Ecosystem Enhancement PROGRAM

Goose Creek Stream Restoration Plan

September 2005

Biohabitats Incorporated

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1.0 INTRODUCTION

1.1 Project Description and Summary

The North Carolina Ecosystem Enhancement Program (NCEEP) is undertaking a stream restoration project for Goose Creek, located in northeast central Durham, North Carolina, in the Neuse River watershed, U.S. Geological Survey (USGS) Cataloguing Unit 03020201. The project is composed of two reaches (Eastway Elementary and Longmeadow Park), separated by a culvert, in an urbanized area. The length of the existing Goose Creek channel within the proposed project area is 1500 linear feet. The length of the proposed Goose Creek channel restoration is 1518 linear feet. The total proposed construction area is 3.8 acres (a table summarizing project information is included at the end of this section).

This stream is degraded due to urban development in the contributing watershed. The City of Durham documented degraded water quality in Goose Creek in its "State of Our Streams Report" published in 2005 by the Water Quality Monitoring Program. The water quality monitoring station on Goose Creek, located on Holloway Street, at the downstream end of the proposed project, had an overall Water Quality Index score of 62-65 out of a possible range of 54-92, the second lowest scoring area in the report. This station had the second highest concentrations of fecal coliform bacteria of the 33 monitoring stations, and had elevated water quality concerns related to the total nitrogen, BOD, and copper parameters measured. Just upstream of the proposed project, approximately 1,180 feet of stream is contained in culverts. In the project area, the stream banks have been hardened by concrete and vertical masonry walls. The degraded condition of the channel, extensive bank armoring, onset of neighborhood revitalization efforts, and presence of willing stakeholders make this an excellent site for stream restoration.

The existing stream buffer is very limited in the upstream Eastway Elementary School Reach and even more limited in the Longmeadow Park Reach. In the Eastway Elementary Reach, the bankfull channel is bordered by mowed areas. A Natural

Resource Conservation Service (NRCS) stream project installed log vanes in the channel in 1998, and herbaceous species and small woody saplings of black willow (*Salix nigra*), princess tree (*Paulownia tomemtosa*), and red mulberry (*Morus rubra*) have occupied the alternate bar deposits. The natural (unmowed) buffer varies in width from 5-15 feet in width. In the Longmeadow Park reach, the existing stream is bracketed by stone walls, beyond which are mowed areas with scattered, planted, large (3-4 foot) diameter trees, mainly willow oaks (*Quercus phellos*). Except for the large oaks, there is no woody vegetative buffer on the Longmeadow Park Reach. Accordingly, the terrestrial and aquatic habitat that the existing buffers offer is very limited.

Biohabitats, Inc. was retained to develop the stream restoration design and investigate the potential for on-site stormwater management facilities. This design effort builds on the "Goose Creek Stream Restoration Feasibility Study" dated July 2004, prepared jointly by CDM and Biohabitats, Inc. In the feasibility report, restoration potential was identified but with limitations posed by existing infrastructure. This Restoration Plan presents existing channel conditions and an overview of the proposed stream restoration design.

The proposed restoration would include reconfiguration of the planform, cross-sectional, and profile properties of the channel to a stable form under the existing hydrologic conditions and limited sediment supply regime. The design would also provide the present incised channel with a new, lower floodplain surface and reestablish an adjacent native riparian buffer.

Summary of Goose Creek Restoration Project Information
Length of Existing Stream = 1500 lf
Length of Proposed Restoration = 1518 lf
(Eastway Elementary- 860 lf + Longmeadow Park 640 lf)
Total Area of Construction Disturbance = 3.8 ac
Location- Upper Neuse USGS CU 03020201

1.2 Goals and Objectives

The stream restoration practices proposed along Goose Creek are intended to achieve the following goals and objectives:

1. Provide a stable stream channel that maintains its dimension, pattern, and profile over the long term, with the capacity to transport flow and incoming sediment load.
2. Improve water quality.
3. Create a new floodplain at a lower elevation to allow access of bankfull flows (since reconnecting the stream to its original floodplain area is not feasible due to flooding and road crossings).
4. Improve aquatic habitats by redesign of the longitudinal profile, removal of channel hardening structures, and installation of in-channel structures that stabilize the channel and enhance variability in its geometry.
5. Create natural riparian buffers and enhance existing riparian buffers, including retaining existing healthy oaks in Longmeadow Park.

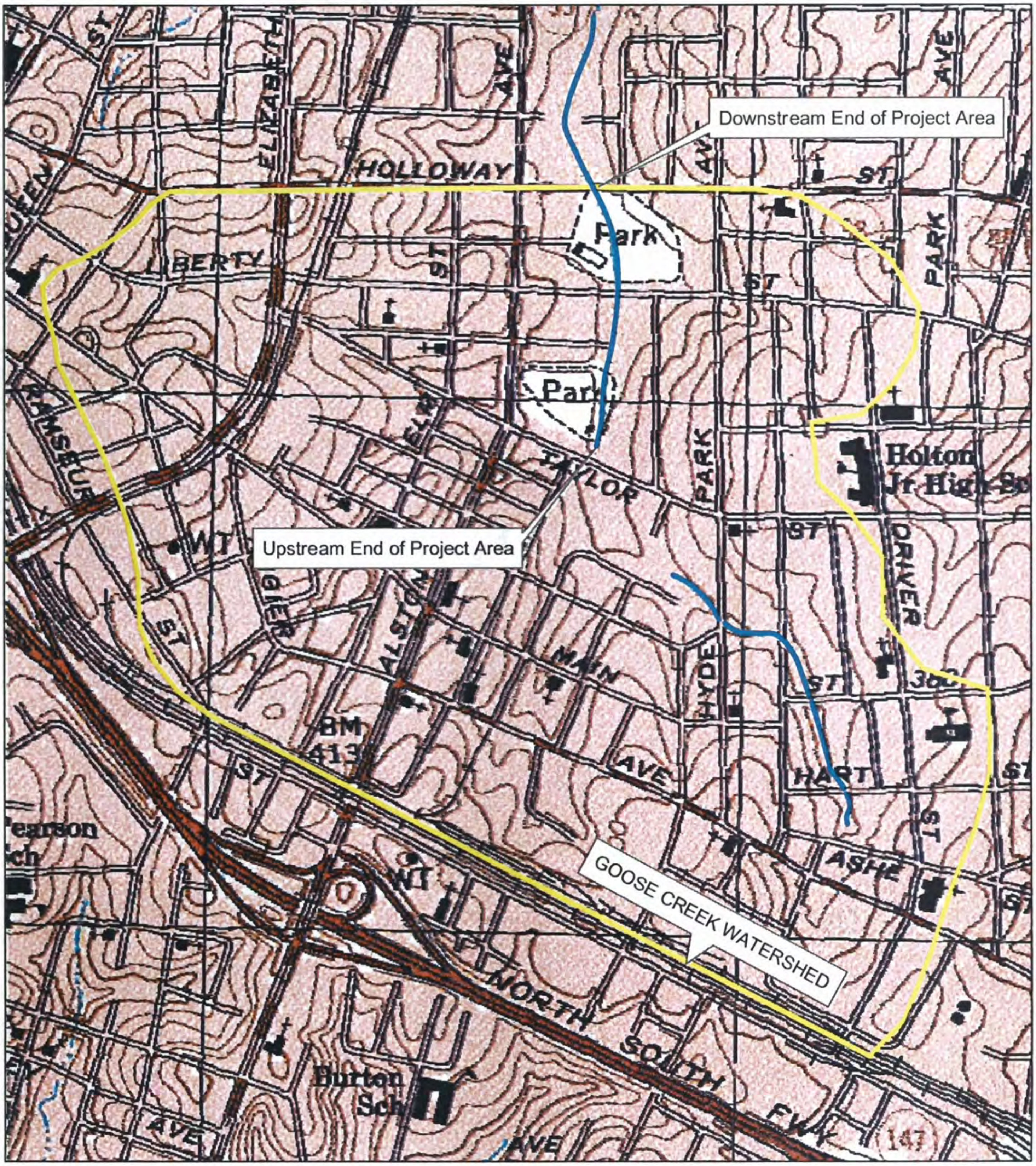
2.0 PROJECT LOCATION

Goose Creek flows through a residential community of the City of Durham in Durham County. The Goose Creek watershed is an old, well-established, low-income neighborhood with limited opportunities for modifications to alter runoff quantity or quality. The project area extends from where the creek exits a culvert, just north (downstream) of Taylor Street downstream to Holloway Street (Figure 1). The stream flows by Eastway Elementary School, the Barnes Avenue Community Redevelopment Project and the City of Durham's Longmeadow Park (Figure 2).

The project is divided into two reaches for the purpose of the stream restoration project (Figure 2). The Eastway Elementary School Reach or Upper Reach extends from just north of Taylor Street to Liberty Street. The Longmeadow Park Reach includes the area along Goose Creek between Liberty Street and Holloway Street. Approximately 1,180 feet of Goose Creek is currently enclosed in a box culvert just upstream of the proposed project within the Few Gardens/Holman Holmes HOPE VI public housing project area, under Taylor Street, and through the Eastway Elementary School parking lot. The creek is enclosed in another box culvert under Liberty Street.

Goose Creek is part of the Neuse River Basin (Upper Neuse, Subbasin 03-04-01) and is a tributary to Ellerbe Creek, which flows into Falls Lake. Because Falls Lake is a water supply source, the Goose Creek watershed is considered a water supply watershed. The project area falls within the USGS Cataloging Unit 03020201. The North Carolina Division of Water Quality (DWQ) Stream Index Number for Goose Creek is 27-5-1.

Goose Creek is located in North Carolina's relatively narrow Triassic Basin geologic area, along the eastern edge of the more generalized Piedmont physiographic province. The Triassic Basin is filled with sedimentary rocks that formed about 200-190 million years ago when streams carried mud, silt, sand and gravel from adjacent highlands into rift valleys. Streams in the Triassic Basin tend to have finer bed material and lower summer flow conditions (due to quick infiltration into sandy soils).



Data Source: Southwest Durham USGS 7.5 minute quadrangle.

N

0 500 1,000 2,000 Feet

Ecosystem Enhancement Program

Goose Creek Restoration
Durham County. North Carolina
Biohabitats Project No. 04802.02

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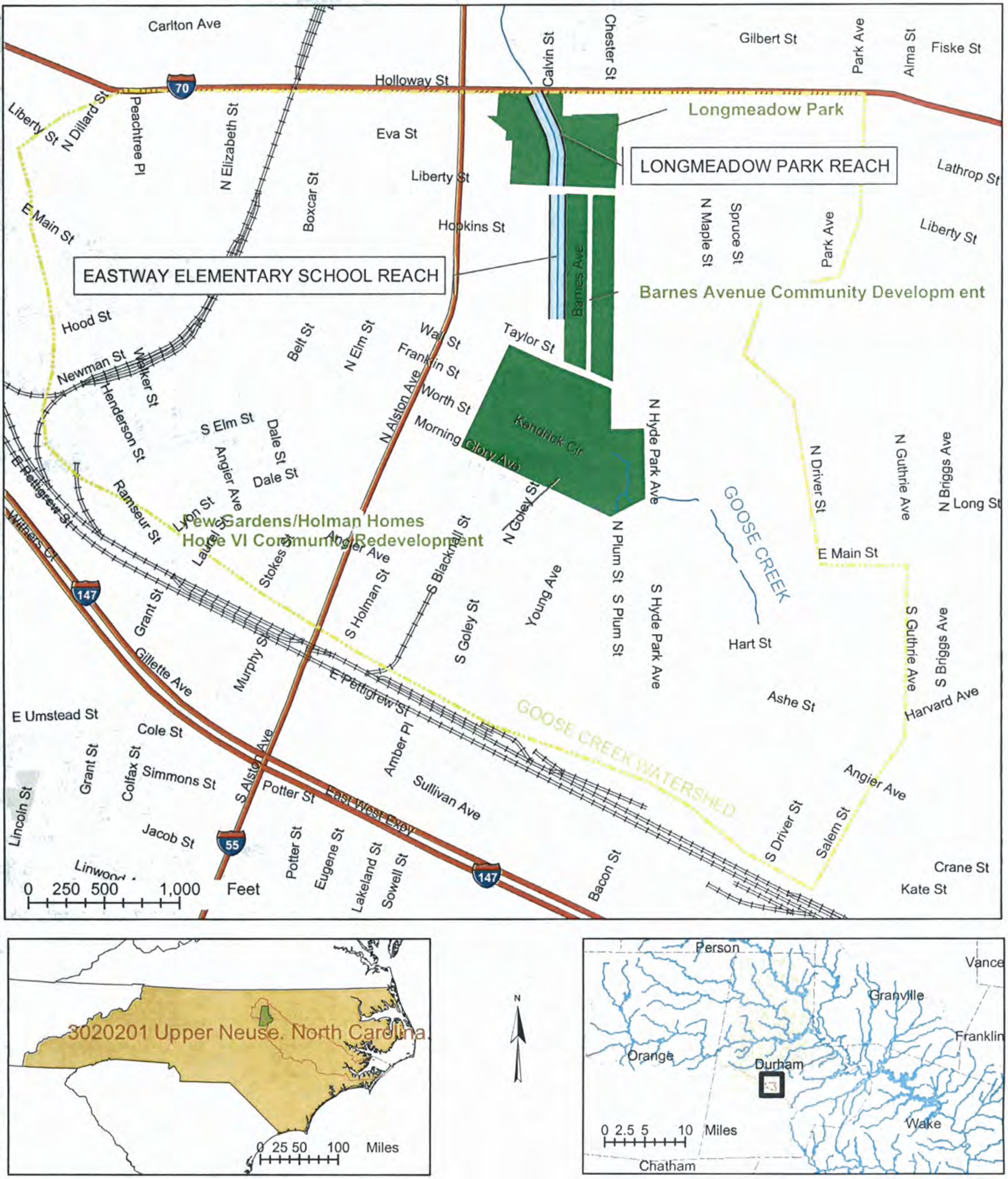
Figure 1
Project Limits and Associated Watershed

September 2005



Goose Creek Restoration
Durham County, North Carolina
Biohabitats Project No. 04802.02

Figure 2
Locations of Project Reaches

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3.0 METHODS

Baseline conditions for Goose Creek have been established through field investigation and review of existing documents. The methods and materials used to collect information, perform the field survey, analyze existing stream conditions, and identify potential reference reaches are identified below.

3.1 DOCUMENT REVIEW

Available basinwide physical data were reviewed to assess existing conditions in the watershed and at the site, to identify potential constraints, and to identify anticipated additional data needs. Data were provided by NCEEP, the City of Durham, project stakeholders, and state agencies.

Data collected and reviewed included available soil and wetland maps, topographic maps, aerial photos, zoning and land use information, National Wetland Inventory maps, FEMA flood zone maps, NC Floodmaps database, City of Durham utility maps, rare species database reports, Historic Preservation Office database reports, and the Durham Soil and Water Conservation District (SWCD) Goose Creek Urban Stream Rehabilitation Project Design Folder (1998). In addition, the project team reviewed proposed projects plans for the Few Gardens/Holman Holmes HOPE VI housing complex, the Barnes Avenue Community Development project, and the City of Durham Parks and Recreation Department's plans for improvements to Longmeadow Park.

Requests for historic properties and endangered species information about the project site were submitted to the North Carolina State Historical Preservation Office, the North Carolina Natural Heritage Program (NHP), and the U.S. Fish & Wildlife Service.

According to correspondence received from the North Carolina State Historic Preservation Office, there are no known historical resources in the project area that will be affected by the stream restoration project.

3.2 FIELD EVALUATION OF STUDY AREA

A site reconnaissance of the study reaches and floodplain was conducted to determine and document existing conditions. Field observations were used to provide an overview of the site. Appendix A includes photographs documenting conditions along each reach. During the site visit, the extent of adjacent property available for possible stream relocation was noted, as was the location of significant constraints such as manholes, large specimen trees, and outfalls. Available maps were used in the field to confirm the locations of infrastructure and were used to record additional spatial information, such as the locations of large trees. Field observations and information compiled from available maps were used together to create a base map for the restoration plan.

During multiple site visits, channel stability was evaluated and a fluvial geomorphologic assessment was undertaken. A cross section was taken within each of the reaches using standard land survey techniques. The riffle cross sections were positioned to illustrate representative characteristics of the channel based on channel appearance, slope, and bed material. Longitudinal profiles were also taken at the Eastway Elementary School Reach cross section to confirm slope indicated from available topographic maps. A longitudinal profile was not taken at the Longmeadow Reach cross section due to poor access. Pebble counts were not conducted in the two project reaches, since bed material was almost entirely sand, however, a 100-particle Wolman pebble count (Wolman, 1954) was conducted upstream of the project (and downstream of Morning Glory Avenue) to characterize bed material and associated channel roughness. Appendix B contains the results from the surveyed cross sections, the local longitudinal profile, and the pebble count.

During the field survey, the bankfull elevation (the elevation of the active floodplain) at each cross section was identified and verified by multiple personnel based on available field indicators. Bankfull elevation was derived from all available indicators including depositional features, changes in bank angle, vegetation patterns, scour lines, and storm debris lines. Because the channel has been impacted significantly by bank protection measures, bankfull identification from these features was difficult in the Eastway

Elementary School and Longmeadow Park Reaches. More consistent bankfull indicators were found upstream of the project, where a cross section and longitudinal profile were measured, and the information was used to determine design discharge downstream.

According to the National Wetland Inventory maps, there are no mapped wetlands located within the project area. Several depressional areas were initially identified for further investigation to establish or preclude wetland classification. However, field study of soils, hydrology, and plant communities in these areas found that none qualified as wetlands.

3.3 STREAM CLASSIFICATION

As part of the field reconnaissance, the Rosgen classification system (Rosgen, 1994) was used to determine channel type at each field cross section on the basis of existing morphological features of the stream channel. While the classification system can be a helpful descriptor of channel properties in many geomorphic settings, urban settings often limit the utility of the classification system. For example, in stream sections that have been highly modified, several complications may confound channel classification because: 1) bankfull indicators may be sparse or absent, 2) channel morphology often does not coincide with a single Rosgen stream type, and/or 3) hydraulic effects of culverts may overprint bankfull indicators that would otherwise be present. Despite these limitations, channel classification was attempted, but was not always feasible in the altered reaches.

3.4 STREAM REFERENCE REACH IDENTIFICATION

Field assessments of impacted streams generally require some example of attainable conditions for restoration. A reference reach—a control stream with similar physical properties but with fewer impacts and greater channel stability—can help establish physical and biological criteria in stream restoration design.

The search for reference reaches began by reviewing reference reach information used by previous NCEEP stream restoration projects. Of the half dozen sites previously identified, two were selected for further investigation based on their proximity to Goose

Creek, small drainage area (<10 mi^2) , channel type (B-type and C-type preferred), and physiographic province. The first stream, Morgan Creek, is located near Chapel Hill in the Piedmont physiographic province. The second stream, an unnamed tributary to Cabin Creek, is located about 0.5 mi northeast of the Durham City limits within the Triassic Basin. The tributary flows east into the Eno River and is located approximately four miles north of Durham on the end of Earl Road (SR 2625). Photographs of each site are included in Appendix C.

Both sites were visited to verify their classification and suitability for use as reference reaches. Existing datasets were used to spot check values at both sites. Based on spot checks, Biohabitats accepted the available datasets for design use. Since the Cabin Creek tributary has the additional merit of being located within the Triassic Basin, supplemental cross-sectional, planform, longitudinal, and bed material measurements were taken along this stream. To define a range of conditions and augment the existing database, these measurements were distributed along two additional reaches ("Reach A" and "Reach B") between Earl Road and the upstream powerline easement. Cross-sectional, profile, and pebble count measurements from the reaches are included in Appendix D. The riparian zone of the Cabin Creek tributary is also in excellent condition and was used to identify a reference stream vegetative community.

3.5 Hydrologic and Hydraulic Modeling and Floodplain Management Requirements

Models of the existing watershed hydrology and channel hydraulics were developed to determine the peak discharges and identify key hydrologic loading points in the system to determine the feasibility of the proposed stream restoration project.

Runoff volumes and peak rates of discharge for various rainfall events were estimated using the US Army Corps of Engineers' HEC-HMS Flood Hydrograph Package. Land use in the subbasins was generalized from the City of Durham land use data and GIS mapping. Subbasin-specific curve numbers were developed based on existing land use and soil type using the Soil Conservation Service's (SCS's) Curve Number method.

These curve numbers and computed travel times then were entered within the HEC-HMS model. Average antecedent moisture conditions (AMC II) were assumed for the modeling effort. The peak flow discharges for the 1-year (24-hour), 2-year, 10-year, and 100-year recurrence intervals then were determined using four subbasins defined by hydrologic boundaries. Subbasin hydrographs were routed by the model through the drainage network to estimate the magnitude of peak discharges for the hypothetical 1-year, 2-year, 10-year, and 100-year 24-hour storms in Durham County. The hydrologic model was originally created for the Goose Creek Stream Restoration Feasibility Study (Durham SWCD, 2004). No changes have been made to that original model, as it is still representative of watershed conditions.

The HEC-RAS model (U.S. Army Corps of Engineers, 2001) was used to predict resulting water surface elevations along the channel system for flood discharges obtained from the HEC-HMS analysis. A hydraulic model was also created for the Goose Creek Stream Restoration Feasibility Study (2004), and was based on best available topographic and culvert information at the time. However, since then, improved field-run survey was obtained to support ongoing, more detailed design work. The existing HEC-RAS was therefore revised to more accurately reflect existing conditions. Geometric information at all culverts was retained from the original hydraulic model, except where the field-run survey required revision of culvert sizes and invert elevations. However, geometric information for all open-channel portions of the project area was revised based on the field-run survey.

Revised geometric data were obtained 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 approximately every 50 feet, with hand verified spot checks. HEC-GeoRAS was used to generate geometric data input for existing conditions of Goose Creek. The resulting geometry files were then imported into HEC-RAS to run the full hydraulic analysis. Standard contraction and expansion coefficients of 0.1 and 0.3 were used for all natural sections with in the study reach and 0.3 and 0.5 were used at the culvert crossing. Output from the existing conditions HEC-RAS model is included in Appendix E.

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.

In May of 2005 revised FEMA/NC Floodplain Mapping Information System mapping of Durham County was published, and the project area, which had not previously been mapped by FEMA in a flood hazard area, was mapped as AE (100-Year Flooding with Base Flood Elevations). Consequently, by FEMA regulations, modifications of the existing floodplain that would cause any rise in the Base Flood Elevation require a Conditional Letter of Map Revision request to be submitted to FEMA.

The restoration design is intended to maintain the current Base Flood Elevation, without a rise. The City of Durham is the administrator of floodplain management and requires a No Impact Certification for stream restoration projects. The No Impact Certification contains the modeling data demonstrating that the Base Flood Elevation does not rise for the proposed restored channel and also for the as-built channel, upon project completion and re-survey. As previously mentioned, an existing conditions HEC-RAS (River Analysis System) model was developed to establish an existing conditions hydrologic/hydraulic parameters "baseline" to which proposed post-restoration conditions can be compared. Following approval of the restoration design, the proposed conditions model will be finalized to reflect proposed changes to the channel and floodplain.

3.6 Selection of Design Discharge

The selection of a bankfull discharge is used as the basis for the proposed design at Goose Creek. The basis for its use is outlined below, followed by a description of the bankfull discharge estimation and its calibration.

3.6.1 Bankfull Discharge Background

Bankfull discharge is commonly used in stream restoration design as a single-value estimate for a flow that may be largely responsible for the resulting geomorphic form. Likewise, the selection of a bankfull discharge was used as the basis for the conceptual design at Goose Creek. The practice is rooted in the work of Wolman and Miller (1960), in which the authors demonstrate that in alluvial, transport-limited rivers in temperate climates, flows of moderate frequency (e.g., the 1.5- to 2-year storm event) and magnitude perform most of the geomorphic work. In many cases, it is thought that the morphological feature of a bankfull elevation corresponds fairly well to the flow stage transporting the long-term peak volume of sediment. Channel morphology is ultimately a result of all flows above a sediment transport threshold that do some geomorphic work; however, bankfull discharge is useful as a guide for sizing of the restored channel.

The bankfull elevation was identified in the field at each of the three surveyed cross sections. Bankfull discharge was estimated at each location 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) based on field observations of bed material, channel geometry, and adjacent riparian vegetation.

For the purpose of comparison, a predicted bankfull discharge was also calculated for Goose Creek using available North Carolina regression relationships for urban streams in the Piedmont physiographic province (Doll et. al, 2002). The urban regression relationship is expressed by the following equation:

$$Q_{bkf} = 306.80\ A_w^{\ 0.63}$$

where A_w is watershed area in square miles (mi^2) and Q_{bkf} is the bankfull discharge in cubic feet per second (cfs). The drainage areas of the streams used in the regression ranged from 0.14 to 42.6 mi^2. The drainage area of reaches along Goose Creek range from 0.18 to 0.79 mi^2 and are within the range used to develop the regression.

Finally, copies of bankfull discharge estimates developed by Durham SWCD (1998) were provided by NCEEP for comparison. The estimates were used to develop the original stream restoration concept plan within the grouted mattress-lined channel along Eastway Elementary School.

3.6.2 Calibration of Bankfull and Peak Flows

Design discharges were selected based on careful review of multiple lines of evidence, including field measurements, regional regressions, and hydrologic modeling. Figure 3 summarizes estimates of bankfull discharge from the field cross sections, regional regression, and work by Durham SWCD (1998). The graph also shows results from the HEC-HMS hydrological model.

Unfortunately, natural bankfull indicators were either absent, limited, or obscured by culvert hydraulics in the study area. As a result, bankfull discharges calculated from field measurement are not as reliable but useful only as first-order estimates. Bankfull indicators were most distinctive upstream of the project, just downstream of Morning Glory Avenue. Measurements made there resulted in a field-based estimate of 149 cfs for bankfull discharge. However, upon review of the hydraulic model, it became clear that the downstream culvert inlet is causing some retardation or temporary storage of incoming flow, which is elevating the water surface elevation during frequent (1- and 2-year) discharge events. This suggests that some indicators like storm debris could have led to a slight overestimation of bankfull discharge in this reach.

Bankfull indicators along the Eastway Elementary School and Longmeadow Park Reaches were not apparent enough to supply reliable estimates. In the Eastway Elementary School Reach, the grouted mattress lining along the banks prevented accurate identification of bankfull. However, recent debris lines at the top of

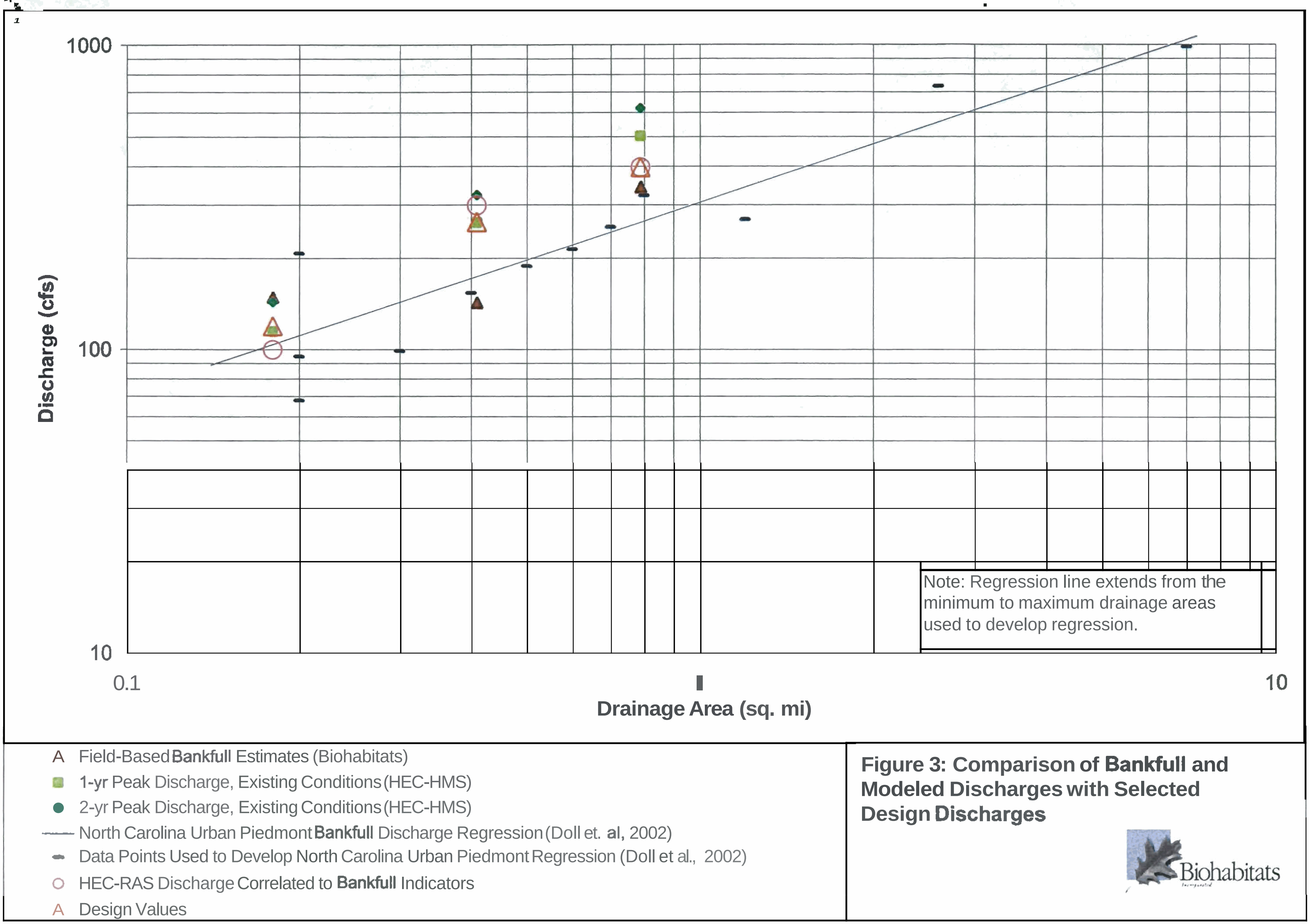


Figure 3: Comparison of Bankfull and Modeled Discharges with Selected Design Discharges

banks suggest that stream stages that fill the channel are not uncommon. This was supported further by fresh sand deposits at the top of instream bars and debris racked in the small trees growing over the bars. Consequently, the estimate of 143 cfs for the discharge at the top of the banks (Appendix B) represents only a minimum value for bankfull discharge at that location. A true bankfull discharge cannot be determined based on field indicators due to the alteration of the channel.

In the Longmeadow Park Reach, masonry walls also preclude clear indicators of bankfull elevation. However, localized sandy bars against the wall suggest a minimum estimate of bankfull elevation. It is unclear how much higher the bankfull elevation is above the fresh sand deposits. Fresh, deep sand along lateral bars in the Longmeadow Park therefore suggest that 343 cfs may also be a reasonable lower bound for bankfull discharge at the downstream end.

Results from HEC-HMS provide estimates of the 1- and 2-year discharges for each reach. Assuming that the bankfull discharge should fall between the 1- and 2-year peak discharges, these results seem to support that the field-based discharge may slightly overestimate the actual bankfull discharge upstream of the proposed project and slightly underestimate the bankfull discharge in the Longmeadow Park Reach.

Results from the regional regression are consistently lower than model results, with differences increasing with downstream distance (Figure 3). A closer look at the regression relationship shows that the modeled values are not unreasonable given the scatter within the regression data set. For example, at the upstream end of Goose Creek, where the drainage area is 0.2 square miles, the regression equation predicts 106 cfs. However, there are three data points with a drainage area of 0.2 square miles used in the regression with bankfull discharges of 68, 95, and 208 cfs (Figure 3). The 1- and 2-year model results of 115 to 144 cfs clearly fall within the data range of the regression and therefore are not considered to be dissimilar enough to warrant concern. Land use in the drainage area may play a role in the range of data point values.

In the area studied upstream of the proposed project, bankfull discharge is well supported by the multiple lines of evidence. As a result, the level of confidence is fairly high in the selection of 120 cfs as an estimate of discharge. However, uncertainty increases with distance downstream, since results from regional regressions, hydrologic modeling, and field measurements diverge. In the Longmeadow Park Reach, the field cross section suggests a lower bound of 343 cfs for bankfull discharge, in keeping with results from HEC-HMS. We believe, therefore, that the prediction by the regional bankfull regression is too low for this reach.

As a final line of evidence, "dummy" flows in 50 cfs increments were entered into the existing conditions HEC-RAS model to identify the flow most closely associated with bankfull elevations identified during field reconnaissance. This approach helped account for hydraulic impacts of culverts that field-based calculation of discharge using Manning's equation could not address. Bankfull indicators within the Upper, Eastway Elementary School, and Longmeadow Park reaches most closely matched water surface elevations associated with 100 cfs, 300 cfs, and 400 cfs, respectively. This finding solidified the decision process, with 120 cfs (Upper Reach), 265 cfs (upstream portion of Eastway Elementary School Reach), and 400 cfs (downstream portion of Eastway Elementary School Reach and Longmeadow Park Reach) selected as the final design flow values.

3.7 Seismic Refraction

Depths to bedrock commonly are shallow in the Durham area. Several bedrock outcrops are apparent along the channel bed downstream of Morning Glory Avenue (upstream of the project area). This precipitated some concern that buried bedrock may restrict efforts to realign sections of Goose Creek. To provide data showing depth to bedrock, a seismic refraction survey was undertaken along transects within the project area. Each transect was positioned along possible alignments developed in the feasibility study. All six transects showed bedrock at a depth of 15 feet or greater in the project area (Geophex, 2005). Since grading will not extend to these depths, the seismic refraction results suggest no bedrock obstacles to channel alignment.

4.0 GENERAL WATERSHED INFORMATION

The Goose Creek stream restoration project watershed is approximately 0.8 square miles in size at its downstream end at Holloway Street. The drainage area is urban and is bounded by Holloway Street to the north, the Durham Freeway (Highway 147) to the south, North Guthrie Avenue to the east, and Dillard Street to the west.

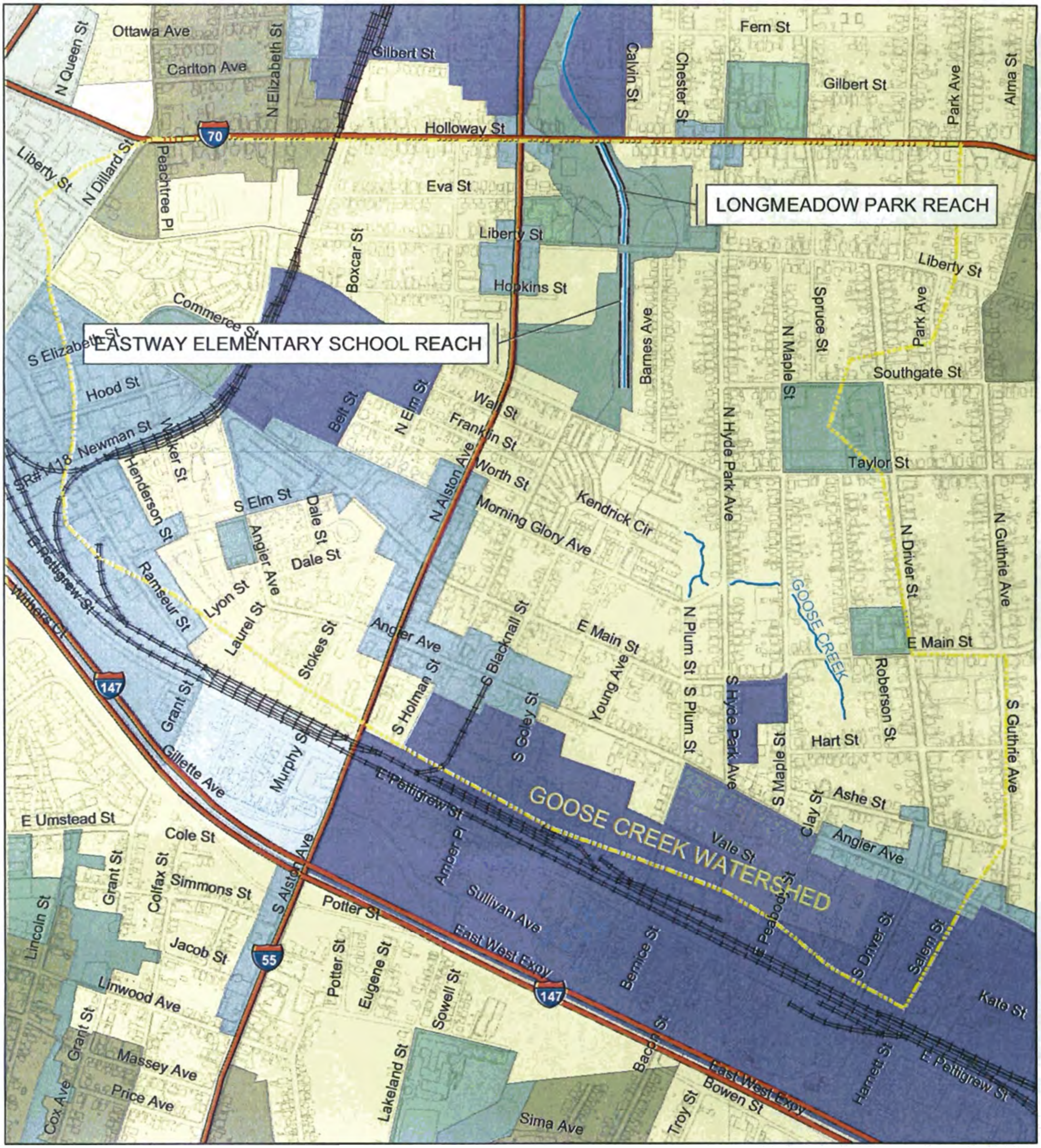
4.1 TOPOGRAPHY

The topographic features of the Goose Creek stream restoration project area are shown in Figure 1. The project area is characterized by relatively flat terrain along the floodplains of Goose Creek. Elevations along the route range from approximately 334 feet above sea level at the downstream end of the route near Holloway Street to around 350 feet at the upstream end of the route near Morning Glory Avenue.

4.2 LAND USE

The Goose Creek stream restoration project watershed is urban and virtually built-out. Zoning in the project area is primarily high-density residential with single-family homes, multi-family housing, and a small area of medium-density residential land use. Also included in the watershed are pockets of industrial, commercial, and institutional land use. Most of the commercial and industrial land use occurs along the major thoroughfares such as Angier Avenue, Alston Avenue, Main Street, and Holloway Street. The land between the Durham Freeway (Highway 147) and Angier Avenue is zoned for industrial, office, and mixed use. The school and park sites and the floodplain areas surrounding Goose Creek have been classified as open space/recreational areas in Durham's future land use plans.

Future land use in the Goose Creek study area watershed is depicted in Figure 4. Table 1 lists the land use types that correspond to the future land uses shown in Figure 4. Because the watershed is virtually built-out, future land use is expected to remain consistent with current use. Excessive development and changes to land use are not likely to occur, nor are future hydrological changes expected. The proposed Holman Home VI Redevelopment and the Barnes Avenue Community Redevelopment efforts are



Future Land Use

NO	LDR
COM	MDR
HDR	MIX
IND	OFC
INS	ROS
LD3	NA

0 500 1,000 2,000 Feet

N

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Figure 4
Future Land Use

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not expected to change land use in the project area. The redevelopment efforts will replace existing residential structures with similar structures.

Table 1. Durham Future Land Use Abbreviations

Code	Land Use Type
COM	Commercial
HDR	High Density Residential
IND	Industrial
INS	Institutional
LD3	Rural Residential
LDR	Low Density Residential
MDR	Medium Density Residential
MIX	Mixed Use
N/A	Downtown District
OFC	Office
ROS	Recreation/Open Space

4.3 SOILS

According to the Durham County Soil Survey, prepared by the USDA Soil Conservation Service (1976), soils in the Goose Creek stream restoration project area consist of the Cartecay and Chewacla soils mapping unit (Cc) and the White Store-Urban land complex (WwC, 0 to 10 percent slopes; Ur). The Cartecay and Chewacla soils mapping unit is comprised of 60 percent Cartecay and 30 percent Chewacla soils. They are poorly drained soils usually found on floodplains along small streams. Cartecay and Chewacla soils are included on the Hydric Soils List for North Carolina and are classified as Hydrologic Soil Group B. Depth to bedrock for Chewacla soils is 5 feet, and depth to bedrock for Cartecay soils is greater than 5 feet.

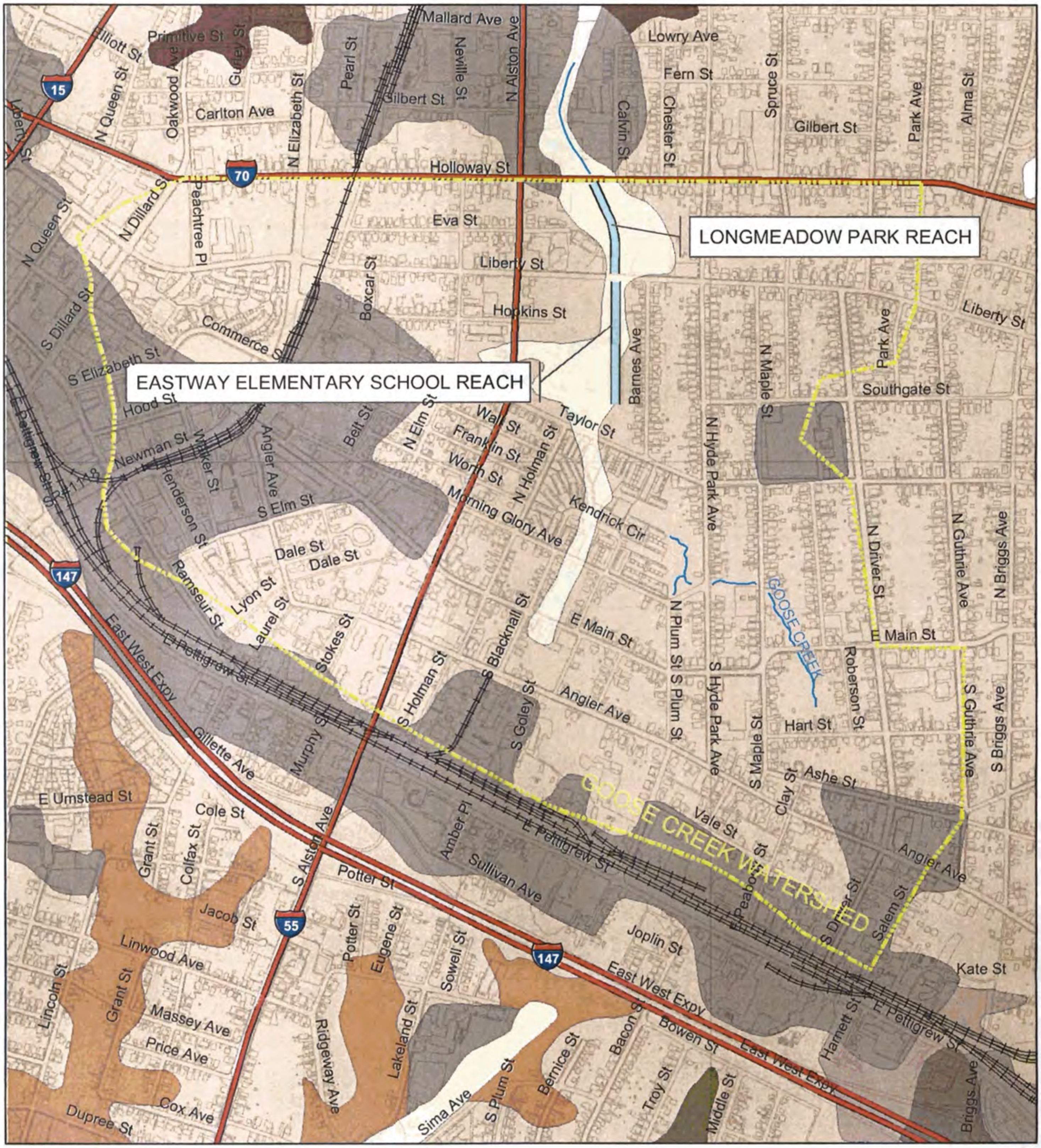
The White Store-Urban land complex consists of White Store soil and Urban land. The complex is comprised of 30 percent streets, houses, and structures; 30 percent undisturbed White Store soil; and 25 percent White Store soil with fill material or where original soil has been removed. White Store soils are classified as Hydrologic Soil Group

D. Depth to bedrock is greater than 4 feet for White Store soils (USDA Soil Conservation Service, 1976). The soil types within the Goose Creek stream restoration project area are shown in Figure 5.

