.90 ft
7.0	4.3	2.19 ft	0.72 ft^2	2.08 ft	2.21 ft	3.02	2.10 ft
17.0	5.7	0.00 ft	0.00 ft^2	0.00 ft	7.85 ft	4.23	7.77 ft
24.9	6.0	0.00 ft	0.00 ft^2	0.00 ft	0.00 ft	0.00	0.00 ft

Trib B Channel



	Bankfull	Floodprone
Max Depth	1.59 ft.	3.18 ft.
Manning's 'n'	0.035	0.060
slope	1.90%	n/a
Q	136.76 ft^3/s	427.75 ft^3/s
V_{avg}	6.19 ft/s	6.15 ft/s
R_h	1.08	0.58
Entenchment	1.97	n/a
W/D Ratio	18.01	n/a
Avg. Depth	1.11 ft	1.77 ft
Avg. Shear	1.28 lbs/ft^2	

1

Increment change
0.1

side slope
2.30:1
43%

		Bankfull			Floodprone		
		Wetted Perimeter	*Cross Sectional Area*	*Top Width*	*Wetted Perimeter*	*Cross Sectional Area*	*Top Width*
offset	*elevation*	**20.41 ft**	**22.10 ft^2**	**19.95 ft**	**40.20 ft**	**69.55 ft^2**	**39.38 ft**
-20.0	6.5	0.00 ft	0.00 ft	0.00 ft	1.85 ft	0.43 ft	1.79 ft
-17.0	5.7	0.00 ft	0.00 ft^2	0.00 ft	1.85 ft	0.43	1.79 ft
-10.0	4.6	0.00 ft	0.00 ft^2	0.00 ft	7.09 ft	7.20	7.00 ft
-7.7	3.6	2.48 ft	1.12 ft^2	2.27 ft	2.51 ft	4.78	2.30 ft
0.0	3.0	7.72 ft	9.93 ft^2	7.70 ft	7.72 ft	22.16	7.70 ft
7.7	3.6	7.72 ft	9.93 ft^2	7.70 ft	7.72 ft	22.16	7.70 ft
10.0	4.6	2.48 ft	1.12 ft^2	2.27 ft	2.51 ft	4.78	2.30 ft
17.0	5.7	0.00 ft	0.00 ft^2	0.00 ft	7.09 ft	7.20	7.00 ft
20.0	6.5	0.00 ft	0.00 ft^2	0.00 ft	1.85 ft	0.43	1.79 ft

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• Inspiring Ecological Stewardship•

LOWER SPRING BRANCH

Preliminary Assessment
Analysis Report

October 2005

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LOWER SPRING BRANCH

Preliminary Assessment Analysis Report

October 2005

Prepared For:

Baltimore County Department of Environmental Protection and Resource Management

401 Bosley Avenue

Towson, MD 21204

Prepared by:

Biohabitats, Inc.

15 West Aylesbury Road

Timonium, Maryland 21093

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APPENDICES

1.0 INTRODUCTION

The Lower Spring Branch Preliminary Assessment and Analysis Report has been completed to provide Baltimore County Department of Environmental Protection and Resource Management (DEPRM) with a range of alternatives for restoring the lower section of Spring Branch, between Pot Spring Road and Dulaney Valley Road (Figure 1.0). The stream has been subjected to numerous anthropogenic impacts, however channelization, concrete armoring, and stormwater runoff from residential development are the primary causes of the current channel condition. This has resulted in considerable bank erosion, generally along the left (north) bank, as the stream flows through the neighborhood adjacent to Chapelwood Lane, and persistent flooding at the downstream end of the project area near Dulaney Valley Road (Route 146).

1.1 PROJECT LOCATION AND DESCRIPTION

Spring Branch is a headwater stream that originates south of Padonia Road in Cockeysville, Maryland and flows generally southeast to Loch Raven Reservoir (Figure 1.0). It is one of several tributaries that feed Loch Raven Reservoir, which is an impounded section of the Gunpowder River

The project study area includes the lower section of Spring Branch between Pot Spring Road and Dulaney Valley Road and 80 feet of an intermittent concrete-lined tributary. The Spring Branch study reach is approximately 2,600 feet long and receives water from a 1.58 square mile watershed. In 1993 Biohabitats was contracted by Baltimore County DEPRM to design and oversee the restoration of the section of Spring Branch between Killoran Road and Pot Spring Road. The current assessment is the first step in a continuation of the previous restoration, and will extend the restored natural channel to Dulaney Valley Road.

1.2 PROJECT OBJECTIVES

It is the intention of Baltimore County DEPRM, in conjunction with Biohabitats, to either repair, maintain, or enhance existing channel structures, while creating long-term, stable channel geometry. In creating a stable channel, the Baltimore County DEPRM and Biohabitats team will also capitalize on opportunities for in-stream and riparian habitat enhancement enhancement. Additional objectives considered when developing the restoration plan for

,ower Spring Branch is that it be practical, economically feasible, and enhance the quality of life surrounding community.

ASSESSMENT OBJECTIVES

The ultimate function and appearance of the Lower Spring Branch restoration will depend on a thorough knowledge of the current conditions of the channel and floodplain, the hydrologic and hydraulic factors influencing their condition, an understanding of the constraints to restoration, and the restoration goals of Baltimore County DEPRM. Specific objectives of this assessment analysis identified by the Baltimore County DEPRM and Biohabitats team, include the following:

- Identify and document existing conditions and problem areas within Lower Spring Branch
- Identify and document existing conditions and problem areas in an additional 80 feet of concrete-lined tributary
  Study the hydrology and hydraulics, and present a preliminary hydrologic and hydraulic model showing existing and proposed changes in hydraulics
- Outline the restoration approaches
- Create an alternatives analyses for each design approach for the concrete-lined reaches

Completing these objectives enables the Baltimore County DEPRM and Biohabitats team to make informed decisions before moving forward with the Concept design phase of the restoration

2.0 ASSESSMENT APPROACH

Conditions of Lower Spring Branch were documented through field investigation and review of existing documents, electronic files, and aerial photographs pertinent to the study area. This section outlines the approach used to collect data, perform the field survey, and create a preliminary hydrologic and hydraulic model.

2.1 DOCUMENT REVIEW

As part of the initial investigation, Biohabitats evaluated maps and documents specific to the Lower Spring Branch watershed. Materials provided by Baltimore County included the following:

- Electronic (GIS) files:
  Baltimore County topography (2.0' contours)
  Baltimore County orthophotographic coverage
  Baltimore County unofficial property maps
  Baltimore County unofficial water and sewer systems maps
  Baltimore County unofficial storm drainage system maps
- Watershed Drainage Study, Spring Branch Final Report (Maryland Surveying and Engineering Co., Inc., 1981)
- Spring Branch Stream Restoration, Roc Valley Hydrology & Hydraulic Study (KCI Technologies, 1995)
- Spring Branch Stream Restoration Hydrology and Hydraulic Report, Volume One (KCI Technologies, 1995)

Biohabitats requested additional materials for the characterization of the watershed, including the following:

- Rare, threatened, and endangered species database review with Maryland DNR and the U.S. Fish & Wildlife Service
- An inventoried historic properties review with the Maryland Historical Trust

Inquiry letters were mailed on September 6, 2005 and are included in Appendix A. As of the date of this report, no response has been received from the above agencies.

2.2 WATERSHED HYDROLOGY

The peak discharge for the Lower Spring Branch study area watershed was estimated using a combination of GIS software (Arcview 3.2 and ArcGIS 8.3, ESRI, 1999) and standard hydrologic models including, HEC-GeoHMS (USACE, 2003), HEC-HMS (USACE, 2003), TR-55 (USDA, 1986) and TauDEM (Tarboton et al., 2005). Varying type-II 24 hour storm events were used to determine peak discharges for the 1-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year flood events.

The Lower Spring Branch watershed was delineated by interpolating a Digital Elevation Model (DEM) from a 2-foot contour GIS layer provided by Baltimore County using ArcGIS 8.3. The watershed was divided into three sub-basins by importing the layer into TauDEM and HEC-GeoHMS programs and run through preprocessing routines to determine exact watershed and sub-basin boundaries. These are the Spring Branch mainstem above the confluence with the concrete-lined tributary that enters from the south (Mainstem Upstream), the concrete-lined tributary, and the mainstem just upstream of the Dulaney Valley Road culvert (Mainstem Downstream) (Figure 2.0).

For each sub-basin a National Resources Conservation Service (NRCS) GIS land-use map (USGS, 1999), was overlain on the watershed map. Hydrologic soil groups were added by hand from the Baltimore County, Maryland Soil Survey data (USDA, 1976). Weighted average Curve Numbers were calculated by imputing the parameters from the overlain land-use, watershed, and soils maps into TR-55 model

The time of concentration for each sub-basin was calculated using TR-55, and HEC-GeoHMS and Arcview 3.2 to determine the longest hydrologic travel time for each sub-basin. Slope and reach lengths were obtained from GIS topographic and hydrologic layers obtained from Baltimore County and the DEM of the watershed area. For each reach in the study area, Muskingum – Cunge routing method was used and the Soil Conservation Service method was used to model each sub-basin using HEC-HMS.

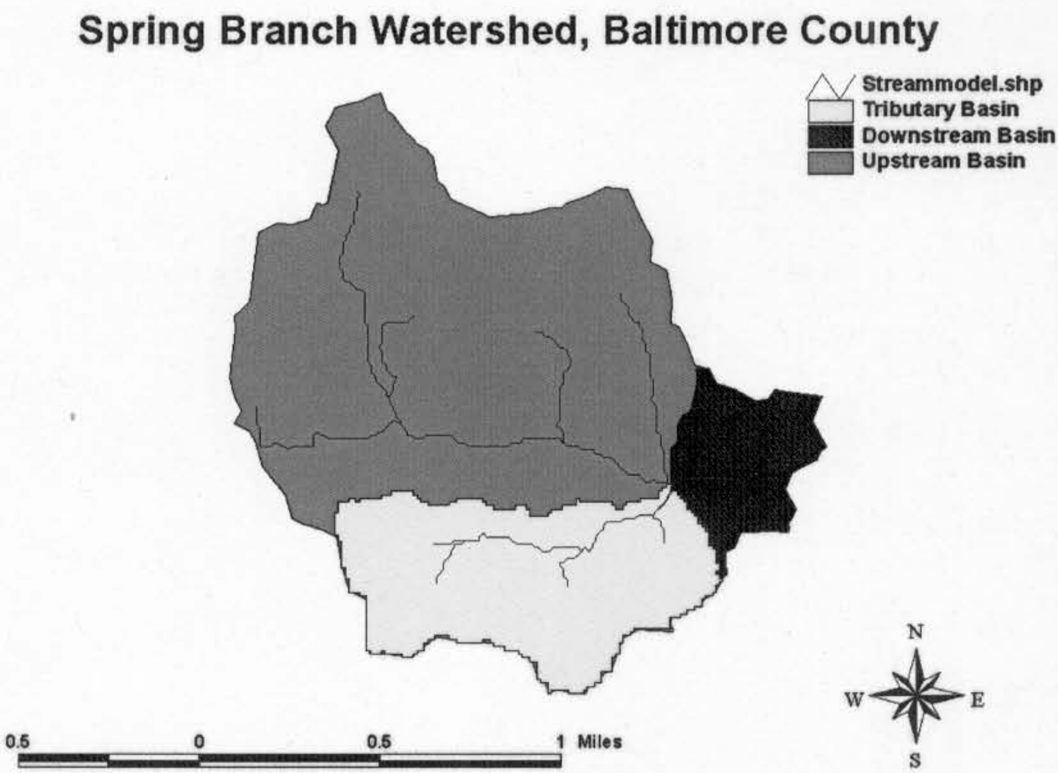

Figure 2.0. Spring Branch Sub-basin Watershed Map.

Results of the hydrologic model were compared to past studies conducted for Baltimore County on the Gunpowder and Spring Branch watersheds (Maryland Surveying and Engineering Co., Inc. 1981 and KCI 1995).

2.3 CHANNEL HYDRAULICS

The HEC-RAS model (USACE, 2001) was used to predict resulting water surface elevations along the channel system for flood discharges obtained from the HEC-GeoHMS analysis. Field-run survey provided by Century Engineering was used to generate geometric information using the Hydrologic Engineering Center's Geo-River Analysis System (HEC-GeoRAS) (Version 3.1)—an extension designed to process geospatial data for easy import into HEC-RAS. Cross along the Mainstem and Tributary B. HEC-GeoRAS was used to generate geometric data input for existing conditions of Lower Spring Branch. The resulting geometry files were then imported into HEC-RAS to run the full hydraulic analysis.

Upon completion of the existing conditions hydraulic model, a preliminary proposed conditions model was created by superimposing the design typical cross sections at the appropriate design inverts and tying in the cross sections to existing topography by hand. Revisions to the proposed model will be made as the iterative design process continues and the grading plan is developed. Comparison of the existing channel condition and proposed models will be used to determine how the project will affect channel hydraulics, including resulting water surface elevations.

2.4 CHANNEL ASSESSMENT

Field assessment and observations were performed by Biohabitats personnel between September 15 and 23, 2005. These observations were used to document existing conditions, forecast the direction of future channel changes, and ultimately to identify opportunities for channel restoration in Lower Spring Branch.

Biohabitats personnel created a field map from GIS layers provided by Baltimore County. In the field, numerous photographs were taken of the stream channel and pertinent notes were transcribed on the field map regarding channel, bank, and riparian conditions. The information gathered from this process was used to create an existing conditions map and to define reach breaks. Reach breaks were selected on a consensus basis between field scientists and were based on obvious changes in morphology including substrate, incision, bank angle, erosion or incision, and floodplain characteristics.

RESTORATION APPROACH

Biohabitats will use experience, defensible engineering, and proven geomorphic techniques to create a long-term, stable channel for Lower Spring Branch. The approach to the restoration of Lower Spring Branch is based on the following organizing principles:

- The preferred approach should be to restore the stream to a natural, self-sustaining system that can adjust to changes in physical processes, with minimum human intervention.
- Restoration planning and design should be based on expected regimes and temporal variability of physical processes, including hydrology, sediment transport, and water quality

Three general techniques to stream restoration were used when creating restoration alternatives for Lower Spring Branch. These include, bed and bank stabilization, riparian buffer enhancement, and channel reconfiguration. Individual techniques or combinations of multiple techniques may ultimately be selected to produce a restoration plan for Lower Spring Branch.

3.1 BED AND BANK STABILIZATION

Stream bed erosion results when the stream begins to downcut into the substrate. This creates an incised condition with high eroding banks and headcuts within the channel. Channel incision can be prevented by adding grade controls such as riffle structures, rock steps, cross vanes, or step/pools to maintain the bed elevation.

Bank erosion can result from a number of factors including changes in the flow regime, changes in the riparian vegetative cover, and human alteration of the bank slope. It can be stopped by using three approaches: 1) modifying channel banks, 2) creating stable cross section, plan, and profile geometry, and 3) re-establishing a densely vegetated banks in areas where vegetation has been cleared. In many cases a combination of these approaches is used to stabilize an eroding bank.

There are three different methods that could be applied to modify the channel banks

Structural – application of materials such as crib walls, boulder retaining walls, etc. to hold the bank in place. These methods are suitable for addressing full bank erosion along steep banks (>2:1 slope) where inadequate right-of-way or extensive tree removal at the top of bank prohibits re-grading of the banks.

Non-structural – bank grading to adjust the bank angle and native vegetation to stabilize the bank slopes. This method works best on moderately sloping banks (maximum 2:1 slope) or conditions where surficial or top of bank erosion occurs.

Soil Bioengineering – a hybrid approach that combines native plant material and rock/wood to control erosion and stabilize slopes. This approach is suitable for treating toe, top of bank, and full bank erosion situations. Specific techniques include the use of rootwads, boulder toe protection, live branch layering, brush mattresses and crib walls, coconut fiber rolls, and coir fabric.

In many cases, natural materials such as rootwads, and large boulders will be used as part of the proposed bank stabilization. Some of these materials (e.g. footer logs and rootwads) are prevalent throughout the study area. If on site material is of suitable size and integrity, it may be used during construction. Appropriate sizes and types of materials will be specified in the design.

3.2 RIPARIAN ENHANCEMENT

Restoring a healthy riparian plant community to Lower Spring Branch will support a healthy stream ecosystem and increase biodiversity by creating a wildlife corridor. Riparian enhancement may be as simple as ceasing mowing activities and preserving a buffer strip along the stream channel, or augmenting the existing vegetation with native species. More intensive riparian enhancement may include clearing the area of invasive species and replanting the area with native vegetation, or regrading the riparian areas to create floodplain wetlands.

3.3 CHANNEL RECONFIGURATION

Channel reconfiguration typically involves modifying the cross-sectional and meander geometry to provide a more stable, efficient morphology and to maintain sediment transport through the stream. In some cases, reconfiguration may involve creating an entirely new morphology, or correcting a specific variable(s) that may be out of balance with the channel flow regime. The channel modifications must reflect, and be consistent with, valley features (i.e. width and slope) watershed inputs, adjacent land uses, and storm flows.

In areas of the channel where reduced sinuosity has altered stable channel flow patterns, meander bend amplitude, meander belt width, and meander length would be adjusted to restore the natural channel pattern. Meander width ratios (belt width/bankfull width) and meander ratios (belt width/meander width) are limited by the stream valley width and available corridor according to adjacent land use and infrastructure. In some cases it may be more advantageous to shift the channel laterally, while maintaining the existing geometry. This would enable bank stabilization where one bank is constricted by infrastructure.

In cases where the channel is severely incised, it may be beneficial to reconfigure the channel by raising the channel invert near to the original elevation. This will reconnect the channel to the original floodplain, and reduce in-channel shear stress during storm events. When raising the invert, it is necessary to perform hydraulic modeling to ensure that the 100 year flood elevation will not be raised. To maintain the elevation, it may be necessary to stabilize the stream bed with one of the structural measures described in Section 3.1.

4.0 ALTERNATIVES ANALYSIS

An alternatives analysis was performed to aid in determining the best approach and restoration techniques to be used in concrete-lined reaches of Lower Spring Branch. These reaches are surrounded by overhead utility lines and underground sewer lines and appear to be a logistic and financial hurdle in the Spring Branch restoration. The alternatives analysis is necessary to guide the decision making process toward the most cost effective way to provide the most environmentally beneficial restoration alternative.

The alternatives analysis was conducted by analyzing the opportunities and constraints of each restoration alternative. The factors examined for each restoration alternative are:

- Opportunity for Channel Habitat Improvement
- Opportunity for Riparian/Floodplain Habitat Improvement
- Constraints from Existing Trees and Vegetation
- Constraints from Existing Utilities
- Estimated Cost

These opportunities and constraints were compared to each other for each alternative to gain an understanding of the costs and benefits of each alternative.

EXISTING CONDITIONS

This section contains the results of the document evaluations, the assessment of existing channel conditions, and channel hydrology and hydraulics. Appendix A contains letters sent to natural and historic resource agencies. Appendix B contains the raw data from the Hydrologic and Hydraulic models, and Appendix C contains the Existing Conditions Exhibit.

5.1 WATERSHED CHARACTERISTICS

This section describes the watershed features that influence the channel morphology and conditions of Spring Branch. Included are results of the literature review on Physiography, Topography, Geology, and Soils, natural resource and historical database reviews, and watershed hydrology.

Physiography, Topography, Geology, and Soils

Maryland is comprised of six physiographic provinces that extend in varying widths across the state in a northeasterly direction. Physiographic provinces, distinctive according to their geologic environments, play an important role in stream processes because the underlying geology influences the size and shape of stream channels and watersheds.

The Spring Branch study area is within the Northern Piedmont Plateau Physiographic Province The Piedmont province is typified by rolling terrain and low ridges with streams of moderate slopes controlled by bedrock outcrops at the surface. It is a transition between the low mountains to the north and west, and the flat coastal plains of the south and east. The original vegetation was predominantly oak forest Through the middle section of the study area, the stream flows through an outcrop of Cockeysville Marble. This rock is made up of predominantly medium-grained metadolomite, calc-schist, and calcite marble (Crowley et al., 1976). These rocks have been exposed along the channel bed and banks throughout the middle of the project site.

Elevations in the drainage area range from approximately 250 ft NGVD at the most downstream end of the study area to 534 ft NGVD at the northeast limits of the watershed. The overall channel slope from Pot Spring Road to Dulaney Valley Road is 0.78%. Slopes in the study area range from 1.98% within the dry concrete tributary that enters Spring Branch from the south, to 0.612% within an incised reach near the center of the study area.

Soils within the immediate watershed and channel of Lower Spring Branch are described below based on the Baltimore County, Maryland Soil Survey (USDA 1976). Three soil types nearest to the channel are described in detail first, followed by a list of other soil units in the drainage area.

<u>Alluvial Land (Av, along and within the stream corridor)</u>
This soil consists of material washed from uplands and deposited along floodplains. This deposition has been especially rapid along streams that drain urban and suburban areas. The materials that make up the Alluvial Land are mostly sandy, because much of the finer material has been carried downstream to estuaries. This soil is somewhat poorly drained to very poorly drained, and floods at least twice a year. It is suited for growth of hardwoods and coniferous trees.

<u>Baltimore Silt Loam, 3-8% slopes, moderately eroded (BmB2, northern immediate watershed)</u>
This is a deep, well-drained nearly level to moderately sloping soils in valleys on the Piedmont Plateau. The properties are strongly influenced by the lime content of the underlying material. These soils are generally well supplied with water, and have no limitations for agricultural use.

<u>Hollinger and Conestoga, very rocky loams 3-15% slopes (HsC, southern immediate watershed)</u>
These soils are found on gently sloping to moderately steep slopes on uplands in the Piedmont Plateau. They are moderately permeable and can have high erodeability on steeper slopes. These soils are formed from weathering of micacious limestone or calciferous schist. Rock exposures in this soil type can be 30to 100 feet apart and may cover 10 to 25% of the ground surface. The rockiness of these soils can make them impractical for agricultural use.

Other soil types in the watershed are predominately silt loams, loamy, and clayey land on nearly level to steep hillslopes:

- Baltimore Silt Loam, 8-15% slopes, moderately eroded (BmC2)
- Beltsville Silt Loam, 2-5% slopes (BtB)
- Baile Silt Loam, 0-3% slopes (BaA)
- Comus Silt Loam (Cv)
  Conestoga Loam, 3-8% slopes, moderately eroded (CwB2)
- Conestoga Loam, 8-15% slopes, moderately eroded (CwB2)
- Hollinger Loam, 3-8% slopes, moderately eroded (HoB2)
- Joppa Gravely Sandy Loam, 2-5% slopes, (JpB)
- Joppa Gravelly Sandy Loam, 5-10% slopes, moderately eroded (JpC2)
- Made Land, slag, cinders, spoils (Ma)
- Manor Loam, 8-15% slopes, moderately eroded (MbC2)
- Manor Channery Loam, 15-25% slopes, moderately eroded (McD2)
- Manor Channery Loam, 15-25% slopes, severely eroded (McD3)
- Manor Soils, 25-50% slopes (MdE)

5.1.2 Listed Species and Historic Sites Information

The U.S. Fish and Wildlife Service (USFWS) and the Maryland Wildlife and Heritage Service (a division of Maryland Department of Natural Resources) were contacted regarding the presence of any federally or state listed or proposed, endangered or threatened species within the project study area (Appendix A). As of October 4th, 2005, no response has been received. Should data on listed species become available after the submission of this report; Biohabitats will be in contact with these agencies to ensure compliance with Section 7 of the Endangered Species Act during the design phase.

Biohabitats, Inc. contacted the Maryland Historical Trust regarding the presence of historical or archeological sites within the study area (Appendix A). As of October 4th, 2005, no response has been received from this agency.

5.1.3 Watershed Hydrology

The TR-55 model was developed for existing land use conditions and soil types in the study area. Storm discharges were evaluated for the three sub-basins within the watershed. The calculations of drainage area, time of concentration, and curve numbers were performed by Biohabitats for each sub-basin used in the model. Final input parameters are listed in Table 5.0.
Predicted peak discharges ranged from 360.09 Cubic Feet per Second (CFS) for a 1-year storm event in the Mainstem Upstream, to 2274.7 (CFS) for the 100-year event (Table 5.0). The discharges predicted within the Mainstem Downstream ranged from 544.03 CFS for the 1-year event, to 3468.7 CFS, for the 100-year event, while discharges from Tributary B ranged from 172.79 CFS for the 1-year event to 1081 CFS for the 100-year event.

