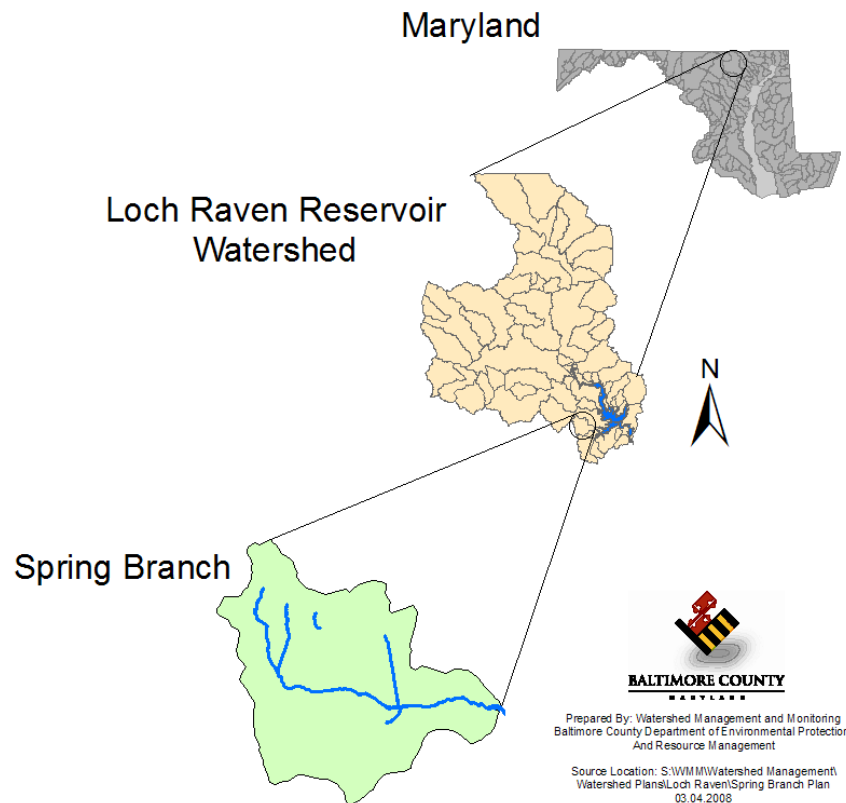


Spring Branch Subwatershed - Small Watershed Action Plan

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

Volume 2: Appendices D Through G



Prepared by
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March 17, 2008

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

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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

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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

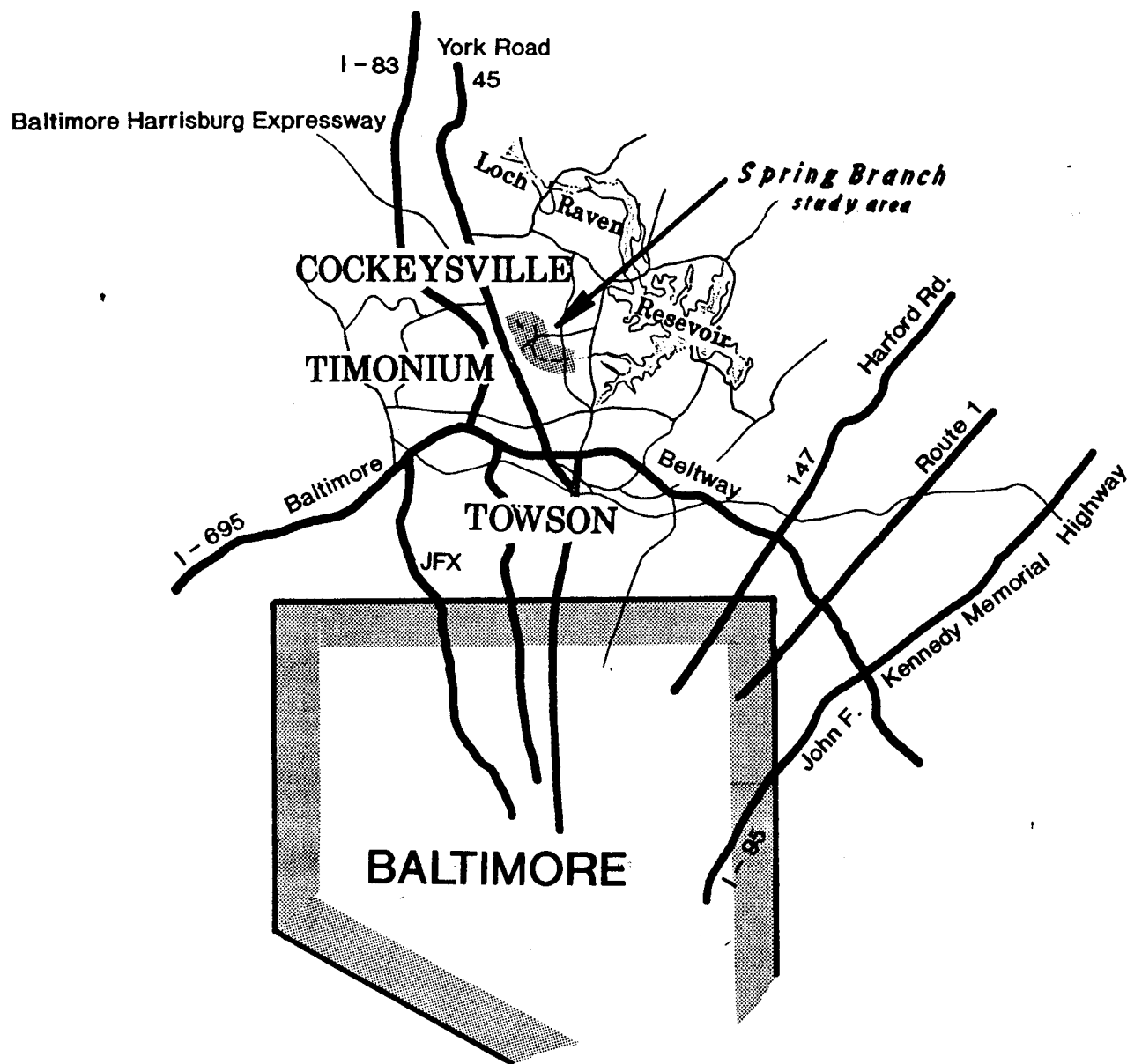
Spring Branch, a tributary stream to Loch Raven Reservoir, is located in Timonium, Maryland (refer to Figure 1.1 Project Location). The stream system has been heavily manipulated as a result of urbanization of the watershed and is currently in a degraded physical condition.

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 included 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 is included in this *Conceptual Plan Report*.



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Figure 1.1
VICINITY MAP

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

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

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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.

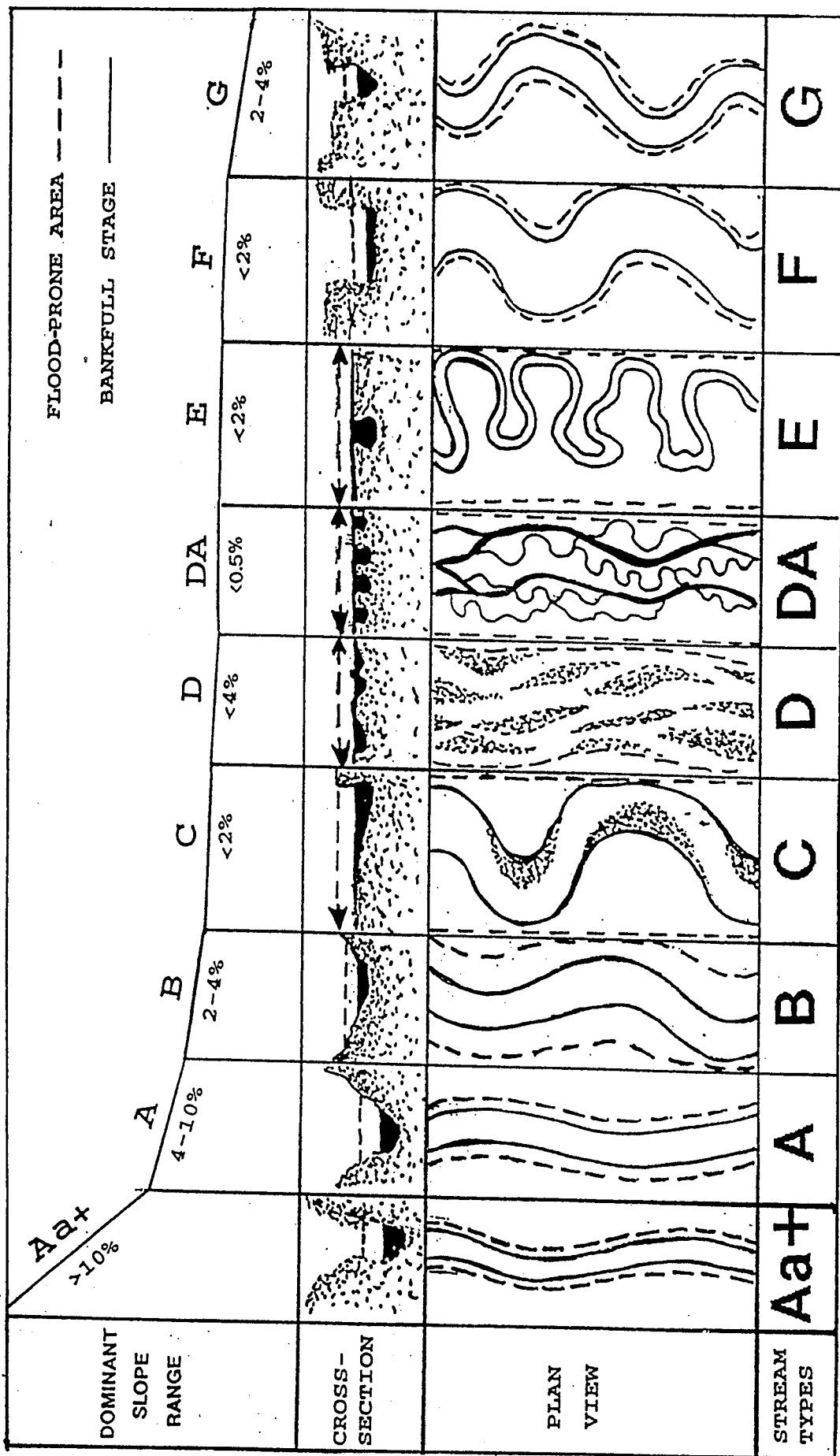
Table 2.1 Rosgen Stream Classification Parameters				
Channel Type	Channel Gradient	Width/Depth Ratio	Sinuosity	Entrenchment Ratio
A	4 to 10%	< 12	Low (< 1.2)	1 to 1.4
B	2 to 4%	> 12	Moderate (> 1.2)	1.41 to 2.2
C	< 1%	> 12	High (> 1.4)	> 2.2
D	1 to 2%	> 50	Unstable	> 2.2
E	< 2%	< 12	Very High (> 1.4)	> 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.



SOURCE: ROSGEN, 1993

STREAM CHANNEL TYPES

Figure 2.1

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.

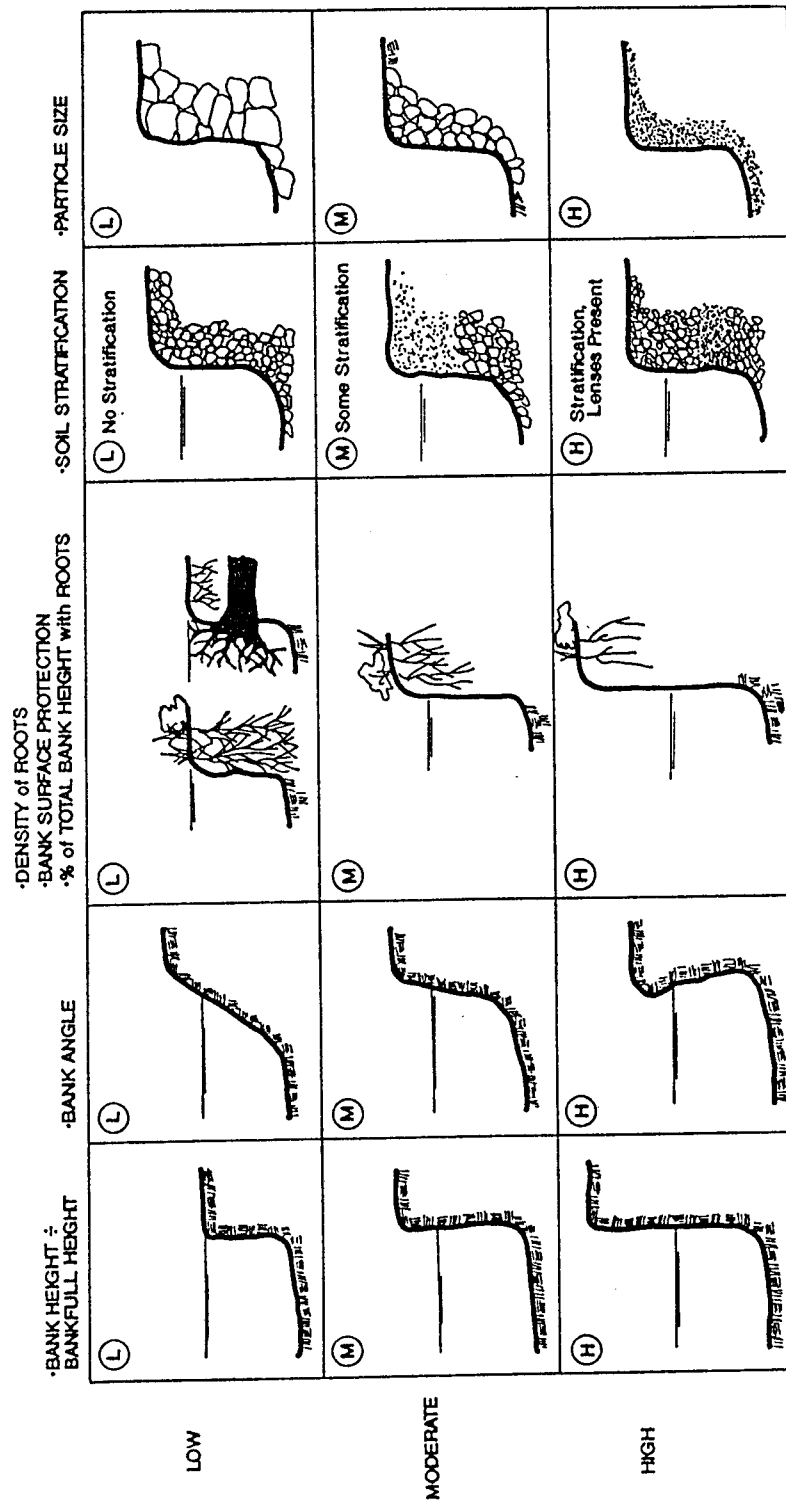
Recent black and white aerial photography at an approximate scale of 1" = 200' was used to review the

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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 erodibility 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



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 separate 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.

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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:

<u>Data Description</u>	<u>Source</u>
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

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.

Alluvial Land

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 desynchronized, 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.

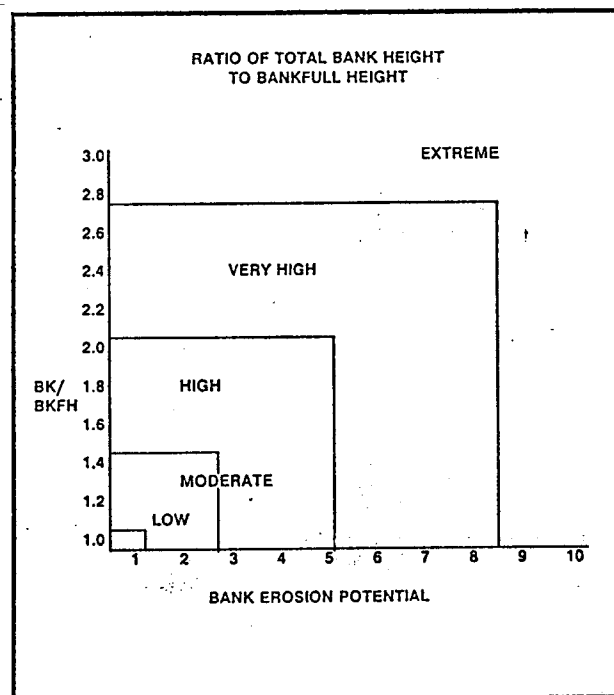


FIGURE 3.2 - EROSION POTENTIAL RATINGS

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

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

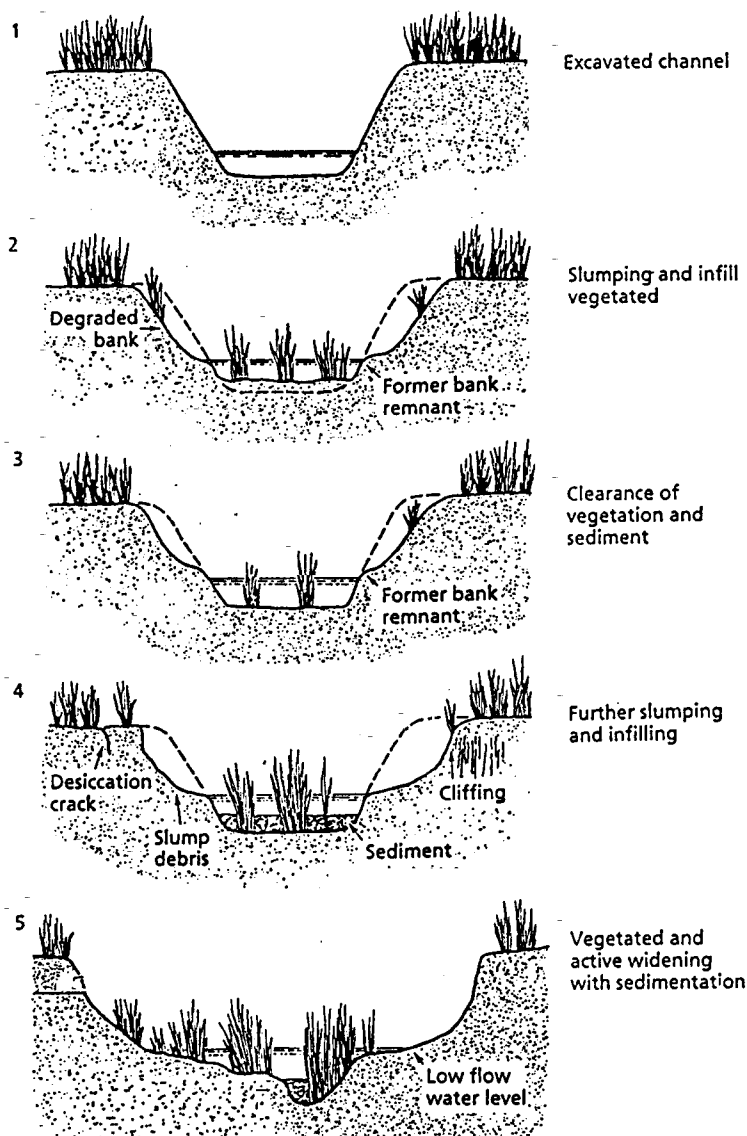


Figure 3.3 Sequence of Channel Changes
(Whitlow & Grady, 1989)

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

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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.

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

<u>Pollutant</u>	<u>Pollutant Concentration (ppm)</u>			
	<u>Event 1</u>	<u>Event 2</u>	<u>Event 3</u>	<u>Nurp Study</u>
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 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.

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:

ER: 1.2
W/D: 20
Sin: 1.15
Slope: 3.0%

Proposed B:

ER: 1.8
W/D: 20
Sin: 1.3
Slope: 3.0%

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

Existing G:

FPAw: $\frac{5.0'}{4.1'} = 1.2$
BFw: 4.1'

Proposed B:

$\frac{8.0'}{4.4'} = 1.8$

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.

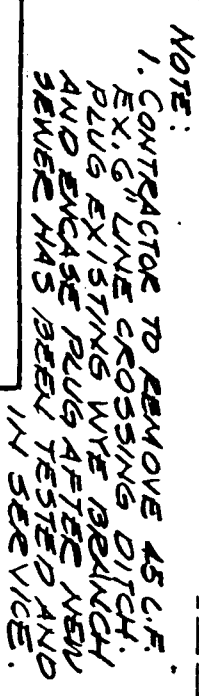
Additional techniques that may assist bank stabilization efforts include debris dam removal and selective tree cutting. Large debris dams formed by trees, construction materials, or dumped refuse should be removed from the channel. Consideration should be given to removing depositional material in mid-channel 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.

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BALTIMORE COUNTY, MARYLAND
DEPARTMENT OF PUBLIC
WORKS
JOB ORDER NO. 21-7
SPRING BRANCH
STREAM RESTORATION
UTILITIES

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 ft³ 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.

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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 complete bank stabilization (1/2 bioengineering and 1/2 revegetation) and rip rap toe protection. ^{to}
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 unforeseen 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. Unforeseen 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.

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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:

<u>Stream Reach</u>	<u>Acreage</u>	<u>(X 80%)</u>	<u>Unit Cost</u>	<u>Total Cost</u>
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	<u>1.9</u>	<u>1.6</u>	\$ 9,000	<u>\$ 14,400</u>
TOTAL	10.7	8.6		\$ 77,400

Quantities

Est. Length
Av. Channel Hgt. N/A 102' 3' 210' 3' 340' 4' N/A 380' 2' 312' 3' 50' 2' 90' 2' 288' 3' 192' 25' 2'

Item	Units	Unit Price	Total Quantities												Cost
			1	2	3	4	5	6	7	8	9	10	11	12	
Remove & Dispose of Debris and Trash	TONS	80.00										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	48,480.00
Class I/II Rip Rap	TONS	23.00		18	5	85		9	8	5	5	7	5	2	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	8,040.00
Revegetate Channel Slopes (shrubs and groundcover)	SY	15.00		8	118	75		21	26	4	2	24	21	2	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

Quantities

Est. Length
Av. Channel Hgt.

N/A 240' 70' 10' 40' 250' 40' 300' 50' N/A
N/A 3' 3' N/A 5' 4' 3' 4' 2' N/A

Item	Units	Unit Price	1	2	3	4	5	6	7	8	9	10	Total Quantities	Cost
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
Revegetate 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
Revegetate 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
Revegetate 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

Quantities

Est. Length . 20' 90' 120' 160' 110' 600' N/A 75' 30' 125'
 Av. Channel Hgt. 5' 5' 4' N/A 5' 4' N/A 5' 3' N/A

Item	Units	Unit Price											Total Quantities	Cost
		1	2	3	4	5	6	7	8	9	10	11		
Remove & Dispose of Debris and Trash	TONS												0	0.00
Remove & Dispose of Concrete	TONS			9			12		2	5			28	4,200.00
Excavation	CY			30									30	300.00
Grading	HRS			16				60			6		82	13,120.00
Class I/II Rip Rap	TONS	5	4	6				30			3		48	1,104.00
Geotextile Fabric	SY	85											85	136.00
Rock/Concrete Weir Structure	EA												0	0.00
Bioengineering Bank Stabilization	SY	22	50	53		88	74			42	10		339	13,560.00
Revegetate Channel Slopes Stabilization	SY							266					266	3,990.00
Repair Gabions	SY											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
Av. Channel Hgt. N/A 102' 210' 340' N/A 380' 312' 50' 90' 288' 192' 25'
 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								5	8	28		8	87	13,920.00
Class I/II Rip Rap	TONS	23.00		6					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			208	6	4		170		650	26,000.00
Revegetate Channel Slopes (shrubs and groundcover)	SY	15.00			70	150				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	Total										Cost
			1	2	3	4	5	6	7	8	9	Quantities	
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
Revegetate 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	Quantities				Total Quantities	Cost
			1	2	3	4		
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
Revegetate 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

Quantities

Est. Length	335'	30'	45'	180'	240'	310'	30'
Av. Channel Hgt.	6'	6'	4'	12'	8'	5'	4'

[illegible]

STREAM SECTOR - RC 2nd Alternative

Quantities

Est. Length
Av. Channel Hgt. 20' 90' 120' N/A 160' 110' 600' n/a 75' 30' 125'
 5' 5' 4' N/A 5' 6' 4' n/a 5' 3' n/a

Item	Units	Unit Price	Total											Cost
			1	2	3	4	5	6	7	8	9	10	11	
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	2,880.00
Class I/II Rip Rap	TONS	23.00			6						4	5	6	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
Revegetate Channel Slopes (shrubs and groundcover)	SY	15.00			53			73	530		42	5	42	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

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5.3 Cost/Benefit Analysis

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

<u>Stream Reach</u>	<u>Preferred Alternative</u>	<u>PER LF</u>	<u>2nd Alternative</u>	<u>PER LF</u>
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	<u>49,835.00</u>	<u>37.47</u>	<u>40,758.00</u>	<u>30.64</u>
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:

- ▶ Desynchronized, 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.

Baltimore County
Spring Branch Stream Restoration Project
J.O. No. 21-7-10

- ▶ 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.

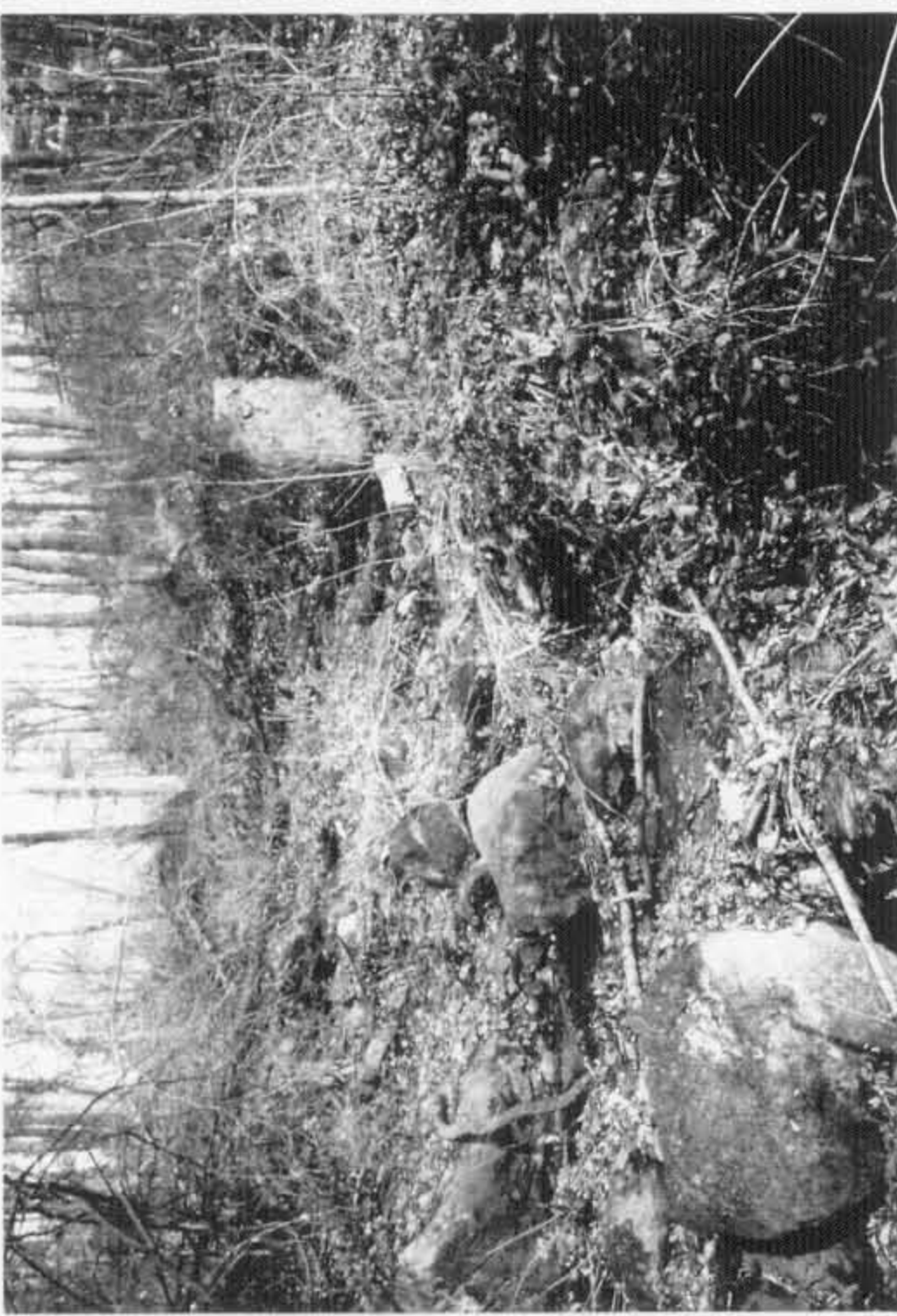
Explore opportunities for establishing community compost areas for disposal of yard waste. Possible locations throughout the watershed include the church on Timonium Road, the water tower property in the Stratford subdivision, open space at the confluence of Spring Branch and the Hollowbrook Tributary,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



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

2. CONFLUENCE - REUTER ROAD SECTOR DOWN-STREAM 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)



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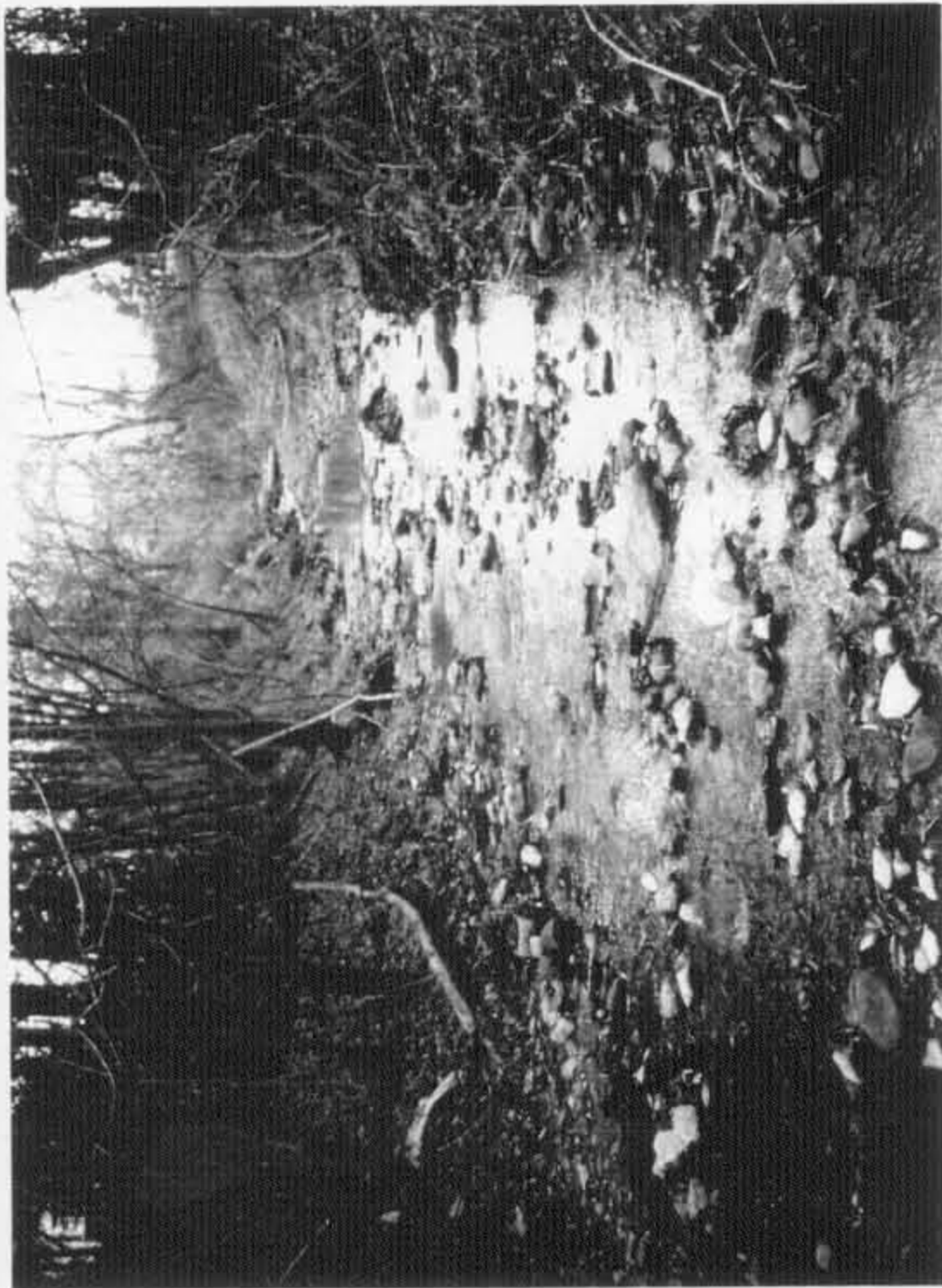


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CHANNEL TYPES



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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



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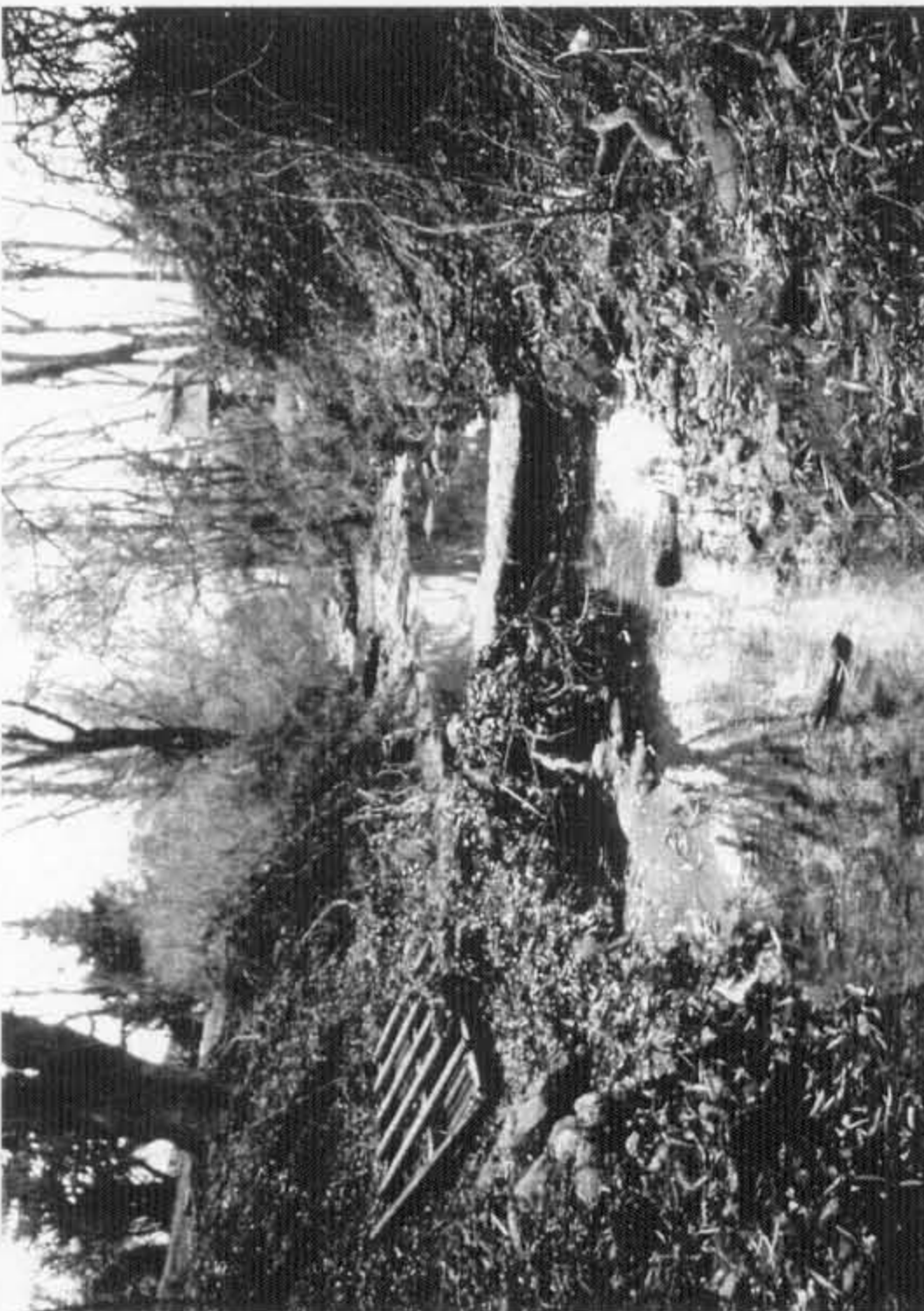


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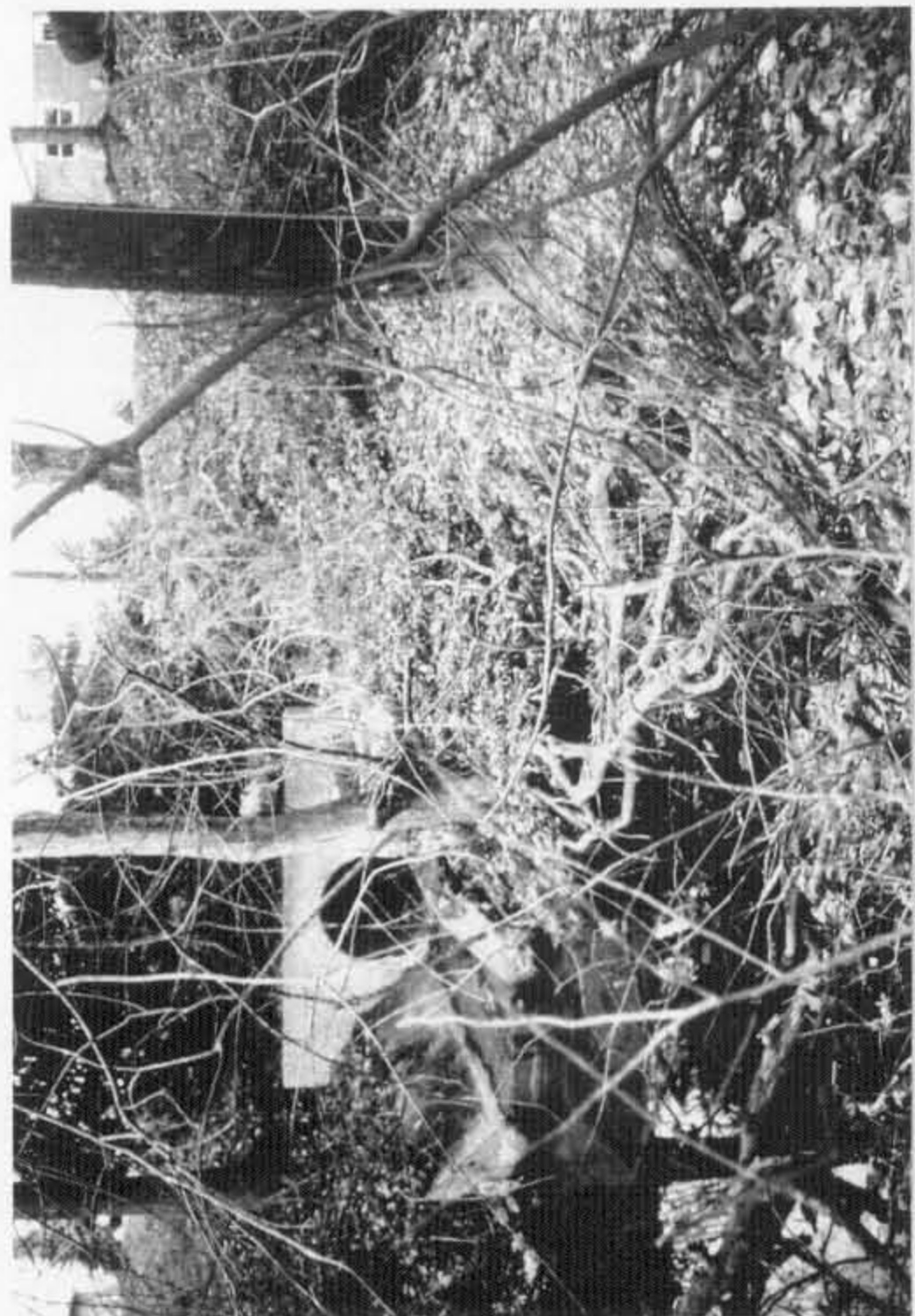


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1. CONCENTRATED OVERLAND FLOW ABOVE KILLORAN ROAD OUTFALL.
2. EXPOSED SEWER TRUNK LINE CROSSING IN REUTER ROAD - CINDER ROAD SECTOR ABOVE TRAVERSE POINT 46.
3. BROKEN SEWER LATERAL IN KILLORAN ROAD - TIMONIUM ROAD SECTOR.
4. EROSION AT KILLORAN ROAD OUTFALL.
5. DEBRIS DAM IN CONFLUENCE - REUTER ROAD SECTOR ABOVE TRAVERSE POINT 35.



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6. FAILED CONCRETE BANK REPAIR ABOVE EASTRIDGE ROAD CULVERT.

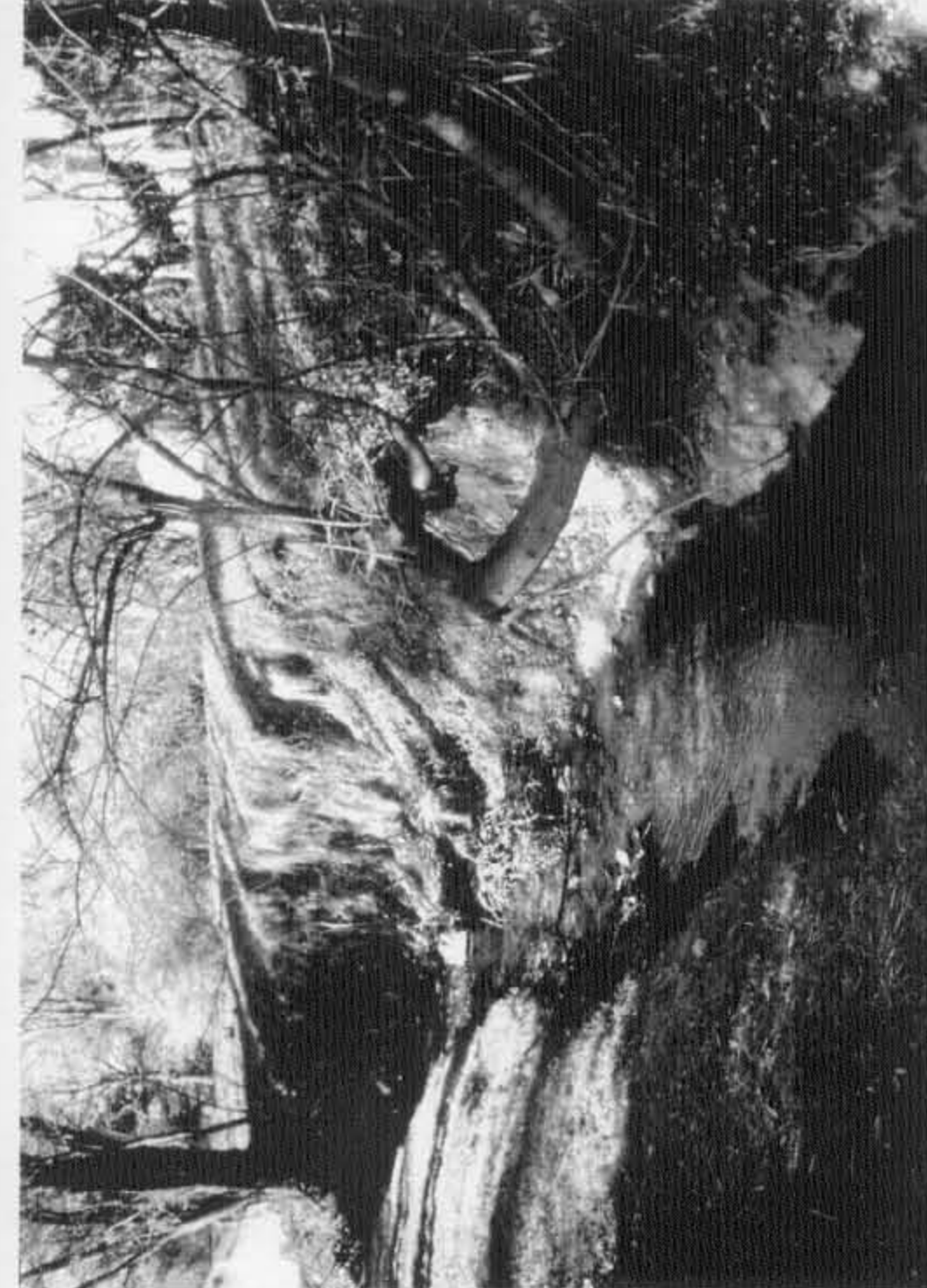
PROBLEM AREAS
OF INTEREST



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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.