4.4 STREAM CLASSIFICATION AND WATER QUALITY

The NC Division of Water Quality (NCDWQ) classifies Goose Creek as a Class WS-IV water. WS-IV waters are those that can be used as sources of potable water where a more protected WS-I, II, or III classification is not feasible. These waters are also protected for Class C uses, which includes such uses as secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, and agriculture. WS-IV waters are generally in moderately to highly developed watersheds or protected areas, and involve no categorical restrictions on discharges. NCDWQ has also given Goose Creek a Supplemental Classificaton as a Nutrient Sensitive Water (NSW). The NSW classification is used for waters needing additional nutrient management to control excessive growth of microscopic or macroscopic vegetation. Management strategies for point and nonpoint source pollution control are site-specific and typically require control of nitrogen, phosphorus, or other nutrients such that excessive growths of vegetation are reduced or prevented and there is no increase in nutrients over target levels (NCDWQ Classifications and Standards Unit and NCDWQ BIMS Waterbodies Reports). The Neuse River Nutrient Sensitive Waters Strategy includes rules for protection and maintenance of riparian buffers along the Neuse River and its tributaries. The Ellerbe Creek watershed is an NCEEP Targeted Local Watershed.

As mentioned in Section 1.1, the City of Durham documented degraded water quality in Goose Creek in its "State of Our Streams Report" published in 2005 by the Water Quality Monitoring Program. The water quality monitoring station on Goose Creek, located on Holloway Street, at the downstream end of the proposed project, had an overall Water Quality Index score of 62-65 out of a possible range of 54-92, the second lowest scoring area in the report. This station had the second highest concentrations of fecal coliform bacteria of the 33 monitoring stations, and had elevated water quality concerns related to the total nitrogen, BOD, and copper parameters measured.



Soil Symbol

Cc		WsC	
CrB		WsE	
MrC		WwC	
Ur		WwE	

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Figure 5
Soil Types

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5.0 DESCRIPTION OF EXISTING STREAM CONDITIONS

Goose Creek is a second-order stream within the project area. The two reaches in the study area have been significantly impacted by adjacent land uses in the historical past. Channel slopes within the three study reaches are determined by the culvert inverts bracketing each reach.

As a result of channel alterations, there are few geomorphic indicators from which to infer the rates and types of ongoing stream processes. However, field observations do provide some insight regarding geomorphic conditions.

5.1 EASTWAY ELEMENTARY SCHOOL REACH

In the Eastway Elementary School Reach, the channel slope is 0.2 percent and the channel bed and banks are armored with a grouted mattress lining (a "Fabriforrn" type lining). The grouted mattress lining covers the entire channel, extending from top-of-bank to top-of-bank. The lining was installed when the school was constructed in 1994, at which time the creek was also relocated approximately 100 feet east toward the property line, with a portion enclosed within a culvert under the school parking lot. It is likely that this reach meandered in the historical past, but was straightened and hardened to confine lateral movement and contain the stream away from adjacent infrastructure.

The channel was "improved" by the local school in 1995. The concrete-lined channel provided no flow attenuation, vegetation, or water quality protection. Log structures were placed within the concrete-lined channel in 1998 to provide habitat and increase dissolved oxygen. With time these structures forced the deposition of alternate bars and subsequent growth of vegetation along the upstream edge of each log structure. As a result, a sinuous lower flow channel has formed within the confines of the grouted mattress banks.

As a result of the channel modifications in the Eastway Elementary School Reach, geomorphic indicators are nearly absent. Alternate bars persist at single log structures placed along the length of the channel. Because of the fixed nature of the log structures and the stabilizing role of vegetation, the bar surfaces do not appear to undergo much geomorphic change. Instead, the alternate bars define a meandering low flow channel through the reach. Debris lines at and above the top of banks indicate that filling of the channel during flood events is somewhat frequent. Classification of this reach is not meaningful given the high degree of channel modification. Bed material is dominated by sand. The natural woody vegetation buffer ranges from 5-15 feet wide and averages approximately 5-10 feet on either side of the stream.

5.2 LONGMEADOW PARK REACH

In the Longmeadow Park Reach, the channel gradient is 0.4 percent and the channel is confined by vertical masonry walls. Because of the high degree of channel alteration, channel classification was not conducted in this reach. In the context of channel improvement, vane structures were placed within the channel in 1998. Locally, these have led to the formation of lateral deposits in the lee of the point of contact between the vane and rock wall. Although the vane structures help create some variability in bed topography, the low flow channel is relatively deep (approximately 4 feet depth on average), homogenous, and sluggish. Bed material is dominated by sand and silt. A natural woody riparian buffer is virtually non-existent.

5.3 EXISTING PLANT COMMUNITIES IN RIPARIAN BUFFER AREAS

The existing plant communities in the riparian buffer areas vary significantly between reaches within the project area. Figure 6 illustrates the existing vegetation communities along the two reaches.

Along the Eastway Elementary School Reach, riparian vegetation is divided between two communities—an upper floodplain terrace and lower vegetated instream bars. Vegetation of the upper floodplain is primarily composed of mowed fescue grass (*Festuca* sp.) and common lawn weeds. Log vanes were installed in this reach in 1998, and point bars formed behind them. A mix of native and invasive woody and herbaceous floodplain species became established on these bars. The dominant hardwood species are black willow (*Salix nigra*) and princess tree (Paulownia tomentosa), which is an invasive species. A mix of native herbaceous species are present including *Rumex* sp. and

Goose Creek Restoration
Durham County, North Carolina
Biohabitats Project No. 04802.02

Ecosystem Enhancement Program

Figure 6
Existing Plant Communities

Biohabitats Incorporated

September 2005

knotweed (*Polygonum* sp.) along with invasive species including Japanese hops (*Humulus japonicus*) and Asiatic dayflower (*Commelina communis*). Table 2 lists the common species along the reach.

Table 2. Existing Vegetation Species, Eastway Elementary School Reach

Scientific Name	Common Name
Trees	
Salix nigra	Black Willow
Morus rubra	Red Mulberry
Shrubs	
Lagerstroemia indica	Crepe Myrtle
Herbaceous	
Rumex sp.	Dock Species
Polygonum sp.	Knotweed
Invasives	
Humulus japonicus	Japanese Hops
Paulownia tomentosa	Princess tree
Commelina communis	Asiatic dayflower
Ligustrum sinense	Chinese privet

Within Longmeadow Park, Goose Creek flows through a maintained park and its channel is confined by stone retaining walls. Within the confined channel some riparian trees and shrubs have become established. Species in the channel area include black willow and red mulberry (*Morus rubra*). Above the retaining walls on the flat upper floodplain (which is park grounds) mowed grass dominates with scattered 24-36" planted willow oaks (*Quercus phellos*) and white oaks (*Quercus alba*). Invasive species in the channel area include Japanese hops, Asiatic dayflower, princess tree and mimosa (*Albizia julibrissin*). On the areas from the top of the walls extending laterally into the park invasive species include Johnson grass (*Sorghum halpense*), Chinese privet, Japanese hops, and wisteria (*Wisteria sinensis*). Table 3 includes common tree, shrub, herbaceous, and invasive species.

Table 3. Existing Vegetation Species, Longmeadow Park Reach

Scientific Name	Common Name
Trees	
Salix nigra	Black Willow
Morus rubra	Red Mulberry
Quercus phellos	Willow oak
Ulmus sp.	Elm
Acer negundo	Box Elder
Quercus alba	White Oak
Shrubs	
Cornus amomum	Silky Dogwood
Lagerstoemia indica	Crepe Myrtle
Herbaceous	
Parthenocissus quinquefolia	Virginia Creeper
Festuca sp., *Polygonum* sp.	Grasses and Knotweed
Invasives	
Sorghum halpense	Johnson grass
Humulus japonicus	Japanese Hops
Paulownia tomentosa	Princess tree
Commelina communis	Asiatic dayflower
Albizia julibrissin	Mimosa
Wisteria sinensis	Wisteria

5.5 THREATENED/ENDANGERED SPECIES REPORT

According to the North Carolina Natural Heritage Program (NHP) and US Fish & Wildlife Service (FWS) databases, three species in Durham are federally protected (Table 4). Those species include the bald eagle (*Haliaeetus leucocephalus*), Michaux's sumac (*Rhus michauxii*), and Smooth coneflower (*Echinacea laevigata*). The Goose Creek stream restoration site does not contain habitat for any of the three federally-protected species. Mature forests near open water for bald eagle nesting areas are not present at the site. The school, park, and home yard sites are planted with monoculture grass that is mowed regularly. The Michaux's sumac record in Durham County is historic. Twelve additional species are listed as Federal Species of Concern (species that may or may not be listed in the future).

Table 4. Federally Protected Species in Durham County

Scientific Name	Common Name	Status	Habitat
Haliaeetus leucocephalus	Bald Eagle	Threatened (proposed for delisting)	Nests in transition zone between forest and marsh/open water, less than 2 miles from open water, in dominant live pines or cypress trees (winter nests may be farther from water)
Rhus michauxii	Michaux's sumac	Endangered	Sandy or rocky open woods in association with basic soils; areas that are open due to disturbance, such as roadsides and edges of clearings
Echinacea laevigata	Smooth coneflower	Endangered	Meadows, open woodlands, cedar barrens, dry limestone bluffs, roadsides, power line rights-of-way, disturbed areas; requires abundant sunlight and little herbaceous competition

The NHP lists several additional species and natural communities in its database of elements of natural diversity of the USGS quadrangle Southwest Durham. Those species and communities are listed in Table 5.

Table 5. Federal Species of Concern for Durham County

Scientific Name	Common Name	Habitat
Vertebrates		
Etheostoma colis lepidinion	Carolina darter	Streams in Roanoke, Tar, Neuse, and Cape Fear drainages (obscure record)
Noturus furiosis pop. 1	"Neuse" madtom	Tar River drainages (historic record)
Lythrurus matutinus	Pinewoods shiner	Tar and Neuse drainages (obscure record)
Invertebrates		
Fusconaia masoni	Atlantic pigtoe	Medium to large streams streams; clean, swift waters with stable gravel or sand/gravel substrate; downstream edge of riffles
Lasmigona subviridus	Green floater	Small to medium streams with good water quality; quiet pools and eddies with gravel/sand substrate; canals
Somotogyrus virginicus	Panhandle pebblesnail	Eno River

Scientific Name	Common Name	Habitat
Gomphus septima	Septima's clubtail dragonfly	Piedmont rivers (historic record)
Lamsilis cariosa	Yellow lampmussel	Fast flowing, medium sized rivers; medium to large creeks; shifting sands downstream of large boulders
Vascular plants		
Juglans cinerea	Butternut	Cove forests; rich woods
Monotropsis odorata	Sweet pinesap	Dry forests; rich woods
Delphinium exaltatum	Tall larkspur	Grassy balds; glades; woodlands; found over mafic rock
Nonvascular Plants		
Plagiochila columbiana	Liverwort	Thin soil over boulders on floodplains

6.0 STREAM REFERENCE RESTORATION STUDIES

Both the unnamed tributary to Cabin Branch and Morgan Creek are appropriate reference reaches for the Goose Creek project. The two creeks encompass a range of conditions that both mirror Goose Creek (e.g., physiographic setting, drainage area) and accommodate the physical constraints of the site (e.g. limited potential for lateral realignment, low slope). The riparian vegetation along the tributary to Cabin Branch also provides some guidance for target riparian species.

The unnamed tributary to Cabin Branch is a second-order stream with a watershed area of 1.3 square miles. The stream channel is 8 to 10 feet wide with 2-ft high banks. The channel meanders through a well-established buffered floodplain within a U-shaped valley. The stream classifies as a C4 channel. Discussions with long-term homeowners along Earl Road suggest that the creek has not changed its shape appreciably in the past few decades. Although the floodplain is not extensively wide and the sinuosity is not extremely high, the floodplain, valley structure, and sinuosity provide a template of a system which can be constructed within the constraints of the Goose Creek project site. Despite its location in the Triassic Basin, the channel substrate is very rocky (instead of sandy) with a considerable amount of bedrock. Appendix F summarizes morphological characteristics included in Stantec's "Stream Restoration Plan: Ellerbe Creek, Durham County, North Carolina," as well as Biohabitats' additional measurements. Biohabitats' measurements are also included in Appendix F.

Table F also includes morphological measurements of Morgan Creek made by North Carolina State University and included in Buck Engineering's "Buffalo Creek Watershed Stream Restoration Projects, Greensboro, North Carolina." This gravel-bedded stream classifies as B4c channel, since it has a relatively low gradient (0.7 percent).

Riparian vegetation of the upper tributary of Cabin Branch consists of a well established southern hardwood riparian forest. This site has a well developed vertical structure with canopy, shrub and herbaceous layers. Predominant trees and shrubs of this reference site include tulip poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), oak species (*Quercus sp.*), hop hornbeam (*Ostra virginiania*), sweetgum (*Liquidambar styraciflua*), hickory species (*Carya sp.*), silky dogwood (*Cornus amomun*), and arrowwood (*Viburnum dentatum*).

7.0 STREAM RESTORATION PLAN

With the Eastway Elementary School and Longmeadow Park Reaches, the project will restore 1318 feet of stream by changing the channel profile, pattern, and cross-sectional shape (thereby meeting definition of Stream Restoration). An additional 200 feet will be enhanced (Enhancement Type 1) in the Longmeadow Park Reach, by changing the profile and pattern of the stream. In these sections, segments of the masonry wall will remain to prevent disturbance to existing oaks, thereby precluding full stream restoration.

7.1 PROPOSED STREAM CLASSIFICATION

The stream restoration design includes several channel types within the project area. These were dependent on lateral space, possible gradient, and existing geomorphic tendencies. Throughout the project area, the restoration will include expansion of the available floodplain area to dissipate shear stresses and improve channel function. The proposed alignment is shown in Appendix G.

The channel dimensions necessary to convey the design discharge are significantly larger in the Eastway Elementary School Reach than immediately upstream. In addition, lateral constraints—the Eastway Elementary School fenceline to the west and Barnes Avenue Community Redevelopment to the east—limit the planform pattern. This reach, therefore, has been designed as a low slope B-type channel.

While the existing concrete-lined channel does not have adequate floodplain for bankfull events and larger, the existing low flow channel is geomorphically stable and provides beneficial aquatic and terrestrial habitat. The design, therefore, seeks to recreate a similar low flow channel meandering within the broader confines of the proposed B channel. The nested low flow channel is designed with standard C-type ratios, such as a radius of curvature to bankfull width ratio exceeding 2. While the design of a nested channel can be problematic in steeper reaches, the low reach slope along Eastway Elementary School limits shear stresses and the risk of avulsion. The short outfall channel from the 60" RCP outfall along the west side of Goose Creek will be regraded and turned slightly to the north to create a smooth transition into the next adjacent riffle along Goose Creek. Design discharges along Goose Creek change from 265 cfs to 400 cfs at this junction.

Between the reaches, the Longmeadow Park Reach is the most incised, with existing banks extending 7 vertical feet. The low channel slope between the two culvert inverts (0.39%) does not allow raising the invert of the channel. To create a C-type channel in this setting, extensive earthworks would be required. Existing lateral constraints, including the adjacent sewer line to the west, large oaks along both channel banks, and ball fields to the east further preclude restoration to a C-type channel. Instead, the park area is well suited to the creation of a low gradient B-channel. Unhealthy willow oaks will be removed to allow some modification of the channel alignment and permit regrading of the banks.

7.2 MORPHOLOGICAL SUMMARY

Typical cross sections for the many design segments within the project reach are included in Appendix H. The proposed longitudinal profiles of each reach are included in Appendix I. Finally, Appendix F summarizes morphologic parameters of the existing channel, the two reference reaches, and the proposed stream types. The proposed channel draws from the range of values established in reference reaches. However, professional judgment has been exercised in several cases to improve performance and/or follow more generally accepted guidelines (e.g., maintain radius of curvature to bankfull width ratio >2). Riffle slopes were set to range from 0.8 to 2.0%, slightly lower than the average of 2.3% which was deemed too high. Glide and run slopes generally range from 5-10%, approximately the range within the reference reach data sets. At some locations a control structure, such as a cross vane or rock step, was used to step the channel down into a pool.

7.3 SEDIMENT TRANSPORT

Sand is the dominant size fraction of surface and subsurface bed material at the two proposed project reaches. Techniques such as Andrews (1984) are therefore not applicable to Goose Creek. The simple Shields (1936) model is instead an appropriate tool for first-order sediment transport analysis at Goose Creek.

Based on empirical data, Shields developed a curve to describe the dimensionless critical shear stress, τ^*_{ci} or Shield parameter, defined as:

$$\tau^*_{ci} = \tau_{ci} / (\rho_s - \rho) g D_i$$

where τ_{ci} is the Shield parameter or critical shear stress at incipient motion for the grain size of interest, D_i; g is the gravitational acceleration, and ρ_s and ρ are the sediment and fluid densities, respectively. Shields demonstrated that in fully rough flow (Reynolds numbers >489), as with gravel-bed rivers, dimensionless critical shear stress attains a constant value of 0.06 at this point.

Given the sand-dominated nature of bed material and sensitivity to changes in shear stresses, sediment transport analysis needs to address the potential for both aggradation and degradation. The design intent is to allow for incipient motion of the majority of the grain size distribution at the bankfull flow. Where the entire grain-size distribution is expected to be mobilized at the bankfull flow, grade control measures will be used to eliminate the risk of headcutting.

Table 7 shows the likely change in incipient particle size from existing to proposed conditions for each reach. Generally speaking, shear stresses between 0.5 lb/ft^2 and 2 lb/ft^2 pose a low erosion potential and shear stresses below 0.5 lb/ft^2 pose a *very* low risk of erosion.

In the Eastway Elementary School Reach, shear stresses are predicted to increase. The existing stream conditions in this reach were very sluggish with pools rather ill-defined. Increasing bankfull shear stresses through this section will help maintain pool depths over the long-term. Degradation is not likely given the low channel gradient forced by the culverts and low shear stress values.

In the Longmeadow Park Reach, shear stresses are expected to remain approximately the same as in existing conditions. The placement of cross vanes and step structures will help control sediment transport locally and maintain pools through the reach.

Table 6. Sediment Transport Results from Shields Equation

Channel Type (Location)	Existing Conditions, Shear Stress	Incipient Grain Size (mm)	Proposed Conditions Shear Stress	Incipient Grain Size (mm)
Eastway Elementary School Reach	0.12	6	0.33	16
Longmeadow Park	0.61	30	0.58	29

7.4 PROPOSED PLANT COMMUNITIES

In conjunction with riparian potential at the project site given existing conditions, the proposed plant lists were developed based upon the reference site. Proposed plant communities are intended to support local ecosystem processes with careful consideration to supporting native wildlife. The goal for restoring the physical conditions at this site is consistent with a piedmont/low mountain alluvial forest as defined in "Classification of the Natural Communities of North Carolina, Third Approximation" (Schafale and Weakley, 1990). Upon creation of the grading plan, planting schedules will be created from the further define which species are appropriate to specific elevations and moisture conditions with distance from the channel. Likely planting zones may include upland forest, streamside forest, meander zone, and low floodplain bench. The preliminary extent of the proposed riparian zone is shown in Appendix G.

Table 7. Proposed Vegetation Communities

Scientific Name	Common Name
Trees	
Betula nigra	River Birch
Platanus occidentalis	Sycamore
Ulmus americana	American Elm
Celtis occidentalis	Hackberry
Fraxinus pennsylvanica	Green Ash
Carya cordiformis	Bitternut Hickory
Carya ovata	Shagbark Hickory
Acer rubrum	Red Maple
Liquidambar styraciflua	Sweet Gum
Liriodendron tulipifera	Tulip Poplar
Juglans nigra	Black Walnut
Acer barbatum	Southern Sugar Maple
Understory Trees	
Acer negundo	Box Elder
Diospyros virginians	Common Pawpaw
Ilex opaca	American Holly
Carpinus caroliniana	Ironwood
Shrubs	
Lindera benzoin	Spicebush
Euonymus americanus	American Strawberry-bush
Aesculus sylvatica	Painted Buckeye
Leucothoe axillaries	Doghobble
Corylus Americana	Beaked Hazelnut
Cornus amomum	Silky Dogwood
Herbaceous	
Solidago caesia	Woodland Goldenrod
Aster divaricata	White Wood Aster
Carex laxiflora	Broad Loose-flower Sedge
Panicum clandestinum	Deertongue Grass
Elymus virginiana	Virginia Wild Rye
Chasmanthium latifolium	River Oats
Chasmanthium laxum	Slender Spikegrass
Polystichum acrostichoides	Christmas Fern
Botrychium virginianum	Rattlesnake Fern
Uvularia sessilifolia	Sessile-leaf Bellwort
Boehmeria cylindrica	False Nettle

7.5 IN-STREAM DESIGN ELEMENTS

7.5.1 Structural Elements

This concept design includes structural elements to augment to initial stability of the natural channel design as vegetation growth occurs, to provide extra protection to those areas subject to high shear stresses, and to maintain preferred bedforms. These structures act to redirect flow, protect vulnerable outer meander bends, and maintain pool depths. Most proposed structures would be comprised of rock, which will not degrade despite strong fluctuations in water depth. Rock that has been used in existing in-stream structures can be salvaged (and augmented) to create the proposed structures. Logs are less desirable, since they deteriorate quickly in the flashy system. In time, it is intended that the riparian zone would protect banks firsthand and add to channel complexity.

Structures shown along the proposed stream alignment in Appendix G are shown schematically. The actual extent and precise locations of these features may be revised as design development continues. Generic design details for the proposed structures are also included in Appendix G. These will also be revised with additional design work.

The following structures are proposed within the project area:

1. **Bank protection practices**
    1. Rootwads
    2. Rock toe protection
    3. Single wing deflector

2. **Grade control**
    1. Rock cross vane
    2. Riffle grade control structures
    3. Rock steps

3. Bank protection and grade control

1. Step/pool sequences

7.5.2 Soil Bioengineering Elements

Soil bioengineering, or non-structural means of stabilizing streambanks, are also proposed within the restoration project. Bank stabilization using soil bioengineering would include standard techniques such as live branch layering and live stakes. The location and extent of these measures will be determined as the design proceeds.

Where soil bioengineering is proposed, the streambanks will be regraded to a stable angle and geometry and utilize vegetative planting and biodegradable materials to stabilize the streambank and prevent or reduce future streambank erosion. These practices are proposed where there is sufficient area available to regrade the streambank and sufficient sunlight to promote the growth of the plant materials.

8.0 STREAM MONITORING PLAN

A technical monitoring plan is necessary to measure the success of the restoration plan. Technical monitoring will provide information needed to diagnose unforeseen problems resulting from changes in the environment, and 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 technical monitoring program should address and document pre-construction and initial post-construction conditions. The monitoring should be performed by a qualified firm with experience in designing and implementing stream restoration using a natural channel design approach.

Streams, by their nature, are dynamic systems which gradually adjust their cross section, profile, and planform with changing environmental conditions. Infrequent catastrophic events can also alter river form and course, though much more quickly. Meander bend cut offs and creation of oxbows are often the result of high magnitude flow events. Because rivers are dynamic systems which are subject to catastrophic events, evaluation of changes in the newly constructed channel must be taken in the context of the entire river system. To facilitate comparison between the relocated and natural channel, a monitoring program is proposed that includes monumented cross sections upstream of and within the relocated channel. General observations of changes in natural morphology along with quantitative changes at the monumented cross sections will help indicate which channel changes deserved immediate attention.

Natural rivers are composed of areas of slow deep water (pools) and shallow fast moving reaches (riffles or glides). Pools are areas of bed scour (hence their greater than average depth), whereas glides and riffles are relatively shallow due to accumulated sediment. Sediment is also accumulated on the insides of meander bends, whereas the outside of a bend is typically a pool. Channel aggradation (bar formation) and/or degradation (bed and bank scour) all occur naturally as part of fluvial processes and one should not be overly concerned when they occur, especially in areas they are expected (i.e. degradation in meander bend pools and aggradation on inside point bars). Unexpected occurrence of channel bars and/or bed scour of the new channel may form after a storm event, but these changes are typically transient and may be reversed by next storm. These features will be noted during all scheduled monitoring to ascertain if they are temporary, static, or growing.

If the bar feature or bed degradation is not chronically increasing, then no action need be taken. However, if a bar is chronically aggrading or laterally accreting, it could expand to the point where flows are directed into one or both banks causing erosion and possible bank failure. In this case the bar needs to be reconfigured before bank failure occurs and the cause of the bar formation should be determined. Bar formation is often caused by debris jams or grade control structures. Debris jams will be removed along with the bar material and grade control structures will be modified to stop the accumulation of sediments. Bar formation can also be caused by an influx of larger than normal sediments. If bed scour progresses, it could threaten the stability of the banks, log vanes, or rock weirs.

Streams may also change through catastrophic events such as floods. Large floods may cause local bank erosion and floodplain scour, and may even create oxbow wetlands by cutting off meander bends. It is important to evaluate the effects of infrequent, large-magnitude events on the newly constructed channel in the context of the entire river system. Changes in channel morphology (bank erosion, bed scour, bar formation) of the newly constructed channel must be compared to reaches upstream and downstream of the relocation. If a catastrophic event passes through the area and causes widespread bank erosion upstream and downstream of the relocated channel, then bank erosion within the relocated channel should be considered part of the natural process. Channel changes within the relocated channel that deviate from those in the natural channel will need to be addressed immediately.

The monitoring period will extend a minimum period of five years. The general format and content of the monitoring report will follow EEP guidance including:

- An executive summary that presents and describes the major attributes of the Goose Creek stream restoration project,
- Project Background, including location and setting, mitigation structure and objectives, project history and background and a monitoring plan view page,
- A Project Condition and Monitoring Results section that includes vegetation assessment, soils data, vegetative problem areas (if any) plan view and summary table, stem counts, vegetation plot photos, a stream assessment that includes morphometric criteria (dimension and profile information), hydrologic criteria (bankfull event information) bank stability assessments (BEHI and NBS), stream problem areas plan view and table, numbered issue photos section, fixed station photos, stability assessment table, and
- Methodology section.

9.0 REFERENCES

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APPENDIX A

PHOTOGRAPHS OF PROJECT AREA

Photograph 1. Looking west along Taylor Street towards Eastway Elementary School. Goose Creek contained in culvert from this location upstream to Upper Reach (1/21/04).

Photograph 2. Looking upstream at culvert outfall from Taylor Street and parking lot at Eastway Elementary School, demarking upstream limit of Eastway Elementary School Reach. (1/21/04)

Photograph 3. Looking downstream from Taylor Street outfall, with spring foliage. (5123105)

Photograph 4. Looking downstream from Taylor Street outfall, with winter foliage. (1121104)

Photograph 5. Looking downstream along left bank in upstream portion of reach. (1/21/04)

Photograph 6. Looking east from right bank at debris line in fence. (5/23/05)

Photograph 7. Looking at concrete **headwall** and *60"* RCP draining west side of Goose Creek. **(1/21/04)**

Photograph 8. Closer view of concrete **headwall** and *60"* RCP draining west side of Goose Creek midreach. **(5123105)**

ʾhotograph 9. **Looking** downstream towards **midreach junction between Goose Creek and channel draining 60"** RCP **outfall,** with thick vegetation. **(5/23/05)**

Photograph **10.** Looking upstream at mowed corridor along right **bank** of Goose Creek. **(1/21/04)**

Photograph 11. Looking downstream along mowed comdor along right bank. **(112 1/04)**

Photograph 12. Looking upstream at meandering low flow channel midreach. **(1/21/04)**

Photographs of Eastway Elementary School Reach
Goose Creek Stream Restoration Plan

Photograph 13. Looking downstream along exposed grouted mattress lining covering right bank. (1/21104)

Photograph 14. Looking at outfall draining into reach. (5123105)

Photograph 15. View upstream from lower portion of reach with log deflectors visible. (1/21/04)

Photograph 16. Looking upstream at alternate bars downstream of elementary school. (5123105)

Photograph 17. Looking downstream at culvert under Liberty Street, spring foliage. (5123105)

Photograph 18. Looking downstream at Liberty Street culvert, winter foliage, downstream reach limit. (1121104)

Photograph 1. Looking downstream along right bank from vicinity of Liberty Street, planted small conifers on terrace. (5/23/05)

Photograph 2. Looking upstream at culvert under Liberty Street. Upstream limit of Longmeadow Park Reach. (1/21/04)

Photograph 3. Looking downstream from Liberty Street with spring foliage. (5/23/05)

Photograph 4. Looking downstream from Liberty Street with winter foliage. (1/21/04)

Photograph 5. Looking downstream at live oaks bracketing stream. (1/21/04)

Photograph 6. Looking upstream at gravel surface with Elementary School in background. (5/23/05)

Photograph 7. Looking at rock cross vane structure, view from right bank *(5123105).*

Photograph 8. Looking downstream in lower portion of reach. (5/23/05)

Photograph 9. Looking downstream towards Holloway Street. (5/23/05)

Photograph *10.* Looking across Longmeadow Park from left bank. Single live oak in middle of field. *(1121104)*

Photograph 11. Looking upstream near left bank and proposed channel alignment. (5/23/05)

Photograph 12. Looking upstream along left bank and live oaks. (5/23/05)

Photograph 13. Looking downstream along left bank mid-reach. (1/21/04)

Photograph 14. Looking upstream and across channel from right bank. (5123105)

Photograph 15. Looking upstream mid-reach. (1/21/04)

Photograph 16. Looking downstream towards culvert under Holloway Street. (1121104)

Photograph 17. Looking downstream along arm of rock vane structure. (5/23/05)

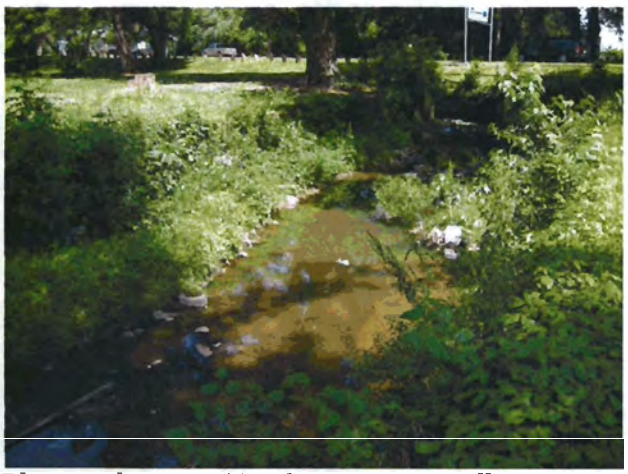
Photograph 18. Looking upstream from right bank towards ballfield. (5/23/05)

Photograph 19. Looking downstream along proposed alignment. (5123105)

Photograph 20. Looking downstream towards Holloway Street. (5/23/05)

Photograph 21. Near left bank looking across stream with Holloway Street in background. (5/23/05)

Photograph 22. Looking across field from left bank, baseball field in background. (5123105)



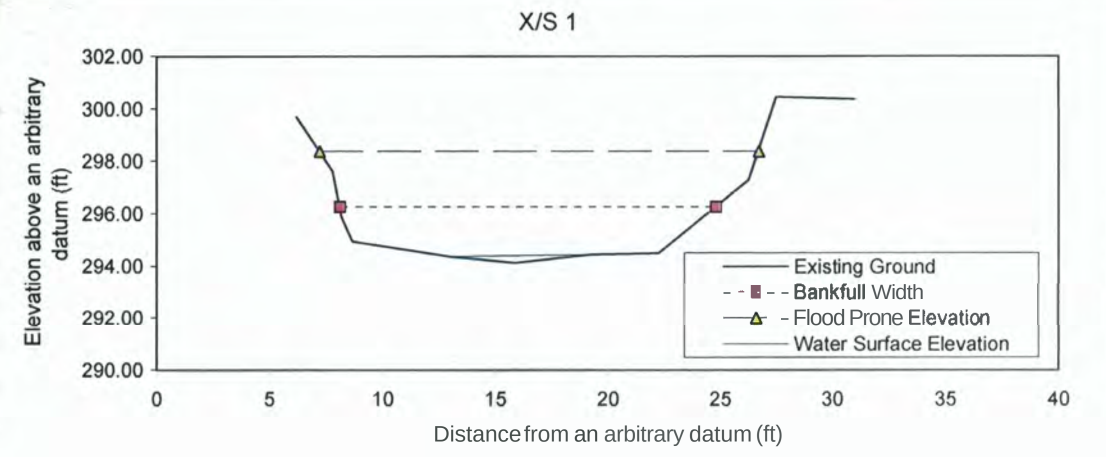
Photograph 23. Looking downstream at Holloway Street culvert, downstream reach limit. (5/23/05)

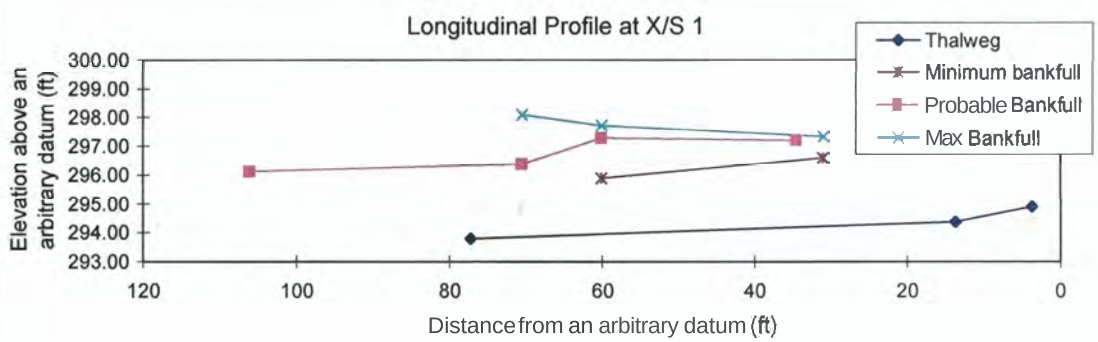
Photograph 24. Looking upstream from Holloway Street. (5/23/05)

APPENDIX B

FIELD CROSS SECTIONS AND PEBBLE COUNT FROM PROJECT AREA

Existing Cross Section and Channel Profile
Goose Creek Restoration Plan
Upper Reach





Rosgen Stream Type Classification	
Bankfull Width	16.69 (ft)
Entrenchment	1.17 (ft/ft)
Width:Depth	10.23 (ft/ft)
Sinousity	1.05 (ft/ft)
Slope	0.0160 (ft/ft)
D_{50}	<2 (mm)
Stream Type	F

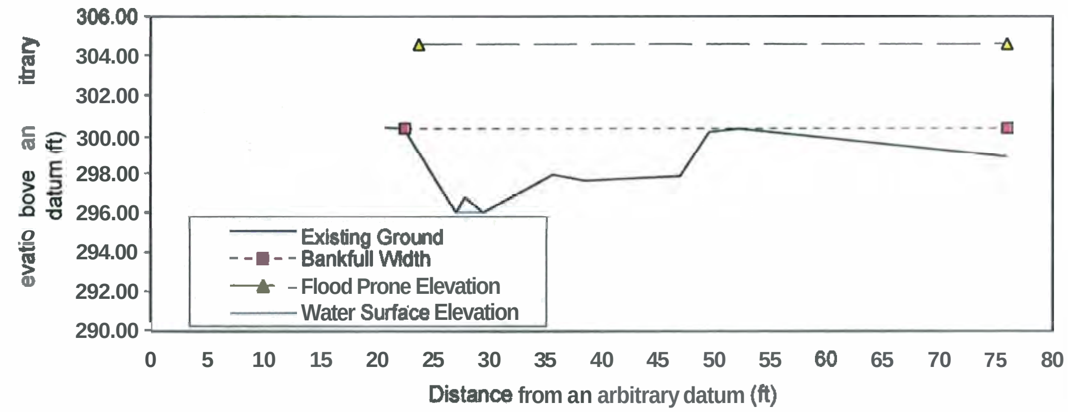
Flow Calculations	
Max BF Depth	2.13 (ft)
Mean BF Depth	1.63 (ft)
X/S Area	27.21 (ft^2)
Manning's n	0.0450
BF Ave. Velocity	5.49 (ft/s)
Discharge	149.29 (cfs)
Shear Stress	1.50 (lb/ft^2)

Bio Project Number:	02803.02	
Surveyed:	May 18,2004	By: EMM (BIO), KB (CDM)

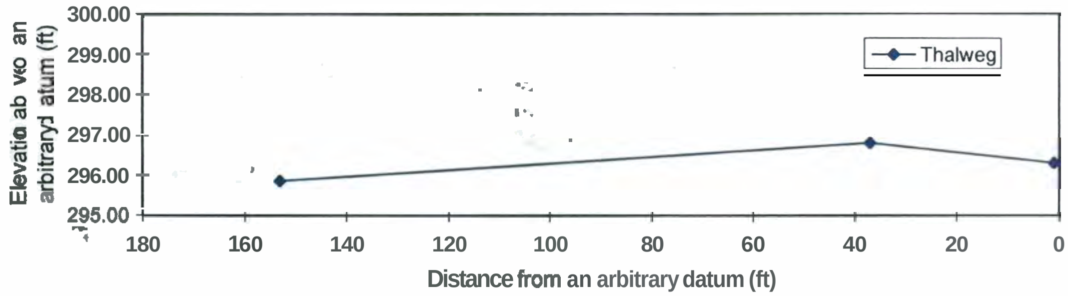
Existing Cross Section and Channel Profile
Goose Creek Restoration Plan
Eastview Elementary School Reach

Biohabitats

XIS 2



Longitudinal Profile at XIS 2

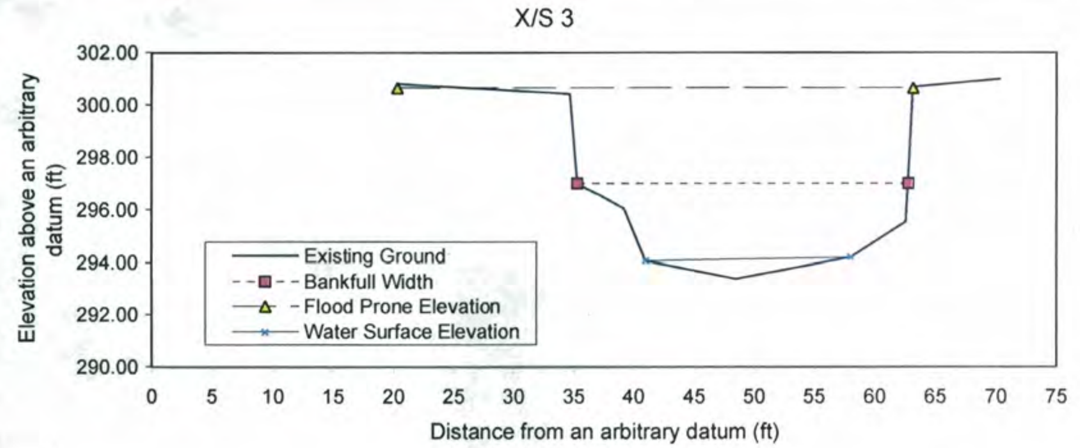


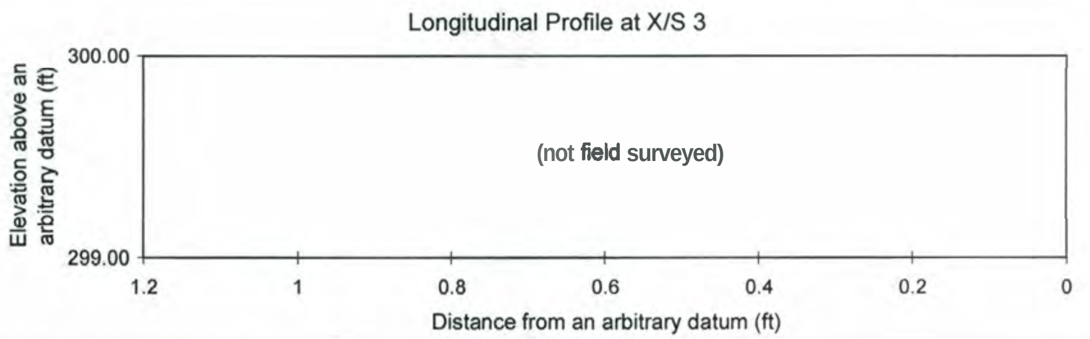
Rosgen Stream Type Classification	
Bankfull Width	53.46 (ft)
Entrenchment	>2.2 (ft/ft)
Width:Depth	16.68 (ft/ft)
Sinousity	1.00 (ft/ft)
Slope	0.0019 (ft/ft)
D_{50}	<2 (mm)
Stream Type	n/a

Flow Calculations	
Max BF Depth	4.27 (ft)
Mean BF Depth	2.14 (ft)
X/S Area	76.12 (ft^2)
Manning's n	0.0350
BF Ave. Velocity	1.88 (ft/s)
Discharge	143.03 (cfs)
Shear Stress	0.12 (lb/ft^2)

Bio Project Number:	02803.02	
Surveyed:	May 18, 2004	By: EMM (BIO), KB (CDM)

Existing Cross Section and Channel Profile
Goose Creek Restoration Plan
Long Meadow Park Reach





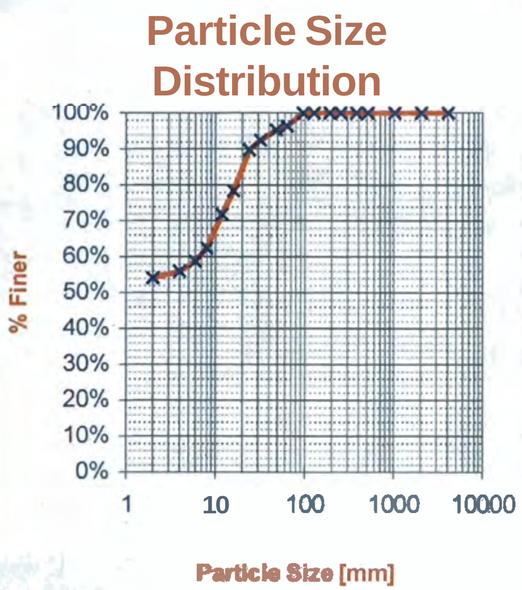
Rosgen Stream Type Classification	
Bankfull Width	27.48 (ft)
Entrenchment	1.35 (ft/ft)
Width:Depth	10.71 (ft/ft)
Sinousity	1.00 (ft/ft)
Slope	0.0042 (ft/ft)
D_{50}	<2 (mm)
Stream Type	n/a

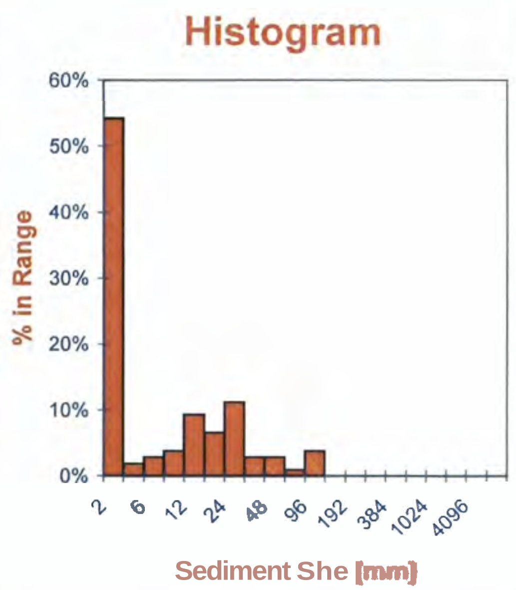
Flow Calculations	
Max BF Depth	3.64 (ft)
Mean BF Depth	2.57 (ft)
X/S Area	70.48 (ft^2)
Manning's n	0.0350
BF Ave. Velocity	4.87 (ft/s)
Discharge	343.38 (cfs)
Shear Stress	0.61 (lb/ft^2)

B b Project Number:	02803.02	
Surveyed:	May 18,2004	By: EMM (BIO), KB (CDM)

Site Name:	Goose Creek			Biohabitats, Inc.	
Project No:	4802.02			Pebble Count Data Sheet	
Date:	5/24/2005			Riffle, Active Channel	

	Particle	Size [mm]	Total #	% in Range	% Cumulative
Sand and Silt	<	2	58	54%	54%
	2 -	4	2	2%	56%
	4 -	6	3	3%	59%
	6 -	8	4	4%	63%
	8 -	12	10	9%	72%
Gravels	12 -	16	7	7%	79%
	16 -	24	12	11%	90%
	24 -	32	3	3%	93%
	32 -	48	3	3%	95%
	48 -	64	1	1%	96%
	64 -	96	4	4%	100%
Cobbles	96 -	128		0%	100%
	128 -	192		0%	100%
	192 -	256		0%	100%
	256 -	384		0%	100%
	384 -	512		0%	100%
Boulders	512 -	1024		0%	100%
	1024 -	2048		0%	100%
	2048 -	4096		0%	100%
Bedrock				0%	100%
		TOTALS:	107	100%	

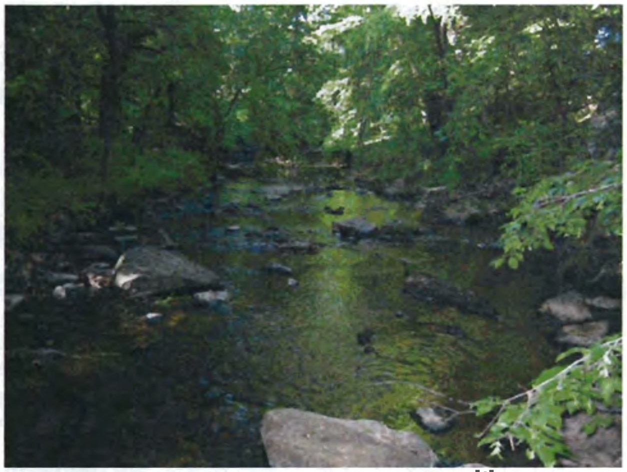




D50=	0	D75=	13.85714	D84=	19.92

APPENDIX C

PHOTOGRAPHS OF REFERENCE REACHES



Photograph 1. Looking upstream at riffle with boulders, Morgan Creek. *(5125105)*