Table 5.0. TR-55 and HEC-HMS Modeled Discharges from Three Spring Branch Sub-basins.

		Mainstem Upstream	**Tributary B**	**Mainstem Downstream**
	Drainage Area (sq mi)	1.03	0.407	1.58
	Tc	0.6084	0.4416	
	RCN	76	76	
Storm Event	24hr Rainfall(inches)		Peak Discharge (CFS)	
1-year	2.6	360.09	172.79	544.03
2-year	3.2	574.12	275.99	870.5
5-year	4.2	975.35	465.76	1495.1
10-year	5.1	1362.9	649.23	2076.7
25-year	5.5	1538.8	735.42	2348.9
50-year	6.3	1903.9	907.75	2902.4
100-year	7.1	2274.7	1081	3468.7

Comparison of the discharges predicted for the downstream end of the study area at Dulaney Valley Road indicate that our preliminary results may be moderately high (Table 5.1). Modeled peak 2-year discharges are nearly twice the magnitude greater than those predicted by past studies (MSE Co., Inc. 1981, and Purdum & Jeske 1985). This discrepancy appears to decrease slightly with increasing storm events (Table 5.1). The discharge values for all of the studies on Lower Spring Branch were high compared to the MGS and USGS regressions. The MSE Co., Inc. (1981) report specifically focused on Spring Branch and appears to be a good model for our study. Further data will be collected and examined for the next submittal to support the MSE Co., Inc. (1981) model. Also baseflow and bankfull (channel forming) discharge will be determined through filed activities. Bankfull discharge values will be compared to existing regional curves and a design discharge will be presented.

Table 5.1 Predicted Peak Discharges at the Downstream end of the Study Area.

Recurrence Interval of Storm Event (yr)	Biohabitats Predicted Peak Discharge (cfs) TR-55	MSE Co., Inc. (1981)	Purdum & Jeske (1985) TR-20	MGS Predicted Peak Discharge (cfs)[1]	USGS Predicted Peak Discharge (cfs)[2]
1	544.03	n/a	n/a	n/a	n/a
2	870.50	480	482	207.6	293.4
5	1495.1	n/a	973	386.3	565.6
10	2076.7	1500[3]	1496	558.6	822.6
25	2348.9	n/a	1805	863.7	1238.8
50	2902.4	n/a	2258	1167.7	1615.8
100	3468.7	2800	2866	1554.2	2055.6

[1] Carpenter, 1983
[2] Dillow, 1996
[3] Value must be verified through further investigation.

5.2 CHANNEL HYDRAULICS

HEC-RAS was used to model the water surface elevation for the 2, 10, and 100-year discharges (Table 5.0) of the existing and proposed channel alignment for the study area. Representative cross sections for Reaches 1, 2 and 4 (where restoration was planned) are located in Appendix B

The cross section for Reach 1 was located between the confluences of the tributaries and Spring Branch. The right bank was not represented because the bank lowers in elevation and ultimately intersects with Tributary B. The channel roughness for the proposed cross section was higher than that of the existing cement channel creating hydraulic jump, and an increase in water surface elevation. Therefore, water elevation was higher for proposed cross sections even though there was a channel adjustment. Still, water surface elevations for the 2 and 10 year flood events were fully contained within the proposed channel. Channel adjustment had no affect on the 100-year flood event for either condition.

The next cross section was located in Reach 1 just downstream of Tributary B. Water surface elevation was found to be higher for the 2 and 10 year events. However, flow was still contained for both events within the top of bank. The higher water surface elevation for these events is expected due to increased boundary roughness of a natural channel relative to the concrete lined channel. The left bank contained the two year flood event while the right bank flattened out into the flood plain and the water flooded this area. he 100 year flood event for the proposed cross section was about a foot lower than the existing cross section.

The representative cross section for Reach 2 was located in the middle of the reach. Water surface elevations for the proposed cross sections were lower, but not significantly. The 2 and 10 year flood events were fully contained within the proposed cross section. The 100 year event was almost fully contained with less than a foot overtopping the left bank.

The proposed cross section representing reach 4 did little to lower the water level even in the 2 year flood event. The inadequately designed culvert created a back water effect which influenced water throughout the reach.

5.3 CHANNEL ASSESSMENT

Where Lower Spring Branch has not been armored with concrete; it appears to be adjusting to past changes in the watershed. These changes are evident in the bank erosion seen though most of the project area. The Spring Branch mainstem and concrete tributary were separated into five distinct reaches for the discussion of the existing conditions presented below. A graphic representation is provided as Appendix C.

5.3.1 Reach 1: Concrete-lined channel

This reach is a trapezoidal concrete channel that begins at the downstream side of the Pot Spring Road double box culvert and extends approximately 450 feet to the end of the concrete section (Appendix C). This reach was channelized in the early 1970's to accommodate underground sewers and overhead utility lines on the south bank, and residential properties along both banks.

Photo 1. Reach 1 looking upstream from the end of the reach.

At the upstream end of this reach sandy debris and vegetation has blocked baseflow through the north side of the double box-culvert forcing baseflow through the south side of the culvert. Currently, only flows at bankfull or greater pass through the north side of the culvert. At approximately 70 feet downstream of the culvert, the concrete channel constricts down to 24.0 feet at the top of the channel. At approximately 140 feet downstream of the Pot Spring Road culvert, a perennial stream (Tributary A) enters the channel from the north (Appendix C). The last 20 feet of the channel enters Spring Branch through a small concrete channel. A dry concrete stormwater channel enters Spring Branch from the south approximately 340 feet downstream from the Pot Spring Road culvert. This reach will be further described below as Tributary B. After Tributary B enters the Spring Branch mainstem, the mainstem concrete channel widens to 34.0 feet at the top of the bank. This width continues until the end of the concrete where there is a sharp drop (≈2.0 feet) in the channel elevation from the concrete to the natural channel below. With the exception of some overhanging vegetation at the upstream end of the reach, there is no significant habitat for aquatic fauna within this reach.

Beyond the concrete banks of Reach 1, the slopes gradually flatten into the residential yards that line both sides of the channel. Here the riparian areas are comprised of primarily maintained lawns, with a few large and small trees.

5.3.2 Tributary B: Trapezoid Concrete Swale Tributary

This reach enters Spring Branch from the south approximately 340 feet downstream of Pot Spring Road. It is a 14 foot wide (at the top of bank) trapezoidal concrete channel that carries no baseflow much of the year. It was constructed at the same time as the concrete armoring of Spring Branch. The reach begins from a single culvert downstream of Pot Spring Road and flows approximately 490 feet to Spring Branch. The slope within the downstream 100 feet of this reach is approximately 2%.

Photo 2. Tributary B looking upstream.

Along the downstream 80 feet of this reach the riparian areas flatten into mowed residential yards that line both sides of the channel. Here the riparian areas are comprised of primarily maintained lawns, with a few mid size White Pine (*Pinus strobus*) trees.

5.3.3 Reach 2: Downstream of the Concrete Channel

This reach begins at the end of the concrete channel and ends where the channel becomes more incised and lined with boulders (Appendix C). At the end of Reach 1, the bed elevation drops approximately two feet sharply from the concrete into a shallow plunge pool, while the channel and riparian areas widen slightly. This reach has flat, extended riffles with a few shallow pools. The stream channel within this reach consists of a mix of small cobbles and boulders that appear to be moderately embedded and generally stable. They provide substantial habitat for macroinvertebrate fauna.

Photo 3. Reach 2 Looking downstream from the upstream end of the reach.

Much of the north bank of this reach is a four to six foot eroding vertical wall that flattens sharply at the top where maintained lawns meet the channel. On the north bank approximately 560 feet downstream of Pot Spring Road, about ten feet of 18 inch concrete pipe have fallen into the channel. This pipe drains a small pond north of Chapelwood Lane (Appendix C). The south bank is more gently sloping, and well vegetated until it reaches the top of bank, where the established stream buffer has been mown. At approximately 700 feet downstream of Pot Spring Road a perennial channel enters the stream from a small, spring-fed pond slightly outside of the Spring Branch floodplain. This small tributary is stable at its confluence with Spring Branch. The remainder of the channel to the end of the reach becomes slightly more incised and lined with boulders before entering Reach 3.

5.3.4 Reach 3: Incised Boulder/Bedrock Channel

This reach begins where the Spring Branch channel becomes more incised and flows through numerous boulders and bedrock outcrops. Both banks are approximately six feet high vertical and eroding for the first 100 feet. At approximately 1115 feet downstream of Pot Spring Road, a sewer line crossing protected with native boulders, provides bed and bank stabilization. After the stable sewer line crossing, the north bank again becomes steep and eroding for the remainder of the reach, while the south bank quickly rises to a high-steep wooded embankment that is generally stable. Large boulders and exposed bedrock outcrops provide stable channel substrate through this reach. They also help maintain the deep pools which make up some of the best fish habitat within the study area.

Photo 4. Reach 3 looking upstream toward Reach 2.

At the top of the north bank, the riparian area flattens sharply and is composed of a few trees scattered within maintained residential lots. The riparian area along the south bank beyond the forested slope flattens more gradually into maintained residential lots.

At the downstream end of the reach, the channel becomes less incised and is dominated by smaller cobble gravel substrate. This signifies the beginning of Reach 4.

5.3.5 Reach 4: Widened Channel with a low Floodplain

Photo 5. Reach 4 looking upstream.

Reach 4 begins where the floodplain and channel widen, the stream begins to meander, and the substrate changes to fine sand, gravel, and small cobble. The reach extends to the end of the study area at Dulaney Valley Road. Both the north and south banks within this reach are vertical and eroding along many of the outside meander bends. Two small intermittent drainage ditches enter the channel from the north at approximately stations 1,740 and 2,100 feet downstream of Pot Spring Road (Appendix C). Both appear to be stable and may only carry water during storm events, or serve to drain the floodplain after high flows. Approximately 300 feet upstream of Dulaney valley Road the stream has downcut and exposed 15 feet of 18 inch concrete sewer line. The line appears to be intact; however, further downcutting may compromise this line. Shortly before reaching Dulaney Valley Road, the stream makes a sharp bend to the southeast. Here the channel has been lined with riprap to protect the road culvert.

Within the channel, there are relatively short, somewhat embedded riffles and larger deep pools (>3ft) with clay and hardpan substrate. The pools have formed along meander bends where the channel may be attempting to widen in response to frequent storm flows.

Like the upstream portions of the study area, the riparian area of the north bank consists of mostly maintained lawns with some large and mid-sized trees. The riparian area along the south bank has a large portion as young forest with a gradual floodplain slope. The remainder is maintained lawn, similar to the northern riparian area. During storms with heavy rain the stream does flood these riparian areas and has been recorded to flood several of the houses at the downstream end of the reach. To protect these properties, any design to stabilize and restore this reach must not raise the current flood elevation.

6.0 RESTORATION ALTERNATIVES

The restoration alternatives focus on improving in-stream and riparian habitat while reducing bank erosion in Lower Spring Branch. The techniques recommended for the restoration concepts range from local bank stabilization, regrading, and revegetation, to riparian enhancement and minor channel realignment.

The following section briefly describes potential restoration concepts for the four previously described reaches and one intermittent tributary (Tributary B). Two restoration concepts have been described for each reach except for the concrete-lined Reach 1, which has three. The concepts range from local stabilization to minor channel reconfiguration. Proposed restoration concepts are shown on the exhibit maps in Appendix D.

6.1 REACH 1, TRIBUTARIES A AND B

The concrete-lined trapezoidal channels in Lower Spring Branch are quite stable, however, the smooth concrete is a major fish blockage and provides no substantial habitat for other aquatic fauna. Leaving these reaches entirely intact would not compromise the stability of a restored Spring Branch channel, but it would be more beneficial if they were reestablished as aquatic habitat and wildlife corridors.

The first, minimal alternative proposed for this reach involves providing a forested buffer along the stream reservation. This will establish a corridor for the movement of wildlife. In addition, growing trees will eventually begin to shade the stream from the sunlight which warms the channel in this reach. To add in-stream habitat three to four sections of the concrete will be removed and cobble riffles will be constructed in their place at a slightly higher elevation (Appendix D, Alternative I). Cobble riffles will add some complexity to the smooth concrete surface as well as locally raise the water elevation to allow fish passage through the reach. In this alternative, only a forested buffer would be planted along Tributaries A and B.

The second alternative for these reaches involves establishing as forested buffer as in the first alternative. In addition, the northern concrete bank of the Reach 1would be removed while the base and southern bank would remain intact. The bed elevation would be raised slightly, and a moderately meandering step/riffle channel would be constructed along the current northern bank (Appendix D, Alternative II). The soil excavated from the north bank would be placed over the remaining concrete to become part of the vegetated riparian buffer. By raising the invert, the reach slope can be lowered, and more stable bank angles can be created. A raised invert will promote access to the floodplain, reduce erosive shear within the channel, and potentially hold more floodwater in this reach.

In addition to the work in Spring Branch; the concrete would be removed from Tributary A and a wetland would be constructed at the confluence with Spring Branch. The downstream 80 feet of Tributary B, would be constructed as a step/pool channel to tie in with Reach

The final alternative for these reaches would include removing all of the concrete along with the restoration measures discussed in the second alternative above (Appendix D, Alternative III). By removing all of the concrete, both sides of the floodplain can be completely graded to accommodate high flows, while creating greater opportunities for in-stream and riparian habitat enhancement

Depending on the size and condition of the concrete rubble obtained from demolishing the concrete channel; it may be feasible to use this material as base fill in other reaches. Although this material may not be suitable for in-stream structures or substrate, it could be used as a cost effective fill in areas where the channel invert is to be raised.

6.2 Reach 2 and Tributary C

The minimal alternative for Reach 2 will involve constructing a step/riffle structure to tie-in with the bed elevation of Reach 1, regrading and stabilizing the north bank, and minor bank shaping along the south bank (Appendix D, Alternative I). The riparian areas within the stream reservation would be replanted with native vegetation. The alignment or elevation of Tributary C would not be altered in this alternative, but the reach would be included in any riparian enhancement. As mentioned in Section 5.3 above, the riffles in this reach appear to be stable, making bank stabilization a viable alternative. In this alternative, the north bank will be regraded to a more stable slope (where feasible), and either stabilized with bioengineering, or through structural means such as boulder toe protection. Where natural boulders exist on the stream banks and in the channel they will be used in the stabilization. The south bank will essentially be grubbed of the existing small trees, and a small floodplain bench will be created. The bank and riparian area would be replanted with native vegetation.

The second alternative for these reaches would include all of the restorative measures explained above, while raising the channel invert approximately 2-4 feet (Appendix D, Alternative II). Prior to raising the invert, the existing channel material would be harvested and stockpiled to be reused on site. By raising the invert, the reach slope can be lowered, and more stable bank angles can be created. A raised invert will promote access to the floodplain, reduce erosive shear within the channel, and potentially hold more floodwater in the upstream reaches.

6.3 REACH 3

Reach 3 is dominated by bedrock and boulder substrate and may be the most entrenched, yet most stable reach in the Lower Spring Branch study area. The minimal alternative proposed for this reach would involve regrading and stabilizing, and planting a native vegetative buffer along the eroding north bank through most of the reach (Appendix D, Alternative I). Regrading the north bank may be limited by existing overhead utility poles and lines, as well as adjacent sanitary sewer lines. These will be located prior to continuing with the design phase of the project. Where boulders exist along the north bank, they will be used in the stabilization of this reach.

The second alternative for this reach will include constructing step/riffle structures to tie-in with the elevation of the raised, downstream end of Reach 2 (Appendix D, Alternative II). A moderately meandering step/riffle channel will be constructed along the current northern bank at the upstream end of the reach. The remainder of the reach would be restored as the first alternative above. Stabilizing the north bank through this reach would reduce sediment load to downstream reaches and help maintain the existing riffle pool habitat.

6.4 REACH 4

In Reach 4 the stream is no longer constricted by bedrock. The channel begins to meander and widen and the floodplain becomes broad and flat on both sides of the stream. Local flooding of several neighboring houses has been reported within this reach. The minimum alternative for this reach includes regrading and bank stabilization along the eroding outside meander bends (Appendix D, Alternative I). There appears to be ample sunlight through this reach, making live branch layering, or live staking viable alternatives for restoration. In addition to bank stabilization, the stream bed would be stabilized over the exposed sewer line with either a step structure, or rock cross vane and the north bank will be enhanced with native vegetation within the stream reservation. At the downstream end of the reach, the channel would be realigned to more directly enter the culvert under Dulaney Valley Road.

The second alternative for this reach will involve grading riparian benches at a lower elevation and minor channel realignment to create a moderately meandering step/riffle channel within the stream reservation (Appendix D, Alternative II). Ideally, a meandering riffle/pool, "C" channel could be created within this reach, however, the narrow stream reservation, the adjacent sewer lines, and overhead utility poles preclude this design This will stabilize the bed and banks, while allowing the stream to access the riparian areas during storm events. Like the first alternative, the stream bed would be stabilized over the exposed sewer line with either a step structure, or rock cross vane and the channel would be realigned to more directly enter the culvert under Dulaney Valley Road.

Measures to potentially reduce local flooding within this reach include constructing a levee along the north bank and installing additional bankfull culverts under Dulaney Valley Road (Appendix D, Alternative III). The vegetated levee could be constructed along the edge of the stream reservation and graded with outlets to direct runoff from Chapelwood Lane and adjacent properties toward the Dulaney Valley Road Culvert (Appendix D, Alternative 2). Bankfull culverts may also be constructed under Dulaney Valley Road. The proposed bankfull culverts could be placed in the newly graded floodplain outside of the wingwalls of the existing box culvert

7.0 ALTERNATIVES ANALYSIS

The alternatives analysis was performed to aid in determining the best approach and restoration techniques to be used in concrete-lined reaches of Lower Spring Branch. These reaches are surrounded by overhead utility lines and underground sewer lines and appear to be a logistic and financial hurdle in the Spring Branch restoration. A comparison of the opportunities and constraints for each alternative is presented in Table 7.0 below. The unit prices used for the preliminary cost estimates are presented as Appendix E.

The first alternative for the concrete-lined tributaries would involve minor demolition of the concrete (approximately 103.3 Cubic Yards), adding riffles within the concrete channel, and native plantings along both banks. While adding riffles to the concrete channel will aid fish passage; it will only moderately improve in-stream habitat within the entire reach. In this alternative there would be no floodplain or riparian grading, therefore, only minor riparian improvement will come from providing a native vegetative buffer within the stream reservation With this alternative there would be little or no impacts to the existing trees, since no site clearing will occur. And since the channel will not be reconfigured or realigned, the existing utilities will not be disturbed. The cost for this alternative is relatively low, since very little in-stream work will be conducted (Table 7.0).

The second alternative would involve removal of the concrete on the north bank (approximately 195 Cubic Yards), all of the concrete in Tributary B, covering the remaining concrete, and minor channel realignment. An advantage to this alternative is that it provides opportunities for additional channel and riparian/floodplain habitat (Table 7.0). It may be necessary to remove a few existing Silver maple (*Acer saccharinum*) and White pine (*Pinus* strobus) trees on the north bank, however, they would be replaced with numerous native riparian trees and other vegetation The sewer lines on the north bank may limit floodplain grading and channel realignment however, their exact locations are not known at this time. The cost for this restoration alternative is obviously higher compared to the first alternative since this alternative would require much more earthwork and channel material for construction (Table 7.0).

Table 7.0. Alternatives Comparison for Reach 1 and Tributary B.

Opportunity/Constraint	Alternative I	Alternative II	Alternative III
Channel Habitat Improvement	Moderate	Good	Excellent
Riparian/Floodplain Habitat Improvement	Minor	Moderate	Excellent
Existing Trees and Vegetation	No Impacts	Moderate Impacts	Moderate Impacts
Existing Utilities	No Impacts	Moderate Impacts	Moderate Impacts[1]
Estimated Cost	$72,000.00	$155,300.00	$318,000.00

[1] The design may be constrained by existing utilities. It is not anticipated that existing utilities will be relocated

The third alternative would involve removal of all of the concrete within Reach and ributary B (approximately 886 Cubic Yards), and minor channel realignment. An advantage to this alternative is that it provides greater opportunities for additional channel and riparian/floodplain habitat compared to both alternatives above (Table 7.0). It would impact existing trees and may be constrained by sewers, similarly to the second alternative. The cost for this restoration alternative is clearly higher compared to the second alternative since this alternative would require much more earthwork, concrete removal and channel material for construction.

The preferred alternative should provide the maximum ecological benefits, produce a stable-natural channel, and be cost effective. Alternatives 2 and 3 appear to provide the most ecological benefit. Few trees would be disturbed and channel habitat would be improved in both alternatives. However, meandering the channel to the north as shown in Alternatives 2 and 3 above may be limited by the location and elevation of adjacent sewer lines. Moreover, removing reinforced concrete may cost as much as $200.00 per cubic yard. This may be an excessive cost for Baltimore County to spend on restoration, although it would create a more natural system Although Alternative 1 would not greatly enhance in-stream habitat; it appears to be a cost effective way to create fish passage and somewhat improve riparian habitat within the concrete reaches

8.0 SUMMARY

Lower Spring Branch has been impacted by channelization, armoring, stormwater runoff, erosion, and riparian clearing. Although it maintains good perennial baseflow, the stream is subjected to extremely high discharges during storm events. The concrete-lined sections within the study area are stable; however they have been designed to quickly conduct water to downstream reaches, presumably causing flooding and erosion. The stream does exhibit some stable riffles and deep pools, as evident in the assessment of Reaches 2 and 3, however, both of these reaches have high-vertical eroding banks that likely contribute excessive sediment to the channel. The channel appears to be widening, and creating new meander geometry as a result of high flows at the downstream end of the study area. Here, severe erosion is occurring along most of the outside meander bends in the reach.

The existing physical conditions and the hydrologic regime presented in the previous sections are the first steps to understanding the appropriate restoration technique to be applied to Lower Spring Branch. The preferred design alternative will also have to consider the exact locations of existing overhead power lines, underground sewer lines, as well as input from adjacent homeowners. These constraints as well as access, geologic features, and regulatory requirements will become more evident in the Concept Design phase of this project.

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RESOURCE INQUIRY LETTERS TO NATURAL RESOURCE AND HISTORIC AGENCIES

APPENDIX A

Biohabitats
Incorporated

15 W. Aylesbury Road
Timonium, MD 21093
tel 410 337 3659
fax 410 583 5678
www.biohabitats.com

September 6, 2005

Lori A. Byrne
Environmental Review Coordinator
MD DNR - Wildlife and Heritage Service
Tawes State Office Building, E-1
580 Taylor Ave.
Annapolis, MD 21401

RE: Lower Spring Branch Threatened and Endangered Species Information Request

Dear Ms. Byrne:

Biohabitats, Inc. is requesting any information you may have regarding state rare, threatened and/or endangered plant or animal species within or near the our Spring Branch project area in Baltimore County. We are in the preliminary stages of a restoration plan for the stream. We will use this information as guidance in the restoration design to avoid the disturbance of species and critical habitat, and to provide the most beneficial habitat for a variety of species.

Spring Branch is within the Gunpowder River watershed. Our project area extends from Pot Spring Lane, east to Dulaney Valley Road (Route 146) and is bordered by Chapelwood Lane to the north, and Dumont Road to the south. It is located on the Baltimore County ADC Map #19, D-12 (Page 23).

Please find the enclosed copy of the ADC map showing the project location. Feel free to call me at 410-337-3659 should you have any questions. Thank you for your time and attention.

Sincerely,

BIOHABITATS, INC.