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BANK EROSION
EXAMPLES

1. HANDBILL CUMM

2. GERARD AVENUE

3. GREENMEADOW DRIVE

4. KILLORAN ROAD

5. FOLKSTONE DRIVE
AT COLDBROOK ROAD

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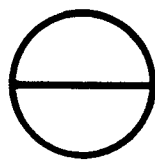
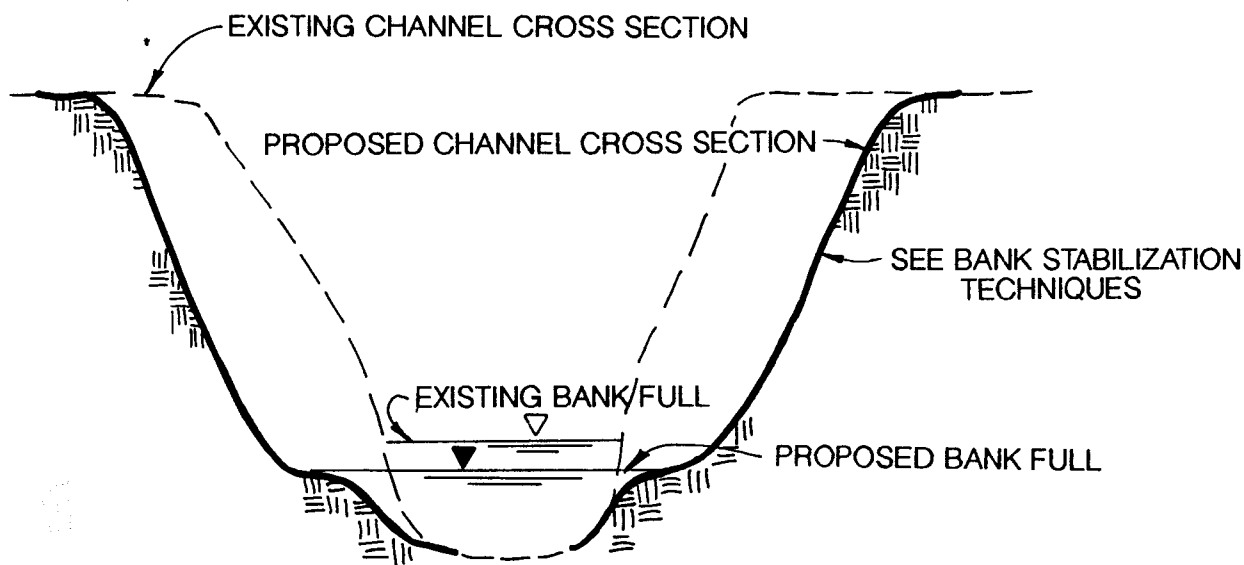
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OUTFALL CONDITIONS

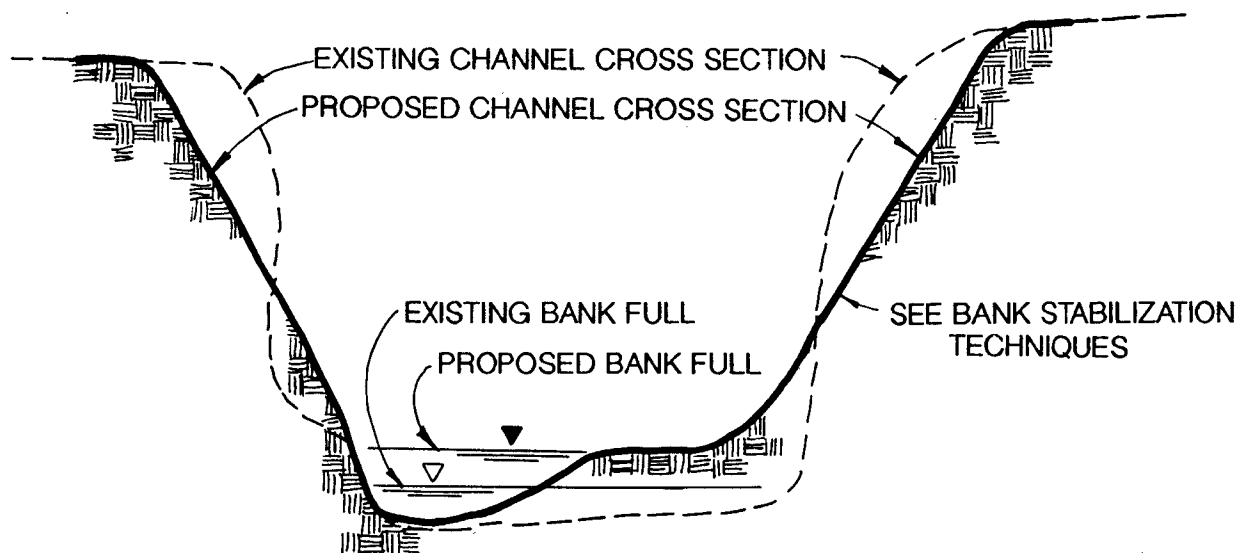
APPENDIX B: TYPICAL DETAILS - PROPOSED RESTORATION TECHNIQUES



CHANNEL GEOMETRY MODIFICATION

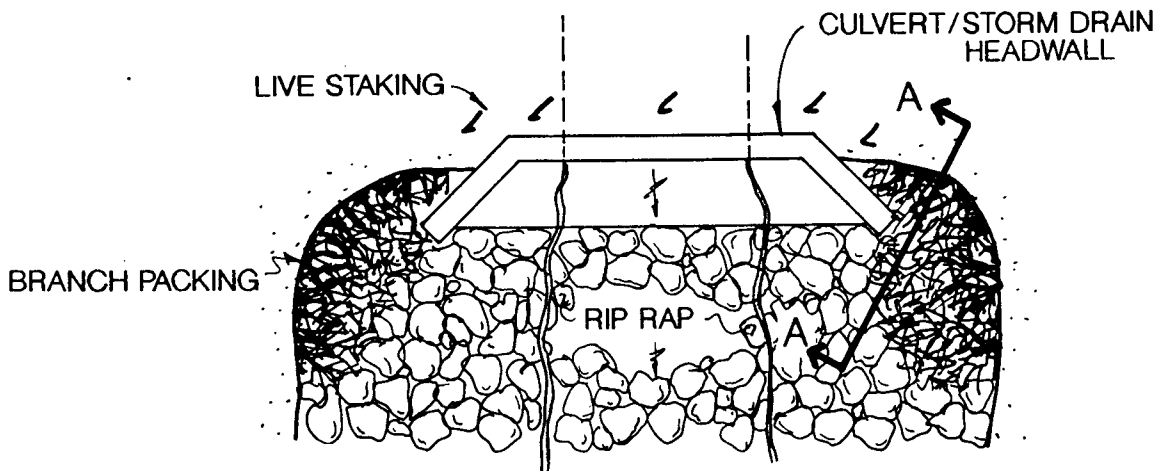
"B" WITHIN A "G"

NTS

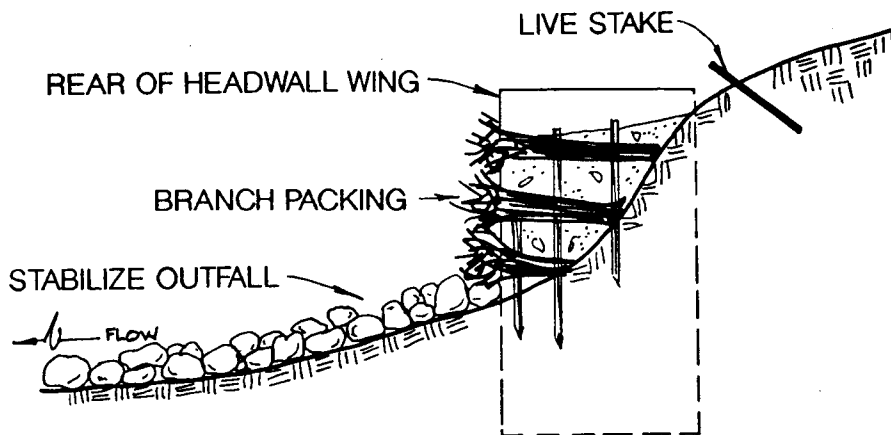


CHANNEL GEOMETRY MODIFICATION

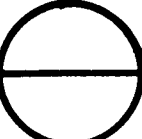
"C" WITHIN AN "F" NTS

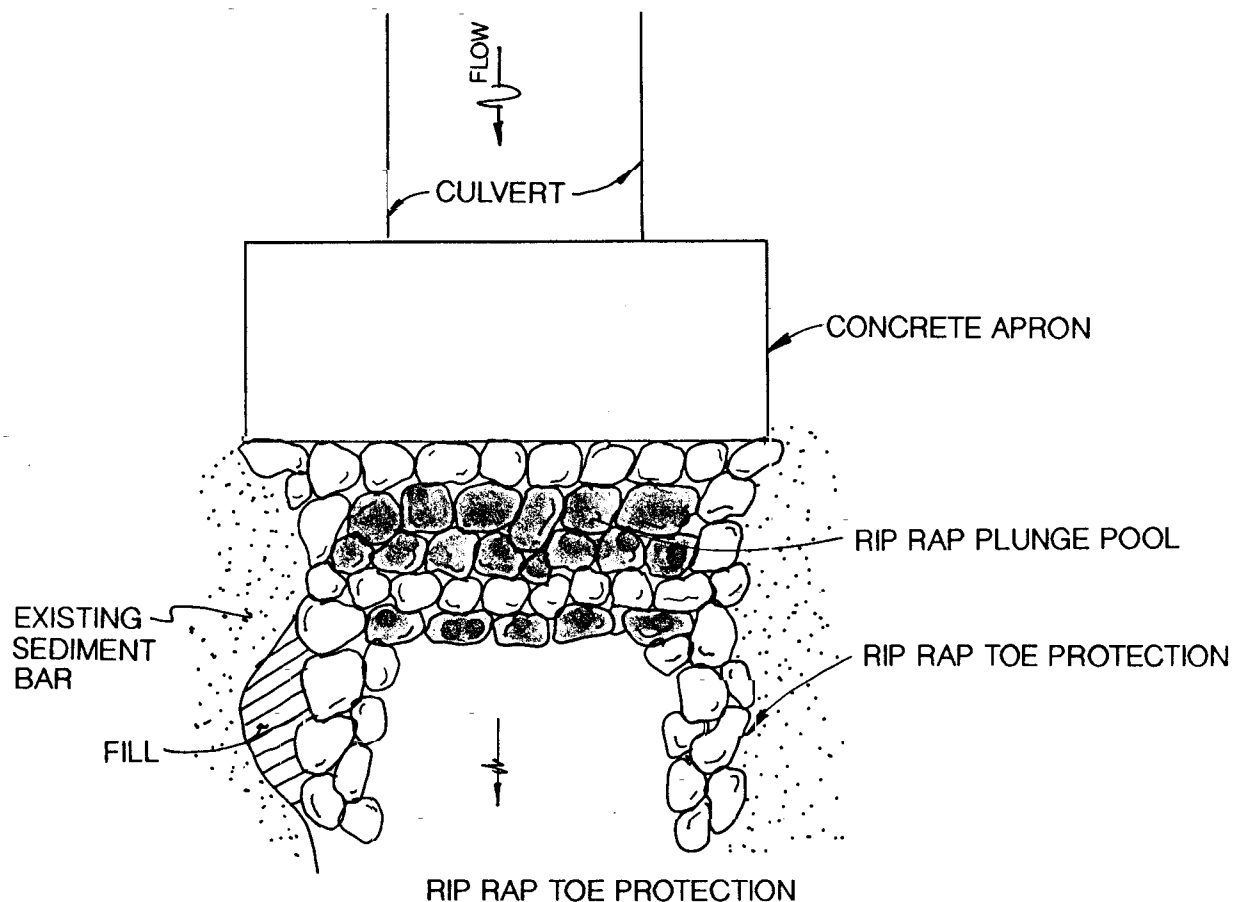


PLAN
NTS

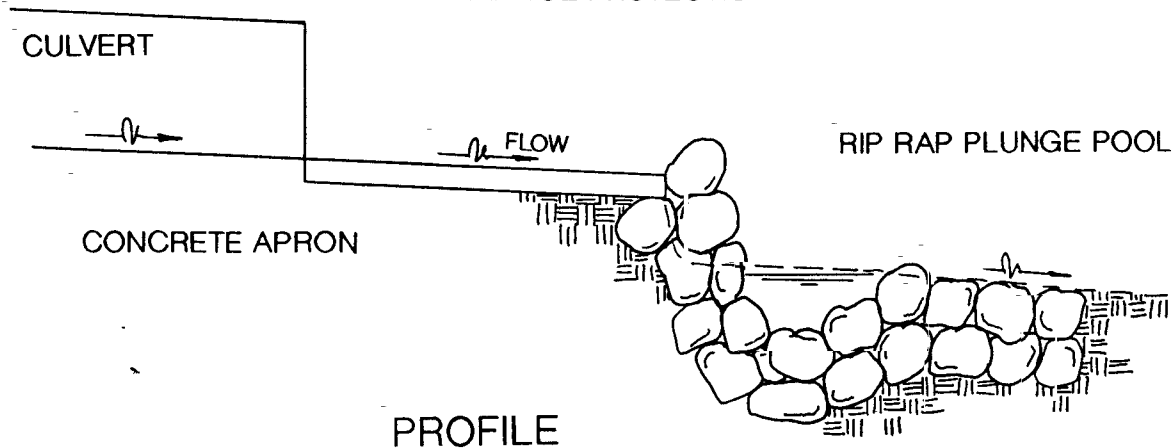


SECTION A - A
NTS

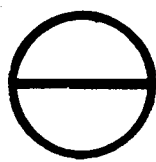
 CULVERT/STORM DRAIN HEADWALL
BRANCH PACKING/BRANCH LAYERING NTS



RIP RAP TOE PROTECTION

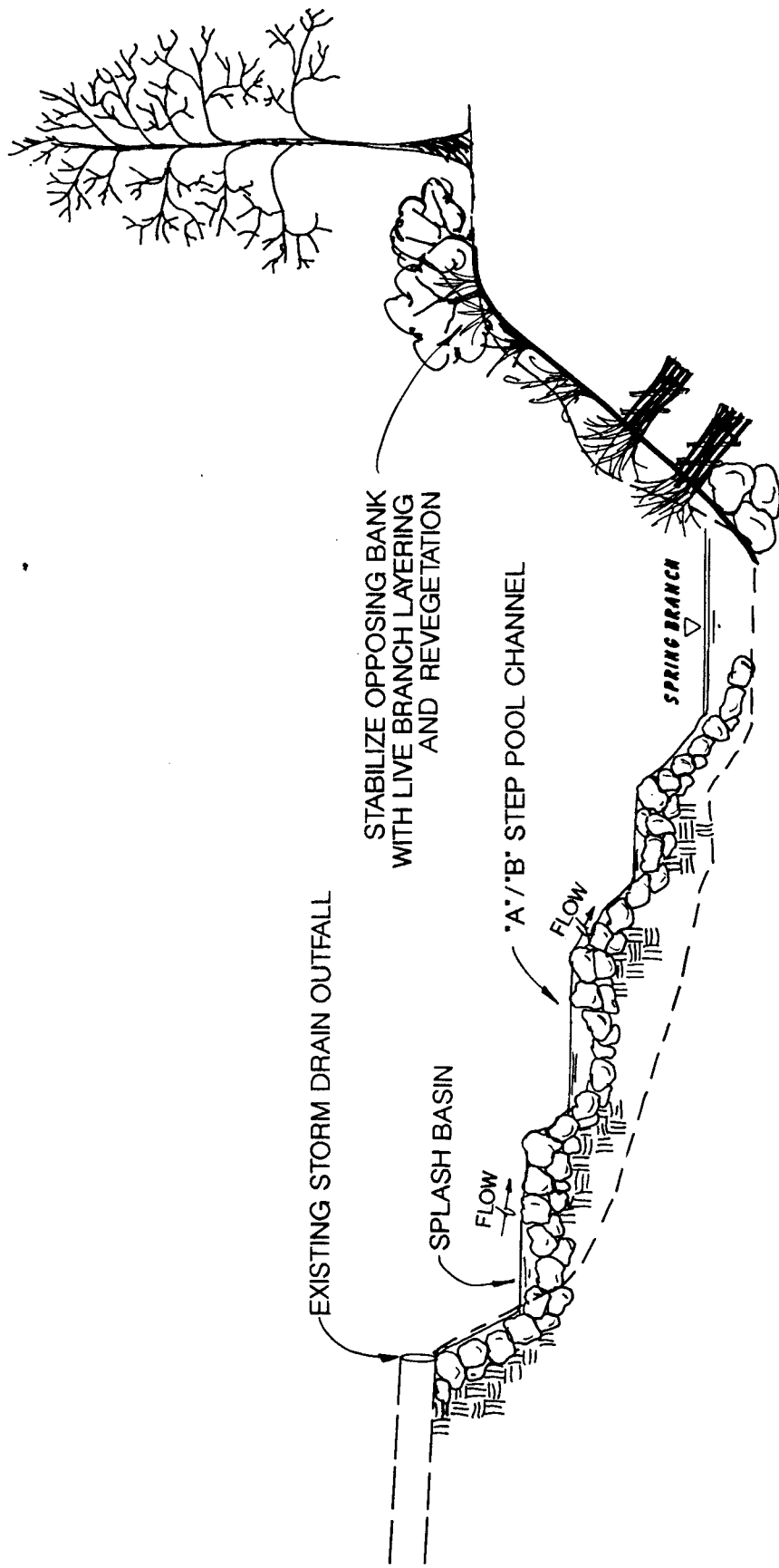


PROFILE



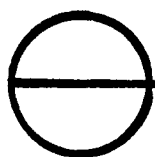
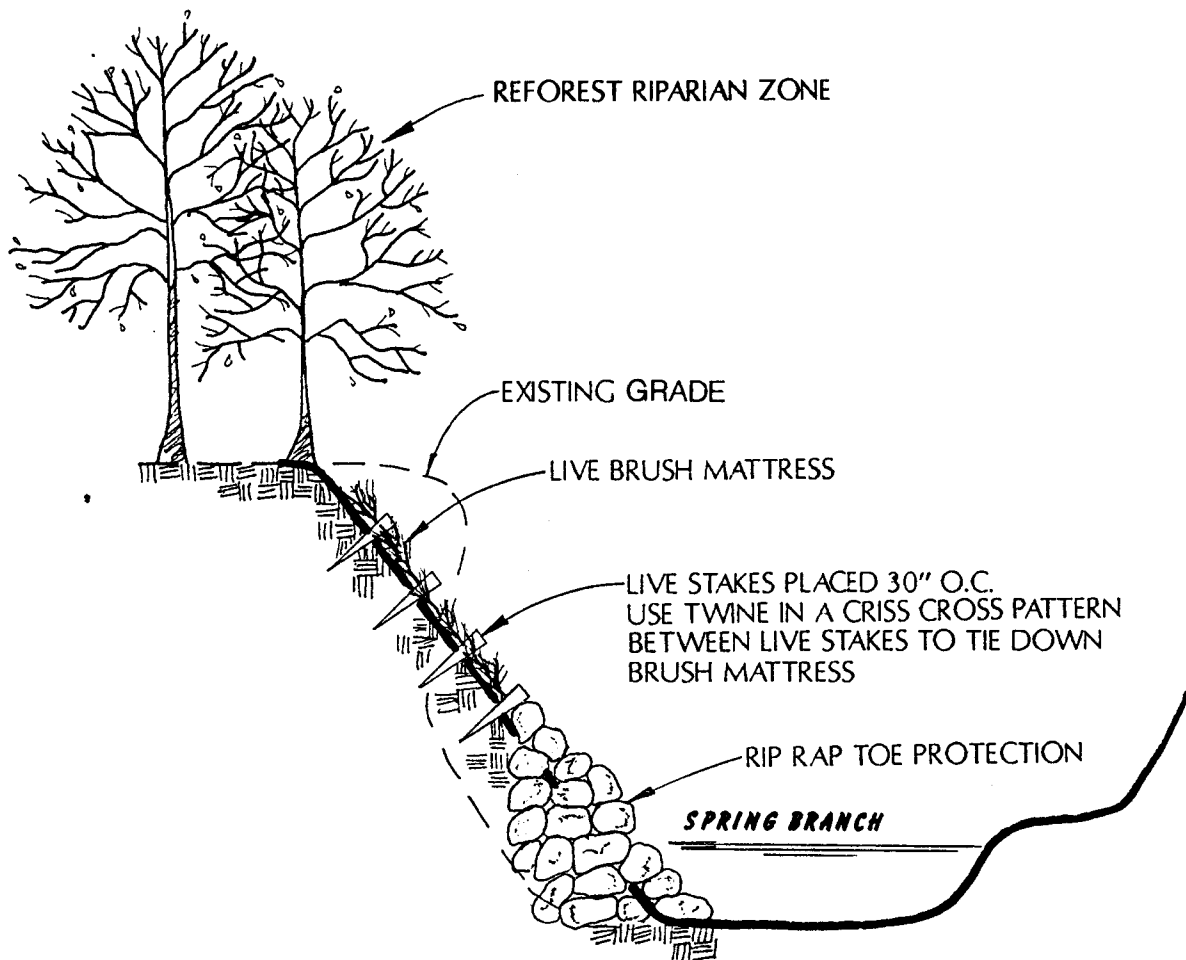
CULVERT OUTFALL RETROFIT

NTS



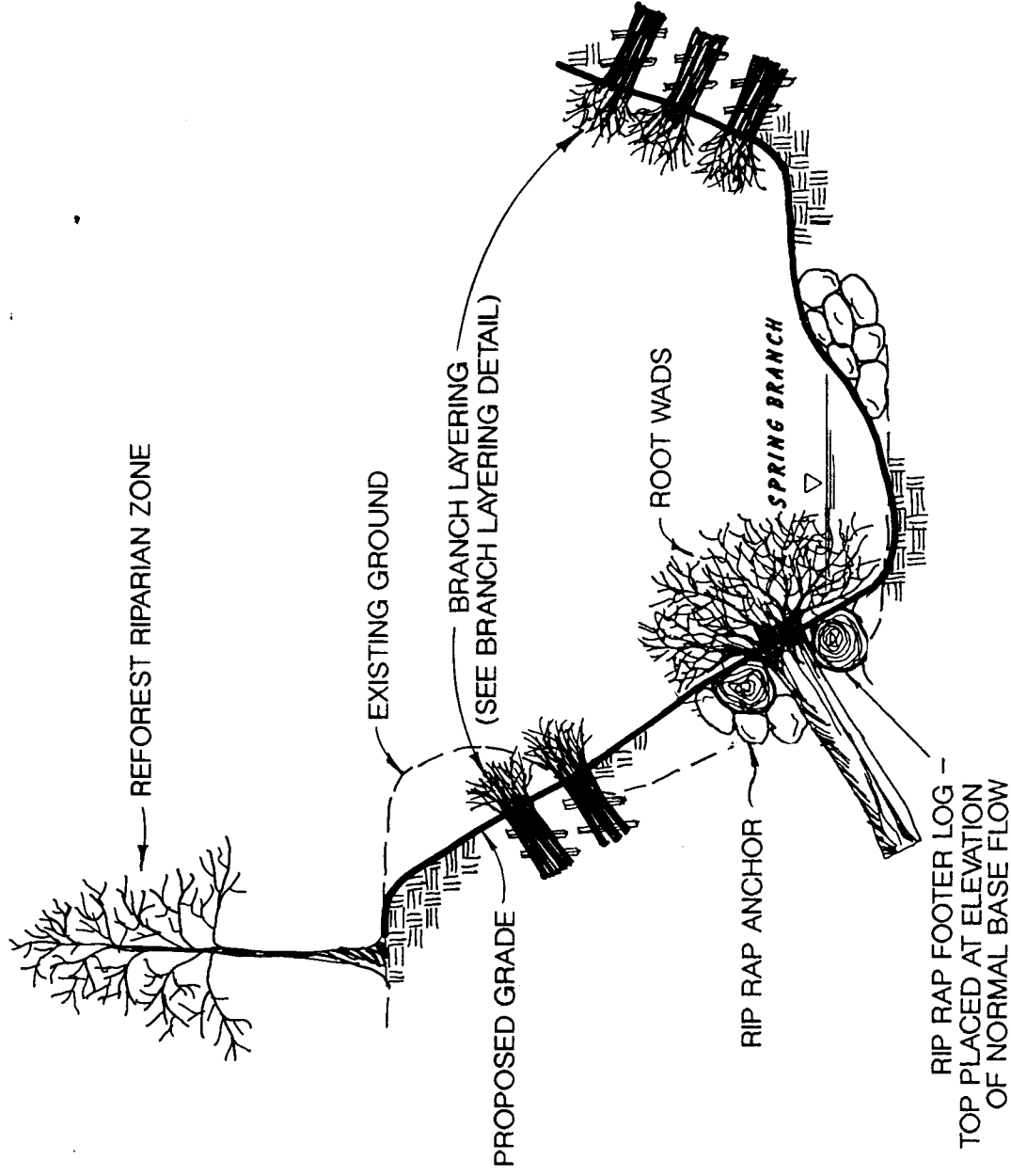
STORM DRAIN OUTFALL RETROFIT
PROFILE

NTS

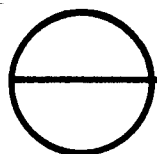
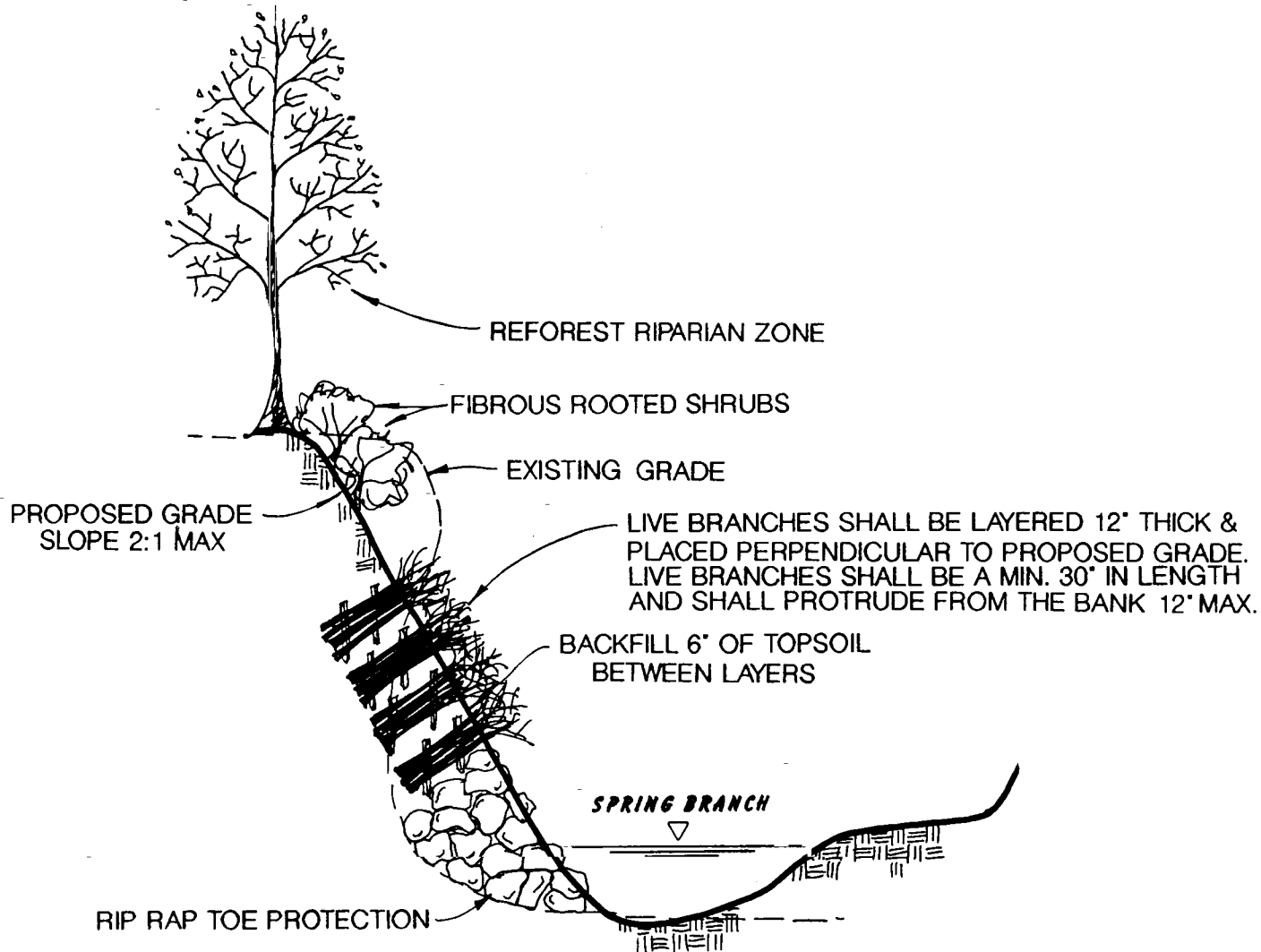


LIVE BRUSH MATTRESS

NTS



ROOT WAD WITH BRANCH LAYERING



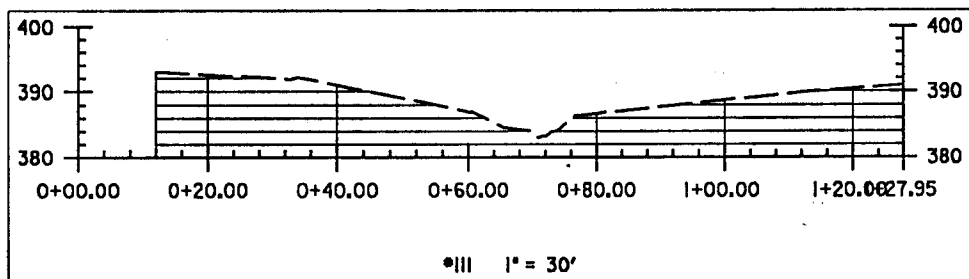
BRANCH LAYERING WITH RIP RAP TOE

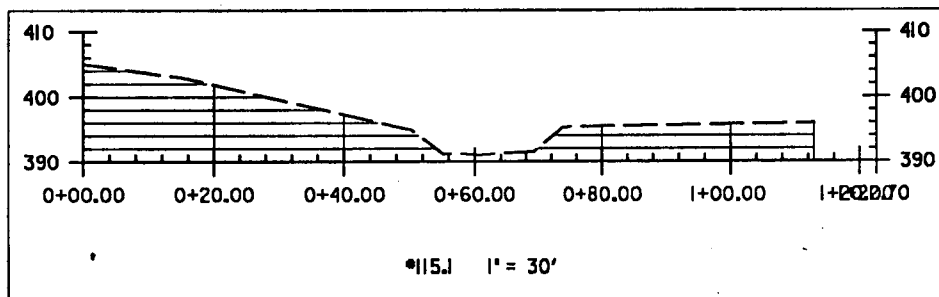
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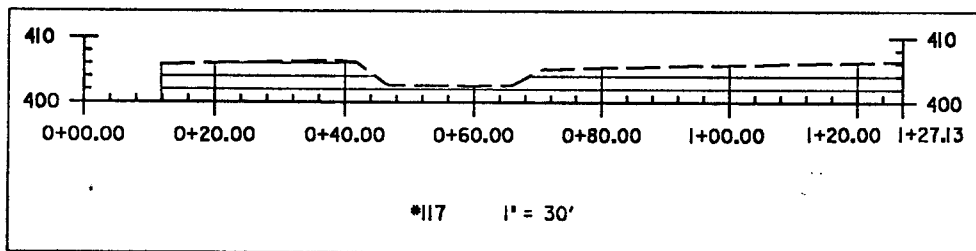


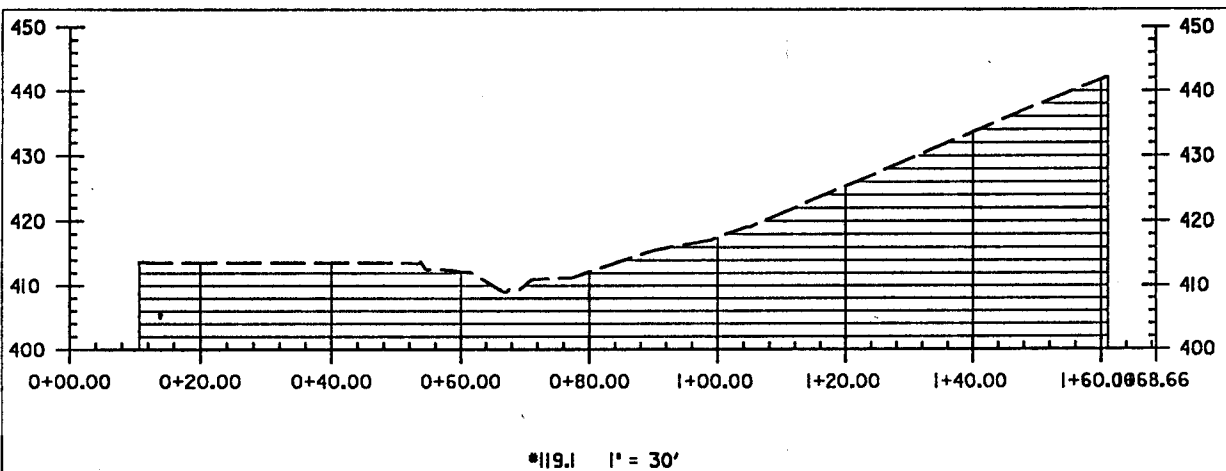
LIVE CRIB WALL W/LIVE BRANCH LAYERING NTS

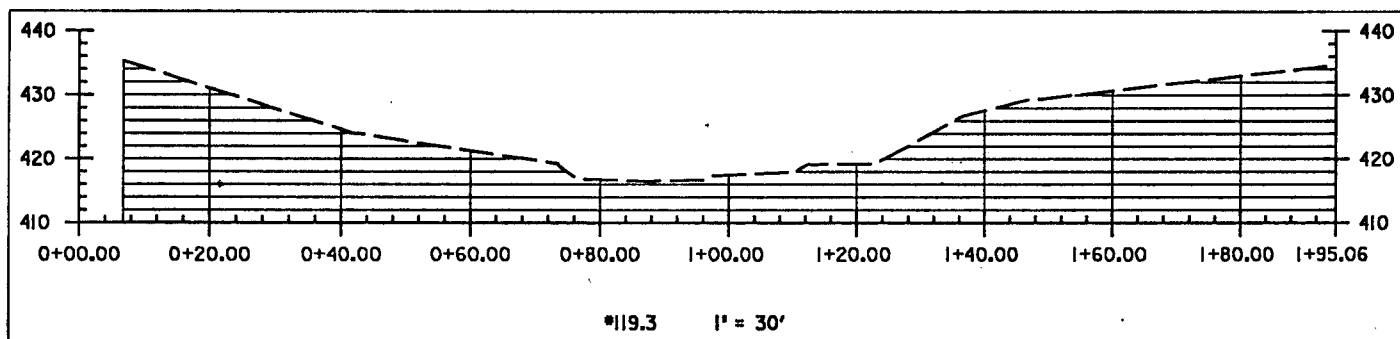
APPENDIX C: SELECT FIELD SURVEYED CROSS SECTIONS

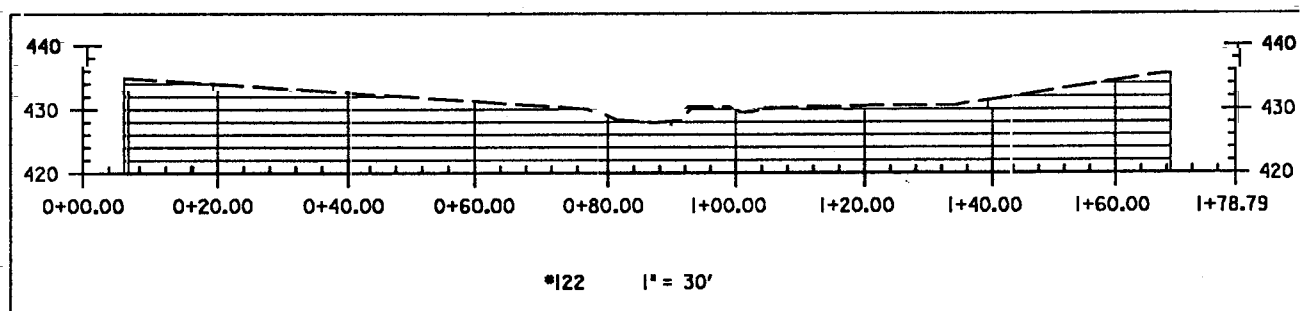


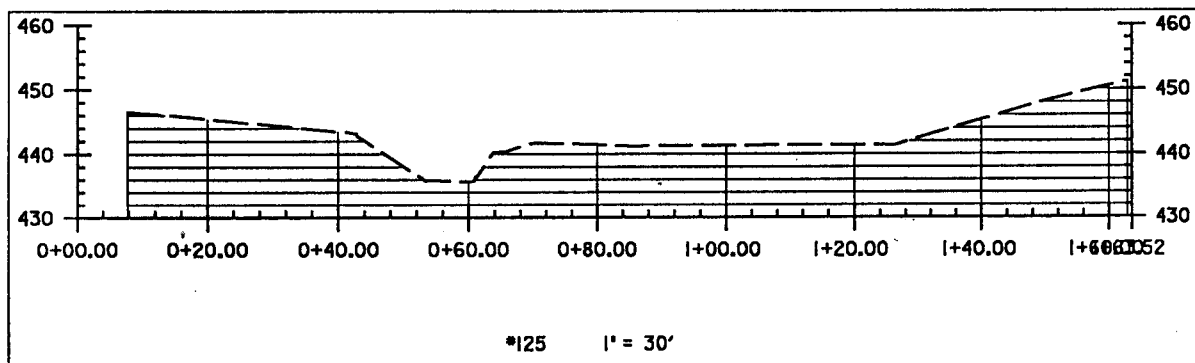


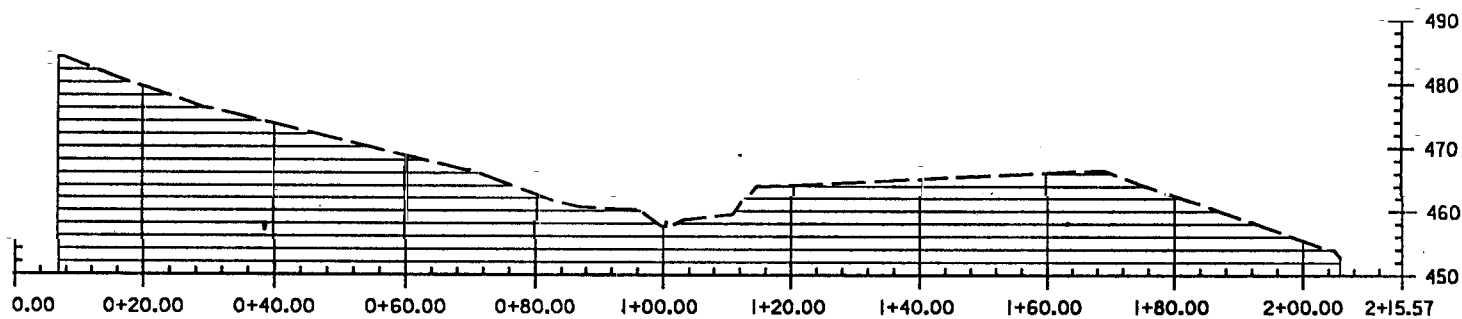




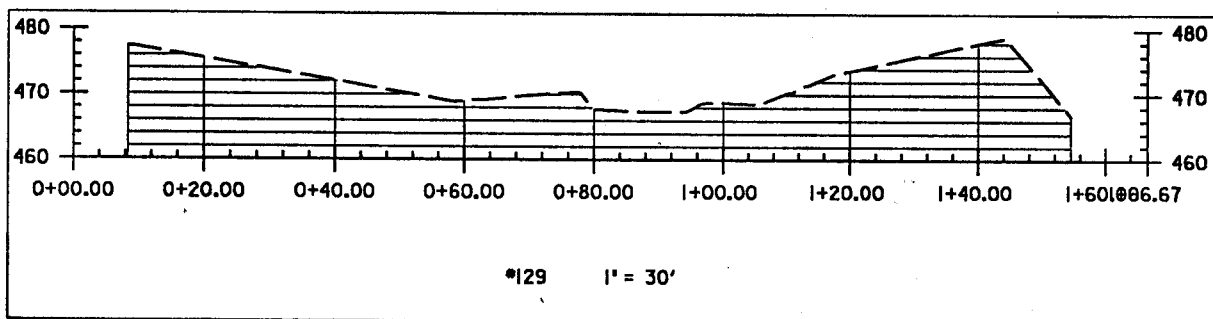


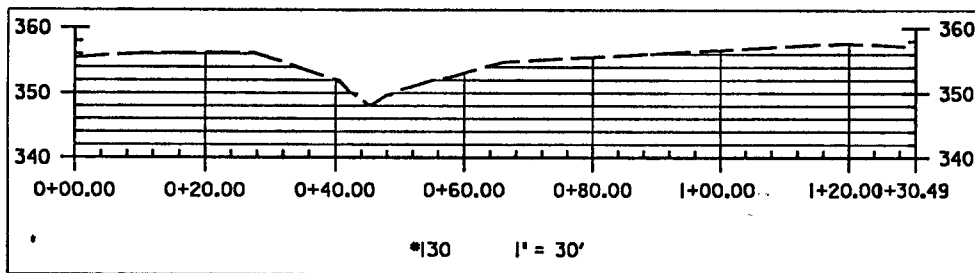


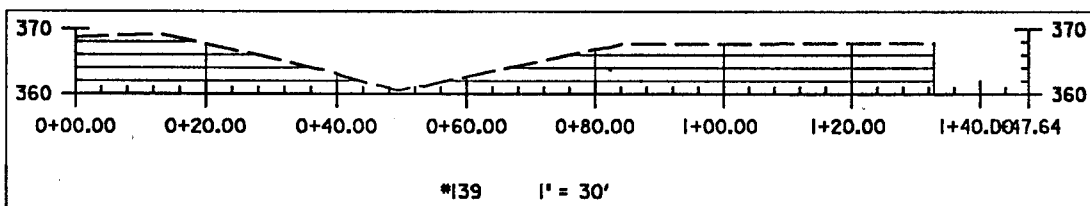




*128 1' = 30'







APPENDIX D: RECOMMENDED PLANT LIST

RECOMMENDED PLANT SPECIES FOR BIOENGINEERING

Scientific Name

Common Name

TREES:

Betula nigra
Cornus alternifolia
Salix nigra

River birch
Alternate-leaved dogwood
Black willow

SHRUBS:

Alnus serrulata
Cornus amomum
Cornus sericea/stolonifera
Hamamelis virginiana
Salix discolor
Salix caroliniana
Salix humilis
Salix interior
Salix sericea
Viburnum dentatum
Viburnum prunifolium

Common/smooth or brookside alder
Silky dogwood
Red twig dogwood
Witchhazel
Glaucous Willow
Ward's willow
Upland willow
Sandbar willow
Silky willow
Arrowwood viburnum
Blackhaw viburnum

RECOMMENDED PLANT SPECIES FOR RIPARIAN REESTABLISHMENT

Scientific Name

Common Name

TREES:

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

RECOMMENDED PLANT SPECIES FOR RIPARIAN REESTABLISHMENT

Scientific Name

Common Name

SHRUBS:

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

FERNS:

<i>Onoclea sensibilis</i>	Sensitive fern
<i>Osmunda cinnamomea</i>	Cinnamon fern
<i>Osmunda regalis</i>	Royal fern
<i>Polystichum acrostichoides</i>	Christmas fern
<i>Thelypteris noveboracensis</i>	New York fern

RECOMMENDED PLANT SPECIES FOR RIPARIAN REESTABLISHMENT

Scientific Name

Common Name

GRAMINOIDS:

Acorus calamus
 Andropogon gerardii
 Andropogon virginicus
 Carex lurida
 Carex stricta
 Carex vulpinoidea
 Eliocharis palustris
 Leersia oryzoides
 Panicum virgatum
 Schizachyrium scoparium
 Scirpus americanus/pungens
 Scirpus cyperinus
 Scirpus validus
 Sorghastrum nutans

Sweetflag
 Big bluestem
 Broomsedge
 Lurid sedge
 Tussock sedge
 Fox sedge
 Creeping spike rush
 Rice cutgrass
 Switchgrass
 Little bluestem
 Common three-square
 Wool grass
 Soft-stem bulrush
 Indian grass

FORBS:

Alisma plantago-aquatica
 Asclepias incarnata
 Aster novae-angliae
 Aster novi-belgii
 Aster puniceus
 Chelone glabra
 Cimicifuga racemosa
 Eupatorium fistulosum
 Eupatorium perfoliatum
 Impatiens capensis (l. bifloral)
 Iris pseudacorus
 Iris versicolor
 Lobelia cardinalis
 Lobelia siphilitica
 Podophyllum peltatum
 Polygonatum biflorum
 Mimulus ringens
 Mitchella repens
 Sanguinaria canadensis
 Saururus cernuus
 Smilacina racemosa
 Sparganium americanum
 Sparganium eurycarpum
 Symplocarpus foetidus
 Verbena hastata
 Vernonia noveboracensis

Water plantain
 Swamp milkweed
 New England aster
 New York aster
 Purple-stem aster
 Turtlehead
 Black snakeroot
 Joe-pye weed
 Boneset
 Jewelweed
 Yellow iris
 Blue flag iris
 Cardinal flower
 Great blue lobelia
 Mayapple
 Solomon's seal
 Monkey flower
 Partridgeberry
 Bloodroot
 Lizard's tail
 False Solomon's seal
 Eastern burreed
 Giant burreed
 Skunk-cabbage
 Blue vervain
 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 Timineen

Level #1 Broad Characterization (Field data sheet)

[illegible]

* 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: _____

Notes: _____

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

	④ A_1 (103)	⑤ A_2 (52)	⑥ A_3 (81)
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	26.0	33.0	15.0"
FPA width (elv.)	13'0"	15'6.5"	8.4'
FPA/BFW = ER	13.0/7.16 = 1.82	15.54/9.42 = 1.64	8.4/6.3 = 1.33
BF width (BFW)	7.16'	9.42'	6.3'
Mean BFD	.55'	.88'	0.31'
BFW/MBFD = %D	13.0'	10.7'	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.

Level #1 Broad Characterization (Field data sheet)

[illegible]

- * 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)

[illegible]

* 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 (Route to Conference) Weather rain rain 24 rain 48 rain >48
Notes: (May be part of "C" reach)

Level #1 Broad Characterization (Field data sheet)

[illegible]

- * 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 (Reentry - Confluence) Weather rain rain 24 rain 48 rain > 48
Notes: _____

Level #1 Broad Characterization (Field data sheet)

[illegible]

- * 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 (Renter - Influence) Weather rain rain 24 rain 48 rain >48
Notes: _____

Level #1 Broad Characterization (Field data sheet)

	B ₁ (13)	B ₂ (14)	B ₃ (15)
BF width (BFW)	14.4'	13.45'	15.3'
BF depth* (BFD)	—	—	—
Mean BFD	17.0'	.72'	0.48'
Max. depth @ BF	16.0"	13.0"	10.0"
Max. depth x 2 = FPA	32.0"	26.0"	20.0"
FPA width (div.)	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 = %D	14.4'	18.68	31.87
Channel slope	~ 2.0% ±	2.07% ±	2.07% ±
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)

[illegible]

* 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) LD RP

BH Project Name/No.

Section/Area E-D (Sub Green - Eastridge Rd)

Weather rain rain 24 rain 48 rain > 48

Notes:

Level #1 Broad Characterization (Field data sheet) 1997.02.64

[illegible]

* Use back or Y-section sheet to calculate.