Photograph 2. Looking downstream from riffle with boulders, Morgan Creek. *(5125105)*

Photograph 3. Looking downstream from pool to riffle, Morgan Creek. *(5125105)*

Photograph 4. Looking upstream along floodplain of Morgan Creek. (5/25/05)

Photograph 5. Looking upstream along floodplain of Morgan Creek. *(5125105))*

Photograph 6. Looking upstream at rib of boulders. (5/25/05)

Photograph 7. Looking upstream along elongated pool, Morgan Creek. (5/25/05)

Photograph 8. Looking upstream along broad, shallow riffle, Morgan Creek. *(5125105)*

Photograph 9. Looking downstream along elongated pool, Morgan Creek. *(5125105)*

Photograph *10.* Looking upstream from pool to riffle, Morgan Creek. *(5125105)*

Photograph 11. Pool-riffle sequence, Morgan Creek. (5/25/05)

Photograph 12. Looking downstream at end of profile along Reach A, UT Cabin Branch. *(5125105)*

Photograph 13. Looking upstream at Cross Section #1, Reach A, UT Cabin Branch. (5/25/05)

Photograph 14. Looking downstream at Cross Section #1, Reach A, UT Cabin Branch. (5/25/05)

Photograph 15. Looking upstream at start of profile, Reach A, UT Cabin Branch. (5/25/05)

Photograph 16. Looking downstream from start of profile along Reach A, UT Cabin Branch. (5125105)

Photograph 17. Looking downstream at Cross Section #2, Reach A, UT Cabin Branch. (5125105)

Photograph 18. Looking upstream at Cross Section #2, Reach A, UT Cabin Branch. (5125105)

Photograph 19. **Example** of bed material along Cross Section #1, Reach A, UT Cabin Branch. Ruler is ***15*** inches **long. (5/25/05)**

Photograph 20. Example of bed material along Cross Section #1, Reach A, UT Cabin Branch. Ruler is 15 inches long. (5/25/05)

Photograph 21. Looking downstream at Cross Section #3, Reach B, UT Cabin **Branch.** ***(5125105)***

Photograph 22. Looking upstream at Cross Section #3, Reach B, UT Cabin **Branch.** ***(5125105)***

Photograph ***23.*** Looking downstream at **Cross Section #4,** Reach B, UT Cabin **Branch.** ***(5125105)***

Photograph 24. Looking upstream at Cross Section #4, Reach B, UT Cabin Branch. (5/25/05)

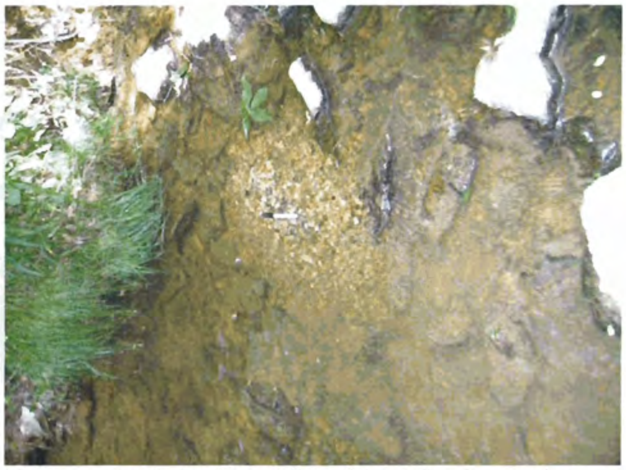
Photograph 25. Looking downstream at Cross Section #5, Reach B, UT Cabin Branch. (5/25/05)

Photograph 26. Looking upstream at end of profile, Reach B, UT Cabin Branch . (5/25/05)

Photograph 27. Looking downstream from Station 0+55 along profile, Reach B, UT Cabin Branch. (5/25/05)

Photograph 28. Looking downstream from Station 0+95, Reach B, UT Cabin Branch. (5/25/05)

Photograph 29. Looking upstream from Station 0+95, Reach B, UT Cabin Branch. (5/25/05)

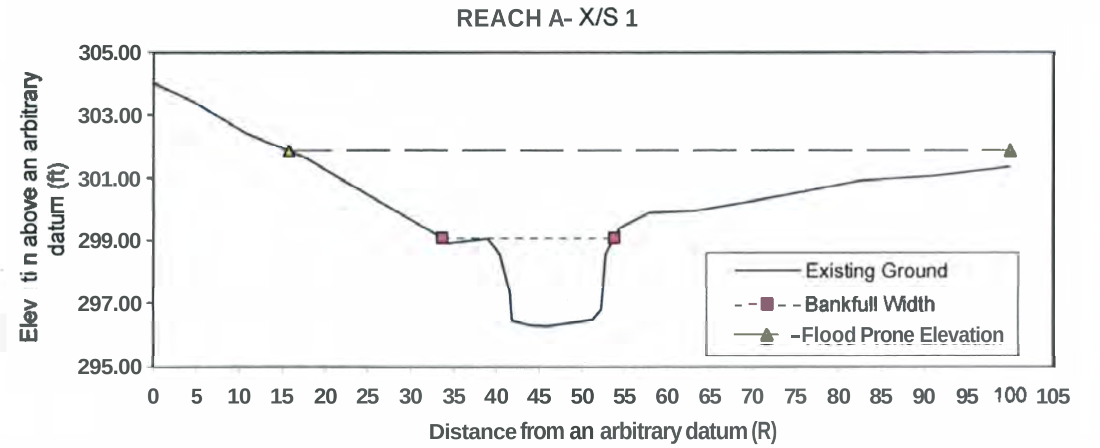


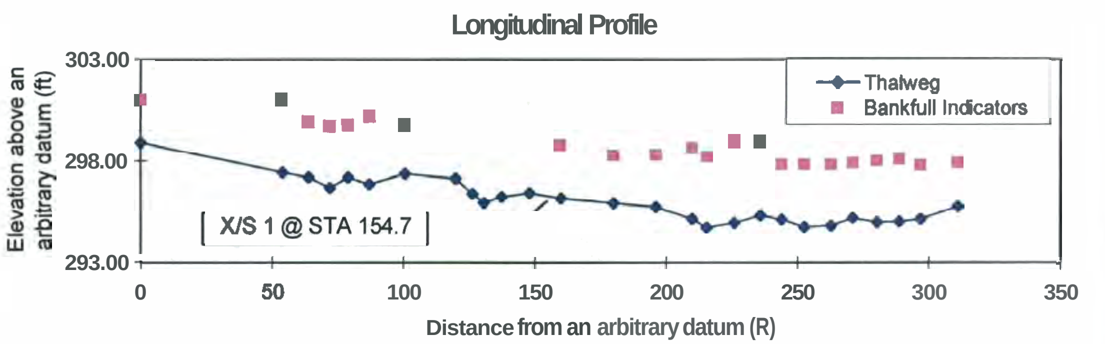
Photograph 30. Bed material with patch of spawning gravels, Sharpie for scale, UT Cabin Branch. (5/25/05)

APPENDIX D

FIELD CROSS SECTIONS AND PEBBLE COUNTS FROM REFERENCE REACHES

Reference Reach Cross Section and Channel Profile
Goose Creek Stream Restoration
Riffle Reach A- Upper Tributary of Cabin Branch





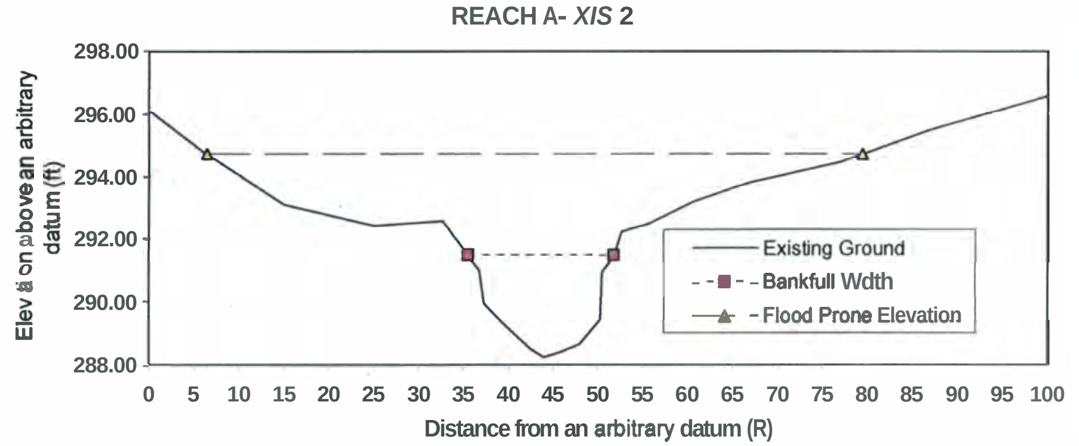
Rosnen Stream Type Classification	
Bankfull Width	20.09 (A)
Entrenchment	3.50 (ft/ft)
Width:Depth	12.86 (ft/ft)
Sinousity	(ft/ft)
Slope	0.0138 (ft/ft)
D_{50}	27 (mm)
Stream Type	B4c

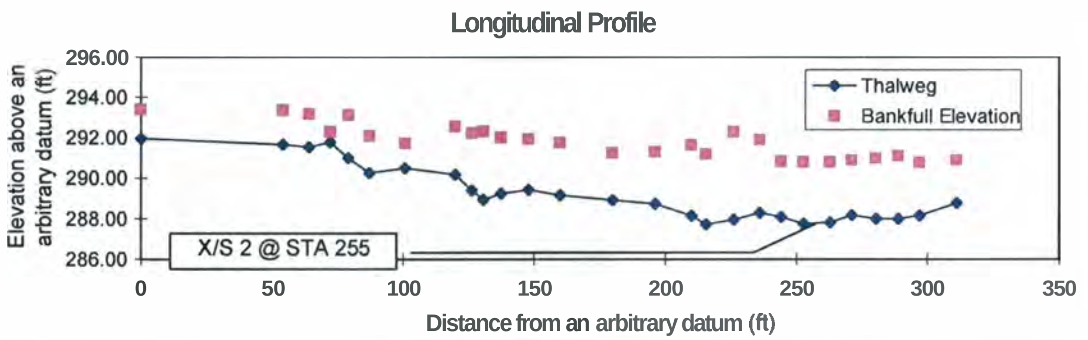
Flow Calculations	
Max BF Depth	2.78 (ft)
Mean BF Depth	1.56 (ft)
X/S Area	31.40 (ft^2)
Manning's n	0.0450
BF Ave. Velocity	4.80 (ft/s)
Discharge	150.76 (cfs)
Shear Stress	1.18 (lb/ft^2)

Bio Project Number.	4802.02	
Surveyed:	May 24,2005	By: EMM & BWS

Reference Reach Cross Section and Channel Profile
Goose Creek Stream Restoration
Pool Reach A- Upper Tributary of Cabin Branch

Biohabitats





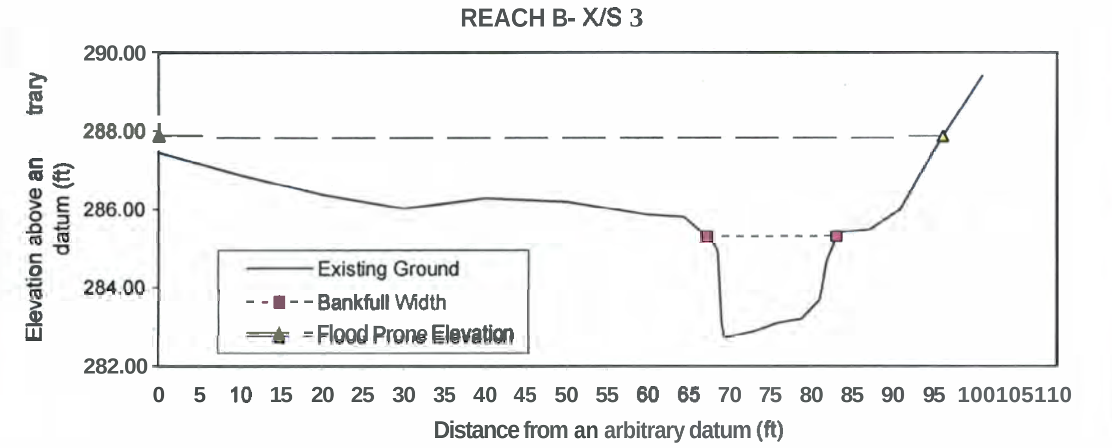
Rosnen Stream Type Classification	
Bankfull Width	16.28 (ft)
Entrenchment	4.48 (ft/ft)
Width:Depth	7.43 (ft/ft)
Sinousity	(ft/ft)
Slope	0.0138 (ft/ft)
D_{50}	27 (mm)
Stream Type	B4c

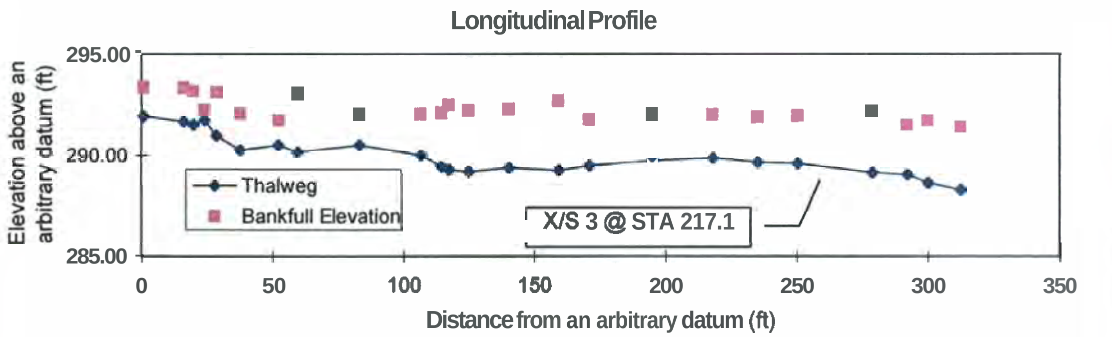
Flow Calculations	
Max BF Depth	3.23 (ft)
Mean BF Depth	2.19 (ft)
X/S Area	35.67 (ft^2)
Manning's n	0.0450
BF Ave. Velocity	5.95 (ft/s)
Discharge	212.31 (cfs)
Shear Stress	1.63 (lb/ft^2)

Bio Project Number.	4802.02	
Surveyed:	May 24.2005	By: EMM & BWS

Reference Reach Cross Section and Channel Profile
Goose Creek Stream Restoration
Riffle Reach B- Upper Tributary of Cabin Branch

Biohabitats





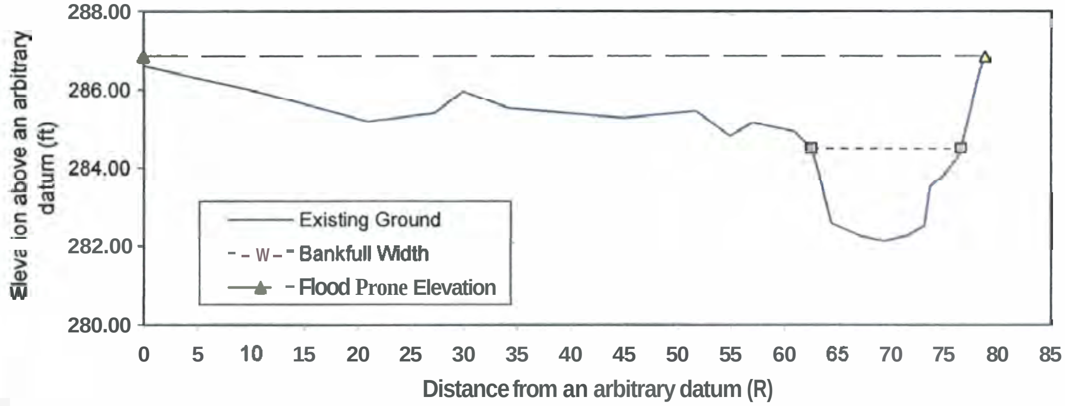
Rosnen Stream Type Classification	
Bankfull Width	15.85 (ft)
Entrenchment	5.43 (ft/ft)
Width:Depth	8.67 (ft/ft)
Sinousity	(ft/ft)
Slope	0.0199 (ft/ft)
D_{50}	27 (mm)
Stream Type	B4c

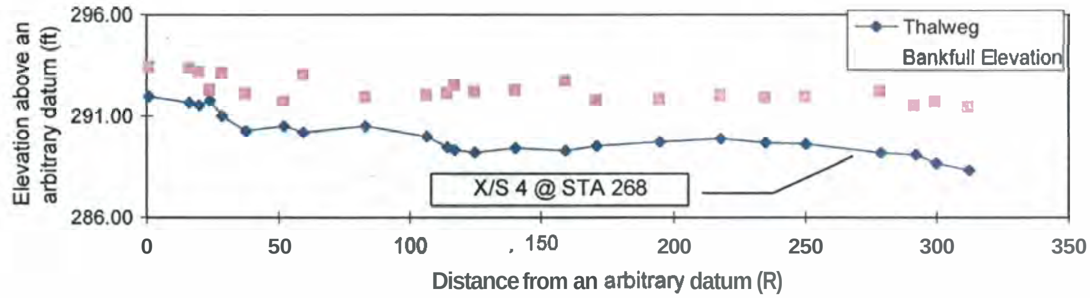
Flow Calculations	
Max BF Depth	2.58 (ft)
Mean BF Depth	1.83 (ft)
X/S Area	28.98 (ft^2)
Manning's n	0.0450
BF Ave. Velocity	6.38 (ft/s)
Discharge	184.99 (cfs)
Shear Stress	1.98 (lb/ft^2)

Bio Project Number:	4802.02.	
Surveyed:	May 25,2005	By: EMM & BWS

Reference Reach Cross Section and Channel Profile
Goose Creek Stream Restoration
Riffle Reach B- Upper Tributary of Cabin Branch

Biohabitats





Rosaen Stream Type Classification	
Bankfull Width	14.00 (ft)
Entrenchment	4.84 (ft/ft)
Width:Depth	8.50 (ft/ft)
Sinousity	(ft/ft)
Slope	0.0199 (ft/ft)
D_{50}	27 (mm)
Stream Type	B4c

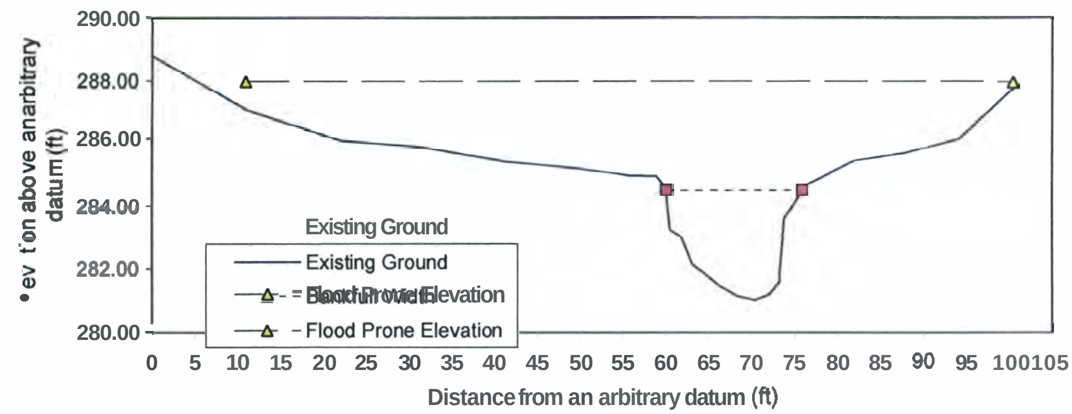
Flow Calculations	
Max BF Depth	2.34 (ft)
Mean BF Depth	1.65 (ft)
X/S Area	23.07 (ft^2)
Manning's n	0.0450
BF Ave. Velocity	6.06 (ft/s)
Discharge	139.71 (cfs)
Shear Stress	1.83 (lb/ft^2)

Bio Project Number:	4802.02	
Surveyed:	May 25,2005	By: EMM & BWS

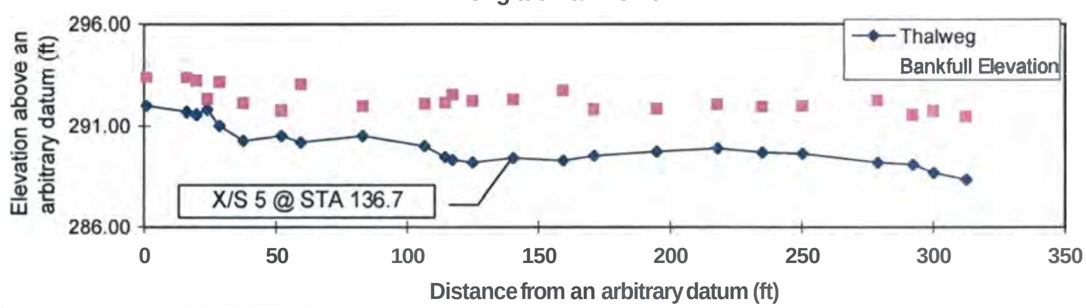
Reference Reach Cross Section and Channel Profile
Goose Creek Stream Restoration
Pool Reach B- Upper Tributary of Cabin Branch

Biohabitats

REACH B- X/S 5



Longitudinal Profile



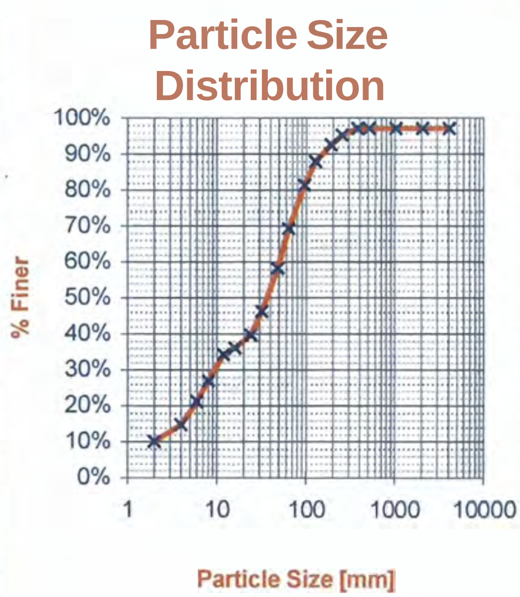
Rosgen Stream Type Classification	
Bankfull Width	15.82 (ft)
Entrenchment	5.27 (ft/ft)
Width:Depth	6.66 (ft/ft)
Sinousity	(ft/ft)
Slope	0.0199 (ft/ft)
D_{50}	27 (mm)
Stream Type	B4c

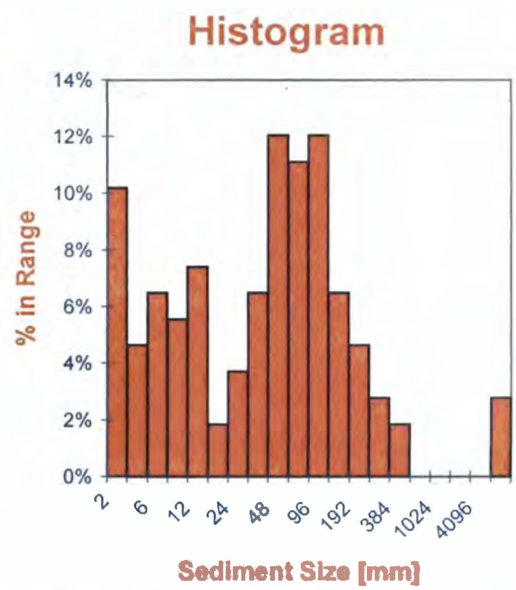
Flow Calculations	
Max BF Depth	3.45 (ft)
Mean BF Depth	2.38 (ft)
X/S Area	37.58 (ft^2)
Manning's n	0.0450
BF Ave. Velocity	7.41 (ft/s)
Discharge	278.38 (cfs)
Shear Stress	2.48 (lb/ft^2)

Bio Project Number:	4802.02	
Surveyed:	May 25,2005	By: EMM & BWS

Site Name:	Tributary to Cabin Branch, Reach B	Biohabitats, Inc.	
Project No:	4802.02	Pebble Count Data Sheet	
Date:	5/24/2005	Riffle, Active Channel	

	Particle	Size [mm]	Total #	% in Range	% Cumulative
Sand and Silt	<	2	11	10%	10%
	2 -	4	5	5%	15%
	4 -	6	7	6%	21%
	6 -	8	6	6%	27%
	8 -	12	8	7%	34%
Gravels	12 -	16	2	2%	36%
	16 -	24	4	4%	40%
	24 -	32	7	6%	46%
	32 -	48	13	12%	58%
	48 -	64	12	11%	69%
	64 -	96	13	12%	81%
Cobbles	96 -	128	7	6%	88%
	128 -	192	5	5%	93%
	192 -	256	3	3%	95%
	256 -	384	2	2%	97%
	384 -	512	0	0%	97%
Boulders	512 -	1024	0	0%	97%
	1024 -	2048	0	0%	97%
	2048 -	4096	0	0%	97%
Bedrock			3	3%	100%
		TOTALS:	108	100%	

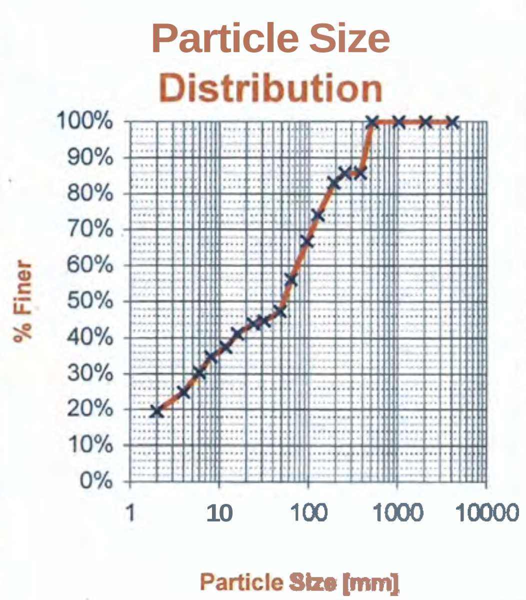


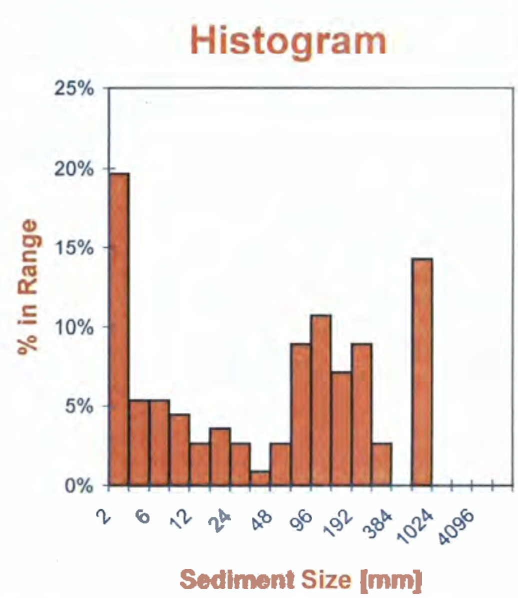


D50=	36.9230769	D75=	78.76923	D84=	108.4342857

Site Name:	Tributary to Cabin Branch, Reach A	Biohabitats, Inc.
Project No:	4802.02	Pebble Count Data Sheet
Date:	5/24/2005	Riffle, Active Channel

	Particle	Size [mm]	Total #	% in Range	% Cumulative
Sand and Silt	<	2	22	20%	20%
	2 -	4	6	5%	25%
	4 -	6	6	5%	30%
	6 -	8	5	4%	35%
	8 -	12	3	3%	38%
Gravels	12 -	16	4	4%	41%
	16 -	24	3	3%	44%
	24 -	32	1	1%	45%
	32 -	48	3	3%	47%
	48 -	64	10	9%	56%
	64 -	96	12	11%	67%
Cobbles	96 -	128	8	7%	74%
	128 -	192	10	9%	83%
	192 -	256	3	3%	86%
	256 -	384	0	0%	86%
	384 -	512	16	14%	100%
Boulders	512 -	1024		0%	100%
	1024 -	2048		0%	100%
	2048 -	4096		0%	100%
Bedrock				0%	100%
		TOTALS:	112	100%	

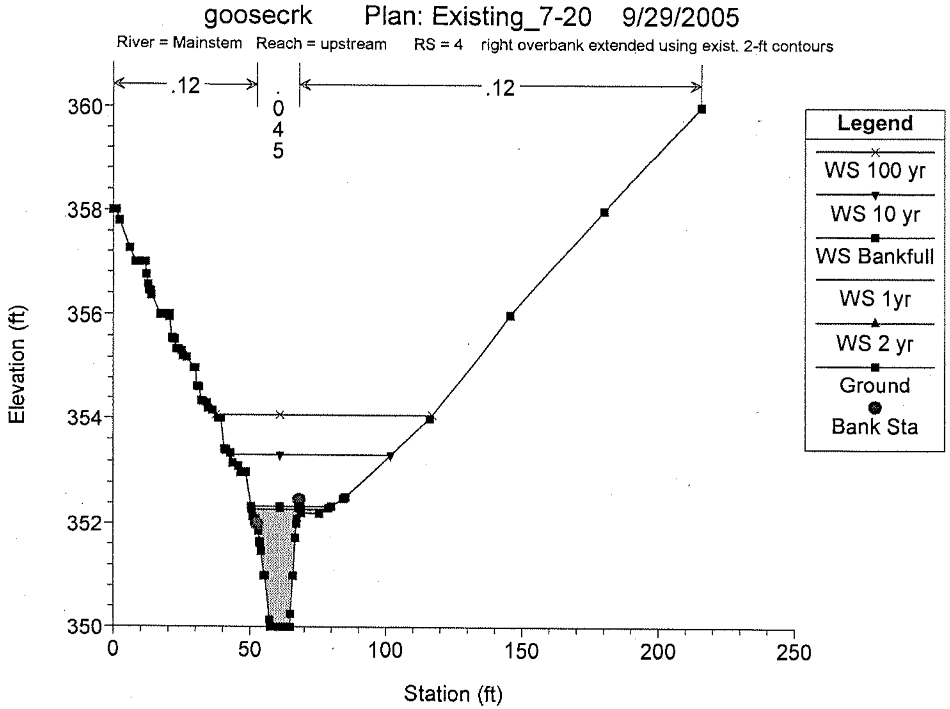


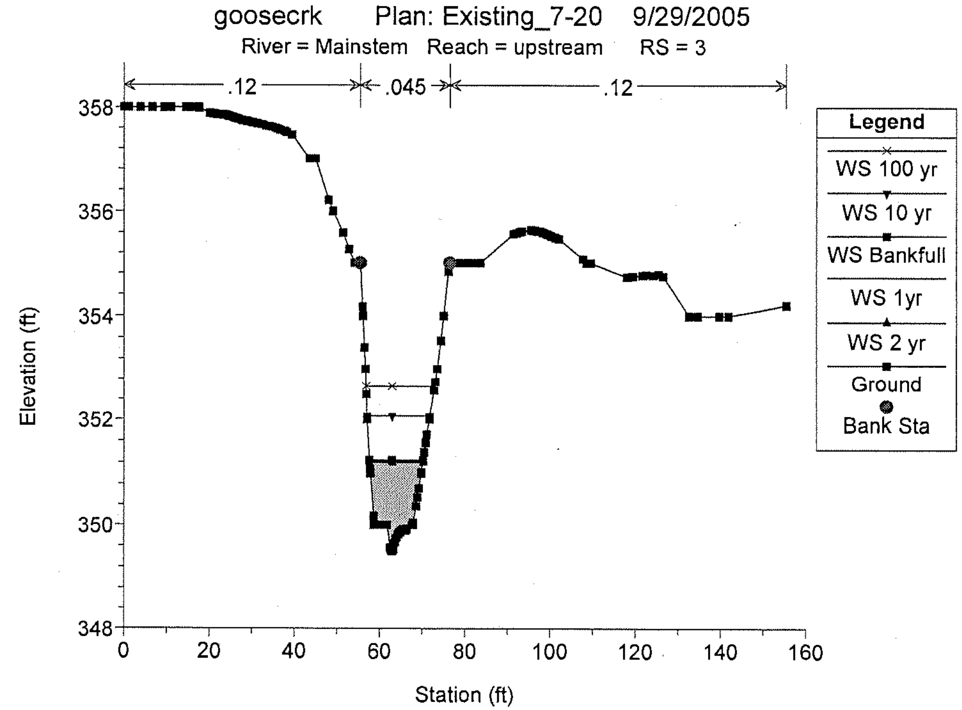


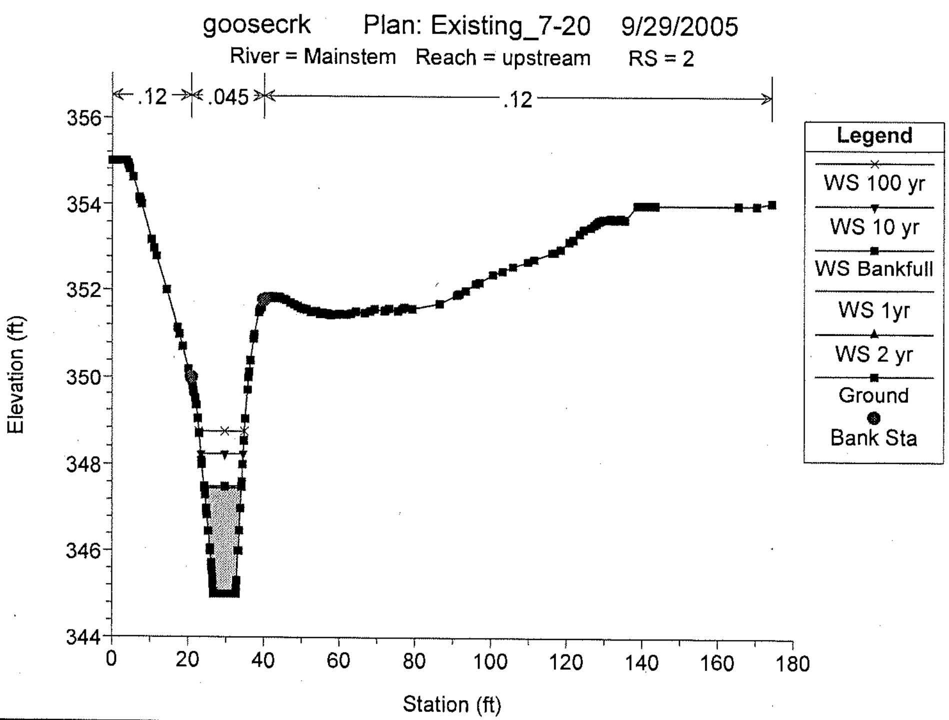
D50=	52.8	D75=	134.4	D84=	215.04

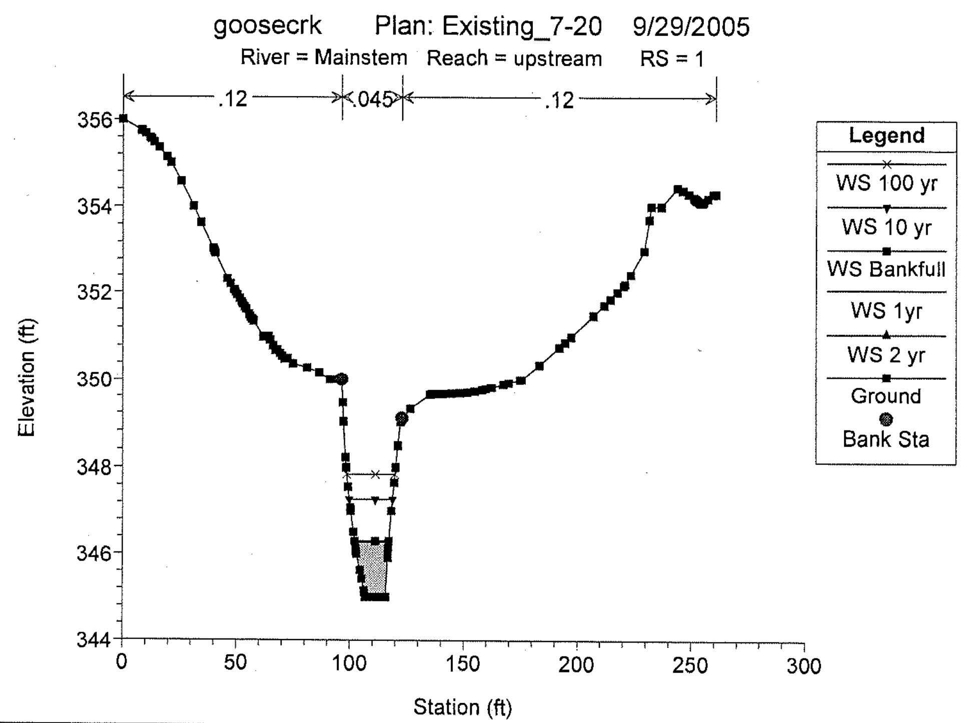
APPENDIX E

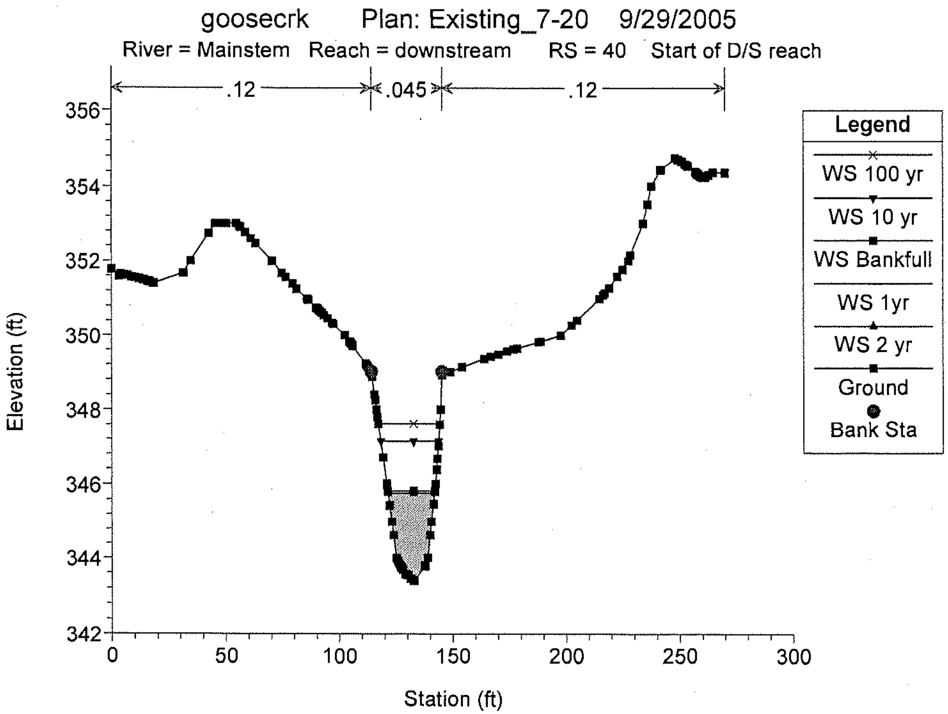
HEC-RAS OUTPUT FILE

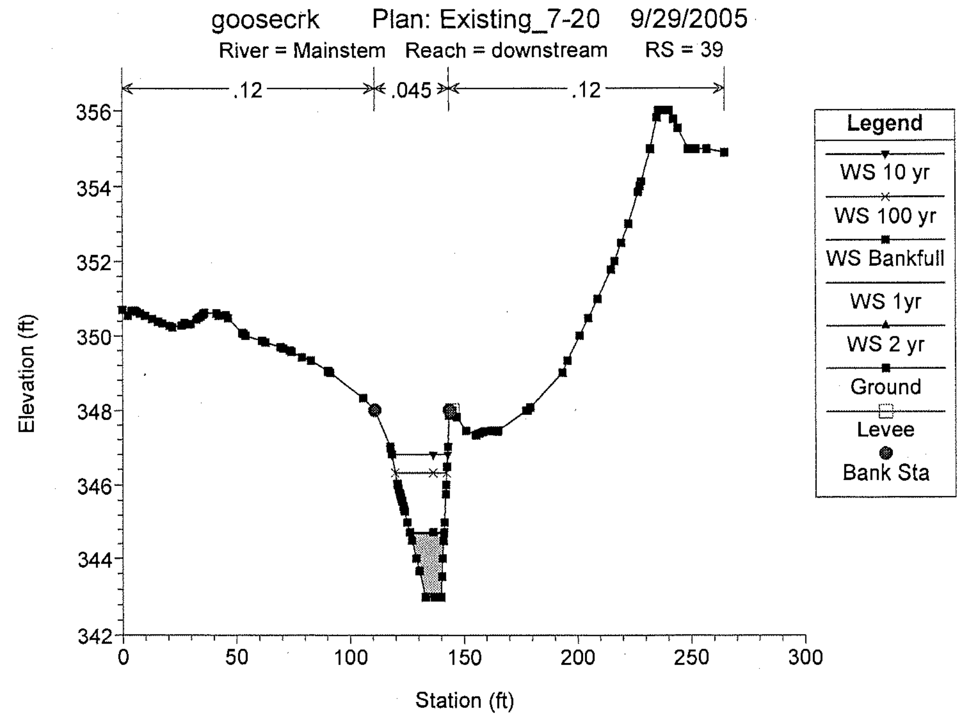

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = upstream RS = 4 right overbank extended using exist. 2-ft contours
.12
.045
.12
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Bank Sta

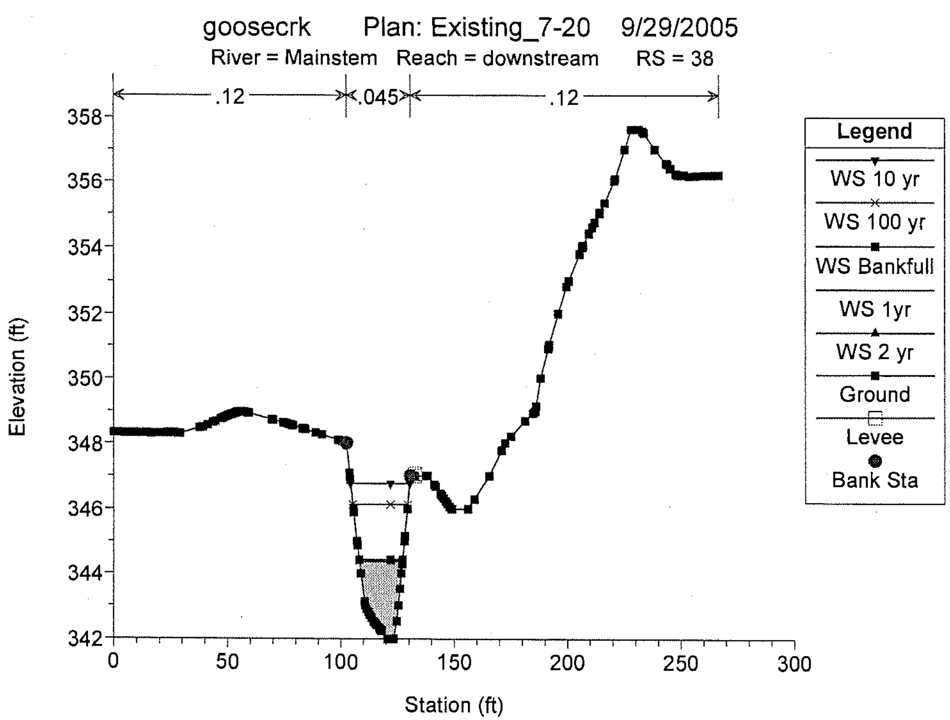

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = upstream RS = 3
.12
.045
.12
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Bank Sta