Paul Kovalcik
Aquatic Ecologist

Enclosure

Biohabitats
Incorporated

15 W. Aylesbury Road
Timonium, MD 21093
tel 410 337 3659
fax 410 583 5678
www.biohabitats.com

September 6, 2005

Ms. Jo Ellen Freese
Review and Compliance Administrator
Office of Preservation Services - Maryland Historical Trust
100 Community Place
Crownsville, MD 21032

RE: **Lower Spring Branch Threatened and Endangered Species Information Request**

SUBJ: **Historic Properties Information Request**

Dear Ms. Freese

The purpose of this letter is to obtain information or assistance with any relevant historic properties information in the vicinity of the above-referenced project site in Baltimore County. It is located on the Baltimore County ADC Map #19, D-12 (Page 23). Specifically, we would like to know whether or not the Maryland Historical Trust's database includes any of the following for the project vicinity:

- Inventoried historic properties,
- National Register listed properties,
- Prior archeological or architectural research conducted in the project vicinity,
- An informed assessment of the project area's potential for containing historic properties that have not yet been identified.

The proposed project is an alternatives analysis for the restoration and stabilization of Spring Branch. Proposed stream restoration concepts may include regrading of the channel banks and installation of structural and bioengineering elements in keeping with natural processes observed at the site. Such activities would require a Corps permit. The predominant land uses in the drainage area are residential and commercial buildings.

Please find the enclosed copy of the ADC map showing the project location. We will incorporate the results of your findings with our project planning. Thank you for your time and attention.

Sincerely,

BIOHABITATS, INC.

Paul Kovalcik
Aquatic Ecologist

Enclosure

Biohabitats
Incorporated

15 W. Aylesbury Road
Timonium, MD 21093
tel 410 337 3659
fax 410 583 5678
www.biohabitats.com

September 6, 2005

Maricela Constantino
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
177 Admiral Cochrane Drive
Annapolis, MD 21401

RE: Lower Spring Branch Threatened and Endangered Species Information Request

Dear Ms. Constantino

Biohabitats, Inc. is requesting any information you may have regarding federally listed, rare, threatened and/or endangered plant or animal species within or near the Spring Branch project area in Baltimore County. We are in the preliminary stages of a restoration plan for the stream. We will use this information as guidance in the restoration design to avoid the disturbance of species and critical habitat, and to provide the most beneficial habitat for a variety of species.

Spring Branch is within the Gunpowder River watershed. Our project area extends from Pot Spring Lane, east to Dulaney Valley Road (Route 146) and is bordered by Chapelwood Lane to the north, and Dumont Road to the south. It is located on the Baltimore County ADC Map #19, D-12 (Page 23).

Please find the enclosed map showing the project location. Feel free to call me at 410-337-3659 should you have any questions. Thank you for your time and attention.

Sincerely,

BIOHABITATS, INC.

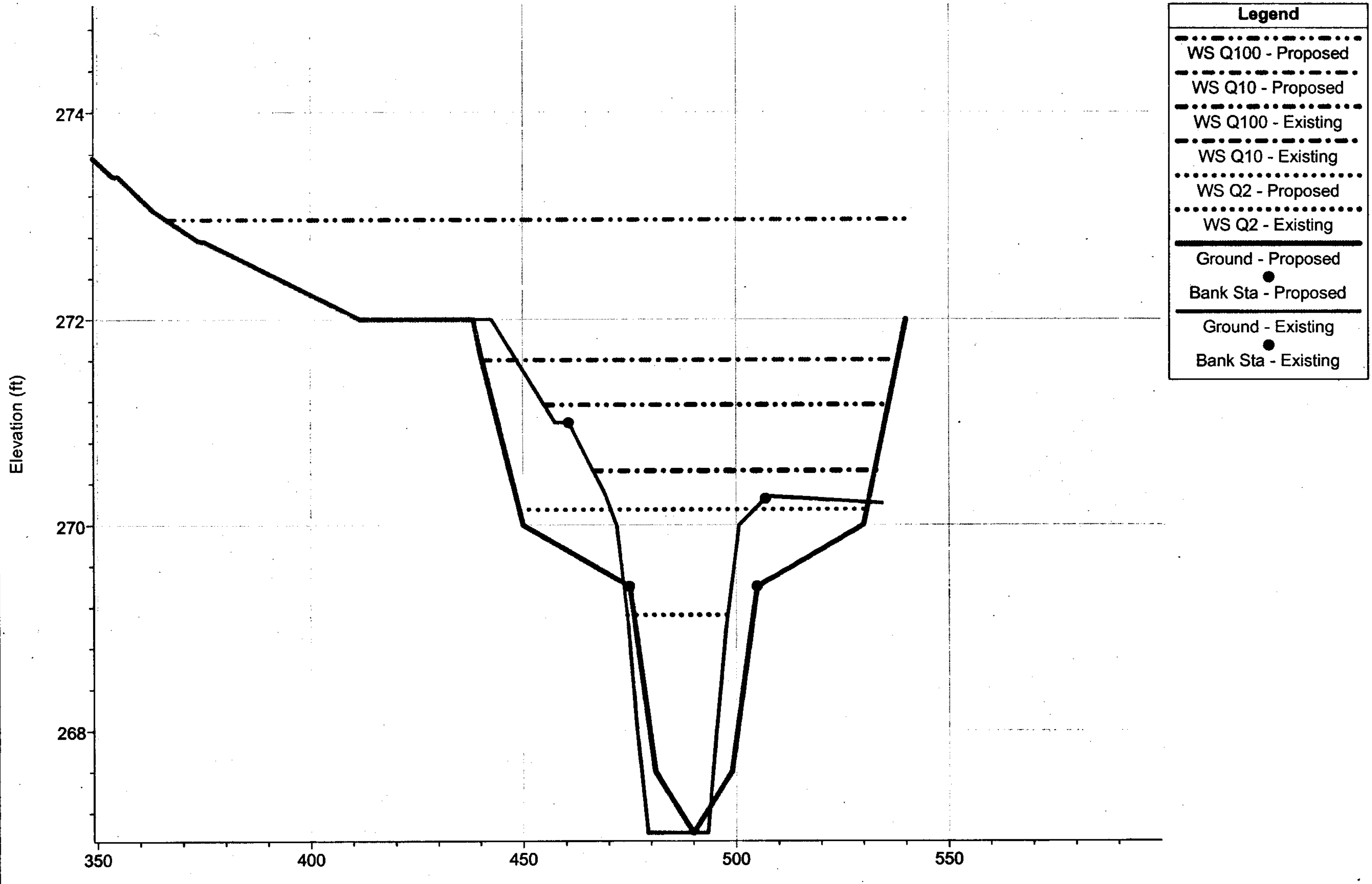
Paul Kovalcik
Aquatic Ecologist

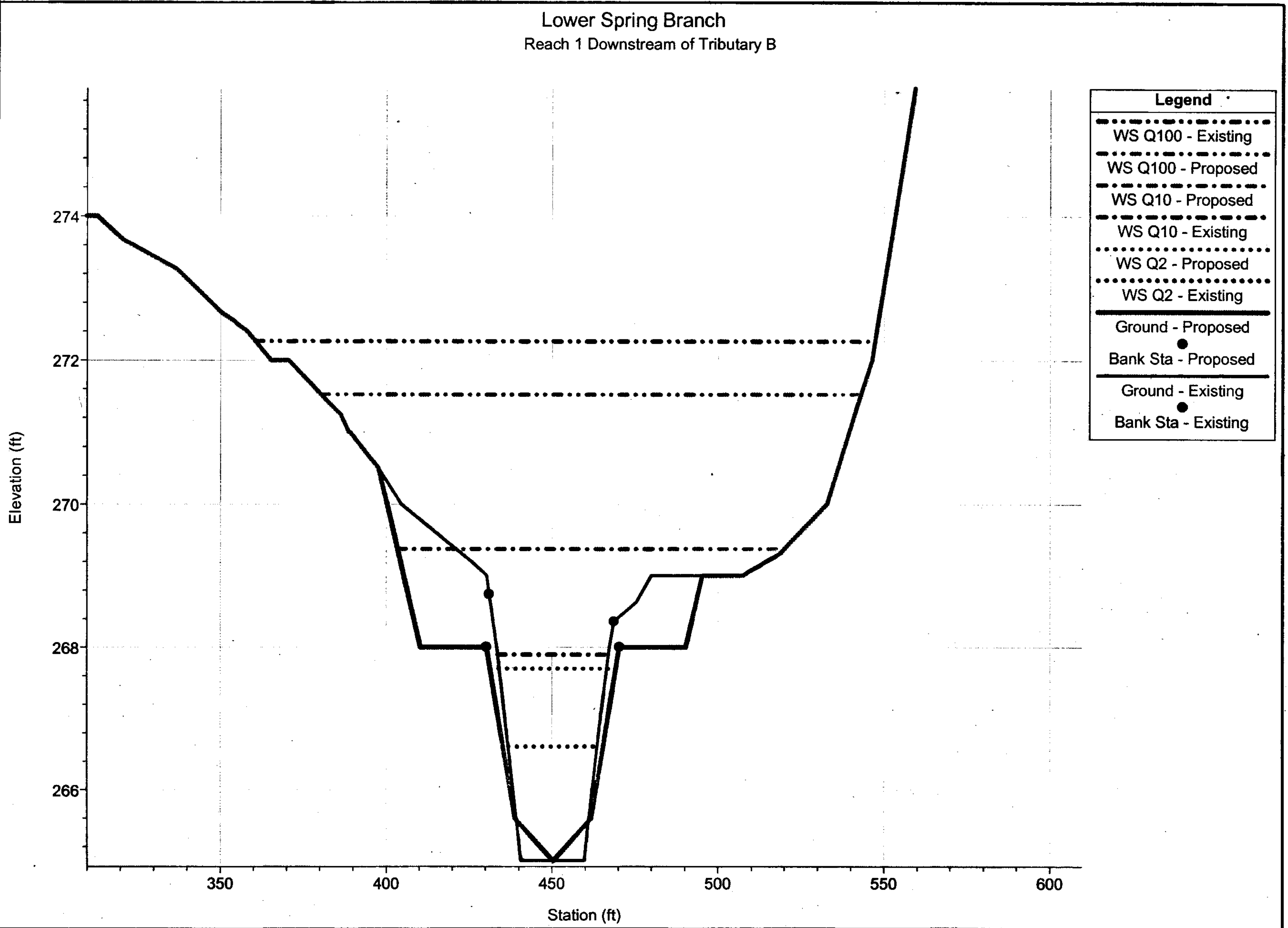
HYDRAULIC MODEL RESULTS

APPENDIX B

Lower Spring Branch

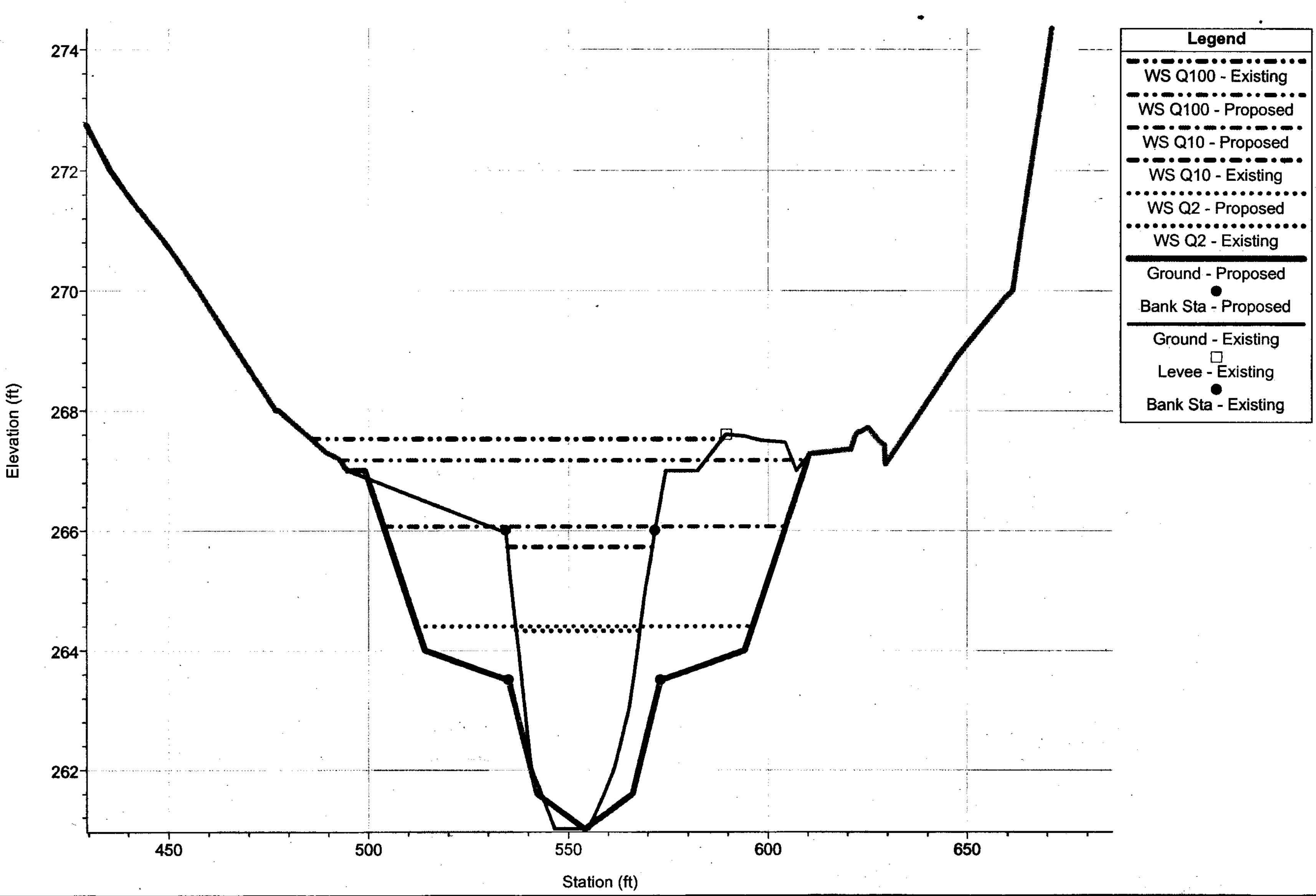
Reach 1 US of Tributary B   Note: Right bank of existing XS extends into Trib B

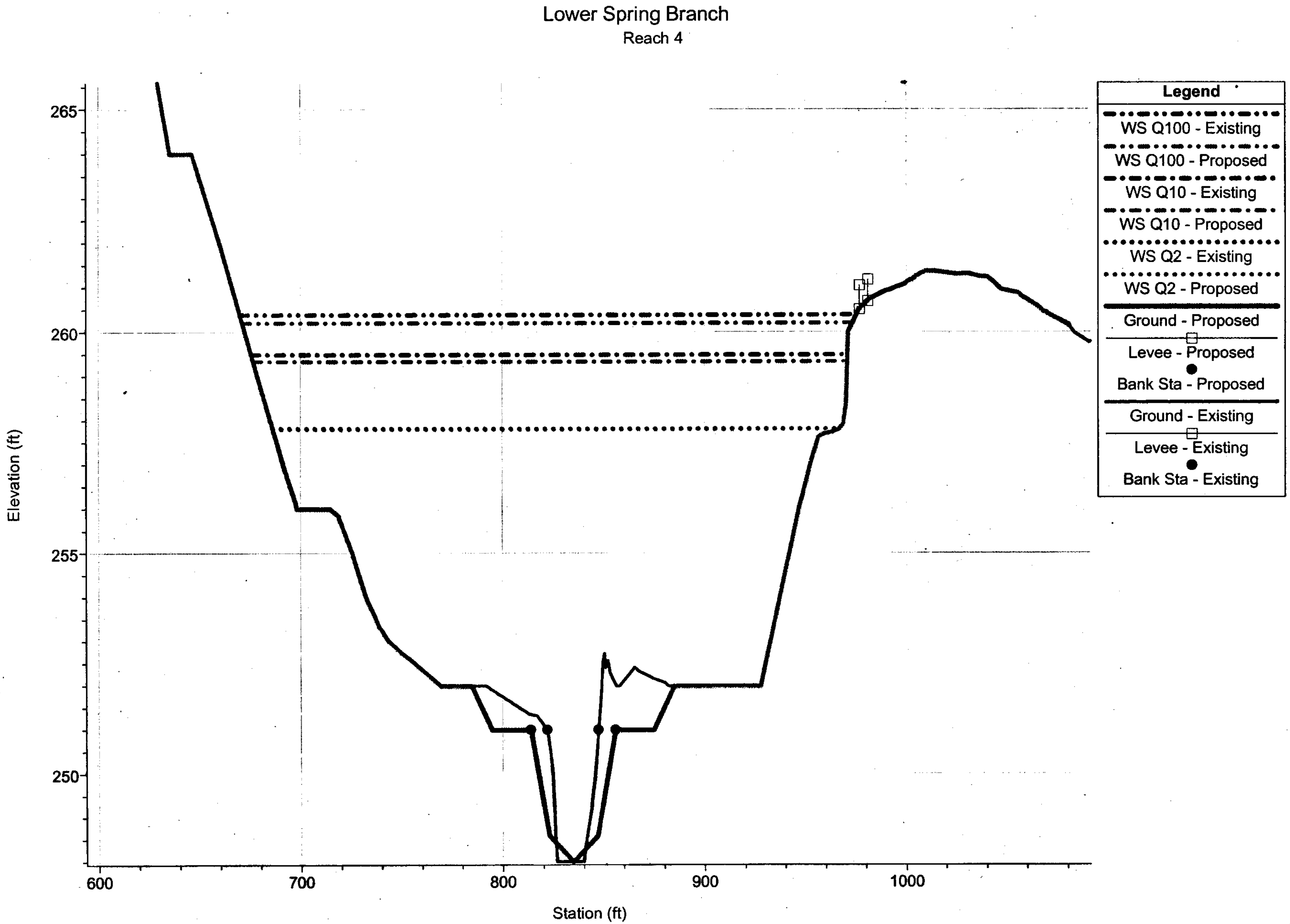




Lower Spring Branch
Reach 1 Downstream of Tributary B
Legend
WS Q100 - Existing
WS Q100 - Proposed
WS Q10 - Proposed
WS Q10 - Existing
WS Q2 - Proposed
WS Q2 - Existing
Ground - Proposed
Bank Sta - Proposed
Ground - Existing
Bank Sta - Existing
Elevation (ft)
274
272
270
268
266
Station (ft)
350
400
450
500
550
600

Lower Spring Branch
Reach 2





Lower Spring Branch
Reach 4
Elevation (ft)
265
260
255
250
Station (ft)
600
700
800
900
1000
Legend
WS Q100 - Existing
WS Q100 - Proposed
WS Q10 - Existing
WS Q10 - Proposed
WS Q2 - Existing
WS Q2 - Proposed
Ground - Proposed
Levee - Proposed
Bank Sta - Proposed
Ground - Existing
Levee - Existing
Bank Sta - Existing

EXISTING CONDITIONS

APPENDIX C

RESTORATION ALTERNATIVES

APPENDIX D

PRELIMINARY CONSTRUCTION COST ESTIMATES FOR THE CONCRETE-LINED REACHES

APPENDIX E

PRELIMINARY CONSTRUCTION COST ESTIMATE

Lower Spring Branch Concrete-lined Reaches

Alternative 1

Item No.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Coir matting	1500	SY	$4.00	$6,000.00
2	Clearing and Grubbing	0	LS	$2,000.00	$0.00
3	Concrete Removal	103	CY	$200.00	$20,660.00
4	Furnishing and Placing Riffle Material, depth varies	413	SY	$25.00	$10,325.00
5	Planting Trees and Shrubs - Riparian Forest Zone 1				
	Trees	153	EA	$40.00	$6,120.00
	Midstory Trees	32	EA	$30.00	$960.00
	Shrubs & Vines	36	EA	$20.00	$720.00
6	Herbaceous Permanent Seeding - Zones 1-2				
	Riparian Forest Zone 1 - Grasses (Seeded)	4,000	SY	$0.60	$2,400.00
	SUBTOTAL				$47,185.00
	10% Contingency				$4,718.50
	TOTAL				$51,903.50

Alternative 2

Item No.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Coir matting	1500	SY	$4.00	$6,000.00
2	Clearing and Grubbing	1	LS	$2,000.00	$2,000.00
3	Salvaging and/or furnishing and Placing Topsoil at 6" depth	1,500	SY	$4.00	$6,000.00
4	Excess Excavation	291	CY	$15.00	$4,365.00
5	Salvaging and placing fill material	100	CY	$5.00	$500.00
6	Concrete Removal	195	CY	$200.00	$39,000.00
7	Boulder Toe	70	ton	$80.00	$5,600.00
8	Furnishing and Placing Riffle Material, depth varies	1433	SY	$25.00	$35,825.00
9	Step	4	EA	$1,800.00	$7,200.00
10	Step Pool	2	EA	$2,500.00	$5,000.00
11	Planting Trees and Shrubs - Riparian Forest Zone 1				
	Trees	180	EA	$40.00	$7,200.00
	Midstory Trees	40	EA	$30.00	$1,200.00
	Shrubs & Vines	44	EA	$20.00	$880.00
12	Herbaceous Permanent Seeding - Zones 1-2				
	Riparian Forest Zone 1 - Grasses (Seeded)	4,840	SY	$0.60	$2,904.00
	SUBTOTAL				$123,674.00
	10% Contingency				$12,367.40
	TOTAL				$136,041.40

Alternative 3

Item No.	ITEM DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Coir matting	1500	SY	$4.00	$6,000.00
2	Clearing and Grubbing	1	LS	$2,000.00	$2,000.00
3	Salvaging and/or furnishing and Placing Topsoil at 6" depth	2,000	SY	$4.00	$8,000.00
4	Excess Excavation	580	CY	$15.00	$8,700.00
5	Salvaging and placing fill material	200	CY	$5.00	$1,000.00
6	Concrete Removal	886	CY	$200.00	$177,200.00
7	Boulder Toe	80	ton	$80.00	$6,400.00
8	Furnishing and Placing Riffle Material, depth varies	1433	SY	$25.00	$35,825.00
9	Step	4	EA	$1,800.00	$7,200.00
10	Step Pool	3	EA	$2,500.00	$7,500.00
11	Planting Trees and Shrubs - Riparian Forest Zone 1				
	Trees	180	EA	$40.00	$7,200.00
	Midstory Trees	40	EA	$30.00	$1,200.00
	Shrubs & Vines	44	EA	$20.00	$880.00
12	Herbaceous Permanent Seeding - Zones 1-2				
	Riparian Forest Zone 1 - Grasses (Seeded)	4,840	SY	$0.60	$2,904.00
	SUBTOTAL				$272,009.00
	10% Contingency				$27,200.90
	TOTAL				$299,209.90

Biohabitats
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Total Maximum Daily Loads of Phosphorus and Sediments for Loch Raven Reservoir And Total Maximum Daily Loads of Phosphorus for Prettyboy Reservoir, Baltimore, Carroll and Harford Counties, Maryland

FINAL

MARYLAND
DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard, Suite 540
Baltimore, MD 21230-1718

Submitted to:
U.S. Environmental Protection Agency, Region III
Water Protection Division
1650 Arch Street
Philadelphia, PA 19103-2029

August 2006

EPA Submittal Date: Sept. 15, 2006
EPA Approval Date: March 27, 2007

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List of Abbreviations

BMP	Best Management Practice
BOD	Biological Oxygen Demand
CBOD	Carbonaceous Biochemical Oxygen Demand
CE-QUAL-W2	U.S. Army Corps of Engineers Water Quality and Hydrodynamic Model, Version 3
Chla	Active Chlorophyll *a*
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
CWAP	Clean Water Action Plan
DO	Dissolved Oxygen
DPW	Baltimore City Department of Public Works
EPA	Environmental Protection Agency
FSA	Farm Service Administration
HSPF	Hydrological Simulation Program Fortran
ICPRB	Interstate Commission on the Potomac River Basin
LA	Load Allocation
lbs/yr	Pounds per Year
MD	Maryland
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MGS	Maryland Geological Survey
mg/l	Milligrams per Liter
MGD	Million Gallons per Day
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NBOD	Nitrogenous Biochemical Oxygen Demand
NMP	Nutrient Management Plan
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System

NPS	Nonpoint Source
POM	Particulate Organic Matter
PO4	Phosphate
RTG	Reservoir Technical Group
SCWQP	Soil Conservation and Water Quality Plan
SOD	Sediment Oxygen Demand
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
W2	CE-QUAL-W2
WLA	Wasteload Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WRAS	Watershed Restoration Action Strategy
WWTP	Waste Water Treatment Plant
µg/l	Micrograms per Liter

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes Total Maximum Daily Loads (TMDLs) for phosphorus and sediments in Loch Raven Reservoir (basin code 02-13-08-05) and for phosphorus in Prettyboy Reservoir (basin code 02-13-08-06).