+ measurements taken at cross-over reach.

8-24-94

Stream Name

CD 4 TB

BH Project Name/No.

AI-BI

not in study area

Weather	rain	rain 24	rain 48	rain >48
---------	------	---------	---------	----------

Notes:

~~Mildt~~

+

+ measurements taken at cross-over reach.

PEBBLE COUNT/DOMINANT PARTICLE SIZE



Reach A1+B-1

PEBBLE COUNT

Size Range		Class Name	Dot & Dash Count :: = 3, : = 9	Tot. No.	% of Tot.	Cum %
Metric-mm	Inches					
Less .062		Silt/Clay	1:	5	4.5	4.5%
.062-.125		Very Fine	::	3	2.7	7.2
.125-.25		Fine	1:	5	4.5	11.7
.25-.50		Medium	□	8	7.2	18.9
.50-1.0		Coarse	⊠	11	9.9	28.8
1.0-2.0		Very Coarse	:	2	1.8	26.1
2.0-4.0		Very Fine	1:	6	5.4	34
4.0-8.0		Fine	1:	6	5.4	41.4
8.0-16	.08-0.6	Medium	::	3	2.7	44.1
16-32	0.6-1.3	Coarse	⊠	9	8.1	52.2
32-64	1.3-2.5	Very Coarse	⊠	9	8.1	29.7
64-128	2.5-5.0	Small	⊠..	12	10.8	71.1
128-256	5-10	Large	⊠⊠:	22	19.8	30.6
256-512	10-20	Small	1:	5	4.5	45.4
512-1024	20-40	Medium	:	2	1.8	97.2
1024-2048	40-80	Large	::	2	1.8	99
2048-4096	80-160	Very Large	•	1	.9	99.9

Total Number of Samples.... 111

 PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____
 Exp. No. | Speed | f # | Subject _____

 GRAVEL /
 CORBBLE (3)

REACH 1 (Below outfall at headwaters)

Pool
||||| |||||
||||| ||||| 1

REBABLE COUNT

Size Range		Class	Dot & Dash Count	Tot.	% of	Cum
Metric-mm	Inches	Name	:: = 3, - = 9	No.	Tot.	%
Less .062		Silt/Clay	::	3	2.3	2.3%
.062-.125		Very Fine	.	1	.7	3.0
.125-.25		Fine	::	4	3	6.0
.25-.50		Medium	::	3	2.3	8.3
.50-1.0		Coarse	::	3	2.3	10.6
1.0-2.0		Very Coarse	!	Ø	Ø	8.3% 10.6
2.0-4.0		Very Fine	..	2	1.5	12.1
4.0-8.0		Fine	☒	10	7.6	19.7
8.0-16	.08-0.6	Medium	☒	9	6.9	26.6
16-32	0.6-1.3	Coarse	☒☒	19	14.5	41.1
32-64	1.3-2.5	Very Coarse	☒☒::	24	18.3	48.8% 59.4
64-128	2.5-5.0	Small	☒☒:	22	16.7	76.1
128-256	5-10	Large	☒::	14	10.7	27.4% 86.8
256-512	10-20	Small	☒::	14	10.7	97.5
512-1024	20-40	Medium	::	3	2.3	99.8
1024-2048	40-80	Large		Ø	Ø	
2048-4096	80-160	Very Large	☒::	Ø	Ø	13%
Total Number of Samples....				131		

PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____			
Exp. No.	Speed	f #	Subject _____

Exp. No.	Speed	f #	Subject
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REACH 2

Pool

PEBBLE COUNT

Size Range		Class Name	Dot & Dash Count :: = 3, = 9	Tot. No.	% of Tot.	Cum %
Metric-mm	Inches					
Less .062		Silt/Clay		0	0	0
.062-.125		Very Fine	:	2	1.6	1.6
.125-.25		Fine		0	0	
.25-.50		Medium	::	3	2.5	4.1
.50-1.0		Coarse	☒:	12	10	14.1
1.0-2.0		Very Coarse	::	4	3.3	17.4
2.0-4.0		Very Fine	::	4	3.3	20.7
4.0-8.0		Fine	☒	7	5.9	26.6
8.0-16	.08-0.6	Medium	☒	9	7.5	34.1
16-32	0.6-1.3	Coarse	☒::	15	12.4	46.7
32-64	1.3-2.5	Very Coarse	☒::	15	12.4	41.9% 59.3
64-128	2.5-5.0	Small	☒::	15	12.6	71.9
128-256	5-10	Large	☒☒::	26	21.8	34.4% 93.7
256-512	10-20	Small		6	5	98.7
512-1024	20-40	Medium	'	1	.8	99.5
1024-2048	40-80	Large		0		
2048-4096	80-160	Very Large		0		5.8%

Total Number of Samples.... 110

GRAVEL
 PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____
 Exp. No. | Speed | f # | Subject _____

REACH 3

Pool
25

PEBBLE COUNT

Size Range		Class Name	Dot & Dash Count :: = 3, :: = 9	Tot. No.	% of Tot.	Cum %
Metric-mm	Inches					
Less .062		Silt/Clay	::	3	2	2%
.062-.125		Very Fine	⌈	7	4.8	6.8
.125-.25		Fine	□	8	5.5	12.3
.25-.50		Medium	⊠	10	6.9	19.1
.50-1.0		Coarse	⊠	10	6.9	26.0
1.0-2.0		Very Coarse	::	3	2	26.1% 28.0
2.0-4.0		Very Fine	::	3	2	30.0
4.0-8.0		Fine	::	4	2.8	32.8
8.0-16	.08-0.6	Medium	⊠	10	6.9	39.7
16-32	0.6-1.3	Coarse	⊠⊠::	24	16.5	56.2
32-64	1.3-2.5	Very Coarse	⊠⊠!:	25	17.2	45.4% 73.4
64-128	2.5-5.0	Small	⊠⊠!:	25	17.2	90.6
128-256	5-10	Large	⊠	10	6.9	24.1% 97.5
256-512	10-20	Small	.	1	.7	98.2
512-1024	20-40	Medium		0	0	
1024-2048	40-80	Large	:	2	1.3	99.5
2048-4096	80-160	Very Large		0	0	2%

Total Number of Samples.... 145

PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____

Exp.No. | Speed | f | Subject

EACH 5

25 POOL

RIFF
13
9
15
31
16
53
17
70

PEBBLE COUNT

Size Range		Class	Dot & Dash Count	Tot.	% of	Cum
Metric-mm	Inches	Name	∴ = 3, ∴ = 9	No.	Tot.	%
Less .062		Silt/Clay		0	0	0%
.062-.125		Very Fine	☐	7	5.5	5.5
.125-.25		Fine	☒	13	10.3	15.8
.25-.50		Medium	1:	5	3.9	19.7
.50-1.0		Coarse	☒	13	10.3	30.0
1.0-2.0		Very Coarse	☐	9	7.1	37.1%
2.0-4.0		Very Fine	☐	8	6.3	43.4
4.0-8.0		Fine	☒	11	8.7	52.1
8.0-16	.08-0.6	Medium	:	2	1.6	53.7
16-32	0.6-1.3	Coarse	☒	13	10.3	64.0
32-64	1.3-2.5	Very Coarse	☒☒	19	15	41.9% 79.0
64-128	2.5-5.0	Small	☒	11	8.7	87.7
128-256	5-10	Large	☐	9	7.1	15.8% 94.8
256-512	10-20	Small	∴	4	3.2	98.0
512-1024	20-40	Medium	.	1	.8	98.8
1024-2048	40-80	Large		0	0	
2048-4096	80-160	Very Large	.	1	.8	4.8% 99.6

Total Number of Samples.... 126

PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____

Exp.No. | Speed | f | # | Subject

REACH 5 → 6

DIFF

POOL

11
11 22
22
12
34
21
55
16
70

PEBBLE COUNT

Size Range		Class Name	Dot & Dash Count :: = 3, : = 9	Tot. No.	% of Tot.	Cum %
Metric-mm	Inches					
Less .062		Silt/Clay		0	0	0
.062-.125		Very Fine	:	2	1.4	1.4
.125-.25		Fine	1:	5	3.6	5.0
.25-.50		Medium	⊠.	11	7.9	12.9
.50-1.0		Coarse	⊠1:	15	10.8	23.7
1.0-2.0		Very Coarse	:	2	1.4	25.1%
2.0-4.0		Very Fine	::	4	2.9	28.0
4.0-8.0		Fine	⊠	9	6.5	34.5
8.0-16	.08-0.6	Medium	⊠	9	6.5	41.0
16-32	0.6-1.3	Coarse	⊠⊠	20	14.4	55.4
32-64	1.3-2.5	Very Coarse	⊠⊠.	26	18.7	49.7%
64-128	2.5-5.0	Small	⊠⊠:	22	15.8	89.9
128-256	5-10	Large	⊠	9	6.5	22.3%
256-512	10-20	Small	.	1	.7	97.1
512-1024	20-40	Medium		0	0	
1024-2048	40-80	Large	..	2	1.4	98.5
2048-4096	80-160	Very Large	..	2	1.4	3.5%

Total Number of Samples.... 139

PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____

Exp. No. | Speed | f # | Subject

GRAVEL

REACH 7

SECTION C- A

RIFF
29
57
14
71

POOL

PEBBLE COUNT

Size Range		Class Name	Dot & Dash Count :: = 3, = = 9	Tot. No.	% of Tot.	Cum %
Metric-mm	Inches					
Less .062		Silt/Clay	:	2	1.6	1.6%
.062-.125		Very Fine	⌈	6	5	2.1
.125-.25		Fine	::	4	3.3	5.4
.25-.50		Medium	⌈	7	5.9	11.3
.50-1.0		Coarse	□	8	6.7	18.0
1.0-2.0		Very Coarse	:	2	1.6	22.5% 19.6
2.0-4.0		Very Fine	::	3	2.5	22.1
4.0-8.0		Fine	⌈	7	5.9	28.0
8.0-16	.08-0.6	Medium	:	5	4.2	32.2
16-32	0.6-1.3	Coarse	⊠⊠□	28	23.5	55.7
32-64	1.3-2.5	Very Coarse	⊠⊠□	28	23.5	59.6% 79.2
64-128	2.5-5.0	Small	⊠::	14	11.8	91.0
128-256	5-10	Large	:	5	4.2	16.9% 95.2
256-512	10-20	Small				
512-1024	20-40	Medium				
1024-2048	40-80	Large				
2048-4096	80-160	Very Large				

Total Number of Samples.... 119

PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____
Exp.No. | Speed | f # | Subject _____

Reach: #1 : Suburban Green to Riprap (1 inch)

PEBBLE COUNT

Size Range		Class Name	Dot & Dash Count :: = 3, - = 9	Tot. No.	% of Tot.	Cum %
Metric-mm	Inches					
Less .062		Silt/Clay		1	.3	.85%
.062-.125		Very Fine		3	2.5	3.3
.125-.25		Fine	☒	9	7.5	10.8
.25-.50		Medium	☒	6	5	15.8
.50-1.0		Coarse	☒	15	12.5	28.3
1.0-2.0		Very Coarse	☒	6	5	32.5% 33.3
2.0-4.0		Very Fine	☒	12	10	43.3
4.0-8.0		Fine	☒	10	8.3	51.6
8.0-16	.08-.05	Medium	☒	9	7.5	59.1
16-32	0.6-1.3	Coarse	☒	11	9.2	68
32-64	1.3-2.5	Very Coarse	☒☒	20	17	52% 85.3
64-128	2.5-5.0	Small	☒	15	12.5	47.8
128-256	5-10	Large	☒	3	2.5	15% 100.3
256-512	10-20	Small				
512-1024	20-40	Medium				
1024-2048	40-80	Large				
2048-4096	80-160	Very Large				0

GRAVEL (4)

Total Number of Samples.... 120

PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____

Exp.No. | Speed | f | Subject

Note: Riprap slopes table

Reach #2 Above Gaybians to Check Dam
Key/A = 10-90 ?

PEBBLE COUNT

Size Range		Class	Dot & Dash Count	Tot. No.	% of Tot.	Cum %
Metric-mm	Inches	Name	∴ = 3, ∴ = 9			
Less .062		Silt/Clay		0		0
.062-.125		Very Fine		0	0	
.125-.25		Fine	∴	4	3.8	3.8
.25-.50		Medium	∴	6	5.8	9.6
.50-1.0		Coarse	⊠ ∴	14	13.6	23.2
1.0-2.0		Very Coarse	∴	1	1	24.2%
2.0-4.0		Very Fine		0	0	
4.0-8.0		Fine	∴	3	2.9	27.1
8.0-16	.08-0.6	Medium	∴	5	4.9	32.0
16-32	0.6-1.3	Coarse	⊠ ∴	16	15.5	47.5
32-64	1.3-2.5	Very Coarse	⊠ ∴ ∴	24	23	46.3% 70.5
64-128	2.5-5.0	Small	⊠ ∴ ∴	22	21	91.5
128-256	5-10	Large	∴	5	4.9	25.9% 96.4
256-512	10-20	Small	∴	3	2.9	99.3
512-1024	20-40	Medium				
1024-2048	40-80	Large				
2048-4096	80-160	Very Large				2.9%

GRAVEL (4)

Total Number of Samples.... 103

PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____

Exp. No. | Speed | f | Subject

Note still riprap

Reach 3: 40/60

PEBBLE COUNT

Size Range		Class Name	Dot & Dash Count :: = 3, :: = 9	Tot. No.	% of Tot.	Cum %
Metric-mm	Inches					
Less .062		Silt/Clay		1	.9	.9%
.062-.125		Very Fine		0	0	
.125-.25		Fine		2	1.9	2.8
.25-.50		Medium		4	3.7	6.5
.50-1.0		Coarse		9	8.4	14.9
1.0-2.0		Very Coarse		4	3.7	17.7% 18.6
2.0-4.0		Very Fine		2	1.9	20.5
4.0-8.0		Fine		8	7.4	27.9
8.0-16	.08-0.6	Medium		15	14	41.9
16-32	0.6-1.3	Coarse		28	26	67.9
32-64	1.3-2.5	Very Coarse		20	18.7	68% 86.6
64-128	2.5-5.0	Small		10	9.3	95.9
128-256	5-10	Large		4	3.7	13% 99.6
256-512	10-20	Small				
512-1024	20-40	Medium				
1024-2048	40-80	Large				
2048-4096	80-160	Very Large				0%

GRAVEL (4)

Total Number of Samples.... 107

PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____

Exp. No. | Speed | f | Subject

Note: concrete on left bank

Rech 4 : 30-70

PEBBLE COUNT

Size Range		Class Name	Dot & Dash Count : = 3, - = 9	Tot. No.	% of Tot.	Cum %
Metric-mm	Inches					
Less .062		Silt/Clay		1	1.1	1.9%
.062-.125		Very Fine		0		
.125-.25		Fine		1	1	2
.25-.50		Medium	SAND	6	5.7	7.7
.50-1.0		Coarse		7	6.6	14.3
1.0-2.0		Very Coarse		2	1.9	15.2%
2.0-4.0		Very Fine		3	2.9	16.2
4.0-8.0		Fine		2	1.9	19.1
8.0-16	.08-0.5	Medium	GRAVEL	5	4.8	21.0
16-32	0.6-1.3	Coarse		26	25	25.8
32-64	1.3-2.5	Very Coarse		41	39	50.8
64-128	2.5-5.0	Small	COBBLE	7	6.6	73.6%
128-256	5-10	Large		2	1.9	89.8
256-512	10-20	Small		2	1.9	96.4
512-1024	20-40	Medium	BOULDERS			100.2
1024-2048	40-80	Large				
2048-4096	80-160	Very Large				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 + Rowler.

PEBBLE COUNT

Size Range		Class Name	Dot & Dash Count :: = 3, :: = 9	Tot. No.	% of Tot.	Cum %
Metric-mm	Inches					
Less .062		Silt/Clay	0	4	3.8	3.8%
.062-.125		Very Fine		0	0	
.125-.25		Fine	0	2	1.9	5.7
.25-.50		Medium		0	0	
.50-1.0		Coarse	1	15	14.3	20.0
1.0-2.0		Very Coarse	1	5	4.7	20.9% 24.7
2.0-4.0		Very Fine	1	7	6.6	31.3
4.0-8.0		Fine	1	9	8.5	39.8
8.0-16	.08-0.6	Medium	1	13	12.4	53.2
16-32	0.6-1.3	Coarse	1 1	20	19	72.2
32-64	1.3-2.5	Very Coarse	1	8	7.6	54.1% 79.8
64-128	2.5-5.0	Small	1	12	11	90.8
128-256	5-10	Large	1	9	8.5	19.5% 99.3
256-512	10-20	Small		1	.9	100.2
512-1024	20-40	Medium				
1024-2048	40-80	Large				
2048-4096	80-160	Very Large				.9%

Total Number of Samples.... 105

PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____
Exp.No. | Speed | f # | Subject _____

Reach 6 : Above Rector Rd 50-50

PEBBLE COUNT

Size Range		Class Name	Dot & Dash Count :: = 3, :: = 9	Tot. No.	% of Tot.	Cum %
Metric-mm	Inches					
Less .062		Silt/Clay		0		0
.062-.125		Very Fine		0	0	
.125-.25		Fine		3	2.6	2.6
.25-.50		Medium	☐	7	6.2	8.8
.50-1.0		Coarse	☒☒	21	18.6	27.4
1.0-2.0		Very Coarse	☒::	11	9.7	37.1% 37.1
2.0-4.0		Very Fine	☒	10	8.8	45.9
4.0-8.0		Fine	☒	9	7.9	53.8
8.0-16	.08-0.6	Medium	☒:	12	10.6	64.4
16-32	0.6-1.3	Coarse	☒☐	17	15	79.4
32-64	1.3-2.5	Very Coarse	☒::	15	13.3	55.6% 92.7
64-128	2.5-5.0	Small	:	2	1.7	94.4
128-256	5-10	Large	::	4	3.5	5.2% 97.9
256-512	10-20	Small	::	2	1.7	99.6
512-1024	20-40	Medium				
1024-2048	40-80	Large				
2048-4096	80-160	Very Large				1.7%

GRAVEL (4)

Total Number of Samples.... 1/3

PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____

Exp.No. | Speed | f # | Subject

#7

40-60 Below Confluence

PEBBLE COUNT

Size Range	Class	Dot & Dash Count	Tot.	% of	Cum
Metric-mm	Inches	Name	:: = 3, :: = 9	No.	Tot. %
Less .062		Silt/Clay	•	1	.8
.062-.125		Very Fine	••	3	2.5
.125-.25		Fine	1•	5	4.2
.25-.50		Medium	••	6	5
.50-1.0		Coarse	⊠•	16	13.5
1.0-2.0		Very Coarse	••	4	3.3

SAND

2.0-4.0		Very Fine	⊠	10	8.5
4.0-8.0		Fine	••	4	3.4
8.0-16	.08-0.5	Medium	⊠	7	5.9
16-32	0.6-1.3	Coarse	⊠••	15	12.7
32-64	1.3-2.5	Very Coarse	⊠⊠•	22	18.6

GRAVEL

64-128	2.5-5.0	Small	⊠⊠•	21	17.8
128-256	5-10	Large	••	4	3.4

COBBLE

256-512	10-20	Small			
512-1024	20-40	Medium			
1024-2048	40-80	Large			
2048-4096	80-160	Very Large			

BOULDERS

0%

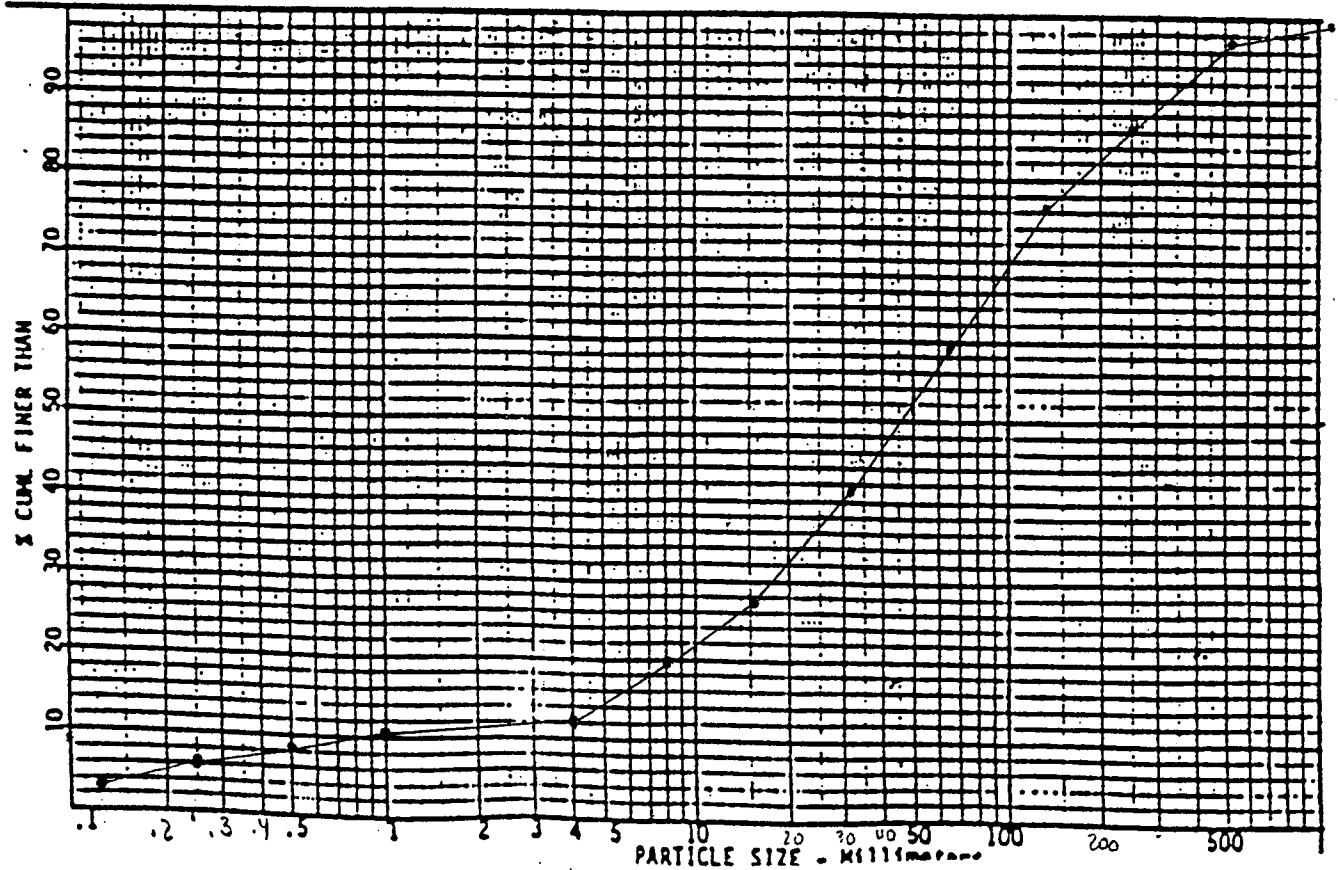
Total Number of Samples.... 118 115

 PHOTOGRAPHIC NOTES: Photographer _____ Date ____/____/____
 Exp. No. | Speed | f | # | Subject _____

PEBBLE COUNT

ite / / Party:
 Site/Reach: **REACH 1 (BELOW OUTFALL AT HEADWATERS)**

Metric mm	Inches	Particle	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum
less - .062		SILT/CLAY												
.062 - .125		Very FINE												
.125 - .25		FINE												
.25 - .50		MEDIUM												
.50 - 1.0		COARSE												
1.0 - 2	.04 - .08	Very CRSE												
2 - 4	.08 - .16	Very FINE												
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	Very CRSE												
48 - 64	1.9 - 2.5													
64 - 96	2.5 - 3.8	SMALL												
96 - 128	3.8 - 5.0													
128 - 192	5.0 - 7.6	LARGE												
192 - 256	7.6 - 10													
256 - 384	10 - 15	SMALL												
384 - 512	15 - 20													
512 - 1024	20 - 40	MEDIUM												
1024 - 2048	40 - 80	LARGE												
2048 - 4096	80 - 160	Very LARGE												
Count Note: 30" 9" X			Totals....				Totals....				Totals....			

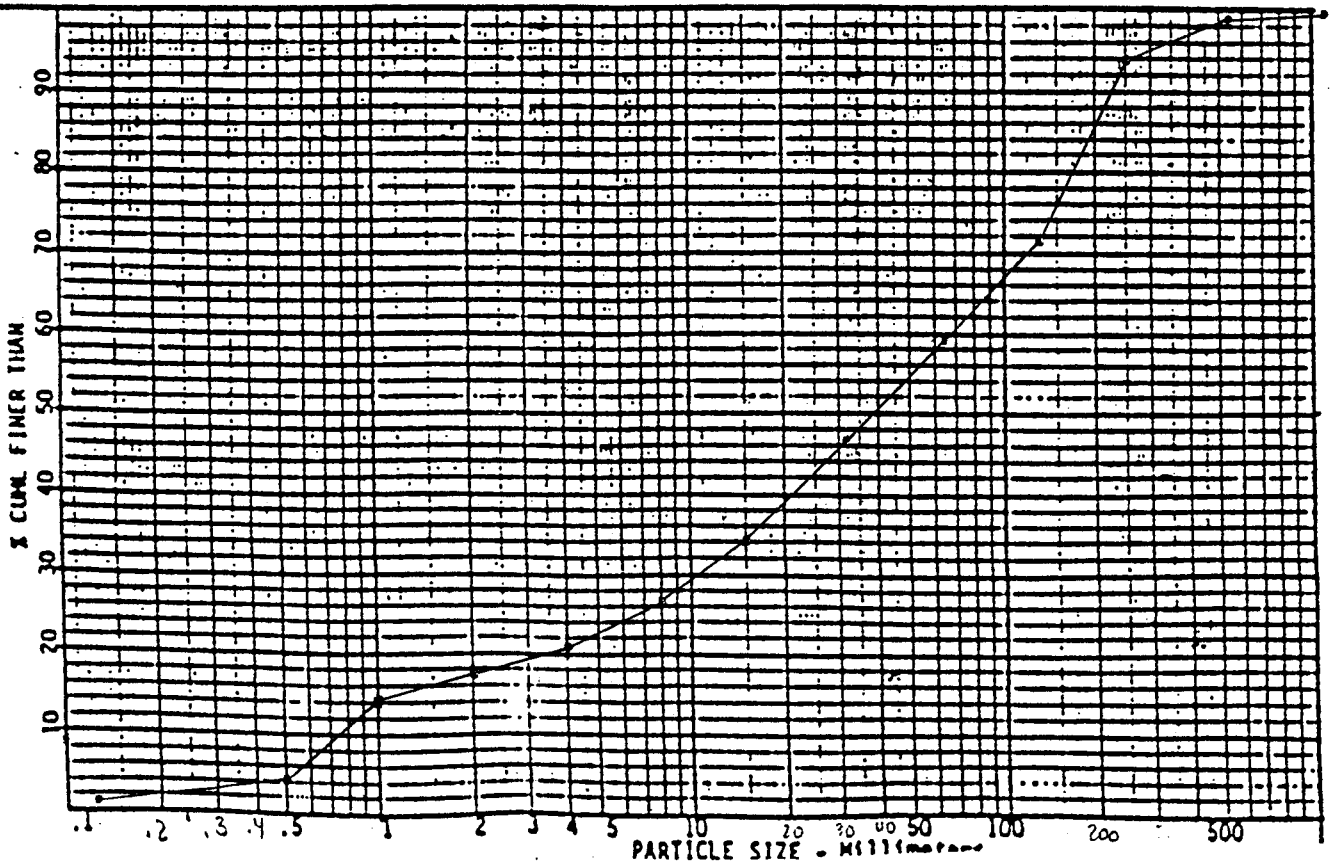


NORTHWEST

Date: 1/1/ Party: ASHD:

Site/Reach: REACH 2

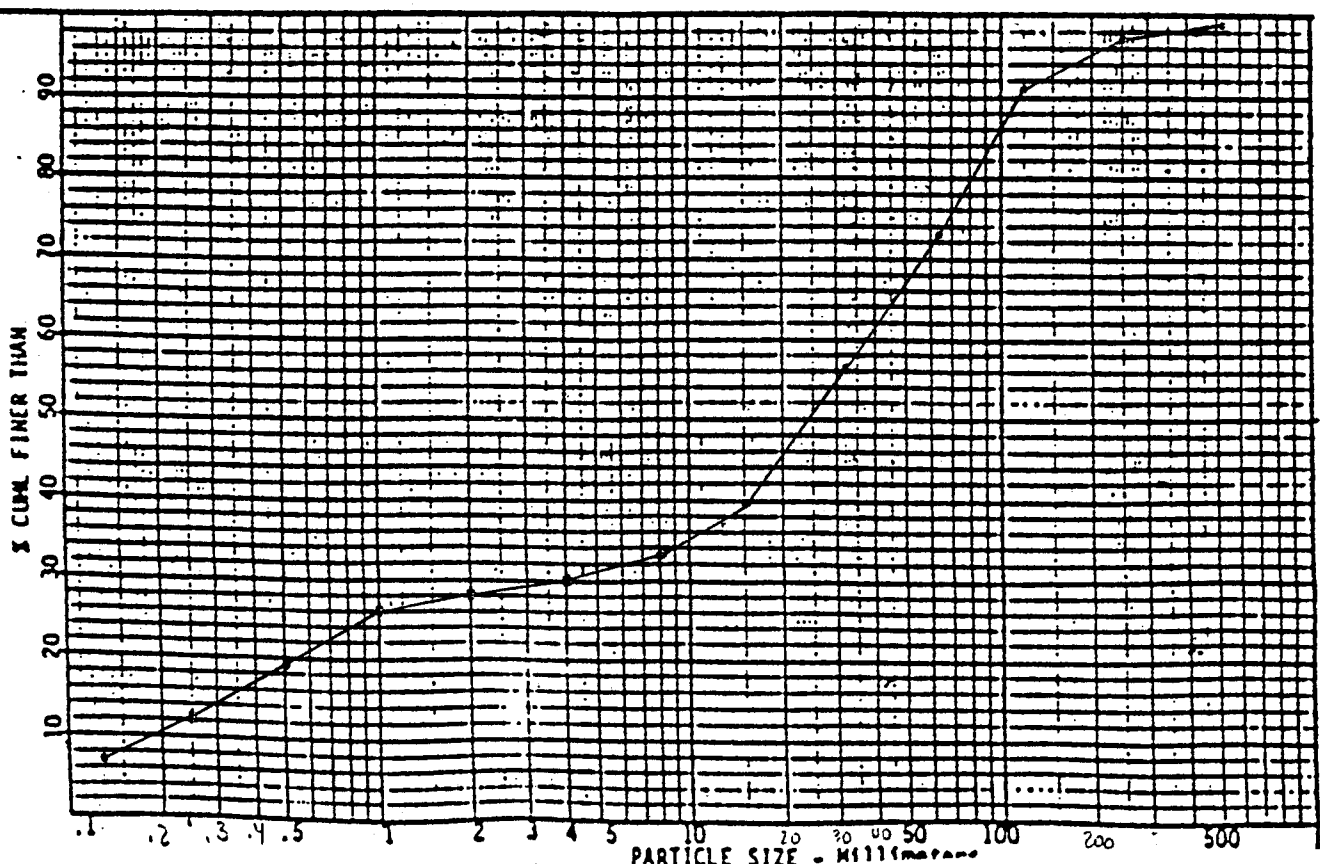
Metric mm	Inches	Particle	Item Count	Total	%Tot	%Cum	Item Count	Total	%Tot	%Cum	Item Count	Total	%Tot	%Cum
Less - .062		SILT/CLAY												
.062 - .125		Very FINE												
.125 - .25		FINE												
.25 - .50		MEDIUM												
.50 - 1.0		COARSE												
1.0 - 2	.04 - .08	Very CRSE												
2 - 4	.08 - .16	Very FINE												
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	Very CRSE												
48 - 64	1.9 - 2.5													
64 - 96	2.5 - 3.8	SMALL												
96 - 128	3.8 - 5.0													
128 - 192	5.0 - 7.6	LARGE												
192 - 256	7.6 - 10													
256 - 384	10 - 15	SMALL												
384 - 512	15 - 20													
512 - 1024	20 - 40	MEDIUM												
1024 - 2048	40 - 80	LARGE												
2048 - 4096	80 - 160	Very LARGE												
Count Note: 3=1 9=2			Totals....				Totals....				Totals....			



NORTHWEST

ate 1/1 Party: PEBBLE COW shd:
 Site/Reach: REACH 3

Metric mm	Inches	Particle	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum
Less - .062		SILT/CLAY												
.062 - .125		Very FINE												
.125 - .25		FINE												
.25 - .50		MEDIUM												
.50 - 1.0		COARSE												
1.0 - 2	.04 - .08	Very CRSE												
2 - 4	.08 - .16	Very FINE												
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	Very CRSE												
48 - 64	1.9 - 2.5													
64 - 96	2.5 - 3.8	SMALL												
96 - 128	3.8 - 5.0													
128 - 192	5.0 - 7.6	LARGE												
192 - 256	7.6 - 10													
256 - 384	10 - 15	SMALL												
384 - 512	15 - 20													
512 - 1024	20 - 40	MEDIUM												
1024 - 2048	40 - 80	LARGE												
2048 - 4096	80 - 160	Very LARGE												
Count Note: 30" 9" X			Totals....				Totals....				Totals....			

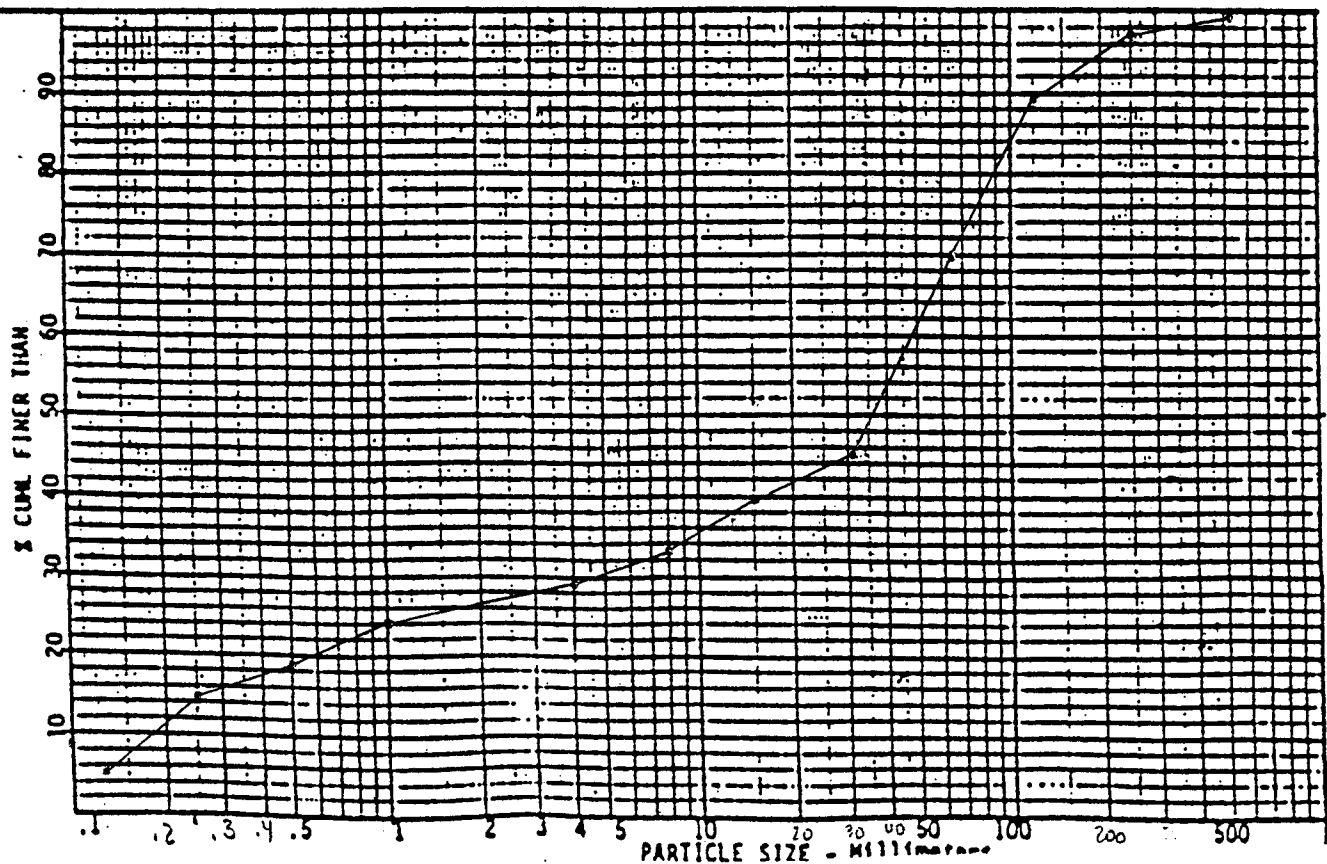


NORTHWEST

ite / / Party: Wshd: _____

Site/Reach: **REACH 4**

Metric mm	Inches	Particle	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum
less - .062		SILT/CLAY												
.062 - .125		Vry FINE												
.125 - .25		FINE												
.25 - .50		MEDIUM												
.50 - 1.0		COARSE												
1.0 - 2	.04 - .08	Vry CRSE												
2 - 4	.08 - .16	Vry FINE												
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												
96 - 128	3.8 - 5.0													
128 - 192	5.0 - 7.6	LARGE												
192 - 256	7.6 - 10													
256 - 384	10 - 15	SMALL												
384 - 512	15 - 20													
512 - 1024	20 - 40	MEDIUM												
1024 - 2048	40 - 80	LARGE												
2048 - 4096	80 - 160	Vry LARGE												
Count Note: 3=" 9="			Totals....				Totals....				Totals....			



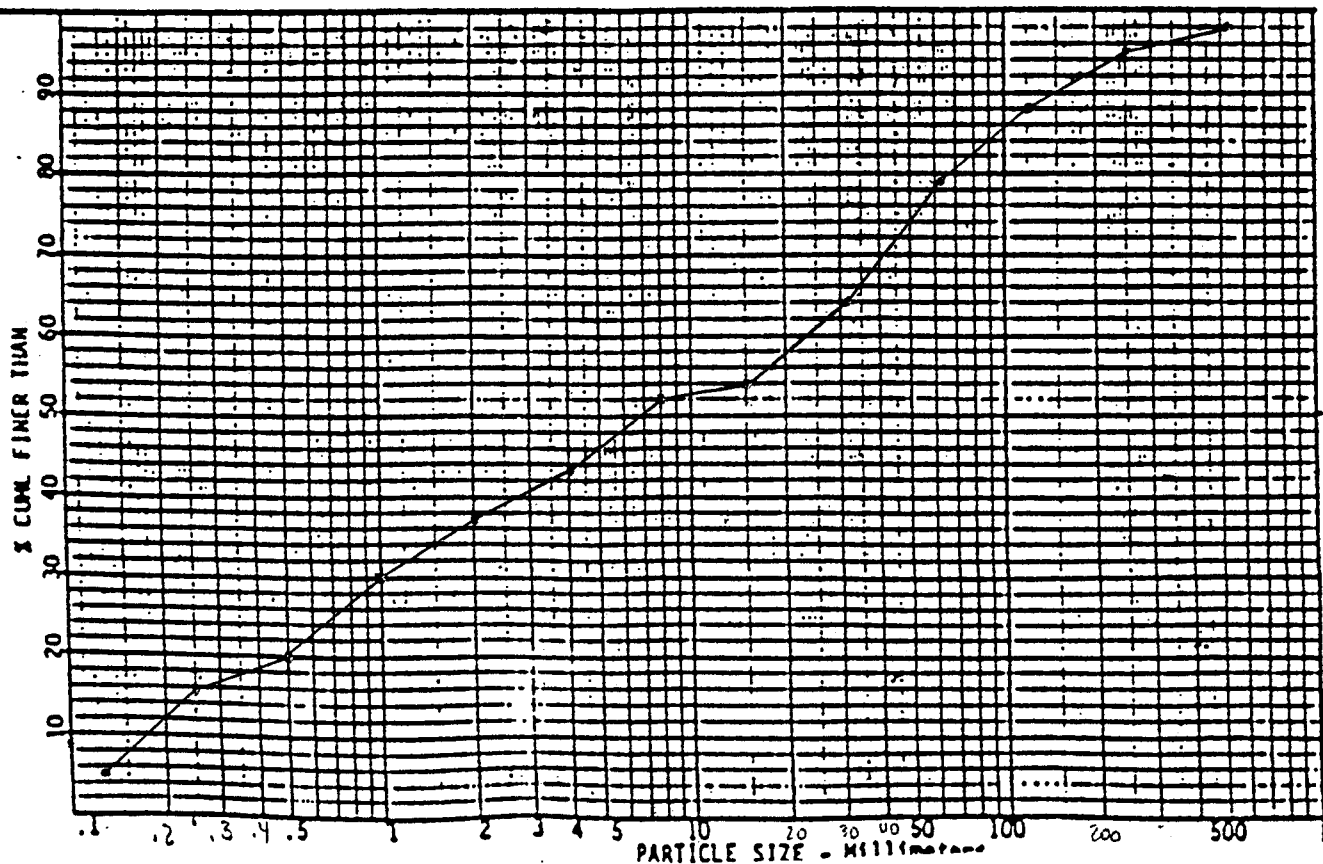
NORTHWEST

PEBBLE COW

ite / / Party: and:

Site/Reach: **REACH 5**

Metric mm	Inches	Particle	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum
Less- .062		SILT/CLAY												
.062- .125		Very FINE												
.125- .25		FINE												
.25 - .50		MEDIUM												
.50 - 1.0		COARSE												
1.0 - 2	.04 - .08	Very CRSE												
2 - 4	.08 - .16	Very FINE												
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	Very CRSE												
48 - 64	1.9 - 2.5													
64 - 96	2.5 - 3.8	SMALL												
96 - 128	3.8 - 5.0													
128 - 192	5.0 - 7.6	LARGE												
192 - 256	7.6 - 10													
256 - 384	10 - 15	SMALL												
384 - 512	15 - 20													
512 - 1024	20 - 40	MEDIUM												
1024 - 2048	40 - 80	LARGE												
2048 - 4096	80 - 160	Very LARGE												
Count Note: 3= 9=			Totals....				Totals....				Totals....			