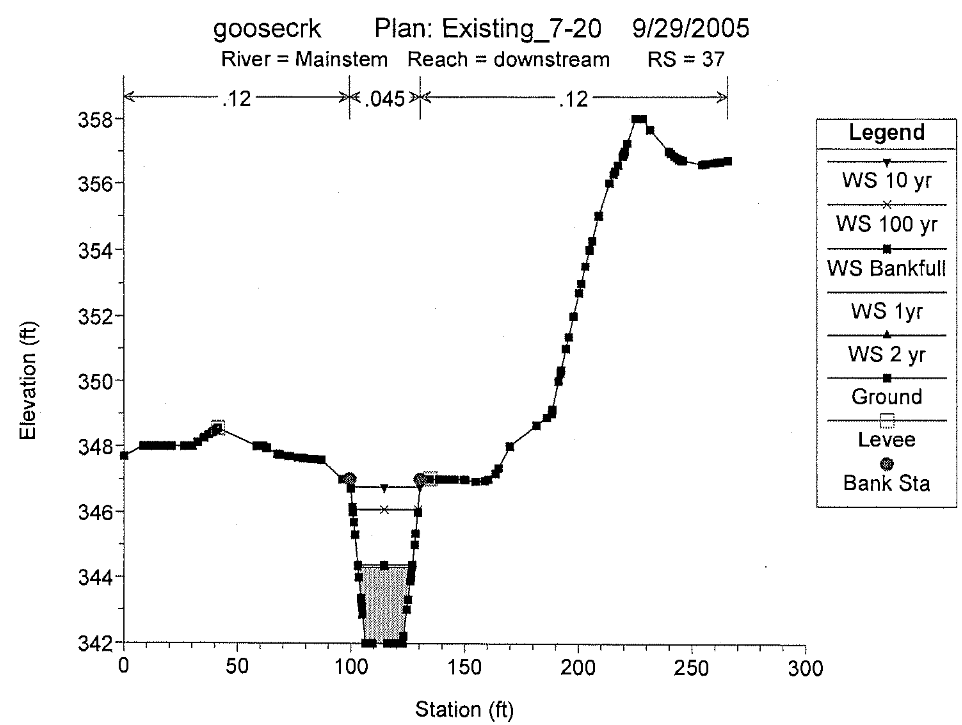

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = upstream RS = 2
.12
.045
.12
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Bank Sta

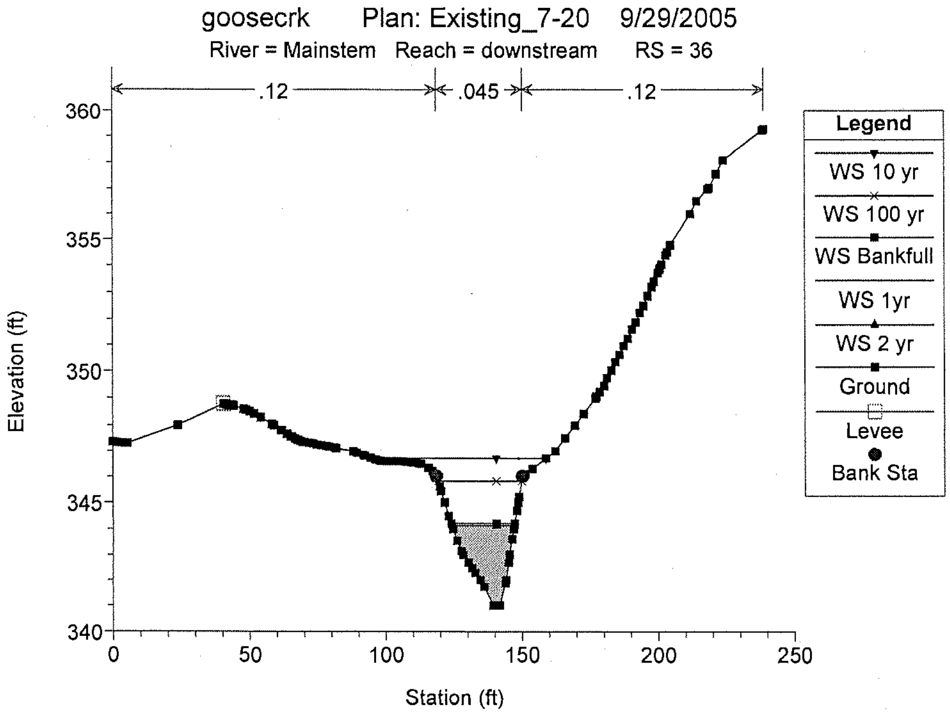

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = upstream RS = 1
.12
.045
.12
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Bank Sta

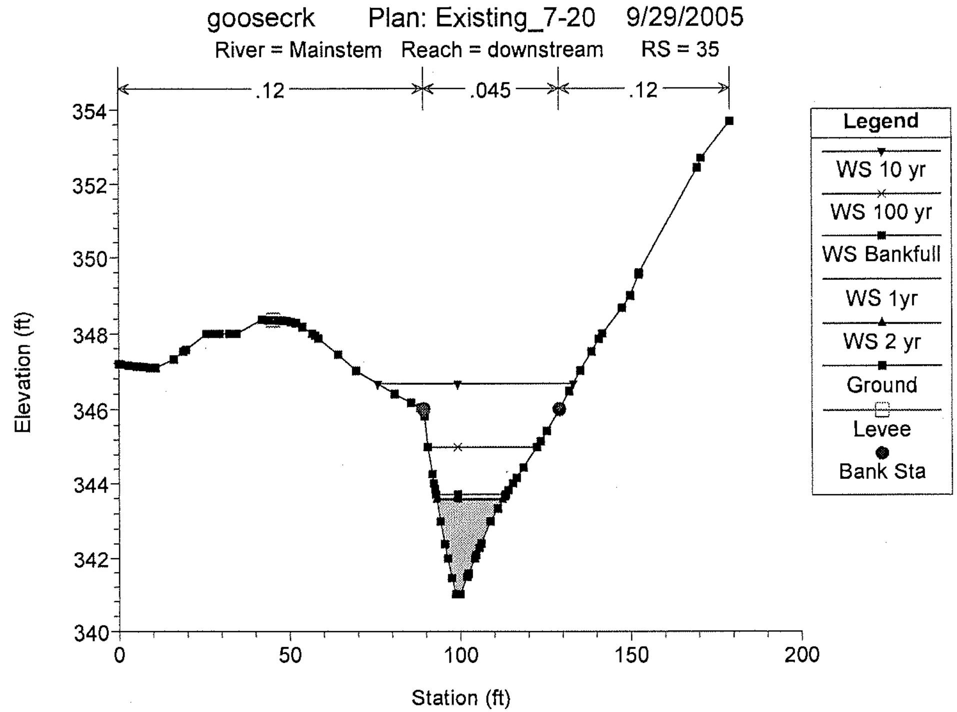

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 40 Start of D/S reach
.12
.045
.12
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Bank Sta

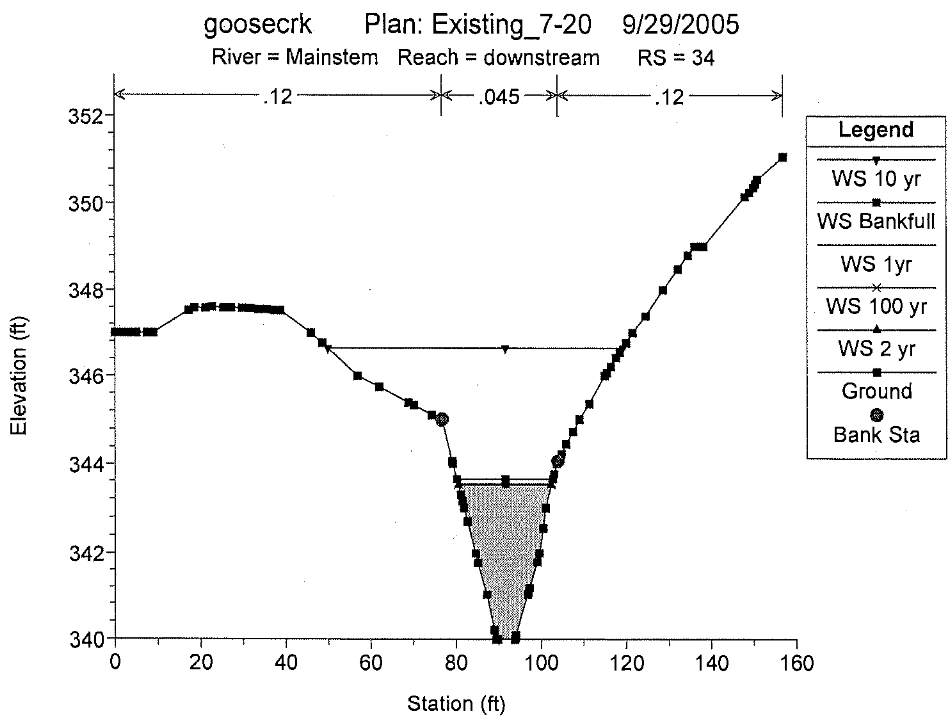

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 39
.12
.045
.12
Elevation (ft)
Station (ft)
Legend
WS 10 yr
WS 100 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Levee
Bank Sta

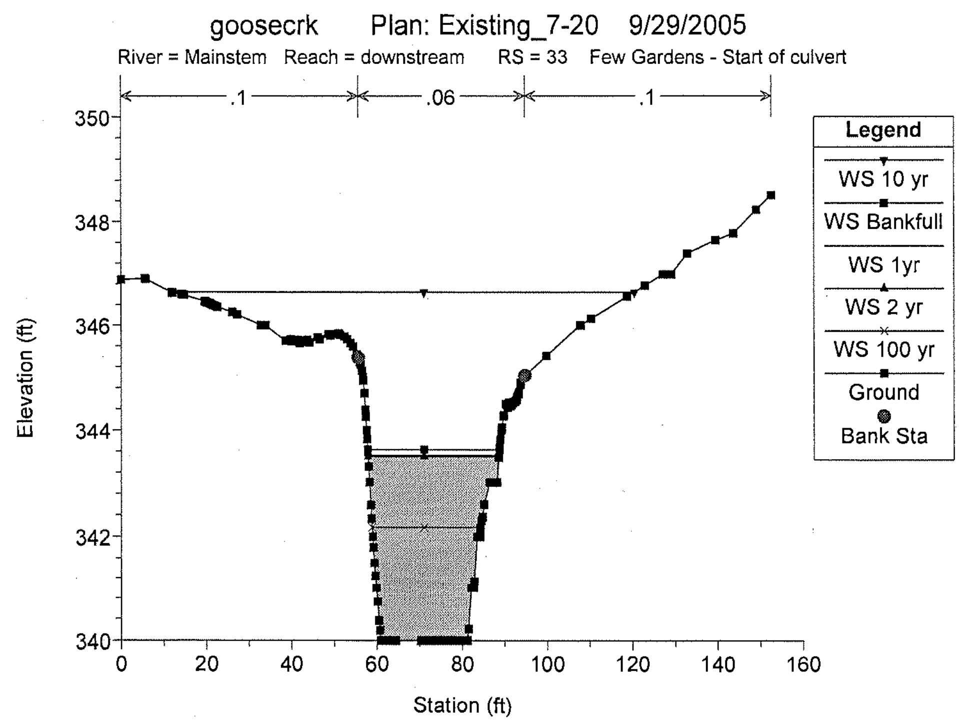

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 38
.12
.045
.12
Elevation (ft)
Station (ft)
Legend
WS 10 yr
WS 100 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Levee
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 37
.12
.045
.12
Elevation (ft)
Station (ft)
Legend
WS 10 yr
WS 100 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Levee
Bank Sta

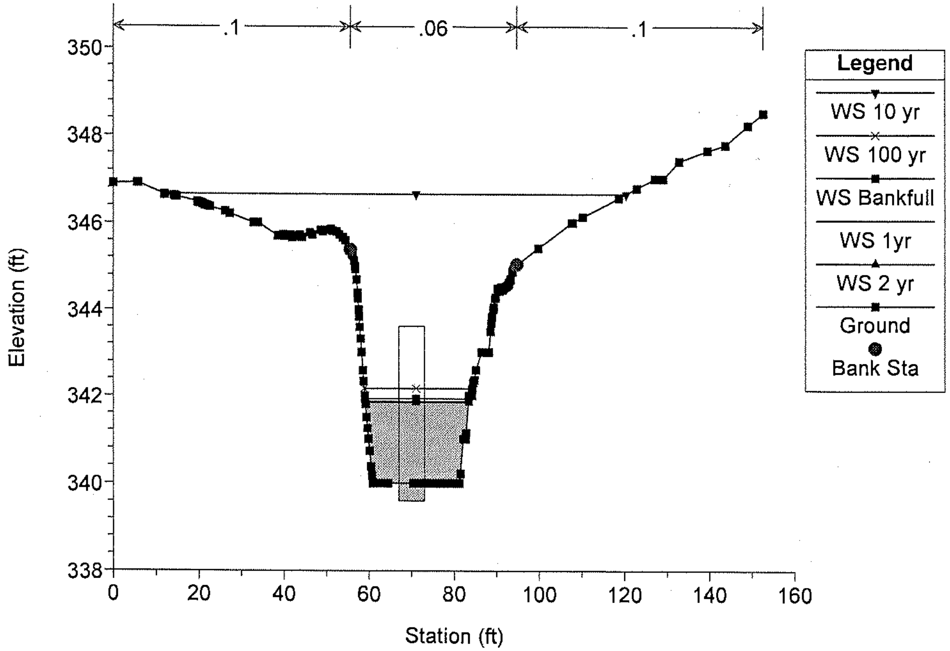

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 36
.12
.045
.12
Elevation (ft)
Station (ft)
Legend
WS 10 yr
WS 100 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Levee
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 35
.12
.045
.12
Elevation (ft)
Station (ft)
Legend
WS 10 yr
WS 100 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Levee
Bank Sta

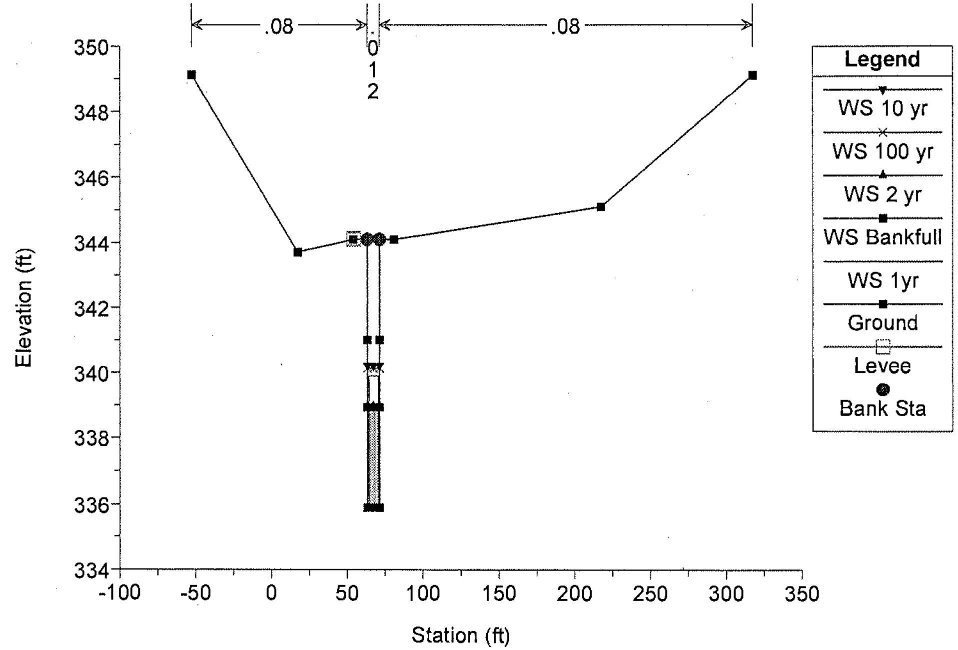

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 34
.12
.045
.12
Elevation (ft)
Station (ft)
Legend
WS 10 yr
WS Bankfull
WS 1yr
WS 100 yr
WS 2 yr
Ground
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 33 Few Gardens - Start of culvert
.1
.06
.1
Elevation (ft)
Station (ft)
Legend
WS 10 yr
WS Bankfull
WS 1yr
WS 2 yr
WS 100 yr
Ground
Bank Sta

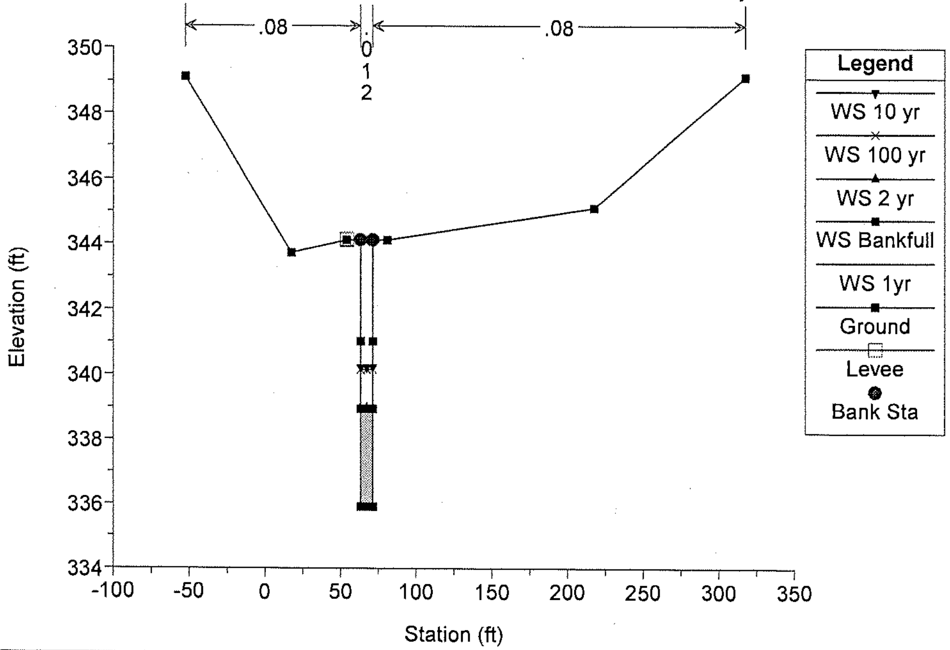
goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 32.9 Culv Few Gardens Box Culvert (4'x6')



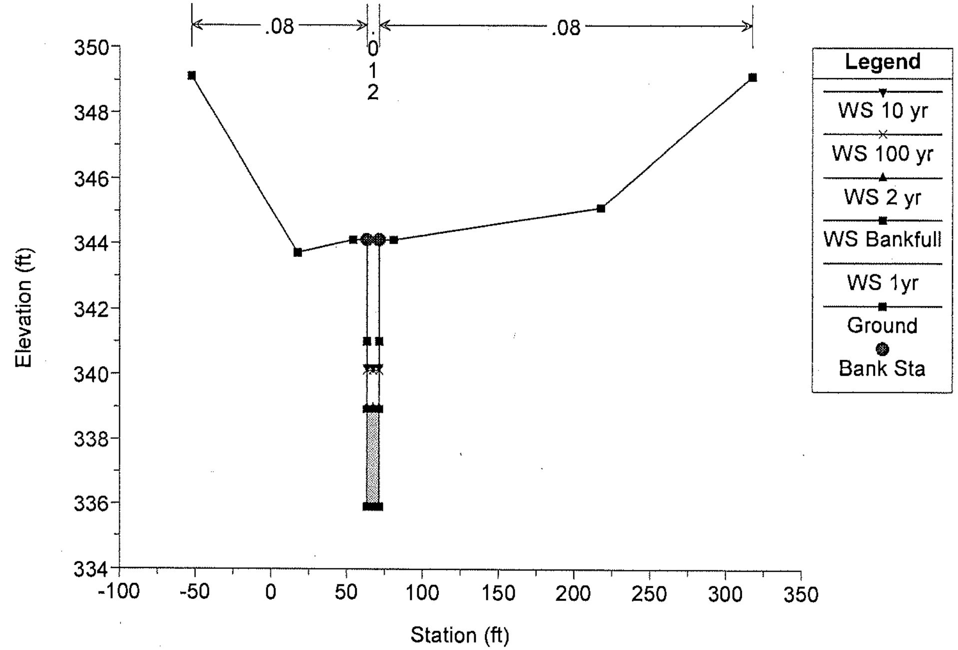
goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 32.9 Culv Few Gardens Box Culvert (4'x6')



goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 32.4 SWM junction

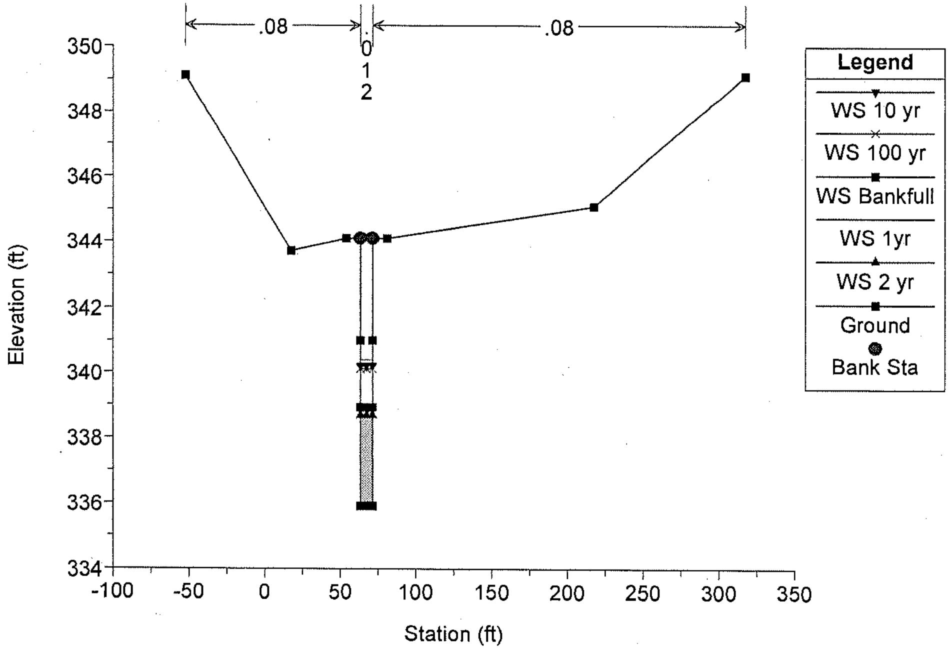


goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 32.3 SWM junction



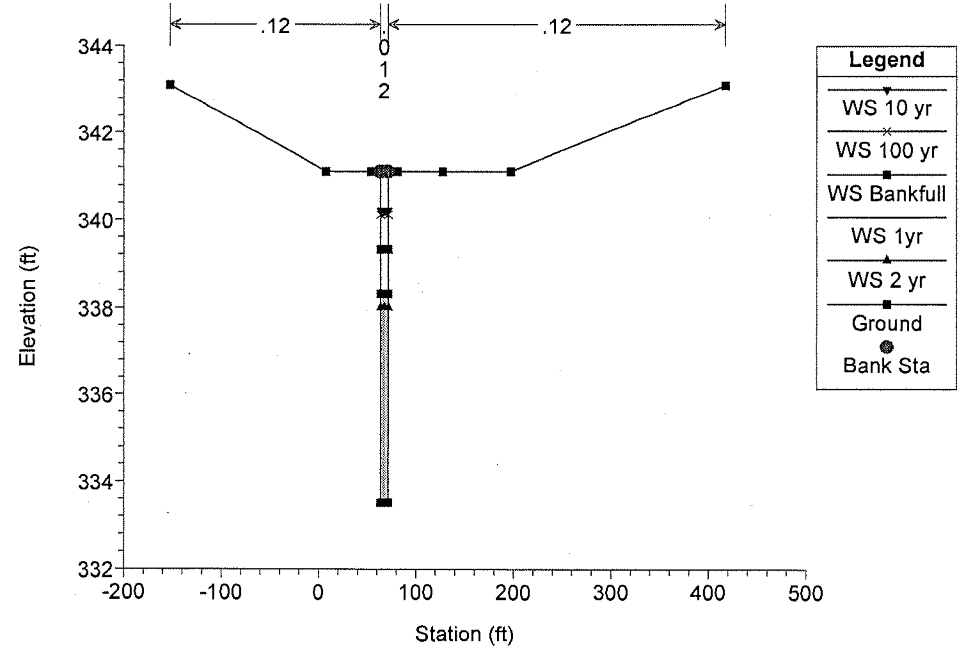
goosecrk Plan: Existing_7-20 9/29/2005

River = Mainstem Reach = downstream RS = 32.25 Culv Few Gardens Box Culvert (5'x7')



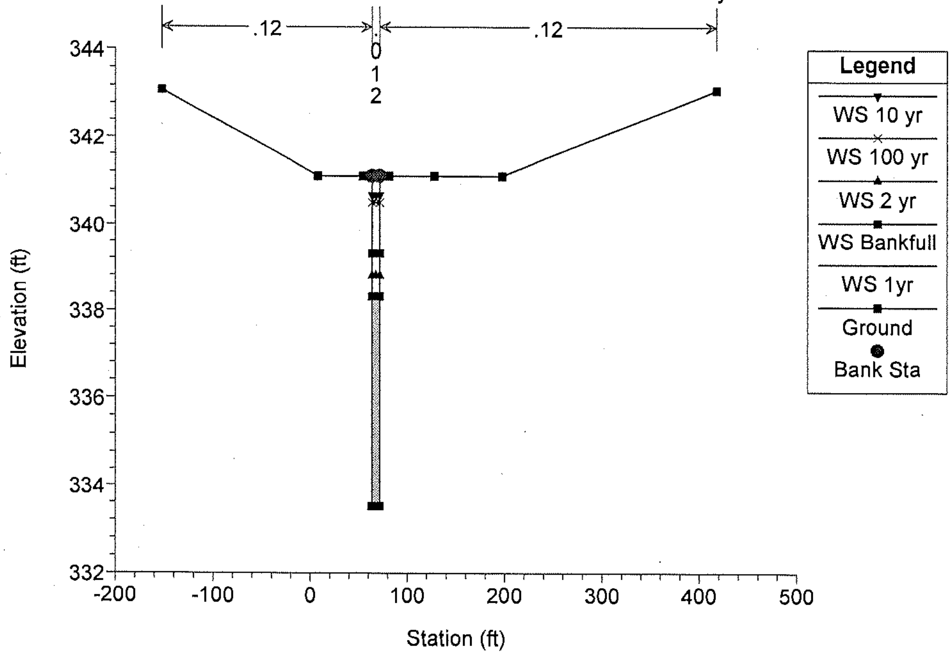
goosecrk Plan: Existing_7-20 9/29/2005

River = Mainstem Reach = downstream RS = 32.25 Culv Few Gardens Box Culvert (5'x7')



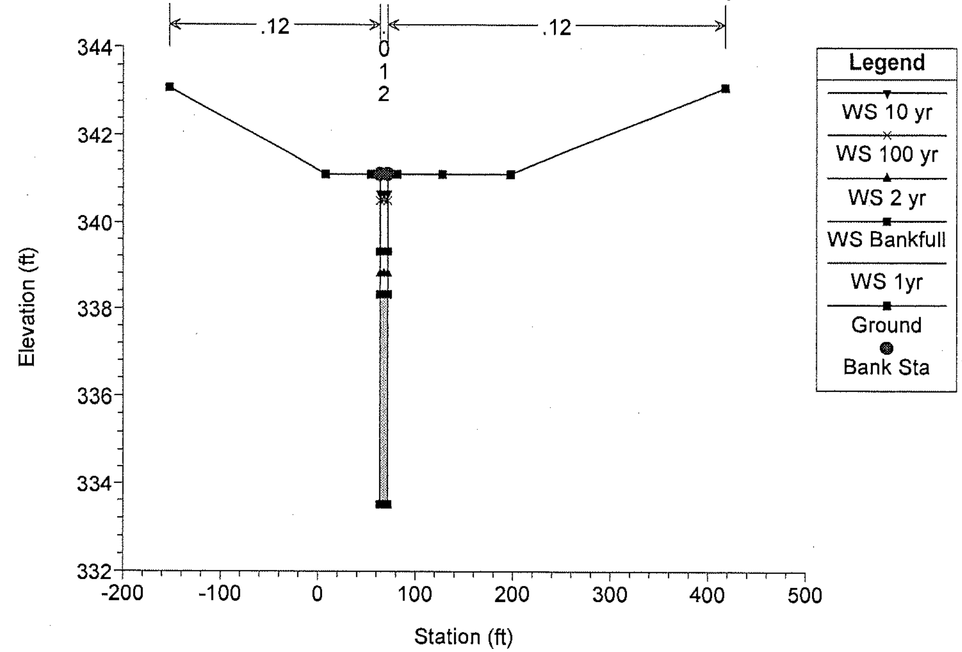
goosecrk Plan: Existing_7-20 9/29/2005

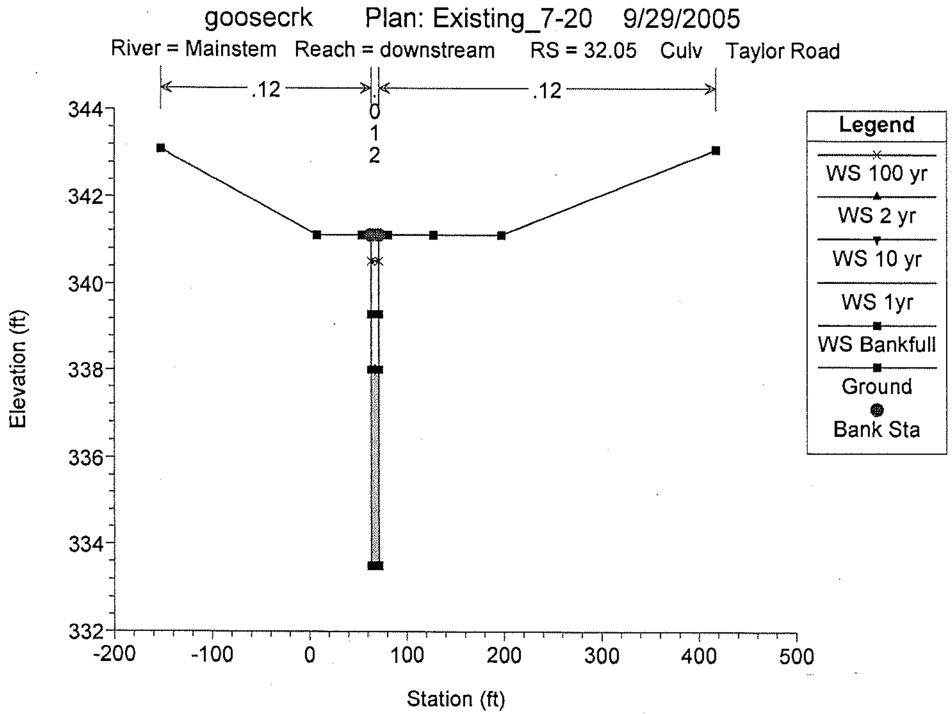
River = Mainstem Reach = downstream RS = 32.2 Taylor Road

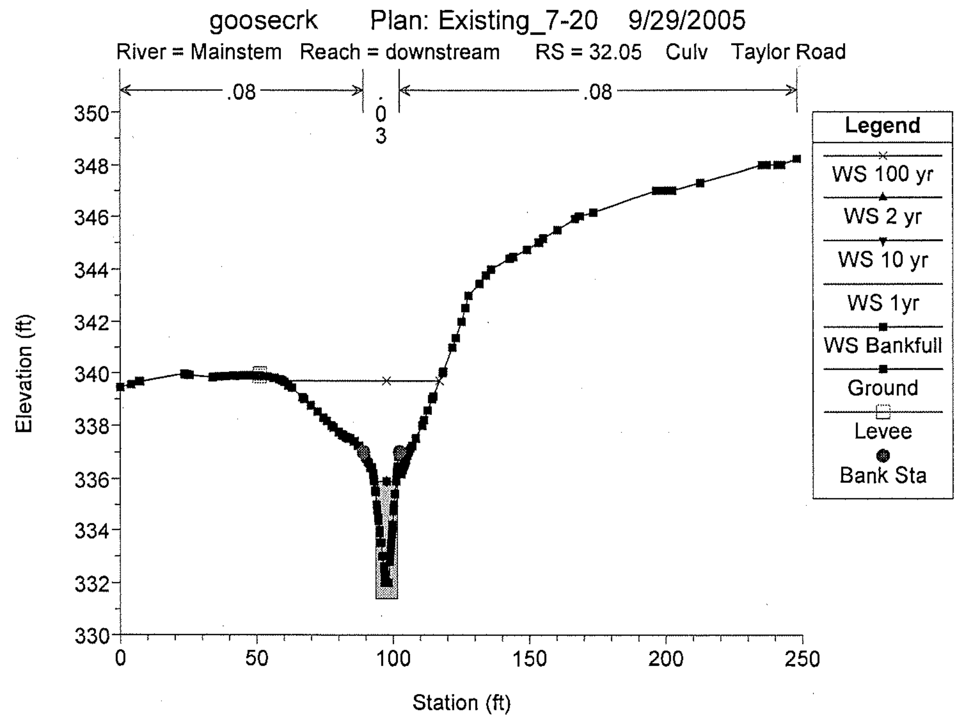


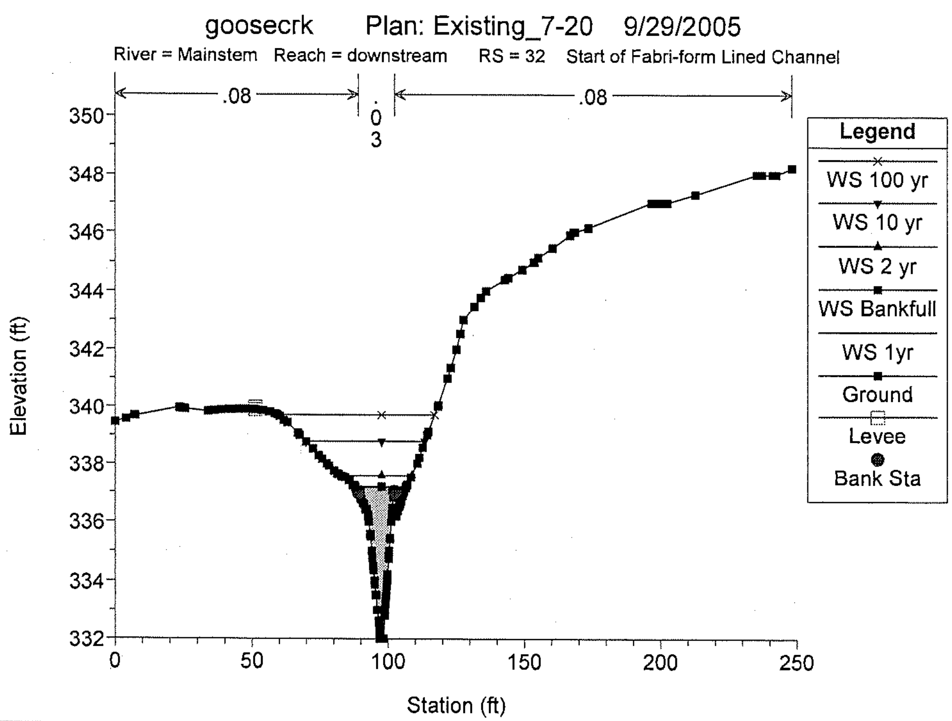
goosecrk Plan: Existing_7-20 9/29/2005

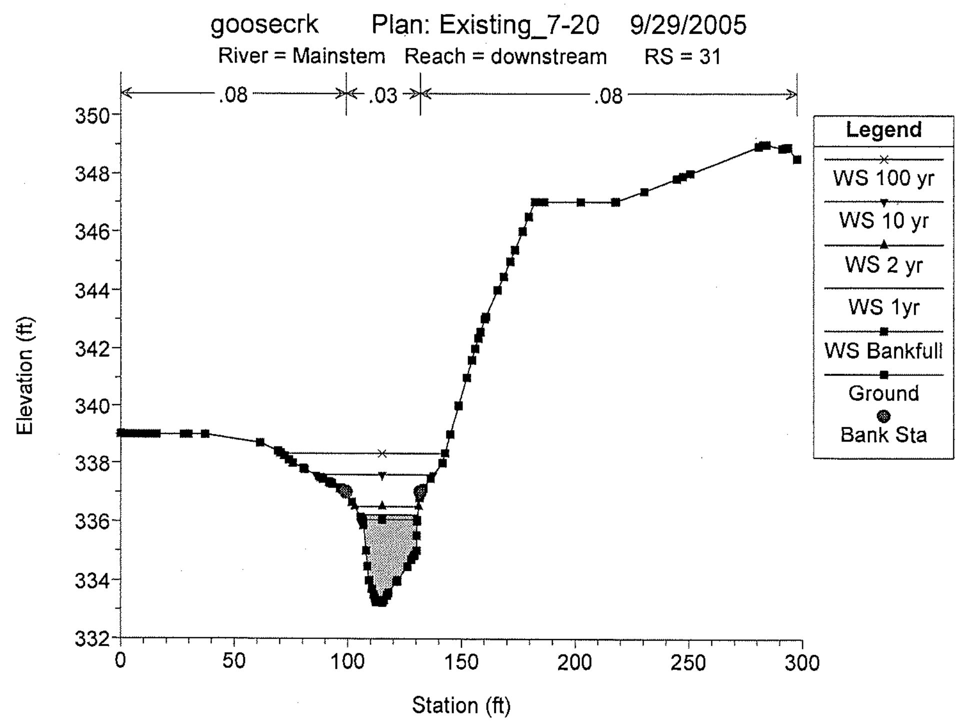
River = Mainstem Reach = downstream RS = 32.1 Taylor Road

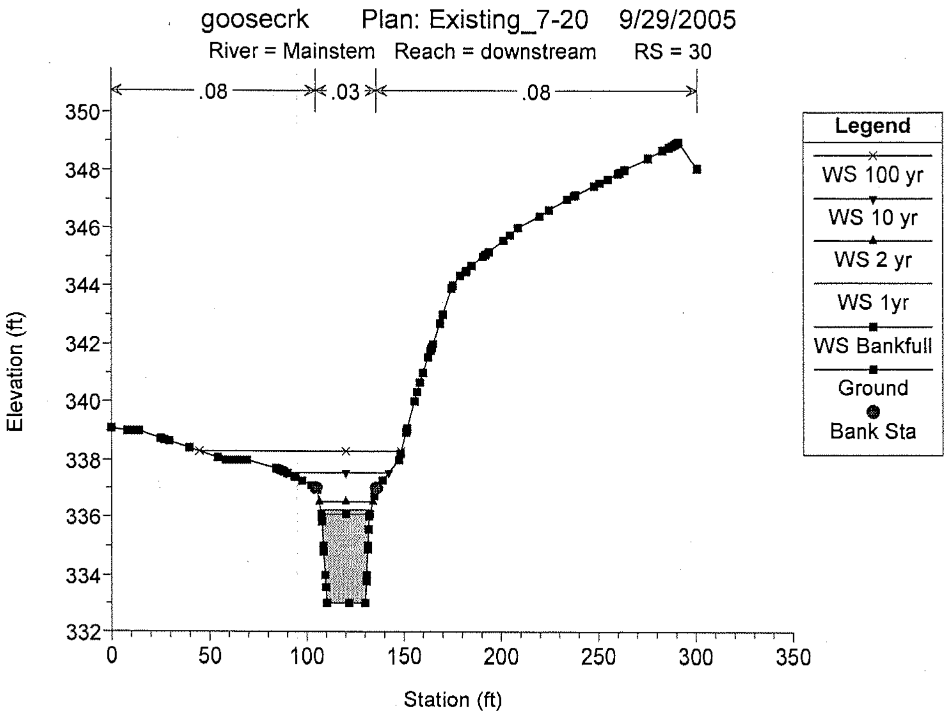


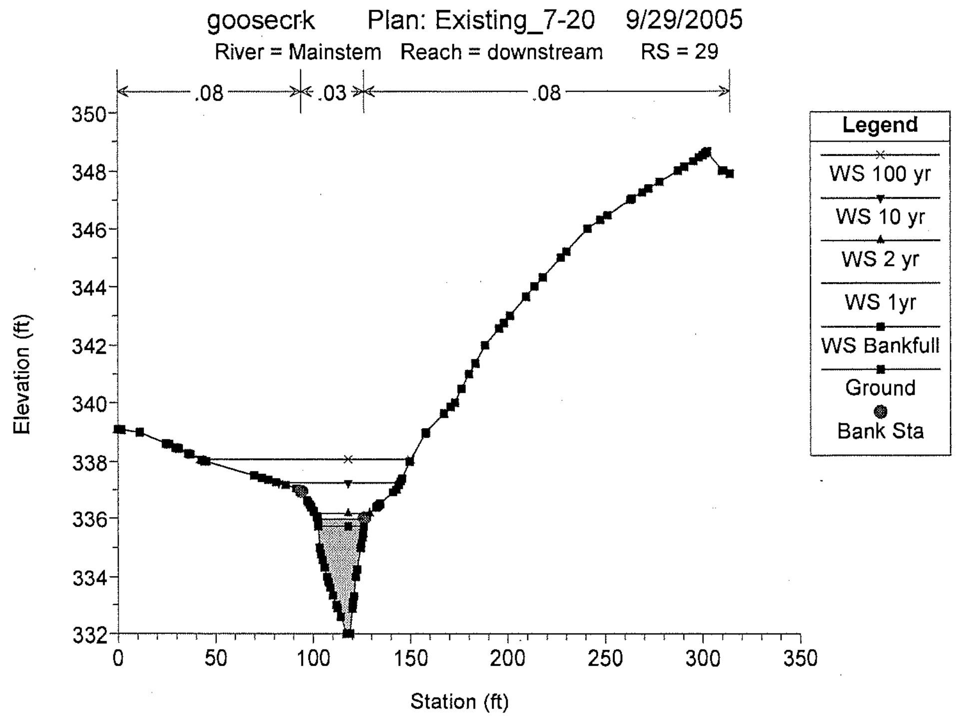

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 32.05 Culv Taylor Road
.12
.12
Legend
WS 100 yr
WS 2 yr
WS 10 yr
WS 1yr
WS Bankfull
Ground
Bank Sta
Elevation (ft)
Station (ft)

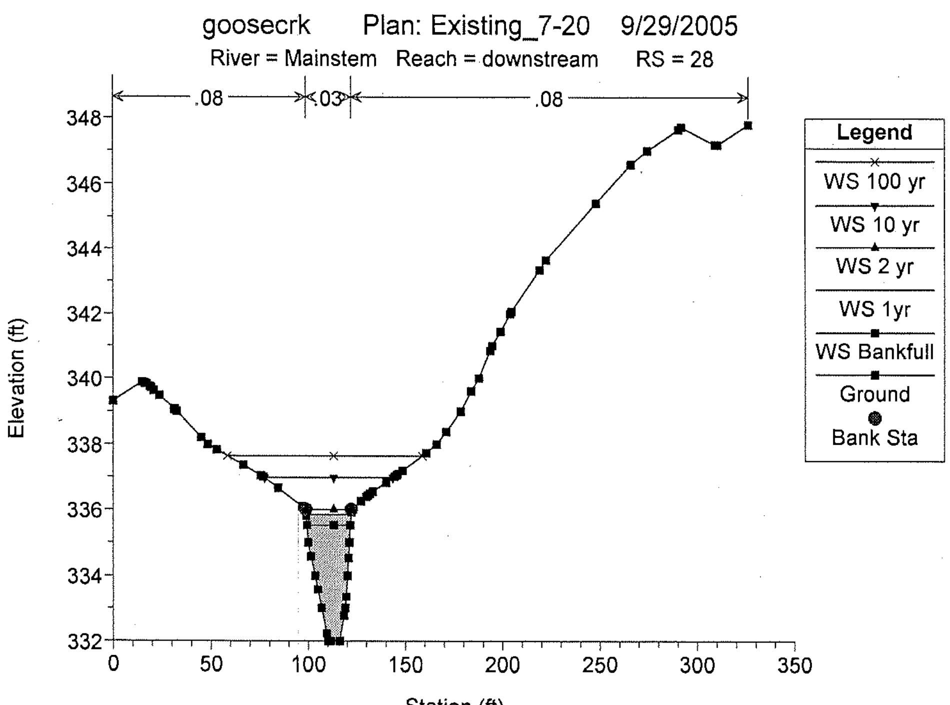

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 32.05 Culv Taylor Road
.08
.08
Legend
WS 100 yr
WS 2 yr
WS 10 yr
WS 1yr
WS Bankfull
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)

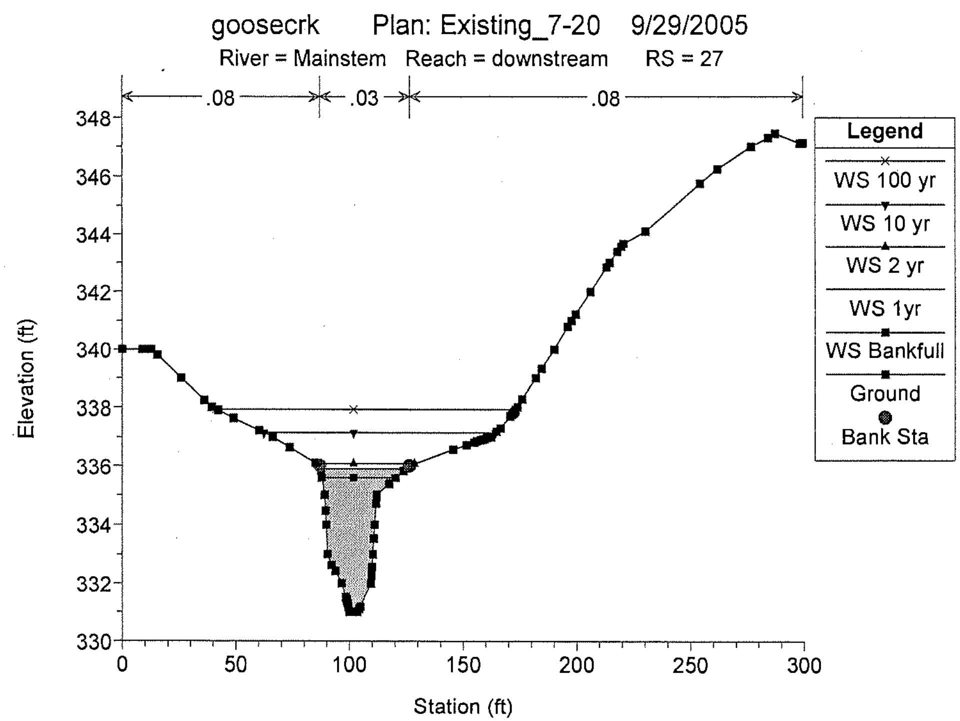

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 32 Start of Fabri-form Lined Channel
.08
.08
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS Bankfull
WS 1yr
Ground
Levee
Bank Sta
Elevation (ft)
Station (ft)