Prettyboy Reservoir and Loch Raven Reservoir (referred to also as the Gunpowder Reservoirs), Use III-P waterbodies (COMAR 26.08.02.08J(4)), were identified on the 303(d) List submitted to EPA by the Maryland Department of the Environment (MDE) as impaired by nutrients (1996), sediments (1996 – Loch Raven), metals (1996), bacteria (2002 – Prettyboy), mercury in fish tissue (2002), and impacts to biological communities (2002 & 2004). This document upon approval from EPA, establishes TMDLs for the nutrient and sediment impairments. TMDLs were completed in 2002 for both reservoirs for the mercury listings. Water Quality Analyses were completed for both reservoirs for the metals listings in 2003. Other impairments within these watersheds will be addressed separately at a future date.

The water quality goal of the nutrient TMDLs is to reduce high chlorophyll *a* (Chla) concentrations that reflect excessive algal blooms, and to maintain dissolved oxygen (DO) at a level supportive of the designated uses for Prettyboy and Loch Raven Reservoirs. The water quality goal of the sediment TMDL for Loch Raven Reservoir is to increase the useful life of the reservoir for water supply by preserving storage capacity.

The TMDLs for the nutrient total phosphorus (TP) were determined using a time-variable, two-dimensional water quality eutrophication model, CE-QUAL-W2 ("W2"), to simulate water quality in each reservoir. The TMDLs are based on average annual total phosphorus loads for the simulation period 1992-1997, which includes both wet and dry years, and thus takes into account a variety of hydrological conditions. Chla concentrations indicative of eutrophic conditions can occur at any time of year and are the cumulative result of phosphorus loadings that span seasons. Thus, average annual phosphorus total loads are the most appropriate measure for expressing the nutrient TMDLs for Prettyboy and Loch Raven Reservoirs. Similarly, the sediment TMDL for Loch Raven Reservoir, which is based on the water quality modeling performed for the nutrient TMDLs, is expressed as an average annual load in keeping with the long-term water quality goal of preserving the storage capacity of the reservoir.

The TMDLs include (1) a wasteload allocation (WLA) to municipal wastewater treatment plants and municipal storm sewer systems, (2) a load allocation (LA) to nonpoint sources, and (3) a 5% margin of safety (MOS) for the nutrient TMDLs and an implicit MOS for the sediment TMDL. The table below summarizes the nutrient and sediment TMDLs.

Summary of Nutrient and Sediment TMDLs for Prettyboy and Loch Raven Reservoirs

Waterbody	Constituent	TMDL	WLA	LA	MOS
Prettyboy Reservoir	TP (lbs/yr)	23,192	2,940	19,072	1,160
Loch Raven Reservoir	TP (lbs/yr)	54,941	22,010	30,184	2,747
Loch Raven Reservoir	Sediment (tons/yr)	28,925	1,210	27,715	Implicit

Numerous factors provide assurance that these TMDLs will be implemented. First, National Pollutant Discharge Elimination System (NPDES) permits for both wastewater treatment plants and urban stormwater systems will play important roles in assuring implementation. Second, Maryland has several well-established programs that may be drawn upon, including Maryland's Tributary Strategies for Nutrient Reductions developed in accordance with the Chesapeake Bay Agreement. Third, Maryland's Water Quality Improvement Act of 1998 requires that nutrient management plans be implemented for all agricultural lands throughout Maryland. Fourth, local jurisdictions, along with MDE and other stakeholders, have implemented a formal agreement, the Reservoir Watershed Management Agreement, to protect water quality in the reservoirs. Fifth, a Watershed Restoration Action Strategy (WRAS) is currently in development for the Prettyboy Reservoir. Sixth, Maryland has adopted a watershed cycling strategy, which will assure that routine future monitoring and TMDL evaluations are conducted. Additionally, the federal Safe Drinking Water Act requires states to develop and implement source water assessment programs to study the safety and evaluate the vulnerability of drinking water sources to contamination. The source water assessment for Loch Raven Reservoir Watershed (including Prettyboy Reservoir) is described fully in MDE, 2004.

1.0 INTRODUCTION

Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to develop a Total Maximum Daily Load (TMDL) for each water quality limited segment (WQLS) on the Section 303(d) List, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

Prettyboy Reservoir and Loch Raven Reservoir (also referred to as the Gunpowder Reservoirs), Use III-P waterbodies (COMAR 26.08.02.08J(4)), were identified on the 303(d) List submitted to EPA by the Maryland Department of the Environment (MDE) as impaired by nutrients (1996) – due to signs of eutrophication, expressed as high chlorophyll *a* (Chla) levels, sediments (1996 – Loch Raven), metals (1996), bacteria (2002 – Prettyboy), mercury in fish tissue (2002), and impacts to biological communities (2002 and 2004). Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients, especially nitrogen and/or phosphorus. The nutrients act as a fertilizer leading to the excessive growth of aquatic plants, which eventually die and decompose, leading to bacterial consumption of dissolved oxygen (DO). Prettyboy Reservoir is also listed as impaired because of seasonal DO concentrations less than 5.0 mg/l in the hypolimnion. This document upon approval from EPA, establishes TMDLs for the nutrient and sediment impairments. TMDLs were completed in 2002 for both reservoirs for the mercury listings. Water Quality Analyses were completed for both reservoirs for the metals listings in 2003. Other impairments within these watersheds will be addressed separately at a future date.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Both Prettyboy and Loch Raven Reservoirs lie in the Gunpowder Falls watershed (Figure 1). Gunpowder Falls drains into Chesapeake Bay north of the City of Baltimore. The portion of the watershed draining to the reservoirs lies primarily in Baltimore and Carroll Counties, but also includes small portions of Harford County and York County, PA. Both reservoirs are part of the water supply system for Baltimore City and surrounding jurisdictions. Water supply intakes in Loch Raven Reservoir feed Baltimore City's

Montebello Water Treatment Plant. Prettyboy Reservoir, which is upstream of Loch Raven Reservoir, is used as a secondary reservoir to maintain capacity in Loch Raven Reservoir.

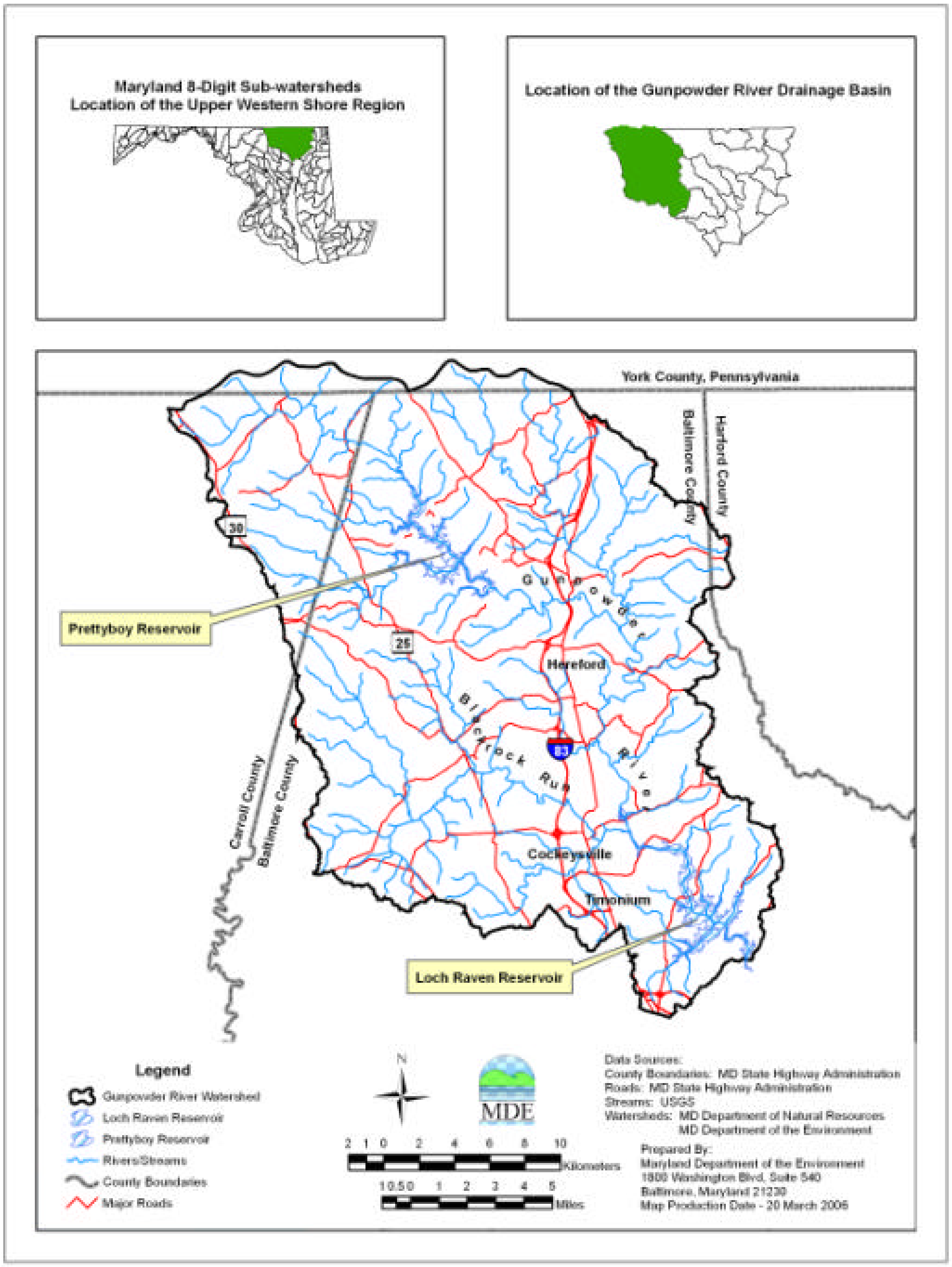

Figure 1: Location of Prettyboy and Loch Raven Reservoirs

Several relevant statistics for Prettyboy and Loch Raven Reservoirs are provided below in Table 1.

Table 1: Current Physical Characteristics of Prettyboy and Loch Raven Reservoirs

Characteristic	Prettyboy	Loch Raven
Location:	Baltimore County, MD Lat. 39° 37’ 12” N Long. 76° 42’ 36” W	Baltimore County, MD Lat. 39° 25’ 48” N Long. 76° 32’ 24” W
Surface Area:	1500 acres (65,340,000 ft^2)	2400 acres (104,544,000 ft^2)
Normal Reservoir Depth[1]:	98.5 feet	76.0 feet
Purpose:	Water Supply Recreation	Water Supply Recreation
Basin Code:	02-13-08-06	02-13-08-05
Volume:	60,100 acre-feet	72,700 acre-feet
Drainage Area to Reservoir:	80.0 mi^2 (51,200 acres)	303 mi^2 (193,920 acres)

Source: Inventory of Maryland Dams and Hydropower Resources (Weisberg *et al.*, 1985). [1]Measured from base of dam to spillway.

2.1.1 Land Use

Figure 2 shows the land use in the Prettyboy and Loch Raven watersheds. The land use is based on 1997 Maryland Department of Planning Land Use/Land Cover data. The Prettyboy Reservoir watershed (excluding the reservoir surface area) covers approximately 49,000 acres or 77 square miles. About half of the watershed is in crops or pasture, 39% in forest, and 12% in residential, commercial, or industrial land uses (Figure 3). The Loch Raven Reservoir watershed, excluding the drainage to Prettyboy Reservoir and the reservoir surface areas, covers approximately 140,000 acres or about 218 square miles. Approximately 21% of the watershed is developed and 38% is forest, with the remainder in crops, pasture or “mixed open” land uses (Figure 4). Mixed open land uses represent a mixture of several categories of anthropogenically modified open land, including low-density urban cover, horse pasture, fallow cropland or transitional agricultural land.

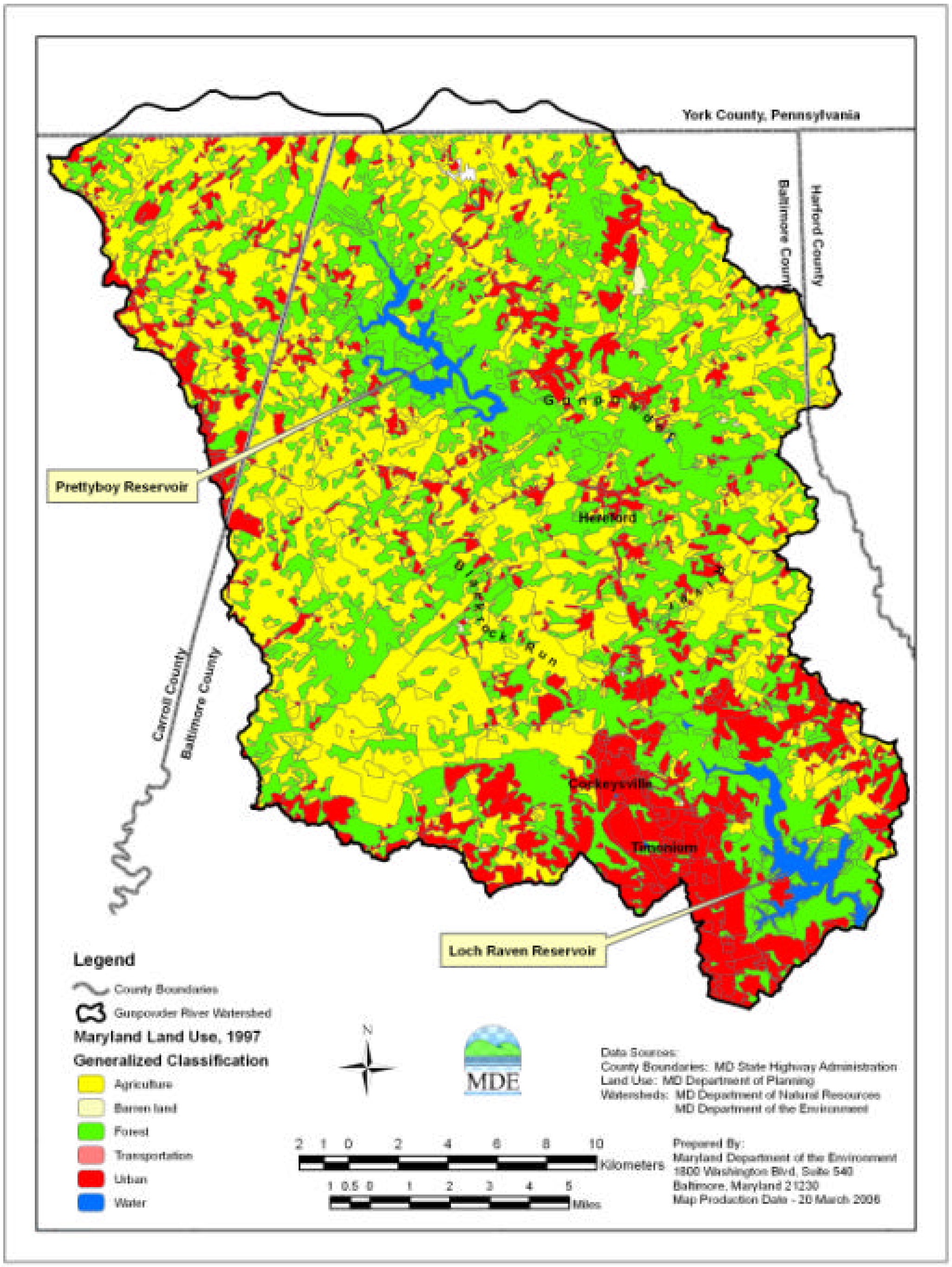

Figure 2: Land Use in Gunpowder Falls Watershed

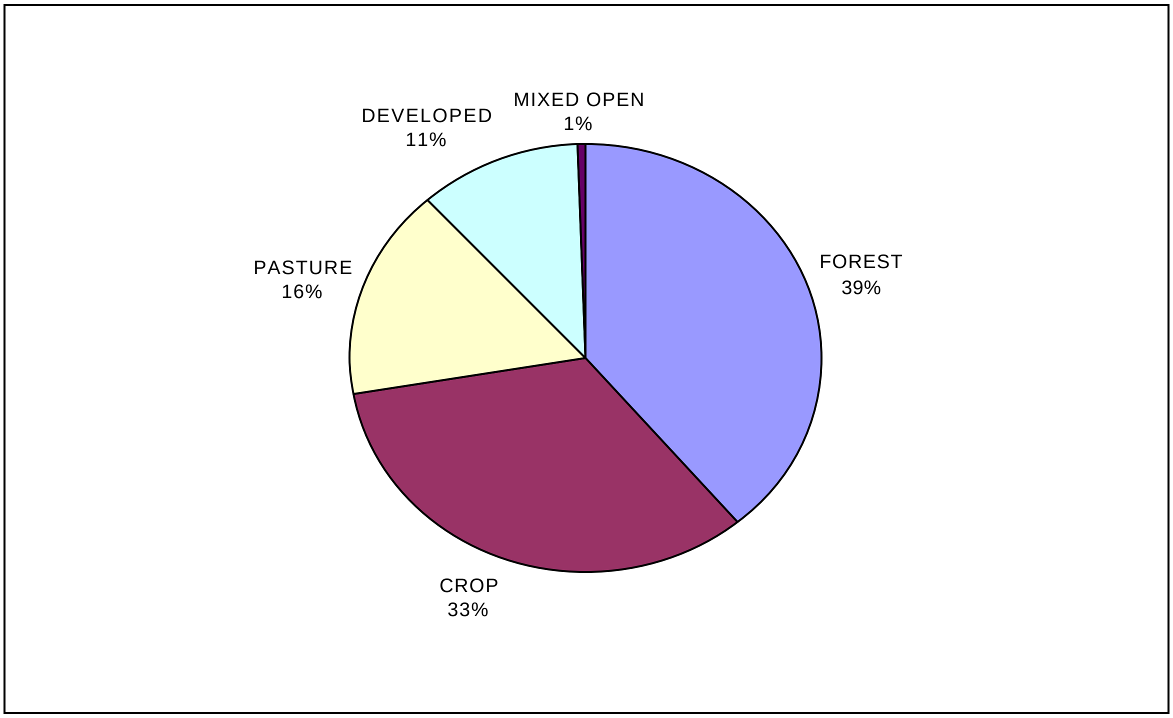

Figure 3: Proportion of Land Use in the Prettyboy Reservoir Watershed

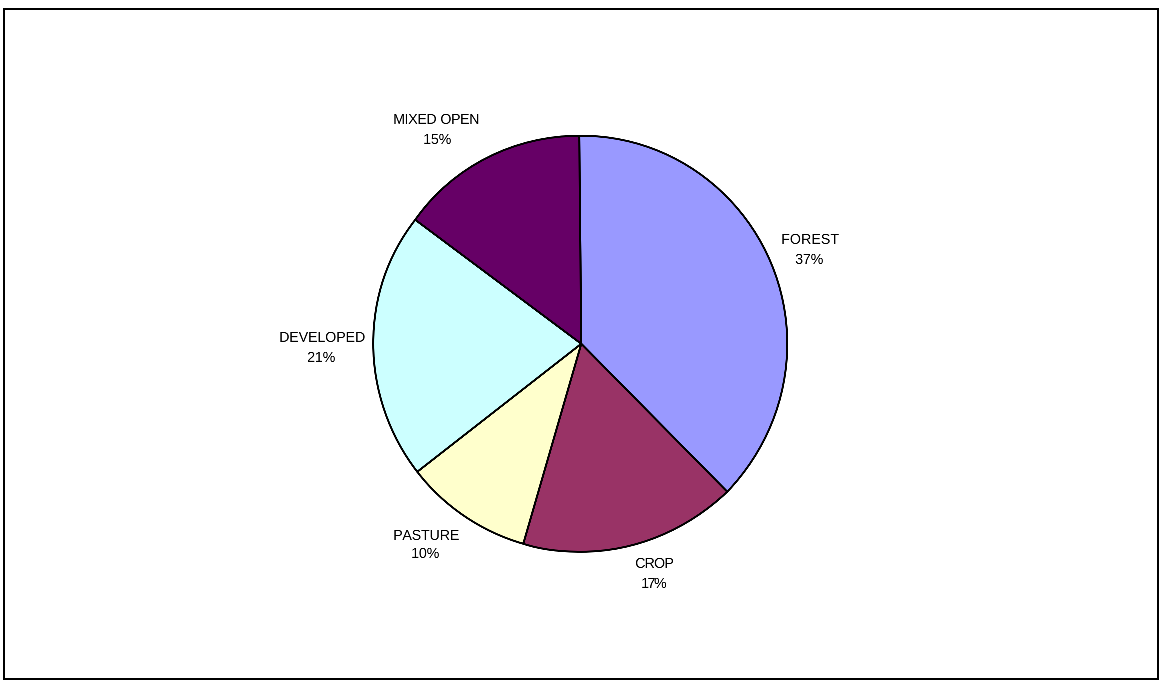

Figure 4: Proportion of Land Use in the Loch Raven Reservoir Watershed

2.1.2 Geology and Soils

The watersheds of Prettyboy and Loch Raven Reservoirs lie in the Piedmont physiographic province. The surficial geology is characterized by metamorphic rock of Precambrian and Cambrian age. Prettyboy schist is the underlying bedrock of the Prettyboy Reservoir watershed (MDE, 2004). The underlying metamorphic rock complex of the Loch Raven watershed downstream of Prettyboy consists mainly of crystalline schists and gneiss with smaller areas of marble. The underlying marble formations, Cockeysville Marble and the Patuxent Formation, are less resistant to weathering than the schists and gneiss and consequently occur mainly in valleys.

The primary soil associations in the watershed are the Manor-Glenelg, Chester-Glenelg, Baltimore-Conestoga-Hagerstown, Beltsville-Chillum-Sassafras, Glenelg-Chester-Manor, and Mt. Airy-Linganore associations. These soils are mainly deep and well-drained to moderately well-drained (Reybold and Matthews, 1976; Matthews, 1969). Within the stream floodplains, alluvial, Codorus and Hatboro soil series predominate. Nearly 85% of the soils in the watershed below Prettyboy Reservoir are classified as Hydrologic Group B, which means that they have low to moderate surface runoff potential, moderate infiltration rates, and moderately fine to moderately coarse soil texture (Tetra Tech, 1997).

2.1.3 Point Sources and Wastewater Treatment Plant Loads

The development of nutrient TMDLs for Prettyboy and Loch Raven Reservoirs was based on computer simulation modeling of water quality conditions from 1992 to 1997. During that time, the Manchester municipal wastewater treatment plant (WWTP) discharged within the Prettyboy Reservoir watershed, and the Hampstead municipal WWTP, along with ten small industrial sources, discharged within the Loch Raven Reservoir watershed. Table 2 shows the annual phosphorus and sediment loads from the municipal WWTPs during the simulation period, 1992-1997.

Table 2: Annual Municipal Wastewater Treatment Plant Loads 1992-1997

	Manchester (MD0022446)			Hampstead (MD0022578)		
Year	PO_4 (lbs/yr)	Organic P (lbs/yr)	TSS (tons/yr)	PO_4 (lbs/yr)	Organic P (lbs/yr)	TSS (tons/yr)
1992	192.33	177.84	2.77	276.41	173.39	0.27
1993	300.08	275.61	4.15	489.03	291.04	0.35
1994	382.14	370.30	7.06	254.56	195.37	0.39
1995	195.65	37.44	0.89	139.16	146.87	0.40
1996	90.65	80.92	0.83	168.81	107.44	0.85
1997	126.78	114.59	3.30	207.61	88.88	0.39
Average	214.60	176.11	3.16	255.93	167.16	0.44

Currently, the Manchester WWTP discharges through spray irrigation from April 1 through November 30, and in March if weather permits. Its current design flow is 0.5 million gallons per day (MGD). The Hampstead WWTP's current design flow is 0.9 MGD.