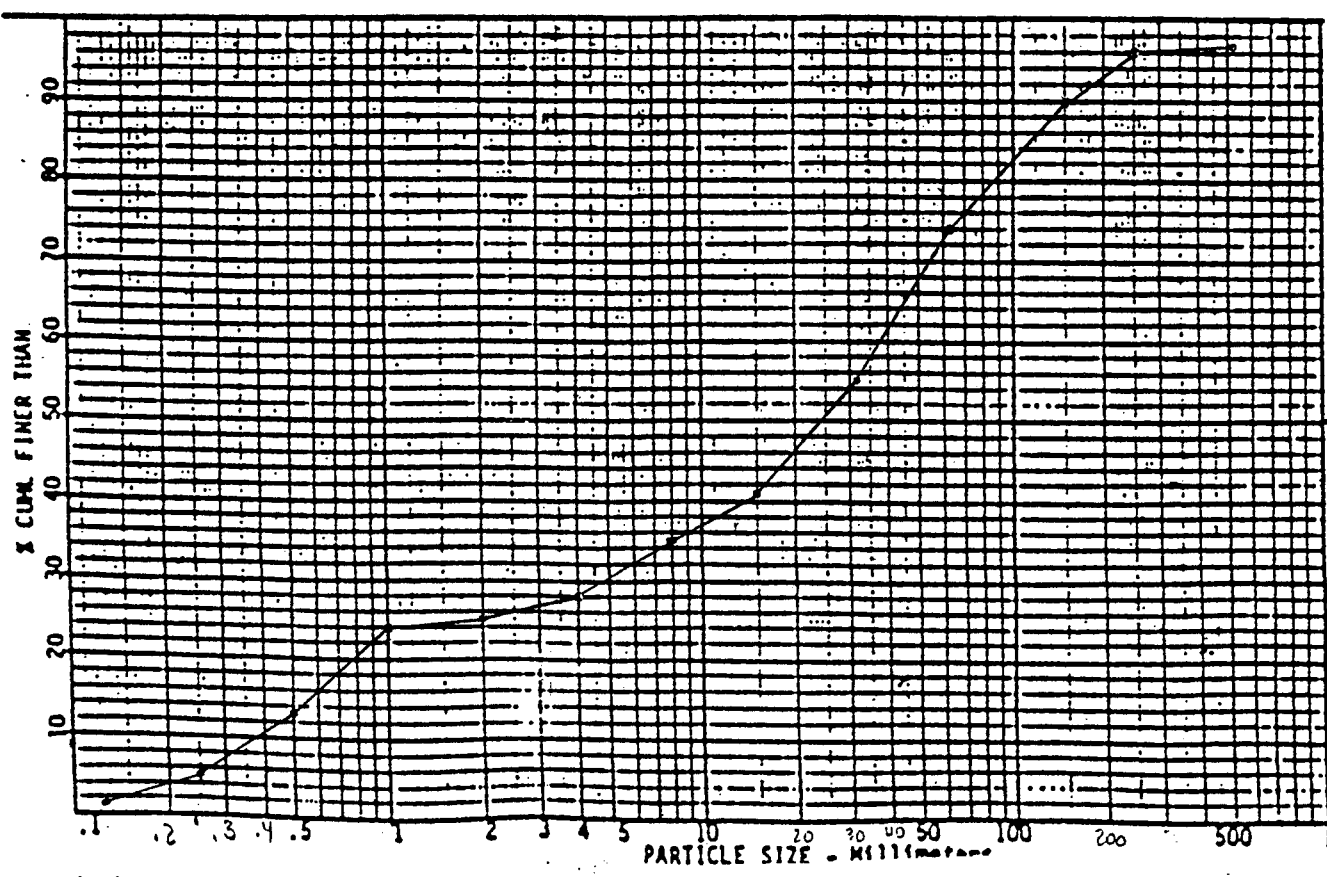


NORTHWEST

to / / Party: crshd:

Site/Reach: **REACH 4**

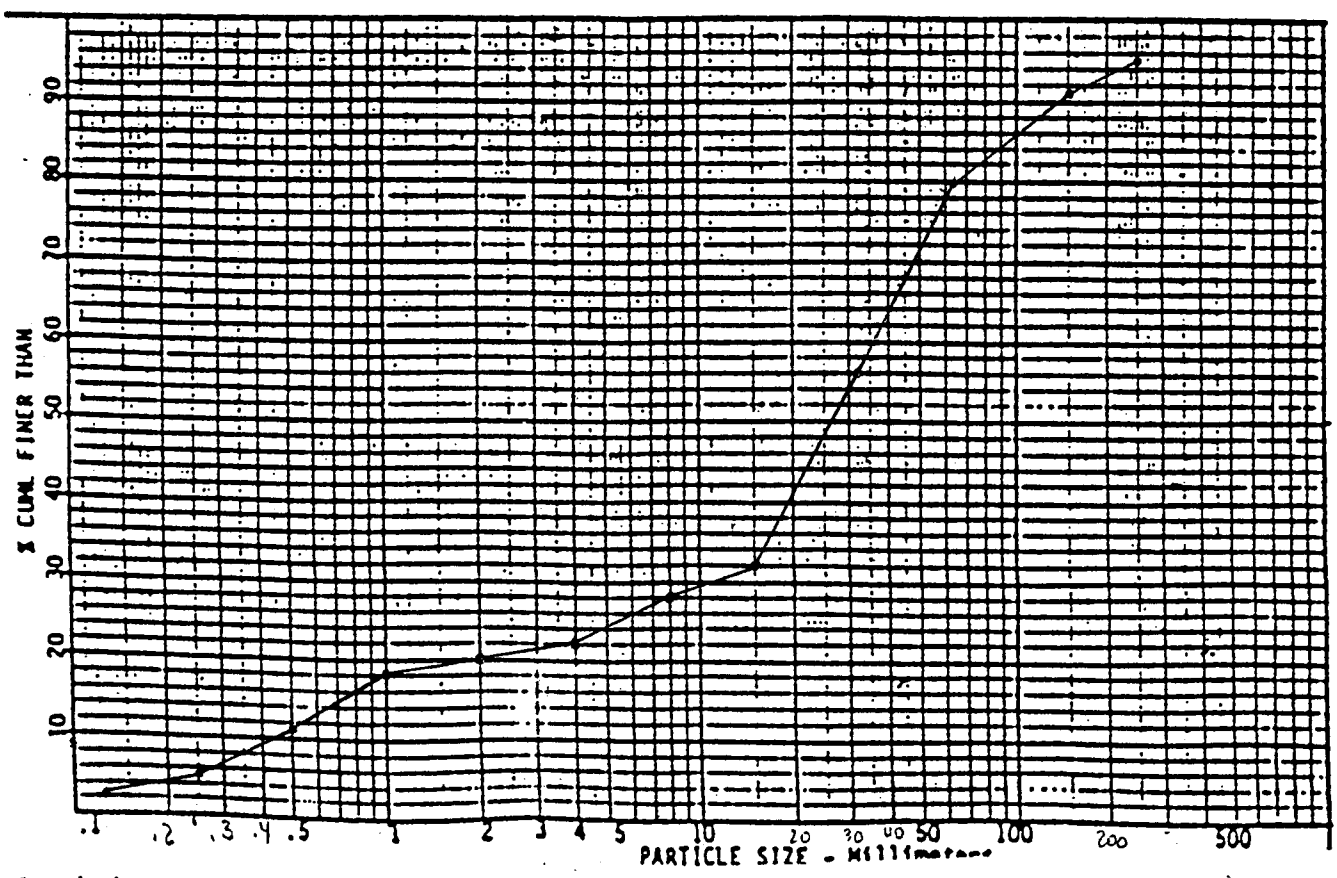
Metric mm	Inches	Particle	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum
less - .062		SILT/CLAY												
.062 - .125		Very FINE												
.125 - .25		FINE												
.25 - .50		MEDIUM												
.50 - 1.0		COARSE												
.0 - 2	.04 - .08	Very CRSE												
2 - 4	.08 - .16	Very FINE												
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	Very CRSE												
48 - 64	1.9 - 2.5													
64 - 96	2.5 - 3.8	SMALL												
96 - 128	3.8 - 5.0													
128 - 192	5.0 - 7.6	LARGE												
192 - 256	7.6 - 10													
256 - 384	10 - 15	SMALL												
384 - 512	15 - 20													
512 - 1024	20 - 40	MEDIUM												
1024 - 2048	40 - 80	LARGE												
2048 - 4096	80 - 160	Very LARGE												
Count Note: 30" 90"			Totals....				Totals....				Totals....			



NORTHWEST

Date: / / Party: PEBBLE COV
 Site/Reach: REACH 7

Metric mm	Inches	Particle	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum
Less - .062		SILT/CLAY												
.062 - .125		Very FINE												
.125 - .25		FINE												
.25 - .50		MEDIUM												
.50 - 1.0		COARSE												
1.0 - 2	.04 - .08	Very CRSE												
2 - 4	.08 - .16	Very FINE												
4 - 6	.16 - .24													
6 - 8	.24 - .31	FINE												
8 - 12	.31 - .47													
12 - 16	.47 - .63	MEDIUM												
16 - 24	.63 - .94													
24 - 32	.94 - 1.26	COARSE												
32 - 48	1.26 - 1.9													
48 - 64	1.9 - 2.5	Very CRSE												
64 - 96	2.5 - 3.8													
96 - 128	3.8 - 5.0	SMALL												
128 - 192	5.0 - 7.6													
192 - 256	7.6 - 10	LARGE												
256 - 384	10 - 15													
384 - 512	15 - 20	SMALL												
512 - 1024	20 - 40	MEDIUM												
1024 - 2048	40 - 80	LARGE												
2048 - 4096	80 - 160	Very LARGE												
Count Note: 3= 9= 24=			Totals....				Totals....				Totals....			



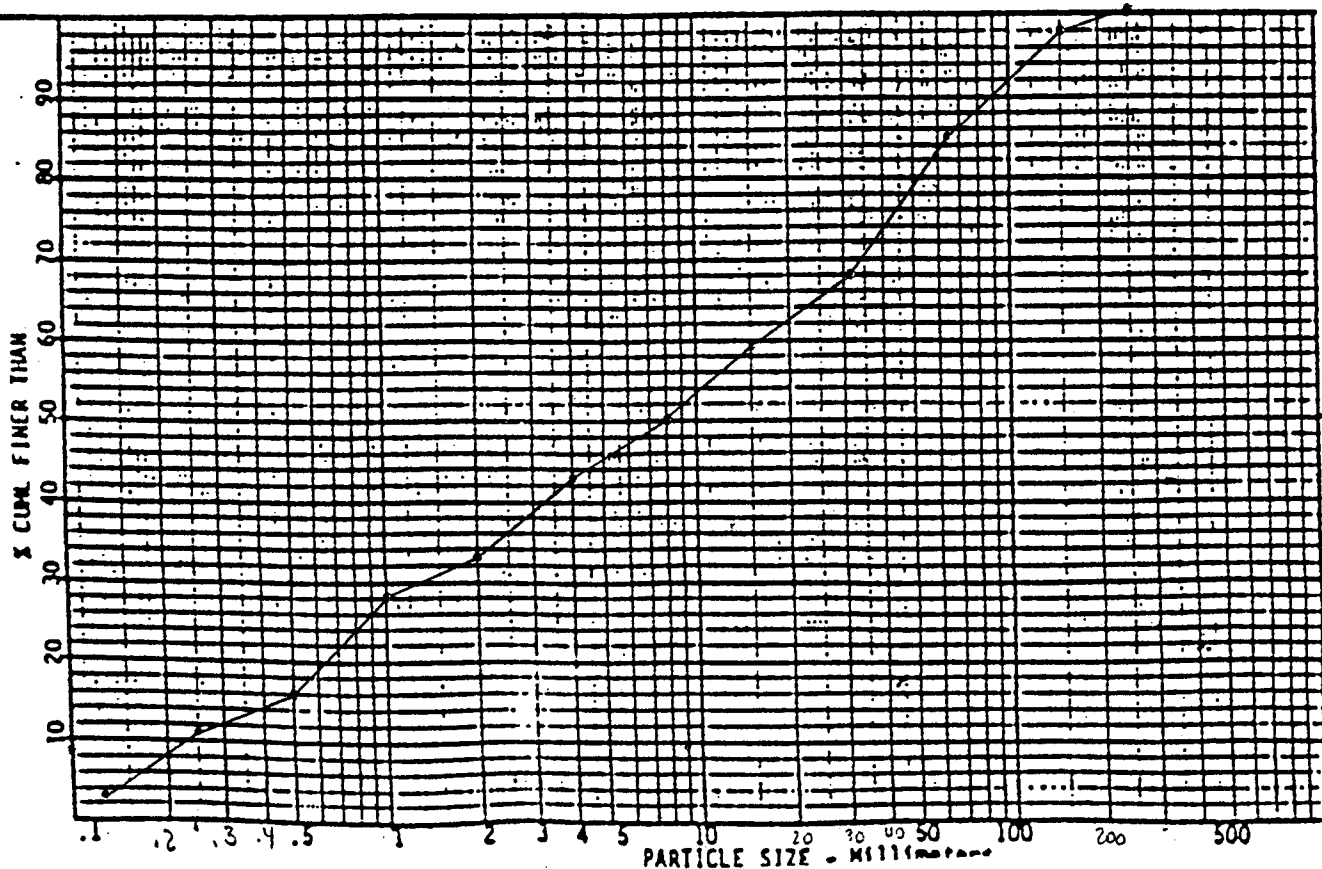
NORTHWEST

PEBBLE COUNT

DATE 1/1/ Party: Wshd:

Site/Reach: REACH 1 (SUBURBAN GREEN TO KIDRAP)

Metric mm	Inches	Particle	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum
Less - .062		SILT/CLAY												
.062 - .125		Very FINE												
.125 - .25		FINE												
.25 - .50		MEDIUM												
.50 - 1.0		COARSE												
1.0 - 2	.04 - .08	Very COARSE												
2 - 4	.08 - .16	Very FINE												
4 - 6	.16 - .24	FINE												
6 - 8	.24 - .31													
8 - 12	.31 - .47													
12 - 16	.47 - .63	MEDIUM												
16 - 24	.63 - .94	COARSE												
24 - 32	.94 - 1.26													
32 - 48	1.26 - 1.9	Very COARSE												
48 - 64	1.9 - 2.5													
64 - 96	2.5 - 3.8													
96 - 128	3.8 - 5.0	SMALL												
128 - 192	5.0 - 7.6	LARGE												
192 - 256	7.6 - 10													
256 - 384	10 - 15	SMALL												
384 - 512	15 - 20													
512 - 1024	20 - 40													
1024 - 2048	40 - 80	LARGE												
2048 - 4096	80 - 160	Very LARGE												
Count Note: 3" = 9" = 18"			Totals....				Totals....				Totals....			



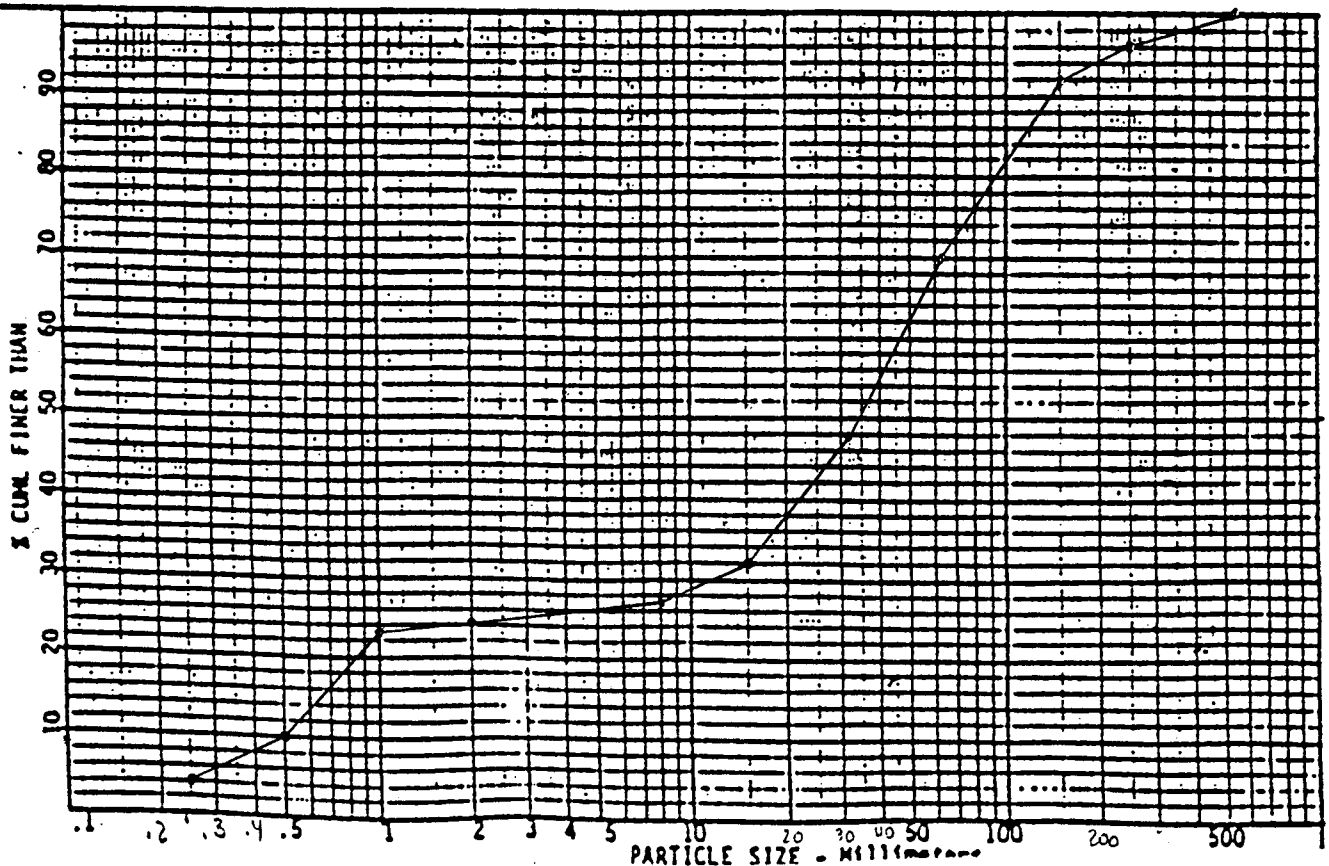
NORTHWEST

PEBBLE COW

Site: 1/1/ Party: and:

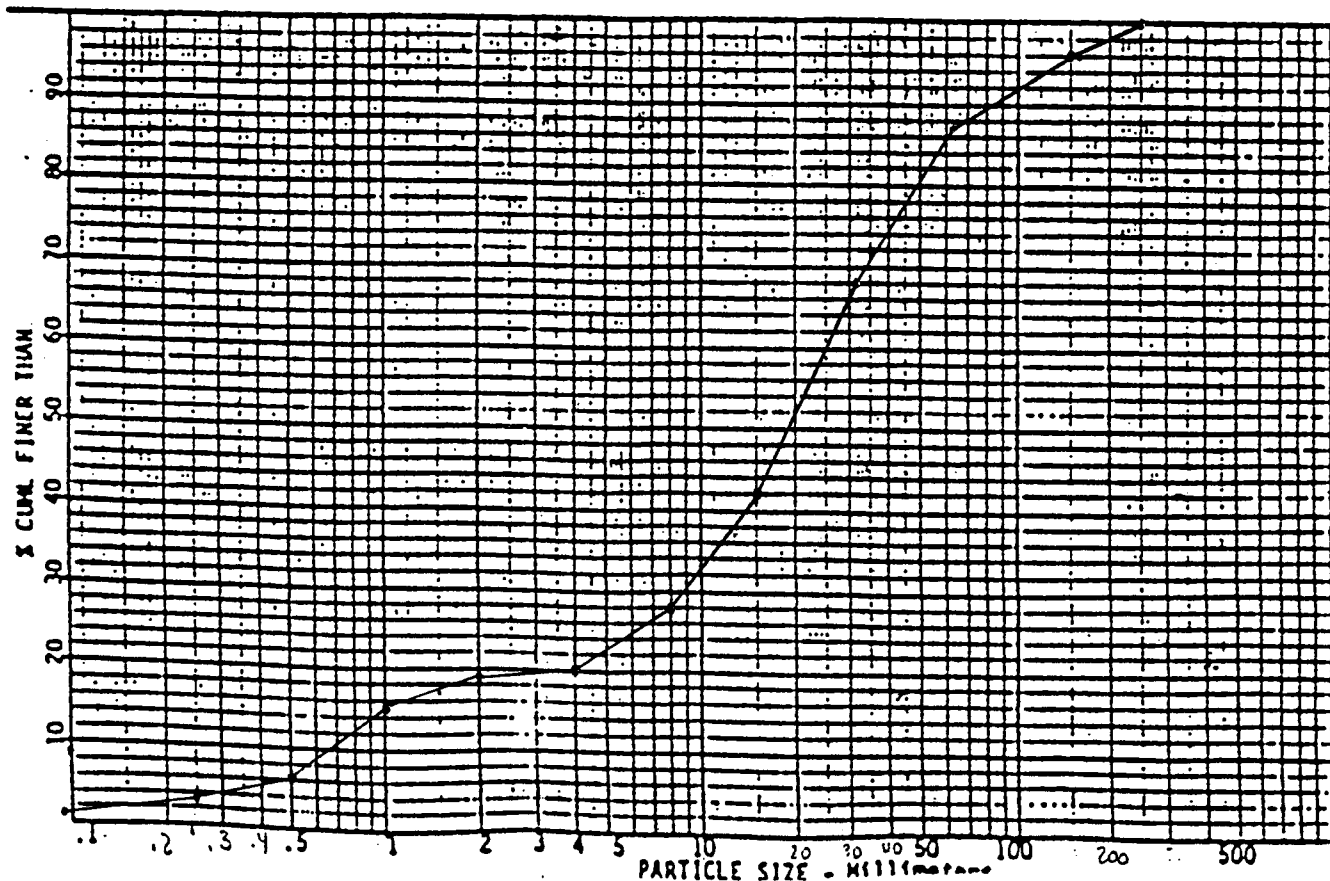
Site/Reach: REACH 2 (ABOVE GABIONS TO CHECK DAM)

Metric mm	Inches	Particle	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum
Less - .062		SILT/CLAY												
.062 - .125		Very FINE												
.125 - .25		FINE												
.25 - .50		MEDIUM												
.50 - 1.0		COARSE												
1.0 - 2	.04 - .08	Very CRSE												
2 - 4	.08 - .16	Very FINE												
4 - 6	.16 - .24	FINE												
6 - 8	.24 - .31													
8 - 12	.31 - .47	MEDIUM												
12 - 16	.47 - .62													
16 - 24	.62 - .94	COARSE												
24 - 32	.94 - 1.26													
32 - 48	1.26 - 1.9	Very CRSE												
48 - 64	1.9 - 2.5													
64 - 96	2.5 - 3.8	SMALL												
96 - 128	3.8 - 5.0													
128 - 192	5.0 - 7.6	LARGE												
192 - 256	7.6 - 10													
256 - 384	10 - 15	SMALL												
384 - 512	15 - 20													
512 - 1024	20 - 40	MEDIUM												
1024 - 2048	40 - 80	LARGE												
2048 - 4096	80 - 160	Very LARGE												
Count Note: 3=" 9="			Totals....				Totals....				Totals....			



NORTHWEST

PEBBLE COUNT													
Date: <u>8/1/1</u>		Party: _____		nd: _____									
Site/Reach: <u>REACH 3</u>		<u>40/60</u>											
SPIC AM	Inches	Particle	Item Count	Total	ΣTot	ΣCum							
ss - .062		SILT/CLAY											
.062 - .125		Very FINE											
.125 - .25		FINE											
.25 - .50		MEDIUM											
.50 - 1.0		COARSE											
0 - 2	.04 - .08	Very CRSE											
2 - 4	.08 - .16	Very FINE											
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	Very CRSE											
48 - 64	1.9 - 2.5												
64 - 96	2.5 - 3.8	SMALL											
96 - 128	3.8 - 5.0												
128 - 192	5.0 - 7.6	LARGE											
192 - 256	7.6 - 10												
256 - 384	10 - 15	SMALL											
384 - 512	15 - 20												
512 - 1024	20 - 40	MEDIUM											
1024 - 2048	40 - 80	LARGE											
2048 - 4096	80 - 160	Very LARGE											
Count Note: 30" 9" X							Totals....						



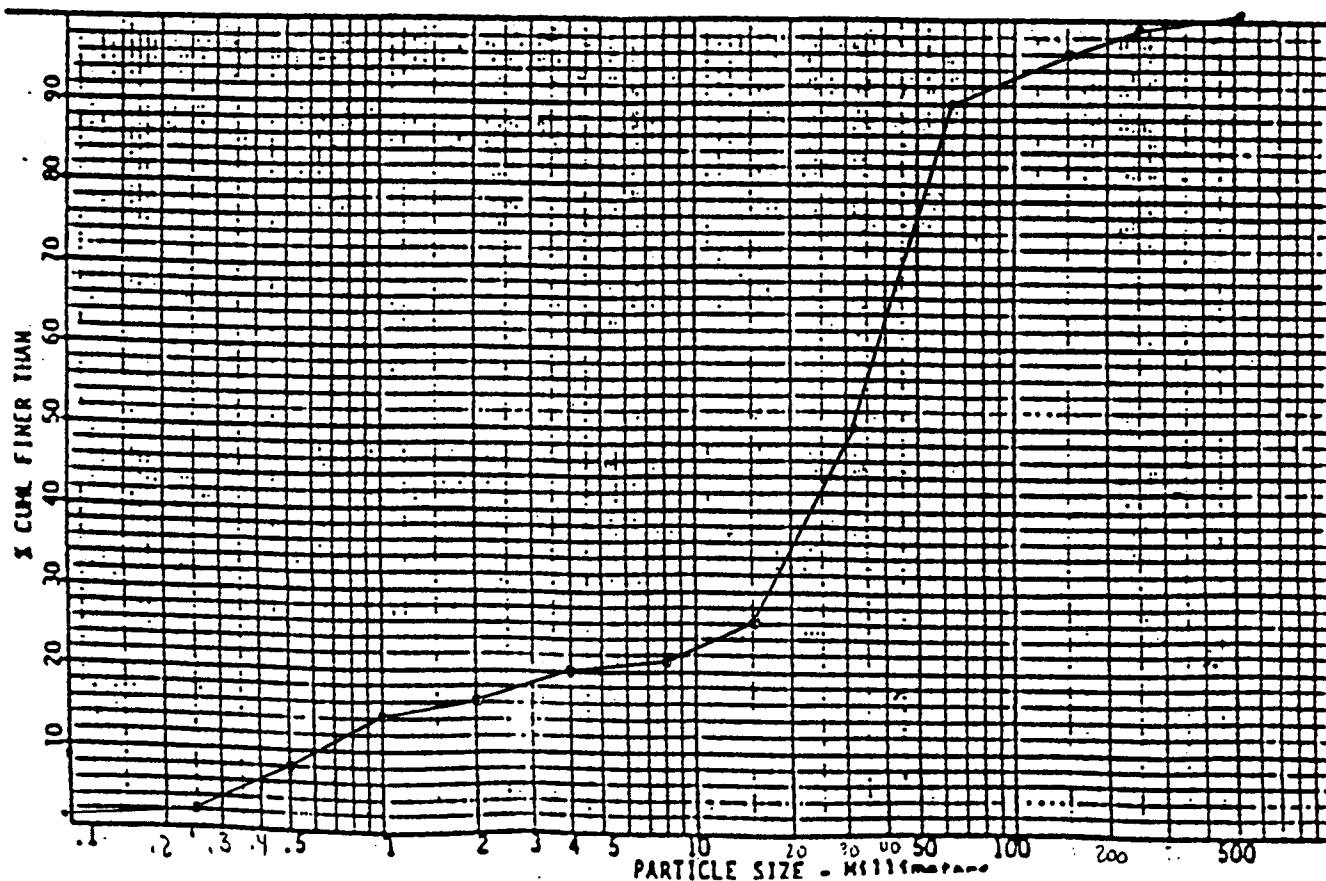
0 8-1-1 Party: _____ and: _____
Site/Reach: REACH 4 30-70

0 8-1-1 Party: _____ and: _____
Site/Reach: REACH 4 30-70

0 8-1-1 Party: _____ and: _____
Site/Reach: REACH 4 30-70

0 8-1-1 Party: _____ and: _____
Site/Reach: REACH 4 30-70

Spec No	Inches	Particle	Item Count	Total	%Tot	%Cum	Item Count	Total	%Tot	%Cum	Item Count	Total	%Tot	%Cum
45- .062		SILT/CLAY												
.062- .125		Very FINE												
.25- .25		FINE												
.5 - .50		MEDIUM												
.50 - 1.0		COARSE												
.0 - 2	.04 - .08	Very CRSE												
2 - 4	.08 - .16	Very FINE												
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	Very CRSE												
48 - 64	1.9 - 2.5													
64 - 96	2.5 - 3.8	SMALL												
96 - 128	3.8 - 5.0													
128 - 192	5.0 - 7.6	LARGE												
192 - 256	7.6 - 10													
256 - 384	10 - 15	SMALL												
384 - 512	15 - 20													
512 - 1024	20 - 40	MEDIUM												
1024 - 2048	40 - 80	LARGE												
2048 - 4096	80 - 160	Very LARGE												
Count Note: 3=" 9="			Totals....				Totals....				Totals....			



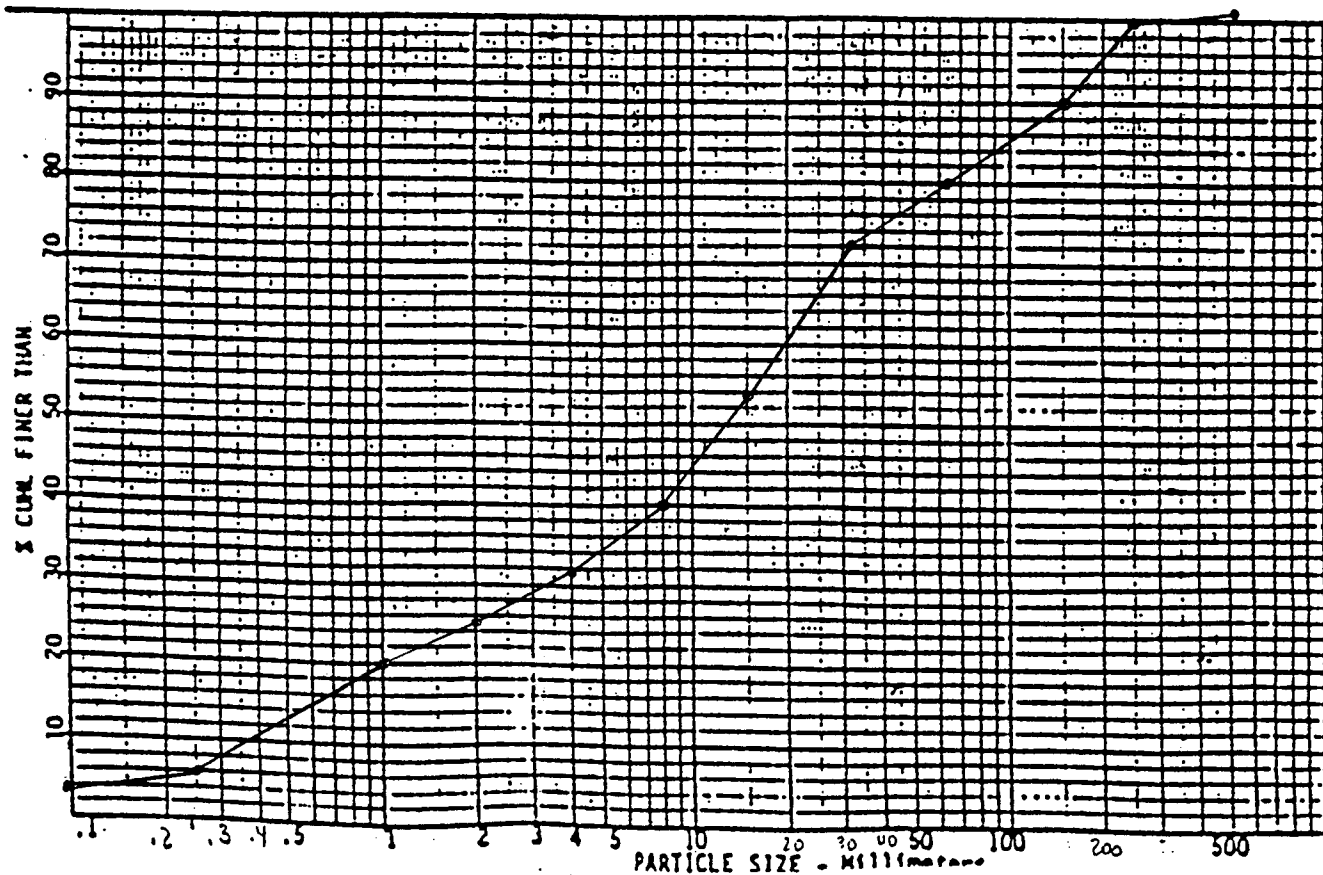
NORTHWEST

PEBBLE COUNT

Party: _____ and: _____

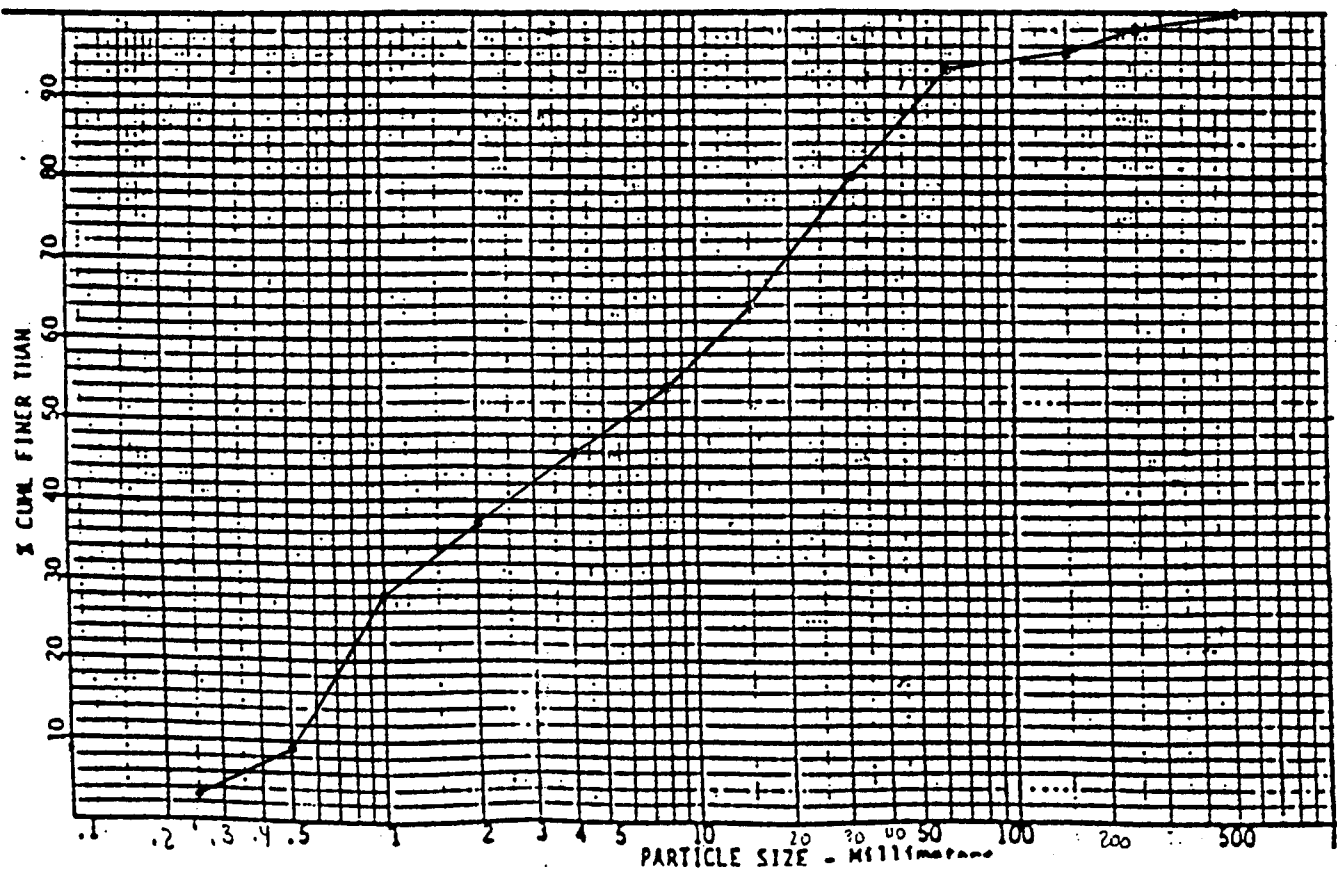
Site/Reach: **REACH 5 50-50**

Size mm	Inches	Particle	Item Count	Total	% Tot	% Cum	Item Count	Total	% Tot	% Cum	Item Count	Total	% Tot	% Cum
ss - .062		SILT/CLAY												
.062 - .125		Very FINE												
.25 - .50		FINE												
.50 - 1.0		MEDIUM												
1.0 - 2.0		COARSE												
2.0 - 4.0	.04 - .08	Very CRSE												
4.0 - 6.0	.08 - .16	Very FINE												
6.0 - 8.0	.16 - .24	FINE												
8.0 - 12.0	.24 - .31													
12.0 - 16.0	.31 - .47	MEDIUM												
16.0 - 24.0	.47 - .63	COARSE												
24.0 - 32.0	.63 - .94													
32.0 - 48.0	.94 - 1.26													
48.0 - 64.0	1.26 - 1.9	Very CRSE												
64.0 - 96.0	1.9 - 2.5													
96.0 - 128.0	2.5 - 3.8	SMALL												
128.0 - 192.0	3.8 - 5.0													
192.0 - 256.0	5.0 - 7.6	LARGE												
256.0 - 384.0	7.6 - 10													
384.0 - 512.0	10 - 15	SMALL												
512.0 - 1024.0	15 - 20													
1024.0 - 2048.0	20 - 40	MEDIUM												
2048.0 - 4096.0	40 - 80	LARGE												
4096.0 - 8192.0	80 - 160	Very LARGE												
Count Note: 3 = 1 9 = 2			Totals....				Totals....				Totals....			



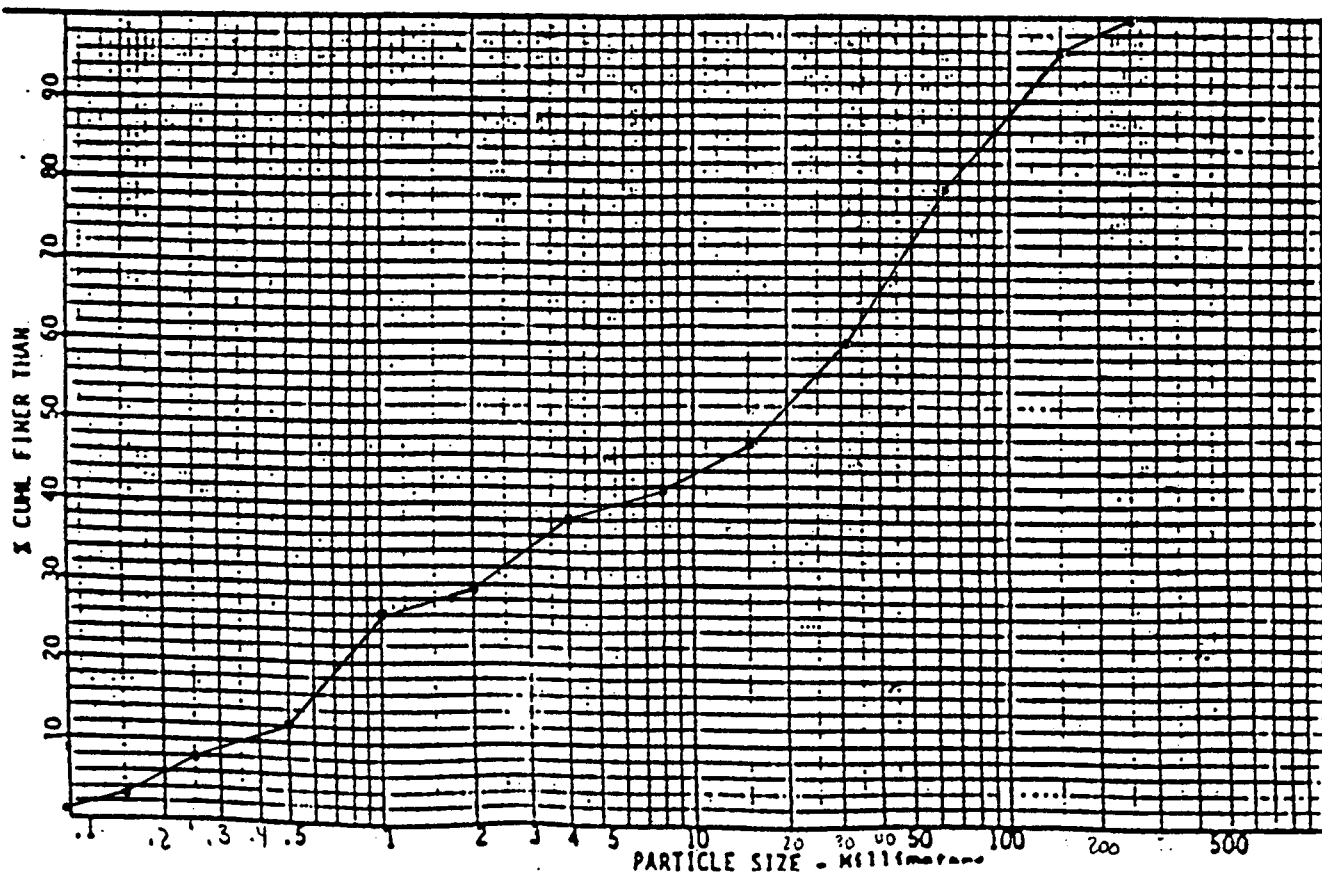
NORTHWEST

PEBBLE COUNT																	
Date: 8/1/1		Party: W		id:													
Site/Reach: REACH 6 Above Rafter Co. 50-50																	
Metric mm	Inches	Particle	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum			
75 - .062		SILT/CLAY															
.062 - .125		Very FINE															
.125 - .25		FINE															
.25 - .50		MEDIUM															
.50 - 1.0		COARSE															
1.0 - 2	.04 - .08	Very COARSE															
2 - 4	.08 - .16	Very FINE															
4 - 6	.16 - .24	FINE															
6 - 8	.24 - .31																
8 - 12	.31 - .47																
12 - 16	.47 - .63	MEDIUM															
16 - 24	.63 - .94	COARSE															
24 - 32	.94 - 1.26																
32 - 48	1.26 - 1.9	Very COARSE															
48 - 64	1.9 - 2.5																
64 - 96	2.5 - 3.8																
96 - 128	3.8 - 5.0	SMALL															
128 - 192	5.0 - 7.6																
192 - 256	7.6 - 10	LARGE															
256 - 384	10 - 15	SMALL															
384 - 512	15 - 20																
512 - 1024	20 - 40																
1024 - 2048	40 - 80	LARGE															
2048 - 4096	80 - 160	Very LARGE															
Count Note: 3 = 1/2 9 = 3/4			Totals....				Totals....				Totals....						



NORTHWEST

PEBBLE COUNT														
Q. # <u>1</u> / <u>1</u> Party: <u>V</u>		d: <u></u>												
Site/Reach: <u>Reach 7 40-60/Below CONFLUENCE</u>														
ERIC mm	Inches	Particle	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum	Item Count	Total	ΣTot	ΣCum
ss - .062		SILT/CLAY												
.062 - .125		Very FINE												
.125 - .25		FINE												
.25 - .50		MEDIUM												
.50 - 1.0		COARSE												
0 - 2	.04 - .08	Very CRSE												
2 - 4	.08 - .16	Very FINE												
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	Very CRSE												
48 - 64	1.9 - 2.5													
64 - 96	2.5 - 3.8	SMALL												
96 - 128	3.8 - 5.0													
128 - 192	5.0 - 7.6	LARGE												
192 - 256	7.6 - 10													
256 - 384	10 - 15	SMALL												
384 - 512	15 - 20													
512 - 1024	20 - 40	MEDIUM												
1024 - 2048	40 - 80	LARGE												
2048 - 4096	80 - 160	Very LRGE												
Count Note: 3 = 1 9 = 10			Totals....				Totals....				Totals....			



STREAM BANK EROSION ASSESSMENT

STREAM BANK EROSION ASSESSMENT

Date: Dec 28 1994
 Project Name/Number: Spring Branch
 Investigators: 213
 Weather/Comments: Fair, 50% - No significant precip for 72 hrs
 Stream Segment Location: Mara Branch - Confluence to Timonium Road
 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

Location	Bh/Bfh	BA	BSP	SS	PS	CC	COMMENTS
$\Delta 24 - \Delta 25$ L	5'6"	M-H	H-M	M-H	H	10-30%	50% - variable CC
$\Delta 24 - \Delta 25$ R	8'6"	M-H	H-M	M-H	H	10%	top bank - very open good for bio den
$\Delta 25 - \Delta 26$ L	4.5/5.6	H	H	H	H	50%	
" " R	1.5-2'6"	M-L	L-M	M-H	H	50-60%	actively eroding @ 2W/C look @ class. 15' back
$\Delta 26 - \Delta 27$ R	2'6"	L-M	L-M	M-H	H	30%	some isolated areas of higher elevation
" " L	4.5/6"	M-H	M-H	M-H	H	30%	
$\Delta 27 - 28$ R	1-2'6"	L	L	L	L	10-30	bedrock, willow
" " L	3-5'6"	H-L	H-L	L	H	30-70	
$\Delta 28 - 29$ L	2-3'6"	L-M	L	M-H	M	30-70	
" " R	2-3'6"	L-M	L-M	M	M	40	
$\Delta 29 - 30 - L$	5-6'6"	M-H	M-H	M-H	H	20	1/2 of work is bed rating - are 1/2 is low even for high E
" " R	5'6"	M-H	H	M	H	10	top of bank erosion
$\Delta 30 - 31 - L$	4-5'	M-H	M	M	H	30	Some bedrock
" " R	"	"	"	"	"	"	Some rip
$\Delta 31 - 32$ L	2-3'6"	L-M	L-M			50-70	rip-rap (random)
" " R	"	L-M	L-M			"	
TriB Confluence to H3	8-9'6"	M	H	M-H	H	40	top bank erosion - some top has been periodically placed rip-rap
" " L	5-6'6"	M	M	M	H	40	some rip-rap spots
H3 - Light pole	1.5'6"	M-H	L-M	*	*	10	actively scouring @ top
" " L	"	"	"	"	"	0	
Light pole to Culvert	17'6"	M	H	H	H	10-70	top & top bank erosion
" " L	4.5'6"	L-M	L	M-H	H	70%	Culvert ratings change to: M-H, M-H,

+ tributary confluence w/ main channel to hollow back rd.