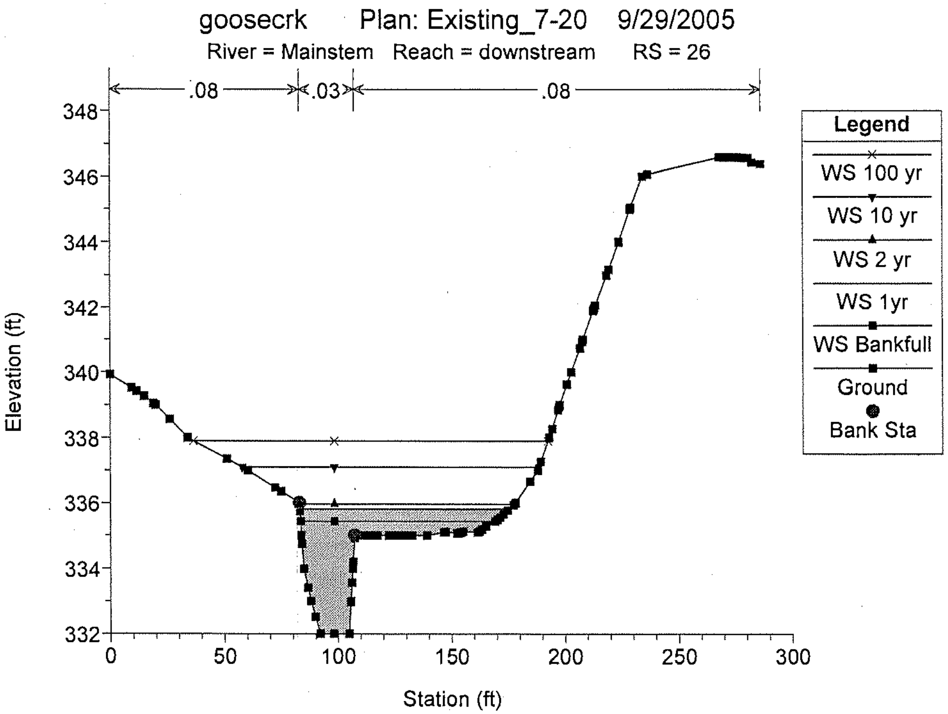

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 31
.08
.03
.08
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta
Elevation (ft)
Station (ft)

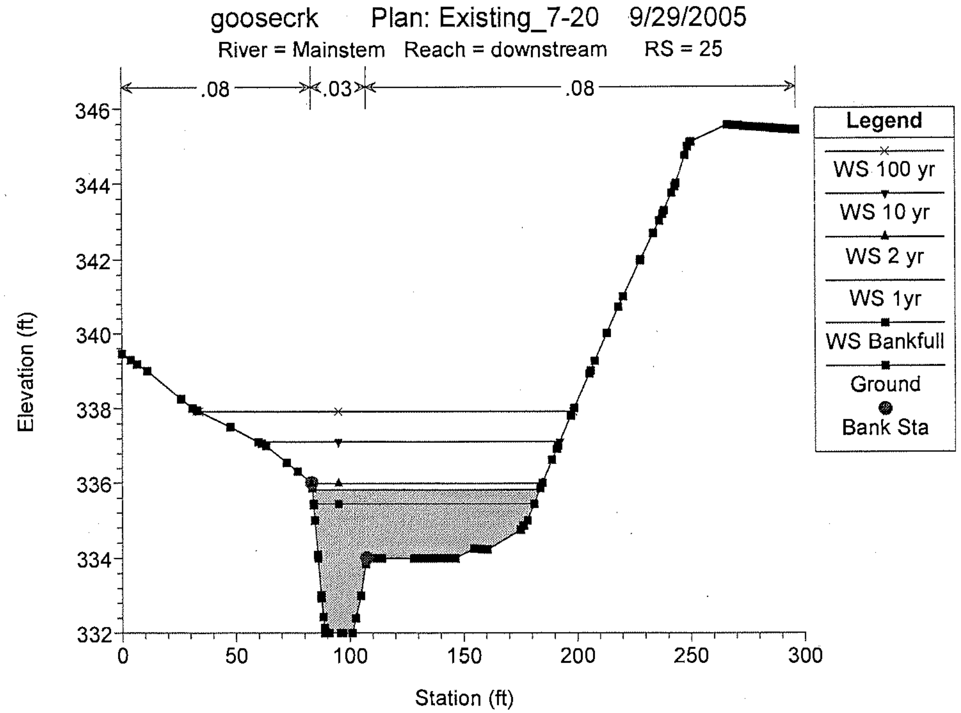

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 30
.08
.03
.08
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta

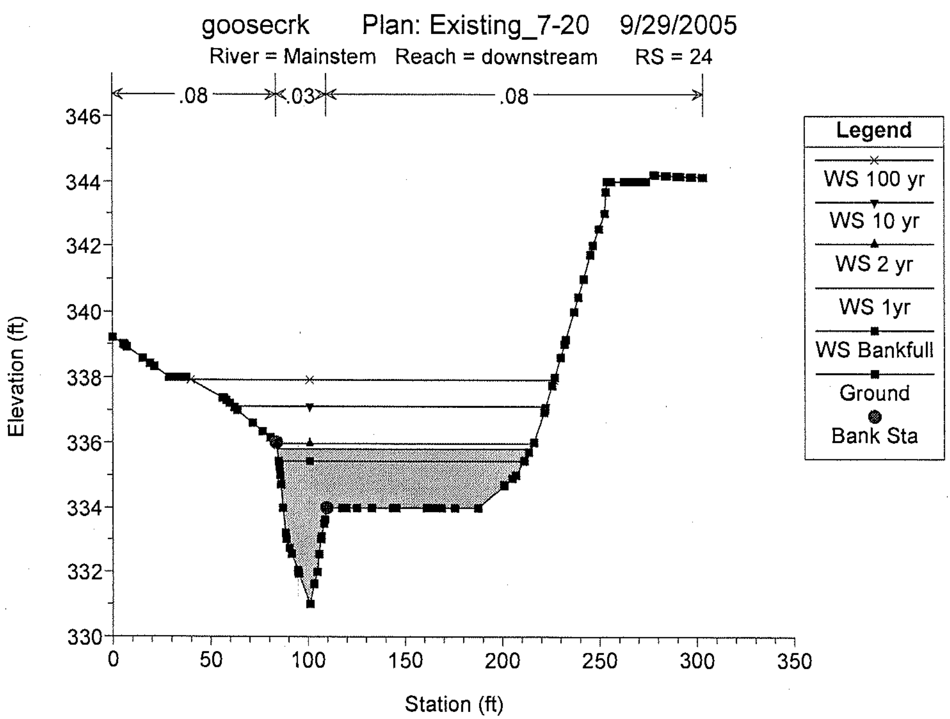

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 29
.08
.03
.08
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta

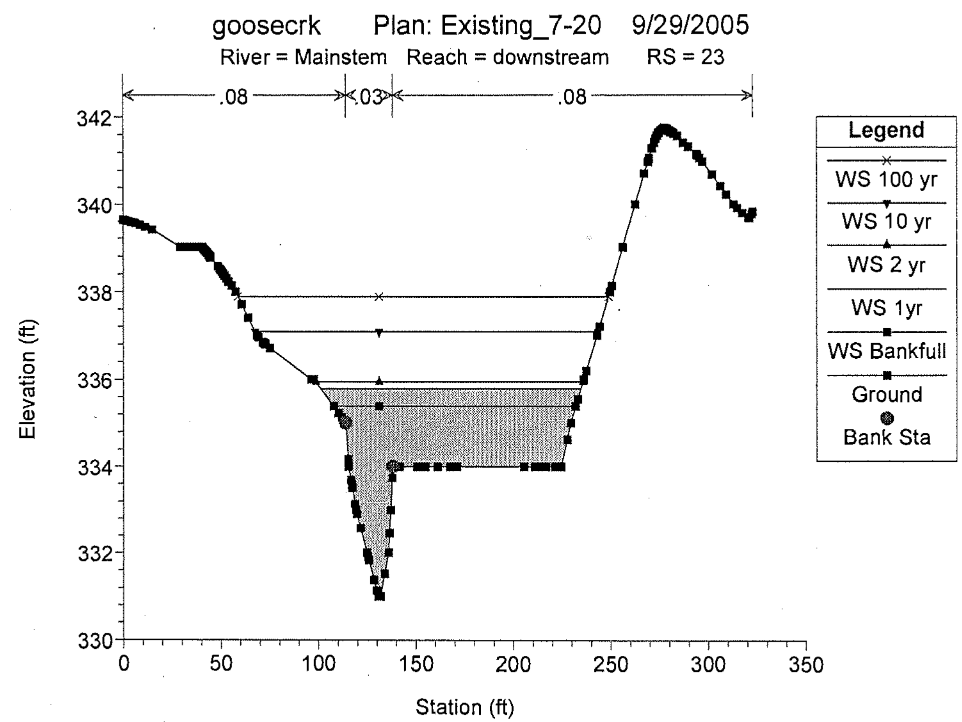

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 28
.08
.03
.08
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta

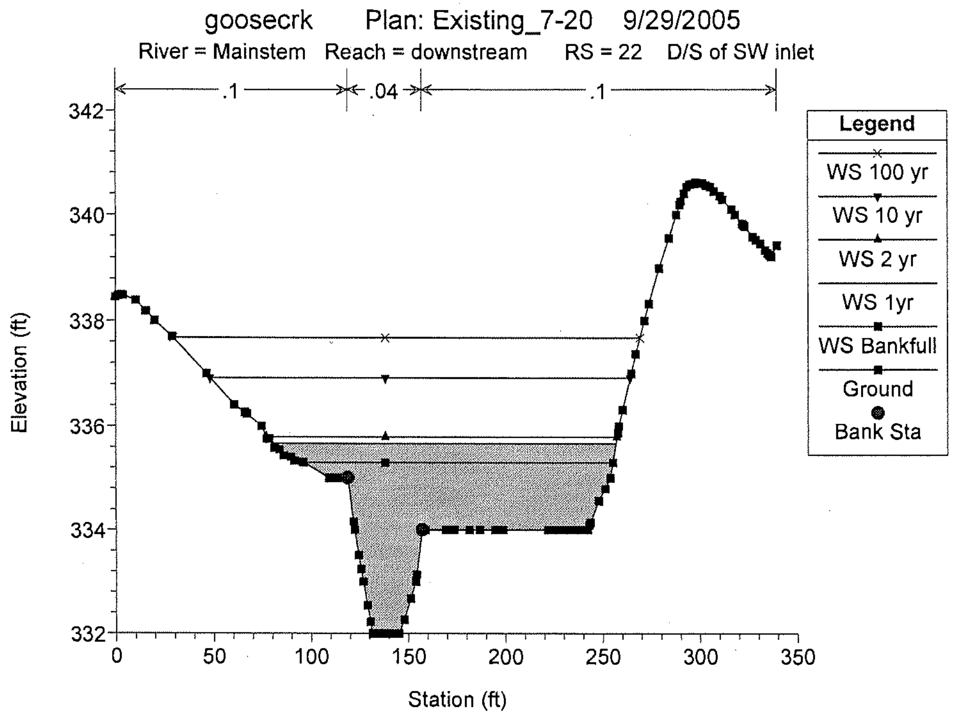

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 27
.08
.03
.08
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta

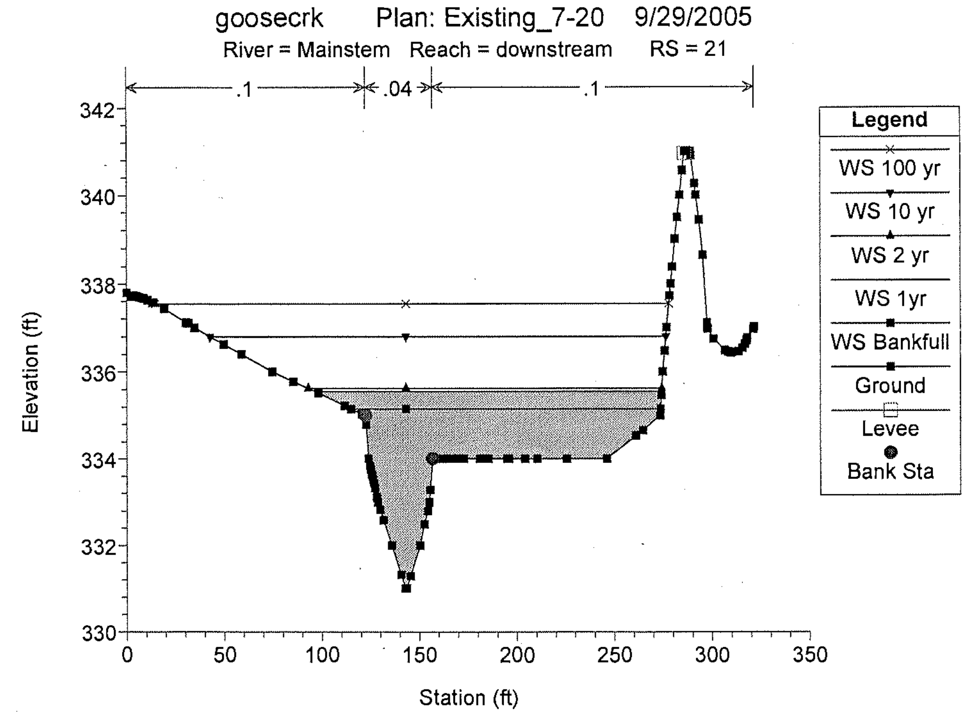

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 26
.08
.03
.08
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta

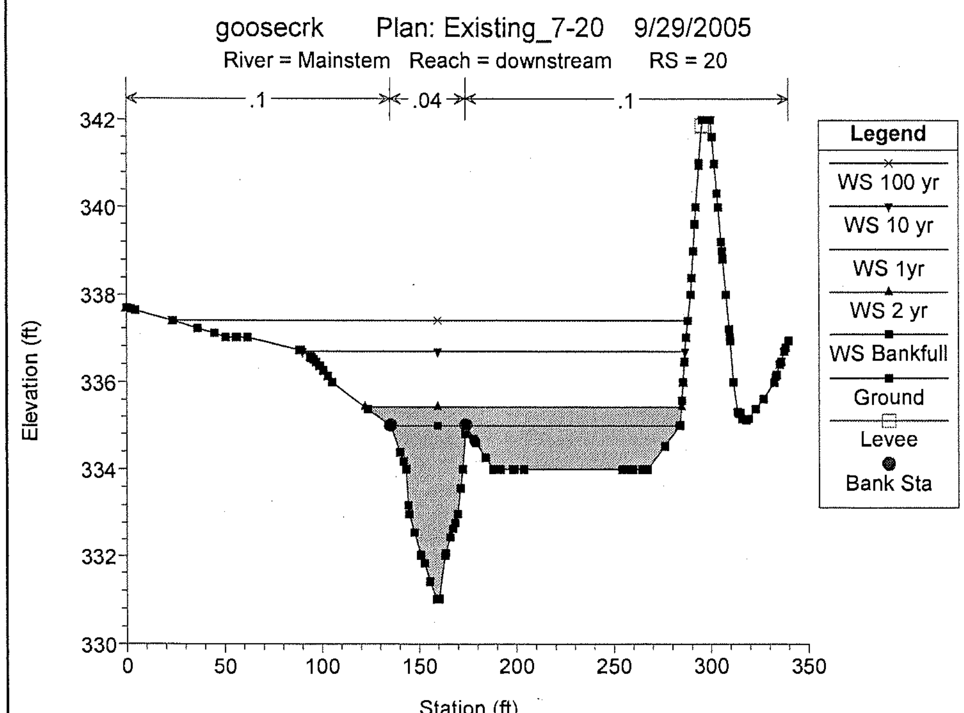

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 25
.08
.03
.08
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta

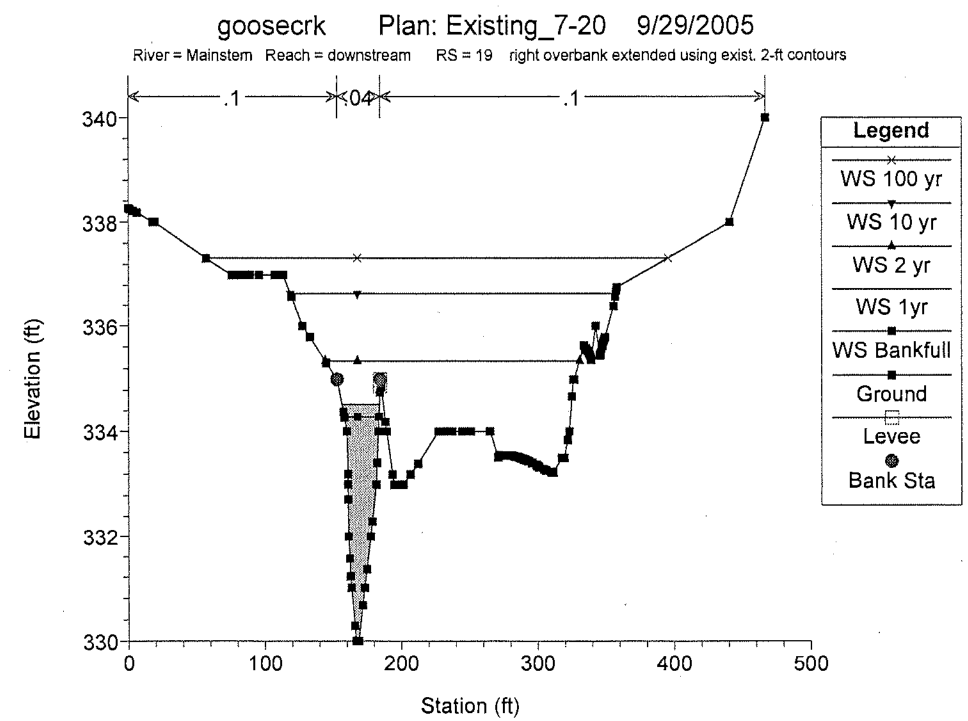

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 24
.08
.03
.08
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 23
.08
.03
.08
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 22 D/S of SW inlet
.1
.04
.1
Elevation (ft)
342
340
338
336
334
332
Station (ft)
0
50
100
150
200
250
300
350
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta

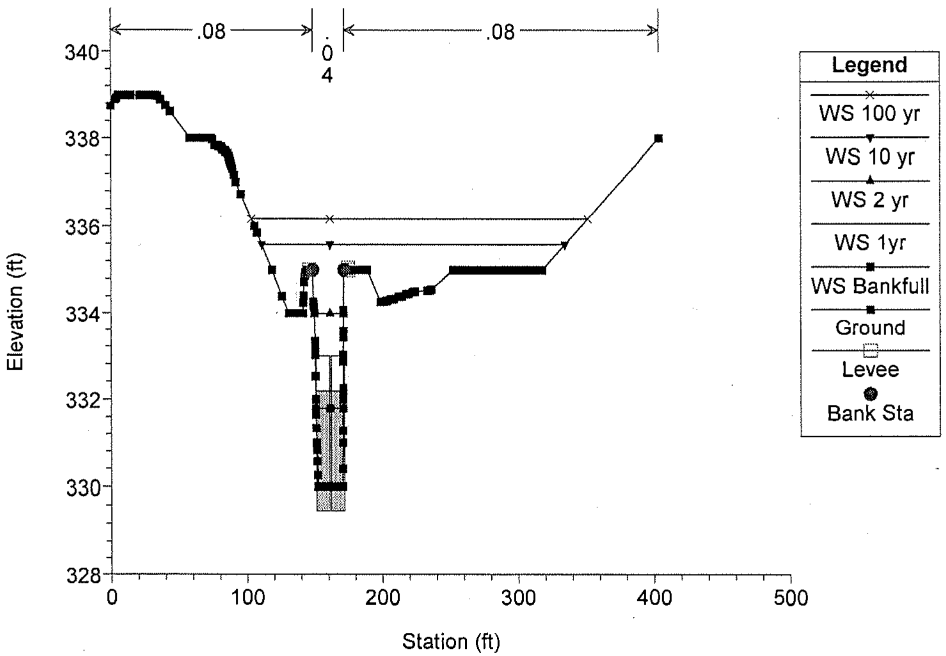

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 21
.1
.04
.1
Elevation (ft)
342
340
338
336
334
332
330
Station (ft)
0
50
100
150
200
250
300
350
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Levee
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 20
.1
.04
.1
Elevation (ft)
342
340
338
336
334
332
330
Station (ft)
0
50
100
150
200
250
300
350
Legend
WS 100 yr
WS 10 yr
WS 1yr
WS 2 yr
WS Bankfull
Ground
Levee
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 19 right overbank extended using exist. 2-ft contours
.1
.04
.1
Elevation (ft)
340
338
336
334
332
330
Station (ft)
0
100
200
300
400
500
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Levee
Bank Sta

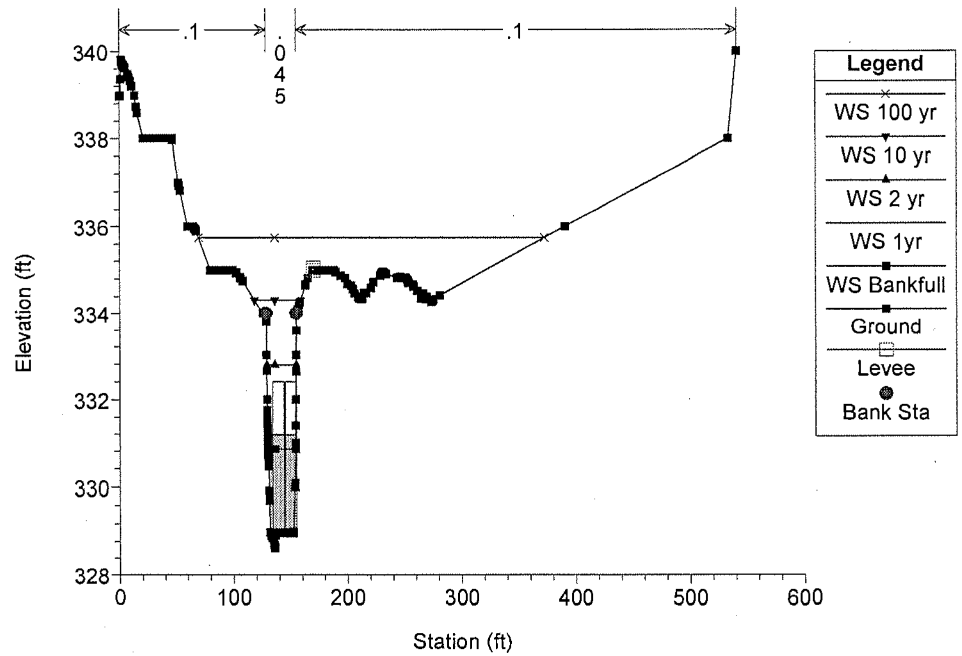
goosecrk Plan: Existing_7-20 9/29/2005

River = Mainstem Reach = downstream RS = 14.5 Culv Liberty Street (2-3.5'x10' box culverts)



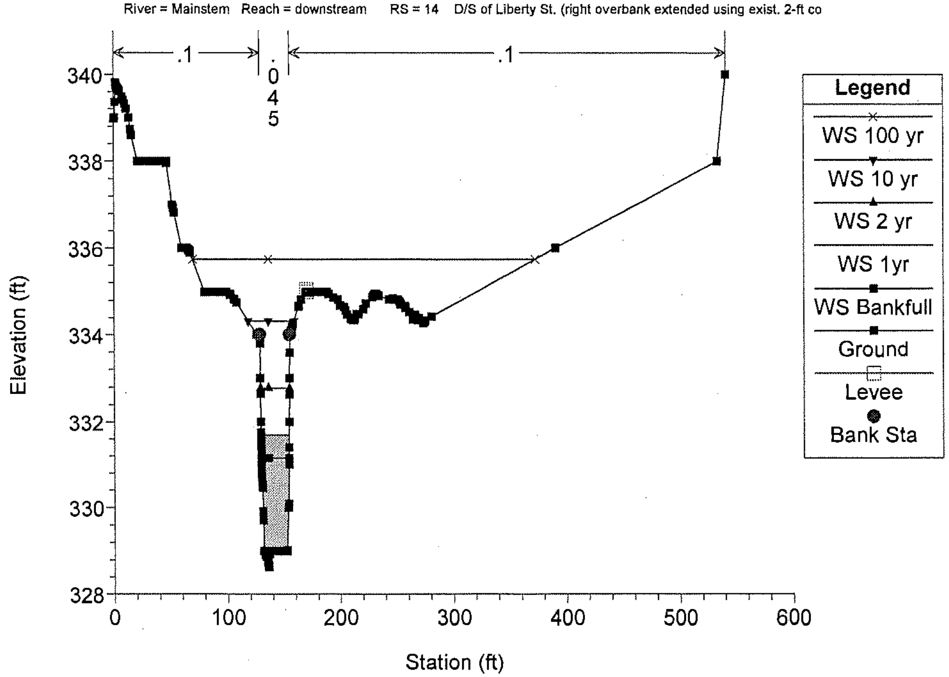
goosecrk Plan: Existing_7-20 9/29/2005

River = Mainstem Reach = downstream RS = 14.5 Culv Liberty Street (2-3.5'x10' box culverts)



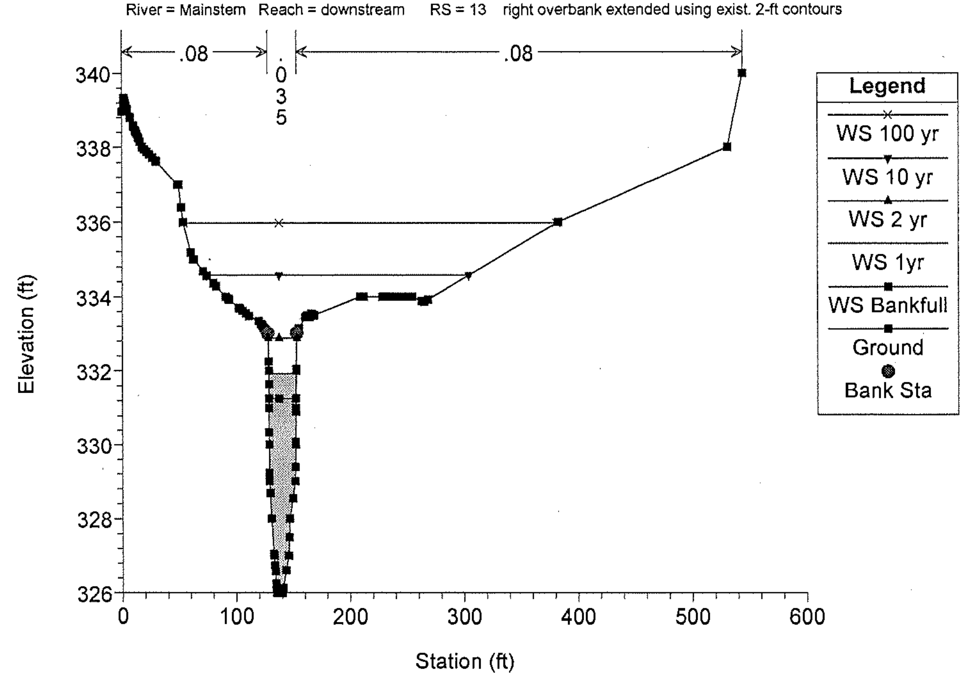
goosecrk Plan: Existing_7-20 9/29/2005

River = Mainstem Reach = downstream RS = 14 D/S of Liberty St. (right overbank extended using exist. 2-ft co



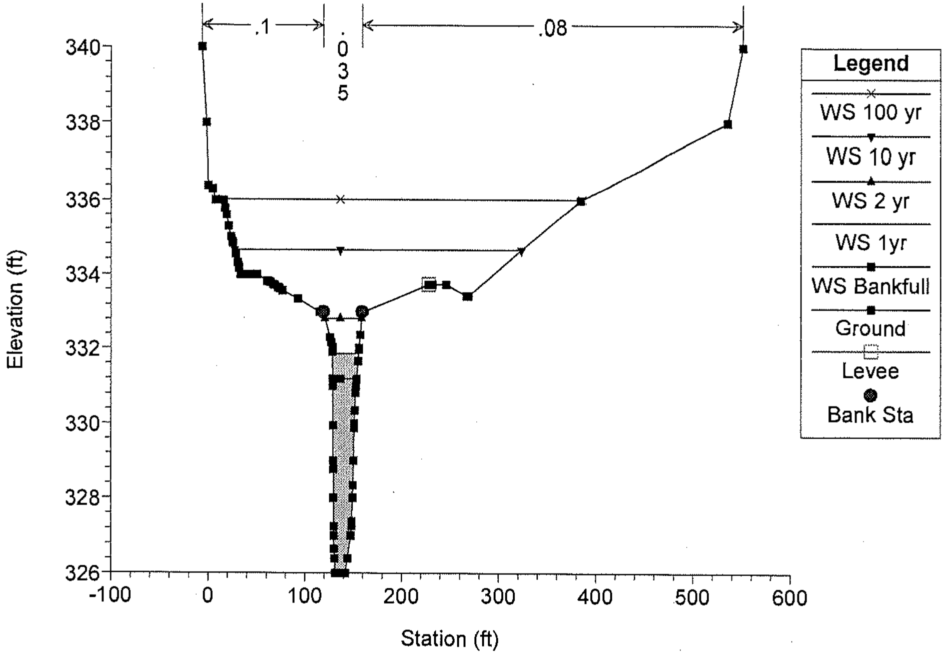
goosecrk Plan: Existing_7-20 9/29/2005

River = Mainstem Reach = downstream RS = 13 right overbank extended using exist. 2-ft contours



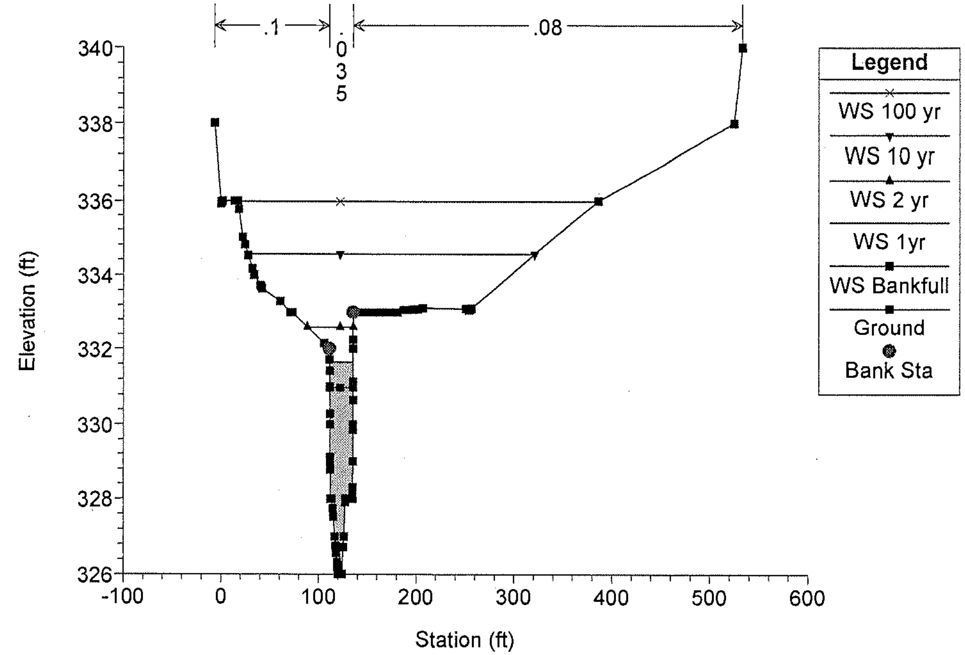
goosecrk Plan: Existing_7-20 9/29/2005

River = Mainstem Reach = downstream RS = 12 left and right overbanks extended using exist. 2-ft contours



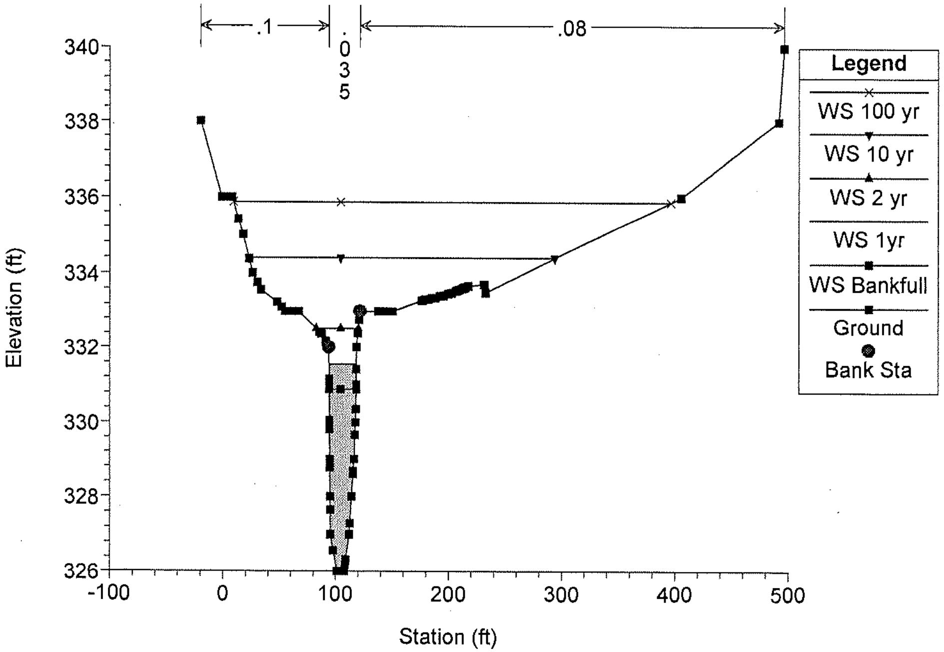
goosecrk Plan: Existing_7-20 9/29/2005

River = Mainstem Reach = downstream RS = 11 left and right overbanks extended using exist. 2-ft contours



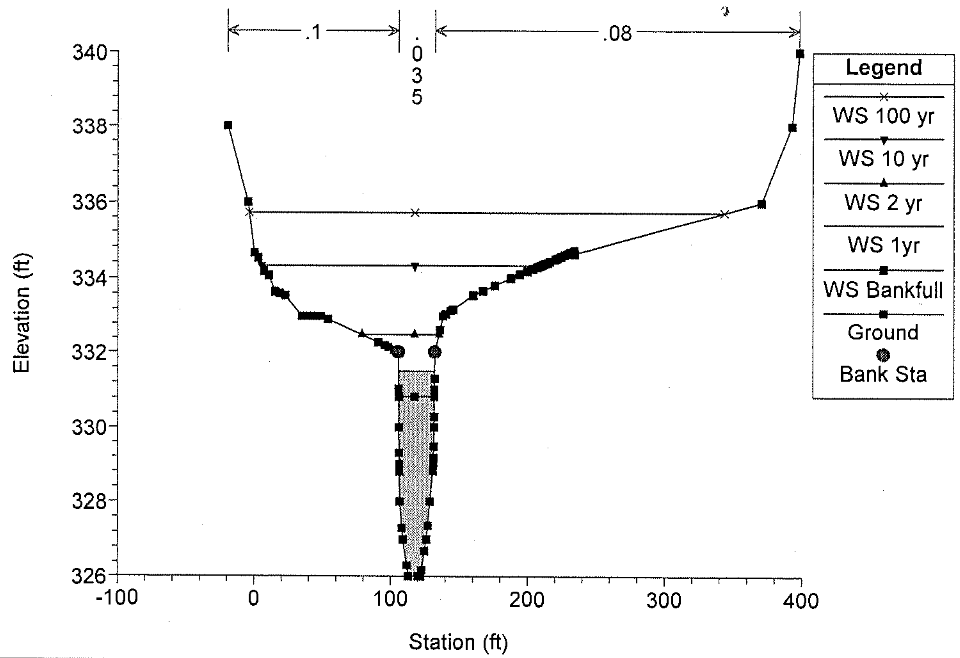
goosecrk Plan: Existing_7-20 9/29/2005

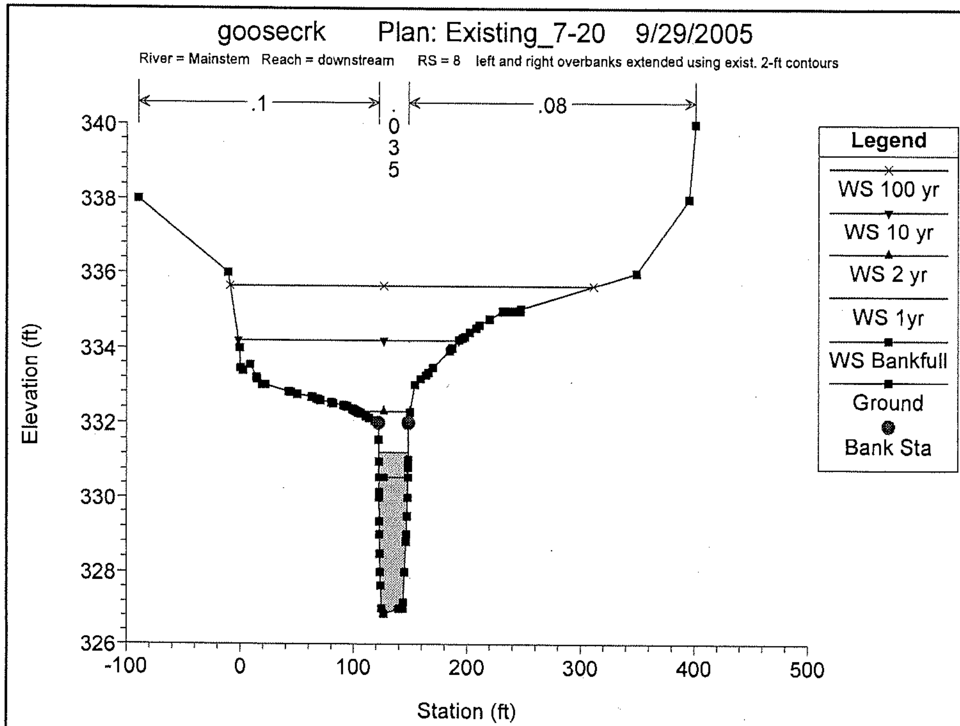
River = Mainstem Reach = downstream RS = 10 left and right overbanks extended using exist. 2-ft contours

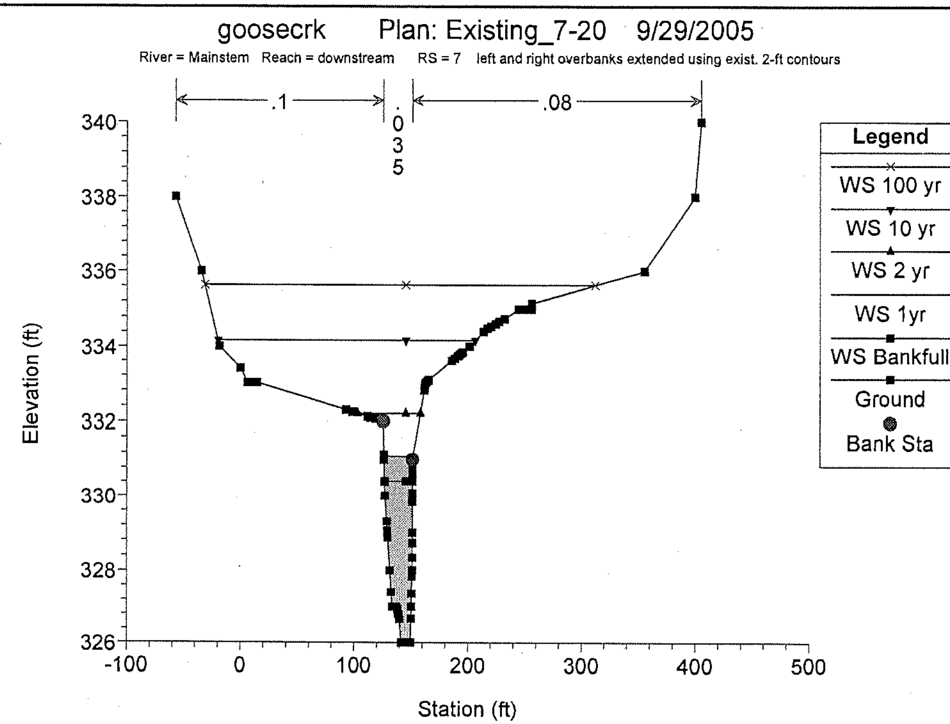


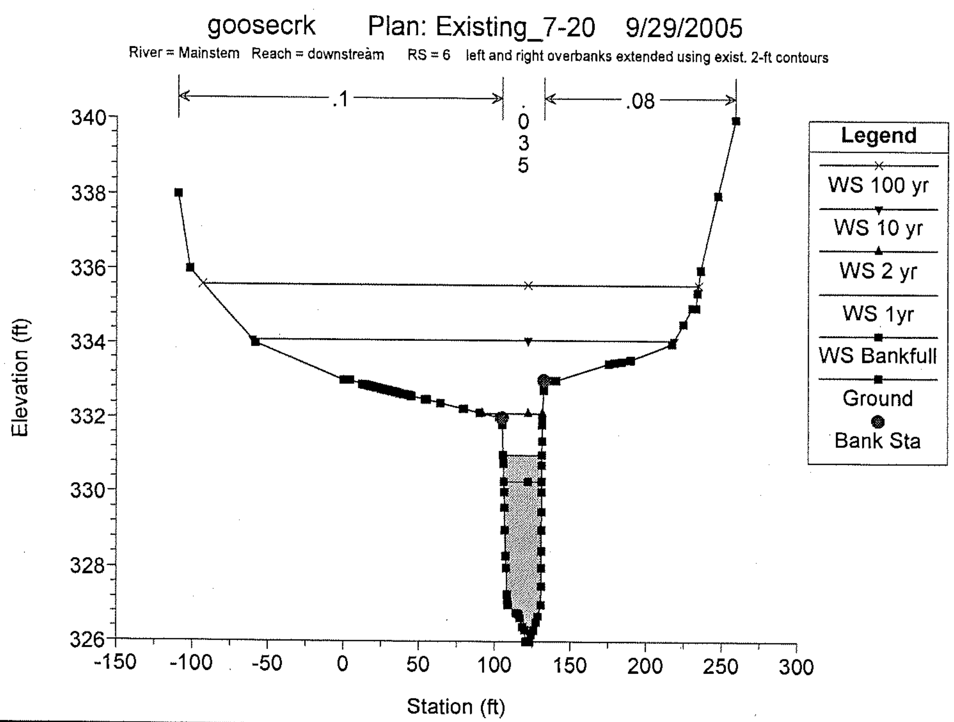
goosecrk Plan: Existing_7-20 9/29/2005

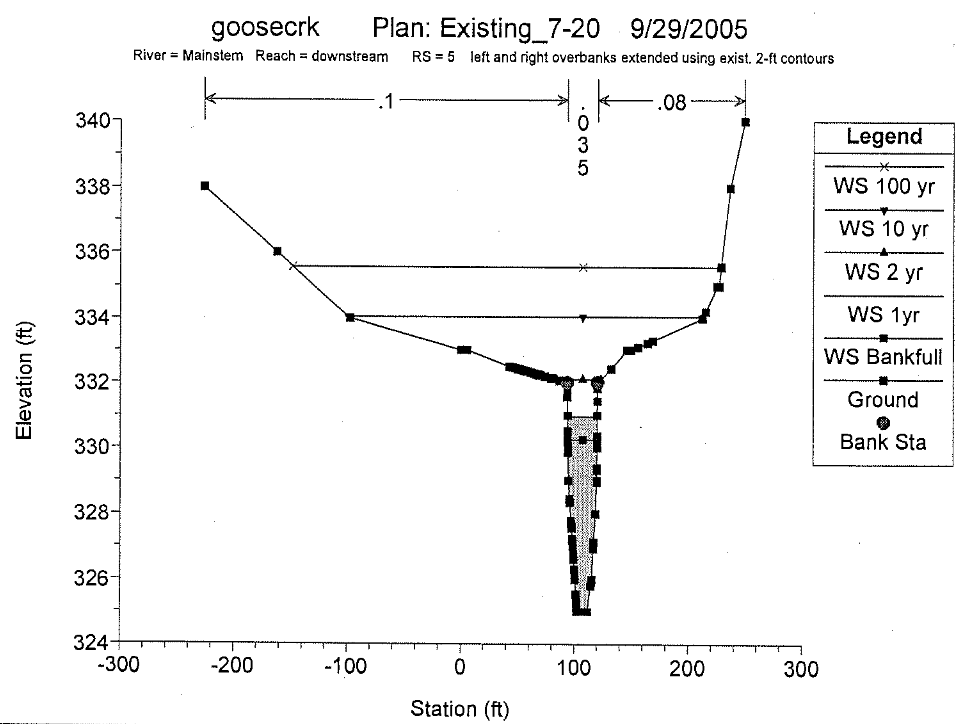
River = Mainstem Reach = downstream RS = 9 left and right overbanks extended using exist. 2-ft contours




goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 8 left and right overbanks extended using exist. 2-ft contours
.1
.035
.08
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta

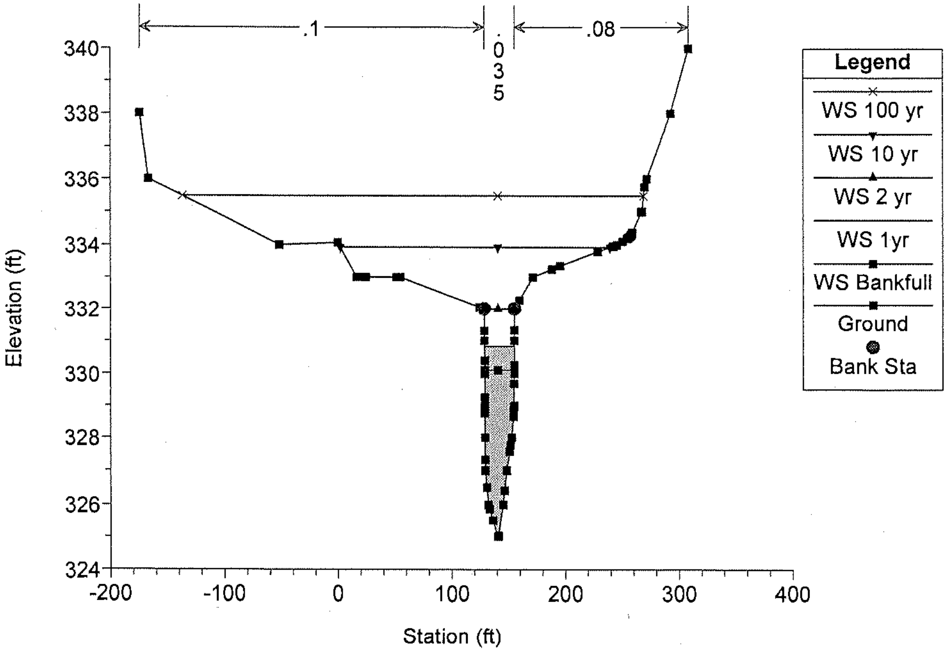

goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 7 left and right overbanks extended using exist. 2-ft contours
.1
.035
.08
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 6 left and right overbanks extended using exist. 2-ft contours
.1
.035
.08
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 5 left and right overbanks extended using exist. 2-ft contours
.1
.035
.08
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta

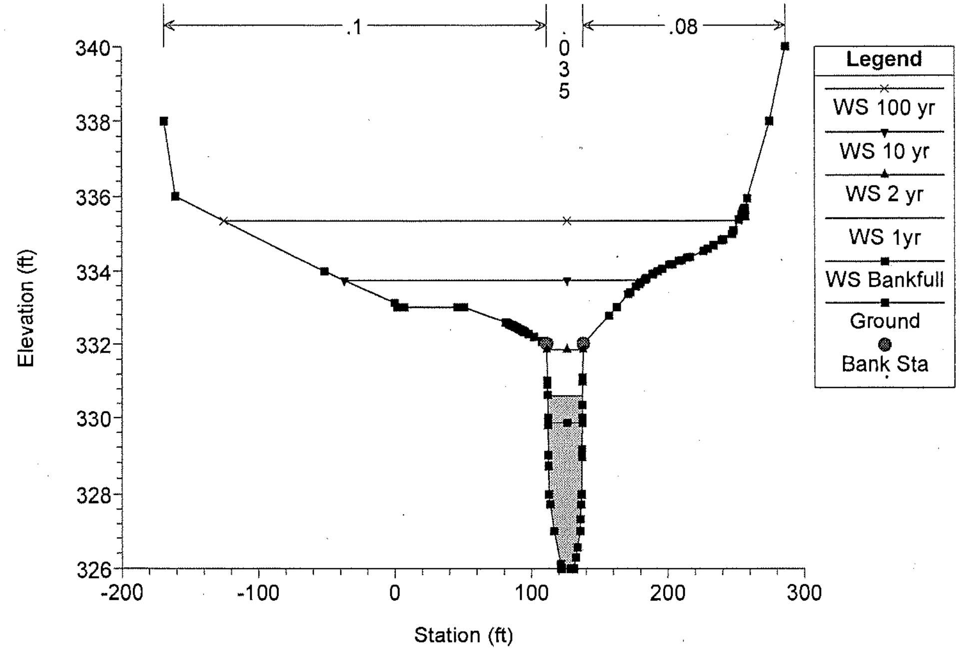
goosecrk Plan: Existing_7-20 9/29/2005

River = Mainstem Reach = downstream RS = 4 left and right overbanks extended using exist. 2-ft contours



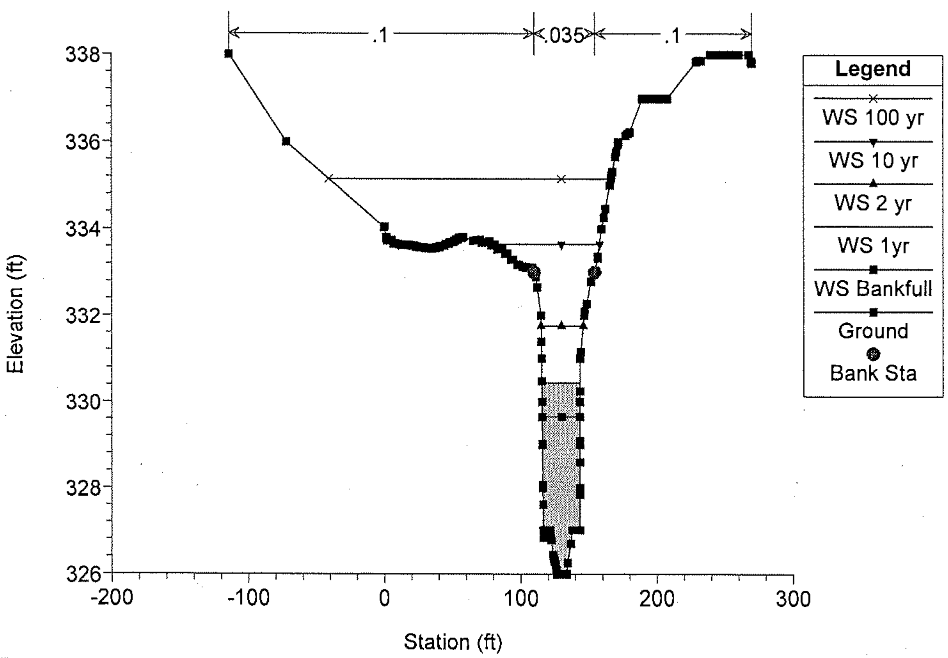
goosecrk Plan: Existing_7-20 9/29/2005

River = Mainstem Reach = downstream RS = 3 left and right overbanks extended using exist. 2-ft contours



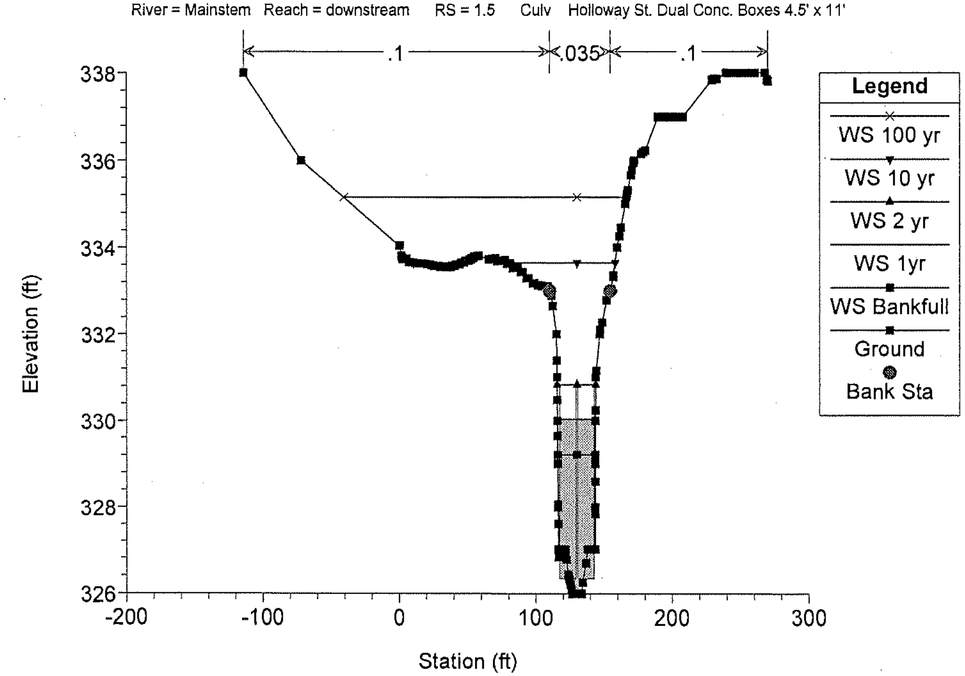
goosecrk Plan: Existing_7-20 9/29/2005

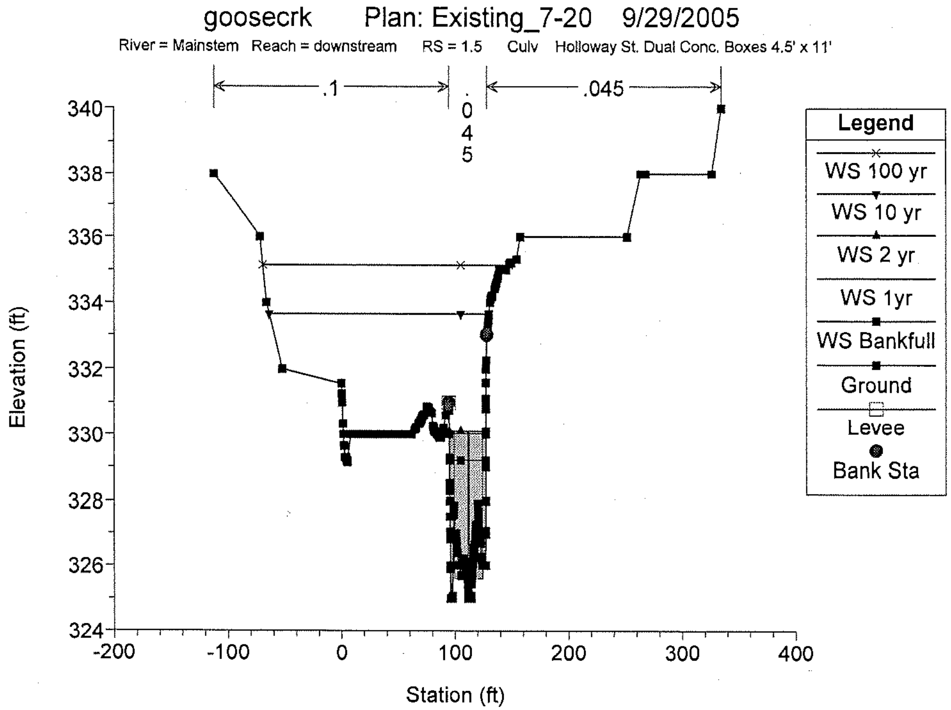
River = Mainstem Reach = downstream RS = 2 U/S of Hollaway St. (left overbank extended using exist. 2-ft co

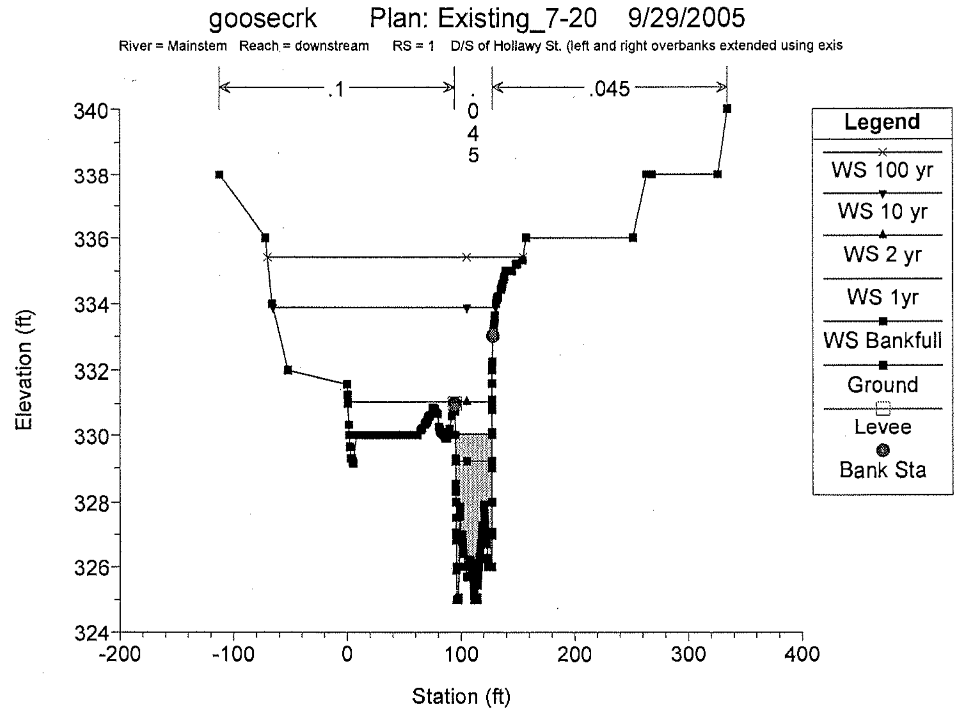


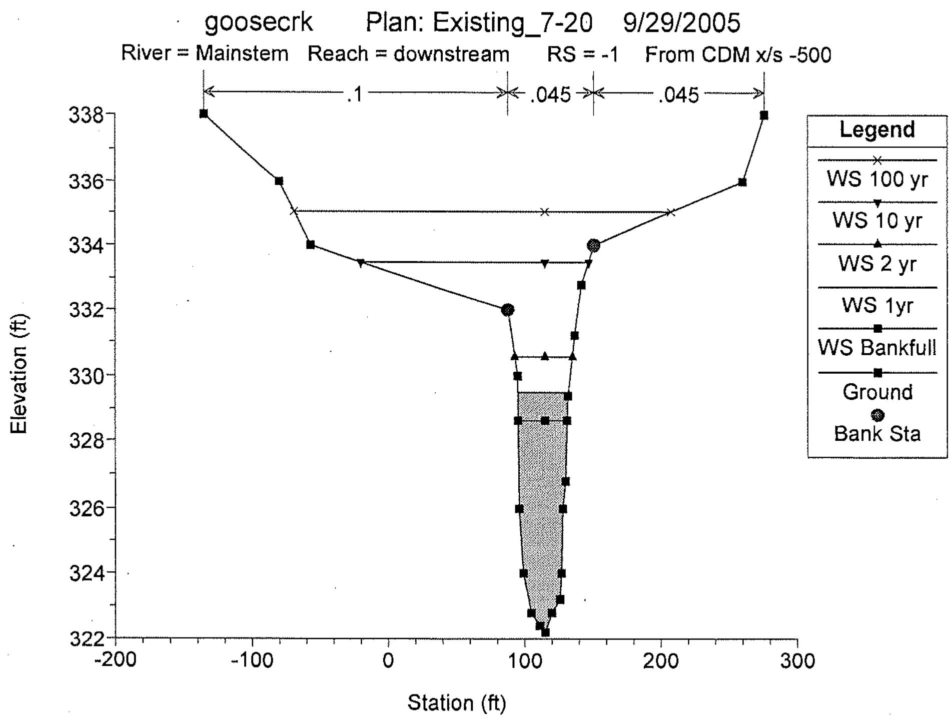
goosecrk Plan: Existing_7-20 9/29/2005

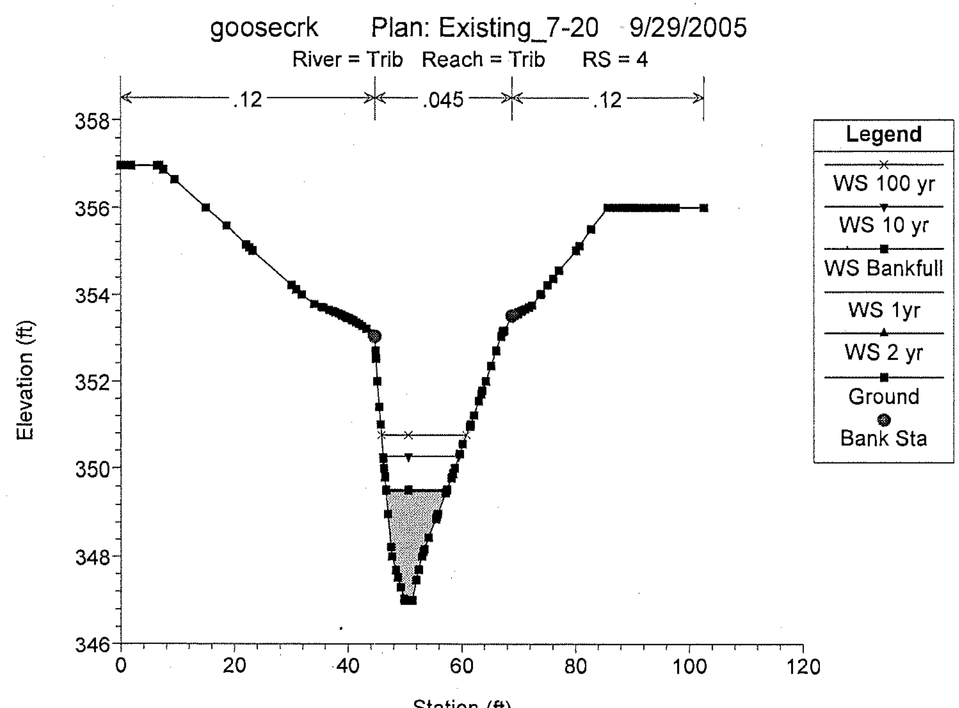
River = Mainstem Reach = downstream RS = 1.5 Culv Holloway St. Dual Conc. Boxes 4.5' x 11'




goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 1.5 Culv Holloway St. Dual Conc. Boxes 4.5' x 11'
.1
.045
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Levee
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = 1 D/S of Hollawy St. (left and right overbanks extended using exis
.1
.045
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Levee
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Mainstem Reach = downstream RS = -1 From CDM x/s -500
.1
.045
.045
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS 2 yr
WS 1yr
WS Bankfull
Ground
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
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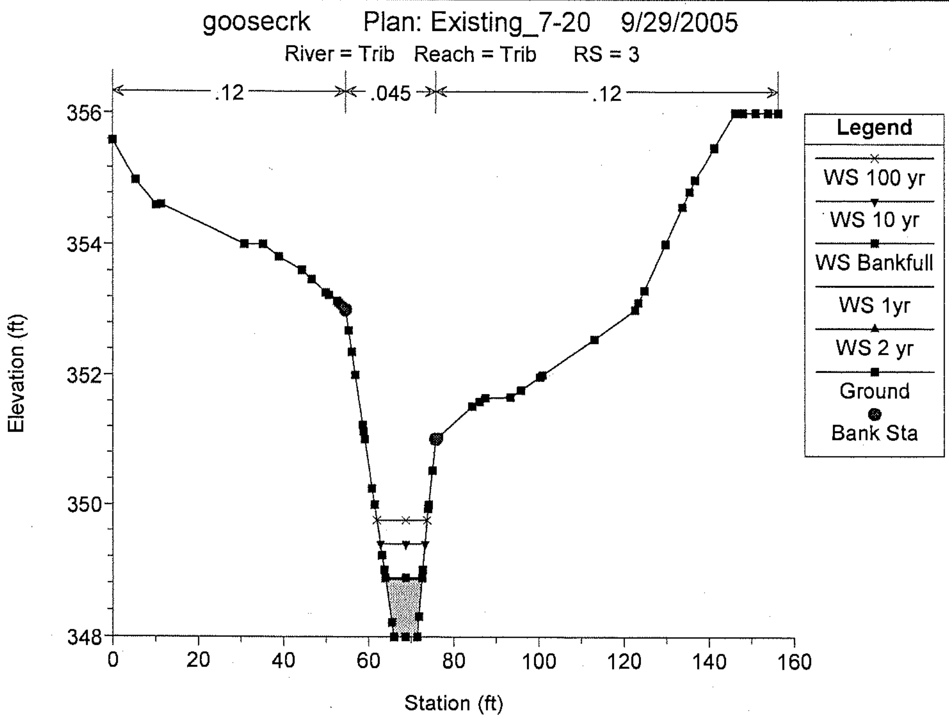
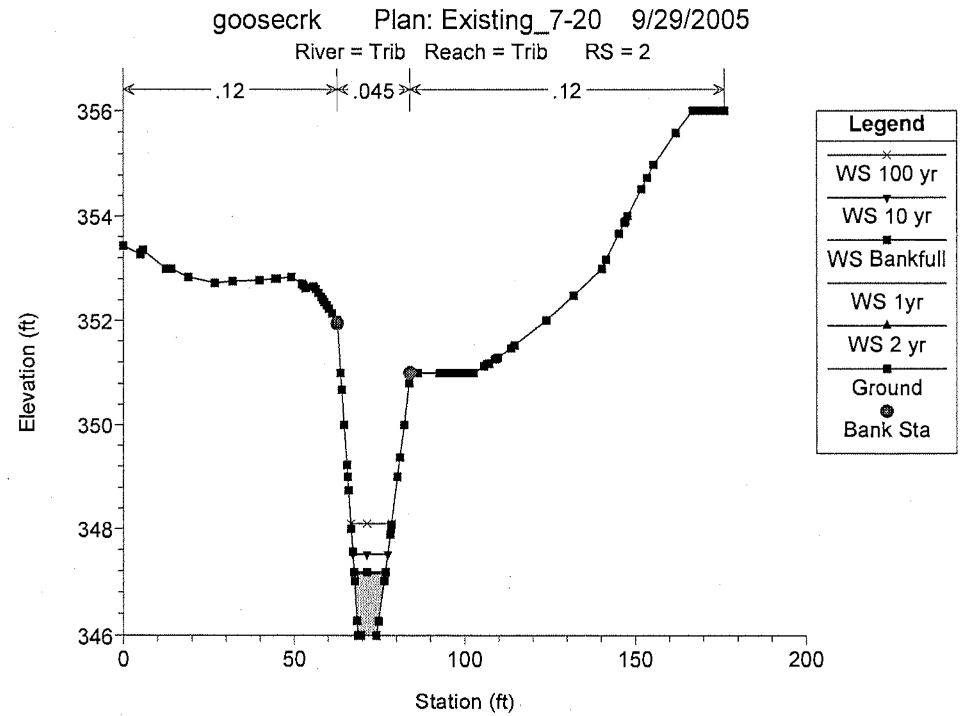
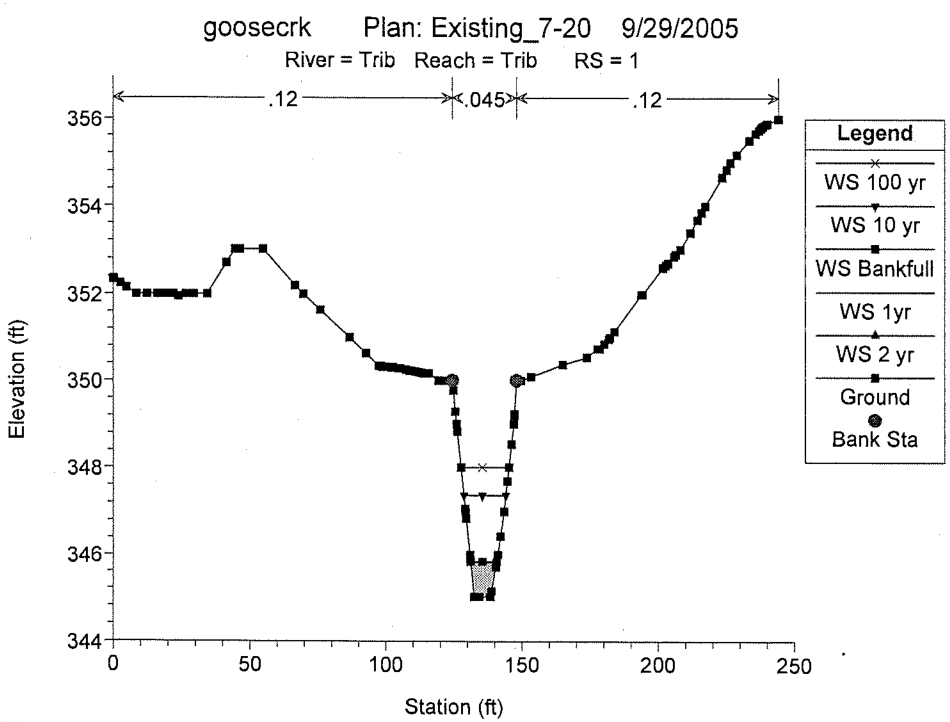
.12
.045
.12
Elevation (ft)
Station (ft)
Legend
WS 100 yr
WS 10 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Trib Reach = Trib RS = 3
.12
.045
.12
Elevation (ft)
Station (ft)
356
354
352
350
348
0
20
40
60
80
100
120
140
160
Legend
WS 100 yr
WS 10 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Trib Reach = Trib RS = 2
.12
.045
.12
Elevation (ft)
Station (ft)
356
354
352
350
348
346
0
50
100
150
200
Legend
WS 100 yr
WS 10 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Bank Sta


goosecrk Plan: Existing_7-20 9/29/2005
River = Trib Reach = Trib RS = 1
.12
.045
.12
Elevation (ft)
Station (ft)
356
354
352
350
348
346
344
0
50
100
150
200
250
Legend
WS 100 yr
WS 10 yr
WS Bankfull
WS 1yr
WS 2 yr
Ground
Bank Sta

APPENDIX F

SUMMARY MORPHOLOGICAL TABLE

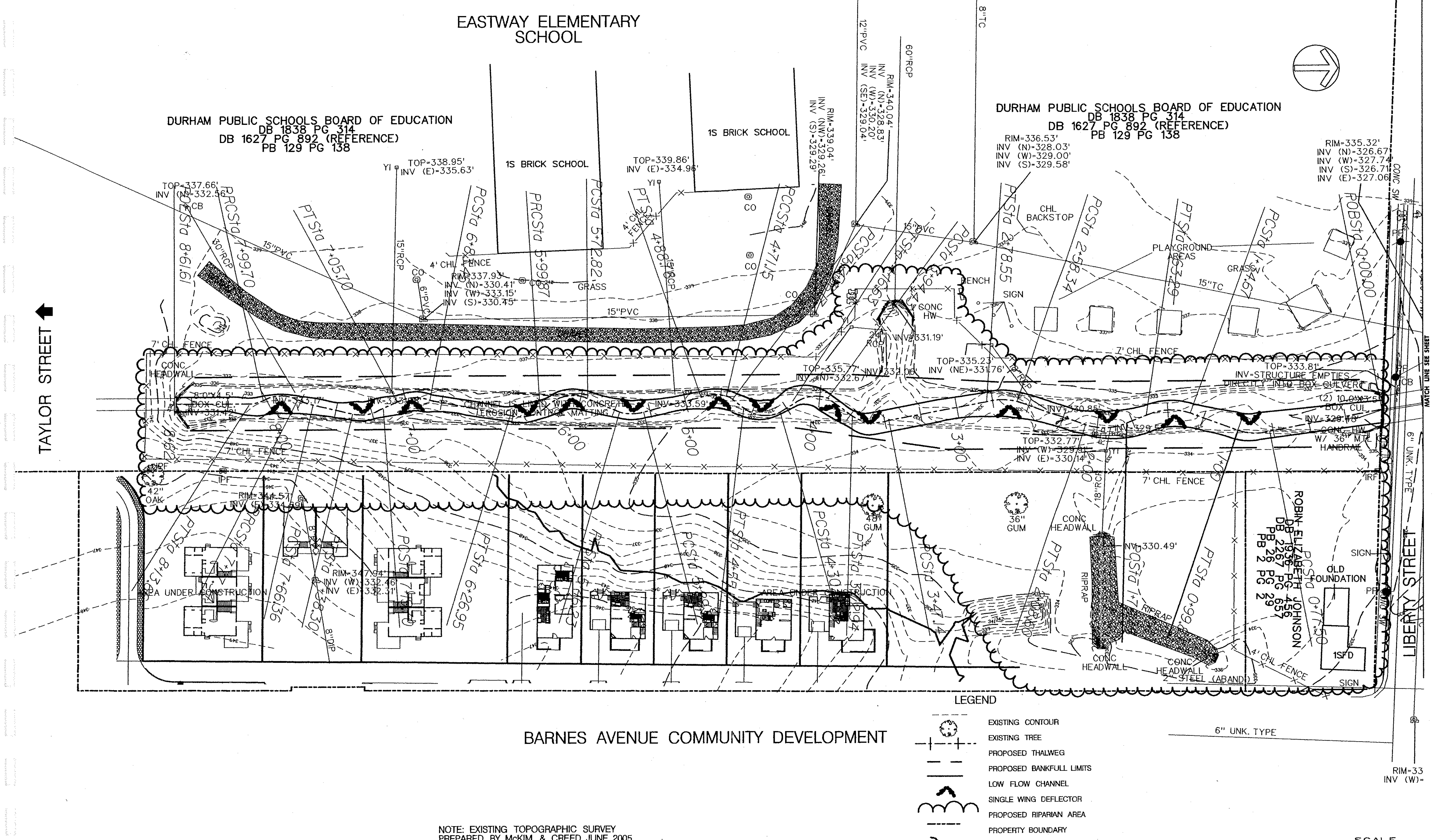
Existing and Proposed Channel Morphology versus Reference Reach Data

Parameters (variable, units)		Existing Conditions	Reference Reaches			Proposed Channel by Location		
		Goose Creek	Unnamed Tributary to Cabin Creek (Biohabitats)	Unnamed Tributary to Cabin Creek (Stantec)	Morgan Creek (NCSU)	Eastway Elementary School Reach: Upstream Portion	Eastway Elementary School Reach: Downstream Portion	Longmeadow Park Reach
General	Rosgen Stream Type	F5	C4	C4b	B4c	Bc5	Bc5	Bc5
	Drainage Area (mi^2)	0.2-0.8	1.3	1.3	8.3	0.41	0.79	0.79
	Estimated Bankfull Discharge (Q_{bkf}, cfs)	30-400	140	105	—	265	400	400
	Channel Reach Length (ft)	2000	624	397	—	513	347	655
Riffle Dimensions	Bankfull Width (W_{bkf}, ft) **Mean** *(Range)*	**24.6** *(16.7-29.7)*	**16.8** (15.0-20.1)	**14.3** *(—)*	**33.5** *(—)*	**36** *(—)*	**46** *(—)*	**38** *(—)*
	Bankfull Mean Depth (d_{bkf}, ft) **Mean** *(Range)*	**2.3** *(1.6-3.1)*	**1.7** (1.6-1.8)	**1.5** *(—)*	**2.4** *(—)*	**2.3** *(—)*	**2.5** *(—)*	**2.4** *(—)*
	Bankfull Cross-sectional Area (A_{bkf}, ft^2) **Mean** *(Range)*	**62.5** *(27.2-84.3)*	**28.5** *(27.1-31.4)*	**21.4** *(—)*	**80.0** *(—)*	**82.5** *(—)*	**113.8** *(—)*	**92.3** *(—)*
	Bankfull Maximum Depth (d_{max}, ft) **Mean** *(Range)*	**3.5** *(2.1-4.3)*	**2.6** *(2.5-2.8)*	**2.2** *(—)*	— *(—)*	**4.0** *(—)*	**4.0** *(—)*	**3.5** *(—)*
	Width of Floodprone Area (W_{fpa}, ft) **Mean** *(Range)*	**29.0** *(19.5-38.5)*	**79.1** *(67.8-85.4)*	**47** *(—)*	— *(—)*	**≥72** *(—)*	**≥92** *(—)*	**≥72** *(—)*
	Bankfull Mean Velocity (ft/s) **Mean** *(Range)*	**4.6** *(1.5-7.0)*	**5.2** *(5.1-5.3)*	**4.9** *(—)*	— *(—)*	**3.3** *(—)*	**3.4** *(—)*	**4.3** *(—)*
	Wetted Perimeter (ft) **Mean** *(Range)*	**41.3** *(18.2-74.7)*	**19.1** *(17.0-22.9)*	— *(—)*	— *(—)*	**37.4** *(—)*	**47.4** *(—)*	**39.0** *(—)*
	Hydraulic Radius (ft) **Mean** *(Range)*	**1.7** *(1.0-2.7)*	**1.5** *(1.4-1.6)*	— *(—)*	— *(—)*	**2.20** *(—)*	**2.40** *(—)*	**2.37** *(—)*
Riffle Ratios	Bankfull Width/Mean Depth Ratio (W_{bkf}/d_{bkf}, ft/ft)	**12.0** *(9.1-16.7)*	**9.9** *(8.3-12.9)*	**10.0** *(—)*	**14.0** *(—)*	**15.7** *(—)*	**18.4** *(—)*	**15.8** *(—)*
	Bankfull Width/Max Bankfull Depth (W_{bkf}/d_{max}, ft/ft), **Mean** *(Range)*	**7.1** *(6.7-7.8)*	**6.4** *(5.8-7.2)*	**6.5** *(—) (-)*	— *(—)*	**9.0** *(—)*	**11.5** *(—)*	**10.9** *(—)*
	Bankfull Max Depth/Mean Bankfull Depth (d_{max}/d_{bkf}, ft/ft), **Mean** *(Range)*	**1.6** *(1.3-2.0)*	**1.5** (1.4-1.8)	**1.5** *(—)*	— *(—)*	**1.7** *(—)*	**1.6** *(—)*	**1.5** *(—)*
	Entrenchment Ratio (W_{fpa}/W_{bkf}, ft/ft) **Mean** *(Range)*	**>2.2** *(1.2->2.2)*	**4.8** (4.2-5.7)	**3.3** *(—)*	— *(—)*	**≥2.0** *(—)*	**≥2.0** *(—)*	**≥2.0** *(—)*
Planform Pattern Dimensions	Meander Length (Lm, ft) **Mean** *(Range)*	**94** *(89-99)*	**98** *(—)*	— *(32-92)*	— *(—)*	— *(—)*	— *(—)*	— *(—)*
	Belt Width (W_{blt}, ft) **Mean** *(Range)*	**80** *(—)*	— *(—)*	**80** *(—)*	— *(—)*	— *(—)*	— *(—)*	— *(—)*
	Radius of Curvature (Rc, ft) **Mean** *(Range)*	**33.6** *(23.2-41.6)*	**33.4** *(11.3-63.5)*	— *(9.0-29.0)*	— *(—)*	— *(—)*	— *(—)*	— *(—)*
Planform Pattern Ratios	Ratio of Meander Length to Bankfull Width (L_m/W_{bkf}, ft/ft), **Mean** *(Range)*	**3.8** *(3.0-5.9)*	**5.8** *(—)*	— *(2.2-6.4)*	— *(—)*	— *(—)*	— *(—)*	— *(—)*
	Meander Width Ratio (W_{blt}/W_{bkf}, ft/ft) **Mean** *(Range)*	**3.3** *(—)*	— *(—)*	**5.6** *(—)*	— *(—)*	— *(—)*	— *(—)*	— *(—)*
	Ratio of Rc To W_{bkf} (Rc/W_{bkf}, ft/ft) **Mean** *(Range)*	**1.4** *(0.9-2.5)*	**2.0** *(0.6-4.2)*	— *(0.7-3.0)*	— *(—)*	— *(—)*	— *(—)*	— *(—)*

Parameters (variable, units)		Existing Conditions	Reference Reaches			Proposed Channel by Location		
		Goose Creek	Unnamed Tributary to Cabin Creek (Biohabitats)	Unnamed Tributary to Cabin Creek (Stantec)	Morgan Creek (NCSU)	Eastway Elementary School Reach Upstream Portion	Eastway Elementary School Reach Downstream Portion	Longmeadow Park Reach
	Sinuosity (Stream Length/Valley Length, ft/ft)	1.0-1.1	—	1.20	1.1	1.0	1.0	1.05
Longitudinal Profile	Valley Length (ft)	1800	—	—	—	490	330	622
	Valley Slope (S_{valley}, ft/ft)	0.011	—	0.014	0.008	0.0012	0.0076	0.004
	Bankfull Slope (ft/ft) **Mean** *(Range)*	0.011	**0.009** *(0.008- 0.010)*	**0.012** *(—)*	**0.007** *(—)*	**0.0023** *(—)*	**0.0023** *(—)*	**0.0039** *(—)*
	Water Surface Slope (ft/ft) **Mean** *(Range)*	— *(—)*	**0.006** *(—)*	— *(—)*	— *(—)*	— *(—)*	— *(—)*	— **(—)**
	Pool Length (ft) **Mean** *(Range)*	— *(—)*	**59** *(19-115)*	— *(—)*	— *(—)*	**47.8** *(21-70)*	**50** ***(32-83)***	**53** *(39-61)*
	Pool Slope (S_{pool}, ft/ft) **Mean** *(Range)*	— *(—)*	**0.0063** *(0.00-0.016)*	**0.008** *(—)*	**0.0** *(—)*	**0.0** *(—)*	**0.0** *(—)*	**0.0** *(—)*
	Riffle Length (ft) **Mean** *(Range)*	— *(—)*	**54** *(25-95)*	— *(—)*	— *(—)*	**42** *(23-68)*	**43** *(26-68)*	**56.2** *(32-106)*
	Riffle Slope Average (ft/ft) **Mean** *(Range)*	— *(—)*	**0.023** *(0.014-0.038)*	— *(—)*	— *(—)*	**0.0053** *(0.0037-0.0089)*	**0.0046** *(0.0023-0.0076)*	**0.0076** *(0.0039-0.011)*
	Run Slope Average (ft/ft) **Mean** *(Range)*	— *(—)*	**0.058** *(0.022-0.098)*	— *(—)*	— *(—)*	**0.073** *(0.06-0.10)*	**0.073** ***(0.06-0.09)***	**0.088** *(0.08-0.09)*
	Glide Slope Average (ft/ft) **Mean** *(Range)*	— *(—)*	**0.030** *(0.0033-0.045)*	— *(—)*	— *(—)*	**0.062** *(0.05-0.08)*	**0.06** *(0.05-0.08)*	**0.082** *(0.07-0.09)*
	Pool to Pool Spacing (P-P, ft) **Mean** *(Range)*	— *(—)*	**62** *(19-87)*	**9-49** *(—)*	**146** *(—)*	**79.3** *(58-107.5)*	**88.8** *(58.0-107.5)*	**99.5** *(41-163)*
	Ratio of Pool Slope to Average Slope (ft/ft)	— *(—)*	**1.05** *(—)*	**0.09-1.25** *(—)*	**0.0** *(—)*	**0.0** *(—)*	**0.0** *(—)*	**0.0** *(—)*
Pool Dimensions	Bankfull Pool Width (ft) **Mean** *(Range)*	— *(—)*	**16.2** *(15.5-16.9)*	**15** *(—)*	— *(—)*	**36.0** *(—)*	**46.0** *(—)*	**46.0** *(—)*
	Pool Mean Depth (d_p, ft) **Mean** *(Range)*	— *(—)*	**2.3** *(2.2-2.3)*	— *(—)*	— *(—)*	**2.2** *(2.0-2.5)*	**2.2** *(2.0-2.5)*	**3.7** *(—)*
	Maximum Pool Depth (ft) **Mean** *(Range)*	— *(—)*	**3.4** *(3.3-3.4)*	**2.5** *(—)*	— *(—)*	**2.3** *(2.0-2.5)*	**2.2** *(2.0-2.5)*	**5.5** *(—)*
	Pool Cross-sectional Area (A_p, ft^2) **Mean** *(Range)*	— *(—)*	**36.9** *(35.3-38.5)*	— *(—)*	— *(—)*	**18.3** (16.5-20.1)	**27.9** (24.5-31.3)	**170.0** *(—)*
Pool Ratios	Ratio of Pool to Pool Spacing to Bankfull Width ($P\text{-}P/W_{bkf}$), **Mean** *(Range)*	— *(—)*	**3.7** *(0.9-5.8)*	**0.6-3.4** *(—)*	**4.4** *(—)*	**2.2** *(—)*	**1.9** *(—)*	**2.6** *(—)*
	Ratio of Pool Width to Bankfull Width (ft/ft)	— *(—)*	**1.0** *(0.8-1.1)*	**1.0** *(—)*	— *(0.8-1.1)*	**1.0** *(—)*	**1.0** *(—)*	**1.2** *(—)*
	Ratio of Mean Pool Depth to Mean Bankfull Depth (ft/ft), **Mean** *(Range)*	— *(—)*	**1.4** *(1.3-1.5)*	**1.7** *(—)*	**1.7** *(—)*	**1.5** *(1.3-1.7)*	**2.2** *(—)*	**1.5** *(—)*
Substrate	D_{50} (mm)	<2 *(—)*	**45** *(37-53)*	— *(—)*	**3.0** *(—)*	**<2** *(—)*	**<2** *(—)*	**<2** *(—)*
	D_{84} (mm)	20 *(—)*	**162** *(108-215)*	— *(—)*	**77** *(—)*	**<2** *(—)*	**<2** *(—)*	**<2** *(—)*

APPENDIX G

PLANFORM LAYOUT AND DETAILS



DATE	BY	REVISION DESCRIPTION

DATE: 9/21/05
DESIGNED: EMM
DRAWN: WC
CHECKED:
APPROVED:
Biohabitats Project No. 4802.02

Biohabitats, Inc.
15 West Aylesbury Road
Timonium, Maryland 21093
Phone: 410-337-3659
Fax: 410-583-5678
• Fostering Ecological Stewardship •

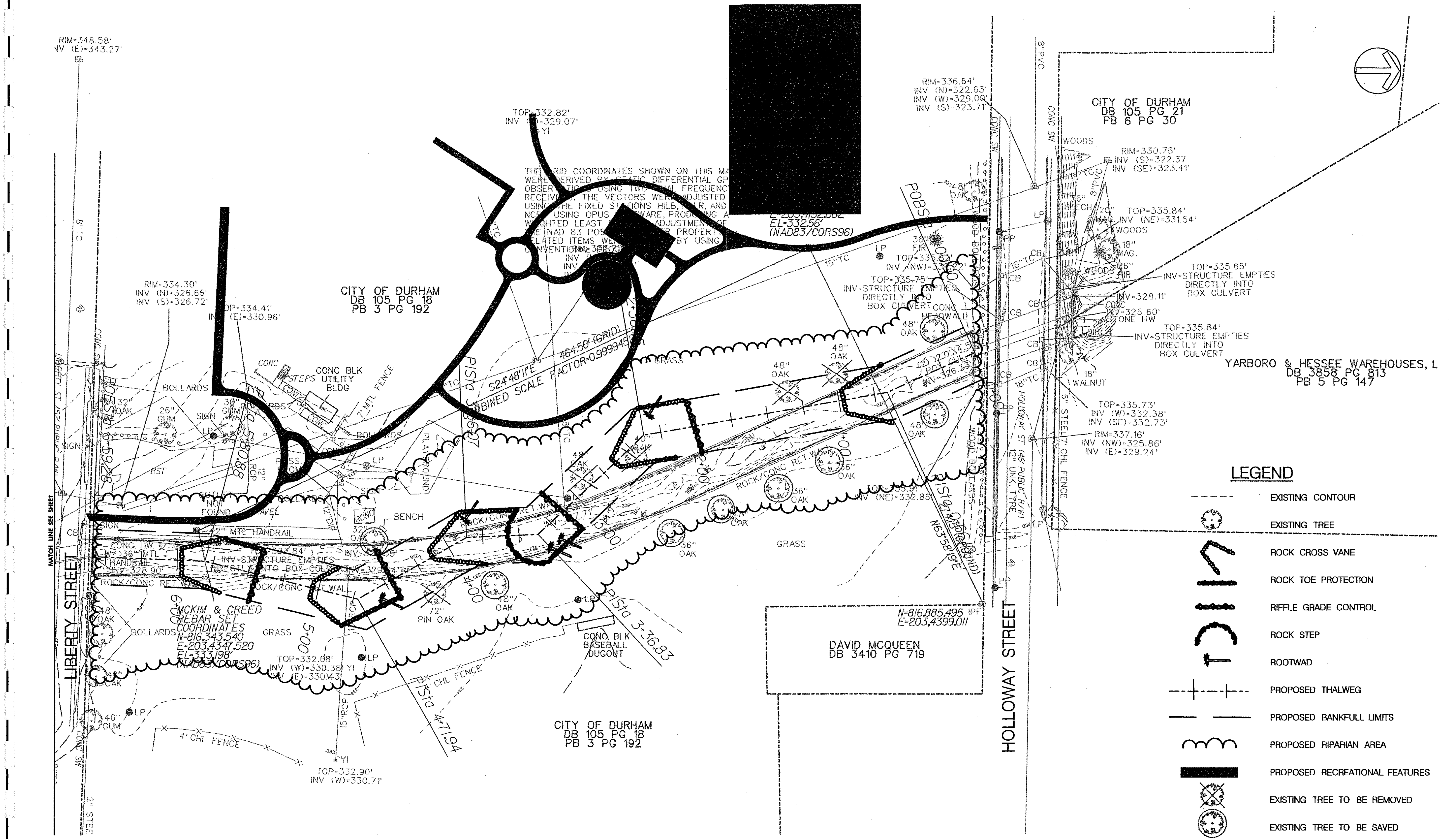
GOOSE CREEK STREAM RESTORATION

DURHAM, NORTH CAROLINA

PROPOSED LAYOUT:

EASTWAY ELEMENTARY SCHOOL REACH

SCALE: 1" = 30'-0"
CONTRACT NO.
SHEET 1 OF 2



NOTE: EXISTING TOPOGRAPHIC SURVEY PREPARED BY McKIM & CREED, JUNE, 2005

REVISION		
DATE	BY	DESCRIPTION

DATE: 9/21/05
DESIGNED: EMM
DRAWN: WC
CHECKED:
APPROVED:
Biohabitats Project No.