There are no industrial sources permitted for discharging phosphorus. Three facilities are permitted to discharge total suspended solids. Only one of them, a limestone quarry and concrete production facility owned by co-permittees Lafarge Mid-Atlantic and Imerys, has the potential to discharge solids in significant quantities.

2.1.4 Nonpoint Source Loads and Urban Stormwater Loads

Nonpoint source loads and urban stormwater loads entering the Prettyboy and Loch Raven Reservoirs were estimated using the Hydrologic Simulation Program-Fortran (HSPF) model. The HSPF model is used to estimate flows, suspended solids and nutrient loads from the watershed's sub-basins, which are linked to two-dimensional CE-QUAL-W2 models of each reservoir. These are used to determine the maximum loads of total phosphorus (TP) that can enter each reservoir while maintaining the water quality criteria associated with their designated uses. The water quality modeling framework is addressed in more detail in Section 4.2.

The simulation of the Loch Raven and Prettyboy Reservoir watersheds used the following assumptions: (1) variability in patterns of precipitation were estimated from existing National Oceanic and Atmospheric Administration (NOAA) meteorological stations; (2) hydrologic response of land areas were estimated for a simplified set of land uses in the basin; and (3) agricultural information was estimated from the Maryland Department of Planning (MDP) land use data, the 1997 Agricultural Census Data (U. S. Department of Commerce, 1997), and the Farm Service Agency (FSA). The HSPF simulates nonpoint source and urban stormwater loads and integrates all natural and human induced sources, including direct atmospheric deposition, and loads from septic tanks, which are associated with river base flow during low flow conditions. Details of the HSPF watershed model developed to estimate these urban and non-urban loads can be found in *Modeling Framework for Simulating Hydrodynamics and Water Quality in Prettyboy and Loch Raven Reservoirs* (ICPRB and MDE, 2006).

Figures 5 and 6 show the relative size of the contribution of point and nonpoint sources of total phosphorus to Prettyboy and Loch Raven Reservoirs, respectively, 1992-1997. Figure 7 shows the relative size of the contribution of sediment sources to Loch Raven Reservoir over the same period.

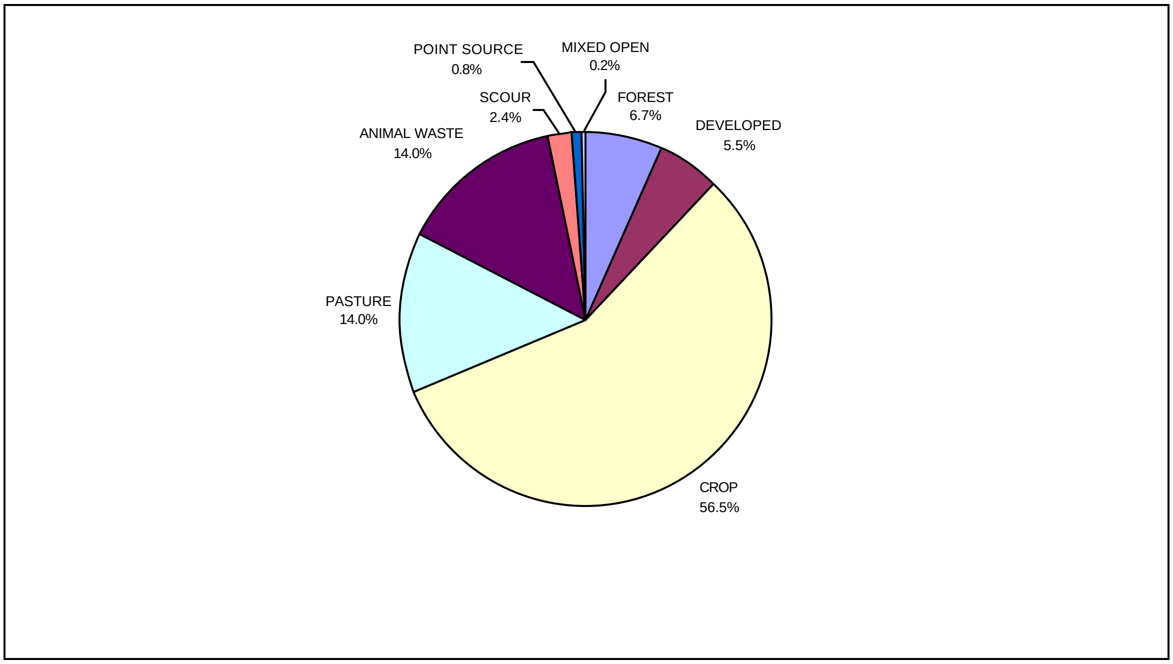

Figure 5: Percent Contribution of Sources to Total Phosphorus Loads to Prettyboy Reservoir

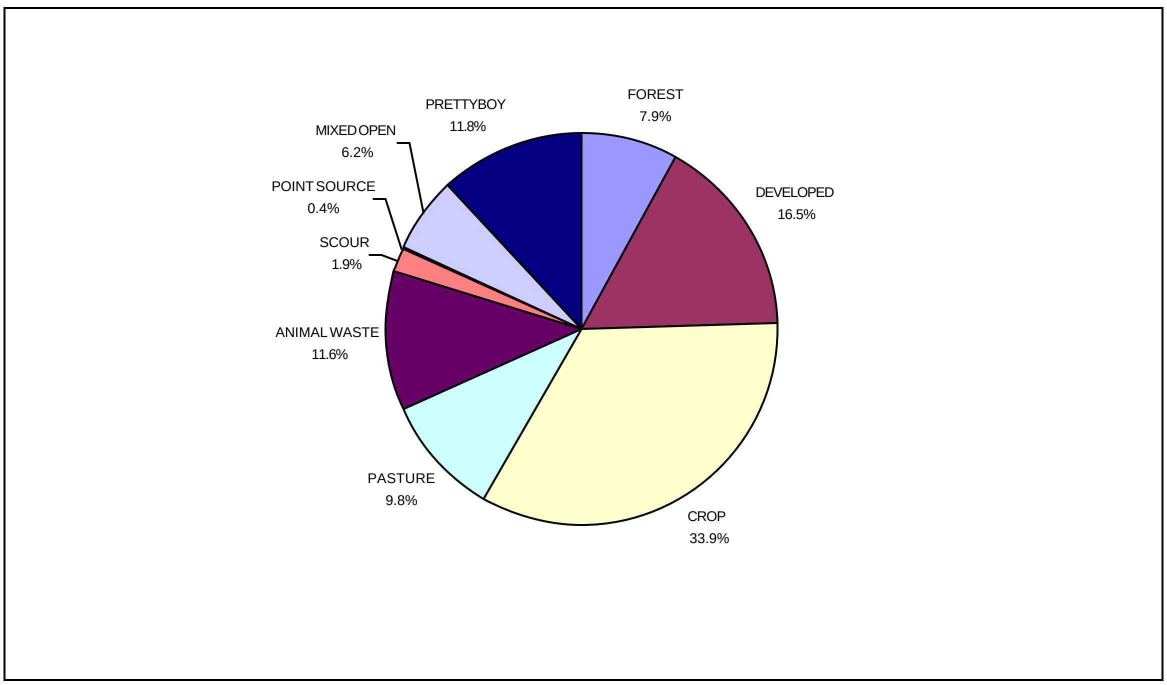

Figure 6: Percent Contribution of Sources to Total Phosphorus Loads to Loch Raven Reservoir

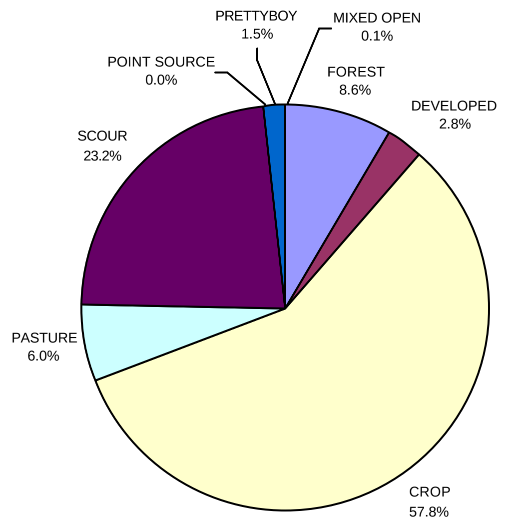

Figure 7: Percent Contribution of Sources to Sediment Loads to Loch Raven Reservoir

2.2 Water Quality Characterization

2.2.1 Baltimore City Department of Public Works Monitoring Program

Baltimore City Department of Public Works (DPW) is the only agency that monitors water quality in the reservoirs. DPW samples at three locations in Prettyboy Reservoir, and at five locations in Loch Raven Reservoir. Figures 8 and 9 show the sites of these sampling locations. Not all locations are sampled at the same time. Sampling is performed by boat at locations GUN0401, GUN0171, and GUN0190 weather permitting; otherwise, in the winter months, sampling is at fixed locations GUN0399, GUN0156, and GUN0174. Sampling at GUN0142 and GUN0437 can occur either by boat or from a fixed platform.

Samples are analyzed for water temperature, dissolved oxygen, total phosphorus, ammonia, nitrate, turbidity, and Secchi depth, among other constituents. Samples are not analyzed for phosphorus species, organic or total nitrogen, or suspended sediment. Starting at the surface, samples are taken every five feet up to sixty feet; samples are taken at ten-foot intervals thereafter.

Not every sample is analyzed for the entire suite of constituents. Generally, only field measurements like temperature and dissolved oxygen are measured at every depth sampled. Lab analysis is performed for Chla for each sample collected at the surface and at ten-foot depths down to 50 feet. In Loch Raven, chemical analysis is performed on samples collected at the surface and every ten feet down to sixty feet. In Prettyboy, chemical analysis is performed on samples taken at the surface and at 10, 20, and 40 feet below the surface, with an additional sample taken at either 60 feet below the surface, in the case of GUN0437, or 80 feet below in the case of the other two stations.

For the purpose of data analysis and the presentation of results, the locations in Loch Raven sampled by boat and the locations with fixed sampling positions have been paired to yield an annual representation of the middle and upper portion of the reservoir. Stations GUN0399 and GUN401 in Prettyboy have been paired to represent the lower portion of the reservoir. GUN0437 by itself represents the middle portion of Prettyboy. There are no sampling locations in the upper portion of Prettyboy reservoir. Table 3 summarizes how the sampling locations are grouped together in this report.

Table 3: Characterization of Reservoir Monitoring Locations

Station	Reservoir	Location	Classification
GUN0142	Loch Raven	Gatehouse	Lower
GUN0156	Loch Raven	Loch Raven Drive bridge	Middle
GUN0171	Loch Raven	Between picnic area and golf course	Middle
GUN0174	Loch Raven	Dulaney Valley Road bridge	Upper
GUN0190	Loch Raven	At the power lines	Upper
GUN0399	Prettyboy	Gatehouse	Lower
GUN0401	Prettyboy	1000 ft. upstream of dam	Lower
GUN0437	Prettyboy	Beckleysville Road Bridge	Middle

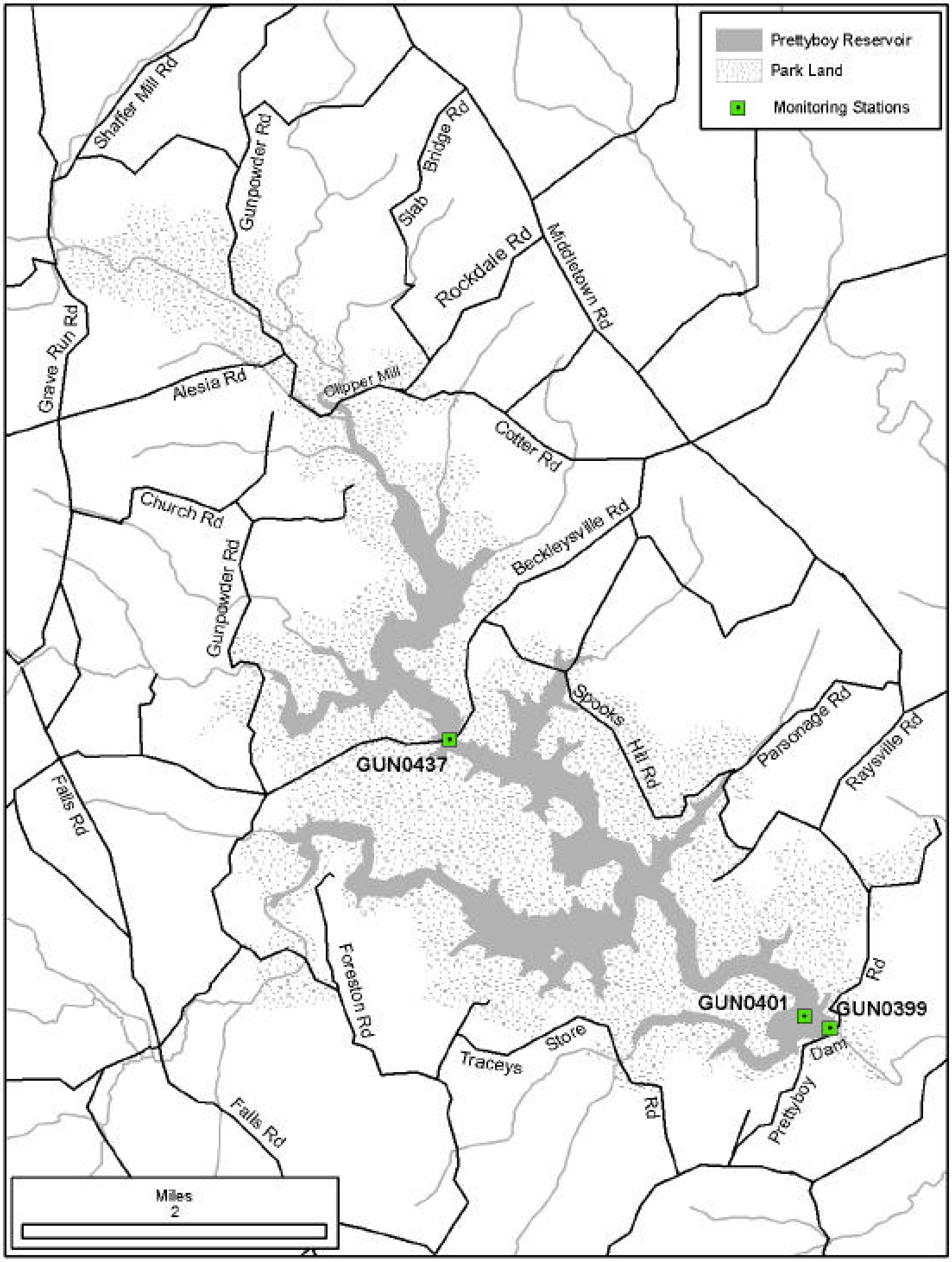

Figure 8: Sampling Locations in Prettyboy Reservoir (from DPW)

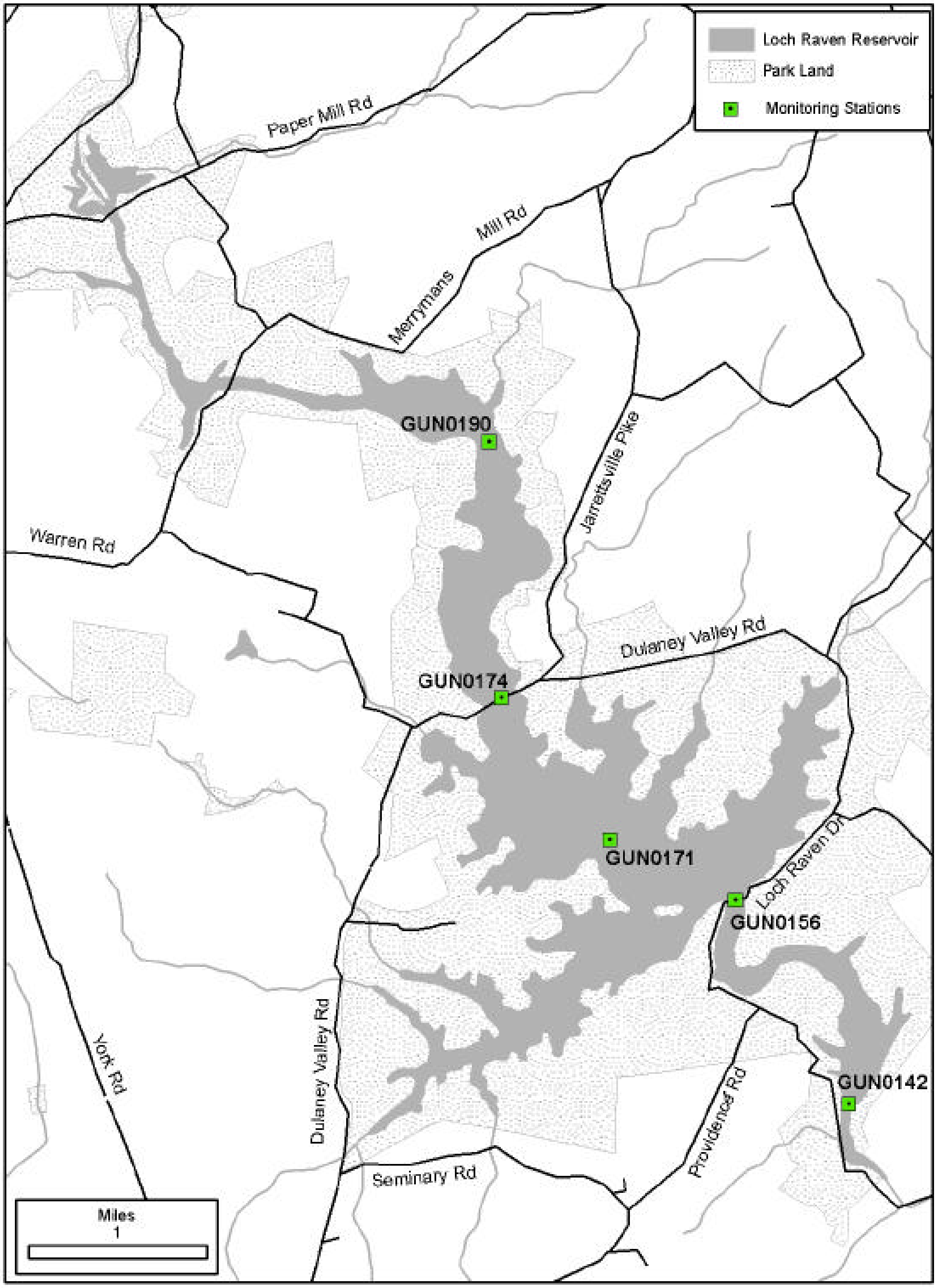

Figure 9: Sampling Locations in Loch Raven Reservoir (from DPW)

2.2.2 Temperature Stratification

Prettyboy and Loch Raven Reservoirs both regularly exhibit temperature stratification starting in April or May and lasting until November. Stratification sometimes occurs in winter but without significant consequences for water quality. Under stratified conditions during the summer and early fall, bottom waters in both reservoirs can become hypoxic, because stable density differences inhibit the turbulent mixing that transports oxygen from the surface. Under such conditions, the reservoirs can be divided vertically into a well-mixed surface layer, or epilimnion; a relatively homogeneous bottom layer or hypolimnion; and a transitional zone between them, the metalimnion, characterized by a sharp density gradient.

Contour plots of isotherms effectively illustrate seasonal position of the well-mixed surface layer or epilimnion. Figure 10 presents a contour plot of isothermals for GUN0142 in Loch Raven Reservoir for 1993, a representative year. Contours are shown only for the first 30 feet from the surface. In the winter, isothermal lines are vertical, showing that the reservoir has fairly uniform temperature over the first 30 feet of depth. In spring, isothermal lines begin to tilt away from the vertical, until by May, at depths greater than 15 to 20 feet, they are parallel to each other horizontally. At the surface, isothermal lines run vertically to a depth of 10 to 15 feet; this defines the epilimnion.

Figures A1 - A20 in Appendix A present contour plots for each monitoring location (lower, middle and upper) over the period 1992-2004. Generally, in both reservoirs, the epilimnion is limited to a depth of 10 to 15 feet in the summer. For the purposes of data analysis, the surface layer is considered to be 20 feet deep, with the understanding that in spring and fall the epilimnion can extend deeper than 20 feet, and in the summer it is likely to be shallower. For screening purposes, samples taken at depths of 40 feet or greater are considered in the bottom layer or hypolimnion.

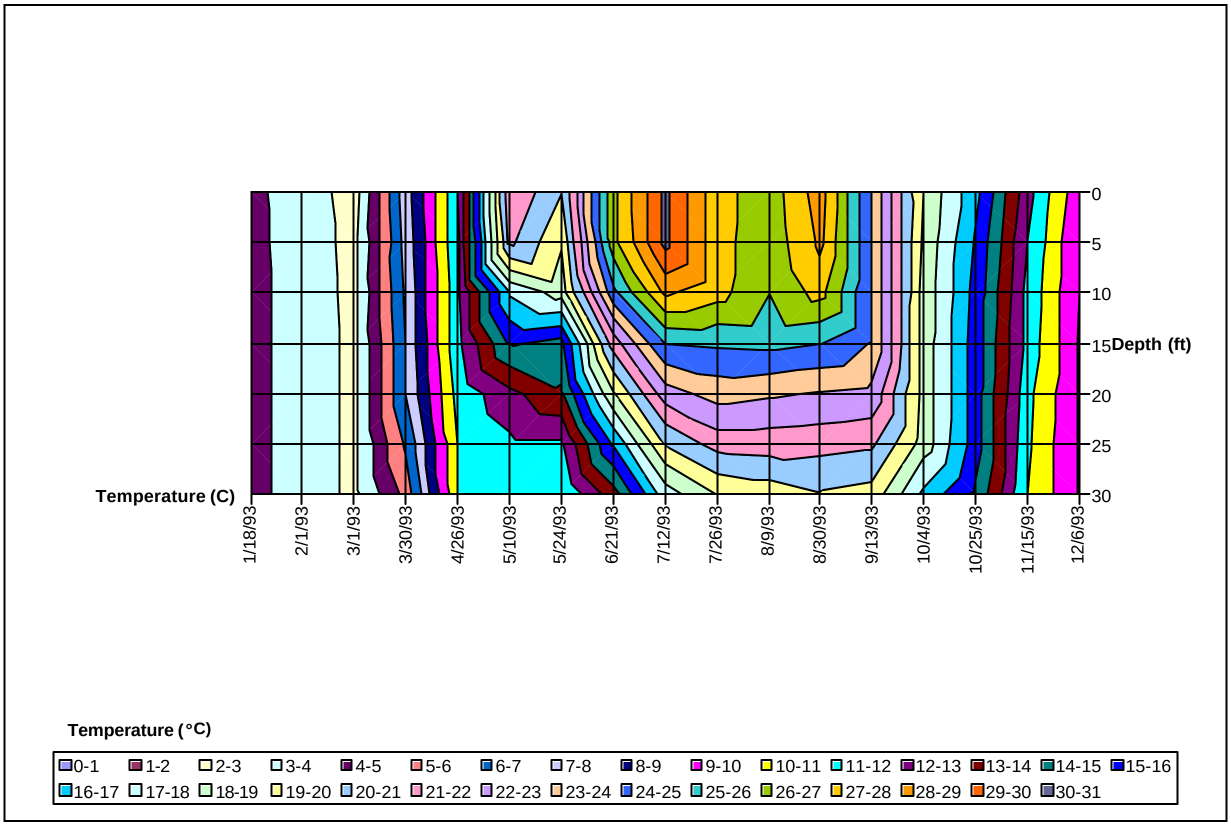

Figure 10: Isothermal Contours, Loch Raven Reservoir, Middle Stations, 1993

2.2.3 Dissolved Oxygen

Figures A21 - A25 in Appendix A show time series of average bottom DO concentrations at all monitoring locations in Prettyboy and Loch Raven Reservoirs. Quite clearly, hypoxia occurs in the hypolimnion of both Prettyboy and Loch Raven Reservoirs with regularity.