ADD photo locations map (ACT 1 EX COND)
 Delineation between T.O.B & TOC erosion to map

Note places for survey re top to 100

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

Location	Bh/Bfh	BA	BSP	SS	PS	CC	COMMENTS
Δ5- Δ6 L	5'	H	H	L	H	50	alternates high & low erosion w/ meanders
" " R	4'	M-H	M-H	L	H	60	see map - avg measurement
Δ6- MH L	1 1/4"	L	L	M	M	50-60	bars
Δ6- MH R	3 1/4"	H	M-H	M-H	M	50	actively undercut
MH- Δ7 L	4 1/4"	M-H	H	M-H	H	50	
MH- Δ7 R	2 5/4"	L	L	-	-	20	
Δ7 L	10 1/6"	H	H	M	H	40	bedrock - right near champion creek - avoided low contribution
Δ7 - just above SD	5 1/10"	M-H	H	M	H	30	
" " R	2 3/4"	L	L	M		30	
above SD- Δ8 L	3 3/4"	L	L	M	M		
" " R	2 1/4"	M	M-H	M	H	30-40	
Δ8- Δ9 L	56'	M	M	M	M	30	G channel + no entrapment, left
" R	5-6'	M	M	M	H	30	side bar top of bank this is under
Δ9- L							toe
" L							toe

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 BH/BFH - Bank Height/Bankfull Height ratio
 M - Moderate " BA - Bank Angle
 H - High " BSP - Bank Surface Protection
 PS - Particle size SS - Soil Stratification
 CC - Canopy Closure

Location	Bh/Bfh	BA	BSP	SS	PS	CC	COMMENTS
Confluence - 1st house down	6'-8 1/4"	M-H	H	M-H	H	30-40%	
SD - Δ24 L	10'-12 1/6"	H	H	M-H	H	30-40%	
SD - Δ24 R	2' 1/6"	L	L	M-H	H	10%	only midway to Δ24 - then doubt cut/severe erosion
Δ1 - 1st house backyard	6' 1/4"	H	H	M-H	H	0-10%	
Δ1 - church peg lot	1' 3/4"	L	L	M-H	H	50	bar
Δ2 - 2nd house	4' 5/6"	M-H	H	H	H	50	toe & top of bank E bedrock
" " (R)	4' 1/6"	L-M	L-M	H	H	50	bedrock outcrops
1st house - Δ3 L	2' 1/6"	L	L	M-H	H	50	bedrock outcrops
" " R	3' 1/4"	M-H	M-H	M-H	H	40	bar is active flow bank - old bank top of bank erosion also what is rated
Δ3 - sec 116 L	1'-3 1/34"	L-H	L-H	H	H	50	rating appears to be because bank heights
" " R	1'-3' "	"	"	"	"	"	
114 - Δ4 L	1' 1/6"	L	L	M-H	M	40	
" " R	"	L	L	M-H	M	40	eroding face of midchannel bar
MH - MH R	12' 1/6"	L	L	M	M+	50	
Δ" " L	2-3'	L-M	L-M	M	M+	50	
MH - Δ5 R	3' 1/6"	L	L	M	M	40-50	bar material build up behind MH & bank scours here
MH - Δ5 L	4' 1/6"	H	H	M	M	40-50	buildup for high E portion

STREAM BANK EROSION ASSESSMENT

94001.01
EX COND TECH

Date: 12/20/94
Project Name/Number: 94001.01
Investigators: JTB
Weather/Comments: Clear 40's - no precip past 72 hrs
Stream Segment Location: Renter - Eastridge, above Renter
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
R 42-41 Eastridge - Renter	2'7"	L	L	*	H	130%	
R-T41-40	6'8"	H	H	M	H	10%	severely eroded
L-T42-41	5'4"	L	L	L	*	0%	concrete
L-T41-40	2'3/7"	M	M	L	H	30%	
Renter T L 2nd new	5'6'6"	M	M-L	M	H	10%	some rip-rap - @ to culvert to 2nd house
Renter T R 2nd new	5'4'6"	L-M	L-M	M	H	30%	
Renter T L 2-7	1'5'5"	L	L	M	H	50%	old & new bars
Renter T R 2	2'3'6"	L	L	M	H	30- 40%	open area behind house on Renter
A 38-36 R	7'6'8"	M-L	M-L	M	H	10- 20%	very clear order
A 38-36 L	3'4'6'8"	L	L-M	L-M	M	30-40%	alternating textures
A 36-40 R	7'8'5"	M	M-H	M	M-H	30-40%	
A 36-40 R	4'8"	M	M	M	M	10-30	
A 35 - last location to	8'8"	H	M-H	M-H	H	30%	
" " R	3'6'8"	L/M	L/M-H	M-H	H	30- 40%	probably, a morph change
A 35-SD R	5'4"	M-H	M-H	M-H	H	30-40%	
A 35-SD L	12'6'8"	M-H	H	M-H	H	30	
SDL-DR R							old top of bank is severely eroded low tree stumps
SDL-SOR-L							

SD =
form
drawn

file
this

RAINFALL DATA

DAWSON

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATION (Climatological)
STATE **MASSACHUSETTS** COUNTY **Barnstable** RIVER **Georges**

MONTH **3** 19 **94**

TEMP. PRECIPITATION STANDARD TIME IN USE

TIME (local) OF OBSERVATION RIVER

TEMPERATURE F.				PRECIPITATION														WEATHER (Calendar Day)				RIVER STAGE		REMARKS (Special observations, etc.)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
24 HRS. ENDING AT OBSERVATION				24-HR AMOUNTS		AI Ob.	Draw a straight line (—) through hours precipitation was observed, and a wavy line (~~~~) through hours precipitation probably occurred unobserved.														CONDITION	GAGE READING AT A.M.	TENDENCY																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
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.)	A.M.						NOON						P.M.						Fog	Ice Pellets	Glaze	Thunder	Hail	Damaging Winds	Time of observation if different from above																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

[illegible]

STATION (Climatological) TOWNSEND		(River Station, if different) TOWNSEND		MONTH 5		19 94	
COUNTY MARYLAND		PRECIPITATION 0.0		STANDARD TIME IN USE DST		RIVER	
TIME (Local or Observation) 1730		TEMP. -		FLOOD STAGE -		PRECIPITATION -	
TYPE OF RIVER GAGE		ELEVATION OF RIVER GAGE ZERO		FLOOD STAGE		PRECIPITATION	
TEMPERATURE F.		PRECIPITATION		WEATHER (Calendar Day)		RIVER STAGE	
24 HRS. ENDING AT OBSERVATION		24-HR AMOUNTS		Mark 'X' for all types occurring each day		GAGE READING AT	
MAX. MIN. AT OBSN.		Snow, melted and puddled (ins.) Snow, ice pellets (ins. and tenths) Rain, ice on ground (ins.)		Fog Ice Pellets Glaze Thunder Hail Damping Winds Time of observation if different from above		CONDITION TENDENCY	
DATE		DATE		DATE		DATE	
1		1		1		1	
2		2		2		2	
3		3		3		3	
4		4		4		4	
5		5		5		5	
6		6		6		6	
7		7		7		7	
8		8		8		8	
9		9		9		9	
10		10		10		10	
11		11		11		11	
12		12		12		12	
13		13		13		13	
14		14		14		14	
15		15		15		15	
16		16		16		16	
17		17		17		17	
18		18		18		18	
19		19		19		19	
20		20		20		20	
21		21		21		21	
22		22		22		22	
23		23		23		23	
24		24		24		24	
25		25		25		25	
26		26		26		26	
27		27		27		27	
28		28		28		28	
29		29		29		29	
30		30		30		30	
31		31		31		31	
SUM		SUM		SUM		SUM	

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

[illegible]

27 TOWSON

RECORD OF RIVER AND CLIMATOLOGICAL OBSERVATIONS

STATION (Climatological)
BALTIMORE TECHNOLOGIES GROUP
COUNTY
BALTIMORE CO.
STATE
MARYLAND
TIME (local) OF OBSERVATION
1700 HRS
TEMP.
1700 HRS
TYPE OF RIVER GAGE
ELEVATION OF RIVER
1700 HRS
FLOOD STAGE
NORMAL POOL STAGE
D/S
STANDARD TIME IN USE
D/S
MONTH
AUG.
19
54
RIVER

TEMPERATURE F.		PRECIPITATION		WEATHER (Calendar Day)		RIVER STAGE		REMARKS (Special observations, etc.)						
24 HRS. ENDING AT OBSERVATION		24-HR AMOUNTS		Mark 'X' for all types occurring each day.		GAGE READING AT		TENDENCY						
MAX.	MIN.	Rain, melted snow, etc. (ins. and hundredths)	Snow, ice pellets (ins. and tenths)	At Obs. hail, ice on ground (ins.)	Fog	Ice Pellets	Glaze		Thunder	Hail	Dam. Winds	Time of observation if different from above	CONDITION	A.M.
DATE	AT OBSN.													
1	56	64	55	.05										Light Sander's
2	85	65	44	.07										Light Sander's
3	85	65	55	.05										Light Sander's
4	90	65	88	.03										Light Sander's
5	88	66	71	.22										Light Sander's
6	97	73	76	.01										Light Sander's
7	74	75	78	.01										Light Sander's
8	85	52	72	.00										Light Sander's
9	83	52	85	.01										Light Sander's
10	83	52	82	.00										Light Sander's
11	83	53	81	.00										Light Sander's
12	85	53	85	.28										Light Sander's
13	91	86	90	.01										Light Sander's
14	85	82	84	.14										Light Sander's
15	84	54	75	1.03										Light Sander's
16	78	54	70	1.00										Light Sander's
17	77	54	77	.65										Light Sander's
18	77	54	71	.15										Light Sander's
19	84	54	81	.01										Light Sander's
20	85	83	85	.01										Light Sander's
21	80	69	80	1.5										Light Sander's
22	80	62	71	2.01										Light Sander's
23	76	56	76	.00										Light Sander's
24	79	55	78	.00										Light Sander's
25	80	78	70	.00										Light Sander's
26	87	81	84	1.35										Light Sander's
27	86	83	85	1.35										Light Sander's
28	86	82	86	1.34										Light Sander's
29	86	85	75	1.55										Light Sander's
30	79	56	77	1.54										Light Sander's
31	65	50	82	.00										Light Sander's
SUM														

TOLSON

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

MONTH: 19 34
RIVER: SEPT.

STATE: MARYLAND
COUNTY: BALTIMORE Co.

TEMP. PRECIPITATION
1700 HAS. 1700 HAS. 1700 HAS.

ELEVATION OF RIVER
GAGE ZERO

TYPE OF RIVER GAGE

TEMPERATURE F.			PRECIPITATION														WEATHER (Calendar Day)				RIVER STAGE			REMARKS (Special observations, etc.)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
24 HRS. ENDING OBSERVATION			24-HR AMOUNTS		At Ob. ground (ins.)	Draw a straight line (—) through hours precipitation was observed, and a wavy line (~~~~) through hours precipitation probably occurred unobserved.														Fog	Ice Pel.	Glaze	Thunder		Hail	Dams Winds	Time of observation if different from above	CONDITION	GAGE READING AT — A.M.	TENDENCY																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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CONDITION OF RIVER AT GAGE

SUM

READING

CHECK BAR (For wire-weight) NORMAL CK. BAR

DATE

SUPERVISING OFFICE

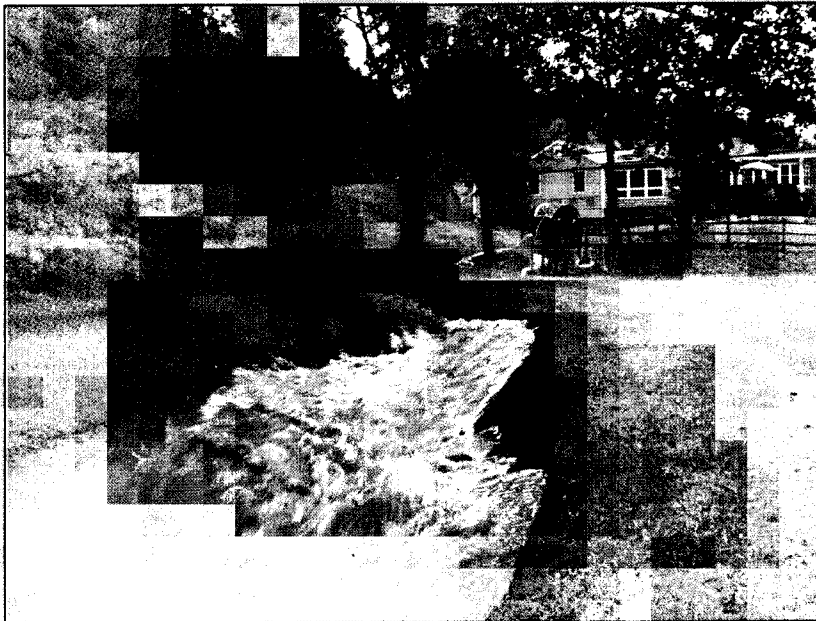
STATION INDEX NO. 18 8877 6



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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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 1 through 6 correspond to different sediment size ranges as follows:

- Bedrock	4 - Gravel
2 - Boulder	5 - Sand
3 - Cobble	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).

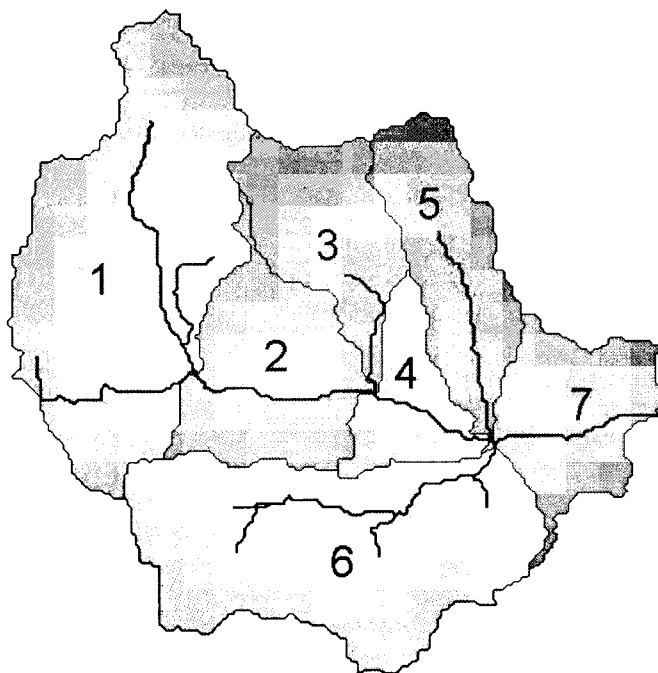


Figure 2.1. Spring Branch Sub-basin Watershed Map.

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

The 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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: $\text{Radius of Curvature} = 2.5\text{-}3.2 \times \text{Bankfull Width}$ (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
<i>Riffle Cross section</i>			
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
<i>Pool Cross Section</i>			
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
<i>Profile</i>			
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 (NISE, Inc. 1981)	Purdum & Jeske (1985) TR-20	MCS Predicted Peak Discharge (cfs) ¹	USCS 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 that 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 returned 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).

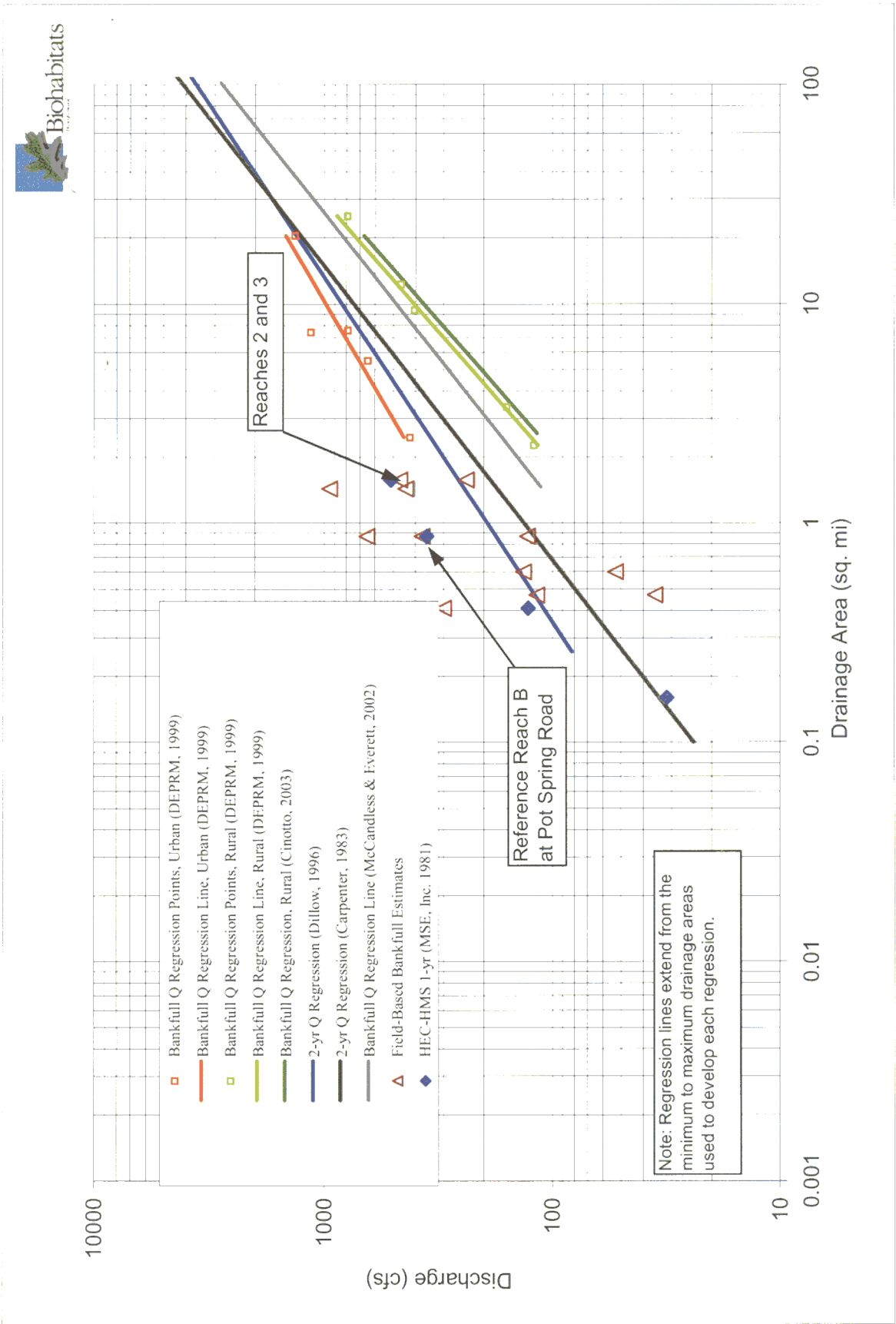


Figure 3.1. Comparison of Field Bankfull Estimates, HEC-HMS Results, and Regional Regressions.

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	<u>261.83</u>	<u>-0.46</u>

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, <i>Juglans nigra</i>	FACU	Native
black willow, <i>Salix nigra</i>	FACW	Native
boxelder maple, <i>Acer negundo</i>	FAC	Native
sycamore, <i>Platanus occidentalis</i>	FACW	Native
Norway maple, <i>Acer platanoides</i>	FACU	Non-Native, Invasive
multiflora rose, <i>Rosa multiflora</i>	FACU	Non-Native, Invasive
goldenrod, <i>Solidago</i> spp.	UNK	Native
honeysuckle vine, <i>Lonicera japonica</i>	FAC-	Non-Native, Invasive
ivy, <i>Hedera helix</i>	FACU	Non-Native, Invasive
oriental bittersweet, <i>Celastrus orbiculatus</i>	FACU	Non-Native, Invasive
watercress, <i>Nasturium officinale</i>	OBL	Native
cattail, <i>Typha latifolia</i>	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 effusus*), 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, <i>Juncus effusus</i>	FACW	Native
jewelweed, <i>Impatiens capensis</i>	FACW	Native
honeysuckle vine, <i>Lonicera japonica</i>	FAC-	Non-Native, Invasive
fowl manna grass, <i>Glyceria striata</i>	FACW	Native
watercress, <i>Nasturium officinale</i>	OBL	Native
privet, <i>Ligustrum japonicum</i>	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, <i>Juglans nigra</i>	FACU	Native
white pine, <i>Pinus strobus</i>	FACU	Native
black willow, <i>Salix nigra</i>	FACW	Native
boxelder maple, <i>Acer negundo</i>	FAC	Native
sycamore, <i>Platanus occidentalis</i>	FACW	Native
norway maple, <i>Acer platanoides</i>	FACU	Non-Native, Invasive
tulip poplar, <i>Lireodendron tulipifera</i>	FACU	Native
red Maple, <i>Acer rubrum</i>	FAC	Native
multiflora rose, <i>Rosa multiflora</i>	FACU	Non-Native, Invasive
privet, <i>Ligustrum japonicum</i> .	FACU	Non-Native, Invasive
honeysuckle vine, <i>Lonicera japonica</i>	FAC-	Non-Native, Invasive
ivy, <i>Hedera helix</i>	FACU	Non-Native, Invasive
oriental bittersweet, <i>Celastrus orbiculatus</i>	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
<i>Riffle Cross section</i>										
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
<i>Pool Cross Section</i>										
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
<i>Profile</i>										
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-p}	290.1'		331.5'		existing		96.5'		145.0'	123.6'

W_{Bkf} = Bankfull Width

A_R (sf) = Riffle Cross Sectional Area (sq. feet)

D_{Pmax} = Max Pool Depth

S_p = Pool Slope

S_{Run} = Run Slope

L_p = Pool Length

D_{Bkf max} = Max Bankfull Depth

W_P = Wetted Perimeter

A_p (sf) = Pool Cross Sectional Area (sq. feet)

S_G = Glide Slope

S_{Rif} = Riffle slope

L_{p-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).

Lower Spring Branch Concept Report

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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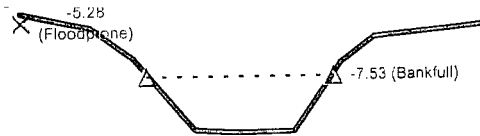
PROJECT REACH CROSS SECTIONS

APPENDIX A



Lower Spring Branch Xsection #1

Rod Height [ft]



Station [ft]

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
floodprone discharge:	2,172.32 ft ³ /s
Avg. shear stress	
at bankfull stage:	1.101 lb/ft ²

Benchmark

Bankfull

Floodprone

-5.28

Elevation

Rod Height [ft]

7.53

measured water

Rod Height [ft] = (2 · max depth_{bf})

Benchmark

channel slope

1.06%

Rod Height

manning's 'n'

0.012

(concrete channel)

Bankfull

Floodprone

Station [ft]	Bankfull			Floodprone		
	Rod Height [ft]	Negative Rod Height [ft]	Wetted Perimeter	Cross Sectional Area	Top Width	Wetted Perimeter
Total			21.97 ft	36.56 ft ²	21.65 ft	49.32 ft

4.85

-4.85

5.45

-5.45

6.74

-6.74

20

9.67

-9.67

5.54 ft

5.78 ft²

5.40 ft

7.59 ft

20.48 ft²

7.00 ft

20.9

9.7

-9.70

0.90 ft

1.94 ft²

0.90 ft

0.90 ft

3.96 ft²

0.90 ft

24

9.77

-9.77

3.10 ft

6.84 ft²

3.10 ft

3.10 ft

13.81 ft²

3.10 ft

26.5

9.78

-9.78

2.50 ft

5.61 ft²

2.50 ft

2.50 ft

11.24 ft²

2.50 ft

31.5

9.74

-9.74

5.00 ft

11.15 ft²

5.00 ft

5.00 ft

22.40 ft²

5.00 ft

37

6.98

-6.98

4.93 ft

5.25 ft²

4.75 ft

6.15 ft

16.94 ft²

5.50 ft

41

5.95

-5.95

4.13 ft

4.74 ft²

4.00 ft

50

5.65

-5.65

9.00 ft

4.68 ft²

9.00 ft

53.5

5.53

-5.53

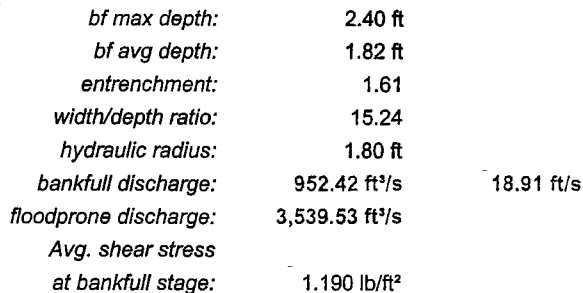
3.50 ft

1.09 ft²

3.50 ft

Ineffective Flow

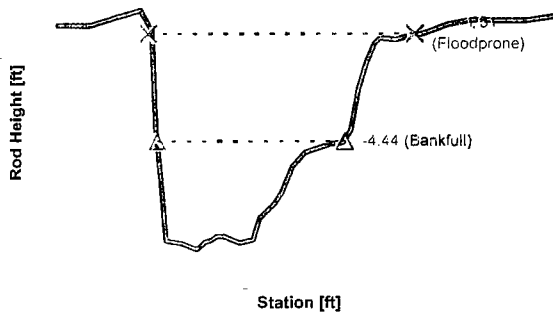
☐ 2.27 ft
☐ 5.00 ft
☐ 7.00 ft
☐ 0.90 ft
☐ 3.10 ft
☐ 2.50 ft
☐ 5.00 ft
☐ 5.50 ft
☐ 4.00 ft
☐ 9.00 ft
☐ 3.50 ft



Benchmark	Bankfull		Floodprone	-5.80
Elevation	Rod Height [ft]	8.20	Rod Height [ft]	$= (2 \cdot \text{max depth}_{br})$
Benchmark	channel slope	1.06%		
Rod Height	mannings's 'n'	0.012		

			Bankfull			Floodprone			Effective Flow
Rod		Negative Rod	Cross			Cross			
Station [ft]	Height [ft]	Height [ft]	Wetted Perimeter	Sectional Area	Top Width	Wetted Perimeter	Sectional Area	Top Width	
Total			28.00 ft	50.37 ft²	27.71 ft	45.86 ft	134.88 ft²	44.53 ft	
		-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	
	10.52		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	

Lower Spring Branch Xsection #3



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
Benchmark Rod Height
Bankfull Rod Height [ft] 4.44
channel slope 1.43%
manning's 'n' 0.035

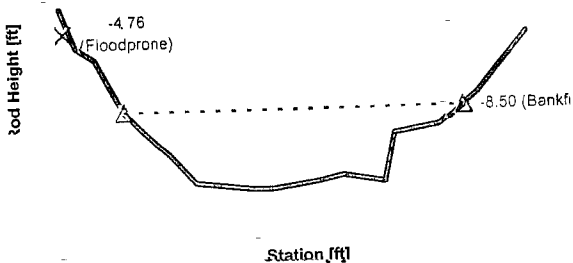
Floodprone -1.51
 Rod Height [ft] = (2 · max depth_{bf})

	Bankfull			Floodprone		
	Negative	Cross	Top	Cross	Top	
Station [ft]	Rod Height [ft]	Wetted Perimeter	Sectional Area	Wetted Perimeter	Sectional Area	Top Width
Total		37.18 ft	61.99 ft²	54.16 ft	178.61 ft²	50.77 ft
	-1.27					
	-1.27					
	-0.84					
	-1.40					
8.5	-4.07			2.67 ft	2.56 ft²	2.00 ft
	-5.54	1.33 ft	0.62 ft²	1.78 ft	3.30 ft²	1.00 ft
	-7.13	1.88 ft	1.90 ft²	1.88 ft	4.83 ft²	1.00 ft
	-7.20	3.00 ft	8.18 ft²	3.00 ft	16.97 ft²	3.00 ft
0.4	-7.37	2.90 ft	8.25 ft²	2.90 ft	16.75 ft²	2.90 ft
7.9	-7.17	1.51 ft	4.25 ft²	1.51 ft	8.64 ft²	1.50 ft
	-7.11	1.10 ft	2.97 ft²	1.10 ft	6.19 ft²	1.10 ft
30.1	-7.01	1.10 ft	2.88 ft²	1.10 ft	6.11 ft²	1.10 ft
31.5	-7.00	1.40 ft	3.59 ft²	1.40 ft	7.69 ft²	1.40 ft
32.8	-7.09	1.30 ft	3.39 ft²	1.30 ft	7.20 ft²	1.30 ft
34.5	-7.18	1.70 ft	4.58 ft²	1.70 ft	9.56 ft²	1.70 ft
37.1	-7.10	2.60 ft	7.02 ft²	2.60 ft	14.64 ft²	2.60 ft
38.4	-6.51	1.43 ft	3.07 ft²	1.43 ft	6.88 ft²	1.30 ft
41.2	-6.11	2.83 ft	5.24 ft²	2.83 ft	13.44 ft²	2.80 ft
42.5	-5.81	1.33 ft	1.98 ft²	1.33 ft	5.78 ft²	1.30 ft
44.5	-5.12	2.12 ft	2.05 ft²	2.12 ft	7.91 ft²	2.00 ft
46.8	-4.73	2.33 ft	1.12 ft²	2.33 ft	7.85 ft²	2.30 ft
51.5	-4.50	4.71 ft	0.82 ft²	4.71 ft	14.59 ft²	4.70 ft
54	-4.46	2.50 ft	0.10 ft²	2.50 ft	7.43 ft²	2.50 ft
55.5	-4.12	0.09 ft	0.00 ft²	1.54 ft	4.17 ft²	1.50 ft
57	-2.96			1.90 ft	3.05 ft²	1.50 ft
58.5	-2.23			1.67 ft	1.63 ft²	1.50 ft
60	-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					
74	-1.23					
79	-1.11					
84	-1.14					
89	-1.13					
94	-1.02					

Ineffective Flow



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 ft ³ /s
floodprone discharge:	2,031.47 ft ³ /s
Avg. shear stress at bankfull stage:	0.900 lb/ft ²

Floodprone	-4.76
Rod Height [ft]	= (2 · max depth _{bf})

Benchmark	Bankfull
Elevation	Rod Height [ft]
Benchmark	channel slope
Rod Height	manning's 'n'

8.50

0.61%

0.036

Bankfull

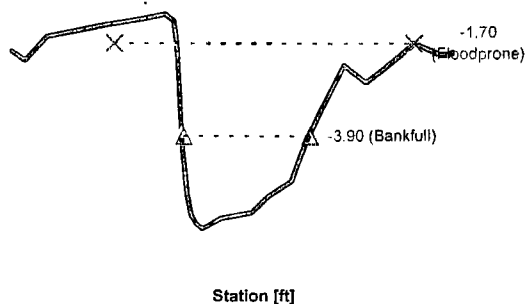
Floodprone

Station [ft]	Negative			Cross			Cross		
	Rod Height [ft]	Rod Height [ft]		Wetted Perimeter	Sectional Area	Top Width	Wetted Perimeter	Sectional Area	Top Width
Total				34.92 ft	82.30 ft ²	32.71 ft	48.58 ft	225.49 ft ²	43.98 ft
	3.52	-3.52					0.77 ft	0.20 ft ²	0.68 ft
	5.36	-5.36					1.90 ft	1.64 ft ²	1.80 ft
		-5.98					3.68 ft	6.67 ft ²	2.70 ft
		-8.48					3.33 ft	13.32 ft ²	3.00 ft
		-9.92	3.28 ft		2.25 ft ²	3.17 ft	1.52 ft	7.64 ft ²	1.40 ft
10.40	10.52	-10.52	1.52 ft		2.41 ft ²	1.40 ft	2.86 ft	16.13 ft ²	2.50 ft
12.90	11.30	-11.90	2.86 ft		6.78 ft ²	2.50 ft	5.61 ft	40.94 ft ²	5.60 ft
18.50	12.24	-12.24	5.61 ft		19.99 ft ²	5.60 ft	1.90 ft	14.19 ft ²	1.90 ft
20.40	12.22	-12.22	1.90 ft		7.09 ft ²	1.90 ft	4.31 ft	31.39 ft ²	4.30 ft
24.70	11.90	-11.90	4.31 ft		15.31 ft ²	4.30 ft	2.31 ft	16.12 ft ²	2.30 ft
27.00	11.64	-11.64	2.31 ft		7.52 ft ²	2.30 ft	4.02 ft	28.24 ft ²	4.00 ft
31.00	12.00	-12.00	4.02 ft		13.28 ft ²	4.00 ft	2.51 ft	6.09 ft ²	1.00 ft
32.00	9.70	-9.70	2.51 ft		2.35 ft ²	1.00 ft	4.32 ft	20.47 ft ²	4.30 ft
36.30	9.34	-9.34	4.32 ft		4.39 ft ²	4.30 ft	3.98 ft	14.25 ft ²	3.70 ft
40.00	7.88	-7.88	2.29 ft		0.94 ft ²	2.24 ft	5.57 ft	8.21 ft ²	4.80 ft
44.80	5.06	-5.06							

Ineffective Flow

Lower Spring Branch Xsection #5

Rod Height [ft]



Slope: 1:1 R: 1.49 Channel Slope: 0.032 Field Slope: 0.032

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 ft ³ /s	5.39 ft/s
floodprone discharge:	824.82 ft ³ /s	
Avg. shear stress		
at bankfull stage:	0.732 lb/ft ²	

Benchmark	Bankfull	
Elevation	Rod Height [ft]	3.90
Benchmark	channel slope	0.79%
Rod Height	mannings 'n'	0.032

Floodprone	-1.70
Rod Height [ft]	= (2 * max depth _{bf})

Total

Bankfull

Floodprone

Station [ft]	Rod Height [ft]	Negative Rod Height [ft]	Bankfull			Floodprone		
			Wetted Perimeter	Cross Sectional Area	Top Width	Wetted Perimeter	Cross Sectional Area	Top Width
			30.02 ft	44.64 ft ²	29.15 ft	71.47 ft	132.29 ft ²	69.08 ft

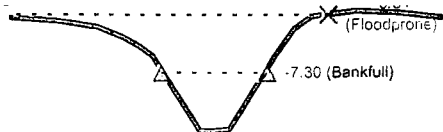
	1.88	-1.88						
3	2.09	-2.09				3.01 ft	0.85 ft ²	3.00 ft
8	1.52	-1.52				3.44 ft	0.67 ft ²	3.44 ft
20	1.26	-1.26						
30	1.09	-1.09						
35	0.99	-0.99						
37	1.15	-1.15						
37.8	1.81	-1.81				0.17 ft	0.01 ft ²	0.16 ft
39.1	4.07	-4.07	0.20 ft	0.01 ft ²	0.16 ft	2.61 ft	1.61 ft ²	1.30 ft
40.3	5.28	-5.28	1.70 ft	0.93 ft ²	1.20 ft	1.70 ft	3.57 ft ²	1.20 ft
41.2	5.77	-5.77	1.02 ft	1.46 ft ²	0.90 ft	1.02 ft	3.44 ft ²	0.90 ft
42.5	6	-6.00	1.32 ft	2.58 ft ²	1.30 ft	1.32 ft	5.44 ft ²	1.30 ft
43.8	6.1	-6.10	1.30 ft	2.79 ft ²	1.30 ft	1.30 ft	5.65 ft ²	1.30 ft
48	5.85	-5.85	4.21 ft	8.72 ft ²	4.20 ft	4.21 ft	17.96 ft ²	4.20 ft
55	5.72	-5.72	7.00 ft	13.20 ft ²	7.00 ft	7.00 ft	28.60 ft ²	7.00 ft
58.9	5.33	-5.33	3.92 ft	6.34 ft ²	3.90 ft	3.92 ft	14.92 ft ²	3.90 ft
64.1	4.98	-4.98	5.21 ft	6.53 ft ²	5.20 ft	5.21 ft	17.97 ft ²	5.20 ft
66	4.43	-4.43	1.98 ft	1.53 ft ²	1.90 ft	1.98 ft	5.71 ft ²	1.90 ft
68	3.92	-3.92	2.06 ft	0.55 ft ²	2.00 ft	2.06 ft	4.95 ft ²	2.00 ft
71	3.25	-3.25	0.09 ft	0.00 ft ²	0.09 ft	3.07 ft	5.66 ft ²	3.00 ft
76	2.22	-2.22				5.10 ft	5.18 ft ²	5.00 ft
81	2.62	-2.62				5.02 ft	3.60 ft ²	5.00 ft
85	2.3	-2.30				4.01 ft	3.04 ft ²	4.00 ft
92	1.69	-1.69				6.91 ft	2.07 ft ²	6.90 ft
98	1.96	-1.96				5.78 ft	0.75 ft ²	5.78 ft
100	1.95	-1.95				2.00 ft	0.51 ft ²	2.00 ft
100.6	1.91	-1.91				0.60 ft	0.14 ft ²	0.60 ft

Ineffective Flow

Lower Spring Branch Xsection Trib B (Dry Concrete Channel)

Sheets

Rod Height [ft]



Station [ft]

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

Bankfull

Floodprone -5.34

Elevation

Rod Height [ft]

7.30

measured water

Rod Height [ft]

= (2 · max depth_{bf})

Benchmark

channel slope

1.98%

Rod Height

manning's 'n'

0.012

(concrete channel)

Bankfull

Floodprone

Station [ft]	Bankfull			Floodprone		
	Rod Height [ft]	Negative Rod Height [ft]	Cross Sectional Area	Wetted Perimeter	Cross Sectional Area	Wetted Perimeter
Total			12.60 ft	15.25 ft²	12.31 ft	41.12 ft

5.42 -5.42

5.51 -5.51

-5.72

-6.07

15 6.39 -6.39

16.5 6.71 -6.71

22 9.24 -9.24

23.5 9.26 -9.26

25.5 9.2 -9.20

30.7 6.75 -6.75

33 5.81 -5.81

35 5.4 -5.40

40 5.21 -5.21

45 5.28 -5.28

50 5.44 -5.44

4.64 ft

4.36 ft²

4.50 ft

1.50 ft

2.93 ft²

1.50 ft

2.00 ft

3.86 ft²

2.00 ft

4.46 ft

4.10 ft²

4.32 ft

5.00 ft

0.63 ft²

5.00 ft

5.00 ft

1.38 ft²

5.00 ft

3.02 ft

1.67 ft²

3.00 ft

2.03 ft

1.78 ft²

2.00 ft

1.53 ft

1.82 ft²

1.50 ft

6.05 ft

14.49 ft²

5.50 ft

1.50 ft

5.87 ft²

1.50 ft

2.00 ft

7.78 ft²

2.00 ft

5.75 ft

13.70 ft²

5.20 ft

2.48 ft

2.16 ft²

2.30 ft

2.04 ft

0.53 ft²

2.00 ft

1.58 ft

0.05 ft²

1.58 ft

3.13 ft

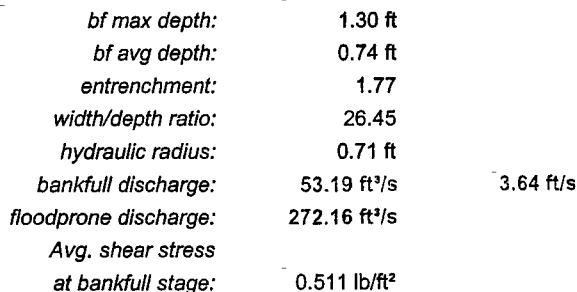
0.16 ft²

3.13 ft

Ineffective Flow

REFERENCE REACH CROSS SECTIONS

APPENDIX B

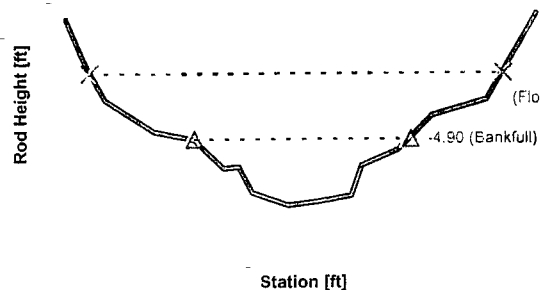


Floodprone	-3.20
Rod Height [ft]	= (2 · max depth _{br}

			Bankfull			Floodprone			Effective Flow
		Negative	Cross			Cross			
Rod	Rod		Wetted	Sectional	Top	Wetted	Sectional	Top	
Station [ft]	Height [ft]	Height [ft]	Perimeter	Area	Width	Perimeter	Area	Width	
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 ft ²		
		-3.75				3.54 ft	1.00 ft ²		
		-3.95				1.02 ft	0.65 ft ²		
		-4.32				1.07 ft	0.94 ft ²		
			0.96 ft	0.10 ft ²	0.95 ft	1.75 ft	2.24 ft ²		
		-5.00	0.94 ft	0.32 ft ²	0.90 ft	0.94 ft	1.49 ft ²		
		-4.55	1.95 ft	0.52 ft ²	1.90 ft	1.95 ft	2.99 ft ²		
		-5.47	1.36 ft	0.51 ft ²	1.00 ft	1.36 ft	1.81 ft ²		
		-5.48	1.70 ft	1.66 ft ²	1.70 ft	1.70 ft	3.87 ft ²		
		-5.65	1.61 ft	1.70 ft ²	1.60 ft	1.61 ft	3.78 ft ²		
	5.8	-5.80	2.01 ft	2.45 ft ²	2.00 ft	2.01 ft	5.05 ft ²		
	5.72	-5.72	1.50 ft	1.89 ft ²	1.50 ft	1.50 ft	3.84 ft ²		
24.	5.71	-5.71	1.10 ft	1.34 ft ²	1.10 ft	1.10 ft	2.77 ft ²		
	5.59	-5.59	1.11 ft	1.27 ft ²	1.10 ft	1.11 ft	2.69 ft ²		
	5.43	-5.43	1.31 ft	1.31 ft ²	1.30 ft	1.31 ft	3.00 ft ²		
	5.5	-5.50	1.00 ft	0.97 ft ²	1.00 ft	1.00 ft	2.27 ft ²		
	4.56	-4.56	1.30 ft	0.48 ft ²	0.90 ft	1.30 ft	1.65 ft ²		
	4.52	-4.52	2.60 ft	0.10 ft ²	2.60 ft	2.60 ft	3.48 ft ²		
33.2	4.22	-4.22	0.12 ft	0.00 ft ²	0.11 ft	1.73 ft	1.99 ft ²		
34.9	3.89	-3.89				1.73 ft	1.45 ft ²		
37.3	3.5	-3.50				2.43 ft	1.19 ft ²		
39.8	3.29	-3.29				2.51 ft	0.49 ft ²		
	2.92	-2.92				0.52 ft	0.02 ft ²		
	2.38	-2.38							
	1.98	-1.98							

Ref Reach B

LOW BKF



<i>bf max depth:</i>	1.81 ft
<i>bf avg depth:</i>	1.09 ft
<i>entrenchment:</i>	1.92
<i>width/depth ratio:</i>	16.98
<i>hydraulic radius:</i>	1.06 ft
<i>bankfull discharge:</i>	129.51 ft ³ /s
<i>floodprone discharge:</i>	704.54 ft ³ /s
<i>Avg. shear stress</i>	
<i>at bankfull stage:</i>	1.453 lb/ft ²

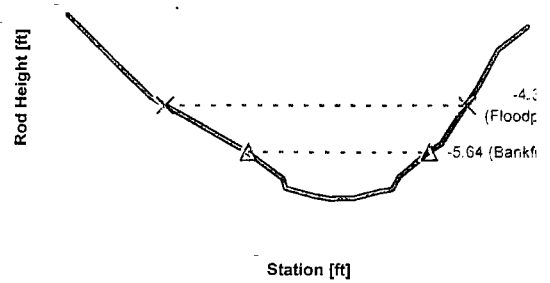
<i>Benchmark</i>	<i>Bankfull</i>	-4.90
<i>Elevation</i>	<i>Rod Height [ft]</i>	4.90
<i>Benchmark</i>	<i>bf channel slope</i>	2.20%
<i>Rod Height</i>	<i>manning's 'n'</i>	0.036

<i>Floodprone</i>	-3.09
<i>Rod Height [ft]</i>	= (2 · depth _{bf})

Rod Height			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						
		70						
		-1.58						
		-2.76						
		-3.31				1.43 ft	0.49 ft²	1.36 ft
		-4.58				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



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 channel slope 0.78%
Rod Height manning's 'n' 0.032

Floodprone -4.38
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			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
			2.40 ft	0.83 ft²	2.37 ft	4.00 ft	3.14 ft²	3.90 ft
			0.33 ft	0.17 ft²	0.20 ft	2.40 ft	3.70 ft²	2.30 ft
			1.91 ft	2.03 ft²	1.90 ft	0.33 ft	0.42 ft²	0.20 ft
			1.10 ft	1.34 ft²	1.10 ft	1.91 ft	4.43 ft²	1.90 ft
			0.50 ft	0.63 ft²	0.50 ft	1.10 ft	2.73 ft²	1.10 ft
			1.00 ft	1.24 ft²	1.00 ft	0.50 ft	1.26 ft²	0.50 ft
			1.71 ft	1.94 ft²	1.70 ft	1.00 ft	2.50 ft²	1.00 ft
17			0.80 ft	0.82 ft²	0.80 ft	1.71 ft	4.08 ft²	1.70 ft
15	6.6	-6.64	0.62 ft	0.41 ft²	0.50 ft	0.80 ft	1.83 ft²	0.80 ft
	6.2	-6.28	2.01 ft	0.63 ft²	1.98 ft	0.62 ft	1.04 ft²	0.50 ft
24		-5.61				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