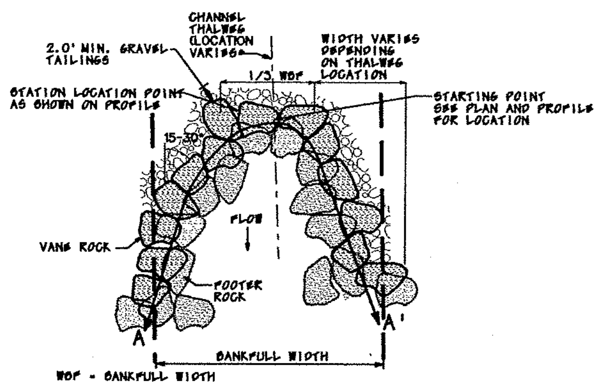
Biohabitats, Inc.
15 West Aylesbury Road
Timonium, Maryland 21093
Phone: 410-337-3659
Fax: 410-583-5678

GOOSE CREEK STREAM RESTORATION

PROPOSED LAYOUT:

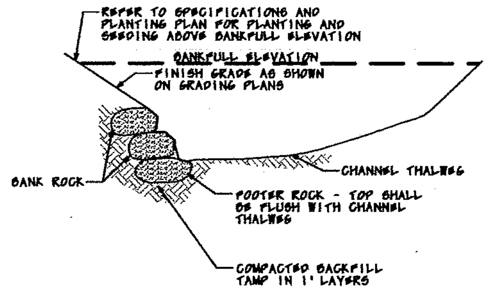
LONGMEADOW PARK REACH

SCALE: 1" = 30'-0"
CONTRACT NO.
SHEET



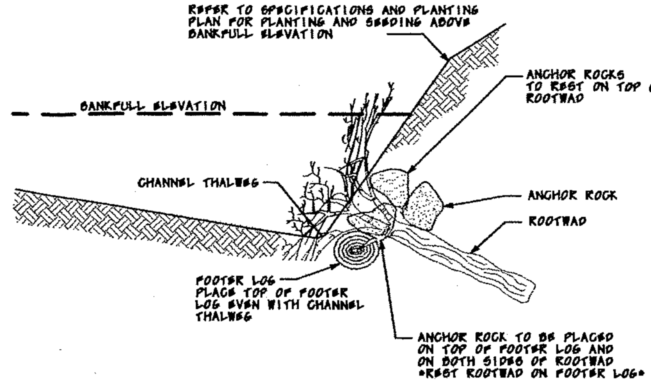
ROCK CROSS VANE
PLAN VIEW

NOT TO SCALE



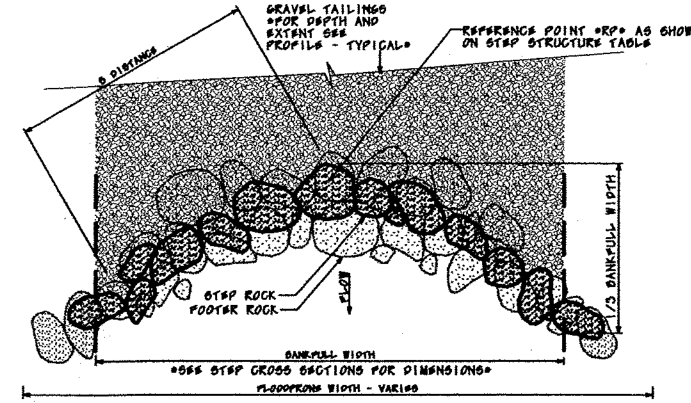
ROCK TOE PROTECTION
CROSS SECTION

NOT TO SCALE



ROOTWAD
CROSS SECTION

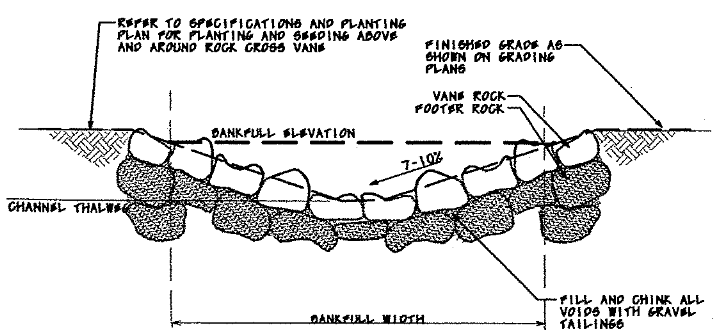
NOT TO SCALE



FOR LOCATIONS AND ELEVATIONS SEE PROFILE, AND STRUCTURE TABLES ON THE GRADING PLAN

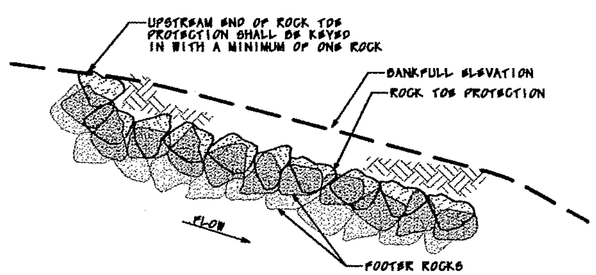
STEP
PLAN VIEW

NOT TO SCALE



ROCK CROSS VANE
SECTION A-A'

NOT TO SCALE



ROCK TOE PROTECTION
PLAN VIEW

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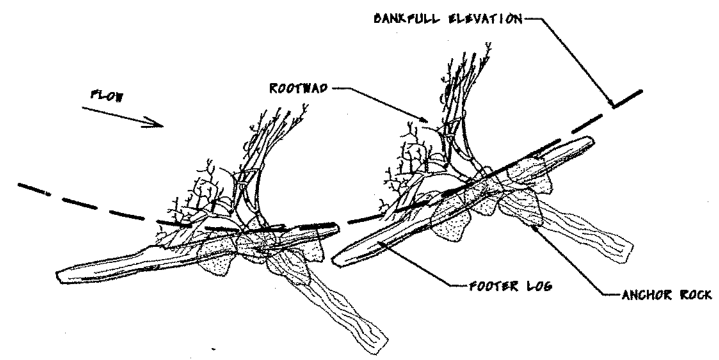
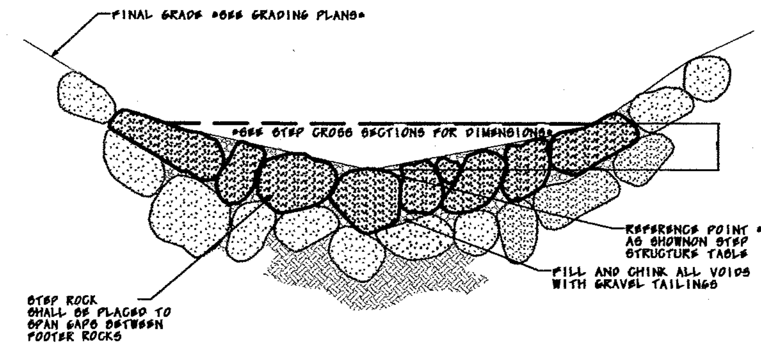


WHEN BACKFILLING OVER AND AROUND FOOTER LOGS AND ROOTWAD LOGS, PACK ROCK AND SOIL IN BETWEEN ALL VOIDS TO FIRMLY SECURE ALL COMPONENTS INCLUDING JOINTS, CONNECTIONS AND GAPS.

ROOTWAD
PLAN VIEW

NOT TO SCALE



FOR LOCATIONS AND ELEVATIONS SEE PROFILE, AND STRUCTURE TABLES ON THE GRADING PLAN

STEP
CROSS SECTION

NOT TO SCALE

REVISION		
DATE	BY	DESCRIPTION

DATE: 7/28/05
DESIGNED: EMM
DRAWN: WC
CHECKED:
APPROVED:
Biohabitats Project No. 4802.02

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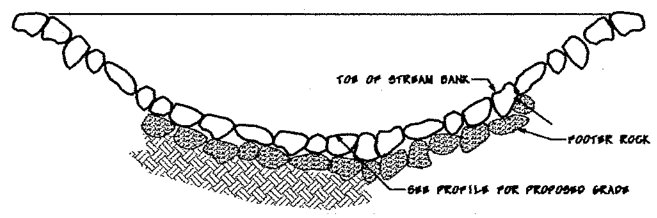
GOOSE CREEK STREAM RESTORATION

DURHAM, NORTH CAROLINA

TYPICAL DETAILS

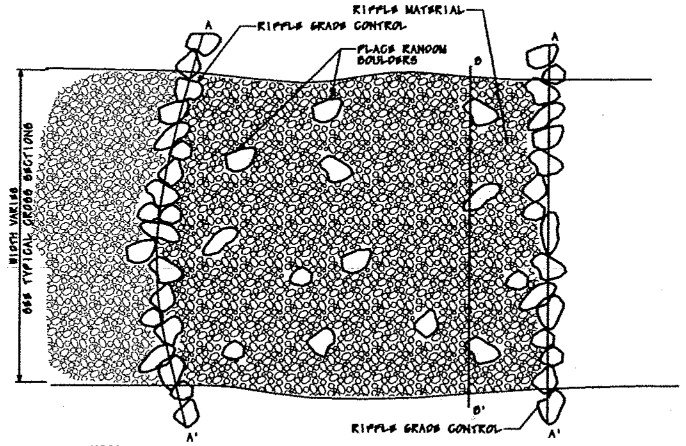
SCALE:
CONTRACT NO.
SHEET 1 OF 2

SEAL



RIFFLE STRUCTURE
SECTION A-A'

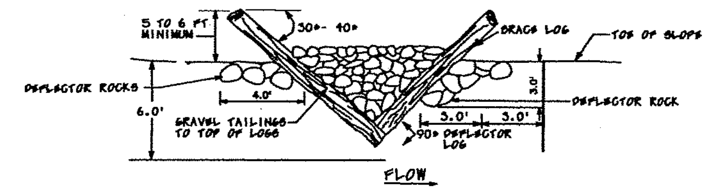
NOT TO SCALE



NOTE:
PLACE 4 RANDOM BOULDERS PER 100 SQUARE FEET OF RIFFLE AREA.

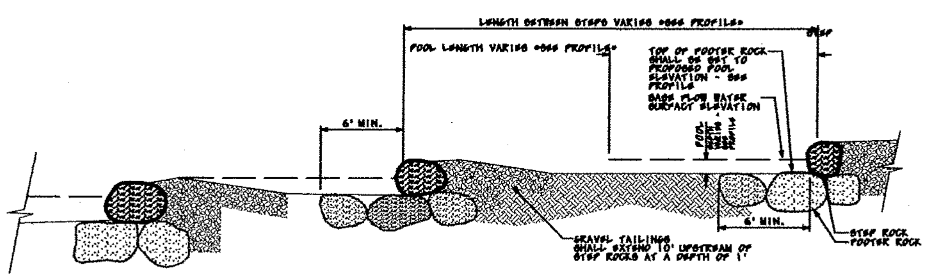
RIFFLE STRUCTURE
PLAN VIEW

NOT TO SCALE



SINGLE WING DEFLECTOR
PLAN VIEW

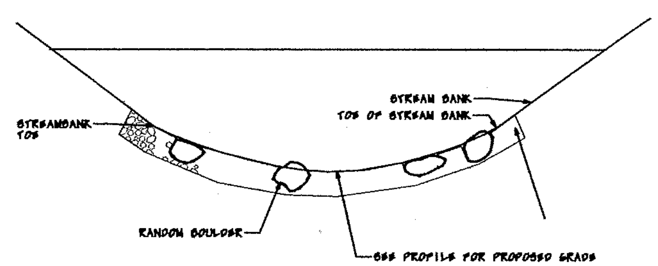
NOT TO SCALE



NOTES:
1. ROCK ARRANGEMENT AND SIZE SHALL BE PLACED IN ACCORDANCE TO GRADING PLANS.
2. SEE "STONE" SPECIFICATIONS FOR FOOTER AND STEP MATERIAL PROPERTIES.
3. SEE "STEPPOOL" SPECIFICATIONS FOR FOOTER AND STEP ROCK SIZES.
4. SEE PROFILE AND GRADING PLANS FOR ELEVATIONS OF STEPS AND POOLS.

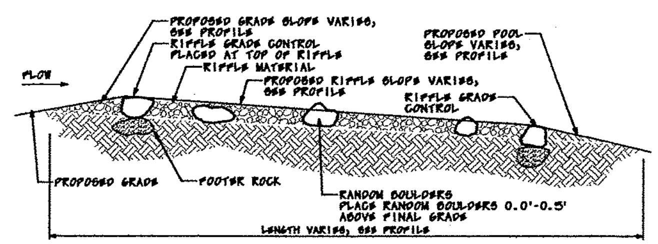
STEPPOOL SEQUENCE
PROFILE

NOT TO SCALE



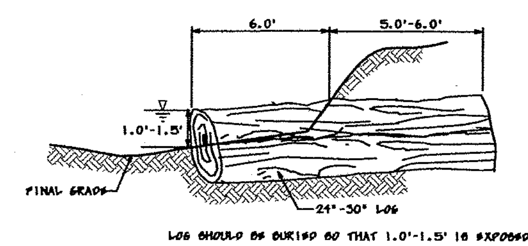
RIFFLE STRUCTURE
SECTION B-B'

NOT TO SCALE



RIFFLE STRUCTURE
PROFILE

NOT TO SCALE



LOG SHOULD BE BURIED SO THAT 1.0'-1.5' IS EXPOSED

SINGLE WING DEFLECTOR
PROFILE VIEW

NOT TO SCALE

REVISION		
DATE	BY	DESCRIPTION

DATE: 7/28/05
DESIGNED: EMM
DRAWN: WC
CHECKED:
APPROVED:
Biohabitats Project No. 4802.02

Biohabitats, Inc.
15 West Aylesbury Road
Timonium, Maryland 21093
Phone: 410-337-3659
Fax: 410-583-5678
• Fostering Ecological Stewardship •

GOOSE CREEK STREAM RESTORATION

DURHAM, NORTH CAROLINA

TYPICAL DETAILS

SCALE:
CONTRACT NO.
SHEET 2 OF 2

SEAL

APPENDIX H

TYPICAL DESIGN CROSS SECTIONS

1

Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/5/2005
Prepared by:	E. McClure
Cross Section Identification:	**Upper Reach Tributary B-type, 30 cfs Riffle**

Stream Design Worksheet

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Biohabitats *Incorporated*

Input Variables

Mannings "n" of channel =	0.038	
Mannings "n" of floodplain =	0.1	
Equivalent "n" for flood flows =	0.04	
Channel Slope =	0.016	
Design B.F. Discharge =	30	[cfs]
Bankfull Elevation =	8.00	[ft]
Floodprone Elevation =	9	[ft]
Bankfull Width =	12	[ft]
Floodprone Width =	24	[ft]

Calculated Quantities

Cross Section Area =	8.2	[sq. ft.]
Wetted Perimeter =	12.3	[ft]
Hydraulic Radius =	0.67	[ft]
Bankfull Discharge =	**31**	**[cfs]**
F.P. XSEC Area =	26.2	[sq. ft.]
F.P. Wetted Perimeter =	24	[ft]
F.P. Hydraulic Radius =	1.07	[ft]
Floodprone Discharge =	133	[cfs]
Average Depth =	0.68	[ft]
W/D Ratio =	17.6	
Entrenchment Ratio =	2.0	
Shear Stress =	0.67	[lb/sq.ft.]
D84=	44	[mm]

Relevant Equations

Continuity Equation:

$$Q = V \times A$$

Manning's Equation:

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

Shear Stress Equation:

□

$$\tau_o = \rho g R S$$

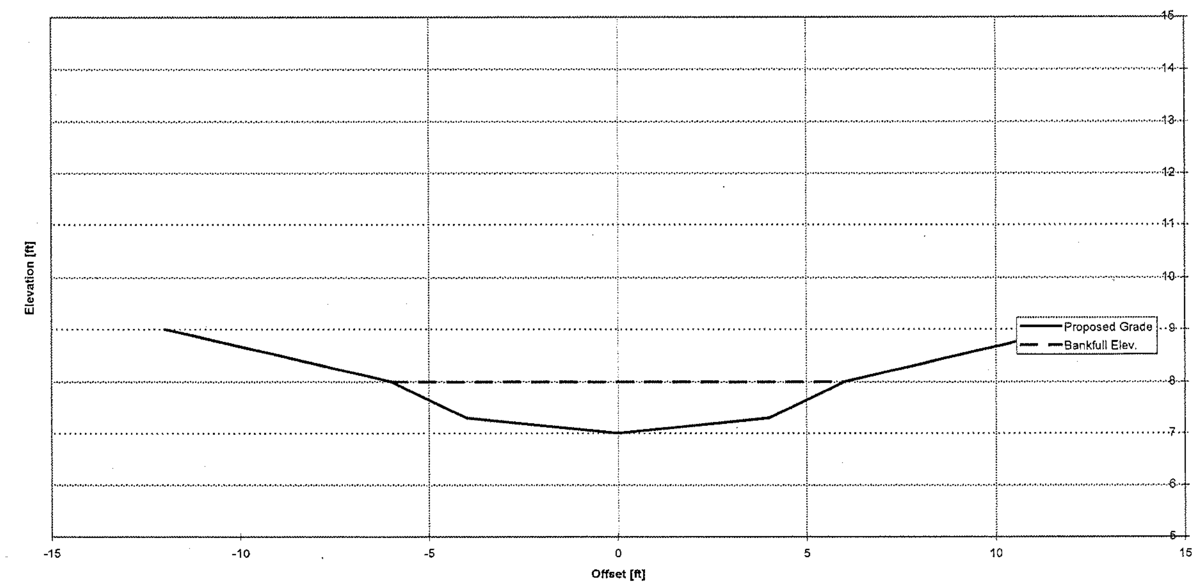
Cross Section Points / **Bankfull Channel Calculations**

Feature	Offset	Elevation		Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
Floodprone	-12	9.0				
	-12	9	bank slope			
Bankfull	-6	8.0	2.9	0.7		2.12
	-4	7.3		3.4		4.01
Max Depth	0	7.0	6.0	3.4		4.01
	4	7.3		0.7		2.12
Bankfull	6	8.0				
	12	9.0				
Floodprone	12	9.0	Total Area =	8.2	Wet Perimeter =	12.26

Floodprone Channel Calculations

	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
	0		0.00
lA.fp	3	lP.fp	6.08
	2.7		2.12
	7.4		4.01
	7.4		4.01
	2.7		2.12
rA.fp	3	rP.fp	6.08
	0		0.00
Total Area =	26.2	Wet Perimeter =	24.43

Typical Riffle Cross Section: Tributary to Upper Reach



2

Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/5/2005
Prepared by:	E. McClure
Cross Section Identification:	**Upper Reach Tributary B-type, 30 cfs Pool**

Stream Design Worksheet

Biohabitats Incorporated

Input Variables

Mannings "n" of channel =	0.038	
Mannings "n" of floodplain =	0.1	
Equivalent "n" for flood flows =	0.04	
Channel Slope =	0.016	
Design B.F. Discharge =	30	[cfs]
Bankfull Elevation =	9.00	[ft]
Floodprone Elevation =	11	[ft]
Bankfull Width =	16	[ft]
Floodprone Width =	0	[ft]

Calculated Quantities

Cross Section Area =	19.6	[sq. ft.]
Wetted Perimeter =	16.6	[ft]
Hydraulic Radius =	1.18	[ft]
Bankfull Discharge =	**109**	**[cfs]**
F.P. XSEC Area =	-52.4	[sq. ft.]
F.P. Wetted Perimeter =	41	[ft]
F.P. Hydraulic Radius =	-1.29	[ft]
Floodprone Discharge =		[cfs]
Average Depth =	1.23	[ft]
W/D Ratio =	13.1	
Entrenchment Ratio =	0.0	
Shear Stress =	1.18	[lb/sq.ft.]
D84=	78	[mm]

Relevant Equations

Continuity Equation:

$$Q = V \times A$$

Manning's Equation:

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

Shear Stress Equation:

$$\tau_o = \rho g R S$$

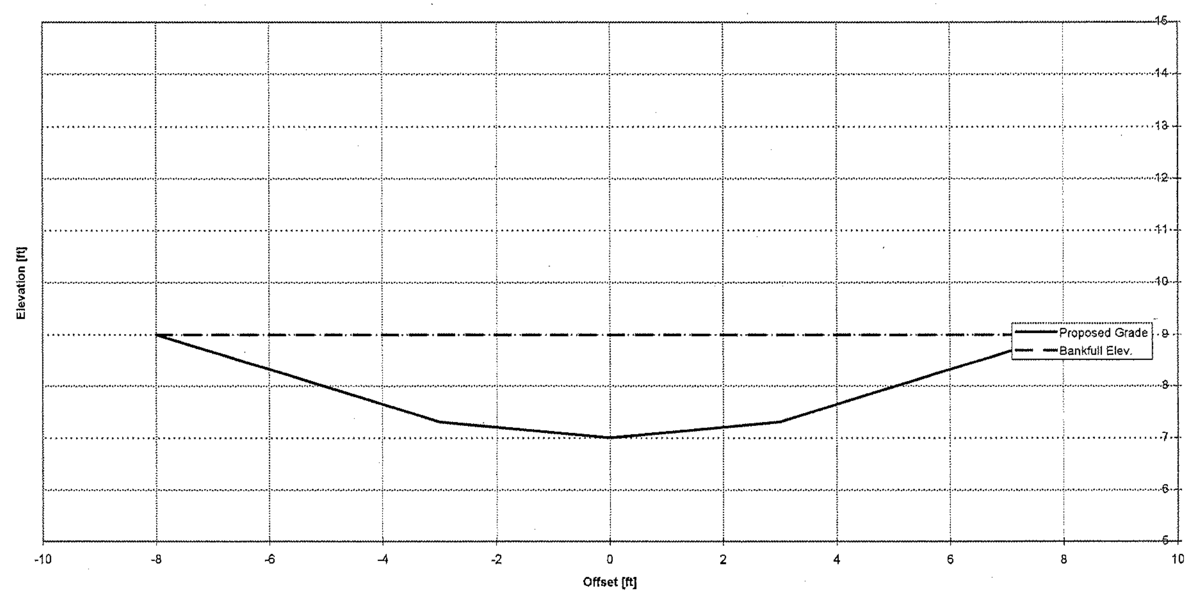
Cross Section Points / **Bankfull Channel Calculations**

Feature	Offset	Elevation		Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
Floodprone						
			bank slope			
Bankfull	-8	9.0	2.9	4.25		5.28
	-3	7.3		5.55		3.01
Max Depth	0	7.0		5.55		3.01
	3	7.3		4.25		5.28
Bankfull	8	9.0				
Floodprone			Total Area =	19.6	Wet Perimeter =	16.59

Floodprone Channel Calculations

	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
	0		0.00
lA.fp	-52	lP.fp	12.04
	14.25		5.28
	11.55		3.01
	11.55		3.01
	14.25		5.28
rA.fp	-52	rP.fp	12.04
	0		0.00
Total Area =	-52.4	Wet Perimeter =	40.68

Typical Pool Cross Section: Tributary to Upper Reach



3

Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/5/2005
Prepared by:	E. McClure
Cross Section Identification:	**Upper Reach C-type, 120 cfs Riffle**

Stream Design Worksheet

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Input Variables

Mannings "n" of channel =	0.038	
Mannings "n" of floodplain =	0.1	
Equivalent "n" for flood flows =	0.04	
Channel Slope =	0.011	
Design B.F. Discharge =	120	[cfs]
Bankfull Elevation =	8.70	[ft]
Floodprone Elevation =	10.4	[ft]
Bankfull Width =	22	[ft]
Floodprone Width =	66	[ft]

Calculated Quantities

Cross Section Area =	25.6	[sq. ft.]
Wetted Perimeter =	22.4	[ft]
Hydraulic Radius =	1.14	[ft]
Bankfull Discharge =	**115**	**[cfs]**
F.P. XSEC Area =	129.3	[sq. ft.]
F.P. Wetted Perimeter =	67	[ft]
F.P. Hydraulic Radius =	1.93	[ft]
Floodprone Discharge =	602	[cfs]
Average Depth =	1.16	[ft]
W/D Ratio =	18.9	
Entrenchment Ratio =	3.0	
Shear Stress =	0.78	[lb/sq.ft.]
D84=	52	[mm]

Relevant Equations

Continuity Equation:

$$Q = V \times A$$

Manning's Equation:

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

Shear Stress Equation:

□

$$\tau_o = \rho g R S$$

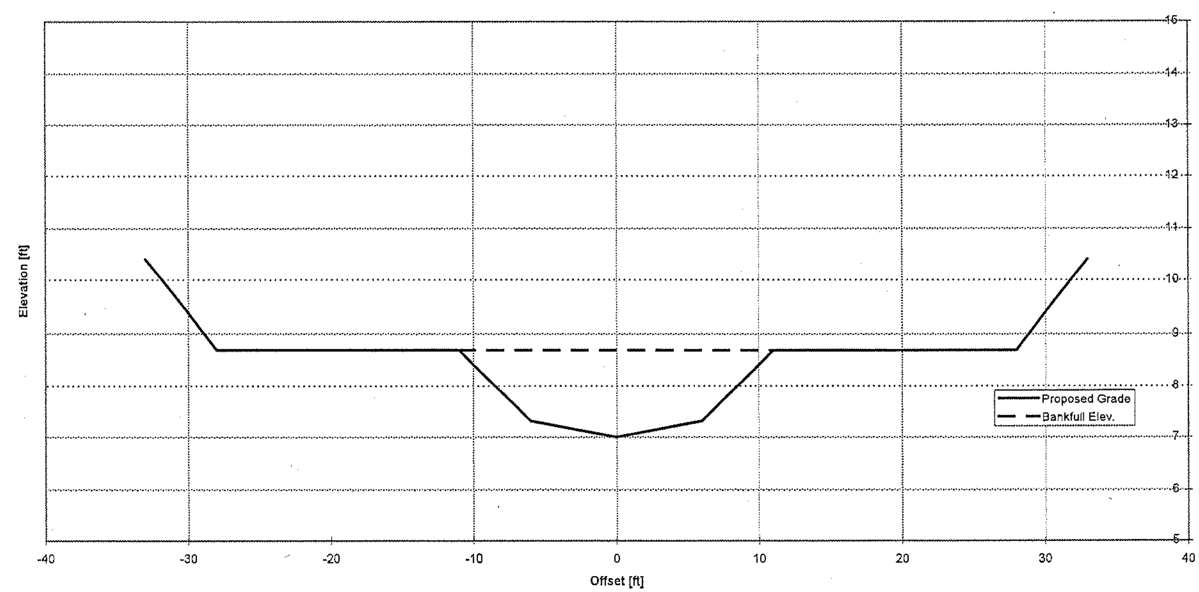
Cross Section Points / **Bankfull Channel Calculations**

Feature	Offset	Elevation		Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
Floodprone	-33	10.4				
	-28	8.7	bank slope			
Bankfull	-11	8.7	3.57	3.5		5.19
	-6	7.3		9.3		6.01
Max Depth	0	7.0	2.94	9.3		6.01
	6	7.3		3.5		5.19
Bankfull	11	8.7				
	28	8.7				
Floodprone	33	10.4	Total Area =	25.6	Wet Perimeter =	22.40

Floodprone Channel Calculations

	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
	4.25		5.28
lA.fp	28.9	lP.fp	17.00
	12		5.19
	19.5		6.01
	19.5		6.01
	12		5.19
rA.fp	28.9	rP.fp	17.00
	4.25		5.28
Total Area =	129.3	Wet Perimeter =	66.96

Typical Riffle Cross Section: Upper Reach



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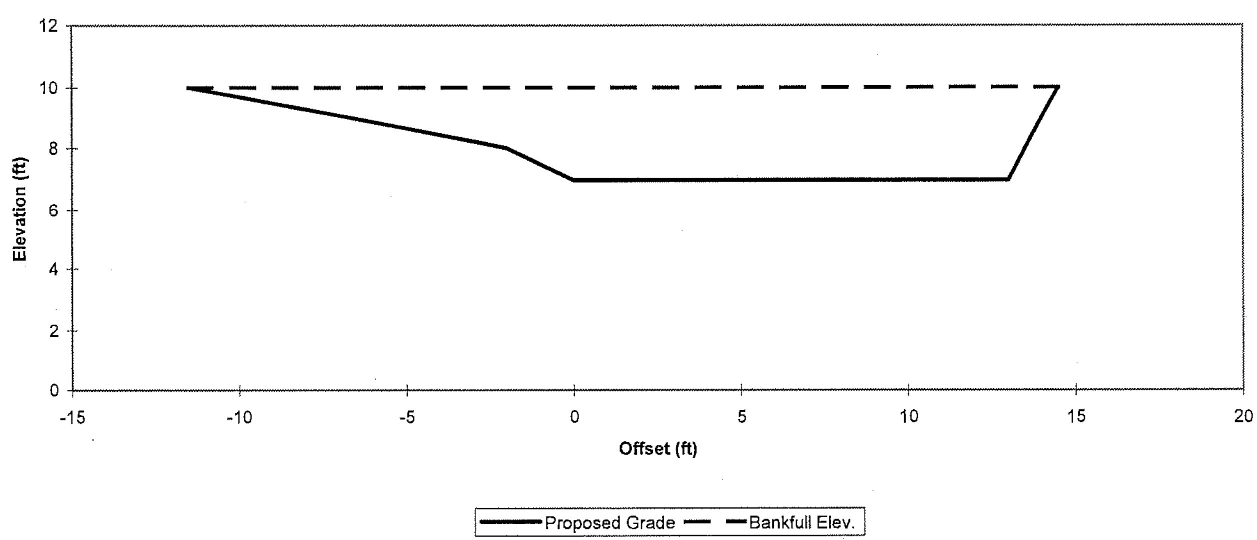
Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/13/2005
Prepared by:	EMM
Cross Section Identification:	**Upper Reach** **C-type, 120 cfs** **3.0 ft Max Depth Pool**

Meander Channel Elevation and Offset Nodes		
Feature	**Offset**	**Elevation**
Floodprone left		10.0
Bankfull Left	-11.5	10.0
Bar to Pool	-2	8.0
Thalweg	0	7.0
Pool	13	7.0
Bankfull Right	14.5	10.0
Floodprone right		10

Meander Channel Dimensions		
		Ratio to Riffle
Meander Width	26.0 ft	0.84
Wetted Perimeter	28.3 ft	0.89
Hydraulic Radius	2.0 ft	1.17
Area	55.8 ft^2	1.04
Max Pool Depth	3.0 ft	1.333333333
Bar Slope	4.8:1	
Bar Toe Slope	2.0:1	
Outer Bank Angle	.5:1	

Typical Meander Cross Section: Upper Reach



5

Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/5/2005
Prepared by:	E. McClure
Cross Section Identification:	**Upper Reach B-type, 120 cfs Riffle**

Stream Design Worksheet

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Input Variables

Mannings "n" of channel =	0.045	
Mannings "n" of floodplain =	0.1	
Equivalent "n" for flood flows =	0.04	
Channel Slope =	0.03	
Design B.F. Discharge =	120	[cfs]
Bankfull Elevation =	8.50	[ft]
Floodprone Elevation =	10	[ft]
Bankfull Width =	20	[ft]
Floodprone Width =	40	[ft]

Calculated Quantities

Cross Section Area =	21.0	[sq. ft.]
Wetted Perimeter =	20.4	[ft]
Hydraulic Radius =	1.03	[ft]
Bankfull Discharge =	**123**	**[cfs]**
F.P. XSEC Area =	66.0	[sq. ft.]
F.P. Wetted Perimeter =	41	[ft]
F.P. Hydraulic Radius =	1.63	[ft]
Floodprone Discharge =	522	[cfs]
Average Depth =	1.05	[ft]
W/D Ratio =	19.0	
Entrenchment Ratio =	2.0	
Shear Stress =	1.93	[lb/sq.ft.]
D84=	127	[mm]

Relevant Equations

Continuity Equation:

$$Q = V \times A$$

Manning's Equation:

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

Shear Stress Equation:

□

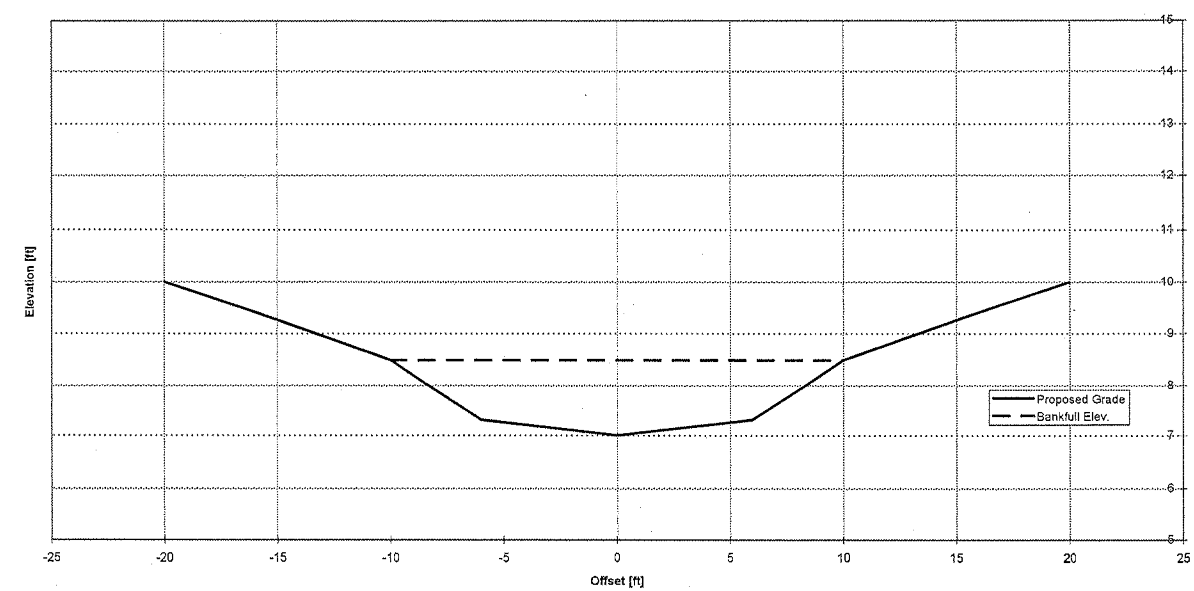
$$\tau_o = \rho g R S$$

Cross Section Points / **Bankfull Channel Calculations**

Feature	Offset	Elevation		Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
Floodprone	-20	10.0				
	-20	10	bank slope			
Bankfull	-10	8.5	3.33	2.4		4.18
	-6	7.3		8.1		6.01
Max Depth	0	7.0	6.67	8.1		6.01
	6	7.3		2.4		4.18
Bankfull	10	8.5				
	20	10.0				
Floodprone	20	10.0	Total Area =	21	Wet Perimeter =	20.37

Floodprone Channel Calculations

	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
	0		0.00
lA.fp	7.5	lP.fp	10.11
	8.4		4.18
	17.1		6.01
	17.1		6.01
	8.4		4.18
rA.fp	7.5	rP.fp	10.11
	0		0.00
Total Area =	66	Wet Perimeter =	40.59



6

Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/5/2005
Prepared by:	E. McClure
Cross Section Identification:	**Upper Reach**
	B-type, 120 cfs
	2.3 ft Max Depth Pool

Stream Design Worksheet

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Input Variables

Mannings "n" of channel =	0.045	
Mannings "n" of floodplain =	0.1	
Equivalent "n" for flood flows =	0.04	
Channel Slope =	0.03	
Design B.F. Discharge =	120	[cfs]
Bankfull Elevation =	9.30	[ft]
Floodprone Elevation =	11.6	[ft]
Bankfull Width =	24	[ft]
Floodprone Width =	40	[ft]

Calculated Quantities

Cross Section Area =	37.8	[sq. ft.]
Wetted Perimeter =	24.7	[ft]
Hydraulic Radius =	1.53	[ft]
Bankfull Discharge =	**288**	**[cfs]**
F.P. XSEC Area =	111.4	[sq. ft.]
F.P. Wetted Perimeter =	41	[ft]
F.P. Hydraulic Radius =	2.70	[ft]
Floodprone Discharge =	1199	[cfs]
Average Depth =	1.58	[ft]
W/D Ratio =	15.2	
Entrenchment Ratio =	1.7	
Shear Stress =	2.87	[lb/sq.ft.]
D84=	189	[mm]

Relevant Equations

Continuity Equation:

$$Q = V \times A$$

Manning's Equation:

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

Shear Stress Equation:

□

$$\tau_o = \rho g R S$$

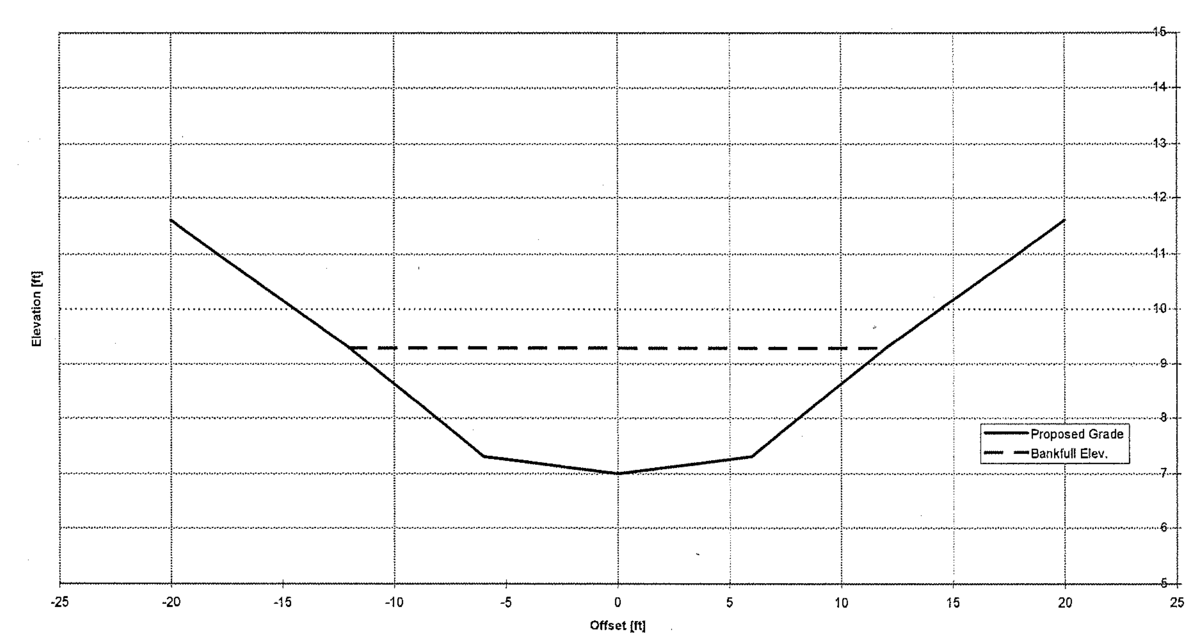
Cross Section Points / **Bankfull Channel Calculations**

Feature	Offset	Elevation		Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
Floodprone	-20	11.6				
	-20	11.6	bank slope			
Bankfull	-12	9.3	3.00	6		6.32
	-6	7.3		12.9		6.01
Max Depth	0	7.0	3.48	12.9		6.01
	6	7.3		6		6.32
Bankfull	12	9.3				
	20	11.6				
Floodprone	20	11.6	Total Area =	37.8	Wet Perimeter =	24.66

Floodprone Channel Calculations

	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
	0		0.00
lA.fp	9.2	lP.fp	8.32
	19.8		6.32
	26.7		6.01
	26.7		6.01
	19.8		6.32
rA.fp	9.2	rP.fp	8.32
	0		0.00
Total Area =	111.4	Wet Perimeter =	41.31

Typical Pool Cross Section: Upper Reach



7

Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/5/2005
Prepared by:	E. McClure
Cross Section Identification:	**Upper Reach**
	B-type, 120 cfs
	2.7 ft Max Depth Pool

Stream Design Worksheet

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Biohabitats Incorporated

Input Variables

Mannings "n" of channel =	0.045	
Mannings "n" of floodplain =	0.1	
Equivalent "n" for flood flows =	0.04	
Channel Slope =	0.03	
Design B.F. Discharge =	120	[cfs]
Bankfull Elevation =	9.70	[ft]
Floodprone Elevation =	12.4	[ft]
Bankfull Width =	24	[ft]
Floodprone Width =	40	[ft]

Calculated Quantities

Cross Section Area =	45.0	[sq. ft.]
Wetted Perimeter =	24.9	[ft]
Hydraulic Radius =	1.80	[ft]
Bankfull Discharge =	**382**	**[cfs]**
F.P. XSEC Area =	131.4	[sq. ft.]
F.P. Wetted Perimeter =	42	[ft]
F.P. Hydraulic Radius =	3.14	[ft]
Floodprone Discharge =	1544	[cfs]
Average Depth =	1.88	[ft]
W/D Ratio =	12.8	
Entrenchment Ratio =	1.7	
Shear Stress =	3.38	[lb/sq.ft.]
D84=	222	[mm]

Relevant Equations

Continuity Equation:

$$Q = V \times A$$

Manning's Equation:

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

Shear Stress Equation:

□

$$\tau_o = \rho g R S$$

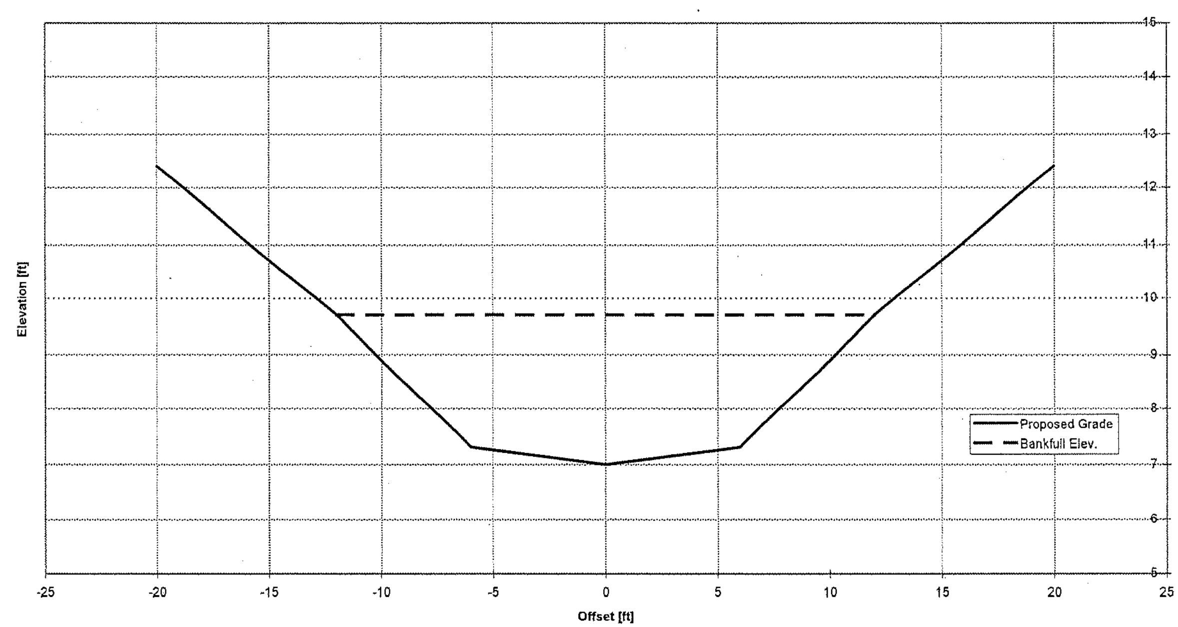
Cross Section Points / **Bankfull Channel Calculations**