Figures A26-30 in Appendix A also show time series of DO at the surface and at five-foot intervals up to 20 feet, the screening-level definition of the epilimnion. For the most part, DO concentrations are above the 5.0 mg/l criterion, but there are periodic excursions below 5.0 mg/l at the 15- and 20-foot depths. In the majority of cases in which apparent hypoxia is observed in the epilimnion, the 20-foot screening depth has over-estimated the depth of the well-mixed layer, as shown by the temperature observations. As noted in the previous section, the depth of the epilimnion ranges between 10 and 15 feet in the summer months. See Tables B1 and B2 in Appendix B for a listing of all dates when DO concentrations were below 5.0 mg/l at either 15- or 20-foot sampling depth in Loch Raven and Prettyboy Reservoirs, respectively.

There are two related causes of these low DO concentrations. The first is temperature stratification, as explained above; the second is the entrainment of low DO waters into the epilimnion. Entrainment refers to the process by which turbulent layers spread into a non-turbulent region (Ford and Johnson, 1986). The onset of cool weather causes the epilimnion to increase in depth by entraining water from the metalimnion. This water can be low in oxygen and reduce the DO concentration in the well-mixed layer. This can occur any time under stratified conditions when the surface mixed-layer deepens, often well before the fall overturn typical of many lakes and reservoirs (including Prettyboy and Loch Raven), when the surface and bottom layers displace one another. All nineteen dates on which low DO occurred in Loch Raven without an approximately 2ºC difference in temperature between the 5- and 20-foot depths occurred in September, October or November, and all but five occurred in September alone.

This is illustrated by the low DO reading recorded on September 13, 1993, in GUN0171, the middle of Loch Raven Reservoir. Figure 11 shows the DO contour at this location. Figure 10 in the previous section, shows the temperature contour. A comparison of the figures indicates that at the end of August the reservoir at this location was highly stratified, with the well-mixed layer extending to about 15 feet. Throughout September, the surface waters cooled and the epilimnion deepened. The layers with low oxygen concentrations in the summer were drawn into the epilimnion. By October, the epilimnion once again had fairly uniform DO concentrations, although the reservoir had not completely overturned.

Entrainment and overturning account for the other low DO oxygen observations in Loch Raven and Prettyboy as well. In Prettyboy, another factor also can influence entrainment: drawdown. Withdrawals from a reservoir can induce currents that enhance mixing. Figure 12 shows the surface elevation of Prettyboy Reservoir from 1994 through 2004. In 1999 and 2002 (drought years), releases from Prettyboy to fill Loch Raven dropped the surface elevation by 30 feet or more. These drawdowns are probably a contributing factor in mixing low DO concentrations into the surface levels of the reservoir.

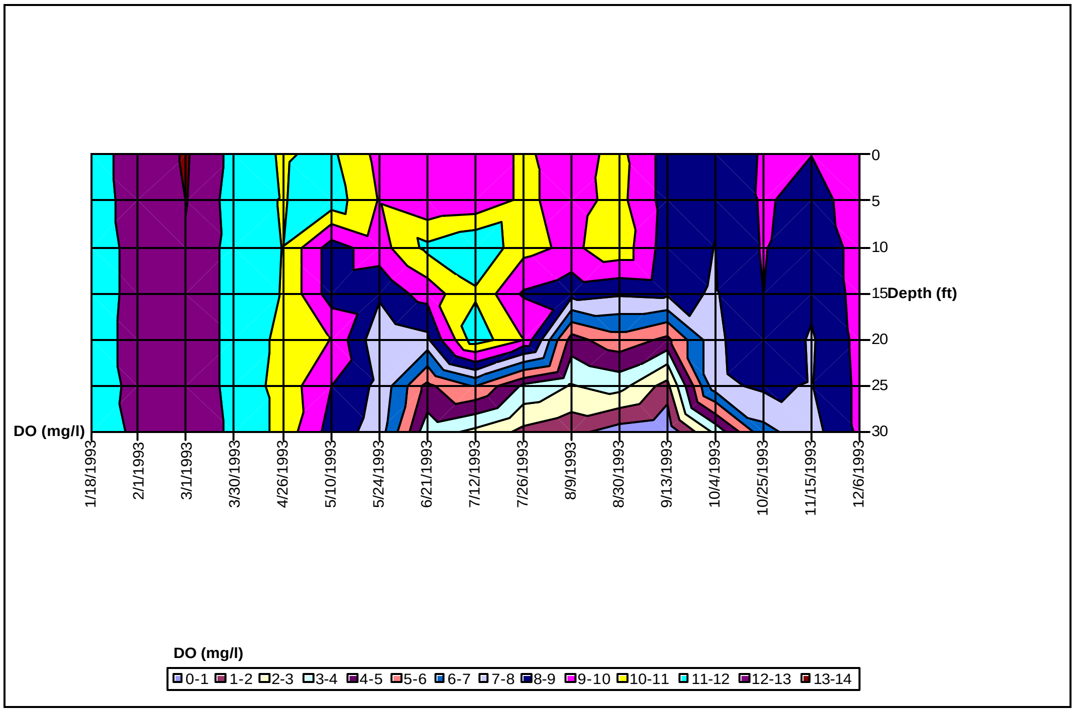

Figure 11: DO Contour, Loch Raven Reservoir, Middle Locations, 1993

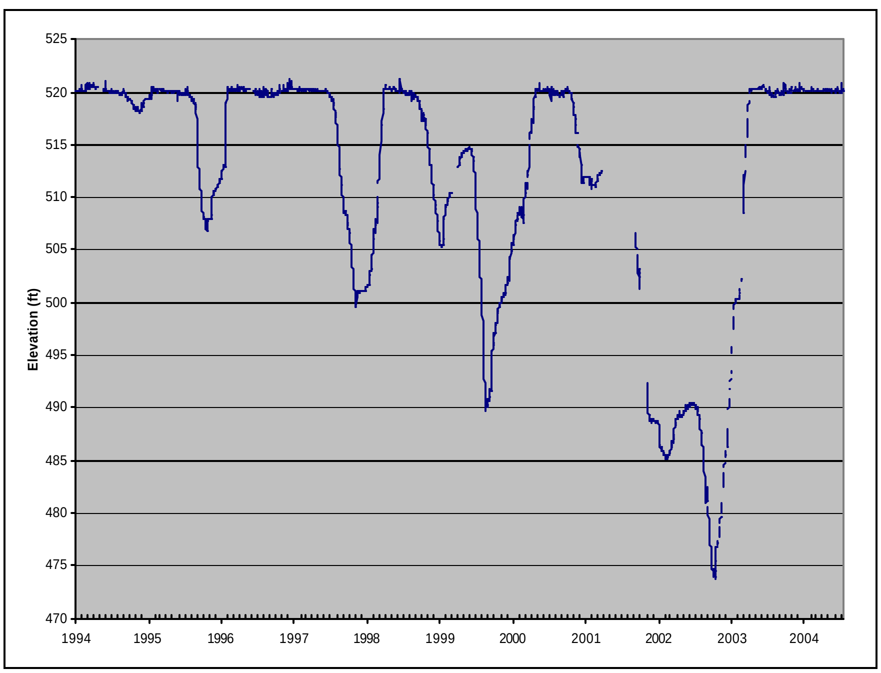

Figure 12: Surface Water Elevations in Prettyboy Reservoir, 1994-2004

2.2.4 Total Phosphorus

Figures A31 - A35 in Appendix A show average total phosphorus concentrations in the top and bottom sampling depths at each monitoring location in Prettyboy and Loch Raven Reservoirs. Surface layer concentrations are an average of the 10- and 20-foot depth samples. Bottom concentrations are averages of samples taken at 40-foot depths or greater. Tables 4 and 5 give summary statistics for TP concentrations (mg/l) in Prettyboy and Loch Raven Reservoirs, respectively. As the tables show, there is a longitudinal gradient to TP concentrations, with concentrations generally decreasing downstream. This is thought to reflect the fact that much of the phosphorus entering the reservoir is bound to sediment, and thus settles out before reaching the dams.

Table 4: Summary Statistics: TP Concentrations (mg/l) in Prettyboy Reservoir, 1992-2004

	Surface		Bottom	
Statistic	Middle	Lower	Middle	Lower
Mean	0.079	0.058	0.075	0.067
Standard deviation	0.112	0.082	0.106	0.110
Minimum	0.002	0.003	0.002	0.002
1st Quartile	0.021	0.019	0.025	0.018
Median	0.045	0.035	0.041	0.040
3rd Quartile	0.078	0.065	0.073	0.066
Maximum	0.675	0.552	0.825	0.970
Count	127	127	127	127

Table 5: Summary Statistics: TP Concentrations (mg/l) in Loch Raven Reservoir, 1992-2004

	Surface			Bottom		
Statistic	Upper	Middle	Lower	Upper	Middle	Lower
Mean	0.078	0.066	0.054	0.084	0.082	0.062
Standard Deviation	0.108	0.102	0.092	0.092	0.148	0.109
Minimum	0.005	0.003	0.002	0.005	0.003	0.003
1st Quartile	0.027	0.023	0.019	0.033	0.026	0.022
Median	0.053	0.042	0.036	0.058	0.045	0.033
3rd Quartile	0.085	0.071	0.060	0.100	0.081	0.078
Maximum	1.010	0.835	1.040	0.580	1.313	1.260
Count	136	139	205	90	138	205

The surface sample itself was excluded from the analysis because samples periodically have concentrations as high as 1.0 mg/l. Some of these high concentrations are confined to the surface layer and are suspected to be surface films. For this reason DPW also excludes surface layer concentrations (Baltimore City DPW, 1996).

2.2.5 Nutrient Limitation

Nitrogen and phosphorus are essential nutrients for algae growth. If one nutrient is available in great abundance relative to the other, then the nutrient that is less available limits the amount of plant matter that can be produced; this is known as the "limiting nutrient." The amount of the abundant nutrient does not matter because both nutrients are needed for algae growth. In general, a Nitrogen:Phosphorus (N:P) ratio in the range of 5:1 to 10:1 by mass is associated with plant growth being limited by neither phosphorus nor nitrogen. If the N:P ratio is greater than 10:1, phosphorus tends to be limiting; if the N:P ratio is less than 5:1, nitrogen tends to be limiting (Chiandani *et al*, 1974).

Since there are no data on organic nitrogen concentrations in the reservoir, nitrate is substituted for total nitrogen (TN) in the TN:TP ratio assessment, and the TN:TP ratio is underestimated. In both reservoirs, only about 7% of the samples taken at the 10- and 20-foot depths have nitrate:TP ratios less than 10:1, which can be taken as a cutoff for distinguishing nitrogen limitation from phosphorus limitation. The median nitrate:TP ratio in Loch Raven is 38:1 and the median in Prettyboy is 47:1. About half the samples from Loch Raven with nitrate:TP ratios less than 10:1 occur on five dates, all of which appear to be associated with storm events. Storm events are likely to have high concentrations of particulate nitrogen and phosphorus, but while particulate phosphorus is accounted for in nitrate:TP ratios, particulate organic nitrogen is not. Storm events therefore inflate TP concentrations and exacerbate the underestimation of TN, so the resultant ratios are considered anomalous. Based on the available monitoring data and prevalent high N:P ratios, the evidence is conclusive that both Prettyboy and Loch Raven Reservoirs are strongly phosphorus limited.

2.2.6 Ammonia and Nitrogen

Figures A36 - A45 in Appendix A show the average surface and bottom concentrations of ammonia and nitrate in Prettyboy and Loch Raven Reservoirs. Since the surface layers of the reservoirs are not nitrogen limited, bottom concentrations of ammonia and nitrate are more important from the water quality standpoint for two reasons.

First, the time series graphs of ammonia show that, particularly for Loch Raven, there are significant releases of ammonia from the sediments. This contributes to oxygen demand. Although observed ammonia concentrations range as high as 4.0 mg/l, Maryland's ammonia water quality criteria (COMAR 26.08.02.03-2H(1)) were not exceeded. Second, nitrate concentrations for the most part remain above 0.5 mg/l. Nitrate is preferred to ferric iron (III) as an electron acceptor in diagenesis. Phosphate in the sediments is bound through ferric iron. It is less likely that phosphate will be released from sediments until ferric iron is reduced in diagenesis. Thus it can be anticipated that the phosphorus release rate from the sediments will remain low.

2.2.7 Algae and Chlorophyll *a*

Figures A46 – A50 in Appendix A show the time series of maximum Chla concentrations in the surface layer at the sampling locations in Prettyboy and Loch Raven Reservoirs. The same information is presented in a different format in Tables B3 and B4 in Appendix B, showing maximum Chla concentrations by month and year, 1992-2004. As these tables indicate, Chla concentrations above 10 µg/l (the approximate threshold of eutrophy) occur frequently but not regularly. Concentrations above 30 µg/l are infrequent.

In Loch Raven Reservoir, the largest concentrations tend to occur in early spring or in October. Concentrations are most consistently above 10 µg/l in the summer months, and most consistently below 10 µg/l in the winter months. In Prettyboy Reservoir, in contrast, surface Chla concentrations are most consistently above 10 µg/l in late winter and early spring. Concentrations above 30 µg/l are most frequently found in March or secondarily in September and October. Surface Chla concentrations tend to be below 10 µg/l from May through July, as well as in November and December.

2.2.8 Sedimentation

The Maryland Geological Survey (MGS) performed a new bathymetry survey of Loch Raven Reservoir in 1998 (Ortt *et al.*, 2000). In conjunction with the survey, MGS also estimated sedimentation rates. Average annual sedimentation rates can be described in many ways: percent loss of capacity, inches of sediment accumulation per year, or tons/mi^2/yr. The latter measure was estimated by the Reservoir Technical Group (RTG) (2004), based on the new survey. Table 6 summarizes the average sediment accumulation rate for Loch Raven Reservoir.

The annual percent capacity loss (volumetric reduction) rate in Loch Raven Reservoir, 0.13%, compares favorably with the national averages. The mean average capacity loss rate for comparably sized reservoirs is 0.43%; the median is 0.27% *(*Ortt *et al., 2000)*. However, sediment accumulation varies spatially within the reservoir. MGS estimated that the Dulaney Branch of Loch Raven has lost 8% of its capacity, the Long Quarter Branch 13% of its capacity, and the upper reservoir 19% of its capacity. Sediment deposits in the former stream channel were greater than 10 feet thick and ran as high as 59 feet thick. The survey was not able to proceed above Warren and Merryman's Mill Road bridge because the reservoir became unnavigable.

Table 6: Sedimentation Rates in Loch Raven Reservoir

Sedimentation Rates	Loch Raven (built 1923)
Total Capacity Lost Since Construction	10.8%
Annual Average Capacity Lost	0.13%
Sediment Accumulation Rate (in/yr)	0.6
Sediment Deposition Rate (tons/mi^2/year)	0.49

2.3 Water Quality Impairments

The Maryland Water Quality Standards Stream Segment Designations for Prettyboy and Loch Raven Reservoirs are Use III-P: Nontidal Cold Water and Public Water Supply (COMAR 26.08.02.08J(4)). Designated Uses present in the Prettyboy and Loch Raven Reservoirs are: 1) growth and propagation of trout; and 2) public water supply.

Maryland's General Water Quality Criteria prohibit pollution of waters of the State by any material in amounts sufficient to create a nuisance or interfere directly or indirectly with designated uses (COMAR 26.08.02.03B(2)). Excessive eutrophication, indicated by elevated levels of Chla, can produce nuisance levels of algae and interfere with designated uses such as fishing and swimming. The excess algal blooms eventually die off and decompose, consuming oxygen. Excessive eutrophication in Prettyboy and Loch Raven Reservoirs is ultimately caused by nutrient overenrichment. An analysis of the available water quality data presented in Section 2.2 has demonstrated that phosphorus is the limiting nutrient. In conjunction with excessive nutrients, Loch Raven Reservoir has experienced excessive sediment loads, resulting in a shortened projected lifespan of the reservoir.

Use III waters are subject to DO criteria of not less than 6.0 mg/l daily average and 5.0 mg/l at any time (COMAR 26.08.02.03-3E(2)) unless natural conditions result in lower levels of DO (COMAR 26.08.02.03A(2)). New standards for tidal waters of the Chesapeake Bay and its tributaries take into account stratification and its impact on deeper waters. MDE recognizes that stratified reservoirs and impoundments (there are no natural lakes in Maryland) present circumstances similar to stratified tidal waters, and is applying an interim interpretation of the existing standard to allow for the impact of stratification on DO concentrations. This interpretation recognizes that, given the morphology of the reservoir or impoundment, the resulting degree of stratification, and the naturally occurring sources of organic material in the watershed, hypoxia in the hypolimnion is a natural consequence. The interim interpretation of the non-tidal DO standard, as applied to reservoirs, is as follows:

- A minimum DO concentration of 5.0 mg/l (and 6.0 mg/ daily average for Use III) will be maintained throughout the water column during periods of complete and stable mixing;
- A minimum DO concentration of 5.0 mg/l (and 6.0 mg/ daily average for Use III) will be maintained in the mixed surface layer at all times, including during stratified conditions, except during periods of overturn or other naturally-occurring disruptions of stratification; and
- Hypolimnetic hypoxia will be addressed on a case-by-case basis, taking into account morphology, degree of stratification, sources of diagenic organic material in reservoir sediments, and other such factors.

The analysis of water quality data in Section 2.2 has shown that all observed DO concentrations below 5.0 mg/l in the surface layers of Prettyboy and Loch Raven Reservoirs are associated with stratification or the mixing of stratified waters into the surface layers during periods of reservoir overturn or drawdown. On the other hand, seasonal hypoxia occurs regularly in both reservoirs in the hypolimnion.

3.0 TARGETED WATER QUALITY GOALS

The overall objective of the TMDLs proposed in this document is to reduce phosphorus and sediment loads to levels that are expected to result in the attainment of the water quality criteria that support the Use III-P designation for Loch Raven and Prettyboy Reservoirs. The Chla endpoints selected for the reservoirs are (1) a maximum permissible instantaneous chlorophyll concentration of 30 µg/l in the surface layers and (2) a 30-day moving average concentration not to exceed 10 µg/l in the surface layers. A concentration of 10 µg/l corresponds to a score of approximately 53 on the Carlson Trophic State Index (TSI). This is the approximate boundary between mesotrophic and eutrophic conditions, which is an appropriate trophic state at which to manage these reservoirs. Mean Chla concentrations exceeding 10 ug/l are associated with peaks exceeding 30 ug/l, which in turn are associated with a shift to blue-green assemblages, which present taste, odor and treatment problems (Walker 1984). These Chla endpoints should thus avoid nuisance algal blooms. Reduction of the phosphorus loads is predicted to reduce excessive algal growth and therefore prevent violations of narrative criteria associated with nuisances, such as taste and odor problems.

In summary, the TMDLs for phosphorus and sediment are intended to:

1. Resolve violations of narrative criteria resulting in excessive algal growth in Prettyboy and Loch Raven Reservoirs;
2. Resolve violations of narrative criteria associated with excess sedimentation of Loch Raven Reservoir; and
3. Assure both Prettyboy and Loch Raven Reservoirs provide dissolved oxygen levels sufficient to support aquatic life.

4.0 TOTAL MAXIMUM DAILY LOADS (TMDLs) AND ALLOCATIONS

4.1 Overview

Section 4.2 describes the modeling framework for simulating hydrodynamics, nutrient and sediment loads, and water quality responses in Prettyboy and Loch Raven Reservoirs. Section 4.3 describes the baseline scenario developed on the basis of modeling results. Section 4.4 explains how the nutrient TMDLs and load allocations for point sources and nonpoint sources were developed for the reservoirs, based on computer modeling of the water quality response to reduced nutrient and sediment loads. Section 4.5 presents the modeling results in the proper format for TMDLs and allocates the TMDLs between point sources and nonpoint sources. Section 4.6 explains the rationale for the margin of safety. Finally, the elements of the equations are combined in a summary of TMDLs for total phosphorus for both Prettyboy and Loch Raven Reservoirs, as well as a TMDL for sediments for Loch Raven Reservoir.

4.2 Computer Modeling Framework

To develop a TMDL, a linkage must be defined between the selected targets or goals and the identified sources. This linkage establishes the cause-and-effect relationship between the pollutant of concern and the pollutant sources. The relationship can vary seasonally, particularly for nonpoint sources, with factors such as precipitation. Once defined, the linkage yields the estimate of total loading capacity or TMDL (U.S. EPA, 1999).

CE-QUAL-W2 is a laterally averaged two-dimensional computer simulation model, capable in its most recent formulations of representing the hydrodynamics and water quality of rivers, lakes, and estuaries. It is particularly well-suited for representing temperature stratification that occurs in reservoirs like Prettyboy and Loch Raven. The W2 reservoir models were used to simulate not only hydrodynamics and temperature but dissolved oxygen and eutrophication dynamics as well. The reservoir models use version

3.2 of CE-QUAL-W2. Cole and Wells (2003) give a general description of the CE-QUAL-W2 model.

Prettyboy Reservoir was represented by eighteen active longitudinal segments in two branches. Each segment contains from four to thirty one-meter thick layers. Loch Raven Reservoir is represented by a single branch of sixteen segments, each with four to sixteen one-meter thick layers. The simulation period was set to 1992-1997 to coincide with the Gunpowder HSPF Model. These six years provide a range of hydrological conditions, including wet years (1993, 1996), dry years (1992, 1997), and average years (1994, 1995), thus fulfilling the requirement that TMDLs take into account a variety of hydrological conditions. Each year was simulated separately, and observed data, where available, were used to set the initial conditions for the simulation.

State variables in the CE-QUAL-W2 model include dissolved oxygen, ammonia, nitrate, dissolved inorganic phosphorus, and both dissolved and particulate organic matter (POM) in labile and refractory forms. In addition, any number of inorganic solids, carbonaceous biochemical oxygen demand (CBOD) variables or algal species can be represented in the model. Organic nitrogen and phosphorus, however, are only implicitly represented through CBOD, organic matter, and algal biomass state variables. In order to preserve a mass balance of all species of phosphorus, the state variables in the W2 models were configured as follows:

1. Inorganic phosphorus attached to silt and clay was modeled as distinct inorganic solids. Sorption between sediment and the water column was not simulated in the model.
2. Three biochemical oxygen demand (BOD) variables were used to represent allochthonous organic matter inputs to the reservoirs: (1) labile dissolved BOD, labile particulate CBOD, and refractory particulate CBOD. The concentration of these CBOD inputs were calculated based on the concentration of organic phosphorus determined by the HSPF model, using the stoichiometric ratio between phosphorus and oxygen demand in the reservoir models.
3. The organic matter state variables were reserved to represent the recycling of nutrients within the reservoir between algal biomass and reservoir nutrient pools. No organic matter, as represented by these variables, was input into the reservoirs. They were used to track nutrients released from algal decomposition.

To use the W2 model in this configuration, several minor changes had to be made to the W2 code. Inorganic solids contribute to light extinction, but inorganic solids representing solid-phase phosphorus do not contribute to light extinction over and above the sediment to which they are attached. The W2 code was altered so solid-phase phosphorus would not contribute to light extinction. Second, in the W2 model, sediment oxygen demand (SOD) can be represented as a first-order reaction based on the quantity of labile organic matter that has settled to the bottom of a segment. In the original code the CBOD variables do not settle and do not contribute to the pool of organic material in the sediments. The code was altered so that (1) CBOD species could be assigned a settling velocity and (2) labile particulate CBOD contributed to sediment organic matter. Each year's simulation was initialized with the final concentrations of sediment organic matter from the previous year's simulation, because no observations of sediment organic matter were available.

4.3 Scenario Descriptions and Results

4.3.1 Scenario Descriptions

TMDL development for the Gunpowder reservoirs involved the following four scenarios:

1. **Calibration Scenario**: The Calibration Scenario represents actual loads over the simulation period 1992-1997. As the name suggests, the loads in this scenario were used to calibrate the CE-QUAL-W2 models of Prettyboy and Loch Raven Reservoirs. Loads from wastewater treatment plants and other point source dischargers are based on reported flows and concentrations for the period. Loads from developed land falling under the National Pollutant Discharge Elimination System (NPDES) permit for stormwater discharge, as well as nonpoint source loads from forests and agricultural land, were determined through the calibration of the Gunpowder Falls HSPF Model.