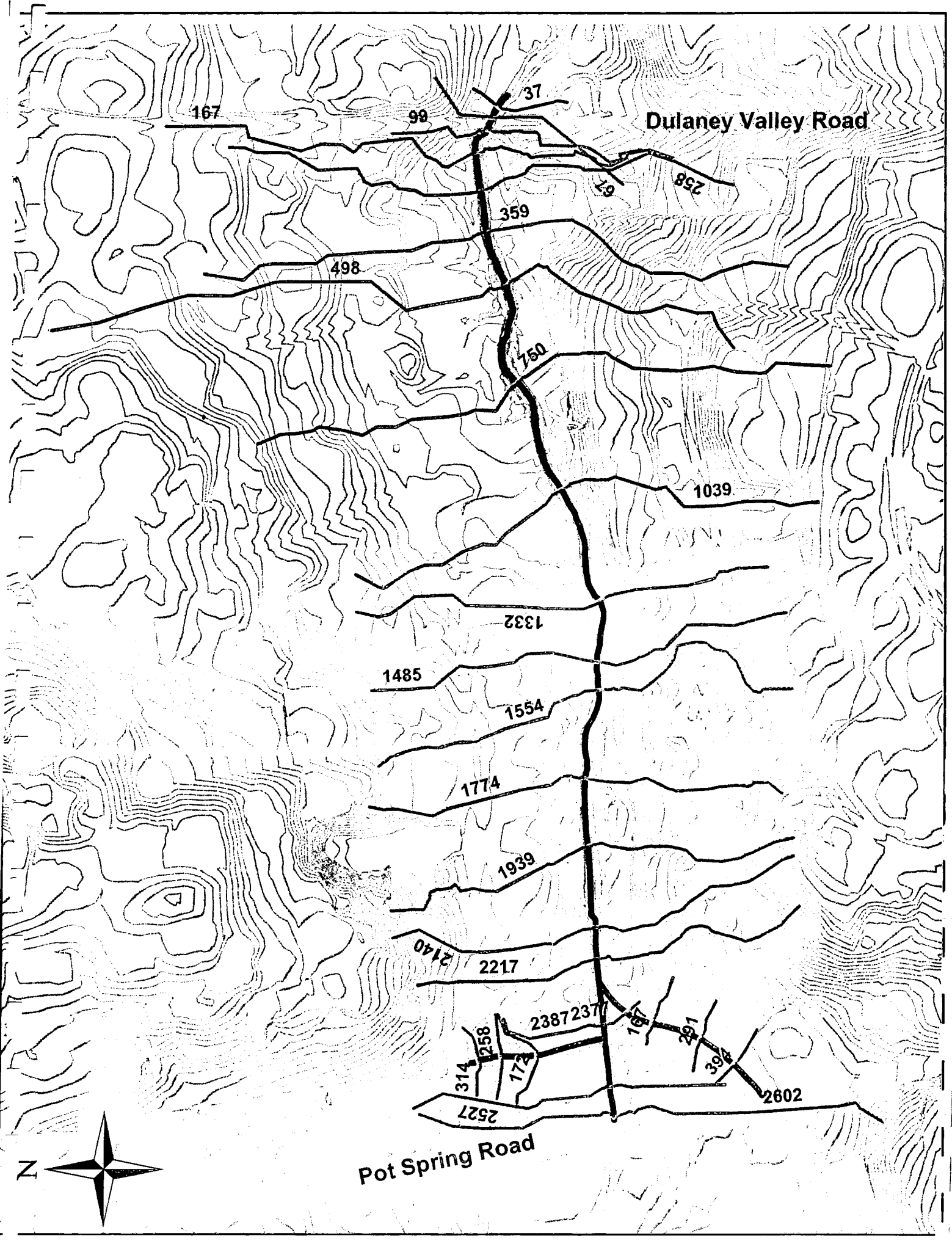
**GEOMORPHIC DATA COLLECTED FROM THE
REFERENCE REACHES**

APPENDIX C

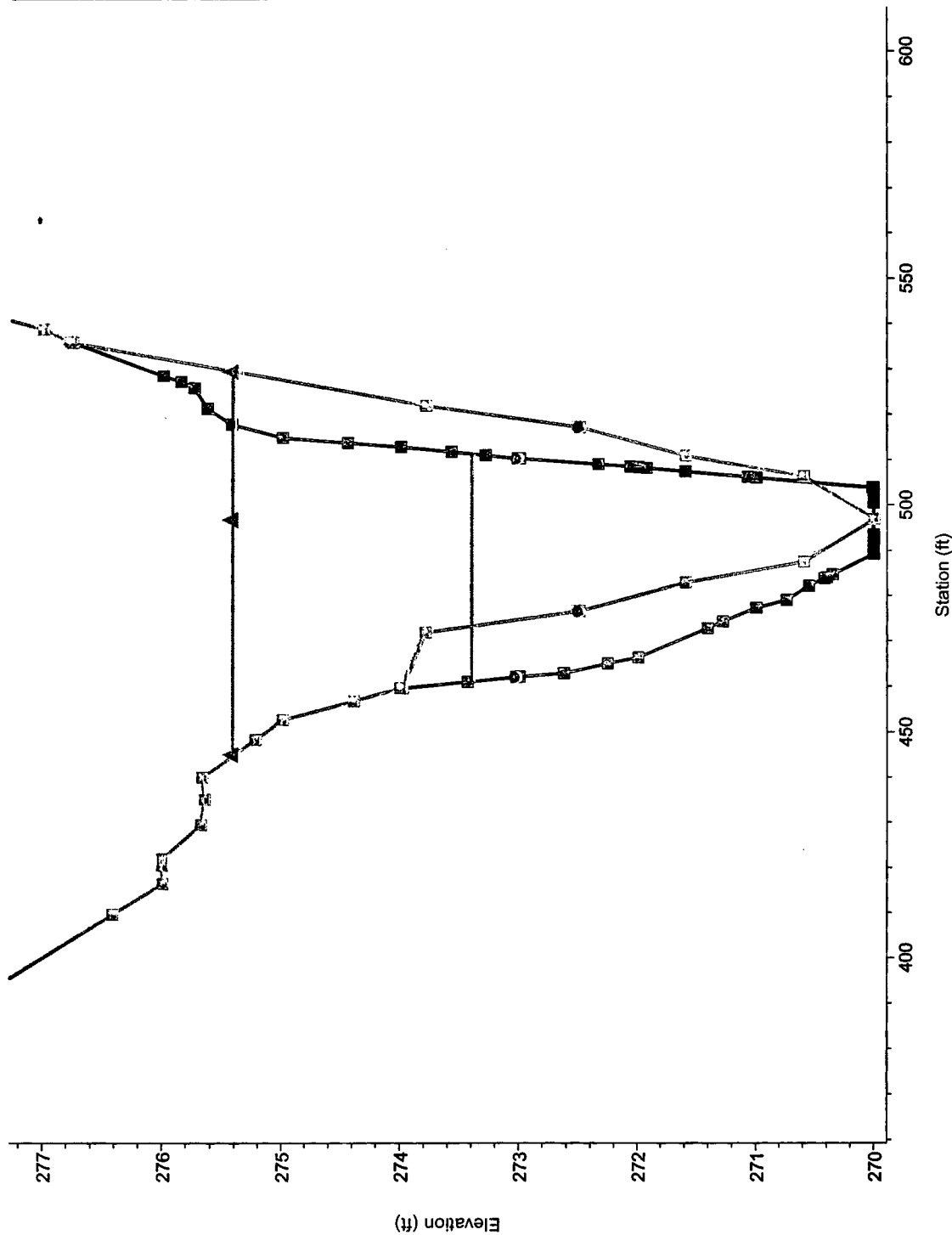
Lower Spring Branch (05015.01)							
Spring Branch Reference Reach A, B, C		2/16/2006		A	B	C	
		Reach BKF Slope		0.0115	0.0219	0.00776	
Spring Branch: Vortex Weir	n	Reach A	Reach C	Reach B	Reach B	Mean	Units
Mean Bankfull Depth	1	1.1	-	-	-	1.1	ft
Maximum Bankfull Depth	1	1.5	-	-	-	1.5	ft
Bankfull Width	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 $W_{bkf}/(\text{mean } D_{bkf})$	1	13.85	-	-	-	13.85	n/a
RATIO $W_{bkf}/(\text{max } D_{bkf})$	1	10.34	-	-	-	10.34	n/a
RATIO (max $D_{bkf})/(\text{mean } D_{bkf})$	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 $W_{bkf}/(\text{mean } D_{bkf})$	3	26.49	17.04	14.51	-	18.66	n/a
RATIO $W_{bkf}/(\text{max } D_{bkf})$	3	15.08	10.26	9.14	-	11.23	n/a
RATIO (max $D_{bkf})/(\text{mean } D_{bkf})$	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 $W_{bkf}/(\text{mean } D_{bkf})$	3	0.37	0.73	0.76	-	0.62	n/a
RATIO $W_{bkf}/(\text{max } D_{bkf})$	3	0.14	0.53	0.57	-	0.35	n/a
RATIO (max $D_{bkf})/(\text{mean } D_{bkf})$	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

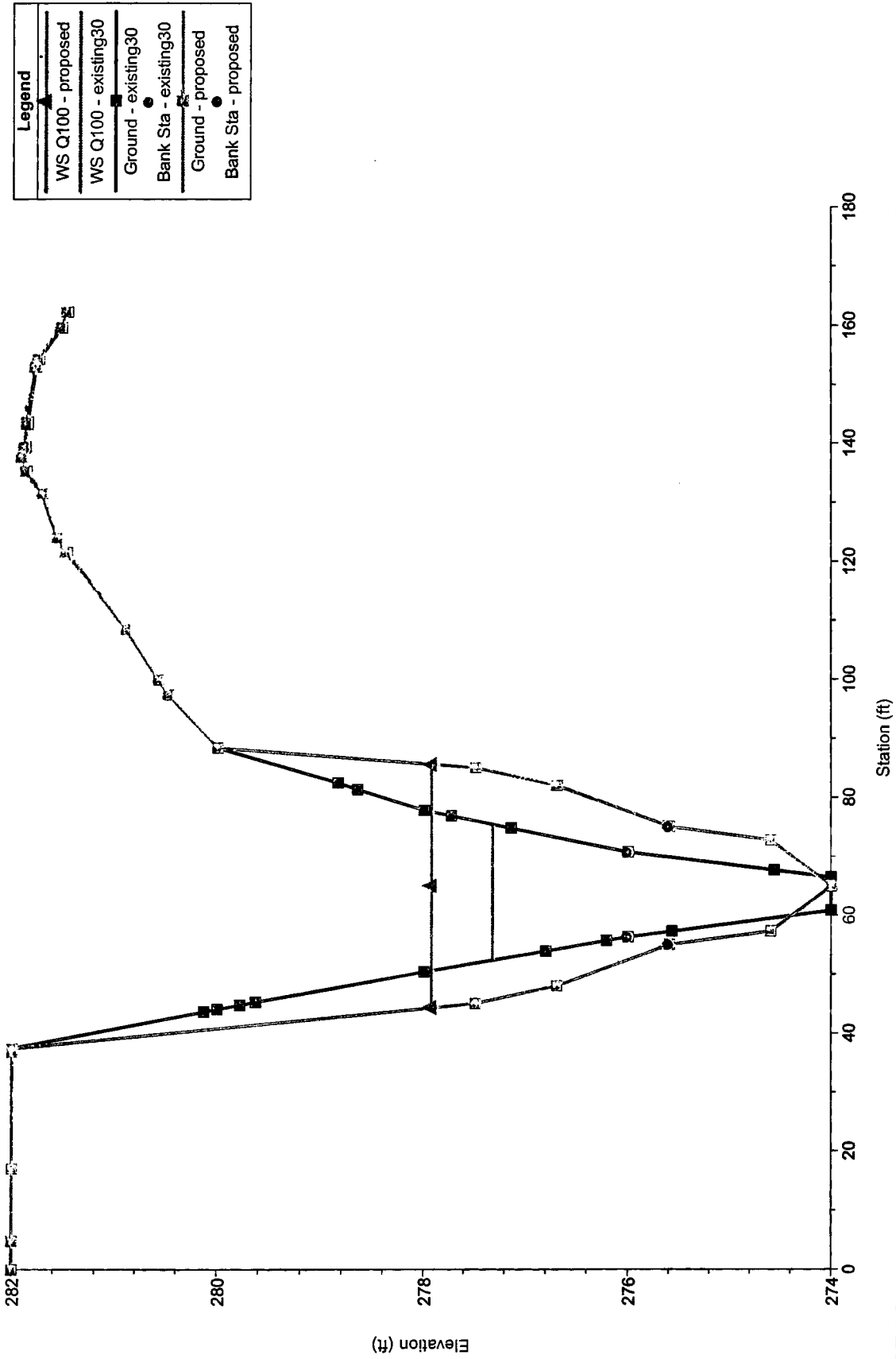


Lower Spring Branch 100-YR WS Comparison Reach: Mainstem Cross Section Station: 2602



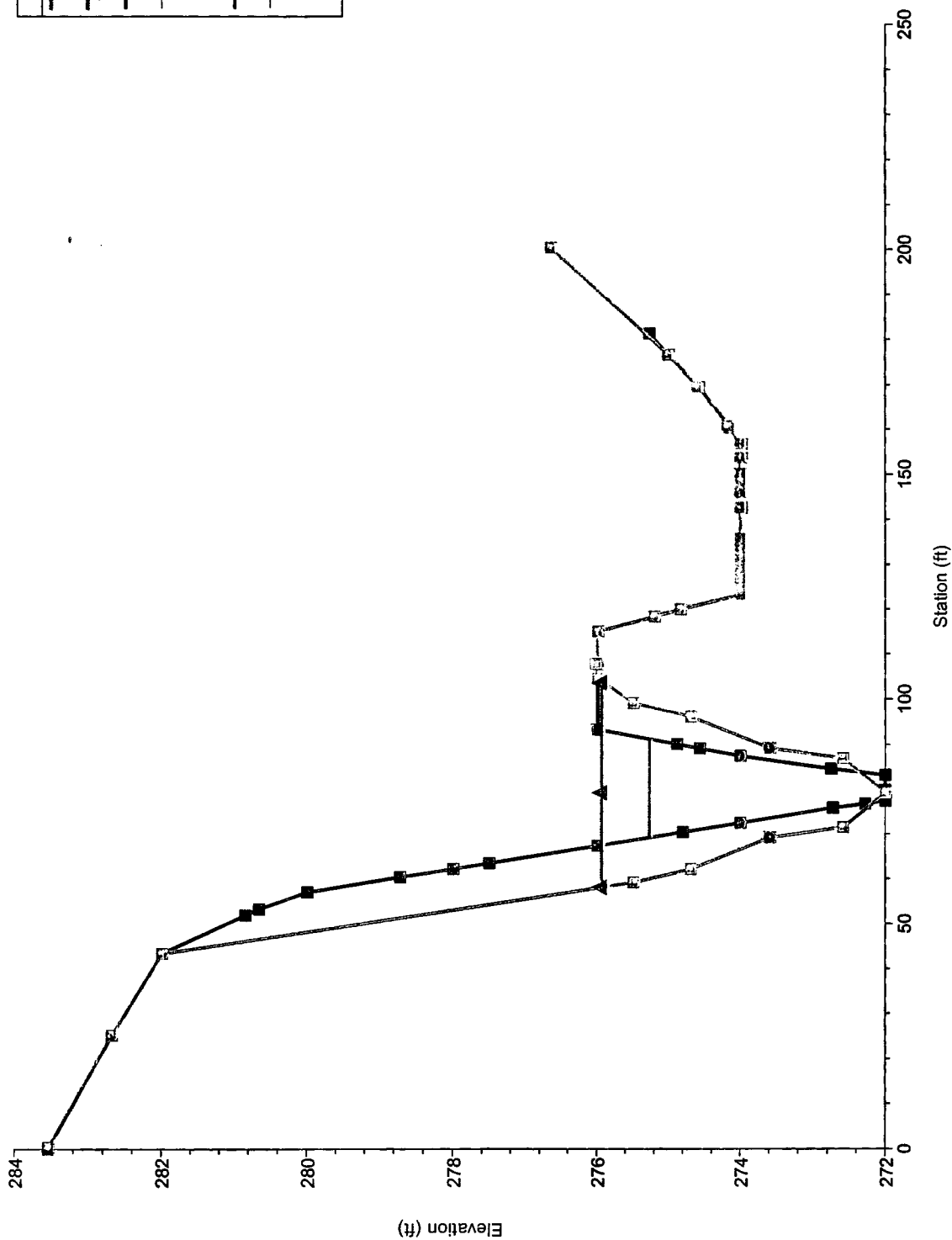
Lower Spring Branch 100-YR WS Comparison

Reach: Tributary B Cross Section Station: 394



Lower Spring Branch 100-YR WS Comparison

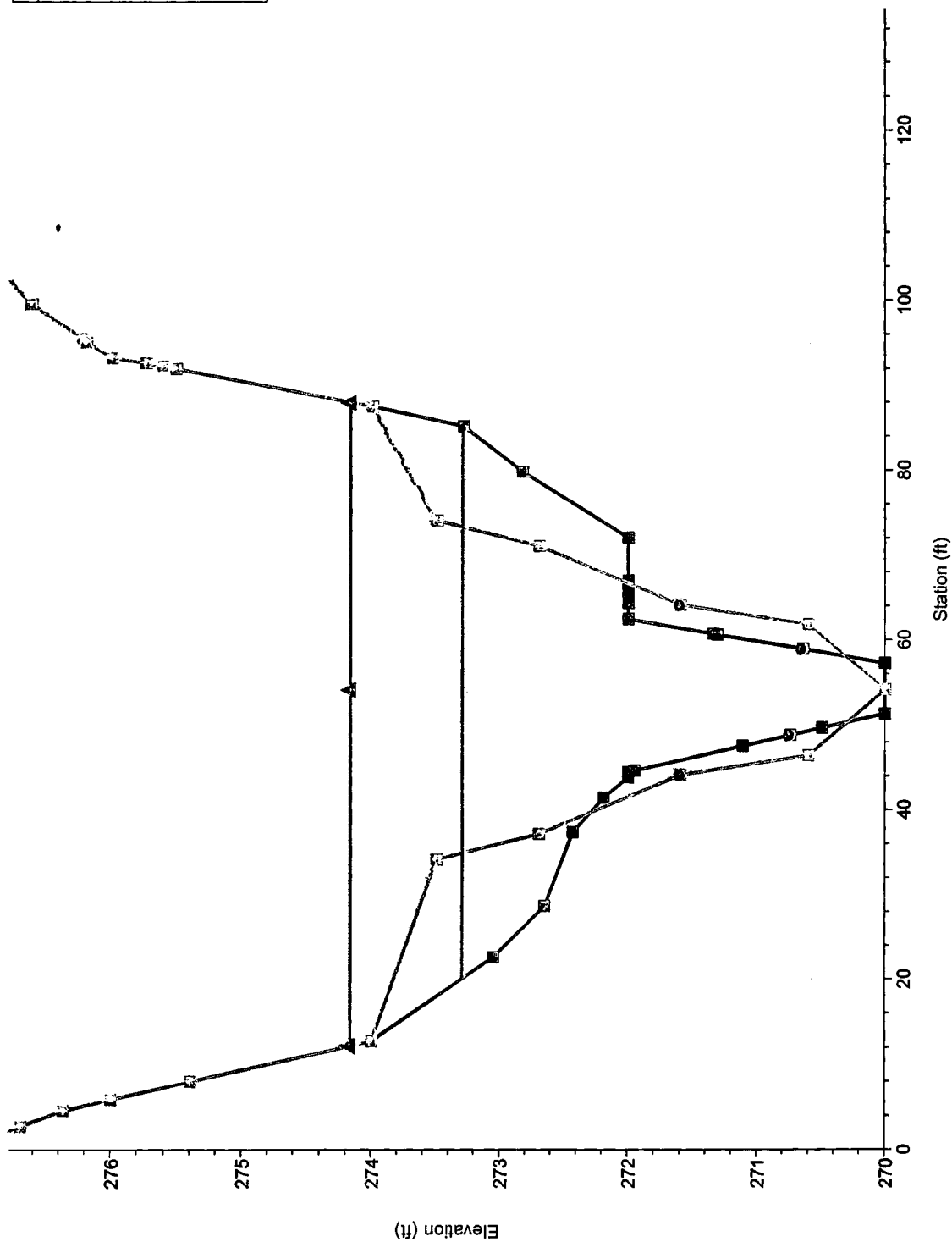
Reach: Tributary B Cross Section Station: 291



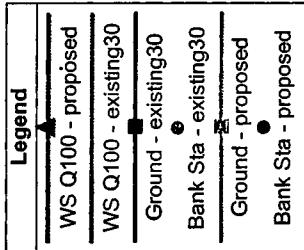
Legend

- WS Q100 - proposed
- WS Q100 - existing30
- Ground - existing30
- Levee - existing30
- Bank Sta - existing30
- Ground - proposed
- Levee - proposed
- Bank Sta - proposed

Reach: Tributary B Cross Section Station: 166

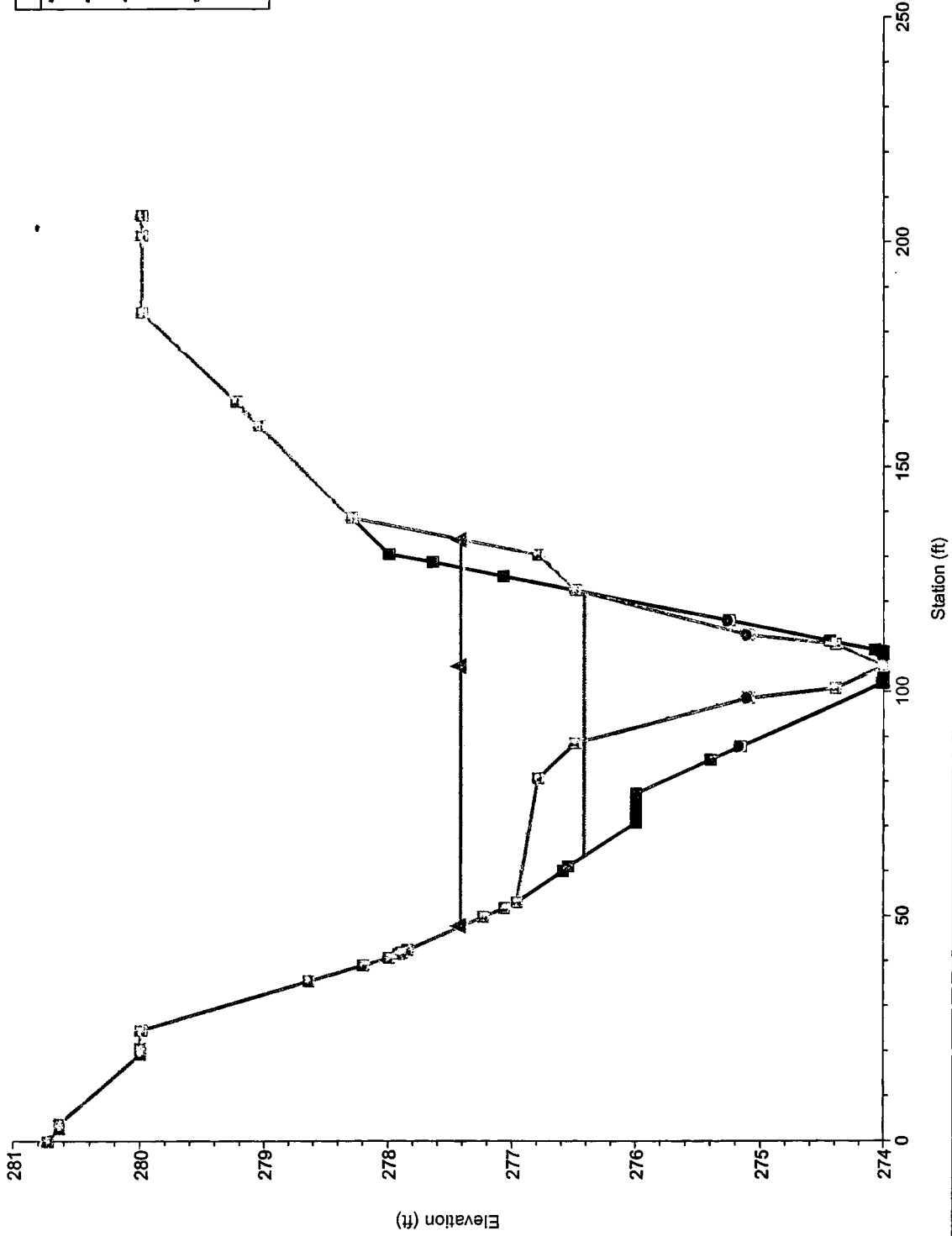


Reach: Tributary A Cross Section Station: 314



Lower Spring Branch 100-YR WS Comparison

Reach: Tributary A Cross Section Station: 258

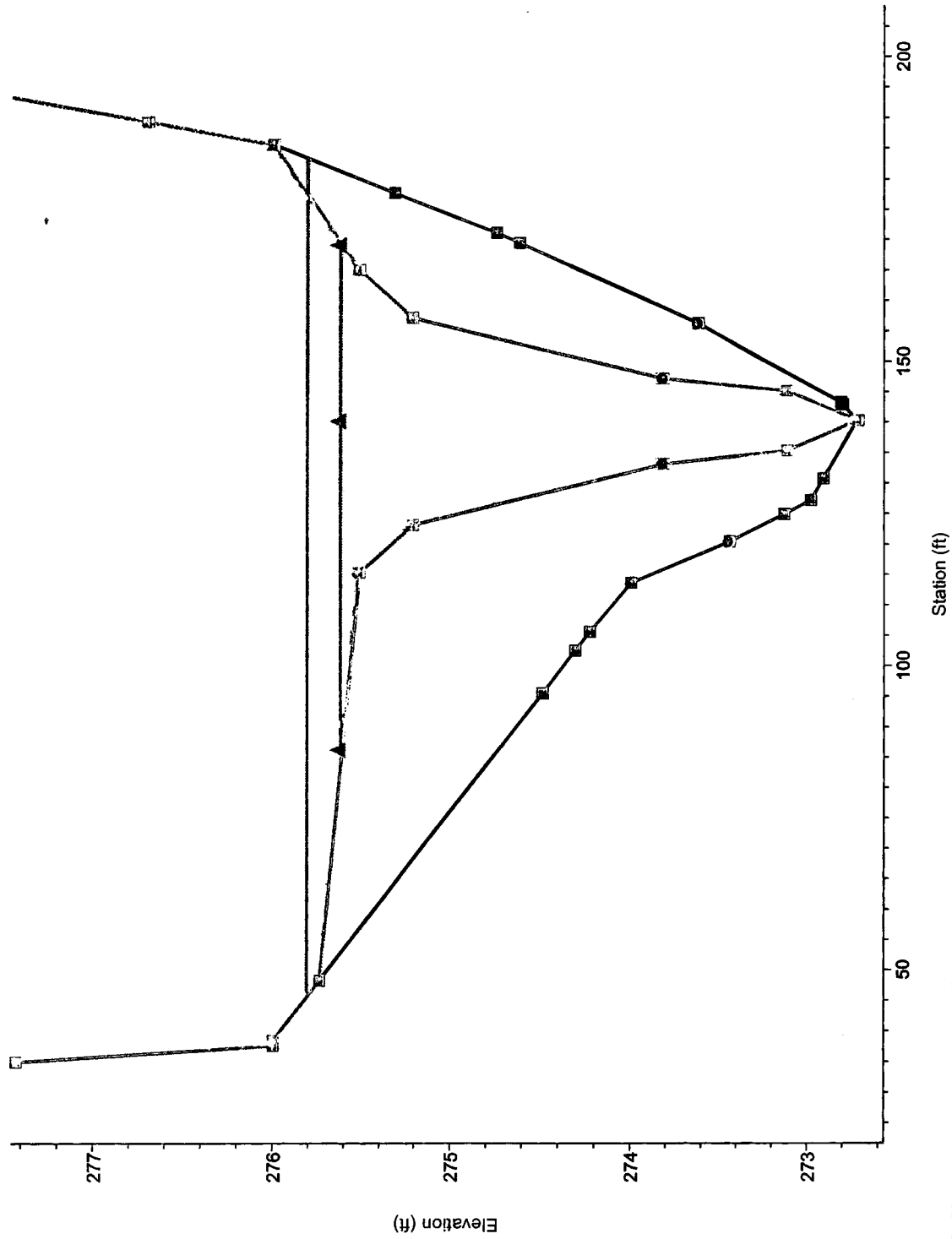


Legend	
WS Q100 - proposed	▲
WS Q100 - existing30	■
Ground - existing30	●
Bank Sta - existing30	■
Ground - proposed	▲
Bank Sta - proposed	●

Lower Spring Branch 100-YR WS Comparison

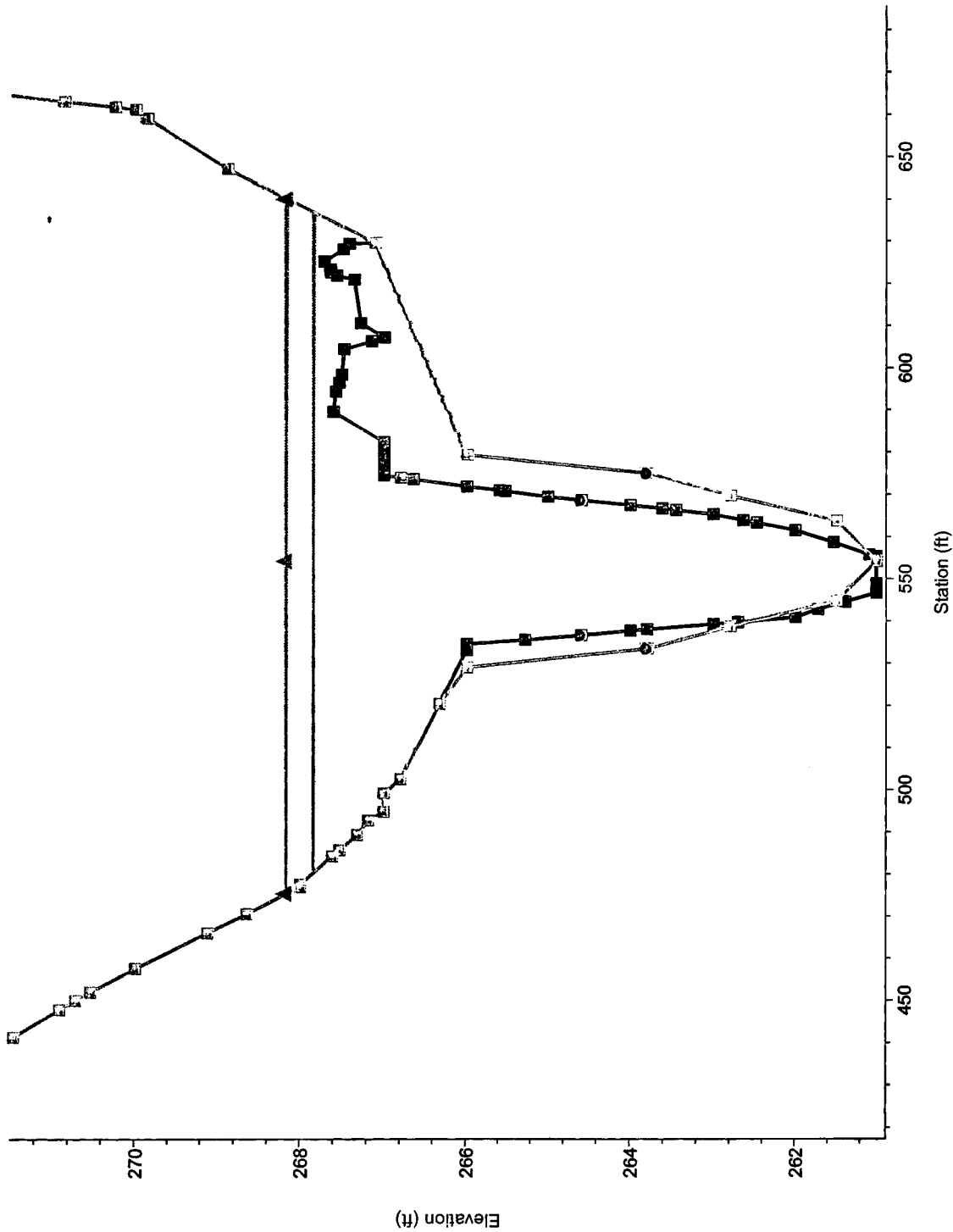
Reach: Tributary A Cross Section Station: 172

Legend	
WS Q100 - existing30	▲
WS Q100 - proposed	■
Ground - existing30	●
Bank Sta - existing30	□
Ground - proposed	○
Bank Sta - proposed	◻



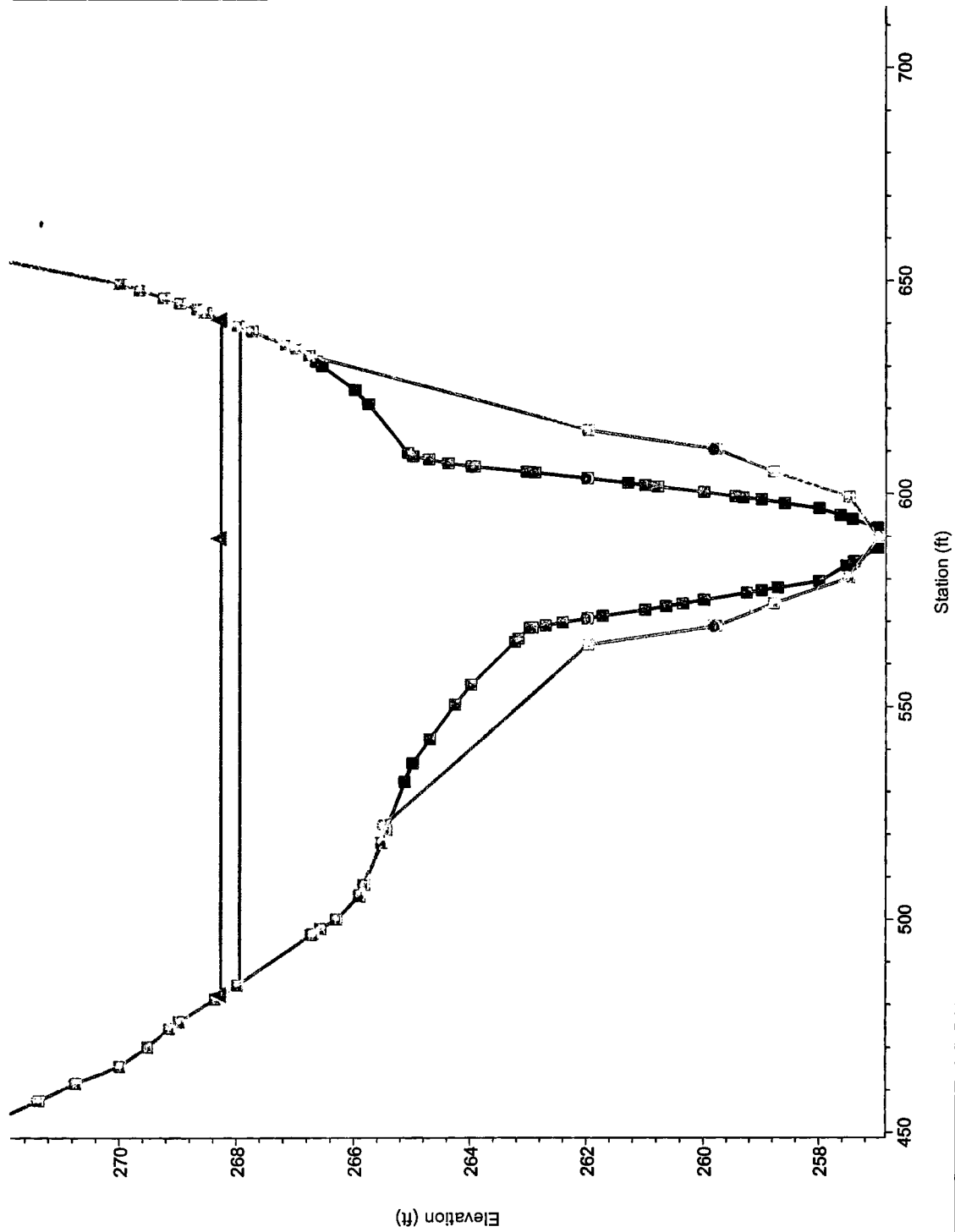
Lower Spring Branch 100-YR WS Comparison

Reach: Mainstem Cross Section Station: 1939



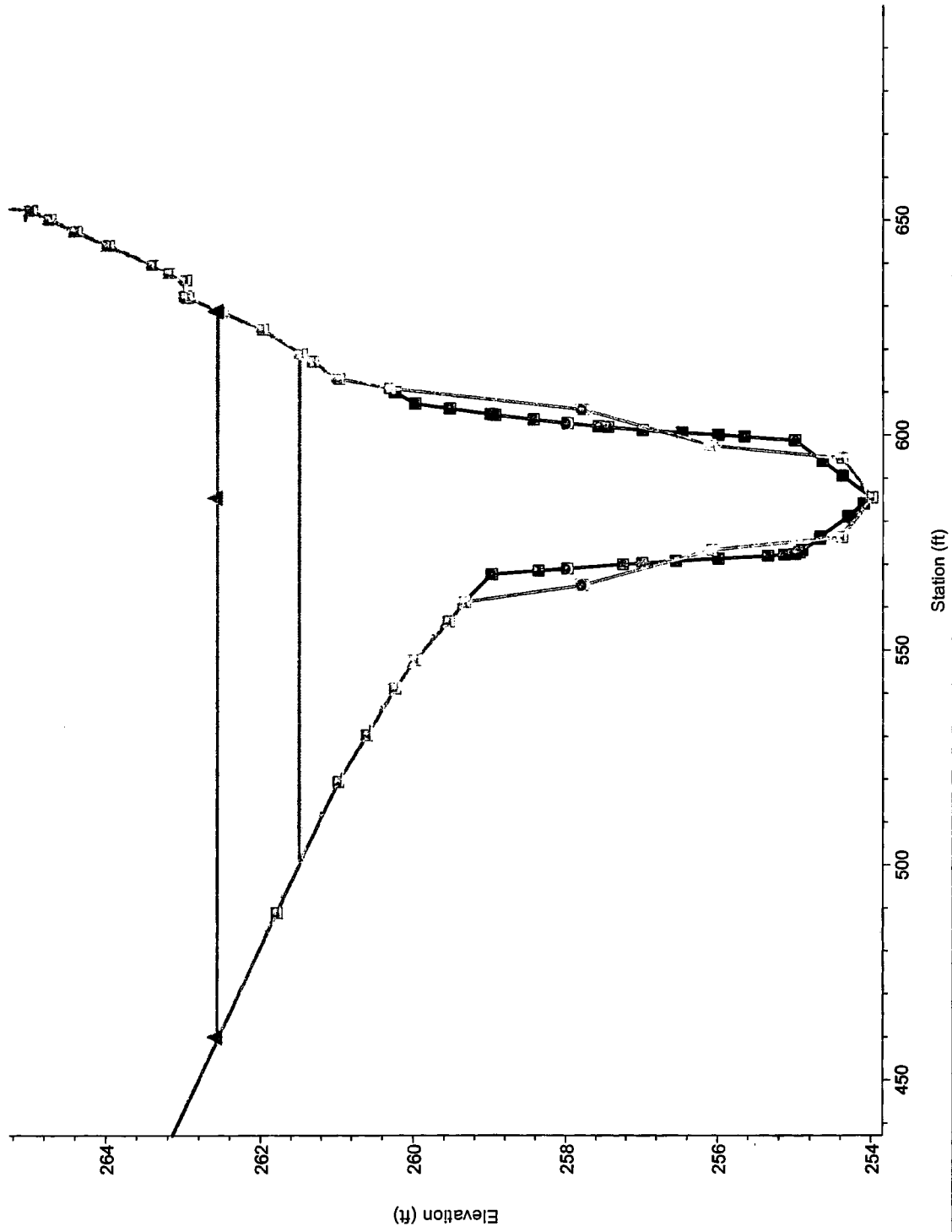
Lower Spring Branch 100-YR WS Comparison

Reach: Mainstem Cross Section Station: 1554

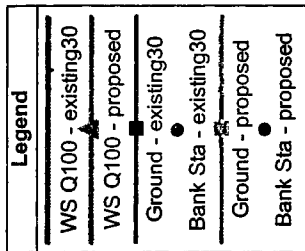


Lower Spring Branch 100-YR WS Comparison Reach: Mainstem Cross Section Station: 1038

Legend	
WS Q100 - proposed	▲
WS Q100 - existing30	■
Ground - existing30	●
Bank Sta - existing30	□
Ground - proposed	○
Bank Sta - proposed	◻

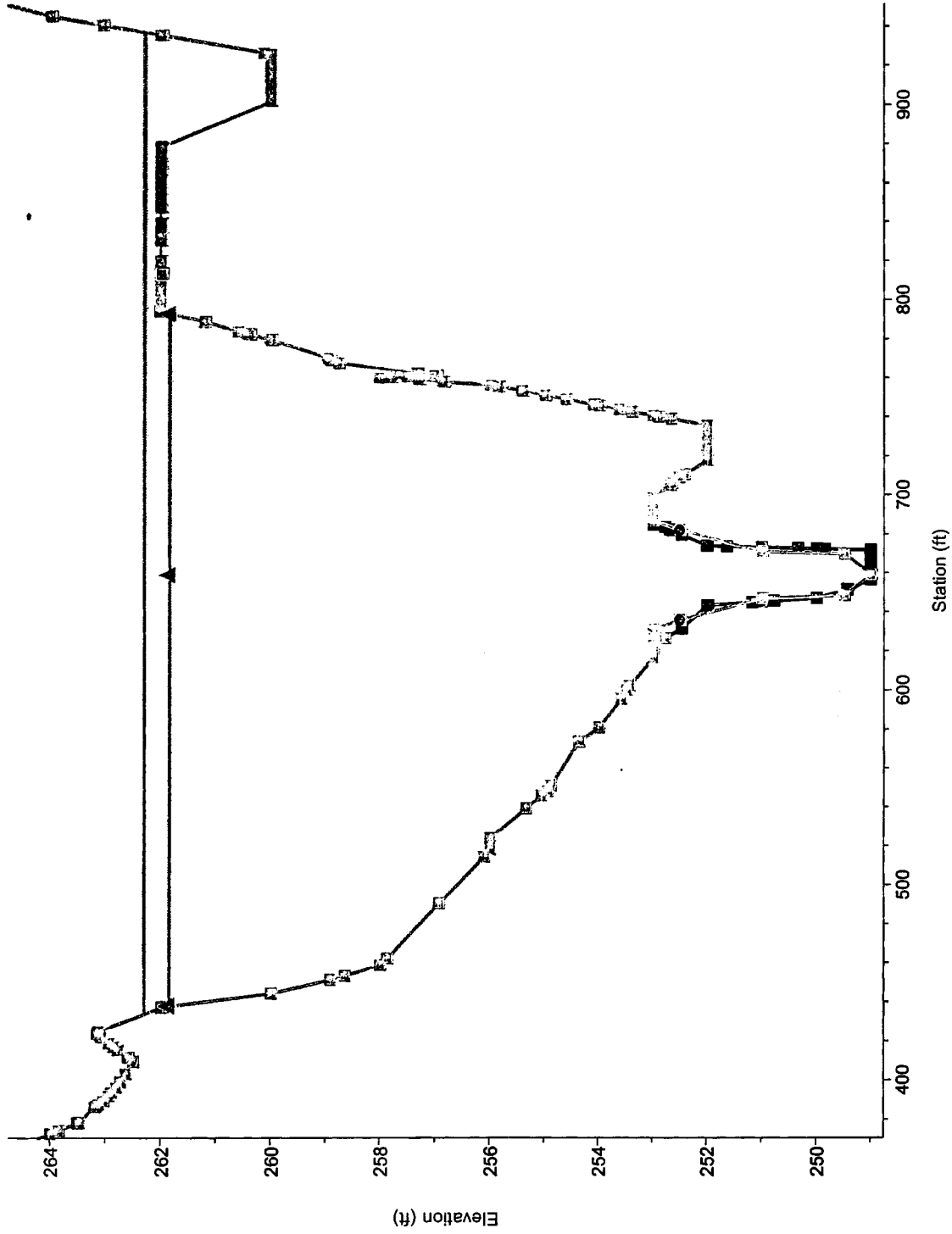


Reach: Mainstem Cross Section Station: 749



Reach: Mainstem Cross Section Station: 258

Reach: Mainstem Cross Section Station: 258



WETLAND DETERMINATION DATA FORMS

APPENDIX E

DATA FORM
ROUTINE WETLAND DETERMINATION
 (1987 COE Wetlands Delineation Manual)

Project/Site: <u>Spruce Branch</u> Applicant/Owner: <u>State of N.C.</u> Investigator: <u>DEP</u>	Date: <u>11/17/05</u> County: <u>Polk</u> State: <u>FLA</u>
Do Normal Circumstances exist on the site? Yes <input type="radio"/> No <input checked="" type="radio"/> Is the site significantly disturbed (Atypical Situation)? Yes <input type="radio"/> No <input checked="" type="radio"/> Is the area a potential Problem Area? Yes <input type="radio"/> No <input checked="" type="radio"/> (If needed, explain on reverse.)	Community ID: <u>1</u> Transect ID: _____ Plot ID: _____

Wetlands - bar inside to proceed - Flg's wt-1-7

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. <u>Watercress (O)</u>	<u>H</u>	<u>OBL</u>	9. <u>Norway spruce</u>	<u>C</u>	<u>FACW</u>
2. <u>Flycatcher (O)</u>	<u>H</u>	<u>OBL</u>	10. <u>English ivy</u>	<u>V</u>	<u>FACW</u>
3. <u>Mullein</u>	<u>S</u>	<u>OBL</u>	11. <u>S. lutea</u>	<u>H</u>	<u>UNK</u>
4. <u>Lonicera caerulea</u>	<u>V</u>	<u>OBL</u>	12. <u>Ornithoglossum</u>	<u>V</u>	<u>FACW</u>
5. <u>black willow</u>	<u>C</u>	<u>OBL</u>	13. _____	_____	_____
6. <u>black willow</u>	<u>C</u>	<u>OBL</u>	14. _____	_____	_____
7. <u>Willow (O)</u>	<u>C</u>	<u>OBL</u>	15. _____	_____	_____
8. <u>Sycamore</u>	<u>C</u>	<u>FACW</u>	16. _____	_____	_____

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-): 5/7 ~ 70%

Remarks: excluding non-native invasives

HYDROLOGY

<p>Recorded Data (Describe in Remarks):</p> <p><input type="checkbox"/> Stream, Lake, or Tide Gauge</p> <p><input type="checkbox"/> Aerial Photographs</p> <p><input type="checkbox"/> Other</p> <p><input checked="" type="checkbox"/> No Recorded Data Available</p> <hr/> <p>Field Observations:</p> <p>Depth of Surface Water: _____ (in.)</p> <p>Depth to Free Water in Pit: _____ (in.)</p> <p>Depth to Saturated Soil: <u>0</u> (in.)</p>	<p>Wetland Hydrology Indicators:</p> <p>Primary Indicators:</p> <p><input type="checkbox"/> Inundated</p> <p><input checked="" type="checkbox"/> Saturated in Upper 12 Inches</p> <p><input checked="" type="checkbox"/> Water Marks</p> <p><input type="checkbox"/> Drift Lines</p> <p><input checked="" type="checkbox"/> Sediment Deposits</p> <p><input type="checkbox"/> Drainage Patterns in Wetlands</p> <p>Secondary Indicators (2 or more required):</p> <p><input type="checkbox"/> Oxidized Root Channels in Upper 12 Inches</p> <p><input type="checkbox"/> Water-Stained Leaves</p> <p><input type="checkbox"/> Local Soil Survey Data</p> <p><input type="checkbox"/> FAC-Neutral Test</p> <p><input type="checkbox"/> Other (Explain in Remarks)</p>
<p>Remarks: <u>frequent inundation by stream - saturated in floodway</u></p>	

DATA FORM
ROUTINE WETLAND DETERMINATION
 (1987 COE Wetlands Delineation Manual)

Project/Site: <u>Spring Branch</u> Applicant/Owner: <u>B&B Co</u> Investigator: <u>DMB</u>	Date: <u>11/17/05</u> County: <u>Bart</u> State: <u>MD</u>
Do Normal Circumstances exist on the site? Yes <input checked="" type="radio"/> No <input type="radio"/> Is the site significantly disturbed (Atypical Situation)? Yes <input checked="" type="radio"/> No <input type="radio"/> Is the area a potential Problem Area? Yes <input checked="" type="radio"/> No <input type="radio"/> (If needed, explain on reverse.)	Community ID: <u>2</u> Transect ID: _____ Plot ID: _____

Wetland 2 - Outlet channel from pond - Plots 1-6

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. <u>Juncus effusus</u>	<u>H</u>	<u>FACW</u>	9. _____	_____	_____
2. <u>Impatiens capensis</u>	<u>H</u>	<u>FACW</u>	10. _____	_____	_____
3. <u>Lotus corniculatus</u>	<u>V</u>	<u>FAC-</u>	11. _____	_____	_____
4. <u>Potamogeton</u>	<u>S</u>	<u>FACV</u>	12. _____	_____	_____
5. <u>Watercress</u>	<u>H</u>	<u>OBL</u>	13. _____	_____	_____
6. <u>Lythrum hyssopifolium</u>	<u>L</u>	<u>FACW</u>	14. _____	_____	_____
7. _____	_____	_____	15. _____	_____	_____
8. _____	_____	_____	16. _____	_____	_____