Feature	Offset	Elevation		Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
Floodprone	-20	12.4				
	-20	12.4	bank slope			
Bankfull	-12	9.7	2.50	7.2		6.46
	-6	7.3		15.3		6.01
Max Depth	0	7.0	2.96	15.3		6.01
	6	7.3		7.2		6.46
Bankfull	12	9.7				
	20	12.4				
Floodprone	20	12.4	Total Area =	45	Wet Perimeter =	24.94

Floodprone Channel Calculations

	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
	0		0.00
lA.fp	10.8	lP.fp	8.44
	23.4		6.46
	31.5		6.01
	31.5		6.01
	23.4		6.46
rA.fp	10.8	rP.fp	8.44
	0		0.00
Total Area =	131.4	Wet Perimeter =	41.83

Typical Pool Cross Section: Upper Reach



Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/5/2005
Prepared by:	E. McClure
Cross Section Identification:	**Upper Reach**
	B-type, 120 cfs
	3.0 ft Max Pool Depth

Stream Design Worksheet

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Biohabitats Incorporated

Input Variables

Mannings "n" of channel =	0.045	
Mannings "n" of floodplain =	0.1	
Equivalent "n" for flood flows =	0.04	
Channel Slope =	0.03	
Design B.F. Discharge =	120	[cfs]
Bankfull Elevation =	10.00	[ft]
Floodprone Elevation =	13	[ft]
Bankfull Width =	24	[ft]
Floodprone Width =	40	[ft]

Calculated Quantities

Cross Section Area =	44.4	[sq. ft.]
Wetted Perimeter =	24.9	[ft]
Hydraulic Radius =	1.78	[ft]
Bankfull Discharge =	**374**	**[cfs]**
F.P. XSEC Area =	140.4	[sq. ft.]
F.P. Wetted Perimeter =	42	[ft]
F.P. Hydraulic Radius =	3.34	[ft]
Floodprone Discharge =	1686	[cfs]
Average Depth =	1.85	[ft]
W/D Ratio =	13.0	
Entrenchment Ratio =	1.7	
Shear Stress =	3.34	[lb/sq.ft.]
D84=	220	[mm]

Relevant Equations

Continuity Equation:

$$Q = V \times A$$

Manning's Equation:

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

Shear Stress Equation:

□

$$\tau_o = \rho g R S$$

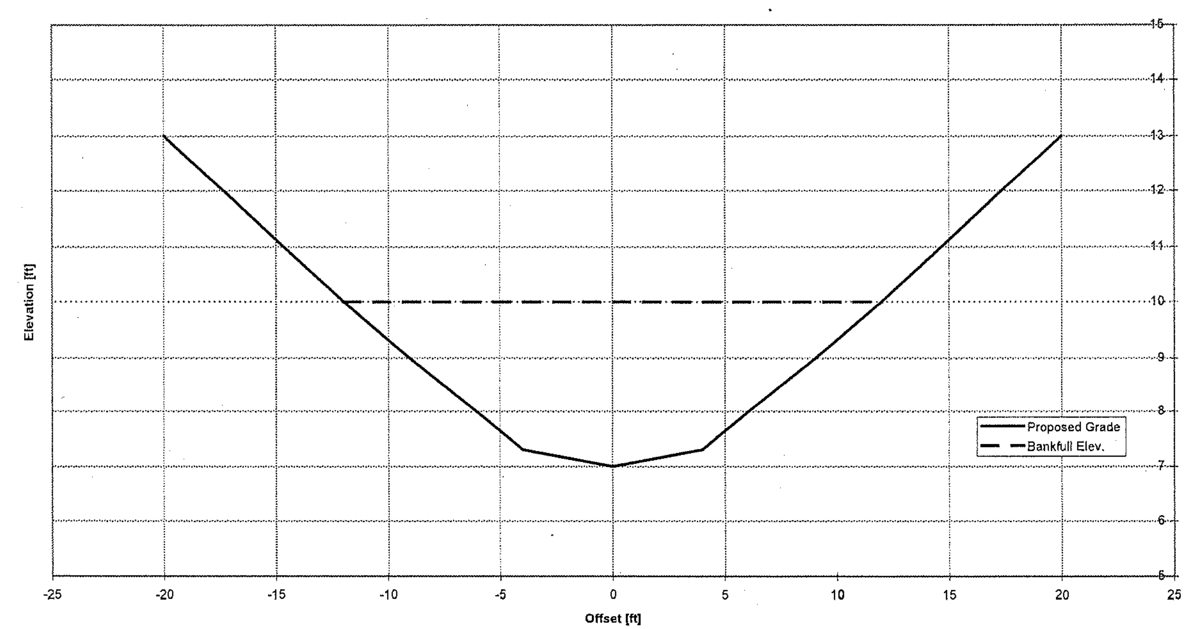
Cross Section Points / **Bankfull Channel Calculations**

Feature	Offset	Elevation		Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
Floodprone	-20	13.0				
	-20	13	bank slope			
Bankfull	-12	10.0	2.96	10.8		8.44
	-4	7.3		11.4		4.01
Max Depth	0	7.0	2.67	11.4		4.01
	4	7.3		10.8		8.44
Bankfull	12	10.0				
	20	13.0				
Floodprone	20	13.0	Total Area =	44.4	Wet Perimeter =	24.91

Floodprone Channel Calculations

	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
	0		0.00
lA.fp	12	lP.fp	8.54
	34.8		8.44
	23.4		4.01
	23.4		4.01
	34.8		8.44
rA.fp	12	rP.fp	8.54
	0		0.00
Total Area =	140.4	Wet Perimeter =	42.00

Typical Pool Cross Section: Upper Reach



Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/5/2005
Prepared by:	E. McClure
Cross Section Identification:	**Eastway Elementary School B-type, 265 cfs Riffle**

Stream Design Worksheet

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Biohabitats Incorporated

Input Variables

Mannings "n" of channel =	0.038	
Mannings "n" of floodplain =	0.1	
Equivalent "n" for flood flows =	0.04	
Channel Slope =	0.0024	
Design B.F. Discharge =	265	[cfs]
Bankfull Elevation =	11.00	[ft]
Floodprone Elevation =	15	[ft]
Bankfull Width =	36	[ft]
Floodprone Width =	36	[ft]

Calculated Quantities

Cross Section Area =	82.5	[sq. ft.]
Wetted Perimeter =	37.4	[ft]
Hydraulic Radius =	2.20	[ft]
Bankfull Discharge =	**268**	**[cfs]**
F.P. XSEC Area =	226.5	[sq. ft.]
F.P. Wetted Perimeter =	37	[ft]
F.P. Hydraulic Radius =	6.05	[ft]
Floodprone Discharge =	1270	[cfs]
Average Depth =	2.29	[ft]
W/D Ratio =	15.7	
Entrenchment Ratio =	1.0	
Shear Stress =	0.33	[lb/sq.ft.]
D84=	22	[mm]
Bankfull Discharge (SubChannel) =	141	

3.216181402

Relevant Equations

Continuity Equation:

$$Q = V \times A$$

Manning's Equation:

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

Shear Stress Equation:

□

$$\tau_o = \rho g R S$$

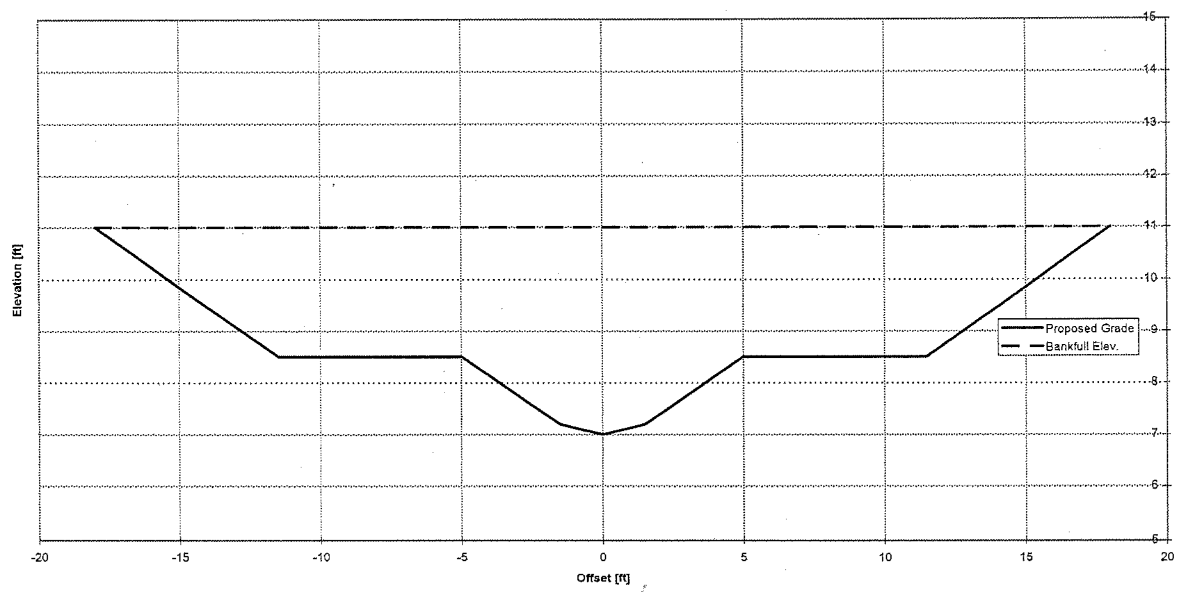
Cross Section Points / Bankfull Channel Calculations

Feature	Offset	Elevation	bank slope	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
Floodprone	-18	11.0	2.6	8.125		6.96
	-11.5	8.5		16.25		6.50
Bankfull	-5	8.5	2.7	11.025		3.73
	-1.5	7.2		5.85		1.51
Max Depth	0	7.0		5.85		1.51
	1.5	7.2		11.025		3.73
Bankfull	5	8.5		16.25		6.50
	11.5	8.5		8.125		6.96
Floodprone	18	11.0	Total Area =	82.5	Wet Perimeter =	37.42
			Sub Area =	33.75	Sub WP=	10.49

Floodprone Channel Calculations

	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
	34.125		6.96
lA.fp	42.25	lP.fp	6.50
	25.025		3.73
	11.85		1.51
	11.85		1.51
	25.025		3.73
rA.fp	42.25	rP.fp	6.50
	34.125		6.96
Total Area =	226.5	Wet Perimeter =	37.42

Typical Riffle Cross Section: Eastway Elementary School



Biohabitats Incorporated

Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/13/2005
Prepared by:	EMM
Cross Section Identification:	**Eastway Elementary School B-type, 265 cfs 2.0 ft Max Pool Depth**

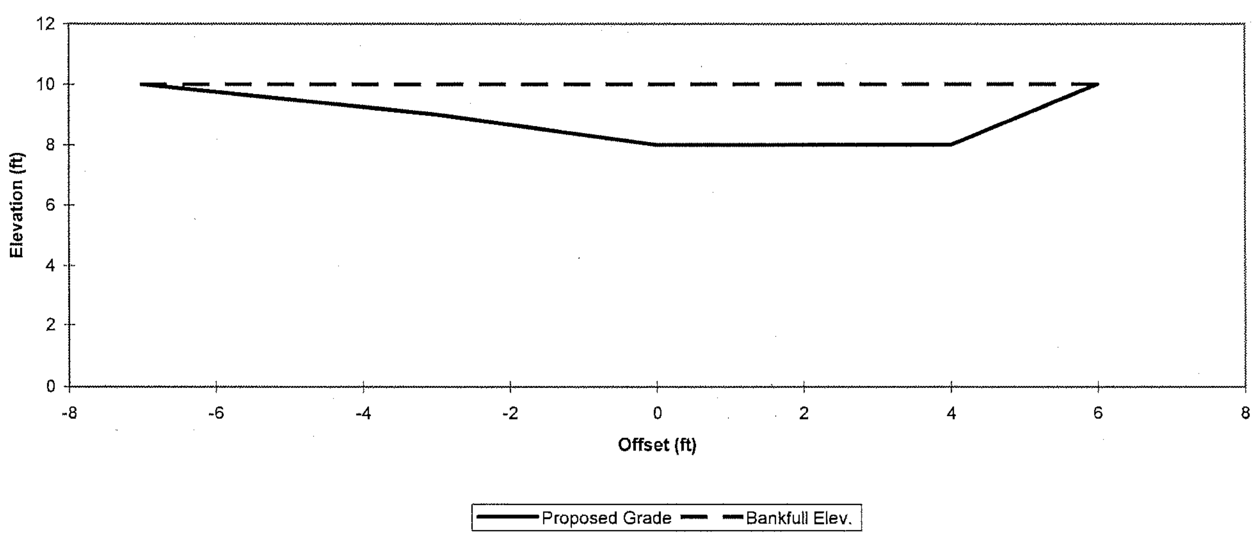
Meander Channel Elevation and Offset Nodes

Feature	Offset	Elevation
Floodprone left		10.0
Bankfull Left	-7	10.0
Bar to Pool	-3	9.0
Thalweg	0	8.0
Pool	4	8.0
Bankfull Right	6.0	10.0
Floodprone right		10

Meander Channel Dimensions

		Ratio to Riffle
Meander Width	13.0 ft	0.42
Wetted Perimeter	14.1 ft	0.45
Hydraulic Radius	1.2 ft	0.69
Area	16.5 ft^2	0.31
Max Pool Depth	2.0 ft	0.888888889
Bar Slope	4.0:1	
Bar Toe Slope	3.0:1	
Outer Bank Angle	1.0:1	

Typical Meander Cross Section: Eastway Elementary School Reach



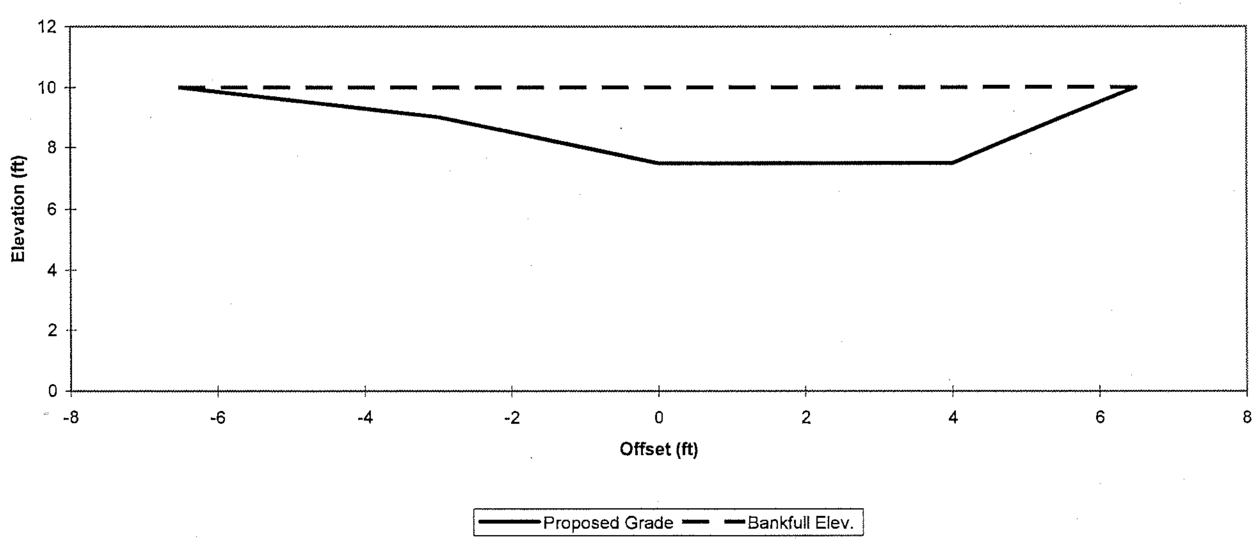
Biohabitats Incorporated

Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/13/2005
Prepared by:	EMM
Cross Section Identification:	**Eastway Elementary School B-type, 265 cfs 2.5 ft Max Pool Depth**

Meander Channel Elevation and Offset Nodes		
Feature	**Offset**	**Elevation**
Floodprone left		10.0
Bankfull Left	-6.5	10.0
Bar to Pool	-3	9.0
Thalweg	0	7.5
Pool	4	7.5
Bankfull Right	6.5	10.0
Floodprone right		10

Meander Channel Dimensions		
		Ratio to Riffle
Meander Width	13.0 ft	0.42
Wetted Perimeter	14.5 ft	0.46
Hydraulic Radius	1.4 ft	0.82
Area	20.1 ft^2	0.38
Max Pool Depth	2.5 ft	1.111111111
Bar Slope	3.5:1	
Bar Toe Slope	2.0:1	
Outer Bank Angle	1.0:1	

Typical Meander Cross Section: Eastway Elementary School Reach



Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/5/2005
Prepared by:	E. McClure
Cross Section Identification:	**Eastway Elementary School B-type, 400 cfs Riffle**

Stream Design Worksheet

Biohabitats Incorporated

Input Variables

Mannings "n" of channel =	0.038	
Mannings "n" of floodplain =	0.1	
Equivalent "n" for flood flows =	0.04	
Channel Slope =	0.0024	
Design B.F. Discharge =	400	[cfs]
Bankfull Elevation =	11.00	[ft]
Floodprone Elevation =	15	[ft]
Bankfull Width =	46	[ft]
Floodprone Width =	46	[ft]

Calculated Quantities

Cross Section Area =	113.8	[sq. ft.]
Wetted Perimeter =	47.4	[ft]
Hydraulic Radius =	2.40	[ft]
Bankfull Discharge =	**392**	**[cfs]**
F.P. XSEC Area =	297.8	[sq. ft.]
F.P. Wetted Perimeter =	47	[ft]
F.P. Hydraulic Radius =	6.29	[ft]
Floodprone Discharge =	1756	[cfs]
Average Depth =	2.47	[ft]
W/D Ratio =	18.6	
Entrenchment Ratio =	1.0	
Shear Stress =	0.36	[lb/sq.ft.]
D84=	24	[mm]
Bankfull Discharge (SubChannel) =	0	

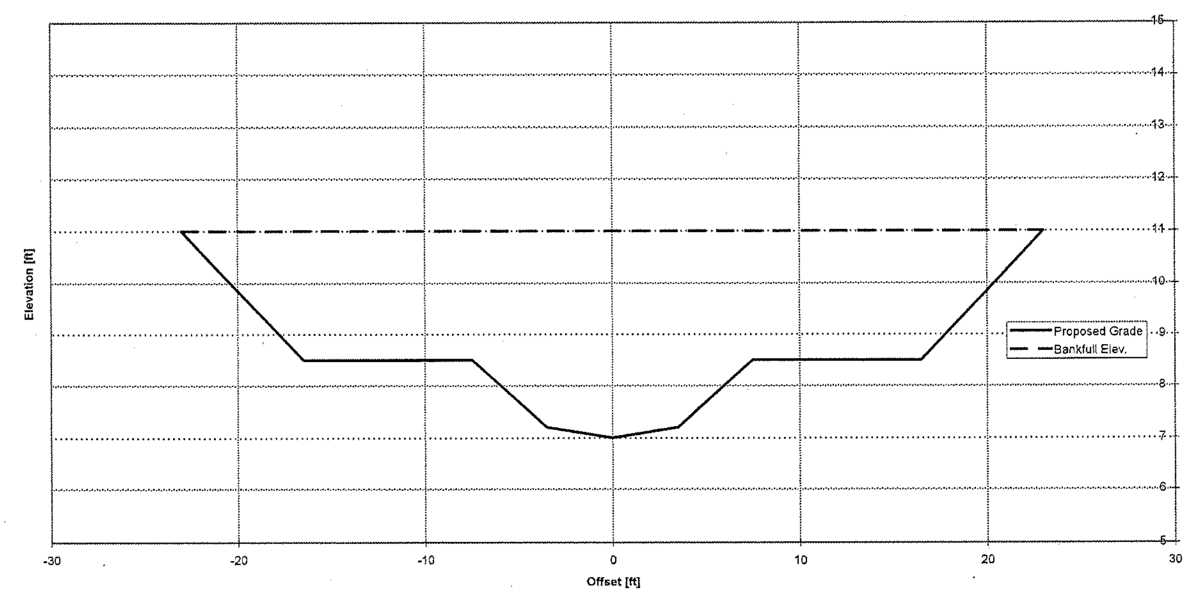
Cross Section Points / **Bankfull Channel Calculations**

Feature	Offset	Elevation	bank slope	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
Floodprone	-23	11.0	2.6	8.125		6.96
	-16.5	8.5		22.5		9.00
Bankfull	-7.5	8.5	3.1	12.6		4.21
	-3.5	7.2		13.65		3.51
Max Depth	0	7.0		13.65		3.51
	3.5	7.2		12.6		4.21
Bankfull	7.5	8.5		22.5		9.00
	16.5	8.5		8.125		6.96
Floodprone	23	11.0	Total Area =	113.75	Wet Perimeter =	47.35
			Sub Area =	52.5	Sub WP=	15.42

Floodprone Channel Calculations

	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
	34.125		6.96
lA.fp	58.5	lP.fp	9.00
	28.6		4.21
	27.65		3.51
	27.65		3.51
	28.6		4.21
rA.fp	58.5	rP.fp	9.00
	34.125		6.96
Total Area =	297.75	Wet Perimeter =	47.35

Typical Riffle Cross Section: Eastway Elementary School



Relevant Equations

Continuity Equation:

$$Q = V \times A$$

Manning's Equation:

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

Shear Stress Equation:

□

$$\tau_o = \rho g R S$$

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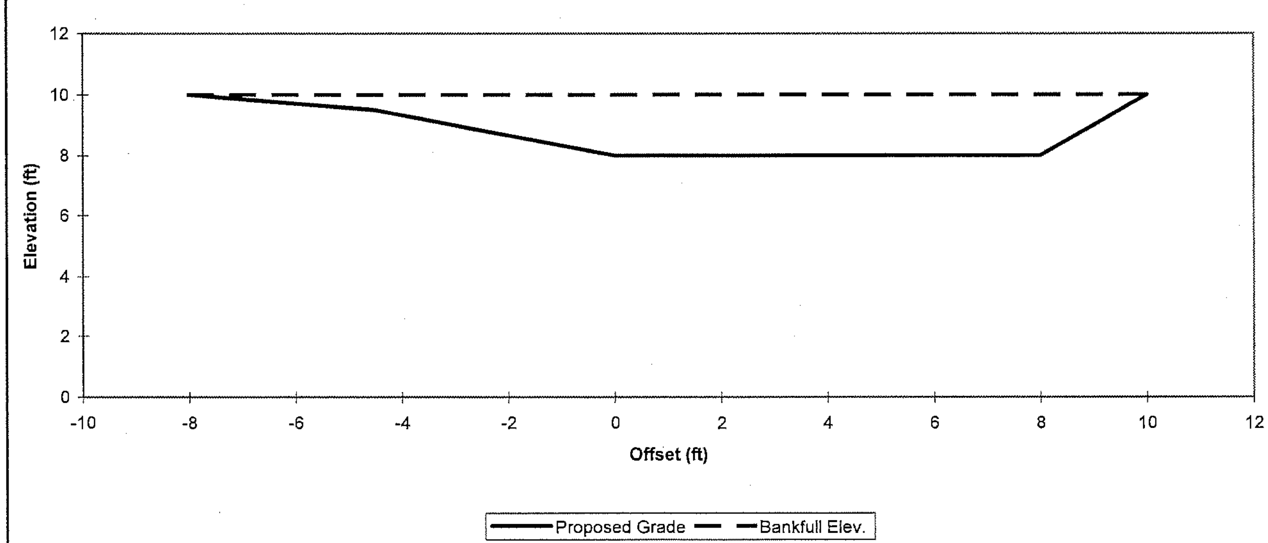
Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/13/2005
Prepared by:	EMM
Cross Section Identification:	**Eastway Elementary School** **B-type, 400 cfs** **2.0 ft Max Pool Depth**

Meander Channel Elevation and Offset Nodes		
Feature	**Offset**	**Elevation**
Floodprone left		10.0
Bankfull Left	-8	10.0
Bar to Pool	-4.5	9.5
Thalweg	0	8.0
Pool	8	8.0
Bankfull Right	10.0	10.0
Floodprone right		10

Meander Channel Dimensions		
		Ratio to Riffle
Meander Width	18.0 ft	0.58
Wetted Perimeter	19.1 ft	0.60
Hydraulic Radius	1.3 ft	0.76
Area	24.5 ft^2	0.46
Max Pool Depth	2.0 ft	0.888888889
Bar Slope	7.0:1	
Bar Toe Slope	3.0:1	
Outer Bank Angle	1.0:1	

Typical Meander Cross Section: Eastway Elementary School Reach



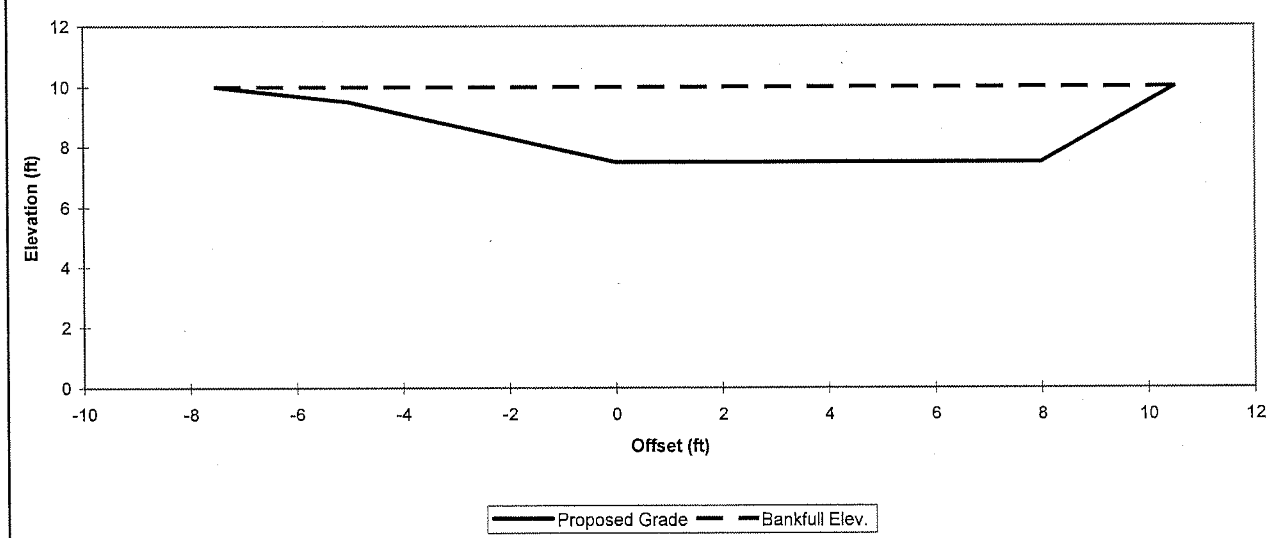
Biohabitats Incorporated

Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/13/2005
Prepared by:	EMM
Cross Section Identification:	**Eastway Elementary School B-type, 400 cfs 2.5 ft Max Pool Depth**

Meander Channel Elevation and Offset Nodes		
Feature	**Offset**	**Elevation**
Floodprone left		10.0
Bankfull Left	-7.5	10.0
Bar to Pool	-5	9.5
Thalweg	0	7.5
Pool	8	7.5
Bankfull Right	10.5	10.0
Floodprone right		10

Meander Channel Dimensions		
		Ratio to Riffle
Meander Width	18.0 ft	0.58
Wetted Perimeter	19.5 ft	0.61
Hydraulic Radius	1.6 ft	0.95
Area	31.3 ft^2	0.58
Max Pool Depth	2.5 ft	1.111111111
Bar Slope	5.0:1	
Bar Toe Slope	2.5:1	
Outer Bank Angle	1.0:1	

Typical Meander Cross Section: Eastway Elementary School Reach



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Project Name:	Goose Creek
Biohabitats Project No.:	04802.02
Date:	7/5/2005
Prepared by:	E. McClure
Cross Section Identification:	**Long Meadow Park B-type, 400 cfs Riffle**

Stream Design Worksheet

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Biohabitats Incorporated

Input Variables

Mannings "n" of channel =	0.038	
Mannings "n" of floodplain =	0.1	
Equivalent "n" for flood flows =	0.035	
Channel Slope =	0.0039	(design alignment)
Design B.F. Discharge =	400	[cfs]
Bankfull Elevation =	10.50	[ft]
Floodprone Elevation =	14	[ft]
Bankfull Width =	38	[ft]
Floodprone Width =	76	[ft]

Calculated Quantities

Cross Section Area =	92.3	[sq. ft.]
Wetted Perimeter =	39.0	[ft]
Hydraulic Radius =	2.37	[ft]
Bankfull Discharge =	401	**[cfs]**
F.P. XSEC Area =	319.8	[sq. ft.]
F.P. Wetted Perimeter =	78	[ft]
F.P. Hydraulic Radius =	4.09	[ft]
Floodprone Discharge =	1740	[cfs]
Average Depth =	2.43	[ft]
W/D Ratio =	15.6	
Entrenchment Ratio =	2.0	
Shear Stress =	0.58	[lb/sq.ft.]
D84=	38	[mm]

Relevant Equations

Continuity Equation:

$$Q = V \times A$$

Manning's Equation:

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

Shear Stress Equation:

□

$$\tau_o = \rho g R S$$

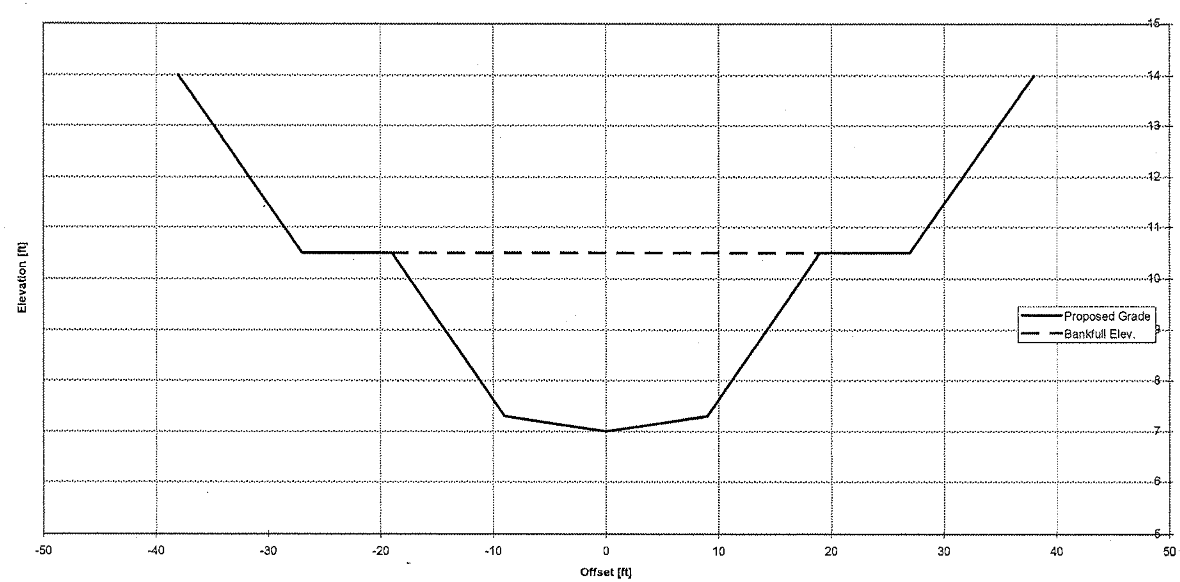
Cross Section Points / **Bankfull Channel Calculations**

Feature	Offset	Elevation		Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
Floodprone	-38	14.0				
	-27	10.5	bank slope			
Bankfull	-19	10.5	3.1	16		10.50
	-9	7.3		30.15		9.00
Max Depth	0	7.0	3.1	30.15		9.00
	9	7.3		16		10.50
Bankfull	19	10.5				
	27	10.5				
Floodprone	38	14.0	Total Area =	92.3	Wet Perimeter =	39.01

Floodprone Channel Calculations

	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
	19.25		11.54
lA.fp	28	lP.fp	8.00
	51		10.50
	61.65		9.00
	61.65		9.00
	51		10.50
rA.fp	28	rP.fp	8.00
	19.25		11.54
Total Area =	319.8	Wet Perimeter =	78.10

Typical Riffle Cross Section: Long Meadow Park



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Project Name:	Goose Creek
Biohabitats Project No. :	04802.02
Date:	7/5/2005
Prepared by:	E. McClure
Cross Section Identification:	**Long Meadow Park**
	B-type, 400 cfs
	5.5 ft Max Depth Pool

Stream Design Worksheet

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Biohabitats Incorporated

Input Variables

Mannings "n" of channel =	0.038	
Mannings "n" of floodplain =	0.1	
Equivalent "n" for flood flows =	0.035	
Channel Slope =	0.0039	(design alignment)
Design B.F. Discharge =	400	[cfs]
Bankfull Elevation =	10.50	[ft]
Floodprone Elevation =	16	[ft]
Bankfull Width =	46	[ft]
Floodprone Width =	76	[ft]

Calculated Quantities

Cross Section Area =	170.0	[sq. ft.]
Wetted Perimeter =	47.9	[ft]
Hydraulic Radius =	3.55	[ft]
Bankfull Discharge =	**969**	**[cfs]**
F.P. XSEC Area =	527.5	[sq. ft.]
F.P. Wetted Perimeter =	80	[ft]
F.P. Hydraulic Radius =	6.55	[ft]
Floodprone Discharge =	4047	[cfs]
Average Depth =	3.70	[ft]
W/D Ratio =	12.4	
Entrenchment Ratio =	1.7	
Shear Stress =	0.86	[lb/sq.ft.]
D84=	57	[mm]

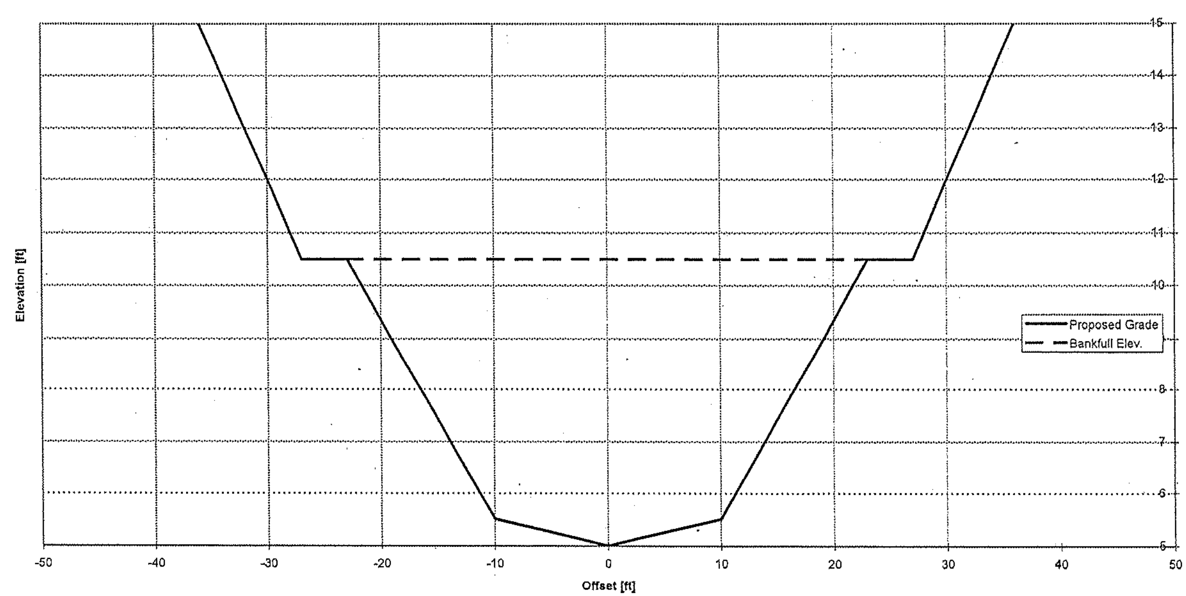
Cross Section Points / **Bankfull Channel Calculations**

Feature	Offset	Elevation		Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
Floodprone	-38	16.0				
	-27	10.5	bank slope			
Bankfull	-23	10.5	2.6	32.5		13.93
	-10	5.5	20.0	52.5		10.01
Max Depth	0	5.0	2.0	52.5		10.01
	10	5.5		32.5		13.93
Bankfull	23	10.5				
	27	10.5				
Floodprone	38	16.0	Total Area =	170	Wet Perimeter =	47.88

Floodprone Channel Calculations

	Cross Section Area [sq. ft.]		Wetted Perimeter [ft]
	30.25		12.30
lA.fp	22	lP.fp	4.00
	104		13.93
	107.5		10.01
	107.5		10.01
	104		13.93
rA.fp	22	rP.fp	4.00
	30.25		12.30
Total Area =	527.5	Wet Perimeter =	80.48

Typical Pool Cross Section: Long Meadow Park



Relevant Equations

Continuity Equation:

$$Q = V \times A$$

Manning's Equation:

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

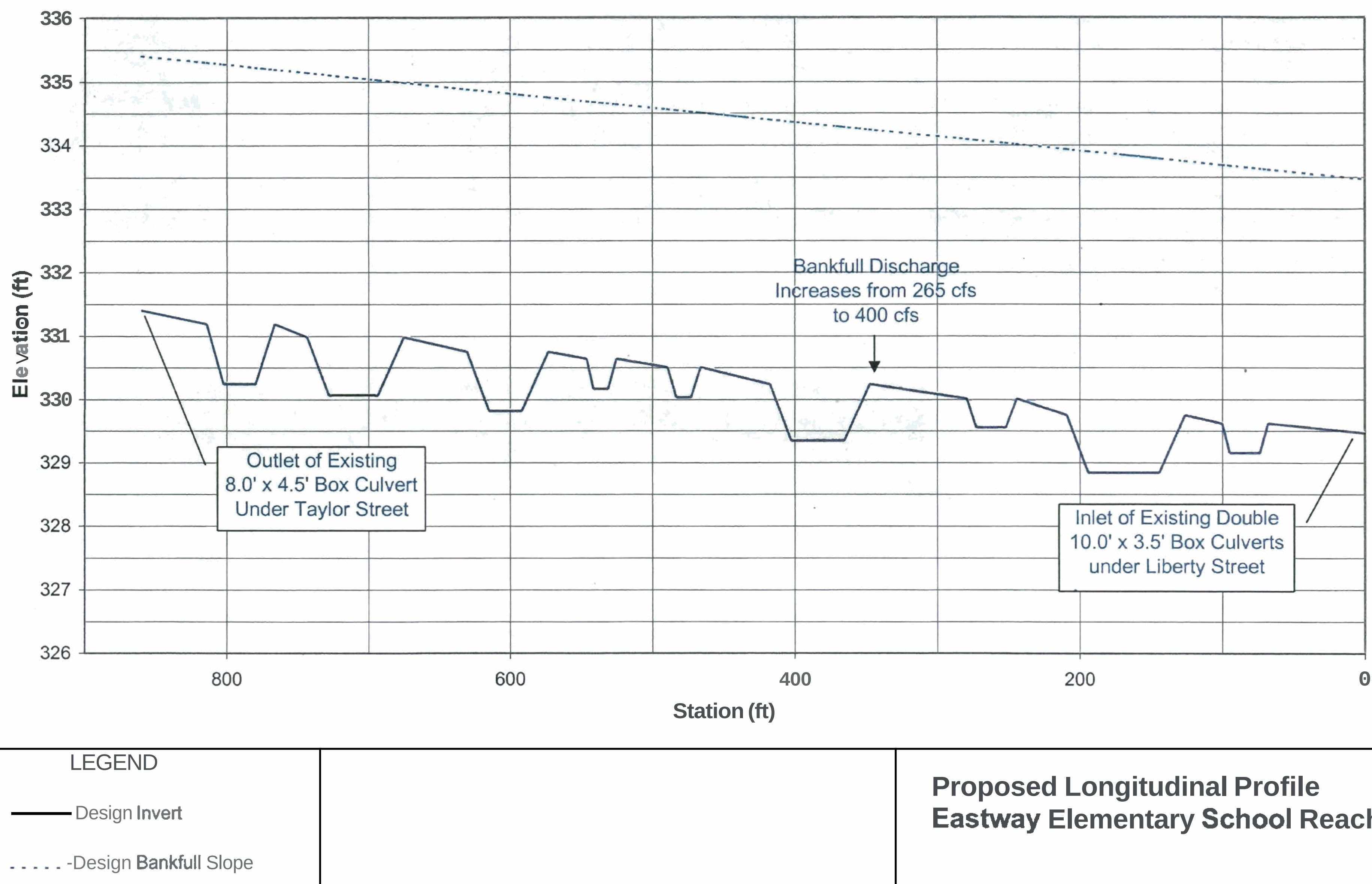
Shear Stress Equation:

□

$$\tau_o = \rho g R S$$

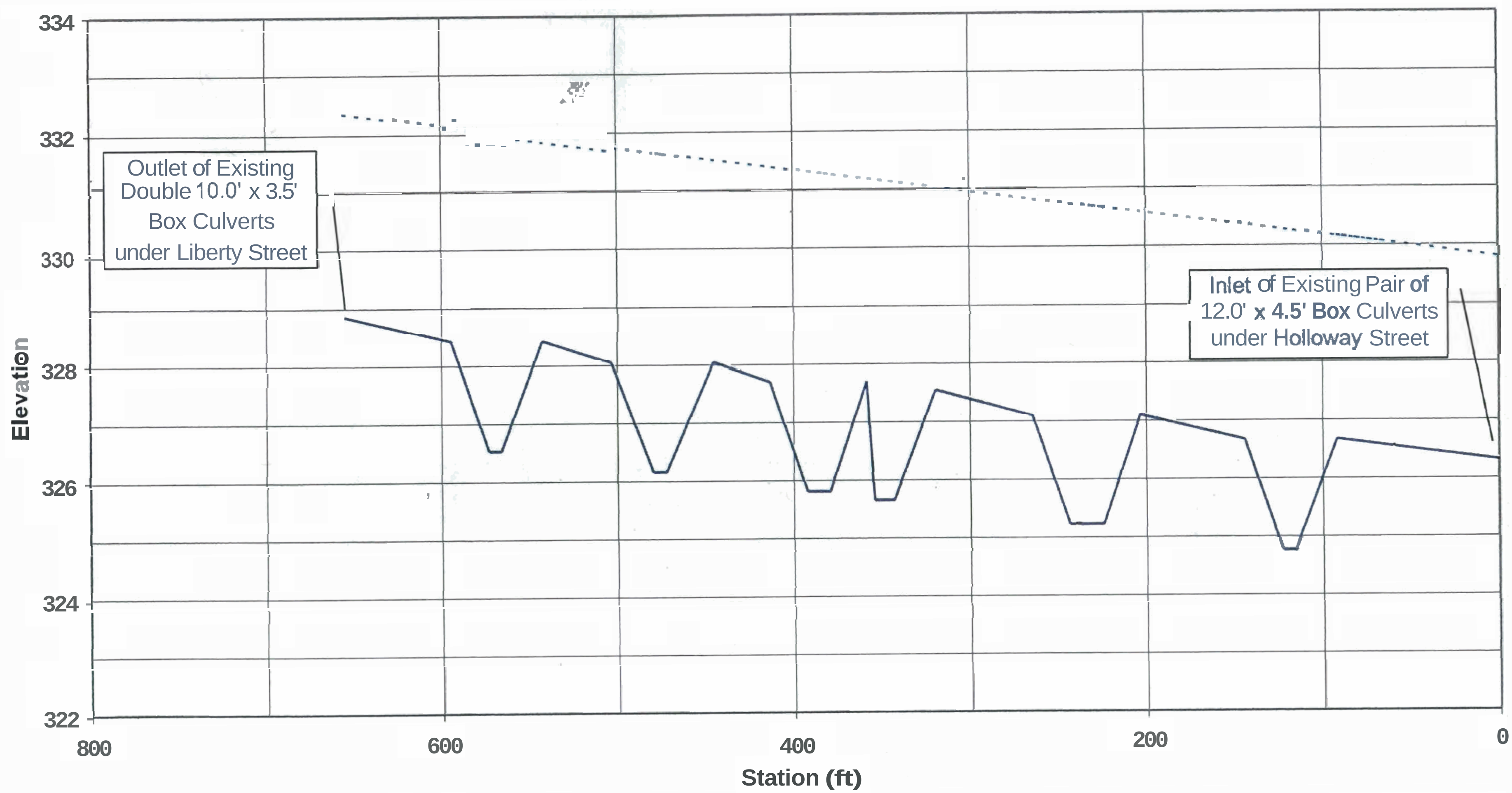
APPENDIX I

PROPOSED LONGITUDINAL PROFILES



Proposed Longitudinal Profile
Eastway Elementary School Reach

Biohabitats Incorporated



LEGEND

- Design Invert
- Design Bankfull Slope

Proposed Longitudinal Profile Longmeadow Park Reach

Biohabitats Incorporated