2. **Baseline Scenario**: The Baseline Scenario differs from the Calibration Scenario only in that design flows and concentrations at the permitted limits are used to determine loads from wastewater treatment plants and other point source dischargers. Loads from developed land under Municipal Separate Storm Sewer System (MS4) permits and nonpoint source loads are the same as in the Calibration Scenario.

3. **TMDL Scenario**: The TMDL Scenario represents the maximum allowable loads from developed land falling under NPDES stormwater permits and the maximum allowable loads from nonpoint sources such that computer simulation predicts water quality standards will be met in Prettyboy and Loch Raven Reservoirs. Loads from permitted dischargers are calculated based on the design flow of the permit and the maximum permitted concentration.

4. **All-Forest Scenario**: The All-Forest Scenario simulates the response of the reservoirs to the phosphorus, sediment, nitrogen, and BOD loading rates that would occur if all of the land in the reservoirs' watersheds were forested. The All-Forest Scenario is used to determine to what extent hypoxic conditions in the hypolimnion are a function of external loading rates or reservoir morphology. The All-Forest Scenario constitutes an estimate of hypolimnetic DO concentrations under natural conditions. Flows and temperature were taken from the Calibration Scenario, while constituent loads were taken from the HSPF model simulation whereby all land in the watershed was forested.

4.3.2 Calibration Scenario Results

The primary function of the CE-QUAL-W2 models of Prettyboy and Loch Raven Reservoirs is to link algae biomass concentrations, as represented by Chla concentrations, to total phosphorus loads. The models were calibrated conservatively, to ensure that simulated Chla concentrations were at least as high as observed concentrations, even if maximum seasonal concentrations were shifted upstream or downstream in simulation, or occurred a month earlier or later than the corresponding observed concentrations.

Figures B1 and B2 in Appendix B compare simulated and observed maximum Chla concentrations in the surface layers of Prettyboy and Loch Raven Reservoirs, respectively, by sampling date. The models capture the observed peak seasonal average Chla concentrations, though sometimes shifted spatially or temporally. Similarly, Figures B3 and B4 show the cumulative distribution of simulated and observed maximum Chla concentrations. In both reservoirs, simulated concentrations are higher than observed concentrations above the 10 µg/l level, demonstrating further the conservative character of the calibration.

Figures B5 and B6 in Appendix B compare simulated and observed average surface DO concentrations at the lower sampling locations in Prettyboy and Loch Raven Reservoir, respectively. The models follow the seasonal trend in DO but tend to over-simulate DO in winter and under-simulate DO in summer. Figures B7 and B8 show the simulated and observed average bottom DO concentrations. The models capture the seasonal trend in bottom DO. The coefficients of determination between observed and simulated values are 0.80 and 0.81 for Prettyboy and Loch Raven Reservoirs, respectively.

Appendix C contains time series plots comparing simulated and observed concentrations at other locations. It also shows time series plots for total phosphorus, nitrate, and ammonia.

4.3.3 Baseline Scenario Results

Wastewater treatment plants and other permitted point sources (excluding MS4 discharges) contribute less than 1% of the total phosphorus load to Prettyboy and Loch Raven Reservoirs, and an insignificant amount to the sediment load to Loch Raven Reservoir. The results of the Baseline Scenario are indistinguishable from the Calibration Scenario. Baseline loads are broken out by land use and jurisdiction in Appendix D.

4.3.4 TMDL Scenario Results

The CE-QUAL-W2 models of Prettyboy and Loch Raven Reservoirs were used to determine the maximum total phosphorus loads compatible with water quality standards. Simulated loads were reduced until two conditions were met: (1) no simulated Chla concentration in any cell was above 30 µg/l, and (2) the 30-day moving average Chla concentration of each modeling cell within 15 meters of the surface was not greater than 10 µg/l. Figures B9 and B10 in Appendix B compare maximum Chla concentrations by date under the Calibration and TMDL Scenarios to observed concentrations in the surface layer of Prettyboy and Loch Raven Reservoirs, respectively.

The TMDL Scenario was also analyzed to determine whether the reservoirs would meet the DO criteria for Use III-P waters under TMDL loading rates. Figures B11 and B12 show the average surface DO concentrations at the lower sampling locations in Prettyboy and Loch Raven Reservoirs, based on a screening depth of 20 feet. To more accurately screen for potential violations, the position of the well-mixed surface layer was more precisely determined on a daily basis. Instantaneous DO concentrations were output from all cells in the surface layer at 0.1-day intervals; the daily average DO concentration was also calculated for each cell in the surface layer. Under the TMDL scenario, there is no cell in the surface layer of either reservoir with an instantaneous DO concentration less than 5.0 mg/l, or a daily average DO concentration of less than 6.0 mg/l, except during periods such as the fall overturn when the surface layer deepens and entrains water with low DO concentrations from the metalimnion.

Seasonal hypoxia persists in the hypolimnion in both reservoirs even under the TMDL Scenario. Figures B13 and B14 in Appendix B show the average bottom DO concentrations at the lower sampling locations in Prettyboy and Loch Raven Reservoirs. As the figures indicate, although the average DO in the bottom layers improves under the TMDL Scenario, neither reservoir maintains a DO concentration of 5.0 mg/l in the hypolimnion throughout the simulation period.

4.3.5 All-Forest Scenario Results

As explained earlier, the purpose of the All-Forest Scenario is to help determine whether hypoxia in the bottom layers of Prettyboy and Loch Raven Reservoirs is primarily due to the stratification induced by reservoir morphology, or to input loads. If hypoxia occurs even under all-forested loading rates, then reservoir stratification is the primary cause of hypoxia and it can be concluded that the reservoir meets the water quality standards for DO as described in Section 2.3.

Average annual TP loads in the All-Forest Scenario are 20% of the load in the Calibration Scenario in Prettyboy Reservoir, and 28% of the load in the Calibration Scenario in Loch Raven Reservoir. The reduction in average annual loads of POM, the precursor to sediment oxygen demand, is not as large. Average annual POM loads in the All-Forest Scenario are 29% of the load in Calibration Scenario in Prettyboy and 41% of the load in Calibration Scenario in Loch Raven. The load decrease is less in the Loch Raven watershed because of the high percentage of forested and developed land.

Figures 13 and 14 below show the average bottom DO concentrations at lower sampling locations in the reservoirs under the All-Forest Scenario. Minimum concentrations at the sampling locations are also shown.

Average DO in the bottom layers of both reservoirs improves considerably under the All-Forest Scenario. The minimum DO concentration, however, frequently drops below 5.0 mg/l. Even under the All-Forest Scenario, the hypolimnion remains hypoxic in many (but not all) years of the simulation. The hypoxia tends to be worse in the lower stations of the reservoirs where the depths are greatest.

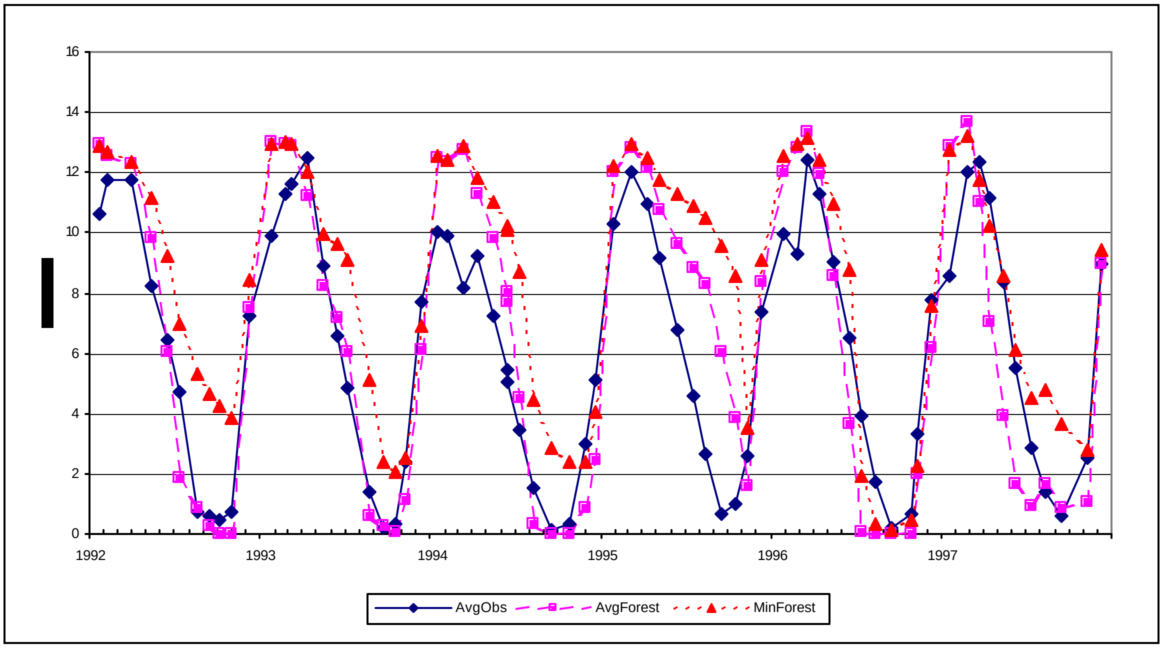

Figure 13: Observed and Simulated Average Bottom DO Concentrations, Lower Stations, All-Forest Scenario, Prettyboy Reservoir

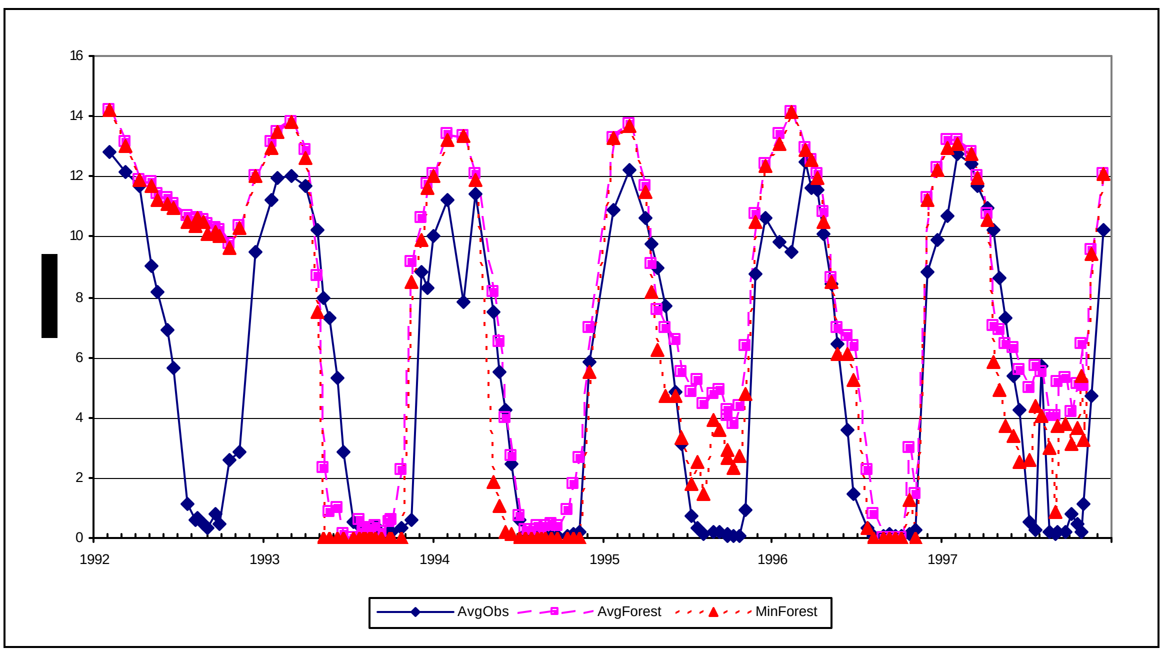

Figure 14: Observed and Simulated Average Bottom DO Concentrations, Lower Stations, All-Forest Scenario, Loch Raven Reservoir

A sensitivity analysis was performed to better determine how phosphorus and organic matter loading rates impact hypoxia in the hypolimnion. POM and TP loading rates were reduced to 50%, 20% and 10% of the loads of the All-Forest Scenario, and the percent of sampling dates where DO < 2.0 mg/l at the sampling locations was calculated. Figure 15 shows the results. Significant hypoxia persists even when loads are reduced to only 10% of the All-Forest Scenario, particularly in Prettyboy Reservoir, which is deeper than Loch Raven even though it has less volume. The sensitivity analysis shows that low DO in the bottom layers of the reservoirs is relatively insensitive to the particular assumptions used to determine organic matter loads in the models, and demonstrates that hypolimnetic hypoxia is primarily driven by stratification and reservoir morphology, rather than by external loads. The All-Forest Scenario demonstrates that current loads, and loads simulated under the TMDL Scenario, do not result in hypoxia that significantly exceeds that associated with natural conditions in the watershed. Low DO concentrations in the bottom layers of the reservoirs are therefore a naturally occurring condition, as described by the interim interpretation of Maryland's water quality standards. The TMDL Scenario thus meets water quality standards for DO under the interim interpretation.

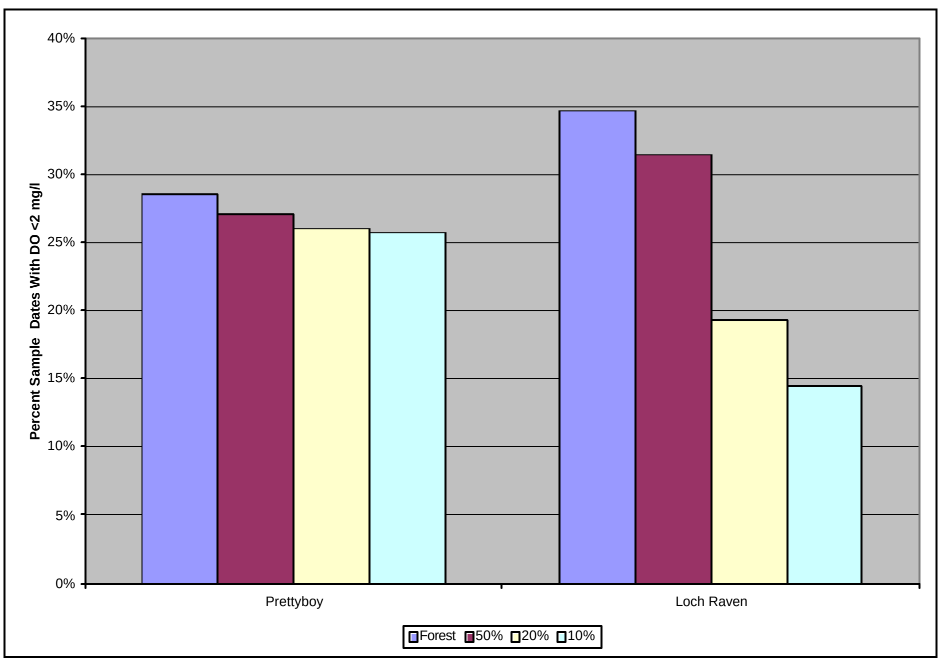

Figure 15: Percent of Sampling Dates on which DO < 2.0 mg/l as a function of proportion of All-Forest Scenario

4.4 TMDL Loading Caps

4.4.1 Phosphorus TMDL Loading Caps for Prettyboy and Loch Raven Reservoirs

This section presents the TMDLs for phosphorus for Prettyboy and Loch Raven Reservoirs. The TMDLs were estimated based on the phosphorus loadings as explained in Section 4.3 and the resulting water quality in the reservoirs for the simulated years 1992-1997. This period was selected to estimate the TMDLs because it covers a period that includes dry years as well as very wet years and thus takes into account a variety of hydrological conditions. Chla concentrations indicative of eutrophic conditions can occur at any time of year, and the simulation period encompasses the spectrum of observed seasonal concentrations (see Tables B3 and B4, Appendix B). Seasonal low DO concentrations in the hypolimnia that occur regularly each year are also represented in the simulation models.

TMDL loads were calculated on an average annual basis. The average residence time of Loch Raven Reservoir is approximately three to four months while the residence time of Prettyboy is approximately one year. Water quality conditions in both reservoirs are the cumulative result of loadings that span seasons, or even, in the case of hypolimnetic hypoxia, years. Average annual TP loads are therefore the appropriate measure in which to express nutrient TMDLs for Prettyboy and Loch Raven Reservoirs.

For Prettyboy Reservoir:

Total Phosphorus TMDL 23,192 lbs/year

For Loch Raven Reservoir:

Total Phosphorus TMDL 54,941 lbs/year

The TMDLs reflect a reduction of 54% from baseline TP loads in Prettyboy Reservoir and 50% from baseline loads in Loch Raven Reservoir. Load reductions are broken out by land use and jurisdiction in Appendix D.

Average Daily Loads:

In Prettyboy Reservoir, the average annual TMDL for TP will result in average daily TP loads of approximately 63.54 lbs/day. In Loch Raven Reservoir, the average annual TMDL for TP will result in average daily TP loads of approximately 150.95 lbs/day.

4.4.2 Sediment TMDL Loading Caps for Loch Raven Reservoir

Excessive sedimentation reduces a reservoir's storage capacity and therefore negatively impacts its ability to function as a water supply reservoir. Excessive sedimentation can also negatively impact a reservoir's fishery and interfere with its recreational uses. Although the maximum sedimentation rates occur during wet weather events, it is the cumulative effect of sedimentation that impacts the reservoir. No single critical period can be defined for the water quality impact of sedimentation. An excessive sedimentation rate negatively impacts a reservoir regardless of when it occurs. Therefore, the efforts to reduce sediment loading to the lake should focus on achieving effective, long-term sediment control. Since some measures to control phosphorus from agriculture sources can also effectively reduce sedimentation, the expected sediment reduction can be estimated based on the degree of phosphorus control needed to improve the water quality of the reservoir.

To quantify the sediment reduction associated with this phosphorus reduction, the EPA Chesapeake Bay Program watershed modeling assumptions were consulted. For the agricultural best management practices (BMPs) that affect both phosphorus and sediments, EPA estimates a 1-to-1 reduction in sediments as a result of controlling phosphorus (EPA, Chesapeake Bay Program Office, 1998). However, this ratio does not account for phosphorus controls that do not remove sediments.

To estimate the applicable ratio, hence the sediment load reduction, it is necessary to estimate the proportion of the phosphorus reduction controls that remove sediments versus those that do not. In general, soil conservation and water quality plans (SCWQPs) remove sediments along with the phosphorus removal, while nutrient management plans (NMPs) do not. It has been assumed that 50% of the phosphorus reduction will come from SCWQPs and 50% from NMPs. This results in a 0.5-to-1 ratio of sediment reduction to phosphorus reduction. The net sediment reduction associated with a 50% NPS phosphorus reduction is about 25% (0.50 * 0.5 = 0.25).

It is assumed that this reduced sediment loading rate would result in a similar reduction in the sediment accumulation rate. The sediment accumulation rate predicted to result from this reduced loading rate would allow for the retention of 85% of the overall impoundment's original volume after 50 years. More important, it will reduce loss of volume in the upper reservoir, which otherwise would have less than 70% of its original capacity after 50 years. Under the TMDL loading cap, the upper reservoir may retain as much as 80% of its original capacity if the reduction in loading rates reduces volumetric loss at a rate proportionate to current capacity loss.

MDE believes that this volumetric retention will support the designated uses of Loch Raven Reservoir (Use III-P) for which it is protected: naturally-breeding trout and public water supply. This estimate is reasonably consistent with technical guidance provided by EPA Region III of a 0.7-to-1.0 reduction in sediment in relation to the reduction in phosphorus. (EPA, 1998) This rule-of-thumb would yield a 35% estimated reduction in sediment [100*(0.7 * 0.50) = 35%]

Assuming that a 50% reduction in total phosphorus load results in a 25% reduction in sediment load, the sediment loading cap for Loch Raven Reservoir is as follows:

For Loch Raven Reservoir:

Sediment TMDL 28,925 tons/year

Average Daily Loads:

In Loch Raven Reservoir, the average annual TMDL for sediment will result in average daily sediment loads of approximately 79.25 tons/day.

4.5 Total Load Allocations Between Point Sources and Nonpoint Sources

The allocations described in this section demonstrate how the TMDLs can be implemented to achieve water quality standards in Prettyboy and Loch Raven Reservoirs. Specifically, these allocations show that the sum of phosphorus loadings to the reservoirs from existing point and nonpoint sources can be maintained safely within the TMDLs established herein. The State reserves the right to revise these allocations provided such revisions are consistent with the achievement of water quality standards.

Phosphorus TMDL Allocations

- Nonpoint Source (NPS) Loads

  Nonpoint source loads including agricultural and forest loads are assigned to the TMDL as the Load Allocation (LA). The Calibration and Baseline Scenario loads were based on the HSPF model of the Gunpowder Falls Watershed. The modeling of the watershed accounted for both natural and human-induced components, including atmospheric deposition and septic loadings. Details on the HSPF model can be found in *Modeling Framework for Simulating Hydrodynamics and Water Quality in Prettyboy and Loch Raven Reservoirs* (ICPRB and MDE, 2006).

- Stormwater Loads

  In November 2002, EPA advised states that NPDES-regulated storm water discharges must be addressed by the wasteload allocation (WLA) component of a TMDL. See 40 C.F.R. § 130.2(h). NPDES-regulated storm water discharges may not be addressed by the load allocation (LA) component of a TMDL. EPA also provided guidance on ways to reflect the TMDL stormwater wasteload allocation (WLA). The stormwater phosphorus loads simulated in the TMDL scenario represent a 15% reduction in TP from baseline urban stormwater loads. Urban stormwater loads are now part of the WLA.

Current stormwater Phase I individual permits and new stormwater Phase II permits are considered point sources subject to WLA assignment in the TMDL, instead of LA assignment as in the past. EPA recognizes that limitations in the available data and information usually preclude stormwater allocations to specific outfalls. Therefore, EPA's guidance allows this stormwater WLA to be expressed as a gross allotment, rather than individual allocations for separate pipes, ditches, construction sites, etc. Available information for the Gunpowder Falls watershed allows the stormwater WLA for this analysis to be defined separately for Carroll, Baltimore and Harford Counties; however, these WLAs aggregate municipal and industrial stormwater, including the loads from construction activity.

Waste load allocations from point source dischargers are usually based on the relative contribution of pollutant load to the waterbody. Estimating a load contribution to a particular waterbody from the stormwater Phase I and II sources is imprecise, given the variability in sources, runoff volumes, and pollutant loads over time. Therefore, any stormwater WLA portion of the TMDL is based on a rough estimate.

- Wastewater Treatment Plant Loads

  In addition to nonpoint source loads and stormwater point sources, waste load allocations to the Hampstead and Manchester WWTP plus a 5% MOS, estimated as explained in the next section, make up the balance of the total allowable load. The Hampstead WWTP maximum allowable design flow of 0.9 MGD is used for this scenario. The total phosphorus limit at Hampstead is 0.3 mg/l year round. The Manchester WWTP maximum allowable current permit flow of 0.5 MGD is used for this scenario; discharges to surface water occur only from December through March. The total phosphorus limit at Manchester is 1.0 mg/l *when discharges occur*. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled "*Significant Nutrient and Sediment Point Sources in the Prettyboy and Loch Raven Reservoir Watersheds.*"

The TMDL, including loads from stormwater discharges, is now expressed as:

TMDL = WLA [non-stormwater point sources + regulated stormwater point source] + LA + MOS

The phosphorus allocations for Prettyboy and Loch Raven Reservoirs are presented in Table 7.

Table 7: Total Phosphorus Allocations (lbs/yr) for Prettyboy and Loch Raven Reservoirs

	Prettyboy Reservoir	Loch Raven Reservoir
Nonpoint Source[1]	19,092	30,184
Point Source[2]	2,940	22,010
Margin of Safety[3]	1,160	2,747
Total Maximum Daily Load	23,192	54,941

[1] Excludng urban stormwater loads.
[2]Including urban stormwater loads.
[3]Representing 5% of baseline nonpoint source and urban stormwater loads.