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-): 4/6 ~ 67%

Remarks: _____

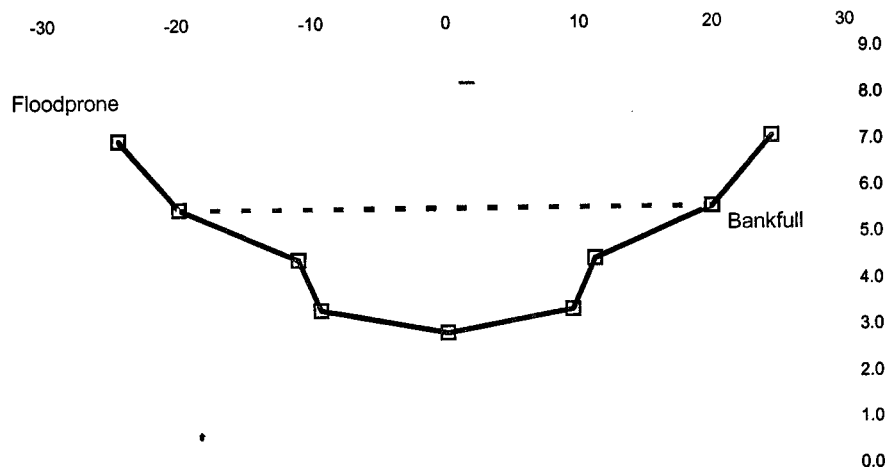
HYDROLOGY

<p>Recorded Data (Describe in Remarks):</p> <p> <input type="checkbox"/> Stream, Lake, or Tide Gauge <input type="checkbox"/> Aerial Photographs <input type="checkbox"/> Other <input checked="" type="checkbox"/> No Recorded Data Available </p> <hr/> <p>Field Observations:</p> <p>Depth of Surface Water: <u>0-6</u> (in.)</p> <p>Depth to Free Water in Pit: _____ (in.)</p> <p>Depth to Saturated Soil: _____ (in.)</p>	<p>Wetland Hydrology Indicators:</p> <p>Primary Indicators:</p> <p> <input checked="" type="checkbox"/> Inundated <input checked="" type="checkbox"/> Saturated in Upper 12 Inches <input checked="" type="checkbox"/> Water Marks <input type="checkbox"/> Drift Lines <input type="checkbox"/> Sediment Deposits <input type="checkbox"/> Drainage Patterns in Wetlands </p> <p>Secondary Indicators (2 or more required):</p> <p> <input checked="" type="checkbox"/> Oxidized Root Channels in Upper 12 Inches <input type="checkbox"/> Water-Stained Leaves <input type="checkbox"/> Local Soil Survey Data <input type="checkbox"/> FAC-Neutral Test <input type="checkbox"/> Other (Explain in Remarks) </p>
<p>Remarks: <u>Outlet from pond</u></p>	

PROPOSED RIFFLE CROSS SECTIONS

APPENDIX F

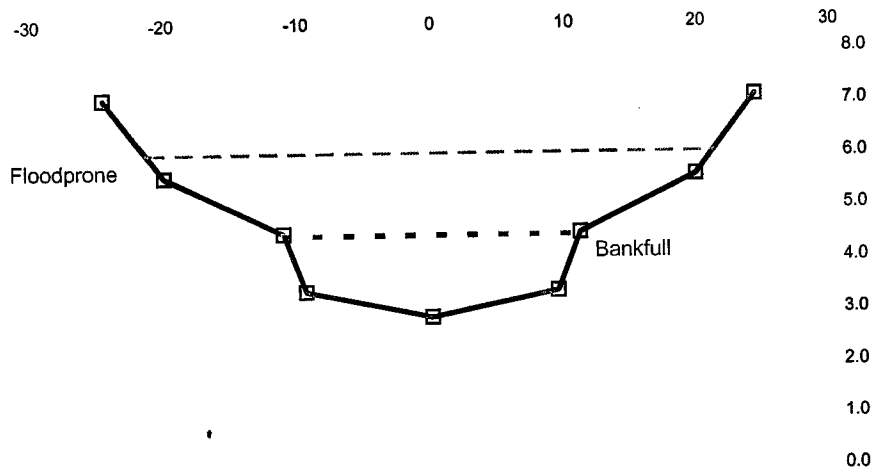
Reach 1 High BKF UPS Trib A&B Bc Channel



	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 ft ³ /s	1946.43 ft ³ /s
V _{avg}	5.98 ft/s	9.98 ft/s
R _h	1.51	0.28
Entrenchment	1.34	n/a
W/D Ratio	25.82	n/a
Avg. Depth	1.54 ft	3.66 ft
Avg. Shear	1.08 lbs/ft ²	

			Bankfull			Floodprone		
			Wetted Perimeter	Cross Sectional Area	Top Width	Wetted Perimeter	Cross Sectional Area	Top Width
Increment change	offset	elevation	40.61 ft	61.34 ft ²	39.80 ft	54.84 ft	195.10 ft ²	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 ft ²	0.00 ft	4.74 ft	8.77	4.50 ft
side slope	-11.1	4.5	8.87 ft	4.84 ft ²	8.80 ft	8.87 ft	28.59	8.80 ft
1.55:1	-9.4	3.4	2.02 ft	2.80 ft ²	1.70 ft	2.02 ft	7.39	1.70 ft
65%	-0.0	2.9	9.41 ft	23.03 ft ²	9.40 ft	9.41 ft	48.40	9.40 ft
	9.4	3.4	9.41 ft	23.03 ft ²	9.40 ft	9.41 ft	48.40	9.40 ft
	11.1	4.5	2.02 ft	2.80 ft ²	1.70 ft	2.02 ft	7.39	1.70 ft
	19.9	5.6	8.87 ft	4.84 ft ²	8.80 ft	8.87 ft	28.59	8.80 ft
	24.4	7.1	0.00 ft	0.00 ft ²	0.00 ft	4.74 ft	8.77	4.50 ft

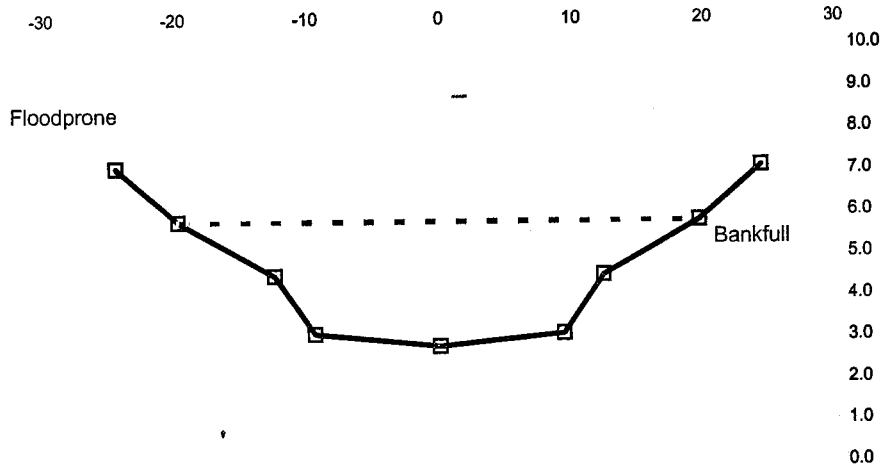
Reach 1 Low BKF UPS Trib A&B Bc Channel



	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 ft ³ /s	389.48 ft ³ /s
V _{avg}	5.05 ft/s	4.87 ft/s
R _h	1.17	0.56
Entrenchment	1.98	n/a
W/D Ratio	18.35	n/a
Avg. Depth	1.21 ft	1.83 ft
Avg. Shear	0.83 lbs/ft ²	

			Bankfull			Floodprone		
			Wetted Perimeter	Cross Sectional Area	Top Width	Wetted Perimeter	Cross Sectional Area	Top Width
1			22.78 ft	26.66 ft ²	22.12 ft	44.85 ft	80.03 ft ²	43.82 ft
Increment change	offset	elevation						
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 ft ²	0.00 ft	1.41 ft	0.30	1.34 ft
side slope	-11.1	4.5	0.00 ft	0.00 ft ²	0.00 ft	8.87 ft	8.77	8.80 ft
1.55:1	-9.4	3.4	1.98 ft	0.89 ft ²	1.66 ft	2.02 ft	3.56	1.70 ft
65%	-9.4	3.4	9.41 ft	12.44 ft ²	9.40 ft	9.41 ft	27.23	9.40 ft
	9.4	3.4	9.41 ft	12.44 ft ²	9.40 ft	9.41 ft	27.23	9.40 ft
	11.1	4.5	1.98 ft	0.89 ft ²	1.66 ft	2.02 ft	3.56	1.70 ft
	19.9	5.6	0.00 ft	0.00 ft ²	0.00 ft	8.87 ft	8.77	8.80 ft
	24.4	7.1	0.00 ft	0.00 ft ²	0.00 ft	1.41 ft	0.30	1.34 ft

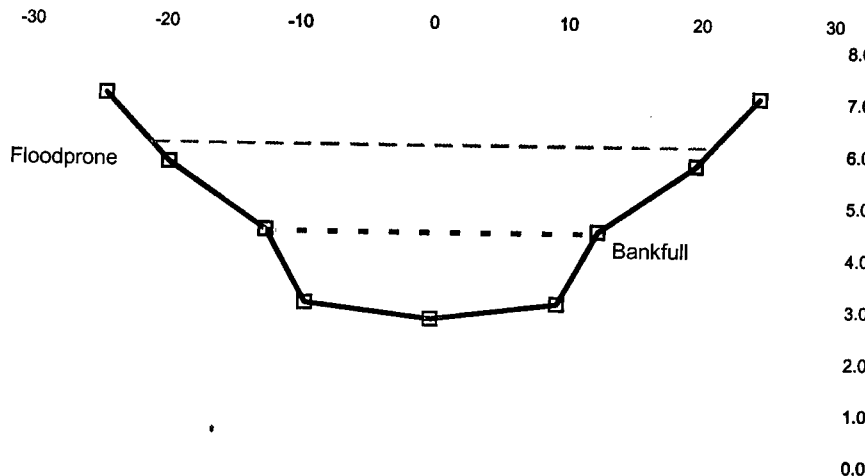
Reach 2 High BKF **UPS Trib A&B Bc Channel**



	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 ft ³ /s	2386.38 ft ³ /s
V _{avg}	6.87 ft/s	10.61 ft/s
R _h	1.86	0.24
Entrenchment	1.36	n/a
W/D Ratio	20.67	n/a
Avg. Depth	1.90 ft	4.21 ft
Avg. Shear	1.32 lbs/ft ²	

			Bankfull			Floodprone		
			Wetted Perimeter	Cross Sectional Area	Top Width	Wetted Perimeter	Cross Sectional Area	Top Width
Increment change	offset	elevation	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 ft ²	0.00 ft	4.88 ft	10.92	4.70 ft
side slope	-12.4	4.5	7.34 ft	4.65 ft ²	7.23 ft	7.41 ft	26.46	7.30 ft
2.14:1	-9.4	3.1	3.31 ft	5.96 ft ²	3.00 ft	3.31 ft	14.92	3.00 ft
47%	0.0	2.8	9.40 ft	26.67 ft ²	9.40 ft	9.40 ft	54.75	9.40 ft
	9.4	3.1	9.40 ft	26.67 ft ²	9.40 ft	9.40 ft	54.75	9.40 ft
	12.4	4.5	3.31 ft	5.96 ft ²	3.00 ft	3.31 ft	14.92	3.00 ft
	19.7	5.8	7.34 ft	4.65 ft ²	7.23 ft	7.41 ft	26.46	7.30 ft
	24.4	7.1	0.00 ft	0.00 ft ²	0.00 ft	4.88 ft	10.92	4.70 ft

Reach 2 Low BKF UPS Trib A&B Bc Channel



	<i>Bankfull</i>	<i>Floodprone</i>
<i>Max Depth</i>	1.68 ft.	3.36 ft.
<i>Manning's 'n'</i>	0.035	0.060
<i>slope</i>	1.14%	n/a
<i>Q</i>	177.53 ft ³ /s	493.25 ft ³ /s
<i>V_{avg}</i>	5.40 ft/s	5.48 ft/s
<i>R_h</i>	1.30	0.49
<i>Entrenchment</i>	1.75	n/a
<i>W/D Ratio</i>	18.60	n/a
<i>Avg. Depth</i>	1.33 ft	2.08 ft
<i>Avg. Shear</i>	0.92 lbs/ft ²	

			<i>Bankfull</i>			<i>Floodprone</i>		
			<i>Wetted Perimeter</i>	<i>Cross Sectional Area</i>	<i>Top Width</i>	<i>Wetted Perimeter</i>	<i>Cross Sectional Area</i>	<i>Top Width</i>
1			25.34 ft	32.85 ft ²	24.71 ft	44.31 ft	89.97 ft ²	43.31 ft
<i>Increment change</i>	<i>offset</i>	<i>elevation</i>						
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 ft ²	0.00 ft	1.35 ft	0.23	1.30 ft
<i>side slope</i>	-12.4	4.5	0.00 ft	0.00 ft ²	0.00 ft	7.41 ft	7.38	7.30 ft
2.14:1	-9.4	3.1	3.26 ft	2.04 ft ²	2.96 ft	3.31 ft	7.08	3.00 ft
47%	0.0	2.8	9.40 ft	14.38 ft ²	9.40 ft	9.40 ft	30.18	9.40 ft
	9.4	3.1	9.40 ft	14.38 ft ²	9.40 ft	9.40 ft	30.18	9.40 ft
	12.4	4.5	3.26 ft	2.04 ft ²	2.96 ft	3.31 ft	7.08	3.00 ft
	19.7	5.8	0.00 ft	0.00 ft ²	0.00 ft	7.41 ft	7.38	7.30 ft
	24.4	7.1	0.00 ft	0.00 ft ²	0.00 ft	1.35 ft	0.23	1.30 ft



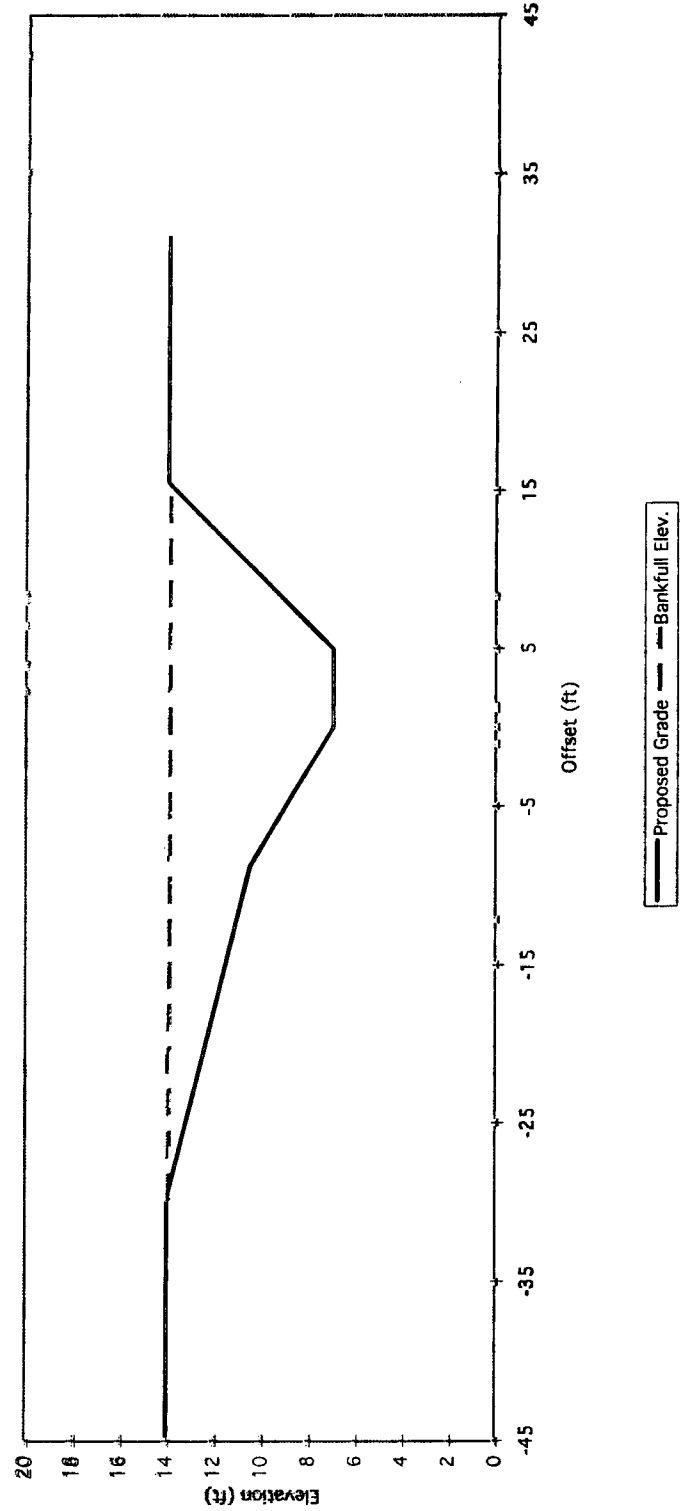
Biohabitats
Incorporated

Project Name: Lower Spring Branch
Biohabitats Project No.: 5015.01
Date: 2/13/2006
Prepared by: PK
Cross Section Identification: Reach 1-2

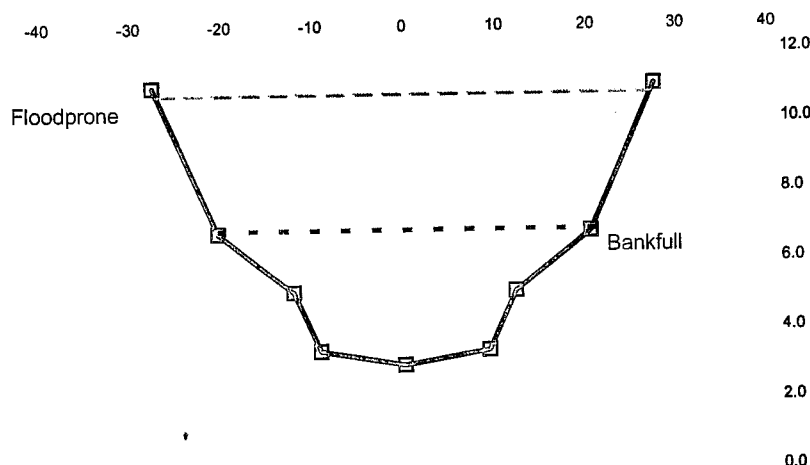
Meander Channel Elevation and Offset Nodes		
Feature	Offset	Elevation
Floodprone left	-44.625	14.0
Bankfull Left	-29.75	14.0
Bar to Pool	-8.75	10.5
Thalweg	0	7.0
Pool	5	7.0
Bankfull Right	15.5	14.0
Floodprone right	31	14

Meander Channel Dimensions		
Meander Width	45.3 ft	Ratio to Riffle 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	

Typical Meander Cross Section Reach 1 and 2



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
Entrenchment	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	

			Bankfull			Floodprone		
			<i>Wetted Perimeter</i>	<i>Cross Sectional Area</i>	<i>Top Width</i>	<i>Wetted Perimeter</i>	<i>Cross Sectional Area</i>	<i>Top Width</i>
1			42.55 ft	98.36 ft²	41.20 ft	65.40 ft	296.29 ft²	60.87 ft
Increment change	offset	elevation						
0.1	-27.5	11.0	0.15 ft	0.01 ft²	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

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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 Discharge = 6.5 [cfs]
 Floodprone Elevation = 9.0 [ft]
 Bankfull Elevation = 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 = 1.6
 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:

$$Q = 1.49 \frac{A}{n} (R)^{\frac{2}{3}} (S)^{\frac{1}{2}}$$

$$\tau_c = \rho g R S$$

Cross Section Points

Feature	Offset	Elevation	Cross Section Area [sq. ft.]	Wetted Perimeter [ft]
Floodprone	-30	9.0	bank slope	2.06
Bankfull	-12	6.5		
	-10.7	5.0		
Max Depth	0	3.4		
	10.7	3.0		
Bankfull	12	3.4	2.99	2.06
Floodprone	17	6.5	Total Area = 76.6	Wet Perimeter = 25.54
	22	9.0		

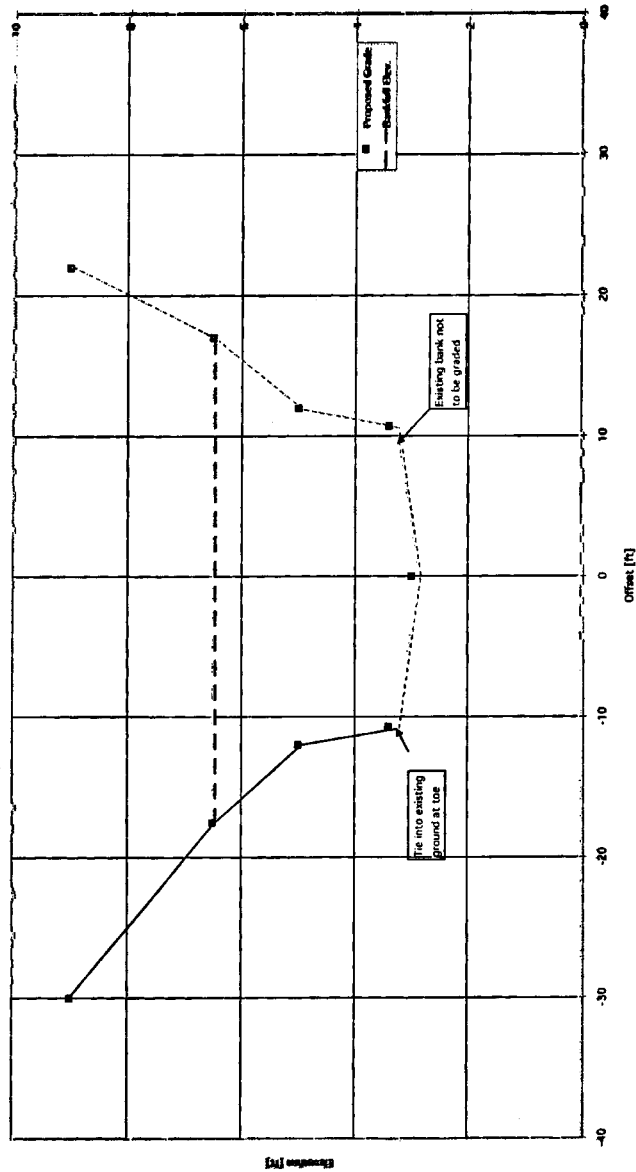
Bankfull Channel Calculations

Feature	Offset	Elevation	Cross Section Area [sq. ft.]	Wetted Perimeter [ft]
Floodprone	-30	9.0	bank slope	2.06
Bankfull	-12	6.5		
	-10.7	5.0		
Max Depth	0	3.4		
	10.7	3.0		
Bankfull	12	3.4	2.99	2.06
Floodprone	17	6.5	Total Area = 76.6	Wet Perimeter = 25.54
	22	9.0		

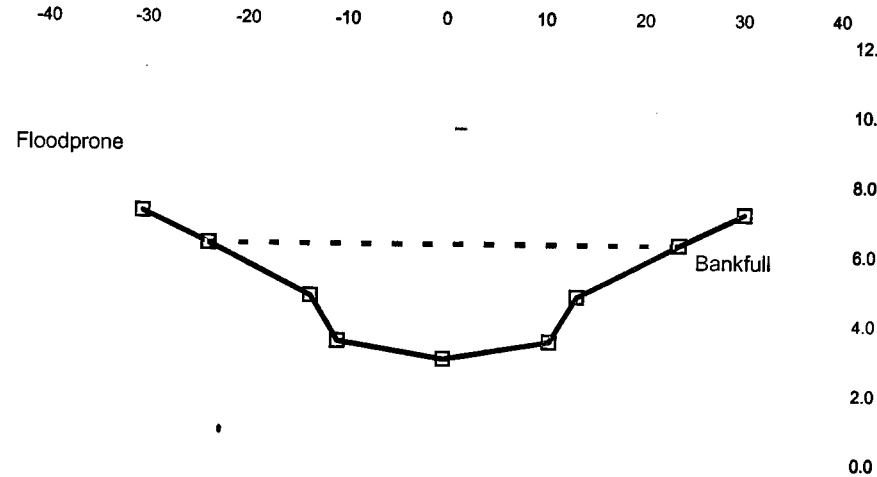
Floodprone Channel Calculations

Feature	Offset	Elevation	Cross Section Area [sq. ft.]	Wetted Perimeter [ft]
Floodprone	-30	9.0	bank slope	2.06
Bankfull	-12	6.5		
	-10.7	5.0		
Max Depth	0	3.4		
	10.7	3.0		
Bankfull	12	3.4	2.99	2.06
Floodprone	17	6.5	Total Area = 76.6	Wet Perimeter = 25.54
	22	9.0		

Typical Riffle Cross Section



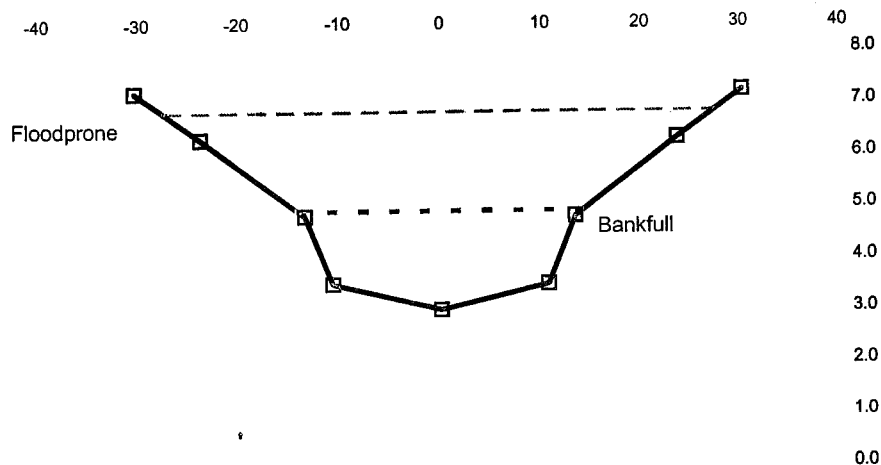
Reach 4 High BKF
DS Near Dulaney Valley C Channel



	<i>Bankfull</i>	<i>Floodprone</i>
<i>Max Depth</i>	3.31 ft.	6.62 ft.
<i>Manning's 'n'</i>	0.035	0.060
<i>slope</i>	0.75%	n/a
<i>Q</i>	527.58 ft ³ /s	2774.26 ft ³ /s
<i>V_{avg}</i>	5.69 ft/s	9.05 ft/s
<i>R_h</i>	1.92	0.22
<i>Entrenchment</i>	1.41	n/a
<i>W/D Ratio</i>	24.43	n/a
<i>Avg. Depth</i>	1.95 ft	4.56 ft
<i>Avg. Shear</i>	0.90 lbs/ft ²	

			<i>Bankfull</i>			<i>Floodprone</i>		
			<i>Wetted Perimeter</i>	<i>Cross Sectional Area</i>	<i>Top Width</i>	<i>Wetted Perimeter</i>	<i>Cross Sectional Area</i>	<i>Top Width</i>
1			48.45 ft	92.79 ft ²	47.61 ft	68.22 ft	306.48 ft ²	67.20 ft
<i>Increment change</i>	<i>offset</i>	<i>elevation</i>						
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 ft ²	0.07 ft	6.66 ft	18.94	6.60 ft
<i>side slope</i>	-13.4	4.8	10.41 ft	7.82 ft ²	10.30 ft	10.41 ft	41.91	10.30 ft
2.08:1	-10.7	3.5	3.00 ft	5.83 ft ²	2.70 ft	3.00 ft	14.77	2.70 ft
48%	0.0	3.0	10.71 ft	32.74 ft ²	10.70 ft	10.71 ft	68.15	10.70 ft
	10.7	3.5	10.71 ft	32.74 ft ²	10.70 ft	10.71 ft	68.15	10.70 ft
	13.4	4.8	3.00 ft	5.83 ft ²	2.70 ft	3.00 ft	14.77	2.70 ft
	23.7	6.3	10.41 ft	7.82 ft ²	10.30 ft	10.41 ft	41.91	10.30 ft
	30.3	7.2	0.07 ft	0.00 ft ²	0.07 ft	6.66 ft	18.94	6.60 ft

Reach 4 Low BKF **DS Near Dulaney Valley C Channel**



	<i>Bankfull</i>	<i>Floodprone</i>
<i>Max Depth</i>	1.91 ft.	3.81 ft.
<i>Manning's 'n'</i>	0.035	0.060
<i>slope</i>	0.75%	n/a
<i>Q</i>	180.27 ft ³ /s	505.48 ft ³ /s
<i>V_{avg}</i>	4.55 ft/s	4.23 ft/s
<i>R_h</i>	1.37	0.50
<i>Entrenchment</i>	2.08	n/a
<i>W/D Ratio</i>	20.17	n/a
<i>Avg. Depth</i>	1.40 ft	2.04 ft
<i>Avg. Shear</i>	0.64 lbs/ft ²	

			<i>Bankfull</i>			<i>Floodprone</i>		
			<i>Wetted Perimeter</i>	<i>Cross Sectional Area</i>	<i>Top Width</i>	<i>Wetted Perimeter</i>	<i>Cross Sectional Area</i>	<i>Top Width</i>
			28.90 ft	39.62 ft²	28.27 ft	59.64 ft	119.57 ft²	58.70 ft
<i>Increment change</i>	<i>offset</i>	<i>elevation</i>						
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
<i>side slope</i>	-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



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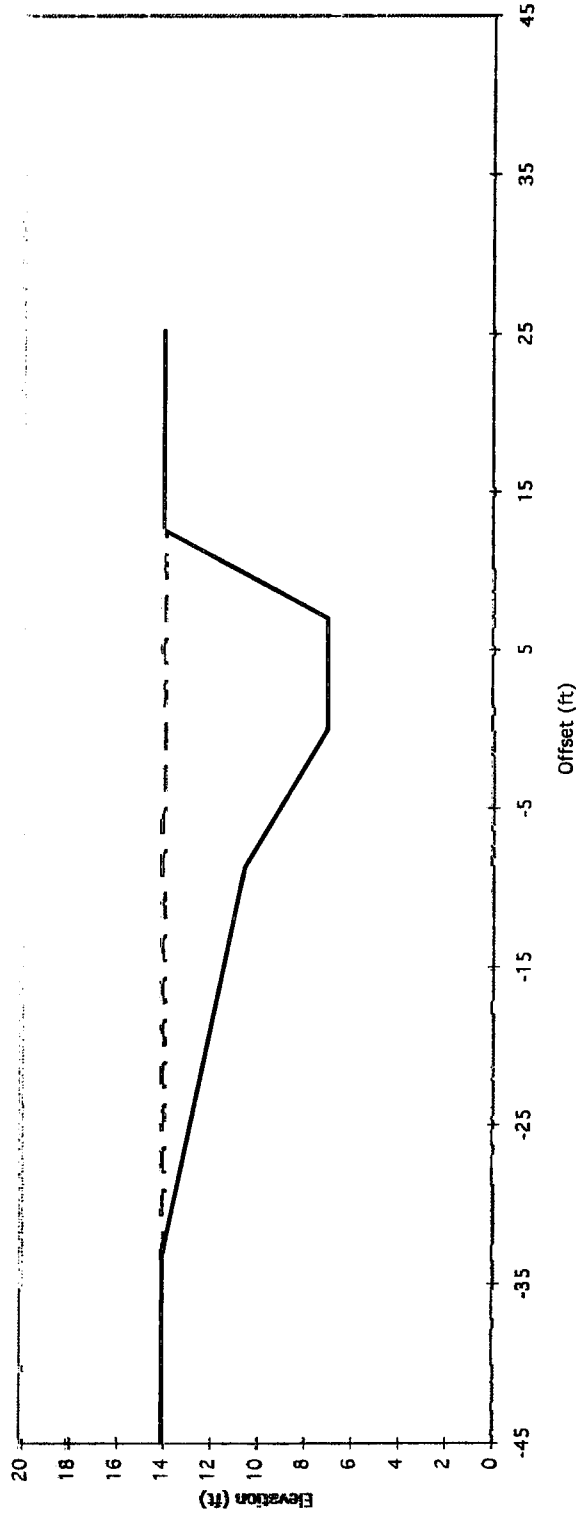
Project Name: Lower Spring Branch
Biohabitats Project No. : 5015.01
Date: 2/13/2006
Prepared by: PK
Cross Section Identification: Reach 4

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		
Meander Width	45.9 ft	Ratio to Riffle 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	

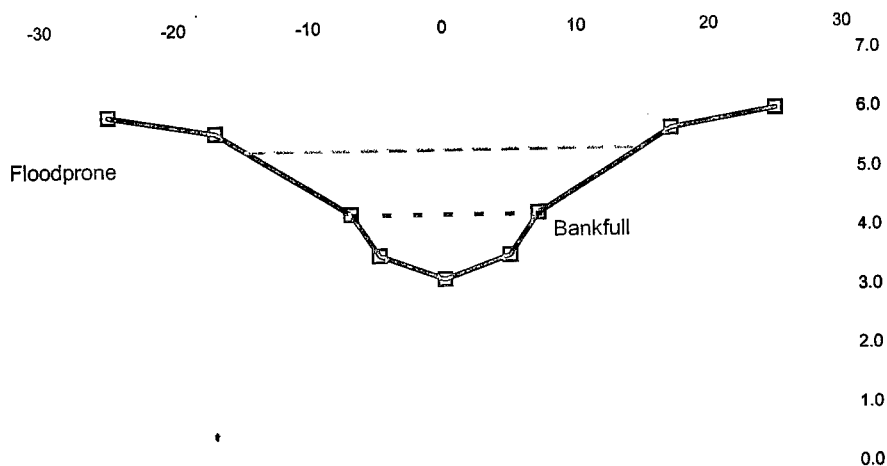
Typical Meander Cross Section

Reach 4



— Proposed Grade — Bankfull Elev.

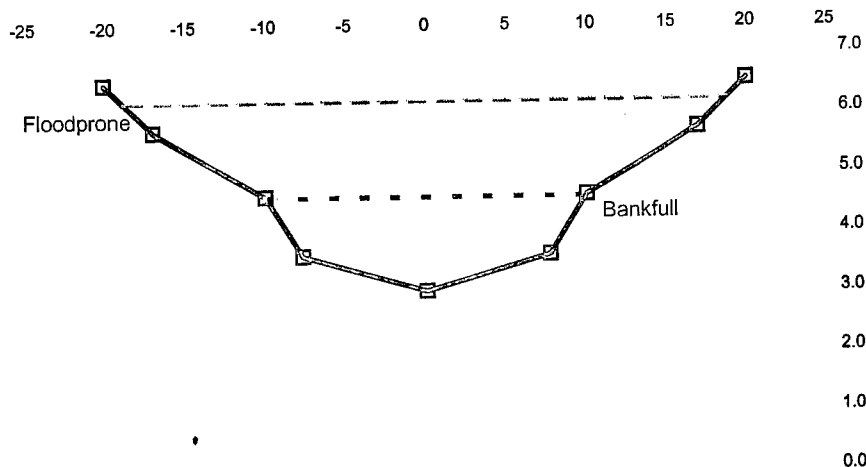
Trib A Channel



	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
Entrenchment	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	

			Bankfull			Floodprone		
			Wetted Perimeter	Cross Sectional Area	Top Width	Wetted Perimeter	Cross Sectional Area	Top Width
1			14.22 ft	10.21 ft ²	13.96 ft	29.96 ft	33.98 ft ²	29.54 ft
Increment change	offset	elevation						
0.1	-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
side slope	-7.0	4.3	0.00 ft	0.00 ft ²	0.00 ft	7.85 ft	4.23	7.77 ft
3.00:1	-4.9	3.6	2.19 ft	0.72 ft ²	2.08 ft	2.21 ft	3.02	2.10 ft
33%	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 _n	1.08	0.58
Entrenchment	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	

Bankfull			Floodprone		
Wetted Perimeter	Cross Sectional Area	Top Width	Wetted Perimeter	Cross Sectional Area	Top Width

Increment change	offset	elevation	20.41 ft	22.10 ft ²	19.95 ft	40.20 ft	69.55 ft ²	39.38 ft
0.1	-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
side slope	-10.0	4.6	0.00 ft	0.00 ft ²	0.00 ft	7.09 ft	7.20	7.00 ft
2.30:1	-7.7	3.6	2.48 ft	1.12 ft ²	2.27 ft	2.51 ft	4.78	2.30 ft
43%	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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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**

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Appendix D.....Restoration Alternatives
Appendix E Preliminary Construction Cost Estimates for the Concrete-lined Reaches

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. Additional objectives considered when developing the restoration plan for

Lower 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.

Spring Branch Watershed, Baltimore County

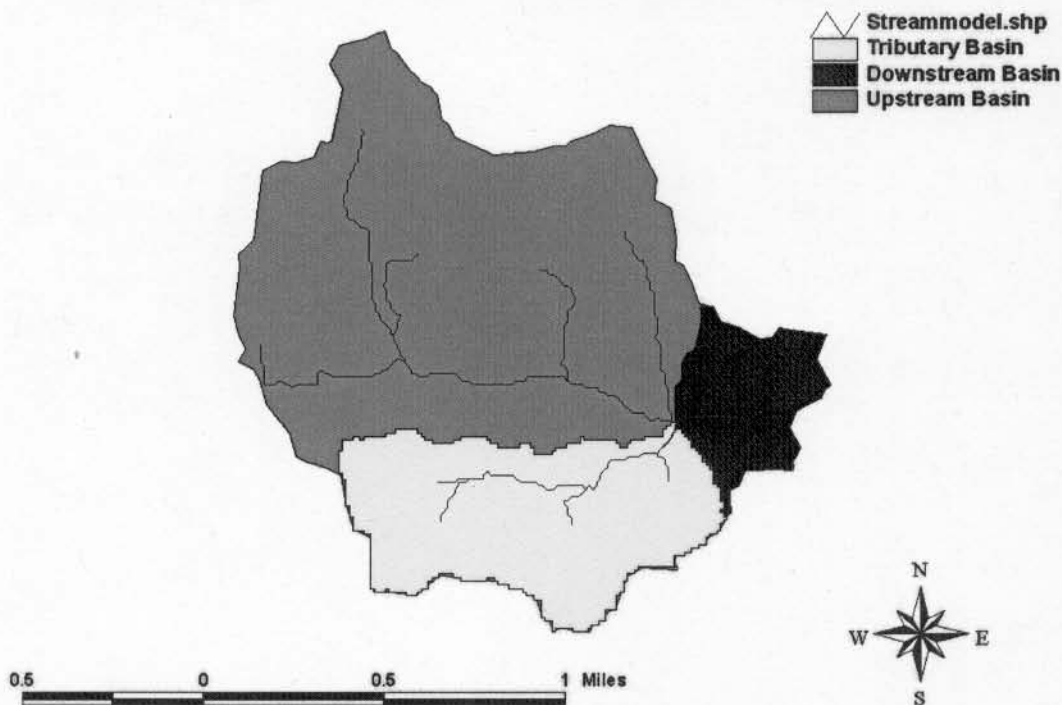


Figure 2.0. Spring Branch Sub-basin Watershed Map.

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.

Alluvial Land (Av, along and within the stream corridor)

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.

Baltimore Silt Loam, 3-8% slopes, moderately eroded (BmB2, northern immediate watershed)

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.

Hollinger and Conestoga, very rocky loams 3-15% slopes (HsC, southern immediate watershed)

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 micaceous limestone or calciferous schist. Rock exposures in this soil type can be 30 to 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 field 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. The 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%.

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.



Photo 2. Tributary B looking upstream.

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.

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.



Photo 3. Reach 2 Looking downstream from the upstream end of the reach.

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.

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.



Photo 4. Reach 3 looking upstream toward Reach 2.

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

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



Photo 5. Reach 4 looking upstream.

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 a forested buffer as in the first alternative. In addition, the northern concrete bank of the Reach 1 would 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 Tributary 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



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September 6, 2005

Lbri 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.

A handwritten signature in black ink, appearing to read 'P. Kovalcik', written over a horizontal line.

Paul Kovalcik
Aquatic Ecologist

Enclosure



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:

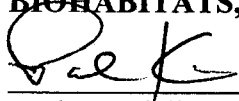
- Inventoried historic properties,
- National Register listed properties,
- Prior archeological or architectural research conducted in the project vicinity,
- An informed assessment of the project area's potential for containing historic properties that have not yet been identified.

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.

A handwritten signature in black ink, appearing to read 'Paul Kovalcik', is written over a horizontal line.

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.

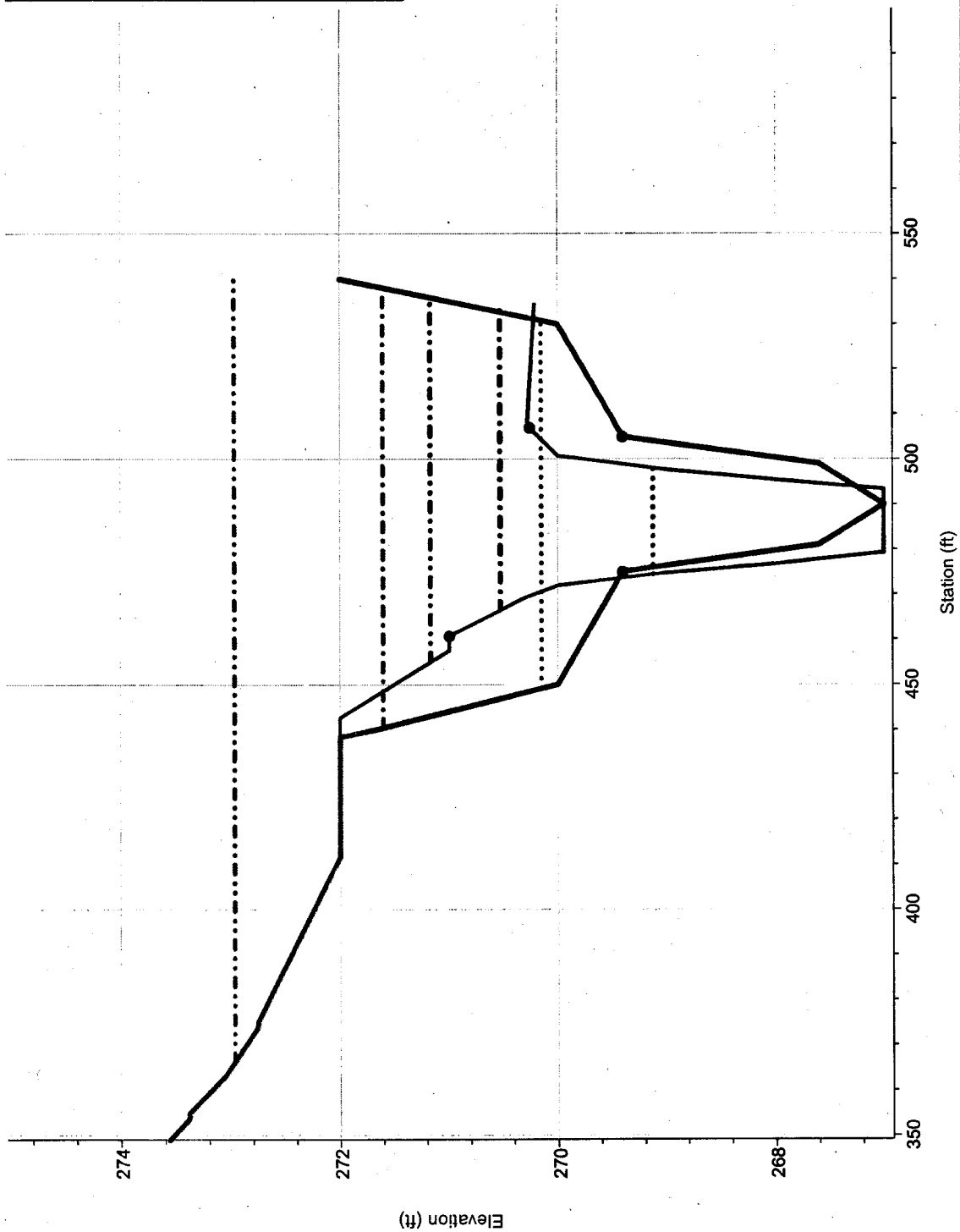


Paul Kovalcik
Aquatic Ecologist

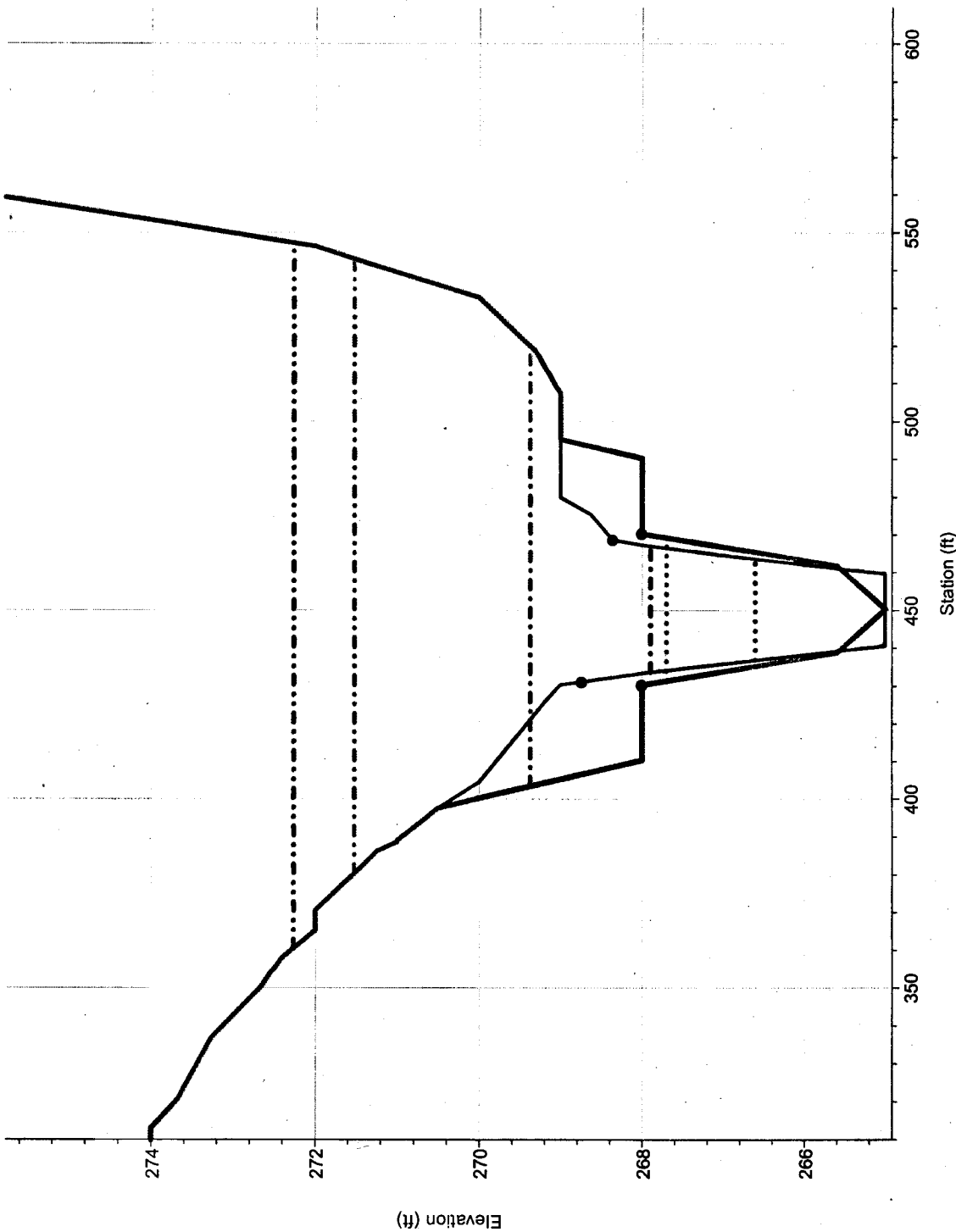
HYDRAULIC MODEL RESULTS

APPENDIX B

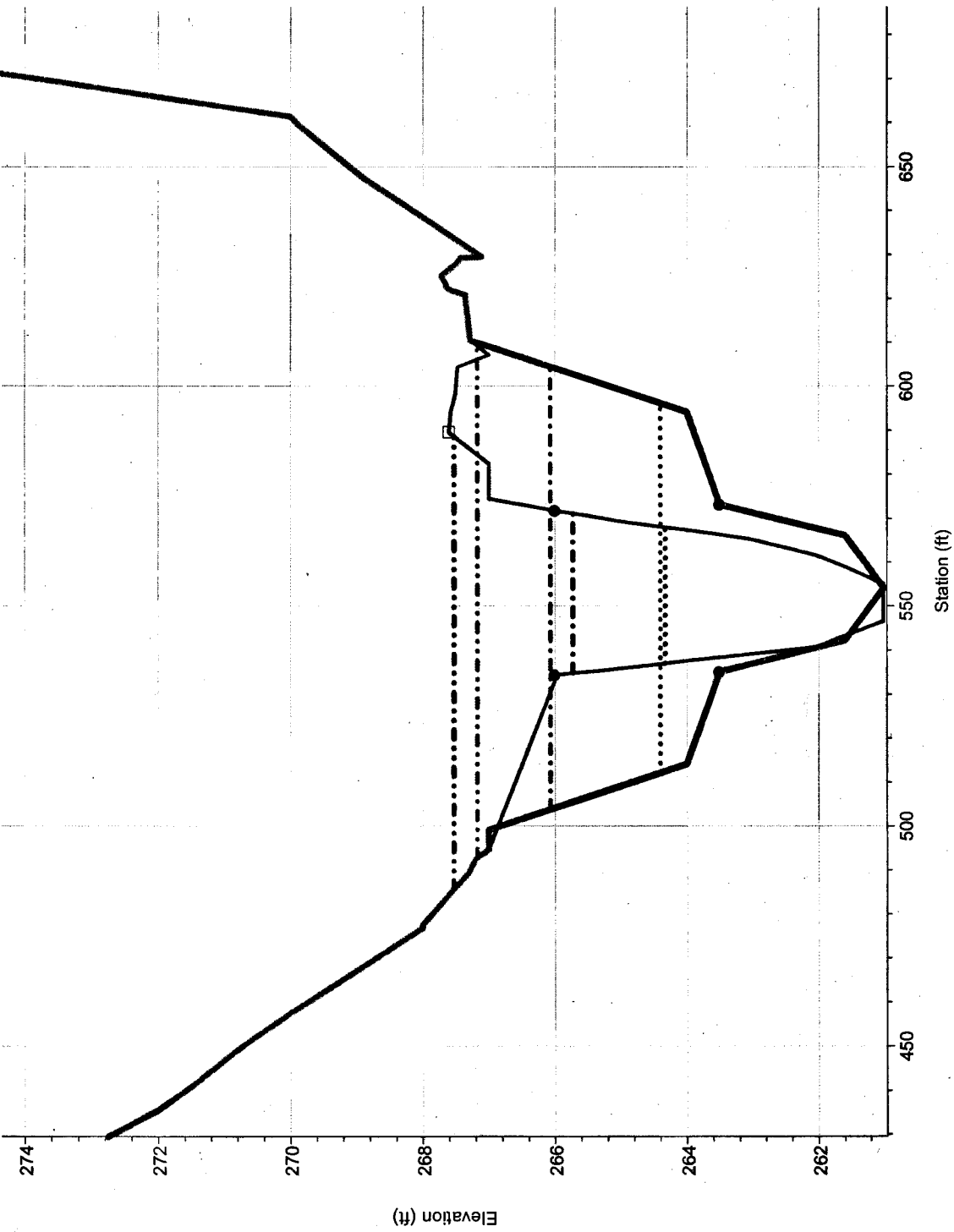
Reach 1 US of Tributary B Note: Right bank of existing XS extends into Trib B



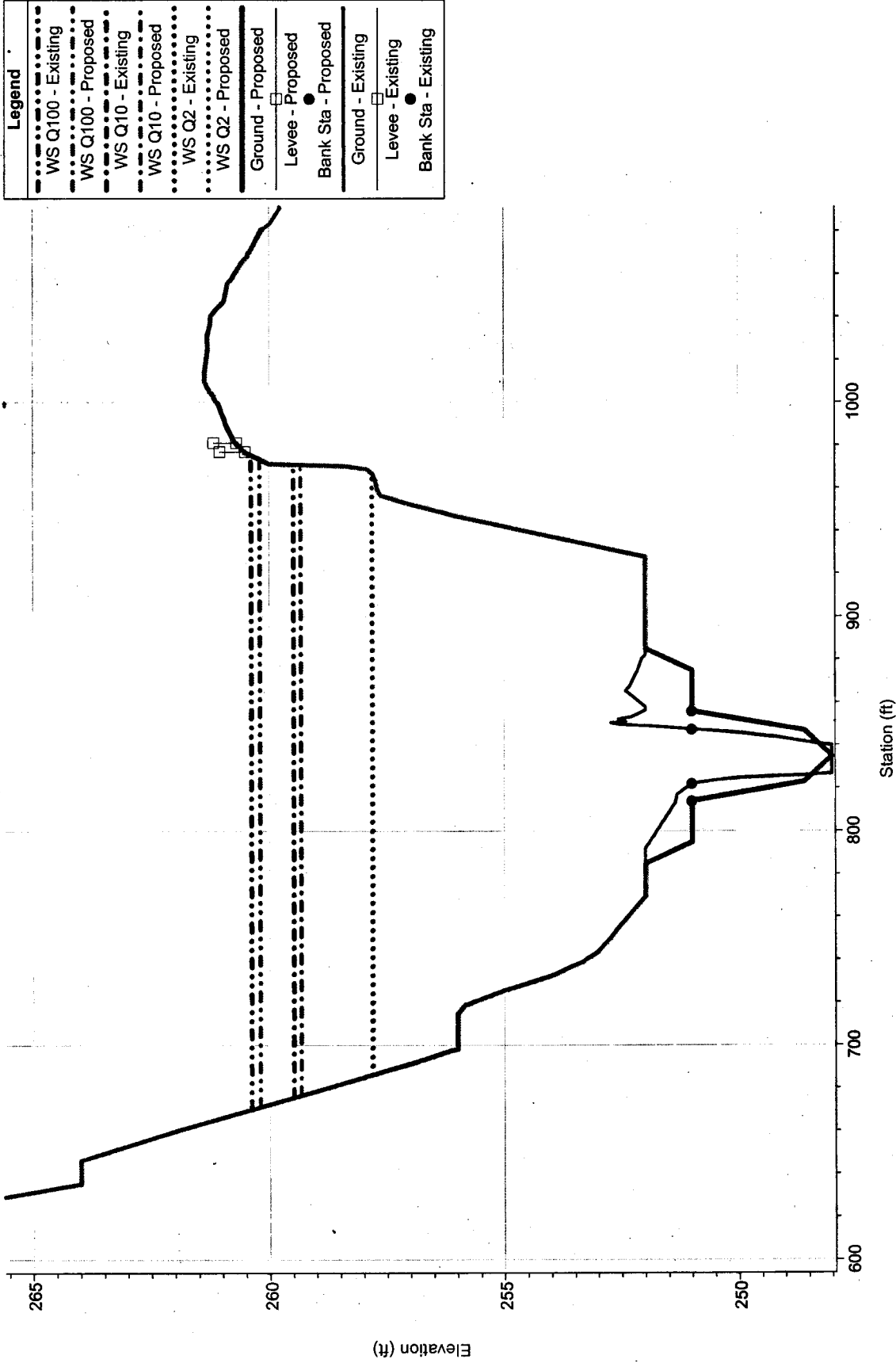
Lower Spring Branch



Lower Spring Branch



Lower Spring Branch
Reach 4



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				UNIT	TOTAL
No.	ITEM DESCRIPTION	QUANTITY	UNIT	COST	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				UNIT	TOTAL
No.	ITEM DESCRIPTION	QUANTITY	UNIT	COST	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				UNIT	TOTAL
No.	ITEM DESCRIPTION	QUANTITY	UNIT	COST	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



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FINAL

**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



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

Gunpowder Reservoirs
Nutrients/Sediment TMDLs
Document version: August 23, 2006

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Gunpowder Reservoirs

Nutrients/Sediment TMDLs

Document version: August 23, 2006

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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 <i>a</i>
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

Gunpowder Reservoirs

Nutrients/Sediment TMDLs

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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.

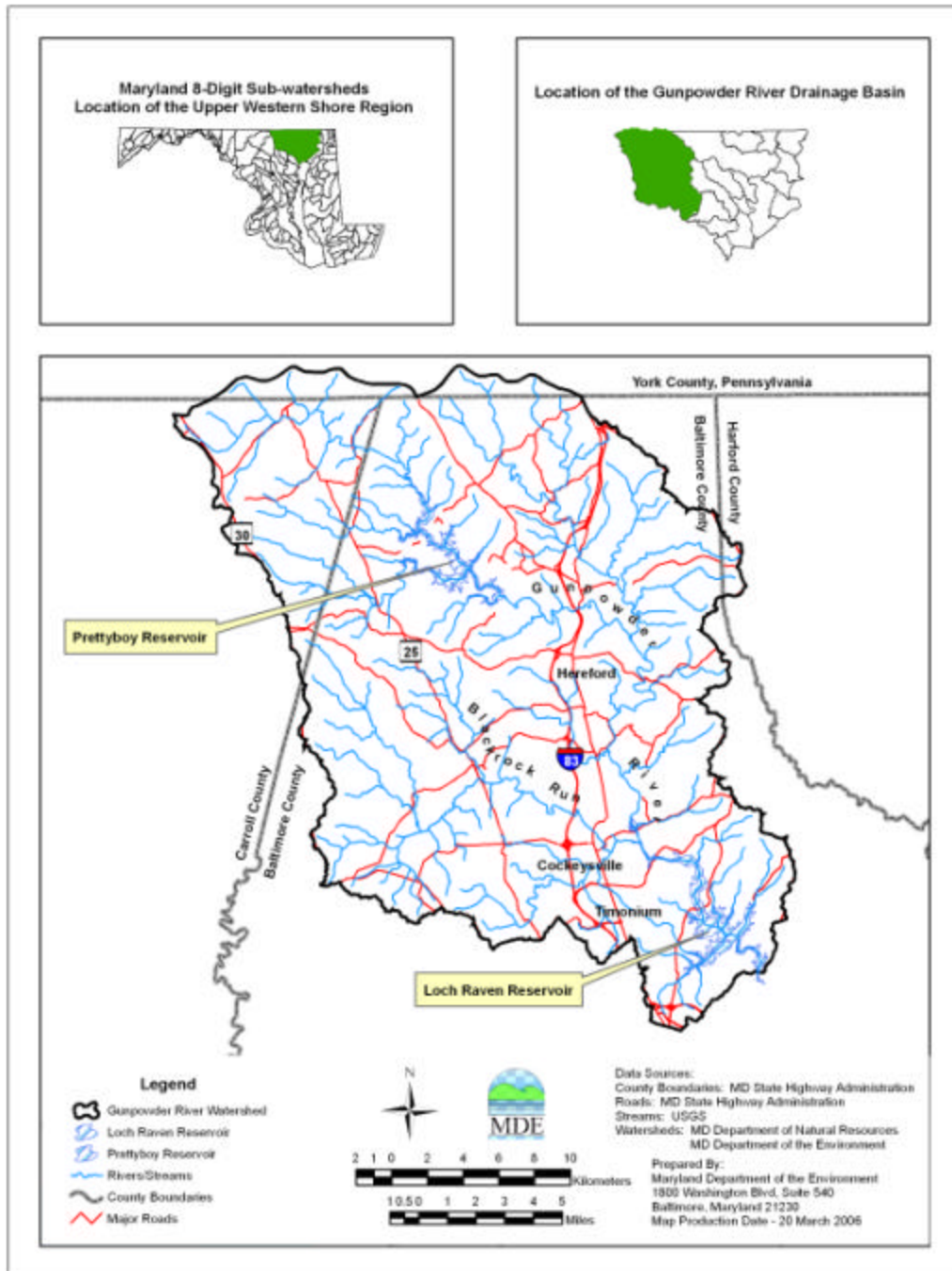


Figure 1: Location of Prettyboy and Loch Raven Reservoirs

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). ¹Measured 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.

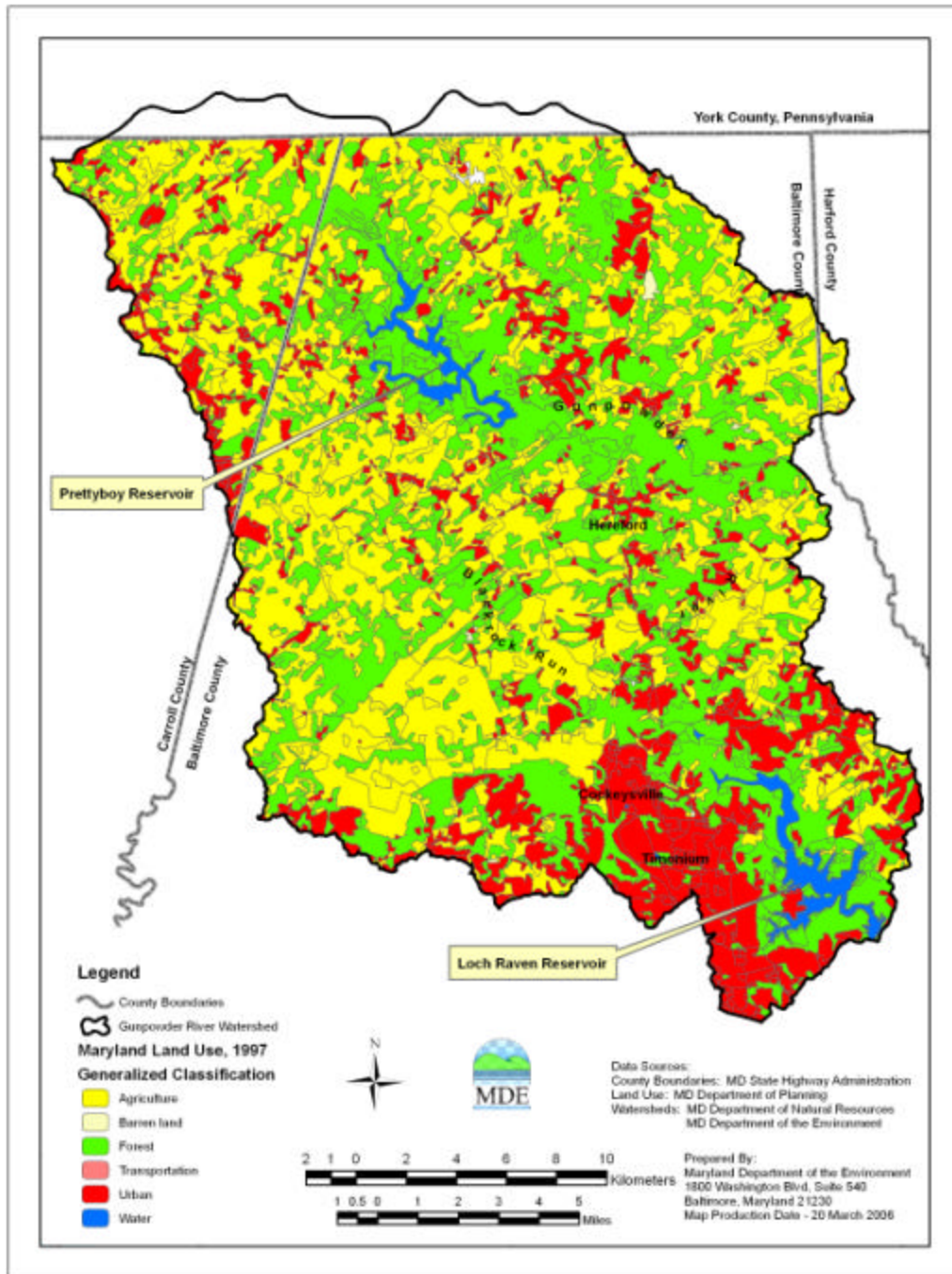


Figure 2: Land Use in Gunpowder Falls Watershed

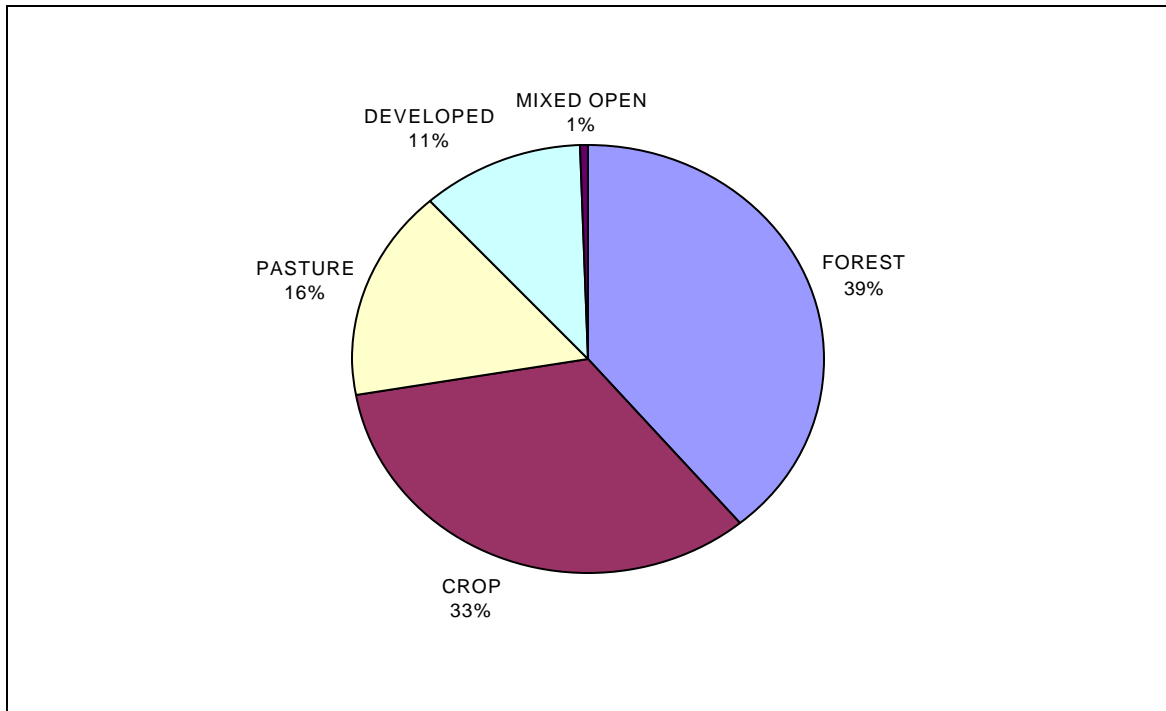


Figure 3: Proportion of Land Use in the Prettyboy Reservoir Watershed

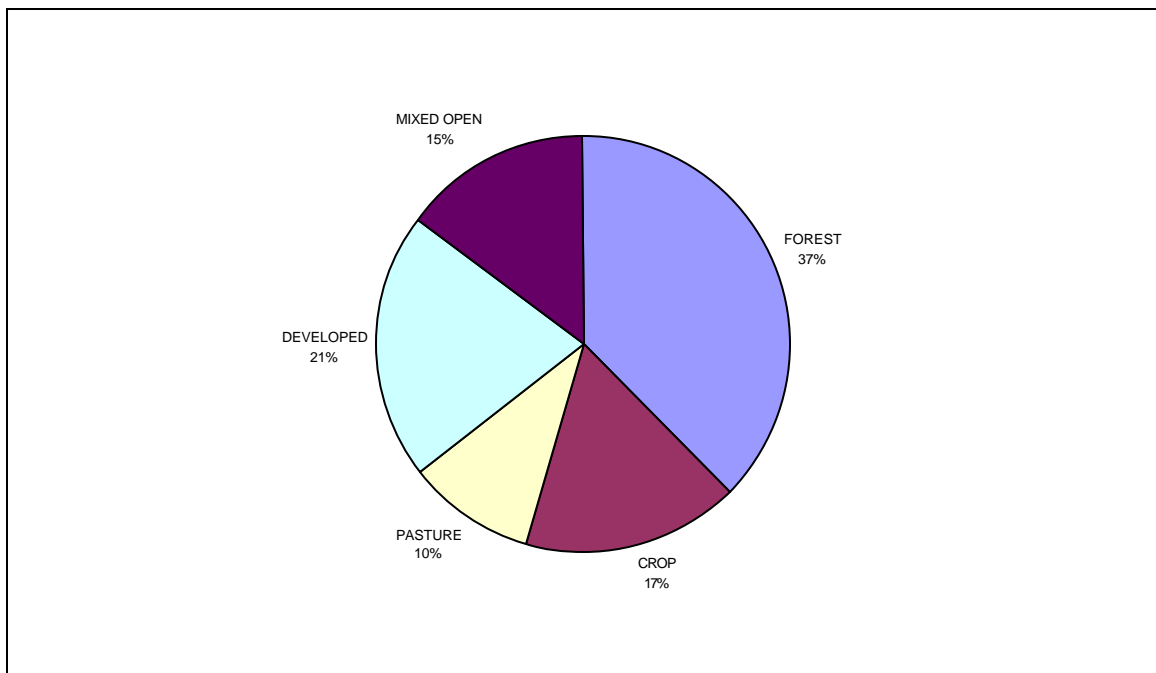


Figure 4: Proportion of Land Use in the Loch Raven Reservoir Watershed

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

Year	Manchester (MD0022446)			Hampstead (MD0022578)		
	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.

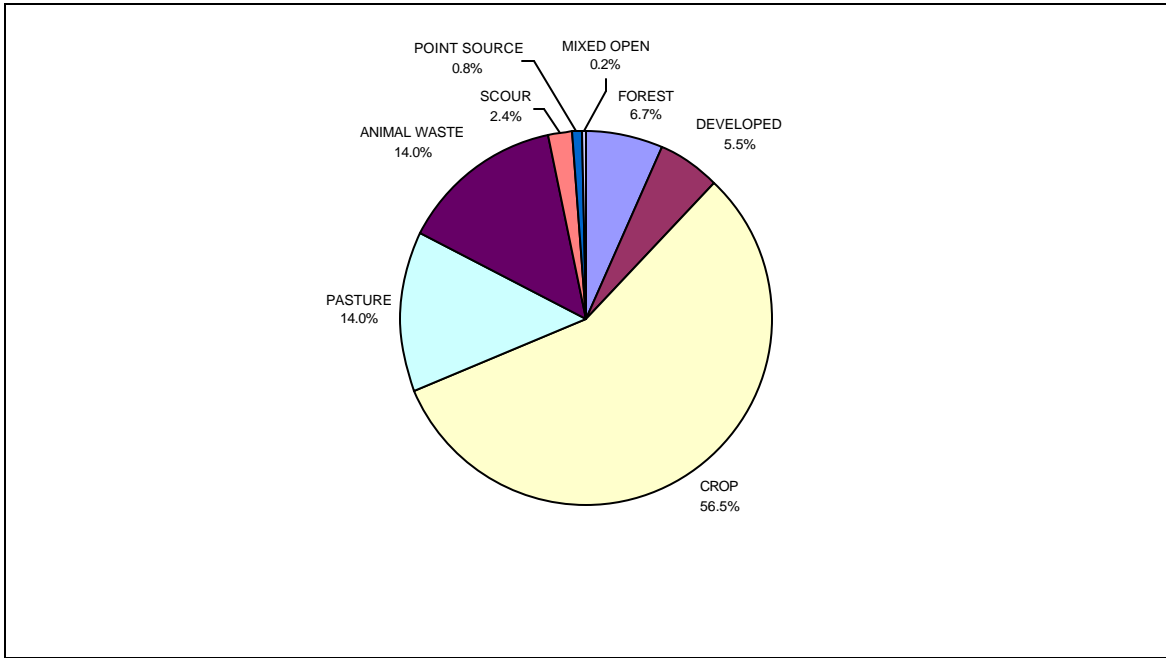


Figure 5: Percent Contribution of Sources to Total Phosphorus Loads to Prettyboy Reservoir

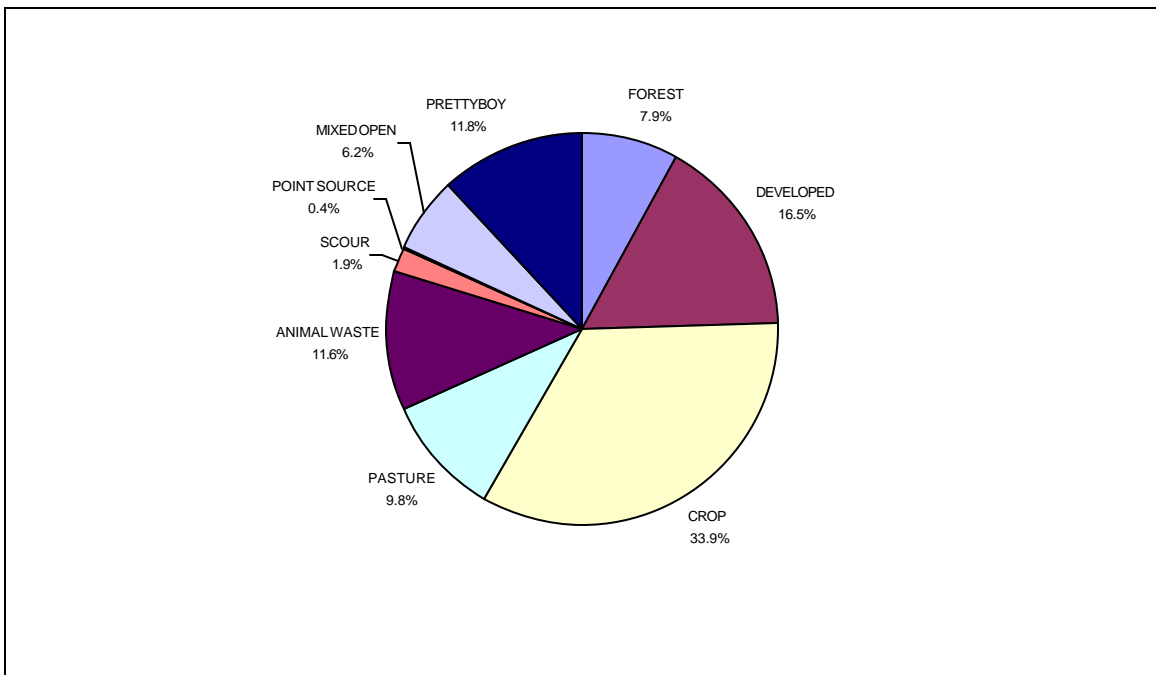


Figure 6: Percent Contribution of Sources to Total Phosphorus Loads to Loch Raven Reservoir

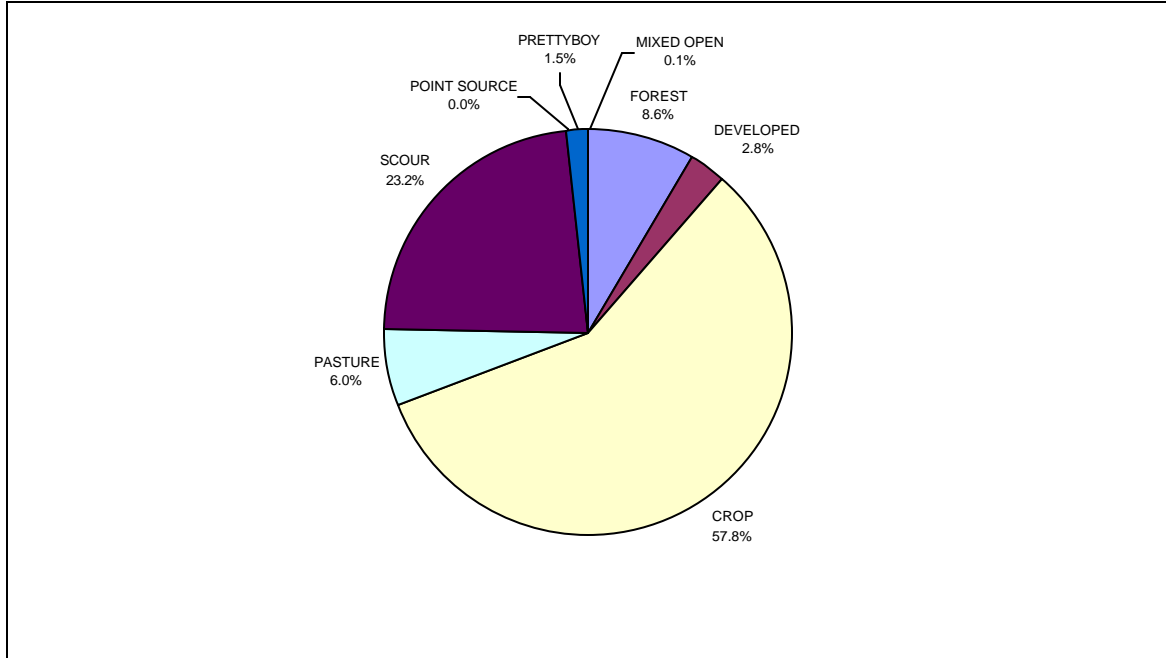


Figure 7: Percent Contribution of Sources to Sediment Loads to Loch Raven Reservoir

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.

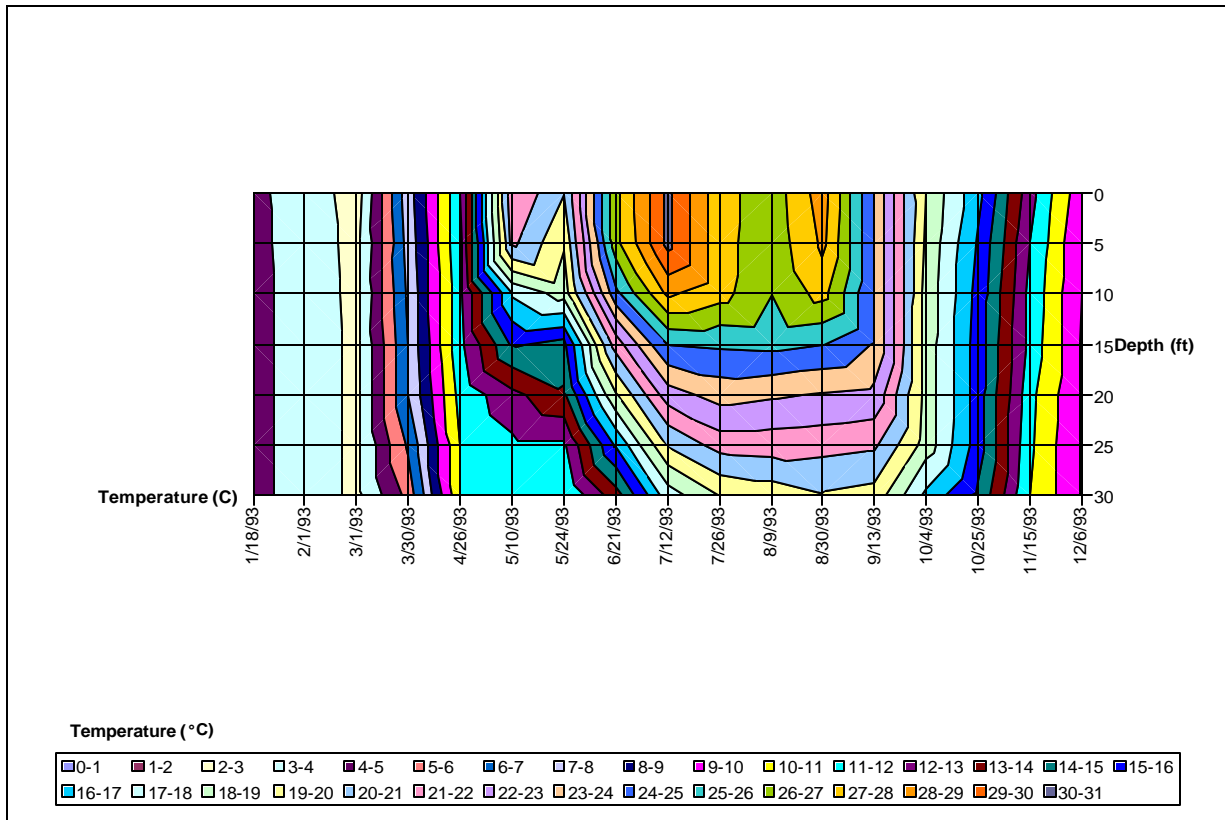


Figure 10: Isothermal Contours, Loch Raven Reservoir, Middle Stations, 1993

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 2°C 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.

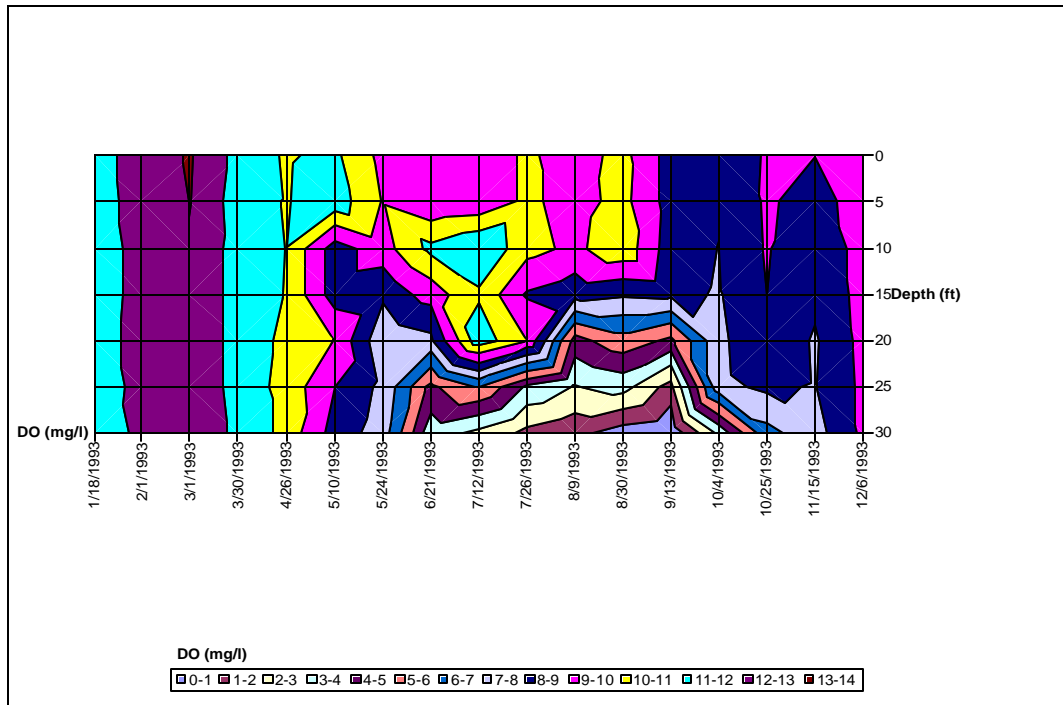


Figure 11: DO Contour, Loch Raven Reservoir, Middle Locations, 1993

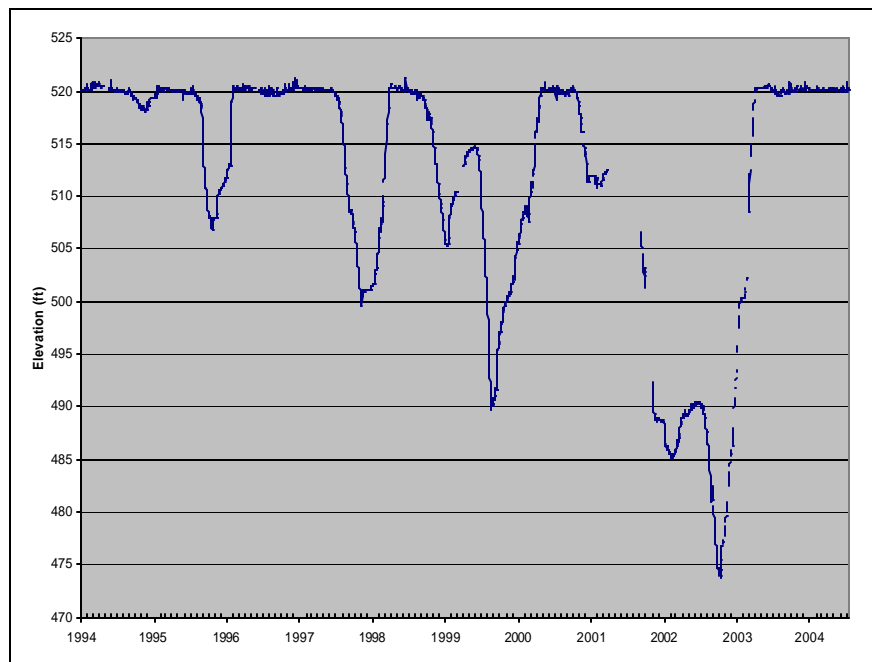


Figure 12: Surface Water Elevations in Prettyboy Reservoir, 1994-2004

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

Statistic	Surface		Bottom	
	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
1 st Quartile	0.021	0.019	0.025	0.018
Median	0.045	0.035	0.041	0.040
3 rd 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

Statistic	Surface			Bottom		
	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
1 st 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
3 rd 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/mi²/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.

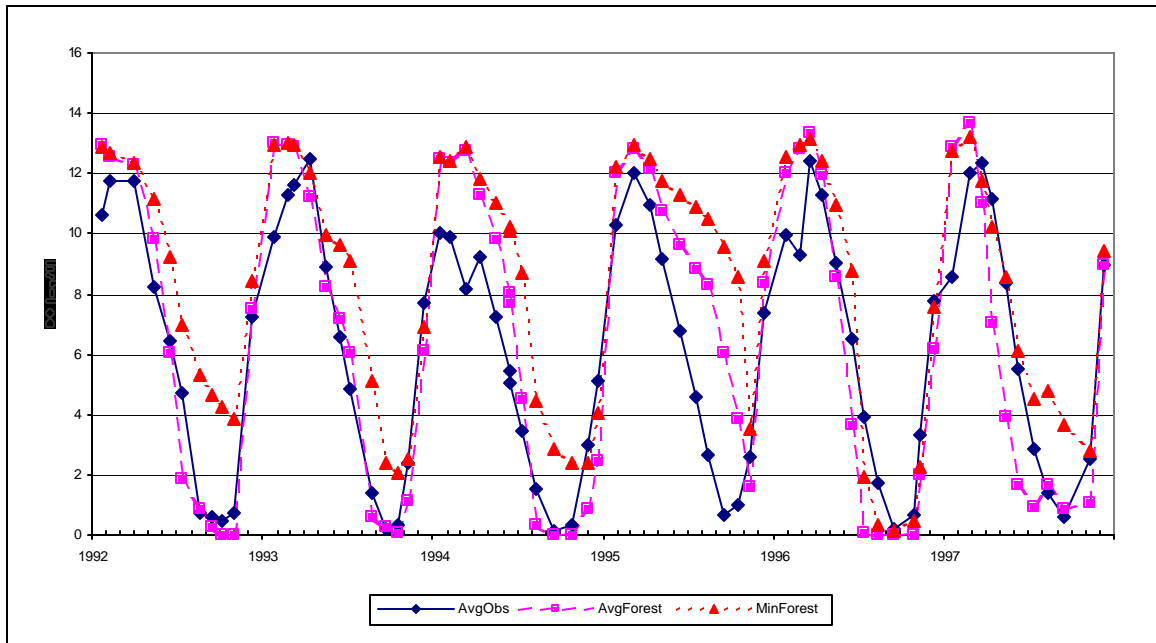


Figure 13: Observed and Simulated Average Bottom DO Concentrations, Lower Stations, All-Forest Scenario, Prettyboy Reservoir

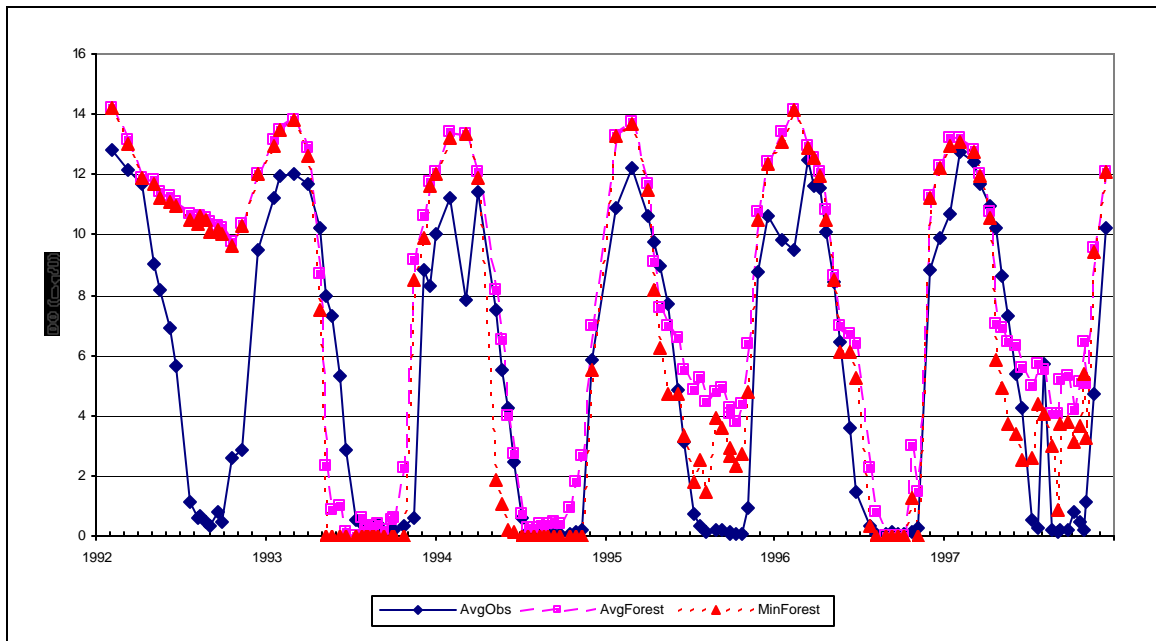


Figure 14: Observed and Simulated Average Bottom DO Concentrations, Lower Stations, All-Forest Scenario, Loch Raven Reservoir

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.

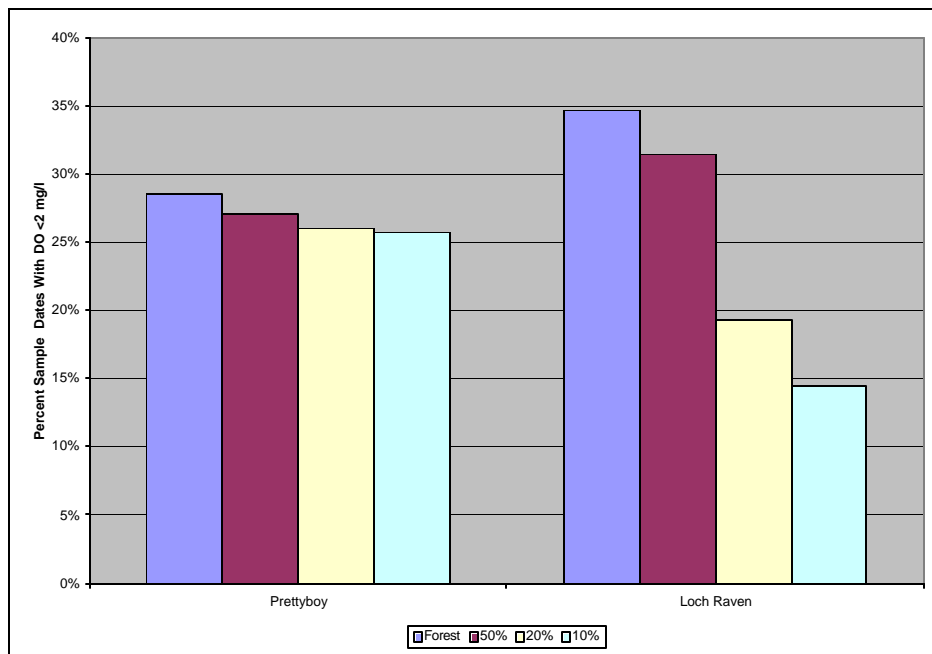


Figure 15: Percent of Sampling Dates on which $DO < 2.0$ mg/l as a function of proportion of All-Forest Scenario

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
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For Loch Raven Reservoir:

Total Phosphorus TMDL	54,941 lbs/year
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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

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Nutrients/Sediment TMDLs

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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
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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:

$$\text{TMDL} = \text{WLA} [\text{non-stormwater point sources} + \text{regulated stormwater point source}] + \text{LA} + \text{MOS}$$

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 Excluding 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:

$$\begin{array}{rclclcl}
 \text{TMDL (lbs/yr)} & = & \text{LA} & + & \text{WLA} & + & \text{MOS} \\
 23,192 & = & 19,092 & & 2,940 & & 1,160
 \end{array}$$

For Total Phosphorus in Loch Raven Reservoir:

$$\begin{array}{rclclcl}
 \text{TMDL (lbs/yr)} & = & \text{LA} & + & \text{WLA} & + & \text{MOS} \\
 54,941 & = & 30,184 & & 22,010 & & 2,747
 \end{array}$$

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

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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					