4.5.1 Sediment Load Allocations for Loch Raven Reservoir

- Nonpoint Source (NPS) Loads

  Nonpoint source loads including agricultural and forest loads are assigned to the TMDL as LA. The Calibration and Baseline Scenario loads were based on the HSPF model of the Gunpowder Falls Watershed. The modeling of the watershed accounted for both natural and human-induced components. The LA to nonpoint sources below the Prettyboy Dam represents a decrease of approximately 25% from baseline loads. Sediment loads from Prettyboy Reservoir are less than 2% of total sediment load. Details on the HSPF model can be found in *Modeling Framework for Simulating Hydrodynamics and Water Quality in Prettyboy and Loch Raven Reservoirs* (ICPRB and MDE, 2006).

- Stormwater Loads

  The reduction in total phosphorus loads from stormwater discharges will result in a reduction in sediment loads, but because of the uncertainty in BMP efficiencies for developed land, no reduction is assumed for sediment loads from stormwater discharges, and their share of the WLA is set equal to baseline conditions.

- Wastewater Treatment Plant Loads

  The waste load allocation to the Hampstead WWTP makes up the balance of the total allowable load. The Hampstead WWTP maximum allowable current permit flow of 0.9 MGD is used for this scenario. The total suspended solids limit is 30.0 mg/l year round. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Nutrient and Sediment Point Sources in the Prettyboy and Loch Raven Reservoir Watersheds."*

- Permitted Industrial Facilities

  There are three industrial facilities with permits regulating the discharge of total suspended solids in the Loch Raven Reservoir watershed. Only one of them, the Lafarge Mid-Atlantic and Imerys facility, has even the potential to discharge significant sediment loads. The waste load allocation for the quarry was set as the product of maximum recorded average discharge at each of the two permitted outfalls and a suspended solids limit of 15 mg/l and 17 mg/l for the respective outfalls. The waste load allocation for the two other industrial facilities was also set as a product of the maximum recorded average flow and the permitted suspended solids concentration. All significant industrial point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Nutrient and Sediment Point Sources in the Prettyboy and Loch Raven Reservoir Watersheds."* Load reductions are broken out by land use and jurisdiction in Appendix D.

The TMDL for Suspended Sediment in Loch Raven Reservoir is as follows:

TMDL (tons/yr)	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
28,925	**=**	**27,715**		**1,210**		**implicit**

4.6 Margins of Safety

A MOS is required as part of a TMDL in recognition of many uncertainties in the understanding and simulation of water quality in natural systems. For example, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural waterbodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection.

Based on EPA guidance, the MOS can be achieved through two approaches (EPA, April 1991). One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (*i.e.*, TMDL = Load Allocation (LA) + Waste Load Allocation (WLA) + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis. Maryland has adopted a MOS for nutrient TMDLs using the first approach. The reserved load allocated to the MOS was computed as 5% of the total loads for phosphorus. These explicit phosphorus margins of safety are **1,160 lbs/yr** for Prettyboy Reservoir, and **2,747 lbs/yr** for Loch Raven Reservoir.

In establishing a MOS for sediments, Maryland has adopted an implicit approach by incorporating conservative assumptions. First, because phosphorus binds to sediments, sediments will be controlled as a result of controlling phosphorus. This estimate of sediment reduction is based on the load allocation of phosphorus (4,150 lbs/yr), rather than the entire phosphorus TMDL including the MOS. Thus, the explicit 5% MOS for phosphorus will result in an implicit MOS for sediments. This conservative assumption results in a difference of about 5,099 tons/yr (see Section 4.5 above for a discussion of the relationship between reductions in phosphorus and sediments). Secondly, as described in Section 4.4.2, MDE conservatively assumes a sediment-to-phosphorus reduction ratio of 0.5:1, rather than 0.7:1 sediment-to-phosphorus reduction ratio given in the technical guidance provided by EPA Region III. Table 8 compares the volumetric preservation under TMDL conditions in Loch Raven Reservoir with that of several other approved TMDLs.

Table 8: Volumetric Preservation of Various Impoundments Under Sediment TMDL Conditions

TMDL	VOLUMETRIC PRESERVATION (TMDL time-span)	VOLUMETRIC PRESERVATION (100 year time span)
Urieville Community Lake (MD)	76% after 40 years	40%
Tony Tank Lake (MD)	64% – 85% after 40 years	10% to 62.5%
Hurricane Lake (WV)	70% after 40 yrs	25%
Tomlinson Run Lake (WV)	30% after 40 yrs	Silted in
Clopper Lake (MD)	98% - 99% after 40 years	96% to 98%
Centennial Lake (MD)	68% - 87% after 40 years	20% to 69%
Lake Linganore (MD)	52% - 80% after 40 years	Silted in to 52%
Loch Raven Reservoir (MD)	85% after 50 years	80%

4.7 Summary of Total Maximum Daily Loads

The following equations summarize the nutrient TMDLs for Prettyboy and Loch Raven Reservoirs, and the sediment TMDL for Loch Raven Reservoir:

For Total Phosphorus in Prettyboy Reservoir:

TMDL (lbs/yr)	**=**	**LA +**	**WLA +**	**MOS**
23,192	**=**	**19,092**	**2,940**	**1,160**

For Total Phosphorus in Loch Raven Reservoir:

TMDL (lbs/yr)	**=**	**LA +**	**WLA +**	**MOS**
54,941	**=**	**30,184**	**22,010**	**2,747**

For Suspended Sediment in Loch Raven Reservoir:

TMDL (tons/yr)	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
28,925	**=**	**27,715**		**1,210**		**implicit**

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the phosphorus and sediment TMDLs will be achieved and maintained. For both TMDLs, Maryland has numerous well-established programs that may be drawn upon: the Water Quality Improvement Act of 1998 (WQIA); the Clean Water Action Plan (CWAP) framework; the Maryland Agricultural Water Quality Cost-Share (MACS) Program; the Low Interest Loans for Agricultural Conservation (LILAC) Program; the Maryland Agricultural Land Preservation Easement (MALPE) Program, and the Chesapeake Bay Agreement's Tributary Strategies for Nutrient Reduction. Also, Maryland has adopted procedures to assure that future evaluations are conducted for all TMDLs that are established. Additionally, the federal Safe Drinking Water Act requires states to develop and implement source water assessment programs (SWAPs) to study the safety and evaluate the vulnerability of drinking water sources to contamination.

The Hampstead WWTP will continue to meet the requirements of its NPDES discharge permit, which since 1997 requires an effluent phosphorus concentration below 0.3 mg/l and a total suspended solids concentration less than 30 mg/l. The Manchester WWTP will continue to meet the requirements of its NPDES discharge permit, which requires it to use spray irrigation to dispose of its wastewater discharge April through November, and to meet an effluent concentration limit of 1.0 mg/l TP and 30 mg/l TSS when discharging to surface water December through March.

Maryland's WQIA requires that comprehensive and enforceable nutrient management plans be developed, approved and implemented for all agricultural lands throughout Maryland. This act specifically requires that nutrient management plans for nitrogen be developed and implemented by 2002, and plans for phosphorus be completed by 2005. Maryland's CWAP has been developed in a coordinated manner with the State's 303(d) process. All Category I watersheds identified in Maryland's Unified Watershed Assessment process are totally coincident with the impaired waters list for 2002 approved by EPA. The State is giving a high priority for funding assessment and restoration activities to these watersheds.

In 1983, the States of Maryland, Pennsylvania, and Virginia, the District of Columbia, the Chesapeake Bay Commission, and the U.S. EPA joined in a partnership to restore the Chesapeake Bay. In 1987, through the Chesapeake Bay Agreement, Maryland made a commitment to reduce nutrient loads to the Chesapeake Bay. In 1992, the Chesapeake Bay Agreement was amended to include the development and implementation of plans to achieve these nutrient reduction goals. Maryland's resultant Tributary Strategies for Nutrient Reduction provide a framework supporting the implementation of nonpoint source controls in the Upper Western Shore Tributary Strategy Basin, which includes the Gunpowder Falls watershed. Maryland is in the forefront of implementing quantifiable nonpoint source controls through the Tributary Strategy efforts. This will help to ensure that nutrient control activities are targeted to areas in which nutrient TMDLs have been established.

In November 1990, EPA required jurisdictions with a population greater than 100,000 to apply for NPDES permits for stormwater discharges. In 1983, the EPA Nationwide Urban Runoff Program found that stormwater runoff from urban areas contains the same general types of pollutants found in wastewater, and that 30% of identified cases of water quality impairment were attributable to stormwater discharges. The two Maryland jurisdictions where the majority of the Loch Raven and Prettyboy watersheds are located, Carroll County and Baltimore County, are required to participate in the stormwater NPDES program, and have to comply with the NPDES permit regulations for stormwater discharges. Several management programs have been implemented in different areas served by the counties. These jurisdiction-wide programs are designed to control stormwater discharges to the maximum extent practicable.

Since 1979, Baltimore City, Baltimore County and Carroll County have had in place a formal agreement to manage the reservoir watersheds and, since 1984, these agreements have been accompanied by an action strategy with specific commitments from the signatories. A revised Reservoir Watershed Management Agreement was signed in 2005, accompanied by a revised Action Strategy. Table 9 lists the parties to the 2005 agreement and some of their major commitments made in the Action Strategy.

In June 2005, the Baltimore County Department of Environmental Protection and Resource Management, in cooperation with MDE and other stakeholders in the region, began to develop a Watershed Restoration Action Strategy (WRAS) document for Prettyboy Reservoir. The purpose of the document is to present a strategy to reduce NPS pollution that contribute to impairments in the watershed, while at the same time conserving the unique, high quality natural resources. The strategy is developed through the combined efforts of the general public, watershed stakeholders, local and county governments, non-profit organizations, and state and federal agencies. The document outlines the conditions in the watershed, the potential sources of pollution and impairments, and actions that can be taken to address these issues. It is anticipated that this strategy, scheduled for completion in late 2006, will assure TMDL implementation for nonpoint sources.

Additionally, Maryland uses a five-year watershed cycling strategy to manage its waters. Pursuant to this strategy, the State is divided into five regions and management activities will cycle through those regions over a five-year period. The cycle begins with intensive monitoring, followed by computer modeling, TMDL development, implementation activities, and follow-up evaluation. The choice of a five-year cycle is motivated by the five-year federal NPDES permit cycle. This continuing cycle ensures that every five years intensive follow-up monitoring will be performed. Thus, the watershed cycling strategy establishes a TMDL evaluation process that assures accountability.

Finally, it is noted that the baseline calibration scenarios inherently include the effects of some BMPs as of the time period affixed in the scenarios (*i.e.*, 1992 – 1997). Additional land use changes and BMP implementation efforts, potentially resulting in water quality changes of as-of-yet unknown type and magnitude, have occurred since then. It is likely that initial phases of the implementation process may include an assessment of these practices and their potential benefits (or detriments) to water quality.

Table 9: Signatories to the 2005 Reservoir Management Agreement and Their Major Commitments under the 2005 Action Strategy (RTG, 2005)

Maryland Department of the Environment	1. Use NPDES program to discourage significant phosphorus discharges in reservoir watersheds from package plants and new industrial dischargers.
Maryland Department of Agriculture	1. Enforce the provisions of Maryland Water Quality Improvement Act of 1998. 2. Offer assistance through the Maryland Agriculture Cost-Share Program. 3. Target assistance to farm operations having problems with the potential to cause water pollution.
Baltimore City	1. Continue water quality monitoring of reservoirs.
Baltimore County	1. Continued water quality monitoring of tributaries. 2. Maintain Resource Conservation zoning in the reservoir watersheds and maintain insofar as possible the Urban-Rural Demarcation Line. 3. Conduct programs of street-sweeping, storm drain-inlet cleaning, and storm pipe cleaning in urban areas.
Carroll County	1. Require enhanced stormwater management practices for all new development in reservoir watersheds. 2. Use master land-use plans to support Reservoir Management Agreement. 3. Limit insofar as possible additional urban development zoning with the reservoir watersheds.
Baltimore County Soil Conservation District Carroll County Soil Conservation District	1. Encourage farmers to participate in federal and state assistance programs that promote soil conservation and the protection of water quality. 2. Prepare Soil Conservation and Water Quality Plans for each farm in the reservoir watersheds, update plans where necessary, and assist operators in implementing them. 3. Encourage and assist operators to comply with nutrient management plans mandated under the Maryland Water Quality Improvement Act.
Baltimore Metropolitan Council	1. Provide staff for coordination and administration of the Reservoir Technical Program through the financial support of its member jurisdictions.

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Technical Memorandum

Significant Phosphorus and Sediment Point Sources in the Prettyboy and Loch Raven Reservoir Watersheds

The U.S. Environmental Protection Agency requires that Total Maximum Daily Load (TMDL) allocations account for all significant sources of each impairing pollutant. This technical memorandum identifies, in detail, the significant surface water discharges of phosphorus (TP) in the Prettyboy and Loch Raven Reservoir watersheds and sediment in the Loch Raven Reservoir watershed used in computing the TMDLs. The Maryland Department of the Environment (MDE) expressly reserves the right to allocate the TMDLs among different sources in any manner that is reasonably calculated to achieve water quality standards.

Waste load allocations have been made to NPDES-regulated wastewater treatment plants (WWTP), municipal separate stormwater dischargers (MS4), and other regulated dischargers in the Prettyboy and Loch Raven Reservoir watersheds. The Manchester WWTP is the only wastewater treatment plant contributing phosphorus loads in the Prettyboy Reservoir watershed and Hampstead WWTP is the only wastewater treatment plant contributing phosphorus in the Loch Raven Reservoir watershed. It also contributes sediment to the Loch Raven Reservoir watershed. Two MS4s discharge phosphorus to the Prettyboy Reservoir watershed: Baltimore County and Carroll County. These same two MS4s, as well as Harford County, also discharge phosphorus and sediment to the Loch Raven Reservoir watershed. In addition to the WWTP and MS4s, there are three small permittees which discharge sediment to the Loch Raven Reservoir watershed.

Wasteload allocations to the WWTPs have been made based on permitted flow and concentrations. Baltimore County, Carroll County, and Harford County are all covered under NDPES Phase I stormwater permits. Annual waste load allocations have been made to these stormwater dischargers based on the Gunpowder Falls Watershed HSPF Model. The stormwater phosphorus and sediment loads account for contributions from developed land. The land use information was based on 1997 Maryland Department of Planning data. Wasteload allocations for smaller permittees were based on permitted concentrations and the maximum reported flow 1996-2005.

Table 1A shows the allocation of total phosphorus loads attributed to point sources in the Prettyboy Reservoir watershed. Table 1B shows the allocation of both phosphorus and sediment loads attributed to point sources in the Loch Raven Reservoir watershed.

Table 1A
Total Phosphorus Loads Attributed to Point Sources in the Prettyboy Reservoir Nutrient TMDL

Point Source Name	Permit Number	Nutrient Loads (lbs/year)	Flow (MGD)	Concentration (mg/l)
		TP		TP
Manchester WWTP	MD0022578	506	0.5*	1.0 mg/l
Baltimore County		862		
Carroll County		1,572		
Total		2,940		

* Discharges are only permitted December 1 - March 31.

Table 1B
Total Phosphorus and Sediment Loads Attributed to Point Sources in the Loch Raven Reservoir Nutrient and Sediment TMDLs

Point Source Name	Permit Number			Flow (MGD)	Concentration (mg/l)	
		TP (lbs/year)	Sediment (tons/year)		TP	Sediment
Hampstead	MD0022446	823	41	0.9	0.3	30
Texas Quarry	MD0000175	N/A	59	1.0 (003) 1.4 (008)	N/A	15 (003) 17 (008)
MD National Guard	MD0067687	N/A	0.05	0.0002	N/A	60
Gray and Sons	MD00063568	N/A	0.02	0.001	N/A	30
Baltimore County		20,753	1,023			
Carroll County		401	80			
Harford County		33	6			
Total		22,010	1,210			

Technical Memorandum

Significant Phosphorus and Sediment Nonpoint Sources in the Prettyboy and Loch Raven Reservoir Watersheds

The U.S. Environmental Protection Agency requires that Total Maximum Daily Load (TMDL) allocations account for all significant sources of each impairing pollutant. This technical memorandum identifies, in detail, the significant nonpoint sources of phosphorus (TP) in the Prettyboy and Loch Raven Reservoir watersheds and the significant sources of sediment in the Loch Raven Reservoir watershed. It also identifies the distribution of the significant nonpoint sources among different land uses. Details are provided for allocating nonpoint source (NPS) loads for phosphorus and sediment to different land use categories. These are conceptual values that are within the TMDL thresholds. The Maryland Department of the Environment (MDE) expressly reserves the right to allocate the TMDLs among different sources in any manner that is reasonably calculated to achieve water quality standards.

The NPS loads for phosphorus and sediment were both estimated using the Gunpowder Falls Watershed HSPF model. The NPS loads that were used in the model account for all sources, including both "natural" and human-induced components. As explained in the main document, the simulation of the Gunpowder Falls watershed used the following assumptions: (1) variability in patterns of precipitation were estimated from existing National Oceanic and Atmospheric Administration (NOAA) meteorological stations; (2) hydrologic response of land areas were estimated for a simplified set of land uses in the basin; and (3) agricultural information was estimated from the Maryland Department of Planning (MDP) land use data, the 1997 Agricultural Census Data, and the Farm Service Agency (FSA). The phosphorus loads account for contributions from atmospheric deposition, cropland, pasture, feedlots, and forest. Urban land contributions are included in the point sources technical memorandum. The land use information was based on 1997 Maryland Department of Planning data.

Tables 1A provides one possible scenario for the distribution of average annual total phosphorus NPS loads between different land use categories in the Prettyboy Reservoir watershed. Tables 1B provides one possible scenario for the distribution of average annual total phosphorus NPS loads between different land use categories in the Loch Raven Reservoir watershed. Table 1C provides one possible scenario for the distribution of average annual sediment NPS loads between different land use categories Loch Raven Reservoir watershed.

Table 1A
Nonpoint Source Phosphorus Loads Attributed to Significant Land Uses for the Prettyboy Reservoir Nutrient TMDL

Land Use Category	Percent of Nonpoint Source Load	TP Nonpoint Source Load (lbs/year)
Mixed Agricultural	76%	14,518
Forest and Other Herbaceous	24%	4,574
Total	100%	19,092

Table 1B
Nonpoint Source Phosphorus Loads Attributed to Significant Land Uses for the Loch Raven Reservoir Nutrient TMDL

Land Use Category	Percent of Nonpoint Source Load	TP Nonpoint Source Load (lbs/year)
Mixed Agricultural	44%	13,419
Forest and Other Herbaceous	56%	16,765
Total	100%	30,184

Table 1C
Nonpoint Source Sediment Loads Attributed to Significant Land Uses for the Loch Raven Reservoir Sediment TMDL

Land Use Category	Percent of Nonpoint Source Load	Sediment Nonpoint Source Load (tons/year)
Mixed Agricultural	56%	15,450
Forest and Other Herbaceous	44%	12,266
Total	100%	27,715

Appendix D

Table D.1: Baseline Scenario Loads By County and Source

Total Phosphorus (lbs/yr), Prettyboy Reservoir					
Type	**Baltimore**	**Carroll**	**Harford**	**York**	**Total**
Crop	13,316	13,900	0	1,261	28,477
Developed	1,005	1,738	0	8	2,750
Forest	2,258	1,013	0	116	3,387
Animal Waste	2,108	4,342	0	625	7,075
Mixed Open	9	105	0	0	113
Pasture	2,599	3,377	0	1,060	7,036
Scour	436	691	0	61	1,188
Point Source		506			506
Total	21,731	25,671	0	3,131	50,532
Total Phosphorus (lbs/yr), Loch Raven Reservoir					
Type	**Baltimore**	**Carroll**	**Harford**	**York**	**Total**
Crop	34,755	200	1,214	1,037	37,206
Developed	17,943	171	22	10	18,146
Forest	8,650	4	17	48	8,719
Animal Waste	11,749	23	138	815	12,725
Mixed Open	6,463	301	16	0	6,780
Pasture	10,035	0	91	691	10,818
Scour	2,032	2	11	21	2,067
Point Source		823			823
Prettyboy Reservoir					12,999
Total	91,627	1,524	1,510	2,623	110,282
Sediment (tons/yr), Loch Raven Reservoir					
Type	**Baltimore**	**Carroll**	**Harford**	**York**	**Total**
Crop	21,107	145	567	473	22,292
Developed	1,085	3	1	0	1,090
Forest	3,291	1	6	17	3,315
Manure	0	0	0	0	0
Mixed Open	20	0	0	0	20
Pasture	2,155	0	18	138	2,311
Scour	8,870	10	25	46	8,951
Point Source	59	41			100
Prettyboy Reservoir					587
Total	36,586	201	617	675	38,666

Table D.2: Possible Scenario For Distribution of TMDL Loads By County and Source

Total Phosphorus (lbs/yr), Prettyboy Reservoir					
Type	**Baltimore**	**Carroll**	**Harford**	**York**	**Total**
Crop	3,887	4,057	0	1,261	9,205
Developed	854	1,477	0	8	2,339
Forest	2,258	1,013	0	116	3,387
Animal Waste	615	1,267	0	625	2,508
Mixed Open	7	89	0	0	96
Pasture	758	986	0	1,060	2,804
Scour	436	691	0	61	1,188
Point Source		506			506
Total	8,816	10,086	0	3,131	22,032
Total Phosphorus (lbs/yr), Loch Raven Reservoir					
Type	**Baltimore**	**Carroll**	**Harford**	**York**	**Total**
Crop	6,183	36	216	1,037	7,471
Developed	15,252	145	19	10	15,426
Forest	8,650	4	17	48	8,719
Animal Waste	2,090	4	25	815	2,934
Mixed Open	5,493	256	14	0	5,763
Pasture	1,785	0	16	691	2,493
Scour	2,032	2	11	21	2,067
Point Source		823			823
Prettyboy Reservoir					6,500
Total	41,484	1,270	317	2,623	52,194
Sediment (tons/yr), Loch Raven Reservoir					
Type	**Baltimore**	**Carroll**	**Harford**	**York**	**Total**
Crop	12,666	87	340	473	13,567
Developed	1,085	3	1	0	1,090
Forest	3,291	1	6	17	3,315
Manure	0	0	0	0	0
Mixed Open	20	0	0	0	20
Pasture	1,293	0	11	138	1,442
Scour	8,870	10	25	46	8,951
Point Source	59	41			100
Prettyboy Reservoir					440
Total	27,284	143	383	675	28,925

Table D.3: Percent Reductions Under Possible Scenario For Distribution of TMDL Loads By County and Source

Total Phosphorus (lbs/yr), Prettyboy Reservoir					
Type	**Baltimore**	**Carroll**	**Harford**	**York**	**Total**
Crop	71%	71%	71%	0%	
Developed	15%	15%	15%	0%	
Forest	0%	0%	0%	0%	
Animal Waste	71%	71%	71%	0%	
Mixed Open	15%	15%	15%	0%	
Pasture	71%	71%	71%	0%	
Scour	0%	0%	0%	0%	
Point Source					
Total					
Total Phosphorus (lbs/yr), Loch Raven Reservoir					
Type	**Baltimore**	**Carroll**	**Harford**	**York**	**Total**
Crop	82%	82%	82%	0%	
Developed	15%	15%	15%	0%	
Forest	0%	0%	0%	0%	
Animal Waste	82%	82%	82%	0%	
Mixed Open	15%	15%	15%	0%	
Pasture	82%	82%	82%	0%	
Scour	0%	0%	0%	0%	
Point Source					
Prettyboy Reservoir					50%
Total					
Sediment (tons/yr), Loch Raven Reservoir					
Type	**Baltimore**	**Carroll**	**Harford**	**York**	**Total**
Crop	40%	40%	40%	0%	
Developed	0%	0%	0%	0%	
Forest	0%	0%	0%	0%	
Manure	0%	0%	0%	0%	
Mixed Open	0%	44%	0%	0%	
Pasture	40%	40%	40%	0%	
Scour	0%	0%	0%	0%	
Point Source					
Prettyboy Reservoir					25%
Total					